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NAME AND ADDRESS

THE SALT LAKE GROUP IN CACHE VALLEY, UTAH AND IDAHO

by

Robert D. Adamson

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Geology

UTAH STATE AGRICULTURAL COLLEGE  
Logan, Utah

1955

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Robert D. Adamson

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## INTRODUCTION

### General statement

Fluvial and lacustrine sediments of great thickness accumulated in the intermountain basins of the western United States during Tertiary time. The Salt Lake group in northern Utah and parts of surrounding states is a conspicuous stratigraphic unit of these basins. The "beds of light color" in Morgan Valley in the Wasatch Mountains of northern Utah were named the "Salt Lake group" by Hayden (1869) because of similar occurrences in Salt Lake Valley and because he reasoned that the succession could be divided into formations. Similar rocks crop out in Ogden Valley, north of Morgan Valley, and in Cache Valley, Utah and Idaho. Cache Valley is bounded by the Wasatch and Malad Ranges to the west and the Bear River Range to the east (Fig. 1). It extends from the divide between Ogden and Cache valleys about 18 miles south of Logan, Utah, to Red Rock Pass, about 19 miles northwest of Preston, Idaho. The Bear River enters Cache Valley northeast of Preston, Idaho, and leaves through the Bear River Narrows west of Logan, Utah, at a point between the northern end of the Wasatch Range and the Malad Range. Red Rock Pass, northwest of Preston, Idaho, was the outlet of Lake Bonneville.

The Salt Lake group of Cache Valley, as described in this paper, includes three formations: (1) the basal Collinston conglomerate, (2) the Cache Valley formation, and (3) the upper Mink Creek conglomerate. The Cache Valley formation is partly equivalent to the Collinston conglomerate of the southern part of Cache Valley and is overlain by the Mink Creek conglomerate in the northern part of the valley. It consists



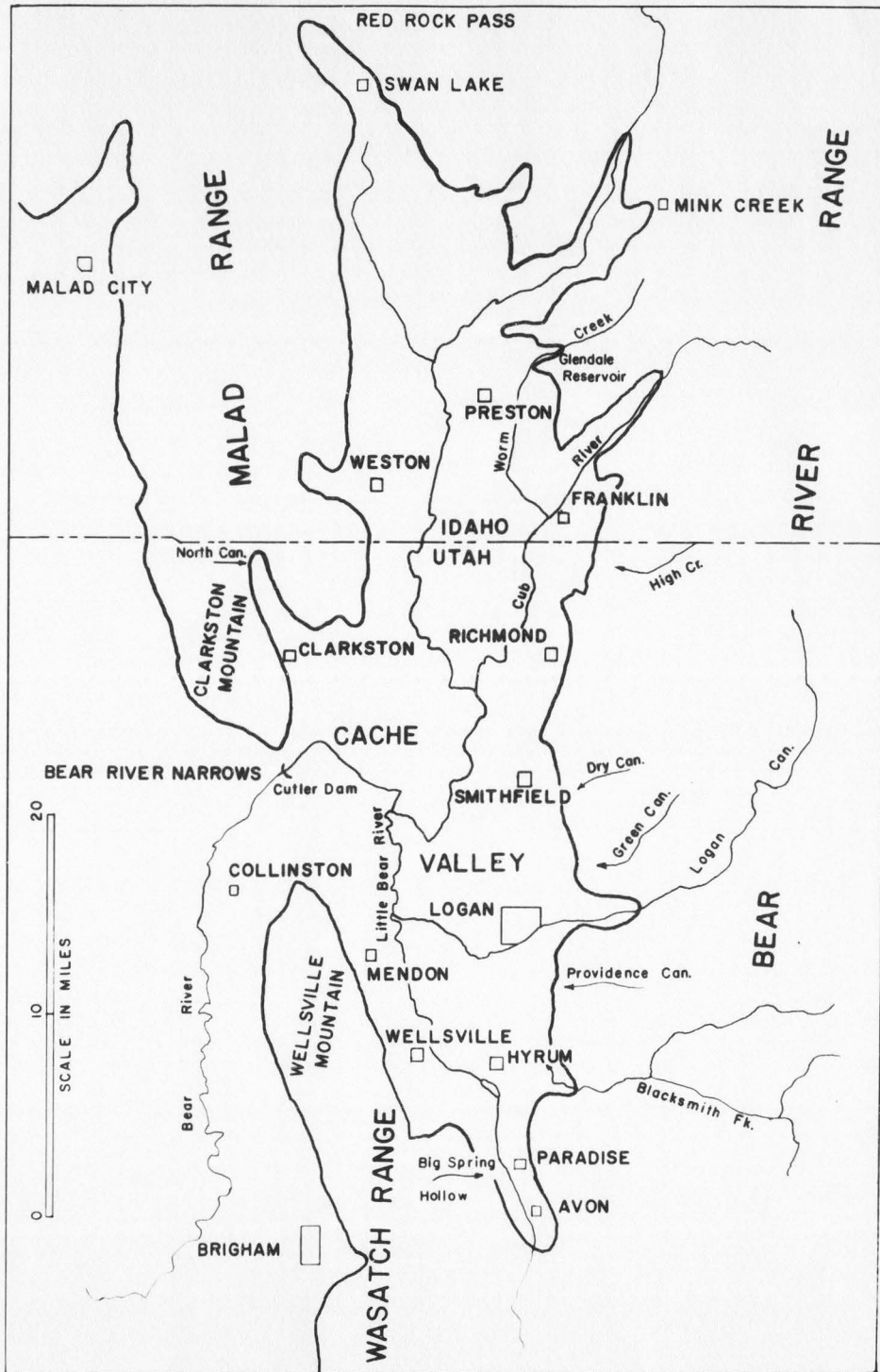


Figure 1. Index map

largely of tuff and some limestone. The upper part of the Cache Valley formation is of Pliocene age, although similar beds in Morgan Valley are as old as late Eocene.

Recent exploration for petroleum in the western United States has concentrated attention on the continental sediments of Tertiary age. Particularly, the commercial discovery of petroleum in volcanic rocks of probable Tertiary age in Nye County, Nevada, has intensified studies of the Salt Lake group and equivalent stratigraphic units of Nevada, Utah, and Idaho. In Cache Valley, these rocks are well enough exposed to warrant a detailed stratigraphic study and correlation with surrounding areas.

#### Geologic setting

Cache Valley is a broad north-south valley located near the northeastern corner of the Great Basin section of the Basin and Range Province. It is bounded on the west by the northern part of the Wasatch Range and the Malad Range and on the east by the Bear River Range. The rocks that constitute these mountain masses are largely of Paleozoic age, and every system is represented except the Permian, which was no doubt eroded prior to deposition of Tertiary rocks. The valley sides are paralleled by high-angle faults, although relief similar to that of today existed previous to deposition of the Tertiary Salt Lake group. Tertiary "Wasatch" beds and rocks of the Salt Lake group are exposed in the foothills adjacent to Paleozoic rocks in the southern part of the valley. In the northern part of the valley, Salt Lake group is exposed adjacent to Paleozoic rocks. Quaternary Lake Bonneville group covers the valley bottom. Rock units exposed in Cache Valley are summarized in a table (Table 1).

Table 1. Rock units exposed in Cache Valley, Utah and Idaho

Age		Rock unit		Lithology	Thickness (Feet)
Quaternary	Pleistocene	Lake Bonneville group		Silt, clay and gravel	120 Williams (Personal communication)
		Pre-Lake Bonneville group		Fanglomerate, gravels	?
Tertiary	Pliocene	Salt Lake group	Mink Creek conglomerate	Light-gray to pale-orange tuffaceous conglomerate	3,435+ Keller (1952)
			Cache Valley formation	Light-colored tuff, limestone, sandstone, and conglomerate	7,674
	Miocene		Collinston conglomerate	Light-gray tuffaceous conglomerate	1,500+
	Oligocene				
Eocene					
Paleocene	"Wasatch" beds		Reddish conglomerate and limestone	530 Williams (1948)	
Paleozoic		Paleozoic rocks		Sandstone, limestone and dolomite	

Light-colored conglomerates, tuffs, limestones, and sandstones of the Salt Lake group crop out in the foothills along the eastern side of Cache Valley almost continuously from Red Rock Pass at the northern end, to Mink Creek, Idaho (Fig. 1). Salt Lake group outcrops also are continuous from Mink Creek to Green Canyon, northeast of Logan, Utah. Between Green and Blacksmith Fork canyons, Quaternary deposits overlie the tuffaceous sediments. South of Blacksmith Fork Canyon, the Salt Lake group reappears and is exposed continuously to the southern end of the valley. Here an extensive pediment has formed on rocks of the Salt Lake group. Along the western side of the valley, from the southern end to within few miles of Hyrum, Utah, Salt Lake group is well exposed. Northward between Hyrum and Mendon, Utah, a pediment has developed probably on Wasatch conglomerate. From Mendon northward, Salt Lake group reappears and crops out continuously to the northern end of the valley. Paleozoic rocks crop out at several places between Mendon and the north end of the valley. Cache Butte and Newton Hill consist of Paleozoic rocks surrounded by Salt Lake group. Northwest of Weston, Idaho, a steep fault scarp (Fig. 2) exposes Paleozoic rocks that are overlain by Salt Lake group.

#### Previous investigations

No detailed stratigraphic studies relating various exposures of the Salt Lake group in Cache Valley have been made previous to this report. Peale (1879) first identified the Salt Lake group in Cache Valley. Williams (1948) published one stratigraphic section and later (Smith, 1953) divided the Salt Lake group of the southern part of Cache Valley into three formations. Keller (1952) applied a new name, Mink Creek formation, to similar rocks in the northern part of Cache Valley in Idaho.



Figure 2. Aerial oblique of the northern end of Cache Valley. Paleozoic rocks overlain by light-colored Cache Valley formation are exposed in the fault scarp in the left foreground. The scarp is about 1 mile northwest of Weston, Idaho.

### Field work

The field season of 1954 was devoted chiefly to detailed stratigraphic studies of critical areas of outcrop of the Salt Lake group in Cache Valley. Poor exposures and obscure structural relationships invariably made the measurement of stratigraphic sections difficult. This restricted the time available for general field work so that detailed maps of particular areas could not be prepared. An attempt was made to find additional vertebrate evidence of the age of the Norwood tuff in Morgan Valley, and the relationships of lava flows to tuffaceous sediments were examined in an area east of Snowville, Utah.

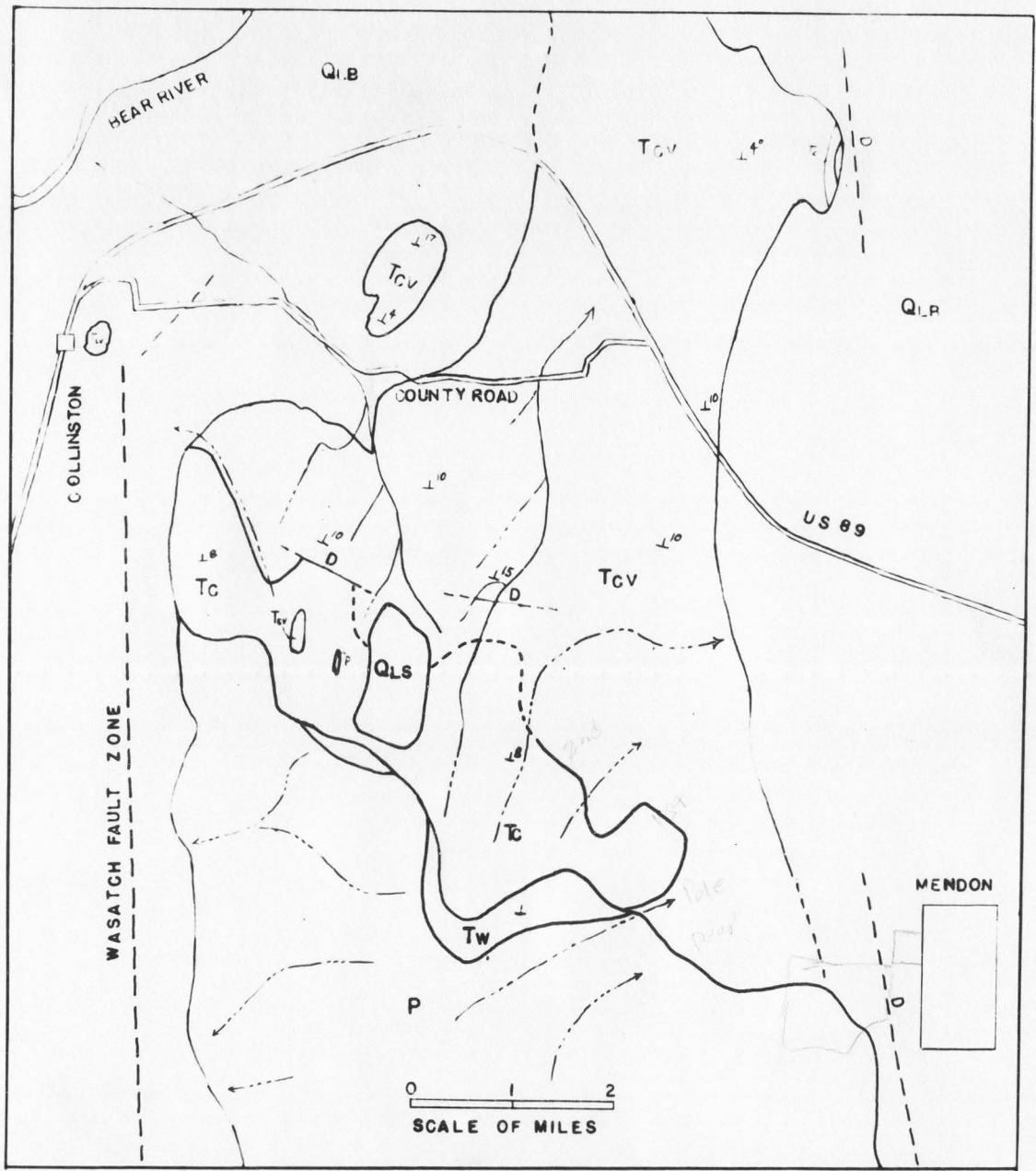
The stratigraphic sections were measured partly with a steel tape and partly with a Brunton compass. Rock colors were determined with reference to the rock-color chart prepared by the Rock-Color Chart Committee (1948) and distributed by the National Research Council. The descriptions of sedimentary rocks follow the classification of Pettijohn (1948). Thus, a tuff may be composed of pure volcanic ejectamenta or a mixture of such material and ordinary sedimentary detritus.

## AREA DESCRIPTIONS

Wellsville Mountains - Clarkston Mountain area, Utah

Northern end of Wellsville Mountains. -- At the northern end of the Wellsville mountains, a thick conglomerate overlies both "Wasatch" beds of Tertiary age and Paleozoic rocks of Carboniferous ages (Fig. 3). Williams (Smith, 1953) has designated this basal stratigraphic unit of the Salt Lake group as the Collinston conglomerate. It is exposed in a wide belt, half a mile to 2 miles wide, along the northern end of the Wellsville Mountains. The outcrop is continuous from a few miles northwest of Mendon, Utah, to the Lake Bonneville shoreline east of Collinston, Utah, a distance of about 5 miles. The beds generally dip northward about  $8^{\circ}$  and are about 1,500 feet thick. The extent of the Collinston into the valley is not known because of the overlying Cache Valley formation.

The Collinston conglomerate is light in color and massive, but outcrops are generally obscure. It consists of rounded to subangular cobbles and pebbles of moderate-yellow-brown limestone, dark-gray finely crystalline limestone, light-brown calcareous sandstone, black chert, moderate-red silty limestone, and a few acidic igneous rocks. Boulders of dark-gray limestone and light-tan quartzite are scattered through the conglomerate. The conglomerate is cemented with calcite which contains tuffaceous material and red silt that in places gives the conglomerate a red hue. Coarse sandstone lenses are interbedded with the conglomerate. The sand grains in these are coarse and angular and are cemented with calcite. The conglomerate was derived from the upper Paleozoic rocks that composed the mountain front adjacent to the site of



- |     |                        |    |                         |
|-----|------------------------|----|-------------------------|
| QLS | LANDSLIDE              | Tc | COLLINSTON CONGLOMERATE |
| QLB | LAKE BONNEVILLE GROUP  | Tw | "WASATCH" BEDS          |
| TCV | CACHE VALLEY FORMATION | P  | PALEOZOIC ROCKS         |

Figure 3. Geologic sketch map of the northern end of the Wellsville Mountains



deposition. The thickness of the conglomerate is estimated at 1,500 feet from an exposure on the first ridge east of Collinston, Utah, where the conglomerate crops out for more than 10,000 feet and dips about  $8^{\circ}$  (Fig. 3).

On the first and second major ridges, about 3 miles northwest of Mendon, Utah, the contact of the Collinston and "Wasatch" beds is well exposed (Fig. 3). Here the Collinston dips northward about  $8^{\circ}$  and unconformably overlies "Wasatch" beds that dip northward more steeply. Tuffaceous beds overlie the Collinston about a quarter of a mile northward from the contact of the conglomerate and "Wasatch" beds. In the lower part of the canyon west of the second ridge, a light-gray tuff underlies the Collinston.

Farther westward on the second major ridge northeast of Collinston, Utah, the Collinston conglomerate successively overlaps "Wasatch" beds and Paleozoic rocks. On this ridge, tuffaceous limestone and tuff beds overlie the conglomerate. A northwest-trending high-angle fault cuts the ridge about half a mile northward from the contact of Paleozoic rocks and Collinston. On the south side of the fault, "Wasatch" beds are overlain by Collinston conglomerate (Fig. 4). The fault has brought tuff beds and tuffaceous limestone beds on the downthrown north side of the fault into contact with Collinston and "Wasatch" beds. This relation indicates that the down-faulted tuff and limestone probably overlapped the Collinston and that the Collinston is basal to the Salt Lake group in this area.

North of the outcrop of the Collinston conglomerate extending from Mendon, Utah, to near Collinston, Utah, beds of tuff, limestone, and conglomerate are exposed. The beds are probably stratigraphically higher than the Collinston, but some may be equivalent. Several east-west high-angle faults and several north-trending faults displace the beds,

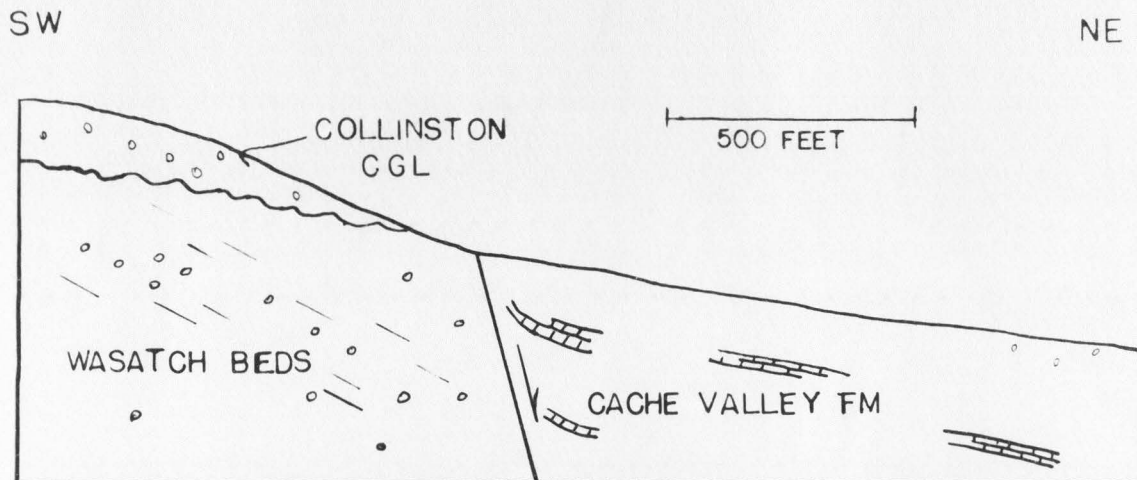


Figure 4. Sketch showing the stratigraphic relations of the Salt Lake group and "Wasatch" beds at the northern end of the Wells-ville Mountains. Before faulting, the Cache Valley formation, on the north side of the fault, overlapped the Collinston conglomerate which overlies "Wasatch" beds.

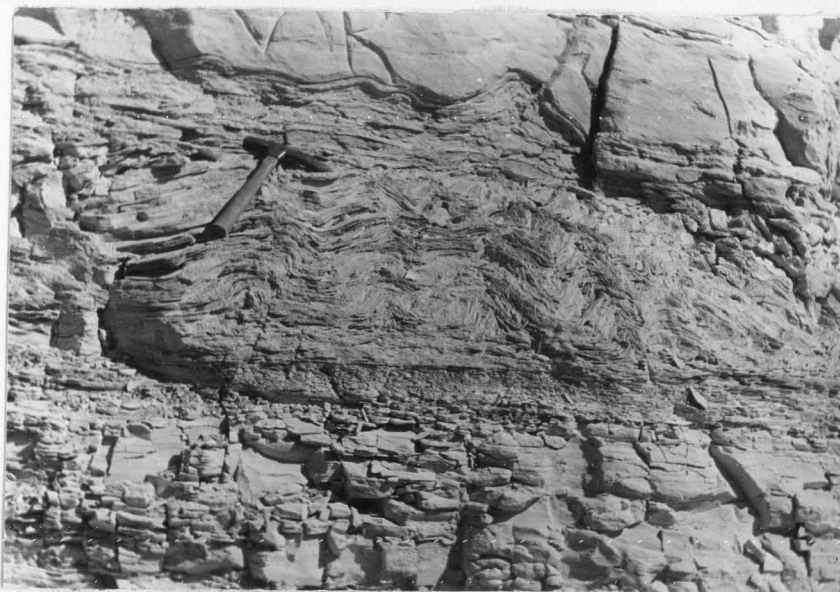


Figure 5. Deformed tuff beds in a roadcut on U. S. Highway 89 west of Logan, Utah

making the stratigraphic position difficult to discern. A stratigraphic section (Appendix, section No. 4) was measured at a point about 1 1/2 miles north of the outcrop of the Collinston conglomerate along an elongate north-trending hill. The dip of the beds steepens northward from 4° at the bottom of the section to 17° near the top. The section begins with a 35-foot pebble conglomerate which is composed chiefly of dark-gray limestone and light-tan quartzite cemented by calcite. A 3 1/2-foot reddish-brown clay bed is interbedded with the conglomerate which may have been derived from "Wasatch" beds. The conglomerate is overlain by a series of white to light-gray tuff beds which are interbedded with tuffaceous conglomerate and sandstone beds. Higher in the section, tuffaceous limestone beds are interbedded with the tuff. Several of the limestone beds contain fossil ostracods. The 294 feet of sediments measured is only part of the total thickness exposed in the area which probably exceeds 2,000 feet.

Tuff beds are well exposed in a roadcut on U. S. Highway 89, nine miles west of Logan, Utah. These beds are stratigraphically higher than the "Wasatch" and are stratigraphically higher or equivalent to the Collinston. Individual beds range in thickness from one-eighth inch to about 8 feet and were measured from the easternmost exposed bed to the western end of the roadcut as follows:

Cache Valley formation	Thickness (feet)
5. Tuff, light gray, thin bedded . . . . .	--
4. Tuff, very light gray, massive . . . . .	10
3. Tuff, light gray to olive gray, thin bedded one-eighth inch to 3 inches) to massive. Near bottom of unit, 2 feet of thin-bedded one-eighth inch common, tuff is folded . . . . .	30
2. Tuff, very light gray, massive, soft, weathers light-olive gray . . . . .	12
1. Tuff, yellowish gray to light gray, thin bedded, weathers white . . . . .	<u>10</u>
Total	62

The deformed beds of unit 3 are folded asymmetrically (Fig. 5) as a result of contemporaneous deformation. The drag folds were produced before the beds were not solidified by overlying beds slumping or gliding over the less competent beds.

Immediately east of Collinston, Utah, a conglomerate of the Salt Lake group crops out through the Lake Bonneville group. It is a pebble conglomerate with pebbles consisting of medium-grained pale-yellow-brown sandstone, dark-gray limestone, light-tan quartzite, and black chert. The pebbles are mostly a quarter of an inch to half an inch in diameter and are subrounded to subangular. The matrix consists of oolitic limestone. In places the very light-gray oolitic limestone predominates over conglomerate. The oolitic limestone contains many fossil gastropods and ostracods. The thickness of the conglomerate is about 100 feet; its base is not exposed.

This conglomerate is separated from the Wellsville Mountains by the Wasatch fault zone or a high-angle fault related to the Wasatch or both (Fig. 3). The west side of the fault is downthrown and has placed the

conglomerate at a lower elevation than the Collinston conglomerate which composes the mountain front in this area; although the oolitic conglomerate is thought to be stratigraphically higher than the Collinston. This oolitic conglomerate is similar in lithology and fossil content to the oolitic limestone and conglomerate (Appendix, section No. 5, units 1 and 2) north of the Bear River Narrows and may be an extension of the same unit.

Cutler Dam. -- In the Bear River Narrows southwest of the Cutler Dam, a red-brown conglomerate unconformably overlies Paleozoic rocks. The only exposure of the conglomerate is in the north bank of a canal about a quarter of a mile southwest of the dam. The conglomerate is about 50 feet thick, strikes east, and dips south  $16^{\circ}$ . It is overlapped by flat-lying sediments of the Lake Bonneville group. Angular fragments of thin-bedded tuff were found immediately down the slope from the conglomerate, and it seems likely that tuff beds overlie the conglomerate.

Pebbles and cobbles in the conglomerate are chiefly dark-gray finely crystalline limestone, black chert, and light-gray limestone. The matrix consists of moderate-reddish-brown tuffaceous clay cemented by calcite. The beds are irregular and vary from resistant beds, 6 inches to 2 feet thick, to less resistant beds, 3 inches to 1 foot thick, which consist chiefly of tuffaceous clay with a few angular pebbles. Most of the conglomerate is probably reworked "Wasatch" beds; and because of its stratigraphic position and lithology, the conglomerate is thought to be Collinston.

North of Bear River Narrows. -- Northward from the Bear River Narrows to a point a few miles southwest of Clarkston, Utah, a thick succession of tuff, marl, and limestone of the Salt Lake group is exposed. On the

west side of the area, a steep fault scarp exposes Salt Lake group that unconformably overlies Paleozoic rocks. Large rock slides containing blocks of oolitic limestone are present along the base of the scarp. A stratigraphic section (Appendix, section No. 5) was measured about 1 mile north of Bear River Narrows starting at a point near the western side of the area and extending northeastward about 1 mile. The beds strike N. 20° W. and dip eastward 2° at the bottom of the section to 27° toward the top. Exposed beds are 1,818 feet thick. An oolitic limestone, 280 feet thick, unconformably overlies Paleozoic rocks at the bottom of the section. The lower 20 feet of this limestone is predominately conglomerate and a few conglomerate beds are interbedded near the top. This limestone is well exposed along the fault scarp on the west side of the area. Fossil mollusks, identified by Yen (1947) and collected by J. Stewart Williams, from this unit included three species of pelecypods and 17 species of gastropods. Yen concluded that the fauna are Pliocene in age, probably later Pliocene. Swain (1947) studied ostracods from the same unit. Of the 12 species described, 11 are new and no definite assignment could be made. However, Swain points out the close relationship of most of the species to Pleistocene and Recent forms. Overlying the oolitic limestone are two limestone beds interbedded with tuff. The first limestone is smoke gray and petroliferous, and the second is wood brown and lithographic. Both limestone beds contain fossil mollusks. Above these limestone beds is a thick series of thin- to medium-bedded light-gray to moderate-yellow-green tuffaceous marls, interbedded light-gray tuffs, and moderate-yellow-green sandstones. These tuff, marl, and tuffaceous sandstone beds, particularly the green tuffaceous sandstone, can be traced from about a half mile north of Cutler Dam to about 1 1/2 miles southwest of Clarkston, Utah, a distance

of about 4 miles. The marl beds commonly contain fossil gastropods and ostracods. The beds in this section are clearly of lacustrine origin.

#### Clarkston area, Utah

In the northern side of North Canyon, about 4 1/2 miles northwest of Clarkston, Utah, a medium-gray aphanitic lava flow about 10 feet thick is interbedded with tuffaceous sediments of the Salt Lake group. The lava overlies about 200 feet of tuffaceous sediments that have been altered near the contact. A yellowish-gray lithographic limestone interbedded with light-gray tuff overlies the flow. The lava is vesicular, and the vesicles, about one-half to 1 millimeter in diameter, are filled with calcite. Massive obsidian is present in places within the flow.

About half a mile up North Canyon from the outcrop of the lava flow, a moderate-yellow-green tuff is present near the base of the Salt Lake group. It contains light-tan quartzite boulders and cobbles scattered throughout and is very fine. The outcrop is in the bottom of the canyon, and Paleozoic rocks crop out on the steep south side of the canyon. This relation suggests that the tuff was deposited in the canyon.

#### Worm Creek - Cub River area, Idaho

In the foothills of the Bear River Range east of Preston, Idaho, between Worm Creek and Cub River, a thick succession of the Salt Lake group is exposed. Tuffaceous sediments 7,674 feet thick unconformably overlie Paleozoic rocks and are overlain by a conglomerate at least 1,026 feet thick (Fig. 6). The conglomerate is well exposed in Cub River Canyon.

In Worm Creek Valley, just north of the Glendale Reservoir, Paleozoic rocks are exposed near the core of an anticline involving tuff of the Salt Lake group (Fig. 7). The Salt Lake group unconformably overlies and

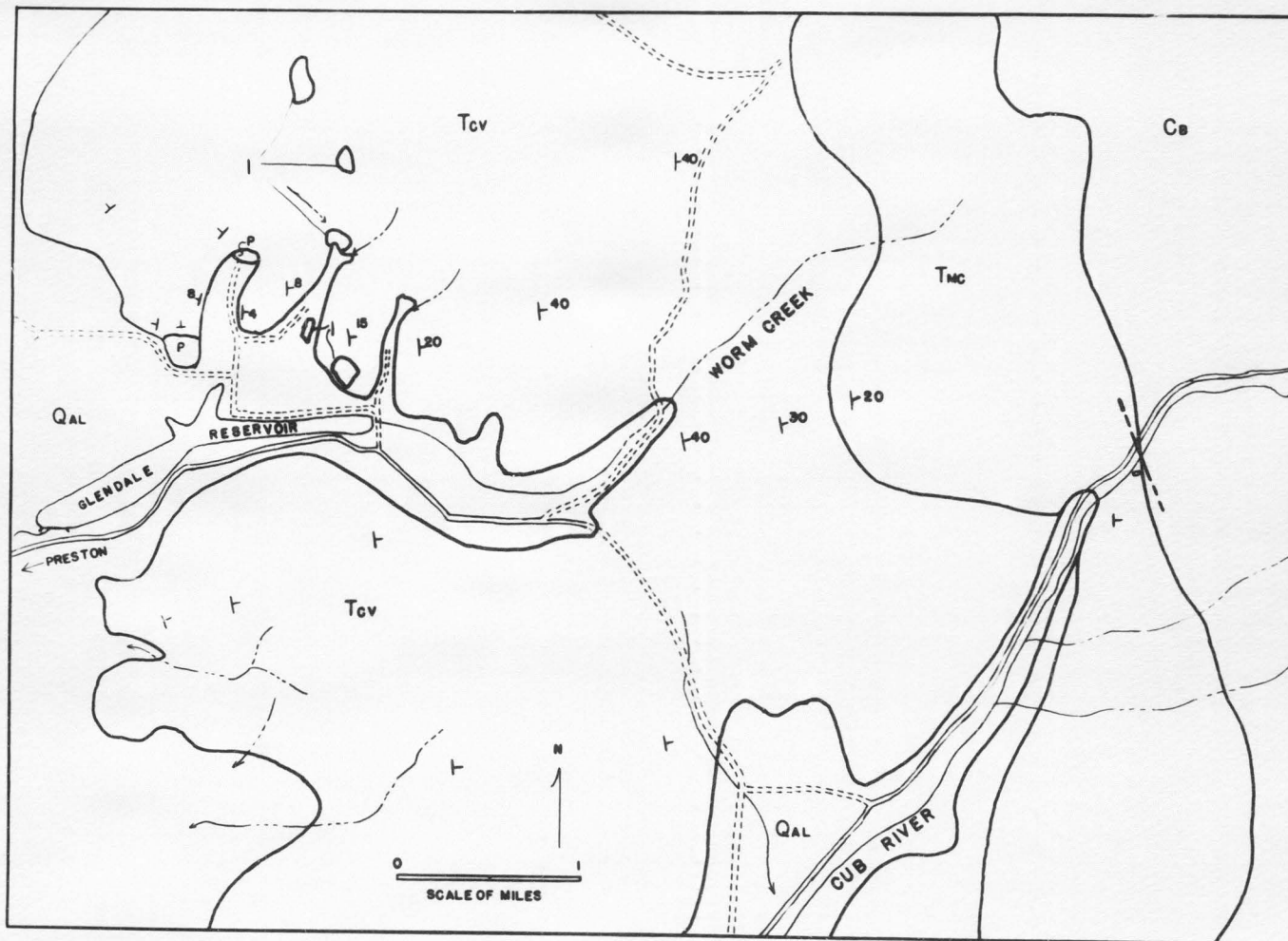


Figure 6. Geologic sketch map of the Worm Creek - Cub River area, Idaho. Qal - alluvium, Tmc - Mink Creek conglomerate, Tcv - Cache Valley formation, Cb - Brigham quartzite





Figure 7. Aerial view of Worm Creek Valley northeastward from the western end of the Glendale Reservoir. The round hill in the right-middle foreground is composed of Paleozoic rocks (P) which are overlain by the Cache Valley formation (Tcv).

dips away from the Paleozoic outcrop on three sides, north, east, and west. A stratigraphic section (Appendix, section Nos. 6 and 7) was measured along the east limb of the anticline. The succession strikes generally north and dips to the east. The dip increases gradually from  $1^{\circ}$  near the crest of the anticline to  $40^{\circ}$  near the middle of the section on the eastern limb. Near the overlying conglomerate, however, the dip is only  $20^{\circ}$ . Coulter (1954) believes that a high-angle north-trending fault displaces the Salt Lake group beds near the base of the upper conglomerate in this area. The writer found no evidence for faulting within the Salt Lake group beds and believes that the section is uninterrupted on the east limb of the anticline.

The lower 7,674 feet of the section consists mostly of well-bedded tuff and limestone of lacustrine origin. The base is marked by a very light-gray to light-green tuff, 82 feet thick, with interbedded thin-bedded light-olive-gray limestone. The remainder of the tuffaceous beds, 5,502 feet, consists of light-gray to light-green, thin- to massive-bedded tuffs interbedded with light-gray to dark-gray, thin- to medium-bedded limestones. A few sandstone and conglomerate beds are interbedded with the tuffs and limestones; light-gray to light-green tuffaceous sandstone beds become abundant near the top. The sandstones and conglomerates are medium- to massive-bedded and in some places are cross-bedded. The light-gray tuffs usually weather to smooth slopes and offer little resistance to erosion. They are thin- to massive-bedded; many massive beds are more resistant and stand out as ridges. In contrast to the weaker light-gray tuffs, the green tuffs are generally more resistant and harder. They weather to small chips with conchoidal surfaces and sharp edges and stand out as ridges. Limestones in the

section are well bedded, thin to medium, and three of the limestones are petroliferous (Appendix, section No. 6, units 10, 12, and 14). A limestone near the top of the section (Appendix section No. 6, unit 14) contains a 2-foot dark-yellowish-orange chert bed. The opaline chert interbedded with limestone described by Keller (1952) is similar to this bed.

The 86 feet of smoke-gray petroliferous limestone and tuff (Appendix, section No. 5, unit 3) of the area north of Bear River Narrows may be equivalent to the petroliferous limestone and tuff of units 12 or 14 in the Worm Creek area (Appendix, section No. 6, units 12 and 14). The only basis for suggesting a correlation of this nature would be the lithologic similarity and the petroliferous character of the limestone.

The tuffaceous conglomerate (Fig. 8) in the upper part of the succession in Worm Creek Valley is at least 1,026 feet thick and overlies the tuffaceous beds conformably. Pebbles and cobbles of the conglomerate consist chiefly of dark-gray limestone, light-gray tuff, light-tan to white quartzite, and black chert. Many boulders of light-tan to white quartzite, and dark-gray limestone are scattered throughout the conglomerate. Some are as large as 5 feet in diameter. The pebbles and cobbles are subrounded to subangular and are cemented by pale-yellow-orange to white tuffaceous marl and white calcareous tuff. A few thin calcareous tuffs, 2 to 10 inches, are present near the bottom. The conglomerate becomes finer toward the top.

Scattered gastropod fossils were found in one limestone bed (Appendix, section No. 6, unit 10), and ostracod tests are abundant in the limestone of unit 13 of the same section. Plant remains were found



Figure 8. Mink Creek conglomerate near the bottom of the formation on the divide between Worm Creek and Cub River



Figure 9. Calcareous tuff beds in the upper part of the Cache Valley formation in Worm Creek Valley. One thin bed, near the hammer, contains abundant matted plant remains.

in two places (Appendix, section No. 7, unit 7; section No. 6, unit 6). In unit 7, the plant fossils are matted and very abundant in one thin calcareous tuff bed (Fig. 9).

A basic igneous mass intrudes the Salt Lake group near the crest of the anticline in Worm Creek Valley about a quarter of a mile north of the middle of Glendale Reservoir. The intrusion has cut and altered tuff and limestone beds overlying it. Later basic dikes have cut both the intrusion and overlying limestone and tuff. Little alteration was produced by the dikes. The beds of the Salt Lake group appear little disturbed by the intrusions; however, the intrusions may have caused the anticline in the area.

In Cub River Canyon about 9 miles east of Preston, Idaho, near the western boundary of the Cache National Forest, a massive conglomerate is exposed in the south wall of the canyon. It forms a sheer cliff, perhaps 200 feet high. The beds dip eastward toward the Paleozoic rocks of the Bear River Range and are probably in fault contact with the Paleozoic rocks. The conglomerate is coarse and contains many boulders and has a tuffaceous marly matrix. The upper conglomerate of the Worm Creek Valley section can be traced into this conglomerate and to the conglomerate of the Richmon-Smithfield area, Utah (Fig. 10). In Cub River Canyon, the conglomerate is well exposed, massive, and apparently overlies light-gray tuff beds conformably.

A basic intrusion penetrating tuffaceous beds of the Salt Lake group is exposed in a roadcut in Cub River Canyon about 5 miles east of Preston, Idaho. This intrusion may be an extension of the basic intrusion in Worm Creek Valley to the north. It also crops out on the south side of the Cub River. The tuffaceous beds at the contact have been altered

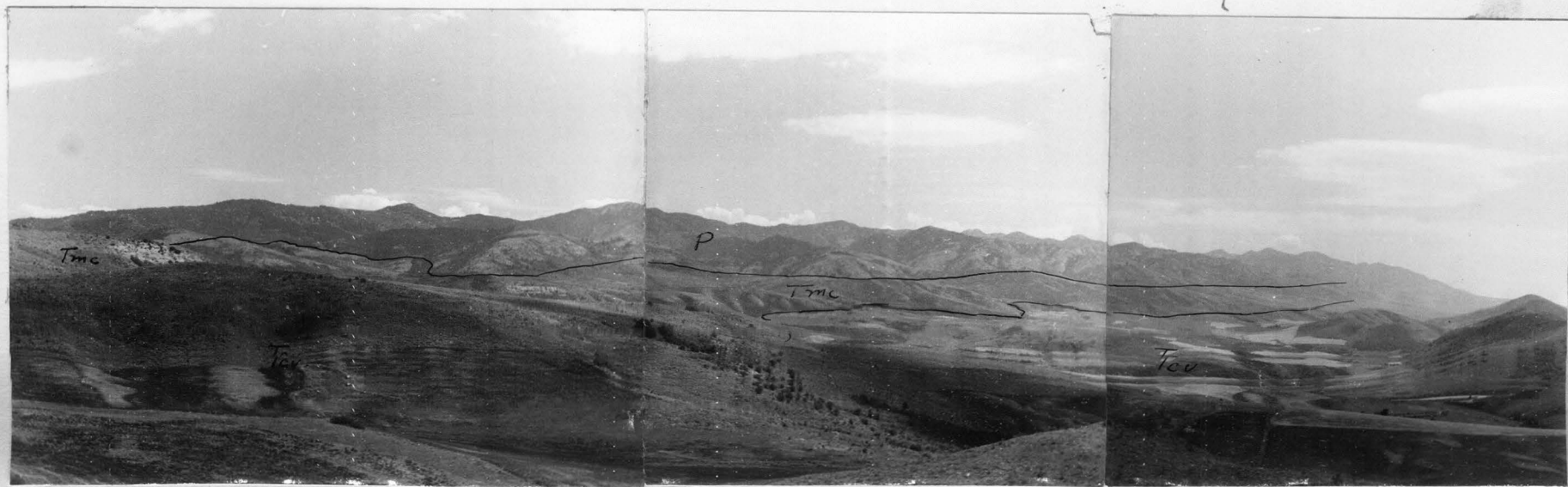


Figure 10. View southward of the Bear River Range across the Cub River. The mountains in the background are composed of Paleozoic rocks (P). The foothills are composed of Mink Creek conglomerate (Tmc) and Cache Valley formation (Tcv).

and are somewhat disrupted.

Richmond - Smithfield area, Utah

In the foothills of the Bear River Range east of Richmond, Utah, and Smithfield, Utah, a conglomerate of the Salt Lake group crops out adjacent to Paleozoic rocks. This conglomerate, as previously noted, can be traced to the Worm Creek - Cub River area, Idaho, but for the most part it is poorly exposed. It consists of subrounded to angular pebbles and cobbles with a few scattered boulders. The pebbles and cobbles are composed chiefly of dark-gray finely crystalline limestone, dark-gray dolomite, light-tan quartzite, and black chert. The boulders consist chiefly of light-tan Brigham quartzite and are strewn on the slopes of the foothills especially northward from Smithfield where the Brigham quartzite composes the mountain front. The matrix of the conglomerate consists of light-gray calcareous sandy tuff and pale-yellow marl. Calcite is the cementing material. The coarseness and angularity of the fragments indicate a nearby source area. Lower Paleozoic formations in the mountains to the east are no doubt the source of the coarse material.

About an eighth of a mile east of Richmond, Utah, the beds of conglomerate dip E.  $20^{\circ}$  and strike north. About half a mile southeast of Smithfield, Utah, the beds dip gently valleyward and strike about N.  $20^{\circ}$  E. The conglomerate in this area is at least 800 feet thick and overlaps Paleozoic rocks low on the mountain front. The conglomerate forms smooth ridges that slope gently toward the valley and form a pediment surface which was subsequently dissected.

Hyrum - Avon area, Utah

In the foothills of the Wellsville Mountains southwest of Hyrum,

Utah, to west of Avon, Utah, a thick succession of Salt Lake group unconformably overlies "Wasatch" beds and Paleozoic rocks. Gently sloping ridges characterize the foothills. These ridges represent a pediment surface which has been truncated on its outer margin by a high-angle fault and which has subsequently been dissected. A stratigraphic section (Appendix, section No. 3) was measured in Big Spring Hollow, about 3 miles west of Avon, Utah, from the contact of Salt Lake group and "Wasatch" beds to a north-trending fault about 1 1/2 miles to the east. The section begins with a light-olive-gray limestone which is largely stromatolitic (Fig. 11). The basal limestone is overlain by a series of interbedded light-gray to white tuffs, pebble conglomerates, tuffaceous limestones, and tuffaceous sandstones. The beds are similar in lithology to the tuffaceous beds of the other measured sections in Cache Valley. However, sandstones and pebble conglomerates comprise a greater part of the Big Spring Hollow section than do such sediments in the other sections. Total thickness of the measured section is 1,597 feet.

A 10-foot resistant tuffaceous limestone bed (Appendix, section No. 3, unit 7) can be traced for several miles northward along the strike west of Avon, Utah. A similar limestone bed is present at the northern end of the Wellsville Mountains. The two limestones have the same thickness and lithology; beds above and below the limestone are similar. These two units might represent a continuous bed.

No evidence of an unconformity was found by the writer within the 1,597 feet of sediments measured in Big Spring Hollow. A conglomerate (Appendix, section No. 3, unit 5) in the section contains stromatolites and tuffaceous pebbles that were derived from older Salt Lake group





Figure 11. Stromatolitic limestone at the base of the Salt Lake group in Big Spring Hollow

sediments, but this conglomerate is thought to be intraformational.

Some fossils, mostly mollusks, were found in the area. About an eighth of a mile southwest of the Hyrum reservoir, in the northwest bank of a wash which is being used as a garbage dump, a series of tuffaceous sandstones, tuffs, and oolitic limestones is well exposed. The oolitic limestone contains abundant fossil mollusks. Takeo Susuki identified the gastropod Planorbula sp. ind. that was collected from a limestone (Appendix, section No. 3, unit 2) near the bottom of the Big Spring Hollow section. A few fragmentary plant fossils were found in tuff beds exposed in the west bank of the Little Bear River a half mile northwest of Paradise, Utah. Brown (1949) studied plant fossils from this area and concluded that they were of Pliocene age, probably middle Pliocene. Also in this area mud cracks are exposed that attain a depth of 2 feet through tuffaceous marl beds. The cracks are preserved as tuffaceous limestone casts about 1 inch thick.

#### Wellsville area, Utah

West of the Wellsville, Utah, about 1 1/2 miles, a small patch of "Wasatch" conglomerate crops out and makes a conspicuous red spot on the front of the Wellsville Mountains. The "Wasatch" is unconformably overlain by a 20-foot thick pebble-cobble conglomerate of the Salt Lake group. This conglomerate contains fragments of dark-gray finely crystalline limestone, light-gray limestone, light-brown calcareous sandstone, and moderate-red limestone. The matrix is sand cemented by calcite and ranges in color from white to moderate-red. The pebbles, cobbles, and sand grains are angular to subrounded. This poorly sorted conglomerate was derived from nearby Carboniferous formations that comprise the east side of the Wellsville Mountains.

## AREAL STRATIGRAPHY

General statement

The stratigraphic nomenclature presented in this paper is a combination of terms used previously by Williams (Smith, 1953) in the southern Cache Valley and Keller (1952) in northeastern Cache Valley (Table 2). Changes in the previous nomenclature consist of inclusion of the West Spring formation, described by Williams (Smith, 1953), and the "lower tuff member" of the Mink Creek formation (Keller, 1952) in the Cache Valley formation. Also, the "upper conglomerate member" of the Mink Creek formation (Keller, 1952) is elevated to formation status as the Mink Creek conglomerate.

Table 2. Salt Lake group nomenclature

Williams (Smith, 1953)	Keller, 1952	This paper
	Mink Creek formation "conglomerate member"	Mink Creek conglomerate
Cache Valley formation	Mink Creek formation "tuff member"	Cache Valley formation
West Spring formation		
Collinston conglomerate		Collinston conglomerate

### Stratigraphic units

Collinston conglomerate. -- The type area of the Collinston conglomerate, as described by Williams (Smith, 1953), is the northern end of the Wellsville Mountains. The Collinston consists of rounded to subangular cobbles, pebbles, and some boulders of Paleozoic rocks. It is cemented by calcite that contains minor amounts of tuff and red silt which in places gives the conglomerate a red hue. Light-gray tuff of the Cache Valley formation intertongues with the Collinston. The conglomerate is at least 1,500 feet thick.

The Collinston conglomerate is nowhere well exposed, but the best and most extensive exposure is at the northern end of the Wellsville Mountains. Here the conglomerate unconformably overlies "Wasatch" beds and Paleozoic rocks. Small exposures of conglomerate about a quarter of a mile southwest of Cutler Dam and about 1 1/2 miles west of Wellsville, Utah, are probably Collinston. The conglomerates in these areas unconformably overlie Paleozoic and "Wasatch" beds respectively. J. Stewart Williams (personal communication) believes that the conglomerate overlying Paleozoic rocks at Cache Butte, Utah, about 9 miles northwest of Logan, Utah, and Red Rock Pass, Idaho, represent the Collinston. Elsewhere in Cache Valley where Salt Lake group was observed overlying older rocks, the Collinston is not present but tuffs and limestones of the Cache Valley formation are in depositional or fault contact with the older rocks.

Cache Valley formation. -- Williams (Smith, 1953) designated the tuffaceous beds that outcrop in the southern and central part of the valley along the banks of the Bear and Little Bear rivers and in the Wellsville Mountain - Clarkston Mountain area, Utah, as the Cache Valley

formation. In the type area it consists of a series of interbedded light-colored tuffs, tuffaceous sandstones, tuffaceous limestones, oolitic limestones, and pebble conglomerates, green tuffaceous sandstones, and dark-colored petroliferous limestone (Appendix, section Nos. 4 and 5).

The writer considers the tuffaceous beds (Appendix, section No. 3) cropping out west of Avon, Utah, which were designated by Williams (Smith, 1953) as the West Spring formation, as part of the Cache Valley formation. These beds are thought to represent Cache Valley formation because of their lithologic similarity to and conformity with the beds of the Cache Valley formation as previously noted.

Tuff and limestone beds of the Cache Valley formation in the Wellsville Mountains - Clarkston Mountain area, Utah, (Appendix, section Nos. 4 and 5) are lithologically similar to tuff and limestone beds in the Worm Creek - Cub River area, Idaho, (Appendix, section Nos. 6 and 7) and are regarded as equivalent. Thin- to massive-bedded light-gray tuffs are similar as are several light-green tuffaceous sandstones. Petroliferous limestone beds, as previously noted, are similar. Both areas contain beds chiefly of lacustrine origin with a few interbedded fluvial sandstones and conglomerates. Fossil mollusks and ostracods are present in both areas although not abundantly in the Worm Creek - Cub River area. The tuff and limestone beds in the two areas have similar stratigraphic positions; they unconformably overlie Paleozoic rocks. The tuffaceous beds of the Worm Creek - Cub River area probably extend at least as far south as Dry Canyon southeast of Smithfield, Utah, as indicated by their position beneath the Mink Creek conglomerate.

The "lower tuff member" of the Mink Creek formation (Keller, 1952) is regarded as Cache Valley formation. This conclusion is based on the occurrence of lithologic similarities between the "lower tuff member" and the succession of tuffs and limestones in the Worm Creek - Cub River area, Idaho, which, as noted in the paragraph above, is considered Cache Valley formation. Petroliferous limestones, cherty limestone, green tuffs, and light-gray tuffs are present in both units at similar stratigraphic positions. The tuffaceous sediments in both areas unconformably overlie Paleozoic rocks and are overlain by a lithologically similar and continuous conglomerate, the Mink Creek conglomerate.

The thickness of the Cache Valley formation varies considerably. This variation of thickness reflects the irregular topography upon which the formation was deposited. The formation is 7,674 feet thick in the northern part of the valley; whereas in the southern part of the valley, its thickness is at least 2,000 feet. Also toward the south, conglomerate beds increase in abundance and thickness. The lower 5,000 feet of the formation in the Worm Creek Canyon area contains a few thin conglomerate beds, while the conglomerate beds in the Hyrum-Avon area and at the northern end of Wellsville Mountains make up a large part of the formation.

The age of the Cache Valley formation seems established as Pliocene, probably middle or upper Pliocene. Yen (1947) has studied molluscan fauna from the oolitic limestone (Appendix, section No. 5, unit 2) north of the Bear River Narrows and assigned the beds to the Pliocene, probably middle or late Pliocene. Brown (1949), from studies of fossil plants from Salt Lake group beds near the mouth of McMurdie Hollow half

a mile northwest of Paradise, Utah, assigned the beds to Pliocene, probably mid-Pliocene. Fossil gastropods were collected by the writer from a tuffaceous oolitic limestone in a wash being used as a garbage dump an eighth of a mile southwest of the Hyrum Reservoir. Takeo Susuki identified the fossils, and an extract of a letter containing his identification states:

Pompholopsis minima Yen  
Vorticifex cf. tryoni Meek (young form)  
Physa sp. ind. . . .

The assemblage present above is not sufficient for evaluating a precise age correlation for the Salt Lake group. The gastropod Pompholopsis minima described from the Salt Lake beds northwest of Logan, Utah is the only form which indicates a probable Pliocene age. Another gastropod Vorticifex cf. tryoni (a young form) occurs in questionable Pliocene or Miocene beds of Oregon and Idaho, and Pliocene of Nevada. From the few species present and the works of other Molluscan Paleontologists, a Pliocene age is most probable with a slight leaning toward Middle Pliocene by the aid of fossil plants described from the Salt Lake beds near the confluence of McMurdie Hollow creek and Little Bear River.

The beds from which the fossils described in the preceding paragraph were taken are probably in the middle or upper part of the Cache Valley formation. The lower part of the formation may be older.

Mink Creek conglomerate. -- The "upper member" of the Mink Creek formation (Keller, 1952) is here elevated to the status of formation and designated as the Mink Creek conglomerate. It overlies the Cache Valley formation as identified in this paper with apparent conformity and unconformably overlaps Paleozoic rocks in the northeastern part of Cache Valley. It can be traced in the foothills adjacent to Paleozoic rocks on the east side of the valley almost continuously from Mink Creek to Worm Creek in Idaho and continuously from Worm Creek to Dry Canyon southeast of Smithfield, Utah.

The type section of the Mink Creek conglomerate is about 1 mile west of Mink Creek, Idaho (Keller, 1952). The conglomerate consists of subrounded to angular cobbles and pebbles with some boulders. They were derived from lower Paleozoic rocks that comprise the front of the Bear River Range. The matrix consists of light-gray, sandy calcareous tuff and pale-yellow marl. In the Mink Creek area, the conglomerate is interbedded with white tuff. No interbedding of tuff with conglomerate was observed south of Worm Creek but may be present inasmuch as the conglomerate is poorly exposed.

The Mink Creek conglomerate apparently overlies tuffaceous sediments, here identified as the Cache Valley formation, conformably. Keller (1952) did not recognize an unconformity in the Mink Creek area, and the writer found none south of Worm Creek. It should be noted, however, that in the Worm Creek Valley area tuff and sandstone beds underlying the conglomerate dip E.  $30^{\circ}$  while the conglomerate dips E.  $20^{\circ}$ . This difference in dip is probably due to the gradual decrease in dip that occurs in this part of the section, but the possibility of an unconformity cannot be overlooked. The stratigraphic relations of the formations and columnar representation of the measured sections are shown in diagrams (Figs. 12 and 13).



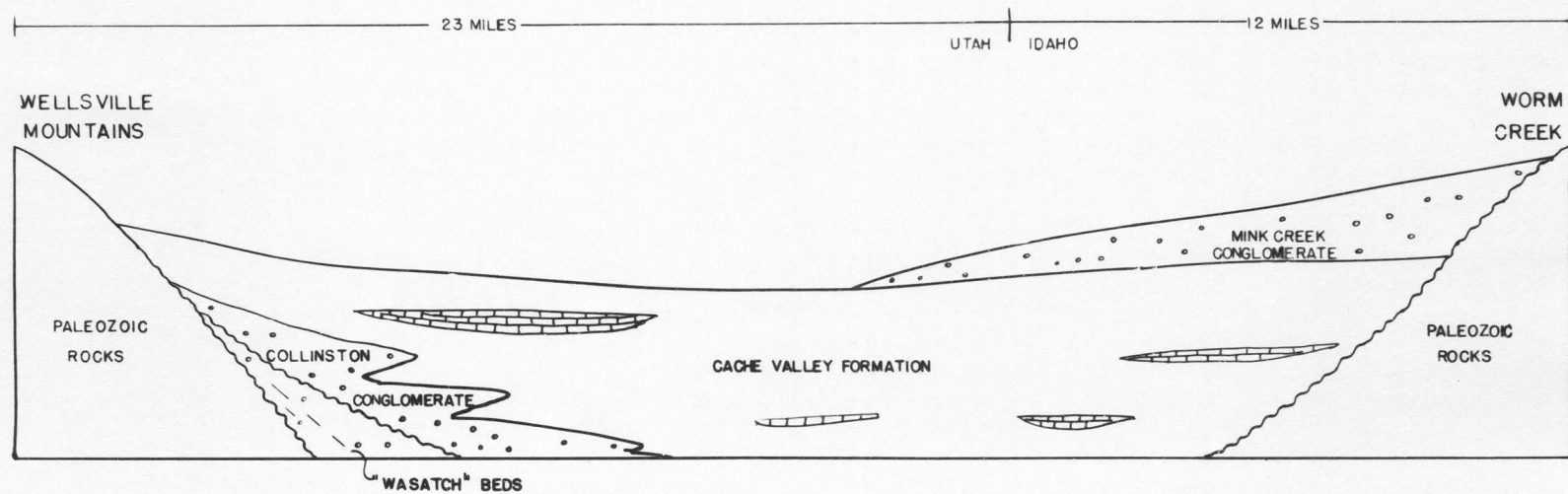


Figure 12. Diagrammatic sketch of the stratigraphic relations of the Salt Lake group

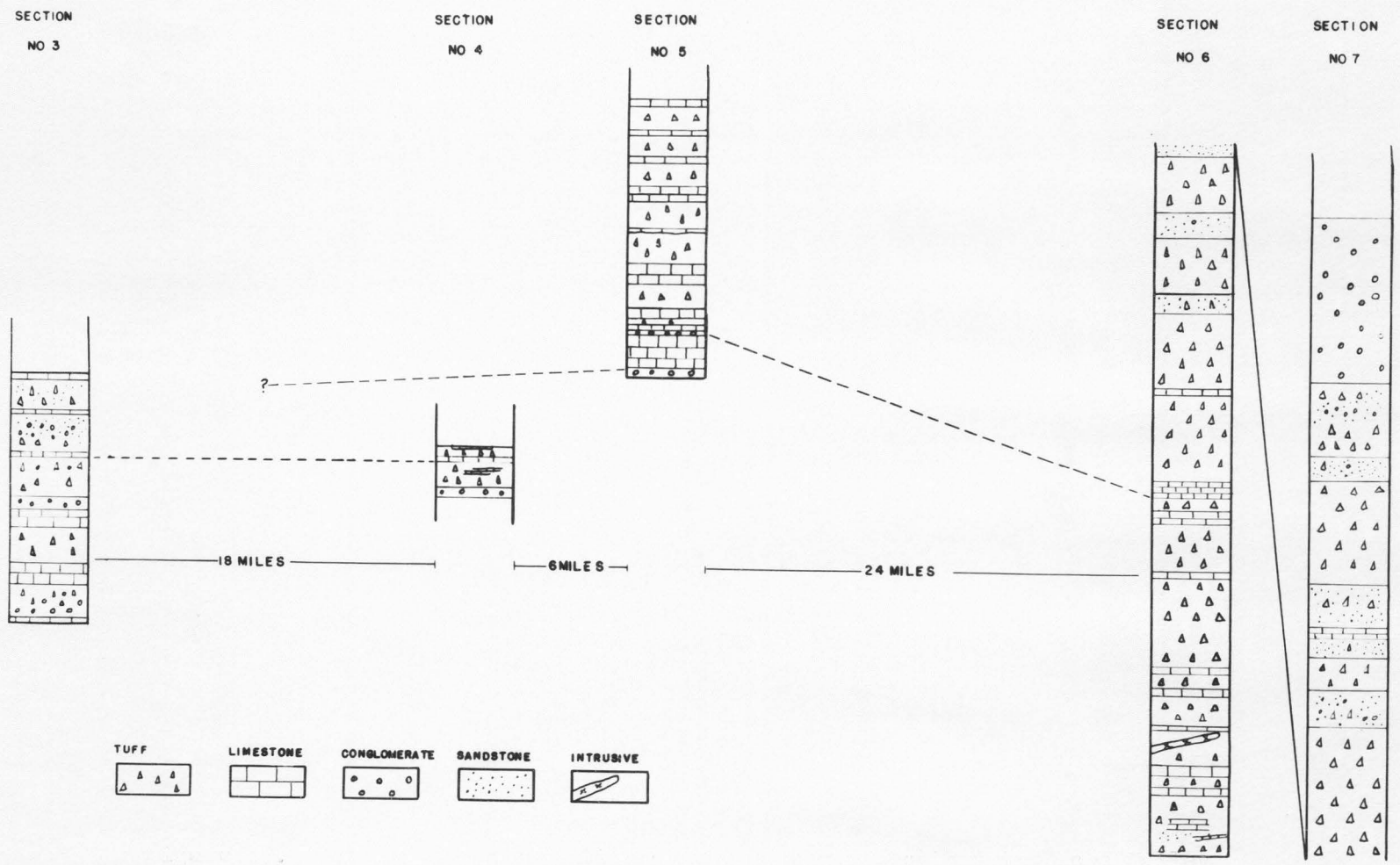


Figure 13. Columnar representation of the measured sections in Cache Valley

## REGIONAL STRATIGRAPHIC RELATIONS

Southeastern Idaho

Mansfield (1927) studied the Tertiary tuffaceous sediments of southeastern Idaho and concluded that the term Salt Lake formation was appropriate in this area. Characteristic rock types include light-gray to buff conglomerate with a white soft calcareous matrix, white marl, calcareous clay, sandstone, and grit. Rhyolitic material is found within the formation in several places, and Mansfield believes that it is equivalent to rhyolite of Yellowstone National Park of Pliocene age. A few poorly preserved mollusks also indicate a Pliocene age (Mansfield, 1927). Yen (1946) assigned the Salt Lake formation to upper Miocene because of mollusks found about 9 miles northwest of Montpelier, Idaho. Yen states that beds designated as Salt Lake formation by Mansfield (1916), 37 miles northeast of Montpelier in Lincoln County, Wyoming, contains molluscan species that indicate an age much younger than upper Miocene.

The Salt Lake formation of southeastern Idaho is probably Miocene or Pliocene in age and is lithologically similar to the Salt Lake group of Cache Valley. The age of the Cache Valley formation is Pliocene, at least in the upper part. The lower part of the Cache Valley formation may be older.

Southwestern Idaho

The Idaho formation and possibly the older Payette formation of southwestern Idaho (Kirkham, 1931) are thought to be time equivalents of the Salt Lake group in Cache Valley. The Idaho formation overlies

the Payette formation. It is widespread and attains a thickness of over 18,000 feet. The sediments accumulated in an ephemeral lake on the subsiding basalt plain of the Columbia River Plateau (Kirkham, 1931). Rock types include light-colored shales, sandstones, and a few conspicuous volcanic ash and diatomite beds. Plant fossils indicate a Pliocene age; vertebrate and invertebrate fossils suggest a Pliocene or Pleistocene age. The Payette formation consists of well consolidated volcanic ash, carbonaceous and coaly shale, and sandstone. Plant and vertebrate fossils indicate a middle-upper Miocene or possibly lower Pliocene age of the formation (Kirkham, 1931).

The well consolidated ash of the Payette formation and the volcanic ash beds of the Idaho formation are similar to Salt Lake group tuff beds of Cache Valley. Yen (1947) states that the molluscan fauna of the Idaho formation and that of the Salt Lake group in Cache Valley are similar.

#### Northeastern Nevada

The Humbolt formation (Sharp, 1939) of northeastern Nevada is divided into three members: (1) a lower member of shale, oil shale, fresh water limestone, sandstone, and conglomerate; (2) a middle member of rhyolitic tuff and ash; and (3) an upper member of fine conglomerate, sandstone, mudstone, siltstone, and shale. Sharp assigned the beds to late Miocene and possibly early Pliocene on the basis of plant and vertebrate fossils.

The middle and upper members of the Humbolt formation are lithologically similar to Salt Lake group in Cache Valley. The lower part of Cache Valley formation, as noted previously, may be older than Pliocene. If this age for the Cache Valley formation is valid, the upper Humbolt

would be its time equivalent.

#### Snowville, Utah, area

Tuffaceous beds of the Salt Lake group are interbedded with three lava flows along U. S. Highway 30, nine and 1/10 miles southeast of Snowville, Utah. Paleozoic rocks are unconformably overlain by a tuffaceous light-yellow-gray thin-bedded limestone containing many gastropods. This limestone is overlain by an aphanitic black basalt. A light-gray thin- to massive-bedded tuff overlies this flow and is in turn overlain by a basalt flow similar to the first, but containing phenocrysts of obsidian. Thin-bedded light-gray tuff overlies the second flow and is overlain by a third flow rock. It is aphanitic black, and vesicular. The tuffaceous beds in this area appear, as in Cache Valley, to have accumulated in a previously formed valley.

#### North-Central Utah

Eardley (1944) named and described the Norwood tuff in Morgan Valley, about 20 miles southeast of Ogden, Utah, as a division of Hayden's (1869) Salt Lake group. It consists of light-gray to light-green tuff, interbedded with tuffaceous sandstone, and pebble and cobble conglomerate. The sandstone and conglomerate are cross-bedded channel deposits. Volcanic conglomerate lenses are interbedded and become abundant to the south (Eardley, 1944). A stratigraphic section (Appendix, section No. 1) represents 541 feet of Norwood tuff in Norwood Canyon. The tuff beds rest with angular unconformity upon Eocene "Wasatch" beds (Eardley, 1944).

The pebbles and cobbles of the volcanic conglomerates in the Norwood tuff are composed of a glassy groundmass with imbedded phenocrysts and microliths of plagioclase, augite, hypersthene,

hornblende, and biotite (Eardley, 1944). The mineralogy of the tuff is similar. A green tuff exposed on the divide between Morgan and Ogden valleys (Appendix, section No. 2, unit 1) is described by Eardley as a very fresh rhyodacite with none of the common secondary clay minerals. The tuffs and conglomerates are similar to the tuff and breccia of the Park City and Kamas prairie volcanic field, about 25 miles east of Salt Lake City, Utah, and Eardley believes they are contemporaneous and that the Park City volcanics are the probable source of the volcanics in the Norwood tuff.

The light-colored tuffaceous beds in Morgan Valley in the vicinity of Norwood Canyon are clearly Oligocene or late Eocene. Eardley (1944) discovered titanotherium remains in the beds near the mouth of Norwood Canyon that were dated lower Oligocene. The writer found a jaw bone with four teeth in a cross-bedded tuffaceous sandstone in Norwood Canyon about an eighth of a mile from the mouth of the canyon. Bone fragments were also found in a cross-bedded tuffaceous sandstone (Appendix, section No. 1, unit 5) farther up the canyon. The jaw bone was identified by C. Lewis Gazin, Curator, Vertebrate Paleontology, Smithsonian Institution. An extract of a letter containing his identification of the fossil states:

. . . The jaw belongs to an agriochoerid type artiodactyl. The Agriochoeridae were oreodon-like mammals represented in the upper Eocene by the genus Protoreodon, and through the Oligocene into the lower Miocene by the genus Agriochoerus. The two forms are not too readily separated by characters of the lower molars; however, I am reasonably satisfied from the form of the last lower premolar and the general, rather primitive appearance of the molars that Protoreodon is represented. The Norwood tuff jaw corresponds very closely in size to material in our collections of Protoreodon pumilus (Marsh) from the upper Eocene Uinta formation in northeastern Utah. I would say that an upper Eocene age is rather strongly indicated. The age is certainly not older.

The Norwood tuff and Salt Lake group in Cache Valley are lithologically similar. Tuffs, both light-gray and light-green, are almost identical. No volcanic conglomerate is found in Cache Valley, but a few igneous pebbles are found in conglomerate of the Cache Valley formation and Collinston conglomerate. The age of the Norwood tuff is unquestionably lower Oligocene or late Eocene. The age of the upper part of the Cache Valley formation is Pliocene. Lack of paleontological evidence indicating an older age of the Salt Lake group beds in Cache Valley preclude correlation with the Norwood tuff.

## GEOLOGIC HISTORY

Pre-Salt Lake group erosion surface

The larger topographic features of Cache Valley appear to have existed prior to deposition of the Salt Lake group. Thus, the Bear River range on the east and the Wellsville Mountains and Malad Range on the west stood out in relief. The low divides, present today, were developed between Wellsville Mountains and the Malad Range at the northern end of the valley near Red Rock Pass, and at the divide between Cache and Ogden valleys. The higher elevations above 6,500 feet stood as positive areas supplying detritus to the valley. Salt Lake group sediments overlap Paleozoic rocks and "Wasatch" beds at lower elevations on the mountain masses. Only on the low divides, such as that between Wellsville Mountains and the Malad Range or the divide between Ogden and Cache valleys, do the sediments cover the older rocks and extend into the adjacent valleys.

Deposition of sediments

Channel deposits of gravels and sands locally accumulated on the pre-Salt Lake group erosion surface. These form conglomerate lenses basal to the Salt Lake group in places. The lacustrine nature of most of the sediments in the Wellsville Mountain - Clarkston Mountain area, Utah, and the Worm Creek - Cub River area, Idaho, indicates that most of Cache Valley was covered by lakes or a lake during deposition of much of the Cache Valley formation. The Collinston conglomerate represents a valleyside facies intertonguing with tuffaceous sediments of the valley. The Mink Creek conglomerate, which overlies



the Cache Valley formation, was locally derived from the mountains and resulted from changed climatic conditions or up-faulting of the mountain front adjacent to the site of deposition (Keller, 1952).

The limestone and tuff of the Cache Valley formation were deposited in lakes that were possibly the result of streams dammed by volcanic ash falls. Volcanic ash comprises the bulk of sedimentary debris that was deposited. Some tuff beds, massive almost pure volcanic ash, resulted directly from ash falls. Other tuff and tuffaceous beds consist of reworked volcanic ash and non-volcanic ejectamenta deposited as well-bedded tuff, tuffaceous limestone, and tuffaceous sandstone. That particular limestone or tuff beds can be recognized only in a limited area within the valley indicates that the lakes were small, but occasionally they would spill over their banks and form larger bodies of water in which thick extensive limestones could accumulate. The 280-foot oolitic limestone (Appendix, section No. 5, units 1 and 2) north of the Bear River Narrows represents one of these. Yen (1947) states that the molluscan fauna from this limestone must have been supported by a lake of large extent. The oolitic conglomerate a quarter of a mile east of Collinston, Utah, is probably equivalent to the limestone, and it probably extends far out into Salt Lake Valley.

Fluvial deposits within the Cache Valley formation are represented by cross-bedded tuffaceous sandstone and pebble conglomerate that are interbedded with the lacustrine limestone and tuff beds. These deposits accumulated in stream channels near the mountains and between the lakes. Mud cracks found at several places indicate that some lakes were shallow and at times withdrew allowing the mud cracks to develop. A tuffaceous limestone (Appendix, section No. 6, unit 14) in

Worm Creek Valley displays many small mud cracks and ripple marks. West of Paradise, Utah, where the Little Bear River has cut through tuff and marl beds, mud cracks are exposed that attain a depth of 2 feet through tuffaceous marl beds.

The Collinston conglomerate was deposited as a valleyside facies intertonguing with the finer tuffaceous sediments of the Cache Valley formation. Deposition of the Collinston may have begun before deposition of the tuffaceous beds, and the conglomerate may have accumulated to a considerable thickness before appreciable sediments were deposited in the central part of the valley. Deposition of the Collinston continued contemporaneously with the Cache Valley formation until it was overlapped by beds of the Cache Valley formation.

The Mink Creek conglomerate was deposited over the lacustrine and fluvial Cache Valley formation in the northeastern part of the valley probably as a result of changing climatic conditions or renewed faulting along the front of the Bear River Range. If deposition resulted from a climatic change, flash floods carried the coarse sediments far and into the valley from the mountain front; if the Bear River Range were faulted up after Cache Valley formation deposition, the conglomerate received its coarse material from the raised block of the mountain mass (Keller, 1952). Volcanic ash falls probably continued through the early part of Mink Creek deposition. The matrix of the conglomerate contains volcanic ash, and a few thin beds of tuff are present in the lower part of the conglomerate.

#### Intrusion

An irregular basic intrusion penetrated rocks of the Cache Valley formation east of Preston, Idaho. It crops out in places for a distance

of about 8 miles forming an irregular outcrop pattern, elongate in a north-south direction extending from the Bear River to the Cub River in Idaho. Good exposures of the intrusion can be seen in a roadcut 5 miles southwest of Mink Creek, Idaho, a quarter of a mile north of the east end of Glendale Reservoir in Worm Creek Valley, and in a roadcut in Cub River Canyon about 5 miles east of Preston, Idaho. Several other good exposures are found between the outcrop at Worm Creek and the Bear River.

The intrusion penetrated tuff and limestone beds of the Cache Valley formation in all instances. Beds near the contact, 1 to 20 feet away, have been silicified. In the Bear River and Cub River exposures, the beds have been disrupted locally by small faults and fractures and have been domed slightly by the intrusion. Beds cut at other places show little or no deformation as in Worm Creek Valley. Also in Worm Creek Valley, irregular dikes of a second intrusion or of a late stage in the first intrusion cut the intrusive mass as well as overlying limestone and tuff beds. The dikes are basic and very fine grained. Little alteration or deformation of the country rock resulted from the intrusion of these dikes. The age of the intrusions is post-Cache Valley formation.

Faulting and folding

The mountain ranges bounding Cache Valley stood in high relief at the time of Salt Lake group deposition possibly as a result of Basin and Range faulting (Williams, 1948) or normal processes of erosion. Evidence for an origin of Cache Valley similar to the synclinal structure of Morgan Valley as described by Eardley (1944) was not found. During the deposition of the Salt Lake group, faulting may have occurred

along the boundaries of Cache Valley resulting in the deposition of the Mink Creek conglomerate over the tuff and limestone of the Cache Valley formation (Keller, 1952). Post-Salt Lake group high-angle faults parallel all mountain fronts that bound the valley. These faults trend essentially northward and probably result from renewed movements in the boundary faults previously delineating the valley (Williams, 1948). The faults displace Salt Lake group and the fault blocks have tilted generally toward the valley except in the northeastern part where they dip generally toward the mountain front. The dip of the beds toward the valley is too great, in most instances, to be accounted for by normal valleyward dips resulting from deposition.

The Mink Creek conglomerate in Cub River Canyon is thought to be in fault contact with the Paleozoic rocks; in Dry Canyon southeast of Smithfield, Utah, the conglomerate is in depositional contact with Paleozoic rocks. Keller (1952) noted several high-angle faults displacing Salt Lake group beds in the Mink Creek area, Idaho. They trend in two directions, northeast and northwest, and have a stratigraphic displacement as much as 3,500 feet (Keller, 1952). Northwest of Weston, Idaho, about 1 mile, a very youthful north-trending fault scarp (Fig. 2) exposes Paleozoic rocks unconformably overlain by the Cache Valley formation. At the northern end of Wellsville Mountains, high-angle faults trending northeast and east are found. A northeast-trending fault has brought limestone and tuff beds of the Cache Valley formation into contact with "Wasatch" beds (Fig. 4).

At least two periods of post-Salt Lake group faulting are recognized in Cache Valley. After the first period of faulting, pediment surfaces were produced on the dipping Salt Lake group beds and adjacent older rocks. The pediment surface is well preserved at McKenzie Flat south

of Avon, Utah, Avon-Hyrum area, Utah, immediately east of Paradise, Utah, and the Richmond-Smithfield area, Utah. This surface was designated by Williams (1948) as the McKenzie Flat surface. The pediment surface has been truncated by north-trending high-angle faults, valley side downthrown, and subsequently has been dissected. This second period of faulting has probably been active to the present as indicated by faults displacing Lake Bonneville group and local earthquakes recorded in historic time.

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## APPENDIX

Measured sections

Section No. 1, Norwood Canyon, Utah, Sec. 13, T. 3N., R 2E.  
 Section of Salt Lake group north of Norwood Canyon, starting at a  
 point about 1 mile from the mouth of the canyon and extending west-  
 ward to Morgan Valley.

## Alluvium

	Thickness (Feet)
8. Tuff, light gray, thin bedded. Largely covered . . . .	17.6+
7. Limestone, pale yellowish brown, finely crystalline, massive . . . . .	3.0
6. Tuff, light gray, thin bedded. Largely covered . . . .	109.5
5. Tuff, light gray, few scattered pebbles, inter- bedded tuffaceous sandstone and pebble conglomerate, cross-bedding common. Pebbles in conglomerate of black chert, red igneous rock, and light-gray tuff, a tuffaceous sandstone contains fossil bones (53 feet from top of unit) . . . . .	149.0
4. Limestone, yellowish gray, calcite-filled vugs, cherty in places, massive, forms conspicuous ledge . . .	5.0
3. Tuff, light gray to light green, interbedded lenses of coarse-grained sandstone, cross-bedding common. Largely covered . . . . .	213.5
2. Limestone, pale yellowish brown, weathers white, massive, contains few gastropods . . . . .	5.0
1. Tuff, light gray, thin bedded. Largely covered . . . .	<u>38.8</u>
Total	541.4+

## Unconformity

## "Wasatch" beds



Section No. 2, Northern Morgan Valley, Utah, Sec. 13, T. 5N.,  
R. 1E., Section of Salt Lake group on north side of Dry Creek at a  
point about 1 mile north of U. S. Highway 30.

## Alluvium

	Thickness (Feet)
5. Tuff, light gray, massive . . . . .	10.0+
4. Tuff, grayish yellow green to light gray, thin bedded. Largely covered . . . . .	321.0
3. Tuff, grayish yellow green, thin bedded, several interbedded pale-green medium-grained sandstone beds 3 inches to 12 inches thick, cross-bedding common . . . . .	23.0
2. Sandstone, moderate yellow brown, medium to coarse grained, few scattered pebbles, cross-bedding common . .	4.7
1. Tuff, grayish yellow green, thin bedded; interbedded white massive tuff. Forms conspicuous green outcrop . .	<u>64.6</u>
Total	418.0+

## Alluvium

Section No. 3, Big Spring Hollow, Utah, Sec. 5, T. 9N., R. 1E.,  
 Section of Salt Lake group measured eastward from "Wasatch" beds  
 along the northern side of Big Spring Hollow to a high-angle fault.

## Fault

	Thickness (Feet)
8. Tuff, light gray to white; interbedded conglomerate, tuffaceous, medium-grained calcareous sandstone and thin-bedded tuffaceous limestone. Pebbles in conglomerate of light-tan quartzite, dark-gray finely crystalline limestone, and light-olive-gray stromatolites of limestone, cobbles chiefly light-tan quartzite and dark-gray finely crystalline limestone. Largely covered . . . . .	508.0+
7. Limestone, light grayish yellow, finely crystalline, weathers light gray, beds 10 inches to 40 inches thick, forms resistant ledge . . . . .	10.0
6. Tuff, white to light gray, upper part friable, weathers to earthy-gray smooth slope. Largely covered . . . . .	249.0
5. Pebble conglomerate, pebbles of light-tan quartzite, light-tan calcareous sandstone, light-olive-gray stromatolites of limestone, white calcareous tuff, light-tan finely crystalline limestone, cement consists of tuffaceous calcite; interbedded light-gray calcareous sandstone, beds 3 inches to 10 inches thick . . . . .	24.9
4. Tuff, yellowish brown and light gray; interbedded yellowish-gray to light-gray tuffaceous limestone beds, stand out as ridges, maximum thickness 20 feet. Largely covered . . . . .	585.0
3. Conglomeratic sandstone, light gray, calcareous, pebbles of light-tan quartzite, dark-gray, dense limestone, and black chert, cobbles chiefly light-tan quartzite, cross-bedding common . . . . .	7.0
2. Tuff, light brownish gray and white; interbedded light-gray tuffaceous limestone. Some limestone beds contain gastropod tests. Largely covered . . . . .	211.0

Thickness  
(Feet)

1. Stromatolitic limestone, light olive gray,  
stromatolites range in size from .1 mm to  
30 mm, forms resistant ledge . . . . . 3.0

Total 1597.9+

Unconformity

"Wasatch" beds

Unconformity

Wells formation

Section No. 4, Northern Wellsville Mountains, Utah, Sec. 15, T. 12N., R. 2W. Section of Salt Lake group measured northward along the western side of an elongate hill surrounded by the Lake Bonneville group.

Lake Bonneville group

	Thickness (Feet)
10. Tuff, light gray; interbedded thin-bedded cross-bedded tuffaceous limestone containing ostracods and dense light-gray finely crystalline limestone. Largely covered . . . . .	_____
9. Tuff, light gray, friable . . . . .	35.8
8. Tuff, light gray; interbedded porous light-gray tuffaceous limestone and resistant lenticular beds of light-gray tuff in lower part, thin bedded layers of light-gray and light-yellowish-gray tuffaceous limestone in upper part . . . . .	39.8
7. Tuffaceous limestone, light grayish yellow, weathers light gray, beds 10 inches to 30 inches thick, somewhat porous, in part finely crystalline . . . . .	10.0
6. Tuff, light gray; interbedded with light-gray tuffaceous limestone with ostracods and dense light-gray finely crystalline limestone, irregular lenticular beds 6 inches to 8 inches thick . . . . .	110.0
5. Tuff, white and light gray; conglomeratic sandstone, tuffaceous, matrix light grayish green, beds 6 inches to 12 inches thick, interbedded in tuff mostly in upper part . . . . .	36.4
4. Tuff, light gray and white, calcareous, several interbedded layers conglomerate with pebbles of yellowish-brown quartzite, black chert, and dark-gray finely crystalline limestone, light-gray and grayish-yellow-green tuffaceous matrix. Ledges of conglomerate conspicuous . . . . .	33.76
3. Pebble conglomerate, pebbles of dark-gray finely crystalline limestone and black chert, light-tan quartzite, dark-gray finely crystalline limestone; few interbedded light-gray quartzitic sandstone beds with a few cobbles (size about 12 cm) . . . . .	33.2

	Thickness (Feet)
2. Sandy clay, reddish brown, few scattered pebbles. Largely covered . . . . .	3.4
1. Conglomerate, pebbles chiefly dark-gray crystalline limestone, cobbles (maximum size about 100 cm) dark-gray finely crystalline limestone, matrix of granules cemented by crystalline calcite. On slope boulders of light-tan fine-grained quartzite (maximum size about 45 cm) and dark-gray finely crystalline limestone (15 cm size common). Largely covered . . .	<u>1.9</u>
Total	294.24+

Lake Bonneville group

Section No. 5, North of Bear River Narrows, Utah, Sec. 15, T. 13N., R. 2W. Section of Salt Lake group starting at Paleozoic rocks measured northeastward from a point about 2 miles north of the Bear River.

## Alluvium

	Thickness (Feet)
6. Tuffaceous marl, light gray to white, ostracod tests abundant in some beds; interbedded light-gray thin-bedded tuff. Largely covered . . . . .	730.0+
5. Tuffaceous marl, light gray, white to moderate yellow green, ostracod tests abundant in some beds; interbedded light-gray thin-bedded tuff, and light-gray to moderate-yellow-green tuffaceous sandstone . . . . .	545.0
4. Limestone, wood brown, lithographic, weathers white, gastropods and pelecypods abundant; interbedded light-gray tuff . . . . .	177.0
3. Limestone, smoke gray, petroliferous, platy, weathers white; interbedded light-gray tuff . . . . .	86.0
2. Oolitic limestone, light gray, sandy, poorly cemented, thick bedded, few beds of pebble conglomerate, shells of gastropods and ostracods common . . . . .	260.0
1. Pebble conglomerate, light gray, oolitic, massive, cross-bedding common . . . . .	<u>20.0</u>
Total	1818.0+

## Unconformity

Paleozoic rocks

Section No. 6, Worm Creek Valley, Idaho, Secs. 3, 4, and 5,  
T. 15S., R 40E. Section of Salt Lake group starting at Paleozoic rocks  
a quarter of a mile north of the middle of Glendale Reservoir and  
extending eastward across the eastern limb of an anticline.

	Thickness (Feet)
15. Tuff, pale yellowish green, light gray to pale yellowish orange, thin bedded to massive, massive beds stand out as ridges especially near top, few beds sandy and calcareous; calcareous sandstone, moderate yellowish brown to light gray, medium to fine grained, few scattered pebbles, few thin pebble conglomerate layers . . . . .	2142.0
14. Limestone, yellowish gray to grayish yellow, thin bedded, platy, petroliferous, tuffaceous. Mud cracks and ripple marks common. One dark-yellowish-orange chert beds 2 feet thick . . . . .	93.0
13. Tuff, grayish yellow green; few light-gray platy marl beds and dark-gray limestone beds near top, ostracod tests abundant in some marl and limestone beds. Largely covered . . . . .	1112.0
12. Tuff, grayish yellow green to very pale orange; interbedded yellowish-gray to dark-gray thin-bedded petroliferous limestone . . . . .	178.0
11. Tuff, grayish yellow green; interbedded very pale-orange to light-gray tuff, and few beds of light-gray limestone. Basic dike 8 1/2 feet thick 112 feet from bottom of unit (beds apparently not disturbed by intrusion). Upper part of unit largely covered . . . . .	444.0
10. Limestone, medium dark gray, thin bedded, compact, resistant, petroliferous, few gastropods . . . . .	66.0
9. Covered. Limestone, tuff, and basic igneous rock float . . . . .	134.0
8. Tuff, yellowish gray, platy; interbedded medium-dark-gray thin-bedded limestone. Largely covered . . . . .	84.0
7. Tuff, grayish yellow green, massive, resistant, forms conspicuous ledge . . . . .	8.0
6. Limestone, light olive gray, weathers white to light yellow, beds up to 2 feet thick, resistant, tuffaceous and thin bedded near top of unit, contains some plant remains near top of unit . . . . .	102.0

	Thickness (Feet)
5. Tuff, light gray to grayish green, thin bedded, a few interbedded thin-bedded tuffaceous lime- stone beds. Largely covered . . . . .	67.7
4. Tuff, light gray to grayish yellow green, thin bedded, platy; interbedded light-gray limestone near top of unit . . . . .	10.6
3. Tuff, grayish yellow green, massive, resistant . . . . .	28.0
2. Limestone, light gray, weathers white, massive, beds up to 3 feet thick. Largely covered . . . . .	15.4
1. Tuff, very light gray to light green, calcareous, platy; interbedded light-olive-gray thin-bedded tuffaceous limestone. Largely covered . . . . .	<u>82.0</u>
	Total 4566.7

Unconformity

Paleozoic rocks



Section No. 7. Section of Salt Lake group measured eastward from a point about 1 1/2 miles east of Glendale Reservoir, starting in the lower part of a valley which joins that of Worm Creek on the south. Bottom of unit 4 is equivalent to top of unit 15, section No. 6.

	Thickness (Feet)
8. Conglomerate, pebble and cobble, many boulders as large as 5 feet in diameter scattered throughout, chiefly light-tan to white quartzite, and dark-gray finely crystalline limestone. Crudely bedded in layers from 4 inches to 10 feet thick. Matrix is pale-yellow-orange to white marl and is tuffaceous; some thin beds with white to light-gray calcareous tuff matrix. Few thin light-gray tuff beds near bottom. Pebbles in conglomerate chiefly dark-gray finely crystalline limestone, light-gray tuff, light-tan to white quartzite, and black chert; cobbles chiefly dark-gray finely crystalline limestone, light-gray to yellowish-gray tuff, light gray tuffaceous sandstone, and pale red quartzite . . . . .	1026.0+
7. Tuff, greenish gray to light gray, massive to thin bedded; interbedded lenses of coarse sandstone, and soft massive light-gray tuff. Massive beds of the former tuff contain scattered subangular pebbles chiefly of light-gray finely crystalline limestone . . . . .	1320.0
6. Tuff, white, light gray to pale yellowish orange, massive to thin bedded, massive beds stand out as ridges, calcareous in places, plant fossils abundant in one thin tuff bed (Fig. 9) . . . . .	318.0
5. Sandstone, light gray, medium to coarse grained, few scattered pebbles, thin bedded, calcareous; interbedded light-gray tuff. Largely covered . . . . .	610.0
4. Tuff, light gray, light greenish gray to pale yellowish green, massive to thin bedded, massive bed near bottom of unit forms resistant ledge . . . . .	860.0
3. Sandstone, very pale orange to light gray, medium grained, tuffaceous, calcareous, interbedded tuff, light gray to grayish yellow green and few beds pebble conglomerate. Predominately tuff near top of unit . . . . .	285.0
2. Tuff, white, light gray to very pale orange, massive to thin bedded, weathers very pale orange . . . . .	167.0

Thickness  
(Feet)

1. Tuff, very light gray to pale yellowish green, thin bedded to massive, few interbedded sandstone beds containing a few scattered pebbles . . . . .	<u>57.8</u>
Total	4643.8+

Alluvium