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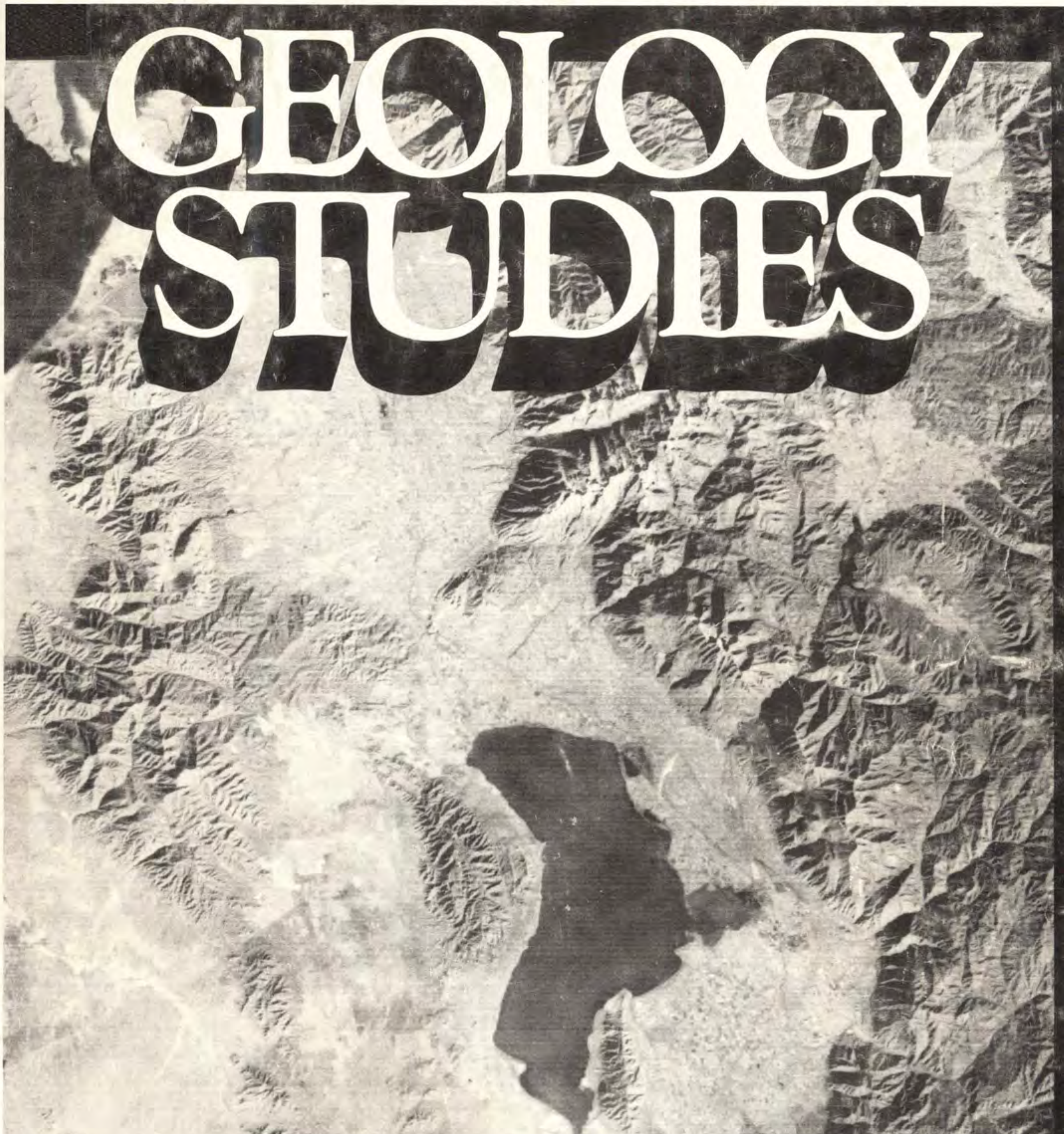

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CONTENTS

Cover: Aerial photo of Utah Valley and surrounding area.

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Geology of the Fairview Lakes Quadrangle: Sanpete County, Utah*

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ABSTRACT.—The Fairview Lakes Quadrangle is located in the northern Wasatch Plateau. The eastern third of the quadrangle is included in the northern Wasatch Plateau coalfield, which has considerable reserves in the Blackhawk Formation.

Approximately 1,050 m of Late Cretaceous and Early Tertiary rocks are exposed. The oldest exposed unit is the Blackhawk Formation, which accumulated in floodplain and coastal plain environments that once bordered the Mancos Sea. These sediments were derived from Cretaceous Sevier orogenic uplands to the west. Thick sandstone and conglomerate of the Castlegate Sandstone and thick sandstone and minor interbedded shale and conglomerate of the overlying Price River Formation accumulated in the subsiding foredeep basin. Variegated mudstone and fluvial sandstone of the North Horn Formation were deposited on eastward extending Cretaceous-Tertiary floodplains. Nonmarine limestone and thin layers of coal occur in the lacustrine middle part of the formation. More extensive lacustrine development is recorded in the Flagstaff Limestone.

Regional uplift in middle to late Tertiary time elevated the area of the Wasatch Plateau and formed the Wasatch Monocline. High-angle normal faults and grabens developed with nearly north-south trends, possibly a result of salt removal from Jurassic beds at depth and collapse of the overlying units or of basin-and-range faulting. The largest of these fault systems is the Gooseberry Graben, which has approximate displacement of 350 m on the downdropped central block.

Faulting in the eastern part of the quadrangle has resulted in drainage diversion in Flat Canyon and Brooks Canyon. Beheaded canyons and barbed tributary drainage are well shown.

Late Pleistocene (Pinedale) valley glaciers eroded well-developed cirques and produced glacial moraines in a few northeastward-draining canyons and in the high southern valley of the Gooseberry Graben.

Land surface instability is primarily confined to slopes underlain by the North Horn Formation. The steepness of slopes and the material upon which roads, reservoirs, and homes are built need to be taken more into consideration in future land management.

INTRODUCTION

The eastern third of the Fairview Lakes Quadrangle is included in the northern Wasatch Plateau coalfield and contains important coal reserves in the Blackhawk Formation. This part of the coalfield is expected to gain more importance as the demand for coal increases and as the easy-to-mine reserves in other areas are depleted.

Interest in possible petroleum accumulations in the Wasatch Plateau increased after discovery of natural gas in Carbon and Emery Counties. It resulted in drilling on two structures within the quadrangle, neither of which was productive in the Cretaceous section tested. However, lower formations that produce east of the plateau remain untested and may be of significant value.

Although the southwest part of the quadrangle had been mapped previously by Pashley (1956), as part of his study of geology of the western monoclinal flexure of the Wasatch Plateau, no recent detailed mapping of the Fairview Lakes Quadrangle had been done. An interest in coal and in possible petroleum and natural gas in this area prompted this more detailed investigation of the geology in the quadrangle.

Location and Accessibility

The Fairview Lakes Quadrangle lies entirely within the Wasatch Plateau in Sanpete County, central Utah. The central part of the quadrangle is approximately 22 km east of Fairview, which is in the northern Sanpete Valley, about 86 km southeast of Provo, Utah, on U.S. 89 (fig. 1).

An extensive network of maintained and unimproved roads branching from Utah 31, which cuts across the southwestern part of the quadrangle, covers the mapped area. However, because the area is at high elevations, road access into remote areas off the main highway is possible only during summer and early fall months after the heavy snowfall has melted and roads have dried out. Permission to cross private land must be obtained from local owners.

Field Methods

Fieldwork began in June and was completed by September 1979. Faults, stratigraphic contacts, and other features were plotted on aerial photographs at a scale of 1:15,000. Stratigraphic sections were measured with a 15-m tape. A Brunton compass and Abney level were used for determination of bedding attitudes and slope angles. The Wentworth scale was used for grain and clast size, and the rock-color chart, published by the Geological Society of America, was used as a standard color guide.

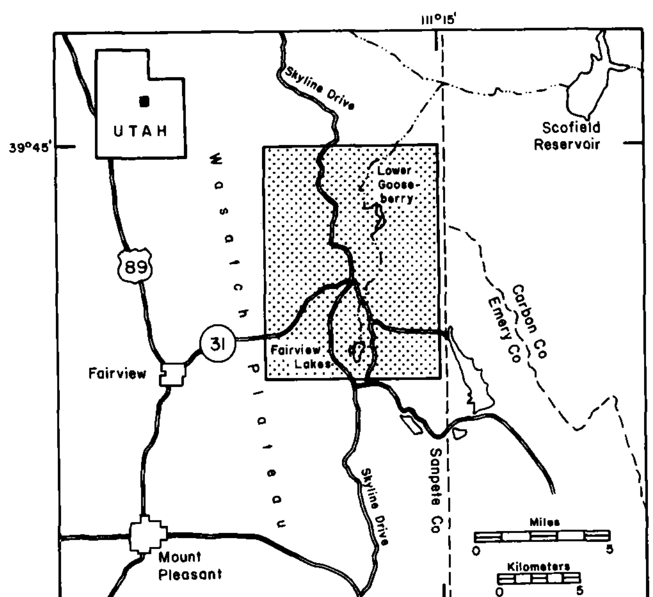

FIGURE 1.—Index map of Fairview Lakes Quadrangle.

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, April 1980. Thesis chairman: J. K. Rigby.

Fossils were collected to help in determining age relationships and environments of deposition from each formation, but they came principally from the Flagstaff Limestone and the North Horn Formations. Samples of the Flagstaff Limestone were collected from several sites in the area. These sites were evaluated as possible sources of limestone for construction aggregate, road metal, and raw material for manufacture of rock dust. Samples were submitted to the Utah Geological and Mineralogical Survey for analysis.

Previous Work

The southwest part of the Fairview Lakes Quadrangle was mapped in reconnaissance fashion by Pashley (1956). The region to the east of the quadrangle was mapped by Spieker (1931). Stratigraphic nomenclature of the area is based upon early studies by Spieker and Reeside (1925). Some revisions were made by Spieker (1946) and Fisher, Erdmann, and Reeside (1960).

Walton (1955) published a regional study on the Wasatch Plateau gas fields and outlined the major faults and folds of the Wasatch Plateau. His reconnaissance study included the Fairview Lakes area.

Spieker and Billings (1940) studied the effects of Pleistocene glaciation on the Wasatch Plateau. Godfrey (1978) did a reconnaissance survey of surface instability on the Wasatch Plateau.

Acknowledgments

The author expresses appreciation to Drs. J. K. Rigby and L. F. Hintze, who served on the thesis committee and gave valuable advice, and to H. H. Doelling for his advice and helpful discussions. Special thanks is given to the Utah Geological and Mineralogical Survey for financial assistance. Steve Sperry assisted in the fieldwork and, along with Steve Robison, gave valuable help on stratigraphy of the Flagstaff and North Horn Formation. Rodney Horrock also assisted in fieldwork. I appreciate the use of a pickup truck and trailer house provided by my wife's parents, and the time spent in typing and in field assistance by my wife, Rhonda.

STRATIGRAPHY

General Statement

Rocks exposed in the Fairview Lakes Quadrangle total approximately 1,050 m and consist mostly of sandstone, conglomerate, limestone, mudstone, and shale. The exposed stratigraphic section includes from the Upper Cretaceous Blackhawk Formation to the Paleocene Flagstaff Limestone (fig. 2). A few coal beds occur in both the North Horn and Blackhawk Formations, but only in the Blackhawk Formation are they of economic importance. Local freshwater lakes deposited nonmarine limestone within the North Horn Formation, whereas later extensive lake development resulted in deposition of the Flagstaff Limestone.

Quaternary deposits include morainal material of late Pleistocene glaciation, and Holocene deposits of colluvium, alluvium, alluvial fans, and landslide debris.

Cretaceous System

Blackhawk Formation

The Blackhawk Formation was named by Spieker and Reeside (1925, p. 443) for exposures near the Blackhawk coal mine on the eastern front of the Wasatch Plateau near Hiawatha. There the formation consists of interbedded sandstone, mudstone, shale, and coal and occurs between the underlying Star Point Sandstone and the overlying Castlegate Sandstone.

The Blackhawk Formation is extensively exposed along the east side of the Wasatch Plateau, and eastward into the Book Cliffs region (Doelling 1972, p. 4). The formation is also exposed on the western flank of the Wasatch Plateau, for example, in the canyon between Spring City and Mt. Pleasant and farther south in Twelve Mile Canyon and Salina Canyon (Pashley 1956, p. 13). The area of outcrop in the Fairview Lakes Quadrangle is in canyons cut into the flat upland east of the Gooseberry Graben in the eastern part of the quadrangle (fig. 19).

In the Fairview Lakes Quadrangle, the Blackhawk Formation is commonly covered with soil and slope wash, with only occasional thick, resistant sandstone beds exposed. The formation is almost entirely concealed by soil and alluvium near the bottom of the prominent eastern wall of the Gooseberry Graben. The best exposure of the formation within the quadrangle is in the canyon of Gooseberry Creek in section 29, T. 12 S, R. 6 E, but even this outcrop is restricted to scattered sandstone beds along the canyon walls and in the bottom of the creek.

No section was measured of the Blackhawk Formation because of its poor exposure. The formation is well exposed, however, in canyons south and east of the mapped area. A section was measured by Pashley (1956, p. 19–25) on the north canyon wall of South Fork of Cove Creek in the SW ¼, NW ¼, section 35, T. 14 S, R. 5 E, Huntington Reservoir Quadrangle,

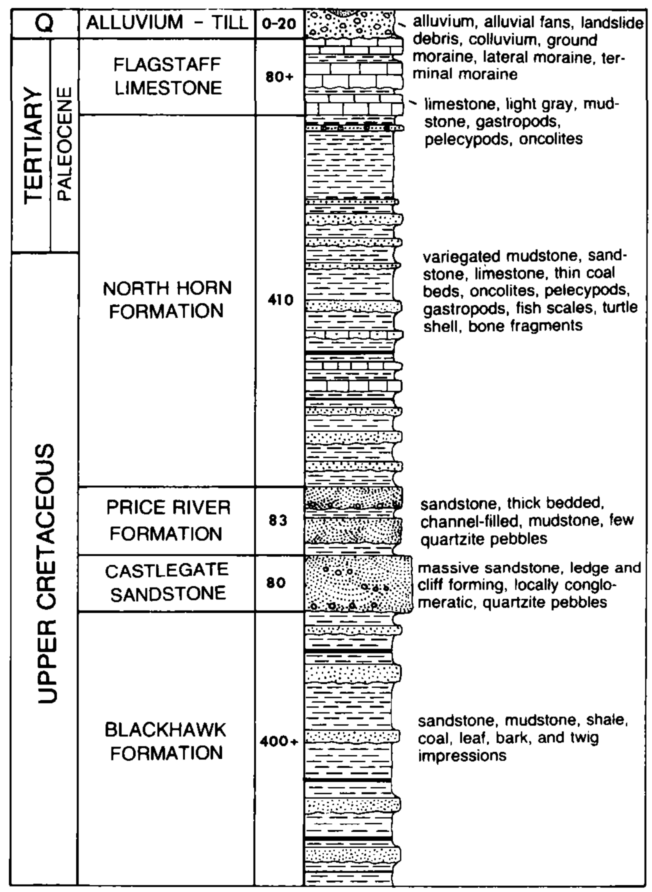

FIGURE 2.–General stratigraphic column of rocks exposed within Fairview Lakes Quadrangle.

FIGURE 3.–Thin beds of sandstone, coal, and mudstone of Blackhawk Formation exposed on north hillside of Flat Canyon, near Boulger Reservoir. Rock hammer is for scale.

immediately south of the Fairview Lakes Quadrangle, also the location of a well drilled by the U.S. Bureau of Mines. Both the measured section and well data are illustrated as stratigraphic columns by Doelling (1972, p. 6).

A few small exposures of interbedded sandstone, mudstone, shale, and thin coal beds occur along canyon walls of Gooseberry Creek and near the mouth of Boulger Canyon, along Flat Canyon (fig. 3). Rocks have been exposed here by recent slumping.

The sandstone beds are, for the most part, thick to very thin bedded and are composed of very-fine- to medium-grained quartz grains. The sandstone ranges from orangish brown to a light yellowish gray and is cemented with calcite and limonite. Well-preserved fossil leaves and impressions of parts of logs and twigs are found in some of the sandstone beds, along with coaly, macerated plant fragments.

Shale and mudstone of the formation are dominantly gray to dark gray and locally grade vertically from carbonaceous shale to nearly pure coal. The proportion of easily eroded shale and mudstone seems to be greater than that of more resistant sandstone, and the result is covered slopes with only occasional outcrops of sandstone beds. Such an outcrop pattern may be deceptive, however, because of the thinness of some sandstone beds.

A few thin beds of coal of the Blackhawk Formation are exposed in the quadrangle. One coal bed, about 20 cm thick, is exposed in a limited outcrop on the north hillside of Flat Canyon, near the mouth of Boulger Canyon in section 33, T. 13 S, R. 6 E. Another coal bed, 20 cm to 30 cm thick, is exposed in the roadcut along Huntington Creek, just south of Little Swens Canyon. East of the mapped area, where coal is being mined from the Blackhawk Formation, the thick persistent coal beds are restricted to the lower part of the formation. Subsurface data, referred to earlier, show the thickest coal beds in this region are in the lower 148 m of the formation (Doelling 1972, p. 6).

Spieker (1931, p. 28) reported a thickness of 230 to 328 m for the Blackhawk Formation in the eastern part of the Wasatch Plateau and said that the formation thins eastward to about 49 m thick north of Green River. The upper 190 to 262 m of the formation is partially exposed in the canyon of Gooseberry Creek, Mill Creek, and French Creek in the northeast corner of the quadrangle. All other exposures in the quadrangle represent only the uppermost 66 m or less of the Blackhawk Formation. Pashley (1956, p. 17) reported a total thickness of 575 m of Blackhawk Formation in his measured section and the U.S. Bureau of Mines well. These data indicate considerable thinning of the formation eastward from the western front of the Wasatch Plateau.

Spieker (1931, p. 36–37) stated that a few poorly preserved fossils collected from the Blackhawk Formation in the Wasatch Plateau and the Book Cliffs coalfields show that the rocks are of Montanan age. Many fossil plants identified by Knowlton (in Spieker 1931, p. 36–37) indicate that the formation is medial Montanan.

The base of the Blackhawk Formation is not exposed in the quadrangle, but elsewhere Spieker (1931, p. 35) has defined the contact as conformable and "clear-cut" with the upper surface of the Star Point Sandstone. The top of the formation is usually drawn at the base of the massive, cliff-forming Castlegate Sandstone. However, in the eastern third of the quadrangle the Castlegate Sandstone does not form a distinctive cliff, and rocks at the contact are not exposed on the covered slopes.

Rocks of the overlying Castlegate Sandstone are often much coarser than those in the Blackhawk Formation. This difference was used to separate the two formations within the mapped area. The contrast of fine-grained sandstone in Blackhawk beds to grit and conglomeratic sandstone in the Castlegate beds is well expressed along the walls of Boulger Canyon, Flat Canyon, and Brooks Canyon in the southeastern exposures, and Gooseberry Creek in northeastern ones. The best-exposed contact can be seen at the west mouth of Brooks Canyon, along the north side of the canyon wall in the SW ¼, SW ¼, section 8, T. 13 S, R. 6 E. There the contact was mapped directly below the thick cross-bedded, channel-filled, conglomeratic sandstone. A very fine-grained sandstone with coaly plant fragments, and a mudstone, parts of which are very carbonaceous, are exposed immediately below this contact. The rest of the lower hillside is covered.

Along the north canyon wall of Gooseberry Creek, near the top of the ridge in the NW ¼, section 29, T. 12 S, R. 6 E, a thick conglomeratic sandstone bed is exposed for some distance eastward from the trace of the north-trending East Goosberry Fault. This sandstone is considered to mark the base of the Castlegate Sandstone, for no other coarse beds are seen below it.

It is difficult to determine the exact relationship between the two formations, but the contrast in grain size of the overlying Castlegate Sandstone indicates depositional energy or source conditions quite different from those that produced the Blackhawk Formation. It is possible that the contact between the two formations is unconformable. Spieker and Reeside (1925, p. 445–46) suggested that the relationship is unconformable, for on the west side of the plateau there is an unconformity of considerable magnitude at the base of a succession of conglomerates and sandstone probably equivalent to the Price River Formation.

The sandstone, mudstone, shale, and coal of the Blackhawk Formation represent sediments deposited on broad floodplains and coastal plains with very low relief (Spieker 1931, p. 37). The sediments originated in what is now considered the Sevier highlands to the west and were carried by rivers onto the broad plain bordering the Mancos Sea (Pashley 1956, p. 18). Extensive swamps developed along the coastal floodplains during times of gradual subsidence and were protected by barrier beaches (Young 1976, p. 10). These swamps produced the persistent thick layers of coal of the lower part of the formation. Higher beds of the Blackhawk Formation represent sediments deposited farther inland on floodplains as the Mancos Sea withdrew eastward. The swamps that existed on the upper floodplains were not so extensive or long lived and thus formed lesser coal beds. Parker (1976, p. 99) studied the taxonomy and paleoecology of fossil plants collected from the Blackhawk Formation in Straight and Salina Canyons, in the central and southern portions of the Wasatch Plateau. He concluded that three major types of sedimentary environments existed on the broad floodplain which included peat-forming swamps, bottomlands, and point bars.

Castlegate Sandstone

The name *Castlegate Sandstone* was originally used by Forrester (1918, p. 24) in referring to a distinctive thick sandstone unit in what was then called the Laramie Formation, from outcrops around Castle Gate and Sunnyside. Spieker and Reeside (1925, p. 445), who referred to Clark's (1928) unpublished work, later used the term for the basal member of the Price River Formation. Fisher, Erdmann, and Reeside (1960, p. 14) later raised the member to formation rank. The Castlegate Sandstone forms a massive sandstone cliff at the type section in Price River Canyon, about 3.2 km above the former town of Castle Gate.

The Castlegate Sandstone is exposed as part of a cliff that extends almost continuously for 400 km from the southern end of the Wasatch Plateau north to Price, Utah, and eastward, as the Book Cliffs, into western Colorado. The formation dips northward beneath the Uinta Basin, and west of Castle Valley it dips northward beneath the Wasatch Plateau (Van de Graaff 1972, p. 558). Castlegate beds are exposed in various parts of the Wasatch Plateau and along the western front of the plateau between Spring City and Fairview, where the formation forms vertical cliffs in the canyon walls (Pashley 1956, p. 27).

In the Fairview Lakes Quadrangle, the Castlegate Sandstone is exposed immediately east of the Frontal Fault in Cottonwood Canyon, in the NE ¼, section 33, T. 13 S, R. 5 E, and in Oak Creek Canyon, in the SE ¼, section 21, T. 13 S, R. 5 E. The formation is also exposed in the eastern part of the quadrangle in the canyons cut into the flat upland east of the Gooseberry Graben (fig. 19).

In Cottonwood Canyon, the formation crops out as massive sandstone cliffs and ledges and is best exposed on the north side of the canyon wall, below Utah 31, at the junction of Blind Fork and Cottonwood Canyon (fig. 4). On the south side of the canyon, the formation is concealed by slope wash and tree cover. In Oak Creek, the next canyon to the north, the formation is poorly exposed in the bottom of the canyon and is covered by slope wash and trees along the hillsides. In these canyons the sandstone is thick bedded and massive, with occasional cross-bedding and channel fills. The sandstone is usually dark yellowish orange to light yellowish gray and composed of medium- to coarse-grained quartz, cemented by calcite and limonite, with quartzite grit and pebble clasts in the bottom of some channel fills. A few carbonaceous plant fragments were found in some of the sandstone beds.

In the eastern part of the quadrangle, the Castlegate Sandstone forms steep slopes with only occasional outcrops along the canyon walls and does not form a prominent cliff, as it does in the eastern part of the plateau. In outcrops along the walls of Boulger Canyon and on the north side of Flat Canyon, the Castlegate Sandstone is light gray to light yellowish gray and conglomeratic, with quartzite pebbles and cobbles in a sandstone matrix. In Brooks Canyon, in the SW ¼ of section 8, T. 13 S, R. 6 E, occasional outcrops of the formation consist of fine- to medium-grained sandstone with a few grit- and pebble-size clasts.

FIGURE 4.—Sandstone ledges and cliff of Castlegate Sandstone, below Utah 31, in Cottonwood Canyon.

The formation is less conglomeratic in the northern part of the mapped area. In the northeast corner of the quadrangle, the upper part of the Castlegate Formation is exposed along Bean Ridge where the sandstone is fine to medium grained and light yellowish gray. On the north side of Gooseberry Creek Canyon, in the NW ¼, section 29, T. 12 S, R. 6 E, the base of the Castlegate Sandstone is defined by a thick conglomeratic sandstone that is light gray, locally stained to orangish brown, cross-bedded and channel filled, containing quartzite pebbles and cobbles. Above this unit the formation is mostly covered with slope wash, but it does crop out in ledges of fine-grained, light gray sandstone at the top of the hill.

At the type locality, the Castlegate Sandstone is about 130 m thick (Clark 1928, p. 119); however, its thickness in the Wasatch Plateau ranges from about 16 to 164 m (Spieker 1931, p. 44). Pashley (1956, p. 32) reported 81 m of Castlegate Sandstone from a section on the north wall of Pleasant Creek, just east of Mount Pleasant. In the eastern part of the Fairview Lakes Quadrangle its thickness ranges from 66 to 98 m. However, only the upper 50 m of the formation is exposed in Cottonwood Canyon and Oak Creek in western exposures.

The age of the Castlegate Sandstone is medial Montanan (Reeside 1956, p. 1786). Recently Van de Graaff (1972, p. 560) assigned a Campanian age to the formation. Spieker (1946, p. 131) reported an age of late Montanan for the Price River Formation from the sandy facies in the Castle Gate area.

The lower contact of the Castlegate Sandstone on the underlying Blackhawk Formation is considered to be unconformable, on the basis of the abrupt change in lithology between the two formations. The upper contact of the Castlegate Sandstone with the Price River Formation is gradational in Cottonwood Canyon and is best exposed in the NE ¼, section 33, T. 13 S, R. 5 E. The contact was mapped at the top of the massive Castlegate Sandstone ledges, where mudstone of the Price River beds first appears. The contact is not exposed throughout the rest of the quadrangle, but the Castlegate Sandstone was separated from the Price River Formation east of the Gooseberry Graben on the basis of differences in slopes and terracing produced by the lithologic differences in the two formations.

In the Fairview Lakes Quadrangle, the conglomerate and sandstone of the Castlegate Sandstone indicate deposition from a nearby highland area that resulted from a strong orogenic pulse of the Sevier orogeny. Van de Graaff (1972) recognized the Castlegate Sandstone as a rock record of sediments from piedmont alluvial fans in western areas, passing eastward into fluvial, delta-plain, shoreline, and delta-front environments, and that the formation is one of several regressive sandstones that intertongue into the Mancos Shale. The increase and decrease in coarseness of Castlegate sediments within the quadrangle indicate localized areas in transition between piedmont facies and fluvial facies, with some areas receiving more coarse sediments than others.

Price River Formation

The Price River Formation was named by Spieker and Reeside (1925, p. 445) for exposures in Price River Canyon above Castle Gate, Utah. There it is a succession of predominantly gray sandstone, grit, and conglomerate beds with minor amounts of shale. The formation originally included the Castlegate Sandstone as the lower member, but Fisher, Erdmann, and Reeside (1960, p. 13–14) restricted the Price River Formation to the upper interbedded sequence by raising the Castlegate Sandstone to formation rank.

The Price River Formation is exposed from the type locality eastward along the Book Cliffs to as far as the Green River in Utah (Risher, Erdmann, and Reeside 1960, p. 14). To the west, it is exposed in upper reaches of Spanish Fork Canyon where it forms part of a series of coarse conglomerate beds. It also extends southward from the type locality as a sheet and is widely exposed throughout the Wasatch Plateau (Spieker 1946, p. 130).

In the Fairview Lakes Quadrangle, the Price River Formation crops out in Cottonwood Canyon and in Oak Creek Canyon, east of the western plateau frontal faults. It is exposed in the deep canyon of Gooseberry Creek, in the NE ¼, section 31, T. 12 S, R. 6 E, but that outcrop belt is truncated by the north-trending East Gooseberry Fault. The formation overlies the Castlegate Sandstone in the canyon walls of the upland area east of the East Gooseberry Fault and on the east hillside of the Gooseberry Graben (fig. 19).

The formation is best exposed in roadcuts on Utah 31 along Cottonwood Canyon, in the NE ¼, section 33, and in the NW ¼, section 34, T. 13 S, R. 5 E. Here it consists of thin- to thick-bedded sandstone and mudstone. The sandstone varies from light yellowish gray to moderate yellowish brown, fine to medium grained, and is cemented with calcite and limonite. The sandstones are cross-bedded and show channeling into the underlying mudstone. Chips from the underlying mudstone are found at the base of some of the channel-filled sandstones, and a few coaly plant fragments are found in some of the sandstone beds.

The sandstone beds thin laterally in both directions from the thick channels and commonly have undulatory bedding surfaces, with evidence of soft-sediment deformation. Farther up the canyon the top part of the formation contains more thick and massive, cross-bedded, channel-filled sandstones (fig. 5). These thick sandstone beds are coarser grained and contain occasional quartzite grit and pebbles. Mudstone beds are thicker and more common in the lower part of the formation and are generally olive gray to light yellowish gray. The mudstone weathers crumbly and splintery, forming slopes and reentrants below resistant sandstone beds.

In Oak Creek Canyon, the formation is poorly exposed but is recognizable as thick, cross-bedded and channel-filled sandstone found in the bottom of the stream bed. In the canyon of Gooseberry Creek, only ocasional sandstone beds are exposed along the hillsides. The covered slopes between thick sandstone beds are assumed to be mudstone and thinner-bedded sandstone. Upper sandstone beds of the formation in Gooseberry Creek exposures are light gray and conglomeratic, with quartzite pebbles and cobbles. The lower sandstone beds are light yellowish gray, medium grained, and thick bedded.

The Price River Formation is poorly exposed east of the Gooseberry Graben along the hillsides and canyon walls of the flat uplands within the quadrangle. The hillsides are covered with slope wash and are forested so that only a few outcrops of thick sandstone occur.

Near the mouth of Boulger Canyon, on the hillside north of Flat Canyon, the formation crops out at the front of the ridge as a light yellowish gray to light gray, fine- to medium-grained sandstone. It is cross-bedded and channel filled and contains occasional grit and pebbles. The lower part of the formation is not exposed beneath slope wash there, but probably contains more mudstone beds, similar to those exposed in Cottonwood Canyon, based on terraces formed between the upper Price River Formation and the underlying Castlegate Sandstone (fig. 6).

In general, the Price River Formation is not as coarse grained as the underlying Castlegate Sandstone, but in a roadcut along Bean Ridge, in the SE ¼, section 33, T. 12 S, R. 6 E, Price River beds are light gray, coarse-grained, cross-bedded, and channel-filled conglomeratic sandstone, with grit- to cobble-size clasts.

Spieker (1946, p. 131) reported an age of late Montanan for the Price River Formation, on the basis of its stratigraphic position and fossils from the sandy facies in the Castlegate area. Runyon (1977, p. 70) concluded that the coarse, westernmost facies is probably slightly older because those rocks are closer to the orogenic highland. He assigned a date of middle and/or late Montanan.

FIGURE 5.–Roadcut exposure of thick cross-bedded sandstone of Price River Formation, in Cottonwood Canyon.

The Price River Formation, at the type section (Spieker 1946, p. 130), was given a thickness of 361 m in the original definition. About half that thickness is now included in the Castlegate Sandstone. In Cottonwood Canyon in the mapped area, the formation is approximately 83 m thick. On the east side of the Gooseberry Graben, the formation ranges from 66 m to 85 m thick, on the basis of map patterns and topography.

In Cottonwood Canyon, the Price River Formation conformably overlies the Castlegate Sandstone. Elsewhere, however, such as east of the Gooseberry Graben, the contact is covered by slope wash and forest, and detailed observations are impossible. In the latter areas, the lower contact was mapped at the lowest terrace above the Castlegate ledges. Mudstone beds in the basal part of the Price River Formation are probably controlling the terraces in the eastern third of the quadrangle. Where terracing is poor, the contact is inferred with reference to thickness of the Price River Formation below North Horn beds.

The upper contact was mapped immediately above the thick sandstone of the Price River Formation, and where reddish mudstone of the North Horn Formation first appears. This contact is somewhat gradational and is well exposed in roadcuts in Cottonwood Canyon, in the NE ¼, NW ¼, section 34, T. 13 S, R. 5 E. It is also clearly defined in parts of the upland area east of the Gooseberry Graben. In small north- and east-facing cirques and related depressions, the thick sandstone beds of the Price River Formation form ledges directly below reddish brown and purplish slope-forming mudstone beds of the North Horn Formation. Exposures are particularly good in cirques in the head of Mill Creek, in the head of Upper Huntington Creek, and along the east side of Winterquarters Ridge, in the northeast corner of the quadrangle. Similar exposures are found in the NW ¼, SE ¼, section 8 and in the NW ¼, NE ¼, section 5, T. 13 S, R. 6 E.

The conglomerate and sandstone of the Price River Formation, like those of the Castlegate Sandstone, indicate deposition near a highland area produced by the Sevier orogeny. Spieker (1949, p. 62) referred to the rocks of the Price River Formation as being a repeated littoral marine sandstone projecting eastward into the Mancos Shale above the Castlegate Sandstone. Within the Fairview Lakes Quadrangle, however, the Price River Formation represents localized environments intermediate between piedmont facies and fluvial facies. This is suggested by local areas of conglomeratic sandstone and interbedded lenticular mudstone and channel-filled sandstone.

Cretaceous-Tertiary System

North Horn Formation

The North Horn Formation was originally defined by Spieker and Reeside (1925, p. 445) as the lower member of the Wasatch Formation. Spieker (1946, p. 132) later raised the North Horn beds to formation rank. The type locality of the formation is on the southwest point of North Horn Mountain, on the east side of the Wasatch Plateau. There, the formation is composed of variegated shale and sandstone, conglomerate, and freshwater limestone, and is divided into four distinct units (Spieker 1946, p. 133) representing alternations between lacustrine and fluvial conditions.

The North Horn Formation is extensively exposed throughout the Wasatch Plateau and surrounding areas (Pashley 1956, p. 37). South of the Wasatch Plateau the formation disappears beneath lavas of the Fish Lake Plateau. Equivalent beds are known in the Wasatch Mountains to the north (Gundersen 1961, p. 13). To the east, the formation passes into the Tuscher Formation between Sunnyside and Thompson Canyon in eastern Utah (Spieker 1949, p. 61).

In the Fairview Lakes Quadrangle, the North Horn Formation is exposed in the deep canyons of South San Pitch Canyon, Dry Creek, Oak Creek, Cottonwood Canyon, and Spring Creek, west of the Gooseberry Graben and caps the uplands east of the East Gooseberry Fault (fig. 19).

Three distinct units are recognizable within the North Horn Formation in the studied area; however, no attempt was

FIGURE 6.–View northward across Flat Canyon, south of mouth of Boulger Canyon, of North Horn, Price River, Castlegate, and Blackhawk Formations. Terracing is produced by lithologic differences between units.

made to map them separately because of poor exposures and uncertain contacts. The lower unit, as seen in Cottonwood Canyon, is about 63 m thick and consists of thick- to thin-bedded sandstone and mudstone. The sandstone, for the most part, is light yellowish gray to grayish orange, fine grained, and cemented with calcite add limonite. The sandstone beds are channel filled and cross-beded with rip-up clasts from underlying mudstone beds near the base of the channel fills. The mudstone beds are variegated reddish brown, purple, and olive gray, and slighty calcareous, and they weather crumbly and splintery. The thicker sandstone beds form small ledges along the hillsides where the mudstone weathers to slopes and reentrants (fig. 7).

The middle unit is at least 130 m thick in Cottonwood Canyon, but could be somewhat thicker because the outcrop is truncated by the Cottonwood Ridge Fault. The middle unit consists of interbedded limestone, sandstone, and mudstone, with a few very thin coal beds. The limestone is medium gray to light yellowish gray, micritic, and thinly bedded. The mudstone is medium gray to light olive gray and calcareous and contains plant fragments in beds nearest to the thin coal beds. The sandstone is grayish yellow, very fine grained, and thinly bedded. Limestone and sandstone units have undulatory lower bedding surfaces.

The upper unit is at least 158 m thick in Cottonwood Canyon, but it is truncated by a fault. This unit consists of interbedded sandstone and mudstone similar to the lower unit. Sandstone beds are thicker in the upper unit than they are in the lower unit. They are yellowish orange to yellowish gray, fine grained, cross bedded and channel filled, and cemented with calcite and limonite. The mudstone is similar in appearance to the mudstone of the lower unit.

The formation is poorly exposed along the floor of the Gooseberry Graben, except where stripped bare along the canyon walls of Gooseberry Creek. Here, the same three generalized units can be recognized. The lacustrine unit is exposed at the head of Boulger Canyon and along the canyon walls of Gooseberry Creek, immediately north of the Lower Gooseberry Reservoir, in section 6, T. 13 S, R. 6 E. Thick-bedded sandstone of the upper unit of the formation is exposed in the canyon walls of Gooseberry Creek in section 19, T. 13 S, R. 6 E.

East of the Gooseberry Graben, the North Horn Formation caps the flat uplands and ridges within the quadrangle. Most of the exposures there are of the lower unit, consisting of reddish brown and purple mudstone and thin-bedded sandstone. The lacustrian middle unit is also well exposed in the cirque wall of Little Swens Canyon.

In the Indianola Quadrangle, immediately northwest of the mapped area, Runyon (1977, p. 70) reported conglomerate containing abundant Paleozoic limestone clasts and large algal balls waithin the North Horn Formation. In the Fairview Lakes Quadrangle, these kinds of rocks occur as a conglomeratic and oncolitic sandstone unit near the top of the formation. This bed crops out along the Left Fork of Cottonwood Canyon in the NW ¼, NE ¼, section 23, on the east side of the road to Lower Gooseberry Reservoir in the NW ¼, NE ¼, section 24, and in the NE ½, NW ¼, section 13, T. 13 S, R. 5 E. The sandstone is light yellowish gray, medium to coarse grained, conglomeratic with occasional medium gray and light gray limestone clasts, abundant oncolites up to 15 cm in diameter, and large algal mats up to 40 cm wide (fig. 8). The sandstone is cross-bedded and channel filled and contains rip-up chips of mudstone.

Weiss (1969, p. 1106) studied the algal balls of the North Horn and Flagstaff Formations in central Utah and concluded that they were formed in near-shore, warm, shallow, active waters, often near the mouth of streams. He also indicated that several types could be distinguished as either autochthonous or allochthonous oncolites.

Runyon (1977, p. 71) proposed that the large oncolites of the North Horn Formation originated in streams and that their growth was due to moderately high stream gradients. There is no doubt that the algal mat fragments and oncolites of the North Horn Formation, found within the study area, were deposited in place as clasts in a fluvial system. The large algal-mat fragments and well-preserved oncolites suggest very little transport before deposition, or that they were capable of floating for some distances. They may have been lightweight if the algal growths contained extensive gas-filled voids. This may also account for their large size.

The North Horn Formation is 541 m thick at the type section (Spieker 1946, p. 133). In the Fairview Lakes Quadrangle, the formation is approximately 410 m thick. East of the Goose-

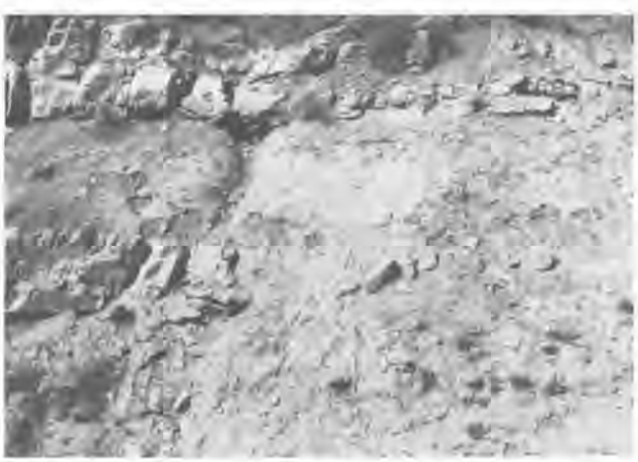

FIGURE 7.–Roadcut exposure of sandstone (2 m thick) and interbedded mudstone of North Horn Formation, in Cottonwood Canyon.

FIGURE 8.–Oncolites, 5 to 15 cm in diameter, and parts of algal mats, in sandstone matrix from North Horn Formation. Note quarter for size.

berry Graben, rocks of the lower 50 to 130 m of the formation cap the uplands within the quadrangle.

Fossils found in the formation include gastropods, pelecypods of the family Unionidae, ostracods, fish scales and bones, turtle shell fragments, and bone fragments (fig. 9). All the fossils collected in the mapped area came from lacustrine facies, except for a few bone fragments which occasionally were found in fluvial sandstones of the lower and upper units. Most of the fossils were collected from roadcuts along Utah 31, in the NW ¼, section 33 and the NE ¼, section 27, T. 13 S, R. 5 E, at the head of Boulger Canyon, from below Lower Gooseberry Reservoir along the canyon walls of Gooseberry Creek, and from the cirque wall of Little Swens Canyon.

The age of the North Horn Formation was originally thought to be early Tertiary by Spieker (1925, p. 450). However, subsequent discovery of dinosaurian bones near the base of the formation indicated an Upper Cretaceous age for at least those beds. Spieker (1946, p. 135) reported that the upper part of the formation yielded mammalian bones thought to be of earliest Tertiary (Paleocene) age. He concluded that the passage from the Cretaceous to the Tertiary system lies within the North Horn Formation. Subsequent study by Spieker (1960, p. 16–17) near the type locality of the North Horn Formation, showed that a horizon of dinosaurian material is only a few feet below that of the unit containing the lowest mammalian remains. On the southwest face of North Horn Mountain, dinosaurian material came from the lowermost two units, a fluvial and a lacustrine unit, totaling about 344 to 377 m thick. The mammalian bones were found in the third unit, a fluvial unit. This unit, along with the lacustrine fourth unit, has a total thickness of 164 to 197 m. The third fluvial unit of the type section is probably equivalent to the third unit in the Fairview Lakes Quadrangle. If so, the Cretaceous-Tertiary boundary in the mapped area lies about two-thirds of the thickness up into the formation.

In Cottonwood Canyon, the formation conformably overlies the Price River Formation with a gradational contact. This contact is also exposed in the eastern highlands of the quadrangle, as described earlier in the discussion of the Price River Formation. The upper contact is also gradational with the overlying Flagstaff Limestone and is best observed at the head of Dry Creek.

The North Horn Formation represents inland floodplain deposits that spread both eastward and westward over the underlying Price River Formation. The sediments came from western highlands of the Sevier orogenic belt during a period

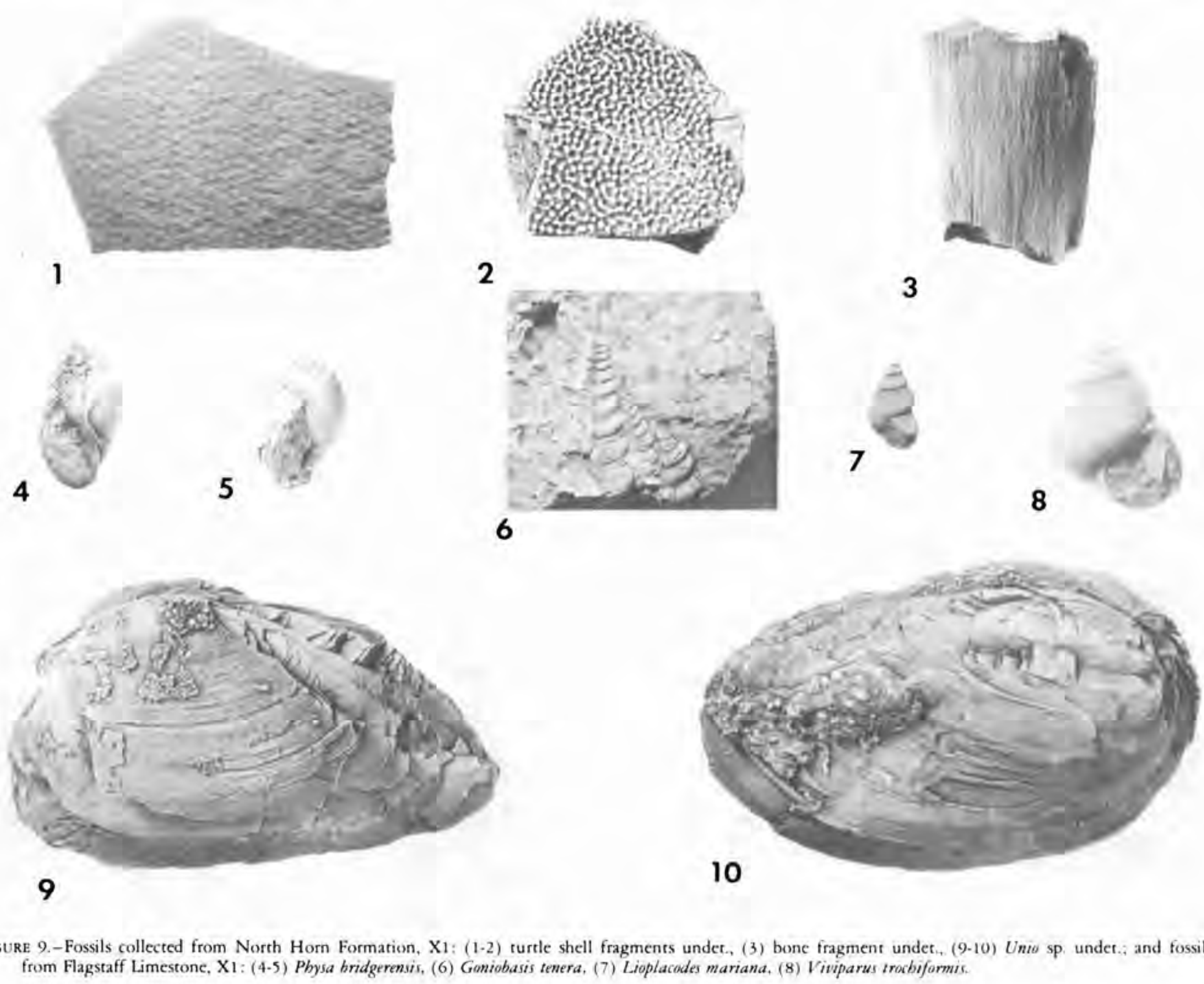

FIGURE 9.–Fossils collected from North Horn Formation, X1: (1-2) turtle shell fragments undet., (3) bone fragment undet., (9-10) *Unio* sp. undet.; and fossils from Flagstaff Limestone, X1: (4-5) *Physa bridgerensis*, (6) *Goniobasis tenera*, (7) *Lioplacodes mariana*, (8) *Viviparus trochiformis*.

of waning deformation that lasted into the Paleocene (Armstrong 1968, p. 449). The formation shows an alternating fluvial and lacustrine facies that interchanged laterally throughout the Wasatch Plateau. The lacustrine facies represents shallow lakes and marshes that developed in local depressions on the broad floodplains.

Tertiary System

Flagstaff Limestone

The Flagstaff Limestone was originally proposed as the Flagstaff Member of the Wasatch Formation by Spieker and Reeside (1925, p. 488–89). Spieker (1946, p. 135–36) later revised the terminology and elevated the member to the Flagstaff Limestone of formation rank. The formation was named for exposures on Flagstaff Peak in the southern Wasatch Plateau. There, the formation consists dominantly of freshwater limestone, gray shale with some oil shale, and sandstone. Ryder, Fouch, and Elison (1976k p. 496–97) used the term *Flagstaff Member of the Green River Formation* in their study of early Tertiary sedimentation in the western Uinta Basin. Gilliland (1951, p. 25–26) thought the term *limestone* inappropriate and substituted *formation* because of different lithologic sequences in some areas, such as the Gunnison Plateau, where he reported considerable thicknesses of sandstone and conglomerate. McGookey (1960, p. 596), La Rocque (1951, 1960), and Runyon (1977, p. 71) called these rocks the Flagstaff Formation. However, all the outcrops in the Fairview Lakes Quadrangle are similar to those on Flagstaff Peak, and the term *Flagstaff Limestone* is used here.

The formation is exposed only in the western half of the Fairview Lakes Quadrangle. There it crops out as thin resistant caps along the crest of ridges and flat broad uplands, where it generally holds up a dip slope. The formation is also exposed in the Cedar Hills, the southern Wasatch Mountains, and the plateaus north of the Book Cliffs. It extends southward into the Fish Lake Plateau and may be represented by units of limestone in the extreme southern regions of the High Plateaus (Pashley 1956, p. 50).

The lower 80 m of Flagstaff Limestone, exposed at the head of Dry Creek, is the most completely exposed section within the quadrangle. Here, the formation consists of thin beds of gray to light yellowish gray, principally micritic limestone, with thin-bedded gray shale and mudstone. The limestone has undulatory bedding surfaces, and beds vary from 1 to 6 m thick. Mudstone beds vary from 20 cm to 6 m thick (fig. 10) and form reentrants below ledges of limestone. Minor sandstone beds less than 1 m thick occur within the limestone and mudstone units. More sandstone beds are observed in other areas within the quadrangle.

Only the lower part of the formation is preserved in the mapped area although more complete sections are exposed along the monocline immediately west of the quadrangle boundary. The preserved part of the formation ranges from 32 to 80 m thick on most of the capped ridges and flat uplands, but in some limited areas, such as on Chokecherry Peak, it is as much as 118 m thick.

The most abundant fossils in the Flagstaff Limestone are gastropods, pelecypods, and ostracods, in decreasing order. The limestone beds range from almost a coquina of gastropod shells to beds with very rare shell fragments. Algal growths have coated gastropod and pelecypod shells, forming oncolites up to 15 cm in diameter, in a few beds. Trace fossils, mostly horizontal and vertical burrows, commonly can be found in many of the limestone beds (fig. 11).

A detailed paleontological study of the Flagstaff Limestone was made by La Rocque (1960) in which he used the molluscan assemblages to zone the Flagstaff. From it he divided the formation into three units: the lowest is of Paleocene age, the middle is of Paleocene or Eocene age, and the upper is of Eocene age. The most common gastropod found in the area is *Viviparus trochiformis,* which is characteristic of the lower part of the formation. Other species of molluska, such as *Lioplacodes mariana, Goniobasis tenera, Elliptio (Plesielliptio) mendax,* and *Physa bridgerensis,* found within the quadrangle also indicate only the lower part of the formation is preserved in the quadrangle (fig. 9).

FIGURE 10.–Interbedded limestone and mudstone of Flagstaff Limestone, exposed at head of Dry Creek. Locations of measured section (section 1, appendix).

FIGURE 11.–Trace fossils along bedding surface of Flagstaff Limestone. Limestone block is about 50 cm wide.

Stanley and Collinson (1979) more recently divided the formation into three members on the basis of lithologic changes. They designated the lower unit as the Ferron Mountain Member, the middle unit as the Cove Mountain Member, and the upper unit as the Musinia Peak Member. It was difficult to apply their subdivision in the mapped area, possibly because only the lower unit is preserved here. The Ferron Mountain Member includes most of the rocks assigned by La Rocque to "unit 1" of late Paleocene age.

The contact between the Flagstaff Limestone and the North Horn Formation is mostly concealed by slope wash and soil. A few good exposures are found, however, at the head of tributaries of Dry Creek, Oak Creek, and Cottonwood Canyon, near the crest of the ridges. They show that the lower contact of the formation is gradational. The contact was mapped at the horizon where the variegated mudstone of the North Horn Formation changes to a dominantly gray mudstone immediately below the limestone outcrops of the Flagstaff Limestone. In the northwest corner of the quadrangle, along the north and west side of Chokecherry Peak, gray units of the lower part of the formation intertongue with reddish fluvial beds of the North Horn Formation. A prominent terrace has formed along many hill slopes at the contact zone just below the continuous outcrops. These beds produce areas of slope instability and slumping, a zone commonly marked by springs. A few of the freshly eroded gullies show this to be due primarily to movement of the underlying North Horn mudstone. The basal contact of the Flagstaff beds shows well on aerial photos.

The Flagstaff Limestone was deposited in a large freshwater lake that once covered much of the area now uplifted to form the Wasatch Plateau and surrounding areas. Although the lake once covered a large area, the evidence of its being shallow is clearly shown by the abundance of gastropods and pelecypods, the lateral and vertical variation of the beds, and few beds that contain oncolites, and the high proportion of shell fragments, found in some beds, that were worked by wave action. Lake Flagstaff formed when drainage over the North Horn alluvial plain became restricted in late Paleocene time. Hunt (1956, p. 73) suggested that an increase in downwarping in the western part of the plateau during Paleocene time resulted in the development of lakes in which were deposited the Flagstaff Limestone and Green River Formation.

Quaternary System

Morainal deposits of late Pleistocene (Pinedale) glaciation, and Recent deposits of alluvium, alluvial fans, and landslide debris are differentiated within the Fairview Lakes Quadrangle.

Morainal deposits are restricted to the high southern valley of the Gooseberry Graben along the north side of the high peak southwest of Fairview Lakes, in the NE ¼, section 2, T. 14 S, R. 5 E; to Boulger Canyon near the intersection of Boulger Canyon and Flat Canyon; and to the head of Little Swens Canyon. These deposits are mapped as numbered series of older to younger terminal and recessional moraines, lateral moraines, and ground moraines. Tarns and kettles were also recognized and mapped. Morainal surfaces are hummocky and irregular, with occasional small depressions or kettles. The till is composed of small to large, angular blocks up to 60 cm in diameter of locally derived sandstone and limestone, all embedded in a matrix of unstratified sand and clay (fig. 12). The thickness of the moraines ranges up to 20 m. Other features of glaciation are discussed under geomorphology.

Alluvial fans occur along the east wall of the Gooseberry Graben, east of Lower Gooseberry Reservoir, and along the east-facing canyon wall of Boulger Canyon. Fans are composed dominantly of clay and sand, but contain occasional small sandstone and limestone clasts.

Alluvium is confined to stream channels in most of the canyon floors and within the valley floor of the Gooseberry Graben. The alluvium consists of fine-grained sand and clay, with pebbles and cobbles restricted to the deeper canyons in which major streams flow, such as Cottonwood Canyon, Oak Creek, and Gooseberry Creek.

Although slumping is active in parts of the quadrangle, only a few small landslides were mapped. They are located along the north canyon walls of Oak Creek, Cottonwood Canyon, Gooseberry Creek, and Boulger Canyon (fig. 19). Major slumping occurs along the deep canyon walls where soil and colluvium are underlain by the North Horn Formation. The north-facing slopes are generally more unstable than the south-facing slopes, but the north-facing slopes are covered with forest, which makes it difficult to identify and map landslides. Much of the landslide material is clay and mud from the North Horn Formation, with a few large sandstone and limestone blocks from disrupted beds. Drainages along Oak Creek and Cottonwood Canyon have been disturbed by recent slumping, recognized by the addition of more coarse material to the stream bed that produced variations in gradient and local areas of rough water within the streams.

STRUCTURE

General Statement

The structural pattern in the Fairview Lakes Quadrangle is dominated by a north-trending system of faults superimposed on the broad westward-dipping monocline of the western Wasatch Plateau. Westward dip of the plateau averages about 5° and is related to continued uplift of the San Rafael Swell and High Plateau, whereas the faulting is of later origin. In the southwest corner of the quadrangle, west of the Frontal Fault, the rocks dip to a maximum of 14° where the steep flexure of the Wasatch Monocline is approached. Hunt 91956, p. 53) attributes the structure of the plateau, with its northward-trend-

FIGURE 12.–Terminal moraine deposit at mouth of Boulger Canyon.

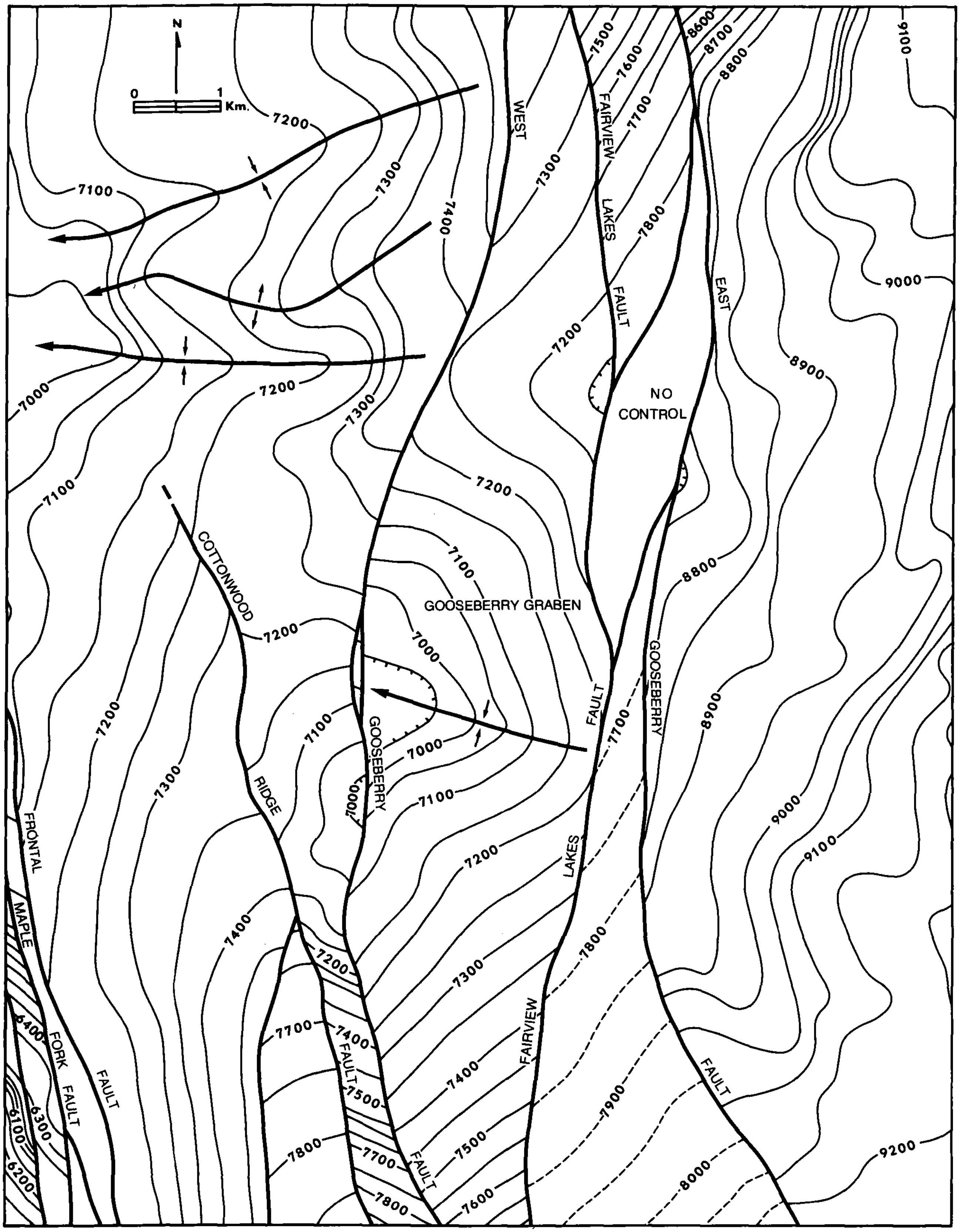

FIGURE 13.—Structural contour map of quadrangle. Contours are drawn on top of Blackhawk Formation. Contour interval is 50 feet.

ing faults, as representing a zone transitional between the Colorado Plateau and Basin and Range Provinces.

For the most part, rocks of the quadrangle are broken by high-angle normal faults, such as those which define the Gooseberry Graben. Smaller faults split from, or trend parallel to, the main faults and form small horsts, grabens, and antithetic systems.

A structural contour map of the quadrangle (fig. 13), contoured on the top of the Blackhawk Formation, provides a picture of fault displacement and also shows an anticlinal nose with a westward plunge in the northwest part of the quadrangle, and a synclinal nose with a westward plunge in the middle of Gooseberry Graben. These are gentle structures and are not obvious on the surface.

Gooseberry Graben

The Gooseberry Graben is defined by a series of high-angle normal faults that have helped to produce the major north-south trending Gooseberry Valley in the Fairview Lakes Quadrangle. The graben is bounded on the west side by the West Gooseberry Fault and on the east by the East Gooseberry Fault. The deepest trough of the graben is bordered on the east by the Fairview Lakes Fault and on the west by the West Gooseberry Fault. At the head of Flat Canyon, the East Gooseberry Fault swings to the southeast and no longer helps define the main trough. The Gooseberry Graben terminates immediately south of the Fairview Lakes Quadrangle. North of the quadrangle, the graben loses its expression where the boundary faults begin to die out. Each of the major faults will be treated separately on following pages.

The faults forming the Gooseberry Graben, along with the Cottonwood Ridge Fault, are superimposed on the gently westward-dipping Tertiary rocks of the Wasatch Plateau. Strata on both sides of the graben continue to maintain a regional strike to the northeast and low dips to the west, which suggest that the Gooseberry Graben is an extensional feature, possibly a collapse feature. Stokes (1956, p. 790) concluded that the complex fault zones of the Wasatch Plateau are related to the tensional features of the Wasatch Monocline and possible extension permitted by solution of the salt-bearing Jurassic rocks underlying Sanpete Valley. Runyon (1977, p. 75) and Hawks (1980, p. 27) recognized structural complexities due to the growth and collapse of salt structures in the Indianola Quadrangle and in the Cedar Hills area, respectively. However, faulting on the plateau is of a different structural style and may be more related to basin and range extensional faulting.

Frontal Fault

The Frontal Fault was described by Pashley (1956, p. 62) as a high-angle normal fault that separates the nearly horizontal beds east of the fault from the steeper dipping beds of the monocline to the west. The Frontal Fault was traced by Pashley (1956, p. 83) from the north wall of Oak Creek, in the Fairview Lakes Quadrangle, southward for about 20 km to Pleasant Creek in the Huntington Reservoir Quadrangle. In the Fairview Lakes Quadrangle, the Frontal Fault is mappable from the south wall of Spring Creek to the north wall of Oak Creek and it generally trends N 20° W.

The trace of the fault was mapped at an abrupt change in slope of forested North Horn beds, at the change from nearly horizontal outcrops to more steeply dipping beds of the North Horn Formation and Flagstaff Limestone, and at the abrupt termination of cliffs of Castlegate Sandstone in Cottonwood Canyon below the level of Utah 31. The westward termination of the outcrop belt of Price River and Castlegate beds by the Frontal Fault is also evident near the bottom of Oak Creek Canyon in section 21, T. 13 S, R. 5 E. The best exposure of the fault is on the north wall of Oak Creek where beds of light gray Flagstaff Limestone have been dropped down against red mudstones of the North Horn Formation.

The western block of the Frontal Fault is dropped down with a stratigraphic throw of about 172 m in Cottonwood Canyon. In the Huntington Reservoir Quadrangle, along the South Fork of Cove Creek, Pashley (1956, p. 83) estimated 437 m of displacement. This suggests that the fault dies out a few kilometers north of the Fairview Lakes Quadrangle.

Antithetic Faults

Most faults west of the Frontal Fault within the quadrangle are antithetic, all downthrown on the east. The only exception to this is a small horst that is well exposed in a roadcut in Cottonwood Canyon in the SE ¼, NE ¼, section 33, T. 13 S, R. 5 E. There, massive sandstones of the Price River Formation have been upthrown against lacustrine units of the North Horn Formation. Displacements on each of the bounding faults along the horst are at least 65 m.

An antithetic fault west of the small horst is here named the Maple Fork Fault. This fault, together with the Frontal Fault, forms a small graben that is expressed well by a broken profile on both ridges overlooking Cottonwood Canyon. At the head of these ridges, Flagstaff Limestone is well exposed and abuts the North Horn Formation along the Frontal Fault. The Maple Fork Fault is traceable southward from the north wall of Cottonwood Canyon to the south ridge of the canyon, where it splits into two faults. From there, both faults are mappable to the south wall of Spring Creek. Displacement of the Maple Fork Fault is about 50 m on the north wall of Cottonwood Canyon, based on offset of the Flagstaff Limestone. The Maple Fork Fault trends nearly parallel to the Frontal Fault.

An additional antithetic fault is exposed in Flagstaff beds immediately west of the Maple Fork Fault, and drops part of the Flagstaff Limestone down to the east. The fault is probably responsible for the bend along Cottonwood Canyon near the mouth of Maple Fork. Because the latter fault cuts only Flagstaff beds, displacement was not estimated.

These antithetic faults were probably formed by extensional strain produced by steep westward flexure of the Wasatch Monocline.

Cottonwood Ridge Fault

A high-angle fault is well expressed on Cottonwood Ridge where the Flagstaff Limestone, which overlies the North Horn Formation and caps the ridge, is downdropped to the east. The Cottonwood Ridge Fault was mapped from the east wall of Oak Creek, in the NE ¼, section 15, T. 13 S, R. 5 E, southward to the SE ¼, section 2, T. 14 S, R. 5 E. The trend of the fault is about N 12° W. Along the north wall of Cottonwood Canyon, at the intersection of sections 22, 23, 26, and 27, T. 13 S, R. 5 E, the fault contact is well exposed in a roadcut of Utah 31 (fig. 14). Two other exposures of the fault occur. One is in the SE ¼, NE ¼, section 2, on the southeast side of the high peak where Flagstaff Limestone is downdropped against the North Horn Formation (fig. 15), and the other is in the NW ¼, SE ¼, section 2, T. 14 S, R. 5 E. There the fault trace cuts across two small cirques on the northeast side of the high peak, where Flagstaff Limestone is dropped down, on the east, against North Horn beds, on the west.

The fault dies out northward in Oak Creek Canyon and also begins to die out southward near the southern border of the quadrangle. Maximum displacement along the fault is almost 100 m, where exposed on the east side of the high peak in the NW ¼, section 35, T. 13 S, R. 5 E. A subsidiary fault splits westward from the main Cottonwood Ridge Fault immediately south of White Pine Fork and continues southward. It is downdropped to the west and forms a horst, with fault displacement increasing southward from about 55 m near White Pine Fork to about 115 m at the southern edge of the quadrangle.

West Gooseberry Fault

The western fault of the Gooseberry Graben is mappable for the entire length of the quadrangle and is here named the West Gooseberry Fault. It trends in a northwesterly direction in the southern part of the quadrangle, but swings to a northeasterly direction in the northern part of the quadrangle.

This fault is a high-angle normal fault with the downdropped block on the east. Displacement is well expressed along Skyline Drive, 1 km north of Utah 31. There, Flagstaff Limestone is dropped down approximately 65 m to the east, producing an east-facing escarpment. Farther north in the quadrangle, the fault displacement decreases to about 30 m. In the southern half of the quadrangle, displacement along the fault is approximately 70 m. The fault is mappable along the west side of the valley, but begins to die out in the high southern valley of the Gooseberry Graben. The fault is not identifiable a short distance south of the quadrangle border.

Fairview Lakes Fault

The Fairview Lakes Fault follows much the same trend as the West Gooseberry Fault and is mappable for the full length of the quadrangle. The Fairview Lakes Fault is downdropped to the west and, with the West Gooseberry Fault, defines the deepest part of the Gooseberry Graben. The fault is mappable northwestward from just south of the quadrangle along the east side of Fairview Lakes. From there, it is traceable along the west side of the Lower Gooseberry Reservoir, but dies out immediately north of the quadrangle border.

The trace of the Fairview Lakes Fault is entirely within blocks of the North Horn Formation. Middle and upper North Horn beds are dropped down against lower beds of the formation in the graben. The greatest displacement along this fault is in the center part of Gooseberry Valley near the Gooseberry Campground. Here, displacement is estimated to be at least 165 m. In the northern part of the mapped area, displacement along the Fairview Lakes Fault is approximately 30 m whereas displacement in the southern part of the quadrangle is approximately 65 m.

East Gooseberry Fault

The East Gooseberry Fault is named here and is plainly expressed by a west-facing scarp that forms the prominent eastern wall of the Gooseberry Graben (fig. 16). In the southeastern part of the quadrangle, the East Gooseberry Fault trends N 30° W, but northward from the head of Flat Canyon the trend is nearly north. The fault is mappable for some distance north of the quadrangle.

Spieker and Billings (1940, p. 1179) reported that this fault continues southeastward as the eastern Joe's Valley Fault. Although it continues through mountainous territory between the two valleys, it is not plainly expressed in surface features southward beyond the head of Flat Canyon.

The North Horn Formation is exposed on the western block that has been downdropped against the Blackhawk, Castlegate, and Price River Formations east of the fault. In the northeast corner of the quadrangle, Price River and North Horn Formations, on the west, abut against the Blackhawk Formation east of the fault, as seen in canyon walls of Gooseberry Creek.

Estimated displacement of the fault ranges from 260 m in the northern part to 360 m in the southern part of the quadrangle.

Two small faults are thought to branch from the East Gooseberry Fault and connect with the Fairview Lakes Fault. Both these small, somewhat obscure faults trend in a northeasterly direction.

The northern of the small faults has dropped the southeast side. It is traceable from Japanese Creek northward along the

FIGURE 14.–Cottonwood Ridge Fault exposed in roadcut of Utah 31, in Cottonwood Canyon, downdropped to east.

FIGURE 15.–Cottonwood Ridge Fault along ridge top, west of Utah 31. Flagstaff Limestone (F) faulted down against North Horn sandstone and mudstone beds (NH).

west-facing slope of a small valley until it merges with the East Gooseberry Fault.

The southern small fault has downdropped the block on the northwest. It connects with the Fairview Lakes Fault immediately south of the Gooseberry campground and to the East Gooseberry Fault near the mouth of Brooks Canyon.

These two faults are based on strong lineaments seen on aerial photos and on topographic expression. The actual faults were not seen on the ground because their traces are buried by alluvium.

GEOMORPHOLOGY

General Statement

Landforms within the Fairview Lakes Quadrangle document changes of drainage patterns due to faulting, the effects of Pleistocene glaciation, and land surface instability.

Drainage Diversion

Two areas within the quadrangle that show evidence of drainage diversion are Brooks Canyon and Flat Canyon. Both have been transected by the scarp of the East Gooseberry Fault, which has resulted in beheaded valleys of the upper and lower parts of Gooseberry Valley. This fault has dropped the Gooseberry Valley floor about 53 m below that of Flat Canyon. However, in Brooks Canyon, this surface expression of the fault has been removed by the stream that was pirated and now flows westward through the lower part of the canyon.

The head of Gooseberry Creek is in the high southern valley of the Gooseberry Graben. From there, the stream flows northward through the broad southern part of the valley until it enters a deep gorge about 1 km east of Utah 31, in the middle of section 24, T. 13 S, R. 5 E, near the center of the graben. The middle segment of the stream flows into a second northern broad valley southeast of the Mammoth Ranger Station. From there it meanders northward into the Lower Gooseberry Reservoir. At the north end of the reservoir, the lower segment of the stream turns abruptly westward into another deep canyon which then swings to the northeast. Where the stream crosses the Fairview Lakes Fault, it makes a sharp westward bend and continues down the steep canyon.

Spieker and Billings 91940, p. 1180) observed this stream pattern in their early study on glaciation and concluded that the present upper part of Gooseberry Creek formerly flowed out through Flat Canyon. Southeastward drainage in the north half of section 25, and in the south half of section 24, T. 13 S, R. 5 E, definitely shows evidence of barbed drainage, with abrupt bends to the east and north, of the headwaters of Gooseberry Creek. The drainage was separated from the downstream valley to the north by the low hills in the center of the

FIGURE 16.–View northward near southern head of Gooseberry Valley: East Gooseberry Fault (1); terminal moraines (2); lateral moraines (3).

graben. They also concluded that the northern valley of Gooseberry Creek and Japanese Creek constituted the headwaters of Huntington Creek and that these streams initially flowed southeastward through Brooks Canyon. Eastward-directed barbed drainage of westward-flowing tributaries in Brooks Canyon in the NE ¼, section 17 and in the NW ¼, section 16, T. 15 S, R. 5 E, suggest that the stream flow was once to the southeast, but that now the stream flow is in the opposite direction into Gooseberry Creek (fig. 17).

Glaciation

Spieker and Billings (1940) were the first to report on extensive Pleistocene glaciation of the Wasatch Plateau and to recognize the role glaciation had in landform development within the quadrangle. Evidences of mountain glaciation within the study area include cirques, U-shaped valleys, morainal deposits, kettles, and tarns. The most impressive development of glacial phenomena within the quadrangle is the series of terminal moraines at the southern end of the Gooseberry Graben. These moraines were deposited in a broad preglacial valley, and lobate deposits were produced by stillstands of each of a succession of receding glaciers. Four stages of retreat are represented by terminal, recessional, and lateral moraines and are designated as 1 to 4, in order, on the geologic map (fig. 19). The north-facing cirque that marks the principal head of the glacier of Gooseberry Valley is mappable on the north side of Utah 31, immediately south of the quadrangle border. Other small cirques occur on the west valley wall and once contributed to the flow of ice down upper Gooseberry Valley to near Fairview Lakes. The farthest advance of the ice was about 4 km down the valley from the cirque wall. The main cirque is approximately 395 m wide and about 10 to 15 m deep. The widest part of the glaciated valley is 1.6 km. Terminal moraines are from 10 to 20 m thick, indicating that the ice sheet was at least that thick. Lateral moraines along the east wall of the valley suggest a possible thickness of ice of about 25 m.

Two other small cirques and associated morainal deposits are located west of the highway on the northeast front of the high peak in section 2, T. 14 S, R. 5 E, southwest of Fairview Lakes. These cirques fed only one small glacier that advanced northward at least 455 m. Both cirques are about 150 m wide and about 10 m deep. Only three advances of ice from these cirques are recognized in the morainal material, which is more than 5 m thick.

Boulger Canyon was once occupied by a glacier that flowed down the canyon and dammed the lower part of Flat Canyon with morainal debris 10 to 20 m thick. The ice sheet started at the head of the canyon, in section 6, T. 14 S, R. 6 E, and flowed down the canyon for at least 4.8 km, carving a spectacular U-shaped valley. This valley is over 200 m wide and, as suggested by the height of the lateral moraines above the valley floor, the tongue of ice was almost 35 m thick. A southern tributary, which heads in SE ¼, section 5, T. 14 S, R. 6 E, was also occupied by a glacier and added to the flow of ice down the main canyon.No well-defined cirque was developed in this area. The morainal material deposited against the north wall at the mouth of Flat Canyon blocked the passage of Flat Canyon Creek and forced the stream to the north wall where it has since cut a narrow gorge. The lowest terminal moraine is pocked by a few water-filled kettles. At least four different stillstands of the ice front are documented by terminal and recessional moraines within the canyon.

FIGURE 17.—Sketches of drainage of upper and lower part of Gooseberry Valley. A, before, and B, after faulting along the East Gooseberry Fault.

The headwaters of Little Swens Canyon were also glaciated. A well-developed cirque about 455 m wide and 65 m deep was formed at the head of the canyon. The glacier advanced about 1.4 km down the canyon and formed four distinct deposits of morainal debris. A small tarn is located below the cirque wall in the NW ¼, SE ¼, section 20, T. 13 S, R. 6 E.

Each of the glaciers, except for the small one west of Fairview Lakes, produced lakes dammed behind a terminal or recessional moraine. These lakes are now artificially enlarged by constructed dams.

Other well-developed cirques are located on the north- and east-facing slopes of the highland east of the Gooseberry Graben. Spieker and Billings (1940, p. 1190) attributed the absence of cirques on similar high ridges to the east to lower precipitation. Degraff and Zsiray (1978, p. 214) reported a predicted precipitation distribution only slightly greater in the westernmost high ridges than in eastern ones and concluded that the primary cirque distribution is the result of airflow patterns and slope aspects, with the amount of precipitation a secondary factor. The principal cirque areas still accumulate more snow than do other areas during the winter months, and these snow banks are the last to melt during the summer.

Spieker and Billings (1940, p. 1174) assigned a Wisconsin age to the glaciation in the Wasatch Plateau. The freshness of the morainal material and virtually unaltered surfaces of the moraines were given as evidence.

Knoll (1977) did a composite chronology of glaciation in the Lemhi Range, Idaho, and compared it to chronologies from northwestern Montana, northeastern Utah, and central and western Wyoming. Although no mention was made of glaciation in the Wasatch Plateau, the description of glacial advances and distribution and condition of morainal material suggests a Pinedale age for glaciation in the Wasatch Plateau.

In the Lemhi Range, four to eight Pinedale glacial advances were recognized from morainal deposits (Knoll 1977, p. 209). The terminal morains occupy canyon floors from mouths to cirques and display little dissection. Soil on the surface of the morainal material is not fully developed, and surface boulder-frequencies are high, with limestone blocks common.

Richmond (1964) reported that Pinedale glaciation of Little Cottonwood and Bell Canyons in the Wasatch Mountains is represented by three deposits of glacial till.

Richmond's (1962, p. 57–58) work in the La Sal Mountains of Utah included Quaternary deposits of glacial origin. He described the Beaver Basin Formation, which correlates with the Pinedale glaciation to the north, as having formed two end moraines in the upper parts of some of the high canyons, at an average elevation of 3,130 to 3,240 m. The Beaver Basin moraines are described as relatively small with little weathering of the till. These moraines form sharp, distinct ridges with steep slopes and average 13 m thick. Kettles are common on some of the end moraines. They appear similar to those in the Fairview Lakes Quadrangle.

Land Surface Instability

Surface instability is a problem within the Fairview Lakes Quadrangle. As mentioned previously, only a few small landslides were separately mapped in the quadrangle, but active land slippage is quite common. Such movement should be taken into consideration in future land use management. Effects of instability on roads, dams, and summer homes need to be considered.

Slopes underlain by the North Horn Formation are unstable because mudstones of the formation become highly plastic when wet by rain or melt water. The north-facing slopes are generally more unstable, even though they are usually covered by forest. The Price River Formation also contains mudstone units, and slope instability increases as the proportion of mudstone increases.

Active slumping occurs along Utah 31 in upper reaches of Cottonwood Canyon where the road crosses the North Horn Formation. During spring runoff and after rainstorms, small mudlfows form above roadcuts and hill slopes and often cover parts of the road. Because of them and occasional slumping of the road itself, much maintenance is required during the wetter parts of the year.

The Fairview Lakes and Boulger Reservoir are artificially enlarged by dams built upon glacial moraines. Although the moraines are generally stable, most of the morainal deposits are composed of North Horn material, and numerous seeps result from elevated water levels within the reservoirs. They increase the hazard of slumping and possible destruction of the dams. Water-filled kettles and seeps suggest that the moraines are becoming increasingly saturated.

The Lower Gooseberry Reservoir and the Beaver Dam Reservoir have been built on the valley floor which is underlain by the North Horn Formation. These dam sites are relatively stable because of their low topography. Because of the unstable nature of the North Horn Formation when it becomes wet, the possibility of danger to these dams should not be overlooked. Ruins of a previous dam immediately northwest of the Lower Gooseberry Reservoir is evidence for this. This dam washed out in the early 1900s in response to a rapid increase of water depth in the reservoir produced by an intense rainstorm.

Other areas of concern about slope stability are identifiable where summer cabins are being built on steep hill slopes. Creep is active along steep hillsides and is recognized by the sharp bends in tree trunks near the base of trees. The steepness of the slopes and the bedrock material upon which they are built need to be taken into consideration. Godfrey's (1978) report discussed land surface instability on the Wasatch Plateau.

ECONOMIC GEOLOGY

Coal

Coal is the main economic deposit in the Wasatch Plateau, and the Blackhawk Formation is the important coal-bearing unit in the area. The eastern third of the Fairview Lakes Quadrangle lies within the Wasatch Plateau coalfield. The western extent of this coal field is effectively terminated by the East Gooseberry Fault, which drops the coal below presently economically recoverable depths.

A few thin coal beds are exposed within the quadrangle in the upper part of the Blackhawk Formation and in the lacustrine unit of the North Horn Formation, but they have little economic potential. All the important thicker beds lie within the lower one-third of the Blackhawk Formation. The thick coal beds are all in the subsurface, with 350 to 500 m of overburden in the bottom of the canyons east of the Gooseberry Graben, and more than 1,150 m of overburden in the Gooseberry Graben. West of the graben, the estimated overburden is approximately 1,100 m along the ridge top and 525 m immediately east of the Frontal Fault, in the bottom of Cottonwood Canyon and Oak Creek.

The only reasonable area of possible coal recovery is in the eastern third of the quadrangle, east of Gooseberry Graben. Doelling (1972, p. 224) reported that in this area at least 60 million potentially recoverable tons are present on leased acreage (about 7,000 acres). The coal beds in the rest of the area, for the most part, are too deeply buried and too broken by faults to be mined. However, underground gasification of coal may be of future interest.

In Dry Creek Canyon, west of the quadrangle, beds of lignite or low-grade bituminous coal are exposed along the canyon walls in the lacustrine unit of the North Horn Formation. This coaly material is up to 4.5 m thick in some places and was mined between 1955 and 1963 (Pratt and Callaghan 1970, p. 59). These exposures are located east of Milburn, in sections 7 and 8, T. 13 S, R. 5 E. The extent of the lignite field is unknown, but similar, thinner beds of coaly material can be found in the bottom of Oak Creek in NE ¼, SE ¼, section 16, T. 13 S, R. 5 E.

Petroleum and Gas Potential

Interest in possible natural gas fields in the Wasatch Plateau increased after the discovery of natural gas in Carbon and Emery Counties. To the southeast of the study area, in Joe's Valley, a small gas field was discovered by El Paso Natural Gas Company. The field produces from the Ferron and Dakota Sandstones.

An up-dip fault-seal structure on the west side of the Gooseberry Graben, in the SE ¼, NW ¼, section 36, T. 12 S, R. 5 E, was tested with a well by Sunray Mid-Continental Oil Company in 1961. The structure has a closure of about 60 m along the West Gooseberry Fault. The well was drilled through the Ferron Sandstone into the Lower Mancos Shale or the Tununk Shale Member and yielded no show of gas.

Carter Oil Company tested a similar structure on the east side of the graben in 1954, in the NW ¼, NE ¼, W ¼, section 16, T. 13 S, R. 6 E. This well was also drilled into the Lower Mancos Shale and produced a show of gas from the Ferron Sandstone, but there was not enough gas for economic production (Pratt and Callaghan 1970, p. 61). Recommendations for further search for natural gas or petroleum within the quadrangle was summarized by Walton (1963, p. 352). He suggested that the structures already tested should be drilled through the Cretaceous section to test lower formations that are productive east of the plateau. Another possibility for gas production is that of other untested structures, such as those produced by fault traps. However, few structures within the quadrangle are large enough to be of major importance.

Construction Materials

The Flagstaff Limestone has been crushed and used as road metal on some of the gravelled roads in the Fairview Lakes Quadrangle. The limstone was excavated from a small pit near where the road to Lower Gooseberry Reservoir branches off from the Skyline Drive (fig. 18). It is the best material for this purpose found within the quadrangle. Most of the alluvium in the quadrangle is too fine to be used as gravel, and that gravel found in the area is restricted to small deposits concentrated in a few streambeds in the bottom of deep canyons, such as along Cottonwood Canyon, Oak Creek, and Gooseberry Creek.

Water Resources

Numerous springs occur throughout the quadrangle, and many are being utilized by cattlemen and sheepmen. Several springs have been developed and water piped into troughs. Many of them flow throughout the summer and fall months. In the eastern highland area, a few summer home owners have piped spring water into their homes. The water seems to be quite pure and potable.

The springs are controlled by permeable sandstone beds within the Blackhawk, North Horn, Castlegate, and Price River Formations, along with faults, also control the spring distributions within the quadrangle. Most of the drainages of the area have permanent flows of water. Reservoirs and lakes within the area provide water storage for parts of Sanpete, Emery, and Carbon Counties. The region is an important watershed and recreatonal area.

Scenic and Recreational Areas

The combination of geologic and geomorphic processes in this part of the Wasatch Plateau have provided a significant resource for the region in scenic and recreational values. The area supports woodland and mountain pastures, lakes, reservoirs, and permanent streams. During the winter months, it also provides potential for a variety of winter sports.

SUMMARY

Approximately 1,050 m of Upper Cretaceous and Tertiary rocks are exposed in this quadrangle. These rocks represent piedmont, floodplain, lacustrine, and coastal plain deposits derived mostly from the Late Cretaceous Sevier orogenic uplifts to the west.

The Blackhawk Formation is the oldest exposed formation, and it has great economic potential in coal reserves. Coal beds of the Blackhawk Formation generally underlie the entire quadrangle, but only in the eastern third of the map area is coal at minable depth.

The Castlegate Sandstone does not form a prominent cliff in the eastern part of the quadrangle as it does in western outcrops but was separately mapped from the overlying Price River Formation on the basis of differences of slopes and terracing produced by variation in the number of interbedded mudstone and sandstone units in the two formations.

In the quadrangle, the North Horn Formation consists of three distinct units. The lowest is a fluvial sandstone, siltstone, and mudstone facies; the middle is a lacustrine mudstone and limestone facies; and the upper unit is a fluvial sandstone, siltstone, and mudstone facies. Only the lower unit of La Roque's (1960) division of the Flagstaff Limestone is preserved in the quadrangle on the basis of fossil evidence.

FIGURE 18.—A pit excavated in Flagstaff Limestone for road metal.

Regional uplift in middle to late Tertiary time raised the block from which the Wasatch Plateau has been produced and formed the Wasatch Monocline. High-angle normal faults were later superimposed on the gently dipping beds of the plateau and developed north-south trending horsts and grabens. Faults near the monocline were formed by tensional strain of the monocline flexure, whereas faults that produced the Gooseberry Graben and related blocks are possible collapse features resulting from removal of salt from Jurassic beds in Sanpete Valley. A more favorable explanation attributes the structure of the plateau, with its northward-trending faults, as representing a zone transitional between the Colorado Plateau and Basin and Range Provinces. A structural contour map, drawn on the top of the Blackhawk Formation, provides a picture of fault displacement and broad folds.

Brooks Canyon and Flat Canyon were beheaded by faulting that has diverted headwaters of upper Gooseberry Creek and upper Huntington Creek into lower Gooseberry Creek–producing excellent examples of barbed drainage and dry valley heads.

Late Pleistocene (Pinedale) valley glaciers eroded into highlands and spread recessional and ground moraines in a few northeast-draining canyons and at the head of the high southern valley of the Gooseberry Graben.

Land surface instability is a potential hazard in areas underlain by the North Horn Formation, particularly where that easily mobilized unit is exposed on steep slopes.

Additional paleontologic and stratigraphic study of the North Horn Formation would be of importance in interpreting stratigraphy at the Cretaceous-Tertiary boundary and in establishing facies relations within the formation. Carbonate petrology and paleontology of the Flagstaff Limestone also would be of interest at the section measured in the quadrangle. A more detailed study of glaciation might be of importance in correlating the Pleistocene history of this area to other glaciated areas within the region.

APPENDIX

Measured Sections

Flagstaff Limestone (section 1)

The section was measured at the head of Dry Creek. Best exposures are in the gully in SW ¼, SE ¼, section 33, T. 12 S, R. 5 E. The rocks are exposed on steplike terraces in the wash because of interbedded resistant limestone, and softer mudstone and shale. This is the best exposure of the lower contact and the rocks of the formation in the study area.

Unit	Description	Thickness (meters) Unit	Cumulative
34	Covered slope and top of hill, probably mudstone.	10.0	80.6
33	Limestone, medium dark gray, weathers yellowish gray, finely crystalline to micritic, few gastropods and pelecypod shell fragments; thin bedded, forms ledge.	1.0	70.6
32	Covered slope, probably mudstone.	3.4	69.6
31	Limestone, pale yellowish brown, weathers dark yellowish orange, micritic, rare shell fragments; weathers blocky and forms ledge.	1.8	66.2
30	Limestone, olive gray, weathers orangish gray, finely crystalline, abundant whole and broken gastropods and pelecypods; thin bedded with thin shaly parting, undulatory bedding surfaces, weathers blocky and forms ledge.	3.1	64.4
29	Calcareous mudstone, light gray, weathers same, finely crystalline, abundant gastropod shells although lower limestone bed has fewer shell fragments, splintery weathering; forms reentrant; interbedded with two very thin limestone beds that are mottled dark medium gray to olive gray, weathers light orange gray.	2.7	61.3
28	Covered slope.	2.6	58.6
27	Limestone, olive gray, weathers grayish orange, micritic, some whole gastropods; thin bedded with shaly partings, weathers blocky, forming a series of small ledges; upper limestone ledge contains limestone rip-up clasts and shell fragments at its base.	1.6	56.0
26	Limestone, medium dark gray, weathers light gray, finely crystalline; thin bedded with shaly parting, weathers blocky and forms a ledge, a few whole gastropods and limestone interclasts; lower 2.0 m, calcareous mudstone, medium gray, form reentrant.	1.4	54.4
25	Limestone, pale yellowish brown mottled to olive gray, weathers grayish orange, micritic, a few gastropod shell fragments and ostracods; weathers blocky and forms a ledge.	0.6	53.0
24	Mudstone, same as unit 17; reentrant former;	0.3	52.4
23	Limestone, olive gray, weathers yellowish gray, micritic with a few whole gastropods and shell fragments; thin bedded with shaly partings, undulatory bedding surfaces, weathers blocky, forms ledge; trace fossils (lateral burrows) on bedding surface; lower third of unit largely covered by alluvium.	6.4	52.1
22	Limestone, dark yellowish brown, weathers grayish yellow, micritic with a few whole gastropods and shell fragments; coquina of ostracods on bedding surface in middle limestone bed; thin bedded, separated by very thin shale beds, undulatory bedding surfaces, weathers blocky.	0.4	45.7
21	Calcareous mudstone (marl), light olive gray, weathers light gray; splintery weathering, forms reentrant below limestone ledge; lower half covered by alluvium.	2.1	45.3
20	Limestone, medium dark gray, weathers yellow gray, finely crystalline, blocky weathering, forms ledge; very fossiliferous with abundant gastropod and pelecypod shells.	0.9	43.2
19	Mudstone, light olive gray, weathers same color, calcareous, splintery, forms reentrant below limestone bed of unit 19, contains a few small gastropods.	1:2	42.3
18	Limestone, olive gray, weathers light olive gray, micritic, very few shell fragments; upper 5 cm coquina of gastropod and pelecypod shells; thin bedded with shaly partings between beds, undulatory bedding surfaces; lower 0.5 m covered by alluvium.	2.1	41.1
17	Mudstone, medium gray, weathers light gray, calcareous, splintery weathering, forms reentrant below overlying unit 18 limestone.	0.5	39.0
16	Limestone, olive gray, weathers light olive gray, micritic, contains a few shell fragments; thin to medium bedded with very thin shaly partings and undulatory bedding surfaces, weathers blocky, forms ledge.	1.4	38.5
15	Limestone, light olive gray, weathers light yellow, slightly mottled to darker gray, micritic, a few shell fragments and ostracods; weathers blocky and forms ledge, thin to medium bedded.	2.8	37.1
14	Limestone, sandy, light olive gray, weathers same, fine crystalline with small micritic interclasts, fine grain sand grains of quartz, slightly mottled to darker gray; weathers blocky, ledge forming.	0.1	34.3

BRIGHAM YOUNG UNIVERSITY GEOLOGY STUDIES
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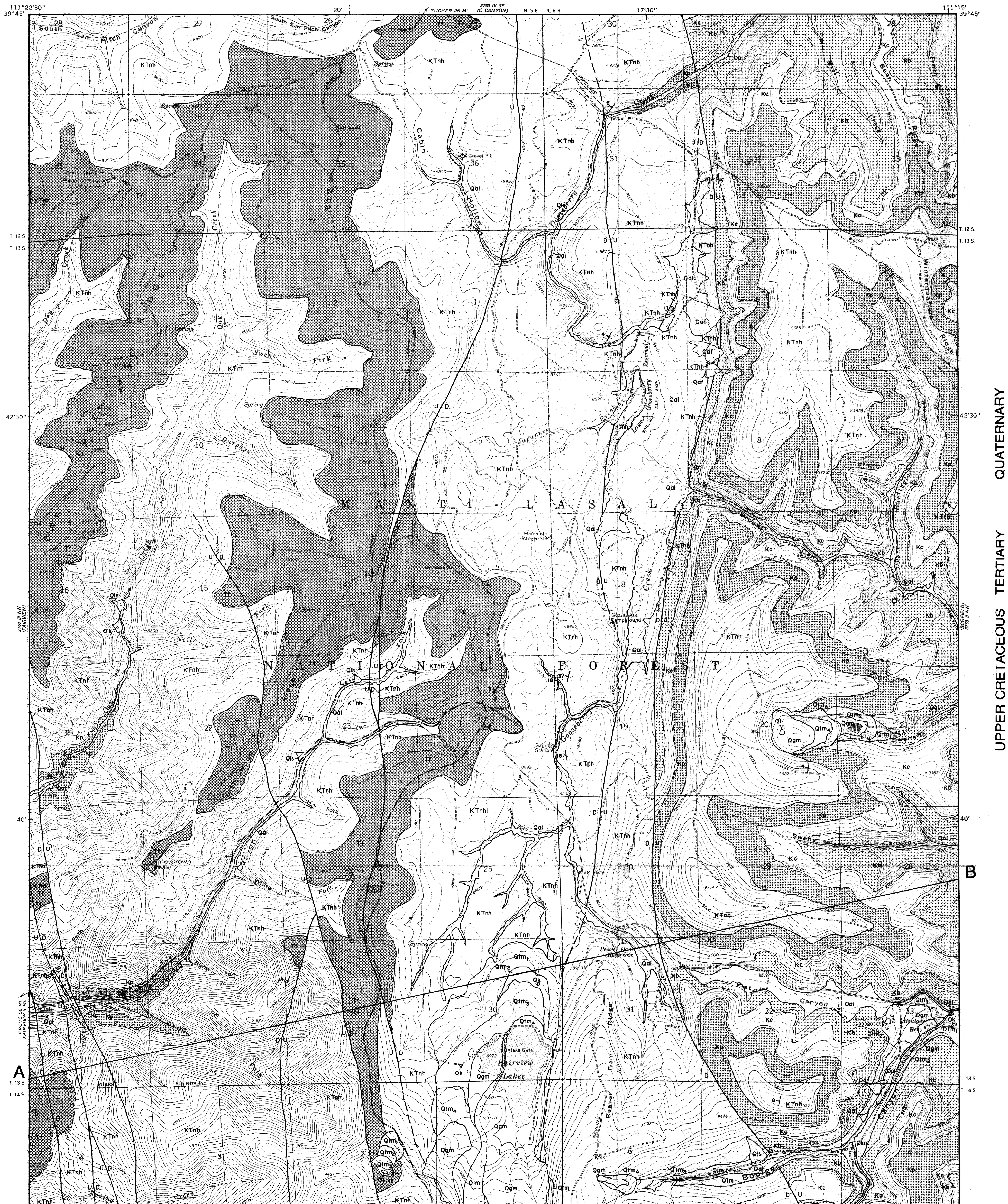
Figure 19



EXPLANATION

QUATERNARY

- Qal — ALLUVIUM
- Qls — LANDSLIDE DEBRIS
- Qaf — ALLUVIAL FAN
- Qtm — TERMINAL and RECESSIONAL MORAINES 1,2,3 and 4
- Qlm — LATERAL MORAINE
- Qgm — GROUND MORAINE

TERTIARY

- Tf — FLAGSTAFF LIMESTONE

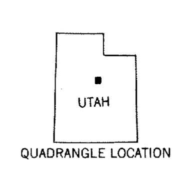
UPPER CRETACEOUS

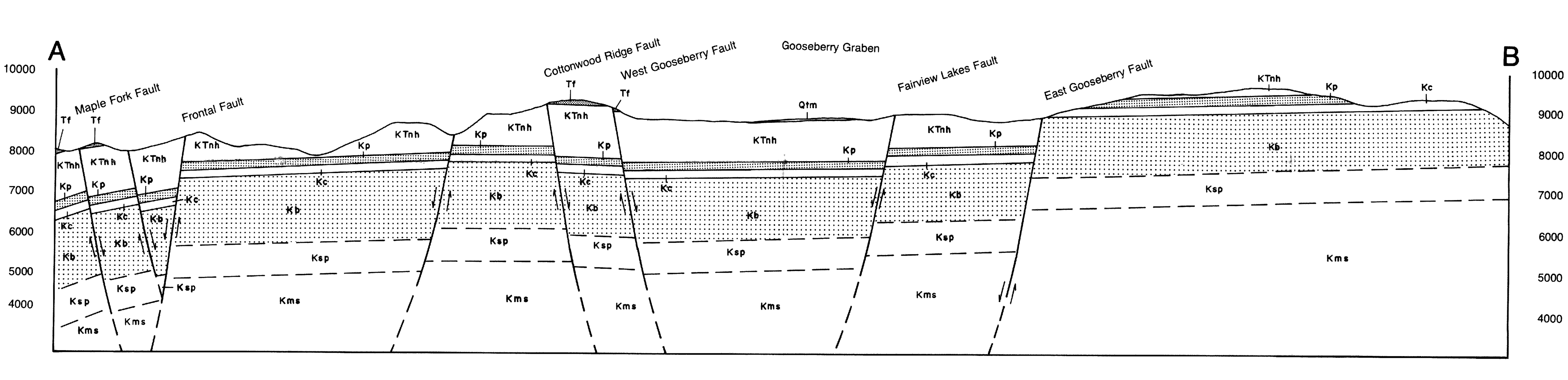
- KTnh — NORTH HORN FORMATION
- Kp — PRICE RIVER FORMATION
- Kc — CASTLEGATE SANDSTONE

UNCONFORMITY

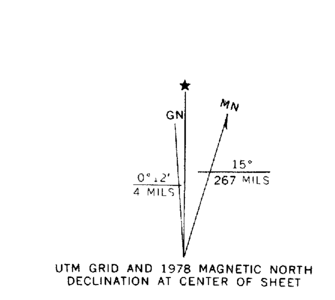
- Kb — BLACKHAWK FORMATION

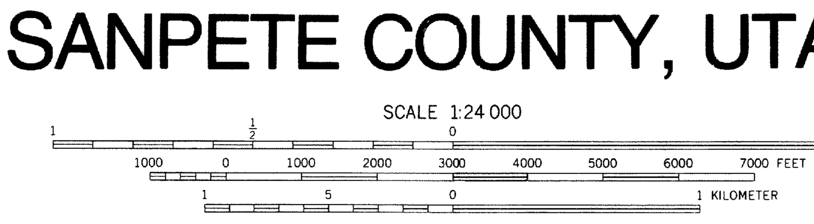
- Qk — KETTLE
- Qt — TARN





GEOLOGY OF THE FAIRVIEW LAKES QUADRANGLE: SANPETE COUNTY, UTAH





BY

GARY G. OBERHANSLEY, 1980

13	Limestone, light olive gray, weathers yellowish gray, finely crystalline, lowest bed very fossiliferous with whole gastropods and clams, and associated shell fragments; upper bed has fewer fossils; thin bedded with shaly partings and undulatory bedding planes.	1.2	34.2
12	Limestone, light olive gray, weathers yellowish gray, micritic, a few shell fragments and whole gastropods; thin to medium bedded with shaly partings between the beds, undulatory bedding surfaces, weathers in large blocks, ledge former.	2.3	33.0
11	Mudstone, brownish gray, weathering yellowish gray; splintery weathering forming reentrant.	0.2	30.7
10	Mudstone, medium gray, weathers light gray; splintery, forming reentrant with upper limestone bed; upper meter limestone, very light gray, weathering same, micritic; few small shell fragments and ostracods, some quartz sand grains, low ledge former.	1.6	30.5
9	Limestone, medium dark gray, weathers yellowish gray, finely crystalline with abundant gastropod shell fragments; weathers in blocky fragments, thin bedded with thin shaly partings of 2- to 3-cm-thick medium gray shale and mudstone, ledge forming, undulatory bedding surfaces.	1.2	28.9
8	Limestone, silty, medium gray, weathering light gray, weathers splintery; small sandstone channel filling, same color as silty limestone, occurs near top of unit and thins laterally in both directions, composed of fine-grained quartz, calcareously cemented; upper 0.2 m limestone, light yellowish gray, micritic; weathers same, blocky and splintery weathering, shoulder forming.	M 1.3	27.7
7	Limestone, yellowish gray, weathers same, micritic; weathering to blocky fragments.	3.7	26.4
6	Limestone, silty, light gray, weathers same; chippy and splintery weathering, slope forming.	2.9	22.7
5	Limestone, silty, greenish gray, weathers light gray; both splintery and blocky weathering.	3.1	19.8
4	Limestone, yellowish gray, weathers same, micritic with a few fine sand grains; weathers blocky, forms small shoulder.	2.9	16.7
3	Siltstone, calcareous, light brownish gray, weathers pale yellow; massive, weathers to splintery fragments, nonresistant slope former.	6.3	13.8
2	Siltstone, calcareous, light brownish gray, weathers pale yellow; massive, weathers splintery, mostly covered by alluvium.	7.5	7.5
	Base of exposed Flagstaff Limestone—top of North Horn Formation		
1	Top 4 m of North Horn Formation siltstone, mottled dusky red and grayish orange, weathers pale red; friable, forms slope.		
	Total thickness of the exposed Flagstaff Formation.		80.6

North Horn Formation, Price River Formation, and Castlegate Sandstone (section 2).

The section was measured up Cottonwood Canyon, starting from stream level at the bottom of the canyon, and continuing in the NW ¼, SW ¼, NE ¼, section 33, T. 13 S, R. 5 E, where the Castlegate Sandstone forms steep ledges and a cliff. From there the section continues through the Price River Formation, wtih units measured in roadcuts along the highway crossing into the NE ¼, section 33, NW ¼, section 34, and the SW ¼, section 27, T. 13, R. 5 E. The section continues in roadcuts along the highway through the North Horn Formation, crossing into the NE ¼, section 27 and SW ¼, section 23, T. 13 S, R. 5 E. The upper contact is covered and was based on the top of an area of mudstone slumping immediately below an exposure of Flagstaff Limestone.

Unit	Description	Thickness (meters) Unit	Cumulative
	Top of the North Horn Formation and base of the Flagstaff Limestone.		
123	Covered slope, area of slumping, probably mudstone and thin beds of sandstone.	49.4	546.4
122	Sandstone, pale yellowish orange, weathers same, very fine grained, both calcite and limonite cement; massive, weathers knobby; forms shoulder; poorly exposed.	2.0	497.0
121	Mudstone, variegated dark reddish brown, pale red, and pale greenish yellow, weathers light brownish gray, slightly calcareous; very crumbly; forms slope; partly covered.	4.5	495.0
120	Covered slope, probably mudstone.	21.9	490.5
119	Sandstone, very pale orange to pale yellowish orange, weathers dark yellowish orange, medium to fine grained, both calcite and limonite cement; thick bedded, cross-bedded, forms high ledge.	7.0	468.6
118	Siltstone, very pale orange, weathers same; crumbly, partly covered; upper part forms small reentrant.	1.0	461.6
117	Sandstone, same as unit 110; partly covered; forms low shoulder and slope.	2.6	460.6
116	Covered slope, probably mudstone.	13.2	458
115	Covered slope, except for upper meter which is sandstone, yellowish gray, weathers same, fine grained, calcite cement; massive; forms low ledge.	6.6	444.8
114	Sandstone, grayish orange pink to grayish orange, weathers pale yellowish orange, very fine grained, calcite cement; thin bedded, massive; forms low ledge.	1.1	438.2
113	Siltstone, variegated moderate reddish brown and dusky yellow, weathers grayish orange; massive; forms slope; partly covered.	4.2	437.1
112	Covered slope, probably mudstone.	5.2	432.9
111	Sandstone, light yellowish gray, weathers yellowish orange, medium grained, quartz arenite, both calcite and limonite cement; thin bedded, cross-bedded; forms low ledge and shoulder.	1.5	427.7
110	Sandstone, light yellowish orange, weathers same, fine grained, calcite cement; massive, medium bedded; forms ledge.	2.5	426.2
109	Covered slope, probably mudstone.	7.2	423.7
108	Sandstone, very pale orange, weathers pale yellowish orange, medium to fine grained, quartz arenite, calcite cement, friable; massive, thick bedded; interbedded with two thin mudstone beds, based on covered slopes that form steplike ledges on sandstones; lower sandstone, grayish orange, weathers same, fine grained, both calcite and limonite cement; massive; forms ledge and slope.	8.7	416.5
107	Covered slope, probably mudstone.	4.1	407.8
106	Sandstone, grayish orange, weathers same, fine grained; thinly bedded, interbedded with very thin mudstone bed, variegated light yellowish green and grayish red purple; forms shoulders and slope.	0.8	403.7
105	Mudstone, variegated light yellowish green, grayish red purple, weathers light brownish gray, slightly calcareous; weathers crumbly and splintery. Interbedded with two very thin sandstone beds, same as unit 104; forms slope.	5.6	402.9

104	Sandstone, pale yellowish orange, weathers grayish yellow, very fine grained, calcite cement; massive, weathers knobby; forms shoulder.	1.8	397.3
103	Mudstone, pale greenish yellow, weathers grayish yellow, slightly calcareous; weathers crumbly; forms slope; partly covered.	6.4	395.5
102	Sandstone, yellowish gray, weathers very pale orange, very fine grained, calcite cement, thin bedded, channeled; forms low ledge.	0.6	389.1
	Fault, downdropped on the east side, approximate displacement–55 m.	(55.0)	388.5
101	Mudstone, same as unit 99	1.0	333.5
100	Sandstone, same as unit 98	2.5	332.5
99	Mudstone, light gray, weathers very light gray, calcareous; splintery and crumbly weathering; forms slope.	1.2	330.0
98	Sandstone, grayish yellow, weathers pale greenish yellow, fine grained, calcite cement; thin bedded, very thin interbedded mudstone and siltstone beds, channeled, small mudstone chips near base of sandstone channels; forms shoulder.	2.1	328.8
97	Covered slope, probably mudstone; slumped.	13.3	325.7
96	Limestone, same as unit 94.	0.4	313.4
95	Shale, carbonaceous, abundant coaly plant fragments, gastropod and pelecypod shell fragments; weathers splintery, interbedded with a few thin coal beds, 8 cm to 10 cm thick; forms slope.	5.0	313.0
94	Limestone, silty, medium gray, weathers light olive gray, micritic, coaly plant fragments and impressions, abundant ostracods, few gastropod fragments; thin bedded, undulatory bedding surface; forms ledge.	1.2	308.0
93	Covered slope, probably shale or mudstone.	4.2	306.8
92	Sandstone, medium gray, weathers grayish orange, very fine grained, calcareously cemented, abundant fine coaly fragments and root impressions; thin bedded, cross-bedded, thickens eastward to cross-bedded channeled sandstone, weathers blocky; forms low ledge.	1.0	302.6
91	Limestone, same as unit 89.	2.1	301.6
90	Covered slope, probably mudstone, shale, and limestone; slumping.	14.3	299.5
89	Limestone, medium gray, weathers light yellowish gray, micritic, abundant gastropod and pelecypod shell fragments, some ostracods and coaly plant fragments; thin bedded, undulatory bedding surface, weathers blocky; forms low ledge.	1.5	285.2
88	Covered slope, probably mudstone.	7.9	283.7
87	Sandstone, grayish orange, weathers pale yellowish orange, very fine grained, calcite cement, few coaly fragments at base; thin bedded, undulatory bedding surface; forms low ledge.	0.4	275.8
86	Siltstone, yellowish gray, weathers light yellowish orange, calcite cement, abundant coaly fragments; massive; forms shoulder.	0.3	275.4
85	Covered slope, probably mudstone.	2.2	275.1
84	Sandstone, moderate yellowish brown, weathers dark yellowish orange, fine grained, both limonite and calcite cement; cross-bedded, channeled; forms ledge.	2.0	272.9
83	Mudstone, light olive gray, weathers pale olive; crumbly weathering; forms slope.	1.5	270.9
82	Mudstone, medium dark gray, weathers medium light gray, abundant coaly fragments; weathers crumbly and splintery; forms slope.	2.3	269.4
81	Siltstone, pale yellowish brown, weathers grayish yellow green, abundant plant impressions; interbedded with very thin mudstone beds, same as unit 79; forms low shoulder.	1.7	267.1
80	Limestone, silty, olive gray, weathers pale olive, micritic, abundant whole gastropods, few ostracods and fish scales; weathers blocky, undulatory bedding surface; forms low ledge.	0.8	265.4
79	Mudstone, medium gray, weathers light gray, abundant plant fragments; weathers splintery; forms slope.	3.2	264.6
78	Sandstone, grayish orange, weathers grayish yellow, very fine grained, calcite cement; thin bedded, channeled, weathers blocky; forms low ledge.	0.7	261.4
77	Mudstone, medium gray, weathers light gray; splintery weathering; interbedded with very thin limestone, micritic, silty, abundant gastropod shell fragments, few ostracods, plant fragments and fish scales; forms slope.	2.9	260.7
76	Limestone, silty, grayish yellow, weathers same, abundant coaly plant fragments, gastropod and pelecypod shell fragments; weathers knobby; forms shoulder.	1.2	257.8
75	Shale, carbonaceous, abundant coaly plant fragments, few shell fragments; weathers splintery; forms slope.	0.5	256.6
74	Sandstone, yellowish gray, weathers grayish orange, very fine grained, calcite cement; massive, thin bedded, weathers blocky; forms low ledge.	0.6	256.1
73	Covered slope, probably mudstone or shale.	3.7	255.5
72	Shale, carbonaceous, abundant coaly plant fragments, very thin coal beds; weathers splintery; two thin interbedded calcareous siltstones, 0.2 m thick, medium gray, weathers light gray, abundant coaly plant fragments; forms slope and low shoulders.	3.0	251.8
71	Mudstone, light yellowish orange, weathers yellowish orange, abundant plant fragments; weathers crumbly, forms slope.	1.8	248.8
70	Siltstone, calcareous, pale yellowish brown, weathers same, abundant coaly plant fragments; weathers blocky; forms low ledge.	0.7	247.0
69	Shale, carbonaceous, abundant coaly plant fragments, very thin coal beds; weathers splintery; forms slope.	0.3	246.3
68	Covered slope, probably mudstone or shale; slumped.	7.1	246.0
67	Sandstone, grayish yellow, weathers pale yellowish orange, fine grained, calcite cement; thick bedded, cross-bedded, channeled, mudstone chips at base of channel fills; forms ledge.	1.9	238.9
66	Mudstone, light olive, weathers grayish yellow green; weathers crumbly and splintery; bone fragment (10 cm long) found on weathered surface, may be float from above; forms slope.	5.3	237.0
65	Sandstone, light yellow gray, weathers same, very fine grained; thin bedded; forms low ledge.	0.6	231.7
64	Covered slope, probably mudstone.	4.3	231.1
63	Sandstone, same as unit 50.	0.5	226.8
62	Covered slope, probably mudstone; slumped.	5.0	226.3
61	Mudstone, dark greenish yellow, weathers pale olive; weathers splintery; forms slope.	2.2	221.3

60	Sandstone, light gray, weathers grayish yellow, very fine grained; thin bedded, weathers blocky; forms low ledge.	0.5	219.1
59	Limestone, silty, light gray, weathers grayish yellow; weathers knobby; forms shoulder.	0.2	218.6
58	Covered slope, probably mudstone; slumped.	6.3	218.4
57	Mudstone; greenish gray, weathers same, calcareous; weathers crumbly; forms slope.	1.0	212.1
56	Sandstone, same as unit 48.	0.5	211.1
55	Mudstone, greenish gray, weathers same, calcareous; splintery and crumbly weathering; forms slope.	3.0	210.6
54	Sandstone, light bluish gray, weathers light yellowish gray, very fine grained, calcite cement; channeled, mudstone chips near base of channel fills, weathers blocky; forms ledge.	1.5	207.6
53	Mudstone, same as unit 51.	5.1	206.1
52	Sandstone, same as unit 50.	1.3	201.0
51	Mudstone, variegated light olive gray and light brownish gray, weathers yellowish gray, slightly calcareous; weathers crumbly; forms slope, partly covered.	2.1	199.7
50	Sandstone, light gray, weathers grayish yellow, very fine grained, calcite cement; thin bedded, channeled, undulatory bedding surface, weathers blocky; forms low ledge.	1.4	198.6
49	Covered slope, probably mudstone; slumped.	5.7	196.2
48	Sandstone, grayish yellow, weathers same; very fine grained, calcite cement; cross-bedded, channeled, thins laterally in both directions, undulatory bedding surface, mudstone chips at base of sandstone; forms ledge.	2.6	190.5
47	Covered slope, probably mudstone; slumped.	3.5	187.9
46	Siltstone, light gray, weathers same; crumbly weathering; forms slope.	2.4	184.4
45	Mudstone, variegated pale olive and pale reddish brown, weathers light olive gray, slightly calcareous; weathers crumbly; forms slope.	4.0	182.0
44	Sandstone, grayish yellow, weathers very pale orange, very fine grained, calcite cement; thin bedded; forms low ledge.	0.6	178.0
43	Covered slope, probably mudstone; slumped.	10.8	177.4
42	Mudstone, same as unit 39.	2.4	166.6
41	Mudstone, yellowish gray, weathers very pale orange, slightly calcareous; weathers crumbly, forms slope.	4.1	164.2
40	Sandstone, light gray, weathers grayish yellow, very fine grained, calcite cement; cross-bedded, channeled, thins laterally in both directions, mudstone chips at base of sandstone, weathers blocky, forms ledge.	2.5	160.1
39	Mudstone, variegated grayish pink, dark yellowish orange, pale red purple, weathers grayish orange, slightly calcareous; weathers crumbly and splintery; forms slope; partly covered.	8.6	157.6
38	Sandstone, light gray, weathers grayish yellow, very fine grained, calcite cement; cross-bedded, channeled, thins laterally in both directions, mudstone chips at base of sandstone; forms ledge.	3.0	149.0
37	Sandstone, as in unit 36 but interbedded with thin mudstone beds, as in unit 35, forms low ledges and reentrant.	0.4	146.0
36	Sandstone, yellowish gray, weathers grayish orange, very fine grained, calcite cement, some coaly fragments and mudstone chips at base of sandstone, friable; thin bedded, undulatory bedding surface, weathers blocky; forms low ledge.	0.8	145.6
35	Mudstone, variegated pale reddish brown, grayish yellow green, moderate yellow, weathers pale red, slightly calcareous; weathers crumbly and splintery; forms slope.	7.5	144.8
	Top of the Price River Formation and base of the North Horn Formation.		
	Total thickness of the North Horn Formation	409.1	
	Top of the Price River Formation and base of the North Horn Formation.		
34	Sandstone, very pale orange, weathers moderate orange, fine grained quartz arenite; thick bedded, cross-bedded; forms ledge.	2.4	137.3
33	Covered slope, probably mudstone, with partly exposed lower sandstone like that of unit 32, and an upper sandstone, finer grained.	5.9	134.9
32	Sandstone, yellowish gray, weathers grayish orange/pink, fine-grained quartz arenite; thinly bedded, grading upward to a siltstone of the same color; forms ledge.	2.6	129.0
31	Mudstone, light olive gray, weathers light gray, slightly calcareous; weathers splintery; forms slope.	1.1	126.4
30	Sandstone, same as unit 29 but interbedded with minor mudstone, variegated light olive and pale brown, weathers light olive gray, slightly calcareous; forms ledges and slope.	5.2	125.3
29	Sandstone, yellowish gray, weathers grayish orange, fine to medium grained, mostly quartz with a few dark mineral grains, calcareous cement; thick bedded, cross-bedded, mudstone rip-up chips near base of cross-beds; forms ledge.	3.0	120.1
28	Mudstone, partly covered, yellowish gray; forms slope.	1.5	117.1
27	Sandstone, yellowish gray, weathers the same, fine grained; thin bedded, forms small ledge.	1.2	115.6
26	Sandstone, light yellowish gray grading to an upper mottled siltstone, same color as unit 25.	0.9	114.4
25	Mudstone, variegated olive gray to pale brown, weathers light orange; weathers splintery; forms a slope.	1.3	113.5
24	Sandstone, very pale orange, weathers pale yellowish brown, very fine grained; thinly bedded, channeled with mud chip clasts at base of channel fills; interbedded with thin beds of mudstone and shale, light gray; forming ledge and reentrant.	3.5	112.2
23	Mudstone, dark olive gray, weathers light olive gray; weathers to splinters and chips; forms reentrant.	1.2	108.7
22	Sandstone, light yellowish gray, weathers same, quartz arenite, calcareous cement; cross-bedded, weathers to blocks, thins laterally in both directions; forms ledge.	4.7	107.5
21	Mudstone, olive gray, weathers light olive-gray, slightly calcareous; splintery; forms slope.	2.7	102.8
20	Sandstone, light olive gray, weathers light yellowish gray, fine to medium grained, calcareous cement; cross-bedded, channeled; forms ledge.	3.2	100.1
19	Sandstone, conglomerate, light olive gray, weathers light yellowish gray, coarse grained with small pebble-size clasts, grades upward to medium and fine grained; cross-bedded, thick bedded; forms cliff.	9.1	96.9
18	Mudstone, olive gray, weathers light gray, splintery weathering; forms reentrant.	0.7	87.8
17	Mudstone, yellowish gray to moderate yellowish brown, lower third is grayish red purple; weathers splintery; forms slope.	4.5	87.1

16 Sandstone, moderate yellowish brown, weathers gray orange, medium grained, both limonite and calcite cement; cross-bedded, channeled; forms ledge.	2.1	82.6
15 Sandstone, light brownish gray, weathers light yellowish gray, medium to fine grained; thin bedded, cross-bedded, channeled. Interbedded mudstone, partly covered, pale brown, weathers yellowish gray; forms ledges and slopes.	2.8	80.5
14 Sandstone, partly covered, grayish orange, weathers same, fine grained, calcareous cement; thin bedded; upper part grades to thin mudstone, same color; forms ledge, reentrant, and shoulder.	3.5	77.7
13 Sandstone, pale yellowish orange, weathers same, very fine grained; massive, thin bedded, channeled, thins laterally in both directions; forms ledge.	1.1	74.2
12 Mudstone, dark yellowish brown, weathers light yellowish gray, same as unit 10.	1.9	73.1
11 Sandstone, moderate yellowish brown, weathers grayish orange, fine grained, quartz arenite, both calcite and limonite cement; massive, channeled, thins laterally in both directions, parts are cross-bedded; forms ledge.	2.4	71.2
10 Mudstone, dark yellowish brown, weathers yellowish gray, slightly calcareous; splintery weathering; with minor interbedded sandstone, moderate yellowish brown, weathers grayish orange, very fine grained; laterally thickens to west into thick channel-fill sandstone; forms slopes and ledge.	5.3	68.8
9 Mudstone, mostly covered slope, poorly exposed contact, base of unit at top of thick cliff-forming Castlegate Sandstone; lower third mudstone, light gray, weathers to light yellow gray; forms steep slope.	9.5	63.5

Top of the Castlegate Sandstone and base of the Price River Formation.
Total thickness of the Price River Formation — 83.3 m

Top of the Castlegate Sandstone and base of the Price River Formation

8 Sandstone, moderate reddish orange, weathers moderate orangish pink, fine to coarse grained with grit and small quartzite pebbles in the bottom of the small channel fills, matrix of subrounded grains with quartz overgrowths, both calcite and limonite cement; thick bedded, cross-bedded and channeled; forms ledge.	8.9	54.0
7 Sandstone, same as unit 6 but ledge former.	5.5	45.1
6 Sandstone, same as unit 3, partly covered by talus.	5.8	39.6
5 Sandstone, dark yellowish orange, weathers light yellowish gray, friable, medium to fine grained quartz arenite, few grit-size clasts; cross-bedded, forms cliff and ledges.	12.9	33.8
4 Sandstone, same as unit 3, but forming cliff.	9.5	20.9
3 Sandstone, dark yellowish orange, weathers light yellowish gray, coarse-grained quartz arenite, subrounded grains, quartz overgrowths, grit- and granule-size quartzite clasts at base of channels, both calcite and limonite cement; thick bedded, cross-bedded, channeled, forms ledges or cliff.	4.1	11.4
2 Sandstone, dark yellowish orange, weathers light yellowish gray, coarse grained with grit-size quartzite clasts near channel bottom, texture fines upward to fine grained, friable, quartz arenite, subrounded grains with overgrowths, both calcite and limonite cement, some coaly fragments; thick bedded, channeled, forms cliff.	2.6	7.3
1 Sandstone, dark yellowish orange, weathers light yellowish gray, fine-grained quartz arenite, subrounded grains with quartz overgrowths, both calcite and limonite cement, thick bedded, cross-bedded, forms cliff.	4.7	4.7

Base not exposed in stream bed.
Total thickness of exposed Castlegate Sandstone — 54.0 m

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