Geology of the Garns Mountain Quadrangle Bonneville, Madison, and Teton Counties, Idaho

GEOLOGICAL SURVEY BULLETIN 1205

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By MORTIMER H. STAATZ *and* HOWARD F. ALBEE

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Description of the stratigraphy, structure, and phosphate and coal deposits of a 215-square mile area at the north end of the Idaho-Wyoming thrust belt

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By MORTIMER H. STAATZ and HOWARD F. ALBEE

ABSTRACT

The Garns Mountain quadrangle except for its southwest corner is in the northwestern part of the Snake River Range, which in turn lies at the north end of the Idaho-Wyoming thrust belt. The southwest corner of the quadrangle lies in the Snake River Plain.

The rocks of the Garns Mountain quadrangle are divided into widespread Paleozoic and Mesozoic sedimentary rocks and local Cenozoic sedimentary and volcanic rocks. The sedimentary rocks of the Snake River Range, which have been repeated by numerous thrusts, were for the most part laid down along the edge of a large miogeosyncline. The Paleozoic and Mesozoic rocks have a total thickness of as much as 18,000 feet and have been divided into 23 formations ranging from Middle Cambrian to Late Cretaceous in age. The rocks of Paleozoic age make up as much as 6,000 feet of this thickness; they are divided into eight formations. The oldest is the Gros Ventre Formation, which consists of a sandy limestone unit overlain by a thin shale unit. The shale is conformably overlain by the Gallatin Limestone of Late Cambrian age. The Bighorn Dolomite of Late Ordovician age disconformably overlies the Gallatin and thins from 325 feet at the southeast corner of the quadrangle to 81 feet in the west-central part of the quadrangle. Above the Bighorn is the Darby Formation of Devonian age, which has a lower member of interbedded limestone and dolomite and an upper member of arenaceous limestone and calcareous siltstone and shale. Above the Darby are the Lodgepole Limestone and Mission Canyon Limestone of Mississippian age. The Mission Canyon is conformably overlain by the Wells Formation and associated rocks, a sequence which consists principally of quartzite with interbedded limestone and dolomite in the lower and upper parts. The youngest unit of Paleozoic age is the Phosphoria Formation of Permian age. It consists of shale, chert, limestone, dolomite, sandstone, and phosphorite. The phosphorite is concentrated mainly in the Meade Peak Phosphatic Shale Member and the Retort Phosphatic Shale Member. The Meade Park, which contains potential phosphate deposits, was mapped separately.

The rocks of Mesozoic age are about three times as thick as those of Paleozoic age, and they are divided into 15 formations. The oldest, which appears to conformably overlie the Phosphoria Formation, is the Dinwoody Formation of Triassic age. The Dinwoody consists primarily of interbedded olive-drab calcareous shale and silty limestone. Other Triassic formations in ascending order are the Woodside Formation, mainly red siltstone; the Thaynes Formation, a brown to gray arenaceous limestone interbedded with calcareous siltstone; and the Ankareh Formation, mainly red siltstone but containing some thin limestone

interbeds. The Nugget Sandstone, a brown fine-grained rock of Jurassic age, overlies the Ankareh. Above the Nugget are the Twin Creek Limestone, a gray fairly thin-bedded silty limestone; the Preuss Sandstone, a thin brown to red calcareous siltstone; and the Stump Sandstone, a unit of interbedded impure calcareous glauconitic sandstone, quartzite, and arenaceous limestone. The lowermost rocks of Cretaceous age are the Gannett Group. This group from bottom to top consists of the Ephraim Conglomerate, as much as 50 feet of resistant conglomerate overlain by interbedded quartzite and red siltstone; the Peterson Limestone, a fresh-water sublithographic limestone; the Bechler Formation, a hematitic-red siltstone and limestone sequence; and the Draney Limestone, a fresh-water sublithographic limestone. Overlying the Gannett is the Bear River Formation, a lacustrine deposit consisting of a lower member made up mainly of impure fine-grained sandstone and some shale and an upper member made up mainly of shale and some interbedded impure sandstone. The Bear River Formation is overlain by the Aspen Shale, a thick sequence of tuffaceous shale and sandstone that is in part silicified and that contains thin porcellanite beds. The uppermost unit of Cretaceous age is the Frontier Formation, a thick sequence of calcareous shale and sandstone that has coal beds in its upper part.

The rocks of Cenozoic age are divided into nine units. Three of these are Tertiary and consist of older conglomerate, younger conglomerate, and Kirkham Hollow Volcanics. The older conglomerate fills small mountain valleys and was formed later in the Laramide orogeny; the younger conglomerate fills small valleys, covers the old Snake River Plain, and was formed after the Laramide orogeny. The Kirkham Hollow is a thick sequence of welded tuffs and some interlayered flows that covers the north end of the Snake River Range.

The oldest rocks of Quaternary age are basalt and associated tuffs and lacustrine sedimentary rocks. These rocks are found chiefly in the Snake River Plain, where they fill irregularities cut on rocks of Tertiary age. A few small basaltic dikes intrude rocks of Mesozoic and Paleozoic age in the northwestern part of the area. The other rocks of Quaternary age, all unconsolidated sediments, are landslide deposits, loess, colluvium, and alluvium.

In the Garns Mountain quadrangle the structure is much more complex in the Snake River Range than in the Snake River Plain. The dominant structural features in the Snake River Range are thrust faults. These thrusts have a general northwestward trend and a southwestward dip. Dips on the thrusts generally flatten downward. The thrust pattern is complicated; thrusts commonly branch off into minor thrusts or intersect other thrusts. Displacement ranges from a few thousand feet to many miles. Ten principal thrusts cross the Garns Mountain quadrangle. Marked facies changes are noted in the sedimentary rocks on opposite sides of the two largest thrusts, the Absaroka and the Jackson. The Absaroka thrust marks the southwest boundary of rocks of Cretaceous age in the Snake River Range. This fault, which is the longest in this region, has been traced to the southwest corner of Wyoming, a distance of 215 miles. In addition to the thrust faults, many steeply dipping normal and high-angle reverse faults are found in the Snake River Range. They are transverse faults, which are generally at right angles to the thrusts, and short strike faults. These faults generally are found within a single thrust block and probably aided in taking up differential movement along the thrusts. The same forces that caused the thrusting produced folding. More than 125 folds occur in the Garns Mountain quadrangle. These folds are generally small and their axes parallel the trend of the major thrusts.

The Snake River Plain is a graben filled with horizontal or gently dipping rocks of late Tertiary or Quaternary age. The graben is bounded on the northeast by the Grand Valley fault and on the southwest by the Snake River fault.

The only two types of deposits of known major economic significance in the quadrangle are phosphate rock and coal. Phosphate rock is confined to the Phosphoria Formation, where almost all of it is found in the Retort and Meade Peak Phosphatic Shale Members. The Retort is 9–39 feet thick, but the phosphorite beds in it are thin, the thickest bed being only 1.5 feet thick. The Meade Peak is generally about 40 feet thick, but within a distance of 10.5 miles along strike in one thrust block, this formation increases from 9.4 to 63 feet in thickness. The phosphcrite beds are generally most common at the top and the bottom of the Meade Peak. In a trench on Piney Peak, the uper 4.3 feet of Meade Peak contained 31.6 percent P_2O_5, and in a trench north of Elk Flat, the lower 10.6 feet of Meade Peak contained 24.7 percent P_2O_5.

Coal is found in the upper part of the Frontier Formation in the Horseshoe Creek district in the northeast corner of the Garns Mountain quadrangle. Approximately 100,000 tons of high-grade bituminous coal has been produced from this district. The coal-bearing sequence has at least seven coal beds 2 or more feet thick. Only four of these beds have been developed to any extent, and most of the coal produced came from two beds, which have average thickness of 4 and 6 feet. The coal is low in ash, sulfur, and moisture content; and average analyses show that it contains between 11,000 and 14,000 Btu. Reserves in the western part of the coal field on the two major beds are estimated to be 3,460,000 indicated tons of coal and 3,560,000 inferred tons of coal.

INTRODUCTION

The Garns Mountain quadrangle was mapped as part of the U.S. Geological Survey program of classifying mineral lands in the Public Domain. Parts of the quadrangle are underlain by the phosphate-bearing Phosphoria Formation, and other parts are underlain by the coal-bearing Frontier Formation. The stratigraphy and structure of the entire quadrangle are discussed, as well as present and potential economic possibilities of the phosphate and coal deposits.

LOCATION AND ACCESSIBILITY

The Garns Mountain quadrangle lies across the northern part of the Snake River Range[1] in Bonneville, Madison, and Teton Counties, Idaho (fig. 1). Its northeast corner touches Teton Valley, and its southwest corner lies across the Snake River Plain. The quadrangle is between lat 43°30′ and 43°45′ N. and long 111°15′ and 111°30′ E., and it covers an area of 215 square miles. About three-quarters of this area is within the Targhee National Forest. Idaho Falls, Idaho, is 27 miles west of the southwest corner of the quadrangle, and Jackson, Wyo., is 24 miles east of the southeast corner of the quadrangle (fig. 1).

Roads cross the corners of the Garns Mountain quadrangle, but none are in the mountainous central part. The only paved roads are

[1] The name Bighole Mountains has been commonly applied to the mountains of the Snake River Range that border Teton Valley on the west. No significant topographic feature, however, separates these mountains from the rest of the Snake River Range.

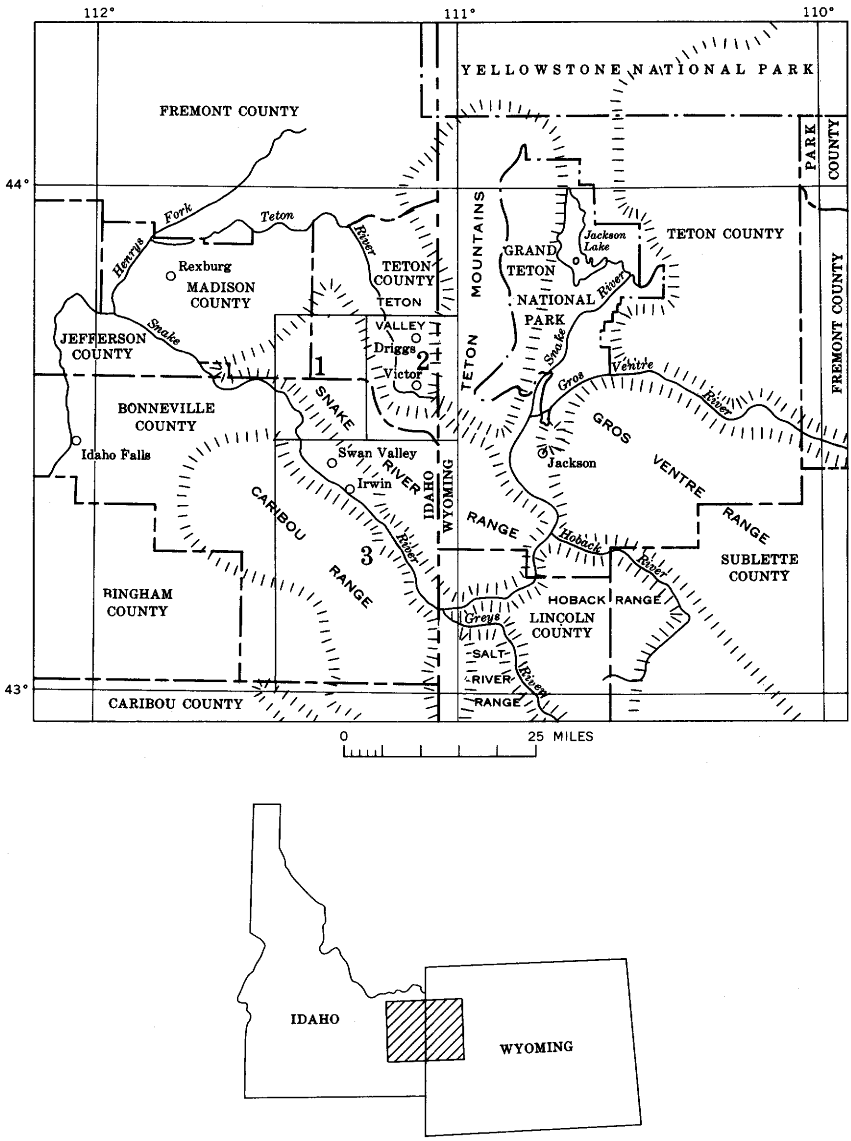

FIGURE 1.—Eastern Idaho and western Wyoming, showing the location of the Garns Mountain and adjacent quadrangles: (1) Garns Mountain quadrangle, (2) Driggs quadrangle, (3) Irwin quadrangle.

U.S. Highway 26 and State Highway 31. U.S. Highway 26, which connects Idaho Falls with Jackson, follows the Snake River Plain across the southwest corner of the quadrangle. State Highway 31, which connects the Snake River Valley with Teton Valley, follows Pine Creek across the southeast corner of the quadrangle. Many dirt roads lead to farms on the Snake River Plain, and a few dirt roads follows some tributaries of Pine Creek. A Forest Service road and several side roads connect Driggs to small nonworking coal mines in the northeast corner of the quadrangle, and a Forest Service road and a few farm roads enter the northwest corner of the quadrangle.

A branch line of the Union Pacific Railroad extends northward from Victor through Driggs (fig. 1) about 7 miles east of the Garns Mountain quadrangle, and Rexburg is on the main line of the Union Pacific Railroad about 15 miles northwest of the quadrangle.

PHYSICAL FEATURES

The Snake River Range is a rugged northwestward-trending range about 47 miles long lying along the northeast side of the Snake River. Altitudes in the Garns Mountain quadrangle, which is in the northern part of these mountains, range from about 5,150 feet along the Snake River at the west edge of the quadrangle to 9,019 feet on Piney Peak in the center of the quadrangle (pl. 1). The mountains are mostly rugged and have steep V-shaped valleys. In the northwest corner of the quadrangle, however, the surface is characterized by low rolling hills and numerous small streams. This part of the quadrangle is covered by resistant upper Tertiary volcanic rocks, and except along a few major streams like Canyon and Calamity Creeks, the area is not nearly as deeply dissected as areas underlain by older rocks.

The Snake River is the major stream in the Garns Mountain quadrangle, and streams on the southwest side of the Snake River Range drain directly into it (pl. 1). Streams on the north and northeast sides of the range, such as Canyon, Packsaddle, Horseshoe, and Mahogany Creeks, drain northward or northeastward into the Teton River before entering the Snake.

The southwestern part of the Garns Mountain quadrangle is a part of the Snake River Plain. It is underlain by upper Tertiary and Quaternary rocks deposited in a graben bounded by normal faults along the fronts of the Snake River and Caribou Ranges. Southeast of Idaho Falls the plain consists of two main surfaces: a flat, discontinuous lower surface adjacent to the Snake River, and a rolling upper surface 400–800 feet above the river. The lower surface forms only small flats along major bends of the river in the quadrangle. The largest flat is found at the mouth of Burns Canyon (pl. 1) and is only about 1 mile long by half a mile wide. The lower surface is more extensive to the southeast in the Irwin quadrangle, where it forms a flat, 13 miles long and as much as 3 miles wide, on which are built the villages of Irwin and Swan Valley (fig. 1). The upper surface makes up most of the Snake River Plain in the Garns Mountain quadrangle, where west of the river it is called Antelope Flat and east of the river, Pine Creek Bench (pl. 1). This surface consists of low, rounded hills underlain by loess, and is used for dryland farming.

CLIMATE AND VEGETATION

The climate of the Garns Mountain quadrangle is mild in summer and cold in winter. In the mountains, snow generally covers the ground from late October to late April. In summer the temperature may reach 95°F, and in winter it may be as low as −30°F. Precipitation is irregular, the lowest and highest amounts falling in almost any month.

Two weather stations are near the Garns Mountain quadrangle. One station is in Driggs, and the other is 2 miles southeast of Irwin (fig. 1). Data from these two stations were compiled for the 10-year period from the Weather Bureau's "Climatological data for the United States by sections (years 1950 to 1959, inclusive)." These data show that the coldest months were December, January, or February and the warmest, July or August. The average temperature of the coldest month over the 10-year period was 16.1°F at Driggs and 19.6°F at Irwin; the average temperature of the warmest month was 65.3°F at Driggs and 66.5°F at Irwin. The average annual temperature for this same period was 40.1°F at Driggs and 43.7°F at Irwin.

The total monthly precipitation ranged from 0 in October 1952 at Driggs and Irwin to 4.37 inches in May 1957 at Driggs and 5.03 inches in December 1955 at Irwin. Total annual precipitation ranged from 8.58 inches in 1958 to 21.37 inches in 1951 at Driggs and from 11.49 inches in 1956 to 19.43 inches in 1955 at Irwin. Average annual precipitation for the 10-year period was 14.15 inches at Driggs and 15.36 inches at Irwin.

The preceding temperature and precipitation data give a fair approximation of the climate in the Garns Mountain quadrangle, although the higher parts of the quadrangle have somewhat cooler weather and more precipitation. Precipitation is also greater in the northwestern part of the quadrangle, where moisture-laden clouds are piled up by prevailing winds against the higher peaks. The greater precipitation in this area supports a denser vegetation than is found in other parts of the quadrangle.

The northwestern part of the Garns Mountain quadrangle is thickly covered by lodgepole pine (*Pinus contorta* var. *latifolia*) except in those areas that are cultivated. In the rest of the quadrangle the northward-facing slopes are also heavily forested. Trees other than lodgepole pine are Douglas-fir (*Pseudotsuga taxifolia*), white spruce (*Picea glauca*), eastern balsam fir (*Abies balsamea*), quaking aspen (*Populus tremuloides* var. *aurea*), and serviceberry or Pacific shadbelow (*Amelanchier florida*). Alpine fir (*Abies lasiocarpa*) and limber pine (*Pinus flexilis*) are found on the higher ridges. The southward-facing slopes are drier, and trees are not as thick. Serviceberry, Rocky Mountain juniper (*Juniperus scopulorum*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), and dwarf maple (*Acer glabrum*) grow on the southward-facing slopes. Many of the trees mentioned grow along streams that have groves of quaking aspen (*Populus tremuloides* var. *aurea*). Along some of the larger streams, coyote willow (*Salix exigua*), arroyo willow (*Salix lasiolepis*), Douglas hawthorn (*Crataegus douglasii*), water birch (*Betula fontinalis*), and willow leaf cottonwood (*Populus angustifolia*) are also found.

PREVIOUS WORK

The first report that includes geology of any part of the Garns Mountain quadrangle was made by Frank H. Bradley, a geologist with the Snake River division of the Hayden Survey. This report covers an expedition made in 1872 from Ogden, Utah, up the Snake River and the Henry's Fork to Yellowstone Park, and then down the east side of the Teton Range to the Snake River, which was followed through the Garns Mountain quadrangle, and on to Fort Hall, Idaho. Bradley (1873a, p. 207; 1873b, p. 221–223) briefly mentioned some of the rocks seen in the Garns Mountain quadrangle. The first report on the part of the Snake River Range included in this quadrangle was made by St. John (1879, p. 425–432), also a member of the Hayden Survey. St. John measured several sections on the east side of the range in 1877.

Between 1911 and 1953 many reports that include parts of the Garns Mountain quadrangle were written on economic possibilities of phosphate, coal, and oil. Blackwelder (1911, p. 461) in 1910 sampled the phosphate rock from exposures along Pine Creek. Schultz (1918, p. 41–42) visited the area in 1912. He made a small reconnaissance map along Pine Creek and sampled the phosphate rocks. Schultz also visited the Horseshoe Creek coal district in the northeast corner of the Garns Mountain quadrangle. He thought that the coal beds lay east of a major thrust, which they do, and that they were repeated east of Horseshoe Creek by being folded into a large anticline and a small syncline, which they are not. In the fall of 1912 Woodruff (1914) made a reconnaissance study of the Horseshoe Creek coal district. He considered the repetition of coal beds to be due to faulting, although he thought the faults were steep-dipping normal faults rather than thrusts. In 1917 Mansfield (1920, p. 137–147) made a reconnaissance map of the Horseshoe district. He noted the thrust west of the coal-bearing beds but did not observe the repetition of the rock sequence, including the coal, east of Horseshoe Creek. In 1917 and again a few years later, this coal district was visited by Evans (1919, 1924), who described the mining and reported the results of three analyses of the coal.

Kirkham (1922, p. 20–23) made some brief comments on the petroleum possibilities of the area in T. 5 N., R. 44 E.; T. 5 N., R. 43 E.; and T. 4 N., R. 43 E. In 1938 Gardner (1944) studied the stratigraphy of the Snake River Range and trenched and sampled the phosphate-bearing rock in several places. Three of these trenches are in the northeastern part of the Garns Mountain quadrangle. In 1945 Staley (1945) briefly visited the coal district and recommended that more work be done in the area. In 1950 Kiilsgaard (1951) made a detailed study of the Horseshoe Creek coal district. He mapped the coal-bearing Frontier Formation in considerable detail and his map, scale of 1: 31,680, includes 38 square miles surrounding the coal mines. In this excellent report, Kiilsgaard described the various coal beds and the mines on these beds; he also gave analyses of the coal. From 1951 to 1953 the Phillips Petroleum Co. drilled a 12,720-foot dry hole near Horseshoe Creek in the SE¼SW¼ sec. 28, T. 5 N., R. 44 E. The stratigraphy in the drill hole is summarized in a short paper by Heikkila (1953). Although this list of reports on the economic possibilities of the area is impressive, with the exception of Kiilsgaard's report they are all reconnaissance in nature, and many deal only with special problems.

In 1947 the U.S. Geological Survey began a detailed study of the western phosphate field with particular emphasis on the stratigraphy of the Phosphoria Formation and its equivalents. The correlation of the Phosphoria in the general area of the Garns Mountain quadrangle is discussed in the following papers: Swanson, McKelvey, and Sheldon (1953); McKelvey, Swanson, and Sheldon (1953); McKelvey and others (1956); Sheldon (1957); McKelvey and others (1959); and Sheldon (1963).

Since 1956 five Master's theses have been written on small areas entirely or partly in the Garns Mountain quadrangle by University of Wyoming students.[2] These theses have been in part summarized in three papers (Espach and Royse, 1960; Hinds and Andrau, 1960; and Sorensen, 1961).

[2] Andrau, W. E., 1957, Geology of the West Pine Creek area, Bonneville County, Idaho: Wyoming Univ., unpub. thesis; Espach, R. H., Jr., 1957, Geology of the Mahogany Ridge area, Bighole Mountains, Teton County, Idaho: Wyoming Univ., unpub. thesis; Hinds, G. W., 1957, Geology of the Mike Spencer Canyon area, Bonneville County, Idaho: Wyoming Univ., unpub. thesis; Royse, Frank, Jr., 1957, Geology of the Pine Creek Pass area, Bighole Mountains, Teton and Bonneville Counties, Idaho: Wyoming Univ., unpub. thesis; and Sorensen, G. E., Jr., 1961, Geology of the Thousand Springs Valley area, Madison and Teton Counties, Idaho: Wyoming Univ., unpub. thesis.

Two geologic maps that cover the east half of the Garns Mountain quadrangle have been published by the U.S. Geological Survey (Staatz and Albee, 1963, and Albee, 1964).

PRESENT WORK AND ACKNOWLEDGMENTS

The present work is both a regional study of a 15-minute quadrangle having an area of 215 square miles and an economic study of the phosphate and coal deposits within this area. Fieldwork totaled 10½ months and was divided into three periods: mid-July to mid-October 1960, mid-June to the end of September 1961, and mid-May to mid-September 1962. During 1961 William E. Bowers assisted M. H. Staatz and John R. Ege assisted H. F. Albee, and during 1962 Henry L. Cullins, Jr., assisted both Staatz and Albee. Mapping in the Garns Mountain quadrangle was done primarily on Commodity Stabilization Service photographs at a scale of 1:20,000. The geology was transferred from these by inspection to orthophotographs at a scale of 1:24,000, and from the orthophotographs it was traced directly onto enlarged topographic maps. Some mapping was also done directly on the topographic maps, which were used to check work done on the photographs and to locate geologic features where their positions were not easily recognizable on the photographs.

Although exposures are good in many areas, in some places the rocks are hidden by colluvium, and some formations are characteristically concealed by soil. The map (pl. 1) is chiefly a bedrock map, and colluvium is shown only where it is sufficiently thick and widespread to mask a significant area of bedrock.

Phosphate-bearing rock and coal beds are rarely exposed on the surface. Data on the phosphate rock were obtained from measured sections and samples obtained from the roadcut along Pine Creek, from three trenches made by Gardner (1944, p. 25–29) in the northeastern part of the quadrangle, from the deepening of one of Gardner's trenches, and from two new trenches on Piney Peak. Coal is exposed only in mines and prospects in the Horseshoe Creek district in the northeast corner of the quadrangle. As none of the mines are operating and as all the workings are caved, most of our data on the coal deposits are compiled from the reports of others who visited the district when it was in operation (Woodruff, 1914; Mansfield, 1920; Evans, 1924; and Kiilsgaard, 1951).

During the first two seasons of fieldwork, E. R. Cressman and E. H. Pampeyan of the U.S. Geological Survey were mapping in the adjoining Driggs quadrangle, and during all three seasons of fieldwork, D. A. Jobin, also of the U.S. Geological Survey, was mapping in the northern part of the Irwin quadrangle (fig. 1). Discussions and joint field trips have been of great aid in solving many of our mutual problems. The authors are indebted to W. C. Gere and R. P. Sheldon, who contributed a considerable amount of information on the Phosphoria Formation.

ROCK UNITS

The rocks in the Garns Mountain quadrangle range in age from Middle Cambrian to Recent. The rocks of Paleozoic and Mesozoic age are all widespread sedimentary rocks; those of Cenozoic age are volcanic rocks and local sedimentary rocks. The rocks of Paleozoic age are mainly limestone but contain minor amounts of dolomite and shale; quartzite is common in the upper part. Those of Mesozoic age are mainly shale and sandstone, but limestone is common in the lower third. The rocks of Paleozoic and Mesozoic age have a total thickness of at least 18,000 feet and are divided into 23 formations. Rocks of Mesozoic age are approximately twice as thick as those of Paleozoic age. Rocks of Cretaceous age make up almost three-quarters of the total thickness of those of Mesozoic age and about half the combined thickness of the rocks of both Mesozoic and Paleozoic ages. A generalized column of these rocks is shown in figure 2. Sediments deposited from Middle Cambrian to some time in the Late Jurassic (post-Twin Creek Limestone) were laid down along the northeastern edge of a miogeosyncline. They in general thicken greatly toward the center of the miogeosyncline in southeastern Idaho and thin toward the craton in western Wyoming.

The rocks of Cenozoic age consist of conglomerates deposited in local basins during Tertiary time, volcanic rocks (salic welded tuffs and flows, and basalts) emplaced during late Tertiary and Quaternary time, and unconsolidated sediments (loess, landslide deposits, colluvium, and alluvium) laid down locally in Quaternary time.

In the Snake River Range, all the rock types mentioned are found. Along the Snake River Plain in the southwestern part of the Garns Mountain quadrangle, however, only rocks of Cenozoic age are exposed.

ROCKS OF CAMBRIAN AGE

GROS VENTRE FORMATION

NAME AND DISTRIBUTION

The Gros Ventre Formation was defined by Blackwelder (1918, p. 417–418) as the calcareous shales and limestones that overlie the Flathead Quartzite and underlie the Gallatin Limestone in the Gros Ventre Range, Wyo. Miller (1936, p. 119–123) noted that in most places in western Wyoming this formation has a three-fold division consisting of a middle limestone member and an upper and a lower shale member. He called the limestone the Death Canyon Member because

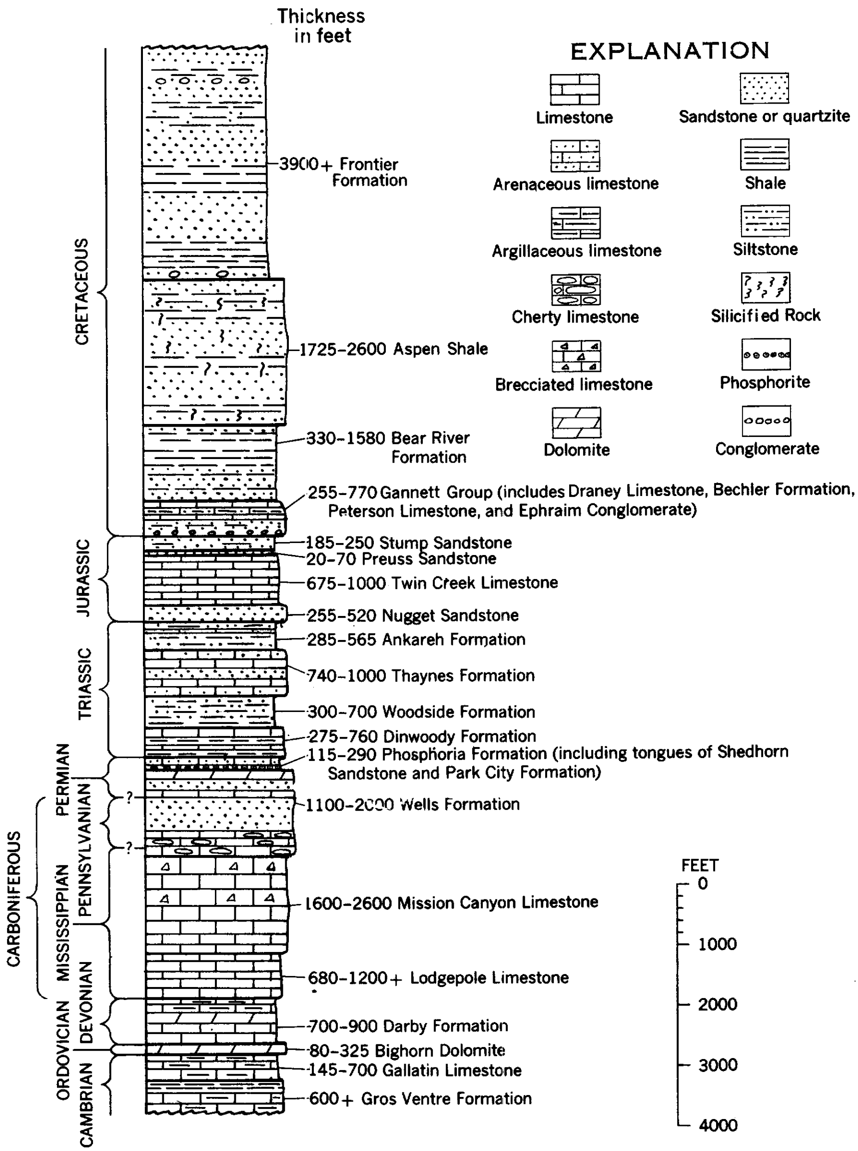

FIGURE 2.—Generalized columnar section of the rocks of Paleozoic and Mesozoic age in the Garns Mountain quadrangle.

of excellent exposures of this unit in Death Canyon in the southern part of the Teton Mountains.

In the Garns Mountain quadrangle the Gros Ventre Formation forms several irregular, narrow outcrop bands along the southwest front of the Snake River Range from the west edge of the quadrangle to just southeast of Pine Creek. None of these outcrop bands is more than 2 miles northeast of the range front.

The Gros Ventre Formation is the oldest unit in the quadrangle, and its lower part is everywhere either covered by unconsolidated Quaternary deposits or cut off by a thrust fault. The Gros Ventre is conformably overlain by the Gallatin Limestone.

LITHOLOGY

The Gros Ventre Formation, as previously noted, is made up of three members in western Wyoming. In the Garns Mountain quadrangle, however, only the upper member and part of the middle member are exposed.

The middle or Death Canyon Member is a bluish-gray thin-bedded to massive limestone that has many yellow to orange irregular limonitic patches of calcareous siltstone. In places, a little tan silt is present along the bedding planes. Some parts of this member closely resemble parts of the overlying Gallatin Limestone.

The upper member consists of grayish-green fissile calcareous shale and a few thin light-gray limestone beds, most of which are composed of intraformational conglomerate. This member is poorly exposed, and along ridges it generally forms shallow saddles in which small pieces of shale float are found intermixed in the overburden.

THICKNESS AND CORRELATION

The Death Canyon Member is not completely exposed, but at least 300 feet of it occurs in this area. The upper member of the Gros Ventre Formation was measured on the ridge on the west side of Woods Canyon in the northwest corner of sec. 2, T. 3 N., R. 42 E., where it is 202 feet thick.

No fossils were found in the Gros Ventre Formation in the Garns Mountain quadrangle, but fossils in the overlying Gallatin Limestone, 30 feet above the Gros Ventre-Gallatin contact, are of middle Late Cambrian age. In Wyoming, Blackwelder (1918, p. 418) in the Gros Ventre Range and Miller (1936, p. 142) at Death Canyon in the Teton Mountains and in the western part of the Owl Creek Mountains both found Middle Cambrian fossils in the Gros Ventre. More recently, Lochman-Balk (1956, p. 596–597) noted that in addition to Middle Cambrian fossils the upper part of the upper shale member contained Upper Cambrian fossils. Thus, the age of this formation is both Middle and Late Cambrian, the Middle-Upper Cambrian boundary being somewhere in the upper part of the shale member. The upper member of the Gros Ventre is correlative to the Park Shale, and the Death Canyon Member, to the Meagher Limestone of southwestern Montana (Sloss and Moritz, 1951, p. 2140).

GALLATIN LIMESTONE

NAME AND DISTRIBUTION

The name Gallatin was first used by Peale (1890, p. 131) for all the Cambrian rocks in the Three Forks area of the Gallatin Range. Peale (1893, p. 20–22) subsequently redefined the Cambrian using Flathead Formation for the basal quartzite and shale and restricting the name Gallatin Formation to the overlying limestone and shale. The name was changed to Gallatin Limestone by Iddings and Weed (1894), who further restricted it to the upper limestone and shale of Late Cambrian age.

In the Garns Mountain quadrangle the Gallatin Limestone is found only on the southwestern side of the Snake River Range. It is much more widespread than the Gros Ventre Formation and, where the Gros Ventre is missing, the Gallatin is the lowest unit on the upper plate of several thrust faults.

LITHOLOGY

The Gallatin Limestone is light- to medium-gray fine- to medium-grained generally thin-bedded limestone that has many thin irregular partings and beds of siltstone and shale. A few massive beds occur in this generally thin-bedded sequence; the thickest, 17 feet thick, marks the base of the Gallatin. Shale is most common in the 60 feet of limestone directly overlying the massive basal bed. Here limestone beds a fraction to about 3 inches thick are separated by and contain irregular green shale partings. In section, the pattern formed by the shale partings in the limestone resembles that of a chicken-wire fence. Limestone showing this distinctive pattern has been found only in the Gallatin. Siltstone rather than shale generally forms the partings in the middle and upper parts of the formation. The siltstone partings are thin, flat, and discontinuous and are restricted to bedding planes. In plan, however, they are commonly irregular and in places are worm shaped. The amount of siltstone in the middle and upper parts of the Gallatin varies in different thrust sheets. On the southwest side of Fleming Canyon, siltstone partings are present throughout; the part of the formation exposed along the mountain front just northwest of Pine Creek and along the mountain front south of Burns Canyon contains a few siltstone partings in the upper part. The Gallatin like the Gros Ventre Formation contains several thin intraformational limestone-conglomerate beds. These conglomerate beds are in the upper quarter of the formation and range in thickness from a few tenths of a foot to 2 feet. One of the most conspicuous of these beds is about 2 feet thick and 6 feet below the top. A detailed stratigraphic section of the Gallatin was measured at the head of Gopher Canyon and is given as follows.

Section in the Gallatin Limestone measured at head of Gopher Canyon in the NW¼NE¼ sec. 36, T. 3 N., R. 43 E.

[Fossils identified by A. R. Palmer]

	Thickness (feet)
Bighorn Dolomite:	
Dolomite, gray (weathers white), medium-grained; beds 2–4 in. thick.	
Gallatin Limestone:	
1. Limestone, light-gray, fine-grained, thin-bedded; contains siltstone partings along bedding planes	6
2. Intraformational limestone conglomerate	2
3. Limestone, like unit 1	31
4. Intraformational limestone conglomerate; pebbles as long as 3 in	2
5. Limestone, like unit 1	67
6. Intraformational limestone conglomerate	.4
7. Limestone, light-gray, fine-grained; contains orange siltstone patches	2
8. Intraformational limestone conglomerate; pebbles ¼–1 in. long	.7
9. Limestone, light-gray, medium-grained; contains white worm-shaped patches of siltstone along bedding planes	14
10. Limestone, limonitic-yellow with gray mottling in places, coarse-grained	2
11. Limestone, like unit 9	44
12. Limestone, light-gray, fine-grained; beds 1 in. to 4 ft. thick; contains irregular limonitic-yellow siltstone partings	51
13. Limestone, limonitic-yellow, medium-grained, smooth-weathering; contains small vugs	2
14. Limestone, dark-gray, fine-grained; contains scattered coarse grains of gray calcite	3
15. Limestone, gray, fine-grained; beds 1 in. to 3 ft thick; contains irregular patches of tan siltstone along bedding planes	73
16. Limestone, gray, fine-grained, massive	8
17. Limestone, like unit 15	51
18. Limestone, light-gray, medium- to coarse-grained; beds mostly 1–3 in. thick; contains numerous irregular green shale partings. Shale is more common towards base. The following fossils were found in the lower half of this unit: *Pseudagnostus* sp., *Wilbernia* sp., *Idahoia* sp., *Croixana* sp., *Taenicephalus* sp., *Billingsella* sp., several species of conodonts, indeterminate merostome and linguloid fragments	58
19. Limestone, gray, coarse-grained, massive, spotted with limonite	17
Thickness of Gallatin Limestone	434
Gros Ventre Formation:	
Covered, but zone contains green shale float.	

THICKNESS AND CORRELATION

The Gallatin Limestone is 434 feet thick at the head of Gopher Canyon. Six miles southeast of the Garns Mountain quadrangle in secs. 7 and 17, T. 1 N., R. 45 E., Gardner (1944, p. 10) measured only 145 feet of Gallatin, and in the same area, D. A. Jobin (1961, oral commun.) measured 150 feet. The Garns Mountain area was on the northeastern edge of a miogeosyncline in Cambrian time. To the north and east lay shallow seas over a broad platform. This transition area between the platform and the miogeosyncline was an area of rapid change in sedimentation. Southwestward the Upper Cambrian rocks thicken considerably; near the Idaho-Utah border on Fish Haven Creek, they are 2,050 feet thick (Mansfield, 1927, p. 36), and in Promontory Range on the north shore of Great Salt Lake, Utah, they are 4,178 feet thick (Olson, 1956, p. 47–49).

Fossils are scarce in the Gallatin Limestone in the Garns Mountain quadrangle. The only ones found were 20–50 feet above the base of the Gallatin. Two collections (loc. F1 and F2) made at this horizon near the head of Gopher Canyon were examined by A. R. Palmer. He identified them as follows:

Pseudagnostus sp.
Wilbernia sp.
Taenicephalus sp.
Idahoia sp.
Croixana sp.
Billingsella sp.
Several species of conodonts
Indeterminate merostome fragments
Linguloid scraps

Palmer stated that these fossils came from the basal part of the *Ptychaspis-Prosaukia* zone of Late Cambrian age.

The name Boysen Limestone has been used by some stratigraphers (Deiss, 1938, p. 1104; Wanless, Belknap, and Foster, 1955, p. 13–14) in parts of western Wyoming to replace the older term Gallatin because an adequate type section for the Gallatin had not been designated. The writers feel, however, that this reason is not sufficient for changing a name that has both precedence and wide usage in western Wyoming and adjacent parts of Idaho.

The Gallatin Limestone is correlative to the Nounan and the St. Charles Formations of northeastern Utah (Williams, 1948, p. 1134–1135) and southeastern Idaho, to the Hasmark and Red Lion Formations of southwestern Montana (Sloss and Moritz, 1951, p. 2144–2147), and to the Pilgrim and Red Lion Formations of the area just west of Yellowstone Park (I. J. Witkind, 1960, oral commun.).

ROCKS OF ORDOVICIAN AGE

BIGHORN DOLOMITE

NAME AND DISTRIBUTION

The Bighorn Dolomite, named Bighorn Limestone by Darton (1904, p. 395–396) for Ordovician carbonate rocks in the Bighorn Mountains, Wyo., is widely distributed throughout western Wyoming.

In the Garns Mountain quadrangle the Bighorn Dolomite forms narrow outcrop bands in several thrust plates along the southwest side of the Snake River Range. Some excellent exposures are near the ridge top south of Flume Creek, on the northeast side of Stouts Mountain, and on the south side of Black Canyon about 2 miles from its mouth (pl. 1).

LITHOLOGY

The Bighorn Dolomite is a gray fine- to medium-grained dolomite or slightly calcareous dolomite that weathers to a characteristic very light gray. The middle and upper parts of this unit have a distinctive light-gray mottling. Mottling is scarce in the outcrop band around the north side of Stouts Mountain (see section below) but is fairly common in the outcrop bands along the west edge of the quadrangle west of Woods Canyon and on the main ridge south of Canal Canyon. The Bighorn for the most part is thick bedded or massive and commonly forms small cliffs. In some places the upper part of the formation contains coarse grains of carbonate in a fine-grained matrix. The base of the Bighorn is placed below the first light-gray-weathering thick-bedded dolomite. The contact is an unconformity. It is well exposed in Black Canyon 2 miles above its mouth; here the unconformity is gently undulating and cuts across beds of the underlying Gallatin Limestone. A detailed stratigraphic section of the Bighorn was measured near the head of Gopher Canyon.

Section in the Bighorn Dolomite measured at the head of Gopher Canyon in the NE¼–NW¼ sec. 36, T. 3 N., R. 43 E.

	Thickness (feet)
Darby Formation:	
Limestone, dark-gray (weathers light gray), fine-grained; contains some chert.	
Bighorn Dolomite:	
1. Dolomite, gray (weathers very light gray), fine-grained, thick-bedded slightly calcareous; contains some coarse grains of carbonate in fine-grained matrix	94
2. Dolomite, gray (weathers very light gray with gray mottling), fine-grained, slightly calcareous, thick-bedded	5
3. Dolomite, gray (weathers very light gray), fine-grained, thick-bedded	53
4. Dolomite, gray (weathers white), medium-grained, calcareous; beds 2–4 in. thick	8
Thickness of Bighorn Dolomite	160

Section in the Bighorn Dolomite measured at the head of Gopher Canyon in the NE¼NW¼ sec. 36, T. 3 N., R. 43 E.—Continued

Gallatin Limestone:

Limestone, light-gray, fine-grained, thin-bedded; contains siltstone partings along bedding planes.

THICKNESS AND CORRELATION

The Bighorn Dolomite is 81 feet thick at the south side of Black Canyon about 2 miles above its mouth and 160 feet thick at the head of Gopher Canyon. It is about 325 feet thick in the southeast corner of the Garns Mountain quadrangle (NW¼NW¼ sec. 17, T. 2 N., R. 44 E.), as measured from the map. Six miles southeast of the Garns Mountain quadrangle on the northwest side of Palisade Creek, Gardner (1944, p. 10) measured 400 feet of Bighorn. As this thickness indicates, the Bighorn thins abruptly to the northwest and in southwestern Montana is absent (Sloss and Moritz, 1951, p. 2141, 2152).

Fossils are scarce in the Bighorn Dolomite; the only ones found were crinoid stems and one poorly preserved bryozoan. Helen Duncan examined the bryozoan and noted that it probably is a *Rhinidictya*-like form but that the features necessary to distinguish the genus and family have not been preserved. Although the age of the Bighorn cannot be determined from the fossils in the Garns Mountain quadrangle, its age has previously been determined by Miller (1930) as late Ordovician.

The Bighorn Dolomite is correlative to the Fish Haven Dolomite of southeastern Idaho and western Utah and to the upper part of the Fremont Limestone of Colorado (Miller, 1930, p. 209).

ROCKS OF DEVONIAN AGE

DARBY FORMATION

NAME AND DISTRIBUTION

The Darby Formation was named by Blackwelder (1918, p. 420–422) from exposures in Darby Canyon on the west flank of the Teton Mountains, about 10 miles east of the Garns Mountain quadrangle.

In the Garns Mountain quadrangle the Darby Formation crops out in several fault blocks along the southwest side of the Snake River Range. The lower part of the formation is commonly well exposed; good sections in this part of the Darby are exposed on the northeast side of Stouts Mountain, on the north side of Black Mountain, and along the north and south sides of Black Canyon (pl. 1). The upper part of the formation is rarely exposed; the only good exposures in this part of the Darby are in the vicinity of McCoullock Spring, three-quarters of a mile southeast of the top of Black Mountain, and on the north side of Black Canyon.

LITHOLOGY

The Darby Formation consists of two members. The lower member, which makes up from ½ to ⅚ of the formation, consists of interbedded limestone, dolomitic limestone, and dolomite. These rocks are not only interbedded, but in places limestone grades laterally to dolomite. The upper part of the lower member commonly is marked by as much as 300 feet of brown dolomitic limestone breccia. Carbonate beds, which are fine or medium grained, are tan, light gray, gray, dark gray, brown, or chocolate brown. Chocolate-brown carbonates are scarce in this area except in the Darby; a few carbonate beds of this color do occur, however, in the Mission Canyon Limestone. Brown colors in the Darby are generally restricted to dolomitic limestones or dolomite, and brown dolomite beds grade into gray limestones along strike. The lower member is medium bedded; many beds are 1–2 feet thick. A few of the beds have a fetid odor, and some of the gray beds have a brown mottling.

The upper member consists of interbedded fine-grained gray, grayish-yellow, or yellow limestone and limestone breccia; yellowish-gray or brown shale; brown siltstone; and fine-grained sandstone. An intraformational limestone conglomerate 30 feet thick is exposed near the middle of this member on the ridge north of McCoullock Spring. Not all these rock types are present at any one place. The rocks are generally thin bedded. Although the upper member is rarely exposed, thin flat pieces of yellow limestone float are common on the slope just below the base of the Lodgepole Limestone. A detailed stratigraphic section measured in Black Canyon is given as follows.

Section in the Darby Formation measured in Black Canyon. Upper member was measured on north side of Black Canyon in the SE¼SE¼ sec. 7, T. 3 N., R. 43 E.; lower member was measured on the south side of Black Canyon in the NW¼NE¼ sec. 17, T. 3 N., R. 43 E.

Lodgepole Limestone:

Limestone, dark-gray (weathers light gray), very fine grained.

	Thickness (feet)
Darby Formation:	
Upper member:	
1. Limestone, limonitic-yellow with pink blotches, fine-grained, argillaceous	3
2. Covered	19
3. Limestone, like unit 1	11

Section in the Darby Formation measured in Black Canyon. Upper member was measured on north side of Black Canyon in the SE¼SE¼ sec. 7, T. 3 N., R. 43 E.; lower member was measured on the south side of Black Canyon in the NW¼NE¼ sec. 17, T. 3 N., R. 43 E.—Continued

	Thickness (feet)
Darby Formation—Continued	
Upper member—Continued	
4. Limestone breccia, tan (weathers to limonitic yellow and pink); consists of fine-grained argillaceous limestone fragments ¼–½ in. across	50
5. Covered	33
6. Limestone, light-gray, fine-grained, thin-bedded; bedding planes stained yellow	11
Thickness of upper member	127
Lower member:	
7. Dolomite, light-gray, fine-grained, calcareous; beds 1 in. to 1 ft thick	17
8. Dolomite, chocolate-brown, grayish-brown, or gray, fine-grained, massive	83
9. Covered	109
10. Limestone breccia, gray	.5
11. Limestone, light-gray, medium-grained, sandy-textured; beds 4–8 in. thick	3
12. Limestone breccia, light-gray, massive; some fragments as large as 5 in. across, some areas have very few fragments	54
13. Limestone, dark-gray (weathers chocolate brown), fine-grained, dolomitic	13
14. Limestone breccia, like unit 12 only maximum size of fragments is ¼ in	42
15. Covered	27
16. Limestone breccia, like unit 14	6
17. Covered	49
18. Limestone breccia, tan; some pink fragments; fragments are as large as ½ in. across	11
19. Covered	9
20. Dolomite, light-gray, medium-grained, thin- to medium-bedded, calcareous	23
21. Dolomite, light-gray, medium-grained, massive, calcareous	4
22. Limestone breccia, massive; consists of gray and brown fragments in a gray matrix	18
23. Dolomite, brown, fine-grained, massive, calcareous	16
24. Breccia; consists of gray and brown dolomite fragments in limestone matrix	9
25. Limestone, gray with brown mottles, medium-grained, dolomitic	6
26. Limestone, gray, medium-grained, sandy-textured, full of small solution cavities	8
27. Limestone breccia, dark-brown (weathers brown with light-brown mottles), dolomitic	28
28. Dolomite, like unit 20	3

Section in the Darby Formation measured in Black Canyon. Upper member was measured on north side of Black Canyon in the SE¼SE¼ sec. 7, T. 3 N., R. 43 E.; lower member was measured on the south side of Black Canyon in the NW¼NE¼ sec. 17, T. 3 N., R. 43 E.—Continued

	Thickness (feet)
Darby Formation—Continued	
Lower member—Continued	
29. Limestone, gray with brown mottles, fine-grained, thick-bedded, dolomitic	35
30. Dolomite, brown, medium-grained; bed 1–2 ft thick	7
31. Limestone, dark-gray with chocolate-brown mottles, fine-grained; thin irregular beds	15
32. Limestone, gray (weathers tan), fine-grained, smooth-weathering, finely laminated, dolomitic	9
33. Limestone, dark-gray (weathers gray with brown mottles), medium-grained, massive	18
34. Covered	29
35. Limestone breccia, chocolate-brown	15
36. Limestone, gray, fine-grained, smooth-weathering, dolomitic; beds about 8 in. thick	9
37. Limestone, grayish-brown, fine-grained; thin irregular beds	2
Thickness of lower member	677.5
Thickness of the Darby Formation	805
Bighorn Dolomite:	
Dolomite, light-gray, medium-grained; beds 6 in. to 12 ft. thick.	

THICKNESS AND CORRELATION

The Darby Formation is 707 feet thick where measured at the head of Gopher Canyon in the NE¼NW¼ sec. 36, T. 3 N., R. 43 E., and 805 feet thick in Black Canyon in the SE¼SE¼ sec. 7 and the NW¼NE¼ sec. 17, T. 3 N., R. 43 E. It is at least 900 feet thick near Rocky Canyon, as indicated on section *C–C'* of plate 1. Six miles southeast of the Garns Mountain quadrangle on the north side of Palisade Canyon, Gardner (1944, p. 10) measured 570 feet of the Darby. The thickness of the Darby varies because in Devonian time this area was a transition zone between the shelf to the east and the miogeosyncline to the west. Westward in the miogeosyncline the Devonian rock sequence becomes much thicker and contains mainly carbonate rocks; eastward on the shelf it thins, but not as abruptly, and contains less carbonate rocks and more clastic rocks (Brooks and Andrichuck, 1953, p. 30).

No fossils identifiable as to genus were found in the Darby Formation in the Garns Mountain quadrangle. Many molds of planospire gastropods were found, however, in a 9-foot bed near the middle of the lower member; these gastropods make this bed a useful marker. Some of the yellow limestone near the top of the upper member also contains small pieces of phosphatic shells. Although the age of the

Darby is undeterminable in the Garns Mountain quadrangle, it has been determined to be Middle and Late Devonian in several parts of western Wyoming by Blackwelder (1918, p. 421), Branson and Branson (1941, p. 130), and Love (1950, p. 26).

The two-fold division of the Darby Formation and the lithology of these divisions suggest that the lower part of the Darby correlates with the Jefferson Limestone and that the upper part correlates with the lower part of the Three Forks Shale.

ROCKS OF MISSISSIPPIAN AGE

MADISON GROUP

Peale (1893, p. 32–39) proposed the name Madison Limestone for about 1,250 feet of Mississippian rocks in the Three Forks area, Montana. He divided these rocks into three units, which in ascending order are "laminated limestones," "massive limestones," and "massive jaspery limestones." Later Collier and Cathcart (1922, p. 173) made the Madison a group, which they divided into the Lodgepole and Mission Canyon Limestones. The Lodgepole was equivalent to the "laminated limestones" and "massive limestones" of Peale and the Mission Canyon to the "massive jaspery limestones." Sloss and Hamblin (1942), summarized previous work and showed that the Lodgepole and Mission Canyon were widespread in Montana.

The Madison Group has been traditionally regarded as Early Mississippian in age. The upper part of the Mission Canyon, however, is poorly fossiliferous and contains some beds of Late Mississippian age (Sloss and Hamblin, 1942, p. 311; Sando and Dutro, 1960, p. 118).

The Mississippian rocks in the Snake River Range consist of two distinct limestone formations. Gardner (1944, p. 10) called the upper formation the Brazer Limestone and the lower formation the Madison Limestone. As there is little resemblance between the upper formation and the Brazer in its type section, we feel that this formation should not be called Brazer. Recent work by W. J. Sando and J. T. Dutro, Jr. (1961, oral commun.) indicated that the Mission Canyon and Lodgepole Limestones can be traced southward from Montana into western Wyoming. We have, therefore, called the two Mississippian formations Mission Canyon and Lodgepole. This nomenclature is also supported by faunal data. Recently Sando and Dutro (1960) found that corals could be used to divide the Madison Group into four major faunal zones. The Lodgepole-Mission Canyon contact falls near the middle of the third zone. Fossils obtained by us from the Garns Mountain quadrangle and identified by Sando and

Dutro indicate that our Lodgepole-Mission Canyon contact also falls in the third zone.

LODGEPOLE LIMESTONE

NAME AND DISTRIBUTION

This limestone was named for Lodgepole Canyon in the Little Rocky Mountains of Montana (Collier and Cathcart, 1922, p. 173).

In the Garns Mountain quadrangle the Lodgepole Limestone forms several irregular broad outcrop bands along the southwestern side of the Snake River Range (pl. 1). It is well exposed along some steep ridges. Good exposures are found on the northeast side of Stouts Mountain, on the ridges on both sides of the upper end of Dry Canyon, and on the northwest side of Black Canyon about 2 miles northeast of its mouth. In most places, however, the Lodgepole forms smooth slopes on which thin slabs of limestone are common.

LITHOLOGY

The Lodgepole Limestone is mainly a fine-grained to sublithographic dark-gray to blue-gray limestone that weathers light gray and white. Some thin coarse-grained beds of fossil debris, mainly recrystallized shell fragments, are in the upper half of the formation. Most of the beds are 2–6 inches thick, but beds as much as 3 feet thick are found locally in the upper 100 feet, and the Lodgepole tends to form cliffs in the lower 200 feet. Thin laminations in the lower part of this formation, however, give this rock the appearance of being thin bedded. A little silt is common along bedding planes in some areas; silty bedding planes weather tan. A massive bed of coarse-grained fetid limestone as much as 20 feet thick is found in some places about 100 feet below the top of the Lodgepole. The general composition and bedding of this bed resembles limestone in the overlying Mission Canyon Limestone.

The base of the Lodgepole Limestone is placed at the base of the first gray limestone above yellow limestone at the top of the Darby Formation. This contact is rarely exposed and is generally mapped at the bottom of the first exposed gray limestone above a long covered slope.

A detailed stratigraphic section of the Lodgepole Limestone measured on the northeast side of Stouts Mountain is given as follows.

Section in the Lodgepole Limestone measured on the northeast side of Stouts Mountain in the SW¼NW¼ sec. 36, T. 3 N., R. 43 E.

[Fossil identified by W. J. Sando]

	Thickness (feet)
Mission Canyon Limestone:	
Limestone, gray (weathers light gray), coarse-grained, massive.	
Lodgepole Limestone:	
1. Covered	27
2. Limestone, gray (weathers light gray), medium-grained; beds 2 in. to 3 ft thick. Some beds are made up of fossil debris	84
3. Limestone, blue-gray (weathers somewhat whitish gray), mainly fine grained; beds 2–6 in. thick; a little silt along some bedding planes. A few coarse-grained beds made up of fossil debris. The coral *Syringopora surcularia* Girty was found about 245 feet above the base of this unit	465
4. Limestone, dark-gray (weathers white), fine-grained to sublithographic, smooth-weathering, finely laminated; beds 2–6 in. thick; a little tan silt along some bedding planes	64
5. Limestone, dark-gray (weathers white), fine-grained to sublithographic, smooth-weathering, finely laminated, fairly massive	183
6. Covered, gray limestone float	32
Thickness of Lodgepole Limestone	855
Darby Formation:	
Covered, yellow limestone float.	

THICKNESS AND CORRELATION

The Lodgepole Limestone is 855 feet thick where measured on the northeast side of Stouts Mountain and 680 feet thick on the north side of Black Canyon. It is 875 feet thick on a spur on the northwest side of Lower Palisade Lake in the central part of the Snake River Range (D. A. Jobin, 1962, oral commun.). The thickness of the Lodgepole varies widely along strike, and near the head of Dry Canyon is apparently close to 1,200 feet. As the Lodgepole is poorly exposed in many areas, some of the apparent thickening may be due to folding.

Sando and Dutro (1960) reported that the Madison Group can be divided into four major faunal zones (A–D). Zones A, B, and the lower part of zone C are in the Lodgepole Limestone. Zone A, the lowest zone, has a rather meager fossil assemblage and is present only in the lower 10–50 feet of the Lodgepole.

Numerous fossils are found in the Lodgepole Limestone in the Garns Mountain quadrangle; most of them, however, occur in the upper part of the formation. The fossils that we collected were identified by J. T. Dutro, Jr., W. J. Sando and E. L. Yochelson. Zone A was not represented. Two collections came from zone B (Dutro and Sando, 1961, written commun.). One zone B collection (loc. F3, pl. 1) from about 50 feet above the base of the formation on the ridge between West Pine

Creek and Dry Canyon in the SE¼SE¼ sec. 14, T. 3 N., R. 43 E., contained the following fossils:

Small horn corals, indet.
Echinoderm debris, indet.
Fenestella sp.
Cystodictya sp.
Schizophoria sp.
Schuchertella? sp.
Productellid brachiopod, indet.
Spirifer sp. [small]
Composita? sp.
Punctospirifer sp.
Straparollus (*Straparollus*) *ophirensis* (Hall and Whitfield)?
Straparollus (*Euomphalus*) cf. *S.* (*E.*) *subplanus* (Hall)

The second zone B collection (loc. F4, pl. 1) was made about 530 feet above the base of the Lodgepole on a ridge on the north side of Stouts Mountain in the southwesternmost corner of sec. 25, T. 3 N., R. 43 E. This collection contained the following:

Echinoderm debris, indet.
Fenestella spp.
Rhynchonelloid brachiopod, indet.
Spirifer sp. [*centronatus*-type]
Spirifer sp.
Cleiothyridina sp. [small]
Punctospirifer sp.

Dutro and Sando (1961, written commun.) noted that the rest of our collections from the Lodgepole came from zone C. These collections can be divided into two general groups: those that came from the rocks in an interval extending from 450 feet above the base to about 100 feet below the top of the Lodgepole and those that came from the rocks of the upper 100 feet. The following fossils were identified from rocks of the lower interval:

Homalophyllites sp.
Vesiculophyllum sp.
Syringopora surcularia Girty
Ramose bryozoans, indet.
Cystodictya sp.
Fenestella spp.
Platycrinus sp.
Echinoid plates, indet.
Echinoderm debris, indet.
Orthotetid brachiopod, indet.
Chonetes sp.
Chonetes cf. *C. logani* Norwood and Pratten
Cleiothyridina sp. [small]
Cleiothyridina aff. *C. obmaxima* (McChesney)
Composita sp.
"*Dictyoclostus*" cf. "*D.*" *viminalis* (White)

Schuchertella sp.
Spirifer sp.
Spirifer sp. [*centronatus*-type]

The following fossils were identified from the rocks of the upper interval:

Homalophyllites sp.
Aulopora? sp.
Horn coral, indet.
Lithostrotionella sp.
Ramose bryozoans, indet.
Fenestella sp.
Echinoderm debris, indet.
Platycrinus sp.
Orthotetid brachiopod, indet.
Chonetes cf. *C. loganensis* Hall and Whitfield
"*Dictyoclostus*" aff. "*D.*" *burlingtonensis* (Hall)
Schuchertella? sp.
Punctospirifer sp.
Spirifer sp. [*centronatus*-type]
Torynifer cf. *T. cooperensis* (Girty)
Platyceras sp.

Dutro and Sando (1961, written commun.) noted that all our collections represent Eary Mississippian fossil assemblages.

MISSION CANYON LIMESTONE

NAME AND DISTRIBUTION

The name Mission Canyon Limestone was first used by Collier and Cathcart (1922, p. 173) for limestone exposed in Mission Canyon in the Little Rocky Mountains, Mont. This limestone in the Garns Mountain quadrangle crops out in several broad irregular bands along the southwest side of the Snake River Range (pl. 1) and on the northeast side of the Snake River Range along a prominent ridge and in the center of an anticline that crosses the South Fork of Mahogany Creek (pl. 1). The Mission Canyon is probably the best exposed formation in the quadrangle. It is very resistant to weathering and forms cliffs as much as 200 feet high.

LITHOLOGY

The Mission Canyon Limestone can be divided into two parts: a lower half made up mainly of light-gray and brownish-gray medium- to coarse-grained limestone, and an upper half made up mainly of gray or limonitic-stained limestone breccia interbedded with gray medium-grained limestone. The beds in the lower part show considerable variation in color; light-gray beds are most abundant, grayish-brown beds are common, and gray and chocolate-brown beds are found in a few places. Chocolate-brown beds are found principally in the lower part of this unit and resemble those found in the Darby Formation. Grain size tends to be coarser in the lower part where fossil debris commonly makes up a large part of some beds. Most beds are 1 foot or more thick; in many places these beds are massive.

The upper part of the Mission Canyon Limestone is characterized by breccia beds. These beds are made up of fragments of a gray medium-grained limestone in a matrix of either silty limestone or limestone similar to the fragments it surrounds. The fragments are angular and are ⅛–3 inches across; most, however, are less than 1 inch across. White chert makes up a small part of the fragments in a few beds. In places the matrix is gray; in other places it is pale yellow or yellowish gray; and in a few places it is pink. The breccias are probably solution breccias which formed in a sequence of limestones interbedded with a more soluble rock type, such as gypsum, anhydrite, or salt. The more soluble rocks apparently dissolved, and the overlying rock collapsed into the space thus formed. In support of this theory, equivalent Mississippian rocks on the north side of the Hoback River in western Wyoming contain interbeds of gypsum (Wanless, Belknap, and Foster, 1955, p. 28–29) and anhydrite(?) molds (Sando and Dutro, 1960, p. 124).

THICKNESS AND CORRELATION

The complete section of the Mission Canyon Limestone is present in only one small area in Fleming Canyon (pl. 1). This section was not measured because of poor exposures. The Mission Canyon was measured along the ridge at the head of Fleming Canyon, where the Fleming Canyon thrust cuts out the top part of the formation. The thickness removed is estimated to be less than 100 feet. The exposed Mission Canyon Limestone along this ridge is 1,595 feet thick. Like the Lodgepole Limestone the Mission Canyon varies considerably in thickness, and west of Dry Canyon it is at least 2,600 feet thick.

Fossils are common in the lower 200 feet of the Mission Canyon Limestone, but none were found in the upper half of the formation. Five small collections (loc. F5–F9, pl. 1) were made in the lower 200 feet: two on the northeast side of Fleming Canyon, two on a ridge on the northwest side of Dry Canyon, and one on the southwest side of the Jackson thrust on the northeast edge of Elk Flat. These collections were identified by J. T. Dutro, Jr., and W. J. Sando (1961, written commun.), who noted that they are all of Early Mississippian age. The five collections contained the following fossils:

Syringopora sp.
Syringopora surcularis Girty
Lithostrotionella sp.
Homalophyllites sp.
Vesiculophyllum sp.
Spirifer cf. *S. rowleyi* Weller

The Madison in this region was considered Early Mississippian, and the Brazer, Late Mississippian. Recent work by Sando, Dutro, and Gere (1959, p. 2741–2769) at the type section of the Brazer in the Crawford Mountains of northeastern Utah showed that there the Brazer is a cherty dolomite, the lower two-thirds of which contains fossils of Early Mississippian age and the upper one-third of which contains fossils of uncertain age that are interpreted to be Late Mississippian. The age, therefore, of the type Brazer is at least in part equivalent to the Mission Canyon. Faunal collections from the Brazer in the Crawford Mountains are different from those collected in other areas. As the type Brazer is lithically and faunally distinct from the Upper Mississippian sequences in Idaho and Wyoming that in the past have been called Brazer, Sando, Dutro, and Gere (1959, p. 2768) suggested that the name Brazer be restricted to the formation in the Crawford Mountains.

The Mississippian beds underlying the Brazer in its type area were originally called the Madison Limestone (Richardson, 1913, p. 412). Sando, Dutro, and Gere (1959, p. 2746–2747) found these rocks contained a fauna similar to that found in the type section of the Lodgepole in Montana. Rocks of Mississippian age in the Crawford Mountains of Utah, hence, may be roughly equivalent in age to the Lodgepole and Mission Canyon Limestones of Montana but differ chiefly in that the Brazer is a different rock type.

ROCKS OF MISSISSIPPIAN(?), PENNSYLVANIAN, AND PERMIAN AGE

WELLS FORMATION AND ASSOCIATED ROCKS

NAME AND DISTRIBUTION

The Wells Formation was named by Richards and Mansfield (1912, p. 689) after Wells Canyon in the phosphate district of southeastern Idaho. This name was given to a sequence that consisted of an upper sandy limestone or siliceous limestone member, a middle sandy series, and a lower sandy and cherty limestone series. This sequence had been mapped in southeastern Idaho as the lower member of the Park City Formation and the Weber and Morgan Formations (McKelvey and others, 1959, p. 7). McKelvey and others (1959, p. 12) in a paper discussing the Permian rocks of the western phosphate field restricted the Wells and returned the uppermost limestone member to the Park City Formation. This part of the Park City, which lies below the lowest phosphate beds, they called the Grandeur Member of the Park City Formation.

In the Garns Mountain quadrangle the Grandeur Member of the Park City Formation is 10–70 feet thick and in most places is too thin

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to show separately on plate 1 at the scale at which we mapped. As one of the main purposes of this paper is to outline the phosphate-bearing areas, we have mapped the thin Grandeur Member with the Wells Formation.

We have also mapped a unit of Mississippian(?) age with the Wells Formation. This unit occurs between the Wells Formation proper and the Mission Canyon Limestone on the northeast side of the Absaroka thrust. It is approximately 80 feet thick, is very poorly exposed, and appears to consist mainly of variegated shales.

In the Garns Mountain quadrangle the mapped unit consisting of the Wells Formation and its associated rocks is present in several fault blocks (pl. 1). It is not present, however, along the southwest side of the Snake River Range where older rocks occur. Massive quartzites in this formation commonly form major ridges and mountains, such as the ridge between North Fork of Pine Creek and West Pine Creek, Argument Ridge, and Farnes Mountain.

LITHOLOGY

The greater part of the Wells Formation, which makes up the greater part of the unit, consists of a resistant white quartzite. The quartzite is fine to medium grained and well indurated; in places it is stained a light brown or pink. Limestone, and in places dolomite, occurs in the upper and lower parts of this formation. In detail the upper and lower parts of the Wells northeast of the Absaroka thrust fault differ considerably from the same parts southwest of the thrust. Northeast of the thrust, thin variegated shale beds of Mississippian(?) age underlie the Wells Formation. Above them at the base of the Wells is more than 200 feet of gray limestone that contains a few gray chert nodules. The base of the mapped unit is here placed on the top of the last gray limestone outcrop below a covered area in which the shale beds are found. Most of the remaining Wells is made up of white quartzite, although a few thin dolomite or calcareous quartzite beds are found in the upper part. The Grandeur Member of the Park City Formation forms the top of this map unit. It consists of 10–20 feet of fine-grained gray white-weathering dolomite.

Southwest of the Absaroka thrust, the variegated shale is missing, and the lower part of the Wells Formation consists of limestone with a few white quartzite interbeds. The base of the Wells is here placed at the base of the first quartzite bed above limestone assigned to the Mission Canyon Limestone. Limestones are similar to those northeast of the Absaroka thrust, except that chert nodules are more common. The middle part of the Wells consists of white quartzite similar to that northeast of the thrust. In the upper 175 feet of the Wells, however, limestone and dolomite units make up about one-quarter of the section. In this upper part the carbonate in the lower half is generally limestone; in the upper half, dolomite. The Grandeur Member of the Park City Formation overlies the Wells. It consists of 40–70 feet of gray white-weathering dolomite.

Limestones in the Wells differ from those of the Mission Canyon Limestone southwest of the Absaroka thrust in that they are generally darker gray, are finer grained, and contain gray chert. Northeast of the thrust the upper part of the Mission Canyon also contains a little chert, but chert is generally scarcer than in the Wells.

A detailed stratigraphic section measured on the northeast side of the Absaroka fault at the head of North Fork of Canyon Creek is given as follows.

Section in the Wells Formation and associated rocks measured on the ridge at the head of North Fork of Canyon Creek in the NW¼ sec. 12, T. 4 N., R. 43 E.

	Thickness (feet)
Phosphoria Formation:	
Phosphorite, black, compact; contains abundant phosphatic shell fragments.	
Wells Formation and associated rocks:	
Grandeur Member of the Park City Formation:	
1. Dolomite, light-gray (weathers white), fine grained	10
Wells Formation:	
2. Siltstone, limonitic-yellow, calcareous	1
3. Covered	43
4. Quartzite, light-gray (in places stained brown and pink), medium-grained	84
5. Dolomite, tan (weathers light grayish brown), fine-grained, slightly calcareous; contains numerous gray chert nodules	15
6. Quartzite, white (in places stained brown)	7
7. Quartzite, light-brown, medium-grained, calcareous	4
8. Quartzite, white (in places stained pink or light brown), fine-grained	178
9. Covered	97
10. Quartzite, same as unit 8	194
11. Covered	58
12. Quartzite, same as unit 8, but has some yellow staining	30
13. Covered	37
14. Quartzite, white (in places stained light yellow and pink), medium-grained	178
15. Covered	56
16. Quartzite, same as unit 8	2
17. Covered	8
18. Quartzite, same as unit 8	4
19. Covered	75
20. Limestone breccia, gray (weathers light gray); some chert fragments	1

Section in the Wells Formation and associated rocks measured on the ridge at the head of North Fork of Canyon Creek in the NW¼ sec. 12, T. 4 N., R. 43 E.—Continued

	Thickness (feet)
Wells Formation—Continued	
21. Quartzite, same as unit 7	27
22. Limestone, gray (weathers light gray), fine-grained, irregularly bedded; a few nodules of gray chert; much fossil debris	10
23. Covered, yellow siltstone float	22
24. Limestone, same as unit 22	8
25. Sandstone, grayish-brown (weathers brown), medium-grained, calcareous; in part crossbedded	14
26. Limestone, brownish-gray (weathers light gray), medium-grained, irregularly bedded; a few elongate gray chert nodules; considerable fossil debris	71
27. Limestone, pink (weathers dull brownish red and yellow), fine-grained, irregularly bedded	1
28. Limestone, same as unit 26; some brachiopods	47
29. Covered	45
30. Limestone, brownish-gray (weathers light gray), medium-grained; fucoids	21
Thickness of Wells Formation	1,338
Rocks of Mississippian (?) age:	
31. Covered	11
32. Shale, black, green, red, and yellowish	11
33. Sandstone, light-brown, medium-grained	3
34. Limestone, light-brown, medium-grained	1
35. Covered	54
Thickness of Mississippian (?) rocks	80
Total thickness of Wells Formation and associated rocks	1,428
Mission Canyon Limestone:	
Limestone, dark-gray (weathers light gray), fine-grained.	

THICKNESS AND CORRELATION

The unit consisting of the Wells Formation and its associated rocks is 1,428 feet thick northeast of the Absaroka fault at the head of North Fork of Canyon Creek. Of this total thickness the Grandeur Member of the Park City Formation makes up 10 feet; the Wells Formation, 1,338 feet; and the variegated shales of Mississippian(?) age, 80 feet. A complete section of the Wells was not found southwest of the Absaroka thrust. On Piney Peak the lower part of the Wells is cut out by the Absaroka thrust and therefore only 1,200 feet of this formation is exposed. The upper limy part of the Wells is 223 feet thick on Piney Peak (E. M. Schell, 1962, written commun.). In the northwestern part of the Garns Mountain quadrangle, the Wells underlies large areas. The Wells is repeated in this part of the quadrangle by several large faults, and measurements from the map indicate that it is at least 2,000 feet thick.

Certain beds in the limestone unit below the massive quartzite in the lower part of the Wells Formation are very fossiliferous. Only one collection has so far been reported on. It came from the limestone unit below the massive quartzite just above the trail in the SE¼ SE¼ sec. 1, T. 3 N., R. 43 E. (loc. F10, pl. 1). This collection, which was identified by J. T. Dutro (1961, written commun.), contained the following:

Rhipidomella sp.
"*Dictyoclostus*" cf. "*D.*" *coloradoensis* Girty
Composita cf. *C. subtilita* (Shepard)
Punctate spiriferoid, indet.

Dutro stated that the fossils are Early or Middle Pennsylvanian in age.

A collection also was made in the variegated shales that underlie the Wells Formation northeast of the Absaroka thrust. This collection, which was made on a small ridge in Packsaddle Basin in the NE¼SW¼ sec. 26, T. 5 N., R. 43 E. (loc. F11, pl. 1), was also examined by J. T. Dutro (1962, written commun.). He identified the following forms:

Orthotetes aff. *O. kaskaskiensis* (McChesney)
Chonetes sp.
Spirifer aff. *S. occiduus* Sadlick
Composita aff. *C. subquadrata* (Hall)
Punctospirifer? sp.

Dutro tentatively assigned a Late Mississippian(?) age to this assemblage, as it is similar to that found in the Mississippian part of the Big Snowy Group in Montana. Thus, the shales beneath the Wells Formation in the Garns Mountain quadrangle are probably of Late Mississippian age and may be tentatively correlated with upper beds of the Amsden Formation. Beds a little above these have been identified as of Pennsylvanian age (J. T. Dutro, 1961, written commun.). No fossils have yet been identified from the upper part of the Wells in this area, but in the vicinity of the Dry Valley anticline in southeastern Idaho, J. E. Heppert and S. J. Reber (Williams, 1962, p. 171) collected Permian fusilinids. Hence, the Wells and associated rocks are of Permian, Pennsylvanian, and Late Mississippian(?) age.

The Wells Formation is equivalent to the Tensleep Sandstone and part of the Amsden Formation of western Wyoming; the Weber Quartzite and the Morgan Formation of northern Utah; the Quadrant Formation of western Montana; and the Wood River Formation of central Idaho (Moore, 1944, chart 6).

ROCKS OF PERMIAN AGE

PHOSPHORIA FORMATION AND ITS STRATIGRAPHIC EQUIVALENTS

NOMENCLATURE AND DISTRIBUTION

The Phosphoria Formation of Permian age was named by Richards and Mansfield (1912, p. 684) for Phosphoria Gulch in the phosphate district of southeastern Idaho. In that area the Phosphoria consists mainly of dark chert, phosphatic and carbonaceous mudstone, phosphorite, cherty mudstone, and minor amounts of dark carbonate rock (McKelvey and others, 1959, p. 20). In other areas carbonates, sandstone, or red beds may predominate and intertongue with chert, phosphorite, and mudstone. Various names have been used for these intertonguing rocks in different areas. Furthermore, the usage of the various names by different authors commonly shows little consistency. An excellent review of the history of the facies and nomenclatures of Permian rocks in the western phosphate field is given by McKelvey and others (1959, p. 5–8). In order to clarify the nomenclature, McKelvey and others proposed that the rocks be identified simply as lithic units and that these units be given names: (1) Phosphoria Formation for phosphatic, carbonaceous, and cherty rocks; (2) Park City Formation for carbonate rock and subordinate sandstone; and (3) Shedhorn Sandstone for sandstone. They also recognized 11 subdivisions of these 3 formations as members. The 11 members have not been found at any one place, and generally not more than 7 are found in any one area.

In the Garns Mountain quadrangle the following seven members have been identified: The Meade Peak Phosphatic Shale, the Rex Chert, and the Retort Phosphatic Shale Members of the Phosphoria Formation; the Grandeur and Franson Members of the Park City Formation; and the lower and upper members of the Shedhorn Sandstone. These seven members have an average total combined thickness of only about 260 feet; hence, mapping of all members at the scale of 1:31,680 was not possible. Furthermore, the most economically important member in this quadrangle is the Meade Peak Phosphatic Shale Member, which is a potential source of phosphate. For the purpose of our work, this member was delineated even though in a few places on the map its thickness was slightly exaggerated. In mapping, we made a threefold division of the seven members. The oldest unit, the Grandeur Member of the Park City Formation, is mapped with the Wells Formation. The overlying part of the Permian is divided into two map units. The lower unit is the Meade Peak Phosphatic Shale Member. The upper unit consists of the Rex Chert Member of the Phosphoria Formation, the Franson Member of the Park City Formation, the lower member of the Shedhorn Sandstone, the Retort Phosphatic Shale Member of the Phosphoria Formation, and the upper member of the Shedhorn Sandstone. Not all the members in the upper unit are found at every locality.

The Phosphoria Formation and its stratigraphic equivalents are found in several areas in the central and northeastern parts of the Garns Mountain quadrangle. The longest outcrop band lies half a mile to about 1½ miles southwest of the Absaroka thrust. This outcrop band, although not entirely continuous, can be traced southeastward from Limekiln Canyon to just southeast of Pine Creek, a distance of almost 13½ miles (pl. 1). The next largest outcrop band lies 0.7–2 miles southwest of the Jackson thrust. It can be traced discontinuously southeastward from Calamity Creek to the east border of the quadrangle, a distance of a little more than 9 miles. Besides these two larger outcrop bands, a few smaller ones occur in fault blocks northeast of the Jackson thrust near the east edge of the quadrangle and south of North Twin Creek.

LITHOLOGY

The Meade Peak Phosphatic Shale Member of the Phosphoria Formation consists mainly of interbedded dark-gray to black phosphorite, phosphatic mudstone, and phosphatic shale (fig. 3). In a few places, minor brown siltstone and dark-gray dolomite are present. The Meade Peak is uniformly thin bedded, fine grained, and poorly exposed. Along ridges, its presence is indicated by float of black phosphorite coated with a pale-blue "phosphate bloom." The top and bottom of the member are generally marked by a few tenths to about a foot of hard black phosphorite made up chiefly of phosphatic shell fragments. The Meade Peak is the principal phosphate-bearing unit in this area and will be discussed more thoroughly in a later section on phosphate resources.

The upper unit is made up of several different lithologies (fig. 3). Black to gray phosphatic mudstone and phosphorite (Retort Phosphatic Shale Member) are found at the top of the unit in areas southwest of the Jackson thrust. Northeast of the thrust, however, a phosphatic sandstone (upper member of the Shedhorn Sandstone) overlies the Retort. Below the Retort and above the Meade Peak Phosphatic Shale Member are interbedded dolomitic limestone, dolomite, sandstone, and chert. Although the thickness and proportion of rock types vary in detail from place to place, many of the thicker units can be traced from section to section (fig. 3). Rocks containing cryptocrystalline silica seem to show the most change, as a little secondary silica can change a sandstone to a chert or a limestone to a cherty limestone. Lithology varies less in the same thrust slice (fig. 3, sections A, B, C,

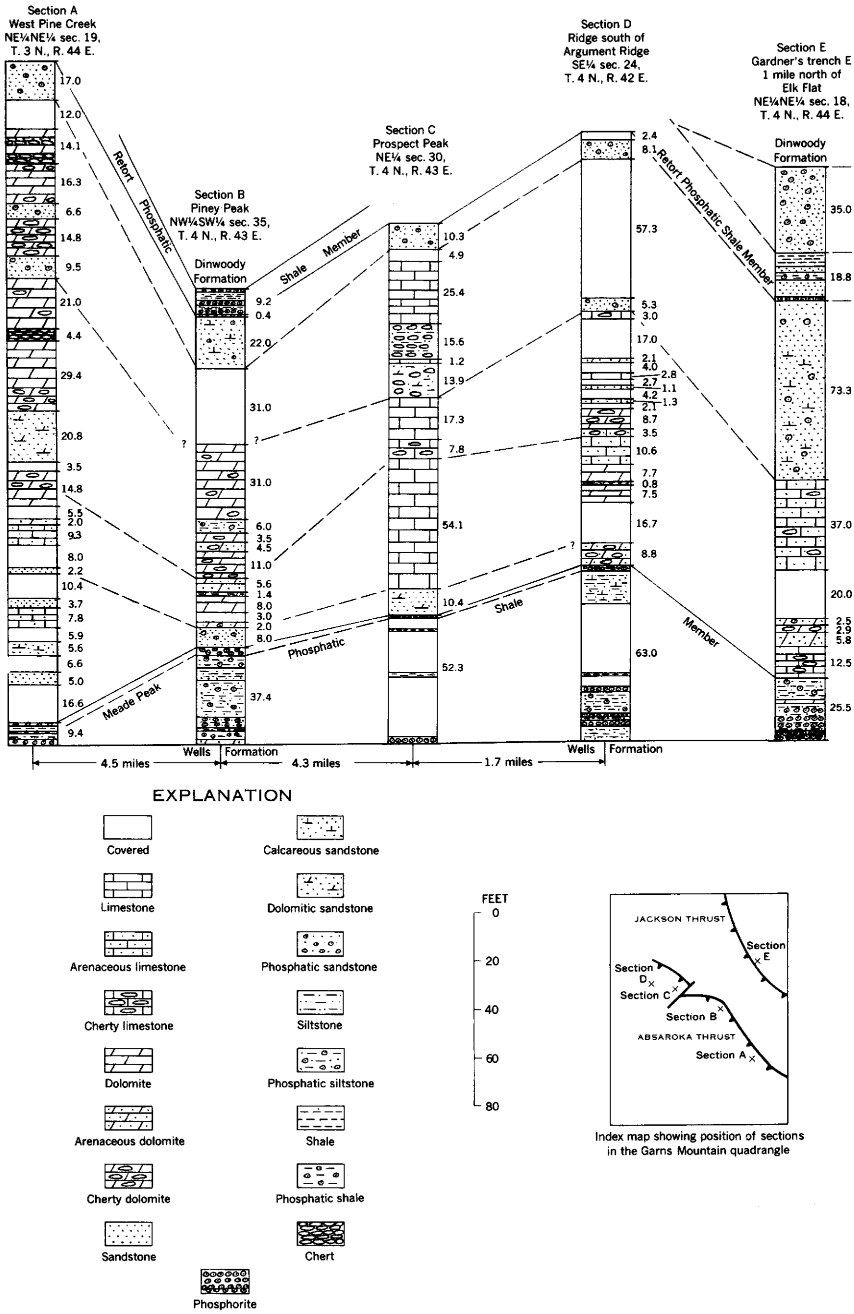

FIGURE 3.—Stratigraphic sections of the Phosphoria Formation and its stratigraphic equivalents in the Garns Mountain quadrangle, Idaho.

and D) than between different thrust slices (compare with section E). The most prominent part in the upper unit is a resistant silicified phosphatic sandstone (lower member of the Shedhorn Sandstone), which underlies the Retort and forms prominent ledges that can be seen from several miles away (fig. 3). This sandstone generally contains 5–20 percent light-brown isotropic apatite and also a little (less than 1 percent) glauconite. The silica in the sandstone is partly in discrete quartz grains and partly in cryptocrystalline silica. The rock seems to be a "hybrid" between a sandstone and a chert.

The carbonate rock is chiefly a light-gray detrital dolomitic limestone or dolomite, and shell debris is common. Some carbonate rock contains a little fine-grained quartz sand, and this rock tends to be light brown. Chert nodules and layers are common in carbonate rock, and in the upper part of this unit, carbonate rock is locally subordinate to chert. At least some carbonate rock was laid down in shallow water, as crossbedding is present in some places. Carbonate rock commonly contains several percent apatite.

In addition to widely scattered discrete grains of apatite in the sandstone and carbonate rocks of the upper unit, a bed of brown phosphorite as much as 10 inches thick is found in some places below the lower member of the Shedhorn Sandstone. This bed, which is well exposed in the roadcut of State Highway 31 along Pine Creek, consists mainly of brown subrounded detrital apatite grains with some quartz and chert grains and a little pale-green chlorite. According to R. P. Sheldon (1962, oral commun.), brown detrital phosphorite is most typical of shallow-water phosphorite deposits formed on the craton.

THICKNESS AND CORRELATION

Measurements of the entire Phosphoria and its stratigraphic equivalents were made only where trenches were available as the Retort Phosphatic Shale Member of the Phosphoria Formation and the lower part of the Dinwoody Formation are rarely exposed. During our mapping, a trenching program under W. C. Gere trenched the Meade Peak and Retort on Piney Peak in the NW¼ sec. 35, T. 4 N., R. 43 E., and on a ridge 1 mile north of Elk Flat in the NE¼ sec. 18, T. 4 N., R. 44 E. (See tables 1, 2, and 3.) This latter locality was on trench E of Gardner (1944, p. 27), of which the Meade Peak part was deepened and remeasured. The Phosphoria and equivalents were measured on Piney Peak by E. M. Schell and Albee and north of Elk Flat by Gere and Albee. In addition, these rocks were trenched and measured on Mahogany Ridge in the NW¼ sec. 22, T. 4 N., R. 44 E., by Sheldon (1963, p. 164–165). The entire Phosphoria Formation and equivalents are 186 feet thick on Piney Peak, 233 feet thick north of Elk Flat, and 209 feet thick on Mahogany Ridge. The Meade Peak made up 40, 25, and 31 feet of the Phosphoria at these three localities; the upper unit made up 146, 208, and 178 feet. In addition, we measured all the Phosphoria and its equivalents except the Retort at three other localities (fig. 3): (1) West Pine Creek, (2) Prospect Peak, and (3) the ridge south of Argument Ridge. At these three localities, the Phosphoria Formation and equivalents are 283, 213, and 250 feet thick, respectively. The Meade Peak at these three localities is 9.4, 52, and 63 feet thick, respectively.

All sections were measured in areas shown by the areal mapping (pl. 1) to be free of either major faults or folds. Small undetected faults, however, could have repeated or omitted a few tens of feet of section. The phosphate members consisting of incompetent argillaceous rocks have been shown in other areas to form zones of weakness along which slippage is common. The thickening of the Meade Peak from 9.4 to 63.0 feet along the Absaroka thrust sheet (fig. 3, sections A, B, C, and D) might be attributed in part to faulting. Furthermore, in southeastern Idaho the Meade Peak shows a general thickening to the southwest toward the center of the geosyncline and remains fairly constant in thickness to the northwest (R. P. Sheldon, 1963, written commun.). We believe, however, that the thickening along the Absaroka thrust sheet is mainly a facies change. The Garns Mountain quadrangle lies along the edge of the geosyncline in the area of greatest facies change, and similar facies change has been noted in other formations. Furthermore, the Meade Peak has a general increase in thickness along strike to the northwest; one would expect a more erratic change along strike, if faulting were the major cause for the thickness change.

Fossils are very scarce in the Phosphoria Formation and its equivalents in the Garns Mountain quadrangle. The only fossils we found came from the top of a phosphatic sandstone a few feet below the Retort Phosphatic Shale Member on the north side of Little Burns Canyon in the NE¼NE¼ sec. 4, T. 3 N., R. 43 E. (loc. F12, pl. 1). At this place, we collected some indeterminate fish remains and a brachiopod identified by E. L. Yochelson and Dianne Van Sickle (1960, written commun.) as *Lingula* sp. Yochelson and Van Sickle noted that similar and similarly preserved fossils are found in the Shedhorn Sandstone on Forellen Peak in northwestern Wyoming.

Although fossils are scarce in the Phosphoria Formation and its equivalents in the Garns Mountain quadrangle, they are common in other areas. Williams (McKelvey and others, 1959, p. 36–41) gave an excellent summary of the fauna and its age; the data indicate that all rocks of Phosphoria age are Permian.

As previously noted, the Phosphoria is at least in part equivalent to and intertongues with the Park City Formation and the Shedhorn Sandstone. It is also equivalent to the Goose Egg Formation of east-central Wyoming and to the Plympton and Gerster Formations of the Confusion Range in west-central Utah (Dunbar and others, 1960, chart 7).

ROCKS OF TRIASSIC AGE

DINWOODY FORMATION

NAME AND DISTRIBUTION

The Dinwoody Formation was named by Blackwelder (1918, p. 425–426) for Dinwoody Canyon on the north slope of the Wind River Mountains.

In the Garns Mountain quadrangle the Dinwoody Formation forms narrow outcrop bands in two general northwestward-trending belts. One of these belts is between two large thrusts and from southeast to northwest lies along Poison Creek, West Pine Creek, and the upper half of Little Burns Canyon (pl. 1). The belt is offset to the north and is found discontinuously from south of Temple Peak to Limekiln Canyon. The other belt, which contains several Dinwoody outcrop bands, extends west from Red Mountain on the east edge of the quadrangle to the North Fork of Canyon Creek (pl. 1).

LITHOLOGY

All the Dinwoody Formation, except the upper 20–40 feet, is made up of thin-bedded fine-grained greenish-brown to olive-drab silty limestone interbedded with greenish-brown to olive-drab calcareous shale and siltstone. Most of the limestone is in beds ½–6 inches thick, although a few beds as much as 3 feet thick occur in the upper part of this formation. Average grain size is about 0.02 millimeter. The rocks vary somewhat in color and may weather tan or brown. Manganese oxide stains are common in some places. All the limestone contains silt-sized quartz grains which, because of their small size, are not easily recognizable in hand specimens. A thin section of a typical limestone contained 20 percent quartz. The Dinwoody-Phosphoria contact is placed between the thin phosphorite or the phosphatic sandstone at the top of the Phosphoria and the first greenish-gray silty limestone and calcareous shale of the Dinwoody.

The upper 20–40 feet of the Dinwoody Formation southwest of the Absaroka fault consists of a dense thick-bedded greenish-brown to brown fine-grained sandy dolomite. The grain size (0.04 mm) is a little larger than that in the underlying limestone. This rock, which contains almost as much quartz as dolomite, forms a resistant unit at the top of the Dinwoody. It closely resembles the sandstone units at the top and bottom of the Thaynes Formation. Northeast of the

Absaroka fault the upper part consists of dense thick-bedded medium- to light-gray fine-grained silty limestone. The Dinwoody, mainly because of its fairly resistant upper unit, commonly forms small ridges, although it rarely caps major ridges. Generally, a small saddle is found at the contact of the Dinwoody and the overlying Woodside Formation.

A detailed stratigraphic section in the Dinwoody Formation measured along the southeast side of Pine Creek is as follows.

Section in the Dinwoody Formation measured along the southeast side of Pine Creek in the SW¼NW¼ sec. 28, T. 3 N., R. 44 E.

[Fossil identified by N. J. Silberling]

	Thickness (feet)
Woodside Formation:	
Covered, red calcareous siltstone float.	
Dinwoody Formation:	
1. Dolomite, greenish-brown (weathers brown), arenaceous, medium-grained, thick-bedded	21
2. Shale, olive-green, calcareous, interbedded with thin beds of greenish-brown silty limestone	26
3. Covered	50
4. Shale, like unit 2	5
5. Limestone, gray (weathers tan), fine-grained, thick-bedded; fossil debris common	4
6. Shale, like unit 2	15
7. Limestone, like unit 5, but has a few inches of shale separating two limestone beds	4
8. Shale, like unit 2	16
9. Limestone light-gray (weathers light brown), fine-grained thin-bedded, with interbeds of greenish-gray shale	9
10. Shale, like unit 2	43
11. Limestone, gray to blue-gray (weathers tan, yellowish brown, or brown), fine-grained, thin- to medium-bedded, interbedded with thin units of greenish-yellow or brown calcareous shale; contains abundant fragments of *Lingula* sp. 25 feet above base of unit	57
12. Covered, but abundant greenish-gray shale float	19
13. Limestone, greenish-brown with some brown mottling, argillaceous, fine-grained, thin-bedded	88
14. Covered	13
Thickness of Dinwoody Formation	370
Phosphoria Formation:	
Sandstone, light-gray (weathers tan), medium-grained, poorly exposed.	

THICKNESS AND CORRELATION

The Dinwoody Formation is 370 feet thick where measured along the southeast side of Pine Creek in the SW¼NW¼ sec. 28, T. 3 N., R. 44 E., and 570 feet thick on Twin Creek ridge in the NE¼NE¼ sec. 16 and the SW¼SW¼ sec. 9, T. 4 N., R. 44 E. It has also been measured in other parts of the Snake River Range, where it is 275 feet thick on the northwest side of Palisade Creek on a southeastward-trending spur of Thompson Peak (D. A. Jobin, 1962, oral commun.); 760 feet thick between Palisade and Trail Creek (Gardner, 1944, p. 8); and 548 feet thick at the south end of the range (Wanless, Belknap, and Foster, 1955, p. 40). The thickness of the Dinwoody varies considerably, and the thicknesses just given do not cover its range, even in the Garns Mountain quadrangle. For example, map measurements indicate that the Dinwoody is about 900 feet thick on the south side of Piney Peak. Southwest of the Snake River Range, the thickness of the Lower Triassic rocks is less erratic and shows a general thickening to the southwest (McKee and others, 1959, pls. 3, 9).

Although fossil debris is common in many parts of the Dinwoody Formation, identifiable fossils are rare in the Garns Mountain quadrangle. The only identifiable fossil was collected from the measured section on Pine Creek. (See p. 38.) This fossil was identified as *Lingula* sp. by N. J. Silberling, who states (1961, written commun.), "Although linguloid brachiopods are not age significant, they are commonly abundant in the Dinwoody Formation." Kummel (1954, p. 182–184) gave an excellent summary of the faunas found in the Dinwoody in other areas; these faunas indicate an early Triassic age for the formation.

Although the Dinwoody Formation is overlain by the Woodside Formation in the Garns Mountain quadrangle, in some areas it is correlative to all or parts of the Woodside. In its type area the Woodside Formation overlies the Park City Formation and underlies the Thaynes Formation (Boutwell, 1907, p. 439); the Dinwoody is found in this interval in some areas of southeastern Idaho (Kummel, 1954, pl. 36). In other areas of southeastern Idaho, the Dinwoody contains tongues of the Woodside (Kummel, 1954, pl. 36). The two formations are separated on the basis of their lithologies. The red-bed sequence is Woodside and the grayish-green limestones and shales are Dinwoody. Thus, in general the Dinwoody is equivalent in age to the Woodside, although in some areas parts of the Dinwoody may be older than the Woodside exposed. In the Garns Mountain area all the Dinwoody underlies all the Woodside, and in this area is, therefore, older.

WOODSIDE FORMATION

NAME AND DISTRIBUTION

This formation was named by Boutwell (1907, p. 446) for exposures in Woodside Gulch in the Park City mining district of northeastern Utah.

In the Garns Mountain quadrangle the Woodside Formation forms narrow outcrop bands in two general northwestward-trending belts in the central and northeastern parts of the Snake River Range (pl. 1). One of these belts extends from the southeast edge of the quadrangle along Poison and West Pine Creeks and the upper part of Little Burns Canyon. The belt is offset to the north by faulting and extends from the south side of Temple Peak to Limekiln Canyon. The other belt extends from the east edge of the quadrangle southeast of Red Mountain to the North Fork of Canyon Creek (pl. 1).

LITHOLOGY

The Woodside Formation is mainly a fairly uniform even-grained hematitic-red calcareous siltstone but has some interbedded hematitic-red shale and in a few places a little sandstone. The formation has little resistance to weathering and is poorly exposed; it weathers to a red soil. The soil formed on the Woodside is very fertile and commonly supports a thick growth of trees. The base of the Woodside is placed at the base of the lowermost hematitic-red siltstone, shale, or soil zone. Along ridges, the base is generally in a small saddle just above the greenish-brown arenaceous dolomite that marks the top of the Dinwoody Formation. Grain size of the siltstone is about 0.04 millimeter. The siltstone consists chiefly of quartz and calcite, most of the calcite being covered by a thin coat of hematite. The siltstone also contains as much as 2 percent magnetite and sericite and trace amounts of apatite, tourmaline, chlorite, and zircon. The sericite is commonly visible in hand specimen.

A detailed section of the Woodside Formation measured along Twin Creek Ridge is given below. Although this section was measured in one of the better exposures of Woodside, only about half the rocks are exposed.

Section in the Woodside Formation measured along Twin Creek Ridge in the SE¼SE¼ sec. 9, T. 4 N., R. 44 E.

	Thickness (feet)
Thaynes Formation:	
Covered, tan soil.	
Woodside Formation:	
1. Covered, red soil	20
2. Siltstone, hematitic-red, calcareous, thin- to medium-bedded	113
3. Siltstone, brownish-gray, calcareous, thin-bedded	2
4. Siltstone, same as unit 2	59
5. Sandstone, light-gray, very fine grained, medium-bedded, calcareous	4
6. Covered, red soil	89
7. Siltstone, light-gray, calcareous	1
8. Siltstone, same as unit 2	22
9. Covered, red soil	100
Thickness of the Woodside Formation	410
Dinwoody Formation:	
Covered, gray soil.	

THICKNESS AND CORRELATION

A complete section of the Woodside Formation on Twin Creek Ridge is 410 feet thick. A partial section of the Woodside on the southeast side of Pine Creek in the SW¼NW¼ sec. 28, T. 3 N., R. 44 E., is 253 feet thick. This section is bounded at the top by a fault, but we estimated that not more than 50 feet of the top of the Woodside was cut out by the fault. Espach and Royse (1960, p. 69–70) also measured the Woodside in the Garns Mountain quadrangle along Mahogany Ridge in the SE¼SW¼ sec. 22, T. 4 N., R. 44 E., where the Woodside is 531 feet thick. Southeastward in the Snake River Range, D. A. Jobin (1962, oral commun.) measured 223 feet of Woodside on the northwest side of Palisade Creek on a southeastward-trending spur of Thompson Peak; Gardner (1944, p. 8) measured 1,130 feet between Palisade and Trail Creeks; and Wanless, Belknap, and Foster (1955, pl. 20) measured 968 feet on Red Creek at the south end of the range. The thickness of the Woodside varies considerably along strike, and map measurements indicate that between Pine Creek and a small ridge 4 miles to the northwest the Dinwoody increases from about 300 to 700 feet in thickness.

Fossils were not found in the Woodside Formation in the Garns Mountain quadrangle, and they are scarce in other areas. The Woodside in this quadrangle is of Early Triassic age as it is between the Dinwoody and Thaynes Formations of established Early Triassic age.

As noted in the preceding section on the Dinwoody Formation, the Woodside Formation in some areas is equivalent to the Dinwoody or parts of it. The Woodside in the Garns Mountain area is equivalent to the upper part of the Dinwoody exposed near Soda Springs in southeastern Idaho (Kummel, 1954, pl. 36). The Woodside in this quadrangle is also equivalent to the lower part of the Moenkopi Formation of eastern Utah (Kummel, 1954, p. 166) and to a part of the Chugwater Formation of central Wyoming.

THAYNES FORMATION

NAME AND DISTRIBUTION

The Thaynes Formation was first described by Boutwell (1907, p. 448–452) from outcrops in Thaynes Canyon in the Park City mining district of northern Utah.

In the Garns Mountain quadrangle the Thaynes Formation is found in four areas in the central and northeastern parts of the Snake River Range. One large area containing several outcrop bands is between the St. John and Absaroka thrust faults (pl. 1), along Poison Creek, West Pine Creek, and the upper part of Black Canyon. A second and smaller area, containing only one outcrop band, trends westward from Temple Peak to Beartrap Canyon. A third area, about 2 miles long and containing only one outcrop band, trends southeastward from

Hinckley Creek. The fourth area, which contains several outcrop bands, is as much as 2½ miles wide and trends northwestward from Red Creek on the east border of the quadrangle for about 9 miles to the North Fork of Canyon Creek (pl. 1).

LITHOLOGY

The Thaynes Formation consists of limestone, silty limestone, and calcareous siltstone. Southwest of the Absaroka thrust, this formation can be divided into five units. These units from bottom to top are: (1) thin-bedded calcareous siltstone, (2) thick-bedded silty limestone and calcareous siltstone, (3) medium- to thick-bedded calcareous siltstone and some red beds, (4) medium-bedded to massive limestone or silty limestone, and (5) thin-bedded calcareous siltstone. Northeast of the Absaroka thrust fault, the calcareous siltstone units are thicker and more common, the limestone units are thinner, and the five units are not so apparent. The base of the Thaynes in eastern Idaho, south of the Snake River, is marked by a limestone bed containing an abundant ammonite fauna characterized by *Meekoceras* (Kummel, 1954, p. 171). Ammonites, however, have not been found in the Thaynes in the Garns Mountain quadrangle. The base of the Thaynes in this area is placed at the base of a thin-bedded brown calcareous siltstone unit just above the red siltstone beds of the Woodside Formation.

The lowest unit (unit 1) in the Thaynes Formation has an average grain size of about 0.07 millimeter and is made up chiefly of quartz and calcite. This unit is only 20–40 feet thick and is rarely exposed.

Unit 2 contains a massive gray silty limestone at the base that commonly weathers chocolate brown but in some places weathers black. Fossil debris is common. The silty limestone is overlain by a massive gray calcareous siltstone or crossbedded sandstone that weathers brown. The sandstone is overlain by poorly exposed interbedded brown-weathering calcareous siltstone and silty limestone. This unit is approximately 200 feet thick.

Unit 3 consists mainly of medium- to thin-bedded brown, tan, light-gray, or yellowish-gray calcareous siltstone and from one to several beds of hematitic-red siltstone near the middle. Along Pine Creek, these red siltstone beds total about 10 feet in thickness, but along the east edge of the quadrangle on Mahogany Ridge, the red siltstone is over 100 feet thick. This thick unit of red siltstone at Mahogany Ridge thins rapidly along strike, and about a mile northwest it is not present. Generally, unit 3 is poorly exposed, although the position of the red siltstone in most places can be determined by red soil. This unit is about 200 feet thick.

Unit 4 is made up mainly of massive to medium-bedded blue-gray limestone interbedded with brown-weathering silty limestone containing considerable fossil debris. Along Pine Creek southwest of its junction with West Pine Creek, this unit is mainly blue-gray limestone; along the east side of Red Mountain, brown-weathering silty limestone makes up at least half of the unit. Where this unit is medium bedded and contains just a little silt, as on the northeast side of Hell Hole Canyon, it may be easily mistaken for the Gallatin Limestone. Northeast of the Absaroka thrust, unit 4 contains many siltstone beds and is difficult to separate from units 3 and 5. This unit southwest of the Absaroka thrust is about 300 feet thick.

Unit 5 is mainly a thin-bedded tan calcareous siltstone. This unit closely resembles unit 1 and, like unit 1, generally is poorly exposed.

A section of the Thaynes Formation measured along Twin Creek Ridge is given as follows.

Section in the Thaynes Formation measured along Twin Creek Ridge in SE¼SW¼ and SW¼SE¼ sec. 9, T. 4 N., R. 44 E.

	Thickness (feet)
Ankareh Formation:	
Covered, red siltstone float.	
Thaynes Formation:	
1. Covered	8
2. Limestone, grayish-pink, brecciated, massive	2
3. Covered	14
4. Limestone, like unit 2	6
5. Covered	28
6. Limestone, like unit 2	2
7. Covered, shale, sandstone, and limestone float	77
8. Siltstone, pink, calcareous	24
9. Siltstone, yellowish-gray, calcareous	15
10. Sandstone, yellowish-gray, very fine grained; forms smooth surface	21
11. Siltstone, light-yellowish	36
12. Limestone, yellowish-gray, medium-bedded	41
13. Limestone, dark-gray (weathers light gray), dense, thick-bedded	17
14. Covered	48
15. Siltstone, light-gray and yellowish-gray, thin-bedded, calcareous	74
16. Covered, yellowish-gray and light-brown shale float	155
17. Siltstone, brown, calcareous	31
18. Limestone, gray with brown spots (weathers white), medium-bedded	11
19. Limestone, medium-gray, oolitic, dense	11
20. Limestone, medium-gray, sandy	18
21. Limestone, dark-gray (weathers white), dense, medium-bedded	28
22. Sandstone, reddish-brown, fine-grained, thin-bedded, calcareous	77
23. Limestone, gray, soft; some pink beds	33
24. Limestone, gray, silty, soft, medium-bedded	6
25. Siltstone, light-gray to yellowish-gray, thin-bedded, calcareous	29
26. Covered, tan soil	28
Thickness of the Thaynes Formation	840
Woodside Formation:	
Covered, red soil.	

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THICKNESS AND CORRELATION

The Thaynes Formation is 840 feet thick where measured on Twin Creek Ridge. Excluding unit 1, the formation is 739 feet thick on the northwest side of Pine Creek at its junction with West Pine Creek; unit 1 is estimated to be about 30 feet thick. In the western part of the Garns Mountain quadrangle, the Thaynes appears to be somewhat thicker, and it may be as much as 1,000 feet thick. Southwest of the quadrangle the Thaynes is 1,000 feet thick between Palisade and Trail Creeks in the central part of the Snake River Range (Gardner, 1944, p. 8) and 1,190 feet thick near Red Creek in the southern part of the range (Wanless, Belknap, and Foster, 1955, pl. 20).

Although fossil fragments are abundant in the limestones in the Thaynes Formation, identifiable fossils were collected at only two localities: along the northwest side of Pine Creek just southwest of West Pine Creek (loc. F13, pl. 1) and on ridge 7507 between Black and Little Burns Canyon in the NE¼ sec. 8, T. 3 N., R. 43 E. (loc. F14, pl. 1). N. J. Silberling identified the fossils. At the Pine Creek locality, several specimens of indeterminate myallinid pelecypods were found in units 3 and 4. A pelecypod, "*Aviculopecten*" cf. "*A.*" *thaynesiana* (Girty) was also found in unit 4. Specimens from the locality between Black and Little Burns Canyons are from unit 4. Silberling identified the following pelecypods:

New genus (?) with affinity to *Mypophoricardium*
"*Aviculopecten*"? cf. "*A.*"? *deseret* Girty
Neoschizodus cf. *N. laevigatus* (Ziethen)
Bakevillia (*Neobakevillia*) sp.

Silberling noted that except for the new genus (?) these pelecypods are well represented in Lower Triassic rocks of the Western Interior of the United States. Worm borings and fucoids have also been found in unit 4. The Thaynes in other areas commonly contains more and better preserved fossils; ammonites are especially prominent. A good discussion on the fossil record is given by Kummel (1954, p. 184–188).

The Thaynes Formation is equivalent in age to part of the Chugwater Formation of central Wyoming and to part of the Moenkopi Formation of eastern Utah and Colorado. Kummel (1954, pl. 34) showed the Thaynes in central Wyoming tonguing out eastward into the Chugwater and in northern Utah tonguing out eastward into the Moenkopi.

ANKAREH FORMATION

NAME AND DISTRIBUTION

The Ankareh Formation was named by Boutwell (1907, p. 452) for a ridge of that name in the Park City mining district, Utah. The name Ankareh Formation has been applied to different parts of the

Triassic of post-Thaynes Formation age in different areas, the name Ankareh being used in some areas for only part of the Ankareh as originally defined by Boutwell and other names being applied to the other parts of the section. In western Wyoming, however, the usage has been fairly standard, and the name Ankareh is applied to all red shale and sandstone lying between the Thaynes and the Nugget Sandstone. Kummel (1954, p. 179), in order to simplify and clarify the nomenclature, proposed that in western Wyoming and northern Utah the name Ankareh be used for all rocks between the Thaynes and Nugget Formations and that all formations that have been proposed for a part of this sequence be reduced to member rank. In the Snake River Range the rocks between the Thaynes and the Nugget form a fairly thin unit consisting mostly of red siltstone.

The Ankareh Formation forms a number of narrow outcrop bands in two main areas. One area is about 2 miles wide and extends from the east border of the quadrangle along Poison Creek, West Pine Creek, to the upper part of Black Canyon. The other area, roughly triangular in shape, extends from the east border of the quadrangle on Red Creek north to North Twin Creek and then west to the North Fork of Canyon Creek (pl. 1). Two small isolated exposures are also found on the northeast side of Hells Hole Canyon.

LITHOLOGY

The Ankareh Formation for the most part consists of a hematitic-red calcareous siltstone that is similar to the red siltstone found in the Woodside Formation. The lower 100 feet of this formation, however, contains intercalated limestone beds less than a foot to about 10 feet thick. The limestone is fine grained. The most distinct of these beds consists of limestone breccia composed of angular fragments ⅛–¾ of an inch long of hematitic-red, limonitic-yellow, dark-brown, and white limestone in a brown limestone matrix. Other limestone beds are a light-gray thin-bedded vuggy limestone and a pink thinly laminated limestone. The limestone is generally somewhat more resistant than the siltstone. The upper 100 feet of the Ankareh contains, in addition to hematitic-red siltstone, some beds of dark-red, purple, green, and gray calcareous and noncalcareous siltstone and a few beds of pink to red silty limestone. A distinctive dark-red silty limestone that contains spheres of pale-green silty limestone ⅛–2 inches in diameter is found in this part of the Ankareh. The pale-green spheres of silty limestone except for containing a little clay are similar in composition to the dark-red silty limestone surrounding them. The difference in color may be due to reduction of small particles of hematite that color the rock red. Because the gray-green siltstone is spherical, the reduction of the hematite in the rock probably took place around a tiny grain of some mineral, possibly a sulfide.

The Ankareh Formation, like the Woodside Formation, is poorly exposed and is commonly covered by a red soil. The uppermost units of the Ankareh, however, weather to a distinctive lavender-pink soil.

THICKNESS AND CORRELATION

The Ankareh Formation is 564 feet thick along the northwest side of Pine Creek southwest of West Pine Creek in the SW¼SW¼ sec. 29, T. 3 N., R 44 E., and 287 feet thick along Twin Creek Ridge in the SE¼SW¼ sec. 9, T. 4 N., R. 44 E. This formation was also measured in the Garns Mountain quadrangle along the headwaters of Mahogany Creek in the SW¼SW¼ sec. 20, T. 4 N., R. 44 E., by Espach and Royse (1960, p. 69), where it is 499 feet thick, and in the Irwin quadrangle in the central part of the Snake River Range between Palisade and Trail Creeks by Gardner (1944, p. 8), where it is 550 feet thick. The Ankareh and other rocks of this same age thicken rapidly to the southwest and are more than 2,000 feet thick near Fort Hall, Idaho (McKee and others, 1959, pl. 4).

Fossils were not found in the Ankareh Formation in the Garns Mountain quadrangle, nor are many found in this red-bed sequence in other areas. Sufficient fossil evidence is not present to date the Ankareh with confidence, but on the basis of stratigraphic correlations it is generally called Early and Late Triassic (McKee and others, 1959, table 1).

The Ankareh Formation, as mapped in the Garns Mountain quadrangle, is equivalent in age to the Higham Grit, the Deadman Limestone, and the Wood Shale of southeastern Idaho in the vicinity of Fort Hall (Kummel, 1954, pl. 34). The Ankareh is also equivalent to parts of the Chugwater Formation of central Wyoming.

ROCKS OF JURASSIC AGE

NUGGET SANDSTONE

NAME AND DISTRIBUTION

The name Nugget was first used by Veatch (1907, p. 56) in southwestern Wyoming for a thick sequence of rocks, consisting of an upper brown sandstone member and a lower red-bed member, that overlie the Thaynes Formation and underlie the Twin Creek Limestone. The same sequence was called Ankareh Shale by Boutwell (1907, p. 452) in his first description of the stratigraphy of the Park City mining district. Later Gale and Richards (1910, p. 479–480) restricted the Nugget to the upper member and applied the name Ankareh to the lower member. This usage was also adopted by

Boutwell (1912, p. 58–59) in a later paper on the Park City district. The name Nugget came from a station of that name on the old Oregon Short Line Railroad.

The Nugget Sandstone forms several narrow outcrop bands in two areas in the Garns Mountain quadrangle. One area, between the Absaroka and St. John thrust faults, extends from the east border of the quadrangle along Poison Creek, West Pine Creek, to the upper part of Black Canyon. The other area is roughly triangular and extends from Red Creek on the east edge of the quadrangle northward to North Twin Creek and then westward to the North Fork of Canyon Creek.

LITHOLOGY

The Nugget Sandstone in most places is a moderate brown sandstone composed of very fine well-sorted quartz grains. The grain size is commonly about 0.1 millimeter. Several thin sections of the Nugget consisted of from 80 to 90 percent angular to subrounded grains of quartz and from 2 to 15 percent feldspar. The feldspar is mainly plagioclase with minor amounts of microcline. Calcite makes up 15 percent of one of the thin sections. Chert, sericite, tourmaline, zircon, biotite, and magnetite are found in some specimens in trace amounts. The Nugget is fairly resistant and commonly caps ridges. In two areas the color of the Nugget changes from the normal brown. On the northwest side of Pine Creek, the upper exposed beds grade into white; and along both sides of Black Canyon in secs. 8 and 17, T. 3 N., R. 43 E., the upper exposed beds are a hematitic red. These red beds are the same color as much of the rock that makes up the Woodside and Ankareh Formations. The rock also differs from the more common Nugget lithology by being calcareous and laminated and by having a slightly smaller grain size.

THICKNESS AND CORRELATION

The Nugget Sandstone was measured near the top of Red Mountain in the SE¼NW¼ sec. 33, T. 4 N., R. 44 E., and on Twin Creek Ridge in the NE¼SW¼ sec. 9, T. 4 N., R. 44 E. At these two places, it is 299 and 255 feet thick, respectively. It was also measured in the Garns Mountain quadrangle by Espach and Royse (1960, p. 68–69) along a small gully in the SW¼SW¼ sec. 20 and the SE¼SE¼ sec. 19, T. 4 N., R. 44 E. Here it is 238 feet thick. In other places in the quadrangle, the thickness of the Nugget changes abruptly, and map measurements indicate that locally the Nugget is at least 520 feet thick. The Nugget has been measured elsewhere in the Snake River Range by D. A. Jobin (1962, oral commun.) on a southeastward-trending spur of Thompson Peak in the central part of the range, where it is 330 feet thick; by Gardner (1944, p. 8) between Palisade and Trail Creeks in the central part of the range, where it is 340 feet thick; and by Wanless, Belknap, and Foster (1955, pl. 36) on Cabin Creek in the southern part of the range, where it is about 260 feet thick. South of the Snake River Range, the Nugget thickens abruptly, and in southeastern Idaho it is as much as 2,000 feet thick (McKee and others, 1956, pl. 4).

Fossils were not found in the Nugget Sandstone in the Garns Mountain quadrangle nor have any diagnostic fossils been found in other areas. The Nugget is overlain by the Twin Creek Limestone, which contains Middle Jurassic fossils, and along the northeast flank of the Wind River Mountains, it overlies the Popo Agie Member of the Chugwater, which contains Late Triassic fossils. The age of the Nugget could, therefore, be wholly Jurassic, wholly Triassic, or both. Oriel, in discussing the Triassic System (in McKee and others, 1959, p. 23), gave an excellent review of this problem. He thought that the boundary between the Triassic and Jurassic most likely lies somewhere within the Nugget. As no concrete faunal evidence exists, however, we do not feel that present evidence is sufficient to change the generally accepted age of the Nugget from Early Jurassic.

The Nugget Sandstone is approximately the same age as the Navajo Sandstone of eastern Utah; the Nugget, however, is probably mainly water laid, and the Navajo, wind deposited (McKee and others, 1959, p. 22–23).

TWIN CREEK LIMESTONE

NAME AND DISTRIBUTION

Veatch (1907, p. 56) named the Twin Creek Limestone for rocks exposed along Twin Creek between Sage and Fossil in southwestern Wyoming.

In the Garns Mountain quadrangle the Twin Creek Limestone forms several lenticular outcrop bands in the northeast quarter of the quadrangle. The Twin Creek was not found southwest of the St. John thrust fault (pl. 1), and most outcrops are northeast of the Absaroka thrust fault. Between these two major thrust faults, the Twin Creek occurs in several fault blocks southeast of Pine Creek. Northeast of the Absaroka thrust the Twin Creek forms a long outcrop band between Canyon Creek on the northwest and Red Creek on the southeast (pl. 1). The Twin Creek is also exposed in the vicinity of Mt. Manning, Twin Creek Ridge, and the North Fork of Mahogany Creek. The two most complete exposures of this formation are at the head of Crag Canyon and along Twin Creek Ridge.

LITHOLOGY

The Twin Creek Limestone is principally a gray fairly thin-bedded limestone. This formation has been divided by Imlay (1953) into seven members (A–G). All seven of these members are found in the Garns Mountain quadrangle, although they are not all present everywhere. The boundaries between the various members at the head of Crag Canyon were pointed out to us by Imlay. The various members of the Twin Creek were not mapped separately as this formation is thin enough that mapping of members is not necessary to outline the structure.

The basal member A is a limestone breccia made up of fragments of light-gray fine-grained limestone, as much as 2 inches across, in a similar limestone matrix. Near the top, this rock contains a few pieces of yellow and pink silty limestone. Member A is generally massive and forms a prominent ledge. It is only 10–15 feet thick in most areas, and, in the northeast corner of the quadrangle, northeast of the Jackson thrust, it is absent.

Member B is a fine-grained gray to light-gray thin- to thick-bedded limestone. Many of the beds are oolitic.

Member C is a fine-grained gray to olive-gray silty limestone. Most of this rock is thin bedded, although some ledges of medium-bedded limestone are present in some areas. The limestone weathers into elongate pencil-shaped splinters, which are characteristic of the Twin Creek Limestone.

Member D consists of calcareous siltstone and very silty limestone. At its base is a gray silty limestone that weathers brown. This limestone is overlain by a hematitic-red siltstone topped by an olive-green siltstone. Member D is easily weathered and commonly covered by a red soil which will in many places aid in locating this member.

Member E consists of fine-grained gray silty limestone that weathers light gray to white. Some of the limestone is thin bedded and weathers to elongate pencil-shaped splinters; it is interbedded with medium-bedded limestone that weathers to blocky-shaped pieces.

Member F consists of a fine-grained gray silty limestone that weathers light gray to white. This member is almost entirely thin bedded and weathers into elongate pencil-shaped splinters.

Member G consists of fine-grained dark-gray or yellowish-gray silty limestone. Some of the beds are oolitic and vary from thin to thick bedded. This member was only noted in the northeast corner of the quadrangle, northeast of the Jackson thrust.

A detailed stratigraphic section of the Twin Creek Limestone measured along the divide at the head of Crag Canyon is given as follows.

Section in the Twin Creek Limestone measured from top of Red Mountain southwestward along the divide at the head of Crag Canyon in the SW¼ sec. 33, T. 4 N., R. 44 E.

[Fossils identified by R. W. Imlay]

	Thickness (feet)
Preuss Sandstone:	
Limestone, light-gray, fine-grained, silty; red bands in upper part.	
Twin Creek Limestone:	
1. Covered	18
2. Limestone, medium-gray (weathers to light gray), fine-grained; fractures into numerous elongate splinters. *Camptonectes* sp. and *Ostrea* sp. collected 10 ft above base of unit; *Gryphaea nebrascensis* Meek and Hayden collected at 145 ft, 240 ft, and 295 ft above base of unit; worm tubes found at 240 ft above base of unit; *Pentacrinus asteriscus* Meek and Hayden, *Trigonia* sp., *Protocardia* sp., *Pronoella*? sp., *Astarte* sp., worm tubes and undetermined gastropods collected at 365 ft above base of unit	444
3. Covered	9
4. Limestone, medium-gray (weathers light gray), fine-grained. Beds that fracture into numerous elongate splinters interbedded with beds that fracture into blocky pieces. Fossil fragments common. *Pronoella*? sp. collected 16 ft above base of unit; *Ostrea* sp. collected 66 ft above base of unit	75
5. Siltstone, pale-olive-green, calcareous	5
6. Siltstone, hematitic-red, noncalcareous, blocky fractured	26
7. Covered	5
8. Limestone, gray (weathers brown along bedding planes), fine-grained, silty; beds platy and about ½ in. thick	21
9. Limestone, same as unit 2. Contains many pelecypods *Pleuromya subcompressa* Meek collected 10 ft above base of unit	81
10. Limestone, black (weathers dark gray), fine-grained; contains *Gryphaea planoconvexa* Whitfield and *Nerinea* sp	0.3
11. Limestone, same as unit 2	61
12. Limestone, gray (weathers light gray with yellow limonitic stains), fine-grained, blocky fracture. Contains numerous pelecypod fragments	4
13. Covered	27
14. Limestone, same as unit 2	11
15. Covered	3
16. Limestone, gray (weathers somewhat lighter), fine-grained; beds 1–1½ ft thick. *Lyosoma powelli* White, *Nerinea* sp., *Ostrea* sp., *Plagiostoma occidentalis* (Hall and Whitfield), *Camptonectes* sp., echinoderm fragments, and worm tubes were collected 33 ft above base of unit	42
17. Covered	15
18. Limestone, same as unit 16. Contains some brachiopod fragments	6
19. Limestone, gray (weathers somewhat lighter with white rodlike bodies), fine-grained, ⅛-in. diameter crystallized calcite; beds 1–8 in. thick	6
20. Limestone breccia; small angular fragments of fine-grained light-gray limestone commonly bordered with chert. Some parts show no brecciation. Some fragments in upper part are yellow and pink silty limestone	12
Thickness of Twin Creek Limestone	871

Nugget Sandstone:

Sandstone, brown, fine-grained, well-sorted.

THICKNESS AND CORRELATION

The Twin Creek Limestone was measured along Twin Creek Ridge in the NW¼SW¼ sec. 9, T. 4 N., R. 44 E., and on the divide at the head of Crag Creek. At these two localities the Twin Creek is 675 and 871 feetthick, respectively. Map measurements indicate that the Twin Creek varies in thickness within the Garns Mountain quadrangle from about 675 to 1,000 feet. Southeast of the quadrangle the Twin Creek has been measured by Gardner (1944, p. 7) on a ridge in the central part of the Snake River Range and by Imlay (1953, p. 61–62) on Cabin Creek at the southeast end of the range. At these two localities the Twin Creek is 970 and 960 feet thick, respectively. The Garns Mountain area was along the northeast edge of a miogeosyncline in Jurassic time. To the north and east lay shallow seas over a broad craton; to the south and west lay the deeper parts of the miogeosyncline. In general, the Twin Creek Limestone thinned to the north and east and thickened to the south and west; at Lower Slide Lake in western Wyoming it is only 410 feet thick (Imlay, 1953, p. 61), but at Thomas Fork Canyon in southwestern Wyoming, it is more than 2,700 feet thick (Imlay, 1950, p. 44–45).

Many fossils were found in members B, C, E, and F of the Twin Creek Limestone. The following fossils (most were collected at loc. F15, pl. 1), which were identified by R. W. Imlay, were found in these members:

Member B:
- *Lyosoma powelli* White
- *Nerinea* sp.
- *Ostrea* sp.
- *Plagiostoma occidentalis* (Hall and Whitfield)
- *Camptonectes* sp.
- Echinoderm fragments
- Worm tubes

Member C:
- *Gryphaea planoconvexa* Whitfield
- *Pleuromya subcompressa* Meek
- *Nerinea* sp.

Member E:
- *Pronoella*? sp.
- *Ostrea* sp.

Member F:
- *Gryphaea nebrascensis* Meek and Hayden
- *Ostrea* sp.
- *Camptonectes* sp.
- *Protocardia* sp.
- *Astarte* sp.
- *Trigonia* sp.

Pronoella ? sp.
Pentacrinus asteriscus Meek and Hayden
Worm tubes
Gastropods, undet.

According to Imlay (1961, written commun.), the presence of *Gryphaea planoconvexa* Whitfield in member C is evidence of Middle Jurassic age. Elsewhere in southeastern Idaho, it has been found only in members B and C of the Twin Creek Limestone. Imlay also noted that the fossil *Gryphaea nebrascensis* Meek and Hayden, found here abundantly in member F, is indicative of late Jurassic age. In other areas, this fossil has been found mainly in member F, although in a few places it has also been found in the upper part of member E.

The Twin Creek Limestone of Middle and Late Jurassic age is equivalent to the Carmel Formation of eastern Utah and the Arapien Shale of central Utah. Member A is called the Gypsum Spring Member of the Twin Creek in west-central Wyoming (Oriel, 1963); the rest of the Twin Creek is equivalent to the "Lower Sundance Formation" of central and eastern Wyoming (Imlay, 1952a, chart 8–c).

PREUSS SANDSTONE

NAME AND DISTRIBUTION

Mansfield and Roundy (1916, p. 81) named the Preuss Sandstone after Preuss Creek in southeastern Idaho. This sandstone occurs in about the same area as the Twin Creek Limestone—mainly in a belt extending from the south end of the Teton Mountains to the south end of the central Wasatch Mountains (Imlay, 1952b, p. 1735).

The Preuss Sandstone is present only northeast of the Absaroka thrust fault in the Garns Mountain quadrangle. Here it forms one long outcrop band extending southeast from Canyon Creek to Red Creek and a faulted outcrop band extending south from Horseshoe Creek to the North Fork of Mahogany Creek.

LITHOLOGY

The Preuss Sandstone consists of a thin lower part of gray fine-grained calcareous siltstone and in places a brown sandstone, and a thicker upper part of brownish- to hematitic-red calcareous siltstone. On Red Mountain the middle of the upper red unit contains a 2-foot bed with ellipsoidal masses of greenish-gray siltstone as much as 3 inches long. Beds in the formation are generally 1–3 feet thick. The Preuss is apparently conformable with both the overlying Stump Sandstone and the underlying Twin Creek Limestone. It weathers easily and crops out only on a few of the better exposed ridges. One of the best exposures of this sandstone is on the ridge extending southwestward from Red Mountain.

THICKNESS AND CORRELATION

The Preuss Sandstone was measured on the ridge extending southwestward from Red Mountain in the SW¼SW¼ sec. 33, T. 4 N., R. 44 E., and on Twin Creek Ridge in the NW¼SW¼ sec. 9, T. 4 N., R. 44 E. At these two places, it is 68 and 21 feet thick, respectively. The Preuss was also measured together with the Stump Sandstone at the mouth of Sweetwater Canyon in the NW¼ sec. 9, T. 4 N., R. 43 E., but a zone equivalent to 62 feet of section was covered at the contact of these two formations. The exposed part of the Preuss at this locality was 35 feet thick. Because of its thinness, the formation was mapped with the overlying Stump Sandstone. The Preuss was also measured in the central part of the Snake River Range on the ridge between Palisade and Trail Creeks by Gardner (1944, p. 7) and at the southeast end of the Snake River Range along Cabin Creek by Wanless, Belknap, and Foster (1955, p. 51). At these two localities, it is 55 and 98 feet thick, respectively. South of the Snake River Range, the Preuss is much thicker, and it is 280 feet thick on Fall Creek in the Caribou Range (Imlay, 1952b, p. 1739); 1,300 feet in southeastern Idaho along the Wyoming border (Mansfield and Roundy, 1916, p. 81); 1,200 feet at the west end of the Uinta Mountains; and 1,270 feet in the central Wasatch Mountains (Imlay, 1952b, p. 1739).

No fossils were found in the Preuss Sandstone in the Garns Mountain quadrangle, and they are scarce in other areas. Fossils found in a limestone in this formation southeast of Idaho Falls, fossils found in adjoining formations, and regional stratigraphic relations caused Imlay (1952b, p. 1747) to conclude that the Preuss is Callovian (Late Jurassic) in age.

The Preuss Sandstone on the basis of stratigraphic position is correlated with part of the Entrada Sandstone of the Colorado Plateau, the Twist Gulch Member of the Arapien Shale of central Utah, and the Lak Member of the Sundance Formation of eastern Wyoming, western South Dakota, and easternmost Montana (Imlay, 1952b, p. 1747).

STUMP SANDSTONE

NAME AND DISTRIBUTION

This formation was named for Stump Peak near the head of Stump Creek in southeastern Idaho by Mansfield and Roundy (1916, p. 81). The Stump Sandstone, found only in western Wyoming, eastern Idaho and northeastern Utah is not as widespread as the Preuss Sandstone and the Twin Creek Limestone.

In the Garns Mountain quadrangle the Stump Sandstone crops out only northeast of the Absaroka thrust fault, where it occurs in two long narrow faulted outcrop bands. One band extends southeastward from Canyon Creek to Red Creek; the other, southward from Horseshoe Creek to the North Fork of Mahogany Creek.

LITHOLOGY

The Stump Sandstone consists mainly of interbedded impure calcareous sandstone, gray and white quartzite, and arenaceous limestone. Its base and its top are marked by light-colored quartzite, which contrasts with the underlying brownish-red siltstone of the Preuss Sandstone and the overlying brown to dark-gray conglomerate of the Ephraim Conglomerate. The upper half of this formation is generally poorly exposed, although the approximate position of the Stump-Ephraim contact is easy to find because of a very resistant and well-exposed conglomerate at the base of the Ephraim. The two best exposed units, which are also the two most distinctive units, are in the lower part of the Stump. The lower of these two units, which is about 23 feet thick, is a gray silty detrital limestone that weathers brown and contains a little glauconite in its upper part. Its principal distinguishing feature is conspicuous crossbedding. The overlying unit is an olive-green impure "salt and pepper" calcareous sandstone. The green color is due to 1–4 percent glauconite. The sandstone is fairly well sorted and has an average grain size of about 0.2 millimeter. Detrital grains are subangular to rounded. Quartz is generally the most common mineral, although in some specimens calcite is almost as common. Chert in small black grains is abundant, and minor amounts of magnetite, plagioclase, apatite, chlorite, zircon, and glauconite make up the other minerals of the sandstone. The apatite here is the varietal form collophane and occurs in brown isotropic oolites.

A detailed stratigraphic section of the Stump Sandstone was measured on the southwest side of Red Mountain and is given as follows.

Section in the Stump Sandstone measured on the southwest side of Red Mountain on a ridge in the SW¼SW¼ sec. 33 and in the SE¼SE¼ sec. 32, T. 4 N., R. 44 E.

	Thickness (feet)
Ephraim Conglomerate:	
Conglomerate, gray, hard; contains chert and quartz pebbles.	
Stump Sandstone:	
1. Quartzite, white, hard, crossbedded; has a few pebbles in places	2
2. Covered	9
3. Limestone, gray (weathers light brown), silty; fine-grained	8
4. Siltstone, khaki-brown, calcareous	6
5. Quartzite, medium-grained, feldspathic; beds 3 in. to 1 ft thick	2
6. Siltstone, khaki-brown	8
7. Quartzite, same as unit 5	2
8. Siltstone, same as unit 6	7
9. Quartzite, same as unit 5	11

Section in the Stump Sandstone measured on the southwest side of Red Mountain on a ridge in the SW¼SW¼ sec. 33 and in the SE¼SE¼ sec. 32, T. 4 N., R. 44 E.—Continued

Stump Sandstone—Continued	*Thickness (feet)*
10. Covered	11
11. Shale, hematitic-red, noncalcareous	2
12. Covered	15
13. Limestone, gray (weathers cream to pale brown), lithographic, silty; fractures into thin splinter-shaped pieces	17
14. Covered	24
15. Sandstone, olive-green, fine-grained, calcareous, glauconitic; contains many black chert grains; in slabby beds 1–8 in. thick	3
16. Covered	18
17. Sandstone, hemattic-red, fine-grained, calcareous, glauconitic; contains many black chert grains; in beds 1–8 in. thick	2
18. Sandstone, same as unit 15	27
19. Siltstone, greenish-gray, calcareous; contains some glauconite; in beds 2 in. to 1 ft thick	23
20. Limestone, gray (weathers light brown), fine-grained, silty, conspicuously crossbedded; contains a little glauconite in upper part, in beds 1–4 ft thick	33
21. Covered	9
22. Quartzite, light olive-gray with small brown mottling, fine-grained, calcareous	11
Thickness of Stump Sandstone	250

Preuss Sandstone:

Siltstone, brownish-red, calcareous.

THICKNESS AND CORRELATION

The Stump Sandstone was measured along the southwest side of Red Mountain in the SW¼SW¼ sec. 33 and the SE¼SE¼ sec. 32, T. 3 N., R. 44 E., where it is 250 feet thick, and along Twin Creek Ridge in the NW¼SW¼ sec. 9, T. 4 N., R. 44 E., where it is 186 feet thick. It has also been measured together with the Preuss Sandstone at the mouth of Sweetwater Canyon in the NW¼ sec. 9, T. 4 N., R. 43 E., where the two formations are 340 feet thick. The contact between the two is covered, but the Stump has a minimum thickness of 243 feet. The Stump has also been measured by Gardner (1944, p. 7) on the ridge between Trail and Palisade Creeks in the central part of the Snake River Range and by Wanless, Belknap, and Foster (1955, p. 51) along Cabin Creek at the southeast end of the Snake River Range. At those two localities it is 140 and 105 feet thick, respectively.

Fossils have not been found in the Stump Sandstone in the Garns Mountain quadrangle, and elsewhere are generally uncommon. Locally, within the limestones, however, such forms as *Ostrea*, *Gryphaea*, *Meleagrinella*, and rhynchonellid brachiopods are common. *Cardioceras* has also been found, and this fossil is found only in rocks of middle Late Jurassic (Oxfordian) age (Imlay, 1950, p. 41).

Eastward the Stump Sandstone passes into the "Upper Sundance Formation" of central Wyoming. In Montana the Stump is equivalent to the Swift Formation, and in Utah it is equivalent to the Curtis Formation (Imlay, 1950, p. 41–42).

ROCKS OF CRETACEOUS AGE

GANNETT GROUP

Mansfield and Roundy (1916, p. 82) proposed the name Gannett Group for a sequence of conglomerate, sandstone, and limestone that overlies the Stump Sandstone and underlies the Bear River Formation. This group was named after the Gannett Hills, which lie in the eastern part of Caribou County, Idaho and the western part of Lincoln County, Wyo. Mansfield and Roundy divided this group into five formations which, from top to bottom, are: (1) Tygee Sandstone, (2) Draney Limestone, (3) Bechler Conglomerate, (4) Peterson Limestone, and (5) Ephraim Conglomerate. W. W. Rubey (quoted in Cobban and Reeside, 1952a, p. 1030) has noted, however, that the sandstone called Tygee is not a part of the Gannett Group but actually is a unit equivalent to the lower part of the Bear River Formation. In the Garns Mountain quadrangle the lower four formations have been recognized. Equivalents to the Tygee Sandstone probably make up all or part of the unit mapped as the lower part of the Bear River Formation.

The Gannett Group crops out in the Garns Mountain quadrangle in two outcrop bands on the northeast side of the Absaroka thrust fault. One of these bands is southwest of the Jackson thrust and extends from Red Creek northwest to Canyon Creek; the other is northeast of the Jackson thrust and extends south from Horseshoe Creek to the North Fork of Mahogany Creek. The four formations of the Gannett Group are mapped separately southwest of the Jackson thrust (fig. 4) except at the very northwest end, where, owing to poor exposures, the formations could not be separated. The southwesternmost band of Gannett thins to the northwest. Near the southeast end of this band between Chicken and Holter Creeks, the Gannett Group is 769 feet thick; near the northwest end of this band, it is 579 feet thick. The Gannett Group is considerably thinner in the outcrop band northeast of the Jackson thrust where, on a spur of Twin Creek Ridge, it is 256 feet thick.

EPHRAIM CONGLOMERATE

Ephraim Conglomerate is the name given by Mansfield and Roundy (1916, p. 82) to about 1,000 feet of red conglomerate and minor amounts of sandstone and a few thin layers of gray to purplish-red limestone exposed in Ephraim Valley in sec. 36, T. 10 S., R. 45 E., Boise Meridian. North and east of the type locality, the formation thins abruptly and becomes finer grained (Moritz, 1953, p. 66).

The Ephraim has a resistant conglomerate, as much as 50 feet thick, at its base. This conglomerate forms a prominent ridge (fig. 4) that makes an excellent marker bed. The conglomerate is the most resistant rock in the quadrangle, and pieces of it more than a foot in diameter are found as float 10 miles downstream from the nearest outcrop. The conglomerate is composed of well-rounded pebbles chiefly of light- to dark-gray chert as much as 1 inch in diameter. A few pebbles of vein quartz are also present. These pebbles are set in a matrix of fine- to medium-grained gray quartzite. Locally, the conglomerate contains lenses of white to gray crossbedded quartzite.

The Ephraim above the conglomerate consists of about 250–300 feet of purplish- to hematitic-red siltstone that contains interbedded fine- to medium-grained white, gray, or red quartzite in the lower part and fine-grained gray limestone in the upper part. Northwest of the Jackson thrust, limestone was not found in the upper part. The rocks above the basal conglomerate are much less resistant than the basal conglomerate, and they are not nearly as well exposed. The top of the Ephraim was placed at the top of the highest red siltstone below the light-gray lithographic limestone that makes up the Peterson Limestone.

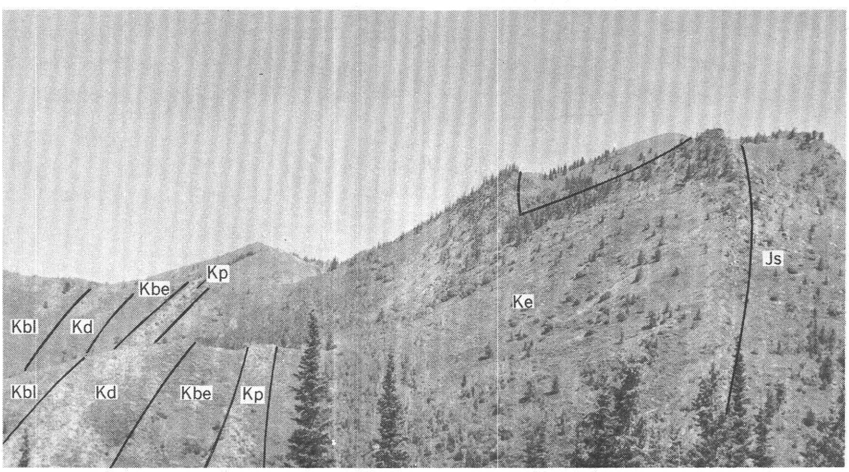

FIGURE 4.—Formations of the Gannett Group exposed on the northwest side of Holter Creek. To the right can be seen parts of the underlying Stump Sandstone (Js) and to the left, the overlying lower member of the Bear River Formation (Kbl). Ke, Ephraim Conglomerate; Kp, Peterson Limestone; Kbe, Bechler Formation; and Kd, Draney Limestone.

The siltstone is made up chiefly of quartz but has a little chert and plagioclase and some calcite. A thin layer of clay is common along the margins of the grains, and this clay is generally admixed with hematite giving the rock its color. Trace amounts of tourmaline, zircon, apatite, and sericite are found in many specimens. The quartzites in addition to quartz contain as much as 15 percent chert; some also contain calcite. Other minerals that make up very minor amounts of the quartzite are plagioclase, apatite, clay, zircon, magnetite, and tourmaline. The apatite is sedimentary in origin and, in thin section, is pale brown, is isotropic, and most commonly occurs in oval-shaped grains. The limestone is generally fine grained, although there are a few thin breccias made of fine-grained gray limestone pieces and oolites in a fine-grained gray limestone matrix. Most of the limestone is silty, containing about 10 percent silt-sized quartz and feldspar.

Detailed stratigraphy of the Ephraim Conglomerate between Chicken and Holter Creeks is given as follows.

Section in the Ephraim Conglomerate measured along the ridge between Chicken and Holter Creeks in the NW¼SE¼ and the NE¼SW¼ sec. 32 T. 4 N., R 44 E.

	Thickness (feet)
Peterson Limestone:	
Limestone, light-gray, lithographic; conchoidal fracture.	
Ephraim Conglomerate:	
1. Covered, red siltstone float	20
2. Siltstone, purplish-red, interbedded with beds as much as 8 in. thick of fine-grained gray limestone containing an irregular network of red siltstone	16
3. Covered	11
4. Siltstone, same as unit 2	10
5. Siltstone, purplish-red	6
6. Siltstone breccia, red, calcareous; fragments as much as ¼ in. in diameter	1
7. Siltstone, hematitic-red and gray, calcareous, resistant	1
8. Covered	23
9. Limestone breccia, gray (weathers tan); about 8 percent limestone fragments in a limestone matrix	11
10. Covered	41
11. Siltstone, gray, silicified	24
12. Quartzite, hematitic-red, fine-grained	19
13. Quartzite, gray, fine-grained	10
14. Covered	15
15. Quartzite, purplish-red, medium-grained; less than 1 percent muscovite	13
16. Quartzite, gray, medium-grained; less than 1 percent muscovite	3
17. Covered	10
18. Quartzite, same as unit 13	2
19. Covered	14
20. Quartzite, same as unit 13	8
21. Covered	10

Section in the Ephriam Conglomerate measured along the ridge between Chicken and Holter Creeks in the NW¼SE¼ and the NE¼SW¼ sec. 32 T. 4 N., R. 44 E.—Continued

	Thickness (feet)
Ephraim Conglomerate—Continued	
22. Quartzite, white, medium-grained, resistant, in places crossbedded	24
23. Siltstone, same as unit 5	2
24. Quartzite, same as unit 22	14
25. Covered	21
26. Conglomerate, gray; consists of well-rounded pebbles of light- to dark-gray chert and a few pebbles of white quartz veins; local lenses of white to gray crossbedded quartzite	24
Thickness of Ephraim Conglomerate	353
Stump Sandstone:	
Quartzite, white, crossbedded.	

The Ephraim Conglomerate is 353 feet thick betwen Chicken and Holter Creeks, 305 feet thick on the ridge on the west side of Sweetwater Canyon in the SW¼NW¼ sec. 9, T. 4 N., R. 43 E., and 125 feet thick on a spur of Twin Creek Ridge in the SW¼SW¼ sec. 8, T. 4 N., R. 44 E. Gardner (1944, p. 7) found the Ephraim to be 535 feet thick in the central part of the Snake River Range between Palisade and Trail Creeks.

Fossils were not found in the Ephraim Conglomerate in the Garns Mountain quadrangle. The Gannett Group as a whole, on the basis of fresh-water fossils in the Peterson and Draney Limestones, has been considered Late Jurassic and Early Cretaceous (Mansfield, 1952, p. 39). The Gannett is now considered to be of Early Cretaceous age.

PETERSON LIMESTONE

Mansfield and Roundy (1916, p. 82) named the Peterson Limestone after Peterson Ranch on Tygee Creek in sec. 34, T. 7 S., R. 46 E., Boise Meridian.

The greater part of the Peterson Limestone is a light-gray lithographic limestone that has a conchoidal fracture. Some beds weather tan, and one light-gray bed, 25 feet above the base of the formation on the southwest side of Red Mountain, has pale-brownish-gray mottling. A little silt is found locally in the upper part of this formation. The Peterson forms a prominent ledge between the soft siltstones in the Ephraim Conglomerate and the overlying Bechler Formation (fig. 4). The limestone has conspicuous joints that strike parallel to the bedding but dip almost at right angles to it. As the bedding is commonly poorly exposed, the joint surfaces are easily mistaken for the bedding.

The Peterson Limestone was measured on a ridge between Chicken and Holter Creeks in the SE¼SE¼ sec. 32, T. 4 N., R. 44 E., and on the ridge on the west side of Sweetwater Canyon in the SW¼NW¼ sec. 9, T. 4 N., R. 43 E. At these two places, it is 84 and 50 feet thick, respectively. In the central part of the Snake River Range, on a ridge between Palisade and Trail Creeks, Gardner (1944, p. 7) found the Peterson to be 125 feet thick.

Fossils were not found in the Peterson Limestone in the Garns Mountain quadrangle. Nonmarine mollusks, however, collected from the Peterson in other parts of southeastern Idaho, including the type area, are similar to fossils found in the Kootenai and Bear River Formations of Early Cretaceous age (Mansfield, 1952, p. 42–43). Charophytes and ostracodes collected in eastern Idaho and westernmost Wyoming also indicate that this formation is of Early Cretaceous age (Peck, 1941, p. 287).

The Peterson Limestone is equivalent at least in part to the lower part of the Cloverly Formation of central and eastern Wyoming, the Lakota Sandstone of northeastern Wyoming and South Dakota, and the lower part of the Kootenai Formation of Montana (Cobban and Reeside, 1952a, chart 10b).

BECHLER FORMATION

Mansfield and Roundy (1916, p. 82–83) gave the name Bechler Conglomerate to a sequence of rocks about 1,700 feet thick exposed at Bechler Creek in Bannock County, Idaho; this sequence consists of gray, hematitic-red, and "salt and pepper" conglomerate interbedded with sandstone. Conglomerate is about twice as abundant as sandstone in the formation at the type section. North and east of the type section, however, the Bechler thins abruptly, and shale, siltstone, and sandstone are more abundant (Moritz, 1953, p. 68). Gardner (1944, p. 7) found only fine-grained clastics in a section he measured in the central part of the Snake River Range; he referred to this section as the Bechler Shale. In the Garns Mountain quadrangle the Bechler is made up predominatly of interbedded siltstone and limestone, although some quartzite is present. The diversity of rock types found in this formation and the change from one type to another in different areas suggest that the name Bechler Formation is more applicable to this rock unit.

The Bechler Formation in the Garns Mountain quadrangle is made up mainly of interbedded hematitic-red siltstone and fine-grained light-gray to hematitic-red limestone. The limestone contains some detrital calcite, quartz, and chert. In the upper 35 feet of this formation, siltstone is interbedded with quartzite. This formation is not resistant to weathering and on ridges commonly forms a small swale between the more resistant Peterson and Draney Limestones (fig. 4). A detailed section of this formation is given as follows.

Section in the Bechler Formation measured on the ridge between Chicken and Holter Creeks in the SE¼SW¼ sec. 32, T. 4 N., R. 44 E.

	Thickness (feet)
Draney Limestone:	
Limestone, light-gray, lithographic; conchoidal fracture.	
Bechler Formation:	
1. Siltstone, reddish-gray with gray mottling in places, calcareous	5
2. Covered	4
3. Quartzite, light-gray, medium-grained, calcareous	12
4. Siltstone, hematitic-red; irregular lenses and pods of gray limestone breccia	8
5. Quartzite, gray to reddish-gray with gray and reddish-gray mottlings, medium-grained; in places crossbedded	9
6. Siltstone, hematitic-red	2
7. Quartzite, same as unit 5 except not mottled	3
8. Covered, red siltstone float	8
9. Limestone, light-gray, fine-grained; in part a limestone breccia	1
10. Covered	12
11. Limestone, mottled light-gray and hematitic-red, silty; splintery fractures	14
12. Limestone, same as unit 9	8
13. Siltstone, mottled gray and hematitic-red, calcareous	6
14. Covered, red siltstone float	35
Thickness of Bechler Formation	127
Peterson Limestone:	
Limestone, light-gray, lithographic; conchoidal fracture.	

The Bechler Formation is 127 feet thick on the ridge between Chicken and Holter Creeks and 111 feet thick on the ridge on the west side of Sweetwater Canyon in the SW¼NW¼ sec. 9, T. 4 N., R. 43 E. The Bechler has also been measured in the central part of the Snake River Range between Palisade and Trail Creeks by Gardner (1944, p. 7); here it is 35 feet thick.

Fossils have not been found in the Bechler Formation in the Garns Mountain quadrangle. The age of this formation, however, is Early Cretaceous as it lies between the Peterson and Draney Limestones which contain fossils of Early Cretaceous age.

The Bechler Formation is equivalent at least in part to the Cloverly Formation of central and eastern Wyoming, the Inyan Kara Group of northeastern Wyoming and South Dakota, and the Kootenai Formation of Montana (Cobban and Reeside, 1952a, chart 10b).

DRANEY LIMESTONE

The name Draney Limestone was given to a 200-foot-thick gray limestone unit that overlies the Bechler Conglomerate at Draney Ranch on Tygee Creek in sec. 10, T. 8 S., R. 46 E., Boise Meridian (Mansfield and Roundy, 1916, p. 83).

The Draney is a light-gray lithographic limestone that breaks with a conchoidal fracture. The upper part commonly weathers tan. In places, this limestone contains a small amount of detrital silt-sized grains of quartz, chert, and calcite. It forms a prominent ledge between the softer siltstones and sandstones of the Bechler and Bear River Formations (fig. 4). The lower part has conspicuous joints that strike parallel to the bedding and dip in the opposite direction. The joints are evenly spaced, and the joint surfaces can be easily mistaken for bedding. In hand specimen the Draney Limestone can not be distinguished from the Peterson Limestone; the two are mapped separately only where the Bechler Formation is present.

The Draney Limestone was measured at two places: southwest of Red Mountain between Chicken and Holter Creeks in the SE¼SW¼ sec. 32, T. 4 N., R. 44 E., and on the ridge to the west of Sweetwater Canyon in the SW¼NW¼ sec. 9, T. 4 N., R. 43 E. At these two localities, it is 205 and 114 feet thick, respectively. Gardner (1944, p. 7) also measured the Draney in the central part of the Snake River Range on the ridge between Palisade and Trail Creeks. Here it is 245 feet thick.

The only fossils found in the Draney Limestone in the Garns Mountain quadrangle were some poorly preserved gastropods, which were collected 20 feet below the Draney Limestone-Bear River Formation contact on the ridge between Chicken Creek and the next creek to the southeast (loc. F16, pl. 1). These specimens are identifiable only as probable fresh-water species (D. W. Taylor, 1962, written commun.). Fresh-water mollusks were collected from this formation in the type area in southeastern Idaho by Mansfield and Roundy (1916, p. 83); and charophytes and ostracodes, in southeastern Idaho and westernmost Wyoming by Peck (1941, p. 287). These fossils indicate that the Draney is Early Cretaceous in age.

The Draney Limestone is equivalent to the upper part of the Cloverly Formation of central and eastern Wyoming, at least part of the Fuson Member of the Lakota Formation of northeastern Wyoming and South Dakota, and to the upper part of the Kootenai Formation of Montana (Cobban and Reeside, 1952a, chart 10b).

BEAR RIVER FORMATION

NAME AND DISTRIBUTION

The name Bear River was first used by Hayden (1869, p. 91–92) for a thick sequence of sedimentary rocks of fresh- and brackish-water origin in the vicinity of Bear River City, Wyo. These rocks consist of shale, sandstone, limestone, clay, and marl. The Bear River Formation is fairly local in extent and is found chiefly in the thrust belt zone in westernmost Wyoming and in the Snake River Range in Idaho.

The Bear River Formation in the Garns Mountain quadrangle is found in three areas, all northeast of the Absaroka thrust (pl. 1). First, the Bear River forms a broad outcrop band extending northwestward from the east border of the quadrangle along the North Fork of Pine Creek drainage to Blacktail Pass. Second, the Bear River is exposed for about 1½ miles on Canyon Creek and the lower part of Hilton Creek. Third, the Bear River occurs in a narrow outcrop band on the northeast side of the Jackson thrust from the headwaters of North Mahogany Creek northward to the Mikesell mine on the north boundary of the quadrangle.

LITHOLOGY

The Bear River Formation differs greatly in lithology and thickness on the two sides of the Jackson thrust. On the northeast side, it is made up chiefly of sandstone and some black shale and is about one-fifth as thick as on the southwest side. The Bear River on the southwest side of the Jackson thrust is mainly interbedded dark-greenish-gray sandstone and shale. The formation is divided into two members (pl. 1): the upper member, which makes up about two-thirds of the formation, consists principally of shale with lesser amounts of interbedded sandstone; and the lower member consists principally of sandstone with lesser amounts of interbedded shale. The sandstone is mainly fine grained, although some of it is medium grained; silt-sized grains were found in a few beds. Most of the sandstone is olive gray or greenish gray, but some beds are light gray or gray, and some beds weather yellowish brown or brown. The sandstone is made up principally of white quartz and dark- to light-gray chert. Quartz is generally predominant although in some beds chert is more abundant. White quartz grains or light-gray chert grains with darker gray chert grains give the rock a speckled or "salt and pepper" appearance. A small amount of calcite may be present, and small amounts of feldspar, generally plagioclase, are common. Some of the sandstone contains as much as 15 percent feldspar. Other minerals found in minor to trace amounts are clay, zircon, biotite, and magnetite. The sandstone is commonly crossbedded and generally forms ledges, especially in the lower member.

The shale is greenish gray, olive gray, light gray, gray, and black. Although both Gardner (1944, p. 7) and Kiilsgaard (1951, p. 12) referred to all the shale as black, black shale is comparatively scarce, and most of the shale is greenish gray and weathers yellowish gray. Some of the shale is calcareous. The black shale is generally carbonaceous. In the vicinity of Horseshoe Creek, thin seams of coaly carbonaceous material as much as a few inches thick are found in some black shale.

In addition to the sandstone and shale, a few thin limestone beds are found in some areas. The limestone beds are gray, olive gray, or brownish gray, and some weather brown. These beds are rarely more than 1 foot thick, are fine grained, generally argillaceous, and are discontinuous along strike.

The base of the Bear River Formation is placed at the base of the first greenish-gray sandstone that overlies the light-gray lithographic Draney Limestone.

A detailed stratigraphic section of the Bear River Formation measured on the southwest side of the Jackson thrust along a ridge that forms Piney Pass (pl. 1) is given as follows.

Section in the Bear River Formation measured along the ridge that forms Piney Pass in the western parts of secs. 24 and 25, T. 4 N., R. 43 E.

Aspen Shale:
Sandstone, gray, fine- to medium-grained, poorly sorted, thick-bedded, well-cemented, crossbedded.

Bear River Formation:	*Thickness (feet)*
Upper member:	
1. Shale, greenish-gray (weathers yellowish gray), calcareous	8
2. Sandstone, gray (weathers brown), fine-grained, "salt and pepper"—composed principally of angular grains of white quartz and black chert, calcareous	3
3. Shale, greenish-gray (weathers yellowish gray), with numerous thin interbeds of sandstone	179
4. Sandstone, light-gray, "salt and pepper," fine-grained; some biotite	1
5. Shale, greenish-gray	10
6. Sandstone, olive-gray (weathers light greenish gray), fine-grained	1
7. Covered	16
8. Sandstone, like unit 6	5
9. Shale, like unit 1	14
10. Sandstone, olive-gray (weathers brownish gray), medium-grained, calcareous, hard	1
11. Covered	121
12. Shale, greenish-gray, slightly calcareous	12
13. Sandstone, greenish-gray, fine-grained, poorly sorted, calcareous	2
14. Shale, olive-gray (weathers yellowish gray)	29
15. Sandstone, greenish-gray (weathers brownish gray), medium grained, thin-bedded; composed of subangular grains of milky quartz, black chert, and a little biotite	17
16. Shale, like unit 1	7
17. Sandstone, like unit 2, thick-bedded	17
18. Shale, gray, calcareous	47

Section in the Bear River Formation measured along the ridge that forms Piney Pass in the western parts of secs. 24 and 25, T. 4 N., R. 43 E.—Continued

	Thickness (feet)
Bear River Formation—Continued	
Upper member—Continued	
19. Sandstone, gray (weathers brownish gray), fine-grained, calcareous, thin-bedded	14
20. Shale, green, calcareous; 1-foot-thick brown-weathering limestone bed in center	37
21. Shale, light-gray, calcareous, interbedded with olive-gray dense shaly limestone	12
22. Sandstone, light-gray, "salt and pepper," calcareous	4
23. Sandstone, light-gray, "salt and pepper," very fine grained, calcareous, interbedded with dark-gray calcareous siltstone	19
24. Covered	165
25. Shale, dark-gray (weathers grayish brown), slightly calcareous	15
26. Sandstone, gray, "salt and pepper," medium-grained, thin-bedded	31
27. Covered	40
28. Sandstone, dark yellowish-brown (weathers gray), medium-grained, thin bedded; composed of angular grains of quartz	31
29. Covered	87
30. Sandstone, greenish-gray, medium-grained, thin-bedded	4
31. Covered, shale float	49
Thickness of upper member	998
Lower member:	
32. Sandstone, light-yellowish-gray, fine- to medium-grained, thin-bedded; composed mainly of quartz grains	239
33. Covered	156
34. Sandstone, light-gray, medium-grained, resistant; composed mainly of angular grains of white quartz and black chert	42
35. Sandstone, gray (weathers brownish red), fine-grained, thick-bedded; composed mainly of clear quartz	128
36. Covered	16
Thickness of lower member	581
Total thickness of Bear River Formation	1, 579
Draney Limestone:	
Limestone, light-gray, lithographic; conchoidal fracture.	

THICKNESS AND CORRELATION

The Bear River Formation was measured in two places about 2½ miles apart. It is 1,579 feet thick along the ridge that forms Piney Pass on the southwest side of the Jackson thrust and 329 feet thick along Twin Creek Ridge in the SW¼SW¼ sec. 8, T. 4 N., R. 44 E., on the northeast side of the Jackson thrust. The tremendous thinning of the Bear River across the Jackson thrust is probably due to a large amount of movement along the thrust in an area of fairly abrupt facies change. The Bear River was also measured in the central part of the Snake River Range by Gardner (1944, p. 7), who obtained a thickness measurement of 880 feet.

The only fossils found in the Bear River Formation in the Garns Mountain quadrangle were collected along the northwestward-trending ridge between Horseshoe Creek and the Mikesell mine. Three collections (loc. F17–F19, pl. 1) were made along this ridge in a distance of 2 miles. These collections were identified by D. W. Taylor and W. A. Cobban, and contained the following:

Loxopleurus belliplicatus (Meek)
Corbicula sp.
Pyrgulifera humerosa Meek

Taylor noted that these fossils are characteristic of the Bear River Formation and of a fresh-water environment. The age of the Bear River according to Cobban and Reeside (1952a, chart 10b) is latest Early Cretaceous.

The Bear River Formation is equivalent in age to the Thermopolis Shale, the uppermost sandstone member of the Cloverly Formation of central Wyoming, and to the uppermost part of the Dakota Sandstone of western Colorado (Cobban and Reeside, 1952a, chart 10b).

ASPEN SHALE

NAME AND DISTRIBUTION

The Aspen Shale was named by Veatch (1907, p. 64) for exposures near Aspen Station on the Union Pacific Railroad in southwestern Wyoming. The Aspen is fairly local in extent and lies mostly within the Wyoming-Idaho thrust belt zone between the Absaroka thrust on the west and southwest and the edge of this zone on the east and northeast.

In the Garns Mountain quadrangle the Aspen Shale crops out in three areas, all northeast of the Absaroka thrust (pl. 1). The first is a broad outcrop band extending from the east border of the quadrangle northwestward along the drainage of North Fork of Pine Creek and to the east end of Thousand Springs Valley in the upper part of the Burns Canyon drainage. The second is a somewhat narrower outcrop band that extends from the headwaters of North Fork of Mahogany Creek northward to the Mikesell mine on the north boundary of the quadrangle. The third is less than one-eighth of a square mile in area, where the Aspen is exposed beneath the volcanic rocks on the lower part of Hilton Creek.

LITHOLOGY

The Aspen Shale consists of shale interbedded with sandstone, siltstone, subgraywacke, porcellanite, and limestone. Porcellanite, an impure chert, characterizes this formation and distinguishes it from the other rocks of Cretaceous age. The other rocks of the Aspen Shale are also commonly silicified or partly silicified, and all gradations are found from clastic rock to porcellanite.

The porcellanite is cryptocrystalline quartz and varies from light gray to greenish gray, dark gray, or pink. Some of it is speckled. Microscopic examination of the sandstone in the Aspen revealed shards and indicates that much of the sandstone is tuffaceous. One welded tuff bed was also noted. The porcellanite, as well as the partly silicified clastic rocks, has probably formed by silica being leached from tuffs and redeposited in certain beds. The silicification and the fine-grain size make it extremely difficult to distinguish the tuffaceous sedimentary rocks from the nontuffaceous ones in hand specimen. We noted, however, that in many places fracture surfaces were coated with thin seams of an orange mineral. X-ray diffraction patterns indicated this mineral to be the zeolite, heulandite (A. O. Shepard, 1964, oral commun.). As zeolites are generally associated with volcanic rocks, the heulandite probably formed by leaching of volcanic material. The heulandite is secondary, and the distance it has been transported by solutions since leaching is not known. To determine if the distance was small, thin sections were made of five rock specimens which contained seams of heulandite. Four of these specimens contained recognizable glass shards. The presence of orange heulandite seams in a rock, hence, is suggestive that the particular rock is tuffaceous.

In gross aspect the sandstone and siltstone, where unsilicified, are greenish gray to gray. In detail, however, they resemble a mixture of salt and pepper because of the abundant white quartz and dark-gray chert grains. In addition to the silica minerals, the sandstone and siltstone commonly contain considerable feldspar, especially plagioclase. Some of the rocks are cemented with calcite. Other minerals in minor amounts include biotite, tourmaline, zircon, hornblende, and glauconite. The sandstone and siltstone grade into subgraywacke as feldspar increases and a little chlorite or sericite is formed in the matrix. No true graywacke occurs here, however, because the sandstone and the siltstone are too well sorted and the chloritic and sericitic matrix makes up too little of the rocks. Where these rocks are silicified or partly silicified, they are lighter in color—many are a light gray—and they form prominent ledges. Generally, the matrix is silicified first.

Nonsilicified shale in the Aspen is chiefly greenish gray or olive gray, and some of it is calcareous. Commonly, however, most shale is silicified or partly silicified and is light to dark gray. Shale is the most common rock type and is poorly exposed except where it is silicified.

Thin limestone beds a few inches to 2 feet thick are found in some areas in the lower part of the Aspen Shale. The limestone is generally fine grained, light gray to pinkish gray, and argillaceous. It weathers to a rusty brown. In some places as many as five limestone beds are in the lower part of the Aspen; in other places there is no limestone.

The Aspen Shale differs from the other Cretaceous rocks in having tuffaceous material, partly silicified clastic rocks, and porcellanite. The Aspen thus forms a fairly resistant unit between two less resistant ones. The lower boundary of the Aspen is placed at the first prominent sandstone ledge below the lowest porcellanite. Our lower contact is probably close to but apparently not the same as that used by Kiilsgaard (1951, p. 14) and Espach and Royse (1960, p. 66). According to their sections, they used one of the thin discontinuous limestone beds as the base of the Aspen.

A detailed section of the Aspen Shale was measured along a ridge north of Piney Peak and is given as follows.

Section in the Aspen Shale measured along a ridge north of Piney Peak from the south-central part of sec. 23 to the central part of sec. 26, T. 4 N., R. 43 E.

Frontier Formation:

Sandstone, brown, medium-grained, crossbedded; made up principally of quartz, chert, and feldspar grains.

	Thickness (feet)
Aspen Shale:	
1. Covered	115
2. Sandstone, light-gray, medium- to coarse-grained, thick-bedded, calcareous; grains mainly of gray and black chert	10
3. Covered, some greenish-gray shale float	170
4. Shale with porcellanite, light-gray, poorly exposed	157
5. Sandstone, grayish-brown (weathers light gray), fine-grained, thick-bedded; composed mainly of chert grains, some biotite	37
6. Porcellanite, light-gray, thick-bedded	38
7. Shale, greenish-gray with interbeds of light-gray porcellanite	46
8. Porcellanite, light-gray, interbedded with light-gray shale and sandstone	53
9. Sandstone, light-gray, very fine grained, well-cemented, thick-bedded	14
10. Shale, light-olive-gray, calcareous	43
11. Sandstone, light-gray, "salt and pepper," slightly calcareous	20
12. Sandstone, light-gray, "salt and pepper," slightly calcareous, interbedded with light-greenish-gray shale	78

Section in the Aspen Shale measured along a ridge north of Piney Peak from the south-central part of sec. 23 to the central part of sec. 26, T. 4 N., R. 43 E.—Continued

	Thickness (feet)
Aspen Shale—Continued	
13. Shale, dark-green, with interbeds of black to gray porcellanite and fine-grained olive-gray well-cemented calcareous sandstone made up principally of gray and black chert grains	152
14. Covered	52
15. Sandstone, olive-gray (weathers yellowish orange), medium- to coarse-grained, crossbedded; composed of subrounded quartz and chert grains	22
16. Siltstone, dark-greenish-gray (weathers to reddish brown), massive	11
17. Sandstone, brownish-orange (weathers to a yellowish brown), medium- grained, massive, crossbedded; composed mainly of quartz and black and white chert	40
18. Shale, greenish-gray	25
19. Sandstone, greenish-gray, medium-grained; composed mainly of chert and quartz	6
20. Sandstone, olive-gray (weathers brownish yellow with brown spots), fine- to medium-grained, poorly sorted, crossbedded; composed mainly of chert and quartz	8
21. Covered, sandstone, shale, and porcellanite float	60
22. Shale, green	9
23. Porcellanite, light-gray (in places weathers to brownish orange)	20
24. Shale interbedded with sandstone	25
25. Porcellanite, light-gray with worm-shaped gray markings	14
26. Covered, some porcellanite float	41
27. Sandstone interbedded with shale, like unit 12 except not calcareous	82
28. Covered, some porcellanite float	23
29. Sandstone interbedded with shale, like unit 12	348
30. Covered, green shale float	17
31. Sandstone, gray (weathers light gray), medium- to coarse-grained, slightly calcareous; composed principally of light- to dark-gray chert and white quartz	4
32. Covered	23
33. Shale, dark-gray, with a few thin interbeds of gray porcellanite	34
34. Sandstone, olive-gray (weathers light gray), medium- to coarse-grained; composed principally of angular pink and white chert and clear quartz grains	5
35. Covered, shale, sandstone, and porcellanite float	102
36. Shale, green	7
37. Sandstone, gray, "salt and pepper," fine-grained, thick-bedded, calcareous	3
38. Covered, shale, sandstone, and porcellanite float	150
39. Shale, greenish-gray, calcareous, with thin interbeds of sandstone	44
40. Sandstone, like unit 37	55
41. Shale, olive-gray, interbedded with "salt and pepper" sandstone	21
42. Shale, dark-olive-gray (weathers light olive gray)	6
43. Sandstone, light-brown (weathers light gray), coarse-grained, poorly sorted; composed of angular grains of milky quartz and light- to dark-gray chert	50

Section in the Aspen Shale measured along a ridge north of Piney Peak from the south-central part of sec. 23 to the central part of sec. 26, T. 4 N., R. 43 E.—Continued

	Thickness (feet)
Aspen Shale—Continued	
44. Covered	196
45. Shale, greenish-gray, slightly calcareous, with a few interbeds of light-gray "salt and pepper" sandstone	76
46. Sandstone, like unit 11	17
47. Shale, greenish-gray; contains limestone nodules in many places	23
48. Shale with interbedded light- to dark-gray porcellanite	26
49. Sandstone, gray, fine- to medium-grained, poorly sorted, well-cemented, thick-bedded, crossbedded; composed principally of angular grains of white quartz and black chert	24
Thickness of the Aspen Shale	2, 602
Bear River Formation:	
Shale, greenish-gray (weathers yellowish gray), calcareous.	

THICKNESS AND CORRELATION

We measured 2,602 feet of Aspen Shale on the southwest side of the Jackson thrust along a ridge on the north side of Piney Peak. The Aspen was also measured in the Garns Mountain quadrangle by Kiilsgaard (1951, p. 14) on the northeast side of the Jackson thrust from the highest point on the ridge in the NW¼NE¼ sec. 30, T. 5 N., R. 44 E., to the mouth of Irene Creek. Here it is 1,725 feet thick. The Aspen is 2,015 feet thick southeast of the quadrangle in the central part of the Snake River Range (Gardner, 1944, p. 6).

Fossils are scarce in the Aspen Shale exposed in the Garns Mountain quadrangle; only plant fossils were found. W. W. Rubey (1961, written commun.) in 1934 collected the fern *Tempskya* near the base of the Aspen on the ridge top in the SE¼SW¼ sec. 19, T. 5 N., R. 44 E. (loc. F20, pl. 1). About a quarter of a mile farther north at approximately the same horizon, he found fragments of coniferous(?) wood. We were unable to find any *Tempskya*, but found wood (loc. F20, pl. 1) which, according to R. A. Scott (1962, written commun.), was from a conifer and probably belongs to the family Cupressacae. In an article on *Tempskya*, Read and Ash (1961, p. 254) stated that, "Re-examination of earlier information on the stratigraphic occurrences of the various species of *Tempskya* and consideration of new discoveries indicate that the age of the genus is more restricted than was formerly thought, and that in the western part of the United States it is restricted to strata that are Albian (uppermost Early Cretaceous) in age." We also found some ferns on the top of a hill in the NW¼NE¼ sec. 28, T. 4 N., R. 43 E. (loc. F21, pl. 1). These came from about 300 feet below the top of the Aspen. The following ferns were identified by J. A. Wolfe (1961, written commun.):

Microtaenia variabilis Knowlton
Anemia fremonti Knowlton
Dennstaedtia? fremonti Knowlton

Wolfe noted that the first two species are known from both the Frontier Formation and the Aspen Shale and that the last has previously been found only in the Frontier. However, he also added that very little is known about floras of "Coloradan" age and that this collection could be interpreted as belonging either to the Aspen or Frontier.

The *Tempskya* is the most diagnostic fossil found in the Aspen Shale in this area and indicates that at least the lower part of the shale is latest Early Cretaceous in age.

The Aspen Shale is equivalent in age to the Mowry Shale of central Wyoming and to the lower part of the Wayan Formation of southeastern Idaho (Cobban and Reeside, 1952a, chart 10b).

FRONTIER FORMATION

NAME AND DISTRIBUTION

The Frontier Formation was named by Knight (1902, p. 721) for exposures near a small coal mining town in southeastern Wyoming.

The Frontier Formation in the Garns Mountain quadrangle is found only northeast of the Absaroka thrust, where it forms three outcrop bands: (1) adjacent to the Absaroka thrust between Pine Creek on the east edge of the quadrangle and Thousand Springs Valley to the northwest, (2) between the Mahogany Creek and the Mount Manning thrusts in the Horseshoe Creek area, and (3) adjoining the Mount Manning thrust on the northeast between the east and north edges of the quadrangle.

LITHOLOGY

The Frontier Formation is the youngest Mesozoic formation in the Garns Mountain quadrangle. At no place is the entire formation present, as the upper part has been cut out by thrusting. The Frontier consists mainly of a thick interlayered sequence of sandstone, siltstone, and shale. The sandstone and siltstone are brown, grayish brown, greenish gray, or olive green, and the shale is generally gray or olive green. Many of these rocks are calcareous and generally composed of fairly well sorted grains. Some of the sandstone is crossbedded, and, in a few places, some of the bedding planes are ripple marked. The sandstone is principally quartz and chert, the ratio of quartz to chert changing from bed to bed. Where the chert is black, the sandstone has a speckled appearance. Feldspar is commonly present in minor amounts, but in a few beds, including the bed at the base of the Frontier, feldspar makes up more than 15 percent of the rock. Calcite interstitial to the detrital silica grains is common in many beds. Other minerals, found generally in very minor amounts, include biotite, magnetite, chalcedony, zircon, chlorite, and amphibole.

In addition to these more common rock types, conglomerate and coal beds are found in some places. Conglomerate occurs discontinuously in the basal bed of the Frontier Formation and at several other horizons. The conglomerate consists mainly of well-rounded pebbles as much as 2 inches in diameter in a sandstone matrix. The pebbles are composed mainly of black or gray chert but include minor white quartz, limestone, or sandstone. The conglomerate beds help to distinguish the Frontier from the Aspen Shale and the Bear River Formation, as conglomerate has not been found in these two formations in this area.

In the Horseshoe Creek area, several coal and carbonaceous shale beds are found in a 1,000-foot-thick sequence of gray to buff sandstone, siltstone, and shale approximately 3,000 feet above the base of the Frontier Formation. These beds range in thickness from less than an inch to more than 10 feet. The coal is described in a later section (p. 110).

The base of the Frontier Formation is marked by a 50- to 70-foot feldspathic sandstone that is one of the most prominent beds in this formation. Generally, this sandstone is a ridge former, and in most places it is not calcareous. It lies about 20 feet above the highest known porcellanite. Conglomerate occurs locally in the basal sandstone. The conglomerate may be traced from a few feet to a quarter of a mile along strike. Although the conglomeratic facies of this bed appears and disappears along strike, the sandstone itself is continuous. Above this sandstone is a fairly thick poorly exposed sequence composed mainly of buff calcareous shale.

The Frontier Formation is easily weathered and in most places is covered with colluvium. It is the most friable and most poorly exposed formation in this area.

THICKNESS AND CORRELATION

As the upper part of the Frontier Formation is not present in this area, the total thickness of this formation is not known. North of the Absaroka thrust on the north side of Piney Peak, we measured 2,615 feet. Kiilsgaard (1951, p. 15–16) measured 3,903 feet of Frontier on a ridge above the Idaho mine where both the top and the bottom of the formation have been removed by faulting.

Uncontorted and unbroken fossils are exceedingly scarce in the Frontier Formation in the Garns Mountain quadrangle. We found identifiable fossils at only one locality, about 1,500 feet above the base of the Frontier on a ridge near the center of the south line of sec. 24, T. 5 N., R. 43 E. (loc. F22, pl. 1). W. A. Cobban (1962, written commun.) identified the fossils as *Ostrea* sp. and *Protodonax* sp. Cobban noted that the pelecypod, *Protodonax*, is a marine form known throughout the Colorado Group from shallow-water nearshore sandstones.

In western Wyoming the Frontier Formation has numerous fossils, which indicate that the Frontier is Late Cretaceous in age (Cobban and Reeside, 1952b, p. 1957–1958).

The Frontier Formation is equivalent to the lower part of the Colorado Shale of Montana and to the Dakota Sandstone and the lower part of the Mancos Shale of Utah and Colorado (Cobban and Reeside, 1952a, chart 10b).

ROCKS OF TERTIARY AGE

Rocks of Tertiary age include two conglomerate units, here designated as older conglomerate and younger conglomerate, and the Kirkham Hollow Volcanics, a new name introduced in this report. The two conglomerates are of local extent; the older one is found in small mountain valleys, and the younger one is found both in the small valleys and in the wide valley of the Snake River. Material for the conglomerate units came from the adjacent mountains. The Kirkham Hollow Volcanics is mainly salic welded tuff but includes some flows. These volcanics extend around the north end of the Snake River Range and are similar to volcanics found in Jackson Hole and Yellowstone Park.

OLDER CONGLOMERATE

A conglomerate of early or middle Tertiary age is found in five areas in the Garns Mountain quadrangle where local basins received material from the mountains that bordered them. Three long lenticular basins that contain conglomerate are in the southeastern part of the quadrangle; they range in size from about half a mile long and an average width of 175 feet to more than a mile long and an average width of 300 feet. The largest of these basins is partly in the neighboring Driggs quadrangle. All three basins lie along the traces of thrusts. The older conglomerate was deposited in valleys carved along these traces. The other two basins are in the northern and northwestern part of the quadrangle, and the conglomerate is in part covered by the Kirkham Hollow Volcanics. The largest of the two basins is an irregularly shaped area adjacent to Moody Meadow (pl. 1); the conglomerate here is also in part along a fault. The other basin contains three patches of conglomerate showing through the Kirkham Hollow Volcanics just east of Warm Creek. The conglomerate unconformably overlies rocks ranging in age from Mississippian to Jurassic. In the southeastern part of the quadrangle, where in places the attitude of the conglomerate can be seen, the conglomerate strikes and dips in the same direction as the older underlying Paleozoic and Mesozoic sedimentary rocks. In two of the basins (pl. 1), the conglomerate dips very gently southwestward, and the dip ranges from 30° to 60° less than that of the underlying rocks; in the other basin, the conglomerate dips moderately southwest, and the dip varies by only a few to 20 degrees from that of the underlying rocks.

The conglomerate is made up of subangular to rounded fragments set in a tan to red fine-grained matrix. The fragments range in size from pebbles ⅛ of an inch in diameter to boulders 4 feet in diameter; most, however, are from ½ to 3 inches in diameter. They consist of gray and brown limestone, red and yellow siltstone, and white quartzite. The fragments were derived mostly from the Thaynes, Woodside, Dinwoody, and Wells Formations. The matrix is calcareous and easily weathered. Exposures of older conglomerate are poor; generally areas underlain by the conglomerate form smooth slopes covered with red soil dotted with pebbles and boulders of limestone and siltstone.

The older conglomerate was formed during a period of uplift and tilting. As some of the conglomerate was deposited in valleys carved along thrust faults, it is younger than at least part of the thrusting. Because the strike and dip of the conglomerate is the same as that of the older rocks, they both were deformed by the same forces. The dip of the conglomerate, however, is less than that of the older rocks, indicating that the conglomerate was deposited during the later part of the regional movement.

The age of the older conglomerate is Tertiary and most likely early or middle Tertiary. This age is indicated by exposures along the eastern part of Mike Spencer Canyon where the older conglomerate overlies the St. John thrust fault, which is probably post-Paleocene in age (Love, 1956a, p. 143). The older conglomerate is older than the younger conglomerate, which is at least in part middle Pliocene in age (Merritt, 1956, p. 119).

YOUNGER CONGLOMERATE

A conglomerate of late Tertiary age is exposed discontinuously along the Snake River Plain from a point 1½ miles west of the Garns Mountain quadrangle to Alpine at the junction of the Snake and Salt Rivers 29 miles southeast of the quadrangle. South of Alpine this conglomerate is found along the Salt River in Star Valley. In the Garns Mountain quadrangle, the conglomerate is found along the present gorge of the Snake River, in terraces as much as 1,000 feet high and 4,700 feet wide bordering the southwest edge of the Snake River Range (pl. 1), and in a northwest-trending band lying along the bottoms of No Cut Timber and Canal Canyons. Although in several places along the Snake River the conglomerate forms steep cliffs (fig. 5) as much as 250 feet high, in most places it weathers easily, and the terrace tops are now covered with a blanket of colluvium.

The younger conglomerate fills valleys cut in Mission Canyon Limestone in No Cut Timber and Canal Canyons, and it is in turn channeled and overlain by basalt at several places along the Snake River. The conglomerate and Kirkham Hollow Volcanics have not been found together in the Garns Mountain quadrangle, but about 2½ miles southwest of the quadrangle on a hill in the NW¼ sec. 29, T. 2 N., R. 42 E., welded tuff of the Kirkham Hollow Volcanics unconformably overlies the conglomerate.

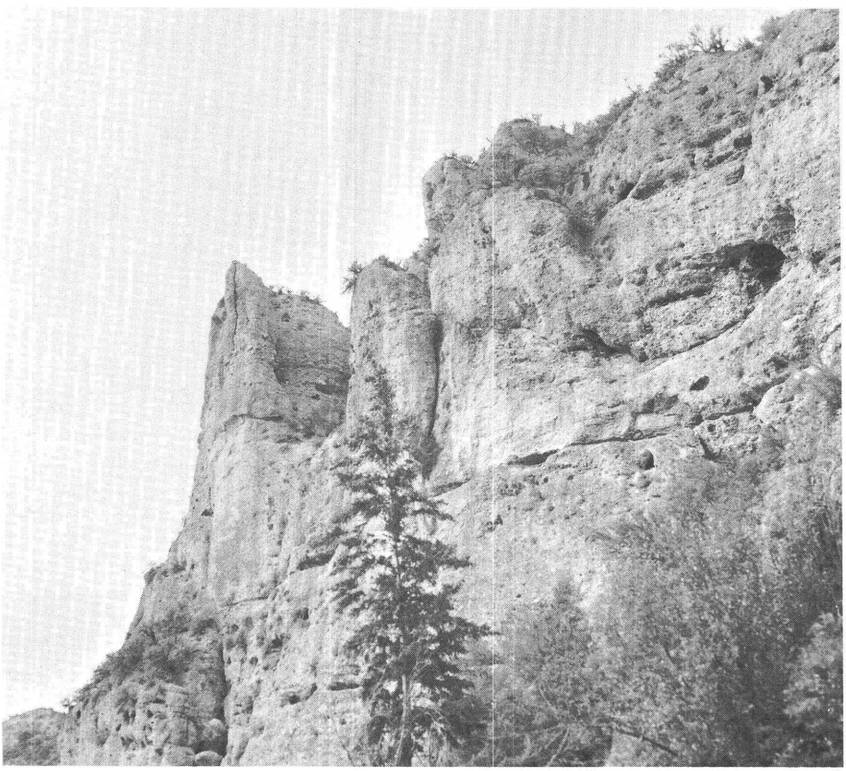

FIGURE 5.—Cliff of younger conglomerate on east side of the Snake River near the mouth of Black Canyon.

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The younger conglomerate is a thick cobble conglomerate (fig. 6) which has here and there a few beds and lenses of sandstone. This rock is generally light brown, although in places it may be gray or pale pink. The color depends on the amount of red siltstone ground up in the matrix. Pebbles and cobbles are subangular to well rounded and range in diameter from 1/8 of an inch to 3½ feet, although most of them are less than 6 inches in diameter (fig. 6). Many beds are fairly well sorted, the cobbles all being fairly uniform in size, but other beds show little or no sorting. The cobbles are mostly gray limestone (fig. 6) derived from either the Mission Canyon or Lodgepole Limestone. Pieces of white quartzite from the Wells Formation, however, are common; in some places they may make up as much as 35 percent of some beds but in other places they are absent. A few pieces of red siltstone from the Woodside or Ankareh Formations are commonly scattered through the conglomerate. In addition to the rocks already mentioned, cobbles of limestone from the Thaynes, Dinwoody, Gallatin, and Gros Ventre Formations have been identified.

A matrix of calcareous fine-grained sand or silt commonly makes up 10–25 percent of the younger conglomerate. In some places the con-

FIGURE 6.—Younger conglomerate. Most of the boulders are limestone, some quartzite, and a few smaller ones are siltstone. Matrix is a calcareous sand. Large boulder in upper left hand corner of picture is 1½ feet in diameter.

glomerate is cemented by the matrix into a hard mass which forms prominent outcrops, but in other places the rock is poorly cemented and is almost a loose gravel.

The age of the conglomerate is middle Pliocene or younger. Southwest of Alpine the conglomerate is underlain by a thick sequence of tuff, pumicite, and clayey siltstone (Merritt, 1956, p. 118). Near the center of this sequence, fragments of jaws and teeth of two rodents, *Pliosaccomys* sp. and *Peromyscus* sp., and one mustilid, *Martinogale* sp., were found (Merritt, 1956, p. 119). *Pliosaccomys* and *Martinogale* are both restricted to the middle Pliocene, and *Peromyscus* is known from lower Pliocene to Recent. The rocks that overlie this conglomerate, the Kirkham Hollow Volcanics and basalt, have not been dated.

KIRKHAM HOLLOW VOLCANICS

NAME AND DISTRIBUTION

The Kirkham Hollow Volcanics is named here for rocks exposed along both sides of Kirkham Hollow in the northwestern part of the Garns Mountain quadrangle. These volcanic rocks encircle the northwest end of the Snake River Range and are found in places along the South Fork and the Henry's Fork of the Snake River and along the Teton River. In the Garns Mountain quadrangle the Kirkham Hollow directly underlies most of the northwest quarter of the quadrangle, a strip along the northeast corner of the quadrangle, and a small area in the southwest corner of the quadrangle. In addition, a remnant of this unit about 250 feet long was found on the north side of Pine Creek about half a mile northeast of its junction with the North Fork of Pine Creek. North and northwest of the Garns Mountain quadrangle, the Kirkham Hollow Volcanics makes up most of the exposed rock in the Snake River Range; eastward in the Driggs quadrangle, this unit is found in scattered patches along the sides of Teton Valley.

Outcrops of the Kirkham Hollow Volcanics are best along the sides of steep canyons, such as those of Canyon Creek, Calamity Creek, and Kirkham Hollow. Ridges underlain by this unit are generally gently rounded, and exposures are few. This rock weathers easily to a fertile soil, which commonly supports a thick growth of lodgepole pines. A complete section of this flat-lying formation is not exposed in the Garns Mountain quadrangle; some of the best exposures are found along the drainage of Canyon Creek, which is designated the type area.

Within the Garns Mountain quadrangle the Kirkham Hollow Volcanics was deposited on an eroded surface carved on older rocks ranging from Mississippian to Late Cretaceous in age. On the south side of Limekiln Canyon, this volcanic unit overlies the Mission Canyon

Limestone of Mississippian age; and at the northwest end of Thousand Springs Valley, along Packsaddle Creek, and north of North Twin Creek, this unit overlies the Frontier Formation of Late Cretaceous age. About 2½ miles southwest of the quadrangle, the Kirkham Hollow Volcanics unconformably overlies the younger conglomerate.

LITHOLOGY

The Kirkham Hollow Volcanics is made up largely of welded tuff but includes interlayered flows. In a few small areas, volcanic breccia was noted.

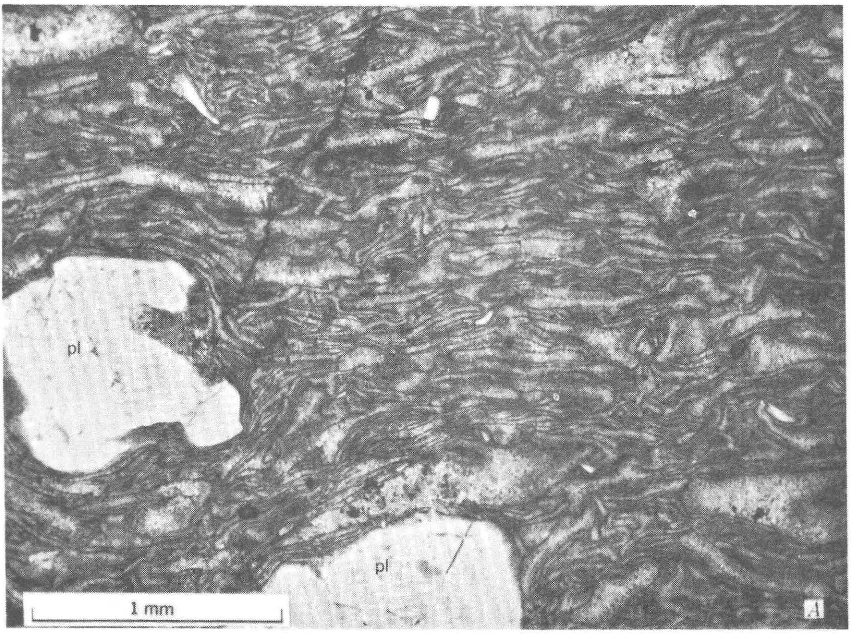
The welded tuff is most commonly light gray, but many specimens are gray, yellowish gray, brownish gray, purplish brown, brown, or black. Rock fragments are visible in less than 10 percent of the rock, but where present, they make up from a fraction of 1 percent to 20 percent of the rock. Most fragments are small and commonly elongate pieces of glass or tuff similar to that of the rest of the rock. One specimen, however, in addition to volcanic rock fragments contained fragments of siltstone and poorly sorted sandstone.

Crystal fragments are generally much more common than rock fragments; they make up from 2 to 35 percent of the welded tuff and average about 15 percent. The tuff, hence, is a welded crystal tuff. The crystal fragments range from anhedral to euhedral, and commonly they are broken pieces of euhedral crystals. The felsic minerals, andesine, sanidine, and quartz, make up the greater part of the crystal fragments; mafic minerals rarely make up as much as 1 percent of the tuff. The amounts of individual minerals vary widely from one place to another. Andesine is the most common crystal fragment in about two-thirds of the tuff and makes up from less than 1 to about 20 percent of the rock. The andesine is in anhedral to euhedral crystals as much as 2 millimeters in length. These crystals are commonly fractured and rarely zoned. Sanidine is the most common crystal fragment in about one-third of the tuff and, although absent in some places, may make up as much as 20 percent of the rock. Quartz is present in most specimens and generally makes up several percent of the tuff. The most common mafic mineral is magnetite, which is present in small rounded crystals in most specimens in amounts as much as 1 percent. Trace amounts of small zircon crystals, generally found adjacent to or within magnetite crystals, are also common. Augite or hypersthene may be present in minor amounts of less than 1 percent in some specimens, and both may be present in a few specimens. One of the more unusual minerals in these tuffs is fayalite, the iron-rich member of the olivine group. This mineral, which is rather rare and which is found in only a few specimens, is pale yellow green and is commonly rimmed with iddingsite. Other minerals found in trace amounts in a few specimens include apatite, biotite, and calcite.

The matrix of the welded tuff is made up of numerous flattened glass shards (fig. 7*A*). Three types of matrix are present: glassy undevitrified, dense devitrified, and porous devitrified. A glassy undevitrified matrix is found only in a few places near the base of a tuff sequence. In hand specimen, the matrix is a black or brown glass that can be seen in thin section to be made up of undevitrified glass shards generally showing a maze structure. A dense devitrified matrix (fig. 7*A*,*B*) is common in the lower third of the tuff where the shards have been divitrified or partly devitrified by later crystallization. Spherulites or incipient spherulites (fig. 7*B*) are formed in some places, and the well-developed ones obliterate the shapes of the shards. Pore spaces are absent or scarce. A porous devitrified matrix (fig. 7*C*) generally is found in the middle and upper parts of the welded tuff pile. Devitrification of the glass shards is similar to that in the dense devitrified matrix, but here oval and tabular pore spaces are common. During late-stage crystallization, these pore spaces are commonly filled or partly filled with tridymite and a little untwinned alkali feldspar (fig. 7*C*). Smith (1960, p. 155) referred to the part of a welded tuff that is dense and devitrified and that contains no pore spaces as the devitrified zone; and to that part of the tuff that is devitrified but has pore spaces filled with crystal growths as the vapor-phase zone. Without pore space, vapor-phase crystallization cannot take place.

The flows in the Kirkham Hollow Volcanics are generally more resistant than the welded tuffs and commonly form small cliffs. Flow banding is found in many places, and a prominent jointing is common parallel to the banding. This results in thin flat slabs of float about 1 inch thick. The flows generally consist of dark-gray or black dense laminated aphanitic rock. Phenocrysts are small and euhedral, and their long axes are subparallel. Andesine, generally the most common phenocryst, makes up as much as 20 percent of some flows but is absent in others. Augite is the most common phenocryst locally but in most places is found in quantities of less than 1 percent. Magnetite and hypersthene in amounts of less than 1 percent are common in many flows. Trace amounts of biotite, zircon, and iddingsite are present in a few places.

The matrix of the flows contains numerous andesine microlites and in some specimens pyroxene and magnetite microlites. The microlites are parallel and are in a brown glass, which in some places is partly devitrified. Pore spaces make up several percent of some of the flows, and these holes are commonly filled with tridymite and a little untwinned alkali feldspar.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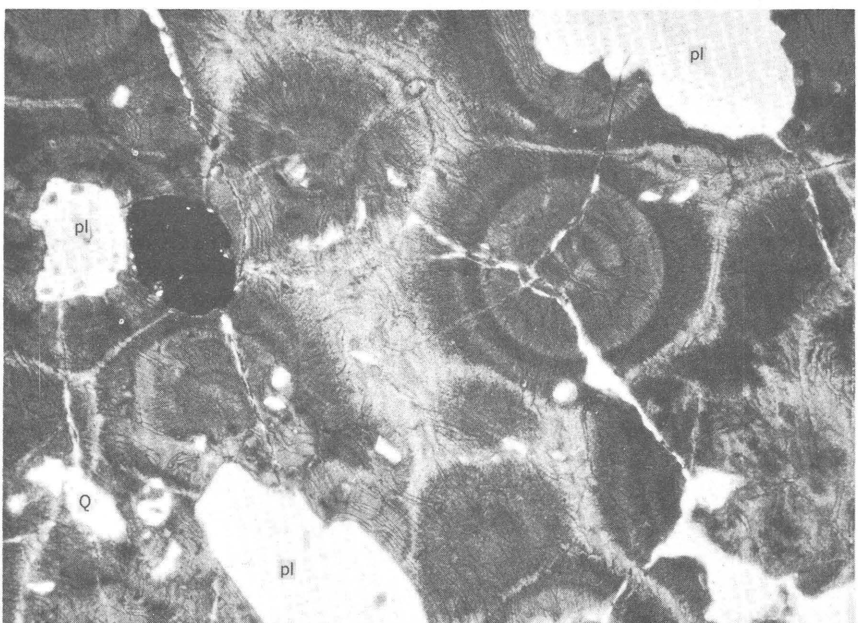
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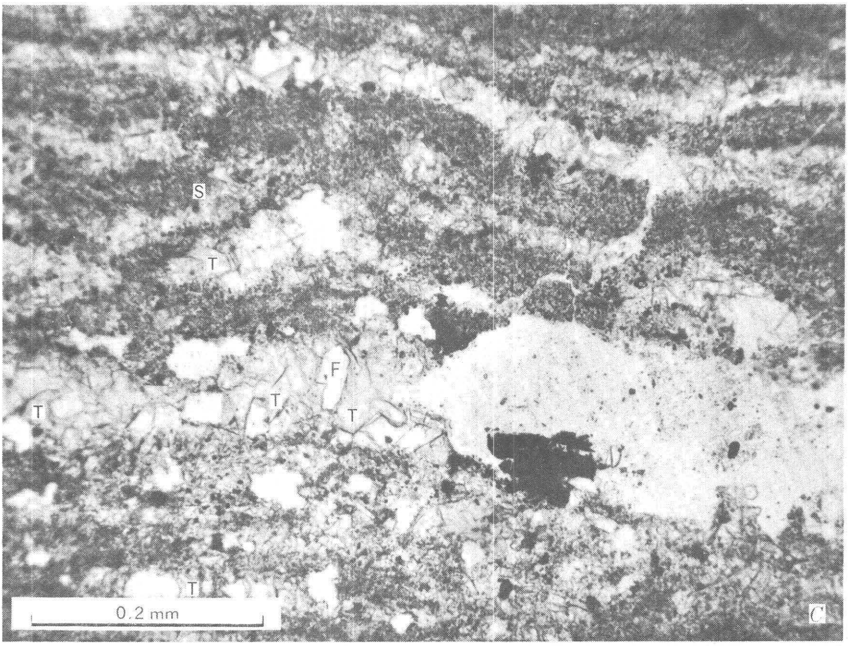

FIGURE 7.—Photomicrographs of welded tuff in the Kirkham Hollow Volcanics. Pictures taken by R. B. Taylor. *A*, Tuff from the devitrified zone showing numerous well-preserved, compressed, and devitrified shards. The two crystals are plagioclase (pl). Specimen collected adjacent to the road along Horseshoe Creek in the NE¼ sec. 28, T. 5 N., R. 44 E. *B*, Tuff showing numerous spherulites formed during devitrification, which here cut across and partly obliterate the shards. Crystals are plagioclase (pl), quartz (Q), and magnetite (black). Specimen was collected from a knoll on the north side of the North Fork of Canyon Creek near the center of sec. 3, T. 4 N., R. 43 E. *C*, Altered tuff from the vapor-phase zone showing almost obliterated shards (S) and numerous pore spaces filled with tridymite (T) and a little alkali feldspar (F). Black mineral is magnetite. Specimen was collected on ridge on north side of Woods Hollow in the SE¼NW¼ sec. 21, T. 5 N., R. 44 E.

Welded tuff that does not contain visible rock fragments is commonly difficult to distinguish from flows in this quadrangle. Certain features, however, are generally useful in distinguishing between these two rock types in hand specimen. Flow rock generally breaks into thin flat slabs about 1 inch thick; the tuff, into irregular pieces. Flow rock is generally black or dark gray; tuff except for the basal glassy facies is mostly light gray, although shades of brown are common. Flow rock is dense; most of the tuff is very porous. Flow rock either has no visible crystals or only a few a fraction of a millimeter in length, but the tuff commonly has visible crystals that may be as long as several millimeters.

Volcanic breccia is scarce in the Garns Mountain quadrangle. One breccia was noted on a ridge on the south side of Canyon Creek on the section line separating secs. 6 and 7, T. 4 N., R. 43 E. This breccia was made up of angular pieces, as much as 2 inches across, of light-pink aphanitic volcanic rock and black glass in a black glassy matrix.

Without chemical analyses the rock type of most volcanic rocks cannot be accurately determined, as the chemical composition of the matrix is commonly different from that of the crystals. The crystals in some volcanic rocks do, however, aid in determining the approximate composition. In volcanic rocks having a high potassium content, such as rhyolites, sanidine crystallizes early and is common in the phenocrysts and crystal fragments. In rocks having only a moderate potassium content, such as quartz latite and some rhyodacites, plagioclase crystallizes early and is generally the only feldspar in crystals. The potassium in these rocks remains in the matrix. In the Kirkham Hollow Volcanics, andesine is the most common phenocryst in the flows and many of the welded tuffs. Sanidine is common in many of the tuffs and in some is the most common mineral. To check for the presence of potassium in the matrix, thin sections of several flows and a number of welded tuffs were stained with sodium cobalt-nitrite solution according to the method of Gabriel and Cox (1929). The results on all specimens indicate that the matrix is high in potassium. Quartz is common in many of the coarser grained welded tuffs. The qualitative data just given indicate the rocks of the Kirkham Hollow Volcanics are rhyolitic in composition, although some of them may be rhyodacitic.

AGE AND CORRELATION

No fossils have been found in the Kirkham Hollow Volcanics. The age of the Kirkham Hollow, however, is middle Pliocene or younger, as it unconformably overlies a sequence of tuff, pumicite, siltstone, and conglomerate that contains middle Pliocene vertebrates (Merritt, 1956,

p. 119). A more definitive age for the Kirkham Hollow Volcanics can be suggested from the geologic history of the area.

After the Kirkham Hollow Volcanics was deposited, a period of erosion occurred, during which hills several hundred feet high were cut in the volcanic rocks. Such hills are now exposed on the northeast side of the Snake River, 7 miles west of the Garns Mountain quadrangle, where they are covered by basalt flows (fig. 8). Several basalt flows are found along the Snake River and in places are separated by tuff or tuffaceous sedimentary rocks. About 1 mile south of the mouth of Dry Canyon on the west side of the Snake River, an irregular erosional surface that had at least a hundred feet of relief was cut on top of a basaltic tuff before the second basalt flow was deposited (fig. 10). Hence, the basalts and their associated rocks were not all deposited at one time.

The events following deposition of the Kirkham Hollow Volcanics suggest that more time has elapsed since the Kirkham Hollow was deposited than elapsed between deposition of rocks containing the middle Pliocene vertebrates and the deposition of the last rocks belonging to the Kirkham Hollow Volcanics. We believe that the Kirkham Hollow is more likely to be Pliocene than Pleistocene in age.

Petrologically similar welded rhyolitic tuffs have been described in several other areas. Love (1956b, p. 1909, 1912) mentioned welded tuffs in the Teewinot Formation of middle Pliocene age and in the Bivouac Formation of late Pliocene or Pleistocene age in the Jackson Hole area, Wyoming. The age of the Teewinot was determined from vertebrate fossils; that of the Bivouac, by its position over the Teewinot. The tuffs in these formations have numerous glassy fragments that resemble shards; their principal mineral fragments are sanidine, quartz, and plagioclase, and their accessories are clinopyroxene, fayalite, and magnetite (Houston, 1956, p. 137).

Welded tuffs are also found in the Yellowstone Tuff in Yellowstone Park (Boyd, 1961, p. 393–400). These tuffs also resemble those of the Kirkham Hollow Volcanics in that both have a glassy matrix full of shards; both have plagioclase, sanidine, and quartz as the principal crystal fragments; both also contain small amounts of augite and the rare mineral fayalite. The Yellowstone Tuff is believed by Boyd (1961, p. 410) to be a correlative of the welded tuffs in the Teewinot Formation and, hence, to be of Pliocene age. Overlying the Yellowstone Tuff are several rhyolite flows. Near the west edge of Yellowstone Park, Richmond and Hamilton (1960) found one of these flows overlapping large moraines of Bull Lake Glaciation, which is in turn overlapped by lateral moraines of Pinedale Glaciation. The rhyolitic volcanic rocks of the Yellowstone-Jackson Hole area, hence, are of both Pliocene and Pleistocene age.

ROCKS OF QUATERNARY AGE

Rock units of Quaternary age include basalt and its associated rocks, basaltic dikes, landslide deposits, loess, colluvium, and alluvium. With the exception of the basaltic rocks, all are unconsolidated sediments. As the principal interest in this report is in the older underlying consolidated rocks, the unconsolidated Quaternary rocks were mapped where the distance between outcrops of consolidated rocks is less than about 1,000 feet. The boundaries between the consolidated and unconsolidated rocks, hence, with the exception of the landslide deposits are approximate. Loess, colluvium, and alluvium commonly are extremely difficult to separate from one another as they may be either of similar composition or, along their contacts, intermixtures of two types of material. It is necessary in some places to separate them on the basis of form and topographic expression as well as composition.

BASALT AND ASSOCIATED ROCKS

Basalt is found along the Snake River Plain throughout most of Idaho. North and east of Idaho Falls, these rocks are found along both the South Fork and the Henry's Fork of the Snake River and along the Teton River, a tributary of the Henry's Fork. Within the Garns Mountain quadrangle, however, basalt and associated rocks are confined to the Snake River Plain in the southwest corner of the quadrangle, except for a narrow tongue of basalt that extends from this plain up Pine Creek. The basalt and associated rocks are the youngest consolidated rocks in the area. In several places along the Snake River, as on the north side of the mouth of Black Canyon, on the north side of the mouth of Gormer Canyon, and west of the mouth of Dry Canyon, these rocks unconformably overlie the younger conglomerate. South and west of the Snake River, basalt overlies the uppermost beds of the conglomerate, but near the present channel of the Snake, basalt fills an old channel cut by the Snake in the conglomerate. The angle of contact between the basalt and younger conglomerate, hence, can range from 0 to 90° and at the mouth of Fisher Canyon near the west boundary of the quadrangle, cliff exposures show an irregular contact that has a dip ranging from 40° to 90°. A thin soil formed on eroded younger conglomerate is preserved between the conglomerate and a siltstone associated with the basalt in the upper part of Fisher Canyon. This weathered zone is 6 inches thick and contains chunks of carbonaceous matter.

Within the Garns Mountain quadrangle the basalt does not crop out in the same areas as the Kirkham Hollow Volcanics, but 7 miles west of the quadrangle along the north side of the Snake River, basalt unconformably overlies the Kirkham Hollow Volcanics (fig. 8). The

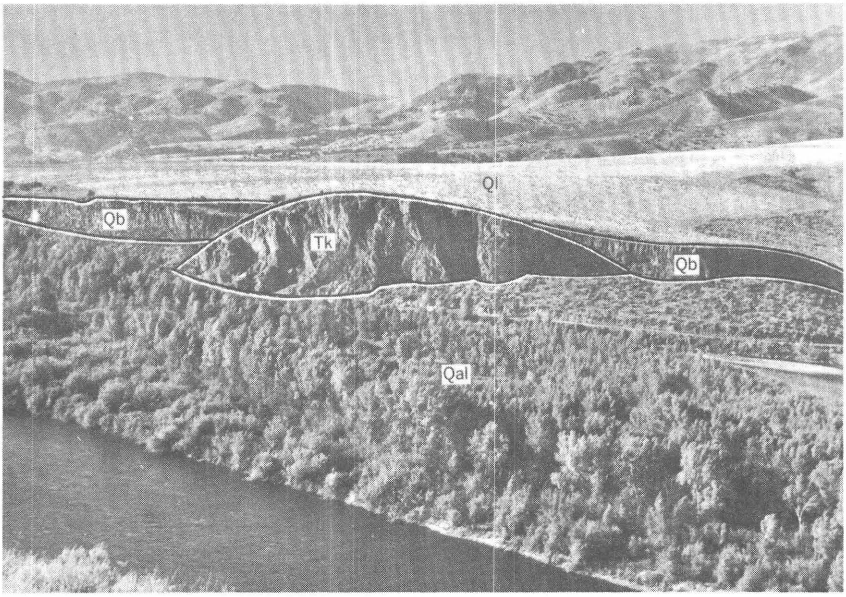

FIGURE 8.—Basalt (Qb) lying on the sides of a hill eroded from Kirkham Hollow Volcanics (Tk). Loess (Ql) overlies the two volcanic rocks, and alluvium (Qal) covers the flat adjacent to the Snake River. View is toward the north; the Snake River Range is in the background.

basalt is overlain along the bottom of the Snake River Valley by alluvium (fig. 8), in places along the steep sides of the river gorge by colluvium, and on the high uplands by loess.

The basalt is a black or brownish-black fine-grained rock. It contains numerous vesicles in the upper part of flows, but vesicles are rarely found in the lower part. The vesicles are oval in shape, have an average maximum diameter of 0.5–2 millimeters, and near the top of a flow commonly make up 15 percent of the rock. The basalt is a holocrystalline rock with a diabasic texture (fig. 9). Approximately a third to half the basalt is made up of lath-shaped plagioclase crystals (An_{52} to An_{72}) which range from 0.02 millimeter wide by 0.08 millimeter long to 0.35 millimeter wide by 2 millimeters long. Mafic minerals make up the rest of the rock. A titanium-rich clinopyroxene, which makes up 10–30 percent of the rock, is generally the most common (fig. 9). In thin section, this clinopyroxene is pinkish brown, has a very faint pleochroism, is biaxial negative, and commonly occurs in laminar sheaves. A similar pyroxene has been reported by Howard Powers (1961, oral commun.) to occur in many places in basalt along the Snake River. Olivine, which is almost as common as the clinopyroxene (fig. 9), is the most abundant mafic mineral in a few places.

The opaque minerals magnetite and ilmenite make up 5–20 percent of the rock. It is difficult to distinguish between these two minerals except where they form euhedral crystals; there magnetite generally occurs as octahedrons and ilmenite, as thin platy crystals. The only other mineral noted was iddingsite, which forms orangish-brown rims on some of the olivine crystals.

Plagioclase was the first mineral to crystallize, and it formed as euhedral crystals (fig. 9). Olivine was next, and it formed as subhedral or euhedral crystals. Clinopyroxene and the opaque minerals were the last to crystallize, and they generally fill the interstices between the other minerals.

Some tuff, sandstone, siltstone, and marl are interlayered with the basalts or, as at Fisher Canyon, are below the lowest basalt. These clastic rocks probably have a small distribution; their exposures are confined to a small area in Fisher Canyon and to about a 1½-mile-long band along the west side of the Snake River south of the mouth of Dry Creek (fig. 10), whereas the basalt exposures are found scattered over an area of about 30 square miles. The clastic rocks are evidently

FIGURE 9.—Basalt collected at the base of the flow near the mouth and on the west side of Black Canyon. Shows characteristic diabasic texture brought out by the plagioclase (pl). Mafic minerals are olivine (O), titanium-rich clinopyroxene (P), and magnetite and ilmenite (black). Photograph taken by R. B. Taylor.

erratically distributed, and some beds disappear a few hundred feet along strike. This erratic distribution is in part due to the deposition of pyroclastics and sediments in small hollows and ponds and in part to later erosion of these materials. Where present, the clastic rocks are of considerable aid in separating the various basalt flows.

The principal clastic rock is tuff, which may be either air laid or water laid. It is black to gray and in places has yellow limonite in the matrix. Water-laid tuffs are well stratified, their fragments are crudely sorted, and some fragments are subrounded or rounded. Fragments are commonly sand size, but in some places the tuff contains boulders as much as 3 feet in diameter. Most fragments are black glass, but some are basalt, and a few are gray limestone. Although this water-laid vitric tuff is made up largely of loosely packed fragments of black glass, crystal fragments are common. The principal crystal is plagioclase with lesser amounts of olivine and opaque minerals.

In addition to the tuff, porous calcareous siltstone, calcareous fine-grained sandstone, and marl are exposed below vitric tuff along the upper part of Fisher Canyon. These rocks are white, brown, or orange, thin bedded, and well stratified. Laminae in some resemble varves. Ripple marks are found in some beds and indicate that the beds probably were deposited in shallow water. Some rock units are separated by unconformities having from a few inches to at least 10 feet of relief. Many of the rocks are tuffaceous and contain rounded pieces of brown glass. Mineral grains are principally quartz and, in some places, calcite. Lesser amounts of plagioclase, sericite, biotite, and zircon are present in some places. Some of these rocks also have a calcite matrix.

No fossils have been found in the sedimentary rocks associated with the basalt. An unconformity cut on tuff along the west side of the Snake River 1 mile south of the mouth of Dry Canyon (fig. 10) shows that the tuff and underlying rocks were eroded before they were covered by the last basalt flow. The position of the basalt and associated rocks above a pronounced unconformity along the Snake River carved on the Kirkham Hollow Volcanics suggests that they are most likely Pleistocene in age.

Many basalt flows with interbedded sediments of Pleistocene and Recent age are found along the Snake River Plain farther to the west (Russell, 1902, p. 36, 59; Stearns, Crandall, and Steward, 1938, p. 25; Malde and Powers, 1962). These have been called the Snake River Group (Malde and Powers, 1962, p. 1198–1199). The basalt and its associated rocks in the Garns Mountain quadrangle possibly are correlatives of these rocks.

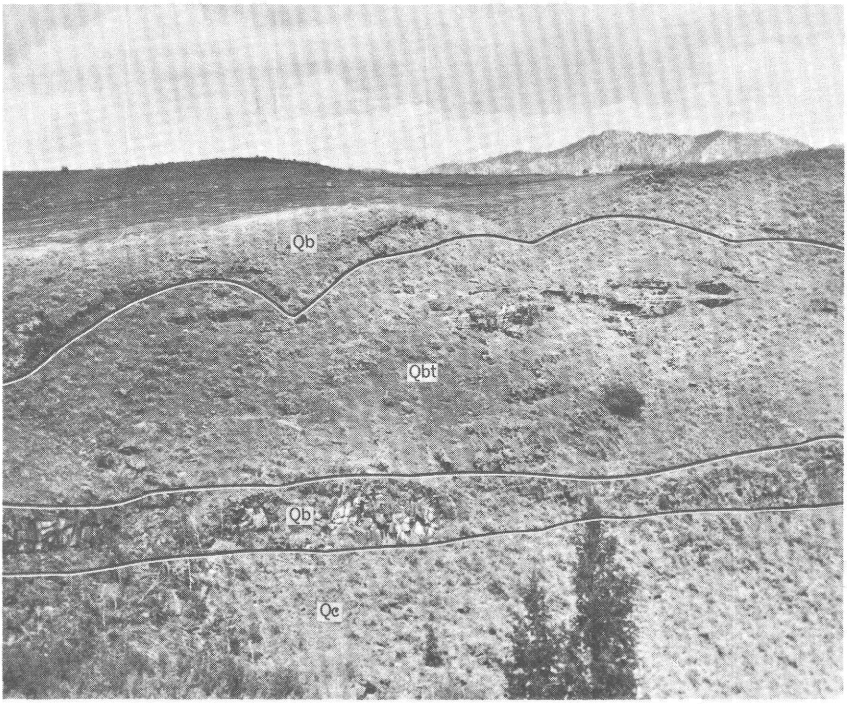

FIGURE 10.—Basalt layers (Qb) separated by basaltic tuff (Qbt). Note unconformity cut on the tuff before the second basalt was extruded. Rocks below the older basalt are covered with colluvium (Qc). Picture was taken looking north at bluff on west side of the Snake River.

A diamond-drill hole made in 1962 by the Bureau of Reclamation along the Teton River north of the Garns Mountain quadrangle in sec. 21, T. 7 N., R. 43 E., entered basalt at a depth of 433 feet below welded tuff of the Kirkham Hollow Volcanics (E. G. Crosthwaite, 1962, written commun.). Whether a similar older basalt occurs in the Garns Mountain quadrangle is not known, but older basalt might be hidden beneath younger rocks on the Snake River Plain.

BASALTIC DIKES

A few small dikes intrude the Paleozoic and Mesozoic sedimentary rocks in the northern part of the Garns Mountain quadrangle. All the dikes occur within a mile of the contact of the sedimentary rocks and the Kirkham Hollow Volcanics.

The dikes show no preferred orientation, and all dip steeply. They range in length from a few tens of feet to 240 feet and in width from about 1 foot to 20 feet. Generally, the dikes are inconspicuous; commonly they are expressed by a few pieces of igneous rock in an otherwise sedimentary rock terrain. The largest dike, however, which is in the southeast end of Thousand Springs Valley, is very prominent and projects about 20 feet above the surrounding land surface (fig. 11). The sides of this dike are marked by numerous steeply dipping flow lines.

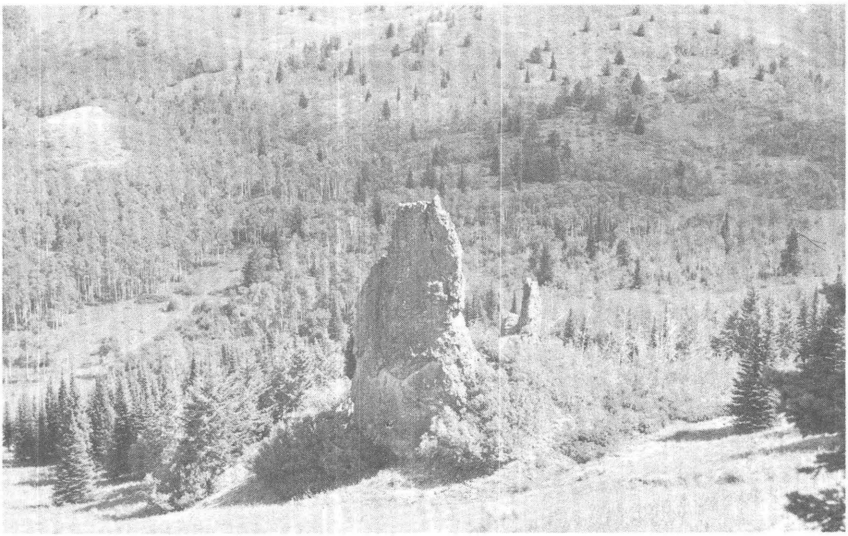

FIGURE 11.—Basaltic dike in Thousand Springs Valley standing above land surface cut in the Frontier Formation. All the far side of valley is an overgrown landslide surface. View is toward the north.

The dikes are light- to dark-gray aphanitic rocks. Some of them have numerous small vesicles; others, like the large dike in Thousand Springs Valley, have none. In general, phenocrysts are not visible in a hand specimen, and they constitute only 1–10 percent of the rock in thin section. In some, the predominant phenocryst is labradorite; in others, pyroxene. Both augite and hypersthene were noted. The groundmass consists of felted plagioclase and minor pyroxene and opaque mineral microlites embedded in glass. Stain tests for potassium made on three specimens using the method of Gabriel and Cox (1929) gave negative results. The results of these stain tests plus the mineralogy of the phenocrysts suggest that the dikes are basaltic.

LANDSLIDE DEPOSITS

Eleven landslide deposits were mapped in the Garns Mountain quadrangle. All except one are in the central part of the north half of the quadrangle.

The landslides extend from 750 feet to 5,500 feet downslope and are from 800 feet to 10,700 feet wide. The largest one, about 2 square miles in area, is on the northwest side of Packsaddle Creek at the north edge of the quadrangle. Only about one-third of it lies within the quadrangle. Another large landslide is on the northeast side of Thousand Springs Valley (fig. 12); this one is 1,600–3,000 feet downslope and 9,700 feet wide. All the landslides are of the slump type (Sharpe, 1938, p. 65–74). Their upper edges are commonly marked by one or more steep arcuate scarps. These scarps are particularly well formed on the large landslide on the north side of Packsaddle Creek and on those along Canyon Creek. The landslides generally have a hummocky surface (fig. 12) on which small springs and ponds are common. They are all probably at least 30 years old and are at present relatively inactive as they are covered by a thick growth of aspen (fig. 12), Douglas-fir, or lodgepole pine. The large landslide on the northeast side of Thousand Springs Valley is younger than the medium-sized one about 0.1 mile north of it. The larger one has prominent hummocks, and in addition to numerous aspen it has Douglas-firs about 6 inches in diameter. The smaller one has more subdued hummocks, and the Douglas-firs are as much as 1 foot in diameter.

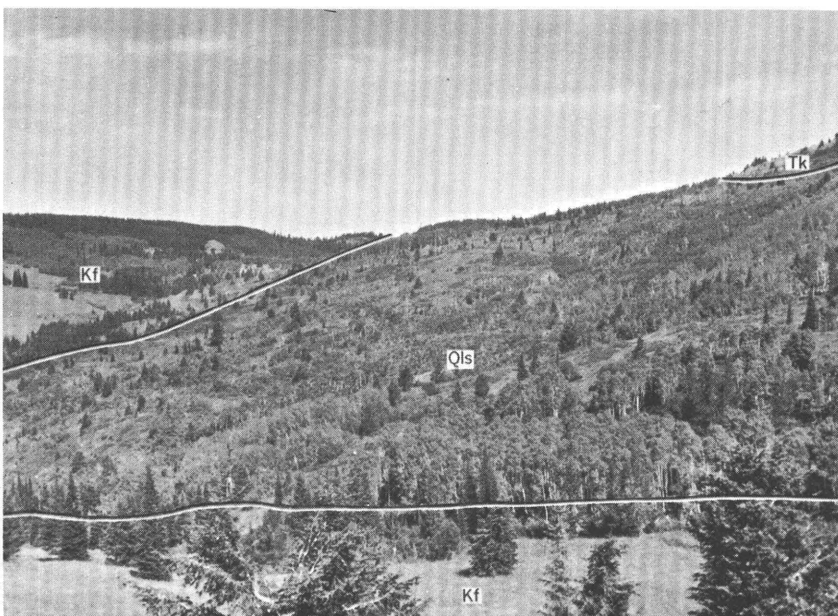

FIGURE 12.—Landslide (Qls) along the northeast side of Thousand Springs Valley as viewed north from Temple Peak. Landslide has hummocky surface and is covered with thick growth of aspen. Tk, Kirkham Hollow Volcanics; Kf, Frontier Formation.

Seven out of the 11 landslides, including the 5 largest, are formed by hard competent rocks sliding down over softer less competent rocks. In five of these seven, the landslide block is hard welded tuff and flows of the Kirkham Hollow Volcanics; the other two consist of quartzite of the Wells Formation and silicified sandstone and shale of the Aspen Formation. These rocks have slid down over the less competent and more easily weathered Cretaceous and Jurassic sedimentary rocks. The four largest landslides have slid over the incompetent Frontier Formation.

Four landslides, two along Elk Flat Fork in secs. 19 and 30, T. 4 N., R. 44 E., one along Dry Canyon in sec. 34, T. 3 N., R. 43 E., and one along Burns Canyon in secs. 31 and 32, T. 4 N., R. 43 E., are formed by slumping of similar type rock units over one another. All four are on the sides of steep canyons and the first three landslides listed probably were caused by stream erosion oversteepening the canyon walls. The landslide on Burns Canyon is along a fault, and an earthquake probably caused it to slide.

The Dry Canyon landslide differs from the other slides in that the slump block slid as one piece and is not broken and jumbled.

LOESS

Loess covers lowlands along the Snake River in the southwestern part of the Garns Mountain quadrangle, the lowlands along the lower part of Canyon Creek in the northwest corner of the quadrangle, and Teton Valley in the northeast corner of the quadrangle. In the southwestern part of the quadrangle, the loess overlies basalt (fig. 8) and Tertiary conglomerate, and in the northwestern and northeastern parts of the quadrangle, it overlies the Kirkham Hollow Volcanics. The loess in the southwestern part of the quadrangle is mostly below an altitude of 6,050 feet and that in the northeastern part is mostly below 6,300 feet, but loess in the northwestern part has been blown up the northward-facing gentle slopes to at least 6,700 feet. In places, especially in the northwestern part, less than a foot of loess covers some of the older rocks, but along U.S. Highway 26 and State Highway 31 in the southwestern part as much as 35 feet of loess is exposed in the roadcuts. The loess forms gently rolling hills with a maximum relief of about 250 feet. Scattered barchans are especially prominent along the Snake River in the southwestern part of the quadrangle. The steep sides of the dunes are generally to the north, indicating that when the dunes were last mobile the prevailing winds came from the south.

In the deeper roadcuts the loess is a light tan, but near the surface, where mixed with humus, it is a darker brown. This sediment is quite cohesive, and little slumping occurs even in the steepest of roadcuts.

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Vertical root holes are common, especially in its upper part. The loess is extremely fertile, and areas underlain by it are generally planted in wheat or barley.

The loess is made up of grains of silt and clay that are about 0.03 millimeter in median diameter. The unit is not very well sorted, having a coefficient of sorting (*So*) that ranges from about 2.50 to 2.90. The grains are unweathered and angular, and consist mostly of calcite and quartz. Other minerals include tridymite, clay minerals, biotite, tourmaline, muscovite, zircon, plagioclase, orthoclase, and amphibole.

COLLUVIUM

Colluvium as shown on plate 1 consists of several types of unconsolidated sediments that cover the lower slopes of the hills and mountains. Most of the colluvium is an unsorted aggregate formed by slope movement. In a few places, however, it includes some small older upland gravel deposits. Colluvium ranges from soil formed by slow disintegration of fine-grained rocks to coarse-boulder talus slides. In many places, it is a heterogeneous mixture. Large areas of colluvium are found along the southwest sides of the North Forks of Pine and Horseshoe Creeks where the poorly consolidated Frontier Formation is covered by a mixture of soil and fragments of quartzite and limestone. Quartzite boulders several feet in diameter from the Wells Formation in the North Fork of Pine Creek area have moved as far as 2 miles downslope by creep. Most colluvium along the Snake River consists of talus slides of basalt that conceal either basalt or the younger conglomerate.

ALLUVIUM

Alluvium, as considered in this report, is the unconsolidated deposits formed in Recent time by streams. These deposits are confined to the valleys and are common along the valleys of the Snake River (fig. 8) and its tributary, Pine Creek.

Alluvium in the Garns Mountain quadrangle consists of well-sorted sands and gravels, as well as finer grained sediments including soils formed in the valleys.

STRUCTURE

Parts of two tectonic elements are present in the Garns Mountain quadrangle: the Snake River Range and the Snake River Plain. The Snake River Range trends northwestward and is characterized by thrust faults and many folds. The Snake River Plain is a northwestward-trending graben bounded by normal faults. It is floored by flat-lying Cenozoic rocks which effectively conceal the complex structure that probably exists in underlying Mesozoic and Paleozoic rocks.

SNAKE RIVER RANGE

The Snake River Range is the northwestward-trending part of an arcuate belt of overthrust faults and folds. This belt of overthrusts rises from beneath the Snake River Plain of eastern Idaho, trends southeastward to west-central Wyoming, and thence follows the Idaho-Wyoming border southward to Utah, where it turns southwestward toward the Wasatch Mountains. This narrow, curving mountainous arc marks the northeast and east edge of a large miogeosyncline which existed from Cambrian until Middle Jurassic time. The craton east of the geosyncline formed a fairly stable buttress against which northeastward-acting forces formed a series of fairly closely spaced thrust faults. This area of closely spaced thrusts is commonly called the Idaho-Wyoming thrust belt. In addition to the main thrusts of this belt, thrusts are also found east of the belt in many of the ranges of western Wyoming and west of the belt in southeastern Idaho.

In the Garns Mountain quadrangle, as well as in the rest of the Snake River Range, the dominant structural features are thrust faults; but normal faults are common, and folds are abundant locally (pl. 2). Most folds and normal faults probably formed as a direct result of thrusting; and most, during the same periods of time.

THRUST FAULTS

The thrust faults in the Garns Mountain quadrangle all have a general northwestward trend and dip to the southwest. Their surface traces range from gently curved to extremely sinuous, depending on the dip of the thrusts and the topography. The thrusts in the central and northeastern parts of the quadrangle have a steeper dip at the surface than do the thrusts near the southeast corner of the quadrangle. The thrusts in the northeastern part in places dip as much as 60°, whereas the Baldy Mountain thrust in the southeastern part dips as little as 10°. (See sec. *D–D′*, pl. 1.) The thrust faults range from relatively minor ones, which lie chiefly within one formation, to large ones with many thousands of feet displacement. A complex pattern formed by thrusts splitting and, in places, intersecting other thrusts shows both in plan and section (pls. 1, 2). The ten principal thrust faults in the Garns Mountain quadrangle from northeast to southwest are: (1) the Mount Manning thrust, (2) the Mahogany Creek thrust, (3) the Jackson thrust, (4) the North Pine Creek thrust, (5) the Absaroka thrust, (6) the Poison Creek thrust, (7) the St. John thrust, (8) the Fleming Canyon thrust, (9) the Gopher Canyon thrust, and (10) the Baldy Mountain thrust (pl. 2). In some places, thrusts die out, and in other places, the principal thrust can not be readily determined in zones where thrusts are close together.

MOUNT MANNING THRUST

The Mount Manning thrust was named by Kiilsgaard (1951, p. 20) from its exposure on the east side of Mount Manning. This thrust extends, in the Garns Mountain quadrangle, for about 6½ miles from near the Mikesell mine on Packsaddle Creek to Mahogany Creek on the east edge of the quadrangle. Eastward in the Driggs quadrangle, E. H. Pampeyan (1962, written commun.) traced this thrust along Mahogany Creek for another 2 miles, where it disappears under alluvium in Teton Valley. The Mahogany Creek thrust splits from the Mount Manning thrust at the junction of the North and South Forks of Mahogany Creek.

The Mount Manning thrust has placed resistant beds ranging from Pennsylvanian to Cretaceous in age above the friable shales and sandstones of the Cretaceous Frontier Formation, and a prominent ridge has formed in most places along its trace. The stratigraphic displacement ranges from approximately 4,500 feet in the north to 9,000 feet at Mahogany Creek. Except for the bend at the forks of Mahogany Creek, the trace of this thrust is fairly straight along most of its length, suggesting a fairly steep dip at the surface.

MAHOGANY CREEK THRUST

The Mahogany Creek thrust can be traced for 6½ miles from where it joins the Jackson thrust to where it joins the Mount Manning thrust (pl. 1). This thrust has a general southeastward trend for 4½ miles from where it splits off the Jackson thrust to North Mahogany Creek where it turns sharply to the northeast and follows North Mahogany Creek to the Mount Manning thrust. The Mahogany Creek thrust northwest of the bend in general parallels the strike of the beds; it brings the Wells Formation over the Frontier Formation with a stratigraphic displacement of about 9,000 feet. East of the bend the thrust cuts across many formations, and the stratigraphic displacement seems to decrease. The area where the thrust is curved, however, has numerous tangential and cross-cutting normal faults and a separate thrust sliver. Thus, in this area much of the total movement is distributed among several smaller faults rather than on one major fault.

JACKSON THRUST

The Jackson thrust, named by Horberg (1938, p. 30), is one of the two largest thrusts that cross the Garns Mountain quadrangle. It has been traced a distance of 46 miles from a point 9 miles east of Jackson, Wyo., to the north end of the Garns Mountain quadrangle. This thrust trace was mapped by Horberg, Nelson, and Church (1949, pl. 2) east of the Driggs quadrangle, by E. H. Pampeyan and E. R. Cressman

(1962, written commun.) in the Driggs quadrangle, and by us in the Garns Mountain quadrangle. The ends of the thrust are concealed by volcanic rocks, and near its middle the thrust is concealed by alluvium in Teton Valley.

Within the Garns Mountain quadrangle the Jackson thrust has placed the Wells and Mission Canyon Formations on rocks ranging from the Wells Formation to the Frontier Formation. The resistant Wells and Mission Canyon Formations overlying the generally less-resistant beds have formed a prominent ridge along the southwest side of the thrust between Packsaddle Creek and Elk Flat (pl. 1). This thrust dips at the surface 20°–60° SW.; the gentler dips are in the northwestern part of the quadrangle.

The stratigraphic displacement on the Jackson thrust is at least 3,500 feet, but the amount of lateral movement is not known, although it is large, probably at least 10 miles. The evidence that suggests a large amount of movement is the length of the thrust and the change in thickness of formations on the two sides of the fault. As previously noted, the Jackson thrust has a minimum length of 46 miles, and a large amount of movement would be expected to produce a thrust of this length. The formations on the southwest side of the thrust are much thicker than those on the northeast side. We measured 10 formations (Nugget Sandstone, Twin Creek Limestone, Stump Sandstone, Preuss Sandstone, Ephraim Conglomerate, Peterson Limestone, Bechler Formation, Draney Limestone, Bear River Formation, and Aspen Shale) on both sides of the Jackson thrust, and all are thicker on the southwest side of the fault. The total thickness of the formations on the southwest side is 6,438 feet; on the northeast side these formations are only 3,447 feet thick. The Bear River Formation showed the greatest change; it is 1,579 feet thick on the southwest side of the thrust and 329 feet thick on the northeast side. This great thickening suggests that the upper sheet of the thrust was moved northeastward at least 10 miles from the deeper parts of the miogeosyncline.

NORTH PINE CREEK THRUST

This small thrust lies wholly within the Garns Mountain quadrangle. It is 5 miles long and extends northward from just south of Pine Creek, where it joins or is overridden by the Absaroka thrust, to just south of the junction of Lookingglass Creek and the North Fork of Pine Creek, where it dies out. This thrust is nowhere exposed, and most of its trace is followed by the North Fork of Pine Creek. It cuts only rocks of Cretaceous age. The south part of this thrust trends northward, cutting across the strike of several formations, but in the central part of the thrust bends northwest and parallels the bedding of the Cretaceous rocks. Movement on the fault has brought southwestward-dipping beds of the upper plate over complexly folded rocks of the lower plate.

ABSAROKA THRUST

The Absaroka thrust is one of the two largest thrusts that cross the Garns Mountain quadrangle. It has been traced from the southwest corner of Wyoming northward to the north end of the Snake River Range, a distance of about 215 miles. The thrust was named by Veatch (1907, p. 109) from Absaroka Ridge, which lies on the west side of this thrust in southwestern Wyoming. This thrust is covered at its south end by flood-plain deposits and at its north end by volcanic rocks. The northernmost known exposure of the thrust is at the north end of Red Butte in the Garns Mountain quadrangle. The Absaroka trends southeastward from Red Butte to Pine Creek on the east edge of the quadrangle. It is offset in two places by northwestward-trending normal faults (pl. 1; fig. 13). The thrust, shown in figure 13, marks the southwest boundary of exposures of all Cretaceous rocks in the Snake River Range, and the upper plate of the thrust in most places moved across the soft rocks of Cretaceous age. In this quadrangle the northeast edge of the upper plate of the fault forms a

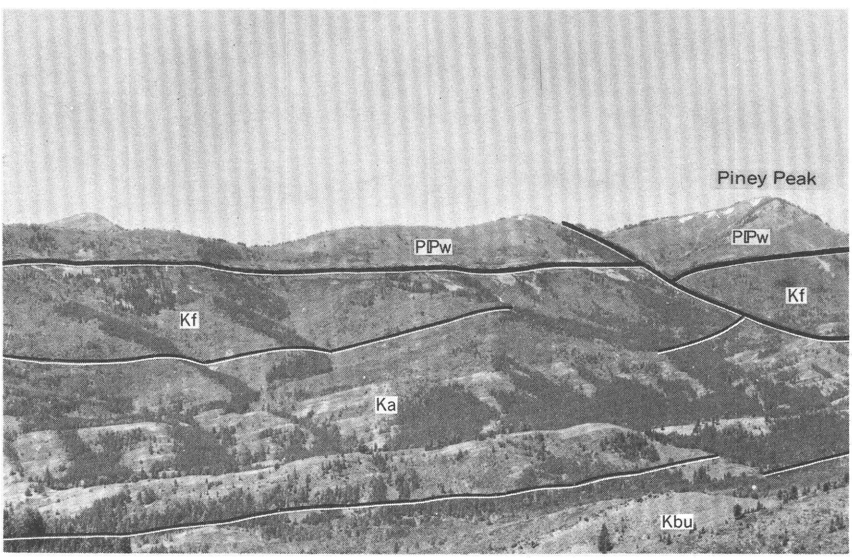

FIGURE 13.—Absaroka thrust along the southwest side of the North Fork of Pine Creek offset by a transverse fault. Upper plate is resistant quartzite of the Wells Formation (PIPw). Lower plate is mainly friable shales and sandstones of the Frontier Formation (Kf), Aspen Shale (Ka), and upper member of the Bear River Formation (Kbu). The Aspen, which is the most resistant of the three Cretaceous formations, stands out as small well-exposed ridges along the sides of the North Fork of Pine Creek.

prominent ridge, and the lower plate forms a broad valley (figs. 13, 14). This ridge and valley reflect the resistant beds of the Wells Formation thrust over the soft shales and sandstones of the Frontier Formation in most places in the quadrangle.

Although the total movement on the fault is unknown, a large amount of movement is indicated by the great length of the fault and the facies changes across the fault. As previously noted, this fault is 215 miles long; a large amount of movement is necessary to produce a fault of this length. The change in facies across the fault is most striking in the Thaynes Formation, which on the southwest side of the thrust has thick limestone units bounded by thin sandstones. On the northeast side of the fault, the Thaynes is much more arenaceous, and the sandstone units are thicker than the limestone units. This facies change across the thrust suggests that the southwest side of the thrust was moved a considerable distance to its present position, because the thick sequence of carbonate rocks on the upper plate indicates that they were deposited considerably farther from the edge of the geosyncline than the sandier rocks of the lower plate.

POISON CREEK THRUST

The Poison Creek thrust was named by Hinds and Andrau (1960, p. 58) from exposures on Poison Creek in the southeastern part of

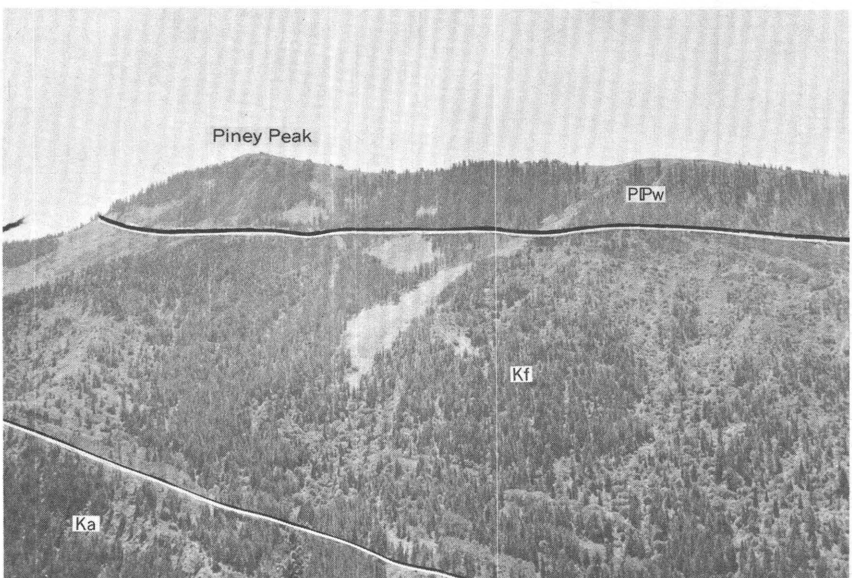

FIGURE 14.—Absaroka thrust. View is to the south across the head of Burns Canyon. Wells Formation (PIPw) is thrust over Frontier Formation (Kf) and Aspen Shale (Ka).

the Garns Mountain quadrangle. This thrust of moderate size has been traced for about 9½ miles within the Garns Mountain quadrangle. From the head of Poison Creek, it trends northwestward up West Pine Creek and crosses the saddle between Chicken and Liars Peaks into the upper part of the Black Canyon drainage (pl. 1), where it probably joins the St. John thrust along the north side of Black Canyon. East of the Garns Mountain quadrangle, E. R. Cressman and D. A. Jobin (1962, written commun.) traced this fault another 12 miles to the Wyoming border. Valleys have been cut along most of its length, and along West Pine Creek the thrust is covered with older conglomerate which was deposited in such a valley. Rocks of Triassic or Jurassic age are on both sides of the thrust. The greatest apparent movement is near the east border of the quadrangle where Dinwoody Formation is pushed over Twin Creek Limestone. Movement apparently decreases to the northwest, where rocks of the Thaynes Formation are on both sides of the fault.

ST. JOHN THRUST

The St. John thrust was named by Kirkham (1924, p. 33–34) during reconnaissance mapping of the northwestern part of the Irwin quadrangle. This fault has been mapped from the Irwin quadrangle across the Driggs quadrangle and into the Garns Mountain quadrangle by E. R. Cressman and E. H. Pampeyan (1962, written commun.). The thrust has been traced across the Garns Mountain quadrangle from Water Fork of Mike Spencer Canyon on the east border of the quadrangle to the west side of Mud Creek on the west border of the quadrangle, a distance of 18½ miles. East of the Garns Mountain quadrangle, the St. John has been traced approximately 25 miles along the Snake River Range and into the north end of the Salt River Range where it joins the Absaroka thrust (Cressman and Pampeyan, 1962, written commun.; D. A. Jobin, 1962, written commun.; and Boeckerman and others, 1956). In the southeastern part of the Garns Mountain quadrangle, this thrust separates resistant carbonate rocks of Paleozoic age from friable clastic rocks of Mesozoic age. Along this part of the thrust, a prominent ridge is formed on the upper plate adjacent to the fault, and a valley is formed on the lower plate. In the western part of the quadrangle, rocks of Paleozoic age are on both sides of the thrust, and the topography is similar on both sides of the fault.

The youngest rocks exposed southwest of the St. John thrust belong to the Wells Formation; hence the phosphate deposits in the Phosphoria Formation are found only on the northeast side of the thrust.

The St. John thrust is more complex in the western part of the quadrangle, and it splits into several branches in Black Canyon and on the north side of Burns Canyon. Along Burns Canyon, a window in the upper plate of the thrust exposes Mission Canyon Limestone and Wells Formation in the lower plate (pl. 1). The trace of this fault suggests that at the surface the thrust plane flattens to the northwest. Northeast of Mike Spencer Canyon the St. John thrust dips 55° SW. (pl. 1, sec. *D–D′*), but west of Woods Canyon it dips only 20° SW. (pl. 1, sec. *A–A′*). The amount of movement on this thrust is not known. Its known length of about 44 miles and the thrusting of the Gallatin Limestone over the Nugget Sandstone suggest that the thrust had a minimum movement of several miles.

FLEMING CANYON THRUST

The Fleming Canyon thrust was named by Hinds and Andrau (1960, pl. 1) after Fleming Canyon in the southeastern part of the Garns Mountain quadrangle. West of Fleming Canyon, this thrust ends against the Gopher Canyon thrust on the southeast side of Dry Canyon. We have traced this fault from Dry Canyon for about 7½ miles to the east border of the quadrangle from where it has been traced by E. R. Cressman, E. H. Pampeyan, and D. A. Jobin (1962, written commun.) another 12 miles to the Wyoming border. Mission Canyon Limestone borders both sides of the Fleming Canyon thrust in most of the Garns Mountain quadrangle. For this reason, rocks on both sides of the fault are almost equally resistant to weather, and a sharp topographic break does not occur at the fault except where a canyon has been cut along it. The amount of lateral movement along this thrust is relatively small, although it may be as much as a mile.

GOPHER CANYON THRUST

The Gopher Canyon thrust was named by Hinds and Andrau (1960, pl. 1) after Gopher Canyon, a small tributary of Fleming Canyon in the southeastern part of the Garns Mountain quadrangle. West of Fleming Canyon, this thrust has been cut off by the Grand Valley fault at the mouth of Ladder Canyon (pl. 1). Southeast of Fleming Canyon, we mapped the Gopher Canyon thrust to the southeast corner of the quadrangle. The total length of this fault in the Garns Mountain quadrangle is 11 miles. Southeast of this quadrangle, it has been traced another 12½ miles to the Wyoming border by D. A. Jobin, E. R. Cressman, and E. H. Pampeyan (1962, written commun.). The Gopher Canyon thrust is not marked by any prominent topographic break, as limestones are on both sides of its trace. Lower Paleozoic rocks have been thrust over the Mission Canyon Limestone of Mississippian age throughout most of the length of the fault. The stratigraphic displacement of about 3,000 feet, and the relatively low angle of dip along the fault plane indicates lateral movement to have been at least several miles.

BALDY MOUNTAIN THRUST

The Baldy Mountain thrust was named for a prominent peak along the thrust in the central part ofthe Snake River Range in the adjoining Irwin quadrangle. This thrust has the lowest angle of dip of any thrust in this area. Owing to its flatness, it is exposed on both sides of the ridge on the south border of the Garns Mountain quadrangle, where the dip of the fault is 14°. This fault is also well exposed along the sides of Diamond X Canyon (fig. 15), where its crooked trace indicates folding after thrusting. The Baldy Mountain thrust extends from the south border of the quadrangle along the southwest front of the Snake River Range northwestward nearly to Ladder Canyon where it is cut off by the Grand Valley fault. Northwest of Ladder

FIGURE 15.—Baldy Mountain thrust along the west side of Diamond X Canyon. Gallatin Limestone (€g) and Gros Ventre Formation (€gv) have been shoved over Mission Canyon Limestone (Mm). The sinuous trace of this fault is caused by folding after thrusting.

Canyon, three segments of a low-angle thrust are exposed south of Black Canyon, between Black and Burns Canyons, and west of Woods Canyon. These segments could be a part of either the Gopher Canyon thrust or the Baldy Mountain thrust for the two thrusts almost converge at Ladder Canyon. The exposed segments of the thrust northwest of Ladder Canyon are more likely part of the Baldy Mountain thrust because they have a low angle of dip similar to that of the Baldy Mountain thrust.

The upper plate of the Baldy Mountain thrust is commonly less than 600 feet thick on the mountain southeast of Pine Creek (pl. 1). Movement along this thrust is probably as much as that on the Gopher Canyon thrust, as in places along both thrusts the Gros Ventre Formation of Cambrian age has been thrust up on the Mission Canyon Limestone of Mississippian age.

NORMAL AND REVERSE FAULTS

Both high-angle normal and high-angle reverse faults are fairly common in the Garns Mountain quadrangle. They range in length from about 1,000 feet to 5 miles and in offset from a few tens of feet to a few thousand feet. In some, the offset is predominantly dip slip, in others, predominantly strike slip. In many, the type of offset cannot be determined as the beds have a moderate dip, and the offset of the contacts could be produced by either lateral or vertical movement. Both strike faults and transverse faults are present, as related to the regional northwest trend of the rocks in the quadrangle.

Three strike faults are on the southwest side of Hell Hole Canyon, several are found in Packsaddle Basin, some occur north of Poison Creek, and one is found in the Horseshoe Creek area. The fault in the Horseshoe Creek area is the largest strike fault in the Garns Mountain quadrangle, and it has been traced for a little more than 3 miles. As the strike faults parallel the thrusts, they are commonly difficult to distinguish from them. Strike faults are found within a single thrust block and hence formed either prior to or simultaneously with the thrusting. The dips of these faults are 70°–90°. In the south half of the quadrangle, these faults generally dip to the southwest; in the north half, they generally dip to the northeast.

Most of the transverse faults strike either northeastward or northward. These faults are both normal and reverse faults that have steep dips. Movement on them is generally small, although on the north side of Burns Canyon a thick block of Wells Formation has been moved at least several thousand feet laterally. In a general way, these faults are at right angles to the thrust faults and probably served to take up differences in the amount of movement in the upper thrust plates.

Most of the transverse faults do not offset the thrust faults, but the two largest of these faults near the middle of the quadrangle offset the Absaroka thrust.

FOLDS

Approximately 125 folds were mapped in the Garns Mountain quadrangle. Most of the axes of these folds trend northwestward parallel to the strike of the major faults. Many of the folds are small (fig. 16) and local in extent, and they range in length from about 100 feet to about 3½ miles. The 3½-mile-long fold, continues eastward into the Driggs quadrangle for another 8 miles (E. H. Cressman and E. R. Pampeyan, 1962, written commun.). Many folds commonly are present in one area. Some of these are of small amplitude (fig. 16), and only one formation will be folded at the surface. In a few areas, such as North Twin Creek, West Pine Creek, and the North Fork of Canyon Creek (pl. 1), folds have a larger amplitude, and several formations are folded.

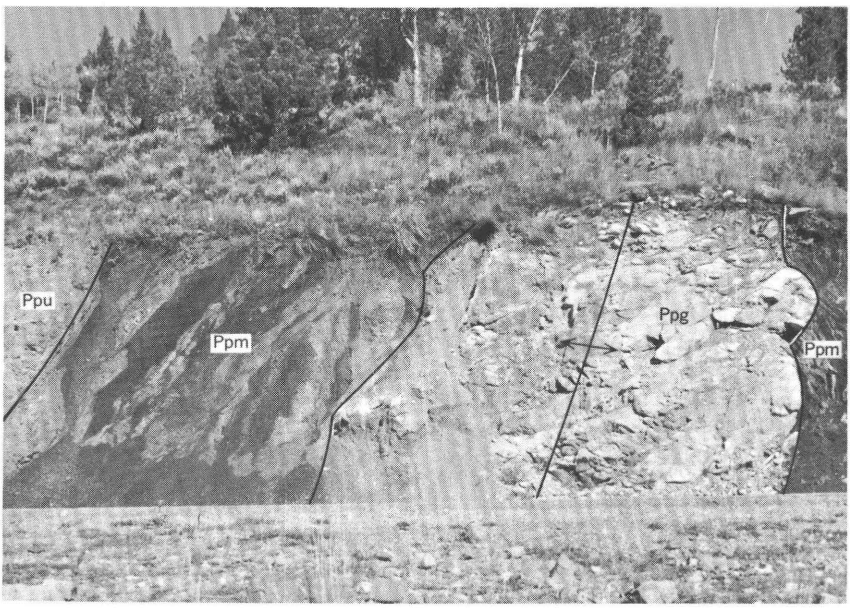

FIGURE 16.—Small anticline exposed in roadcut along northwest side of Pine Creek, a quarter of a mile southwest of the mouth of the North Fork of Pine Creek. Rock units are the Grandeur Member of the Park City Formation (Ppg), the Meade Peak Phosphatic Shale Member of the Phosphoria Formation (Ppm), and the upper unit of Phosphoria (Ppu). The Meade Peak shown is only about 12 feet thick; it is one of the thinnest sections of Meade Peak in the Garns Mountain quadrangle.

The folds probably were formed by the same forces that formed the thrusts. Some of the folds, especially the larger ones, probably were formed just prior to the actual thrusting by forces that eventually produced the thrusts. Other folds, such as those on the thin upper plate of the Baldy Mountain thrust (fig. 15), were probably formed by drag on the upper plate during the thrusting.

SNAKE RIVER PLAIN

The Snake River Plain crosses the southwest corner of the Garns Mountain quadrangle (pl. 1). This relatively flat area is a graben bounded by two steeply dipping faults. In the Garns Mountain quadrangle the rocks exposed within the graben are conglomerate and the Kirkham Hollow Volcanics of late Tertiary age and volcanic rocks and unconsolidated sediments of Quaternary age. These rocks are horizontal or gently dipping and were laid down after most of the movement that caused the folding in the Snake River Range had ceased. The Grand Valley fault, on the northeast side of the graben, and the Snake River fault, on the southwest side of the graben, are the principal structural features of the Snake River Plain.

GRAND VALLEY FAULT

The Grand Valley fault was named for exposures in the vicinity of Alpine, Wyo. by University of Michigan graduate students and was reported on by Boeckerman and Eardley (1956, p. 183). It bounds the southwest edge of the Snake River Range. The trace of this fault is mostly hidden beneath rocks of Tertiary and Quaternary age a short distance to the southwest of the present mountain front. In the Garns Mountain quadrangle the mountain front and the fault trace coincide from Dry Canyon for a distance of about 2½ miles to the northwest (pl. 1). Northwest and southeast of this area, the Grand Valley fault lies as much as half a mile to the southwest of the mountain front. Northwest of Dry Canyon, sheared and brecciated surfaces on the Darby Formation indicate that here the fault dips approximately 70° SW. The Grand Valley fault cuts off the thrusts along the front of the Snake River Range and hence is younger than the thrusts. The fault also forms the contact between the Darby and the younger conglomerate of Tertiary age. To the northwest at the mouths of Black and Burns Canyons, however, the younger conglomerate covers the fault trace. This fact suggests that movement on the Grand Valley fault began prior to the deposition of the younger conglomerate but ceased prior to the deposition of at least the uppermost part of this conglomerate.

SNAKE RIVER FAULT

The Snake River fault was named by Kirkham (1924, p. 33), who traced it for more than 30 miles along the northeast side of the Caribou Range. This fault crosses the southwesternmost corner of the Garns Mountain quadrangle (pls. 1, 2), where it is concealed by colluvium. Its position in the quadrangle was determined by extending its trace from the northern part of the Irwin quadrangle, where it was mapped by D. A. Jobin (1962, written commun.). In this part of the Irwin quadrangle, the trace of the Snake River fault is straight. This fact suggests that the dip of the fault is steep. Locally, the trace of the fault is marked by hot springs and travertine deposits.

ECONOMIC GEOLOGY

Most of the economically valuable deposits in the Garns Mountain quadrangle are found in the sedimentary rocks. At present the mineral commodities of major economic significance are phosphate rock in the Phosphoria Formation and coal in the Bear River and Frontier Formations. Oil and gas may have some potential value, although none has been discovered in this general area. Several other commodities have a small potential value. Sand and gravel deposits occur in a few places in the colluvium and alluvium, and a small amount of gravel has been removed from a pit in colluvium just southwest of U.S. Highway 26 in the southwest corner of the quadrangle. Veins are scarce in this area; only one small quartz vein 2 inches thick by 2 feet long was noted. The possibility of finding metalliferous lodes, hence, is very poor.

PHOSPHATE ROCK

Phosphate rock in this area has been found only in the Phosphoria Formation. Much of this formation is abnormally high in phosphate and even the carbonate rock commonly contains several percent apatite. Economic or potentially economic concentrations of phosphate, however, are confined to two members of this formation: the Meade Peak Phosphatic Shale Member and the Retort Phosphatic Shale Member. The Meade Peak ranges in thickness from about 9 to more than 60 feet and is most commonly about 40 feet thick. (Fig. 3 gives the thickness of the Retort in two places and the Meade Peak in five.) The Retort is generally thinner, commonly about 10 feet thick, and contains fewer beds of high grade phosphorite than the Meade Peak.

Both the Retort and Meade Peak Phosphatic Shale Members consist mainly of poorly consolidated phosphorite, mudstone, and siltstone. These rocks weather easily and are generally covered with a thick soil layer. Hence, a trench or a favorably situated roadcut is needed to determine the character of these two members or to sample the phosphorite. Three localities in the northeastern part of the Garns Mountain quadrangle were trenched in 1938 (Gardner, 1944, p. 25–29). Two of these trenches were dug across both the Retort and Meade Peak (Gardner's trenches D and E), and one trench was dug only in the Meade Peak (Gardner's trench F). (For these trench locations see pl. 1.) Prospectors trenched with a bulldozer the Meade Peak just south of Argument Ridge in the western part of the quadrangle in about 1958. This trench is on Idaho Government phosphate lease 09704 and was made by the lessees. All these trenches were rather shallow and, although most of the various rock units were exposed, the trenches were not deep enough in most places to get below the zone of weathering. To obtain additional data on the Retort and Meade Peak Members, the Geological Survey did additional trenching and sampling. This work was done under the direction of W. C. Gere, who was assisted by E. M. Schell. Work consisted of two hand-dug trenches across the Retort and Meade Peak on Piney Peak in the central part of the Garns Mountain quadrangle, deepening and resampling Gardner's old trench E where it crossed the Meade Peak, and measuring and sampling the Retort where it is exposed in a roadcut along Pine Creek. The results of this work are given in tables 1–4.

TABLE 1.—*Section of Retort Phosphatic Shale Member of the Phosphoria Formation and upper part of the lower tongue of the Shedhorn Sandstone in trench on Piney Peak in the NW¼SW¼ sec. 35, T. 4 N., R. 43 E.*

[Section measured by H. F. Albee. Analyses by K. P. Moore]

Description	*Thickness (feet)*	P_2O_5 *(percent)*	*Acid insoluble (percent)*	V_2O_5 *(percent)*	Cr_2O_3 *(percent)*
Dinwoody Formation:					
Siltstone, pale-brown, thin-bedded, calcareous.					
Retort Phosphatic Shale Member of the Phosphoria Formation:					
Phosphorite, dark-gray, weathered, hard, thin-bedded; small to large pellets; considerable fossil debris; limonite fragments	0.6	--------	--------	--------	--------
Mudstone, grayish-brown, silty, soft, thin-bedded	1.3	--------	--------	--------	--------
Mudstone, grayish-brown, silty, dolomitic, hard, thin-bedded	2.8	--------	--------	--------	--------
Mudstone, grayish-brown, soft, fissile	.5	--------	--------	--------	--------
Phosphorite, grayish-brown, argillaceous, slightly calcareous, soft; small to large pellets	1.3	28.55	14.07	--------	--------
Mudstone, black to dark-gray, silty, slightly carbonaceous, slightly phosphatic, soft. Lower half fissile. Upper half is thin bedded	2.0	3.04	65.08	0.08	0.15
Phosphorite, brownish-gray, hard, sandy, glauconitic; small to medium pellets; abundant fossil debris; some shark teeth; contains nodules or pebbles of older phosphorite	.7	27.84	21.38	--------	--------
	9.2				
Shedhorn Sandstone:					
Sandstone, medium-dark-gray, hard, medium-grained, phosphatic, slightly calcareous	0.4	9.23	73.10	--------	--------
Sandstone, brownish-gray, fine- to medium-grained, slightly phosphatic, slightly calcareous, glauconitic, massive	--------	--------	--------	--------	--------

TABLE 2.—*Section of Meade Peak Phosphatic Shale Member of the Phosphoria Formation in trench on Piney Peak in the NW¼SW¼ sec. 35, T. 4 N., R. 43 E.*

[Section measured by E. M. Schell. Analyses by K. P. Moore]

Description	Thickness (feet)	P_2O_5 (percent)	Acid insoluble (percent)	V_2O_5 (percent)	Cr_2O_3 (percent)
Franson Member of the Park City Formation:					
Sandstone, brownish-gray, fine-grained, silty, calcareous, phosphatic.					
Meade Peak Phosphatic Shale Member of the Phosphoria Formation:					
Phosphorite, medium-gray, calcareous, hard, massive; small to large pellets; slightly cherty, becoming more calcareous and cherty towards top of unit; sparse orbiculoid brachiopods and shark teeth; fossil debris	3.2	33.38	4.0	--------	--------
Phosphorite and siltstone, interbedded and intermixed. Phosphorite is dark gray, silty, calcareous; has small to large pellets. Siltstone is medium yellowish brown and soft	.2				
Siltstone, grayish-orange, soft; a few small to medium phosphorite pellets; indistinct bedding	.3	26.59	16.91	--------	--------
Phosphorite, grayish-brown with orange-brown staining, slightly calcareous, hard; argillaceous matrix; small to large pellets	.4				
Siltstone, medium-yellowish-brown, soft; contains small to medium phosphorite pellets; indistinct bedding; has 0.05 foot phosphorite bed at base	.2				
Mudstone, dusky yellowish-brown, soft, micaceous; sparse small to medium phosphorite pellets	3.6	--------	--------	--------	--------
Mudstone, brownish-black, medium-hard, carbonaceous, slightly calcareous, laminated, thick-bedded	4.3	--------	--------	--------	--------
Mudstone, grayish-black, soft, fissile, carbonaceous; phosphatic in part	1.3	--------	--------	--------	--------
Mudstone, dusky yellowish-brown, soft, calcareous, carbonaceous; sparse medium phosphorite pellets	2.7	--------	--------	--------	--------
Phosphorite and mudstone, brownish-black, carbonaceous, soft; medium to large pellets; phosphatized fish teeth; indistinct bedding	4.4	16.04	27.05	0.38	0.39
Mudstone, brownish-black (weathers dark-brown) slightly siliceous, slightly calcareous, carbonaceous, hard; sparse small to large phosphorite pellets	1.4	--------	--------	--------	--------
Mudstone, dark-yellowish-brown, slightly carbonaceous, partly siliceous, micaceous; sparse small to medium phosphorite pellets; laminated in part; indistinct bedding	1.3	--------	--------	--------	--------
Mudstone, brownish-black, micaceous, carbonaceous, soft, fissile; small to large phosphorite pellets; fish teeth and other fossil debris	1.2	--------	--------	--------	--------
Mudstone, brownish-black, carbonaceous, calcareous, soft; sparse small to medium phosphorite pellets	.9	--------	--------	--------	--------
Mudstone, black, carbonaceous, soft, fissile; medium to large phosphorite pellets	3.0	6.11	33.82	.30	.74
Mudstone, brownish-black, carbonaceous, partly dolomitic, soft; small to medium phosphorite pellets	3.0	5.64	44.14	.37	.35
Phosphorite and mudstone, brownish-black (limonite staining) slightly calcareous, carbonaceous, soft; large pellets. Phosphorite is dominant rock type; fissile in part; indistinct bedding in part	2.2	20.31	19.66	.18	.37
Mudstone, dusky-brown, carbonaceous, slightly calcareous, partly sandy, soft; small to large phosphorite pellets; indistinct bedding	1.1				
Phosphorite, brownish-black, friable, argillaceous, small to large pellets	.4	28.82	6.47	--------	--------
Mudstone, dusky yellowish-brown, carbonaceous, slightly calcareous, soft, laminated; fine- to medium-grained phosphorite pellets	.7	4.14	66.75	--------	--------
Mudstone, grayish-black, carbonaceous, soft, fissile; sparse small to large phosphorite pellets	.5	7.14	37.40	--------	--------
Phosphorite, brownish-black, argillaceous, slightly calcareous, oolitic, hard; abundant secondary apatite; phosphatic fossil debris	.7	29.98	8.39	--------	--------
Siltstone, medium-yellowish-brown, medium-hard; sparse small to medium phosphorite pellets and thin stringers	.3	--------	--------	--------	--------
Phosphorite, brownish-black, slightly calcareous, slightly silty, hard; abundant secondary apatite; small to large pellets	.2	--------	--------	--------	--------
	37.45				
Wells Formation:					
Dolomite, yellowish-gray, very fine grained, sandy-textured, thick-bedded.					

Table 3.—*Section of Meade Peake Phosphatic Shale Member of the Phosphoria Formation in Gardner's trench E, 1 mile north of Elk Flat in the NE¼NE¼ sec. 18, T. 4 N., R. 44 E.*

[Section measured by W. C. Gere and H. F. Albee. Analyses by K. P. Moore]

Description	Thickness (feet)	P_2O_5 (percent)	Acid insoluble (percent)	V_2O_5 (percent)	Cr_2O_3 (percent)
Franson Member of the Park City Formation:					
Limestone, yellowish-gray, fine-grained, dolomitic; small pods of chert.					
Meade Peak Phosphatic Shale Member of the Phosphoria Formation:					
Phosphorite, medium-gray, argillaceous, slightly calcareous, hard; small to large pellets; upper part has brachiopod debris	0.4	--------	--------	--------	--------
Siltstone, dark-yellowish-brown, phosphatic, hard; dolomitic in lower part	4.0	--------	--------	--------	--------
Siltstone, dark-yellowish-brown: contains three thin interbeds of medium to large pelletal phosphorite	3.8	--------	--------	--------	--------
Phosphorite, dark-gray, hard; medium to large pellets	.2	--------	--------	--------	--------
Dolomite, dark-yellowish-brown, very fine grained, silty	1.2	--------	--------	--------	--------
Phosphorite, dusky yellowish-brown, argillaceous, silty, soft; small to large pellets	.2	--------	--------	--------	--------
Dolomite, dark-yellowish-brown, fine-grained, silty, slightly phosphatic	.4	--------	--------	--------	--------
Phosphorite, dusky yellowish-brown, argillaceous, slightly calcareous, hard; medium pellets	.5	--------	--------	--------	--------
Dolomite, light-olive-gray, very fine grained, silty; sparse small to medium phosphorite pellets	.6	--------	--------	--------	--------
Phosphorite, dusky yellowish-brown, silty, calcareous, hard; medium to large pellets	.1	--------	--------	--------	--------
Siltstone, medium-brown, hard; numerous small to large phosphorite pellets	.2	--------	--------	--------	--------
Mudstone, dusky yellowish-brown, carbonaceous, micaceous, soft, fissile; numerous small to medium phosphorite pellets	2.2	--------	--------	--------	--------
Dolomite, olive-gray, very fine grained, calcareous, silty, partly phosphatic	.6	--------	--------	--------	--------
Phosphorite, brownish-black, argillaceous, soft, fissile; medium pellets	.3	--------	--------	--------	--------
Mudstone, dark-gray, dolomitic, carbonaceous, slightly phosphatic, hard, thin-bedded	.2	--------	--------	--------	--------
Phosphorite with interbeds of mudstone, black, carbonaceous, soft. Phosphorite has medium to large pellets and is argillaceous. Mudstone is calcareous and phosphatic	6.2	[1]23.95 [2]20.06	14.55 18.37	0.24 .27	0.26 .52
Phosphorite, brownish-gray, argillaceous, silty soft; small to large pellets. Upper part has large pellets, is calcareous, and contains scattered fluorite crystals	1.5	25.74	15.90	.21	.13
Phosphorite, dusky yellowish-brown, argillaceous, silty, soft; small to medium pellets	1.2	27.46	13.39	.16	.13
Mudstone, brownish-black, carbonaceous, soft, fissile; some small phosphorite pellets	.1				
Phosphorite, medium-dark-gray, slightly argillaceous, hard; medium to large pellets; increasingly pelletal towards top of unit; reworked mudstone and siltstone nodules; small weathered white clay-like concretions	1.6	32.00	12.51	.05	.02
	25.5				
Wells Formation:					
Dolomite, medium-dark-gray, very fine grained; some fine quartz grains; phosphatic fossil debris in uppermost part.					

[1] Upper 3.2 ft.
[2] Lower 3.0 ft.

TABLE 4.—*Section of Retort Phosphatic Shale Member of the Phosphoria Formation in highway cut on northwest side of Pine Creek in the NW¼SE¼ sec. 29, T. 3 N., R. 44 E.*

[Section measured by W. C. Gere. Analyses by K. P. Moore]

Description	Thickness (feet)	P_2O_5 (percent)	Acid Insoluble (percent)	V_2O_5 (percent)
Dinwoody Formation:				
Mudstone, olive-green, calcareous, thin-bedded.				
Retort Phosphatic Shale Member of the Phosphoria Formation:				
Phosphorite, argillaceous, interbedded with phosphatic mudstone	1.5	30.68	14.03	0.008
Mudstone, phosphatic	4.7	9.98	57.07	.01
Mudstone, phosphatic	1.7	5.61	63.50	.007
Sandstone, phosphatic	1.1	16.36	52.92	.006
	9.0			
Shedhorn Sandstone:				
Sandstone, light-gray, medium-grained.				

The sections of Retort Phosphatic Shale Member of the Phosphoria Formation reported in tables 1 and 4 are on the southwest side of the Absaroka thrust and about 6 miles apart. At both places the Retort is approximately 9 feet thick and has prominent phosphorite beds at the top and bottom of the sections. The intervening part is mainly mudstone, with some thin beds of phosphorite. Gardner (1944, p. 25–28) reported on two sections of the Retort northeast of both the Absaroka and Jackson thrusts. The Retort here is thicker, being 39 feet thick in trench D and 19 feet thick in trench E. The phosphorite in these two trenches is found in the central part of the Retort instead of the top and bottom. The thickest phosphorite bed reported in all four trenches is only 1.5 feet thick. The Piney Peak trench has the greatest thickness of phosphatic rocks containing 21 percent or more P_2O_5, and these beds have a total thickness of only 2.0 feet. Phosphate deposits of the Retort in this area, hence, are not likely to be mined in the foreseeable future.

The Meade Peak Phosphatic Shale Member of the Phosphoria Formation contains more phosphorite and in most places is thicker than the Retort Phosphatic Shale Member of the Phosphoria Formation. The two trenches on the Meade Peak are in different thrust blocks: the trench on Piney Peak is southwest of the Absaroka thrust and Gardner's trench E is northeast of both the Absaroka and the Jackson thrusts. The Meade Peak at these two places is 37 and 25 feet thick (tables 2 and 3). A much greater change in thickness was noted along strike in the thrust block that contains the Piney Peak trench. Within a distance of 10.5 miles, the Meade Peak seems to increase in thickness from 9.4 to 63.0 feet (fig. 3).

Hard phosphorites are at both the top and bottom of the Meade Peak throughout the Garns Mountain quadrangle, and on ridges these two units are commonly exposed. Other phosphorites in the Meade Peak are less resistant and rarely exposed. Both hard and soft phosphorites are found in both trenches near the base of the Meade Peak. In Gardner's trench E the greater part of the phosphorite is in the lower 10.6 feet of section, which averages 24.7 percent P_2O_5. In the trench on Piney Peak, this phosphate zone is not as thick, and the thickest continuous sequence in this part of the section was found 2.4 feet above the base of the Meade Peak, where 3.7 feet of phosphorite and phosphatic mudstone have an average P_2O_5 content of 21.2 percent. The section in the Piney Peak trench, however, has a thicker phosphate zone at the top of the Meade Peak, where the upper 4.3 feet of phosphorite and a little phosphatic siltstone has an average P_2O_5 content of 31.6 percent. The uppermost phosphate zone is also found in Gardner's trench E but is only 0.4 of a foot thick.

The V_2O_5 and Cr_2O_3 content of some of the samples was also obtained. Vanadium has been recovered in the past by The Anaconda Co. from their wet process for phosphoric acid on ore mined at Conda, Idaho (Caro, 1949, p. 284). In addition, the production of elemental phosphorus by electric furnaces from western phosphate deposits yields a ferrophosphorus slag containing 7–8 percent V_2O_5 and 6 percent chromium (R. P. Fisher, 1963, oral commun.). Thus, these two oxides are important as potential byproducts in the treatment of any phosphate mined from the Garns Mountain quadrangle. The phosphatic shale of the Phosphoria Formation has long been known as a potential oil shale, and an area south of Dillon, Mont., contained as much as 20 gallons of oil per ton of shale (Condit, 1919, p. 24). In the Garns Mountain quadrangle, W. C. Gere collected 25 channel samples in the Meade Peak Phosphatic Shale Member of the Phosphoria Formation in the trench on Argument Ridge. These samples contained only traces of oil, the highest yield being 0.6 of a gallon of oil per ton of rock.

The phosphate deposits have neither been mined nor extensively prospected in the Garns Mountain quadrangle. A phosphate lease (Idaho 09704) was issued in May 1959 for a block of land that covers the Phosphoria Formation from Marlow Creek to the southeast end of Argument Ridge. This lease was issued jointly to G. F. Terry of Route 2, St. Anthony, Idaho and Samuel and Dayton Grover of Route 1, Thornton, Idaho. Exploration on the lease to 1963 consisted of two bulldozer workings and a small adit in the Meade Peak Phosphatic Shale Member. A bulldozer trench was made across the Meade Peak on the main ridge just south of Argument Ridge. The Meade Peak shown in section D, figure 3, was measured along this trench. A second bulldozer cut was made where the Meade Peak crosses Coalmine Canyon, but subsequent dozing has covered all outcrops. The small adit is on the mountainside between these two bulldozer workings. It was made prior to 1917, as it was mentioned by Mansfield (1920, p. 137). When the adit was driven, the black phosphorite and mudstones were thought to be coal beds, and Coalmine Canyon was named after this small adit.

COAL

Coal and carbonaceous seams occur in the Bear River and Frontier Formations in the Garns Mountain quadrangle. The Bear River Formation contains mainly thin carbonaceous and coaly seams, and no potentially important coal beds are known. Coal beds of economic significance are found, however, in the upper part of the Frontier. Beds of coal in this part of the Frontier are limited to the vicinity of Horseshoe Creek in the northeastern part of the quadrangle, where prospecting for coal started as early as 1882 (Schultz, 1918, p. 70). The earliest recorded production in this district began in the early 1900's (Kiilsgaard, 1951, p. 34–35) and continued intermittently to the early 1950's. During this period, coal was produced from at least eight mines. The total amount of coal produced from the Horseshoe Creek district is not accurately known, as most of the early production was to the local wagon trade, and no records were kept. Kiilsgaard (1951, p. 32) stated, however, that "a very rough estimate for the district might be in the neighborhood of 100,000 tons."

The coal in the Horseshoe Creek district is easily weathered and is exposed only in the prospects or mines which, when we mapped in 1961 and 1962, were either caved or filled with water. Most of the rest of this section on coal, therefore, is abstracted from published reports by Kiilsgaard (1951), Evans (1924), and Mansfield (1920), who studied this area while the mines were still active. The reader is referred to Kiilsgaard (1951) for the most comprehensive report of the district to date.

The coal-bearing part of the Frontier Formation is about 900–1,000 feet thick and at least 3,000 feet above the base. The more economically important coal beds are found in the lower part of the coal-bearing zone (Kiilsgaard, 1951, p. 23). The major coal beds extend northwestward across the Horseshoe Creek district with little variation in character or thickness. The sequence of coal-bearing beds has at least seven coal beds 2 feet or more thick. Only four of these beds have been developed to any extent, and only two of these, the Brown Bear and Progressive, have produced significant amounts of coal. The Progressive bed lies from 88 to 92 feet stratigraphically above the Brown Bear bed, and thus they have been developed largely through the same workings.

Coal is found in two separate belts. The western belt, which is the more extensively explored, crosses the area just east of the Jackson thrust (pl. 1). Coal beds within this belt strike N. 20°–40° W. and dip 30°–85° SW. toward the fault. These beds have been traced by prospecting from a point north of Packsaddle Creek, where they are overlain by volcanic rocks, to a short distance south of Superior Creek where they are covered by thick colluvium. The strike length of this belt of coal beds is a little more than 3 miles.

The eastern coal belt lies just east of the Mount Manning thrust fault (pl. 1). These beds have been partially explored from the Mikesell mine on Packsaddle Creek to Horseshoe Creek. No potentially economic coal beds have been found south of Horseshoe Creek.

Both coal belts occur in tilted fault blocks. Coal beds of the eastern belt are probably the same beds as those of the western belt (Kiilsgaard, 1951, p. 25). This conclusion is based on exposures at the Mikesell mine where the sequence and character of the coal beds are identical with exposures at the old Brown Bear mine and other western belt properties.

The eastern coal beds probably do not extend to any great depth. Their attitudes and their nearness to the Mount Manning thrust indicate they are probably terminated by that fault at rather moderate mining depths. On the other hand, coal beds of the western belt probably extend beyond the depths of profitable mining (Kiilsgaard, 1951, p. 25). At the Samuels tunnel at the Brown Bear mine (pl. 1), most of the economically important coal beds were intersected at a depth of about 600 feet below the surface. At the points of intersection, there was little change in the dips from those at the surface.

The following sections were measured by Kiilsgaard (1951, p. 30–31).

Progressive coal bed

[Horseshoe mine]

	Thickness	
	Feet	*Inches*
Hanging wall, sandy shale:		
Coal, hard, good quality	2	8
Clay, sandy		9
Coal		6
Bone		2
Coal, good	4	0
Bone		2
Coal	2	0
Footwall, dark shale.		

Brown bear coal bed

[Brown Bear mine]

	Thickness	
	Feet	*Inches*
Hanging wall, sandstone:		
Clay, gray		2
Coal, blocky	2	6
Clay, stringer, discontinuous		1. 5
Coal, blocky	2	6
Footwall, clay, gray		6
Sandstone, dark		4

Coal in the district is of excellent quality. It ranges from subbituminous to high-grade bituminous and is low in ash, sulfur, and moisture. For the most part, the coal is high in heating value, and average analyses range from 11,000 to 14,000 British thermal units. It is generally friable and breaks to a small size if handled, but this characteristic is no longer the detriment that it once was. Following are the results of tests on coal from the Brown Bear and Horseshoe mines as reported on an "as received" basis by the U.S. Bureau of Mines (1947, p. 37):

Test results on coal from Brown Bear and Horseshoe mines

	Moisture (percent)	Ash (percent)	Volatile matter (percent)	Fixed carbon (percent)	Btu
Brown Bear	11. 5	4. 3	37. 2	47. 0	12, 090
Horseshoe	7. 8	2. 2	39. 7	50. 3	12, 880

Tests were also made on the oil yield of the Brown Bear bed by Lewis Karrick, fuel engineer for the U.S. Department of the Interior (Campbell, 1939, p. 267), who reported the following results per ton of coal treated:

1,380 pounds of semicoke.
2,500 cubic feet of gas that has a heating value of approximately 1,000 Btu per cubic foot.
32.2 gallons of crude oil from which can be refined:
 10 gallons of gasoline
 10 gallons of diesel fuel
 5 gallons of road oil

The indicated reserves of the Horseshoe Creek district are large compared to its relatively small size. Observations by Kiilsgaard (1951, p. 33) in the western coal belt, both on the surface and underground, indicate the probability that a block of ground 3 miles long and 600 feet wide contains coal beds in which the thickness remains fairly uniform. Using a factor of 1,630 tons of coal per acre-foot and assuming a minable thickness of 4 feet for the Brown Bear bed and 6 feet for the Progressive bed to the depth of the deepest working in the area, indicated reserves are about 1,400,000 tons of coal in the Brown Bear and 2,000,000 tons in the Progressive. An additional 4,600,000 tons can be inferred by extending the coal beds 600 feet below the present workings. Another coal bed, known as the Boise bed, contains about 1,070,000 indicated and 1,070,000 inferred tons of coal.

The grade of the coal and the estimated reserves show this district to have the greatest potential for economic development of any coal-bearing district in Idaho.

OIL AND GAS

Although the oil and gas possibilities of the Snake River Range have been considered for more than 40 years (Kirkham, 1922), little drilling has been done, and most of it, on only a few anticlines. In the Garns Mountain quadrangle, six holes have been drilled on the Horseshoe Creek anticline (pl. 1). Five of these were fairly shallow holes and were drilled by the Grand Teton Oil Co. and the Teton Valley Land and Leasing Co. between 1924 and 1934 (table 5). The only deep test hole (No. 4 [3] on map) was drilled from 1951 to 1953 by Phillips Petroleum Co. No data are available on which formation holes 1, 3, and 5 reached; probably holes 3 and 5 did not get out of the Frontier Formation, and hole 1, out of the Gannett Group. Holes 1, 2, and 6 had showings of either gas or oil. Hole 2 bottomed in red shales interbedded with limestone beds, a sequence typical of the Bechler Formation in the Garns Mountain quadrangle. Hole 6 bottomed in a fossil-bearing black shale similar to some exposures of the Bear River Formation about 1½ miles northwest of the hole. Hole 4 penetrated a fairly normal sequence from the Frontier Formation to the Mission Canyon Limestone. Heikkila (1953, fig. 2) noted a normal fault and a thrust fault that almost meet at the drill hole. He indicated that where the drill hole crosses the normal fault, the Frontier Formation has been moved down against the Bear River Formation and at the thrust, the Bear River has been shoved over the Aspen Shale. Heikkila in the lithologic description of the Upper Cretaceous (1953, p. 93) erroneously believed that porcellanites occur in the Bear River as well as in the Aspen in the Garns Mountain area. Because we found no evidence of these faults during mapping, we do not feel that their existence has been well substantiated.

The oil potential of the quadrangle cannot be entirely judged by tests at Horseshoe Creek anticline. Many structural features capable of forming traps for oil or gas occur in other places in the Garns Mountain quadrangle. Furthermore, several of the formations that occur in this quadrangle are oil bearing in Wyoming. These formations, however, may not contain suitable reservoir rocks in this area. Lack of such suitable reservoir rocks was noted in hole 4 by Heikkila (1953, p. 94), who stated: "With the possible exception of water-bearing Upper Cretaceous sandstones, no reservoir development was indicated, especially in deeper formations in which there was excessive fracturing and mineralization. The lack of reservoir development in the Horseshoe area may be typical of a large part of the overthrust belt."

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[3] Numbers used are those shown on plate 1 and in table 5.

TABLE 5.—*Wells drilled for oil and gas*

[Data from files of Conservation Division, U.S. Geological Survey, and from Heikkila, 1953]

Operator	Well No.	Map No.	Location (T. 5 N., R. 44 E.)	Date completed	Total depth (ft)	Approximate collar altitude (ft)	Lowest rock reported	Remarks
Teton Valley Land and Leasing Co.	2	1	W½NE¼SE¼, sec. 28	1924	269	6,200		Gas shows.
Do	Blevins 3	2	SW¼NW¼SE¼, sec. 28	1930	1,392	6,200	Bechler Formation.	Oil and gas shows.
Grand Teton Oil Co.	Dewey 1	3	W line SE¼SE¼, sec. 28	1934	950	6,425		
Phillips Petroleum Co.	Dewey 1	4	C SE¼SW¼, sec. 28	1953	12,724	6,379	Mission Canyon Limestone.	
Teton Valley Land and Leasing Co.	1	5	SE¼SE¼NE¼, sec. 32	1924	100	6,600		
Grand Teton Oil Co.	Blevins 1	6	SW¼SE¼, sec. 33	1929	3,304	6,875	Bear River Formation.	Gas shows.

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