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Structural Geology of Eastern Part of Dairy Ridge Quadrangle and Western Part of Meachum Ridge Quadrangle, Utah

Val A. Kienast
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STRUCTURAL GEOLOGY OF EASTERN PART OF DAIRY RIDGE
QUADRANGLE AND WESTERN PART OF MEACHUM
RIDGE QUADRANGLE, UTAH
by
Val A. Kienast

A thesis submitted in partial fulfillment
of the requirements for the degree
of
MASTER OF SCIENCE
in
Geology

Approved:

UTAH STATE UNIVERSITY
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1985
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Val A. Kienast
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A detailed geologic investigation was made of the eastern part of the Dairy Ridge Quadrangle and the western part of the Meachum Ridge Quadrangle, Utah. The area is located in north-central Utah in Rich County. It lies between lat. 41°22'30" N. and lat. 41°28'50" N. and between long. 111°21'40" W. and long. 111°25'15" W. The area measures 13.8 km in the north-south direction and 5.5 km in the east-west direction. It is on the eastern side of the Wasatch Range about 20 km west-southwest of Randolph, Utah.

Stratigraphic units of Precambrian to Cambrian age crop out in the western part of the area, above the Woodruff thrust fault, and dip west. These include the Precambrian Mutual Formation and the Cambrian Geertsen Canyon Quartzite. Units of Pennsylvanian to Jurassic age crop out in the eastern part of the area below the Woodruff thrust fault. They dip west and are overturned to the east. These units include the following: Pennsylvanian Weber Formation,
Permian Grandeur Member of the Park City Formation, Permian Phosphoria Formation, Triassic Thaynes Limestone, Triassic Ankareh Formation, Jurassic Nugget Sandstone, and Jurassic Twin Creek Limestone. The Tertiary Wasatch Formation unconformably overlies all older units in places.

The Woodruff thrust fault is the major structural feature of the area. Quartzite of the Precambrian Mutual Formation is thrust eastward over the Pennsylvanian Weber Formation as well as over formations of Permian and Triassic ages. The Woodruff thrust fault strikes about N. 20° E. and dips 18° W. to 33° W. Stratigraphic throw is at least 5,800 m. Probable horizontal displacement is tens of kilometers. The stratigraphic units, under the thrust fault, dip west and are overturned to the east. They form the western limb of a large asymmetrical syncline. The overturned units are cut by a west-dipping high-angle thrust fault. The syncline and the thrust faults were produced by the Sevier orogeny which began in latest Jurassic or earliest Cretaceous time. Deformation may have continued into Paleocene time.
INTRODUCTION

Purpose and Scope

A detailed study of the eastern part of the Dairy Ridge Quadrangle and the western part of the Meachum Ridge Quadrangle, Utah, was undertaken to contribute to the understanding of regional geology. The purposes of this investigation were: (1) prepare a detailed geologic map (pl. 1), (2) relate the stratigraphy and structure of the area to that of the region, and (3) outline the sequence of geologic events.

Location and Accessibility

The area of investigation is located in north-central Utah in Rich County (fig. 1). It lies about 20 km west-southwest of the town of Woodruff, Utah. Utah State Highway 39 provides access to the northern part of the area. The central and southern parts can be reached with difficulty by means of unimproved roads.

The mapped area is on the eastern side of the Wasatch Range in the Middle Rocky Mountains Province. Walton Canyon cuts across the northern end of the area. Much of the area, however, is along the upper part of the valley of Woodruff Creek. Woodruff Creek is a tributary of the Bear River.

The area measures 13.8 km in the north-south direction and 5.5 km in the east-west direction. This represents about 47 square km.
FIGURE 1. Index map of northern Utah showing location of mapped area (center rectangle).
The mapped area lies between lat. 41°22'30" N. and lat. 41°28'50" N. and between long. 111°21'40" W. long. and 111°25'15" W. It encompasses only 3.8 km of the eastern part of the Dairy Ridge Quadrangle and 1.6 km of the western part of the Meachum Ridge Quadrangle, Utah.

Field Work

The field study of the eastern part of the Dairy Ridge Quadrangle and the western part of the Meachum Ridge Quadrangle, Utah, was accomplished during the summer and fall of 1981. Field observations were plotted on vertical aerial photographs (scale 1:20,000) obtained from the U.S. Forest Service.

Information, plotted on the aerial photographs, was transferred to a base map at a scale of 1:12,000. The base map was prepared from the eastern part of the 7.5-minute Dairy Ridge Quadrangle and the western part of the 7.5-minute Meachum Ridge Quadrangle, Utah.

Samples were collected from each stratigraphic unit to aid in identification of the units. Fossils were collected and identified by the author when necessary for the identification of stratigraphic units.

Previous Work

The region of north-central Utah was examined by Hayden (1872, 1873), Hague and Emmons (1877), and King (1878). They determined the general nature of the geology. Veatch (1907) reported on the
structure and stratigraphy of southwestern Wyoming. Weeks and Ferrier (1907, p. 455) were first to note phosphate deposits along Woodruff Creek. Gale and Richards (1910, p. 526-529) followed up this early work, with emphasis on phosphate deposits, and published a map of the Woodruff Creek area. Richardson (1913) did preliminary work on the Randolph Quadrangle, Utah, and later published a geologic map of that area (Richardson, 1941). Schultz (1918) continued investigations on the economic phosphate and coal deposits of Idaho and Wyoming. The regional structure and stratigraphy of southeastern Idaho were studied, in some detail, by Mansfield (1927). Eardley (1944) worked in the north-central Wasatch Mountains and Williams (1948) later mapped the Logan Quadrangle, Utah.

Armstrong and Cressman (1963) identified the Bannock thrust zone of southeastern Idaho. Previously, the major thrust faults of the Bannock thrust zone were thought to connect to make the Bannock overthrust (Richards and Mansfield, 1912, p. 695). Since these early works on thrust faulting in the region, much has been published on the overthrust belt and a controversy has arisen over the possible connections of thrust faults throughout southeastern Idaho and north-central Utah.
STRATIGRAPHIC UNITS

General Statement

The area of investigation is divided into two parts by a major, west-dipping thrust fault. Precambrian and Cambrian stratigraphic units comprise the allochthonous plate on the west. The oldest unit, immediately above the thrust fault, is the Mutual Formation of Precambrian age. It consists mainly of quartzite. The Geertsen Canyon Quartzite of Cambrian age overlies the Mutual. East of the thrust fault, the stratigraphic units range in age from Pennsylvanian to Jurassic. The oldest unit, beneath the thrust fault, is the Weber Formation of Pennsylvanian age. Above the Weber, in normal stratigraphic succession, is an undifferentiated unit of Permian age. It includes the Grandeur Member of the Park City Formation, in the lower part, and the Phosphoria Formation in the upper part. A high-angle thrust fault separates the Permian unit from younger formations of Triassic and Jurassic age on the east. These include the Thaynes Limestone and the Ankareh Formation of Triassic age and the Nugget Sandstone and the Twin Creek Limestone of Jurassic age. The Tertiary Wasatch Formation unconformably overlaps all older rock units throughout much of the mapped area.

Unconsolidated stratigraphic units of Quaternary age, in the mapped area, consist of colluvial deposits and alluvial deposits. The colluvial deposits locally overlie older Precambrian, Paleozoic,
and Mesozoic rocks. The alluvial deposits are located along the valley bottoms. A large landslide, involving Jurassic and Tertiary rocks, is present in the south-central part of the mapped area.

**Precambrian Units**

**Mutual Formation**

The Mutual Formation was named by Crittenden and others (1952, p. 6) with reference to quartzite and shale in Big and Little Cottonwood Canyons southeast of Salt Lake City, Utah. The quartzite is red purple and the shale is variegated red and green. The unit is as much as 1,200 ft. (366 m) thick in Big Cottonwood Canyon. The Mutual is the youngest Precambrian formation in the area southeast of Salt Lake City, Utah (Crittenden and others, 1952, p. 6).

Crittenden (1972b) recognized the Mutual Formation in the area northeast of Huntsville, Utah, where it ranges in thickness from 435 to 1,200 ft. (133 to 366 m). The Mutual is considered to be of Precambrian age (Crittenden and others, 1952, p. 6).

In the study area, the Mutual Formation consists of red-purple and white quartzite. The quartzite is locally conglomeratic and contains interbedded argillite in places. The exposed thickness of the Mutual is 450 m based on an estimate.

The quartzite of the Mutual Formation is medium to coarse grained and thick bedded to massive bedded. Lenses of conglomeratic quartzite contain well-rounded, quartzite pebbles as large as 40 mm in diameter. The interbedded argillite is mostly dark red to dark purple; however, it is olive to light greenish gray in places. The
argillite is laminated (2-5 mm). Individual beds of argillite are as thick as 7 m.

The characteristic red-purple color of the quartzite readily differentiates the Mutual Formation from the overlying Geertsen Canyon Quartzite. The latter consists of white to light-brown quartzite. The Geertsen Canyon seems to conformably overlie the Mutual (fig. 2). The Precambrian Browns Hole Formation that separates Mutual and Geertsen Canyon in the Huntsville area, Utah, is not recognized in the study area (Crittenden, 1972b). The Browns Hole consists of two members: (1) lower volcanic member, 180 to 460 ft. (56 to 142 m) thick, and (2) upper quartzite member, 100 to 150 ft. (31 to 46 m) thick. The volcanic member may not have been deposited in the study area. The quartzite member may be represented by the lower part of the Geertsen Canyon Quartzite.

**Cambrian System**

**Geertsen Canyon Quartzite**

The Geertsen Canyon Quartzite was named by Crittenden and others (1971, p. 592) with reference to a unit of light-gray to light-brown quartzite that overlies the Browns Hole Formation near Huntsville, Utah. This unit was previously called the Brigham Formation.

The Brigham Formation was established by Walcott (1908a, p. 8) with reference to a section of quartzite and sandstone, 2,000 ft. (610 m) thick, that crops out northeast of Brigham City, Utah. The base of the section is not exposed (Walcott, 1908b, p. 199). This
FIGURE 2. Mutual Formation and Geertsen Canyon Quartzite in Walton Canyon; view north. Mutual Formation (PEm) and Geertsen Canyon Quartzite (Ggc) dip west on northern side of Walton Canyon in sec. 28, T. 9 N., R. 5 E.
led to inconsistencies in describing other occurrences of the Brigham Formation. Some investigators have included all quartzite below Cambrian carbonate rocks in the Brigham. Other workers have restricted the Brigham to the uppermost 2,000 to 5,000 ft. (610 to 1,524 m) of light-gray to light-brown quartzite.

Due to repeated conflicts in defining the Brigham Formation, Crittenden and others (1971, p. 590) elevated the formation name to group rank. The light-gray to light-brown quartzite directly above the Browns Hole Formation in the Huntsville area, Utah, was then named Geertsen Canyon Quartzite (Crittenden and others, 1971, p. 592). Crittenden (1972b) reported a range in thickness of 3,426 to 4,833 ft. (1,044 to 1,473 m) for the Geertsen Canyon. The Browns Hole Formation is not present in the mapped area. There, the Geertsen Canyon Quartzite rests with apparent conformity on the Precambrian Mutual Formation.

The Geertsen Canyon Quartzite is considered by Crittenden and others (1971, p. 593) to be Precambrian and Early (?) Cambrian in age. Williams (1948, p. 1132) argued that the upper part of the Brigham Formation is probably of Early Cambrian age based on the occurrence of Middle Cambrian trilobites in the overlying Langston Formation. The fossil tubes, Skolithus, have been used to date the upper part of the Geertsen Canyon as Cambrian (Williams, 1948, p. 1132; Crittenden and others, 1971, p. 593).

In the study area, the Geertsen Canyon Quartzite is mainly medium- to very coarse-grained, light-brown to white quartzite. It is approximately 1,250 m thick in Sugar Pine Canyon. The
quartzite is locally conglomeratic. Well-rounded clasts of quartzite are as large as 55 mm in diameter; however, the majority of the clasts range in size from 10 to 30 mm. Cross-stratification is common in thick beds of quartzite. Weathered surfaces are generally darker in color than the surfaces of freshly broken rock.

Fossil tubes, Skolithus, are present near the top of the Geertsen Canyon Quartzite in sec. 30, T. 9 N., R. 5 E. They are oriented perpendicular to the bedding (fig. 3). The tubes are about 25 to 30 mm long and about 2 mm in diameter.

Pennsylvania System

Weber Formation

The Weber Formation was named by King (1876, p. 477-479) with reference to a quartzite unit exposed along the Weber River southeast of Ogden, Utah. King described the Weber as consisting mostly of quartzite but with some interbedded sandstone and limestone. Gale and Richards (1910, p. 527) noted the Weber Formation along Woodruff Creek in the study area.

Early workers considered the Weber Formation to be of Pennsylvanian age based on its stratigraphic relationship to fossiliferous limestone both below and above. Boutwell (1912, p. 46) obtained paleontological evidence from the Weber thereby verifying the Pennsylvanian age.

The Weber Formation, in the mapped area, consists mainly of massive-bedded, light-brown quartzite with some interbedded sandstone. It weathers light reddish brown. The Weber forms resistant
FIGURE 3. Fossil tubes, *Skolithus*, in Geertsen Canyon Quartzite. Outcrop is located in sec. 30, T. 9 N., R. 5 E.
cliffs on the western side of Woodruff Creek in secs. 4, 9, and 16, T. 8 N., R. 5 E.

The exposed thickness of the Weber, in the study area, is approximately 600 m. The base is not exposed due to the fact that quartzite of the Precambrian Mutual Formation is thrust over the Weber on the Woodruff thrust fault (pl. 1 and 2). No fossils were found in the Weber Formation in the mapped area.

Permian System

Grandeur Member of Park City Formation

The Grandeur Member of the Park City Formation was named by Cheney, Swanson, Sheldon, and McKelvey with reference to a unit of carbonate rock that overlies the Weber Formation in the central Wasatch Mountains in Salt Lake County, Utah (McKelvey and others, 1959, p. 1215). In the Crawford Mountains, east of the study area, the Grandeur Member is 50 to 75 ft. (17 to 25 m) thick (McKelvey and others, 1959, p. 15). The Grandeur Member of the Park City Formation is of Permian age (McKelvey and others, 1959, p. 39).

In the study area, the Grandeur Member is grouped with the overlying Phosphoria Formation for mapping purposes. Limited exposures of the Grandeur Member make separation of the two units difficult. The Grandeur Member consists of limestone, cherty dolomite, calcareous sandstone, and siltstone. It weathers light gray.
Phosphoria Formation

The Phosphoria Formation was named by Richards and Mansfield (1912, p. 684) for exposures of phosphatic shale and chert in Phosphoria Gulch, east of Georgetown, Idaho. The lower phosphatic shale was named the Meade Peak Phosphatic Shale Member by McKelvey (McKelvey and others, 1959, p. 22). The upper chert was named the Rex Chert Member by Richards and Mansfield (1912, p. 684).

McKelvey and others (1959, p. 9) restricted the Phosphoria Formation to phosphatic, carbonaceous, and cherty rock. They placed intertonguing carbonate rock in the Park City Formation. Thus, in the mapped area, the Grandeur Member of the Park City Formation underlies the Phosphoria Formation. The Phosphoria Formation is of Permian age (McKelvey and others, 1959, p. 39).

In the mapped area, the Phosphoria Formation overlies the Grandeur Member of the Park City Formation along the western side of the upper part of Woodruff Creek and northward to Phosphate spring. The section is overturned to the east. Quartzite of the Precambrian Mutual Formation is thrust over the Grandeur Member of the Park City Formation and the Phosphoria Formation along the upper part of Woodruff Creek south of Road Hollow and also north of Sugar Pine Canyon. The Phosphoria, in turn, is thrust over Triassic and Jurassic formations along a high-angle thrust fault. This fault was probably controlled by the phosphatic shale of the Meade Peak Phosphatic Shale Member and accounts for the absence of the Rex Chert Member of the Phosphoria Formation in the mapped area.

The Phosphoria Formation consists of micritic to fine-crystalline, light- to medium-gray, cherty limestone and dark-gray
to black phosphatic shale. The exposed section is about 300 m thick; however, it is limited at its top by a high-angle thrust fault. The Phosphoria is best exposed in secs. 4 and 9, T. 8 N., R. 5 E. Near the base of the phosphatic shale north of the mouth of Road Hollow, in sec. 16, T. 8 N., R. 5 E., an extremely fossiliferous limestone contains Spiriferina, Productus, and Polypora (fig. 4).

Triassic System

Thaynes Limestone

The Thaynes Limestone was named by Boutwell (1907, p. 448) with reference to exposures in Thaynes Canyon, Park City mining district, Utah. Boutwell reported that the Thaynes Limestone consists of three units: (1) lower limestone, (2) red shale, and (3) upper limestone (Boutwell, 1907, p. 448). The total thickness is 1,190 ft. (363 m). Cressman (1964, p. 40) noted that the Thaynes is 2,500 to 3,200 ft. (762 to 976 m) thick in the Snowdrift Mountain Quadrangle in southeastern Idaho. The Thaynes is of Early Triassic age (Kummel, 1954, p. 166).

The Thaynes Limestone, in the mapped area, consists of thick-bedded, micritic, medium-gray to reddish-gray limestone. In places, thin-bedded limestone predominates. The greatest estimated thickness of Thaynes, in the mapped area, is 550 m. This thickness is from outcrops on the eastern side of Woodruff Creek, south of Road Hollow, in sec. 21, T. 8 N., R. 5 E.

The Thaynes forms slopes and is generally poorly exposed (fig. 5). Except for fresh exposures along roads or streams, the lithology was inferred from rock fragments in the regolith.
Figure 4. Fossiliferous limestone of Phosphoria Formation. Outcrop is located near mouth of Road Hollow in sec. 16, T. 8 N., R. 5 E.
FIGURE 5. Phosphoria Formation and Thaynes Limestone in mouth of Road Hollow; view north. Phosphoria Formation (Pp) is thrust eastward over Thaynes Limestone (Trt) on high-angle thrust fault in sec. 16, T. 8 N., R. 5 E.
Brachiopod and pelecypod fragments may be found but none of the ammonoids, for which the Thaynes is noted, were found.

The formation, exposed in a road cut on the northern side of Utah State Highway 39 in Walton Canyon in sec. 28, T. 9 N., R. 5 E., was difficult to identify; however, it seems probable that it is the Thaynes Limestone. The outcrop consists of medium- to light-gray and red-gray limestone with some interbedded silty shale. This lithology is similar to that of the Thaynes Limestone.

South of Utah State Highway 39, the bedrock is generally concealed by colluvium; however, a small ridge of Jurassic Nugget Sandstone is present to the southeast (pl. 1). If the strike of the Nugget is projected northward, the Nugget should be present about 150 m east of the road cut. Allowing for the Ankareh Formation, between the road cut and the projected location of the Nugget, the stratigraphic succession seems to be conformable. Thus, it seems evident that the rock in the road cut is the Thaynes Limestone.

**Ankareh Formation**

The Ankareh Formation was named by Boutwell (1907, p. 452) for a red unit in the Park City mining district, Utah. In his original description, Boutwell included coarse-grained, light-gray sandstone in the uppermost part of the Ankareh. Later, he identified the sandstone as the Nugget Sandstone.

The nomenclature of the red beds between the Thaynes Limestone and the Nugget Sandstone has been subject to some confusion. Williams (1945) proposed three formations for the area of the central Wasatch Mountains and the western Uinta Mountains: (1) Ankareh
Formation, (2) Higham Grit, and (3) Wood Shale. Thomas and Krueger (1946, p. 1270-1271) divided this section into three formations: (1) Ankareh Formation, (2) Cartra Grit, and (3) Stanaker Formation. Kummel (1954, p. 179-180) proposed that the section be identified as the Ankareh Formation and divided into members: (1) Mahogany, (2) Cartra Grit, and (3) Stanaker. In this report, the red beds between the Thaynes Limestone and the Nugget Sandstone will be called the Ankareh Formation.

The Ankareh Formation was dated as Early Triassic by Boutwell (1912, p. 59) on the basis of rather meager fossil evidence. It is generally devoid of diagnostic fossils. Kummel (1954, p. 171-172) considered the Ankareh to be Middle to Late Triassic in age. In this report, it is regarded as of Triassic age.

In the mapped area, the Ankareh Formation crops out between Road Hollow and Girl Hollow. It is apparently conformable with the Thaynes Limestone below and the Nugget Sandstone above. Good exposures are not common except in recent road cuts. To the north, in Sugar Pine Canyon, the Ankareh is absent due to thrust faulting.

The Ankareh Formation is mostly thin-bedded, red to reddish-purple, siliceous shale that is commonly sandy. Some gray-green to light-blue-green limestone is interbedded. The estimated thickness of the Ankareh, in Road Hollow, is 150 m.

**Jurassic System**

**Nugget Sandstone**

The Nugget Sandstone was named by Veatch (1907, p. 56) with reference to exposures near Nugget Railroad Station in southwestern
Wyoming. Cressman (1964, p. 45) noted a range in thickness of 900 to 1,700 ft. (274 to 518 m) in the Snowdrift Mountain Quadrangle in southeastern Idaho. High and Picard (1969, p. 1091) determined that the Nugget Sandstone is of Jurassic age based on structural and stratigraphic relationships with the Chugwater Group of Wyoming.

In the mapped area, the Nugget Sandstone crops out along the eastern side of Woodruff Creek and between Road Hollow and Girl Hollow. The Nugget consists of massive-bedded, fine- to medium-grained, reddish-orange sandstone. It is cross-stratified and beds of conglomeratic sandstone are present in places.

**Twin Creek Limestone**

The Twin Creek Limestone was named by Veatch (1907, p. 56) for limestone, shale, and sandstone between the Nugget Sandstone and the Preuss Formation in southwestern Wyoming. The type locality is along Twin Creek between Sage and Fossil, Wyoming. The formation was divided into seven members, designated A through G, by Imlay (1950, p. 37-39). Member A was renamed the Gypsum Spring Member by Oriel (1963). Later, Imlay (1967, p. 3) renamed the other members. The members of the Twin Creek Limestone, recognized by Imlay, are:

- (1) Gypsum Spring,
- (2) Sliderock,
- (3) Rich,
- (4) Boundary Ridge,
- (5) Watton Canyon,
- (6) Leads Creek,
- (7) Giraffe Creek. It is Middle and Late Jurassic in age (Imlay, 1967, p.4).

The Twin Creek Limestone crops out along Woodruff Creek, in Road Hollow, in the canyon south of Road Hollow, and in Girl Hollow. Good exposures are rare because of the shaly nature of the formation. It overlies the conspicuous Nugget Sandstone. The top of
the Twin Creek is not exposed in the mapped area.

The Twin Creek consists of micritic, light- to medium-gray limestone that is sandy in places. The limestone displays characteristic weathering to pencil-like laths (fig. 6). The Twin Creek commonly weathers light olive brown. No fossils were noted during field mapping. The Twin Creek is 2,577 ft. (795 m) thick along Birch Creek north of the study area (Imlay, 1967, p. 13).

Tertiary System

Wasatch Formation

The Wasatch Formation was named by Hayden (1873, p. 191) with reference to conglomerate in Echo Canyon, Utah. Veatch (1907, p. 78) recognized the Wasatch Group and subdivided it into three formations: (1) lower Almy, (2) Fowkes, and (3) upper Knight. Mansfield (1927, p. 109) demonstrated that separation of Almy and Knight is difficult if the Fowkes is not identified between them. Richardson (1941, p. 33) also found it impractical to make this threefold subdivision of the Wasatch Group. Tracey and Oriel (1959, p. 128-130) found that the Fowkes Formation does not separate the Almy and Knight in the Kemmerer and Sage Quadrangles, Wyoming. Thus, distinction of the Almy and Knight Formations is difficult. The Wasatch Group has since been treated as a formation by the U.S. Geological Survey and will be treated as a formation in this report.

In the Randolph Quadrangle, Utah, the Wasatch Formation consists of conglomerate and sandstone with subordinate shale, limestone, and tuff (Richardson, 1941, p. 33). There, the Wasatch
FIGURE 6. Twin Creek Limestone south of Woodruff Creek. Characteristic weathering of limestone of Twin Creek is evident. Outcrop is located in sec. 4, T. 8 N., R. 5 E.
is 1,000 ft. (309 m) thick (Richardson, 1941, p. 34). The Wasatch is Eocene in age based on fossil evidence from Fossil Basin in southwestern Wyoming (Oriel and Tracey, 1970, p. 1).

The Wasatch Formation covers the divides throughout the study area. In the canyons, it rests unconformably on all older rock units. The Wasatch consists mostly of red conglomerate and sandstone; however, a unit of light-gray, algal limestone caps hills in the western part of the area. The exposed thickness of the Wasatch, in the study area, is about 300 m.

The conglomerate and sandstone of the Wasatch is pink, orange, light brown, and gray. Quartzite clasts, in the conglomerate, are well rounded and range up to cobble size (fig. 7). The algal limestone is light gray and contains oncolites ranging from 0.5 mm to 18 cm in diameter (fig. 8). The conglomerate and associated sandstone were deposited by streams. The limestone represents a fresh-water lacustrine deposit.

The lake, in which the algal limestone was deposited, may have been quite extensive. Williams (1948, p. 1144) identified a basal limestone member of the Wasatch Formation in the southern half of the Logan Quadrangle, Utah. Richardson (1941, p. 33-34) recognized a similar limestone in the Randolph Quadrangle, Utah. Mansfield (1927, p. 109) reported a limestone in the Wasatch of the Montpelier Quadrangle, Idaho.
FIGURE 7. Conglomerate of Wasatch Formation in Girl Hollow; view northeast. Outcrop is located near northeastern corner of sec. 32, T. 8 N., R. 5 E.
FIGURE 8. Algal limestone, containing oncolites, from Wasatch Formation. Specimen is from outcrop on ridge in sec. 9, T. 8 N., R. 5 E.
Quaternary System

Colluvial deposits

Colluvial deposits consist of pebbles, cobbles, and boulders in an unconsolidated matrix of clay, silt, and fine-grained sand. Most of the clasts are pebbles and cobbles. They are generally well rounded although some subangular clasts occur. The clasts are mainly quartzite, limestone, and dolostone. The quartzite clasts are purple, red purple, pink, light brown, and white. The carbonate clasts are generally dark gray to gray and commonly contain chert.

The colluvial deposits are not extensive in the study area. They occur in the upper parts of small valleys; however, some mantle slopes on the sides of canyons. The clasts were probably derived from conglomerate of the Wasatch Formation. The colluvial deposits are probably Pleistocene to Holocene in age.

Landslides

A landslide of the Tertiary Wasatch Formation is located on the northern side of the canyon south of Road Hollow in sec. 28, T. 8 N., R. 5 E. The Wasatch slid southward down the side of the canyon over the Jurassic Twin Creek Limestone (pl. 1).

Recently, a road was cut along the northern side of Girl Hollow in sec. 33, T. 8 N., R. 5 E. It is in somewhat incompetent sandstone and shale of the Wasatch Formation. Numerous small slides moved onto the unimproved road. They are too small to show on the geologic map (pl. 1).
Alluvial deposits

The alluvial deposits consist of unconsolidated silt, sand, and gravel. They are the result of stream deposition along valley bottoms. The main deposit is along the upper part of Woodruff Creek. Other deposits occur in Sugar Pine Canyon and in Girl Hollow. The alluvial deposits are Holocene in age.
STRUCTURAL FEATURES

General Features

A major, low-angle thrust fault extends from the southern limit of the mapped area to the northern limit. It is known as the Woodruff thrust fault due to its location along the upper part of Woodruff Creek (fig. 9). This fault certainly extends far beyond the limits of the mapped area; however, it is covered by the essentially horizontal Tertiary Wasatch Formation near the southern limit of the mapped area as well as near the northern limit. The Woodruff thrust fault dips west and the direction of movement was east.

The allochthonous rocks, above the Woodruff thrust fault, are Precambrian and Cambrian in age. The Precambrian stratigraphic unit is the Mutual Formation. It consists mainly of quartzite. The oldest rock unit beneath the thrust fault is the Weber Formation of Pennsylvanian age. The Weber, together with younger units of Permian, Triassic, and Jurassic age, is overturned to the east.

Regional Structure

The mapped area lies within the overthrust belt of Wyoming, Idaho, and Utah. The Crawford thrust fault is located near the Utah-Wyoming border about 25 km east of the study area (Stokes and Madsen, 1961). It dips west and probably underlies the mapped area.
FIGURE 9. Woodruff thrust fault along Woodruff Creek north of Road Hollow; view north-northwest. Mutual Formation (Pém) is thrust eastward over Weber Formation (Pw) in sec. 16, T. 8 N., R. 5 E. Grandeur Member of Park City Formation forms slope to right of Woodruff Creek. Wasatch Formation (Tw) unconformably overlies Mutual Formation at upper left.
The Absaroka and Darby (Hogsback) thrust faults are located east of the Crawford thrust fault. The Willard thrust fault is located in the Wasatch Mountains about 50 km west of the study area (Stokes and Madsen, 1961). The Willard thrust fault dips east and places rocks of late Precambrian age over Paleozoic rocks. The Bannock thrust zone of southeastern Idaho is north of the mapped area (Armstrong and Cressman, 1963). It consists of two west-dipping, imbricate thrust faults. The Paris thrust fault is the western fault of the Bannock thrust zone. In Paris Canyon, 85 km north of the mapped area, it places the Cambrian Geertsen Canyon Quartzite over the Permian Phosphoria Formation. It dips about 30° W.

The possible connection of the Paris thrust fault, the Woodruff thrust fault of the study area, and the Willard thrust fault has been the subject of much discussion. Crittenden (1972a) advocated such a regional connection. He referred to the overthrust plate as the Cache allochthon. The Paris thrust fault, however, cannot be traced southward to the Woodruff thrust fault because of an extensive cover of Tertiary and Quaternary rocks. Armstrong and Cressman (1963, p. 18) have indicated that displacement diminishes southward on the Paris thrust fault and that such a regional connection is improbable.

Structural Features

Folds

The Paleozoic and Mesozoic rocks that crop out east of the Woodruff thrust fault strike north-northeast. They dip steeply west but are overturned to the east. Gale and Richards (1910, p. 527)
believed that these rocks form the eastern limb of a major overturned anticline and the western limb of a major overturned syncline. The eastern limb of this syncline is evident to the southeast along Lost Creek where a normal, west-dipping section of Mesozoic rocks is located (Stokes and Madsen, 1961). Thus, the overturned section of Paleozoic and Mesozoic rocks, in the mapped area, represents the common limb of an overturned anticline on the west and a related overturned syncline on the east.

**Thrust faults**

Thrust faults, in the study area, can be classified as low-angle and high-angle thrust faults. The westernmost fault, the Woodruff thrust fault, is a major, west-dipping, low-angle thrust fault. A high-angle thrust fault is located east of the Woodruff thrust fault. It also dips west. This imbricate relationship suggests that the two faults may be related.

The Woodruff thrust fault extends across the mapped area from south to north. Along the upper part of Woodruff Creek, in sec. 29, T. 8 N., R. 5 E., quartzite of the Precambrian Mutual Formation is thrust eastward over the Triassic Thaynes Limestone. The Thaynes dips steeply west but is overturned to the east. Northward, in sec. 16, T. 8 N., R. 5 E., the Precambrian Mutual is thrust eastward over the Pennsylvanian Weber Formation. The Weber dips west but is overturned to the east. In Sugar Pine Canyon, in secs. 4 and 9, T. 8 N., R. 5 E., the west-dipping thrust fault makes a conspicuous V-shaped pattern that points westward up the canyon. In the canyon bottom, the Mutual is thrust eastward over the Weber. On the northern side of Walton Canyon, near the northern limit of the mapped area in
sec. 28, T. 9 N., R. 5 E., the Mutual is again thrust eastward over the Triassic Thaynes Limestone. The Thaynes dips steeply west but is overturned to the east.

The Woodruff thrust fault strikes about N. 20° E. and dips west at a low angle. The dip ranges from 18° W. to 33° W. The actual fault plane is not exposed due to extensive regolith and cover by the overlying Tertiary Wasatch Formation.

In a map view, a systematic outcrop pattern is evident below the Woodruff thrust fault. To the north and south, where only the major through-going thrust fault is evident, the Precambrian Mutual Formation is thrust over the Triassic Thaynes Limestone. In the intermediate segment located between the Woodruff thrust fault and the parallel high-angle thrust fault to the east, the Mutual is thrust over Permian rocks near the northern and southern junctions of these faults. Centrally, the Mutual is thrust over the Pennsylvanian Weber Formation. This pattern may be explained by differential erosion of the allochthonous plate in the deep canyons.

The stratigraphic throw of the Woodruff thrust fault is about 5,800 m based on the Precambrian Mutual Formation thrust over the Pennsylvanian Weber Formation. This is about the same at the stratigraphic throw reported for the Paris thrust fault in southeastern Idaho (Armstrong and Oriel, 1965, fig. 15). The Paris thrust fault places the Cambrian Brigham Quartzite (Geertsen Canyon Quartzite) over the Triassic Thaynes Formation. This relationship indicates a stratigraphic throw of about 20,000 ft. (6,172 m).

Horizontal displacement on the Woodruff thrust fault is probably as great as that of other major thrust faults of the region.
Armstrong and Oriel (1965, p. 1847) indicated at least 10 to 15 mi. (16 to 24 km) of eastward displacement for the major thrust faults of the Idaho-Wyoming thrust belt. The Willard thrust fault in the vicinity of Ogden, Utah, may have eastward displacement on the order of 40 mi. (64 km) according to Crittenden (1961, p. 129).

A high-angle thrust fault is located east of the Woodruff thrust fault in the central part of the mapped area. It strikes nearly parallel to the Woodruff thrust fault; however, it dips 45° W. to 58° W. This fault seems to connect with the Woodruff thrust fault to the south in sec. 20, T. 8 N., R. 5 E., and it is believed to connect with the Woodruff thrust fault to the north under cover of the Tertiary Wasatch Formation. To the north in the vicinity of Sugar Pine Canyon, the undifferentiated Permian stratigraphic unit, consisting of the Grandeur Member of the Park City Formation and the Phosphoria Formation, is thrust eastward over the Jurassic Nugget Sandstone. This relationship is especially well displayed in secs. 3, 4, and 9, T. 8 N., R. 5 E. To the south in the lower part of Road Hollow, in sec. 21, T. 8 N., R. 5 E., the Permian unit is thrust over the Triassic Thaynes Limestone. The phosphatic shale of the Permian Phosphoria Formation could have provided a control on the location of this fault and could have facilitated its movement.

The general structure of the overthrust belt of Wyoming, Idaho, and Utah has been characterized as involving imbricate thrust faults that climb up section from a regional decollement (Royse and others, 1975, pl. 1 and 2). Thus, the Woodruff thrust
fault probably joins a regional decollement at depth. The high-
angle thrust fault, located immediately east of the Woodruff
thrust fault, may also join the decollement.
STRUCTURAL EVENTS

General Statement

The tectonic deformation of the eastern part of the Dairy Ridge Quadrangle and the western part of the Meachum Ridge Quadrangle, Utah, can be correlated with a prolonged geologic event of regional extent. This event was responsible for the continent-long belt of folds and eastward-directed thrust faults that constitute the Cordilleran fold belt (King, 1969, p. 64). Armstrong (1968, p. 435-440) named the segment of this fold belt that extends from southern Nevada to southeastern Idaho the Sevier orogenic belt. He attributed the folds and thrust faults to the Sevier orogeny (Armstrong, 1968, p. 451). Although this event has commonly been included with the Laramide orogeny, Armstrong suggested limiting the Laramide to basement uplifts of the type that is well known in southeastern Wyoming. The classic Laramide orogeny, furthermore, is generally younger than the Sevier orogeny (Armstrong, 1968, p. 452).

The Sevier orogeny was a time of east-west compression which produced north-south-trending folds of great extent. The folding was closely followed by eastward-directed thrust faulting. The thrust faulting is thought to be the culminating effect of the compressive forces which produced the folds (Mansfield, 1927, p. 178, 198; Armstrong and Cressman, 1963, p. 13).
The inception of folding and thrust faulting has been dated as latest Jurassic or earliest Cretaceous by Armstrong and Cressman (1963, p. 8-14) based on stratigraphic relationships seen in the Gannett Hills northeast of Montpelier, Idaho. The depositional record of the Ephraim Conglomerate shows concurrent tectonic deformation to the west. Thus, the Sevier orogeny started in latest Jurassic or earliest Cretaceous time. The deformation may have continued into Paleocene time (Armstrong and Cressman, 1963, p. 14).

**Sevier Events**

The Paleozoic and Mesozoic rocks, in the eastern part of the mapped area, were overturned to the east and subsequently overthrust by the quartzite of the Precambrian Mutual Formation on the Woodruff thrust fault. The overturned section seems to represent the common limb between a major anticline to the west and a syncline to the east. The youngest formation of the overturned section is the Twin Creek Limestone of Late Jurassic age. The Wasatch Formation of Eocene age unconformably overlies the Twin Creek and has not been folded. The Wasatch also overlaps the Woodruff thrust fault. The youngest formation cut by this thrust fault is the Triassic Ankareh Formation. Thus, the folding and thrust faulting occurred between Late Jurassic and Eocene.

To the north, in the Idaho-Wyoming thrust belt, Armstrong and Oriél (1965, p. 1857) demonstrated that the thrust faulting ranges in age from Late Jurassic on the west to Early Eocene on the east. Armstrong and Cressman (1963, p. 14) gave evidence for the beginning of movement on the Paris thrust fault during latest
Jurassic or earliest Cretaceous time. This regional evidence is consistent with the evidence from the mapped area. It suggests that the folding and thrust faulting of the mapped area probably started during late Jurassic time.

The folding was followed closely by thrusting on the Woodruff thrust fault. This is suggested by the west-dipping Woodruff thrust fault cutting the middle limb of large-scale folds. Dahlstrom (1970, p. 342) suggested that it is common for thrust faults to propagate upward from pre-existing faults. Armstrong and Oriel (1965, p. 1857), however, suggested that folding accompanied the thrust faulting in the Idaho-Wyoming thrust belt.

The high-angle thrust fault, east of the Woodruff thrust fault, could have formed soon after the major movement on the Woodruff thrust fault; however, it is more probable that it formed before major movement on the Woodruff in association with the folding. Thus, the Precambrian Mutual Formation was thrust over the high-angle fault on the Woodruff thrust fault. For major thrust faults in the Idaho-Wyoming thrust belt, Armstrong and Oriel (1965, p. 1857) have indicated that the younger faults are to the east.

Structural models for the Wyoming-Idaho-Utah thrust belt have been developed in which concentric folds, decollements, and reverse faults are typical (Royse and others, 1975, p. 41). Royse and others (1975, p. 41) also noted seismic, aeromagnetic, and surface data indicating that the crystalline basement was not significantly deformed over most of the thrust belt region and, therefore, the overlying sedimentary rocks were detached from the basement by a decollement. In consideration of these concepts,
it is probable that the Woodruff thrust fault joins at depth with a regional decollement. The high-angle thrust fault, east of the Woodruff thrust fault, could also join this decollement.
LITERATURE CITED


King, Clarence, 1876, Paleozoic subdivisions on the 40th parallel: American Journal of Science, 3rd ser., v. 11, p. 475-482.


Figure 1. Structure section A-A'

Figure 2. Structure section B-B'

Refer to Plate 1 for explanation

Structure sections of eastern part of Dairy Ridge Quadrangle and western part of Meachum Ridge Quadrangle, Utah

GEOLOGY BY VAL A. KIENAST, 1981-82