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The Lower Devonian Water Canyon formation of Northeastern Utah

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THE LOWER DEVONIAN WATER CANYON FORMATION

OF NORTHEASTERN UTAH

by

Michael E. Taylor

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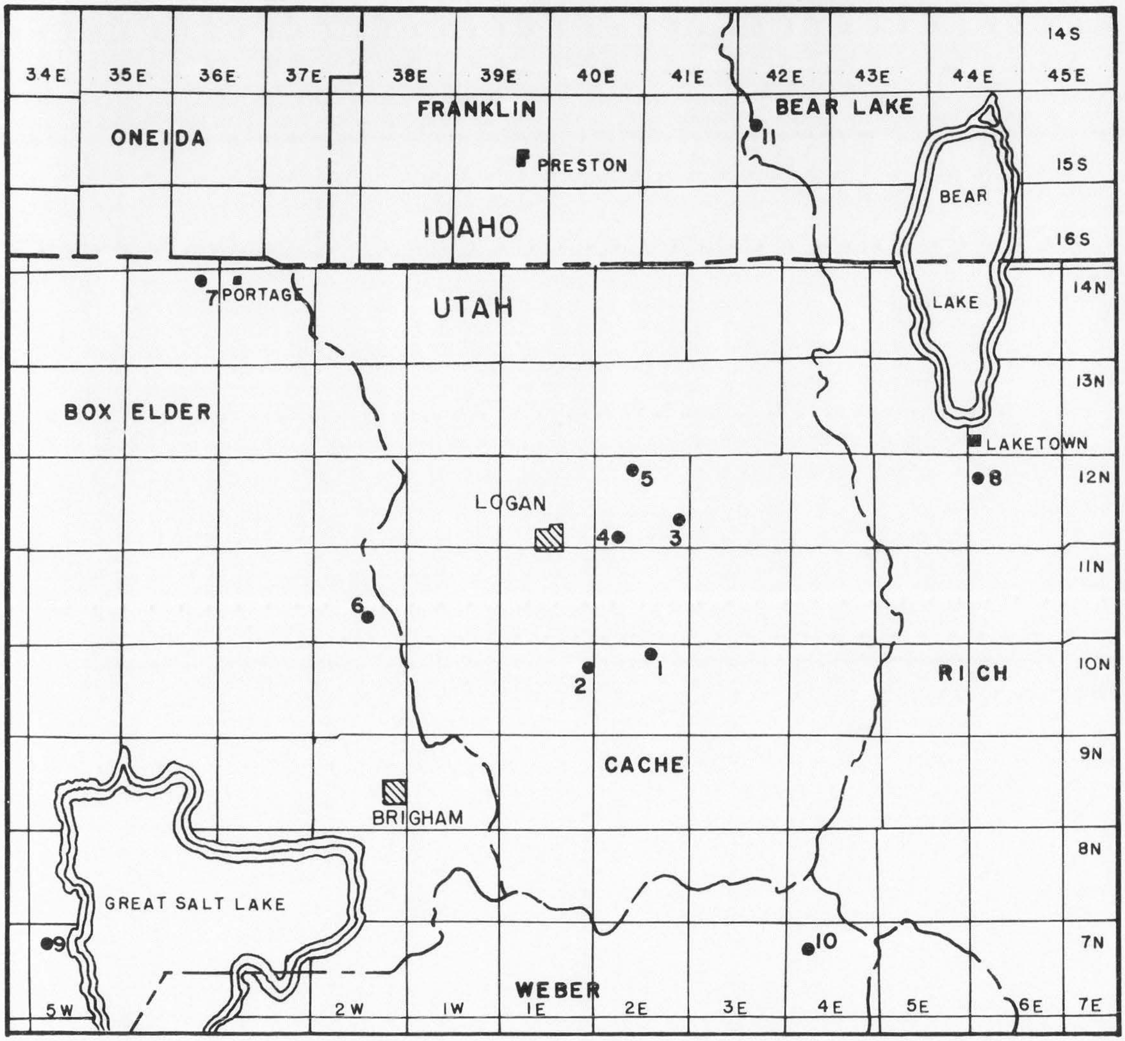
General statement

In 1948 Williams subdivided the Jefferson Formation of northeastern Utah into two formations. The upper formation was referred to as the Late Devonian Jefferson Formation and the lower formation the Early Devonian Water Canyon Formation (Williams, 1948, p. 1138). Since that time detailed study of the Water Canyon Formation has not been made. It is the purpose of this investigation to describe in detail the lithology and paleontology of the formation and their implication as to the environment of deposition of Early Devonian time in northeastern Utah.

Data were secured for this work during the summer and early fall of 1962. Nine stratigraphic sections of the Water Canyon were measured. Two sections each were measured at Logan and Blacksmith Fork canyons, in the Bear River Range. Other sections were measured at Water Canyon, a tributary to Green Canyon 14 miles northeast of Logan, Utah; at Coldwater Canyon in Wellsville Mountain, 14 miles southwest of Logan; at Portage Canyon in the Blue Springs Hills, 2 miles west of Portage, Utah; at Old Laketown Canyon, 1 mile south of Laketown, Utah; and on the east flank of the southern Promontory Range in Box Elder County, Utah. The measured sections are reproduced in the appendix and an index map to sections measured or cited from other authors is shown in Figure 1.



1. Blacksmith Fork Canyon (east)
2. Blacksmith Fork Canyon (west)
3. Logan Canyon (east)
4. Logan Canyon (west)
5. Water Canyon
6. Coldwater Canyon
7. Portage Canyon
8. Old Laketown Canyon
9. Southern Promontory Range
10. Wheatgrass Canyon (Smith, 1960)
11. Bloomington Canyon (Armstrong, 1953)

Figure 1. Index map to northeastern Utah showing the location of measured sections.

The stratigraphic sections were measured with a steel tape and a Brunton compass. Thicknesses were calculated by use of formulae presented by Palmer (1918, p. 122-128) and Mertie (1922, p. 39-52). An attempt was made to standardize descriptions of stratigraphic units. Color was determined with reference to the "Rock-Color Chart" (Goddard et al., 1948). Terminology used for bedding characteristics was taken from Ingram (1954) as modified from McKee and Weir (1953).

Laboratory investigations were conducted to determine the percentage of insoluble residue and the identity of the residue minerals from the Water Canyon Formation. No attempt was made to determine the percentage of grain-size fractions other than by eye estimation under the binocular microscope.

Geologic setting

The geology of the Logan, Utah area and vicinity is typical of the Basin and Range Province. The mountain ranges trend north-south and are composed of some 20,000 feet of Paleozoic rocks which were deposited in the Cordilleran geosyncline. The deep valleys have been filled with alluvium thus disrupting the continuity of outcrops of Paleozoic rocks. This factor greatly hinders study of facies change.

The Paleozoic strata composing the Bear River Range have been folded into a symmetrical syncline that trends approximately N. 22° E. The syncline has been referred to as the Logan Peak syncline (Williams, 1948, p. 1148). The syncline is nearly parallel to the East Cache fault which controls the western front of the range. Many deep canyons dissect the Bear River Range furnishing excellent exposures of the lower Paleozoic strata on the west and east flanks of the syncline.

External stratigraphic relations

In the Bear River Range the Devonian system is represented by 2,300 feet of rocks comprising the Jefferson and Water Canyon formations (Williams, 1948, p. 1121). Disconformably underlying the Devonian strata is the Laketown Dolostone of Middle Silurian age. The Laketown consists of about 1,500 feet of medium- to dark-gray-weathering dolostone that weathers so as to form ledges. The formation contains a prolific marine fauna suggesting a Niagran age (Nolan, 1935, p. 18). The Water Canyon Formation overlies the Laketown without angular discordance and the contact is not distinct in northeastern Utah. In most outcrops the upper few feet of Laketown are apparently bleached to light-gray color and the lower beds of the Water Canyon also weather light gray. However, with the use of the hand-lens abundant detrital grains can be seen in Water Canyon strata. In opposition to this the dolostone of the Laketown is nearly free from detritus. A difference in resistance to weathering exists between the Laketown and Water Canyon Formation and on this basis the contact between the two formations is placed at a distinct change in slope between the thick-bedded resistant Laketown beds and the relatively less resistant Water Canyon beds.

The Water Canyon Formation, named by Williams in 1948, was defined as argillaceous dolostone and buff-weathering-sandstone disconformably underlying the Jefferson Formation and disconformably overlying the Middle Silurian Laketown Dolostone. The Water Canyon had previously been included in the Jefferson Formation (Richardson, 1941, p. 19; Cooley, 1928, p. 12). The Water Canyon Formation is disconformably overlain by the Hyrum Dolostone Member of the Jefferson Formation of Late Devonian age. The upper part of the Water Canyon is dolomitic sandstone breccia and limestone breccia that weathers light brown and light blue, respectively. The base of the Hyrum Dolostone is fossiliferous limestone that weathers dark gray. At Old Laketown Canyon and in the southern Promontory Range the upper breccia of the Water Canyon is absent and the contact is placed at the base of the dark-gray-weathering limestone of the Hyrum Dolostone. At all localities visited the contact between the Water Canyon and Jefferson formations is distinct and no angular discordance is recognized. Beus (1963, p. 29) states that in the Blue Springs Hills of north-central Utah and south-central Idaho the Water Canyon-Jefferson contact is disconformable and locally displays several inches of relief. A chart showing a diagrammatic representation of the stratigraphic relationships between the Middle Silurian, Upper Devonian, and typical Water Canyon Formation is produced in Figure 2.

Cooley (1928) was apparently the first to describe in detail the stratigraphy of the Devonian system of northeastern Utah. Cooley recognized the Jefferson Formation as 2,400 feet of dolostone and quartzitic sandstone in Blacksmith Fork Canyon, 2,000 feet north of Logan, and about 1,500 feet at Wellsville Mountain 14 miles west of Logan (Cooley, 1928, p. 12). The Jefferson Formation was named by Peale (1893, p. 27) for exposures near

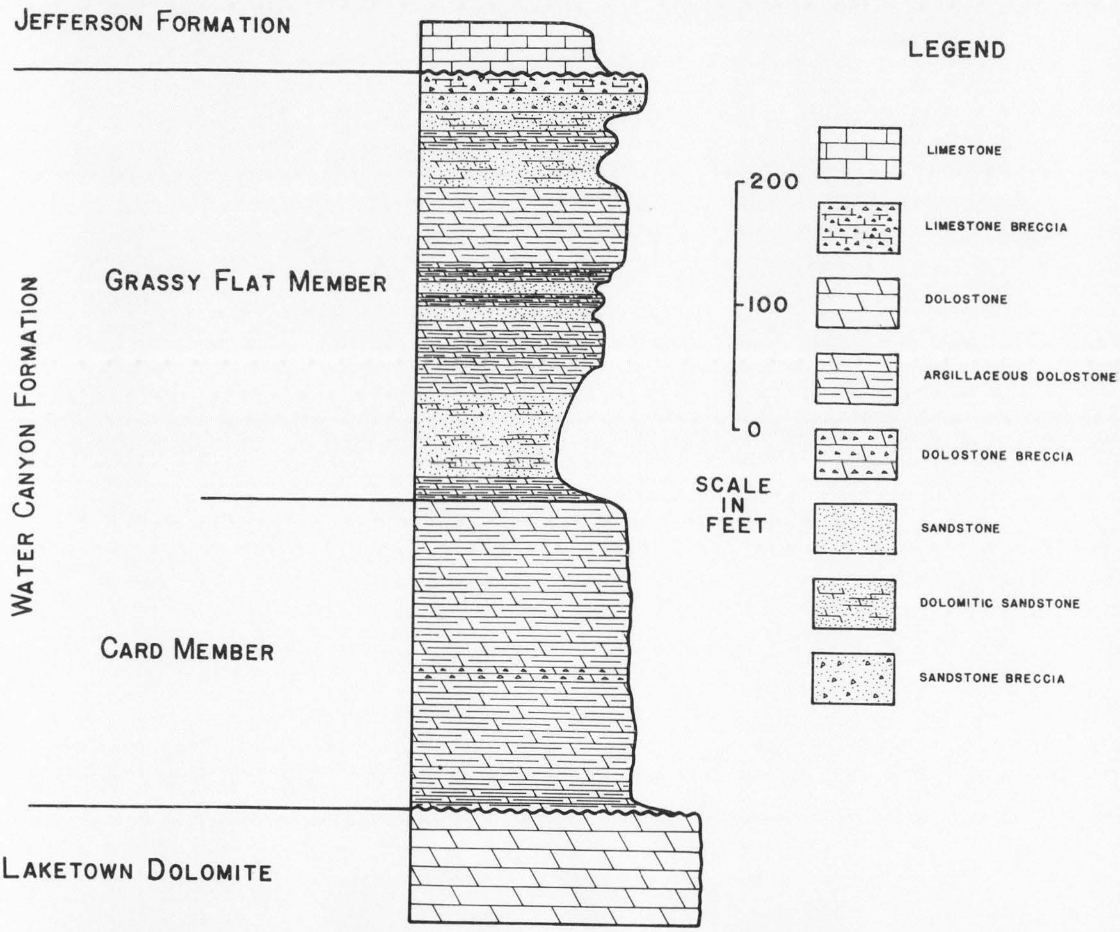


Figure 2. Diagrammatic representation of the relationships between Silurian and Devonian formations showing general lithology and relative resistance to erosion of various units.

Three Forks, Montana. The formation was defined as a magnesian limestone with a wide distribution in Montana, Idaho, Wyoming, and Utah. The fauna of the Jefferson has been described in some detail by Kindle (1908).

WATER CANYON FORMATION

General statement

The Water Canyon Formation was named by Williams in 1948 (Williams, 1948, p. 1138) for exposures in Water Canyon, a tributary to Green Canyon, 4 miles northeast of Logan. Williams recognized two members in the formation: (1) a lower argillaceous dolostone member, and (2) an upper sandstone member that weathers buff in color.

When the formation and the two members were first defined the two members were not measured at the same locality. This situation has led some authors to speculate that the two members are actually lateral facies rather than superposed members (Denison, 1952, p. 265-266; Beus, 1963, p. 27). In opposition to this hypothesis this author has found both members to be present in a superposed relationship at all occurrences visited.

Sufficient information is now available concerning the two members to warrant member names. Member names are proposed for the lower and upper members of the Water Canyon Formation on the basis of: differential weathering of the two members, characteristic weathering color, percentage of insoluble residue, and the occurrence of abundant sand-size quartz grains in the upper member.

Card Member

The name Card Member is proposed for the lower member of the formation for exposures in the vicinity of Card Canyon Ranger Station 6.8 miles from the mouth of Logan Canyon. The member is well exposed on a south facing slope about 80 yards northwest from the Card Canyon Ranger Station.

The Card Member of the Water Canyon Formation is composed of light-gray-weathering argillaceous dolostone and intraformational breccia. The beds are commonly medium to thick bedded in the lower part and laminated in the upper part. The rock is generally compact and has moderate resistance to erosion. Ledges and cliffs are fairly common but not so much so as in the underlying Laketown Dolostone. The upper laminated part of the member weathers into beds of thick to moderate thickness.

In Green Canyon the lower part of the Card Member contains chert beds from 3 to 8 inches thick. The beds are laterally discontinuous and generally pinchout after 10 to 20 feet. The chert weathers moderate brown in color.

The lower part of the Card Member contains about 43 percent insoluble residue. The residue is composed of clay-size detrital quartz grains. Occasionally a sand-size quartz grain is observed in the rock. The larger grains comprise less than 3 percent of the total volume of the rock. The grains are commonly frosted and pitted suggesting deposition by wind action.

In northeastern Utah the upper part of the Card Member is almost entirely laminated in beds one-eighth to one-quarter inches in thickness.

The laminated beds contain about 48 percent silt- and clay-size detrital quartz grains. The detrital grains in the laminated beds are size-sorted in each laminae. At the base of each laminae silt-size detrital grains are concentrated and grade upwards to clay-size grains at the top of the laminae.

The silt-size quartz particles that occur in the Card Member are well rounded and lack frosted and pitted surfaces suggesting that the smaller detrital grains may have been partly dissolved on their outer surfaces thus removing any evidence of transportation from the source area. The average insoluble residue content of the Card Member is 45 percent.

Occasionally a sand-size quartz grain is seen at the base of a laminae. The larger grains are frosted and pitted similar to the larger grains in the lower part of the member. The sand-size grains are not abundant and comprise less than 3 percent of the total volume of the rock. The laminated beds in the Card Member weather slightly darker in color than the lower beds.

The laminae in the upper part of the Card Member are commonly folded or otherwise distorted and at some localities miniature thrust faults have been formed. The distorted laminae suggest that the sediments were deformed while still in a plastic state. Apparently the sediments were deformed under the influence of gravity on gently dipping water-saturated surfaces. A photograph showing a hand sample from the Card Member exhibiting folding and miniature thrust faulting of the laminae is shown in Figure 3.

Locally the Card Member contains intraformational breccia. The breccia is composed of laminated argillaceous dolostone fragments that

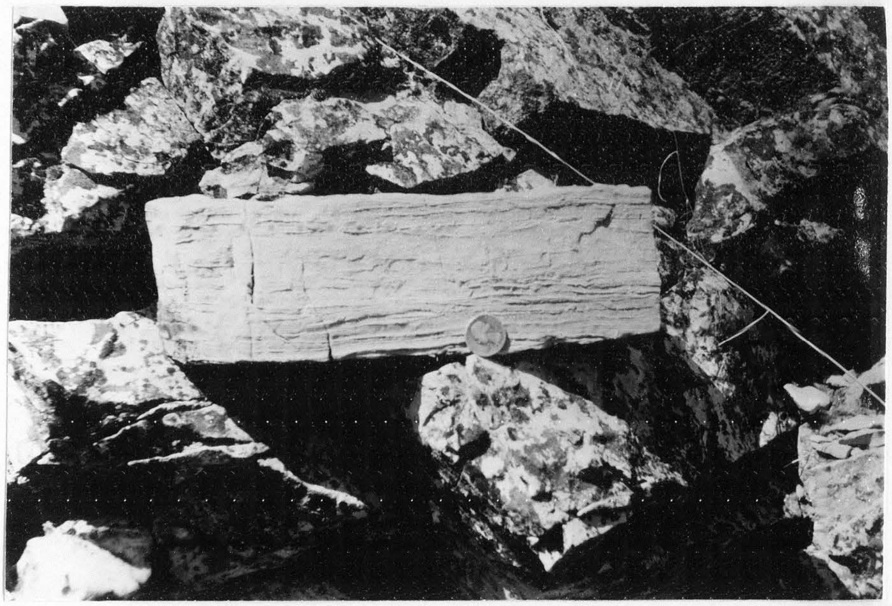


Figure 3. Photograph of hand sample from upper part of Card Member showing typical laminae distorted by contemporaneous deformation.

weather light gray in color. The fragments are angular shaped and range in size from one-quarter inch to 1 inch in diameter. The fragments are often laminated in the same manner as is characteristic of the upper part of the Card Member. The matrix of the breccia is composed of the same material as the fragments. The intraformational breccia occurs in beds 1 inch to 4 feet in thickness. The beds are moderately resistant to erosion. The intraformational breccia probably formed in a similar manner as the folded and distorted laminae.

When the insoluble residue from both the lower and upper parts of the Card Member is observed under a binocular microscope small black specks can be seen. Qualitative chemical analysis showed that the black material was carbon. The carbon particles are not common in the Card Member. The particles compose about 1 part per 8 hundred of the total volume of insoluble residue.

In Green Canyon and Logan Canyon the Card Member contains abundant stylolites occurring normal to the bedding planes. The stylolites are generally 6 to 12 inches long and stand out in relief on weathered surfaces. It is common to find detrital quartz grains concentrated along the stylolites surfaces. This suggests that the stylolites were formed by dissolution of the carbonate in the rock thus allowing the concentration of the insoluble grains along the stylolite surfaces.

Mud cracks occur in the middle part of the Card Member at Portage Canyon and Water Canyon. The mud cracks are polygonal shaped and from 3 to 6 inches across. Detrital grains are sometimes concentrated along the mud-cracked surfaces.

The Card Member thins to the northeast. At Logan Canyon the member is 251 feet thick and at Old Laketown Canyon, 24 miles to the east, 69 feet thick. An isopach map of the Card Member is illustrated in Figure 4. Photographs of typical outcrops of the Card Member are shown in Figures 5 and 6.

Grassy Flat Member

The name Grassy Flat Member is proposed for the upper member for exposures on the east side of Grassy Flat Canyon, a tributary to Logan Canyon 1.7 miles from the canyon mouth. At this locality the member is well exposed along an east-trending ridge about 80 yards from the Logan Canyon road.

The Grassy Flat Member is composed of interbedded calcareous sandstone, arenaceous dolostone, intraformational breccia and some argillaceous dolostone. Also some minor amounts of dolomitic calcarenite and calcarenite occur in the upper part.

The contact between the Card Member and the Grassy Flat Member is distinct. The top of the Card Member is characteristically light-gray weathering argillaceous dolostone while the base of the Grassy Flat Member weathers light to moderate brown, slightly silty dolomitic sandstone. The lowermost beds of the Grassy Flat Member contain abundant fish fragments and less common plant and invertebrate remains. The contact is further marked by a change in slope between the moderately resistant Card Member

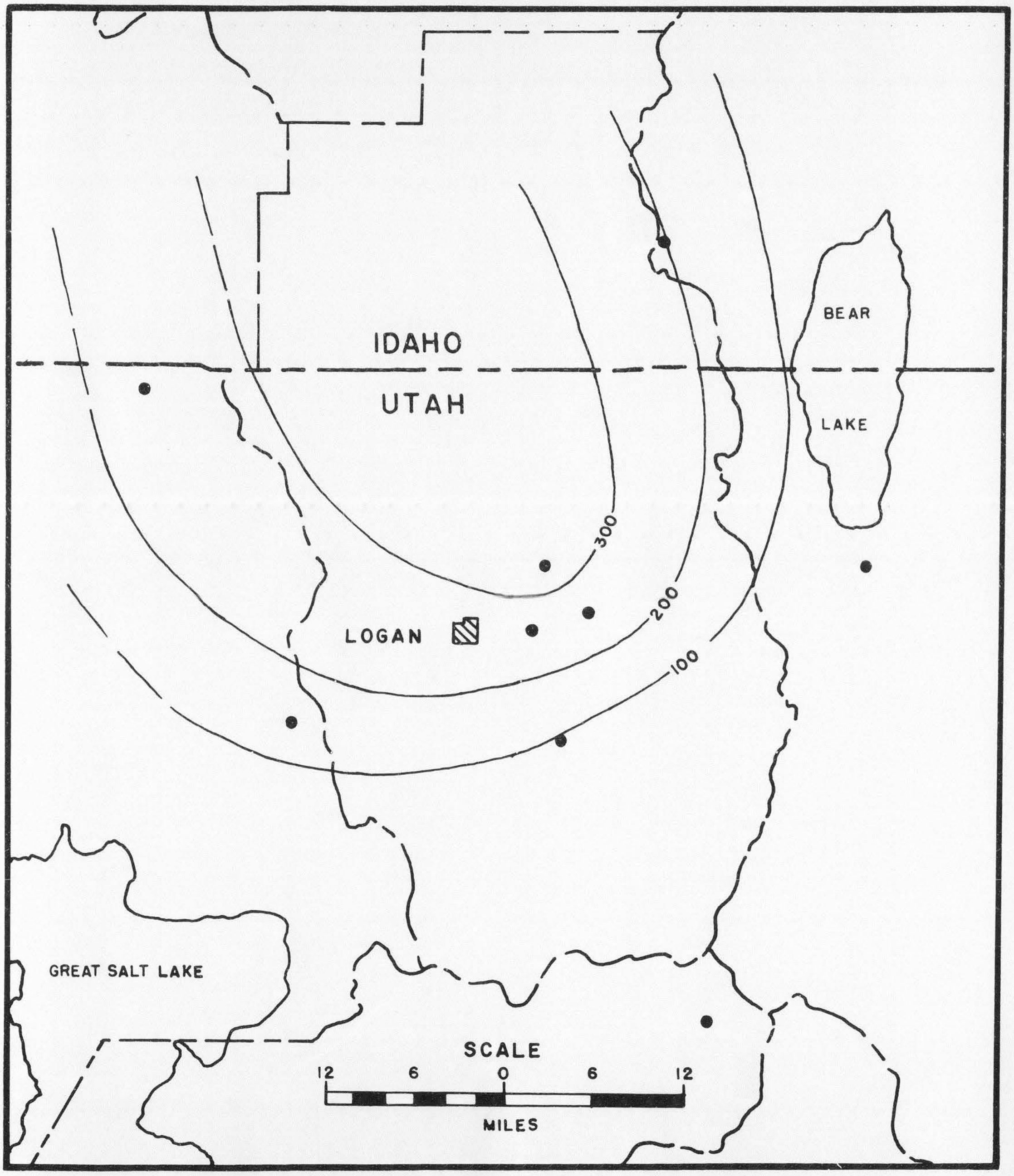


Figure 4. Isopach map of Card Member.

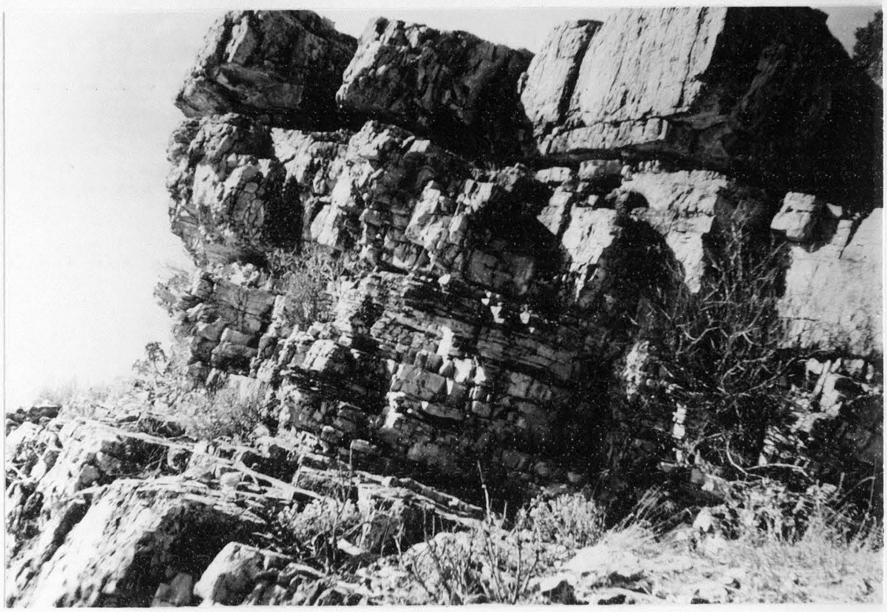


Figure 5. Typical outcrop of upper part of Card Member showing strata weathering so as to form medium to very thick beds. All beds shown are laminated. Photograph taken at Green Canyon looking north.

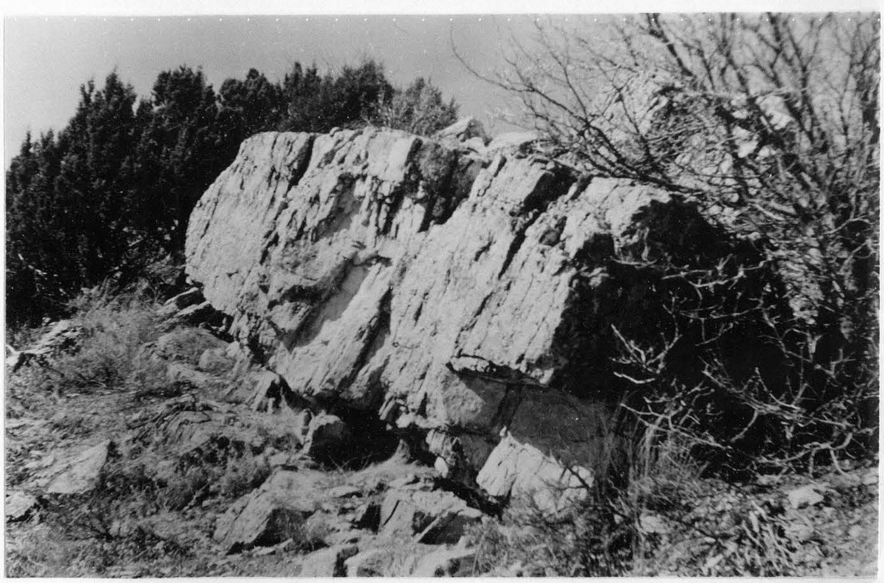


Figure 6. Typical outcrop of lower part of Card Member showing very thick bedded non-laminated argillaceous dolostone. Photograph taken at Green Canyon looking north.

strata and the less resistant Grassy Flat strata.

The Grassy Flat Member was found to contain about 55 percent sand-size quartz grains. This average content is 10 percent greater than the percentage of detritus in the Card Member. The significant difference between the two members, however, is that the detritus in the Grassy Flat Member is almost entirely sand-size quartz grains as opposed to predominantly clay- and silt-size grains in the Card Member.

The lower part of the Grassy Flat Member is composed of silty dolomitic sandstone interbedded with minor amounts of argillaceous and arenaceous dolostone. The dolomitic sandstone beds commonly weather light to moderate brown in color and exhibit poor resistance to erosion. Some dolomitic sandstone beds are darker brown in color due to a relatively higher concentration of organic debris. Both the argillaceous dolostone and dolomitic sandstone strata are thin bedded.

Some thin shale beds occur in the lower part of the Grassy Flat Member. The shale is dark gray to black and occurs as an occasional interbed in silty dolomitic sandstone. The shale beds have not been observed to exceed 2 inches in thickness. Two shale beds occurring in Section 3 (Appendix) have yielded carbonaceous impressions of plants.

Above the interbedded argillaceous and arenaceous dolostone and dolomitic sandstone beds is an interval of arenaceous dolostone that weathers moderate brown in color. The unit is thick bedded for the most part but some laminated beds do occur. The arenaceous dolostone of the Grassy Flat Member contains abundant sand-size quartz grains. The quartz grains are frosted and pitted suggesting that they were deposited by wind action similar to the sand-size detrital grains occurring in the Card Member.

Above the arenaceous dolostone is a unit of calcareous sandstone that weathers light brown in color. The sandstone is composed of sand-size quartz grains. The unit exhibits well developed cross-bedding in the Grassy Flat Canyon section. At other localities the cross-bedding is weakly developed.

At Coldwater Canyon in the Wellsville Mountain and at Water Canyon the sandstone unit contains iron sulfide concretions ranging in size from 1 to 4 inches in diameter. The concretions are commonly oxidized on the outer surface to a dark reddish brown color. Where the concretions occur the rock around them is stained a dark reddish brown color.

Above the calcareous sandstone beds occurs a thin bed of dolomitic calcarenite. The dolomitic calcarenite is coarse grained and weathers to a dark bluish-gray color. The bed is thin and rarely exceeds 8 inches in thickness. The dolomitic calcarenite bed has been observed in the Water Canyon, Logan Canyon, and Old Laketown Canyon sections.

Near the top of the Grassy Flat Member occurs a unit consisting of dolomitic sandstone breccia. The sandstone breccia bed ranges in thickness from 0 to 30 feet and weathers to a light- to moderate-brown color. The fragments in the breccia are angular to subangular and range in size from 1 to 8 inches in diameter. The fragments are composed of dolomitic sandstone that weathers light to moderate brown in color. A great number of the fragments are laminated in beds one-eighth to one-quarter inches thick.

The matrix of the breccia is composed of the same material as the fragments and is also light to moderate brown in color. The matrix effervesces freely with dilute hydrochloric acid suggesting that the cementing material is calcium carbonate. In the Blacksmith Fork Canyon sections small vugs in the breccia have been filled with white-weathering and some brown-weathering calcite.

Above the dolomitic sandstone breccia is a limestone breccia bed ranging in thickness from 6 to 8 feet. The limestone breccia is composed of moderate bluish-gray-weathering limestone fragments ranging from 1 to 8 inches in diameter. The limestone fragments are angular to subangular in shape. The matrix of the limestone breccia is composed of moderate bluish-gray limestone of the same composition as the fragments. In both the dolomitic sandstone breccia and the limestone breccia faint bedding can be recognized. The breccia may represent sediments deposited in a shoal and later disrupted by waves when only partly lithified.

The limestone breccia occurs in all sections measured except in the southern Promontory Range and at Old Laketown Canyon. Photographs showing typical outcrops of the breccia units are shown in Figures 7, 8, and 9.

Throughout the Grassy Flat Member mud cracks and interference ripple marks are common. In Blacksmith Fork Canyon, well-developed polygonal mud cracks are found as large as 6 inches in diameter and 5 inches deep. These particular mud cracks are found in calcareous sandstone beds just below the sandstone breccia unit in Section 2 (Appendix). A photograph showing typical mud cracks from the Grassy Flat Member is shown in Figure 10.

Figure 7. Close-up of typical limestone breccia from upper part of Grassy Flat Member. Photograph taken at Logan Canyon on the west flank of the Logan Peak syncline.

Figure 8. Close-up of typical dolomitic sandstone breccia from upper part of Grassy Flat Member. Photograph taken at Logan Canyon on west flank of Logan Peak syncline.

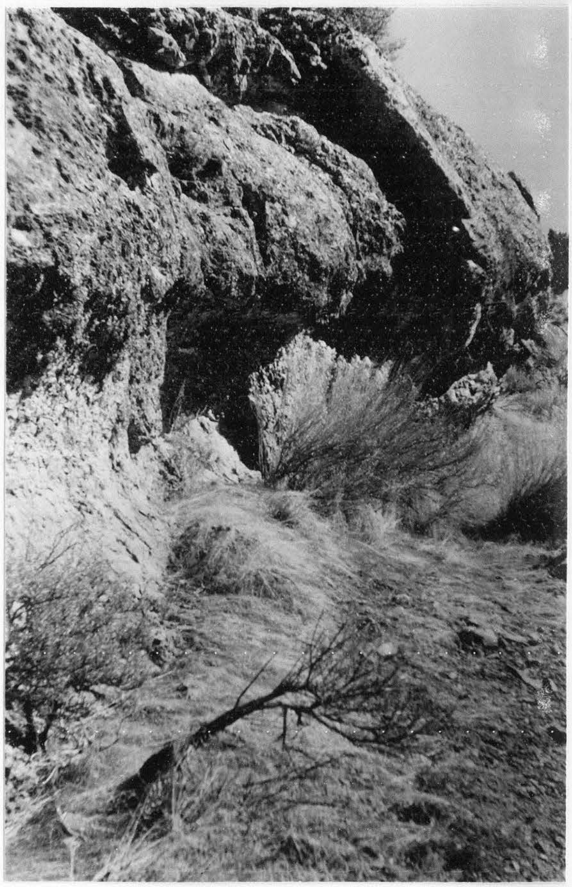


Figure 9. Typical outcrop of limestone and dolomitic sandstone breccia from the upper part of Grassy Flat Member. Resistant ledge is limestone breccia, less resistant bed is dolomitic sandstone breccia. Bush in center of photograph is about 24 inches high. Photograph taken at Blacksmith Fork Canyon looking north.

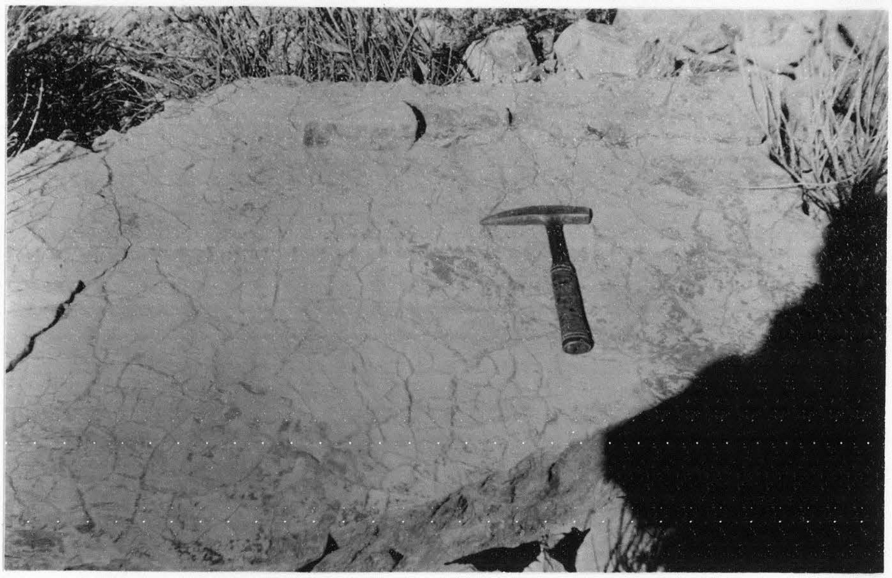


Figure 10. Typical mud cracks from upper part of Grassy Flat Member. These particular mud cracks occur at base of dolomitic sandstone breccia near the top of member. Photograph taken in Blacksmith Fork Canyon on west flank of Logan Peak syncline.

The contact between the Water Canyon Formation and the Hyrum Dolostone Member of the Jefferson Formation is placed between the limestone breccia unit of the Grassy Flat and dark gray limestone beds locally characteristic of the Hyrum. The base of the Hyrum contains a well-developed marine fauna of Late Devonian age described by Williams (1948, p. 1140).

The Grassy Flat Member ranges in thickness from 150 to 530 feet in the northeastern Utah area. The member shows a rapid thinning to the east. At Wellsville Mountain the member is 527 feet thick while to the east at Old Laketown Canyon the member is 152 feet thick. An isopach map of the Grassy Flat Member is shown in Figure 11. Photographs of typical outcrops of the Grassy Flat Member are shown in Figures 12 and 13.

Areal distribution

The Water Canyon Formation and its correlatives have a wide distribution in Nevada, Utah, Idaho, Wyoming, and Montana. An isopach map showing the thickness distribution of the Sevy Dolomite and related units is presented by Osmond (1962, p. 2050). The isopach map shows a general thinning of lower Devonian strata from west to east. The Sevy Dolostone apparently attains maximum thickness in central Nevada south of the Eureka area where the formation is 1,400 feet thick. In west-central Nevada the Sevy has apparently been removed from the Antler orogenic belt and may be represented by eugeosynclinal facies thrust in from the west (Osmond, 1962, p. 2052). To the south, in Clark County, Nevada, the Sevy thins from 1,100 to 0 feet thickness in about 60 miles (Osmond, 1962, p. 2050). In central

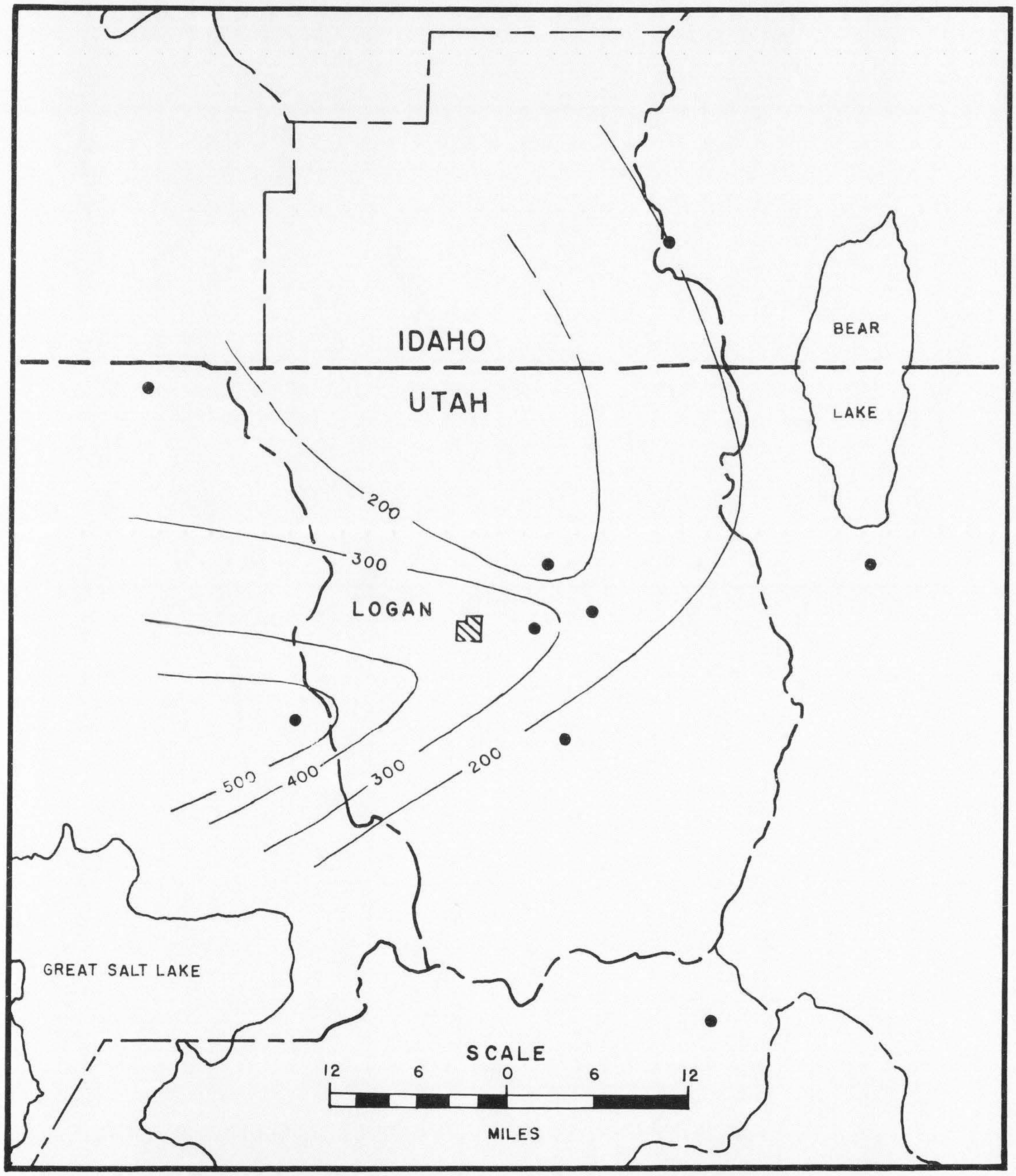


Figure 11. Isopach map of Grassy Flat Member.

Figure 12. Typical outcrop of Grassy Flat Member showing contact with Card Member. Note resistant breccia beds at top of Grassy Flat Member. Photograph taken at Logan Canyon on the east flank of the Logan Peak syncline looking northeast.

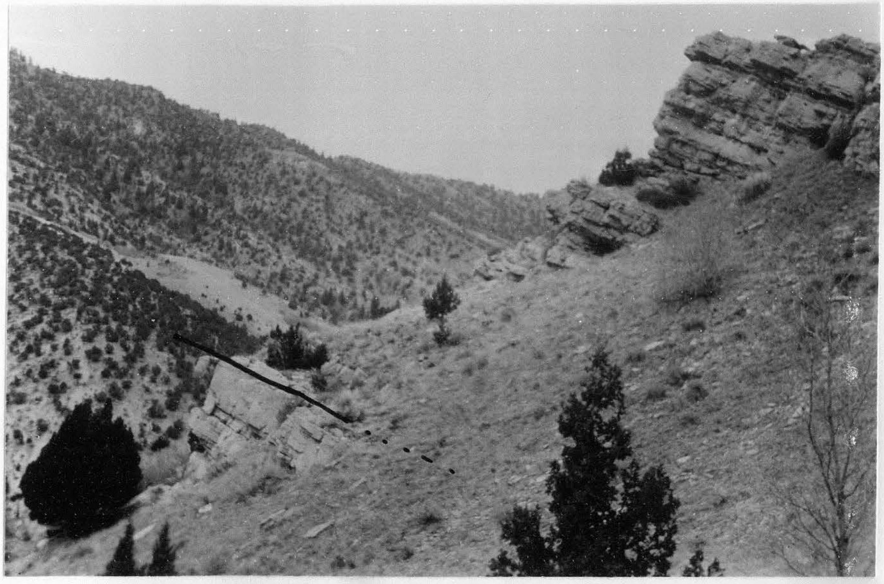


Figure 13. Outcrop of Grassy Flat Member showing contact with Card Member. Resistant beds in upper right of photograph are cross-bedded sandstone. Upper contact of Grassy Flat Member is not shown. Photograph taken in Logan Canyon on west flank of syncline looking east.

Arizona, deposits similar to the Beartooth Butte Formation have been described by Teichert and Schopf (1958). The deposits are marginal to the Sevy-Water Canyon miogeosyncline and may represent the southernmost occurrence of Early Devonian strata.

In central Utah the Sevy Dolostone thins from about 1,000 feet in west-central Utah to 0 feet in the central Wasatch Mountains. In northwestern Utah Early Devonian rocks are absent, probably because of post-depositional erosion. In northeastern Utah the Water Canyon Formation ranges in thickness from 245 to 683 feet. The thinning is generally to the east and to the south. At Coldwater Canyon, in Wellsville Mountain 14 miles west of Logan, the Water Canyon Formation is 683 feet thick and at Old Laketown Canyon, 24 miles east of Logan, the formation is 253 feet thick. Southward from Logan Canyon the Water Canyon Formation thins rapidly. At East Canyon, 15 miles south of Logan, the Water Canyon Formation is less than 40 feet thick. At Mantua, about 25 miles southwest of Logan, the Devonian system is absent and the Mississippian Lodgepole Limestone rests directly on Laketown Dolostone (Williams, 1948, p. 1141). An isopach map of the Water Canyon Formation is shown in Figure 14.

In Idaho the Water Canyon Formation thins to the north and east. The formation is 214 feet thick in the Chesterfield Range, northeastern Bannock County, and thins to 86 feet in the Snake River Range, east-central Bonneville County (Williams, 1955, p. 46). In northeastern Idaho, in the southern Beaverhead Range, Scholten (1957, p. 159) states that the Silurian Laketown Dolostone is absent and a few isolated exposures of light-colored dolostone

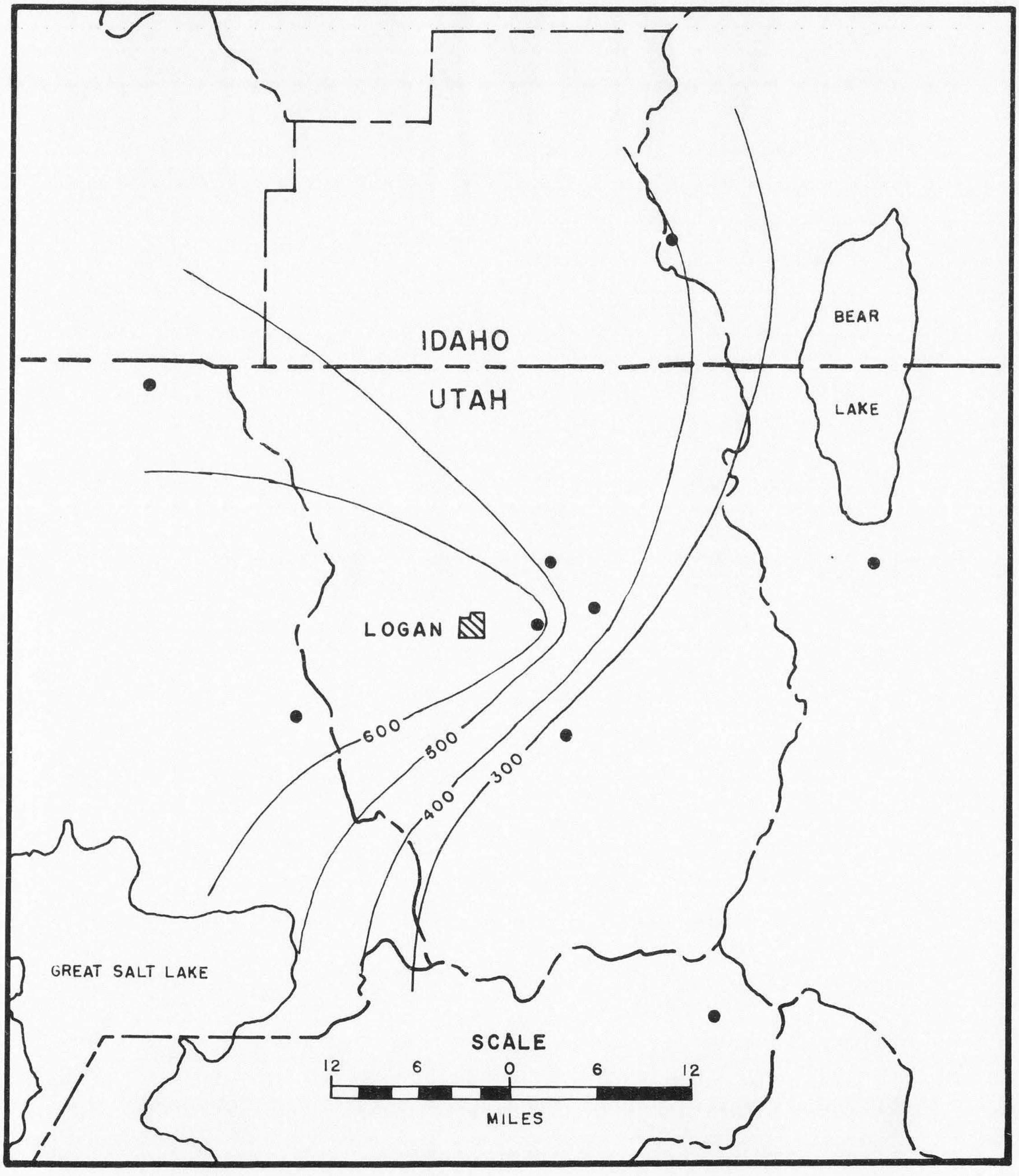


Figure 14. Isopach map of Water Canyon Formation.

occur overlying the Ordovician Kinnikinic Formation. Scholten (1957, p. 159) believes that the light-weathering dolostone belongs to the Jefferson Formation. However, the thin deposits may represent an equivalent of the Water Canyon Formation. If this is the case the strata may represent the northernmost occurrence of the Water Canyon Formation.

In northwestern Wyoming and southwestern Montana the Early Devonian Beartooth Butte Formation ranges in thickness from 0 to 150 feet (Sandberg, 1961, p. 1301). The Beartooth Butte Formation is a channel fill deposit that thins to the northeast (Sandberg, 1961, p. 1302). The formation probably represents sediments deposited along the northeastern margin of the Sevy-Water Canyon depositional basin.

Positive elements active during Early Devonian time have controlled the thickness distribution of the Sevy and Water Canyon formations. The Tooele arch of western Utah probably had positive tendencies during Early Devonian time (Osmond, 1962, p. 2049). This positive element may be responsible for the thinning of Sevy strata northward from west-central Utah. Southeastern Utah was probably also a highland during the Devonian. Rigby (1959) describes an uplift that was active in Late Devonian time in central Utah. The general thinning of lower Devonian strata to the south in the Bear River Range may indicate that the strata have been removed by erosion from the northern flank of the uplift.

Paleontology

The Water Canyon Formation is noted for a prolific fish fauna described in detail by Branson and Mehl (1931) and Denison (1952, 1953, 1956, 1958). The assemblage consists mostly of ostracoderm forms but some placoderms do occur.

The fish fauna occurs within the lower 10 feet of the Grassy Flat Member. This is the only interval within the formation from which fossil fish have been found by the author. No fossils have been found in the Card Member of the Water Canyon Formation by the author. The following genera and species have been collected from the Grassy Flat Member and identified by the author, unless otherwise stated, during this investigation:

Allocryptaspis utahensis Denison

Cardipeltis wallacii Branson and Mehl

cf. Protaspis sp.

cf. Protaspis n. sp.

cf. Glossoidaspis giganteus Branson and Mehl

Acanthaspida gen. and sp. indet.

A specimen identified as Allocryptaspis utahensis consists of a dorsal plate showing well preserved lengthwise ornamental striations. The dorsal plate is somewhat oval in outline and highly convex in shape on the dorsal surface. The orbital plates are not preserved due to abrasion on the lateral margins of the dorsum.

Cardipeltis wallacii was identified from an exceptionally well-preserved specimen of a cephalic plate. The specimen consists of the internal and external molds of the dorsal-cephalic region. The mineralized skin is also intact between the two molds. The cephalic plate of C. wallacii is subcardiform in shape with the length and width about equal. Orbital notches occur at about midlength on the lateral margins of the plate (Branson and Mehl, 1931, p. 517). The surfical ornamentation consists of moderately-coarse closely spaced vermiform ridges. The interior mold shows impressions of laterally radiating growth rings spaced about one-eighth inch apart. A photograph showing the cephalic plate and growth rings of C. wallacii is produced in Figure 15.

Two of the specimens from the lower part of the Grassy Flat Member in Logan Canyon were identified by Denison (1963, personal communication). The first specimen represents the dorsal plate of cf. Protaspis sp. The second specimen represents a heretofore undescribed pteraspid with important differences from the genus Protaspis. The specimen is characterized by an oval-shaped highly convex dorsal shield with an erect, slender dorsal spine. The specimen represents a new species and possibly a new genus.

Glossoidaspis giganteus was identified from numerous partial cephalic plates and ornamented surfical fragments. The ornamentation of the skin material consists of closely spaced coalescing striations. The striations are similar to those found in Allocryptaspis but are finer and coalesce more frequently. Complete plates of G. giganteus were not found. However, fragments of cephalic plates closely resembling specimens presented by Branson and Mehl (1931, p. 525) are common.

Associated with G. giganteus are abundant spines. The spines are nearly straight and range in length from 1 to 3 inches. The spines are oval in outline and hollow thus forming a rounded v-shaped cross section.

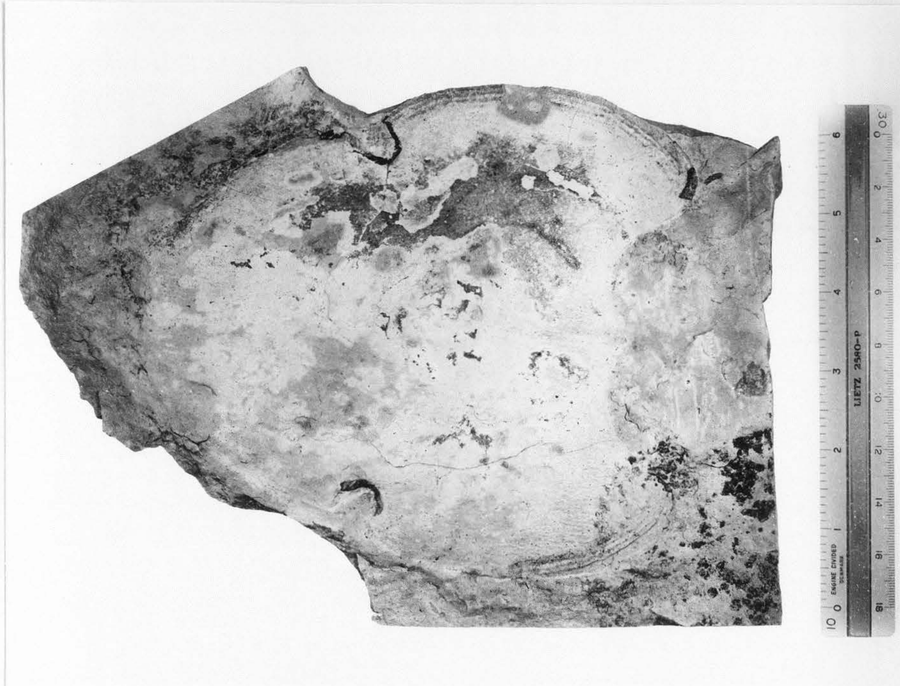


Figure 15. Photograph of Cardipeltis wallacii showing superior view of cephalic plate (internal mold).

Figure 16. Photograph of Glossoidaspis giganteus (?) showing partial plates and dermal fragments.

Although spines have not been found attached to body fragments they are commonly associated with Glossoidaspis remains (Branson and Mehl, 1931, p. 528). Assorted dermal fragments and partial cephalic plates identified as G. giganteus are reproduced in Figure 16, page 30.

Occasionally in the lower part of the Grassy Flat Member small fragments occur that show some characteristics of Camptaspis and Aspidichtys. The specimens, however, are highly fragmental and are not large enough to warrant generic or specific classification. The fragments consist of nodose dermal material and broken nodose spines. Due to the indeterminate nature of the specimens they have been referred to as Acanthaspida.

Nearly all the fish fragments from the Water Canyon Formation consist of abraded fragments and no articulate specimens were found. Some silty sandstone beds contain as much as 30 percent total volume of worn fish parts. A photograph showing the abundant abraded fish fragments is reproduced in Figure 17.

Invertebrate fossil remains have been found in two stratigraphic positions within the Water Canyon Formation. The first occurrence is in the lower 10 feet of the Grassy Flat Member. In Logan Canyon unidentified pelecypods were found associated with fish remains. At the same locality the brachiopod Lingula was also found to occur. In Portage Canyon unidentified gastropods were found in a thin dark-gray dolostone bed about 60 feet below the upper contact of the Grassy Flat Member. Invertebrate fossils recovered by the author from the Water Canyon Formation are tabulated below:

Figure 17. Photograph of typical abraded fish fragments from lower 10 feet of Grassy Flat Member.

Lingula sp.

Pelecypoda gen. and sp. indet.

Gastropoda gen. and sp. indet.

Lingula most commonly occurs in thin argillaceous dolostone beds interbedded with the silty dolomitic sandstone near the base of the Grassy Flat Member. Pelecypods, the most abundant invertebrate in the formation, occur as molds preserved along bedding planes in the silty dolomitic sandstone in the lower 10 feet of the Grassy Flat Member.

Plant fossils have been found in thin shale beds interbedded with fish-bearing silty dolomitic sandstone beds in the lower 10 feet of the Grassy Flat Member. Dorf (1963, personal communication) indicates that some of the plant remains show certain similarities with the early vascular plant *Psilophyton*. The delicate plant impressions are not well preserved therefore making specific or generic classification difficult. To date these plant specimens are the first plant fossils reported from the Water Canyon Formation.

The occurrence of fossil plants is unlike other fossil occurrences in the Water Canyon Formation in the respect that the plants are preserved as delicate carbonaceous impressions that have not been abraded. This may suggest that the plants were preserved in place rather than transported as seems to be the case for the fish fragments.

Age

Fish fossils and stratigraphic position are the only criteria from which an age assignment can be given the Water Canyon Formation. The fish genera Glossoidaspis and Protaspis strongly suggest an Early Devonian age for the formation (Branson and Mehl, 1931, p. 530). Cardipeltis also supports an Early Devonian age (Bryant, 1933, p. 287). Bryant (1934, p. 158) has compared the fish fauna of the Beartooth Butte Formation with a highly similar fauna from Early Devonian strata near Overath, Germany, and concluded that the Beartooth Butte is Early Devonian age. The occurrence of similar faunas in the Beartooth Butte and Water Canyon formations strongly suggests an Early Devonian age for the Water Canyon. Further study of plant fossils from the Water Canyon Formation may furnish new evidence of the age of the formation.

The stratigraphic position of the Water Canyon Formation and the correlative Sevy Dolostone suggests an Early Devonian age. The occurrence of Halysites at the base of the Sevy (Osmond, 1954, p. 1928) suggests a Silurian age but the occurrence of Middle Devonian fossils in the Simonson Formation, which is interbeeded with the upper part of the Sevy, supports an Early Devonian age for at least the upper part of the formation.

The Sevy-Water Canyon sea probably began a northeastward transgression as early as Late Silurian time. The occurrence of a probable Silurian fauna from the base of the Sevy and the absence of fossils in the Card Member of the Water Canyon may suggest that the base of the Sevy dolostone is older than the base of the Water Canyon Formation.

Because of the extreme lithologic similarity between the Water Canyon and Sevy and similar stratigraphic position an Early Devonian age seems most tenable. An Early Devonian age is given by Williams (1948, p. 1138) and Osmond (1962, p. 2049).

Correlation

The Water Canyon Formation correlates with the Sevy Dolostone of east-central Nevada. The Sevy Dolostone was named by Nolan (1930, p. 427) for exposures in the vicinity of Sevy Canyon in the Deep Creek Mountains south of Gold Hill, Utah. The Sevy consists of a homogeneous well-bedded medium-gray dolostone. The 6- to 12-inch beds weather to a light gray color. Nolan (1935, p. 18) recognized the presence of laminations parallel to the bedding which are visible because of slight variations in color between adjacent laminae. Near the top of the Sevy darker colored dolostone beds occur and some beds contain small nodules of light colored chert (Nolan, 1935, p. 18).

In the area south of Gold Hill Osmond (1954, p. 1914) divided the Sevy Dolostone into two members: (1) a lower argillaceous dolostone member, and (2) an upper sandy member. The Sevy Dolostone ranges in thickness from 500 to 1,600 feet (Osmond, 1954, p. 1914). Osmond described the lower member of the Sevy as a compact laminated argillaceous dolostone overlying the Laketown Dolostone (Osmond, 1954, p. 1914-1915). The laminations contain graded detrital quartz grains which show a high degree of similarity with the laminations in the Card Member of the Water Canyon Formation. Osmond reported an occasional sand-size quartz grain in the argillaceous dolostone. The sand grains are frosted (Osmond, 1954, p. 1920) similarly to frosted and pitted sand grains found in the Card Member. The upper, sandy member of the Sevy, consists of arenaceous dolostone interbedded with argillaceous dolostone (Osmond, 1954, p. 1919-1920). The abundant sand grains in the upper member are frosted and pitted suggesting deposition by wind action. Fossils are rare in the Sevy but Halysites occur in the lower beds of the formation (Osmond, 1954, p. 1928). The Sevy is conformably overlain by the Simonson Dolostone which contains Middle Devonian fossils (Osmond, 1954, p. 1929).

Nolan (1935, p. 19) classified the Sevy as Middle Devonian age because it truncates the upper part of the Laketown Dolostone and is interbedded with the overlying Simonson Dolostone at the top which contains Middle Devonian fossils. In opposition to this classification the Eastern Nevada Geological Association Stratigraphic Committee (1953, p. 146) dated the lower part of the Sevy as Late Silurian and the upper part Early Devonian. The occurrence of Halysites would suggest that at least the lower part of the Sevy is Silurian age (Osmond, 1954, p. 1929).

The striking lithologic similarity between the Water Canyon and Sevy formations and similar stratigraphic positions suggest that a correlation can be made between the two formations. The identification of a lower argillaceous dolostone and upper sandy member in the Sevy adds impetus to the argument for correlation between the two formations.

The Water Canyon Formation can be correlated with the Beartooth Butte Formation of northwestern Wyoming and southwestern Montana on the basis of similar plant fossils and similar fish faunas. The Beartooth Butte

Formation was named by Dorf (1934) for exposures of reddish limestone and calcareous conglomerate at the type locality Beartooth Butte in northwestern Wyoming near the Wyoming-Montana border. The formation was described as an esturarine channel-fill deposit in the Ordovician Big Horn Dolostone.

The Beartooth Butte Formation rests on rocks ranging in age from Precambrian through Ordovician and it is these various rock types that control the lithology of the conglomerate in the formation (Sandberg, 1961, p. 1304-1306). The Beartooth Butte is a thin discontinuous formation usually less than 10 feet thick but local occurrences increase to as much as 150 feet (Sandberg, 1961, p. 1301). An Early Devonian age was assigned the Beartooth Butte Formation by Dorf (1934) on the basis of a fish fauna described in detail by Bryant (1932, 1933, and 1934). The Early Devonian age was further substantiated by a prolific psilophyton flora described by Dorf (1933).

The fish faunas of both the Water Canyon and Beartooth Butte formations have important similarities. The dominance of particular genera and in some cases even species (Denison, 1956, p. 414) is strong evidence for correlation between the two formations. Protaspis, Allocryptaspis, and Cardipeltis occur regularly in both formations (Denison, 1956, p. 414). Further study of plant remains from the Water Canyon Formation may also yield important evidence for correlation between the Water Canyon and Beartooth Butte formations.

Environment of deposition

The environment of deposition of the Water Canyon Formation is difficult to determine because of the scarcity of fossil remains. Some hypotheses can be formed however when the internal structures of the formation and the nature of the fossil remains are considered.

The Card Member of the Water Canyon Formation was probably deposited in a shallow zone of the sea. This is supported by the graded nature of the laminae which suggests that the sediments were repeatedly reworked along the bottom before lithification. The occurrence of mud cracks in the Card Member is also evidence of shallow water. The absence of marine fossils is thought by Denison (1956, p. 414) to indicate conditions were unfavorable for life. Another explanation is that organisms lived but were not preserved because of slow deposition. This hypothesis is supported by the fact that invertebrates that occur in the Grassy Flat Member are very poorly preserved and organic carbon occurs in the Card Member.

The detritus in the Card Member was probably introduced, to a great extent, by wind action. The large frosted and pitted sand grains represent evidence for this type of origin. The silt-size particles have smooth surfaces which may indicate that partial dissolution of outer surfaces has occurred.

The Grassy Flat Member was probably deposited in a somewhat different environment than the Card Member. Abundant mud cracks and cross-bedded sandstone suggest that some subaerial deposition did occur. Oscillation ripple marks are evidence for shallow water. The occurrence of *Lingula* and pelecypods also suggests a shallow depositional environment (Craig, 1952).

The highly fragmental condition of fish fragments in the Grassy Flat Member suggests that the remains represent a thanatocoenose assemblage. Denison (1956, p. 365) asserts that worn and fragmented fossils do not necessarily indicate transportation after death. Fossils could occur in this condition by the action of waves and tides in shallow water. The present author believes, however, that under these conditions fragmentation would not be as extreme as is the case with fish fragments occurring in the Water Canyon Formation. When fish fossils from the Water Canyon Formation are compared with those collected from the Beartooth Butte Formation of northwestern Wyoming a striking difference in their condition is noted. Photographs of fish from the Beartooth Butte presented by Bryant (1933 and 1934) show that these specimens are not worn or fragmented to such a high degree as those in the Water Canyon Formation. In some cases, head, body, and tail sections have been found intact in the Beartooth Butte strata. This evidence plus the fact that the rock containing the Beartooth Butte fossils may be a fluviatile deposit (Dorf, 1934, p. 735-736) leads this author to believe that the Water Canyon-Beartooth Butte fish had a fresh-water origin and that the fish occurring in the Water Canyon Formation were transported after death. A fresh-water origin for early vertebrate forms is supported by A. W. Smith (1932) and Romer and Grove (1935).

Two types of intraformational breccia occur in the Water Canyon Formation. The intraformational breccia in the Card Member was probably formed by subaqueous gravitational sliding of the carbonate mud before lithification. This hypothesis is supported by the occurrence of folded and thrusted laminae that probably also formed in this manner. The dolomitic sandstone breccia at the top of the Grassy Flat Member is much thicker and coarser grained than the breccia occurring in the Card Member. For this reason it is thought that a gravitational mechanism could not be supported for its origin. The dolomitic sandstone breccia is thought to have formed because of periodic storm waves disrupting the sediments in shoal areas. The name "shoal breccia" is given to this type of deposit by Dunbar and Rogers (1958, p. 179). The limestone breccia that occurs above the dolomitic sandstone breccia probably also represents a shoal breccia.

The Beartooth Butte Formation of northwestern Wyoming probably represents some marginal marine and some fluviatile deposits (Dorf, 1934, p. 735-736). The Beartooth Butte lithology and external structures leave little doubt that the formation represents the northeasternmost extension of Early Devonian marine deposition. The shore line was probably contained in the Beartooth Butte Formation.

Source of detritus

Osmond (1954, p. 1926) reported that the source of detritus for the Sevy Dolostone was the eroded Laketown Dolostone and Eureka-Swan Peak quartzite sequence in central Utah and east of the Wasatch Range. The occurrence of detritus in the Sevy and Water Canyon formations supports this hypothesis in the respect that the lower part of the two formations is predominantly dolostone while in the upper part quartz sand grains are abundant (Osmond, 1954, p. 1915). This is an inversion of the quartzite-dolostone sequence of the older rock units. Webb (1953) studied the grain-size distribution in the Eureka Quartzite. Osmond (1954, p. 1926) states that the modal grain-size in the Sevy Dolostone were smaller than those in the Eureka. This suggests that the quartz-sand detritus in the upper member of the Sevy may represent sand derived from the eroded Middle Ordovician quartzites exposed along the flanks of gentle upwarps along the eastern hinge of the Millard belt in Utah (Osmond, 1954, p. 1926), and the area east of the Wasatch Range. Study of cross-bedding in the Sevy has shown that currents ran generally from east to west in Early Devonian time (Osmond, 1962, p. 2054).

SUMMARY

The Early Devonian Water Canyon Formation is disconformably underlain by the Middle Silurian Laketown Dolostone and overlain by the Late Devonian Hyrum Dolostone Member of the Jefferson Formation. The Water Canyon is divided into two members. The lower, Card Member, consists of argillaceous dolostone. The Card Member weathers light gray forms resistant ledges. The upper, Grassy Flat Member, is characterized by interbedded sandstone, arenaceous dolostone, and argillaceous dolostone. The Grassy Flat Member weathers light brown and forms smooth slopes. Both members are recognized throughout the type area, northeastern Utah.

Fossils, collected by the author, were restricted to the lower 10 feet of the Grassy Flat Member. The fossiliferous zone contains a notable fish fauna as well as pelecypods, Lingula sp., and unidentified plants.

The Card Member with its lesser clastic content appears to have been deposited during a transgressive phase of the Early Devonian sea. The Grassy Flat Member was probably deposited during a regressive phase.

The Sevy Dolostone of east-central Nevada, the Water Canyon Formation of northeastern Utah, and the Beartooth Butte Formation of northwestern Wyoming and southwestern Montana, are recognized as correlatives. The formations represent miogeosynclinal facies to the southwest and near shore facies to the northeast.

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APPENDIX

Water Canyon Formation

Section 1

Section measured 0.2 miles north of the forks in Blacksmith Fork Canyon, Utah. The traverse was made near the center of Sec. 3, T. 10 N., R. 2 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
6. Intraformational breccia, fragments subangular to angular, dolomitic sandstone, light gray to moderate gray, 1 to 4 inches in diameter. Matrix calcareous and sandy with some white calcite, some thin-bedded calcareous sandstone, weathering light brown	4
5. Sandstone, calcareous, silty, moderate purple, weathers grayish red-purple, medium-bedded, some intraformational breccia	30
4. Dolostone, laminated, fine-grained, medium to dark gray, weathers medium gray, massive-weathering. Some intraformational breccia in upper part, cemented with calcite	3
3. Covered. Probably calcareous sandstone and interbedded argillaceous dolostone	115
Total thickness . . .	152
Card Member	
2. Argillaceous dolostone, compact, medium gray, weathers very light gray, some laminated beds, more argillaceous in upper part	74
1. Argillaceous dolostone, compact, laminated, medium gray, weathers light gray, weathering medium-bedded .	19
Total thickness . . .	93
Total thickness Water Canyon Formation . .	245

Water Canyon Formation

Section 2

Incomplete section measured 1.1 miles east from the mouth of Blacksmith Fork Canyon, Utah, in the NE 1/4 Sec. 12, T. 10 N., R. 1 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
15. Calcareous sandstone and limestone, interbedded. Sandstone reddish purple, weathers moderate reddish brown. Limestone, medium gray, weathers light gray, in beds 2 to 3 feet thick. Topmost bed intraformational breccia. Fragments dolostone, 1 to 4 inches in diameter, subangular to subrounded. Matrix very light brown, sandy and silty. Some small lenticular shale beds below breccia. Mud cracks common in lower part	21
14. Limestone, fine-grained, light bluish gray, weathers moderate bluish gray. Medium bedded in lower part, thick bedded in upper part	8
13. Argillaceous dolostone, silty, laminated, medium gray, weathers moderate reddish brown. Laminae deformed in parts	7
12. Limestone, laminated, medium gray, weathers very light gray, fine-grained. Upper part weathers medium to dark gray. Some medium bedding in upper part . . .	21
11. Intraformational breccia, medium gray. Fragments one-half inch to 1 foot in diameter, smaller fragments most common. Fragments angular and composed of argillaceous dolostone and limestone. Matrix calcareous with much fine sand and silt	10
10. Interbedded dolomitic limestone and dolostone, thin bedded. Dolomitic limestone, fine-grained, medium gray, weathers light gray, laminated. Laminae about one-quarter inch thick, commonly distorted, many laminae exhibit miniature	

	Thickness (feet)
thrust faults. Dolostone, argillaceous, medium gray, weathers light to medium brown	13
9. Same as Unit 11	9
8. Argillaceous dolostone, silty, fine-grained, medium brownish gray, weathers very light brownish gray. Thin to medium bedded. Some laminated beds, laminae about one-quarter inch thick. Mud cracks in middle part .	16
7. Intraformational breccia, medium to light gray. Fragments angular to subrounded. Limestone and dolostone, one-half inch to 1 foot in diameter. Some larger fragments laminated. Matrix and cement mostly white calcite with some sand and silt	15
6. Dolomitic limestone, dolostone, and limestone interbedded. Dolomitic limestone fine grained, moderate brownish gray, weathers light brownish gray, some cross-bedding. Dolostone, medium gray, weathers medium gray, contains some breccia. Limestone, medium grained, very light gray, weathers light gray. Limestone bed locally ranges in thickness from 6 to 24 inches in a lateral distance of 30 feet	5
5. Silty calcareous sandstone and argillaceous dolostone, interbedded. Sandstone moderate grayish green. Dolostone moderate greenish red, weathers very light reddish brown	8
4. Calcareous sandstone, compact, fine to medium grained, very light greenish brown, weathers very light brown. Beds about 1 foot thick. Upper part, dolomitic, very fine grained, medium gray, weathers light brownish gray, thin bedded, some laminated beds. Upper 8 feet covered	18
3. Argillaceous dolostone, very light greenish gray, weathers light grayish brown, thick bedded. Some interbedded shale, dark green, weathers moderate green, thin bedded	5
2. Same as Unit 4	4

Thickness (feet)

1. Sandstone, calcareous, fine grained, silty, moderate to dark purple, weathers light purple. Some lenticular interbeds of very coarse sandstone to pebble conglomerate in beds 2 to 4 inches thick. Some beds are cross-bedded. Purple color is laterally and vertically discontinuous. Some very light brown beds are splotched with purple near upper part of unit	17
Incomplete thickness Grassy Flat Member .	177

Water Canyon Formation

Section 3

Section measured 6.8 miles east from the mouth of Logan Canyon, Utah, in the NE 1/4 Sec. 24, T. 12 N., R. 2 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
10. Intraformational breccia, fragments mostly calcareous sandstone, angular to subangular, 1 to 6 inches in diameter. Matrix sandy and silty with a great amount of white calcite. Cementing material calcite. Weathers light reddish brown to very light brown	25
9. Argillaceous dolostone and calcareous sandstone, interbedded. Dolostone fine grained, light gray, weathers reddish brown, laminated in parts. Sandstone very light brown, weathers light brown. Beds 1 to 4 feet thick .	29
8. Argillaceous dolostone, fine to medium grained, light to medium gray, weathers light brownish gray in lower part, light brown in upper part. Silty in upper part. Near middle of unit is 1-foot bed of dolomitic calcarenite, coarse grained, medium blue, weathers bluish gray. Mud cracks common in upper 6 feet	31
7. Argillaceous dolostone, and dolomitic sandstone, interbedded. Dolostone light gray, weathers very light brown. Some intraformational breccia, in beds about 3 feet thick. Sandstone, silty, fine grained, light brown, weathers moderate brown. Some beds splotched with purple	43
6. Argillaceous dolostone, compact, medium gray, weathers light brownish gray, thick bedded. Contains some chert in stringers normal to bedding planes	16
5. Argillaceous dolostone, very fine grained, medium gray, weathers moderate brown. Laminated in lower part, some intraformational breccia in upper part	22

	Thickness (feet)
4. Argillaceous dolostone, very light gray, weathers light brown, thick bedded. High content of clay-size particles. Sandy and silty in upper part	33
3. Silty sandstone and silty dolostone, interbedded. Silty sandstone, calcareous, light brown, weathers light brown, thin bedded. Silty dolostone, dark gray, weathers medium gray, some beds weather very light grayish brown, some sandy beds, thin bedded. Fossil fish, plants, and pelecypods common; Lingula less common in some argillaceous beds	8
Total thickness . . .	207
Card Member	
2. Argillaceous dolostone, compact, fine grained, laminated in parts. Light blue, weathers bluish gray, thick-weathering	123
1. Argillaceous dolostone, compact, fine grained, laminated in parts. Medium gray, weathers light gray, thick-weathering	98
Total thickness . . .	221
Total thickness Water Canyon Formation . . .	428

Water Canyon Formation

Section 4

Section measured 1.7 miles east of the mouth of Logan Canyon, Utah, near the northeast corner of the NW 1/4 Sec. 32, T. 12 N., R. 2 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
12. Intraformational breccia, fragments sandstone and limestone, angular to subangular, one-quarter to 6 inches in diameter. Matrix sandy and silty, some bedded layers of calcareous sandstone. Cementing material calcareous, much white calcite	30
11. Calcareous sandstone and argillaceous dolostone interbedded. Calcareous sandstone, very light brown, weathers medium reddish brown, thin bedded, some cross-bedding. Argillaceous dolostone, medium gray, weathers light brownish gray, medium bedded. Some reddish purple sandstone in middle part, silty, fine grained, thin bedded. Lower 2 feet dolomitic calcarenite, medium gray, weathers medium gray	61
10. Argillaceous dolostone, medium gray, weathers light gray, thick bedded, some laminated beds. Some intraformational breccia beds about 3 feet thick	67
9. Argillaceous dolostone and calcareous sandstone interbedded. Argillaceous dolostone, medium gray, weathers light brownish gray. Sandstone very light brown, weathers medium brown, silty, fine grained, thin bedded	43
8. Argillaceous dolostone, compact, medium gray, weathers very light gray to white. Very fine grained, medium to thick bedded, some laminated beds	35

Water Canyon Formation

Section 5

Section measured about 1 mile north of the junction of Water Canyon and Green Canyon, Utah, in the NE 1/4 Sec. 4, T. 12 N., R. 2 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
7. Intraformational breccia, light brown, weathers light brown, fragments angular to subangular, matrix very silty and sandy. Cement calcareous, some brown calcite	10
6. Sandstone and argillaceous dolostone interbedded. Sandstone, fine grained, silty, very light purple, weathers light brown, thin bedded. Argillaceous dolostone, gray, weathers light gray, beds 4 to 6 inches thick	14
5. Dolomitic calcarenite, coarse grained, medium to dark gray, weathers medium gray. Fragments mostly dolostone with some calcite. Thin bedded	2
4. Sandstone, calcareous, very light brown, weathers brown, medium bedded. Some moderately developed cross-bedding. Some thin dolostone beds in lower part, medium gray, weathers brown, medium grained, arenaceous	35
3. Argillaceous dolostone, fine grained, light gray, weathers light brown, reddish gray in lower part. Some medium beds, some laminated beds, laminae commonly sandy at base grading to argillaceous size particles at top of laminae. Laminae one-eighth to one-quarter inch thick	6

	Thickness (feet)
2. Argillaceous dolostone, light brown, weathers very light brown, medium bedded. Some interbedded calcareous sandstone, light brown, weathers very light brown. Intraformational breccia bed 6 feet thick near top of unit. Particles dolostone, medium gray, subangular to subrounded. Matrix silty, cement calcareous	94
Total thickness . . .	161
Card Member	
1. Argillaceous dolostone, compact, very fine grained, medium gray, weathers light gray, thick bedded in lower part. Some laminated beds, one-quarter to one-eighth inch thick. Some laminae grade between fine sand at base and argillaceous grains at the top of individual laminae. Some intraformational breccia in thin stringers increasing to 1 foot beds. One intraformational breccia bed more persistent, 4 feet thick, near top of unit. Mud cracks common in middle part of unit	334
Total thickness . . .	334
Total thickness Water Canyon Formation . .	495

Water Canyon Formation

Section 6

Section measured on the second ridge south of Coldwater Canyon, Wellsville Mountain, Utah, in the SW 1/4 Sec. 22, T. 11 N., R. 2 W., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
8. Intraformational breccia, sandstone and limestone fragments, subangular to subrounded, 1 to 4 inches in diameter. Matrix sandy and silty, yellowish brown in color. Cement calcareous with some white calcite . .	19
7. Argillaceous dolostone, fine grained, light gray, weathers light bluish gray, medium bedded. Some laminated beds. Darker weathering in upper part . . .	128
6. Argillaceous dolostone, medium to light gray, weathers very light brown, thin bedded. Some interbedded dolomitic sandstone, gray, weathers light brown. Some cherty beds. Some thick beds contain iron sulfide concretions from one-half inch to 2 inches in diameter . .	84
5. Argillaceous dolostone, very fine grained, gray, weathers very light gray, thick bedded, resistant. Stylolites common in parts. Some intraformational breccia in upper part. Dolostone slightly lighter in color in upper part	145
4. Arenaceous dolostone, medium gray, weathers light brown, medium to thick bedded. Contains abundant medium size quartz grains suspended in gray dolostone	118
3. Calcareous sandstone, silty, medium gray, weathers medium brown, thin bedded, some laminated beds. Fossil fish fragments and interference ripple marks common	33
Total thickness . . .	527

		Thickness (feet)
Card Member		
2.	Argillaceous dolostone, fine grained, medium to dark gray, weathers dark brownish gray, cherty in part, thin bedded	124
1.	Dolomitic sandstone, medium to fine grained, light brown, weathers very light brown, compact. Laminated in part	32
	Total thickness . . .	156
	Total thickness Water Canyon Formation . .	683

Water Canyon Formation

Section 7

Section measured 2 miles west of the town of Portage, Box Elder County, Utah, in Portage Canyon. Traverse made along the north ridge parallel to, and about one-half mile from, the canyon road in T. 14 N., R. 4 W., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
8. Argillaceous dolostone, medium gray, weathers light to medium gray, laminated. Some interbedded dark gray dolostone. Upper part argillaceous dolostone, arenaceous dolostone, and calcareous sandstone, interbedded. At the top of unit is an intraformational breccia bed about 6 feet thick composed of subangular calcareous sandstone fragments	78
7. Interbedded shale breccia, argillaceous dolostone, and calcareous sandstone. Shale breccia grayish green, weathers dark gray. Fragments platy, about three-eighths inch in diameter. Matrix silty, cement chert. Argillaceous dolostone, fine grained, medium gray, weathers light grayish brown, thin bedded, some sandy beds, some very silty beds. Calcareous sandstone, medium grained, light brown, weathers light brown, thin bedded. Unit more sandy in upper part, silty in lower part	64
6. Dolostone, arenaceous, medium grained, dark gray, weathers dark brownish gray, thick bedded. Poorly preserved marine fossils common	15
5. Argillaceous dolostone, compact, very fine grained, moderate brown, weathers light brown, thin bedded, some laminated beds. Some interbeds of medium grained, medium gray arenaceous dolostone	84

	Thickness (feet)
4. Dolomitic sandstone, silty, fine grained, moderate brownish gray, weathers light brown, thin bedded. Some interbedded arenaceous dolostone, fine to medium grained, medium gray, weathers medium to light gray, medium bedded. Some dark gray dolostone in upper 7 feet	27
Total thickness . . .	268
Card Member	
3. Argillaceous dolostone, very fine grained, compact, light gray, weathers light gray. Some intraformational breccia. Some beds weather very light gray. Upper part of unit sandy	121
2. Argillaceous dolostone, medium gray, weathers light gray, thick bedded. Upper part laminated, some thin sandy beds. Mud cracks common in upper part . . .	73
1. Argillaceous dolostone, medium gray, weathers medium to dark gray, laminated. Thin laminae of sand common. Laminae commonly distorted and exhibit small miniature thrust faults. Laminae about one-quarter inch thick. Unit weathers in beds 1 to 2 feet thick	84
Total thickness . . .	278
Total thickness Water Canyon Formation . .	546

Water Canyon Formation

Section 8

Section measured 100 yards south of the earth dam 1.5 miles south of the mouth of Old Laketown Canyon, Utah. Traverse made on west ridge parallel to the canyon road in the NE 1/4 Sec. 7, T. 12 N., R. 6 E., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
5. Argillaceous dolostone, light gray, weathers very light gray. Some dolostone gray, weathers medium gray, with abundant poorly preserved marine fossils. Some intraformational breccia near middle of unit	29
4. Calcareous sandstone, light brown, weathers light brown, medium grained, compact, well-cemented. Dolomitic in lower part.	94
3. Dolostone, medium grained, very dark gray, weathers gray, medium to thick bedded. Upper 10 feet intraformational breccia, contains dolostone fragments, sandy and silty matrix, calcareous cement	29
2. Interbedded sandstone and dolostone. Sandstone, brown, weathers reddish brown, medium grained, medium bedded. Dolostone, sandy and silty, medium gray, weathers medium brown, medium bedded. Some intraformational breccia in dolostone beds	32
Total thickness . . .	184
Card Member	
1. Argillaceous dolostone, fine grained, light gray, weathers medium to light brown, medium bedded. Slightly sandy in upper part	69
Total thickness . . .	69
Total thickness Water Canyon Formation . .	253

Water Canyon Formation

Section 9

Incomplete section measured three-quarters mile west of the Promontory road, Box Elder County, Utah, in the Southern Promontory Range. The traverse was made in Sec. 8, T. 7 N., R. 5 W., Salt Lake base and meridian.

	Thickness (feet)
Water Canyon Formation	
Grassy Flat Member	
5. Dolomitic sandstone, compact, fine to medium grained, thin bedded. Moderate brown to light brownish gray, weathers reddish brown. Surfaces of bedding planes rough and irregular suggesting poorly preserved interference ripple marks. Above unit is a covered interval about 60 feet thick below the base of the Jefferson Formation. Faulting probably present in covered interval	13
4. Dolomitic sandstone, compact, very fine grained, laminated, moderate brown, weathers light brown. Some beds splotched with light red and light purple color. Beds weather moderately thick. Stringers of medium-grained quartz sand common along bedding of laminae. Some laminae distorted, pinched out, and broken due to contemporaneous deformation	20
Incomplete thickness .	33
Card Member	
3. Argillaceous dolostone, compact, fine grained, laminated, medium gray, weathers light gray, weathers slightly darker in color near base. Unit thick weathering. Some thin stringers of coarse-grained dolomite sand occur in lower part. Some laterally discontinuous intraformational breccia occurs in upper part	56

	Thickness (feet)
2. Covered. Talus material similar to Unit 1	21
1. Argillaceous dolostone, compact, fine grained, medium gray, weathers light gray, thick bedded, thick weathering, some dark gray beds occur in middle part. Single isolated medium-sized quartz sand grains common in fine-grained matrix. Some laminated beds, but less common than in Unit 3. Laminae commonly distorted, pinched out, and broken due to contemporaneous deformation	22
Incomplete thickness .	99

(A fault probably occurs between the base of Unit 1 and the Laketown Dolostone. For this reason some Water Canyon Formation beds may be missing.)

Incomplete thickness Water Canyon Formation .	132