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Geology of the Sharp Mountain Area, Southern Part of the Bear River Range, Utah

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GEOLOGY OF THE SHARP MOUNTAIN AREA, SOUTHERN PART OF THE BEAR RIVER RANGE, UTAH

by

Preston L. Hafen

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

of

MASTER OF SCIENCE

in

Geology

Approved:

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1961

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Preston L. Hafen

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INTRODUCTION

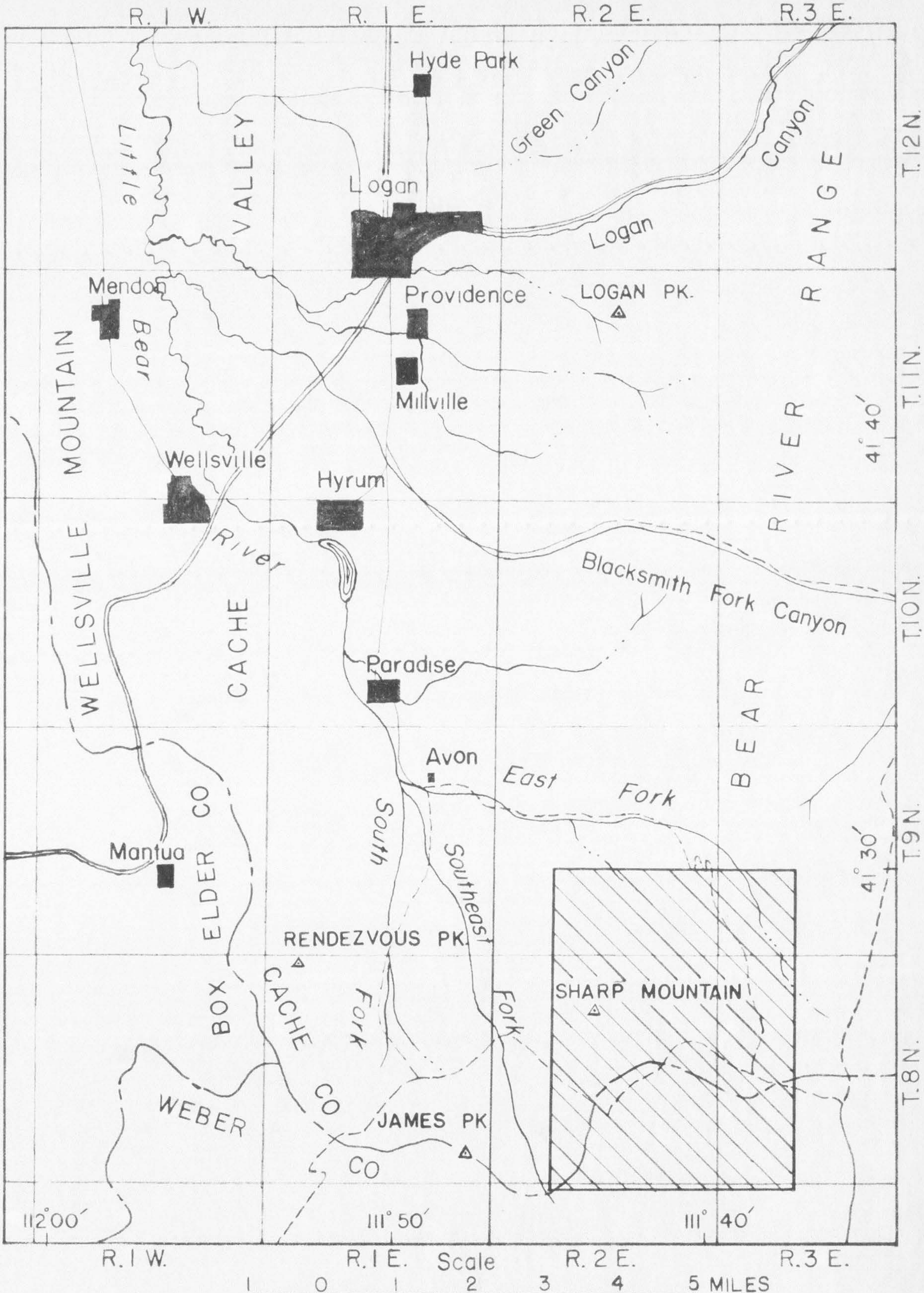
Extent of Investigation

The Sharp Mountain area is situated in the southern part of the Bear River Range in Utah. The geology of the Bear River Range to the north of this area, in Utah and Idaho, has been mapped; however, prior to this study little was known about the Sharp Mountain area. The purposes of this investigation are as follows: (1) to map and describe the geology of the area, and (2) to relate the stratigraphic and structural features of the Sharp Mountain area to those of the surrounding region.

Location of Area

The region included in this study is between $41^{\circ}22'30'' - 41^{\circ}30'$ north latitude and $111^{\circ}37'30'' - 111^{\circ}45'$ west longitude (Figure 1). The southern boundary of the Logan quadrangle forms the northern boundary of the Sharp Mountain area. James Peak 7 1/2-minute quadrangle forms the western boundary of the Sharp Mountain quadrangle. The northwestern corner is approximately 4 miles southeast of Avon, Utah. From this point the northern boundary extends eastward about 6 1/2 miles and the western boundary extends southward about 8 1/2 miles. The mapped area includes about 55 square miles. La Plata mine is situated near the center and Sharp Mountain is located in the west-central part of the area. James Peak is 2 1/2 miles west of the southwest

Figure 1. Index map of part of northeastern Utah showing Sharp Mountain quadrangle


R. I W.
R. I E.
R. 2 E.
R. 3 E.
Hyde Park
Green Canyon
Logan
Logan
Canyon
Little
Bear
River
VALLEY
CACHE
Mendon
Providence
LOGAN PK.
Millville
Wellsville
Hyrum
MOUNTAIN
WELLSVILLE
BEAR RIVER RANGE
Blacksmith Fork Canyon
Paradise
Avon
East Fork
South Fork
Southeast Fork
Mantua
BOX ELDER CO
CACHE CO
WEBER CO
RENDEZVOUS PK.
SHARP MOUNTAIN
JAMES PK
T.12N.
T.11N.
T.10N.
T.9N.
T.8N.
41° 40′
41° 30′
112° 00′
111° 50′
111° 40′
Scale
1
0
1
2
3
4
5 MILES

corner and is separated from the mapped area by the southeast Fork of the Little Bear River.

Review of Literature

Hayden (1869, pp. 191-192) named the Wasatch group with reference to exposures west of Fort Bridger, Wyoming, and the Salt Lake group with reference to exposures in the valley of Weber River between Morgan City, Utah and Devil's Gate. Geologic exploration, which included northeastern Utah, was conducted by the 40th Parallel Survey under King in 1867-1877. During this time Hague, a member of the expedition, made a preliminary reconnaissance of Cache Valley (Hague, 1877, pp. 408-409). Hayden (1877, p. 7) states that the Bear River Mountains are composed of limestones and quartzites, the edges of which rise to high peaks on the east side of Cache Valley. Hayden also identified Wasatch sandstones and conglomerates in the vicinity of the Upper Bear River Valley where they unconformably overlie the upturned edges of older rocks. Peale (1879, p. 603) interpreted Cache Valley as a broad syncline at the southern end which northward develops into several smaller folds. Gilbert (1890, p. 99) mentioned the Tertiary deposits in the southern part of Cache Valley and stated that they were derived from a lake more ancient than Lake Bonneville.

Walcott (1908a) described and named the formations of the Cambrian section from Blacksmith Fork Canyon, Utah. His intensive study of this section did much to establish it as one of the most important Cambrian sections of the West. In 1913 Richardson studied the Paleozoic section of northern Utah and made many significant contributions to the geology of the region. These included naming the three

Ordovician formations in addition to the single Silurian formation recognized in northeastern Utah (Richardson, 1913). Gilbert (1928) made notable observations that contributed to the understanding of the frontal faults of the Wasatch Range. He observed recent fault scarps paralleling the western front of the Wasatch Mountains and suggested that they were the result of recent movement along pre-existing fault planes. Eardley (1939) described the regional structure of the Wasatch-Great Basin area. The Cambrian stratigraphy of northern Utah was described in detail by Maxey (1941 and 1958). The results of a detailed study of the Logan quadrangle, which is located immediately north of the Sharp Mountain quadrangle, was published by Williams (1948).

Field Work

The field work for this report was done in the summer of 1960. Geologic contacts and faults were stereoscopically plotted on aerial photographs (scale 1:20,000) and the data were then transferred to a semicontrolled mosaic (scale 1:24,000) obtained from the Cartographic Division of the Soil Conservation Service. The geology, important drainage lines, section corners, and major roads were then traced on a transparent overlay (scale 1:24,000).

Stratigraphic sections of all formations from the Langston through Water Canyon, with the exception of the Garden City formation, were measured and described. All sections were measured either with a Brunton compass or with a steel tape used in conjunction with a Brunton compass and were subsequently converted to true thickness. Rock samples were taken at critical points and fossils collected wherever observed. The fossils have been tentatively identified by the writer and are available at Utah State University for future reference.

STRATIGRAPHIC GEOLOGY

Regional Stratigraphic Relations

The Sharp Mountain area is situated within the region occupied by the Cordilleran geosyncline during the Paleozoic era. The Cambrian sea transgressed eastward across Utah and had reached eastern Utah by the end of Early Cambrian time (Maxey, 1958, p. 647). Early Cambrian sediments, represented by the clastic material of the Prospect Mountain quartzite and Pioche formation, were laid down as initial near-shore deposits. The source of these clastics was probably land to the east of the fluctuating shore line.

Sedimentation in northeastern Utah was generally continuous from Middle Cambrian into Late Cambrian with only local breaks in the sedimentary record (Mansfield, 1927, p. 180). The sediments deposited during this time constitute the Langston, Ute, Blacksmith, Bloomington, and Nounan formations and are predominantly carbonates. The first stratigraphic break of regional character occurs at the base of the St. Charles formation. During deposition of the upper part of the Nounan formation the sea regressed westward. The basal part of the St. Charles formation, the Worm Creek member, was laid down as near-shore sediments of the eastward transgressing early Franconian sea (Hanson, 1953, p. 20). The source of the clastic material which constitutes the Worm Creek quartzite was an uplifted area in south-central Idaho (Hanson, 1953, p. 20 and Haynie, 1957, p. 33).

In areas where Lower Ordovician limestones occur deposition is known to have been continuous from Cambrian into Ordovician time (Hintze, 1959, p. 46). Throughout northeastern Utah and adjacent areas the Garden City formation is of Lower Ordovician age. Hintze states that in western Utah and elongate northeasterly-trending positive area, the Tooele Arch, was active during Medial Ordovician time. During this period the Lower Ordovician limestones, which were probably deposited continuously over this region, were truncated by erosion (Hintze, 1959, p. 46). In northeastern Utah the Middle Ordovician is represented by the Swan Peak formation which thickens in southwesterly, northwesterly, and northerly directions from a central area near the southeastern corner of the Logan quadrangle (Ross, 1953, pp. 24-25). In parts of the Logan quadrangle the upper part of the Swan Peak formation is absent indicating local post-Swan Peak erosion (Williams, 1948, p. 1,136). Upper Ordovician in northeastern Utah is represented by the Fish Haven dolomite. In Wyoming and Montana the Bighorn dolomite represents the same time of deposition (Ross, 1953, p. 25). Ross suggests, based on fossil evidence, that an unconformity separates the Swan Peak formation from the overlying Fish Haven dolomite.

Silurian time in northeastern Utah is represented by a single formation, the Laketown dolomite, which is Middle Silurian in age (Stokes, 1953, p. 27). This indicates that pronounced disconformities are present both below and above the formation. In the latter part of the Silurian period the sea withdrew from the Cordilleran geosyncline and all of western North America became emergent (Mansfield, 1927, p. 182).

In northern and northeastern Utah, Devonian rocks are characterized by rapid changes in thickness and lithology (Brooks and Andrichuk, 1953, pp. 28-29). During Early Devonian time the Water Canyon formation was laid down in northeastern Utah and western Wyoming (Williams, 1958, p. 25). In Late Devonian the Cordilleran geosyncline was occupied by the sea and the Jefferson formation was conformably deposited on the Water Canyon formation (Williams, 1948, p. 1,157). The Beirdneau sandstone member of the Jefferson formation is composed largely of clastic material which was derived from an uplifted area in central and northeastern Utah (Rigby, 1959, pp. 207-218). Williams (1948, p. 1,157) states that during deposition of the Beirdneau sandstone the shore line extended through the Logan quadrangle.

Mississippian rocks are represented in the Logan quadrangle and adjacent areas by the Lodgepole limestone and the Brazer formation. Throughout much of northeastern Utah deposition continued with little if any interruption from Mississippian into Pennsylvanian time. During Pennsylvanian and Permian times northeastern Utah occupied the marginal area of the Oquirrh Basin and probably received sediments throughout much of this time; however, subsequent erosion has removed a large part of these deposits. Beus (1958, pp. 39-40) measured 6,643 feet of Pennsylvanian and Permian (?) rocks in Wellsville Mountain.

There are no Mesozoic deposits present in the Logan quadrangle or the Sharp Mountain quadrangle; however, Mansfield (1927, p. 99) reports over 10,000 feet of Mesozoic rocks in southeastern Idaho. Eardley (1944, p. 837) reports a corresponding thickness south of the Logan quadrangle on the Upper Weber River near Peoa, Utah. This evidence strongly implies that northeastern Utah was also blanketed by Mesozoic sediments of about this same thickness. In southeastern Idaho the change from Paleozoic to Mesozoic was marked by strong faunal contrasts rather than with noteworthy discordance of strata (Mansfield, 1927, p. 174).

During early Tertiary time the Wasatch formation was unconformably deposited over older rocks throughout parts of northeastern Utah. In middle Tertiary time the Herd Mountain and correlative erosion surfaces were developed. The Salt Lake group was deposited unconformably over older rocks in late Tertiary time.

General Statement

Rocks representing every Paleozoic system from Cambrian to Devonian are present within the Sharp Mountain quadrangle (Table 1). The best and most accessible outcrops are along the north-facing slope of East Canyon where, beginning at the northeast corner of the quadrangle and extending westward, Cambrian through Devonian rocks are found (Plate 1). There are no Mesozoic rocks present within the mapped area. Cenozoic deposits are represented by the Wasatch formation and the Salt Lake group, both of Tertiary age, which unconformably overlie older rocks along the eastern edge of the area. The Salt Lake group is also exposed in the northwestern corner of the area (Plate 1).

Cambrian System

Rocks of Cambrian age are exposed along East Fork of the Little Bear River which parallels the northern boundary of the mapped area. Beginning in the northeast corner of the area and extending westward

Table 1. Stratigraphic units

Unit	Lithology	Approximate thickness (feet)
Tertiary		
Tertiary boulders	Quartzite boulders and cobbles	-----
Salt Lake group	Limestone and tuff	-----
Wasatch formation	Conglomerate and sandstone	-----
Devonian		
Jefferson formation	Dolomite and sandstone	1,500*
Water Canyon formation	Dolomite, sandstone, and limestone	460
Silurian		
Laketown dolomite	Dolomite	1,240
Ordovician		
Fish Haven dolomite	Dolomite	125
Swan Peak formation	Quartzite and shale	20
Garden City formation	Limestone and shale	1,500*
Cambrian		
St. Charles formation	Dolomite and sandstone	970
Nounan formation	Dolomite	1,145
Bloomington formation	Limestone and shale	600
Blacksmith formation	Limestone and dolomite	410
Ute formation	Limestone and shale	1,090
Langston formation	Dolomite and limestone	270
Pioche formation	Quartzite and shale	200*
Prospect Mountain quartzite	Quartzite	-----

* Estimated thickness.

Plate 2. General view

View, looking west, of the east-facing slope south of East Fork. Formations exposed on near slope from bottom of canyon upward are as follows: Prospect Mountain quartzite, Pioche formation, Ute formation, Blacksmith formation, Bloomington formation, Nounan formation, and St. Charles formation.

along East Fork part of the Prospect Mountain quartzite in addition to complete sections of the Pioche, Langston, Ute, Blacksmith, Bloomington, Nounan, and St. Charles formations crop out. Also complete sections of the Blacksmith formation through the St. Charles formation are present along the east flank of Sharp Mountain (Plate 1). The aggregate thickness of the Cambrian rocks, excluding the exposed part of the Prospect Mountain quartzite, is approximately 4,700 feet. The Worm Creek member of the St. Charles formation and the brown-weathering dolomites of the Langston formation are exceptionally good marker beds and were helpful in stratigraphic identification and mapping.

Prospect Mountain quartzite

The Prospect Mountain quartzite was named by Hague (1883, p. 27) with reference to exposures in the Eureka District, Nevada. It has been recognized in eastern California, northern Arizona, Nevada, Utah, and southeastern Idaho (Maxey, 1958, p. 667). In the Bear River Range, Utah, a stratigraphic unit correlative with the Prospect Mountain quartzite, has been mapped as the Brigham quartzite. Because of the occurrence of alternating beds of arenaceous and micaceous shale and impure quartzite in approximately the upper 200 feet of the Brigham quartzite, the writer substituted the name Prospect Mountain for the underlying quartzites and mapped the upper alternating beds of quartzite and shale as the Pioche formation. This follows the usage of Maxey (1958, p. 667).

In the Sharp Mountain area the base of the quartzite is not exposed. The outcropping beds consist predominantly of clean quartzite; however, there are a few thin beds of quartz-pebble conglomerate exposed in the lower part of the formation. The quartzite consists of well-sorted and well-rounded medium- to coarse-grained sand cemented with silica and iron oxide. The iron oxide gives the entire formation a brown color. The conglomerate is composed of well-rounded pebbles that range in color from white to maroon.

The conglomerates occur as relatively thin patchy sheets and were probably laid down along the margin of the eastward transgressing sea. The quartz sands were deposited under more stable conditions near the margin of the shallow sea and are conspicuously cross-bedded in places. The well-sorted and well-rounded character of the particles in both the conglomerates and the quartzites indicate that they were deposited under stable shelf conditions and that the depositional area was sufficiently distant from the source area to allow for sorting and abrasion.

No fossils have been found in the Prospect Mountain quartzite. The age of the quartzite, as determined from diagnostic fossils which occur in the Glossopleura-Zacanthoides zone of the overlying Langston and Ute formations, is Lower Cambrian with the possibility that the uppermost part is of lowermost Middle Cambrian age (Maxey, 1958, p. 667).

Pioche formation

The Pioche formation was named by Walcott (1908a, p. 11) from exposures near the town of Pioche, Nevada. At the type locality the formation consists of argillaceous shale with some interbedded limestone. Maxey (1958, pp. 668-669) identifies, with reservation, the Pioche formation in the northern Wasatch Mountains and in part of the

Bear River Range. He states that here arenaceous beds constitute a large part of the formation at the expense of the argillaceous shale.

In the Sharp Mountain area the Pioche formation is estimated to be about 200 feet thick. The formation is composed largely of quartzite (Maxey, 1958, p. 668) which occurs in beds 6 inches to 2 feet thick. The quartzite is cemented with silica and with iron oxide which gives it a brown color. Some of the quartzites are friable on weathered surfaces, this suggests the presence of relatively easily decomposed minerals such as feldspars, muscovite, and sericite. Olive-green to brown micaceous and arenaceous shales are interbedded with the impure quartzite and occur in beds 1 inch to 3 inches in thickness.

The Pioche formation was deposited in the littoral and neritic parts of the sea under moderately unstable shelf conditions. The sand was deposited near the margin of the sea and the shale was deposited seaward from the sandy facies. Possibly during periods when coarse clastic material was lacking the shale facies extended nearly to the shore line (Maxey, 1958, p. 681). This condition or a minor oscillatory nature of the shore line or both was responsible for the alternating sequence of shale and quartzite beds in the Pioche formation of the Sharp Mountain area.

No fossils were found in the Pioche formation by the writer; however, fossils of Early Cambrian age have been found in the Pioche formation in western Utah (Maxey, 1958, pp. 668-669). Maxey believes that the Pioche formation of northern Utah and southern Idaho is both late Early Cambrian and early Middle Cambrian age.

Langston formation

The Langston formation was named by Walcott (1908a, p. 8) from exposures in the valley of Langston Creek, Idaho. Walcott designated Blacksmith Fork Canyon, Utah, as the type locality. The Langston formation is 380 feet thick at the type locality (Williams and Maxey, 1941, pp. 279-281).

In the Sharp Mountain area the Langston formation is 270 feet thick and marks the beginning of a long period of deposition of predominantly carbonate rocks. Here the formation consists of two thick-bedded, sandy, dolomite beds separated by a thin-bedded limestone unit. The dolomites are conspicuous because of their resistant nature and because of their dark-brown to reddish-brown color (Appendix). The brown coloring of the dolomite beds in the Langston formation is the result of limonite stain and distinguishes it from the rest of the Cambrian dolomites (Maxey, 1958, pp. 669-671). Northward from the Sharp Mountain area the formation thickens and the lower dolomite bed thins and is finally replaced by the Naomi Peak member and the Spence shale member (Williams and Maxey, 1941, pp. 279-281).

Maxey (1958, p. 682) suggests that the sandy and silty dolomites of the Langston formation represent a facies intermediate between the carbonate and shale facies. The increase in thickness of the lower dolomite bed southward, along with the silty nature of the dolomite, may indicate deposition in a more negative area adjacent to the Uinta positive element visualized by Lochman-Balk (1959, p. 43). This positive element could have been the source of the clastic material contained in the dolomite. The thin-bedded limestone separating the two dolomite units could have been deposited during a stable period when very little clastic material was being derived from this positive element.

Although the writer observed no fossils in the Langston formation of the Sharp Mountain area the Naomi Peak and Spence shale members of the formation, which appear to the north, have yielded abundant fossils. Maxey (1958, pp. 668-669) dated the Langston formation as earliest Albertan and assigned it to the Glossopleura-Zacanthoides zone.

Ute formation

The name Ute limestone was given by members of the 40th Parallel Survey to 2,000 feet of limestones containing Cambrian fossils that overlie the Cambrian quartzites. Walcott (1908a, pp. 7-8) defined the Ute formation and designated Ute Peak of the Bear River Range as the type locality. Maxey (1958, p. 672) recognized the Ute formation in northern Utah and southern Idaho.

In the Sharp Mountain area a section of the Ute formation 1,090 feet thick was measured (Appendix). This thickness is 300 feet more than in any previously measured section and is probably the result of bedding plane slippage. Within the Sharp Mountain area, as elsewhere throughout northeastern Utah, the Ute formation consists of alternating beds of green shale, thin-bedded limestone, and silty limestone. The silt weathers to various shades of red and brown and is one of the conspicuous characteristics of the formation. The limestone beds are frequently oolitic or pisolitic. Maxey (1958, p. 683) refers to the pisolitic limestone as Girvanella limestone and considers it to have formed by accumulation of carbonates around the alga *Girvanella*.

The shale beds of the Ute formation were laid down when the influx of clastic material was greater and may record minor oscillations of the shore line. The mottled, silty, limestones are mostly thin-bedded and are regarded as indurated mixtures of calcareous ooze and fine clastic material that were deposited too distant from the shore to be diluted with large amounts of clastic material. The clean limestone was laid down farther seaward or during periods of greater stability when the influx of clastics was less. The Ute formation was probably deposited in the epineritic part of the sea under stable to moderately unstable shelf conditions.

Maxey (1958, pp. 671-672) assigns the Ute formation to the upper part of the *Glossopleura-Zacanthoides* zone and considers it to be Albertan in age. The writer collected and identified the following fossils from near the base of the Ute formation:

- Brachiopoda
  - *Acrothele artemis* Walcott
  - *Linguella*, sp.
- Trilobita
  - *Glossopleura producta*
  - *Glossopleura similaris* (?)

Blacksmith formation

The Blacksmith formation was named from exposures in Blacksmith Fork Canyon about 15 miles east of Hyrum, Utah (Walcott, 1908a, p. 7). In the Left Fork of Blacksmith Fork the formation is 325 feet thick, while on the west flank of Wellsville Mountain the Blacksmith formation is over 800 feet thick (Williams, 1948, p. 1,133).

In the Sharp Mountain area the Blacksmith formation is 410 feet thick and consists of limestone and dolomite. Limestone makes up about 300 feet of the formation and is light- to dark-gray in color and fine-crystalline to aphanitic. The dolomite is light- to moderate-gray and medium- to coarse-crystalline (Appendix).

The large variation in thickness between Wellsville Mountain and Sharp Mountain, with no observable discordance of either the underly- or overlying formations, suggests differing conditions of deposition between the two areas. The formation seems to become progressively more dolomitic and thicker westward. The depositional basin must have been subsiding more rapidly westward during at least part of Blacksmith deposition. The absence of clastic material indicates that the Blacksmith formation was laid down under stable conditions too far seaward to be diluted with appreciable amounts of detritus.

In most localities the Blacksmith formation is relatively unfossiliferous. This may be the result of either destruction by dolomitization or deposition under conditions unfavorable to inhabitance by easily preserved organisms. Maxey (1958, p. 678) assigns the lower part of the Blacksmith formation to the <u>Bathyuriscus-Elrathina</u> zone and the upper part of the formation <u>Thompsonaspis</u> zone. The Blacksmith formation is Albertan in age (Williams, 1948, p. 1,133 and Maxey, 1958, p. 672). The writer found no fossils in the Blacksmith formation.

Bloomington formation

The type locality of the Bloomington formation is west of the town of Bloomington, Idaho, and was designated by Walcott (1908a, p. 7) when he named the formation. Throughout the Logan quadrangle the formation contains four members which are as follows: (1) the basal Hodges shale member, (2) lower limestone member, (3) the Call's Fort shale member, and (4) upper limestone member (Williams, 1948, pp. 1,133-1,134). The maximum thickness of the Bloomington formation in the Logan quadrangle is about 1,200 feet (Maxey, 1941, p. 12).

In the Sharp Mountain area the formation is only 600 feet thick and the members are not distinguishable. Here the formation consists principally of fine-crystalline to aphanitic limestone. A shale bed, 45 feet thick, occurs about 100 feet below the top of the formation (Appendix). Near the center of the formation a 2-foot bed of conglomerate consisting of rounded limestone pebbles in an aphanitic limestone matrix occurs. About 7 miles west of the Sharp Mountain quadrangle, in Threemile Canyon, the Bloomington formation is estimated to be at least 1,000 feet thick and all four members are well developed.

The fine-crystalline and aphanitic limestones of the Bloomington formation are believed to represent deposition in the neritic part of the sea under stable shelf conditions. The shale was deposited in moderately unstable periods when greater amounts of clastic material were supplied to the sea. The conglomerate bed was probably laid down as a result of reworking of lime sediments by wave action. The relative thinness and lack of development of the four widespread members of the Bloomington formation in the Sharp Mountain area could have resulted from slower deposition or from local disconformities in this area.

The Bloomington formation belongs to the Asaphiscus-Bolaspidella zone which is regarded as latest Albertan in age (Maxey, 1958, p. 672). Hanson (1953, p. 19) suggests the possibility that the lower part of the Nounan formation is of uppermost Medial Cambrian age. If this is the case, the Bloomington formation would be somewhat older than Maxey suggests. The writer found no fossils in the Bloomington formation.

Nounan formation

The Nounan formation was named from exposures on the east flank of Soda Peak, west of the town of Nounan, Bear Lake County, Idaho (Walcott, 1908a, p. 6). Within the Logan quadrangle and adjacent areas the Nounan formation varies in thickness from 825 feet to 1,125 feet (Williams, 1948, p. 1,134). Hanson (1953, p. 19) states that in northern Utah the proportion of sand in the Nounan increases upward.

In the Sharp Mountain area the Nounan is 1,145 feet thick. The lower part of the formation consists of clean, fine-crystalline dolomite and contains oolitic beds. The upper part of the formation contains considerable amounts of silt and sand and the dolomite becomes coarse-crystalline. There are a few beds composed predominantly of silt (Appendix).

The lower part of the Nounan formation was probably deposited in the epineritic part of the sea under stable shelf conditions. Oolitic beds were laid down at various times during the earlier Nounan deposition and indicate that waves and currents were active. During deposition of the upper part of the Nounan formation shelf conditions became unstable and a considerable amount of clastic material was carried into the sea. Hanson (1953, p. 19) believes the source of the detritus was uplifted sandstone formations in southern Idaho and that this uplift gradually pushed the sea westward and southward, until near the end of Dresbachian time the seas were briefly excluded from the northern Utah-southeastern Idaho region, resulting in a sedimentary break separating the Nounan and overlying St. Charles formations. The character of the Nounan could, however, have resulted from influx of clastic material due to adjacent uplift without necessitating complete withdrawal of the sea from this region. This influx of clastics could have produced a minor regression of the sea which was more of an oscillatory nature instead of complete withdrawal.

The Nounan formation is regarded as Dresbachian in age. It contains a fauna which represent the Cedaria and Aphelaspis zones and probably the intermediate Crepicephalus zone also (Howell, 1944, pp. 993-1,004). The writer observed no fossils in the Nounan formation within the Sharp Mountain area.

St. Charles formation

Walcott (1908a, p. 6) named the St. Charles formation from exposures west of the town of St. Charles, Bear Lake County, Idaho. Richardson (1913, p. 408) described the Worm Creek quartzite member of the St. Charles formation as a massive gray quartzite occurring at the base of the formation. Throughout northeastern Utah the St. Charles formation generally consists of three members which are as follows: (1) the basal Worm Creek quartzite, (2) a light-gray-weathering dolomite, and (3) a dark-gray dolomite.

In the Sharp Mountain quadrangle the Worm Creek quartzite member is well developed, but the twofold division of the dolomite is not evident; however, 7 miles to the west in Threemile Canyon all three members are easily recognizable. The St. Charles formation is about 970 feet thick in the Sharp Mountain area with the Worm Creek member constituting approximately the basal 90 feet of the formation. The Worm Creek member consists of 30 feet of sandy dolomite overlain by two quartzite beds totaling 16 feet in thickness which are separated by a sandy dolomite 7 feet thick. Above the upper quartzite is about 40 feet of sandy dolomite. The dolomite of the St. Charles formation is silty in the lower part and becomes clean and contains cherty and oolitic beds in the upper part (Appendix).

The Worm Creek member of the St. Charles formation is regarded as a transgressive basal sand deposit (Lochman-Balk, 1955, pp. 29-37, Hanson, 1953, p. 20, and Haynie, 1957, p. 33). The upper part of the underlying Nounan formation, which contains considerable clastic material, is regarded as the regressive deposit. The opinions of Lochman-Balk, Hanson, and Haynie differ as to the possible source area of the detritus. Hanson suggests that the sand may have come from central Idaho, Lochman-Balk visualized the Uinta Mountain area as the source, and Haynie believes the source area to be in the vicinity of Soda Springs, Idaho. Because of the detailed work done by Haynie (1957), the writer favors the southern Idaho source area and the arkosic nature of the Worm Creek member in the vicinity of Soda Springs as contrasted with the pure quartz present in the Sharp Mountain area strongly indicates that the southern Idaho area is nearer the source.

The upper dolomites of the St. Charles formation were deposited seaward from the sandy facies represented by the Worm Creek member. The carbonate facies was laid down in the epineritic part of the sea

Plate 3. St. harles formation

Figure 1. Quaartzite of Worm Creek member of the St. Charles formation along the north-facing slope of East Fork

Figure 2. Fuccoids on quartzite of Worm Creek member of St. Charles formmation

under stable shelf conditions. The occurrence of oolitic beds indicates that the sea was shallow and waves and currents were active during at least part of late St. Charles deposition. The scattered chert nodules and stringers in the upper part of the formation are probably of secondary origin. Dolomitization of the St. Charles probably occurred penecontemporaneous with deposition.

The Worm Creek member of the St. Charles is in the Elvinia faunal zone as defined by Howell (1944, pp. 993-1,004). The only fossils identified by Haynie (1957, p. 28) from the Worm Creek are U-shaped markings which resemble those of Polychaeta and are completely undiagnostic. Howell (1944, pp. 993-1,004) regards the St. Charles formation as Franconian and Trempealeauian in age. The writer identified the inarticulate brachiopod Linguella from the Worm Creek member of the St. Charles formation.

Ordovician System

The area of the Ordovician miogeosyncline contains a rather uniform threefold succession in which the Lower Ordovician sediments are essentially clastic limestones, the Middle Ordovician sediments quartz sandstones, and the Upper Ordovician deposits crystalline dolomites (Hintze, 1959, p. 46). These three groups of rocks are well represented in the Sharp Mountain area by the Garden City formation, which varies in thickness in northeastern Utah and southeastern Idaho from 1,200 feet to 1,800 feet (Ross, 1949, pp. 472-475); the Swan Peak formation, which thins and disappears southeastward from the Logan quadrangle; and by the Fish Haven dolomite that is represented by approximately 125 feet of medium-gray dolomite in the Sharp Mountain area. All three Ordovician formations are well exposed on the southwest-facing slope of Porcupine Canyon (Plate 1). The upper cherty member of the Garden City formation and the Swan Peak formation were both useful as stratigraphic marker beds within the mapped area.

Garden City formation

The Garden City limestone, herein called the Garden City formation, was named from exposures along Garden City Canyon by Richardson (1913, p. 408). Throughout northeastern Utah and adjacent parts of southeastern Idaho the Garden City formation ranges from about 1,200 feet to 1,800 feet in thickness (Ross, 1949, pp. 472-475). The formation can be divided into two members in the Preston, Logan, and Randolph quadrangles. The lower member is a complex of interbeds of intraformational conglomerate, muddy limestone, crystalline limestone, and a few layers of compact cryptocrystalline limestone. Most of the beds vary in thickness within a short distance along any outcrop. The upper member of the formation, comprising about one-third of its thickness, is characterized by a high content of chert. Some coarse-crystalline dolomite is found at the top of the formation at most localities (Ross, 1953, p. 23).

In the Sharp Mountain area the Garden City formation is estimated to be about 1,500 feet thick and the two members are easily recognizable. The conformable contact of the Garden City formation with the underlying St. Charles formation throughout the Sharp Mountain area strongly suggests that there was no sedimentary break between late Cambrian and early Ordovician in this region. Hintze (1959, p. 46) states that where Lower Ordovician limestones occur deposition was apparently continuous from preceding Late Cambrian time.

The presence of intraformational conglomerate, ripple marks, and cross-bedding indicates that at least the lower part of the Garden City formation was deposited in shallow water under moderately unstable shelf conditions. The widespread occurrence of chert in the upper part of the formation suggests that it is of primary origin and indicates that streams were supplying larger amounts of silica to the sea during this period. The increased influx of silica could have resulted from change in climatic conditions which permitted weathering processes to break the quartz grains down to a soluble state. The silica could thus have been transported as a colloid and under favorable conditions deposited as primary chert.

Because of the detailed paleontological work done by Ross on the Garden City formation of northeastern Utah the writer made no attempt to collect fossils in the Sharp Mountain area. Ross (1949, p. 478) states that the Garden City fauna include sponges, graptolites, pelmatozoans, brachiopods, nautiloids, ostracods, and trilobites. He defined twelve faunal zones, designated by the letters A through L, within the formation. Hintze (1952, p. 5) recognized all but the basal zone, zone A, in the Pogonip group of western Utah and eastern Nevada and tentatively correlated them with Ross' zones of northeastern Utah. Hintze subdivided zone G into two zones. Rigby (1958, p. 917) tentatively assigned graptolites to Ross' zones G through N with the exception of zones I and L. The Garden City formation ranges from earliest Ordovician to early Chazyan in age (Ross, 1953, p. 22).

Swan Peak formation

The Swan Peak formation was named from exposures at Swan Peak in the Bear River Range, Utah by Richardson (1913, p. 409). In the Logan quadrangle the Swan Peak formation consists of three persistent members which total about 340 feet in Green Canyon. These members are as follows: (1) a lower fucous-black shale with interbeds of sandy limestone, (2) a middle thin-bedded quartzite, and (3) an upper thick-bedded quartzite. In Blacksmith Fork Canyon the formation is represented by the basal beds of sandy limestone only (Williams, 1948, p. 1,136). According to Ross (1953, pp. 24-25) the Swan Peak formation thickens in southwesterly, northwesterly, and northerly directions from a central area near the southeastern corner of the Logan quadrangle. In the Ibex Basin Hintze (1959, p. 50) recognized a threefold division of the middle Ordovician deposits which include from older to younger: (1) the Swan Peak quartzite, (2) the Crystal Peak dolomite, and (3) the Eureka quartzite. Hintze regards the Swan Peak and Crystal Peak as regressive deposits and the Eureka quartzite as an eastward transgressive deposit.

In the Sharp Mountain area the Swan Peak formation is represented by approximately 20 feet of quartzitic sandstone overlain by 3 feet of greenish-brown shale. The basal black shale and sandy limestone described by Williams (1948, p. 1,136) from Blacksmith Fork Canyon are absent.

In Middle Ordovician time an arch or offshore uplift, the Tooele Arch, appeared dividing the miogeosyncline of Utah into two basins. The arch extended approximately southwestward from the vicinity of Salt Lake City, Utah, into eastern Nevada. At the same time as the arch appeared the cratonal interior emerged, shedding the regressive detritus into the sea (Webb, 1956, p. 19). In northeastern Utah the Swan Peak formation constitutes these regressive Middle Ordovician sediments. The widespread black shale, which is present at the base of the formation throughout most of the Logan quadrangle, represents deposition in the epineritic part of the sea under relatively stable shelf conditions, and the overlying quartzites represent regressive deposits laid down along the margin of the sea under unstable shelf conditions. The absence of the black shale at the base of the Swan Peak formation and the relative thinness of the quartzite beds in the Sharp Mountain area indicate that this area was either very near the region of nondeposition throughout much of Middle Ordovician or that it was subjected to periods of erosion during this time. The presence of the black shale equivalent in Blacksmith Fork Canyon and its absence immediately to the south in the Sharp Mountain quadrangle, coupled with the absence of the overlying quartzite beds in Blacksmith Fork Canyon and their presence southward, indicates that there were probably local uplifts in this region during deposition of the Swan Peak formation.

Ross (1949, p. 479) recognized the Swan Peak formation as constituting a single faunal zone that he designated zone M. Hintze (1952, p. 20) and Rigby (1958, p. 910) recognized this zone as constituting the basal part of the Kanosh shale of western Utah based on trilobites and graptolites, respectively. The Swan Peak formation of northeastern Utah, as dated on the basis of the trilobite, brachiopod, and ostracod fauna, is lower Chazyan in age (Ross, 1949, p. 472).

The writer collected the trilobite Eleutherocentrus petersoni Clark from the thin shale above the quartzites of the Swan Peak formation.

Fish Haven dolomite

The type locality of the Fish Haven dolomite is along Fish Haven Creek which is about 2 miles north of the town of Fish Haven, Idaho. This Upper Ordovician dolomite was named by Richardson (1913, pp. 409-410). The Fish Haven dolomite is the most widely distributed and the most uniform in thickness and lithology of any Ordovician formation in the West. This period of deposition represents the most widespread invasion of any Paleozoic sea in North America (Hintze, 1959, p. 52).

In the Sharp Mountain area the Fish Haven dolomite is about 125 feet thick and consists of medium-gray fine-crystalline dolomite. The Fish Haven is a conspicuous cliff-forming unit in most exposures.

The Upper Ordovician dolomite represents a widespread transgressive deposit and in different regions overlies formations of widely differing ages. The uniform dolomitic character of the formation and its amazingly constant thickness throughout much of Utah, Wyoming, and Montana indicate that deposition took place under stable shelf conditions over areas exhibiting little topographic relief.

The known fauna of the Fish Haven dolomite is meager and consists of a few brachiopods and such corals as Streptelasma, Columnaria, and Halysites. It is generally believed to be of Richmondian age; however, opinions differ somewhat in the lower age limit of the formation (Ross, 1953, p. 25). The writer collected Halysites (Catenipora) sp. from the Fish Haven dolomite.

Silurian System

The Rocky Mountain geosyncline was occupied by a single marine embayment during the Silurian period. At this time the Laketown dolomite was deposited in a slowly subsiding north-trending trough. The lithology of the Laketown dolomite suggests very shallow water origin (Stokes, 1953, p. 27). Silurian rocks are well exposed in the mapped area on the north-facing slope at the head of Porcupine Creek (Plate 1).

Laketown dolomite

The Laketown dolomite was named from Laketown Canyon, 4 miles southeast of the town of Laketown, in the Randolph quadrangle by Richardson (1913, p. 410). Richardson also restricted the name to beds of Silurian age. The Laketown dolomite is 1,150 feet thick in Green Canyon, Utah (Williams, 1948, pp. 1,137-1,138).

In the Sharp Mountain area the best outcrops of Laketown dolomite occur at the head of Porcupine Canyon. Here the formation is 1,240 feet thick and consists predominantly of medium- to fine-crystalline, light- to medium-gray dolomite. There are several beds that contain chert nodules and stringers and one bed, 5 feet thick, near the top of the formation is composed entirely of chert (Appendix).

During Laketown deposition in northeastern Utah and southeastern Idaho, Wyoming was completely emergent (Thomas, 1949). Williams (1958, p. 25) states that bioherms and biostromes are well developed in parts of the Laketown dolomite of northeastern Utah. This evidence is in agreement with the shallow-water origin suggested by Stokes (1953,

p. 27) and indicates that the sea was sufficiently shallow and clear to permit light to penetrate deep enough for the development of large numbers of organisms during at least part of the interval of deposition. The poorly preserved fossils throughout much of the Laketown dolomite of Utah suggest that dolomitization took place after deposition and recrystallization probably destroyed a large percentage of the contained fossils.

Well-preserved fossils are relatively rare in the Laketown dolomite of northeastern Utah and consist mostly of corals and stromatoporoids (Williams, 1958, p. 25). The Roberts Mountain formation of Nevada; however, contains a fairly large faunule of brachiopods, corals, and graptolites and is equivalent to some and possibly all of the Laketown dolomite of Utah (Nolan, 1956, p. 37). Nolan lists the corals _Halysites_, _Heliolites_, and _Favosites_ and the brachiopods _Conchidium_, _Dicoelosia_, and _Homoeospira_ from the Roberts Mountain formation and dates it as Niagaran. The writer identified the following faunule from the Laketown dolomite of the Sharp Mountain area:

Stromatoporoida

Tabulata
- _Circophyllum_, sp.
- _Favosites_ (_Favosites_), sp.
- _Favosites_ (_Paleofavosites_ ?), sp.
- _Halysites_ (_Halysites_ ?), sp.
- _Lichenaria_, sp.
- _Palaeophyllum_, sp.

Rugosa
- _Zelophyllum_, sp.

Devonian System

In northeastern Utah three formations are assigned to the Devonian system. They are as follows: (1) the Water Canyon formation, (2) the Jefferson formation, and (3) the Three Forks formation. Williams (1948) recognized only the Water Canyon and Jefferson formations in the Logan quadrangle. This twofold division was followed in mapping the Sharp Mountain quadrangle; however, the Beirdneau sandstone member of the Jefferson formation may be chronologically a close correlative of the Three Forks formation recognized elsewhere in the region (Brooks and Andrichuk, 1953, pp. 28-29).

In northern Utah rapid changes in vertical stratigraphic sequence characterize rocks of Devonian age (Brooks and Andrichuk, 1953, pp. 28-29). This feature is well exemplified by the great variation in thickness of the Jefferson formation between Blacksmith Fork Canyon, Utah, where Williams (1948, pp. 1,139-1,140) reports 1,848 feet, and Wheat Grass Canyon, Utah, just south of Little Monte, where the Jefferson formation is less than 500 feet thick.

Water Canyon formation

The Water Canyon formation was named from a tributary of Green Canyon east of the town of Smithfield, Utah (Williams, 1948, pp. 1,138-1,139). Williams recognized two members in the Water Canyon formation throughout most of the Logan quadrangle. In Blacksmith Fork Canyon the lower member is missing and about 15 miles to the southwest, near Dry Lake, the upper member is absent while the lower member is well developed with an estimated thickness of 400 feet.

In the Sharp Mountain area the Water Canyon formation is represented by approximately 460 feet of limestone, dolomite, and sandstone. At the base of the formation a bed of breccia occurs which is 5 feet thick and consists of angular dolomite fragments in a calcareous matrix (Appendix). The Water Canyon formation in the Sharp Mountain quadrangle probably represents the upper member of the formation as recognized by Williams in the Blacksmith Fork section. Beds of dolomite near the base of the formation which weather chalk-white are conspicuous stratigraphic markers wherever exposed.

Williams (1958, p. 27) suggests that the Water Canyon formation of the Logan quadrangle corresponds closely, both lithologically and paleontologically, to the Beartooth Butte formation of Wyoming. Dorf (1934, p. 728) described the Beartooth Butte formation as consisting of interbedded limestone conglomerates, impure limestones, and limy shale and regards it as having been deposited in fresh to brackish estuarine waters. The fauna of the Beartooth Butte formation of western Wyoming includes 29 species of ostracoderms, anthrodires, elasmobranchs, and a dipnoan, in addition to a large eurypterid. The flora consists of five species of the primitive psilophytales. The Water Canyon formation of northeastern Utah has yielded abundant fish fossils (Williams, 1958, p. 27). The presence of fossils of fish, believed to have lived in fresh water, and the apparent absence of undoubtedly marine fossils from the Water Canyon formation of northeastern Utah suggests that it was deposited in fresh to brackish water; however, the uniform lithology and widespread occurrence of the formation in northeastern Utah implies a marine depositional environment. The absence of marine fossils from the Water Canyon formation may be either the result of deposition under conditions unfavorable to preservation of organisms or the result of insufficient attempts to collect fossils from the formation. The occurrence of fish fossils, that are generally regarded as being fresh water in origin, may have resulted from influx of streams which carried the fresh-water fish into the marine depositional environment.

Williams (1958, p. 27) dates the Water Canyon formation of northeastern Utah as Lower Devonian. This is in agreement with the Lower Devonian age suggested for the Beartooth Butte formation of Wyoming by Cooper (1942, p. 1,746). The writer observed no fossils in the Water Canyon formation of the Sharp Mountain quadrangle.

Jefferson formation

The name Jefferson formation was proposed by Peale (1894, pp. 26-28) for rocks exposed at Three Forks, Montana, that probably represent part of the Garden City formation along with the Silurian and Devonian systems. The name was subsequently restricted to rocks of Devonian age. In the Logan quadrangle, the Jefferson formation has been divided into two members which are as follows: (1) the basal Hyrum dolomite and (2) the upper Beirdneau sandstone (Williams, 1948, pp. 1,139-1,140). In Blacksmith Fork Canyon the Hyrum dolomite member consists predominantly of black dolomite and limestone and is 1,100 feet thick. The Beirdneau sandstone member is composed mostly of buff-weathering sandstones and is 740 feet thick (Williams, 1948, pp. 1,139-1,140). The contact between the two members is gradational with dolomite and sandstone interbedded.

Within the Sharp Mountain area only the Hyrum dolomite member is exposed, but immediately northwest of the area there are exposures which probably represent the Beirdneau sandstone member. Because of incomplete exposures it was not possible to measure a section of the Jefferson formation in the Sharp Mountain quadrangle. East of the mapped area in Wheat Grass Canyon the Jefferson is less than 500 feet thick. In the Wheat Grass Canyon section the upper part of the Jefferson formation is composed of sandy and silty red beds that may represent the Beirdneau sandstone member.

The rapid variation in thickness of the Jefferson formation between Blacksmith Fork Canyon, Utah, where it is 1,842 feet thick and Wheat Grass Canyon, Utah, where the formation is less than 500 feet thick, indicates that deposition was either much slower or that the Wheat Grass area was emergent at times. Red beds in the upper part of the Jefferson formation of the Wheat Grass section support the latter alternative, but do not completely discount the first possibility.

During deposition of the lower part of the Jefferson formation in northeastern Utah sediments were accumulating in the shelf area and in a more rapidly subsiding geosynclinal basin, both under relatively stable conditions, as evidenced by the clean carbonate sediments of the Hyrum dolomite member of the formation. During deposition of the Beirdneau member of the Jefferson formation an uplift in the vicinity of the Stansbury Mountains shed considerable amounts of clastic material into the Devonian sea (Rigby, 1959, p. 217). This uplift was probably slow or intermittent during early Beirdneau deposition and alternating periods of rapid influx of clastics and periods of relative stability produced the alternating beds of sandstone and dolomite that characterize the contact between the Hyrum dolomite member and the Beirdneau sandstone member of the formation. During the latter part of Beirdneau deposition large amounts of clastic material were continually shed into the northeastern Utah basin.

A widespread breccia occurs at the base of the Jefferson formation throughout much of the Logan quadrangle. Above this breccia a fauna zone occurs that includes *Tenticospirifer utahensis*, *Atrypa missouriensis*, and *Favosites limitaris* which marks this zone as the *Spirifer argentarius* zone of the Devils Gate limestone of Nevada (Williams, 1958, p. 27). The *Spirifer argentarius* zone is regarded as Upper Devonian (Nolan, 1956, p. 51). The writer collected no fossils from the Jefferson formation.

Tertiary System

The Tertiary system is represented by the Wasatch formation, the Salt Lake group, and Tertiary boulders within the Sharp Mountain area. The Wasatch formation and Salt Lake group are exposed along the eastern margin of the mapped area. The Wasatch formation unconformably overlies the Prospect Mountain quartzite over much of the eastern and southeastern part of the Sharp Mountain quadrangle and the Salt Lake group unconformably overlies the Wasatch in scattered patches in the eastern part of the area. Along the east flank of Sharp Mountain the Salt Lake group overlaps the Wasatch and unconformably overlies the Ute formation. Tertiary boulders cover a large area in the southeastern part of the mapped region and also occur in a large patch east of the La Plata mine (Plate 1).

Wasatch formation

The Wasatch group, herein called Wasatch formation, was named by Hayden (1869, p. 191) with reference to exposures west of Fort Bridger, Wyoming. Here the Wasatch consists of variegated sands and clays with very little calcareous material and is characterized by its red coloring. Williams (1948, p. 1,144) describes a red pebble and cobble conglomerate in the eastern and southern part of the Logan quadrangle that he designates "Wasatch" conglomerate. He also describes a stromatolitic limestone at the base of the Wasatch that he calls the Cowley Canyon member.

The Wasatch formation in the Sharp Mountain area consists of interbeds of cobble and pebble conglomerates and coarse- to fine-grained sandstones. The only stromatolitic limestone observed in the mapped area overlies the red Wasatch beds in scattered outcrops in the eastern part of the area and unconformably overlaps the Paleozoic rocks along the eastern flank of Sharp Mountain. Because of its stratigraphic position above the red beds of the Wasatch formation and its similarity to the stromatolitic limestone unconformably overlying the "Wasatch" beds west of Avon, Utah (Adamson, 1955, p. 25), the limestone was mapped as Salt Lake group. The Wasatch formation was not measured by the writer; however, Williams (1948, p. 1,144) estimates the average thickness of the formation in the Logan quadrangle to be about 300 feet. This thickness is in general agreement with that observed for the Sharp Mountain area.

The Wasatch formation was deposited on a broad plain over which numerous sluggish, heavily laden streams flowed. In times of heavy precipitation the entire plain became inundated and the finer sediments were deposited in shallow lakes. The varied lithology and discontinuous nature of the Wasatch beds attest to the frequently changing conditions of deposition suggested for this period.

Eardley (1955, pp. 37-44) regards the Wasatch formation of Cache Valley and adjacent regions as early Eocene in age. Adamson, Hardy, and Williams (1955, pp. 1-22) believe the Wasatch formation is both Paleocene and Eocene. Jones, Picard, and Wyeth (1954, pp. 2,219-2,239) are in agreement with Adamson, Hardy, and Williams and date the Wasatch formation of northeastern Utah as both Paleocene and Eocene. No fossils were found in the Wasatch formation by the writer.

Salt Lake group

The name Salt Lake group was applied to sands, sandstones, and marls of light color exposed along the margins of Salt Lake Valley and Weber Valley by Hayden (1869, p. 192). Williams (1948, p. 1,147) states that light-colored tuffs, tuffaceous sandstones, and conglomerates of the Salt Lake group underlie the foothill benches of Cache Valley and extend in irregular patches through the passes to adjacent valleys. Adamson (1955, p. 25) describes a stromatolitic limestone unconformably overlying the "Wasatch" beds west of Avon, Utah and assigns it to the Salt Lake group.

It is believed that the scattered outcrops of stromatolitic and tuffaceous limestone that overlie the Wasatch formation along the eastern margin of the Sharp Mountain area represent remnants of a sheet which originally completely covered the Wasatch beds and overlapped the Paleozoic rocks exposed on the east flank of Sharp Mountain. Tuffaceous and stromatolitic limestones also are present in the lower parts of the valley of East Pole Creek along the western margin of the mapped area. The limestone and tuff of the Salt Lake group possibly accumulated as a result of streams being dammed by volcanic ash falls that caused a shallow lake to occupy Ant Valley and adjacent low elevations.

Brown (1949, pp. 224-229) and Eardley (1955, pp. 40-41) believe the Salt Lake group of Cache Valley is Pliocene in age, whereas Jones, Picard, and Wyeth (1954, pp. 2,219-2,239) along with Adamson, Hardy, and Williams (1955, p. 2) regard it as being both Miocene and Pliocene in age. The writer found no fossils from the Salt Lake group of the Sharp Mountain area.

Tertiary boulders

Quartzite boulders and pebbles occur in patches in the southeastern part of the Sharp Mountain area. The south-central part of the area is covered with a sheet of quartzite boulders that form a continuous, gently sloping surface up to the exposures of pre-Cambrian rocks to the south and west of the mapped area. Eardley (1955, pp. 41-44) dates the initial period of erosion which produced the Herd Mountain surface, which is continuous with the surface in the south and west part of the Sharp Mountain quadrangle, as mid-Oligocene to early Miocene. Ezell (1953, pp. 21-22) describes a similar upland surface from the Rendezvous Peak area, which is about 10 miles west of Sharp Mountain, and dates it as pre-Salt Lake group.

STRUCTURAL GEOLOGY

Regional Structural Relations

The Sharp Mountain area is situated in a region of north-south Laramide folds and related thrusts along which eastward and also probably westward movement has occurred. Wellsville Mountain, about 15 miles to the northwest of Sharp Mountain, is regarded as a fault-block bounded by north northwest-trending high-angle faults (Gelnett, 1958, p. 58). Gelnett recognized no evidence of important thrusting in Wellsville Mountain and visualized normal and strike-slip faulting of the Laramide orogeny and high-angle faulting of Basin and Range deformation to explain the structural features. The Rendezvous Peak area, located 7 miles west of Sharp Mountain, is believed to have been folded and faulted during Laramide deformation. Faulting of Basin and Range age produced high-angle faults that trend in three major directions in the Rendezvous Peak area which are as follows: (1) north-south, (2) east-west, and (3) northeast-southwest (Ezell, 1953, pp. 25-26). The Wasatch Mountains, west and south of Sharp Mountain, contain both north-trending and west-trending folds. Three overthrusts have been mapped in this area, the easternmost of which is the Willard overthrust (Eardley, 1939, pp. 1,286-1,287). The Willard overthrust parallels the eastern margin of the Northern Utah Highland and is located about 10 miles west of Sharp Mountain. Eardley concluded that pre-Cambrian rocks of the highland acted as a resistant shield caught in the area of Laramide compression and about its margins the sedimentary rocks buckled and sheared. The Paleozoic rocks were probably first gently folded by early Laramide compressional forces and later, as the forces increased, the buttress became crowded against the stratified rocks to the east which failed by shearing along planes parallel to the margins of the highland (Eardley, 1939, pp. 1,286-1,287). Eardley also states that the high-angle faults of the central Wasatch Mountains, which trend east-west, are older than Basin and Range faults and that some were produced either by vertical forces that acted during folding or by forces resulting from differential release of pressure after folding.

The Bannock overthrust has been recognized in the Randolph quadrangle, northeast of the Sharp Mountain area, and has been traced northward into Idaho. The overthrusting was northeastward with a maximum overlap of about 35 miles (Mansfield, 1927, p. 158). Richardson (1941, pp. 38-39) identified the overthrust west and northwest of Garden City, Utah, where it is exposed for about 2 miles. South of the Garden City area the overthrust is obscured by overlying Tertiary and Quaternary deposits; however, it has been suggested that the thrust extends at least as far south as Woodruff Creek which is about 20 miles east of Sharp Mountain.

The Paleozoic Rocks of the Logan quadrangle, immediately north of the Sharp Mountain area, were folded into a broad syncline and anticline by the Laramide deformation. In the Logan quadrangle Williams (1948, pp. 1,153-1,155) identified several high-angle north-trending faults that cut the Wasatch formation and the Salt Lake group. Williams believes that these faults are primarily responsible for the major topographic relief of the Bear River Range and Cache Valley.

The East Cache faults, which define the east margin of the floor of Cache Valley and the west face of the Bear River Range, may be traced into the canyon of Southeast Fork where they apparently die out (Williams, 1948, pp. 1,153-1,155). It seems probable, based on observation of aerial photographs of the region, that at least one of the East Cache faults described by Williams intersects the north-trending marginal faults of Sharp Mountain west of where Davenport Creek passes out of the mapped area. No evidence was found indicating that the East Cache fault continued southeastward across the marginal faults of Sharp Mountain.

Geologic Structure

General features

The Sharp Mountain quadrangle is a segment of the westernmost of two ridges which make up the Bear River Range. This ridge is limited on the west by the East Cache faults (Williams, 1948, pp. 1,153-1,155). Sharp Mountain is bounded on the west by a separate set of north-trending faults that apparently intersect the East Cache faults north of James Peak. Upper Logan River occupies the northern part of the central depression that separates the two high ridges of the Bear River Range. Southward this depression becomes wider and makes up Ant Valley (Williams, 1948, pp. 1,125-1,126).

The geologic structure of the mapped area, which includes Sharp Mountain and the southwestern part of Ant Valley, constitutes the west flank of a broad anticline that is a southward continuation of the Strawberry Valley anticline. There are also several high-angle faults within the Sharp Mountain quadrangle. No evidence of thrusting was found within the area. While there were undoubtedly intermittent periods of deformation during the Paleozoic Era the region was not appreciably deformed until late Mesozoic-early Tertiary time when the Laramide orogeny produced broad folds and associated faults. In middle Tertiary time the region was again subjected to widespread deformation. Although diastrophism was more intense during these two periods, there were probably minor disturbances in mid-Tertiary time as well as in Recent time.

Folds

The west-dipping Paleozoic formations exposed in Sharp Mountain make up the west flank of the Strawberry Valley anticline. The axis of the anticline is visible in Scare Canyon, east of the northeastern corner of the mapped area, where the Prospect Mountain quartzite is exposed. Southward, the axis of the fold is obscured by overlying Tertiary rocks, but the west-dipping Paleozoic formations exposed in Sharp Mountain indicate that the fold continues southward. On the South Fork of Ogden River, about 5 miles east of Huntsville, Utah, the east limb of the Strawberry Valley anticline is evident (Hardy, 1956, p. 25). This would place the axis of the anticline approximately 5 miles east of the crest of Sharp Mountain.

At the mouth of Porcupine Canyon, near the northwestern corner of the mapped area, the Laketown dolomite dips gently westward and farther west the beds seem to be dipping gently eastward. South of Porcupine Canyon, faulting has obscured any evidence of a major fold extending through this area (Plate 1). The apparent eastward dip of the beds at the mouth of Porcupine Canyon may be the result of faulting, but no conclusive evidence was found to extend the north-trending faults across the canyon.

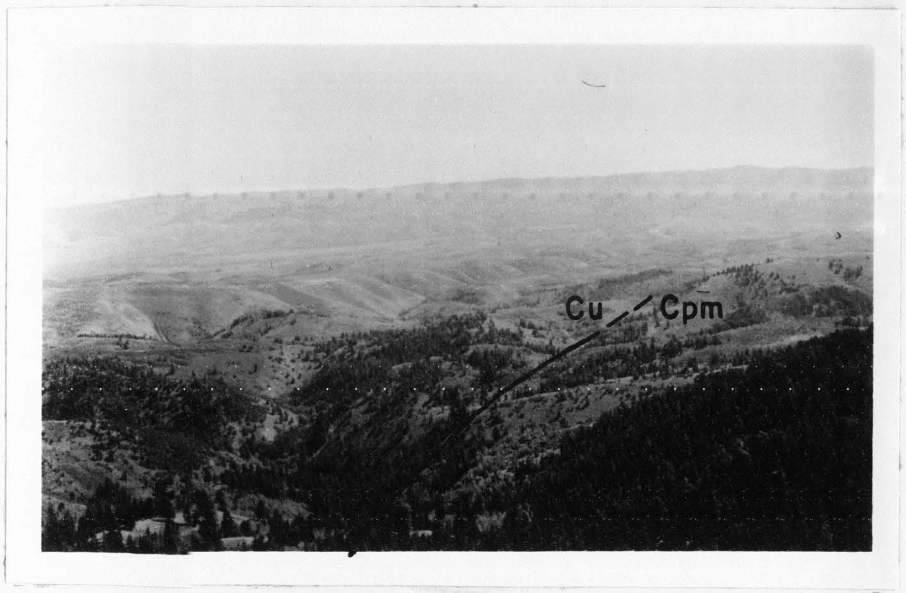
There are minor folds in most of the formations where interbedded shale is abundant. These minor folds are most conspicuous in the Ute, Bloomington, and Garden City formations and are the result of deformation within the incompetent beds which occurred contemporaneous with the major folding of the region. The Strawberry Valley anticline and the associated minor folds were produced by the Laramide orogeny which probably acted intermittently during late Cretaceous and early Tertiary time.

Faults

Faults within the Sharp Mountain quadrangle may be divided into two groups which are as follows: (1) northwest- to west-trending faults and (2) north-trending faults. The first group of faults occur in the vicinity of the Mineral Point mine and the La Plata mine. The north-trending faults are along the western margin of Sharp Mountain (Plate 1).

Northwest- to west-trending faults.--The first major fault of this group trends westward through the La Plata mine and extends across the low ridge west of the mine and up the bottom of the canyon to near the crest of Sharp Mountain (Plate 1). Displacement along the fault progressively decreases westward and the fault dies out just below the crest of Sharp Mountain. The maximum stratigraphic displacement is at least 500 feet and is evident east of the La Plata mine where the Prospect Mountain quartzite is faulted against the Ute formation. Eastward the fault is obscured by overlying Tertiary rocks.

Plate 4. High-angle faults



View, looking east, of La Plata mine area

There are numerous minor faults and fractures associated with the major fault in the vicinity of the La Plata mine.

The second major west-trending fault extends from near the bottom of Cinnamon Ridge up the east-facing slope of East Fork where it apparently dies out before reaching the ridge crest (Plate 1). The maximum displacement is near the bottom of Cinnamon Ridge east of the Mineral Point mine where the Prospect Mountain quartzite is faulted against the Ute formation indicating about 500 feet of stratigraphic displacement.

The area between the Mineral Point mine and the easternmost of the northwest-trending faults is essentially a tilted-fault block. The southernmost fault of this group swings sharply northward as it reaches the bottom of the canyon southwest of the Mineral Point mine and follows the canyon bottom until it intersects the northernmost fault. There is little stratigraphic displacement along either of the bounding faults. The main effect of the faulting was to tilt the included block eastward. The maximum stratigraphic displacement, which is less than 100 feet, is in the bottom of the canyon south of the Mineral Point mine. There are several minor faults and fractures within the tilted block.

The faulting in the vicinity of the Mineral Point and La Plata mines was produced by the Laramide deformation as evidenced by the undisturbed Wasatch formation which overlies the faults in places. The movement may have taken place along pre-existing fault planes of possible pre-Cambrian origin or movement may have occurred along wrench-faults produced by the Laramide orogeny. Moody and Hill (1956, pp. 1,207-1,246) discuss the wrench-fault tectonic system and believe that it may be a dominant type of failure in the crust. If the wrench-fault analyses is applied to the faults of the Mineral Point-La Plata region some remarkable similarities are observed. Assuming the primary-stress direction to be about N. 70° W., the Strawberry Valley anticline and associated Logan Peak syncline conform to the hypothetical primary-fold direction. The trend of the major fault through the La Plata area closely corresponds to the primary first-order wrench-fault which is at approximately 30° to the primary-stress direction. Also right-lateral movement can be inferred along this fault. The major fault south of Cinnamon Ridge corresponds to the complementary first-order wrench-fault and the left-lateral movement, suggested for this type of fault by Moody and Hill (1956, p. 1,213), can also be inferred. The northwest-trending faults in the vicinity of the Mineral Point mine could be second-order left-lateral wrench-faults also of the type suggested by Moody and Hill. Although the trend of the faults of this area deviate somewhat from the hypothetical directions, the general fault pattern is so similar to the wrench-fault system that the possibility of wrench-fault deformation under general east-west compressional forces cannot be discounted. As Moody and Hill (1956, pp. 1,213-1,214) state, the hypothetical directions need not be vigorously adhered to because there are several factors which may modify the trend of any particular fault.

North-trending faults.--Paralleling the western margin of Sharp Mountain are several north-trending faults that converge and die out just south of Porcupine Canyon (Plate 1). The faults expose two nearly vertical blocks of the Garden City formation which are separated by a block of Laketown dolomite. The blocks of Garden City are cut by minor faults that appear to be bedding plane shears. There are two possible explanations as to the origin of these faults. The first possibility is that during Laramide deformation the James Peak region was uplifted relative to Sharp Mountain immediately to the east. This uplift could have folded the overlying Paleozoic rocks and as the James Peak area continued to rise reverse faults could have been produced. Later, during Basin and Range deformation, reverse movement may have taken place along the pre-existing Laramide fault planes. The second possibility is that regional uplift occurred during Basin and Range deformation. Following the regional uplift the Sharp Mountain area subsided relative to the adjacent area to the west. This could have initially folded the Paleozoic formations, exposed in Sharp Mountain, downward while the Paleozoic rocks in the vicinity of James Peak remained high. As the eastward collapse continued, normal faults may have developed parallel to the nonsubsiding area.

Although the north-trending faults along the western margin of Sharp Mountain may have been initially produced by either Laramide or Basin and Range deformation it is probable that movement occurred, at least along the westernmost of these faults, during Basin and Range deformation. This movement is evidenced by the occurrence of the Jefferson formation adjacent to the Garden City formation along the western margin of the quadrangle (Plate 1). No post-Salt Lake group movement has been observed along any of the north-trending faults.

ECONOMIC GEOLOGY

General Statement

Within the Sharp Mountain quadrangle and the adjoining area immediately to the north there has been considerable exploration for mineral deposits. This exploration was most intense in the vicinity of the Mineral Point mine and the La Plata mine (Plate 1). Although a few mines were developed in this area, only a small amount of ore has actually been sold. These shipments consisted principally of lead ore which was mined at La Plata between 1890 and 1895 (Butler and Loughlin, 1920, pp. 217-218).

Mineral Point Mineralization

In the vicinity of the Mineral Point mine there are several west-trending faults and fractures that cut the Prospect Mountain quartzite, Pioche formation, and Langston formation. Only minor displacement has occurred along these breaks. The mineralization, which is associated with the faults and fractures, consists of pure coarsely crystalline specular hematite existing as replacements in limestone of the Langston formation (Crawford and Buranek, 1943, pp. 12-13). There have been two main mine openings excavated in the Mineral Point area. The larger is a tunnel about 100 feet below the ridge crest on the southeast-facing slope at the Mineral Point mine. This tunnel intersects a 6-foot vein of hematite which is enclosed by about 3 feet of hematite ocher. The smaller shaft is about 160 feet lower on the slope and also intersects the hematite vein (Vic E. Peterson, unpublished report, Utah State University, Logan). In addition to the two main shafts there are several small excavations in this general area, none of which exceed 30 feet in depth. Several holes were drilled in an attempt to establish the extent of the ore body. Peterson, using data obtained from this drilling, calculated that there should be over 900,000 tons of recoverable ore; however, this seems an excessive amount in the light of the limited extent of the Langston formation present here. Several samples of ore collected from Mineral Point were analysed and found to contain 64.2 percent iron (Crawford and Buranek, 1943, pp. 12-13). Crawford and Buranek believe that mineralization resulted from ascending solutions with a high concentration of iron that occurred contemporaneous with, or closely following, the deformation producing the faults and fractures of the area.

La Plata Mineralization

The La Plata mine is approximately 1 mile east of Sharp Mountain and is located on a major west-trending fault that places the Prospect Mountain quartzite adjacent to the Ute formation. There are several minor faults and fractures in the immediate vicinity of La Plata. Several excavations are located on or very near the major fault. Numerous other excavations are present within the surrounding area. Ores containing principally lead with small amounts of gold, silver, copper, and zinc have been shipped from the La Plata region (Butler and Loughlin, 1920, pp. 217-218). The mineralization of the La Plata area, like that of Mineral Point, is controlled by faults and fractures and was probably produced by solutions which moved upward along the fissures and formed replacement bodies primarily in the limestones of the Langston formation.

GEOLOGIC HISTORY

Paleozoic Events

The Sharp Mountain area is situated within the region occupied by the Cordilleran geosyncline during the Paleozoic Era. Sedimentation in the Sharp Mountain area began in late Waucoban time and continued with little interruption through Albertan, Croixian, and into Chazyan time. During this interval over 8,000 feet of sediments were laid down. A local unconformity separates the Garden City formation from the overlying lower Chazyan Swan Peak formation. In Richmondian time the Fish Haven dolomite was deposited. In Lower Devonian time the Water Canyon formation was deposited and in Upper Devonian the Jefferson formation was conformably deposited over the Laketown dolomite. Although Mississippian, Pennsylvanian, and Permian rocks are not exposed within the Sharp Mountain area, they undoubtedly were laid down over this region as evidenced by their occurrence in adjacent areas. Erosion initiated by late Mesozoic uplift removed these sediments from the Sharp Mountain quadrangle.

Mesozoic Events

The Sharp Mountain area was blanketed by at least 10,000 feet of Mesozoic sediments as evidenced by the occurrence of Mesozoic rocks of this general thickness both to the north in southeastern Idaho (Mansfield, 1927, p. 99) and to the south along the Upper Weber River (Eardley, 1944, p. 827). All of these deposits were subsequently removed by erosion initiated by the regional uplift in late Mesozoic time. The Laramide orogeny, which produced this regional uplift, began in the latter part of the Mesozoic Era and continued into early Cenozoic time. This period of deformation produced the Strawberry Valley anticline, from which the Paleozoic formations in Sharp Mountain dip westward, and the associated faults in the vicinity of the Mineral Point mine and the La Plata mine. Also the north-trending faults west of Sharp Mountain may have been initially formed during the Laramide orogeny. Folding and thrusting in the surrounding region also occurred during this general period of deformation.

Cenozoic Events

During and following the several phases of deformation produced by the Laramide orogeny much erosion occurred. A period of erosion initiated in early or middle Paleocene continued into late Paleocene and stripped the overlying rocks from the axis of the Strawberry Valley anticline. In the latter part of Paleocene and in early Eocene the Wasatch formation was unconformably deposited over the Prospect Mountain quartzite near the axis of the anticline.

From Oligocene to mid-Miocene was a period of relative crustal stability during which time the upland surface, called the Herd Mountain erosional surface (Eardley, 1955, pp. 41-44), was initially eroded. In middle Tertiary time displacement occurred along the north-trending faults that parallel the western flank of Sharp Mountain. Displacement may have taken place along pre-existing faults that were initially formed by Laramide deformation or the faults may have originated during this period of diastrophism. The Salt Lake group was deposited over the lower elevations within the Sharp Mountain quadrangle during late Miocene and Pliocene time.

Since Pliocene time the Sharp Mountain area has been subjected to dissection by streams and other erosional processes. The quartzite boulders east of the La Plata mine were probably derived from the outcrops of Prospect Mountain quartzite immediately to the west, south, and east and were transported to their present position either by ice flows during Pleistocene time or by streams during times of rapid runoff. No evidence of post-Salt Lake group faulting was found within the Sharp Mountain quadrangle.

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APPENDIX

Measured Sections

Section No. 1, East Fork of Little Bear River, Utah. Section of Langston formation on northeast-facing slope about 1 mile south of Mineral Point, starting about 200 feet up the slope and extending westward up the slope to the Ute contact.

Ute formation

Langston formation	Thickness (feet)
4. Dolomite, light- to very light-gray, fine-crystalline, weathers moderate brown, unit is resistant and forms cliffs in most exposures	122.3
3. Dolomite, light- to medium-gray, fine-crystalline, weathers dark reddish brown, unit is resistant and forms cliffs in most exposures	71.5
2. Limestone, medium-gray, fine-crystalline, weathers medium gray, beds 1 inch to 1 foot thick with thin interbeds of silt which weather in relief	35.7
1. Dolomite, medium-gray, medium- to coarse-crystalline, weathers dark brown, beds 1 foot to 4 feet thick with thin interbeds of silt and chert. Entire unit is resistant and forms cliffs in most exposures	40.8
Total	270.3

Pioche formation

Section No. 2, East Fork of Little Bear River, Utah. Section of Ute formation on northeast-facing slope about 1 mile south of Mineral Point, beginning at the top of the steep slope and extending westward up the gentle slope to the Blacksmith contact.

Blacksmith formation

	Ute formation	Thickness (feet)
23.	Limestone, medium-gray, weathers light gray, beds 2 inches to 3 feet thick, resistant unit	79.0
22.	Limestone, medium-gray, fine-crystalline, weathers light gray, beds 2 inches to 1 foot thick, nonresistant slope-forming unit	89.7
21.	Limestone, dark-gray, aphanitic, weathers light gray, beds 2 inches to 1 foot thick	57.3
20.	Limestone, dark-gray, weathers light gray, beds 1/8 inch to 1 inch thick	74.7
19.	Limestone, silty, dark-gray, weathers medium gray, silt specks are scattered throughout and weather yellowish brown, beds 4 inches to 6 inches thick	152.0
18.	Shale and limestone interbedded, slope-forming unit	74.7
17.	Limestone, silty, dark-gray, sand weathers out in relief and forms orangish brown specks, some thin shale beds	47.4
16.	Limestone and siltstone. Limestone, medium-gray, weathers light gray, beds 1/2 inch to 3/4 inch thick. Silt, reddish-orange, beds 1/4 inch to 1/2 inch thick	10.0
15.	Limestone, medium-gray, weathers light gray, contains patches of siltstone which weathers orangish brown, beds 6 inches to 1 foot thick	19.9
14.	Shale, dark-green, weathers brownish green and to a smooth slope	39.9
13.	Limestone, dark-gray, weathers light gray to medium gray, contains thin silty beds. Limestone beds 1 inch to 6 inches thick. Silt beds 1/8 inch to 1/4 inch thick	59.7

Ute formation (continued)		Thickness (feet)
12.	Shale, moderate-yellow-green, slope-forming unit	29.9
11.	Limestone, dark-gray, weathers light gray, contains thin beds of yellowish-brown siltstone. Limestone beds average about 1 inch in thickness. Silt beds are 1/8 inch to 1/4 inch thick	24.9
10.	Shale, olive-green, slope-forming unit	12.4
9.	Limestone, oolitic, dark-gray, weathers light to medium gray, contains thin beds of orangish brown weathering siltstone. Limestone beds 1 inch to 6 inches thick	67.2
8.	Shale, limy, greenish-brown, weathers yellowish brown with crinkly surface	10.0
7.	Limestone and shale. Limestone, oolitic, medium-gray, contains thin orangish brown weathering silt beds. Shale, olive-green	54.8
6.	Shale, greenish-brown, forms smooth slope	19.9
5.	Limestone, oolitic, medium- to dark-gray, weathers medium gray, contains thin silty beds	24.9
4.	Limestone, shaly, light-gray, aphanitic, beds 1/2 inch to 2 inches thick	19.9
3.	Shale, brownish-green, weathers to smooth slope	13.5
2.	Limestone, medium-gray, fine-crystalline, weathers medium gray, beds 1 foot to 2 feet thick, resistant, cliff forming unit	55.7
1.	Shale, olive-green, slope-forming unit	53.1
	Total	1,090.5

Langston formation

Section No. 3, East Fork of Little Bear River, Utah. Section of Blacksmith formation on northeast-facing slope about 1 mile south of Mineral Point, beginning about half way up the slope and ending at the base of the smooth slope about two-thirds the way up the ridge.

Bloomington formation

Blacksmith formation	Thickness (feet)
6. Limestone, medium-gray, aphanitic, weathers medium gray, beds 1 foot to 2 feet thick. Oolitic near the top	210.0
5. Limestone, very light-gray, weathers very light gray to light gray, beds 1/2 inch to 1 inch thick	45.0
4. Dolomite, light-gray, fine-crystalline, weathers light gray, well-bedded	47.5
3. Dolomite, brecciated, medium-gray, fine-crystalline, weathers medium gray with reddish brown stains, thick-bedded, resistant unit	52.9
2. Limestone, dark-gray, fine-crystalline, weathers moderate gray with thin beds of orangish brown weathering siltstone	46.0
1. Dolomite, very light-gray, coarse-crystalline, weathers yellowish brown with granular surface	7.7
Total	409.1

Ute formation

Section No. 4, Sharp Mountain, Utah. Section of Bloomington formation on the east-facing slope of Sharp Mountain, section begins approximately 1/2 mile west of La Plata mine and extends westward across the road to about 150 feet up the slope.

Nounan formation

Bloomington formation	Thickness (feet)
12. Limestone and shale. Limestone, dark-gray, aphanitic, weathers very light gray, beds 1 inch to 1 foot thick. Shale forms covered intervals	77.5

	Bloomington formation (continued)	Thickness (feet)
11.	Limestone, silty, medium-gray, aphanitic, weathers light gray, beds 6 inches to 3 feet thick, forms cliffs, silt weathers yellowish brown to light red	9.8
10.	Limestone and shale. Limestone, silty, medium-gray, aphanitic, weathers medium gray, silt weathers yellowish orange. Shale forms covered intervals	136.2
9.	Dolomite, medium-gray, fine-crystalline, weathers medium gray	4.9
8.	Covered interval, probably shale	45.5
7.	Limestone, dark-gray, fine-crystalline, weathers medium gray, beds 2 inches to 1 foot thick	58.5
6.	Limestone, medium-gray, aphanitic, weathers light gray to medium gray, beds 2 inches to 1 foot thick. Contains beds 2 feet thick of limestone with rounded pebbles of limestone which weather very light gray	24.3
5.	Limestone, dark-gray, fine-crystalline, weathers very light gray, beds 1/4 inch to 1 inch thick	18.1
4.	Limestone, medium-gray, aphanitic, weathers very light gray to medium gray, beds 4 inches to 1 foot thick	85.5
3.	Limestone, medium-gray, aphanitic, weathers medium gray, thick-bedded, cliff-forming unit	103.5
2.	Limestone, medium-gray, aphanitic, weathers medium gray, beds 3 inches to 1 foot thick	13.5
1.	Limestone, medium-gray, fine-crystalline, weathers light gray to medium gray, beds 1/2 inch to 3 feet thick, some thin beds of dolomite interbedded	27.0
	Total	604.3

Blacksmith formation

Section No. 5, East Fork of Little Bear River, Utah. Section of Nounan formation on north-facing slope about midway between the mouth of Porcupine Canyon and Scare Canyon, beginning approximately 200 feet up the slope and extending about half way to the ridge crest.

St. Charles formation

	Nounan formation	Thickness (feet)
21.	Dolomite, medium-gray, medium-crystalline, weathers light gray. Upper 100 feet covered	212.0
20.	Limestone, medium-gray, aphanitic, weathers medium gray with brown-weathering interbedded silty layers	4.1
19.	Dolomite, light-gray, medium-crystalline, weathers brownish gray, cliff-forming unit	16.4
18.	Dolomite, oolitic, medium-gray, weathers medium gray, some interbedded brown-weathering silty beds	57.3
17.	Dolomite, medium-gray, fine- to medium-crystalline, weathers medium gray, upper part is silty and weathers yellowish brown	57.3
16.	Dolomite, light-gray, medium- to coarse-crystalline, weathers light gray to brownish gray	46.7
15.	Dolomite, light-gray, fine-crystalline, weathers light gray to brownish gray	8.2
14.	Dolomite, light-gray, medium- to coarse-crystalline, weathers light gray, resistant cliff-forming unit	45.0
13.	Dolomite, medium-gray, fine-crystalline, weathers medium gray, thin interbeds of oolitic dolomite, entire unit is nonresistant	217.0
12.	Dolomite, white to light-gray, medium- to coarse-crystalline, weathers very light gray	77.5
11.	Dolomite, medium-gray, fine-crystalline, weathers light gray	22.4
10.	Dolomite, medium-gray, fine-crystalline, weathers medium gray	20.4

Nounan formation (continued)		Thickness (feet)
9.	Dolomite, silty, light-gray, fine-crystalline, weathers light gray with thin brown-weathering silty beds	24.5
8.	Dolomite, light-gray, fine-crystalline, weathers light gray, few thin oolitic beds	81.9
7.	Dolomite, oolitic, light-gray, weathers light gray	4.1
6.	Dolomite, medium-gray, fine-crystalline, weathers medium gray	40.8
5.	Dolomite, light-gray, fine-crystalline, weathers light gray	38.2
4.	Dolomite, medium-gray, weathers medium gray	12.3
3.	Dolomite, oolitic, medium-gray, fine-crystalline, weathers medium gray, beds 1 foot thick	4.1
2.	Dolomite, light-gray, weathers medium gray, beds 1 foot to 2 feet thick	135.0
1.	Dolomite, cherty, medium-gray, fine-crystalline, weathers medium gray, beds 1 inch to 6 inches thick	20.4
	Total	1,145.6

Bloomington formation

Section No. 6, East Fork of Little Bear River, Utah. Section of St. Charles formation measured on north-facing slope about midway between the mouth of Porcupine Canyon and Scare Canyon, beginning approximately half way up the slope and extending to the base of the vertical Garden City cliffs on the crest of the ridge.

Garden City formation

St. Charles formation		Thickness (feet)
18.	Dolomite, medium-gray, fine-crystalline, weathers light gray	262.0
17.	Dolomite, light-gray, medium-crystalline, weathers light gray, thin-bedded	80.9

St. Charles formation (continued)		Thickness (feet)
16.	Dolomite, medium-gray, medium-crystalline, weathers medium gray	47.9
15.	Dolomite, oolitic, dark-gray, fine-crystalline, weathers medium gray	2.7
14.	Dolomite, cherty, dark-gray, fine-crystalline, weathers medium gray	38.2
13.	Dolomite, dark-gray, weathers dark gray, cliff-forming unit	29.4
12.	Dolomite, very light-gray, coarse-crystalline, weathers light gray, cliff-forming unit	136.3
11.	Dolomite, medium-gray, weathers dark gray, cliff-forming unit	57.2
10.	Dolomite, medium-gray, fine-crystalline, weathers medium gray	23.8
9.	Dolomite, cherty, medium-gray, fine-crystalline, weathers medium gray	80.8
8.	Dolomite, sandy, medium-gray, weathers yellowish brown, thin-bedded with crinkly sandy partings	71.5
7.	Dolomite, silty, medium-gray, fine-crystalline, thin silt beds weather brownish gray	29.8
6.	Dolomite, light-gray, medium-crystalline, weathers light gray	19.0
5.	Dolomite, sandy, medium-gray, weathers dark brown	40.5
4.	Quartzite, light-gray, weathers light yellowish brown, cliff-forming unit	7.1
3.	Dolomite, sandy, medium-gray, weathers grayish brown	7.1
2.	Quartzite, brownish-yellow, weathers dark yellowish brown, cliff-forming unit	9.5

St. Charles formation (continued)	Thickness (feet)
1. Dolomite, sandy, medium-gray, fine-crystalline, weathers brownish gray with resistant moderate brown layers standing out in relief. Beds are 1 inch to 1 foot thick	28.6
Total	972.3

Nounan formation

Section No. 7, East Fork of Little Bear River, Utah. Section of Swan Peak formation on the northeast-facing slope at the head of Porcupine Canyon. Section begins near the bottom of the canyon and extends up the slope to the base of the dark Fish Haven cliffs.

Fish Haven dolomite

Swan Peak formation	Thickness (feet)
3. Shale, greenish-brown, beds 1/8 inch to 1/2 inch thick	3.0
2. Sandstone, quartzitic, light-brown, weathers grayish brown, beds 1/2 inch to 1 inch thick	4.7
1. Sandstone, quartzitic, light-brown, weathers moderate brown and pale red purple, beds 2 inches to 8 inches thick	14.1
Total	21.8

Garden City formation

Section No. 8, East Fork of Little Bear River, Utah. Section of Fish Haven dolomite on northeast-facing slope at the head of Porcupine Canyon. Section begins about 75 feet from the canyon bottom and extends southwestward up the slope.

Laketown dolomite

Fish Haven dolomite	Thickness (feet)
1. Dolomite, medium-gray, fine-crystalline, weathers medium gray, thick-bedded, cliff-forming unit	124.0
Total	124.0

Water Canyon formation

Section No. 9, East Fork of Little Bear River, Utah. Section of Laketown dolomite measured up the northeast-facing slope at the head of Porcupine Canyon. Section begins about one-third of the way up the slope and extends southwestward approximately two-thirds the way up the slope.

Water Canyon formation

Laketown dolomite	Thickness (feet)
18. Dolomite, medium-gray, medium-crystalline, weathers light gray	38.1
17. Dolomite, cherty, medium-gray, medium-crystalline, weathers medium gray	38.1
16. Dolomite, very light-gray, fine- to medium-crystalline, weathers very light gray to white	23.8
15. Chert, white to light-gray, forms resistant ledge	4.8
14. Dolomite, very light-gray, fine-crystalline, weathers nearly white, thick-bedded, cliff-forming unit	162.0
13. Dolomite, light-brownish-gray, fine-crystalline, weathers medium gray	38.2
12. Dolomite, medium-gray, fine-crystalline, weathers light gray, beds average about 6 inches thick, fossiliferous	81.2

	Laketown dolomite (continued)	Thickness (feet)
11.	Dolomite, light-gray, medium-crystalline, weathers light gray, thick-bedded	52.3
10.	Dolomite, dark-gray with white specks, medium- to coarse-crystalline, weathers dark gray, thick-bedded	23.8
9.	Dolomite, light-gray, medium- to coarse-crystalline, weathers light gray, upper 5 feet cherty	71.5
8.	Dolomite, oolitic, dark-gray, fine-crystalline, weathers medium gray	6.3
7.	Dolomite, very light-gray, medium-crystalline, weathers light gray with some white weathering patches, thick-bedded	61.8
6.	Dolomite, light-gray, medium-crystalline, weathers light gray with some white weathering patches, thick-bedded	307.7
5.	Dolomite, cherty, medium-gray, fine-crystalline, weathers light gray, thick-bedded	151.5
4.	Dolomite, medium-gray, fine- to medium-crystalline, weathers medium gray with fine light colored specks which are more resistant	46.5
3.	Dolomite, light-gray, fine-crystalline, weathers light gray, thick-bedded	105.0
2.	Dolomite, cherty, light-gray, fine-crystalline, weathers light gray, thick-bedded	12.6
1.	Dolomite, medium-gray, fine-crystalline, weathers medium gray, thick-bedded	16.9
	Total	1,242.1

Fish Haven dolomite

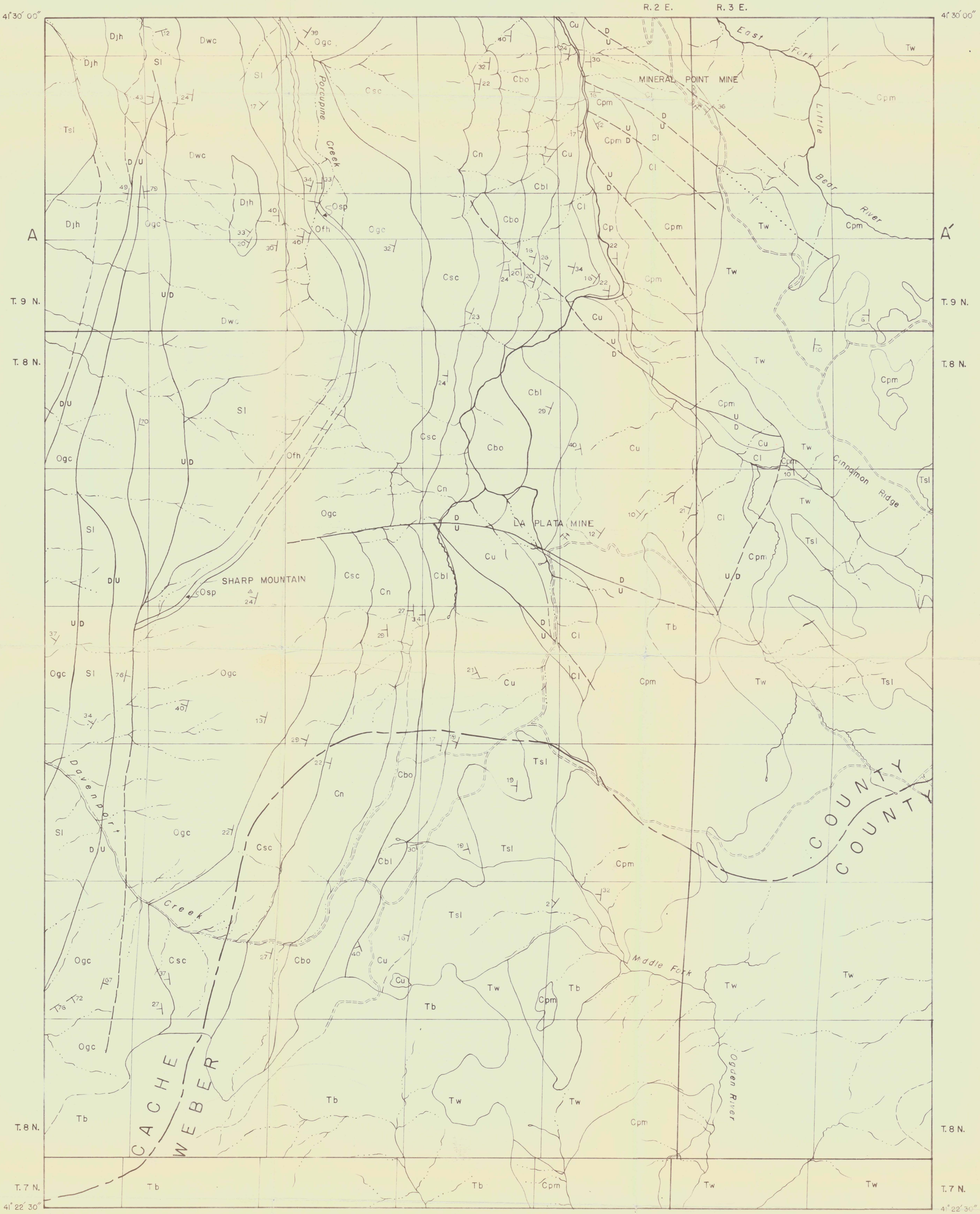
Section No. 10, East Fork of Little Bear River, Utah. Section of the Water Canyon formation on the northeast-facing slope at the head of Porcupine Canyon, section begins about half way up the slope and extends southwestward to just below the crest of the ridge.

Hyrum dolomite member of Jefferson formation

	Water Canyon formation	Thickness (feet)
9.	Dolomite, medium-gray, fine-crystalline, weathers medium gray, thick-bedded	97.6
8.	Dolomite, medium- to light-gray, fine-crystalline, weathers very light gray, beds 1 foot to 1½ feet thick	24.3
7.	Dolomite, dark-gray, fine-crystalline, weathers dark gray, beds 6 inches to 1 foot thick	93.0
6.	Limestone, light-gray, aphanitic, weathers very light gray, interbedded with medium gray, brown-weathering dolomite	21.8
5.	Dolomite, sandy, reddish-brown, thin-bedded	38.8
4.	Limestone and dolomite. Limestone, medium- to light-gray, beds 1 foot to 2 feet thick with thin beds of pale purple limestone. Dolomite, dark-gray, thin-bedded	92.2
3.	Sandstone, reddish-brown, fine-grained	2.4
2.	Dolomite, light-gray, medium-crystalline, weathers white, thick-bedded	107.0
1.	Breccia, angular fragments of medium-gray, fine-crystalline dolomite in a calcareous matrix	4.9
	Total	462.0

Laketown dolomite

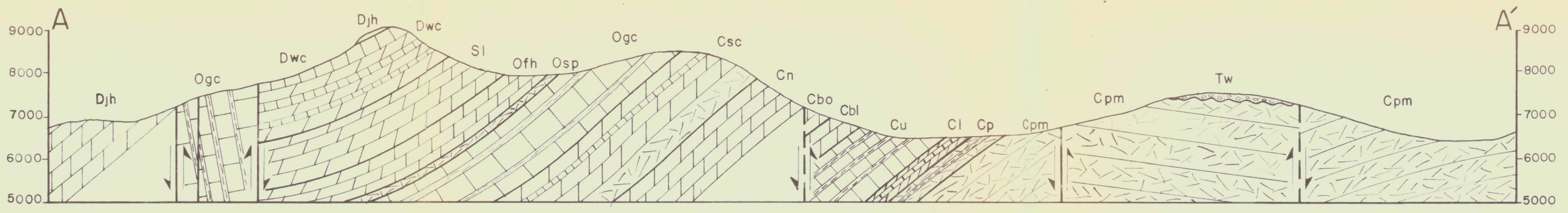
PLATE I



EXPLANATION

Era	Period	Symbol	Unit
CENOZOIC	Tertiary	Tb	Tertiary boulders
			UNCONFORMITY
		Tsl	Salt Lake group
			UNCONFORMITY
		Tw	Wasatch formation
			UNCONFORMITY
PALEOZOIC	Devonian	Djh	Hyrum dolomite member of Jefferson formation
		Dwc	Water Canyon formation
	Silurian	Sl	Laketown dolomite
	Ordovician	Oth	Fish Haven dolomite
		Osp	Swan Peak formation
			UNCONFORMITY
		Ogc	Garden City formation
	Cambrian	Csc	St. Charles formation
		Cn	Nounan formation
		Cbo	Bloomington formation
		Cbl	Blacksmith formation
		Cu	Ute formation
		Cl	Langston formation
		Cp	Pioche formation
		Cpm	Prospect Mountain quartzite

COUNTY LINE
FAULT
CONTACT
UNCONFORMITY
ROAD
STREAM
STRIKE AND DIP



Base taken from semi-controlled mosaic constructed in
1954 by the Cartographic Unit, U.S. Soil Conservation Service

by PRESTON L. HAFEN 1960

GEOLOGY OF THE SHARP MOUNTAIN AREA, BEAR RIVER RANGE, UTAH

SCALE 1:24000