GEOLOGY OF THE SANPETE VALLEY AREA, EPHRAIM, UTAH

by

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Contents

Page

Introduction 1

Geography 2

Stratigraphy 2

General Statement 2

Jurassic System 3

Arapien Shale 3

Definition and Extent 3

Lithologic Character 3

Stratigraphic Relations 4

Age and Correlation 4

Twist Gulch Formation 4

Definition and Extent 4

Lithologic Character 5

Environment of Deposition 5

Stratigraphic Relations 5

Age and Correlation 6

Morrison(?) Formation 6

Definition and Extent 6

Lithologic Character 7

Environment of Deposition 7

Stratigraphic Relations 7

Age 8

Cretaceous System 8

Indianola Group 8

Definition and Extent 8

Page

Lithologic Character 8

Environment of Deposition 9

Stratigraphic Relations 10

Age 10

Price River Formation 10

Definition and Extent 10

Lithologic Character 11

Environment of Deposition 11

Stratigraphic Relations 11

Age and Correlation 12

Cretaceous - Tertiary System 12

North Horn Formation 12

Definition and Extent 12

Lithologic Character 12

Environment of Deposition 13

Stratigraphic Relations 13

Age and Correlation 14

Flagstaff Formation 14

Definition and Extent 14

Lithologic Character 15

Environment of Deposition 15

Stratigraphic Relations 15

Age 16

Colton Formation 16

Definition and Extent 16

Lithologic Character 16

Page

Environment of Deposition 17

Stratigraphic Relations 17

Age 18

Green River Formation 18

Definition of Extent 18

Lithologic Character 18

Environment of Deposition 19

Stratigraphic Relations 19

Age and Correlation 20

Crazy Hollow Formation 20

Definition and Extent 20

Lithologic Character 20

Environment of Deposition 21

Stratigraphic of Deposition 21

Age and Correlation 21

Structural Geology 21

Folds 21

Faults 23

Unconformities 25

Geologic History 27

References 30

LIST OF ILLUSTRATIONS

Figure

1. Geologic Map of Wasatch Monocline South of the mouth of Ephraim Canyon, Ephraim, Utah.

2. Stratigraphic Column (for Fig. 1).

3. A Geologic Map of the Rock Canyon Region, Utah.

4. Stratigraphic Column (for Fig. 3).

5. A Geologic Map of Wales Canyon Region, Wales, Utah.

6. Cross-Sections of Wales Canyon Region

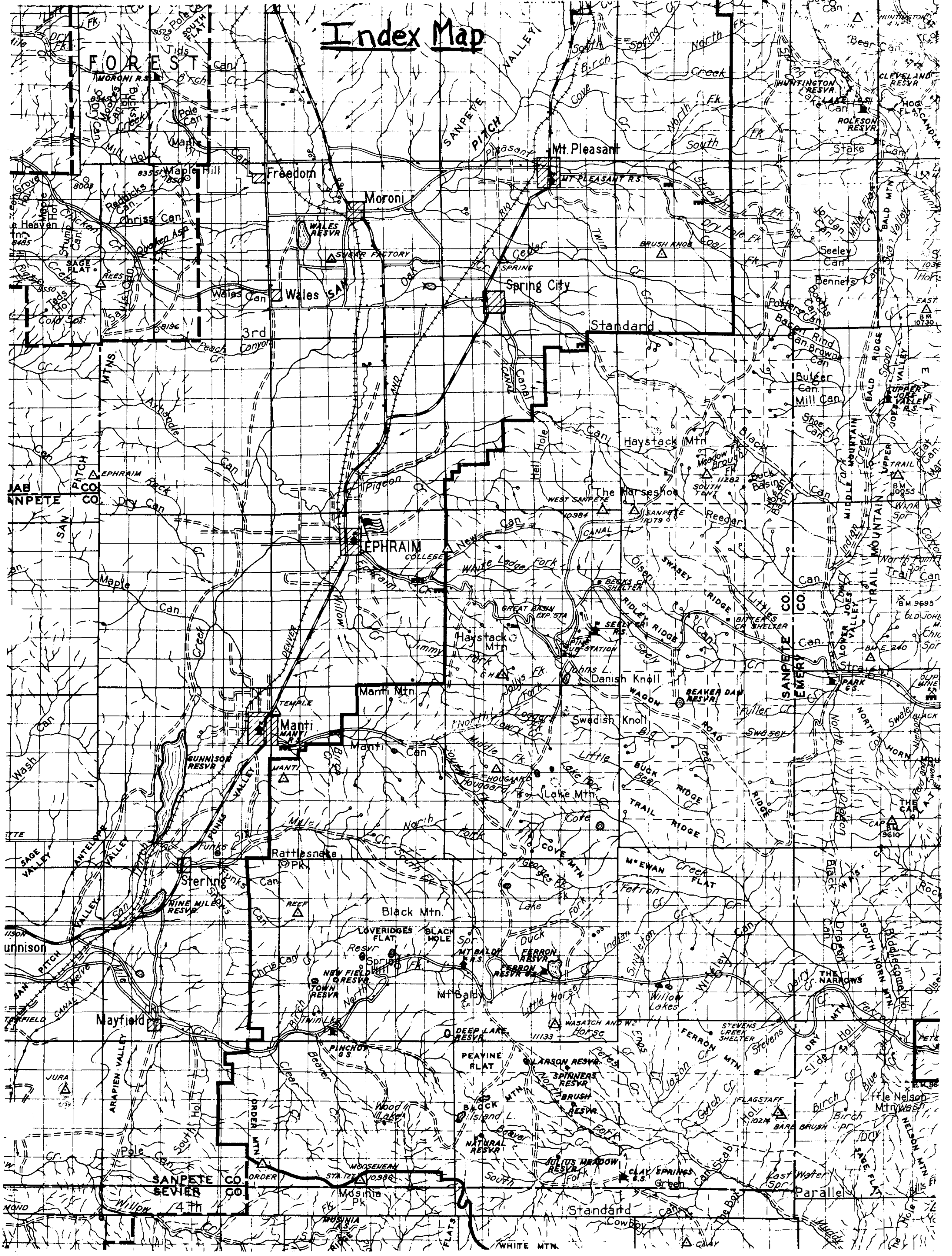
7. Explanation with Figures 5 & 6.

8. Stratigraphic Column for Fig. 5.

9. Cross-Section of Sixmile Canyon and Southern Sanpete Valley, Sterling, Utah

10. Cross-Section of western margin of Northern Sanpete Valley and eastern flank of Gunnison Plateau, Wales, Utah.

Index Map



FOREST
MORONI R.S.
Freedom
Moroni
Mt. Pleasant
MT PLEASANT R.S.
SANPETE
PITCH
VALLEY
WALES RESVR
SUGAR FACTORY
Wales
Wales Can
Spring City
Standard
3rd
Peach Canyon
MTNS.
BRUSH KNOB
HUNTINGTON RESVR
CLEVELAND RESVR
ROLFSON RESVR
Huntington
Stake Can
Jordan Can
Seeley Can
Bennets Can
BALD MTN
Bulger Can
Mill Can
Haystack Mtn
The Horseshoe
WEST SANPETE
SANPETE
SOUTH TENT
Reeder
EPHRAIM
COLLEGE
Ephraim Cr
White Ledge Fork
New Can
Pigeon Cr
Dry Can
Maple Can
GREAT BASIN EXP. STA
SEELY CR R.S.
SUBSTATION
BEAKER DAM RESVR
Haystack Mtn
Danish Knoll
Johns L.
Swedish Knoll
SWASEY RIDGE
RIDLEY RIDGE
BITTER CR SHELTER
SANPETE CO.
EMERY CO.
TRAIL MOUNTAIN
MIDDLE MOUNTAIN
LOWER JOES VALLEY
PARK G.S.
Straight Cr
Manti
TEMPLE
MANTI R.S.
Manti Mtn
Manti Can
GUNNISON RESVR
FUNKS VALLEY
Funks L.
MANTI
HOUGAARD
Lake Mtn
BUCK RIDGE
TRAIL RIDGE
WAGON ROAD RIDGE
Rattlesnake Pk
Sterling
NINE MILE RESVR
Gunnison
COVE MTN
McEWAN FLAT
Ferron Cr
Black Mtn.
REEF
LOVERIDGES FLAT
BLACK HOLE
NEW FIELD RESVR
TOWN RESVR
MT BALDY R.S.
FERRON RESVR
Mt Baldy
Willow Lakes
THE NARROWS
Mayfield
Twin Lks
PINCHOT G.S.
DEEP LAKE RESVR
WASATCH AND W2
PEAVINE FLAT
LARSON RESVR
SPINNERS RESVR
BRUSH RESVR
STEVENS CREEK SHELTER
FERRON MTN
FLAGSTAFF
BARE BRUSH
JURA
ARAPIEN VALLEY
ORDER MTN
Wood Lake
BLACK MTN
Island L.
NATURAL RESVR
JULIUS MEADOW RESVR
CLAY SPRINGS G.S.
MUSSENTUCHIT
Musinia Pk
SANPETE CO.
SEVIER CO.
4th
Standard
Cowboy Can
Parallel
Last Water Spr
Little Nelson Mtn
SOUTH HORN MTN
NORTH HORN
NELSON MTN
SAGE FLAT
WHITE MTN

Introduction

Location and Extent - This report describes the geology of the Sanpete Valley Area, Utah, which includes the eastern flank of the Gunnison Plateau, from just north of Wales Gap to one canyon north of Pete's Canyon, and the western margin of the Wasatch Monocline from Ephraim Canyon south to Salina Canyon. The structure and stratigraphy of Sixmile Canyon, south of Sterling, and Wales Canyon and Chicken Creek Canyon in the Gunnison Plateau, west of Wales, Utah, are included in the study. A reconnaisse field trip was made to Salina Canyon in order to see the structure of the Southern end of the Wasatch Plateau and is included in this report.

A plane table map was made by the writer, with assistance, of Temple Hill, Manti, Utah. The stratigraphy of this area is included also.

Purpose of Work - This report is in partial fulfillment of Bachelor of Science degree requirements. The field work that forms the basis for this report was part of the summer field camp course at the Ohio State University Geology Field Station, Ephraim, Utah.

Field Methods - The field methods employed in mapping the study regions were field reconnaisance, and mapping with aerial photographs and topo maps. The measured sections were done with Jacob's Staffs and Brunton compass and clinometer. The thickness of many of the units was derived from the maps

graphically in the office. Strikes and dips were measured with a Brunton compass and clinometer.

The field work for the major cross-sections of the Sanpete Valley were done by observing the attitude and relationships of exposed beds and formation on field trips closely approximately the line of cross-section.

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Geography

The Sanpete Valley region is sparsely populated with most inhabiants living in small towns. Much of the land is used for sheep and cattle grazing, growing hay, and large and numerous turkey farms.

The climate is semi-arid, vegetation is junipers, conifers, sagebrush, and grass.

The topography of the area is that of valley and plateau. The planks of the plateaus have been gullied, producing gullies and canyons.

The maximum relief between the valley floor and the plateau top is about 4900 feet.

Stratigraphy

General Statement

The stratigraphic section exposed in the study area is from Upper Jurassic Arapien Shale to the lower to Middle Tertiary Crazy Hollow Formation. Comprising the section are limestone, shale, mudstone, sandstone, coal, and minor volcanic

tuff beds toward the top. These rocks represent, in general, alternating fluvial and lacustrine environments.

The study of this area is important for establishing the Cretaceous - Tertiary boundary and dating the Laramide orogenic phases in this area. The Sanpete area is considered the border between the Colorado Plateau and the Basin and Range Provincess.

Jurassic System

Arapien Shale

Definition and Extent - The Arapien Shale was defined by Spieker (1946, p. 123) as the "red to gray shale and fine grained sandstone" that had earlier been known as 'Jurassic Shale'. The type locality is Arapien Valley, which is parallel to the western base of the Wasatch Plateau about six miles southeast of Gunnison.

The formation contains the oldest strata exposed in the study area. It crops out in Salina Canyon, and in Chicken Creek Canyon on the west side of the Gunnison Plateau. It is perhaps the thickest unit of the study area, being over 5000 to 7000 feet northeast of Salina (Spieker, 1946, p. 125).

Lithologic Character - The Arapien Shale that crops out in the study area is contorted greenish shale. The non-resistant beds, which comprise most of the formation are interbedded with more resistant beds 10-12 inches thick.

The Arapien Shale, as described by Spieker (1946, p.124),

consists of four units:

"1. Gray limestone generally thin bedded;
2. Light gray siltstone and shale, very thin bedded, with occasional thin beds of finely rippled sandstone;
3. Gray shale, argillaceous and gypsiferous, with irregular red blotches, which locally become dominant;
4. Compact red salt-bearing shale..."

Stratigraphic Relations - The Arapien shale is ovelain by the Twist Gulch Formation. The contact is placed at the definite color change from bluish-gray or gray to dark brown-red. This contact is exposed only in Salina Canyon.

Age and Correlation - The Arapien Shale is Upper Jurassic, and has been correlated with the Carmel Formation of the San Rafael Swell (Spieken, 1946, p. 125).

Twist Gulch Formations

Definition and Extent - The Twist Gulch Formation was originally the upper member of the Arapien Shale (Spieken, 1946, p. 124). It was the upper predominantly red sandstone, siltstone, and shale.

Gilliland (1951, p.12) elevated the Twist Gulch to formational rank. The type section is that used by Spieker at Arapien Valley (1946, p.123-124). The formation is 3000 feet thick in Salina Canyon (Spieken, 1946, p.125) and over 900 feet thick in the Wales Gap region.

The formation crops out in discontinuous areas along the eastern flank of the Gunnison Plateau and in Salina Canyon.

Lithologic Character - The Twist Gulch Formation consists of brown-red medium - and coarse - grained sandstone with subrounded to subangular quartz and chert grains held in a calcerous cement. Lenses of conglomeratic sandstone are present also. These beds range from texturally mature sandstone to immature sandstones and conglomerates. The color varies little throughout the formation. There is a sparse distribution of cross-bedding and scours. The beds range from two-three centimeters to two and half feet thick.

The mudstone present in the Twist Gulch is similiar to the sandstone. It has blocky structure and may be interbedded with gypsum deposits averaging five centimeters thick.

Environment of Deposition - The Twist Gulch was deposited in mudflat, floodplain, and channel environments. Gilliland (1951, p.11) states it was a marine and brackish-water environment.

Stratigraphic Relations - The Twist Gulch is overlain by the Morrison(?) Formation throughout the study area. The contact was placed at the change in color between the brick red of the Morrison(?) and the dark chocolate red of the Twist Gulch. This is generally an easily defined contact in the study area.

The lower contact between the Arapien Shale was observed on the Gunnison Plateau and in Salina Canyon. This contact is between contorted shales; blue-gray, gray, and brick-red; and the dark chocolate red sandstone and siltstone of the Twist Gulch.

In Salina Canyon an angular unconformity is exposed with the Arapien, Twist Gulch, Morrison(?) and Indianola Group in vertical unconformity with the Colton, Flagstaff, North Horn and Price River Formations.

Age and Correlation - The Twist Gulch is Upper Jurassic in age. It has been correlated with the Entrada, Curtis, and Summerville Formations of the San Rafael Swell (Hardy, 1949). The Preuss and Twist Gulch Formations of north central Utah are equivalent to the Twist Gulch of Sanpete Valley (Gilliland, 1951, p.15)

Morrison (?) Formation

Definition and Extent - The Morrison Formation was defined by Eldridge (1896) in its type locality at Morrison Jefferson County, Colorado. At this location it consists of light brown sandstone containing many fossil remains.

In the study area the beds considered Morrison are much different from those at the type locality. This raises doubt whether these beds are equivalent to those at the type locality. Previous work (Spieker, 1946, p. 126-6) has regarded them as Morrison on the basis of lithology and stratigraphic relations. In this study, the beds will be refered to as qualified Morrison(?) Formation.

The Morrison(?) Formation is exposed on the eastern flank of the Gunnison Plateau, in the Wales Gap region, Salina Canyon, and at the base of the Gunnison Plateau near the Gunnison

Reservoir spillway, and in the middle of southern Sanpete Valley. It extends eastward throughout the Colorado Plateau and thins westward to a western limit in the Gunnison Plateau.

Lithologic Character - The Morrison(?) Formation exposed in the study area consists of brick red coarse-medium-grained sandstone of subrounded to subangular quartz, chert, and jasper grains with hematitic calcerous cement. Beds of red conglomerate with quartzite pebbles and thin-bedded mudstone also comprise the formation. The lithologic character varies from area to area to include variegated shale and brown, gray, and white sandstone.

Enrivonment of Deposition - The Morrison(?) Formation was deposited in an fluvial environment that had sufficient energy at stages of the deposition to carry and deposit large pebbles and boulders. There is evidence that floodplains were present also. The source of sediments for the formation was to the west or northwest although this is uncertain (Spieker, 1946, p. 126)

Stratigraphic Relations - The Morrison(?) Formation is overlain by the Indianola Group. The contact is placed below the conglomerate and light brown sandstone at the base of the Indianola Group and above the top of the uppermost red bed of the Morrison(?)

The Morrison(?) - Twist Gulch contact is placed at the horizon between the brickred sandstone and mudstone of the Morrison(?) and the dark chocolate-brown-red sandstone of the Twist Gulch. Color is the most distinguishing and useful

criteria for differienting the Morrison(?) and Twist Gulch Formation.

Age - The Morrison Formation is considered to be Upper Jurassic in age.

Cretaceous System

Indianola Group

Definition and Extent - The Indianola Group was defined as those stata below the Price River Formation and above the Morrison(?) Formation (Spieken, 1946, p. 127). In Salina and Sixmile Canyons, Spieken (1946, pp. 127-128) divided the group into four formation; in ascending order, the Sanpete Formation, Allen Valley Shale, Funk Valley Formation, and the Sixmile Canyon Formation. The type area for these formations is three miles southwest of Manti, Utah, west of the mouth of Sixmile Canyon.

In the Gunnison Plateau the group is undifferiented. Here the lower conglomerate may be equivalent to the Sanpete Formation and the upper conglomerate roughly equivalent to the Sixmile Canyon Formation. This area lacks the marine beds present in other areas.

The Indianola is present throughout both the Gunnison and Wasatch Plateaus, north to Cedar Hills, and south to Salina Canyon.

Lithologic character - The Indianola Group (undifferiented) exposed in the eastern flank of the

Gunnison Plateau consists of light brown conglomerate of quartzite and minor limestone pebbles in subrounded to subangular quartz sand with a calcerous cement. The formation has minor sandstone beds of light brown medium-grain comprised of smoky quartz and chat. chert

The Sanpete Formation consists of brown sandstone, gray shale, and gray conglomerate. Conglomerate lenses and beds are fairly abundant near the base of the formation.

The Allen Valley Shale consists of evenbedded nonresistant gray shale. Spieker (1946, p. 128) describes the formation as interbedded gray marine shale, yellowish bentonitic siltstone, very fine grained sandstone, and gray limestone. It contains marine fossils.

The Funk Valley Formation consists of yellow-brown fine-grained marine sandstone. Spieker (1946, p. 128) divides the formation into three units: 1. a basal sandstone interbedded with shales; 2. gray marine shale, and 3. an upper sandstone unit.

The Sixmile Canyon Formation consists mainly of coarse-grained gray conglomeratic sandstone. It also contains gray, cream, white fine-grained sandstone, carbonaceous shale, and coal.

Environment of Deposition - The Indianola Group displays different facies in various areas. The rocks along the eastern flank of the Gunnison Plateau indicate deposition in an alluvial fan environment close to the high source area to

the west, in order for the large boulders to be carried and deposited. To the east the group shows marine characteristics including marine fossils in the Allen Valley Shale. In Sixmile Canyon, the Sixmile Canyon Formation contains deposits of coal, indicating swamp environments.

Stratigraphic Relations - The Indianola Group is overlain by the Price River Formation. In the Wales Gap Region the contact is an angular unconformity between Price River conglomerates dipping 81° East and the Indianola dipping about 55° East; both units strike N 10°W.

In Sixmile Canyon the group lies in angular unconformity beneath the Price River, North Horn, and Flagstaff Formations (see Sixmile Canyon cross section).

The Indianola Group conformably overlies the Morrison (?) Formation; where exposed at Wales Gap, this contact is between lightbrown sandstone of the Indianola Group and redbeds of the Morrison(?) Formation.

Age - The Indianola Group is of Lower Cretaceous age. The coal in the Sixmile Canyon Formation was determined by Brown and Reeside (Spieker, 1946, p. 128) to be late Colorado age based on fossil plants and mollusks.

Price River Formation

Definition and Extent - The Price River Formation was defined by Spieker and Reeside (1925, p. 445) as those strata consisting of gray sandstone, conglomerate, grits, and small

amounts of shale below the former Wasatch Formation and above the former Mesaverde Group (1925, p. 445). The type section is Price River Canyon, northwest of Castlegate, Utah.

The formation extends from the Gunnison Plateau eastward to the Utah-Colorado border. In the study area, it overcrops along the eastern front of the Gunnison Plateau. outcrops

Lithologic Character - The Price River contains mostly conglomerate with lesser amounts of sandstone and shale. The conglomerate consists of quartzite boulders and pebbles cemented in light brown sugary quartz sand with a calcerous cement. Toward the top of the formation is light brown medium-grained sandstone and non-resistant light brown sandy shale.

Environment of Deposition - The Price River Formation is a fluvial deposit marking an increase in the carrying power of streams over broad flats. This increase has been attributed to Laramide orogenic activity to the west(Spieker, 1946, p. 132). It has been regarded as the basal conglomerate formation for the North Horn Formation.

Stratigraphic Relations - The Prive River lies unconformably over the Indianola Group. This angular unconformity is exposed in Wales Gap on the eastern flank of the Gunnison Plateau, west of Wales. It is between brown sandstone dipping 53°E of the Indianola and conglomerate dipping 81°E of the Price River, the strike being consistent N 10°W.

The Price River - North Horn is exposed in the Wales Canyon region. Here it is placed between light brown sandstone

of Price River and lowermost red bed of the North Horn.

Age and Correlation - The Price River is assigned to Upper Cretaceous age on the basis of fossils (Spieker, 1946, p. 132). It has been traced to the east to the Book Cliffs. Work done on correlation has shown the Price River to be equivalent to part of the Mesaverde Group near Grand Mesa, Colorado and the Fruitland and Kirkland Formations in San Juan Basin.

Cretaceous - Tertiary System

North Horn Formation

Definition and Extent - The North Horn Formation was originally the lower member of the Wasatch Formation (Spieker and Reeside, 1925, p. 448) and later was given formational rank (Spieker, 1949, p. 132). It consists of red and purplish shale, sandstone, some limestone, and coal. The type section is on North Horn Mountain, Utah.

The North Horn extends continously in all directions from the study area. The formation thickens to the east and north, to 2,200 feet, and thins westward to a minimum of 500 feet observed in Salina Creek (Spieker, 1946,p. 133). It is only 30 feet thick at the mouth of Dry Canyon. . In Coal Canyon the formation measures over 1000 feet, 810 feet measured and mapped in this study.

Lithologic Character - The North Horn Formation consists mostly of shale and mudstone with beds of ledge-form-

ing sandstone.

Exposed near the middle of the formation at the head of Coal Canyon are interbedded limestone, coal, and carbonaceous shale beds.

The limestone is light gray fine-grained and massive. It is interbedded with bituminous coal and carbonaceous fossileferous shale.

The coal beds range from less than an inch to a maximum of $3\frac{1}{2}$ feet thick.

The shale is dark gray to light gray, fine-grained, and fissile. Many of these beds are carbonaceous. The mudstone is similar in color to the shale with platy to blocky structure.

The sandstone ranges from red to yellow, white, and gray. It is coarse-to fine-grained with angular to subrounded quartz, chert, and jasper grains and a calcerous cement. Some beds are conglomeratic with quartz pebbles. These occur with alternating red and white mottled sandstone toward the base of the formation.

Environment of Deposition - The North Horn Formation was deposited in alternating lacustime and fluvial environments with the fluvial deposits predominat. The fluvial units show floodplain and channel deposit features.

Stratigraphic Relations - Underlying the North Horn is the Price River Formation. The contact between them is placed where the conglomerate of the Price River changes to red and white sandstone of the North Horn. This transition occurs through about two feet of section in Deer Creek Canyon.

The North Horn - Flagstaff contact is defind as the top of the uppermost redbed of the North Horn and below arenaceous limestone of the Flagstaff. It is exposed only in Sixmile Canyon and the head of Wales Canyon. In Sixmile Canyon the contact is an angular unconformity regarded as depositional (Spieker, 1946, p. 133)

Age and Correlation - The age of the North Horn Formation is late Cretaceous and early Paleocene, based on fossil evidence (La Rocque, 1956, p. 141)

Tertiary System

Flagstaff Formation

Definition and Extent - The Flagstaff Formation was defined as those strata, mostly limestone, above the North Horn Formation and below the Colton Formation (Spieker, 1946, p. 135). These three formations, the North Horn, Flagstaff and Colton, were collectively the Wasatch Formation (Spieker and Reeside, 1925) and were later separated and promoted to formational rank by Spieker (1946).

The Flagstaff is present in the Gunnison and Wasatch Plateaus and the bedrock underlying Sanpete Valley. This formation extends in all directions from the study area. Babisak (1948, p. 50) states it is absent in the northern end of the Gunnion Plateau. Gunnison

The Flagstaff exposed in Rock Canyon is 770 feet thick and averages 800 to 1000 feet thick in the Wasatch Plateau

(Spieker, 1946, p. 136).

Lithologic Character - The Flagstaff Formation consists mostly of buff to light-gray dense fine-grained arenaceous limestone interbedded with lenses of shale and sandstone. It is locally silicified and has beds of fossiliferous limestone and platy limestone. The sand grains are subrounded to sub-angular medium-grained smoky quartz. The amount of sand in the limestone ranges from 25% to 45%.

The shale is light gray and non-resistant. The sandstone is medium-grained consisting of sub-rounded smoky quartz and usually a high content of calcium carbonate.

There are no marked color changes within the formation. The writer divided the formation into three units on the basis of rock resistance and the location of a red marker bed in the lower part of the Flagstaff. The middle unit of the Flagstaff is ledge-forming and the upper unit of the Flagstaff is slope-forming.

Environment of Deposition - The Flagstaff Formation was deposited in a large fresh-water lake. The sand grains indicate that the lake was also receiving clastic sediments. Evidence of fresh water are gastropods and pelecypods present in some of the beds (Spieker, 1946, p. 136).

Stratigraphic Relations - The Flagstaff - North Horn contact is gradational from North Horn red sandstone and shale to buff and light gray limestone of the Flagstaff. In Sixmile Canyon the contact is an angular unconformity with the

Flagstaff truncating the North Horn. This is due to a pre-Flagstaff disturbance that folded the pre-Flagstaff beds whereafter they were truncated.

The contact with the Colton Formation above is between platy fine-grained dark gray carbonaceous fossiliferous limestone of the Flagstaff and yellow brown fine-grained sandstone of the basal Colton. This conformable contact represents a change in environments from lacustrine to fluvial.

Age - The Flagstaff Formation is Early Tertiary, Paleocene and Eocene, on the basis of mollusks (Spieker, 1946, p. 136; La Rocque, 1956, p. 141)

Colton Formation

Definition and Extent - The Colton Formation was originally the upper member of the Wasatch Formation (Spieker and Reeside, 1925, p. 449). Spieker (1946, p. 139) redefined the unit as a formation, and set its limits as the Flagstaff Formation below and the Green River Formation above. The type section is in the hills north of Colton (Spieker, 1946, p.139).

The Colton Formation crops out in many areas between Salina Canyon and Mount Pleasant along the base of the western flank of the Wasatch Monocline and at the head of Rock Canyon.

Lithologic Character - The dominant rock type of the Colton is sandstone. It is redbrown, to light gray, red, and brown medium - to coarse - grained with subrounded to subangular to angular quartz, chert, jasper grains and varied

amounts of muscovite. It is friable, has some cross-bedding and consists of beds ranging from fine lamina to massive beds of 2-3 feet thick.

Mudstone also comprises the Colton Formation. The mudstone is red, green, and variegated fine-grained calcerous with blocky and platy structures. It forms beds ranging from six inches to one and half feet.

Lesser amounts of limestone comprise the formation. It is white, buff, and light gray medium-to fine-grained limestone often with platy or blocky structure.

Environment of Deposition - The Colton Formation represents alternating fluvial and lacustrine environments. The fluvial deposits show floodplain and channel features. The base of the Colton (fluvial deposits)marks the drying up of the Flagstaff lake, with each lacustrine unit representing a return of lake environments of this area.

Stratigraphic Relations - The base of the Colton is at the base of the lowermost red sandstone above the Flagstaff and the top is at the base of green and yellow-green sandstone of the Green River Formation. The Flagstaff - Colton contact is easily recognized by the sharp color change from dark gray carbonaceous limestone to red sandstone and mudstone. Locally the Colton and Flagstaff are graditional, as in Rock Canyon where limestone grades into green and yellow-green sandstone in about five feet of section. This contact was not exposed in other regions of the study area.

Age - The Colton Formation is Lower Tertiary in age, probably Eocene (La Rocque, 1956, p. 141).

Green River Formation

Definition and Extent - The Green River Formation was defined by Hayden (1869, p. 191) as the Green River Shales.

In the Sanpete Valley region, the Green River Formation consists of those strata above the Colton Formation and disconformably below the Crazy Hollow Formation. It consists of mudstone and shale, limestone, and sandstone. The type section is Green River Canyon above Green River City, ~~Utah~~ Wyoming

The Green River Formation is present in the upper part of Rock Canyon, underneath the Sanpete Valley, and on Temple Hill near Manti, Utah. A row of cuestas along the east side of the valley north of Temple of Hill is composed of Green River strata.

Lithologic Character - The Green River Formation consists of interbedded mudstone, shale, limestone and sandstone.

The most abundant rock type is mudstone, which with shale comprises about 50% of the formation. The mudstone is green-gray, green, darkgray, fine-grained, micaceous, with blocky structure. In Rock Canyon mudstone is in alternating sequences with different colored mudstone and other rock types of the formation. On White Hill mudstone forms beds ranging from 2 inches to 3 feet thick.

The sandstone is composed of medium-grained to fine-grained yellow and light green-gray well-sorted subrounded quartz, chert, and jasper grains. The beds range from three to ten centimeters in thickness; some show cross bedding. Calcerous cement is common. Sandstone comprises about 20% of the formation.

The limestone in the Green River is creamy white to buff medium fine-grained micritic rock. Locally it contains angular quartz grains. Some beds contain gastropods and pelecypod fossils. Weathering results in a very bleached white limestone. On Temple Hill an oolitic limestone bed about three feet thick is exposed. Three tuff beds and silicified limestone beds crop out on Temple Hill also.

The shales of the formation grade into and are interbedded with mudstone and are similiar in color to the mudstone.

Environment of Deposition - The Green River Formation was deposited in a lacustrine environment. The interbedding of the rock types indicates that the shoreline and water depth must have been ever-changing. The fossils are gastropods and pelecypods, which show a lacustrine environment. Hayden (1869, p. 192) regarded the formation as entirely fresh water deposits.

Stratigraphic Relations - The Green River Formation is overlain disconformably by the Crazy Hollow Formation. This contact lies between different facies at different places but the Crazy Hollow is characterized by anabundance of black chert grains.

The lower contact is placed at the top of the uppermost red bed of the Colton and below the lowermost greenish sandstone of the Green River.

Age and Correlation - The Green River is assigned a Tertiary Age.

Crazy Hollow Formation

Definition and Extent - The Crazy Hollow Formation was defined as those strata present above the Green River Formation in the Sanpete Valley area (Spieker, 1949, p. 36) The type section is in Crazy Hollow, east of Salina, Utah.

The contact is between Green River mudstone or limestone and cherty sandstone of the Crazy Hollow. The Crazy Hollow lies disconformably on the Green River Formation.

The Crazy Hollow is exposed near the head of Rock Canyon; On Temple Hill near Manti, Utah; and on the valley floor of Sanpete Valley.

Lithologic Character - The Crazy Hollow Formation contains sandstone, red mudstone, and conglomerate. The sandstons is coarse-grained and brown-gray, and is composed of subrounded to subangular quartz, jasper, and diagnostic black chert grains. It is friable and compositionally and texturally mature with large-scale festoon bedding . The cementing agent is calcarous. calcareous

On Temple Hill the formation consists of conglomerates with large pebbles in a sand matrix.

Environment and Deposition - The Crazy Hollow Formation is a fluvial sandstone that lies on the Green River. The formation outlines the stream beds (and banks) that were cut into the pre-existing Green River sediments.

Stratigraphic Relations - The Crazy Hollow is disconformable with the Green River. The contact is sharp and is marked by the change from limestone to sandstone with black chert. In the study area the Crazy Hollow is the youngest bedrock formation.

Age and Correlation - The Crazy Hollow Formation is probably Eocene age, maybe late Eocene (Spieker, 1949, p.36). This is based solely on physical evidence as no fossils have been found. Correlation can not be safely made with post-Green River strata outside the study area.

Structure

Folds - The oldest fold in the study area is the Sanpete-Sevier Valley Anticline, which involves pre-Price River beds. The east limb of this anticline is well exposed on the western flank of the Wasatch Plateau in Sixmile Canyon where the Indianola Group, dipping east, lies in angular unconformity beneath the Price River, which dips east also. This angular unconformity is not exposed on the western flank of the Sanpete Valley, but the Morrison(?) and Sanpete Formation do outcrop in near vertical beds with the top to the west. This structure is a fan-shaped anticline originating post-

Indianola - pre-Price River.

The sediments of subsequent formations did not extend over this anticline evidenced by the beds being truncated. (The North Horn and Price River Formations in Sixmile Canyon, dipping 20°E are truncated by the Flagstaff Formation.) On the west side of the valley the North Horn directly overlies the Sanpete Formation in angular unconformity. The North Horn beds are gently dipping west above the Sanpete Formation, dipping 63°E. The thickness of the North Horn Formation is not uniform across the valley, which further suggests that the formation did not extend across the anticline.

The west limb of the anticline can also be seen near Wales, where the structural relief was not as great as at Sixmile Canyon. The anticline in the north is not as fan-shaped as it was in the south with the eastern limb being right side up and the western limb overturned.

Following the structure to the west into the Gunnison Plateau the pre-Price River beds form a broad shallow syncline, the western limb exposed in the center of the plateau, dipping east. The east limb of this anticline is truncated and overlain by Price River.

In the Wasatch Plateau, pre-Price River beds are nearly horizontal.

In the northern part of Sanpete Valley the Post-Indianola beds have been folded. This is most evident at Wales Cap where the Price River forms a long reef with the beds over-

turned to the east. The beds of the overlying North Horn quickly start to flatten to the west. The Flagstaff above the North Horn dips 22° West and shows slight sign of folding, unlike the Price River. This may indicate the Flagstaff in the north was deposited continously across the pre-existing anti-cline.

A large monocline, the Wasatch Monocline, forms the western flank of the Wasatch Plateau in Sanpete Valley. Beds as young as the Crazy Hollow are involved, which dates this folding at post-Crazy Hollow. The beds on the monocline in the study area strikes N.35 E and dip 35° W. The cuestas along the eastern margin of Sanpete Valley, consisting of Green River strata dipping 8°W, were formally connected to formerly the monocline and have been subsequently isolated by erosion.

Faults - The oldest faults in the study area are in Rock Canyon and Dry Canyon. These faults bound a graben visible from the highway, between the north wall of Rock Canyon and the south wall of Dry Canyon. The evidence for the fault in Rock Canyon is discontinous beds and nearby fracture zones with calcite veins in the lower Flagstaff. This fault can be traced from inside the mouth of Rock Canyon on the north wall, westward, down and across the bottom of the canyon, then up the south side where it becomes poorly exposed. The fault on the south side of the graben block, which the displacement along it can be seen from the highway, is on the south wall of Dry Canyon.

The North Horn Formation in the graben block is about 30 feet thick while on either side of the graben the formation is about 1,500 feet thick (Spieker, 1949, p. 26). This indicates two things: 1. the fault must have been active pre-/or during North Horn time and continued to be active until post-Colton, and 2. the block must have been a horst, at least during North Horn time. This means there was a reversal of movements on these faults (Spieker, 1949, p. 74-75).

The next period of faulting in the study area occurred in the canyons south of Wales Gap. These faults are thrust faults, dipping about 60°E along which older rocks overlie younger rocks. These faults are most likely to be concurrent with the post - North Horn folding, trending north south. In Wales Gap the compressional forces folded the beds and the structure of the Price River reef. South of Wales Gap, in Coal Canyon to Pete's Canyon, these forces were the cause of the north-south trending thrust faults. The earliest of these is probably the east ernmost; then continued compression caused more parallel faulting, advancing in the direction of the compressional forces, west. The western faults have less displacement.

The evidence for these faults is the repeating stratigraphic sequence in the area and beds, all dipping east, right side-up alternating with overturned beds. The latter evidence may show broken folds, the folding being caused by the same compressive forces as caused the faulting. The repeat-

ing stratigraphic sequence involves older rocks overlying younger rocks; specifically the Twist Gulch Formation above the Morrison(?) Formation. The western most thrust fault plane has Price River below and Morrison(?) and Twist Gulch above.

These folds and faults are post-North Horn and possibly post-Flagstaff. The basal North Horn in Wales Gap is folded and forms a syncline to the west of the Price River reef.

The youngest faults are in Sixmile Canyon and on the western margin of Sanpete Valley. In Sixmile Canyon the Wasatch Monocline is well-exposed in cross-section. Antithetic faults in the monocline are most likely contemporaneous with the monoclinal folding, which is post-Green River. These faults displace Flagstaff and Indianola strata.

The faults are vertical or dip 60° E and strike N35E, parallel to the monocline. A major fault along the east base of the Gunnison Plateau extends for the full length of the plateau along which the displacement between the plateau and valley has occurred. This fault is a gravity fault dipping about 60° E. It is covered by alluvium in the valley floor. A pediment scarp near the road into Wales Canyon might be evidence of this major fault, or possibly a minor fault associated with the major fault.

Unconformities - Most of the unconformities in the study area are angular unconformities. They mark periods of uplift and subsequent erosion.

The oldest unconformity lies between the Indianola and the Price River Formations in Sixmile Canyon. The uplift at

that time was the Sanpete-Sevier Valley anticline to the west. The Indianola beds are truncated by the Price River. On the east side of the Wasatch Plateau these beds are conformable, making the angular unconformity local.

This angular unconformity is also exposed at Wales Gap. The Indianola beds overturned and dipping 55° East, are in contact with Price River, overturned and dipping 81° E.

In the Rock Canyon Graben of the Gunnison Plateau the angular unconformity cuts down into the Twist Gulch Formation. Differiential erosion before the deposition of the Price River is the cause of this uneven erosional surface.

If the Price River beds were rotated back to horizontal, the Indianola beds would dip 30° W, which must have been their dip at the time of deposition of the Price River Formation.

The next younger unconformity lies between the North Horn and the Flagstaff Formations. This is a local angular unconformity exposed only in Sixmile Canyon. Post-North Horn uplift occurred followed by erosion. The Flagstaff limestone truncates beds of the Price River and North Horn, and locally rests on beds of the upper part of the Sixmile Canyon Formation. The beds directly under the unconformity dip at angles ranging from 35°E to about vertical and the overlying Flagstaff dips at 8°E. Within a short distance these beds become conformable.

The youngest unconformity is a disconformity between the lacustrine Green River Formation and the fluvial channel

deposits of Crazy Hollow Formation.

Geologic History

The oldest bedrock exposed in this region is the Upper Jurassic Arapien Shale, which was deposited in shallow marine water. It consists of shale, limestone, sandstone, salt, and gypsum. The marine Twist Gulch consists of sandstone, mudstone and gypsum. Deposition of the Morrison(?) Formation in fluvial channel and floodplain environments followed. In Late Late Jurassic time, the area was receiving fluvial sediments, probably from the west, that were coarse conglomerates becoming finer and increasingly texturally mature to the east.

The oldest Cretaceaus rocks are the marine sandstone, shale, and conglomerate of the Indianola Group. Evidence for marine origin of this unit increases to the east in the Wasatch Plateau, the shore line must have been the western margin of Sanpete Valley or directly west of it. The coarse conglomerate suggest a highland source nearby to the west.

A period of folding and subsequent erosion ensued. This is represented by the angular unconformity between the Price River Formation and Indianola Group and marks the beginning of the Sanpete-Sevier Valley anticline. The highland source for the Price River was probably the same for the preceding Indianola (Spieker, 1946, p.144). Erosion at this time exposed

older rocks, including Arapien and produced a stratigraphically uneven surface upon which the Price River was deposited. Fluvial environments, channels, and shifting floodplain, existed during North Horn Time.

The Cretaceous - Tertiary boundary is thought to be in the upper strata of the North Horn Formation; based on fossils (La Rocque 1956, p.141).

Lacustrine environments were dominant at the beginning of the Tertiary Period. To the south, folding and uplift of the Sanpete - Sevier Valley anticline occurred, resulting in the local angular unconformity between North and Price River Formations and Flagstaff Formation.

Fluvial and lacustrine environments alternated throughout the Poleocene and Eocene, ending with the deposition of the Crazy Hollow Formation disconformably.

Post - Crazy Hollow the pre - Colton beds in the Gunnison Plateau were folded into a shallow syncline trending north - south. The thrust faults exposed along the eastern flank of the Gunnison Plateau must also be dated to this time. Both of these events must have occurred before the major uplift of the Gunnison Plateau in order for any compressional forces to be transmitted by the bedrock thereby affecting the rocks in this region. It is not known whether these events are contemporneous and caused by the same forces but this seems possible. It would involve deep thrust faulting concurrent with folding closer to the surface.

Subsequent to these events the Gunnison and Wasatch were uplifted. It is not known for certain if this happened concurrently but this is plausible.

The Wasatch Monocline on the western flank of the Wasatch Plateau was folded with the uplift of the Wasatch Plateau.

Periods of uplift of the Gunnison Plateau are evident by the various levels of pediment surfaces and the pediment scarp at Wales Gap. It is difficult to precisely date these events but they must be post-Crazy Hollow.

The present day topography is a result of subsequent erosion and deposition of alluvium in streams channels and in the valley.

REFERENCES

1. Billings, M.P., 1933, Thrusting younger rocks over older, Am. Jour. Sci., 5th ser., vol. 25, pp. 153-155.

2. Cobban, W.A., and Reeside, J.B., Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States, Geol. Soc. America, Bull., vol. 63, pp. 1011-1044.

3. Gilliland, W.N., 1951, Geology of the Gunnison quadrangle, Utah, Univ. Nebraska Studies, new ser., no. 8, 101pp.

4. -----, 1963, Sanpete - Sevier Valley anticline of Central Utah, Geol. Soc. Amer., Bull., vol. 74, no. 2, pp. 115-124.

5. Gilluly, J. and Reeside, J. B., Jr., 1928, Sedimentary Rocks of the San Rafael Swell and some adjacent areas in eastern Utah, U.S. Geol. Survey, Prof. Paper 150, pp. 81, 91-92.

6. Hardy, C. T., and Zeller, H.D., 1953, Geology of the west-central part of the Gunnison Plateau, Utah, Geol. Soc. America, Bull., vol. 64, pp. 1261-1278.

7. Hayden, F. V., 1869, U.S. Geol. Survey Terr., 3rd Ann. Rpt., 155 pp.

8. Imlay, R. W., 1952, Correlation of the Jurassic formations of North America, exclusive of Canada, Geol. Soc. Amer., Bull., vol. 63, pp. 953-993.

9. La Rocque, Aurele, 1956, Tertiary mollusks of central Utah, Intermt. Assoc. Petrol. Geol., Guidebook 7th Ann. Fld. Conf., pp. 140-145.

10. Schoff, S. L., 1951, Geology of the Cedar Hills, Utah, Geol. Soc. America, Bull., vol. 62, pp. 619-646.

11. Spieker, E. M., 1946, Late Mesozoic and Early Cenozoic history of central Utah, U. S. Geol. Survey, Prof. Paper, 205-D, pp. 117-161.

12. -----, and Reeside, J. B., Jr., 1925, Cretaceous and Tertiary formations of the Wasatch Plateau, Utah, Geol. Soc. America, Bull., vol. 36, pp. 435-454.

13. Stokes, W. L., Peterson, J.A., and Picard, M.D., 1955, Correlation of Mesozoic formations of Utah, Bull. Amer. Assoc. Petrol. Geol., vol. 39, pp. 2003-2019