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STRATIGRAPHY AND STRUCTURAL GEOLOGY OF THE BUCKLEY MOUNTAIN AREA, SOUTH-CENTRAL WASATCH MOUNTAINS, UTAH

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THE STRATIGRAPHY AND STRUCTURAL GEOLOGY OF THE BUCKLEY MOUNTAIN AREA, SOUTH-CENTRAL WASATCH MOUNTAINS, UTAH

A thesis

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by

James A. Rhodes

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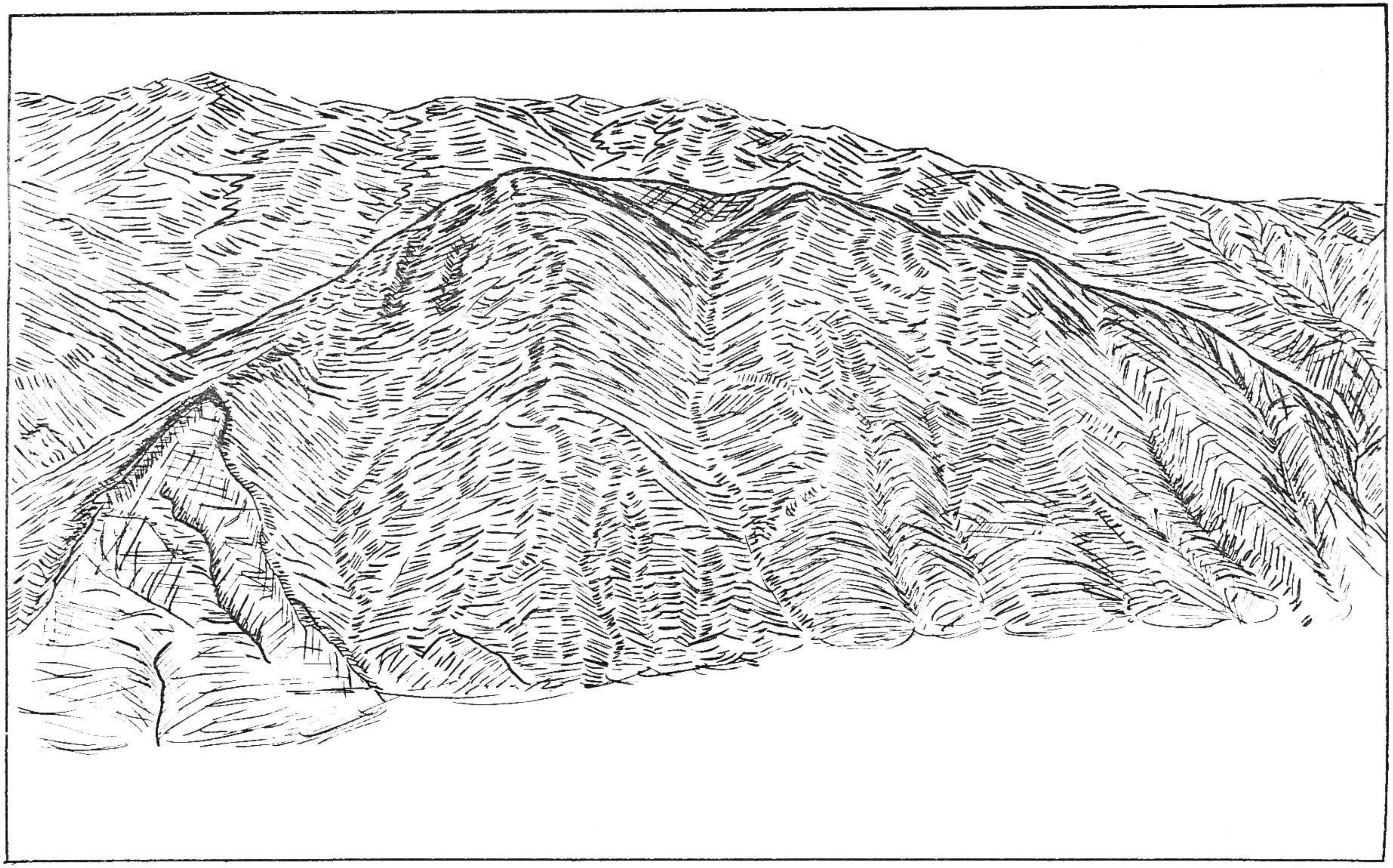
ABSTRACT

The Buckley Mountain area occupies approximately twelve square miles of the western margin of the south-central Wasatch Mountains immediately to the east of U. S. Highway 91 between the towns of Provo and Springville in central Utah County, Utah. The terrane of this area is mountainous and forms a sharp contrast with low lying Utah Valley which lies immediately to the west.

Exposed sedimentary rocks of this area have an approximate thickness of 9, 000 feet. These rocks have been divided into twelve formations. Two are pre-Cambrian, three Cambrian, five Mississippian, one Mississippian and Pennsylvanian, and one Pennsylvanian. Additional mapped units are a thin Cambrian diabase flow and unconsolidated Pleistocene lake sediments which lie unconformably against the older rocks adjacent to the range front.

The area is dominated structurally by two distinct lines of Laramide folding, which intersect at near right angles, a thrust fault of probably the same age, and Quaternary, and older normal faults.

At the present time the economic potential of the Buckley Mountain area appears to be limited to the development of new and the operation of existing sand and gravel pits from the Lake Bonneville sediments.



VEIW OF THE BUCKLEY MOUNTAIN AREA LOOKING EAST

FIGURUE I

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Buckley Mountain area is located on the western margin of the south-central Wasatch Mountains between the cities of Provo and Springville in Utah County, Utah. The area is bounded on the north by Slate Canyon and extends south to the vicinity of Round Peak. Its western limit is largely defined by the range front and its eastern margin by the southern extension of the Provo Peak ridge. In reference to the Salt Lake Base and Meridian the area occupies all or parts of sections 8, 9, 10, 14, 15, 16, 17, 21, 22, 23, 26, 27, and 28 Township 7 South, Range 3 East.

The area is not readily accessible with the exception of its western flank which is paralled by U. S. Highway 91. A stock road extends into the southeastern portion of the area from Pole Haven by way of the north fork of Hobble Creek Canyon. This road, however, can be utilized only during the summer and early fall due to the inclement weather which prevails in the higher portion of the Wasatch Mountains throughout much of the year. One good foot trail is present within the area. It extends from the mouth of Slate Canyon eastward to the base of Provo Peak near Knight Spring hence south to Camel Pass where it joins with the previously mentioned stock road.

PHYSICAL FEATURES

In a fashion which is typical of the Wasatch front Buckley Mountain rises in a near wall-like manner from the floor of Utah Valley to the east of Provo and Springville. The terrane of this area is abruptly mountainous with little or no transition between the range and the valley; maximum relief is in excess to 4, 500 feet.

In this vicinity the range consists of two near-parallel northsouth trending ridges which are separated by an erosional strike valley. Though the morphology of the range is youthful, the westernmost of the two ridges exhibits the less sharp and angular features and in general appears to be in a later stage of youth than does the eastern ridge. Also, the western ridge has been deeply dissected into deep canyons by youthful eastwest trending streams. Intermittent streams fed by water from melting snow flow through these canyons during the spring and early summer of the year.

Unconsolidated sediments deposited in the Pleistocene lake which previously occupied Utah Valley comprise the youngest morphological features of this area. These features are benches which are juxtaposed against the range front and alluvial fans which radiate valleywards from the mouths of the canyons. The morphological significance of these young features appears near inconspicuous due to the massiveness and abruptness with which the range front rises from the valley floor.

PURPOSE AND SCOPE OF REPORT

The purpose of this report is to contribute a more thorough understanding to the geology of the Buckley Mountain area. Special emphasis is placed on the interpretation of stratigraphy and structural geology.

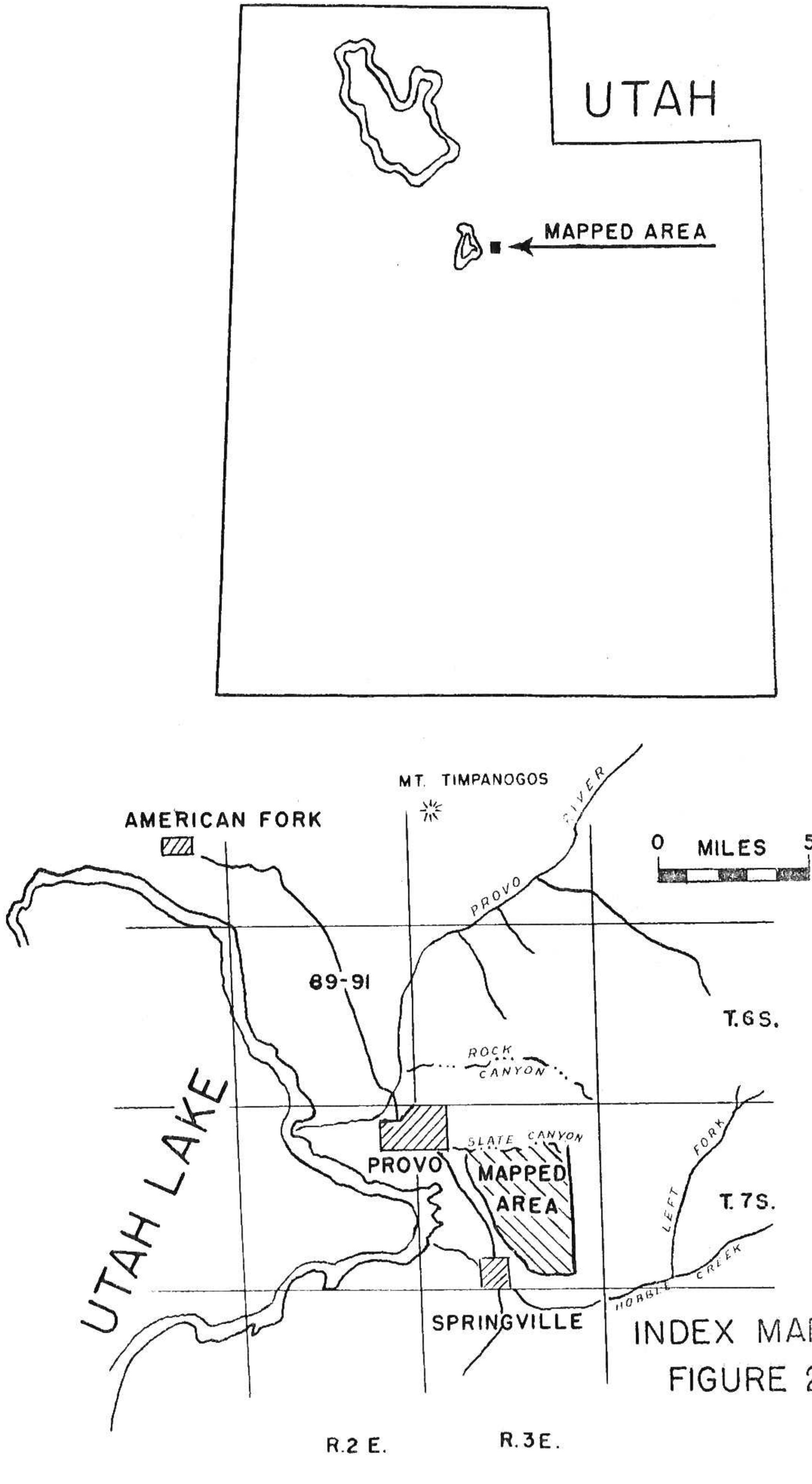
The rocks within this area of formation rank are described and are discussed in respect to age and correlation. They have also been delineated on the geologic map which accompanies this report. The degree to which the detailed structural aspects of this area could be mapped and adequately expressed was limited to the scale (1:12, 000) of the aerial photographs which were used as a mapping base.

Available data relating to and concerning the geology of this area have in many instances been incorporated into this report.

PREVIOUS WORK

Geologists of the 100th Meridian and 40th Parallel Surveys for the Engineer Department of the U. S. Army were the first to publish information concerning the geologic features of the Wasatch Mountains (Howell, 1875; King, 1878). Only brief mention was made of the range near Provo (Howell, 1875, pp. 233-237). These pioneer geologic studies were of a rapid reconnaissance nature; however the geologists of these early surveys did prepare the first geologic map (Atlas), and delineated the fundamental major stratigraphic units.

Gilbert's (1881, pp. 169-200) early study of Lake Bonneville makes reference to the lake sediments which are present along the base of the range. He also briefly discussed recent movement along the Wasatch Fault which has displaced the lake sediments some tens of feet. In a later study Gilbert (1928) examined the structure of the Wasatch Range in greater detail. This study represents the first attempt to explain the Wasatch escarpment as due to normal faulting.



INDEX MAP
FIGURE 2

A study of the glaciation in the Uinta and Wasatch Mountains was conducted by Atwood (1909). This study includes but brief mention of glacial features in the Provo Peak area, northeast of Buckley Mountain.

In a reconnaissance study of the Wasatch Mountains Loughlin (1913) but briefly examined the range to the east of Provo.

Schneider (1925, pp. 28-48) has discussed various geologic features of the Wasatch range front near Provo. He concluded that the Wasatch escarpment is an initial fault-scarp modified by erosion and not a fault-line scarp. He also noted that in the vicinity of Provo Rock Canyon the strata have been folded into an overturned east limb of an anticline.

Blackwelder's (1932, pp. 289-304) study of the pre-Cambrian tillite (?) in and about the Wasatch Mountains mentions these outcrops in both Slate and Rock Canyons to the east of Provo.

Eardley has made several studies pertaining to the geology of the Wasatch Mountains (1933, 1934, 1944). These studies are unusually fine in dealing with the broad stratigraphic and structural features.

Bissell (1936, pp. 239-243) was the first to extend the term Oquirrh formation to the thick sequence of Pennsylvanian strata in the southern Wasatch Mountains. He (1939, 87-89) later subdivided the Oquirrh formation of this region into faunal zones on the basis of fusulinids. Bissell's (1948, pp. 319-321) latest study in southern Utah valley, though concerned chiefly with Lake Bonneville sediments, includes a description of the structural and tectonic features of parts of the south-central Wasatch Mountains.

Baker has been engaged in an extensive mapping program in the south-central Wasatch Mountains since 1937. In connection with his earliest studies he published a preliminary stratigraphic chart (Baker, 1947), and later discussed in greater detail the large problems of correlation and structure (Baker, Huddle, and Kenney, 1949).

Several master's thesis presented to the Department of Geology of Brigham Young University concern problems of the Wasatch Range. Three such thesis are pertinent to the present study: Mecham (1948) made a structural study of the Little Rock Canyon area northeast of Springville. His study includes a plane table map of the area on the scale of 1:2,400. Gwynn (1948) made a study of the geology of the Slate Canyon area. His study includes stratigraphic descriptions as well as a topographic and geologic maps of the area. Abbott (1951) made a detailed petrographic study of a Cambrian flow rock found in the south-central and southern Wasatch Mountains. In addition to the petrographic study he mapped the aerial distribution of the flow in the Buckley Mountain area on the scale of 1:12, 000.

PRESENT WORK

The field work for this problem was begun in the fall of 1952 and was continued intermittently until the spring of 1954. This work consisted essentially of studying, interpreting, and mapping structural and stratigraphic field relationships. While in the field the geologic data were plotted directly on aerial photographs of a scale of 1:12, 000, which served as a base for mapping. Where possible stratigraphic sections were measured and described in detail. The data plotted in the field on the photographs were later transferred to a topographic sheet and inked.

Laboratory investigations constituted a minor portion of the study and were engaged in chiefly when conditions did not permit field work. These investigations included the preparation and study of insoluble residues, disagregated sediments, cellulose peels, and thin sections of both paleontologic and petrographic specimens.

GEOLOGY

STRATIGRAPHY

The sedimentary rocks of the Buckley Mountain area, whose outcrop pattern and distribution are shown on the geologic map which accompanies this report, have an estimated exposed thickness in excess of 9,000 feet, of which over 7,000 feet is Paleozoic. This thickness is but a small portion of the nearly 40,000 feet of geosynclinial Paleozoic sediments reported to be present in the southern Wasatch Mountains by Baker, Huddle and Kinney (1949, 1. 1162).

The oldest strata exposed in this area are pre-Cambrian slates, shales, and quartzites. These strata are separated in very restricted locations from overlying Cambrian strata by a tillite.

The Cambrian system, which unconformably overlies the pre-Cambrian, is represented by three very distinct lithofacies. In ascending stratigraphic order these are: the Tintic quartzite, the Ophir shale, and the Maxfield limestone.

Rocks of Ordovician, Silurian, and Devonian ages are not present in this area. Thus, the Cambrian system is unconformably overlain by a thick Mississippian system. The following formations are recognized within this system: Lower Mississippian dolomite, Madison limestone, Deseret limestone, Humbug formation, Great Blue limestone, and the lower portion of the Manning Canyon shale. The upper portion of the Manning Canyon shale is dated as Pennsylvanian and is overlain by the Oquirrh formation.

These formations with the possible exception of the pre-Cambrian can all be traced with lateral continuity to Provo Rock Canyon where Baker (1947) has worked out the stratigraphic sequence, nomenclature, and preliminary age correlations.

Regional correlations of the Paleozoic stratigraphy of the southern Wasatch Mountains have been in part limited by the complex regional structural picture. Baker (1947) has found that a large overthrust, whose surface trace is present to the east of the small town of Alpine in northern Utah County, has brought into juxtaposition sharply contrasting lithofacies and thickness of Upper Mississippian and Pennsylvanian stratigraphy. Bissell (1952, p. 622) has mapped the eastern trace of this overthrust into Strawberry Valley. Though the magnitude of the thrust sheet has not yet been determined Bissell postulates that the whole south-central and southern Wasatch Mountains may be a large allochthonous mass which has been displaced eastward from its original position some tens of miles.

SEDIMENTARY ROCKS

Pre-Cambrian Rocks

Big Cottonwood Series

General Statement and Distribution. - The name "Big Cottonwood Series", was recently proposed for a thick sequence of clastic sediments of pre-Cambrian age in the Big Cottonwood Canyon area of the Wasatch Mountains, southeast of Salt Lake City (Crittenden, Sharp, Calkins, 1952, pp. 3-4).

Geologists of the 40th Parallel Survey considered this thick barren sequence and the overlying fossiliferous portion of the Cambrian to be conformable, and therefore referred all of it to the Cambrian (King, 1878, pp. 229-230). Later an angular unconformity was detected within this thick sequence of sediments by Blackwelder (1910, pp. 520-522) at the base of strata (Tintic quartzite) which is now considered to be Lower Cambrian in age.

The oldest rocks exposed within the mapped area are dark colored shales and quartzites. Due to their lithologic character and stratigraphic position, unconformably beneath the Tintic quartzite, they are considered by the writer to be the upper portion of the Big Cottonwood series. These sediments are exposed in a continuous but irregular outcrop pattern which can be traced from Slate Canyon south to a position just north of the large draw which tends to bisect Buckley Mountain.

Character and Lithology. - The Big Cottonwood series as exposed here is composed entirely of bedded clastics. These have been highly indurated and compacted by what appears to have been regional and/or dynamic metamorphism. A detailed measurement of the uppermost portion of the exposed section indicates the lithology to be dominantly slates, phyllites, argillites, quartzites, and gritstones with numerous thin beds of subangular to subrounded pebbles. These strata vary in color but are dominantly deep red, maroon, purple, green, and brown such as tend to characterize much of the upper pre-Cambrian of the eastern Great Basin.

The lower portion of the Big Cottonwood series in this area is masked by talus and Bonneville sediments. The uppermost strata of the series are unconformably overlain by the Mineral Fork tillite along the north wall of Slate Canyon and in one small area on the south side of the canyon. Where the tillite is absent, as is frequently the case, the upper contact of the Big Cottonwood series lies beneath the Tintic quartzite. This contact is discussed in greater detail on following pages.

Age and Correlation. - The diagnostic lithology and stratigraphic position of these barren strata unconformable below the Tintic quartzite suggest correlation with the younger pre-Cambrian rocks (Big Cottonwood series) of the Cottonwood-American Fork area of the central Wasatch Mountains (Crittenden, Sharp, and Calkins, 1952, pp. 3-4; Calkins, 1943, pp. 7-9) as well as those of the Dry Mountain area in the southern Wasatch Mountains where Eardley (1933, pp. 312-313) reports a thickness of from 500 to 1, 000 feet. Correlation is also suggested with the pre-Cambrian rocks of Long Ridge where Muessig (1951, detailed section No. 9, pp. 193, 194) measured 2, 340 feet of slates and quartzites.

In Slate Canyon to the north of Buckley Mountain the writer measured 1, 088 feet of the Big Cottonwood series. Additional strata are exposed in this area below that which was measured, but for the most part they are not sufficiently well exposed to be described with accuracy.

Mineral Fork Tillite

Distribution. - A unique pre-Cambrian lithofacies which overlies the Big Cottonwood series in the upper basin of Mineral Fork in Big Cottonwood Canyon is regarded as tillite and has recently been named "Mineral Fork tillite" (Crittenden, Sharp, Calkins, 1952, p. 4). This rock unit or a similar lithofacies has been observed in several localities of the Wasatch Range between Provo and Brigham City as well as on several of the islands of Great Salt Lake (Blackwelder, 1932, p. 290).

In the Buckley Mountain area a dark brown to black conglomeratic rock which overlies the Big Cottonwood series and underlies the Tintic quartzite has been referred to as tillite by Baker (1947). The lithology and stratigraphic position of this facies agrees so closely with that of the Mineral Fork tillite of the type locality (20 to 25 miles to the north) that it shall here be referred to as the Mineral Fork tillite.

This unit is well exposed along the north wall of Slate Canyon adjacent to the mapped area. It does not however extend across the canyon in its normal stratigraphic position, but is present only on the south side of the canyon in two small exposures on the hanging wall block of the Maple Flat fault. These outcrops constitute the only so-called tillite encountered in the immediate mapped area and to the writer's knowledge are the southernmost such exposures in the Wasatch Mountains.

Character and Lithology. - Though the writer was unable to devote time to original study of this conglomeratic facies other than a brief field examination, its character suggests that it might possibly be a graywacke conglomerate of the molasse type rather than a tillite.

In general this unit is best described as a terestrial facies composed of subangular to subrounded boulders, cobbles, and pebbles of quartzite, granitic rock, and dolomite, which are well cemented in a dark brown to black fine grained matrix. Blackwelder (1932, p. 299) in his study of the tillite in Provo Rock Canyon states that the various rock types are present in the following proportions:

	Per Cent
Dense gray dolomite, with some black chert	about 55
Metaquartzites of white, brown and dull gray colors	about 50
Miscellaneous rocks various types of schist, and gneissic granitoid rocks	about 5

(Note: Blackwelder's figures for the above rock types total 110 per cent. This is confusing and appears to be an error)

To the writer's knowledge carbonates are unknown in the pre-Cambrian of Utah. This suggests that the above described dolomites, within the so-called tillite, are not from a local source but possibly were derived from a relatively distant source. In light of the present scant information concerning this formation it seems plausible to conjecture that the dolomite may be from a source as distant as the Belt series of western Montana.

Age and Correlation. - The Mineral Fork tillite was formerly regarded by Calkins (1943, 1. 9-10) to be of probable Cambrian (?) age. However, a more recent study by Calkins, Crittenden, and Sharp (1952, pp. 4-6) dates the tillite as pre-Cambrian.

Blackwelder (1932, p. 303) in an early study of this formation proposed a tentative correlation of the various exposures of tillite south of the Willard overthrust in the Wasatch range.

Thickness. - An erosion surface at the top of the Mineral Fork tillite has caused a great variation in its thickness. In the greater part of the Buckley Mountain area the tillite has been eroded from the section. Where the tillite is present along the north wall of Slate

Canyon the writer measured a thickness of 139 feet. In this same locality Baker (1947) measured 145 feet. In the type locality variable thicknesses of the tillite are also reported, the maximum being approximately 3,000 or more feet thick (Crittenden, Sharp and Calkins, 1952, p. 4).

Pre-Tintic Unconformity

Where the tillite is absent from the stratigraphic section the Tintic quartzite rests directly on the Big Cottonwood formation. The two formations are lithologically very similar near the contact and locally there appears to be little or no angular discordance between them.

The presence of the unconformity can most readily be detected and studied by comparing detailed sections of the strata contiguous to the contact. The writer compared a detailed section measured on the north wall of Slate Canyon, which includes the tillite, with a section measured on the mountain front to the south of Buckley Draw. This comparison clearly indicated an erosion surface between the Tintic quartzite and the underlying Big Cottonwood formation in which all of the tillite and a portion of the uppermost Big Cottonwood strata is absent.

During mapping it appeared that the dominant folding in the pre-Cambrian rocks and overlying rocks is the same. However, it was also noted that the lower exposed strata of the Big Cottonwood series in Buckley Draw exhibits folding which does not appear to be reflected in the younger rocks. The ruggedness and inaccessibility of Buckley Draw as well as the structural nature of the strata makes it an area of difficult study and one in which apparent rock relationships are not easily interpreted. It is possible that what appears as older folding may be features which have resulted from fault drag or from small local faults.

Cambrian System

Tintic Quartzite

Distribution. - The name Tintic quartzite was applied by Lindgren and Loughlin (1919, p. 25) to a thick quartzite section in the Tintic mining district of central Utah. In the Wasatch Range this quartzite or an equivalent lithofacies forms bold and conspicuous outcrops along much of the range front. This same stratigraphic unit is also recognized in the Buckley Mountain area a complete and well developed section of Tintic is exposed. It forms a broad and continuous outcrop band from Slate Canyon south across much of the west face of Buckley Mountain. On the ridge to the south of Buckley Draw the outcrop pattern is thickened due to folding and faulting.

Character and Lithology. - The Tintic quartzite varies from an orthoquartzite to a metaquartzite, but appears to be composed largely of the latter. Minor amounts of shale (phyllites and shale) occur within the quartzite as thin seams along the bedding planes. The Tintic is predominantly white to light cream colored and weathers various shades of brown, orange, and red from the oxidation of an inherent iron content. Close examination with a hand lens shows the mass of the quartzite to be composed predominantly of clean, well-rounded and generally well-sorted fine to medium quartz grains which are tightly cemented by a siliceous cement. Several intercalations of angular grit and well-rounded quartz pebbles, some of which appear to be vein quartz, occur in the lower half of the formation. Bedding is well developed and is variable from thick to thin beds, with the latter being most characteristic. Pronounced jointing is present but no dominant joint sets were noted. Due to composition and tight cementation the Tintic is highly resistant to weathering and characteristically occurs as a ledge former.

The contact of the Tintic quartzite with underlying pre-Cambrian rocks is variable, but with the exception of a small amount of tillite in Slate Canyon the Tintic rests unconformably on quartzites and slates of the Big Cottonwood series. This unconformity is normally undetectable and a sharp separation of the two formations is often difficult. In the American Fork Canyon area Calkins (1943, p. 11) noted that where the tillite is lacking the base of the Cambrian (Tintic quartzite) is characteristically marked by a conglomerate bed about one foot thick. The same or similar conglomerate bed appears to be present in this area. For mapping purposes, a practice was made of selecting it as the base of the Tintic quartzite in the absence of the tillite. Abbott, (1951, p. 32) in working with the diabase flow in this area, found the flow to occur at a near uniform stratigraphic distance of 160 feet above the base of the Tintic.

Age and Correlation. - Stratigraphic position and lithology indicates that this formation is directly correlatable with the Tintic quartzite of the type locality and with the same formation in the Cottonwood-American Fork district of the central Wasatch Mountains and the Stockton Fairfield quadrangles of the southern Oquirrh Mountains. These same criteria supplemented by paleontologic evidence suggest correlation with the lower portion of the Brigham quartzite in the northern part of the state.

Peterson's (1952, p. 17) study of the Little Valley area on Long Ridge makes mention of and includes a photograph of a trilobite (*Olenellus*) fragment in the Tintic quartzite. This, to the writer's knowledge, is the only recognizable fossil detected within this formation.

Dating the Tintic quartzite by paleontologic means has been done entirely with fossils collected from the Ophir shale which overlies it. In the type locality Lindgren and Loughlin (1919, p. 24) placed the top of the Tintic quartzite near the boundary between Middle and Lower Cambrian on the basis of paleontologic evidences marshalled from studies made in the Wasatch, Oquirrh, and House ranges and Tintic district of Utah.

Thickness. - The base of the Tintic quartzite is not exposed in the type locality where Lindgren and Loughlin (1919, p. 24) estimated it to be 6,000 feet thick. A more recent study by Lovering (1949, p. 9) in that area reports a more conservative figure of 3,500 feet of exposed Tintic. In the Cottonwood-American Fork area of the Wasatch Mountains, Calkins reports 800 feet of Tintic. In Slate Canyon of the Buckley Mountain area, Baker (1947) measured 1,080 feet of Tintic. Approximately two miles to the northeast of Slate Canyon, Bissell (unpublished field notes, March 10, 1943) measured and described in detail 1,017 feet of Tintic.

Ophir Formation

Distribution. - The Ophir formation was named after the mining camp of Ophir in the Oquirrh Mountains of central Utah (Lindgren and Loughlin, 1919, p. 25). In the type locality as well as in the central and southern Wasatch Mountains and the Tintic district, the Ophir separates the Lower Cambrian quartzites from the Upper Cambrian limestones (carbonates). Within the mapped area the Ophir forms a continuous outcrop band which extends from Slate Canyon south across the west face of Buckley Mountain to a point shortly above the valley floor where it becomes obscured by talus and Lake Bonneville sediments.

Character and Lithology. - The Ophir conformably overlies and forms a contrasting lithofacies with the Tintic quartzite. The lithologic break between the two formations is transitional from a predominantly quartzite lithotope below to one which is predominantly shale above. The basal contact selected by the writer is the lowest thick bed of fine grained green quartzite, which is easily identified as it forms a contrast with underlying typical Tintic quartzites.

The Ophir consists of three main lithotopes which are essentially two shales separated by a limestone. The lowest lithotope is a phyllitic shale, which contains some quartzites and is primarily dark green to dark gray and weathers to light green, red, brown, and orange. It is thin bedded and ordinarily is very fissile. Some of the shale surfaces are rough or uneven and they commonly exhibit a texture which resembles wormlike bodies. The limestone lithotope occurs well above the center portion of the formation. It is gray and weathers light gray with argillaceous bands occurring between the bedding planes. In Slate Canyon where the detailed section for this paper was measured the limestone is considerably less pronounced and less well developed than is the limestone lithotope of the Ophir formation of the American Fork Canyon area. To the south of Slate Canyon this lithotope is poorly developed and is often entirely absent from the section. The upper shale lithotope above the limestone is green, brown to gray, and weathers dull red, brown, and greenish gray. It is thin bedded and in part calcareous. The formation is typically a slope former between cliffs of limestone and dolomite.

Age and Correlation. - No recognizable fossils were collected from this formation by the writer. But, the position of this characteristic shale facies above the diagnostic Tintic quartzite makes it easily correlated with the Ophir formation of adjacent areas in the Wasatch Mountains, as well as the type locality in the Oquirrh Mountains and the Tintic district.

From the Ophir formation at the type locality Walcott (1912, pp. 164-165) lists the following Middle Cambrian fossils: Obolus (Westonia) ella, Micromitra sp., Micromitra (Paterina) labradorica utahensis, and Olenoides.

Muessig (1951, p. 15) in general concurs by stating the Ophir formation of the Long Ridge area falls within the Middle Cambrian faunal zones of Glossopleura-Kootenia and Ehmania-Belaspia-Glyphasipis.

Lithology and stratigraphic position suggest that the Ophir formation is at least in part correlative with the numerous Cambrian shales of the eastern Great Basin which overlie the lower Cambrian quartzite.

Maxfield Limestone

Distribution. - The name Maxfield was first used by Hintze for calcareous beds which outcrop above the Ophir formation near the Maxfield mine in the Cottonwood mining district, Utah (Calkins, 1943, p. 14). At the present time this unit is recognized only in the central and south-central Wasatch Mountains.

In the Buckley Mountain area the Maxfield conformably overlies the Ophir and forms a continuous outcrop band directly above it. The band extends from Slate Canyon south across much of the west face of Buckley Mountain. Small irregular outcrops of this formation are also present on the large fault horse of Paleozoic sediments which lies on the range front between Slate Canyon and Buckley Draw.

Character and Lithology. - The term "limestone" as it is locally applied to this formation implies a carbonate facies. The formation consists essentially of two distinct carbonate lithotopes, the lower one being predominantly an argillaceous limestone and the upper lithotope a light gray weathering dolomite. The two lithotopes are treated as a single stratigraphic unit in this paper as they were in Rock Canyon by Baker (1947).

The lower lithotope comprises most of the thickness of the formation. It is essentially a dark gray to dark blue, thin to massive bedded limestone, which weathers a light shade of gray and is diagnostically mottled with thin argillites bands which parallel the bedding. The argillite bands are most conspicuous on a weathered surface where they stand in relief in a chicken wire-like effect. The limestone appears fine grained beneath the hand lens and where it has fractured or jointed, the void has commonly filled with calcite.

The upper or dolomitic lithotope is considerably different in lithologic appearance and character than the underlying limestone. It appears sharply in the upper portion of the formation with little or no transition between it and the lower lithotope. The upper limit of the dolomite is placed at the base of a grit to sandstone unit which marks the unconformity between Cambrian and Mississippian strata in the central Wasatch Mountains. The thickness of the dolomite lithotope varies in a mild but irregular manner throughout the area. This irregular variance in thickness is suggestive of a pre-Mississippian erosion surface.

The dolomite lithotope is thin to massive bedded, a medium gray color and weathers a light gray to dirty cream color. It is easily detected from a distance for it forms a contrasting white band between contiguous gray strata. The lower stratum of this lithotope exhibits a fine oolitic texture, while some of the higher strata are mottled with characteristic twig-like bodies.

Age and Correlation. - No recognizable fossils were collected from this formation by the writer. A direct correlation however can be made with the Maxfield formation of the Cottonwood-American Fork area on the basis of a distinctive lithologies and stratigraphic position. In that area, Calkins (1943, pp. 14-18) has divided the Maxfield into three members: from the middle member Zacanthoides cf. Z. spinosus and Obolus (Westonia) ella of Middle Cambrian age are reported to have been found.

The criteria of lithologic similarity and stratignapic position of the various members of lithotopes of the Maxfield would suggest correlation with the Cambrian limestones (Hartman limestone, Bowman limestone, and Lynch dolomite) of the Oquirrh Mountains (Gilluly, 1932, pp. 12-18). These same criteria also suggest that a partial correlation may exist with the thick Cambrian carbonate facies of the Tintic district (Lindgren and Loughlin, 1919, pp. 27-32). However, a direct correlation of the Maxfield limestone with the Cambrian units in the afore mentioned adjacent areas is not thought to be possible by Crittenden, Sharp, and Calkins (1952, p. 8).

Thickness. - In the central Wasatch Mountains to the east of Salt Lake City pre-Mississippian erosion has caused such a wide variation in the thickness of the Maxfield limestone that is completely absent in places (Crittenden, Sharp, Calkins, 1952, pp. 7-8). A maximum thickness of 1,039 feet is reported in City Creek Canyon by Granger (1953, pp. 2-6). The thickness of this formation is considerably less in the Wasatch Range to the east of Provo. Baker (1947) reports a thickness of 579 feet of Maxfield in Provo Rock Canyon and the writer measured but 482 feet of the same formation in Slate Canyon.

Pre-Mississippian Unconformity

The upper or dolomitic facies of the Maxfield limestone in the central Wasatch Mountains is unconformably overlain by a diagnostic thin dolomite lithotope. This unit was formerly termed the Jefferson (?) dolomite of probable Devonian age (Calkins, 1943, p. 20; Baker, 1947). Recent paleontologic studies made by the U. S. Geological Survey of a fauna collected from this formation in both the Wasatch and Oquirrh Mountains indicate its age to be Lower Mississippian (Crittenden, Sharp, and Calkins, 1952, p. 9).

In the Wasatch Range to the southeast of Salt Lake City the unconformity is marked with angular discordance (Crittenden, Sharp, and Calkins, 1952, p. 8). In the Buckley Mountain area no angular unconformity is evident. This may be due in part to the structural conditions, for here the strata have been greatly disturbed and in general do not lie in horizontal or normal enough position to allow an adequate study to be made of possible angular discordance adjacent to the unconformity. However, a vauge and poorly defined erosion surface is suggested by minor variations in the thickness of the strata immediately contiguous to the unconformity and by the conglomeratic facies of grit and small quartz pebbles at the base of the Lower Mississippian rocks.

Sediments of Ordovician, Silurian, and Devonian ages as recognized to the west in the Tintic mining district do not appear to be present in the south-central Wasatch Mountains. It is conjectured that at least a part of these sediments may possibly have been present in this region but were removed by erosion prior to deposition of Mississippian sediments. It is more probable however that the zero isopach for sedimentation during Ordovician, Silurian, and Devonian times exists to the west of the region under discussion and that the region comprising the south-central Wasatch Mountains was present as a positive region subject to slight or moderate erosion.

Mississippian System

Lower Mississippian Dolomite

General Statement. - In the Oquirrh and central Wasatch Mountains of Utah the term Jefferson (?) dolomite has been applied to a thin dolomite lithofacies which underlies the Madison limestone (Gilluly, 1932, p. 20; Calkins, 1943, p. 19). This unit was thought by Gilluly (1932, p. 21) to be of probable Devonian age and in part correlative with the Jefferson dolomite of the Randolph quadrangle of northern Utah. Recent paleontologic studies, the results of which have been noted on previous pages, have shown the age of this unit to be Mississippian rather than Devonian (Crittenden, Sharp, and Calkins, 1952, p. 9). This correction in age precludes the possibility of this dolomite facies being the Jefferson dolomite as it has previously been thought (Baker, 1947). Therefore, until this lithofacies is adequately studied it seems justifiable to make reference to it not as it was formerly known, that is, Jefferson (?) dolomite, but for the time being and in this paper it shall be referred to simply as the Lower Mississippian dolomite.

Distribution. - The Lower Mississippian dolomite forms a near continuous outcrop band from stream level in Slate Canyon south across the west face of Buckley Mountain. The width of this band is narrow and suggests a near constant thickness throughout the area of study.

Character and Lithology. - The dolomite unconformably overlies the Maxfield limestone in this area though no angular discordance is evident such as is found to the north in the central Wasatch Mountains (Crittenden, Sharp, and Calkins, 1952, p. 8). The dolomite is highly resistant to weathering and is a persistent cliff former. Both contacts of this dolomite are easily located and sharply defined. The lower contact is placed at the base of a yellow to brown sandstone, which varies in thickness and is dolomitic in part. The upper contact is placed at the top of a thin to medium thick bed of crystalline to sublithographic light gray dolomite, which weathers a contrasting white color between contiguous gray colored beds. The dolomite is predominantly dark to light gray with a crystalline texture. It weathers to lighter shades of gray and contains numerous small calcite stringers and veinlets as well as minor amounts of true limestone. The bedding is commonly thick to massive but a zone near the center of the formation is thin bedded. Characteristic vugs occur in the middle and lower portion of this stratigraphic unit. These vugs are usually hollow though some are filled solid with white calcite such as those described as "eyes" by Gilluly (1932, p. 20) in the Ophir district.

Age and Correlation. - The few fossils which are present in this unit are highly dolomitized and are poorly preserved. Syringopora sp. is the only fossil repeatedly recognized with any certainty. In the Ophir district Kirk of the U. S. Geological Survey reported but three fossils: Cyathophyllum sp., Syringopora, 2 species, and Spirifer sp. (Gilluly, 1932, p. 21). Correlation with the characteristic dolomite (so-called Jefferson (?) dolomite by some geologist) of the central Wasatch and southern Oquirrh Mountains can quite definitely be made on the basis of lithology and stratigraphic position. The same criteria are indicative that an accurate correlation can be effected with the lower portion of the Gardner dolomite (that is, below the "Curley" bed) of the Tintic district and contiguous areas. Clark's (1954, p. 12) study of the Gardner formation states that Syringopora, Caninia sp., and Triplophyllites sp. occur in the basal beds of lower dolomite lithotope of that formation.

Thickness. - A thickness of 169 feet of Lower Mississippian strata was measured in steeply dipping beds on the south side of Slate Canyon. This measurement is considerably thinner than the 259 feet measured in nearby Provo Rock Canyon by Baker (1947), but is approximately the same as measured by Calkins (1942, pp. 20-21), who found 156 feet in American Fork Canyon: Gilluly (1932, p. 20) described 185 feet of this formation in the southern Oquirrh Mountains. These three geologists have considered this formation to be the Jefferson (?) dolomite and have indicated it as such on their maps and sections.

Madison Limestone

Distribution. - The Madison limestone was named for the Madison Range of Western Montana (Gilluly, 1932, p. 24). The name and stratigraphic nomenclature have been extended southward through Idaho and Wyoming as far as the Wasatch Mountains of Utah.

In the Buckley Mountain area the Madison outcrops in a continuous band from stream level of Slate Canyon south across the west face of Buckley Mountain. At its southernmost surface exposure, just north of Little Rock Canyon, the Madison is sharply down-folded with adjacent formations toward the valley floor where it is obscured by Lake Bonneville sediments.

Character and Lithology. - The Madison limestone is characterized by a near similar lithology and well developed bedding, which is normally one foot thick or less. It is typically a cliff former but is also in places expressed as a series of cliffs with minor terraces. Lithologically it is blue to dark gray crystalline limestone, which contains some dolomite and minor amounts of chert, both of which become increasingly abundant toward the upper contact. It weathers various shades of dark blue to gray which appear somewhat black from a distance. The section of Madison limestone found within the mapped area closely resembles other sections of Madison limestone which the writer has seen in other portions of the Wasatch Mountains.

Fossils occur throughout the Madison but are especially abundant in a zone confined to the lower fifty to sixty feet of the formation. In this zone the fossils occur in such great profusion as to form a highly fossiliferous limestone which is essentially near biostromal. In this zone the fossils appear abruptly and form a sharp contrast to the barren and near barren underlying strata.

Age and Correlation. - A faunal collection consisting of Schuchertella lens, Triployphyllites sp., Loxonema sp., Syringopora sp., Euomphalus sp., Multitheocopora sp., Spirifer (Centronatus), and crinoid stems and fragments was made from this unit by the writer. These fossils are indicative of a Madison fauna as well as suggestive of a Kinderhookian age. Correlation with the Madison limestone as suggested by the forementioned fauna is verified by lithology and stratigraphic position. The same criteria also prove precise correlation with the upper Gardner dolomite (above the "Curley" bed) of the Tintic district and adjacent areas.

Thickness. - In Provo Rock Canyon Baker (1947) was unable to define a satisfactory contact between the Madison and Deseret limestones. His stratigraphic section of that area indicates 544 feet of Madison and 496 feet of intermediate strata designated as Madison and Deseret. In the Buckley Mountain area the same intermediate zone appears to be present between what can be recognized as true Madison and Deseret strata. The writer was unable to detect any sharp lithologic break with which to sharply define the upper limit of the Madison; nor was he able to detect a zone of black phosphatic shale such as is used to define the upper contact of the Madison limestone in adjacent areas of the Wasatch and Oquirrh Mountains. An arbitrary upper contact of the Madison was chosen for mapping purposes. This contact is discussed in greater detail on following pages in reference to the Deseret limestone.

In the area under consideration a thickness of 639 feet of strata was measured and designated as Madison limestone. This thickness no doubt includes some of the strata designated as Madison and Deseret in Provo Rock Canyon by Baker.

Additional stratigraph thicknesses of the Madison limestone as reported by Baker, Huddle, and Kinney (1949, p. 1174) are: 460 feet in the Oquirrh Mountains, 376 feet northwest of Midway, 617 feet near the mouth of American Fork Canyon, 660 feet near the head of American Fork, and tentative thickness of 544 feet in Rock Canyon.

Deseret Limestone

Distribution. - The Deseret limestone was named for outcrops near the Deseret mine in the southern Oquirrh Mountains by Gilluly (1932, p. 25). The name was subsequently adopted and used in the central Wasatch Mountains by Calkins (1943, pp. 24-26) and in the south-central Wasatch Mountains by Baker (1947).

In the Buckley Mountain area the Deseret crops out as a continuous band conformably above the Madison limestone. Its extreme southern outcrop is highly folded and forms the north wall of Little Rock Canyon.

Character and Lithology. - The lithologic similarity and the lack of key horizons in the Madison and Deseret limestones near their contact makes the separation of these two formations difficult. In the type locality the lower contact of the Deseret is placed at the base of a thin black shale, the upper portion of which is phosphatic (Gilluly, 1932, p. 25). A similar contact is recognized in the central Wasatch Mountains to the east of Salt Lake City (Crittenden, Sharp, and Calkins, 1952, pp. 9-10). This unit does not appear to be present in the Wasatch Range to the east of Provo, for Gaines (1950, p. 33) states that he was unable to find it in the Provo Rock Canyon area and the writer also was unable to locate such a shale bed in the Buckley Mountain area. The contact used by Gaines (1950, p. 33) in Provo Rock Canyon is a thin-bedded limestone which weathers with a shale-like texture. A similar thin-bedded limestone is present in the Madison-Deseret zone of the mapped area. This unit however is not sufficiently well developed to be detected with the ease and frequency which is necessary for use as a key horizon.

For mapping purposes in this area it was deemed prudent to select an arbitrary contact in the apparent absence of a well defined boundary. The contact selected is a diagnostic bedded black chert facies which appears shortly above what appears to be typical Madison strata.

The lack of abundant fossils and a general increase toward massive bedding helps to distinguish the Deseret limestone from the underlying Madison limestone. The Deseret consists largely of gray to dark gray crystalline limestones and dolomites which weather to somber dark shades of gray. Crinoidal or allochthonous limestones are abundant and are present in beds which are especially thick and well developed near the upper contact. The lower contact is characterized by thin bands and blebs of black chert essentially parallel to the bedding. Frequently what appears to be chert in this formation is only a case hardened limestone, which is easily detected with a weak solution of hydrochloric acid on a freshly broken surface.

Age and Correlation. - Stratigraphic position and distinctive lithology indicate correlation with the Deseret limestone of the Cottonwood-American Fork district as well as with the type locality in the southern Oquirrh Mountains.

Horn corals and bryozoans were collected from this formation by the writer, but no generic identifications were made. Fossils collected from the Deseret in the type locality by Girty, New, and Gilluly (1932, p. 26) of the U. S. Geological Survey show the age of that formation to be Middle Mississippian.

Weller, et.al. (1948, pp. 91-196) date the Deseret as Meramecian and correlate it in part with the Pine Canyon formation of the Tintic area, and the Woodman limestone of the Gold Hill area of western Utah.

Much of the strata designated as upper Pine Canyon limestone in localities to the north of the Tintic district resembles more closely the Deseret lithofacies of the Oquirrh and Wasatch Mountains than it does the true Pine Canyon lithofacies of the type locality. This facies change most probably reflects a change in depositional environment and was called to the writer's attention by Dr. H. J. Bissell during a field trip to the Cedar Valley Hills area. Beds number six through eight (the upper 205 feet) of a detailed section of Pine Canyon limestone measured in this locality by Calderwood (1951, pp. 35-36) shows the bedding to be thick to massive. Such bedding is more typical of the Deseret limestone than of the normally well developed thin bedded Pine Canyon limestone.

Thickness. - A complete section of the Deseret limestone was not measured in the Buckley Mountain area due to the fact that complex folding and faulting or heavy cover prevent accurate measurement or description. However, the lower 358 feet of the section was measured and described in two large units, the results of which are contained herein.

In the type locality Gilluly (1932, p. 25) measured 650 feet of Deseret. Other thicknesses of the Deseret limestone as reported by Baker, Huddle, and Kinney (1949, p. 1175) are 733 feet in Rock Canyon, 900 feet in the Cottonwood-American Fork area, 388 feet near the head of American Fork, and 600 to 650 feet in the canyon of the Duchesne River.

Humbug Formation

Distribution. - The Humbug formation was named and first described by Tower and Smith (1898, pp. 625-626) for exposures in the Humbug mine of the Tintic mining district of Utah.

In the area considered in this report the area of outcrops of the Humbug is second only to the Oquirrh formation. The Humbug caps the crest and dip slope of Buckley Mountain proper from Slate Canyon south to Little Rock Canyon. To the south of Little Rock Canyon Humbug strata have been intensely folded and in such a manner that they form the near-vertical sheer south wall of the canyon.

Character and Lithology. - The Humbug formation forms a diagnostic lithofacies composed essentially of alternating limestones and sandstones, which readily make it distinguishable from adjacent formations which consist essentially of limestone. The basal Humbug forms a conformable succession with the underlying Deseret limestone. The contact between the two formations is placed at the base of the lowest thick (usually 2' to 4' thick) sandstone in the Humbug. This contact is purely arbitrary and is not always at the same stratigraphic horizon due to the lenticular nature of the sandstones.

The limestones within the Humbug formation vary in texture from coarse encrinites to sublithographic types. In general however they are medium to finely crystalline, light to dark gray in color and are thin to thick bedded. Small amounts of black, brown, and red chert are present as blebs and thin seams parallel to the bedding planes.

The sandstones and orthoquartzites of the Humbug locally make up as much as an estimated 25 to 30 per cent of the formation. They are fine to medium grained, buff to brown colored and occur in individual beds less than one foot to over ten feet in thickness. The cementing material of the sandstones is in part calcareous, but is predominantly siliceous.

Zones of recemented limestone and sandstone breccia are commonly present throughout much of the formation.

The Humbug is a dominant cliff former. This is in part due to stratigraphic position and structural conditions. For the Humbug is tilted at a high angle of dip and lies stratigraphically beneath the relatively non-resistant Great Blue limestone. Viewed from a distance, outcrops of the Humbug have a dominant buff tone which set them apart from the underlying black and gray limestones.

Age and Correlation. - The characteristic lithology and stratigraphic position of this formation constitute sufficient criteria to make possible a precise correlation with the Humbug formation in adjacent areas of central Utah. The Humbug is shown by Weller, et. al. (1948, pp. 91-196) as probable upper Meramecian in age.

Recognizable fossils collected from this formation by the writer consist entirely of small zaphrentid-type corals and crinoid fragments. Fossils collected from this formation in the Cottonwood-American Fork area by Butler and Loughlin (1916, p. 173) and determined by Girty to be Upper Mississippian in age are as follows: Fenestella sp., Chonetes sp., Diaphragmus elegans, Martinia sp., Composita sp., Cliothyridinia hirsuta.

Thickness. - In a manner which typifies the formation of the Mississippian system in this region, the Humbug formation becomes progressively thinner to the east. Measurements of this formation as reported by Baker, Huddle, and Kinney (1949, p. 1176) are: 600 to 650 feet in the Oquirrh and central Wasatch Mountains; approximately 400 feet in the valley walls of the Duchesne River, Lake Fork, and Whiterock River along the south flank of the Uinta Mountains.

In Provo Rock Canyon 547 feet of the Humbug formation was measured and described.

Great Blue Limestone

Distribution. - The Great Blue limestone was named and first described by Spurr (1895, pp. 374-376) in the Mercur mining district of the southern Oquirrh Mountains, Utah. It has been recognized to the south of the type locality in the region of Long Ridge and to the east in the south central Wasatch Mountains.

In the Buckley Mountain area, the Great Blue is confined mainly to a medial ridge in the north-south trending strike valley at the base of the Provo Peaks in the south-central Wasatch Mountains. To the south of Kolob Basin the medial ridge becomes obscured and the outcrop band of Great Blue assumes a roughly semi-crescent shape which parallels the trend of Little Rock Canyon. The Great Blue of this area is not exposed in the grandeur which it is a few miles to the north in the vicinity of Provo Rock Canyon. This is thought to be due mainly to structural complexities rather than unusual facies changes southward.

Character and Lithology. - In much of this area the surface exposures of the contact between the Great Blue and the underlying Humbug formation have been obscured by erosion and are covered by talus or a thick mantle of soil. Where the bed rock is exposed the contact appears conformable and is arbitrarily placed at the base of a thick encrinite bed which lies a short stratigraphic distance above the last sandstone unit in the Humbug. The basal Great Blue, where exposed, consists of medium bedded limestones followed by a poorly defined green to black shale which contains pseudomorphs of limonite after pyrite. Position and lithology suggest that this unit is the equivalent of the Long Trail shale member of the Great Blue. But locally it is so poorly defined that it cannot correctly be recognized as such. Above this basal unit the exposed Great Blue appears quite homogeneous. It is composed of thin, well developed beds of dark gray to black, finely crystalline to sub-lithographic limestone, which weathers to thin slabs with a characteristic soft red to pink color.

Age and Correlation. - Fenestella sp., Rombopora sp., and Fenestralia sp. were collected from this unit by the writer and identified by Dr. J. K. Rigby. Composita-type brachiopods and a horn coral were also collected, but no generic identifications were possible.

The lithology and stratigraphic positions of this formation permit correlation with the Great Blue limestone of the type locality and adjacent areas. Studies made by Girty of a large and varied fauna collected from the Great Blue of the southern Oquirrh Mountains date it as tentatively Upper Mississippian (Gilluly, 1932, pp. 30-31). This age is in general agreement with Weller, et. al. (1948, pp. 91-196) who date the Great Blue of the Oquirrh Mountains in respect to series as lower Chesterian.

Thickness. - The Great Blue was not measured in the area considered in this report due to the obscurity of contacts and probable fault relationship. Surface mapping shows it to be considerably less thick in this area than in the Rock Canyon area where Baker (1947) reportedly measured a thickness of 2,800 feet. In the southern Oquirrh Mountains near the vicinity of the type locality, Gilluly (1932, p. 29) made several measurements of the Great Blue and reports its thickness to be about 3,600 feet thick,.

Mississippian and Pennsylvania (Undifferentiated)

Manning Canyon Shale

Distribution and Topographic Expression. - The Manning Canyon shale was name by Gilluly (1932, p. 31) for outcrops in Manning Canyon of the Ophir mining district in the Oquirrh Mountains. This shale formation is recognized to the west of the type locality in the Gold Hill area, to the south in the vicinity of Lake Mountain, and to the east in the south-central Wasatch Mountains.

In the Buckley Mountain area the Manning Canyon shale is exposed in a thin linear outcrop pattern which extends from Knight Spring at the base of Corral Mountain south to a position in Kolob Basin near the back of Little Rock Canyon. The exact southernmost surface exposure of the shale cannot readily be determined as outcrops are commonly poorly defined. However, topographic expression and other evidence suggest to the writer that the Manning Canyon shales are present just below the soil in Kolob Basin as far south as the N. E. 1/4 of Sec. 27, T. 7 South R. 3 East. West of this position in the small eastwest trending valley between the Three Sisters and Round Peak the Manning Canyon shales are totally absent from the section, due in part to folding but mainly to thrust faulting.

Outcrops of the Manning Canyon shales within the mapped area are restricted to a few irregular shaped exposures which protrude through the overlying soil. The best such exposures are to be found in the narrow washes near Horse Mountain where the spring runoff has removed the overlying soil as well as a portion of the shales so that fresh relatively unweathered exposures are visible.

Due to the lithologic character of the Manning Canyon shale it is typically a valley former. The inability of the shales to resist weathering and erosion has been of primary importance in shaping the present morphology of the Wasatch Range to the east of Provo and Springville. The origin and position of the strike valley which extends in a general north-south direction from Spring Dell in Provo Canyon south to Camel Pass east of Springville can be attributed directly to the erosion of the Manning Canyon shale from between more resistant formations.

Character and Lithology. - In Rock Canyon Gaines (1950, p. 43) reports that the Manning Canyon shale lies conformably between the Great Blue limestone and the Oquirrh formation. For the most part within the mapped area these same contacts are not normal. Evidence from mapping suggest that the upper and lower contact of the Manning Canyon shale may be normal in the northern most portion of the mapped area. However, as the formation is traced southward it thins considerably until it is pinched entirely from the section at the surface and the Great Blue limestone lies in contact with the Oquirrh formation. Mapping and paleontological evidence show that the Manning Canyon shales thin and pinch from the section due to thrust faulting.

Due to the impervious nature of the shale a linear system of springs occur along strike from Knight Spring south to a position east of the Three Sisters. Most of the springs are small but flow sweet cold water year around.

Where exposed the Manning Canyon shales are black to dark brown, soft fissile carbonaceous shales which weather a medium dull gray with some yellow and orange tones. Stratigraphically above the shales exposed within the mapped area are some medium green colored siliceous clastics composed of grains ranging from fine to grit size and some thick but mainly thin-bedded, almost shaly, dark gray to black limestones. Exposures of this formation within the area being considered are so few and poorly defined that an adequate descriptive study of the lithology was not possible. However, it might be mentioned that in Provo Canyon, ten miles to the north along strike, where the Manning Canyon shale is better exposed thin seams of a poor grade coal are present with the shale.

Age and Correlation. - No fossils were collected from this formation by the writer, but stratigraphic position and diagnostic lithology are sufficient criteria to assure a near precise correlation with the Manning Canyon shale of the Oquirrh Mountains.

Abundant fossils were collected from this formation in the type locality by Girty and Gilluly (1932, pp. 32-34) and Girty's study of the collections indicate the formation to be Upper Mississippian and Lower Pennsylvanian. Gilluly (1932, p. 33) was unable to find a systemic break with which to separate the strata for mapping purposes.

Baker, Huddle, and Kinney (1949, p. 1179) state that the coarse clastic sediments found in this formation in the Wasatch Mountains suggest discontinuity of deposition, but found no evidence to show an unconformity between the Mississippian and Pennsylvanian portions of the formation.

Direct correlation appears to be restricted essentially to the occurrence of the formation in the Gold Hill area of western Utah where it is estimated to be near 1,000 feet thick (Nolan, 1935, p. 32) and the south-central Wasatch Mountains near Provo Rock Canyon where Baker (1947) reports a thickness of 1,670 feet.

No measurement of this formation was attempted in the Buckley Mountain area due to the lack of good exposures and the complexity of structure.

Pennsylvanian System

Oquirrh Formation

Distribution. - The Oquirrh formation was named by Gilluly (1932, p. 34) for a widespread and very great thickness of alternating limestones and sandstones in the Oquirrh Mountains. This same formation was first recognized in the Wasatch Mountains by Bissell (1936, pp. 239-243), where it forms the larger portion of the range proper from American Fork Canyon on the north to Mt. Nebo on the south.

In the Buckley Mountain area the Oquirrh outcrops in a continuous semi-arcuate like band along the extreme eastern and southern boundaries of the area. It forms the summit of the range in this area and occurs in bold topographic expression as a north-south trending ridge, which is the southern extension of the Provo Peak Mountain.

Character and Lithology. - Due to the great thickness of this near homogenous mass of rocks it is estimated that only strata of the lower one-fourth of the formation are present within the mapped area. The lower contact of the Oquirrh formation with the Manning Canyon shale is in no portion of the area sharply visible and readily enough exposed, due to a heavy mantle of soil and vegetative cover, to permit sufficient observations for a detailed study. However, structural and paleontologic evidences indicate a thrust contact between the two formations is present in the larger portion of the mapped area and perhaps in all of it. The thrust contact is quite obvious in the southern part of the area near Round Peak and becomes less conspicuous as it is traced north. The greater amount of Morrowan age limestones which normally constitute the lower Oquirrh formation is locally absent from the stratigraphic section in this area due to the thrust fault. Thus, in much of the area and especially near Round Peak strata of Atokan age are present as the lowermost Oquirrh exposure.

This great thickness of sediments is essentially interbedded limestones, sandstones, and orthoquartzites; the latter two rock types appear to predominate. The limestones are dark blue to dark gray in color and weather medium gray to light brown or tan and normally have a sandy texture. Many of the limestones are so arenaceous that they weather to what appears to be a dense sandstone. They can however be easily detected as limestones by the use of a weak solution of hydrochloric acid on a freshly broken surface. Much of the limestone is fetid and contains some dark gray to black chert. The bedding is normally medium to massive. The sandstones range to orthoquartzites, both rock types are buff, brown, or tan and weather with a characteristic red tone. They are fine to medium grained and in places exhibit pronounced cross bedding. These arenaceous size clastics are most commonly cemented with a limy material.

Thickness, Age, and Correlation. - Preliminary work indicates a total thickness of near 26,000 feet for the Oquirrh formation (Baker, Huddle, and Kinney, 1949, p. 1185). Of this tremendous thickness 16,200 feet is referred to the Pennsylvanian and 9,800 feet to the Permian, though no lithologic systemic break has yet been recognized within the formation (Thompson, Verville, and Bissell, 1950, p. 430).

Both microfossils and megafossils occur abundantly in the limestones and sandy limestones of this formation. Fusulinids are especially abundant, Fusulinella sp. (recognition determined by Prof. H. J. Bissell) along with other genera were collected from the lower exposed Oquirrh of this area and were instrumental in determining the stratigraphic displacement of the aforementioned thrust fault which is present at the base of the Oquirrh formation.

In recent years considerable work has been done with the stratigraphy and micropaleontology of this formation in the south-central Wasatch Mountains. Bissell (1936) studied this formation in the Hobble Creek Canyon area to the east of Springville and recognized it to be composed of two lithofacies; the lower one consisting of interbedded sandstone and limestone which he proposed be called the Kelly formation and the upper lithofacies composed essentially of sandstone he proposed be called the Hobble formation. Baker (1947) in working with the stratigraphy of this formation reports that a preliminary study of some fusulinids indicates its age to range from Morrow (?) through Atoka, DesMoines, Missouri, and Virgil to middle or upper Wolfcamp and possibly Leonard. Thompson, Verville, and Bissell (1950, pp. 430-465) have made a detailed study of the Pennsylvanian fusulinids collected from this formation in which several new species of fusulinids were described.

Baker, Huddle, and Kinney (1949, p. 1185) report that paleontologic evidence indicates that the Morgan formation, Weber quartzite, and the Hermosa formation are of lower Pennsylvanian age and may be in part equivalent to the lower part of the Oquirrh formation.

Quaternary System

Lake Bonneville Sediments

General Statement and Distribution. - Unconsolidated sediments of the Lake Bonneville group are present along the westernmost portion of the mapped area. These sediments occur in the form of wave-cut and wave-built terraces and lie unconformably against the pre-Cambrian and Paleozoic bedrock of the range front. The wave-cut terraces are locally referred to as foothills for they tend to form somewhat of a transition between the valley and the mountain front.

The true lake terrace morphology is not as well developed in the Buckley Mountain area as in adjacent portions of Utah Valley, where three sharp and well defined terraces or benches can easily be distinguished. These three terraces represent the various major stages and water levels of the ancient lake, the highest level being approximately 5, 135 feet above mean sea level.

The lake deposits of Utah Valley have been divided into three formations. These are in order of deposition, the Alpine, the Bonneville, and the Provo formations. According to Bissell (1948, pp. 126-263) the Alpine formation is composed of generally well-sorted silt, arenaceous, and gravel-size particles; the Bonneville formation, which accumulated at the highest level of the lake, is composed mostly of coarse clastics ranging from gravel to boulder size; and the Provo formation is composed of gravel, sand, silt, and clay members. The latter formation was deposited at a lower lake level and during a greater period of time than were the two older formations.

Age and Correlation. - These unconsolidated lake sediments have been dated as Pleistocene by Gilbert (1890), Bissell (1948)*, Hunt, Varnes, and Thomas (1952). They are directly correlatable with the Lake Bonneville sediments of comparable stratigraphic position which are found in the Pleistocene lake basin of western Utah, southern Idaho, and northeasternmost Nevada.

IGNEOUS ROCKS

The only igneous rock found in the area considered in this report is a dark reddish colored tabular shaped rock body confined to the lower Tintic Quartzite. Abbot (1951), has studied and mapped in detail this igneous rock in several localities within the south-central and southern Wasatch Mountains, as well as Long Ridge. His study indicates the rock to be a relatively widespread Cambrian diabase flow which appears at a near uniform stratigraphic distance of 160 feet above the base of the Tintic quartzite. Prior to Abbot's study, Eardley (1933, pp. 342-344) had studied this rock in the southern Wasatch Mountains and had considered it to be a sill of probable Tertiary age.

In the Buckley Mountain area the flow is mappable within the lower Tintic quartzite from Slate Canyon south across the west face of Buckley Mountain. It is less resistant to weathering and erosion than the adjacent quartzite and generally forms a slight depression where it outcrops. The diabase with few exceptions is highly weathered and altered. Surface exposures and float commonly appear a dull dark red color with a slight purple tone. Without close examination, weathered diabase float may easily be mistaken for float from the finer grained clastics of the Big Cottonwood series.

*(The writer is indebted to Dr. H. J. Bissell for the use of his Bonneville maps from which information was obtained and incorporated into the geologic map which accompanies this report.)

In an adit on the west face of Buckley Mountain the diabase is present in a relatively unaltered form as a green to grayish green porphyritic rock containing conspicuous phenocrysts of feldspar. Amygdaloids filled with a secondary white to light green colored mineral, described as chlorite-serpentine by Abbot (1951, p. 34) are common to much of the diabase. At the top of the flow is a conglomerate, normally one foot or more in thickness composed essentially of rounded to sub-rounded quartz and diabase pebbles, the quartz pebbles being predominant. The contact metamorphic or chilled zone at the base of the flow is so slight it is detected only by close examination.

Abbot (1951, pp. 57-59) describes the microscopic character of the diabase as:

> "the flow has a diabasic tecture with large phenocrysts of labradorite. The groundmass is a rather confused aggregate of plagioclase (labradorite), ferromagnesium minerals, and products of their alteration. The primary minerals are basic plagioclase (labradorite, pyroxene (augite), iron oxide (magnetite), and possibly illminite. The secondary minerals include sericite (paragonite and kaolinite as alteration products of plagioclase: and limonite, hematite, chlorite, serpentine, calcite, and kaolinite as alteration products of the ferro-magnesium minerals."

The thickness of the diabase is variable due to post-flow erosion. In the mapped area the diabase varies in thickness from less than a foot to twenty-five feet. The greatest thickness noted by Abbot (1951, p. 43) was in North Canyon where he states the flow varies from 21 to 61 feet in thickness.

To the south of the mapped area, in the central portion of the western 1/2 of section 35, Township 7 South, Range 3 East, Dr. H. J. Bissell called the writer's attention to an additional igneous rock. Rapid field examination of this rock suggests it to be a partially exposed dike in Bonneville sediments. A hand sample which was collected did not appear to be highly altered, and showed the texture to be an aphanitic porphry with small but apparent phenocrysts of biotite (?). In megascopic des-cription the rock is a dark gray color and weathers a lighter gray. No laboratory analysis of this rock was attempted by the writer, but Bissell* reports it as a relatively fresh lamprophyre dike.

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*Personal communication, May, 1954

STRUCTURAL GEOLOGY

GENERAL STATEMENT

Since the initial investigation by the geologists of the 40th Parallel Survey, the Wasatch Mountains have received considerable geologic study. Of these studies probably the works of Gilbert (1928) and Eardley (1934, 1939, 1944) have contributed most to the detailed structural interpretation of large portions of the range.

In central Utah the Wasatch Mountains from the eastern front of a north-south trending belt of intense Laramide folding. To the east of the range this intense folding fades into the more stable epeirogenically uplifted region of the Colorado Plateaus and the Uinta Mountains.

The Wasatch Mountains are frequently grouped with the Uinta Mountains to form what is physiographically known as the southernmost portion of the Middle Rocky Mountains. Structurally and tectonically however, the Wasatch Mountains are most closely related to the basin ranges.

The Buckley Mountain area is dominated structurally by a truncated eastern limb of a large overturned north-south trending fold upon which has been impressed at near right angles a broad and more gentle fold. Only portions of both folds are represented within the confines of the mapped area. The near right-angle intersection of the two individual fold axes has formed an anticlinal feature which culminates structurally in the vicinity of Slate Cayon. From this position of culmination the anticline plunges gently to the north and more marked and steeply to the south. The axial trend of the anticline is essentially conformable with the north-south trending regional structural grain. Strike in general deviates little from north and dip is dominantly east.

Folds

North-South Axis of Folding

The north-south axis of folding in the Wasatch Range to the east of Provo is not readily apparent from the range front. However, the small canyons (Provo Rock Canyon and Slate Canyon) which are incised within the frontal portion of the range in this vicinity afford excellent normal cross sectional views of this folding. Eardley's (1939, p. 1) map containing the structural trends of north-central Utah shows this line of folding to be a continuous structural trend extending from the vicinity of Nebo Mountain on the south to the Cottonwood uplift on the north.

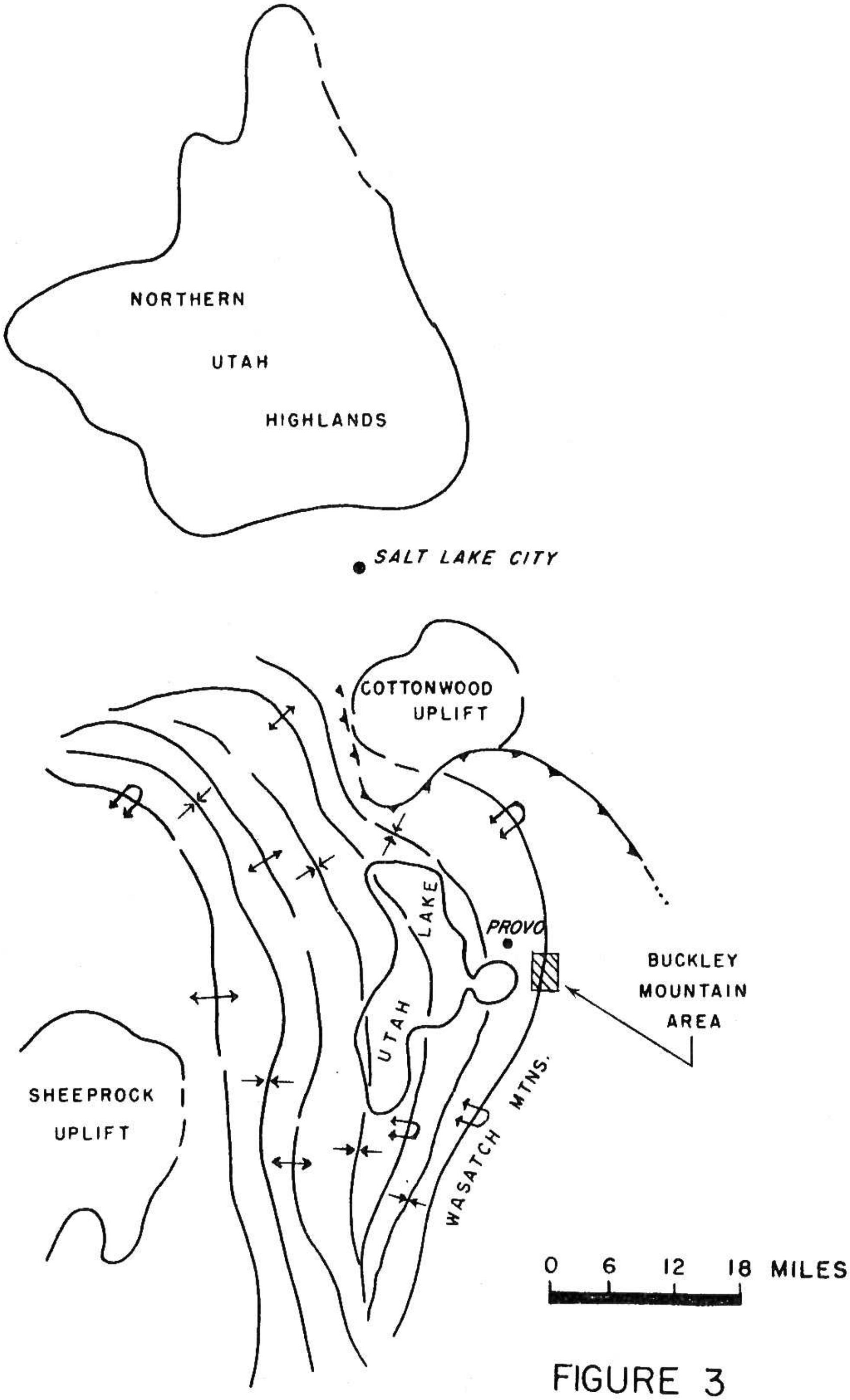

FIGURE 3

STRUCTURAL TRENDS OF CENTRAL UTAH

A local study of this folding made in Slate Canyon reveals the fold to be slightly asymmetrical and of an open type in which the strata in the bottom of the canyon adjacent to the Big Cottonwood formation-Tintic quartzite contact are overturned. To the south of Slate Canyon in the vicinity of Little Rock Canyon, where the fold noses and plunges steeply to the south, Cambrian and Mississippian strata are vertical to overturned.

Only conjecture can be made as to the structural nature of the strata in this area which has been downdropped to the west of the present range front by the Wasatch fault. However, it is most probable that a large west-dipping limb, the counterpart of the mapped east-dipping limb, did exist prior to inception of Wasatch normal faulting. This postulation is strongly supported by the presence of reversal in the strata of the Big Cottonwood formation exposed in Buckley Draw.

East-West Axis of Folding

A relatively gentle east-west trending fold has been superposed on the more dominant north-south trending fold axis in the range to the east of Provo and Springville. In cross sectional view this fold extends from a position near Hobble Creek Canyon northward to Provo Canyon with only a portion of the south dipping limb lying within the mapped area. The structural low or trough of the south dipping limb appears to intersect the more dominant north-south axis of folding in the vicinity of Hobble Creek Canyon. At this intersection of folding a very conspicuous south plunging anticlinal nose has developed on the more dominant axis of folding. The beds plunge most steeply and the closure is most apparent in the strata below the massive bedding of the thick Oquirrh formation in the vicinity of Little Rock Canyon. Here also the exposed strata have shifted from a dominantly north strike to a strike which is prevailing northeast to east. Near the crest of the anticlinal nose in this vicinity east-west trending drag folds are present which reflect the broad and gentle major east-west trending fold axis. These drag folds are most pronounced and highly developed within the Humbug formation to the south of Little Rock Canyon. Adjacent to the range front the drag folds are large and conspicuous, when traced eastward they fade rapidly into the overlying rocks. Erosion has removed much of the strata which forms them in such a manner that they appear more highly contorted than they actually are. In general the larger drag folds are tightly closed and are recumbent to the north. They are characterized by numerous small faults of a few inches to normally less than five feet displacement, as well as in places by zones of intense brecciation. The numerous small faults and more especially the zones of brecciation which have developed with this tight folding have greatly increased the difficulty of mapping a single unit throughout the folded interval.

Faults

Thrust Faults

Only one thrust fault was mapped in the Buckley Mountain area and in this report it is referred to as the Kolob Basin thrust. The trace of this fault extends from a small draw to the north of Round Peak near the range front northeastward through the northwestern corner of Section 26, hence almost due north through Kolob Basin near Knight Spring the fault trace is not clearly discernible due in part to a dense vegetative cover and lack of outcrops. It is thought most probably by the writer that the fault extends northward from Section 14; however, it is not shown as such on the accompanying geologic map due to lack of sufficient evidence.

This fault is most apparent and can best be observed in the draw immediately to the north of Round Peak where the fault displacement is greatest. In this locality strata of the Humbug formation rest in thrust contact with Atokan age strata (determined by the occurrence of Fusulinella sp.) of the Oquirrh formation. It is estimated that a minimum of 6, 000 feet and possibly as much as 8, 000 feet of Upper Mississippian and Lower Pennsylvanian strata have been locally cut out by this thrust fault.

Normal Faults

General Statement. - Normal faulting is very evident in this area and is of great structural significance, as it is in all of the region adjacent to the western margin of the Wasatch Range. Locally the larger normal faults are of the high-angle longitudinal type. This type of faulting has formed the latest major structural features of the range and in many localities these faults have shown active movement as late as Recent time.

Wasatch Fault. - Eardley (1951, p. 479) regards the Wasatch fault as a master fault which forms the eastern limit of the fractured part of the Great Basin. In the mapped area the range front represents the trace of a fault zone which locally trends west of north.

In recent years it has become common knowledge that there is no single fault which has resulted in the present Wasatch front. But, rather a wide fracture and complex fault zone of echelon or distributive type faulting are now regarded to be present largely to the west of the present range front.

In an early study Davis (1905) postulated that the entire relief of the Wasatch Range had resulted from block faulting of approximately 10, 000 feet displacement. He visualized the region of the present Wasatch Mountains as a peneplain prior to faulting. A more recent study by Eardley (1944, pp. 880-881) in the north-central Wasatch Mountains points out that the range in that region was approximately as high before faulting as after. He further concludes that the maximum fault displacement there is approximately 3,000 feet. The writer considers the fault displacement of the Buckley Mountain area to be approximately 4,500 to 5,000 feet, which approximates the present topographic relief.

Fault dips of varying magnitude have been measured along the Wasatch front. Gilbert (1928, pp. 16-19) measured slickenside dips of 35° - 45° on what he considered to be the hanging wall of the fault in the Ogden reservoir region. A fault scarp uncovered in a gravel pit near Beck's Hot Spring to the north of Salt Lake City has been described as the "Wasatch Fault" and dips 72° west (Park, 1926, pp. 339-410).

Features along the Wasatch front which have resulted from post-Lake Bonneville movement have been recognized in several localities. These features have been described largely through the works of Gilbert (1890, pp. 340-352) and Hunt (1953, pp. 37-38).

It is of interest to note that since the Wasatch front is the center for repeated mild seismic distrubances it has recently been postulated that the mountain blocks may possibly be rising today as vigorously as they have in the past (Hunt, 1953, p. 38).

Maple Flat and related fault. - Trending slightly to the east from the range front in sections 9 and 16 of the mapped area are two near-parallel normal faults. Both faults dip steeply to the west and when traced to the south they appear to join before the fault trace is obscured by Bonneville sediments. These faults at depth undoubtedly belong to the same system as the various faults which comprise the Wasatch Fault zone in this area. The easternmost fault is easily traced northward across Slate Canyon where it passes farther east from the mountain front and has dropped a large fault block toward the valley. The top of this block forms a step or a relatively small flat area which is known as Maple Flat and from which the fault has derived its name. The displacement of this fault is most apparent on the north wall of Slate Canyon where the Upper Mississippian Humbug formation on the hanging wall block is in juxtoposition with the Lower Cambrian Tintic quartzite of the footwall block. At this position minimum stratigraphic displacement of the fault is estimated at 2,350 feet.

The westernmost of the two faults, though not traced to the north, crosses Slate Canyon but is not readily conspicuous.

Fault Drag and Horse. - Drag material though present along the fault front in the mapped area is not abundant or conspicuous. It appears that the fault break and movement was very clean, or if not and appreciable amounts of drag did develop during faulting it has subsequently been removed from the hanging wall block by erosion. However, a large conspicuous wedge-shaped horse of Paleozoic sediments is present on the northwesternmost portion of Buckley Mountain immediately to the south of Slate Canyon. This feature though highly fractured and marked by both large and small faults stands in bold relief roughly in the shape of an eastward facing hunched-up toad, thus the name on the topographic map "Toad Head" at the apex of the horse.

From field observations it is obvious that the horse has resulted from normal fault movement along the Wasatch fault zone. To be structurally more implicit it should be noted that the horse is bounded on the east by the Maple Flat fault. As previously mentioned this fault is but the easternmost of the faults of the fault system in this area.

Age of Structural Features

Due to the lack of a sedimentary record younger than Lower Pennsylvanian in age, direct evidence with which to date the folding and faulting within the Buckley Mountain area is lacking. The writer has therefore found it necessary to search the geologic literature of adjacent areas for evidences which are applicable to the structural features of this area.

The work of both Eardley (1951, pp. 315-319) and Spieker (1946, pp. 117-167) have contributed greatly to our understanding of the time and space relationship of orogeny in the Wasatch Mountains and adjacent regions. According to Eardley probably the first orogenic movement to affect the Wasatch Mountain area was the Cedar Hills orogeny of Colorado time, in which thrust faults occurred in the north-central portion of the range. This movement was followed by the early phase of the Laramide orogeny during late-middle Montana time with uplift, extensive folding, and overthrusting. According to Bissell (1952, p. 630) the Deer Creek-Strawberry Valley overthrust of the south-central Wasatch Mountains occurred at this time. Also, it was probably during this early phase that the large arcuate fold trends developed in central-Utah, of which the north-south trending overturned strata of Buckley Mountain is but one of the easternmost folds. A second Laramide phase followed during late Montana and Paleocene time with continued folding and overthrusting. The last phase of the orogeny occurred during middle of late Eocene time with uplift and development of east-west fold axes in the Wasatch Mountains. It is most likely that the broad east-west trending fold in the range to the east of Provo as well as the associated drag folds in the vicinity of Little Rock Canyon and the Kolob Basin thrust are of this age. Eardley (1951, pp. 313-332) states that the Eocene or late phase of the Laramide defined for the first time the modern ranges and inter-montane valleys of the Wasatch region.

Additional diastrophic adjustments (Absarokan Orogeny) during middle Oligocene time caused further folding along the late Laramide trends as well as uplift and high angle faulting which further tended to shape the modern range stature.

Mature erosional surfaces developed during Miocene time in both the Wasatch and Uinta Mountains. Renewed epeirogenic uplift in Miocene and Pliocene time raised the ranges higher causing the present erosion cycle. Uplift has continued into Recent time with high-angle Basin and Range faulting occurring during Pleistocene time; the Wasatch fault, Maple Flat, and related faults most probably occurred throughout a long epoch of time beginning as early as Eocene and continuing to the present.

The orogenies of late Cretaceous and Tertiary age within the Rocky Mountain region are now commonly regarded to be the youngest deformation of an older and larger near-continuous orogenic system. Longwell (1950, p. 424) has discussed this tectonic theory. In brief, he believes that waves of deformation began in California and western Nevada during Jurassic or possibly late Paleozoic time and advanced eastward throughout the remainder of Mesozoic and part of Cenozoic time to the Rocky Mountain front.

ECONOMIC GEOLOGY

GENERAL STATEMENT

At the present time the economic potentialities of the Buckley Mountain area appear to be limited to the development of certain non-metallic resources to be used as raw material in the local building industry. Foremost of these resources are the Bonneville sediments which presently serve as an abundant source of sand and gravel. The development of any mineral deposit seems highly unlikely in light of the writer's present knowledge.

Pit Operations

Sand and Gravel Pits

Several sand and gravel pits are located in the Lake Bonneville sediments along the western portions of the mapped area. Production from these pits has comprised the major portion of the economic development within this area. Current daily activity is confined to two pits. The largest, "Thorns Rock Products Company," is located on a fan which radiates valleyward from Slate Canyon to the northwest of the immediate mapped area. The greater amount of sand and gravel obtained from this operation is used as concrete aggregate.

Limestone Quarries

Limestone has been quarried from several positions along the western base of the range. These operations are not presently active and appear to have been abandoned several years ago. The various quarries are confined almost entirely to the Humbug formation. To the north of Little Rock Canyon the limestone has been quarried entirely from large fault horses or drag blocks which lie against the base of the range. South of the canyon in the highly folded area of the Three Sisters Peaks the limestone has been quarried from in place.

Abandoned equipment and furnaces near the quarries suggest that the limestone was placed in kilns at the quarry site and a finished product of quick lime recovered.

Slate Quarries

In the past attempts have been undertaken to produce commercial slate from the upper portion of the Big Cottonwood series in the area of Slate Canyon. These attempts were apparently uneconomical and appear to have been short lived. Stacks of shaped and sized slate slabs are yet visible in what was apparently an old quarry site on the north side of Slate Canyon approximately a mile and a half to two miles east of the canyon mouth. Eckel (1904, p. 422) briefly discusses the slates of this location and states that surface exposures are so badly broken that large slabs cannot be obtained. Gwynn (1948, p. 89) states that a commercial slate operation was attempted near the mouth of Slate Canyon in 1933 but proved unsuccessful.

Mine Prospects and Mineralization

Numerous audits and shafts are present throughout the mapped area. These are generally shallow and appear to have shown little promise to those who engaged in their development. Most of the prospects are located along small faults or folds where the bed rock is brecciated and slightly mineralized, or in or adjacent to the diabase flow.

Many of the prospects in the limestones are located on false gossans. At these locations the mineralization appears to be moderately strong at the surface, but a short distance beneath the surface it diminishes and vanishes altogether. No primary ore minerals were detected in the prospects or in the adjacent small muck piles.

With the exception of small amounts of copper oxide stain in the diabase flow mineralization appears to be limited to little more than traces of hemitite and limonite and small amounts of calcite and aragonite. These minerals appear to have been carried through and concentrated in the void space formed by cracks, faults, or zones of breccia by cool weak mineralizing solutions or ground water, as rock alteration is generally not apparent at all, or if present it is very weak.

Stringers and veinlets of specular hematite and milky quartz are common to much of the strata of the Big Cottonwood series. The origin of these minerals is not readily apparent within these metamorphosed rocks, but they do suggest a possible hydrothermal origin.

Pseudomorphs of limonite after pyrite are abundant in the lower strata of the Great Blue limestone. These crystals are most probably authigenic in origin and are present largely in euhedral pyriteahedron and cubic forms. Though these crystals have been highly oxidized many of them still have a pyritic center.

Watershed

The Buckley Mountain area constitutes a portion of an important watershed from which considerable water is shed from melting snow during the spring and early summer of the year. As the water drains westward toward Utah Valley much of it enters the porous gravels and sands of the Lake Bonneville sediments which fringe the mountain front. These gravels and sands are normally sealed by layers of silt and clay and constitute aquifers through which the water moves valleyward. Many of the domestic artesian wells in Utah Valley flow from these aquifers.

Numerous springs find their source within or adjacent to the mapped area. The largest flow of water from such springs rise from the toe of the Lake Bonneville bench a short distance to the southeast of Round Peak. These springs are the source of Spring Creek which supplies water to the federal and Utah state fish hatcheries located adjacent to U. S. Highway 91 north of Springville.

Water from Knight Spring, which rises from the Manning Canyon shale, is piped through Slate Canyon to the Utah State Mental Hospital. The several springs to the south of Knight Spring, in Kolob Basin, are generally smaller, but furnish a constant supply of water to the livestock which graze that area.

APPENDIX

Stratigraphic Section

Oquirrh Formation

An estimated 3,000 feet of Oquirrh strata are exposed within the confines of the mapped area.

Manning Canyon Shale

This formation is poorly represented locally due to structural complexities. An estimated 300 feet of Manning Canyon shales are exposed in the Buckley Mountain area.

Great Blue Limestone

Due to thrust faulting only a partial section of Great Blue limestone is locally exposed. This partial section is estimated to be 700 feet thick.

Stratigraphic Section of the Humbug Formation

Measured on the north wall of Provo Rock Canyon in Section 28, Township 6 South, Range 3 East by Ted Livingston, September 1954.

Great Blue limestone
Conformable contact

Unit	Description	Thickn. In Ft.
12	Limestone, medium gray to light tan, weathers light gray, are dense and siliceous	67.0
11	Sandstone, medium gray, weathers light brown gray, medium grained, medium bedded in part calcareous.	11.0
10	Limestone, various shades of gray, weathers light gray, crystalline fine grained, medium to thick bedded with some calcite stringers, contains some fossil hash and some beds of dolomite.	124.5

(Continued)

Humbug Formation (Continued)

Unit	Description	Thickn. In Ft.
9	Sandstone, light brown, weathers light brown to orange brown, medium grained, medium bedded with laminations, friable on weathered surface, in part calcareous	6.0
8	Limestone, gray, weathers medium to light gray with some brown tones, fine to medium grained and hashy in part, thin medium and massive bedded, contains some calcite stringers and in part is siliceous	46.5
7	Sandstone, light brown, weathers medium to dark brown, fine grained, medium to thick bedded, calcareous in part	7.0
6	Limestone, medium gray, weathers brown to gray, fine grained, medium bedded with some white rosettes, slightly siliceous along some horizons adjacent to thin beds of sandstone	67.8
5	Interbedded sandstones and limestone in which the sandstones predominate. The sandstones are brown and weather dark brown to blackish brown, fine grained, thin to medium bedded and in part cross-bedded. The limestones are light to medium gray, and weather to gray with a brownish tone, with a sandy texture, and are crystalline to fine-grained for the most part. This unit is dolomitic in the lower portion	147.7
4	Dolomite, medium gray, weathers light gray to brownish gray, fine grained, medium bedded, is siliceous in part and contains some rosettes	12.0
3	Limestone, medium gray, weathers light gray, is crystalline to fine grained, medium bedded with some thick beds.	38.5
2	Dolomite, dark gray, weathers medium gray, fine grained, massive to medium bedded	18.0
1	Quartzite, tan to light brown, weathers medium to dark brown, fine grained, sandy and calcareous . . .	1.5
Conformable Contact	Total Thickness	547.5

Partial Stratigraphic Section of the Desert Limestone

Measured on the north side of Little Rock Canyon in the NW 1/4 of Section 27, Township 7 South, Range 3 East by H. J. Bissell, Dave Clark, and the writer, December 30, 1952.

Section not complete, due to fault relations and alluvium

Unit	Description	Thickn. In Ft.
2	Predominantly dolomite, dark gray, medium to finely crystalline, with numerous 1 to 2 mm. white specks scattered throughout rock; massive to thick-bedded, weathers dull drab gray; contains zones of 2-4 inch thick bedded to blebby-nodular light gray to pink and orange chert. Lower portion of unit contains some interbedded magnesian encrinital limestone, with dense medium to dark gray limestone with dark gray to black chert.	250.0
1	Limestone, dark blue-gray to light gray, dense exsolution type, thin-bedded to medium-bedded, with 3-8 inch beds of black to gray chert. Contains few magnesian limestone encrinites, banded to striped, some pure finely to medium-crystalline dolomite beds. Lower portion of unit (25 to 30 feet) is a thin-bedded to platy and slabby-platy, dark-gray, carbonaceous shaly limestone	358.0

Stratigraphic Section of the Madison Limestone

Measured on the west face of Buckley Mountain in the SW 1/4 of Section 15, Township 7 South, Range 3 East, April 16, 1954.

Deseret limestone

Unconformable contact

Unit	Description	Thickn. In Ft.
13	Limestone, dark blue to black, weathers light gray, crystalline to medium grained approximately every 3 ft. 2 inches to 6 inch argillaceous limestone beds are present, bedding is thick to massive, first conspicuous black chert occurred at top of this unit	83.0

(Continued)

Madison Limestone (Continued)

Unit	Description	Thickn. In Ft.
12	Limestone, largely concealed.	90.0
11	Limestone, dark blue to black, weathers medium to light gray, coarse crystalline to medium grained, medium bedded, contains minor yellow to orange tinted gray chert lenses and blebs in lower portion, calcite stringers are present throughout	55.5
10	Dolomite with some limestone, dark bluish-gray to light gray, weathers light gray, contains some light orange tinted chert lenses in lower portion	72.5
9	Limestone and dolomites, dark to light gray, weathers light gray, crystalline, contains minor amounts of shale in extreme lower portion	49.5
8	Limestone and dolomite, color blue to light gray, weathers into alternating dark and light beds, mainly crystalline, medium bedded, contains minor amounts of light orange to yellow tinted chert, blebs and nodules, some shale present between bedding planes. .	85.5
7	Limestone, blue to dark gray, crystalline, weathers lighter shade of blue to gray, thin bedded (1 inch to 4 inches thick).	17.0
6	Limestone and dolomite, dark to light blue, crystalline, weathers darker shades of blue and gray, contains minor amounts of light to yellow tinted chert in small lens, and is medium to thick bedded	34.0
5	Limestone, dark blue to black, crystalline is sandy in part and weathers dark gray to black, medium to thick bedded.	20.0
4	Limestone, with some interbedded calcareous shales, light blue and gray, weathers dark blue to dark gray, bedding is 4 inches to 18 inches thick, the shale is light yellow to orange, weathers a soft yellowish brown, the limestone is well bedded and contains abundant fossil hash.	34.0

(Continued)

Madison Limestone (Continued)

Unit	Description	Thickn. In Ft.
3	Limestone, blue to dark blue, weathers dark blue to dark gray, crystalline, medium bedded with some shale between bedding planes which weathers a red tone.	40.0
2	Limestone, light blue, weathers soft dark blue to black color with some yellow to orange tones, crystalline and in part shaly, is very fossiliferous with zaphrentid type corals, <u>Euomphalus</u> sp. and <u>Loxonema</u> sp. being especially abundant	27.0
1	Limestone, light blue to gray, crystalline and highly fossiliferous, in part sandy, weathers a medium gray with some light red to orange tones, the prolific occurance of fossils in this unit forms a sharp contrast with the underlying near barren dolomite. . . .	31.0
	Total Thickness	639.0

Conformable Contact

Stratigraphic Section of the Lower Mississippian Dolomite

Measured on the south side of Slate Canyon, in the E. 1/2 of Section 10, Township 7 South, Range 3 East, by Ted Livingston and the writer, May 4, 1954

<u>Madison limestone</u>
Conformable Contact

Unit	Description	Thickn. In Ft.
9	Dolomite, light gray, weathers white, crystalline to sub-lithographic, contains some calcite in small stringers	3.0
8	Dolomite, dark gray to blue, weathers medium to dark gray, crystalline, contains calcite in small stringers, minor amounts of chert near top of unit massive bedded, lower 10 feet contains some vugs . .	57.7

(Continued)

Lower Mississippian Dolomite (Continued)

Unit	Description	Thickn. In Ft.
7	Dolomite, lithology same as unit No. 8 but bedding is thin to medium (9 inches to 3 feet), becomes increasingly vuggy toward base.	35.0
6	Dolomite, lithology same as unit No. 8 but vugs are filled solid with calcite, vugs range up to 3 inches in diameter.	4.8
5	Dolomite, lithology same as unit No. 8 but thin bedded (6 to 18 inches thick), Syringopora sp. are present in this zone.	16.0
4	Dolomite, light gray, crystalline, weathers medium gray, massive bedded, contains few vugs	21.0
3	Dolomite, same lithology as unit No. 4, but thin bedded.	7.0
2	Dolomite, dark gray to blue, weathers light gray to buff, crystalline, contains 20% to 30% sand and weathers to a sandy surface	5.0
1	Sandstone and dolomitic sandstone, white to orange brown, weathers orange to yellow, medium to fine grained predominantly but contains some grit and pebble size particles, subangular to subrounded.	19.0
	Total Thickness	169.0

Unconformable Contact

Stratigraphic Section of the Maxfield Limestone

Measured on the north side of Slate Canyon in the SE 1/4 of Section 4, Township 7 South, Range 3 East, by the writer, May 15, 1954.

Lower Mississippian dolomite
Unconformable Contact

Unit	Description	Thickn. In Ft.
6	Dolomite, light gray, weathers white with a meringue surface, fine crystalline, medium bedded. .	6.0

(Continued)

Maxfield Limestone (Continued)

Unit	Description	Thickn. In Ft.
5	Dolomite, lithology similar to Unit No. 3, but is thick to massive bedded, contains small twiggy like bodies which are most conspicuous on a weathered surface.	86.0
4	Dolomite, medium blue, weathers gray to blue with spots or eyes of light gray color one inch or less in diameter, the spots are most conspicuous on a weathered surface	4.0
3	Dolomite, medium gray to blue, weathers light gray, thin to thick bedded contains oolites in zone near the base as well as numerous calcite stringers throughout, this unit is more resistant to weathering than the underlying limestone and forms a steeper cliff face	32.0
2	Limestone, dark gray to dark blue, weathers blue to medium gray, crystalline, fine grained, thin bedded (2-7 inches thick) with bedding well defined, argillaceous bands up to 1 inch thick parallel the bedding and are conspicuous on weathered surfaces where they appear in colors of light brown, gray, orange, and red, they normally stand in relief from the limestone. Small stringers of calcite occur throughout this unit.	31.0
1	Limestone, dark blue to dark gray, weathers a gray to blue gray, crystalline texture, thin bedded though not well defined, thin argillite bands 1/2 inch thick weather in relief from the limestone in chicken wire-like appearance. Limestone is shot through with calcite stringers, upper 20 feet of bedding is well developed.	323.0
	Total Thickness	482.0

Conformable Contact

Stratigraphic Section of the Ophir Formation

Measured on the north side of Slate Canyon in the SE 1/4 of Section 4 Township 7 South, Range 3 East, by the writer, May 15, 1954

Maxfield limestone
Conformable contact

Unit	Description	Thickn. In Ft.
7	Shale, light olive green to gray, weathers shades of brown, green and gray, thin bedded (2 inches and less), in part calcareous. Upper two to three feet of unit covered by talus from overlying Maxfield limestone.	15.3
6	Shales and interbedded calcareous shales, green to brown, weathers brown to gray and in part to a sandy surface	37.8
5	Limestone, gray, weathers light gray with a brown tone, crystalline texture- fine to medium grained, thin bedded with alternating argillaceous bands, shaly along bedding planes	26.8
4	Calcareous shales, a transitional zone between the true shales and limestone, shales are green with brown stripes, weathers olive green to green, thin bedded	14.7
3	Phyllite and shales, dark green to dark gray weathers lighter green, brown and orange, thin bedded, contains conspicuous orange bands or streaks throughout the phyllite. Many of the bedding planes are rough and resemble ripple marks and worm like bodies.	95.0
2	Quartzites and phyllites interbedded, quartzites are green and weather brown to green, are fine grained, cross bedded. Phyllites with shales are dark green and weather a lighter shade of green to brown, thin bedded.	48.4
1	Quartzite, green, weathers light green with brown tone, fine grained, cross bedded, medium bedded . . .	11.0
	Total Thickness	249.0

Conformable (?) contact

Stratigraphic Section of the Tintic Quartzite

Measured on the west face of -Y- Mountain in Section 32, Township 6 South, Range 3 East, by H. J. Bissell* March 10, 1943.

Ophir shale
Conformable (?) contact

Unit	Description	Thickn. In Ft.
11	Quartzite, white to cream-colored and buff, the latter color predominates. Poorly bedded, coarse-grained, in places there are crystallized quartz masses. Badly fractured, in part friable. Slope-former; grades through dark reddish-brown metaquartzite, dense very fine-grained, hard and sericitic phyllitic metaquartzite and interbedded quartzitic, hard, phyllites, dark olive-green to brown. . .	260.0
10	Metaquartzite, white to cream-colored, but somewhat more buff than underlying unit; coarse to medium grained. In part stained with hydrous iron oxide; less resistant than beds below or above. The upper 25 feet of unit is a slope former of white, fine-grained metaquartzite. The series as a whole is fractured, has less well pronounced bedding than underlying unit.	250.0
9	Metaquartzite, mainly massive, white, cream-colored, medium to fine-grained, somewhat fractured. Few reddish brown iron oxide stains on joints and bedding planes. Most of the rock is dense, semi-crystalline, homogeneous. Tends to fracture easily along joints and bedding planes. Bedding is 1 to 5 feet thick. Two slope-forming units, one 50 to 90 feet above the base of the unit, the other 170 feet above base	190.0
8	Metaquartzite, predominantly buff-colored, some cream-colored and medium gray, some reddish-brown highly stained with hydrous iron oxide. White beds are ledge-formers; in general the whole unit is a semi-cliff former. Some beds highly jointed and fractured. Mainly coarse-grained to medium grained some beds dense; most rocks very hard . . .	95.0

(Continued)

*Unpublished field notes of March 10, 1943

Tintic Quartzite (Continued)

Unit	Description	Thickn. In Ft.
7	Metaquartzite, white to light gray, fine-grained highly jointed, hard, semi-crystalline, very resistant, rather distinct, though thin-bedded.	5.0
6	Metaquartzite, fine to medium grained, bedding 1 inch to 3 feet thick. Colored bands emphasize bedding planes, though little parting evidence. Very hard, not badly fractured, buff, gray, few cream-colored beds. Reddish-brown weathered surfaces predominant. Is well-bedded.	63.0
5	Metaquartzite, buff to reddish-brown, with few streaks and 4 inch beds of white, subrounded quartz pebbles some as much as 2 inches in diameter. Grades upward into white and cream-colored metaquartzite, medium to coarse grained, hard to semi-friable, fractured and jointed.	26.0
4	Conglomerate, of subrounded to rounded white and cream-colored quartz pebbles up to 3 inches in diameter in matrix of coarse buff to reddish-brown quartzite.	5.0
3	Metaquartzite, buff, gray, and reddish-brown, coarse-grained, with numerous pebbles and rarely cobbles, of gray to white quartz up to 1/2 inch in diameter, forms first ledge above pre-Cambrian. . .	55.0
2	Metaquartzite, buff, and reddish-brown, oxidized iron stain, coarse-grained with quartz pebbles up to 4 inches in diameter, average of 1 inch, more or less a slope-former	18.0
1	Metaquartzite, basal Tintic formation. Rock is hard white to cream colored, highly jointed, partially fractured. Has clear and cream colored quartz pebbles up to 1/2 inches in diameter and re-crystallized quartz masses at various horizons. In the main is fine-grained, dense, locally friable. Contact with bed above gradational, but is sharp above slight angular unconformity with pre-Cambrian below.	

(Continued)

Tintic Quartzite (Continued)

Unit	Description	Thickn. In Ft.
	Contact at base contrasted by color demarcation from dark, reddish-brown below to white and cream color above, Cliff to semi-cliff former. . . .	50.0
	Total thickness	1,017.0

Unconformable Contact

Partial Stratigraphic Section of the Big Cottonwood Series

A partial stratigraphic section of the Big Cottonwood Series measured on the north wall of Slate Canyon in the northwest corner of Section 9, Township 7 South, Range 3 East by Paul Jorgensen and the writer.

Mineral Fork Tillite

Unconformable contact (?)

Unit	Description	Thickn. In Ft.
22	Shale, green, weathers light green, sheared and not well defined with upper contact obscured with talus from overlying tillite.	2.0
21	Quartzite, light yellow to greenish gray, weathers brown to orange, fine grained with some grit-size grains, predominantly subangular, medium to thick bedded.	46.0
20	Shale, green to gray, weathers green, very fissile . .	5.0
19	Quartzites, white to tan, weathers light brown, appears highly laminated on weathered surface. . . .	5.0
18	Shale (slate), lower 10 feet purple, weathers light purple, upper portion green, weathers light green to gray	23.5
17	Quartzite, white with some purple tint, weathers brown to orange, medium grained, subangualr, thin to medium bedded characterized with some cross bedding	48.5

(Continued)

Big Cottonwood Series (Continued)

Unit	Description	Thickn. In Ft.
16	Shale (phyllitic), medium purple, weathers dark purple to dark red, very fissile.	22.0
15	Quartzite, light purple, weathers dark purple, medium to fine grained, medium bedded, in part cross bedded, contains some purple to dark gray shales.	28.0
14	Shale (slate), green and purple, weathers lighter shades of both colors, very dense and fissile	22.0
13	Quartzites and siliceous metagritstone, red and purple, weathers dark purple, red, and brown, angular to subangular, medium bedded, highly jointed	26.0
12	Quartzites and siliceous metagritstone, red and purple, weathers dark purple, red, and brown, angular to subangular, thick bedding, highly jointed, with some zones of subrounded to subangular white and clear quartz pebbles	103.0
11	Quartzites and shales predominantly obscured.	72.0
10	Quartzites and siliceous metagritstone (partially obscured) purple, red, and white, weathers dark purple and red, poorly sorted, angular to subangular, thin to medium bedded	52.0
9	Shale (slate), dark purple, weathers lighter shade of purple to a purplish gray with a silver luster along bedding planes from parallel alignment of mica minerals	60.0
8	Quartzites and silicious metagritstone, purple and red, weathers dark red and purple, medium bedded. . .	25.0
7	Quartzites and shales (slates to phyllites), partially obscured, bedding thin to thick.	73.5

(Continued)

Big Cottonwood Series (Continued)

Unit	Description	Thickn. In Ft.
6	Quartzite and metagritstone, purples, reds and white, weathers darker purples, reds and brownish red, angular to subangular, arenite size particles predominate, with some horizons of angular pebbles, often poorly sorted, bedding very pronounced (3 inches to 3 feet thick), some cross bedding present, minor shale horizons along bedding planes, also numerous stringers of white vein quartz containing specular hemitite.	92.0
5	Shale (slate), dark purple and red, weathers light purple highly sheared, is a bench former between quartzites.	18.0
4	Quartzites and metagritstone, description same as unit No. 6.	167.0
3	Shales (slates and phyllites), green and purple, weathers dark purple and lighter shades of green, thin bedded and contains some thin beds of quartzites. .	23.0
2	Quartzites, white to brownish gray, weathers brown, thin bedded (1 foot thick and less), medium grained, small stringers of vein quartz abundant throughout. . .	14.0
1	Shale (slate, phyllite, and some hornfel), light gray to medium green with minor red horizons, weathers brown to green, sheared in part, predominantly thin bedded.	44.5
	Total	1087.5

Base obscured by talus

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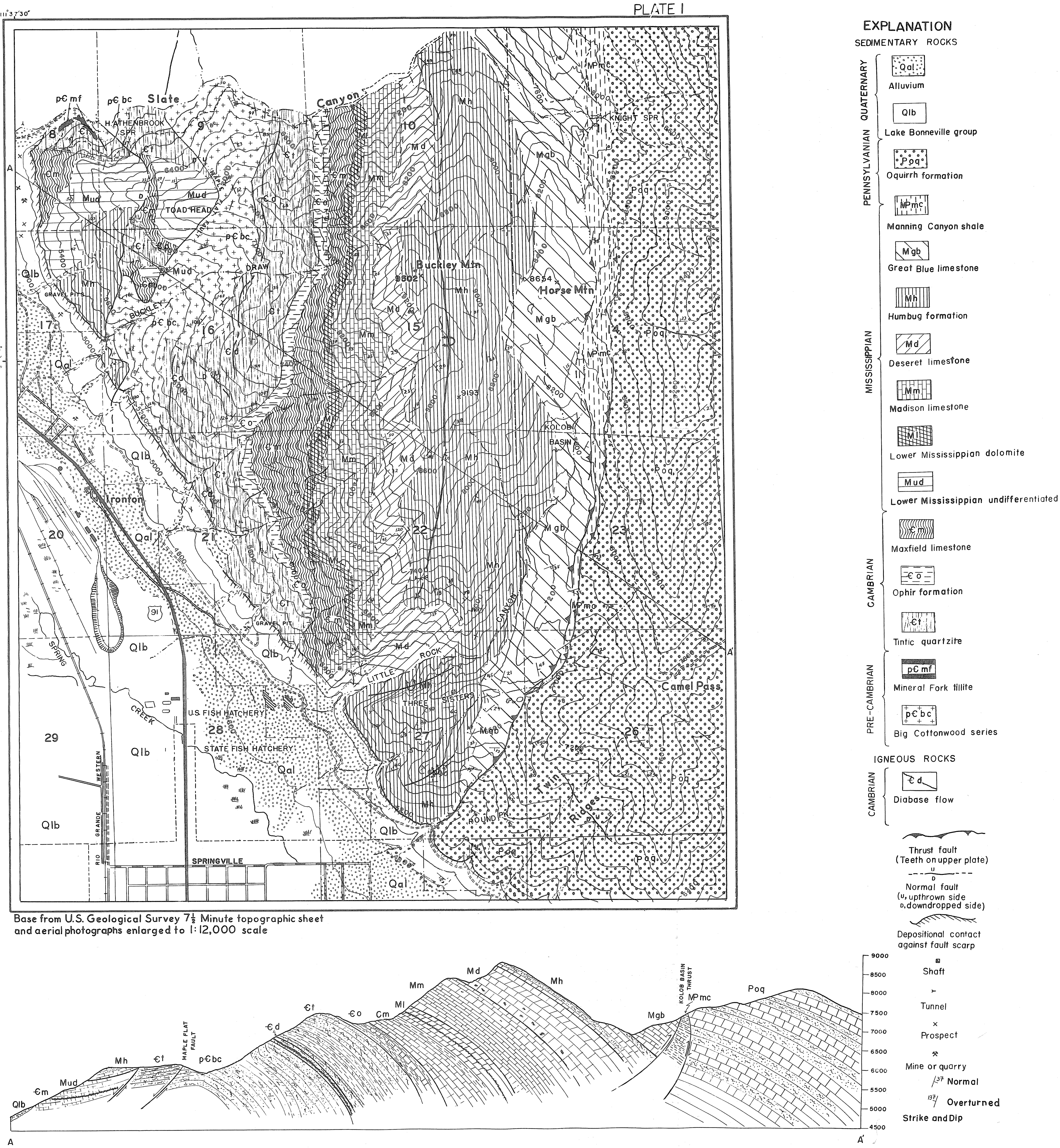
PLATE I



GEOLOGIC MAP-CROSS SECTION OF THE BUCKLEY MOUNTAIN AREA, UTAH

by

James A. Rhodes

Scale

0 1/4 1/2 3/4 1 MILE