CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

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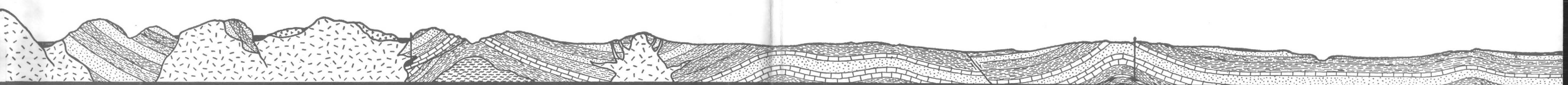
GEOLOGY OF THE GARNET-BEARMOUTH AREA, WESTERN MONTANA

By

MARVIN E. KAUFFMAN

CHAPTER ON METALLIC RESOURCES
by F. N. EARLL



MONTANA BUREAU
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Butte, Montana

STATE OF MONTANA
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GEOLOGY OF THE GARNET-BEARMOUTH AREA, WESTERN MONTANA

ABSTRACT

Sedimentary rocks of the Garnet-Bearmouth area consist of approximately 11,000 feet of Precambrian Belt Series, 6,500 feet of Paleozoic rocks, 2,000 feet of Mesozoic rocks, and several hundred feet of Cenozoic sediments. Strata have been observed from every period except Ordovician, Silurian, and Triassic.

The Precambrian Belt Series consists of the Missoula Group, containing the Miller Peak, Bonner, McNamara, Garnet Range, and Pilcher (Sheep Mountain) Formations.

Paleozoic rocks in the Garnet Range comprise the following: Cambrian 1,900-2,850 feet, Devonian 2,100 feet, Mississippian 2,200 feet, Pennsylvanian 450 feet, and Permian 290 feet.

The Flathead Quartzite, Silver Hill Formation, and lower part of the Hasmark Formation are Middle Cambrian, and the upper part of the Hasmark and the Red Lion Formations are Late Cambrian in age.

The Devonian system includes the Maywood, Jefferson, and possibly the Three Forks Formations. The Mississippian is composed of the Madison Group (Lodgepole and Mission Canyon Formations) and the lower part of the Amsden Formation. The upper part of the Amsden and the Quadrant Formation are Pennsylvanian in age. The Permian Phosphoria Formation is the youngest Paleozoic unit in western Montana.

Paleontologic and physical evidence indicates that the Silver Hill Formation correlates with the Wolsey Shale of central Montana; the Hasmark Formation with the Meagher Limestone, Park Shale, and Pilgrim Limestone; and the Red Lion Formation with the Dry Creek Shale and the Snowy Range Formation of central Montana.

Earliest Middle Jurassic (Bajocian) fossils were obtained from the basal part of the Ellis Group (Sawtooth, Rierdon, and Swift Formations), consisting of approximately 400 feet of marine Jurassic strata. Nonmarine rocks 150 to 200 feet thick, overlying the Ellis Group, probably correlate with part of the Morrison Formation of Wyoming.

Four members can be recognized locally in the Lower Cretaceous Kootenai Formation, which is 1,100 feet thick. The regional extent of these members was not determined. Overlying the Kootenai Formation is a series of fine-grained sandstone, siltstone, shale, minor limestone, and a carbonaceous sandstone, all part of the Blackleaf Formation of the Colorado Group. The youngest Cretaceous in the area is the black shale unit of the Colorado Group, 150 feet of marine black shale, found only in the center of an isoclinally folded syncline along the Clark Fork.

Volcanic-rich Tertiary sediments and welded tuff are associated with Tertiary extrusive and shallow intrusive igneous bodies, including andesite, basalt, rhyolite, and trachyte(?) porphyry.

Pre-Middle Cambrian deformation tilted the Belt Series, resulting in deposition of Cambrian clastics across bevelled edges of Precambrian strata. Several periods of nondeposition or epeirogenic uplift and erosion are indicated by hiatuses in the geologic column and by regional unconformities between the Cambrian and Devonian Periods, within the Devonian, and between the Permian and Jurassic Periods.

Laramide orogenic forces formed isoclinal folds trending approximately N. 75° W. and tectonic transport in a direction normal to this trend, and later normal faulting at various angles to these trends.

Granodioritic stocks and dikes and aplite dikes associated with the Laramide orogeny intruded the sediments, metamorphosed the adjacent rocks, and produced gold lodes, which ultimately were eroded and the gold concentrated as placer deposits.

Cenozoic block faulting and differential erosion have produced the present topographic configuration of the Garnet-Bearmouth area.

INTRODUCTION

LOCATION

The Garnet-Bearmouth area comprises about 140 square miles of the northwestern part of the Garnet Range between longitudes 113°10′ and 113°40′ west and between latitudes 46°40′ and 47°00′ north in western Montana. (See fig. 1.) It includes parts of Townships 11 and 12 North, Ranges 13, 14, 15, and 16 West, of Montana base line and principal meridian, respectively.

Most of the area is in northern Granite County, with small portions in Powell and Missoula Counties. Drummond is 2 miles southeast, Missoula approximately 20 miles northwest, Butte 60 miles southeast, Helena 55 miles east, and Philipsburg 25 miles south.

The area is served by the Northern Pacific and the Chicago, Milwaukee, St. Paul and Pacific Railroads. U. S. Highway 10 traverses the southern part of the region. Numerous good gravel roads penetrate the area, especially those along Bear Creek, Rattler Gulch, Mulkey Gulch, Little Bear Gulch, Tenmile Creek, Dry Gulch, and Cramer Creek. Secondary gravel roads, logging roads, and jeep trails form an intercommunicating network of accessibility.

TOPOGRAPHY AND DRAINAGE

The average relief in the study area is approximately 2,000 feet with an absolute relief of 3,220 feet. The highest point is Mount Baldy, 6,940 feet, and the lowest is in the Clark Fork valley with an elevation of 3,720 feet.

The Clark Fork with its several tributaries provides drainage of the area. There are very few permanent streams; most streams are dry by mid-summer. Bear Creek flows permanently over most of its course. Approximately three miles from its mouth most of the water goes underground in a cavernous limestone region, emerging as a warm spring in the valley of the Clark Fork just east of Bear Creek. The Clark Fork drains into the Columbia River.

The area is characterized by a rather early-mature topography with steep-walled valleys, rolling uplands, and well-drained slopes.

Exposures are generally good in the gullies and ravines and poor on the upland slopes and in the heavily forested areas. The quartzite layers commonly form ridges that can be traced laterally for miles. Where sufficiently exposed to weathering, the massive limestone units are carved into "hoodoo" towers and spires. Shales and siltstones usually underlie grass-covered slopes.

CLIMATE AND VEGETATION

The region has a mean annual temperature of 42°, normal winter temperatures ranging from —30° to 40°F and normal summer temperatures ranging from 32° to 85°F. The average annual precipitation is approximately 15 inches. Vegetative cover consists of native bunchgrasses in the open park areas and conifers and a few deciduous trees in the forested regions. The most common trees in descending order are yellow pine, lodgepole pine, Douglas fir, Engelmann spruce, larch, ponderosa pine, aspen, willow, and alder.

The southern slopes are generally barren of forest cover, while the northern two-thirds of the area is rather heavily forested. None of the ridges rise above timber line, although Mount Baldy and Union Peak apparently approach the upper limit of continuous cover.

PREVIOUS WORK

The Garnet-Bearmouth region was included in the guidebook for the Northern Pacific route (Campbell, 1915), in which several geologic cross sections were presented. Pardee (1918) studied the ore deposits and presented the first comprehensive geologic map of the area. Emmons and Calkins (1913) mapped the Philipsburg quadrangle to the south. Clapp's (1932) geologic map of northwestern Montana includes this area. Ross and others (1955) published the state geologic map, basing the geology of the Garnet-Bearmouth area on previous work by Pardee (1918), Clapp (1932), and an unpublished Anaconda Company map by Grimes and Rosenkranz (1919).

Most recently, adjacent areas have been studied during the course of a mapping project supervised by J. C. Maxwell, Princeton University. Doctoral studies have been completed by Poulter (1958) on the Georgetown Thrust area, by McGill (1959) on the northwest flank of the Flint Creek Range, by Gwinn (1961) on the Drummond area, and by Mutch (1961) on the northeast flank of the Flint Creek Range. Current projects are being completed by B. Csejtey and J. C. Allen of Princeton University. Several students have studied portions of the area while pursuing degrees at Montana State University.

ACKNOWLEDGMENTS

The writer is indebted to the faculty of the Department of Geology, Princeton University, for assistance so generously rendered during the course of this study. Special thanks are due J. C. Maxwell, the principal advisor, for suggestions and supervision; E. Dorf for his advisory role; F. B. Van Houten for editorial criticism and advice; A. G. Fischer for valuable suggestions on stratigraphy; S. Judson for advice on the geomorphology; A. F. Buddington for suggestions on the igneous and metamorphic rocks; B. F. Howell for fossil identifications and advice on Cambrian stratigraphy; and R. W. Imlay of the U. S. Geological Survey for identification of Jurassic fossils.

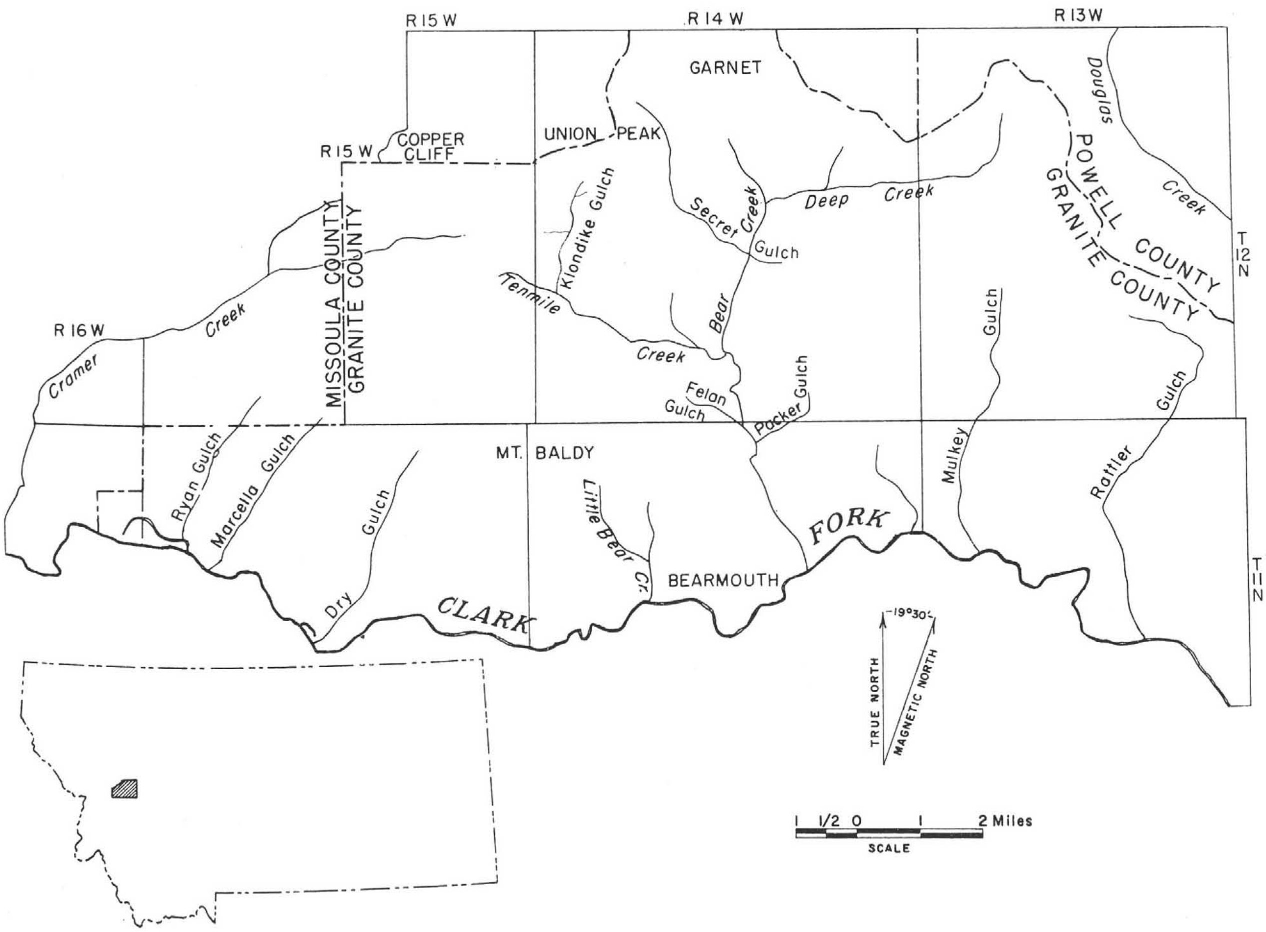

FIGURE 1.—Index map showing location of area described.

Financial assistance was provided by Princeton University and by the National Science Foundation, whose aid is gratefully acknowledged. Assistance in the field was ably provided by W. S. Ford and V. R. Broz. The many courtesies extended the writer and his family by the residents of Hall and Drummond are cheerfully remembered.

Untiring assistance was rendered by my wife Dorothy, who typed the manuscript.

While acknowledging the help of others, the writer alone must assume responsibility for errors and omissions.

STRATIGRAPHY

The sedimentary rocks of the Garnet-Bearmouth area consist of approximately 11,000 feet of Precambrian Belt Series, 6,500 feet of Paleozoic rocks, 2,000 feet of Mesozoic rocks, and up to several hundred feet of Cenozoic sediments. Strata have been observed from every Period except the Ordovician, the Silurian, and the Triassic (table 1).

The stratigraphic column (table 1) represents a concensus from various sources on the most widely accepted age for each formation.

PRECAMBRIAN BELT SERIES—MISSOULA GROUP

The oldest sedimentary rocks in the Garnet-Bearmouth area, the Missoula Group of the Belt Series, consist mainly of argillites and quartzites. Numerous ripple marks and mud cracks attest to the shallow-water accumulation of these fine- to medium-grained clastic deposits.

The Missoula Group was differentiated into five formations by Clapp and Deiss (1931). From oldest to youngest these are Miller Peak, Hellgate, McNamara, Garnet Range, and Pilcher (Sheep Mountain). Although the thicknesses of these formations differ markedly from the type sections, the lithic characters are sufficiently similar to permit identification.

Modification of the original nomenclature has been suggested by Nelson and Dobell (1961) as a result of mapping in the vicinity of Missoula and

ERA	PERIOD	SERIES	STAGE	BEARMOUTH-GARNET AREA	LITHOLOGY	THICKNESS
CENOZOIC	QUATERNARY	Recent			Alluvium, talus, etc.	
		Pleistocene			Glaciofluvial gravels	
	TERTIARY	Pliocene			Gravel cappings	
		Miocene				
		Oligocene			(?) Volcanic-rich sands, silts and clays	
		Eocene				
		Paleocene				
MESOZOIC	CRETACEOUS	Upper Cretaceous	Maestrichtian			
			Campanian			
			Santonian			
			Coniacian			
			Turonian			
			Cenomanian	COLORADO GROUP / BLACKLEAF FM	Black shale	150'
		Lower Cretaceous	Albian		Sandstone, "transition"	232'
			Aptian	KOOTENAI FM	Siltstone, sandstone, shale and limestone	860'-1100'
			Neocomian			
	JURASSIC	Upper Jurassic	Purbeckian			
			Portlandian			
			Kimmeridgian	MORRISON FM	Siltstone, claystone	0'-190'
			Oxfordian	ELLIS GROUP: SWIFT FM	Glauconitic sandstone	490'
			Callovian	ELLIS GROUP: RIERDON FM	Limestone, shale	
		Middle Jurassic	Bathonian	ELLIS GROUP: SAWTOOTH FM	Calcareous shale and siltstone	
			Bajocian			
		Lower Jurassic				
	TRIASSIC	Upper Triassic	Rhaetian			
			Norian			
			Karnian			
		Middle Triassic	Ladinian			
			Anisian			
		Lower Triassic	Scythian			
PALEOZOIC	PERMIAN	Ochoan	Tartarian			
			Kazanian			
		Guadalupian	Kungurian	PHOSPHORIA FM	Chert, carbonate, phosphate rock, quartzite	0'-290'
		Leonardian	Artinskian			
		Wolfcampian	Sakmarian			
	PENNSYLVANIAN	Virgilian	Stephanian	QUADRANT FM	Quartzite	140'
		Missourian				
		Desmoinesian	Westphalian			
		Atokan				
		Morrowan		AMDSEN FM	Calcareous siltstone, shale, dolomite	310'
		Springeran	Namurian			
	MISSISSIPPIAN	Chesterian				
		Meramecian	Visean			
		Osagian				
		Kinderhookian	Tournaisian	MADISON GROUP	Limestone, chert	1765'-2200'
	DEVONIAN	Bradfordian	Conewangoan			
		Chautauquan	Cassadagan	THREE FORKS FM (?)	Calcareous shale	0'-150'
		Senecan	Chemungian			
			Fingerlakesian	JEFFERSON FM	Limestone, fetid, sugary	1700'±
				MAYWOOD FM	Dolomitic sandstone	360'
		Erian	Taghanican			
			Tioughniogan			
			Cazenovian			
		Ulsterian	Onesquethawan			
			Deerparkian			
			Helderbergian			
	SILURIAN	Cayugan				
		Niagaran				
		Albion				
	ORDOVICIAN	Cincinnatian	Gamachian			
			Richmondian			
			Maysvillian			
			Edenian			
		Champlainian	Trentonian			
			Blackriveran			
			Chazyan			
		Canadian				
	CAMBRIAN	Croixian	Trempealeauian	RED LION FM: LIMESTONE MBR	Limestone, argillaceous laminae	358'
			Franconian	RED LION FM: DRY CREEK SH	Shale, dolomitic siltstone	
			Dresbachian			
		Albertan		HASMARK FM	Dolomite	1200'-1800'±
				SILVER HILL FM	Limestone, shale	0'(?)-345'
				FLATHEAD QUARTZITE	Quartzite	0'-100'
		Waucoban				
PRECAMBRIAN	PROTEROZOIC	Beltian		MISSOULA GROUP: PILCHER FM, GARNET RANGE, MC NAMARA FM, BONNER FM, MILLER PEAK	Quartzite, argillite	10,300'-11,800'±
	ARCHEOZOIC					

TABLE 1.—Stratigraphic column.

Bonner, Montana. That area includes some of the type sections of Clapp and Deiss. The nomenclature followed in the present work has been the modification suggested by Nelson and Dobell.

MILLER PEAK FORMATION

The oldest formation of the Missoula Group consists of approximately 1,900 feet of purple, red, gray, and green argillites and sandy argillite, and rare micaceous, ripple-marked gray quartzites and sandstones. This formation typically weathers to thin-bedded green and red exposures.

Green copper stains are found within the Miller Peak Formation east of Nimrod and have led to the opening of several prospect mines within the limits of outcrop of this unit. Typical exposures are found in road cuts along U. S. Highway 10 from Little Bear Gulch westward for 2 miles.

The Miller Peak Formation seems to have conformable lower and upper contacts. It rests on the siliceous limestone of the Newland Formation (not exposed in the Garnet-Bearmouth area) and is the unit overlain conformably by the Bonner Quartzite.

BONNER QUARTZITE

Overlying the Miller Peak Formation is 2,600 feet of pink, buff, red, and purple fine- to medium-grained quartzites, which weather rusty purple. Numerous current ripples are found throughout. These strata are thick bedded to massive and produce angular, blocky talus slopes.

Typical exposures occur between Byrne's Gulch and the Miller Peak exposures along U. S. Highway 10. Numerous ripple-marked bedding surfaces are found in these road cuts.

There are no good exposures in this area of the upper contact of the Bonner Quartzite with the overlying McNamara Formation, but a similarity of attitudes suggests that the two formations are conformable.

McNAMARA FORMATION

Rock types resembling those of the Miller Peak form the bulk of the McNamara Formation, which consists of approximately 2,800 feet of maroon and green argillites, some sandstones and quartzites, and a few layers of mud-chip conglomerates ("clay galls") near its top. It can be distinguished from the Miller Peak in many places only by its stratigraphic relationship.

The conformable contact of the McNamara with the overlying Garnet Range Formation is exposed along the east flank of Beavertail Hill in the extreme southwestern corner of the study area. There, the top of the McNamara consists of red micaceous quartzites with intercalated red micaceous argillite and some buff and white thin-bedded quartzites with interbedded maroon mud-flake conglomerates. The overlying strata consist of rusty-brown, gray, and green, very micaceous, fine-grained quartzites of the Garnet Range Formation.

GARNET RANGE FORMATION

Overlying the McNamara Formation is a unit comprising a minimum of 3,000 feet of brown, red, gray, and green micaceous quartzites called the Garnet Range Formation. Structural complications obscure its true thickness. The quartzites are characterized by abundant muscovite on the bedding planes. The formation characteristically weathers reddish brown or rusty and contains numerous examples of blocks exhibiting strong weathering rinds.

Approximately 1,000 feet from the top there occur several lenticular bodies of medium-grained gray quartzites with calcareous cement. Clapp and Deiss (1931, p. 682) reported a lens of limestone with some oolites and irregular shaly bands in the upper part of the formation.

Nelson and Dobell (1961) reported the Garnet Range Formation to be much thinner than Clapp and Deiss had indicated, much of the supposed greater thickness being due to structural repetition.

PILCHER (SHEEP MOUNTAIN) FORMATION

The youngest formation of the Missoula Group consists of about 1,500 feet of strikingly cross-bedded, white to purple, medium- to coarse-grained quartzite, which weathers deep red or purple. Nelson and Dobell (1961) suggested that the name Pilcher Formation be used because "Sheep Mountain" had been adopted for another stratigraphic unit.

The Pilcher Formation is preserved only in the western part of the Garnet-Bearmouth region, having been removed from much of the area by pre-Flathead uplift and erosion. In the eastern and southern part, Cambrian units rest on the bevelled edges of successively older formations.

Along the upper part of Marcella Gulch the Silver Hill Formation overlies the Pilcher with only a slight angular unconformity. No exposures were observed of the contact with the Flathead Quartzite.

CAMBRIAN SYSTEM

Cambrian rocks in the Garnet-Bearmouth area are approximately 2,000 feet thick and comprise the Flathead, Silver Hill, Hasmark, and Red Lion Formations. The Flathead is quartzite, and the others are carbonates containing minor amounts of intercalated argillaceous and siliceous material.

In the Garnet Range, the formations overlying the Flathead Quartzite are lithically similar to those of the Philipsburg area and distinct from those of other regions. For this reason the Philipsburg terminology is used in this report.

FLATHEAD FORMATION

Ranging to 300 feet in thickness, the Flathead Quartzite extends over much of Montana and northern Wyoming. The maximum thickness along Deep Creek and Rattler Gulch noted in the Garnet-Bearmouth area is approximately 100-150 feet. Locally the Flathead is missing and the Silver Hill rests directly on Precambrian quartzite.

The Flathead Formation varies from a friable sandstone to a quartzite. In the Garnet-Bearmouth area it occurs in lenticular pockets as a medium- to coarse-grained, brown, white, or pink to red quartzite containing rare glauconite grains, some hematite staining, and occasional white to pink rounded quartz pebbles, in a matrix of sand-size particles.

The lower Flathead contact is marked by a very slight angular discordance with the underlying Belt Series. The upper contact grades through a 20-foot transition zone into the lower shale member of the Silver Hill Formation.

No fossils have been found in the Flathead in this area, but as it grades upward into Middle Cambrian shale, it is probably also Middle Cambrian, slightly older than the Silver Hill.

SILVER HILL FORMATION

The threefold subdivision of the Silver Hill Formation by Emmons and Calkins (1913) can be carried into the Garnet-Bearmouth area in a gross sense. The Silver Hill Formation in the Garnet Range is typified by a middle laminated limestone member separating two green shale units. There is a thin (20 to 30-foot) gray to green micaceous, platy shale member at the base of the formation, which has yielded a large trilobite fauna belonging to the *Albertella* zone, near the base of the Middle Cambrian (B. F. Howell, 1959, personal communication).

The middle limestone member consists of light-gray, lenticular masses of limestone separated by reddish-brown to buff, argillaceous to silty, cherty, or dolomitic laminae, which stand in relief on the weathered surface. The limestone is fragmental in many places. In its upper part, "balls" of compacted mud enclosed in an indurated calcareous ooze have been observed. The rounded masses, 0.5 to 1 cm or more in diameter, resemble organic material (such as *Girvanella*) but lack any apparent concentric growth features. Some weather yellow or red, the enclosing material remaining steel blue or black.

The top of the Silver Hill Formation is typified by another green shale member, which has yielded a brachiopod fauna found in the Wolsey Shale of southwestern Montana. This upper green shale was observed in float along Rattler Gulch (west ridge) and as a 20-foot outcrop along Bear Gulch near Secret Gulch. Green shale layers 2 to 4 feet thick are also common in the upper 50 feet of the middle laminated limestone member. Both the lower and the upper green shale units contain illite as the dominant clay mineral.

The Silver Hill Formation is best exposed along Secret Gulch, where the lower shale member and the middle limestone member total approximately 325 feet. The upper 20-foot shale member is well exposed in a borrow pit along Bear Creek, 50 yards south of its intersection with Secret Gulch. The total thickness of the formation apparently decreases from east to west. Its thickness along Rattler Gulch is about 400 feet; along Secret Gulch it is about 345 feet. Typical Silver Hill along Marcella Gulch was observed to be 150 feet thick, and slightly farther west along Ryan Creek it was missing entirely, dolomite (Hasmark?) resting directly on Pilcher Quartzite of Precambrian age.

This greatly reduced section of Silver Hill Formation in the western part of the area can best be explained as a facies change from laminated limestone and shale, which typify this formation in the east, to dolomite in the west. The total thickness of the dolomite in the western part of the area is greater than the combined thickness of the Silver Hill Formation and the Hasmark Formation in the east. The lowest 280 feet of dolomite in the west is marked by raised laminae every inch or two, composed of siliceous dolomite(?) and chert. This unit may be equivalent to the Silver Hill Formation.

The formation does not crop out as prominent exposures. Grass-covered slopes with greenish-gray shale float generally mark the lower and upper shale units. The middle laminated limestone member, however, locally forms prominent marker ridges, such as those along Rattler and Secret Gulches.

HASMARK FORMATION

The Hasmark Formation is a thick dolomite sequence ranging from approximately 1,200 feet in the eastern part of the area to about 1,800 feet in the western part. It seems to increase in thickness westward simultaneous with the decrease in thickness of the Silver Hill Formation.

The Hasmark is almost exclusively a medium-crystalline dolomite, although several magnesian limestone zones have been observed. Sandy layers are common in the upper part of the Hasmark. Most weathered surfaces of this formation are white to light gray and have a rough gritty appearance. The rough character is said to be due to dolomite crystals standing in relief above the irregular grains of calcite (Emmons and Calkins, 1913), but quartz grains have been observed to contribute greatly.

The Hasmark in places has a creamy-yellow hue, especially where highly fractured or adjacent to faulted or mineralized zones. It also seems to be preferentially replaced by agate. Siliceous solutions have deposited agate and chalcedony in veins and cavities at many places.

At several locations the Hasmark contains a black sooty manganese-rich matrix in which fine calcite crystals are dispersed. Commercial-grade manganese was obtained from this rock. West of Cramer Creek similar manganese-rich Hasmark is found in a highly fractured zone associated with the Bearmouth thrust.

RED LION FORMATION—DRY CREEK SHALE MEMBER

The base of the Red Lion Formation is marked by approximately 30 feet of red and yellow shale, calcareous siltstone, and dolomite. The red shale has abundant worm burrows and markings.

RED LION FORMATION—LAMINATED LIMESTONE MEMBER

The upper 330 feet of the Red Lion Formation consists of laminated limestone strata very similar to the laminated limestone of the Silver Hill Formation, except for the greater preponderance of red colors. A light-gray crystalline limestone is interbedded with fine yellow-red laminae of argillaceous and siliceous material, averaging approximately four laminae per inch. The laminae do not follow bedding precisely but form an interweaving lacework, causing lensing of the limestone layers in many places. Locally the rock is dominated by argillaceous material to such an extent that the limestone becomes a subordinate constituent. The argillaceous material is yellow brown on a fresh surface and becomes reddish brown upon weathering. Beds of fossil "hash" and of intraformational conglomerate are found at several horizons.

DEVONIAN SYSTEM

The Devonian system of the Garnet-Bearmouth area consists of the Maywood Formation, the Jefferson Formation, and a sequence overlying the Jefferson Formation that may correlate with the Three Forks Formation of central and southern Montana. The Devonian strata rest unconformably on the Upper Cambrian Red Lion Formation, no record representing the Ordovician and Silurian Periods.

MAYWOOD FORMATION

The Maywood Formation is the poorly exposed sequence lying between the resistant limestones of the Red Lion Formation below and the Jefferson Limestone above. It consists in its type area of "thin-bedded calcareous rocks, including reddish, gray, and whitish flaggy magnesian limestones, gray and olive-green calcareous shales, and near the base some light-colored calcareous sandstone" (Emmons and Calkins, 1913, p. 64).

The Maywood Formation in its type area of the Philipsburg quadrangle is 200 to 300 feet thick (Emmons and Calkins, 1913). In the Garnet-Bearmouth area the Maywood Formation has been measured as 360 feet thick, including 102 feet of transition beds between typical Maywood lithologies and the typical limestone of the overlying Jefferson.

In the Garnet-Bearmouth area the Maywood consists of a basal unit of dolomite, dolomitic siltstone, and dolomitic sandstone, which forms a resistant and prominent outcrop. It is light gray to gray yellow on fresh surfaces and weathers to a laminated and cross-bedded grainy surface. Above this unit is a succession of covered units and thin resistant limestone ledges. The covered parts are chiefly light-gray to gray-yellow dolomitic siltstone and dolomite. The limestone beds are dark gray, medium crystalline. Bedding is 1 to 4 inches, averaging 2 inches. The upper 102 feet of this formation shows a greater predominance of dark-gray limestone and fewer beds of yellow-gray dolomite and dolomitic siltstone. The upper contact with the Jefferson is arbitrarily placed at the top of the last yellowish siltstone. The limestone beds above this contact are consistently similar in lithic characteristics and are separated from the transition beds of the upper part of the Maywood Formation.

Sloss and Laird (1947) demonstrated a later Devonian age for the basal Devonian unit of central and northwestern Montana. It was shown to be intergradational with the overlying fossiliferous Jefferson Formation of Late Devonian age (Senecan). The Maywood is correlated with the "basal Devonian unit" of central Montana (Sloss and Laird, 1947), the unit designated DC by Sloss and Laird (1946) in northwestern Montana, the Souris River Formation of the Williston Basin area, and the lower part of the Beaverhill Lake Formation of the Alberta Basin (Wilson, 1955).

JEFFERSON FORMATION

Peale (1893) included under the name "Jefferson limestones" all the beds from the top of the Cambrian pebbly limestones to the "top of the crystalline limestones, just above which the Devonian fossils occur in great abundance" (1893, p. 26). He recognized the fact that his lower contact was purely arbitrary and might be better established with "future careful search."

In the type area near Three Forks, Montana, the Jefferson Formation is 640 feet thick. In southwestern Montana it ranges in thickness from about 150 to 600 feet, 300 feet representing a common average (Sloss and Moritz, 1951, p. 2151). In the Garnet-Bearmouth area of western Montana, the Jefferson is approximately 1,700 feet thick. Equivalent rocks in northwestern Montana average 1,000 feet in thickness.

The Jefferson Limestone was described by Peale (1893) in its type area as being dominated by "black limestones," microgranular in texture, occurring in alternations of massive beds of very dark limestones, 10 to 15 feet thick, and lighter-colored laminated limestone layers 2 to 6 feet thick. In places the top was observed to be a brecciated limestone. In a review of the type area and the general region of central Montana, Sloss and Laird (1946, 1947) reported a general subdivision of the Jefferson Formation into a lower limestone member and an upper dolomite member. Poulter (1958) subdivided the Jefferson in the Georgetown area into three major units: an upper limestone, gray, petroliferous, breccia zones fairly common, some stromatoporoids, some interbedded finely crystalline saccharoidal black dolomite (699 feet thick); a middle dolomite, black, finely crystalline, saccharoidal, commonly with petroliferous odor, some interbedded aphanitic cream-colored limestone (103 feet thick); and a lower dolomite, medium to dark gray, finely crystalline, common petroliferous odor, some beds with abundant stromatoporoids (62 feet thick).

Continuous exposures of the Jefferson are extremely rare, the best outcrops being found along Rattler Gulch, where approximately 40 percent of the formation is exposed. A generalized subdivision of the formation can be made as follows:

Upper limestone member—light to dark gray and gray brown, highly brecciated, with poorly preserved fossil remains, occasionally highly sheared, thick bedded to massive, weathers to towers and spires; approximately 800 feet thick.

Middle dolomite member — dark gray, gray brown to black, saccharoidal, fetid, strong petroliferous odor, due to intergranular hydrocarbons; approximately 300 feet thick.

Lower limestone and dolomite member—dark gray, fetid, fairly strong petroliferous odor, finely cyrstalline, stromotoporoidal structures fairly common, abundant tan-buff or orange-yellow stringers and lacework; approximately 600 feet thick.

A large percentage of anhydrite was reported from subsurface localities in central and north-central Montana (Sloss and Laird, 1947). These writers suggest (1947, p. 1410) that the breccias at the top of exposed Jefferson sections are the result of the solution of these evaporites, the anhydrite having been removed by ground-water leaching causing collapse of the overlying limestone beds.

In the easternmost part of the Garnet-Bearmouth area, the top of the Jefferson is marked by a 150-foot covered sequence in which the dominant float is orange-yellow calcareous siltstone. The upper part of this covered section is in fault contact with the overlying Madison Limestone. It is possible that this is the only occurrence in the Garnet-Bearmouth area of the Three Forks Formation, tentatively reported by Poulter (1958) to be present in the Georgetown Thrust area. It is also possible that this unit is actually a part of the Maywood Formation that has been faulted into this position, although this seems mechanically improbable.

The following fossils were collected from the Jefferson Formation in the Garnet-Bearmouth area (identifications by B. F. Howell):

Crania, sp. ind.
Acrospirifer jasperensis Warren
A. cf. *A. argentarius* (Meek)
Spirifer utahensis Meek
Atrypa spinosa montanensis Kindle
Atrypa hystrix occidentalis (Hall)
Tetracamera, sp. ind.
Reticularia, sp. ind.
Chonetes, sp. ind.
?Solemya, sp. ind.
?Pleurotomaria, sp. ind.

Stromatoporoid, gastropods, corals, bryozoans, and other brachiopods unidentified

Cooper (1945) described conodonts from the "basal Devonian unit" of Sloss and Laird (1947) as best correlated with Upper Devonian (Senecan) forms from the eastern United States. The Jefferson Formation, therefore, would be as young as, or younger than, Senecan in age, ranging from upper Finger Lakes stage to lower Chemung stage (Sloss and Laird, 1947).

MISSISSIPPIAN SYSTEM

The Mississippian System of the Garnet-Bearmouth area consists of the Madison Group, a thick limestone unit, and the basal part of the Amsden Formation, a thin siltstone unit. The Madison Group consists of a lower thin-bedded limestone and shaly limestone sequence called the Lodgepole Formation and an upper massive, cliff-forming limestone unit called the Mission Canyon Formation. The Amsden is composed of brick-red calcareous siltstone containing some gray limestone in its lower part.

The Madison Group typically forms cliffs, towers, and spires, giving a "hoodoo" appearance. It forms the resistant core of numerous anticlinal mountains. At Bearmouth it is folded into a tightly overturned anticlinal structure, which can readily be seen from the main highway and railroads that follow the Clark Fork canyon. In the eastern part of the Garnet-Bearmouth area the Madison Limestone forms the lip of a thrust sheet on the south side of the Clark Fork valley.

MADISON GROUP

Peale (1893) applied the term Madison Formation to lower Carboniferous limestones in the Three Forks area. He gave no type section for this unit but apparently named it for the Madison River. He divided the Madison Formation into the following (from the base upwards): laminated limestones, massive limestones, jaspery limestones (Peale, 1893, p. 33).

Collier and Cathcart (1922) raised the Madison to the rank of a group and defined a lower unit as the Lodgepole Limestone and an upper unit as the Mission Canyon Limestone, with type sections on the north flank of the Little Rocky Mountains.

The Madison Limestone includes some of the most widespread stratigraphic units of the western United States. The Madison is in conformable relationship with the underlying Devonian in much of the Montana-Wyoming area. The Mississippian strata overlap the Devonian in parts of the Wyoming shelf and rest disconformably on Ordovician rocks. General isopach studies of the Lower Mississippian strata indicate thicknesses greater than 3,000 feet in the trough areas of southwestern and northwestern Montana, more than 2,500 feet in the Williston Basin area, and thinner amounts on the Wyoming shelf area and in north-central Montana. The zero edge of Lower Mississippian sedimentation passes through central Alberta, central to southeastern Saskatchewan, and southward from north-central toward south-central North Dakota. A positive area possibly existed in central and south-central Idaho (Sloss, 1950).

In the Garnet-Bearmouth area of western Montana the Madison Group has been measured as 1,635 feet thick along Rattler Gulch in the eastern part of the area and approximately 2,200 feet thick in its westernmost exposures.

In the area the Madison Group can be divided in several places into the lower thin-bedded Lodgepole Formation and the upper massive Mission Canyon Formation. The Lodgepole consists of extremely well-bedded limestone intercalated with shaly limestone in beds 2 to 6 inches thick. The limestone is dark gray to black, fine to very coarsely crystalline, with patches of large crinoid stems composing the bulk of the rock. The stems range from 1/16 to ¾ inch in diameter, averaging ⅛ inch. Chert and black cherty limestone nodules and layers 2 inches thick occur throughout. Small calcite veinlets fill closely spaced joints. The black cherty limestone and dark-gray limestone weather brownish gray. The formation is approximately 500 feet thick at Rattler Gulch.

The Mission Canyon is composed of thick-bedded to massive limestone and limestone breccia ridges. Interbedded units of less resistant limestones result in covered sections. The limestones are generally coarsely crystalline and dark gray and contain abundant broken fossil debris of cup corals, brachiopods, and crinoid stems. The limestones weather to a rough pitted surface. The entire formation generally forms cliffs, towers, and spires. The "hoodoo' character of the weathered exposures results from differential weathering along fractures and joints and by differential resistance of certain zones.

The upper contact is marked by collapse sinkholes into which Amsden-like red clastics have slumped. Along the ridge east of Sleepy Tom, north of Tenmile Creek, is a section of Madison Limestones capped by red chert and red-stained gray to tan chert, approximately 150 feet thick, which may be lenticular in cross section. The limestones below this chert do not seem thick enough to represent the entire Madison Group. The chert is massive and brecciated and seems to be conformable on the underlying fairly well bedded limestone. Some limestone beds interfinger with the chert breccia and a few tan chert layers about 2 inches thick; limestone matrix surrounds the chert breccia. It is possible that this breccia represents reworking of the upper Mission Canyon Formation prior to Amsden deposition. Weathering of the upper Madison Limestone may have concentrated the chert, which was eventually recemented, together with the limestone fragments, into these breccia beds.

Fossils collected from the Madison Group in the Garnet-Bearmouth area include the following (identifications by B. F. Howell):

Spirifer forbesi Norwood & Pratten
Menophyllum? excavatum Girty
Spirifer centronatus Winchell
Clisiophyllum teres Girty
Syringopora surcularia Girty
Cyrtina acutiorostris (Shumard)
Spirifer platynotus Weller
Brachythyris peculiaris (Shumard)
Syringothyris hannibalensis (Swallow)
Schellwienella inaequalis (Hall)
Crinoid stem plates, unidentified
Spiriferid brachiopods, unidentified
Bryozoans, unidentified
Stromatoporoid, unidentified

The Madison Group is characterized by the *Spirifer centronatus* fauna, suggestive of a late Kinderhookian and Osagean age (Weller and others, 1948, p. 138). A basal black shale unit has been observed in many places in Montana (Cooper and Sloss, 1943; Knechtel and others, 1954; McGill, 1959) and has been assigned a Kinderhookian age.

AMSDEN FORMATION

Darton (1904, p. 396) named the Amsden Formation for a branch of Tongue River west of Dayton, Wyoming, where it consists of a succession of red shales, limestones, and cherty and sandy members. Its basal member is a red, sandy shale or fine-grained red sandstone, resting with apparent conformity on the underlying Mississippian limestone.

As defined by Darton (1904), the Amsden Formation included beds of both Late Mississippian and Early Pennsylvanian age. Later writers variously assigned this stratigraphic unit to the Mississippian or to the Pennsylvanian Period or to both.

The Amsden Formation is characterized in the Garnet-Bearmouth area, as elsewhere, by reddish-brown calcareous siltstone and reddish shale. Reddish-brown and gray dolomite and limestone can be observed at several horizons. The top of the formation is marked by a 10-foot zone of limestone pebble conglomerate and limestone concretions in a tan to red calcareous matrix. This unit is overlain by fine-grained tan, calcareous sandstone, probably marking the bottom of the Quadrant Formation.

The controversy as to the age of the Amsden continues to the present. It is suggested here again (following Perry and Sloss, 1943, p. 1293) that it possibly does bridge the artificially constructed boundary between the Mississippian and Pennsylvanian Periods, its lower faunas being of Late Mississippian and its upper faunas of Early Pennsylvanian age.

PENNSYLVANIAN SYSTEM

The Quadrant Formation and upper part of the Amsden Formation constitute the Pennsylvanian strata of the Garnet-Bearmouth area. The Amsden was previously discussed under the Mississippian System, as its lower part is probably of Late Mississippian age.

The Quadrant Quartzite is one of the better markers in this area. It generally forms resistant ridges, hogbacks, and cuestas, above the very much less resistant Amsden and below the sporadically occurring and poorly exposed Phosphoria Formation.

The Quadrant readily can be distinguished from most of the other stratigraphic units. It is a white to tan quartzite and is especially prominent when contrasted against the bluish Madison Limestone and the brick-red Amsden lying stratigraphically below the Quadrant.

QUADRANT FORMATION

Peale (1893, p. 39) first published the name Quadrant after a field conference with Iddings and Weed, who named the unit for exposures at Quadrant Mountain in the Gallatin Range, in the northwest corner of Yellowstone Park (Scott, 1935, p. 1013).

Part of the originally defined Quadrant has been included in the Amsden Formation. Strata lithically and stratigraphically similar to the Quadrant are called "Tensleep" in Wyoming and central and southern Montana.

According to Sloss and Moritz (1951, p. 2164), the term Quadrant is used now to refer to the strata "in areas where the sands are tightly cemented by silica and secondary grain enlargement" and the term Tensleep is applied "in areas where the sands are relatively loose and friable."

In the Garnet-Bearmouth area the Quadrant was found to be 140 feet thick. It has been observed to thicken markedly into southwestern Montana and eastern Idaho (Sloss and Moritz, 1951, p. 2165), to as much as 2,600 feet in the Tendoy Range (Scholten and others, 1957).

The formation consists almost entirely of fine- to medium-grained, white to tan, vitreous quartzites, which are poorly bedded to massive. The Quadrant typically weathers to a greenish-gray or rusty brown surface spotted by black lichen. Its lower contact is apparently conformable and gradational with the underlying Amsden. The upper contact may be disconformable with the overlying Phosphoria of Permian age in the Garnet-Bearmouth area, although in most of Montana the Quadrant-Phosphoria contact is gradational and conformable (Sloss and Moritz, 1951).

The formation has been observed to contain the fossils *Wedekindellina* and *Fusulina* in Montana and northwestern Wyoming (Scott, 1935), suggesting a middle Desmoinesian age. As no definite Missourian fossils have been recognized, the upper limit of the Quadrant is placed below that stage, although Henbest (1954, p. 53) suggests that some beds may be found to extend stratigraphically higher, locally.

PERMIAN SYSTEM

The Permian System is represented in the Garnet-Bearmouth area by part of the Phosphoria Formation. This rock unit has been widely studied in western Montana, Wyoming, and Idaho because of its commercial phosphates. It is mined in the Garrison region, 15 miles east of the study area. Facies studies have demonstrated that this area marks the approximate shoreline of deposition in the Permian seas (McKelvey and others, 1956; Swanson and others, 1953).

All the Permian strata are here termed the Phosphoria Formation, following wide usage in southwestern Montana, Idaho, and Wyoming, although McKelvey and others (1956), suggest additional formational and member names for much of the Permian section. Exposures of the Permian are so poor in this region that the entire section has been mapped as one unit. A lower quartzite member could be recognized at many locations and is tentatively called the Shedhorn Member, after McKelvey and others (1956).

PHOSPHORIA FORMATION

Richards and Mansfield (1912, p. 684) named the Phosphoria Formation for typical exposures along Phosphoria Gulch, which joins Georgetown Canyon about 2½ miles northwest of Meade Peak, Idaho.

In its type locality the Phosphoria consists of an upper Rex Chert member 240 feet thick, composed of black cherty shale, thick beds of chert, and gray to black cherty limestone, and a lower phosphatic shale member 175 feet thick.

The Phosphoria was divided into five members in southwestern Montana by Klepper and others (1950). McKelvey and others (1956) adopted an end-member classification of the Phosphoria and its equivalents; they recognized three intertonguing lithic units as formations.

In the Garnet-Bearmouth area of western Montana the Phosphoria Formation is as much as 290 feet thick. Exposures in this area are extremely poor, only the Shedhorn quartzite member cropping out consistently. This unit consists of fine- to medium-grained, white to tan and gray, quartzose quartzite, resembling the Quadrant Quartzite, from which it is usually separated by a covered area a few hundred feet wide. It is by no means continuous in the Garnet-Bearmouth area, but seems to be lenticular, being absent at many localities. Where it is present, however, the Shedhorn makes a convenient marker unit, which can usually be mapped by its float. Other lithic types in the Phosphoria Formation include some fine-grained, yellow to buff sandstone with minute black phosphate(?) grains near the base in the eastern part of the area. This unit does not crop out prominently but was observed by trenching the zone overlying the Quadrant Quartzite. Along Rattler Gulch are exposed brecciated chert and carbonate and small patches of black fine-grained phosphate(?) rocks.

The Shedhorn Quartzite occurs near the top of the Permian section in other parts of western and southwestern Montana. In the Garnet-Bearmouth area this quartzite was observed to be separated from the underlying Quadrant Quartzite by less than 100 feet, suggesting that much of the lower part of the Permian section may be missing in this area, that is, a hiatus is present in western Montana.

JURASSIC SYSTEM

The Jurassic System in the Garnet-Bearmouth area consists of the Ellis Group of Middle and Late Jurassic age and the Morrison Formation (restricted) of Late Jurassic age. The Ellis Group has been subdivided into the Sawtooth, Rierdon, and Swift Formations.

SAWTOOTH FORMATION

Cobban (1945, p. 1270) named the oldest unit of the Ellis Group the Sawtooth Formation from the well-developed exposures in Rierdon Gulch in the Sawtooth Range in northwestern Montana.

In its type area the Sawtooth is 137 feet thick and consists of a basal fine-grained sandstone, a middle dark-gray shale containing a few thin dark limestone layers, and an upper very calcareous siltstone.

In the Garnet-Bearmouth area, the Sawtooth Formation consists of a basal fossiliferous calcareous buff-weathering siltstone; a middle very calcareous dark-gray shale or argillaceous limestone, which weathers to a creamy-white surface; and an upper unit of interbedded calcareous shale, siltstone, and limestone.

Fossils collected in the Garnet-Bearmouth area from the Sawtooth Formation include the following (identifications by B. F. Howell, R. W. Imlay, and the writer):

Stemmatoceras aff. *S. palliseri* McLearn
Lucina? sp.
Normannites sp.
Pleuromya subcompressa (Meek) (= *P. obstutsiprorata* McLearn)
Trigonia montanaensis Meek
Camptonectes platessiformis White
Lopha sp.
Arctocephalites sp. juv.
Gryphaea impressimarginata McLearn
Isocyprina? sp.
Astarte? sp.
**Volsella* sp.
**Ostrea* sp.

In his original definition of the Sawtooth Formation, Imlay (1945, p. 1270) reported a Bathonian age as indicated by the faunal assemblage. Subsequent studies have proved the presence of Bajocian fossils as well. Fossils collected in the Garnet-Bearmouth area have shown the existence of strata as old as middle Bajocian. The middle Bajocian ammonites *Stemmatoceras* and *Normannites* had not previously been known from western Montana (Imlay, 1959, personal communication), but have been found to the north at Swift Reservoir near Glacier Park, and to the south and southeast in the Yellowstone Park area, in western Wyoming, and in south-

* Identified by Imlay (1948)

eastern Idaho. These ammonites occur in a basal brownish siltstone in the study area. The upper member of the Sawtooth Formation was found to contain the diagnostic fossils *Gryphaea impressimarginata* McLearn and *Arctocephalites.* The beds containing *Arctocephalites* were originally assigned by Imlay to the Bathonian, following Spath (1932), but Arkell (1956, p. 549) assigned them to the basal Callovian.

RIERDON FORMATION

Cobban (1945, p. 1277) named the Rierdon Formation and gave as its type locality Rierdon Gulch in sec. 23, T. 24 N., R. 9 W., where strata of alternating gray limy shales and limestones overlie the upper sandy beds of the Sawtooth and disconformably underlie the dark-gray micaceous shale and sandstone of the Swift Formation.

In the Garnet-Bearmouth area the Rierdon is 60 to 75 feet thick, and it consists of oolitic fine to medium crystalline limestone overlain by gray calcareous shale and shaly limestone. The lower limestone forms a resistant ridge in many localities and weathers to a gritty surface; ripple marks and droplet(?) impressions are common on bedding surfaces. Platy, dark-brown, finely crystalline to medium crystalline limestone characterizes the upper part of this lower unit. Many fossil fragments occur along bedding planes, which often show very large ripple marks, as much as 6 inches in amplitude and 36 inches in wave length. The upper unit rarely crops out and is typified by covered slopes with occasional outcrops of dark-brown to gray and black shaly to slaty limestone, which breaks into fissile fragments and weathers to a white, creamy, or light-gray surface.

Fossils collected from the Rierdon formation in the Garnet-Bearmouth area are listed below:

Pentacrinus asteriscus Meek and Hayden
Camptonectes sp.
Cadoceras sp.
**Gryphaea nebrascensis* Meek and Hayden
**Pleuromya subcompressa* (Meek)
**Protocardia* sp.
**Cucullaea* sp.
**Arctica* sp.

Imlay (1945, p. 1022) recognized three faunal zones in the beds assigned to the Rierdon by Cobban (1945). The lowest zone is of late Bathonian age, the middle zone of early Callovian age, and the highest zone of middle and late Callovian age. In 1952, Cobban indicated only a Callovian age for the Rierdon Formation (Correlation Chart, Imlay, 1952b).

* Identified by Imlay (1948)

SWIFT FORMATION

The Swift Formation was named by Cobban (1945, p. 1281) for exposures on the north shore of Swift Reservoir on Birch Creek. In some localities the Swift is overlain unconformably by the basal Kootenai sandstones. In others the Swift is conformably overlain by the fine-grained continental deposits equivalent to the lower part of the Morrison Formation of southern Montana and Wyoming.

In the Garnet-Bearmouth area the Swift Formation ranges from 114 feet (Imlay and others, 1948) in the central part of the area to 244 feet in the eastern part.

The Swift Formation consists of a basal sandstone containing abundant conglomeratic lenses, especially common in the upper part, several siltstone units, occasional limestone zones, and an upper glauconitic sandstone unit. The lower sandstones give a "salt and pepper" appearance because of the presence of abundant black chert and white quartz grains. The approximate composition of the lower sandstone is 60 percent quartz and light chert, 15 percent black chert, 10 percent feldspar, 10 percent calcite matrix, and 5 percent other materials, including fossil fragments. The limestone is dense, finely crystalline, and light green to greenish gray, and contains a few detrital black chert grains. It weathers to a greenish-gray sandy surface. The upper part weathers to a knobby or gnarly surface. The upper sandstone forms a resistant ridge of "salt and pepper" appearance, is very calcareous and very similar to the lower sandstone, except for the presence of greenish-black glauconite(?) grains and the absence of conglomeratic lenses.

A microscopic count of 200 points in a thin section from the lower sandstone gave these percentages: chert 37.5 percent, quartz 30.0 percent, calcite 26.0 percent, biotite 1.0 percent, glauconite 1.0 percent, and others 4.5 percent.

In the Garnet-Bearmouth area, the only fossils found in the Swift Formation are oyster fragments and wood fragments. Cobban (1945) reported that the lower member of the Swift contains abundant water-worn belemnites.

The occurrence of two identifiable faunal zones within the Swift has permitted regional and world-wide correlations to be attempted. The *Quenstedtoceras collieri* zone generally occurs near the base of the formation. It is correlated with the earliest part of the Oxfordian stage of Europe. In much of western and northwestern Montana it is commonly overlain by the *Cardioceras cordiforme* zone, which is also correlated with the early Oxfordian of Europe. The middle and late Oxfordian faunal zones have not yet been recognized in Montana, although a thick section of unfossiliferous glauconitic sandstones does overlie the *Cardioceras* zone of Montana. This upper unit of sandstones may well represent all of late Oxfordian time.

MORRISON FORMATION (RESTRICTED)

Eldridge (1896) named this formation for exposures near Morrison, Colorado. Waldschmidt and LeRoy (1944) re-examined the unit in the type area and designated a new type section along West Alameda Parkway road cut, 2 miles north of Morrison, Colorado.

In its type area the Morrison Formation comprises an average of 200 feet of sediments. The basal unit is fresh-water marl, green, drab, or gray, with numerous lenticular bodies of limestone in the lower two-thirds. This is overlain by alternating sandstone and limestone, and a succession of sandstones and marls, the sandstones being characterized by small rusty dots of brown iron oxide stain. This upper sandstone generally has a basal conglomeratic member containing red jasper grains.

Curry (1959, unpublished Ph.D. dissertation, Princeton University) has sugested, on the basis of physical and biostratigraphic evidence, that the Morrison Formation of Colorado and Wyoming may be represented in Montana by the entire nonmarine sequence, including both the so-called Morrison and the overlying Kootenai. For this reason the phrase used in this study is "Morrison (restricted)" to designate the nonmarine beds exclusive of the Kootenai Formation.

Thicknesses measured for the Morrison (restricted) in the Garnet-Bearmouth area range from 162 feet in the central part of the area to approximately 220 feet at the extreme eastern edge.

In the Garnet-Bearmouth area the formation is characterized by fine-grained clastics, ranging from claystone through shale and siltstone to medium-grained sandstone. The sediments typically are some shade of green or yellow, and more rarely gray, purple, and maroon. The clay mineral in the Morrison was found by X-ray examination to be kaolinite. The siltstone unit near the base of the formation is olive green, very calcareous, platy, slabby, and flaggy. This unit includes an 18-inch bed of extremely dense calcareous mudstone, which breaks with a conchoidal fracture and weathers to a purplish-brown surface. The middle part of the formation is typified by a dense, olive to gray, fine- to medium-grained sandstone with a "salt and pepper" appearance due to white quartz and black chert grains. The sandstone is locally slightly calcareous, is fairly well sorted, and weathers to platy beds. The upper part of the Morrison is generally covered but produces some float of olive and purple siltstone, silty shale, and mudstone.

In most exposures the Morrison is overlain by a conglomerate of black chert and white quartz pebbles, which is very lenticular and locally absent. If the conglomerate is not present, the Morrison is overlain by a thin maroon siltstone and shale unit capped by a medium- to coarse-grained "salt and pepper" sandstone, distinguished by red jasper grains. This red jasper sandstone is very widespread and is used by many workers as a field criterion for marking the base of the overlying Kootenai Formation.

No fossils except wood fragments were found in the Garnet-Bearmouth area within the formation. Elsewhere in the Rocky Mountain region the Morrison is typified by its vertebrate remains, especially dinosaur bones, and other nonmarine fossils, including reptiles, mammals, mollusks, ostracodes, charophytes, and plants.

Almost since it was first named as a formation there has been controversy as to its age, whether Late Jurassic or Early Cretaceous. The currently accepted age seems to be Late Jurassic (Reeside, 1952), the major differences of opinion centering on the boundaries of the formation.

Dorf (*in* Lammers, 1937) suggested a probable Jurassic age for a flora from the coaly part of the Great Falls section reported by Fisher (1909). Dorf assigned an early Cretaceous age to the flora from above this coaly sequence. Brown (1946) examined fossil plants from the Great Falls area and concluded that the strata up to the first sandstone above the coal bed were probably Morrison equivalents of Jurassic age.

Peck (1956, 1957) reported that charophytes and ostracodes are abundant in the calcareous shale and limestone of the Morrison Formation in central Montana and tend to support a Kimmeridgian age assignment to the Morrison. The abundance of *Latochara,* however, indicates that the Morrison may include strata younger than Kimmeridgian, as this genus is unknown in the Kimmeridgian of Germany, but is common in the Purbeckian of England (Peck, 1956, p. 97).

CRETACEOUS SYSTEM

The rocks of the Cretaceous System have been divided into three separate groupings. The Kootenai Formation consists of four members, which have been named informally as follows (from oldest to youngest): lower clastic member, lower calcareous member, upper clastic member, upper calcareous member. Above the Kootenai Formation is a "transition" from the dominantly continental Kootenai deposits to the dominantly marine beds of the Colorado Group. These "transition beds" have been correlated with the Blackleaf Formation of the Colorado Group (Cobban and others, 1959). The youngest Cretaceous rocks in the Garnet-Bearmouth area consist of a thin black marine shale sequence belonging to the black shale member of the Blackleaf Formation.

KOOTENAI FORMATION

The Kootenai Formation was named and defined by Dawson (1885, p. 2). He reported that this group consists of sandstone and interbedded shale, shaly sandstone, and occasional conglomerate and coal seams.

In the Garnet-Bearmouth area the Kootenai Formation has been divided into four mappable units. The basal unit has been designated the "lower clastic member," and is characterized by maroon and gray sandstone, interbedded with a few shale and siltstone layers. At the base of this member is typically developed a channel conglomerate, which is very lenticular and contains pebbles and cobbles as much as 18 inches in diameter. This conglomerate is only locally developed and ranges to 50 feet in thickness. Overlying the conglomerate is a thin maroon shale and siltstone sequence, overlain by a diagnostic sandstone and quartzite zone, which has been used by some workers to mark the base of the Kootenai Formation. This unit is very widespread and persists even where the basal conglomerate is absent. It consists of white quartz grains, a few black and some white chert grains, a small amount of silica cement, and very commonly distinctive red jasper(?) grains, which give a red specked appearance to the rock. As measured in the central part of the Garnet-Bearmouth area, this "lower clastic member" is 50 to 75 feet thick.

The "lower calcareous member" of the Kootenai Formation is typified by several zones of dark-gray to black very fine grained limestone, which weathers to a creamy-white surface. This "lower calcareous member" is approximately 160 to 180 feet thick and is readily mappable on air photos. Commonly there are interbedded maroon, green, and gray shale and siltstone, and occasional beds of calcareous concretions, some as large as 3 feet across. Extremely large concretions are found in the railroad cut on the south side of the Clark Fork in SW¼ sec. 16 and SE¼ sec. 17, T. 11 N., R. 13 W.

The "upper clastic member" is composed of green, gray, and maroon siltstone and shale, and a few thin sandstone and limestone units. The sandstones have a "salt and pepper" appearance because of the white quartz and black chert grains making up most of the rock. There are also some rock fragments, a matrix of clay, and calcite cement. This member is the thickest part of the Kootenai Formation in the Garnet-Bearmouth area, consisting of approximately 440 feet of strata.

The "upper calcareous member" (gastropod limestone) is typified by white-weathering, fine to medium crystalline limestone, but includes a few shale and siltstone layers and one major sandy unit. The top of the member is marked by the widespread and well-known "gastropod limestone," a dark-brown to dark-gray coarsely crystalline limestone composed almost entirely of gastropod shells in partly or completely recrystallized calcite. This unit consists of two or even three distinct limestone beds in some areas, the limestones being separated by calcareous shales and siltstones. The "gastropod limestone" (containing *Reesidella montanaensis*) has been reported over much of western and central Montana (Gardner, 1945; Klepper, 1957) and is generally taken to mark the top of the Kootenai Formation.

An Early Cretaceous age for the Kootenai Formation has been widely accepted. On the basis of fresh-water mollusks, Yen (1951) correlated the Kootenai with part of the Cloverly Formation of Montana and Wyoming and with part of the Peterson Limestone of Wyoming and Idaho. On the basis of charophytes, Peck (1956) correlates the Kootenai of western Montana with at least parts of the Lakota of the Black Hills, the Cloverly of central Wyoming, and the Ephraim, Peterson, Beckler, and Draney Formations of southeastern Idaho.

BLACKLEAF FORMATION

Hayden (1876, p. 45) named the Colorado Group for exposures along the eastern base of the Front or Colorado Range, where it consists of dark to black shale and includes a few laminated sandstone layers in the lower part. It was defined as including the Fort Benton, Niobrara, and Fort Pierre divisions. The lower part of the Colorado Group is termed the sandy member of the Blackleaf in much of Montana. The Dakota Group, from its type area in northeastern Nebraska, probably correlates with the lower part of the Blackleaf sandy member of the Colorado Group. In northern Wyoming and parts of Montana a portion of the lower part of the Colorado Group is known as the Thermopolis and Mowry Shales. Klepper and others (1957) have called this sequence the "Lower black shale unit" of the Colorado Formation. Cobban and others (1959) called this the Flood Member of the Blackleaf Formation of the Colorado Group. In the map area all Blackleaf Formation deposits belong to the Flood Member.

The "transition beds" in the lower part of the Flood Member are approximately 230 feet thick, and only the lowest 150 feet of the black shale unit is present in the Garnet-Bearmouth area; post-Cenomanian erosion has stripped the overlying strata. In adjacent areas, however, more than 3,000 feet of Colorado strata has been reported (McLaughlin and Johnson, 1955). The Colorado Formation was reported to be 1,100 to 1,500 feet thick in the southern Elkhorn Mountains of western Montana (Klepper and others, 1957) and about 1,600 feet thick in the Great Falls area (Fisher, 1909, p. 36).

In the Garnet-Bearmouth area the upper part of the Flood Member consists of sandstones, siltstones, some thin limestones, dark-gray to black fissile shale, and a few thin fine-grained sandstone partings. The single occurrence of this group in the area is in the center of a doubly plunging syncline, which is isoclinally folded. The shale has been strongly squeezed and has many slickensided bedding surfaces, indicating considerable movement within the unit. Many calcite veins cut the black shale layers. Rust-stained surfaces are common, especially on the thin sandstone beds.

A prominent ridge-forming sandstone bed approximately 5 feet thick lies about 150 feet above the base of the Colorado Group and consists of fine-grained sandstone with abundant carbonaceous fragments on the bedding surfaces. These fragments range from microscopic to 1 inch in length. The few thin limestones in the "transition beds" are finely crystalline and very resistant, forming hogback ridges. There are a few reddish-purple fissile shale beds approximately 2 feet thick and several 1-foot dark-gray to black shale layers.

As the "transition beds" crop out at only one place in the Garnet-Bearmouth area, it is impossible to note any lateral variations in the unit within this area. Approximately 12 miles to the east, however, this rock sequence is marked by a greater predominance of sandstone and almost no limestone.

In his standard reference sequence, Cobban (1951) assigned the Colorado Shale to an age beginning in Early Cretaceous time (Albian) and continuing through much of the early part of Late Cretaceous (through Santonian). This same age assignment was used in the Cretaceous correlation chart (Cobban and Reeside, 1952), by Klepper and others (1957), and in this report.

The Colorado Group is correlated, at least in part, with the Frontier Formation and the Cody Shale of Wyoming and with the Dakota Sandstone of Wyoming and the Dakotas.

SUMMARY OF TECTONIC SETTINGS

A brief summation of the inferred tectonic setting and the source of the major constituents in each formation is listed in Table 2.

IGNEOUS AND METAMORPHIC ROCKS

The distribution of igneous rocks in the Garnet-Bearmouth area is illustrated by the geologic map. (See pl. 1, in pocket.) Large granodioritic masses occur in the Garnet region along the north-central margin of the area. A granodioritic dike traverses part of the southwest quadrant of the map area. The Union Peak intrusive is a trachyte(?) porphyry intruded at shallow depth between Bear and Tenmile Creeks; probably of similar genesis is the included rhyolitic intrusive mass.

Rhyolitic dikes, sills, and plugs are scattered throughout the area but most are concentrated in the northeast, southeast, and central igneous belts.

Many basalt and andesitic basalt plugs, dikes, and sills are to be observed, especially along the Clark Fork valley and in the northeast part of the area.

Metamorphic aureoles occur locally around several intrusions. Marble and hornfels developed around the Garnet stock and hornfels around the granodioritic dike in the southwestern extremity of the map.

Several extrusive rocks have been noted, particularly in the northeast corner of the area.

Tuffaceous sediments, suggesting explosive igneous activity, have been found in the Secret Gulch area and south of the intersection of roads along Tenmile and Cramer Creeks. Charred carbonaceous fragments locally constitute a major part of these sediments.

No detailed petrographic examinations were made of the igneous and metamorphic rocks. Megascopic examination of hand specimens and cursory microscopic study of rock thin sections provided the basis for the following descriptions.

IGNEOUS ROCKS

The igneous rocks in the Garnet-Bearmouth area belong mainly to the group of acid igneous rocks of the granodiorite, adamellite, and granite clans. All contain at least 10 percent modal or normative quartz, and in all of them alkali feldspar makes up at least one-eighth of the total feldspar content. Two major exceptions are the trachyte(?) porphyry found in the Union Peak area and in the southwestern part of the region, and in the basic dikes classified as gabbros or mafic diorites.

Fluidal banding can be observed in several of the finely crystalline rocks. It is accentuated by red and brown oxidized streaks, which are formed by volatiles streaming into minute tension cracks diagonal to the fluidal lamination; some of these cracks are lined with dusty hematite.

GRANODIORITE STOCKS

Light-gray to greenish-gray crystalline igneous bodies occur near Garnet and Top o' Deep; they consist of quartz, plagioclase, orthoclase, hornblende, biotite, chlorite, apatite, and magnetite. Their feldspar composition ratios place them in the granodiorite group very close to its border with adamellite (or quartz monzonite). The plagioclase crystals are normally zoned; some have been altered to sericite and calcite, especially near the margins of the Garnet stock.

TABLE 2.—Summary of tectonic settings.

Formation	Dominant lithology	Depositional environment	Source of constituents
Quaternary and Recent	Gravel, alluvium, colluvium	Continental land surfaces	Landslide, talus, slope wash; glacio-fluvial, fluvial, mass wastage
Colorado Group Tuffaceous sediments "Lake beds"	Sand, gravel, silt; volcanic contributions	Fresh-water lakes	Volcanic "fall out" combined with normal clastics from adjacent slopes
Black shale unit	Black shale	Marine to restricted marine	Fine clastics (clays) settling in seas; carbonaceous contributions retained
"Transition beds"	Siltstone, sandstone, shale, limestone	Transitional; marine transgression over nonmarine	Clastics derived from erosion of older sediments; some carbonaceous fragments
Kootenai	Shale, siltstone, limestone, conglomerate	Continental, lacustrine, fluviatile	Clastics derived from erosion of older sediments and from landmass to west
Morrison	Claystone, sandstone	Continental, fluviatile, floodplain	Clastics derived from erosion of older sediments
Ellis Group	Shale, sandstone, limestone, conglomerate	Marine, littoral	Chemical precipitates; clastics derived from erosion of older sediments
Phosphoria	Phosphate rock, chert, carbonate, quartzite	Near shore	Reworking of adjacent units; possible volcanic source for silica in chert
Quadrant	Quartzite	Near shore	Earlier sandstones exposed in source areas; deposition in shallow seas; wave action removed fines and allowed sands to accumulate
Amsden	Shale, calcareous siltstone	Near shore; transgressive sea	Silt derived from weathered and reworked regolith(?); trangressing sea
Madison	Limestone	Marine, luxuriant life, approaching reef conditions	Fragmental, fossiliferous calcareous debris; recrystallized limestone; some secondary(?) chert
Jefferson	Limestone, dolomite	Marine	Chemical precipitates; brecciation by solution of evaporites or by secondary dolomitization
Maywood	Sandstone, quartzite, dolomitic	Transgressive sea	Redeposited clastics laid down by advancing sea; recrystallized to quartzite; calcareous to dolomitic cement
Red Lion Sage member	Limestone, argillaceous, laminated	Alternating clear and muddy marine	Chemical precipitate and intercalated silts and clays; squeezing of fine clastics into lime ooze prior to and during lithification
Dry Creek member	Shale, dolomite	Marine	Transgression by marine waters over erosion surface
Hasmark	Dolomite, sandy	Marine	Chemical precipitate; possibly organic contribution; some quartz grains as clastic contribution; subsequent dolomitization may have been penecontemporaneous or secondary
Silver Hill	Shale, limestone	Muddy to clear marine, shallow; possibly some marine-brackish	Muds from nearby land area
Flathead	Sandstone, quartzite	Marine, littoral, beach	Sands derived from erosion of earlier quartzite, and possibly also some basement rocks
Missoula Group	Argillite, sandstone	Shallow seas and mud flats	Current ripples from west-northwest; coarser clastics from scattered islands

GRANODIORITE DIKES

A finer-grained dike occurs along the Clark Fork in the extreme southwestern part of the Garnet-Bearmouth area. Another extends for several miles from the bend at the top of Rattler Gulch westward past Mulkey Gulch. These dikes contain the same minerals as the granodiorite stocks. The dike along the Clark Fork, however, has fewer ferromagnesian minerals, giving the rock an overall lighter color. Several darker inclusions were noted in this dike. Some of these are probably autoliths—segregations of early-formed minerals—whereas others are reconstituted xenoliths. Although their composition is essentially the same as the enclosing granodiorite, their content of mafic minerals is probably higher.

APLITE DIKES

Small dikes as much as 3 feet across were observed cutting the Garnet stock. They are very light colored and fine grained and consist of quartz, potash feldspar, plagioclase, muscovite, and a small amount of biotite. Several associated pegmatite dikes have been reported in the mine workings (Pardee, 1918).

TRACHYTE(?)

Several trachyte bodies occur in the Garnet-Bearmouth area. They are indicated on the map (plate 1) as trachyte(?). Microscopic examination showed them to fall close to the trachyte field. A trachyte mass around Union Peak contains phenocrysts of plagioclase, quartz, sanidine, and some biotite. The groundmass is very fine grained to vitreous.

A dike (or flow?) of similar composition occurs near the confluence of Dry Gulch and the Clark Fork. It is in contact with Belt sediments and its exact relationship is not clear. It is possible that it lies on an eroded surface cut on the Belt argillite (Pardee, 1918, p. 169). Although mapped only on the north side of the Clark Fork, this trachyte body was observed to extend short distances east and west along the south valley wall. A dacite porphyry mapped south of the Clark Fork was reported to have the following composition: 35 percent oligoclase (An_{24}-An_{30}), 7 percent biotite, 5 percent orthoclase, 3 percent quartz, 50 percent glassy groundmass, and traces of magnetite and apatite (Montgomery, 1958).

BASALT AND ANDESITE

Several large masses of dark-red, purple, green, and gray aphanitic igneous rocks occur in large patches along the eastern half of the area for distances of 2 miles north of the Clark Fork. A large nearly continuous body 8 miles in length and 2 miles in width covers the area from Bearmouth north and west, broken only by patches of rhyolitic material. Several large areas of similar igneous material in the northeastern part of the region may include scattered rhyolitic masses not indicated on the map.

Darker masses are poorly exposed but do crop out in some areas sufficiently extensive to permit lateral examination. Approximately 1 mile west of the entrance to Bear Gulch, basaltic or andesitic material is fairly well exposed. Agglomeratic debris is observed in the middle of well-foliated andesite and olivine basalt. The foliation displays a funnel shape, outlining a conduit or vent through which flowed some extrusive or shallow intrusive basic lava. At several other locations where the foliation can be examined in detail over sufficient areas this funnel-shaped foliation is evident. At many places, however, only the nearly horizontal foliation can be observed. Large areas exhibiting only horizontal foliation would ordinarily give the impression of great horizontal sheets covering wide areas. Scattered indications of vents and conduits suggest that these may represent local patches of extrusive and hypabyssal igneous materials, never much more extensive than now mapped.

RHYOLITE

White to light-gray, porphyritic volcanic and hypabyssal rhyolite is found in small exposures at many places in the region. A few bodies cover areas of about a square mile within the large volcanic area north and west of Bearmouth.

The rhyolite contains phenocrysts of smoky quartz and orthoclase ¼ inch across. They constitute about 20 percent of the rock by volume, but range from 5 to 35 percent. They are generally subhedral to anhedral but some display euhedral faces. The fine-grained groundmass is generally white to gray but may be stained yellow, brown, or red by small amounts of iron impurities.

A small patch of rhyolite (not shown on map) occurs in contact with basaltic rock along the Clark Fork valley on the southern tip of Beavertail Hill. An indication of the relative ages of the light and dark hypabyssal rocks can be obtained from this exposure. The lighter rhyolite seems much fresher and less altered, therefore younger, than the darker basalt, which is sheared, crumbly, and altered (?) by the rhyolite.

Included under the heading "Rhyolite" are several bodies that proved to be tuffs when examined in thin section. These commonly contain large quartz crystals ¼ inch across.

BASIC DIKES

Several thin dark greenish-gray to black medium to coarsely crystalline igneous dikes are found in the area. They generally consist of plagioclase, hornblende, and chlorite and would probably be classed as gabbros or mafic diorites.

METAMORPHIC ROCKS

Metamorphic aureoles surround most of the larger intrusives in the area. These aureoles range from tens of feet to thousands of feet in width. Metamorphic effects extend more than a mile from the Garnet stock of granodiorite. The actual distance down to the igneous body is probably much less, however.

Marble, spotted hornfels, and garnetiferous mica schist have developed from the Paleozoic carbonates and Precambrian Belt quartzites. Much of the limestone adjacent to the granodiorite has been metasomatized to a brown garnet rock, locally rich in green copper minerals. The marble weathers to a white, sandy, crumbly rock resembling sugar and contains needles of tremolite and flakes of golden-yellow mica. The spots or knots in the hornfels are "aggregates of mica or crystals of cordierite" (Pardee, 1918, p. 173).

The granodioritic dikes have also caused some metamorphic changes. Near the large bend at the head of Rattler Gulch the Silver Hill Formation has been altered by a small granodioritic dike. The shale has remained virtually unchanged, but the limestone has been altered to marble containing ½-inch anhedral garnet crystals, epidote staining, some orthoclase, and chlorite. The small granodioritic dike north of the Clark Fork in the southwest corner of the map has caused baking of the Belt argillite, resulting in a change from brown and maroon to gray and greenish gray.

TUFFACEOUS SEDIMENTS

Associated with some of the volcanic and hypabyssal rocks are several remnants of tuffaceous sediments trapped in upland basins. They have remained in these locations because they have been sufficiently lithified to resist erosion or because the topographic sills resisted the erosion of the basins and thereby prevented flushing out of the volcanic-rich sediments.

Some of the explosive volcanic material fell onto slopes and was eroded away; some fell into basins, was trapped, and formed ash beds, some of which are composed mainly of glass shards; and some fell into basins undergoing normal sedimentation and there became mixed with mud, silt, sand, and gravel from the surrounding country rocks. Such accumulations of tuffaceous sediments are found in the upper basin of Secret Gulch and in the highlands south of the intersection of the roads along Tenmile Creek and lower Cramer Creek. These volcanic-rich sediments near Cramer Creek contain large carbonized fragments of wood, altered now to charcoal. Associated with these fragmental sediments are laminated silt and clay penetrated by small vertical impressions of fossil rootlets, probably indicative of a lacustrine environment.

The tuffaceous sediments in the upper basin along Secret Gulch are suggestive of fluviatile origin. The beds are well stratified and contain materials ranging from clay size to pebbles half an inch in diameter. Eruptions of hot dust clouds resulted in the development of welded tuffs associated with these volcanic-rich sediments.

STRUCTURE OF THE GARNET—BEARMOUTH AREA

Laramide orogenic stresses resulted in overturning, isoclinal folding, and thrust faulting in the Garnet-Bearmouth area. Trends of the major structures are N. 60° to 70° W. (pl. 1).

Prolonged stress caused failure by rupture of the southwest flank of the Bearmouth fold, causing thrusting toward the northeast along several planes. Near Nimrod, thrusting has moved Missoula Group strata over younger Missoula Group rocks in the west and over progressively younger rocks farther east. Precambrian Miller Peak(?) strata are in contact with Pennsylvanian Quadrant Formation just east of Kearn's Gulch.

East of Little Bear Gulch a "klippe" of Mississippian and Pennsylvanian rocks lies on Cretaceous rocks. It is the erosional remnant of a larger thrust sheet associated with the Bearmouth thrust. A high-angle reverse fault is exposed in Kearn's Gulch and may represent another plane of failure associated with this thrusting, or may be an extension of the Little Bear klippe where the stratigraphic throw has diminished to such an extent that lower Quadrant rocks (Pennsylvanian) have been thrust against lower Ellis strata (Middle or Late Jurassic).

One or more periods of faulting in the area produced high-angle normal faults and steep reverse faults. In only a few places were actual fault planes observed, so it is only through indirect evidence that these two kinds of faults may be distinguished.

FOLDS

Nearly all the folds in the Garnet-Bearmouth area trend northwest-southeast. Some folds are very tight, even isoclinal, whereas others are open gentle. Some are symmetrical; others are markedly asymmetrical. A few cross folds cause distortion of the axial plane and result in doubly plunging structures.

DEEP CREEK ANTICLINE

The highest structure showing much continuity within this region is the doubly plunging Deep Creek anticline. The general trend of this fold is N. 50° to 60° W. This structure can be traced from the eastern border of the map near the southeastern part of T. 12 N. to the south edge of the town of Garnet. Here the axis may have been displaced about a mile to the south, and the trend may be represented by the anticlinal fold continuing toward the northwest corner of the map.

Along the Deep Creek anticline, several cross warps form pitch culminations and sags. One structural high, or dome, is near Anderson Hill, where the granodioritic stock may have caused the doming. The Deep Creek anticline plunges northwest and southeast from this area.

MULKEY GULCH SYNCLINE

The youngest Mesozoic formation in the Garnet-Bearmouth area (Lower Cretaceous Colorado Shale) is preserved in the center of the Mulkey Gulch syncline, an isoclinal doubly plunging fold trending N. 60° to 70° W. The outcrop patterns on the map indicate a southeast plunge of the western part of this fold. Actual measurements in the eastern part demonstrate northwest plunge. Exposures of the axis in the railroad cut between Rattler and Mulkey Gulches illustrate a plunge of approximately 12° to the northwest. Both limbs of this fold dip to the southwest, indicating overturning of the syncline by forces acting toward the northeast. The southwest limb is overturned to such an extent that dips as shallow as 43° are recorded.

Examples of slippage out from the center of the syncline along bedding-plane thrusts are numerous. Schuppen structure is well exposed in the upper calcareous member of the Kootenai Formation along the north side of the highway cut in sec. 16, T. 11 N., R. 13 W. In this section several branching, imbricate thrusts can be observed following bedding planes for some distance, cutting across bedding, and then paralleling the bedding planes once again. In the center of the Mulkey Gulch syncline, slippage along bedding planes and along faults at oblique angles to the bedding is extensive, as is movement along cleavage planes that nearly parallel the bedding.

The Mulkey Gulch syncline is observed to be an open, more gentle "synclinorium" near the northwestern limit of the Mesozoic exposures where the outcrop pattern takes on a sinuous trend. This irregular pattern is caused in part by the structural warping and in part by a topographic effect of differential weathering and erosion of different members of the Kootenai Formation. Nevertheless, several smaller anticlinal and synclinal folds can be mapped on the major fold.

BEARMOUTH ANTICLINE

A major anticlinal structure crosses the Clark Fork just east of Bearmouth and continues at least a mile along the south side of the valley. This structure should really be called an "anticlinorium" because several associated anticlines and synclines make up the major structure. The bizarre folds exposed in cliffs on the south side of the Clark Fork present a good cross-section of the Bearmouth anticline. The intensity of deformation of these Laramide structures can be observed in this section.

The large features of the Bearmouth anticline consist of an anticline and a syncline, both overturned toward the northeast. The trend of these folds is approximately N. 70° W. north of the Clark Fork and N. 60° W. south of the river. The dip of the north limb is approximately 60° to the southwest, that of the south limb ranges from shallow to nearly 60° to the southwest.

The overturned anticline exhibits marked thinning on the limbs of the fold and tremendous thickening in the crest. The "toothpaste" squeezing of the Madison Limestone illustrates the large amount of flowage associated with the folding. Farther southeast this overturned fold is breached, the south limb overriding the younger strata adjacent to the break. Toward the northwest the great volcanic and hypabyssal igneous mass may mark the presence of another break in the anticlinal fold. Although no fault has been mapped there, it is possible that the location and linear trend of this material was controlled by a break along the axis of the Bearmouth anticline.

MOUNT BALDY SNYCLINE

Southwest and west of the Bearmouth anticline is a series of folds constituting the Mount Baldy syncline or, more properly, "synclinorium." Two pronounced synclines, one minor syncline, and two anticlines make up this complex structure. The limbs are tightly folded but are not isoclinal. The south limb has failed by rupture, resulting in an imbricate thrust series. These faults will be discussed later.

The Mount Baldy syncline trends N. 70° to 80° W. and extends from the Clark Fork in the center of the map to the west edge of the Garnet-Bearmouth area. The fold opens toward the northwest, a phenomenon characteristic of this belt of folds lying near the boundary between the Northern Montana Rockies with their open folds, and the Transverse Igneous Belt and associated lineaments and tightly compressed folds.

OTHER FOLDS

Several folds of lesser structural significance occur in the Garnet-Bearmouth area. The Douglas Creek syncline parallels the northeast border of the map. Madison Limestone forms the center of this open fold, the Jefferson Formation on both limbs dipping 30° to 40° toward the synclinal axis.

The Secret Gulch anticline extends for 5 or 6 miles toward Bear Creek from near the northwest corner of the map. A high-angle fault has brought Belt rocks to the surface in the center of the anticline. Folds northwest of Union Peak may be the northwestern extension of the folds already described. They are separated from the other folds by a mass of volcanic debris.

Near the upper reaches of Cramer Creek is an asymmetrical syncline with Jefferson Limestone forming its center. This syncline trends approximately N. 45° W. and plunges to the southeast. The north limb is very gentle, dips ranging from 7° to 40° SW. The southwest limb is very steep; dips in the Maywood(?) Formation are nearly vertical. Numerous reversals of attitude appear to distort the trend of the fold northwest of Cramer Creek.

THRUST FAULTS

BEARMOUTH THRUST

The south limb of the Mount Baldy syncline has been overturned and thrust over younger strata toward the central part of the fold. Stratigraphic displacement seems to increase from west to east. Near the southwest corner of the Garnet-Bearmouth area the McNamara Formation is in thrust contact with the Garnet Range Formation, the next younger unit of the Belt Series. Farther east the older Belt formations are thrust over younger and younger units of the Belt Series, then over Cambrian, Devonian, Mississippian, and finally Pennsylvanian. At a location near the Clark Fork in sec. 17, T. 11 N., R. 14 W., the oldest formation of the Belt Series in the area (the Miller Peak Formation) has been brought against the Pennsylvanian Quadrant Formation. The minimum stratigraphic throw is 15,000 feet, and a figure of 18,000 or 19,000 feet is possible.

Along Byrne's Gulch a slice of Hasmark Dolomite has been dragged along with the Bearmouth thrust block, forming an imbricate pattern. This fault seems to die out westward. The Quadrant Quartzite has also been faulted against younger formations near Kearn's Gulch. This high-angle reverse fault represents another plane of failure associated with the Bearmouth thrust. Only the upper 25 to 50 feet of Quadrant and 25 to 40 feet of Permian Phospohria Formation are missing. This fault seemingly dies out within 2 miles toward the northwest, where float indicates the presence of Phosphoria.

The sinuous trace of the Bearmouth thrust suggests variation in dip along the thrust plane. Actual measurements along Byrne's Gulch show the fault to be dipping approximately 32° to the south at that location. At other spots along the trace, higher angles have been inferred; dip of 50° was estimated 1½ miles west of Ryan Gulch near the west edge of the area. An eastern extension of the Bearmouth thrust cuts the tip of the southward-extending promontory near the section corner between sec. 15, 16, 21, and 22, T. 11 N., R. 14 W., along the north side of the Clark Fork valley. At this location Precambrian Bonner Formation is thrust against Mississippian Madison Limestone.

The trace of the Bearmouth thrust is lost beneath Recent alluvium in the Clark Fork valley and is hidden by Tertiary volcanics and volcanic-rich sediments south of the valley. Recent mapping by Maxwell (1959) has indicated possible extension of this thrust southeast of the Garnet-Bearmouth area.

LITTLE BEAR KLIPPE

Imbricate faulting associated with the Bearmouth thrust has produced an outlier of Paleozoic rocks lying on Cretaceous strata. This segment does not seem to be completely detached, but the root zone portion of the thrust sheets is covered by Recent alluvium, hence the exact relationship is not clear. It is apparent, however, that the Madison, Amsden, and Quadrant Formations are nearly completely surrounded by the Cretaceous Kootenai Formation on the south, west, and north sides of this "klippe." The northeast and east borders are obscured by Tertiary volcanics. The southeast flank is covered by a portion of the Bearmouth thrust block, which brings the Bonner Formation of the Precambrian Belt Series in contact with the Mississippian Madison Limestone. The dip of the Little Bear klippe, as determined by plotting a section through part of the structure, was estimated to be 20° to 25° to the south-southwest.

HIGH-ANGLE FAULTS

In only a few places were fault planes actually observed. Most fault zones in this area produce zones of weakness along which great differential weathering and erosion obscure the true relationships. For this reason it is difficult to make the distinction between high-angle normal faults and steep reverse faults. Indirect structural and topographic evidence has been brought to bear on this determination whenever possible.

Major normal faults are generally unlikely in a compressional belt such as this zone of Laramide orogeny. Such faults may exist, however, as secondary faults sympathetic to the major fault movement. In addition, normal faults may represent a later unrelated period of tectonic activity. Poulter (1958) interpreted the normal faults in the Georgetown area as being transverse to the older compressional features, indicating a later period of movement, not merely a relaxation phenomenon resulting from release of the compressional forces.

CRAMER CREEK FAULT

An extensive zone of displacement has been postulated near the northwestern corner of the area. Although a fault plane was not seen, several indirect lines of evidence suggest the presence of this Cramer Creek fault. Precambrian Garnet Range Formation has been brought adjacent to Cambrian and Devonian strata, giving a possible stratigraphic throw of approximately 3,000 feet.

This fault may actually be a reverse fault or even a thrust. An examination of the structural relationships, however, suggests that a normal fault is a better interpretation. The syncline located north of this fault may be a down-dropped portion of the Mount Baldy syncline. The general characters and trends of these two synclines are very similar. The present configuration could have been produced by dip-slip movement of approximately 8,500 feet, the Cramer Creek fault dipping 45° to the north.

The displacement seems to be greater near the west end of the Cramer Creek fault, dying out abruptly toward the northeast end, where Hasmark occurs on both sides of the fault. This decrease in displacement can be explained in terms of a hinged fault or pivotal fault, in which the northeast end of the fault would serve as the pivot.

COPPER CLIFF FAULTS

Pardee (1918) examined the ore deposits in the Garnet Range and mapped the faults in the mining districts in considerable detail. His mapping of the faults at Copper Cliff was modified only slightly in this study. High-angle faults trend northeast and dip northwest or southeast, forming horst and graben structures. The greatest movement for any one fault, as estimated by examination of the total displacement of units, is 1,500 feet.

Intensely sheared zones are associated with the Copper Cliff faults and contain extensively developed breccias, in which the copper ores are found (Pardee, 1918, p. 215). These breccias consist of angular fragments of Beltian quartzite and silicified shale or argillite, cemented by finely crystalline silica.

BEAR CREEK FAULT

Closely paralleling the trend of the stream valley for much of its extent, the Bear Creek fault, south of the town of Garnet, strikes approximately N. 25° W. This fault is nearly vertical and can be observed at the mouth of a tributary to the main valley along the line between sec. 15 and 16, T. 12 N., R. 14 W. The Precambrian Garnet Range Formation is faulted up against the Silver Hill Formation. Total movement along this fault seems to be a few hundred feet. A sheared zone follows the trace of this fault in the Bear Creek valley; deformed Hasmark Dolomite forms the matrix of a zone containing angular fragments of red siltstone and quartzite, possibly derived from Precambrian formations at depth.

FINN GULCH FAULT

A fault trending nearly east-west cuts the Bear Creek fault almost at a right angle ¼ mile south of Finn Gulch and seems to offset the Bear Creek fault about 2 miles to the west. An elongate body of andesitic basalt parallels the Finn Gulch fault for more than 2 miles and may be material intruded into a zone of weakness along the fault. The age relations of the faults in this area are not clear. Although it is possible that the north-south faults may be later than the Finn Gulch fault and may terminate at or near this fault zone, the similarity in relative displacement and the similarity in attitude of the north-south faults suggest they were once continuous and were subsequently displaced by the later east-west fault.

OTHER FAULTS

Several additional high-angle faults occur in the Garnet-Bearmouth area. One of these bounds a graben(?) of Hasmark Dolomite near the mouth of Cramer Creek. Normal faulting prior to thrusting may have produced a down-dropped block of Cambrian rocks in the Beltian terrane. Subsequent thrusting has brought McNamara Formation over this block of Hasmark. Another possible interpretation for this structure is that a slice of Hasmark was caught in the Bearmouth thrust and formed the present structure as an imbricate thrust, but no source for the Hasmark is apparent. For this reason a pre-thrust normal fault has been inferred.

Another high-angle fault occurs along Secret Gulch and trends approximately N. 40° E. Precambrian Garnet Range Formation has been raised against the Silver Hill Formation. Maximum stratigraphic displacement is only a few hundred feet.

West of the lower part of Rattler Gulch is a fault associated with the north limb of the tightly folded Mulkey Gulch syncline. Slickenside surfaces associated with this fault dip steeply to the north. These planes were interpreted as being parallel to the main fault, suggesting a later normal fault down-dropped to the north. Another equally valid interpretation is that this structure is a breached anticline, the south limb of the fold being faulted up to the north across younger strata in the adjacent syncline. The first interpretation has been used in making cross section D-D' (pl. 1).

Part of the Cambrian and Devonian strata are repeated along a small fault crossing Mulkey Gulch. This high-angle fault trends about N. 50° W. and has raised the southwest side approximately 500 feet.

TRANSVERSE FAULTS

MONTANA LINEAMENT

The possibility has been suggested that some transverse movement has occurred along the Clark Fork valley in the zone of faulting termed the Montana Lineament. If so, it must have preceded movement of the Bearmouth thrust. Left-lateral movement near Nimrod may have moved Belt Series strata toward the east on the south side of the Clark Fork. Such movement would reduce the total displacement that must be postulated to produce the present configuration by thrusting alone. Thrusting on the order of 6 or 8 miles is needed if the Bearmouth thrust really is a low-angle overthrust. If its angle of dip is about 50° the total dip-slip would still have to be about 20,000 feet or nearly 4 miles. Transverse movement prior to thrusting could have reduced considerably the thrust displacement required.

FINN GULCH FAULT

The spatial relations along the Finn Gulch fault suggest that some transverse movement may have offset the two parts of the Bear Creek fault. Presumed right-lateral displacement could explain the present configuration but would also create other problems to be explained, such as the approximate continuity of the Red Lion and Maywood Formations across the southeast juncture of the two faults. The previous interpretation of normal dip-slip movement along these faults seems a better solution.

OTHER FAULTS

Several apparent tear faults are associated with the Bearmouth thrust. These faults probably involve slight transverse movements. One such fault occurs east of Dry Creek, another with the Little Bear klippe.

INTRUSIVE RELATIONSHIPS

Structural features associated with the large Garnet stock and related intrusive bodies are negligible, although there is some indication that the country rocks have been arched over the rising igneous masses. The granodiorite outcrop near Anderson Hill seems to have been punched up through the dome of the Deep Creek anticline. Arching of this structural high may have occurred simultaneously with the intrusion of the granodiorite.

Metamorphic aureoles around the granodiorite stock and along the granodiorite dikes generally are characterized by dense marble, hornfels, and quartzite.

EXTRUSIVE AND HYPABYSSAL RELATIONSHIPS

Volume expansion (dilation) of the country rocks may have accompanied the shallow intrusion of large masses of igneous material. East of Rattler Gulch and east of Mulkey Gulch are igneous bodies around which the sedimentary units seem to bend. West of Rattler Gulch is an overturned syncline associated with doming of an adjacent igneous body.

The large number of igneous masses along the trend of the Clark Fork valley suggests that it may coincide with a major zone of weakness serving as the means of exit for large quantities of material from depth. Igneous activity is one of the reasons for suggesting the presence of a major lineament in this region.

There is some question whether many of these igneous bodies are of extrusive or shallow intrusive (hypabyssal) origin. The funnel-shaped foliation patterns suggest that many vents and conduits gave rise to local patches of extrusive and hypabyssal rocks rather than to great horizontal sheets covering wide areas. (See discussion under Igneous Rocks.)

ASYMMETRY OF OVERTURNING

Folds are overturned toward the northeast in most of the Garnet-Bearmouth area, but in the higher parts of the Garnet Range, and especially in the Flint Creek Range, overturning toward the southwest is noted. It has been interpreted by McGill (1958) as underthrusting of the lower limb of an anticline. In the Flint Creek area massive Madison Limestone transmitted the forces that resulted in underthrusting below the less competent Mesozoic shale and sandstone. This explanation will not hold for the Garnet-Bearmouth area, however, because here the less competent Mesozoic strata lie topographically lower than the Madison Limestone.

A better explanation for overturning toward the southwest in this area might be gravity flow off the uplifted mountain front. Although no faulting is apparent along the front of the Garnet Range, the difference in elevation may have been sufficient to cause gradual overturning of the Madison section.

Differential uplift of the mountain range relative to the Clark Fork basin may also have produced overturning of the strata along the hinge line between uplifting and downwarping blocks. The amount of differential movement necessary would probably be so great as to make this hypothesis untenable.

ANOMALOUS TREND OF GARNET RANGE

A glance at the landform map of Montana or Figure 1 shows that the west-northwest trend of the Garnet Range is anomalous among the predominantly north-trending adjacent ranges. The reason for this shift in topographic trend may have been the development of west-northwest-trending Laramide folds and subsequent differential erosion of the region.

GEOMORPHOLOGY

TOPOGRAPHY

The Garnet-Bearmouth area comprises a rugged terrane composed of an upland surface dissected by numerous v-shaped canyons. The upland surface gives the general appearance of a rolling plateau, several peaks rising above—and valleys cutting into—an otherwise featureless plain.

In much of the area, relationship between bedrock and topography is evident. The massive limestones of the Jefferson and Madison Formations in most places form resistant ridges and knobs. The Mesozoic shales, siltstones, and limestones erode more easily and form the lowlands and valleys. The Precambrian quartzites and the larger igneous masses resist weathering and form the higher portions of the area.

The Tertiary volcanics and shallow intrusives offer intermediate resistance to the denuding processes. They produce nondescript, undulating, pockmarked topography, with poorly integrated, intermittent, and locally interior drainage. On air photos the patches of volcanic materials can readily be distinguished by their irregular topography, characterized by swells and swales in random shape and orientation, relief measured in tens of feet, and sparse vegetative cover.

Air photos and topographic maps dating from 1908 indicate several recent changes in the position of the Clark Fork. Cutoff meanders, oxbow lakes, and diversion of the stream by roads and railroads attest to the transient position of the stream channel.

Pardee (1918, p. 164) suggested that part of the Clark Fork east of Nimrod has reversed its direction of flow. He based this suggestion in part on the fact that some of the tributaries enter the Clark Fork at acute angles pointing toward the east, i.e., up the present stream gradient. Among such streams are Bear Creek, Mulkey Gulch, and Rattler Gulch on the north side of the Clark Fork, and Bateman Creek, Harvey Creek, and Tigh Creek on the south side. A definite joint set was observed by the writer to trend approximately N. 15° to 20° E., the precise trend of most of the streams on the south side of the Clark Fork and many of the streams on the north side in the western part of the area. Structure, therefore, has played an important part in determining the location and the angle of incidence of these streams; the hypothesis of reversal of stream direction is not necessary.

UPLANDS OF WESTERN MONTANA

The summit surface of the Garnet Range has been called an early Tertiary peneplain (Pardee, 1918, p. 164); relief is only a few hundred feet except for several isolated monadnocks such as Mount Baldy and Anderson Hill. Umpleby (1912) had suggested the occurrence of such a plateau surface in eastern Idaho and adjacent parts of Montana, Washington, and British Columbia, and assigned an Eocene age to it. Atwood (1916) examined the "summit peneplain" in southwestern Montana and eastern Idaho. He thought that the intermontane basins were downwarped or tilted and down-faulted blocks.

Mansfield (1927) was the first to recognize the existence of more than one erosion surface in the Northern Rocky Mountain region. He agreed with the idea of an earlier erosion surface but suggested that later erosional cycles occurred at different times in different parts of the region, rather than simultaneously throughout the entire area.

Perry (1934) examined the physiographic history of the Big Hole Basin in southwestern Montana. He concluded that in this area three general drainage systems have developed. The first and most ancient drainage is recorded by high plateaus and concordant summit levels, crests of ridges and peaks of nearly equal elevation. The second river system is shown by wide valley trends, high well-developed remnants of old erosion surfaces, "which merge into the surrounding mountains with broad sweeping curves" (Perry, 1934), and extensive areas of "lake beds" deposited in dammed stream valleys. The third system is the present drainage, which in places follows the second drainage system and elsewhere cuts across divides of the earlier systems.

Other workers have recognized three erosion surfaces developed in the topography in southwestern Montana (Scholten and others, 1955) and in the Georgetown thrust area (Poulter, 1958).

Pardee (1950) summarized his findings on the physiography of western Montana. Areas uplifted during the Laramide revolution were gradually reduced to a low surface of moderate relief by erosion prior to the end of the Eocene. Ponding of drainage in Oligocene and Miocene time resulted in deposition of "lake beds" in the intermontane basins, accompanied by further reduction of the surrounding areas to a gently sloping or level surface, termed by Pardee the Late Tertiary peneplain. Renewed uplift of the mountain areas and subsidence of the basins during late Miocene, Pliocene, and early Pleistocene time disrupted the peneplain. The "Old Valley cycle" of stream development occurred during a pause in the uplift of the area (Pardee, 1950, p. 366). During this cycle, streams eroded wide valleys to moderate depths, and the "lake beds" were partly destroyed by erosion. Resumption of uplift caused the diversion of weaker streams and the entrenching and excavating of gorges by the more vigorous streams. The present cycle resulted in dissection of Old Valley Cycle plains and formation of lower plains and terraces along the modern valley bottoms. Correlation of the resulting benches and terraces from one valley to another was considered by Alden (1953).

Abandoned valleys are often cited as evidence of former erosion surfaces. Several abandoned valleys occur in the uplands of the Garnet-Bearmouth area. One is found along the main divide of the Garnet Range, just southeast of Anderson Hill, between Cayuse Gulch and Day Gulch. According to Pardee (1918, p. 235; 1950, p. 402), this divide is a level tract in a small, shallow gap, and it contains gold-bearing gravel deposited by the former stream. Quartzite cobbles have decayed in this old deposit, formed by an ancient stream long since diverted to other channels as the modern topography evolved. Other abandoned channels are represented by Gambler's Gulch and by a gap at the head of Elk Creek, both short distances from the example on the main divide.

Several upland basins contain volcanic-rich sediments of lacustrine and fluviatile origin (discussed under the heading "Igneous and Metamorphic Geology"). The occurrence of "lake beds" at elevations as much as 2,000 feet above the Clark Fork in the Garnet-Bearmouth area can be explained by several hypotheses: (1) They may represent deposits formed at the same time as the "lake beds" in the lowlands and may formerly have been part of a continuous cover extending to the altitude at which they are now found, the intervening deposits of corresponding origin having been subsequently removed by erosion; (2) the upland deposits may represent a different age of volcanically enriched sedimentation, either younger or older than the lowland "lake beds"; or (3) the volcanic-rich upland deposits may be the same age as the lowland "lake beds," trapped in upland depositional basins, which have not yet been flushed of these semiconsolidated and consolidated sediments. The writer favors the last hypothesis. The persistence of these remnants may be due to a more resistant "sill" holding up the lip of the basin and thus preventing removal of the sediments; to the fact that these sediments have been sufficiently compacted and lithified to resist erosion; or simply to accidental preservation.

EROSION SURFACES IN THE GARNET-BEARMOUTH AREA

Several topographic features in the mapped area suggest remnants of former erosion surfaces. These include high shoulders or benches on the valley slopes, gravel-capped spurs, and low terraces.

UPLAND SURFACE

The highest surface of the Garnet Range may be the remains of a formerly widespread erosional surface, corresponding to the "summit peneplain" of earlier workers. It is probable that none of the present land surfaces correspond to the actual earlier erosion surface, but remnants approximate the level of that surface. In the Garnet-Bearmouth area, altitude of this highest surface ranges from 6,000 to 6,500 feet, except for peaks rising almost to 7,000 feet.

HIGH-LEVEL BENCHES

High shoulders or benches along the north side of the Clark Fork, especially in the eastern third of the region, between Rattler and Mulkey Gulches, are found at an altitude of about 4,500 to 4,700 feet, 800 feet above the present stream. This level corresponds approximately to the very extensive surface underlain by the Madison Limestone on the south side of the Clark Fork, east and southeast of Bearmouth. These shoulders may represent pedimentation during late Pliocene or early Pleistocene as suggested by Poulter (1958) and McGill (1959).

INTERMEDIATE SPURS

Gravel-capped spurs at consistently similar altitudes at several places along the Clark Fork range from 100 feet to as much as 500 feet above the present stream level, depending on their position along its course. Included in this category are Beavertail Hill, 400 to 500 feet above the Clark Fork near the west edge of the area, Medicine Tree Hill, 300 to 400 feet above the stream in the center of the area, and gravel-capped spurs underlain by the Kootenai Formation, 100 to 200 feet above the Clark Fork in the eastern part of the area. These spurs maintain a fairly uniform altitude of 4,000 to 4,100 feet above sea level. It is possible that these spurs are remnants of extensive erosional surfaces graded to Glacial Lake Missoula (discussed below).

Gravel deposits on the low saddle of Beavertail Hill consist of pebbles and cobbles ranging from 1 to 6 inches in length and averaging about 2 inches. They are derived almost exclusively from the underlying quartzite bedrock, the Garnet Range Formation of the Precambrian Belt Series. Lithic components include gray, green, and brown micaceous quartzite and a few buff to rusty quartzose quartzite cobbles. The pebbles are fairly well rounded (approximately 0.7) and possess a fair degree of sphericity (about 0.8), according to visual charts of Krumbein and Sloss (1951).

LOW-LEVEL TERRACES

Other terraces are evident at lower levels than the intermediate gravel-capped spurs. These low terraces, a few tens of feet above the present stream level, probably represent latest Pleistocene to Recent fluctuations of the Clark Fork in its meandering back and forth across its valley. Some of these terraces are composed of well-bedded and stratified sand and gravel, much coarser than materials in the present stream load.

They are probably of glaciofluvial origin. At some places these lower terraces can be observed to merge with the present flood plain, although at most locations a distinct bluff separates these earlier sediments from the modern stream deposits. On the geologic map (pl. 1) the earlier stream deposits are labelled Qgl (Quaternary alluvium), and the present floodplain deposits are labelled Qal (Recent alluvium). (It is recognized, of course, that standard usage includes the Recent as part of the Quaternary Period of the Cenozoic Era.)

GLACIAL FEATURES

Glaciers seemingly did not traverse any part of the Garnet-Bearmouth area, although the sand and gravel in the low-level terraces along the Clark Fork, if of glaciofluvial origin, are indicative of mountain glaciation in nearby areas. Cirques are numerous in the Flint Creek Range and the Anaconda Range, south of this area, but there the peaks reach altitudes above 9,000 feet, whereas altitude of the Garnet Range is nowhere as high as 7,500 feet, hence probably too low to be the locale of mountain glaciers during the Pleistocene.

GLACIAL LAKE MISSOULA

Although others had alluded to its possible occurrence, Pardee (1910) was the first to publish a serious discussion of the widespread late Pleistocene feature known as "Glacial Lake Missoula." Several observed features were explicable in terms of Pardee's theory: fairly prominent horizontal "buffalo trails" on the mountain slopes around Missoula at altitudes as high as 4,200 feet; large erratic boulders as high as 1,000 feet above the present valleys in nonglaciated areas; and gravel flats at about the same altitude. He said there once existed a large lake or sea whose highest level was approximately 4,200 feet above sea level. The old "buffalo trails" represent the remnants of the wave terraces. Gravel flats in some tributary valleys of the Clark Fork are explained as delta deposits in a lake. The lake is believed to have receded gradually, recording many brief pauses (and a fairly long one at 3,700 feet) by the various terrace levels (Pardee, 1910).

Lobes of the Cordilleran ice cap extended great distances south of the main body of ice. The Clark Fork was completely blocked near the Montana-Idaho border south of the Pend Oreille Lake basin. The large number of shore lines indicated numerous fluctuations in the water level of the lake. Melting and recession of the glacial ice in northern Montana allowed the lake to drain. Alden (1953) suggested that more than one glacial stage may have been involved in the existence of Glacial Lake Missoula.

Deposits in the glacial lake consist of laminated lacustrine silts, widespread near Missoula and in the Clark Fork valley down stream. Very little gravel or sand is interbedded with the fine silts (Alden, 1953). No such deposits have been observed along the Clark Fork in the Garnet-Bearmouth area, although the lake must have invaded this region (the 4,200-foot contour extends upstream almost as far as Garrison, 20 miles east of the mapped area). The gravel-capped spurs at 4,000 to 4,100 feet along the Clark Fork may be remnants of either a former extensive erosional surface or a plain of fill graded to the level of Glacial Lake Missoula.

ECONOMIC GEOLOGY

METALLIC RESOURCES

by

F. N. Earll

INTRODUCTION

The development of the rich mineral resources of the Garnet-Bearmouth area began early in Montana's history. As the more easily available deposits at the first discovery site at Bannack began to play out, the hungry prospectors started to search for new lodes, their search carrying them far to the north and east where they opened the many rich placer and lode localities, such as Virginia City, Butte, Silver Star, and Philipsburg. One of the great discoveries was at the mouth of Bear Creek in the Garnet Range, or as commonly described, at Bearmouth. This deposit first produced in 1865 and in its short but lusty and often violent life is estimated to have produced more than $7,000,000 in gold and silver (Pardee, 1918).

The discovery of placer gold at Bearmouth naturally led to prospecting of the interior of the range, which in turn led to the discovery of the lode deposits at Top o' Deep (1866), First Chance or Garnet (1867), Copper Cliff (1891), and Coloma (1897).

The geology and production history of these districts, from their discovery until 1917, has been covered in detail by Pardee (1918). All of these districts have enjoyed a second period of production since that publication, however, one district more than doubling previous production totals; hence it was felt that a restudy of the various districts and their present potential was in order. Unfortunately, this study has produced more of statistical data than of geological. The deplorable state to which the mines have been allowed to sink prevented all but the most cursory examination of a few properties. Pardee, in his 1918 report, noted the presence of considerable tonnages of mineable ore in the primary zone in many of the mines, particularly those in the First Chance (Garnet) district. The truth of his observation is borne out by subsequent production. Today the pertinent question is whether and where such ore remains. Unfortunately, the answer to this question will require the expenditure of considerable sums of money, as all the major mines are either caved or flooded with water at the present time. Certainly if ore such as was described by Pardee remains in any of the mines, it could be profitably extracted by modern methods and equipment. Investors willing to risk their capital on a caved shaft complete with rumors of ore have become rare in recent years, however. From this brief summary, one is left to wonder whether the mining districts of the Garnet-Bearmouth area died of old age or committed suicide.

GEOLOGY

The detailed geology of the several mining districts of the Garnet-Bearmouth area is well described in Pardee's report of 1918. For present purposes it is sufficient to state that all the lode deposits of the area are more or less directly related to intrusive rocks of generally granodioritic composition. They include replacement lodes along the contact between granodiorite and the intruded Cambrian and Precambrian sediments, and fissure veins both within the intrusive rocks and in the intruded sediments. An exception is Copper Cliff, where the deposit is found in greatly brecciated Precambrian quartzite and argillite, which seem to be remote from any large granitic intrusive. The presence of several "porphyry dikes," however, and the general character of mineralization strongly suggest the presence of an intrusive body at no great depth.

The placer deposits of the area derive naturally from their parent lodes and extend from Bearmouth to the headwaters of Bear Creek at Garnet (First Chance district); along Deep Creek to its headwaters (Top o' Deep); and Elk Creek, which drains northward beyond the area covered by this report, deriving its gold from the First Chance, Top o' Deep, and Coloma districts, which crown the divide south of its drainage.

ORE DEPOSITS

Bear Creek Placer District—The placer gold deposits along Bear Creek and its major tributary Deep Creek came into production in 1865, making the Bear Creek district one of the first of major Montana mining districts. Beartown, located where Deep Creek empties into Bear Creek, was the main population center and is estimated to have had a population in excess of 5,000 persons (Pardee, 1918). If Beartown grew rapidly, it declined at the same rate. By 1900 production had dwindled to a few ounces of gold per year, and by 1916 the once busy placers were dormant when visited by Pardee. At that time, Pardee concurred in the estimates of others that the district had produced at least $7,000,000 in gold and silver, the product being almost entirely gold. Since that time the district has enjoyed several rejuvenations. During the depression years, as many as 28 placers were reported in operation at the same time. Although these were officially credited to the First Chance district, most were undoubtedly Bear Creek properties. Also, during the 40's and again in the 50's, the coarse boulder deposits of Bear Creek from its mouth to the "narrows" 2 miles upstream were worked by means of a floating dredge. No accurate data on the value of this production were available, but some estimates can be made. Based on known recoveries upstream, the dredges must have recovered at least $500,000 in gold and probably recovered several times that amount. Add to this the production of small operations during the depression, and it seems safe to conclude that the total production of the Bear Creek district to date is valued at not less than $10,000,000.

Having been worked over with care, and then reworked, the district might be expected to be barren of promise, and yet this is not entirely true, as indicated by recent activity in the district. In the last few years the Valley Mining Co. has acquired title to virtually all claims from the mouth of Bear Creek to the town of Garnet, and up Deep Creek to Top o' Deep. Although this group had not gone into regular production at the time of the writer's last visit, they had operated a portable drag-line-fed trommel for about 3 months recovering a reported $20,000 in gold. Although "pay gravel" on these claims can be expected to be of irregular occurrence and of lower grade than that mined in the early days, it seems likely that a modest profit can be obtained provided only that the group practices reasonable circumspection in its operation.

There was also some preliminary test work being done on Tenmile Creek, about a mile above its mouth, and near the head of Elk Creek at the time of the writer's visit, but no report of results can be made at this time.

Coloma District—Although the deserted town of Coloma and its mines lie just off the northern margin of the area under consideration in this report, its history and production are so closely allied to that of Garnet that it hardly seems proper to omit reference to the district.

Coloma lies 2 miles northwest of Garnet, just on the other side of the main divide of the Garnet Range. Its geology and mineralization so closely parallel those of the First Chance district at Garnet that no special comment on them seems necessary. Its deposits were first exploited in 1897, 30 years later than its neighbors, a fact that seems strange in view of their close proximity.

Pardee estimates district production to have totaled $250,000 from 1897 through 1916. At the time of his visit he describes the town as "almost deserted" saying, "in 1916 the only important work in progress was a tunnel being driven by the Montana Gold Mines Co. at a point half a

TABLE 3.—Metal production of the Coloma mining district.

Year	Gold (oz.)	Silver (oz.)	Copper (lb.)	Lead (lb.)	Zinc (lb.)	Value
1897-1916	12,000	9,000	5,000	—	—	$250,000
1917	—	—	—	—	—	—
1918	43	8,968	491	16,000	—	11,174
1919	70	50	100	—	—	1,526
1920	—	—	—	—	—	—
1921	40	40	100	—	—	866
1922-1926	—	—	—	—	—	—
1927	4	30	—	—	—	101
1928-1931	—	—	—	—	—	—
1932	112	71	333	—	—	2,367
1933	374	200	1,281	—	—	7,894
1934	978	628	1,700	—	—	34,721
1935	464	117	60	—	—	16,341
1936	327	315	43	565	—	11,733
1937	576	415	248	—	—	20,511
1938	536	464	541	739	—	19,149
1939	490	296	346	22	—	17,388
1940	361	249	460	—	—	12,864
1941	394	308	600	300	—	14,097
1942	281	291	—	—	—	10,042
1943	132	128	—	—	—	4,711
1944	90	114	400	—	—	3,285
1945	71	90	200	—	200	2,599
1946	16	10	—	—	—	568
1947	52	53	—	—	600	1,941
1948	14	10	—	—	—	499
1949	17	21	—	—	—	614
1950	10	10	—	—	—	359
1951	—	—	—	—	—	—
1952	4	71	—	1,230	—	402
1953-1955	—	—	—	—	—	—
1956	—	1	1,600	—	—	681
1957-1960	—	—	—	—	—	—
Total	17,456	21,950	13,503	18,856	800	$446,433

mile north of Coloma and 600 feet lower." This was the Mammoth drain tunnel, which was to cause the rebirth of Coloma almost before the echoes of his footsteps were to die out. The district was in production from 1918 to 1921, and again from 1932 to 1950. Since 1950 only minor work has been done, and at the time of the writer's visit in 1960 the town's last citizen, a blacksmith, resident since the early days of the camp, had left at least temporarily. Total production of the Coloma district through 1960 is given in table 3.

Most of the metal production of the Coloma district is credited to the Mammoth and Comet mines, the Mammoth being by far the larger producer of the two. A considerable but uncertain portion of the production of recent years is apparently from the Dandy mine, which is hardly in the Coloma district. Why this mine, located at the head of Elk Creek, should be reported from the Coloma district is uncertain, but this is far from being the only such irregularity in published statistics.

Two fairly recent prospects were accessible to the writer at the time of his visit. The first of these was an inclined shaft apparently intended to intersect the workings of the Mammoth mine at depth. A 3½-foot vein was intersected by this shaft, but the writer's samples proved it to be virtually barren. The shaft had been abandoned and all equipment removed at the time of the visit, although the condition of timber and buildings suggested that the work had been done recently.

The second accessible property, located to the north and at lower elevation than the town, has been called the Ness prospect after its most recent occupant. The workings consist of a short adit, an equally short drift, and one raise to surface. The ore body includes 12 inches of vein plus 5 inches of clay gouge. The writer's samples show the vein to carry 1.185 ounces gold and 2.30 ounces silver, and the clay assayed 1.26 ounces gold and 3.70 ounces silver. The prospect had been idle for about 5 years at the time of visit, and timbers were beginning to take considerable weight. It is doubtful whether this property will remain open for long. The Dandy mine was also visited, and there was evidence of a recent effort to reopen one of the adits, but at the time of the writer's visit, this effort seemed to have been abandoned.

The history of the district is one of narrow veins carrying fair to good values in gold and silver. There is certainly some hope for future production, but interest is lacking.

Copper Cliff District.—The mines of the Copper Cliff district first came into production in 1891, and in the years prior to 1916 produced a small tonnage of copper ore containing some gold and silver, valued at approximately $18,000 (Pardee, 1918). In the years since Pardee's report there have been a few sporadic shipments bringing the total for the district just over $20,000.

Probably the first factor that strikes the visitor to Copper Cliff is the cliff itself, stained blue by copper mineralization. This sight unquestionably affected the early prospectors and the investors who followed them. The second factor to attract the visitor's attention is the fact that any one of the several dumps represents the expenditure of more money than the value of the entire production of the district. The major mines of the district, the Copper Cliff, Crescent, Tiger, and Leonard, contain several thousands of feet of drifts and several shallow shafts. Some high-grade ore, containing 22 percent copper, is said to have been found, but the best piece of selected material the writer could find (about the size of an orange) assayed but slightly more than 5 percent. Pardee's guess that the deposit as a whole might average 1 percent seems optimistic.

The district's only other claim to fame involves the pale-blue, copper phosphate mineral that has formed on the face of the cliff. This mineral is something of a collector's item, and has not yet been fully described to this writer's knowledge.

At the time last visited, an attempt was underway to reopen the lower two adits of the claim group for examination. The writer and his assistant, D. C. Lawson, succeeded in entering one of these adits for a distance of 150 feet but were unable to ascertain the condition of workings beyond that point at the time.

Tabulated production of the district is given in table 4.

TABLE 4.—Metal production of the Copper Cliff mining district.

Year	Gold (oz.)	Silver (oz.)	Copper (lb.)	Value
1891-1916	230	500	100,000	$18,000
1917-1937	—	—	—	—
1938	14	31	3,888	891
1939	—	—	—	—
1940	5	14	1,310	333
1941	2	—	500	129
1942-1943	—	—	—	—
1944	6	7	—	215
1945	2	15	5,200	691
1946-1960	—	—	—	—
Total	259	567	110,898	$20,259

First Chance (Garnet) District.—The First Chance mining district first came into production in 1867, and in the 49 years before Pardee's visit in 1916 is estimated to have produced a total of $1,500,000 worth of ore (Pardee, 1918). It continued in production until 1928, then again from 1931 until 1952. One shipment of ore was recorded in 1955. In the 44 years since Pardee's visit, district production more than doubled, bringing the total to more than $3,500,000 and making the district by far the most important of the lode-mining districts in the Garnet-Bearmouth area (table 5).

About 20 individual mines have been productive at one time or another during the nearly 100 years since the district was first discovered. During the first half of this period (1867-1916) the most important producers were the Dewey, Nancy Hanks, Shamrock, Magone and Anderson, and the Crescent-Lead King-Red Cloud group mines. In more recent times, production continued from the Nancy Hanks, Shamrock, Magone and Anderson, and Crescent-Lead King-Red Cloud group, but important contributions were made also by the Fourth of July, International, Robert Emmet, Free Coinage, and San Jose mines.

At the time of the writer's visit in 1960, only two of the properties were at all accessible. The Nancy Hanks is said to have been open the preceding year, but the shaft had since caved near surface. One short development adit at the Fourth of July was open. This adit had been driven well below the main workings in an apparent effort to develop ore at depth, but the project was left unfinished.

The Spokane mine at the head of Kearn's Creek, now renamed the Jackie Marie, is the only active property in the district. An adit level, 100 feet below the old shaft collar, has been under development for several years. The adit had been driven almost 1,000 feet, on three headings, at the time of examination. One heading had holed through into old workings farther up the creek valley; one was terminated at the contact of Precambrian metasediments with the granodiorite stock that lies between Kearn's Creek and Garnet; and the third and present heading is intended to pass below the old shaft and develop rich ore believed to remain there. At the time of the writer's visit, no ore nor any ore structure had been encountered in these workings. The vein

TABLE 5.—Metal production† of the First Chance (Garnet) mining district.

Year	Gold (oz.)	Silver (oz.)	Copper (lb.)	Lead (lb.)	Zinc (lb.)	Value
1867-1916	60,000	50,000	50,000	—	—	$1,500,000
1917	1,700*	1,700*	8,500*	—	—	40,000
1918	1,014	1,870	19,056	—	—	27,549
1919	1,810	3,961	7,732	—	—	43,286
1920	1,059	1,518	4,923	—	—	24,458
1921	1,899	2,403	—	1,031	—	41,714
1922	1,324	1,434	468	—	—	28,871
1923	390	319	—	169	—	8,345
1924	695	801	599	—	—	14,982
1925	533	590	162	—	—	11,451
1926	162	124	—	—	—	3,434
1927	233	226	—	—	—	4,946
1928	62	67	—	—	—	1,336
1929-1930	—	—	—	—	—	—
1931	64	443	818	—	—	3,425
1932	312	188	1,000	—	—	6,578
1933	799	948	2,984	54	—	17,053
1934	3,468	4,302	9,550	108	—	124,750
1935	3,579	6,016	904	700	—	129,696
1936	3,738	4,718	424	1,870	—	134,609
1937	3,804	4,750	4,000	—	—	137,298
1938	2,875	3,216	6,735	218	—	103,374
1939	3,578	2,958	1,827	489	—	127,451
1940	8,675	3,735	1,717	400	—	306,495
1941	7,524	2,607	2,000	—	—	265,430
1942	2,928	571	—	—	—	102,886
1943	41	—	500	—	—	1,500
1944	69	1,388	12,800	—	—	350,371
1945	26	180	—	—	—	1,938
1946	82	42	—	—	—	2,904
1947	66	21	—	—	600	2,402
1948	80	32	—	—	—	2,829
1949	95	32	—	—	—	3,354
1950	105	74	2,000	—	—	4,158
1951	108	590	28,000	—	—	11,090
1952	—	138	—	2,403	1,144	702
1953-1954	—	—	—	—	—	—
1955	242	—	—	—	—	8,470
1956-1960	—	—	—	—	—	—
Total	113,139	101,962	166,699	7,442	1,744	$3,599,135

† Production figures exclude placer production.
* Quantity estimated from known value.

was exposed in a stope in the old workings, however, but samples at this point indicated a submarginal grade of ore.

Looking to the future, it would seem that most of the First Chance district's production is behind it. Quartz-pyrite-gold veins such as are found there do not ordinarily extend to great depth, and an undetermined but undoubtedly large portion of these has been eroded to form the extensive placers of Bear Creek. The mines had been developed to depths of 300 feet or more below the surface at the time of Pardee's visit in 1916, and it can be assumed that the more productive properties had gone to 500 or 600 feet before they finally closed. Remaining ore, if any, is likely to be low grade, and is certainly discouragingly inaccessible. It will require a series of most fortuitous and unlikely circumstances to encourage re-entry to these mines.

Top o' Deep District.—A group of small mines, located just below the divide at the head of Deep Creek, compose the Top o' Deep mining district.

Most of the production seems to have been from placer mining, including the washing of dumps and loose overburden at the lode mines themselves. Most, if not all, of this production has been credited to the Bear Creek placer district, leaving very little production of record to the Top o' Deep.

Pardee, in 1918, estimated the total production of the district prior to 1916 at $50,000. Since that time, minor shipments are recorded in 1918, 1921 through 1926, 1931, and 1953. Although specific data on these ore shipments are lacking, it seems unlikely that they have increased district production by more than an additional $5,000. The principal value of the Top o' Deep veins has been their gold content, although minor bodies of copper ore have been mined from contact deposits located southeast of the central part of the district.

Only one mine, the Gold Leaf, was accessible at the time of the writer's visit. The workings include an adit 484 feet long with one small stope-raise to surface, and a short winze extending 40 feet on dip below the sill. There was one abandoned shaft and several caved adits on the same property. A 3-foot channel sample, including 6 inches of vein, cut at the bottom of the winze assayed 0.44 ounce gold and 0.15 ounce silver. The same vein at the end of the adit was nearly barren.

Future prospects of the district include the probability that considerable placer gold remains, plus possibly some small-scale lode mining. The available evidence suggests that past placer operations were lacking in efficiency. Most work was by hand methods, which frequently leave considerable low-grade gravel unwashed, and there was a deficiency of water, which forced the miners to "boom" their sluices, or make sporadic use of water, collected in small dams for the purpose. Exploitation of veins has been very shallow to date. Although the veins are narrow, they contain shoots of fairly rich ore, and careful mining should allow profitable operation on a small scale. At present, most of the mining property in the district is controlled by the Valley Mining Co.

NONMETALLIC RESOURCES

LIMESTONE

Limestone occurs throughout much of the Garnet-Bearmouth area. Chemical analyses are lacking for some of these limestones, making it difficult to predict their possible value as sources for metallurgical flux or lime.

Several analyses of limestone and dolomite have been made by the Montana Bureau of Mines in the Philipsburg-Garnet Range area (table 6). These carbonates have been classified according to the nomenclature of Pettijohn (1957). The mottled limestone of the Silver Hill Fomation was analyzed by segregating the gray portions from the tan portions and analyzing each separately. The average of five analyses of the Hasmark Formation from Princeton, Montana, was taken from Hanson (1952), disregarding two analyses showing widely divergent percentages of insolubles. Those two samples were probably taken from the top sandy portion of the formation (McGill, 1958, p. 158).

In 1939, a quarry was opened 4 miles west of Drummond, 1 mile east of Rattler Gulch, and 1 mile north of the Clark Fork. Rock from vertical beds in the upper part of the Madison Limestone is quarried, crushed, hauled about 2 miles to the railroad, and shipped to various plants in western Montana, Idaho, and Washington. The limestone is reported to average 98 percent calcium carbonate (Perry, 1949, p. 36).

Travertine is quarried elsewhere* in Montana for interior decorative building stone. A deposit of very vuggy travertine and calcareous tufa at Nimrod along the Bearmouth thrust fault is probably of negligible commercial value because of its small extent and vuggy character.

* Gardiner, Montana

TABLE 6.—Analyses of samples* of limestone and dolomite from Philipsburg and Garnet-Bearmouth areas.

FORMATION	LOCALITY		CaO	MgO	Insol.	CLASSIFICATION**	REMARKS
Silver Hill	Garnet Range	(H)	52.7	1.2	1.6	Magnesian ls	Gray segregate
Silver Hill	Garnet Range	(H)	41.4	7.5	3.5	Dolomitic ls	Tan segregate
Silver Hill	Silver Hill	(H)	29.5	0.9	30.4	——	Metamorphosed
Hasmark	Princeton	(H)	31.0	20.9	1.7	Dolomite	Ave. of 5 spls.
Red Lion	Princeton	(H)	38.8	3.5	20.4	Dolomite ls	Ave. of 7 spls.
Maywood	Princeton	(H)	21.7	10.1	28.0	——	Siliceous rock
Jefferson	Princeton	(H)	37.3	13.3	6.4	Calcitic dolo.	——
Jefferson	Gird Creek	(M)	36.5	15.0	1.7	Calcitic dolo.	Ave. lower 200 ft.
Madison	Maxville	(M)	51.6	0.7	5.2	High-calcium ls	Ave. suite of unit

* Samples marked (H) are from Hanson, 1952
Samples marked (M) are from McGill, 1958
** Classification terminology after Pettijohn, 1957

A gastropod limestone in the Kootenai Formation has been quarried at Drummond (Perry, 1949, p. 36). This limestone is also present in the Garnet-Bearmouth area.

PHOSPHATE ROCK

The Phosphoria Formation of Permian age has produced large quantities of phosphate minerals at many places in southwestern Montana and Idaho. No commercial phosphate deposits are found within the Garnet-Bearmouth area. The Phosphoria Formation is observed to thin markedly from southeast to northwest. Its presence in much of the Garnet-Bearmouth area is indicated by calcareous, phosphatic, and cherty siltstone and sandstone overlying the Quadrant Quartzite and underlying the calcareous shale and siltstone of the Ellis Group. The phosphate occurs as minute black specks disseminated throughout the clastics.

GRAVEL

Deposits of Pleistocene and Pliocene(?) gravel are numerous along the Clark Fork and on the spurs adjacent to the river. Some of this gravel has been used for road metal, although it is poorly sorted and hence of poor quality.

APPENDIX

Section No. 1. Cretaceous formations.

Location: sec. 16, 17, T. 11 N., R. 13 W.

Colorado Group: Blackleaf Formation:

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	THICKNESS (ft.) CUMULATIVE
	Colorado Group: Blackleaf Formation: Black shale unit (Lower Cretaceous)		
87.	Shale, black, highly sheared; contains a few fine-grained sandstone layers 4 to 6 inches thick	150	150
	"Transition beds" Blackleaf Formation		
86.	Siltstone, shaly, buff to green, iron-stained concretions to 3 inches in diameter	10	10
85.	Limestone, resistant, buff to gray, dense, fine to medium crystalline; weathers to rusty surface with rust-stained joints	3	13
84.	Shale, brown, silty	2	15
83.	Shale, gray, silty	1	16
82.	Limestone, resistant, buff to gray, dense, finely crystalline; joints coated with rust, which in turn is covered with calcite	4	20
81.	Shale and limestone; brown silty shale interbedded with dense, finely crystalline limestone	5	25
80.	Shale, dark gray to black, fissile	1	26
79.	Shale and limestone; brown silty shale interbedded with dense, finely crystalline limestone	3	29
78.	Shale, gray to black, fissile	1	30
77.	Shale and limestone; silty shale and dense limestone	3	33
76.	Shale, gray to black, fissile	1	34
75.	Siltstone, olive drab with smears of purple staining, shaly; cleavage well developed	3	37
74.	Shale and limestone; buff shale beds 2 to 3 inches thick interbedded with beds of dense finely crystalline limestone 3 to 12 inches thick	10	47
73.	Shale, purple, fissile	2	49
72.	Shale, olive drab, fissile	1	50
71.	Shale, purple, fissile	2	52
70.	Shale and limestone; buff shale beds 2 to 3 inches thick interbedded with beds of dense finely crystalline limestone 3 to 12 inches thick; some bedding-plane slickensides	30	82
69.	Siltstone and sandstone; very resistant medium-buff to gray siltstone; sandy layers contain abundant carbonaceous fragments on bedding surfaces; unit forms a prominent resistant hogback across the exposure; bottom contact wavy; lensing of unit results; may be disconformity	5	87
68.	Shale, greenish gray to brown, silty and fissile, a few 2- to 3-inch calcareous siltstone beds and one 3-inch maroon fissile shale bed near the bottom	10	97
67.	Shale and limestone; buff silty shale layers 2 to 3 inches thick interbedded with beds of dense buff to gray finely crystalline limestone 6 to 18 inches thick	6	103
66.	Shale, olive drab to gray, silty	8	111
65.	Like unit 67	3	114
64.	Shale, maroon and olive drab, fissile; a few calcareous concretions to 1½ inches across	5	119
63.	Limestone, buff to green, fine grained, silty	1	120
62.	Shale and limestone; purple, green, and buff fissile shale, some 3-inch limestone beds, and some limy concretions, especially in purple shale near base of unit	30	150
61.	Limestone, buff to gray, finely crystalline, massive and blocky; some impressions of fossils near top; some cross faulting with displacements of a few inches	5	155
60.	Shale, buff and purple, olive drab and gray, silty and fissile	10	165
59.	Like unit 67	21	186
58.	Shale, purple, fissile	2	188

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMULATIVE
57.	Shale and limestone; buff, silty shale layers 2 to 3 inches thick interbedded with gray finely crystalline limestone layers 6 to 18 inches thick; several beds of gray silty and fissile shale and some calcareous concretions	44	232
			(End cumulative total)
	Kootenai Formation — Upper calcareous member (Lower Cretaceous)		
56.	"Gastropod limestone"; dark-brown to dark-gray, coarsely crystalline limestone containing many gastropod shells partly or completely replaced by crystalline calcite; an apparent break in deposition or hiatus appears in middle of unit, shaly or limy and shaly crumbly material appearing in interval which ranges from zero thickness near top of exposure to 6 inches near bottom; unit is very resistant and forms prominent hogback ridges across top of exposure; bottom of unit is very irregular surface	13	13
55.	Siltstone, shaly, fissile, calcareous; iron-stained limy concretions ½ to 2 inches in diameter	5	18
54.	Limestone, dense finely crystalline, light gray, much calcite veining; one calcareous shale layer 2 inches thick	7	25
53.	Limestone, siltstone, shale, and claystone; calcareous shale interbedded with 6- to 24-inch light-gray finely crystalline limestone and fine-grained sandstone with calcareous matrix; sandstone contains some black chert grains, some clay matrix (equals subgraywacke); a few maroon shaly units and rust-stained units within this sequence	92	117
52.	Shale and limestone; pink to red, calcareous shale and limestone	9	126
51.	Sandstone, quartzite, and limestone; stained maroon on weathered and joint surfaces, light to dark green and gray green on fresh surface; fine to medium grained, "salt and pepper" appearance due to white quartz and black chert grains; two ½- to 3-inch shaly siltstone beds included, as well as a few calcareous layers and dense finely crystalline limestone beds; entire unit stained red to maroon	48	174
50.	Like unit 51 but much less red stain	29	203
49.	Limestone, shale, siltstone, and claystone; light-gray finely crystalline limestone, calcareous shale, and siltstone	5	208
48.	Limestone and shale; dense finely crystalline limestone, fairly resistant, interbedded with calcareous shale	12	220
47.	Limestone, shale, and siltstone; interbedded light-gray to buff-weathering, calcareous, fissile shale, siltstone, and finely crystalline to dense limestone	52	272
	Kootenai Formation—Upper clastic member		
46.	Shale and siltstone; slightly calcareous, red to purple	36	308
45.	Sandstone and siltstone; fine grained greenish gray on fresh surface, weathers to green and red appearance	36	344
44.	Limestone; gray to red, fine, dense	10	354
43.	Quartzite; greenish gray, fine grained, salt and pepper, slightly calcareous	10	364
42.	Sandstone, subgraywacke; green, medium to fine grained, calcareous	30	394
41.	Shale; maroon on weathered surface, gray to maroon on fresh surface, calcareous; includes a few thin fine-grained limestone layers	18	412
40.	Sandstone; shaly, fine grained, light green (subgraywacke); approximately 5% yellowish-brown mica (muscovite?)	30	442
39.	Limestone conglomerate; limestone pebbles ¼ to 1 inch in diameter, in calcareous, sandy matrix, salt and pepper appearance	1	443
38.	Limestone and shale; maroon, calcareous shale, fissile, interbedded with fine-grained limestone	26	469
37.	Sandstone; medium grained, calcareous, salt and pepper appearance	2	471
36.	Siltstone; gray to maroon, calcareous in much of unit	18	489
35.	Quartzite; dense, green, noncalcareous; silt size predominates	4	493
34.	Limestone; light gray, fine grained, platy	4	497
33.	Siltstone and claystone; green, weathers red to green, slightly calcareous	12	509
32.	Quartzite; fine grained, light gray, salt and pepper appearance due to white quartz and black chert grains	9	518
31.	Siltstone; light green, slightly to very calcareous	24	542
30.	Shale and siltstone; green to olive; a few thin platy salt-and-pepper sands as much as 1 foot thick	42	584
29.	Siltstone; green, noncalcareous to slightly calcareous	48	632
28.	Shale, red to maroon, fissile	4	636
27.	Siltstone; green, noncalcareous	12	648
26.	Shale; red to gray, fissile	10	658
25.	Siltstone and shale; green, slightly calcareous, slightly shaly	52	710
	Kootenai Formation — Lower calcareous member		
24.	Limestone; very fine grained, dark gray to black on fresh surface, weathers to creamy white, powdery surface (fresh-water origin?)	20	730
23.	Siltstone and sandstone; maroon and green, shaly	6	736
22.	Like unit 24	6	742
21.	Shale; green, silty	2	744
20.	Like unit 24	22	766
19.	Shale; green, silty	3	769

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMU-LATIVE
18.	Like unit 24	2	771
17.	Shale; green, silty, weathered surfaces rusty to maroon	6	777
16.	Like unit 24	2	779
15.	Siltstone, shale, and claystone; green, purple; some white to gray calcareous concretions	12	791
14.	Limestone similar to unit 24 with green and maroon silty shale squeezed around boudins of limestone	3	794
13.	Shale and claystone; maroon and green, silty	8	802
12.	Limestone; like unit 24	1	803
11.	Shale; green; cobble-size white to gray calcareous concretions	6	809
10.	Shale and claystone; purple, silty	2	811
9.	Limestone; like unit 24	30	841
8.	Limestone and shale; gray shaly or slaty limestone and shale containing white to gray calcareous concretions	6	847
7.	Shale; purple, silty shale, containing white to gray calcareous concretions to boulder size	6	853
6.	Limestone; like unit 24	18	871
5.	Shale; purple, silty shale, containing white cobble-size calcareous concretions	6	877

Kootenai Formation—Lower clastic member

UNIT	DESCRIPTION	UNIT	CUMU-LATIVE
4.	Shale, siltstone, and claystone; maroon silty shale and well-cemented siltstone	18	895
3.	Sandstone; light gray, salt and pepper in calcareous matrix	7	902
2.	Shale; maroon, silty	3	905
	Fault zone with change in attitude of rocks.		
1.	Sandstone and quartzite; very resistant ridge of dense red-stained, greenish-gray sandstone and quartzite, some pockets of red jasper(?); at other places in the area there occurs below this zone a very coarse conglomerate of black chert and white quartz and quartzite pebbles, this conglomeratic zone is very lenticular and contains fragments and components to 18 inches in length; the conglomerate has been observed to range to 50 feet in thickness	24	929

Total Kootenai Formation 929 feet

Morrison(?) Formation: Claystone, siltstone, sandstone; green to greenish gray and olive, some yellowish green, a few salt-and-pepper sandstones.

Section No. 2. Jurassic formations.

Location: Railroad cut south of Rattler Gulch, along north side of Clark Fork; S½ NE¼ sec. 21, T. 11 N., R. 13 W.

Kootenai Formation (Lower Cretaceous) Sandstone and quartzite; thick massive purplish (salt and pepper sandstone) with red jasper(?) grains; overlain by red to maroon shale and calcareous concretions

Morrison Formation (restricted) (Upper Jurassic)

UNIT	DESCRIPTION	UNIT	CUMU-LATIVE
18.	Covered interval; some purple silty shale float	40	40
17.	Covered interval, some olive drab siltstone and claystone float	60	100
16.	Sandstone; very dense black and white to olive drab; noncalcareous; knobby appearance on weathered surfaces; some purple staining; medium grained, fairly well sorted; "salt and pepper" appearance caused by black chert and white quartz grains	62	162
15.	Sandstone and shale; greenish-gray chunky shale, slightly silty, with 2- to 4-inch sandstone beds, "salt and pepper" appearance, weathers to greenish-gray surface; slightly calcareous; some shale almost black; 18-inch sandstone bed at top	19	181

Total Morrison Formation (restricted) 181 feet.

Ellis Group — Swift Formation (Upper Jurassic)

UNIT	DESCRIPTION	UNIT	CUMU-LATIVE
14.	Sandstone; massive, thick bedded, coarse grained, with a few shale interbeds; ripple-marked, undulating bedding surfaces; some faulting; slickensides parallel bedding; color near top is yellowish-green	39	39
13.	Sandstone; crumbly, gray, weathers yellow gray, contains scattered black shell fragments; rusty staining along joints	7	46
12.	Shale; black, bluish black, greenish black, silty, carbonaceous, platy	6	52
11.	Sandstone and limestone; coarsely crystalline limestone, black, weathers to brown surface, interbedded with sandstone and silty or shaly beds; black chert grains, green glauconite(?) grains, red hematite(?) grains	10	62
10.	Siltstone and sandstone; blue-black to greenish-black, dirty, carbonaceous, platy siltstone and fine-grained sandstone; platy, contains black chert pebbles and black shell fragments scattered through unit; breaks with fine platy to shaly fracture; crumbly	10	72
9.	Sandstone and conglomerate; basal 1-foot conglomerate bed with matrix of calcareous gray-brown sandstone, black chert pebbles, water-worn belemnites to 4 inches in length (German: "belemnite battlefield"); many black shell fragments, some a few inches in length; many rusty-colored wood fragments, some 18 inches long and 4 inches across; 1-foot shale, siltstone, and claystone layer 4 feet from base, dark bluish gray to black, chunky, with balls of coarsely crystalline limestone, many black chert pebbles to 1 inch in length, many black fossil shell fragments; overlain by 2 feet more		

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMULATIVE
	of sandstone, light gray coarse grained, weathers to yellow-brown surface; contains many pelecypod fragments and ripple-marked surfaces; ripples have amplitudes of 1 inch and wavelengths of 3 to 5 inches; contains clay pellets and fragments averaging ¾ inch in diameter, maximum length noted was 9 inches	6	78
	Total Swift Formation 78 feet.		
	Ellis Group—Rierdon Formation (Upper Jurassic)		
8.	Limestone; light to medium gray, shaly, two 4-inch beds and one 16-inch bed; conchoidal fracturing, irregular surface contact, overlying sandstone filling irregularities	2	2
7.	Shale and limestone; black to brown, fissile shale, some bluish black, much darker than unit 6; a few 3-inch limestone beds in middle; upper 3 feet stained to rusty color; very irregular upper surface; crumbling of upper 3 feet perhaps by thrusting; upper 5 inches bright yellow clay with yellow-stained joint surfaces cutting down approximately 4 feet into unit	15	17
6.	Shale; limy, hackly, dark brownish gray on fresh surface, weathers to yellow gray or whitish gray; several ammonites and fragments found in unit similar to *Kepplerites* with forked ribs found 6 feet above base; several specimens of *Cadoceras* sp. found 9 feet above base; several resistant shaly limestone beds through entire unit	43	60
	Total Rierdon Formation 60 feet.		
	Ellis Group—Sawtooth Formation (Middle Jurassic)		
5.	Limestone; silty, 3-foot massive bed, gray brown, weathers yellowish brown, sandy, slightly oolitic?; overlain by limestone, silty to sandy, with ripple marks, mud cracks, strongly undulating surface; overlain by limestone, sandy, platy, with interbedded covered intervals, top very undulating, rusty stained, upper 1 to 2 inches virtual "hash" of fossil debris	55	55
4.	Shale and limestone; silty, platy bedding, yellowish brown; many fossil fragments on bedding surfaces; dense limestone in upper third; surface irregularly marked by impressions (raindrops?), worm borings, fucoids, fossil fragments	46	101
3.	Shale and limestone; silty limestone, black or brown shale, knobby, nodular limestone with irregular surface; 1-foot layer of steel-blue shaly limestone topped by silty limestone 12 feet above base; 6-inch gray-brown dense limestone at base; nodular limestone beds 6 to 12 inches thick containing *Gryphaea* cf. *impressimarginata,* interbedded with brownish-black shale layers 6 to 18 inches thick; limestone beds become thicker toward top at expense of shales, although some beds of nodular limestone actually pinch out along strike; limestone surfaces near top contain many shell fragments including *Trigonia, Camptonectes?,* crinoid spines, small gastropod shells	58	159
2.	Shale and limestone; light gray, weathers to whitish-gray surface; several ribs of limestone with shaly fracture interspersed through less resistant limy shale; some fragments of *Pleuromya subcompressa* on float at surface; three 1-foot shaly limestone beds separated by 1-foot limy shale beds 50 feet above bottom of exposure; dense rib of limestone with splintery, hackly fracture and pencil shale 87 feet above base	111	270
1.	Covered interval; coarse gravel and boulders capping hillside for several tens of feet.		
	Total Sawtooth Formation 270+ feet.		
	TOTAL ELLIS GROUP 408+ feet.		

Section No. 3. Upper Paleozoic formations

Location: Rattler Gulch

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMULATIVE
	Ellis Group (Sawtooth Formation—Middle Jurassic)		
	Covered interval; float dominantly tan quartzite from Phosphoria Formation; some fragments of calcareous shale and siltstone, some shaly limestone		
	Phosphoria Formation (Permian)		
	Quartzite; tan, fine grained, very well sorted, quartzose, subangular; probably Shedhorn member, approximately 30 to 50 feet thick		
	Quartzite, limestone, chert; pink, calcareous quartzite, sandy limestone, and some dark-gray to black chert fragments; black phosphate(?) grains ½ inch in diameter; most of interval is covered; float ranges from fractions of inch to boulders 5 feet in diameter; (total Phosphoria approximately)	290	290
	Quadrant Formation (Pennsylvanian)		
	Quartzite; white to tan, medium to coarsely crystalline, massive quartzite; weathers to rough angular surfaces, generally forming distinct hogback ridges; usually weathers to greenish-tan surface, greatly exaggerated by greenish-gray to black lichen, which commonly grow on the surfaces (total Quadrant Formation approximately)	140	140
	Amsden Formation (Late Mississippian and Early Pennsylvanian)		
	Siltstone; brick-red, calcareous siltstone, shale, and silty shale; much of interval is covered; includes red siltstone and gray limestone float		

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMULATIVE
	in lower 130 feet (total Amsden Formation approximately)	310	310
	Madison Group—Mission Canyon Formation (Mississippian)		
33.	Collapse breccia; resistant ridge of tightly cemented breccia (collapsed sinkhole ?), red to buff calcareous silt matrix and angular light- and dark-gray finely crystalline limestone fragments ⅛ inch to 12 inches across, averaging 2 inches; several 1-inch black chert fragments; cobble-size fragments tend to have rounded edges; grades down into massive light-gray, medium-crystalline limestone, nonbrecciated, weathers to pitted, rough surface	23	23
32.	Covered interval; abundant float, averaging 7 inches, of dark-gray medium-crystalline limestone, weathering to rough surface; also dark-gray to black finely crystalline limestone with much red-stained calcite veining	197	220
31.	Limestone; ridge of extremely fine grained, tan to light-gray limestone with much calcite veining and some red staining	20	240
30.	Breccia; matrix similar to limestone above, but contains black chert fragments and nodules; fragments ⅛ to 2 inches and angular; nodules 4 to 8 inches and rounded	18	258
29.	Covered interval; float from both adjacent vertical ridge formers	17	275
28.	Breccia; similar to unit 30, but showing greater amounts of black to tan limestone fragments as well as chert; includes open fault(?) or joint along which some movement may have occurred	90	365
27.	Covered interval; float from adjacent units	15	380
	Note: Units 27 through 33 were measured along west side of Rattler Gulch, others along east side.		
26.	Limestone; dark gray to black, coarsely crystalline, forms ridge, weathers to nodular and pitted brownish-gray surface	18	398
25.	Limestone; quarried; dark gray to black coarsely crystalline, similar to unit 26	37	435
24.	Limestone; dark gray coarsely crystalline; weathers to white and reddish-white surface	5	440
23.	Limestone; fractured, light tan to light gray; fractures and joints filled with calcite	15	455
22.	Covered interval	15	470
21.	Limestone; light gray medium crystalline; gray to black chert nodules; weathers to brownish-gray surface; fossil hash of cup corals, brachiopods, and crinoid stems; slight petroliferous odor	34	504
20.	Covered interval	15	519
19.	Limestone; similar to unit 21	5	524
18.	Covered interval	45	569
17.	Limestone; dark gray to black, finely crystalline, weathers to light-gray surface; much calcite cement; thick bedded, (5 to 10 feet); this unit has been quarried	45	614
16.	Limestone; dark gray to black, finely crystalline, much recrystallized fossil hash; forms ridge	10	624
15.	Covered interval	10	634
14.	Breccia; light-tan to light-gray brecciated limestone fragments in limestone matrix	6	640
13.	Covered interval	45	685
12.	Limestone; light pinkish white, fractured, weathers to gray surface; contains much calcite, including fragments of pure-white calcite in limestone matrix	27	712
11.	Limestone; dark gray, crystalline, weathers to light-gray pitted surface; forms ridge	40	752
10.	Limestone; dark tan to gray, finely crystalline; weathers to rough light-gray surface; contains a few lenses of cherty limestone	43	795
9.	Limestone; light gray, very coarsely crystalline, weathers to rough sandy surface, contains some thin banded black chert lenses	15	810
8.	Limestone; light gray to tan, finely crystalline, fractured, weathers to red-stained pitted surface; slight petroliferous odor on fresh surface; (side valley to Sheep Gulch on west side of Rattler Gulch)	60	870
7.	Covered interval	90	960
6.	Limestone; light gray, finely crystalline, with fossil hash of crinoid stems and a few brachiopod shells	25	985
5.	Limestone; siliceous, pinkish gray, medium grained, sandy; quartz approximately 25 percent; contains a few white to light-gray chert lenses in lower 10 feet; weathers to thin beds	35	1020
4.	Covered interval; float from adjacent units	110	1130
	Madison Group—Lodgepole Formation		
3.	Limestone; dark gray to black, fine to very coarsely crystalline; large crinoid stems form bulk of the rock; stems range from 1/16 to ¾ inch in diameter, averaging ⅛ inch; 2-inch black chert layers filled with small calcite veinlets along joints; black cherty limestone nodules and lenses common; black cherty limestone and dark-gray limestone weather to brownish-gray surface; bedding 2 to 6 inches, averaging 3 inches; very well bedded	340	1470
2.	Covered interval	60	1530
1.	Limestone; dark gray, finely crystalline; petroliferous odor; beds 6 to 18 inches thick; weathers to light-gray mottled surface	105	1635
	Total Madison Group		1635
	Total Mission Canyon Formation		1130
	Total Lodgepole Formation		505

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	THICKNESS (ft.) CUMULATIVE
	Three Forks Formation(?) (Devonian)		
	Siltstone; red to yellow and buff dolomitic and calcareous silty shale, siltstone, and silty dolomite; resembles Maywood Formation lithologies; may represent Three Forks Formation; entire unit covered except for a few scattered outcrops (approximate thickness)	150	150
	Jefferson Formation (Devonian) — generalized subdivisions		
3.	Limestone; upper member; light to dark gray and gray brown, brecciated to sheared, thick bedded to massive, weathers to towers and spires; some poorly preserved fossils; approximate thickness	800	800
2.	Dolomite; middle member; dark gray, gray brown, to black, saccharoidal, fetid, strong petroliferous odor due to intergranular hydrocarbons(?); approximately thickness	300	1100
1.	Limestone; lower member; dark gray, fetid, fairly strong petroliferous odor, finely crystalline, stromatoporoidal structures fairly common; abundant tan-buff or orange-yellow stringers and lacework; approximate thickness	600	1700
	Total Jefferson Formation approximately		1700
	Maywood Formation (Devonian)		
	Siltstone, dolomite, sandstone; yellow to brown and buff, calcareous to dolomitic		

Section No. 4. Lower Paleozoic units.
Location: Ridge east of Dry Gulch.

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	THICKNESS (ft.) CUMULATIVE
	Jefferson Formation (Devonian)		
36.	Limestone and dolomite; dark gray to black, finely crystalline, slightly sugary, "fetid"; forms resistant ledges interbedded with less resistant units forming float-covered saddles		
35.	Covered interval; float from Jefferson ledge covers slope; probably also Jefferson Formation	20	20
	Maywood Formation (Devonian) (Transition zone)		
34.	Covered interval; float of yellow-brown (buff), slightly calcareous siltstone	14	14
33.	Siltstone and dolomite; outcrop of platy slightly calcareous yellow and red siltstone and very dense light-gray, extremely finely crystalline dolomite; weathers yellow	31	45
32.	Dolomite and limestone; dark gray, finely crystalline, yellow stained blotches; weathers to brownish-gray pitted surface; very resistant ledge former	14	59
31.	Covered interval; float dominated by limestone and dolomite blocks from above unit	9	68
30.	Covered interval; float of unit 32 as well as flakes and plates of yellow calcareous siltstone	34	102
	(End Transition zone)		
29.	Siltstone; very calcareous, light gray; weathers yellow brown or buff, platy; a few thin light-gray limestone beds as much as 6 inches thick, very finely crystalline, weathers to pale-gray fairly smooth surface	34	136
28.	Limestone; very finely crystalline, dark gray, weathers to pale-gray fairly smooth surface showing fine laminae parallel to bedding	4	140
27.	Limestone; silty, gray, weathers to yellow surface, platy	10	150
26.	Limestone; dark gray, medium crystalline, weathers to medium-gray surface; bedding 1 to 4 inches, averaging 2 inches	4	154
25.	Covered interval; a few outcrops of dolomite and siltstone; dolomite medium crystalline light gray, weathers to yellow-brown (buff) surface; siltstone very calcareous, brown to yellow on fresh surface, weathers to red and yellow, laminated surface; some float of dark-gray dolomite from unit 26	20	174
24.	Limestone; prominent ledge; dark gray medium crystalline, weathers to thin-bedded dark-gray surface with small weathered pits	10	184
23.	Covered interval; much float of red and yellow calcareous siltstone; thin bedded to platy	21	205
22.	Limestone; very finely crystalline, black with yellow stained blotches; weathers to fairly prominent ledge, thin bedded to thick bedded (2 to 8 inches), medium-gray, finely pitted weathered surface; some layers seem to be strongly brecciated	11	216
21.	Covered interval; much float of dark-gray very finely crystalline limestone weathering to yellow surface; platy, some red and yellow calcareous siltstone float	85	301
20.	Dolomite, siltstone, and sandstone; prominent outcrop of fine crystalline light-gray to gray-yellow dolomite, siltstone, sandstone, and silty dolomite; weathers to laminated and cross-bedded yellow-gray grainy surface; includes covered interval of 22 feet near the center with a few outcrops and much float similar to above lithology	67	368
	Total Maywood Formation		368
	Red Lion Formation—Sage member (Upper Cambrian)		
19.	Limestone; light gray finely crystalline, fine yellow-red laminae of argillaceous (dolomitic ?) matter, approximately four laminae per inch; laminae do not follow bedding precisely but form an interweaving lacework causing lensing of the limestone	23	23
18.	Limestone; red, extremely finely crystalline, some yellow blotches and laminae; seems to be dominated by argillaceous material to such an extent that the limestone		

UNIT	DESCRIPTION	THICKNESS (ft.) UNIT	CUMULATIVE
	becomes subordinate to calcareous argillaceous material; unit seems to lense out along strike	2	25
17.	Limestone; similar to unit 19	84	109
16.	Covered interval; occasional outcrop and much float similar to unit 19	151	260
15.	Limestone; more outcrops and much float; lithology similar to unit 19, but greater dominance of red over yellow is noted	23	283
14.	Covered interval; much float similar to unit 15, dark-red argillaceous laminae predominating	40	323

Red Lion Formation — Dry Creek shale member

UNIT	DESCRIPTION	UNIT	CUMULATIVE
13.	Siltstone, shale, and dolomite; yellow-red, slightly calcareous siltstone and dolomite, some light-green shaly beds; siltstone weathers to yellow-brown and red laminated surface, very similar to above Maywood Formation; this unit includes light gray-yellow dolomite weathering to rough yellow-gray surface similar to Hasmark Formation	35	358
	Total Red Lion Formation		358

Hasmark Formation (Middle and Upper Cambrian)
(Only gross lithologies and approximate thicknesses are given; this section may have some duplication by faulting.)

UNIT	DESCRIPTION	UNIT	CUMULATIVE
12.	Dolomite; very dense finely crystalline, white to light gray on fresh surface, weathers to yellow-gray sandy surface	423	423
11.	Dolomite; slightly darker, slightly coarser grained	517	940
10.	Dolomite; cream-gray weathered surface	230	1170
9.	Dolomite; jagged lacework of chert(?)	35	1205
8.	Dolomite; dark gray finely crystalline; weathers to light-gray or creamy rough surface	113	1318
7.	Dolomite and chert; black	28	1346
6.	Dolomite; dark gray sugary, medium crystalline, weathers to brownish-gray surface, which is very rough	244	1590
5.	Covered interval; float from units above and below fall into this saddle	141	1731
4.	Dolomite; prominent outcrop; dark gray medium crystalline, weathers to dark-gray surface	94	1825
3.	Dolomite; white medium crystalline dolomite similar to unit 12	47	1872
2.	Covered interval; float from unit 3	94	1966
1.	Dolomite; light-gray, medium crystalline dolomite and dolomitic sandstone with raised laminae every inch or two, composed of siliceous dolomite(?); may be the western equivalent of the Silver Hill Formation	282	2248
	Total Hasmark Formation		2248

Belt series sediments; green and red quartzites, argillites(?), cross-bedded purple, white, and red, medium-grained quartzose quartzites

Section No. 5. Cambrian Silver Hill Formation.
Location: Upper Rattler Gulch near Boiler Gulch.
Hasmark Formation (Middle Cambrian)
12. Dolomite; white, medium crystalline

Silver Hill Formation (Middle Cambrian)

UNIT	DESCRIPTION	UNIT	CUMULATIVE
11.	Shale; light green, fissile to papery	10	10
10.	Covered interval; some float of green fissile shale 1 foot below surface; some minute brachiopods on bedding surfaces	40	50
9.	Limestone; mottled, red and yellow "balls" dotting the surface; dark-gray limestone, weathers to light-gray surface; mottled appearance due to lacework of gray limestone and tan to dark-gray or buff dolomitic limestone; some fine argillaceous material interspersed in the carbonate	120	170
8.	Dolomite and magnesium limestone; dark-gray to black, medium to coarsely crystalline dolomite with calcite(?) tubules dispersed in the dolomite	102	272
7.	Limestone; mottled, similar to unit 9, thickness of this unit is only approximate	275	547
6.	Covered interval; thick section near Boiler Gulch; much rubble of mottled limestone, no outcrops, apparently paralleling strike in much of this distance; actual stratigraphic thickness approximately	25	572
5.	Siltstone; calcareous, brown yellow with liesegang weathering bands of red	9	581
4.	Mottled limestone, similar to unit 9	9	590
3.	Shale; green, fissile to papery, grading upward into mottled limestone	15	605
2.	Limestone; mottled tan and gray, similar to unit 9	30	635
1.	Shale and hornfels; green fissile to papery shale with some dense gray to greenish-gray and black hornfels	36	671
	Total Silver Hill Formation		671

Flathead Formation (Middle Cambrian) with 50-foot transition zone.

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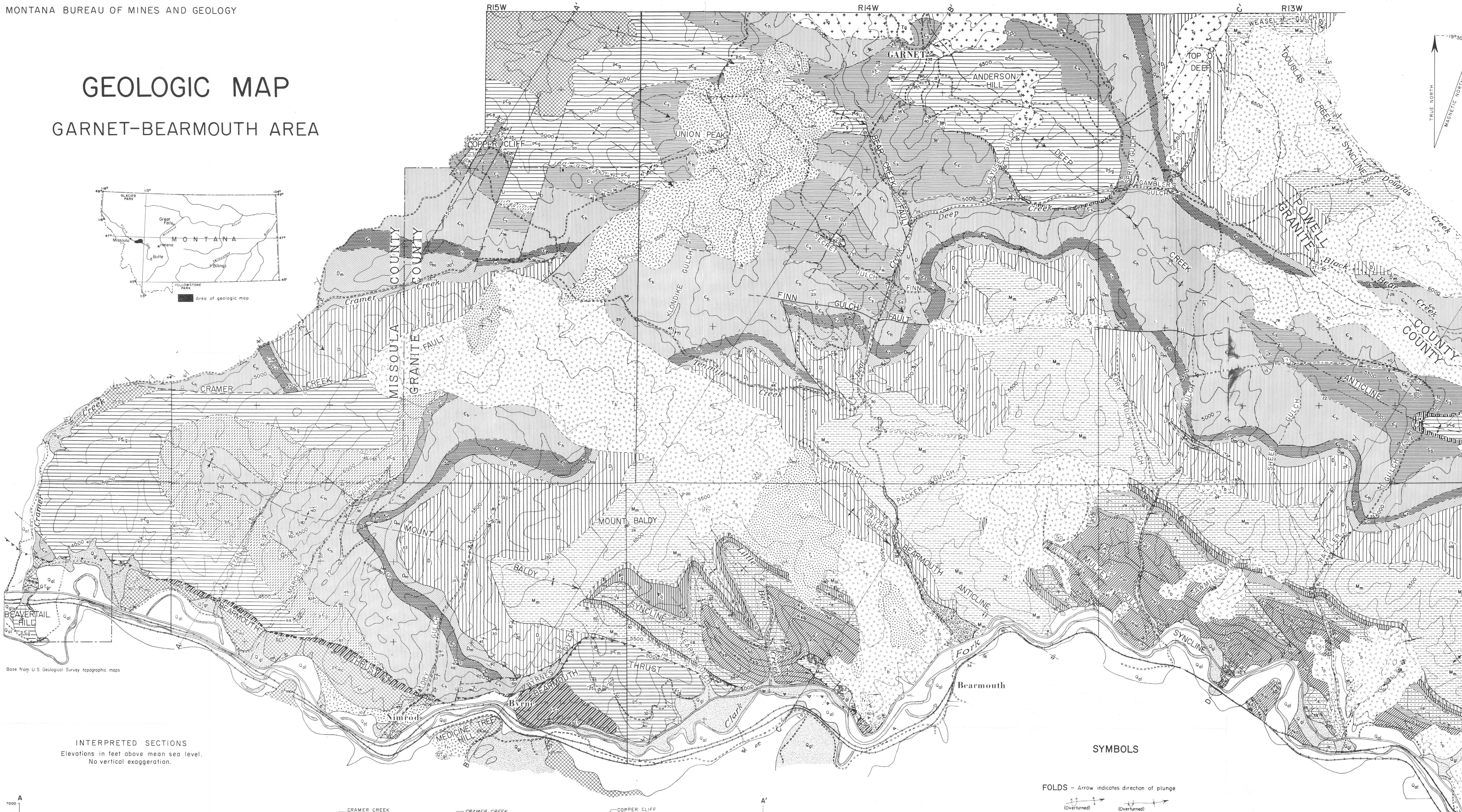
MONTANA BUREAU OF MINES AND GEOLOGY

GEOLOGIC MAP
GARNET-BEARMOUTH AREA



SEDIMENTARY ROCKS

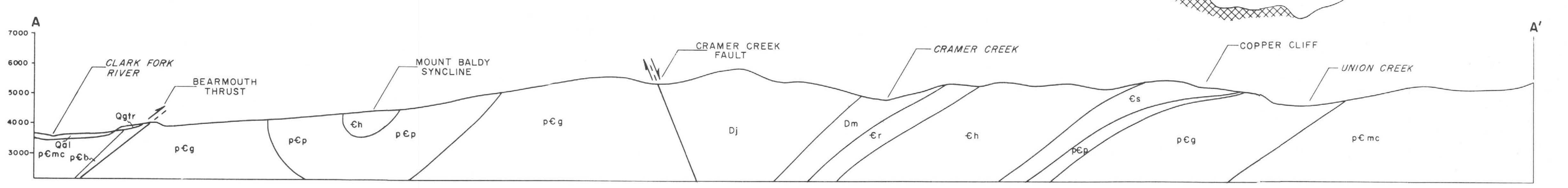
CENOZOIC	Quaternary	Qal	Alluvium, colluvium, floodplain deposits, etc.
		Qgl	Glaciofluvial gravel
	Tertiary	QTgr	Gravel capping erosion surfaces
		Ts	Volcanic-rich sediment
MESOZOIC	Cretaceous, Upper	Kc	Colorado Group
	Cretaceous, Lower		Kootenai Formation: Kkd, upper calcareous mbr.; Kkc, upper clastic mbr.; Kkb, lower calcareous mbr.; Kka, lower clastic mbr.
	Jurassic	Jm	Morrison Formation (restricted)
		Je	Ellis Group
PALEOZOIC	Permian	Pp	Phosphoria Formation
	Penn-sylvanian	Pq	Quadrant Formation
	Missis-sippian	Pa	Amsden Formation
		Mm	Madison Group
	Devonian	Dj	Jefferson Formation (Three Forks Formation? at top)
		Dm	Maywood Formation
	Cambrian	Єr	Red Lion Formation
		Єh	Hasmark Formation
		Єs	Silver Hill Formation
		Єf	Flathead Formation
PRECAMBRIAN		pЄp	Pilcher Formation
		pЄg	Garnet Range Formation
		pЄmc	McNamara Formation
		pЄb	Bonner Formation
		pЄm	Miller Peak Formation

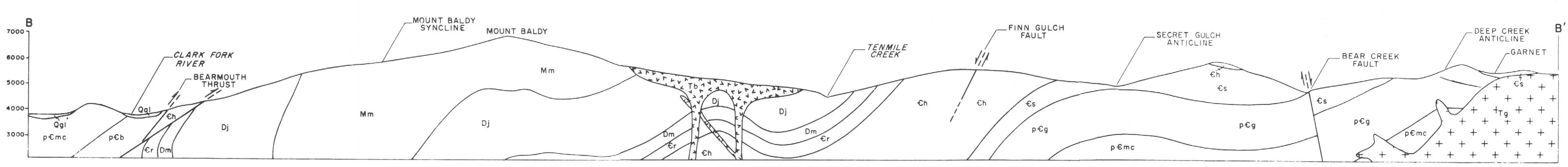
IGNEOUS ROCKS

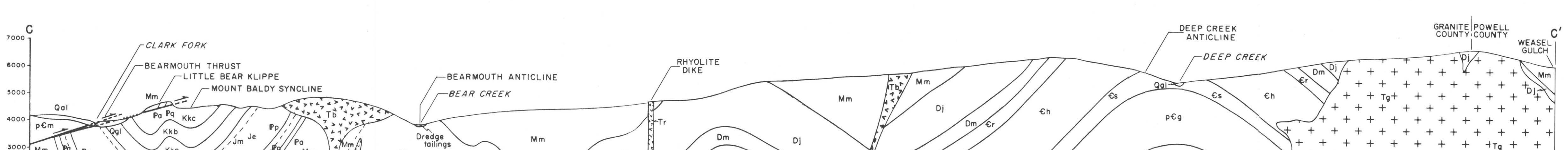
	Rhyolite
Tb	Basalt, andesite
Tt	Trachyte (?)
Tg	Granodiorite stocks, dikes, and sills

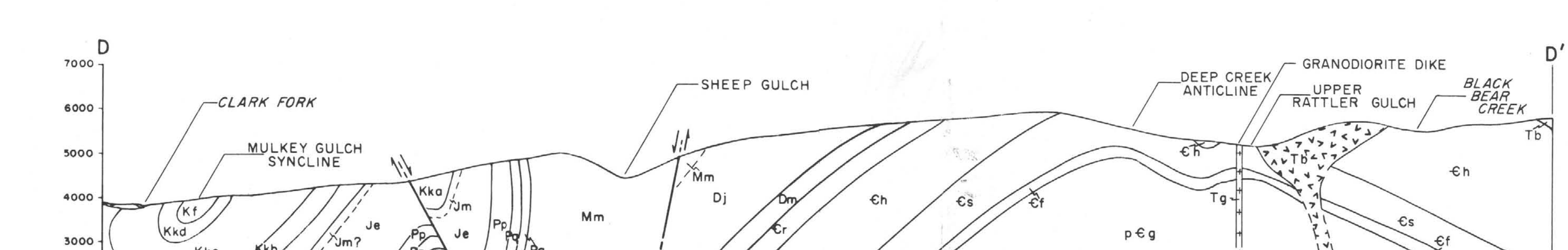
INTERPRETED SECTIONS

Elevations in feet above mean sea level.
No vertical exaggeration.









SYMBOLS

FOLDS - Arrow indicates direction of plunge
(Overturned) ANTICLINE (Overturned) SYNCLINE

FAULTS - Established - Inferred - Concealed
THRUST - Points on upthrown side
NORMAL
REVERSE - Hachures on upthrown side
STRIKE-SLIP

CONTACTS
Established Inferred Concealed

ATTITUDES
STRIKE AND DIP OF SEDIMENTS
VERTICAL
OVERTURNED
STRIKE AND DIP OF JOINTS
FOLIATION

TOPOGRAPHY
STREAMS Permanent Ephemeral
DREDGE TAILINGS

CULTURE
ROADS Surfaced Gravel Jeep trail
RAILROADS

SCALE
1 ½ 0 1 2 miles
Contour interval 500 feet

Geology by M. E. Kauffman
Assisted by W. S. Ford, 1957 and V. R. Broz, 1958