Igneous Rocks and Related Mineral Deposits of the Barker Quadrangle, Little Belt Mountains, Montana

GEOLOGICAL SURVEY PROFESSIONAL PAPER 752

Igneous Rocks and Related Mineral Deposits of the Barker Quadrangle, Little Belt Mountains, Montana

By IRVING J. WITKIND

GEOLOGICAL SURVEY PROFESSIONAL PAPER 752

A laccolithic complex in central Montana is examined in detail with special attention given to the igneous rocks, the intrusions, and the related silver-lead-zinc deposits

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1973

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 72-600361

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price: Paper covers—$1.00, domestic postpaid; 75 cents, GPO Bookstore Stock No. 2401-00312

CONTENTS

ILLUSTRATIONS

TABLES

IGNEOUS ROCKS AND RELATED MINERAL DEPOSITS OF THE BARKER QUADRANGLE, LITTLE BELT MOUNTAINS, MONTANA

By Irving J. Witkind

ABSTRACT

The Barker quadrangle is astride the north flank of the Little Belt Mountains, one of several laccolithic and volcanic groups that rise above the broad plains of central Montana. The northern third of the quadrangle includes pediments and sedimentary rocks which slope gently northward from the mountains; the remainder of the quadrangle is a mountainous terrain of domelike heights separated by long, narrow, sinuous valleys.

Precambrian paragneiss and orthogneiss are exposed in the southwest corner of the quadrangle, and comparable rocks probably underlie the remainder of the quadrangle. This Precambrian basement is overlain unconformably by a sedimentary mantle some 4,800 feet thick.

Both the Precambrian crystalline rocks and the sedimentary rocks have been warped, broken, intruded, and elevated by a host of large and small igneous masses. The igneous rocks which form these bodies have been subdivided, on the basis of their contained silica, into felsic, intermediate, and mafic groups. All the major plutons are formed of either felsic or intermediate rocks; the mafic rocks constitute only a small fraction of the total volume of igneous rock emplaced. The felsic rocks, mainly rhyolite and granite porphyries, have been divided into old and young groups. The intermediate rocks are chiefly quartz latite porphyries, which locally grade into latite porphyries or quartz rhyolite porphyries. There is also some syenite. The mafic rocks consist of medium- to coarse-grained shonkinite and fine-grained lamprophyres, which include such varied types as minette, kersantite, and vogesite. Several composite dikes characterized by mafic margins (kersantite) and felsic interiors (quartz rhyolite porphyry) imply that two magmas of diverse composition coexisted in the area and were emplaced almost synchronously.

Eleven major plutons are recognized; these are: one stock, eight laccoliths, a bysmalith, and a buried ovoid pluton which trends northeast, extending from near Neihart, Mont., to near Barker. Significant deposits of silver, lead, and zinc have been mined from the pluton, and it seems likely that comparable deposits are still concealed in the pluton. Molybdenite, pyrite, and quartz fill fractures in both the exposed part of the pluton and the surrounding Precambrian crystalline rocks.

The height of the range and the configuration of each individual mountain are the direct results of the emplacement of one or more of these intrusions. A few of the major intrusions are well exposed owing to the removal of their sedimentary cover, but elsewhere erosion has not been as extensive and only parts of the underlying intrusion are visible. In general, the structural framework of the quadrangle consists of a parent stock (the Hughesville stock) encircled by three laccoliths, which radiate from the stock much like spokes from the hub of a wheel.

Radiometric (potassium-argon) ages that were determined for both mineral separates and whole rock from various of the intrusions indicate that the intrusions were emplaced during early Tertiary, most likely the Eocene.

Silver-lead sulfide ore deposits in the quadrangle were mined from about 1879 to 1943. In 1968, all the mines were closed, and many were flooded. Two mining districts are in the mapped area: the Barker mining district centered about the Hughesville stock near the middle of the quadrangle and the San Miguel mining district centered about a group of small mines and prospects in Precambrian crystalline rocks exposed along the south edge. Most of the ore produced has come from the Barker district. Tenor of the mined ore probably averaged 25 ounces of silver and 30 percent lead per ton.

The stock is intensely fractured. Two conjugate fracture systems were noted: the first fracture system consists of a vertical joint set that trends N. 62° E. and a second set that trends N. 40° W. and dips about 80° southwestward; the second fracture system consists of a joint set that trends northerly and a second set that trends easterly. Both dikes and veins follow the fractures.

Ore has been produced from fissure veins in and near the stock and from contact-replacement deposits along the margin of the stock. Although the ore deposits are considerably younger than the stock, they nevertheless are localized in and near it. Such localization may be due to a master conduit which, somewhat like an inverted funnel, guided the various magmas and ore solutions repeatedly toward the same site.

The fissure veins are crustified, and three major paragenetic stages are recognizable. During the first stage, quartz, pyrite, and some sphalerite were deposited on the fissure walls. During the second stage, argentiferous galena and sphalerite were deposited; and during the third stage, the remaining voids were filled with gangue minerals such as barite and rhodochrosite. Although most of the ore minerals were deposited in an environment marked by intermediate (mesothermal) temperature, a few (molybdenite, scheelite, wurtzite) may have formed under high-temperature (hypothermal) conditions. Tenuous evidence suggests that some ore minerals were deposited before the formation of the dikes that cut the stock, whereas the major veins were formed after the dikes were consolidated and fractured.

Geologic and geophysical evidence both suggest that part of the ovoid pluton underlies the stock. The ore potential of the area rests heavily on (1) the sulfide veins in the stock, and (2) the size, shape, and metal content of this buried pluton.

INTRODUCTION

The Little Belt Mountains are one of several Tertiary laccolithic and volcanic mountain groups which rise above the plains of central Montana (fig. 1). The height of the "Little Belts" and the specific structural features within them are directly attributable to one or more of the major intrusions. The composition and form of these intrusions and of their related mineral deposits within the Barker quadrangle—astride the north flank of the Little Belts—are the subjects of this report.

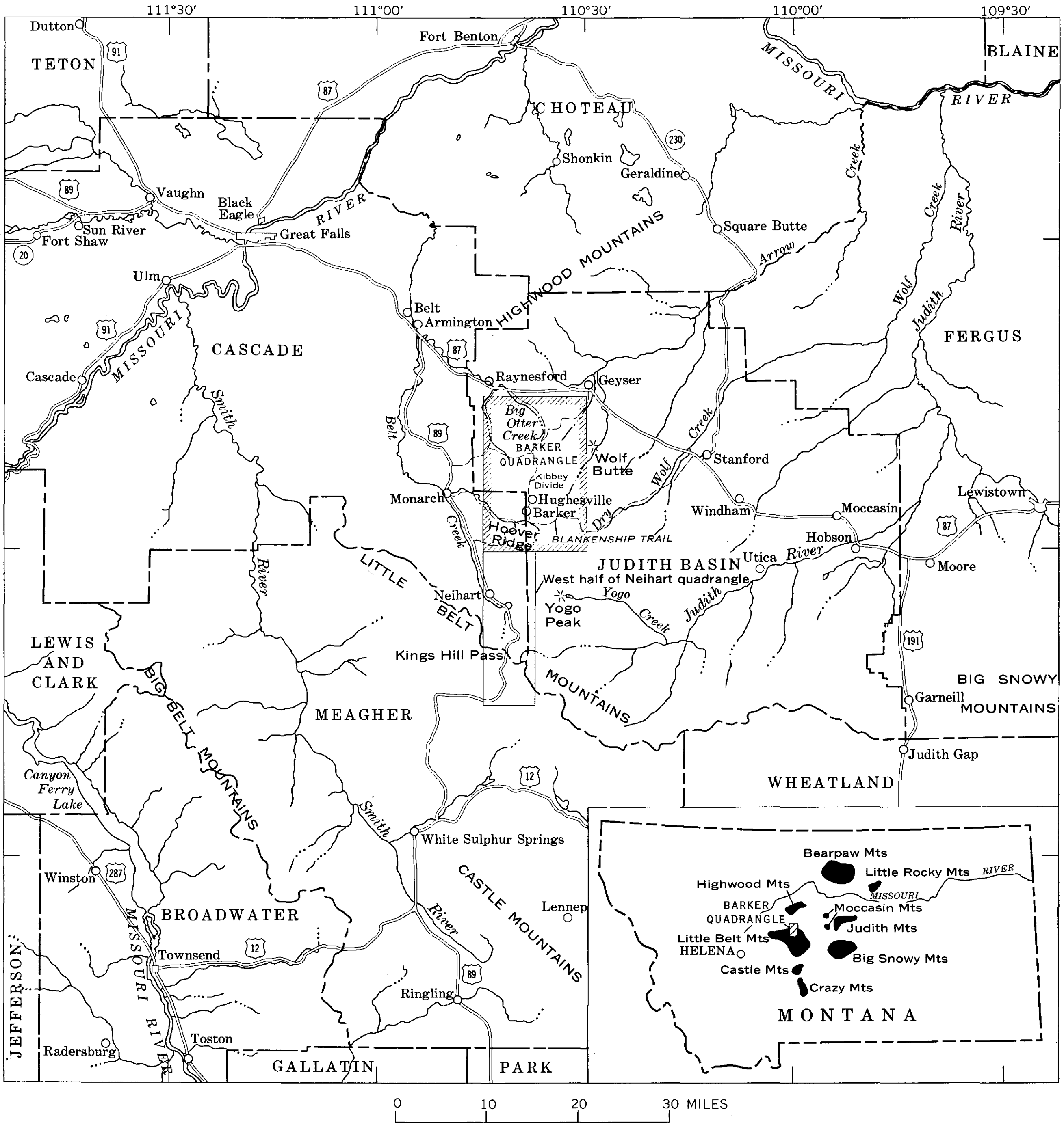


Figure 1.—Part of central Montana showing Barker quadrangle (hachured) and the mapped part of the Neihart quadrangle.

The geology of the Barker quadrangle is shown on U.S. Geological Survey Geologic Quadrangle Map GQ–898, issued in 1971. Readers will find the map a necessary adjunct to this report.

Eleven large plutons have been mapped in the Barker quadrangle. Of these, one is a stock, eight are probably laccoliths, one is a bysmalith, and one is a buried ovoid pluton (fig. 2). These have intruded the Precambrian basement rocks, as well as the overlying sedimentary units, and have warped and broken them. As a result, the once nearly horizontal sedimentary strata have been deformed into domes and elongate anticlines which reflect the underlying intrusion. Between these upwarps are oval basins and plunging synclines.

The general format followed in this report is (1) a description of the different igneous rocks, (2) a discussion of the forms of the intrusions, and (3) an examination of the relations of the ore deposits to these igneous bodies.

PREVIOUS AND PRESENT WORK

Although the nearby Highwood and Judith Mountains have been studied intensively in recent decades, the Little Belt Mountains have been comparatively neglected since the turn of the century. Weed (1899a, b) furnished brief descriptions of the geology and structure of the Little Belt Mountains and later presented a comprehensive report (1900) which includes detailed petrographic descriptions of the igneous rocks by L. V. Pirsson.

Schafer (1935) studied the geology and ore deposits of the Neihart mining district.

Catanzaro and Kulp (1964) and Catanzaro (1967) briefly described the metamorphic rocks that crop out near Neihart.

No mention will be made here of the many workers, beginning with Weed, who have contributed to the knowledge of the stratified rocks of the quadrangle, for these rocks are not discussed in this report.

Previously, I have offered some preliminary views on the structural framework of the Little Belt Mountains (Witkind, 1965), on the petrographic relations suggested by the clinopyroxenes from intrusive rocks in the quadrangle (1969), on composite dikes (1970), and with M. D. Kleinkopf and W. R. Keefer (1970), on a buried pluton beneath the Precambrian complex. Detailed results of ground-gravity and airborne magnetometer surveys across the Barker and Neihart quadrangles have been published as Geophysical Investigations Map GP–837 (Kleinkopf and others, 1972).

In an attempt to determine the time and sequence of emplacement of the intrusions, potassium-argon ages were determined for some 32 samples from the Barker-Neihart area. The pertinent data and the conclusions resulting from this study have been published (Marvin and others, 1973).

MacKnight (1892) described the prominent lead-silver mines in the Barker mining district. Robertson and Roby (1951) described the mines and mineral deposits of Judith Basin County including the Barker mining district.

Spiroff (1938) studied and described the now-flooded Block P mine, the major producer of lead-silver ore in the district. He (1939) also described some of the common minerals in the Neihart-Hughesville area.

Taylor (1935, 1938) reported on specimens from a contact metamorphic zone south of Neihart.

My work began in the Barker quadrangle in 1963 and was completed in 1966. Field compilation was on topographic sheets at a scale of 1 : 24,000. A geologic map of the quadrangle at a scale of 1 : 62,500 with an expanded explanation was published as U.S. Geological Survey Geologic Quadrangle Map GQ–898 (Witkind, 1971).

ACKNOWLEDGMENTS

I owe special thanks to Mrs. Gwenllian Vaughan-Rhys McBride of Monarch, Mont., for many stimulating discussions and for guiding me through several mines. Mr. Roy Thorson of Barker, Mont., and Mr. George A. Croff of Monarch, Mont., supplied valuable out-of-print maps and much first-hand information on the ore deposits.

Mr. Fred Cornell and Mr. John Hook, District Rangers in the Lewis and Clark National Forest, were helpful in many ways.

Jon P. Thorson, Benjamin L. Peterson, and Thomas E. Redlinger served competently as geologic field assistants.

GEOGRAPHIC AND GEOLOGIC SETTING

The Barker 15-minute quadrangle includes part of the north flank of the Little Belt Mountains, a mountain group that occupies about 1,250 square miles in parts of Cascade, Judith Basin, Meagher, and Wheatland Counties. Of the 215 square miles

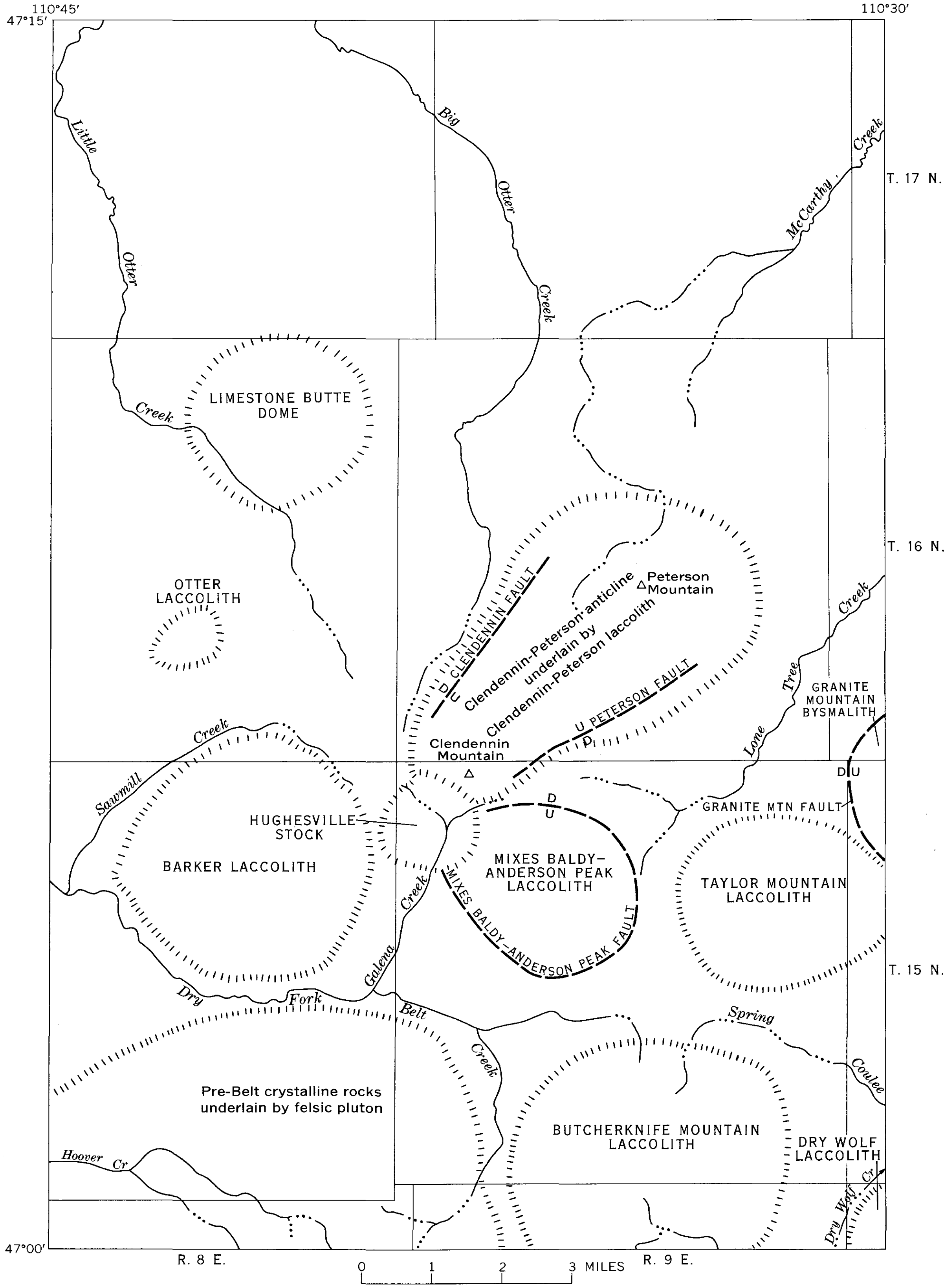


Figure 2.—Pattern of intrusions in the Barker quadrangle. U, upthrown side of fault; D, downthrown side.

within the margins of the quadrangle (Witkind, 1971), about 70 square miles is plains and pediments which slope gently northward from the mountains. The remainder of the quadrangle is a mountainous terrain of rounded, elongate ranges separated by narrow, sinuous valleys.

The sedimentary mantle rests on a basement complex of medium- to coarse-grained metamorphic crystalline rocks that have been mapped as nine distinct units (Witkind, 1971). Of these, three are regarded as paragneiss and six as orthogneiss. Although exposed only over about 20 square miles in the southwest corner of the quadrangle, they probably underlie the entire report area. All nine units are more or less foliate as a result of repeated compression. Dips of the foliation are generally northward, suggesting that these units form the north flank of the eastward-trending anticlinorium as noted by Catanzaro and Kulp (1964, p. 89).

These Precambrian crystalline rocks are the products of medium- to high-grade regional metamorphism, and they are probably best grouped in the amphibolite facies. The paragneisses have been derived from impure arkosic sandstone and other fine-grained clastic rocks; the orthogneisses from both small and large igneous intrusions.

During the Precambrian the gneisses underwent at least two metamorphic episodes (Catanzaro and Kulp, 1964; Catanzaro, 1967) and were further altered when they were lifted and baked by the emplacement of a compound rhyolitic pluton either in the Late Cretaceous (Catanzaro and Kulp, 1964) or in the early Tertiary (Marvin and others, 1973).

The consolidated sedimentary rocks that overlie the Precambrian gneisses range in age from Middle Cambrian (Flathead Sandstone) to Early Cretaceous (Kootenai Formation) and include rocks assignable to six systems (fig. 3). The sequence is broken by six unconformities, of which two (post-Cambrian–pre-Upper Devonian, and post-Pennsylvanian–pre-Jurassic) represent major gaps in the sedimentary record.

IGNEOUS ROCKS

The rocks that form the various intrusions belong to the Little Belt subprovince, one of Larsen's (1940) divisions of the central Montana petrographic province. In the Peacock (1931) classification, the rocks have an alkali-lime index of 51.2 and so are just within the alkali-calcic group.

In this report the igneous rocks are grouped on the basis of their silica (SiO_2) content as felsic (>70 percent), intermediate (60–70 percent), or mafic (45–60 percent). The intermediate rocks form most of the large intrusions. The felsic rocks have been divided into (1) those that were likely formed before most of the major intrusions were emplaced—old felsic rocks, and (2) those that were formed after the large intrusions—young felsic rocks. The mafic rocks make up small lamprophyric plugs, dikes, and sills which are considered to be younger than the large intrusions and so may be correlative in age with the young felsic rocks. This age relation is suggested by several composite dikes which imply that salic and femic magmas coexisted and were emplaced almost synchronously. The mafic rocks constitute only an infinitesimal fraction of the total volume of emplaced igneous rock.

Samples of all rock types have been analyzed chemically and the data have been processed by computer through the U.S. Geological Survey's C.I.P.W. Rock Norm Program to obtain a calculated mineral composition—the norm—of the rock. The actual mineral composition—the mode—has been determined for the more significant rock types by mineral point counts made on representative thin sections. These data are presented in various tables throughout the report.

FELSIC ROCKS
(More than 70 percent silica)

In the field the felsic rocks appear as light-gray to light-tan porphyries marked by sparse to many rounded quartz phenocrysts. By contrast the intermediate rocks are gray porphyries speckled with phenocrysts of tabular white feldspar and black needles of hornblende and biotite. Quartz phenocrysts are rare in the intermediate rocks.

OLD FELSIC ROCKS

Two large intrusions are composed of old felsic rocks: the Clendennin-Peterson laccolith formed by the porphyry of Clendennin Mountain, and the Mixes Baldy–Anderson Peak laccolith formed by the Wolf Porphyry (fig. 2). Although both porphyries are similar mineralogically and chemically (table 1), they differ markedly in texture.

PORPHYRY OF CLENDENNIN MOUNTAIN
(Samples 1–5, table 1)

Weed (1900, p. 356–358) thought that the Clendennin-Peterson anticline, 6 miles long and 3½ miles wide, resulted from the juxtaposition of several igneous bodies. In his opinion, the distal end, at

TABLE 1.—*The petrography and chemical composition (in percent) of old and young felsic rocks from the Barker quadrangle and of a similar rock from Wolf Butte, Little Belt Mountains*

[All analyses by rapid-rock methods. Analysts: P. L. D. Elmore, Lowell Artis, John Glenn, James Kelsey, Samuel Botts, H. Smith, and Gillison Chloe]

	Old felsic rocks			Young felsic rocks		
Intrusion	Clendennin–Peterson laccolith	Mixes Baldy–Anderson Peak laccolith	Wolf Butte	Granite Mtn. bysmalith	Dikes	Dikes
Rock name	Porphyry of Clendennin Mountain	Wolf Porphyry		Rhyolite of Granite Mtn.	Porphyry of Galena Creek	Snow Creek(?) Porphyry.
Petrography: Rock type	Rhyolite porphyry	Granite porphyry		Rhyolite	Rhyolite porphyry	Rhyolite porphyry.
Petrography: Color	Light gray	Light gray		Light gray	Light gray to light brown	Light gray.
Petrography: Texture	Porphyritic	Porphyritic		Fine grained	Porphyritic	Porphyritic.
Petrography: Phenocrysts	Sparse sanidine (or anorthoclase), oligoclase (An_{16}), hornblende, and biotite.	Large, round smoky quartz, sanidine, oligoclase (An_{18}), hornblende, and biotite. Sparse salite.		Albite (An_8), topaz.	Quartz, sanidine, albite (An_8), and biotite.	Quartz, sanidine, albite (An_8), locally biotite.
Petrography: Groundmass	Microgranitic mixture of anhedral quartz and alkalic feldspar, some plagioclase microlites, and some opaque minerals. Micropegmatite common.	Holocrystalline assemblage of anhedral quartz and alkalic feldspar.		Anhedral quartz and alkalic feldspar.	Microgranular mixture of anhedral quartz and alkalic feldspar.	Microgranular mixture of anhedral quartz and alkalic feldspar; some biotite.
Petrography: Mode (percent)	Alkalic feldsar, 59.6; quartz, 32.4; plagioclase feldspar, 4.2; biotite, 1.5; hornblende (more or less altered to chlorite), 1.0; opaque minerals, 1.0; other, 0.3.	Groundmass, 40.9; plagioclase feldspar, 32.7; alkalic feldspar, 11.8; quartz, 11.1; hornblende, 1.7; biotite, 0.7; others, 1.1.		Not available	Not available	Not available

Oxides

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Laboratory No.	163683	163684	163682	163686	163689	163690	163685	163691	163696	163695	W–169695	W–169699	W–169697	W–169698	W–167707
Field No.	WL–63	WL–64	WL–48	WL–71	WL–89	WL–101	WL–70	WL–112	WL–103	WL–124	WL–270B	WL–470	WL–449	WL–450	WL–488
SiO_2	72.0	72.1	72.0	71.3	70.8	70.5	71.1	71.7	75.4	74.6	74.1	73.9	78.8	76.9	76.5
Al_2O_3	14.2	13.9	13.8	14.2	14.6	15.0	14.6	14.5	13.6	13.3	13.9	12.8	11.4	12.7	13.5
Fe_2O_3	1.5	1.5	1.4	1.4	1.5	1.6	2.3	1.3	.23	.94	2.5	1.5	.20	.40	.45
FeO	.36	.44	.44	.80	.72	.68	.12	.60	.20	.24	.04	.16	.04	.08	.16
MgO	1.0	.85	.42	.72	.77	.10	.65	.68	.25	1.0	.31	.34	.06	.00	.28
CaO	1.1	1.2	1.3	1.2	1.4	1.4	.42	1.1	.50	.53	.25	1.3	.10	.03	.22
Na_2O	3.1	3.6	3.7	4.0	4.1	4.1	3.7	3.8	4.5	2.1	.66	.72	2.0	4.1	3.2
K_2O	4.4	4.5	4.4	4.4	4.2	4.2	4.5	4.4	4.2	4.3	6.1	5.5	5.8	4.4	4.2
H_2O^-	.55	.36	.37	.34	.32	.54	.82	.66	.14	.94	.40	.35	.15	.04	.07
H_2O^+	.95	.64	.83	.76	.68	.56	.98	.56	.20	1.4	1.4	1.7	.49	.34	.51
TiO_2	.24	.21	.22	.23	.26	.36	.31	.28	.02	.22	.14	.17	.09	.07	.09
P_2O_5	.31	.28	.31	.25	.14	.21	.30	.14	.00	.11	.04	.06	.00	.00	.02
MnO	.03	.07	.07	.07	.07	.02	.06	.02	.10	.02	.06	.07	.00	.00	.00
CO_2	.21	.18	.45	.21	.40	<.05	.05	.06	.08	.10	<.05	.53	.06	<.05	<.05
Sum	99.95	99.83	99.71	99.88	99.96	99.32	99.91	99.80	99.42	99.80	99.95	99.10	99.19	99.11	99.25

C.I.P.W. norms

Q	34.75	31.44	30.76	27.85	28.23	28.23	31.46	30.01	31.97	43.98	46.22	47.45	45.20	36.49	41.43
or	26.01	26.64	26.34	26.14	24.83	25.00	26.62	26.05	24.96	25.46	36.09	32.82	34.55	26.25	25.01
ab	26.24	30.51	31.72	34.03	34.71	34.95	31.34	32.22	38.30	17.81	5.59	6.15	17.06	35.02	27.28
an	2.11	2.99	6.21	5.66	3.50	5.61	.00	4.17	1.99	1.28	.66	2.73	.12	.15	.65
C	3.57	2.02	.71	.80	2.03	1.68	3.65	1.97	.93	4.73	5.98	4.72	1.80	1.15	3.48
hy {en	2.49	2.12	1.06	1.75	1.92	.25	1.55	1.70	.63	2.50	.77	.86	.15	.00	.70
hy {fs	.00	.00	.00	.06	.00	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00
mt	.56	1.04	1.44	2.04	1.80	1.22	.00	1.19	.34	.20	.00	.02	.00	.06	.26
ap	.73	.66	.02	.12	.33	.50	.71	.33	.00	.26	.10	.14	.00	.00	.05
il	.46	.40	.00	.44	.49	.69	.38	.53	.04	.42	.08	.33	.09	.13	.17
hm	1.11	.79	.43	.00	.26	.77	2.30	.48	.00	.01	2.50	1.50	.20	.37	.28

1. West flank, Clendennin-Peterson laccolith, E½ sec. 29, T. 16 N., R. 9 E.
2. West flank, Clendennin-Peterson laccolith, NW¼ sec. 32, T. 16 N., R. 9 E.
3. Crest, Clendennin-Peterson laccolith, SW¼ sec. 32, T. 16 N., R. 9 E.
4. East flank, Clendennin-Peterson laccolith, NE¼ sec. 5, T. 15 N., R. 9 E.
5. East flank, Clendennin-Peterson laccolith, SE¼ sec. 32, T. 16 N., R. 9 E.
6. East flank, Mixes Baldy–Anderson Peak laccolith, C. sec. 9, T. 15 N., R. 9 E.
7. Altered rock, northwest flank, Mixes Baldy–Anderson Peak laccolith, C. sec. 5, T. 15 N., R. 9 E.
8. Wolf Butte, S½ sec. 32, T. 16 N., R. 10 E.
9. Northwest flank, Granite Mountain bysmalith, N½ sec. 6, T. 15 N., R. 10 E. (unsurveyed).
10. Dike along fault, south flank, Granite Mountain bysmalith, E½ sec. 7, T. 15 N., R. 10 E. (unsurveyed).
11. Dike in Hughesville stock, SW¼ sec. 6, T. 15 N., R. 9 E. (unsurveyed).
12. Dike in Precambrian crystalline rocks, C. sec. 2, T. 14 N., R 8 E. (unsurveyed).
13. Dike in Precambrian crystalline rocks, C. sec. 36, T. 15 N., R. 8 E. (unsurveyed).
14. Dike in Precambrian crystalline rocks, S½ sec. 35, T. 15 N., R. 8 E. (unsurveyed).
15. Dike in Precambrian crystalline rocks, N½ sec. 31, T. 15 N., R. 9 E. (unsurveyed).

Peterson Mountain (then known as Otter Mountain), was underlain by a single laccolith, whereas the proximal end, at Clendennin Mountain, was formed either by several thick sills or by small laccoliths. I believe, however, that the structural feature is best explained as being the result of the emplacement of but one large single tonguelike laccolith that extends northeastward from the Hughesville stock (Witkind, 1971, cross section *B–B′*).

The porphyry of Clendennin Mountain is light gray, dense, hard, fine grained, and rhyolitic and breaks with conchoidal fracture into angular boulders. In hand specimen sparse phenocrysts, mainly white angular feldspar laths, and black needlelike

SYSTEM	SERIES	UNIT		Approx. thickness (feet)	LITHOLOGY
Cretaceous	Lower Cretaceous	Kootenai Formation	Upper part	350	Light-red to red claystone and siltstone.
			Basal sandstone	150	Light-gray medium- to thick-bedded fine- to coarse-grained "salt-and-pepper" sandstone.
	UNCONFORMITY				
Jurassic	Upper Jurassic	Morrison Formation		200–300	Variegated claystone, siltstone, and sandstone; some carbonaceous shale or coal at top.
		Ellis Group	Swift Sandstone	90–120	Brown conglomeratic sandstone and sandstone.
			UNCONFORMITY		
	Middle Jurassic		Piper Limestone	15–30	Light-gray thin-bedded finely crystalline limestone.
	UNCONFORMITY				
Pennsylvanian		Amsden Formation		0–170(?)	Red thin-bedded to platy siltstone and fine-grained sandstone.
Mississippian	Upper Mississippian	Big Snowy Group	Heath Shale	400±	Dark-gray thin-bedded shale; interleaved limestone.
			Otter Formation	300±	Light-gray claystone, shale, and limestone.
			Kibbey Sandstone	65–100	Pale-red siltstone and fine-grained sandstone; locally a gypsum bed, 15–25 feet thick near middle of unit.
	UNCONFORMITY				
	Upper Mississippian	Madison Group	Mission Canyon Limestone	860[1]	Gray thick-bedded to massive finely to coarsely crystalline limestone; brecciated in upper part.
	Lower Mississippian		Lodgepole Limestone	730[1]	Gray thin-bedded, finely crystalline limestone; much black chert.
	UNCONFORMITY				
Mississippian – Devonian	Lower Mississippian and Upper Devonian	Three Forks Formation	Sappington(?) Member	25	Pale-red to light brown thin-bedded siltstone; few thin dolomite beds.
			Trident(?) Member	15	Light-gray to green massive calcareous claystone.
			Logan Gulch(?) Member	30	Light-gray thin-bedded to platy siltstone; few interleaved dolomite beds.
Devonian	Upper Devonian	Jefferson Dolomite	Birdbear Member	60	Light-gray thin-bedded finely crystalline dolomite.
			Middle member	170	Gray to dark-gray coarsely crystalline dolomite.
			Lower member	100	Light-gray thin- to medium-bedded finely crystalline limestone.
	Upper and Middle Devonian	Maywood Formation		80	Red, light-brown, thin-bedded siltstone; may include some Upper Cambrian Dry Creek Shale at base.
	UNCONFORMITY				
Cambrian	Upper Cambrian	Pilgrim Limestone		115	Light-gray thin- to medium-bedded limestone; contains many intraformational conglomerates.
	Middle Cambrian	Park Shale		170–250	Gray to light-red thin-bedded to platy shale; few nodular limestone beds in upper part.
		Meagher Limestone		75	Gray thin-bedded mottled limestone; dark-gray shale, about 12 feet thick, near base.
		Wolsey Shale		200	Green micaceous glauconitic shaly siltstone.
		Flathead Sandstone		200+	Reddish-brown thin- to thick-bedded medium- to coarse-grained sandstone and conglomeratic sandstone.
	UNCONFORMITY				

[1] W. J. Sando, U.S. Geological Survey, (written commun., 1965).

FIGURE 3.—Generalized section of sedimentary rocks exposed in the Barker quadrangle. Total thickness is 4,830 feet.

grains of hornblende and biotite are scattered irregularly through the groundmass.

WOLF PORPHYRY
(Samples 6–8, table 1)

This granite porphyry was named by Weed (1900, p. 342) after Wolf Butte, a prominent conical igneous mass (just beyond the east margin of the Barker quadrangle) about a quarter of a mile northeast of the Granite Mountain bysmalith (fig. 2). At Wolf Butte, the porphyry forms an asymmetric laccolith of which the butte is but a small part (Pirsson, 1900, p. 498). In the Barker quadrangle the Wolf Porphyry makes up the enormous mass of the Mixes Baldy–Anderson Peak laccolith plus several small dikes and sills.

In hand specimen the Wolf Porphyry is a light-gray granite porphyry crowded with large phenocrysts of round smoky quartz, angular white feldspar, and a few needles of hornblende and flakes of biotite (fig. 4 *A, B*).

YOUNG FELSIC ROCKS

Various rhyolitic and quartz rhyolitic porphyries are here grouped as the young felsic rocks. All are similar; their difference is mainly in the type and size of the phenocrysts. Field relations suggest that all were emplaced after the major intrusions were formed.

RHYOLITE OF GRANITE MOUNTAIN
(Sample 9 of table 1)

Only the west edge of the Granite Mountain bysmalith is within the Barker quadrangle (fig. 2). The bysmalith is capped by a light-gray, dense, hard, and exceedingly fine grained rhyolite. This rock, here called the rhyolite of Granite Mountain, was classified by Pirsson (1900, p. 521–522) as a "Rhyolite-Porphyry (Quartz porphyry)"; he considered it (1900, p. 500) to be the chilled phase of the Wolf Porphyry which makes up the Wolf Butte laccolith. Since his work, however, several prospect pits and access roads have uncovered a fault breccia that separates the rhyolite from the adjacent rocks (see section on "Granite Mountain Bysmalith").

In thin section the rhyolite can be seen to consist of an even-grained holocrystalline mixture of anhedral quartz, alkalic feldspar, and a few scattered grains of plagioclase, biotite, and opaque iron ore. Small phenocrysts, chiefly of albite (An_8) and topaz, are widely scattered through the groundmass.

PORPHYRY OF GALENA CREEK
(Samples 10–12 of table 1)

The Hughesville stock is cut by thin dikes of a distinctive quartz rhyolite porphyry which is here called the porphyry of Galena Creek (fig. 4*C, D*). These dikes are 10–50 feet wide, and some can be traced for several miles.

The porphyry is characterized by abundant large round smoky quartz phenocrysts in a dense almost aphanitic light-brown groundmass. It resembles the finer grained facies of the Wolf Porphyry, but it is believed to be much younger.

The thin section is dominated by the quartz phenocrysts, many of which are well rounded (fig. 4*D*). Other quartz grains, however, are euhedral, and examples of good bipyramidal crystals are common. Sanidine is the alkalic feldspar, and Carlsbad twins are plentiful. A few sparse grains of albite (An_8) and biotite are present. The groundmass consists of a holocrystalline mixture chiefly of anhedral quartz and alkalic feldspar.

SNOW CREEK(?) PORPHYRY
(Samples 13–15 of table 1)

Quartz rhyolite porphyry dikes and plugs intrude the Precambrian metamorphic rocks in the southwest corner of the Barker quadrangle (Witkind, 1971). These small intrusions are believed to be apophyses from a large buried felsic pluton, a small part of which is exposed along Carpenter and Snow Creeks near Neihart (fig. 31). This exposed part has been mapped by Johnson (1964), who considered it to be a compound body consisting of four very similar quartz rhyolite porphyries. In the Neihart quadrangle similar rocks have been grouped and mapped as the Snow Creek Porphyry by Keefer (1969).

These dikes and plugs are marked by quartz and feldspar phenocrysts set in a light-gray aphanitic groundmass; none of the phenocrysts are as large or as conspicuous as those in the porphyry of Galena Creek.

In thin section the various porphyries are characterized by abundant clusters of feldspar phenocrysts —both alkalic (orthoclase) and plagioclase (albite, An_8) phenocrysts are represented—in a microgranular groundmass of anhedral quartz and alkalic feldspar. Some of these clusters are marked by micrographic intergrowths of quartz. Round and euhedral quartz phenocrysts are common, and a few form clusters. Biotite is common as phenocrysts and in the groundmass in some of the rhyolites but is absent from others.

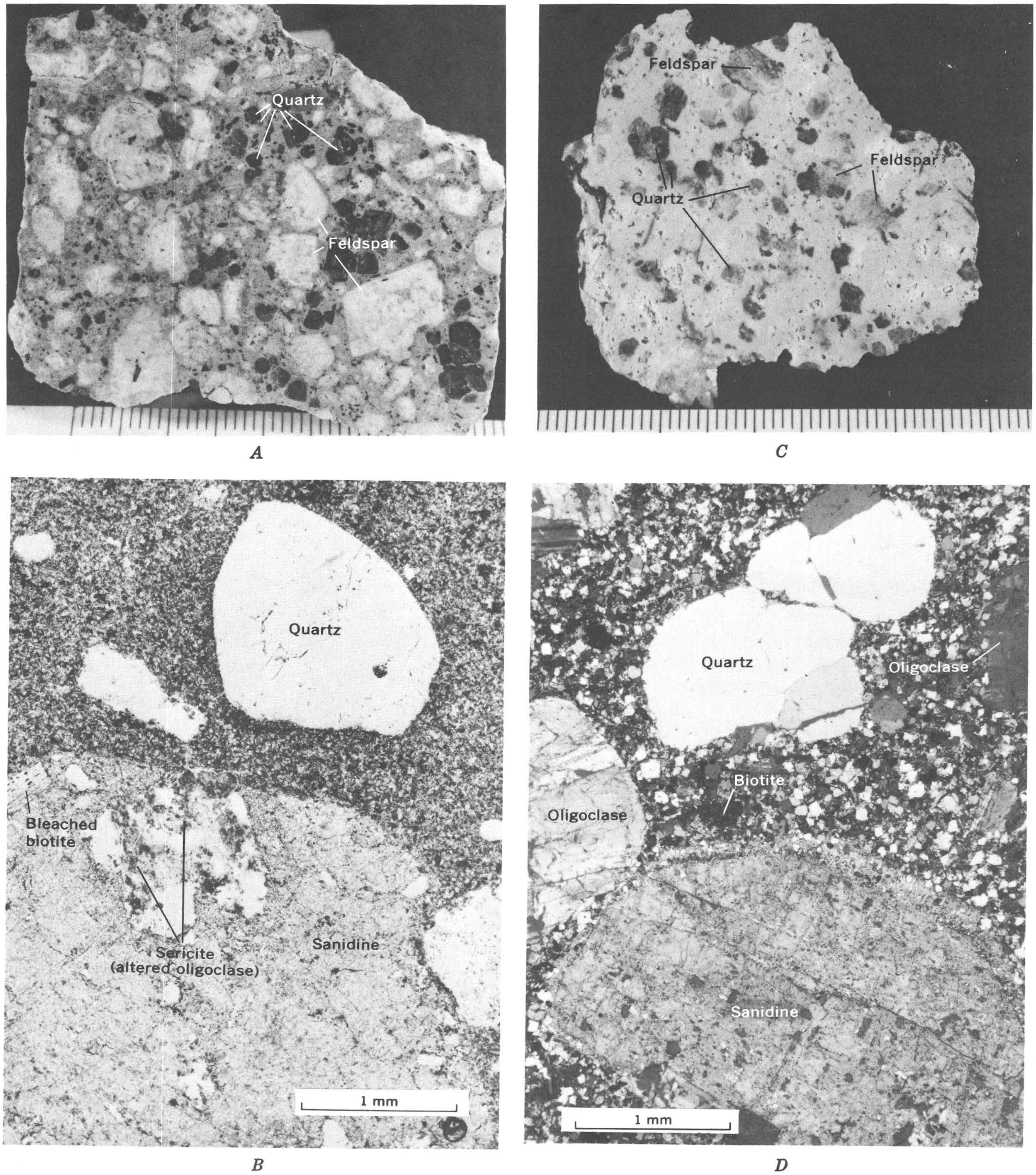


FIGURE 4.—Felsic igneous rocks from the Barker quadrangle. Scale of hand specimens in centimeters (smallest divisions are millimeters). Photographs by R. B. Taylor, Sandra Brennan, and Louise Hedricks. *A*, *B*. Wolf Porphyry. *A*, Hand specimen. Light-gray granite porphyry crowded with phenocrysts of white angular feldspar and round smoky quartz set in an aphanitic groundmass. *B*, Photomicrograph showing nature of groundmass and juxtaposition of phenocrysts. *C*, *D*. Porphyry of Galena Creek. *C*, Hand specimen. Light-brown rhyolite porphyry containing abundant round smoky quartz grains, sparse feldspar laths, and biotite flakes scattered through a fine-grained groundmass. *D*, Photomicrograph showing general nature of phenocrysts and microgranular texture of groundmass.

CHEMISTRY OF THE FELSIC ROCKS

The older and younger felsic rocks differ strikingly in their silica content; the younger felsic rocks consistently contain more silica (~76 percent) than the older ones (~72 percent). The percentages of the other major oxides fail to show such a strong contrast. In general, the younger felsic rocks contain somewhat less magnesia, iron, and lime than the older felsic rocks, but they contain comparable amounts of soda and potash (fig. 5).

INTERMEDIATE ROCKS
(60–70 percent silica)

The intermediate rocks form the Hughesville stock, many of the laccoliths, and most minor intrusions. Details of the petrography and chemistry of these rocks are given in table 2.

QUARTZ MONZONITE OF HUGHESVILLE
(Sample 1 of table 2)

The Hughesville stock, composed of the quartz monzonite of Hughesville, is a crudely circular mass about 1 mile in diameter which underlies parts of sections 6 and 7, T. 15 N., R. 9 E. (fig. 6). Virtually all the major ore bodies were either in the stock or adjacent to it, and as a result it is pitted with mines and innumerable prospect holes. The abandoned mining towns of Barker and Hughesville are within its confines.

Weed (1900, p. 353) originally described this rock under the heading "Hughesville syenite stock"; Pirsson (1900, p. 465) in the same report, referred to the identical rock as the "Barker syenite." The rock, however, is not a syenite, for it contains considerable plagioclase and quartz. Although Pirsson (1900, p. 466) commented that "The amount of plagioclase is always small in comparison with the alkali feldspar," the samples I have examined invariably contain about equal amounts of orthoclase (38 percent) and oligoclase (37 percent). Furthermore, much quartz is in the groundmass. Pirsson (1900, p. 467) noted this, and commenting on a chemical analysis of the rock stated: "The silica is toward the upper limit of the syenite group, verging on the granites, and this explains the amount of quartz which is present. Since the quartz, however, is small and entirely microscopic, it appears best to classify the rock as a syenite rather than a granite." Although I have in the past (Witkind, 1970, 1971), following previous usage, employed the term "syenite" for this rock, I believe the term is both incorrect

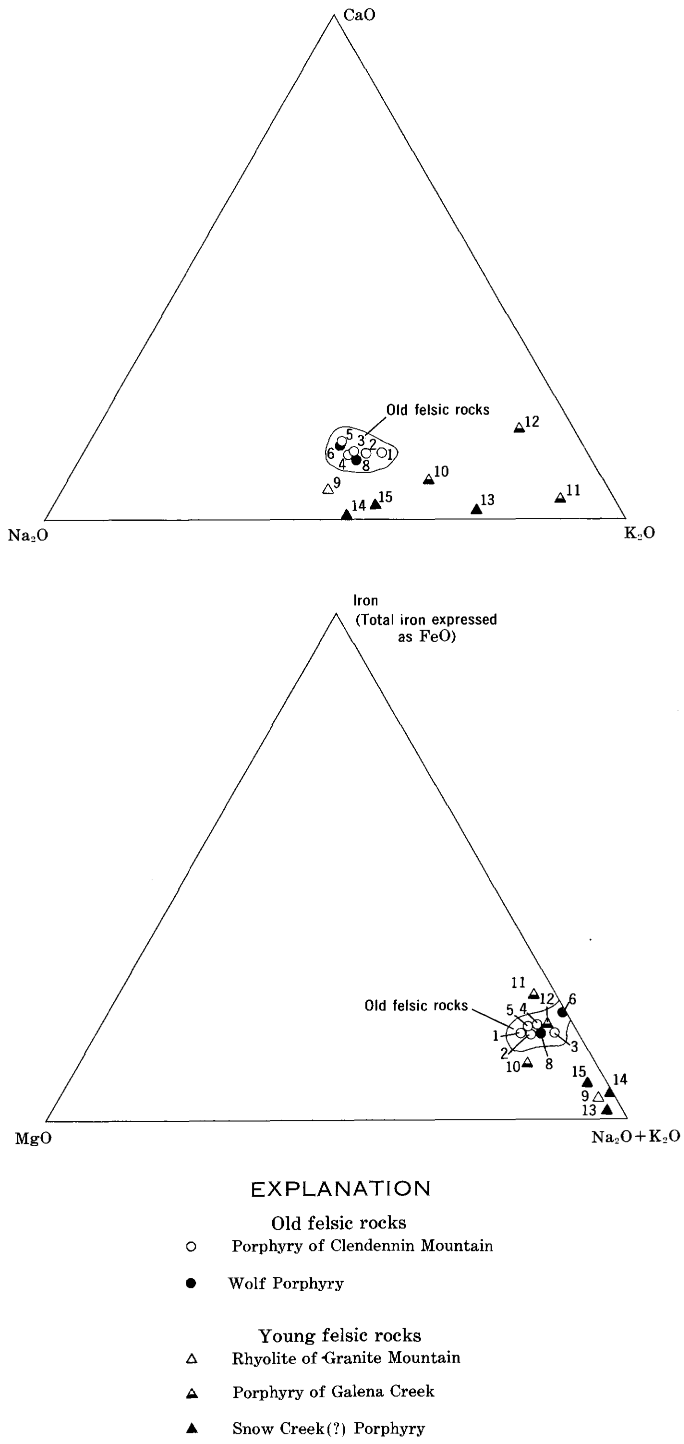


FIGURE 5.—Some chemical characteristics of old and young felsic rocks from the Barker quadrangle. See table 1 for locations; sample 7 of highly altered Wolf Porphyry omitted.

TABLE 2.—*The petrography and chemical composition (in percent) of intermediate rocks from the Barker*

[Rapid-rock analyses. Analysts: P. L. D. Elmore, Samuel Botts,

Area	Barker quadrangle						
Intrusion	Hughesville stock	Otter laccolith	Sill northeast of Irene Peak	Barker laccolith	Taylor Mountain laccolith	Butcherknife Mountain laccolith	Dry Wolf laccolith
Rock name	Quartz monzonite of Hughesville.	Barker porphyry					
Petrography: Rock type	Quartz monzonite	Quartz latite phorpyry					
Petrography: Color	Brownish gray	Light gray to gray					
Petrography: Texture	Fine to coarse grained.	Porphyritic					
Petrography: Phenocrysts	Locally tabular feldspar laths.	White angular feldspars and black flakes of biotite and needles of					
Petrography: Groundmass	Intergrown unoriented mixture of feldspar, hornblende, biotite.	Holocrystalline mixture of quartz, alkalic feldspar, and a few grains					
Petrography: Mode (percent)	Orthoclase, 38.3; oligoclase, 36.8; quartz, 9.2; biotite, 6.0; salite, 4.5; others, 5.2.	Sanidine,46.1; oligoclase (An_{21}), 26.9; quartz, 17.7; hornblende, 4.9; biotite, 1.6; opaque minerals, 2.0;					

Oxides

	1	2	3	4	5	6	7	8	9
Laboratory No	163688	163678	W-169659	163681	163692	163693	165857	165854	165858
Field No	WL-79	WL-37	WL-38	WL-44	WL-115	WL-118	WL-169	WL-148	WL-170
SiO_2	61.2	62.4	60.6	66.8	67.1	67.6	68.5	63.7	64.6
Al_2O_3	16.4	16.1	15.8	16.4	16.1	16.3	16.1	15.9	15.9
Fe_2O_3	3.2	3.4	3.0	2.1	1.1	1.1	1.0	2.0	1.3
FeO	2.2	1.5	2.5	1.0	1.2	1.1	1.1	1.8	1.8
MgO	1.9	2.2	2.9	1.1	1.0	1.5	1.1	2.4	2.6
CaO	3.0	3.0	3.9	2.0	2.1	2.2	2.0	3.0	3.1
Na_2O	4.6	4.2	3.9	4.5	4.1	4.6	4.7	4.5	4.5
K_2O	4.5	4.2	4.3	4.3	4.2	3.7	4.0	3.8	3.8
H_2O^-	.16	.59	.24	.20	.61	.29	.07	.61	.10
H_2O^+	.36	.81	1.2	.62	.89	.48	.59	1.0	1.6
TiO_2	.92	.47	.62	.35	.25	.24	.26	.48	.40
P_2O_5	.44	.46	.52	.34	.27	.22	.18	.34	.23
MnO	.22	.07	.12	.06	.05	.03	.03	.07	.06
CO_2	.15	<.05	<.05	.14	.38	.06	.11	.08	.13
Sum	99.25	99.45	99.65	99.91	99.35	99.74	99.42	99.68	100.12

C.I.P.W. norms

	1	2	3	4	5	6	7	8	9
Q	9.61	13.70	10.41	19.60	22.69	19.47	20.42	13.79	13.82
or	26.79	29.96	25.50	25.43	24.98	22.11	23.70	22.53	22.43
ab	39.22	35.74	33.12	38.11	34.92	39.35	39.87	38.20	38.03
an	10.89	11.63	12.95	6.82	6.29	11.03	8.07	12.00	11.95
C	0	0.41	0	1.85	2.53	.74	1.10	0	0
di en	.09	0	.89	0	0	0	0	.06	.33
di fs	.01	0	.16	0	0	0	0	.01	.09
di wo	.11	0	.14	0	0	0	0	.08	.46
hy en	4.68	5.51	6.38	2.74	2.51	3.38	2.75	5.93	6.14
hy fs	.28	0	1.16	0	.98	1.06	.82	.98	1.60
mt	4.68	3.72	4.37	2.41	1.61	1.61	1.45	2.91	1.88
ap	1.05	1.10	1.24	.81	.64	0	.42	.81	.54
il	1.76	.90	1.18	.67	.48	.08	.50	.91	.76
hm	0	.85	0	.44	0	0	0	0	0

[1] See Vine (1956).

1. West valley wall of Galena Creek, sec. 7, T. 15 N., R. 9 E. (unsurveyed).
2. North valley wall of McGee Coulee, sec. 28, T. 16 N., R 8 E.
3. West valley wall of Big Otter Creek, N½ sec. 36, T. 16 N., R 8 E.
4. Ridge at head of McKay Gulch, NW¼ sec. 1, T. 15 N., R. 8 E. (unsurveyed).
5. Head of Bower Gulch, N½ sec. 7, T. 15 N., R. 10 E. (unsurveyed).
6. Ridge between Frenchies Coulee and Bower Gulch, N½ sec. 12, T. 15 N., R. 9 E.
7. Near head of Butcherknife Gulch, NE¼ sec. 35, T. 15 N., R. 9 E.
8. One-half mile north of crest of Butcherknife Mountain, SE¼ sec. 27, T. 15 N., R. 9 E. (unsurveyed)
9. East valley wall of Dry Wolf Creek, W½ sec. 6, T. 14 N., R. 10 E.

and Neihart quadrangles, Little Belt Mountains, and of a similar rock from the Stanford-Hobson area

Gillison Chloe. Lowell Artis, H. Smith, John Glenn, and James Kelsey]

				Neihart quadrangle	Stanford–Hobson area [1]	
Irene Peak sill	Sill on Butcherknife Mtn.	Sill on Limestone Butte	Sill	Big Baldy laccolith	Four-M laccolith	Windham Dome
			Chocolate prophyry of Weed (1900). Chocolate-brown porphyry.	Barker (?) Porphyry.		
			Quartz latite porphyry	Quartz latite prophyry.		
			Grayish brown	Light gray to gray.		
			Porphyritic	Porphyritic.		
hornblende			Light-gray angular feldspars and dark-gray to black needles of mafic minerals.	White angular feldspars and black flakes of biotite and needles of hornblende.		
of plagioclase feldspar			Microgranular groundmass composed of quartz and alkalic feldspar.	Holocrystalline mixture of quartz, alkalic feldspar, and a few grains of plagioclase feldspar.		
apatite, sphene, others, 0.8			Orthoclase, 47.4; oligoclase (An_{28}), 31.6; quartz, 8.1; hornblende, 8.8; biotite, 1.0; salite, 0.2; others, 3.7.	Not available.		

Oxides—Continued

10	11	12	13	14	15	16	17	18	19
163680 WL–43	165855 WL–165	W–167706 WL–483	163687 WL–78	165859 WL–176	165860 WL–177	165856 WL–167	D–112804–W WL–4	D–112802–W WL–1	W–169052 WL–496
67.1	65.1	68.1	65.7	65.0	65.6	66.3	66.0	67.2	67.4
15.3	16.5	16.2	16.3	16.2	15.7	15.6	16.0	16.0	16.2
1.7	1.3	2.1	1.3	1.7	1.4	1.3	1.2	1.5	3.3
1.5	1.3	.04	1.4	.60	1.2	1.7	1.8	1.1	.60
1.6	1.6	.35	1.1	1.1	1.7	1.9	2.5	2.0	1.0
2.8	2.8	2.2	2.2	3.0	2.4	2.8	2.6	2.1	2.4
4.5	5.0	4.1	5.2	4.3	4.3	4.5	4.6	4.0	3.9
3.8	3.6	4.5	3.8	3.6	3.5	3.9	3.8	4.3	4.4
.18	.55	.56	.25	.62	1.2	.38	1.3	.40	.37
.49	.95	1.1	.75	1.2	1.4	.56	0	1.0	.73
.35	.33	.46	.34	.30	.31	.40	.36	.34	.34
.31	.22	.19	.20	.21	.21	.28	.23	.24	.19
.07	.05	0	.04	.03	.04	.05	.05	.05	.05
.06	.31	.15	.64	1.7	.80	.07	<.05	<.05	.15
99.76	99.61	100.05	99.22	99.56	99.76	99.74	100.49	100.28	101.03

C.I.P.W. norms—Continued

18.92	14.99	22.73	16.54	23.48	22.07	16.87	15.29	20.61	21.96
22.51	21.36	26.58	22.63	21.37	20.73	23.11	22.35	25.34	25.74
38.17	42.47	34.68	44.35	36.55	36.47	38.18	38.73	33.75	32.66
10.35	10.54	8.72	5.61	2.78	5.49	10.88	11.03	8.51	9.62
0	.53	1.39	1.61	4.24	2.84	0	0.26	1.63	1.45
.36	0	0	0	0	0	.23	0	0	0
.08	0	0	0	0	0	.07	0	0	0
.49	0	0	0	0	0	.32	0	0	0
3.64	4.00	.87	2.76	2.75	4.24	4.52	6.20	4.97	2.47
.82	.87	0	1.02	0	.61	1.41	1.80	.31	0
2.47	1.89	0	1.90	1.17	2.34	1.89	1.73	2.17	1.10
.74	.52	.45	.48	.50	.50	.66	.54	.57	.45
.67	.63	.08	.65	.57	.59	.76	.68	.64	.64
0	0	2.10	0	.90	0	0	0	0	2.51

10. Irene Peak, W½ sec. 36, T. 16 N., R. 8 E.
11. Crest of Butcherknife Mountain, C. sec. 34, T. 15 N., R. 9 E. (unsurveyed).
12. Ridge at head of unnamed tributary to Hansens Coulee, NW¼ sec. 35, T. 17 N., R. 8 E.
13. North valley wall of Dry Fork of Belt Creek, N½, sec. 19, T. 15 N., R. 9 E.
14. Mouth of Gray Creek, N½ sec. 29, T. 15 N., R. 9 E. (unsurveyed)
15. North valley wall at head of Blankenship Gulch, E½ sec. 21, T. 15 N., R. 9 E.
16. Ridge at head of Snow Creek, SE¼ sec. 4, T. 14 N., R. 9 E.
17. Near head of Running Wolf Creek, NW¼ sec. 5, T. 14 N., R. 11 E.
18. East valley wall of Coyote Creek, E½, sec. 13, T. 16 N., R. 12 E.
19. North valley wall of Willow Creek, NE¼ sec. 19, T. 16 N., R. 13 E.

496-189 O - 73 - 3

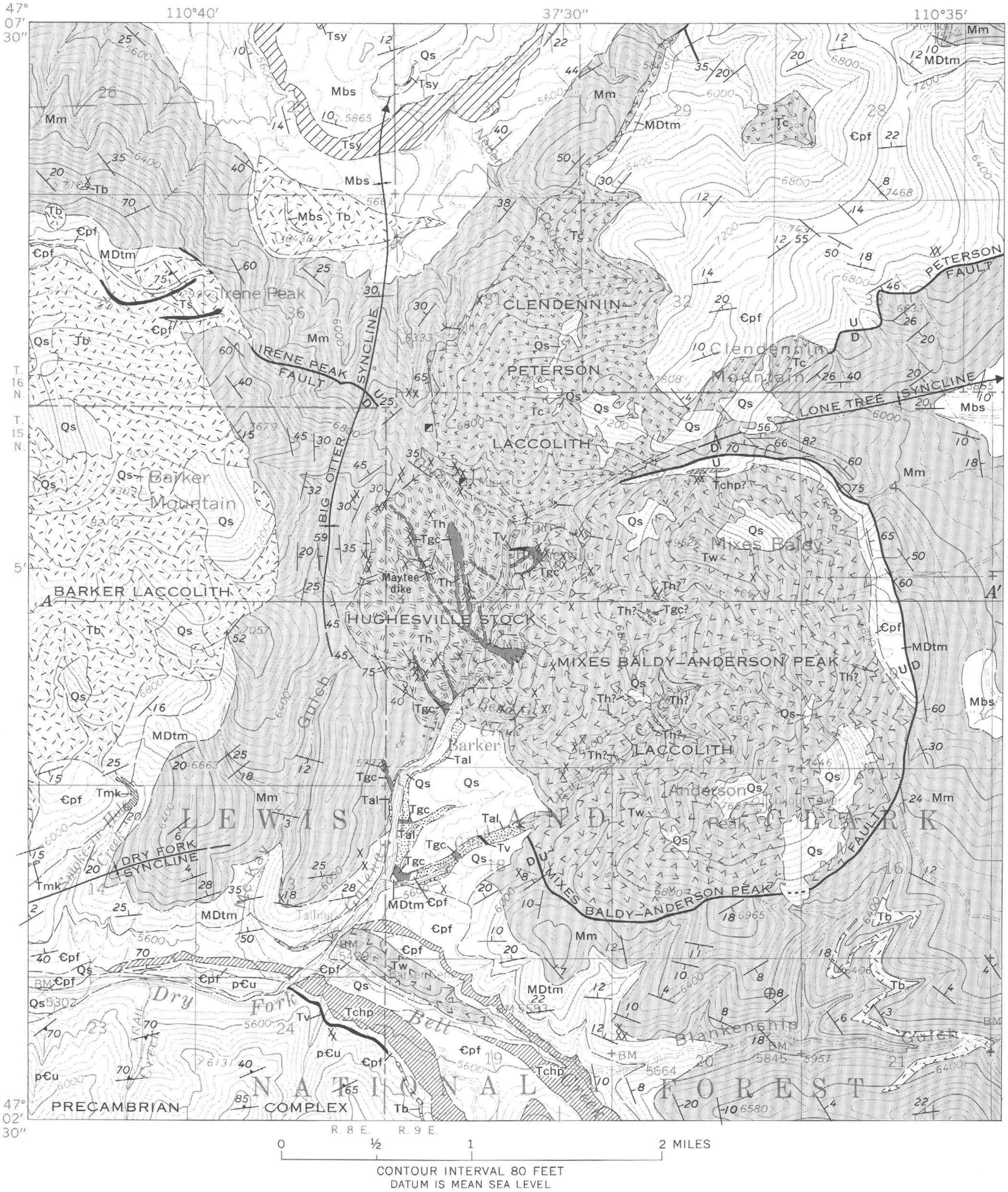
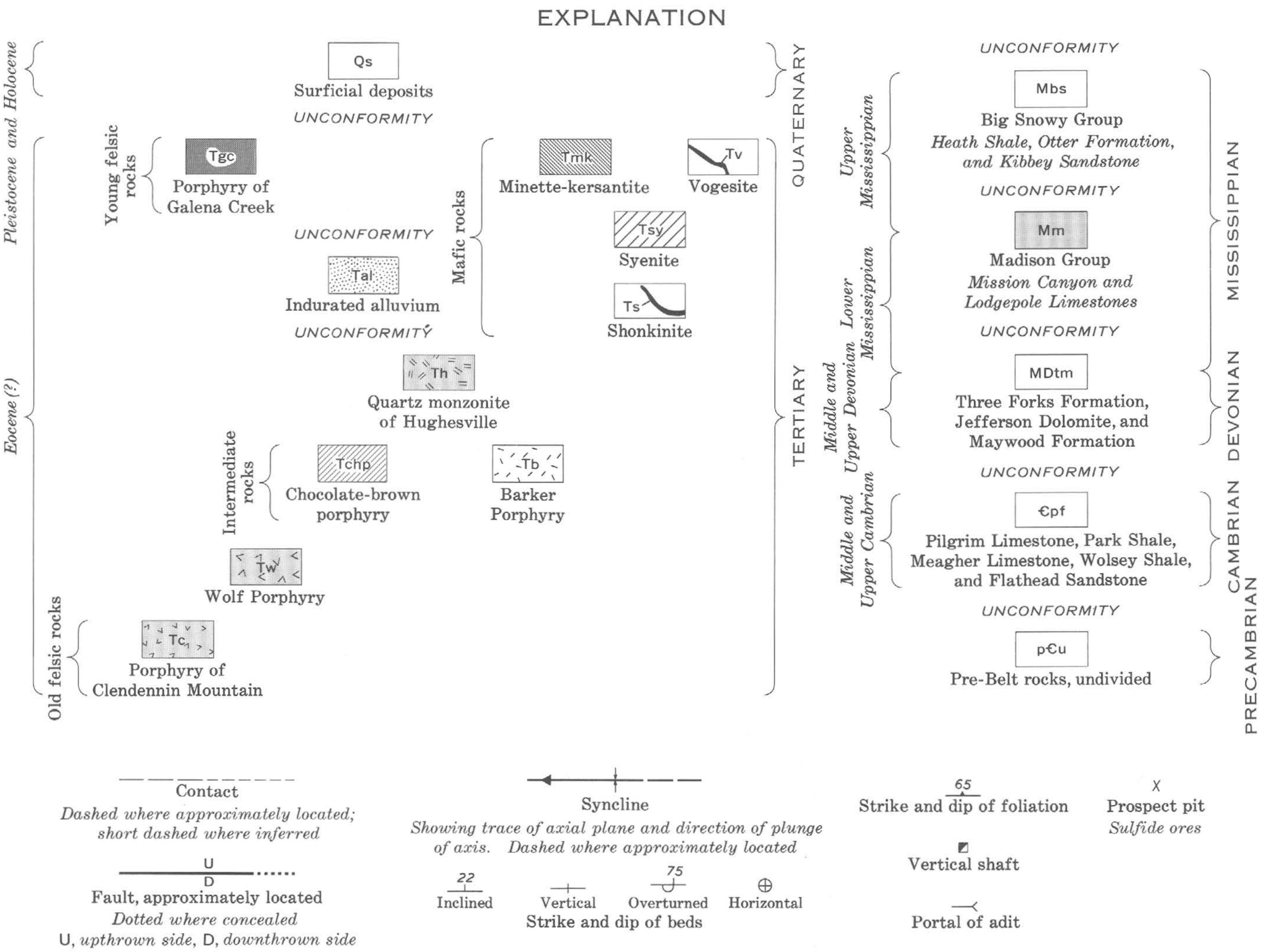
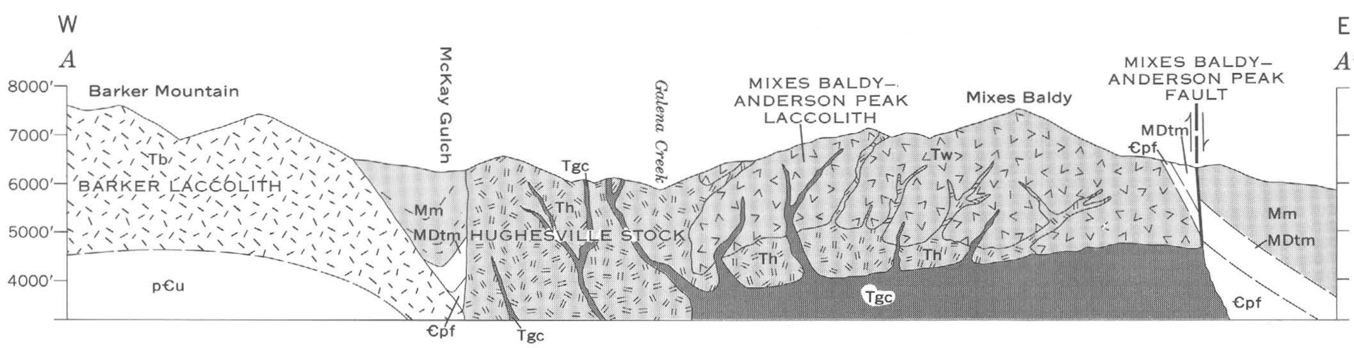


FIGURE 6.—The Hughesville stock and adjacent intrusions. Geology by I. J. Witkind, assisted by J. P. Thorson, 1964, B. L. Peterson, 1965, and T. E. Redlinger, 1966. Base from U.S. Geological Survey, Barker quadrangle, 1:62,500, 1961. Section and explanation on opposite page.


EXPLANATION
Qs
Surficial deposits
UNCONFORMITY
Pleistocene and Holocene
QUATERNARY
Young felsic rocks
Tgc
Porphyry of Galena Creek
UNCONFORMITY
Tal
Indurated alluvium
UNCONFORMITY
Mafic rocks
Tmk
Minette-kersantite
Tv
Vogesite
Tsy
Syenite
Ts
Shonkinite
Th
Quartz monzonite of Hughesville
Intermediate rocks
Tchp
Chocolate-brown porphyry
Tb
Barker Porphyry
Tw
Wolf Porphyry
Old felsic rocks
Tc
Porphyry of Clendennin Mountain
Eocene (?)
TERTIARY
UNCONFORMITY
Mbs
Big Snowy Group
Heath Shale, Otter Formation, and Kibbey Sandstone
Upper Mississippian
UNCONFORMITY
Mm
Madison Group
Mission Canyon and Lodgepole Limestones
Lower Mississippian
MISSISSIPPIAN
UNCONFORMITY
MDtm
Three Forks Formation, Jefferson Dolomite, and Maywood Formation
Middle and Upper Devonian
DEVONIAN
UNCONFORMITY
€pf
Pilgrim Limestone, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone
Middle and Upper Cambrian
CAMBRIAN
UNCONFORMITY
p€u
Pre-Belt rocks, undivided
PRECAMBRIAN
Contact
Dashed where approximately located; short dashed where inferred
U
D
Fault, approximately located
Dotted where concealed
U, upthrown side, D, downthrown side
Syncline
Showing trace of axial plane and direction of plunge of axis. Dashed where approximately located
22
Inclined
Vertical
75
Overturned
Horizontal
Strike and dip of beds
65
Strike and dip of foliation
Vertical shaft
Portal of adit
X
Prospect pit
Sulfide ores


W
A
E
A′
8000′
7000′
6000′
5000′
4000′
Barker Mountain
Tb
BARKER LACCOLITH
p€u
McKay Gulch
Mm
MDtm
€pf
HUGHESVILLE STOCK
Tgc
Th
Galena Creek
MIXES BALDY—ANDERSON PEAK LACCOLITH
Mixes Baldy
Tw
MIXES BALDY—ANDERSON PEAK FAULT
MDtm
€pf
Mm
MDtm
€pf

and inappropriate and here suggest that it be known as the "quartz monzonite of Hughesville." The rock is classifiable as a quartz monzonite (2–2–6″) in the Johannsen (1939, p. 141–148) classification.

The quartz monzonite of Hughesville is brownish gray, fine to coarse grained, dense, and hard. In most exposures it is equigranular, but locally it is markedly porphyritic and has large tabular feldspar laths.

In thin section it can be seen to consist of a tightly intergrown unoriented mixture of orthoclase, oligoclase (An_{23}), quartz, common hornblende, biotite, clinopyroxene (salite), opaque iron ores, and accessory minerals such as sphene and apatite.

Several dikes and plugs of latite porphyry that intrude the Mixes Baldy–Anderson Peak laccolith resemble somewhat those igneous rocks that make up the east edge of the Hughesville stock.

BARKER PORPHYRY
(Samples 2–12 of table 2)

Most of the floored intrusions and their related dikes and sills are composed of a quartz latite porphyry named the Barker Porphyry by Weed (1900, p. 356). Comparable rocks exposed along the valley walls of Dry Fork Belt Creek and called the "chocolate porphyry" (samples 13–15 of table 2) by Weed (1900, p. 349–351) are similar mineralogically and chemically to the Barker Porphyry.

The rock invariably is some shade of gray and is markedly porphyritic (fig. 7). In hand specimen it is distinguished by abundant large white angular feldspar phenocrysts and by black flakes and needles of mafic minerals scattered irregularly through an aphanitic groundmass (fig. 7 *A*, *B*). In some exposures the phenocrysts are so large and plentiful that the rock looks coarse grained, but near its contact with sedimentary units it develops a chilled zone as much as 10 feet thick. Here the phenocrysts dwindle in size, and the rock takes on a dense fine-grained appearance much like that of the rhyolite porphyry of Clendennin Mountain. (See section on "Porphyry of Clendennin Mountain.")

In thin section it can be seen that the phenocrysts of sanidine, oligoclase (An_{23}), hornblende, biotite, and pyroxene are set in a holocrystalline mixture of quartz, alkalic feldspar, and a few grains of plagioclase feldspar. Poikilitic texture is common in the groundmass (Pirsson, 1900, p. 505), with minute unoriented specks of alkalic feldspar in the quartz. Quartz, common in the groundmass, is rarely found as phenocrysts. Common accessory minerals are apatite, sphene, magnetite, and opaque iron ore.

CHEMISTRY OF THE INTERMEDIATE ROCKS

The intermediate rocks differ from the felsic rocks in having less silica ($\sim$66 percent versus $\sim$74 percent), more magnesia, iron, and lime; but they have about comparable amounts of soda and potash. A comparison of the chemistry of the intermediate rocks suggests a general pattern of $MgO<CaO<K_2O<Na_2O$.

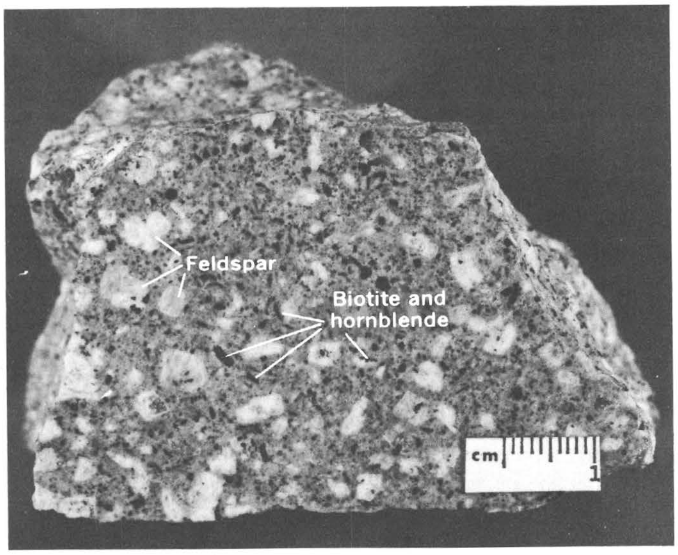
In figure 8 the percentages of various oxides are plotted on a silica variation diagram. The grouping indicates clearly that both large and small intrusions from different parts of the area were formed by the same magma. This close similarity is also shown on various triangular diagrams (fig. 9).

Three of the intrusions—the Hughesville stock, the Otter laccolith, and the sill northeast of Irene Peak (samples 1, 2, and 3 respectively of table 2 and figs. 8 and 9)—contain significant amounts of clinopyroxene and so differ somewhat mineralogically from other intrusions of comparable size and shape. Despite this difference, the chemistry of the rocks from these intrusions deviates only in having less silica ($\sim$61 percent versus $\sim$66 percent). I have no explanation for this divergence.

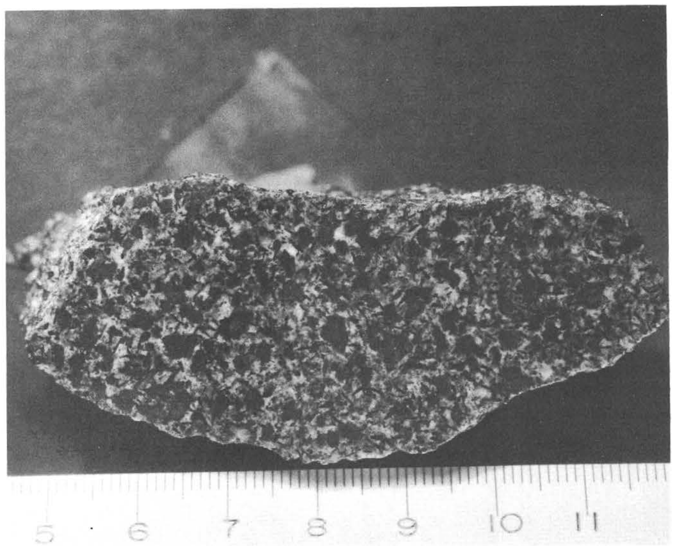
In general, there seems to be a gradational transition from the high-silica rocks ($\sim$74 percent SiO_2) which form the large felsic intrusions through high-silica intermediate rocks ($\sim$68 percent SiO_2), as found in phases of the Barker and Butcherknife laccoliths, to other intermediate rocks that form the other laccoliths and which contain but moderate amounts of silica ($\sim$65 percent). The low-silica end member of this sequence is the quartz monzonite that forms the Hughesville stock ($\sim$61 percent SiO_2).

MAFIC ROCKS

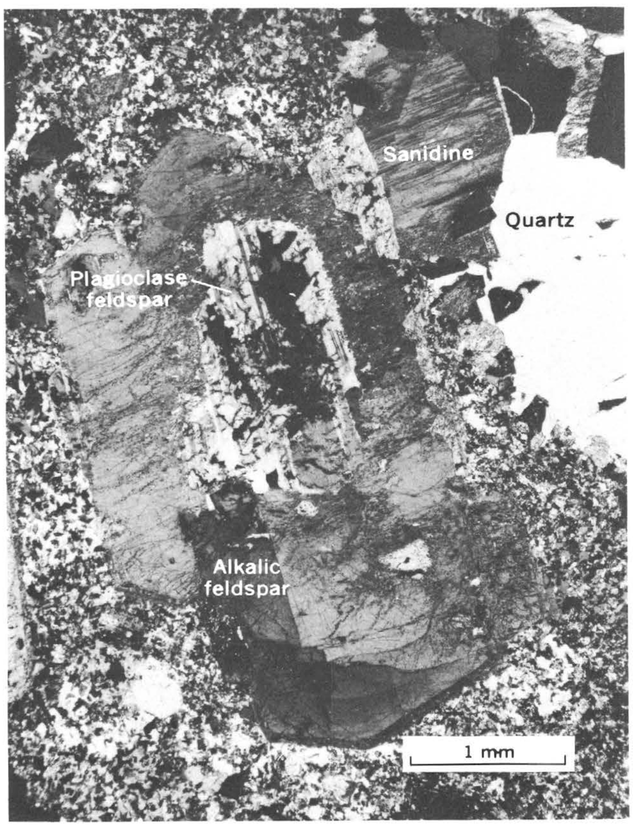
In striking contrast to the light-colored felsic and intermediate rocks are the gray to dark-gray mafic rocks which cut both sedimentary and igneous rocks. They form thin sills, dikes, and small plugs. These rocks have been divided into five groups: (1) shonkinite, composed of orthoclase, pyroxene, olivine, and biotite; (2) plagioclase shonkinite, similar to the shonkinite, but containing much sodic plagioclase; (3) syenite, composed of much alkalic feldspar and some plagioclase feldspar, and moderate amounts of biotite and pyroxene; (4) minette-ker-



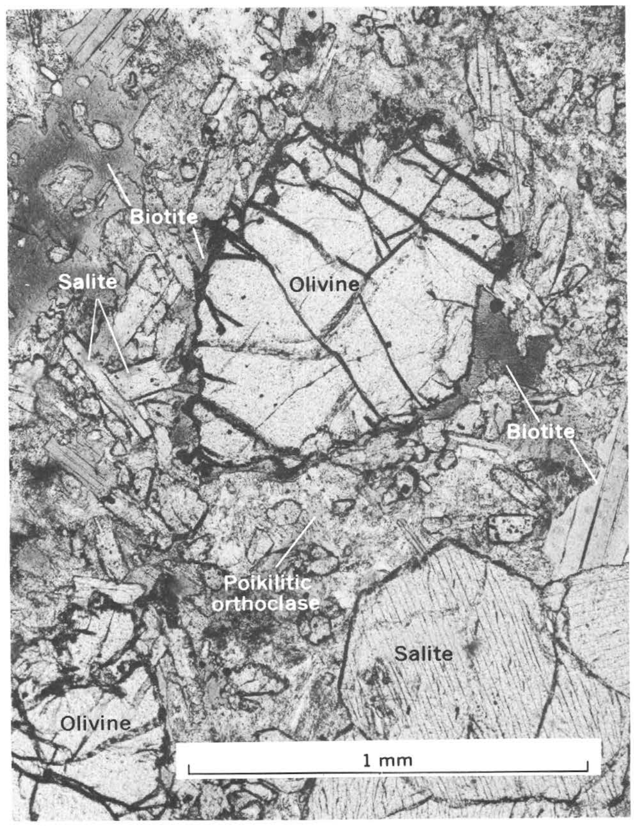
A



C



B



D

FIGURE 7.—Intermediate and mafic igneous rocks from the Barker quadrangle. Scale of both hand specimens in centimeters. Photographs by R. B. Taylor, Sandra Brennan, and Louise Hedricks. *A*, *B*. Barker Porphyry. A, Hand specimen. Light-gray quartz latite porphyry characterized by angular white laths of feldspar and black needles of hornblende and flakes of biotite in a fine-grained groundmass. *B*, Photomicrograph showing sanidine, quartz, and a plagioclase grain jacketed by alkalic feldspar enclosed in a microgranular groundmass. *C*, *D*. Shonkinite. *C*, Hand specimen. Dark-gray to black mafic rock marked by medium- to coarse-grained texture. Large dark-gray to black partly rounded minerals are olivine. *D*, Photomicrograph showing ovoid olivine grain broken by curving fractures and encircled by biotite flakes.

santite, composed of biotite, orthoclase, and plagioclase; and (5) vogesite, similar to the minette-kersantite, but including much pyroxene or hornblende (table 3). Petrographic details and modal and chemical analyses of these rocks are given in table 4.

The mafic rocks do not seem to be distributed at random. Most of the shonkinite, plagioclase shonkinite, and syenite crops out in the northwestern part of the Barker quadrangle (closer to the shonkinite-rich Highwood Mountains); most of the minette-

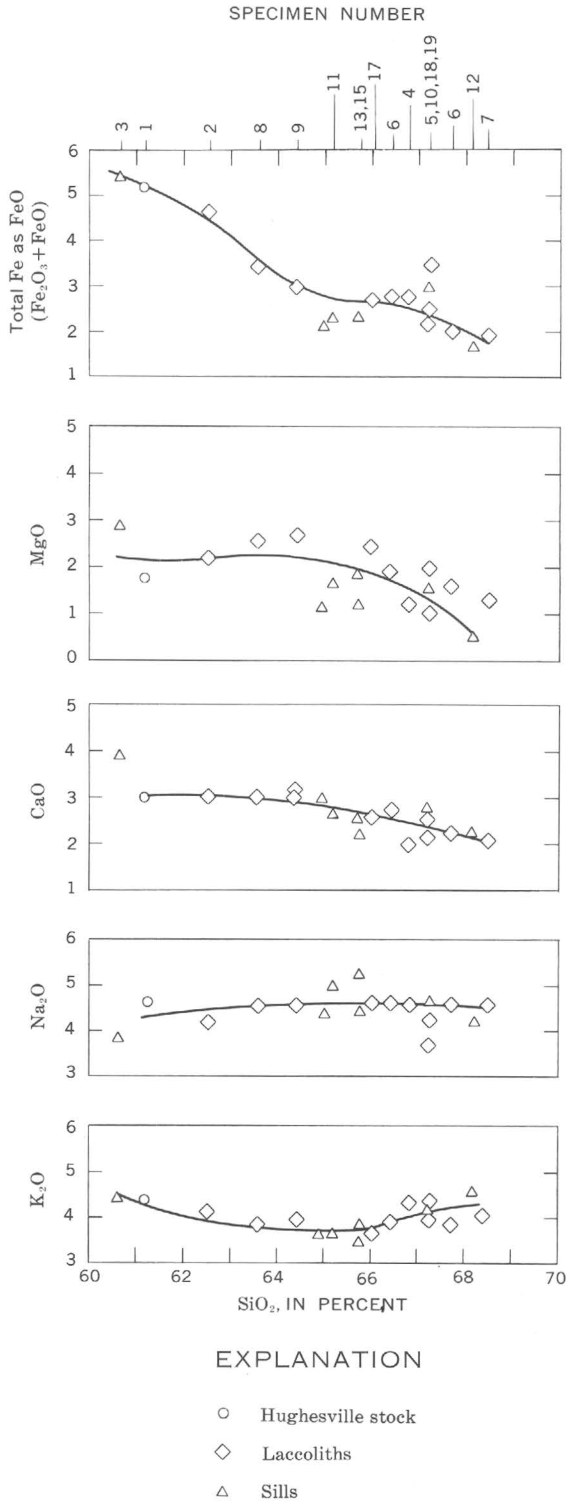


FIGURE 8.—Silica variation diagrams for intermediate rocks from both large and small intrusions scattered through the Barker quadrangle. The grouping indicates that the intrusions came from the same magma. Specimen numbers are identified in table 2.

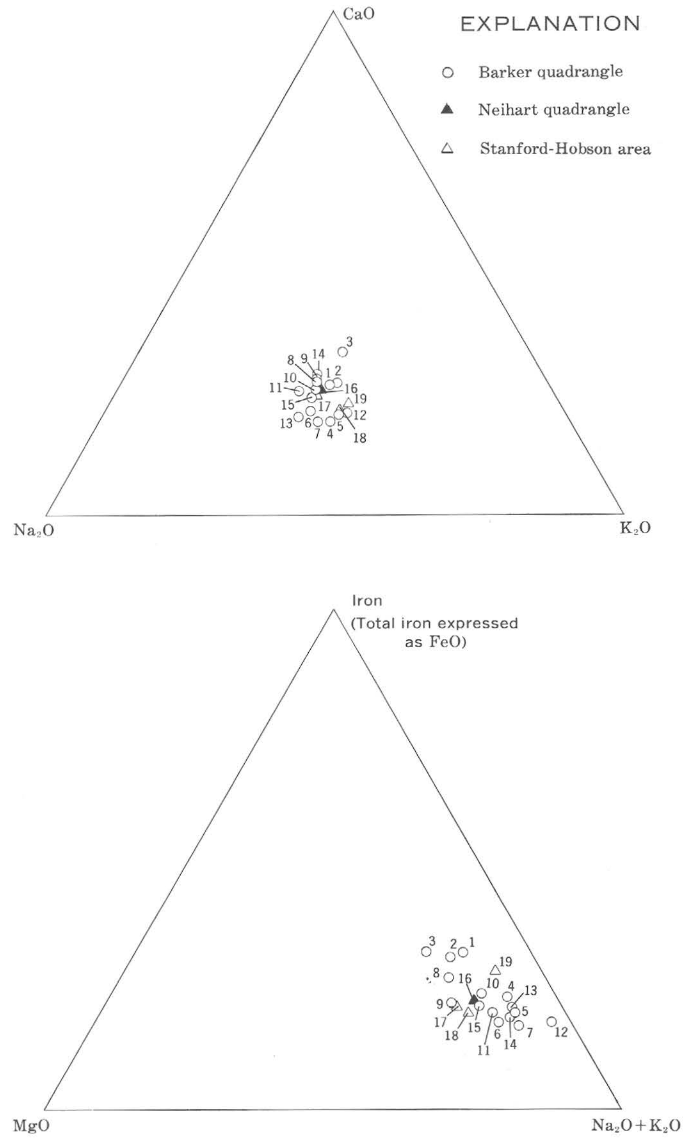


FIGURE 9.—Comparison of some chemical characteristics of the intermediate rocks from the Barker quadrangle with comparable rocks from the Neihart quadrangle and from the Stanford-Hobson area. See table 2 for sample locations, and Vine (1956, p. 454–455) for location of samples from the Stanford-Hobson area.

TABLE 3.—*Lamprophyre terminology*

		Dominant feldspar	
		Orthoclase	Plagioclase
Dominant mafic	Biotite	Minette	Kersantite
	Pyroxene or amphibole	Vogesite	Spessartite

kersantite and vogesite is in the southern half. I am uncertain whether this pattern has more than local significance, inasmuch as shonkinite is also exposed to the south at Yogo Peak (Weed, 1900, p. 397)

SHONKINITE
(Sample 1 of table 4)

The largest shonkinite intrusion, a blunt plug about 1,600 feet wide at its base and some 400 feet high, bows up and alters Paleozoic (Big Snowy Group) and Mesozoic (Ellis Group and Morrison Formation) sedimentary rocks exposed along Little Otter Creek in the SE¼ sec. 18, T. 17 N., R. 8 E. (Witkind, 1971). In this general area shonkinite sills, some as much as 160 feet thick, are common—especially in the Heath Shale of the Big Snowy Group.

The shonkinite is dark gray and even grained, ranging from medium to coarse grained with the coarser types much more common (fig. 7*C, D*). Hand specimens show discrete grains of biotite, pyroxene, and olivine enclosed in a matrix of feldspar.

In thin section the rock is seen to consist of a heterogeneous crystalline mixture of olivine, clinopyroxene, biotite, and some plagioclase (albite, An_{5-7}) that is tightly cemented by orthoclase. Many of the orthoclase grains are poikilitic, enclosing grains of pyroxene and biotite. Orthoclase dominates the assemblage and is wrapped around all other grains. Accessory minerals include apatite, sphene, ilmenite, magnetite, and the zeolites analcime and thomsonite.

The shonkinites grade from those in which there is but little plagioclase feldspar to others in which plagioclase feldspar is a major constituent.

PLAGIOCLASE SHONKINITE
(Sample 2 of table 4)

Several minor plagioclase shonkinite intrusions around Barker Mountain are indistinguishable in hand specimen from the shonkinites; their greater plagioclase content is apparent only in thin section.

The plagioclase feldspar is albite (An_{5-7}), and it dominates the mineral assemblage. It forms elongate laths that are enveloped by alkalic feldspar.

Many of the olivine grains have been altered to a fibrous mesh of alteration products, which (because they probably include both antigorite and chrysotile) are here grouped as serpentine.

SYENITE
(Samples 3–5 of table 4)

A few thin syenite sills are interlayered in the sedimentary units of the Big Snowy Group exposed along the valley walls of both Little and Big Otter Creeks. And several more are exposed in the steeply tilted beds that form part of the nose of the Clendennin-Peterson anticline (sec. 20, T. 16 N., R. 9 E.) (Witkind, 1971).

In hand specimen, the syenite is light gray to gray, holocrystalline, and medium to coarse grained and is distinguished by abundant biotite flakes and long thin needles of pyroxene scattered through a light-gray groundmass of feldspar.

In thin section the rock is seen to be a crystalline, equigranular mixture of orthoclase, oligoclase (An_{23}), biotite, augite, and sparse hornblende. The orthoclase predominates over the oligoclase and commonly jackets it. Some of the plagioclase grains are altered to analcime. Apatite, sphene, magnetite, and ilmenite are common accessories.

MINETTE-KERSANTITE
(Samples 6 and 7 of table 4)

The minette-kersantite is composed of biotite, orthoclase, and plagioclase, and minor amounts of hornblende or pyroxene. In a few rocks, the plagioclase content increases somewhat, and these grade toward the kersantites. In others, the hornblende becomes more abundant, and they are like the vogesites. I have selected the combined term "minette-kersantite" to reflect the approximately equal amounts of alkalic and plagioclase feldspar. Those lamprophyres that contain much clinopyroxene or hornblende have been called vogesite, although some contain considerable plagioclase feldspar and so are like spessarite.

TABLE 4.—*The petrography and chemical composition (in percent) of mafic rocks from the Barker quadrangle, Little Belt Mountains, and of similar rocks from the Stanford-Hobson area*

[Rapid-rock analyses. Analysts: P. L. D. Elmore, Samuel Botts, Gillison Chloe, Lowell Artis, H. Smith, John Glenn, and James Kelsey]

Area	Barker quadrangle					Stanford–Hobson area [1]	
Petrography							
Rock type	Shonkinite	Plagioclase shonkinite.	Syenite	Minette-kersantite	Vogesite	Vogesite	Shonkinite.
Color	Dark gray	Dark gray	Light gray to gray	Gray	Gray to dark gray	Gray to dark gray.	Dark gray.
Texture	Medium to coarse grained.	Medium to coarse grained.	Medium to coarse grained	Fine to medium grained.	Very fine grained	Very fine grained.	Medium to coarse grained.
Phenocrysts	Biotite, pyroxene, olivine.	Biotite, pyroxene, olivine.	Biotite and pyroxene	None	Biotite and pyroxene	Biotite and pyroxene.	Biotite, pyroxene, olivine.
Xenocrysts	None	None	None	Quartz, feldspar, mafics(?).	Quartz, sanidine, plagioclase, feldspar (oligoclase (An_{17}) to labradorite (An_{60})).	Quartz, feldspar.	None.
Groundmass	Mixture of biotite, olivine, pyroxene cemented by orthoclase.	Mixture of biotite, olivine, pyroxene cemented by plagioclase plus orthoclase.	Equigranular mixture of orthoclase, oligoclase (An_{28}), biotite, augite, hornblende, and zeolites. Orthoclase jackets plagioclase. Sodalite(?).	Holocrystalline, anhedral grains of orthoclase, plagioclase microlites, biotite, and hornblende. Some pyroxene.	Holocrystalline mixture of pyroxene (augite, salite), biotite, orthoclase, and plagioclase microlites. Some apatite, sphene, opaque minerals.	Mixture of pyroxene, biotite, and feldspar.	Mixture of biotite, olivine, pyroxene, cemented by orthoclase.
Mode (percent)	Orthoclase, 39.2; olivine, 24.6; pyroxene, 15.7; biotite, 14.4; albite, 2.2; others, 4.0.	Albite (An3–7)–38.1; biotite, 22.2; orthoclase, 17.6; salite, 10.7; serpentine, 9.6; others, 1.8.	Orthoclase, 51.0; oligoclase (An_{28}), 32.4; biotite, 8.6; augite, 5.7; opaque minerals, 2.2; others (analcite, heulandite, thomsonite), 0.1.	Alkalic and plagioclase feldspar, 59.3; biotite, 22.7; clinopyroxene, 7.7; opaque minerals, 3.4; others (including xenocrysts), 6.9.	Alkalic and plagioclase feldspar, 56.7; clinopyroxene, 26.0; biotite, 6.4; opaque minerals, 7.0; others (including xenocrysts), 9.9.	Not available.	Not available.

Oxides

	1	2	3	4	5	6	7	8	9	10	11	12
Laboratory No	163677	163679	D–112806	W–169661	W–169662	D–112805	W–169663	163694	W–167705	W–169696	D–112803	W–169051
Field No	WL–31	WL–42	WL–15	WL–32	WL–35	WL–11	WL–108	WL–120	WL–286	WL–417	WL–3	WL–495
SiO_2	48.3	56.3	51.1	55.0	54.5	50.0	52.2	49.2	53.7	56.9	50.7	50.1
Al_2O_3	10.4	14.1	16.9	18.3	18.8	13.2	13.3	12.9	15.2	17.2	14.4	13.0
Fe_2O_3	2.0	2.3	3.7	2.9	2.6	4.2	4.1	3.9	2.3	6.5	3.2	4.0
FeO	7.7	3.3	3.8	2.8	3.4	2.9	3.3	3.1	3.8	.02	4.8	3.6
MgO	16.0	7.6	3.1	2.2	2.0	6.8	5.6	6.9	3.4	1.0	5.7	9.8
CaO	6.8	5.4	5.6	3.3	3.9	8.9	6.7	9.4	5.4	5.0	7.2	7.1
Na_2O	1.4	5.0	4.6	3.6	4.4	2.4	3.6	2.1	3.4	3.9	2.5	2.8
K_2O	3.6	3.2	6.6	8.2	6.0	4.9	3.2	4.6	3.3	3.7	4.1	4.7
H_2O^-	.31	.38	.30	0	.18	1.3	.93	1.6	.94	1.3	2.6	1.2
H_2O^+	1.7	1.0	2.4	2.1	2.6	2.2	2.2	1.4	2.3	1.4	2.0	1.7
TiO_2	.75	.45	.96	.51	.62	1.4	.73	1.3	1.1	.86	.78	.69
P_2O_5	.65	.57	.77	.45	.40	1.3	.52	1.6	.56	.60	.65	.65
MnO	.16	.13	.12	.12	.14	.08	.12	.10	.42	.13	.10	.14
CO_2	.08	.09	.37	.36	.06	.43	3.4	1.3	4.2	1.5	1.6	.35
Sum	99.85	99.82	100.32	99.84	99.60	100.01	99.90	99.40	100.02	100.01	100.33	99.83

TABLE 4.—*The petrography and chemical composition (in percent) of mafic rocks from the Barker quadrangle, Little Belt Mountains, and of similar rocks from the Stanford-Hobson area*—Continued

	1	2	3	4	5	6	7	8	9	10	11	12
Laboratory No.	163677	163679	D–112806	W–169661	W–169662	D–112805	W–169663	163694	W–167705	W–169696	D–112803	W–169051
Field No.	WL–31	WL–42	WL–15	WL–32	WL–35	WL–11	WL–108	WL–120	WL–286	WL–417	WL–3	WL–495
C.I.P.W. norms												
Q	0	0	0	0	0	0	1.28	0.22	5.95	13.66	1.60	0
or	21.27	18.91	38.88	48.53	35.60	28.95	19.58	27.18	20.47	21.89	24.15	27.82
ab	11.84	42.30	14.73	21.57	30.60	20.31	31.54	17.76	30.20	33.04	21.08	18.66
an	11.46	6.59	5.95	9.57	13.88	10.77	11.06	12.19	17.29	11.42	15.91	9.04
C	0	0	0	0	0	0	0	0	0	2.60	0	0
ne	0	0	13.04	4.84	3.67	0	0	0	0	0	0	2.75
di en	5.18	5.00	4.15	.45	.61	8.00	6.49	5.56	1.01	0	1.53	6.63
di fs	1.50	.97	1.38	.17	.41	0	.75	.17	.67	0	.55	.66
di wo	7.31	6.64	6.01	.67	1.06	9.26	8.17	6.58	1.76	0	2.25	8.26
hy en	3.35	1.47	0	0	0	1.29	7.95	11.62	7.88	2.50	12.62	0
hy fs	.97	.28	0	0	0	0	.92	.35	5.29	0	4.50	0
ol fo	22.03	8.80	2.49	3.53	3.08	5.36	0	4.82	0	0	0	12.48
ol fa	7.03	1.87	.91	1.51	2.27	0	0	.76	0	0	0	1.37
mt	2.90	3.33	5.35	4.21	3.79	5.55	6.15	5.66	3.50	0	4.62	5.81
ap	1.54	1.35	1.82	1.07	.95	3.08	1.28	3.79	1.39	1.42	1.53	1.54
il	1.42	.86	1.82	.97	1.18	2.66	1.53	2.47	.22	.04	1.48	1.31
hm	0	0	0	0	0	.37	0	0	0	6.51	0	0

[1] See Vine, (1956, p. 454–455).
1. Plug along Little Otter Creek, SE¼ sec. 18, T. 17 N., R. 8 E.
2. Sill at Irene Peak, W½ sec. 36, T. 16 N., R. 8 E.
3. Sill along northwest flank, Clendennin–Otter anticline, sec. 20 T. 16 N., R. 9 E.
4. Sill at Hansen's Coulee, secs. 28 and 33, T, 17 N., R. 8 E.
5. Sill along west valley wall Big Otter Creek, sec. 18, T. 16 N., R. 9 E.
6. Sill along northeast flank, Clendennin–Otter anticline, C. sec. 24, T. 16 N., R. 9 E.
7. Sill(?) along northwest flank, Granite Mountain, S½ sec. 31, T. 16 N., R. 10 E.
8. Dike, Frenchies Coulee, NW¼ sec. 18, T. 15 N., R. 9 E.
9. St. Louis mine, S½ sec. 7, T. 15 N., R. 9 E. (unsurveyed).
10. Dike (altered), Gold Run Creek, C. sec. 18, T. 15 N., R. 9 E.
11. Sill, Skull Butte, NE¼ sec. 1, T. 15 N., R. 11 E.
12. Dike, Skull Butte, S½ sec. 35, T. 16 N., R. 11 E.

Scattered sills and small plutons of minette-kersantite intrude Cambrian shales and limestones exposed along Dry Fork Belt Creek between Barker and Servoss Mountains (center T. 15 N., R. 8 E.) (fig. 6). They range in thickness from a few feet to as much as 100 feet; most can be traced for several miles. One sill contains much hornblende; and it is this sill, 4 miles west of Barker, that Weed (1900, p. 352) described as a vogesite sheet. The Pilgrim Limestone seems to be the favored host rock, although a few sills are in the Park Shale.

One minette-kersantite sill that contains considerable pyroxene is interleaved in Big Snowy strata along the northeast flank of Peterson Mountain (center sec. 24, T. 16 N., R. 9 E.); dikes of similar rock are along the fault that encircles the Granite Mountain bysmalith (fig. 23).

VOGESITE

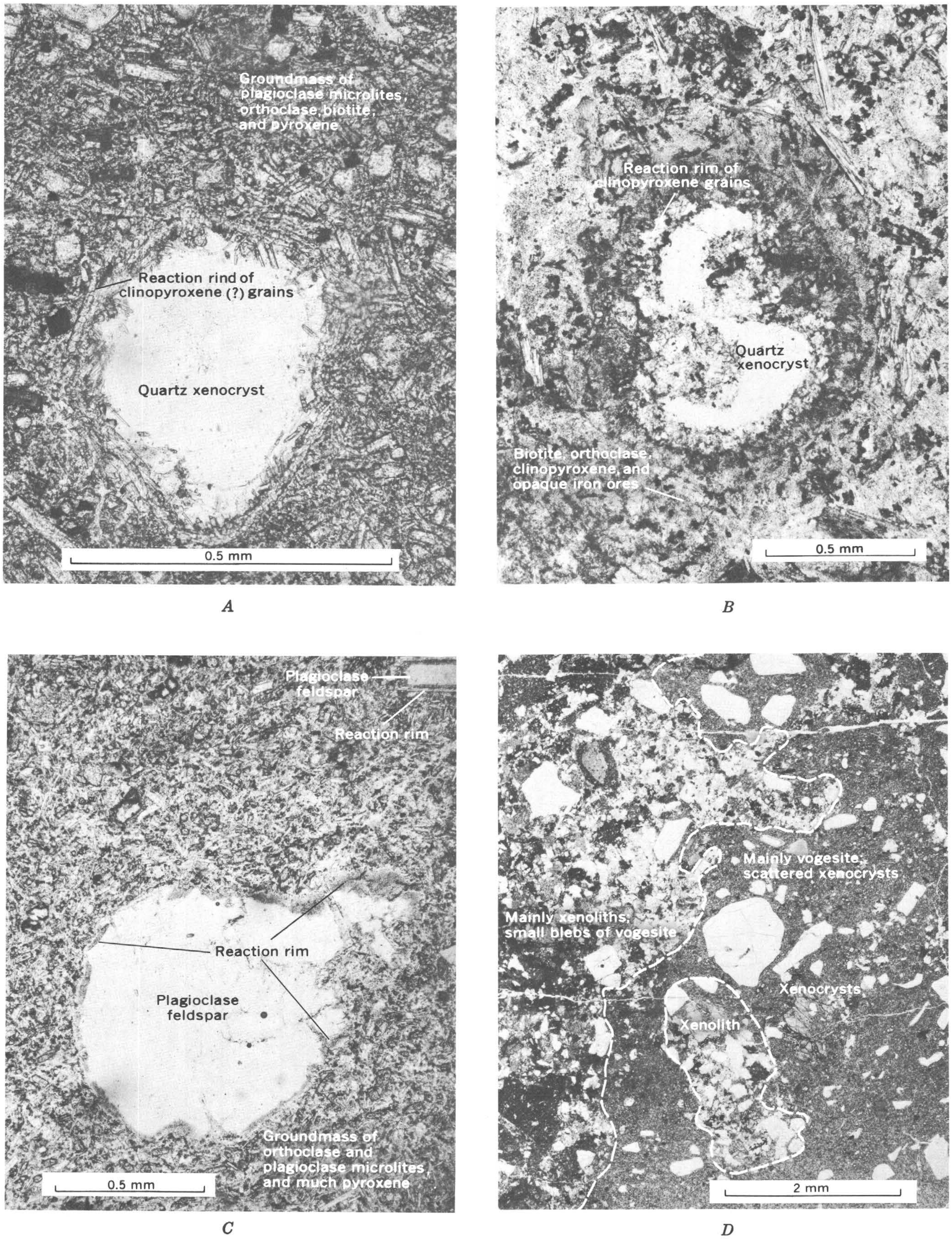
(Samples 8–10 of table 4)

A few sills and dikes of vogesite crop out in the south half of the quadrangle. One sill in the E½ sec. 24, T. 15 N., R. 8 E. follows the unconformity between the Flathead Sandstone and the Precambrian crystalline rocks; and another, following the same unconformity, is exposed in the E½ sec. 31, T. 15 N., R. 9 E. (unsurveyed) (Witkind, 1971). A vogesite dike, exposed in Frenchies Coulee, cuts the Taylor Mountain laccolith (NW¼ sec. 12, T. 15 N., R. 9 E.); another intrudes an old indurated alluvium (p. 41) exposed in the valley of Gold Run Creek (center sec. 18, T. 15 N., R. 9 E.). Still a third dike was intersected by the workings of the St. Louis mine (fig. 25; S½ sec. 7, T. 15 N., R. 9 E., unsurveyed), as shown by vogesite fragments found in the mine tailings.

In hand specimen the vogesite is a gray to dark-gray, very fine grained rock speckled with phenocrysts of brownish-black biotite. Locally near contacts, it contains xenoliths and xenocrysts of country rock. In thin section those vogesites that are more or less free of inclusions consist of phenocrysts of clinopyroxene (augite and salite) and biotite in a holocrystalline groundmass of the same minerals, and abundant orthoclase and plagioclase microlites. Accessory minerals are apatite, sphene, and magnetite.

All the vogesites examined contain xenocrysts chiefly of quartz, sanidine, and plagioclase feldspar. An assortment of different plagioclase feldspars extending from oligoclase (An_{17}) to labradorite (An_{60}) is included. Each xenocryst is rounded, corroded, and encircled by a distinctive reaction rim

496-189 O - 73 - 4


Groundmass of plagioclase microlites, orthoclase, biotite, and pyroxene
Reaction rind of clinopyroxene (?) grains
Quartz xenocryst
0.5 mm
A
Reaction rim of clinopyroxene grains
Quartz xenocryst
Biotite, orthoclase, clinopyroxene, and opaque iron ores
0.5 mm
B
Plagioclase feldspar
Reaction rim
Reaction rim
Plagioclase feldspar
Groundmass of orthoclase and plagioclase microlites and much pyroxene
0.5 mm
C
Mainly vogesite, scattered xenocrysts
Mainly xenoliths, small blebs of vogesite
Xenocrysts
Xenolith
2 mm
D

(probably of clinopyroxene) which varies in thickness from mineral to mineral (fig. 10). In general, it is thickest around the plagioclase feldspars and thinnest around the sanidines.

The source of the xenocrysts is uncertain; most apparently are relics of country rocks, inasmuch as xenoliths of both metamorphic and sedimentary rock have been found in the vogesites. So, some xenocrysts are obviously derived from the pulling apart of the xenoliths; others, however, may represent transferred phenocrysts—relics of blebs of salic magma picked up as fingers of femic magma breached and moved up through a salic one (Witkind, 1970, p. C87).

The vogesite dike that cuts the indurated alluvium has been thoroughly weathered to a light tan, and the included xenocrysts of quartz and feldspar give it a superficial appearance strikingly like that of the porphyry of Galena Creek. Its texture and composition (sample 10 of table 4), however, show that it is a lamprophyre.

CHEMISTRY OF THE MAFIC ROCKS

Compared to the intermediate rocks, the mafic rocks contain less silica, soda, and potash, and more iron, lime, and magnesia. A comparison of the rocks within the mafic group indicates that a close relation exists between the vogesites and the minette-kersantites—both are characterized by high iron, magnesia, and lime, and low soda and potash (fig. 11). (Sample 10 of table 4, a weathered vogesite, is disregarded in this comparison.)

Possibly most of these lamprophyres are a result of the differentiation of a parental femic magma that has the composition of shonkinite. As a result of crystal fractionation—mainly settling of the heavier olivine and pyroxene—the parental magma differentiated into two contrasting magmas: a lighter fraction represented by the syenite, the plagioclase shonkinite, and some of the pyroxene-poor and hornblende-poor minette-kersantite; and a heavier fraction represented by the pyroxene-rich vogesite.

This differentiation pattern is reflected by the chemical analyses; the syenite, plagioclase shonkin-

FIGURE 10.—Xenoliths and xenocrysts in lamprophyres. All photomicrographs by R. B. Taylor and Sandra Brennan. *A*, Corona of clinopyroxene(?) grains about a rounded quartz xenocryst. *B*, Corona of clinopyroxene(?) grains about a corroded quartz xenocryst. *C*, Reaction rim about plagioclase feldspar xenocryst. *D*, Xenoliths and xenocrysts derived from Precambrian crystalline fragments enclosed in vogesite.

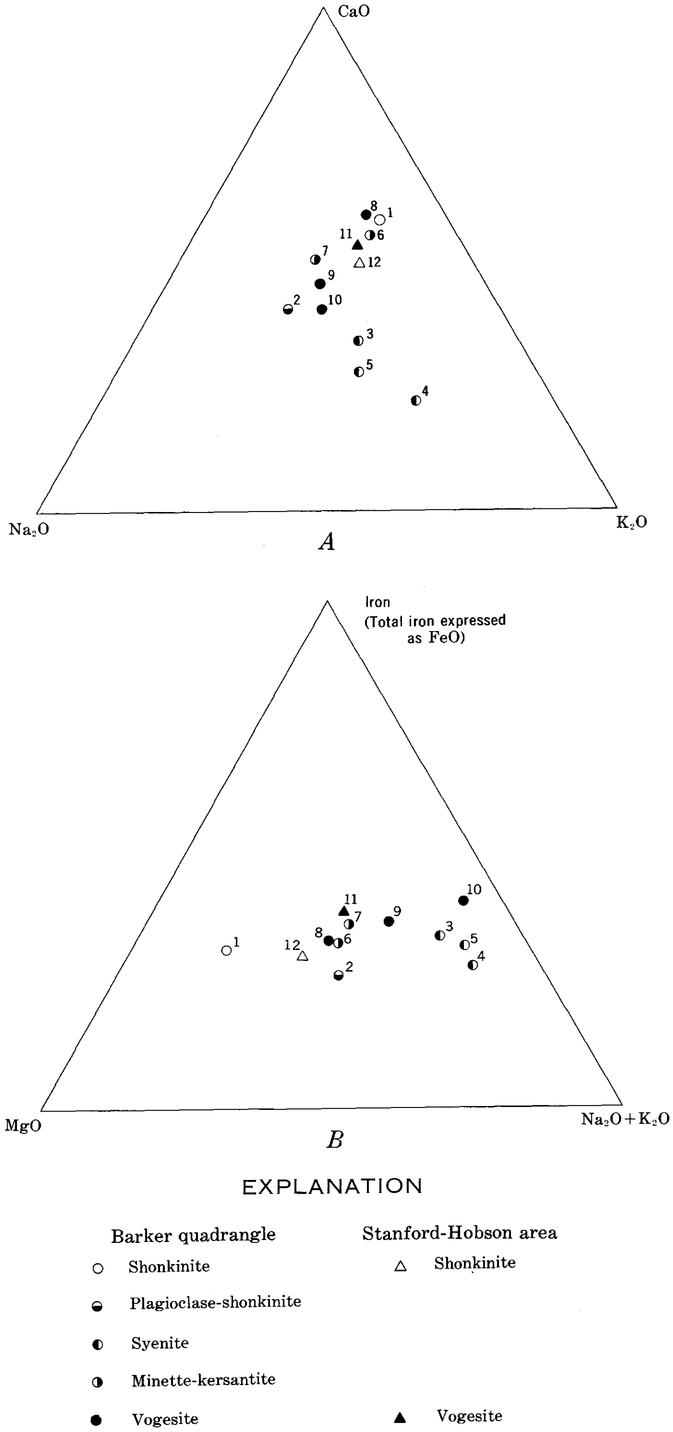


FIGURE 11.—Some chemical characteristics of the mafic rocks. *A*, CaO-Na_2O-K_2O ratios. *B*, FeO-MgO-Alk ratios (FeO = Total iron expressed as FeO; Alk = Na_2O+K_2O). See table 4 for sample locations, and Vine (1956, p. 454–455) for location of samples from the Stanford-Hobson area.

ite, and the minette-kersantite—the lighter fraction of the differentiated magma—contain, in general, more alkalies and less iron, magnesia, and lime than the vogesite (fig. 11).

COMPOSITE DIKES

At least two composite dikes—characterized by mafic margins that contain quartz xenocrysts and by felsic interiors that contain quartz phenocrysts—have been recognized in the Barker quadrangle, and at least one more is known in the Neihart (Witkind, 1970). It is highly likely that many more are in the Little Belt Mountains, either concealed under the thick foliage or unrecognized. The darker margins, marked by conspicuous large round quartz grains, have been interpreted as chilled borders of felsic dikes. Their mineralogy and chemistry, however, differ completely from the mineralogy and chemistry of their felsic cores (table 5). Moreover, the field relations of these bodies indicate that they are composite dikes, the products of coexisting salic and femic magmas.

TABLE 5.—*Chemical analyses, in percentage, of the mafic margin, transitional zone, and felsic interior of the Maytee composite dike, secs. 6 and 7, T. 15 N., R. 9 E. (unsurveyed), Judith Basin County, Montana*

[Rapid rock analyses. Analysts: P. L. D. Elmore, Gillison Chloe, James Kelsey, S. D. Botts, H. Smith, Lowell Artis, and John Glenn]

	Mafic margin	Transitional zone	Felsic interior
Rock name	Kersantite	Kersantite(?)	Porphyry of Galena Creek
Lab No.	W–170181	W–171084	W–171083
Field No.	WL–270–c	WL–552–a	WL–551–a
Oxides			
SiO_2	57.5	68.6	75.9
Al_2O_3	16.0	15.7	13.0
Fe_2O_3	2.4	1.4	.74
FeO	2.8	.92	.60
MgO	3.1	.88	.29
CaO	3.9	1.0	.11
Na_2O	3.3	2.9	.53
K_2O	4.0	4.6	6.3
H_2O^-	.22	.69	.51
H_2O^+	.78	2.1	1.7
TiO_2	.89	.77	.15
P_2O_5	.42	.33	.02
MnO	.16	.03	.00
CO_2	3.9	$<.05$	$<.05$
Sum	99.37	99.97	99.90
C.I.P.W. norms			
Q	19.33	31.74	48.12
or	23.79	27.18	37.23
ab	28.10	24.54	4.49
an	0	2.49	.10
C	6.28	5.04	5.27
hy en	4.85	2.19	.72
hy fs	2.00	0	.24
mt	3.50	.83	1.07
ap	1.00	.78	.05
il	1.70	1.46	.29
hm	0	.83	0

The two composite dikes recognized in this quadrangle intrude the quartz monzonite of Hughesville. One, called the Maytee dike, is well exposed on an old mine road near the Maytee tunnel of the Block P mine (SW¼ sec. 6, T. 15 N., R. 9 E., unsurveyed) (fig. 6). The other, the Annie E dike, has been cut through by the Annie E tunnel of the Liberty mine (fig. 12) (center sec. 7, T. 15 N., R. 9 E., unsurveyed; see fig. 25 for mine locations).

SIMILARITIES OF CLINOPYROXENES

More than half a century ago Pirsson (1905, p. 38) noted that clinopyroxenes from igneous bodies scattered through central Montana are similar regardless of rock type. A study of clinopyroxenes concentrated from the diverse rocks exposed in this quadrangle has confirmed Pirsson's observation. Pyroxenes from felsic rocks such as granite porphyry are remarkably like those from mafic rocks such as shonkinite in optical and chemical properties and in unit cell dimensions.

It was concluded that this close similarity of pyroxenes from widely disparate rock types implies a genetic relationship of the parent magmas.

Detailed results of this study have been reported elsewhere (Witkind, 1969).

THE INTRUSIONS

The configuration of the mountains and valleys reflects the distribution and shape of the various intrusions (Weed, 1900, p. 384–400). Each upwarp, anticline or dome, is more or less shaped by the subjacent intrusion; the intervening synclines or basins are formed of sedimentary strata squeezed between adjacent intrusions (fig. 13).

The 11 larger mapped plutons have been emplaced or are exposed at various stratigraphic levels. The single stock intrudes strata of the Madison Group. Three, and probably four laccoliths, are emplaced along the Cambrian-Precambrian unconformity and so are roofed by the Flathead Sandstone or younger

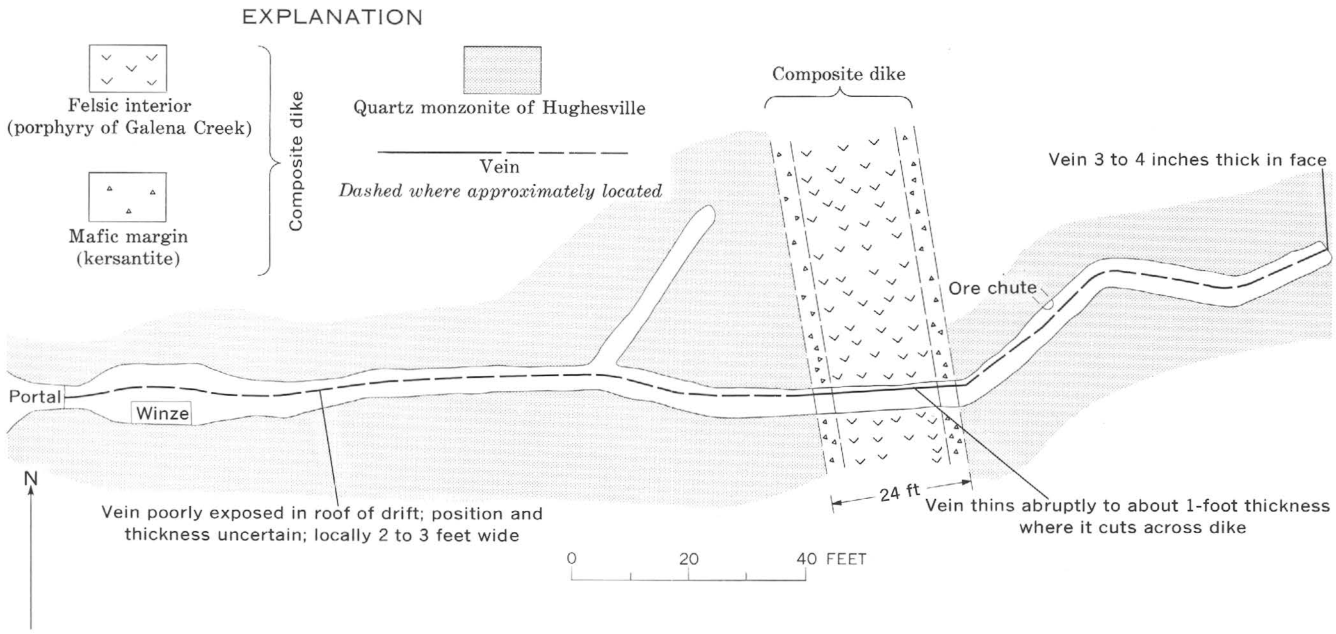


FIGURE 12.—The Annie E dike intrudes the quartz monzonite of Hughesville, as revealed in the Annie E tunnel of the Liberty mine. Mapped June 26, 1967 by I. J. Witkind, assisted by Mrs. Gwenllian Vaughan-Rhys McBride.

Cambrian rocks. Two laccoliths are higher in the section, possibly resting on Devonian strata and roofed by limestone beds of the Madison Group. One laccolith is in fault contact with comparable beds of the Madison, and another laccolith rests chiefly on the Heath Shale, the uppermost unit of the Big Snowy Group. The lone bysmalith is in fault contact with the Park Shale of Cambrian age. A buried pluton intrudes and domes the Precambrian crystalline rocks and likely extends northeastward beyond the exposed Precambrian rocks (fig. 31).

Near the center of the quadrangle three laccoliths form a radial pattern about the circular stock. This stock-laccolith grouping, interpreted as denoting a genetic relationship (fig. 13), has been noted elsewhere, especially on the Colorado Plateau. There, for example, each of the mountain groups that together constitute the Henry Mountains consists of a parent stock and its surrounding tongue-shaped satellitic laccoliths (Hunt, 1946, 1953). The laccoliths radiate from the parent stock much like spokes from the hub of a wheel. Hunt's illustration showing the ground plan of the intrusions around the Mount Ellen stock in the Henry Mountains is reprinted as figure 14*A* of this report. A similar pattern between parent stock and satellitic laccoliths was found in the Abajo Mountains by Witkind (1964); and another was reported by C. E. Erdmann (oral commun., 1964) in the Sweetgrass Hills of north-central Montana.

On the Colorado Plateau, sulfide mineralization is concentrated in and near the stocks; the laccoliths are barren. Consequently, the stocks are considered to be far more significant than the encircling laccoliths. In the Barker quadrangle the main sulfide ore deposits are in and near the Hughesville stock. Hence this stock also is believed to be of special significance.

STOCK

HUGHESVILLE STOCK

The Hughesville stock is bounded on the north, west, and south by variably altered limestone beds of the Madison Group and on the east by various intrusions (fig. 6). On the north boundary, the limestone beds directly adjacent to the stock dip steeply toward the stock; on the west and south, they dip steeply away from it. On the northeast the exact relations between the stock and the Clendennin-Peterson laccolith are concealed beneath the alluvial fill of Green Creek. Locally, there appears to be an intrusive contact between the two, but elsewhere the two are separated by a narrow tight syncline of Madison beds. On the east the stock intrudes the west flank of the Mixes Baldy–Anderson Peak laccolith. Fingers of the stock extend into the laccolith, and other dikes and plugs of a latite porphyry similar to that which forms the east margin of the stock (p. 16) intrude the laccolith.

The stock, in turn, is intruded by felsic, mafic, and

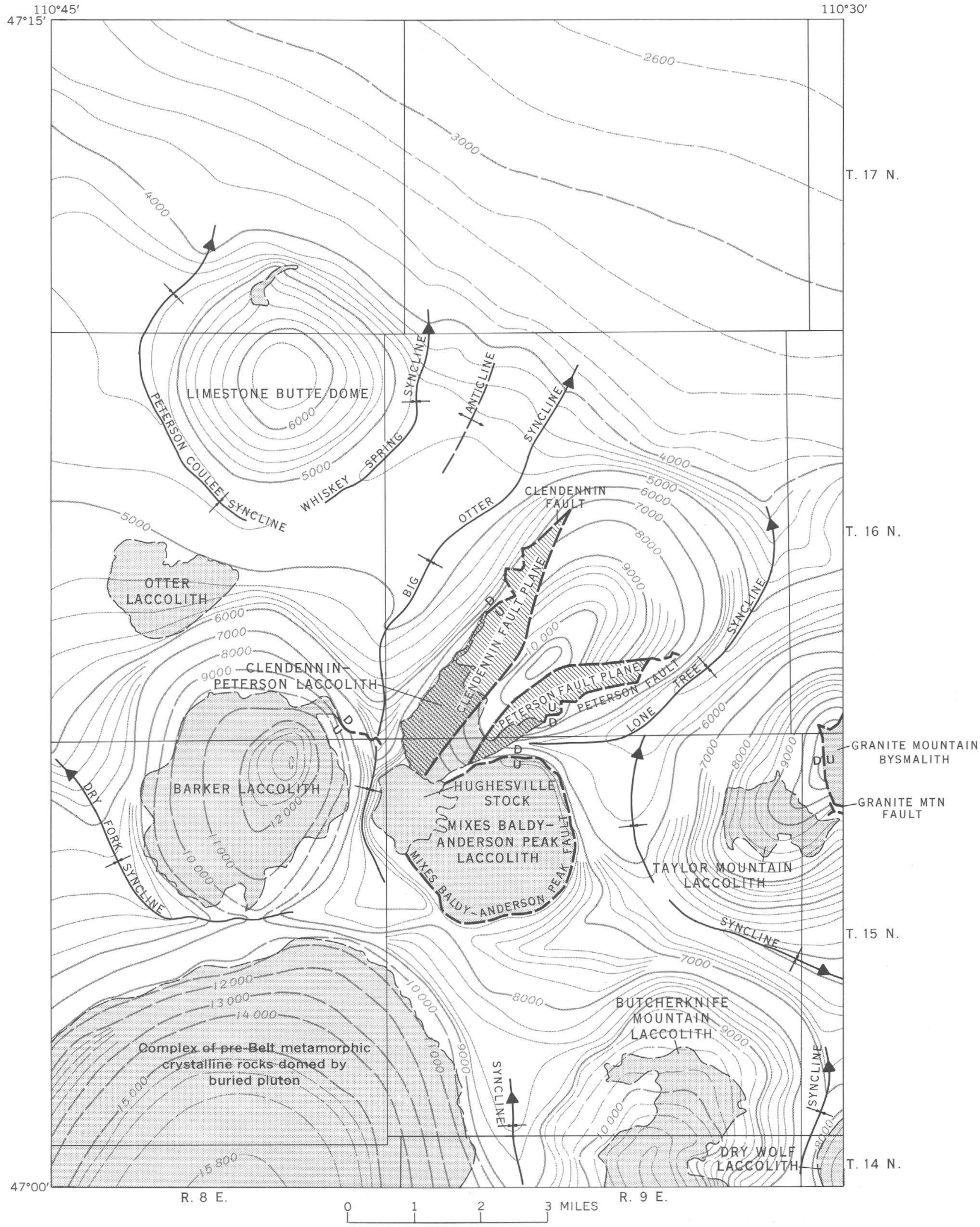
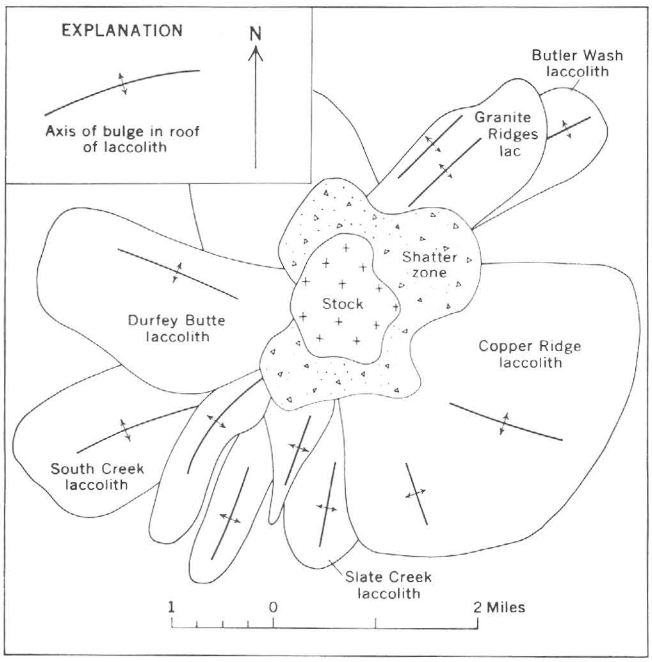


FIGURE 13.—Distribution and shape of the various intrusions as shown by structure contours which are drawn on or projected to the top of the Madison Group. Shaded areas are exposures of various igneous and metamorphic rocks. Projected fault planes are hachured. Contour interval 200 feet; datum is mean sea level.

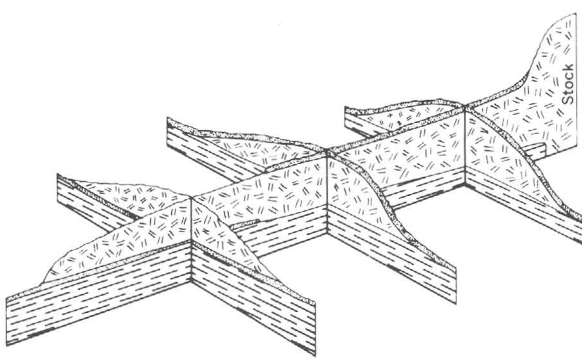
a few composite dikes, all of which follow fractures that break the stock. Locally, veins of sulfide minerals follow the contact between the dikes and the stock (p. 45). None of the dikes and veins extend beyond the margins of the stock.

The stock is intensely jointed. Many of the joints are isolated curved fractures which are either vertical or steeply dipping. Others, however, are very closely spaced and form zones 2–6 inches wide. All are stained by limonite, and locally the adjacent rock is sericitzed (p. 49). Because of thick foliage, neither individual joints nor joint zones are traceable for more than a few hundred feet.

The fracture pattern was not studied in detail, but the attitudes of many conspicuous joints were measured. The poles of perpendiculars to these joints have been plotted and then contoured on an equal-area stereographic net (fig. 15). This plot shows that all the joints are very steep with the great majority being vertical or nearly so. Two conjugate fracture systems are postulated. One system consists of a joint set that trends about N. 60° E. and that is vertical; at almost right angles to this set is another set that trends N. 40° W., and dips about 80° SW. The second fracture system, locally the more dominant of the two, consists of a set of almost vertical joints, which trend in a general northerly direction (ranging from N. 15° E. to N. 15° W.), and a second set, at right angles to the other set, which trends easterly. These two fracture systems seem to be dominant in the stock; most of the other joints appear to be diversely oriented.



A



B

FIGURE 14.—Tonguelike satellitic laccoliths. *A*, "Ground plan of intrusions around the Mount Ellen stock in Henry Mountains, illustrating radial distribution of the laccoliths." From Hunt (1956, fig. 30). *B*, "The laccoliths * * * are tongue-shaped and are bulged linearly and radially from the stocks." From Hunt (1956, fig. 31*A*).

LACCOLITHS

Most of the large intrusions in the Barker quadrangle are here classed as laccoliths, although only three are demonstrably floored. It could be argued, therefore, much as Goddard (1950) has done for comparable intrusions in the nearby Judith Moun-

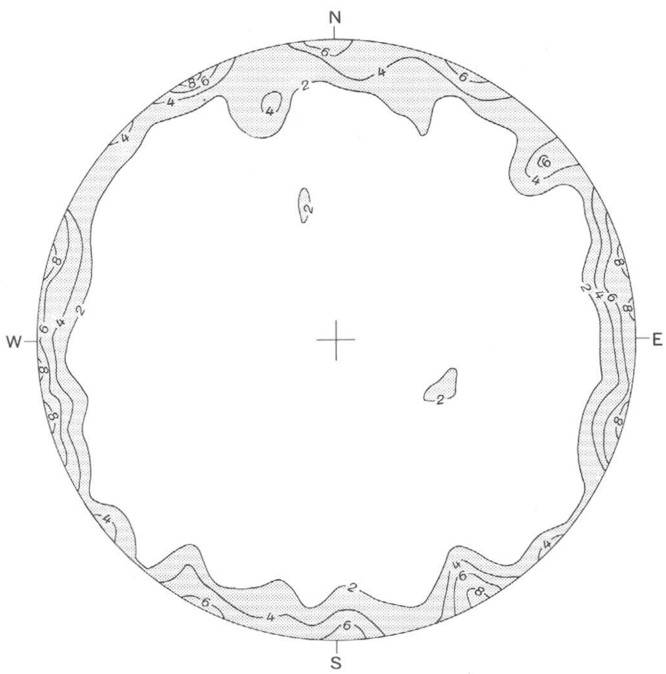


FIGURE 15.—Joints in the Hughesville stock. Lower hemisphere plot; 127 poles. Contoured in percent.

tains, that those masses without visible floors are not laccoliths but rather are deep-seated plugs. But I prefer to think of them as laccoliths, as did Weed (1900), because they are similar in both structure and petrography to the floored bodies, and because the overall character of this intrusive complex is so much like that of demonstrable laccolithic complexes elsewhere, such as in the Henry Mountains (Hunt, 1953) and the Abajo Mountains (Witkind, 1964) in Utah.

Moreover, the alkalic feldspar in all but one of the laccoliths is marked by low to moderate optic angles ($\sim 30°$ to $\sim 50°$) that imply sanidine, rather than by high optic angles (75°) that imply orthoclase. The presence of orthoclase suggests slow cooling and gradual crystallization, whereas the occurrence of sanidine implies high temperatures quickly quenched. Conditions favoring sanidine would prevail during the formation of a laccolith. Being isolated somewhat from the main heat source, laccoliths should crystallize before their sanidine could transform to orthoclase. Stocks, on the other hand, are connected at depth with a continuous source of heat, and the transformation is likely to occur as it did in the Hughesville stock.

The previous work done on laccolithic complexes has demonstrated that laccoliths assume at least three different shapes: (1) a planoconvex (mushroomlike) type (fig. 16*A*, *B*), (2) a tonguelike satellitic type attached to a parent stock (*C*, *D*), and (3) an asymmetric (half a mushroom type (*E*, *F*). It seems likely that all three types are in this quadrangle.

PLANOCONVEX LACCOLITHS

Gilbert's (1880, p. 19) original work in the Henry Mountains gave rise to the classic concept of a laccolith—a lenticular planoconvex (mushroomlike) body presumably fed by a nearly vertical dike or pipe (fig. 16*A*, *B*).

This type of laccolith probably underlies Taylor and Butcherknife Mountains and possibly the Limestone Butte dome (fig. 13).

TONGUE-SHAPED SATELLITIC LACCOLITHS

These include those linear laccoliths (Hunt, 1946, 1953) that are attached to a parent stock. They are tongue-shaped masses, thick where they are attached to the stock and thin at their distal ends (fig. 16*C*, *D*, and fig. 14*B*). As the individual laccoliths may be emplaced in different stratigraphic units, some laccoliths can be either wholly or in part above or beneath others.

In the Barker quadrangle this stock-laccolith relation is suggested by the three intrusions that seem to radiate from the Hughesville stock (figs. 2 and 13): the Barker laccolith, the Clendennin-Peterson laccolith, and the Mixes Baldy–Anderson Peak laccolith. Of the three intrusions, however, only the Clendennin-Peterson laccolith appears, on the basis of its deformed sedimentary cover, to have the requisite tonguelike shape of a satellitic laccolith.

ASYMMETRIC LACCOLITHS

Asymmetric laccoliths resemble half a planoconvex (mushroomlike) laccolith; one flank is blunt and the other flanks taper to thin edges (fig. 16*E*, *F*). These igneous bodies have been given various names: Hunt (1946, 1953, and 1956, fig. 31*B*) referred to them as "bysmaliths"; Pratt and Jones (1961, p. C164) called them "trap-door laccoliths," and Cross (1894, p. 237), Weed (1899c, p. 25), Pirsson (1898, p. 581) and Harker (1909, p. 66–67), among others, called them "asymmetric laccoliths." This latter name is used here.

How they formed is uncertain; there are several possibilities. One explanation, advanced by Hunt (1956, fig. 31*B*), involves the dilation of the distal end of a tonguelike laccolith (fig. 17*A*). A second explanation, offered by Cross (1894, p. 237) and by others involves either a vertical or an inclined feeder beneath the laccolithic floor (fig. 17*B*, *C*). I would add a third alternative: The laccolith developed adjacent to and along a preexisting fracture which served as a channel for the ascending magma (fig. 17 *D*).

Of the laccoliths in the Barker quadrangle, only the Barker laccolith is asymmetric. Weed (1900, p. 355, fig. 43) considered the north flank to be the blunt end, whereas I think the east flank near the stock is the blunt side (fig. 6, cross section *A–A′*, and fig. 13).

DESCRIPTIONS OF LACCOLITHS

PLANOCONVEX LACCOLITHS

BUTCHERKNIFE MOUNTAIN LACCOLITH

An intensely dissected dome known as Butcherknife Mountain occupies the southeast corner of the quadrangle (fig. 2). The dome, astride Tps. 14 and 15 N., R. 9 E., is almost 4½ miles across and rises about 2,200 feet above the floor of Dry Wolf Creek. It is underlain by the Butcherknife Mountain laccolith, from which much of the sedimentary cover has been stripped.

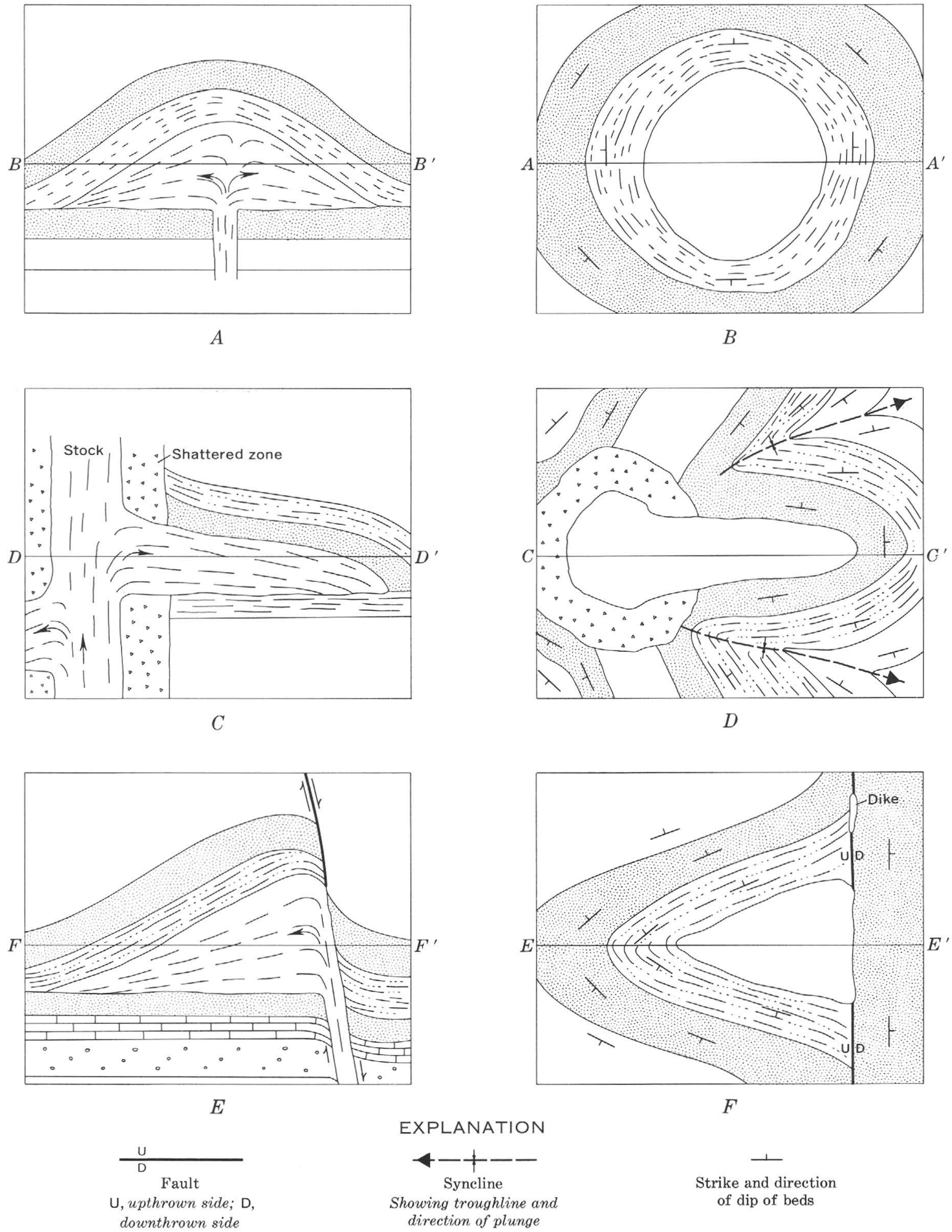


FIGURE 16.—Three types of laccoliths. Dark arrows and dashed lines indicate direction and general sequence of magma emplacement. *A*, Cross section of the simple planoconvex (mushroomlike) laccolith (from Gilbert, 1880, fig. 8). *B*, Diagrammatic map of the planoconvex laccolith assuming erosion has reached line *B–B′* on section *A*. Line *A–A′* represents plane of cross section shown in *A*. *C*, Cross section of tonguelike satellitic laccolith attached to the parent stock (from Hunt, 1953, fig. 70). *D*, Diagrammatic map of satellitic laccolith assuming erosion has reached line *D–D′* on section *C*. Line *C–C′* represents plane of cross section shown in *C*. *E*, Cross section of an asymmetric laccolith developed adjacent to and along a preexisting fracture. *F*, Diagrammatic map of asymmetric laccolith assuming erosion has reached line *F–F′* on section *E*. Line *E–E′* represents plane of cross section shown in *E*.

Inasmuch as only the roof is exposed, the shape and size of the laccolith can only be surmised. Likely it is planoconvex. I estimate it to be about 3 miles in diameter and a maximum of about 3,000 feet thick.

The laccolith and its related sills are composed of the Barker Porphyry (samples 7 and 8 of table 2).

Most of the laccolith underlies the Flathead Sandstone, but locally it cuts across the sandstone to younger Cambrian strata. The youngest rocks deformed by the laccolith belong to the Big Snowy Group, and remnants of these are preserved in a triangular trough north of Butcherknife Mountain.

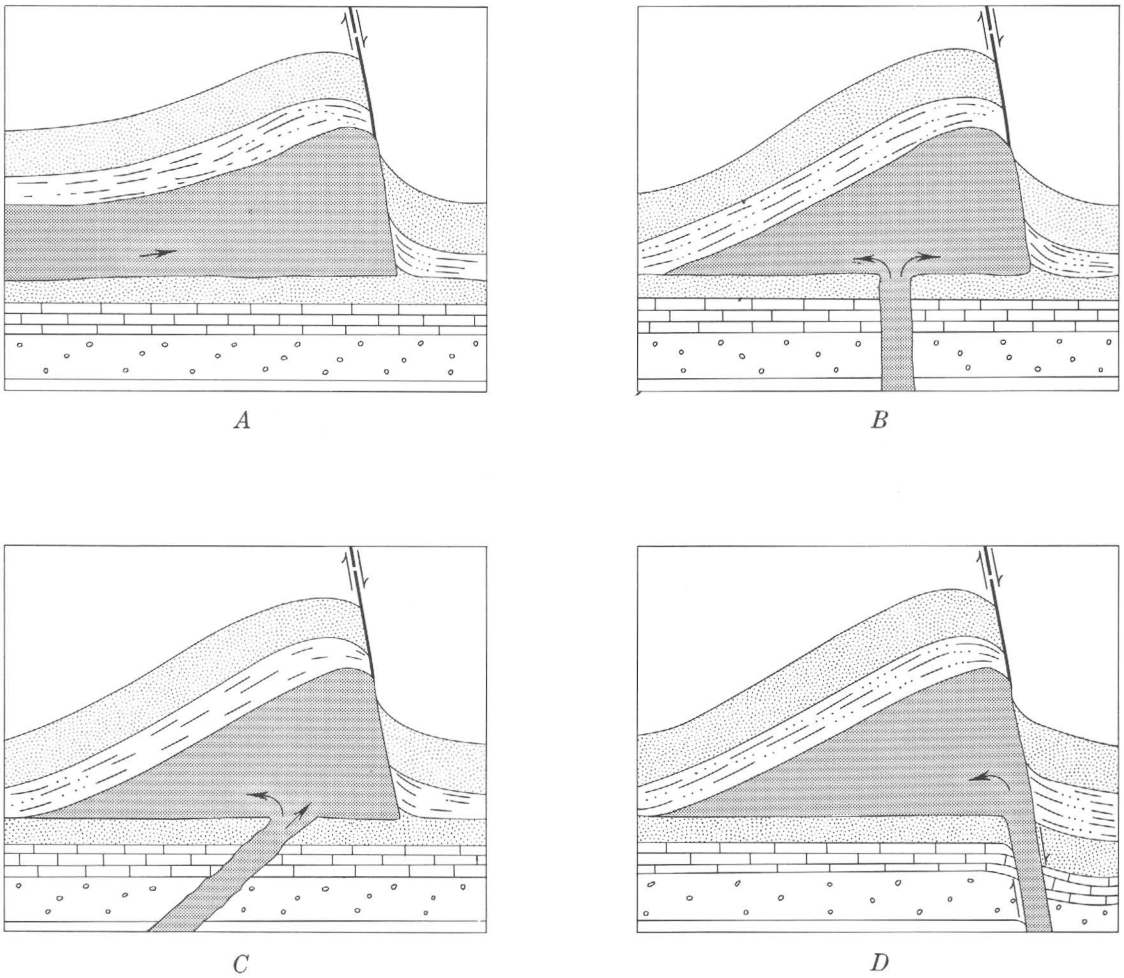


FIGURE 17.—Four ways in which an asymmetric laccolith might develop. In the first three (*A*, *B*, and *C*), the magma (arrow) moves generally toward the fracture; in the fourth (*D*), it moves away from the fracture. *A*, Magma intruded along a near-horizontal bedding plane moves laterally to form first a sheet and then a tonguelike satellitic laccolith. As the distal edge of the laccolith dilates, the overlying strata are raised, folded back, and finally broken. Fault does not extend below laccolithic floor. From Hunt (1956, fig. 31B). *B*, Magma rises in a nearly vertical conduit which crosscuts host rocks. When upward progress of magma is halted, it moves laterally to form first a sheet and subsequently an asymmetric laccolith. Here also the fault does not extend below laccolithic floor. From Cross (1894, fig. 30). *C*, Magma rises in an inclined conduit which crosscuts host rocks. The greatest thickness of the laccolith develops opposite the mouth of the inclined conduit owing to the intrusive force of the magma. Fault does not extend below laccolithic floor. From Howe (1901, p. 299). *D*, Magma rises in a preexisting fracture. Where the upward progress of the magma is halted—possibly because the fracture closes—the magma moves laterally along a bedding plane. Dilation of the laccolith causes the overlying beds to break; consequently these are offset more than those beneath the laccolith.

TAYLOR MOUNTAIN LACCOLITH

Taylor and Granite Mountains together form a compound dome which dominates the east edge of the quadrangle. The dome, astride the junction of four townships (Tps. 15 and 16 N., Rs. 9 and 10 E.), is underlain in its southern half by the Taylor Mountain laccolith and in its northern half by the Granite Mountain bysmalith (fig. 18). Field relations indicate that after the laccolith was emplaced, it was bowed upward and likely broken in two by the developing bysmalith (fig. 19). The northern half of the laccolith has since been eroded away, leaving the southern half tilted to the southwest (fig. 19 *D* and Witkind, 1971 cross section *D–D′*).

The dome is about 5 miles in diameter and rises some 2,200 feet above the floor of Lone Tree Park; only the western two-thirds is within the Barker quadrangle. Originally the laccolith may have been a somewhat linear body that trended about N. 55° E. I estimate it to have been some 4 miles long and about 2½ miles wide. It probably had a maximum thickness of about 1,800 feet.

The laccolith rests on the Jefferson Dolomite and directly underlies the Madison. In the N½ sec. 12, T. 15 N., R. 9 E., (unsurveyed) a thin sliver of Madison is preserved along the laccolithic crest (fig. 19 *D* and Witkind, 1971 cross section *D–D′*).

The laccolith is composed of the Barker Porphyry (samples 5 and 6 of table 2) but contains orthoclase rather than sanidine as in the other laccoliths. This laccolith is the only floored intrusion that contains orthoclase; possibly it is connected at depth with a part of the stock.

To determine whether any significant variation or differentiation occurred as the laccolith dilated, one sample was collected from the floor of the laccolith (sample 5) and another from the roof (sample 6). The rocks are alike mineralogically and chemically, implying that the magma was emplaced rapidly enough to preclude any differentiation.

LACCOLITH(?) UNDERLYING THE LIMESTONE BUTTE DOME

Limestone Butte dome, in the northwest corner of the quadrangle (NE¼, T. 16 N., R. 8 E.), is about 4 miles in diameter and almost perfectly circular. Its top rises smoothly and evenly some 1,000 feet above the adjacent stream floors. Softer strata have been stripped, leaving a surface held up by the more durable limestone beds of the Madison Group. The flanks of the dome are outlined by moderately dipping strata of the Big Snowy Group (Witkind, 1971).

I believe that the dome is underlain by a planoconvex laccolith whose general composition is suggested by a plug and sill which intrude the strata along the north flank. The igneous rock (sample 12 of table 2) is like the Barker Porphyry.

The dome was tested unsuccessfully for oil in 1957 by the Oien Oil Co. The test, known as the J. W. Bodner 1, was collared on the crest of the dome at an altitude of 5,761 feet in the SW¼ sec. 2, T. 16 N., R. 8 E. It was abandoned as a dry hole in the Jefferson Dolomite at a total depth of 1,887 feet. Inasmuch as the test did not penetrate any igneous rock, the laccolith must have formed at greater depth, possibly along the unconformity between the Precambrian basement complex and the overlying Middle Cambrian strata (Witkind, 1971 cross section *A–A′*).

DRY WOLF LACCOLITH

A small part of the north flank of the Dry Wolf laccolith is exposed in the southeast corner of the quadrangle; this exposure occupies most of sec. 6, T. 14 N., R. 9 E. (fig. 2). Practically all the sedimentary cover has been stripped from the laccolith; and the laccolithic floor, sloping gently northward, is exposed along the east valley wall of Dry Wolf Creek. The floor truncates limestone beds (which here dip about 10° NE) of the Madison Group. A few limestone beds of the Madison Group are still preserved on the laccolith's flank; the implication is that the laccolith was emplaced wholly in the Madison Group.

The laccolith is composed of the Barker Porphyry (sample 9 of table 2).

SATELLITIC LACCOLITHS

CLENDENNIN-PETERSON LACCOLITH

The north flank of the mountains is dominated by the nose of an elongate northeast-trending anticline whose general shape, length, and width are believed to result from the emplacement of the Clendennin-Peterson laccolith (fig. 20). The anticline, which trends northeast from the Hughesville stock (fig. 2), is about 6 miles long and 3 miles wide; it rises about 2,500 feet above the adjacent valleys. Parts of the laccolith are exposed in various streams; all exposures are believed to be parts of the laccolithic roof. The laccolithic floor is not exposed.

On the basis of exposures and the general configuration of the anticline, I suggest that the underlying laccolith is about 5 miles long, about 2 miles wide,

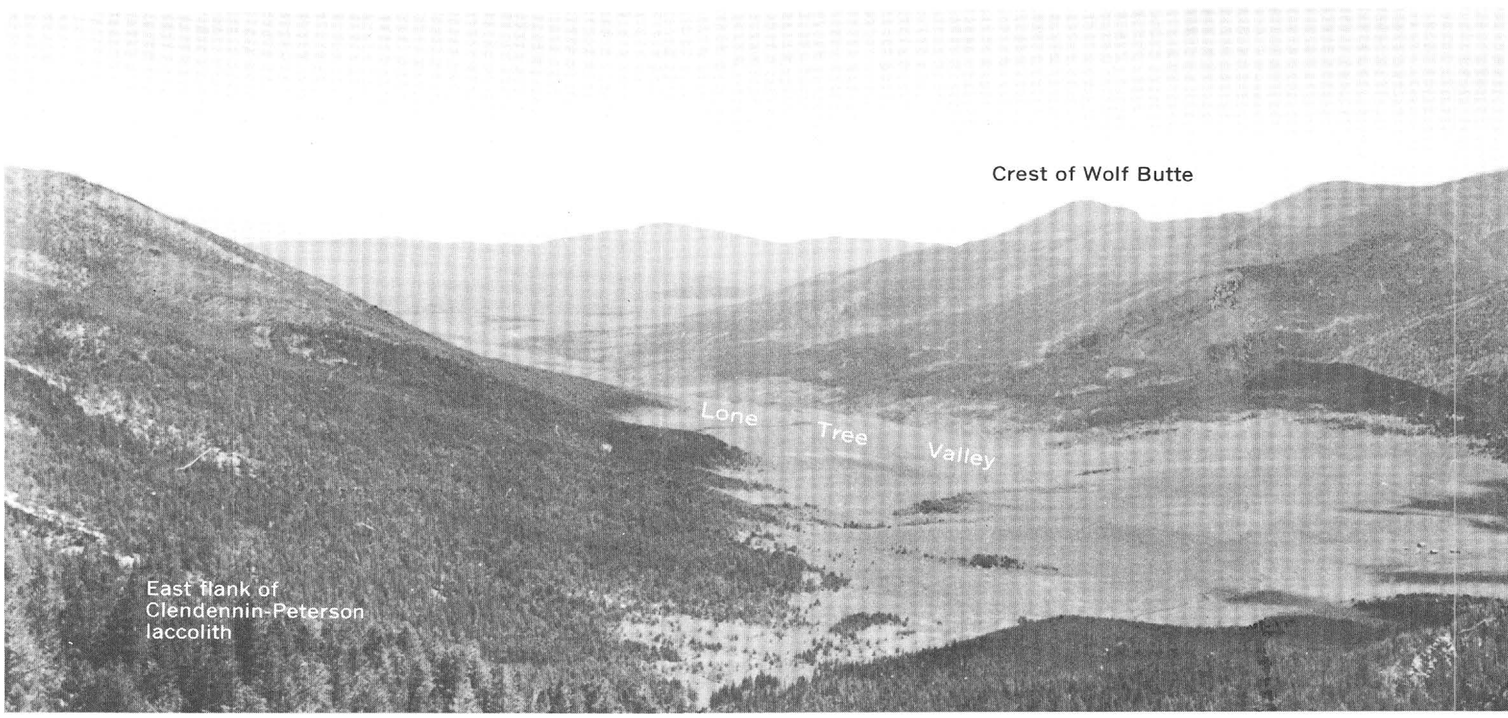


FIGURE 18.—Panoramic view of the compound dome underlain by both the Taylor Mountain laccolith and the

and possibly as much as 3,500 feet thick near the stock (Witkind, 1971, cross sections *B–B′* and *C–C′*).

The oldest sedimentary unit that is domed by the laccolith is the Flathead Sandstone. The laccolith cuts younger beds, possibly because of faults, so that beds as young as the Jefferson Dolomite rest on its roof. Commonly, however, the Wolsey Shale directly overlies the laccolith. In sharp contrast to most of the other laccoliths, those beds that overlie the crest and upper flanks of the thick end of the laccolith have been intensely metamorphosed.

Two major faults cut the laccolithic flanks. The northwest flank is broken by the Clendennin fault, and the southeast flank by the Peterson fault (fig. 21). The field relations imply that the faults may have formed during dilation of the laccolith (Witkind, 1965).

Clendennin Fault

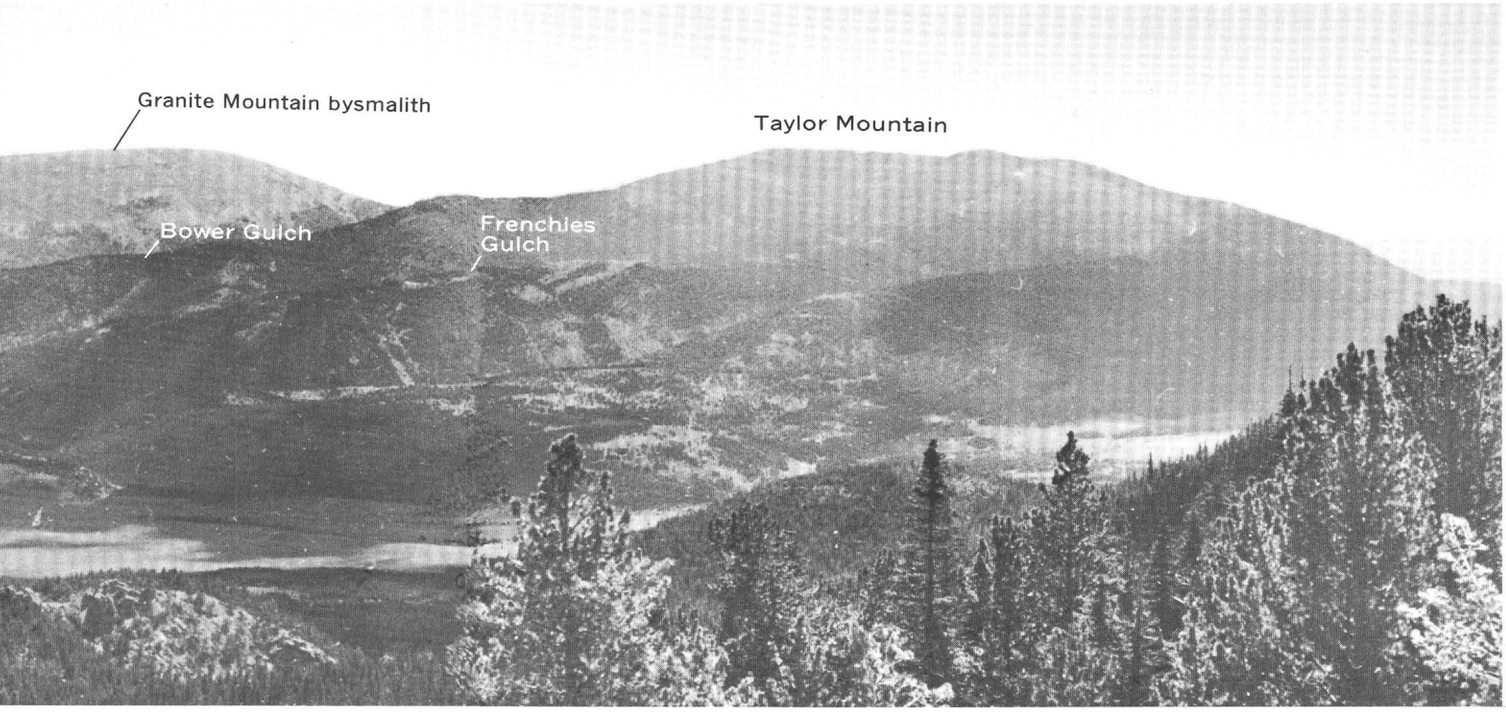
The Clendennin fault is normal. It dips valleyward (northwestward) at a high angle—at least 60° locally—and the beds southeast of the fault have been raised. The fault can be traced northeastward for about 2 miles from near Lost Creek (fig. 21, and Witkind, 1971). Originally it may have extended for a distance of 4 miles, for southwestward from Lost Creek a thin dike of the porphyry of Clendennin Mountain follows the fault trace for about 1 mile before the dike passes into the main mass of the laccolith. Southwestward beyond this point the linearity of this flank of the laccolith implies that it developed against a preexisting fault. I interpret these relations to mean that even as the sedimentary strata were arched and broken by the dilating laccolith, magma from the laccolith invaded and obliterated part of the fault trace.

The stratigraphic throw along the fault increases toward the Hughesville stock. So, at the northeast end of the fault, Madison strata are juxtaposed; and near the midpoint of the fault trace, Madison beds are in fault contact with the Jefferson Dolomite.

Peterson Fault

The Peterson fault (along the southeast flank of the anticline, like the Clendennin fault is normal and dips valleyward (southeastward) at a high angle (fig. 21). The beds on the northwest side of the fault have been raised. The fault can be traced southwest for about 2½ miles where it ends against the southeast flank of the laccolith. Here also, the straightness of the laccolithic flank implies that the southeast flank, like the northwest flank, is fault controlled. If so, this fault too may have been as much as 4 miles long.

The stratigraphic throw, as along the Clendennin fault, increases toward the stock. So, at the north-



Granite Mountain bysmalith. View is northeastward across Lone Tree Park from the east flank of Mixes Baldy.

east end of the fault Madison strata are juxtaposed; near the midpoint Cambrian and Devonian beds are in fault contact with the Madison; and near the southwest end the Madison rests against the Flathead Sandstone.

Both faults, thus, increase differentially in stratigraphic throw toward the stock. This increase is attributed to the pattern of dilation followed by the laccolith. The magma was probably fed northeastward from the parent stock. As the laccolith dilated, it first raised the overlying sedimentary strata, then arched them until they finally broke to form the two faults.

OTTER LACCOLITH

The otter laccolith, here tentatively classed as a satellitic laccolith, occupies the center of T. 16 N., R. 8 E. (fig. 2). I believe it is closely related to the thickened sill northeast of Irene Peak some 2 miles to the southeast in the NE¼ sec. 36, T. 16 N., R. 8 E. (Witkind, 1971). Probably both features were once joined to form an elongate thin igneous mass which encircled the north flank of Barker Mountain.

The laccolith is completely stripped of sedimentary cover and now appears as a pile of igneous rock resting on various units of the Big Snowy Group, chiefly the Heath Shale. Its floor conforms to the underlying strata and slopes gently northward. It is about 2 miles in diameter and some 700 feet thick. Its original size and shape are unknown.

It is composed of a rock similar to the Barker Porphyry (sample 2 of table 2) but has more clinopyroxene than other samples of the porphyry. Much the same is true of the porphyry that forms the thickened sill northeast of Irene Peak (sample 3 of table 2).

The laccolith was probably fed from the parent stock through the thickened sill.

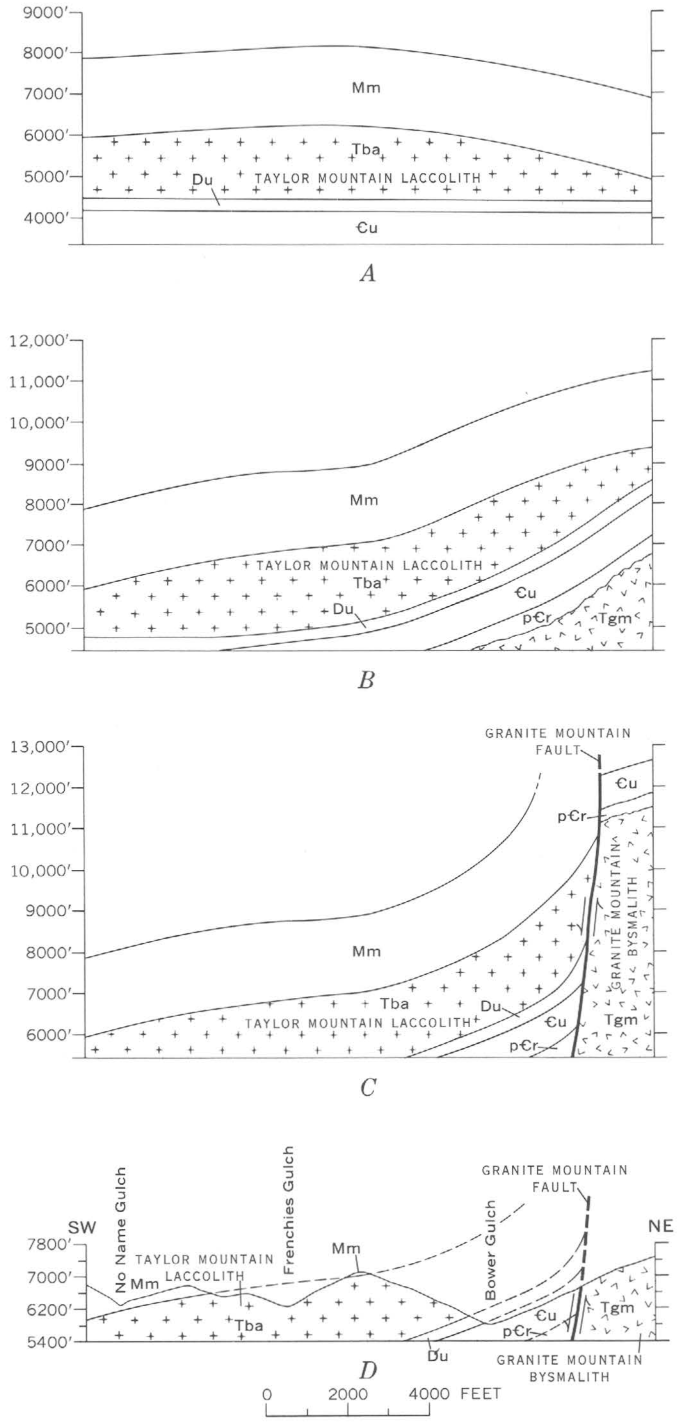
ASYMMETRIC LACCOLITHS

BARKER LACCOLITH

Due west of the Hughesville stock is Barker Mountain, a circular dissected dome about 3 miles in diameter which rises about 3,000 feet above the floor of Dry Fork Belt Creek (fig. 22). The mountain is underlain by the Barker laccolith (Witkind, 1971, cross sections *A–A′*, *D–D′*). Extensive dissection has stripped the sedimentary cover from the laccolith's crest and upper flanks, and the remaining sedimentary beds are now preserved chiefly along the lower flanks (fig. 6).

Inasmuch as the floor is nowhere exposed, only a general estimate can be made as to the size of the laccolith. It is crudely circular, 3–3½ miles in diameter, and possibly as much as 4,000 feet thick.

On the north, west, south, and southeast the lac-



colith is overlain by Cambrian strata. On the northeast it is in sharp linear contact with the Madison Group, and its edge may conform to a preexisting fault. If so, the northeast flank is steep, whereas all other flanks thin laterally and pinch out beneath the sedimentary cover.

The laccolith is semiconcordant, transgressing to younger beds. Thus, the northwest flank of the laccolith underlies the Flathead Sandstone; farther south the laccolith underlies the Wolsey; and still farther south the laccolith has cut across the Meagher Limestone and Park Shale and underlies the Pilgrim Limestone. These relations imply that the floor of the laccolith, particularly its north half (Witkind, 1971, cross sections *A–A′* and *D–D′*), rests on Precambrian crystallines, whereas its south half rests on one or more Middle Cambrian units.

The Barker laccolith, formed by the Barker Porphyry (sample 4 of table 2), is classed as an asymmetric laccolith chiefly because I think it was formed by magma that moved up a preexisting fracture, possibly one related to the Irene Peak fault. I suspect that the position of the laccolith—radial to the parent stock—was determined by an old high-angle fracture which trended about N. 30° W. from the west flank of the Hughesville stock (fig. 6). The former trace of the fracture is now followed by the linear northeast flank of the laccolith.

Probably the magma that fed the Barker laccolith rose in the same master conduit (now occupied by the Hughesville stock) responsible for the Clendennin-Peterson and Mixes Baldy–Anderson Peak laccoliths. During its upward progress it was probably diverted westward into the high-angle fracture that intersected the conduit. The magma rose in the fault until its upward progress was slowed or stopped, then it migrated laterally along the Cambrian-Precambrian contact and slowly raised and arched the beds. With the gradual addition of magma, those beds closest to the former fracture, which served as a feeder conduit, were raised the most.

MIXES BALDY–ANDERSON PEAK LACCOLITH

Southeast of the Hughesville stock is the Mixes Baldy–Anderson Peak laccolith, an igneous mass al-

FIGURE 19.—Four sections offering one possible explanation for the structural relations between the Taylor Mountain laccolith and the Granite Mountain bysmalith. pЄr, Precambrian crystalline metamorphic rocks; Єu, Cambrian units; Du, Devonian units; Mm, Madison Group; Tba, Barker Porphyry; Tgm, rhyolite of Granite Mountain. *A*, Taylor Mountain laccolith develops as a planoconvex body. *B*, The rhyolite of Granite Mountain invades the area and differentially tilts both the sedimentary rocks and the enclosed laccolith. *C*, With continued uplift, the sedimentary rocks and the laccolith finally break along part of the high-angle circumferential Granite Mountain fault. *D*, Erosion strips some of the sedimentary cover from the laccolith and the bysmalith.

most completely encircled by a high-angle fault (fig. 2). The laccolith is about 2½ miles in diameter and rises some 2,000 feet above the floor of Dry Fork Belt Creek. Its thickness is unknown; on cross section *A–A′* of figure 6 I have shown it as underlain by a younger pluton.

Virtually the entire sedimentary cover has been stripped from the laccolith exposing the coarsely phenocrystic Wolf Porphyry (samples 6 and 7 of table 1). Only a very thin layer of steeply dipping Cambrian and Devonian beds is preserved around the north and northeast flanks. The laccolith, thus, is even more denuded than the Barker laccolith and is far better exposed than the Clendennin-Peterson laccolith.

Locally, the evidence for the circumferential fault is tenuous. On the north and northeast the evidence is incontrovertible—the Cambrian and Devonian beds wrapped around the laccolith have been raised and are in fault contact with the Mississippian Madison Group. On the south and southeast, however, the Wolf Porphyry is juxtaposed with Madison strata. In that area the limestone beds adjacent to the porphyry are unbleached and unbaked, and the texture of the porphyry in contact with the Madison is as coarse as its texture distant from the contact, suggesting a fault relation. On the southwest the relations between the laccolith and adjacent strata are concealed beneath a pediment deposit, and on the west the laccolith is intruded by the Hughesville stock (fig. 6). Possibly the laccolith crystallized at depth and then was punched upward by a younger pluton; if so, it formed much like the trapdoor laccoliths in the Little Rocky Mountains (Knechtel, 1944). According to this interpretation the southeastern edge was raised the most, and the hinge was along the west edge (fig. 6, cross section *A–A′*).

The general size, shape, and extent of such a pluton is uncertain. Presumably if a younger pluton did raise this laccolith, the resultant heat should have converted the sanidine of the laccolith to orthoclase. One possible explanation for the lack of such an inversion is that this younger pluton may have been relatively thin—possibly it was a sill some 600–1,000 feet thick. (This thickness is implied by the stratigraphic displacement along the Mixes Baldy–Anderson Peak fault; fig. 6, cross section *A–A′*.) The causative magma could have risen in a nearly vertical fracture and then spread laterally beneath the laccolithic floor. A second alternative is that this younger pluton may be part of a much larger subjacent body of magma and that it, in fact, did heat the floor of the laccolith and did modify the alkalic feldspar. If so, erosion has not as yet cut deeply enough to expose this basal part of the laccolith. I favor this second alternative.

A gravity map of the Barker-Neihart area suggests that the north edge of an elongate northeast-trending buried pluton does, in fact, underlie the Mixes Baldy–Anderson Peak laccolith (fig. 31).

BYSMALITH

The term "bysmalith," coined by Iddings (1898), has been used to describe wholly different igneous bodies. In common usage (Am. Geol. Inst., 1960, p. 41; Billings, 1942, p. 273), it describes a more or less vertical cylindrical body of igneous rock that has pushed the overlying strata up along one or more circumferential faults. Hunt (1956, fig. 31*B*), however, has applied the term to the kind of intrusions here called asymmetric laccoliths, but I use the term in its customary sense.

GRANITE MOUNTAIN BYSMALITH

Granite Mountain, along the east edge of the quadrangle, consists of a plug of igneous rock encircled by a high-angle fault—the Granite Mountain fault. I have called this plug the Granite Mountain bysmalith; only its west flank is within the quadrangle (fig. 2, and Witkind, 1971).

The plug is composed of the extremely fine grained rhyolite of Granite Mountain (sample 9 of table 1) which is in fault contact with steeply upturned Cambrian and Devonian beds (fig. 23).

For most of its extent the circumferential Granite Mountain fault is concealed, but it is well exposed in a roadcut along the south flank of the mountain (N½ sec. 7, T. 15 N., R. 10 E.). There, the fault gouge is about 15 feet thick and consists of angular fragments of rhyolite and Park Shale firmly held in a finely comminuted matrix chiefly of the rhyolite and of intermixed smaller amounts of shale. The fault dips valleyward at angles between 60° and 80°, but locally it is vertical.

In several places dikes of felsic and mafic rocks follow the fault. As an example, a dike of the porphyry of Galena Creek follows the south flank of the bysmalith (east of quadrangle boundary), and nearby is a dike of minette-kersantite (fig. 23).

How the bysmalith developed is uncertain. One possibility involves the gradual dilation of a laccolith until its roof, partly congealed, is punched upward by rising magma. Another interpretation is that large segments of other previously emplaced

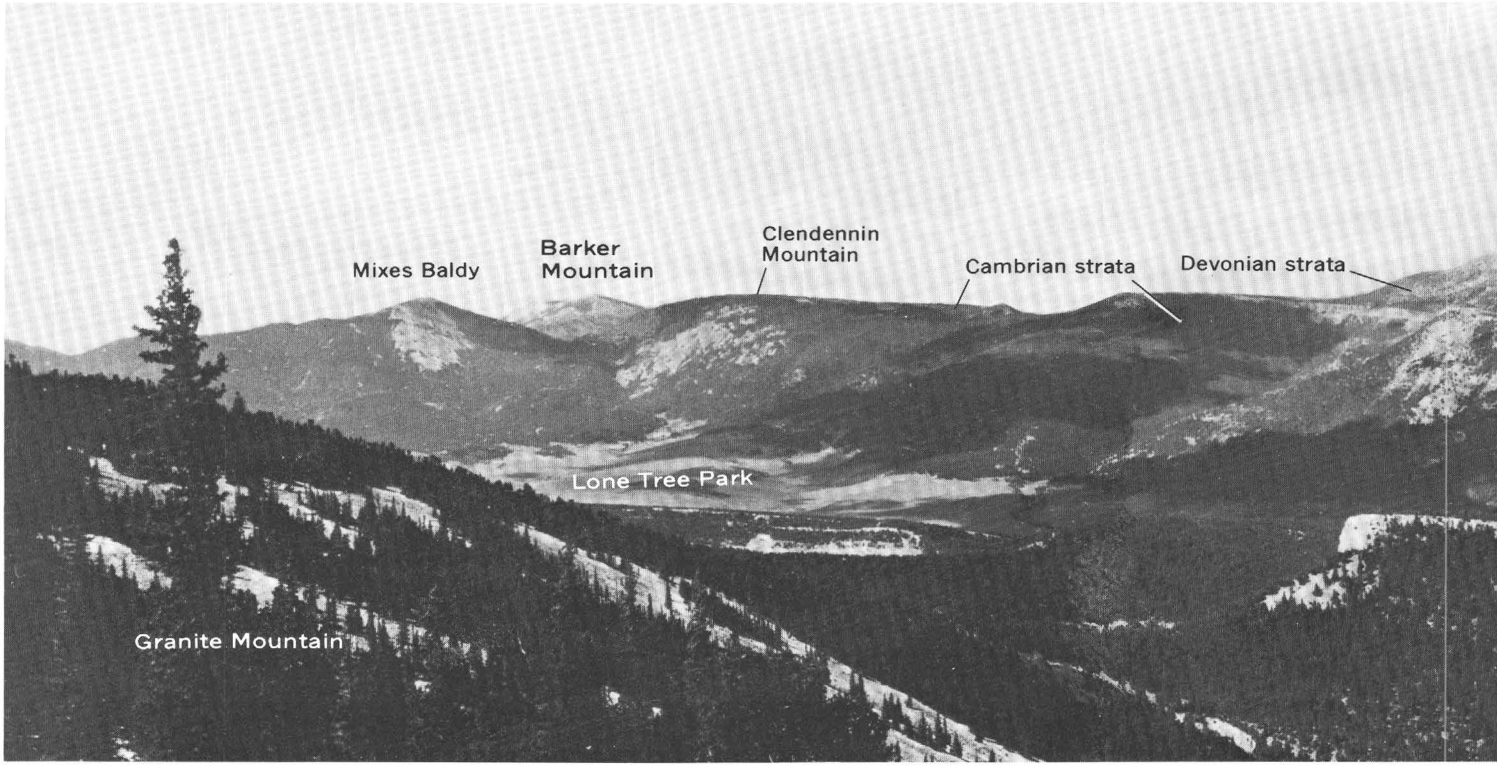


FIGURE 20.—View from the crest of Granite Mountain looking westward across Lone Tree Park toward the southeast flank of the elongate anticline underlain by the Clendennin-Peterson laccolith. The configuration of the anticline is believed to reflect the laccolith, part of which is exposed at Clendennin Mountain. The nose of the anticline

and congealed intrusions were punched upward by younger subjacent masses of magma. Some of the dikes that follow the fault may be apophyses of this younger magma.

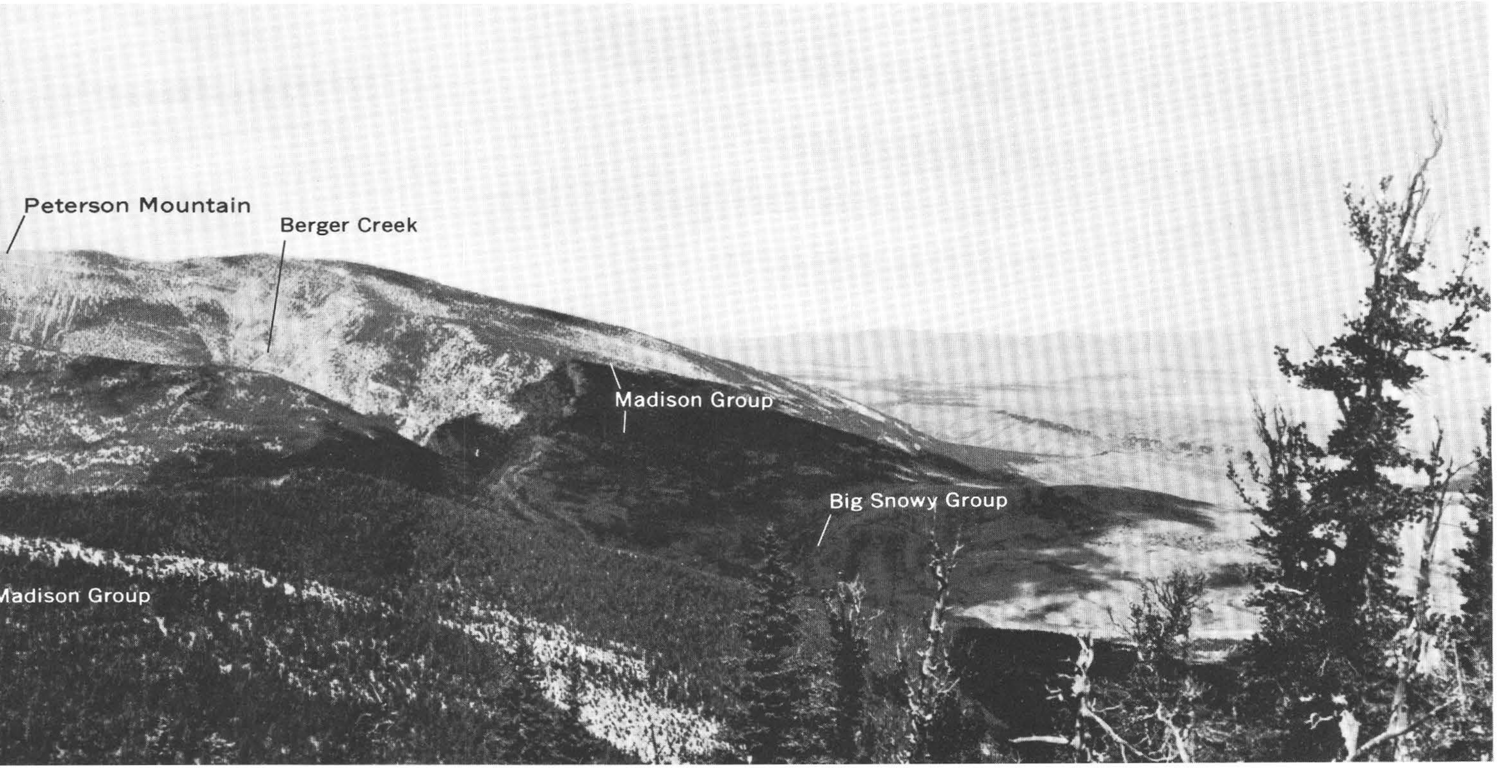
BURIED PLUTON

A very large compound pluton has intruded and raised the Precambrian crystalline rocks that form the core of the Little Belt Mountains. In this quadrangle the pluton is completely concealed, and only here and there do small dikes and plugs of felsic rock give some idea of its lithology. Its northern flank is reflected by steeply tilted Cambrian strata which wrap around the Precambrian complex. Wherever exposed, these beds dip at high angles away from the complex; dips average 70°, but locally the beds are vertical or nearly so (Witkind, 1971). To the south, however, in the Neihart quadrangle, a cupola of the pluton is exposed along Carpenter and Snow Creeks (fig. 31). In those areas it is a compound mass that consists of at least four bodies of quartz rhyolite porphyry, all strikingly similar (Johnson, 1964), which have been mapped as the Snow Creek Porphyry (Keefer, 1969). The thickness of the pluton is unknown, but the presence of orthoclase in various of the quartz porphyries that form it implies that it is floorless.

What is very likely the same pluton is exposed beneath a cover of metamorphic rocks in the nearby open pit of the Silver Dyke mine. Here, Precambrian xenoliths in the porphyry, dikes of one or more porphyries in the Precambrian cover, and brecciated porphyry indicate that many intrusive pulses formed the pluton.

Extending northeastward from this point into the southwest corner of the Barker quadrangle is a zone of felsic dikes and plugs which intrude the Precambrian rocks (fig. 31, and samples 13–15 of table 1). These minor intrusions , singularly like various of the rhyolite porphyries that constitute the Snow Creek Porphyry, form a zone about 1 mile wide and 3½ miles long that trends N. 50° E. through the SE¼ T. 15 N., R. 8 E. (unsurveyed) (Witkind, 1971). I interpret them as apophyses from the crest of the central part of the pluton.

Still farther to the northeast in the San Miguel area (N½ sec. 31, T. 15 N., R. 9 E., unsurveyed) of the Barker quadrangle, the hornblende-biotite gneiss



is formed by limestone beds of the Madison Group. The crest of the Barker laccolith shows along the skyline through the low pass—underlain by faulted Paleozoic rocks—between Mixes Baldy and Clendennin Mountain.

country rock has been severely deformed and altered. There the rocks are intensely sheared and thoroughly impregnated with chlorite. No faults were detected in the San Miguel area, and this cataclasis is attributed to localized deformation during emplacement of the pluton.

The geologic evidence, thus, suggests that the pluton is an oval body elongate to the northeast. Some recent geophysical work involving both ground gravity and aeromagnetic surveys confirms this interpretation (fig. 31) (Witkind and others, 1970).

Where exposed, the pluton is mineralized and contains in different localities, molybdenum, galena, and sphalerite. In the past, significant amounts of silver, lead, and zinc have been mined from the pluton, and it seems likely that comparable amounts are still concealed elsewhere in the pluton (see section on "Buried Mineralized Pluton").

INDURATED ALLUVIUM

Of the surficial deposits in the quadrangle, one unit—the indurated alluvium—is here considered in detail because it offers evidence on the relative ages of several igneous rock types.

The indurated alluvium consists of a heterogeneous mixture of sedimentary, igneous, and metamorphic rocks which crop out in scattered deposits along the sides of Galena, Daisy, and Gold Run Creeks (fig. 6). These deposits, part of a fill that was once continuous across the valleys of these streams, either were not deposited or are not preserved downstream from the mouth of Gold Run Creek.

In the upper reaches of Daisy and Galena Creeks, the indurated alluvium is preserved as thin discontinuous layers 2–3 feet thick. Southward along Galena Creek the deposit is thicker and finer grained. There, the base of the alluvium extends below the stream floor.

Inasmuch as the base of the indurated alluvium is nowhere clearly exposed, its total thickness is uncertain. None is preserved downstream from the mouth of Gold Run Creek, and its absence must be due to erosion by modern Galena Creek. At the mouth of Gold Run Creek, the bottom of the indurated alluvium—as indicated by truncated bedrock exposures—must have been at or near an altitiude of about 5,500 feet. Upstream and along the walls of Gold Run Creek, the top of the old alluvium, truncated by pediment deposits, is at a maximum altitude

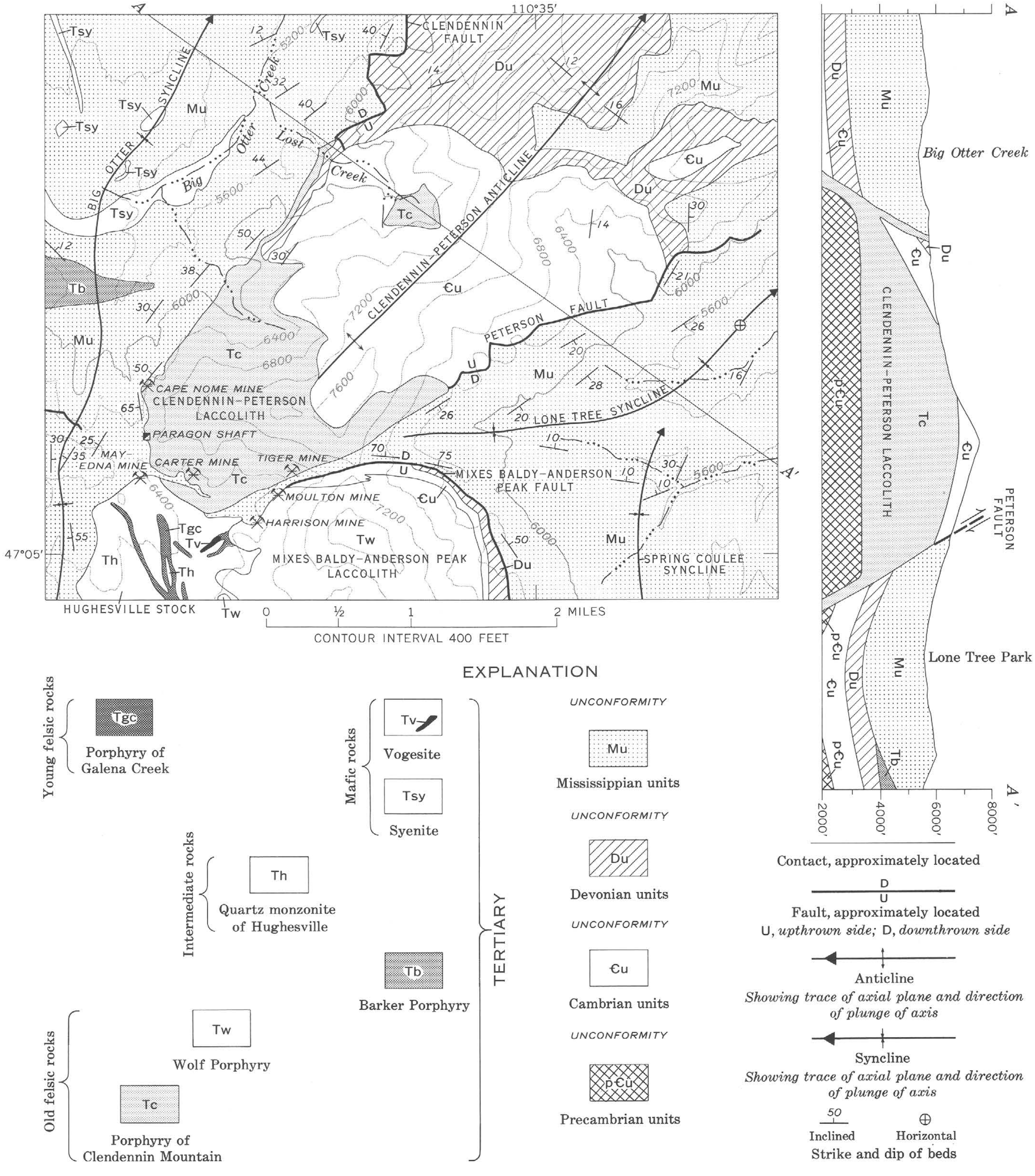


FIGURE 21.—Map of the proximal end of the Clendennin-Peterson laccolith showing relations between the Clendennin and Peterson faults and the laccolith. Paragon and Cape Nome mines probably followed veins localized along the northwest flank of the laccolith (which likely developed against the Clendennin fault). The Tiger mine probably followed a vein localized along the southeast flank of the laccolith (which likely developed against the Peterson fault). The Harrison and Moulton mines are believed to have mined veins localized along the southwestward extension of the Mixes Baldy–Anderson Peak fault. All mines contained sulfide ores and are inactive.

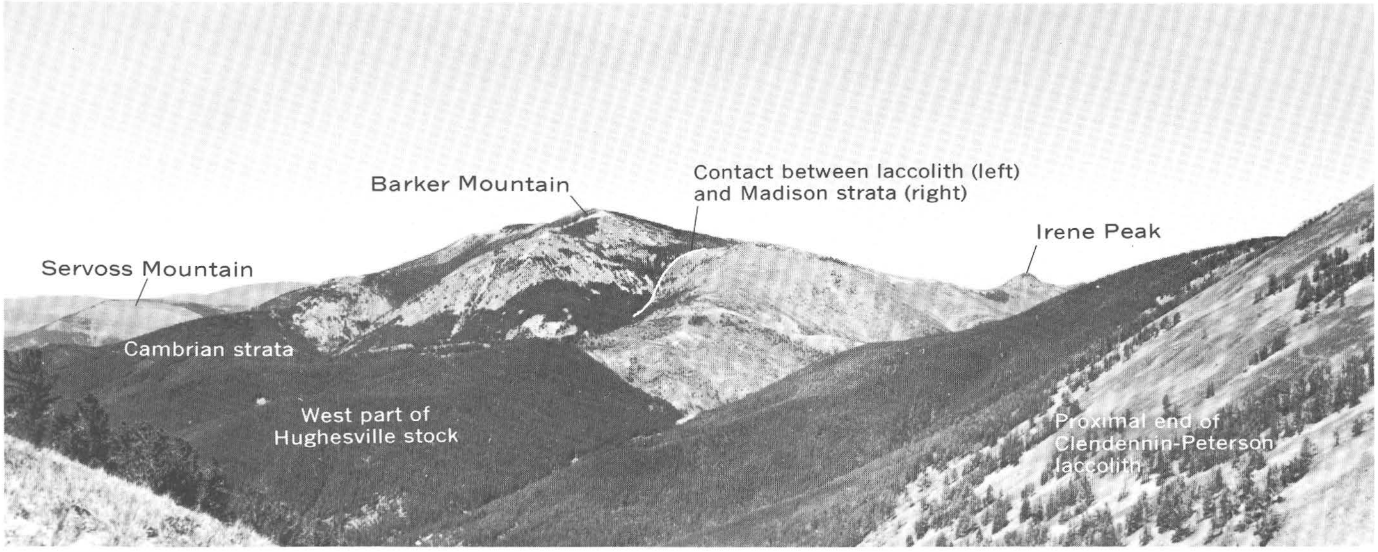


FIGURE 22.—View looking westward from Mixes Baldy at the north and east flanks of Barker laccolith. The northeast flank of the laccolith is in intrusive contact—possibly as a result of a preexisting fault—with Madison strata, whereas all other flanks pass below Cambrian strata, chiefly the Pilgrim Limestone. Heavily wooded area in left foreground is part of the west edge of Hughesville stock. Rockslides in right foreground are part of the denuded southwest end of the Clendennin-Peterson laccolith. Irene Peak is the upturned edge of a resistant sill.

of about 5,750 feet. Here the indurated alluvium extends down to and passes beneath the valley floor; the altitude of its base is unknown. If, however, the gradient of modern Gold Run Creek, 100 feet to the mile, is accepted as the gradient of its ancestor, then the altitude of the base of the indurated alluvium in this locality can be calculated to be about 5,600 feet. The 150-foot difference between exposed top and calculated base is probably an average thickness for the indurated alluvium. It seems doubtful that the alluvium exceeds 200 feet in thickness.

Commonly, the indurated alluvium stands as a steep or nearly vertical wall, and is veined by manganese-stained fractures. Locally, steeply tilted blocks of the alluvium, 50–100 feet across, are enclosed in the main mass and invariably dip toward the embankment. These features suggest that they are slide blocks.

In most exposures the indurated alluvium is a light-brown to grayish-brown, firm, well-cemented jumble of angular to well-rounded rock fragments which range in size from a quarter of an inch to 1 foot; most, however, are about half an inch long. A few beds are composed of moderately well sorted sand and pebbles; crossbedding is common; and here and there cobbles of the indurated alluvium, as much as 6 inches in size and rather well rounded, are incorporated in other masses of indurated alluvium. The deposits were clearly laid down by streams.

The indurated alluvium includes poorly sorted angular to subrounded cobbles of Wolf Porphyry, of the porphyry of Clendennin Mountain, and of the quartz monzonite of Hughesville. In these cobbles, many of the feldspars have been intensely altered to white clay. Grains and seams of pyrite and chalcopyrite are in fragments of both the quartz monzonite of Hughesville and the Wolf Porphyry.

The matrix invariably is brown and consists of a motley of fine to coarse particles more or less cemented by silica and limonite. Much of it consists of minerals derived from the disintegration of the Wolf Porphyry, of the quartz monzonite of Hughesville, and of various metamorphic rocks. As a result, round and angular quartz grains (from the Wolf(?) Porphyry), as well as altered alkalic and plagioclase feldspars (from the quartz monzonite.), are common. Small amounts of garnet (from the metamorphic rocks) are present. Small specks of pyrite are also scattered irregularly through the matrix. Mafic minerals are rare, presumably because most have been weathered and removed.

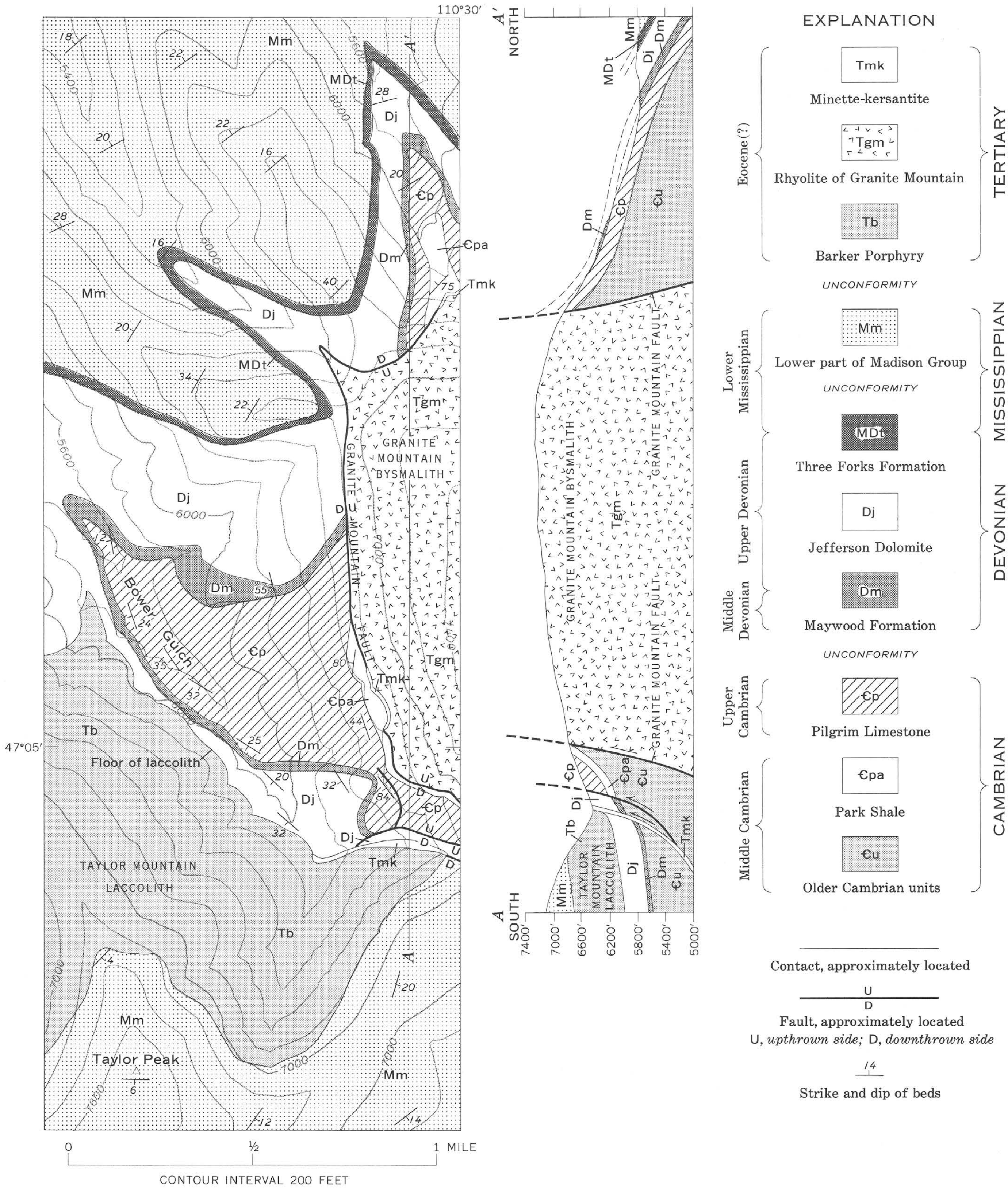


FIGURE 23.—The west flank of the Granite Mountain bysmalith. Base from U.S. Geological Survey, Mixes Baldy quadrangle, 1:24,000, 1961.

The sedimentary rock fragments are mainly dark-gray Paleozoic shale, but include some bluish-gray limestone from the Madison Group. A few fragments of a coarse-grained sandstone, likely from the Flathead Sandstone, were also found.

Inasmuch as neither the Flathead Sandstone nor the metamorphic rocks are exposed in the headwaters of any stream now flowing into Barker basin, the presence of these fragments imply that the ancestral drainage pattern was somewhat different than it is now. The Flathead Sandstone and a broad variety of metamorphic rocks, however, are exposed south of Barker basin where they form part of the north flank of the upland that is domed by the buried pluton (Witkind, 1971). I suggest that the ancestral streams rising in this highland flowed northward into Barker basin and added their detritus to that of those other streams confined within the basin. This drainage pattern was disrupted as the Mixes Baldy–Anderson Peak laccolith was punched up. This laccolith effectively blocked access to the basin from the south, and the northward-flowing streams were forced into a new outlet through Dry Fork Belt Creek.

Dikes of both felsic and mafic rock cut the indurated alluvium. For example, along both Galena and Gold Run Creeks, dikes of the rhyolite of Galena Creek, as much as 25 feet wide, intrude the alluvium. And a dike of vogesite, about 5 feet wide, cuts the alluvium along the north wall of Gold Run Creek (center sec. 18, T. 15 N., R. 9 E.).

The presence of fragments of the Wolf Porphyry (from the Mixes Baldy–Anderson Peak laccolith), of the quartz monzonite of Hughesville (from the Hughesville stock), and of the porphyry of Clendennin Mountain (from the Clendennin-Peterson laccolith) indicates that these igneous bodies had been partly denuded before emplacement of the dikes.

The gross pattern of intrusion suggested by the indurated alluvium and the dikes that cut it, therefore, is: emplacement of the old felsic and intermediate rocks, then their partial destruction to form the indurated alluvium, followed by the intrusion of the felsic and mafic dikes. The validity of this sequence is examined in the following section.

EMPLACEMENT SEQUENCE OF THE INTRUSIONS

Although the relations between the indurated alluvium and the dikes that cut it suggest a general sequence of emplacement, there is still much uncertainty as to the exact sequence of emplacement of the individual intrusions. The available geologic evidence is fragmentary, and for some rock types inconclusive. Only here and there do crosscutting relations, chilled zones, or xenoliths demonstrate that one igneous rock is older than another (table 6).

TABLE 6.—*Tabular summary of known and inferred crosscutting relations in the Barker quadrangle*

[U = unsurveyed]

	Relative age of the intrusions								Field locality
	Oldest			Intermediate			Youngest		
	Intrusion	Lithology		Intrusion	Lithology		Intrusion	Lithology	
Known crosscutting relations	Mixes Baldy–Anderson Peak laccolith	Old felsic (Wolf Porphyry)	intruded by	Fingers of Hughesville stock	Intermediate (quartz monzonite of Hughesville)				Secs. 6 and 7, T. 15 N., R. 9 E. (U).
	Mixes Baldy–Anderson Peak laccolith		intruded by	Dikes and plugs	Intermediate (quartz monzonite of Hughesville)				Secs. 7, 8, 17, 18, T. 15 N., R. 9 E. (U).
				Hughesville stock	Intermediate (quartz monzonite of Hughesville)	intruded by	Dikes	Young felsic (rhyolite of Galena Creek)	Secs. 6 and 7, T. 15 N., R. 9 E. (U).
				Hughesville stock	Intermediate (quartz monzonite of Hughesville)	intruded by	Dikes	Mafic (vogesite, kersantite)	Sec. 6, T. 15 N., R. 9 E. (U).
				Taylor Mountain laccolith	Intermediate (Barker Porphyry)	intruded by	Dike	Mafic (vogesite)	Secs. 11 and 12, T. 15 N., R. 9 E.
Inferred crosscutting relations	Mixes Baldy–Anderson Peak laccolith	Old felsic (Wolf Porphyry)	intruded by				Dikes	(1) Young felsic (rhyolite of Galena Creek)	E½ sec. 18, T. 15 N., R. 9 E.
								(2) Mafic (vogesite)	S½ sec. 7, T. 15 N., R. 9 E. (U).

The geologic evidence suggests that there have been three intrusive episodes; two marked by the emplacement of mainly felsic rocks (old felsic (see section on "Old Felsic Rocks") and young felsic rocks (see section on "Young Felsic Rocks")) separated by one during which intermediate rocks (see section on "Intermediate Rocks") were emplaced. Many, if not all, of the mafic intrusions (see section on "Mafic Rocks") seem to have been emplaced after the intermediate intrusions, likely during the third intrusive episode. The potassium-argon data (fig. 24) suggest that a localized resurgence of igneous activity occurred near the Hughesville stock, lowering the radiometric age of the stock and of several of the adjacent intrusions (Marvin and others, 1973).

FIRST INTRUSIVE EPISODE

During the first episode, it is likely that the Clendennin-Peterson and Mixes Baldy–Anderson Peak laccoliths were emplaced. This sequence began when a highly siliceous magma moved up a master conduit (now occupied by the Hughesville stock) (fig. 29) and started to form the Clendennin-Peterson laccolith. At the time—as indicated by the porphyry of Clendennin Mountain that forms the laccolith—only a few phenocrysts of mafic minerals and feldspar had crystallized.

As the laccolith grew, a time came when increased resistance to the addition of magma forced the magma to seek new conduits. One conduit was found to the southeast, and a new pulse of magma from the same chamber moved laterally into the available space and began to form the Mixes Baldy–Anderson Peak laccolith. By this time many more phenocrysts had formed, and most of them had become large. This magma solidified to become the Wolf Porphyry, mineralogically and chemically like the porphyry of Clendennin Mountain, but much coarser.

SECOND INTRUSIVE EPISODE

After the development of the Mixes Baldy–Anderson Peak laccolith, a magma of intermediate composition, now represented by the Barker Porphyry, used the same master conduit as the previous felsic magma to form the Barker laccolith. In time other channels were used to form such large intrusions as the Butcherknife Mountain, Taylor Mountain, and Dry Wolf laccoliths, as well as in the inferred laccolith that underlies the Limestone Butte dome.

Subsequently, a somewhat less siliceous phase of the magma—similar in composition to the quartz monzonite that now forms the Hughesville stock—moved through the master conduit and formed various floored intrusions. Among these are the Otter laccolith, the expanded sill northeast of Irene Peak, and the various latite porphyry plugs and dikes that cut the Mixes Baldy–Anderson Peak laccolith.

The final stage in this episode was the crystallization of the magma in the master conduit, exposed now as the Hughesville stock.

FORMATION OF INDURATED ALLUVIUM

After these intrusions were emplaced, part of their sedimentary cover was removed and the igneous rock exposed. The resultant sedimentary and igneous debris was deposited in a partly enclosed basin to form the indurated alluvium (p. 41).

THIRD INTRUSIVE EPISODE

A highly siliceous magma—whose composition is represented by the young felsic rocks—gave rise to a compound pluton which further deformed the rocks in the area. The southern edge of the magma elevated the Precambrian complex in the southwest corner of the quadrangle. The northern edge of the magma, emplaced below the floor of the Mixes Baldy–Anderson Peak laccolith, punched up the solid igneous laccolithic plug, even as it sent dikes cutting through the Hughesville stock and the indurated alluvium. And another apophysis from the northern edge may have formed the Granite Mountain bysmalith. Finally the small lamprophyric intrusions were emplaced, the earliest of them overlapping the young felsic rocks in time and the composite dikes in space.

RADIOMETRIC AGES OF THE INTRUSIONS

In an attempt to fix both the time and sequence of emplacement of the various intrusions, 16 samples of igneous rock were submitted for radiometric age determinations. Details of the study have been reported on elsewhere (Marvin and others, 1973). The location of the 16 samples analyzed and the pertinent data derived from their analyses are given in figure 24 and table 7.

It was concluded that the great majority of the intrusions were formed during the Tertiary, most likely the Eocene, in the time span from 54 to 48 m.y. ago. The time sequence of the three intrusive episodes (see section on "Emplacement Sequence of the Intrusions") recognized in the field could not be resolved with the potassium-argon ages available.

Local resurgence of igneous activity occurred near the Hughesville stock about 42 m.y. ago resulting in lower ages for these intrusions.

MINERAL DEPOSITS

Mining began in this region with the discovery of placer gold in Yogo Creek in 1865.[1] Hostile Indians drove off the first prospectors, and active prospecting was not resumed until 1879. In October of that year Buck Barker and Patrick W. Hughes, grubstaked for a trapping expedition by U.S. Senator Thomas C. Powers, came upon an outcrop of what they thought was tin where the Block P vein crosses Galena Creek. Their "tin" was quickly recognized as galena, and the Barker and Gold Eagle claims were staked on this discovery. The news of the strike spread quickly, and the Barker area boomed. Prospects were staked and mines opened along promising veins. The ore, reportedly of high quality, was hauled by wagon across the Kibbey Divide (fig. 1) to Fort Benton on the Missouri where it was loaded onto steamers, ferried down the river, and eventually shipped to smelters overseas.

To reduce haulage costs two small smelters were constructed, one at Hughesville and the other at Clendennin—now known as Barker. Neither was used extensively, and by 1883 both were dismantled. Mining declined slowly until 1891 when a railroad spur was constructed to Barker from Monarch. In response to this stimulus several of the larger mines increased production. The silver panic of 1893 forced most of the mines to close, and shortly thereafter the railroad spur from Monarch was dismantled. The smaller mines continued to operate until the financial depression of 1897 ended all mining activity. The community turned to logging operations to survive. In 1902, Senator Powers formed the Block P Mining Co., named after the flag design of his Missouri River steamboats.

The Block P and several other mines in the Barker area were operated intermittently on a small scale until 1927 when the St. Joseph Lead Co. purchased the Block P Mining Co. The new owners rebuilt the railroad spur and constructed a new 400-ton selective flotation plant just south of Barker at the junction of Galena Creek and the Dry Fork Belt Creek (fig. 6). To connect the Block P mine with the plant, a 10,250-foot aerial tramway was constructed. Mining and milling continued until 1930 when unfavorable market conditions forced the suspension of mining activity. Mining was resumed in 1941 but was finally ended in 1943 by government order, mainly because the mine was considered to be a marginal producer and lead was no longer a critical metal (Woodward and Luff, 1945, p. 400–401). In 1944, the mill was dismantled, the railroad tracks removed, and the railroad right-of-way abandoned. In that year the Thorson Brothers and Brazee purchased part of the holdings of the St. Joseph Lead Co. and produced a small amount of ore.

In 1946, the Block P properties passed into the hands of the American Smelting and Refining Co. The Thorson Brothers and Brazee continued mining the upper workings under a lease agreement until 1952.

The amount of ore produced since then has been small; most of it has come from the reopening of former mine drifts by various miners, who continue to live in and near the area in hope that a new strike will revitalize the district.

BARKER MINING DISTRICT

About $6 million worth of metals, chiefly silver, lead, and zinc, has been recovered from mines in the Barker quadrangle. Most of this ore came from those mines in and near the Hughesville stock—the unorganized Barker (Hughesville) mining district (fig. 25). Several other mines in the quadrangle are some 3½ miles south of the Barker district and are grouped as the San Miguel mining district. Very little ore has been produced from these mines.

My attention will go largely to the geologic relations of the ore deposits in the Barker mining district.

Geologically, the heart of the district is the Hughesville stock (see section on "Stock"). All the mines that have produced significant tonnages of sulfide ore are either within the stock or along and near its margins. The major veins are near its center; these dwindle in tenor and size toward the margins. Beyond the stock the ore deposits are small; several are alined along the laccolithic flanks of the Clendennin-Peterson and Mixes Baldy–Anderson Peak laccoliths, seemingly localized in the various faults that limit these laccoliths (see section on "Clendennin-Peterson Laccolith" and fig. 21).

For purposes of discussion the ore deposits have been grouped as those formed (1) in fissure veins in

[1] The cited historical data come from various sources, mainly Robertson and Roby's (1951) Bureau of Mines report on the mines of Judith Basin County.

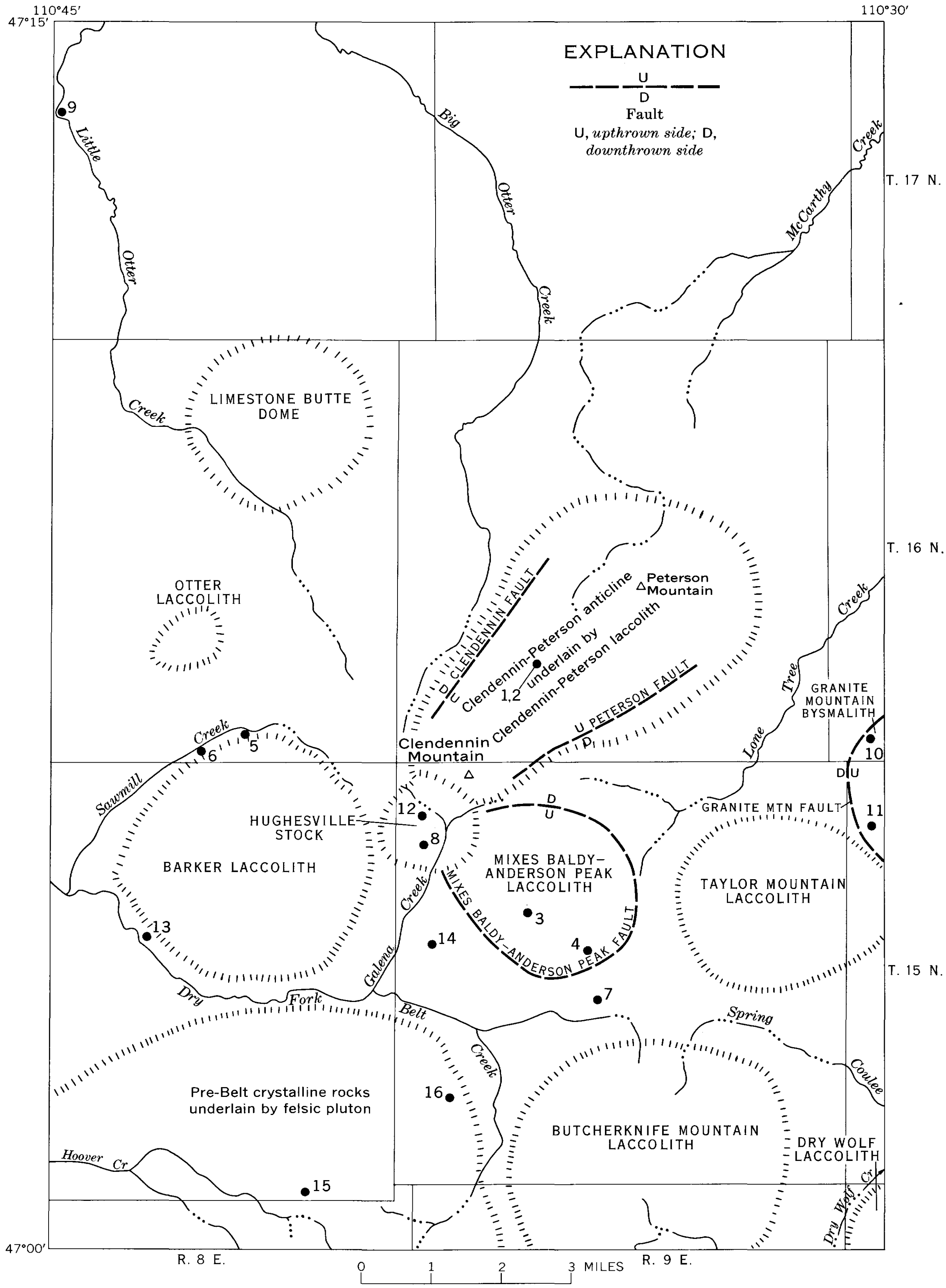


FIGURE 24.—Sample localities for radiometric age determinations of various intrusions in the Barker quadrangle. Ages are given in table 7 on facing page.

TABLE 7.—*Radiometric ages of various intrusions in the Barker quadrangle*

[Analysts: R. F. Marvin, H. H. Mehnert, Violet Merritt, and Wayne Mountjoy]
Decay constants: K^{40} $\lambda_{\epsilon} = 0.584 \times 10^{-10}$ per year
$\lambda_{\beta} = 4.72 \times 10^{-10}$ per year
Atomic abundance: $K^{40} = 1.19 \times 10^{-4}$

No.	Laboratory No. D-	Field No. WL-	Intrusion	Rock name	Material analyzed	K_2O% (avg.)	Radiogenic argon (moles/gm.) ($\times 10^{-10}$)	Percent radiogenic argon	Calculated age (millions of years) $\pm 2\sigma$[1]
1	1032	210	Clendennin-Peterson laccolith	Porphyry of Clendennin Mountain.	Biotite	8.66	7.218	92	55.6±2.3
							7.116	92	54.9±2.3
					Sanidine	4.80	3.705	92	51.6±1.8
2	1922	575	do	do	Biotite	8.54	6.438	85	50.4±1.9
3	1030	208	Mixes Baldy–Anderson Peak laccolith.	Wolf Porphyry	Biotite	8.75	6.054	86	46.4±1.6
					Sanidine	6.59	4.420	87	44.9±1.5
4	1924	579	do	do	Biotite	7.58	5.353	91	47.3±1.8
					Hornblende [2]	0.904	0.6248	86	46.3±1.7
5	1589	404	Barker laccolith	Barker Porphyry	Biotite	8.18	5.907	80	48.3±1.6
					Sanidine	9.94	7.247	89	48.8±1.7
6	1959	582	do	do	Biotite	7.90	5.875	80	49.7±2.3
7	1925	580	Sill	do	Biotite	7.20	5.706	94	53.0±2.0
8	1031	209	Hughesville stock	Quartz monzonite of Hughesville.	Biotite	9.05	6.075	81	44.9±1.5
					Orthoclase	8.81	5.931	86	45.1±1.5
9	1029	31	Plug	Shonkinite	Biotite	8.06	6.719	82	51.3±1.5
						8.10	5.876	83	48.5±1.5
					Orthoclase	8.74	8.257	93	61.0±1.8
						8.42	8.336	92	65.9±2.0
					Barium orthoclase(?)	7.68	5.215	94	45.4±1.4
10	1911	103	Granite Mountain bysmalith.	Rhyolite of Granite Mountain.	Whole rock	4.10	2.991	84	48.8±2.0
11	1927	589	do	do	Whole rock (Rb/Sr)				[3] 50.0±5.0
12	1923	576	Composite dike	Kersantite	Biotite	8.84	5.802	87	44.0±1.7
13	1960	583	Sill	Vogesite	Hornblende [2]	0.674	0.5841	72	57.8±2.2
14	1590	417	Dike	Weathered vogesite	Biotite	8.56	5.430	93	42.5±1.3
					Sanidine	11.02	6.807	94	41.4±1.2
15	1591	450	Plug	Snow Creek(?) Porphyry.	Biotite	7.16	5.451	82	50.9±1.7
					Orthoclase	6.16	4.566	87	49.6±1.7
16	1926	581	Dike	do	Whole rock	4.36	3.453	92	52.9±2.0

[1] Standard deviation.
[2] Potassium determined by isotope dilution.
[3] Z. E. Peterman, written commun., 1970.

Sample No.	Rb (ppm)	Sr_n (ppm)	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
WL-589-2	529	8.51	179.9	0.8341
WL-589-4	523	8.91	169.8	0.8269

the stock, (2) in contact-replacement deposits along the stock's margin, and (3) along contacts between the laccoliths and the intruded sedimentary rocks. The fissure veins in the stock have provided, by far, the most ore.

FISSURE VEINS IN THE STOCK

Many of the fissure veins in the stock formed in fractures of the two systems that have been discussed. One system of joint sets trends N. 60° E., and N. 40° W.; the other, a northerly set and its companion set, trends easterly. In the Block P mine, for example, the major vein is concave to the north (Spiroff, 1938, fig. 3); this fact indicates that the ore minerals were deposited in the northwest-northeast system. Other veins in the Block P mine follow the northwest-trending fractures (Spiroff, 1938, p. 559). In the Liberty mine both the northeast- and northwest-trending fractures are also followed by major veins—the Liberty and Angela veins follow the northeast set and the Transverse vein follows a northwest-trending fracture (fig. 26). Most of the mines west of Galena Creek followed veins that trend northwestward, whereas most of the mines east of Galena Creek followed veins that trend northeastward.

In general, all joint sets are followed by both dikes and veins, and locally the dikes have one or more veins along their flanks (Weed, 1900, p. 353; Spiroff, 1938, p. 559; G. VR. McBride, written commun., 1967). Some dikes are also cut by veins (fig. 12).

Further, the veins are broken by a postmineralization fracture set which trends N. 10° W. (Spiroff, 1938, p. 560; G. VR. McBride, written commun., 1968). The stock, thus, appears to have been broken repeatedly: one or more times before the dikes were emplaced, again after the dikes solidified, and again after the veins formed. Each of these minor deformational episodes may have been caused by the re-

496-189 O - 73 - 2

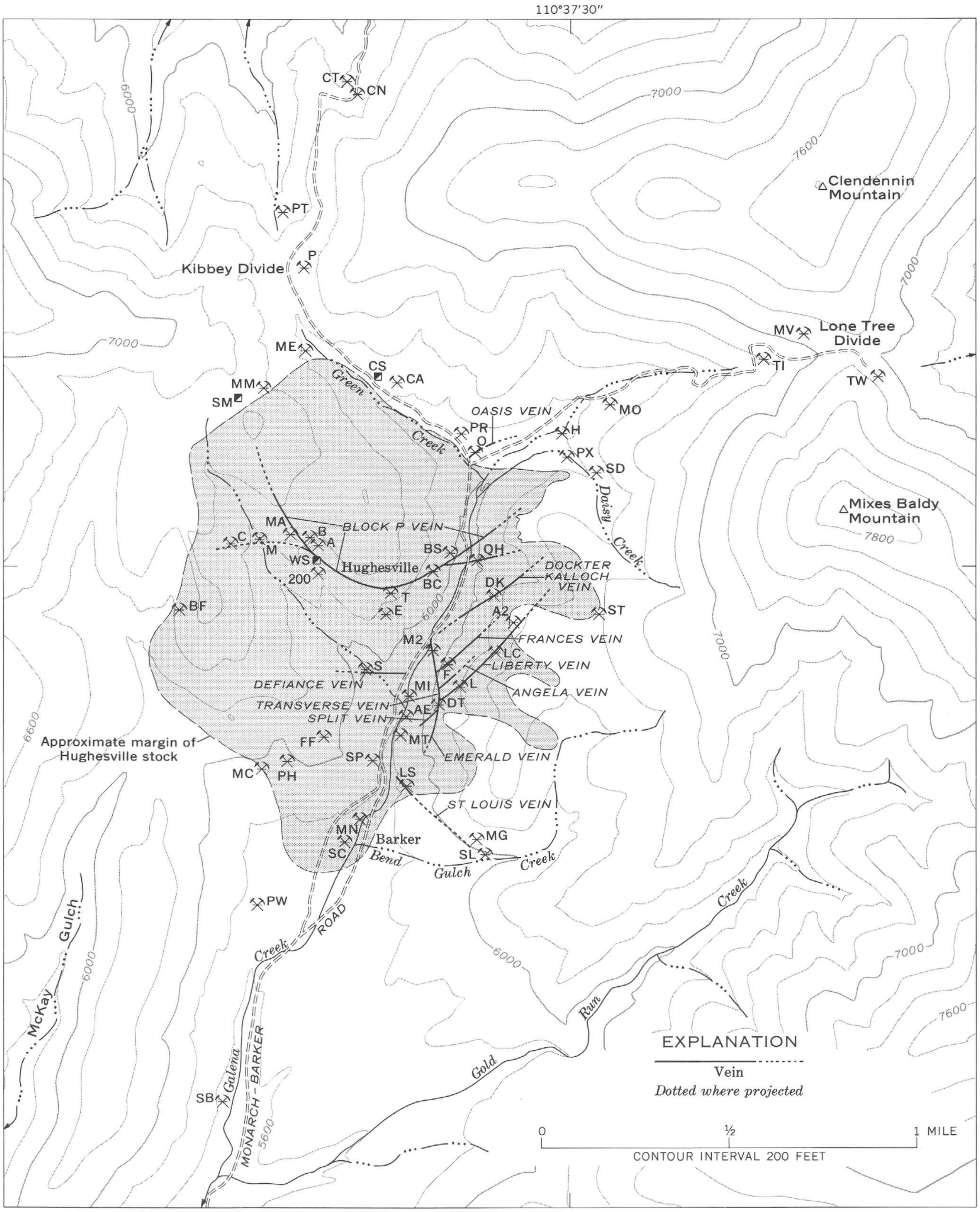


FIGURE 25.—Mines in and near the Barker mining district. Almost all were inactive as of August 1968. Base from U.S. Geological Survey, Barker and Mixes Baldy quadrangles, 1: 24,000, 1961. Key to lettered symbols given on opposite page.

Symbols used in figure 25

A.	"A" tunnel of Block P.	L.	Liberty tunnel of Liberty.	PR.	Plymouth Rock.
AE.	Annie E tunnel of Liberty.	LC.	Last Chance tunnel of Liberty.	PT.	Paragon tunnel.
A2.	August No. 2 tunnel of Liberty.	LS.	Lucky Strike.	PW.	Pride of the West.
B.	"B" tunnel of Block P.	M.	Mayflower tunnel.	PX.	Phoenix.
BC.	Barker crosscut of Block P.	MA.	Maytee tunnel of Block P.	QH.	Queen of the Hills.
BF.	Bon Ton–Fairplay.	MC.	McKinley.	S.	Sinclair.
BS.	Barker shaft of Block P.	ME.	May and Edna.	SB.	Silver Bell.
C.	Chesapeake tunnel.	MG.	Magnolia.	SC.	St. Charles.
CA.	Carter.	MM.	Middle tunnel of May and Edna.	SD.	Snow Drift tunnel.
CN.	Cape Nome.	MN.	Myrtle-Navy.	SL.	St. Louis.
CT.	Cape Nome tunnel.	MO.	Moulton.	SM.	Shaft of May and Edna.
CS.	Carter shaft.	MT.	Main tunnel of Liberty.	SP.	St. Patrick.
DK.	Dockter Kalloch.	MV.	McVeda.	ST.	Spruce tunnel.
DT.	Danny T tunnel of Liberty.	M1.	Marcelline tunnel No. 1 of Liberty.	T.	Thorson tunnel of Block P.
E.	Equator tunnel of Block P.	M2.	Marcelline tunnel No. 2 of Liberty.	TI.	Tiger.
F.	Frances tunnel of Liberty.	O.	Oasis.	TW.	TW.
FF.	Double Eff.	P.	Paragon.	WS.	Wright and Edwards shaft of Block P.
H.	Harrison.	PH.	Philharmonic.	200.	200-foot level, Wright and Edwards shaft of Block P.

peated emplacement of magma (see section on "Localization" and fig. 29).

The fissure veins are sinuous tabular bodies as much as 6 feet thick which dip steeply. Commonly, they pinch and swell, and in places dwindle to mere leads a few inches thick. Here and there they split for short distances and then coalesce to enclose a wedge of country rock.

Locally, they show excellent nearly symmetrical crustification that indicates at least three paragenetic stages (fig. 27*A*). During the first stage (I), quartz and pyrite and small amounts of sphalerite were deposited on the fracture walls. In the second stage (II), the dominant ore minerals of the district, argentiferous galena and sphalerite, formed; and during the third stage (III), various gangue minerals, mainly barite and rhodochrosite, filled the remaining voids. Sparse ore minerals were also deposited during this stage. Pyrite apparently was deposited during all three stages.

Subsequently, these veins were fractured and were displaced a few millimeters; and veinlets of rhodochrosite, barite, and pyrite formed in these minute fractures (fig. 27*B*, *C*).

Many of the veins are filled, but in places their centers contain small vugs lined with well-developed crystals of pyrite, galena, and sphalerite.

Most of the ore minerals are hypogene; very few supergene minerals are present. Argentiferous gal-

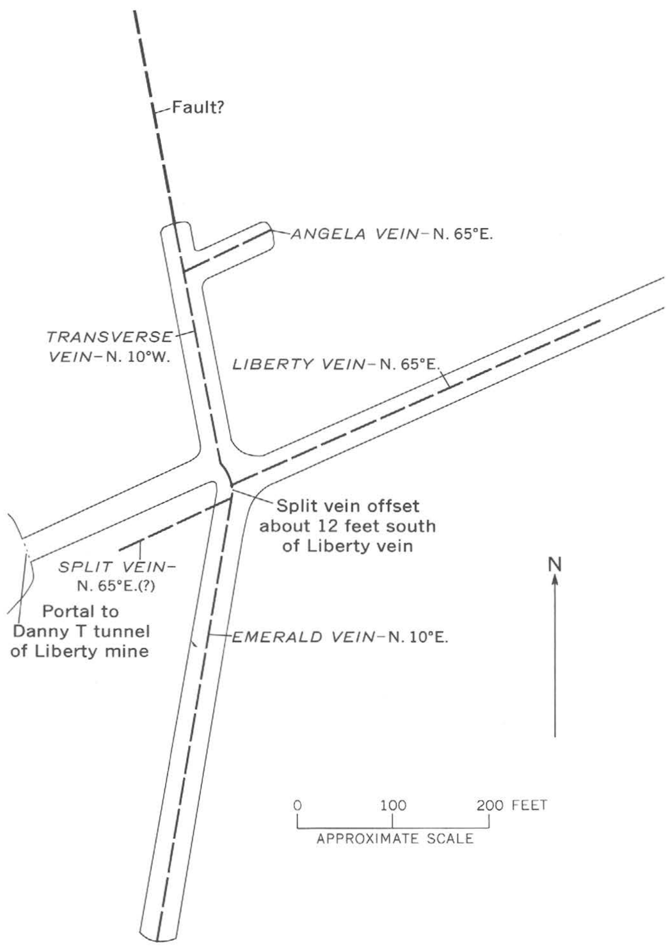


FIGURE 26.—The pattern and trend of major veins in the Danny T tunnel of the Liberty mine. Modified from sketch supplied by G. VR. McBride (written commun., 1967).

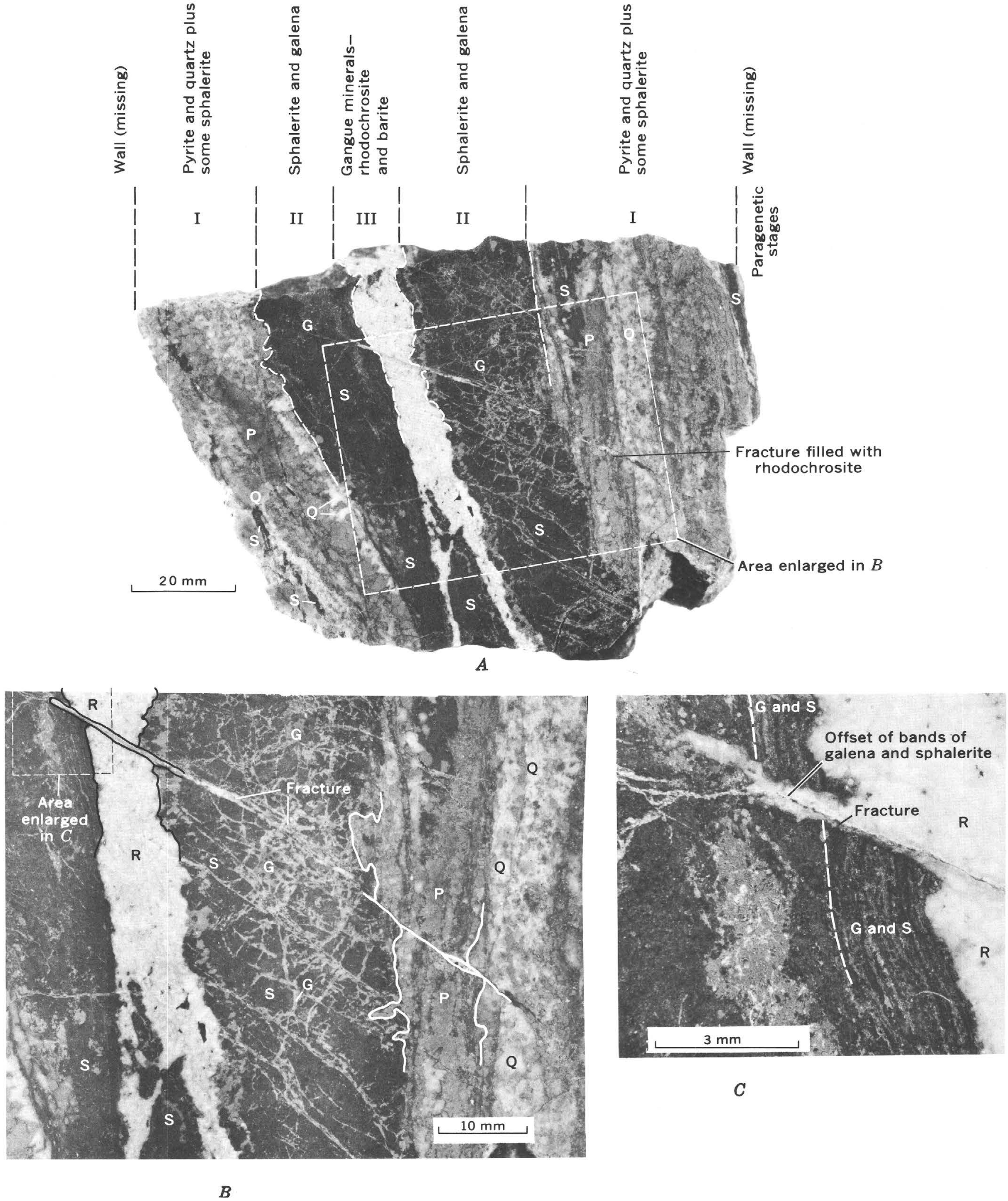


FIGURE 27.—Explanation on opposite page.

ena, sphalerite, and pyrite are the principal ore minerals. Others that have been found by me or reported by other geologists (Spiroff, 1938; G. VR. McBride, oral commun., 1967; J. J. Wallace, Jr., written commun., 1968; H. D. Hess, written commun., 1953) follow:

Common	*Rare*
Barite	Anglesite
Chalcopyrite	Arsenopyrite
Marmatite	Azurite
Rhodochrosite	Bornite (?)
	Cerrusite
	Covellite
	Gold
	Malachite
	Marcasite
	Molybdenite
	Scheelite
	Siderite
	Tetrahedrite
	Wurtzite

Most of the ore minerals were deposited under mesothermal (intermediate-temperature) conditions, but three of them, molybdenite, scheelite, and wurtzite, imply hypothermal (high-temperature) conditions. In the Lucky Strike mine (LS of fig. 25), a small veinlet of molybdenite and quartz cuts the stock. Blebs and streaks of molybdenite disseminated in shattered and brecciated quartz rhyolite are found as fragments in the mine tailings. Molybdenite has also been reported from the Frances tunnel (F of fig. 25) of the Liberty mine. From the Frances tunnel, 2 tons of molybdenite-bearing rock was mined, but not shipped, from a 3- to 4-inch-thick eastward-trending vein (G. VR. McBride, oral commun., 1966).

A few grains of scheelite have been identified in samples collected at the 10- to 20-foot depth from a newly opened prospect on the St. Patrick–Double Eff properties (J. J. Wallace, Montana Bur. Mines and Geology, written commun., 1968). And wurtzite has been identified by Bureau of Mines personnel in samples collected from the Transverse vein of the Liberty mine (H. D. Hess, U.S. Bur. Mines, written commun., 1953).

FIGURE 27.—Crustified vein, Barker mining district. Photographs by R. B. Taylor. *A*, Crustified fissure vein from the Liberty mine showing three paragenetic stages. I. Pyrite, quartz, and a little sphalerite deposited. II. Argentiferous galena and sphalerite formed. III. Remaining voids filled by rhodochrosite and barite. *B*, *C*, Vein broken and slightly offset by a minor fracture which is now filled with rhodochrosite. G, galena; S, sphalerite; P, pyrite; Q, quartz; R, rhodochrosite.

Zones of intensely altered rock flank the sulfide veins. On the surface the altered zones appear as bands 10–20 feet wide composed of strongly sericitized rock much stained by limonite. Alteration has been severe, for both the stock and dike rocks are converted chiefly to quartz, sericite, and pyrite. Virtually all the normal rock-forming minerals, except quartz, have been changed. Both the alkalic and the plagioclase feldspars have been converted almost completely to a fine-grained mixture of quartz and sericite. In places the alteration has been so complete that the original texture of the feldspars has been wholly obliterated.

It is difficult to estimate how much of the stock has been altered; a conservative estimate is that between 20 and 30 percent of the rock shows significant effects of hydrothermal alteration. Locally, the intensely altered rocks and the related sulfied veins are cut by small veinlets of mosaic quartz indicating a late-stage episode of silicification. Whether the quartz-molybdenite veinlets are similarly cut is unknown.

Neither kaolinite nor clay minerals have been found in the altered rocks of the Hughesville stock; likely their absence is due to the temperature of the hydrothermal solutions. Experimental evidence suggests, among other possible factors, that at a depth in the earth's crust of about 10,000 feet, kaolinite is not stable above 400°C, whereas the quartz-sericite couple remains more or less unchanged to 640°C (Creasey, 1966, p. 55). This absence of kaolinite is explicable, then, if the temperature of the hydrothermal solutions fell somewhere between these two values.

To the south in the Neihart area, there is much evidence of potassic alteration (Johnson, 1964, p. 60). Orthoclase has been added to the Precambrian crystalline rocks as well as to the Tertiary intrusions. Comparable feldspathization has not been found in the Barker area.

FISSURE VEINS BEYOND THE STOCK

Little is known about fissure veins outside the stock. The Paragon and Cape Nome mines along the northwest flank of the Clendennin-Peterson laccolith and the Tiger mine along its southeast flank are believed to have followed veins localized along the Clendennin and Peterson faults respectively (fig. 21). In like fashion the Harrison and Moulton mines, along the northwest flank of the Mixes Baldy–Anderson Peak laccolith, probably mined veins that followed the circumferential Mixes Baldy–Anderson Peak fault. It seems likely that the ore solutions moved up through the stock and then migrated along the preexisting faults using them as channelways.

CONTACT-REPLACEMENT DEPOSITS

Contact-replacement deposits have formed along the contact between the Hughesville stock and the limestone beds of the Madison Group. These were tapped by the May and Edna mine and the McKinley mine (ME and MC of fig. 25). The major ore extracted from these deposits was massive galena which, in contrast to that in the fissure veins, carried very low silver values (6–8 ounces versus 20–40 ounces per ton) (G. VR. McBride, written commun., 1968).

Elsewhere in the Little Belt Mountains, blanket like replacement deposits of iron and manganese locally follow contacts between laccolithic flanks and overlying sedimentary beds. These appear to be tabular bodies which more or less conform to the intrusion. So, the McVeda mine (fig. 28) on the southeast flank of the Clendennin-Peterson laccolith taps such a deposit. A similar deposit is exposed in the open pit of the Whittaker mine east of the Barker quadrangle (sec. 7, T. 14 N., R. 11 E., Judith Basin County) (Westgate, 1920).

TENOR

Exactly how much ore has been produced from the Barker mining district will never be known, for early records are few and notoriously inaccurate. During the period 1921–48, however, about 416,000 short tons was extracted, mainly from the Block P mine. From this were recovered approximately 4,000 ounces of gold, 2,700,000 ounces of silver, 850,000 pounds of copper, 46 million pounds of lead, and 18 million pounds of zinc (Robertson and Roby, 1951, p. 7).

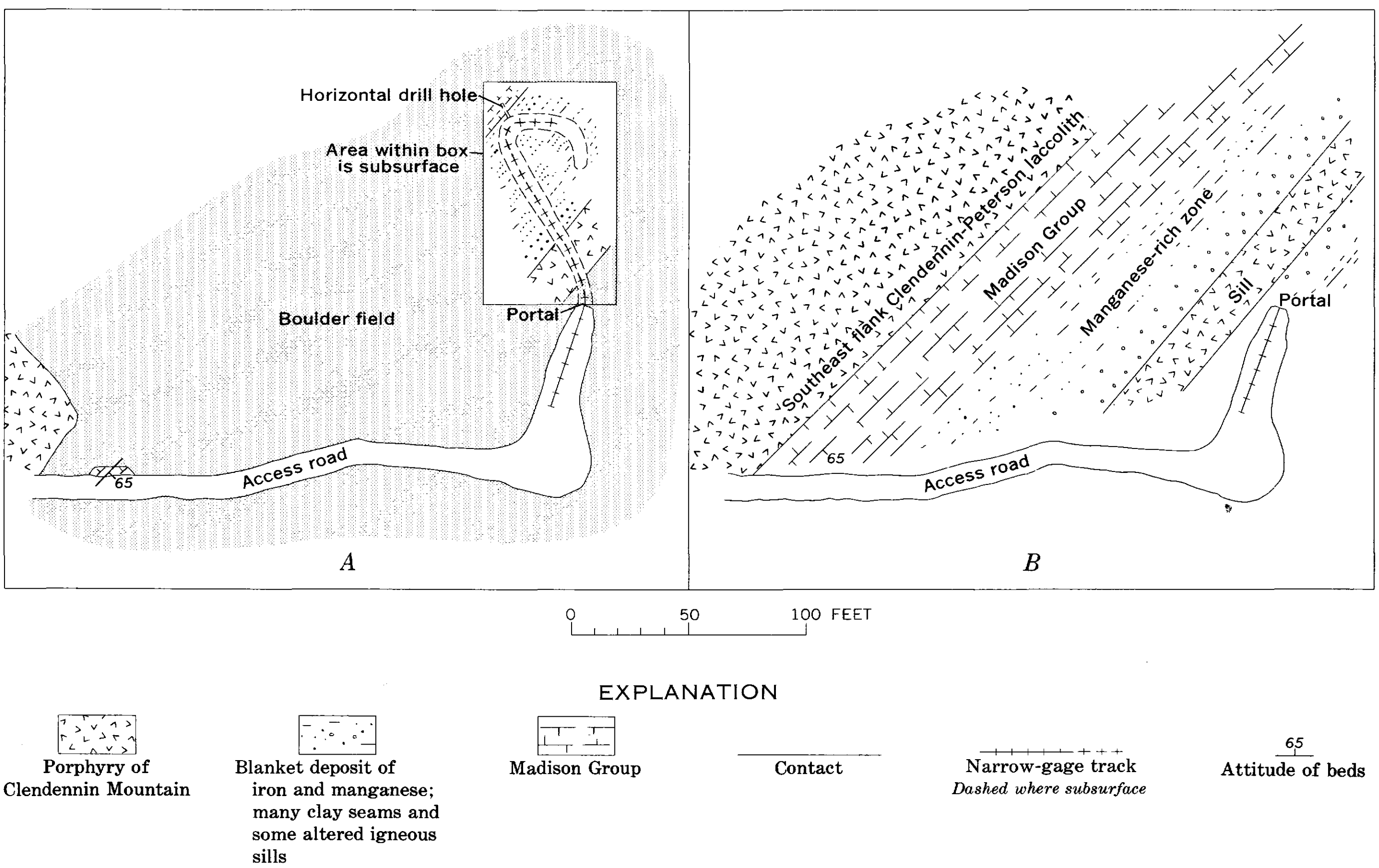


FIGURE 28.—McVeda mine along southeast flank of the Clendennin-Peterson laccolith. *A*, Geologic relations in and near the mine. Much of the area is covered by boulder fields weathered from the laccolith. *B*, Inferred geologic relations. A blanketlike deposit of iron and manganese is adjacent to a sill in limestone mantling the southeast flank of the laccolith.

The dominant metal is lead; and galena, its source mineral, probably contains most of the silver although some may be carried by sphalerite and pyrite. Silver minerals are rare in the district. Polished sections of ore show no silver minerals; this lack implies silver either is very finely admixed or is carried in solid solution by the other ore minerals.

Minor amounts of gold have been produced. No gold minerals were found in the polished sections, and here too, I suspect that the gold is carried by other minerals, possibly the pyrite.

Any estimate concerning the tenor of the ores produced from the fissure veins in the stock is based on the production records of the two major mines in the area: the Block P and the Liberty. It is regrettable that the information is contradictory. As an example, MacKnight (1892) reported that in the early 1890's the Block P produced ore that contained values of 40–65 ounces of silver and 40–48 percent lead per ton. The production data for the mine for the period 1915–48 (table 8), however, indicate a much lower tenor. Of the 406,000 tons of ore produced, the weighted average values recovered were close to 6½ ounces of silver and 5 percent lead per ton.

There seems to have been some drastic variations in metals produced from time to time (table 8). Although in several periods, the recovered values were as high as 31 ounces of silver and 29 percent lead per ton, during other periods the values dipped to as low as 5 ounces silver and 4 percent lead per ton. This wide variation in tenor suggests to me a major change in mining operations rather than a change in the veins that were mined. The higher values probably represent careful selective mining of the veins, whereas the lower values may indicate dilution of vein material with wall rock. If this is true, this implies that the metal content of the veins alone is probably closer to the higher values. This higher value, which is supported by the production data available for the Liberty mine, indicates that for the period 1900–64 the produced ore contained a weighted average of 24 ounces of silver and 30 percent lead per ton (table 9). These values, I believe, more closely approximate the tenor of veins in the district.

AGE OF THE ORES

It seems likely that there have been at least two episodes of sulfide ore mineralization: one older than the young felsic dikes, and a second younger than the dikes. This is suggested by field relations: a dike of the porphyry of Galena Creek, exposed near the Sinclair mine (S of fig. 25), contains fragments of galena (as well as xenoliths of the stock). The implication is that some galena was in existence prior to the time the young felsic dikes were emplaced. But other veins are younger than these dikes, inasmuch as several dikes are cut by the veins. The sulfide vein that cuts the Annie E composite dike is an example of this group (fig. 12).

I believe that most of the ores were formed during this younger episode of mineralization, likely from mineralizing solutions expelled during the crystallization of the salic magma responsible for the felsic dikes. The time of emplacement of the high-temperature minerals is uncertain.

Some evidence indicates that parts of the stock were broken after the veins were formed. For example, in the Block P mine a vein of steel galena is adjacent to a felsic dike (G. VR. McBride, written commun., 1968). I interpret this relation to mean that a vein of massive galena crystallized alongside the previously formed dike. Then, as the stock was jostled—possibly during a local resurgence of igneous activity—the galena was mylonitized and recrystallized to steel galena. Inasmuch as not all veins contain steel galena, the movement in the stock

TABLE 8.—*Production data for the Block P mine*

[Modified from data supplied by Robertson and Roby (1951, p. 18)]

Period	Ore (tons)	Gold		Silver		Copper		Lead		Zinc	
		Ounces				Pounds					
		Recovered	Ounces per ton	Recovered	Ounces per ton	Recovered	Percentage	Recovered	Percentage	Recovered	Percentage
1915–20	1,560	66.11	0.04	49,247	31.0	6,469	0.21	904,733	29.0	—	—
1921–30	316,054	2,877.02	.009	2,090,173	6.6	550,911	.09	34,964,584	5.5	14,579,545	2.3
1942–45	87,963	378.00	.004	430,569	4.9	216,315	.12	6,689,323	3.8	3,209,200	1.8
1947–48	275	11.00	.04	8,235	29.9	1,417	.26	191,777	34.9	59,653	10.8
Total	405,852	3,332.13	—	2,578,224	—	775,112	—	42,750,417	—	17,848,398	—
Metal content; weighted average			0.008	—	6.4	—	0.10	—	5.3	—	2.2

TABLE 9.—*Production data for the Liberty mine*

[Modified from data supplied by Mrs. G. VR. McBride, Faith Mining Co.]

Vein	Productive years	Ore (dry weight)		Gold		Silver		Copper		Lead		Zinc	
				Ounces				Pounds					
		Pounds	Tons	Recovered	Ounces per ton	Recovered	Ounces per ton	Recovered	Percentage [1]	Recovered	Percentage	Recovered	Percentage
Liberty	1900, 1916, 1917, 1921	1,151,553	575.8	24.60	0.04	15,859	27.5	2,824	0.3	295,239	25.6	108,952	9.5
Emerald	1921, 1924, 1927	812,254	406.2	8.96	.02	10,128	24.9	884	.1	296,260	36.5	61,952	7.6
August No. 2	1921–1924, 1926, 1933, 1935	558,719	279.2	10.44	.04	6,444	23.1	346	------	231,482	41.4	23,278	4.2
Danny T	1923, 1936–1947, 1950, 1951, 1953, 1958	496,261	248.3	5.90	.02	4,331	17.4	353	------	91,550	18.5	49,527	10.0
Marcelline	1939, 1941, 1963, 1964	359,831	179.9	3.80	.02	3,522	19.6	377	------	104,415	29.0	27,220	7.6
Queen of the Hills	1916	88,349	44.2	.40	.01	1,648	37.3	------	------	22,355	25.3	17,432	19.7
Total		3,466,967	1,733.6	54.1	------	41,932	------	4,784	------	1,041,301	------	288,361	------
Metal content; weighted average		------	------	------	0.03	------	24.2	------	------	------	30.0	------	8.3

[1] Based on incomplete data.

probably was differential because some parts were more severely affected than others.

LOCALIZATION

The Hughesville stock has been the center of repeated igneous and hydrothermal activity. At least three intrusive episodes, each more intense than the preceding one, can be recognized on the basis of geologic evidence, and a fourth is implied by the radiometric data (p. 43). This has led me to propose that a master conduit—now occupied by the Hughesville stock—has acted much like an inverted funnel (fig. 29). Successive diverse magmas as well as mineralizing fluids from crystallizing magmas at depth have been repeatedly channeled into the conduit and so localized in the stock.

During the first intrusive episode, salic magma rose in the conduit to form first the Clendennin-Peterson laccolith and then the Mixes Baldy–Anderson Peak laccolith (p. 42).

Subsequently, magma of intermediate composition, using the same conduit, flushed out the salic magma as it formed the Barker laccolith (p. 42). A more basic phase of this magma, again using the same conduit, formed the Otter laccolith, the sill northeast of Irene Peak; and when it finally crystallized in the conduit, it formed the Hughesville stock (p. 42). Minor amounts of mineralizing fluids possibly accompanied this activity (fig. 29*A*).

The third intrusive episode is represented in and near the Hughesville stock by felsic, mafic, and composite dikes (fig. 29*B*). The major sulfide veins probably represent mineralizing fluids expelled during the final stages in the crystallization of the felsic magma of this episode. There is some geologic and geophysical evidence that the felsic pluton which was formed at this time extends as an ovoid mass beneath the Precambrian crystallines from near Neihart to near Barker (see section on "Buried Pluton" and fig. 31).

Evidence for the fourth intrusive episode is largely radiometric and has been presented elsewhere (Marvin and others, 1973). In brief, the potassium-argon data imply that another young felsic pluton is concealed beneath the stock. Clear geologic evidence of such a pluton is lacking.

SAN MIGUEL DISTRICT

The San Miguel district is centered on a group of abandoned mines in the N½ sec. 31, T. 15 N., R. 9 E. (unsurveyed). The district, about 3½ miles south of Barker, is along the west valley wall of the Dry Fork Belt Creek and is accessible by way of mountain roads (fig. 30).

The ore deposits in the district were discovered about 1881 (Robertson and Roby, 1951, p. 39). At that time considerable exploratory work was done, but it is unknown whether any ore was shipped. MacKnight, writing in 1892 (p. 108), commented on the activity in the Dry Fork Mining Co.'s mines and claims 3 miles south of Barker. It seems likely that these are the properties here grouped in the San Miguel district.

It is certain that mining was active in the district during the late 1920's because at least one carload of silver-lead ore was produced and shipped in 1927 (Gerry, 1930, p. 769). And in 1929, "about 2,000 feet of tunnel work was done at the San Miguel property

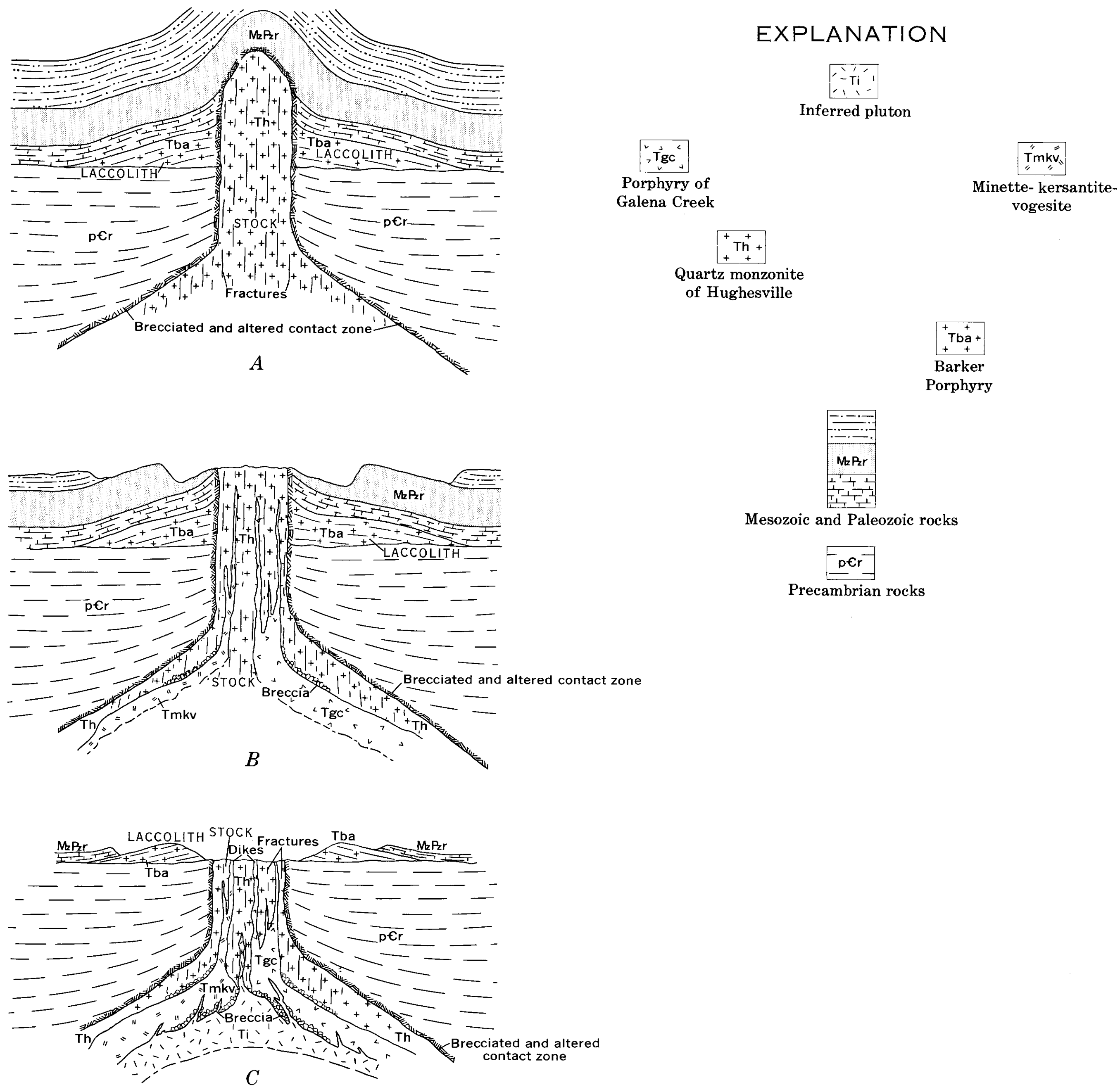


FIGURE 29.—How a master conduit may have repeatedly guided diverse magmas and ore solutions into the Hughesville stock.

The magmas and their related ore solutions were channeled into an old master conduit which acted somewhat like an inverted funnel. Presumably the radial pattern of laccoliths about the stock (fig. 2) is the result of ascending magma repeatedly using the same parent conduit. *A*, At the conclusion of the second intrusive episode, intermediate magma congeals in the throat of the conduit. This plug, now known as the Hughesville stock, has solidified and been broken by fractures. *B*, During the third episode, young salic and femic magmas, guided into the master conduit, invade fractures in the stock to form felsic, mafic, and composite dikes. Upon cooling, the salic pluton expels mineralizing solutions. These solutions rise in available fractures to higher and cooler parts of the stock and form veins which locally are adjacent to the dikes but elsewhere cut across them. *C*, During a renewed surge of localized intense igneous activity, another pluton is again guided into the master conduit. It jostles the stock and reactivates some fractures.

* * *" (Gerry and Miller, 1932, p. 859). Work stopped shortly thereafter, and since then only minor amounts of assessment work, chiefly the bulldozing of exploration pits, have been carried on by the owners, the Faith Mining Co. of Helena, Mont. During the summer of 1968, a small prospect pit dug in the Montgomery property along the nose of a knoll in the NE¼ sec. 31 exposed small discrete pods, seams, and lenses of sulfide minerals, mainly galena.

The district is near the east edge of the uplifted Precambrian complex of crystalline rocks, and the intensely fractured and altered rocks are believed to reflect the east flank of a buried pluton (see section on "Buried Pluton" and fig. 31). The host rock for the ore deposits is chlorite schist, the alteration product of hornblende-biotite gneiss.

Very little is known about the veins in the district. A mineralized seam that is exposed in the prospect pit which was dug on the Montgomery property strikes about N. 5° W. According to G. VR. McBride (oral commun., 1968), most veins strike almost due north. Robertson and Roby (1951, p. 40) reported a N. 5° E. trend for a narrow stringer containing galena that is exposed at the San Marcos adit.

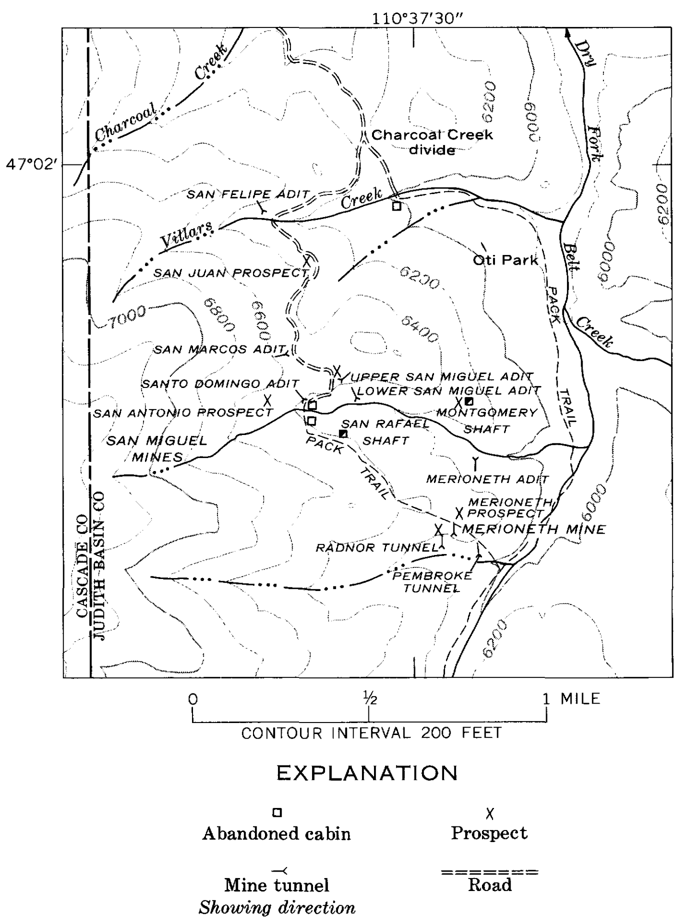


FIGURE 30.—Mines and prospects in the San Miguel area. Base from U.S. Geological Survey, Barker and Mixes Baldy quadrangles, 1:24,000, 1961.

The thickness and tenor of the veins are also uncertain. A sample of ore from the Montgomery property contained about 0.10 ounce gold, 19 ounces silver, and about 78 percent lead per ton, according to G. VR. McBride (oral commun., 1968). The carload of silver-lead ore that was shipped in 1927 was reported to contain 0.70 ounce gold, 18 ounces of silver, about 51 percent lead, and 3.0 percent zinc per ton (Robertson and Roby, 1951, p. 40).

Galena, sphalerite, and pyrite occur as small pods, stringers, and disseminations in the schist. Other ore minerals found in rock fragments in the mine dumps include chalcopyrite, azurite, malachite, and bornite(?).

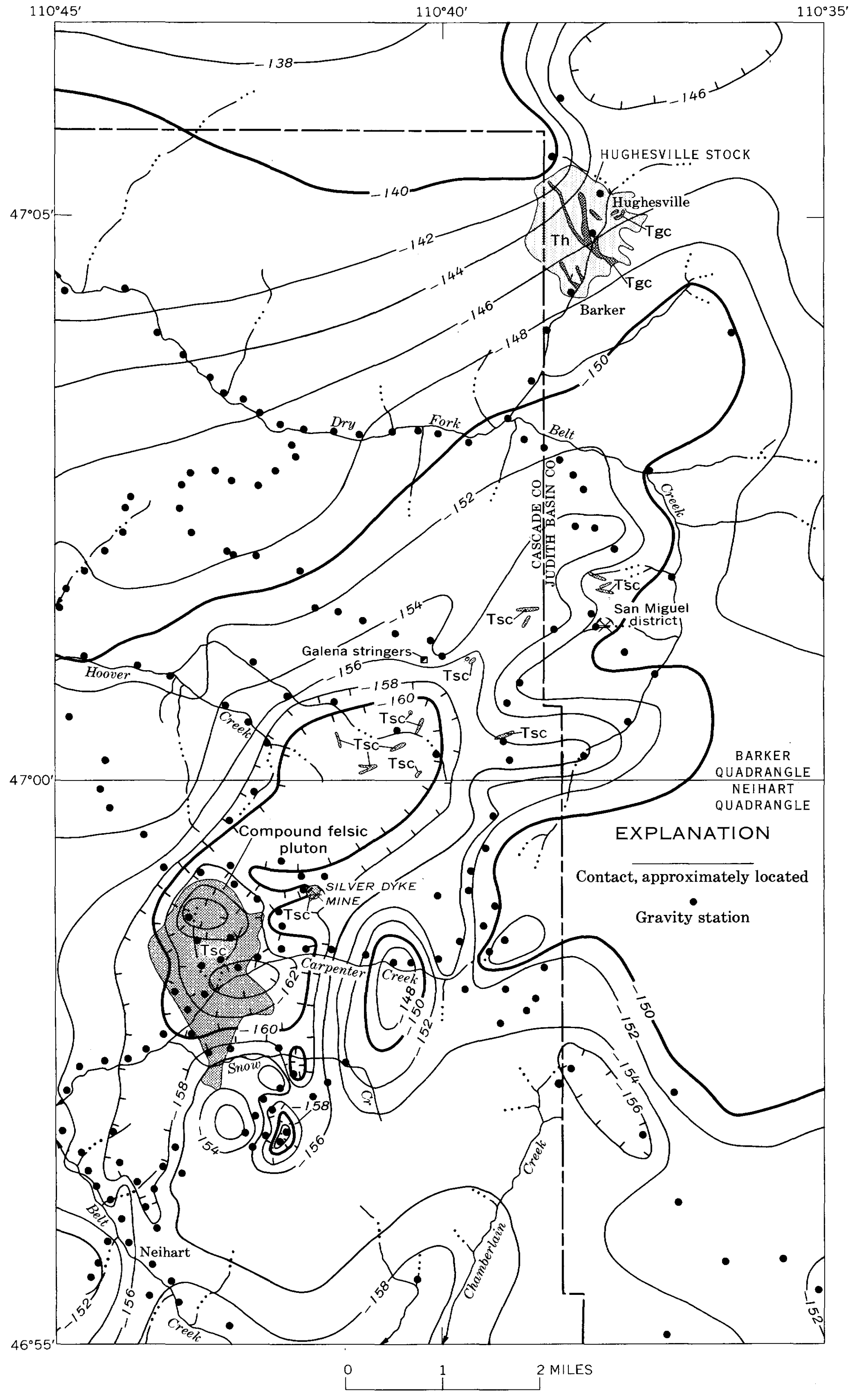
ORE POTENTIAL

The ore potential of the Barker quadrangle lies in two types of deposits: first, the sulfide veins in the stock, and second, disseminated ore minerals that may be in part of a deeply buried pluton beneath the Hughesville stock. Geologic and geophysical evidence both indicate that a large Tertiary pluton underlies the southwest corner of this quadrangle and the northwest corner of the Neihart quadrangle (see section on "Buried Pluton" and fig. 31). It is the northwest flank of this pluton that may extend beneath the stock.

SULFIDE VEINS

Inasmuch as most of the mines were caved or flooded in 1968, it was not possible to determine the thickness and nature of those veins exposed in the workings. Many of the mines have been closed for more than half a century, presumably because the veins are so thin that mining them is uneconomic, but other undiscovered veins may still contain sizable deposits of ore minerals. One of the last large mines to close was the Block P which ceased operations in 1943. At that time the vein being worked

FIGURE 31.—The trend, size, and shape of the buried mineralized pluton. Gravity contoured by M. D. Kleinkopf; contour interval is 2 milligals. Geology north of lat 47°00′ by I. J. Witkind in 1967; south of it by W. R. Keefer in 1965. Base from U.S. Geological Survey, Barker and Neihart quadrangles, 1:24.000, 1961. Tsc, Snow Creek Porphyry, Th, quartz monzonite of Hughesville; Tgc, porphyry of Galena Creek (all units of Tertiary age). All mines shown are abandoned.


110°45′
110°40′
110°35′
47°05′
47°00′
46°55′
138
140
142
144
146
148
150
152
154
156
158
160
162
HUGHESVILLE STOCK
Hughesville
Th
Tgc
Barker
Dry Fork
Belt Creek
CASCADE CO
JUDITH BASIN CO
Tsc
San Miguel district
Galena stringers
Hoover Creek
BARKER QUADRANGLE
NEIHART QUADRANGLE
Compound felsic pluton
SILVER DYKE MINE
Carpenter Creek
Snow Cr
Chamberlain Creek
Neihart
EXPLANATION
Contact, approximately located
Gravity station
0 1 2 MILES

reportedly contained "good ore" and was about 3 feet wide (Roy Thorson, miner, Barker, Mont., oral commun., 1966). Apparently there was considerable difficulty in bringing sufficient ore to the surface through the one available shaft. As a result the government concluded that the mine was a marginal producer and ordered it closed (Woodward and Luff, 1945, p. 401).

Since then, intermittent mining in the Block P and Liberty mines has resulted in the production of minor amounts of ore.

Under current economic conditions the sulfide veins do not seem to offer much chance of successful exploitation except by small-scale low-overhead operations.

BURIED MINERALIZED PLUTON

The general size and shape of the buried pluton is expressed by a large northeast-trending gravity anomaly which extends from Neihart to near Barker (fig. 31). A part of the south flank of the pluton is exposed beneath Precambrian rocks in the Carpenter Creek–Snow Creek area near Neihart. Farther to the northeast the axis of the pluton is followed by a zone of quartz rhyolite porphyry dikes (Snow Creek Porphyry) which intrude the Precambrian crystallines. I interpret these dikes to be offshoots from the crest of the buried pluton. And in the Barker area the small felsic dikes (porphyry of Galena Creek) that cut the stock are interpreted to be apophyses from the northwestern flank of the pluton. The collinearity between these intrusions and the gravity anomaly can hardly be fortuitous. I believe that these relations indicate that the pluton is a northeast-trending ovoid body at least 11 miles long and some 4 miles wide.

All offshoots or exposures of the pluton are composed of felsic rock. The general composition of the pluton is probably well represented by the outcrops along Carpenter Creek. In that area, the deroofed part of the pluton is a compound mass composed of four quartz rhyolite porphyries similar in mineralogy and chemical composition (Johnson, 1964). These units have been mapped as the Snow Creek Porphyry (Keefer, 1969, 1973).

Mineralized exposures are along the axis of the pluton. At its southwest end near Neihart, veins of argentiferous galena and sphalerite have been mined. About 2 miles to the northeast in the Carpenter Creek–Snow Creek area, molybdenite and pyrite fill fractures in the Snow Creek Porphyry as well as in the Precambrian crystalline rocks. Still farther to the northeast the pluton is exposed in the open pit of the Silver Dyke mine, a once famous producer of silver, lead, and zinc. In the pit parts of the pluton are seen to be a breccia tightly cemented by sulfides. Northeast of the Silver Dyke mine and along the trend of the buried pluton, small stringers of galena and pyrite cut the Precambrian rocks. And still farther to the northeast, also along the axis of the buried pluton, is the San Miguel district (see section on "San Miguel District") in which stringers and lenses of galena are in the Precambrian crystalline rocks. At its inferred northeast end is the Hughesville stock.

Several factors suggest that the pluton merits investigation. (1) The potassium-argon data (fig. 24) indicate that the intrusions, and by implication the related mineral deposits, were emplaced in the early Tertiary, a time during which many of the large ore deposits in the western United States were formed. (2) The ore deposits in both quadrangles are spatially related to felsic rocks, quartz rhyolite porphyries and quartz monzonite. These are quartzose host rocks that have been repeatedly cited as being favorable for the deposition of ore. (3) Sulfide mineralization of varying degrees of intensity is scattered erratically along the length of the pluton from Neihart to Barker.

Although certain segments of the pluton are more promising than others, it seems to me that the area most worthy of test by deep drilling is the Hughesville stock. This conclusion is suggested by the following factors: (1) In other laccolithic complexes in the western United States, the ore deposits are spatially related to stocks. (2) The known major ore deposits in this quadrangle are localized in the Hughesville stock; other likely as-yet-undiscovered ore deposits may be similarly localized. (3) The quartz-molybdenite veinlets and the few scheelite blebs imply geochemical leakage from more extensive deposits at depth. In the past, minor amounts of molybdenum in the surface rocks have indicated richer deposits of copper and molybdenum at depth (Kinney and others, 1968). (4) Major volumes of mineralizing fluids are implied by the amount (20–30 percent) of rock that has been hydrothermally altered. Such extensive alteration implies a large source of heat and mineralizing solutions at depth. (5) A favorable structure is suggested by the large volumes of mineralizing solutions which have been channeled through the stock.

REFERENCES CITED

American Geological Institute [Howell, J. V., chm.], 1960, Glossary of geology and related sciences with supplement [2d ed.]: Natl. Acad. Sci.–Natl. Research Council Pub. 501, 325 p.

Billings, M. P., 1942, Structural geology: New York, Prentice-Hall Inc., 473 p.

Catanzaro, E. J., 1967, Correlation of some Precambrian rocks and metamorphic events in parts of Wyoming and Montana: Mountain Geologist, v. 4, no. 1, p. 9–21.

Catanzaro, E. J., and Kulp, J. L., 1964, Discordant zircons from the Little Belt (Montana), Beartooth (Montana), and Santa Catalina (Arizona) Mountains: Geochim. et Cosmochim. Acta, v. 28, no. 1, p. 87–124.

Creasey, S. C., 1966, Hydrothermal alteration, *in* Titley, S. R., and Hicks, C. L., eds., Geology of the porphyry copper deposits, southwestern North America: Tucson, Ariz., Arizona Univ. Press, p. 51–74.

Cross, Whitman, 1894, The laccolithic mountain groups of Colorado, Utah, and Arizona: U.S. Geol. Survey 14th Ann. Rept., pt. 2 (1892–93), p. 157–241.

Gerry, C. N., 1930, Gold, silver, copper, lead, and zinc in Montana, *in* Mineral resources of the United States, 1927, pt. I, Metals: U.S. Bur. Mines, p. 745–782.

Gerry, C. N., and Miller, T. H., 1932, Gold, silver, copper, lead, and zinc in Montana, *in* Mineral resources of the United States, 1929, pt. I, Metals: U.S. Bur. Mines, p. 831–876.

Gilbert, G. K., 1880, Report on the geology of the Henry Mountains, [Utah] [2d ed.]: U.S. Geog. and Geol. Survey Rocky Mtn. Region (Powell), 170 p.

Goddard, E. N., 1950, Structure of the Judith Mountains, Montana [abs.]: Geol. Soc. America Bull., v. 61, no. 12, pt. 2, p. 1465.

Harker, Alfred, 1909, The natural history of igneous rocks: London, Methuen & Co., 384 p.

Howe, Ernest, 1901, Experiments illustrating intrusion and erosion, *in* Jagger, T. A., Jr., The laccoliths of the Black Hills, chap. 5 *of* General geology, ore and phosphate deposits, Philippines: U.S. Geol. Survey 21st Ann. Rept., (1899–1900), pt. 3, p. 291–303.

Hunt, C. B., 1946, Guidebook to the geology and geography of the Henry Mountain region: Utah Geol. Soc. Guidebook, no. 1, 51 p.

——— 1953, Geology and geography of the Henry Mountains region, Utah: U.S. Geol. Survey Prof. Paper 228, 234 p. [1954].

——— 1956, Cenozoic geology of the Colorado Plateau: U.S. Geol. Survey Prof. Paper 279, 99 p.

Iddings, J. P., 1898, Bysmaliths: Jour. Geology, v. 6, p. 704–710.

Johannsen, Albert, 1939, A descriptive petrography of the igneous rocks, v. 1 [2d ed.]: Chicago, Chicago Univ. Press, 318 p.

Johnson, A. C., 1964, The geology of the Big Ben area, Cascade County, Montana: Michigan Univ. unpub. Ph.D. thesis, 104 p.

Keefer, W. R., 1969, Preliminary geologic map of the Neihart (7½′) quadrangle, Cascade and Judith Basin Counties, Montana: U.S. Geol. Survey open-file map.

——— 1973, Geologic map of the west half of the Neihart 15-minute quadrangle, Montana: U.S. Geol. Survey Misc. Geol. Inv. Map I–726 (in press).

Kinney, D. M., Izett, G. A., King, R. U., and Taylor, R. B., 1968, The Poison Ridge volcanic center and related mineralization, Grand and Jackson Counties, Colorado: U.S. Geol. Survey Circ. 594, 8 p.

Kleinkopf, M. D., Witkind, I. J., and Keefer, W. R., 1972, Aeromagnetic, Bouguer gravity, and generalized geologic map of the central part of the Little Belt Mountains, Montana: U.S. Geol. Survey Geophys. Inv. Map GP–837.

Knechtel, M. M., 1944, Oil and gas possibilities of the plains adjacent to the Little Rocky Mountains, Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 4.

Larsen, E. S., Jr., 1940, Petrographic province of central Montana: Geol. Soc. America Bull., v. 51, no. 6, p. 887–948.

Macknight, J. A., 1892, Mines of Montana—Their history and development to date: Helena, Mont., C. K. Wells Co., 138 p.

Marvin, R. F., Witkind, I. J., Keefer, W. R., and Mehnert, H. H., 1973, Early Tertiary intrusions in the Little Belt Mountains, Montana: Geol. Soc. America Bull. (in press).

Peacock, M. A., 1931, Classification of igneous rock series: Jour. Geology, v. 39, no. 1, p. 54–67.

Pirsson, L. V., 1898, Dynamic and structural geology [chap. VI] *in* Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: U.S. Geol. Survey 18th Ann Rept. (1896–97), pt. 3, p. 576–587.

——— 1900, Petrography of the igneous rocks of the Little Belt Mountains, Montana, *in* Weed, W. H., Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts: U.S. Geol. Survey 20th Ann. Rept. (1898–99), pt. 3, p. 463–581.

——— 1905, The petrographic province of central Montana: Am Jour. Sci., 4th ser., v. 20, p. 35–49.

Pratt, W. P., and Jones, W. R., 1961, Trap-door intrusion of the Cameron Creek laccolith, near Silver City, New Mexico, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–C, p. C164–C167.

Robertson, A. F., and Roby, R. N., 1951, Mines and mineral deposits (except fuels), Judith Basin County, Montana: U.S. Bur. Mines Inf. Circ. 7602, 51 p.

Schafer, P. A., 1935, Geology and ore deposits of the Neihart mining district, Cascade County, Montana: Montana Bur. Mines and Geology Mem. 13, 62 p.

Spiroff, Kiril, 1938, Geological observations of the Block P mine, Hughesville, Montana: Econ. Geology, v. 33, no. 5, p. 554–567.

——— 1939, Some of the common minerals found in the Neihart and Hughesville mining districts, Montana: Rocks and Minerals, v. 14, no. 4, p. 109–111.

Taylor, J. H., 1935, A contact metamorphic zone from the Little Belt Mountains, Montana: Am. Mineralogist, v. 20, no. 2, p. 120–128.

——— 1938, The contact zone of Sheep Creek, Little Belt Mountains, Montana: Geol. Mag., v. 75, no. 5, p. 219–226.

Vine, J. D., 1956, Geology of the Stanford-Hobson area, central Montana: U.S. Geol. Survey Bull. 1027–J, p. 405–470.

Weed, W. H., 1899a, Description of the Fort Benton quadrangle, Montana: U.S. Geol. Survey Geol. Atlas, Folio 55, 9 p., 4 maps.

——— 1899b, Description of the Little Belt Mountains quadrangle, Montana: U.S. Geol. Survey Geol. Atlas, Folio 56, 11 p., 4 maps.

——— 1899c, Laccoliths and bysmaliths [abs.]: Science, new ser., v. 10, p. 25–26.

——— 1900, Geology of the Little Belt Mountains, Montana, with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts; accompanied by a report on the petrography of the igneous rocks of the district, by L. V. Pirsson: U.S. Geol. Survey 20th Ann. Rept. (1898–99), pt. 3, p 257–581.

Westgate, L. G., 1920, Deposits of iron ore near Stanford, Montana: U.S. Geol. Survey Bull. 715–F, p. 85–92 [1921].

Witkind, I. J., 1964, Geology of the Abajo Mountains area, San Juan County, Utah: U.S. Geol. Survey Prof. Paper 453, 110 p.

——— 1965, Relation of laccolithic intrusion to faulting in the northern part of the Barker quadrangle, Little Belt Mountains, Montana, *in* Geological Survey research 1965; U.S. Geol. Survey Prof. Paper 525–C, p. C20–C24.

——— 1969, Clinopyroxenes from acidic, intermediate, and basic rocks, Little Belt Mountains, Montana: Am. Mineralogist, v. 54, nos. 7–8, p. 1118–1138.

——— 1970, Composite dikes in the Little Belt Mountains, central Montana, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700–C, p. C82–C88.

——— 1971, Geologic map of the Barker quadrangle, Judith Basin and Cascade counties, Montana: U.S. Geol. Survey Geol. Quad. Map GQ–898.

Witkind, I. J., Kleinkopf, M. D., and Keefer, W. R., 1970, Geologic and gravity evidence for a buried pluton, Little Belt Mountains, central Montana, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700–B, p. B63–B65.

Woodward, G. E., and Luff, Paul, 1945, Gold, silver, copper, lead, and zinc in Montana, *in* Minerals yearbook, 1943: U.S. Bur. Mines, p. 381–407.

U.S. GOVERNMENT PRINTING OFFICE : 1973 O—496–189