Geology of the American Falls Quadrangle Idaho

GEOLOGICAL SURVEY BULLETIN 1121-G

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By WILFRED J. CARR *and* DONALD E. TRIMBLE

CONTRIBUTIONS TO GENERAL GEOLOGY

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Geomorphic features and the rocks of this area reveal a history of volcanic eruptions, damming of the Snake River, and flooding by overflow waters from glacial Lake Bonneville

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GEOLOGY OF THE AMERICAN FALLS QUADRANGLE, IDAHO

By Wilfred J. Carr and Donald E. Trimble

ABSTRACT

The American Falls quadrangle, 25 miles west of Pocatello, Idaho, on the southern edge of the Snake River Plain, contains exposures of marine sedimentary rocks of Paleozoic age, rhyolitic and basaltic volcanic rocks of Tertiary age, and basaltic flows, lake beds, loess, and alluvium of Quaternary age. Deposits of Pleistocene age cover most of the quadrangle.

Rocks of Paleozoic age consist of the Laketown dolomite of Silurian age, the Jefferson(?) dolomite of Devonian age, and the Madison(?) limestone of Mississippian age.

Three units, Starlight formation, Neeley formation, and Walcott tuff, all of Pliocene age, make up the Tertiary rocks of the area. The Starlight, a new formation used in part for rocks previously mapped as Salt Lake formation, is mainly rhyolitic friable bedded tuff, subordinate amounts of marl, sandstone, and conglomerate, and, locally, much basalt and basaltic tuff. In places the Starlight can be divided into three members by means of a middle unit, which is a vitric-crystal tuff, widely, but not continuously distributed, in this part of southeastern Idaho. The Starlight is unconformably overlain by the Neeley formation, a massive poorly bedded impure rhyolitic tuff. Conformably above the Neeley is the Walcott tuff—a bedded tuff and an overlying obsidian welded tuff that are widespread in the region. The Walcott is at most only 35 feet thick in this quadrangle; the welded part averages about 10 feet thick. Hand specimens of the central part of the welded tuff are identical to obsidian. Mollusks from the Starlight and Neeley are similar to those of the middle Pliocene Teewinot formation of Jackson Hole, Wyo.; to middle Pliocene mollusks from the Salt Lake formation in the Goose Creek area, Cassia County, Idaho and Elko County, Nev.; and to mollusks dated by associated mammals as middle Pliocene from the Banbury formation in Gooding County, Idaho.

The Little Creek formation of Pleistocene(?) age overlies the Walcott tuff and is composed of two members: a lower tuff unit that contains a mixture of basaltic and rhyolitic pyroclastic debris, and an upper basalt unit. Part of this formation is equivalent to rocks previously mapped as Massacre volcanics.

The stratigraphy of late Quaternary deposits of this part of the Snake River valley can be closely related to the geologic history and geomorphology of the area. After deposition of the lacustrine and fluvial Raft formation, the Big

Hole basalt erupted from several vents on the Snake River Plain and flowed southeastward across the Raft to the middle of a gentle ancestral Snake River valley. Locally thick loessial deposits were laid down on the Big Hole basalt and on the hills southeast of American Falls, where, at about the same time, the Sunbeam formation, a thick fine-grained alluvium, was deposited. Eruption of basalt from a center several miles downstream from American Falls then filled and dammed the Snake River valley for about 8 miles, creating a lake in which the American Falls lake beds were deposited. When this basin had become nearly filled with clay and silt, ancient Lake Bonneville spilled over at Red Rock Gap about 50 miles southeast of American Falls, and the ensuing large volume of water emerging from the Portneuf Valley at Pocatello deposited the Michaud gravel in the American Falls lake. The great volume of Lake Bonneville outflow spread over the top of basalt damming the American Falls lake and created large falls on the downstream side of the dam. Several channels were cut in the basalt and some were successively abandoned as the falls retreated upstream, until eventually the lava dam was breached. During the erosion of the lava dam, changes in base level caused several broad terraces to be cut upstream in the American Falls quadrangle by the American Falls lake and by fluvial processes. These terraces were thinly covered by alluvial materials. As the river cut down to its present channel, alluvial deposits, mainly gravels, were reworked downward nearly to the present stream level. In Recent time, sand dunes overspread a large area, extending into the southwest corner of the quadrangle, and minor amounts of alluvium were deposited along Snake River and its tributaries.

Structure of the rocks exposed in the quadrangle is relatively simple. The Paleozoic rocks are cut by a few faults and dip 35°–40° N. All the Tertiary rocks, the Little Creek formation, and probably the Raft formation dip northwest toward the Snake River, from 1° to as much as 35° in the Starlight formation. The Pleistocene American Falls lake beds and all younger formations are structurally undisturbed.

A series of northwestward-trending minor folds formed in the Tertiary rocks near American Falls. Faults of small and moderate displacement that cut the Tertiary rocks belong, in general, to two distinct sets. One set is believed to represent recurrent movement in some places on older Basin and Range faults that are not exposed in the quadrangle. The other fault set may be related to a major northeastward-trending structural break, which probably parallels the edge of the Snake River Plain.

Presently and potentially useful economic resources of the area include sand and gravel, crushed rock, ground water, pumice and tuff, and diatomaceous clay.

INTRODUCTION

The American Falls quadrangle in southeastern Idaho (fig. 1) is mostly within the Snake River Plain section of the Columbia Plateau physiographic province, but the boundary with the Great Basin province crosses the southeastern corner of the quadrangle. The Snake River, which flows southwest through the area, is dammed at American Falls, impounding a reservoir that covers about 15 percent of the quadrangle.

American Falls is about 25 miles west of Pocatello, the major commercial center for the region. This part of the Snake River valley is served by the Union Pacific Railroad, U.S. Highway 30 N., several

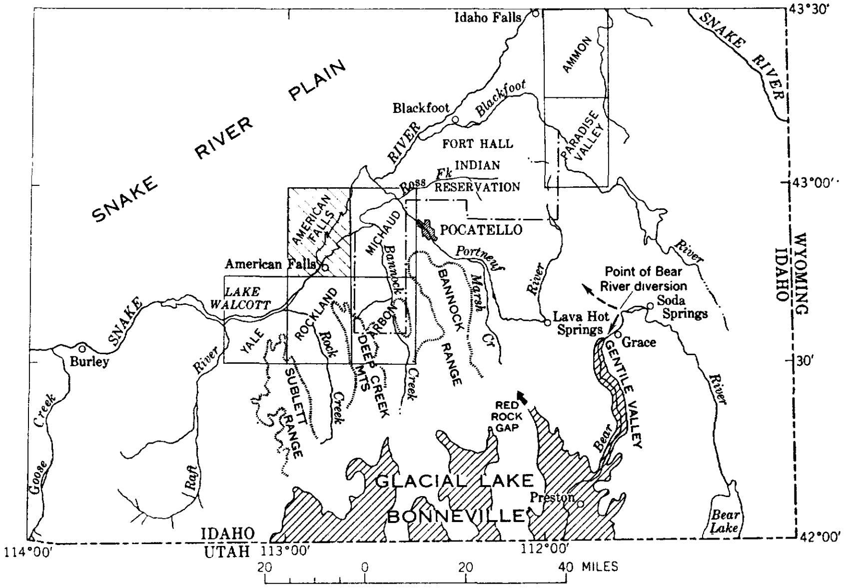

FIGURE 1.—Index map of southeastern Idaho showing the location of the American Falls quadrangle with reference to other quadrangles and to geographic features.

State highways, and many good secondary roads. Except for the northwest, southwest, and southeast corners, nearly all the land in the quadrangle is farmed.

The climate is semiarid, although rainfall is considerably less on the plains northwest of the Snake River than it is in the hills and mountains south of the river. At Aberdeen, out on the plains, the average annual precipitation is about 9 inches, whereas at American Falls, at the foot of the hills, it is about 13 inches. Mean annual temperature in the area is about 45 degrees.

The quadrangle was mapped in 1958. We are indebted to Roth Finlay, resident manager of the American Falls Dam, U.S. Bureau of Reclamation, for assistance and use of a boat in examining exposures along the shoreline of the reservoir. Logs of water wells and drill holes in this area were supplied by Elmer Isaac of the Aberdeen-Springfield Canal Company, and by Boyd Walter, resident engineer, Michaud Flats project, U.S. Bureau of Reclamation.

STRATIGRAPHY

Marine sedimentary rocks, mainly limestone and dolomite, of Paleozoic age, rhyolitic tuff, welded tuff, vitrophyre, basalt and basaltic tuffs of late Tertiary age, and lake beds, basalt, loess, and alluvium of Quaternary age are exposed in the quadrangle (pl. 1). Surficial deposits and basalt of Pleistocene age cover more than 90 percent of the area, and, except along the Snake River, older rocks crop out only in small scattered patches. Paleozoic rocks are exposed only in the vicinity of Paps Mountain.

SILURIAN SYSTEM

LAKETOWN DOLOMITE

The Laketown dolomite crops out in a small area on Paps Mountain, about 3 miles southeast of American Falls. Older rocks are not exposed in the American Falls quadrangle, but in the Rockland quadrangle to the south the Laketown is underlain by the Fish Haven dolomite of Ordovician age. The Laketown is overlain by the Jefferson(?) dolomite of Devonian age, but the contact is not exposed. The Laketown is probably between 600 and 1,000 feet thick.

The Laketown dolomite is a light-bluish-gray medium-bedded, sandy-textured dolomite with a "crinkly" but rather smooth weathered surface on many beds. The lower part of the formation contains a few interbeds of darker dolomite. The lower contact was arbitrarily placed at the top of the highest distinctly darker bed of the Fish Haven.

Fossils were not found in the Laketown in the American Falls quadrangle, but the stratigraphy is characteristic of the formation elsewhere in the region (Richardson, 1941, p. 18; Williams, 1948, p. 1137; Ross, 1947, p. 1105–1106) where it is Middle Silurian in age.

DEVONIAN SYSTEM

JEFFERSON(?) DOLOMITE

Rocks probably correlative with the Jefferson dolomite overlie the Laketown dolomite of Silurian age and are overlain by the Madison(?) limestone of Mississippian age on Paps Mountain, but neither the upper nor the lower contact is exposed.

The Jefferson(?) is composed mainly of gray medium-bedded fine-grained dolomite, but it also contains a few beds of black sandy-textured dolomite and has conspicuous white thin-bedded dolomite at the top. The formation is probably between 600 and 1,000 feet thick.

The Jefferson(?) on Paps Mountain is unfossiliferous, but, in the Deep Creek Mountains to the south, beds underlying a white thin-bedded dolomite like that mentioned above contain *Amphipora*, and are Devonian in age (J. T. Dutro, Jr., and W. J. Sando, oral communication, 1958). The name Jefferson has been widely used in western Montana, eastern Idaho, and northern Utah (Kindle, 1908; Andrichuk, 1951) for rocks similar to those described here, and in most of the region the formation includes the majority of beds of Devonian age. The name therefore has been used in the American Falls area, but here it may include rocks equivalent to other formations of Devonian age.

MISSISSIPPIAN SYSTEM

MADISON(?) LIMESTONE

The higher parts of Paps Mountain and its northern slopes are underlain by Madison(?) limestone, but the upper and lower contacts of the formation are not exposed.

The lower part of the formation exposed on the south side of Paps Mountain is mainly gray to black thin-bedded slabby to shaly, silty, and sandy limestone. It also contains some siltstone and a little brown fine-grained sandstone. These beds, mainly the siltstone, weather purple, pink, or tan. The formation becomes thicker bedded to massive upwards and consists mostly of medium-gray fine-grained limestone and dolomitic limestone with abundant irregular discontinuous brown or gray chert layers. The upper part of the formation weathers gray with a smooth surface. The Madison(?) is at least 1,000 feet thick.

The thin-bedded silty lower part of the formation contains a few fossils that, according to J. T. Dutro, Jr., and W. J. Sando (oral communication, 1958), suggest correlation with the Madison limestone. Elsewhere in Utah, Wyoming, Idaho, and Montana the Madison has been subdivided (Holland, 1952), but lack of good exposures and fossils prohibits any subdivision of the formation in the American Falls quadrangle.

TERTIARY SYSTEM

Tertiary rocks in this area comprise the Starlight formation (new name), the Neeley formation, and the Walcott tuff. These rocks are predominantly rhyolitic: the Starlight is mainly bedded friable tuff and welded tuff with minor amounts of marl, sandstone, and conglomerate; the Neeley is poorly bedded friable tuff; and the Walcott is bedded friable tuff and obsidian welded tuff. In addition the Starlight locally contains numerous basaltic flows and tuffs. The present stratigraphic classification is a subdivision of part of the rocks formerly assigned in a few places to the Payette formation, but mainly to the Salt Lake formation, by earlier workers in adjacent areas.

The name "Salt Lake formation" was introduced by Hayden (1869, p. 92) for Pliocene sediments, mainly fluvial, in the Salt Lake Valley and in Weber Canyon in the Wasatch Range, Utah. The term subsequently was applied by Peale (1879, p. 588, 640) to somewhat similar rocks in southeasternmost Idaho. Mansfield (1920, p. 54–55; 1927, p. 110) and others, however, applied the name "Salt Lake formation" to all middle and upper Tertiary rocks in southeastern Idaho, even though, as originally described, the Salt Lake contained no volcanic material such as makes up most of the rocks on and bordering the Snake River Plain. Rocks as old as Eocene(?) (Mansfield, 1952,

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p. 111) and as young as Pleistocene (Mansfield, 1952, p. 46, 59) have been included in the Salt Lake formation.

Tertiary volcanic rocks in the Fort Hall Indian Reservation, a mile east of the American Falls quadrangle, were mapped as Salt Lake formation of Pliocene(?) age by Mansfield (1920, pl. 3). In this same area, however, he also mapped a unit that he called "deposits of volcanic ash, hill wash, etc." of Tertiary and Quaternary age. Much of what he assigned to the latter unit is loess and alluvium of Pleistocene age, but some is rhyolitic tuff of Pliocene age.

Rocks in eastern Cassia County, to the southwest of the American Falls quadrangle, were mapped as Payette or Salt Lake formation (one unit) by Anderson (1931, p. 37–44). He concluded that "there is no difficulty in correlating the sedimentary series * * * in Cassia County with the Payette formation farther west, since both lie below the rhyolite horizon." Presumably the rhyolite to which he referred is a widespread series of welded tuff and flows, mainly latitic in composition, which can be traced westward from the west side of the Sublett Range into and beyond the Goose Creek district (fig. 1) south of Burley, Idaho. These are a part of what Kirkham (1931c, p. 579) termed the "Tertiary late lavas," which mark in some areas the division between the Payette and Idaho formations as revised by him (1931a, p. 232, 235). Anderson, however, also correlated the Tertiary rocks in Cassia County with the Salt Lake formation to the east, noting a lithologic similarity with the beds described by Mansfield in the Fort Hall Indian Reservation. He further remarked that

> because the stratigraphic relations, lithology, and other factors are so similar between the series in Cassia County and the region described by Mansfield and Kirkham, and because the volcano-sedimentary series is beneath similar essentially continuous sheets of acidic lava, the suggestion is very strong that the two are of the same age and remnants of a former continuous blanket deposit.

Salt Lake formation was mapped in the Goose Creek district 70 miles southwest of American Falls by Mapel and Hail (1959). They divided the Salt Lake into upper and lower map units; the upper one contains many flows of latitic welded tuff. They also distinguished the Payette formation of probable late Miocene age, which underlies the Salt Lake with slight angular unconformity. Their Payette rests unconformably on Tertiary rhyolite.

The Salt Lake formation was mapped in the American Falls area by Ross and Forrester (1947). They also mapped separately Snake River basalt, Tertiary silicic volcanic deposits, and Payette formation, all of which the present study shows are interbedded with the rocks they mapped as Salt Lake.

The Tertiary rocks along the Snake River in the American Falls area include two formations defined by Stearns and others (1938,

p. 43–50): the Neeley lake beds, and the Eagle Rock tuff (Walcott tuff of this report). The Massacre volcanics, Rockland Valley basalt, and Raft lake beds also were assigned by Stearns to the Tertiary; but the Raft is now known to be Pleistocene in age, and the Rockland Valley basalt and Massacre volcanics are considered by us as probably Pleistocene in age, and are discussed later. The Neeley and Eagle Rock (Walcott) are distinctive mappable units that are extensively distributed in and near the Snake River valley. Tertiary rocks older than the Neeley in the American Falls area were not mapped by Stearns, but later (Stearns and Isotoff, 1956, p. 20) he noted the similarity of the Tertiary rocks of this area to the Salt Lake formation.

Although most workers in this region have assigned beds of Tertiary age to the Salt Lake formation, much confusion exists in the relation of these rocks to those in other areas, and the term Salt Lake has been used to include many rocks whose age and lithologic character are far different from those in the original description of the formation. Present work in the American Falls region has shown the need for subdivision and redefinition of the stratigraphy of rocks in this area formerly assigned to the Salt Lake, and to a smaller extent, to the Payette formation. The two units, Neeley lake beds and Walcott tuff, as defined by Stearns (Stearns and others, 1938, p. 43)and Stearns and Isotoff (1956, p. 23), are retained for use in this area with minor modifications.

STARLIGHT FORMATION (PLIOCENE)

Rocks of late Tertiary age that underlie the Neeley formation in the American Falls area are here named the Starlight formation. The type area is Starlight Creek, about 10 miles southeast of American Falls in the Arbon quadrangle (fig. 2), where the lower and middle parts of the formation are fairly well exposed. The Starlight is subdivided into upper and lower members separated by a vitric-crystal tuff member. The upper member is mainly bedded rhyolitic friable tuff. The lower member also contains much rhyolitic tuff, but with many local beds of marl and basalt flows. In many areas where the vitric-crystal tuff member is missing, the upper and lower members cannot be identified on the basis of lithology. A few of the tuff beds in the Starlight are so loosely indurated that they would properly be called ash, but in general terms we refer to Starlight pyroclastic material as tuff.

The formation is exposed in the American Falls quadrangle in upper Ferry Hollow (pl. 2) and in the southeastern part of the quadrangle east of Sunbeam Creek. The upper contact with the Neeley formation is exposed at only one place, near the center of sec. 4, T. 8 S., R. 31 E. Here the upper member of the Starlight is overlain with slight angular unconformity by about 15 feet of cobble gravel at the

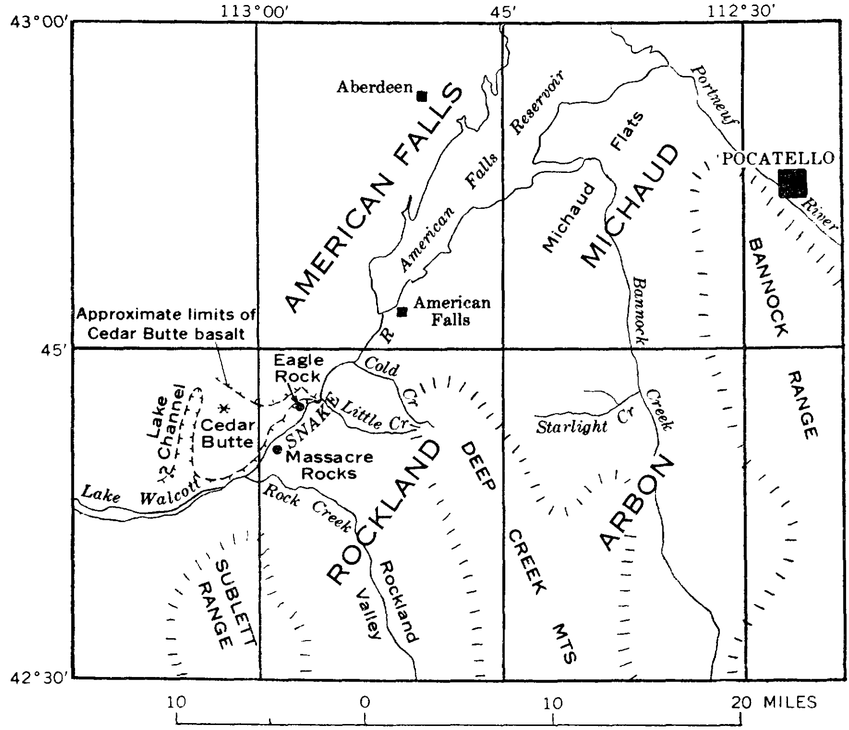

FIGURE 2.—Index map of the American Falls region showing location of American Falls, Rockland, Michaud, and Arbon quadrangles, and other geographic features.

base of the Neeley. At the base of the Starlight, there is a major unconformity, as the formation rests on Paleozoic rocks in most, if not all, of the area. The formation probably is more than 800 feet thick.

LOWER MEMBER

The lower member of the Starlight formation is that part beneath the vitric-crystal tuff member. In the American Falls quadrangle it crops out only east of Sunbeam Creek. This part of the formation is probably more than 500 feet thick.

In the southeastern corner of the American Falls quadrangle, the lower member consists of white to gray bedded rhyolitic friable tuff, with many interstratified basalt flows and minor basaltic tuff and breccia. At a few places, a red welded tuff with small obsidian pellets is exposed between basalt flows. The basalt crops out extensively but the rhyolitic tuff beds are mostly concealed by loess, colluvium, or talus. In Rockland Valley (fig. 2), 10 to 20 miles south of American Falls, few, if any, of the exposures of the lower member of the Starlight contain basalt, but in that area there are many local marl beds in the upper part of the member.

VITRIC-CRYSTAL TUFF MEMBER

The vitric-crystal tuff member is exposed in a series of small outcrops east of Sunbeam Creek. It crops out more extensively in the adjoining Rockland, Arbon, and Michaud quadrangles, and has been found near Cedarhill more than 35 miles south of American Falls, and in the southwestern part of the Paradise Valley quadrangle (fig. 1), about 60 miles northeast of American Falls. These widely separated exposures are believed to represent a single unit, and it is probable that with further work in this region additional occurrences will be discovered. The vitric-crystal tuff is as much as 77 feet thick.

The vitric-crystal tuff member is a light-colored partly welded rhyolitic tuff. It contains about 30 percent broken and embayed but normally conspicuous crystals, particularly of euhedral quartz and a little biotite, and a few lithic or pumice fragments in a fine mostly devitrified dense ashy matrix that may or may not show distinct pyroclastic texture. The lack of pyroclastic texture is probably more common toward the top of the unit where the rock, locally, may be a lava flow. At some localities, the lower part of the vitric-crystal tuff is unwelded, soft, and friable, and, in a few places, it is separated from the lower member of the Starlight formation by a layer of gravel.

Microscopic examination shows that sanidine composes about 11 percent of the vitric-crystal tuff, and plagioclase and quartz about 9 and 7 percent respectively; the rest of the crystals are biotite (2 percent), hypersthene, augite, and opaque minerals (1 percent). The light-colored minerals are as much as 3 mm across, but the average size is about 1 mm. Many of the quartz crystals are bipyramidal, and some are smoky. Composition of the plagioclase ranges from An_{10} to An_{50}, but crystals with a composition of An_{20} to An_{30} (calcic oligoclase) are by far the most common. The groundmass (about 70 percent of the rock) is typically a weakly birefringent, partly devitrified glass with a faint pyroclastic texture. More rarely the groundmass may show distinct shards or no pyroclastic texture.

Immediately southeast of the American Falls quadrangle, are several exposures of a dark-glassy welded rock that may be a conformable phase of the vitric-crystal tuff. One exposure is at the junction of Blind Spring Canyon with a tributary in SW¼ sec. 29, T. 7 S., R. 32 E., just outside the quadrangle. Gaps exist in the outcrops, but this phase appears to overlie rather closely normal hard vitric-crystal tuff. The lowest zone consists of a glassy, locally platy, grayish-brown welded tuff containing a few small crystals and, locally, numerous lithic fragments. Overlying this is a black to dark-gray perlitic obsidian welded tuff with a few small feldspar and quartz phenocrysts. Total thickness of both zones is probably about 25 feet.

UPPER MEMBER

Only the upper part of the upper member crops out in the American Falls quadrangle. The upper member is probably at least 200 feet thick. The exposures of this unit, in upper Ferry Hollow (pl. 2), are mainly of white parallel-bedded rhyolitic friable tuff, but unbedded pumiceous tuff, breccia, and marl are also present. In the well-bedded tuff, the layers range from less than 1 to as much as 12 inches thick. Locally, the upper member was intruded by vitrophyre shortly before the end of accumulation of ash in the Starlight formation. Along Sunbeam Creek in the Rockland quadrangle, the member contains interstratified basalt flows. In Rockland Valley, the member contains conglomerate interlensed with tuff and tuffaceous sediments, and locally the conglomerate contains well-rounded, weathered pebbles of the vitric-crystal tuff member.

VITROPHYRE

Vitrophyre, a dark glassy porphyritic rock, crops out at several places in the American Falls quadrangle and adjoining areas. Several exposures, mainly of breccia, are in upper Ferry Hollow in sec. 4, T. 8 S., R. 31 E., a larger group of exposures is east of American Falls, mostly along the main canal of the Michaud Flats irrigation project in the N½ sec. 28, T. 7 S., R. 31 E., and others occur in small valleys a mile or more east of American Falls.

Approximate contemporaneity of the vitrophyre with the upper part of the upper member of the Starlight is indicated by the incorporation of large angular blocks of vitrophyre in tuff beds of the upper part of the Starlight in Ferry Hollow. The blocks were probably emplaced by explosions at a vent. The intrusive character of some of the rock near American Falls is suggested by steeply dipping flow structure and probable high-angle contacts.

Although there are many variations in texture and color, the lithology of all of the occurrences of the vitrophyre is similar. It is normally a black perlitic glass with abundant large white feldspar phenocrysts. In places, the rock is brick red with much streaked obsidian, but locally it is gray and purplish. The vitrophyre in Ferry Hollow is mainly a flow breccia of black porphyritic obsidian that, locally, is incorporated in a white tuff and contains some layers of streaked fibrous pumice. East of American Falls, however, the vitrophyre typically has well-defined steeply dipping flow lines. In general, the flow structure strikes northeast, but dips range from 45° NW to 75° SE. There is some local alteration and breccia structure. One-half mile east of American Falls on new U.S. Highway 30 N.

road cuts expose a highly altered breccia phase of the vitrophyre, which is soft and clayey in places and contains angular pieces and pebbles of older rocks. Some of the rock is highly pumiceous and contains blobs of obsidian. Here also blocks of the vitrophyre are incorporated in bedded ash of the upper member of the Starlight formation. This may be a vent area in which the rocks were altered by fumarolic action.

Microscopic examination indicates a correlation of all of the vitrophyre bodies. Identifiable crystals compose 10 to 30 percent of the rock. Oligoclase is the most abundant crystal constituent and forms 5 to 25 percent of the rock; sanidine makes up 0 to 10 percent, quartz is 0 to 2 percent, and hypersthene and augite compose 0 to 3 percent of the rock. In addition, ilmenite and zircon are present in small but conspicuous amounts in most of the thin sections examined. The feldspar crystals average about 1.5 mm, but in places are as much as 4 mm across and are embayed in some specimens. The groundmass is fresh to highly devitrified brown glass, with an index of refraction of about 1.496. It has flow structure and perlitic cracks, and contains many crystallites.

BASALT OF THE STARLIGHT FORMATION

Basalt and basaltic tuffs are present in both the upper and lower members of the Starlight, but southeast of American Falls they are more abundant in the lower member. In this area, there are probably no basalt flows in the upper part of the upper member. Although some unconformities exist between the basalt flows and other beds of the Starlight formation, they are generally conformable; in most places the flows have roughly the same strike as the enclosing beds of pyroclastic materials even though the angle of dip may be somewhat different.

In this quadrangle there are no obvious features that can be used to distinguish basalt of the lower part of the Starlight from that in the upper part of the Starlight. In general, the basalt is dense, has minor olivine, and has a slightly weathered appearance, but there is considerable variation in texture and proportion of feldspar, olivine, and pyroxene. Some of the basalt contains practically no olivine, whereas some has as much as 30 percent. Both augite and pigeonite are present in combined amounts from 5 to nearly 40 percent. A little hypersthene was noted in a few thin sections of the basalts. Composition of the plagioclase ranges from about An_{30} to An_{50} (andesine) in the phenocrysts of a few flows to An_{50} to An_{70} (labradorite) in the microlites and smaller crystals. A few flows may be classified as basaltic andesite. Microscopic texture of these rocks varies widely and includes ophitic, intergranular, intersertal, and trachitic textures, and combinations of these.

HEAVY MINERALS OF THE STARLIGHT FORMATION

A potentially useful mineralogic difference has been determined from identification of the heavy mineral separates from rhyolitic tuff beds of the members of the Starlight. The upper member and the vitric-crystal tuff member contain relatively abundant heavy minerals, but most of the lower member contains very small amounts. More significant, perhaps, is that the upper member contains augite, hypersthene, zircon, magnetite, and ilmenite, but most friable tuff beds in the lower member contain only ilmenite and zircon. However, beds in the lower part of the Starlight just below the vitric-crystal tuff member contain hornblende, oxyhornblende, magnetite, ilmenite, zircon, and probably some augite.

AGE AND CORRELATION

Fossils have been found in both upper and lower members of the Starlight formation, and all indicate a Pliocene age. Mollusks are abundant in both members, particularly in marl beds, and a few vertebrate fossils have been found in conglomerate of the upper member. Diatoms are common locally throughout the upper and lower members.

Mollusks identified by D. W. Taylor are given in table 1.

Concerning the above collections, Taylor (written communication, 1960) stated:

> The mollusks from the Starlight formation are considered of middle Pliocene age because of similarities to those in three independently dated assemblages in southern Idaho, and because of marked differences from other mollusks in southeastern Idaho. The three other units in which similar mollusks occur are the Teewinot formation [defined by Love, 1956] of Jackson Hole, Wyo., and Grand Valley and Star Valley, Wyoming-Idaho; the Banbury volcanics in south-central Idaho; and the Salt Lake formation in the Goose Creek area [fig. 1], 70 miles southwest of American Falls. Mollusks from the Teewinot and Banbury are associated with middle Pliocene mammals; those from Goose Creek were stratigraphically higher than mammals of early or middle Pliocene age.
>
> The assignment of a late middle Pliocene age (Mapel and Hail, 1959, p. 236) to the mollusks of the Starlight formation is overly precise and may be wrong. On present evidence the age is well established as middle Pliocene, but probably not from the latest part of this interval.

Taylor has also studied some earlier collections made by W. C. Mendenhall, G. R. Mansfield (1920, p. 54), and P. V. Roundy. All these fossils are from beds mapped as Salt Lake formation or from similar rocks in southeastern Idaho, and all have a few mollusks in common with those listed above for the Starlight formation. Little or no stratigraphic information is available for these localities, however.

In the American Falls region, only one locality has yielded Tertiary vertebrate fossils. Two camel bones and a horse tooth were recov-

TABLE 1.—*Distribution of mollusks in the Starlight formation in the Rockland and Arbon quadrangles, Idaho*

	Locality [1]			
	Lower member			Upper member
	21669	21670	21671	21673
Freshwater clams:				
Sphaerium sp. a	×		×	×
sp. b				×
Pisidium spp				×
Freshwater snails:				
Valvata humeralis (Say)			×	?
Hydrobiidae indet	×		×	
Stagnicola n. sp		×		
albiconica (Taylor)	×			
sp				×
Fossaria dalli (Baker)			×	
Bulimnea sp			×	×
Planorbarius n. sp. a	×		×	×
n. sp. b			×	
Promenetus umbilicatellus (Cockerell)			×	?
Planorbidae, genus uncertain		×		
Ferrissia sp				×
Physa aff. *P. skinneri* (Taylor)			×	
P. sp				×
Land snails:				
Gastrocopta (*Albinula*) n. sp			×	
Vertigo spp			×	
Vallonia n. sp			×	
cf. *Succinea*			×	
Bulimulus n. sp. a			×	
n. sp. b			×	
Oreohelix peripherica (Ancey)			×	

[1] Locality 21669: SE¼ sec. 29, T. 10 S., R. 31 E., Power County, Idaho; marl beds, lower east side of Mollies Nipple. Locality 21670: NW¼SE¼ sec. 18, T. 8 S., R. 33 E., Power County, Idaho. Locality 21671: NE¼NW¼ sec. 31, T. 8 S., R. 33E., Power County, Idaho; small hill of silicified marl(?) in type area of Starlight formation. Locality 21673: SE¼ sec. 24, T. 9 S., R. 30 E., Power County, Idaho.

ered from the Starlight formation by D. W. Taylor and the writers from a pit in gravel interbedded with rhyolitic tuff in SW¼ sec. 28, T. 11 S., R. 31 E., about 10 miles south of Rockland. The gravel contains pebbles of the vitric-crystal tuff member of the Starlight, and is therefore in the upper member. G. E. Lewis (written communication, 1957) reported on these fossils as follows, "antero-external fragment of upper molar of an advanced species of *Hipparion*; two metapodials of a giant camel ?*Megatylopus* sp., ?late early or early medial Pliocene age." A mastodon jaw recovered from this same pit was tentatively identified at Idaho State College as *Pliomastodon* (M. L. Hopkins, written communication, 1958).

Thus, to date paleontologic evidence indicates an early or middle Pliocene age for all members of the Starlight formation. The similarity of the mollusks with those of the well-dated Teewinot formation, Banbury basalt, and Salt Lake formation, however, tends to weight the age in favor of middle Pliocene.

Paleontologic correlation of the Starlight formation with the Teewinot formation of the Jackson Hole region has already been suggested and lithologic correlation with parts of the Salt Lake formation is well established.

In the Ammon and Paradise Valley quadrangles (fig. 1), 70 miles northeast of American Falls, we examined Tertiary rocks mapped by Mansfield (1952) as Salt Lake formation, basalt, and rhyolitic rocks. Some of these rocks are similar to the Starlight formation of the American Falls region, and to the overlying Walcott tuff and Neeley formation. White bedded rhyolitic friable tuff, a major constituent of the Starlight, is found in both areas, and a vitric-crystal tuff identical to the vitric-crystal tuff member of the Starlight was found interbedded with basalt along the road in the S½ sec. 16, T. 4 S., R. 39 E., Paradise Valley quadrangle.

Mansfield did not distinguish between the various kinds of rhyolitic welded tuffs in the Ammon-Paradise area, and he concluded (1952, p. 46, 59) that the welded tuffs and ash in the Ammon quadrangle are Pleistocene in age on the basis of a few plant fossils found below them. We examined this locality and concluded that either the beds containing fossils are young valley fill or the state of preservation alone led to their identification as Pleistocene. In any case the conclusion that the nearby welded tuffs are Pleistocene seems unwarranted.

The sequence of volcanic rocks in the Ammon area extends at least as far northeast as Willow Creek (fig. 1) northeast of Idaho Falls. Earlier, Mansfield (1927, p. 112) noted that

> Rhyolites occur westward along the northern parts of the ranges from the Yellowstone National Park to the region here described [southeastern Idaho], and to the Fort Hall Indian Reservation. The rhyolite is probably not absolutely continuous, but the occurrences are so numerous and the character of the rock so similar that there seems little reasonable doubt that the rhyolites in this region and in the Yellowstone National Park are essentially of the same geologic age. * * * In the Fort Hall Indian Reservation * * * the rhyolite and the Salt Lake formation are interbedded here and there and are associated with beds of volcanic ash.

Mapping and reconnaissance has established that some of the rhyolite to which Mansfield referred is the vitric-crystal tuff, which is the middle member of the Starlight formation in the American Falls region.

To the southwest of American Falls in Cassia County, the Starlight formation probably correlates with at least part of what Anderson (1931, p. 37–44) mapped as Payette or Salt Lake formation. However, as the latitic welded tuff that overlies these beds has not been found east of the Sublett Range in the Rockland quadrangle, and the vitric-crystal tuff member of the Starlight has not been found west of the Sublett Range, exact lithologic correlation cannot be made at present. However, rocks dated as middle or early Pliocene age and mapped as Salt Lake formation by Mapel and Hail (1959) in the

Goose Creek area underlie a series of latite flows and welded tuffs that are probably of the same age as those overlying the rocks mapped by Anderson in eastern Cassia County.

In summary, the Starlight formation is early or middle Pliocene in age, or both, with present evidence favoring middle Pliocene. It correlates with part of what has been mapped as Salt Lake formation in southeastern Idaho, and on the basis of mollusks is closely related to the Teewinot formation of the Jackson Hole region. Rocks referable to the Starlight may extend northeastward to the general area of Idaho Falls. To the west, the Starlight correlates with at least part of the Salt Lake formation of the Goose Creek district.

The majority of the Salt Lake formation as mapped in this region, and the Starlight formation, are thus not correlative with the Payette formation as suggested by Anderson (1931, p. 43) and Kirkham (1931c, p. 581), but represent a later stage of extensive volcanic activity along the southern edge of the Snake River Plain.

NEELEY FORMATION (PLIOCENE)

Tan to orange, tuffaceous clayey sandstone and tuff beneath the Walcott tuff along the Snake River downstream from American Falls were named the Neeley lake beds by Stearns and others (1938, p. 43). Because the gross lithologic character of the formation, particularly of the lower part not seen by Stearns, is not particularly suggestive of a lacustrine deposit, the name is here changed to Neeley formation. In addition to the type exposures along the Snake River, the Neeley also crops out in draws in and near the town of American Falls, and discontinuously all the way up Ferry Hollow. It overlies the Starlight formation with slight angular unconformity and is conformably overlain by the Walcott tuff. The basal contact with the Starlight is exposed only in upper Ferry Hollow (pl. 2), but the upper contact is exposed at many places.

The Neeley is at least 100 feet thick at the type locality along the Snake River (Stearns and others, 1938, p. 43), but is only 49 feet thick, including 15 feet of basal conglomerate, in upper Ferry Hollow. It pinches out along the valley of Rock Creek in the Rockland quadrangle to the south.

Lithologically the Neeley formation differs little from place to place. The lower part tends to be coarser grained, and contains more nonvolcanic debris than the upper, and has a layer of gravel at the base. At the type locality in the Snake River bluffs, between the mouth of Ferry Hollow and the quadrangle boundary, all but the upper 5 to 10 feet of the formation is a clayey sand that in general contains a small amount of volcanic material, although some zones have abundant rhyolite shards, some small pumice fragments, and scattered pebbles.

The upper 5 to 10 feet of the Neeley is almost invariably tan fine-grained unbedded friable tuff. Bedding, sorting, and consolidation are poor throughout the formation, and the color is typically orange to tan. Minor features include small manganese and calcite nodules and local pinhole weathering. Not exposed in this quadrangle but cropping out in several places about 5 miles downstream is a marl, 5 to 10 feet thick, that contains a few mollusks. The gravel at the base of the Neeley, as exposed in upper Ferry Hollow, is a rather poorly sorted deposit of well-rounded pebbles and cobbles, mainly of vitric-crystal tuff from the Starlight formation, in a brown clayey sand matrix containing some shards. That a large part of the Neeley is not lacustrine in origin is suggested by the presence of gravel and scattered pebbles. In some samples, quartz sand is fairly abundant and many of the rhyolitic shards appear to be frosted and the sharp corners removed, probably by transportation.

Stearns (Stearns and others, 1938, p. 43) regarded the Neeley as early Pliocene(?) in age, but he found no fossils. A collection of mollusks made from the marl in the SW¼ sec. 28, T. 8 S., R. 30 E., was examined by D. W. Taylor, who reported (written communication, 1959) the following:

Freshwater clams:
- *Sphaerium* sp. a
- *Pisidium* spp.

Freshwater snails:
- *Valvata humeralis* (Say)
- *Lithoglyphus* n. sp.?
- *Stagnicola albiconica* (Taylor)
- *Bulimnea* sp.
- *Planorbarius* n. sp. a
- *Promenetus umbilicatellus* (Cockerell)
- *Physa* sp.

Land snail: Indeterminate gastropod

Taylor considers (written communication, 1960) this assemblage not significantly different from that of the Starlight formation, and its faunal correlatives are the same as those previously discussed for the Starlight. Thus the Neeley appears to be practically the same age as the Starlight even though the two are separated by an unconformity, and both have the same correlatives. The Neeley formation may extend as far northeastward as the Idaho Falls region.

WALCOTT TUFF (PLIOCENE)

The Walcott tuff was named by Stearns and Isotoff (1956, p. 23) from Lake Walcott, a few miles down the Snake River from this area. Stearns (Stearns and others, 1938, p. 44) originally named these obsidian welded tuffs and bedded tuffs the Eagle Rock tuff. Our report follows the usage of Stearns and Isotoff. The Walcott is exposed in the same general area as the Neeley formation, though more extensively. The obsidian tuff or upper part of the Walcott is thickest along the Snake River; to the southeast various parts or all of this unit may be missing locally, but the lower bedded tuff unit is more persistent. The type locality is in the cliff on the west side of the Snake River below the railroad trestle at American Falls. The formation is exposed in the new irrigation canal along the southeast side of town (fig. 3).

The total thickness of the Walcott tuff in the American Falls quadrangle ranges from about 35 feet near the American Falls Dam to 16 feet in upper Ferry Hollow. The formation is more than 50 feet thick, however, along the Snake River a few miles downstream, and with the Neeley formation it pinches out along the east side of Rock Creek valley in the Rockland quadrangle to the south.

The Walcott tuff contains two distinctive rhyolitic members (not mapped separately), a lower white or light-gray bedded friable tuff member and an upper dark obsidian welded tuff member. It conformably overlies the Neeley formation and is unconformably overlain by the Little Creek formation. The basal contact is rather sharp and is recognized by the abrupt change from massive tan tuff of the Neeley to well-bedded white or light-gray tuff of the Walcott. The top of the Walcott at most exposures is a pink welded tuff, 1 to 2 feet thick, and the upper contact in this area generally is marked by a thin colluvial breccia at the base of the overlying Little Creek formation. The breccia commonly contains fragments of welded tuff of the Walcott.

The lower bedded tuff member is composed of white to light-gray, parallel-bedded rhyolitic ash and looks very much like some of the bedded tuff of the Starlight formation. The tuff is medium to fine grained and composed almost entirely of clear shards. In some beds, in the lower 4 feet of the unit, it contains ash pellets as much as 2 mm across. The tuff is friable, but varies in induration. The bedding is remarkably uniform, but locally is slightly distorted at the contact with the overlying welded tuff member. The thickness of the bedded tuff member ranges from about 7 to 12 feet. The thickest sections are in the vicinity of American Falls.

The upper or welded tuff member, generally ranging from 8 to 25 feet thick, consists largely of a massive central section of black, dense perlitic spherulitic obsidian welded tuff, 5 to 20 feet thick. In the lower 2 to 4 feet of the member, the black glassy welded tuff grades downward into a progressively less dense tuff that is dark gray, hard and welded at the top, and gray to brownish gray, soft, and porous at the base. In the upper few feet of the member, the black glassy tuff grades upward into a black fine-textured welded tuff with a pink or brick-red glassy welded tuff at the top. Faint horizontal partings in the pink tuff cause it to break into platy fragments. In other areas, soft, unwelded tuff locally overlies the pink tuff. Because the Walcott tuff occupies a large area near the surface in the vicinity of American Falls, a detailed description of its lithologic character is given below.

Composite section of the Walcott tuff measured in lower Ferry Hollow in the SW¼NE¼ sec. 6, T. 8 S., R. 31 E., American Falls quadrangle, Idaho

	Thickness (feet)
Little Creek formation.	
Unconformity.	
Walcott tuff:	
Obsidian tuff, welded, black; about 10 percent white rectangular feldspar crystals 1 mm long; grades upward abruptly into a thin zone of pink to brick-red glassy welded tuff with faint horizontal lineation; unit breaks with conchoidal fracture, but forms platy fragments at top	2.6
Obsidian tuff, welded, black, nonspherulitic	1.5
Obsidian tuff, welded, black, massive, but friable and perlitic; contains about 25 percent gray spherulites from 1 mm to 35 mm in diameter; the spherulites are solid, have a small core, crude radial structure, and increase in number downward	6.5
Obsidian tuff, welded, black, massive; breaks with smooth conchoidal fracture; contains a few scattered white feldspar crystals; much of unit has a fine "granular" vesicular texture with no apparent lineation	2.5
Obsidian tuff, massive, porous; gray and soft at base grading to dark gray, hard and welded at top; contains scattered small white feldspar crystals; shards are flattened in horizontal plane, but lower part has many thin-walled glass bubbles	2
Tuff, white to light gray, medium-grained, friable; varies in induration; uniformly well bedded in layers 6 inches thick to thin laminae; composed almost entirely of clear shards but contains ash pellets as much as 2 mm across in some beds in lower 4 feet of unit	10.6
Total Walcott tuff	25.7
Neeley formation:	
Tuff, light-tan, fine-grained, massive, friable.	
Base of exposures.	

In thin section, the upper obsidian tuff part of the Walcott shows a rather uniform texture despite the variations described above. The upper unit has a eutaxitic to wormlike texture throughout, almost identical to that described by Mansfield and Ross (1935) for a similar rock in the Ammon area, 70 miles northeast of American Falls. The individual particles have no sharp corners but many are Y-shaped and there is no doubt that they are distorted shards squeezed, fused, and alined so that they conform to one another. A few of the shards were evidently bubble-shaped before fusion. The glass is dark brown to clear, has an index of about 1.495, and is fairly fresh in most specimens, but highly devitrified in a few. Spherulites are common in the more devitrified specimens. Crystals, generally making up less than 5 percent of the tuff, include oligoclase, sanidine, hypersthene, and augite and a little magnetite; no quartz has been found.

The uniformity and perfection of bedding, and absence of cross-bedding, in the lower part of the Walcott tuff suggest deposition in a quiet lake. Some of the bedded tuff contains many small pellets of loosely aggregated fine shards called pisolites by Stearns (Stearns and others, 1938, p. 45). He cites these as evidence of subaerial deposition of the ash, but we believe that such pellets could just as well, if not more easily, form by gentle rolling of floating volcanic dust and ash on the surface of a lake. Locally the bedding has been slightly distorted at the top of the bedded tuff member, suggesting that the ash was somewhat plastic when the welded tuff was deposited.

No fossils have been found in the Walcott tuff, but the conformity of the contact with the Neeley formation and the presence in both of nearly pure rhyolitic shards suggest that the age of the Walcott is very nearly the same as that of the Neeley—middle Pliocene.

Welded obsidian tuffs in the northwestern part of the Ammon quadrangle southeast of Idaho Falls resemble the Walcott tuff closely. Rocks similar to the Neeley and Starlight formations are also present beneath the obsidian tuff in the Ammon area. The lithologic and stratigraphic resemblance is so great that these tuffs almost certainly belong to the same epoch of rhyolitic eruptive activity, if not to the same source, as the Walcott. The Ammon obsidian tuff and Walcott were so correlated by Mansfield and Ross (1935, p. 310). As discussed earlier (p. G14) Mansfield's conclusion that the welded tuff of the Ammon area is Pleistocene in age seems unwarranted; the mollusks found in the Neeley formation are probably a more reliable indication of the age of the Walcott than the plant fragments from the Ammon quadrangle.

QUATERNARY SYSTEM

LITTLE CREEK FORMATION (PLEISTOCENE?)

The Little Creek formation is herein established because mapping in the Rockland quadrangle shows the need for revising the stratigraphy of the Massacre volcanics as used by Stearns (Stearns and others, 1938, p. 46–47; Stearns and Isotoff, 1956, p. 24–27). The Massacre volcanics of Stearns appears to include at least two groups of volcanic rocks separated by an unconformity. The older and more widespread of these two groups is here distinguished from the Massacre volcanics (which in our definition do not occur in the American Falls quadrangle) and named the Little Creek formation from exposures along the creek of that name (fig. 2) in the adjoining Rockland quadrangle. The formation, which consists of an upper basalt member and a lower tuff member, is exposed in the American Falls quadrangle only along the Snake River and in lower Ferry Hollow, but underlies much of the northwestern one-third of the Rockland quadrangle. The type locality of the tuff member is in the N½ sec. 6, T. 8 S., R. 31 E., and SW¼ sec. 31, T. 7 S., R. 31 E., near the mouth of Ferry Hollow and in the south bluff of the Snake River. The type locality of the basalt member is at American Falls. The base of the Little Creek is defined as the base of formation A of Stearns and Isotoff (1956, p. 23), a unit of pinkish-tan, fine-grained rhyolitic tuff that commonly contains fragments of Walcott tuff. In the American Falls quadrangle, the Little Creek lies on the Walcott in all places seen. The top of the formation is normally the top of the basalt member, but the upper contact is an unconformity and the basalt may be entirely absent, as it is along Ferry Hollow. The Little Creek may be overlain by any of the younger formations, but at most exposures near the Snake River it is overlain by the Raft formation. The Little Creek formation is generally 20 to 50 feet thick.

The tuff member of the Little Creek formation crops out in this quadrangle only in lower Ferry Hollow. In general, it is composed of interbedded basaltic and rhyolitic tuffs. The rhyolitic material is more prevalent at the base and is overlain by predominantly basaltic cindery tuff and tuff-breccia that range in color from light yellow brown to dark purplish gray. The following section was measured in lower Ferry Hollow where the upper basalt member is absent:

Section of the tuff member of the Little Creek formation measured in Ferry Hollow, SW¼NE¼ sec. 6, T. 8 S., R. 31 E., American Falls quadrangle, Idaho

	Thickness (feet)
Raft(?) formation:	
Gravel, locally well indurated with caliche; contains pebbles and cobbles, mainly of Walcott welded obsidian tuff.	
Unconformity.	
Little Creek formation:	
Tuff-breccia, tan- to light-gray, poorly sorted; contains pieces of Walcott tuff as much as 1 ft. across, in a shardy matrix	15
Tuff, light-gray; contains grains of obsidian, pumice, and basalt cinders	2.9
Tuff, light-gray, well stratified, waterlaid; contains basaltic cinder lapilli; upper and lower contacts irregular	.6
Tuff, dark-gray to tan, basaltic; poorly stratified in places, contains basaltic lapilli	.6
Ash, light-brown, sandy and clayey, poorly sorted; contains a few lenses of sand and gravel and many rhyolitic shards; at base a zone of platy pieces of pink welded tuff of the Walcott in a soft white to tan matrix	6.8
Total Little Creek formation	26
Unconformity.	
Walcott tuff: Obsidian tuff, welded, black grading up into pink.	

Microscope examination shows that the basaltic shards have been altered to yellow palagonite in a few specimens. Diatoms are common in some layers, indicating accumulation of parts of the formation in lakes or ponds.

In other areas, particularly in the Rockland quadrangle between Massacre Rocks and Eagle Rock, the tuff member of the Little Creek is as much as 75 feet thick, and locally may contain many large ejecta of older Tertiary rocks.

The upper or basalt member of the Little Creek formation, exposed along the Snake River and underlying the southwest part of the town of American Falls, is present over a wide area in the northern part of the adjoining Rockland quadrangle. The basalt member consists of a single flow, generally 5 to 30 feet thick, but at the power plant on the river at American Falls the basalt apparently flowed into an old canyon of the river and is a maximum of 80 feet thick. At American Falls, the basalt is separated from the Walcott tuff by only a few feet of baked rhyolitic ash and colluvium, and it is petrographically similar to basalt of the Little Creek exposed in the northern part of the Rockland quadrangle. The absence of the tuff member of the Little Creek at American Falls indicates an unconformity beneath the basalt.

Basalt of the Little Creek commonly is a dark-gray dense fine-grained relatively fresh-looking rock with patches, mostly in the upper part of the flow, of diktytaxitic texture—an open meshwork of crystals with cavities or voids between the crystals. The diktytaxitic texture is characteristic of basalt of the Little Creek in this area, although it is rare or absent in some exposures. Much of the rock has streaky flow banding or platy jointing parallel to the banding. The microscopic texture of most of the rock is subophitic to ophitic, but some is intergranular or intersertal. The basalt contains about 35 percent plagioclase, 35 percent augite or pigeonite, 15 percent olivine, 10 percent opaque minerals, and very little groundmass, most of which is glass.

No fossils have been obtained from the Little Creek formation except for some diatoms, whose age has not yet been determined. The underlying formation is probably middle Pliocene in age, and the overlying one is middle to late Pleistocene. The Little Creek formation is therefore probably late Pliocene or early Pleistocene in age, but the freshness of the basalt and the presence of an unconformity at the base of the formation tend to favor a Pleistocene age.

RAFT FORMATION (PLEISTOCENE)

Light-colored beds of massive silt, and of clay, stratified silt, and sand, widely distributed between American Falls and the mouth of the Raft River (fig. 1), 23 miles to the southwest, were named the

Raft lake beds by Stearns and others (1938, p. 48). The name has been changed to Raft formation (Trimble and Carr, 1961) because much of the unit, as indicated by Stearns (1938, p. 48, 50), and as observed by us in other areas, appears to be of fluviatile rather than lacustrine origin. A large part of the formation, however, probably did accumulate in a lake.

We include in the Raft part of what was called American Falls lake beds by Stearns and others (1938, p. 69). The American Falls of Stearns included beds that are older than the basalt (not present in this quadrangle) that dammed the Snake River creating the lake in which the American Falls lake beds were deposited.

In this quadrangle, the Raft formation is exposed only along the Snake River and in lower Ferry Hollow, but probably underlies at depth a large part of the quadrangle west of the Snake River. It unconformably overlies the Little Creek formation, Walcott tuff, or Neeley formation, although in other localities it overlies Massacre volcanics. The Raft in the American Falls quadrangle is unconformably overlain by the Big Hole basalt and the American Falls lake beds. A thin, lensing deposit of gravel, mapped as part of the American Falls lake beds, immediately overlies the Raft at an altitude of about 4,320 feet along the northwest side of the Snake River; this gravel is apparently a local aquifer for many seeps and springs such as Reuger Springs.

In the American Falls area, the Raft formation is about 75 feet thick, but in areas farther west, near the mouth of the Raft River, the formation is more than 200 feet thick, and includes about 100 feet of an upper massive thick-bedded silt unit. The formation also appears to thicken to the northwest of American Falls where a well in NE¼ sec. 26, T. 7 S., R. 30 E., passed through 157 feet of silt and clay that is probably Raft.

The Raft formation in the American Falls area is composed mainly of parallel-bedded, calcareous quartzose silt and fine sand with local crossbedding. The presence of nodular calcareous concretions in many beds characterizes the formation.

The following section was measured on the bluffs on the west side of the Snake River about 1 mile south of the margin of the American Falls quadrangle. It includes the overlying American Falls lake beds as well as the Raft formation. Stearns and Isotoff (1956, p. 28) apparently included in the American Falls lake beds part of the section here referred to the Raft. This is evident from their figure of more than 100 feet for the thickness of the American Falls lake beds in this general locality, and their mention of a basaltic tuff, which we include within the Raft. The contact between the Raft and American Falls is here placed at the base of a persistent gravel layer, which is at about the same altitude as the base of the basalt dam responsible for creating the ancient American Falls lake.

Section of Raft formation and American Falls lake beds measured on the west bank of the Snake River opposite Neeley in SE¼SW¼ sec. 10, T. 8 S., R. 30 E., Rockland quadrangle, Idaho

	Thickness (feet)
Top of bluff.	
Dune sand:	
Sand, gray to tan, fine- to medium-grained, loosely indurated	10–15
American Falls lake beds:	
Clay, gray-green, noncalcareous; breaks into small conchoidal fragments and forms loose "shaly" slope	7
Clay, white to light-tan, diatomaceous, massive, blocky; local platy and prismatic jointing, particularly near top; forms ledge	7
Clay, greenish-gray, sandy; pinkish-brown in lower 2.5 ft and slightly calcareous; blocky fracture at top; breaks into fine granular or "shaly" rubble; sharp upper contact	9.3
Sand, pinkish-brown, calcareous, fine-grained, loosely indurated; a few pinkish-brown clay layers near the bottom; upper contact gradational	5
Clay, pinkish-brown, calcareous, laminated, brittle; in beds 0.5 to 2 in thick; alternates with tan crossbedded silt in layers 6 in to 18 in thick; silt shows wavy oscillatory bedding; contains mollusks; forms ledge	14
Sand, gray to tan, fine to very fine grained, loosely indurated; crossbedded on small scale and contains local thin silty layers	8.3
Gravel, coarse, pebbly, moderately indurated; pebbles are well rounded, and consist mainly of quartzite (about 80 percent) but also of basalt and Walcott tuff; layer of yellow clay containing rhyolitic shards and basalt cinders, about 0.5 in thick, at base; contains mollusks; thickens to about 5 feet about 30 feet downriver from line of section	.7
Total American Falls lake beds	51.3
Unconformity.	
Raft formation:	
Silt, light-tan, massive; poorly indurated but forms ledge	1.3
Clay and silt, calcareous, laminated; a layer of light-brown loose sand at top of unit. Upper contact gradational	5.9
Sand, tan to light-gray, well-bedded and locally crossbedded; contains several pebbly sand lenses; beds 3 to 4 in thick; pebbles well-rounded and less than 0.5 in. in diameter; composed of Paleozoic rocks and a few lime concretions	5
Silt, tan, calcareous, moderately indurated, massive, with lenses of laminated silt. Forms ledges	1.3
Sand, light-gray to tan, fine-grained, clean, loose; interbedded with tan thin-bedded to laminated silt with platy partings and some crossbedding; pebbly zones about 4 in thick about 2 ft above base and at top of unit; lower pebbly zone contains small concretions, platy fragments of Walcott, and rare quartzite	6.4

Raft formation—continued	*Thickness (feet)*
Silt and fine sand, light-tan to tan, calcareous, moderately well cemented, massive, ledge-forming; fractured case-hardened surface in places and some prismatic jointing; hard irregular concretionary areas in lower and middle parts of unit	13.8
Sand, tan, very fine- to coarse-grained; very loosely cemented by films of calcium carbonate; granular texture in places; contains a few shards and scattered white soft calcareous lumps, 1 to 6 mm across, and lenses of pumice fragments and pebbles of Walcott(?) tuff; upper contact very gradational. Approximate horizon of basaltic ash exposed about 0.25 mile up river	7.6
Sand, fine-grained, and tan calcareous silt in beds 4 to 5 in. thick; sand beds contain 0.5 to 3 mm white irregular calcareous particles and very irregular calcareous sandstone concretions, many of which are spindles as much as 1 ft long that are perpendicular to the bedding	6.8
Silt, tan, calcareous, moderately indurated; rather massive to faintly bedded, with a little very fine sand and several zones of concretions in lower part; forms a ledge together with unit above	13.1
Sand and silt, light tan, calcareous, in alternate beds 1 to 4 in. thick, with prominent concretion zone at top	2.1
Sand, tan, calcareous, fine-grained to very fine grained, crossbedded; mostly quartz; contains 3 or 4 discontinuous zones of nearly pure calcareous concretions 2 to 5 in. long and 0.5 to 1 in. thick	2.1
Silt and sand, light-tan, calcareous, fine-grained, poorly indurated; contains platy layers and 1 in. nodules of calcareous moderately indurated sand	3
Total Raft formation measured	77.9

Base of section—15 ft above river level.

Although Stearns and Isotoff (1956, p. 27) assigned a tentative age of late Pliocene to the Raft formation, they found no fossils. A few mollusks, however, have been obtained from two stratigraphic levels in beds of the Raft, one near the base of, the other about half way up, a steep bluff along the south side of the Snake River in SW¼ sec. 24, T. 9 S., R. 28 E., about 20 miles southwest of American Falls. A third collection was made by D. W. Taylor from limy silt beds at the base of the west bank of the Snake River opposite Neeley in the NE¼ sec. 10, T. 8 S., R. 30 E., in the Rockland quadrangle. All these mollusks were identified by D. W. Taylor, who considers them to be middle or late Pleistocene, probably late Pleistocene, in age (D. W. Taylor, written communication, 1959):

Freshwater clams:
- *Sphaerium striatinum* (Lamarck)
- *Pisidium compressum* Prime

Freshwater snails:
- *Valvata humeralis* (Say)
- *V. utahensis* Call

Freshwater snails—continued
- *Stagnicola caperata* (Say)
  - *traskii* (Tryon)
  - sp. a
  - sp. b
- *Gyraulus parvus* (Say)

Land snails:
- *Pupilla* indet.
- *Vallonia cyclophorella* Sterki
  - cf. *Succinea*
- *Discus shimeki cockerelli* Pilsbry
  - indet.
- *Oreohelix strigosa depressa* (Cockerell)

BIG HOLE BASALT (PLEISTOCENE)

In the American Falls quadrangle, basalt flows north of the Snake River that overlie the Raft formation are here named the Big Hole basalt. It includes flows from different eruptive centers, but the flows could not be separated in mapping. The name is taken from the basalt-rimmed inlet on the west side of the American Falls Reservoir, about 3 miles east of Aberdeen. This locality at Big Hole is the type locality. The basalt is present under almost all of the area northwest of the reservoir and the Snake River. It crops out over most of the northwest quarter of the quadrangle, in places on the terrace levels, and in several areas along the margin of the American Falls Reservoir.

The Big Hole basalt is overlain by loess, sand dunes, American Falls lake beds, and terrace deposits. The lower contact with the Raft formation is exposed at only one locality, on the west bank of the reservoir in SE¼SW¼ sec. 7, T. 7 S., R. 31 E. Stearns (Stearns and others, 1938, p. 69) thought that this basalt was intercalated with the American Falls lake beds, because he included the beds above and below the basalt in the American Falls, whereas we believe that the beds underlying the basalt are Raft formation. Interpretation of logs of several water wells indicates that the Raft formation underlies the basalt with slight unconformity.

The distribution of the Big Hole basalt and altitude of its base indicate that the town of American Falls is on the east side of an ancestral channel of the Snake River that apparently had a floor of low gradient about 4,320 feet above sea level. The contact of the Big Hole basalt with underlying sediments in a water well about 7 miles north of American Falls is also at an altitude of about 4,320 feet, but the lower contact of the basalt about 5.5 miles west of American Falls is about 4,350 feet. The basalt is 150 feet thick in the last mentioned well, but is thinner to the east, ranging from 56 to about 20 feet thick beneath the Aberdeen terrace.

The basalt characteristically is dense, blue gray to blue black, and commonly contains a few megascopic olivine crystals. In many places, the flows have a pahoehoe surface that has buckled into pressure ridges.

Texture of the basalt is intersertal to intergranular. The rock contains 30 to 40 percent labradorite laths, 0.1 to 0.2 mm in length, and 10 to 20 percent olivine crystals. Well-crystallized augite constitutes only a very small percentage of the rock; it may, however, in a poorly crystallized form compose much of the groundmass, which commonly is 35 to 50 percent of the basalt. Locally the groundmass is mostly glass. In places magnetite, mainly in the form of skeletal crystals, makes up as much as 10 percent of the rock. Basalt in the southwestern part of the quadrangle, in the sand dune area, has features, mainly microscopic, that set it apart from the rest of the Big Hole. This basalt, which extends southwestward into the Rockland quadrangle, has subophitic texture and contains about 30 percent augite.

LOESSIAL DEPOSITS (PLEISTOCENE)

Calcareous silt, probably of eolian origin, forms an extensive mantle on the basaltic plain in the western half of the American Falls quadrangle. A similar deposit, possibly of the same age, mantles the Tertiary and Paleozoic rocks in the southeast part of the area above an altitude of about 4,750 feet. Loess in the western part of the quadrangle commonly is less than 30 feet thick and appears to thin northward. The thickness of the loess in the southeast part of the area is unknown, but 4 miles south of American Falls it may be at least 100 feet.

The loess is light-tan poorly indurated uniform silt that is very well sorted and contains about 20 percent calcium carbonate. It stands in rather steep slopes in some areas, due mainly to surficial "case hardening" or induration.

No diagnostic fossils have been found in the loess, but west of American Falls it is younger than the Big Hole basalt, and most of it is probably older than the Grandview terrace deposits. Its relation to the American Falls lake beds has not been established with certainty. The loess east of the Snake River may be of the same general age but contemporaneity has not been demonstrated. The loess may have been derived largely from the Raft formation.

SUNBEAM FORMATION (PLEISTOCENE)

Alluvial and colluvial deposits of silt and minor interstratified sand and gravel in the southeastern part of the American Falls quadrangle, mainly below an altitude of about 4,750 feet and above American Falls lake beds and younger deposits, are here named the Sunbeam formation from their distribution adjacent to Sunbeam Creek. The type area is a series of cuts along the Michaud Flats irrigation canal east of American Falls in secs. 22, 23, 24, 27, and 28, T. 7 S., R. 31 E.

The Sunbeam is separated from younger deposits by a marginal scarp at an elevation of about 4,430 feet (pl. 1). The altitude of about 4,750 feet used as the upper limit of the Sunbeam is partly arbitrary, as it represents a very approximate location of a gradational contact with the loessial deposits. The Sunbeam formation is well exposed along the U.S. Bureau of Reclamation canal from American Falls northeastward. The deposits extend into the Michaud and Rockland quadrangles, but their limits of distribution are not known. The Sunbeam is at least 100 feet thick.

Most of the Sunbeam formation is not bedded to poorly bedded, tan, calcareous silt, with some fine-grained sand. Sand and gravel occur mainly as lenses in the silt, but at least three gravel layers are at the base of the poorly bedded silt in exposures along the canal in southeast American Falls. The gravel contains fragments of Paleozoic rocks, tuff from the Starlight formation, basalt, Neeley formation, Walcott tuff, and vitrophyre. The lowermost gravel deposit in the canal section is moderately well cemented with clay; the middle gravel deposit is much coarser than the other two and contains boulders as much as 2 feet in diameter. Such gravel deposits are scarce, except near the base of the Sunbeam.

The Sunbeam formation is difficult to distinguish from the Raft formation or the loessial deposits. The loess lacks bedding and particles coarser than silt, whereas the Sunbeam commonly shows at least some bedding and contains a few lenses of sand and gravel. The Raft formation has calcareous nodules and, in some areas, thick caliche; the Sunbeam and loess do not. The Sunbeam is probably derived in part from the loess, which in turn was probably derived from the Raft formation. This accounts in part for the difficulty in distinguishing these units.

As good exposures are scarce in this area, the limits of the Sunbeam were determined mainly by topography. A slight steepening of slopes above an altitude of about 4,750 feet is common southeast of American Falls. Silt exposures above this altitude invariably lack bedding and rock particles coarser than silt. The good exposures below this altitude commonly show some bedding or contain sand and gravel lenses.

A few species of land snails are present locally in the Sunbeam, and according to D. W. Taylor (written communication, 1959) "the absence of extinct species tends to suggest a late Pleistocene age, but the small number of species makes even this age uncertain." As mapped, the Sunbeam probably includes deposits ranging in age from post-Raft to Recent.

AMERICAN FALLS LAKE BEDS (PLEISTOCENE)

Stearns and others (1938, p. 69) named the American Falls lake beds. The term was applied to the sediments deposited in a lake upstream from a lava dam (pl. 3) formed by the Cedar Butte basalt (not exposed in this quadrangle; see section on late Quaternary history). We restrict the American Falls to the upper part of the beds named by Stearns, who included in the formation beds older than the basalt dam that caused their deposition. We also include at the base of the formation a gravel deposit that lies at an altitude of about 4,320 feet. The beds beneath this gravel and older than the basalt dam are referred to the Raft (p. G22).

The American Falls lake beds are well exposed in bluffs that rim most of the American Falls Reservoir and in the bluff along the west side of the Snake River in the adjoining Rockland quadrangle, in secs. 10 and 15, T. 8 S., R. 30 E., where the stratigraphic section of the American Falls lake beds and the underlying Raft formation was measured (p. G23). The American Falls lake beds are underlain also by the Big Hole basalt in many areas west of the American Falls Reservoir. They are overlain by the Michaud gravel and younger deposits.

The formation unconformably overlies the Raft and commonly includes at the base the alluvial gravel mentioned above. The gravel, which is as much as 15 feet thick, is exposed at an altitude of about 4,320 feet at many places downstream from American Falls, but it is rarely exposed along the margin of the American Falls Reservoir and then only when the water level is low. Variations in altitude of the gravel are slight, indicating that it was deposited in a valley of very low gradient, probably less than 1 foot per mile. The upper limit of the main body of the lake beds appears to be about 4,400 feet above sea level, which indicates that the thickness is as much as 80 feet. The maximum thickness exposed in any known section, however, is little more than 50 feet.

In contrast to the Raft formation, which is largely silt, the American Falls lake beds consist mainly of clay, with subordinate silt, sandy silt, and locally abundant fine sand. Some of the clay is very diatomaceous, and some of the beds are calcareous. The stratigraphy (see p. G23) of the formation is fairly uniform laterally, but the persistent conspicuous layer of blocky, white, diatomaceous clay near the top of the section varies in thickness. It thickens and the base commonly is lower where it is underlain by, or adjacent to, crossbedded sandy deposits that are apparently deltaic in origin. The clay layer is more than 20 feet thick locally, but the normal thickness is 5 to 7 feet. The deltaic deposits are particularly abundant northeast of Seagull Bay to beyond the mouth of Bannock Creek in the Michaud quadrangle.

The molluscan fauna obtained from the American Falls lake beds (table 2) is considered to be late Pleistocene in age by D. W. Taylor (written communication, 1959). This assemblage suggests a cool wet environment.

The gravel at the base of the American Falls lake beds is locally fossiliferous and has yielded an abundant vertebrate and molluscan fauna. A collection of fragmentary vertebrate remains from the alluvial gravel at the base of the formation near the southwest corner of sec. 15, T. 8 S., R. 30 E., in the Rockland quadrangle, includes mammoth, *Equus* sp., *Camelops* sp., and bison, and is considered by G. E. Lewis, C. B. Schultz, and L. G. Tanner (written communication, 1958) to be middle to late Pleistocene in age. The faunal association is similar to that in the Sappa formation of Nebraska. Specimens of *Bison* (*Gigantobison*) *latifrons* from the gravel, were described by M. L. Hopkins (1951).

The paleontologic evidence mentioned above does not firmly date the American Falls lake beds, in particular the basal gravel. The mollusks are thought to indicate a late Pleistocene age. The mollusks in the underlying Raft formation are considered by D. W. Taylor to be middle to late, probably late, Pleistocene. The vertebrate collection suggests an age of middle to late Pleistocene. There is disagreement on the age of the Great Plains occurrences of *Bison latifrons.* Hibbard (1955, p. 221–223) believes this bison is no older than Illinoian, whereas, Schultz and Frankforter (1946, p. 8) consider it indicative of Kansan and Yarmouth age.

If all the geologic and paleontologic evidence is weighed and considered, the most reasonable age for the gravel at the base of the American Falls lake beds is probably Illinoian. The fact that this gravel was transported and deposited on a very low gradient suggests a period when the Snake River carried a larger than normal amount of water. This in turn suggests a glacial rather than interglacial period and lends support to the date of Illinoian for the gravel.

MICHAUD GRAVEL (PLEISTOCENE)

Gravel and sand deposits above a scarp base with an altitude of 4,420 feet overlie American Falls lake beds between lower Sunbeam Creek in the American Falls quadrangle and the city of Pocatello to the east. This unit, the Michaud gravel, is also bounded by a scarp at most places on the south.

The Michaud gravel in the American Falls quadrangle is a marginal remnant of unconsolidated pebbly silt and sand, rather than gravel. The deposit becomes coarser grained eastward, however, and at Michaud,

TABLE 2.—*Mollusks from the American Falls lake beds, American Falls area, Idaho*

	Locality [1]							
	19169	21638	21057	21642	21639	21643	21635	14858
Freshwater clams:								
Sphaerium striatinum (Lamarck)	×	×	×	×	×	--	×	
indet	--	--	--	--	--	--	×	
Pisidium compressum Prime	×	--	--	--	×			
indet	--	--	--	--	--	--	×	
Freshwater snails:								
Valvata humeralis (Say)	×	×	×	--	--	×	×	
utahensis Call	×	×	×	--	--	×	×	×
Lithoglyphus fuscus (Haldeman)	×	×	×	--	--	--	--	×
Stagnicola exaperata (Say)	?	--	×	--	--	×	--	
palustris (Müller)	×	--	×	--	--	--	--	
n. sp	?	--	×	--	--	--	--	
sp. a	--	--	×	--	--	--	--	
sp. b	×	--	--	--	--	--	--	
Gyraulus circumstriatus (Tryon)	×	--	--	--	--	--	--	
parvus (Say)	×	--	×	--	--	×	×	
Carinifex newberryi (Lea)	×	--	×	--	--	--	--	×
Helisoma anceps (Menke)	×	--	--	--	--	--	--	
subcrenatum (Carpenter)	--	--	×	--	--	--	--	
indet	--	--	--	--	--	×	×	
Promenetus exacuous (Say)	×	--	--	--	--	--	--	
umbilicatellus (Cockerell)	×	--	--	--	--	×	×	
Ferrissia indet	×	--	--	--	--	--	--	
Physa indet	×	--	--	--	--	--	×	
Land snails:								
Pupilla muscorum (Linnaeus)	×	--	--	--	--	--	--	
Vertigo gouldii (Binney)	×	--	--	--	--	--	--	
Vallonia cyclophorella Sterki	×	--	--	--	--	--	--	
gracilicosta Reinhardt	--	--	--	--	×	--	--	
cf. *Succinea*	×	--	×	--	--	--	--	
Discus cronkhitei (Newcomb)	×	--	--	--	--	--	--	
Retinella indet	×	--	--	--	--	--	--	
Hawaiia minuscula (Binney)	×	--	--	--	--	--	--	
Zonitoides arboreus (Say)	×	--	--	--	--	--	--	

[1] Collections are arranged in approximate order of stratigraphic succession, oldest beds to left, but stratigraphic position of collection 21057 is uncertain; it may be from a gravel younger than American Falls lake beds (Michaud gravel). Locality 19169: basal gravel, SE¼ sec. 3, T. 6 S., R. 32 E.; edge of American Falls Reservoir. Locality 21638: basal gravel, NE¼NW¼ sec. 15, T. 8 S., R. 30 E.; bluff on Snake River. Locality 21057: sand and gravel in lower part of formation, or Michaud gravel, S½NE¼ sec. 3, T. 6 S., R. 32 E.; cliff at edge of American Falls Reservoir. Locality 21642: about 15 feet below prominent white blocky clay layer, NE¼SW¼ sec. 30, T. 7 S., R. 31 E.; cliff at edge of American Falls Reservoir. Locality 21639: about 15 feet below prominent white blocky clay layer, NE¼NW¼ sec. 15, T. 8 S., R. 30 E.; bluff on Snake River. Locality 21643: 10 feet below prominent white blocky clay layer, same location as 21642. Locality 21635: below prominent white blocky clay layer, SE¼ sec. 9, T. 6 S., R. 32 E.; cliff at edge of American Falls Reservoir. Locality 14858: prominent white blocky clay layer, SW¼NE¼ sec. 21, T. 6 S., R. 32 E.; cliff at edge of American Falls Reservoir.

just east of Bannock Creek, it is composed mainly of cobbles. Still farther east it is bouldery, and at Pocatello it is made up mostly of large boulders. Thickness of the Michaud gravel in the American Falls quadrangle is variable but averages about 15 feet.

The gravel is probably deltaic in character and was deposited in and along the shore of the late Pleistocene American Falls lake by spillover water from glacial Lake Bonneville. According to D. W. Taylor (written communication, 1960)—

> the Michaud gravel has yielded only a small molluscan fauna. All of the species occur also in the American Falls lake beds and other late Pleistocene deposits, and are species of perennial freshwater bodies.

GRANDVIEW TERRACE DEPOSITS (PLEISTOCENE)

A terrace surface that is well developed below the upland west of Aberdeen was named the Grandview-Pingree terrace by agronomic soils scientists (Poulson, Nelson, and Poulson, 1943, p. 5). Deposits of silt and sand forming this surface are here called Grandview terrace deposits. The west boundary at the back of the terrace is determined in many places by the base of a scarp at an altitude of 4,450 to 4,460 feet. The front of the terrace is marked by another scarp that is very well defined locally. The Grandview terrace forms a continuous surface from a point about 3 miles southwest of Aberdeen to the northern margin of the area. Two remnants of the terrace lie farther south, 4 miles and 5.5 miles northwest of American Falls.

The deposits of the Grandview terrace are tan, brown, or pinkish brown, consist mostly of silt and fine sand, and locally contain noticeable amounts of heavy minerals, and are unconsolidated and unbedded to locally well bedded. The physiographic position of these deposits beneath a rather easily recognizable terrace surface permits their delineation, although in large part they differ but little from the loess to the west. The deposits are 10 to 40 feet thick.

The Grandview terrace deposits probably are marginal deposits of the late Pleistocene American Falls lake, possibly including fine-grained equivalents of the Michaud gravel, with some colluvial and eolian capping material.

ABERDEEN TERRACE DEPOSITS (PLEISTOCENE)

The Aberdeen terrace, also named by Poulson, Nelson, and Poulson (1943, p. 5), is widely developed on both sides of the American Falls Reservoir, and is underlain by clay, silt, sand, and local sparse gravel. The base of a well-defined scarp with a persistent altitude of 4,420 to 4,430 feet separates the Aberdeen terrace from the Grandview terrace on the west, and from the Michaud gravel east of the reservoir. The terrace surface is nearly flat and over much of its extent is about 4,400 feet in altitude. The terrace deposits rest on American Falls lake beds or Big Hole basalt on both sides of the reservoir, but south of American Falls they are underlain by Tertiary rocks, and the Little Creek and Raft formations. Big Hole basalt crops out extensively through the Aberdeen terrace deposits, and this resistant underlying basalt may have controlled, in part, the temporary base level that determined the terrace. The lack of gradient on the scarp base bounding the back of the terrace suggests that it is a lacustrine wave-cut scarp. The Aberdeen terrace and its deposits therefore probably record a change from lacustrine to fluvial conditions.

The Aberdeen terrace deposits underlying the front part of the terrace just west of the reservoir consists mainly of fluvial crossbedded sand with a thin layer of pebbles at the base. At other places, mostly on the back part of the terrace, the deposits are a silty alluvium or parallel-bedded fine sand, silt, and clay. The deposits west of the reservoir are 5 to 10 feet thick.

East of the reservoir, the deposits of the Aberdeen terrace consist mainly of a pebbly sandy silt overlying pebble to cobble gravel. In most places in the adjoining Michaud quadrangle, the Aberdeen terrace deposits cannot be distinguished from the Michaud gravel except by topographic position, because they are in part reworked from the Michaud gravel. The Aberdeen terrace deposits contain a few mollusks of late Pleistocene age like those of the Michaud gravel.

STERLING TERRACE DEPOSITS (PLEISTOCENE)

The lowest and youngest extensive terrace formed in the area was named the Sterling terrace by Poulson, Nelson, and Poulson (1943, p. 5). It is present only in the northeastern part of the quadrangle where its deposits overlie the Big Hole basalt, on which most of the terrace is cut. The Sterling is separated from the Aberdeen terrace by a locally well defined scarp with a base at 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.

OLDER ALLUVIUM (PLEISTOCENE)

Alluvial deposits, mainly of Pleistocene age, that cannot be referred to any of the foregoing terrace deposits with any degree of confidence are mapped as older alluvium. This unit is mapped along the east side of the reservoir between the American Falls Dam and the mouth of Sunbeam Creek, and along the Snake River downstream from the dam.

The older alluvium is mainly gravel that probably has been reworked downward from older deposits, and probably originally from the Michaud gravel. Locally it contains abundant angular fragments of Walcott tuff, but most of the gravel is derived from Paleozoic chert, quartzite, and carbonate rock.

Vertebrate and molluscan fauna of late Pleistocene age occur in the older alluvium. The mollusks are indistinguishable from those of the Michaud gravel and other late Pleistocene deposits. Gazin (1935, p. 297–307) described a varied collection of vertebrates from these gravels at the east end of the American Falls Dam.

DUNE SAND (RECENT)

Longitudinal sand dunes in a northeastward-trending belt overlie the Aberdeen terrace, Big Hole basalt, and loess in the American Falls quadrangle between the Snake River and a nearly straight northern margin ending near the mouth of Spring Hollow.

The sand is mainly quartz with a few basalt fragments. It was probably derived from fluvial sand of late Pleistocene age in channeled areas to the southwest. The dunes are still active and are therefore of Recent age.

ALLUVIUM (RECENT)

Alluvial deposits cover the bottoms of small valleys in the area, such as Sunbeam Creek, and form islands and bars in and along the Snake River. The Recent alluvium is mainly sand and gravel along the Snake River, but it is finer grained in the smaller drainage courses. Much of the Recent alluvium cannot be shown at the scale of the map.

LATE QUATERNARY HISTORY OF THE SNAKE RIVER

Little is known of early Pleistocene history in this part of the Snake River valley, but for events of middle or late Pleistocene time there is considerable geologic and geomorphic evidence that suggests an interesting and rather complex history (Trimble and Carr, 1961).

After the Raft formation was deposited, a shallow ancestral Snake River valley was cut, perhaps as the result of bypassing of a lava dam that caused the deposition of part of the Raft. This valley, cut mainly in the Raft formation, was probably about 2 miles wide in the vicinity of American Falls. Local base level was about 4,320 feet above sea level and the gradient was very low. A thin but persistent alluvial gravel was deposited on the floor of this valley, possibly in Illinoian time.

Big Hole basalt erupted from several vents northwest of the Snake River valley and flowed over a large area, reaching the margins of the valley. The river may have been dammed by these lavas, but, if this occurred, the dam was quickly bypassed.

Later eruption at Cedar Butte (pl. 3) and associated vents north of the Snake River and about 11 miles southwest of American Falls, however, built up a low shield and filled the Snake River valley with basaltic lava for a distance of at least 8 miles. These flows abutted against the Big Hole basalt on the north, and extended upriver to a point within about 2 miles of the American Falls quadrangle. The upper surface of the lavas sloped gently upstream. The altitude of this surface between the vent area and Massacre Rocks was a little over 4,450 feet, and at the upstream edge its altitude was probably about 4,370 feet. The basalt dammed the river and water was impounded to a maximum level of about 4,450 feet above sea level. This level probably was determined by the altitude of the surface of the basalt at its northern and southern margins, the places where the water spilled westward. The elevation of these two points of spillover was evidently about the same.

The American Falls lake beds were deposited in the lake thus formed, accumulating to an altitude of about 4,400 feet. Soon after this time, glacial Lake Bonneville spilled over through Red Rock Gap (fig. 1) about 50 miles southeast of Pocatello, and the discharge of a large volume of water probably cut down the gap rather rapidly. The outflow descended northward by way of Marsh Creek into the Portneuf River and entered the American Falls lake near Pocatello, where it deposited the Michaud gravel as a deltaic deposit on the American Falls lake beds. Large boulders, as much as 7 feet in diameter, compose the gravel at Pocatello where the discharge entered American Falls lake, but the grain size decreases rapidly northwestward on Michaud Flats (fig. 2). The level of the American Falls lake may have been near maximum at the time of spillover of Lake Bonneville, but subsequently, as the level of the lake fell, owing to downstream channeling of the lava dam, the finer gravel, pebbles, and cobbles were moved westward along the shore of the lake nearly as far as American Falls.

The initial spillover of Lake Bonneville may have been caused by diversion of the Bear River from the Snake River drainage system into the Bonneville Basin (R. C. Bright, written communication, 1960). A radiocarbon date of 32,500±1,000 years B.P. (U.S. Geological Survey, Washington laboratory No. W–704) was obtained on shells from sediments deposited in a lake caused by this diversion. The lapse of time between this date and spillover of Lake Bonneville, however, has not been determined.

The added volume of Lake Bonneville water greatly increased the American Falls lake discharge, which was soon concentrated in major spillway channels across or around the dam of basalt from Cedar Butte (pl. 3). The lower course of one of these spillways became Lake Channel (pl. 3), 12 miles southwest of American Falls, which received that part of the water diverted north of Cedar Butte. Another spillway was apparently in nearly the present position of the Snake River south of Cedar Butte. Deep channels were formed by receding falls along both these streamways until the Lake Channel stream was diverted into the Snake River channel east of Cedar Butte at about the time that conditions upstream changed from lacustrine to fluvial. The altitude of the point of diversion is about 4,410 feet.

At some time before Lake Channel was abandoned, the level of the American Falls lake was held at an altitude of 4,420 feet long enough so that scarps with a persistent base at that altitude were cut on beds marginal to the American Falls lake beds and on the Michaud gravel. Those scarps form the lower edge of the Grandview terrace in the western part of the area, and the upper edge of the Aberdeen terrace. When the water level receded by lowering of base level across the Cedar Butte basalt, the shallow lake that cut the back of the Aberdeen terrace was replaced by the river that deposited sand

and gravel on the front parts of the Aberdeen terrace. Shells from these Aberdeen terrace deposits have been dated by radiocarbon at 29,700±1,000 years B.P. (U.S. Geological Survey, Washington, laboratory No. 731), which is compatible in a general way with the approximate date for diversion of the Bear River mentioned above.

The falls in the Snake River channel at the time Lake Channel was abandoned probably was between Massacre Rocks and Eagle Rock, about 2 or 3 miles downstream from the eastern margin of the Cedar Butte basalt. The water that formerly flowed out Lake Channel was diverted into the Snake River channel below the main falls, and marginal spillway alcoves were cut southwest of Eagle Rock. Recession of the main falls continued northeastward until the falls nearly reached the edge of the basalt from Cedar Butte; the marginal spillway alcoves were cut and abandoned as the falls receded. The base level of cutting below the falls at this time was about 4,320 feet above sea level.

The Sterling terrace of fluvial origin, with a back part at an altitude of about 4,380 feet northeast of Aberdeen, may have been cut as the result of a temporary base level graded to the surface of the Cedar Butte basalt near its eastern margin.

Breaching of the basalt at the margin permitted rapid downcutting through the soft sediments upstream to a new base level at an altitude of about 4,300 feet. Confinement of the water (which may have included contributions from Lake Bonneville) to the newly cut narrow channel at and below the former dam increased the velocity and the competency of the stream, and bars of huge, locally derived, basalt boulders, some as much as 20 feet in diameter, were built across the mouths of abandoned spillway alcoves downstream. These bars are largest on the north side of the Snake River, 1 mile southwest of Eagle Rock.

If Lake Bonneville spilled over again at a later time, as now seems likely, no good record of the second spillover is preserved in the American Falls area, unless the boulder bars mentioned above can be correlated with this event.

Abandonment of the Red Rock Gap spillway, because of the lowering of Lake Bonneville, and the return to normal volume of the Snake River, reduced the competency of the stream and the boulder bars were no longer built. The stream was established in its present course, and has cut to its present level by normal stream processes since the end of Lake Bonneville overflow.

STRUCTURE

In most of the American Falls quadrangle the structure is relatively simple. Rocks younger than the Raft formation, with the possible exception of the Big Hole basalt, are unfaulted and flat lying, or have only initial dips. The American Falls lake beds show no evidence of faulting or warping. All rocks older than the Raft formation are progressively more deformed, with greater age. Both minor folds and normal faults are present in the southeastern part of the quadrangle, but exposures are very poor in this area.

The dominant structural feature of the Tertiary rocks is a gentle regional dip toward the Snake River (pl. 1). The Walcott tuff and Neeley and Little Creek formations dip 1° to 2° NW in most of the area, but the Starlight formation dips generally between 10° and 35° NW; locally the strike of the Starlight varies from east to about N. 45° W., although the general attitude is about the same as that of the Walcott and Neeley. In the American Falls quadrangle, the vitric-crystal tuff member of the Starlight strikes N. 40° E. and dips about 13° NW. Basalt flows in the lower part of the Starlight along Sunbeam Creek dip more steeply than the overlying vitric-crystal tuff member. Angular unconformities are thus indicated at the top of, and probably within, the Starlight, particularly between the middle and lower members.

The Paleozoic rocks in the Paps Mountain area are disoriented with respect to Paleozoic rocks farther south between Cold and Sunbeam Creeks, and to the rocks in the central Deep Creek Mountains. In the Paps Mountain area the rocks strike nearly east and dip northward about 35° to 40°, an attitude that also contrasts with that of the adjacent Tertiary rocks.

Several small folds have been noted near American Falls. These are gentle northwest-trending synclines and anticlines in the Walcott tuff and Neeley formation. The flanks of these folds dip commonly as much as 8° to 10°, and, locally, more. The basalt over which the Snake River flows at American Falls occupies a valley created mainly, if not entirely, by a rather sharp flexure in the Walcott tuff and underlying beds and not by erosion or faulting as seems likely at first observation. Some of the minor flexures in this area are well shown by the fence diagram (fig. 3).

Faults in this area and in the northeastern part of the Rockland quadrangle are clearly divisible into two major sets (pl. 1), one trending N. 10° to 20° W., the other N. 25° to 65° E. A few small faults strike northward to N. 15° E. In some places, faults of the northwest-trending set appear to offset those of the other set, but such a relation cannot be proved consistent. As far as is known, all the faults are normal and the throw on most of them is small, generally a few hundreds of feet or less.

One of the more obvious structural features of the area is the northwest-trending Ferry Hollow graben (pl. 2). Its bounding faults, which are well exposed in the bluffs along the south side of the Snake River, can be traced at least 5 miles south of the quadrangle where they appear to be continuations of the fault system along the west margin of the Deep Creek Mountains. The displacement on these faults in the Ferry Hollow area is only about 50 feet.

Topography and adjacent rocks suggest that Sunbeam Creek is controlled by a prominent fault system (pl. 1) of the northeast-striking set. It is paralleled by several faults in upper Ferry Hollow and in the southeast corner of the quadrangle. Some of the faults of this group probably dip southeast, but the fault surfaces are not exposed.

The northeastward-trending set of faults also parallels the edge of the Snake River Plain, and may have been an important factor in its formation. We believe that this set of relatively small faults in the American Falls quadrangle may reflect recurrent movement on a major fault system striking about N. 45° E., whose main part probably passes between American Falls and Lone Rock. Additional evidence that such a fault zone exists in the Starlight formation and older rocks are: (1) the linear alinement of scattered vitrophyre outcrops and accidental ejecta of vitrophyre in younger volcanic rocks bordering the Snake River from the north end of the Sublett Range (15 miles southwest of American Falls) to at least the north end of the Bannock Range (20 miles northeast of American Falls); (2) attitude of flow lines in this vitrophyre, which near American Falls is mainly an intrusive rock, indicating bodies having a long dimension that trends northeastward; (3) highly brecciated and silicified character and probable northeastward trend of Paleozoic rocks in Lone Rock; and (4) a strong positive gradient toward the Snake River in the American Falls area indicated by gravity data (W. E. Bonini, written communication, 1959).

The foregoing evidence suggests that the Snake River Plain is not formed entirely by simple downwarp, as suggested by Kirkham (1931b), but is controlled in part by faulting along its edges. Much more work in areas of better exposure needs to be done, however, before the structure of the plain can be adequately interpreted.

Most of the observed displacement on faults in the American Falls quadrangle probably represents late Pliocene or early Pleistocene recurrent movement on preexisting faults, of which those trending northwestward are probably related to the Basin and Range episode of faulting. Faults that cut the Starlight formation generally show greater displacement than those that cut the younger formations, and some of the younger faults cut the Walcott tuff but not the Little Creek formation. The northwest-trending set closely parallels the margins of Rockland Valley, and the northeast-trending set appears

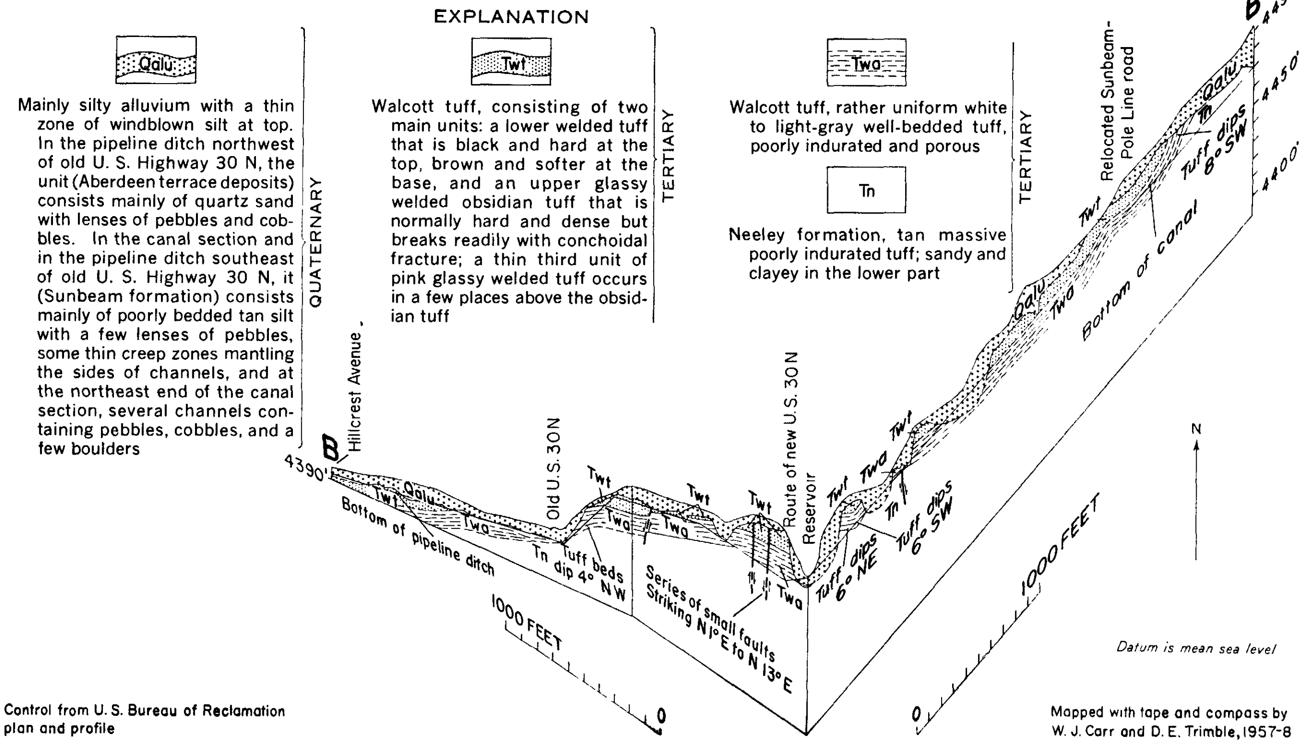

FIGURE 3.—Fence diagram of sections along part of Michaud Flats irrigation project pipeline ditch and canal, southeast of American Falls, Idaho.

to be parallel to some of the larger faults in the Paleozoic rocks of the the central Deep Creek Mountains, and to the southern margin of the Snake River Plain. Thus there has been faulting at several periods in the area, and indirect evidence suggests that the major part of the faulting that parallels and was partly responsible for the Snake River Plain, occurred in or before middle Pliocene time but after the main Basin and Range faulting, which cannot be accurately dated at present. According to H. E. Malde (written communication, 1959), the period of major subsidence of the western Snake River Plain probably occurred in early or middle Pliocene time.

ECONOMIC RESOURCES

Sand and gravel, crushed rock, and ground water are the only earth materials of present economic importance in this area, although uses may eventually be found for silicic pumice and tuff and diatomaceous clay. The sand and gravel has been exploited to a small extent, and ground water is now being utilized for irrigation, especially in the northwestern part of the area above the High Line canal.

SAND AND GRAVEL

Gravel has been obtained from pits in the older alluvium, the Aberdeen terrace deposits east of the Snake River, the Michaud gravel, and the Sterling terrace deposits. The Michaud gravel of this area is too fine grained to be satisfactory, but farther east it is a major source of gravel. The only gravel west of the reservoir is in small deposits of the Sterling terrace. A little gravel from this source was obtained in the past from pits on the Sterling terrace about 4 miles northeast of Aberdeen, and prospecting in this area might disclose a few more similar deposits.

Sand has been obtained from the Aberdeen terrace deposits near the west edge of the reservoir about 2.5 miles southeast of Aberdeen, and an unlimited supply of fine sand is present in the sand dune area west of American Falls.

CRUSHED ROCK

Basalt or limestone and dolomite of the area have not been used as a source of crushed rock to any great extent, but they constitute a vast reserve of material that can be crushed and sized, and utilized for road surfacing and concrete aggregate. Most of the basalt of this area is dense, hard, and unweathered.

GROUND WATER

The ground-water characteristics of most of the rocks of this area are poorly known, but many irrigation wells drilled in the Big Hole basalt in the western part of the area have high yields. The importance of the basalt of the Snake River Plain as an aquifer has been pointed out by Stearns and others (1938, p. 58) and more recently by Crosthwaite (1957, p. 120). Most other units in this area are likely to yield only small to moderate amounts of domestic water (Crosthwaite, 1957, p. 118–119). The gravel at the base of the American Falls lake beds is an important local aquifer, especially along the Snake River opposite Ferry Hollow.

PUMICE AND TUFF

Materials that might be suitable for abrasives or lightweight concrete aggregate are present in the Walcott tuff and Starlight formation of the southeastern part of the American Falls quadrangle and adjoining areas. Friable fine-grained silicic tuff, composed of 85 to 95 percent glass shards, crops out in secs. 3 and 4, T. 8 S., R. 31 E., in upper Ferry Hollow. Pumiceous indurated tuff crops out in this same area (SE¼NW¼ sec. 4). Most of this material contains a notable amount of impurities (heavy minerals and quartz grains), but closer examination might reveal beds of more suitable mineralogy. Very friable pure silicic tuff is known to occur in the lower member of the Starlight formation in the Arbon quadrangle, but beds of this material do not crop out in the American Falls quadrangle. The lower part of the Walcott is fairly pure silicic tuff.

DIATOMACEOUS CLAY

A clay bed averaging about 6 feet thick that underlies many square miles around the American Falls Reservoir is estimated to contain about 70 percent diatoms. In one sample tested, 55 percent of the material was clay size and 41 percent silt size, leaving only 4 percent of the sample 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. This clay bed occurs in the American Falls lake beds (see p. G28).

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