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Geology of the Southwestern Part of the Randolph Quadrangle, Utah-Wyoming

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GEOLOGY OF THE SOUTHWESTERN PART OF THE RANDOLPH QUADRANGLE, UTAH-WYOMING

by

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INTRODUCTION

General Statement

A detailed study of the southwestern part of the Randolph quadrangle was undertaken in view of the fact that Richardson (1941) mapped a large area of undifferentiated Ordovician rock. Therefore, the purposes of this investigation are: (1) to prepare a more detailed geologic map of the southwestern part of the Randolph quadrangle (Plate 1), (2) to describe the structure, stratigraphy, and geologic history of the area, and (3) to relate the geology to adjacent areas.

The elevation of the area mapped ranges from approximately 8,910 to 6,700 feet above sea level with the major part of the area above 8,000 feet. This area forms part of the eastern ridge of the Bear River Range (Williams, 1948, p. 1,125-1,126). The southern boundary of the area extends east from the southwest corner of the Randolph quadrangle for a distance of about 4 miles. The eastern boundary extends northward about 11 miles and is parallel to the mountain front. The northern boundary is less well defined and is taken as the ridge separating Curtis Creek from the next canyon to the north. The western boundary extends south approximately 10 miles to the southwest corner of the Randolph quadrangle. The southwestern part of the Randolph quadrangle (Figure 1) covers approximately 56 square miles and lies approximately 60 per cent in Cache County and 40 per cent in Rich

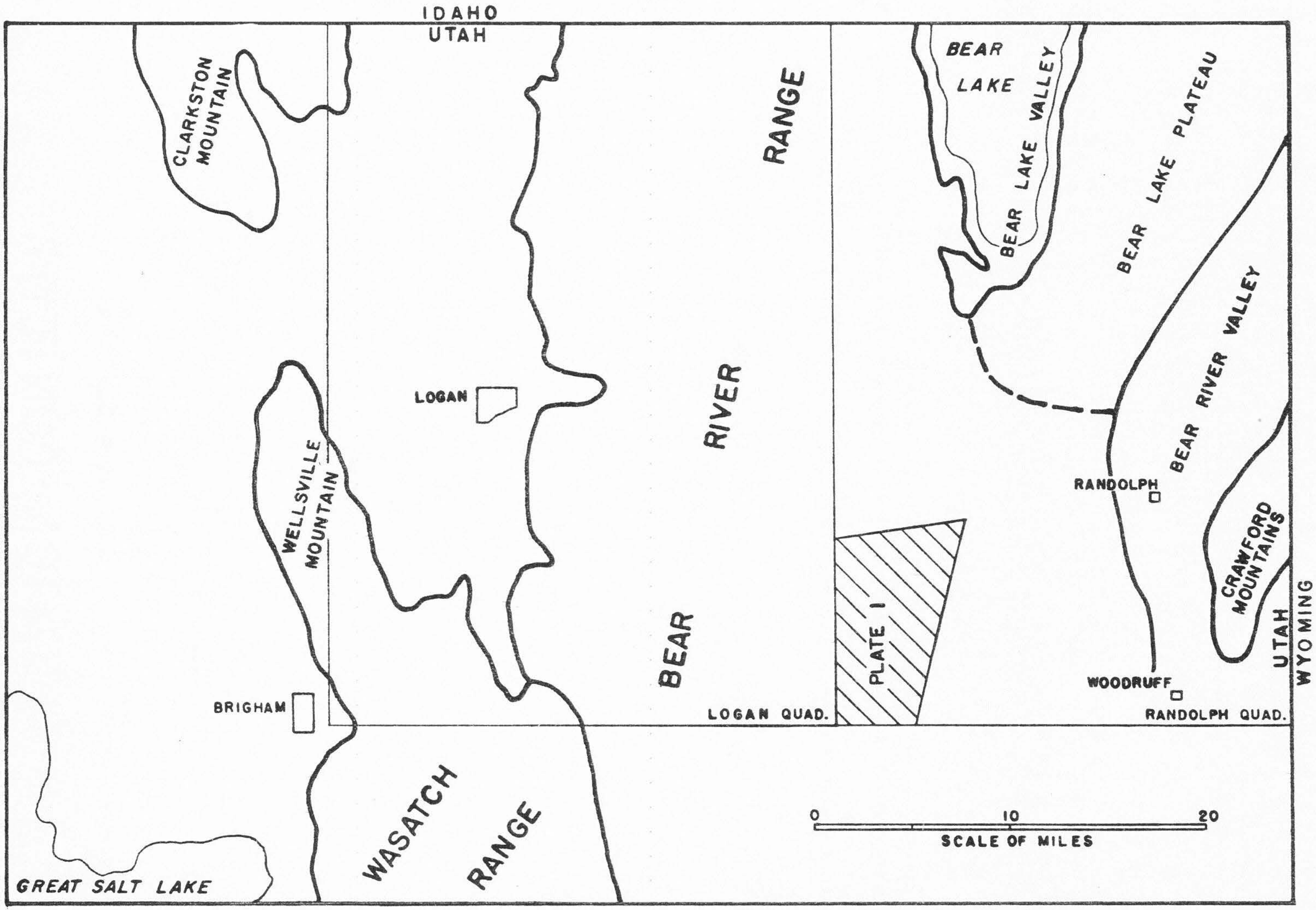

Figure 1. Index map of part of northwestern Utah, showing area mapped.

County. The major part of the area lies within the Cache National Forest.

The area mapped is generally accessible from mid-June to mid-September. A road is maintained along the length of the area by the U. S. Forest Service and is passable by automobile except during heavy rainstorms in the summer months.

Field Work

The field work was done during the summer of 1963. Formation contacts, attitudes, and faults were mapped in the field on aerial photographs of the approximate scale 1:20, 000. This information, concerning the southwestern part of the Randolph quadrangle, was transferred to a base map constructed from the topographic map of the U. S. Geological Survey of the same area (1912 edition). The base map was enlarged to the scale 1:24, 000. Stratigraphic sections were measured with a 50-foot steel tape. A Brunton compass was used to measure attitudes and slope angles. Sample rock types were collected from each unit and compared with the rock-color chart (Goddard, 1951) to obtain standard color names. Fossils were collected and identified in the laboratory by the author.

Previous Investigations

The earlier geologic reports from the general area of the Randolph quadrangle are found in the Hayden Survey and the survey of the Fortieth Parallel supervised by King. Hayden (1871, p. 150-156), Peale (1877, p. 573-609), Hague (1877, p. 393-442), and Emmons (1877, p. 326-393) all commented upon the general area. Walcott (1908) studied the Cambrian rocks of the Bear River Range and defined eight formations. Veatch (1907) studied the area adjacent to the Randolph quadrangle in Wyoming. In the Randolph quadrangle, Richardson (1913) divided the Ordovician rocks into three formations, identified the Silurian rocks as a formation, defined one Mississippian formation, and later (1941) published a geologic map of the quadrangle. Mansfield's (1927) study of southeastern Idaho provided valuable information concerning regional structure and stratigraphy. Williams (1948) mapped the Logan quadrangle which is adjacent to the area on the west. Specific studies (Ross, 1949, 1951; Maxey, 1941, 1958) have given more detailed information concerning Cambrian and Ordovician rocks of the area. A recent publication by Armstrong and Cressman (1963) is important in dating the uplift and thrust faulting in the ancestral Bear River Range. The Geologic Map of Utah (Stokes, 1961) followed the interpretaion of Richardson (1941), for the southwestern part of the Randolph quadrangle, except in the designation of the Wasatch formation which is shown as Knight conglomerate.

STRATIGRAPHIC GEOLOGY

General Statement

The Cambrian System of the southwestern part of the Randolph quadrangle is represented by the Bloomington, the Nounan, and the St. Charles formations (Table 1). The Bloomington formation is Middle Cambrian in age, the Nounan formation is Late Cambrian and possibly Middle Cambrian (Hanson, 1949, p. 27-30), and the St. Charles formation is Late Cambrian. These formations are conformable in the mapped area. The upper dolomite member of the St. Charles formation has not been dated accurately due to the lack of fossils. This unit represents the last Cambrian deposition in the region.

The Ordovician System is represented by the Lower Ordovician Garden City formation and the Upper Ordovician Fish Haven dolomite. The absence of the Middle Ordovician Swan Peak formation which is present to the north and west is evidence for unconformity; however, the formations are parallel in the area. The Fish Haven dolomite is consistent with descriptions given of the formation from adjacent areas.

The Silurian and Devonian Systems are each represented by one formation. They are respectively the Laketown dolomite and the Water Canyon formation. A Middle Silurian age for the Laketown dolomite is suggested by fossils collected from the formation; however, it is not known if

Table 1. Stratigraphic units of the southwestern part of the Randolph quadrangle and surrounding region

System	Units	Age	Thickness (feet)
Tertiary	Wasatch formation	Eocene or latest Paleocene	800[a]
Devonian	Water Canyon formation	Early Devonian	170
Silurian	Laketown dolomite	Middle Silurian	1, 000[a]
Ordovician	Fish Haven dolomite	Late Ordovician	130
	Garden City formation	Early Ordovician	1, 280
Cambrian	St. Charles formation	Late Cambrian	970[b]
	Nounan formation	Middle (?) or Late Cambrian	1, 025
	Bloomington formation	Middle Cambrian	1, 500[c]

[a]Estimated.
[b]East Fork of Little Bear River (Hafen, 1961, p. 67-68).
[c]High Creek (Williams, 1948, p. 1, 130).

Lower or Upper Silurian rocks are present (Williams, 1958, p. 25). The Lower Devonian Water Canyon formation conformably overlies the Laketown dolomite. No Paleozoic rocks younger than the Devonian Water Canyon formation are found in the area mapped.

There seems to be little doubt that a great thickness of Paleozoic and Mesozoic rocks was eroded from the mapped area. Richardson (1941, p. 26-31) mapped and described Mesozoic rocks approximately 4 miles east of the mapped area; however, no Mesozoic rocks are found in the southwestern part of the Randolph quadrangle. Mansfield (1927, p. 99) reported a thickness of over 10, 000 feet of Mesozoic rock north of the area in southeastern Idaho, and Eardley (1944, p. 837) reported a similar thickness south of the area near Peoa, Utah. Armstrong and Cressman (1963, p. 12) gave a thickness of 22, 000 feet for sediments eroded from the ancestral Bear River Range.

The Tertiary Wasatch formation is the only Cenozoic formation identified in the area. It is of Eocene or latest Paleocene age (Tracy and Oriel, 1959, p. 128-129) and overlies older formations unconformably.

Cambrian

Bloomington formation

The Bloomington formation was named after Bloomington Creek by Walcott (1908, p. 7) who designated the type locality as about 6 miles west of Bloomington, Bear Lake County, Idaho. He reported a thickness of 1, 320 feet and assigned a Middle Cambrian age in a measured section of the formation from Blacksmith Fork Canyon, Cache County, Utah (Walcott, 1912, p. 149-150). Richardson (1913, p. 406) designated the lower 350 feet of the Bloomington formation as the Hodges shale member in the Randolph quadrangle. Mansfield (1927, p. 55) changed the type locality, as given by Walcott, to Mill Creek near Liberty, Idaho, and retained the Hodges shale as named by Richardson. He reported a thickness of about 1,200 feet for the Bloomington formation. Deiss (1938, p. 1,122) accepted Mansfield's section.

In the Bloomington formation of the Randolph quadrangle, Richardson recognized another shale unit above the Hodges shale member. Williams (1948, p. 1,134), in the Logan quadrangle which borders the area studied on the west, identified four units in the Bloomington formation. They are: (1) a lower shale which is the Hodges shale, (2) a limestone, (3) a shale, and (4) an upper limestone.

Only the upper 280 feet of the formation is exposed in the mapped area. This thickness was measured in sec. 33, T. 10 N., R. 4 E. The upper two units, shale and limestone, as defined by Williams (1948, p. 1,134) are present with part of a lower unit of limestone also exposed. The rock is composed of dark-gray to bluish-gray aphanitic to medium-crystalline limestone with a poorly exposed unit of olive-green shale separating the two main units of limestone. Pebble conglomerate beds were noted near the top of the lower limestone unit. Both limestone units are thin bedded.

Nounan formation

Walcott (1908, p. 6) named the Nounan formation from the town of Nounan, Bear Lake County, Idaho. He designated the east slope of Soda Peak, which is located west of Nounan, as the type locality. His detailed description was obtained in Blacksmith Fork Canyon (1912, p. 149). He recorded a thickness of 1, 041 feet and reported a Middle Cambrian age for the formation. Mansfield (1927, p. 55-56) studied the type locality and gave a detailed description. He reported a thickness of 1, 050 feet. The type locality has been accepted by later workers. Maxey (1941, p. 17) identified the Nounan formation as Middle (?) and Late Cambrian. Hanson (1949, p. 27-30) reported a similar conclusion from the Malad Range where he found the upper limestone unit to be early Late Cambrian and the lower dolomite is thought to be latest Middle Cambrian or earliest Late Cambrian.

The Nounan formation of the Randolph quadrangle is a massive- to medium-bedded blue-gray limestone approximately 950 feet thick (Richardson, 1941, p. 12). Williams (1948, p. 1, 134) indicated that dolomite is the major rock type of the formation with some limestone which weathers to slopes. He considered the formation to be less resistant than other dolomite units above and below.

The Nounan formation, in the area studied, was found to be massive- to medium-bedded dolomite alternating in color from very light gray to dark gray, with a medium-gray, thin-bedded limestone as the upper unit of the formation. The very light-gray finely crystalline dolomite forms massive cliffs. A thickness of 1,025 feet was measured in sec. 33, T. 10 N., R. 4 E. The Nounan is extensively exposed in the area studied.

St. Charles formation

The first description of the St. Charles formation was given by Walcott (1908, p. 6). He designated the type locality as St. Charles Canyon, Bear Lake County, Idaho, and reported a thickness of 1,227 feet which was measured in Blacksmith Fork Canyon (Walcott, 1912, p. 148-149). Richardson (1913, p. 408) recognized a massive gray quartzite at the base of the formation in the Randolph quadrangle to which he applied the name Worm Creek Quartzite. He recorded a thickness of 1,300 feet for the formation. The St. Charles is Late Cambrian in age (Walcott, 1908, p. 6).

Deiss (1938, p. 1,123) misinterpreted the Blacksmith Fork section of the St. Charles formation as pointed out by Williams (1948, p. 1,135). Richardson (1941, p. 13) apparently followed the incorrect interpretation by Deiss of the St. Charles and Garden City formations. In his 1941 publication, pertaining to the Randolph quadrangle, the thickness of the St. Charles is changed from the original 1,300 feet to 400 feet and the Garden City thickness is changed from 1,000 to 1,900 feet. Present workers follow the measurements made by Walcott, realizing the inaccuracies of those made by Deiss. Williams (1948, p. 1,130) reported 1,015 feet of St. Charles formation at High Creek in the Logan quadrangle. Mansfield measured the St. Charles at three locations and obtained three different thicknesses ranging from 950 feet at St. Charles Creek, Idaho, to 1,200 feet at Mill Creek which is about 5 miles west of Liberty, Idaho.

The St. Charles formation is extensively exposed throughout the area; however, only a partial stratigraphic section was measured due to faulting of well-exposed sections and poor exposures elsewhere. The formation is composed of three units. They are: (1) the Worm Creek quartzite, (2) a limestone member, and (3) a dolomite member.

The Worm Creek quartzite is an excellent stratigraphic marker and can be used effectively to determine stratigraphic position. The quartzite is pale pink to pale orange with occasional light red beds and is fine grained with cross-bedding common. Rock fragments from the Worm Creek quartzite are distinguished from rock fragments of the Wasatch formation by their angular character. No well-exposed section of Worm Creek quartzite is present in the area. A carbonate unit between two units of quartzite was recognized at one location (Haynie, 1957, p. 29).

The limestone unit above the Worm Creek quartzite is easily identified by its stratigraphic position. It is composed of thin-bedded limestone which is medium light gray and argillaceous with shale partings common. This limestone changes upward into thin-bedded shaly limestone and silty limestone. It is similar to the Garden City formation but lacks intraformational conglomerate and is darker in color when freshly exposed. Trilobites and other fossils are found in the limestone unit from which Maxey (1941, p. 28) identified Elvinia, Iddingsia, and Irvingella among others.

The upper dolomite is medium to light gray, mottled in part, with occasional chert nodules in the lower half. The dolomite is resistant and forms cliffs. The exact age of this unit has not been established due to the lack of fossils.

A composite partial section measured in sec. 3, T. 9 N., R. 4 E. and sec. 33, T. 10 N., R. 4 E. gave a thickness of 594.5 feet. The contact between the Nounan formation and the St. Charles formation is not well exposed at either location. Faulting and erosion have destroyed the complete section. The contact, where exposed in the area mapped, between the St. Charles formation and the Garden City formation is conformable and is marked by a lithologic change. The estimated thickness of the St. Charles formation is 1,100 feet.

The transition from limestone to dolomite is gradual and may offer a key to the age of the dolomite. A sequence of alternating beds of limestone, compact silty limestone, and dolomite is present in the transition zone. If a dolomite can be produced by the weathering of a limestone, as postulated by Dunbar and Rodgers (1958, p. 239), the silty limestone could have acted as a barrier to downward percolation of ground water and the subsequent weathering of the middle limestone unit. The different thicknesses of the St. Charles formation may represent evidence of an ancient land surface which shows relief, and may support the weathering theory for the origin of the upper dolomite member. If this theory of origin for the dolomite is true, it could be approximately the same age as the limestone unit.

Ordovician

Garden City formation

The Garden City limestone, hereafter referred to as Garden City formation, was named by Richardson (1913, p. 408-409). The name is taken from Garden City Canyon, Randolph quadrangle, Utah-Wyoming, where the type section is found. A thickness of 1, 000 feet was originally reported. Richardson (1941, p. 14) revised his definition and apparently followed the interpretations of Deiss (1938, p. 1, 123) which increased the thickness by 900 feet.

Ross (1949, 1951) found in his studies of the Garden City formation that Richardson's original definition was more nearly correct. Trilobite fragments are abundant at various horizons in the formation (Plate 2). Other fossils are common in the formation including sponges, ostracods, graptolites, nautiloids, pelmatozoans, gastropods, and brachiopods. Ross (1951, p. 27-32) zoned the formation using the trilobite fauna and placed the boundary between the Canadian and the Chazyan Series in the upper cherty member of the formation. Williams (1948, p. 1, 135) measured 1, 400 feet in Green Canyon northeast of Logan, Utah.

A composite stratigraphic section is recorded from the area mapped. The lower limestone member is 1, 084 feet thick in sec. 35 and 36, T. 10 N., R. 4 E. The upper cherty dolomite member is 196 feet thick at the head of Curtis Creek Canyon in sec. 1, T. 10 N., R. 4 E. The formation is 1, 280 feet thick. A composite section is reported to obtain a more representative

Figure 1. Scour and fill in lower member of the Garden City formation in sec. 22, T. 10 N., R. 4 E. about 1 mile northwest of where the trail to Hardware Ranch leaves the road maintained by the U. S. Forest Service.

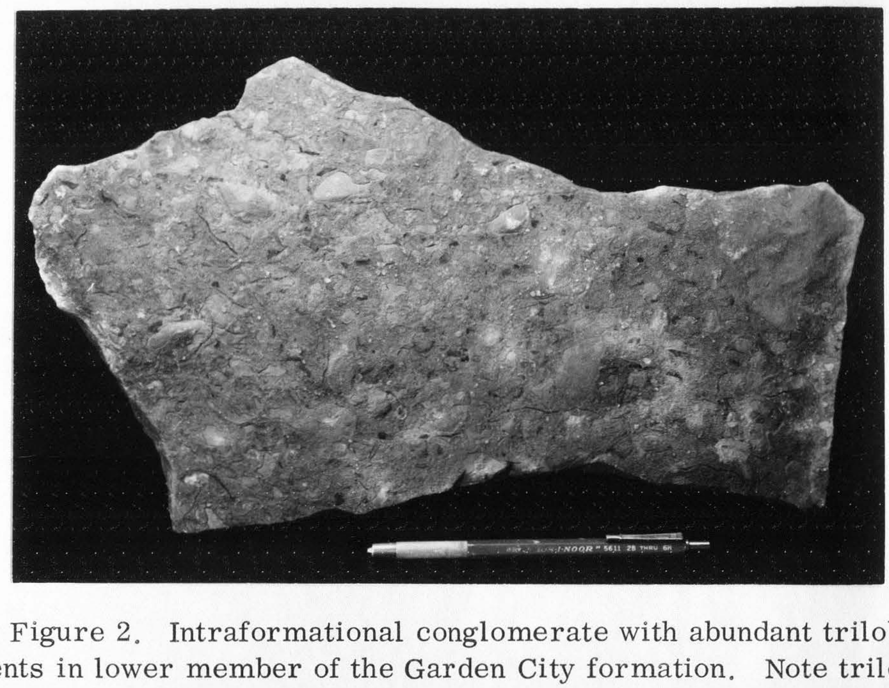

Figure 2. Intraformational conglomerate with abundant trilobite fragments in lower member of the Garden City formation. Note trilobite thorax segment above head of pencil. Rock sample is from Curtis Creek Canyon, sec. 2, T. 10 N., R. 4 E.

Plate 2. Garden City formation

section which approaches the regional thickness (Ross, 1951, p. 36).

The lower member of the Garden City formation is composed of rock types as follows: (1) interbedded light-bluish-gray thin-bedded limestone, (2) intraformational thin-bedded limestone conglomerate, and (3) silty to muddy thin-bedded to laminated limestone. The limestone is aphanitic in texture. The conglomerate contains pebbles 1 to 4 inches long of aphanitic limestone which are often cemented in a matrix of medium crystalline dark-bluish-gray limestone. The silty limestone is nonresistant and poorly exposed.

The intraformational conglomerate is characteristic of the formation and has long been explained as originating by "vigorous stirring of the bottom by wave action" (Barrell, 1917, p. 768). This theory of origin has been generally accepted by subsequent workers. Channels and truncation of beds are common (Plate 2). This theory calls for deposition of at least the lower member at shallow depths where wave action can be effective. The slight thinning of the formation to the east suggests that it was deposited east of the axis of the Cordilleran geosyncline (Ross, 1951, p. 37). Kay (1951, p. 36-37) believed that the sediments came from the east.

The upper member is composed of light- to medium-gray dolomite, mottled in part, with chert nodules and stringers which increase downward until they comprise over 50 per cent of the unit. The chert decreases towards the base and is absent at the contact with the lower limestone member. The upper cherty dolomite member thins to the south and the character of the chert changes from black to light gray and white. The upper member is

196 feet thick in Curtis Creek Canyon, 117 feet thick in sec. 36, T. 10 N., R. 4 E., and in sec. 2, T. 9 N., R. 4 E. the chert unit could not be recognized. A covered area with minor chert float is present between the Fish Haven dolomite and the limestone member of the Garden City formation. If this covered area represents the upper cherty dolomite member, the thickness is greatly reduced from the Curtis Creek area. The apparent thinning does not seem to affect the Fish Haven dolomite but may explain the absence of the Swan Peak formation. Ross (1951, p. 37-38) suggested upwarp to the east or a northwesterly source of sediments to explain the thinning of the Swan Peak formation. The evidence reported here tends to support upwarp to the east.

The chert of this member may be of primary origin. It could have been derived from a peneplaned land mass when climatic conditions enabled silica to be broken down by chemical weathering and carried in solution to the area of deposition (Tarr, 1917, p. 427-433). Eardley (1947, p. 340) believed the silica may have been of volcanic origin. Ross (1951, p. 34) believed the "chert was replacing limestone penecontemporaneously throughout the time represented by the upper member."

Fish Haven dolomite

The Fish Haven dolomite was first described by Richardson (1913, p. 409-410) who designated the head of Fish Haven Creek, 5 miles north of the Utah-Idaho state boundary, as the type locality. Subsequent workers have accepted Richardson's original definition.

The following corals were collected from the formation:

Halysites (Catenipora) sp.

Favosites (Palaeofavosites) sp.

Palaeophyllum sp.

Calapoecia (?)

Duncan (1956) stated that these corals are characteristic of a Late Ordovician fauna, especially Palaeophyllum (Duncan, 1956, p. 225).

The Fish Haven dolomite of the Randolph quadrangle is medium bedded, dark gray to blue black, locally cherty, finely crystalline, and it is about 500 feet thick. A Richmond fauna is present in the formation (Richardson, 1941, p. 17). Williams (1948, p. 1, 137) measured 140 feet of Fish Haven dolomite in Green Canyon northeast of Logan, Utah.

The Fish Haven dolomite in the area mapped is composed of dark-gray medium to finely crystalline dolomite which may acquire a brown cast when weathered. Chert nodules and stringers are present in the lower third and a fetid odor is common. The formation is well exposed east of the road in sec. 36, T. 10 N., R. 4 E. where the section was measured and is extensively exposed on the east side of the county line in sec. 25 and 36, T. 10 N., R. 5 E. Limited outcrops are found in sec. 15 and 16, T. 10 N., R. 4 E. The formation is 128 feet thick which is in agreement with other workers (Williams, 1948, p. 1, 137). This thickness does not reflect any thinning as observed in the Garden City limestone.

The contact between the Fish Haven dolomite and Garden City formation is not as clear as in adjacent areas where the Swan Peak quartzite is found between the two formations. The lithologic change from a light-gray-mottled dolomite to a dark-gray to medium-gray fetid dolomite was taken as the lower contact. The upper contact was taken as the first bed of light-gray dolomite.

Silurian

Laketown dolomite

Richardson (1913, p. 410) named and described the Laketown dolomite from exposures in Laketown Canyon 4 miles southeast of Laketown in Rich County, Utah. He stated that the thickness is approximately 1, 000 feet and restricted his definition to beds of Silurian age. The Utah fauna from the Laketown dolomite is undoubtedly of Silurian age but was not correlated with the Niagaran fauna by Kindle (1908, p. 127-128). A Middle Silurian or Niagaran age is reported for the Laketown dolomite (Schwartz, 1942).

The Laketown dolomite of the Randolph quadrangle is massive bedded and light gray to white in color. Bands of siliceous limestone and calcareous sandstone are present in the formation (Richardson, 1941, p. 18). Williams (1948, p. 1, 137) measured 1, 510 feet of Laketown dolomite in the Logan quadrangle and assigned it to the Niagaran Series of Silurian System.

The formation is exposed along the eastern part of the area. No section was measured due to faulting, erosion, and lack of exposure. The formation was found to be light-gray medium- to massive-bedded medium-crystalline dolomite with calcite nodules. Dolomite crystals on weathered surfaces were noted in the area mapped. An estimated thickness of 1,000 feet is present in the area.

The lower contact is taken as the first bed of light-gray dolomite above the characteristic dark-gray dolomite of the Fish Haven dolomite. The upper contact was marked by a color change and a change in the character of the dolomite. The Laketown dolomite, below the contact, weathers medium gray to light gray. It is medium to massive bedded and often forms cliffs. The Water Canyon formation above the contact weathers white, is thin bedded, and forms slopes.

The brachiopod _Pentamerus_ sp. was identified from molds found in sec. 17, T. 10 N., R. 5 E. (Plate 3). Stromataporoids are found in sec. 1, T. 9 N., R. 4 E. Crinoid columnals often aided in distinguishing the formation from other dolomite.

Devonian

Water Canyon formation

Williams (1948, p. 1,138-1,139) described and named the Water Canyon formation from exposures in Water Canyon which is a tributary to Green Canyon northeast of Logan, Utah. He gave a composite thickness of 393 feet for the formation and recognized two members. The study of fish from the Water Canyon formation by Denison (1952) led to his confirmation of an Early Devonian age for the formation as suggested by other workers (Williams, 1948, p. 1,139).

Figure 1. Molds of the brachiopod Pentamerus sp. in the Laketown dolomite, sec. 17, T. 10 N., R. 5 E., approximately 1 mile southeast of Red Spur.

Figure 2. Fault breccia of Laketown dolomite on the south side of Curtis Creek Canyon in sec. 16, T. 10 N., R. 4 E.

Plate 3. Laketown dolomite

Coulter (1956, p. 31) gave a thickness of 357 feet from the Franklin, Idaho, area. Richardson (1941, p. 19), in his study of the Randolph quadrangle, recovered fishbone fragments from a horizon about 150 feet above the base of the Jefferson formation. Williams (1948, p. 1, 141) used the occurrence of fish fragments to identify the lower member of the Water Canyon formation. Richardson undoubtedly mapped what is now known as Water Canyon formation in what he identified as Jefferson dolomite.

The formation is not extensively exposed in the southwestern part of the Randolph quadrangle but is readily identified by the white color, when weathered, of the lower thin-bedded dolomite unit. The upper unit contains a thin-bedded limestone which weathers pale red and is interbedded with dolomite which weathers yellowish gray. Neither unit is resistant and both form slopes. The lower dolomite member is exposed on the north side of the road approximately 1, 000 feet west of Campground Spring, sec. 4, T. 10 N., R. 5 E. A partial section, measured in sec. 9, T. 10 N., R. 5 E., is 169 feet thick. The lower contact is well exposed and the white-weathering less resistant dolomite rests on medium-gray to light-gray cliff-forming Laketown dolomite. No upper contact is present due to erosion.

A bed containing snails, identified as Meekospira (?), is located in the measured section. A fish fragment was recovered in sec. 4, T. 10 N., R. 5 E. but no identification was made.

Tertiary

Wasatch formation

Hayden (1870, p. 147) used the name Wasatch as a provisional group name for strata beneath the Bridger Group on the north flank of the Uinta Mountains. He did not designate a type locality but included beds exposed in Echo and Weber Canyons in his description. Later workers have accepted the type locality for the formation as Echo Canyon and Weber Canyon.

The Wasatch Group was divided by Veatch (1907, p. 88) into three formations: (1) the Almy formation at the base, (2) the Fowkes formation, and (3) the Knight formation. This division, made by Veatch for south-western Wyoming, was not applicable in Mansfield's (1927, p. 109) study of southeastern Idaho due to the difficulty in separating the Almy formation from the Knight formation when the Fowkes formation was not identified between them. Richardson (1913, 1941) failed to recognize any division in the Wasatch within the Randolph quadrangle. No division was established throughout the area studied; therefore, group status was not recognized for the unit.

Stokes (1961) represented the Tertiary rock of the Randolph quadrangle as Knight conglomerate but gave no explanation for this designation. Tracy and Oriel (1959, p. 128-130) did not advise the use of the names Almy and Knight as divisions of the Wasatch without explicit statements as to their meaning. They found that Veatch (1907) had misidentified the

Fowkes formation in the Kemmerer and Sage quadrangles which made separation of the Almy and Knight formation inaccurate.

Richardson (1941, p. 33) found the Wasatch formation to be principally conglomerate and sandstone with subordinate amounts of clay, limestone, and tuff. The dominant color is red with many variations and shades which range from pale red to maroon. The conglomerates are composed of older rock of the Uinta and Wasatch mountains. Individual pebbles and boulders are well rounded.

The Cowley Canyon member was identified by Williams (1948, p. 1,144-1,145) as the basal member of the Wasatch formation in the southern half of the Logan quadrangle. Williams stated that the lake in which this algal limestone member was deposited occupied much of the Randolph quadrangle. Algal limestone has been recognized by workers in adjacent areas. Mansfield (1927, p. 109), in the Montpelier quadrangle, and Richardson (1941, p. 33-34), in the Randolph quadrangle, recognized such a limestone. A similar limestone was found in the area studied; however, the exposures were limited and did not justify mapping as a separate unit.

The Wasatch formation in the area mapped consists mostly of pebble and cobble red conglomerate overlying pale-red to pale-yellow limestone (Plate 4). A basal fossiliferous limestone with two gastropods tentatively identified as follows:

Physa copei White

Planorbis spectabilis utahensis Meek

is found in sec. 15, T. 9 N., R. 4 E. in Arbs Basin. These fossils support

Figure 1. Poorly consolidated cobble conglomerate overlying red silty limestone of the Wasatch formation. Exposed in the road cut on Red Spur, sec. 9, T. 10 N., R. 5 E.

Figure 2. Coarse cobble conglomerate cemented by calcite in the Wasatch formation. This conglomerate is exposed in sec. 30, T. 10 N., R. 5 E. approximately 3 miles south of Campground Spring.

Plate 4. Wasatch formation

an Eocene age for the Wasatch and give evidence of a fresh-water lake over this area at that time.

Williams (1948, p. 1, 146-1, 147) listed the following fossils from the Wasatch formation:

Physa bridgerensis Meek

Planorbis sp. indef.

They were identified by F. Steans MacNiel of the U. S. Geological Survey who stated the known range of P. bridgerensis is lower and middle Eocene. Veatch (1907, p. 89, 92) identified Physa sp. and Planorbis sp. from the lower two formations of the Wasatch Group in Wyoming.

A coarse cobble conglomerate cemented by calcite is located in sec. 30, T. 10 N., R. 5 E. (Plate 4). The majority of the cobbles were dark-bluish-gray limestone.

STRUCTURAL GEOLOGY

General Statement

The area mapped is part of the east flank of the Strawberry Valley anticline which formed during the Laramide orogeny. No thrust faults are known in the mapped area.

High-angle faults are prominant in the mapped area. The age of the faulting is inferred by comparison of the trend of the faults and the type of structure which they form with fault trends and related structure from adjacent areas. Two periods of high-angle faulting have been recognized in the Bannock thrust zone of southeastern Idaho which includes part of the Bear River Range (Armstrong and Cressman, 1963, p. 20). The first set of faults originated during the folding of the Laramide orogeny and have an east to northeast trend. The second set is younger than deposition of the Wasatch formation, generally trends north to northwest, and resulted from block faulting.

North-northeast-trending faults are found near the east and west boundaries of the mapped area. The fault or fault zone near the west boundary is not in the mapped area but lies in the adjacent Logan quadrangle and was named the Hayes Ridge fault (Williams, 1948, p. 1,148). The fault near the east boundary of the area has little displacement and was not traced the entire length of the area. The areas adjacent on the east and west are down relative to the area between the two faults mentioned above. Several northwest-trending faults cross the mapped area.

Folds

Richardson (1941, p. 38) identified and named the Strawberry Valley anticline from exposures in Strawberry Valley north of the area mapped. Williams (1948, Plate 1) traced the anticline across the southeast corner of the Logan quadrangle. The axis of the anticline is recognized in Blacksmith Fork Canyon and in outcrops in Ant Valley, west of the area mapped, as well as in Strawberry Valley. The Strawberry Valley anticline formed during the Laramide orogeny contemporaneously with the Logan Peak syncline which is the next fold to the west. Sharp Mountain is situated on the west flank of the anticline (Hafen, 1961, p. 43). The area mapped is situated on the east flank and has a general east dip. This direction of dip has been disrupted by faulting over much of the area.

Richardson (1941, p. 38) mapped a fold which he named the Curtis Creek syncline. Folding in Curtis Creek Canyon near the western mountain front was noted by the author (Plate 5). This folding is associated with faulting and is not related to a syncline. Richardson's evidence for the fold was the south dip of Cambrian rocks exposed to the north in Rock Creek Canyon. He also recorded a fault concealed by Wasatch formation between Curtis Creek and Rock Creek. It is the author's opinion that this fault is

Figure 1. Fold in lower member of Garden City formation at the mouth of Curtis Creek Canyon, sec. 9, T. 10 N., R. 4 E.

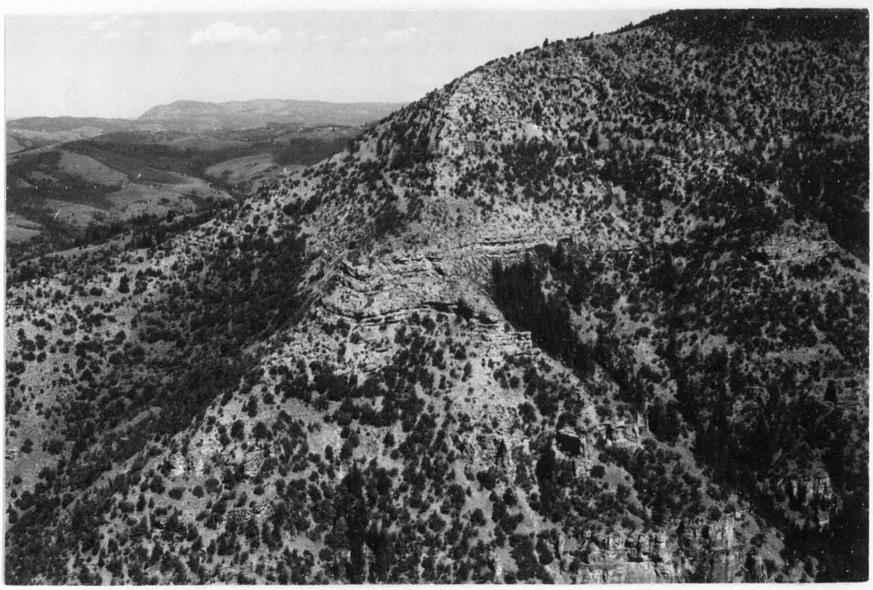

Figure 2. View looking north at the north side of Curtis Creek Canyon showing folds in the lower member of the Garden City formation, sec. 9, T. 10 N., R. 4 E.

Plate 5. Folds in the Garden City formation

present and that the south dip recorded in Rock Creek Canyon is a result of the fault and not evidence of a fold.

Faults

North-northeast-trending faults

Faults which trend north-northeast are found near the east and west boundaries of the mapped area. The high-angle fault which is near the east boundary has no great displacement. Near the north end of the fault, on the east side, Devonian Water Canyon formation has been lowered approximately 100 feet. The displacement appears to decrease to the south. In the field, the fault could not be traced the entire length of the mapped area. An east-facing scarp which trends north-northeast is evident from sec. 9, T. 10 N., R. 5 E. (Plate 6). The high-angle fault near the west boundary is not in the area mapped. This fault lies just west of the area in the Logan quadrangle and is named the Hayes Ridge fault (Williams, 1948, p. 1,154). The approximate displacement is 1,000 feet with the west side down relative to the east side. This fault, or fault zone, has caused the west dip in rock formations along the west side of the mapped area. This faulting occurred after the deposition of the Wasatch formation.

Northwest-trending faults

The three major northwest-trending high-angle faults are designated: (1) the north, (2) the middle, and (3) the south. The north fault is the best exposed and is evident, east of the road in sec. 25 and 26, T. 10 N., R. 4 E.,

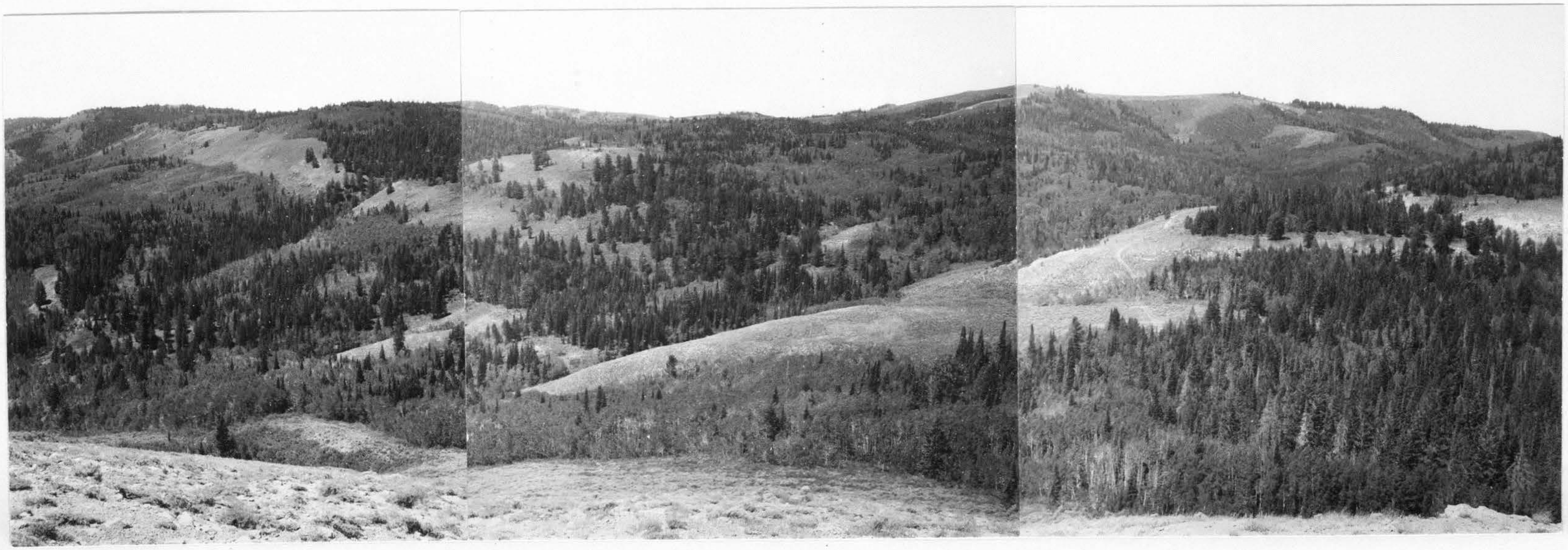

Plate 6. East-facing scarp. View looking west at east side of mapped area, sec. 2, T. 10 N., R. 5 E. The scarp is evident on the right of the view at the break in the slope below the obvious curve in the road. It continues toward the upper left of the view and is marked by a break in the slope. The ridge in the background, to the right of the center, is Red Spur.

1 mile north of Blind Spring where the St. Charles formation is brought in contact with the Garden City formation. The south side of this fault is down relative to the north side. The displacement is approximately 1, 000 feet in sec. 15, T. 10 N., R. 4 E. where Fish Haven dolomite is in contact across the fault with the Garden City formation just above the Garden City-St. Charles contact. The displacement decreases to the southeast along the fault and fault breccia is found in some areas (Plate 3, Figure 2, page 20). The middle fault is best exposed in sec. 21, T. 10 N., R. 4 E. approximately 2 1/2 miles west from where the trail to Hardware Ranch leaves the road maintained by the U. S. Forest Service. Worm Creek quartzite is brought in contact across the fault with dolomite of the St. Charles formation just below the contact with the Garden City formation. The north side of the fault is down. The displacement is approximately 1, 000 feet and decreases to the southeast. The south fault is best identified, in sec. 33, T. 10 N., R. 4 E., 2 miles west of Zion Spring where Worm Creek quartzite is brought in contact with dolomite of the Nounan formation. The displacement is approximately 500 feet and decreases to the southeast.

Minor faults are common in the area but are not of sufficient magnitude to be treated individually. Arbs Basin, in sec. 15, T. 9 N., R. 4 E., is a small graben. The fault which forms the northeast side is evident where the road turns northeast to leave the basin. Wasatch formation is in contact with St. Charles formation across this fault. The fault on the southwest side of the basin is poorly exposed. Garden City formation is brought into contact with the St. Charles formation near the south end of this fault. The northwest-trending faults are thought to be of the same age as the north-northeast-trending faults.

Thrust faults

Richardson (1941, p. 39) correlated the fault west of Garden City, Utah, with a thrust fault in Birch Creek Canyon, 3 miles east of the area mapped. He considered these faults to be a southern extension of the Bannock overthrust which was identified as one of the major structural features of the Rocky Mountains (Richards and Mansfield, 1912, p. 681-707). Recent work has shown the fault west of Garden City, Utah, is a high-angle fault and the Bannock overthrust is a thrust zone of many disconnected thrusts (Armstrong and Cressman, 1963, p. 12-20). They further stated that the connecting of the fault in Birch Creek Canyon with the one west of Garden City, Utah, is not justified. Their work gives no support to a possible thrust fault passing under the area mapped. Stokes (1961) showed a high-angle fault west of Garden City, Utah, and connected it with a similar fault in Birch Creek Canyon. The area mapped contained no evidence for thrust faulting.

Eardley (1944, p. 865-868) suggested the connection of the Bannock overthrust with the Willard thrust which is approximately 30 miles southwest of the area mapped. If this connection is factual, the plane of the thrust would pass under the area. The southern extension of the Bannock and Willard thrusts is supported by isopach information which also supports the connection of these faults with the Charleston and Nebo thrusts of the southern Wasatch Mountains (Crittenden, 1961, p. 128-133).

SURFICIAL GEOLOGY

Geomorphology

Fenneman (1917, p. 80-82) assigned the Bear River Range, which includes the area mapped, to the Middle Rocky Mountain province. Mansfield (1927, Plate 15) and Richardson (1941, p. 1) followed this interpretation. Nolan (1943, Figure 10) included the Wasatch Range and part of the Bear River Range in the Basin and Range province but stated (p. 142): "The eastern boundary (of the Basin and Range province) is made up by the western borders of the Wasatch Range and the Colorado Plateau." Nolan's Figure 10, mentioned above, leads one to believe he meant the eastern boundary of the Wasatch Range instead of the western boundary.

The structure of the area mapped is similar to that of the Basin and Range province. The general trend of the mountain block parallels that of other mountain blocks included in the Basin and Range province and it is separated from the valleys on either side by high-angle faults.

Surface Water

Springs are common in the area mapped and consist of two types: (1) springs in the Wasatch formation and (2) springs in canyon bottoms originating from unknown sources. Springs in the Wasatch formation are found above the contact with older rock and are due to the impermeability of the older rock. These springs are generally of low capacity and dry up by the end of the summer. Sink holes are common in the Wasatch formation. Springs found in the canyon bottoms were not large but seemed to be more persistent than those in the Wasatch formation. Catching ponds for livestock use are often found by the springs. The area is used extensively as summer range for both cattle and sheep. Curtis Creek is the only perennial stream in the area but it is of little use to livestock because the canyon in which it flows is too steep and rugged to be easily accessible.

GEOLOGIC EVENTS

Paleozoic Events

The area mapped is situated in the region occupied by the Cordilleran geosyncline of the Paleozoic age. Deposition began in the region when the Cambrian Brigham quartzite was deposited from a transgressive sea; however, the oldest exposed rocks in the area mapped are of the Bloomington formation, Middle Cambrian age. Older rocks are exposed to the north and east in the Randolph quadrangle and to the west in the Logan quadrangle. Uninterrupted deposition occurred from the Bloomington formation to the Nounan formation in the area mapped. The movement of a transgressive sea across the area has been interpreted from the presence of the Worm Creek quartzite at the base of the St. Charles formation. Normal sedimentary deposition of sandstone, shale, and limestone has been noted (Haynie, 1957, p. 28-33). Lochman-Balk (1955, p. 29-37) thought the source area was the Uinta Mountains which she believed to be a highland during Late Cambrian time. The exact age of the upper dolomite member of the St. Charles formation is not known due to the lack of fossils; however, it is the latest Cambrian unit in the region.

Uplift occurred between deposition of the Garden City and Fish Haven formations (Ross, 1951, p. 37). The Swan Peak formation of Middle

Ordovician age is not present in the area mapped. A thinning to the south was noted in the upper member of the Garden City formation which would support the theory of uplift. The Late Ordovician Fish Haven dolomite conformably overlies the Garden City dolomite.

The Laketown dolomite was deposited from the sea which occupied the area during Silurian time. The formation is Middle Silurian in age. Early and Late Silurian rocks have not been identified in the Bear River Range.

The sea invaded the area again in Devonian time. The environment of deposition during Early Devonian time was variable. Fish fragments in the Water Canyon formation may be evidence for fresh-water or brackish-water deposition (Denison, 1941, p. 553-555). Red beds which occur in the Water Canyon formation may represent deposition of red debris from other areas (Dunbar and Rodgers, 1958, p. 217-218). Paleozoic events younger than Early Devonian time are not evident in the area mapped due to the removal of the rock record by erosion.

Mesozoic Events

Seas invaded the area during the Mesozoic Era. Rocks of this age are located 4 miles east of the area mapped (Richardson, 1941, p. 26-31); however, no Mesozoic rocks are found in the area. The folding of the ancestral Bear River Range began as early as Late Jurassic and continued into Paleocene time (Armstrong and Cressman, 1963, p. 13-14). Thrust faulting, north of the mapped area, is thought to be associated with the folding of the ancestral Bear River Range (Armstrong and Cressman, 1963, p. 13-15). This period of folding and faulting is named the Laramide orogeny. Most of the Mesozoic rock, 1,300 feet thick, was removed before the end of the era.

Cenozoic Events

A fresh-water lake, in which the basal unit of the Wasatch formation of Paleocene or Eocene age was deposited, covered the area mapped and much of the surrounding region (Williams, 1948, p. 1,144-1,145). The thick conglomerates of the Wasatch formation give evidence of rapid erosion. No later formations of Tertiary age are identified in the mapped area. Fault block mountains and graben valleys formed after the deposition of the Wasatch formation.

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APPENDIX

Section No. 1, upper part of the Bloomington formation, measured on the north side of the canyon in sec. 33, T. 10 N., R. 4 E. The section begins at the base of a 50-foot ledge of limestone exposed in the canyon bottom and continues to the base of a cliff a third of the way up the slope. A partial section of the Bloomington formation, the Nounan formation, and the Worm Creek member of the St. Charles formation were measured at this location. The location is approximately 4 1/2 miles east of the Lamar Anderson ranch.

Nounan formation

Bloomington formation (upper part)		Thickness (feet)
6.	Limestone, medium bluish gray, aphanitic texture dominant, minor medium-crystalline limestone in lower 10 feet, thin bedded, silty shale partings, poorly exposed, nonresistant, forms slope, weathers dark gray	123.9
5.	Shale, olive green, poorly exposed, forms slope	38.7
4.	Limestone, dark gray, aphanitic texture, thin bedded, nonresistant, forms slope, weathers medium bluish gray	6.8
3.	Shale, olive green, poorly exposed, forms slope	20.0
2.	Interbedded shale, intraformational conglomerate, and limestone. Shale, grayish olive, 72 per cent, poorly exposed. Intraformational conglomerate, 25 per cent, red hematite stain common on freshly exposed pebbles. Limestone, bluish gray, similar to Unit one, 3 per cent	26.7
1.	Limestone, dark gray, aphanitic texture, thin bedded, platy, weathers bluish gray, medium-gray argillaceous bands 2- to 5-mm thick intertongue	65.0
	Total	280.0

Section No. 2, Nounan formation, measured in sec. 33, T. 10 N., R. 4 E. from the base of a cliff a third of the way up the slope to the Worm Creek quartzite.

St. Charles formation

Nounan formation		Thickness (feet)
7.	Limestone, dark gray, aphanitic texture, thin bedded with laminae of argillaceous limestone which weathers pale yellow, shale partings, weathers medium gray, occasional chert nodule or stringer, silica content increases in upper beds, finely crystalline, upper contact poorly exposed	93.2
6.	Dolomite, medium light gray, argillaceous, thin bedded, shale partings, aphanitic texture, forms slope, weathers medium yellowish gray, occasional bed of medium-gray finely crystalline dolomite which weathers light gray	124.4
5.	Dolomite, interbedded light gray and medium gray, thin bedded to laminated in part, finely crystalline with occasional beds of coarsely crystalline dolomite, forms slope	124.4
4.	Dolomite, medium dark gray, mottled with very light-gray dolomite, occasional beds of laminated dark-gray to medium-gray dolomite, argillaceous in part, thin to medium bedded, forms slope, weathers medium gray	134.5
3.	Dolomite, interbedded light-gray and medium-gray to dark-gray mottled dolomite; medium crystalline, thick bedded, light-gray mottled dolomite above lower 126 feet, dolomite crystals on weathered surface	312.7
2.	Dolomite, light gray, finely crystalline, massive bedded, forms cliffs, dolomite crystals on weathered surface, weathers very light gray	163.5
1.	Dolomite, medium gray, stringers of dark-gray dolomite, massive bedded, forms cliffs, weathers light gray	81.9
	Total	1,025.0

Bloomington formation

Section No. 3, composite section of the St. Charles formation. The lower Worm Creek quartzite member measured in sec. 33, T. 10 N., R. 4 E. from outcrops directly above the Nounan formation. The remainder of this section is located in sec. 3, T. 9 N., R. 4 E. approximately 2 miles down the intermittent stream which drains Arbs Basin. This segment was measured from the bottom of the canyon to the top of the ridge on the west side of the canyon. A fault is present in the upper third of this section.

St. Charles formation (upper part eroded)		Thickness (feet)
5.	Dolomite, medium dark gray, medium to thin bedded, mottled with light-gray dolomite, light-gray chert nodules in lower 40 feet, finely crystalline, weathers medium gray	73.0
4.	Dolomite, medium light gray, thin bedded, mottled in part with very light-gray dolomite, resistant, forms ledges, weathers light gray	123.7
	Fault	
3.	Dolomite, medium light gray, thin bedded, very light-gray chert nodules in upper 50 feet, resistant, forms ledges, weathers light gray	107.8
2.	Limestone, medium gray, argillaceous, shale partings, alternating units 6 inches to 2 feet thick of shaly thin-bedded to laminated limestone and thin-bedded limestone in upper 50 feet, occasional medium-gray 2- to 4-cm beds of dolomite in upper 10 feet, trilobite fragments, weathers medium light gray	235.0
1.	Quartzite, pale pink to pale orange with occasional light-red beds, fine grained, thin bedded, forms minor ledges, cross-bedding common, poorly exposed	55.0
	Total	594.5

Nounan formation

Section No. 4, composite section of the Garden City formation. The upper member is located at the head of Curtis Creek Canyon in sec. 1, T. 10 N., R. 4 E. approximately a quarter mile southwest of the Curtis Creek Ranger Station. The lower member, measured in sec. 35 and 36, T. 10 N., R. 4 E., begins approximately 800 feet south of Blind Spring above the top of a small ledge visible on the east side of the road and continues west across the road, approximately 4,000 feet, to the St. Charles Garden City contact.

Wasatch formation

Garden City formation (upper contact poorly exposed)		Thickness (feet)
	Upper member (Curtis Creek area)	
11.	Dolomite, light gray to medium gray, mottled with argillaceous limestone which weathers yellowish gray, thin bedded, weathers light gray	42.6
10.	Dolomite, light gray to medium gray, black to brownish gray chert nodules and stringers, chert increases to over 50 per cent of unit in middle, thin bedded, weathers light gray	131.6
9.	Dolomite, medium light gray, thin bedded, aphanitic texture, weathers light gray to light bluish gray	11.5
	Lower member (sec. 35 and 36, T. 10 N., R. 4 E.)	
8.	Covered	34.6
7.	Limestone, dark bluish gray, aphanitic texture, interbedded with medium to coarsely crystalline intraformational limestone conglomerate, 1- to 4-inch elongate aphanitic limestone pebbles cemented by medium crystalline limestone, pebbles often have reddish oxide stain when freshly exposed, thin bedded, weathers light bluish gray; gastropods, sponges and trilobite fragments common	112.0
6.	Covered	39.4
5.	Same lithology as Unit 7	310.1

4.	Limestone, dark bluish gray, aphanitic texture, interbedded with medium to coarsely crystalline limestone, conglomerate less abundant, shale partings, argillaceous content increases downward, weathers light bluish gray	237.5
3.	Limestone, dark bluish gray, conglomerate less common, light-olive-gray chert nodules and stringers common, thin bedded, aphanitic texture, weathers light bluish gray	92.6
2.	Limestone, dark bluish gray, aphanitic texture, thin bedded due to shale partings, argillaceous, thin bedded to laminated units common, forms slope, weathers light bluish gray, trilobite fragments	152.5
1.	Limestone, dark bluish gray, thin bedded, shaly limestone alternating with intraformational conglomerate, nonresistant, forms slope, aphanitic texture, weathers light bluish gray	118.6
	Total	1,280.1

St. Charles formation

Section No. 5, Fish Haven dolomite, measured in sec. 36, T. 10 N., R. 4 E. approximately 3,000 feet south of Blind Spring beginning at the base of the slope 200 feet east of the road and continuing up the slope to the contact between Fish Haven dolomite and Laketown dolomite.

Laketown dolomite

Fish Haven dolomite		Thickness (feet)
1.	Dolomite, dark gray, finely crystalline, thick bedded, occasional coral, chert nodules and stringers in lower third, fetid odor, resistant, forms ledges, weathers dark olive gray to medium gray	128.2

Garden City formation

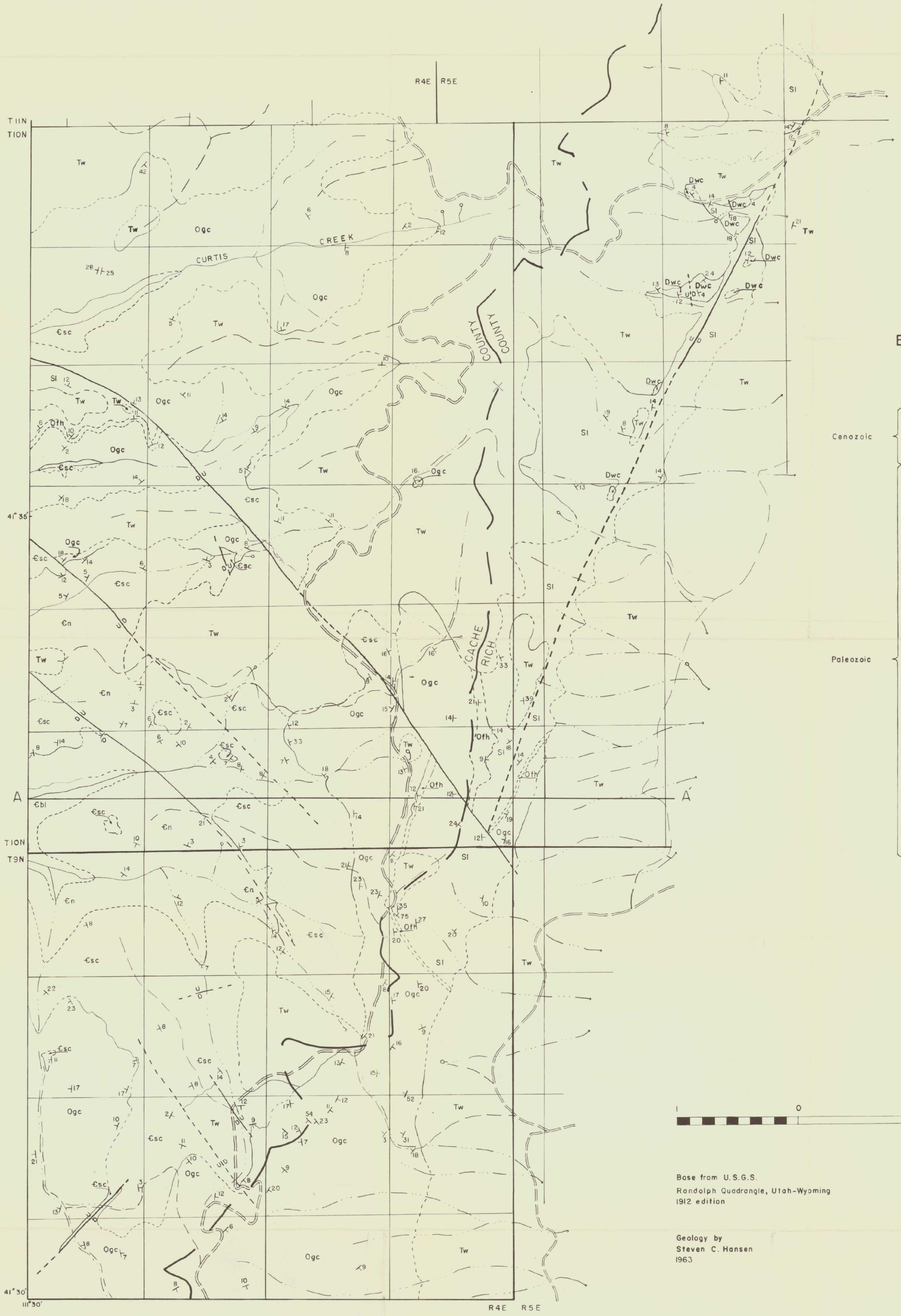
Section No. 6, Water Canyon formation, measured in sec. 9, T. 10 N., R. 5 E. This location is approximately 1 mile south of Campground Spring at the mouth of the next east-west-trending canyon. The section begins at the top of the Laketown dolomite cliff, on the north side of the canyon, and continues to the top of the ridge.

Water Canyon formation (about 30 feet at the top eroded)		Thickness (feet)
11.	Limestone, pale brown, finely crystalline, thin bedded, forms slope, poorly exposed, weathers light olive gray	11.1
10.	Covered	4.4
9.	Dolomite, light olive gray, thin bedded, poorly exposed, forms slope, weathers yellowish orange pink	9.7
8.	Covered	12.0
7.	Dolomite, dark bluish gray, finely crystalline, thin bedded, weathers medium dark gray to light olive gray	0.8
6.	Covered	8.4
5.	Dolomite, dark bluish gray, argillaceous, thin bedded, resistant, forms ledge in upper third of unit, 3-inch zone containing snails at top of unit, weathers medium dark gray to light olive gray	18.4
4.	Limestone, pale reddish brown, argillaceous, calcite prominent along bedding planes, bedding planes warped and distorted, poorly exposed above lower 5 feet, forms slope, occasional bed of light-gray limestone, weathers pale red	11.2
3.	Limestone, medium gray, coarsely crystalline, resistant bed supports argillaceous red limestone above, weathers light gray to pinkish gray	0.6

2.	Dolomite, calcitic, grayish red, argillaceous, non-resistant, forms slope, thin bedded, weathers grayish orange to pale reddish brown, occasional bed of olive-gray aphanitic dolomite which forms minor ledges and weathers light brown	29.7
1.	Dolomite, pale yellowish brown to light gray, yellow laminae dominant in lower third, dolomite resembles lithographic limestone, conchoidal fracture, aphanitic texture, thin bedded to laminated in part, less resistant than underlying Laketown dolomite, forms slope, weathers white to yellowish gray	62.2
	Total	168.5

Laketown dolomite

GEOLOGY OF THE SOUTHWESTERN PART OF THE RANDOLPH QUADRANGLE, UTAH-WYOMING



EXPLANATION

Cenozoic	Tertiary	Tw	Wasatch formation
Paleozoic	Devonian	Dwc	Water Canyon formation
	Silurian	Sl	Laketown dolomite
	Ordovician	Ofh	Fish Haven dolomite
		Ogc	Garden City formation
	Cambrian	€sc	St. Charles formation
		€n	Nounan formation
		€bl	Bloomington formation

County line

Intermittent stream

Spring

Secondary road

Jeep trail

Contact
Dashed where approximately located

Fault
Relative movement indicated.
Dashed where approximately located.

Strike and dip of beds

1 0 1 Mile

Base from U.S.G.S.
Randolph Quadrangle, Utah-Wyoming
1912 edition

Geology by
Steven C. Hansen
1963

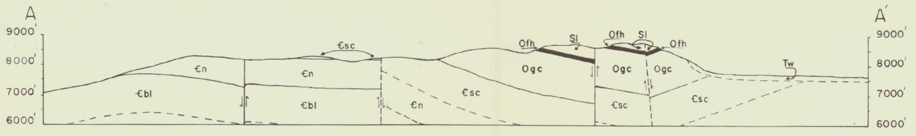


PLATE I