5-1972

Tertiary Igneous Rocks of Northeastern Cache Valley, Idaho

Parry D. Willard
Utah State University

UtahStateUniversity
MERRILL-CAZIER LIBRARY

TERTIARY IGNEOUS ROCKS OF NORTHEASTERN

CACHE VALLEY, IDAHO

by

Parry D. Willard

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

of

MASTER OF SCIENCE

in

Geology

Approved:

_____
Major Professor

_____
Committee Member

_____
Committee Member

_____
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1972

ACKNOWLEDGMENTS

It is with appreciation that I recognize the help of my thesis advisor, Dr. Donald R. Olsen, for suggesting the project and for his direction during the preparation of the manuscript. I thank him also for his suggestions concerning the laboratory and field interpretations. I am grateful for the critical review of the manuscript by Dr. Clyde T. Hardy and Dr. Raymond L. Kerns. Dr. J. Stewart Williams was generous with his assistance in identifying the fossils.

Others that I wish to thank include Dr. Paul S. Taylor for obtaining the chemical analysis, and J. J. Crawford for his helpful suggestions in the preparation of the map. The companionship of Randy L. Willard in the field is appreciated. I also appreciate the interest of Edwin H. McKee, U. S. Geol. Survey, in the project. Under his direction, K-Ar age determinations are now in progress. I am grateful for the financial support provided by the Bear Creek Mining Company and the Utah State University Development Fund.

Finally to my wife, Linda, I give a special thanks for her love, encouragement, understanding, and patience during the research and preparation of this manuscript.

Parry D. Willard

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

Tertiary Igneous Rocks of Northeastern

Cache Valley, Idaho

by

Parry D. Willard, Master of Science

Utah State University, 1972

Major Professor: Dr. Donald R. Olsen
Department: Geology

The tuffs and limestones of the Tertiary Salt Lake Formation in northeastern Cache Valley, Franklin County, Idaho, are intruded by basic and intermediate igneous dikes and sills. The Tertiary intrusives are exposed in an area 10 miles long and 2 miles wide between Bear River and Maple Creek in the foothills of the Bear River Range east of Preston, Idaho. They trend north-northwest. The intrusives are mostly diabase but include a small body of syenodiorite and several small andesite dikes. The intrusives seem to be emplaced along early Basin and Range faults. They are limited to the Cache Valley Member of the Salt Lake Formation and pre-date the Mink Creek Member of the Salt Lake Formation in the mapped area. The probable age of the intrusive activity is late Pliocene. Because the igneous rocks are well exposed on both sides of the Cub River valley, they will be referred to as the Cub River Diabase. The Cub River Diabase could represent a southward extension of the early igneous activity in the Snake River Plain.

(62 pages)

INTRODUCTION

Purpose of Investigation

This investigation was undertaken with the intention of studying

the igneous rocks of northeastern Cache Valley and reaching some con-

clusions as to rock composition, extent of the intrusives, and

Cenozoic geologic history of this part of the valley. This report in-

cludes a geologic map (Plate 1) and petrographic and chemical analyses

of the igneous rocks. An attempt is made to describe the structural

features that may have controlled the location of the intrusives, and

to determine the types of igneous structures involved. The alteration

effects and the age of the intrusives are discussed and an effort is

made to correlate the intrusive rocks of Cache Valley with other ig-

neous activity in the region of northern Utah and southeastern Idaho.

Location and Accessibility

Cache Valley, trending north-south, is 60 miles long and 12 miles

wide at the widest part, with the northern portion extending 25 miles

into southeastern Idaho and the southern portion 35 miles into Utah.

The valley lies within the eastern boundary of the Basin and Range

Province (Fenneman, 1917, p. 22). It is a graben, bounded on the west

by Wellsville Mountain, the Malad Range, and Bannock Range, and on the

east by the Bear River Range. The mapped area is about 11-1/3 miles

long, north to south, and about 4-1/4 miles wide in secs. 19 to 23 and

26 to 35, T. 14 S., R. 40 E., secs 2 to 11 and 14 to 36, T. 15 S.,

R. 40 E., and secs. 1 to 18, T. 16 S., R. 40 E., on the Boise Base
Grid System.

Maximum relief within the mapped area is 1,725 feet. The lowest
elevation, 4,500 feet, is at the mouth of the Cub River, and the high-
est peak, 6,224 feet, is in sec. 33, T. 14 S., R. 40 E.

Most of the study area is readily accessible by improved dirt
roads and paved highways (Figure 1). U. S. Highway 91 cuts across the
southwest part of the mapped area 1 mile north of Franklin, Idaho.
The Cub River road offers rapid travel across the southern part of the
area as does Idaho State Highway 36 which follows the Bear River along
the northern edge of the mapped area. Since most of the area is under
cultivation or is used for range land there is good access in the dry
seasons along improved and unimproved dirt roads and jeep trails used
by the farmers and ranchers of the vicinity.

Field and Laboratory Methods

The study area was mapped during the summer months of 1970 with
some reconnaissance and field checking done in the spring and fall of
1970. The geology was mapped on Forest Service aerial photographs
dated 7-17-64 and 8-2-64, at an approximate scale of 1:20,000. A base
map was made from the air photos at the 1:20,000 scale, then the
geology was traced from the photos to the base map. The geology and
base map were then reduced to 1:24,000 scale using an opaque reducer.
A Brunton compass was used in the field to measure orientations of
bedding, faulting, and jointing in the sedimentary rocks, and directions
of structural trends in the intrusive rock.
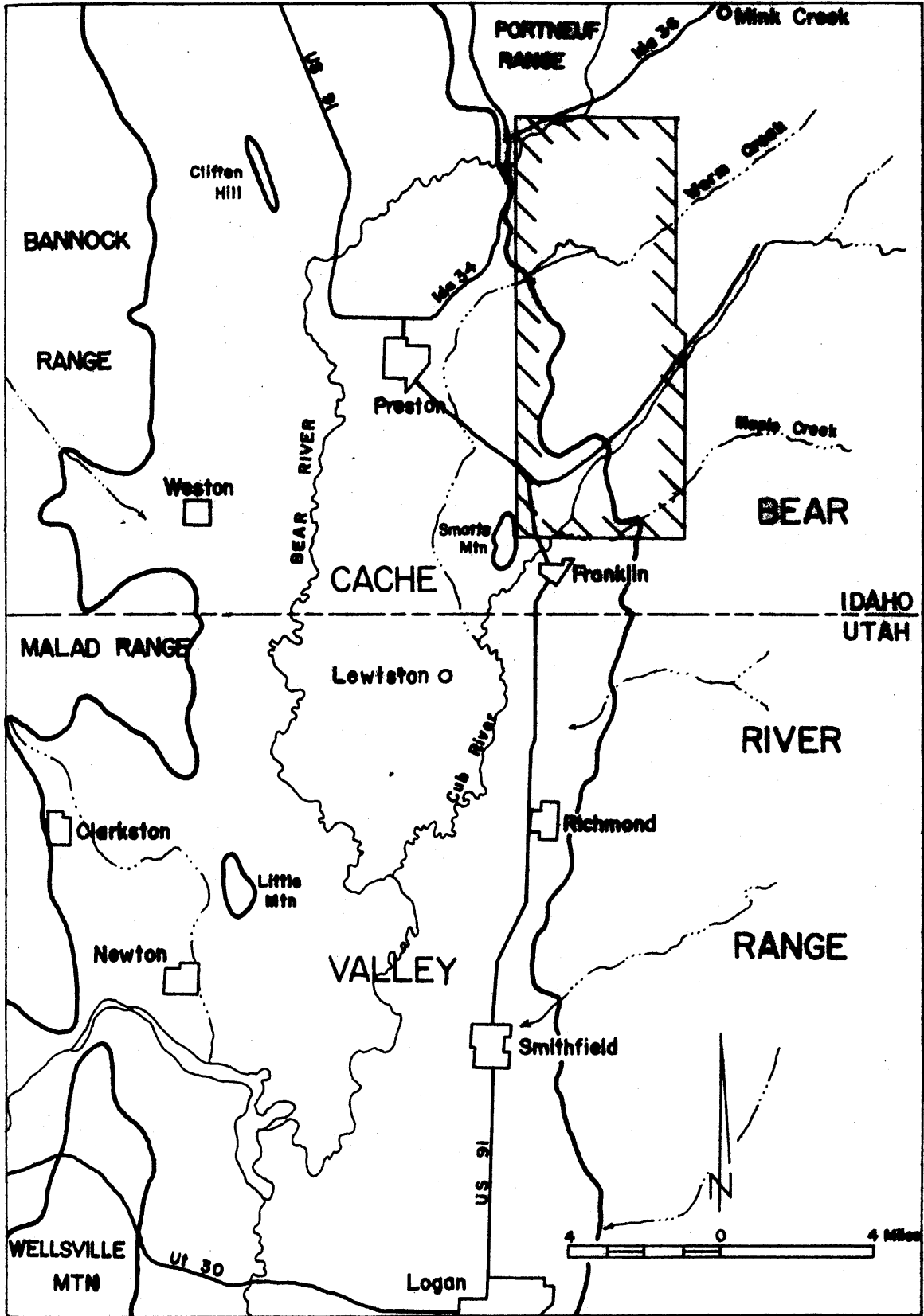
Figure 1. Index Map of northeastern Cache Valley, Idaho.

Numerous samples of the igneous rocks were collected, including textural varieties of each rock type. Thin sections of the samples were prepared and petrographically analyzed. Classifications of the igneous rocks were based on the Johannsen Classification System (Johannsen, 1939). The colors of the rocks in hand samples were based on the Rock Color Chart distributed by the Geological Society of America.

Previous Investigations

Basic igneous rocks were recognized in northeastern Cache Valley by Keller (1952, p. 17) just southwest of this thesis area. The igneous rocks, rich in hornblende and plagioclase, intruded Keller's Mink Creek tuff unit as irregular dikes.

The intrusives were observed by Adamson, Hardy, and Williams (1955, p. 14 and 18) in their studies of the Salt Lake Formation. They reported a basic igneous mass intruding the Salt Lake Formation near the crest of an anticline north of Glendale Reservoir in Worm Creek Valley. They observed that the igneous mass was cut by other basic dikes and noted alteration of the sedimentary rocks by the intrusive. They also mentioned a basic intrusive in a road cut in Cub River Canyon. In the Clarkston, Utah, area they described outcrops of lavas interbedded with the Salt Lake Formation.

The southeast portion of the Preston Quadrangle was mapped by Coulter (1956). He mapped the western bench area of the Bear River Range as Tertiary Salt Lake Formation but didn't mention the intrusives.

Peterson (1956, p. 6) mentioned the basic igneous rocks north of Franklin, Idaho, in his description of Cache Valley geology. According to his report the intrusion probably took place at the same time as the faulting and was intruded along the major fault. The rocks were described as "Hornblende diorite traversed with several dykes of absidian." He suggested that the igneous intrusion "apparently had to do with the positioning of the Smart Mountain."

Prammani (1957, p. 37) mapped the east-central part of the Malad Range and described lava flows or intrusives intercalated with the Salt Lake Formation west of Weston, Idaho. He considered these flows to be contemporaneous with the Salt Lake Formation.

Murdock (1961, p. 35) described basalt flows of Tertiary age lying unconformably on top of the Salt Lake Formation (Cache Valley Member) in the Weston Canyon area of the Bannock Range.

On the Reconnaissance Geologic Map of the Preston Quadrangle by Oriel and Platt (1968), the area of this report is mapped as Tertiary Salt Lake Formation but the intrusives are not shown. Their map does, however, show faults in the area which are parallel with the intrusives.

Stanley (1971, p. 43-44) described a magnetic anomaly and a corresponding gravity anomaly northeast of Lewiston, Utah, in his ground-water studies along the Utah-Idaho state line in Cache Valley. He interprets them as representing an intrusive body in the form of a dike which may be related to faulting in the area.

REGIONAL SETTING

The oldest rocks in the mountains around Cache Valley are Pre-
cambrian metamorphic rocks unconformably overlain by a thick sequence
of Paleozoic sediments. Laramide folding and faulting disrupted the
older rocks, following which Cenozoic terrestrial and lacustrine sedi-
ments were deposited on them. Subsequently, and in part contempo-
raneously with sedimentation, mountains and valleys were formed,
bounded by normal faults. Lacustrine sediments and deltas of
Pleistotene lakes cap the older sediments at lower elevations. The
sequence of rock units exposed in the study area is shown in Table 1.

Stratigraphy

Precambrian. No Precambrian rocks are exposed in the study area,
but Cache Valley and its surrounding mountains are underlain by a
thick section of Precambrian quartzite, phyllite, limestone, tillite,
and metavolcanics (Bright, 1960, p. 4; Eardley, 1969, p. 670; Ludlum,
1943, p. 977).

Paleozoic. A thick sequence of Paleozoic sediments deposited
at the eastern hinge area of the Cordilleran Geosyncline unconformably
overlies the Precambrian sediments around Cache Valley. The miogeo-
synclinal facies of the geosyncline includes about 30,000 feet of
limestone, dolomite, quartzite, and shale in the mountain ranges
east and west of Cache Valley (Williams, 1962, p. 132). Formations
of every Paleozoic Period are present.

Table 1. Stratigraphic units in study area, northeastern Cache Valley, Idaho

Unit	Lithology	Thickness
Quaternary		
Alluvium	Mud, sand, gravel	(thickness unknown in study area)
Lake Bonneville Group and alluvium undiff.	Mud, sand, gravel	"
Tertiary		
Cub River Diabase	Diabase, syenodiorite, and andesite	
Salt Lake Formation		
Mink Creek Member	Pebble and cobble conglomerate with tuffaceous matrix	1026 feet[a]
Cache Valley Member	Interbedded tuff, tuffaceous limestone and sandstone, and pebble conglomerate	7674 feet[b]
Ordovician		
Garden City Formation	Dolomitic limestone with chert stringers	(thickness unknown in study area)
Cambrian		
Langston Formation		
upper member (?)	Limestone and dolomitic limestone	"
Spence Shale Member	Dark olive green shale fissile, highly fossiliferous (trilobites)	"
Brigham Formation	Pink to red quartzite	"

[a]Adamson (1955). East of Glendale Reservoic.

[b]_____. Worm Creek Valley, north of Glendale Reservoir

In the mapped area (Plate 1) Paleozoic rocks are exposed through windows in the Cenozoic sediments. Coulter (1956, p. 20) recognized Ordovician Garden City Formation north of Maple Creek. He believed the brecciated limestone was exposed in the East Cache fault zone. Exposures mapped as Garden City Formation in sec. 11, T. 16 S., R. 40 E., (Plate 1) are brecciated limestone and are assumed to be those recognized by Coulter. Farther north, steeply dipping beds of quartzite, shale, and limestone are mapped as Cambrian Brigham Formation and Langston Formation. The shale unit is very fossiliferous and according to Williams (personal communication) the fauna and lithology match the Spence Shale Member of the Langston Formation.

Paleozoic rocks exposed in the core of an anticlinal arch north of Glendale Reservoir in Worm Creek Valley were first recognized by Adamson, Hardy, and Williams (1955, p. 15). Oriel and Platt (1968) mapped the eastern part of the outcrop as Ordovician Garden City Formation and the western part as Cambrian St. Charles Formation. Fossils collected from the western extreme of the outcrop were identified by Williams as representative of the Garden City Formation, so the entire outcrop is shown as Garden City on Plate 1.

Mesozoic. Sediments of the Mesozoic Era are completely missing in Cache Valley, although there may have been deposition during the Triassic and Jurassic Periods with subsequent removal of the sediments by erosian during and after Laramide deformation (Williams, 1962, p. 132).

Cenozoic. The Tertiary sediments in the Cache Valley area are several thousand feet thick and consist of the Wasatch Formation and

the Salt Lake Formation. The Wasatch is made up of red sandstone and conglomerate and is considered equivalent to the Knight-Formation of Early or Middle Eocene Age in north-central Utah (Williams, 1964, p. 271). The red conglomerate is exposed in several places in Cache Valley and in the Bear River Range. According to Williams (1958, p. 69) it may have covered the entire area at one time. Red tuffaceous (?) siltstone crops out in the northern part of the mapped area below the Salt Lake Formation, and could be a remnant of the Wasatch Formation. These outcrops are not shown on the map since their extent is limited and identification is uncertain.

The Salt Lake Formation in Cache Valley and nearby valleys has been studied by numerous authors (Adamson, Hardy and Williams, 1955; Hayden, 1869, p. 92; Keller, 1952; Mansfield, 1927, p. 110; Peale, 1879, p. 602; and Smith, 1953, p. 73). To synthesize the work done in the Salt Lake "Group," as it had been called, in Cache Valley, Adamson, Hardy, and Williams (1955) regrouped the Tertiary rocks. They recognized Williams' Collinston Conglomerate as a valley-side facies of his Cache Valley Formation and included his West Spring Formation in the Cache Valley Formation. Keller's Mink Creek tuff unit was correlated with the upper Cache Valley Formation giving the Cache Valley Formation a total thickness of 7,674 feet in the northern part of the valley. Keller's Mink Creek conglomerate unit was raised to a formation status and called the Mink Creek Conglomerate with a thickness of 3,400 feet. According to Adamson, Hardy, and Williams (1955, p. 17), the Salt Lake Formation is about 8,700 feet thick in Worm Creek Valley.

The Salt Lake unit has been referred to as a formation rather than a group in more recent literature (Maw, 1968; Oriel and Platt, 1968; Peterson and Oriel, 1970; Williams, 1962). The term Salt Lake Formation will here be used with a recognition of the units named by Adamson, Hardy, and Williams—Cache Valley Formation and Mink Creek Formation—at a member status (Table 1).

From the work of Swain (1947), Yen (1947), and Brown (1949), the Cache Valley Member has been assigned a Middle or Late Pliocene age. Williams (1964, p. 272) had potassium-argon isotope age-determinations run for samples collected from the Salt Lake Formation in Cache Valley to determine the minimum and maximum ages of the formation. The ages were found to range from 74 m.y. in the basal samples to 11.6 m.y. in the upper parts of the formation. The oldest dates are too great since the Salt Lake Formation rests on Eocene Wasatch Formation, but with some corrections for contamination, Williams' West Spring Formation could be as old as Early Eocene, and it is probably equivalent to the Norwood Tuff or Fowkes Formation. The younger dates in the Cache Valley Member fall in the range of the Miocene and Pliocene.

The lower parts of Cache Valley are filled with Quaternary sediments which were mostly deposited in Pleistocene Lake Bonneville. The lacustrine silts and clays, interbedded with gravels from interlake periods are most readily recognized along the valley edges as valley aprons and at the mouths of the large streams draining into the valley where deltas are developed. In Cache Valley the upper elevation of the Bonneville Group is 5,135 feet (Williams, 1962).

Structure

The present mountain-valley system was probably initiated by the
Laramide orogeny, commencing in Late Cretaceous. It included several
phases of folding and faulting due to compression (Eardley, 1963,
p. 24-26). Most of the present topographic expression in northern
Utah and southeastern Idaho is due to normal faulting, which generally
began in the Oligocene (Nolan, 1943, p. 183) but may have had its in-
ception in Late Eocene (Eardley, 1963, p. 27) or even possibly Early
Eocene (Hamilton and Meyers, 1966, p. 527). Most of the movement has
occurred since Early Miocene. Minor adjustments along these north-south
faults continued through the Pleistocene up to the present.

Cache Valley is a graben bounded by north-trending Basin and
Range faults along the eastern and western sides of the valley.
According to Peterson and Oriel (1970, p. C117) and Stanley (1971,
p. 41) 7,000 feet of Cenozoic sediments have accumulated in the graben.
This necessitated considerable displacement along the valley faults
while deposition was going on. The fault zone on the east side of
the valley was called the East Cache fault zone (Williams, 1948,
p. 1154). It is a relatively narrow zone in the southern part of
the valley but from Hyde Park northward the zone widens and becomes
more complex. Peterson and Oriel (1970, p. C117) explain the fault
zone at Logan as two separate faults on the basis of gravity survey
results. In the northeastern part of the valley there are at least
three major parts of the East Cache fault zone expressed by the topo-
graphy (Figure 2). The area mapped for this study is between seg-
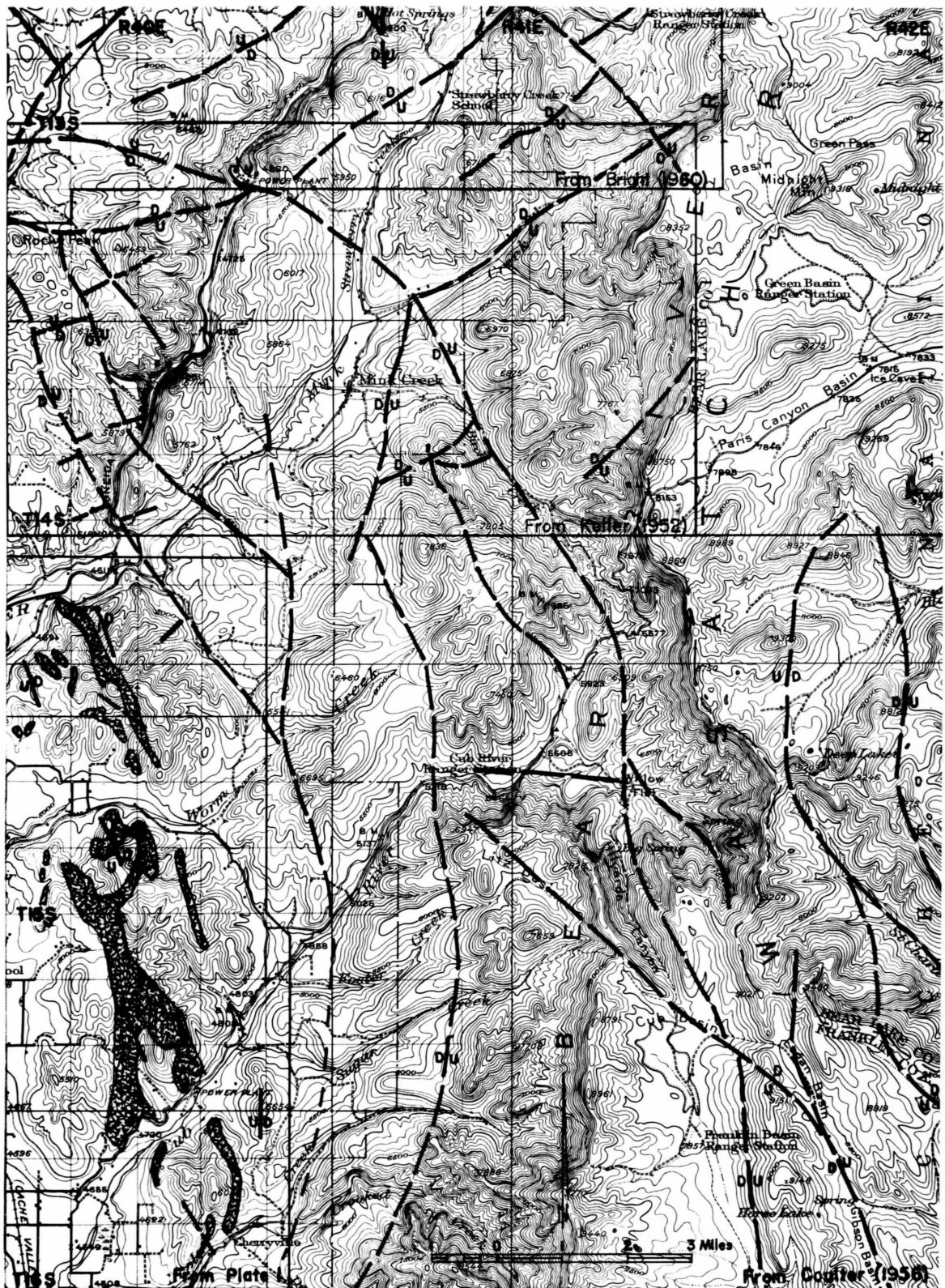ments of the East Cache fault zone. Late Tertiary or Quaternary

Figure 2. Structure map of part of Preston Quadrangle. Shows faults
mapped by Bright (1960), Coulter (1956), and Keller (1952),
and the faults and outcrop pattern (stippled area) of the
igneous rocks from Plate 1. Base from Preston, Idaho.
Quadrangle 1:125,000.

movement has dropped the central part of the valley floor and left the
Tertiary rocks exposed as benches along the edges of the valley.
Faults within Cache Valley have left horsts or tilted blocks ex-
posed as windows of Paleozoic and Precambrian rocks standing above the
valley floor. Folding and unconformities within the Salt Lake For-
mation could be a result of intermittent movement on the valley faults
(Smith, 1953, p. 76).

The north-trending Bear River Range intersects the northwest-
trending Portneuf Range north of the study area in the vicinity of the
Oneida Narrows. This area is also the intersection of regional struc-
tures. As seen in Figure 2, the north-trending Basin and Range faults
of the Bear River Range tend to swing toward the northwest as they
approach the Portneuf Range. There is also a strong northeast fault
system in the areas mapped by Keller (1952) and Bright (1960). The
latter system is reflected in the major drainages such as Mink Creek,
Worm Creek, and Cub River, as well as many of the minor drainages, and
in a fault shown in the northeast part of Plate 1 of this report.
According to Armstrong and Cressman (1963, p. 20) these northeast-
trending faults are older than the north-trending Basin and Range
faults and may have originated as tear faults associated with north-
east and eastward Laramide thrusting.

The igneous bodies near Cub River trend north-northwest (Figure
3), parallel with the major faults of the surrounding mountain ranges.
The magmas were probably injected along similar faults. Minor
appendages of the dike system trend north or northeast, probably along
Laramide faults. Most of the andesite dikes also trend north-north-
west.

The intrusive could be responsible in part for the minor uplift of the Tertiary block which it intrudes. It is also possible that movement along the faults which controlled the intrusion elevated the block prior to the igneous activity.

INTRUSIVE IGNEOUS ROCKS

Diabase

Distribution. Diabase is the most common igneous rock type in the area and occurs in all major outcrops. On that basis the igneous rocks in the study area are collectively referred to here as the Cub River Diabase although minor amounts of other rock types are included. The outcrops are semi-continuous from Maple Creek valley on the south to the Bear River valley on the north (Plate 1). The diabase dikes are especially well exposed in the southern part of the mapped area between Maple Creek and Cub River (Figure 3). However, the igneous rocks are partly covered by Recent valley sediments at the lower edge of the outcrops and by float from the weathered Cache Valley member at the top of the outcrops. Soil cover generally restricts mapping. It appears that the diabase intruded the Cache Valley Member and was exposed by erosion before deposition of the Mink Creek conglomerate. The occurrence of diabase pebbles in the conglomerate near the mouth of Maple Creek is the basis for dating the Cub River Diabase pre-Mink Creek Member.

One part of the contact exposed in a small prospect pit south of the mouth of Cub River (Figure 4) has a 2-foot-wide diabase dike transecting the bedding upward for a few feet then trending off northward into a small sill. The sill has a thickness of 6 inches near the dike, and tapers to 1 inch within 8 feet of the dike then is covered by soil.
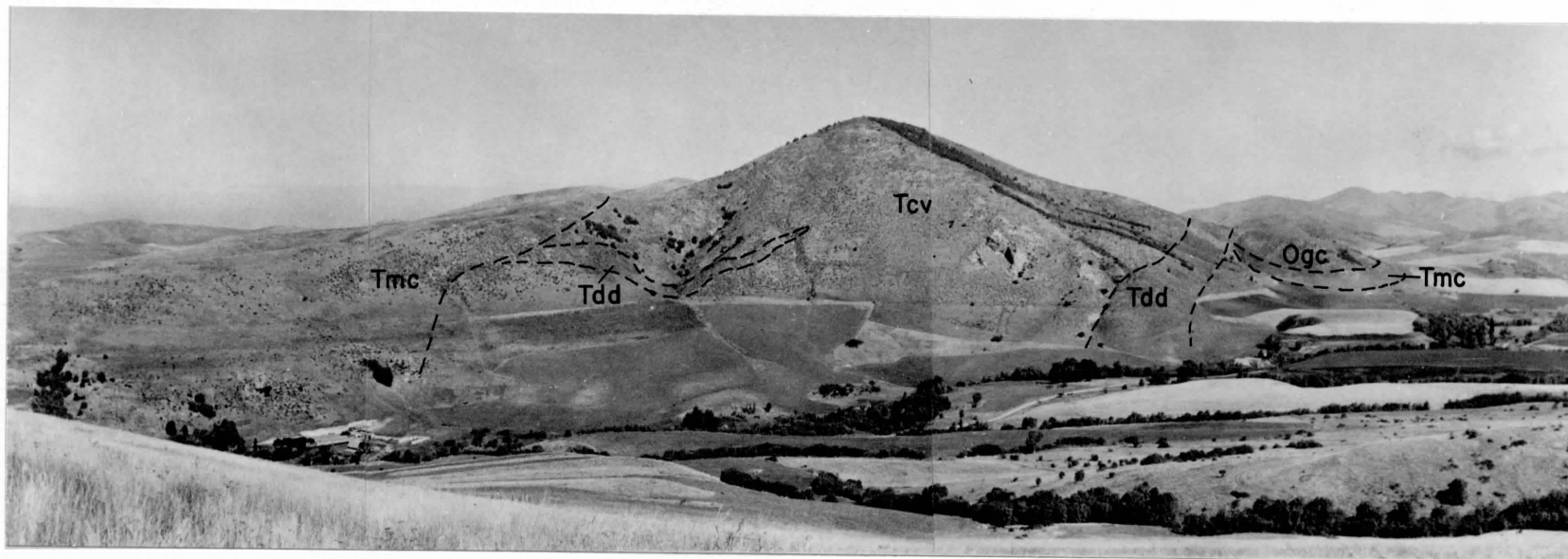
Figure 3. Panoramic view of southern part of mapped area. View is northward across Maple Creek. Cache Valley Member (Tcv) dips to the right. Mink Creek Member (Tmc) is nearly horizontal. Diabase (Tdd) intrudes the Cache Valley Member and is truncated by Mink Creek Member. Garden City Formation (Ogc) exposed on east side of hill.

Figure 4.   Diabase dike and sill intruding thin-bedded limestone of Cache Valley Member.
Prospect pit south of Cub River in sec. 10, T. 16 S., R. 40 E.

North of Cub River the intrusive contacts are poorly exposed but outcrops of well-weathered diabase extend northward to the Glendale Reservoir as wide irregular masses and as narrow dikes. Rocky Peak in secs. 21, 22, 27, 28, T. 15 S., R. 40 E., is the only major outcrop of diabase in the mapped area which forms a topographic high. The peak is made up of large blocks of weathered diabase in place. Most diabase outcrops are topographic lows with float of the Cache Valley Member covering the contacts and parts of the dikes. The major part of the north end of the hills south of Glendale Reservoir is intrusive outcrop. North of the reservoir the intrusives are less continuously exposed, but they are thought to be continuous and interconnecting subsurface. Road cuts along the Cub River valley and Bear River valley expose wide resistant dikes of diabase in cuts 20 to 30 feet deeper than the original erosional surface. Many of the smaller diabase outcrops are in gullies at the base of the hills where the valley floor begins. These small outcrops are probably continuous and interconnect to form larger masses subsurface. On some small hills such as the hill just south of Glendale Dam on Worm Creek the diabase is exposed about halfway down on the northeast part of the hill and again on the southeast part of the hill and obviously represents a continuous mass extending through the hill. Road and canal cuts were helpful in mapping since the diabase is so easily weathered and the Tertiary Salt Lake materials provide much slope cover and obliterate many of the diabase contacts. Some peaks composed of Cache Valley Member have diabase surrounding the peak, giving the blocks of Tertiary sediments the appearance of roof pendants.

Richmond Bluff, south of Maple Creek, consists of the Mink Creek
Member of the Salt Lake Formation, and covers any possible southward
extension of the Cub River Diabase. North of the Bear River there are
no known diabase outcrops, and any northward extension would probably
be covered by Lake Bonneville sediments in the valley. Northeast, in
the area of Oneida Narrows, the rocks have been mapped as Cambrian
(Coulter, 1956) and there is no indication of Tertiary intrusives.
There is strong geophysical evidence that the dikes may extend south-
west of the mapped area under the valley fill toward Lewiston, Utah
(Stanley, 1971, p. 43; Peterson and Oriel, 1970).

Structure. The Cub River Diabase of Cache Valley forms an ir-
regular composite dike structure. The dikes cut across the bedding of
the Cache Valley Member for about 10 miles. The system reaches a
maximum width of three-fourths of a mile. Local appendages of the
dikes extend into small sills intruding the Cache Valley Member.
These apophyses are narrow and extend for a few tens of feet from the
major intrusives. Where a contact is exposed in a road or canal cut
the sedimentary beds are sometimes truncated against the igneous con-
tact, although a 1 to 15 foot fracture zone usually forms the contact.
Cub River Diabase-Cache Valley Member contacts are shown in Figures
5 and 6.

There are some peaks in the mapped area made up of Cache Valley
Member surrounded on the flanks by igneous rocks. These could be
roof pendants although, according to Frankel (1967, p. 77), roofed
dikes are uncommon. The intrusives cannot be seen in the valley
bottoms of the two major drainages--Cub River and Worm Creek--but

Figure 5. Cub River Diabase-Cache Valley Member contact south of Bear River. Exposed in a canal cut in sec. 29, T. 14 S., R. 40 E. Note the undisturbed bedding in the Cache Valley Member.

Figure 6. Cub River Diabase-Cache Valley Member contact south of Glendale Reservoir. Outcrop is in a road cut in sec. 21, T. 15 S., R. 40 E. Note undisturbed bedding, and flow alignment (?) parallel to contact.

they probably extend across the valleys beneath the alluvium. The width of the dikes varies in outcrops from a few tens of feet to three-fourths of a mile and then appears to increase downward. The widest outcrops usually occur at lower elevations along valley edges. The overall orientation of the intrusives is N. 10° W. to N. 30° W. with some smaller branches trending northward or north-northeastward. Based on studies of previous mapping it is believed that these dikes were emplaced along earlier-formed faults of the East Cache fault zone. Near the surface the dikes split and separate into variously orientated dikes and sills.

A few blocks of Cache Valley Member are surrounded completely by the diabase. These xenoliths have been highly altered and tend to be rich in magnetite and carbonates. They represent stopping in the intrusion process though magmatic stoping generally plays a minor role in the emplacement of dikes (Frankel, 1967, p. 94).

Vesicles in the outer edges of the dikes are aligned as if in flow bands parallel to the contacts. Some are relatively large and are deformed into tubular or pipe vesicles. There are small ropy-looking flow lobes along some contact surfaces. These are probably formed by penecontemporaneous deformation in the soft Cache Valley tuffs during the emplacement of the diabase.

Some outcrops show fracturing with hints of columnar jointing perpendicular to the upper contact. The diabase has been offset against itself along vertical fractures near the edges. These shears are probably related to very late stages of intrusion with movement taking place after the upper part of the dike had solidified. Near the

contacts with the Cache Valley Member the diabase is fractured and
jointed. There is a prominent set of joints parallel to the contact
and another set perpendicular to the contact. Spheroidal weathering
of blocks outlined by joints is apparent in most diabase and syenodior-
ite outcrops.

Field Description. The diabase is usually phaneritic in the inner
parts of the intrusive and varies in texture to glassy at the chilled
margins. The color is dark green to medium gray in phaneritic samples
and dark gray to brownish gray in glassy chilled zones. The common
megascopic minerals of the diabase are plagioclase, pyroxene, and mag-
netite, with occasional quartz (amethyst) and calcite in amygdales.
In some locations large crystals of plagioclase and skeletal crystals
of hornblende (?) occur up to about 7-1/2 inches in length. Por-
phyritic and intersertal textures are common in some samples. Large
crystals of plagioclase, pyroxene, and magnetite occur in a glassy
matrix. Occasional euhedral plagioclase phenocrysts are seen in the
glassy chilled zones near contacts.

Petrography. Petrographic examination reveals that most of the
diabase is holocrystalline, becoming hypocrystalline in the chilled-
contact zone (Figures 7 and 8). The crystalline portions range from
fine-grained to medium-grained. The diabase usually shows an inter-
granular texture with euhedral plagioclase crystals. Porphyritic
intersertal or intersertal textures with euhedral plagioclase crystals
are also noted.

The diabase consists primarily of plagioclase, pyroxenes, biotite,
and magnetite. The plagioclase is generally sodic labradorite with
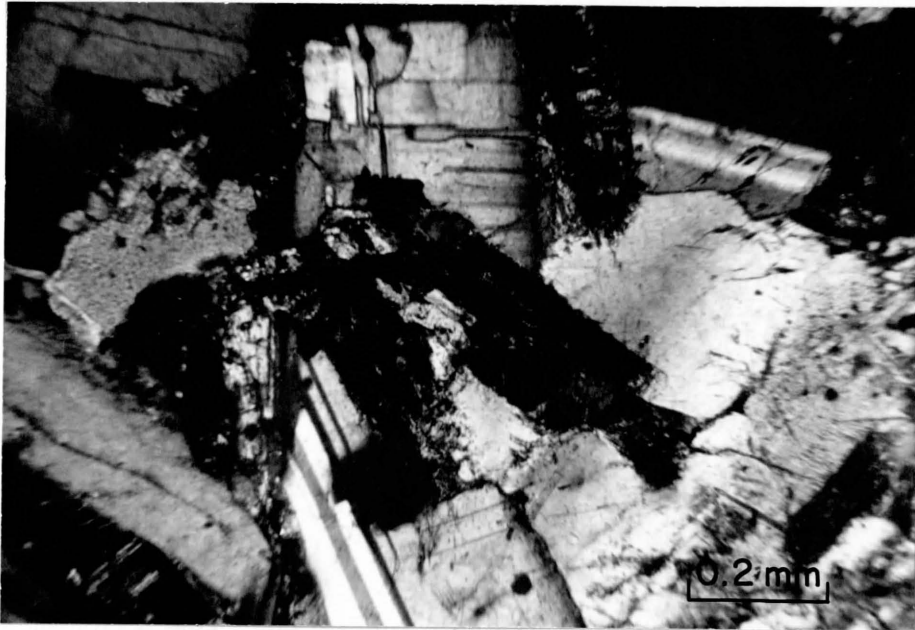
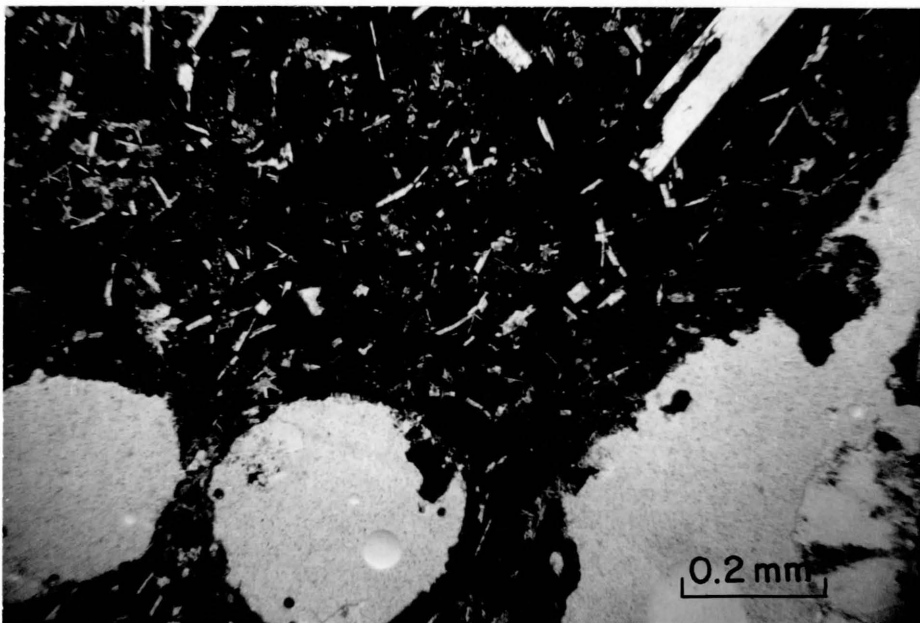Figure 7. Holocrystalline diabase in thin section. Nicols crossed.

Figure 8. Hypocrystalline diabase in thin section. Chilled border at contact with the Cache Valley Member. The diabase has the appearance of vesicular basalt. Note the intersertal texture. Nicols uncrossed.

composition ranging from An_{45} to An_{65}, with some wider variations

where zoning of the plagioclase occurs. The determinations of

plagioclase composition were based on extinction angles of albite twins.

The crystals are occasionally euhedral but mostly subhedral, and range

from 0.2 mm to 5.0 mm in length, with 1.0 mm a common crystal length in

the medium-grained samples. The plagioclase crystals usually exhibit

either albite twinning, carlsbad twinning, or both. Plagioclase is

the predominant mineral and makes up 50 to 65 percent of the total

volume of the diabase.

There are usually two different pyroxene minerals present in the

diabase. The axial angles (2V angles) were used to determine the

composition of the pyroxenes. Pigeonite and augite are the most com-

mon associates but less commonly diopside and hypersthene, pigeonite

and hypersthene, or pigeonite and enstatite were found together.

Where pigeonite and augite occur together pigeonite is much more abun-

dant than augite, and clinopyroxenes are more abundant than orthopyro-

xenes when they occur together. The pyroxenes are in a variety of

shapes. The pigeonite crystals are usually elongate laths while the

augite crystals are short and stubby. Some augite crystals are

slightly zoned, indicating compositional changes within the individual

crystals. Pyroxene crystals are usually smaller than the plagioclase

laths and range from o.1 mm to 2.0 mm in length. A common crystal

size is 0.5 mm to 1.0 mm. The size difference could be indicative of

a late beginning of crystallization of the less abundant pyroxene

(Williams, Turner, and Gilbert, 1954, p. 29). Pyroxenes are some-

times found surrounded by plagioclase crystals suggesting that pyroxene

crystallized before plagioclase in at least some locations (Figure 7).
The pyroxene crystals are deformed, strained, and broken, which could
indicate post-crystallization movement. Deuteric solutions have re-
acted with and altered some pyroxenes to biotite and magnetite along
some fractures and clearage planes. The pyroxene abundance ranges from
10 to 30 percent in the diabase, but 15 to 20 percent is most common.

Magnetite occurs as an abundant accessory mineral and in some
instances as a secondary or deuteric mineral. It is found in diabase
in concentrations of 5 to 10 percent. Skeletal crystals of magnetite
are common. Sizes range from 0.1 mm to 1.5 mm in stubby to long thin
crystals. Hematite is present as an oxidation product and forms a
mantle around some magnetite crystals. Ilmentite may also be present
in small amounts with the magnetite.

Biotite is present in concentrations of 5 to 10 percent and usually
occurs as a fine-grained secondary mineral in the fractures and cleavage
traces of early formed pyroxene. Small brown hexagonal plates of pri-
mary biotite are also present in minor amounts.

Common accessory minerals in the diabase include apatite, micro-
pegmatite, microperthite, quartz, orthoclase and calcite. The small
euhedral apatite crystals are always fresh and either occur as ir-
regular hexagons or as elongate laths up to 0.8 mm in length. Micro-
pegmatite and microperthite are found in the mesostasis of some dia-
base samples as well as minor amounts of free quartz, orthoclase,
calcite, and glass. The color index of the diabase ranges between 26
and 41.

Contact Zone. Toward the contact with the sedimentary rocks the
diabase gets finer grained and even glassy in a chilled zone with a
dark glassy fringe a few inches thick (Figures 8 and 9). The dia-
base near the contact resembles vesicular basalt and in some cases is
porphyritic or intersertal. The vesicles are aligned in bands parallel
to the contact. They range in diameter from 1/4 mm to 5 mm and some
pipe vesicles are several centimeters long (Figure 9). The basaltic
fringe is between 20 and 95 percent glass. The glassy varieties have
an intersertal texture with euhedral crystals of plagioclase, magne-
tite, and pyroxene or biotite. Plagioclase, An_{40} to An_{60} composition,
is the major mineral and makes up 25 to 50 percent of the crystallized
material. The plagioclase ranges in size from 0.1 mm to 0.9 mm.
Occasionally the plagioclase crystals are zoned, and crystals from
some samples have oscillatory zoning. Pyroxene, usually augite or
pigeonite (?), is less abundant than in the granitoid diabase, making
up from 0 to 25 percent of the crystalline material. The pyroxene
crystals are generally smaller than the plagioclase and are partially
altered to secondary biotite. Biotite makes up 12 to 25 percent of
some basaltic samples and is usually fine-grained replacement material.
Magnetite varies in abundance from 10 to 50 percent of the crystalline
material. It occurs as a disseminated primary mineral. Apatite
is occasionally present in minor amounts.

The vesicles in the contact zone are usually filled or partially
filled with deuteric or secondary minerals. Quartz is the most com-
mon mineral in most amygdales and forms as subhedral to anhedral
crystals growing from the walls of the vesicles and meeting toward

Figure 9. Pipe vesicles in glassy chilled zone of diabase.
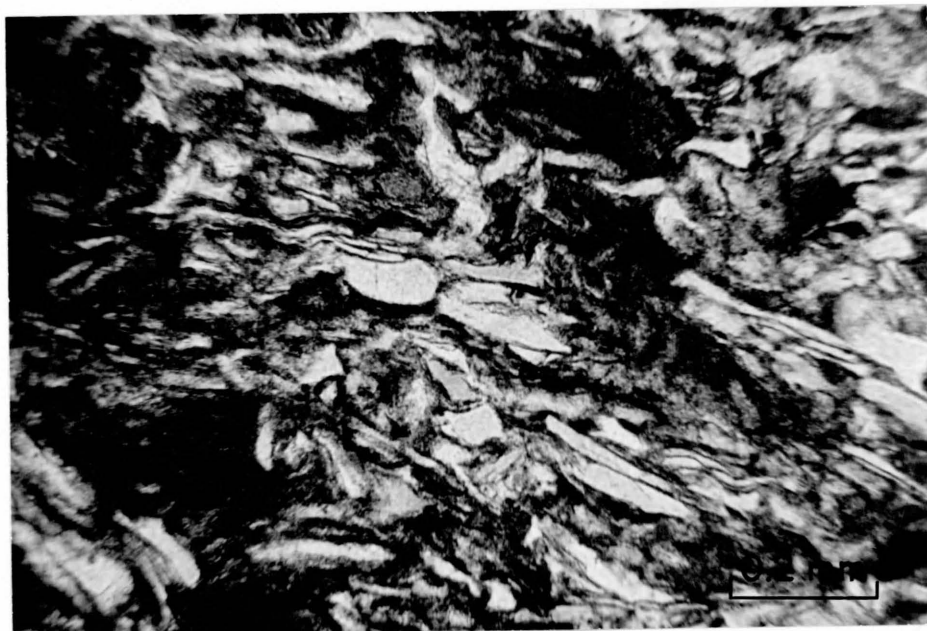Major mineral in the amygdales is tridymite.
Nicols crossed.

Figure 10. Fused tuff of Cache Valley Member near contact with
Cub River Diabase. Glass shards in fused matrix.
Nicols uncrossed.

the center of the void. There is some straining in the quartz expressed by undulatory extinction. Tridymite is abundant in some amygdales (Figure 9). The quartz and tridymite commonly contain very small inclusions of acicular amphibole (?) crystallites. Hematite occurs as psuedomorphs after pyrite or magnetite growing from the vesicle walls. Other minerals found in the amygdales are secondary biotite and pyrolusite (dendrites). Some vesicles are not completely filled with mineral matter, but most have fine-grained calcite filling all open spaces around the quartz, tridymite, and hematite.

Chemical Analysis. A chemical analysis was made on a diabase sample collected near the road in the northeast part of sec. 29, T. 14 S., R. 40 E. The analysis was done by Rocky Mountain Geochemical Corporation, Salt Lake City. The oxide percentages are as follows:

SiO_2	49.2 Percent
TiO_2	3.65
Al_2O_3	13.0
Fe_2O_3	10.7
MnO	1.10
MgO	3.15
CaO	3.13
Na_2O	3.2
K_2O	1.1
P_2O_5	1.68
	Total 89.91

The chemical analysis generally agrees with analyses of tholeiitic basalts from other provinces (Turner and Verhoogen, 1960) except for the percentages of MgO and CaO. Error in the chemical analysis might account for low percentages of MgO which is usually around 6 percent and CaO which is usually around 10 percent. If those values were used the total of the oxide percentages would be very close to 100 percent.

Based on the results of the chemical analysis the diabase appeared to be too acidic in composition. This problem was considered further in the light of different kinds of petrographic analyses. A chart from Kerr (1959, p. 258) was used for the plagioclase composition determinations of this report utilizing the Michel-Levy Method. More recent work by Suwa, Mizutani, and Tsuzuki (1968) with high-temperature plagioclase has provided up-dated charts for plagioclase determinations. With the newer charts for extinction angles of high-temperature plagioclases of volcanics and near-surface intrusives the plagioclase determinations were more sodic than determined with the charts in Kerr (An_{35} to An_{63} rather than An_{45} to An_{65}). With the use of the high-temperature charts all but one diabase sample would be classified as diorite. The syenodiorite and andesite dikes would remain in the same classification but would be more sodic. The plagioclase determinations in the following sections are still based on the Michel-Levy Method, however.

Alteration. The most obvious alteration effect of the Cub River Diabase on the Cache Valley Member is the baking or fusion of the tuff units (Figure 10). In numerous places in the area near contacts there are absidian-like tuff beds with a fused matrix along with

remnant glass shards of the original tuff. In some cases only partial

fusion has taken place and there is a gradation from nearly fresh-

looking tuff to a dense glassy matrix with included shards.

Along some diabase-Cache Valley Member contacts an obvious pale-

violet color in the sedimentary beds occurs near the contact. Locally,

brown hydrothermal iron staining is present. A few xenoliths of

sedimentary rocks are found in the diabase. In these blocks the car-

bonates are recrystallized and quartz and magnetite are concentrated

in veins.

The Cache Valley Member is generally fractured near contacts

with the diabase but extreme fracturing is uncommon. Undisturbed beds

come to within a foot of some diabase contacts (Figures 5 and 6). A

thin zone of brecciation and argillization of sedimentary rocks often

borders the contact, and rock cleavage is parallel to the contact.

Radiating fine- to medium-grained actinolite is crystallized on the

fracture planes in the Cache Valley Member from the diabase contact

outward. The crystal size of the actinolite decreases outward from

the diabase contact.

Hydrothermal alteration of the diabase is weak to absent. Wall-

rock material was probably assimilated during the intrusion and cool-

ing process as indicated by xenoliths in the diabase. Actinolite

and calcite are crystallized on the fracture surfaces near the con-

tact. There are considerable numbers of amethyst crystals in parts of

the intrusion, and quartz, tridymite, hematite, and calcite occur in

the amygdales. Some of the inter-growths of quartz and feldspar in

the diabase and syenodiorite could be from assimilation of acidic

wall-rock materials.

Weathering Features. The resistance of the Cub River Diabase
tends to decrease with an increase in grain size. In nearly all cases
where the diabase is fine grained, such as near a chilled contact, it
is more resistant to weathering. It is difficult to find good un-
weathered outcrops of the intrusive except along road or canal cuts.
According to Frankel (1967, p. 74), where dikes intrude permeable beds,
circulating ground water tends to increase weatherability. The per-
meability of the Salt Lake Formation could account for the rapid dis-
integration of the diabase.

In only a few locations does the diabase form a topographic high.
One of these topographic highs is Rocky Peak. Here the intrusive is
exposed across a wide area and the peak is made up entirely of rounded
boulders of diabase etched out and rounded by rapid weathering along
jointing planes. At large outcrops there seems to be an increase in
weathering toward the center of the intrusion up to a limit of 20 to
50 feet, then there is a slight increase in resistance to weathering.
This could be due to a decrease in the number of fractures and joints
toward the center of the intrusive. In some outcrops there appears to
be weathering along horizontal plates. These plates are probably
parallel to the upper contact of the intrusive and zones of weakness
are probably caused by flow alignment in the upper part of the intru-
sive (Turner and Verhoogen, 1960, p. 56). More commonly spheroidal
weathering occurs. The spheres are bounded by joints from two or
more directions and range in size from a few inches to several feet.
A hint of columnar jointing is evident in some larger outcrops.

The diabase is nearly always less resistant than the Cache Valley Member it intrudes. The intrusive outcrops on hillsides disintegrate to form amphitheater-type depressions on the lower parts of the slope. The more resistant float of the host rock often obliterates the contacts of the diabase and tuff as less-resistant, crumbling diabase is eroded and the broken sediments collapse downhill across the contact. Many of the discontinuous diabase outcrops could probably be mapped farther if they weren't covered by float of the Salt Lake Formation.

The decomposition of diabase causes a characteristic deep red-brown coloration of nearby soils which is a helpful guide to the location of small outcrops in the area. The andesite dikes are more resistant than the diabase and stand out in strong contrast to the decomposed diabase. The andesite is probably more resistant because of the lower percent of ferromagnesian minerals and the fine-grained texture.

Chemical weathering seems to be the major weathering process, because blocks of diabase rubble do not stack up at the bottom of outcrops. Fine granules of feldspar and magnetite are commonly found because the chemical break-down of pyroxenes and biotite has caused the disintegration of the rest of the rock.

Syenodiorite

Field Description. Rocks of a more felsic nature occurring in the intrusives of northeastern Cache Valley were found to have the composition of syenodiorite (Johannsen, 1939). The syenodiorite is more leucocratic than the diabase, and at first was thought to represent leached or altered diabase. The syenodiorite must represent a

separate intrusion or a segregated fraction of the original melt, be-
cause it contains plagioclase and ferromagnesian minerals of compo-
sition different from the diabase, an increase of biotite, and a lack
of apatite. This rock type was found at two locations. One is an
outcrop in the bottom of a valley (sec. 32, T. 14 S., R. 40 E.) 1 mile
south of Bear River valley (Figure 11). Syenodiorite float was also
found 8 miles south in the alluvium of a hayfield half a mile north of
the mouth of Cub River Canyon, but an outcrop was never located.
Syenodiorite may be present in more areas in the intrusive but is not
exposed.

The syenodiorite has a color index of 20, but is quite vuggy and
perhaps had more mafic constituents in the original unweathered or
unaltered rock.

Petrography. The syenodiorite is holocrystalline and contains
more plagioclase, of more sodia composition, than the diabase (Figure
12). The plagioclase, ranging from An_{30} to An_{54} in composition, is
generally andesine and makes up 65 to 70 percent of the total volume
of the cyenodiorite. The largest crystals are andesine, measuring
up to 15 mm in length. They vary from euhedral to subhedral in shape
There is very little albite twinning in the plagioclase but zoning is
common. Most of the plagioclase crystals are mantled by a fringe of
microperthite which makes up 5 to 10 percent of the sample. Micro-
graphic quartz and orthoclase are also abundant in the mesostasis and
makes up an average of 5 percent of the syenodiorite (Figure 12).
There are also minor amounts of unmixed quartz and orthoclase present.

Figure 11.   Syenodiorite outcrop.   Found in a dirt road outcrop in a valley 1 mile south of
the Bear River in sec. 32, T. 16 S., R. 40 E.   Spheroidal weathering is
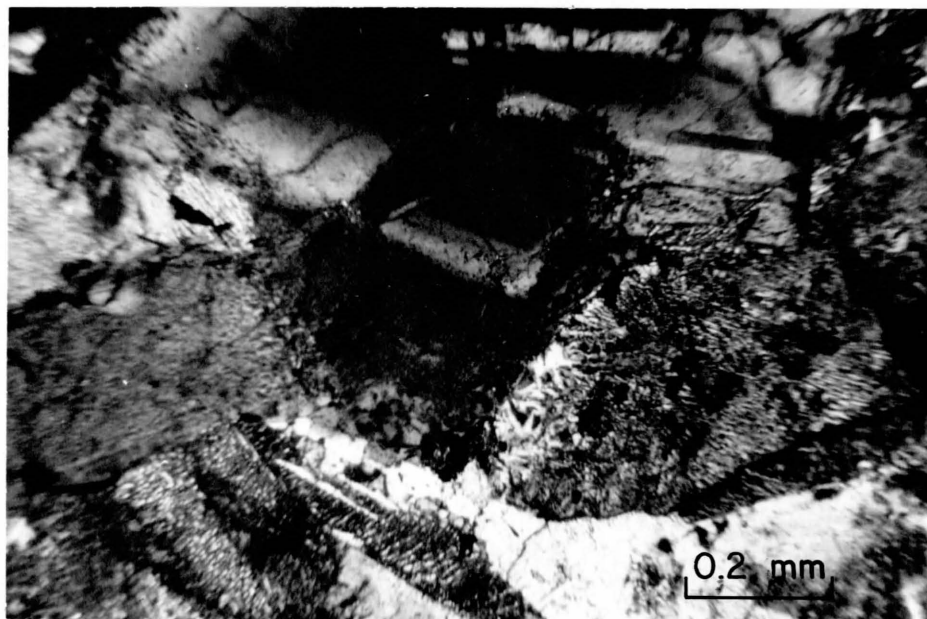characteristic of the syenodiorite and diabase.

Figure 12. Syenodiorite in thin section. Note plagioclase
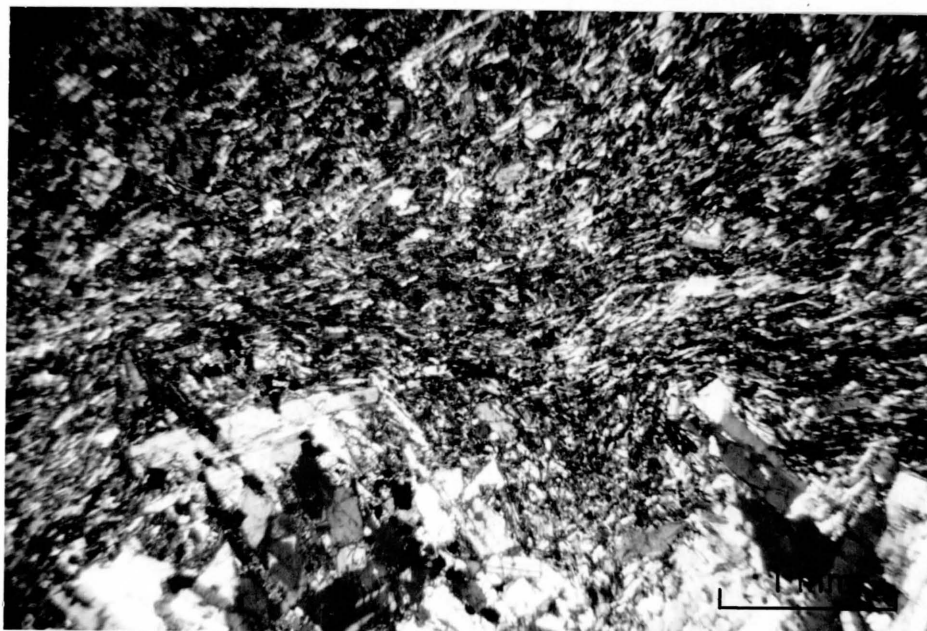laths mantled by micrographic intergrowths.
Nicols crossed.

Figure 13. Andesite in thin section. Note flow alignment
of fine-grained andesite in contact with medium-
grained andesite. Nicols crossed.

The ferromagnesian minerals include interstitial hornblende,
which makes up about 10 percent of the syenodiorite. There is possibly
some pyroxene. Some small acicular crystals are also thought to be
an amphibole. Biotite is present both as primary hexagonal plates and
as deuteric replacement of altered pyroxene or amphibole, and makes up
2 to 5 percent of the syenodiorite. Magnetite has been extensively
altered to, or at least is associated with, hematite and makes up 5
percent of the volume. There is no observable apatite in the
syenodiorite.

Andesite

Field Description. Small dikes of intermediate composition in-
truded the diabase and syenodiorite at various locations within the
mapped area. These dikes have an andesitic composition and are fine-
grained hypocrystalline. The andesite in hand specimen is light gray,
light olive gray, or pale yellowish brown, with a matte appearance due
to the fine-grained texture. The dikes are from 1 inch to 6 inches
wide and vary in outcrop from linear to a highly irregular trace (Fig-
ure 14). The linear dikes often trend north-northwest while the ir-
regular dikes have no preferred orientation and probably were con-
trolled by the boundaries of flow lobes in the cooling diabase host
rock. In field occurrence there appears to be dark bands along the
inner edges of the andesite dikes indicating possible leaching of the
host diabase by the andesite, but no such feature was recognized in
thin section examination. It does not seem to be a chilled margin,
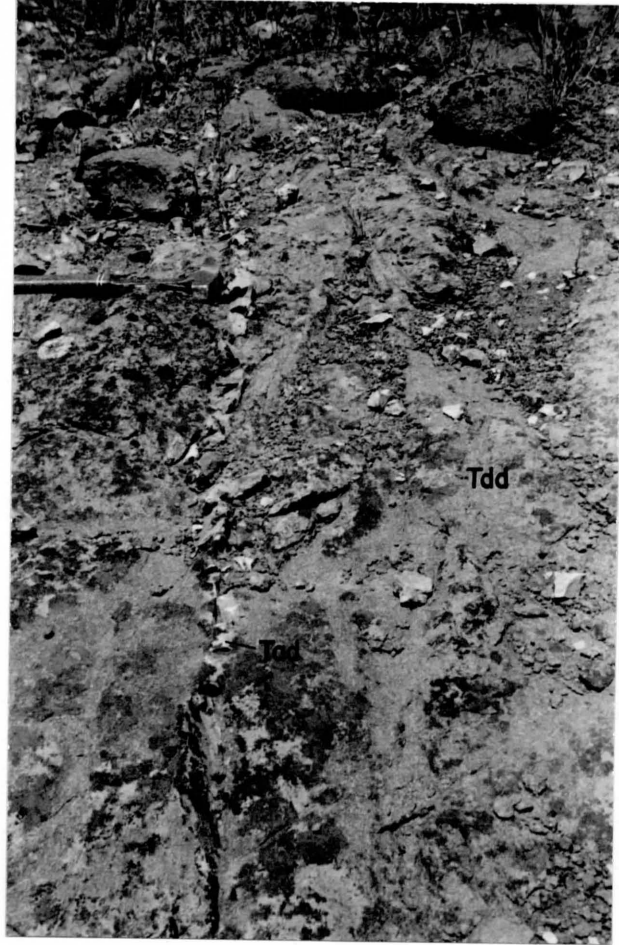either, because no change in the glass content was noted.

Figure 14. Andesite dikes. These thin linear andesite dikes (Tad) are in sec. 4, T. 14 S., R. 40 E. They trend north-northwest and range in thickness from 1 to 6 inches, and are near vertical. The host rock is diabase (Tdd).

Petrography. The major mineral constituent of the andesite dikes is plagioclase, with lesser amounts of pyroxene, biotite, and magnetite (Figure 13). The plagioclase, with a composition of An_{30} to An_{55}, is mostly andesine and makes up 50 to 70 percent of the rock. The crystal size varies up to a maximum of 1 mm, but 0.2 mm to 0.4 mm is most common. Most of the plagioclase crystals are zoned. Albite twinning is less common than in the diabase. The crystals are mostly euhedral to subhedral laths.

Pyroxene comprises up to 10 percent of the andesite. The pyroxene is commonly found to be pigeonite, where proper identification can be made, and augite or hypersthene accompanies the pigeonite in some dikes. The pyroxene crystals range in length up to 1.8 mm but are generally smaller. In many samples of andesite the pyroxenes are partially altered to magnetite or biotite. Magnetite, commonly 5 to 15 percent of the rock, is usually formed as skeletal crystals and could represent strong replacement or alteration of the pyroxenes. Interstitial glass is present in some dikes and one sample contains up to 10 percent glass. Hematite, micropegmatite, quartz, orthoclase, apatite, and calcite are subordinate minerals. The color index of the andesite ranges from 20 to 40.

Some of the andesite dikes contain amygdales, which make up to 15 percent of the rock. The secondary materials are mostly quartz and calcite. Quartz grows as euhedral crystals from the walls of the vesicles along with some magnetite, and biotite. Fine-grained calcite fills the remainder of the opening, obviously the last mineral to form.

It was found upon close examination that there has been more than one injection of andesite along some of the dikes (Figure 13). In one dike studies a fine-grained andesite dike is about 1-1/2 inches wide. At one boundary of the dike is a medium-grained diabase with a schistose appearance. There is a sharp contact between this diabase and the fine-grained andesite dike. The andesite has flow structure along the bottom and top near sharp contacts. The plagioclase laths are parallel with the irregular surface of the contact with alignment of the grains decreasing near the center of the dike. The andesite dike contains mostly plagioclase with lesser amounts of pyroxene, biotite, magnetite, and orthoclase. The largest crystals are 0.1 mm to 0.3 mm in length. Small xenoliths of the host rock containing plagioclase, pyroxene, and magnetite occur in the fine-grained andesite and increase in abundance toward the boundary with the schistose diabase. At the other contact of the fine-grained andesite dike there is 1 inch of medium-grained andesite which has a gradational contact into medium-grained diabase above.

The favored explanation of this dike is that along this zone there have been multiple intrusions. Following intrusion of the diabase, shearing or faulting caused the schistose texture of the lower diabase. Next, an andesite intrusion must have entered the zone, perhaps in the late cooling stage of the diabase to develop a gradational contact with the upper diabase. Another later intrusion of andesite entered the fractured zone, but at a lower temperature, and solidified with sharp boundaries. The second intrusion had already started to

crystallize before the last movement of the magma or the plagioclase laths wouldn't be so well aligned to the contacts of the dike.

REGIONAL IGNEOUS ACTIVITY

The Cub River Diabase is not the only occurrence of igneous rock in Cache Valley. Basaltic lavas have been mapped on the west side of the valley, and numerous other areas in northern Utah and southeastern Idaho have had igneous activity during Tertiary and Quaternary time. Following are descriptions of some of these areas.

Cache Valley--Malad Range

Adamson, Hardy, and Williams (1955, p. 14) mentioned the occurrence of medium-gray aphanitic lava near Clarkston, Utah, in the southeast end of the Malad Range. They described a vesicular lava flow 10 feet thick with calcite filling the vesicles within the tuffaceous sediments of the Salt Lake Formation.

Lavas were described by Prammani (1957, p. 37) between Harris Canyon and Steele Canyon in the east-central part of the Malad Range. He described the lavas as scoriaceous basalt composed of labradorite, olivine, augite, and small amounts of ilmenite and magnetite. He recognized two occurrences of the basaltic rock. The lower unit is an intrusive mass about 50 feet thick which altered the Salt Lake beds above and below. The upper unit is thinner and is overlain by unaltered tuff, so is considered to be a flow. Prammani called the age of these igneous rocks Pliocene--contemporaneous with the Salt Lake Formation.

Basalt flows were mapped farther north in the Weston Canyon area by Murdock (1961, p. 35). He reported several small outcrops of

basalt which he considered to represent the last remnants of a small Tertiary flow. The basalt lies unconformably on the Cache Valley Member and is considered to be younger than the flows described by Prammani.

Probable subsurface basic dikes were located north of Lewiston, Utah, near the state line by Stanley (1971, p. 44). Using magnetic and gravity surveys in a ground-water study, he located a tabular positive anomaly stretching across the state line. He considered it an extension of the mafic dikes of this report. Oriel (personal communication) agreed that a gravity high east of Preston (Peterson and Oriel, 1970) could be caused by basic dikes.

Box Elder County, Utah

In the Promontory Range, 30 miles west of Cache Valley, dark-gray to black, vesicular basalt flows cap a Tertiary welded tuff (Adams, 1962, p. 30-34). The basalt has a labradorite and glass matrix with small anhedral olivine phenocrysts. Accessory minerals are magnetite and augite. The maximum thickness of the flows is about 40 to 50 feet. These flows post-date the Salt Lake Formation and pre-date the Lake Bonneville sediments. The flows were reported by Smith (1953, p. 74) to be an extension of the Snake River basalt flows of Late Pliocene age. The basalt is exposed north and south of Highway 30 between Blue Creek and Snowville, in the North Promontory Range, and north of Hansel Valley.

Howes (personal communication) has mapped and described a volcanic center farther west in Curlew Valley. This sequence of rhyolite-perlite flows, welded tuffs, andesites, and tholeiitic basalts represent Late Tertiary activity.

Bear Lake Plateau

In 1941 Richardson (p. 35) mapped a small outcrop of alkaline-olivine basalt on Black Mountain, south of North Eden Creek, on the Bear Lake Plateau. He described the basalt as an erosional remnant of a flow that formerly covered a much more extensive area. In a more recent study McClurg (1970, p. 18) described the basalt as a part of a former crater rim that encircled a volcanic vent. The basalt post-dates the Tertiary Wasatch Formation (Middle Eocene or younger) and is considered by McClurg to be Late Tertiary or Early Quaternary. The main constituents of the basalt are olivine, labradorite, and augite.

Snake River Plain

The Snake River Plain north of Cache Valley is an arcuate graben structure in the western end, and a downwarp structure toward the east. Hamilton and Meyers (1966, p. 540) explain the Snake River Plain as a "... lava-filled tension rift formed in the lee of the northwestward-drifting plate of the Idaho Batholith," with the crust of the western plain faulted and rifted and the crust of the eastern plain thinned and downwarped by tensional forces.

The Idaho Group of the western Snake River Plain, which includes clastics and intercalated basalt flows, accumulated in a subsiding basin from Early Pliocene to Middle Pliestocene (Malde and Powers, 1962, p. 1202). In the eastern Snake River Plain the basalts are all Pleistocene age. The lower Bruneau Basalts of the eastern plain are more weathered than the upper basalts and probably represent

Middle Pleistocene flows from rift vents near the middle of the plain.
The basalts of the younger Snake River Group came from a source area
farther east and are Late Pleistocene in age. There are numerous
eruptive centers throughout the plain and there appears to be some
structural control of eruptive centers shown by the alignment of the
centers in northeastern and northwestern directions. There is mag-
netic evidence indicating that there are troughs trending across the
plain in an alignment sub-parallel with Basin and Range faulting--
also indicating tectonic activity in the area (Malde, 1965).

According to Hamilton (1965, p. C30) the lavas of the Snake
River Plain are bimodal: low alkaline-olivine basalt and rhyolite
assemblages, and both originate from the same tholeiitic magma by
liquid fractionation. Yoder (1971, p. 144), however, describes
rhyolite-basalt associations as a result of differential melting or
fractional fusion of a single parent quartz normative ultrabasic rock.

The closest occurrence of the Snake River Plain basalts to the
study area is the Blackfood Lavas in Gem Valley near Grace, Idaho.
Coulter (1956, p. 5) reported the Snake River basalts as far south
as 5 miles northeast of the town of Mink Creek, Idaho. The Blackfoot
Lavas are mostly Pleistocene in age with local rhyolitic cinder cones
of Recent age (Mabey and Oriel, 1970, p. E3).

Keetley-Kamas Volcanic Area

The Keetley-Kamas volcanic area is 85 miles south of Cache Valley
in the northeastern part of the Park City mining district. The
Keetley-Kamas volcanics is a sequence of andesite flows, andesite
flow breccia, and andesite agglomerate (O'Toole, 1951, p. 10).

They overlie the "Peoa Tuff," a white to buff volcanic ash, which is probably correlative with the Norwood Tuff of the north-central Wasatch Range. The layered flows are intruded by a later diorite porphyry which was considered, O'Toole (1951, p. 37) to be later than Early or Middle Oligocene. Crittenden (1965) concluded that the volcanics are from a local source buried beneath the andesite flows.

CONCLUSIONS

In late Eocene or early Oligocene large volumes of volcanic
debris probably from the Park City district (Eardley, 1963, p. 27) be-
gan filling the valleys in the eastern part of the Wasatch Mountains.
The lower tuffs of the Salt Lake Formation in Ogden Valley and Cache
Valley may be from this same volcanic episode. During the Miocene
and Pliocene, volcanic ash, probably from a northern source, was de-
posited in Cache Valley along with fresh-water limestone, sandstone,
etc. The basin was subsiding during the Pliocene, which accounts
for the great thickness of debris and the minor unconformities within
the Salt Lake Formation (Williams, 1962, p. 146). No stratigraphic
break has been identified between older and younger volcanic sediments
in Cache Valley, however, a middle Miocene hiatus has been recognized
on a regional scale (McKee, 1971, p. 3497). The middle Miocene hiatus
could exist in the Cache Valley Member of the Salt Lake Formation.

The Cache Valley Member of the Salt Lake Formation in north-
eastern Cache Valley was intruded by basic and intermediate dikes
and sills. Petrographic analyses of the igneous rocks revealed that
the composition of the greater mass of the Cub River dikes is that of
tholeiitic diabase, a smaller part is syenodiorite, and a later set
of small dikes cutting the diabase and syenodiorite are andesite.

The dike system is parallel with regional faults, and intrusion
probably took place along the East Cache fault zone. The intrusives
have caused minor alteration of the Cache Valley Member, primarily

fusion of the tuff units and introduction of actinolite along fractures in the sediments. The weak alteration probably eliminates the possibility of the dikes acting as feeders for volcanic vents, and there is also a lack of any significant basalt flows in Cache Valley. Geophysical evidence indicates that the dikes may occur farther out in the valley, also associated with faults, under Cenozoic cover.

The intrusive activity may account for some warping and deformation in the host rock, but according to Hamilton and Meyers (1966, p. 534) Cenozoic block faulting was caused by regional extension, and volcanism has added material to the thinned and fragmented crust. This could be the case in northeastern Cache Valley because block faulting within the valley has left horsts or tilted blocks, such as Smarts Mountain, standing above Cenozoic valley sediments. It seems evident that late Pliocene movement along the boundary faults of these blocks has caused the folding in the Cache Valley Member.

There appears to be no obvious relationship between some of the volcanic activity of the region and the Cub River Diabase. The Keetley-Kamas volcanics are probably intimately related to the uplift of the Uinta Arch and subsequent intrusive epochs of the central Wasatch region and Oquirrh Mountains, etc. They are older than the Cub River Diabase and are probably related in age to the lower tuffs of the Salt Lake Formation.

The Cub River Diabase may be genetically related to the Bear River Plateau basalts, the olivine basalts of western Cache Valley, and the Snake River Plain basalts. The intrusion of the diabase, however, was probably earlier than most of the Snake River basalts.

The diabase may be related to the olivine basalt masses of the region as a differentiation product of a parent olivine basalt magma, though such an origin is doubtful. It could be part of a parent tholeiitic basalt such as Hamilton (1965, p. C30) suggested for the Snake River Plain. It could be from a contaminated olivine basalt magma, or it may be from an entirely different source magma. None of the above possibilities is certain.

The age, composition, and structural trends suggest that the Cub River Diabase is very likely an expression of early Snake River volcanic activity and probably relates closely in age to the basalts of the lower Idaho Group of the Snake River Plain. One unanswered question is why olivine basalt would occur in the same valley, only 10 miles away from the tholeiitic Cub River Diabase, and have similar age relations and structural controls.

The age of the igneous intrusion is probably late Pliocene, or more precisely, post-Cache Valley Member and pre-Mink Creek Member of the Salt Lake Formation. The Cub River Diabase intruded a block of the Cache Valley Member bounded by segments of the East Cache fault zone. The intruded block of sediments was uplifted by the intrusion itself or by late Pliocene faulting. Erosion of this uplifted block left the diabase exposed. Another block faulting episode occurred toward the end of the Pliocene or in early Pleistocene (Eardley, 1955, p. 43) which resulted in deposition of extensive fanglomerates in what was probably a semi-arid climate. The Mink Creek Member of the Salt Lake Formation is this fanglomerate in Cache Valley. It truncates and overlaps the area intruded by the diabase dikes and contains some diabase pebbles.

LITERATURE CITED

Adams, O. Clair. 1962. Geology of the Sumner Ranch and North Promontory Mountains, Utah. MS thesis. Utah State University, Logan, Utah.

Adamson, Robert D. 1955. The Salt Lake Group in Cache Valley, Utah and Idaho. MS thesis. Utah State University, Logan, Utah.

_____, Clyde T. Hardy, and J. Stewart Williams. 1955. Tertiary Rocks of Cache Valley, Utah and Idaho. in A. J. Eardley (Ed.). Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geol. Soc. Guidebook to the Geology of Utah 10:1-22.

Armstrong, Frank C. and Earle R. Cressman. 1963. The Bannock thrust zone, southeastern Idaho. U. S. Geol. Survey Prof. Paper 374-J.

Bright, Robert C. 1960. The geology of the Cleveland area, Idaho. MS thesis. University of Utah, Salt Lake City, Utah.

Brown, Roland W. 1949. Paleobotony--Pliocene plants from Cache Valley, Utah. Washington Acad. Sci. Jour. 39:224-229.

Coulter, Henry W., Jr. 1956. Geology of the southeast portion of the Preston Quadrangle, Idaho. Idaho Bur. Mines and Geology, Pamph. 107.

Crittenden, Max D., Jr. 1965. in Geological Survey Research 1965, Chap. A, p. A94. U. S. Geol. Survey Prof. Paper 525-A.

Eardley, A. J. 1955. Tertiary history of north-central Utah. in A. J. Eardley (Ed.). Tertiary and Quaternary geology of the eastern Bonneville Basin: Utah Geol. Soc. Guidebook to the Geology of Utah 10:37-44.

_____. 1963. Structural evolution of Utah. Gas and oil possibilities of Utah re-evaluated, edited by Arthur L. Crawford. Utah Geol. and Mineralog. Survey Bull. 54:19-29.

_____. 1969. The Willard thrust and Cache uplift. Geol. Soc. America Bull. 80:669-679.

Fenneman, Nevin M. 1917. Physiographic divisions of the United States. Assoc. Am. Geographers Annals 1:19-98.

Frankel, J. J. 1967. Forms and sources of intrusive basaltic rocks, pp. 63-102. in H. H. Hess and Arie Poldervaart (Editors). Basalts--The Poldervaart Treatise on Rocks of Basaltic Composition, Vol. 1. Interscience Publishers, New York.

Hamilton, Warren. 1965. Geology and petrogenesis of the Island Park caldera of rhyolite and basalt, eastern Idaho. U. S. Geol. Survey Prof. Paper 504-C.

_____, and W. Bradley Meyers. 1966. Cenozoic tectonics of the western United States. Am. Geophys. Union Review of Geophysics 4:509-549.

Hayden, F. V. 1869. U. S. Geol. Survey of Territories Embracing Colorado and New Mexico. Third Annual Report.

Johannsen, Albert. 1939. A Descriptive Petrography of the Igneous Rocks, Vol. 1. The University of Chicago Press, Chicago, Ill. 318 p.

Keller, Allen S. 1952. Geology of the Mink Creek region, Idaho. MS thesis. University of Utah, Salt Lake City, Utah.

Kerr, Paul F. 1959. Optical Mineralogy. Third Edition. McGraw-Hill Book Company, New York. 442 p.

Ludlum, John C. 1943. Structure and stratigraphy of part of the Bannock Range, Idaho. Geol. Soc. America Bull. 54:973-986.

Mabey, Don R. and Steven S. Oriel. 1970. Gravity and magnetic anomolies in the Soda Springs region, southeastern Idaho. U. S. Geol. Survey Prof. Paper 646-E.

Malde, Harold E. 1965. Snake River Plain, pp. 255-263. in H. E. Wright, and D. G. Frey (Editors). The Quaternary of the United States. Princeton University Press, Princeton, New Jersey.

_____, and Howard H. Powers. 1962. Upper Cenozoic stratigraphy of Western Snake River Plain, Idaho. Geol. Soc. America Bull. 73:1197-1219.

Mansfield, G. R. 1927. Geography, geology, and mineral resources of part of southeastern Idaho. U. S. Geol. Survey Prof. Paper 152.

Maw, G. Glayde. 1968. Lake Bonneville history in Cutler Dam Quadrangle, Cache and Box Elder Counties, Utah. MS thesis. Utah State University, Logan, Utah.

McClurg, Larry W. 1970. Source rocks and sediments in the drainage area of North Eden Creek, Bear Lake Plateau, Utah-Idaho. MS thesis. Utah State University, Logan, Utah.

McKee, Edwin H. 1971. Tertiary igneous chronology of the Great Basin of western United States--Implications for tectonic models. Geol. Soc. America Bull. 82:3497-3502.

Murdock, Clair N. 1961. Geology of the Weston Canyon area, Bannock Range, Idaho. MS thesis. Utah State University, Logan, Utah.

Nolan, Thomas B. 1943. The Basin and Range Province in Utah, Nevada, and California. U. S. Geol. Survey Prof. Paper 197-D.

Oriel, Steven S., and L. B. Platt. 1968. Reconnaissance geologic map of the Preston Quadrangle, southeastern Idaho. U. S. Geol. Survey open-file map.

O'Toole, Walter. 1951. Geology of the Keetley-Kamas volcanic area. MS thesis. University of Utah, Salt Lake City, Utah.

Peale, A. C. 1879. U. S. Geol. Surveys of Territories Embracing Idaho and Wyoming. Eleventh Annual Report.

Peterson, Donald L., and Steven S. Oriel. 1970. Gravity anomalies in Cache Valley, Cache and Box Elder Counties, Utah, and Bannock and Franklin Counties, Idaho. U. S. Geol. Survey Prof. Paper 700-C.

Peterson, William. 1956. Physical description and geology, Chap. 1, pp. 1-20. In Joel Ricks (Ed.). The History of a Valley-- Cache Valley, Utah-Idaho. Cache Valley Centennial Commission, Logan, Utah.

Prammani, Prapath. 1957. Geology of the east-central part of the Malad Range, Idaho. MS thesis. Utah State University, Logan, Utah.

Richardson, G. B. 1941. Geology and mineral resources of the Randolph Quadrangle, Utah-Wyoming. U. S. Geol. Survey Bull. 923.

Smith, Neal. 1953. Tertiary stratigraphy of northern Utah and southeastern Idaho, pp. 73-77. In Intermountain Assoc. Petroleum Geologists Guidebook, 4th Ann. Field Conf.

Stanley, William Dal. 1971. An integrated geophysical study related to ground water conditions in Cache Valley, Utah and Idaho. PhD dissertation. University of Utah, Salt Lake City, Utah.

Suwa, K., S. Mizutani, and Y. Tsuzuki. 1968. Extinction angles in zone perpendicular to (010) of low- and high-temperature plagioclase. <u>Proc. Japan Acad.</u> 44:1090-1095.

Swain, Frederick M. 1947. Tertiary non-marine ostracods from the Salt Lake Formation, northern Utah. <u>Jour. Paleontology</u> 21:518-528.

Turner, Francis J., and John Verhoogen. 1960. <u>Igneous and Meta-morphic Petrology.</u> Second Edition. McGraw-Hill Book Company, New York. 694 p.

Williams, H., F. J. Turner, and C. M. Gilbert. 1954. <u>Petrography.</u> W. H. Freeman and Co., San Francisco. 406 p.

Williams, J. Stewart. 1948. Geology of the Paleozoic rocks in the Logan Quadrangle, Utah and vicinity. <u>Geol. Soc. America Bull.</u> 59:1121-1164.

_____. 1958. Geologic atlas of Utah, Cache County. <u>Utah Geol.</u> and Mineralog. Survey Bull. 64.

_____. 1962. Lake Bonneville: Geology of southern Cache Valley, Utah. U. S. Geol. Survey Prof. Paper 257-C.

_____. 1964. The age of the Salt Lake Group in Cache Valley, Utah-Idaho. <u>Utah Academy of Sciences, Arts, and Letters Proc.</u> 41(2):269-277.

Yen, Teng-Chien. 1947. Pliocene fresh-water mollusks from northern Utah. <u>Jour. Paleontology</u> 21:268-277.

Yoder, H. S., Jr. 1971. Contemporaneous rhyolite and basalt <u>in</u> <u>Annual Report of the Director, Geophysical Laboratory,</u> <u>Carnegie Institute of Wash., Yearbook 69,</u> 1969-70, pp. 141-145.

VITA

Parry D. Willard

Candidate for the Degree of

Master of Science

Thesis: Tertiary Igneous Rocks of Northeastern Cache Valley, Idaho

Major Field: Geology

Biographical Information:

Personal Data:
Born: April 4, 1944, at Ogden, Utah.
Parents: Earl S. and Ruth G. Willard.
Married: Linda Rae Owen, August 24, 1967.
Children: Chad Owen Willard.

Education:
Elementary: Attended Ogden, Utah city schools.
High School: Graduated from Ben Lomond H. S., Ogden, Utah, 1962.
College: Bachelor of Science degree from Weber State College, 1970, geology major, chemistry minor.
Graduate: Completed requirements for Master of Science degree from Utah State University in geology, 1972.
Awards: Bear Creek Mining Company Field Research Grant Utah State University Research Development Fund research grant.

Professional Experience:
1971-72, Geologist for Vanguard Exploration Company, Salt Lake City, Utah.
1970-71, Geology instructor for Utah State Extension Service, Uinta Basin Center, Roosevelt, Utah.
Summer 1969, Technical Aid for Kennecott Copper Corp. in Pit Geology Dept., Bingham Canyon, Utah.
Summer 1968, Geological Field Assistant for U. S. Geol. Survey, Menlo Park, Calif., in Black Hills, South Dakota.
1968-69, Lab Instructor for Geology Dept., Weber State College, Ogden, Utah.
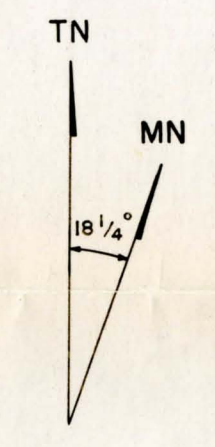
Professional Affiliations:
Utah Geological Association.

TERTIARY IGNEOUS ROCKS

OF NORTHEASTERN CACHE VALLEY, IDAHO
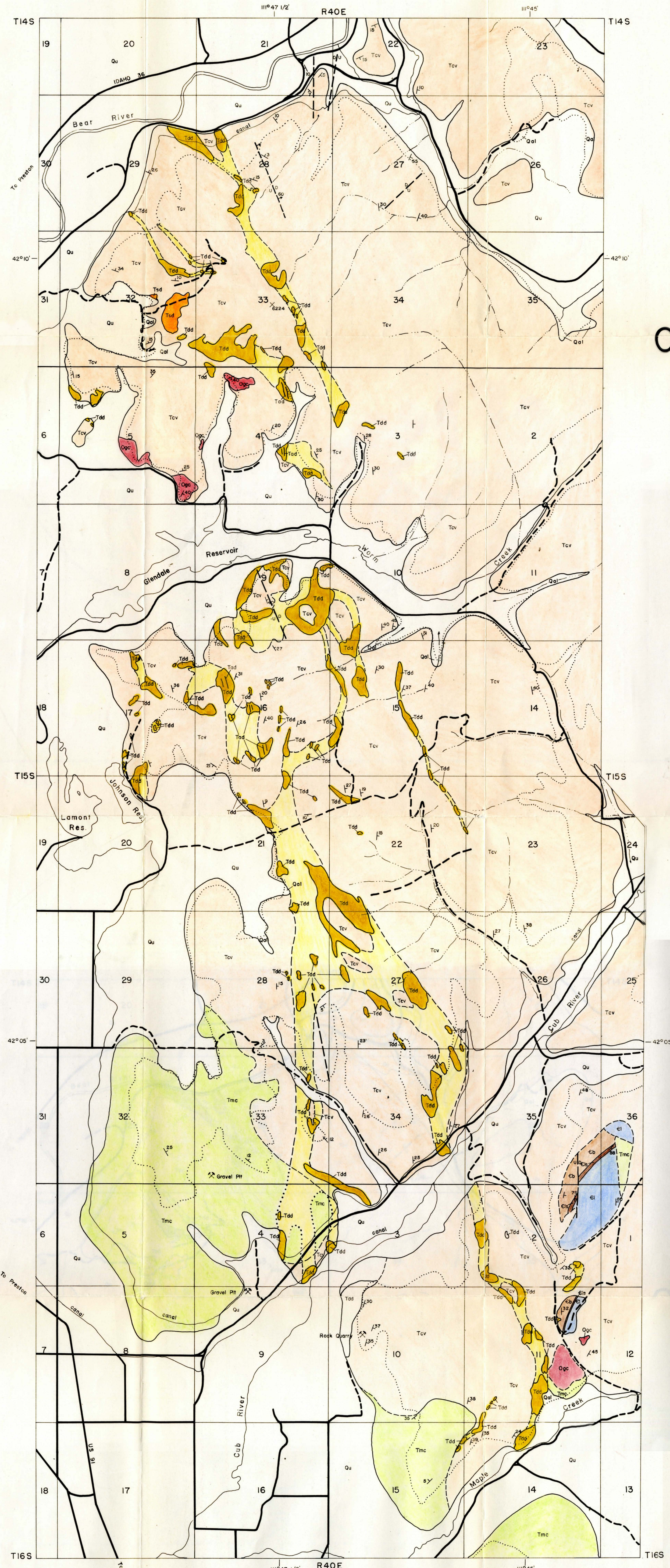
EXPLANATION

Quaternary
- Qal — alluvium
- Qu — undifferentiated alluvium and Lake Bonneville Group

Tertiary
- Tad — andesite dikes
- Tdd — diabase dikes
- Tsd — syenodiorite dikes
- Tmc — Salt Lake Formation — Mink Creek Member
- Tcv — Salt Lake Formation — Cache Valley Member

Ordovician
- Ogc — Garden City Formation

Cambrian
- Cl — Langston Formation — middle member (?)
- Cls — Langston Formation — Spence Shale Member
- Cb — Brigham Formation

········ Contact, dashed where inferred, dotted where covered

— — — Fault, dashed where inferred

·········· Lake Bonneville shoreline

— · — Roads, dashed where unimproved

✕ Rock quarry or gravel pit

⤢ Strike and dip of beds

TN
MN

Scale 1:24000

2000   0   2000   4000   6000 Feet

Geology by Parry D. Willard, 1972