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**GEOLOGY OF THE MONTE CRISTO
AREA, BEAR RIVER RANGE, UTAH**

ROBERT B. SMITH

UTAH STATE UNIVERSITY

1965

GEOLOGY OF THE MONTE CRISTO AREA,
BEAR RIVER RANGE, UTAH

by

Robert B. Smith

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

of

MASTER OF SCIENCE

in

Geology

Approved:

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1965

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Robert B. Smith

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INTRODUCTION

General Statement

The Monte Cristo area is a 7 1/2-minute quadrangle located in the southeastern part of the Bear River Range, northern Utah. It is within the Middle Rocky Mountain province and is 10 miles east of the Basin and Range province. Previous to this investigation little was known about the detailed geology of the area except for a reconnaissance study and general geologic map of the Cache County part included in the Geologic Atlas of Utah, Cache County, published by Williams (1958).

The purposes of this investigation were as follows: (1) to determine the formations present in the area and their relation to regional stratigraphy, (2) to determine the structure of the area and its relation to regional structure, and (3) to produce a geologic map of the area (Plate 1).

Location of Area

The area of investigation (Figure 1) is located in the southern part of the Bear River Range, Utah, and includes the southern part of Monte Cristo Ridge and Ant Valley. The northern limit is the southern boundary of the southeast quarter of the 30-minute Logan quadrangle, the 41°30'00" N. parallel. The southern limit is the 41°22'30" N. parallel which roughly follows the

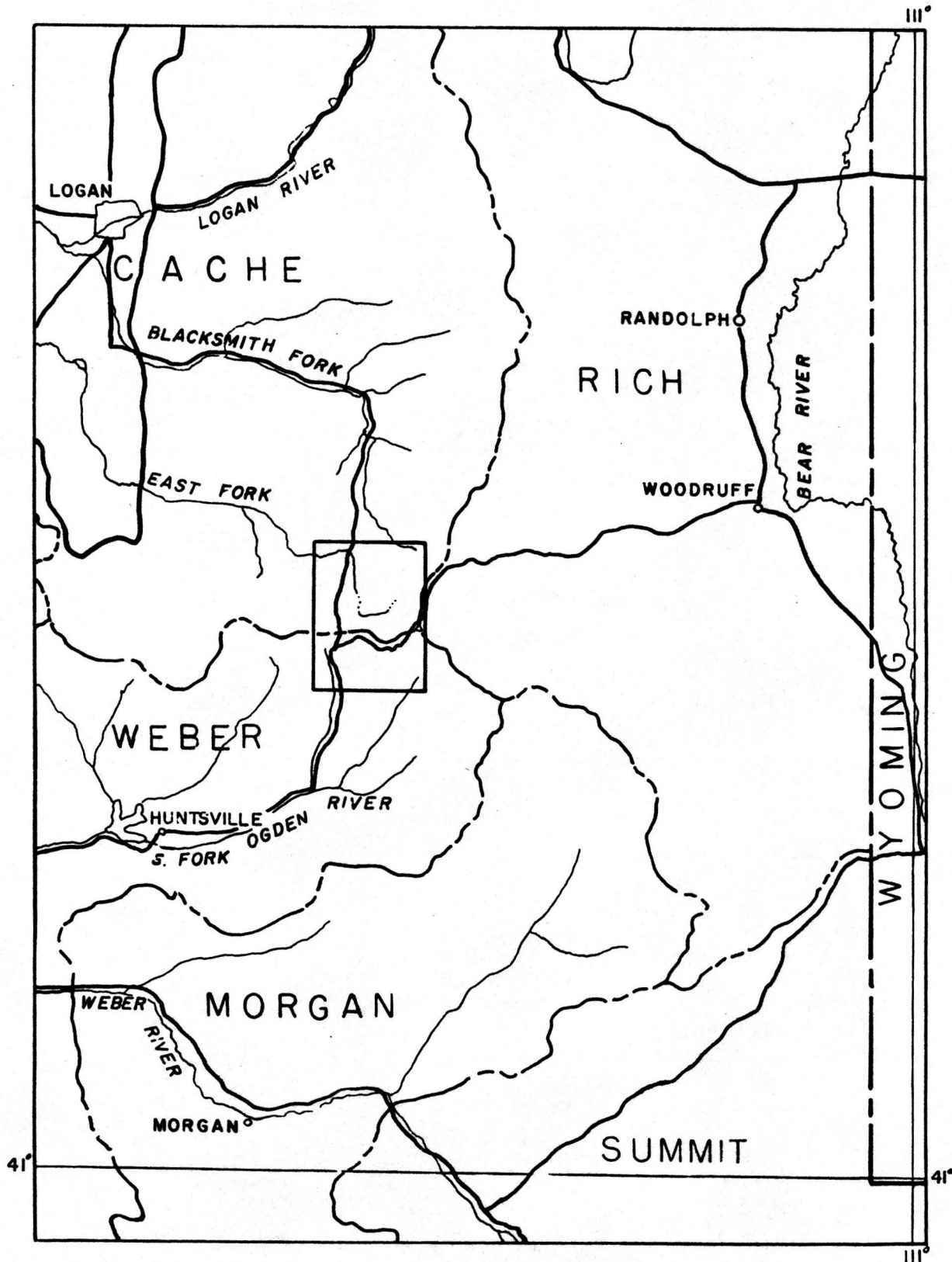


Figure 1. Index map of northern Utah showing location of Monte Cristo area (center rectangle).

northern extent of the tributaries of the South Fork of the Ogden River. The western boundary is the $111^{\circ}37'30''$ W. meridian and the eastern boundary is the $111^{\circ}30'00''$ W. meridian. The 30-minute Randolph quadrangle is northeast of the area and east of the Logan quadrangle. The mapped area lies within parts of three northern Utah counties: (1) Cache, (2) Rich, and (3) Weber. It is 6.5 miles wide and 8.6 miles long.

Good access to the area is provided by paved and graveled roads from Logan, Ogden, and Woodruff, Utah; however, access away from main roads is on unimproved roads and jeep trails. Most of the area lies within private properties but approximately a fourth of the area on the east side is within the Cache National Forest.

Previous Investigations

Initial geological reconnaissance of the northern Utah region began in 1869 when Arnold Hague (Hague and Emmons, 1877, p. 393-419) of the Fortieth Parallel Survey made brief observations of the geology of the Bear River Range east of Cache Valley. Of particular interest are his observations made during a traverse from the southern Bear River Range into the South Fork of the Ogden River. He described Ant Valley as a "Cambrian Plateau" with a broad anticlinal fold of Cambrian quartzite striking N. 10° - 15° E. with dips of 16° W. and 30° E. This anticline is exposed in the northwest part of the mapped area in the vicinity of the East Fork. Hague also described Tertiary sandstone, in the Ant Valley area, now identified as the Wasatch formation.

In 1869 F. V. Hayden (1873, p. 191-192) made a brief geological reconnaissance of northern Utah and western Wyoming where he named and described the Wasatch formation from exposures immediately west of Ft. Bridger, Wyoming. On the same survey he named and described the Salt Lake group from exposures in Weber River Valley, Utah. In the following year, 1870, Hayden (1872) worked west through Echo and Weber Canyons and noted the horizontal nature of the Wasatch. A. C. Peale (1873, p. 105), in 1872, worked through Ogden and Weber Canyons where he described Carboniferous and Silurian limestone and quartzite. He also described the southern end of Cache Valley as a syncline and the northern end as a series of folds.

In 1872 Bradley (1873, p. 192-200), working north from Ogden, Utah, to Malad City, Idaho, briefly described the west side of the Wasatch Range. Hayden (1877), working southeast from Ft. Hall, Idaho, to the head of the Bear River, described the Bear River Range as being in part composed of Silurian and Carboniferous limestone and quartzite. He described Wasatch conglomerate and sandstone lying unconformably upon upturned edges of older rocks in the Bear River Valley and made a brief description of a syncline between Bear River Valley and Cache Valley.

Gilbert (1890, p. 99) described Tertiary rocks in the southern end of Cache Valley which he stated were deposited from a lake more ancient than Lake Bonneville. A detailed description of the Wasatch formation was given by Veatch (1907) in his paper on the geology of southwestern Wyoming. Walcott (1908a, p. 5-7) first described in detail the Cambrian section in Blacksmith

Fork Canyon, and later, Richardson (1913, p. 408-410) published a complete Paleozoic section of northern Utah and named five new formations: the Garden City limestone, Swan Peak quartzite, Fish Haven dolomite, Laketown dolomite, and Brazer formation. More information concerning the regional geology of the intermountain region was added by Mansfield (1927) in his paper on southeastern Idaho.

Regional structure of the Basin and Range area was discussed by Gilbert (1928) and later Eardley (1939, 1944) described regional structure and physiography of the Wasatch and Great Basin region. The 30-minute Logan quadrangle immediately north of the mapped area was studied by Williams (1948) who published a geological map of the area. Geology of the South Fork of the Ogden River immediately to the south of the Monte Cristo area was studied and mapped by Laraway (1958). Recent work in southeastern Idaho by Armstrong and Cressman (1963) gives important details of thrust faulting and uplift associated with the ancestral Bear River Range.

Field Work

Field study of the Monte Cristo area was accomplished during the summer of 1960 in collaboration with Preston L. Hafen (1961) who completed a study and geologic map of the adjacent Sharp Mountain area to the west. The writer and Mr. Hafen worked together in both areas to insure complete coverage and a better understanding of relationships that exist between them.

The geology was plotted on aerial photographs (scale 1:20,000) obtained

from the U. S. Soil Conservation Service. Detail was then transferred to a semicontrolled mosaic of the U. S. Soil Conservation Service (7 1/2-minute quadrangle semicontrolled mosaic, no. Utah 34, NE 1/4, scale 1:24,000) and then traced on an overlay with a base constructed from a planimetric map of the U. S. Forest Service and the 7 1/2-minute James Peak quadrangle topographic map.

The thicknesses of stratigraphic sections were measured with a Brunton compass and Jacobs staff. Rock colors were determined by comparison with the "Rock Color Chart" prepared by a committee of the National Research Council in 1948 (1st printing).

STRATIGRAPHIC GEOLOGY

General Statement

Paleozoic rocks of the Monte Cristo area range in age from Cambrian to Mississippian; units of the Cenozoic represent both Tertiary and Quaternary. No Precambrian or Mesozoic rocks were found in the mapped area. It is generally considered that a great thickness of Paleozoic and Mesozoic rocks once covered the northern Utah area but was subsequently eroded during uplift of the ancestral Bear River Range (Armstrong and Cressman, 1963, p. 12). Paleozoic rocks are exposed on the west side of Monte Cristo Ridge and in Wheat Grass Canyon which is located in the extreme southeast corner of the area. Tertiary rocks are widely exposed throughout the area but are best described and measured east of Ant Valley on the west flank of Monte Cristo Ridge.

An estimated total thickness of 6,700 feet of sedimentary rocks is exposed in the Monte Cristo area of which 6,200 feet are Paleozoic and 500 feet are Cenozoic. Pennsylvanian and upper Mississippian rocks, identified by Laraway (1958, p. 42-46), and Permian rocks, identified by Williams and Hanson (1942, p. 8), are located south of the area and west of Wheat Grass Canyon. These units are not exposed in the Monte Cristo area but are presumably located within the southern part of the area beneath a cover of the Tertiary Wasatch formation.

Cambrian System

General statement

The formations of the Cambrian period in the Monte Cristo area are poorly exposed. Only one complete section of the Upper Cambrian St. Charles formation is present. A section of the upper part of the Upper Cambrian Nounan formation is exposed in the northern part of the area and an incomplete section of Lower Cambrian Prospect Mountain quartzite is exposed in the north-northeast-trending Strawberry Valley anticline. Other Cambrian formations, Pioche, Langston, Ute, Blackmith, and Bloomington, normally found in the Cambrian section of northern Utah, are not seen but are presumably present beneath a cover of Tertiary rocks in Ant Valley.

If these Cambrian formations are present beneath the surface of Ant Valley, they probably dip east as they are located on the east flank of the Strawberry Valley anticline.

The Cambrian section of northern Utah has long been known due to early extensive stratigraphic studies. The earliest investigations were carried out by Walcott in 1906 who published the original Blacksmith Fork section (Walcott, 1908b, p. 1-12). Richardson (1913, p. 406-408) did extensive work on the Cambrian section in the Randolph quadrangle where he utilized Walcott's Cambrian stratigraphic nomenclature and added the Worm Creek quartzite as the basal member of the St. Charles formation. Cambrian stratigraphy of part of the Cordilleran trough, which included an investigation of the Cambrian stratigraphy of northern Utah, was published by Deiss (1938).

Maxey (1941, p. 44-50) investigated the Cambrian stratigraphy of the northern Utah region and measured a section in Blacksmith Fork Canyon; however, in his most recent work (Maxey, 1958, p. 647-687) emphasis was placed on lower and middle Cambrian stratigraphy of northern Utah and southeastern Idaho. An important aspect of his latest study was the identification of the Early Cambrian Prospect Mountain quartzite in the northern Utah region.

Prospect Mountain quartzite

The name Prospect Mountain quartzite was defined by Hague (1883, p. 254) who designated the west side of Prospect Peak near Eureka, Nevada, as the type locality. Here it is composed of brownish white quartzitic sandstone, weathering dark brown, and intercalated with thin layers of arenaceous shale.

The area included in this paper contains rocks which were previously assigned to the Brigham quartzite; however, in agreement with Maxey (1958, p. 667), who seems to have done the latest detailed stratigraphic study of the Cambrian section of northern Utah, the name Prospect Mountain quartzite will be used in place of Brigham quartzite. The identification of the Prospect Mountain is based on the occurrence of alternating beds of shale and quartzite in the upper units of the Brigham quartzite. These were identified as the Pioche shale by Hafen (1961, p. 13) in the Sharp Mountain area. The underlying quartzite is identified as Prospect Mountain and thus follows Maxey's nomenclature.

The Prospect Mountain can be seen in the northwest corner of the Monte Cristo area in the north-northeast-trending Strawberry Valley anticline. Here it dips gently to the east and is covered by subhorizontal Tertiary rocks. A west-flowing tributary of the Little Bear River, the East Fork, cuts through the anticline in this corner of the area and provides excellent exposures of the Prospect Mountain.

In the mapped area the Prospect Mountain quartzite is composed of light- to medium-brown medium-bedded quartzite which weathers in blocks. It is a clean well-sorted quartzite and contains some cross-bedding and quartz-pebble conglomerate. No stratigraphic thickness was determined as the bottom of the formation is not exposed and the top has been removed by erosion.

No diagnostic fossils were found in the Prospect Mountain of the Monte Cristo area. Numerous worm borings are present but are not indicative of age. According to Maxey (1958, p. 667), the oldest known fossils of the Bear River Range which are diagnostic of age are found in the Albertella-Kochaspis subzone of the overlying Middle Cambrian Langston formation. This subzone is of earliest Middle Cambrian age and thus indicates that the Prospect Mountain in northern Utah is Early Cambrian or older. The oldest known diagnostic fossils of the central Utah area are found in the Early Cambrian Ollenelus zone of the Pioche formation which overlies the Prospect Mountain in the central and southern Wasatch Range. Here the Prospect Mountain is certainly Early Cambrian or older. In the Sharp Mountain area, immediately to the west of the mapped area, the Pioche formation is identified as a distinct unit above the

Prospect Mountain (Hafen, 1961, p. 11-15); whereas, in other northern Utah areas it is included in the upper part of the Prospect Mountain. Thus from the general age and relationship of the Pioche, the underlying Prospect Mountain quartzite can probably be dated as Early Cambrian or older in the southern Bear River Range.

The Prospect Mountain was likely deposited as a blanket-type deposit in a shallow northeastward-transgressing sea (Maxey, 1958, p. 685) where the sediments were sorted by extensive wave action which produced quartz-pebble conglomerate and cross-bedding and also destroyed most of the evidence of plant and animal life.

The Pioche formation, Langston formation, Ute formation, Blacksmith dolomite, and Bloomington formation are not present at the surface in the mapped area; however, they are probably present beneath a cover of Tertiary Wasatch in the Ant Valley area. They are presumably dipping east in a normal succession between the gently east-dipping Prospect Mountain on the east flank of the anticline and the moderately east-dipping Nounan formation on the east side of Ant Valley. The assumption that the above mentioned formations are present is based upon good exposures of these formations in the Sharp Mountain area (Hafen, 1961, p. 7-25) and in the Logan quadrangle (Williams, 1948, p. 1, 129-1, 135) to the north. In the Sharp Mountain area they are located on the west flank of the north-northeast-trending Strawberry Valley anticline and are dipping to the west.

Nounan formation

The Nounan formation was named by Walcott (1908a, p. 6) from exposures on the east side of Soda Peak west of the town of Nounan, Bear Lake County, Idaho. Here it is composed of light-gray to dark-gray arenaceous limestone (Walcott, 1908a, p. 6). Walcott measured 1,041 feet of Nounan in Blacksmith Fork Canyon, Utah, and 814 feet near Liberty, Bear Lake County, Idaho.

In the mapped area, the Nounan is found in two places: (1) on the south side of Sheep Creek near the north boundary, and (2) in a poor exposure 3 miles south of Sheep Creek on the eastern side of Ant Valley. It is found dipping 25° E. near the north boundary and is composed of medium- to dark-gray medium-bedded finely crystalline dolomite. Within the mapped area it does not contain limestone as does some upper Nounan of other areas. It is conformably overlain by the St. Charles formation and the contact is easily recognized with the upper dark-gray dolomite lying beneath the light-brown-weathering light-gray dolomite of the Worm Creek quartzite member of the St. Charles formation. A complete section of the Nounan is not seen within the mapped area as the lower part is covered by the Wasatch formation. It was for this reason that a stratigraphic section was not measured.

The writer found no fossils in the Nounan of the mapped area; however, there have been good fossil identifications from the Nounan in Blacksmith Fork of northern Utah and in the Malad Range of southern Idaho. Howell et al. (1944, p. 993-1,004) placed the Cedaria, Crepicephalus, and Aphelaspis zones

in the Nounan. Earlier, Maxey (1941) found some Dunderbergia fossils in the upper limestone of the Nounan in other areas to the northwest, and recent work by Palmer (1960, p. 53-57) indicated that there may be a Dunderbergia zone in the upper part of the Nounan. Hanson (1953, p. 19-21) indicated that Crepicephalus and Aphelaspis zones are present in the upper Nounan of northern Utah and he suggested an age of early Late Cambrian. The Nounan present was probably deposited under fairly stable conditions within the Cordilleran geosyncline with the shoreline far to the east of the area.

St. Charles formation

The St. Charles formation was named and defined by Walcott (1908a, p. 6) from exposures in the Bear River Range, west of St. Charles, Bear Lake County, Idaho; but his original published section, 1,225 feet thick, was measured in Blacksmith Fork Canyon, Utah. He described it as "bluish-gray to gray arenaceous limestone with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstones." Deiss (1938, p. 1, 108-1, 109) remeasured the Blacksmith Fork section and found only 450 feet. Richardson (1913, p. 408) modified the original St. Charles definition by differentiating the lower part as the Worm Creek quartzite member in the Randolph quadrangle.

The St. Charles formation is found in the Sheep Creek area and south along the eastern flank of Ant Valley. A fair exposure is located in the northeast corner of the area on the east side of a major normal fault with only the upper part of the formation present at the surface. An outcrop in Wheat Grass

Canyon lies just east of the east boundary of the area. A complete section is present in the Sheep Creek area where the stratigraphic section was measured. Here it is composed of two distinct units: (1) the lower Worm Creek quartzite member, and (2) an upper dolomite unit. The Worm Creek member has a total thickness of 106 feet and contains: (1) a basal sandy gray dolomite, (2) a white quartzite, (3) a sandy gray dolomite, (4) a white quartzite, (5) a sandy gray dolomite, and (6) a thin olive-green shale. This thickness is considerably less than the 400 feet of Worm Creek of the Randolph quadrangle (Richardson, 1941, p. 13) and is 32 feet more than the section measured by Haynie (1957, p. 10) in Blacksmith Fork Canyon 8 miles to the northwest.

The upper dolomite unit of the St. Charles is composed of a basal limestone conglomerate, 7 feet thick, and a dolomite with some oolitic dolomite and chert stringers, 610 feet thick. The total thickness of the St. Charles is 724 feet. Haynie (1957, p. 25) reported a distinctive middle limestone member in the Blacksmith Fork Canyon section but this member is not present in the mapped area. Its absence in the Monte Cristo area was probably due to erosion as evidenced by the thin limestone intraformational conglomerate unit, although no other major break in the stratigraphic sequence was found.

Fossil evidence indicative of the age of the St. Charles was not found in the Monte Cristo area; however, U-shaped markings which resemble those produced by Polychaeta (Haynie, 1957, p. 28), a class of marine worms distinctive of the littoral zone, were found in the Worm Creek. Howell et al. (1944, p. 993-1, 004) indicated that the Elvinia zone is located within the Worm

Creek, but no fossil evidence was found in the area to indicate this feature. In other localities of northern Utah the Conaspis zone with a lower Eoorthis subzone and an upper Taenicephalus subzone has been identified within the St. Charles (Howell et al., 1944, p. 993-1,004). Prammani (1957, p. 22-24) collected from the middle limestone units in the central Malad Range, southern Idaho, and dated the St. Charles as upper Croxian in accordance with Maxey's (1941, p. 61-62) age. On the basis of fossil evidence, the age of the underlying Nounan formation, and the age of the overlying Ordovician Garden City limestone, the St. Charles is middle through late Late Cambrian in age.

The clastic blanket-type deposit of the Worm Creek member was probably derived from a granitic land mass which Haynie (1957, p. 32-33) postulated to have existed in southern Idaho. Haynie also indicated that the Worm Creek member should become more carbonate in composition southward from its source area. In the Monte Cristo area this change is recognized as 89 percent of the Worm Creek is predominantly carbonate. This relationship substantiates Haynie's theory of a northern origin of the Worm Creek.

The upper member of the St. Charles does not contain the prominent "crinkly" limestone unit of other localities, but it does contain a basal limestone intraformational conglomerate which may be indicative of a littoral environment.

Ordovician System

General statement

The Ordovician system in the Monte Cristo area is represented by the Garden City limestone and the Fish Haven dolomite with a total stratigraphic thickness of 1,327 feet. Richardson (1913, p. 408) named and described these Ordovician formations from exposures in the Randolph quadrangle. The distinctive Swan Peak quartzite (Richardson, 1913, p. 409) which normally overlies the Garden City limestone in northern Utah and southern Idaho is not present in the Monte Cristo area.

A complete stratigraphic section of the Garden City was measured by Ross (1949, p. 472-491) north of the northeast corner of the Monte Cristo area along Davenport Creek and Buck Springs road. Here he described three distinctive units: (1) a lower muddy limestone and intraformational conglomerate unit, (2) a cherty limestone unit, and (3) an upper sandy dolomite unit. The writer used Ross's measured section as the standard Garden City section of the Monte Cristo area as it was measured three-quarters of a mile away from the area.

Garden City limestone

The Garden City limestone was named from exposures in Garden City Canyon, Rich County, Utah, by Richardson (1913, p. 408). He described the formation as consisting of a thick- to thin-bedded gray limestone with a prominent limestone conglomerate. Deiss (1938, p. 1, 123) remeasured a section

previously measured by Walcott in Blacksmith Fork Canyon and described an additional 777 feet of basal limestone in the Garden City which had been previously assigned to the St. Charles formation by Walcott. The Garden City ranges in thickness from 1,900 feet near Garden City, Utah, 1,800 feet in the southern Malad Range, Idaho, 1,400 feet in the Logan, Utah, area to approximately 1,200 feet along Monte Cristo Ridge in the mapped area.

Williams (1948, p. 1, 135) measured and described 1,400 feet of Garden City in Green Canyon, near Logan, Utah. An extensive and detailed stratigraphic and paleontological study of the Garden City was completed by Ross (1951, p. 7-9) in which he recognized two members: (1) a lower member of intraformational limestone conglomerate, muddy limestone, and crystalline limestone, and (2) an upper member of cherty limestone and dolomitic limestone.

The Garden City is well exposed throughout the northeast quarter of the Monte Cristo area from Sheep Creek south along the west side of Monte Cristo Ridge to the northern part of Skunk Hollow. Isolated outcrops are located along the eastern side of Ant Valley. A complete section is located in Wheat Grass Canyon, but only part lies within the boundaries of the mapped area. As described by Ross (1948, p. 46-48), along Davenport Creek and Buck Springs road, the Garden City consists of three members with a total thickness of 1,204 feet: (1) a lower member of intraformational limestone conglomerate, muddy limestone, aphanitic limestone, and crystalline limestone, (2) a middle member of intraformational limestone conglomerate, crystalline limestone, and cherty

limestone, and (3) an upper unit of sandy dolomite, black chert, and shale.

The Garden City is highly fossiliferous in northern Utah and southeast Idaho and yields numerous species of trilobites, graptolites, brachiopods, and sponges. The writer collected a sparse assemblage in the northeast corner of the area along Sheep Creek consisting of cephalopods, bryozoans, and gastropods.

Ross (1949, p. 478) subdivided the Garden City into 12 faunal zones, lettered A through L, using distinctive trilobite faunas as a basis of subdivision. Hintze (1952, p. 5), in subdividing the Pogonip group of western Utah, recognized 15 faunal zones of which he correlated zones B through L with those of Ross. Four graptolite zones of the Pogonip were recognized by Rigby (1958, p. 907-917) which he correlated with Ross's and Hintze's G, H, J, and K zones.

On the basis of fossil evidence, the age of the Garden City is Early Ordovician to earliest Middle Ordovician and the apparent conformable relationship between the Cambrian St. Charles and the Garden City indicates continuous deposition from Cambrian to Ordovician.

The lithology of the Garden City suggests deposition in a near sea-level environment as evidenced by ripple marks, mud cracks, intraformational conglomerate, and cross-bedding (Ross, 1951, p. 33-35).

An important aspect of the Monte Cristo area is the absence of the Swan Peak quartzite, a distinctive early Middle Ordovician quartzite and shale formation of northern Utah and southern Idaho. In the Monte Cristo area, the Fish

Haven dolomite lies conformably on the Garden City limestone and the distinctive Swan Peak quartzite normally found between the two formations is missing. Its absence is thought to be due to nondeposition. Ross (1951, p. 33-36) suggested that probable thinning of the Swan Peak in a southwesterly direction from northern Utah would result in wedge-outs and areas of nondeposition. The possibility of deposition and erosion in the Monte Cristo area still remains but the upper Garden City appears to have maintained its thickness and lithology in the area. The writer could not find any evidence of a major erosion surface between the Garden City and Fish Haven to indicate the presence of a major unconformity; however, the presence of a disconformity separating the Garden City and Fish Haven is probable based on the hiatus between the formations.

Fish Haven dolomite

The Fish Haven dolomite was first identified and named by Richardson (1913, p. 409-410) from exposures on Fish Haven Creek, Bear Lake County, Idaho. At this southeastern Idaho locality, he described the Fish Haven as a finely textured medium-bedded dark-gray to blue-black dolomite. A total of 500 feet was measured by Richardson at the type locality in contrast to 140 feet reported by Williams (1948, p. 1, 137) in Green Canyon near Logan, Utah.

The writer measured 123 feet of Fish Haven dolomite in the Sheep Creek area where it is composed of dark-gray medium-bedded finely crystalline dolomite. Throughout the northeast quarter of the area and in Wheat Grass Canyon, the Fish Haven forms distinctive dark-gray cliffs above the Garden City.

The Fish Haven yields a sparse fossil assemblage consisting primarily of brachiopods and corals. The writer collected and identified Calapoecia and Halysites from the Fish Haven of the Sheep Creek area.

The age of the Fish Haven is middle Late Ordovician and is believed to correlate with the Big Horn dolomite of Wyoming (Ross, 1953, p. 25). The widespread occurrence of the Fish Haven dolomite and its correlatives in Idaho, Wyoming, Montana, and Nevada suggests primary origin in a transgressing sea on a stable shelf.

Silurian System

General statement

A single formation of Silurian age, the Laketown dolomite, is identified in the Monte Cristo area. It was named by Richardson (1913, p. 410) from exposures in Laketown Canyon near Laketown, Rich County, Utah, where he described it as a massive light-gray to gray dolomite, containing lenses of calcareous sandstone, with a total thickness of 1,000 feet. Three members are recognized by Williams (1948, p. 1, 137-1, 138) in Green Canyon near Logan, Utah, as follows: (1) a lower light-gray dolomite, 224 feet, (2) a middle dark-gray dolomite, 619 feet, and (3) an upper light-gray dolomite, 667 feet. Here the total thickness is 1,510 feet. Throughout northern Utah, the Laketown ranges in thickness from 1,000 to 2,000 feet.

Laketown dolomite

The Laketown dolomite overlies the Fish Haven dolomite in the mapped area with no apparent angular discordance, but according to Williams (1948, p. 1, 137) a major hiatus based on faunal evidence separates the formations. Throughout the northeast quarter of the area and in Wheat Grass Canyon, the massively bedded Laketown dolomite is exposed in prominent cliffs and is composed of light- to dark-gray dolomite with some chert stringers in the upper units. No stratigraphic section was measured in the area but the writer estimates that approximately 1,000 feet is exposed along the west side of Monte Cristo ridge.

The writer collected corals and brachiopods in the Sheep Creek area as follows: Halysites, Catenipora, and two species of Pentamerella. Duncan (1956, p. 215-220) indicated that no Lower or Upper Silurian fossils are found in the middle Rocky Mountain region and that rocks of Early and Middle Silurian age may not be present in this area. If this situation exists, there are major disconformities at the base and top of the Laketown. According to Stokes (1953, p. 27) fossil evidence indicates a Middle Silurian age for the Laketown which was probably deposited in a narrow marine embayment of southern Idaho and northern Utah.

Devonian System

General statement

Devonian rocks, exposed in the Monte Cristo area, are identified as the

Water Canyon and Jefferson formations with a total thickness of 761 feet. These formations are found in the east-central part of the area along the west side of Monte Cristo Ridge and in Wheat Grass Canyon. A dual classification of the Jefferson formation in the Monte Cristo area follows the subdivision in the Logan area by Williams (1948, p. 1, 138-1, 141) into the Hyrum dolomite member and Beirdneau sandstone member.

The Devonian rocks lie disconformably on the Silurian Laketown dolomite and unconformably beneath the Mississippian Lodgepole limestone. There also appears to be a marked disconformity between the Water Canyon and the Jefferson.

Water Canyon formation

The Water Canyon formation was named by Williams (1948, p. 1, 138-1, 139) from exposures in Water Canyon near Logan, Utah. He described two members: (1) a lower member of thin-bedded silty and sandy buff-weathering dolomite, and (2) an upper member of sandy dolomite, dolomitic sandstone, and sandstone intraformational conglomerate.

The Water Canyon of the Monte Cristo area, described and measured in Wheat Grass Canyon, consists of light- to medium-gray medium- to thin-bedded dolomite and which is oolitic in the lower part. It contains some chert stringers and at this locality measures 296 feet.

The Water Canyon of northern Utah has long been noted for fish fossils and was first studied paleontologically by Branson and Mehl (1931, p. 509-531) who dated it as possibly Early Devonian. Additional work by Bryant (1932,

p. 230) compared the fauna of the Water Canyon with that of the Bear Tooth Butte formation of northwest Wyoming and indicated an age of Early Devonian for both formations. Denison's Devonian fossil fish investigations (1952, p. 265-287; 1953, p. 291-355) also indicated an age of Early Devonian for the Water Canyon.

The Lower Devonian Bear Tooth Butte formation of Wyoming, with a similar lithology and fossil fish assemblage as that of the Water Canyon, has been described by Dorf (1934, p. 736-737) as containing terrestrial plants including a Psilophyton flora. Recent work by Sandberg (1961, p. 1, 301-1, 309) indicated that the Bear Tooth Butte formation was deposited in streams in areas which were subsequently flooded by marine to brackish waters. Brooks (1959, p. 54-59) suggested that the Water Canyon was deposited within a transitional marine embayment of northern Utah. Osmond (1962, p. 2, 033-2, 056), who correlated the Water Canyon with the Sevy dolomite of western Utah and Nevada on age and lithology, indicated that the Sevy and its equivalents were deposited under shallow marine conditions. He furthermore stated that the Sevy was deposited as a primary evaporitic dolomite with some redeposited dolomite debris over essentially flat dolomite mud flats.

A marked disconformity exists at the top of the Water Canyon in northern Utah. In Wellsville Mountain, 20 miles west of the mapped area, the upper member of the Water Canyon is completely missing, and in Blacksmith Fork Canyon the upper member lies directly on the Silurian Laketown dolomite. In the Monte Cristo area, the basal bed of the Jefferson formation directly above

the Water Canyon is a limestone-dolomite intraformational breccia. This may be considered evidence for the disconformity. The disconformity is marked by fossil evidence which indicates an age of Early Devonian for the Water Canyon and Late Devonian for the Jefferson with the intervening hiatus indicative of nondeposition or erosion.

Jefferson formation

The Jefferson formation was named by Peale (1893, p. 27) from exposures of brown to black crystalline limestone, 640 feet thick, near Threeforks, Montana. Williams (1948, p. 1, 139) subdivided the Jefferson formation of northern Utah into two members as follows: (1) the lower Hyrum dolomite, and (2) the upper Beirdneau sandstone. The Hyrum dolomite was named from exposures of black dolomite and limestone, 1,200 feet thick, in Blacksmith Fork Canyon, Cache County, Utah. The Beirdneau sandstone was named from exposures of buff-weathering sandstones, 820 feet thick, in the Beirdneau Peak area of Logan Canyon, Cache County, Utah. In the Blacksmith Fork area, the Beirdneau sandstone measures 2,120 feet but in the Randolph area it is only 1,200 feet thick.

The Jefferson of the Monte Cristo area is well exposed along the west side of Monte Cristo Ridge in Wheat Grass Canyon (Plate 2) and near the southern end of Skunk Hollow. The Hyrum dolomite, described and measured in Wheat Grass Canyon, is composed of light- to dark-gray finely crystalline dolomite which weathers brownish black in the upper part. Bedding is medium to thin, and the basal unit is a limestone-dolomite breccia. The total thickness

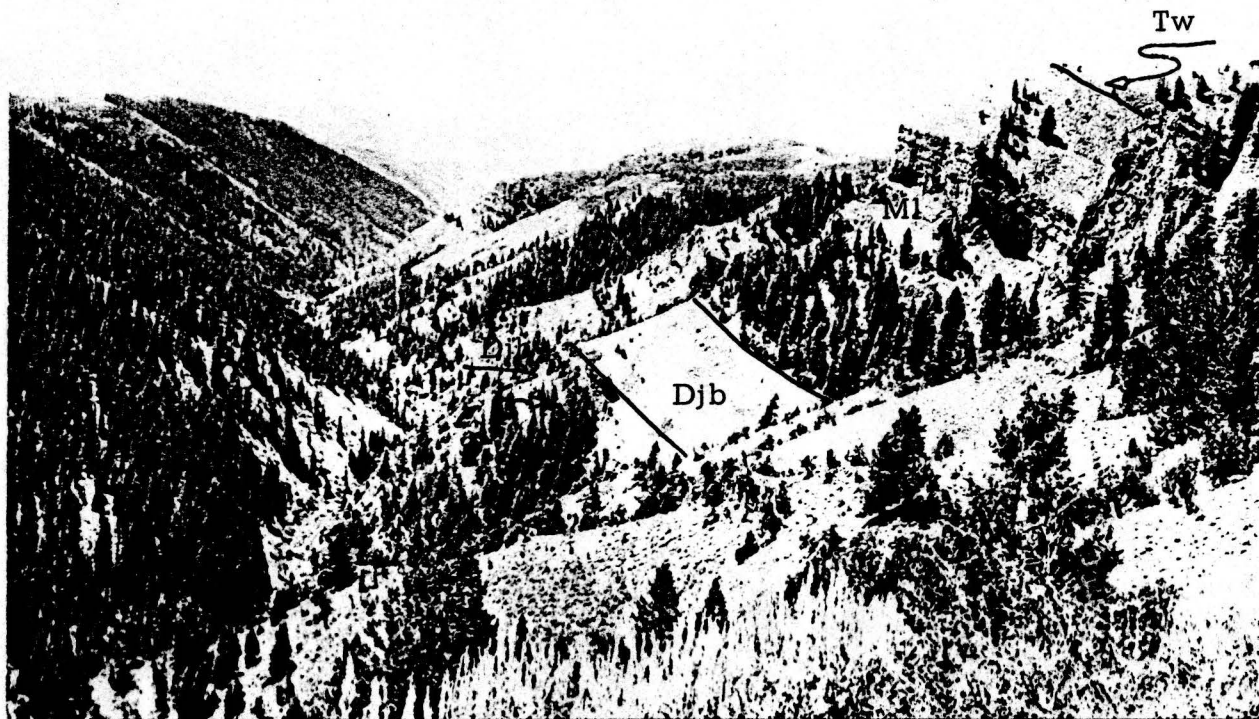


Plate 2. Wheat Grass Canyon, view looking south along east-facing slope (Djh--Devonian, Hyrum dolomite member, Jefferson formation; Djb--Devonian, Beirdneau sandstone member, Jefferson formation; MI--Mississippian, Lodgepole limestone; Tw--Tertiary, Wasatch formation).

of the Hyrum dolomite measured here is 221 feet and it appears as a dark band along the bottom of Wheat Grass Canyon (Plate 2).

The Beirdneau sandstone of the Monte Cristo area, measured and described in Wheat Grass Canyon, is composed of two units: (1) a basal silty, light yellow-gray, reddish gray-weathering aphanitic limestone unit in beds 2 inches to 3 feet thick with some thin silt partings, and (2) an upper unit of yellow to reddish gray fine-grained well-rounded calcareous sandstone in thin beds. The upper unit contains some interbedded silty limestone. A thickness of 245 feet of Beirdneau was measured in Wheat Grass Canyon making a total thickness of the Jefferson in the Monte Cristo area 465 feet. An interesting feature of the Beirdneau of the Wheat Grass Canyon is the occurrence of lenses of red to blue-green shale which appear to be thin lenticular wedge-shaped deposits a half to 5 feet thick and up to 10 feet long.

No fossils were found in the Jefferson of the mapped area but paleontological evidence from adjacent northern Utah areas indicates that the Spirifer argentarius zone of the Devils Gate formation of Nevada correlates with the Hyrum dolomite (Cooper, 1942, p. 1, 768-1, 769; Merriam, 1940, p. 67-68). Based upon paleontological evidence, Williams (1948, p. 1, 139-1, 141) indicated an age of Late Devonian for the Jefferson.

The Jefferson formation was widely deposited throughout the Cordilleran geosyncline and its equivalents are found throughout much of the western United States. Brooks and Andrichuk (1953, p. 28-29) indicated that the Jefferson is closely related to the Threeforks formation of northern Utah.

The Hyrum dolomite member is thought to have been deposited as a geosynclinal facies near the western edge of the Cordilleran geosyncline. Williams (1958, p. 29) suggested that the Beirdneau sandstone member was deposited in a littoral environment as evidenced by the presence of casts of halite crystals found in the sandstones of the upper Beirdneau of the Logan quadrangle. In the Monte Cristo area evidence of crystal casts could not be found; however, the presence of halite crystal casts in the lower unit of the Threeforks formation (Laraway, 1958, p. 34) of the Ogden River area substantiates a littoral deposition for part of the Beirdneau member of the Jefferson.

A late Devonian period of instability in northern Utah, suggested by Rigby (1959, p. 60), may possibly be reflected in changes between the Hyrum dolomite and the Beirdneau sandstone. If instability occurred between deposition of the Hyrum and Beirdneau in the Monte Cristo area, Late Devonian uplift could have been responsible for partial littoral deposition of the Beirdneau. Profound variations in thickness of the Jefferson throughout northern Utah (Cooley, 1928, p. 12; Williams, 1948, p. 1, 139-1, 140; Ezell, 1953, p. 19-20) are indicative of the pronounced unconformity between the Jefferson and the overlying Mississippian Lodgepole limestone.

The conspicuous Devonian "contact ledge" (Holland, 1952, p. 1, 697-1, 734), found overlying the Beirdneau sandstone in the Logan quadrangle, was not recognized by the writer in the Monte Cristo area. A poorly exposed limestone unit overlies the Beirdneau in Wheat Grass Canyon but was almost totally covered by Mississippian Lodgepole talus. Due to the dense talus cover the

writer was unable to identify or describe the unit.

Mississippian System

General statement

Mississippian rocks in the Monte Cristo area are the **youngest** exposed rocks of the Paleozoic section. These are identified as the **Lower Mississippian Lodgepole limestone**, defined in western Montana by Collier and Cathcart (1922, p. 173).

Mississippian and Pennsylvanian rocks identified by Laraway (1958, p. 42-46) and Permian rocks identified by Williams and Hanson (1942, p. 8) are located just south of the Monte Cristo area and west of **Wheat Grass Canyon**. These units are on the southern tip of Monte Cristo Ridge on the **east flank** of the Beaver Creek syncline. They are presumably located at **depth** within the Monte Cristo area beneath a Wasatch cover and have a low **northwest** dip just south of the area.

The Leatham formation (Holland, 1952, p. 1,719), the **lowest Mississippian** formation identified in Leatham Hollow, **Blacksmith Fork Canyon**, Utah, was not recognized in the mapped area. The writer did not recognize any distinct stratigraphic unit between the underlying Jefferson and the overlying Lodgepole. In Wheat Grass Canyon, however, a thin limestone unit is partly exposed beneath Lodgepole cliffs but the writer was unable to identify or describe the unit due to its inaccessibility and almost complete covering by Lodgepole talus. This limestone unit is approximately 15 feet **thick** and

appears to have the same lithology as the Lodgepole and was mapped as such.

Lodgepole limestone

The Lodgepole limestone was originally named and described by Collier and Cathcart (1922, p. 173) from exposures in Lodgepole Canyon near Threeforks, Montana. Here it was described as the lower formation of the Madison group (Peale, 1893, p. 33-39) and is composed of 800 feet of thin-bedded limestone and shale.

Williams (1948, p. 1, 141-1, 142) used the term Madison limestone for lower Mississippian rocks exposed in the Logan quadrangle but in later publications substituted the term Lodgepole limestone. Williams (1943, p. 609) correlated the "Madison" of the northern Utah area with that of western Montana, basing the correlation on similar lithologies. Holland (1952, p. 1, 731) correlated the "Madison limestone" of northern Utah with the Lodgepole limestone of Montana, basing his correlation on similar lithologies and fossil assemblages.

In the Monte Cristo area the Lodgepole limestone was recognized on the south end of Monte Cristo Ridge and in Wheat Grass Canyon. It was found lying unconformably on the Beirdneau sandstone with the top not exposed due to a cover of the Tertiary Wasatch formation.

In the mapped area, the Lodgepole is composed of thin- to medium-bedded gray fossiliferous limestone containing chert nodules. In Wheat Grass Canyon the Lodgepole is exposed in prominent cliffs up to 70 feet high. Along Monte Cristo Ridge it is less conspicuous. Just southwest of Monte Cristo

Peak, a main road passes through an outcrop of Lodgepole where a variety of rugose corals may be collected from the talus.

The writer collected the following assemblage from the Lodgepole along the west side of Monte Cristo Peak:

Crinoid stems

Fenestrillina sp.

Large cephalopods

Rugose corals

Cleiothyridina cf. C. obmaxima (McChesney)

Cleiothyridina hirsuta (Hall)

Spirifer centronatus

Dictyoclostus cf. D. fernglenensis Weller

Sandro and Dutro (1960, p. 117-126) zoned the Madison group of Montana into four provisional faunal zones, lettered A, B, C, and D, and characterized by distinct coral assemblages. They recognized that assemblages of the Lodgepole of northern Utah were similar with their A, B, and lower C zones. Zeller (1957, p. 679-704) zoned the Lodgepole of Blacksmith Fork Canyon on the basis of endothyroid foraminifera and found the Lodgepole characterized by a lower Granuliferella and an upper Plectogyra tumula zone. Based upon faunal and stratigraphic evidence, the age of the Lodgepole is placed at Early Mississippian (Kinderhook and lowest Osage). The Lodgepole of the Monte Cristo area is thought to have been deposited in an eastward-transgressing sea (Sadlick, 1957, p. 57) which was close to a stable shelf

region to the southeast (Crittenden, 1959, p. 67-74).

Tertiary System

General statement

Tertiary rocks are widely exposed in the Monte Cristo area and are identified as the Wasatch formation and the Salt Lake group with an estimated total thickness of 500 feet. In addition, a limited area of large quartzite boulders is located at the northern end of Ant Valley. The writer has identified these boulders as being Tertiary in age.

The Wasatch of the Monte Cristo area is composed primarily of prominent red conglomerate and sandstone which apparently covers part of the Cambrian sequence in Ant Valley and overlaps other Paleozoic rocks eastward onto Monte Cristo Ridge. The Salt Lake group unconformably overlies the Wasatch and is represented by isolated outcrops of white oolitic limestone in the Ant Valley area.

Wasatch formation

The Wasatch group is a name originally applied by Hayden (1873, p. 191) to rocks exposed immediately west of Ft. Bridger, Wyoming, which consist of "variegated sands and clays" approximately 1,500 feet thick. Later, Veatch (1907, p. 87-96) subdivided the Wasatch group into three formations: (1) the Almy, (2) the Fowkes, and (3) the Knight. The U. S. Geological Survey now considers the Wasatch as a formation. This terminology will be used in place of group throughout this paper.

The Wasatch exposed in the Ant Valley area is either horizontal or dips gently northward. In the intermediate area between Ant Valley and Monte Cristo Ridge the beds dip up to 12° W. while on top of Monte Cristo Ridge they dip gently east to southeast.

The Wasatch of the Monte Cristo area is composed of pebble- to boulder-conglomerate and red calcareous sandstone. The conglomerate contains pebbles, cobbles, and boulders of quartzite and Paleozoic limestone with a matrix of very coarse-grained red calcareous sandstone. The sandstone is yellow to light red, fine to coarse grained, and subrounded to subangular. It contains approximately 50 percent quartz grains and a fine matrix of limestone, dolomite, and iron oxides.

The total thickness of the Wasatch measured on the eastern side of Ant Valley, 1 1/2 miles south of Sheep Creek, is 317 feet. Here it is dipping 11° W. and lies unconformably on the Garden City limestone. The Cowley Canyon member (Williams, 1948, p. 1, 143), the basal unit of the Wasatch in the Logan quadrangle composed of stromatolitic limestone, was not identified in the mapped area.

The Wasatch of the Monte Cristo area is believed to be in part equivalent to the Knight on the basis of lithology but no fossil evidence was found in the mapped area. Eardley (1955, p. 37-41) and Laraway (1958, p. 46-47) also indicated that the Wasatch of the southern Bear River Range and upper Ogden River area is probably equivalent to the Knight. According to Gazin (1959, p. 131-138) the Knight is Early Eocene evidenced by the presence of

vertebrate fossils.

Oriel and Tracy (1959, p. 126-130) indicated that the Almy and the Knight are invalid formation definitions unless they are clearly defined for each locality in which they are used. Williams and Madsen (1959, p. 122-125) have shown that rocks in Weber River Valley, originally defined as the Almy formation, are actually Upper Cretaceous and have renamed them the Echo Canyon conglomerate. Oriel and Tracy showed that the Fowkes has, in some cases, been found to overlie Almy, Knight, and Green River formations. This indicates erroneous use of the name Fowkes and necessitates the definition of the formations of the Wasatch for each locality used.

The Wasatch is believed to have been deposited under continental conditions as evidenced by fresh-water lacustrine deposits of sandstone and conglomerate as well as by continental vertebrate fossils. The massive red conglomerate units were probably deposited under deltaic conditions as only rivers would have sufficient energy to move the large boulders and cobbles. The prominent red color was derived from oxidation of iron. Continuously changing depositional conditions evidenced by the discontinuous nature of the Wasatch were probably due to differential crustal movements.

Salt Lake group

The Salt Lake group was originally defined by Hayden (1873, p. 192) from exposures of 1,200 feet of sandstone, sand, and light-colored marl in Weber and Salt Lake Valleys, Utah. Tentative separation of the Salt Lake group in the northern Utah area was worked out by J. Stewart Williams and

published by Smith (1953, p. 73-77). Williams subdivided the Salt Lake group of southern Cache Valley into three formations: (1) the Collinston conglomerate, (2) the West Spring formation, and (3) the Cache Valley formation; however, recent work by Williams (1962) redefined the Salt Lake group into three lithologic units without formational or unit names.

The Salt Lake is seen in the Monte Cristo area in isolated exposures lying unconformably on the Wasatch on the north and west sides of Ant Valley. Here approximately 175 feet of white tuffaceous calcareous limestone and pale yellow-brown oolitic limestone is exposed.

The flora and fauna of the Salt Lake group are not well described but gastropods, ostracods, mollusks, and some plant remains have been collected by several workers. The writer collected one Planorbis sp. in northern Ant Valley which was the only fossil found in the Salt Lake group of the Monte Cristo area.

Yen (1946, p. 485) indicated an age of Middle to Late Pliocene for the Salt Lake group of Cache Valley while Brown (1949, p. 224-229) concluded that the age of the Salt Lake group of the southern Cache Valley area is Late Pliocene based upon fossil plant identification. Adamson, Hardy, and Williams (1955, p. 1-10) indicated the age of the Salt Lake group as being possibly Late Miocene and Pliocene. The Norwood tuff of the lower Salt Lake group in the Ogden Valley area, northern Utah, was dated as Oligocene by Eardley (1944, p. 845-846); however, work by Gazin (1959, p. 137) indicated that a vertebrate fossil, found within Norwood tuff of Eardley, is Late Eocene or Early

Oligocene. This relationship suggests that the Norwood tuff may be as old as Late Eocene.

The general age of the Salt Lake group in the northern Utah region may be as old as Late Eocene and Oligocene for the lower units in the Ogden Valley area to Late Miocene and Pliocene in the Cache Valley area. The lower units of the Salt Lake group in the Cache Valley area have not yet been definitely dated and the possibility remains that they are equivalent to the Norwood tuff and are possibly as old as Late Eocene to Oligocene while the upper units are progressively younger, Late Miocene and Pliocene.

By Late Tertiary time, perhaps Miocene (Williams, 1958, p. 78), the general topographic features of Cache Valley and surrounding mountains had developed and it is likely that the Salt Lake group was deposited in a lacustrine environment in local fresh-water lakes. These lacustrine deposits are represented by the oolitic and tuffaceous limestones in the mapped area. Based upon similar lithologies the writer tentatively correlated the Salt Lake of the Monte Cristo area with the tuff unit of the Salt Lake group described by Williams (1962, p. 133-135) in Cache Valley.

Tertiary boulders

A large area of boulders of Prospect Mountain quartzite is located at the northern end of Ant Valley. Here it forms a striking boulder field with a gentle northwest-dipping slope. The boulders are composed of light-brown to orange-brown quartzite and range from a few inches to 2 feet in diameter.

Correlation of the boulder field in Ant Valley to Late Cenozoic erosion surfaces of northern Utah and southern Idaho is not justified due to the limited size of the field and the lack of criteria for such a correlation. It appears likely that the boulders are an erosional product of the Wasatch formation with autochthonous deposition and let down from a local source area. There are limited indications in the Ant Valley area of the quartzite boulders overlapping the Salt Lake group and it appears reasonable to date the deposition of the boulders as post-Salt Lake.

Quaternary System

Recent stream deposits were mapped in the northern Ant Valley area where the East Fork of the Little Bear River passes through the Tertiary boulder area. These deposits are limited in extent and represent a period of deposition when the river, now only a small intermittent stream, was much larger.

Within the Monte Cristo area, the writer did not find any evidence of Pleistocene glacial activity; however, limited glaciation did occur in the Bear River Range as evidenced by cirques and moraines at high elevations (Young, 1939).

STRUCTURAL GEOLOGY

General Features

The major structural features of the Monte Cristo area are: (1) the southern end of the Strawberry Valley anticline (Richardson, 1941, p. 38), located in the northwest corner of the area, and (2) major north-trending normal faults along the west side of Monte Cristo Ridge, located in the eastern half of the area (Plate 1).

Major north-trending normal faults bound Ant Valley on the east and a graben associated with the normal faulting is located between the first normal fault west of Monte Cristo Peak and a northeast-trending normal fault along the west side of Skunk Hollow. A minor normal fault of small displacement and limited extent, apparently associated with the major faults, is located on the eastern side of the southern tip of Monte Cristo Ridge.

The Strawberry Valley anticline is the only major fold in the mapped area and is well exposed in the deep canyon of the East Fork near the northwest edge of the area. Ant Valley is apparently underlain by some Cambrian formations which are located on the east flank of the anticline but are unconformably overlain by the subhorizontal Wasatch formation and Salt Lake group. The Beaver Creek syncline, identified and mapped by Laraway (1958, p. 52) in the upper Ogden River area southwest of Monte Cristo Peak, likely extends beneath

a Wasatch cover in the southeast corner of the area.

The writer did not find any evidence of thrust faulting which is so well defined and mapped to the west as the Willard thrust in the Ogden area and to the northeast as the Bannock thrust zone in the Bear Lake area.

Regional Structure

The Monte Cristo area is located within the southern Bear River Range in a region of Laramide north-trending folds and large-scale overthrusts as well as north-trending normal faults of Basin and Range origin. Williams (1948, p. 1, 148) stated that Paleozoic rocks of the Logan quadrangle were folded into a broad anticline and syncline during the Laramide orogeny. In addition Williams identified some major north-trending normal faults in the Logan quadrangle which dislocate Wasatch and Salt Lake rocks and are associated with Basin and Range faulting. These major faults are thought to be responsible for the major part of the topographic relief of the Bear River Range. A major north-trending normal fault was identified in the northeast corner of the area by the writer and mapped as an extension of the Hayes Ridge fault of the Logan quadrangle (Williams, 1948, p. 1, 154).

Eardley (1944, p. 847-866) described north-trending and west-trending folds in the Wasatch Mountains south of the Monte Cristo area. In addition, he described three major thrusts in the Ogden, Utah, area: the Taylor, the Ogden, and the Willard. The principal exposures of the Willard thrust are located approximately 15 miles west-southwest of the Monte Cristo area, but

some remnants can be seen in the Ogden and Weber River Valleys 10 miles southwest of the area.

The Bannock thrust zone, identified as a series of westward dipping imbricate thrusts in southeastern Idaho and north-central Utah (Armstrong and Cressman, 1963, p. 1), was originally mapped in the Randolph quadrangle by Richardson (1941, p. 38-39) as the Bannock overthrust. Recent work by Armstrong and Cressman (1963, p. 18) indicated that the thrust fault originally identified by Richardson just west of Garden City, Utah, is actually a high-angle fault with the downthrown side, Garden City limestone, on the east against Brigham quartzite on the west. The southernmost mapped thrust fault of the Bannock thrust zone, the Paris thrust fault, is found to the north of Garden City, Utah, near the Utah-Idaho border. The extent of the zone south of the Utah-Idaho border is unknown due to a cover of Tertiary and Quaternary rocks; however, a thrust fault can be seen in the Woodruff Creek area 13 miles east of the mapped area (Stokes, 1961) where Cambrian Brigham quartzite is thrust eastward over Permian Park City and Triassic Thaynes formations.

Wellsville Mountain, approximately 23 miles northwest of the mapped area, is a northern extension of the Wasatch Range and is regarded as a homocline bounded by normal faults (Gelnett, 1958, p. 58). Ezell (1953, p. 25-26) recognized normal faulting of Basin and Range age in the Rendezvous Peak area 13 miles west of the Monte Cristo area.

Structure of Western Part of Area

The principal topographic feature of the western part of the Monte Cristo area is Ant Valley, a north-trending upland valley 7 miles long and 3 miles wide. It is situated at approximately 7,000 feet above sea level and is drained principally to the west by the East Fork of the Little Bear River.

The geologic structure of Ant Valley is simple compared to surrounding areas. In the northwest part of the valley, the Strawberry Valley anticline is exposed with a general north-northeast trend. This fold is the only major fold displayed in the Monte Cristo area and can be seen in the canyon of the East Fork. The anticline is wholly within the Prospect Mountain quartzite and neither the top nor the bottom of the Prospect Mountain is exposed.

Rocks of the Wasatch formation unconformably overlap the anticline and are exposed eastward across Ant Valley. Salt Lake group rocks are found lying unconformably in isolated outcrops over the Wasatch. No evidence of faulting within the Salt Lake group rocks could be found; however, to the east along the eastern side of Ant Valley, Wasatch rocks are displaced along normal faults and are found dipping 11° W. This normal faulting and subsequent warping is dated as Basin and Range and is associated with faulting along Monte Cristo Ridge.

The upland valley, of which Ant Valley is a part, is the southern segment of a central intermontane valley within the Bear River Range and is bounded on the east and west sides by two high ridges. The highest ridge, the Front Ridge of the Logan quadrangle, is bounded on its western side by the

East Cache faults (Williams, 1948, p. 1, 125-1, 126), and the eastern, Monte Cristo Ridge, is bounded on its western side by similar normal faults one of which, the Hayes Ridge fault, extends south from the Logan quadrangle into the Monte Cristo area.

The central intermontane valley, known as Ant Valley, was originally termed the "Cambrian Plateau" by Hague and Emmons (1877, p. 412-417). To the north within the Bear River Range, this valley is occupied by Logan River and is bounded on its eastern side by Temple Ridge.

The area to the south of Ant Valley is a series of intermediate hills and valleys developed in horizontal to gently north-dipping Wasatch. No indication of faulting could be found within these Tertiary deposits; however, the gentle north warping indicates minor movement associated with Basin and Range faulting. To the south, just beyond the boundary of the area, the writer identified Mississippian and Pennsylvanian rocks which according to Laraway (1958, p. 52) are part of the north-trending Beaver Creek syncline of Laramide age which extends into the Monte Cristo area but is not seen due to the Tertiary overlap.

Structure of Eastern Part of Area

General statement

The area between Ant Valley and Monte Cristo Ridge, including the southern segment of Monte Cristo Ridge and the northern part of Wheat Grass Canyon, is somewhat more structurally complex than that of Ant Valley. This

area contains the major faults of the area as well as the highest point which is Monte Cristo Peak, 9,148 feet above sea level.

The writer did not find any evidence of major folding in this area but found minor intraformational folds within the Garden City limestone in secs. 19 and 30, T. 9 N., R. 4 E., along Sheep Creek. These folds are the result of bedding plane slippage along incompetent layers. The Paleozoic rocks exposed just east of Ant Valley and along the west side of Monte Cristo Ridge are apparently on the east flank of the Strawberry Valley anticline and dip up to as much as 37° E. in secs. 24 and 25, T. 9 N., R. 3 E.

North-trending faults

Two generally parallel major normal faults were mapped by the writer on the west side of Monte Cristo Ridge (Plate 3). The general trend of the faults is north; however, the easternmost fault swings to the southwest near its southern extent.

The westernmost of these faults, an extension of the Hayes Ridge fault (Williams, 1948, p. 1, 154) of the Logan quadrangle, is located 1 mile east of Ant Valley. It extends south from the Logan quadrangle through the junction of Sheep Creek and Buckskin Fork for 4 miles to its termination on a north-northeast-trending fault just south of Skunk Hollow in sec. 18, T. 8 N., R. 4 E. In the Sheep Creek area the fault places Garden City, up on the east side, against Fish Haven on the west with approximately 700 feet of displacement. To the south, the fault places Fish Haven against Fish Haven indicating a reduction in displacement to approximately 200 feet. An intermittent trace of the



Plate 3. Skunk Hollow, view looking north along west side of Monte Cristo Ridge. View shows graben between easternmost north-trending normal fault on right and a north-northeast-trending normal fault on left. (Faults and contacts are shown with solid lines; Pu--Paleozoic rocks, undifferentiated; Tw--Tertiary, Wasatch.)

fault between Sheep Creek and Skunk Hollow is inferred as poor exposures limit mapping; however, a line of springs and a topographic lineation suggests its presence.

The second and easternmost major normal fault on the west side of Monte Cristo Ridge extends south from the Logan quadrangle for 7 1/2 miles into the mapped area. It apparently terminates a half mile east of Wheat Grass Canyon just southwest of Monte Cristo Peak. This fault, located immediately west of Monte Cristo Ridge, appears to have delineated Monte Cristo Ridge as a distinct topographic feature. An exposure of the fault can be seen in the upper Sheep Creek area, secs. 29 and 32, T. 9 N., R. 4 E., where Garden City is on the east side up against Laketown and Fish Haven on the west. In sec. 32, T. 9 N., R. 4 E., St. Charles is on the east side up against Garden City on the west with approximately 700 feet of displacement. To the south along Monte Cristo Ridge, Wasatch is exposed on top whereas to the west, in Skunk Hollow, it has been displaced approximately 400 feet down against Laketown, Water Canyon, and Hyrum on the east. In sec. 17, T. 8 N., R. 4 E., a poor exposure of Hyrum is faulted against Hyrum and suggests decreasing displacement to approximately 200 feet. Near the southern end of Monte Cristo Ridge, Wasatch has been faulted against Wasatch and a further decrease in displacement is indicated until at a point in sec. 31, T. 8 N., R. 4 E., no displacement is evident. This major fault maintains a general north trend in the Monte Cristo area except where it curves west around Monte Cristo Peak.

A point of interest in the faulted area is a lineation of topography

beginning in sec. 1, T. 8 N., R. 3 E., and extending south-southwest into sec. 13, T. 8 N., R. 3 E. This lineation is suggestive of a fault within the Garden City limestone and is supported by a lineation of topographic relief and an alignment of springs. The writer found no direct evidence of faulting due to poor exposures in the area.

No evidence of faulting is known on the east side of Monte Cristo Ridge except for a minor normal fault in Wheat Grass Canyon, sec. 32, T. 8 N., R. 4 E., and sec. 5, T. 7 N., R. 4 E., which places Lodgepole limestone up on the east against Wasatch on the west. The displacement is apparently small, perhaps on the order of 150 feet.

North-northeast-trending fault

A normal fault was mapped from sec. 18, T. 8 N., R. 4 E., north-northeast into sec. 5, T. 8 N., R. 4 E. This fault places Laketown up on the west side against Wasatch on the east and is the western boundary fault of a graben which forms Skunk Hollow. The major normal fault just west of Monte Cristo Peak is the eastern boundary fault. In secs. 8 and 18, T. 8 N., R. 4 E., Laketown, Water Canyon, and Wasatch are faulted up on the west side against Wasatch on the east and a half mile south the fault apparently terminates at the intersection with the major north-trending normal fault just west of Monte Cristo Peak. The intersection is inferred as poor exposures obscure any distinct field relations; however, a topographic lineation along the north-northeast-trending fault suggests its presence.

Age of Structures

The structures of the Monte Cristo area may be dated generally as Laramide and Basin and Range. The major fold of the area, the Strawberry Valley anticline, is associated with the Laramide orogeny and was apparently developed by a northwest-southeast resultant compressive force of the general east-west Laramide compressional direction of the northern Utah region.

A more precise dating of Laramide events in northern Utah and southeastern Idaho has been given by Armstrong and Cressman (1963, p. 14) who stated that the Laramide orogenic events, which produced the ancestral Bear River Range and associated Laramide structures, began in Late Jurassic time and may have continued into Paleocene. Evidence for these events is the presence of fragments of Swan Peak quartzite and Brigham quartzite in the Evanston formation of Late Cretaceous-Paleocene age in western Wyoming. The fragments are thought to have been derived from a positive area to the west, the ancestral Bear River Range. Additional evidence from the Gannet Hills east of Georgetown, Idaho (Armstrong and Cressman, 1963, p. 9), indicates the time of initial Laramide activity to be Early Cretaceous. This later period of orogenic movements is evidenced by the presence of white quartzites, limestone fragments, and fossils, in the Ephraim conglomerate of the Gannet group, which were derived from the ancestral Bear River Range to the west.

The normal faults on the west side of Monte Cristo Ridge are associated with Basin and Range faulting and are contemporaneous in age with the normal

faulting of the Logan quadrangle. The normal faults of the Monte Cristo area are closely related to the Hayes Ridge fault (Williams, 1948, p. 1, 154) which bounds the west side of Hayes Ridge in the Logan quadrangle. The close relationship is readily indicated as the westernmost normal fault of Ant Valley is a southward continuation of the Hayes Ridge fault and the easternmost normal fault continues a short distance into the Logan quadrangle and is generally parallel with the Hayes Ridge fault.

General dating of Basin and Range orogenic events in the Monte Cristo area is highly interpretive as the only evidence for time designation is the displacement of Wasatch rocks against Paleozoic rocks along normal faults. This relationship indicates inception of Basin and Range faulting in the area to be post-Wasatch (post-Eocene). Eardley (1962, p. 497-499) showed evidence of Basin and Range fault development in central Nevada indicating its inception as early as Late Miocene and its continuation intermittently to Late Pleistocene or Recent. In the north-central Wasatch Range, the Wasatch fault was active during mid-Tertiary time as evidenced by displacement of a mid-Tertiary erosion surface which had attained most of its displacement by early Pleistocene time (Eardley, 1944, p. 874-887). Salt Lake group rocks are displaced along Basin and Range faults in Cache Valley and this indicates post-Salt Lake movement for that area.

It thus appears likely that the normal faulting associated with Basin and Range crustal movements in the Monte Cristo area began as early as Late Miocene with intermittent movement along the original fault planes until Early

Pleistocene and likely into Recent. There is no evidence of faulting within the Salt Lake group of the Monte Cristo area but the exposures are very limited in size and are not found near any of the mapped faults.

Work by Thompson (1959, p. 217-256), which dealt with the rate of crustal extension in the Basin and Range area, suggested general east-west distension of the crust up to 1 1/2 miles in west-central Nevada. Thompson postulated the distension to have taken place between the Sierra Nevada and Wasatch Ranges for the last 15 million years as suggested by deformation of Miocene-Pliocene and younger rocks. Eardley (1962, p. 506-514) followed Thompson's postulate of distension in the Basin and Range region during Cenozoic time and suggested that the development of the Basin and Range structures are a result of crustal extension. Eardley (1962, p. 512) furthermore suggested the possibility of uplift of this region during Late Cenozoic time which included subsidence of Tertiary valley deposits in valley blocks and uplift of mountain blocks along normal faults.

Differential uplift associated with tensional crustal elongation is evidenced in the Monte Cristo area by the presence of the graben located west of Monte Cristo Peak and by the presence of the north-south normal faults in the eastern part of the area. Tensional development of normal faulting is very likely contemporaneous and associated with the development of the graben.

Williams (1948, p. 1, 155-1, 160) stated that the general topographic relief of Cache Valley was delineated by Basin and Range fault development in pre-Salt Lake time, possibly Oligocene. The development of the major relief

of the Monte Cristo area is probably contemporaneous with that of the Cache Valley area, if as the writer believes, that the East Cache faults of the Logan quadrangle are related to the normal faults of the mapped area. Throughout Cenozoic time there may have been additional movement on pre-existing normal faults, but the writer could not find any evidence for this displacement.

SURFICIAL GEOLOGY

The Monte Cristo area is a 7 1/2-minute quadrangle lying within the Middle Rocky Mountain province in northern Utah. The area lies within the southern Bear River Range and contains two major types of mountain topography: (1) upland valley, and (2) ridge. Ant Valley which covers the western part of the mapped area is an upland intermontane valley 7 miles long and up to 3 miles wide with a general north trend. This valley is bounded on the east and west sides by ridges with up to 3,500 feet of relief. The ridge to the east, Monte Cristo Ridge, reaches an elevation of 9,148 feet at Monte Cristo Peak.

The average elevation of Ant Valley is approximately 7,000 feet above sea level. Only one perennial stream is located within the Ant Valley area, the East Fork of the Little Bear River, which drains westward near the north end of the valley. This stream has its beginnings farther to the east on Monte Cristo Ridge but is fed by some springs in Ant Valley. An occurrence of Tertiary boulders, 1 square mile in area, is located in the north part of Ant Valley.

The vegetation of Ant Valley is sparse compared to that of surrounding ridges. This is due in part to poor growth on the Tertiary Wasatch sandstone and boulder areas. Sagebrush, aspen, willow, and grasses are the main types of vegetal cover at these lower elevations.

Monte Cristo Ridge, named from Monte Cristo Peak, lies in the eastern half of the area. The ridge rises steadily eastward from Ant Valley to an average elevation of 8,600 feet above sea level. The western faces of this ridge expose the main Paleozoic outcrops of the area. The major north-trending normal faults, which produce the higher relief, are located between the ridge and Ant Valley.

The vegetal cover of Monte Cristo Ridge changes from that of Ant Valley as the elevation increases. Large stands of pine and fir are dispersed throughout areas of aspen and sagebrush. On Paleozoic rocks, stands of mountain mahogany and juniper are common, whereas on top of Monte Cristo Ridge large areas of grasses are well developed due to increasing amounts of moisture at these higher elevations.

Wheat Grass Canyon is located on the east side of the southern end of Monte Cristo Ridge and contains excellent exposures of Paleozoic rocks. An intermittent stream, which flows southward, drains this basin into the South Fork of the Ogden River.

A series of hills and valleys of low relief, with intermediate elevations between those of Ant Valley and Monte Cristo Ridge, parallels the limits of the southern boundary of the area. This intermediate area consists of coarse clastics of the Wasatch formation which are apparently underlain by Paleozoic rocks. The area is well drained to the south into the South Fork of the Ogden River and contains one perennial stream, Beaver Creek, which is fed by a series of springs throughout its course. Large stands of aspen and willow are

the main types of vegetal cover in this southernmost part of the area.

Skunk Hollow, located in the intermediate area between Monte Cristo Ridge and Ant Valley, is a graben at the northern end; however, to the south it swings west out from the graben as a stream valley toward Ant Valley just northwest of Monte Cristo Peak and contains the main tributary of the East Fork of the Little Bear River.

Sheep Creek, a perennial stream located in a canyon 2,000 feet deep near the northeast limits of the area, is a west-flowing tributary of Blacksmith Fork. It is fed by a large spring located in a fracture zone in the Garden City limestone and has formed large tufa terraces in the canyon bottom. These dam the stream and cause a braided stream pattern. Many intermittent springs are found in the Monte Cristo area, most of which are contact springs between Wasatch and Paleozoic rocks; however, there are some fracture springs associated with faults and intraformational folds.

No glacial features were found in the mapped area although a large part of the area is located above 6,000 feet in elevation which is thought to be the lower limit of glaciation in the Rocky Mountains. Pleistocene lake deposits are not found in the Monte Cristo area as the highest elevation of Lake Bonneville was 5,135 feet above sea level in the Cache Valley area (Williams, 1948, p. 1, 147), well below any elevation in the mapped area.

GEOLOGIC HISTORY

Precambrian Events

Precambrian rocks are not seen in the Monte Cristo area; however, quartzite and phyllite were mapped by Eardley (1944, p. 827) 6 miles to the southwest in the Huntsville, Utah, area. These rocks are believed to be equivalent to the Big Cottonwood series and record deposition in a deep late Proterozoic trough (Eardley, 1944, p. 827) which covered northern Utah. A large positive area termed the Northern Utah Highland (Eardley, 1939, p. 1, 285) existed late in Precambrian time in northern Utah and was located southwest of the Monte Cristo area in the general region southwest of Ogden, Utah.

Paleozoic Events

The Monte Cristo area is located near the eastern margin of the Cordilleran geosyncline, a large depositional trough which received up to 25,000 feet of sediments during Paleozoic and Early Triassic times. During Early Cambrian time, seas invaded the area from the southwest (Maxey, 1958, p. 647) and deposited clean sands represented by the Prospect Mountain quartzite of the mapped area. These sands, thought to have been derived from the Northern Utah Highland, were deposited in littoral conditions over Precambrian

rocks in the northern Utah region. Littoral deposition of the Prospect Mountain is evidenced by the presence of ripple marks, pebble conglomerates, and the well-sorted nature of the sand. The apparent conformable relationship between Precambrian and Cambrian rocks suggests continuous deposition through this time. Continued deposition in shallow seas followed through the Cambrian except for a brief regression in Late Cambrian time when the Worm Creek member of the St. Charles formation was deposited.

Deposition in a transgressive sea from Late Cambrian through Early Ordovician time is represented by the conformable relationship of the St. Charles formation and the Garden City limestone. In late Early Ordovician time, however, the sea was probably in a brief regressive stage during the deposition of the Swan Peak quartzite in the northern Utah area. The absence of the Swan Peak in the Monte Cristo area is thought to be due to nondeposition rather than erosion. As the Late Ordovician sea continued its transgression, the Fish Haven dolomite was deposited throughout an extensive area of Utah, Idaho, Wyoming, Montana, and Nevada (Ross, 1953, p. 25). Deposition of the Laketown dolomite in the northern Utah area is thought to have taken place during middle Silurian time as indicated by marked disconformities below and above the Laketown.

Early Devonian time was marked by the appearance of a shallow marine sea in which the Water Canyon formation was deposited. Middle Devonian time is not recorded in the Monte Cristo area and the sea was probably not present again until Late Devonian time when the Jefferson formation was deposited.

This formation was deposited in a regressing sea (Williams, 1948, p. 1, 157) during a period of increasing diastrophism as indicated by the clastic nature of the Beirdneau sandstone member and its variable thickness throughout northern Utah.

The thin nature of the Beirdneau in the Monte Cristo area is evidence of deposition near the shelf area and presumably close to the regressive shoreline. At the end of Late Devonian time, the sea had completely regressed from the area and a period of erosion and diastrophism was taking place (Williams, 1948, p. 1, 157).

In Early Mississippian time a widespread transgressive sea swept over the northern Utah region and deposited the Lodgepole limestone. The Lodgepole is the only Mississippian and the youngest Paleozoic formation seen in the Monte Cristo area. The presence of Late Mississippian and Pennsylvanian seas in the mapped area is indicated by the presence of Late Mississippian and Pennsylvanian rocks just south of the area, in the Beaver Creek drainage (Laraway, 1958, p. 42-46) and in the Logan quadrangle (Williams, 1948, p. 1, 141-1, 144).

Permian deposition in the Monte Cristo area is evidenced by exposures of the Phosphoria formation (Williams and Hanson, 1942, p. 8) just south of the area. Within the mapped area Permian rocks are not seen but are believed to exist at depth in the southern part beneath a Wasatch cover.

Mesozoic Events

Rocks of Triassic and Jurassic ages are not present in the Monte Cristo area but are well exposed to the southwest in Weber Canyon, Utah, and northeast of the area on the north and east sides of Bear Lake Valley, Utah and Idaho (Eardley, 1944, p. 837; Mansfield, 1927, p. 99). The Triassic and Jurassic rocks record extensive deposition over the northern Utah region and undoubtedly covered the Monte Cristo area prior to erosion.

Laramide Orogeny

It is postulated that beginning as early as Late Jurassic time and extending into Tertiary, the Laramide orogeny was active in the Monte Cristo area and is evidenced by the existence of the Strawberry Valley anticline. During this major diastrophic period, the Monte Cristo area underwent folding and uplift followed by subsequent erosion of Mesozoic and some Paleozoic rocks. General folding and thrust faulting occurred contemporaneously throughout northern Utah at this time and are responsible for the major Laramide folds and large-scale thrusting in the Wasatch range (Eardley, 1944, p. 847-872).

Cenozoic Events

Following the Laramide orogeny, the continental Wasatch formation was deposited over folded and truncated Paleozoic rocks in the Monte Cristo area. After deposition of the Wasatch, gentle warping took place along the east side of

Ant Valley and was probably contemporaneous with (Eardley, 1944, p. 862) post-Wasatch gentle folding in the north-central Wasatch region.

Following Wasatch deposition, a major erosional interim existed throughout northern Utah and southeastern Idaho. During the earlier stages of this erosional period, the development of the present topography of the Bear River Range possibly began and continued during late Tertiary time during which the deposition of the lacustrine Salt Lake group of Pliocene age took place. Extensive normal faulting, which occurred during Basin and Range development, presumably began in Late Miocene time and continued throughout Tertiary possibly to Late Pleistocene or Recent time. The normal faulting along the west side of Monte Cristo Ridge was presumably associated with the Basin and Range fault development of northern Utah. Deposition of the Tertiary boulders in Ant Valley likely took place after Salt Lake deposition during periods of high erosional activity.

Pleistocene glacial events were not noted in the mapped area, however, to the west in Cache Valley, Lake Bonneville existed with shoreline development up to 5,135 feet during the Bonneville stage (Williams, 1948, p. 1, 147). A period of glaciation, probably contemporaneous with Lake Bonneville, is recorded in places at higher elevations in the Bear River and Wasatch Ranges (Young, 1939). Glaciation in the Monte Cristo area may have existed at the higher elevations along Monte Cristo Ridge. Normal faulting probably continued into Pleistocene time along pre-established Basin and Range faults but

was not noted in the mapped area. Recent developments are recorded by minor stream deposition near the north edge of the area.

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APPENDIX

Measured Sections

St. Charles formation

Section No. 1, Sheep Creek, a tributary of Blacksmith Fork, Utah. Section of the St. Charles formation measured on a northwest-facing slope of a small canyon approximately a half mile west of the junction of Sheep Creek and Buckskin Fork, and a quarter mile south of Sheep Creek, sec. 24, T. 9 N., R. 3 E. Section begins near base of slope.

Garden City limestone

St. Charles formation	Thickness (feet)
16. Dolomite, medium-gray, crystalline, medium- to thick-bedded, weathers light gray brown to brown. Unit forms prominent ledge in most exposures	53.9
15. Dolomite, light-gray, medium-crystalline, medium-bedded, weathers very light gray to light brownish gray	112.8
14. Dolomite, cherty, medium-gray, crystalline. Unit contains white chert stringers and nodules	93.0
13. Dolomite, medium dark-gray, medium-crystalline, medium-bedded, weathers dark gray to brownish gray. Unit forms ledge and contains some oolitic beds 1 to 2 feet thick	142.0
12. Dolomite, medium-gray, crystalline, medium-bedded. Unit forms block-covered slopes	83.4
11. Dolomite, cherty, medium-gray, crystalline, thin-bedded at top. Unit weathers medium dark gray, contains some chert stringers	73.5
10. Covered interval	24.5
9. Dolomite, medium dark-gray, medium-crystalline, medium-bedded, weathers light gray	26.9

8.	Conglomerate, intraformational, fine-pebble. Pebbles, limestone, medium-gray, weather light brownish gray. Matrix, calcareous, gray	4.9
7.	Conglomerate, intraformational, pebble, silty. Pebbles, limestone, reddish gray, weather brownish gray, elongate 2 to 3 inches in length. Matrix, calcareous, gray	2.4
6.	Shale, pale-olive, thin laminae	2.4
5.	Dolomite, sandy, medium-gray, crystalline, beds 1 to 3 feet thick, weathers orange-brown. Unit forms block-covered slopes	24.5
4.	Quartzite, white, finely crystalline, cross-bedded, weathers very light brown. Unit forms block-covered slopes and contains 1/8-inch brown laminae	5.4
3.	Dolomite, sandy, medium light-brown, medium-crystalline, weathers orange brown. Unit contains some sandy dolomite near top	44.0
2.	Quartzite, white to very light-brown, finely crystalline, with some cross-bedding. Unit forms block-covered slopes and contains 1- to 2-inch layers of medium-gray sandy dolomite which weathers medium brown	4.4
1.	Dolomite, sandy, medium light-gray, crystalline, medium-bedded, weathers orange brown. Unit forms block-covered slopes and contains laminae 1/16 to 1/8 inch thick of brown sandy dolomite which weather in relief	25.9
	Total	723.9

Nounan formation

Fish Haven dolomite

Section No. 2, Buckskin Fork of Sheep Creek, Blacksmith Fork, Utah. Section of the Fish Haven dolomite measured on the south-facing slope of the Buckskin Fork a quarter mile east of the Buckskin Fork-Sheep Creek junction, sec. 19, T. 9 N., R. 4 E. Section begins near top of slope at base of cliffs.

Laketown dolomite

Fish Haven dolomite

	Thickness (feet)
1. Dolomite, dark-gray, finely crystalline, thick-bedded, weathers light gray. Unit forms cliffs	122.6
	—
Total	122.6

Garden City limestone

Water Canyon formation

Section No. 3, Wheat Grass Canyon, a tributary of the South Fork of the Ogden River, Utah. Section of the Water Canyon formation measured on the east-facing slope of Wheat Grass Canyon, sec. 5, T. 7 N., R. 4 E. Section extends a quarter of the way up slope.

Jefferson formation, Beirdneau sandstone member

Water Canyon formation	Thickness (feet)
13. Dolomite, light-gray, finely crystalline, 1/2- to 4-inch beds, weathers light gray	18.8
12. Dolomite, light- to medium-gray, finely crystalline, medium-bedded, weathers light to medium gray. Unit contains some beds 1/2 to 4 inches thick	46.1
11. Dolomite, medium-gray, finely crystalline, medium-bedded, weathers medium gray	8.9
10. Dolomite, light- to medium-gray, crystalline, beds 12 to 18 inches thick, weathers light to dark gray. Unit contains interbedded light- to dark-gray beds	13.9
9. Dolomite, light-gray, finely crystalline, beds 1/2 to 6 inches thick, weathers very light gray	4.5
8. Dolomite, light-gray, crystalline, medium-bedded, weathers medium gray. Unit forms prominent ledges	18.8
7. Dolomite, light-gray, finely crystalline, beds 1/2 to 6 inches thick, weathers light gray to light yellow brown	49.2
6. Dolomite, light-gray, crystalline, medium-bedded, weathers medium gray	17.9
5. Dolomite, light-gray, finely crystalline, beds 2 to 6 inches thick, weathers white	8.9
4. Dolomite, light-gray, finely crystalline, beds 12 to 18 inches thick, weathers very light gray. Unit contains chert stringers near base	58.3

3.	Dolomite, light-gray, finely crystalline, beds 6 to 12 inches thick, weathers very light gray. Unit contains some oolitic layers near top	22.4
2.	Dolomite, oolitic, light-gray, medium-crystalline, beds 2 to 4 feet thick	4.0
1.	Dolomite, light-gray, finely crystalline, thin-bedded, weathers very light gray	24.6
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	Total	296.3

Laketown dolomite

Jefferson formation, Hyrum dolomite member

Section No. 4, Wheat Grass Canyon, a tributary of the South Fork of the Ogden River, Utah. Section of the Hyrum dolomite member of the Jefferson formation measured on the east-facing slope of Wheat Grass Canyon, sec. 32, T. 8 N., R. 4 E. Section begins a third of the way up slope.

Jefferson formation, Beirdneau sandstone member

Jefferson formation, Hyrum dolomite member	Thickness (feet)
11. Dolomite, light-gray, finely crystalline, beds 1 to 4 inches thick, weathers light brownish gray	22.4
10. Dolomite, medium-gray, finely crystalline, medium-bedded	31.4
9. Dolomite, light-brown, finely crystalline, beds 1 to 6 inches thick, weathers gray brown	9.0
8. Dolomite, light-gray, finely crystalline, medium-bedded, weathers light gray	9.0
7. Dolomite, medium-gray, finely crystalline, medium-bedded, weathers brownish black. Contains beds 2 to 4 inches thick near middle of unit	49.3
6. Dolomite, medium-gray, finely crystalline, beds 1/4 to 6 inches thick, weathers light gray	13.4
5. Dolomite, medium dark-gray, medium-crystalline, thick-bedded, weathers dark gray. Unit contains some interbedded layers 2 to 4 inches thick near middle of unit	39.4
4. Limestone, light-gray, crystalline, medium-bedded. Unit contains some limestone intraformational breccia	9.1
3. Intraformational breccia, angular fragments of dolomite, dark-gray, crystalline, medium-bedded, calcareous matrix	6.8
2. Limestone, medium-gray, crystalline, medium-bedded. Unit contains minor amounts of intraformational limestone breccia	9.0

1. Intraformational breccia, angular fragments of dolomite and limestone. Dolomite, medium light-gray. Limestone, medium-gray, aphanitic. Breccia is composed of 70 percent limestone and 20 percent dolomite in angular fragments 1 to 2 inches long

22.4

Total

221.2

Water Canyon formation

Jefferson formation, Beirdneau sandstone member

Section No. 5, Wheat Grass Canyon, a tributary of the South Fork of the Ogden River, Utah. Section of the Beirdneau sandstone member of the Jefferson formation measured on the east-facing slope of Wheat Grass Canyon, sec. 32, T. 8 N., R. 4 E. Section begins half way up slope and extends from Hyrum dolomite up slope to the base of prominent ledges of Lodgepole limestone.

Lodgepole limestone

Jefferson formation, Beirdneau sandstone member	Thickness (feet)
8. Limestone, silty, reddish gray, crystalline, thin-bedded. Unit contains some thin sandstone and siltstone layers which separate limestone layers. Sandstone, light-gray. Siltstone, yellow-brown	59.1
7. Sandstone, calcareous, light-gray to reddish gray, forms thin beds 1/8 to 2 inches thick, weathers to very light reddish gray. Unit contains some very thin layers of reddish gray siltstone separating the sandstone beds in the lower part of the unit	13.9
6. Limestone, silty, light yellow-brown, crystalline, beds 1/8 to 4 inches thick, weathers light red. Unit contains some thin interbedded sandy limestone which weathers in relief	62.7
5. Sandstone, calcareous, yellow, beds 1/4 to 2 inches thick, weathers light reddish yellow, medium-grained, well rounded. Unit contains some minor sandstone-limestone breccia	8.9
4. Limestone, silty, yellow-gray, crystalline, beds 1/4 to 8 inches thick. Unit contains some silty partings	13.4
3. Limestone, silty, yellow-brown, crystalline, beds 6 to 10 inches thick, weathers light reddish brown, smooth slope	31.4
2. Limestone, silty, medium-gray, aphanitic, beds 1 to 3 feet thick, weathers reddish gray	31.8

1.	Limestone, silty, light yellow-gray, aphanitic, beds 2 to 6 inches thick, weathers reddish gray	23.7
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	Total	244.9
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Jefferson formation, Hyrum dolomite member

Wasatch formation

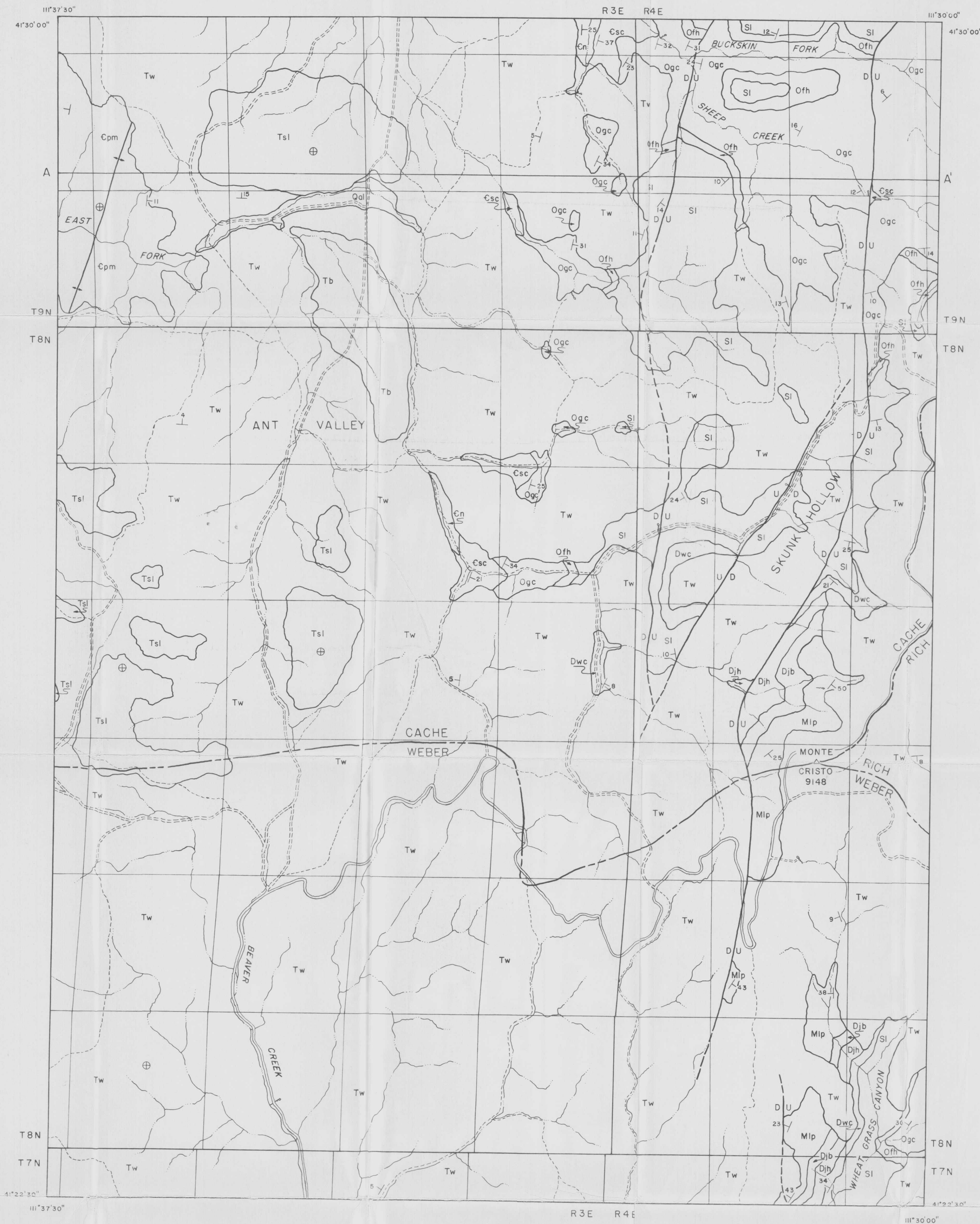
Section No. 6, Ant Valley, East Fork of the Little Bear River, Utah. Section of the Wasatch formation measured on east-facing slope of small hill a quarter mile east of Ant Valley and 1 1/4 miles south of Sheep Creek, sec. 36, T. 9 N., R. 3 E. Section of Wasatch measured from unconformable contact of Laketown dolomite up slope to top of ridge.

Wasatch formation	Thickness (feet)
11. Conglomerate, pebble through boulder, composed of limestone and quartzite with a calcareous sandstone matrix. Boulders, cobbles, and pebbles composed of limestone, medium-gray, and quartzite, yellow-red to orange-brown. Matrix, sandstone, calcareous, light-red, fine-grained, weathers medium pink. Minor amounts of a white calcareous silty material are present within the sandstone matrix	37.0
10. Sandstone, calcareous, yellow-red, fine-grained, subangular to subrounded, weathers medium red. Unit forms smooth slope	37.0
9. Sandstone, calcareous, light-red, coarse-grained, subrounded, weathers light pink. Unit forms conspicuous ledge	5.3
8. Sandstone, calcareous, yellow to light-pink, variegated, medium-grained, subangular. Unit forms smooth slope	21.1
7. Conglomerate, pinkish gray, very fine pebble, composed of 90 percent quartzite, orange-brown, and 10 percent limestone, light-gray. Matrix composed of pinkish-white calcareous siltstone	42.3
6. Conglomerate, boulders composed of 70 percent quartzite, 20 percent limestone, and 10 percent dolomite. Quartzite, orange-brown, appears to have been derived from Prospect Mountain quartzite. Limestone and dolomite, light- to dark-gray, appears to be Paleozoic detritus. Matrix, sandstone, yellow-red, fine-grained, with minor amounts of a silty calcareous fine-grained matrix	50.1

5.	Sandstone, calcareous, medium-pink, coarse-grained, subrounded, medium-bedded, weathers very light pink. Unit forms distinctive ledge	10.6
4.	Same as Unit 11	10.5
3.	Same as Unit 8	26.4
2.	Sandstone, calcareous, light-red to yellow, fine-grained, medium-bedded, weathers medium pink at surface	42.8
1.	Covered interval, soil light red	34.4
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	Total	317.5

Laketown dolomite

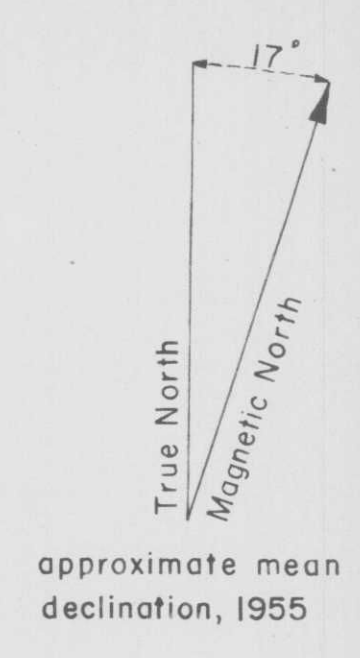
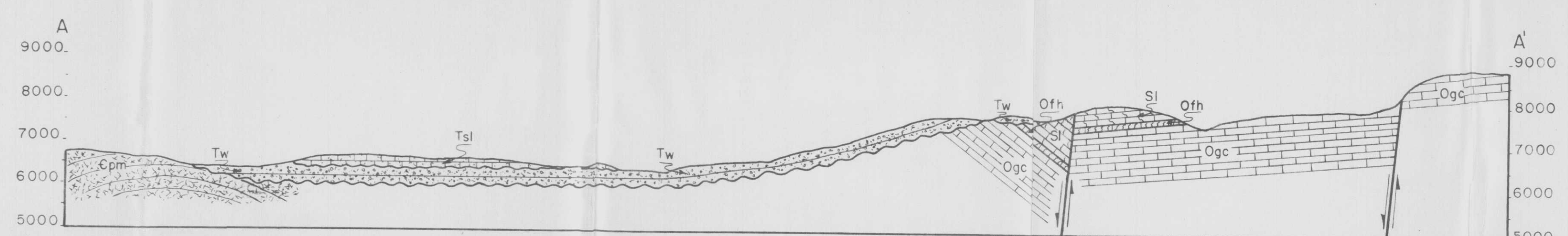
PLATE I



EXPLANATION

- Quaternary
 - Qal Alluvium
 - UNCONFORMITY
- Cenozoic
 - Tertiary
 - Tb Tertiary boulders
 - UNCONFORMITY
 - Tsl Salt Lake group
 - UNCONFORMITY
 - Tw Wasatch formation
 - UNCONFORMITY
 - Mississippian
 - Mip Lodgepole limestone
 - UNCONFORMITY
 - Devonian
 - Djb Jefferson formation, Beirneau sandstone member
 - Djh Jefferson formation, Hyrum dolomite member
 - Dwc Water Canyon formation
 - Paleozoic
 - Silurian
 - Sl Laketown dolomite
 - Ordovician
 - Ofh Fish Haven dolomite
 - Ogc Garden City limestone
 - Csc St Charles formation
 - Cambrian
 - Cn Nounan formation
 - Cpm Prospect Mountain quartzite

- Contact
- D
- U Fault
- Anticline
- Strike and dip of beds
- Horizontal beds
- Unconformity
- County Line
- Primary road
- Secondary road
- Jeep road



Base constructed from a semi-controlled mosaic, Utah 34, NE 1/4, produced in 1954 by the Cartographic Unit, U.S. Soil Conservation Service.

Geology by ROBERT B. SMITH, 1960

GEOLOGY OF THE MONTE CRISTO AREA, BEAR RIVER RANGE, UTAH

SCALE 1:24,000

