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GEOLOGY OF THE NORTHERN PART OF DRY MOUNTAIN, SOUTHERN WASATCH MOUNTAINS, UTAH

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A Thesis

Submitted to the

Faculty of the Department of Geology

Brigham Young University

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In Partial Fulfillment

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Master of Science

by

Lorenzo C. Demars

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ABSTRACT

This thesis is a detailed report of the geology of approximately six square miles of the southern Wasatch Mountains, Utah. The area is located on Dry Mountain in southern Utah County between the cities of Payson and Santaquin.

The rocks range in age from Precambrain to Recent and the thickness of the exposed rocks is about 6,000 feet. Two formations of pre-Cambrian age, eight of Cambrian age, three of Mississippian age, and two of Tertiary age are present. Quaternary formations consist of gravel, silt, and clay of the Lake Bonneville group. Unconformities exist at the top of the Archean, Algonkian, Cambrian, and Mississippian.

Near the close of the Mesozoic Era the rocks were compressed to form large folds, having a north-south trend, as part of the Laramide Orogeny. The increase in intensity of the folding caused thrust faulting and tear faulting. After Wasatch formation time, volcanic eruptions distributed latite flows and tuffs in the general area. Some metal mineralization developed at this time. The structure was then modified by normal faulting of the Basin-Range type.

The mineralization consists of small and spotty veins and bedded replacements of silver-bearing lead-zinc, and veins of copper. The lead-zinc deposits occur in rather pure limestone, whereas the copper occurs in veins in the pre-cambrian granitic-gneiss and quartzite.

Fig. 1 View of Dry Mountain looking East.

1. Crooked Canyon 2. Tie Canyon 3. Yellow Rock Canyon 4. Henry McGee Canyon

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The Dry Mountain area is one of considerable geologic interest. In the vicinity of Dry Mountain, structural and stratigraphic relations are complex; furthermore, mining development within the area gives an economic aspect to the geology. The desire for an economic problem led to the selection of the area. Dry Mountain offers a distinct possibility for the discovery of valuable minerals, and some production is recorded.

The main objective of this thesis is a detailed study of the geology of the Dry Mountain area. The writer hopes that this study will contribute to the increasing knowledge of stratigraphic, structural, and economic geology of Dry Mountain in particular, and to the mountain ranges of this part of Utah in general.

LOCATION

The thesis area is situated along Dry Mountain, east and northeast of Santaquin, Utah (see Fig. 2). Dry Mountain is part of the southern Wasatch Mountains, and forms a bold western escarpment to the range. Piccayune Canyon marks the northern boundary of the area, and Henry McGee Canyon the southern boundary. Payson Canyon is the eaternmost part of the mapped area, and the Lake Bonneville sediments along the west base of Dry Mountain are near the western boundary.

U. S. Highway 89 and 91 is located just west of Dry Mountain and trends in the general north-south direction.

The area encompasses parts of sections 27, 28, 29, 30, 31, 32, 33, and 34 of T - 9 - S, R - 2 - E, and parts of sections 3, 4, 5, and 6 of T - 10 - S, R - 2 - E, Salt Lake Base and Meridian. Parallels 39°57'30" and 40°02'30", and Meridians 111°43'00" and 111°45'00" enclose the area. Approximately nine square miles are included on the base map (see Plate 1), and (Fig. 2).

PHYSICAL FEATURES

From Mount Nebo north to Utah Lake, the Wasatch Mountains bend gradually to the east, while the regional trend is about N - 5° - W. The canyons and mountain slopes are very steep, and Dry Mountain gains in elevation southward, becoming increasingly steep and rugged. The altitude of the northern part of the area is approximately 6,400 feet above sea level. At the southern part of the mapped area the altitude is nearly 8,600 feet.

The Bonneville level of ancient Lake Bonneville is impressed along the base of the west slope of Dry Mountain throughout the length of the mapped area, and coalescing alluvial fans form parts of the

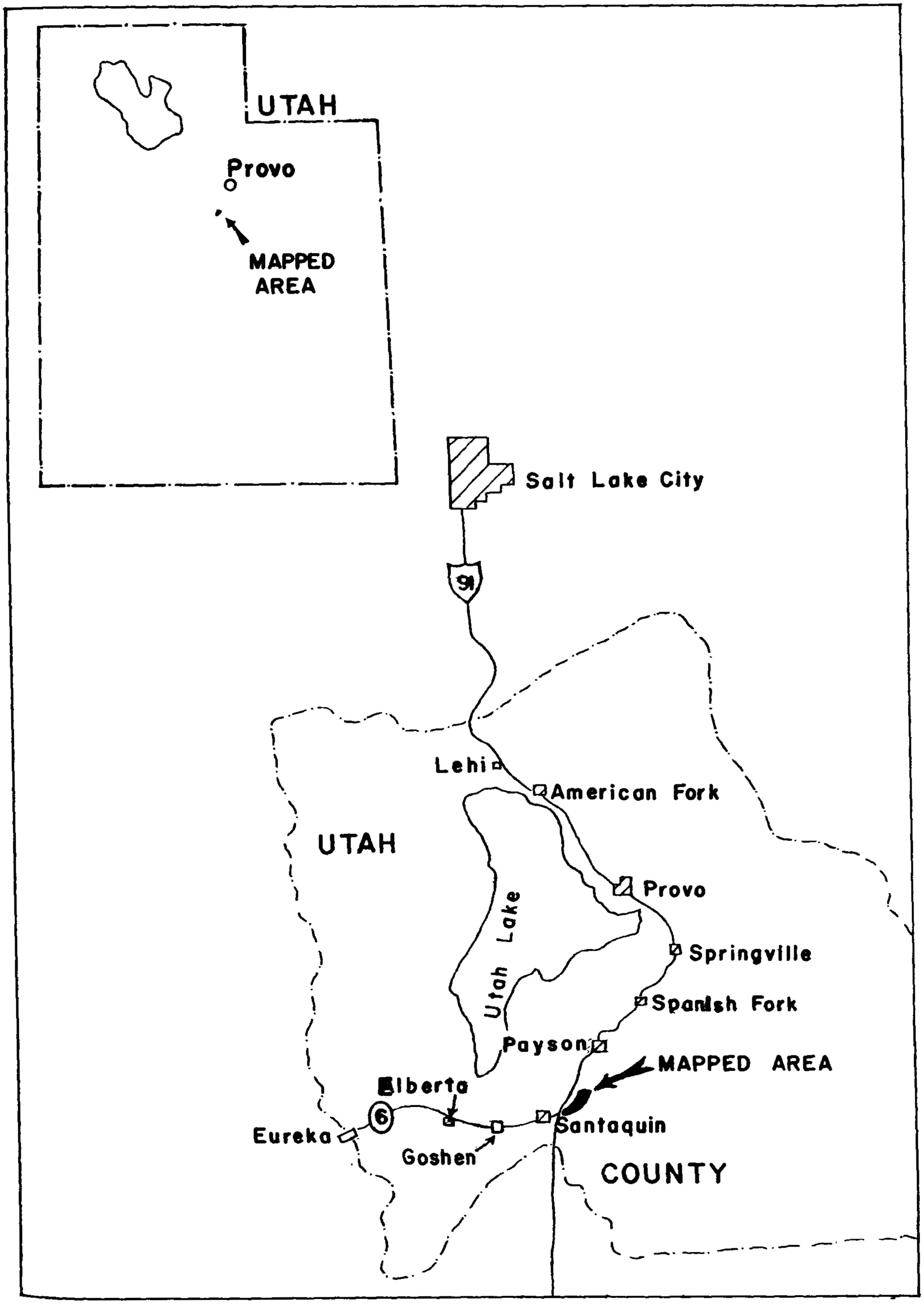

Fig. 2-- Index Map of Utah County, Utah showing location of Dry Mountain.

piedmont slope also along the west slope of Dry Mountain.

No perennial streams are present, but near the mouth of Piccayune Canyon a spring with excellent quality water flows from an old mine tunnel. The spring produces an estimated flow of 200 gallons per minute, and the water is used in the town of Spring Lake for culinary purposes.

The climate is semi-arid in this region. The average annual rainfall for Santaquin over the past 40 years is 18.38 inches*. The average rainfall for Payson during the same period of time is 14.26 inches*. The low precipitation in the valleys is supplemented by considerably greater precipitation in the mountains.

The vegetation is characteristic of a semi-arid climate. Pines, Cedars, Juniper, Scrub Maple, Cactus, and Mountain Mahogany predominate in the mountains, while on the lower slopes Sage Brush, Rabbit Brush, Greasewood, and Cactus abound.

The man-made features of the area include the skyline irrigation canal which runs in a southerly direction along the base of the west slope of Dry Mountain, a large sand and gravel pit which is located at the south end of the mapped area along the Bonneville terrace, and several old mine prospect pits.

PREVIOUS WORK

The first published data on the area is recorded in the report of the geological exploration of the Fortieth Parallel. Emmons (see Hague, 1877, pp. 343-344) briefly described the area. G. F. Loughlin (1913, pp. 447-452) briefly noted the geology of the southern Wasatch Mountains and published a small scale map which includes the thesis area. G. F. Loughlin (see Butler, 1920, pp. 322-333) added considerably to the data on the ore deposits of the Santaquin, Mount Nebo, and Payson districts, as did Higgins (1912, p. 12). Hayes (1926, p. 6) studied the erosional epochs in the southern Wasatch Mountains, and Gilbert (1875, p. 60), Le Conte (1889, pp. 257-265), and Ransome (1915, p. 243) have contributed ideas related to the Basin-Range type faulting.

Eardley (1930) wrote his Doctoral Dissertation on the stratigraphy, structure, and physiography of the Southern Wasatch Mountains. Although his map did not extend as far north as Piccayune Canyon, the southern half of the thesis area was included in his study. Eardley (1933), (1934), (1938), and (1949) is also recognized for other publications on the geology of the southern Wasatch Mountains. Eardley and Hatch (1940) studied the Proterozoic (?) rocks in Utah, and they mention the pre-Cambrian rocks in the area around Santaquin.

The latest work is that of Brown (1950), dealing with the geology of the Payson Canyon-Piccayune Canyon area, which lies adjacent to, and north of the present area.

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* Data obtained from records in the office of the U. S. Weather Bureau, in Salt Lake City, Utah.

PRESENT STUDY

The thesis area was pointed out by Dr. Paul D. Proctor in October 1952; field work was started the same month, and some week-end time was devoted to field work during the remainder of the 1952-53 school year. A certain amount of field work was accomplished in the field during the summer of 1953. During the Autumn quarter of 1955 field work was completed.

Mapping was done on aerial photographs having a scale of 1:12, 000. The final base map was drafted from the photos, and from parts of four 7.5 minute topographic sheets: Nebo Creek, West Mountain, Nephi No. 1, and the Spanish Fork sheet.

The photos were prepared by the Western Region Laboratory, in Salt Lake City, Utah, on August 25, 1946, for the U. S. Department of Agriculture.

Stratigraphic sections were measured with a Brunton compass and a steel tape. Work in the laboratory consisted of making thin sections of rock and ore samples for microscopic study. Fossil specimens were collected, studied, and classified.

In mapping the formations, it proved possible to extend southward formational contacts as mapped by Brown (1950) in the area to the north. The geologic map which accompanies this report covers in detail the Dry Mountain section of the Wasatch Mountains from Payson Canyon on the east to the Bonneville sediments on the west, and from Piccayune Canyon on the north to Henry McGee Canyon on the south.

STRATIGRAPHY

GENERAL RELATIONS

The rocks of the thesis area range in age from Precambrian to recent. They consist of Archean metamorphics and intrusives, Algonkian metamorphics and sedimentary rocks, Paleozoic sedimentary rocks and extrusives, and Tertiary and Quaternary sedimentary rocks (Eardley, 1933, pp. 311-312). The stratigraphy has been studied by Loughlin (see Butler, 1920, pp. 322-333), Eardley (1933), Brown (1950) and others. Stratigraphic relations are complicated by overthrust (?) and block faults.

Tertiary rocks are represented by the North Horn formation and Moroni formation. Utah valley is composed of gravel, sand, and silt of the Lake Bonneville group; the finer sediments deposited at the greatest distance from the mountains. Post-lake-Bonneville fluvial material, including gravel and sediments are still being deposited at the mouths of canyons and in stream valleys.

Some regional stratigraphic correlation has been done. Eardley (1933, p. 308) mentions a close similarity of the Archean, Algonkian, and Cambrian of the Dry Mountain area with nearby areas. The stratigraphic nomenclature of the thesis area is the same as that used by Lovering (1949, pp. 5-9). Justification of this procedure is based on the marked lithologic and paleontologic similarity of the rock units in both areas (see Table 1)

PRECAMBRIAN ROCKS

General Statement

Though Precambrian rocks are exposed only in some of the mountain ranges of Utah, these formations, according to Blackwelder (1940, pp. 25-30), must underlie the entire state. The Precambrian rocks seem to be readily divisible into two main groups, the Farmington Canyon Complex of Archean age, and the Big Cottonwood Series of Algonkian age. The older group is highly metamorphosed; the younger group is much less altered. Both groups are complexly folded, and much work needs to be done in order to determine the stratigraphic relations. Sections of these rocks up to 3, 000 feet thick have been measured in some places in the state.

In the Dry Mountain area, the Precambrian schist and gneiss have been invaded and intensely deformed by granitic intrusions. Associated with them are dikes of pegmatite and quartz. The orogeny of Archean time altered shale to slate and phyllite, orthoquartzite to metaquartzite, and granite to granitic-gneiss. No subsequent orogeny so profoundly affected the rocks of the area. So far as is known the orogeny has not been named in this area, but perhaps it correlates in age with the period of orogeny in the Grand Canyon area that produced the Vishnu schist.

Table 1

GENERAL STRATIGRAPHIC COLUMN

ERA	AGE PERIOD	FORMATION	THICKNESS IN FEET	LITHOLOGY
Cenozoic	Quaternary	Lake Bonneville group	Unknown	Lacustrine gravel, silt, and clay.
	unconformity			
	Tertiary	Moroni formation	Unknown	No outcrops seen, but only an aggregate of loose cobbles and boulders of andesite scattered over the ground.
	unconformity			
	Tertiary	North Horn formation	Unknown	Pebbles and small boulders of quartzite, limestone, and black chert, in a soft, red, sandy matrix.
	unconformity			
Paleozoic	Mississippian	Humbug formation	898	Yellowish-brown, quartzitic sandstone interbedded with thin beds of light to dark-gray limestone.
	Mississippian	Pine Canyon limestone	538	Cherty, thin-bedded limestone, interbedded with brown orthoquartzite.
	Mississippian	Gardner dolomite	327	Limestone and dolomite, cherty, thin to massive-bedded, crystalline, and has abundant fossils.
	unconformity			
	Upper Cambrian	Opex dolomite	206	Dolomite, light-gray, thin to massive-bedded, some small calcite geodes.
	?			
	Middle Cambrian	Cole Canyon dolomite	454	Dolomite, light to dark gray in alternating bands, locally brecciated.
	Middle Cambrian	Bluebird dolomite	153	Dolomite, blue-gray, pitted, small white twiggy bodies present.

(continued)

Table 1 (Contd.)

ERA	AGE PERIOD	FORMATION	THICKNESS IN FEET	LITHOLOGY
Paleozoic	Middle Cambrian	Herkimer limestone	442	Limestone and dolomite; limestone is dark to blue-gray, mottled and thin-bedded; dolomite is mottled with discontinuous sandy lenses.
		Dagmar limestone	42 and 46	Locally dolomite, yellow to grayish-white, banded to laminated, argillaceous, very fine-grained, good marker bed.
		Teutonic limestone	413	Limestone, light to dark-blue gray, thin to massive-bedded, discontinuous argillaceous banding in lower part.
		Ophir formation	244	Phyllite and shale, thin quartzite partings, phyllite and shale are olive-drab in color, thin-bedded, sericite on parting planes.
	Lower	Tintic quartzite	959	Quartzite, pink and gray, and clay slates; quartzite is compact, fine to medium-grained, weathers buff to brown, occasional beds of fine quartzite pebbles. Several yellowish-brown to maroon beds occur in one of the units. Diabase flow, 47 feet thick occurs 66 feet above base.
		Diabase flow		
	Unconformity			
Precambrian	Algonkian	Big Cottonwood Series	373 and 863	Quartzite, dark maroon-red, interbedded with maroon to brown and olive drab shale. Section measured twice.
	Unconformity			
	Archean	Farmington Canyon Complex	Unknown	Schist, gneiss, granite and pegmatite.

Farmington Canyon Complex

Distribution. -- The Farmington Canyon Complex, of Archean age (see Eardley, 1933; p. 311) is the oldest formation in the region, and is exposed for more than two miles along the lower part of Dry Mountain east of Santaquin. The thickness of the formation was not measured because of the poorly exposed outcrops in the area. It is estimated that about 900 feet of the formation could be measured. The outcrop is exposed on the north side of Henry McGee Canyon and continues south beyond the mapped area. To the south, the Farmington Canyon complex is the thickest formation in the region.

Lithology. -- The formation occurs as a complex band of Precambriam-granitic-gneiss that contains large included bodies of schist. The plane of schistosity dips about N 53° E.

In general aspect the Archean rocks are pink to red, varying in color according to the percentage of red alkalic feldspar. The formation consists of schist, gneiss, granite, and pegmatite. Some of the schist and gneiss contains so much mica and hornblende that they are green to greenish-black. The presence of abundant gneiss in the complex is evidenced by the coarse banding of many of the rocks. Eardley (1933, p. 311) mentions that thin sections of the Dry Mountain schist and gneiss correspond closely to those from Ogden and Farmington Canyons, described by Zirkel. [1]

The texture of the granite ranges from coarse to fine-grained and is composed of plagioclase, quartz, orthoclase, microcline, chlorite, and minor amounts of magnetite and apatite. The magnetite occurs as small inclusions or veinlets, and several specimens found contain small pockets of magnetite.

Good exposures of pegmatite were found by the writer on the north side of Henry McGee Canyon, where malachite, azurite, and minor chalcopyrite occur in association with quartz and microcline.

Intrusive Relations. -- According to Eardley (1933, p. 312) the schist and gneiss are the oldest of the Archean rocks, and they are intruded by the granite and pegmatite.

Separation between the Farmington Canyon Complex and Big Cottonwood Series

The Archean schist, gneiss, granite, and pegmatite are separated from the dark-red to maroon quartzites and shales (locally slates) of the Big Cottonwood Series by a pronounced unconformity. Eardley (1933, p. 313) mentions finding a conglomerate bed that occurs as the lowermost unit of the Big Cottonwood Series. The present writer found no such conglomerate bed in Henry McGee Canyon, the only place in the area where the two formations and the contact are exposed.

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1. Zirkel, Ferdinand, U.S. Geological Exploration 40th Parallel, 6:22, 25, 26, 1876.

Big Cottonwood Series

Distribution. -- The Big Cottonwood series is exposed as a continuous band along the west slope of Dry Mountain from Santaquin Canyon to Yellow Rock Canyon, a distance greater than two miles. Another exposure of the Big Cottonwood series extends from Yellow Rock Canyon to just beyond Tie Canyon where the formation plunges in the ground and is covered by alluvium (see Plate I).

According to Eardley (1933, p. 313) the Big Cottonwood series has a thickness of 500 to 1,000 feet. The thickest section is found at Santaquin Canyon, but to the north the section thins and is terminated by faults. Two sections of the formation were measured, and due to a difference in lithology both sections are given below:

Stratigraphic Sections of the Big Cottonwood Series

Section I measured in Tie Canyon by Lorenzo C. Demars and Joel Montgomery, Oct. 12, 1955, in Section 32, T. 9 S., R. 2 E. The section is incomplete, and only the upper 373 feet could be measured.

Tintic quartzite: Orthoquartzite, light-gray to light-pink.

Contact, unconformable, basal conglomerate four feet thick.

Big Cottonwood Series:

Unit	Description	Thickness (feet)
4	Quartzite, and quartzite float, grape-purple to flesh-pink, massive-bedded, blocky weathering pattern, increase in iron content getting higher in the section	65
3	Quartzite, and quartzite float, brownish-pink to light-purple beds alternating with dark-gray to maroon slate beds, poorly banded, few small white pebbles embedded in an Indian-brown matrix	79
2	Quartzite, and quartzite float, maroon to dark-pink, medium to massive-bedded, iron stained, alternating with light to dark Indian-brown slates.	66
1	Quartzite, and quartzite float, alternating maroon-gray to buff-maroon beds, thin to massive-bedded, abundant iron stain in some beds	163
	Total thickness	373

Unconformable contact.

Farmington Canyon complex.

Section II measured on the north side of Henry McGee Canyon by Lorenzo C. Demars, Sept. 24, 1955, in section 5, T. 10 S., R. 2 E., This is a complete section.

Tintic quartzite: Orthoquartzite, light-gray to light-pink.

Contact, unconformable, no basal conglomerate found at the contact in this area.

Big Cottonwood Series:

Unit	Description	Thickness (feet)
9	Quartzite, mostly white to gray with some buff-brown beds, thick to massive-bedded, fine to medium-grained, abundant iron stain near center of unit, and abundant float near the center of the unit	178
8	Quartzite, generally light-gray to buff-brown, some finely banded maroon quartzite present, massive bedded, wavy-banded maroon quartzite present near top of the unit, and abundant iron	113
7	Quartzite, very light-gray to buff, crystalline, medium-graned, medium iron stain, formation is distorted and crumpled, (abundant float in the lower part of the unit)	114
6	Quartzite, reddish-brown to light-maroon-metallic colored in upper part, massive-bedded, cliff-former, abundant whitish-gray to buff-brown float. Beds have a metallic gray color in the lower part of the unit, surgary to crystalline texture	83
5	Quartzite, light-pinkish-gray to buff-gray-brown, massive bedded, medium-grained, minor iron staining, near the bottom of the unit the quartzite is flesh-pink to purple-pink with dark brown iron stain occurring in patches	82
4	Quartzite, mostly maroon to buff-brown and gray float, few thick quartzite beds, some quartzite is banded with orange-brown argillaceous material, abundant iron stain	83
3	Quartzite, gray to buff-brown, fine to medium grained, massive bedded, a 14 foot bed of light maroon-gray quartzite occurs in the lower part of the unit	65
2	Quartzite, light-brown to buff-gray, thick to massive bedded, medium to coarse grained, finely laminated, minor iron stain	70

Big Cottonwood Series (Cont.)

Unit	Description	Thickness (feet)
1	Quartzite, mostly dark maroon-brown float, some thick to massive beds, medium to intense iron staining, no basal conglomerate bed	75
	Total thickness	863

Unconformable Contact

Farmington Canyon Complex

Lithology. -- The Big Cottonwood series consists of clay-slates and quartzites. The quartzites are whitish-gray to maroon, and weather brownish-red; they are very pure, compact, and fine-grained, with occasional beds of fine quartz pebbles. Several beds of green, yellow, and red clay slates occur near the top of the formation.

The basal beds of the Algonkian quartzite contain quartz and coarse, red feldspar fragments derived from the pegmatitic facies of the granite. The formation varies in texture from conglomerate to shale, and in color from dark to reddish-brown. Blackwelder (1910, p. 520) indicates that the Algonkian rocks are probably not marine, but of continental origin like similar formations in Arizona and Montana. The absence of limestone in the formation suggests a continental origin.

Correlation. -- The Algonkian rocks lie unconformably on the Archean basal complex. An unconformity exists also at the top of the section where a conglomerate bed separates the Big Cottonwood series from the overlying Tintic quartzite of Cambrian age. A marked angular divergence is found in the strike direction of the two formations.

According to Gilluly (1932, p. 313) the lithology of the Algonkian rocks on Dry Mountain correlates roughly with that of the Algonkian of the Cottonwood and American Fork districts. Fossil evidence is scanty or lacking in the formation. Worm borings (?) were found in a few specimens.

Separation between the Big Cottonwood Series and Cambrian Formations

According to Blackwelder (1910, pp. 517-542), earlier explorations of the Wasatch Range revealed a great series of quartzite and slate beneath the oldest fossiliferous rocks having an estimated thickness of 12,000 feet. Walcott (see Blackwelder, 1910, p. 520) found the *Olenellus* fauna at the top of this succession, near Salt Lake City, Utah, and recommended that the great quartzite series be placed in the Algonkian System, since it lies beneath the *Olenellus* horizon.

Several facts suggest the existence of an unconformity within the quartzite. One is that the beds show remarkable variations in thickness. Eardley and Hatch (1940, p. 822) found a conspicuous angular unconformity on Dry Mountain between the Tintic quartzite and the underlying quartzites and shales. The unconformity is characterised by a basal conglomerate in the Tintic quartzite and an angular divergence of 15 to 25 degrees between the Tintic quartzite and the underlying Angonkian beds. An angular divergence of 17 degrees was measured by the writer at the contact in Tie Canyon (see Plate I).

The basal conglomerate of the Tintic quartzite is approximately four feet in thickness. The beds beneath the unconformity thicken from 500 to 1, 000 feet in about three miles because of truncation of an old erision surface. The section was briefly described by Loughlin (see Butler, 1920, p. 324), and later by Eardley (1933, pp. 311-314).

CAMBRIAN SYSTEM

General Statement

A thick section of Cambrain rocks, consisting of eight formations, is present in the area. The oldest is the Tintic quartzite, overlain in succession by the Ophir formation, Teutonic limestone, Dagmar limestone (locally dolomite), Herkimer limestone, Bluebird dolomite, Cole Canyon dolomite, and the Opex dolomite. An erosional unconformity exists at the top of the Opex dolomite.

Loughlin noted a lithologic similarity of the Lower Cambrain of the Tintic region with that of the southern Wasatch Mountains east of Santaquin (1919, p. 41). Correlation of the Cambrain sections at Tintic and the southern Wasatch Mountains was accomplished by the use of fossils, lithologic similarity, and stratigraphic position.

Tintic Quartzite

Distribution. -- The Tintic quartzite is 959 feet thick and is exposed in the northern part of the area in a belt extending from Crooked Canyon southward for a distance of about two miles to Henry McGee Canyon. The regional strike of the formation is about N. 5°W., with an average dip of about 45°E. The Tintic quartzite is not exposed north of Crooked Canyon because the formation plunges to the north in a fold and is covered beyond this point by alluvium.

The Tintic quartzite has been involved in an impressive series of block faults with the down-dropped side situated along the lower part of Dry Mountain. These faulted segments are located near the mouth of Henry McGee Canyon and form the second major outcrop area of Tintic quartzite in the area. Due to the block-faulting the second outcrop of the formation is located nearly one mile to the west. Eardley (1933, p. 315) reported 900 feet of Tintic quartzite on the west slope of Dry Mountain.

Stratigraphic section of the Tintic Quartzite

Section measured by Lorenzo C. Demars and Glen Milner, on the north side of Tie Canyon in Section 32, T. 9 S., R. 2 E., on October 15, 1955.

Ophir formation: Shale and phyllite, interbedded with sandstone and limestone, shale, and phyllite are olive-drab to light-green in color.

Contact, conformable and gradational.

Tintic quartzite:

Unit	Description	Thickness (feet)
11	Quartzite, greenish-gray, lots of Ophir float, massive-bedded, iron-stained, (some quartzite float)	139
10	Quartzite, maroon to steel-gray, (some dark maroon quartzite and olive drab phyllite and shale float coming from the overlying Ophir formation)	42
9	Quartzite, mostly buff-brown quartzite float, This is associated with reddish-maroon quartzite float and olive-drab shale float from the Ophir formation	66
8	Quartzite, buff-gray to brown, massive-bedded, spotted, banded, some Tintic and Ophir float	51
7	Quartzite, gray to brownish-red, massive-bedded, iron stained, and abundant buff-gray to light-brown quartzite float	93
6	Quartzite, buff to brown, and reddish-brown, mostly float, banded, float boulders are very large	99
5	Quartzite, buff-gray, intense iron stain, few highly broken quartzite beds are exposed	92
4	Quartzite, mostly intense iron stained quartzite float, some buff-green, poorly banded quartzite float is present	50
3	Quartzite, mostly medium iron-stained quartzite float, few massive quartzite beds are present, in the lower part much of the quartzite is highly fault brecciated	214
2	Diabase flow rock, maroon to black, and contains large olivine phenocrysts	47
1	Quartzite, white to pink and buff-gray, massive-bedded, fine-grained, some beds are composed of fine conglomerate, basal conglomerate present	66
	Total Thickness	959

Unconformable contact

Big Cottonwood Series

Lithology. -- The Tintic quartzite is predominantly an orthoquartzite that is light gray on fresh surfaces. Some beds are flesh-pink in color, whereas other beds range in color from buff-gray to medium reddish-brown depending upon the amount of iron oxide present. The more iron present in the formation, the more rapidly the rocks seem to weather. There appears to be a relation between the thickness of bedding and the amount of iron present. The greater concentration of iron is associated with the thin-bedded, dirty quartzite beds. With an increase in the thickness of beds it appears there is a decrease in the amount of iron present.

The grain size varies from fine to medium-grained, and under the microscope the grains are easily recognized. The matrix is sufficiently hard so that the quartzite breaks through the grains. The matrix material and the sand grains vary from clear to milky-white in color. A few beds contain granule-size quartz grains, and this gives the beds a very rough-weathered surface. A quartzite conglomerate bed averaging about four feet in thickness separates the Tintic quartzite from the underlying Big Cottonwood series.

One bed near the middle of the formation contains much iron oxide stain on the weathered surface. In the upper part of the formation a few dark-green-weathering beds are present that contain an abundance of iron. These beds are in the transitional zone between the typical Tintic quartzite and the overlying quartzite and phyllite of the lower part of the Ophir formation.

A diabase flow measuring 47 feet in thickness occurs in the Tintic quartzite about 66 feet above the base of the formation. The flow has been mapped both to the north and south of this area by Ward O. Abbott (1951). More information is given on the diabase flow in the section on igneous rocks on page 33.

Correlation and age. -- No fossils were found in the Tintic quartzite, but the overlying Ophir formation has been dated paleontologically as Lower-Middle Cambrain in age. The Tintic quartzite was assigned to the Lower Cambrain in the Tintic mining district by Lindgren and Loughlin (1919, p. 25), and the same age is given the Tintic quartzite in the Dry Mountain area.

Ophir Formation

Distribution. -- The Ophir formation is 244 feet thick and is exposed in the area from Crooked Canyon on the north to the southern boundary of the mapped area. The formation forms a well-defined band that extends in a north-south direction along the west slope of Dry Mountain for a distance slightly over one and one-half miles. This comprises the largest outcrop of the Ophir formation in the area. A less conspicuous band is found to the north and south of the mouth of Yellow Rock Canyon (see Plate I). The exposure is associated with the block faulting.

The name Ophir was proposed by B. S. Butler for the shale, sandstone, and intercalated limestone beds underlying the Teutonic limestone in the mountain ranges of central Utah (see Lindgren and

Loughlin, 1919, pp. 25-27). Eardley (1933, p. 316) estimated the thickness of the Ophir formation to be about 250 feet.

Stratigraphic Section of the Ophir Formation

Measured by Lorenzo C. Demars and Joel Montgomery, on the north side of Tie Canyon, on a very prominent ridge, in Section 32, T. 9 S., R. 2 E., on September 2, 1955.

Teutonic limestone: Dark blue-gray, mottled limestone with brownish-orange argillaceous partings.

Contact, conformable.

Ophir formation:

Unit	Description	Thickness (feet)
4	Float, the surface of the ground is covered with brush, and Teutonic float. Since there was a gentle depression formed at this place below the Teutonic limestone, it was called Ophir	97
3	Shale, mostly Ophir and Teutonic float, olive-drab color, shale is finely broken and forms slopes readily, some sericite present on the parting surfaces, some phyllite beds about three feet thick are present. They are also olive-drab, Phyllite beds alternate with shale beds	112
2	Shale and phyllite, phyllite is thick-bedded, and alternates with thin to medium bedded, olive drab phyllite and shale. Phyllite alternates with some quartzite bands	25
1	Quartzite, metallic-gray, dirty, iron-stained, overlies a massive, olive-drab phyllite, which in turn overlies a massive maroon quartzite bed four feet thick	10
	Total thickness	244

Conformable contact

Tintic quartzite

Lithology. -- The Ophir formation is composed predominantly of phyllite and shale; thin partings of quartzite are present. The shale varies from olive-drab to brownish-green in color. The shale alternates with beds of olive-drab to brownish-green phyllite that have sericite on the bedding planes and range in thickness from a few inches to over four feet. In the lower part of the formation angular to subrounded fragments of quartz occur in the phyllite. Shale becomes increasingly more abundant toward the top of the formation and comprises a very prominent slope former above the more resistant Tintic quartzite.

Near the middle of the formation several beds of dark blue-gray limestone occur as intercalations. These comprise a unit known as the Medial limestone member of the Ophir formation. Perhaps Butler was not the first to recognize the Medial limestone unit, but he was the first to name it (see Lindgren and Loughlin, 1919, pp. 25-27). In Tie Canyon the Limestone unit is covered by float, but a good exposure of the Medial limestone unit occurs near the mouth of Henry McGee Canyon. The limestone is dense, shaly, and is characterized by the presence of orange to brown argillaceous material. The limestone beds are mostly thin, but a few medium beds are present.

Correlation and age. -- The Ophir formation is conformable and evidently gradational with the underlying Tintic quartzite, and with the overlying Teutonic limestone. The contact between the Tintic quartzite and the Ophir formation was selected at the base of a three-foot bed of quartzite which is overlain by the first bed of phyllite or shale of notable thickness.

Eardley (1933, p. 316) mentioned that he collected the following fossils near the Union Chief mine, southeast of Santaquin, which were identified by Professor B. F. Howell of Princeton University: *Bathyuriscus sp.*, *Olenopsis sp.*, and *Ptychoparia sp.* These fossils represent either an uppermost Lower Cambrian, or lowermost Middle Cambrian age. Two brachiopods were found in the Ophir formation on Long Ridge by Muessig (1951), and they were identified as *Obolus sp.*, and *Micromitra sp.* The writer found only poorly preserved specimens of the brachiopod *Acrothele.* On the basis of fossil evidence and stratigraphic position the writer considers the Ophir formation of Dry Mountain to be Lower-Middle Cambrian in age (see Table I.)

Teutonic Limestone

Distribution. - The Teutonic limestone is 413 feet thick and is well exposed along the west slope of Dry Mountain from Piccayune Canyon on the north to the southernmost part of the mapped area. This band of limestone, measuring more than two miles in length, is the major occurrence of the formation in the mapped area. The regional strike of the beds is N. 5°W., and the average dip is about 53°E. Minor occurences of Teutonic limestone are found in the down-dropped blocks located near the mouth of Yellow Rock Canyon. Here, the beds follow the regional strike, but dip generally at a more gentle angle. Several small isolated blocks, or horses, of Teutonic limestone are found along the base of Dry Mountain, and they extend from a point just north of Tie Canyon to the Bullock mining Camp (see Plate I).

The formation was named by Lindgren and Loughlin after Teutonic Ridge in the Tintic mining district (1919, p. 27).

Stratigraphic Section of the Teutonic Limestone

Measured by Lorenzo C. Demars, and Fred Thompson on the north side of Tie Canyon, in the northeast one quarter of section 32, T. 9 S.,

R. 2 E., on October 3, 1955.

Dagmar limestone: Light-gray to white, finely-laminated, dolomitic-limestone, weathers to a cream color.

Contact, conformable and gradational.

Teutonic limestone:

Unit	Description	Thickness (feet)
8	Limestone, medium blue-gray, massive bedded, banded, some calcite stringers	16
7	Limestone, dark-gray, massive-bedded, mottled, fault brecciated, abundant brownish-pink argillaceous material present, smooth weathering	22
6	Limestone, gray to medium-blue-gray, thick to very-massive-bedded, some small twiggy calcite bodies, extensive pitting, calcite stringers along joints and fractures	51
5	Limestone, medium to dark-blue-gray, massive to very-massive bedded, pitted, small round calcite concretions present, slope former, blotches of yellow argillaceous material present	89
4	Limestone, light-gray to medium-blue-gray, buff to brown iron-stained, medium to massive bedded, buff to orange argillaceous material present, some calcite stringers	130
3	Limestone, dark and light-gray alternating beds, thick-bedded, buff to yellow argillaceous banding, small calcite beads, some iron staining	30
2	Limestone, light-gray, white-weathering, thin to medium-bedded, wavy argillaceous bands present	14
1	Limestone, light-blue-gray, very massive-bedded, some dark-gray ribbons present, discontinuous argillaceous banding, milky-white calcite stringers, some dark-gray banding present	61
Conformable contact	Total thickness	413

Ophir formation

Lithology. -- The formation consists of a sequence of light to dark blue-gray, medium-thick to very massive limestone beds. The top of the formation consists of brecciated limestone with some white calcite stringers present. Abundant small calcite geodes are present near the top of the section. A bed of dense, crystalline, well-bedded, light-blue dolomite occurs near the middle of the section. The lower part of the formation consists of massive bedded, light-blue-gray limestone that is striped with gray to yellowish-brown, discontinuous argillaceous bands. These are good marker beds.

In some parts of the area, the Teutonic limestone has been affected by dolomitization to the extent that the usual characteristic lithology has been altered almost beyond recognition. The prominent ridge just north of Tie Canyon has been dolomitized to a greater extent than any other part of the mapped area. It is believed that a close relationship exists between the dolomitization and the emplacement of galena ore in the formation.

Correlation and age. -- The Ophir-Teutonic contact is gradational, and was taken at the base of the lowest massive limestone bed.

No fossils were found in the Teutonic limestone by the writer, but Lindgren and Loughlin assigned the Teutonic limestone to the Middle Cambrian because of its stratigraphic position between strata known to be of Middle Cambrian age (1919, p. 27). Meussig found fossils in the Teutonic limestone that were identified as: Bolasphis labrosa; and Glyphasphis sp., an undescribed trilobite genus belonging to the Ehmania, Bolasphis, Glyphasphis faunal zone known to be Middle Cambrian in age (1951, p. 23).

The Teutonic limestone is very similar to the Herkimer limestone lithologically, and can be easily confused with it, except for the presence of the Dagmar limestone. The Dagmar is situated between the two formations, and served as a good marker bed in mapping formational contacts.

Eardley (1933, p. 317) did not differentiate between the Cambrian limestones and dolomites, and does not discuss any formation individually; had he done so, it would have been a great help in correlating the formations.

Dagmar Limestone

Distribution. -- The Dagmar limestone (locally dolomite) measures from 42 to 46 feet in thickness. The formation is well exposed along the west slope of Dry Mountain from Piccayune Canyon on the north to Henry McGee Canyon, a distance of about two miles. The second major occurrence of Dagmar limestone is in the down-dropped fault blocks near the mouth of Henry McGee and Yellow Rock Canyons.

Near the mouth of Crooked Canyon the Dagmar limestone is involved in an impressive series of faults. At Piccayune Canyon the formation assumes an almost overturned position. The regional strike of the beds is about N. 5° W., with a dip of about 39° E.

Two measurements of thickness were made of the Dagmar limestone. The formation measured 42 feet thick in the northeast one quarter of section 32, T. 9 S., R. 2 E. In the southeast one quarter of the same section the formation measures 46 feet thick.

The formation was named by Lindgren and Loughlin after the Dagmar mine in the Tintic mining district (1919, p. 27).

Stratigraphic Section of the Dagmar Limestone

Measured by Lorenzo Demars and Joel Montgomery in the southeast one quarter of section 32, T. 9 S., R. 2 E., on the north side of Tie Canyon, on September 21, 1955.

Herkimer limestone: Mottled, shaly limestone, finely crystalline near the base.

Contact, conformable, very sharp and well defined.

Dagmar limestone:

Unit	Distribution	Thickness (feet)
1	Dolomite, medium to light-gray on fresh surfaces, grayish to yellowish-white on weathered surfaces, argillaceous and very finely banded	46
	Total thickness	46

Conformable contact

Teutonic limestone

Lithology. -- The formation is generally medium to dark-gray in color, and weathers a very characteristic yellowish to milky-white. In this area the formation consists of fine-grained, argillaceous, and slightly calcareous dolomite. The formation is a cliff former and is characterized by a blocky weathering habit. Fine banding or laminations are characteristic of the formation. The Dagmar was used as a marker bed in mapping certain structural features of the area because of its distinctive lithology.

Correlation and age. -- The contact between the Dagmar limestone and the underlying Teutonic limestone was taken at the first cream to white-colored, laminated bed of the younger formation.

No fossils were found in the formation by the writer, but Lindgren and Loughlin assign it to the Middle Cambrian age because of its stratigraphic position between two known Middle Cambrian formations (1919. p. 28).

The characteristic color of the formation and its stratigraphic position permit the correlation of the Dagmar limestone of this area with contiguous areas.

Herkimer Limestone

Distribution. -- The Herkimer limestone is 442 feet thick and is one of the most important formations in the area because of its thickness and wide surface exposure. The formation is exposed on the west slope of Dry Mountain, and trends in a north-south direction. The regional strike of the formation is about N. 5° W., and the dip is about 40° E.

The major exposure of the Herkimer limestone extending from Piccayune Canyon to Henry McGee Canyon, measures over two miles in length. A minor occurrence of the formation is located at the foot of the mountain just east of the town of Santaquin. This occurrence is associated with the block faulting near the base of the mountain.

The Herkimer limestone was named by Lindgren and Loughlin after the Herkimer shaft which is found to the east of Quartzite Ridge in the Tintic minig district (1919, p. 28).

Stratigraphic Section of the Herkimer Limestone

Measured by Lorenzo C. Demars on the north side of Tie Canyon, in the southeast one quarter of section 32, T. 9 S., R. 2 E., on October 3, 1955

Bluebird dolomite: Light-blue-gray, massive, deeply-pitted, dolomite, contains abundant white twiggy bodies.

Contact, conformable and gradational.

Herkimer limestone:

Unit	Description	Thickness (feet)
5	Limestone, very light to medium-gray in alternating beds, massive-bedded, medium-grained, brecciated, mottled, calcite present	82
4	Limestone, light-gray to dark-blue-gray, mainly thin to medium-bedded, minor massive bedding, fine to medium-grained, buff to pink argillaceous material present, few calcite stringers	158
3	Limestone, buff-gray to dark blue-gray, medium to massive-bedded, fine-grained, platy, mottled, dirty brown-weathering, buff argillaceous material present	82
2	Limestone, medium to dark-gray, thick to massive-bedded, medium-grained, dirty brown-weathering, dark-gray banding, brecciated, white and green twiggy bodies present	75

(continued)

Herkimer limestone (cont.)

Unit	Description	Thickness (feet)
1	Limestone, dark-blue to dirty-dark-gray medium to thick-bedded, fine to medium grained, calcite stringers at right angles to the bedding, buff argillaceous material in the lower part	45
	Total thickness	442

Conformable contact

Dagmar limestone

Lithology. -- The formation consists of mottled, shaly, carbonaceous, massive limestone that ranges in color from light-gray to dark bluish-gray. The limestone is mottled by thin discontinuous layers and blotches of yellowish-brown material containing an abundance of clay and iron. A few dolomite beds are present that contain twiggy bodies of calcite and silica, and discontinuous sandy lenses that display a sandy-weathered surface. The dolomite beds range in color from blue to steel-gray. In the lower part of the section, the dolomite is light to dark-gray, mottled, cross-bedded, and contains abundant white twiggy bodies.

The Herkimer limestone commonly is a good cliff former, but the thin-bedded units often occur as a steep slope. Lithologically, the Herkimer limestone resembles the Teutonic limestone.

Correlation and age. -- The Herkimer limestone is conformable with the underlying Dagmar limestone, and is conformable and gradational with the overlying Bluebird dolomite.

On the basis of stratigraphic position the Herkimer limestone is assigned to the Middle Cambrian. No fossils were found in the Herkimer limestone until Muessig found many shells of Lingulella sp. near the top of the formation in the east fork of Spring Canyon, in Utah County, Utah (1951, p. 26).

Bluebird Dolomite

Distribution. -- The Bluebird dolomite is 153 feet thick and lies conformably on the Herkimer limestone. It occurs as a steep slope along the west face of Dry Mountain and trends in a north-south direction throughout the entire mapped area.

In Piccayune Canyon, the Bluebird dolomite assumes an almost overturned position due to folding. At Crooked Canyon the Bluebird dolomite is involved in a conspicuous assemblage of faults (see Plate I).

The Bluebird dolomite was named by Lindgren and Loughlin after the Bluebird spur in the Tintic mining district (1919, p. 28).

Stratigraphic Section of the Bluebird Dolomite

Measured by Lorenzo Demars and Fred Thompson, on the north side of Tie Canyon, in the southeast one quarter of section 32, T. 9 S., R. 2 E., on October 3, 1955.

Cole Canyon dolomite: Alternating dark and light-gray dolomite beds that contain some twiggy bodies, some beds are mottled, some intraformational conglomerates are present.

Contact, conformable and gradational.

Bluebird dolomite:

Unit	Description	Thickness (feet)
3	Dolomite, light to dark-gray, massive-bedded, smooth-wearing, light-gray banding, splotchy buff argillaceous material, alternating light and dark beds, some twiggy bodies	43
2	Dolomite, dark-gray, massive-bedded, fine-grained, banded, slightly-pitted, no twiggy bodies present	28
1	Dolomite, light to medium-gray, massive-bedded, pitted, medium-grained, weathers with a brownish surface, white twiggy bodies present, locally brecciated, travertine along broken beds, a good cliff former	82
	Total thickness	153

Conformable contact

Herkimer limestone

Lithology. -- The Bluebird dolomite consists of light to dark bluish-gray, deeply pitted dolomite that gives a fetid odor when broken. The formation weathers a lighter gray than is found on broken fresh surfaces, and the term "speckled gray" is appropriate to describe the color and character of the weathered surface.

Abundant white to gray twiggy bodies characterize most of the beds in the Bluebird dolomite, these twiggy bodies measuring between 1/4 and 3/4 of an inch in length, and about 1/8 of an inch in diameter. Lindgren and Loughlin (1919, p. 28) suggest that the white twiggy bodies may be the remains of crinoid stems, or corals. They may be the remains of bryozoans, or else worm borings.

Correlation and age. -- No fossils were found by the writer in the Bluebird dolomite, but Lindgren and Loughlin classify it as Middle Cambrian in age because of its stratigraphic position between two formations of known Middle Cambrian age (1919, p. 28).

Cole Canyon Dolomite

Distribution. -- The Cole Canyon dolomite is 454 feet thick and occurs as a rather wide band that follows the upper part of the west slope of Dry Mountain from Piccayune Canyon southward to beyond Henry McGee Canyon (see Plate I). This north-south trending band measures over two miles in length.

The formation was named by Lindgren and Loughlin after Cole Canyon in the Tintic mining district (1919, p. 29).

Stratigraphic Section of the Cole Canyon Dolomite

Measured by Lorenzo Demars and Joel Montgomery, on the north side of Tie Canyon, in the south-east one quarter of section 32, T. 9 S., R. 2 E., on October 7, 1955.

Opex dolomite: Light to dark-gray, mottled, coarsely-crystalline, spotted dolomite, interbedded with dolomitic, brown to buff, cross-bedded, sandstone and intraformational conglomerate.

Contact, conformable and gradational.

Cole Canyon dolomite:

Unit	Description	Thickness (feet)
1	Dolomite, light to medium and dark-gray, very coarse-grained, pitted, banded, porous, earthy, calcareous coating on partings, massive weathering habit, some calcite inclusions	85
5	Dolomite, light to buff-gray, poorly-banded, massive weathering habit, slope former, abundant limonite iron, medium to thick-bedded, small calcite geodes	92
4	Dolomite, light-gray, massive-bedded, fine grained, crystalline, poorly-banded, minor light-brown shale float, some gray twiggy bodies in middle part	50
3	Dolomite, light to medium-gray, medium to massive-bedded, buff-weathering, alternating fine to medium grained beds, mottled, calcite stringers, twig-like projections	43
2	Dolomite, light to medium and dark-gray, generally thick to massive-bedded, locally brecciated, fine to medium-grained, mottled, massive milky-white calcite bands	117

Cole Canyon dolomite (cont.)

Unit	Description	Thickness (feet)
1	Dolomite, buff to light and dark-gray, massive-bedded, alternating medium-gray and dark-gray beds, poorly-banded, cliff-former, dirty buff-brown stain on fresh surfaces, some chert nodules	67
	Total thickness	454

Conformable contact

Bluebird dolomite

Lithology. -- The formation consists of alternating light and dark-gray dolomite beds that are medium-thick to massive. Some beds in the formation are finely laminated and fine-grained. The characteristic thickness of the beds in the Cole Canyon dolomite section is from ten to 25 feet.

One bed near the top of unit one is 24 feet in thickness and resembles the Dagmar limestone. It is finely laminated dolomite that weathers to a characteristic yellowish to milky-white color. When broken the dolomite displays iron oxide stain on the fresh surface rather than the uniform light blue-gray color of the Dagmar limestone. Another distinguishing characteristic of the Cole Canyon dolomite is that its laminations appear to be surface features only.

Some beds in the formation are dense and finely crystalline while others are coarse in texture. About 130 feet from the top of the formation a thin shale bed is found; it is yellowish-brown in color, and is a slope former. The formation consists of alternating resistant and non-resistant beds, and the weathering pattern gives rise to a ledge-and-bench slope. This is perhaps the most easily recognized feature of the formation.

Correlation and age. -- Both the upper Cole Canyon-Opex and lower Cole Canyon-Bluebird contacts are conformable and gradational. The lower contact was selected at the first bed that showed the typical Cole Canyon alternating light and dark laminated dolomites, and above the upper-most bed which contains white twiggy bodies.

Weeks, in 1905, was mentioned by Lindgren and Loughlin as the person who found the only reported fossils in the Cole Canyon dolomite (1919, p. 29). The fossils were classified as *Obolus mcconnelli*, and they range in age from lower to upper Middle Cambrian. On the basis of this evidence Lindgren and Loughlin dated the formation as Middle Cambrian in age.

Opex Dolomite

Distribution. -- The Opex dolomite is 206 feet thick and is well exposed along the west slope of Dry Mountain near the summit. The presence of abundant vegetation at this elevation on Dry Mountain made accurate mapping difficult. The outcrops of the Opex dolomite and younger formations are mostly covered at this locality. At Piccayune Canyon, however, the formation is well exposed and is dipping nearly vertical. The regional strike of the formation is N. 5^{o} W., and the dip is about 40^{o} E. The formation is continuous from Piccayune Canyon on the north to Henry McGee Canyon on the south.

The Opex dolomite was named by Lindgren and Loughlin (1919, p. 30) after the Opex mine in the Tintic mining district.

Stratigraphic Section of the Opex Dolomite

Measured by Lorenzo Demars and Joel Montgomery on the north side of Tie Canyon in the south-east one quarter of section 32, T. 9 S., R 2 E., on September 7, 1955.

Gardner dolomite: Dolomite, fine-grained, gray to dark bluish-gray, contains abundant recognizable fossils.

Contact, unconformable.

Opex dolomite:

Unit	Description	Thickness (feet)
2	Dolomite, dark-gray, coarse to medium-grained, crystalline, some small calcite geodes	123
1	Dolomite, light-gray to dark-gray, very massive-bedded, medium-grained, included large grains of clear and milky quartzite (BB size), some calcite geodes, brown weathering streaks	83
	Total thickness	206

Conformable contact

Cole Canyon dolomite

Lithology. -- The Opex dolomite is composed of light to dark-gray, very coarse-grained, massive-bedded dolomite. Mottling is characteristic of most of the beds in the formation, and a vermiculate aspect is shown by a few of the beds, especially in the lower part of the formation. Near the middle of the formation some small calcite geodes are present that are typical of the Opex dolomite.

Correlation and age. -- The contact of the Opex dolomite with the underlying Cole Canyon dolomite is conformable and gradational, but an unconformity is present between the Opex dolomite and the overlying Mississippian Gardner dolomite. Because of this erosional unconformity, perhaps much of the upper part of the Opex dolomite is missing.

Weeks, who was mentioned by Lindgren and Loughlin, found fossils in 1905 in the Opex dolomite in the Tintic mining district, and dated them as Upper Cambrian in age (1919, p. 30). From fossil evidence and stratigraphic position, dating the Opex dolomite as Upper Cambrian appear.

Unconformity at the top of the Upper Cambrian

A pronounced erosional unconformity is responsible for the absence of formations of Ordovician, Silurian, and Devonian age. In other words, the Ajax limestone, Opohonga limestone, Bluebell dolomite, Pinyon Peak limestone, and Victoria quartzite which are found in the Tintic mining district are not present here.

In Utah the presence of an unconformity at the base of the Mississippian has been pointed out by Loughlin (1919, pp. 36-37) and (1913, pp. 436-452), Gilluly (1932, p. 22), Nolan (1935, p. 39), and others. North of Crooked Canyon, in the north-west quarter of section 33, T. 9 S., R. 2 E., the writer recognized a slight angular divergence of about four degrees at the contact between the Cambrian and Mississippain formations. Brown (1950, p. 25) states that although the Cambrian-Mississippian contact is exposed for a distance of about one mile south of Piccayune Canyon, he found no evidence of an angular unconformity.

MISSISSIPPIAN SYSTEM

General Statement

Three formations of Mississippian age were mapped in the area. The lowermost formation is the Gardner dolomite which rests unconformably on the Opex dolomite of Upper Cambrain age. The Pine Canyon limestone conformably overlies the Gardner dolomite, and above the Pine Canyon is the Humbug formation. The Pine Canyon-Humbug contact is also conformable.

The Humbug formation forms the summit of Dry Mountain. Since the formations dip to the east, the Humbug formation is exposed down the dip slope almost to the bottom of Payson Canyon (see Plate I). Near the Maple Dell Boy Scout Camp in Payson Canyon, the Tertiary (?) North Horn formation lies unconformably on the Humbug formation. The formation has been mapped by Deverl Petersen (unpublished thesis, B.Y.U. 1956).

Ralph Brown (1950, pp. 31-32) mapped the Pine Canyon limestone; it consists of 13 units and is 1594 feet thick. The writer believes that in this thick section, Brown has included some of the Humbug formation. The writer measured 538 feet of Pine Canyon limestone; however, this thickness does not correlate with the scaled thickness of the formation on the structural cross sections (see Plate I). The greater thickness shown on the geologic map may be due in part to faulting within the formation, but more likely, the writer was inaccurate in his measurement of the formation. Late snow fall in the mountains made it impossible to re-measure the Pine Canyon limestone in time for publication.

Gardner Dolomite

Distribution. -- The Gardner dolomite is 327 feet thick, and is a slope former throughout much of the mapped area. The Gardner dolomite is the uppermost formation that is exposed in the main part of Piccayune Canyon. The formation forms a band which follows the same general north-south trend as do the other formations. The average dip of the formation is about 41° E.

A minor occurrence of Gardner dolomite is found in the normal down-dropped block which is located near the mouth of Yellow Rock Canyon. The exposure is found on Saw Mill flat. The presence of abundant fossils was helpful in recognizing the formation.

The Gardner dolomite was named after Gardner Canyon in the Tintic mining district by Lindgren and Loughlin (1919, p. 39).

Stratigraphic Section of the Gardner Dolomite

Measured by Lorenzo Demars about one quarter of a mile north of Crooked Canyon, in the north-east quarter of section 32, and the north-west quarter of section 33, T. 9 S., R. 2 E., on October 15, 1955.

Pine Canyon limestone: Limestone, dark-gray, dense, thin-bedded, black chert occurs as nodules and in bands.

Contact, conformable.

Gardner dolomite:

Unit	Description	Thickness (feet)
5	Limestone, dark-gray, crystalline, medium-grained, pitted, vuggy, carbonaceous, black chert nodules	87
4	Limestone, and dolomite, light to medium-gray, thin to medium-bedded, small beds of chert	58
3	Limestone, alternating beds of medium and dark-gray, finely banded, medium-bedded	35
2	Dolomite, and some limestone, medium-gray, thick to massive-bedded, some black chert nodules, fossiliferous, and carbonaceous	73
1	Dolomite and minor limestone, fine-grained, light to dark-gray, crystalline, black chert occurring in bands, abundant fossils	74
	Total thickness	327

Unformable contact

Opex dolomite

Lithology. -- The formation consists of gray to dark-bluish-gray dolomite and limestone beds that range in texture from fine to medium-grained. Some beds contain an abundance of chert nodules, bands, and stringers. The lower dolomite beds are very dark in color, highly carbonaceous, and very fossiliferous. An abundance of crinoid columnals are present in addition to nondescript brachiopods, cup corals, and the gastropod Euomphalus sp. The dolomite is recognized as a distinct time rock unit because it contains a great variety of recognizable fossils.

The upper limestone and dolomite beds contain an abundance of chert nodules and stringers, and they are very dark in color due to the presence of carbonaceous material.

Correlation and age. -- The contact with the overlying Pine Canyon limestone is conformable and was taken at the base of the first bed of black cherty limestone.

In the Tintic mining district, fossils were found in the Gardner dolomite by Lindgren and Loughlin (1919, pp. 39-40), who assigned it to the Lower Mississippian. On Dry Mountain the following fossils were found and identified: Euomphalus sp., Syringopora sp., Triplophyllites sp., Zaphrentis sp., Aulopora sp., and Corinoid columnals. On the basis of fossil evidence and stratagraphic position the Gardner dolomite is assigned a Lower Mississippian age.

Pine Canyon Limestone

Distribution. -- The Pine Canyon limestone is 538 feet thick, and forms the crest of Dry Mountain. It also forms part of the dip slope to the east; this is why it appears as an extremely wide band. The exposure extends from the crest of the mountain eastward for several hundred feet to the Pine Canyon-Humbug contact.

The formation was named by Lindgren and Loughlin after Pine Canyon in the Tintic mining district (1919, p. 40).

The formation is exposed along Dry Mountain near its summit and trends in a north-south direction along the entire mapped area. The regional strike of the beds is about N. 5°W., and the dip is about 42° E. Immediately south of the Bullock mining camp an exposure of the formation is found associated with the normal faulting. The down-dropped blocks are responsible for the present topography found in the area between Henry McGee Canyon and Tie Canyon.

Stratigraphic Section of the Pine Canyon Limestone

Measured by Lorenzo Demars and Joel Montgomery on the north side of Tie Canyon, in the south-east quarter of section 33, T. 9 S., R 2 E., on September 15, 1955.

Humbug formation: Interbedded limestone, lenticular sandstone, and quartzite, generally massive-bedded limestone, varies from medium light-gray to black in color.

Contact, conformable and (?) gradational.

Pine Canyon limestone:

Unit	Description	Thickness (feet)
5	Limestone, medium to light-gray, some fossils present, medium-grained, thick to massive-bedded	157
4	Limestone, light-gray, well-bedded, some chert present	56
3	Limestone, light to medium-gray, medium-grained, cross-bedded, some quartz fragments present, fossil hash	180
2	Limestone, medium to light-gray, massive-bedded, some beds contain chert nodules, cliff former	102
1	Limestone, dark-gray, abundant white calcite stringers, reddish-brown chert nodules	43
	Total thickness	538

Conformable contact

Gardner dolomite

Lithology. -- The Pine Canyon limestone consists of beds that vary from light to medium-gray in color; however, some beds are found that are almost black. The beds are dense, fine-grained, thick to massive-bedded, and contain large black chert nodules. Occasionally the black chert occurs as thin layers in the bedding, or is found associated with fractures. The formation is a typical ledge former.

Near the base of the formation some cherty limestone beds alternate with beds of light to medium-gray, cross-bedded, and medium-grained limestone. Near the middle of the section the limestone is light to medium-gray and cross-bedded, but differs from the beds lower in the section in that they are fine-grained enough (almost aphanitic) as to be classed as sub-lithographic. An abundance of fossil hash typifies the beds at this horizon. Near the top of the formation the beds of quartzite become thicker and occur more frequently.

Correlation and age. -- The contact between the Pine Canyon limestone and the overlying Humbug formation is gradational, and was selected at the base of the first notable quartzite beds in the section.

Lindgren and Loughlin found two fossils in the Pine Canyon limestone in the Tintic mining district: *Zaphrentis sp.*, and *Batostomella sp.* (1919, p. 41). On the basis of these poorly preserved fossils Girty assigned the formation to an Upper Mississippian age.

Humbug Formation

Distribution. -- The Humbug formation is 898 feet thick and is exposed over more area than any other formation due to the dip slope to the east (see Plate I). The Humbug formation is exposed from the summit of Dry Mountain eastward nearly to Payson Canyon, a distance of about one mile. The reason for the extremely thick section of Humbug measured is not clearly known, but repetition of beds due to faults is suggested as one possibility. The formation forms a continuous band that trends in a north-south direction along the east flank of Dry Mountain.

A minor exposure of Humbug is found immediately south of the Bullock mining camp and is associated with the normal faulting in the area.

The formation was named after the Humbug mine in the Tintic mining district by Tower and Smith (1889, pp. 625-626).

Stratigraphic Section of the Humbug Formation

Measured by Lorenzo Demars on the north side of Tie Canyon, in sections 33 and 34 of T. 9 S., R. 2 E., on October 17, 1955.

North Horn formation: Pebbles and small boulders of quartzite, limestone, and black chert, in a soft-red sandy matrix.

Contact, unconformable.

Humbug formation:

Unit	Description	Thickness (feet)
9	Limestone, light to medium-gray, thick-bedded, mottled, crystalline, dense, fossiliferous	150
8	Quartzite, covered over with float	55
7	Limestone, dark-gray to black, very fine-grained, broken, carbonaceous, some is light to medium-gray	86
6	Quartzite, buff-gray to yellowish-brown, cross-bedded, iron-stained, some BB size quartz grains present, mostly float	46
5	Limestone, dark-gray to black, dense, carbonaceous, sublithographic, minor chert	13
4	Limestone, light to medium-gray, medium- to thick-bedded, fine to medium-grained	146

Humbug formation (cont.)

Unit	Description	Thickness (feet)
3	Limestone, light to medium-gray, interbedded with rather thin beds of buff to yellow-weathering quartzite, much float	62
2	Limestone, light to medium-gray, alternating with buff to yellow quartzite	202
1	Limestone, light to medium-gray, fine to medium-grained, alternating with reddish-brown-weathering quartzite, quartzite medium to coarse-grained	138
	Total thickness	898

Conformable contact

Pine Canyon limestone

Lithology. -- The Humbug formation consists of alternating beds of fossiliferous limestone, limey sandstone, and lenticular standstone and quartzite. The sandstone varies from buff to yellowish-brown in color, and is medium to coarse-grained. It alternates with beds of light to medium-dark-gray cherty limestone that is medium-thick to massive. In the lower part of the formation near the contact, a very distinctive encrinite bed is found. Throughout the formation the beds vary in thickness from about two to ten feet. Fossils found in the formation were identified by Dr. J. Keith Rigby as: Dictyoclostus burlingtonensis.

Correlation and age. -- The contact with the underlying Pine Canyon limestone is taken at the base of the first notable beds of quartzite.

In the Tintic mining district, the type locality, Lindgren and Loughlin (1919, p. 42) found the following fossils: Zaphrentis sp., and crinoid columnals. From the position of the formation in the section, they classed it as Upper Mississippian in age. On the basis of stratigraphic position and lithologic comparison the Humbug formation on Dry Mountain can be correlated with similar exposures at other localities in north-central Utah.

TERTIARY SYSTEM

North Horn Formation

Distribution. -- Exposures of the North Horn formation are limited to the area near Maple Dell in Payson Canyon. Just east of Maple Dell the Payson Canyon road and canal cut the formation, exposing a few beds. West of Maple Dell the formation outcrops on a low hill. The hill slopes to the north and is covered by alluvium, but southward the formation rapidly increases in elevation. Eardley (1933, p. 325) mentioned the presence of this low hill, indicating his belief that it is composed of beds of Tertiary age. In the formation Eardley found large richly fossiliferous blocks, some of which are more than six feet in diameter and are firmly embedded in the conglomerate. These blocks were derived from erosion of the Humbug formation.

Lithology. -- The North Horn formation consists of pebbles, cobbles, and small boulders of quartzite, limestone, and black chert, all enclosed in a matrix of soft red sandy material. The discrete fragments have been derived from rocks of Algonkian, Cambrian, and Mississippian age; the fragments of Cambrian rocks predominate. The red matrix weathers rapidly, and the formation is readily reduced to an aggregate of loose pebbles, cobbles, and boulders in a soft red soil.

Correlation and age. -- Eardley (1933, pp. 335-336) referred this formation to the Wasatch conglomerate. He mentions that within the conglomerate there is a fresh-water limestone bed which has yielded gastropod fossils that have been determined as Lower Eocene in age.

Moroni (?) Formation

Distribution. -- The only exposure of the Moroni (?) formation is found immediately south of Piccayune Canyon near the Elsie Jane Adit. The exposure is small, covering a nearly square area which measures about 200 feet on each side.

Lithology. -- In the mapped area the formation consists of andesite cobbles, pebbles, and boulders that are sub-rounded to rounded. They are dense, aphanitic, and dark-gray to black in color. According to Harris (1953, p. 90) the formation was named by Schoff after outcrops at a prominent cliff, located six miles north of the town of Moroni.

Eardley refers to a similar formation in Salt Creek Canyon, east of Nephi (1933, p. 343), and calls it volcanic conglomerate. Here the andesite pebbles, cobbles, and boulders are enbedded in a roughly stratified, water-laid matrix of volcanic ash. Eardley classifies the rocks as andesite or hornblende andesite, with some augite present (1933, p. 340). The phenocrysts in the porphyritic rocks are largely labradorite. The writer regards these rocks in the mapped area to be composed principally of andesite.

Correlation and age. -- The Moroni formation correlates closely in age with the Laguna latite named by Lindgren and Loughlin (1919, p. 55) after Laguna station in the Tintic district.

Eardley (1933, p. 340) states that the volcanic conglomerate in Salt Creek Canyon is post Eocene in age because it lies unconformably on the Wasatch conglomerate.

According to Harris (1953, pp. 97-98) no fossils were found in the Moroni (?) formation in the area south of Thistle; however, the formation overlies the Flagstaff limestone. On these grounds Harris said that the formation may be as old as Early or Middle Tertiary.

QUATERNARY SYSTEM

Pre-Lake Bonneville Fanglomerate

Surficial deposits of Quaternary age occupy the lower part of the west slope of Dry Mountain. The Pre-Lake Bonneville fanglomerate is found above the Bonneville shore line of the ancient lake. The most extensive surface exposure of the fanglomerate is located near the base of Dry Mountain south of Henry McGee Canyon. Coalescing alluvial fans have formed the piedmont slope along the base of the west slope of Dry Mountain.

Lake Bonneville Sediments

Utah Valley is largely floored by lacustrine deposits that were laid down in Lake Bonneville. The coarser materials are found near the mountains, whereas the fine sands, silts, and clays have been laid down in the lower parts of the valley. Along the high shoreline formed by Lake Bonneville the gravel and sand have been reworked, and as a result they are very well sorted.

Recent Sediments

A small amount of post-Lake Bonneville alluvium is found near the mouths of canyons, or occurs as recent fan material which has formed since the recession of Lake Bonneville, and it has in places covered the old lake built terraces. Gullying has in some areas resulted in the dissection of sediments along the old lake terraces.

IGNEOUS ROCKS

General Statement

Various types of igneous rocks and a few metamorphic rocks are found in the area. The oldest rocks are Archean schist and gneiss that are cut by pegmatite dikes and quartz veins. An extrusion of diabase flow rock was made during early Cambrian time.

Archean Complex

During Archean time the rocks were highly metamorphosed to schist and gneiss, and these were later invaded by pegmatite dikes and quartz veins. Some granitic-gneiss occurs in the area just north of the Bullock cabins, south of Tie Canyon. The major occurrence of granitic-gneiss begins at Yellow Rock Canyon and continues uninterrupted southward to Santaquin Canyon. The best exposures of pegmatite dikes and quartz veins occur on the north side of Henry McGee Canyon, and they are associated with some copper mineralization.

Cambrian Diabase Flow

A Cambrian diabase flow was studied by Abbott(1951, p. 2) and mapped over a wide area from Provo, south to Starr, a distance of about 40 miles. In the area studied, a band of diabase outcrops from a point just north of Tie Canyon nearly to the Syndicate tunnel in Yellow Rock Canyon, a distance of about one half mile (see Plate I).

The diabase is a basic igneous rock that is texturally intermediate between gabbro and basalt. The diabase is dark-gray to dark-maroon in color and contains green plagioclase phenocrysts. In color it is similar to the upper beds of the Big Cottonwood series, and can be mistaken for it. The diabase is generally a slope former, and in two places it forms a slight depression. On the south side of Tie Canyon, weathering has reduced the diabase to a coarse, maroon-colored soil.

In the area mapped, the lower contact with the Tintic quartzite is very sharp, and near the contact the quartzite is slightly altered as a result of contact metamorphism by the diabase flow. It was not possible to determine the nature of the contact that exists between the top of the flow rock and the overlying Tintic quartzite beds because the contact is everywhere covered by float.

On Long Ridge a basal conglomerate was found separating the Tintic quartzite from the diabase flow (Abbott, 1951, p. 53). This suggests a period of slight orogeny during early Cambrian time. The basal conglomerate was not seen on the west slope of Dry Mountain.

STRUCTURE

GENERAL RELATIONS

Strata in the southern Wasatch Mountains have undergone four major crustal disturbances, according to Eardley (1934, p. 378); the post Archean Revolution, the post Algonkian Revolution, the Laramide Revolution, and the Basin-Range Deformation. In the southern Wasatch Mountains, the Laramide trends follow the crystalline rock formation with only small angular divergence.

The revolution at the close of the Archean Era was the greatest of all Earth distrubrances, and evidence of its intensity can still be seen in the southern Wasatch Mountains. The foliation of the schist and gneiss strikes roughly parallel with the axes of the later Laramide trends, which indicates that the structural lines of this ancient period of diastrophism may have exerted some control over the present Rocky Mountain trends of the region.

PRE-LARAMIDE DEFORMATION

During the Algonkian Revolution, compressional forces caused great folds to be formed. However, evidence of this revolution seems to be lacking in the mapped area.

Epeirogenic warpings occurred in Ordovician, Silurian and Devonian time causing a hiatus which is marked by a low angle unconformity estimated at about four degrees at the Opex-Gardner contact on the north side of Crooked Canyon, in the southeast quarter of section 32 and the southwest quarter of section 33, T. 9 S., R. 2 E.

LARAMIDE DEFORMATION

Laramide Orogeny is the term given to the great compressional disturbances that occurred in late Cretaceous and early Tertiary time, according to Eardley (1934, p. 384). In the southern Wasatch Mountains, the major structural feature is the Nebo overthrust. In the mount Nebo area, the overthrust block forms an isoclinal anticline, but in the Dry Mountain area, the overthrust block forms a broad open anticline. Dry Mountain comprises the east limb of the anticline. The west limb has been faulted downward to the west and is covered by alluvium.

The regional strike of the beds is N. 5°W., and the average dip is about 41° E. In Piccayune Canyon, the northern portion of the anticline is sharply bent so that the axis of the fold strikes east-west, and the recumbent limb dips 56° south. The Wasatch fault, which was formed later, follows the axial plane of the north-south trending fold for seceral miles.

The youngest beds affected by the Laramide Deformation are Upper Jurassic in age (Eardley, 1934, p. 385). The folded and truncated beds are overlain by the Wasatch Conglomerate, which has been determined as Lower Eocene in age by Spieker and Reeside (1925, p. 445). This dates the Laramide Deformation in the southern Wasatch Mountains as pre-Lower Eocene age.

FAULTS

General Statement

The most characteristic structures associated with the Laramide Revolution are thrust faults, tear faults, and folds. Loughlin (1913, p. 438) mentions that Boutwell was the first to recognize overthrust faults in the Wasatch Mountains.

Prior to the Laramide Revolution some normal east-west faulting occurred in the area. Eardley found such a fault on the north side of the mouth of Santaquin Canyon which is cut by the Santaquin overthrust, and is therefore older than the thrusting (1934, p. 379).

Thrust Faults

Santaquin Overthrust. -- Eardley (1934, pp. 381-383) mapped two major overthrust sheets, the Nebo overthrust and the Santaquin overthrust. Eardley further states that the overthrusts are marked by Cambrian quartzite resting upon Mississippian limestone. The east-west trending faults were likely formed at the same age.

On his geologic map, Eardley (1934, p. 382a) shows the Santaquin overthrust separating the upper-most Tintic quartzite outcrop from the overlying major Cambrian limestone and dolomite formations. According to Eardley, the overthrust fault is exposed in a north-south direction all along the west slope of Dry Mountain. The writer disagrees with Eardley as to the location and presence of the Santaquin overthrust. From Crooked Canyon to Henry McGee Canyon, the writer found no evidence of overthrusting, but a normal formational sequence. The dip of the Cambrian formations is nearly the same. It is believed that all of the features can best be explained by normal block faults.

The weathering pattern of the Ophir formation, in addition to the down-dropped sequence of formations south of Yellow Rock Canyon give the appearance of thrust faulting.

In discussing the normal fault sequence south of Yellow Rock Canyon, Eardley (1933, pp. 243-277) said:

> "So far as the positions of the rocks are concerned, reverse or thrust faulting seems the only interpretation; but the absence of distrubance in the overridden limestone is not easily explained. It is a striking feature along the Wasatch Mountains that even though the shales and thinner bedded quartzites are much contorted along the fault zones, the adjacent heavily bedded limestones are practically free from such deformations."

Continuing on, Eardley (1933, pp. 243-274) said:

> "Northeast of Santaquin the granite pinches out and the main body of Cambrian quartzite overlies a dark brecciated limestone (Teutonic), which passes downward into shale and quartzite. The lower quartzite exposure, in turn, overlies fossiliferous Mississippian limestone, which is free from any of the crumpling or brecciation which is likely to accompany overthrusting. The Mississippian limestone is underlain conformably by fossiliferous Cambrian shale and a third quartzite exposure."

The down-dropped blocks mentioned by Eardley are shown on the geologic map (Plate I).

Payson Canyon Thrust. -- The Payson Canyon thrust fault strikes in a north-west to south-east direction and has been instrumental in forming Payson Canyon. The throw of the fault is about 2,000 feet, and has placed Cambrian quartzite adjacent to, and at the same elevation as the Mississippian limestone. The fault plane dips about 56° West.

At exposure of the Cretaceous-(?)-Tertiary North Horn formation is found on the west side of the mouth of Payson Canyon. The northern-most exposure of the formation on the east side of the canyon is near the Maple Dell Scout camp. This suggests a horizontal displacement of about three miles.

Tear Faults

Tear, or wrench faults, occur in Piccayune Canyon, Crooked Canyon, and Yellow Rock Canyon. They strike in a general east-west direction and were formed during the Laramide Revolution. The horizontal displacement of the tear faults is not great, as can be seen on the geologic map (Plate I). The greatest amount of horizontal movement is found at Crooked Canyon, where the displacement may be as great as 1,000 feet.

The tear faults have been instrumental in forming the east-west canyons shown on the geologic map (Plate I). In Tie canyon, the Tintic quartzite beds can be traced across the canyon, showing that no horizontal displacement has occurred here.

Normal Faults

General Statement -- Following the Laramide orogenic movements, Basin-Range type normal faulting was instrumental in blocking out the form of the range (see fig. 3). In a study made on structural trends of the Wasatch Mountains, the eastern part of the Great Basin, and the west end of the Uinta Mountains, Eardley (1938, p. 1879) found that one of the most striking features is the lack of alignment of the Laramide and Basin-Range trends.

Nature of the faults. -- The Wasatch Range is in the form of a north-south trending monocline having a gentle dip slope to the east and a steep fault slope on the west. An important feature of the Basin-Range system is the Wasatch fault which is believed to be continuous from near

Fig. 3 View of Dry Mountain showing some structural features.

1. Normal down-dropped blocks 2. Well developed facet 3. Wasatch type fault

the Idaho-Utah border south to Nephi, a distance of about 130 miles. The fault trends about 12° west of north, and dips from 50° to about 70° West. The simplicity of the Wasatch fault is disrupted in the southern Wasatch Mountains (Eardley, 1933a; map 11, and Fig. 10), where a group of faults are most easily recognized by topographic unconformities between the ranges and the alluvial valleys. Well developed fault facets are seen along the west slope of Dry Mountain (see Fig. 3), and were formed by the Wasatch type faulting.

According to Fox (1906), the form of the Wasatch Mountains is in general that common to all ranges of the Basin region, and is known as the Basin-Range type.

Cause of the Faulting. -- According to Le Conte (Elements of Geology, p. 377) the region was gently arched by upward pressure from beneath. The crust, unable to withstand the tension, broke into blocks, which after readjusting themselves were left as mountain ranges. The occasional and slight earthquakes felt in places adjacent to the Wasatch Mountains are probably due to slight movements along the fault planes.

Gilbert (1875, p. 60) supposed that the region was broken into a series of blocks by vertical pressure from below. The vertical or nearly vertical adjustments of the brittle surface rocks were due to folds in a deep-seated layer that were induced by regional compression.

Le Conte (1889, pp. 257-263) suggests that the region was first raised by volcanic forces. When the upward pressure was relieved by the extrusion of vase amounts of lava, the weight of which was added to the overlying portion, subsidence of the whole region occurred. The subsidence was in the nature of a collapse in which the curst broke into blocks that settled irregularly.

Ransome (1915, p. 243) agrees with Le Conte that the structures were produced by a collapse of the region rather than an elevation, but sees no reason for supposing that any elevation by volcanic forces preceded the collapse. Butler (1920, p. 105) also believes that settling of the region is the most rational explanation.

The writer believes that a period of relaxation following the compressional stresses that occurred during the Laramide Revolution resulted in the normal type faulting as a means of restoring the isostatic equilibrium of the earth blocks.

Age of the Faulting. -- Normal Basin-Range faulting was the last type in the area, and this type is still in progress. Evidence of this was an earthquake, with subsequent movement along the fault blocks, which occurred as late as the Spring of 1950, in the southern Wasatch Mountains.

According to Eardley (1939, p. 1300), the Basin-Range faulting is post Laramide, post Wasatch conglomerate, post-mineralization, and is younger than an extensive early Tertiary erosional interval. On the basis of physiographic evidence in the Oquirrh Range, Gilluly (1932, pp. 40, 77, 86) thinks that faulting began not later than Middle Pliocene. Eardley believes that faulting in the Wasatch began in late Pliocene and proceded through the Pleistocene to the present (1933a, pp. 394-397). According to Loughlin (1919, p. 452) the block faults are post Eocene in age.

Mineralized Fissues

For the development of veins and replacement deposits, it is necessary to have pathways that can be followed by the mineralizing solutions. Joins and seams may produce them, but more commonly they are fissures brought about by faulting. When the waters have entered a fissure, the processes of replacement begin immediately, spreading in all directions, guided by the structural planes. Because of this, the replacement deposits in the limestone formations are characteristically irregular.

SUMMARY OF GEOLOGIC HISTORY

During late Archean time, the existing rocks were highly metamorphosed by increased temperature and pressure brought about in part by folding of the Earth's crust, causing schist and gneiss to be formed. These were then invaded by granite-pegmatite and quartz veins.

During Algonkian time the Big Cottonwood Series was formed. According to Blackwelder (1910, p. 520) the Algonkian rocks are probably not marine, but of continental origin.

The Paleozoic history of the region begins with submergence and marine sedimentation during the Cambrian Period with the deposition of sandstone, shale, limestone, and dolomite; probable emergence and erosion as indicated by the absence of sediments of Ordovician, Silurian, and Devonian age; and this was followed by resubmergence and marine deposition during the Carboniferous period with deposition of dolomite, limestone, and sandstone.

No sedimentary record of the interval between Mississippian and Tertiary time is to be found in the mapped area, but the presence of Triassic, Jurassic, and Tertiary rocks of considerable thickness to the south-east suggests that during at least part of this time, the region was receiving sediments (Eardley, 1933, pp. 307-310). The area was probably emergent during most of Cretaceous time.

Toward the end of the Mesozoic Era the rocks were compressed to form large folds with a north-south trend, probably as part of the Laramide Orogeny. The development of present land forms in the southern Wasatch Mountains began with this folding. The folding became intense and was followed by thrust faults, with subsequent development of tear faults. The east-west trend of the canyons seems to be a result of the latter.

After Wasatch formation time, volcanic eruptions distributed latite flows and tuffs in the general area. In the mapped area, only loose pebbles and boulders of andesite are left to show this part of the history. Some metal mineralization probably developed at this time, and is post-Laramide orogeny, and pre Basin-Range in age. The structure was then modified by intense normal faulting of the Basin-Range type, the entire stratigraphic column being affected by north-south trending faults.

During the Pleistocene Epoch, Lake Bonneville was present and extended eastward against the west base of Dry Mountain. Evidence of this includes terraces and other deposits which are prominent physical features in the area. Utah valley is veneered with sand, silt, and clay that were deposited in the Old Lake.

ECONOMIC GEOLOGY

GENERAL RELATIONS

Several mine adits and shallow shafts are present along the west slope of Dry Mountain, but only few show effects of mineralization. Of the prospects which show some mineralization, very few have actually produced ore. The occurrences are described as to their character, size, occurrence, distribution, and the geologic controls that have influenced the formation of minerals.

The mine adits and shafts are generally found along fault zones, especially in the zones of brecciation associated usually with normal faults. Several adits and shafts are found near the base of Dry Mountain from Piccayune Canyon on the north to Henry McGee Canyon (see Plate I). Most of these show little of anything except brecciation.

In the limestone the adits and shafts are concentrated in areas having a high iron content. Limonite is associated with minor fissures and fractures along faults that trend about N. 54°E., and some of these bear metalliferous minerals. The east-west and north-south faults, so far as can be determined, are non-mineralized. In some areas the limonite pinches out, leaving no trace of mineralization at depth. Abundant limonite containing finely disseminated and crystalline pyrite was found on some of the mine dumps. An abundance of pyrite-bearing limonite occurs near the mouth of Piccayune Canyon, in the Teutonic and Herkimer limestones.

HISTORY AND PRODUCTION

V. C. Heikes (see Butler, 1920, pp. 33-334) discusses the history and production of the Santaquin mining district. The mining district was organized in 1871, and it occupies an area that measures nearly six square miles, lying east of Santaquin, Utah. The U. S. Geological Survey has no records of production previous to 1901. From 1910 to the end of 1917, 470 tons of ore was produced, yielding 3,449 ounces of silver, 208 pounds of coper, and 206,552 pounds of lead, valued in all at $11,630. This production, however, was from the Santaquin, Mona, and Mount Nebo districts.

ORE DEPOSITS

Character and Size of Ore Deposits

The ore occurrences in the Dry Mountain area are characteristically small, varying from tiny stringers to a few pods containing less than 70 tons of ore. The ore minerals present include silver-bearing lead-zinc carbonates, galena, pyrite, and limonite; and copper occurrences that contain minor amounts of chalcopyrite, malachite, and azurite. Gangue minerals include minute quartz crystals, scalenohedral and massive forms of calcite, and minor amounts of dolomite and barite. Iron-stained calcite is commonly found along fissures. Most of the minerals found are highly oxidized. They consist of (1) deposits in sedimentary rocks, consisting of small veins and bedded-replacement deposits, and (2) deposits in metamorphic rocks consisting of vein-type copper deposits. The occurrences are probably epithermal, but have been altered by secondary processes.

Mineralogy

Lead-zinc mineralization. -- The lead-zinc minerals occur in small fissure veins, cavity fillings, and bedded-replacements in limestone and dolomite. The most favorable host rock is the coarse-grained limestone and dolomite that is free from clay and iron impurities. Mineralization is found in shattered zones, or in favorable beds that afford an opportunity for replacement. Silver occurs with the lead and zinc carbonates and galena. The presence of oxidizing pyrite has greatly facilitated the movement of silver in the mineralized areas, suggesting a possible increase in the silver content with increasing depth.

Pyrite and Limonite. -- Pyrite is characteristically a persistent mineral which forms in a wide range of temperature and is probably the most abundant primary mineral deposited. The pyrite has characteristically been altered to limonite, but occasionally some original pyrite is found with the limonite. Oxidation or weathering almost always results in the concentration of iron near the surface. In Piccayune Canyon, the limonite found shows a characteristic boxwork patter, suggesting that galena may have been present, but has been removed by weathering.

Dolomite. -- Some dolomitization has taken place along the fissures, primarily noted in the Syndicate adit.

Calcite. -- The calcite was introduced along bedding planes, faults, and fissures. It occurs most frequently as stringers, but some massive calcite and scalenohedral crystals do occur.

Barite. -- The barite present occurs in fissures and as replacement pods. The barite was probably introduced along fissure veins by ascending hydrothermal solutions. The pods of barite are small and not important economically.

Quartz. -- Massive quartz is associated with the barite in the Syndicate tunnel, and also with the copper occurrences in Henry McGee Canyon. In the lead-zinc deposits the quartz is clear, and occurs as a multitude of minute quartz crystals finely disseminated in the porous lead-zinc ore.

Copper. -- Small quantities of copper occur in veins and as stringers that follow fissure zones in the pre-Cambrian granite-gneiss and schist. The copper minerals include chalcopyrite, malachite, and asurite; these are associated with specularite and quartz. The Brownstone adit is representative of this type of occurrence.

Genesis

The ore deposits in the Dry Mountain area were formed by ascending aqueous solutions. Later, descending meteoric waters have been responsible for the oxidation of primary minerals to secondary, and for concentrating the minerals at greater depth along fissures. The hypogene minerals include: quartz, calcite, galena, barite, pyrite, sphalerite, and argentite. The supergene minerals include: azurite, malachite, limonite, cerussite, and anglesite(?).

Wall Rock Alteration

It is believed that all of the veins in the Santaquin district are of the low temperature, shallow-seated type. The basis for this conclusion lies in the fact that the zone of alteration associated with the mineralization on Dry Mountain is inconspicuous, or absent. The emplacement of pyrite, sphalerite, and galena may take in the epithermal zone.

Associated with the lead-zinc deposits, some dolomitized and silicified zones are found. Some sericite occurs with the copper minerals. The nature and intensity of alteration depend upon the nature of the wall-rock and the chemical character, temperature, and pressure of the mineralizing solutions.

Geologic Relations of the Ore Deposits

Stratigraphic Control

The most favorable host rock for ore emplacement is the coarse textured limestone and dolomite which is free from clay and iron impurities. The Teutonic limestone, especially the massive basal unit, is the most susceptible to the mineralizing solutions. So far as is known, all of the mineralization found occurs in the lower part of the Teutonic limestone.

In the veins, the wall rock shows evidence of selective replacement; this may be the reason for the spotty character of the mineralization.

Structural Control

Folding. -- Folds that were formed during the Laramide Revolution have likely been partial contr ls in the later emplacement of ore. Three adits are found in, or near the base of Piccayune Canyon in the vicinity of a large fold. Two are orebearing. The fold has an east-west axis and the recumbent limb dips about 56° South. The north-south direction of folding may also be a control for the concentration of minerals.

Faults. -- Systems of mineralized fissures traverse the area. The mineralized zone is associated with a series of faults that strike about N. 54° E., and dip about 65° to the west. These fault zones have acted as channelways for the ascending solutions to follow, and have been important controls in the concentration of minerals along the fissures and as bedded replacements. In the limestone and dolomite beds where the mineral-bearing fissures intersect the bedding planes, the minerals form in small vugs and replacements. Non-mineralized faults strike in a north south direction and have a dip of about 70° West.

Workings Present in the Area

General Statement

Most of the drifts and shafts are so badly caved that no attempt was made to map them. The properties that were investigated are summarized on Table No. 2. The best source of information was by personal communication with J. E. Nelson, Ben and Vern Bullock, and others.

Mine maps of the Elsie Jane and Syndicate drifts are included in the report (see Plates 2 and 3). The map of the Syndicate drift is in part duplicated from a map made in 1923 by G. W. Crane, mining geologist. The Elsie Jane drift was mapped in February, 1956 by the writer and Mack Croft.

Elsie Jane drift

Mr. J. E. Nelson of Spring Lake, owner of the Elsie Jane, informed the writer that prior to 1941 he shipped about 60 tons of lead ore, bearing a minor amount of silver. The ore assayed between 15 and 20 per cent lead. No shipments have been made since 1941, but Mr. Nelson has continued exploration work on the property until the present time.

In mapping the drift, the most significant structural feature is a north-south fault which dips between 43^{o} and 66^{o} West. The fault may be associated with the Wasatch fault system. No mineralization was found in the mapped part of the drift, but according to Mr. Nelson the ore came from a cross-cut that is now caved. The presence of water in the cross-cut caused Mr. Nelson to run another cross-cut to the south, then to work east and north-east to try again to intersect the mineralized zone (see Plate 3). Several samples of ore from the Elsie Jane drift were studied, and for the most part it is a porous mass of intergrown galena, cerussite, limonite, and finely disseminated microscopic quartz crystals.

Bullock drift

One drift and two steeply inclined shafts are located high on the south ridge above the Syndicate drift in Yellow Rock Canyon. No mineralization was found in the drift, but just beneath the surface of the ground large vugs lined with calcite, containing lead carbonate and galena were found.

Syndicate drift

The Syndicate drift is situated about mid-way up Yellow Rock Canyon, and has about 5,000 feet of workings. No lead mineralization was found except for a few small stringers of galena. An abundance of limonite occurs along the fissures, associated with yellow to buff-colored clay. The limonite and clay are associated with calcite and barite. Small replacement pods of barite also occur in the Syndicate drift.

Santaquin Central drift

The Santaquin Central or Brownstone drift is located about mid-way up Henry McGee Canyon, and has about 800 feet of workings. In the

Table No. 2 Prospects Present in the Area

No.	(D) Drift (S) Shaft Owner	Location	Production	Estimated Workings in Feet
1	Elsie Jane (D) J. E. Nelson	South of the mouth of Piccayune Canyon	60 tons of 10 to 15% Pb, Zn, and Ag.	600
2	El Dorado (D) Ben Bullock	South side of Piccayune Canyon near the base	10 tons of 15 to 20% Pb, Zn, and Ag.	300
3	Hope Standard (D) Ben Bullock	Mid-way up Piccayune Canyon	Assays only, no production	500
4	Spring Lake (D) Ben Bullock	South of the mouth of Crooked Canyon	No assays, no production	1,000
5	Bullock (D) (S) Ben Bullock	On ridge south of Yellow Rock Canyon, above Syndicate tunnel	70 tons of high grade Pb, Zn, and Ag.	200
6	Syndicate (D) Ben Bullock	Mid-way up Yellow Rock Canyon	Assays only, no production	5,000
7	Orelander (D) Ben Bullock	Near the base of Yellow Rock Canyon.	Assays only, no production	500
8	Golden Relief (D) Unknown	Just above the Bullock Mining Camp.	Assays only, no production Cu, Au, and Ag.	600
9	Will Croft (D) Will Croft	South of the base of Yellow Rock Canyon.	No assays, no production	750
10	Yellow Jacket (D) Unknown	On the ridge south of the Syndicate Adit.	No assays, no production	50
11	Wasatch Mining and Milling Co. (D) Unknown	Base of Dry Mountain, above large sandpit, several short adits	No assays, no production	1,800
12	Brownstone (D) Unknown	Mid-way up Henry McGee Canyon	Assays only, no production Fe, and Cu.	800
13	Neggley (S) Unknown	Western part of Sawmill flat, north of Yellow Rock Canyon	Assays only, no production Fe, and Pb.	40
14	Oppenshaw (D) (S) Unknown	Near the base of Henry McGee Canyon, Several tunnels and one shaft.	Assays only, no production Fe.	200

drift the mineralized zone is in an argillite member of the Precambrian quartzite. Some ore-forming minerals are present, but so far as is known, no production has come from the property.

Other properties

All of the properties listed on Table 2 were examined, and samples that reportedly came from the properties were studied. The mineralized rock suggests secondary mineralization.

Potential of the District

Up to the present time, the most profitable venture on Dry Mountain is probably the production of sand and gravel from the pits located on the west slope of the mountain between Payson and Santaquin. The most extensive workings is found immediately north of the mouth of Yellow Rock Canyon along the Lake Bonneville terrace.

Since the organization of the mining district in 1871, perhaps less than 200 tons of ore have been mined from the northern half of Dry Mountain. The production record speaks for itself. The writer regards the ore potential of the area to be nil, and discourages further exploration or development work.

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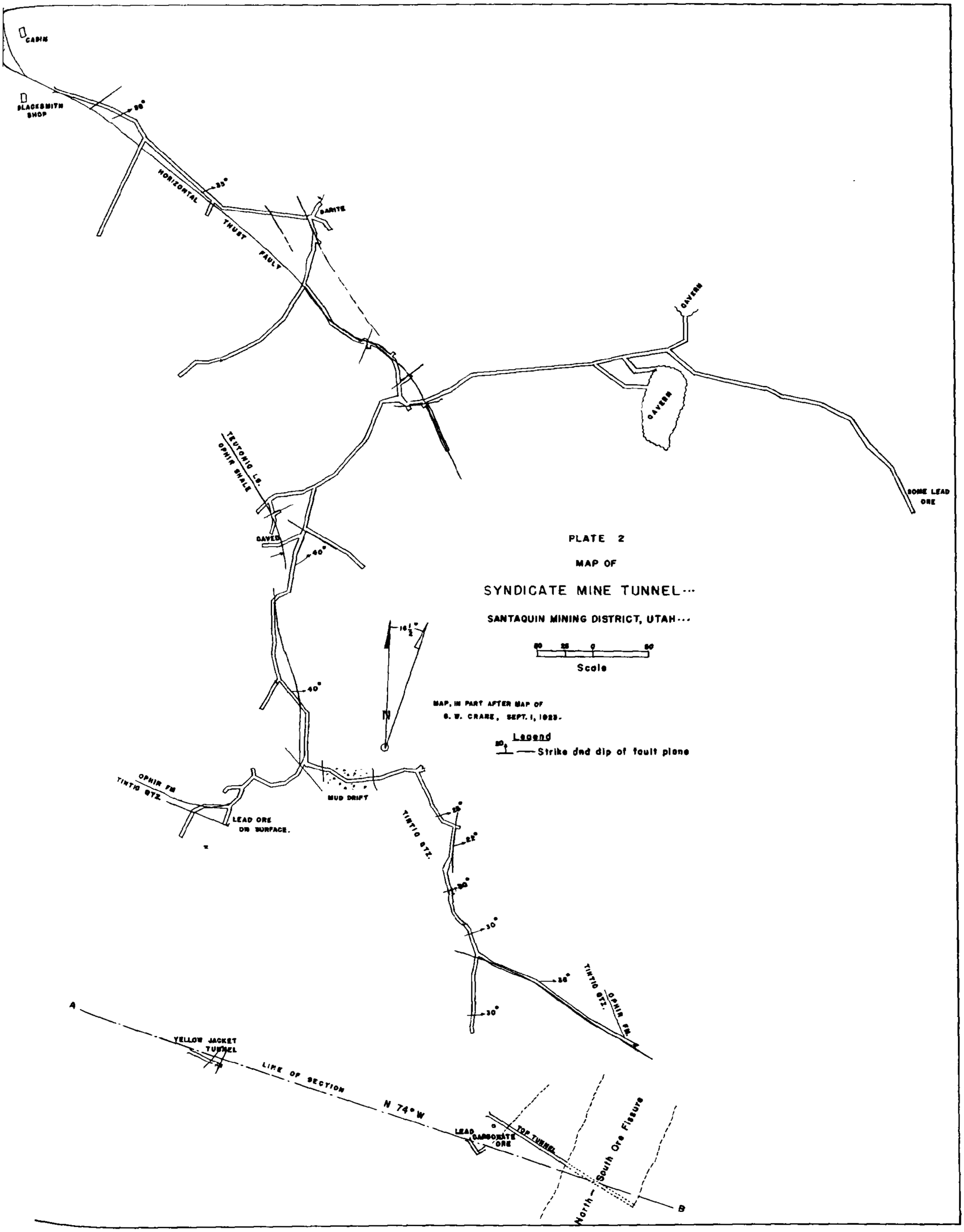
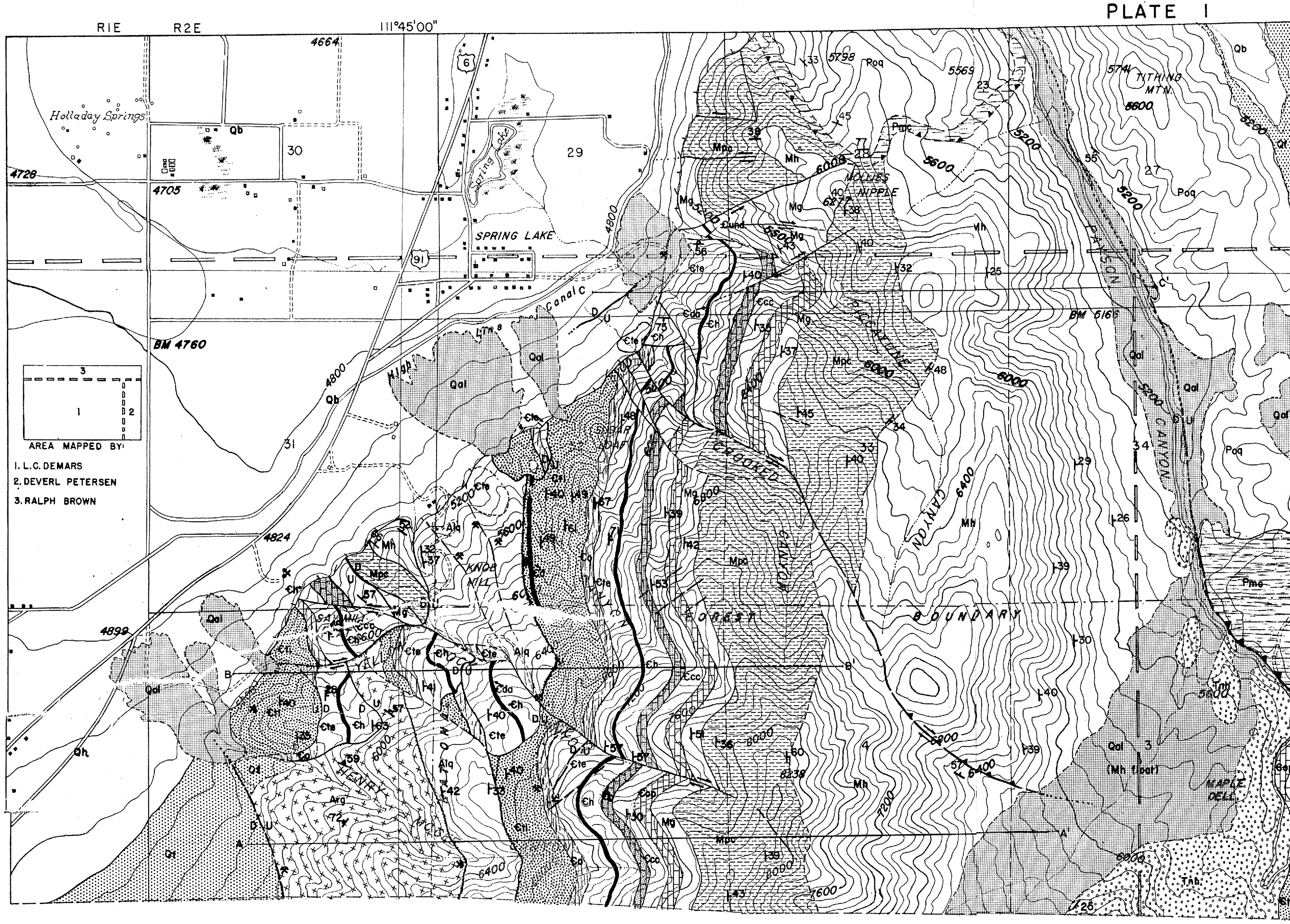


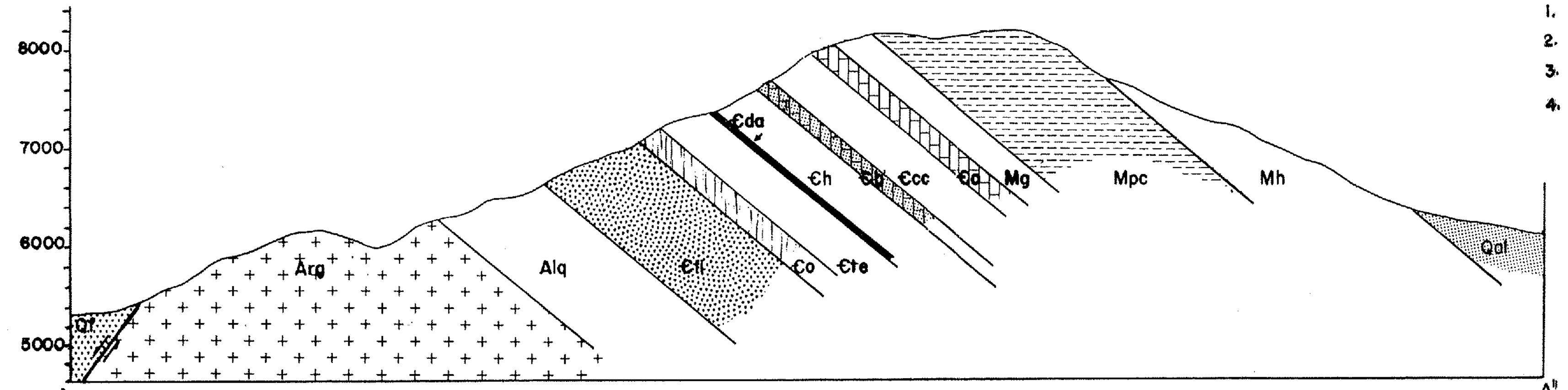
PLATE 2
MAP OF
SYNDICATE MINE TUNNEL...
SANTAQUIN MINING DISTRICT, UTAH...
Scale
MAP, IN PART AFTER MAP OF
G. W. CRANE, SEPT. 1, 1923.
Legend
Strike and dip of fault plane
CABIN
BLACKSMITH SHOP
HORIZONTAL THRUST FAULT
BARITE
CAVERN
CAVERN
SOME LEAD ORE
TEUTONIC LS.
OPHIR SHALE
CAVED
OPHIR FM
TINTIC QTZ.
LEAD ORE ON SURFACE.
MUD DRIFT
TINTIC QTZ.
TINTIC QTZ.
OPHIR FM
YELLOW JACKET TUNNEL
LINE OF SECTION
N 74° W
LEAD CARBONATE ORE
TOP TUNNEL
North - South Ore Fissure
A
B
N

PLATE I

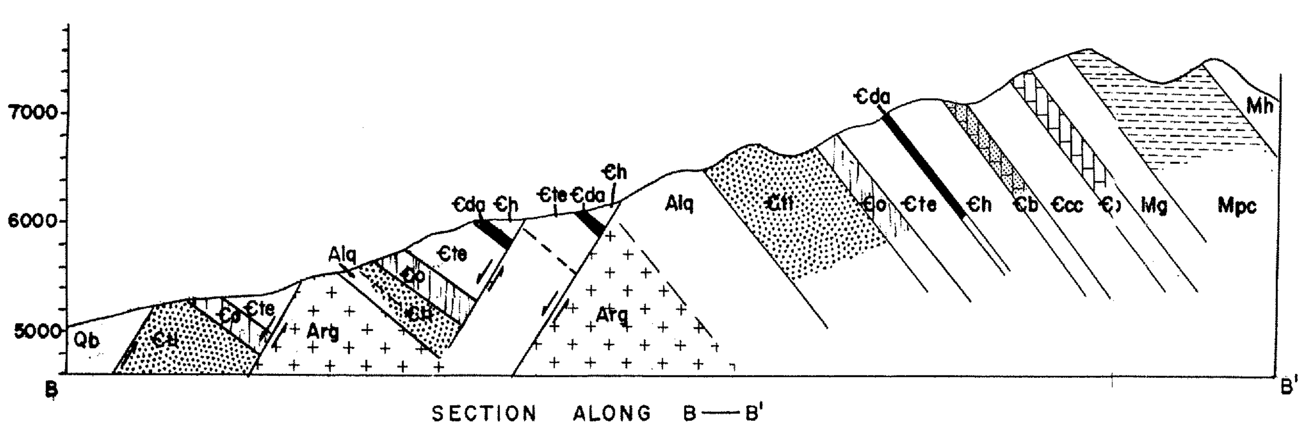


MAPPED ON 1:12,000 AERIAL PHOTOGRAPHS FROM 1953-55

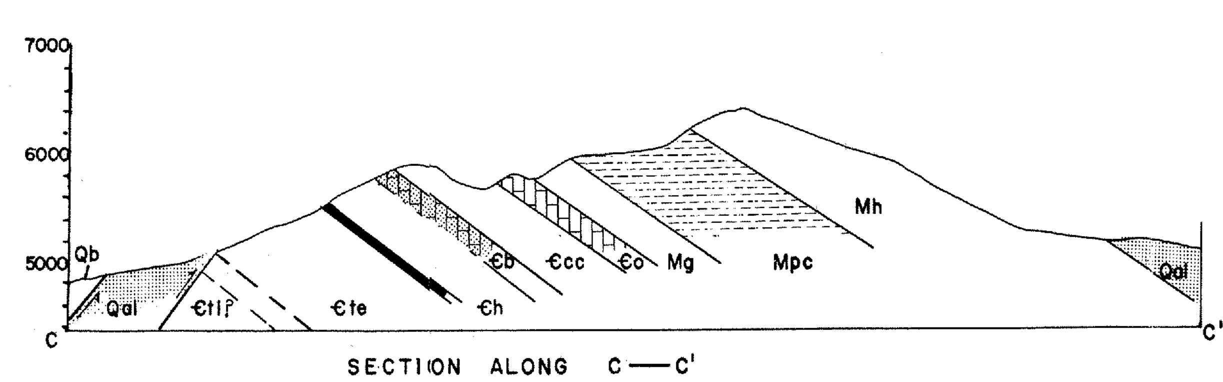
BASE MAP FROM THE FOLLOWING TOPOGRAPHIC SHEETS:
1. NEBO CREEK
2. WEST MOUNTAIN
3. NEPHI NO. 1
4. SPANISH FORK



SECTION ALONG A—A'



SECTION ALONG B—B'



SECTION ALONG C—C'

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY
- Qal — Alluvium
- Qb — Lake Bonneville group
- Qf — Fanglomerate

TERTIARY
- Tm — Moroni formation
- Tnh — North Horn formation

PENN.
- Poq — Oquirrh formation
- Pmc — Manning Canyon shale

MISSISSIPPIAN
- Mh — Humbug formation
- Mpc — Pine Canyon limestone
- Mg — Gardner dolomite

CAMBRIAN
- €op — Opex dolomite
- €cc — Cole Canyon dolomite
- €b — Bluebird dolomite
- €h — Herkimer limestone
- €da — Dagmar limestone
- €te — Teutonic limestone
- €o — Ophir formation
- €ti — Tintic quartzite

PRE CAMBRIAN
- Alq — Big Cottonwood series
- Arg — Farmington Canyon complex

IGNEOUS ROCKS

CAMB.
- €d — Diabase flow

PRE CAMB.
- Arg — Archean granite

SYMBOLS

- 40 — Dip and strike
- 55 — Dip and strike of overturned beds
- U D — Fault-dashed where approximately located, dotted where concealed, D= Downdropped side, U= Upthrown side
- Fault showing relative movement
- Thrust fault, saw teeth on side of upper plate
- 39 — Strike and dip of foliation
- 75 — Strike and dip of joints
- Formational contact inferred
- Sand and gravel pit
- Mine or prospect
- Hachures on side of overlapping beds over fault contact

$16\frac{1}{2}°$

TRUE NORTH

MAGNETIC NORTH

GEOLOGIC MAP AND CROSS SECTIONS OF THE DRY MOUNTAIN AREA SOUTHERN WASATCH MOUNTAINS, UTAH

BY

LORENZO C. DEMARS

1956

1000 500 0 1000 2000 Feet

Scale

Contour interval 80 Feet.