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Upper Cenozoic Stratigraphy of Western Snake River Plain, Idaho

stract: The Snake River Plain west of Twin Idaho, contains a section of upper Cenozoic anic and detrital rocks several thousand feet k. The rocks are entirely continental but extend w sea level, thereby demonstrating regional idence. Based partly on terminology of earlier ifications, these rocks are divided in this paper four broad units: an unnamed sequence of cene age, the Idavada Volcanics, the Idaho p, and the Snake River Group.

The Miocene rocks include thick lava flows of and layers of rhyolite, interbedded with tone, shale, and water-laid silicic pyroclastic rial generally altered to yellow, gray, and n clay. The rhyolite contains conspicuous ocrysts of quartz, sanidine, and oligoclase, and y hornblende and biotite. Several thousand of this unit is exposed in highlands north and of the central lowland, where it is cut by bearing veins and considerably disarranged by -trending faults and folds.

The Idavada Volcanics, locally more than 3000 thick, unconformably overlie the Miocene and consist dominantly of nonmineralized flows of welded ash and beds of vitric tuff. rarely contain quartz or sanidine and contain hornblende or biotite. The Idavada Volcanics large parts of the uplands and are broken by northwest-trending faults that define the central lowland. For the most part, this unit is of early Pliocene age in the western Snake River Plain but contains fossils of middle Pliocene age in the eastern Snake River Plain.

The Idaho Group, at least 3000 feet thick, occupies the central lowland, where the successively younger rocks usually lie in troughs bounded in part by the next older rocks. The group is divided, in ascending order, into the Poison Creek Formation (lower Pliocene), the Banbury Basalt (middle Pliocene), the Chalk Hills Formation (middle Pliocene), the Glenns Ferry Formation (upper Pliocene and lower Pleistocene), the Tuana Gravel (lower Pleistocene), the Bruneau Formation (middle Pleistocene), and the Black Mesa Gravel (middle Pleistocene).

The Snake River Group, which crops out mostly in the eastern Snake River Plain, was formed during entrenchment of the present Snake River canyon. The group is subdivided into formations of comparatively local extent, which are from oldest to youngest: the Madson Basalt, the Sugar Bowl Gravel, the Thousand Springs Basalt, the Crowsnest Gravel, the Sand Springs Basalt, the Bancroft Springs Basalt, the Melon Gravel, and Recent basaltic lava flows.

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INTRODUCTION

General Statement

Since 1954 we have studied the Cenozoic rocks exposed along the Snake River downstream from Twin Falls, Idaho, paying particular attention to stratigraphic relations between Hagerman and Glenns Ferry (Pl. 1). Dwight W. Taylor participated in a substantial part of the field work and independently collected numerous fossils. Altogether, about 1000 square miles have been examined in moderate detail, and about 5500 additional square miles have been mapped in reconnaissance. Traverses on roads outside the mapped area include the region extending as far downstream as Homedale. The geography of this region is described by Freeman, Forrester, and Lupher (1945). In this paper the valley area and marginal plateaus along the Snake River downstream from Twin Falls are identified as the western Snake River Plain. The mountainous areas are usually referred to as highlands or are designated by their proper names. Some areas at intermediate altitudes, chiefly between mountains south of the Snake River, are referred to simply as uplands. The type localities of the geologic units named in this paper are shown in Plate 1; they can be located in greater detail on the U. S. Geological Survey's topographic maps.

During this investigation other workers have made related geophysical and paleontological studies that depend partly on stratigraphy. We therefore summarize our present understanding of the rock sequence, even though our geologic comprehension of the western Snake River Plain is still far from complete.

So little detailed geologic work has been done previously in the western Snake River Plain that most of the terminology used in this paper is new. Furthermore, it has been necessary to redefine some old names and to abandon others. These changes are briefly explained, but most of the observations on which this classification is based will be given later in more comprehensive reports.

Previous Terminology

The early geologists and paleontologists who studied the western Snake River Plain were not in the field concurrently, and exchange of knowledge of the stratigraphic relations consequently suffered. John C. Frémont collected the first fossils (mollusks) from fresh-water deposits near Glenns Ferry (Hall, 1845). Actual geolo[gic] studies date from the exploration of the 40[th] parallel begun by Clarence King in 1867. B[y] about 1920, through the work of Cope (188[3]), Lindgren (1898), Russell (1902), Schrad[er] (1912), Merriam (1918), and Buwalda (192[4]), the rock sequence had been classified, in ascen[d]ing order, into the intertonguing Payette For[]mation (Miocene lake beds) and Columb[ia] River Lava (Miocene basalt); two sets [of] rhyolite lava flows (Miocene and Pliocen[e]); and the intertonguing Idaho Formation (Pl[io]cene and younger lake beds) and Snake Riv[er] Basalt (Pliocene and younger basalt). Th[e] sequence made a section several thousand fe[et] thick.

Development of Present Classification

The Cenozoic rocks of the western Snak[e] River Plain, as the earlier work has shown, a[re] divisible into broad geologic units that differ [in] lithology, age, geographic distribution, and de[]gree of deformation. Although these units ar[e] nowhere displayed in a continuous sequence, partly because of initial irregular distribution and partly because of deformation and erosion during and after accumulation, they can be widely recognized and traced. Discernible sub[]divisions of these broad units, although com[]monly hundreds of feet thick, are usually lenticular or intertongue complexly with other deposits of contrasting lithology; for example, the intertonguing of sedimentary and volcan[ic] rocks. Because of such local stratigraphic com[]plexities and the need for both regional and local terminology, the broader geologic units are ranked as groups and the smaller units a[s] formations. The Cenozoic rocks of the western Snake River Plain are therefore broadly divided into four units: an unnamed sequence of Miocene age, the Idavada Volcanics, the Idaho Group, and the Snake River Group.

These broad units correspond in large part with the rock units of former usage. The Mio[]cene rocks include sedimentary deposits and associated gold-bearing rhyolite and basalt [in] the Owyhee Mountains and along the Payette River. The Idavada Volcanics consist of non[]mineralized silicic latite and rhyolite. The Idaho Group includes younger sedimentary deposits and some interbedded basalt. The Snake River Group corresponds with the prin[]cipal part of the Snake River Basalt but in[]cludes some subordinate sedimentary deposits.

The choice of formations in this region ha[s] been governed as much by areal extent and [stru]ctural relations as by lithology and fossils. [In] continental areas, where the deposits ac[cu]mulate as thick wedges and change facies [later]ally, a rock unit may extend over several [hun]dred square miles, yet disappear or change character a short distance beyond. In order to emphasize the principal geologic events, only those mappable rock units that have considerable extent and structural or geomorphic significance have been classed as formations. Smaller units of local importance generally have been relegated to stratigraphic divisions of lesser rank.

In this, as in most stratigraphic classifications, the younger rocks are subdivided in much greater detail than the older rocks, partly because they are more completely preserved and better exposed, but partly because such subdivision expresses important features in late geologic history (Fig. 1).

SERIES		GROUPS AND FORMATIONS	
Recent			Recent lava flows
Pleistocene	Upper	Snake River Group**	Melon Gravel*
			Bancroft Springs Basalt*
			Sand Springs Basalt
			Crowsnest Gravel*
			Thousand Springs Basalt**
			Sugar Bowl Gravel*
			Madson Basalt
	Middle	Idaho Group**	Black Mesa Gravel*
			Bruneau Formation*
	Lower		Tuana Gravel*
			Glenns Ferry Formation*
Pliocene	Upper		
	Middle		Chalk Hills Formation*
			Banbury Basalt
			Poison Creek Formation
	Lower	(West) Idavada Volcanics* (East)	
Miocene	Upper and Middle		Undifferentiated rocks

* New stratigraphic names
** Old stratigraphic names, redefined

Figure 1. Sequence of Cenozoic rocks in western Snake River Plain

ACKNOWLEDGMENTS

The stratigraphic relations described here are based mainly on geologic mapping, but substantial contributions to the stratigraphy have been made by paleontologists, some of whom

have seen the relations in the field. Those who have studied the fossils include: D. W. Taylor and H. B. Herrington (mollusks); C. W. Hibbard, G. E. Lewis, D. E. Savage, C. B. Schultz, J. A. Shotwell, T. M. Stout, L. G. Tanner, and F. C. Whitmore (mammals); Pierce Brodkorb (birds); D. H. Dunkle, Carter Gilbert, and Teruya Uyeno (fishes); I. G. Sohn (ostracodes); R. A. Scott (wood); Estella B. Leopold (pollen, spores, and seeds); K. E. Lohman (diatoms); and the late R. W. Brown (other remains of plants).

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ROCKS OF MIOCENE AGE

The western Snake Plain is bordered by a variety of clastic, basaltic, and rhyolitic rocks that have yielded fossils of middle to late Miocene age. These rocks are exposed in mountainous areas such as parts of the Owyhee Mountains, the Jarbidge Mountains, the highlands along Goose Creek, the Mount Bennett Hills, and the highlands along the Payette River.

The Miocene rocks consist of an assortment of deposits that intertongue in a complex poorly understood manner. In the Owyhee Mountains and along the Payette River upstream from Emmett, the basal part consists of thick lava flows of basalt that Lindgren (1900, p. 90, 100) correlated with the Columbia River Basalt. In the Silver City district of the Owyhee Mountains the basalt rests unconformably on granite of the Idaho batholith (Lindgren and Drake, 1904) and is overlain by extrusive rhyolitic rocks. Schrader (1912, p. 46) considered this rhyolite to be similar to his old rhyolite in the Jarbidge Mountains, by reason of comparable structural features and ore deposits[1]. The rhyolite at both places is mineralized with gold and silver and contains phenocrysts of quartz, sanidine, and oligoclase. Some also has phenocrysts of hornblende and biotite. In places these rhyolitic rocks intertongue with basalt. In addition to the Owyhee and Jarbidge areas, mineralized rhyolitic rocks have been recognized along Goose Creek (Mapel and Hail, 1959), the Bruneau River (Littleton and Crosthwaite, 1957), and on the north side of the Mount Bennett Hills (Piper, 1926). These rocks resemble some rhyolitic rocks in the Challis Volcanics of south-central Idaho.

Several hundred feet of clastic beds that overlie the basal beds of basalt and mineralized rhyolite were named the Payette Formation by Lindgren (1898, p. 632–634; 1900, p. 97–100, Pl. 8), based principally on exposures along the Payette River near Horseshoe Bend 20 miles north of Boise. Outcrops along the Payette River and along Sucker Creek northwest of the Owyhee Mountains show that these beds consist largely of water-laid silicic pyroclastic material, more or less altered to variegated yellow, gray, and brown clay, but they also include sandstone, shale, and some coal. Along Crane Creek, 12 miles northeast of Weiser, the clastic beds are reported as overlain by at least 1000 feet of basalt correlative with the Columbia River Basalt (Kirkham, 1931, p. 220–221).

The Miocene rocks are considerably deformed by north-trending faults and folds and by younger faults of northwesterly trend.

IDAVADA VOLCANICS

The name Idavada Volcanics is here applied to various nonmineralized silicic volcanic rocks, chiefly welded ash flows but including some bedded vitric tuffs and lava flows, that unconformably overlie the Miocene rocks. The name is taken from Idavada, a place on the railroad near U.S. Highway 93 at the Idaho-Nevada state line, but the typical exposures are 10 miles northwest of Idavada in an escarpment parallel to Salmon Falls Creek (Pl. 1, loc. 1). Farther east, along Goose Creek, the Idavada Volcanics are also well exposed in a section more than 3000 feet thick (Salt Lake and Payette(?) formations of Mapel and Hail, 1959), which overlies gold-bearing rhyolite. Reconnaissance indicates that the Idavada Volcanics extend from Goose Creek westward through the Jarbidge Mountains, where the Idavada lies on mineralized rhyolite. Farther west, in the Owyhee Mountains, the Idavada overlies clastic beds of Miocene age. On the north side of the Snake River a thick section of the Idavada Volcanics, unconformable on granite and older rhyolite, makes up most of the Mount Bennett Hills.

The Idavada Volcanics have been discussed by other writers under a variety of names all of which are herein abandoned. During exploration of the 40th parallel, geologists de-

[1] R. R. Coats, U.S. Geological Survey (written communication, Feb. 3, 1960), recognizes the rhyolite at

Emmons, 1877, p. 498, 502, 520). Russell (1902, p. 42–44) described silicic volcanic rocks north of the Snake River as the Mount Bennett Rhyolite and mentioned that this rhyolite is exposed in the Snake River canyon near Twin Falls, an outcrop that Stearns (1936, p. 435; 1955; Stearns, Crandall, and Steward, 1938, p. 37–42) discussed under the names Shoshone Falls Andesite and Pillar Falls Mudflow. Kirkham (1931) combined the Idavada Volcanics with the older rhyolite under the name of Owyhee Rhyolite. These two rock units are also combined on the geologic map of Idaho, but most of the outcrop mapped in the western Snake River Plain consists of the Idavada Volcanics.

The Idavada Volcanics vary in chemical composition somewhat according to mode of occurrence. The dominant welded ash flows and the less abundant lava flows are nearly all silicic latite, as shown by several chemical analyses to be published later, and contain phenocrysts of andesine, clinopyroxene, hypersthene, and magnetite. Glass in the groundmass is rhyolitic in chemical composition. The ash flows and lava flows characteristically form layers of porphyritic, black, resinous obsidian and thinly banded, lavender and gray felsite. The vitric tuffs, like the glassy groundmass of the ash flows and lava flows, are rhyolitic in composition. They are mixed locally with other clastic material but consist dominantly of massive beds of well-sorted, angular, transparent glass shards having the texture of sand. Unlike the older, gold-bearing rocks, the Idavada Volcanics rarely contain phenocrysts of quartz or sanidine and have no hornblende or biotite.

Although the Idavada Volcanics have a broad regional continuity, they are broken by northwest-trending faults. These faults trend obliquely across the northerly oriented geologic structures that disrupt the Miocene rocks, and they partly account for the present restriction of the Idavada Volcanics to the uplands and mountains north and south of the Snake River. Because the Idavada Volcanics nowhere appear along the Snake River within the topographic basin downstream from Hagerman, the faults are probably related to diastrophism that outlined the present shape of the western Snake River Plain.

Evidence from fossils suggests that the Idavada Volcanics in the western Snake River Plain are early Pliocene and that similar rocks in the eastern Snake River Plain are partly of west of the Owyhee Mountains overlie clastic beds of transitional middle to late Miocene age (Scharf, 1935; Chaney and Axelrod, 1959, p. 112–115) and are overlain by early Pliocene beds of the Poison Creek Formation. Plant fossils collected by R. R. Coats from vitric tuff (Jenny Creek Tuff) in the lowest part of the Idavada Volcanics in the Jarbidge Mountains include *Quercus browni* Brooks and are dated late Miocene (R. W. Brown, written communication, Feb. 15, 1956). However, hornblende-biotite rhyolite tuff at Copper Basin on the southern flank of the Jarbidge Mountains, below an unconformity indicative of prolonged diastrophism and erosion, has yielded plant fossils also regarded as late Miocene (D. I. Axelrod, oral communication to R. R. Coats, U. S. Geological Survey, 1960). Molluscan fossils collected by Coats somewhat higher in the Idavada Volcanics (Couger Point Tuff) in the Jarbidge Mountains include a new species of the land snail *Vallonia* and are dated middle Pliocene (D. W. Taylor, written communication, May 27, 1959). Diatoms, leaves, and seeds have been collected along Goose Creek from the lower part of the Idavada Volcanics (Payette(?) Formation of Mapel and Hail, 1959, p. 224–229). R. W. Brown regarded the leaves and seeds as "latest Miocene in age," but K. E. Lohman dated the diatoms as early Pliocene. Tooth fragments from higher beds in the Idavada Volcanics along Goose Creek (lower part of the Salt Lake Formation of Mapel and Hail, 1959, p. 229–237) were identified by Jean Hough as *Neohipparion*, probably *N. occidentale* (Leidy), of early or middle Pliocene age[2]. Pollen from this part of the section, according to Estella B. Leopold, contains an abundance of *Zelkova* which "suggests a late Miocene rather than a Pliocene age." Mollusks from this part of the section, according to D. W. Taylor, include *Lymnaea albiconica*, *Lymnaea* cf. *L. megasoma* Say, a species of *Valvata*, and an indeterminate planorbid, all of which occur in the middle Pliocene Teewinot Formation of western Wyoming.

IDAHO GROUP

Introduction

Cope (1884, p. 135) applied the name, Idaho Formation, to sedimentary deposits at Castle Creek (Pl. 1, loc. 2) where J. L. Wortmann had collected fossil fish. Cope thought the fish indicated a Pliocene age. Related deposits exposed along the Snake River as far upstream as Hagerman were described by Lindgren (1900, p. 93–99), Russell (1902, p. 51–59), Merriam (1918), Buwalda (1923, 1924), Kirkham (1931, p. 235–239), Stearns (1936), and Stearns, Crandall, and Steward, (1938, p. 52–56). The descriptions indicated that the Idaho Formation of Cope also includes Pleistocene deposits and unconformably overlies rhyolite rocks (Idavada Volcanics). These deposits, comprising clastic beds and intercalated basalt flows, are here divided into seven overlapping formations and are named the Idaho Group. The clastic beds are consolidated, although usually not lithified. They generally range in texture from sand to clay but include some gravel, volcanic ash, and diatomite. The beds form massive, light-colored sequences hundreds of feet thick that commonly erode into badlands.

The formations of the Idaho Group are nowhere exposed in a continuous sequence, and no single locality displays all the lithologies characteristic of the group, but typical exposures occur almost continuously along the Snake River from Homedale to Hagerman and in the lower reaches of the southern tributaries. Especially good outcrops are found along the lower reach of Reynolds Creek 7 miles northwest of Murphy, along lower Castle Creek, along the lower Bruneau River, along the Snake River near Glenns Ferry, and in the canyon wall west of Hagerman. A composite section assembled from these exposures would aggregate nearly 5000 feet thick, but the preserved thickness at any particular locality, because of erosion and local thinning, is necessarily considerably less. However, drilling indicates that the thickness midway between Bruneau and Glenns Ferry exceeds 3000 feet (Littleton and Crosthwaite, 1957, p. 161–163).

The distribution of the Idaho Group suggests that these deposits accumulated in a subsiding basin. In general, in plateaus north and south of the Snake River, the Idaho Group overlaps fault blocks of older rocks, chiefly the Idavada Volcanics, and is represented by the older part of the group; along the Snake River it is represented dominantly by the younger part. This distribution probably resulted from subsidence on faults that bound the basin (Fig. 2). The relations are especially clear be-

successively lower positions topographicall usually in troughs bounded in part by th next older unit.

The seven formations recognized in th Idaho Group are, in ascending order: th Poison Creek Formation, the Banbury Basalt the Chalk Hills Formation, the Glenns Ferr Formation, the Tuana Gravel, the Brunea Formation, and the Black Mesa Gravel. Fossil from these formations range in age from early Pliocene to middle Pleistocene.

Poison Creek Formation

The Poison Creek Formation was named by Buwalda (1923, p. 3) for Poison Creek Grade at the north end of the Owyhee Mountains 9 miles south of Homedale (Pl. 1, loc. 3) and is herein adopted. The name was applied to beds of volcanic ash, clay, and sand that lie unconformably on the Idavada Volcanics and that contain early Pliocene fossil mammals. The best preserved section of the formation is not at Poison Creek Grade, however, where the thickness is less than 100 feet, but in the foothills 7 miles northwest of Murphy along the road that leads to upper Reynolds Creek; here the exposed thickness is at least 400 feet. The Poison Creek Formation also crops out in Sinker Creek 8 miles south of Murphy and along lower Squaw Creek 2 miles east of U. S. Highway 95 near the northern end of the Owyhee Mountains. At these places the Poison Creek Formation lies on tilted and faulted Idavada Volcanics. Near Murphy the formation is overlain by lava flows probably correlative with the Banbury Basalt. Near Homedale the Poison Creek is overlain by the Glenns Ferry Formation.

Most of the Poison Creek Formation consists of siliceous volcanic ash and fine-grained tuffaceous detrital material in massive beds arranged in monotonous sequences, but it includes some layers of locally derived granitic sand and gravel as well as thin beds of basaltic pyroclastic material. The beds are consolidated but usually are not indurated. The formation is somewhat disturbed along zones of faulting within which the coarse-textured beds are opalized and the fine-textured beds are altered to montmorillonitic clay and stained yellow, brown, and green. The massive monotonous beds of volcanic ash and tuffaceous detrital material probably represent lake deposits, but the more thinly bedded, coarse-textured

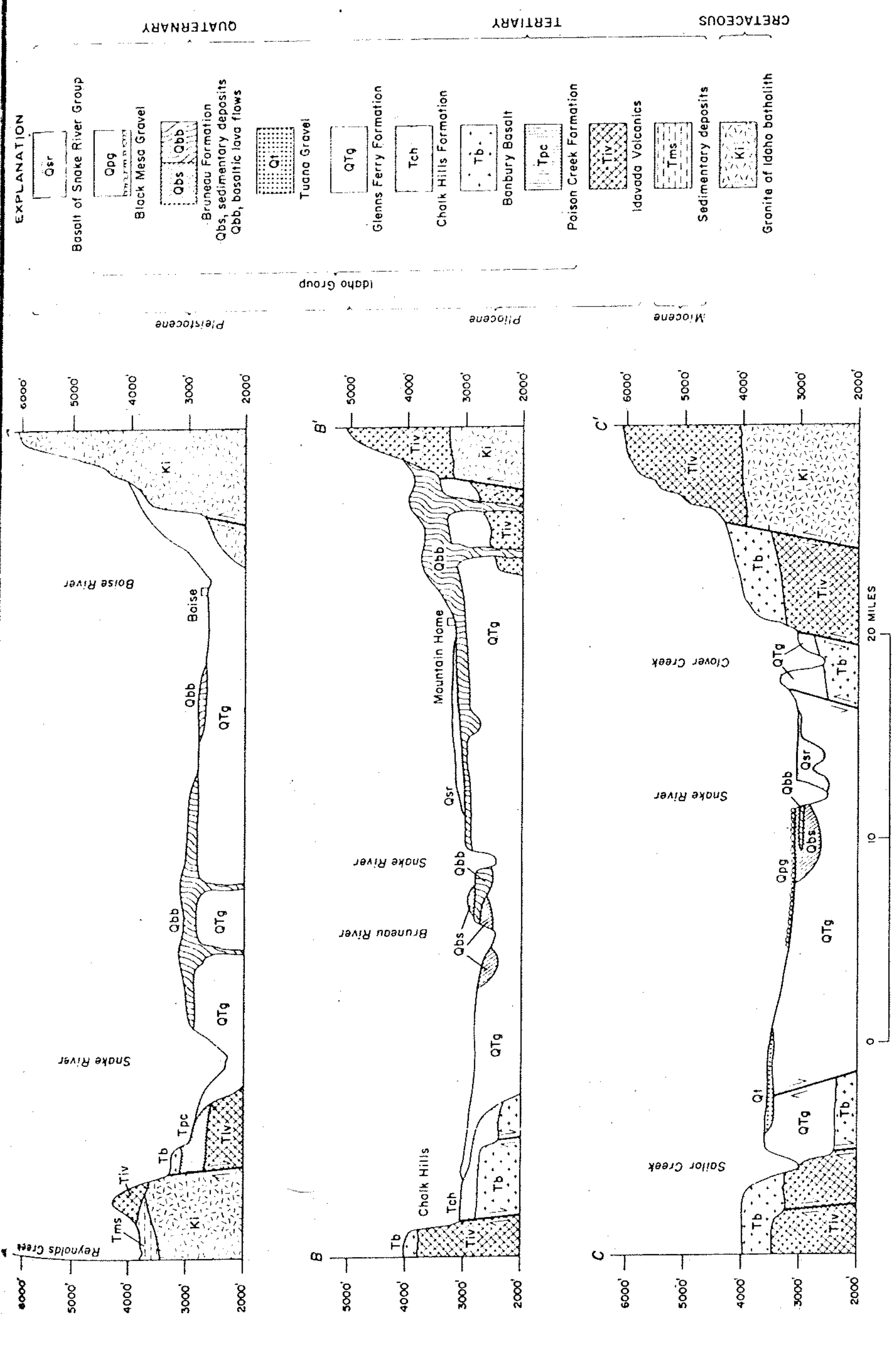

Figure 2. Diagrammatic geologic cross sections in western Snake River Plain along lines shown on Plate 1: *A-A'*, from upper Reynolds Creek through Boise; *B-B'*, from the Chalk Hills through Mountain Home; *C-C'*, from upper Sailor Creek through Clover Creek

the Poison Creek Formation. Mammalian fossils collected by Buwalda (1924) at Sands, an abandoned community at the mouth of Jump Creek Canyon 9 miles south of Homedale, include fragmentary *Hipparion* teeth and rodent teeth that indicate early Pliocene age. A collection from the beds near Reynolds Creek 7 miles northwest of Murphy was examined by J. A. Shotwell who identified teeth of *Hipparion* and a mandible fragment of *Sthenictis* (written communication, Aug. 20, 1959). These specimens resemble forms associated with a large fauna of early Pliocene age studied by Shotwell at Juntura, Oregon, about 70 miles farther west. This relationship, along with a lack of *Pliohippus* in the Idaho collections, suggests to Shotwell that the Poison Creek Formation is early Pliocene.

Banbury Basalt

Stearns (1936, p. 435) named the Banbury Volcanics for exposures near Banbury Hot Springs on the Snake River near the mouth of Salmon Falls Creek (Pl. 1, loc. 4) and applied the term to "massive, dark-brown weathered basalt flows and coarse and fine tuff beds" that extend 60 miles downstream along the Snake River from a place near Twin Falls (Stearns, Crandall, and Steward, 1938, p. 50–51, pl. 5). The Banbury Basalt is now recognized also in uplands north and south of the Snake River as well as at some places farther downstream. North of the Snake River, between Glenns Ferry and Gooding, the Banbury emerges from beneath a cover of younger rocks and forms a dissected upland plateau that extends to the eastern summit ridge of the Mount Bennett Hills. About 15 miles south of the Snake River, between Bruneau and Hagerman, the Banbury rises along a steep escarpment to form a basalt plateau that extends southward for about 40 miles to the foothills of the Jarbidge Mountains. An area of Banbury Basalt about 8 miles south of Bruneau was mapped by Littleton and Crosthwaite (1957, p. 161–162, Pl. 6) as "basalt of Pliocene(?) age." West of Bruneau, exposures of basalt beneath the younger beds of the Idaho Group are intermittent and less well studied, but the faulted and decomposed basalt that overlies the Poison Creek Formation near Murphy is probably stratigraphically equivalent to the Banbury.

The Banbury Basalt, in the type area, is divisible into three parts. The lowest part consists of at least 100 feet of ... olivine basalt that usually occurs as amygdular lava flows about 15 feet thick, although some makes columnar flows about 30 feet thick. The middle part, about 100 feet thick, consists mainly of brownish sand and pebble gravel in lenticular stream deposits but includes some light-colored clay, silt, and diatomite in lake deposits, as well as beds of siliceous volcanic ash. The upper part, in places 500 feet thick, is composed mainly of olivine basalt and some porphyritic plagioclase-olivine basalt in columnar lava flows as much as 50 feet thick. Thin lenticular beds of sand and silt locally separate the flows. The upper part, although considerably weathered, is less decomposed than the lower part.

The base of the Banbury is not widely exposed but probably represents an important unconformity. In the type area, the Banbury lies on faulted Idavada Volcanics that were eroded prior to burial, although residual hills and valleys were preserved. This erosion may have been partly contemporaneous with deposition of the Poison Creek Formation.

The Banbury Basalt is broken by steep northwest-trending faults. Although displacements across some zones of faulting probably exceed a thousand feet, the Banbury is much less deformed than the underlying Idavada Volcanics. The basalt near Murphy is separated from the underlying Poison Creek Formation by a low-angle unconformity and is comparatively less broken by faults.

Thus far, fossils from the Banbury have been identified from a single locality, a bed of diatomite in the middle part of the formation along Clover Creek 16 miles northwest of Gooding. The fossils include two mammals and several fresh-water mollusks. One of the mammalian fossils is a rodent jaw, which is identified by C. W. Hibbard (written communication, Dec. 5, 1959) as *Microtoscoptes disjunctus* (Wilson), previously known only from middle Pliocene rocks in Jackson Hole, western Wyoming, and near Rome, southeastern Oregon. The other mammal is represented by a castorid tooth which T. M. Stout (written communication, June 28, 1960) has identified as follows:

"The specimen is a loose right M¹ or M² that I refer to *Dipoides stirtoni* Wilson. It is nearly identical to the right M¹ in a skull of *Dipoides fricki* from near Cambridge, Nebraska. It also compares well with the specimens in the U.S.G.S. collection from Jackson Hole, Wyoming. The typical material of *Dipoides stirtoni* is from Rome, Oregon. I would ... be equal in age to what we call late Pliocene in Nebraska; that is, equivalent to the Sidney Member of the Kimball Formation in the uppermost part of the Ogallala Group."

The mollusks were studied by D. W. Taylor (written communication, Dec. 10, 1959) who reports nine species that are similar to specimens from the middle Pliocene of Jackson Hole.

Chalk Hills Formation

The Chalk Hills Formation is here named for the Chalk Hills, an area of badlands at the head of Little Valley 14 miles southwest of Bruneau (Pl. 1, loc. 5) where the formation is about 300 feet thick. The Chalk Hills Formation is continuously exposed as badlands from Little Valley eastward to the head of Bruneau Valley at Hot Creek 10 miles south of Bruneau. Similar badlands are carved in the formation along the middle reach of Castle Creek and its western tributaries known as Brown Creek and Hart Creek.

The Chalk Hills Formation contains large amounts of siliceous volcanic ash, but the ash is subordinate to other fine-grained detrital material, chiefly silt and sand. The ash is comparatively fresh, although opal has been formed locally. The detrital material and volcanic ash are consolidated and make variegated sequences of white, brown, pink, and gray beds ranging in thickness from 5 to 10 feet. Because the beds display considerable lateral continuity, they may have accumulated in a shallow lake, but the abrupt vertical changes in texture and color imply the action of streams.

Structural relations indicate a moderate hiatus at the base of the Chalk Hills Formation. At the type locality and at the head of Bruneau Valley, the Chalk Hills Formation rests on faulted Banbury Basalt, which is not eroded noticeably. At Castle Creek, the Chalk Hills overlies the Idavada Volcanics. Farther west, between Sinker Creek and Murphy, as much as 100 feet of the Chalk Hills is preserved on eroded basalt that is probably correlative with the Banbury. Later deformation has tilted the formation at low angles and has created some gentle open folds. Ordinarily, the beds dip northward toward the Snake River, but some are inclined toward the south.

Mammalian and Molluscan fossils have been collected at several places in the Chalk Hills Formation. A few fragments of camel and *Hipparion* from exposures at the head of Little Valley ... age (J. A. Shotwell, written communication, Nov. 17, 1958), but larger collections of mammals from Hot Creek are dated by Shotwell (written communication, Aug. 20, 1959) as middle (possibly late middle) Pliocene. In addition to fragmentary specimens of camel, rhinoceros, citellid rodent, and *Hipparion*, these collections include teeth of the beaver *Dipoides*, one specimen being closely related to *D. stirtoni* Wilson from middle Pliocene rocks at Rome, Oregon, and another being similar to *D. wilsoni* Hibbard from late Pliocene rocks at Saw Rock Canyon, southwestern Kansas. The same specimens are identified by T. M. Stout and G. E. Lewis (written communications, May 4 and June 28, 1960) as "*Dipoides*-like castorids of middle to late Pliocene age." The fresh-water mollusks have been studied by D. W. Taylor (written communication, Dec. 10, 1959), who identified three species of clams and six species of snails. None of these is found in the collection from the underlying Banbury Basalt or in the middle Pliocene rocks of western Wyoming. The Chalk Hills mollusks were collected in the Castle Creek area by Taylor and N. R. Anderson, University of Puget Sound, and at Chalk Hills by Taylor and R. T. Littleton, U. S. Geological Survey. Taylor reports that these collections contain several distinct species; namely, a clam *Anodonta decurtata* Conrad and new species of the snails *Valvata*, *Vorticifex*, and *Carinifex*. Taylor reports that the remaining snails consist of two species of *Lithoglyphus* and one species of *Gyraulus* that are either closely related to, or identical with, species from a locality in Sand Hollow 16 miles southwest of Vale, Oregon (Henderson and Rodeck, 1934), which are dated as middle Pliocene from remains of the beaver *Dipoides* (J. A. Shotwell, oral communication, 1959). The clam *Sphaerium* in these collections is represented by one or two species that occur also in the overlying Glenns Ferry Formation. Based on the mollusks, Taylor dates the Chalk Hills Formation as late middle Pliocene.

Several other fossils have been reported from the Chalk Hills Formation. At Little Valley, Russell (1902, p. 56–57) found internal casts of the snail *Carinifex* (his *Cannifex*), together with abundant fossil wood, a few fish bones, and fragmentary mammalian remains. The toe bone of *Morotherium* reported by Russell has been reidentified by F. C. Whitmore (written communication, Mar. 31, 1960) as a small species of the sloth *Megalonyx*. Some unusual plant remains from the Chalk Hills Formation have also been described. A fungus at a locality about 6 miles southwest of Bruneau, associated with fossil wood of fir, alder, poplar, oak, and hickory, was described by Brown (1940) as *Fomes idahoensis*. Brown thought the hickory indicated a much moister climate than the present climate and an age not younger than early Pliocene. A number of fossil pine cones have been collected from the Chalk Hills Formation at Little Valley and along Castle Creek (Russell, 1902, p. 57). The cone described by Knowlton, (1901) as *Pinus lindgrenii* may possibly have been derived from this formation, although it has not been compared with specimens of known source.

Glenns Ferry Formation

General features. The Glenns Ferry Formation is here named for Glenns Ferry where clastic deposits that characterize the formation are exposed both north and south of the Snake River and for some miles upstream and downstream (Pl. 1, loc. 6). The typical exposures begin 11 miles east of Glenns Ferry at the junction of Hog Creek and Clover Creek and extend westward along the canyon walls of the Snake River to Indian Cove, 14 miles west of Glenns Ferry. From the type area the Glenns Ferry is exposed continuously upstream as far as the canyon wall west of Hagerman where the formation includes part of the Hagerman Lake Beds as used by Stearns (1936, p. 435). Hagerman is a valid name for a large local vertebrate fauna collected west of Hagerman, but the Hagerman Lake Beds are here abandoned as a formal stratigraphic unit, because abrupt lithologic changes and poor exposures make these beds unmappable beyond Hagerman, although they are a recognizable sedimentary facies duplicated in several other parts of the Glenns Ferry.

The Glenns Ferry Formation crops out almost continuously westward as far as Homedale and is extensively exposed in badlands south of the Snake River. Evidence from fossils suggests that stratigraphically equivalent deposits may be present from Boise to Ontario and Weiser (D. W. Taylor, written communication, Feb. 4, 1960). Thus, the area covered by the Glenns Ferry embraces several thousand square miles. The exposed thickness of the formation in the type area is about 2000 feet.

The Glenns Ferry Formation is a collection of nonindurated, complexly intertonguing, lake and stream deposits of

thickness. The varieties of deposits are conveniently discussed as facies, although not all outcrops are uniquely assignable to a particular lithologic type. Three principal facies are recognized: lacustrine, fluviatile, and flood-plain. These facies are rarely continuously exposed, and their intertonguing relations have been determined only by detailed stratigraphic study. Even so, many of the relations are still poorly understood.

The lacustrine facies is greatest in volume and in area of outcrop. It is exposed intermittently along the Snake River from Glenns Ferry as far downstream as Homedale and may be present in adjacent eastern Oregon. The facies consists dominantly of massive layers of tan silt, which form drab monotonous outcrops having little lithologic variety but marked by faint, diffuse, gray bands arranged parallel to bedding and spaced several feet apart. Some outcrops contain alternating thin beds of ripple-marked sand and silt. Along the lower reach of Castle Creek, 13 miles northwest of Grand View, the area of a recent unpublished study by N. R. Anderson, University of Puget Sound, the lacustrine facies consists of featureless, pale-yellow silt overlying a basal oölite bed as much as 100 feet thick. Similar oölite occurs at the base of the lacustrine facies south of Grand View and near Murphy; thin beds of oölite also occur at places south of Glenns Ferry. Along Hot Creek, 10 miles south of Bruneau, the base of the lacustrine facies is a bed of algal limestone about 20 feet thick (Littleton and Crosthwaite, 1957, p. 163). Although the silt of the lacustrine facies is nonindurated, the deposits are sufficiently consolidated to stand in cliffs 100 feet high. At Glenns Ferry a section of the lacustrine facies is 650 feet thick.

The fluviatile facies is best exposed in outcrops north and south of the Snake River near Hammett, 9 miles downstream from Glenns Ferry, where the facies is 350 feet thick. It also crops out at the head of Bruneau Valley 8 miles south of Bruneau and is exposed along the paved road 17 miles northwest of Grand View. This facies is composed mostly of thick, evenly layered beds of drab, very pale brownish-gray sand and some silt. Some of the layers are cross-bedded and ripple marked, but bedding planes between layers are parallel. Among the layers of gray and brown sand and silt are some beds of olive silt, dark-olive clay, and paper shale, which are characteristic of the flood-plain facies

exposures in the west wall of the Snake River canyon at Hagerman, but it also crops out at several places as far downstream as Homedale. Some noteworthy exposures are found in the lower reach of Clover Creek about 10 miles east of Glenns Ferry, in the upper part of the northern canyon wall of the Snake River from Glenns Ferry to Hammett, and in the northern canyon wall of the Snake River from the mouth of Bruneau River to the mouth of Castle Creek. The facies consists mostly of fine-grained graded beds 1–3 feet thick composed of calcareous pale-olive silt in the lower part and dark clay in the upper part. Plant fragments are commonly preserved in the dark clay. The graded beds are repeated monotonously and can be traced laterally several thousand feet. Intercalated among the beds of silt and clay are a few layers of sand that rest on scoured surfaces, which are apparently the floors of channels. A few beds consist of paper shale that seems to be largely the decomposed remains of plant fragments. At Hagerman this facies is more than 550 feet thick.

In addition to the principal facies, the Glenns Ferry Formation contains some minor sedimentary deposits that are important locally but of small areal extent. The basal beds along Clover Creek from 8 to 11 miles east of Glenns Ferry consist of 150 feet of massive arkosic sand and fine granitic gravel. Similar arkosic debris also occurs between Clover Creek and Glenns Ferry about 600 feet higher stratigraphically. About 15 miles south of Glenns Ferry a sequence of sandstone, siltstone, and quartzite cobble conglomerate has been cemented with opal. The conglomerate probably once extended westward to the area south of Bruneau, because the younger deposits of that area contain lag concentrates of quartzite cobble gravel.

The Glenns Ferry Formation contains very little material precipitated chemically, other than the minor amounts of oölite and algal limestone, but the lacustrine facies locally contains some secondary gypsum. The most notable gypsiferous beds are in yellow lacustrine silt above the oölite at Castle Creek where the gypsum is associated with thin beds of siliceous volcanic ash.

Volcanic materials occur in the Glenns Ferry in minor amounts. The formation contains several small lava flows of olivine basalt and some beds of basaltic pyroclastic debris. A little siliceous volcanic ash is also present as beds a few inches thick. The siliceous ash is fresh, but

basalt is thoroughly decomposed to basaltic saprolite.

The intertonguing of sedimentary facies in the Glenns Ferry Formation, demonstrated with the aid of volcanic marker beds, involves sequences several hundred feet thick (Powers and Malde, 1961). The lower 400 feet of flood-plain facies at Hagerman grades westward into a lacustrine facies at Deer Gulch 8 miles southeast of Glenns Ferry and into arkosic deposits between Clover Creek and Glenns Ferry. These arkosic deposits are overlain by 650 feet of lacustrine facies at Glenns Ferry. A flood-plain facies in the upper part of the northern canyon wall at Glenns Ferry grades southwestward into the fluviatile facies at Hammett. A flood-plain facies at Castle Creek merges northwestward with yellow silt of a lacustrine facies near the mouth of Sinker Creek, 8 miles distant. Such stratigraphic relations demonstrate the order of beds in local areas, but numerous minor angular unconformities have hindered the establishment of a complete stratigraphic sequence. These unconformities generally do not exceed 3°, but near the edges of the basin they are larger—5°–10°. The areal extent of these unconformities is so broad, and the number of identified marker horizons so few, that the sequence of beds is still poorly known.

Near Glenns Ferry and Hagerman the Glenns Ferry Formation overlies Banbury Basalt, but from the Bruneau River to Sinker Creek the Glenns Ferry lies on the Chalk Hills Formation. Farther west the Glenns Ferry overlies the Poison Creek Formation and basalt correlative with the Banbury. In the type area, the underlying Banbury has been extensively beveled by erosion, although insufficiently to obliterate relief amounting to at least several hundred feet, which was caused by an earlier period of faulting. The underlying Chalk Hills Formation, slightly tilted and folded, is beveled by algal limestone and oölite at the base of the Glenns Ferry Formation. The deformed Poison Creek Formation between Murphy and Homedale is also beveled by the basal beds of the Glenns Ferry. These relations indicate a moderate angular unconformity at the base of the Glenns Ferry Formation, apparently less marked than the unconformities that separate the older units of the Idaho Group.

Fossils and age. Because the fossil assemblages in the Glenns Ferry Formation are they occur, the facies assemblages are summarized separately.

The formation contains a great variety of freshwater mollusks. From studies thus far, D. W. Taylor recognizes 109 species, distributed among 40 genera and 20 families. Only two species, representing two of the families, are terrestrial. Of the 109 species, 87 are restricted to or are characteristic of the lacustrine facies. Concerning these mollusks, Taylor reports as follows (written communication, Feb. 4, 1960):

"Most of the mollusks from the lacustrine facies are prosobranch gastropods of the families Hydrobiidae, Pleuroceridae, and Thiaridae, but *Payettia*, *Vorticifex*, and the peculiar *Orygoceras* are common (Dall, 1924). Nearly all of these lacustrine species are extinct (94 per cent), and a large number of them belong to extinct genera. Although practically all mollusks of this lacustrine assemblage are endemic, the unusual diversity of genera and families suggests that the Glenns Ferry mollusks may have descended from a former diversified lacustrine fauna. In degree of endemism, in the variety of species and genera, and in the great variety of individual forms, the mollusks of the lacustrine facies of the Glenns Ferry Formation are similar to those living in Lake Ohrid, Yugoslavia, and in Lakes Tanganyika and Nyassa, Africa, as well as being similar in these respects to the fossil mollusks from the former Pontian, Dacian, and Levantine basins of southeastern Europe.

"Mollusks of the lacustrine facies of the Glenns Ferry Formation are most closely related to those described by Yen (1947) from Cache Valley, Utah. Closely related species of *Payettia* and *Lithoglyphus*, and new hydrobiids occur in both areas. Other molluscan affinities are less close. New species of *Vorticifex* from the lacustrine facies show affinity to those described by Yen from Utah, as well as to new species of probable middle Pliocene age from the Mitchell Butte quadrangle south of Vale, Oregon, where the genera *Orygoceras* and *Payettia* are also found. The clams *Sphaerium kettlemanense* Arnold and *Gonidea coalingensis* Arnold from the lacustrine facies are otherwise known only from the late Pliocene of the Kettleman Hills, California.

"The mollusks from the lacustrine facies of the Glenns Ferry Formation are thought to indicate a late Pliocene age, because of their relation to mollusks in other areas, and because of the high percentage of extinct forms."

Mammalian fossils are rare in the lacustrine facies, but fossil fish are relatively common. Teeth of a mole found in this facies in the Bruneau River valley have been reported as *Desmana moschata*, similar to species known from the upper Pliocene to Pleistocene of England and Belgium (Littleton and Crosthwaite, 1957, p. 164). A skull and front limb bones of a horse from this facies near Glenns Ferry are identified as *Equus (Plesippus)* cf. *E. (P.) shoshonensis* Gidley by G. E. Lewis, C. B. Schultz, and L. G. Tanner (written communication, June 25, 1957), who believe this horse to be closely comparable to other species of Aftonian age from Garden and Morrill counties, Nebraska. This species is based on numerous skeletons collected at the celebrated locality west of Hagerman, mentioned below. Representatives of six families of fossil fish described by Leidy and Cope (Cope, 1884, p. 153–165) from the lacustrine facies along Castle Creek include a salmonlike fish of the genus *Rhabdofario* and a mollusk-eating cyprinid of the genus *Mylocyprinus*. Miller (1958, p. 194) mentions a catfish of the genus *Ictalurus* not now native to this part of the Pacific slope and a sunfish of the genus *Lepomis* now restricted to eastern North America. Cyprinid fishes also are found near Glenns Ferry (Uyeno, 1961).

The fluviatile facies of the Glenns Ferry Formation has yielded a great many molluscan and a few mammalian fossils. This facies contains eight species of mollusks that have not been found elsewhere in the formation as well as other species that occur also in the lacustrine and flood-plain facies. Taylor reports (written communication, Feb. 4, 1960) that the characteristic forms include new species of *Lithoglyphus* and *Pleurocera* together with *Lithoglyphus weaveri* (Yen). He regards the molluscan fauna of the fluviatile facies as "latest Pliocene or earliest Pleistocene" (written communication, Aug. 24, 1960). The Shell Mountain locality of Russell (1902, p. 54–56) and the Hammett locality of Yen (1944) are probably close to, or identical with, an outcrop of the fluviatile facies south of Hammett in which Hibbard and Taylor report fossil mammals and mollusks (Hibbard, 1959, p. 19–22, locs. 19128 and 19129). The few mammals include two species of voles: *Pliophenacomys idahoensis* Hibbard, which is regarded as more advanced than *P. primaevus* Hibbard from the late Pliocene Rexroad Formation of southwest Kansas; and a species of *Pliopotamys* which is different from *P. minor* (Wilson) of the flood-plain facies of the Glenns Ferry Formation at Hagerman. The first appearance of *Pliopotamys* in the Great Plains is in the early Pleistocene. The horse *Plesippus* is also recorded at the Hammett locality.

The flood-plain facies of the Glenns Ferry

Formation locally contains numerous molluscan and vertebrate fossils. Altogether the exposures at Hagerman have yielded 26 species of freshwater mollusks, most of them from the part which is laterally equivalent to a lacustrine facies at Deer Gulch. Taylor reports (written communication, Feb. 4, 1960) that 13 of these species are extinct and that they include representatives of two extinct genera and one extinct family.

Vertebrate fossils have been collected at several localities from the flood-plain facies. A few vertebrates have been found at Hagerman in the lower exposures that are laterally equivalent to the lacustrine facies at Deer Gulch (Hibbard, 1959, locs. 19217 and 20765), but the principal collections are from the "Hagerman horse quarry" in beds stratigraphically higher. The vertebrate remains found at the horse quarry include those of shrew, gopher, vole, weasel, otter, rabbit, peccary, camel, antelope, horse, and mastodon, as well as those of fish, reptiles, and birds. This vertebrate assemblage was considered by Gazin (1936) to be late Pliocene and comparable to the Blanco local fauna of Texas. Subsequently, some authorities have correlated the Blanco with the Villafranchian of Europe, which was defined as lower Pleistocene at the 18th International Geological Congress. C. B. Schultz, L. G. Tanner, and G. E. Lewis (written communications, May 6 and June 25, 1957) date the Hagerman fauna early Pleistocene, as does Hibbard (1959). The flood-plain facies in the lower reach of Clover Creek is stratigraphically below the Hagerman horse quarry, as shown by an intercalated lava flow, and grades southward into the lacustrine facies at Deer Gulch. Mammal remains found in the Clover Creek exposures are identified by Schultz, Tanner, and Lewis (written communications, May 6 and June 25, 1957) as the metapodial of a large Pleistocene bear such as *Arctotherium* sp. and as fragments of the upper and lower dentition of a horse that falls within the range of variation of specimens of *Plesippus* from the Hagerman horse quarry. Rodent and other mammalian fossils from a flood-plain facies at Jackass Butte, 13 miles downstream from Grand View, were considered by Hibbard (1959) to be middle Pleistocene, but on the basis of analyses of very large collections made in 1958 at Jackass Butte, J. A. Shotwell (written communication, May 1, 1959) believes that the Jackass Butte and Hagerman vertebrates are probably paleontologically equivalent.

Diatoms approximately contemporaneous with the vertebrate remains at the Hagerman horse quarry include 72 species and varieties, of which about one-half occur in the Pliocene and Pleistocene(?) Tulare Formation of California, according to K. E. Lohman (written communication, Sept. 19, 1957).

A beaver tooth found in a conglomeratic sequence 15 miles south of Glenns Ferry is identified by T. M. Stout (written communication, Oct. 30, 1959) as ?"*Castor*" cf. "*C.*" *californicus* Kellogg of early Pleistocene age.

The various facies also contain ostracodes and plant remains such as wood, pollen, spores, and algae that are significant ecologically.

The age of the Glenns Ferry Formation is uncertain. Its mollusks are interpreted as largely late Pliocene and its vertebrates as early Pleistocene, despite the apparent intertonguing of sedimentary facies containing both. Until the conflicting ages are resolved and until the stratigraphic relations within this formation become better known, the Glenns Ferry is assigned to the late Pliocene and early Pleistocene.

Tuana Gravel

The Tuana Gravel is here named for Tuana Gulch, a tributary valley that drains the upland plains west of Hagerman. The name is applied to a typical sequence of brown and gray beds of pebble gravel, sand, silt, and clay in Indian Butte, a prominence along Tuana Gulch 10 miles southwest of Hagerman (Pl. 1, loc. 7). Here the Tuana Gravel is 200 feet thick. Eastward and northward from Indian Butte, the Tuana extends to the bluffs of the Snake River, where the base of the gravel is about 600 feet above river level. Southward the Tuana extends to the upland plains drained by the lower reach of Salmon Falls Creek. The name is applied, also, to a patch of pediment gravel in the upland drained by the Bruneau River. This gravel extends northward from the upland plains to an eroded terminus 850 feet above the Snake River 6 miles southeast of Bruneau.

Exposures of Tuana Gravel at Indian Butte and along the upper canyon wall of the Snake River west of Hagerman show that the formation is well bedded and that individual beds are well sorted. At least five beds of gravel are preserved, and these consist dominantly of pieces of welded tuff from the Idavada Volcanics. The brown sand, silt, and clay between the gravel beds are apparently subaerially weathered and commonly contain secondary carbonates. The pediment gravel southeast of Bruneau consists of cobbles and boulders of quartzite mixed with finer gravel from the Idavada Volcanics.

In the area drained by Tuana Gulch the Tuana Gravel overlies beds of the flood-plain facies of the Glenns Ferry Formation, which are truncated at the base of the Tuana by an angular unconformity that dips gently northward at an average gradient of 15–20 feet per mile. The base of the pediment gravel southeast of Bruneau dips northward at a similar gradient and also truncates the Glenns Ferry Formation. The eroded upper surface of the Tuana Gravel is marked by a cap of hard caliche several feet thick.

The only fossils found thus far in the Tuana Gravel were collected 3½ miles north of Indian Butte. R. A. Scott (written communication, Jan. 14, 1959) identified wood from this locality as *Quercus* sp., belonging to the white oak group, and G. B. Schultz, L. G. Tanner, and G. E. Lewis (written communication, June 1, 1959) identified fragments of leg and foot bones from the same locality as a "proboscidean (probably mastodontoid)" of Pleistocene age. Because of relations to other units of the Idaho Group, the Tuana Gravel is regarded as early Pleistocene.

Bruneau Formation

The Bruneau Formation is here named for the town of Bruneau, near which the lake and stream deposits and basaltic lava flows characteristic of the formation are well exposed. The typical exposures begin east of the mouth of Bruneau River about 9 miles northwest of Bruneau and extend southeastward to the pediment gravel 6 miles southeast of Bruneau (Pl. 1, loc. 8). The thickest sections of the Bruneau Formation lie close to the present course of the Snake River and outline an ancient canyon fill about 800 feet thick. Sedimentary deposits of the canyon fill are exposed from the type area upstream to Hagerman and downstream to the vicinity of Murphy. The canyon fill farther downstream is largely eroded or concealed by younger deposits. Basaltic material of the Bruneau Formation forms a canyon fill more than 1000 feet thick near the mouth of Sinker Creek east of Murphy and a fill 500 feet thick at Crane Falls on the Snake River north of Bruneau. Basaltic lava flows also mantle the plateau that extends

River. Other volcanic rocks of the Bruneau occur on the dissected plateaus north and east of Glenns Ferry.

In the canyon wall west of Hagerman, the Bruneau Formation lies against a steep former canyon wall eroded in the Glenns Ferry Formation and in the overlying Tuana Gravel. Caliche fragments derived from a calcareous soil developed on the Tuana are preserved in colluvium at the base of the Bruneau. At Bruneau, the formation similarly lies against a steep slope eroded in the Glenns Ferry and in the overlying pediment gravel. Material from the pediment gravel has been reworked into the Bruneau. Although the Tuana Gravel and Bruneau are not in actual contact, these relations show that the Bruneau is stratigraphically younger.

The sedimentary deposits and volcanic rocks that comprise the Bruneau are extremely lenticular because of the damming of the former canyon by lava flows and the impounding of sediments at various places. The formation contains numerous unconformities which indicate that the lava dams were periodically breached, causing erosion upstream. These unconformities cannot be traced far, and correlation of the canyon-filling sequences is poorly understood, even though the stratigraphic relations from Bruneau to Hagerman have been worked out in some detail.

Sedimentary deposits of the Bruneau Formation consist mainly of lake beds but include minor amounts of fine-grained stream deposits and pebble gravel. The principal component of the gravel is material from the Idavada Volcanics. The lake beds between Bruneau and Hagerman lie mainly south of the Snake River where they rise to a uniform altitude of 3200 feet. The base is graded upstream from 2450 feet altitude at the mouth of the Bruneau River to 2700 feet at Hagerman. These beds consist dominantly of laminated tan clay and massive silt in layers 50 feet or more thick. Although some exposures are nearly all clay, most contain also thick beds of silt and diatomite and some layers of fine sand. Intercalated among these beds are widespread layers of iron-stained, well-sorted pebble gravel as much as 25 feet thick. The lake beds and gravel erode into distinctive white badlands streaked horizontally with thin rusty bands. From the top of the lake beds, particularly at the basin margin on plateaus north of Glenns Ferry, a section of colluvium, fan gravel, and other

These marginal deposits are intercalated with lava flows that, near the Snake River, rest on erosion surfaces within the lake beds. The erosion surfaces rise toward the north and truncate older rocks. Similar colluvial and stream deposits near Hagerman overlie a widespread soil developed at the top of the lake beds. An identical soil is preserved locally on the lake beds 12 miles south of Glenns Ferry.

The volcanic materials in the Bruneau consist of lava flows and pyroclastic debris of olivine basalt derived from several volcanic centers. One source of lava was a group of vents near Mountain Home from which plagioclase-olivine basalt poured west, south, and east onto stream-cut terraces of Bruneau age where the basalt cooled as columnar flows. This lava fills a former canyon 500 feet deep north of Bruneau where part of the fill has pillow structure. A related lava fill 5 miles southwest of Glenns Ferry is more than 200 feet thick. Another distinctive olivine basalt, characterized by dense texture, inflated vesicles, and abundant microphenocrysts of plagioclase, spilled southward from the Mount Bennett Hills onto fan gravel of Bruneau age 12 miles north-northwest of Glenns Ferry. A similar basalt from a source farther east in the Mount Bennett Hills spilled southwestward onto an upland erosion surface that terminates 4 miles north of Glenns Ferry. Basalt rich in olivine and plagioclase also erupted at least twice from vents in the foothills of the Mount Bennett Hills 10 miles north of Glenns Ferry. Downstream from Bruneau the volcanic materials of the formation were derived mainly from a remarkable chain of volcanoes that extends northwestward along the Snake River nearly as far as Homedale. Much of the volcanic material preserved in this downstream area consists of water-laid and subaerial pyroclastic debris, but it includes some columnar lava. These various lava flows are locally interbedded with the sedimentary deposits. The volcanic materials, are comparatively fresh but are weathered locally. Yellowish-brown hydrated iron oxides stain some lava flows, and clayey alteration products of similar color are disseminated in some pyroclastic deposits. In a few places, the lava flows have decomposed to a brown rubble.

The Bruneau Formation has yielded a few mammalian fossils and various mollusks and diatoms that indicate middle Pleistocene age. Bone fragments from a gravel bed of the Bru-

identified by C. B. Schultz, L. G. Tanner, and G. E. Lewis (written communication, June 25, 1957) as laminae from the cheek teeth of *Mammuthus* sp. They identify another bone from the same gravel bed three-fourths of a mile farther south as a "distal fragment of humerus of *Gigantocamelus* sp. of Aftonian to late Kansan age." Mammalian fossils collected from Sailor Creek 11 miles southwest of Glenns Ferry are identified by Schultz, Tanner, and Lewis (written communication, March 31, 1958) as follows:

> "*Equus* sp. indet.; distal end of tibia, 4 tarsalia, 2 phalanges (of ?pes), and many small fragments. This is a very large Pleistocene horse whose measurements fall within the range of those of *E. giganteus* Gidley, hitherto reported only from Yarmouth to mid-Wisconsin rocks."

Other mammals from this locality are identified by them (written communication, Oct. 30, 1959) as fragments of a calcaneum and astragalus of a large cervid, ?*Sangamona* sp., the lateral phalanx of a small cervid, ?*Odocoileus* sp., and two fragments of equid cheek teeth, all probably equivalent in age to the Hagerman local fauna. Various mammalian fossils collected by N. R. Anderson, University of Puget Sound, from the Bruneau Formation in the Castle Creek area are identified by D. E. Savage as *Paramylodon* sp. and as mastodon or mammoth of late Pliocene or younger age.

D. W. Taylor (written communication, Feb. 11, 1960) reports on the molluscan fossils as follows:

> "The mollusks of the Bruneau Formation represent 25 species, distributed among 19 genera and 12 families. The assemblage is strikingly more modern than that in the underlying Glenns Ferry Formation, because only one of the species is extinct, and most of the others are living in southwestern Idaho. The abundant species of the Snake River today, such as *Gonidea angulata* (Lea), *Valvata utahensis* Call, *Lithoglyphus fuscus* (Haldeman), and *Vorticifex effusus* (Lea), appear first in the Bruneau Formation.
>
> "The almost completely modern character of the molluscan fauna suggests middle or late Pleistocene age. The only extinct species, *Promenetus kansasensis* (Baker), is known from deposits as young as Sangamon in the southern High Plains.
>
> "The molluscan contrast between the Glenns Ferry and Bruneau formations indidates a major stratigraphic gap."

Diatoms from several beds of diatomite in the Bruneau Formation near Glenns Ferry

K. E. Lohman (written communication, July 2, 1958), of which 84 per cent are represented in living assemblages elsewhere. Lohman reports that several of the extinct species range from early to late Pleistocene. One form, *Stephanodiscus carconensis* var. *pusilla* Grunow, has previously been found only in late Pliocene to early Pleistocene rocks. Another form, probably reworked judging from its rarity and battered condition, ranges from late middle Miocene to middle Pliocene.

The Bruneau Formation has yielded also a quantity of pollen that contributes useful paleoecological information.

On the basis of ages assigned to the mammalian and molluscan fossils, and because of its relations to other units of the Idaho Group, the Bruneau Formation is dated as middle Pleistocene.

Black Mesa Gravel

The soft beds of the Bruneau and Glenns Ferry Formations south of the Snake River near Glenns Ferry are extensively beveled by an erosion surface that terminates 550 feet above river level. This surface is veneered with about 25 feet of sand and gravel, here named the Black Mesa Gravel for Black Mesa, an upland area 5 miles southeast of Glenns Ferry where the gravel is typically exposed Pl. 1, loc. 9). Remnants of the Black Mesa Gravel, formerly part of a continuous pediment deposit, extend from Black Mesa southward about 10 miles to a gentle erosional escarpment somewhat above 3200 feet altitude. Remnants of gravel of the former pediment also extend from Black Mesa 15 miles westward. Other upland deposits of sand and gravel, at a comparable stratigraphic position at various places farther west, physiographically resemble the Black Mesa Gravel and are probably correlative. For example, a deposit of gravel and sand as much as 250 feet thick that overlies the Bruneau Formation along Hart Creek, a tributary of Castle Creek midway between Grand View and Murphy, is probably equivalent to the Black Mesa Gravel. Similar deposits also cap the upland of the Shoofly Desert 15 miles south of Grand View.

Most of the Black Mesa Gravel near Glenns Ferry was derived locally from gravel beds in the underlying Bruneau Formation. Some of the gravel may be merely residual Bruneau that has been only slightly reworked. Erosion of the Tuana may have contributed gravel to the sures of the Black Mesa Gravel are poor, but that which can be seen suggests uneven lenticular bedding. Brown and gray colors prevail. The Black Mesa deposits that extend southward beyond the margins of the Bruneau Formation contain very little gravel and consist mostly of sand reworked from the underlying Glenns Ferry Formation. Thus, the Black Mesa has inherited its texture from the deposits on which it lies. On the other hand, the gravel and sand along Hart Creek represents an alluvial fan derived from the Owyhee Mountains to the south.

A conspicuous feature of the Black Mesa Gravel is a cap of hard caliche several feet thick that forms a protective shield. From Black Mesa the caliche extends also over older deposits of the uplands, such as the Tuana Gravel. Because the caliche cap is resistant to erosion, dissection of the Black Mesa Gravel progresses by encroachment of badlands. The undissected caliche surface meanwhile remains as tablelands.

No fossils have been found in the type area of the Black Mesa Gravel, but from the probably equivalent gravel along Hart Creek N. R. Anderson, University of Puget Sound, collected a bone that D. E. Savage (written communication to Anderson, Jan. 11, 1957) identified as the mandible of a new mylodont ground sloth "closest morphologically to a form from the mid-Pliocene of Florida, *Thinobadistes*." A horse tooth from the same locality is tentatively assigned by Savage (written communication to Anderson, Sept. 5, 1957) to "plesippine *Equus*" of late Pliocene or early Pleistocene age, although he notes that "horses of the later Pleistocene in Mexico and South America sometimes have a tooth with characters very much like this specimen." The Black Mesa Gravel is older than the inception of the present Snake River canyon and is therefore regarded as middle Pleistocene. Caliche such as is developed on the gravel is not known on late Pleistocene deposits of this region.

SNAKE RIVER GROUP

Introduction

Russell (1902, p. 59, Pl. 1) applied the name, Snake River Lava, to "the basaltic rocks that underlie . . . the Snake River Plains, and to a great extent form their actual surfaces." His reconnaissance geologic map shows Snake

Most of the basalt farther west is related, as Russell recognized, to the sedimentary deposits of the Idaho Group. Subsequent writers followed the broad classification adopted by Russell, although various lava flows have been differentiated locally. However, during studies of ground water in the great reservoir of basaltic lava flows east of Hagerman, the name, Snake River Basalt, has been used for the unaltered, water-bearing basalts of the Snake River Plain. This fresh basalt was extruded at various times during entrenchment of the modern Snake River canyon and is, accordingly, interbedded at some places with river deposits. The combined basalt and river deposits make a distinctive assemblage of eight overlapping formations here named the Snake River Group.

Because the rocks of the Snake River Group were deposited during a period of canyon cutting, not all formations within the group are displayed at a single locality, but typical exposures that show the dominant lithologies and most of the stratigraphic relations occur in the east wall of the canyon segment that extends from Bliss, 9 miles north of Hagerman, to Thousand Springs, 5 miles south of Hagerman (Pl. 1, loc. 10). From the type area, lava flows of the Snake River Group extend eastward and northeastward 250 miles along the Snake River and into the bordering plains to the north and south. Thus the group lies mainly in the eastern Snake River Plain. In the type area, the maximum thickness of the Snake River Group is about 550 feet, although a composite thickness assembled from local outcrops of the individual formations would be much greater. Drilling near Arco, about 100 miles northeast of Hagerman, shows that the Snake River Group of that area is at least 900 feet thick and is composed of thick lava flows of basalt interbedded with layers of clay, sand, and gravel (M. J. Mundorff, U.S. Geological Survey, oral communication, 1960).

A small part of the Snake River Group occurs as lava flows of olivine basalt that issued from vents west of Mountain Home and that cascaded southward into the Snake River canyon opposite the mouth of the Bruneau River (Pl. 1). This basalt lies on eroded basalt, diatomite, and clay of the Bruneau Formation.

Because fossil mollusks and mammals in the Snake River Group have affinities with modern species and because of physiographic relations, the group is assigned to the late Pleistocene and

Madson Basalt

The Madson Basalt was named by Stearns (1936, p. 434–439; Stearns, Crandall, and Steward, 1938, p. 72–74) for Madson Spring on the east wall of the Snake River canyon 6 miles downstream from Hagerman (Pl. 1, loc. 11). The name was applied to fresh columnar lava of olivine basalt that crops out beneath a capping lava flow above the spring and on the opposite (western) canyon wall where the basalt overlies the Glenns Ferry Formation. From Madson Spring, this basalt crops out intermittently in the northern canyon wall of the Snake River as far as 12 miles downstream and for about 3 miles upstream to the lower reach of the Big Wood River—a gorge known as Malad Canyon. These exposures, as Stearns recognized, show that the Madson Basalt fills a former shallow canyon. The canyon floor lies about 250 feet above the Snake River and is well graded from an altitude of 3000 feet at Malad Canyon to 2800 feet near Bliss Dam 10 miles downstream. The base of the Madson basalt therefore lies about 300 feet topographically below the Black Mesa Gravel that is preserved south of the Snake River.

Exposures at windows in the former canyon show that the Madson Basalt is composed of at least four flows of columnar lava, each about 50 feet thick. Pillow lava is scarce and generally occurs only at the base of the lower flows, but an exposure at Malad Spring near the mouth of Malad Canyon shows 40 feet of pillow lava overlain by 30 feet of columnar basalt. The maximum exposed thickness of the Madson Basalt is 200 feet near Bliss Dam, but topographic relations of other outcrops nearby demonstrate that the Madson Basalt filled the former canyon to a depth of at least 300 feet.

Sugar Bowl Gravel

The Sugar Bowl Gravel is here named for the Sugar Bowl, a hill 4 miles northeast of Glenns Ferry where the gravel forms a 20-foot thick cap 400 feet above the Snake River (Pl. 1, loc. 12). The Sugar Bowl Gravel is preserved also as gravel-capped knobs and benches elsewhere along this part of the Snake River, particularly within wide segments of the canyon at tributary junctions. These gravel deposits are the remnants of a graded terrace which is essentially parallel to the present stream gradient (2 feet per mile) but 400 feet higher. The principal upstream remnants lie of the Snake River, where they form a dissected terrace that covers several square miles of area. At a place on the northern canyon wall 9 miles southeast of Glenns Ferry the Sugar Bowl Gravel lies on eroded Madson Basalt. The most westerly remnants of Sugar Bowl Gravel thus far recognized are in Indian Cove 15 miles downstream from Glenns Ferry.

The lithology of the Sugar Bowl Gravel shows that it was derived from distant sources, probably from Paleozoic and granitic rocks in mountains north of the Snake River Plain. Unlike the gravels in the Idaho Group, which were derived mostly from the Idavada Volcanics, the Sugar Bowl Gravel is dominated by quartzite, porphyry, granite, and conglomerate. A minor amount of the gravel consists of rocks from the Idavada Volcanics and pieces of basalt, chert, and argillite. The Sugar Bowl Gravel is well sorted, ranging from large pebbles and cobbles in the upstream outcrops to medium-sized pebbles downstream. A thin layer of caliche, rather poorly indurated, caps the gravel.

The composition and texture of the Sugar Bowl Gravel indicate that it was deposited during an interval of augmented runoff, probably caused by seasonal melting of glaciers in mountains north of the Snake River Plain. The freshness of the gravel suggests that the inferred interval of glaciation occurred during the late Pleistocene.

Thousand Springs Basalt

The Thousand Springs Basalt was named by Stearns (1936, p. 434, 437; Stearns, Crandall, and Steward, 1938, p. 75–76) for the Thousand Springs which issue from the base of a canyon-filling basalt 5 miles south of Hagerman (Pl. 1, loc. 13). As used in this paper the name is applied not only to the Thousand Springs Basalt of Stearns but also to his Malad Basalt (Stearns, Crandall, and Steward, 1938, p. 74–75) that forms the eastern rim of the Snake River Canyon from the vicinity of Hagerman northward to Malad Canyon. The Malad Basalt is here redefined as the Malad Member of the Thousand Springs Basalt. These lava flows are combined into a single formation because they cannot be separately distinguished in the upland plains east of Hagerman—into which they extend many miles—although they are easily differentiated in the good exposures near Hagerman. The Thousand Springs Basalt

Gooding) and Sonnickson Butte (4 m south-southwest of Jerome).

The Thousand Springs Basalt occupies former canyon carved below the upper surf of the Madson Basalt and below the projec- grade of the Sugar Bowl Gravel. The form canyon is not a simple trough but was cut progressive stages as successive lava flo diverted the ancestral Snake River southwar Thus, the earliest canyon-filling lavas (t Malad Member) are perched relatively hig in the area near Hagerman, and the lat canyon-filling lavas are lower in the area sou of Hagerman. The base of the Thousan Springs Basalt is about 250 feet above th Snake River 1 mile south of Malad Canyo and about 150 feet above the river nea Thousand Springs. The maximum thickness 225 feet near Malad Canyon and 75 feet nea Thousand Springs.

The various lava flows of the Thousan Springs Basalt are entirely fresh and range fro olivine basalt to porphyritic plagioclase-olivin basalt. The Malad Member overlies Madso Basalt in Malad Canyon and there consists o two flows of porphyritic plagioclase-olivine basalt capped with a flow rich in olivine. Thes flows extend southward along the canyon rim of the Snake River to a place 5 miles southeas of Hagerman. The Thousand Springs Basalt at Thousand Springs lies in a canyon partly bounded by the Malad Member and includes three flows of porphyritic plagioclase-olivine basalt. From Thousand Springs the basalt extends eastward and is continuously exposed along the northern canyon rim of the Snake River nearly as far upstream as Twin Falls. Pillow lava is comparatively scarce in the Thousand Springs Basalt; the flows are mainly columnar. The basalt is highly permeable, judging from the large yield of ground water at springs along the present canyon.

The drainage that was diverted southward across the canyon-filling flows of the Thousand Springs Basalt deposited an alluvial veneer as much as 50 feet thick. From this alluvium on the Malad Member about 3 miles southeast of Hagerman, D. W. Taylor collected an assemblage of molluscan fossils on which he reports as follows (written communication, Feb. 18, 1960):

"The fossils from alluvium on the Thousand Springs Basalt represent 12 species of freshwater clams and snails. None is extinct, but 4 are not

currence of *Valvata sincera* Say, a species of arkedly northern distribution in North America, d of other locally extinct species indicates significantly cooler waters than are now found locally d, hence, a glacial age."

rowsnest Gravel

The Crowsnest Gravel is here named for the rowsnest Road which leads from the highway miles south of Hagerman to the upland plains west of the Snake River. The typical exposures re in gravel pits near the lower end of the Crowsnest Road where the gravel is 25–50 feet thick and where its base is about 200 feet above the Snake River (Pl. 1, loc. 14). The gravel also crops out on the opposite (eastern) canyon wall of the Snake River where it overlies the Thousand Springs Basalt and clay of the Bruneau Formation. Other exposures of Crowsnest Gravel, as far as 10 miles upstream from Hagerman, show that the Crowsnest deposits are remnants of a terrace that is more steeply graded than the Snake River. Erosion at the Canyon walls marginal to this terrace has formed a minor pediment surface that is still widely preserved southwest of Hagerman and at some places upstream. Some remnants of terrace gravel near Glenns Ferry, although lithologically different from the exposures on Crowsnest Road, are also regarded as Crowsnest Gravel because of similar stratigraphic relations and topographic position. The Crowsnest Gravel at Glenns Ferry is also bordered by a pediment surface marginal to the canyon walls. From Glenns Ferry westward the Crowsnest Gravel crops out at progressively lower elevations relative to the Snake River. At Grand View the Crowsnest Gravel forms the canyon floor. The remnants of Crowsnest Gravel from Hagerman to Grand View together represent a terrace with a gradient of 8 feet per mile.

The Crowsnest Gravel varies in lithology according to its outcrop area. Near Hagerman the larger portion of the gravel consists of pebbles from the Idavada Volcanics; the remainder is dominantly chert and quartzite. From Glenns Ferry to Grand View the Crowsnest Gravel closely resembles the Sugar Bowl Gravel by reason of a large content of quartzite, porphyry, and granite, but it is more coarse grained—mostly cobbles. This lithology probably shows that the Crowsnest Gravel near Glenns Ferry was derived largely from a tributary valley, perhaps the ancestral Big Wood River which today carries gravel con-

like that of the Sugar Bowl, suggests deposition during an interval of augmented runoff, probably coincident with mountain glaciation. This inference is especially applicable to the area downstream from Hagerman, but even at Hagerman the Crowsnest Gravel contains a significant proportion of chert and quartzite derived from the mountains. The steep gradient of the gravel (8 feet per mile), when considered with respect to the evident aggradation and terrace cutting, indicates that the river was considerably loaded, and this condition suggests glacial melting.

Sand Springs Basalt

The Sand Springs Basalt was named by Stearns (1936, p. 434, 439–440; Stearns, Crandall, and Steward, 1938, p. 80–83) for Sand Springs 8 miles south-southeast of Hagerman where the basalt fills a former canyon of the Snake River (Pl. 1, loc. 15). The basalt has been identified from its terminus in the Snake River canyon 2 miles north of Hagerman to its source in the eastern Snake River Plain 20 miles northwest of Burley. The Sand Springs Basalt thus forms part of the upland plain north of the Snake River. The former canyon occupied by the Sand Springs Basalt coincides with the present canyon downstream from Sand Springs, and the basalt in this reach lies near river level about 200 feet topographically below Crowsnest Gravel. Upstream from Sand Springs the former canyon was eroded in the Thousand Springs Basalt and in older basalt of the Idaho Group. The filled canyon lies north of the Snake River but is exposed near Twin Falls at Blue Lake alcove, which indents the north wall of the Snake River canyon. At this alcove the thickness of the Sand Springs Basalt is about 300 feet. A small patch of Sand Springs Basalt is preserved on the southern canyon rim of the Snake River 8 miles downstream from Twin Falls, and another small remnant occurs on the western canyon wall opposite the canyon fill near Sand Springs.

The Sand Springs Basalt consists of a single flow of fresh gray pahoehoe basalt, poor in plagioclase phenocrysts but rich in olivine. Springs issue from the base of the basalt at several places, the permeability being caused by vesicularity and jointing rather than by pillow lava which is rare. The surface of the Sand Springs Basalt on the upland plain is mostly concealed by a mantle of windblown silt, although broken ridges of lava appear here

Bancroft Springs Basalt

The Bancroft Springs Basalt is here named for Bancroft Springs which issue from talus near the base of this basalt in the northeastern wall of the Snake River canyon 7 miles east of Glenns Ferry (Pl. 1, loc. 16). Here the Bancroft Springs Basalt consists of columnar lava, at least 300 feet thick, that lies in a former canyon about as deep as the present Snake River canyon. The basalt extends eastward from Bancroft Springs, forming an upland plain and cropping out as rimrock of columnar lava on the northern canyon rim as far upstream as Malad Canyon. Here the Bancroft Springs overlies the Madson and Thousand Springs basalts. A small patch of Bancroft Springs Basalt is preserved on the southwestern rim of the Snake River canyon near the terminus of the flow. The columnar lava of the Bancroft Springs was considered by Stearns (Stearns, Crandall, and Steward, 1938, p. 78) as part of the recognizably younger McKinney Basalt which is herein restricted to the Recent lava flow from McKinney Butte. From Malad Canyon to a place 7 miles downstream the columnar rimrock of the Bancroft Springs Basalt lies on pillow lava that is included in the Bancroft Springs, because the crystalline parts of the pillows are petrographically identical to the rimrock. The pillow lava of the Bancroft Springs Basalt is as much as 500 feet thick and lies in a canyon as deep as the present. The base of the basalt is therefore lower than the grade of the Crowsnest Gravel. Some talus buried by pillow lava near the floor of the former canyon was derived from the Madson Basalt. The pillow lava was termed the Bliss Basalt by Stearns (Stearns, Crandall, and Steward, 1938, p. 78–80), but this name is here abandoned.

The Bancroft Springs Basalt is a distinctive olivine basalt crowded with large phenocrysts of plagioclase arranged in rosettes and is entirely fresh, even in the pillow facies. This basalt probably erupted from a source about 8 miles northwest of Gooding that has been concealed by Recent basalt. The Bancroft Springs Basalt is somewhat mantled with windblown silt, but much of the surface is bare.

The stratigraphic relation of the Bancroft Springs Basalt to the Sand Springs is indefinite, as they are nowhere in contact. The pillow lava of the Bancroft Springs occupies a canyon as deep as the canyon of the Sand Springs and deeper than any earlier canyon formed during accumulation of the Snake River Group. The canyon occupied by the Bancroft Springs pillow facies probably is a downstream portion of the canyon occupied by the Sand Springs Basalt but filled with lava from a different source. The equally deep canyon exposed at Bancroft Springs and filled with columnar lava may represent a canyon of the ancestral Big Wood River. The comparative bareness of the surface of the Bancroft Springs Basalt suggests that it is younger than the rather completely mantled Sand Springs Basalt.

Melon Gravel

The Melon Gravel is here named for Melon Valley, a wide segment in the Snake River canyon 5 miles north of Buhl (Pl. 1, loc. 17). On the canyon floor at Melon Valley the gravel forms a great bouldery bar more than a mile long, half a mile wide, and 150 feet thick. The Melon Gravel is typically exposed in a borrow pit at the downstream end of the bar. About 5 miles downstream from Melon Valley the gravel overlies eroded Sand Springs Basalt and farther downstream it lies against canyon walls eroded in the Bancroft Springs Basalt. The Melon Gravel has been identified intermittently in the Snake River canyon as far downstream as the area between Murphy and Homedale—150 miles. Upstream from Melon Valley the Melon Gravel forms bars within the canyon nearly as far as Milner, 40 miles east. Remnants of the gravel also occur on the upland plain north of the canyon along State Highway 25 about 11 miles east-northeast of Twin Falls and along U.S. Highway 93 about 5 miles north of Twin Falls.

Within the Snake River canyon downstream from Melon Valley the gravel displays a variety of physiographic features that indicate deposition in rapidly moving deep water. The gravel occurs mainly in wide segments of the canyon between canyon constrictions where it forms huge bars and boulder terraces that partly fill the canyon to a depth as great as 300 feet. The gravel bars block the mouths of tributary valleys, and at most places they are separated from the canyon walls by marginal troughs as much as 150 feet deep. The tributary valleys locally contain fine-grained backwater deposits, the highest of which are 300 feet above the canyon floor, a height commensurate with the thickest sections of the gravel. Backwater near Glenns Ferry, for instance, which was impounded by a canyon constriction, inundated about 80 square miles of area and covered the local deposits of Melon Gravel.

Internal features of the Melon Gravel also indicate that the gravel was deposited in deep water. The gravel varies in texture but consists mainly of boulders and sand, both derived almost entirely from the local basalt. The boulders in the gravel average 3 feet in diameter, although some reach 10 feet. The boulders ordinarily are distributed at random, but some are in inclined layers, alternating with layers of sand. The inclined layers resemble deltaic foreset beds arranged in courses as much as 50 feet thick between horizontal crossbeds. Such bedding indicates deposition in deep water. The surfaces of the gravel bars and terraces are conspicuously strewn with lag boulders (melon patches!) that indicate reworking during subsidence of the water.

The Melon Gravel, in its internal and physiographic features, is similar to the gravel bars in the channeled scabland of eastern Washington and, like the scabland bars, can be explained by passage of a catastrophic flood. This flood probably was caused by outflow from Pleistocene Lake Bonneville during rapid lowering of its outlet at Red Rock Pass. The outflow from Lake Bonneville entered the Snake River at Pocatello via Marsh Creek and the lower reach of the Portneuf River. (Trimble and Carr, 1961.)

According to D. W. Taylor (written communication, Oct. 28, 1957), a small collection of molluscan fossils from silt near Glenns Ferry that probably represents a backwater deposit related to the Melon Gravel includes *Stagnicola cockerelli* (Pilsbry and Ferriss) and *Helisoma subcrenatum* (Carpenter). Remains of *Bison alleni* reported near Glenns Ferry (Lucas, 1899, p. 766) presumably came from the Melon Gravel.

Recent Lava Flows

The Recent lava flows within the Snake River Plain usually can be distinguished by their comparatively unmodified surfaces and, along the Snake River canyon, by their stratigraphic relations. The Recent lavas are covered only locally by surficial material, whereas older lavas of the Snake River Group are more or less concealed. Much of the outcrop area of the Sand Springs Basalt and the Thousand Springs Basalt, for example, is cultivated, but the opposite is true for Recent lavas. Individual lava flows of Recent age can be distinguished from one another in some places by lithologic and physiographic comparisons.

Two Recent lava flows near Hagerman and Glenns Ferry are comparable in size to the older flows of the Snake River Group. A lava flow of olivine-rich basalt that cascades from the upland plain onto talus younger than the Melon Gravel at Wendell Grade, a road 2 miles east of Hagerman, was named the Wendell Grade Basalt by Stearns (1936, p. 434; Stearns, Crandall and Steward, 1938, p. 84) (Pl. 1, loc. 18). It issued from Notch Butte, 4 miles south of Shoshone. A lava flow of highly porphyritic plagioclase-olivine basalt that issued at McKinney Butte 8 miles northwest of Gooding was named the McKinney Basalt by Stearns (1936, p. 434, 439; Stearns, Crandall and Steward, 1938, p. 76–78) (Pl. 1, loc. 19). The McKinney extends 20 miles west of McKinney Butte to the Snake River near Glenns Ferry where it overlies eroded Melon Gravel. Boulders of the Melon Gravel frozen in the base of the basalt are seen in a low cliff about 20 feet above the Snake River. At a place on the Malad River (the lower Big Wood River) 8 miles southwest of Gooding the McKinney Basalt overlies the Wendell Grade Basalt.

REFERENCES CITED

Brown, R. W., 1940, A bracket fungus from the late Tertiary of southwestern Idaho: Washington Acad. Sci. Jour., v. 30, no. 10, p. 422–424

Buwalda, J. P., 1923, A preliminary reconnaissance of the oil and gas possibilities of southwestern and south-central Idaho: Idaho Bur. Mines and Geology Pamph. 5, 10 p.

—1924, The age of the Payette formation and the old erosion surface in Idaho: Science, new ser., v. 60, no. 1564, p. 572–573

Chaney, R. W., and Axelrod, D. I., 1959, Miocene floras of the Columbia Plateau: Carnegie Inst. Washington Pub. 617, Contr. Paleontology, 237 p.

Cope, E. D., 1884, On the fishes of the Recent and Pliocene lakes of the western part of the Great Basin, and of the Idaho Pliocene lake: Philadelphia Acad. Nat. Sci. Proc. 1883, v. 35, p. 134–166

Dall, W. H., 1924, Discovery of a Balkan fresh-water fauna in the Idaho formation of Snake River valley, Idaho: U.S. Geol. Survey Prof. Paper 132-G, p. 109–115

Freeman O. W., Forrester, J. D., and Lupher, R. L., 1945, Physiographic divisions of the Columbia intermontane province: Assoc. Am. Geographers Annals, v. 35, no. 2, p. 53–75

Gazin, C. L., 1936, A study of the fossil horse remains from the upper Pliocene of Idaho: U.S. Natl. Mus. Proc., v. 83, no. 2985, p. 281–320

Hague, Arnold, and Emmons, S. F., 1877, Descriptive geology: U.S. Geol. Explor. 40th Parallel (King), v. 2, 890 p.

Hall, James, 1845, Descriptions of organic remains, p. 304–310 *in* Frémont, J. C., Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and north California in the years 1843–1844: Washington, D. C., Senate and House Executive Docs. 174, 693 p.

Henderson, Junius, and Rodeck, H. G., 1934, New species of Pliocene Mollusca from eastern Oregon: Jour. Paleontology, v. 8, no. 3, p. 264–269

Hibbard, C. W., 1959, Late Cenozoic microtine rodents from Wyoming and Idaho: Michigan Acad. Sci. Papers 1958, v. 44, p. 3–40

Hintze, L. F., 1956, Geologic map of the State of Oregon: Provo, Utah, privately printed

Kirkham, V. R. D., 1931, Revision of the Payette and Idaho formations: Jour. Geology, v. 39, no. ... p. 193–239

Knowlton, F. H., 1901, A fossil nut pine from Idaho: Torreya, v. 1, p. 113–115

Lindgren, Waldemar, 1898, The mining districts of the Idaho Basin and the Boise Ridge, Idaho: U.S. Geol. Survey 18th Ann. Rept., pt. 3, p. 617–719

——1900, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U.S. Geol. Survey 20th Ann. Rept., pt. 3, p. 65–256

Lindgren, Waldemar, and Drake, N. F., 1904, Description of the Silver City quadrangle [Idaho]: U.S. Geol. Survey Geol. Atlas, Folio 104, 6 p.

Littleton, R. T., and Crosthwaite, E. G., 1957, Ground-water geology of the Bruneau-Grand View area, Owyhee County, Idaho: U.S. Geol. Survey Water-Supply Paper 1460-D, p. 147–198

Lucas, F. A., 1899, The fossil bison of North America: U.S. Natl. Mus. Proc., v. 21, no. 1172, p. 755–...

Mapel, W. J., and Hail, W. J., Jr., 1959, Tertiary geology of the Goose Creek district, Cassia County, Idaho, Box Elder County, Utah, and Elko County, Nevada: U.S. Geol. Survey Bull. 1055-... p. 217–254

Merriam, J. C., 1918, New mammalia from the Idaho formation: California Univ. Pubs. Geol. Sci., v. ... no. 26, p. 523–530

Miller, R. R., 1958, Origin and affinities of the freshwater fish fauna of western North America, p. 187–... *in* Hubbs, C. L., *Editor*, Zoogeography, a symposium: Am. Assoc. Adv. Sci. Pub. 51, 509 p.

Piper, A. M., 1926, Ground water for irrigation on Camas Prairie, Câmas and Elmore counties, Idaho: Idaho Bur. Mines and Geology Pamph. 15, 46 p.

Powers, H. A., and Malde, H. E., 1961, Volcanic ash beds as stratigraphic markers in basin deposits near Hagerman and Glenns Ferry, Idaho, p. 167–170 *in* Geological Survey Research 1961: U.S. Geol. Survey Prof. Paper 424-B, 344 p.

Russell, I. C., 1902, Geology and water resources of the Snake River plains of Idaho: U.S. Geol. Survey Bull. 199, 192 p.

Scharf, D. W., 1935, A Miocene mammalian fauna from Sucker Creek, southeastern Oregon: Carnegie Inst. Washington Pub. 453, Contr. Paleontology, p. 97–118

Schrader, F. C., 1912, A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nevada: U. S. Geol. Survey Bull. 497, 162 p.

Stearns, H. T., 1936, Origin of the large springs and their alcoves along the Snake River in southern Idaho: Jour. Geology, v. 44, no. 4, p. 429–450

—— 1955, Pillar Falls mudflow and Shoshone andesite near Twin Falls, Idaho: Geol. Soc. America Bull., v. 66, p. 463–464

Stearns, H. T., Crandall, Lynn, and Steward, W. G., 1938, Geology and ground-water resources of the Snake River plain in southeastern Idaho: U.S. Geol. Survey Water-Supply Paper 774, 268 p.

Trimble, D. E., and Carr, W. J., 1961, Late Quaternary history of the Snake River in the American Falls region, Idaho: Geol. Soc. America Bull., v. 72, p. 1739–1748

Uyeno, Teruya, 1961, Late Cenozoic cyprinid fishes from Idaho with notes on other fossil minnows in North America: Michigan Acad. Sci. Papers 1960, v. 46, p. 329–344

Yen, Teng-Chien, 1944, Notes on fresh-water mollusks of Idaho formation at Hammett, Idaho; Jour. Paleontology, v. 18, no. 1, p. 101–108

—— 1947, Pliocene fresh-water mollusks from northern Utah: Jour. Paleontology, v. 21, no. 3, p. 268–277

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