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Geology of the Mill Fork Area, Utah

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ABSTRACT.—The Mill Fork area comprises about 70 square miles of Cretaceous (?) and Tertiary sediments at the northern end of the Wasatch Plateau in Utah County, Utah. Over 9000 feet of nonmarine sediments are present and belong to the North Horn, Flagstaff, and Green River formations. These sediments record a significant part of the post-Laramide geologic history of this region and reflect the change from piedmont to fluvial, lacustrine, and fluvial-lacustrine environments of deposition.

A series of conglomerates previously assigned to the Price River Formation and later assigned to the Bennion Creek Formation are here included in the North Horn Formation.

The geologic structure of the Mill Fork area is typical of the Wasatch Plateau, with broad folds and high angle faulting being the common structural style. The major structural features are the Soldier Monocline, the Tie Fork Syncline, the Thistle Dome, the Martin Mountain Fault, and the Dairy Fork Fault.

The Mill Fork area contains few minerals of economic importance. Tar sands in the Green River Formation suggest the presence of larger petroleum accumulations, but drilling has so far been unproductive.

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*A thesis submitted to the faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science.

INTRODUCTION

The Mill Fork area comprises about 70 square miles of Cretaceous (?) and Tertiary sediments at the northern end of the Wasatch Plateau in Utah County, Utah (Text-fig. 1). It is bounded on the north by the 40th parallel and on the east by the 111° 15' meridian. U.S. Highway 50-6 and the Denver and Rio Grande Railroad cross the area east to west following the valley of Soldier Creek. The abandoned townsite of Mill Fork lies in the north central part of the area.

This area was selected for study for two reasons: (1) to investigate the controversy regarding the identity of the coarse conglomerates in Red Narrows east of Thistle, and (2) as an addition to the geologic mapping program carried out by Brigham Young University in this part of Utah.

Previous Work

E. M. Spieker was the first to do extensive work in this part of Utah. In 1931 he published a map of the Wasatch Plateau Coal Fields, located south of the Mill Fork area, and later published results of his reconnaissance work in central Utah (1946, 1949a). A. A. Baker (1960) mapped the area north of Soldier Creek. H. D. Harris (1953), P. R. Peterson (1952), M. W. Prescott (1958), and G. V. Henderson (1958), all of Brigham Young University, have mapped nearby areas. A. M. Khin (1956) mapped the area north of Indianola, and M. T. Moussa (1965) remapped the Soldier Summit Quadrangle. None of the previous works shows more than reconnaissance-type maps of the Mill Fork area.

Present Work

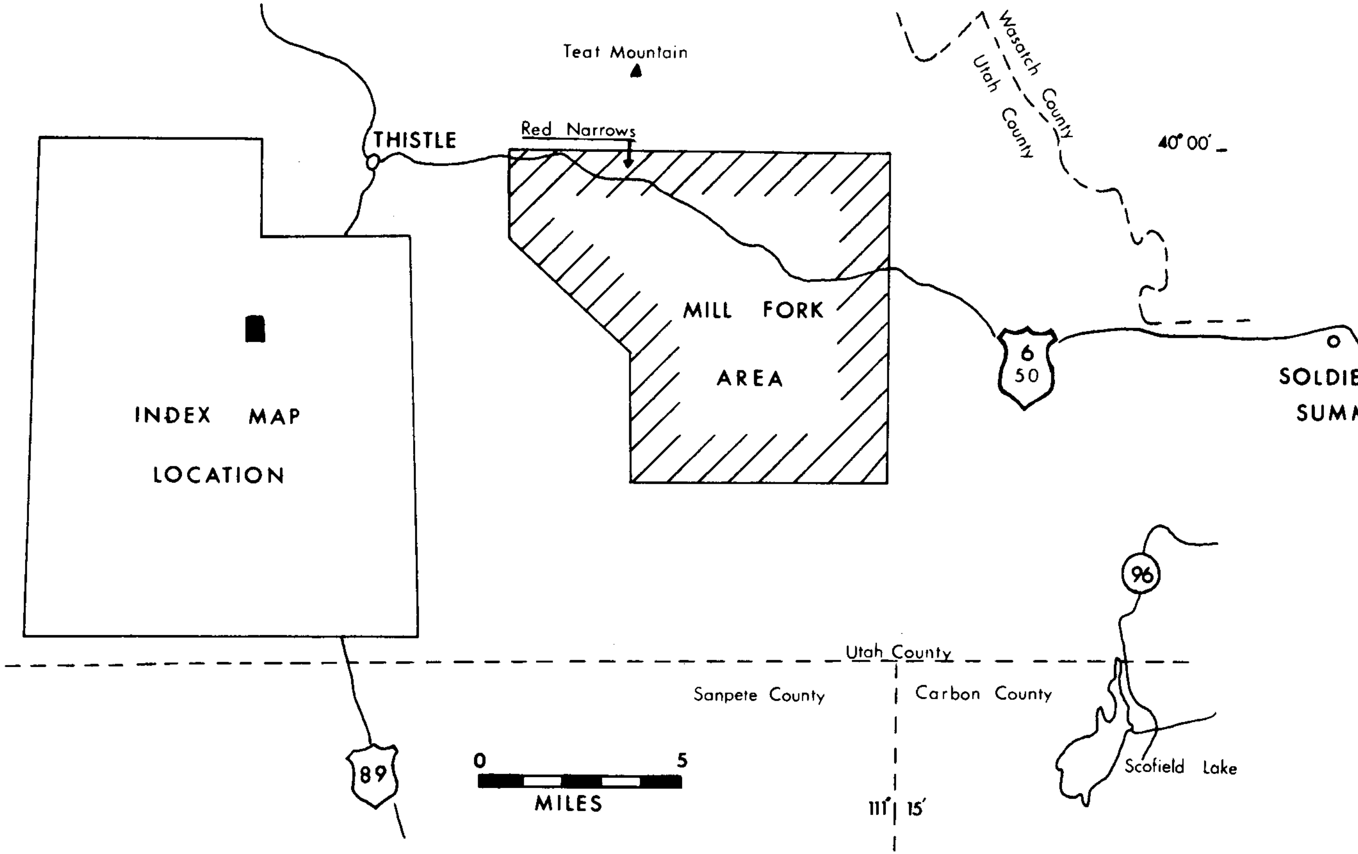
Field work was carried out during the summer of 1966. Mapping was done on aerial photographs with an approximate scale of 1:20,000. Photo data were then transferred to 1:24,000 preliminary copies of the northeast and northwest quarters of the Mill Fork Quadrangle. Stratigraphic sections were measured and described by conventional methods.

Acknowledgments

The writer expresses his thanks to Dr. Lehi F. Hintze, who suggested the problem, served as committee chairman, and reviewed the study in the field. Dr. W. K. Hamblin and Dr. J. K. Rigby also served on the committee. J. W. Davis, of Ohio State University, gave the writer much assistance in the field and consulted on stratigraphic problems. Dr. H. K. Lautenschlager gave the writer information on tectonic activity obtained from his private fieldwork. The Mountain Fuel Supply Company allowed the writer to examine data gained from drilling a well north of the mapped area. Special thanks are due to my wife Judith, who gave help and consideration in all phases of the work.

STRATIGRAPHY—GENERAL

Over 9000 feet of Tertiary and possibly Cretaceous nonmarine sediments are present in the Mill Fork area. These beds belong to (from the bottom up) the North Horn, Flagstaff, and Green River formations. Formation contacts are transitional, making selection of mappable contacts difficult. These sedi-



TEXT-FIGURE 1.—Index map of the Mill Fork area.

ments record a significant part of the post-Laramide geologic history of the region.

A series of conglomerates previously assigned to the Price River Formation and later assigned to the Bennion Creek Formation is here included in the North Horn Formation.

In addition to the above beds, fluvial deposits of Quaternary and possibly Late Tertiary age are present in the Mill Fork area.

The general stratigraphic sequence exposed in the Mill Fork area is summarized in Text-figures 2 and 3.

CRETACEOUS (?) AND TERTIARY ROCKS

North Horn Formation

Definition and Distribution.—Rocks of the North Horn Formation were originally included in the Wasatch Formation (Spieker and Reeside, 1925, p. 448). Later Spieker (1946, p. 133) gave the name North Horn Formation to those rocks between the Price River and Flagstaff formations on the slopes of North Horn Mountain in the east central part of the Wasatch Plateau. At the type locality, the North Horn Formation spans the passage from Cretaceous to Tertiary time as shown by fossil evidence.

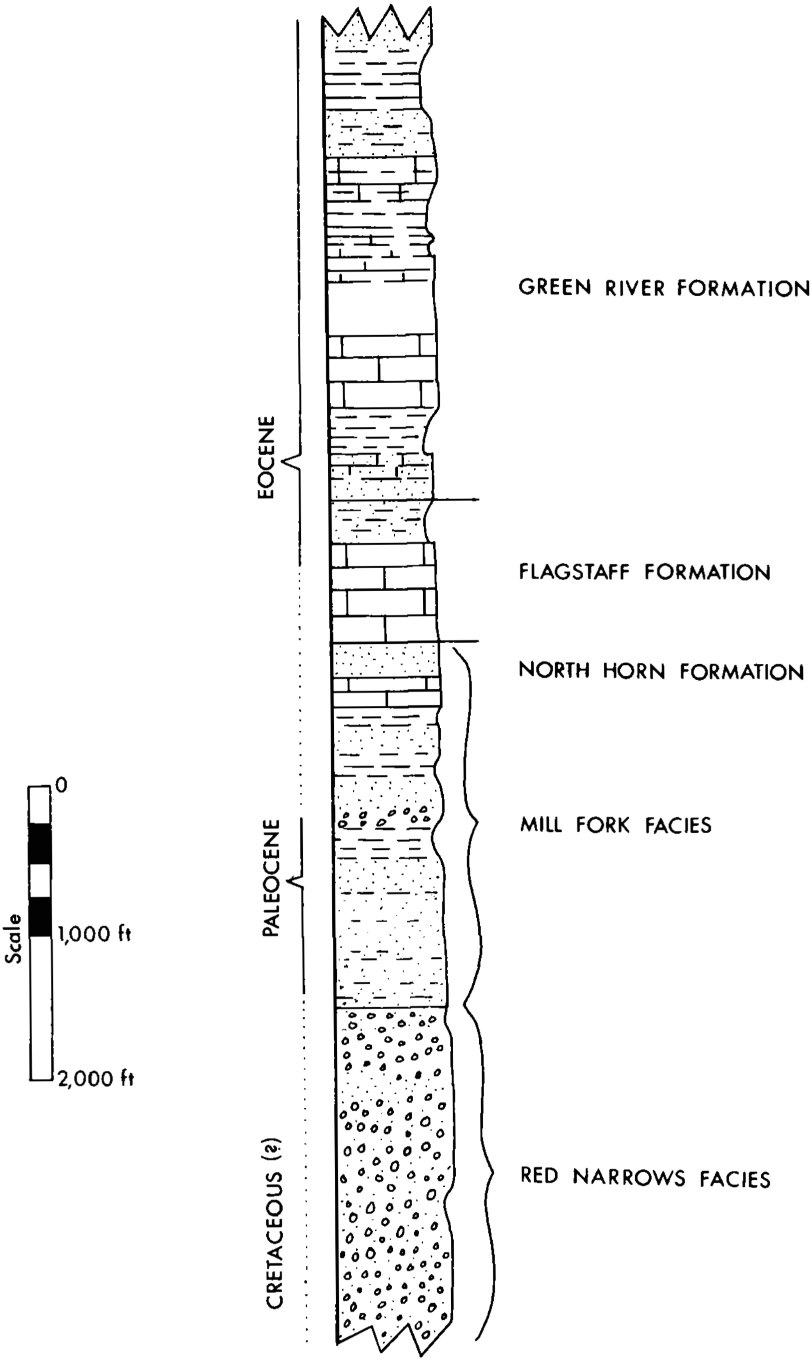
The North Horn Formation, as here mapped in the Mill Fork area, includes beds previously identified as Price River and Bennion Creek formations. It is widespread in the Mill Fork area and is present over much of the southern portion of the area. It is particularly well exposed in Red Narrows and on slopes of Martin Mountain.

Stratigraphic Relations.—The lower contact of the North Horn Formation with the Price River Formation is exposed three miles to the southeast in Bennion Creek but is not exposed within the Mill Fork Quadrangle. The North Horn Formation is gradationally overlain by the Flagstaff Formation, with some evidence of intertonguing. This contact is difficult to define in the field; however, the upper boundary of the North Horn Formation has been mapped at the highest significant sandstone. The gradational contact reflects the gradual shift from the dominantly alluvial fan to fluvial North Horn to the lacustrine Flagstaff Formation.

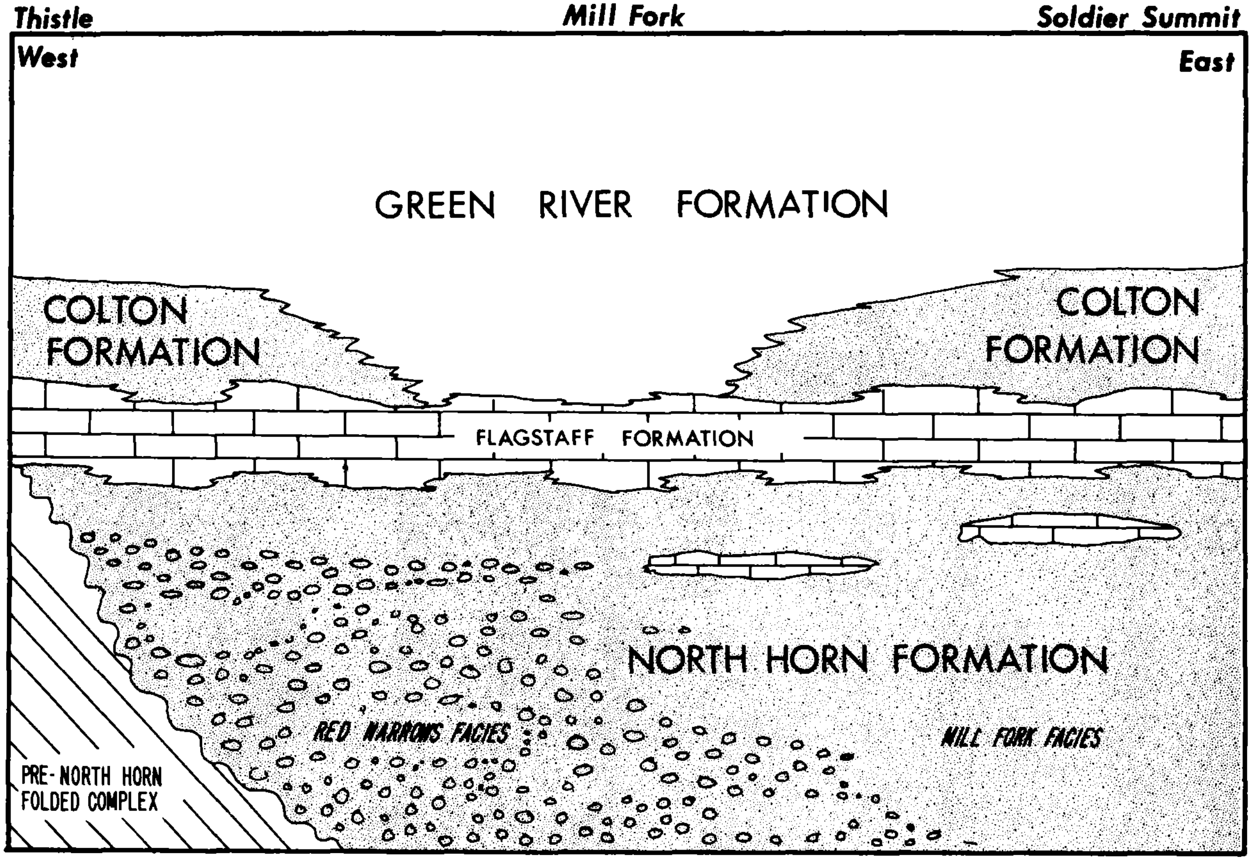
Thickness and Topographic Expression.—Lowermost North Horn beds are not exposed in the Mill Fork area; however, calculations based on the map indicate a thickness of at least 2500 feet in the southern part of the area. In Red Narrows the formation is nearly 3000 feet thick, with the lower 2000 feet belonging to the conglomeratic Red Narrows facies and the upper 1000 feet to the finer-grained Mill Fork facies. Moussa (1965) estimated the total North Horn and Bennion Creek Formations south of Soldier Summit to be approximately 2200 feet thick. Both of his units are here included in the North Horn Formation.

Conglomerate of the North Horn Formation forms imposing cliffs along the valley of Soldier Creek in Red Narrows. In the remainder of the Mill Fork area, the formation forms slopes, with occasional ledges held up by resistant conglomerate or sandstone.

Lithologic Character.—In the Mill Fork area the North Horn Formation presents a variety of lithologies and can be divided into two facies. One is



TEXT-FIGURE 3.—Generalized stratigraphic relations of the Mill Fork area.



TEXT-FIGURE 2.—Generalized stratigraphic column of rocks exposed in the Mill Fork area.

the conglomeratic, Red Narrows facies as exposed in Red Narrows; and the other is the finer-grained Mill Fork facies, as exposed in Mill Fork Canyon, consisting of sandstone, shale, and lacustrine limestone.

The Red Narrows facies is a thick, clastic wedge of piedmont conglomerates and sandstones which thin eastward from over 2000 feet in Red Narrows to a feather edge a short distance south of Soldier Summit. This facies occurs as conglomerate lenses intercalated with lenses of sandstone. Although the outcrop gives the appearance of uniform, horizontal layering, individual sandstone and conglomerate lenses are interlayered, with cut-and-fill structures common. Individual lenses rarely extend more than several hundred feet laterally. Bedding is massive and distinct, averaging 10 to 20 feet thick. Conglomerate in the lower part of the formation is mature and is composed of approximately 85% quartzite and 15% limestone phenoclasts (Pettijohn, 1957, p. 245) in a quartz sand matrix. Mixed composition of the phenoclasts places this conglomerate in the petromict class (Pettijohn, 1957, p. 257). Phenoclasts range in size from several feet down to ½ inch, are well rounded, and generally dip to the west. In places the conglomerate displays moderately defined graded bedding, with cobbles varying from 6 to 12 inches in diameter at the base to several inches smaller at the top of 15- to 20-foot-thick beds. The conglomerate is dominantly grain supported by phenoclasts, with a sandy matrix filling voids within the conglomeratic framework. Locally, phenoclasts display fracturing as a result of overburden stress. Matrix of the conglomerate is coarse to medium-grained, moderately sorted sandstone and in places is red, as in cliffs in Red Narrows. Sandstone lenses within the conglomerate have the same general appearance as the matrix and weather as reentrants in the cliff face. Calcium carbonate cement is present in moderate amounts in the sandstone lenses as well as in the matrix. Cross-bedding is common in the sandstones, as seen in loosened blocks, but poor exposures do not permit accurate measurement.

The upper North Horn Formation (Mill Fork facies) consists of interbedded sandstone, lacustrine limestone, and shale, with minor amounts of conglomerate. Beds within this facies are laterally discontinuous, and correlation of individual layers within the poor exposures is difficult. Sandstones within the formation are commonly light brown, fine to medium grained, and composed almost entirely of quartz grains. Sandstones are commonly present as lenses and form ledges in outcrop. A few beds display cross-bedding and other directional structures. Shales are light brown and erode to slopes. Isolated limestones present in the upper part of this facies are similar to those in the overlying Flagstaff Formation. Conglomerate lenses, similar to those in Red Narrows, occur irregularly spaced through the upper North Horn Formation.

An interesting feature of the North Horn Formation is the irregular distribution of red coloration. In Red Narrows, for example, the North Horn Formation changes from a gray to brick red color over a short horizontal distance. The North Horn Formation is also locally red east of Red Narrows. Perhaps this color was derived from erosion and redeposition of the red Triassic rocks in a nearby area. Detailed mapping of the red part of the North Horn Formation may yield useful paleocurrent information if the postdepositional redistribution of color has not been extensive.

Age and Correlation.—No fossils of diagnostic age were found in the North

Horn Formation of the Mill Fork area. At the type locality the North Horn Formation includes beds of latest Cretaceous and early Tertiary age (Spieker, 1946, p. 135). It is thought by the writer that the lowest North Horn Formation in the southeast portion of the Mill Fork area may be late Cretaceous in age, but the formation appears to become younger toward the west. Schoff (1951, p. 630) concluded that the North Horn Formation in the Cedar Hills, 30 miles to the southwest, is of Paleocene and early Eocene age. On this basis it is concluded that the North Horn Formation in the Red Narrows area is probably Early Tertiary as well.

Age of North Horn beds in the Mill Fork area will remain in question until the palynology or other distinctive fossils are worked out in detail.

Part of the North Horn Formation is correlated with the lower part of the Wasatch Formation in adjacent areas and with the Lance and Fort Union beds of the northern plains (Spieker, 1946, p. 135). Walton (1964, p. 141) correlates the Red Narrows conglomerates with the Currant Creek Formation of the Strawberry Valley area.

Environment of Deposition.—The North Horn Formation is of continental origin and reflects conditions present immediately following or synchronous with the main Laramide orogeny in central Utah.

The coarse conglomeratic Red Narrows facies is probably of piedmont origin and represents alluvial fan, stream, and perhaps mass movement debris swept eastward from the newly formed mountains to the west. This piedmont relationship is clearly visible near Thistle and to the east where these beds were deposited across the eroded edges of Upper Cretaceous and older rocks.

The Red Narrows facies grade upward into the Mill Fork facies, which represents cyclic fluvial and lacustrine sedimentation. The North Horn Formation displays a regular decrease in grain size both vertically and laterally to the east until clastic deposits give way to lacustrine carbonates. This gradual change from the fluvial environment represented by the North Horn deposition to the lacustrine environment of the Flagstaff Formation may reflect a change in climate, obstruction of drainage by crustal movement, or a combination of the two.

Flagstaff Formation

Definition and Distribution.—The name Flagstaff Member was originally proposed by Spieker and Reeside (1925, p. 448) for a limestone unit of the Wasatch Formation, with the type section on Flagstaff Peak in the southern Wasatch Plateau. The member was later raised to formation rank by Spieker (1946, p. 135).

The Flagstaff Formation crops out in an east-west trending band across the central part of the mapped area to a point about one and one-half miles west of Mill Fork near the center of the quadrangle, where it has been cut out by the Dairy Fork Fault. The formation reappears to the west, capping Martin Mountain, and is present on the down-dropped side of the Martin Mountain Fault in Soldier Canyon. Flagstaff Formation caps most of the Wasatch Plateau and is present at higher elevations in the southern part of the mapped area at the crest of the Soldier Monocline.

Stratigraphic Relations.—The Flagstaff Formation conformably overlies the North Horn Formation and is gradationally overlain by the Green River Formation in the Mill Fork area. Both the upper and lower contacts are difficult to define because of probable intertonguing and gradational lithology. In the western part of the area, the upper Flagstaff and lower Green River formations are similar; however, the upper Flagstaff Formation contains a distinctive algal ball limestone. In the Mill Fork area there are crossbedded sandstones, minor conglomerate, and coaly, marsh-like deposits between the two formations.

Thickness and Topographic Expression.—Accurate determination of the thickness of the Flagstaff Formation is difficult because of gradational contacts with the enclosing formations. The Flagstaff Formation is approximately 300 feet thick in Beaver Dam and Mill Fork canyons, but it thickens westward to over 700 feet at Martin Mountain. In the latter area it is difficult to distinguish between Flagstaff and Green River formations. In comparing these two units, however, algal ball limestone is confined to Flagstaff beds. Algal ball limestone rubble occurs at the top of Martin Mountain and must have been derived from erosion of Flagstaff beds.

Prescott (1958, p. 39) measured 706 feet of Flagstaff in Starvation Canyon, east of the Mill Fork area, but this includes some of what is here considered as the lacustrine, upper part of the North Horn Formation. Metter (1955, p. 135) measured 350 feet of Flagstaff Formation a short distance south of Thistle in the southern Wasatch Mountains.

Lithologic Character.—The Flagstaff Formation in the Mill Fork area is made up of fine-grained limestone, calcareous mudstone, algal ball limestone, sandstone, and minor amounts of conglomerate. Spieker (1946, p. 135) states that in addition to the above lithologies, oil shale, gypsum, volcanic ash, and chert are also present in the formation.

Limestone beds are dominantly fine grained to micritic, silty, and locally dolomitic. They are generally light gray on fresh fracture and weather buff and chalky white, and they contain hairline cracks filled with calcite spar. In some beds calcite spar has replaced fossils and pellets.

The Flagstaff Formation of this area is known for the oncolitic limestone within the formation, which is locally called "Birdseye Marble" where quarried for building stone. Oncolites are nearly spherical, range from 1 to 25 millimeters in diameter, and consist of roughly concentric calcite bands around a nucleus, commonly a shell fragment or ball of mud. Eardley (1932, p. 404-414) attributes these oncolites to growth by blue-green algae. These algal balls probably developed in shallow, agitated water and are good depositional environment indicators.

Algal ball limestone is well developed south of Thistle near Birdseye, where the rock was once quarried, but is not present to any extent east of Dairy Fork in the Mill Fork area. In the Martin Mountain area, the Flagstaff Formation contains beds of algal ball limestone. These beds are laterally discontinuous and cannot be used for intraformational correlation. The lack of this algal ball limestone east of Dairy Fork suggests that this portion of the Flagstaff Lake was deeper, since evidence of strong agitation is wanting. Weiss (1969, p. 1118) found a clear preferential association of algal ball limestone with shore or nearshore facies of the Flagstaff Formation.

Westward thickening of the Flagstaff Formation to the Martin Mountain area is accompanied by an increase in clastic content. Almost half of the 700 feet of Flagstaff Formation measured at Martin Mountain is mudstone and sandstone. The mudstone is calcareous, brown to maroon, and contains a small amount of algal balls. The sandstone is fine grained and light brown.

A small amount of conglomerate was found in the Flagstaff Formation at various points in Soldier Canyon.

Age and Correlation.—Fossil content of the Flagstaff Formation is not definitive as to an exact age. LaRocque (1960, p. 73) divided the Flagstaff Formation in Sanpete Valley into three zones. Zone 1 is of Paleocene age, but the fauna of Zone 3 suggests an Eocene age for those beds. Metter (1955, p. 137) states that the Flagstaff Formation of the Thistle area is equivalent to only the uppermost Flagstaff Formation of the Sanpete Valley. Therefore, it is likely that at least the upper units of the Flagstaff Formation of the Mill Fork area are of Eocene age.

Flagstaff Formation is a widespread unit of central Utah. The area of deposition of the Flagstaff covers about 7000 square miles (LaRocque, 1960, p. 11). It is probably equivalent to the Cedar Breaks Formation in southern Utah (Schneider, 1967, p. 144). Schoff (1951, p. 632) suggests that most of the Flagstaff Formation in the Cedar Hills may be equivalent to the Paleocene Puerco and Torrejon formations of the San Juan Basin and the Ferris Formation of central Wyoming, and may be correlated with part of the Fort Union Formation of Wyoming and Montana.

Environment of Deposition.—Fossil content, lithology, and stratigraphic position indicate that the Flagstaff Formation in the Mill Fork area is mainly lacustrine but contains some fluvial sandstone and conglomerate lenses. Lacustrine lenses also occur locally through the upper North Horn Formation, but the Flagstaff Formation is the first evidence of widespread Tertiary lacustrine conditions in this part of Utah.

The western part of the Mill Fork area underwent a different regimen of sedimentation during Flagstaff time than did the eastern area. In the area of Martin Mountain, the Flagstaff Formation contains abundant clastic material as well as algal ball limestone. Distribution of these lithologies indicates a shallow, nearshore environment with a western source of clastics. Lack of clastic material and algal growths in the Flagstaff Formation of the central and eastern parts of the Mill Fork area suggests a less agitated environment, perhaps related to slightly deeper water.

LaRocque (1960, p. 82) states that the Flagstaff Lake probably formed as a result of pre-Flagstaff crustal movement which created a closed basin. The lake expanded to its maximum extent but became almost extinct by the basin nearly filling with fluvial sediments. Local remnants later merged to initiate younger Lake Green River, which expanded to cover much of the area previously occupied by Flagstaff Lake. Climatic variation probably also had a great effect on the birth and extinction of the Flagstaff Lake, but definitive evidence is difficult to obtain.

Conglomerate found in the Flagstaff Formation in Soldier Canyon probably represents stream deposits or mudflows in the nearshore region of the lake.

Colton Formation

Red beds of the Colton Formation do not occur in the Mill Fork area but are present to the east (Prescott, 1958, p. 10), to the west (Metter, 1955, p. 137), and to the north (J. W. Davis, per. comm., 1966). However, the lower part of the gray-green Green River Formation in the Mill Fork area contains some fluvial or deltaic deposits that may be time equivalent to the

Colton Formation. Text-figure 3 diagrammatically shows the relationships of these beds in the Mill Fork area.

Green River Formation

Definition and Distribution.—The Green River Formation was defined by Hayden (1869) for rocks exposed along the Green River west of Rock Springs, Wyoming.

In the Mill Fork area, the Green River Formation is present throughout much of the northern part of the mapped area and crops out in the Dairy Fork Graben. The valley of Soldier Creek follows the general strike of the Green River beds, and many excellent exposures of this formation are found along U.S. Highway 50-6.

Stratigraphic Relations.—The Green River Formation conformably overlies the Flagstaff Formation in the Mill Fork area. To the west and east of the Mill Fork area, however, the Green River Formation occurs above Colton beds.

Thickness and Topographic Expression.—A total section of the Green River Formation was not measured, but map calculations indicate about 5000 feet of the formation present near the Mill Fork area. A section of the lower 1700 feet was measured and studied in the present investigation. Roberts (1964, p. 197) measured a complete section east of the mapped area at Gilluly, where the formation is 3400 feet thick. The Green River Formation thins to the west and is only a few hundred feet thick a few miles east of Thistle.

Cyclic nature of the Green River Formation gives the outcrop a ledgy appearance, and in the Mill Fork area the lower part of the formation forms prominent cuestas south of Soldier Creek and east of Dairy Fork.

Lithologic Character.—The Green River Formation in the Mill Fork area is quite varied and consists of interbedded sandstone, siltstone, marlstone, limestone, "paper" shale, shale, mudstone, tar sand, and cherty limestone. The lower 600 feet of the Green River Formation in this area is of deltaic, fluvial, and marginal marsh origin (Baer, 1969, p. 13) and correlates with the delta facies of Picard (1955, p. 83). The remainder of the Green River Formation in the Mill Fork area is the more typical interbedded lacustrine green shale and marlstone.

Sandstones and siltstones of the Green River Formation are characteristically cross-bedded, friable, and poorly sorted. Sand bodies in particular are almost exclusively distinctly lenticular. Immediately west of the mapped area, sandstone beds of the lower Green River Formation are saturated with heavy hydrocarbons (Pinnell, 1972).

Limestones and marlstones are silty, and some contain chert and fossil hash and are usually brown to buff. Some of the limestones yield a hydrocarbon odor on fresh fracture.

Shales in the lower part of the Green River Formation are brown and become gray and green in the upper part. In Dairy Fork a thin bed of red mudstone is present in the upper part of the Green River Formation. "Paper" shales are very thin, brown, dolomitic units and form very conspicuous outcrops. No tuff was observed in the Green River Formation of the Mill Fork area, although such rocks are common in the Uinta Basin and Wasatch Plateau.

Age and Correlation.—The Green River Formation is generally accepted as Eocene in age.

Environment of Deposition.—The Green River Formation has been cited many times as a typical lacustrine sediment. In the Mill Fork area, however, the basal beds are in part of fluvial origin (Baer, 1969, p. 13). The lower beds of the Green River Formation in the Mill Fork area are equivalent to the Delta Facies of Picard (1955, p. 83). Beds above these basal clastic deposits are the typical green shales and marlstones of the lacustrine phase of the Green River Formation.

TERTIARY (?) AND QUATERNARY ROCKS

Stream gravels are present along modern drainages as well as on higher levels. These higher-level terrace gravels represent drainage gradients perhaps associated with high stands of Lake Bonneville. Terrace gravels are composed of fragments from the North Horn, Flagstaff, and Green River formations, Most gravel south of Soldier Creek was derived from the North Horn and Flagstaff formations when the Green River Formation was not extensively exposed in the source area south of Mill Fork.

Quaternary and Recent deposits of tufa are present around a spring in the southwest corner of Sec. 34, T. 9 S., R. 5 E. This spring is near the Martin Mountain Fault and owes its existence to fracturing associated with this fault.

The Red Narrows Conglomerates

A thick sequence of coarse conglomerate and sandstone is exposed in the Red Narrows of Soldier Creek, several miles east of Thistle, Utah. These beds belong to the Red Narrows facies of the North Horn Formation. Identity of these beds has been a subject of controversy for a number of years. Because of this controversy a re-examination of the correlation of these beds has been made part of the present work.

Conglomerate exposed in Red Narrows was first identified as the basal Wasatch Formation of the Tertiary System (Moore, 1931, p. 537). Later, Spieker (1946, p. 131), in discussing the geologic history of central Utah, correlated these conglomerates with the type Price River Formation in Price River Canyon, where the formation is dominantly sandstone and siltstone. He concluded that the Price River Formation is an eastern facies of conglomerate in Red Narrows. Spieker (1946, p. 132) offered as proof of this transition a stratigraphic section measured in the canyon of Bennion Creek (Sec. 14, T. 11 S., R. 6 E.) southeast of the Mill Fork area. Correct interpretation of this section of conglomerate and sandstone is critical, since it was Spieker's only basis for including the postorogenic conglomerates of central Utah in the Price River Formation.

Since much of the geologic work in the outcrop area of this conglomerate has been done by students of Spieker, the name Price River Formation has been widely applied to these beds.

In 1960, A. A. Baker made available his map of the Strawberry Valley Quadrangle (USGS open file). Baker does not recognize the North Horn Formation northeast and east of Thistle, but classifies all beds between the Flagstaff Formation and pre-Laramide folded complex as Price River Formation. Spieker (1949, p. 25) quotes Baker as saying that the North Horn and Price River formations become very much alike in the country north and east of Thistle and it is impossible to differentiate the two. Baker (1947) had concluded earlier that there is no basis for recognition of the North Horn Formation north of Soldier Creek.

Boyd and others (1959), in a road log, concluded that the conglomerates in the Red Narrows belong to the North Horn Formation and do not recognize any Price River Formation in the area, a position reversed in a similar guide in 1964.

Hardy (1962, p. 57), in reviewing the Mesozoic and Cenozoic stratigraphy of central Utah, doubts that the Price River Formation could change from a sandstone, in the valley of the South Fork of Soldier Creek, to the conglomerate of Red Narrows, a horizontal distance of approximately eleven miles. He thinks that the conglomerates of Red Narrows possibly belong to the North Horn Formation.

Hintze (1962) compiled a geologic map of the Southern Wasatch Mountains and identified beds below the Flagstaff Formation, east of Thistle, as Price River-North Horn, as did Rigby, Hamblin, and Young (1966, p. 139).

The most recent attempt at solving this problem is by W. T. Moussa (1965), who mapped the Soldier Summit Quadrangle, which includes the section of conglomerate measured by Spieker (1946) in Bennion Creek at Sec. 14, T. 11 S., R. 6 E. Moussa (1965, p. 9) thinks the conglomerate exposed in Bennion Creek belongs to neither the Price River nor the North Horn formations but in a new stratigraphic unit which he calls the Bennion Creek Formation. Moussa (1965, p. 9) states that the conglomerates exposed in Bennion Creek overlie the Price River Formation, and thus are younger. He does not include them in the North Horn Formation, however, for the following reasons: (1) the conglomerates are angularly overlain by the North Horn Formation; and (2) lithologically, the conglomerates are markedly different from beds in the North Horn Formation (Moussa, 1965, p. 14). Both conclusions are open to some question.

Moussa's belief that the North Horn Formation overlies the postorogenic conglomerates in angular unconformity appears to be based in large part on the following statements by Spieker (1949b, p. 71): "In some parts of the southern Wasatch Mountains, the Price River conglomerate wedges out against the old erosion surface which is overlapped by the North Horn and younger formations." Also from Spieker (1949a, p. 24):

> In some places it (the conglomerate) is absent where relief persisted in the foothill zone of the early Laramide Mountains, and the North Horn Formation overlies the folded complex in angular unconformity. At Thistle, in fact, it abuts against the actual late Cretaceous mountain front and is superseded westward on the unconformity by the North Horn Formation: here 500 to 1000 feet of relief on the old mountain front can be seen today.

These two statements note the marked relief on the post-Laramide erosional surface, as in the Thistle area, where the coarse conglomerates are not present due to nondeposition. They do not support the conclusion, however, that an angular unconformity exists between the upper North Horn Formation and the underlying conglomerates at some distance east of Thistle. Reinvestigation of the Bennion Creek area indicates that no unequivocal evidence of angularity exists between the two clastic units.

Significant amounts of conglomerate are not present in the type section of the North Horn Formation, as pointed out by Moussa, due to its distance from the early Laramide front. Teat Mountain, for example, is capped by beds, identified as North Horn Formation (Walton, 1964, Fig. 2), that are conglomerates identical to those exposed in Red Narrows and Bennion Creek. Conglomerates found in the North Horn Formation southeast of Thistle in Lake Fork are similar to those in Red Narrows. Schoff (1951, p. 629) found conglomerate in the Cedar Hills, in beds which he identified as North Horn Formation, that was impossible to distinguish from the conglomerates in what he called the Price River Formation. In the area southwest of Thistle, the North Horn Formation contains a large amount of conglomerate similar to the Red Narrows conglomerate (Metter, 1955, p. 129).

In the Mill Fork area and surrounding areas a mappable boundary does not exist between the postorogenic clastic unit here identified as the Red Narrows facies and finer-grained Mill Fork facies of the North Horn Formation. These two facies grade into each other laterally and vertically. Others have also noted this lack of a distinct boundary elsewhere. Spieker (1949b, p. 77) and Peterson (1952, p. 44) found it difficult to define a contact between the conglomerate (which they identified as Price River Formation) and the North Horn Formation. Harris (1953, p. 63) could not find a well-defined lithologic break and mapped the clastic rocks as Price River-North Horn undifferentiated.

Because of the lack of a mappable contact between the conglomerate and the overlying beds of the North Horn Formation, it is the writer's opinion that these beds in the Mill Fork Quadrangle should not be separated into two distinct formations but should be included in the North Horn Formation. It is recognized, however, that the postorogenic conglomerates and the overlying and laterally gradational finer-grained sequence of beds are lithologically and genetically gradational. For this reason the North Horn Formation is divided into the Red Narrows facies and Mill Fork facies in this area.

It is concluded that the Red Narrows facies of the North Horn Formation overlies and is distinct from the Price River Formation. This relationship is well exposed in the canyon of Bennion Creek (Moussa, 1965, p. 9). Perhaps the best evidence of the distinction between these beds is found in the Cedar Hills area to the west, where Hintze (1962, p. 71) shows beds identified as Price River Formation overlain in angular unconformity by conglomerates of the North Horn Formation.

In summary, it is concluded that (1) the conglomerate exposed in Red Narrows and Bennion Creek is younger than the Price River Formation and belongs to the North Horn Formation, and (2) the Red Narrows facies of the North Horn Formation is not sufficiently distinct from the overlying beds to be separately mappable.

STRUCTURAL GEOLOGY

General Statement

The geologic structure of the Mill Fork area is typical of the Wasatch plateau, with broad folds and high angle faults. Faulting in the plateau area is attributed by some to tension caused by solution of salt from underlying Jurassic rocks (Stokes, 1956). It is the opinion of others, however, that faulting and folding of the Wasatch Plateau is closely related to the block faulting of the basin and range and is not due to localized salt solution. Ultimate relationships are still speculative.

Detailing of structure in the Mill Fork area was hampered by heavy vegetive cover. Many of the minor faults could not be followed beyond road cuts, and some other minor faults may have gone undetected. General structure of the area is shown by Text-figure 4, and the more salient structural features are described below.

Folds

Folds are the dominant structures of the Mill Fork area, and major folds in the area include: Soldier Monocline, Tie Fork Syncline, and Thistle Dome.

Soldier Monocline.—Along U.S. Highway 50-6 east of Dairy Fork, beds in the Mill Fork area have a general dip to the north of about 15 to 20 degrees. This dip rate decreases to the south to where it is only a few degrees at the southern boundary of the mapped area. Farther south on the plateau the beds are nearly horizontal. To the north, attitude of the beds reverses and dips to the south in Tie Fork Syncline. This structure is called the Soldier Monocline and is the dominant structural feature of the Mill Fork area. It was formed when the Wasatch Plateau was elevated to its present position and is the counterpart of the Wasatch Monocline on the west side of the Wasatch Plateau. Structural relief on this feature in the Mill Fork area is about 3000 feet. Soldier Creek follows the general strike of the moncline.

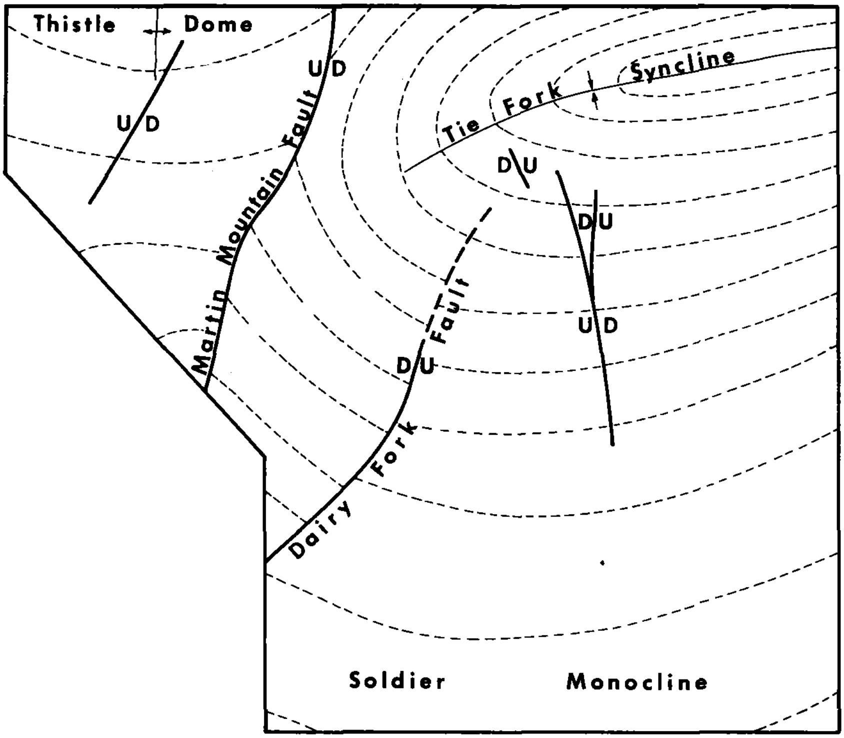
Tie Fork Syncline.—In the northern third of the Mill Fork area the Green River Formation is folded into an east-plunging syncline called the Tie Fork Syncline by Walton (1954, Fig. 4).

Thistle Dome.—North of Martin Mountain the beds are folded into a north-south, doubly-plunging anticline called Thistle Dome. Only the extreme southern portion of this structure is present in the mapped area, but its structural expression can be seen while traveling along the valley of Soldier Creek. There is about 2000 feet of structural relief on this anticline, and it is a potential petroleum prospect.

Faults

General Statement.—Many small fracture zones and faults of small displacement were observed in the field, but only faults with a throw of more than 10 feet were mapped. Most faults are high-angle and normal, as far as can be determined from their very limited exposures. Rocks in the area are not well enough exposed to trace many of the small faults across the more vegetated country. The two major fault zones which bound the Dairy Fork Graben are topographically expressed and mappable and are here named the Martin Mountain and Dairy Fork faults.

Martin Mountain Fault Zone.—This north-south fault zone bounds the Dairy Fork Graben on the west and is well exposed in the valley of Soldier Creek at the southwest corner of Section 34, T. 9 S., R. 5 E. At this point more than ten separate faults can be seen. In the south wall of Soldier Canyon a sliver of Flagstaff Limestone is present in the fault zone approximately 1000 feet above stream level. The fault zone is nearly 200 feet wide in Soldier Canyon and here has a total throw of approximately 1500 feet, down to the east. The fault zone is not exposed anywhere else in the Mill Fork area, but it can be traced by the contrast in lithology across the fault zone and



TEXT-FIGURE 4.—Form line structure contour map of the Mill Fork area.

its scarp. The fault extends an unknown distance to the south but dies out to the north on the east flank of Thistle Dome.

Dairy Fork Fault.—This fault bounds the Dairy Fork Graben on the east and is inferred from the disappearance of Flagstaff Formation west of the fault. The Dairy Fork Fault has a throw of approximately 1000 feet and is subparallel to the Martin Mountain Fault. The two faults are separated by about two miles. The Dairy Fork Fault is nearly vertical, as inferred from its map pattern, and dies out to the north, for it is not recognizable in Soldier Canyon.

Joints

The rocks of the Mill Fork area are highly jointed. No systematic measurement of joint trends was made; however, random measurements indicate a general north-south and east-west orientation which agrees with data given by Henderson (1958, p. 16).

Age of Faulting and Folding

Spieker (1946, p. 149) defines three orogenic episodes in central Utah. The first orogeny is called the mid-Cretaceous, the second early Laramide, and the third pre-Flagstaff.

No evidence of the mid-Cretaceous orogeny is exposed in the Mill Fork area. The early Laramide orogeny evidences itself, not in a structural feature, but by the coarse clastic wedge of the Red Narrows facies of the North Horn Formation which was shed by the newly formed early Laramide mountains to the west. Evidence of the pre-Flagstaff orogeny is missing from the mapped area. To the east, however, near Soldier Summit, the North Horn Formation thins markedly across the Clear Creek Anticline (H. K. Lautenschlager, personal comm., 1966), thus showing pre-Flagstaff tectonic activity in this area.

The most recent evidence of tectonism in this area is the Thistle, Utah, earthquake of 1919, which destroyed much of the town (E. Nelson, personal comm., 1966).

Age of the Early Laramide Orogeny

The early Laramide orogeny (Spieker, 1946, p. 149) of central Utah is evidenced in the area around Thistle by a prominent angular unconformity (Pinnell, 1972). Here the Triassic, Jurassic, and Cretaceous beds folded in the orogeny are angularly overlain by unfossiliferous conglomerate and sandstone belonging to the Red Narrows facies of the North Horn Formation. This conglomerate is well exposed in the Red Narrows east of Thistle.

Spieker used this angular unconformity to date the early Laramide orogeny. As mentioned above, Spieker correlated the conglomerate overlying the folded complex near Thistle with the Price River Formation in Price River Canyon, where fossils indicate a Late Montanan age for the formation. Using this information, Spieker assigned a Medial to Late Montanan age to the early Laramide orogeny.

However, as stated earlier, the conglomerates which overlie the folded complex near Thistle belong to the North Horn Formation, which probably has a latest Cretaceous or early Tertiary age. Therefore, the Laramide folding here is younger than Spieker thought.

Hintze (1962, p. 71) found that near the head of Hop Creek in the northern Cedar Hills, the North Horn Formation overlies the Price River Formation in angular unconformity. This also suggests a period of deformation younger than Late Montanan. However, the relationship of this unconformity to Spieker's early Laramide orogeny is unknown.

GEOMORPHOLOGY

The Mill Fork area is an excellent example of structural control of landforms. The area exhibits a cuestaform topography formed on the dip slopes of the Flagstaff and Green River formations. The Martin Mountain Fault expresses itself as a scarp along part of its trace. Soldier Creek is a subsequent stream flowing in a strike valley. The Dairy Fork Graben has a somewhat more subdued topography than the area on either side of the bounding faults due to the presence of less resistant Green River Formation in the graben.

Three levels of the Soldier Creek drainage system are present. The highest level is marked by the gravel terraces shown on the map. This material probably represents the stream level during the existence of Lake Bonneville. The second level is the alluvium contact as mapped, and the third level is the present stream level. The stream system has entrenched itself in its alluvium due to static rejuvenation resulting from an increase in runoff.

The dip slopes of the Flagstaff and Green River formations are the site of mass movement during wet periods. Slump scars can be seen on the south side of Soldier Canyon east of Mill Fork where material has broken away and moved along the dip slopes of the Green River Formation.

ECONOMIC GEOLOGY

The Mill Fork area is impoverished with regard to geological materials of economic importance. The area is used extensively for grazing of sheep and cattle, and water is of minor importance since no one lives near the area.

Gravel was once removed from two pits near the townsite of Mill Fork in the north central portion of the area. This gravel is of such coarse texture that it is of little value, except as fill material.

Several exploratory holes have been drilled in the area. One abandoned site is located within the Dairy Fork Graben in the southwest corner of Section 15, T. 10 S, R. 5 E. However, the well did not go below the North Horn Formation and was plugged and abandoned. Mountain Fuel Supply Company drilled a dry hole in 1966 on the east flank of Thistle Dome, to the north of the area.

Approximately four miles southwest of Martin Mountain, tar sands are present in the lower Green River Formation, in an area called Oil Hollow. These tar sands were once exploited for use as road material. This indicates that petroleum is present in the rocks of this area, and future drilling may prove fruitful, particularly along the east side of the Martin Mountain Fault and Thistle Dome. Oil may also be found in traps associated with the unconformity between the folded pre-Laramide rocks and the overlying sediments.

GEOLOGIC HISTORY

Geologic history recorded in rocks which crop out in the Mill Fork area begins with the shedding of coarse, clastic material from the newly uplifted Sevier orogenic belt west of Mill Fork. This material is preserved as the Red Narrows facies of the North Horn Formation, and was deposited as alluvial fan, mass movement, and braided stream deposits on a steep piedmont slope. These conditions gradually gave way to fluvial and lacustrine conditions represented by the Mill Fork facies of the North Horn Formation. Minor deformation took place during the deposition of the North Horn Formation.

A change in climate, along with some crustal shift, caused a large, freshwater lake to form in this area in which the Flagstaff Formation was deposited. This lake was then gradually filled in by encroaching fluvial or deltaic sediments of the basal Green River and Colton formations. Lacustrine conditions again became widespread, and the great thickness of the upper Green River Formation was deposited.

The major structural features of the Mill Fork area are the result of the late Tertiary Basin-Range disturbance. During this period, folds such as the Wasatch and Soldier monoclines formed as a response to vertical movements. The same period of deformations resulted in high-angle, normal faulting in other areas of Utah, which allows general dating of the disturbance as Middle to Late Tertiary.

The next geologic event recorded in the Mill Fork area is the Late Tertiary and Quaternary erosion which has produced the present physiographic surface.

APPENDIX A

North Horn Formation

Partial section of the North Horn Formation measured in Mill Fork Canyon, Sections 19, 30, and 31, T. 10 S., R. 6E.

Unit No.	Description	Thickness in Feet	Total Feet above Base
27	Limestone, light gray, weathers same, contains a few algal balls, highly fractured, forms ledge.	30	1517
26	Sandstone, buff, weathers gray, fine grained, very calcareous, forms cliff.	29	1487
25	Limestone, silty, buff, weathers chalky, contains flecks of spar.	5	1458
24	Shale, dark gray, weathers light gray, forms slope.	33	1453
23	Sandstone, buff, weathers buff, fine grained, friable, medium scale crossbeds, forms cliff.	95	1420
22	Shale, dark gray, forms slope.	98	1325
21	Limestone, silty, dark gray, weathers chalky, massive bedded, forms ledge.	28	1227
20	Shale, brittle, light brown, calcareous, forms slope.	70	1199
19	Siltsone, gray, weathers tan, very calcareous, forms crumbly rubble when weathered.	46	1129
18	Sandstone and shale, interbedded; sandstone is fine grained, buff, weathers gray; shale is greenish gray. Unit forms low ledges in a slope.	43	1083
17	Limestone composed almost entirely of ½-inch algal balls, light gray, weathers same.	27	1040
16	Sandstone, gray, weathers buff, medium grained, small pebbles scattered throughout unit.	72	1013
15	Shale, dark gray, weathers light gray, fissile.	90	941
14	Limestone, dark gray, weathers chalky, contains pellets and flecks of spar, forms ledge.	59	851
13	Siltstone, red with yellow blotches, weathers to crumbly slope.	7	792
12	Covered, probably shale.	103	785
11	Sandstone, tan, weathers same, medium grained, massive weathering but contains some crossbeds, forms ledge.	19	682
10	Siltstone, gray, weathers red, forms slope.	30	663
9	Covered.	93	633
8	Sandstone, tan, weathers buff, medium to coarse, crossbedded, lower part is mottled red and tan, forms cliff.	84	540
7	Limestone, brown, weathers buff, massive bedded, contains a few pellets and algal balls, forms ledge.	13	456
6	Shale, green, weathers tan, brittle, highly fractured, slightly calcareous.	50	443
5	Conglomerate, pebble 3 to 6 inches in diameter, matrix is gray and weathers same.	21	393
4	Siltstone, tan, weathers buff, very calcareous, contains several small lenses of sandstone.	31	372
3	Shale, mostly covered.	48	341
2	Sandstone, gray, weathers buff, fine grained, slightly calcareous, forms cliff.	20	293
1	Covered interval, probably interbedded sandstone and shale.	272	273
	....		
	Total	1517	

Base of canyon wall

APPENDIX B

Flagstaff Formation

Measured section of the Flagstaff Formation, measured in Beaver Dam Canyon, Section 20, T S., R. 6 E.

Unit No.	Description	Thickness in Feet	Total Feet above Base
	Green River Formation (gradational contact)		
18	Limestone, dark gray, micritic, has cavities filled with pelletal limestone Contains spar-filled vugs. Upper one foot contains algal balls up to one inch diameter and scattered gastropods.	3	258
17	Limestone, cream colored, weathers same, very fine grained Contains spar-filled vugs and hairline cracks filled with spar Upper contact with unit 18 is irregular due to erosion.	5	255
16	Limestone, dark gray, weathers light gray, fine grained, contains light gray pellets.	3	250
15	Limestone, light gray, weathers same, silty, dolomitic, unit similar to unit 1.	8	247
14	Limestone, like unit 1.	10	239
13	Limestone, light gray, weathers buff, fine grained, contains pellets and a few gastropods More pellets near top.	9	229
12	Limestone, light gray, weathers buff, similar to unit 10.	12	220
11	Limestone, dark gray, weathers light gray, fine grained, silty. Contains gastropods, pellets, and some microfossils.	9	208
10	Limestone, light gray, weathers buff, flecks of spar throughout and some iron staining. Forms ledge	9	199
9	Limestone, light gray, weathers same, micritic, contains pellets, spar-filled cracks, and cavities. Forms ledge	6	190
8	Limestone, light gray, weathers light gray, fine grained, silty, flecks of spar and yellow stain throughout, with some pellets.	5	184
7	Badly covered slope.	17	179
6	Like unit 4 but with no silt.	25	162
5	Limestone, dark gray, micritic and silty, dolomitic in part, weathers crumbly.	16	137
4	Limestone, light gray, weathers light gray, fine grained, silty, dolomitic, some iron staining, forms cliff, weathers by spalling. The above grades into a light gray, pelletal, fine-grained limestone. Contains blotches of pure limestone.	14	121
3	Siltstone, gray, weathers gray, calcareous, contains flecks of spar	9	107
2	Limestone, light gray, weathers buff and gray, fine grained, dolomitic, contains flecks of iron staining, forms rubble-covered slope.	10	98
1	Covered slope	88	88
	Total	258	

APPENDIX C

Flagstaff Formation

Partial section of the Flagstaff Formation measured approximately 12,000′ due west of Martin Mountain in the NE¼, Section 7, T. 10 S., R. 5 E. This is an incomplete section and represents less than the true thickness of the Flagstaff Formation at this locality.

Unit No.	Description	Thickness in Feet	Total Feet above Base
	Top of hill.		
23	Limestone, fine grained, brown, weathers gray, contains algal balls, forms ledgy slope.	3	641
22	Limestone, silty, buff to gray, weathers same, contains pellets with algal balls near top, forms ledgy slope.	55	638
21	Mudstone, gray and buff, mostly covered slope.	30	503
20	Sandstone, medium grained, gray, weathers buff, forms ledge.	3	553
19	Siltstone, covered slope.	66	550
18	Limestone, fine grained, cream color, weathers same, silty, contains flecks of organic matter, forms slope.	17	484
17	Covered.	11	467
16	Siltstone, gray, calcareous, sandy in places, contains a few algal balls, forms slope.	32	456
15	Covered, appears to be mostly siltstone and silty limestone.	77	424
14	Limestone, like unit 12 but with scattered algal balls, grades upward into a calcareous sandstone, forms ledge, medium bedded.	11	347
13	Covered slope.	18	336
12	Limestone, fine grained, very silty, gray, weathers gray, forms ledge.	22	318
11	Mudstone, calcareous, gray, forms slope.	18	296
10	Limestone, silty, gray, weathers buff, contains small grains of white material, grades upward into a siltstone, forms ledge.	3	278
9	Covered, small outcrop of limestone like unit 8 but may not be in place.	50	275
8	Limestone, fine grained, silty, gray, weathers gray, flecks of spar throughout, sublithographic.	9	225
7	Limestone, silty, dark gray, weathers light gray, contains algal balls up to 25 mm. in diameter. The algal balls decrease in number toward the top of unit. Top part of unit contains pellets. Forms cliff.	33	216
6	Mudstone like unit 4, but grades to yellow gray toward top.	16	183
5	Limestone, ranges from lithographic limestone to 100% algal balls. The algal balls range in size from 1 to 10 mm. with a complete gradation in size and abundance. Medium bedded, forms cliff.	13	167
4	Mudstone, calcareous, maroon, contains small amount of grit, forms slope.	55	154
3	Limestone, composed almost entirely of algal balls, light gray, weathers buff and gray, algal balls range in size from 1 to 15 mm., pore space between algal balls filled with spar. Forms cliff, thick bedded.	13	99
2	Limestone, lithographic, gray, weathers gray, contains shot-sized algal balls, flecks of spar throughout, becomes grayer toward the top. Forms cliff and slope.	71	86
1	Limestone, lithographic, brown, forms cliff.	15	15
	Total	641	

North Horn Formation—gradational contact

APPENDIX D

Green River Formation

Partial section of Green River Formation measured in Beaver Dam Canyon, Section 18 and 20, T. 10 S, R 6 E

Unit No.	Description	Thickness in Feet	Total Feet above Base
44	Sandstone, light gray, weathers same, fine grained, poorly sorted, micro cross laminated, forms ledge.	20	1767
43	Shale, green and gray, poorly exposed slope.	96	1747
42	Limestone, gray, weathers buff, sublithographic, concoidal fracture, forms ledge.	1	1651
41	Shale, like unit 35, small amount of argillaceous, buff limestone in middle of unit. Forms slope.	29	1650
40	Limestone, buff, weathers same, fine grained, contains pellets, thin bedded, forms ledge.	5	1621
39	Shale, like unit 35.	20	1616
38	Interbedded limestone and shale. Shale is greenish gray like unit 35 Limestone is brown, weathers buff, fine grained, argillaceous, thin bedded, contains blebs of dark brown chert Unit forms ledge and slope	50	1596
37	Shale, like unit 35	39	1546
36	Mudstone, chocolate brown, weathers buff, slightly calcareous, thin bedded, concoidal fracture, forms ledge.	1	1507
35	Shale, greenish gray, weathers same, forms slope.	15	1506
34	Interbedded shale and mudstone. The shale is chocolate brown, weathers tan, papery, oil smell on fresh break, appears massive on fresh surface but weathers papery Mudstone is brown, weathers tan, unit forms ledge	54	1491
33	Shale, chocolate brown, weathers buff, papery at base, organic, several thin bedded layers present in unit, forms slope.	50	1437
32	Marlstone, brown, weathers buff, fine grained, dolomitic, thin bedded, grades into upper unit, forms ledge.	7	1387
31	Shale, gray, calcareous, forms slope.	68	1380
30	Unit covered by the alluvium of Soldier Creek	250	1312
29	Shale, gray, interbedded with buff, fine-grained limestone, forms slope.	135	1062
28	Limestone, black, weathers light brown, fine grained, shaly, slight odor on fresh fracture.	4	927
27	Shale, gray, forms slope, mostly covered.	55	923
26	Shale, papery like unit 24.	5	868
25	Shale, tan, weathers tan, contains fossil hash, calcareous forms slope.	49	863
24	Shale, dark brown, weathers buff, papery, forms ledge	6	814
23	Interbedded shale and silty limestone Limestone is cream to brown, weathers buff, fine grained, contains fossil hash in places. Shale is light gray, weathers buff. Unit forms ledgy slope	148	808
22	Limestone, cream, weathers cream, fine grained, argillaceous, medium bedded, forms ledge	10	660
21	Shale, gray with some thin beds of limestone Mostly covered slope.	45	650
20	Limestone, dark gray, weathers buff, fine grained, contains pelecypod hash, forms ledge.	3	605
19	Shale, gray, mostly covered slope.	45	602
18	Limestone, brown, weathers light brown, fine grained, contains some fossil hash, forms ledge	6	557
17	Shale, light gray, mostly covered slope	10	551
16	Sandstone, gray, fine grained, slope forming at base,	30	541

Appendix D (Continued)

	grades upward to a medium grained, yellow ledge former at top.		
15	Limestone, chocolate brown, weathers brown, fine grained, silty, contains flecks of spar, forms ledge.	3	511
14	Sandstone like unit 12.	15	508
13	Limestone dark gray, fine grained, almost lithographic, slight odor on fresh break, forms poorly exposed slope.	33	493
12	Sandstone, light gray, weathers light gray, fine grained at base and grades upward into medium grained at top. Angular to subangular, poorly sorted, massive bedding but thin bedded in part.	35	460
11	Sandstone, light gray, weathers light gray, fine grained, poorly sorted, calcareous, forms slope with several small ledges.	40	425
10	Mudstone, brown, weathers reddish brown, calcareous, forms slope.	23	385
9	Limestone, brownish gray, weathers brown, fine grained, contains a few pellets and spar-filled vugs, forms ledge.	2	362
8	Sandstone, light gray, weathers light gray, fine grained, poorly sorted, cross bedded, calcareous.	35	360
7	Limestone, dark brown, weathers rust, fine grained, slight hydrocarbon odor on fresh fracture. Pelecypod hash present.	3	325
6	Shale, dark brown, weathers light gray, calcareous, forms slope.	40	322
5	Covered.	30	282
4	Sandstone, brownish-gray, medium grained, poorly sorted, poorly cemented with calcite, forms cliff, angular.	9	252
3	Interbedded limestone and shale. Shale like unit 3. The limestone is gray, weathers buff, fine grained, slightly vuggy, contains fossil hash. Limestone beds are about 1 to 2 feet thtick and become lithographic near the top. Poor exposure.	150	243
2	Shale, dark gray, weathers light gray, several thin siltstone beds present, forms poorly exposed slope.	80	93
1	Siltstone, light gray, weathers buff and light gray, highly calcareous. Forms ledge.	13	13
	Total	1,767	

Exposures south of Soldier Creek are in general worse than those to the north of the creek.

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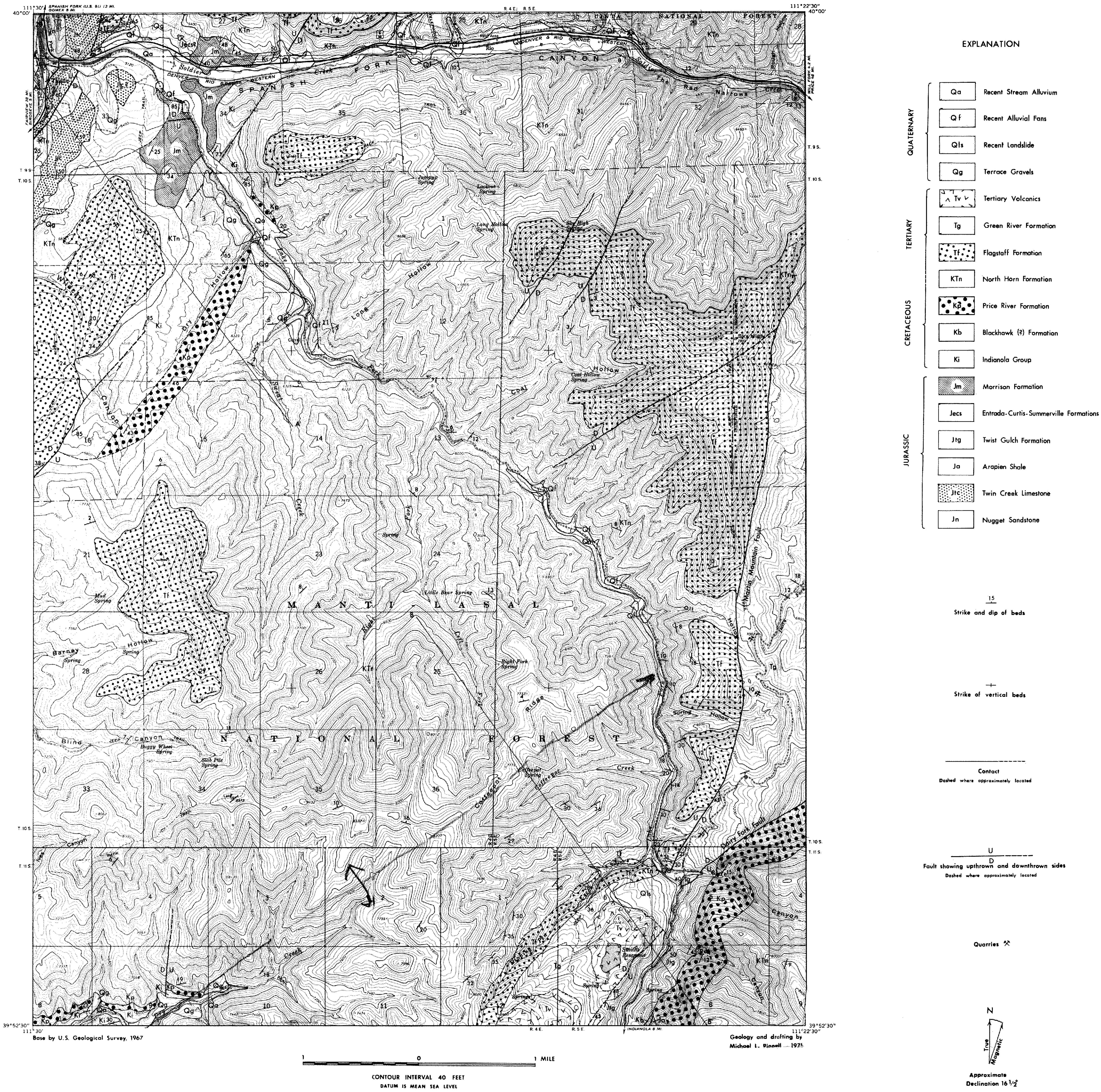

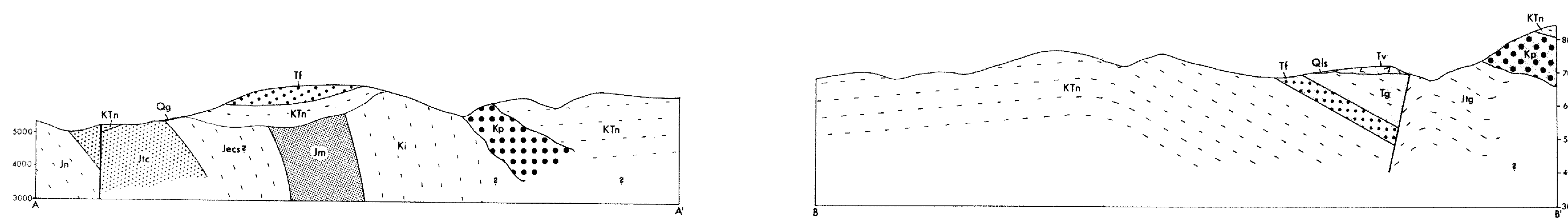

GEOLOGIC MAP AND SECTIONS OF THE THISTLE QUADRANGLE, UTAH

By
Michael L. Pinnell
1971