Geology of the Michaud and Pocatello Quadrangles, Bannock and Power Counties, Idaho

GEOLOGICAL SURVEY BULLETIN 1400

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By DONALD E. TRIMBLE

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Stratigraphy and structure of an area at the southeastern margin of the Snake River Plain, including a subdivision of upper Precambrian rocks

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SYSTEM OF MEASUREMENT UNITS

The following report uses English units of measure throughout. These English units can be converted to metric units by multiplying by the following factors.

English unit *To convert*	*Multiply by*	*Metric unit* *To obtain*
Feet	0.3048	Metres (m).
Inches	25.4	Millimetres (mm).
	2.54	Centimetres (cm).
Miles	1.609	Kilometres (km).
Square miles	2.59	Square kilometres (km^2).

GEOLOGY OF THE MICHAUD AND POCATELLO QUADRANGLES, BANNOCK AND POWER COUNTIES, IDAHO

By DONALD E. TRIMBLE

ABSTRACT

The Michaud and Pocatello quadrangles comprise an area in southeastern Idaho extending eastward from the American Falls Reservoir, in the Snake River Plain, and including the Pocatello Range and the northern part of the Bannock Range, in the Basin and Range physiographic province. The mountainous parts are underlain principally by marine sedimentary rocks of Precambrian and Cambrian age but also contain a fairly complete section of Paleozoic rocks. Tertiary rocks crop out extensively in the foothills. Quaternary deposits cover more than half the area and include basalt, pediment gravel, loess, and lacustrine and fluvial deposits.

More than 20,000 feet of sedimentary rocks, principally marine, is assigned to the Precambrian System. The oldest rocks, which make up the Pocatello Formation, are divided into four members. An unnamed lower member, at least 1,000 feet thick, is mainly slate and slaty argillite. Several thousand feet of interbedded quartzite and submarine-deposited diamictite, later metamorphosed, constitutes the overlying Scout Mountain Member. Metavolcanic rocks, principally greenstone and greenstone schist, compose the Bannock Volcanic Member, which tongues or lenses into the Scout Mountain Member. The upper member of the Pocatello, at least 1,800 feet thick, consists of slaty to phyllitic argillite that is interbedded with quartzite in the upper half. The Blackrock Canyon Limestone, commonly several hundred feet thick, overlies the Pocatello Formation and forms a distinctive marker. Overlying quartzitic rocks are also divided into four formations. The Papoose Creek Formation (oldest) consists of 600 to perhaps 2,500 feet of distinctively, irregularly bedded very fine grained quartzite and siltite. The overlying Caddy Canyon Quartzite consists of several thousand feet of quartzite, separated by about 50 feet of dolomite or limestone. The succeeding Inkom Formation is a distinctive clastic marker unit characterized by fine grain size and pale-green color. The Precambrian unit, the Mutual Formation, consists of 2,500-3,000 feet of medium-to coarse-grained crossbedded quartzite, much of which is grayish red or purple, and red and green argillites and slates.

The Precambrian and Cambrian Camelback Mountain Quartzite conformably overlies the Mutual Formation. It consists of as much as 3,500 feet of light-colored vitreous orthoquartzite. It is overlain by the Gibson Jack Formation, 1,500-2,300 feet of mainly argillaceous siltstone and shaly argillite that contains the arthropod *Naraoia*, which is thought to be Early Cambrian but may be Middle Cambrian. The succeeding Elkhead Limestone, more than 2,000 feet thick, consists principally of gray limestone. This formation is Middle Cambrian.

The area contains partial exposures of two younger Cambrian formations—the Bloomington Formation (upper-Middle Cambrian) and the Nounan Dolomite (Middle and Upper Cambrian).

Post-Cambrian Paleozoic rocks, exposed poorly and only in the northern part of the Pocatello quadrangle, are the Ordovician Fish Haven Dolomite, the Silurian Laketown Dolomite, the Devonian Hyrum Dolomite, the Mississippian Lodgepole Limestone and Deep Creek Formation, and the Pennsylvanian lower part of the Wells Formation.

There are no Mesozoic rocks, and Tertiary rocks are limited to volcanic rocks of the middle Pliocene Starlight Formation. The Starlight Formation is mostly airlaid rhyolitic tuff with an interstratified ash-flow tuff that is used to subdivide the formation into three members, the ash-flow unit being the middle member. Interstratified with the lower member are basaltic breccias, tuffs, and flows from a local eruptive center. The youngest rock assigned to the Starlight is a thick flow of porphyritic trachyandesite.

In the northern part of the Pocatello quadrangle the rhyolitic tuff intertongues with sedimentary mudflow breccia that is composed mostly of fragments of Ordovician rocks in a calcareous matrix.

Rhyolite, basalt, and andesite porphyry younger than Starlight may be either late Tertiary or Quaternary.

Quaternary loess and alluvial deposits form a nearly continuous mantle, except in the higher parts of the Bannock and Pocatello Ranges—mainly above an altitude of 6,000 feet. The American Falls Lake Beds were deposited in a Pleistocene lake formed by damming of the valley of the ancestral Snake River. Basalt flows—basalt of Porteneuf valley—were emplaced in the valley of the tributary Portneuf River 30,000-35,000 years ago. Later, floodwaters of catastrophic proportions originating in a spillover of pluvial Lake Bonneville deposited a great combined delta and fan, the Michaud Gravel, which contains boulders more than 8 feet in longest dimension. Deposits of the first terrace cut on the Michaud Gravel (the Aberdeen terrace) have been dated at about 30,000 years before the present, which is thought to approximate the time of the flood. The still younger Sterling terrace probably is of Pinedale age.

The region has had a complex structural history. Nearly all the pre-Tertiary rocks of the area are within a large klippe that is more than 50 miles wide and is about 120 miles long. The western margin is at a thrust fault in the Deep Creek Mountains to the southwest, and the eastern margin is at the west edge of the Bannock thrust zone. An inferred fault in the northern part of the Pocatello quadrangle may be part of the boundary of this klippe. The rocks of the klippe are much broken by normal faults that may be the result of relaxation of stress after thrusting. Post-thrusting basin-and-range faults bound the mountain blocks. The Snake River Plain is interpreted as a graben that truncates the mountain blocks outlined by earlier basin-and-range faulting. The timing of thrusting and of basin-and-range faulting in this region is imperfectly known. The thrusting can only be dated as post-Early Permian and older than basin-and-range faulting. Basin-and-range faulting may have begun as early as Miocene and must have been nearly complete before the middle Pliocene volcanic rocks were erupted. Younger faults cutting the Tertiary volcanic rocks commonly are offset less than 100 feet.

Earth materials of present economic importance are sand and gravel, crushed rock, silica (quartzite), limestone for cement, and ground water. Mining has reportedly produced only small amounts of copper and gold.

INTRODUCTION

The Michaud and Pocatello 15-minute quadrangles are in southeastern Idaho (fig. 1). Pocatello, the second largest city in Idaho, is located in this area, which is served by the main line of the Union Pacific Railroad and by U.S. Highways 30N., 91, and 191, and by Interstate Highways 15 and 15W. Much of the Michaud quadrangle and the northern part of the Pocatello quadrangle are part of the Fort Hall Indian Reservation.

The area covered by this report is part of a much larger area recently mapped by the U.S. Geological Survey. The American Falls quadrangle, which is described in U.S. Geological Survey Bulletin 1121-G (Carr and Trimble, 1963), adjoins the west side of the Michaud quadrangle. The Rockland and Arbon quadrangles, which adjoin the Michaud quadrangle on the southwest and south, respectively, are described in U.S. Geological Survey Bulletin 1399 (Trimble and Carr, 1976).

A thick sequence of Precambrian and Cambrian rocks is exposed in the Bannock and Pocatello Ranges. Tertiary volcanic rocks lap onto the older rocks of the mountains and fill the intermontane valleys and are, in turn, covered by Quaternary deposits at lower altitudes and on the Snake River Plain. Most of the Tertiary and Quaternary units are described in the above listed reports, but the stratigraphy of the lowermost Cambrian and Precambrian rocks of this area is newly established (Crittenden and others, 1971).

PREVIOUS INVESTIGATIONS

Early explorers and field parties of the Hayden surveys of the territories (1871 and subsequent years) passed through this area. The broad outlines of the geology as determined by them are shown on geologic map by Peale, St. John, and Endlich (1883), which accompanies the twelfth annual report of the Hayden survey. Russell made a reconnaissance study of the Snake River Plain in 1901 (Russell, 1902), but his traverse did not extend into the area of this report.

The first geologic study confined to this area was made by Weeks and Heikes (1908), who investigated the Fort Hall mining district, which was established in 1902 on land ceded from the Fort Hall Indian Reservation. They erroneously concluded that the sequence of strata exposed along the canyon of the Portneuf River was of Ordovician age.

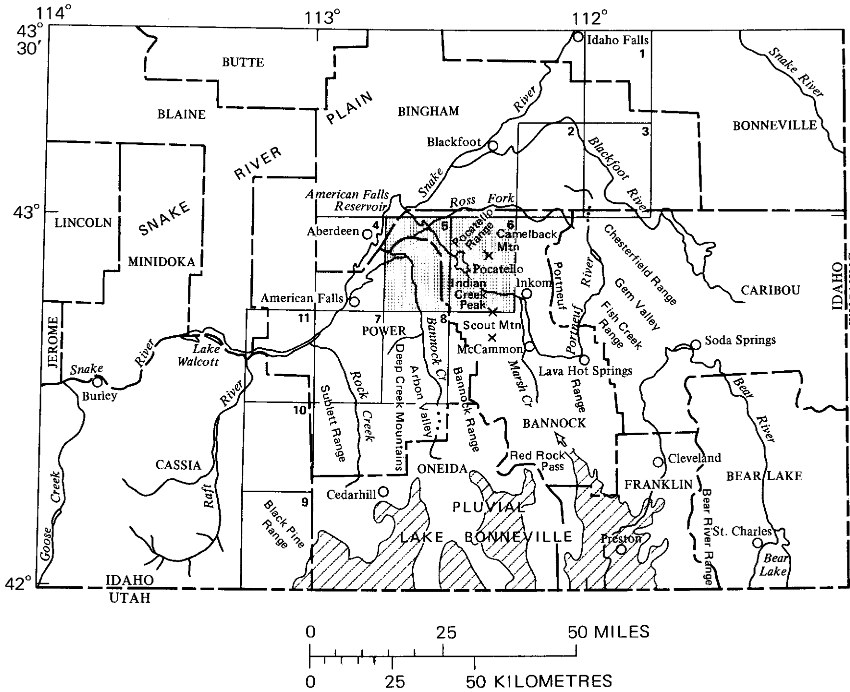

FIGURE 1.—Index map of southeastern Idaho, showing location of the area of this report (patterned) and other quadrangle study areas mapped or being mapped by the U.S. Geological Survey. Quadrangles are designated by number: 1, Ammon; 2, Yandell Springs; 3, Paradise Valley; 4, American Falls; 5, Michaud; 6, Pocatello; 7, Rockland; 8, Arbon; 9, Strevell; 10, Sublett; 11, Yale.

G. R. Mansfield studied the Fort Hall Indian Reservation (1920). Although much of the Michaud and part of the Pocatello quadrangles lie within the reservation, few pre-Tertiary rocks are exposed in that part of the reservation, and the Tertiary volcanic rocks apparently received only cursory attention from Mansfield. A reconnaissance of part of this area by Piper (1924) used some of Mansfield's work.

Anderson (1928), 20 years after Weeks and Heikes' initial study, examined the area adjacent to the canyon of the Portneuf River between Portneuf and Inkom to determine the potential for a cement industry, which later was established at Inkom. Anderson considered as Cambrian the rocks that Weeks and Heikes thought were Ordovician.

Ludlum, a student of Anderson, whose study area included the southern two-thirds of the Pocatello quadrangle and the adjoining areas to the south, later concluded (Ludlum, 1942, 1943) that the lower part of the stratigraphic sequence exposed along the Portneuf canyon was of Precambrian age. Ludlum also further divided the stratigraphic sequence, which had been partly divided by Anderson. Many of the stratigraphic names used in the present report were introduced by Anderson and Ludlum.

The most comprehensive study of the geology and ground-water resources of the Snake River Plain was made by Stearns, Crandall, and Steward (1938). They devoted special attention to an evaluation of the source of the many large springs along the lower course of the Portneuf River below Pocatello and on Fort Hall Bottoms, along the northeastern margin of American Falls Reservoir.

FIELDWORK AND ACKNOWLEDGMENTS

The northwest quarter of the Pocatello quadrangle and all but the southeast quarter of the Michaud quadrangle were mapped jointly by Donald E. Trimble and Wilfred J. Carr, mostly during 1960. Most of the southeast quarter of the Michaud quadrangle was mapped during the summer of 1962 by Donald E. Trimble, assisted for 3 weeks by W. Neal Bowman. The part of the Pocatello quadrangle south of the Portneuf River was mapped in 1963 by Trimble, assisted by Robert L. Reinking. The mapping of that part of the Pocatello quadrangle north of the Portneuf River was completed by Trimble in 1964 and 1965.

The cooperation of the Shoshone-Bannock Tribal Council in granting permission for the geologic studies on the Fort Hall Indian Reservation is gratefully acknowledged. I am also indebted to John G. Brooks, Supervisory Civil Engineer of the Michaud Unit of the Bureau of Indian Affairs, for well data on Michaud Flats. Other subsurface information came from water-well records provided by the Boise regional office of the U.S. Geological Survey and from auger-hole samples obtained with a truck-mounted power auger brought to the area in 1959 by T. C. Nichols of the U.S. Geological Survey.

The studies benefited from discussions with members of the faculty of Idaho State University, especially Andreii Isotoff and Marie L. Hopkins.

R. C. Bright, of the University of Minnesota, made available his unpublished descriptions of the rocks of the Cleveland area, Idaho. His study of the Pleistocene history of the Bear River contributed greatly to an understanding of the history of spillover from pluvial Lake Bonneville into the Snake River valley.

Special acknowledgment is made of the contribution of Frederick E. Schaeffer, then with Idaho State University, who in the course of a reconnaissance study of Bannock County for the State of Idaho

Bureau of Mines and Geology first recognized, in 1962, a sequence of mappable units in the quartzitic rocks formerly assigned to the Brigham Quartzite. This sequence of units, which, with some revisions, subsequently was verified by me and reported on elsewhere (Crittenden and others, 1971), is used in this report. Schaeffer's major role in the recognition of the stratigraphic units within the Precambrian-Lower Cambrian sequence is here acknowledged with pleasure and appreciation.

Paleontologic identifications of the fossils of the Cambrian rocks were made by A. R. Palmer, who visited the area in 1963. Correlations of the lower part of the Cambrian sequence with similar rocks elsewhere are based in part on the meager faunal assemblage.

GEOGRAPHY

The boundary between the Basin and Range province and the Snake River Plain section of the Columbia Plateaus physiographic province trends northeastward through the Michaud and Pocatello quadrangles. The major streams in the area are the Snake River and the Portneuf River (fig. 1).

The Snake River, which flows southwestward through the northwestern part of the Michaud quadrangle, has been dammed a few miles to the west of the town of American Falls to form American Falls Reservoir. This reservoir, part of which covers about 40 square miles of the northwestern part of the Michaud quadrangle, is the largest body of water in southeastern Idaho. Its fluctuating level, with a maximum at the spillway altitude of 4,384 feet, provides a local base level.

The Portneuf River flows northwestward through a narrow steep-walled valley to join American Falls Reservoir in the northeastern part of the Michaud quadrangle. Lesser tributaries of the Snake River are Bannock Creek, which flows northward through the southern part of the Michaud quadrangle and drains the Deep Creek Mountains to the southwest and the Bannock Range to the east, and Ross Fork, which joins American Falls Reservoir from the northeast, just north of the mouth of the Portneuf River. South Fork Ross Fork also flows through the extreme northeastern part of the Pocatello quadrangle. Other lesser streams head in the mountains and are tributary to the major drainages or disappear into the alluvium of the area marginal to the Snake River Plain.

A gently undulatory surface east and south of the vertical wavecut bluffs bounding American Falls Reservoir is mostly between 4,400 and 4,500 feet in altitude (pl. 1). That part between Bannock Creek and the Portneuf River is called Michaud Flats. This surface is bounded on the south and east by a nearly continuous scarp, generally about 40 or 50 feet high.

This scarp marks the edge of loess-covered benchlands that rise gradually southward or eastward toward the adjacent mountains. The upper limit of these benchlands ranges in altitude from about 4,750 feet west of Bannock Creek to more than 5,250 feet in other places. Above these benchlands, hilly terrain, generally underlain by Tertiary volcanic rocks, extends up to altitudes of more than 6,000 feet.

The highest point in the area, at an altitude of 7,265 feet, is on Rock Knoll, near the southwest corner of the Pocatello quadrangle. Several remnants of a surface more than 7,000 feet in altitude include Big Flat, in the Pocatello quadrangle, and some ridge crests in the southeastern part of the Michaud quadrangle. These higher altitudes are all in the northern part of the mountain block referred to as the Bannock Range, which is east of Bannock Creek and south of the Portneuf River. The northward extension of the same mountainous terrain, but separated from the Bannock Range by the sharply incised valley of the Portneuf River, is called the Pocatello Range. The mountainous areas are underlain mainly by Precambrian and Cambrian rocks.

The climate is semiarid, with an annual precipitation of about 13 inches at the lower altitudes; consequently, except for some dry farming of the benchlands, crops are grown under irrigation. Potatoes, sugar beets, and alfalfa are the most common of the irrigated crops. The lowland area north of the Portneuf River is heavily cultivated and is irrigated from an extensive canal system. Parts of Michaud Flats and much of the benchlands are cultivated and are irrigated by sprinklers using well water. The Bureau of Indian Affairs recently has constructed a canal system that will irrigate other parts of Michaud Flats and the alluviated valley of Bannock Creek. The water for this system is pumped from the Portneuf River by a pumping plant in the SW¼ sec. 36, T. 5S., R. 33 E.

The city of Pocatello, the second largest city in Idaho, with its population of more than 40,000, is a mercantile center and railroad junction point, located where the valley of the Portneuf River opens onto the Snake River Plain. Alameda, formerly a separately incorporated community, is now the northern part of Pocatello. The community of Chubbock adjoins Alameda on the north. Inkom, with a 1960 population of 528, is in the Portneuf River valley at the east edge of the Pocatello quadrangle.

Pocatello is a major junction point for travelers, whether by railroad, highway, or air. The main line of the Union Pacific Railroad follows the valley of the Portneuf River to Pocatello and then swings westward near the southern margin of the Snake River Plain, following the old Oregon Trail. It is paralleled by U.S. Highway 30N-Interstate Highway 15W. A branch line of the Union Pacific Railroad from the north, which joins the main line at Pocatello, is paralleled by Interstate Highway 15 and U.S. Highway 191. Two airlines serve the area, using the Pocatello municipal airport, which is located north of the highway about 9 miles west of the city. An extensive network of section-line roads covers the cultivated area north of the Portneuf River, but, south of the Portneuf River outside Pocatello, the only hard-surfaced roads are the interstate highway. and the highways that follow the valleys of Bannock Creek, in the Michaud quadrangle, and of Mink Creek, southeast of Pocatello, in the Pocatello quadrangle.

Agriculture is the major industry of the area, but two large chemical plants are located south of the highway west of Pocatello. Both utilize phosphate rock, mined from the Phosphoria Formation about 35 miles northeast of Pocatello, as their primary raw material, one to produce elemental phosphorous and the other to produce phosphatic fertilizers. The only cement plant in Idaho is located at Inkom.

STRATIGRAPHY

Most rocks of the Bannock and Pocatello Ranges are of Precambrian and Cambrian age (pl.1). The Cambrian rocks have been described in a report on neighboring quadrangles (Trimble and Carr, 1976). The thick Precambrian sequence has also been described (Crittenden and others, 1971). Paleozoic rocks younger than Cambrian are exposed only in the north-central part of the Pocatello quadrangle.

The Tertiary rocks of the area are mostly volcanic rocks of the Pliocene Starlight Formation, which crop out extensively in the foothills area. Rhyolite and basalt in the northern part of the Pocatello quadrangle and a small area of rhyolite in the southern part of the Pocatello quadrangle probably are younger than most of the other volcanic rocks and may be of either late Tertiary or early Quaternary age.

Basalt of the Snake River Group of Quaternary age crops out along the west edge of American Falls Reservoir in the northwest corner of the Michaud quadrangle. Quaternary gravel, probably older than this basalt, is distributed widely in the area of benchlands and at higher altitudes; however, below an altitude of about 5,500 feet, it is covered by a mantle of loess that is younger than the basalt of the plain.

Most of the northern half of the Michaud quadrangle and part of the northwest quarter of the Pocatello quadrangle is covered by Quaternary lacustrine deposits and fluvial deposits of a flood of catastrophic proportions from pluvial Lake Bonneville.

Remnants of basalt flows older than the Bonneville flood occur in the valley of the Portneuf River. Dune sand occurs locally in the western part of the area, and Holocene alluvium mantles valley floors.

PRECAMBRIAN SYSTEM

The rocks here assigned to the Precambrian System include those formerly thought to be of Ordovician age by Weeks and Heikes (1908) and later tentatively referred to the Cambrian by Anderson (1928), who divided the sequence into the Bannock Volcanic Formation at the base, the Blackrock Limestone, and the Brigham Quartzite (fig. 2). The Brigham Quartzite of Anderson included all the rocks above the Blackrock Limestone of Anderson and below the lowermost Cambrian limestone above the sequence of quartzitic rocks. Anderson noted the possibility that the rocks below his Blackrock Limestone might be Precambrian.

Ludlum (1942) divided the Bannock Volcanic Formation of Anderson, applied the name Pocatello Formation to the upper part, and retained Anderson's nomenclature for the lower part. Ludlum (1942, 1943) followed Anderson's usage of the name Brigham Quartzite for the rocks above the Blackrock Limestone of Anderson. Ludlum believed that Anderson's Blackrock Limestone and older rocks were precambrian but thought that the rocks Anderson had assigned to the Brigham Quartzite were of Cambrian age, although Ludlum also noted that the lack of fossils made any age assignment doubtful.

Ludlum's term "Pocatello Formation" is retained for the oldest Precambrian rocks of this area, but the rocks assigned by Ludlum to the Bannock Volcanic Formation now are known to be lenses of mainly metavolcanic rocks in the Pocatello Formation and are considered to be a member of the Pocatello Formation.

The name Blackrock Canyon Limestone has been given to the unit called Blackrock Limestone by Anderson and Ludlum (Crittenden and others, 1971). The change is required because of the many other usages of the name Blackrock in stratigraphic nomenclature.

More than two-thirds of the rocks that Anderson and Ludlum assigned to the Cambrian Brigham Quartzite are now thought to be of Precambrian age. The rocks involved in this revision constitute more than 10,000 feet of stratigraphic section and have been

<table>
<tr><th colspan="2">Weeks and Heikes (1908)</th><th colspan="2">Anderson (1928)</th><th colspan="2">Ludlum (1942)</th><th colspan="3">This report</th></tr>
<tr><td rowspan="10">Ordovician</td><td rowspan="10">Undifferentiated</td><td rowspan="10">Cambrian</td><td rowspan="6">Brigham Quartzite</td><td rowspan="6">Cambrian</td><td rowspan="6">Brigham Quartzite</td><td>Cambrian</td><td colspan="2">Gibson Jack Formation</td></tr>
<tr><td rowspan="9">Precambrian</td><td colspan="2">Camelback Mountain Quartzite</td></tr>
<tr><td colspan="2">Mutual Formation</td></tr>
<tr><td colspan="2">Inkom Formation</td></tr>
<tr><td colspan="2">Caddy Canyon Quartzite</td></tr>
<tr><td colspan="2">Papoose Creek Formation</td></tr>
<tr><td>Blackrock Limestone</td><td rowspan="4">Precambrian</td><td>Blackrock Limestone</td><td colspan="2">Blackrock Canyon Limestone</td></tr>
<tr><td rowspan="3">Bannock Volcanic Formation</td><td rowspan="2">Pocatello Formation</td><td rowspan="3">Pocatello Fm</td><td>Upper member</td></tr>
<tr><td>Scout Mountain Member / Bannock Volcanic Member</td></tr>
<tr><td>Bannock Volcanic Formation</td><td>Lower member</td></tr>
</table>

FIGURE 2.—Nomenclature of Precambrian and Lower Cambrian rocks and previous nomenclature.

subdivided into four well-defined, readily mapped units (fig. 3). The revised stratigraphy and nomenclature of the Precambrian and basal Cambrian rocks of this area are described elsewhere (Crittenden and others, 1971). The lower three units in the sequence of rocks formerly assigned to the Brigham Quartzite have been named the Papoose Creek Formation, the Caddy Canyon Quartzite, and the Inkom Formation (Crittenden and others, 1971). The fourth unit—the next-to-youngest Precambrian unit of this report—is tentatively correlated with the Mutual Formation of the Wasatch Range, Utah (Crittenden and others, 1952), and is given that name. The remainder of the rocks assigned to the Brigham Quartzite by Anderson and Ludlum are included in the Camelback Mountain Quartzite and the Gibson Jack Formation and will be discussed in other sections.

The Precambrian and Cambrian rocks of this area represent nearly continuous deposition, probably near the center of a depositional basin. No apparent disconformity or unconformity marks the boundary between the Precambrian and the Cambrian rocks (fig. 3), and this boundary is inferred on the basis of lithologic similarities to units in the Wasatch Range, Utah, where the systemic break is marked by an angular unconformity (Crittenden and others, 1952). Crittenden, Schaeffer, Trimble, and Woodward (1971) discussed the placement of this boundary and the correlation of the Pocatello sequence with similar sequences near Huntsville, Utah, Dugway Range, Utah (Staatz and Carr, 1964), and the Beaver Mountains, Utah (Woodward, 1968). Misch and Hazzard (1962, p. 297) inferred a similar boundary probably at the same stratigraphic position in a sequence of continuous deposition in central-northeastern Nevada and adjacent Utah.

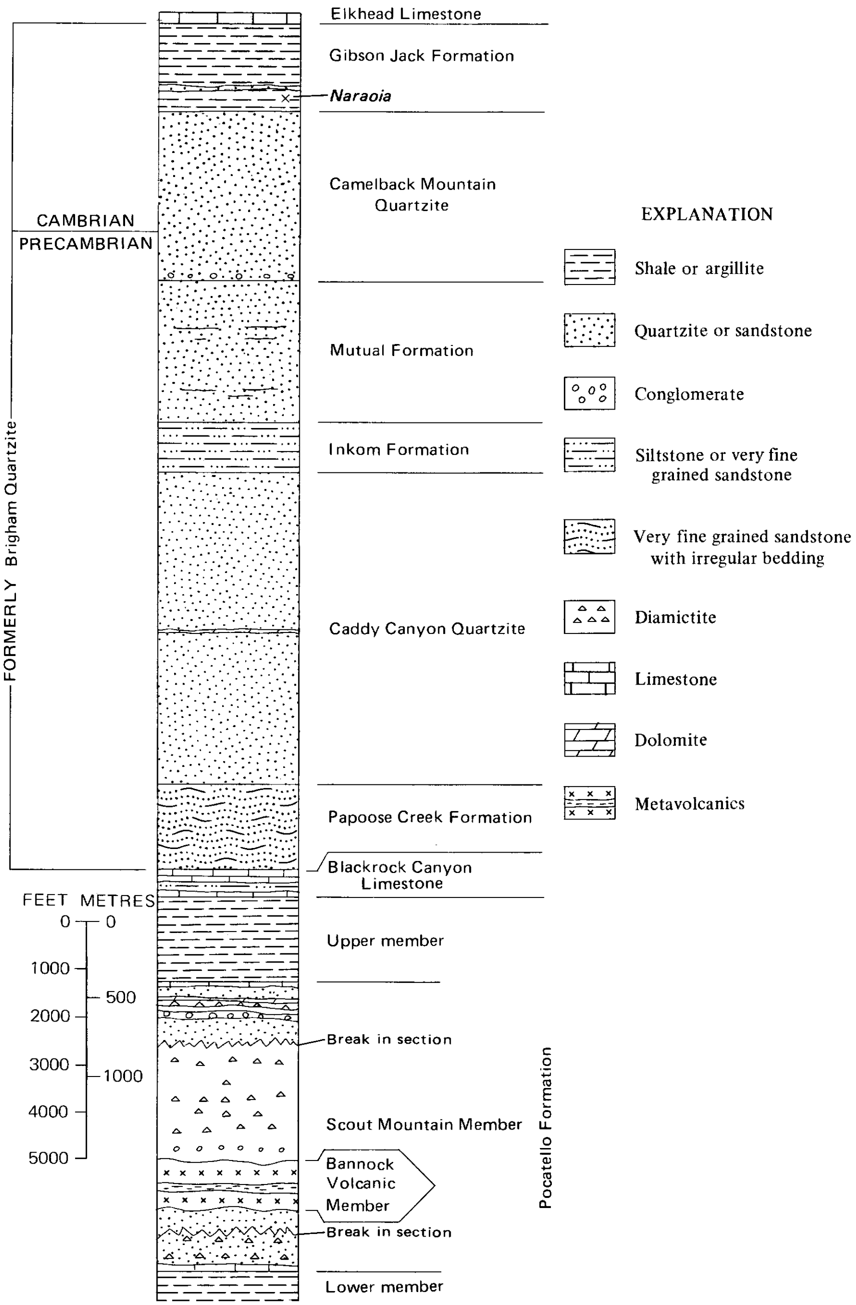

FIGURE 3.—Stratigraphic sequence of the Precambrian and lowermost Cambrian formations.

POCATELLO FORMATION

The Pocatello Formation was named by Ludlum (1942), who applied the name to the greater part of the sequence of rocks that Anderson (1928) had called the Bannock Volcanic Formation. Ludlum restricted the name Bannock Volcanic Formation to rocks that he considered to be of volcanic origin and that he believed to be older, and stratigraphically lower, than the Pocatello Formation. The Pocatello Formation, as defined by Ludlum (1942, p. 89), included all the sedimentary rocks bracketed by the Bannock Volcanic Formation (as restricted by Ludlum) below and the Blackrock Limestone (of Anderson) above; the Pocatello consisted of a lower "tillite series" and an upper "varved slate series."

The name Pocatello Formation is retained here in essentially the same stratigraphic sense as it was used by Ludlum, except that the rocks which he referred to the Bannock Volcanic Formation are now known to be local thick lenses in rocks of the lower part of the Pocatello Formation. The Pocatello Formation of present usage, then, corresponds to the Bannock Volcanic Formation of Anderson. Because the rocks of volcanic origin constitute a minor part of the formation, the name Bannock is applied here to only that part of the sequence composed mostly of altered volcanic rocks which forms lenses in, and is considered to be a member of, the Pocatello Formation.

The Pocatello Formation consists of four members: A lower member, the Scout Mountain Member (which is the "tillite series" of Ludlum), the Bannock Volcanic Member, and an upper member that is essentially the same as the "varved slate series" of Ludlum. In the study area the formation is mainly confined to the Pocatello quadrangle. South of the Portneuf River it forms most of the ridge between Papoose Creek and the canyon leading to the Fort Hall mine.The outcrop widens north of the Portneuf River, where it underlies the ridge area west of the Blackrock Canyon. and north of the east fork of Blackrock Canyon it widens still more. The formation crops out northward continuously to South Fork Pocatello Creek and to West Fork Rapid Creek. North of this limit it is exposed in isolated fault blocks, generally of small extent, and extends only about 1 mile north of the junction of North and South Forks Pocatello Creek. The Bannock Volcanic Member covers the area bounded approximately by Moonlight Creek and the two branches of North Fork Pocatello Creek. The outcrop of the Pocatello Formation extends northward to the Pocatello Creek road, east of the headwaters of Moonlight Creek, as shown by Ludlum (1942, 1943). The western margin of the exposures north and south of the Portneuf River is determined by a fault, but the eastern boundary is mainly a stratigraphic contact with the overlying Blackrock Canyon Limestone. The upper member of the Pocatello Formation also crops out west of Trail Creek, southwest of Pocatello. A small part of this outcrop area is in the Michaud quadrangle.

The thickness of the Pocatello Formation varies and is poorly known. Most thickness values have been obtained from map measurements of wide areas of poor exposure which may contain undetected faults. The aggregate thickness of the entire unit, however, probably is not less than 8,000 feet.

Lower Member

The oldest rocks in the area, constituting the lower member of the Pocatello Formation (Crittenden and others, 1971), are exposed only in a steep-walled canyon cut northward into the ridge north of Portneuf, where they have been arched into an anticline. The rocks of the lower member are silvery-weathering very thinly laminated dark-gray to black siltite and slaty argillite. About 700 feet is exposed, but total thickness is not known. The upper contact is drawn at the base of a limestone included in the overlying Scout Mountain Member.

Scout Mountain Member

The rocks of the Scout Mountain Member of the Pocatello Formation (Crittenden and others, 1971), which form the ridge north and south of Portneuf and east of the headwaters of Moonlight Creek, are those that Ludlum (1942) termed the "tillite series." This member is characterized by thick layers of unsorted nonstratified rock (metadiamictite) that probably is a submarine tillite. Some of these layers are more than 400 feet thick. The Scout Mountain Member also contains abundant interstratified quartzite and conglomerate, minor amounts of argillite and siltite, and a few beds of limestone and dolomite. Thickness of the Scout Mountain is not known, but it probably is not less than 5,000 feet.

The metadiamictite that characterizes this member is not localized near the top of the member, as Ludlum believed, but is distributed throughout nearly all of it. The metadiamictite is absent only in the lowermost part, which consists of 65 feet of limestone at the base of overlain by 100 feet of quartzite containing much interbedded siltite, and in the uppermost part, which overlies the highest metadiamictite and consists, in stratigraphic succession, of a 2-foot thick bed of dolomite, 100-800 feet of quartzite and argillite, and 15 feet of limestone. The metadiamictite commonly is grayish red purple or gray to greenish toned, depending on the valence state of the iron. Lateral gradations in color occur in short distances locally. The rock is composed mainly of quartzose material ranging in size from silt and sand to boulders several feet in diameter. Most of the larger clasts are rounded pebbles, cobbles, and boulders of quartzite, although some are of granite, argillite, and dark volcanic rocks. The smaller grain sizes are mostly angular or subangular, but some of the sand-sized grains are rounded and frosted. The matrix of the rock is mostly silt- and sand-sized grains of quartz and feldspar in a finely comminuted chloritic or sericitized groundmass. Much of the rock has been sheared and breaks into plates. In most places pebbles and larger constituents are sparse, but in some places the large percentage of rounded stones gives the rock the appearance of a poorly sorted conglomerate. Locally, many of the pebbles and cobbles are elongate and have a definite alinement and preferred orientation. In places the metadiamictite grades both laterally and vertically into quartzite.

Quartzite is the second most abundant lithology in the Scout Mountain Member, and locally, especially south of the Portneuf River, it is the dominant lithology. The quartzite is not uniform in grain size, color, or composition throughout the member. Much of the quartzite is calcareous and might more properly be termed a "calcareous sandstone." Much, however, is hard orthoquartzite, some of which is arkosic. Color varies from white or tan to purple to green. Grain size, too, is not predictable and ranges from fine or medium to very coarse or grit size in some places, particularly where the quartzite is laterally gradational with metadiamictite.

Argillite and siltite also form conspicuous parts of the Scout Mountain Member locally. Color ranges from light gray or tan to green to red or purple. Much of the fine-grained clastic rock is very thinly bedded.

One of the most striking lithologic units in the Scout Mountain Member is an interbed of quartzite cobble conglomerate, 150-350 feet thick, that occurs near the top of a thick quartzite sequence in the upper part of the member and is a good marker bed. It forms a prominent continuous ledge along the upper part of the ridge east of the Fort Hall mine, from Portneuf to the Fort Hall mine. It is also present on the west side of Scout Mountain, 7 or 8 miles to the south, and probably is present on the ridge east of Moonlight Creek near its headwaters. This very distinctive bed commonly is only 100 feet to a few hundred feet below the highest metadiamictite. The conglomerate is composed almost entirely of quartzite constituents but also contains sparse granite and argillite. Most of the quartzite clasts are white or pink, but a few are green. All the stones are well rounded. Most range in diameter from 1 to 10 inches; a few are as much as 14-16 inches in diameter.

Carbonate beds form other distinctive layers in the Scout Mountain Member, Commonly, overlying and resting directly on the highest metadiamictite is about 2 feet of pink buff-weathering thin-bedded (about one-quarter in.) dense dolomite. This dolomite or its equivalent is thought to be present in a similar sequence near Huntsville, Utah, 125 miles to the south (Crittenden and others, 1971). A hundred feet to as much as 800 feet higher is about 15 feet of tan to light-gray fine-grained limestone, the top of which is designated as the top of the Scout Mountain Member. At the base of the member and exposed only along the upper walls of a small canyon north of Portneuf, where it rests on the argillaceous rocks of the lower member, is about 65 feet of limestone, the base of which is designated as the base of the Scout Mountain Member. This limestone is thin bedded and contains quartzite interbeds in its lower part but is recrystallized into a creamy white fine-grained marble in the upper 20-25 feet.

The metadiamictite, which characterizes this member, is distributed throughout the member and is interstratified with bedded clastic and carbonate rocks that suggest a marine environment of deposition for most of the sequence. In places the metadiamictite grades both laterally and vertically into bedded rocks. In these respects the metadiamictite does not appear to be a tillite. It is, however, lithologically similar to the Mineral Fork Tillite of the Wasatch Range, Utah (Crittenden and others, 1952). This general similarity in mineralogy, lack of sorting and stratification, and the presence of large quartzite boulders had led to the conclusion that the metadiamictite is a submarine tillite equivalent to the ground-contact tillite of the Mineral Fork but deposited from shelf ice into a marine environment in the same manner as the eastern facies of diamictite in the Falkland Islands described by Frakes and Crowell (1967).

Bannock Volcanic Member

The name Bannock Volcanic Formation, which was first applied to all the rocks stratigraphically below the Blackrock Canyon Limestone by Anderson (1928), was restricted by Ludlum (1942) to the rocks of largely volcanic origin that he thought were the lowermost and oldest rocks of the area. These metavolcanic rocks now are known to be lenses in the Scout Mountain Member of the Pocatello Formation and have been termed the "Bannock Volcanic

Member of the Pocatello Formation" (Crittenden and others, 1971). They occur in only three areas: a large area west of Chinks Peak, a smaller area in fault blocks on the north side of the Portneuf valley, and another, larger area bounded approximately by Moonlight Creek and the two branches of North Fork Pocatello Creek. Rocks south of the Portneuf River that Ludlum included in his Bannock are nonvolcanic and have been included here in the Scout Mountain Member.

The rocks of the Bannock Volcanic Member are largely of volcanic origin but include some interstratified sedimentary rocks. The rocks of the member have all been altered to greenschist facies and consist mainly of greenstone and greenstone schist. The rocks are composed of chlorite, calcite, albite, and epidote, except for some locally abundant magnetite and some original quartzose constituents that are unaltered, such as quartzite clasts in the sedimentary rocks. The metavolcanic character of most of the rocks, particularly in the upper part of the member, is well documented by preserved megascopic structures, such as columnar jointing and vesicles in the flow rocks and breccia structures in some of the pyroclastic rocks, and by relict microscopic igneous textures ranging from intersertal or intergranular to pilotaxitic. The sedimentary interbeds, generally less than 50 feet thick, are mainly metadiamictites, but some are pebbly greenschist rocks whose original character is indeterminate.

Few attitudes are determinable in these rocks, and the few that have been measured, because they do not indicate any uniformity of attitude, are not particularly meaningful, but they suggest that the metavolcanics do not conform well in attitude to the adjoining sedimentary rocks.

Marker beds are rare in these rocks, but one very distinctive unit somewhat below the middle of the member west of Chinks Peak serves as a marker bed that permits the best evaluation of the attitude of the rocks there. This unit is an unusually thick altered flow—about 250 feet thick—that is characterized by large thin oval plates of albite, some more than 1 inch across. The rocks of the member above this porphyroblastic unit are dominantly of volcanic origin, and those below are dominantly of sedimentary origin, although both types are found both above and below the unit. Measurement of dip computed from altitudes determined at a number of localities at the top of this unit indicate that it, and presumably the rest of the Bannock Volcanic Member west of Chinks Peak, dips less than 25° W., which probably is compatible with the dip of the Scout Mountain Member at this locality. Local dips measured in the metavolcanics, therefore, probably are anomalous.

The metavolcanics in the area west of Moonlight Creek appear to constitute a generally low dipping pile of volcanic rocks, probably less than 1,000 feet thick, consisting mostly of altered pyroclastic rocks in the lower part of the sequence and of metaflows in the upper part. They probably represent a low shieldlike accumulation from a local source vent separate from the one responsible for the volcanics west of Chinks Peak. Perhaps the metavolcanics also include those in the fault blocks north of Portneuf.

The rocks of the Bannock Volcanic Member overlie those of the Scout Mountain Member west and southwest of Chinks Peak and are overlain by Scout Mountain Member near the head of Moonlight Creek, as well as in one locality west of Chinks Peak. At the eastern margin of the area west of Chinks Peak, only a few hundred feet below the peak, the metavolcanic rocks can be seen to wedge out or tongue out into the sedimentary rocks of the Scout Mountain Member. The Bannock Volcanic Member, therefore, forms lenses in the Scout Mountain Member of the Pocatello Formation.

Upper Member

The upper member of the Pocatello Formation is essentially the same stratigraphic sequence that Ludlum (1942) called the "varved slate series," South of Portneuf the upper member overlies rocks of the Scout Mountain Member in normal stratigraphic sequence, but north of Portneuf it lies in fault contact with rocks of the Scout Mountain Member. In the area east of the headwaters of Moonlight Creek, the upper member probably overlies the Scout Mountain member in normal stratigraphic contact; elsewhere, it is exposed only in small isolated areas.

The broad outcrop are north of the east fork of Blackrock Canyon suggests that the member may be nearly 5,000 feet thick there, but the exposure is so poor that undetected faults may repeat the section. The true thickness may be less than 2,000 feet. It probably is about 1,800 feet thick east of Fort Hall mine and about the same thickness east of the south end of Scout Mountain, several miles south of the report area.

The lower half of the upper member consists of black to gray and tan or olive thinly laminated slaty to phyllitic argillite that weathers silvery (fig. 4). This is the "varved slate" of Ludlum. The laminations, which commonly are conspicuous because of alternating light- and dark-color tones, are a prominent feature of this rock. Where slaty cleavage is strongly developed, the rock splits into plates along cleavage planes that do not parallel the laminae. In other places, it splits along the planes of lamination. Midway up in

FIGURE 4.—Thinly laminated argillite of the upper member of the Pocatello Formation, showing double-chevron en echelon folds along Buckskin Road in the SE¼ sec. 20, T. 6 S., R. 35 E., Pocatello quadrangle.

the member are quartzite interbeds, which become increasingly abundant upward. About two-thirds of the way up in the upper member, the unit consists of intimately interbedded quartzite and argillite, and the upper 100 feet is mostly rusty weathering gray quartzite.

The base of the upper member is a sharp and conformable contact with a bed of limestone, 15 feet thick, at the top of the Scout Mountain Member of the Pocatello Formation. The top of the upper member is the base of the lowermost limestone of the conformably overlying Blackrock Canyon Limestone. The slate and slaty argillite of the upper member is likely to be confused only with that of the lower member, which it greatly resembles. The lower member, however, is exposed only in the one locality previously discussed.

BLACKROCK CANYON LIMESTONE

The Blackrock Canyon Limestone is the name now applied (Crittenden, and others, 1971) to the limestone and interstratified clastic sedimentary rocks that Anderson (1928) named the Blackrock Limestone. The name is taken from Blackrock Canyon, northeast of Portneuf, where the formation is well exposed along the east wall of the canyon.

The Blackrock Canyon Limestone can be traced from the head of Kinney Creek, at the south edge of the Pocatello quadrangle, northward along a much-faulted line of outcrop to the upper part of West Fork Rapid Creek. There, it apparently is offset to the west to two small exposures northeast of Camelback Mountain. These two exposures are east of a klippe of younger rocks, and the Blackrock Canyon Limestone also crops out just west of this klippe in a much-faulted discontinuous line of outcrop that crosses North Fork Pocatello Creek about 1 mile east of the junction with South Fork Pocatello Creek and swings westward north of the North Fork. Small exposures of the Blackrock Canyon Limestone are in the Michaud quadrangle southwest of Pocatello, near the head of Trail Creek.

The formation has an apparent range in thickness from less than 100 feet to more than 1,500 feet north of the east fork of Blackrock Canyon. Ludlum (1942, p. 93) gave a maximum measured thickness of 535 feet for the Blackrock Canyon Limestone. The great change in apparent thickness across a west-trending fault about 1½ miles north of the east fork of Blackrock Canyon probably is due to repetition by faulting. Some apparent abrupt thinning may be the result of facies change or lensing out of a limestone layer.

The Blackrock Canyon Limestone consists locally of at least four limestone units separated by sandstone, quartzite, siltite, and argillite. The two lower units commonly are 25-40 feet thick and are made up of dark-gray to gray crossbedded sandy limestone. The upper units commonly are much thicker (the uppermost unit locally is 200 or more thick) and are made up of thick-bedded to massive layers of gray to dark-gray limestone. The uppermost part commonly is distinctively freckled with many small white balls of calcite, 1-4 mm in diameter. The limestone units are separated by fine- to medium-grained tan- to brown-weathering sandstone and quartzite and varicolored siltite and argillite. The quartzite is very similar to that in the upper part of the upper member of the Pocatello Formation and to some in the lower part of the overlying Papoose Creek Formation.

The Blackrock Canyon Limestone appears to overlie the upper member of the Pocatello Formation conformably and to be locally conformable with the overlying beds.

Ludlum (1942, 1943) placed the Precambrian-Cambrian boundary at the top of the Blackrock Canyon Limestone because of an unconformity at the top, which he inferred from differences in attitude between the Blackrock Canyon and younger beds. These differences in attitude may be only local structural variations, but the great variations in thickness do suggest an erosional unconformity.

Fossils were not positively identified in the Blackrock Canyon Limestone, but oolitic structures seen near the top of the formation in one place, at an altitude of 5,440 feet, in sec. 17, T. 6 S., R. 35 E., suggest organic structures. The Cambrian-Precambrian boundary is thought to be many thousands of feet above the top of the Blackrock Canyon Limestone, which is considered to be of Precambrian age.

PAPOOSE CREEK FORMATION

Fine-grained clastic rocks and minor amounts of medium-grained quartzite overlying the Blackrock Canyon Limestone were considered by Anderson (1928) and Ludlum (1942, 1943) to be the lowermost part of the Brigham Quartzite. These rocks have now been named the Papoose Creek Formation, from Papoose Creek in the Pocatello quadrangle (Crittenden and others, 1971). The Papoose Creek Formation forms the base of exposure of the pre-Tertiary rocks in several fault blocks along the west side of the Bannock Range in the Michaud quadrangle and south of Trail Creek in the Michaud and Pocatello quadrangles. The formation stratigraphically overlies the Blackrock Canyon Limestone along most of its line of outcrop in the Pocatello quadrangle. It is also exposed within a large klippe in the central part of the Pocatello quadrangle.

The Papoose Creek Formation has a wide apparent range in thickness. It is a little more than 600 feet thick at the head of Papoose Creek, south of the Portneuf River, but appears to be more than 1,500 feet thick south of West Fork Rapid Creek and as much as 2,500 feet thick in the south end of the klippe, west of upper Blackrock Canyon. The Papoose Creek Formation also has an apparent thickness of about 1,700 feet at Indian Creek Peak, just south of the Pocatello quadrangle, and of about 2,400 feet east of the south end of Scout Mountain, several miles farther south. These great differences may be largely the result of repetition of strata by unrecognized faulting in the Papoose Creek Formation, which generally is very poorly exposed.

The rocks of the Papoose Creek Formation are mostly a very distinctive irregularly banded gray or reddish-brown and light-gray very fine grained quartzite and siltite. The unit also contains some rusty-weathering fine- to medium-grained quartzite and some greenish-gray to dark-gray variegated argillite. The bedding in the very fine grained quartzite and siltite is greatly distorted and deformed, probably as a result of intraformational deformation, and this irregularity of the bedding gives the rock its distinctive appearance, which makes it recognizable even in small chips in float.

The formation locally appears to conformably overlie the Blackrock Canyon Limestone. The contact between the two, however, is seldom observable and is drawn at the top of the highest limestone of the Blackrock Canyon that is detected.

The Papoose Creek Formation is unfossiliferous, and the formation is thought to be of Precambrian age.

CADDY CANYON QUARTZITE

The lowermost unit, consisting mostly of quartzite that was included in the Brigham Quartzite by Anderson (1928) and Ludlum (1942, 1943), has been named the Caddy Canyon Quartzite, from Caddy Canyon north of the Portneuf River in the Pocatello quadrangle (Crittenden and others, 1971).

The Caddy Canyon Quartzite is the most widespread rock unit in the Bannock Range in the Michaud quadrangle. In the Pocatello quadrangle it is exposed in the hills south of Pocatello and extends across Portneuf valley to Red Hill, southeast of the city. The formation crops out in a wide band that trends northward from the upper part of Indian Creek, at the south edge of the quadrangle, across the valley of the Portneuf River, north to Moonlight Creek, and beyond. It is also present within the large klippe in the central part of the quadrangle and occurs in small isolated exposures a short distance north of Pocatello Creek.

The Caddy Canyon Quartzite is highly variable in its lithology in different parts of the Pocatello quadrangle, and local similarities to other parts of the quartzitic sequence make it the great impostor and difficult to identify in many places. Despite its great thickness, however, its gross features generally are consistent.

In the eastern part of the Pocatello quadrangle, both north and south of the Portneuf River, the Caddy Canyon Quartzite appears to be about 6,500 feet thick. This great thickness, as well as the lithologic variations, is responsible for much of the difficulty in identifying the unit locally. In places, a lithology similar to that of one of the other units persists through a considerable thickness before a change occurs that indicates the true identity of the sequence.

In general, the lower part of the Caddy Canyon Quartzite consists of light-colored vitreous orthoquartzite, white to tan weathering and locally pinkish tan, with interbedded green argillite or siltite. Darker toned quartzite and argillite beds are generally lacking, but in places, especially in the lowermost part, there are many interbeds, some rather thick, of irregularly bedded fine-grained quartzite and siltite much like that of the Papoose Creek Formation. Some of the thicker light-colored quartzite can be mistaken for the Camelback Mountain Quartzite, but the presence of the argillaceous interbeds should serve to distinguish the Caddy Canyon from the Camelback Mountain.

Above the middle of the Caddy Canyon Quartzite and overlying the light-colored quartzite at many places is a bed of dolomite or limestone about 50 feet thick. Locally, there are at least two thin dolomite beds below the thicker dolomite. The dolomite or limestone is commonly dark gray to gray and weathers light gray. East of Caddy Canyon, where the carbonate bed is especially persistent, and south of the Portneuf River, the carbonate is a dolomite, but south of Pocatello Creek it is a limestone. Where the carbonate is a limestone, it may superficially resemble the Blackrock Canyon Limestone.

Above the dolomite or limestone, the quartzite and argillite beds in many places are pink or purplish gray or maroon. The various colors are especially well displayed east of Caddy Canyon, in the eastern part of the Pocatello quadrangle. In places the reddish-toned quartzite is much like that of some parts of the younger Mutual Formation. The Mutual, however, commonly is coarser grained and conglomeratic. Farther north, south of North Fork Pocatello Creek, light-colored quartzite with argillaceous interbeds both underlies and overlies the carbonate layer, and no pink or purple beds are present. West of City Creek, south of Pocatello, the dolomite is overlain by light-tan quartzite, but reddish-gray quartzite and maroon argillite occur higher in the sequence. There is a slight possibility, however, that these reddish-toned rocks are part of the Mutual Formation in fault contact with the Caddy Canyon.

In the uppermost few hundred feet of the Caddy Canyon are several interbeds of pale-green argillite similar to that of the Inkom Formation. The highest of these is 50-75 feet thick and is separated from similar argillite in the overlying Inkom by about 50 feet of rusty-weathering quartzite. There are also several grit and conglomerate layers in the upper part of the Caddy Canyon.

Because of the similarities noted above of parts of the Caddy Canyon Quartzite to other formational units, much caution must be used and a great thickness of stratigraphic section must be examined before rocks can be identified with confidence as Caddy Canyon in many parts of the area.

The contact with the underlying Papoose Creek Formation is placed at the base of the lowermost light-toned quartzite in the transitional sequence between the predominantly siltite sequence of the Papoose Creek and the light-colored orthoquartzites of the Caddy Canyon. Rocks similar in lithology to the Papoose Creek occur mainly near the base of the Caddy Canyon as it is here defined.

This unit is unfossiliferous and is thought to be of Precambrian age.

INKOM FORMATION

The dominantly quartzitic sequence of rocks assigned to the Brigham Quartzite by Anderson (1928) and by Ludlum (1942, 1943) is interrupted by green phyllitic and argillaceous rocks that have been named the Inkom Formation (Crittenden and others, 1971). These rocks occur along a band of outcrop from upper Midnight Creek, in the southeastern part of the Michaud quadrangle, across the head of Gibson Jack Creek, in the Pocatello quadrangle, and northward into the drainage area of Cusick Creek. Two small areas of the Inkom, which lie against a fault, crop out west of upper South Fork Gibson Jack Creek and 1 mile farther southwest. Another faulted belt of outcrop extends from the south edge of the Pocatello quadrangle northward to the upper part of Caddy Canyon, north of the Portneuf River. The only exposures farther north are those north and south of South Fork Pocatello Creek.

The Inkom Formation has an apparent thickness of about 2,300 feet in the headwaters area of Gibson Jack Creek, but north and south of the Portneuf River east of Blackrock Canyon, it is about 850 feet thick, which probably is a more normal thickness. The great apparent thickness in the Gibson Jack Creek area probably is due to repetition by faulting.

The lower part of the Inkom is mainly green phyllite. This grades upward into greenish-gray to light-olive-gray argillite or slate, siltite, and very fine grained quartzite. The unit also contains a few beds (5 to 30 ft thick) of conglomerate or dirty quartzite, some of which is micaceous.

The lower contact of the Inkom is placed at the top of the highest quartzite of the Caddy Canyon. Some beds lithologically similar to the rocks of the Inkom are in the upper part of the Caddy Canyon.

The Inkom Formation is part of the sequence of unfossiliferous rocks here considered to be of Precambrian age.

MUTUAL FORMATION

The name Mutual Formation was proposed by Crittenden, Sharp, and Calkins (1952, p. 5) for some Precambrian rocks in the Wasatch Range, east of Salt Lake City, Utah. The Mutual of the Wasatch Range is composed of medium- to coarse-grained red-purple quartzite and variegated red and green shales or argillites, and the formation there is overlain with angular unconformity by the Tintic

Quartzite of Cambrian age. A unit similar in lithology and stratigraphic position to the Mutual Formation of the Wasatch Range conformably overlies the Inkom Formation in the area of this report and is here provisionally called the Mutual Formation.

The Mutual Formation is present in the Michaud quadrangle mostly north and south of the main area of exposure of the Caddy Canyon Quartzite and is separated from that unit by faults. In the Pocatello quadrangle the Mutual forms two belts of outcrop, one of which crosses the valley of the Portneuf River in the southeastern part of the quadrangle. It also occurs in several fault blocks. The northernmost occurrence, north of North Fork Pocatello Creek, is interpreted from an extensive cover of angular boulder gravel, derived almost entirely from the Mutual Formation, although bedrock is not exposed.

The Mutual Formation is roughly 2,500 to 3,000 feet thick.

The Mutual consists mainly of quartzite and minor conglomerate (fig. 5) but also contains some diagnostic beds of argillite and slate. Although much of the quartzite is light colored and locally is indistinguishable from quartzite of the Caddy Canyon Quartzite, much is darker tones of grayish red and purple. Crossbedding is common, and many of the quartzite beds are coarse grained to very coarse grained and pebbly or conglomeratic. Some of the argillite is green, but most is dusky red to very dark red. The dark-red argillite forms several layers, at least one of which is more than 200 feet thick. The crossbedding and coarse texture of much of the quartzite and the distinctive thick argillite beds, as well as the stratigraphic position, serve to identify the Mutual Formation, although it contains much quartzite that is indistinguishable from that of the Caddy Canyon.

The basal contact of the Mutual Formation is placed at a conspicuous and abrupt change from argillite of the underlying Inkom to quartzite. In most places, grayish-red quartzite overlies green beds of the Inkom Formation, but locally the underlying argillite is red, like that higher in the Mutual.

The Mutual Formation is unfossiliferous and is thought to be of Precambrian age. Its composition, color, and texture and its stratigraphic position beneath a quartzite unit similar to the Tintic Quartzite of the Wasatch Range, Utah, suggest that this formation is correlated with the Mutual Formation of the Wasatch.

PRECAMBRIAN AND CAMBRIAN SYSTEMS

CAMELBACK MOUNTAIN QUARTZITE

The rocks of Precambrian and Cambrian age in this area are quartzites that have been named the Camelback Mountain Quartzite

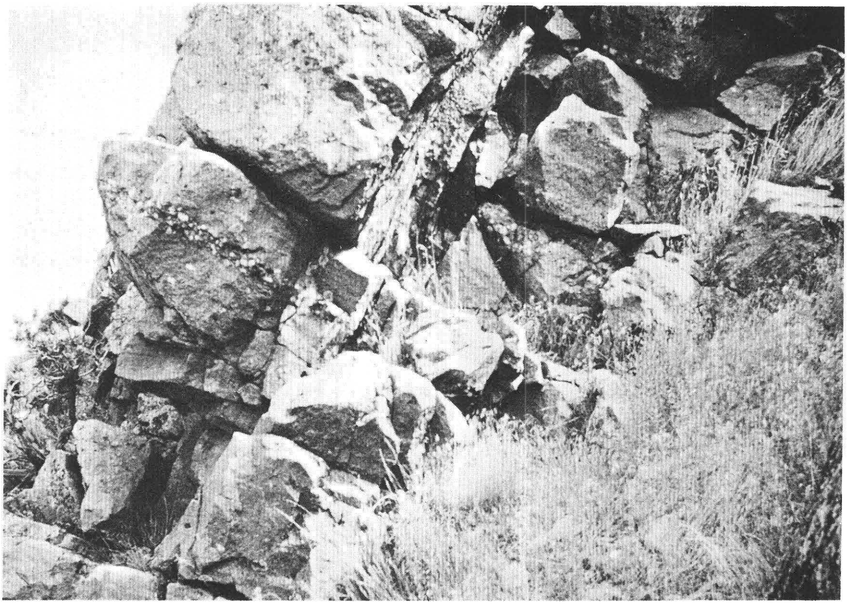

FIGURE 5.—Mutual Formation west of ridge crest between Papoose Creek and Trough Canyon, south of the Portneuf River in the Pocatello quadrangle. East-dipping quartzite of the Mutual contains conglomerate interbeds.

(Crittenden and others, 1971). The type section is Camelback Mountain, between North and South Forks Pocatello Creek, in the Pocatello quadrangle.

The Camelback Mountain Quartzite stratigraphically overlies the Mutual Formation in a much-faulted belt of outcrop extending from the southeast corner of the Michaud quadrangle northeastward into the Pocatello quadrangle, to the valley of the Portneuf River. The Camelback Mountain forms two other faulted belts of lesser extent south of the Portneuf River farther east. North of the Portneuf River the Camelback Mountain forms a discontinuous band near the east edge of the Pocatello quadrangle, mostly south of West Fork Rapid Creek. It also is present in the large klippe in the central part of this quadrangle, which includes the type section, stratigraphically overlying the Mutual Formation. The Camelback Mountain is as much as 3,500 feet thick in the vicinity of Wild Horse Mountain, south of Pocatello, if it has not been repeated by unrecognized faulting. Great apparent thinning only a few miles to the southwest makes this great thickness suspect.

The Camelback Mountain Quartzite is medium-grained vitreous orthoquartzite that weathers white, tan, brown, and brownish gray. It is mostly white at the base. It lacks the red quartzite found in the older units and contains little argillite or phyllite. The Camelback Mountain is mostly thick bedded to massive, but some is crossbedded.

The basal contact is conformable and transitional with the underlying Mutual Formation. Locally, the base is marked by a pebble conglomerate, 5-10 feet thick, that contains light-colored quartzite pebbles, as much as 1½ inches across, in a pink quartzitic matrix.

Although the Camelback Mountain Quartzite is unfossiliferous, it is thought to be of Early Cambrian and late Precambrian age. It probably is the equivalent of the Cambrian Tintic Quartzite of the Wasatch Range, Utah, as described by Baker and Crittenden (1961), and of the Precambrian and Cambrian Prospect Mountain Quartzite of Nevada and western Utah as restricted by Bick (1959), Cohenour (1959, p. 29), and Misch and Hazzard (1962, p. 304). Because of the nonconformity between the Tintic Quartzite and the Mutual Formation and older rocks in the Wasatch Range (Baker and Crittenden, 1961), I prefer to consider the Camelback Mountain Quartzite to be of Early Cambrian age.

CAMBRIAN SYSTEM

The Cambrian rocks of this area have been described in part in a report on the Rockland and Arbon quadrangles (Trimble and Carr, 1976). The name Gibson Jack Formation has been applied (Crittenden and others, 1971; Trimble and Carr, 1976) to the lowermost unit of the Cambrian sequence. The rocks of both the Camelback Mountain Quartzite, which may be Precambrian, at least in part, and the Gibson Jack Formation formerly were included in the Brigham Quartzite by Anderson (1928) and Ludlum (1942, 1943). Formational names from the classic section in the Bear River Range in northern Utah and southeastern Idaho, originally described by Walcott (1908), are retained for the remainder of the Cambrian sequence in this area. The Gibson Jack Formation, Elkhead Limestone, Bloomington Formation, and Nounan Dolomite are present in the area of this report, but the Worm Creek Quartzite Member and the upper member of the Upper Cambrian St. Charles Formation do not crop out here.

South of the Porneuf River in the vicinity of Pocatello, Cambrian units from the Camelback Mountain Quartzite to the Bloomington Formation are exposed in a structurally repeated stratigraphic sequence. Between the Portneuf River and Pocatello Creek, the only Cambrian unit present is the Gibson Jack Formation, except for one small isolated area of Elkhead(?) Limestone in a fault block near the east edge of the mapped area. North of North Fork Pocatello Creek, Cambrian rocks crop out in two small tributary valleys. Limestone, probably of the Elkhead Limestone, crops out on the east side of a small valley in the NE¼ sec. 15, T. 6 S., R. 35 E., and Nounan Dolomite crops out at the head of a short valley, or draw, in the SW¼ sec. 11, T. 6 S., R. 35 E.

GIBSON JACK FORMATION

Argillaceous siltstone and shaly argillite with interbeds of quartzite and sandstone that overlie the Camelback Mountain Quartzite have been named the Gibson Jack Formation (Crittenden and others, 1971).

The Gibson Jack Formation crops out in the Michaud quadrangle only in a group of downfaulted blocks in the southeast corner and in the Pocatello quadrangle mostly south of the Portneuf River, where it stratigraphically overlies the Camelback Mountain Quartzite along two belts of outcrop west of Mink Creek. In the eastern part of the Pocatello quadrangle, it is largely covered by loess, but small exposures of shaly argillite near the mouth of Indian Creek probably are the Gibson Jack Formation. North of the Portneuf River it crops out only in two areas, one southeast of Camelback Mountain north of South Fork Pocatello Creek, and the other, south of South Fork Pocatello Creek.

Because of the dominance of shaly rocks, especially in its upper two-thirds the Gibson Jack is poorly exposed in nearly all localities. Its thickness is not accurately known, but map measurements indicate that the formation is probably 1,500 to 2,300 feet.

Three members of the Gibson Jack Formation have been mapped and are designated, from oldest to youngest, as members A, B, and C.

The lowermost member is member A, which is 365 feet thick where it was measured in the northeast corner of the Arbon quadrangle, about half a mile south of the Michaud quadrangle. The lower 30 feet of the member is quartzite and sandstone that contains interbeds of siltstone, mostly tan but some variegated tan, purple, and brown. The rest of member A is argillaceous siltstone and shaly argillite with some interbeds of sandstone and quartzite. The siltstone and argillite are mainly tan, olive, or gray green, but a few beds are purplish gray or brown. Some beds are micaceous. The argillite is papery to shaly. The quartzite of member A is similar to that of the Camelback Mountain Quartzite.

Member B of the Gibson Jack Formation is simply the first thick quartzite in the shaly sequence above the Camelback Mountain, but it represents a marked lithologic change and provides an additional mapping horizon. It is 115 feet thick in the northeastern part of the

Arbon quadrangle but may be cut off by a fault there. The quartzite or sandstone of member B is light gray, fine to medium grained, and thin bedded and weathers light tan to gray or brown with conspicuous weathering rinds as much as 1/4-1/2 inch thick. Locally, it is so poorly cemented that it is a friable sandstone. Other similar thick sandstone or quartzite units occur higher in the formation.

The upper two-thirds of the Gibson Jack Formation constitutes member C, which probably is more than 1,000 feet thick in most places. This member commonly is very poorly exposed and consists of pale-yellowish-brown shaly argillite with many interbeds of sandstone or quartzite, some of which are comparable to the quartzite of member B in thickness. At least two beds of tan-weathering very thin bedded argillaceous limestone, tens of feet thick, occur near the top of member C but are so poorly exposed at most localities that they cannot be satisfactorily mapped.

The basal contact of the formation is mapped at the base of the first major siltstone or argillite overlying the nearly continuous section of quartzite of the Camelback Mountain. A few thin argillaceous zones are included in the Camelback Mountain below this contact, which is arbitrarily located on the basis of the thinning of quartzite beds and thickening of shaly beds in a transitional sequence.

A few fossils have been found in the Gibson Jack Formation in the Pocatello quadrangle. A nontrilobite arthropod, *Naraoia* (USGS colln. 4312-CO, identified by A. R. Palmer), and *Protospongia* were found near the top of member A, north of Gibson Jack Creek in the SE1/4NE1/4 sec. 27, T. 7 S., R. 34 E. *Protospongia* also was found only a few tens of feet above the base of the formation there. According to A. R. Palmer (written commun., 1963), *Naraoia* was known previously only in the Middle Cambrian Burgess Shale of British Columbia. In the Fish Creek Range, about 35 miles southeast of Pocatello, Oriel (1965) reported *Olenellus* from beds that, because of some similarities in lithologic sequence, I think may be equivalent to part of the Gibson Jack Formation. They overlie rocks that probably are equivalent to the Camelback Mountain Quartzite.

The Gibson Jack Formation is Lower Cambrian. Lithologic equivalents of the Gibson Jack Formation are not known to be present elsewhere, unless part of the Gibson Jack is the lithogenetic equivalent of the Pioche Shale, as suggested by Maxey (1958, p. 649).

ELKHEAD LIMESTONE

The lowermost unit of unequivocal Cambrian age composed mostly of limestone has been named the Elkhead Limestone (Trimble and

Carr, 1976). This unit probably is essentially equivalent to all of the Langston, Ute, and Blacksmith Limestones, which are not easily discriminated in this area.

In the Michaud quadrangle the Elkhead Limestone is present only east of Midnight Creek, in the extreme southeast corner of the quadrangle, and in three small isolated localities west of a fault on the west side of the Bannock Range. In the Pocatello quadrangle, however, the unit is extensively exposed south of the Portneuf River in three outcrop belts. The first, and westernmost, is a much faulted belt of outcrop that extends from the south edge of the quadrangle across West Fork Mink Creek to Gibson Jack Creek. North of Gibson Jack Creek the outcrop is offset eastward, but the Elkhead Limestone crops out around hill 5,418. A second large area of outcrop extends northward from the south edge of the quadrangle on both sides of Mink Creek. The third outcrop belt is mostly covered by loess, but Elkhead Limestone is exposed in several large outcrops north of the bend of Indian Creek and in a hill south of Inkom at the east edge of the quadrangle. North of the Portneuf River the Elkhead Limestone is exposed in only two localities—one in a fault block about 2 miles north of Inkom, and the other on the east side of a small tributary to North Fork Pocatello Creek in the NE¼ sec. 15, T. 6 S., R. 35 E.

An area north of this latter locality, mapped as Cambrian limestone unassigned, is covered by gravel composed almost entirely of Cambrian limestone that cannot be assigned with confidence to a particular formation but that probably is derived in place from Cambrian limestone formations, mainly Elkhead.

The thickness of the Elkhead Limestone in the northeastern part of the Arbon quadrangle as determined by map measurement is about 2,100 feet. It may be more than 3,000 feet thick in the vicinity of Mink Creek, but this apparent thickness may be much greater than the true thickness as a result of repetition of part of the unit by undetected faulting.

The Elkhead consists almost entirely of limestone except for a dark-gray to grayish-brown shale unit, about 100 feet thick, that lies a few hundred feet above the base. The limestone, for a few hundred feet above the shale, especially, is thin-bedded ledge-forming platy gray limestone; the upper two-thirds of the Elkhead is mainly thick-bedded to massive gray oolitic limestone. Yellowish-tan silty partings are common, and, locally, the unit contains intraformational conglomerate. The rock weathers gray to tannish gray and, locally in the upper part, to very light gray.

The lower contact generally is obscured by colluvium or soil cover, but it is placed at the base of the first thick mappable carbonate unit.

The shale unit a few hundred feet above the base of the Elkhead contains lower Middle Cambrian trilobites (*Ehmaniella*) (USGS colln. 4314-CO) of the *Bathyuriscus-Elrathina* zone present at the base of the Ute Limestone at the type locality in Blacksmith Fork, Utah (A. R. Palmer, written commun., 1963). Trilobites, which according to A. R. Palmer (written commun., 1958, 1961) probably belong to the genus *Alokistocare*, were found 300-700 feet below the top of the formation in the northeastern part of the Arbon quadrangle. Another collection from about 170 feet below the top of the unit there contained trilobites belonging to the generalized groups often referred to as *Ehmania* and *Solenopleura*.

These collections indicate a Middle Cambrian age for the Elkhead Limestone, and probable equivalence of most of the unit to the Ute Limestone and the Blacksmith Limestone. The limestone below the shale, which so far has not yielded fossils, may be equivalent to the Langston Limestone.

BLOOMINGTON FORMATION

The Bloomington Formation is a distinctive sequence of interbedded limestone and shale. The formation crops out in this area only in the southwestern part of the Pocatello quadrangle, south of the Portneuf River. The Bloomington stratigraphically overlies the Elkhead Limestone in a series of fault blocks northeast and southwest of Gibson Mountain and also overlies the Elkhead east of the main valley of Mink Creek.

The Bloomington is 1,800 feet thick where it was measured, less than a mile south of the Michaud quadrangle, in the northeast corner of the Arbon quadrangle.

Gray to blue-gray oolitic limestone of the Bloomington is interbedded in nearly equal amounts with fine-grained clastic rocks, mainly tannish-green to olive-drab shale, argillite, and siltstone. Brown to reddish fine- to medium-grained quartzite, more than 80 feet thick, that occurs about 700 feet above the base in the Arbon quadrangle to the south has not been seen here. Much of the limestone has yellow silty laminae and partings and in the upper half of the unit much contains intraformational conglomerate. The shale, argillite, and siltstone units contain abundant nodules of green dense fine-grained limestone. As a whole the unit is characterized by the alternation of shale and limestone, the oolitic character of the limestone and the abundant intraformational conglomerate in the upper half, and the distinctive green limestone nodules in the fine-grained clastic beds.

The lower contact is drawn at the base of the first shale or siltstone above the thick-bedded to massive carbonate beds of the upper part of the Elkhead Limestone. In the Pocatello quadrangle the formation is everywhere truncated by faults, and the top of the unit is not exposed.

Trilobites and primitive brachiopods indicating a late Middle Cambrian age were obtained from the upper part of the Bloomington Formation in the Arbon quadrangle, to the south. Many roughly spherical concentrations of algae (*Girvanella*?) as much as half an inch in diameter occur at several horizons in the unit. The fossils and lithology of the Bloomington of this area indicate that it is the same general sequence of beds that is called the Bloomington Formation in other areas.

NOUNAN DOLOMITE

Dolomite and limestone that crop out in several exposures in the SW¼ sec. 11, T. 6 S., R. 35 E., north of North Fork Pocatello Creek, are assigned to the Nounan Dolomite. Only part of the formation, which is about 550 feet thick in the Arbon quadrangle (Trimble and Carr, 1976), is exposed here.

The exposures in the northern part of the Pocatello quadrangle are pink and gray dolomite and gray oolitic limestone that almost certainly are part of the upper half of the Nounan Dolomite.

Neither the lower nor the upper contact of the Nounan is exposed in this area. In the Arbon quadrangle the lower contact is placed at the top of the highest shale or siltstone in the underlying Bloomington.

No fossils were found in the Nounan in this area, but its lithology and stratigraphic position indicate that it is equivalent, at least in part, to the Nounan Dolomite of Middle and Late Cambrian age in other areas in southeastern Idaho.

ORDOVICIAN SYSTEM

The Ordovician System in the surrounding region is represented by the Garden City Limestone, the Swan Peak Quartzite, and the Fish Haven Dolomite. These three formations are exposed to the south and southwest in the Rockland and Arbon quadrangles and to the northeast, north of the narrows of Ross Fork, in the Yandell Springs quadrangle. In the area of this report, however, only the Fish Haven Dolomite is exposed.

FISH HAVEN DOLOMITE

The Fish Haven Dolomite is exposed only in a series of fault blocks north of Two and a Half Mile Creek, except for an outcrop of brecciated dolomite that probably is Fish Haven, at an altitude of about 6,500 feet, west of a small knob in the NW¼NW¼ sec. 1, T. 6 S., R. 35 E. The formation is not fully exposed in the Pocatello quadrangle, but its measured thickness in the Arbon quadrangle to the southwest is 879 feet.

In the Arbon quadrangle, where the formation is fully exposed, the lower half of the Fish Haven is a fairly uniform gray to dark gray fine- to medium-grained dolomite that locally contains abundant chert nodules or stringers and forms conspicuous ledges. The lower 20 feet commonly is very sandy dolomite. The upper half of the formation consists of two parts—a lower unit of gray dolomite, some of which is rather thin bedded, together with several ledges of very light gray dolomite and an upper unit of faintly mottled gray dolomite that becomes lighter upward. The lithology of much of the Fish Haven in the Pocatello quadrangle is like that of the lower half of the formation elsewhere, but the lithology of the northernmost area of exposure is like that of the upper part elsewhere and is in contact with the overlying Laketown Dolomite. The contact of the Fish Haven Dolomite with the underlying Swan Peak Quartzite is not exposed in the Pocatello quadrangle.

In Utah the Fish Haven contains an abundant coral and brachiopod fauna of Late Ordovician age.

SILURIAN SYSTEM

LAKETOWN DOLOMITE

The Silurian System is represented by one formation, the Laketown Dolomite, which crops out only in fault blocks north of Two and a Half Mile Creek. No continuous section of the Laketown is exposed, but the thickness appears to be comparable with the 1,136 feet measured in the Arbon quadrangle.

Nearly all of the Laketown Dolomite is a distinctive uniform light-gray fine- to medium-grained dolomite, but the upper 400 feet contains some beds of darker dolomite.

The lower contact with the Fish Haven Dolomite is placed at the base of the distinctive light-gray dolomite above the mottled-gray dolomite of the Fish Haven.

Diagnostic fossils were not found in the Laketown in this area, but the lithology is characteristic of the formation elsewhere, where it is Middle and Late Silurian in age (Richardson, 1941, p. 18; Williams 1948, p. 1137).

DEVONIAN SYSTEM

HYRUM DOLOMITE

All rocks of Devonian age in this area are assigned to the Hyrum Dolomite. The Hyrum, too, occurs only in fault blocks north of Two and a Half Mile Creek. The formation is not fully exposed here, but it is 542 feet thick in the Arbon quadrangle to the southwest.

The Hyrum Dolomite is mainly dark-gray to black dolomite, mostly medium grained, that weathers dark gray to light gray and locally contains some intraformational breccia. Some of these beds form prominent ledges.

The lower contact is exposed in two fault blocks. It is placed at the base of the lowest very dark gray or black dolomite in the nearly continuous section of dark dolomite.

Fossils were not found in the Hyrum in this area, but *Amphipora* found in these rocks in the Arbon quadrangle indicates a Devonian age.

MISSISSIPPIAN SYSTEM

Nearly 6,000 feet of rocks in the Deep Creek Mountains to the southwest, in the Rockland and Arbon quadrangles, is of Mississippian age. They were divided (Trimble and Carr, 1976) into the Lodgepole Limestone, the Deep Creek Formation, the Great Blue Limestone, and the Manning Canyon Shale, most of which is Mississippian in age.

Only the Lodgepole Limestone and the lower member of the Deep Creek Formation are represented in the area of this report.

LODGEPOLE LIMESTONE

The Lodgepole Limestone in most places is an abundantly fossiliferous limestone that overlies the Devonian and is the oldest unit of Mississippian age. Rocks assigned to the Lodgepole crop out in the Pocatello quadrangle in two small areas a quarter of a mile north of the boundary of the Fort Hall Indian Reservation, in the NE¼SE¼ sec. 21, T. 5 S., R. 35 E. The Lodgepole, which is not fully exposed here, ranges in thickness from less than 100 feet to perhaps more than 1,000 feet in the Arbon quadrangle.

The rocks in the Pocatello quadrangle referred to the Lodgepole Limestone are nonfossiliferous gray limestones containing no chert. Because of the lack of stratigraphic context and the lack of fossils, rock identification can only be tentative; however the occurrence of the limestones in a much-faulted area nearly contiguous to both the Devonian dolomite and the younger Mississippian Deep Creek Formation and the lithologic similarity they bear to limestone of the Lodgepole indicate that identification of these rocks as Lodgepole probably is valid.

The Lodgepole of the Arbon quadrangle to the southwest (according to W. J. Sando and J. T. Dutro, Jr., written commun., 1958, 1961, 1964) is Early Mississippian in age.

DEEP CREEK FORMATION

The Deep Creek Formation was named by Carr and Trimble (1961) for its occurrence in the Deep Creek Mountains, Idaho. There, it consists of a lower, silty limestone member and an upper, cherty limestone member, and it is more than 2,000 feet thick.

Only part of the lower member of the Deep Creek Formation is exposed in the Pocatello quadrangle, where it crops out in a single small area in SE¼ sec. 21, T. 5 S., R. 35 E., north of the boundary of the Fort Hall Indian Reservation.

The rocks of the lower member of the Deep Creek Formation in the Pocatello quadrangle are gray to dark-purple to black thin-bedded to laminated calcareous siltstone and silty limestone that locally weathers purplish. Platy fragments commonly litter the surface. The siltstone locally contains flattened brachiopods.

The Deep Creek of the Rockland and Arbon quadrangles is the temporal and lithologic equivalent of the Little Flat Formation in the Chesterfield Range, Idaho, named by Dutro and Sando (1963), which is middle Meramecian (Late Mississippian) in age. The name Deep Creek Formation is used here because these rocks in the Pocatello quadrangle are thought to be within a large klippe that has translated them many tens of miles east of their original site of deposition, which could have been west of the type Deep Creek.

PENNSYLVANIAN SYSTEM

WELLS FORMATION (LOWER PART)

The Wells Formation was named by Richards and Mansfield (1912, p. 689-693). Equivalent rocks of Pennsylvanian and Permian age that form most of the Deep Creek Mountains in the Rockland and Arbon quadrangles to the southwest have been assigned to the Oquirrh Formation (Trimble and Carr, 1976). The Oquirrh Formation there is part of a tripartite sequence that includes the successively underlying Mississippian and Pennsylvanian Manning Canyon Shale and the Mississippian Great Blue Limestone; the Great Blue overlies the Deep Creek Formation. Rocks in the Fort Hall Indian Reservation in the northern part of the Pocatello quadrangle are referred to the Wells Formation, rather than to the Oquirrh Formation, because they contain no lithologic equivalents to the Manning Canyon Shale, either there or to the east. Rocks of the Wells Formation in the northern part of sec. 21, T. 5 S., R. 35 E., are separated by a fault from the Mississippian and older rocks south of the fault; probably, 2,500 feet or more of Mississippian and Lower Pennsylvanian rocks are missing. The Wells Formation crops out northward and northeastward to within a quarter of a mile of the north edge of the quadrangle, but only the lower part of the formation is present. The Wells is about 2,400 feet thick in other parts of the Fort Hall Indian Reservation, according to Mansfield (1920, p. 36-37).

The rocks of the Wells Formation in the westernmost outcrop areas probably are the lowest and oldest Wells rocks exposed, and these, for the most part, are interbedded rusty-weathering limestone, limy sandstone, and quartzite. In one locality, in the SE¼ sec. 16, T. 5 S., R. 35 E., the base of exposure of east-dipping Wells is medium-gray thin-bedded silty to sandy dolomite. This rock is crossbedded in part and contains little or no chert. It weathers gray to purplish gray. Above this, at the crest of the ridge, is gray to medium-gray cherty limestone. The chert in places is interbedded in irregular layers about 2 inches thick. Similar rusty-weathering cherty limestone crops out extensively in the NW¼ sec. 14, T. 5 S., R. 35 E. To the northeast, in the SW¼ sec. 11, T. 5 S., R. 35 E., the Wells Formation is medium-gray limestone, lacking chert, that contains large caninid horn corals. The noncherty limestone is overlain by gray cherty limestone containing chert nodules and stringers. Above the cherty limestone is tan-weathering silty to sandy limestone that, near the top, has many interbedded chert layers about 2 inches thick. These local lithologies are typical of the lower units of the Oquirrh Formation in the Deep Creek Mountains and undoubtedly are equivalent.

The Wells Formation in other areas has been dated as Middle Pennsylvanian to Permian (Cressman, 1964, p. 27). The Oquirrh of the Deep Creek Mountains is well dated as Pennsylvanian and Permian, primarily on the basis of abundant fusulinids which have been identified by R. C. Douglass (Trimble and Carr, 1976). In the report area only the lower, or Pennsylvanian, part of the Wells is believed to be present.

TERTIARY SYSTEM

The rocks here referred to the Tertiary System are widely distributed in the southern part of the Michaud quadrangle and in the northern part of the Pocatello quadrangle. They all are considered to be part of the Starlight Formation of Pliocene age (Carr and Trimble, 1963; Trimble and Carr, 1976). Not present in this area are the Neeley Formation and the Walcott Tuff, which overlie the Starlight in the American Falls and Rockland quadrangles to the west and southwest.

STARLIGHT FORMATION

The Starlight Formation was named by Carr and Trimble (1963). The type locality is along Starlight Creek in the Arbon quadrangle

(Trimble and Carr, 1976), only a few miles south of the Michaud quadrangle, where the lower part of the formation is well exposed. The Starlight Formation adjacent to the margin of the Snake River Plain is composed mainly of bedded rhyolitic tuff, but it is divided into lower and upper members by an intervening middle member consisting mainly of an ash-flow tuff—the tuff of Arbon Valley—which probably is best exposed in the southern part of the Michaud quadrangle. Locally, the lower member also contains much basaltic tuff, breccia, and flows. Away from the Snake River Plain, the tuffs become interstratified with rocks of primarily sedimentary origin. In the northern part of the Pocatello quadrangle, these rocks consist largely of sedimentary breccias, probably of mudflow origin.

The Starlight Formation fills intermontane valleys and laps onto the Paleozoic and older rocks of the mountains. In the Michaud quadrangle the Starlight crops out extensively west of Bannock Creek, mainly above an altitude of about 4,750 feet. The formation extends southward and southwestward into the Arbon and Rockland quadrangles and laps onto the Paleozoic rocks of the Deep Creek Mountains at altitudes of as much as 6,200 feet. East of Bannock Creek the formation extends up to about the same maximum altitude, but most of it is below an altitude of 5,750 feet. The Starlight crops out intermittently, especially in valleys and draws, from the south edge of the Michaud quadrangle northward around the north end of the Bannock Range into the Pocatello quadrangle. Southeast of Pocatello and south of the Portneuf River, the exposures of Starlight are nearly confined to the canyon leading to the Fort Hall mine and to the crest and east side of the ridge to the west, except for two small areas. One of these is at an altitude of about 5,000 feet on the south valley wall of the Portneuf River valley between Papoose Creek and Trough Canyon; the other is at an altitude of about 5,050 feet on the east side of hill 5,418 between Johnny Creek and Gibson Jack Creek. Nearly all these exposures are of stratified rhyolitic tuff. Gravel covering much of the area between Mink Creek and Fort Hall mine canyon and the northern part of the ridge between Johnny Creek and Mink Creek is interpreted as having been derived in place from sedimentary breccia of the Starlight and as reflecting widespread distribution of Starlight Formation in these areas. North of the Portneuf River in Pocatello quadrangle, outcrops of the Starlight are nearly all in the foothills area, mostly above 4,750 feet in altitude, west of the Pocatello Range to Pocatello Creek, and north of Pocatello Creek to the northern border of the quadrangle, locally to altitudes of more than 6,000 feet. Angular bouldery gravel, probably derived from sedimentary breccia of the Starlight, occurs up to 6,250 feet or more in altitude.

The Starlight Formation crops out through a vertical range in altitude of about 1,500 feet, but much of the range in altitude is the result of structural movement. Its maximum thickness is not known but is more than 800 feet in some areas.

Lower Member

The lower member of the Starlight Formation is that part beneath the ash-flow tuff of the middle member. Its thickness is not known but probably is about 500 feet. West of Bannock Creek in the Michaud quadrangle, the lower member consists mainly of nonporphyritic basalt flows which have a wide range in plagioclase composition and olivine content. These flows overlie basaltic tuff and breccia, which, in turn, overlie a sequence of bedded rhyolitic tuff. A porphyritic basalt flow is locally interstratified in the basaltic tuff. Plagioclase of composition An_{60-80} composes about 60 percent of this flow. The basaltic rocks are exposed in windows in the capping ash-flow tuff and in strips around the flanks of the foothill area. The rhyolitic tuff is exposed in only a few small areas. East of Bannock Creek, however, the rhyolitic tuff is much more prevalent, and, although the lower member contains at least two interstratified basalt flows, it lacks the basaltic pyroclastic rocks. There, the member contains white, tan, and cream-colored marl and claystone beds that locally constitute most of the unit, and the member also includes some gravel and conglomerate.

Sedimentary breccia, or diamictite, composed almost entirely of poorly sorted angular fragments of quartzite crops out intermittently for about 4 miles along the west side of the Bannock Range in the Michaud quadrangle, where it is interstratified and intertongued with rhyolitic tuff of the lower member of the Starlight Formation. Some of the quartzite fragments in the breccia are many feet in diameter. The distribution of the breccia and the lithologic character, angularity, and size of its constitutents indicate that it was derived from the adjacent Bannock Range and that it is a cemented rubble or gravel apron that accumulated along the mountain front, intertonguing with, and cemented by, the rhyolitic ash of the Starlight during its deposition in Pliocene time.

All of the Starlight Formation exposed in the Pocatello quadrangle, except for a small area of ash-flow tuff, probably is part of the lower member. South of the Portneuf River southeast of Pocatello, the exposed formation is white to gray stratified rhyolitic tuff. A mantling gravel, which is widely distributed, mostly east of Mink Creek, probably came from sedimentary breccia interstratified with the tuff. East and northeast of Pocatello, the Starlight is mainly white bedded to massive rhyolitic tuff, but locally it contains interbeds of alluvial and colluvial gravel or conglomerate, some of which has oxidized to a bright red.

North of Pocatello Creek along a northeast- to north-trending zone, probably less than 1 mile wide and located in about the middle of the northern part of the quadrangle, sedimentary breccia, or diamictite, to the east intertongues with the rhyolitic tuff that forms most of the Tertiary sequence to the west. The tuff sequence locally contains pebbles and lenses of very pebbly bedded tuff, as well as interbeds of conglomerate and sedimentary breccia. Some of the conglomerate and sedimentary breccia, especially in the lower part of the sequence, is oxidized and forms bright-red slopes. The larger particles and most of the smaller constituents in both the conglomerate and the breccia are mainly subangular to angular, but some pebbles, less than 1 inch in diameter, are subrounded to rounded. Interbeds in the lower part of the sequence, however, appear to have a larger percentage of rounded constituents, including larger particle sizes, than those higher in the sequence.

The sedimentary breccia east of the zone of intertonguing is generally unbedded and unsorted and contains mostly subangular to angular fragments, mainly of Ordovician Garden City Limestone, Swan Peak Quartzite, and Fish Haven Dolomite. This sedimentary breccia also contains some Cambrian limestone and Precambrian quartzite in a calcareous matrix that locally has oxidized to a brick red (fig. 6).

Exposures of sedimentary breccia are few because boundery gravel, derived by weathering of the breccia, forms a nearly complete cover. This weathering extends more than 10 feet deep, and the structure of the parent breccia is entirely destroyed in the upper 5 or 6 feet. Some of the boulders apparently derived from the breccia are as much as 25 feet in diameter. Most of the large boulders are derived from the Swan Peak Quartzite (fig. 7), although Fish Haven Dolomite boulders (fig. 8) are also common.

A mile east of the head of Buffalo Creek, sedimentary breccia, in beds 5-15 feet thick, interbedded with layers of rhyolitic tuff of similar thickness, crops out through a stratigraphic interval of about 200 feet. A few miles to the north, on the north side of a draw in the SW¼ sec. 16, T. 5 S., R. 35 E., sedimentary breccia is especially well exposed where it overlies marl or freshwater limestone of the Starlight Formation. The largest fragments are at the base of thin mudlfow deposits, and the sequence apparently is a multiple mudflow deposit. Each mudflow in the sequence is characterized by poorly graded bedding in the lower part and crude nongraded bedding in the upper part, which perhaps was a slurry. No evidence was found of weathering between mudflow pulses. Because of the dominance of Ordovician rocks in the sedimentary breccia in the

FIGURE 6.—Sedimentary breccia of the lower member of the Starlight Formation on west side of canyon in the NW1/4 sec. 15, T. 5 S., R. 35 E., in northern part of Pocatello quadrangle.

northern part of the Pocatello quadrangle and because of the apparent thickening of the breccia to the east, it seems likely that the deposit here was derived from the area of Ordovician rocks north of the narrows of Ross Fork, only 10 miles or so to the northeast, in the southwestern part of the Yandell Springs quadrangle.

Sedimentary breccia does not crop out in the Pocatello quadrangle south of the Portneuf River, but bouldery gravel, composed mostly of locally derived Precambrian quartzite, covers much of the ridge between Mink Creek and Fort Hall mine canyon, and some gravel lies west of lower Mink Creek. This gravel contains boulders as much as 10 feet in diameter and probably was derived by weathering from concealed interbeds of sedimentary breccia in the Starlight in this area.

MIDDLE MEMBER

The middle member of the Starlight Formation consists of a sequence of cooling units of ash-flow tuffs with minor intercalated material. The principal unit is the tuff of Arbon Valley (fig. 9), which crops out in this area only in the Michaud quadrangle except for one locality northeast of Pocatello, where it is exposed beneath basalt north of upper Little Pocatello Creek. West of

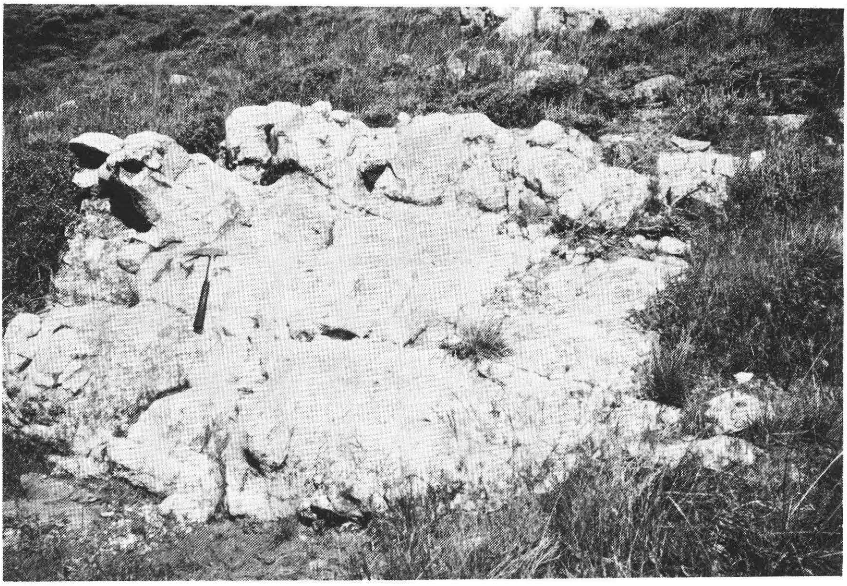

FIGURE 7.—Fifteen-foot Swan Peak Quartzite boulder on slope above outcrop of sedimentary breccia shown in figure 6.

Bannock Creek in the Michaud quadrangle, the tuff of Arbon Valley underlies much of the surface above an altitude of about 4,750 feet and unconformably overlies the lower member. East of Bannock Creek, the tuff of Arbon Valley forms an interrupted hogback that extends northward for about 3 miles from the south edge of the quadrangle, 1-2 miles west of the pre-Tertiary rocks of the Bannock Range. Nearer Bannock Creek the tuff of Arbon Valley crops out in three or four places high on isolated hills capped by basalt and, north of these exposures, in small valleys, where it apparently has been downfaulted. North of an inferred fault in the northern part of T. 7 S., R. 33 E., ash-flow tuff crops out at several localities, mostly on hill crests or slopes, both east and west of Michaud Creek. Intermittent exposures and lines of boulders of ash-flow tuff below and nearly paralleling the base of the porphyritic trachyandesite on the hill east of Michaud Creek and northwest of upper Trail Creek indicate that the tuff is separated from the trachyandesite by 150-300 feet of the upper member of the Starlight Formation. The middle, or ash-flow tuff, member probably is less than 100 feet thick in most places.

The tuff of Arbon Valley is a light-colored poorly indurated to well-indurated rhyolitic ash-flow tuff. The lower part of this tuff is unwelded, soft, friable, and pumiceous. Locally, a thin glassy welded

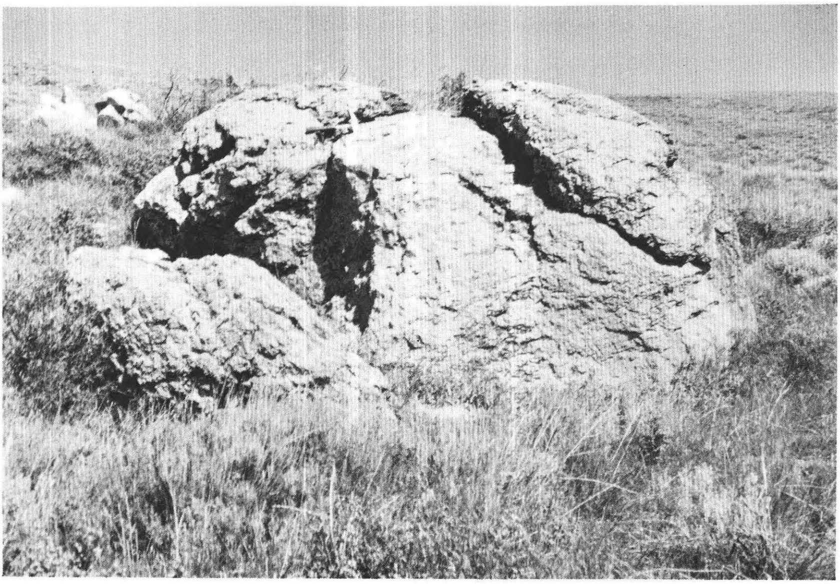

FIGURE 8.—Thirteen-foot Fish Haven Dolomite boulder on slope southwest of outcrop of sedimentary breccia shown in figure 6.

zone occurs at the top of the unwelded lower part. In its upper part the tuff commonly contains about 30 percent of broken and embayed, but normally conspicuous, phenocrysts of euhedral quartz and sanidine and a little biotite, as well as a few lithic and pumice fragments in a fine, slightly devitrified dense ashy matrix that may or may not have a pyroclastic texture. The lack of evident pyroclastic texture is a local feature and probably is more common toward the top of the exposed unit.

Although the tuff of Arbon Valley in most places appears to consist of a single cooling unit composed only of ash-flow tuffs, in a small tributary of Blind Spring Creek, in the NW¼ sec. 32, T. 7 S., R. 32 E., near the west edge of the Michaud quadrangle, it appears to be a single cooling unit consisting of two sequences of ash-flow tuffs separated by 4-10 inches of quartz crystals and biotite in a matrix of shards (fig. 10). This crystal-rich layer is bedded and contains a few exotic pebbles of basalt. It probably is a thin eruptive tuff bedded by air fall. The lower contact of this layer is cemented, or welded, to the underlying dense jointed vitric-crystal tuff, which is a welded tuff, although most of the shards are undeformed. Most of the crystals and crystal fragments are quartz. The hard underlying vitric-crystal tuff is about 25 feet thick and grades downward into an estimated 50 feet of massive pumiceous tuff that is virtually lacking

FIGURE 9.—Ledge of tuff of Arbon Valley (part of the middle member of the Starlight Formation) on the east side of Blind Spring Creek in the NW¼ sec. 32, T. 7 S., R. 32 E., Michaud quadrangle.

in quartz crystals. There, the pumiceous tuff overlies bedded rhyolitic tuff of the lower member of the Starlight Formation apparently conformably.

Above and in sharp contact with the bedded crystal-rich layer is vitric-crystal tuff that is light gray and glassy in the lower 3 feet. The shards in the matrix are well formed and alined and are not devitrified. The rock for at least 7 feet above the glassy tuff appears progressively coarser grained upward and richer in crystals. Good shard structure is lacking in the matrix, which appears to be a turgid dark glass that is not devitrified and that contains some obviously collapsed pumice. Most of the phenocrysts and fragments of phenocrysts are quartz, but some are sanidine and biotite.

The lithologic character of the tuff of Arbon Valley is perhaps best shown by exposures in the SE¼ sec. 26, T. 7 S., R. 32 E. There the basal part of the unit is a white or creamy massive unwelded pumiceous tuff that consists mostly of collapsed pumice only slightly devitrified and includes a few crystals. This light-colored tuff grades upward into brown unwelded pumiceous tuff that contains perhaps a few more crystals. The brown unwelded tuff grades upward into a zone a few feet thick of brown glassy tuff that consists of a turgid-appearing mass of shards, some devitrified, which are alined

FIGURE 10.—Parts of two ash-flow units in the tuff of Arbon Valley (part of the middle member of the Starlight Formation) in a small tributary to Blind Spring Creek in the NW¼ sec. 32, T. 7 S., R. 32 E., near the southwest corner of the Michaud quadrangle. About 4 inches of air-fall tuff separates the ash-flow units at level of the hammer.

but only slightly deformed. Pumice fragments are devitrified and have been deformed, stretched, and darkened. This glassy phase contains perhaps 20- to 30-percent crystals of quartz and sanidine and a little biotite. The glassy tuff, in turn, grades upward into jointed crystal-rich welded tuff that contains collapsed pumice. The matrix is a welded mass of poorly formed and only slightly deformed shards, which are only slightly devitrified. The abundant phenocrysts are mostly quartz but include some plagioclase and potash feldspar and biotite. Some are incorporated in collapsed pumice. Still higher in the sequence across a small valley to the east of the locality just described a phase contains similar, but even more abundant, crystals which probably account for the more than 50 percent of the rock. The groundmass consists of welded, moderately deformed shards that are not devitrified. This phase also includes some vapor-phase mineralization in small cavities. These exposures probably represent a multiple ash-flow deposit that cooled as a single cooling unit. Successive ash-flows within the cooling unit evidently were increasingly richer in crystals, possibly as a result of either crystal settling within the magma chamber or progressive crystallization in the magma chamber caused by rapid cooling due to the change in conditions of temperature and pressure following each eruption.

A similar increase in abundance of crystals upward in an ash-flow tuff in southern Nevada was described by Quinlivan and Lipman (1965), who attributed the cause to zonal layering of a differentiated magma within the magma chamber.

A glassy welded tuff, mapped as a separate unit, appears to overlie the tuff of Arbon Valley at several places in the southwestern part of the Michaud quadrangle and in the northwestern part of the Arbon quadrangle, to the south. The contact relations between the glassy welded tuff and the tuff of Arbon Valley were determined by trenching at a locality in the Arbon quadrangle at the section line along the west edge in the NW¼ sec. 11, T. 7 S., R. 32 E. There the tuff of Arbon Valley is unconformably overlain by about 18 inches of gray, tan, and nearly white rhyolitic tuff that is stratified in the lower 6-8 inches and nonstratified and coarser in the upper part. The tuff contains only a few quartz crystals. This, in turn, is overlain by ash-flow tuff that is brown and unwelded at the base, becomes welded and glassy about 2 feet above the base, and becomes increasingly welded upward into a black perlitic obsidian welded tuff about 4 feet above the base. Only about 8 feet of the perlitic obsidian welded tuff is exposed at this locality.

The upper part of the glassy welded tuff unit is best exposed in a ravine in the SW¼ sec. 21, T. 7 S., R. 32 E., in the Michaud quadrangle. At this locality the lowest part of the exposure is perlitic obsidian welded tuff that contains large lithophysae, some as much as 8 inches in diameter. The perlitic obsidian tuff, more than 25 feet thick, grades upward into brown welded tuff that becomes lighter in color and less welded and finally into tan pumiceous tuff containing some sanidine crystals.

Exposures of the glassy ash-flow tuff unit at the different localities probably represent small local ash-flow deposits, closely related to each other in time and, probably, in source but not physically interconnected. These deposits lie unconformably on the tuff of Arbon Valley and in at least one place are separated from it by 18 inches of air-fall tuff, although they probably are closely related to it in time. Both of these ash-flow tuff units differ in genesis from the bedded tuffs of the upper and lower members of the Starlight and are grouped as the middle member of the Starlight Formation.

UPPER MEMBER

The upper member of the Starlight Formation is made up of bedded rhyolitic tuff, a locally overlying trachyandesite flow, and related intrusive rocks. With the exception of some dikelike intrusive bodies in the Michaud quadrangle, rocks of the upper member of the Starlight crop out only east of Bannock Creek. West of upper Michaud Creek, in secs. 11 and 12, T. 7 S., R. 33 E., the tuff of Arbon Valley is overlain by several hundred feet of bedded rhyolitic tuff capped by basalt. Bedded rhyolitic tuff also crops out at several places stratigraphically above the tuff of Arbon Valley in the hogback exposures farther south. Although the upper member probably is present between the ash-flow tuff of the middle member and younger basalt on the hill north of Little Pocatello Creek in the Pocatello quadrangle, it is concealed by basalt talus. Most of the hill west of Pocatello and north of the divide at the head of Trail Creek (B.M. 5,343) is composed of tan, light-gray, and white bedded tuff of the upper member overlain by a porphyritic trachyandesite flow. This north-dipping porphyritic trachyandesite overlies the bedded tuff of the upper member apparently with only minor unconformity, as the tuff of Arbon Valley on the south and west sides of the hill is 150-300 feet below the contact. The trachyandesite presently is considered to be part of the upper member of the Sarlight Formation. It probably is 500-600 feet thick at the crest in the NW¼NW¼ sec. 29, T. 6 S., R. 34 E. The preserved thickness elsewhere probably is generally much less.

The porphyritic trachyandesite commonly is a bluish-gray or grayish- to purplish-brown dense devitrified glassy rock with as much as 25-percent phenocrysts, most of which are altered plagioclase feldspar 0.5-5.0 mm long and less basic than andesine. The rock generally contains less than 5 percent each of quartz and andesine phenocrysts and some pyroxene, mainly pigeonite. The groundmass commonly is a completely devitrified glass now composed of potash feldspar and chalcedony with some tridymite. The rock commonly is iron stained. The main mass appears to be a single thick flow, with conspicuous columnar jointing and, locally, some platy jointing. The base of the flow on the east side of the hill, in the NE¼ sec. 29, T. 6 S., R. 34 E., is perlitic; locally, on the west side of the hill there appears to be 15-20 feet of possible breccia or flow breccia at the base. The base of the flow is at an altitude of about 5,650 feet on the south side of the hill, and the basal contact dips northward, or northeastward, nearly parallel with the underlying units of the Starlight Formation.

Two dikelike bodies west of Bannock Creek in the Michaud quadrangle, in the W½ sec. 24, T. 7 S., R. 32 E., are composed of a dense porphyritic gray rock consisting of about 35-percent phenocrysts of plagioclase feldspar 1-5 mm long (15 percent), quartz (10 percent), and lesser amounts of hypersthene, augite, and biotite in a matrix of labradorite microlites (55 percent of the rock) and glass (10 percent). Many of the feldspar phenocrysts are zoned with labradorite cores and andesine rims; some are unaltered oligoclase. Some of these feldspar phenocrysts have rims of quartz, orthoclase, and oligoclase. Many are altered and rounded by resorption. The dikes contain zenoliths of fine-grained basalt. Petrographically similar dike rocks intrude tuffs of the lower member in the northern part of the Arbon quadrangle, to the south. Because of the gross mineralogic similarities, these intrusive rocks are thought to be related to the porphyritic trachyandesite flow, perhaps as feeders of similar flow rocks now removed by erosion.

Black, red, and gray, banded perlitic vitrophyre and vitrophyre breccia near the center of sec. 20, T. 6 S., R. 34 E., near the west wall of a canyon cut in the trachyandesite flow, possibly is a plug. Similar vitrophyre is along the township boundary in sec. 13, T. 6 S., R. 33 E., and sec. 18, T. 6 S., R. 34 E. (fig. 11), and along the section line in secs. 13 and 24, T. 6 S., R. 33 E. The vitrophyre locality along the township line shows marked near-vertical flow banding that also suggests pluglike intrustion. The glass of the vitrophyre is totally unaltered in contrast to the nearly complete devitrification of the flow rock. Although this is the main difference in the two types, flow banding is much more common and pronounced in the vitrophyre. Bodies in the American Falls quadrangle, where contemporaneity with tuff of the upper member is indicated (Carr and Trimble, 1963, p. G10), and in the Rockland quadrangle (Trimble

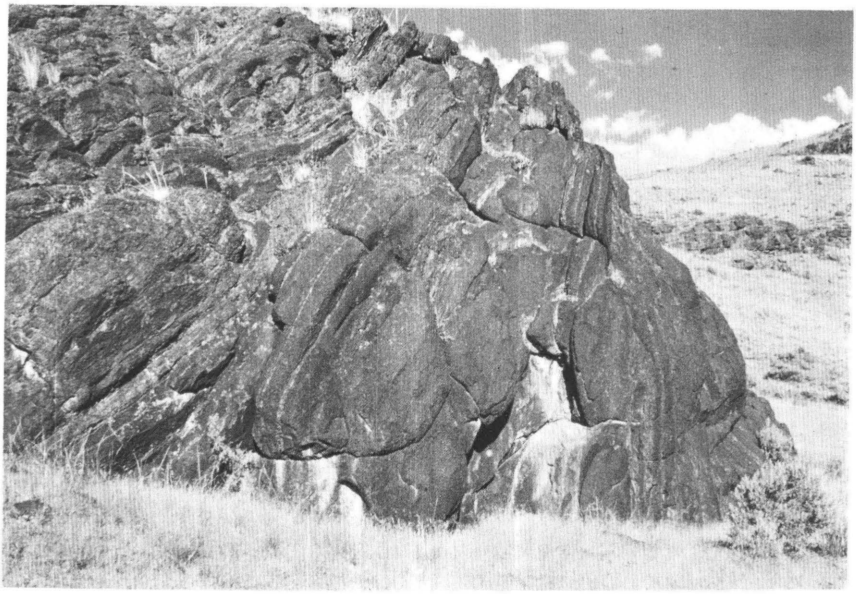

FIGURE 11.—Flow lines in vitrophyre on line between Rs. 33 and 34 E., about 1 mile south of curve on U.S. Highway 30N in the east-central part of Michaud quadrangle.

and Carr, 1976) are of similar mineralogic character and probably are petrologically related bodies. The apparent intrusion of the vitrophyre into the porphyritic trachyandesite is the best evidence for assigning the trachyandesite to the upper member of the Starlight Formation.

AGE OF THE STARLIGHT FORMATION

On the basis of vertebrate and molluscan faunas collected from it in the Rockland and Arbon quadrangles and other areas to the southeast, the Starlight Formation has been dated as early or middle Pliocene, probably middle Pliocene (Carr and Trimble, 1963; Trimble and Carr, 1976). Fossils have not been collected from the Starlight in the Michaud or Pocatello quadrangles.

TERTIARY OR QUATERNARY SYSTEM

Rhyolite in the Pocatello quadrangle and basalt in the northern part of the Pocatello quadrangle and east and west of Bannock Creek in the southern part of the Michaud quadrangle intrude or overlie rhyolitic tuffs of the Starlight Formation and are capped only by Quaternary loess or gravel. They seem to be wholly younger than the tuff sequence of the Starlight Formation but may be related to the upper member of the Starlight. More probably, however, they are younger than the Starlight. They may be late Pliocene or early Pleistocene in age.

RHYOLITE

Rhyolite occurs in two areas in the Pocatello quadrangle—one, a rather large area in the northern part of the quadrangle, and the other, a small area at the south edge.

The rhyolite in the northern part of the quadrangle is almost entirely within the Fort Hall Indian Reservation, where it crops out extensively and, in some places, forms large hills. It is localized along and north of an inferred concealed fault and west of a divide underlain by Paleozoic rocks. This rhyolite, which locally is 200 feet or more thick, unconformably overlies bedded tuff of the Starlight Formation and is overlain by Quaternary loess. At the base of the rhyolite locally is about 50 feet of breccia that contains large blocks of perlitic obsidian. Above the breccia is 40-50 feet of dark-gray perlitic obsidian that is overlain by more than 100 feet of light-gray to pink or purple rhyolite.

The rhyolite locally is flow banded. Some flow surfaces are nearly flat, but others dip steeply to almost vertically. Locally, the rhyolite contains many spherulites and lithophysae as much as 1.5 inches in diameter. Phenocrysts form 15-25 percent of the rock and include plagioclase (andesine and oligoclase), sanidine, quartz, and biotite. The groundmass commonly is devitrified to spherulites of orthoclase, tridymite, and chalcedony. The devitrified groundmass is not everywhere spherulitic and, in places, contains much tridymite in cavities.

The rhyolite near the south edge of the quadrangle is almost entirely on the south wall and in the valley of West Fork Mink Creek. It appears to have had a source only a few miles to the southwest, south of Elk Meadows, and to have poured into the valley of West Fork Mink Creek from the southwest.

The rhyolite here is light gray to pink and vesicular. The groundmass is devitrified, and the rock contains phenocrysts of both orthoclase and plagioclase feldspar, quartz, and biotite.

This rhyolite flowed into a valley cut along a fault contact between Cambrian limestone and Precambrian quartzite—a valley that had been cut to its present depth at the time the rhyolite was emplaced. This suggests that the rhyolite is much younger than the Starlight, which was erupted shortly after basin-and-range faulting, for the dissection of minor tributary valleys, such as that of West Fork Mink Creek, must have occurred after the faulting and must have required considerable time.

The Little Creek Formation to the southwest (Carr and Trimble, 1963; Trimble and Carr, 1976) contains both rhyolitic and basaltic constituents, and the eruption of rhyolite in the Pocatello quadrangle and to the southwest may be related to the Little Creek eruptive episode.

BASALT AND ANDESITE PORPHYRY

Basalt in the north-central part of the Pocatello quadrangle and basalt east of Bannock Creek in the Michaud quadrangle, between Birch Creek and Michaud Creek, unconformably overlie rhyolitic tuff and sedimentary breccia of the Starlight Formation. In most places the basalt caps hills and buttes and the high points on ridges. In many places the contact is an angular unconformity. The basalt probably is less than 50 feet thick in most places. West of Bannock Creek an unusual hypersthene basalt, younger than the tuff of Arbon Valley, forms Eagletail Rock and nearby outcrops and is exposed in a hill 1 mile north of Eagletail Rock.

The basalt of these areas generally is dark gray, dense, and fine grained. It contains 55-60 percent of plagioclase, commonly labradorite (An_{55}-An_{60}), of which 5-15 percent forms phenocrysts. The rock contains 30-40 percent of augite and commonly little olivine, but locally it may have as much as 12 percent or more of olivine. The texture is intergranular.

The hypersthene basalt in Eagletail Rock and other outcrops west of Bannock Creek is different from other basalts of this group mainly in texture, which commonly is trachytic, and in the presence of 5-15 percent of slender euhedral cyrstals of nonpleochroic hypersthene. The hypersthene is a very low iron hypersthene, perhaps bronzite, that commonly is intergrown with the labradorite phenocrysts (An_{63}). Augite, which forms 5-10 percent of the rock, occurs both as small crystals scattered throughout the groundmass and as narrow jackets or overgrowths on many of the hypersthene crystals.

Several vents appear to be localized along the trace of an east-northeast-trending inferred fault in the north-central part of the Pocatello quadrangle. The basalt of most of these vents is mineralogically similar to that of the other occurrences, although perhaps more porphyritic. One vent, however, located nearly on the fault trace in the NW¼SE¼ sec. 21, T. 5 S., R. 35 E., is basalt or andesite porphyry that is purplish gray and contains phenocrysts of dark-green hornblende as much as half an inch long. Most of the phenocrysts are altered to iron oxide. The plagioclase phenocrysts are labradorite (An_{60}), but plagioclase in the groundmass, which is partially devitrified glass that forms about 40 percent of the rock, may be andesine. Oxyhornblende composes about 10 percent of the rock, and pigeonite, about 5 percent.

Several bodies of oxidized basaltic rock intrude sedimentary breccia and rhyolitic tuff of the Starlight Formation along and across Jimmie Creek in secs. 26, 27, 34, and 35, T. 5 S., R. 35 E., and appear to be segments of a hook-shaped or U-shaped dike structure somewhat like an incomplete ring dike. A similar type of intrusive segment is in sec. 34 on the west side of the divide between Two and a Half Mile Creek and Jimmie Creek. These dike rocks are much altered and oxidized and contain calcite-filled vesicular areas. In many places the rock has flow structure, but the orientation is not uniform. In places the dike rocks contain much foreign material, and some parts of the dikes are made up of an intrusive breccia that contains blocks of silicified tuff.

The basalt and the andesite porphyry mapped as Tertiary or Quaternary units intrude or overlie the Starlight Formation wherever they occur. In most places the contact is an angular unconformity. Most of these basalts are high-level erosional remnants capped only by Quaternary gravel deposits or loess. These physical relations suggest that these basalts are wholly younger than the Starlight but older than the Big Hole Basalt in the Snake River Plain. They also appear to be less weathered, in general, than basalt of the Starlight Formation.

The basalt and andesite porphyry probably are about equivalent in age to the Massacre Volcanics to the southwest (Trimble and Carr, 1976), which were erupted from at least three separate centers, but petrologic differences suggest that the basalt of the Pocatello and Michaud quadrangles was erupted from a different magma chamber. The Massacre rocks commonly contain 15 percent or more of olivine and have diktytaxitic or ophitic or subophitic textures. The basalt of the Pocatello and Michaud quadrangles, thought to be younger than Starlight, has little olivine and generally has an intergranular texture. Like the Massacre volcanics, the basalt and andesite porphyry probably are of late Pliocene or early Pleistocene age.

QUATERNARY SYSTEM

Quaternary rocks, mostly unconsolidated, cover more than three-quarters of the Michaud quadrangle and completely cover the northern part. They are less extensive in the Pocatello quadrangle but cover about one-third of that quadrangle, mostly in the northern half.

The oldest deposits assigned unequivocally to the Quaternary are gravel deposits adjacent to the mountain fronts and along valleys, and the Big Hole Basalt, which is present only west of American

Falls Reservoir in the northwesternmost part of the Michaud quadrangle. Loess younger than the basalt mantles the gravel deposits over much of their extent and covers large parts of the area.

The northern part of the Michaud quadrangle and the adjoining part of the Pocatello quadrangle are covered mainly by Pleistocene lacustrine deposits, gravel, terrace deposits, and dune sand. Many of the Pleistocene deposits are related to the ancestral American Falls Lake, or to catastrophic floodwaters that resulted from spillover of pluvial Lake Bonneville. Basalt flows in the valley of the Portneuf River southeast of Pocatello originated outside this area and were emplaced before the catastrophic flooding. Holocene alluvium covers valley floors.

TRAVERTINE

Two long masses of creamy white travertine in NW¼SE¼ sec. 26, T. 5 S., R. 35 E., extend from the ridge crest downslope to the northwest. The travertine probably was deposited in and adjacent to a fracture in the Starlight Formation, but its relation to the younger basalt is uncertain. The travertine probably is younger than the basalt and is thought to be early Pleistocene in age.

PEDIMENT GRAVEL

Loess-capped gravel and rubble aprons several miles wide mantle pediment surfaces cut on Tertiary rocks adjacent to the west front of the Bannock Range in the Michaud quadrangle and along the margins of the Pocatello Range in the Pocatello quadrangle, and these together with the loess-covered alluvial gravel along the valley of the Portneuf River form the "benchlands" of the area.

The pediment gravel in the Michaud quadrangle consists almost entirely of quartzite derived from the adjacent mountains. Near the mountain front the deposits are a rubble composed mostly of large angular boulders several feet in diameter. Size and angularity decrease away from the mountains, and near Bannock Creek valley the deposits are a pebble gravel.

In the Pocatello quadrangle pediment gravel, mostly covered by loess, is exposed principally on south-facing slopes of draws cut into the benches north and south of Pocatello Creek. This gravel, as much as 125 feet thick, overlies a surface cut on Tertiary rhyolitic tuff. The gravel is angular to rounded and is bedded and poorly cemented. South of Pocatello Creek it is composed mainly of quartzite but contains some limestone and dolomite. In places north of Pocatello Creek, the lower parts of these gravel deposits are different in lithologic character from the upper parts. Locally, the lower part consists mostly of Precambrian rocks with many rounded constituents, and the upper part consists of angular to subangular fragments, mostly of Cambrian and Ordovician rocks. This lithologic difference suggests that the upper part was derived from sedimentary breccia in the Tertiary sequence and that the lower part was reworked from a conglomerate that perhaps was also in the Tertiary section.

Deposits of cobbly gravel north and south of the lower end of Pocatello Creek probably are fanglomerate deposits related to the pediment gravel, and gravel beneath loess farther up North and South Forks Pocatello Creek probably is alluvial gravel graded to the pediment surface.

Coarse angular gravel along the south wall of the Portneuf valley near Pocatello probably is an alluvial gravel equivalent in age to the pediment gravel but occurring in a major Pleistocene stream course. Bedrock is at a lower altitude than in tributary streams or on pediment surfaces and is not exposed.

All the gravel deposits described thus far are older than the loess which mantles them over wide areas, and all are graded to a level much higher than the present base level. This temporarily high base level may have been determined by the Raft Formation of middle or late Pleistocene age (Carr and Trimble, 1963; Trimble and Carr, 1976), which is primarily an alluvial deposit that occurs at altitudes of as much as 4,600 feet. If so, the pediment gravel and associated gravel deposits are of late Pleistocene age. These deposits and the mantling loess probably constitute most of the unit that Mansfield (1927, 1929, 1952) called "hillwash and older alluvium."

BIG HOLE BASALT

Basalt flows along the west side of American Falls Reservoir in the northwest corner of the Michaud quadrangle have been named the Big Hole Basalt in the adjoining American Falls quadrangle (Carr and Trimble, 1963). The basalt is as much as 170 feet thick near Aberdeen, only a few miles west of the Michaud quadrangle, but in most places it is much thinner.

The basalt characteristically is dense blue gray to blue black and commonly contains a few megascopic crystals of olivine. Locally, however, megascopic olivine is absent. In many places the flows have a pahoehoe surface and have been buckled into pressure ridges. The basalt commonly has an intersertal texture and is composed of 25-35 percent of plagioclase (An_{48-70}) and 15-25 percent of euhedral olivine in a groundmass composed of fibrous, poorly crystallized pyroxene, glass, and magnetite. The groundmass commonly forms about half the rock, and magnetite may form as much as one-third of the groundmass.

The Big Hole Basalt unconformably overlies the middle or upper Pleistocene Raft Formation (which is not exposed in the Michaud quadrangle) and is overlain by the upper Pleistocene American Falls Lake Beds. The age of the Big Hole Basalt, therefore, is middle or late Pleistocene, probably late Pleistocene.

LOESS DEPOSITS

Calcareous silt, probably of eolian origin, mantles pediment gravel and related gravel and older rocks in the Michaud and Pocatello quadrangles. In the western part of the American Falls quadrangle to the west, similar deposits form an extensive mantle on the Big Hole Basalt (Carr and Trimble, 1963). The loess overlying the pediment gravel east of Bannock Creek in the Michaud quadrangle generally is more than 25 feet thick. West of Bannock Creek, logs of two deep wells indicate that the loess locally is more than 200 feet thick. The loess is thinner at higher altitudes and adjacent to the mountain fronts generally is not present or is too thin to be mapped above an altitude of about 5,750 feet. In many places, however, especially in and east of the Pocatello Range, loess is present in mappable thickness to more than 6,000 feet in altitude.

The loess is a light-tan poorly indurated uniform silt that is very well sorted and that contains about 20-percent calcium carbonate. It stands in steep slopes in some places, owing mainly to surficial "case hardening" or induration. Most valleys cut in the loess of the benchlands have concave slopes, but locally the valley sides are near vertical to vertical.

No diagnostic fossils have been found in the loess. It overlies the Big Hole Basalt in the American Falls quadrangle and overlies gravel deposits in the Michaud and Pocatello quadrangles. The Pleistocene American Falls Lake cut scarps on the loess, which is therefore older than the American Falls Lake Beds. The loess probably is late Pleistocene in age and may have been derived in part from the Raft Formation (Carr and Trimble, 1963).

SUNBEAM FORMATION

Alluvial and colluvial deposits of silt and interstratified sand and gravel that are widespread in the American Falls and Rockland quadrangles have been named the Sunbeam Formation (Carr and Trimble, 1963). The Sunbeam is mapped in the Michaud quadrangle only west of Blind Spring Creek, along the west edge of the quadrangle. It is locally at least 100 feet thick in the American Falls quadrangle, but it is probably much thinner in the Michaud exposures.

Most of the Sunbeam is unbedded to poorly bedded tan calcareous silt containing some fine sand. Sand and gravel occur as lenses in the silt.

The Sunbeam, where fine grained, is difficult to distinguish from either the Raft Formation or the loess deposits on the basis of lithology. The loess lacks bedding and lacks particles coarser than silt, whereas the Sunbeam commonly is, at least in part, faintly bedded and contains a few lenses of sand and gravel. The Raft Formation is distinguished from the Sunbeam mainly by containing calcareous nodules and, in some places, thick caliche, neither of which are found in the Sunbeam or in the loess.

The Sunbeam in the American Falls quadrangle is widespread below an altitude of 4,750 feet. Its pattern of distribution suggests that it may be fan material, mainly from Blind Spring Creek and Sunbeam Creek to the west but also from lesser tributaries, and it may be derived, at least in part, from the loess deposits during their accumulation. The Sunbeam does not have a significant mantle of loess, but it, too, has been scarped by the waters of the late Pleistocene American Falls Lake. The Sunbeam is probably late Pleistocene for the most part and at least partly contemporaneous with the loess deposits. The mapped unit may also include some deposits of Holocene age.

AMERICAN FALLS LAKE BEDS

The American Falls Lake Beds were named by Stearns, Crandall, and Steward (1938, p. 69), who applied the name to sediments deposited in a lake formed when basalt dammed the Snake River in the Rockland quadrangle to the southwest. The term "American Falls Lake Beds" was restricted by Carr and Trimble (1963, p. G28; Trimble and Carr, 1976) to the upper part of the beds named by Stearns, who included beds older than the basalt that dammed the river. At the base of the formation, under the 1963 definition, is a gravel deposit that lies at an altitude of about 4,320 feet. The beds below the gravel are referred to the Raft Formation.

The American Falls Lake Beds in the Michaud quadrangle are well exposed in the bluffs that rim most of American Falls Reservoir and along the valley walls of the lower parts of Bannock Creek and the Portneuf River. The upper limit of the American Falls Lake Beds is at an altitude of about 4,400 feet, and the total thickness is about 80 feet.

The American Falls Lake Beds consist mainly of clay and has subordinate amounts of sand, sandy silt, and, locally, fine sand. Some of the clay is very diatomaceous, and some beds are calcareous. The most persistent layer is white to light-tan massive blocky diatomaceous clay that forms a conspicuous ledge in the upper part of the sequence. This layer normally is about 5 to 7 feet thick, but locally it is as little as 2 or 3 feet thick and as much as 20 feet thick. In general, the top of the clay layer is near an altitude of 4,375 feet, or about 25 feet below the highest level of the lake beds, but rarely is more than 10 feet of lake beds exposed above the top of the diatomaceous clay. These overlying beds commonly are gray or grayish-green prismatic-jointed clays. The diatomaceous clay commonly is underlain by lacustrine clay, sandy clay, silt, and sand, but, where the diatomaceous clay is abnormally thick, it is underlain in most places by crossbedded sandy deposits that apparently are deltaic in origin. In the Michaud quadrangle, deltas of ancestral Bannock Creek and the Portneuf River underlie the diatomaceous clay layer along the entire bluff line west of the Portneuf River, except for about 4 miles between the NW. cor. sec. 32, T. 5 S., R. 33 E., and the quarter-section line in sec. 3, T. 6 S., R. 32 E., where a normal lacustrine sequence of clay, silt, and sand underlies the diatomaceous layer. The deltaic sands lie below the diatomaceous clay for more than 2 miles on each side of the mouths of the present streams, which apparently shifted their positions as they built deltas into the Pleistocene lake. The contact between the deltaic deposits and the diatomaceous clay is locally disconformable.

Three or four feet of well-sorted pebble gravel underlies the lacustrine beds below the diatomaceous clay at several places between the ancestral deltas of Bannock Creek and the Portneuf River. These exposures probably are of the gravel at the base of the American Falls Lake Beds, which also was encountered at an altitude of about 4,320 feet in an auger hole in SW¼SW¼ sec. 10, T. 6 S., R. 32 E. *Bison* (*Gigantobison*) *latifrons* obtained from the beach 1 mile to the north in the SE¼ sec. 3, T. 6 S., R. 32 E. (Hopkins, 1951), probably came from this gravelly horizon, which, there, is overlain by deltaically bedded sand that is overlain by the diatomaceous clay layer. The contact at the base of the diatomaceous clay undulates considerably for about 1 mile to the southwest, to the dune-covered point; locally, such as just east of the point, the contact drops sharply, truncating the beds below.

In 1960 a pipeline trench, about 30 feet deep, was excavated in the SE¼SW¼ sec. 36, T. 5 S., R. 33 E., and the NW¼ sec. 1, T. 6 S., R. 33 E., for the Bureau of Indian Affairs. The upper part of the American Falls Lake Beds was exposed in this trench and was overlain by about 16 feet of gravel. A layer of dark-brown peat, 6-10 inches thick, was 13 feet below the top of the exposed lacustrine beds, which may be the little-eroded top of the formation. The upper 13 feet was massive silty clay, greenish gray in the lower part, grading upward into tannish brown. The peat was underlain by about 4 feet of yellowish- to cream-colored clay with some carbonaceous streaks at the bottom and, locally, by another thin layer of impure peat, not more than 6 inches thick, at the base. Base of exposure in the trench was a blue-green massive silty clay that contained a few mollusks and some thin seams of marcasite or pyrite. The yellowish clay contained abundant mollusks. Mastodon bones, which have since been studied by Marie L. Hopkins of Idaho State University, were obtained from the upper part of the yellowish clay and from the overlying peat layer. The upper peat layer has been dated as more than 42,000 years B.P. (before present) (USGS loc. No. W-929, Ives and others, 1964, p. 54). This entire sequence is thought to be stratigraphically above the diatomaceous clay that is so prominent in the bluffs around the reservoir. The top of the clay, if present, should be only about 5 feet below the base exposed in the trench in 1960. M. L. Hopkins reported (written commun., 1961), however, that subsequent deepening of the trench exposed gravel beneath the blue-green clay. This gravel probably is alluvial gravel of the Portneuf River equivalent in age to much of the American Falls Lake Beds, including the diatomaceous clay layer, which probably was not deposited here. The exposures of the American Falls Lake Beds in the bluffs rimming the reservoir and the exposures of the upper part seen in the trench, therefore, together probably constitute the entire sequence of beds in this formation.

The age of the American Falls Lake Beds, based on vertebrate and invertebrate evidence, is middle to late Pleistocene, probably late Pleistocene (Carr and Trimble, 1963; Trimble and Carr, 1976). The basal gravel, which contains *Bison* (*Gigantobison*) *latifrons*, likely was deposited during a glacial, rather than an interglacial, interval and probably is Illinoian in age (Carr and Trimble, 1963, p. G29). Additional data on stratigraphic position of this *Bison* were given by Hopkins, Bonnichsen, and Fortsch (1969). New evidence of a pre-Bull Lake (Sangamon) age for *Bison latifrons* from the mountain front area in Colorado (Glenn R. Scott, oral commun., 1969) now seems to vindicate a pre-Bull Lake age (Illinoian) for the lower gravel and the American Falls Lake Beds.

BASALT OF PORTNEUF VALLEY

Two superimposed diktytaxitic basalt flows are exposed nearly continuously in the valley of the Portneuf River, from Inkom to a point opposite the mouth of Blackrock Canyon, and from just west of the narrows at Portneuf to Ross Park at the southeast edge of Pocatello. The name McCammon Basalt was informally used by R. C. Bright (Ives and others, 1964, p. 54), who applied the name to the same flows in the vicinity of McCammon, Idaho. Each flow is about 50 feet thick. The flows are covered along their north edge by Quaternary alluvium, mostly fan deposits.

The basalt of Portneuf valley is dark gray to black and, locally, has a well-developed diktytaxitic texture. Columnar structure is pronounced in both flows. The exposed surfaces of the flows have been scoured by floodwaters from pluvial Lake Bonneville and stripped of their pahoehoe and scoriaceous phases, and they are now of smoothed vesicular basalt, which is channeled locally.

The basalt flowed over a valley floor that was at nearly the same altitude as the present floor. The base of the basalt is at an altitude of about 4,460 feet in a well drilled in the SW¼NE¼ sec. 7, T. 7 S., R. 35 E. The present valley floor just to the south is between 4,450 and 4,460 feet in altitude.

The basalt flows can be traced nearly continuously up the valley of the Portneuf River past McCammon to an area beyond Lava Hot Springs, and they probably flowed into the Portneuf valley from Gem Valley, as suggested by R. C. Bright (Ives and others, 1964, p. 54). The lower basalt flowed over valley alluvium that was 31 feet thick in the well near Pocatello. Organic material from a black baked zone beneath the lower flow near McCammon has been dated by carbon-14 methods (Ives and others, 1964, p. 54) as 33,000 ± 1,600 years B.P. (USGS No. W-1121) and 35,000 ± 3,000 years B.P. (USGS No. W-1177). South of McCammon the flows dammed Marsh Creek valley, and mollusks from the resulting lake beds have been dated as 32,500 ± 1,500 years B.P. (USGS No. W-221, Ives and others, 1964, p. 53). These dates for the basalt of Portneuf valley are also limiting dates for the flood from pluvial Lake Bonneville, which eroded the surface of the basalt and, therefore, is younger than the basalt.

BOULDER BARS

The flood from pluvial Lake Bonneville not only scoured the surface of the basalt flows of Portneuf valley but, in the confined valley of the Portneuf River between Inkom and Pocatello, it also ripped sections of columns from the cliffed margins of the flows and tumbled them into heaps and piles to form boulder bars that locally are more than a mile long. Most of these boulder bars are between Inkom and Portneuf, but one bar is about 1 mile northwest of Portneuf, and boulder bars can be seen at Ross Park at the southeast edge of Pocatello.

Some of these boulder bars rest on the surface of the lower flow and locally cover its south edge. These bars were derived from the south-facing cliff face of the upper flow. The largest and most spectacular of the boulder bars, however, lies between the southern cliffed margin of the lower flow and the railroad track and begins about half a mile west of Inkom. This flood deposit is more than 1 mile long and 0.3 mile wide at its widest point. Near its east end are slightly rounded column fragments, as much as 15 feet long, which obviously have been moved only a few hundred feet from the face of the flow. Near the west end, however, the basalt boulders are well rounded, and some are as much as 10 feet in diameter (fig. 12) and the deposit contains much admixed gravel of pebble to small boulder size that is not basalt.

The boulder bars are impressive evidence of the energy of the floodwaters from Lake Bonneville that emplaced them.

FIGURE 12.—Boulder bar north of railroad track about 1½ miles west of Inkom, Pocatello quadrangle. Largest boulder is about 10 feet in diameter. Boulders are of locally derived basalt. White coating on some is hardened crust of cement dust from cement plant at Inkom.

MICHAUD GRAVEL

Gravel and sand deposited by the flood from pluvial Lake Bonneville upon its emergence onto the Snake River Plain have been named the Michaud Gravel (Trimble and Carr, 1961a; Carr and Trimble, 1963). The Michaud Gravel was dumped into the Pleistocene American Falls Lake as a composite delta-and-fan deposit, and it overlies the American Falls Lake Beds over much of its extent. The Michaud Gravel extends from the mouth of the canyon of the Portneuf River at Pocatello southwestward for about

18 miles almost to American Falls and northward to slightly beyond the north edge of the Pocatello and Michaud quadrangles. Its southern boundary is determined by a scarp cut on loess deposits by water of the American Falls Lake, against which the gravel was deposited.

The Michaud Gravel is 50-80 feet thick. The basal contact with the American Falls Lake Beds is uniformly about 4,400 feet in altitude, and its upper surface ranges in altitude from about 4,450 to 4,480 feet.

The Michaud Gravel has a mixed lithology but contains mostly basalt and quartzite. At Pocatello it consists mainly of large boulders. The largest boulder now exposed is about 8 feet in diameter, but even larger boulders were seen in excavations for buildings in the downtown business area of Pocatello. The maximum size of boulders in the deposits decreases rapidly to the north and west, however, and the largest boulders in the Michaud quadrangle are about 4 feet in diameter and at Michaud siding the largest size is cobble or small boulder size. West of Bannock Creek the deposit is a pebbly sand. The fine sand and silt deposits of the Grandview terrace, west of American Falls Reservoir in the American Falls quadrangle (Carr and Trimble, 1963), probably are correlative deposits of the fine-grained material at the distal margin of the Michaud Gravel.

Contours of the maximum particle size in the Michaud Gravel in figure 13 demonstrate the rapid decrease in size away from the mouth of Portneuf valley. Maximum boulder size was used to compute the approximate current velocity of the floodwaters at Pocatello (Trimble and Carr, 1961b), and it was concluded that 8-foot boulders in the deposit at Pocatello indicated a current velocity of more than 16 miles per hour, which is greater than the maximum recorded velocity of any natural stream.

The Michaud Gravel is younger than the basalt of Portneuf valley, which has been dated at more than 30,000 years in age, and is older than a terrace cut on the gravel that is about 29,700 ± 1,000 years B.P. (See following discussion entitled "Aberdeen Terrace Deposits.") The Michaud Gravel was emplaced by floodwaters from Lake Bonneville, probably about 30,000 years ago. The flood deposits locally contain mollusks, and *Bison alleni* has been obtained from a gravel pit in the Michaud Gravel in the SW¼SW¼ sec. 19, T. 6 S., R. 33 E. (Hopkins, 1951).

ABERDEEN TERRACE DEPOSITS

A terrace surface widely developed on both sides of American Falls Reservoir in the American Falls and Michaud quadrangles was named the Aberdeen terrace by agronomic soil scientists (Poulson

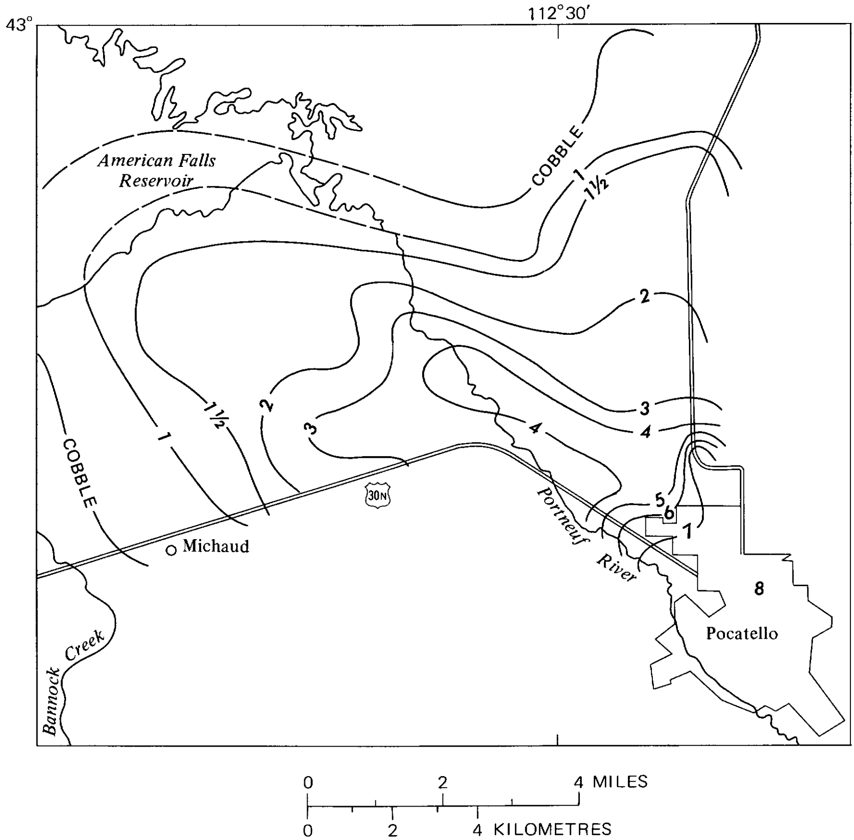

FIGURE 13.—Areal variation in maximum boulder size in the Michaud Gravel. Contours, in feet, of longest dimension of largest boulders. Dashed where no control available.

and others, 1943, p. 5). The Aberdeen terrace deposits in the Michaud quadrangle extend from the top of the bluff at the edge of the reservoir, at an altitude of about 4,400 feet, to the scarp bounding their south edge at 4,420 to 4,430 feet. In the northeast quarter of the quadrangle the terrace is not fully developed as a broad uninterrupted surface; instead, the terrace forms channels through islands of Michaud Gravel. The Aberdeen terrace deposits are 10 feet thick at the pipeline trench in the SE¼SW¼ sec. 36, T. 5 S., R. 33 E., where they are underlain by about 6 feet of bouldery gravel thought to be Michaud. The Aberdeen terrace deposits probably are nowhere more than 15 or 20 feet thick and in most places probably are 10 feet thick or less.

The Aberdeen terrace deposits in the Michaud quadrangle commonly consist of pebble gravel, probably reworked from the Michaud Gravel. They rest on locally coarser bouldery gravel of the Michaud and, in places, on the American Falls Lake Beds. In places the underlying Michaud is finer than the Aberdeen deposits.

The terrace deposits contain a few mollusks of late Pleistocene age. A radiocarbon date (W-731, Rubin and Alexander, 1960, p. 158) on mollusk shells obtained from the fore part of the terrace in the American Falls quadrangle is 29,700±1,000 years B.P. The Aberdeen terrace was cut on the Michaud Gravel, probably while the flood from Lake Bonneville was still in progress, and this date is thought to date the flood.

STERLING TERRACE DEPOSITS

The lowest and youngest extensive terrace formed in the area was named the Sterling terrace by Poulson, Nelson, and Poulson (1943, p. 5). Only two remnants of the Sterling terrace are present in the northwest corner of the Michaud quadrangle, where they overlie the Big Hole Basalt and the American Falls Lake Beds. The Sterling terrace is separated from the Aberdeen terrace in the adjoining American Falls quadrangle by a locally well defined scarp with a base at an altitude of 4,380 to 4,390 feet above sea level.

The deposits of the Sterling terrace consist mainly of silt, pebbly sand, and local gravel. Some of the gravel fills potholes or scours cut in the basalt.

The height of this terrace above present normal stream level (25-30 ft) suggests that this is a Pinedale terrace.

OLDER ALLUVIUM

Alluvial deposits that cannot be referred to either the Aberdeen or the Sterling terrace with any degree of confidence, but which are younger than the Michaud Gravel and older than the Holocene alluvium, are mapped as older alluvium. The older alluvium forms poorly defined to well-defined terraces along the Portneuf River and along Bannock Creek and floors a channel and distributary system that extends northward from Pocatello.

The older alluvium along the Portneuf River is a well-sorted pebble gravel; that of Bannock Creek is pebbly sand. The abandoned channel in and north of Pocatello, however, is floored with silty alluvium that is more than 25 feet thick at the old county fair grounds, in the NW¼N¼ sec. 14, T. 6 S., R. 34 E.

All the deposits mapped as older alluvium in this area probably are nearly equivalent in age to the Aberdeen terrace deposits.

DUNE SAND

Large sand dunes have formed at two points along the bluff marginal to the American Falls Reservoir—one a little more than 1 mile north of the mouth of Bannock Creek and the other about 2 miles farther northeast. Longitudinal sand dunes are poorly developed in the northeast-trending area of Michaud Gravel south of the railroad track and southwest of Bannock Creek. The surface deposits of the Michaud, which, there, are mainly sand, have been reworked by wind, and most of the area is covered by dunes or incipient dunes of sand. This area is mapped separately, indicating the presence of the Michaud Gravel and the dunes reworked from it. Locally, dunes are reworked from alluvium and are also mapped separately.

The dunes are, therefore, composed of sand that has been locally derived and has been moved only short distances. They are still active and are of Holocene age.

YOUNGER ALLUVIUM

Alluvium covers the floors of the major streams and their tributaries. Mapped with it are the many alluvial fans at the mouths of tributary canyons that merge with the alluvium of the valleys.

In Fort Hall Bottoms and in Portneuf valley the alluvium is mainly gravel covered by a layer of silt. The alluvium of Bannock Creek is mainly silt and sand. Most tributary valleys are floored with fine-grained alluvium. The alluvial-fan deposits are poorly sorted and commonly consist of a mixture of fine- to coarse-grained material, including many small boulders that commonly are angular to subangular. The alluvial fans along the front of the benchlands north of Pocatello, however, were derived largely from loess deposits and are, therefore, composed chiefly of silt.

GRANITIC(?) DIKES OF UNCERTAIN AGE

Two dikes of granitic(?) composition of uncertain age, too small to be mapped at the scale used, intrude greenstone of the Bannock Volcanic Member of the Pocatello Formation. One, in the SE¼NW¼ sec. 9, T. 7 S., R. 35 E., is an aplite. It is a sill-like tongue that intrudes greenstone schist at an altitude of about 5,050 feet. The other dike intrudes greenstone at an altitude of about 5,200 feet on a spur in the SW¼NE¼ sec. 5, T. 7 S., R. 35 E. It is about 3 feet thick and is nearly vertical. Widely distributed quartz veins and minor sulfide mineralization (mostly copper) suggest that these intrusions may be apophyses of a larger igneous body at relatively shallow depth.

STRUCTURE

The Precambrian and Paleozoic rocks of the Bannock and Pocatello Ranges in the Michaud and Pocatello quadrangles are within, and at the north end of, a huge klippe of about 6,000 square miles in areal extent (fig. 14). The klippe is terminated at its north end by the southeastern margin of the Snake River Plain, and it extends southward to the vicinity of Ogden, Utah. The pre-Tertiary rocks of these ranges, which for the most part have an eastward regional dip, have been broken by a complex of thrust slices that is not well understood—partly because of inadequate exposure, partly because of lack of geologic information in adjoining areas to the east and south, and partly because of a marked change in structural pattern within the klippe east and west of long 112°00′. Imbricate thrust slices that break the rocks of the klippe have subsequently been warped. Basin-and-range faulting later created the mountain and valley blocks both within and west of the klippe. Post-basin-and-range faulting that affected the Pliocene volcanic rocks was minor, and offsets commonly are less than 100 feet.

The thrust faults in the area of this report are all thought to be related to an intermittently continuing episode of gravity sliding that produced a large-displacement slide plate that covered parts of several States. Evidence for this thrust plate is best known from other areas (Trimble and Carr, 1976). The klippe of this great thrust plate that contains that pre-Tertiary rocks of the Pocatello area is bounded by a thrust fault in the Deep Creek Mountains to the southwest (Trimble and Carr, 1976), by the Putnam thrust of Mansfield (1920) to the northeast, by the Paris thrust fault to the east (the westernmost thrust fault of the Bannock thrust zone of Armstrong and Cressman, 1963), and by the Willard thrust far to the south, near Ogden, Utah (fig. 14). The thrust faults within the area seem to delineate three main imbricate thrust plates within this large-scale klippe (fig. 15, thrust plates I, II, and III; pl. 1), cross sections *A-A′, B-B′, C-C′*.

Exposures of fault planes are few in this area, and a nearly flat thrust plane can be seen at only one locality. Therefore, the interpretation of many of the faults of this area as thrust faults is made on the basis of their position within a known larger thrust plate, the great amount of throw that would be required if they were interpreted as normal faults, the unlikelihood of pre-basin-and-range normal faults with 10,000-25,000 feet of displacement breaking the

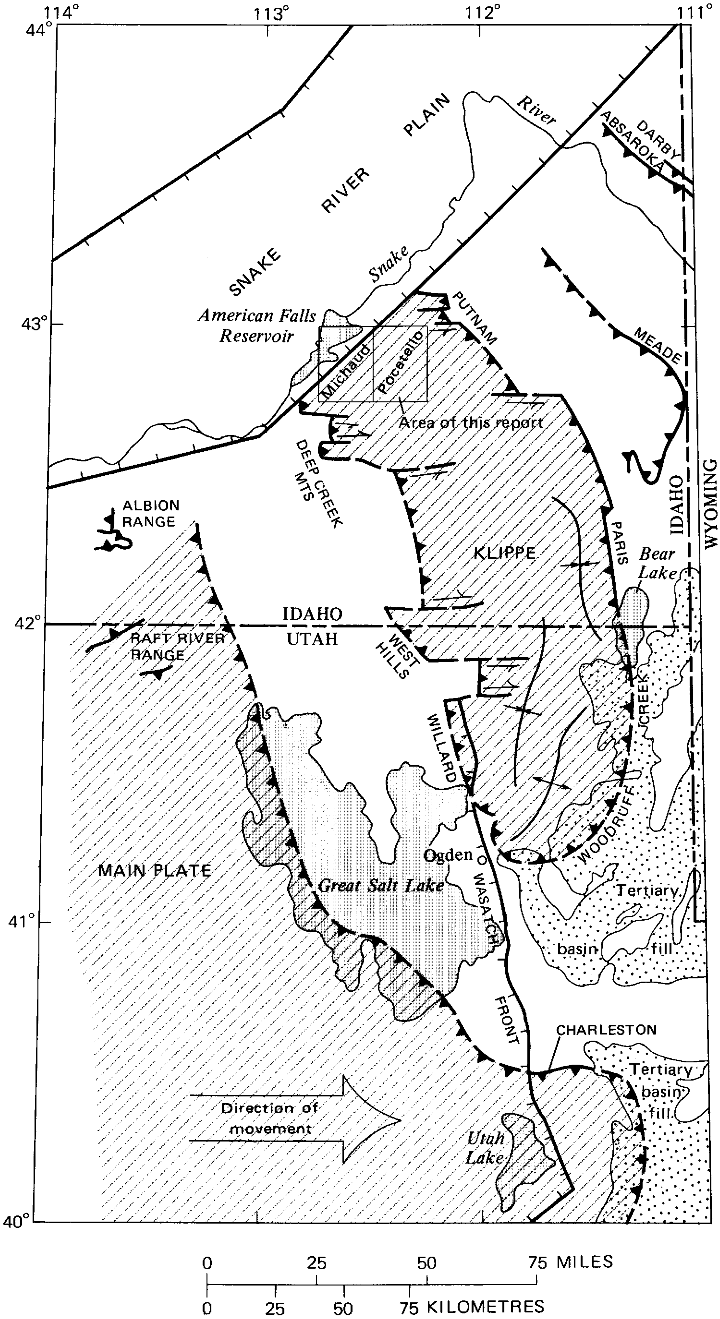

FIGURE 14.—Interpreted relationships of thrust faults in southeastern Idaho and northern Utah. Thrust faults are shown by sawteeth, which are on upper plate. Normal faults are shown by hachures, which are on downdropped side. Arrows show direction of movement along tear faults.

thrust plate, and the offsetting of truncation of some of these faults, such as the northeast-trending fault east of Gibson Mountain, by tear faults. In all the faults—except those bounding the two windows in the Scout Mountain Member of the Pocatello Formation—the upper plate is determined from a rule of thumb which states that the oldest rocks adjacent to the trace of a thrust fault that cuts homoclinally dipping beds are in the upper plate, where the direction of movement was in the direction of dip. Movement is believed to have been in the direction of dip in the Michaud and Pocatello quadrangles.

The area of the Bannock Volcanic and Scout Mountain Members of the Pocatello Formation north of West Fork Rapid Creek is entirely bounded by faults that seem to dip away from these older rocks and everywhere juxtapose them against younger rocks. This fault-bounded area of older rocks (fig. 15, thrust plate I) is most readily explained as a window in a thrust plate of younger rocks (fig. 15, thrust plate II). This plate (II) is bounded on the west by faults.

South of the fault juncture in the upper part of Blackrock Canyon, the upper member of the Pocatello Formation in thrust plate II is emplaced against the Scout Mountain Member along the entire length of a fault whose trace indicates that it dips eastward. In two places small masses of east-dipping Blackrock Canyon Limestone, probably horses, are exposed along the fault. This fault is interpreted to be the trace of the emerging sole of the plate of younger rocks (thrust plate II) to the east and, therefore, to be a thrust fault. A similar stratigraphic break across South Fork Pocatello Creek to the northwest suggests that the continuation of this fault is present there, but concealed. The area of the Bannock Volcanic and Scout Mountain Members of the Pocatello Formation that lies between Portneuf and South Fork Pocatello Creek is, then, part of thrust plate I.

South of Portneuf a fault noted by Weeks and Heikes (1908) in rocks of the Scout Mountain Member exposed in the tunnel of the Fort Hall mine was interpreted by them as a thrust fault. If that fault is projected upward to the west at an angle of 35°, it emerges at a thick silicified zone, about 100 feet wide, at an altitude of about 5,500 feet. Beds above this silicified zone are well exposed and can be correlated with strata in the mine tunnel described by Weeks and Heikes. This fault is thought to be the southward continuation of the emerging sole of thrust plate II. Imbricate faults break the plate to the east.

The trace of the emerging sole of thrust plate II north of Portneuf is interrupted north of the head of Blackrock Canyon by a fault-bounded area of rocks, younger than Blackrock Canyon Limestone, that is a klippe of a still younger thrust plate (fig. 15,

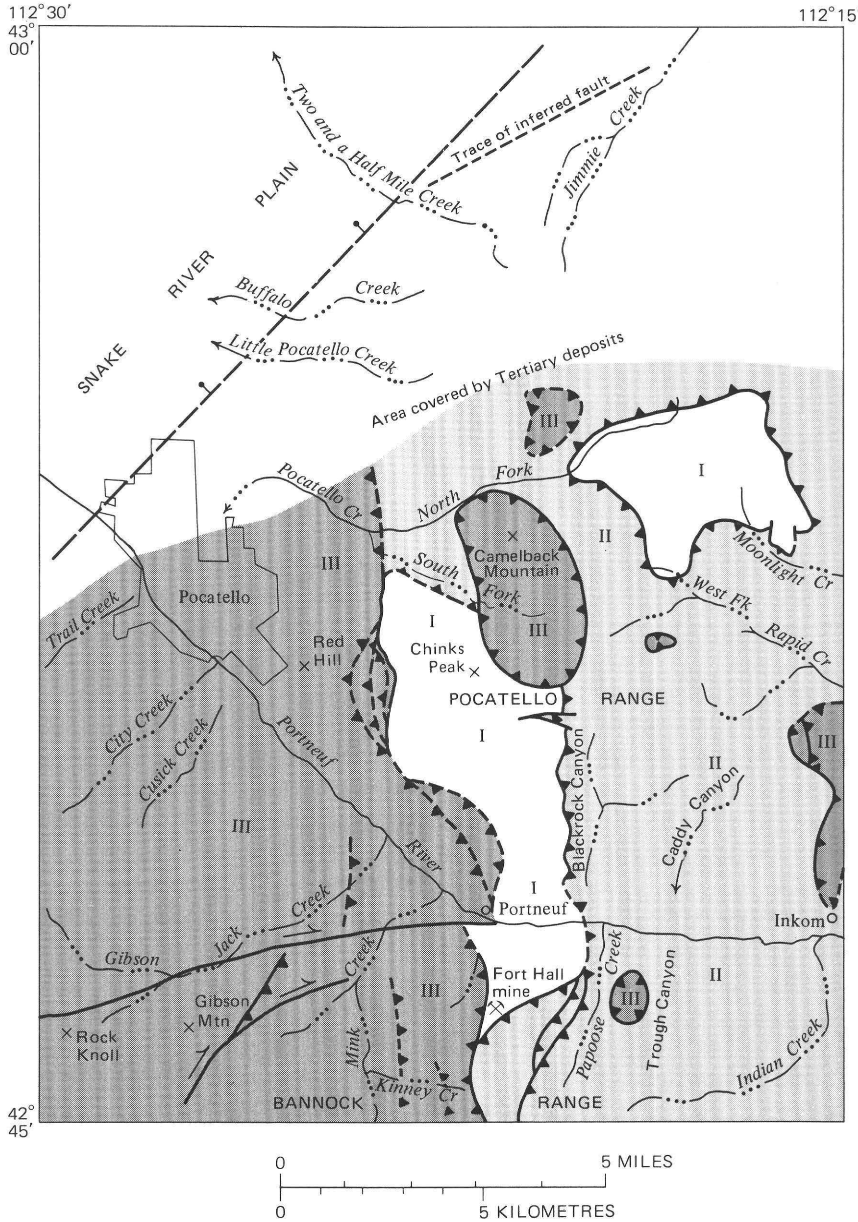

FIGURE 15.—Succession of thrust plates I, II, and III in the Pocatello quadrangle. Sawteeth on upper plates. Arrows indicate direction of movement along tear faults. Bar and ball on downdropped side of normal fault. Faults dashed where inferred.

thrust plate III). This klippe extends northward to North Fork Pocatello Creek. The rocks within the klippe are much broken by normal faults probably related to the thrusting. About 1 mile to the east is a small area of Mutual Formation in fault contact with older rocks, and Mutual Formation also caps a divide between Papoose Creek and Trough Canyon, south of the Portneuf River, where it rests in fault contact on Caddy Canyon Quartzite. These two localities are interpreted as small klippen of the younger plate (thrust plate III). The area of Cambrian rocks represented by the few exposures north of the North Fork Pocatello Creek and the area north of Inkom that includes the Precambrian Caddy Canyon Quartzite in its southern part and the Mutual Formation and Camelback Mountain Quartzite in its northern part probably are also klippen of this younger plate. Cambrian limestone adjoining Mutual Formation north of Inkom probably is in an imbricate sliver.

A thrust fault along the west base of the ridge east of the Fort Hall mine was postulated by previous investigators (Weeks and Heikes, 1908; Anderson, 1928; Ludlum, 1943, structure section E-E′). This fault, together with its extension north of Portneuf, is also interpreted here as a thrust fault that marks the eastern boundary of the thrust plate (III) of which the above-described klippen are a part. The trace of the fault west of Chinks Peak that emplaces Mutual Formation on the west against the Bannock Volcanic Member of the Pocatello Formation on the east indicates that this is a west-dipping fault. Because this trace probably is the northward continuation of the same fault that emplaces Mutual against Pocatello Formation south of the Portneuf River, the fault surface south of the river probably also dips west. Blackrock Canyon Limestone which lies against rocks of the Scout Mountain Member of the Pocatello Formation west of the ridge north of Portneuf probably is in an imbricate thrust sliver along this fault. Limestone is also present in several other slices between Red Hill and the west base of Chinks Peak.

For a mile or more along lower Trough Canyon, quartzite of the Caddy Canyon Quartzite is strongly brecciated on both sides of the canyon throughout a vertical span of about 250 feet (pl. 1, section *C-C′*). This brecciation seems to parallel bedding planes and regional dip, but the rocks are completely brecciated, except for many horses of quartzite. This brecciation may have been produced by local bedding-plane adjustments of relatively minor displacement, or it may be a bedding-plane thrust of unknown but probably small displacement because it is confined to the Caddy Canyon Quartzite of the middle thrust plate (II). Whatever its cause, the brecciation reflects lateral stress and probably is related to the episode of thrust faulting.

Other thrust faults have not been recognized in this area, although there are some only a short distance south of the Pocatello quadrangle (F. E. Schaeffer, written commun., 1964). Brecciated Mutual Formation in small exposures north and south of Kinney Creek in the central part of sec. 4, T. 8 S., R. 35 E., and the proximity of a small exposure of Mutual Formation to outcrops of Bloomington Formation north of Kinney Creek indicate fault relationships. That these are subsidiary thrust faults can be inferred from their probable northward trends and from the unrealistic amount of stratigraphic throw required if they were to be interpreted as normal faults.

An early episode of normal faulting appears to be related to, and penecontemporaneous with, the thrust faulting. The rocks of the klippe between Blackrock Canyon and North Fork Pocatello Creek are broken by normal faults entirely within the klippe. Most of the other normal faults that break the pre-Tertiary rocks are thought to be of this early generation of normal faulting; however, all may not be of exactly the same age. Some other faults, mostly east-northeast trending, would appear to have displacements on the order of several thousand feet, if they are interpreted as normal faults. Such large displacements on normal faults, which break up the rocks of a thrust plate, are unlikely; therefore, these faults of large apparent displacement may more properly be interpreted as tear faults. The fault extending from the north side of Rock Knoll eastward along Gibson Jack Creek, for example, has an apparent stratigraphic displacement of more than 5,000 feet. Although, locally, the fault trace suggests that the plane of this fault dips steeply to the south, its linearity and very large apparent stratigraphic displacement more strongly suggest a tear fault than a normal fault. The linear fault zone of large apparent stratigraphic displacement east of Gibson Mountain is interpreted as the trailing edge of a subsidiary thrust slice offset by a tear fault.

The stratigraphic omission of Upper Mississippian rocks in the northern part of the Pocatello quadrangle indicates a fault that separates Pennsylvanian rocks of the Wells Formation from Mississippian and older rocks north of Two and a Half Mile Creek. The trace of this fault is inferred from the coincidence of the southern limit of exposure of the Wells Formation with a line of eruptive centers of mafic igneous rocks. This inferred trace also marks the southern limit of the main body of rhyolite, which extends northward beyond the quadrangle boundary. Basalt, probably related to the eruptive centers, is mostly south of the fault line. The inferred coincidence of the eruptive centers with the fault trace suggests that this is a high-angle, rather than a low-angle, fault. It could be a normal fault that offsets the sole thrust of the large-scale klippe near its margin, or, because of its inferred linearity, it could be a tear fault that offsets the margin of the large-scale klippe. Interpreted either way, this fault probably represents a segment of the boundary of the large-scale klippe, even though it is not a thrust fault.

The mountain block made up of the Bannock and Pocatello Ranges and the intermontane valleys flanking it were formed by basin-and-range faulting. A frontal breccia, silicified in places, is exposed at several localities along the west foot of the Bannock Range. These localities include breccia zones north and south of Birch Creek in sec. 36, T. 7 S., R. 33 E., a silicified zone in NE¼NE¼ sec. 13, T. 7 S., R. 33 E., and a brecciated quartzite east of Michaud Creek in SE¼NE¼ sec. 12, T. 7 S., R. 33 E. The amount of displacement on the basin-and-range faults is large but is not accurately known. The mountain block that forms the Bannock Range apparently was not tilted, because Big Flat (in the Pocatello quadrangle), which must be a remnant of a pre-basin-and-range erosional surface, has not been tilted. A few other remnants of this surface, which truncates east-dipping quartzite and is nearly level, are preserved on the ridge crest to the southwest.

The major basin-and-range faulting occurred before the outpouring of the middle Pliocene silicic volcanic rocks that partly fill the intermontane valleys, but the faulting cannot be more accurately dated at this time.

Several lines of evidence suggest that the eastern Snake River Plain is a large graben (Carr and Trimble, 1963, p. G37; Trimble and Carr, 1976). The mountain ranges both north and south of the plain probably were truncated by faults that bound the plain. If this structural interpretation is correct, then the Snake River Plain was formed by normal faulting after the basin-and-range mountain blocks were formed but probably still during the major episode of basin-and-range faulting. This faulting, too, predates the eruption of the middle Pliocene volcanic rocks, but its age is not accurately known. According to Malde (1959), the period of subsidence of the western Snake River Plain probably was in early or middle Pliocene time. Coats (in U.S. Geological Survey, 1964, p. A109), however, has suggested that the Snake River Plain may have been outlined by faulting as early as Miocene.

The Tertiary rocks have been warped and faulted, but the faults are offset much less than those that displace the older rocks. Maximum displacement probably is less than 200 feet. The Tertiary rocks in general dip toward the Snake River Plain, but warping of the rocks, illustrated by structure contours (fig. 16) on the tuff of Arbon Valley, greatly complicates the regional structure. The present surface in the southern part of the Michaud quadrangle conforms in a general way to the structure of the underlying rocks. The high area in the southwestern part of the quadrangle is a structural high, and Bannock Creek follows the axis of a synclinal valley. These structures in the tuff of Arbon Valley may be in part initial, but (despite apparent large-scale disconformity within parts of the Starlight Formation) the general parallelism of rhyolitic tuff beds both above and below the tuff of Arbon Valley and of the porphyritic trachyandesite above the tuff of Arbon Valley on the hill west of Pocatello suggests that most of this warping is tectonic and post-middle Pliocene. The warping may be largely the result of renewed subsidence of the structural valleys formed during basin-and-range faulting and of renewed subsidence of the Snake River Plain, owing perhaps to the removal of quantities of material at depth by volcanic eruptions.

The Quaternary deposits of the area, nearly all unconsolidated or poorly consolidated, are undeformed.

GEOLOGIC HISTORY

During latest Precambrian, the study area was shallowly submerged near the axis of an elongate depositional basin, which extended far to the south and probably a short distance to the north of the present Snake River Plain. This basin may have been separated from a contemporary basin far to the north (the Windermere sea) by an intervening area of exposed older Precambrian rocks of the Belt Supergroup, or, more probably, the eastern shoreline between the two areas may simply have swung westward. This shoreline, which extended southward for several hundred miles, in northern Utah was west of, but probably near, the front of the present Wasatch Range. This basin persisted into and through the Paleozoic.

The record of history in this area opens with the deposition of clay and silty clay in thin parallel layers (lower member of the Pocatello Formation) in the quiet water at the floor of a sea of some depth. The gradual filling of this sea by 1,000 feet or more of these sediments brought about a shallow-water environment in which limy sediment accumulated to a depth of 100 feet before shelf ice from the east extended across this shallow sea. Sandy and bouldery debris from the floating ice accumulated in great thicknesses (Scout Mountain Member of the Pocatello Formation). As the front of the ice shelf migrated backward and forward, some of this debris remained

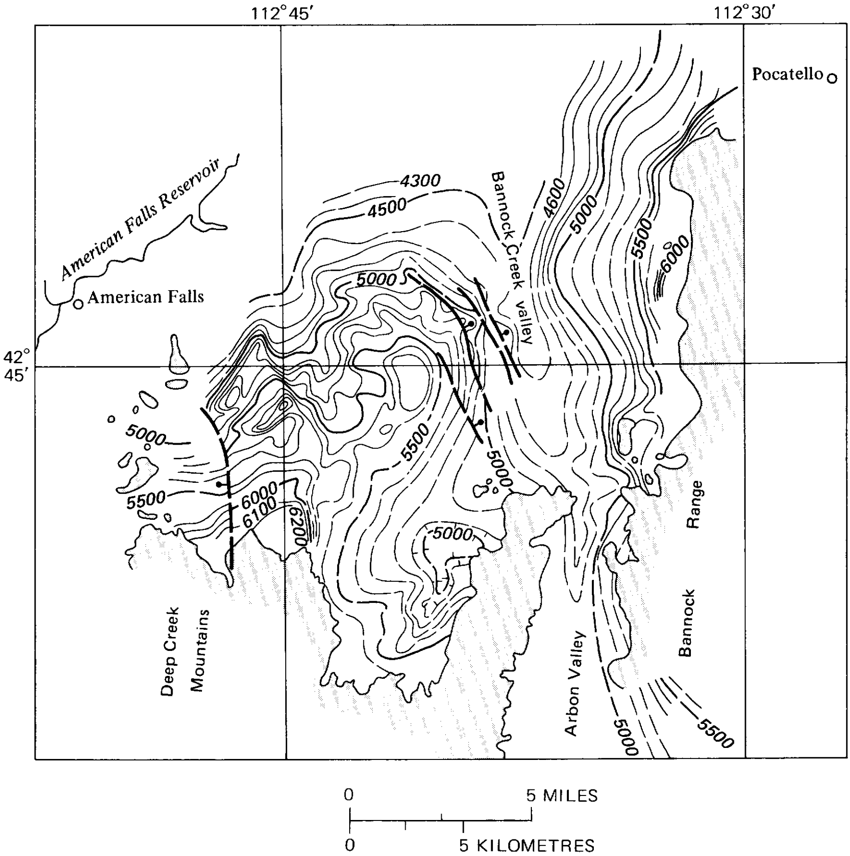

FIGURE 16.—Structure contours on the tuff of Arbon Valley (part of the middle member of the Starlight Formation). Shadded areas are pre-Tertiary rocks. Normal faults shown by heavy lines, dashed where inferred; bar and ball on downthrown side. Contour interval 100 feet; contours dashed in areas of extremely limited control or no control.

essentially unsorted and nonstratified as it fell to the sea floor, but some was reworked seaward as stratified layers of sand. Locally, submarine volcanoes erupted basaltic lavas onto this sea floor. As the ice shelf withdrew, hundreds of feet of mud and sand (upper member of the Pocatello Formation) were deposited, along with some limy layers in the upper few hundred feet (Blackrock Canyon Limestone).

The seas then became still shallower, and fine sands were deposited into shallow water that perhaps was nearly tidal (Papoose Creek Formation). The gradually subsiding basin continued to be covered by only very shallow water, for the several thousand feet of succeeding deposits were dominantly stratified sand (Caddy Canyon Quartzite). Some limy layers were deposited in the middle of this sequence of sand. The sea then became deeper because of an increased rate of subsidence, and about 2,000 feet of mud and sandy mud (Inkom Formation) was deposited. Following this episode of deposition the sea withdrew to the west, and the Precambrian ended with streams depositing very coarse sand containing some pebbles and minor gravel (Mutual Formation). The climate was arid in this region at the end of the Precambrian time, and oxidation of iron imparted a red or purple color to the rocks.

At the beginning of the Cambrian, deposition of sand continued, but these sands of Early Cambrian age probably were deposited in shallow water nearshore, rather than subaerially. The shoreline of this very shallow sea was remarkably migratory, and these nearshore or beach deposits were spread widely. The basin then was deepened somewhat, and trilobites crawled on the muds and sands being deposited on the floor of a sea that contained *Protospongia.* The basin was further deepened, and limestone began forming on the sea floor in this area and continued to form throughout most of Cambrian time.

Although there were subsequent variations in depth of the sea in Late Cambrian time, which resulted in the deposition of great quantities of sand (Worm Creek Quartzite Member of the St. Charles Limestone), deposition was nearly uninterrupted throughout the rest of the Cambrian time, and, indeed, throughout all of Paleozoic and into Mesozoic time. Orogeny that disturbed the Cordilleran geosyncline in areas to the west apparently did not affect this area. There were shifts in the position of the shoreline at the margins of the basins and fluctuations in the depth of water. However, this area was nearly continuously submerged throughout all of Paleozoic and much of Mesozoic time and was near the center of the basin of deposition for all of Paleozoic time, at least. The record of Mesozoic deposition is not preserved in this area but is present only a short distance to the northeast (Mansfield, 1920, 1952).

At the end of the Mesozoic, probably before the miogeosyncline was destroyed, a large mass of sediment detached itself from the west side of the miogeosyncline and slid eastward, probably motivated by gravity. Some beds within the slide plate were gently folded, some imbricately broken by small-displacement thrust faults, and some subsequently broken by normal faults as a result of relaxation of stress within the plate after sliding ceased. The late Mesozoic age for this gravitational sliding is inferred from probable relations to thrust faults dated in another area (Paris thrust, Armstrong and Cressman, 1963).

After regional uplift and destruction of the miogeosyncline, an early Tertiary erosion surface was developed. Although no remnant remains in this area, the erosion surface probably is represented by peaks, 8,700-9,000 feet in altitude, in the Portneuf Range, a few miles to the east. The land surface then was lowered 1,500-2,000 feet by erosion, leaving only some high points. Perhaps during the Miocene an erosional surface was formed, of which Big Flat, in the Pocatello quadrangle, and some of the broad ridge crests in secs. 19, 20, 29, and 30, T. 7 S., R. 34 E., are remnants.

This erosional surface was broken by basin-and-range faulting, probably in late Miocene or early Pliocene time. The north-trending structural valleys and the mountain blocks so formed were then truncated by the subsidence of the Snake River Plain graben some time before middle Pliocene time.

The major drainage pattern was outlined by structural valleys and by headward erosion of tributaries. Portneuf valley between Inkom and Portneuf developed along faults as a tributary to the Marsh Creek-Ross Fork valley, the major valley to the east. The valley segment between Portneuf and Pocatello developed as a tributary to the ancestral Snake River. These valley segments were separated by a drainage divide at Portneuf.

Volcanism, perhaps related to the subsidence of the Snake River Plain, then began. Huge volumes of silicic air-fall tuffs and ash flows erupted onto the Snake River Plain and marginal areas, and basaltic rocks were erupted from some local centers and became interstratified with the silicic rocks. The tremendous accumulation of silicic air-fall tuffs interrupted the drainage, forming lakes in which some of the air-fall tuff was deposited. A series of increasingly quartz-rich ash flows, erupted in the middle of this volcanic episode, was very widespread and generally cooled together to form a blanket of distinctive vitric-crystal tuff. Locally, hotter ash-flow deposits cooled to glassy rocks. Silicic air-fall tuffs again were deposited and transgressed drainage divides, such as the one at Portneuf. The last phase of the silicic eruptions was less violent, and porphyritic trachyandesite was erupted onto the tuffs west of Pocatello.

Subsequently, the Tertiary volcanic rocks were warped perhaps in part because of the renewed subsidence of the basin-and-range valleys and in part because of the renewed subsidence of the Snake River Plain. Minor local faulting accompanied this warping.

Drainage was reestablished and was superposed on the surface of the great thickness of accumulated volcanic rocks. Many new stream courses were established in the region as a result of this superposition, and in this area the Portneuf River established its course across the former drainage divide at Portneuf and cut its way down through the Precambrian rocks that formed the divide.

Stream and tributary valleys were cut down almost to present levels when volcanic eruptions were renewed locally, probably in late Pliocene or in early Pleistocene. Basalt and porphyritic andesite were erupted from a series of vents localized along a fault in the northern part of the Pocatello quadrangle and, for the most part, flowed southward across an erosional surface cut on the silicic tuffs. Rhyolite was erupted north of the fault and flowed westward and northward for a short distance. Rhyolite also was erupted from a vent source south of the southwest corner of the Pocatello quadrangle and flowed northeastward and into the valley of the West Fork Mink Creek, part of which is in the Pocatello quadrangle.

The Pleistocene was a time of basaltic eruptions on the Snake River Plain. Successive eruptions produced a locally thick pile of basalt flows that nearly covered the great structural depression. These basaltic eruptions probably were intermittent and came from many source vents, such as the many shield-volcano vents that dot the basaltic plain. The intermittent eruptions repeatedly diverted streams or dammed them to form lakes.

In middle to late Pleistocene time the ancestral Snake River probably flowed near the north edge of the plain. Tributaries, such as the Raft River, Rock Creek, and Bannock Creek, flowed northward, graded toward the Snake River. A rise in local base level (probably the result of basaltic eruption onto the plain and the southward shift of the master stream) caused aggradation by tributary streams, and fine sediments of the Raft Formation were deposited to altitudes of as much as 4,650 feet and covered a large area which probably included much of the Michaud quadrangle and some adjoining parts of the Pocatello quadrangle, although the sediments are not exposed there.

The temporary base level that forced the deposition of the Raft Formation apparently determined levels of erosion and deposition in this area for a considerable period of time. Pediments were cut mainly on the Pliocene volcanic rocks adjacent to the mountain fronts and were graded to a level higher than the present one. The pediment surfaces subsequently were extensively mantled with rubble and gravel shed off the adjacent mountains. Some major valleys, like that of the Portneuf River, were alluviated, and large alluvial fans were formed by some tributaries.

As base level was lowered, the Pleistocene Snake River cut a broad shallow valley into the surface of the Raft Formation. Basalt flows displaced the river to the south and covered much of the Raft Formation, but large areas remained exposed to the prevailing winds, which whipped out great quantities of silt and redeposited it as a thick blanket of loess over much of the region.

In late Pleistocene time the streams entrenched the loess-covered pediment surfaces and the alluvial deposits of the major valleys.

Another eruption of basalt from vents north of the Snake River and west of the Rockland quadrangle (Trimble and Carr, 1976) again dammed the broad valley of the Snake River and formed a lake (the American Falls Lake) that had a maximum pool level of about 4,450 feet. The waters of this lake cut scarps on the loess deposits at the margins of the lake. About 80 feet of lake beds was deposited into the lake, and sandy deltas formed in the lake at the mouths of tributary streams. A period of volcanic activity that could have supplied greatly increased amounts of silica to the lake perhaps is recorded by the abundance of diatoms in one persistent layer near the top of the sequence of lake sediments. More than 42,000 years ago the junction of the Portneuf River with this late Pleistocene lake was a swampy area where mastodons foundered.

Eruptions of basalt continued intermittently in this region in great lava fields to the east, as well as in the Snake River Plain to the west. Sometime between 30,000 and 35,000 years ago, two tongues of basalt from the east flowed down the Portneuf valley to the vicinity of Pocatello, over a valley floor that, near Pocatello, was at about its present level.

The Pleistocene American Falls Lake was still at or near its maximum level when, about 30,000 years ago, pluvial Lake Bonneville spilled across a drainage divide at Red Rock Pass into the valley of Marsh Creek, a tributary to the Portneuf River. The summit of the divide was rapidly lowered by flushing away several tens of feet of colluvium and alluvium, which produced a flood of catastrophic proportions that lasted until the level of Lake Bonneville was lowered to a bedrock lip and the outflow was retarded (Malde, 1968). The floodwaters passed over the basalt in Portneuf valley, scoured its surface, and plucked great columnar blocks from its southern margins. These blocks were abraded and piled in heaps to form huge boulder bars.

Upon emerging onto the Snake River Plain, the floodwaters engulfed the American Falls Lake and deposited a great deltaic-fan deposit, the Michaud Gravel. The increased cutting of the basaltic dam to the west by the floodwater rapidly lowered the base level, the initial flood deposits were dissected, and subsequent valley levels were formed. The first stable level of dissection (the Aberdeen terrace level) was cut 29,700 ± 1,000 years ago, probably while the abated flood was still of considerable proportions. A still lower level (the Sterling terrace level) was cut later in Pinedale time.

Subsequent dissection of the floor of the Snake River valley has left remnants of these levels, as terraces, along the valley. Although

Lake Bonneville undoubtedly spilled once more across the bedrock lip at Red Rock Pass 18,000-20,000 years ago, this outflow was not of catastrophic proportions. It enlarged the streamflow in the downstream areas for probably thousands of years but not sufficiently to leave a recognizable record of its effects.

Since the catastrophic flooding produced by the first spillover of the waters of Lake Bonneville, the only major geologic effects in the area are as follows: The continued downcutting of the Snake River valley, probably at an increased rate during the second spillover of Lake Bonneville; the deposition locally of sand dunes and thin loess deposits; the deposition of alluvium on the valley floors; and the deposition of alluvial fans at the mouths of tributary canyons.

ECONOMIC RESOURCES

Sand and gravel, crushed rock, silica (quartzite), limestone for cement, and ground water are the only earth materials of present economic importance in the study area; eventually, uses may be found for the abundant pumiceous silicic tuff and diatomaceous clay. Mining and prospecting once were major activities in the region, as is attested by many abandoned prospect pits, as well as the old mines of the Moonlight Creek area and the intermittently active Fort Hall mine. There has been no production from these mines, however, since the early part of the century, when small amounts of copper and gold were produced.

SAND AND GRAVEL

Sand and gravel has been obtained from several Cenozoic units, including the Michaud Gravel, gravel of the Aberdeen terrace deposits, both Holocene and older alluvial gravel of the Portneuf River, Pleistocene pediment and fanglomerate deposits, and Tertiary conglomerate. All these gravel deposits are composed of a mixture of lithologic constituents, including quartzite, limestone, and basalt, and all are essentially unweathered and sound. There is great variation in size and cementation of the materials, however, and in degree of sorting. The alluvial gravels of the Portneuf River and the gravel of the Aberdeen terrace probably are the most desirable sources, for they are both unconsolidated and well sorted. The Michaud Gravel, east of Michaud Creek, is unconsolidated but contains abundant large boulders and is poorly sorted. The older Pleistocene deposits and the Tertiary deposits commonly are stained and moderately cemented, but they have been used as highway aggregate and road metal.

CRUSHED ROCK

Crushed rock has been utilized in only a few places in this area because of the general availability of gravel, but some small quarries, which are now abandoned, were developed near Pocatello in the basalt of Portneuf valley, and a quarry was developed near Inkom in the Camelback Mountain Quartzite, from which large quantities of crushed rock were taken.

SILICA (QUARTZITE)

Quartzite of the lower part of the Precambrian Caddy Canyon Quartzite is quarried southwest of Pocatello for use as flux in the electrometallurgical extraction of elemental phosphorus at the Pocatello plant of the Food Machinery and Chemical Corp. This quarry, operated by Wells Cargo, Inc., is in the SW¼ sec. 6, T. 7 S., R. 34 E. This locality has the advantage of proximity to the industrial plant; however, other quartzites in the area that are not so close probably are equally suitable chemically for use.

CEMENT

Cement is produced at the only cement plant in Idaho, at Inkom. Both plant and limestone quarry are astride the eastern boundary of the Pocatello quadrangle, south of Inkom, although most of the quarry operations to date (1976) have been just east of the quadrangle. The limestone of the quarry is impure, has many shale splits, and probably is part of the Middle Cambrian Elkhead Limestone. A fault at the east side of the quarry has been dolomitized, and the rock there is avoided, but—with this exception—almost all the rock in the hill is utilized.

The plant, operated by the Idaho Portland Cement Co., has a reported capacity of 949,000 barrels a year, but operates at about 83 percent of capacity, producing about 788,000 barrels of cement a year, for which it uses 178,000 short tons of limestone (Savage, 1964, p. 116).

PUMICITE AND TUFF

Tuffaceous and pumiceous parts of the Starlight Formation may be suitable for use as abrasives or in the production of cinder bricks. Some very pure silicic tuff occurs in both the upper and the lower members of the Starlight, but it has not been exploited in this area.

DIATOMACEOUS CLAY

The diatomaceous clay layer in the upper part of the American Falls Lake Beds averages about 6 feet thick and underlies many square miles around American Falls Reservoir. It contains an estimated 70 percent of diatoms. In one sample tested, 55 percent of the material was clay size, and 41 percent, silt size. Only 4 percent of the sample was coarser than 0.062 mm. Ultrasonically segregated slime from this sample was found, by X-ray methods, to contain montmorillonite as a major constituent, quartz as a minor constituent, and traces of mica, kaolinite, and calcite.

METALLIFEROUS DEPOSITS

In 1902 the Fort Hall mining district was established on land ceded from the Fort Hall Indian Reservation. The following appraisal of the metalliferous mineral deposits of the area is quoted from Weeks and Heikes (1908, p. 179-182), who visited the area in 1905:

> Prospecting work has been done at several points since this portion of the Fort Hall Reservation was thrown open to the public, but the most important mining operations have been carried on by the Pocatello Copper and Gold Mining Company, owning the Moonlight group of claims in the northern part of the district, and the Fort Hall Mining Company in the southern part * * *. The valuable metals of the ores are copper, silver, and gold. The occurrence of lead is limited to small quartz veins in the limestone, and a little of this metal is also associated with the copper minerals in the Fort Hall prospects. * * *.
>
> The Moonlight property is located at the head of Rabbit [Rapid] Creek, about 9 miles east of Pocatello, and has been worked steadily since the opening of the reservation in 1902. * * *. During 1904 two carloads of copper ore of a good grade were shipped to the smelters. The development consists of a crosscut tunnel 830 feet long driven westward, at the end of which is an upraise opened for 90 feet for the purpose of connecting with known ore bodies. This part of the work was abandoned, however, and attention was given to taking out the ore near the surface. Two tunnels have been driven near the top of the hill, 275 feet and 75 feet long. The ore deposits occur in the conglomerate as opened in the workings near the top of the hill. The minerals, bornite and copper glance, associated with some carbonate copper near the surface, are found in small kidneys and in fractures or fissures in the conglomerate.
>
> The Fort Hall Mining Company owns property located about 1½ miles west of Portneuf siding * * *. The development consists of a crosscut tunnel driven for 3,890 feet to the east. * * *.
>
> Adjoining the Fort Hall property are claims owned by the Papoose Mining Company. The development consists of a 400-foot tunnel driven * * * toward the west.
>
> In the southern part of the district, in the Fort Hall and adjacent mines, the most abundant mineral is chalcopyrite, occurring as veinlets in the sharply compressed folds. There is also some pyrite. A small amount of galena is reported in the limestone strata. The company reported that a general sample from the ore zone 125 feet in width along the tunnel level was tested to determine the proper methods of milling the product. A ratio of concentration of 11.05 tons of crude ore to 1 of concentrates gave the following results: copper, 12.3 percent; gold, 0.13 ounce per ton; silver, 4.30 ounces per ton; iron, 26.4 percent; silica, 16.1 percent; and lead, 0.8 percent.

Weeks and Heikes' appraisal of the potential of the district was not optimistic, and they concluded (1908, p. 182) that "From present

[1905] knowledge it is doubtful whether the ore bodies shown are of sufficient value to warrant the expenditure of the large amount of capital required for their extraction and reduction."

Although economics and technology have changed greatly in the ensuing 70 years, the record of the district indicates that the early appraisal of Weeks and Heikes was fully justified, and, although there has been subsequent work done at the Fort Hall mine, there seems to be no reason to change their early appraisal. Examination of scores of small prospect pits in the area has shown that a great amount of effort has been expended for no financial return.

GROUND WATER

Ground water is one of the most important economic resources of the study area, but the ground-water characteristics of the area are imperfectly known. The water table in the area was delineated by contours by Stearns, Crandall, and Steward (1938, pl. 19) and more recently by Kilburn (West and Kilburn, 1963, pl. 1). According to West and Kilburn (1963, p. D11), "The well sorted alluvial sand and gravel beneath the Gibson terrace and Michaud Flats is a highly productive aquifer and probably is the best source of ground water for irrigation in the Fort Hall Reservation." The name Gibson terrace to which they referred was applied by Mansfield (1920) to surfaces adjacent to the Snake River above the floodplain and below the benchlands and includes the surface of the Michaud Gravel, the Aberdeen terrace and equivalent channel levels, and the Sterling terrace. West and Kilburn (1963) also noted that the average depth to water in these areas is 48 feet.

Very productive wells have been drilled on the benchlands, too. These, however, probably obtain their water from Tertiary rocks of the Starlight Formation. Some of these wells, which are as much as 800 feet deep, produce as much as 3,000 gallons per minute (West and Kilburn, 1963, table 5). According to West and Kilburn (1963, p. D16), several of these wells tap artesian aquifers. Their report gives performance records of several large-capacity wells in the area :1963, table 6).

In the lower valley of the Portneuf River, beyond the margins of the benchlands, and in the Fort Hall Bottoms northwest of the mouth of Ross Fork, several streams of considerable size originate in springs on the alluvial flood plain and flow into the Portneuf River, into Ross Fork, or directly into American Falls Reservoir. The streams northwest of the mouth of Ross Fork are Spring Creek and Clear Creek. Tributary to the Portneuf River are several springs with an aggregate flow of about 185 cubic feet per second, or more than 100,000 acre-feet per year (West and Kilburn, 1963, table 8, p.

D24). West and Kilburn (p. D24) estimated the total discharge from springs in Fort Hall Bottoms to be at least 1,000 cubic feet per second and suggested that it may be as much as 1,500 cubic feet per second.

In 1914 W. B. Heroy (Mansfield, 1920, p. 137) did some of the earliest ground-water studies in this area. He called these springs the most remarkable ground-water feature in the region and concluded that a deep underground source of the spring water seemed most reasonable. Stearns, Crandall, and Steward (1938, p. 142), however, concluded that most of the supply of water for the springs comes from the underflow of the Snake River, probably augmented by underflow of the Portneuf river. This view is also held by West and Kilburn (1963, p. D23), who believed that the water percolating downward from the Snake and Blackfoot Rivers (both of which are above the water table in the vicinity of Blackfoot) moves southwest to join the ground water percolating into the area from the south and discharges as springs on the Fort Hall Bottoms.

The city of Pocatello draws its water from wells in the Portneuf valley. Stearns, Crandall, and Steward (1938, p. 223) reported that 49,500 acre-feet of water per year passes under Pocatello as underflow and (p. 226) that, apparently, Pocatello is assured of an ample water supply from underground sources.

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