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GEOLOGY OF THE BISMARK PEAK AREA
NORTH TINTIC DISTRICT
UTAH COUNTY, UTAH

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GEOLOGY OF THE BISMARK PEAK AREA, NORTH TINTIC DISTRICT, UTAH COUNTY, UTAH

A Thesis

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ABSTRACT

The Bismark Peak area is part of the Boulter and East Tintic Mountains near Eureka, Utah. It comprises part of the North Tintic Mining District. The area has a strategic location because of its position in respect to well-known mining areas such as Bingham, Mercur, and Ophir only a few miles to the north and Park City, American Fork, Cottonwood Canyon, and Alta Mining Districts to the northeast. The Tintic Mining District which has produced approximately one-half billion dollars in metals adjoins the Bismark Peak area on the south.

Seventeen Paleozoic formations are present ranging in age from Lower Cambrian to Upper Mississippian. Over 11, 000 feet of stratigraphic section is exposed. Some volcanic rocks of very minor extent occur in the area.

The major structural feature is a north trending north plunging anticline known as the North Tintic Anticline. It is overturned on the east flank and has moderate to gently dipping beds on the west flank. This fold is approximately six miles wide with a minimum known length of fifteen miles and an amplitude of 16, 000 feet. Erosion has breached the anticline so that a valley is now present along the axis except in the area of this report.

An overthrust has occurred in the Boulter Peak area which has displaced the beds along the east limb approximately one and one-half miles eastward.

The writer mapped the geology of the area and in addition has produced a map showing areas where there has been alteration of the rocks by hydrothermal activity.

It is hoped that this report discussing the geology and showing areas of interest to prospectors and miners will serve to stimulate renewed interest in the Boulter Mountains and consequently help to add new metallic reserves to the State of Utah.

INTRODUCTION

PURPOSE

The purpose of this study is to map the areal geology of an area in the Boulter Mountains of the North Tintic Mining District and to delineate areas of alteration and mineralized zones as a guide to prospective mining developments.

LOCATION AND ACCESSIBILITY

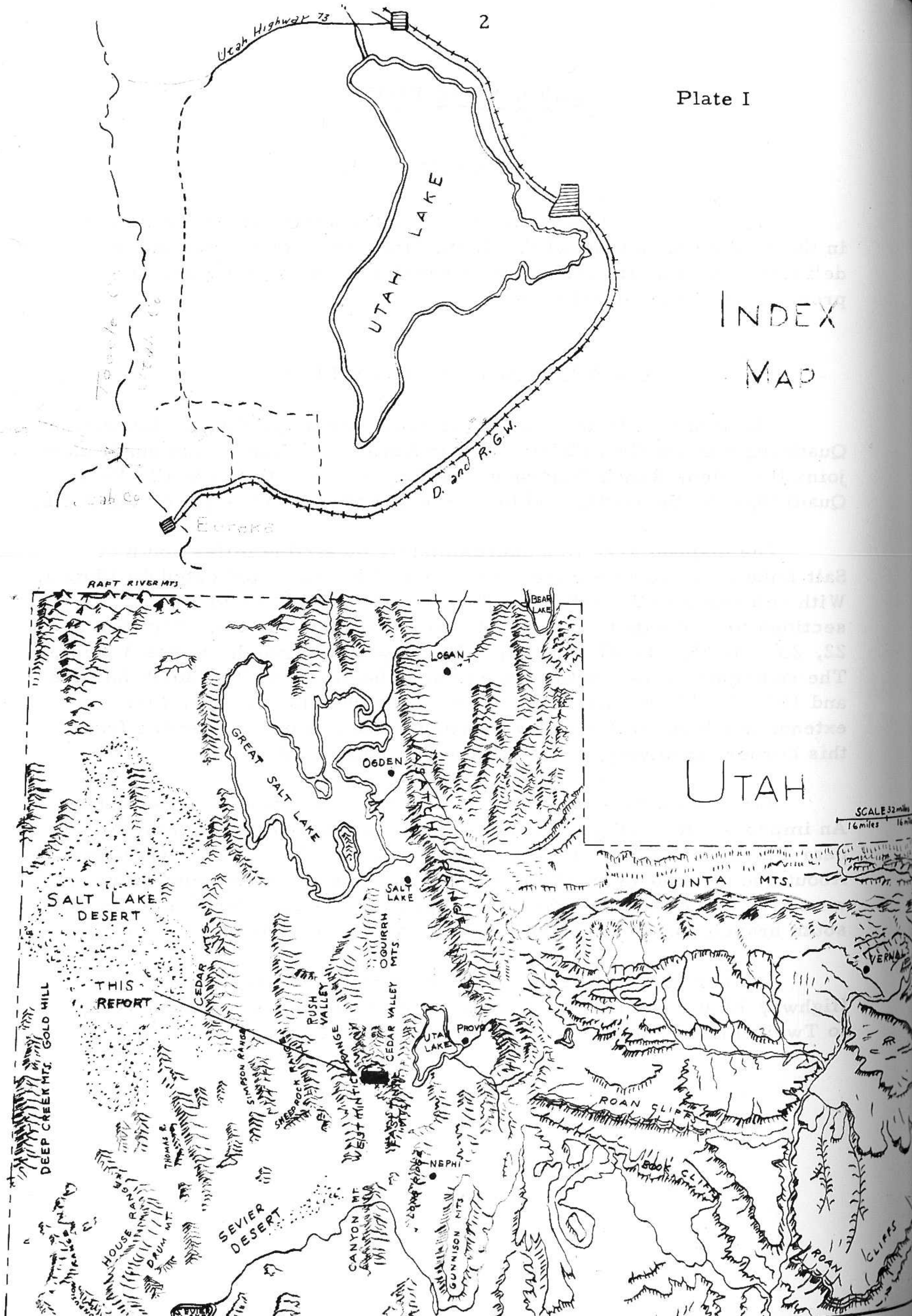
The Bismark Peak area lies entirely within the Boulter Mountains Quadrangle in the North Tintic Mining District of Utah. This quadrangle joins the Allens Ranch Quadrangle on the east, and the Fivemile Pass Quadrangle on the north, and the Tintic Junction Quadrangle on the south.

The mapped area lies approximately 60 airline miles south of Salt Lake City and 19 airline miles west of Provo as indicated on Plate I. With reference to the Salt Lake Standard Meridian, the following sections or parts thereof are included in the mapped area: Sections 21, 22, 23, 24, 25, 26, 27, and 28, all in Township 9 South, Range 3 West. The southeast corner of the present area begins at 49°00' north latitude and 112°07' 30" west longitude. The area consists of a strip that extends north two miles and west about three and one-half miles from this corner, involving an area nearly six square miles.

Various roads make the Bismark Peak area readily accessible. An improved dirt and graveled road extends from Utah Highway No. 73 near Fairfield southward the length of Cedar Valley past Allens Ranch. About one mile north of Allens Ranch an unimproved dirt road extends westward to Twelvemile Pass. At this point the road forks and the south branch continues through Broad Canyon to the mapped area.

Another dirt road from the north, which departs from U. S. Highway 73 at Fivemile Pass, follows the eastern edge of Rush Valley to Twelvemile Pass and the entrance to Broad Canyon.

Plate I



Approach from the east and south is by U. S. Highway No. 6. An improved dirt road extends northward from the hard-surfaced road at Elberta and leads to Allens Ranch through Rattlesnake Pass and Greeley Pass. An unimproved dirt road departs northward from U. S. Highway No. 6 about four miles east of Eureka, and enters Cedar Valley west of Pinyon Peak.

From the west a road leads through Black Rock Canyon through the only pass in the southwestern part of the Boulter Mountains, through Barlow Canyon and south down Broad Canyon. This route is recommended for field cars only.

The nearest railroad is a branch of the Denver and Rio Grande Western located eleven miles to the south via the Homansville Pass road into Eureka.

PREVIOUS WORK

The first investigation of the Tintic Mining District was made almost eighty years ago by Wheeler (1875). He noted that Cedar Valley was an intermontane valley between north trending parallel ridges. Gilbert (1890, p. 128) stated that an embayment of Pleistocene Lake Bonneville occupied part of Cedar Valley, while Smith and Tower published data on the Tintic District eight years later (1898, pp. 601-767). Emmons, Tower and Smith mapped the Tintic District and published the results in a Geologic Folio (1900). Jones (1902) contributed new information on the mineralization of the Tintic District (1919), but made only a rapid reconaissance of the North Tintic District (1919, pp. 265-266), and described some of the stratigraphy and faults of the area. This remained the most comprehensive report of the area until 1950. They mentioned a north-northeastward trending anticlinal axis which pitched northward beneath Broad Canyon.

Kildale (1937) mapped an area to the east and southeast of the New Bullion Area. Morris (1946) provided descriptions of the volcanic rocks in the East Tintic Mining District.

Lovering has been undertaking detailed studies of the alteration zones in the volcanics of the East Tintic Mining District for the U. S. Geological Survey.

A report and map of the geology of the Allens Ranch seven and one-half minute quadrangle has been made by Proctor for the U. S. Geological Survey.

Johns (1950) made a detailed study of a small area near Twelve Mile Pass.

Renzetti, Axenfeld, and Sargent, graduate students at Indiana University, worked in areas of the Boulter Mountains west of Broad Canyon with the results of their work being used as Masters theses (1952).

Dearden recently mapped the Central Boulter Mountains (1954).

Disbrow was engaged in mapping the Boulter Mountains seven and one-half minute quadrangle for the U. S. Geological Survey during the latter part of 1953. He finished this work together with the mapping of the Five Mile Pass Quadrangle in 1957. A preliminary map on the latter has been published (Morris and Disbrow, 1957).

PRESENT WORK

This report is the result of field investigations that were begun in August, 1953, and continued intermittently to August, 1954, as an M. S. thesis requirement in geology at Brigham Young University. During the course of this study the writer usually worked alone.

Standard field methods were used during the mapping of the area, with a Brunton compass and an altimeter being the instruments used. Base maps consisted of topographic sheets and aerial photographs, both enlarged to a scale of 1:12,000. Final drafting of the geologic map was facilitated with the aid of a Kail Plotter.

PHYSICAL FEATURES

The mapped area is located in the south-central part of the Boulter Mountains, which includes some of the most rugged physical features of the Tintic Mining District. Bismark Peak (also known as Bismark Hill) stands as the highest prominence in this range, and it rises in marked relief above Cedar Valley. The Peak itself consists of three prominences with relatively minor elevation differences, the highest being over 8,050 feet above sea level. This elevation is closely approached but not exceeded by three peaks located along the southern boundary of the area. The valley floor in the area is at 6300 feet.

The major topographic feature of the southern part of the area is an east-west trending ridge averaging about 7800 feet elevation, which represents not only a drainage divide but also the dividing line between counties; this is called "Skyline Ridge" in this report.

All drainage is intermittent.

The vegetation is typical of a semi-arid climate. Juniper trees and sage brush predominate, with needle grass and bunch grass providing food for foraging sheep and cattle. In the higher elevations pine trees provide a luxuriant cover for the hillside, with quaking aspens on some slopes.

The total annual precipitation recorded at the Tooele City Station is as follows:

TOTAL ANNUAL PRECIPITATION

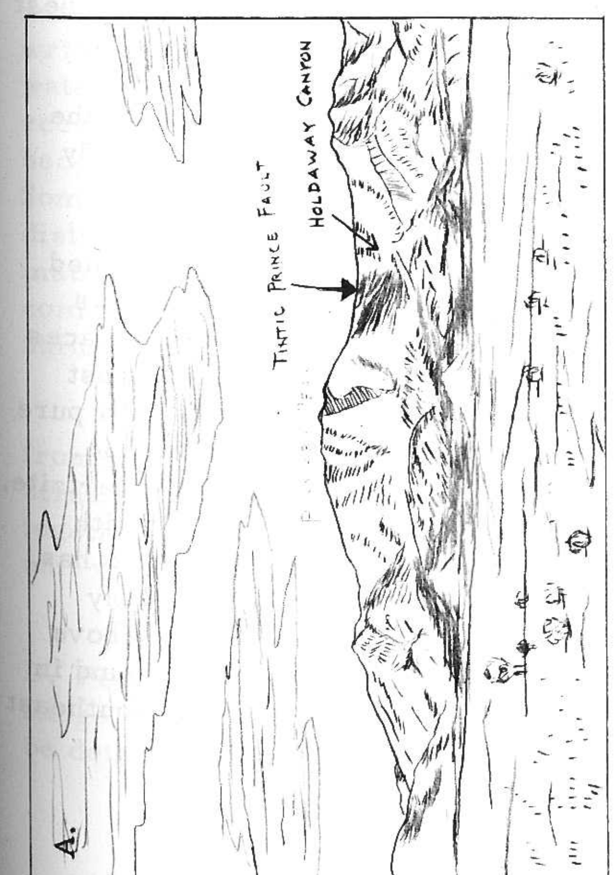
Year	Inches of ppt.
1944	18.45
1945	18.21
1946	14.03
1947	22.27
1948	16.43
1949	16.67
1950	13.80
1951	15.97
1952	15.67
1953	12.20
1954	9.14

Table I.

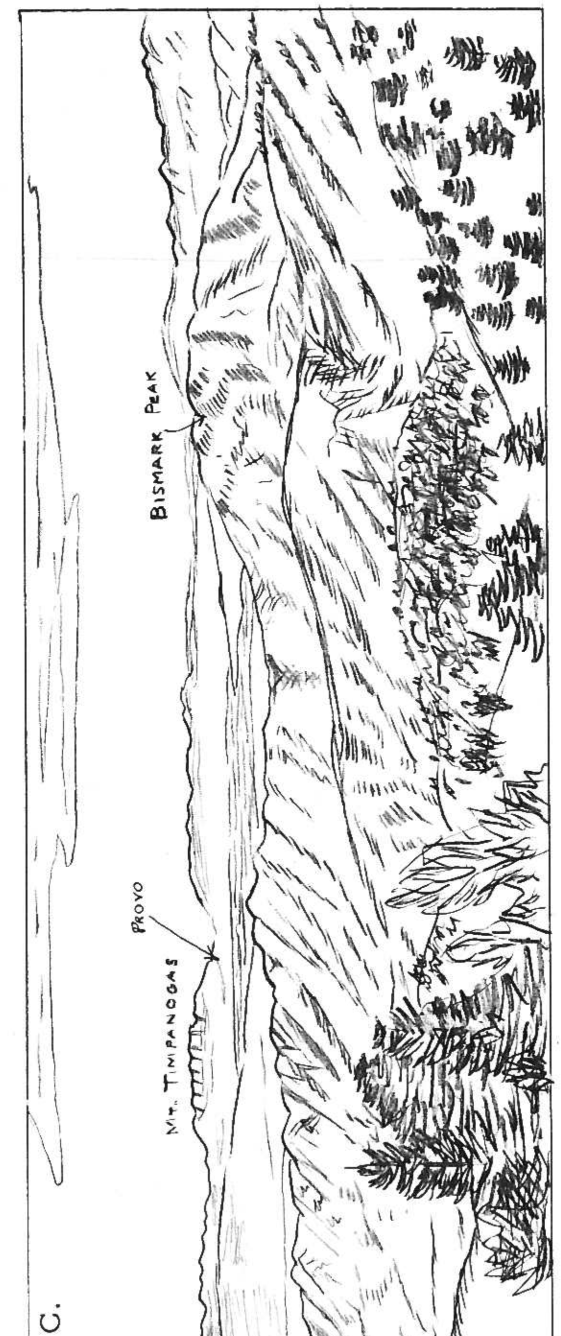
An asymmetrical anticline comprises the main structural feature of the area. The anticline has an overturned east limb. It has a known length of approximately fifteeen miles as of the present time and a width of six miles with an average plunge of 20 degrees to the north.

Some of the world's foremost mining districts are located within the general region. Tintic, approximately three miles to the south, Stockton (which includes the Ophir, and Mercur assemblage of mines) is to the north about 25 miles, Bingham is within fifteen miles of Stockton, and the Park City, American Fork, and Cottonwood Canyon Mining Districts, all of which have produced metals valued at many hundreds of millions of dollars are east of Bingham, within approximately 35 miles. Some of these mining districts such as at Bingham, Stockton, and Tintic are in close relationship to folds. Culminations or plunging folds, particularly anticlines, have been given special consideration in this study because of their localizing effect on ore bodies near extrusives.

B.



A.



C.

A. Bismark Peak as seen from Allen's Ranch.

B. Panorama looking east toward Utah Lake from central part of Bismark Peak area.

C. Broad Canyon showing East Limb of North Tintic Anticline.

Upper plate of overthrust occupies most of East Limb to the left of Bismark Peak.

STRATIGRAPHY

CAMBRIAN SYSTEM

Tintic Quartzite

The Tintic Quartzite is by far the most extensive formation in the area; the great thickness of the formation, exposure by the erosion of the axis of an anticline, and faulting, all combine to give the wide areal distribution. It forms the top of "Skyline Ridge, " the principal divide which forms the boundary line between Utah and Juab Counties, from the extreme west part of Section 26 to the west part of Section 27 and for the most part occupies Sections 22 and 23, with a small part in Section 28. Near the north boundary of the area, the Tintic Quartzite disappears beneath alluvium. The Tintic Quartzite was named by Tower, Smith and Emmons (1899, p. 1) from outcrops in the Tintic Mining District.

The exposed thickness is 3500 feet, but the base of the formation is not revealed. The upper contact is taken at the quartzite bed highest in the stratigraphic column. The 6000 foot thickness for the Tintic Quartzite reported by Loughlin (1919, p. 24) is thought by some members of the U. S. Geological Survey to be due to repetition of the beds by folding and faulting and that 2300 to 3200 feet is more nearly correct (Morris, 1957, p. 4).

The Tintic Quartzite has three lithofacies which may be termed typical. The first type is white with a grayish or greenish hue; this variety is usually a finely-crystalline, pure quartizte. In some places bedding is fairly good, but generally it is very indistinct. The most common type is light pink in color, with a reddish hue. It too is a pure crystalline quartzite with true bedding planes difficult to determine. The least common of the three types is light to medium-brown quartzite, commonly with a sandy appearance on weathered surfaces, and with some sandstreaking and cross-bedding evident. Much of this type has a reddish hue on the weathered surface, the grain size is generally coarse, and the bedding is more readily seen. Each one of the above varieties grades into others. Several conglomerate beds are found in the formation. One of the most prominent is exposed near the southeast

part of Section 27 near the southern boundary of the area. This is approximately four feet thick and has rounded white quartz pebbles typically five mm. to fifteen mm. in diameter in a purple matrix. This dark-colored conglomerate is believed to lie close to the basal Cambrian. Usually the beds are much thinner although the pebbles seem to have much the same appearance and size. The fault breccia fragments are angular and are usually in a brown matrix. Although slate and/or shale has been mentioned by others (Lindgren and Loughlin, 1919, p. 23; Johns, 1950, p. 10) the writer did not find any, although there is a small occurrence of slaty beds on the crest of a north-south ridge in Section 27 it appeared to be a shattering of the beds due to folding and possible faulting and not a sedimentary feature. Johns (1950, p. 10) states that several shale and sandy shale beds occur in the upper part of the formation becoming more abundant toward the younger sediments. The present writer noticed a decrease in the thickness of bedding in the same direction and found some ripple marks in that part of the section. Loughlin also found ripple marks (1919, p. 23).

Under a hand lens the grains comprising the lighter colored varieties of Tintic Quartzite appear to be very clean, well sorted and rounded. The general character of the grains suggests deposition on a stable shelf. The presence of ripple marks and cross-bedding would indicate that the depth of water was not deep, probably in the epineritic and infraneritic zones (from 30 to 120, and 120 to 480 feet deep). This writer envisions a broad geosynclinal area about 50 feet deep with the water rarely exceeding 200 feet in depth, gradually subsiding and receiving sediments from a nearby land mass, with the detritus becoming reworked and well-sorted many times before final deposition. Some of the finer sediments became shale. Occasional minor tectonic disturbances and cross-currents introduced a varied assortment of material that became buried before it could be well sorted, more commonly along the margins of the geosyncline. This became conglomerate. Shifts in current direction helped to create interbedding.

Tintic Quartzite was traced by the writer as a continuous unit from the type locality in the Tintic District. It is in the correct relative stratigraphic position at the base of the stratigraphic sequence, this together with its thickness and lithology places the correlation of this unit with the Tintic Quartzite of the Tintic District beyond any doubt.

No fossils had been found in the Tintic Quartzite until 1953 when D. Peterson reported and photographed an incomplete trilobite at Long Ridge near Goshen, Utah. The correct identity of this fossil could not be determined. Lindgren and Loughlin (1919, p. 24) assigned the top of the Tintic Formation a position very close to the boundary between Lower and Middle Cambrian on the basis of trilobites reported in overlying shales in the Oquirrh Mountains (Emmons, 1895, p. 362). These trilobites were thought to be of Lower Cambrian age, but this age assignment was in error. Walcott (1908, p. 171) also found fossils which were thought to be of Lower Cambrian age in Big Cottonwood Canyon in the Wasatch Mountains near Salt Lake City, Utah. This identification also is now considered to be erroneous. He also found Middle Cambrian fossils in the Blacksmith Fork section of the Northern Wasatch Mountains near Logan, Utah. Weeks found Middle Cambrian fossils in the Tintic District in the overlying shale. Walcott (1891, pp. 319-320) calls attention to the discovery of what was thought to be Lower Cambrian fauna in a very low zone in the overlying shale, while the Middle Cambrian forms are located about 100 feet higher and suggests that the same relation exists at Ophir. On the basis of this discussion, Gilluly (1832, p. 90), placed the Lower-Middle Cambrian boundary to include a few feet of the overlying shale. Today, the belief is strongly held that no Olenellus has been found in the part of Utah discussed above and all older reports listing the fossil and using it as evidence of Lower Cambrian formation-dating likely are based on wrong identification. The nearest verified occurrence of Olenellus is in the House Range of central Utah.

In conclusion, a Lower Cambrian age is most likely for the Tintic Quartzite.

Ophir Formation

Named after the mining town in the Oquirrh Mountains, Utah, by B. S. Butler, the Ophir Formation at its type locality consists of shales which are locally slaty, and some sandstones with intercalated beds of limestone. It crops out on Skyline Ridge in the SW¼ of Section 26 and in Sections 21, 22, 23, and 24. On the ridge it forms a saddle wedged between the Tintic Quartzite on the west and the overlying Teutonic Limestone on the east. Its thickness here is 146 feet compared to 320 feet at the type locality, 430 feet in the Twelvemile Pass area, and 297 to 475 feet in the Tintic District. Lindgren and Loughlin (1919, p. 26) noted that there is considerable lensing and variation in the thickness of the shale and limestone beds within the Ophir Formation. A comparison of lithology with other sections shows that approximately the upper half to two-thirds of the formation is missing at the saddle on Skyline Ridge, the missing portion consisting largely of limestone, with some interbedded shale. The thinning and pinching out is possibly due to the lensing of some

of the beds and to the effect of compression on incompetent beds. The Ophir Formation is also found at the Hot Stuff Mine also in the northeast quarter of section 22, and near the base of the ridge separating Tooele and Utah Counties in the east half of Section 22. Ophir Shale is seen also on the dump of a shaft near the floor of Rattlesnake Canyon in the SE¼ of Sections 24 and 14. The Ophir Formation was measured in this area and was 547 feet thick. The uppermost shale bed is chosen as the contact with the Teutonic Limestone Formation.

The dominant color of the shale is yellowish-green, with local changes to reddish-brown in outcrops subject to jointing. Near the contact with the Tintic Quartzite the formation is reddish-brown in color and is platy rather than shaly; within fifty feet of the contact there is a thin to medium bed of purple colored phyllite that is markedly micaceous. Farther up the section the shale becomes very thin bedded. Several beds of limestone occur up-section, with some interbedding with shale occurring. The limestone is generally medium-gray or reddish-brown and weathers to medium-grey or yellowish-brown often with argillaceous streaking. Much of it is thin-bedded but it ranges to thick-bedded. An especially resistant sequence is near the top. This often forms the only outcrop of the formation. The limestone beds may easily be mistaken for the overlying Teutonic Limestone or in faulted areas for the Herkimer Limestone, or some parts of the Opohonga Limestone as they also possess argillaceous partings colored yellow, brown, and red in limited areas. The limestone is noteworthy for the irregularity of weathered surfaces. It is difficult in isolated outcrops to procure a dependable attitude.

On the basis of lithology and stratigraphic position, this formation is correlated with the Ophir Formation of the Tintic District. The known variability in thickness of the formation in other areas may partly account for the relatively small thickness measured by the writer in some places. The limestone beds seen in other areas are known to be lenticular in nature, in addition the incompetent beds are possibly thinned or eliminated by the great compressional forces involved during folding.

The writer found no fossils in his area, but according to Gilluly (1932, p. 11) Dr. C. E. Resser reported Dolichometopus productus, and Neolenus found fifty feet above the base of the Ophir Shale group of the type locality and also found in the nearby Wasatch Mountains, appear to occupy a position below the middle of the Middle Cambrian. E. B. Weeks in 1905 (Lindgren and Loughlin, 1919, p. 26) thought the age to be Middle Cambrian after identifying Obolus mcconnelli and O. rotundatus found 100 feet above the base. Walcott (1912, pp. 164-165) listed Obolus (Westonia) ella, Micromitra sp., Micromitra (Paterina) labradorica utahensis, Olenoides (?), all of which are assigned to the Middle Cambrian. However, in discussion of the collections of the Wheeler Survey, Lingulella ella, Olenellus gilberti, and Bathyuriscus producta were listed as occurring at the base of the shale. Walcott later reported that the Olenellus actually had been collected from the House Range rather than from the originally designated locality.

Walcott restricted Olenellus to the Lower Cambrian and never relinquished the belief that in the absence of other fossils it should be given any other age. According to Gilluly (1932, p. 11) both Ulrich and Burling questioned this restriction, although Burling later agreed with Walcott in assigning the lower part of the Ophir Formation to the Lower Cambrian. Gilluly (1932, p. 27) agrees that the bottom part of the formation might possibly be Lower Cambrian age, but since Dr. Resser identified fossils as Middle Cambrian that were collected within fifty feet of the base, the Lower Cambrian certainly will not extend beyond the basal fifty feet. Ulrich (1911, pp. 619-620) maintained that Olenellus survived into the Middle Cambrian as it was reported to have done in the Appalachian region.

The Ophir Formation because of fossil evidence cited above, is almost certainly Middle Cambrian.

Muessig (1951, p. 18) found the following fossils in the Long Ridge area:

F-17 Ehmania cf. either E. weedi (Walcott) or E. oweni (Hall and Whitfield)
Obolus sp.
Lingulella sp.
F-35 Glossopleura producta (Hall and Whitfield, many specimens
Alokistocare cf. A. subcoronatum (Hall and Whitfield)

The above fossils were identified by Christina Lochman who thought that the collection F-35 came from the Glossopleura-Kootenia zone of the Middle Cambrian; from the overlying fauna, she suspects that it lies in the upper half of the zone. This would help substantiate a lower Middle Cambrian age for much of the Tintic Quartzite Formation. Collection F-17 is from the lower part of the Ehmania-Bolaspis-Glyphaspis zone and therefore provides a rather exact correlation for the top of the Ophir and base of the Teutonic Limestone overlying it.

It is now possible to extend correlation of the Ophir Formation to the south to southeastern Nevada. The Ophir appears to be equivalent lithogenetically to the upper part of the Lyndon Limestone, and to the Chisholm Shale in the Pioche District, Nevada. On the basis of fauna, the Ophir is equivalent to the Chisholm and quite probably part of the Lyndon. The Spence Shale member of the Langston Formation and the upper Langston appear to be time equivalents of the Ophir because of the position above the Brigham (Tintic) Quartzite, and the presence of Glossopleura and Alokistocare in the Spence Shale (Williams and Maxey, 1941, p. 282). As suggested by Wheeler (1943, p. 1815) and others it is now possible to say that the shales above the quartzites, present from the Grand Canyon region to northern Utah and southeastern Idaho are lithogenetic equivalents, which become progressively younger toward the north and east (Muessig, 1951, p. 19).

Teutonic Limestone

This formation was named from Teutonic Ridge in the Tintic District by Lindgren and Loughlin (1919, p. 27). It crops out in Sections 21, 22, 23, 24, 25, and 27.

It is 626 feet thick compared to 564 feet in the Tintic District.

The Teutonic Limestone typically weathers to blue-grey with discontinuous yellow, brown, or red-tinted argillaceous partings. The contact with the Ophir Shale is at the base of a massive oolitic limestone. The contact with the Dagmar Limestone is gradational.

The Teutonic Limestone resembles parts of both the Herkimer Limestone and the Opohonga Limestone, and correct identification can only be obtained by the location of the Dagmar Limestone and the top shale member of the Ophir Formation.

Fossils were not found in this formation in the writer's area and few had been found until Muessig (1951, p. 23) reported the presence of:

Bolaspis labrosa (Walcott)
Glyphaspis sp. undetermined
Undescribed trilobite genus

On the basis of the above fossils Muessig (op. cit.) states that the lower Teutonic Limestone at least, is correlative with the upper Muav Limestone and that the whole formation is represented by the lower part of the Meagher Limestone of Montana.

Loughlin (1919, p. 27) placed the age of the Teutonic Limestone in the Middle Cambrian because of its position between known Middle Cambrian beds.

Correlation of the formation in the writer's area and that of the Tintic District is on the basis of stratigraphic position and lithology.

In 1920 Wichman (pp. 560-563) correlated the Hartmann Limestone of the Ophir District with the Teutonic and Dagmar Limestones of the Tintic Mining District. In 1921 Olmstead (p. 44) also made this correlation. Gilluly, (1932, p. 13) found fossils scarce but collected a few which were reported by Dr. C. E. Resser to be Middle Cambrian. Because of the thirty miles separating Ophir and Tintic, Gilluly would not correlate the formations in their entirety, but he thought there was little doubt that the lower part of the Hartmann Limestone is equivalent to the lower part of the Teutonic Limestone of Tintic. However, the distinctive lithology of the overlying Dagmar Limestone of the Tintic region does not have its counterpart in the Ophir District, and since paleontologic evidence is lacking or scarce, precise correlation is not advisable.

Dagmar Limestone

Dagmar Limestone was named from the Dagmar mine of the Tintic District by Loughlin (1919, p. 27). It crops out in Sections 21, 22, 24, 26, and 27. The thickness is 77 feet. In the type locality the thickness is 100 feet.

Although lithologically it is a limestone in the type locality, the Dagmar Formation is a dolomite in the mapped area. Light-grey on fresh fracture the color when weathered is pale greenish-yellow or light yellow-brown. It is fine to medium grained with fine laminations accentuated on weathered surfaces and it possesses a blocky fracture-habit.

The Dagmar Limestone is an outstanding marker bed in the lower Paleozoic strata and has a somewhat gradational contact with the underlying formation.

Correlation with the Dagmar Limestone is on the basis of distinctive lithology and the stratigraphic position.

According to Lindgren and Loughlin (1919, p. 27) the age is Middle Cambrian. No recognizable fossils have yet been found although some calcite blebs may represent replaced fossil remnants.

Herkimer Limestone

Named after the Herkimer shaft of the Tintic District by Loughlin (1919, p. 28), the Herkimer Limestone is located in Sections 21, 22, 24, 26, 27 and 28.

It is 367 feet thick compared to 225 to 235 feet in the Tintic District.

This formation consists of medium to dark blue-grey limestones and dolomites which weather to medium blue-grey. The texture is sub-lithograhic to fine-grained. It is thin to medium-bedded. Oolites are present in some places. Yellow to red discontinuous argillaceous partings are present, and some shale. Portions resemble both the Opohonga Limestone and the Bluebird Dolomite.

Correlation with the type locality is on the basis of stratigraphic position and distinctive lithology. Prior to 1951 fossils had not been found in the formation. Muessig (1951, p. 26) found many Lingulella which suggested L. (Westonia) wasatchensis Walcott, but according to G. Arthur Cooper who made the identification, some difficulty was experienced concerning the ornamentation of the valves. Some inarticulate brachiopods were found but could not be identified as any known genus. Middle Cambrian fossils occur stratigraphically below the formation and because the fossils found fail to contribute anything new to previous knowledge the age is likely Middle Cambrian.

Bluebird Dolomite

The Bluebird Dolomite name was derived from Bluebird Spur in the Tintic District by Loughlin (1919, p. 28). It is exposed along the top of the west ridge enclosing Holdaway Canyon, where it is truncated by a large tear fault in the area. It is present in Sections 21, 22, 24, 26, 27 and 28.

The thickness of the Bluebird Dolomite is 175 feet compared with 175 feet in the type locality, and 152 feet in the Twelvemile Pass area (Johns, 1950, p. 31).

The Bluebird Dolomite has one of the most distinctive lithologies of the entire Paleozoic System. The color is grayish-black, which weathers to dark-grey with a purple hue; it is crystalline to fine grained, and thick to massive-bedded. Numerous white "twiggy" bodies from one to four mm. wide, five to eighteen mm. long and with an average of one to two mm. wide and ten mm. long provide the notable identification characteristics of the formation. These white rods may be the remains of crinoid stems, but all original structure has been destroyed. The white bodies are usually composed of white crystalline dolomite, although some are of calcite. A fetid odor is emitted upon fracturing. Similar "twiggy" beds are found in the Opex Dolomite, the Ajax Limestone, and in the Cole Canyon Dolomite and Herkimer Limestone, but they are much thinner and the lithology of adjacent rocks is different.

The distinctive lithology and the stratigraphic position make possible the correlation of this formation with that of the type locality in the Tintic District.

No fossils have yet been found in the Bluebird Dolomite, but the presence of Middle Cambrian fossils stratigraphically below and above identify this as a Middle Cambrian formation.

Cole Canyon Dolomite

The Cole Canyon Dolomite was named from Cole Canyon in the Tintic District by Loughlin (1919, p. 29). It has outcrops in Sections 21, 22, 24, 26, 27, and 28.

The lower contact is drawn where the white rods of the Bluebird Dolomite end and the first white dolomite bed of the Cole Canyon Formation begins. The upper contact is drawn at the top of the uppermost white bed adjacent to several feet of Opohonga-like dolomite, which are overlain by more than 40 feet of oolitic dolomite. A small bed of flat-pebble conglomerate is located in the Opex Formation within ten feet of the contact.

The thickness of the Cole Canyon Dolomite is 838 feet. In the Tintic area the thickness is 500 to 510 feet (Lindgren and Loughlin, 1919, p. 29), and in the Twelvemile Pass area (Johns, 1950, p. 34) it is 540 feet. It is to be noted that Loughlin did not use the large oolitic bed as the upper contact, consequently he measured approximately 150 feet less Cole Canyon Dolomite and an increased thickness of Opex Dolomite.

This formation is characteristically an alternating series of light and dark dolomite beds. These beds alternate about every ten to twenty-five feet. In the lower part of the section the color differences are accentuated. The dark beds are dark grey, weathering slightly lighter in color, they range from crystalline to fine grained, are often

massive-bedded and in places obscurely mottled. The light colored beds are light grey or medium grey, weathering to cream-white. The texture is sub-lithographic to medium-grained, and structurally it is massive bedded, commonly with chert stringers. The formation weathers to a subdued "meringue" surface. Some Opohonga-like beds with red argillaceous partings are present, together with an edgewise pebble conglomerate bed. Other parts of this formation resemble the Bluebird Dolomite, Dagmar Limestone, and Herkimer Limestone. In the Twelvemile Pass area half the formation is limestone (Johns, 1950, p. 35), although in the writer's area it was less than one-fourth limestone and in the type locality it is all dolomite.

Because of very distinctive lithology and well-defined stratigraphic position this formation is correlatable with that of the same form at the type locality in the Tintic District.

The only fossils identified from this formation are Obolus sp. (Loughlin, 1919, p. 29) and Obolus mcconnelli found by Weeks, which does not appear to be diagnostic because of its known range from Lower to upper Middle Cambrian (Walcott, 1912, p. 397). The age is considered to be Middle Cambrian.

Opex Dolomite

The Opex Dolomite was named from the Opex mine in the Tintic District by Lindgren and Loughlin (1919, p. 29). It outcrops in Sections 21, 22, 16, 24, 26, 27, and 28.

In the present area the thickness is 378 feet. In the Tintic District it is 388 to 393 feet and at Twelvemile Pass Johns (1950, p. 41) measured 700 feet.

The Opex Dolomite is one of the most difficult to identify of all the formations of the Paleozoic strata in this region. Many of the beds comprising the formation resemble certain beds of other formations. This formation resemblance includes the lithology of the Opohonga Limestone and the Bluebird Dolomite. Dolomite, limestone, and shale beds are present. Near the base of the formation the beds are dolomite. This is generally light or medium-grey, fine to medium-grained and is medium to massive-bedded. The basal contact taken at massive oolitic beds forty feet thick or more, has a bed of flat-pebble conglomerate within ten feet of the contact with the Cole Canyon Formation while dolomite, in the Opex, superficially resembling the Opohonga is near this contact and is overlain by medium grey dolomite with abundant oolites. The oolites are larger in size and much more abundant than at the upper contact with the Ajax Formation. Up-section the dolomite is cross-bedded and has some flat-pebble conglomerate and laminations. Above this is a five-foot bed of shale, then medium blue-grey limestone with numerous calcite stringers and this in turn is overlain by dolomite which responds slightly to cold dilute HCl acid, the yellow argillaceous partings give this the appearance of Opohonga Limestone, overlying this is more Opohongish-looking material but instead of dolomite it is limestone. The top seventy-five feet is medium dark-grey dolomite which weathers slightly lighter, is crystalline to medium grained, and thin to massive-bedded. The bedding size increases going down the section in this upper portion. There are small blebs of chert and some mottling of the beds.

This formation is correlated with that of the Tintic District on the basis of lithology and stratigraphic position. Billingsella sp., an Upper Cambrian brachiopod, was found in this formation twenty-five feet from the upper contact during the course of this study. As far as is known this is the first reported occurrence of this brachiopod here. Weeks found fossils which are not listed. These were found in 1905 about 300 feet above some fossiliferous beds of Middle Cambrian age in the Cole Canyon Dolomite (Lindgren and Loughlin, 1919, p. 30). The boundary between Middle and Upper Cambrian has not been definitely located so was arbitrarily placed at the uppermost colored bed in the Cole Canyon Dolomite by those authors.

Lindgren and Loughlin (1919, p. 30) consider the possibility of an obscure unconformity at the top of the Upper Cambrian. They found a limestone conglomerate marking the base of the "Ordovician Ajax" Limestone. They point out the presence of quartzite and limestone conglomerate which would indicate emergence in certain areas. They note the finding of scattered pebbles typical of the Bluebird Dolomite and a few higher Cambrian horizons embedded in argillaceous limestone of the Opohonga. Their conclusion is that the unconformity is confined to Central Utah. The Ajax, however, is now considered to be Cambrian. The writer as the result of field observation and compiling a correlation fence diagram believes that a local unconformity in other areas exists between the Upper Cambrian and the Ordovician. The massive oolitic bed and conglomerates at the base of the Opex and those at the top might be the result of shallowing seas which may possibly have permitted emergence or near-emergence of the region. This would be but the local reflection of a rising area twelve miles to the east near Long Ridge which interrupted the usual sequence at the end of Opex deposition; the Ajax, Opohonga, Victoria, and Pinyon Peak Formations pinch out between Bismark Peak and Long Ridge.

Ajax Limestone

The Ajax Limestone was named from the Ajax mine in the Tintic Mining District by Loughlin (1919, p. 31). It crops out in Sections 23, 24, 26, 27, and 28.

The formation is comprised of three members. The lower member is 319 feet thick, the middle member (the Emerald bed) is 22 feet thick, and the upper member is 239 feet thick, totalling 580 feet. In the Tintic District Lindgren and Loughlin measured 570 feet for the Ajax Limestone, including the Emerald Dolomite member (1919, p. 22). In the Twelvemile Pass area Johns (1950, p. 43) noted a total thickness of 738 feet.

The upper member of the Ajax Limestone is limestone which has interbedded quartzites, but near the base it is dominantly a highly-magnesium limestone. The color is olive-grey which weathers light or medium-grey to blue-grey, the texture ranges from crystalline to coarse-grained, with the bedding being thin to thick. The uppermost contact with the Opohonga Limestone is gradational and difficult to place with an accuracy of better than forty feet. Chert blebs are present, but not restricted to light-colored chert ("ice cream chert"). Some black, pink, and light-grey chert stringers are present.

The middle member, the Emerald Dolomite, is a light blue-grey which weathers to a creamy hue, and it is crystalline to fine-grained. It is massive-bedded. Chert is absent. This bed, like the Dagmar Dolomite of the Middle Cambrian, is a very distinctive marker bed although it is not as thick as the Dagmar.

The lower member of the Ajax Limestone consists of dolomite, blue-grey in color, crystalline to fine-grained. The bedding is thick to massive. Dark chert blebs and stringers with a thickness of one inch to one and one-half inches are present. It is to be noted that both light and dark cherts have been found together in the same member.

One hundred feet from the Emerald bed some pisolites ("carrot bodies") are present; they are believed to be dolomitized Girvenella. A thin section was prepared but the internal structure was so destroyed by dolomitization that positive identification could not be accomplished. "Twiggy" bodies and pisolites occur 52 to 74 feet from the base. Near the base a bed of wavy laminations occurs which is underlain by a bed containing "rosettes". The rosettes are five to ten mm. in diameter and are spherical in shape. They appear to be white $CaCO_3$, but actually consist of crystalline dolomite, possibly representing replaced fossil remnants. The basal contact is taken at and above the first dark small oolites and detrital appearing beds.

Correlation is on the basis of lithology and stratigraphic position. Lindgren and Loughlin (1919, p. 32) report that Edwin Kirk identified Straparollus. This is suggestive of the lower Pogonip Limestone found in Nevada and consequently the age was placed close to the base and in the Ordovician. Muessig (1951, p. 37) found a Lingulella sp. near the base of the lower member. In 1954 members of the U. S. Geological Survey were regarding the lower member of the Ajax Limestone as Upper Cambrian in age and the Emerald bed and upper member as Ordovician. By 1957 additional fossils had been found and the entire Ajax Formation is now considered to be Cambrian.

ORDOVICIAN SYSTEM

Opohonga Limestone

This formation was named from the Opohonga mine of the Tintic Mining District by Loughlin (1919, p. 32). It outcrops in Sections 23, 26, and 28.

The Opohonga Limestone is 1107 feet thick compared to 740 feet in the type locality. Johns (1950, p. 48) measured 1040 feet in the Twelvemile Pass area.

The Opohonga Limestone is one of the most distinctive formations of the Paleozoic rocks in this area. Light to medium-grey limestone is lined with discontinuous partings of yellow and red material. Typically "eye-shaped" lenses are formed measuring two or three inches long and occupying the entire rock surface without interruption. The color of the partings is generally red or yellow instead of these colors being present in limited areas only, as is the case with the Teutonic and Herkimer Limestones, which resemble the Opohonga Limestone Formation.

The coloration is evidently due to weathering because in underground workings the Opohonga is difficult to recognize, and an acid bottle may be the only means of assistance in identifying it from the overlying Bluebell Dolomite.

There are several beds of conglomerate in the Opohonga Limestone, most of them seem to be of the flat-pebble or intraformational variety.

In the Twelvemile Pass area the formation has 220 feet of dolomite at the top, although the dolomite is striped and mottled much like the limestone (Johns, 1950, p. 48).

Correlation with the Opohonga Limestone of the Tintic District is on the basis of distinctive lithology and stratigraphic position.

Edwin Kirk (Lindgren and Loughlin, 1919, p. 33) determined the presence of Dalmanella cf. D. hamburgensis Walcott, Cyrtolites sp., Ophileta sp., and Asaphus sp. (fragments) from this formation. These fossils are suggestive of the lower Pogonip.

Hintze (1951, pp. 87-89) found the following fossils in the upper Opohonga in the Tintic District:

Brachiopod:	Syntrophina cf. S. carinifera Ulrich and Cooper (Slightly larger than S. carinifera)
Trilobites:	Protopliomerops superciliosa Ross Hystricurus oculiluratus Ross Goniophyrs prima Ross Pachycranium faciclunis Ross Asaphellus? sp.

Cystid stem fragments

The above faunal collection would indicate an early Canadian age. Above the base of the Garden City Formation in northeastern Utah from 300 to 400 feet a faunal zone is found with the same characteristic fossils. There is a hiatus from Lower to Upper Ordovician between the Tintic District north to Ogden, Utah (Hintze, 1951, p. 88).

An unconformity exists between the Opohonga Limestone and the Lower Bluebell Dolomite Formations to which the omission of the Swan Peak Quartzite may be attributed. This unconformity can be seen on the Isometric Fence Diagram of this report.

ORDOVICIAN, SILURIAN AND DEVONIAN

Bluebell Dolomite
(Laketown Dolomite and Fish Haven Dolomite)

The Bluebell Dolomite was named from the Blue Bell mine of the Tintic District by Loughlin (1919, p. 34). It crops out in Section 26. The total measured thickness is 1369 feet but faulting makes this figure unreliable. Lindgren and Loughlin (1919, p. 34) say that the thickness cannot be accurately stated at the type locality but cite 700 and 900 feet for two different places where measurements were made within the area. Johns measured 920 feet in the Twelvemile Pass area (1950, p. 56). The Bluebell has been tentatively divided by Lovering and others into two parts, the lower part is assigned to the Ordovician and in the present area is 633 feet thick, and the upper part is assigned to the Silurian and is 736 feet thick. Due to faulting it is likely that the Ordovician Bluebell is 320 feet instead of 633 feet.

The Bluebell Dolomite is light to dark-grey, from crystalline to coarse-grained and is thin to massive-bedded. In general the Ordovician Bluebell is mottled and the Silurian Bluebell is not. There are various distinctive beds within the formation which are called the "Crinkley beds," "Leopard beds," "Pentamerid beds," etc. The Crinkley beds have fine but distinct laminations with the contortions forming undulating irregular patterns, possibly a result of slumping or algal development. As many as five Crinkley beds have been reported in the formation, most are found in the upper member of the Bluebell. The "Leopard beds" are highly mottled dolomites, usually dark-grey with light-grey mottling marks. The "Pentamerid beds" are thought to have dolomitized or calcitized pentamerid remains. Gypidula (?) has been reported from the uppermost "pentamerid bed" in the Twelvemile Pass area. Numerous white calcite or dolomite blebs of about ten mm. in diameter are present in such a bed, which may measure up to 27 feet in thickness. The Silurian Bluebell can be divided into two nearly equal thicknesses at one distinctive curley bed nearly ten feet thick.

The Systemic break between the Ordovician and Silurian is drawn at the top of the uppermost "Leopard bed" of the Bluebell Dolomite. In some places a one inch "ribbon" bed overlies the "Leopard bed," but it was missing in this particular area.

The Bluebell Dolomite is the correlative of the same formation in the Tintic Mining District. This identification is based upon the lithology and the stratigraphic position.

Lindgren and Loughlin reported some poorly preserved fossils found in the Bluebell Dolomite (1919, p. 35). Identification was made by Mr. Kirk, who established the presence of Maclurea annulata Walcott and Helicotoma sp. These two species were considered to be of Beekmantown (Lower Ordovician) age. Correlative formations are the Lower Pogonip of Nevada, the Garden City Limestone of northeastern Utah, and the El Paso Limestone of Texas. Other fossils found are Solenopora sp., Orthis sp.; these are considered post-Beekmantown. At another location (on Pinyon Peak) a specimen of Streptelasma sp. and some gastropods were found about 400 feet below the top of the dolomite. These may be correlated in part, according to Mr. Kirk, with the Lone Mountain Limestone of the Eureka District, Nevada, and in part with the Fish Haven Dolomite of northeastern Utah. Their conclusion was that the Bluebell Ranges from Lower to Upper Ordovician and it is possible that the upper 400 feet may include Silurian or Devonian strata. The Ordovician is to be called Fish Haven (Morris, 1957, p. 10).

On the basis of lithology the Laketown Formation appears to be the equivalent of the upper two-thirds of the Bluebell. The probable age of the Silurian part of the Bluebell is Niagaran. This is the assigned age of most of the Silurian dolomites of the eastern Great Basin. An unconformity is present at the top of the Fish Haven Dolomite which omits the Lower Silurian formations, and another unconformity within the Silurian Bluebell Dolomite omits Upper Silurian and Lower Devonian.

The names of fossils, recently discovered in the "Fish Haven Dolomite" by members of the U. S. Geological Survey in the Tintic District upon which the assignment of the Ordovician-Silurian contact are listed in part by Morris (1957, p. 10):

Aulacera cf. A. undulata (Billings)
Streptelasma trilobatum Whiteaves
Palaeophyllum sp.
Catenipora rubra Sinclair and Bolton
Calapoecia sp.
Favosites (Favosites) sp.
Lepidocyclus perlamellosus (Whitfield)
Lepidocyclus rectangularis Wang

Upper Ordovician, Middle Silurian, Middle and Upper Devonian fossils from the Bluebell Dolomite of Morris (1957, p. 11) (the Silurian Bluebell of this report)

Bothriolepis cf. B. coloradensis
Virgiana sp.
Reuschia? sp.
Tetradium cf. T. tubifer

DEVONIAN SYSTEM

Victoria Quartzite

The Victoria Quartzite outcrops in Sections 26 and 23. It has a thickness of 205 feet compared to 85 feet reported in the Tintic area by Loughlin (1919, p. 38), however Lovering measured 100 to 200 feet in the same area (1951, p. 1506).

The Victoria Quartzite was named from outcrops near the Victoria mine in the Tintic District by Loughlin (1919, p. 36). The U. S. Geological Survey now includes nearly 80 feet of dolomite formerly placed in the Gardner Dolomite by Loughlin but now recognized as Devonian, in the "Victoria Formation."

The Victoria Quartzite Formation consists of interbedded dolomites and quartzites. The contact with the Bluebell Formation has Favosites sp. in some areas although not found in the present area. It is marked by a five feet thick "Porphyry bed" which is overlain by an "Eyebed" ten feet thick. The "Porphyry bed" is filled with numerous white "pimples," the "Eyebed" has numerous white blebs of calcite about the size of a human eye. The contact with the Pinyon Peak Formation is taken at the first limestone above the Bluebell Dolomite. This is usually a pure, flaky, light-blue limestone with abundant brachiopods.

The quartzites are tan to light-brown in color and weather to a darker brown with a red hue locally being present. They are fine-grained and are medium to thick-bedded. The dolomites of the formation are medium olive-grey which weather light to medium-grey. A reticulated pattern is found on weathered surfaces. The lithology is sublithographic to medium-grained, medium to massive-bedded. This formation is more or less a slope-former although part of it is a ledge-former. In places where outcrops are difficult to find, the presence of brown sandy-appearing float provides the mapping datum.

Correlation is effected on the basis of lithology and stratigraphic position. Lindgren and Loughlin (1919, pp. 38-39) originally listed the Victoria Quartzite in an incorrect stratigraphic order and thus assigned a wrong age to it. They listed the sequence from top to bottom as Gardner Dolomite, Victoria Quartzite, Pinyon Peak Limestone, and Bluebell Dolomite. They assigned a Lower Mississippian age to the Victoria. The correct order is Gardner Dolomite, Pinyon Peak Limestone, Victoria Quartzite, and Bluebell Dolomite.

Fossils have been found a short distance above the Victoria Quartzite in the Tintic District by members of the Geological Survey. According to Lovering (Muessig, 1951, pp. 44-45) the fossils are Upper Devonian in age and are probably equivalent to the fauna from the Three Forks Formation of Montana. The U. S. Geological Survey currently includes all of the Victoria as described by Lindgren and Loughlin plus 70 to 80 feet of Devonian beds these authors had placed in the Gardner Dolomite (Morris, 1957, p. 13).

H. Petersen (1953, p. 24) found Spirifer sp., Cyrtospirifer sp., and Zaphrentis sp. in the Victoria Quartzite. These suggest Devonian age also.

Loughlin (1919, pp. 36-39) thought the Victoria is the basal unit of the Mississippian and that there was a disconformity at the base of the Victoria; the disconformity, he thought, marked the separation of the Mississippian and the Devonian and considered it widespread in Utah.

There is a resemblance between the upper 100 feet of the Bluebell and the Devonian Jefferson (?) Formation at Ophir which would cause the observer to conclude that this part of the Bluebell is also Devonian, hence the overlying Victoria beds are also Devonian, providing unconformities present, if any, are small.

The sandy facies of the Victoria is one aspect of the gently fluctuating sea-level and partly represents the regression of the water. Channeling and irregularities seen at the base of the Victoria tend to support this idea.

An unconformity exists at Ophir and at Long Ridge of probable late Devonian age but this action is only suggested in the present area by a decrease in thickness and pinch-out of beds of the Devonian Victoria and Pinyon Peak Formations between Bismark Peak and nearby areas to the east and southeast. Morris (1957, p. 13) states that a pre-late Late Devonian unconformity occurred in the East Tintic Mountains of no consequence but it was an important one in the Stansbury, Oquirrh, E. Uinta, and Central Wasatch Mountains.

DEVONIAN AND MISSISSIPPIAN (?) SYSTEMS

Pinyon Peak Limestone

The Pinyon Peak Limestone outcrops in Sections 23 and 26. Named by Loughlin (1919, p. 36) it has a thickness of 201 feet compared to 150 feet in the Tintic District.

The Pinyon Peak Limestone weathers in some beds to a light brownish-red float. Generally it is medium grey, fine to coarse-grained, thin to medium-bedded. The upper contact is drawn about twenty feet below the appearance of the corals Syringopora sp., and Caninia sp., in the Lower Gardner dolomites. This is a gradational contact and is arbitrarily drawn. The contact with the Victoria Quartzite is drawn at the base of the limestone of the Pinyon Peak Limestone and the top of the quartzites and dolomites of the Victoria Formation.

Pinyon Peak Formation is the most notable slope-former in the district. It is also known to change along the strike from limestone to dolomite in irregular intervals as little as five feet apart. In places where the outcrop is poorly exposed and the location of the formation difficult to find identification is accomplished using the criteria of the slope-forming characteristics and the usual presence of a pink-tinged limestone float.

Correlation is based on the lithology and the stratigraphic position. Loughlin had included the Pinyon Peak in the lower part of his Gardner Dolomite. On fossil evidence the U. S. Geological Survey now places the Devonian-Mississippain boundary in the upper part of the Pinyon Peak and considers this formation to be Late Devonian and Mississippian (?) (Morris, 1957, p. 13).

Some fossils have been reported found in the Pinyon Peak Limestone. Lindgren and Loughlin (1919, p. 36) state that Mr. Kirk identified Pleurotomaria sp., Cyathophyllum sp., Rhombopora sp., and Spirifer sp.: all suggest Upper Devonian (Threeforks?) age, but none are sufficiently critical for precise age assignment. H. Petersen (1953, p. 26) assisted by Dr. H. J. Bissell found the following forms in the Pinyon Peak:

Spirifer argentarius (?) Meek
Atrypa cf. montanensis Kindle
Cyrtospirifer whitneyi (Hall) Kindle
Cyrtospirifer cf. portal (?) Merriam
Cyathophyllum (?) sp.

H. Petersen states this fauna is characteristic of the Spirifer argentarius-Cyrtospirifer zone, and is believed to indicate upper Middle to Upper Devonian age. It correlates with the Upper Devils' Gate Formation of Nevada (Merriam, 1940, p. 9).

MISSISSIPPIAN SYSTEM

Gardner Dolomite

The Gardner Dolomite outcrops in Sections 23, 24, 25, and 26. Named by Loughlin (1919, p. 34) it is 943 feet thick, of which the lower 456 feet is considered to be a lower member. In the Tintic Mining District the thickness for the total Gardner is about 700 feet. At Twelvemile Pass Johns found it to be 885 feet thick.

The Gardner Dolomite is light to medium olive-grey which weathers light to medium-grey. It is fine to coarse-grained and is medium to massive-bedded. It is very fossiliferous, particularly the upper portion. The upper contact is taken at the presence of the first dark chert beds of the Pine Canyon Limestone. The lower contact is taken about twenty feet below the first appearance of Caninia sp. and Syringopora sp. The writer has divided the Gardner into two parts, an upper and a lower. The division is drawn at the "Curley" bed, a two and one-half foot thick bed of lithographic rather pink-tinged limestone noted because of the crinkling and involutions of its laminations, probably an algal-growth phenomenon. Although it is similar in form to slump structures, the distribution is so extensive, comprising over 600 square miles, that it is now believed by the writer and others, Proctor and D. Clark (1956) D. Clark (1954, p. 30) R. Clark (1953, p. 50), D. Peterson (1953, p. 67), H. Petersen (1953, p. 28), and Sirrine (1953, p. 39) that the algal genus Codonophycus illustrated by Fenton and Fenton (1939, plate II) or similar algae is evidence for its biostromal origin. Proctor and Clark (1956, p. 320) cite the results of a study by J. Harlan Johnson who states the laminations represent growth layers of "Algae felt." The "Curley bed" is dolomitized in the Long Ridge area (Peacock, 1953, p. 51). The formation is half limestone in that area and nearly all limestone in the writer's area although it is dolomite in the Tintic District. Loughlin (1919, p. 40) found the dolomite and limestone left an oily film when they were dissolved, plus a hydrogen sulfide odor. The importance to the oil industry should receive more intense investigation.

Correlation with the Gardner Dolomite of the Tintic District is on the basis of lithology, stratigraphic position, and faunal assemblage.

Lindgren and Loughlin (1919, p. 40) give a list of seventeen fossils found in the Tintic Mining District and identified by G. H. Girty. These fossils were considered to be of Madison age, and the age of the Gardner Dolomite was assigned to the Lower Mississippian. The Gardner has lately been called the Madison Limestone (Morris, 1957, p. 14).

Muessig (1951, pp. 47-50) made an extensive fossil collection and concluded that the Mississippian part of the Gardner is correlatable with at least the lower part of the Madison Limestone and other formations of Upper Kinderhookian and Lower Osagian age. Apparently the base of the Mississippian lies somewhere below the lowest horizon where he collected fossils. This was 360 feet above the Victoria Quartzite. Fossils occurred lower but could not be chipped out of the rocks and so were not collected. He thought that they would probably be Devonian.

D. Clark made an extensive study of the Gardner Formation and concluded that it is Lower Mississippian in age; Kinderhookian below the "Curley bed" and Upper Kinderhookian to Lower Osagean above. The foraminifera Granuliterelia in the beds below the "Curley bed" and Plectogyra tumula in the beds above it plus megafossils permitted the age identification (D. Clark, 1954).

The writer has discovered a contorted laminated bed identical to the Gardner "Curley bed." The location is 50 feet below the top of the Redwall Limestone of the Grand Canyon. The thickness is 1 ½ feet. It is pink-stained. The writer does not believe it can be correlated with the Gardner "Curley bed" due to age variation and lack of points of control. A table showing the occurrence of fossils within the Gardner Formation is given herein. This is adapted from one by D. Clark (1954, p. 7) with additions from Muessig and others.

No unconformities existed in the present area; from the Lower Mississippian to the Permian there was continuous deposition, although at Ophir there is one between the Devonian and Mississippian if present age and formation determinations are correct.

Pine Canyon Limestone

The Pine Canyon Limestone outcrops in Sections 24 and 25. Loughlin named it (1919, p. 40) .

The thickness is 840 feet thick compared with an estimated 1,000 feet in the Tintic Mining District.

The Pine Canyon Limestone is medium-grey in color and distinctively and characteristically cherty. It is fine-grained and varies from medium to massive-bedded. Some varieties do not contain the characteristic chert lenses and bands. The lower contact is taken at the base of the first dark prominent chert band. The upper contact is taken below an eight foot encrinite bed which marks the base of the Humbug Formation.

Within the Pine Canyon Limestone there are two silicious shaly beds which weather into a red-colored slope. The platy shale emits a "tinkly" noise when struck against other pieces of shale. These beds are consequently known as the "Tinkley beds". The uppermost "Tinkley bed" might designate a Lower and Upper Mississippian boundary.

Correlation is on the basis of distinctive lithology, stratigraphic position, and faunal assemblage.

Lindgren and Loughlin found poorly preserved fossils (and fragments), mostly Zaphrentis. Mr. Girty identified Zaphrentis sp. and Batostomella? sp. He refers this to the Upper Mississippian. The conclusion Loughlin makes is that the lower and probably the greater part of the Pine Canyon Limestone is of Madison age, but the upper 300 feet at least is Upper Mississippian (1919, p. 41).

Muessig (1951, p. 52) has found additional fossils in the Pine Canyon Formation, as follows:

F-29 Spirifer af. S. haydenianus Girty
Martinia cf. M. lata Girty
Productus" sp. indet.
Productus" sp. indet.

F-38 Syringothyris sp. (from float)

The fossils in collection F-29 are incomplete and are of no help in dating the Pine Canyon Formation according to Mr. Bowsher, who identified them. The specimen of Syringothyris sp. was poorly preserved but resembled Syringothyris texta (Hall). H. Petersen (1953, p. 34) with Dr. H. J. Bissell found and positively identified Syringothyris texta in the same locality as Muessig's fossil. The age of the part of the formation that yielded this fossil is probably not older than Mid-Osage and not younger than Upper Osage. This type of Syringothyris is known from the Fern Glen, the Burlington, Keokuk and Warsaw Formations and is not known from older or younger rocks. According to Weller (1943, chart 5, et seq.), the Upper Madison is Osage, therefore, the Lower Pine Canyon is probably equivalent to the Upper Madison, but probably none of the Pine Canyon is Upper Mississippian, as believed by Loughlin.

The U. S. Geological Survey is currently applying the name Deseret Limestone to the Pine Canyon (Morris, 1957, p. 18).

OCCURRENCE OF FOSSILS WITHIN THE GARDNER

	Tintic Area	Selma Hills	North Selma Hills	Rattlesnake Spur	Bismark Peak	Lake Mt.	West Mt.	Piccayune Canyon	N. Long Ridge	S. Long Ridge	Goshen Canyon	Rock Canyon
Aulopora sp.	x			x				x				
Avonia parviformis Girty										x		
Brachythyris sp.								x				
Baylea n. sp.										x		
Bustonia sp. indet.										x		
Chonetes ellenoensis	x											
Chonetes loganensis	x	x	x					x		x		
Cleiothyridina transversa (?)	x	x								x	x	
Caninia sp.			x	x	x	x	x	x	x	x	x	
Clisiophyllum sp.	x									x		
Camarotoechia herrickana Girty	x	x										
Concardium sp.	x											
Composita cf. C. humilis Girty	x	x	x	x				x		x		
Cystodictya sp.	x											
Composita trinuclea									x			
Crinoid fragments	x	x	x	x	x	x	x	x	x	x	x	x
Euomphalus cf. E. luxus	x	x	x	x	x	x	x	x	x	x	x	x
Dictyoclostus burlingtonensis									x	x	x	
Dielasma									x		x	
Eumetria verneuiliana (Hall)										x		
Euphemites n. sp.										x		
S. (Euomphalus) subplanus (Hall)										x		
Fenestellid									x			
Granuliferella sp.				x						x		
Lithostrotionella sp.		x	x	x	x	x	x		x	x	x	
Loxonema sp.			x	x	x		x		x	x	x	

(Continued)

Occurrence of Fossils Within the Gardner (Continued)

	Tintic Area	Selma Hills	North Selma Hills	Rattlesnake Spur	Bismark Peak	Lake Mt.	West Mt.	Piccayune Canyon	N. Long Ridge	S. Long Ridge	Goshen Canyon	Rock Canyon
*Leptoptygma sp.										x		
Marginifera (?) sp.		x										
Martinia (?) sp.				x								
Multithecopora sp.			x	x	x	x	x	x	x	x	x	
*Naticopsis sp.										x		
*an Orthoceracone										x		
Plectogyra sp.				x			x		x	x		
*Pleurotomarian--Worthenia?, Borestes?										x		
*Productus galeanus Girty		x									x	
*Productus gallatinensis												
Productella sp.									x			
Reticularia (?) sp.	x											
Spirifer centronatus	x	x	x	x	x	x	x	x	x	x	x	x
Syringopora jurcularia	x	x	x	x	x	x	x	x	x	x	x	x
*Schuchertella chemungensis(?)								x				
Syringothyris sp.											x	
Straparolus ophirensis								x				
*Schizophoria compacta Girty										x		
*Sulcoretepora sp.										x		
Triplophyllites sp.			x	x	x	x	x	x	x	x	x	
Tylothyris cf. Spirifer centronatus var. semifurcatus Girty												
Zaphrentis sp.	x	x	x	x	x		x	x	x	x	x	

*The two previously known species of Euloxoceras are both from the Pennsylvanian.

The Pine Canyon Limestone is unusual and distinctive because of the many chert beds. Evidently at the time of deposition considerable silica was present in solution in the waters. The silica must have been derived from igneous activity which could well have been located quite a long distance away. The silica was precipitated and formed the beds of chert. This activity lessened with time, although there were some sporadic outbursts.

The fossil content of the formation indicates that at least part of the time there was probably a neritic environment existing. This depth of water, based on modern observations, is most conducive to prolific marine life. Probably this area was part of a stable shelf with deposition of relatively pure limestones (which now are sub-lithographic in part). Some sand-streaking occurred when cross-currents brought previously re-worked material into the vicinity.

Humbug Formation

The Humbug Formation was named from the Humbug mine in the Tintic Mining District by Tower and Smith (1899, p. 625). It crops out in Section 24 on Bismark Hill and Section 25. Its thickness is 811 feet, compared to 250 feet reported in the Tintic Mining District. Morris (1957, p. 20) states that it averages 650 feet in the East Tintic Mountains. In the Twelvemile Pass area it is 900 feet.

The Humbug Formation consists of an alternating series of sandstone, limestone, orthoquartzite, and dolomite. The limestone is typically medium-grey, crystalline to medium-grained, and thick-bedded sometimes with "twiggy bodies" and possible algal growths. The dolomites are often olive-grey and weather to some degree of white, they are fine grained and thin to medium-bedded. The quartzites vary but one example is yellow brown, weathering to a reddish-brown, fine-grained, thin-bedded with red bands. The entire formation is generally thin to medium-bedded and upon weathering large slope areas are often covered with a shaly talus.

The base according to Lindgren and Loughlin (1919, p. 42) is drawn at the lowest sandy or shaly beds. The writer established that the lower contact with the Pine Canyon Formation is taken at the base of a sandy-appearing eight foot encrinite bed. The upper contact with the Great Blue Limestone is taken at the beginning of the first massive, blue limestone above the highest of the interbedded limestone and quartzite beds.

The correlation of the Humbug Formation with that of the Tintic Mining District is strictly on lithology and stratigraphic position.

On the basis of Zaphrentis fragments and crinoid stems and lithogenetic similarity Lindgren and Loughlin assign the Humbug to the Upper Mississippian (1919, p. 42).

Fossils collected from the Humbug Formation at Ophir and identified by G. H. Girty are as follows:

5800.	Fenestella, several sp.	Orthotetes? sp.
	Pinnatopora sp.	Productus brazerianus
	Polypora sp.	Girtyella? sp.
	Rhombopora sp.	Spirifer aff. S. centronatus
6257.	Syringopora sp.	Productus ovatus?
	Cyathophyllum sp.	Productus sp.
	Pentremites sp.	Pugnoides aff. P. ottumwa
	Crinoid indet.	Spirifer n. sp. aff. S. breckenridgensis
	Echinocrinus sp.	Productus brazerianus

The closest affinities of the above collections is the earlier faunas of the Brazer Limestone according to the report of Girty (Gilluly, 1932, p. 28). Thus the age was assigned to the Upper Mississippian. The Brazer is Meramecian and Chesterian in age according to Williams (1943, p. 620). Weller, et. al. (1943, chart 5) consider the Humbug to be Upper Osagean and Lowermost Meramecian. This indicates that it is equivalent to the lowermost Brazer.

The 250 feet of strata found in the Tintic District by Lindgren and Loughlin (1919, pp. 41-42), according to their report, form only the lowest part of a formation at Mercur, Utah, designated as the "upper intercalated series" 5,000 to 6,000 feet thick, of which the upper part at least is of Pennsylvanian age. The lower part of the intercalated series carries Upper Mississippian fossils according to Loughlin (op. cit.). He correlates the Humbug Formation with a formation in the Lake Mountains located 30 miles to the northeast, on the basis of lithology and stratigraphic position. Gilluly on the same basis and on fossil determination of age correlates the Humbug Formation of the Tintic District with a generally similar formation in Ophir Canyon. Gilluly is prone to extend the correlation to Gold Hill, in the Deep Creek Range, Utah, and to the Cottonwood District of the Wasatch Mountains. He states that the similarity of the formation differs greatly in details but not in the larger features such as the presence of the interlensing brown quartzite, brown and reddish sandstone, and blue and grey limestones, with little shale.

How did such a varied lithofacies occur? Seemingly rapidly changing sedimentary conditions would be required for the fragmental, clastic limestones, cross-bedded sandstones, and quartzites,--and the lithographic limestones which rest directly on the quartzites and interfinger with them. The former rocks would require strong littoral currents and current agitation, probably these conditions would be found in a shallow sea. The limestones would represent a changed environment with long periods of relative quiescence. These alternating periods of agitation and calm could be provided by a moderately unstable shelf area in the epineritic zone. The dolomites strengthen such a theory. Shallowing seas would exist with their possible increasing magnesium content and with subsequent marine replacement of fine-grained limestone by dolomite.

Many of the dolomites have sharply defined contacts with adjacent limestone or quartzitic beds, but do not generally grade laterally into other types of rocks. Some of the sandstone beds may change to shale to the west, such as the Chainman Shale (Livingston, 1955).

Quaternary System

The Quaternary alluvium is not very extensive in the Bismark Peak area. It consists of the clays, silts, sands, pebbles, cobbles, and boulders that are found in the beds of intermittent streams and occasional small mudflows, alluvial fans, talus slopes, and soil development.

Some of the north slopes are covered with soil and are heavily forested. Other slopes such as some located in Section 21 are as steep as forty-seven degrees.

The floor of Broad Canyon north of the mapped area has been covered with alluvial deposits. The elevation was too high to receive any of the sediments of Lake Bonneville. Rock outcrops are less plentiful and less prominent than those in the area to the north, due in part to the presence of small forests, slope wash and soil development.

IGNEOUS ROCKS

General Features

The igneous rocks of the East Tintic District and the North Tintic District appear to be closely allied. The North Tintic District has much less volcanism in evidence today than the East Tintic area which has been described by some geologists as the eroded remnant of a large composite volcano that had buried an already structurally complex mountain range. The eruptive centers are now marked by stocks, plugs, and dikes in the center of the range. The Bismark Peak area may have at one time received a large quantity of effusive rocks but today there are only a few remnants that are of very small areal extent.

The principal types of extrusive rocks present consist of the Packard Rhyolite series which was followed by the Laguna Latite sequence. These were followed by a late sequence of basalt flows.

Intrusive rocks of East Tintic consist of dikes, stocks, and plugs ranging in composition from quartz monzonite, monzonite, monzonite porphyry, latite porphyry to diabase. After most of the volcanics and prior to metallization there was a rather unique occurrence of silica breccia dikes and pebble dikes.

Extrusive Rocks

The sequence of extrusive rocks established by Morris (1957, pp. 30-34) in the Tintic District is as follows:

Youngest	Basalt	Basalt, dense to scoriaceous
		5. Agglomerate, thick and widespread
		4. Upper flow series
	Latite volcanic series	3. Tuff and agglomerate
		2. Lower flow series. Up to 1,000 feet thick.
		1. Basal tuff
Oldest		4. Upper vitrophyre
		3. Massive flow. Up to 2300 feet thick.
	"Packard Rhyolite"	2. Lower vitrophyre. Up to 700 feet thick.
		1. Tuff. Up to 100 feet thick.

The Packard Rhyolite series was the first to occur in the region. It was named by Tower and Smith (1899, pl. 74) from abundant effusives at Packard Peak. The composition is that of quartz latite. The amount of plagioclase is approximately equal to orthoclase (sanidine), in addition to other constituents such as quartz. It has a purplish or bluish-purple color and a porphyritic texture. It is composed of phenocrysts of feldspar of which sanidine plagioclase is prominent, biotite, some quartz (although it may be absent), and sometimes hornblende. The groundmass is glassy or fine grained. Flow structure can be seen in large outcrops. There is apatite, sphene and magnetite in some of the flows. It is distinguished from the Laguna Latite in the field by the usual presence of quartz.

The later Laguna Latite-andesite series differs from the Packard Rhyolite by a greenish color rather than purple, the usual lack of quartz phenocrysts and the presence of more ferromagnesian minerals other than biotite. Latite agglomerate, tuff, latite porphyry dikes and latite-andesite flows were extruded during this period of activity. Some of the dikes are very dark green; biotite is in a fine grained groundmass and there are small lath shaped phenocrysts of plagioclase. Some of the flows contain sufficient magnetite that they influence the behavior of a compass needle.

The basalt flows are nearly black and are fine to medium-grained porphyritic. Phenocrysts consist of labradorite, augite, and olivine; magnetite and apatite are common accessory minerals (Morris, 1957, p. 34).

The largest occurrence of igneous rocks found by the writer in the mapped area is in the northeast quarter of Section 23 on each side of Rattlesnake Canyon. This is the Packard Rhyolite. At the head of the canyon on the drainage divide in the southeast quarter of Section 23 a few boulders of Laguna Latite are present. Dearden did not find any of the Laguna Latite in the area he mapped to the north, although he did find tuff and flow rocks belonging to the Packard Rhyolite series.

Intrusive Rocks

In Section 27 a dike or sill with the appearance of an olivine basalt is found accordant with the bedding of the country rock, which is near-vertical.

Dearden found an intrusive olivine basalt dike on the east side of the Boulter Mountains near the top of the hill in the northwest quarter of Section 12, Township 9 South, Range 3 West. This dike had been previously reported by Johns (1950, p. 90). Petrographic analysis of the dike material

by Dr. Kenneth C. Bullock and Mr. Dearden revealed a composition much the same as some basalt flows in the floor of Broad Canyon, slightly north of this writer's area. The dike rock was a typical diabase and was somewhat coarser and had more abundant augite phenocrysts than the flow rock (Dearden, 1954, p. 39). It was their opinion that the dike may have represented the source of the basalt flows of Broad Canyon.

Silica Breccia Dikes

In the east and southeast part of the quadrangle mapped by this writer there is a very unusual, almost unique occurrence of silica breccia dikes. The writer has observed some of the pebble dike occurrences in the East Tintic locality and although their appearance is somewhat different he considers them to be of origin similar to the silica breccia dikes. Pebble dikes have been found at the Traverse Range, southeast of Bingham, at Bingham, Utah, at the Drum Mountains, in the Ouray District, and perhaps at Nagyag, Austria (Ransome, 1900)

The silica breccia dikes occur in the part of the quadrangle closest to the East Tintic District and are dike-like in appearance with a general northeast strike. They often stand as high as fifteen feet and may extend for fifty feet in length with a width of seven feet. The material composing them ranges from sand sized particles up to cobbles ten inches in diameter, commonly the larger pieces are two or three inches in diameter. This agglomeration is cemented together with silica which more often than not is stained red, although it may change color along the same dike. The particles composing the dike appear to have been derived from underlying formations; if the full sequence of formations is present below, a dike may contain limestone, dolomite, quartzite, sandstone, and perhaps some chert. The pebbles and cobbles of identical lithology show various degrees of roundness as though they had become worn while traveling different distances on their way up the walls of the fissure which provided a channelway for them. Kildale (1937) has had opportunity to study the pebble dikes of the East Tintic District underground. He reports that the dikes have a known vertical range of 6,000 feet and that the pebbles (rounded) are more abundant near the surface as though the rounding was the result of abrasion during the dike-making activity. Also he postulates that the onion skin, concentric structure of some quartzite pebbles is a spalling acting resulting from a sudden drop in temperature and pressure. It affects the quartzite pebbles but not the limestone or any shale fragments due to the larger coefficient of thermal expansion of the more silicious material. The dikes occur along steep fracture planes of tensional movements in areas of intrusion, alteration, and mineralization.

Although intrusion evidence is meager in the Bismark Peak region it is certainly evident that the most extensive alteration of the area mapped is located in the general vicinity of the silica breccia dikes. The writer observed more angularity of the pebbles of the dikes in the area he mapped than he saw in the East Tintic District, but no quantitative study of comparison was made.

The origin of these dikes has long been an enigma and is still undetermined. At first they were thought to be the place of deposition of erosional products from some ancient surface which filled an open fissure, but this hypothesis has been discarded because of the great vertical extent, the fact that some fissures containing them do not reach the surface, and the character of materials comprising the dikes. The writer believes that gases, vapors, and solutions found a means of escape from the magmatic reservoir, or perhaps groundwater or connate water was turned to vapor by invading magma and exploded upward through fault fissures. As the gases and solutions made their way toward the surface under tremendous pressure and heat they dislodged parts of the wall rock. In the lower part of the sedimentary section quartzite from the Tintic Quartzite Formation was dislodged, this was melted in part and rose to the surface coating and cementing the other particles and pieces from other formations that ground their way past the wall obstructions and each other on their journey. They were deposited in the more open spaces of the fissure. The chert of the Pine Canyon Formation would have also been a likely source for silica. Perhaps the magma itself provided silica. There has been very little subsequent movement if any, in the fault fissures where the dikes formed.

Age of Igneous Activity

The silica breccia dikes were formed after the monzonite porphyry of the Tintic District and before the period of mineralization (Kildale, 1937, p. 84).

There is insufficient and too scattered distribution of igneous rocks in the writer's area to permit an attempt to date them. The dating attempts in nearby areas probably apply as well to the Boulter Mountain region.

Lindgren and Loughlin (1919, p. 70) gave the Late Tertiary or early Pleistocene as a reasonable age for the occurrence of the basalt flows. Eardley (1933) considered the volcanism in the Southern Wasatch Mountains to be later than the Eocene Wasatch conglomerate. Tower and

Smith (1899, p. 673) drew the same conclusion for the southern part of the East Tintic Mountains. Bullock (1951, p. 36) found that the volcanic rocks of the Lake Mountain area overlaid the Paleozoic rocks and showed wave cut features due to the action of waters of Lake Bonneville and he concluded they were therefore younger than the folding and older than Lake Bonneville. Rigby (1949, pp. 105-106) reports that the flows followed the normal faulting in the Selma Hills locality but were later subjected to east-west movements in that area. Kildale (1937, p. 50) thought that the igneous epoch was connected with the Late Oligocene or Early Miocene disturbances in the Cordilleran. He believed that the extrusive rocks were earlier than the intrusive rocks, but the period of intrusion followed that of extrusion very closely. Thirty miles south-southeast of Eureka, in Sage Valley, Muessig (1951, p. 234) found fossil plants which were of Middle Eocene age and used these to date latite and andesite rocks which probably occurred after the early Packard "Rhyolite" tuff and flows and before the last sequence--consisting of basalt flows. Radioactive zircons from monzonite were dated by the U. S. Geological Survey and were found to be 38 and 46.5 million years old. One sample was from the Silver City stock and the other from the North Lily mine which is located a mile northwest of Dividend in the East Tintic District (Morris, 1957, pp. 29-30).

In conclusion it appears that the Packard Rhyolite (of which ash and other effusive rocks were a part) was extruded, followed a short time later by the Laguna Latite series and then by the basalt flows. The age of the material just preceding the basalt flows was probably Middle Eocene or younger, possibly as young as Pliocene. These volcanics were local expressions of the Miocene activity which is known to have been affecting the nearby Wasatch Mountains.

STRUCTURE

GENERAL FEATURES

The Boulter Mountains are comprised of strata that have been twisted by folds and displaced by numerous small and several large faults. In the Bismark Peak area these contortions appear to reach their maximum development.

The principal feature is a north-south asymmetrical anticline which has been eroded along the axis to form a valley known as "Broad Canyon" and also "Broad Valley." The anticline is known as the "North Tintic" and the "Broad Canyon" anticline. It has an axis which is approximately in line with that of the Ophir anticline in the Oquirrh Mountains. The plunge of the anticline changes from about forty-five degrees to the north in the vicinity of "Skyline Ridge" to twenty degrees near Twelvemile Pass. The west limb dips to the west at approximately thirty degrees, but the east limb has beds overturned and dipping as much as fifty-five degrees to the west. These overturned beds of the east flank extend as far as Twelvemile Pass to the north. The asymmetric east flank of the anticline comprises the asymmetric west limb of the Tintic syncline. The area of this report is one of the places along the axis of the North Tintic anticline which has not wholly succumbed to the valley-making erosional processes.

Along the anticline, formations from the Precambrian Big Cottonwood (?) to the Pennsylvanian and Permian Oquirrh are found. An amplitude in excess of 16, 000 feet is probable for the fold, its width is approximately six miles.

The formations leave the Eureka region where they have been molded into a complicated pattern by folding and faulting and strike toward the north in a generally orderly array. Shortly after arriving in the Bismark Peak area they are displaced over one mile to the east. The southern edge of the overthrust is bounded by the Tintic Prince fault. After leaving the area mapped by the writer they begin to gently swing around the nose of the anticline but are again displaced to the east, this time approximately one-half mile by the Cedar Valley Fault which nearly parallels the Tintic Prince fault and is but a mile distant to the north. The axis of the anticline is nearly due north in the Bismark Peak area but it begins to swing to the west and is nearly northwest across Topliff Hill nine miles north of the Bismark Peak area.

The Tintic Prince fault was first mapped in the Tintic District where it is close to the Tintic Prince mine. The connection between a large tear fault on the east limb of the anticline just north of Bismark Peak and the Tintic Prince fault is believed to be first established during the course of the present mapping project. The Cedar Valley fault strikes southwest toward the area of this report and disappears under alluvium in the floor of Broad Canyon; considerable alteration and faulting occur in the mapped area where the fault might be expected to reappear from the alluvium. The segment of beds wedged between the two faults acted as an overthrust plate. The "bumper" leading edge or rupture plane can be seen approximately half-way up the hills that separate Broad Canyon from Cedar Valley. The rupture is found on the eastern slope of these hills. That faulting as well as folding has had an important effect on the topography is evidenced by several gulches which mark fault scarps.

A series of north-south trending folds are found in the Tintic Mining District and they are found at least as far east as the Wasatch Mountains, twenty miles distant. Twenty-five miles to the north and northeast of Tintic these folds begin to swing toward the west as though they represent drag folds of great magnitude or they are the surface manifestation of some great force directed toward the east northeast. Perhaps they represent waves from the Laramide "orogeny" impinging and dying out against the shoreline of the trough--influenced by huge subjacent competent masses.

It is postulated herein that forces came from the west and after a period of intense compression arched up the strata into the asymmetrical North Tintic anticline. Continued stresses created forces of great magnitude and the tangential strains generated expressed themselves as strike-slip and tear faults. It is known that in the Tintic mines to the south faulting in a northeast direction was in part contemporaneous with the east-west compressive forces.

The Bismark Peak area had remained quite stable during most of the Paleozoic except for possible uplift of regional dimensions. In the Mesozoic it may have been a positive area for brief intervals. Lack of sediments due to erosion or non-deposition make it difficult to determine the history of the area after Pennsylvanian time. It may have been a source area for some of the Triassic, Jurassic, and Cretaceous sediments of the nearby Wasatch Mountains. Most probably it was during Upper Jurassic Oxfordian time that the area was emergent, if at all. This was the time of the deposition of the Summerville, Curtis, Upper Sundance and other sediments which became as thin as 300 feet in nearby areas to the east. Most of the early Mesozoic deposition was on the order of

1,000 to 1,500 feet in the Lower, Middle, and Upper Jurassic, each. By projection, these thicknesses are here estimated to have been deposited at the Tintic region.

The deformation probably took place during the Laramide Orogeny. From the rocks present it is only possible to date the deformation as post-Pennsylvanian, but 15 miles to the east at Long Ridge near Santaquin, Utah, a conglomerate thought to be of the Price River and North Horn Formations is found unconformably overlying the eroded surface of southeast dipping Great Blue Limestone (Peacock, 1953, p. 74). Andrews and Hunt (1948) found some Price River Conglomerate lying in angular unconformity upon the Pennsylvanian Oquirrh Formation of West Mountain. Correlation could not be established between the two deposits because of their isolated occurrences.

The lower unit of the conglomerate at Long Ridge is described as ranging from cobble to boulder sized lime stone and dolomite with a matrix of red carbonate silt and clay (which weathers readily to a soil). The constituents of the conglomerate indicate they were probably derived from beds ranging from Cambrian through Mississippian age, according to Peacock. The upper unit of the conglomerate consists mostly of quartzite cobbles and boulders and indicates a different source area.

The Price River-North Horn Conglomerates have been assigned to the Upper Cretaceous and Lower Tertiary by Spieker and Reeside.

These conglomerates appear to have been deposited rapidly in an orogenic to post-orogenic environment; based upon the meta-stable rock types present, the wide range in size, and percussion marks. The presence of angular limestone and metaquartzite fragments indicate a short distance of travel.

Where did these rocks come from? In assigning their source to the Ancestral Wasatch Mountains some people appear to have overlooked the possibility of the Boulter Mountains and their associated ranges as the source area. A projection of the North Tintic anticline made by the writer and based on a cross-section about two miles north of the writer's area and assuming the uneroded top of the Pennsylvanian Great Blue Formation as the crest, would show an elevation above sea level of approximately 22,000 feet! This computation ignores approximately 7,000 feet of Permian this writer believes was deposited also, plus any Mesozoic beds. The erosion that would progress and be accentuated as the relief increased during folding would help to fill structural troughs on each side. Certainly Cedar Valley to the east

and Rush Valley to the west contain fill which must extend to a considerable depth and was derived from the Boulter Mountains in part.

This entire region began undergoing folding and erosion and in the latter part of the Mesozoic the eastern margin was depressed and the Upper Cretaceous and Lower Tertiary conglomerates were deposited in a transgressional sea environment.

A belt of orogeny may have extended from southern Nevada to western Montana. In the southern part of the Wasatch Mountains large deposits of conglomerates, sandstones, shales, and some fossiliferous marine beds were deposited in the Cedar Hills, Gunnison Plateau, and Sanpete Valley, probably in the Late Cretaceous. Called the basal Indianola group these deposits grade into the Mancos Shale to the east. They become coarser and absent toward the west. Spieker (1946) considered that a belt of intense deformation lay west of the Cedar Hills where he found conglomerate resting unconformably on Upper Jurassic Shale. The greatest thickness of the conglomerates is approximately 15,000 feet in the Cedar Hills, and the events that caused them have been called the Cedar Hills Orogeny by Eardley.

In the Muddy Mountains of Nevada the Overton Conglomerate rests on folded and thrust Mesozoic rocks, the youngest being of Jurassic age. In North Central Utah the Kelvin Conglomerate 3,000 feet thick is believed to have been derived from an uplift which lay to the west and close to the present Wasatch Mountains,--Permian cherts and Pennsylvanian quartzites comprise most of the pebbles in this conglomerate.

The Lower Cretaceous Gannett group of southeastern Idaho which has several conglomerates and coarse sandstones is believed to represent a high positive area which was to the west, these are thought to reflect one pulse of orogeny, while another and probably the main orogeny deposited 3,000 feet of the Wayan Formation on them unconformably.

The source of the clastics mentioned has been from the west and judging from the degree of sorting, size, and roundness, the source most of the time was not far away. The writer would suggest the East Tintic Mountains of which the Boulter Mountains are part as a very likely source for at least some of the clastics.

FOLDS

North Tintic Anticline

This is the principal fold of the region and is known also as the Broad Canyon anticline. It is asymmetrical and overturned on the east limb with dips of 55 degrees overturned to the west in some places. The west limb is considerably gentler in slope with dips of 25 degrees common, some 5 and 10 degree dips are also present. The plunge varies from approximately 45 degrees near "Skyline Ridge" to 20 degrees near Twelvemile Pass. The overturning to the east together with the direction of drag of beds near faults, jointing, and fracture patterns are evidence of forces acting from the west.

Minor Folds

Some small folds are drag folds resulting from the folding and faulting.

FAULTS

Tear Faults

Two major tear faults are in the mapped area. One of these passes through the area to its southern termination. It has been mapped by Dearden (1954) and named the Cedar Valley fault. In his thesis area it has a stratigraphic displacement of 2,000 feet and places Middle Cambrian Cole Canyon Formation against Lower Cambrian Tintic Quartzite. This tear fault forms the northern edge of the overthrust sheet which moved from west to east through this writer's mapped area for a distance of approximately one mile, to one and a half miles.

The Cedar Valley fault disappears in the alluvium of Broad Canyon in its southerly trend. Where it probably emerges from the alluvium it displaces the formations approximately 1,000 feet, disrupting the southerly continuance of the Cole Canyon Formation and placing it against other formations normally lower in the Middle Cambrian sequence. It then continues to the southwest beyond the County line which forms the boundary of the writer's area. There is a possibility that either a branch of the Cedar Valley fault or possibly the main fault emerges from the alluvial fill and plays a part in the faulting found in Section 22.

The major tear fault found by the writer is the Tintic Prince fault which extends in a generally north 68 degrees east direction and virtually bisects the entire Bismark Peak area. During the course of this mapping project the continuation of a tear fault of large magnitude on the east limb of the North Tintic anticline was traced two and one-half miles to the southwest and out of the writer's area past the mine known as the Tintic Prince. Disbrow (U. S. Geological Survey) informed the writer that the fault was known in the immediate vicinity of the mine and bore the same name as the mine. It is only logical to apply this name to the entire extent of the fault.

The Tintic Prince fault has moved all of the formations comprising the east flank of the North Tintic anticline over 7,000 feet to the east. Strata from the Lower Cambrian Tintic to the Pennsylvanian Great Blue participated in this move. At one point it places Lower Cambrian Ophir Formation against the Upper Mississippian Humbug Formation. Where it crosses the ridge near the north base of Boulter Peak it appears to have had a prominent part in the forming of the topography as the fault trace apparently helped to form a part of the south "arm" of Holdaway Canyon. On the south side of the canyon the beds dip gently to the east but they are vertical to overturned on the north side. The fault trace lies between the types of attitudes. Where the fault trace crosses the ridge crest leading down from Bismark Peak there are extensive areas of intense hydrothermal alteration; some areas of brecciation and alteration are 150 feet wide. Alluvium in part of Holdaway Canyon makes it difficult to follow the fault trace in its entirety, but acute drag folding evidences its nearness in places. Where the fault cuts through Tintic Quartzite it is often difficult to follow with accuracy.

The southwestern trace of the Tintic Prince fault places the Tintic Quartzite against various Middle Cambrian formations.

The axis of the North Tintic anticline occurs in the Tintic Quartzite and has been moved to the east-riding on the overthrust sheet of which the Tintic Prince tear fault is the southerly lateral component. The southern termination of the leading edge of this thrust can be observed about one-fourth mile north of the writer's area. The eroded leading edge of the overthrust and the thrust plane itself can be observed in part, it is about 7,000 feet long and over the greater portion of its length places the Silurian Bluebell Dolomite over the Lower Gardner Dolomite.

Other Faults

The fault system is dominated by the large Tintic Prince tear fault but there are numerous other faults which are also predominantly northeast-southwest. Another pattern of faults trends northwest-southeast, but these are fewer and generally not as large. In addition there are some faults that have a nearly east-west direction. The writer found slickensides in several places in the Boulter Mountain region which indicated either faulting on the bedding plane of various formations or slippage caused by drag folding or otherwise related to the main arching of the North Tintic anticline. The striations were generally north-south. Perhaps they were caused by a lengthwise stretching of the beds comprising the structure at the time it was being compressed into an anticline, or marks caused by relaxation of the pressure that caused the folding. Bedding plane thrusts could also have caused the slickensides, some of which were nearly horizontal.

The writer measured the jointing attitude and fracture pattern in several places throughout the area with the conclusion that most of the stress has come from the west but some has come from the southwest.

The northeast and the northwest trending faults, of which many are of the strike-slip variety, would be the result of forces from the west or slightly south of west, this would also account for the reverse faults that are present. When compressional pressure was relaxed natural faulting occurred. The east-west faulting very likely occurred at this time also reflecting relaxational adjustment to the north-south stretching which occurred during the process of folding. Some of the east-west faulting probably happened during the folding.

Age of Tectonics

From the rocks present in the mapped area it is only possible to date the deformation as post-Mississippian. Nearby evidence permits extension of dating to post-Pennsylvanian and Permian. The folding with its accompanying and resulting faulting must have been expressions of the Laramide Orogeny. The folding probably began in the Late Jurassic so that only shallow deposition of sediments took place, perhaps 300 feet. At this time there was regional uplift accompanied by thrust faulting in nearby areas. By early Late Cretaceous time broad east-trending flexures had occurred in the East Tintic Mountains. During Middle to Late Montana time the major north-trending anticlines and synclines were formed as a result of east-west compressive forces. The increasing height of some areas due to folding resulted in sympathetic elevation decrease in other places such as at Long Ridge and West Mountain where conglomerates were deposited of Late Cretaceous or Early Tertiary age. As the folds increased in amplitude thrust and shear faults occurred. From the latest Montana time to the Paleocene the compressive forces subsided and east-west trending normal faulting resulted from tensional adjustments. The East Tintic Mountain area stood as a highland during the late Middle Eocene and was affected by normal faulting, igneous intrusives, volcanism, and mineralization. Then followed the development of the Basin and Range Province as a result of block faulting in the Late Eocene through the Early Miocene. During the Late Pliocene to the early Pleistocene there was renewed movement and mountain and valley fault blocks were tilted (Morris, 1957, pp. 54-55). This was the time when previous activity culminated in the Wasatch Fault which today delineates the east boundary of the Basin and Range Province in Utah. It is interesting to note that the west boundary was formed at about the same time by faulting along the east flank of the Sierra Nevada Mountains.

The Basin and Range Province is still tectonically active and faulting in the last few years in Nevada has necessitated repairs to transcontinental highways and formed vertical displacements of several feet along some foothills. Faulting has displaced the most recent terraces left by Lake Bonneville. In the Five Mile Pass Quadrangle to the north such terraces have been elevated a considerable distance above the known maximum level of the lake.

Mechanics of Thrusting

The tremendous forces needed to create great overthrust blocks have been so incredible that many geologists have questioned reports and maps which indicated such activity. Blocks have been reported in Norway to have been displaced eighty miles. In other countries overthrust blocks have been reported to have skidded fifty miles across younger rocks. Considering the coefficient of friction involved, experimentally it was feasible that thrust blocks could not occur for a distance of over twelve miles.

While observing the relationship of rocks involved in an overthrust of thirty miles displacement in the Alps an idea occurred to one geologist which may well provide the solution to the question of how great overthrusts can occur. He applied Archimedes principle to subterranean buoyancy. During experiments to test his hypothesis he found that there was a fifty per cent increase in the buoyancy effect by simply changing from the use of dry to wet rocks. The results of experiments and observations of rocks and pressures have been found to support his reasoning.

The conclusion is that if strong tectonic forces act on the interstitial fluids of subterranean rocks the pressure of the fluid builds up until it practically floats the overburden. The closer the pressure approaches the weight of the overburden, the greater the weight of rocks that can be pushed. The result is that in some cases very little lateral force is required to move the blocks, which practically "float" (Hubbert and Rubey, 1959).

That abnormal hydrostatic pressures exist is well known. Wells drilled in the Punjab Plateau of Pakistan encountered hydrostatic pressures of 2,000 pounds per square inch. These pressures approached 94 per cent of the calculated weight of the overburden at one mile depth. At Chia-Surkh in Iraq, well drilling programs drilling from 4,000 to 12,000 feet required a mud with a density of nearly .9 that of the overburden. At Surinam in the East Indies, drilling mud with a density of 1.1 that of the overburden had to be used and the drilling was still precarious and in danger of blow-outs. Ventura, California, and the island of Trinidad are other places with abnormal pressures. The hydrostatic pressure probably also prevents the closing of all pore spaces in a rock which has been deeply buried, where sufficient such pressure is present to help absorb the overlying weight.

ECONOMIC GEOLOGY

GENERAL STATEMENT

The ore-rich Tintic District occupies a unique geologic position. It is within twenty miles of the eastern margin of the Great Basin and the western margin of the Rocky Mountain Province, it is close to the northwest edge of the Colorado Plateau, and is but a short distance to the southwest of the east-west Uinta uplift.

As geologists became increasingly aware of the relation of local structures to ore deposits they began to probe the regional structural implications of the distribution of mining districts and their ores. The cluster of these mineral concentrations close to the dividing line of the Great Basin and the Rocky Mountain Province appeared to have a significant relationship as well as their nearness to the Colorado Plateau.

Butler (1920) was probably the first to attempt to explain the Tintic Mining District on a regional basis. After studying the distribution of Precambrian rocks he thought there had been an early east-west uplift from the Deep Creek Mountains eastward to the Tintic Mountains, a structure which he thought had flattened out before it reached the Tintic Mountains. Later north-south Cordilleran folding had placed both Tintic and Gold Hill in the vicinity of the junction of the cross-folds. He also postulated an extension of the Uinta uplift to the west which placed Park City and Bingham reasonably close the the axis of the folding, here again he thought the north-south cross-folding helped to create world-famous ore deposits. A few years later (1929) he thought that the roughly marginal distribution of the Tintic and other mining districts around the border of the positive block comprising the Colorado Plateau and the adjoining deeply filled Paleozoic basin held significance because of the strong deformation, igneous activity and resulting mineralization that might be expected in such a border zone. Some factors against this hypothesis are the geologically recent Wasatch faulting, the intervening south tip of the Wasatch Range, and that the north-south folding and easterly overthrusts are not limited to this area but are found in various other places such as at Mt. Nebo, Ely, and Eureka, Nevada.

Billingsley (1933, p. 24) interpreted minor features at Tintic and postulated, "at Tintic a northeast Uinta fold is driven in and overturned on the west by north-south Cordilleran thrusting." This hypothesis has been based on insufficient evidence.

Gilluly (1932) stated that the extension of the Uinta anticline through Bingham is definitely NOT a fact.

Kildale (1937, p. 96) considered that Park City could probably be related to the Uinta east-west uplift due to its proximity and that here the intersecting north-south cross-folding might be important in causing ore deposition. He mentions that at both Bingham and Tintic the main intrusive mass is along the axis of a downwarped or synclinal north-south fold. Because of Archean rocks in the Wasatch Mountains east of Tintic and Archean rocks in the West Tintic Mountains west of the Tintic Mining District, he considers that the intervening terrain with its 10,000 feet or more of Paleozoic sediments represent a trough--a natural area for intense folding and the deep fracturing which is conducive to igneous intrusion and metallization.

After a regional stratigraphic study of Utah and nearby states new evidence of an east-west uplift was found in 1954 by Dr. Harold J. Bissell (presented at a meeting of the Geological Society of America in March, 1955). It extended from Provo westward toward Wendover, Utah, and began in Early Ordovician time, becoming quite prominant by Early Mississippian time and by the time the Joana Limestone was deposited the high had nearly split the Utah-Nevada trough. He also found a northerly trending high through Milford, Utah, toward Wendover.

A stratigraphic correlation chart made by the writer and included with this report shows that local high existed, beginning in Ordovician time, notably in the Long Ridge locality. In referring to this chart the reader should remember that some geologists have asserted that correlation of some of the formations of the Basin and Ranges with those of the Wasatch Mountains is impossible. The writer has endeavored to attempt such correlations as seemed reasonable, based on accepted age and lithologic likeness. In general, the variation in relative thickness has supported the attempted correlation.

Although various geologists have thought that Bingham and Tintic are located in the same syncline, that belief is not tenable. Probably Bingham is located in the Lake Mountain syncline or possibly the Pole Canyon syncline or a fold very close to them. Bullock supports the Lake Mountain syncline correlation.

The north-south folding together with transverse folds east and west provided exceptionally favorable opportunities for the concentration of igneous activity and mineralization. Stratigraphically the rising areas would have importance too because of the effect on variations in lithology, porosity, permeability, and other factors that would affect the movement, trapping and deposition of fluids and gases. The abundant faulting not only provided avenues of movement for the hydrothermal fluids and vapors but sometimes also sealed off their complete escape. The presence of the hydrothermal activity is marked by alteration of the rocks and ore deposits.

ALTERATION AND MINERALIZATION

Hydrothermal alteration is found widely distributed throughout the area. The number of altered areas together with the degree of alteration would lead many prospectors to believe the region to be a very desirable place to explore. The many prospect pits, often chosen with considerable skill, reflect the acumen of those who saw their dreams, sweat, and dollars commonly result in nothing more exciting than an empty hole with beautifully red-stained rock-bound walls.

The alteration ranges from the early barren stage to the productive stage. Although assay values in lead, silver, copper, and gold are reported by those interested in the Deluxe mine the only productive stage seen by the writer was that of the Hot Stuff mine.

Located between the highly productive mining areas of Bingham, Ophir, Mercur, Park City, Cottonwood Canyon, and American Fork to the north and northeast, and Tintic only a few miles to the south, -- the area of this study is part of a region that could prove to be of critical importance in the unending search for new ore deposits. With such illustrious neighbors a thorough investigation of most of the intervening ground is sound mining practice.

In addition to his investigation of the stratigraphy and structure of the Bismark Peak area of the Boulter Mountains, this writer undertook a comprehensive alteration mapping program. Over 120 locations were found which contained alteration products. Those localities suitable for the scale of map reproduction are shown on the alteration map of this report.

A notable study of rock alteration in the East Tintic Mining District with its use as a guide for finding ore has been made by T. S. Lovering and his associates (1949). This investigation is expected to be helpful in its application to other districts, also.

In the Bismark Peak area, lack of sufficient metallization prevented the observation of the complete relationship of hydrothermal alteration and ore minerals. The paragenetic sequence found by Lovering does not appear as closely allied to the mapped region as that found by Proctor in the adjacent Allens Ranch Quadrangle to the east.

Numerous pits, shafts, and adits attest to the interest the region once held for the prospector. A long-deserted shack still stands near the intersection of two roads in Section 25, the only evidence remaining of the Assay Office of the North Tintic Mining District.

There are only two mines in this area and no commercial ore has been shipped for many years.

The principal alteration features recognized by Lovering (1949, p. 16) consist of dolomitization, jasperization, ferruginous and white rhombic calcitization, and metallization by sulfides, sulfosalts, tellurides, gold, quartz, and carbonates. The relationship is more clearly presented in the following table, an adaptation of the sequence listed by Lovering.

Paragenetic Sequence

Stage of Mineralization	Dominant Minerals Formed
Early barren stage	Dolomite and chlorite
Mid-barren stage	Argillites, pyrites
Late barren stage	Silica, jasperoid, pyrite, calcite
Early productive stage	Sericite, clear quartz, pyrite
Productive stage	Ore sulphides, carbonates

Table III

The writer observed the following sequence of alteration and mineralization:

1. Dolomite
2. White rhombohedral calcite
3. Ferruginous calcite
? Jasperoid

Proctor (May, 1954) told the writer that the sequence of mineralization in the Allens Ranch Quadrangle consists of:

1. Dolomite and white rhombohedral calcite
2. Jasperoid
3. Ferruginous calcite
4. Ore sulphides

Hydrothermal dolomite, representative of the early barren stage and ferruginous calcite, representative of the late barren stage are the two most common types of hydrothermal alteration. Each may be found without the other but in areas of pronounced alteration, particularly near fissures the two are usually both present.

Hydrothermal dolomite is identifiable by the coarsening of grain that has occurred during the process of alteration, sometimes the dolomite has acquired the texture of fine to medium sand. The writer has found limestone partly altered to dolomite and the two types of rock were readily identifiable by using the grain-size criteria. In most places only an acid bottle provided the means to distinguish the dolomitization. Twig-shaped bodies in the rocks are accentuated through selective replacement by a lighter-colored dolomite than the surrounding rock. Medium-grey limestones become slightly lighter in color. Light colored limestones can become cream colored dolomites. Dolomitic alteration had the effect of increasing the porosity of the limestones from approximately one to five per cent according to Lovering (Ibid, p. 22). Although these early alteration solution channels were more diverse and longer than those later channels, about ninety per cent of the time they were the channels used by the ore-bearing solutions.

Beds particularly susceptible to the dolomitizing solutions are some of the limestone beds of the Ophir Formation, the Upper Teutonic Limestone, the Dagmar Limestone, the lower part of the Herkimer Limestone, the Cole Canyon Dolomite, Pinyon Peak Limestone, and the Gardner Formation.

The Cole Canyon Dolomite is known to change to limestone quite abruptly about 1½ miles northwest of Eureka after leaving the vicinity of a prominent fault. It is dolomite again in the Bismark Peak Quadrangle. Several other formations that are dolomites within several miles of the Silver City monzonite stock change to limestone farther away.

The Gardner Dolomite Formation is more dolomitic near Twelvemile Pass than it is in this writer's area. The Pinyon Peak Limestone is noted for changing along strike to dolomite and back again to limestone within a few feet.

Chloritization, representative of the early barren stage of mineralization is found in the southeast part of Section 27 where a dike, sill, or possibly a flow outcrops in an accordant attitude in near vertical beds of Tintic Quartzite. It is probably a dike as it has approximately the same composition of known dikes in the Tintic region. The upper side of this "dike" has been chloritized. The bottom side has been kaolinized for about one foot. Kaolin represents the argillic alteration of the mid-barren stage.

Another occurrence of argillization is in the south half of Section 22 in a prospect pit about 15 feet deep. The rocks have a bleached appearance and there has been deposition of clay and mica.

Jasperoid has been defined as a calcareous rock in which the carbonates have been replaced by fine-grained quartz aggregates or chalcedony. This term has been used for a siliceous rock formed by the metasomatic replacement of limestone. Iron oxide present in the silica gives it a reddish color. Both red and brown varieties were seen, the brown is the most common. Zones of jasperoid alteration were relatively scarce in the mapped area and of insignificant size except in four localities. Jasperization is thought to be a product of the late barren stage.

In the northwest quarter of Section 26 there is a deposit of white "bull" quartz of notable purity. It is about eight feet wide and fifty feet long and is five feet high in places. It has a dip of 38 degrees to the south and strikes 78 degrees west of north. Inclusions of dolomitized Ajax Limestone, the same as the country rock, were present in the quartz along the contact and some quartz had penetrated the country rock at the contact. A similar occurrence of quartz was found in the northwest quarter of Section 22 in the Tintic Quartzite. This outcrop or vein is six feet wide and fifteen to twenty feet long and two or three feet high. It occurs where a ridge slope temporarily flattens. Probably a continuation of the same vein is located 300 feet uphill. The purity of these quartz deposits led the writer to make inquiries concerning their possible value in smelter operations, but the results were completely discouraging. Silica is a part of the late barren stage of mineralization processes.

Both ferruginous calcite and white rhombohedral calcite can be found designating paths of fault movement, sometimes as alternately banded vein fillings along the fissure walls. A rather unusual arrangement of these differently colored alteration features is at locations which appear to be the remnants of hot-spring orifices. In

such places the ferruginous calcite and the white rhombohedral calcite are interlayered and encrust and fill the circular-shaped openings. Hydrothermal dolomite is usually present and replaces the calcite in the surrounding limestone rocks for a short distance.

Upon fracturing by a blow from a hammer, the calcite emits the odor of hydrogen sulphide. Whether the odor comes from gas that might be contained within the calcite or from other causes has not been determined.

Ferruginous calcite alteration is very prominent in the upper workings of the Hot Stuff mine where it clearly gained access along fissures. It replaced and permeated part of the shale and limestone (or dolomite) of the Ophir Formation.

The only representative of the productive stage seen in the mapped area was some azurite found on a dump at the Hot Stuff mine. The owners of the Deluxe mine reported interesting assay values from their workings, however.

In conclusion, the ore-finding potentialities have been found best in the Tintic District where the alteration sequence is limestone to dolomite to jasperoid to pyritic baritic jasperoid. Hope is dimmed somewhat by the realization that Lovering, after twelve years of study in the area, has come to the conclusion there is no sure guide to ore.

Supergene Alteration

In humid climates rock-weathering would be expected to result in kaolin minerals. In the semi-arid climate of the Tintic District, favored by a slightly alkaline soil the igneous rocks tend to weather to allophane and montmorillonite. Kaolinite and halloysite are supergene minerals only where sulfides have oxidized.

High grade halloysite has been recovered by a small prospect pit in Section 15, just north of the writer's area. At the main Silver City monzonite stock where the Dragon fissure passes in a southerly direction from limestone into igneous rocks nearly 500,000 tons of halloysite have been mined up to 1957.

MINES AND METALLIC PROSPECTS

The Bismark Peak area is nearly surrounded by mines, all of which are in relatively close proximity. The rich Tintic Mining District is to the south, several mines are located to the east, particularly along the east edge of Cedar Valley, several small mining attempts are present toward the north within a mile or two, and some former producers are to the west and northwest. The mine to the northwest a couple of miles is the Scranton. It produced over 1½ million dollars in lead and zinc from 1902-1929 and a few small shipments in 1941 to 1946 (except for 1943) according to Renzetti (1951, p. 24). Disbrow and Morris (1957, p. 142) give production figures from 1902 to 1955 of 62,411 tons of ore. This included 38,048 ounces of silver, 11,900,099 pounds of lead, 20,920,306 pounds of zinc, 3,749 pounds of copper, and 11.57 ounces of gold. The copper and gold content was only recovered from a small portion of the ore shipped.

The mine to the west approximately two miles was formerly called the Ballhinch, but was renamed the New Bullion mine. It is in the southeast part of Section 30, Township 9 South, Range 3 West. Production between 1912 and 1916 has been estimated at $60,000 (Sargent, 1951, p. 41). The chief ores were primarily lead with zinc and some silver, gold, and copper.

The entire Tintic District has produced close to half a billion dollars worth of ore.

The Bismark Peak area is pitted with numerous "diggings," but there are only two mines: the Hot Stuff mine, located in Section 22 was an active shipper near the turn of the century; the Deluxe mine in Section 25 is still in the development stage.

The Deluxe mine was discovered by a Norwegian named Swanson and with high aspirations it was named the "Silver Dollar" mine. Due to non-payment of an $800 lien the mine was lost to "Art" Sorenson. In February of 1926 it was reincorporated under the name of "Eureka Deluxe." After further unprofitable development it was reincorporated in 1946 and with new capital, personnel and a new name, the "Deluxe" resumed mining operations. It was capitalized at $10,000 with permission to issue 1,000,000 shares of stock.

According to Mr. Clarence Olson, Heber, Utah, a director of the company, the workings as of 1954 consisted of two adits. The main adit was 1300 feet long. There are several drifts, most of them old and some caved, but two drifts extend for a total of 450 feet. Each of the

adits is on a different level. The upper one has a winze and better grade ore. The lower adit is the main one and at a cross-cut 450 feet from the portal a very small ore body was found which had a dip of 60 degrees east, a northeast strike, and a rake of 45 degrees. Assay reports showed an "eleven per cent lead valuation, 1.8 ounces of silver and .04 ounces of gold (per ton), with some copper present," according to Mr. Olson.

This mine was dormant during most of the time that the writer was engaged in his mapping project, but on the day he arrived with an assistant to map it, new activity had started. The mine was filled with fumes from blasting operations and could not be entered. The writer subsequently left the state without further opportunity to map the mine.

At the portal of the Deluxe a fault places the Humbug Formation on the west against Pine Canyon on the east, reversing the normal sequence. One of the most intensively altered locations in the mapped area is uphill east of the portal and extends along the top of the spur. Not far to the southeast barite has been found, one of the favorable indicators for the possible proximity of ore. Due south of the portal approximately one-half mile, one of the most intensive as well as extensive alteration areas is present adjacent to the road leading to the mine, due in part to volcanics. This general locality is where most of the silica breccia dikes are found.

If, as is generally believed, the North Tintic District is in the fringe zone of the principal area of ore deposition, then the closer the prospect is to Eureka and East Tintic the greater the chance for discovery of a worthwhile ore body. The Deluxe is relatively close and is also favored by areas of brecciation and sizable faults to provide avenues for ore solutions, together with favorable host-rocks. There is abundant evidence that hydrothermal solutions have found these channels, but have the fissures penetrated deep enough to be available to the ore solutions? Have the solutions traveled so far that they arrive in the Bismark Peak region with very little left of the valuable minerals, or did they arrive and were deposited--but just have not been found, perhaps because they are deeper than any exploration has penetrated? Perhaps they arrived from the north instead of from the main Tintic centers.

The Hot Stuff is the only mine that has shipped ore in the mapped area. Several wagon loads were freighted out about 1890 and 1893, according to George Chiulos an "old-timer" and resident of the district. In the early 1900's work was resumed and additional ore was taken out by wagon. Most of the production was sold for its copper values, but there may have been some zinc and galena present also. There has been a cessation of mining activities for several years although the rights are still owned by nearby residents. Access is by road, but the last quarter mile is traversable best by jeep because of overhanging growth. A three room building is located at the lowermost adit, it is still habitable. Mine rails are still intact. The only spring in the Bismark Peak area was at this mine, but it was dry during the summers of 1953-54.

Tintic Quartzite is present on each side of the lower adit, yet the adit is in the Ophir Formation; a block of the Ophir has dropped down, although the actual fault scarps are concealed by slope wash. Three dumps are uphill a short distance colored red by the alteration products they contain. The size of two dumps indicates considerable excavation in the adits. A winze approximately eighty feet deep is located in the southernmost excavation, and two fissures come together to form a "V" with the apex near the back (top) of the adit. To the writer, this mine seems to have many favorable possibilities for ore: Faults and fissures to provide avenues of entrance of ore-bearing solutions or vapors, cross-fissuring, faulting, and the relatively incompetent and impermeable Ophir Shale with its limestone, dolomite, and shale overlying the competent Tintic Quartzite. The adits were highly altered and some carbonate of copper ore was found on the dump. Acting on the advice of persons familiar with the caving dangers in the mine this writer did not enter it.

NON-METALLIC PROSPECTS

The relatively pure dolomites and limestones of the Boulter Mountains were long considered as a possible source for raw materials, particularly by those interested in smelter operations. That the United States Steel Corporation has established its quarrying operation in the nearby low-lying hills east of Cedar Valley is proof that other deposits are more economically mined.

Spectographic analyses (Sargent, 1951, p. 43) has indicated that the pink lithographic and adjacent "Curley" bed of the Gardner Formation, together with some beds in the Devonian Pinyon Peak Formation, are the most pure limestones. The first-mentioned beds comprise a 20 foot thickness, the latter has two beds seven feet thick separated by seven seven feet of dolomite. The Bluebell dolomites appear to contain some rather pure beds also, but are irregular in occurrence. These formations are vertical or very steep on the east limb of the North

Tintic anticline and are less steep on the west limb. In most places underground mining methods would be required. These possible sources of metallurgical flux and lime, remote as their mining now appears are still more readily accessible in the Rattlesnake Spur area (in the vicinity of Twelvemile Pass) than in the Bismark Peak area.

Although there are not any known non-metallic prospects in the Bismark Peak area a claim just to the north has been undergoing development in Section 15, Township 9 South, Range 3 West. It appears to be a small deposit of halloysite. Lovering has stated that kaolinite and halloysite in the Tintic District are supergene minerals only where sulfides have oxidized. This prospect is just over a hill from the Scranton mine and might well be the surficial evidence of a sulfide deposit.

CONCLUSIONS AND RECOMMENDATIONS

The Bismark Peak area is encouraging to prospectors because of the numerous indications of alteration, the proximity to known ore deposits, abundant channelways for ore solutions and gases, faults and overthrusts which help to seal off the escape of metallizing solutions, favorable and proven host-rocks for ore, and the production and assay values from the two mines, the Deluxe and the Hot Stuff.

On the discouraging side is the small amount of productive stage alteration and metallization at the surface, the distance from the main Tintic District, the termination of the four main metallizing faults of the Eureka-Silver City locality long before they reached the Bismark Peak region. These faults provided bonanzas at Tintic. Further discouraging factors include the abandonment or suspension of nearly all prospects and mining activities, and the various features of mine operation intimately related to market price and production costs.

The writer would recommend a much more complete exploration program for this area. Particular attention should be given the places where the most intensive and advanced stages of alteration are present, the front margin of the overthrust and the side margin (provided by the Tintic Prince fault) possibly below the plate itself could be investigated by the use of geophysics, favorable combinations of structure and lithology should be examined closely. Geochemical prospecting would provide a relatively inexpensive exploration tool; field testing chemical costs are presently 15 cents per test. Analyses of plants, soil, and altered rocks might reveal the minute presence of valuable minerals. Northeast-trending fissures should receive special attention. Interesting areas should be explored by drill, pick, and shovel.

SUMMARY OF GEOLOGIC HISTORY

The Bismark Peak area is located in a portion of what was once the Cordilleran geosyncline. It was probably a miogeosynclinal shelf area during most of its earlier history.

Near the area Upper Precambrian beds of the Big Cottonwood (?) series were deposited and then eroded. Though not exposed they probably also underlie the Bismark Peak area.

Throughout the Lower Cambrian the sea remained quite shallow and the geosyncline was sinking at about the same rate as sediments were deposited. Paleogeologic maps by Eardley from Cambrian through Silurian time show positive areas about 300 miles to the north and 300 miles to the south, and these may have provided the sediments or possibly widespread transgressive and regressive seas provided the vast quantity of sand and pebbles of the Tintic Quartzite. Ripple marks and cross-bedding tend to indicate a shallow depth for the stable shelf, although photographs of the present ocean bottom have recently revealed ripple marks at depths of several thousand feet. From time to time fluctuations occurred and the sediments became less well sorted, these beds today express cross-bedding that is indicative of several changes of current direction and/or velocity in relatively short stratigraphic intervals. Some conglomerate beds are present which might be ascribed to the source area rather than to evidence unconformity. During the latter part of Lower Cambrian time the sea became deeper or the source area changed in character and there was a decrease in thickness of beds and an increase in clay content.

More clays and silts were laid down, this time in great abundance, and after time advanced to the Middle Cambrian there was still no more than fifty feet of the Ophir Shales in existence. After additional thicknesses were deposited either due to a change in source area, to longshore currents bringing in a relatively clean water, to increased faunal activity, or a combination of several factors, perhaps the creation of basins was an important factor--limestone began to be deposited. From time to time currents still swept clay into the site. The Ophir sea extended from Grand Canyon to southeast Idaho according to Wheeler, becoming younger toward the north and east. Conditions of sedimentation became shallower for awhile as evidenced by the presence of oolites. Throughout this period until the Mississippian the faunal life recorded was not abundant.

The status began to change again, the water became shallower, clays and sand infiltrated the limy deposits almost continuously, oolites were formed. Near the end of Teutonic Limestone deposition the water became very shallow and somewhat stagnant, forming a very dark grey limestone and oolites.

While the time was still Middle Cambrian deposition of an exceptionally pure limestone occurred under very stable conditions. This has probably since been altered to dolomite (the Dagmar). If dolomite is ever proven to be of primary origin under marine conditions, the Dagmar Formation might be cited as an example. It is likely that the previous restricted circulation permitted favorable organisms and reactions to change the lime ooze to dolomite almost contemporaneous with deposition.

Later sedimentation proceeded similar to that of the Teutonic phase except slightly more clay was deposited. When over half of the new formation was deposited the water again became shallower with very restricted circulation; this persisted for only a short time and precipitated a limestone with small white inclusions resembling twigs averaging 10 mm. in length and 1 to 2 mm. in width--typical of the later Bluebird Formation. During subsequent time the limestone became dolomitized. Later there were two different periods of time when a super-abundance of clayey materials were deposited (the shaly beds of the Herkimer Limestone).

After a period of renewed circulation and deposition of clay particles and limy ooze, more oolites were produced and then the Bluebird Dolomite Formation--a singular thickness of very dark limestone was laid down. This was also probably in a place of restricted circulation for the organic content appears to be high as evidenced by a fetid odor. Post-depositional changes have converted the material to dolomite and destroyed most of the evidence of any faunal life it possessed.

During the next interval of time most of the conditions of sedimentation of the Middle Cambrian were repeated and the Cole Canyon Dolomite Formation resulted, this too has an abundance of argillaceous sediments near the middle. Post-depositional dolomitization has affected most of the formation.

The time changed to Upper Cambrian and the sediments became subject to more agitation by currents and waves, probably a slight emergence occurred, then re-submergence and a sixty foot thickness of oolites was produced--some of quite large size. The Opex sediments became more clastic, ripple marks, cross-bedding, and flat-pebble conglomerates were created indicating that the water may have become shallow enough to form clay galls or flakes, or it may have allowed the dessication of limy mud and its redeposition in a similar matrix, or it might simply reflect changing currents. The environment continued to be that of a stable to slightly unstable shelf of probable neritic depth. To the east about twelve miles the strata was becoming elevated so that by the end of Opex time it was a positive area.

Sedimentation continued much as during the Opex deposition except for the formation of an increasing amount of silica in the form of chert, possibly there was more magnesium in solution also. Volcanism may have been taking place at a considerable distance. Most of the limestones have since been changed to dolomite. The end of Cambrian time is thought to be represented by the top of the Ajax Formation.

The 22 foot thickness of the Emerad Member of the Ajax was deposited and time advanced to the Upper Ajax when deposition of material occurred which closely resembles the Lower Ajax except that there is less cross-bedding and fewer wavy laminations (probably due to deeper water), and in the latter part of the time of deposition argillaceous material began to come in considerable quantities with the material that was to become limestone. A positive area continued to rise 12 miles to the east.

With no clear-cut differentiation in lithology between formations, the argillic materials increased and continued while 1107 feet of Ordovician Opohonga Limestone was deposited with its occasional beds of flat-pebble conglomerate. The positive area remained and probably spread to the Tintic area or very close before Bluebell time. The Tooele arch formed to the north and the Sevier arch to the south.

Sedimentation changed markedly during the rest of Ordovician time when the Lower Bluebell Formation was laid down. Although it is dolomite now it must have been deposited as a limestone and quite probably with a rather high magnesium content. Basins had formed in the region, some with restricted circulation. After dolomitization and weathering severe mottling occurred and the top of the youngest such bed is taken as the division between the Ordovician and Silurian Systems.

The Silurian Bluebell Formation may have resulted from shallowing seas as bedding became more prominant and some of the beds are more argillaceous. A high organic content is thought to be represented by the fetid odor. During Middle Ordovician the area was emergent, then it subsided. Later it again came out of the water. An unconformity is believed to be present at the top of the Silurian and due to erosion the

entire thickness is not known. Probably some of the Lower Devonian is also missing. To the west a long overthrust belt extending nearly the length of Nevada occurred during the Silurian. The Silurian changed into Middle and Upper Devonian time and possibly deposited more Bluebell sediments containing several "Crinkley" beds which are recognized by their highly contorted laminations. They may represent algal biostromes rather than slump structure as they were once thought to be. The original limestone has changed to dolomite.

During Middle (?) and Upper Devonian time, sand and limestone were deposited as shallow water prevailed. Considering that in the preceding interval non-deposition or erosion took place, the area must have been resubmerging. During the first part of the renewed sedimentation the Victoria Quartzite was deposited containing more sand than the later Pinyon Peak Limestone; limestone beds were also formed. The source of the materials could have been in part from the positive areas mentioned by Bissell and from the Manhattan geanticline to the west, or the Ancestral Rockies to the east. A very slight local disconformity occurred before deposition of the Pinyon Peak Formation. This was the local reflection of an important unconformity in the Oquirrhs, Stansbury Mountains, eastern Uintas, and Central Wasatch ranges.

When the Gardner Dolomite was deposited (as a limestone) in probable Lower Mississippian time the environment for the flourishing faunal assemblages arrived at optimum conditions. The shelf was beginning to get more unstable, but the water fluctuated mostly between the epineritic and neritic zones. Wavy laminations help to indicate the presence of wave or current action or both. The contorted laminated "Curley" bed of the Gardner, believed due to algal growth, covered over 600 square miles. Either this bed or a very similar one was seen by the writer as far south as the Grand Canyon of Arizona, conditions for algal development were favorable over wide areas. Some clay sediments were also deposited. The division of the Gardner into Upper Kinderhookian below and Upper Kinderhookian-Lower Osage above is made at the "Curley" bed. This is also thought to mark the division of the Upper and Lower Madison Limestone--the correlative of the Gardner Dolomite.

During the Mississippian, sedimentation processes proceeded to deposit 840 feet of limestone together with some silica and clay (the silicious-shale "Tinkley" beds of the Pine Canyon Limestone resulted). Of considerable importance and geologic interest is the abundant chert that is present as nodules and thin beds in this formation. Volcanism was proceeding not far away and it is believed that by weathering of volcanic ash the sea was able to carry large amounts of silica in suspension. There are several theories regarding the origin of chert and it is not the writer's purpose to discuss them here, however, it should be mentioned that theories involving diatomites cannot be discarded because of lack of evidence that they lived prior to the Mesozoic, because it may be they have not been recognized in such rocks. One plausible theory is that the acidity of marine water increases with depth. Silica is more soluble in water of high acidity. When currents carry silica-bearing waters toward the surface the silica becomes less soluble and is precipitated. This might be an explanation for some of the bedded cherts.

Limestone beds that are sand-streaked and cross-bedded, others that are comprised mostly of broken fragments of crinoids, all suggest that wave and current action was strong enough to rework the sediments considerably; this idea is augmented by other beds containing fossil detritus. Burial occurred too fast in some places to permit much reworking of the material.

In Upper Osagean and Lower Meramecian time the Humbug Formation was deposited on a somewhat unstable shelf environment. Limy ooze was precipitated in substantial thicknesses and overlain by sand; this occurred many times, particularly in the lower part of the formation. In the upper part greater thicknesses were deposited before changes occurred. Today, the well-formed ripple marks, cross-bedded sandstones, orthoquartzites and limestones suggest the agitation of waves and strong currents that would be present in shallow seas. Fossil assemblages support a neritic environment. Dolomites are present and must be of secondary origin. The alternation of beds of such diverse lithology suggests that for a considerable time the environment was undergoing sporadic change. Probably it was due to a combination of local shelf unstability and changing source areas or source rocks. Cross-bedding reveals that the currents came from all four quadrants of the compass.

During Mississippian time the area was located close to the axis of the Madison and Brazer basins. About 250 miles to the west the Manhattan Geanticline was providing sediments and silica to nearby basins, this lasted into Pennsylvanian time. One east-west high nearly split the Utah-Nevada trough from Provo westward toward Wendover, and a north and northwest trending high separated the Joana basin on the west from the Madison-Gardner basin on the east. The Ancestral Rockies, particularly the Uncompahgre and possibly the Defiance Uplifts were also contributing sediments. The Upper Mississippian Great Blue Limestones comprise the youngest Paleozoic rocks found in the Boulter Mountains, although Permian rocks are nearby.

In the Pennsylvanian Period, the Ancestral Rockies were rejuvenated and contributed increasing amounts of sediments. The Transcontinental Arch, which had sagged in the central portion was rejuvenated enough that erosion there proceeded as far down as the Precambrian rocks. The deepest part of the Oquirrh basin became located within a few miles of the Boulter Mountain area. About fifteen miles to the north the Oquirrh Mountains prove sedimentation continued into the Permian. Probably on the order of 7,000 feet of Permian rocks were deposited in the Tintic area. No Mesozoic rocks have been found in or near the Boulter Mountains, but the writer believes approximately 5,200 feet of Jurassic sediments were formed. In the Upper Jurassic only 300 feet of material was added. Many of the Jurassic rocks were of terrestrial, mud flat, and lagoonal types. During the Cretaceous there may have been some slight resubmergence, particularly a few miles to the east. Throughout the Tertiary the area was probably positive.

The great North Tintic anticline probably began to rise in the early part of the Jurassic. By Late Jurassic time it had become of considerable magnitude. The Laramide Orogeny had begun. It reached its climax in Middle to Late Montana time (latter half of Upper Cretaceous). The tremendous stress involved in the folding was squeezing the rocks together in an east-west direction and stretching them in a north-south direction. The strain became too great and rupture occurred in the form of sizable tear faults. Strike-slip faults occurred also. Compression continued and thrust disjoined segments of strata over some of the younger rocks to the east with displacement exceeding one mile. The pressure was relieved and relaxational stresses caused normal faulting.

Meanwhile, a deep-seated magmatic reservoir was forming and becoming rather well differentiated. As it began to upwell the stresses caused penetration of the rocks by means of fault fissures and passage was made to the upper regions. The East Tintic region was the scene of much volcanism. Latitic tuffs, agglomerates and flows up to 1,000 feet thick spread out upon the surface, followed by basaltic flows. The upwelling magma crystallized below the surface and formed monzonitic stocks, plugs, and dikes. Volcanism had been occurring in the Rocky Mountains from the time of the Laramide Orogeny to Early Miocene. Some disturbances began in the Cordilleran in the Oligocene.

While the magmatic reservoir was still under tremendous heat and pressure, relatively minor faulting tapped the reservoir and the gases and solutions belched forth and forced their way to the surface dissolving silica from the quartzites and cherts they encountered as they rose and disrupting pebble and cobble-sized fragments. These pebbles and cobbles were rounded during their travel to the surface and upper regions where they were deposited in the more open parts of the fissures, forming the "pebble dikes" of the Tintic District and the "silica-breccia dikes" of the Bismark Peak area.

The next phase of activity produced the ore deposits of the Tintic District and is probably quite closely related to the puncturing of the magmatic reservoir. In the Tintic-Eureka area the ore is considered to be hypogene and related to the Silver City Stock. It followed four great ore channels which consist of the Paxman, Beck, Centennial, and Grand Central northeast-trending faults. They all have a tendency to converge in a northward direction and disappear beneath volcanic cover. The most favorable places for ore deposition were along the intersection of fissures and the contact between the Tintic and overlying volcanics and formations. Minor faulting ensued in the general region. The intrusion, volcanism, and mineralization occurred during the late Middle Eocene.

From Late Eocene through Early Miocene time the Basin and Range Province developed by block faulting. During the Late Pliocene to Early Pleistocene there was renewed faulting and tilting of mountain and valley blocks.

Post-volcanism faulting has displaced volcanic flows located a few miles east of the Boulter Mountains. This occurred possibly as late as the Pleistocene.

During the Pleistocene the climate became warmer and ice deposits melted. Lake Bonneville was formed and extended nearly the entire length of the State of Utah. At is maximum elevation of 5135 feet it invaded the floor of Cedar Valley to the base of the Boulter Mountains. As the lake receded it split into two parts, the southern part is represented by Utah Lake and the northern part is the Great Salt Lake. The present topography has been carved in part since the latter part of the Pleistocene.

Appendix

Detailed Measured Stratigraphic Sections

Stratigraphic Sequence of the Humbug Formation and Pine Canyon Limestone Formation

Measured by John M. Foster, Melvin O. Dearden, Vaughn E. Livingston, and Charles Hyde, south of Rattlesnake Spur in Section 12, T9S, R3W, Utah County, Utah, May 15, 1954.

Great Blue Limestone
----Conformable contact----
Humbug Formation

Humbug Formation

Description	Thickness (feet)
Orthoquartzite, yellowish-brown, weathering to reddish-brown, medium to coarse grained, thin to medium-bedded, cross-bedding which dips to the north.	7
Orthoquartzite, 3 feet thick, reddish-grey which weathers the same color, fine grained, thin bedded, banded with scintillating bands. Underlain by 37 feet of dark grey limestone weathering to light bluish-grey, fine to medium grained, thin to thick-bedded. A 2 foot orthoquartzite bed is in middle of this unit. Black chert blebs and silicious brachiopods are present.	40
Limestone, reddish dark grey weathers to medium grey, crystalline to coarse-grained, medium-bedded, with saccharoidal weathering habit; silicious. Black chert blebs and horn corals are present.	11
Limestone, pinkish-grey, weathers the same color, crystalline to coarse grained, thin-bedded, encrinitic. Underlain by 11 feet of yellow-brown orthoquartzite which weathers reddish-brown, fine-grained, thin-bedded with red bands.	12

(Continued)

Humbug Formation (Continued)

Limestone, dark grey which weathers the same color, crystalline to medium-grained, medium-bedded.	4
Limestone, dark grey, weathers dark to medium-grey, fine to coarse-grained, medium-bedded. Underlain by 3 feet of buff-grey orthoquartzite, fine-grained and thin-bedded. .	6
Limestone, medium olive-grey which weathers medium-grey, fine to medium-grained, thin to medium-bedded, mottled at the base. Saccharoidal weathering habit. Underlain by 3 feet of reddish-grey orthoquartzite, fine to medium-grained with saccharoidal weathering habit.	19
Limestone, dark to medium-grey which weathers to same color, crystalline, thin-bedded with saccharoidal weathered texture, underlain by 5 1/2 feet of reddish-grey orthoquartzite, fine-grained, thin-bedded, with scintillating bands.	9 1/2
Orthoquartzite, 14 feet, reddish-grey which weathers the same color, fine-grained, thin-bedded, with scintillating bands; underlain by 1 foot limestone bed, light olive-grey which weathers to light-grey, sub-lithographic. This is underlain by 19 feet of orthoquartzite of the same description as the upper part of this unit.	34
Limestone, light olive-grey, weathers to light grey, medium-bedded, sub-lithographic with meringue appearance on weathered surfaces.	19
Limestone, 12 feet, light brownish-grey weathers to light grey, sub-lithographic, thick-bedded, an exsolution limestone. This is underlain by 11 feet of buff orthoquartzite which weathers the same color, fine grained and thin bedded. .	23
Limestone, pink, weathers to medium-grey, crystalline, thick-bedded with saccharoidal weathered appearance. This is 16 feet thick and is underlain by 26 feet of cover with orthoquartzite float.	42
Limestone, 5 foot bed, light brown which weathers the same color, sub-lithographic, medium-bedded. Small 1/16 inch darker brown bodies are present. This is underlain by 59 feet of orthoquartzite outcrops and float.	64

(Continued)

Humbug Formation (Continued)

Limestone, 8 feet, dark to medium-grey, weathers medium to light grey, crystalline, fine-grained, medium-bedded, meringue weathering; underlain by 3 feet of dolomite, olive-grey which weathers white; underlain by 35 feet of orthoquartzite, reddish-grey, weathers the same color, fine-grained and thin-bedded.	46
Orthoquartzite, reddish-grey weathers to the same color, fine-grained, thin-bedded, banded with scintillating bands. Underlain by 3 feet of olive-grey dolomite which weathers white.	26
Dolomite, medium-grey weathers to magnesium-white, fine-grained, medium-bedded, calcareous; underlain by 4 feet of limestone, dark grey, weathers medium to light grey, fine-grained, medium-bedded, possibly algal. Underlain by 4 feet of olive-grey dolomite which weathers magnesium-white, fine-grained, medium-bedded and calcareous.	11
Dolomite, light brownish-grey weathers to a magnesium-white, crystalline, thin bedded, calcareous, meringue weathered texture. Underlain by 2 feet of reddish-brown orthoquartzite, which weathers reddish-brown, fine to medium-grained, medium-bedded.	3
Limestone, medium-grey weathers the same color, crystalline to fine-grained, thick-bedded. White twiggy bodies present near the top, possibly algal.	32
Dolomite, medium-grey weathers to light grey, fine grained, thin-bedded, with saccharoidal weathering habit.	1 1/2
Orthoquartzite, maroon, weathers to brown, fine to medium-grained, thin-bedded.	9
Limestone, olive to pinkish-brown, weathering to the same color, sub-lithographic, medium-bedded.	2
Orthoquartzite, medium-grey to reddish-grey, weathering to reddish-brown. Coarse-grained, thin to medium-bedded. Cross-bedding dips to the southwest.	35
Limestone, olive-brown, weathers to medium-grey, crystalline, medium-bedded, with saccharoidal weathering habit and small white "twiggy" bodies.	10

(Continued)

Humbug Formation (Continued)

Orthoquartzite, reddish-grey weathers brown, coarse-grained, medium-bedded.	4
Limestone, olive-brown, weathers to light grey, sub-lithographic, thick-bedded.	10
Orthoquartzite, same as the 47 feet described below.	23
Limestone, light grey, weathers to medium-grey, crystalline, medium-bedded, silicious; with saccharoidal weathering habit.	4
Orthoquartzite, buff to pink-grey, weathers to reddish-brown, medium to coarse-grained, thin to medium-bedded. Cross bedding present; dips south, north, east. Two foot orthoquartzite breccia bed, and 2 feet of white orthoquartzite 10 feet from base.	47
Dolomite, olive-brown to grey, weathers to light-grey, crystalline to fine-grained, thin-bedded with 1/32 inch brown chert stringers. Weathers with slightly saccharoidal appearance.	10
Orthoquartzite, yellowish-brown weathers to light-brown, coarse-grained, thin-bedded; cross-bedding near the middle dips to the south	20
Limestone, medium-grey, weathers the same color, crystalline to coarse-grained, thick-bedded with cross-bedded encrinites. Cross bedding dips to the south.	9
Orthoquartzite, pinkish-grey, weathers to dark reddish-brown, fine-grained, medium-bedded with dark red bands.	9
Dolomite, greyish-pink, weathers olive-grey to light-grey, crystalline to fine-grained, thin-bedded with platy weathering habit, becomes medium-bedded at top.	40
Orthoquartzite, pink-grey, weathers to reddish-brown, fine-grained to medium size grains, thin-bedded.	9
Sandstone, pink-grey, weathers to brownish-grey, coarse-grained, thin to medium-bedded, slightly calcareous. . . .	18

(Continued)

Humbug Formation (Continued)

Sandstone, light-grey, weathers the same color, coarse-grained, laminated, thin-bedded, sub-angular grains presenting a saccharoidal texture on weathered surfaces, with calcareous cementing of grains. 42

Limestone, olive-grey, weathers to light brownish grey, medium to coarse-grained, medium to thick-bedded, fetid on fresh fracture, interbedded with orthoquartzite beds. 56

Limestone, light grey which weathers slightly darker, medium to coarse-grained, encrinitic. Medium to thick to massive-bedded. Fetid on fresh fracture. 44

Total thickness 811

Conformable contact

Pine Canyon Limestone

Measured by John M. Foster, and Melvin O. Dearden, June 8, 1954.

Limestone, olive-grey with a maroon tinge which weathers to white or light cream. Sub-lithographic to fine-grained. Thick to massive-bedded. Contains some chert in the upper part. Some fossils present which include Lithostrotionella sp. (a round type--not hexagonal). 54

Limestone, medium grey-blue which weathers light blue-grey. Fine-grained, thick to massive-bedded. Contains blebs, stringers, nodules, and bands of light brown chert which become darker up section. 59

Limestone, same as above. This is massive ledge-former with sandy weathering surface. Some chert in large blebs is black colored. Chert stringers are generally brown with sandy appearance. 51

Limestone, medium-grey which weathers to a lighter grey, coarse-grained, encrinitic, thick to massive-bedded, sand streaked. In lower part very little chert is present. 42

Limestone, same as above but more encrinitic. The lower 13 feet stands out in relief due to weathering habit. 60

(Continued)

Pine Canyon Limestone (Continued)

Limestone, medium-grey which weathers the same, crystalline to fine-grained, thick to massive-bedded. A 3 foot "porphyry" bed is present consisting of white calcite inclusions 2 to 5 mm in diameter. Chert occurs again down section and forms brown lenses, nodules, and bands and becomes more black in color. A sand-streaked bed is near the middle of this unit. 121

Limestone, same as above, but more sand-streaked, chert is less plentiful and consists of a few black nodules and blebs. 50

Limestone, light grey which weathers lighter but with a sandy appearance. Coarse-grained to very coarse-grained, encrinitic. Massive ledge-former near top of unit. Very little chert in upper part of unit, but some calcite stringers are present. Encrinite content disappears down-section, chert increases. 89

Limestone, light grey which weathers to the same color, fine-grained, thin-bedded. This is silicious and has a very shaly weathering habit. It is one of the two "Tinkley" beds of this formation. A breccia dike is present locally in the basal 20 feet. This "Tinkley" bed becomes more shaly down-section and changes to a reddish-pink color. At 159 feet a 1 1/2 foot limestone bed is present containing chert. At base all beds contain plentiful black chert beds. 161

Limestone, medium-grey which weathers to a lighter color, fine-grained, thin to medium-bedded. Bedding becomes thicker down-section, becomes ledge-former, finely laminated. Black bands of chert present in upper part of unit change to medium-brown in basal part. 101

Limestone, medium dark grey which weathers the same. Very coarse-grained. Thick to massive-bedded, encrinite bed 10 feet thick. Down-section from the encrinite bed the limestone is ledge-forming and has specks and streamers that are white. Chert beds and blebs become abundant, the chert is medium-brown in color. The contact is taken at the lowermost black chert bed. Syringopora sp. within 20 feet of the contact and Lithostrotionella sp. within 50 feet, both in the Upper Gardner dolomite help identify this contact. 52

Total thickness 840

Conformable contact

Stratigraphic Sequence of the Gardner dolomite, Pinyon Peak limestone, Victoria quartzite, Bluebell dolomite, Opohonga limestone, Ajax limestone, and Opex dolomite formations.

Measured in the north half of Section 26, T9S, R3W, Utah County, Utah. The Gardner dolomite, Pinyon Peak limestone, Victoria quartzite, and Bluebell dolomite measured by John M. Foster, Melvin O. Dearden, and Mack Croft on April 24, 1954.

Upper Gardner Dolomite

Limestone, medium to dark blue-grey which weathers light blue-grey, fine grained with saccharoidal weathered appearance; thick-bedded. Thick, dark, black and brown bands of chert disappear down section after becoming thinner and lenses or blebs of the same kind of chert. Just below the most distinctive chert the fossils are abundant. Euomphalus sp., Lithostrotionella sp., Triplophyllites sp., (also found in lower Pine Canyon fm.). Other types of gastropods and numerous crinoid stems and fossil fragments. The limestone has a fetid odor. 34

Limestone, medium blue-grey, weathers medium to light blue-grey; fine-grained with saccharoidal weathered appearance; thick-bedded with a fetid odor. Decrease in fossil abundance. Fossils present include Triplophyllites sp. (abundant), and Euomphalus sp. near upper part of unit; several encrinite beds. 151

Limestone, medium to dark blue-grey, weathers medium blue-grey, very fine-grained; medium to thick-bedded. At the top of this unit is a biozone. Abundant fossils include the following genera: medium-sized Euomphalus, Loxonema, a high-spired-gastropod, Triplophyllites, Small Caninias, Productid-type brachiopods, Unidentified brachiopod, encrinites. Several fossiliferous beds present throughout this unit. 62

Limestone, dark olive-grey, weathers light to medium-grey with slight yellowish hues, very fine-grained, thick-bedded (thicker bedded than above); fetid odor on fresh fracture. Fossils also very abundant in this unit. Approximately 30 feet from the top, genera present include: Multithecopera,

(Continued)

Triplophyllites, Euomphalus, another high-spired-gastropod, large Caninia (first appearance), Lithostrotionella, a long lean type of coral (not Zaphrentid), Spirifer centronatus (a few), Orthid type (?) brachiopod, encrinites, Productid "hash". . . 162

Limestone, same as above but laminated appearance on weathered surfaces begins. Near the "Curly bed" the beds have a sandy appearance. Euomphalus sp. becomes more plentiful together with small brachiopods and Triplophyllites sp. 78

Total thickness of Upper Gardner dolomite 487

Conformable contact

Lower Gardner Dolomite

Limestone, 2 1/2 feet thick, medium-grey, wavy laminated. This is the "Curley" bed. No chert bed found overlying it. The "Curley" bed is immediately underlain by pink lithographic limestone with a few blebs of limestone that weather with a sandy appearance, this comprises a 5 foot bed. 7 1/2

Limestone, light olive-grey, weathers to light grey, very fine-grained to lithographic, thick-bedded. Some magnesium limestones, contains sandy-weathering blebs. Fossils less abundant include following genera: Caninia, Euomphalus, Multithecopera, a Zaphrentid type and thin lean brachiopods. 15 1/2

Limestone, same as above, but more massive-bedded except at the top of unit beds are thick. 61

Dolomite or high magnesium limestone, dark blue-grey, weathers to medium blue-grey, very fine-grained, thick-bedded to massive-bedded. Small calcite blebs and stringers present. This might be the "black dolomite" of Lindgren and Loughlin. 41

Limestone, medium to dark-grey which weathers to medium-grey, very fine-grained, thick-bedded. Colonies of Syringopora sp. are very common, there are a few Euomphalus sp., Syringopora sp., and Caninia sp. . . . 91

(Continued)

Lower Gardner Dolomite (Continued)

Limestone, medium olive-grey, weathers to light olive-grey, fine-grained, massive-bedded. Stringers of red to purple $FeCO_3$ on fractured surfaces. 37

Limestone, dark olive-grey, weathers pink to light olive-grey, fine to very fine-grained, medium to thick-bedded. . . . 40

Limestone, medium olive-grey which weathers medium to light olive-grey, medium-grained, massive-bedded. A pink tinge is present but the pink weathering habit is not as pronounced as above. Zaphrentid type corals and the long lean type brachiopod mentioned above. 91

Limestone, light olive-grey which weathers approximately the same color, medium to coarse-grained, massive-bedded. Large Syringopora sp. are present together with Caninia sp. and other Zaphrentid types of coral. 72

Total thickness for Lower Gardner dolomite 456

Gradational contact

Pinyon Peak Limestone

Limestone, light olive-grey, which weathers the same color. Medium to coarse-grained with massive-bedding. The following genera are present: large Syringopora, Caninia and probably other Zaphrentid type corals. Lower in section the bedding becomes thinner and begins to display an argillaceous appearance, thin shaly weathering beds occur. 24

Limestone, same as above but with shaly limestone weathering to a light brownish-red color. Something like Opohonga limestone in weathered appearance. 177

Total thickness 201

Victoria Quartzite

Orthoquartzite, tan to light brown which weathers to a darker reddish-brown, fine-grained, medium to thick-bedded. . 10

(Continued)

Victoria Quartzite (Continued)

Dolomite, medium olive-grey, weathers light to medium grey, sub-lithographic to very fine crystalline, thick-bedded. The beds become more massive down-section and become laminated in part, they also weather alternating light and dark. An "eye" bed and a "porphyry" bed appear at bottom of this unit. 90

Dolomite, olive-grey which weathers to light olive-grey, fine to medium crystalline, thick to massive-bedding. 29

Orthoquartzite, same as described above, interbedded. 15

Dolomite, dark olive-grey which weathers the same color, very fine crystalline, thick-bedded. Interbedded light and dark dolomite. 33

Orthoquartzite, same as described above. 10

Dolomite, medium grey with white inclusions the size of eyes. This type of bed is called an "Eye bed". It is underlain by a 3 foot bed of orthoquartzite, which is underlain by a 5 foot "Porphyry bed" consisting of medium to dark grey dolomite with numerous white "pimples". This sequence marks the contact of the Devonian Victoria quartzite and the Silurian Bluebell dolomite. 18

Total thickness 205

Disconformable contact

Silurian Bluebell Dolomite

Quartzite, tan to light brown, fine-grained, medium to thick-bedded. 11

Dolomite, dark to medium olive-grey, weathers to light tannish-grey to light blue-grey. Very fine to fine-grained. Massive bedding becomes thick to massive down-section. The color becomes more medium-grey down-section. Blebs and spangles of $CaCO_3$ and some small veinlets of $CaCO_3$. . . 87

Dolomite, medium-grey, medium-grained, slightly mottled. . . 35

Dolomite, olive-grey, weathers to light tan with pink staining, fine-grained. This is 1 1/2 feet thick and is underlain by dolomite which gradually changes a lighter shade to medium-grey. 63

(Continued)

Silurian Bluebell Dolomite (Continued)

Dolomite, medium olive-grey which weathers light grey to tan. Fine-grained and thin-bedded. Characteristic shaly weathering with argillaceous appearance. In the basal part of this unit there is 25 feet of coarse-grained dolomite.	98
Dolomite, light olive-grey, weathers slightly lighter, medium-grained, medium-bedded. This has a pseudo cross-bedded sandy appearance on weathered surfaces and is weakly mottled. A fetid odor is emitted upon fracturing.	62
Dolomite, laminated bed.	17
Dolomite, "Pentamerid bed" (containing numerous white inclusions thought to be fossil remnants).	26
Dolomite, medium olive-grey which weathers light grey, medium to coarse-grained, thin to medium-bedded. This becomes slightly darker colored and fine-grained down section and weathers somewhat shaly with occasional cherts.	143
Dolomite, light to medium grey which weathers light grey to cream color, fine-grained. This weathers to a light colored shale. Occasional large chert bands in the thin to medium-bedded rocks. A 2 foot laminated bed is present in the basal part of this unit.	100
Dolomite, medium to dark grey which weathers light to medium and to dark grey with slightly mottled appearance. Light and dark dolomite is interbedded. Medium-grained, medium to thick-bedded.	94
Total thickness	736*

Conformable contact

Ordovician Bluebell Dolomite

Dolomite, dark blue-grey, weathers to medium dark grey, medium grey and to light grey. Prominent mottling with more dark than light coloring, fine-grained, thick

Ordovician Bluebell Dolomite (Continued)

to massive-bedded. This unit presents a "meringue" appearance on weathered surfaces. This is the "Leopard Bed" highest in the stratigraphic section and marks the Ordovician-Silurian contact.	35
Dolomite, olive-grey which weathers to a bluish-white, crystalline texture, thick-bedded. Bands of chert approximately 1/4 inch thick that are somewhat discontinous. Some dark colored dolomite is interbedded in upper part of this unit.	79
Dolomite, medium olive to dark olive-grey which weathers medium to light olive-grey, fine-grained to medium-grained, medium to thick-bedded. Forms a gray shaly slope. Blebs of light and dark chert are present in upper part of unit, 67 feet of cover in lower part of unit.	267
Dolomite, olive-grey weathering to light bluish-grey, fine-grained, thick to massive-bedded. Numerous black, white, and grey chert blebs and stringers (3/4 inch thick) are present, but not together. Slightly mottled.	118
Dolomite, same as above except for presence of small mottled bed similar to the "leopard" bed but lighter in color.	134
Total thickness	633*

Unconformable contact

Opohonga Limestone

Measured by John M. Foster, and Melvin O. Dearden, June 4, 1954

Dolomite (slightly calcareous), blue-grey to olive-brown, weathers slightly lighter color. Fine to medium-grained, thin to medium-bedded. Considerable argillaceous partings which are yellow-brown and light red. Contact is taken at the last mottled dolomites in the Ordovician Bluebell formation. Becomes less dolomitic toward base	183
Limestone, same description as above with increasing amount of light red-colored partings. Bedding slightly more massive.	91
Cover, float is the same typical lithology as the Opohonga formation.	286

(Continued)

*Because of structural complications (excessive faulting), the writer was unable to obtain an accurate measured section of the Ordovician Bluebell. The thickness as estimated from measured sections in near-by areas is 320 feet.

Opohonga Limestone (Continued)

Limestone, yellowish-grey which weathers to a medium-grey. Fine to medium-grained, medium to massive-bedded. Highly mottled with yellow to dull red mildly-argillaceous partings. Partings form a series of oval like inclusions about 18 mm. to 25 mm. long and half that thickness. A cross section view of this outcrop reveals that the axis of elongation of the partings is dipping 62^{o} to the west. . .	7
Limestone, yellowish-grey which weathers to a medium-grey. Fine to medium-grained, medium to massive-bedded. Highly motttled with yellow to dull red argillaceous partings. Red coloration becoming less prominent. . . .	58
Limestone, same as above except color becomes more yellow and less red and less intense. Color in general becomes more dull down section.	102
Limestone, dull medium-grey which weathers the same color. Medium to coarse-grained, and thick to massive-bedded. The argillaceous partings are present but are dull-yellow and brown, not very colorful.	40
Limestone, same as above with more intense coloration. Some flat pebble conglomerate beds are present. Prominent ledges formed.	76
Limestone, same as above but not ledges, some cover of Opohonga-like float.	98
Limestone, same as above, but with fewer argillaceous partings in the bottom half of this unit.	132
Dolomite and limestone, interbedded, thin to medium bedded. This marks the transitional zone and gradational contact between the Opohonga and Ajax formations.	34
Total thickness	1107

Conformable contact

Ajax Limestone

Measured by John M. Foster, Melvin O. Dearden, and Paul J. Jorgenson, April 24, 1954.

Upper Ajax Limestone

Limestone, medium olive-grey weathers to light or medium-grey with argillaceous red to brown partings, Opohongish-appearance. Crystalline to fine-grained weathering to a sucrose texture, thin-bedded with shaly weathering. A few light-grey chert blebs are present.	59
Limestone, light olive-grey, weathers to light blue-grey and light brown-grey. The argillaceous partings are almost completely absent. Medium to coarse-grained, medium to thick-bedded, thickening toward bottom of this unit. Black chert stringer 1/4 inch to 1 1/2 inches thick.	62
Limestone, medium olive-grey, weathers to light or medium grey with argillaceous red to brown partings, but not as numerous as in previous section described. Crystalline to fine-grained texture, thin-bedded with shaly weathering. Some light-colored chert blebs present ("ice cream chert"). This unit contains interbedded quartzites which are medium tan in color, weathering to light tan, crystalline medium, and coarse-grained, with thin to medium bedding.	61
Limestone, highly magnesium, possibly hydrothermally dolomitized, light blue-grey with a pink hue weathering to light tan-grey. Crystalline to medium texture and thick-bedded. Large pink chert stringers ("ice cream chert") minute calcite stringers, sandy appearance when weathered.	57
Total thickness	239

Conformable contact

Emerald Bed

Dolomite, light blue-grey, weathers to cream, crystalline to fine-grained, massive bedded. Chert absent.	22
Total thickness Upper Ajax Limestone	261

Conformable contact

Lower Ajax Limestone

Dolomite, dark blue-grey, weathers to medium blue-grey, crystalline to fine-grained, thick to massive-bedded.

(Continued)

Lower Ajax Limestone (Continued)

Dark chert blebs and stringers 1 inch to 1 1/2 inches thick. Thinner light-pink chert stringers ("ice cream chert"). Pisolites or "carrot bodies" 100 feet from the Emerald bed. These "pisolites" are probably "<u>Girvanella</u>".	199
Dolomite, medium-dark blue-grey, weathers to the same color but slightly mottled, crystalline to fine-grained, thin to medium-bedded. Twiggy bodies throughout 3 mm. to 10 mm. long (carrot bodies?). Black border reported in other areas on twiggy bodies indistinguishable. A few light colored chert bands. The twiggy bodies and pisolites 52-74 feet from base. Near the base wavy laminations alternately light and dark-colored are present. These are 1/2 inch thick and spaced 1/2 inch to 1 inch apart. They are probably a feature of sedimentation, rather than local alteration. Underlying the wavy laminations is a bed containing rosettes, these are generally spherical and about 5 to 10 mm. in diameter. They appear to be white $CaCO_3$, but are dolomite (probably replaced fossil remnants). The basal contact taken at and above the presence of first dark oolites (very small), and "hashy" appearing beds.	120
Total thickness of Lower Ajax limestone	319

Disconformable contact

Opex Dolomite

Dolomite, medium dark-grey, weathers to light medium-grey, crystalline, fine, medium-grained, thin to massive-bedded, increasing in bedding-size going down the section. Contains small blebs of chert. Some beds are mottled and the mottled beds are lighter in color. Small beds of "hashy" material which are probably fossil remains. Twenty-five feet from the contact with the Ajax limestone a 3 inch bed contains Billingsella (identified by Dr. J. Keith Rigby), an Upper Cambrian brachiopod. This is the first reported time-rock occurrence of this species in this area.	75
Limestone, medium-grey, medium-grained thin to medium-bedded. Yellow argillaceous partings and platy weathering gives this the appearance of Opohonga limestone.	39

(Continued)

Opex Dolomite (Continued)

Dolomite, medium blue-grey weathering to light-grey, crystalline to fine-grained, thick to massive-bedded. No oolites present. Thin platy beds of Opohongish appearing magnesium limestone with yellow argillaceous partings extend throughout.	57
Limestone, medium blue-grey weathering to light grey, fine-grained to medium, thick-bedded. This is a magnesium limestone with numerous calcite stringers. Sandy appearance on weathered surfaces.	22
Shale, yellowish-tan, same color on weathered surfaces, some red-brown colored zones present, but probably due to alteration. Clay size grain, fissile.	5
Dolomite, medium blue-grey weathering to light blue-grey and light tan, fine to medium-grained, medium to thick-bedded. Upper part has sandy weathering appearance which shows cross-bedding on weathered surface. In the lower portion a light blue color becomes prominent. Flat-pebble conglomerate and some laminations are present.	78
Dolomite, medium-blue to tan-blue, fine-grained, thick-bedded. The tan-blue colored material appears to be arenaceous.	42
Dolomite, light to medium blue-grey, weathers to light or medium-grey, with a tan hue, oolitic, massive-bedded grading to thin-bedded near Opohongish-appearing dolomite the Opex-Cole Canyon contact. This entire unit is oolitic, the oolites are more abundant and larger in size than at the Opex-Ajax contact. Flat pebble conglomerate is located 10 feet from the Cole Canyon contact.	60
Total thickness	378

Conformable contact

Stratigraphic sequence of the Cole Canyon dolomite, Bluebird dolomite, Herkimer limestone, Dagmar limestone, Teutonic limestone, and Ophir formations, all measured by John M. Foster, and Melvin O. Dearden east of Rattlesnake Canyon in the east half of section 14 and west half of section 13, T9S, R3W, Utah County, Utah, July 17, 1954.

Cole Canyon Dolomite

Dolomite, dark grey, weathers to medium grey, crystalline to medium-grained, massive-bedded. Some mottling is present. Beds of this description alternate approximately every 10 to 25 feet with lighter-colored beds as follows:	
Dolomite, light grey to white, weathers to light cream, fine to medium-grained, massive-bedded, somewhat mottled. Approximately 147 feet from the top of the formation the beds grade into a greyish-black dolomite with numerous white "twiggy" bodies, similar to the Bluebird dolomite, this sequence is 84 feet thick. . . .	442
Dolomite, light grey to white, weathering to light cream, fine to medium-grained, massive-bedded. Some mottling and banding is present. Some Opohonga-like shaly dolomite with red argillaceous partings occurs.	89
Dolomite, greyish-black, weathers to dark-grey, crystalline to fine-grained, thick to massive-bedded with numerous white "twiggy" bodies. This resembles the Bluebird dolomite, but grades into limestone. In general this unit is not as dark colored as the Bluebird dolomite.	157
Limestone and dolomite, dark grey with light grey mottling, highly mottled, mottling is in bands often 4 feet thick, overlain by Dagmar-type dolomite that is somewhat darker grey than the Dagmar, overlain by light grey dolomite, overlain by 30 feet of Bluebird type dolomite. This forms a massive ledge.	60
Dolomite, greyish-black, weathers to dark grey, thick to massive-bedded. Prominent white "twiggy" bodies. This resembles the Bluebird dolomite formation but the white inclusions are less numerous. Ledge-forming.	50
Dolomite, same as above but with less prominent white inclusions and with bands of lighter grey color. This is overlain by a medium-grey dolomite without the white inclusions.	40
Total thickness	838

Conformable contact

Bluebird Dolomite

Dolomite, greyish-black, weathers to dark grey with a purple hue; crystalline to fine-grained, thick to massive-bedded, with numerous white "twiggy" bodies from 1 to 4 mm. wide, 5 to 18 mm. long, with an average width of 1 to 2 mm. and length of 10 mm.	175
Total thickness	175

Conformable contact

Herkimer Limestone

Limestone, medium-grey, weathers to the same color, medium-grained, medium to thick-bedded. Pink argillaceous partings. Oolites are present at 40 feet from bottom of this unit.	48
Limestone, same as above except this is a ledge-former with a 2 foot bed of oolites 12 feet from base of this unit. Argillaceous partings are not as pink, become yellowish-brown.	55
Limestone, same as above, but no oolites.	19
Limestone, same as above, but with greyish-pink argillaceous partings and well developed mottling. Ledge-former. . .	20
Dolomite, medium-grey with pink to yellowish-brown argillaceous partings which weather at 40 feet and from 43 to 55 feet into a pinkish-red shale, resembling the weathered product of Opohonga limestone. In the basal part of this unit is a small bed of very dark grey dolomite with many white specks and spangles which cause this part of the unit to resemble the Bluebird dolomite. Many streaks of white $CaCO_3$. A ledge is present in the basal part of the unit.	61
Limestone, medium grey, medium-grained and medium-bedded. Argillaceous partings present but not colored as much as up section. At 10 feet from base of unit a small bed of Bluebird-type rocks (as described above) is present.	51
Limestone, medium grey, very fine-grained with argillaceous partings but not colored as much as up section. At 24 to 36 feet a bed of small oolites is present which give a	

(Continued)

Herkimer Limestone (Continued)

sandy appearance. At 60 feet this unit is a ledge-former. 63

Limestone, medium grey which weathers to the same color. This is medium-grained and medium-bedded and becomes somewhat "sand" streaked up section. 50

Total thickness 367

Conformable contact.

Dagmar Limestone

Dolomite, light olive-grey, weathers to a light greyish-white with a tannish hue, very fine-grained to sub-lithographic, medium-bedded. Laminated throughout which weather into fine ridges. Reticulated banding by $CaCO_3$ stringers 1/4 or 1/2 mm. wide. 13

Dolomite, same as above but less laminated. 64

Total thickness 77

Conformable with a gradational contact.

Teutonic Limestone

Limestone, near contact with the Dagmar formation it is banded, some of the bands are wavy and oolitic. Underlain by very dark grey, almost black limestone with many white "pimples". 30

Limestone, medium bluish-grey weathering the same, fine-grained, medium to thick-bedded. Some mottling but generally more streaked by a darker grey superimposed on medium-grey than it is mottled. 41

Limestone, medium bluish-grey, fine-grained, medium to thick-bedded. In the lower 15 feet of this unit there is a bed of medium-sized oolites. At 42 feet in this unit there is a bed resembling Opohonga limestone, but with more subdued coloration. 53

Limestone, same as above but the upper 18 feet is a massive ledge-former with some beds of medium-sized oolites. . . 31

(Continued)

Teutonic Limestone (Continued)

Limestone, same as before, but dull grey at the base of the unit. 42

Limestone, same as before, but ledge-former at the base. Pisolites present at 24 to 31 feet from base. This is generally well mottled and greyish tan. 41

Limestone, same as above. Pisolites at 24 to 26 feet from base of unit. 66

Limestone, same but more massive forming a ledge at 24 to 41 feet and without pisolites. 66

Limestone, same general description as before. 90

Limestone, same general description as before. Mottling has decreased and is no longer as highly colored. Mottling here consists of yellowish-grey blotches. 92

Limestone, same general description as before, not mottled, oolitic. Mottling increases up section. 74

Total thickness 626

Conformable with a gradational contact.

Ophir Formation

Cover, float consists of shale particles. 90

Limestone, olive-brown, weathers to yellowish-grey, sub-lithographic, thick to massive-bedded. This may be slightly altered 34

Limestone, medium grey, fine-grained, medium to thick-bedded. At 69 feet this unit becomes sand-streaked and 6 foot bed of very small oolites is present. 78

Cover, medium-grey limestone float of lighter color than previous float. 69

Limestone, medium-grey to reddish-brown, weathers medium-grey to yellowish-brown, sub-lithographic, thin-bedded. Argillaceous partings. 30

(Continued)

Ophir Formation (Continued)

Cover.	76
Cover. Limestone float, probable shale underneath.	97
Limestone, medium-grey to reddish-brown which weathers medium-grey to yellowish-brown, fine-grained, medium to thick-bedded. Argillaceous partings.	21
Phyllite, dark purple (weathers same), with some darker bands 1 inch wide. Micaceous, thick-bedded. Blocky weathering. Iron content prominent in the darker streaks.	13
Shale, reddish-brown, weathers the same, fine grained, micaceous. Probably altered by hydrothermal activity.	39
Total thickness	547

Conformable and gradational contact.

Tintic Quartzite

Measured by John M. Foster, Melvin O. Dearden, and Paul J. Jorgenson on Skyline Ridge in the west half of section 26, and nearly all of section 27, T9S, R3W, Utah and Juab Counties, Utah, April 24, 1954.

Quartzite, light to medium-brown with variations to white. Ranging from crystalline to coarse-grained and from thin to massive-bedded. Cross-bedding prominent in some areas, but generally inconspicuous. Some beds of conglomerate, particularly in lower part of section.	1000+
(Base not exposed)	
Total thickness	*1000+

*An additional 2500 feet ± is indicated by the width of outcrop.

Conformable and gradational contact.

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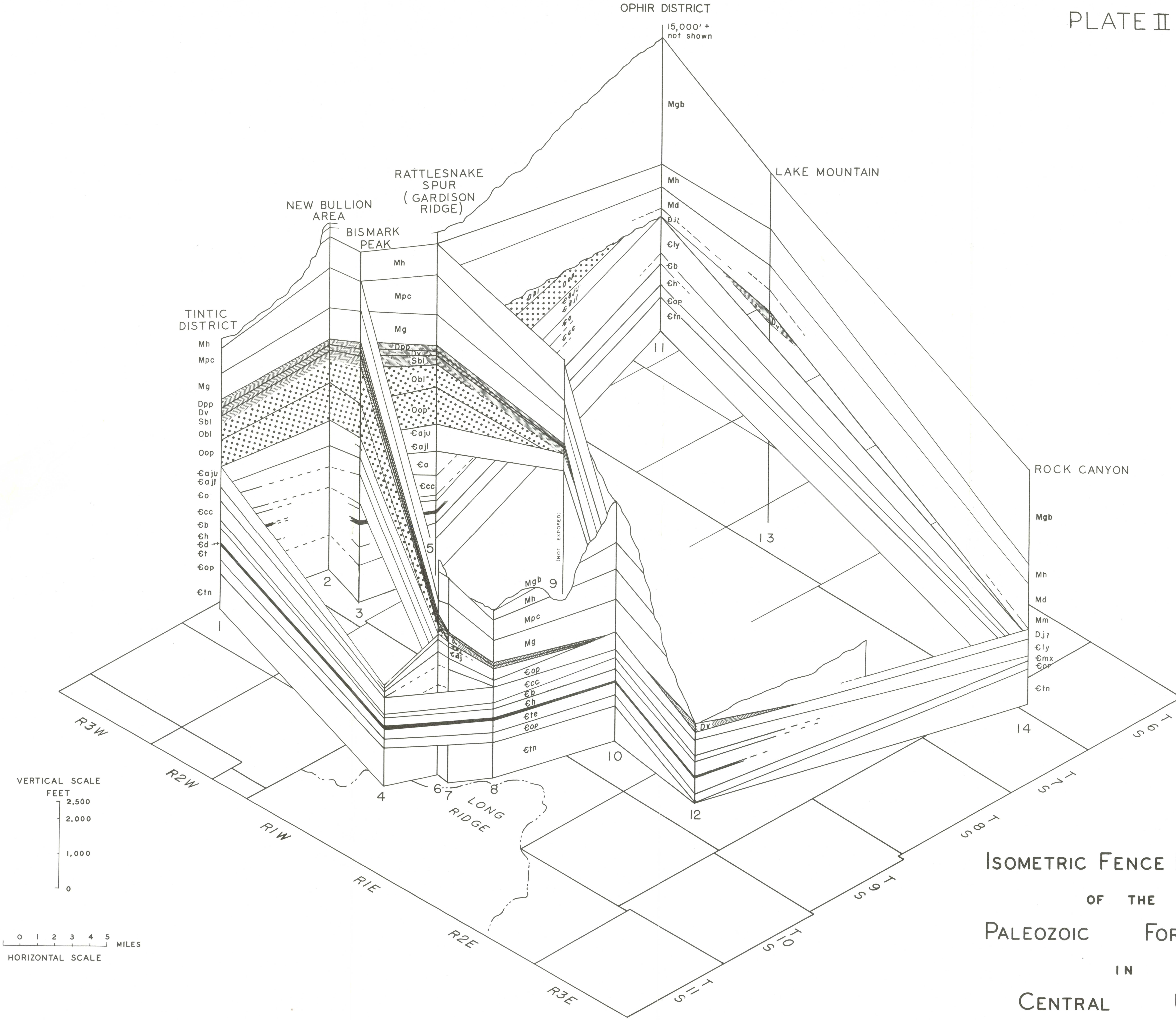
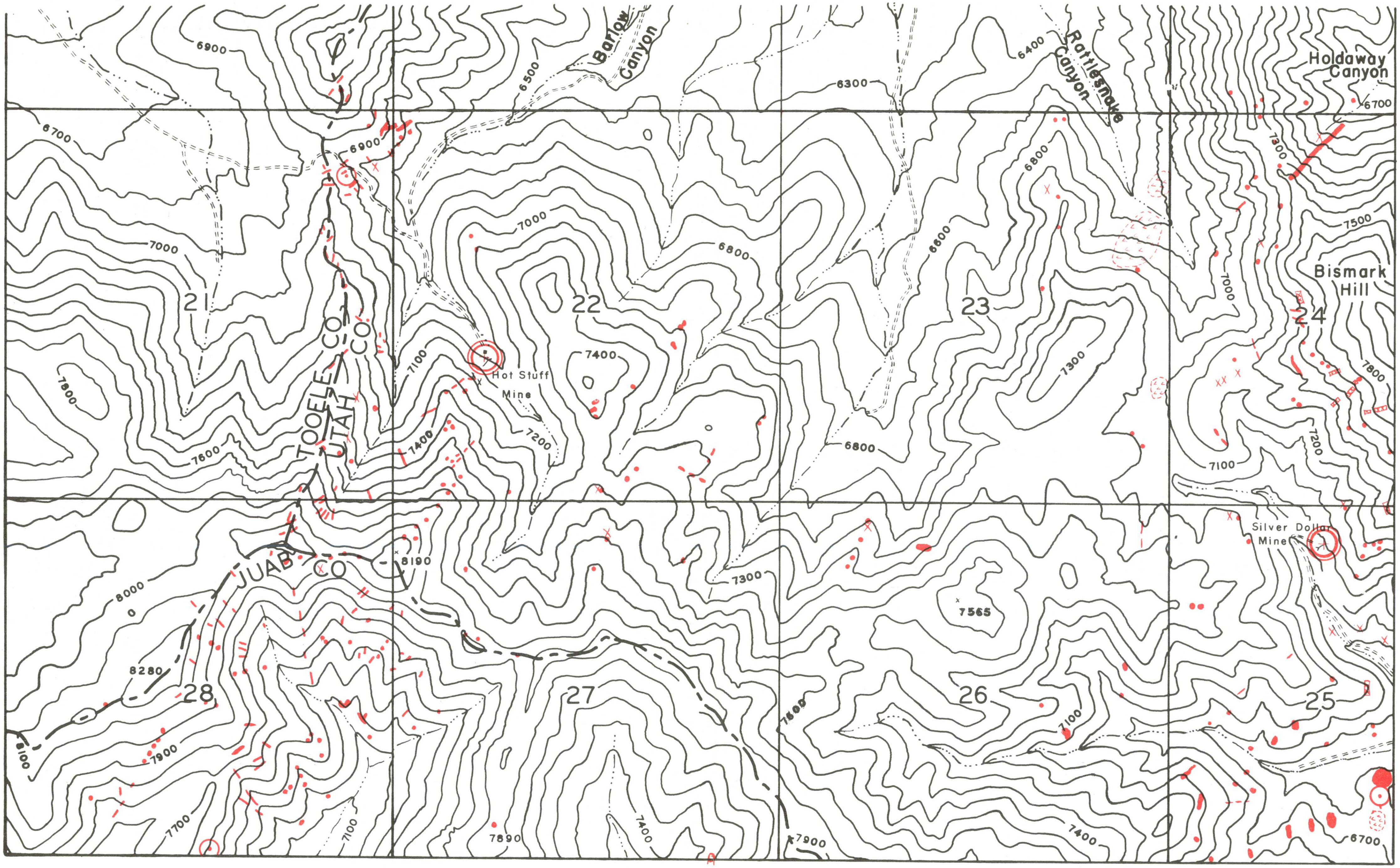
PLATE II



Isometric Fence Diagram
of the
Paleozoic Formations
in
Central Utah

by

John Foster 1955



Base Map traced from enlarged U.S.G.S.
Boulter Mountains Quadrangle

Mapped by John M. Foster
during 1953-54

X Prospect

Early, Middle, or Late Barren Stage

Notable Jasperoid

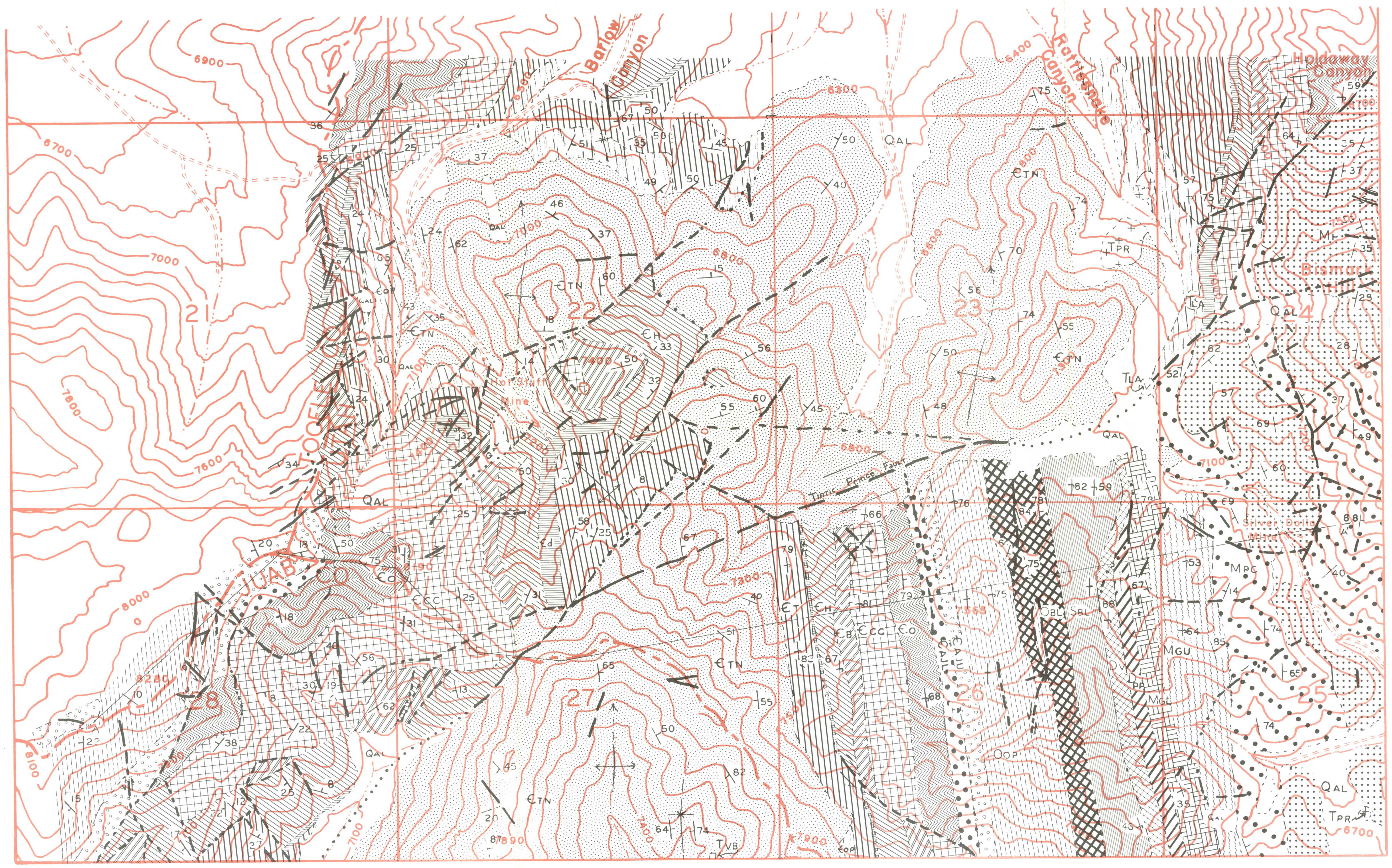
Productive Stage

Silica Breccia Dike

Igneous Rocks

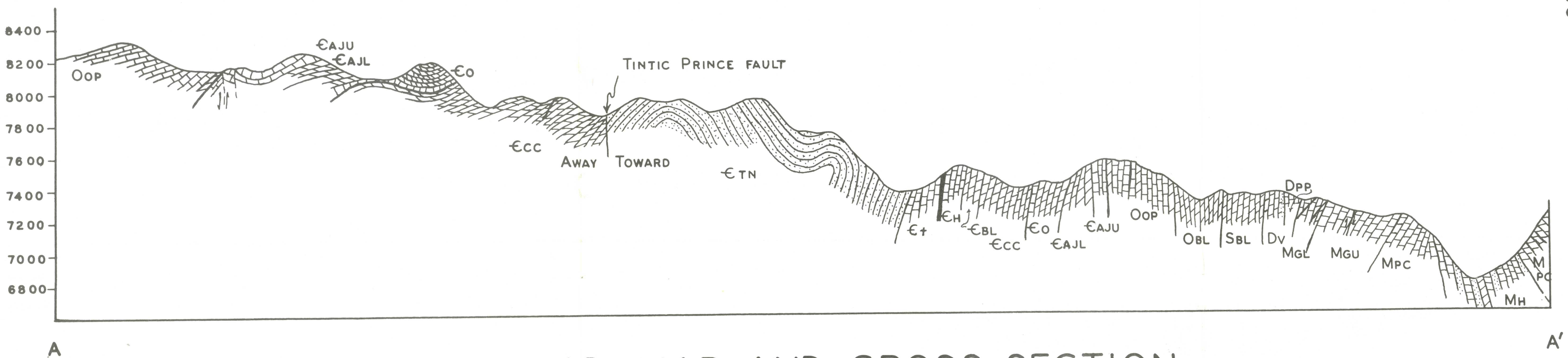
ALTERATION MAP OF THE BISMARK PEAK AREA
NORTH TINTIC MINING DISTRICT, UTAH
1954

PLATE IV



Base Map traced from enlarged U. S. G. S. Boulter Mountains Quadrangle

Mapped by John M. Foster during 1953-54



GEOLOGIC MAP AND CROSS-SECTION OF THE BISMARK PEAK AREA, UTAH

BY

JOHN M. FOSTER

1954

1,000 500 0 1000 2000 3000 4000 5000 FEET

Contour Interval 100 feet

LEGEND

SEDIMENTARY ROCKS

- Qal — Quaternary alluvium

MISSISSIPPIAN
- Mh — Humbug formation
- Mpc — Pine Canyon limestone
- Mgu — Gardner dolomite (upper)
- Mgl — Gardner dolomite (lower)

DEVONIAN
- Dpp — Pinyon Peak limestone
- Dv — Victoria quartzite

SIL.
- Sbl — Bluebell dolomite (Laketown dolomite)

ORDOVICIAN
- Obl — Bluebell dolomite (Fish Haven)
- Oop — Opohonga limestone

CAMBRIAN
- €aju — Ajax limestone (upper)
- €ajl — Ajax limestone (lower)
- €o — Opex dolomite
- €cc — Cole Canyon dolomite
- €b — Bluebird dolomite
- €h — Herkimer limestone
- €d — Dagmar limestone
- €t — Teutonic limestone
- €op — Ophir formation
- €tn — Tintic quartzite

IGNEOUS ROCKS

- Tla — Laguna latite series
- Tpr — Packard rhyolite
- Tvb — Basalt

SYMBOLS

Dip and Strike

Strike of Overturned Beds

Strike of Vertical Beds

— Fault, - - probable, ···· concealed
U upthrown side
D downthrown side

Fault showing relative movement

Anticline
Showing trace of axial plane and bearing and plunge of axis
Dashed where approximately located

Syncline
Showing trace of axial plane and bearing and plunge of axis
Dashed where approximately located

Prospect Pit or Adit

Portal of Tunnel or Adit

TRUE NORTH — MAGNETIC NORTH 16½°