

**THE GEOLOGY OF THE SKINNER PEAKS QUADRANGLE,
JUAB AND SANPETE COUNTIES, UTAH**

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By

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TABLE OF CONTENTS

LIST OF PLATES, FIGURES, AND TABLES.....	v
ABSTRACTix
ACKNOWLEDGEMENTSxi
INTRODUCTION	1
Study Area.....	1
Objectives	1
Previous Work.....	4
Method of Study.....	5
STRATIGRAPHY.....	6
General Statement.....	6
JURASSIC SYSTEM.....	6
Arapien Shale	6
Definition	9
Distribution.....	11
Lithology and Stratigraphic Relationships	11
Thickness.....	16
Age and Correlation	20
CRETACEOUS-TERTIARY SYSTEMS	21
North Horn Formation.....	26
Definition	26
Distribution.....	28
Lithology and Stratigraphic Relationships	28
Thickness.....	31
Age and Correlation	31
TERTIARY SYSTEM.....	32

Flagstaff Limestone.....	32
Definition	32
Distribution.....	34
Lithology and Stratigraphic Relationships	35
Thickness.....	38
Age and Correlation.....	39
Colton Formation	39
Definition	40
Distribution.....	40
Lithology and Stratigraphic Relationships	41
Thickness.....	44
Age and Correlation	44
Green River Formation.....	44
Definition	45
Distribution.....	46
Lithology and Stratigraphic Relationships	46
Thickness.....	51
TAWNY FACIES	52
Age and Correlation	58
Interpretation of the Stratigraphy of Skinner Peaks	59
Description of Units.....	59
Interpretation of Units	63
Goldens Ranch Formation	66
Definition	66
Distribution.....	67

Lithology, Stratigraphic Relationships and Thickness.....	67
Age and Correlation	79
TERTIARY-QUATERNARY SYSTEMS.....	81
Older Alluvial Fans and Pediment Alluvium.....	81
QUATERNARY SYSTEM	86
Older Coalescing Alluvial Fans.....	86
Lake Bonneville Sediments.....	87
Younger Coalescing Alluvial Fans.....	93
Colluvium, Alluvium, and Landslide Deposits	94
IGNEOUS INTRUSIONS	95
STRUCTURAL GEOLOGY	98
Introduction.....	98
SEVIER OROGENY	99
DEVELOPMENT OF THE GUNNISON PLATEAU.....	105
BASIN AND RANGE EXTENSION	107
DIAPIRISM OF THE ARAPIEN SHALE	109
ECONOMIC GEOLOGY	113
GEOLOGIC HAZARDS.....	115
GEOLOGIC HISTORY AND INTERPRETATIONS	116
REFERENCES CITED	119
APPENDIX.....	131

LIST OF PLATES, FIGURES, AND TABLES

PLATE

- | | |
|---|--------|
| 1. Geologic map of the Skinner Peaks quadrangle | pocket |
| 2. Cross-section A-A'..... | pocket |

FIGURE

- | | |
|---|----|
| 1. Map showing the location of the Skinner Peaks quadrangle..... | 2 |
| 2. Map of major physiographic features in central Utah..... | 3 |
| 3. Simplified stratigraphic column for the Skinner Peaks quadrangle..... | 7 |
| 4. Paleogeographic map of Utah showing the extent of the Jurassic sea..... | 8 |
| 5. Index map showing outcrops of the Arapien Shale in central Utah..... | 12 |
| 6. Current ripple marks in calcareous sandstone of unit C of the Arapien Shale..... | 14 |
| 7. Typical outcrop of grayish-green and red mudstone of the Arapien Shale..... | 15 |
| 8. Unconformity between the Arapien Shale and the overlying Green River Formation | 17 |
| 9. Index map of central Utah showing the locations of wells drilled in or adjacent to the Skinner Peaks quadrangle..... | 18 |
| 10. Unconformity between the Arapien Shale and overlying Cretaceous-Tertiary strata..... | 19 |
| 11. Correlation chart for the Jurassic of central Utah..... | 22 |

12. Paleogeographic map showing the Sevier Highland and corresponding foreland basin.....	23
13. Stratigraphic column of formations that represent foreland basin sediments in the vicinity of the Skinner Peaks quadrangle.....	25
14. Quartzite and carbonate clasts in poorly-sorted conglomerate of North Horn Formation	29
15. Paleogeographic map showing the relative locations and extents of Lake Flagstaff and Lake Uinta.....	33
16. Flagstaff, Colton, and Green River Formations	36
17. Cross-bedded sandstone in the Flagstaff Limestone.....	37
18. Quartzite and carbonate clasts in conglomerate of the Colton Formation.....	43
19. Stromatolitic limestone in the mudstone facies of the Green River Formation	47
20. Yellowish-gray, poorly-sorted, conglomeratic sandstone in the clastic facies of the Green River Formation.....	48
21. Platy micrite beds in the mudstone-micrite facies of the Green River Formation	50
22. Red and green mudstone and yellowish-tan sandstone, limestone, and conglomeratic sandstone of the Tawny Facies of the Green River Formation	54
23. Vertebrate fossils in coarse-grained, quartz sandstone of the Tawny Facies of the Green River Formation.....	55
24. Oncolitic limestone in North Horn or Flagstaff strata.....	61

25. Stratigraphic column of the Goldens Ranch Formation in the Skinner Peaks quadrangle.....	69
26. Units I-IV (Tvg1-4) of the Goldens Ranch Formation.....	70
27. Outcrop of epiclastic conglomeratic sandstone of Unit I of the Goldens Ranch Formation.....	72
28. Handsample of the crystal vitric tuff of Unit II of the Goldens Ranch Formation.....	74
29. Typical outcrop of the epiclastic sandstone of Unit III.....	75
30. Flattened pumice in vitric lithic tuff.....	77
31. A typical outcrop of Hall Canyon Conglomerate.....	78
32. Remnants of an old alluvial fan.....	83
33. Poorly-sorted, unconsolidated material of an old alluvial fan.....	84
34. Map showing the extent of Lake Bonneville during the Bonneville Stage.....	89
35. A: Soft-sediment deformation structures in basal Lake Bonneville sediments.....	92
B: Lamination and ripple cross-lamination in basal Lake Bonneville sediments.....	92
36. A landslide in the Green River Formation.....	96
37. A: Cross-section from the West Hills to the Gunnison Plateau.....	100
B: Cross-section from Juab Valley to the Wasatch Plateau.....	101
38. Green River Formation strata offset by a high-angle fault.....	112

TABLES

1. Former terminology and revisions in stratigraphic nomenclature of the Middle Jurassic Arapien Shale.....	10
2. Wells drilled in the vicinity of the Skinner Peaks quadrangle.....	27
3. Thickness variations of the North Horn and Flagstaff Formations.....	65

ABSTRACT

The geology of the Skinner Peaks 7.5 minute quadrangle has been mapped at a scale of 1:24,000. The quadrangle is located in central Utah, just west of the leading edge of the Sevier fold-and-thrust belt, and in the transition zone between the Colorado Plateau and the Basin and Range. The stratigraphy and structure of the quadrangle reflect several tectonic events, including the Sevier Orogeny, monoclinal warping, and Basin and Range extension. Local diapiric movement of the Arapien Shale, which probably was initiated by these major tectonic events, further modified the structure and affected the stratigraphy.

Exposed bedrock units in the quadrangle include sedimentary, pyroclastic, and intrusive rocks that range in age from Middle Jurassic to Late Oligocene. An unconformity separates Middle Jurassic marine strata of the Arapien Shale from the overlying Cretaceous-Tertiary strata. These Cretaceous-Tertiary strata include, in ascending stratigraphic order, the North Horn, Flagstaff, Colton, Green River, and Goldens Ranch Formations.

Strata of the North Horn, Flagstaff, and Colton Formations represent the alluvial fan/plain, lacustrine, and alluvial plain/fluvial conditions that dominated the Sevier foreland basin from the Latest Cretaceous through Early Eocene. Eocene Green River strata record inundation of the basin by Lake Uinta, and the volcaniclastic Goldens Ranch Formation is representative of the widespread volcanism that was occurring throughout Utah during the Oligocene. Two small igneous intrusions also were mapped as

were unconsolidated surficial lacustrine, fluvial, colluvial, alluvial fan, and landslide deposits ranging in age from Late Tertiary to Recent.

Major structures in the quadrangle are West Gunnison monocline, the Juab Valley graben, the Sage Valley Fault, the Western Juab Valley Fault Zone, the Wasatch Fault Zone, and Flat Canyon graben.

Economic deposits include sand and gravel, gypsum, tuff, carbonate rock, manganese, and water. Earthquakes, mass movements, karst development, and groundwater contamination are potential geologic hazards in the Skinner Peaks quadrangle.

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INTRODUCTION

Study Area

The Skinner Peaks 7.5 minute quadrangle is located approximately 100 miles south of Salt Lake City (Figure 1) in Juab and Sanpete Counties, central Utah (Plate 1). The quadrangle extends from $39^{\circ} 22' 30''$ to $39^{\circ} 30'$ North Latitude, and from $111^{\circ} 52' 30''$ to 112° West Longitude. It lies in the transition zone between the Colorado Plateau and Basin and Range Provinces (Figure 1); the Colorado Plateau Province is represented by the Gunnison Plateau (Figure 2), which terminates just east of Utah Highway 28 (Plate 1). In addition to the Gunnison Plateau, the Skinner Peaks quadrangle also includes the southern end of the West Hills, Mills Gap, the South Hills, and part of Juab Valley (Figure 2, Plate 1). Total relief in the quadrangle is approximately 1,700 feet; base elevation is 5,000 feet above sea level (Plate 1).

Objectives

The main objective of this project was to map and interpret the geology of the Skinner Peaks 7.5 minute quadrangle. Secondary objectives related to stratigraphic and structural problems within the quadrangle were:

- 1) to redefine and map in detail the stratigraphic units of the volcaniclastic Goldens Ranch Formation.
- 2) to determine whether Tawny Beds (Zeller, 1949) are a facies of the Tertiary Green River Formation or a separate formation.

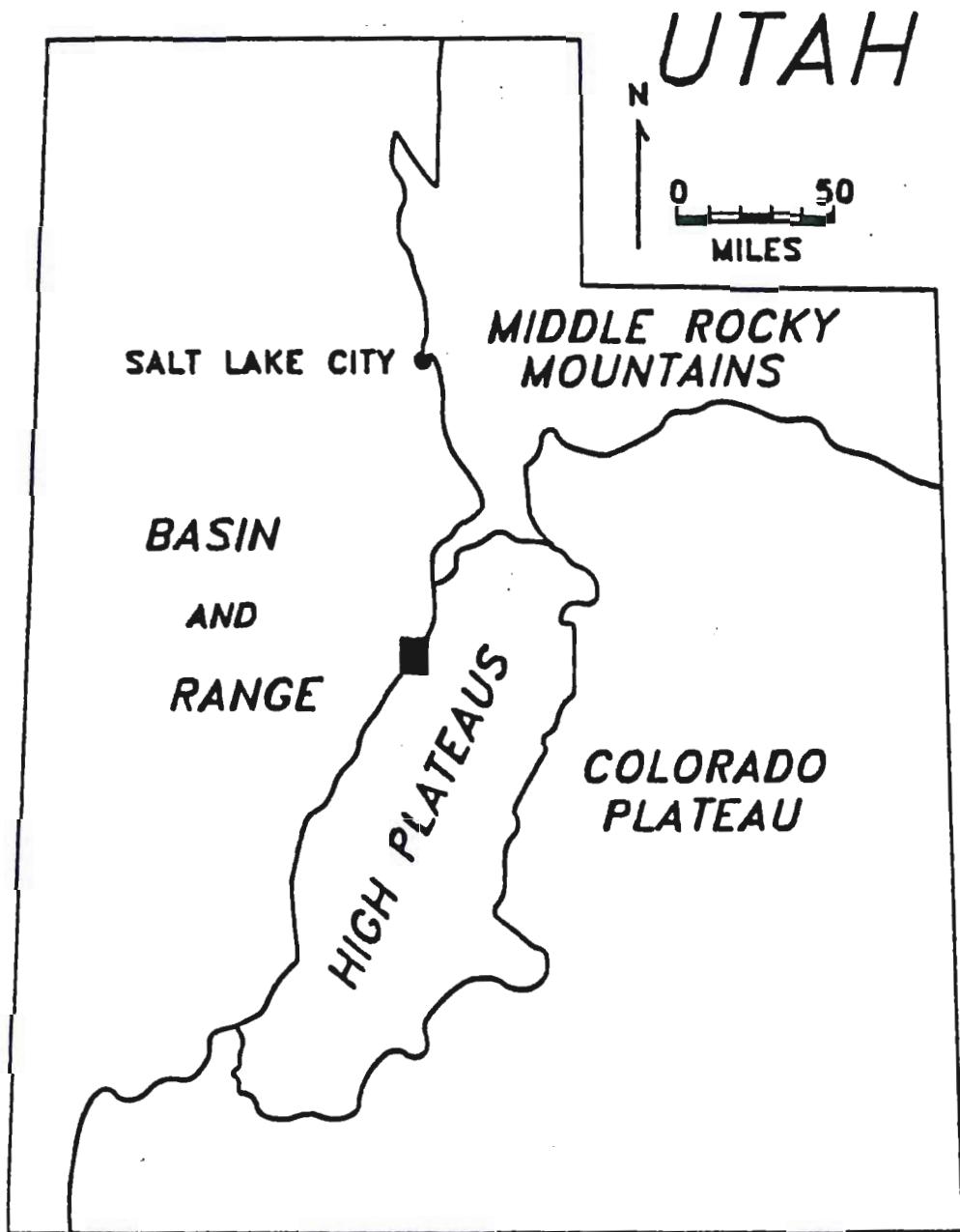


Figure 1: Map showing the location of the Skinner Peaks quadrangle (black rectangle) with respect to Salt Lake City and major physiographic provinces of Utah. (Modified from Clark, 1987.)

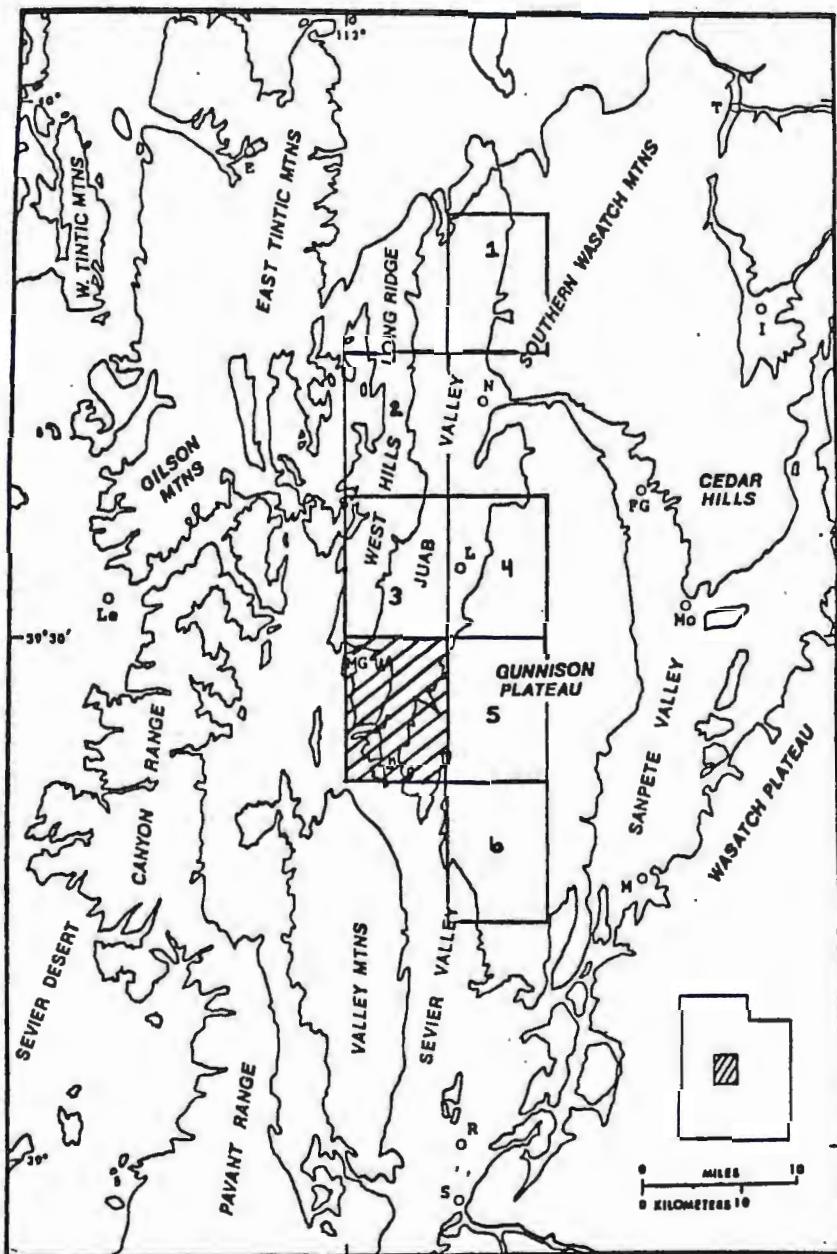


Figure 2: Map of major physiographic features in central Utah. E=Eureka, T=Thistle, I=Indianola, N=Nephi, FG=Fountain Green, L=Levan, Le=Leamington, Mo=Moroni, MG=Mills Gap, M=Manti, R=Redmond, S=Salina. The hatched rectangle is the Skinner Peaks quadrangle. Other quadrangles that are referred to throughout the manuscript are: 1=Mona quad., 2=Sugarloaf quad., 3=Juab quad., 4=Levan quad., 5=Chriss Canyon quad., 6=Hells Kitchen Canyon SE quad. (Modified from Standee, 1982.)

- 3) to map all Quaternary units and structural features.
- 4) to determine the nature of the contact between the Jurassic Arapien Shale and adjacent Tertiary units, specifically hunting for evidence of diapiric movement of the Arapien Shale.
- 5) to evaluate the economic geology and geologic hazards in the quadrangle.

Previous Work

Early investigations of the structure and stratigraphy of central Utah were conducted by E. M. Spieker (1946, 1949) and his students from Ohio State University (e.g., Zeller, 1949; Muessig, 1951; Vogel, 1957). Faculty and students from Ohio State, Brigham Young, and Northern Illinois Universities have continued to expand and modify Spieker's earlier work.

The first geologic map of the Skinner Peaks quadrangle was made by James W. Vogel of Ohio State University in 1957. Vogel mapped the geology at a scale of 1:31,680 on an imprecise planimetric base map constructed from aerial photos; no suitable topographic map of the area existed at that time. Witkind and others (1987) included the Skinner Peaks quadrangle as part of the Manti 30' x 60' quadrangle, although most of the geology that appears on the Manti Sheet was compiled from Vogel's original work. Recent mapping studies of quadrangles adjacent to the Skinner Peaks quadrangle (Figure 2) include the following:

- 1) Juab quadrangle: Clark, 1987

- 2) Levan quadrangle: Auby, 1987
- 3) Chriss Canyon quadrangle: McDermott, in prep.
- 4) Hells Kitchen Canyon SE quadrangle: Mattox, 1986

Method of Study

Field work for this project was done during the summers of 1988 and 1989. The area was traversed on foot and mapping was done on aerial photos at a scale of 1:20,000; structural data were obtained using a Brunton compass, and representative rock samples were collected for future reference. Formation contacts and structural data were transferred onto a 1:24,000 topographic map of the quadrangle, and from there onto a mylar copy of the topographic map; diazo copies of the map were then printed from the mylar.

Rock samples were re-examined in the laboratory with a binocular microscope. Thin sections of samples taken from the Goldens Ranch were stained for potassium feldspar and examined under a petrographic microscope.

Stratigraphic sections (Appendix) were measured using a Jacob's staff and a Brunton compass; the Geological Society of America Rock-Color Chart (Goddard and others, 1979) was used in making rock descriptions.

STRATIGRAPHY

General Statement

Sedimentary, pyroclastic, and igneous rocks ranging in age from Middle Jurassic to Late Oligocene are exposed in the Skinner Peaks quadrangle (Figure 3). These rocks consist of the Arapien Shale, North Horn Formation(?), Flagstaff Limestone, Colton Formation, Green River Formation, Goldens Ranch Formation, and two igneous intrusions. Unconsolidated lacustrine, fluvial, colluvial, alluvial fan, and mass-movement sediments (Figure 3) ranging in age from Late Tertiary to Recent were mapped in addition to the bedrock units.

Precambrian and Paleozoic strata are not exposed as bedrock in the quadrangle, but they are exposed in the nearby Valley Mountains, Canyon Range, and southern Wasatch Mountains (Hintze, 1975; Figure 2, this study); well data indicate these strata also underlie the study area (Standley, 1982). Although Precambrian and Paleozoic strata are not exposed in the study area, clasts of Precambrian and Paleozoic strata are prevalent in the conglomerates of the North Horn, Flagstaff, Colton, Green River, and Goldens Ranch formations, and in the various unconsolidated Tertiary-Quaternary deposits.

JURASSIC SYSTEM

Arapien Shale

A shallow arm of the sea (Figure 4) extended southward from Canada through central Utah and into northern Arizona during

SYSTEM	SERIES	FORMATION	MAP SYMBOL
QUATERNARY	MIOCENE - RECENT	SURFICIAL DEPOSITS	Qal Qls Qc Qacf1 Qdf Qacf2 Qaf QTap QTaf
		Goldens Ranch Formation	Tvg
		Green River	Ti
		Colton	Tgr
		Hornblende monzonite porphyry intrusions	Tc
		Flagstaff	Tf
		North Horn	TKnh
		Arapien Shale	Ja
		Limestone	

Figure 3: Simplified stratigraphic column for the Skinner Peaks quadrangle.

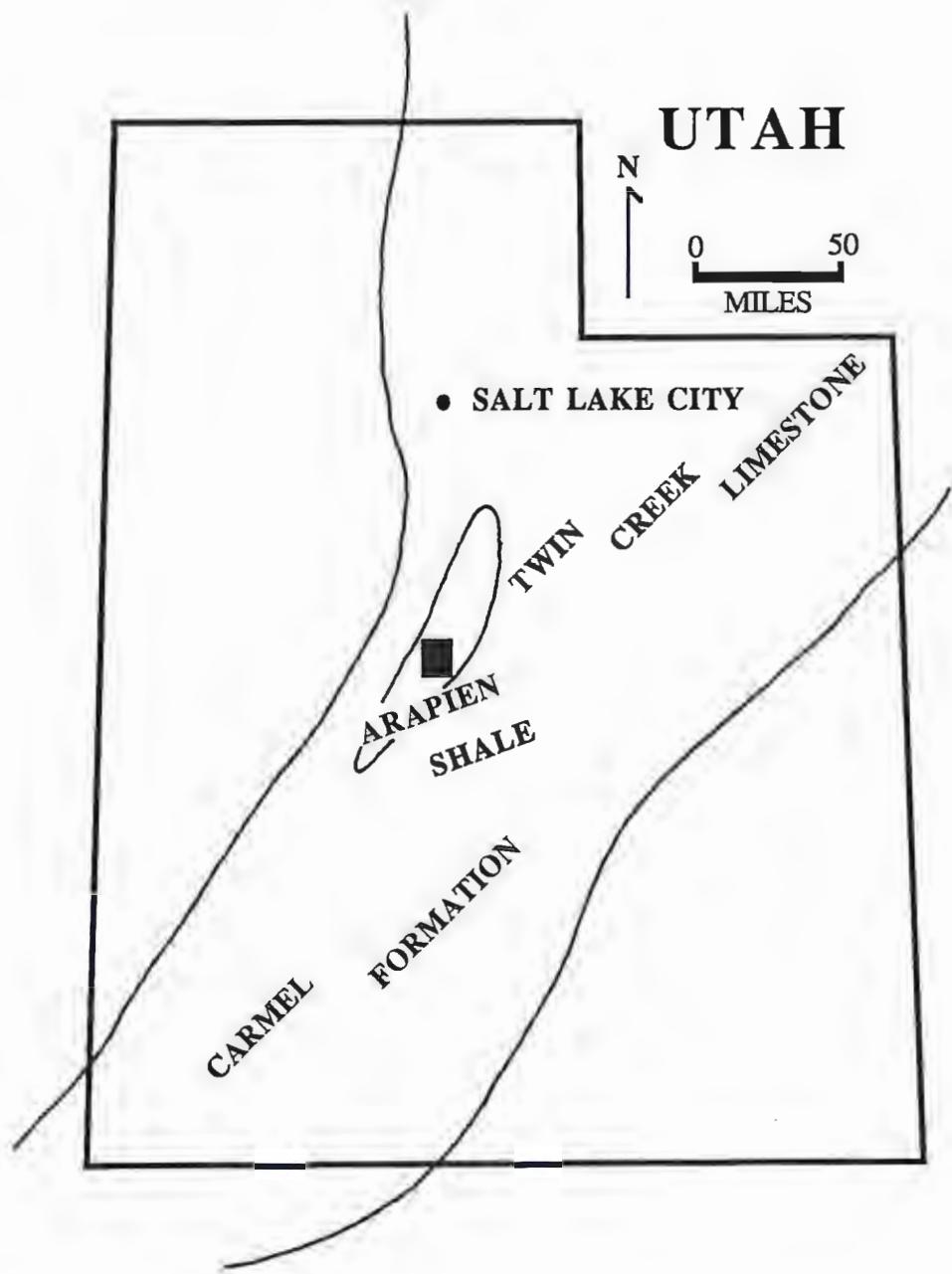


Figure 4: Paleogeographic map of Utah showing the extent of the Jurassic sea, the general areas of deposition of the Twin Creek Limestone, Arapien Shale, and Carmel Formation, and the location of the Skinner Peaks quadrangle (black rectangle). (Modified from Hintze, 1988, and Stokes, 1986.)

Middle Jurassic time (Hintze, 1988; Stokes, 1986). Thousands of feet of mudstone, siltstone, limestone, and evaporites (Hintze, 1988) that now are assigned to the Arapien Shale, Twin Creek Limestone, and Carmel Formation accumulated in the basin (Figure 4). The deepest part of the basin, referred to as the Arapien Basin, was the depocenter for more than 6,000 feet (Hintze, 1988) of Twin Creek Limestone and the evaporite-rich Arapien Shale.

Sediments assigned to the Arapien Shale accumulated when the sea retreated to the north, isolating the Arapien Basin from the main body of water (Sprinkel, per.comm., 1989); this basin provided the ideal setting for the formation of evaporites such as gypsum and salt, both of which are abundant in the Arapien.

Definition

The Arapien Shale was named by Spieker (1946) for exposures of varicolored limestone, siltstone, mudstone, and evaporites found along the east side of the Sevier Valley (Figure 2). Spieker's original classification (Table 1) separated the Arapien into five units; units 1-4 were named the Twelvemile Canyon Member, and unit 5 was named the Twist Gulch Member. In 1952, Hardy revised Spieker's (1946) classification by dividing the Arapien into units A-E. These units (excluding unit B) correspond to Spieker's units 1-4, respectively (Table 1). Hardy (1952) also suggested that Spieker's stratigraphy be modified further by restricting the term Arapien Shale to the units within the Twelvemile Canyon Member, and by elevating the Twist Gulch Member to formation status

European Stages (Imlay,1980)		Original Definition (Spieker,1946)		Proposed Revision (Hardy,1952)		Accepted (Witkind & Hardy, 1984)		
Middle Jurassic	Callovian	Middle Jurassic	Twist Gulch Member	unit 5	Twist Gulch Formation		Twist Gulch Formation	
	Bathonian		Twelvemile Canyon Member	unit 4	Arapien Shale	unit E	Arapien Shale	
				unit 3		unit D		
				unit 2		unit C		
				unit 1		unit B		
				unit A				

Table 1: Former terminology and revisions in stratigraphic nomenclature of the Middle Jurassic Arapien Shale. (From Witkind and Hardy, 1984.)

(Table 1). Spieker and Hardy planned to redefine Spieker's (1946) stratigraphy formally using the modifications suggested by Hardy (1952), but this paper was not written and both classification schemes have been used throughout the literature--a practice that has resulted in considerable confusion (Sprinkel, 1982; Witkind and Hardy, 1984; Mattox, 1986). Witkind and Hardy (1984) have attempted to rectify this problem by formally proposing that Hardy's (1952) modifications be accepted (Table 1).

Distribution

The Arapien Shale is exposed as a narrow, discontinuous band that begins approximately two miles north of Nephi and ends just east of Richfield (Figure 5). Arapien Shale also is exposed in a window through the Charleston-Nebo Thrust in the southern Wasatch Mountains, and along the west flank of the Gunnison and Wasatch Plateaus (Picard and Uygur, 1982; Figure 5, this study).

Within the present study area, the Arapien Shale is exposed east of Utah Highway 28 along the west flank of the Gunnison Plateau (Plate I). The Arapien underlies Skinner Peaks, and it also is exposed in and adjacent to Little Salt Creek Canyon (Plate I). The best exposures of Arapien Shale in the Skinner Peaks quadrangle are in Little Salt Creek Canyon.

Lithology and Stratigraphic Relationships

The Arapien Shale is composed regionally of reddish-brown to grayish-green siltstone and calcareous mudstone, grayish-green

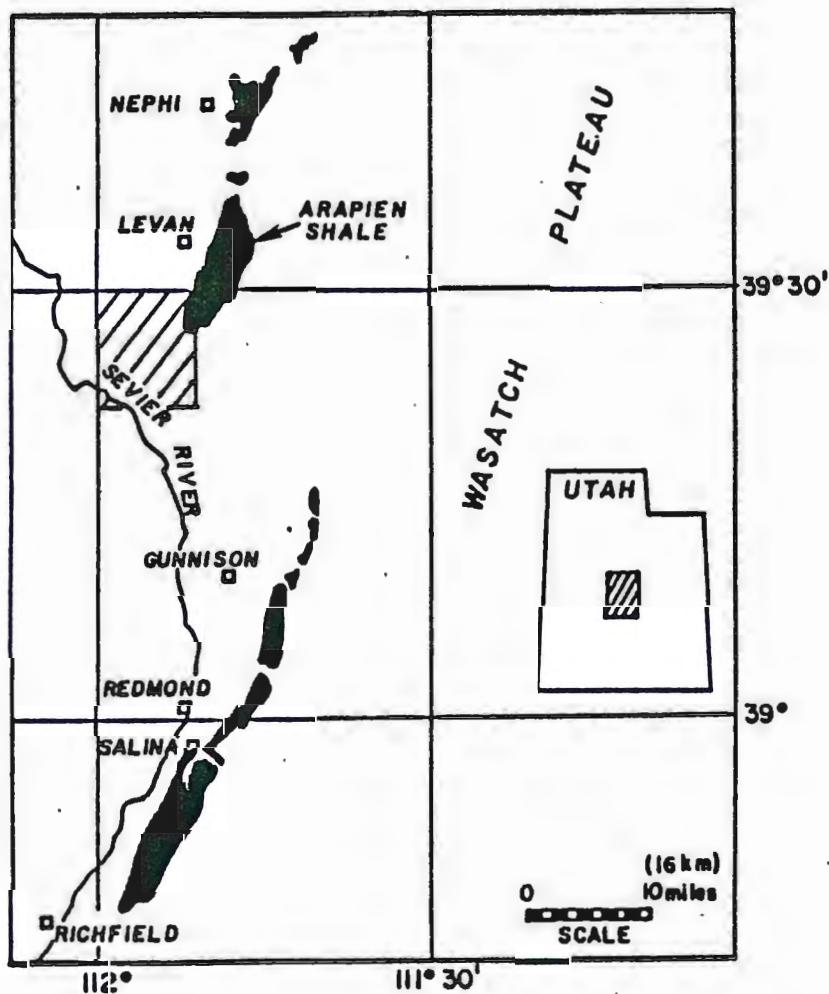


Figure 5: Index map showing outcrops of the Arapien Shale in central Utah. The Skinner Peaks quadrangle is represented by the hatched rectangle. (Modified from Picard and Uygar, 1982.)

calcareous sandstone and argillaceous limestone, and evaporites (Spieker, 1946; Sprinkel, 1982). Within the Skinner Peaks quadrangle the Arapien is composed of grayish-green, thinly-bedded limestone, micrite, and calcareous siltstone; thinly-bedded, rippled, calcareous sandstone (Figure 6), and grayish-green or red calcareous mudstone (Figure 7) with locally occurring pods of gypsum. These rock types are representative of units B and C of Hardy (1952), an interpretation that disagrees with that of Vogel (1957), who recognized units A and B, but not C. Vogel (1957) based his interpretation on a stratigraphic section (Vogel, 1957, Stratigraphic Section 1) that he measured north of Little Salt Creek Canyon. Vogel (1957, p.33) suggests that the top of unit A is present in this section; however, I was unable to reach the same conclusion due to the highly deformed (folded and faulted) nature of the strata in this section.

Vogel (1957) did not recognize unit C within the quadrangle; however, thinly-bedded siltstone, shale, and rippled sandstone (Figure 6) matching the description of unit C occurs in both the Little Salt Creek Canyon and Skinner Peaks vicinity (Plate 1). These beds locally contain fossils tentatively identified as *Ostrea* sp., an observation that is congruent with that of Zeller (1949, p.19), who noted the occurrence of *Ostrea* sp. in unit C sandstone in upper Little Salt Creek Canyon.

In outcrop the Arapien shale "...generally occurs as highly folded, contorted and faulted strata..." (Vogel, 1957, p. 32) that weather to form steep, rugged, sparsely vegetated, gray hills



Figure 6: Current ripple marks in calcareous sandstone of unit C of the Arapien Shale. Photo taken approximately 0.5 miles south of Little Salt Creek Canyon.



Figure 7: Typical outcrop of grayish-green and red mudstone of the Arapien Shale. Photo taken approximately 0.25 miles west of the north end of Skinner Peaks. (Photo courtesy of S. R. Mattox.)

(Figure 8). Most of the units within the Arapien weather into small chips or thin plates (Figure 7); ledges occur locally where more resistant sandstone or siltstone is present.

Stratigraphic relationships between the Arapien and adjacent units are complex. The base of the formation is not exposed within or adjacent to the study area; however, data collected from drill-holes in SE Juab County (Figure 9) indicate that the Arapien is underlain conformably by the Twin Creek Limestone (Sprinkel, 1982). This relationship can be observed in outcrop in the Mona quadrangle, 15 miles NE of the Skinner Peaks quadrangle. In normal sequences the Arapien is overlain conformably by the Twist Gulch Formation; however, in the Skinner Peaks quadrangle the Arapien is most commonly overlain unconformably by the Green River Formation (Figure 8). Locally it is overlain unconformably by the North Horn Formation (Figure 10), or the Goldens Ranch Formation. These unconformable relationships are best observed immediately south of Little Salt Creek Canyon and on the Skinner Peaks themselves (Plate I).

Thickness

The thickness of the Arapien Shale varies from 3,000 to 11,000 feet throughout the area of its exposure. Spieker (1946) reported 5,000 to 7,000 feet near Salina Canyon, Hardy (1952) reported a minimum of 3,000 feet at the same locality, Eardley (1933) estimated 3,000 to 11,000 feet in Salt Creek Canyon, and Standlee (1982) reported approximately 5,000 feet in wells drilled

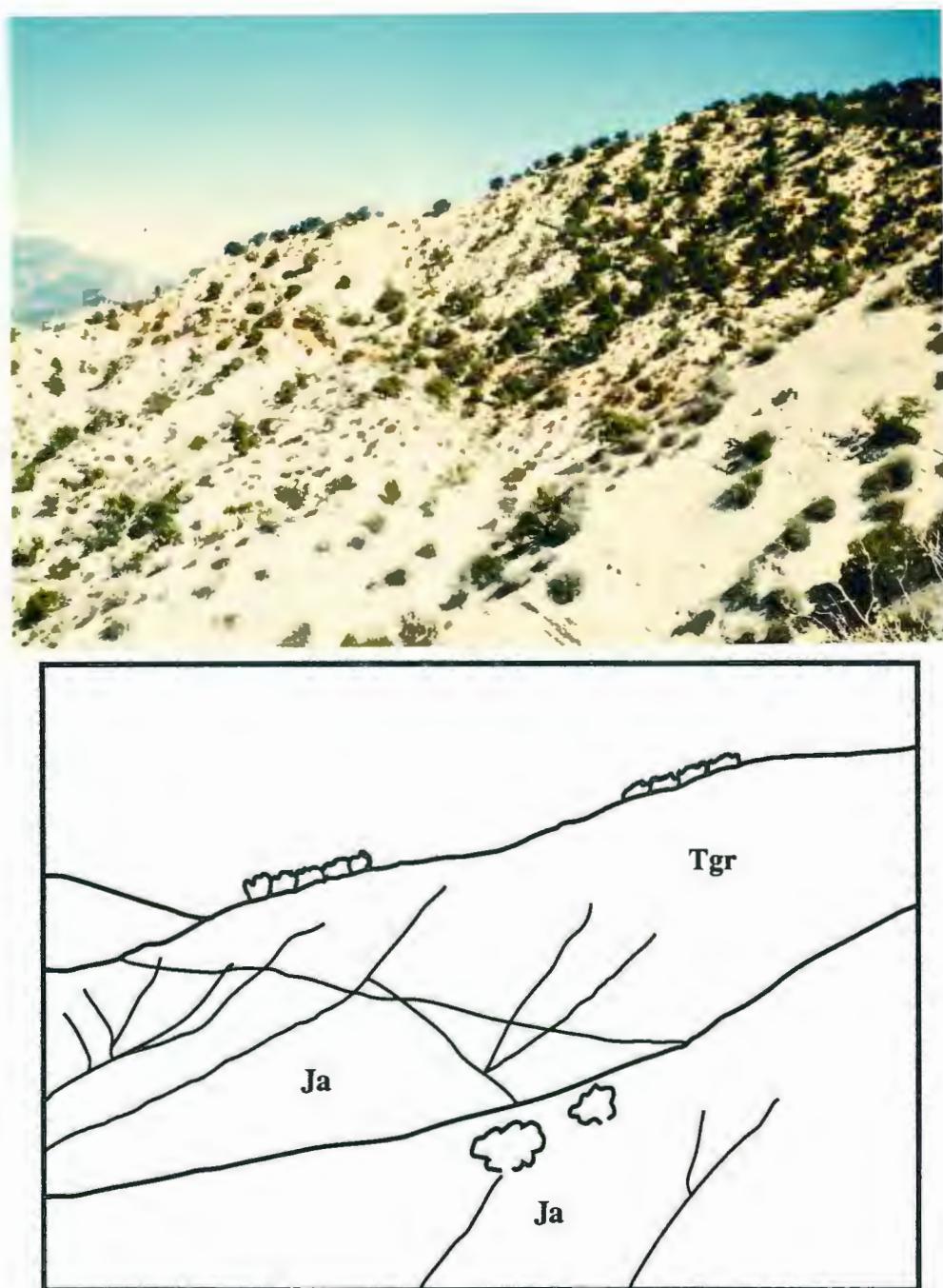


Figure 8: Unconformity between the Arapien Shale (Ja) and the overlying Green River Formation (Tgr) south of Little Salt Creek Canyon. The contact between the two units follows the base of the red zone. Note the steep, sparsely-vegetated, gray hills of the Arapien, and the Tawny color of the Green River strata.

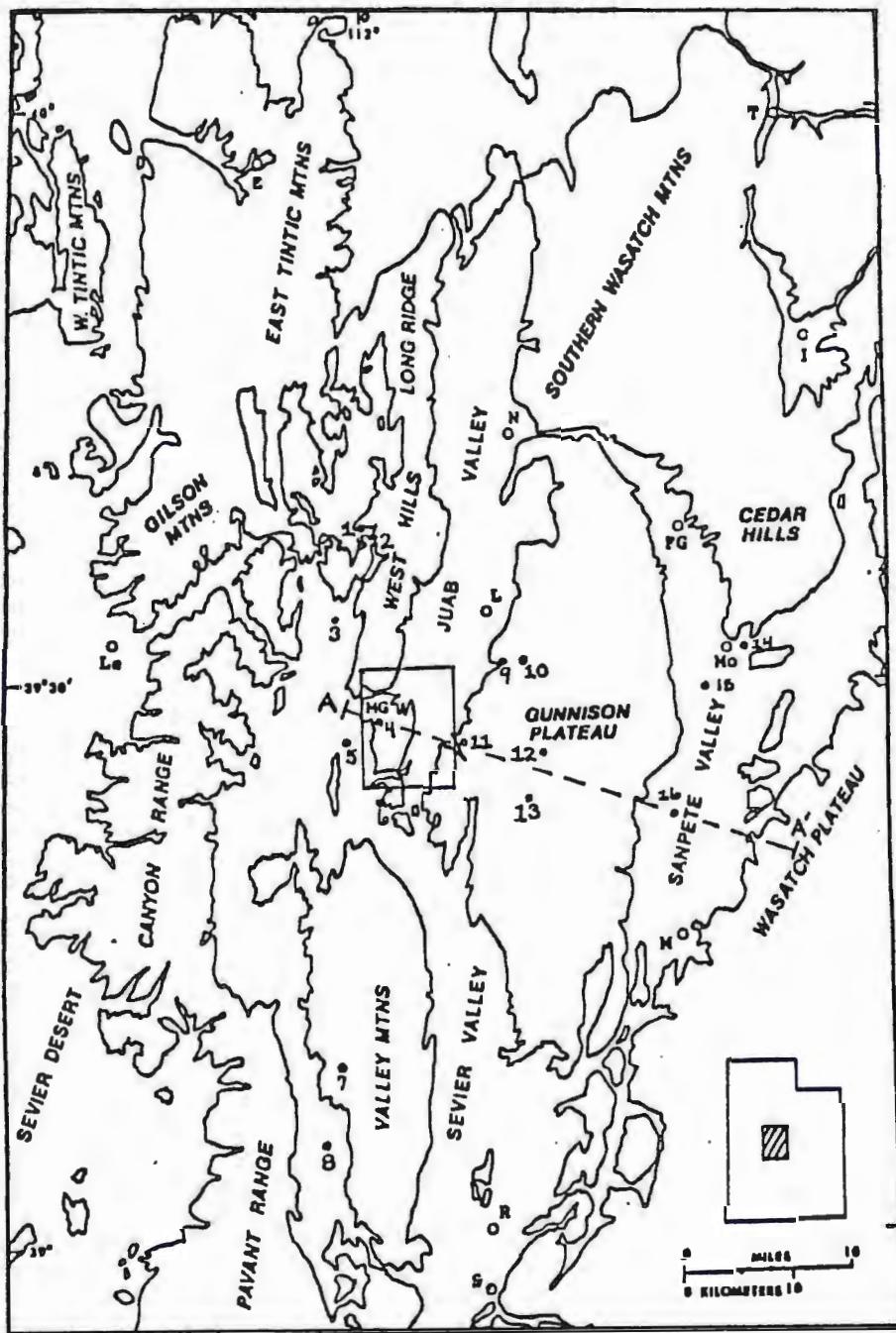


Figure 9: Index map of central Utah showing the locations of wells drilled in or adjacent to the Skinner Peaks quadrangle (rectangle). Well names and specific locations are given in Table 2. (Modified from Standlee, 1982.)

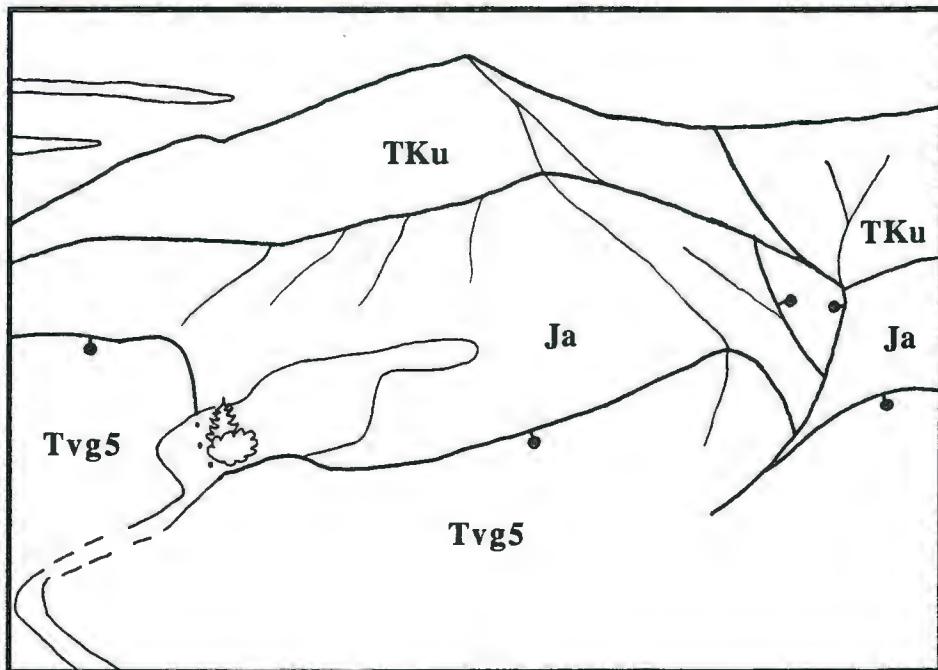


Figure 10: Unconformity between the Arapien Shale (Ja) and overlying Cretaceous-Tertiary strata (TKu) as seen on the NE side of Skinner Peaks. A fault separates the Arapien from the Goldens Ranch formation (Tvg₅). The roads in the foreground lead to a recently developed gypsum mine in the Arapien Shale.

in nearby Juab Valley (Figure 9, Table 2). Vogel (1957) measured approximately 400 feet of Arapien north of Little Salt Creek Canyon in the Skinner Peaks quadrangle. In this study a thickness of approximately 440 feet was calculated from an undeformed section of Arapien south of Little Salt Creek Canyon in section 1, T. 16 S., R. 1 W.

Determination of an accurate thickness for the Arapien has been hampered by poor exposure (Sprinkel, 1982) and the intense deformation of the strata (Sprinkel, 1982; Standlee, 1982); consequently, thickness estimates of the formation and of individual units within the formation differ according to each worker's interpretation of the structure and stratigraphy of the section in question.

Age and Correlation

The age and correlation of the Arapien Shale has been a source of controversy among workers in central Utah (Sprinkel, 1982; Picard, 1980; Standlee, 1982) because: 1) the Arapien cannot be traced directly to better-known Jurassic stratigraphy, 2) facies changes are poorly understood and, 3) the rocks generally are not fossiliferous (Standlee, 1982). These problems are compounded by intense structural deformation and poor exposure (Sprinkel, 1982; Standlee, 1982).

The accepted age of the Arapien is Middle Jurassic; more precise estimates differ with stratigraphic interpretation and regional correlation. Sprinkel (1982) correlates the Arapien with

the Leeds Creek and Giraffe Creek Members of the upper Twin Creek Limestone and the lower Preuss Sandstone to the north, and with the gypsiferous siltstone and shale unit of the upper Carmel Formation to the south and east (Figure 11). This interpretation implies a Lower Callovian age for the Arapien.

Another interpretation (Hardy 1952; Picard, 1980) is that the Arapien is correlative with the entire Twin Creek section and the lower Preuss Sandstone to the north, and with the entire Carmel Formation to the southeast (Figure 11). This interpretation suggests a Bajocian-Lower Callovian age for the Arapien. Standlee's (1982) interpretation is similar to that of Hardy (1952) and Picard (1980) except that he correlates the top of the Arapien with the top of the Preuss Sandstone--an interpretation that yields a Bajocian-Upper Callovian age for the Arapien (Figure 11).

Based on exposures in the window through the Charleston-Nebo thrust, and a discussion with Douglas A. Sprinkel of the UGMS, I accept Sprinkel's interpretation regarding the age and correlation of the Arapien.

CRETACEOUS-TERTIARY SYSTEMS

The sea that deposited the Arapien Shale had retreated by the Late Jurassic (Stokes, 1986). The Sevier Orogeny, which dominated the Cretaceous Period, may have started around this time (Armstrong, 1968). Deformation by the Sevier Orogeny produced the Sevier Highland (orogenic belt) and corresponding foreland basin (Figure 12). The Skinner Peaks quadrangle was located in the

European Stages of the Middle & Lower Jurassic	Northern Utah	Central Utah			Southern & Eastern Utah		
		Imlay (1967, 1980)	Sprinkel (1982)	Hardy (1952) Picard (1980)	Standlee (1982)		
CALLOVIAN	Preuss Sandstone	Twist Gulch Formation	Twist Gulch Formation	Arapien Shale	Entrada Sandstone Gypsiferous red siltstone and shale		
	Giraffe Creek Member	Arapien Shale	Watton Canyon Member				
	Leeds Creek Member						
	Watton Canyon Member						
BATHONIAN	Boundary Ridge Member	Twin Creek Limestone	Boundary Ridge Member	Arapien Shale	Carmel Formation Lower Carbonates		
BAJOCIAN	Rich Member	Twin Creek Limestone	Rich Member	Arapien Shale			
	Sliderock Member		Sliderock Member				
	Gypsum Spring Member		Gypsum Spring Member				
TOARCIAN	Navajo Sandstone	Navajo Sandstone	Navajo Sandstone	Navajo Sandstone	Navajo Sandstone		

Figure 11: Correlation chart for the Jurassic of central Utah.
(Modified from Sprinkel, 1982 and Standlee, 1982.)

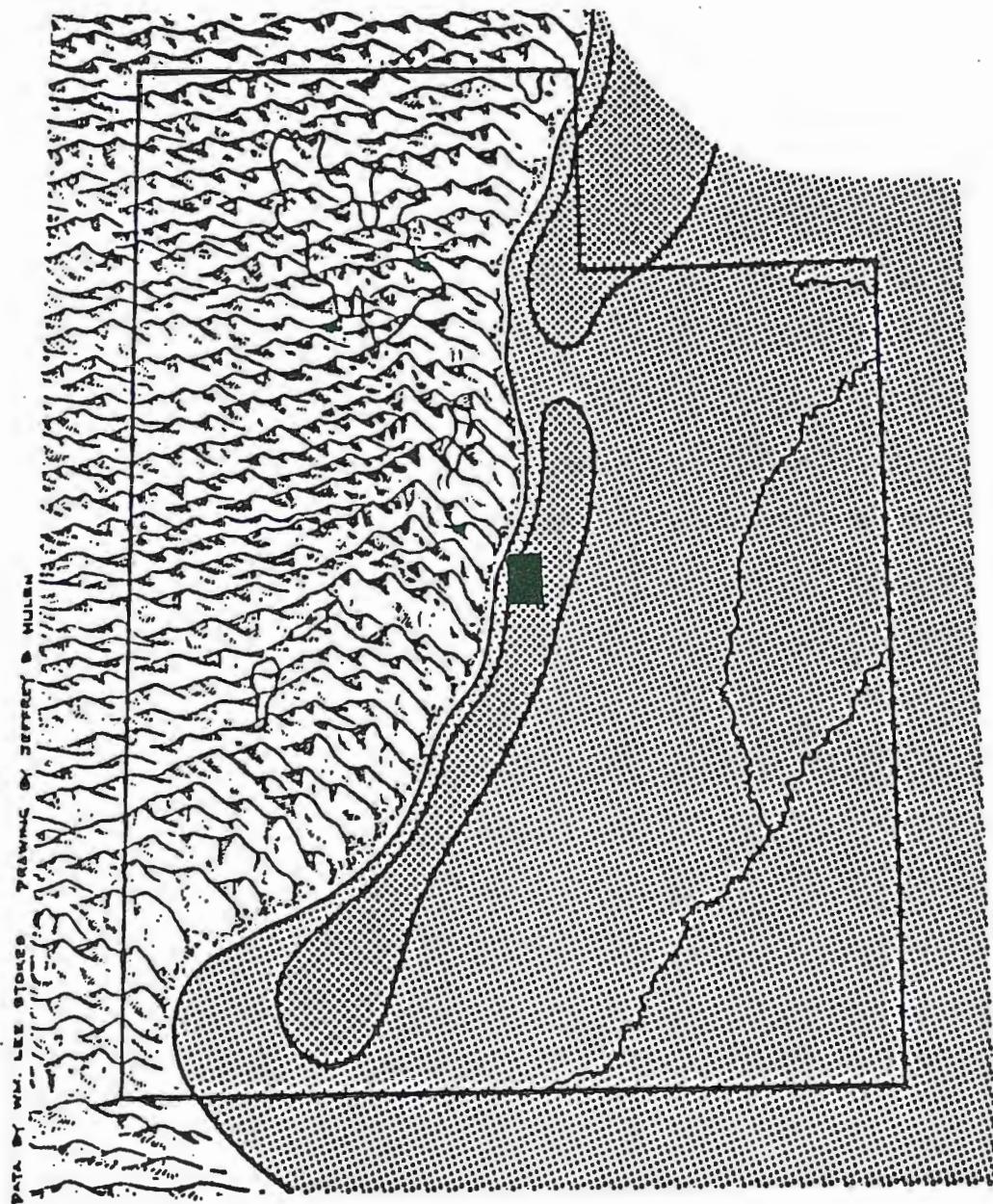


Figure 12: Paleogeographic map showing the Sevier Highland and corresponding foreland basin. The Skinner Peaks quadrangle is represented by the black rectangle. (Modified from Stokes, 1986.)

foreland basin very close to the eastern margin of the Sevier Highland (Figure 12).

The timing of the onset of thrusting and initial deposition of foreland basin sediments in central Utah is the subject of considerable debate (Schwans, 1988; Lawton, 1986). Sedimentation in the Sevier foreland basin may have occurred as early as Late Jurassic (Armstrong, 1968); it lasted into the Late Paleocene-Early Eocene (Stanley and Collinson, 1979), with most sedimentation occurring during the Late Cretaceous (Armstrong, 1968). The stratigraphy of foreland basin sequences, and the relationship of foreland basin sequences to thrust activity is discussed in Schwans (1988), Blair and Bilodeau (1988), Heller and others (1988), Jordan and others (1988), Lawton (1986), Allen and others (1986), and Wiltschko and Dorr (1983).

In central Utah, sediments were eroded from the Sevier Highland and deposited in the basin as fluvial, alluvial fan, lacustrine, and alluvial plain sediments. In the vicinity of the Skinner Peaks quadrangle, these foreland basin sediments are represented by the Cedar Mountain Formation, Indianola Group, Price River Formation, North Horn Formation, Flagstaff Limestone, and Colton Formation (Hintze, 1988; Figure 13). Within the Skinner Peaks quadrangle, only the Flagstaff, Colton, and approximately 300 feet of Cretaceous-Tertiary conglomerate are exposed.

SYSTEM	SERIES	UNIT
CRETACEOUS	EOCENE	Colton Formation
		Flagstaff Limestone
	PALEOCENE	North Horn Formation
	UPPER	Price River Formation
		Indianola Group, undivided
	LOWER	Cedar Mountain Formation

Figure 13: Stratigraphic column of formations that represent foreland basin sediments in the vicinity of the Skinner Peaks quadrangle. (Modified from Witkind and Marvin, 1989.)

North Horn Formation

Large quantities of coarse-grained, clastic sediments were eroded from the Sevier Highland during the Late Cretaceous and Early Tertiary and deposited as a series of alluvial fans in the foreland basin to the east. These alluvial fans formed a conglomerate sequence that is represented by the Indianola Group, Price River Formation, and North Horn Formation. This sequence of conglomerates is almost 10,000 feet thick on the Gunnison Plateau (Hintze, 1988). Only 300 feet of these Late Cretaceous conglomerates, tentatively identified as North Horn Formation in this study, are exposed in the Skinner Peaks quadrangle, although approximately 2,900 feet of Late Cretaceous conglomerates (including 1,700 feet of North Horn Formation) were logged in a test hole (Hole #4, Figure 9, Table 2) in the NW corner of the quadrangle (Clark, 1987).

Definition

The North Horn Formation was originally the lower member of the Wasatch Formation of Spiker and Reeside (1925); it was raised to formation status by Spiker in 1946. The North Horn Formation consists of a sequence of varicolored sandstone, conglomerate, and freshwater limestone, which was deposited in an alluvial plain environment. The type locality of the North Horn Formation is at North Horn Mountain on the southeastern Wasatch Plateau.

HOLE	NAME	LOCATION Sec.-T.-R.
1	Placid #1-A WXC-Howard	5-14S-1W
2	Placid #2 WXC-Howard	5-14S-1W
3	Placid #2 WXC-State	1-15S-2W
4	Placid #1WXC-State	36-15S-1.5W
5	Placid #13-7 Monroe	13-16S-2W
6	Placid #1 Barton	32-16S-1W
7	Placid #1-2 WXC-USA	24-19S-2W
8	Anschutz #1 Monroe Fee	14-20S-2W
9	Standard Oil of California #1 Levan Unit	17-15S-1E
10	American Quasar #16-34 Chicken Creek Federal	16-15S-1W
11	AMOCO #1 Sevier Bridge Unit	11-16S-1W
12	Dixel Resources #1 Gunnison State	15-16S-1E
13	Chevron U.S.A. #1 Chriss Canyon	33-16S-1E
14	Hanson #1-AX Moroni	14-15S-3E
15	Phillips Petroleum #1 Price "N"	29-15S-3E
17	Mobile #1 Larson Unit	1-17S-2E

Table 2: Wells drilled in the vicinity of the Skinner Peaks quadrangle. Wells are located by hole number in Figure 9. (Modified from Standee, 1982.)

Distribution

The North Horn Formation occurs extensively throughout central Utah; outcrops of North Horn strata are found on the Fishlake, Wasatch and Gunnison Plateaus, and in the Uinta Basin, Cedar Hills, Valley Mountains, Pavant Range, and West Hills (Clark, 1987; Figure 2, this study).

In the Skinner Peaks quadrangle, beds that tentatively have been identified as North Horn Formation are exposed in a narrow band on the NE side of Skinner Peaks (Plate 1). The North Horn Formation is not exposed anywhere else in the quadrangle, although it does crop out in the West Hills just north of the NW corner of the quadrangle (in the Juab quadrangle). It also occurs in the subsurface in Juab Valley (Clark, 1987).

Lithology and Stratigraphic Relationships

Outcrops of North Horn Formation in the Skinner Peaks quadrangle are composed of poorly sorted, bimictic, cliff- and ledge-forming conglomerate (Appendix, Skinner Peaks Section). Clasts are subangular to subrounded pebbles, cobbles, and boulders of purple and tan quartzite and dark blue-gray carbonate (Figure 14). Purple clasts were derived from the Precambrian Mutual Formation, and tan clasts were derived from the Cambrian Tintic Quartzite; dark blue-gray carbonates represent a variety of Paleozoic formations. Matrix is poorly-sorted, medium- to fine-grained, calcareous sandstone.



Figure 14: Quartzite and carbonate clasts in poorly-sorted conglomerate of North Horn Formation (?) on the north end of Skinner Peaks. Hammer for scale in upper right corner of photo. (Photo courtesy of S. R. Mattox.)

Clast size decreases up-section; the top of the section consists of interbedded conglomerate and sandstone. There is also an increase in the quartzite-to-carbonate clast ratio up-section; the lower part of the section has a 0% / 100% carbonate/ quartzite clast ratio, whereas the top of the section has a 75% / 25% carbonate/ quartzite clast ratio. The color of the unit also varies in an up-section direction; it is gray at the base, red in the middle, and gray at the top. The description of this section of North Horn is similar to Mattox's (1986, p. 80) description of "high escarpment and inner canyon" North Horn strata.

In most sections, especially farther east, the North Horn Formation lies conformably on top of the Price River Formation; however, in the Skinner Peaks quadrangle the North Horn Formation lies unconformably on top of the Jurassic Arapien Shale (Figure 10). One explanation for this unconformity is that Late Jurassic through Late Cretaceous sediments were deposited in the area and later removed by an erosional event. Another possible explanation is that the Arapien formed local topographic highs due to Sevier thrusting or thrusting-induced diapirism, and deposition of Late Jurassic through Late Cretaceous sediments did not occur over these highs. In a normal sequence, the North Horn Formation is overlain conformably by the Flagstaff Limestone; however, on Skinner Peaks the relationship between the North Horn Formation and the overlying strata is unclear. This relationship is discussed in the "Interpretation of the Stratigraphy of Skinner Peaks".

Thickness

The North Horn Formation, which is 1,650 feet thick at the type locality, is only approximately 300 feet thick in the Skinner Peaks quadrangle. This value is also significantly less than values reported by Clark (1987) in the Juab quadrangle to the north, and by Mattox (1986) in the Hells Kitchen Canyon SE quadrangle to the southeast (Figure 2). Clark (1987) reported 880 feet of North Horn in the West Hills. Mattox (1986) reported North Horn thicknesses of 830 feet and 330 feet; at one location the North Horn beds pinch out altogether against an Indianola paleo-high (Mattox, 1986; p. 107). The attenuated section of North Horn Formation on Skinner Peaks may be due to a paleo-high of Arapien that was present during the deposition of the North Horn.

Age and Correlation

At the type locality the age of the North Horn Formation, based on fossil evidence, is considered to be Latest Cretaceous to Paleocene (Spieker, 1946, 1949). It is unclear whether or not this is a valid age for North Horn strata west of the type locality (Spieker, 1946; Muessig, 1951). Clark (1987) and Mattox (1986) present discussions concerning the possibility of an entirely Paleocene age for the North Horn Formation west of the Wasatch Plateau; however, in lieu of conclusive evidence for a Paleocene age, Late Cretaceous to Paleocene was accepted for the age of the North Horn by Clark (1987), Mattox (1986), and also is accepted in this study.

Hintze (1988) correlates a part of the North Horn Formation with part of the Evanston Formation, Ft. Union Formation, Claron Formation, Grapevine Wash Formation, Kaiparowits Formation, Canaan Peak Formation, and the Ohio Creek Conglomerate.

TERTIARY SYSTEM

Flagstaff Limestone

In the Early Paleocene, lacustrine conditions replaced the alluvial fan and alluvial plain conditions that had dominated the Late Cretaceous to Early Paleocene interval. Lake Flagstaff formed in the lowland that was bounded on the west by the Sevier Highland, and on the east and north by the Laramide uplifts of the San Rafael Swell, Circle Cliffs, and Uinta Mountains (Stokes, 1986; Stanley and Collinson, 1979; Figure 15, this study). Although the southern extent of the lake has not been determined conclusively (Stanley and Collinson, 1979; Stokes, 1986), it reached at least as far south as Richfield (Hintze, 1988).

The Skinner Peaks quadrangle was located along the western shoreline of Lake Flagstaff (Figure 15); the lake-marginal position of the quadrangle is reflected in the lithology, sedimentary structures and thickness of the formation.

Definition

The Flagstaff Limestone Member of the Wasatch Formation (Spieker and Reeside, 1925), which was elevated to formation status by Spieker (1946), represents a major lacustrine phase of

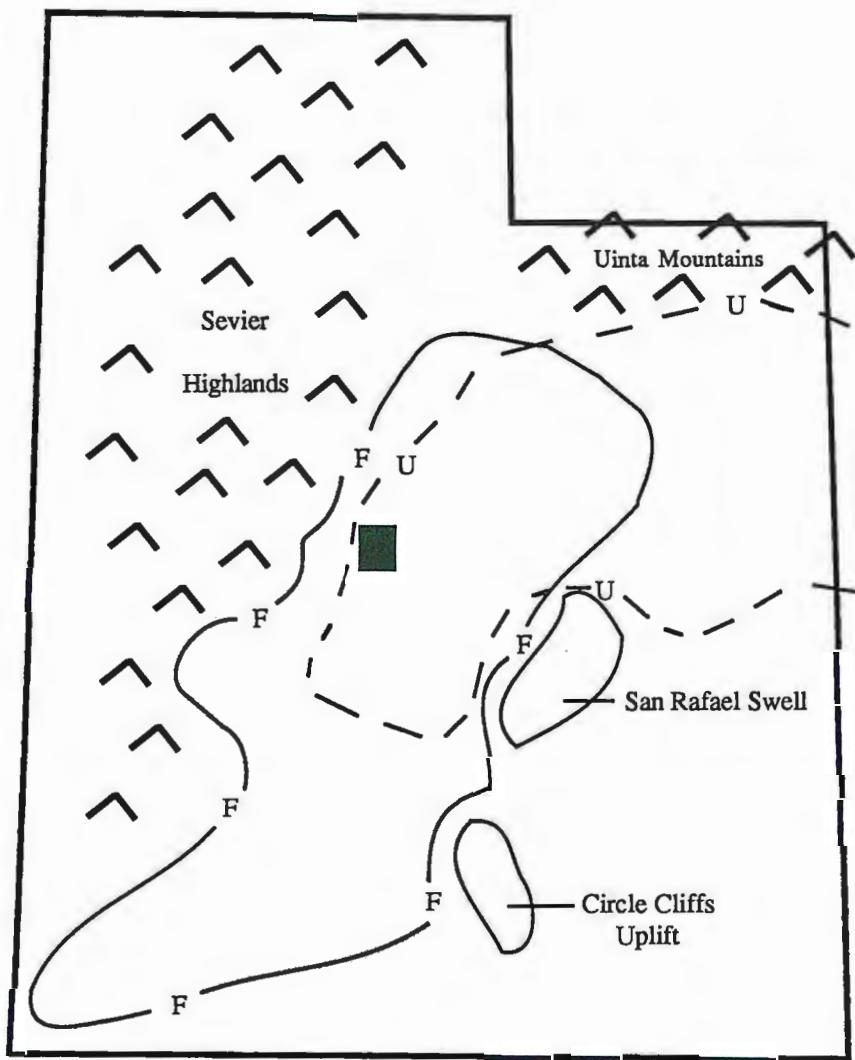


Figure 15: Paleogeographic map showing the relative locations and extents of Lake Flagstaff (solid line) and Lake Uinta (dashed line) with respect to the Sevier Highland, Uinta Mountains, San Rafael Swell, and Circle Cliffs Uplift. The Skinner Peaks quadrangle is represented by the black rectangle. (Modified from Hintze, 1973.)

deposition that occurred between the alluvial fan and floodplain conditions represented by the North Horn Formation and the Colton Formation. At the type locality (Flagstaff Peak on the southern Wasatch Plateau) the Flagstaff Limestone consists of freshwater limestones interbedded with gray shales and minor amounts of sandstone, gypsum, oil shale, and local coal seams (Spieker, 1946); conglomerate and sandstone are also prevalent in areas, such as the Skinner Peaks quadrangle, that were close to the margin of the lake (Gilliland, 1949; Clark, 1987).

Distribution

The Flagstaff Limestone occurs on the Wasatch, Fishlake, Pavant, and Gunnison Plateaus, in the Cedar Hills and Valley Mountains (Vogel, 1957), and in the northern Book Cliffs (Weiss, per. comm., 1990). The Flagstaff Limestone caps much of the Gunnison and Wasatch Plateaus, and it also forms the dip-slopes along the outer flanks of the Wasatch and West Gunnison monoclines (Spieker, 1946, 1949; Mattox, 1986).

In the Skinner Peaks quadrangle the Flagstaff Limestone is exposed in the east-dipping cuestas of the West Hills in the NW corner of the quadrangle (Plate 1). Beds tentatively identified as Flagstaff Limestone also are exposed along the NE side of Skinner Peaks (Plate 1); these beds are discussed in the "Interpretation of the Stratigraphy of Skinner Peaks".

Lithology and Stratigraphic Relationships

A section of Flagstaff Limestone (Appendix, Mills Gap Section) was measured in the West Hills north of Mills Gap (Plate 1). Calcareous mudstone, sandstone, sandy limestone, limestone, and conglomerate (listed in order of decreasing abundance) are the major rock types in this section. These strata are equivalent to the carbonate-clastic facies defined by Clark (1987) in the Juab quadrangle to the north.

The color of the strata varies from grayish-yellow (5Y 8/4) to pale reddish-orange (10R 5/4), with various hues of yellow being most common (Figure 16). The calcareous mudstone is massive; it weathers to a slope and ranges from 20-80 feet in thickness. The sandstone is usually calcareous and composed of medium- to coarse-grained quartz and lithic sand; locally it is cross-bedded (Figure 17). Compositonally, the sandstones are quartz arenites, sublitharenites, and lithic arenites (Clark, 1987; Auby, 1985). Beds of sandstone form ledges that are 1-4 feet thick, and commonly are laterally discontinuous. Massive beds of sandy limestone and limestone form resistant ledges 2-20 feet thick; locally these carbonate units are platy, weathering to slopes with local ledges. Beds of clast-supported conglomerate and conglomeratic sandstone occur locally throughout the section. These units are laterally discontinuous, often channel-form in shape, and 1-10 feet thick. Clasts are subangular to subrounded, poorly-sorted, pebbles and cobbles of quartzite and sandstone. The matrix is medium- to

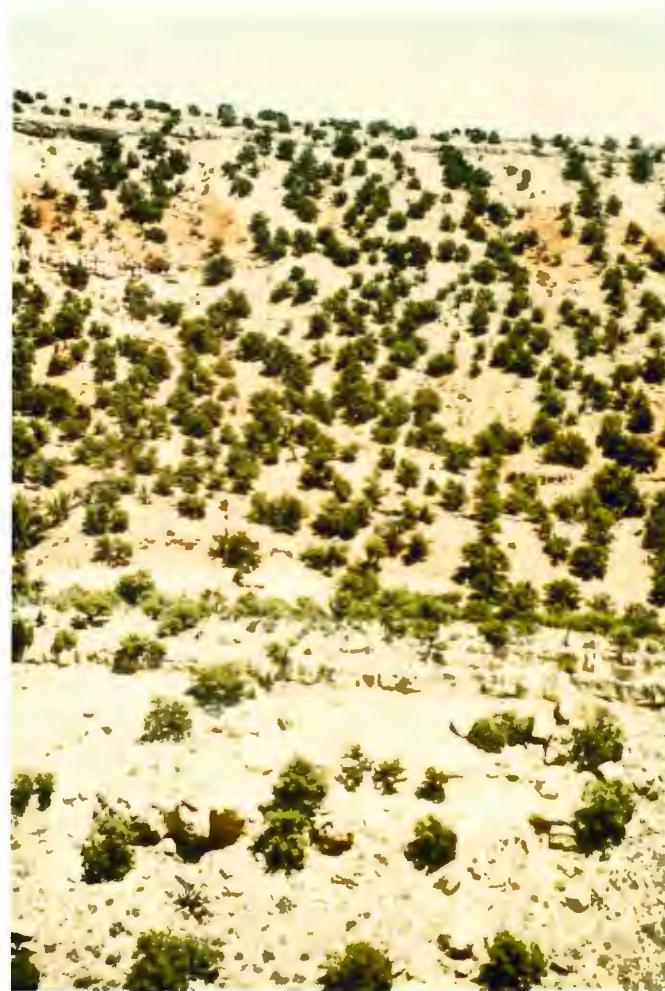
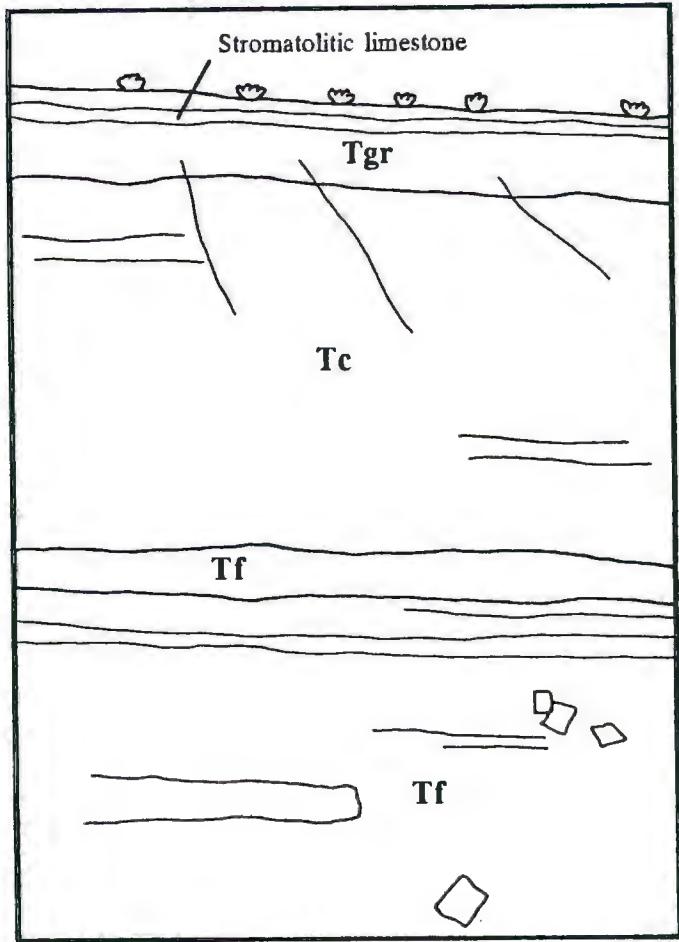


Figure 16: Flagstaff (Tf), Colton (Tc), and Green River (Tgr) Formations in the West Hills north of Mills Gap. Note the yellow color of the Flagstaff and Green River Formations. The nonresistant, red strata of the Colton Formation form a saddle between the more resistant beds of the Flagstaff and Green River Formations. (Photo courtesy of S. R. Mattox.)



Figure 17: Cross-bedded sandstone in the Flagstaff Limestone in the West Hills north of Mills Gap. (Photo courtesy of S. R. Mattox.)

coarse-grained calcareous sandstone that is composed of quartz and lithic sand.

The relative abundance of coarse-grained clastic material, the presence of cross-bedded sandstone, and the lateral discontinuity of the sandstone and conglomerate beds suggests that the Flagstaff in the Mills Gap section was deposited in a near-shore, shallow-water environment. This interpretation is consistent with those of Muessig (1951), Lambert (1976), and Clark (1987). A complete discussion of the depositional setting of the Flagstaff Limestone in the West Hills is given by Clark (1987).

The base of the Flagstaff Limestone is not exposed in the West Hills within the Skinner Peaks quadrangle; however, it is exposed in the Juab quadrangle to the north, and there the contact with the underlying North Horn is conformable and gradational (Clark, 1987). The contact between the Flagstaff and the overlying Colton Formation is also conformable (Figure 16).

Thickness

The Flagstaff Limestone is 200-1,500 feet thick on the Wasatch Plateau (Spieker, 1946), and approximately 900 feet thick on the Gunnison Plateau (Hintze, 1988). Clark (1987), and Mattox (1986) provide a compilation of thickness data from various workers throughout central Utah.

In the Skinner Peaks quadrangle the Flagstaff Limestone is approximately 525 feet thick in the West Hills north of Mills Gap. This value is consistent with those of Muessig (1951), Lambert

(1976), and Clark (1987) who measured 650, 522-620, and 82-554 feet respectively, in the West Hills area north of the Skinner Peaks quadrangle.

Age and Correlation

Strata of the Flagstaff Limestone range in age from Paleocene to Eocene; this age range is based primarily on paleontologic evidence that has been gathered by various workers throughout central Utah (LaRocque, 1951; Newman, 1974; Fouch and others, 1982). A complete discussion concerning the age of the Flagstaff in the vicinity of the Gunnison Plateau and Long Ridge is found in Clark (1987) and Mattox (1986).

Hintze (1988) correlates the Flagstaff Limestone with the Claron Formation of southern Utah, and with part of the Evanston Formation of NE Utah.

Colton Formation

Alluvial plain conditions returned to the basin in the Late Paleocene and Early Eocene (Stokes, 1986) as Lake Flagstaff diminished in size and migrated to the west and north (Stanley and Collinson, 1979). The decrease in the size of the lake and the migration of the depocenter was due to the westward progradation of terrigenous material that was being derived from the uplifts that bounded the basin to the east and southeast; comparatively minor amounts of clastic material were being derived from the highlands within and to the west of the lake (Stanley and Collinson, 1979).

These fluvial and alluvial plain sediments, which are assigned to the Colton Formation, represent the final infilling of the Sevier foreland basin.

Definition

The Colton Formation, which was originally defined as the upper member of the Wasatch Formation (Spieker and Reeside, 1925), was named for exposures of red, gray, and variegated sandstone, siltstone, and shale (Spieker, 1946). The floodplain and channel deposits of the Colton are sandwiched between the evenly bedded lacustrine strata of the Flagstaff Limestone and Green River Formation (Figure 16). The type section for the Colton Formation is northeast of the Skinner Peaks quadrangle near Colton, Utah, at the north end of the Wasatch Plateau.

Distribution

The Colton Formation is exposed in discontinuous patches throughout central Utah; it occurs in the Uinta Basin, Cedar Hills, Valley Mountains, and on the Wasatch, Gunnison, and Fishlake Plateaus (Clark, 1987; Mattox, 1986). In the Skinner Peaks quadrangle the Colton Formation is exposed in a conspicuous red swath (Figure 16) in the east-dipping cuestas of the West Hills (Plate 1). Beds that tentatively have been identified in this study as Colton Formation are exposed on Skinner Peaks (Plate 1); these beds are discussed in the "Interpretation of the Stratigraphy of Skinner Peaks".

Vogel (1957) did not recognize the Colton Formation in the Skinner Peaks quadrangle; he mapped the red mudstones and conglomerates in the West Hills as part of the Flagstaff Limestone, stating that much of the Flagstaff is fluvial and similar in nature to the Colton (Vogel, 1957, p. 46). It is true that in the West Hills the Flagstaff is dominated by lake-marginal/fluvial deposits; however, nowhere in the underlying Flagstaff strata is there such a conspicuous occurrence of reddish-brown floodplain mudstones and channel conglomerates as there is in the red saddle in the West Hills. Therefore, it is reasonable to conclude that the red swath of mudstones, sandstones, and channel-form conglomerates is Colton Formation; this interpretation is congruent with those of Clark (1987) and Witkind and others (1987).

Lithology and Stratigraphic Relationships

In the West Hills (Plate 1) in the Skinner Peaks quadrangle the Colton Formation is composed of reddish-brown mudstone, sandstone, and conglomerate (Figure 16); thin beds of limestone occur locally throughout the section (Appendix, Mills Gap Section), and are considered to be the deposits of short-lived local lakes. The Colton Formation as a whole is not well indurated, and it weathers to form a saddle between the more resistant Flagstaff Limestone and Green River Formation (Figure 16). The mudstone is calcareous and weathers to a slope. The sandstone is friable, and weathers to a slope with locally occurring ledges. It is calcareous, and is composed of subrounded, medium- to coarse-grained quartz,

feldspar, lithic fragments, and mica. Studies by Marcantel and Weiss (1968) and Stanley and Collinson (1979) show that Colton sandstones are commonly finer grained and contain greater amounts of mica and feldspar than the sandstones in the Flagstaff. Beds of limestone are sandy, and they occur locally as low, discontinuous ledges.

The conglomerate (Figure 18) is clast-supported, moderately sorted, and bimictic; clasts are subrounded pebbles of approximately equal amounts of purple and tan quartzite (from the Mutual Formation and Tintic Quartzite), and dark blue-gray Paleozoic limestone. This suite of clasts indicates derivation from the Sevier Highland to the west. The matrix, which comprises approximately 20 percent of the rock, is sandstone that is calcite-cemented and composed of medium- to coarse-grained, quartz and lithic sand. Conglomerate beds are 5-10 feet thick, channel-form, and laterally discontinuous; they occur as ledges and cliffs. Regionally, conglomerate is rare in the Colton and it occurs here only because the area was close to the edge of the basin.

The high percentage of mudstone, laterally discontinuous beds of conglomerate, sandstone, and limestone, and the red color of the strata attest to the fluvial (floodplain and channel) origin of the Colton Formation (Marcantel and Weiss, 1968).

In the West Hills in the Skinner Peaks quadrangle the Colton Formation is underlain conformably by the Flagstaff Limestone, and overlain conformably by the Green River Formation (Figure 16).



Figure 18: Quartzite and carbonate clasts in conglomerate of the Colton Formation in the West Hills north of Mills Gap.

Thickness

Near the type locality at Colton, Utah the Colton Formation is approximately 1,500 feet thick; at the few localities where the Flagstaff Limestone is succeeded conformably by the Green River Formation, the Colton Formation is absent. In the West Hills in the Skinner Peaks quadrangle (Plate 1) the Colton Formation is approximately 300 feet thick. In the Juab quadrangle to the north Clark (1987) measured a section of Colton that was 255 feet thick.

Age and Correlation

The Colton Formation ranges in age from Late Paleocene to Middle Eocene (Clark, 1987); Early Eocene generally is the accepted age for Colton strata in the Sanpete-Gunnison Plateau area (Spieker, 1946; LaRocque, 1960; Clark, 1987; Mattox, 1986).

Throughout central Utah the Colton Formation intertongues with and grades into the Green River Formation; Spieker (1946) concluded that the Colton is correlative with part of the Green River Formation. Hintze (1988) correlates the Colton with part of the Wasatch Formation of the Uinta Basin.

Green River Formation

During the Early Eocene, Laramide uplift of the Uinta Mountains and development of the Uinta Basin occurred. Lake Uinta, which was part of an enormous lake complex known as the Green River Lakes (Stokes, 1986), formed in the Uinta Basin (Figure 15). By the Middle Eocene, Lake Uinta completely occupied

the Uinta Basin and a long arm that extended into central Utah. The lake was bounded on the north by the east-west trending Uinta Mountains, on the south by the San Rafael Swell, and on the west by the Sevier Highland (Figure 15). At some time during the Eocene the expanding body of Lake Uinta merged with the diminishing body of Lake Flagstaff as it (Lake Flagstaff) was migrating to the north and west (Stanley and Collinson, 1979; Stokes, 1988). Sediments that were deposited in Lake Uinta formed the strata of the Green River Formation. In the Skinner Peaks quadrangle strata of the Green River Formation reflect the lake-marginal location of the quadrangle (Figure 15).

Definition

The Green River Formation was defined by Hayden (1896); the type section is along the Green River west of Rock Springs, Wyoming. At the type locality, the Green River Formation consists of finely laminated marlstone, oil shale, and minor amounts of sandstone, and sandy or limy shale (Bradley, 1964).

In the Skinner Peaks quadrangle four distinct lithofacies of the Green River Formation are recognized; from the base of the unit upward they are the mudstone, clastic, and mudstone-micrite lithofacies of Clark (1987), and the Tawny facies of Zeller (1949). The definition, distribution, lithology, and stratigraphic relationships of the Tawny facies are discussed separately. A summary of the age and correlation of the Green River Formation as a whole is presented at the end of the Tawny Facies section.

MUDSTONE, CLASTIC, and MUDSTONE-MICRITE FACIES

Distribution

Outcrops of Green River strata occur in northeast and central Utah, northwestern Colorado, and southwestern Wyoming. In the Skinner Peaks quadrangle the best exposures of strata of the mudstone, clastic, and mudstone-micrite lithofacies of the Green River Formation are in the cuestas of the West Hills. Strata of these lithofacies also are exposed north and south of Little Salt Creek Canyon (Plate 1); however, in these areas strata of the Tawny Facies are dominant.

Lithology and Stratigraphic Relationships

The mudstone lithofacies is composed mostly of thinly bedded, grayish-yellow mudstone that is very incoherent and subsequently weathers to a slope (Figure 16). Thin, laterally discontinuous beds of quartzite pebble conglomerate and sandy limestone also occur locally throughout the unit. The unit is capped by a resistant bed of stromatolitic limestone (Figures 16 and 19) that contains brown and gray chert nodules. The stromatolites occur as laterally-linked hemispheroids up to 2 feet in diameter.

The clastic lithofacies consists of conglomerate, conglomeratic sandstone, mudstone, and sandstone. The conglomerate and conglomeratic sandstone (Figure 20) are reddish-brown or grayish-yellow; it is bimictic with poorly-sorted pebbles and cobbles of quartzite and carbonate in a medium- to coarse-grained sandstone



Figure 19: Stromatolitic limestone in the mudstone facies of the Green River Formation in the West Hills north of Mills Gap. (Photo courtesy of S. R. Mattox.)



Figure 20: Yellowish-gray, poorly-sorted, conglomeratic sandstone in the clastic facies of the Green River Formation in the West Hills north of Mills Gap.

matrix. These conglomerate and conglomeratic sandstone units are poorly indurated, and laterally discontinuous. Mudstones are reddish brown, thinly laminated slope-formers. Sandstones are gray, calcite-cemented, and composed of quartz and lithic fragments; compositionally these sandstones are sublitharenites, lithic arenites, and lithic wackes (Clark, 1987). Sandstone beds form low ledges that are laterally discontinuous. Beds of oolitic limestone that have been replaced by silica also occur locally throughout the clastic facies; ripple marks commonly are preserved on the tops of these oolitic beds.

Alternating beds of red or yellow mudstone, and yellow or gray micrite dominate the mudstone-micrite lithofacies. The mudstones are very thinly-bedded, poorly indurated, and consequently they weather to slopes; mudstones total over 50% of the mudstone-micrite facies (Clark, 1987). The micrite beds are relatively coherent, and consequently they form a resistant cap over the easily-eroded mudstones. These micrite beds are commonly platy (Figure 21) and fossiliferous; fossils include plant fragments, gastropods, and Clark (1987) noted pelecypods and ostracodes as well.

Millen (1982) divided the Green River Formation into the following facies according to the environment of deposition: the shallow-lacustrine phase, the transitional facies, and the alluvial facies. The strata of the mudstone, clastic, and mudstone-micrite facies of Clark (1987) correspond to Millen's (1982) shallow-lacustrine phase (facies) and transitional facies. Strata of the

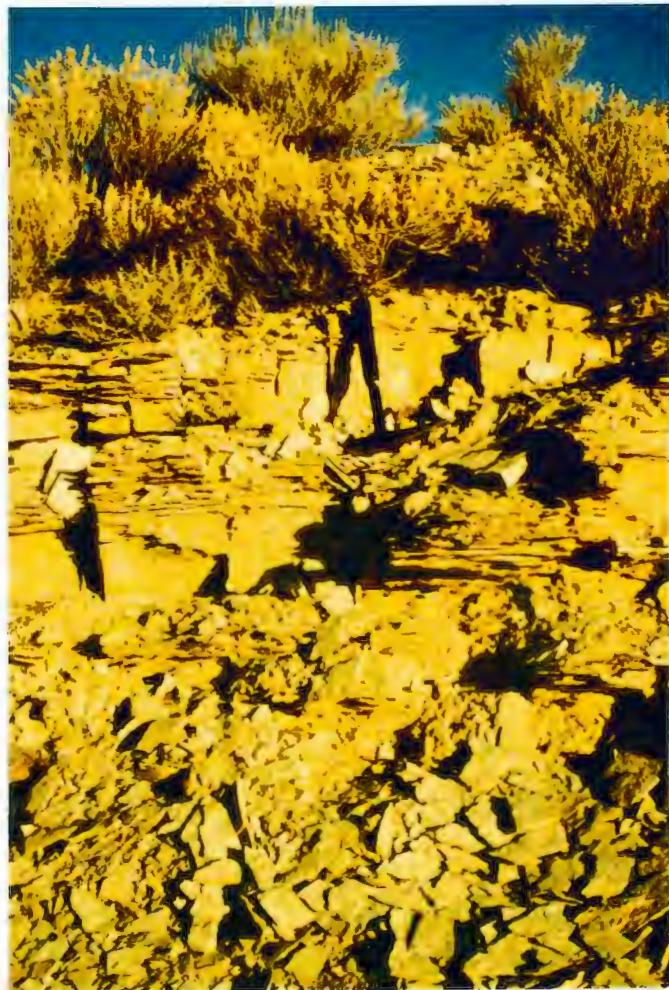


Figure 21: Platy micrite beds in the mudstone-micrite facies of the Green River Formation, West Hills.

shallow-lacustrine facies consist of gray or green calcareous mudstone, yellowish-gray carbonates, and thinly-bedded sandstone; these strata were deposited in a fresh-water lake carbonate flat environment. Strata of the transitional facies, which were deposited in beach-bar complexes and deltas, have a greater clastic fraction than the shallow-lacustrine phase, but less conglomerate and channel sandstone than the alluvial facies of Millen (1982).

In the West Hills area of the Skinner Peaks quadrangle, strata of the mudstone facies of the Green River Formation are underlain conformably by the Colton Formation (Figure 16), and strata of the mudstone-micrite facies are overlain conformably by the Goldens Ranch Formation. Along the east edge of the quadrangle the contact between the Colton and Green River is not exposed; strata of the mudstone-micrite facies grade conformably into the overlying strata of the Tawny Facies.

Thickness

A thickness of 1,200 feet was calculated from outcrop width and bedding attitude for the Green River Formation in the West Hills of the Skinner Peaks quadrangle. This thickness is approximately 300 feet greater than thicknesses calculated by Vogel (1957) and Clark (1987) for the same general area. This suggests the presence of a fault in the section, but no evidence for a fault was seen in the field. Elsewhere throughout central Utah the Green River Formation ranges in thickness from 0-5,800 feet (Clark, 1987).

TAWNY FACIES

Definition

The term Tawny Beds or Tawny Facies was coined by Zeller (1949) for tawny colored beds that conformably overlie the Green River Formation at some localities, and unconformably overlie the Arapien Shale at others (Figure 8). Zeller (1949) distinguished these beds from normal Green River strata based on their tawny color and greater amounts of sandstone; however, based on the gradational, conformable contact, and some lithologic similarities between the Tawny Beds and underlying Green River strata, he considered the Tawny Beds to be an upper Green River facies.

Hunt (1950), however, noted that Tawny beds northeast of Levan did not conformably overlie Green River strata as Zeller (1949) had suggested; because of this he concluded that the Tawny Beds were a separate unit and not a facies of the upper Green River. The stratigraphic relationship between the Tawny Beds and the Green River Formation has been the subject of debate ever since; work by Vogel (1957), Millen (1982), and Norton (1986) has contributed to the solution of this dilemma, which is discussed below.

Distribution

Strata of the Tawny Facies are exposed along the west margin of the Gunnison Plateau from the south end of Juab Valley to Twomile Canyon which is NE of Levan (Vogel, 1957). In the Skinner

Peaks quadrangle, strata of the Tawny Facies are exposed in a nearly-continuous strip along the Gunnison Plateau (Plate 1), and they also form the SW dipping dip-slope of Skinner Peaks. Tawny Beds are also exposed at the southern end of the West Hills east of Interstate 15 on the border between sections 25 and 36 of T. 15 S., R. 1.5 W.

Lithology and Stratigraphic Relationships

In the Skinner Peaks quadrangle, Tawny Beds consist of green, red, and variegated mudstone, and yellowish-tan coarse-grained sandstone, conglomerate, conglomeratic sandstone, and limestone (Figure 22). The sandstone is very coherent; it is usually cemented with calcite, and composed of quartz and minor amounts of lithic fragments. Sandstone beds form ledges that are several feet thick and laterally discontinuous; numerous vertebrate fossils are contained in sandstone beds near the top of the section (Figure 23). Channel-form beds of conglomerate and conglomeratic sandstone also are very coherent. Clasts are subrounded to rounded pebbles of dark blue-gray carbonate (>75%), and tan and purple quartzite (<25%); matrix is sandstone similar to that described above. Limestone is very dense and commonly fossiliferous, containing teeth and bone fragments, as well as gastropods of the species *Australorbis* (LaRocque, 1960). Strata of the Tawny facies match the description of strata in Millen's (1982) alluvial facies, which represents an alluvial or delta plain environment of deposition.



Figure 22: Red and green mudstone and yellowish-tan sandstone, limestone, and conglomeratic sandstone of the Tawny Facies of the Green River Formation. Photo taken approximately 0.75 miles south of Skinner Peaks.



Figure 23: Vertebrate fossils in coarse-grained, quartz sandstone of the Tawny Facies of the Green River Formation. Photo taken approximately 0.75 miles south of Skinner Peaks just below the contact between the Goldens Ranch and Green River Formations.

Complex stratigraphic relationships separate the Tawny Beds from adjacent units. With the exception of Hunt (1950), all workers (Vogel, 1957; Millen, 1982; Norton, 1986) agree that the contact between the Tawny Beds and the underlying Green River Formation is conformable and gradational; this relationship was confirmed in this study as well. Tawny Beds also unconformably overlie the Arapien Shale south of Little Salt Creek Canyon (Figure 8). The Tawny Beds are overlain conformably by strata of the Goldens Ranch Formation. This relationship is discussed in detail in the "Goldens Ranch Formation" section of this manuscript.

Lateral stratigraphic relationships between the Tawny Beds and adjacent units are more confusing than the vertical relationships. Zeller (1949), Vogel (1950), Millen (1982) and this study designate the Tawny Beds as a facies of the upper Green River that is correlative with the Crazy Hollow Formation; Norton (1986) prefers to include the Tawny Beds in the Crazy Hollow Formation.

Strata of both the Tawny Beds and the Crazy Hollow Formation were deposited in an alluvial fan or delta plain environment (Millen, 1982; Norton, 1986) so the deposits are similar, which makes distinction between the two units difficult. Evidence which supports the interpretation of the Tawny Beds as a facies of the Green River Formation and not the Crazy Hollow Formation is as follows:

1. The contact between the Tawny Beds and the underlying upper Green River Formation is gradational and conformable (Zeller,

1949; Vogel, 1957; Millen, 1982; Norton, 1986); the contact between the upper Green River Formation and the Crazy Hollow Formation is often disconformable (Spieker, 1949; Norton, 1986).

2. The lithology of the Tawny Beds (described above) matches that of the Green River Formation more closely than it does that of the Crazy Hollow Formation, which is composed of red mudstone, light-gray, salt-and-pepper (quartz, white feldspar, and black chert) sandstone, purplish-red and brownish-red sandstone, yellowish-orange sandy limestone, and local beds of black chert pebble conglomerate and limestone (Norton, 1986). Sandstone beds of the Tawny Facies locally match the description of the salt-and-pepper sandstones of the Crazy Hollow; however, the prevalent red mudstones and sandstones, and the distinctive, black chert pebble conglomerates of the Crazy Hollow are absent in the Tawny Beds.

3. *Australorbis* sp., which occurs throughout the Green River Formation and the Tawny Beds, has not been observed in the Crazy Hollow Formation (Vogel, 1957 after LaRocque, 1956).

The evidence cited above suggests that the Tawny Beds are a local facies of the upper Green River Formation; these beds should not be raised to formation status or included in the Crazy Hollow Formation. Consequently, the Tawny Beds were not mapped as a separate unit in this study, but were simply included in the Green River Formation.

Thickness

The regional thickness of the Tawny Beds ranges from 0-1,100 feet (Millen, 1982). Vogel (1957) measured two stratigraphic sections through strata of the Tawny Facies. A section over Skinner Peaks totaled 755 feet; however, the lower 725 feet of this section are composed of a thick sequence of conglomerate, conglomeratic sandstone, and oncolitic limestone which I tentatively have identified as Cretaceous-Tertiary strata. Based on this interpretation only approximately 30 feet of this incomplete section is Tawny Facies strata. A second section measured across the west-dipping cuesta that is east of Utah Highway 28 in the south end of the quadrangle totaled 743 feet (Vogel, 1957). A thickness of approximately 850 feet was calculated from outcrop width and bedding attitude of an incomplete section of Tawny Beds south of Skinner Peaks in this study.

Age and Correlation

An Eocene age generally is accepted for strata of the Green River Formation in central Utah. Clark (1987) presents a discussion that outlines the paleontologic, stratigraphic and radiometric evidence for an Eocene through Early Oligocene age for the Green River Formation. Most of the evidence cited in support of an Early Oligocene age was inconclusive; therefore, Early to Late Eocene is accepted for the age of the Green River Formation in this study area.

Hintze (1988) correlates the lower part of the Green River Formation with the upper part of the Wasatch Formation of NE Utah, Idaho, and Wyoming; Vogel (1957), Millen (1982), Norton (1986), and this study correlate the upper Green River Formation with the Crazy Hollow Formation.

Interpretation of the Stratigraphy of Skinner Peaks

The stratigraphy on Skinner Peaks is complex and abnormal, and thus, poorly understood. Approximately 550 feet of conglomerate, conglomeratic sandstone, sandstone, sandy limestone, and oncolitic limestone grade vertically into strata of the Tawny Facies of the Green River Formation (Appendix, Skinner Peaks Section). Vogel (1957), and Witkind and others (1987) mapped these strata as part of the Tawny Facies of the Green River Formation. A closer evaluation of these units indicates that they more accurately represent Late Cretaceous-Early Tertiary strata as suggested by Douglas A. Sprinkel of the Utah Geological and Mineral Survey (UGMS). Evidence to support this interpretation is cited throughout the following section. Unit numbers (e.g., unit 4) correspond to the unit numbers found in the Skinner Peaks Section in the Appendix.

Description of Units

A section of poorly sorted conglomerate and conglomeratic sandstone, which is approximately 300 feet thick, lies unconformably on the Arapien Shale. These conglomerates were

described in detail in the section on the North Horn Formation; only a summary description is presented here.

The conglomerate in the lower 220 feet of the section (unit 4) is massive, clast-supported, poorly-sorted, and bimictic. Clasts include subangular to subrounded pebbles, cobbles, and boulders of purple and tan quartzite, and a small percentage of dark blue-gray carbonate (Figure 14); matrix is poorly-sorted, medium- to fine-grained lithic sandstone. Clast size, and quartzite/carbonate clast ratio decreases up-section. The color of the unit also changes from gray to red up-section. This unit, which represents an alluvial fan deposit, is overlain by 55 feet of interbedded conglomerate and sandstone (unit 5).

The conglomerate of unit 5 is gray, clast-supported, moderately-sorted, and bimictic. Clasts are subangular to subrounded cobbles of carbonate (75%) and quartzite (25%). The sandstone is composed of quartz; it is light-gray, medium-grained, well-sorted, and locally cross-bedded. This unit is indicative of an alluvial plain environment.

The conglomerate sequence is overlain by approximately 100 feet of limestone (unit 6) and oncolitic limestone (unit 8). The limestone is light-gray (N7), massive, and finely-crystalline; it forms a ledge that is 10 feet thick. The oncolitic limestone (Figure 24), which contains oncolites up to three inches in diameter, forms cliffs and is 80 feet thick.

Oncolites are concretions of algae and sediment that form in shallow water, near-shore lacustrine environments (Weiss, 1969).



Figure 24: Oncolitic limestone in North Horn or Flagstaff strata on Skinner Peaks. (Photo courtesy of S. R. Mattox.)

Oncolites do occur in the Green River Formation (Bradley, 1929); however, they are far more characteristic of North Horn and Flagstaff strata, and Weiss (1969) has shown that oncolite-bearing beds in the North Horn and Flagstaff Formations occur preferentially along what were--during sedimentation--actively-rising tectonic ridges.

The oncolitic limestone is overlain by 110 feet of interbedded sandy limestone and sandstone (unit 9), and interbedded sandstone and conglomerate (unit 10). The interbedded sandstone and sandy limestone is reddish-brown. The sandstone in this unit is calcareous and is composed of medium-grained quartz and minor amounts of lithic fragments; it forms local ledges throughout the slope-forming sandy limestone. This sequence is overlain by interbedded sandstone and conglomerate. The sandstone in this unit is also calcareous and is composed dominantly of medium-grained, well-sorted quartz sand. It also contains algal mat pieces and oncolites that may have been derived partially from the underlying oncolitic limestone. The conglomerate is clast-supported, moderately-sorted, and bimictic. It is composed of approximately equal amounts of subrounded pebbles of dark-blue-gray carbonate and purple and tan quartzite. Approximately 20% of the rock is matrix which is composed of quartz sandstone. Strata of these units represent a lake-marginal and fluvial environment, which was typical of both the Flagstaff Limestone and Colton Formation in this area; these strata grade vertically into the overlying Tawny Beds. The contacts between the lower units appear to be conformable.

Interpretation of Units

The section is a fining-upward sequence that represents a transition through the following environments across the Skinner Peaks area: alluvial fan (unit 4), alluvial plain (unit 5), lake-marginal and shallow-water lacustrine (units 6-10). The lithology and stratigraphy of the units described above are characteristic of the North Horn Formation, Flagstaff Limestone, and Colton Formation. It is difficult, however, to assign each unit to a specific formation. The conglomerates of units 4 and 5 match the regional description of North Horn strata. The limestone and oncolitic limestone of units 6-8 could be placed in either the North Horn Formation or the Flagstaff Limestone. The sandy limestone, sandstone, and conglomerate of units 9 and 10 could be placed in either the Flagstaff Limestone or Colton Formation, although the lack of a distinctive red color and abundant mudstone suggests that these strata are more representative of the Flagstaff Limestone than they are of the Colton. Regardless of which formation each unit is assigned to, this section is far more representative of the regional sequence of Late Cretaceous-Early Tertiary strata than it is representative of Tawny Beds.

Based on this interpretation of the stratigraphy, very attenuated sections of North Horn Formation and Flagstaff Limestone are present on Skinner Peaks. The North Horn Formation is 300-400 feet thick depending on where the North Horn/Flagstaff contact is drawn. Likewise, the Flagstaff Limestone is 110-220 feet

thick. These thickness values are significantly less than values from the West Hills to the west and from the Gunnison Plateau to the east (Table 3). The most logical explanation for the drastic thickness variations that occur over such a short distance is that welts of Arapien Shale formed local topographic highs in the basin during Late Cretaceous-Middle Tertiary time. This conclusion is supported by the presence of an unconformity between the Arapien Shale and Late Cretaceous-Early Tertiary strata, and the presence of the oncolitic limestone.

Because the units described above were identified only tentatively, the strata of this section were mapped as Cretaceous-Tertiary undivided.

<u>FORMATION</u>	<u>WEST HILLS</u>	<u>SKINNER PEAKS</u>	<u>GUNNISON PLATEAU</u>
North Horn	880-1700 ft	300-400 ft	830 ft
Flagstaff	525 ft	110-220 ft	900 ft

Table 3: Thickness variations of the North Horn and Flagstaff Formations from the West Hills to the Gunnison Plateau.

Goldens Ranch Formation

The onset of wide-spread volcanism in Utah occurred during the Early Oligocene. This volcanism produced deposits, such as the volcaniclastic Goldens Ranch Formation, which are prevalent throughout the Skinner Peaks quadrangle.

Definition

The volcaniclastic Goldens Ranch Formation was described by Muessig (1951, p.89) as "...the series of volcanic conglomerate, tuff, bentonite, sandstone, and other assorted sediments, which overlies the Green River Formation conformably wherever the two are both exposed." Included in this description is the Sage Valley Limestone Member, "which occurs at varying distances above the base of the Goldens Ranch Formation..." Muessig's description of the Goldens Ranch Formation is based on exposures found in the Middle Fork of Sage Valley in the Juab quadrangle (Figure 2). The section originally measured and described by Muessig (1951) is located in the NW 1/4 of section 18, T.14 S., R.2 W. of the Juab quadrangle (Meibos, 1983). This section was designated as the type section for the formation by Meibos (1983) who was working in the Sugarloaf quadrangle to the north (Figure 2). Meibos also divided the Goldens Ranch Formation into the three currently recognized members: the Chicken Creek Tuff, the Hall Canyon Conglomerate, and the Sage Valley Limestone.

Distribution

Exposures of the Goldens Ranch Formation have been documented by various workers. Muessig (1951), Meibos (1983), and Clark (1987) recognized the formation on and adjacent to Long Ridge and the West Hills (Figure 2). Evernden and James (1964) named the Chicken Creek Tuff for exposures found along Chicken Creek Reservoir (southern end of the West Hills), and Vogel (1957) mapped undifferentiated Goldens Ranch Formation in southern Juab Valley. Rocks equivalent to the Goldens Ranch have been described as far north as the East Tintics (Morris, 1975).

The Goldens Ranch Formation occurs throughout approximately one-third of the area of the Skinner Peaks quadrangle (Plate 1). In the western half of the quadrangle the formation can be traced southward from the Chicken Creek Reservoir through the South Hills and into the outcrops that flank the eastern side of the Sevier Bridge Reservoir (Plate 1). In the eastern half of the quadrangle it occurs south of Chriss Canyon, and forms a "moat" that surrounds Skinner Peaks (Plate 1).

Lithology, Stratigraphic Relationships and Thickness

The Goldens Ranch Formation as defined by Meibos (1983) consists of the following members, listed in ascending order:

- 1) the Chicken Creek Tuff Member, composed of interbedded tuffs (including the Chicken Creek Tuff of Evernden and James (1964)) and bentonitic shales.
- 2) the Hall Canyon Conglomerate, Members Q and V

- a) Member Q, composed of quartzite and limestone boulders in a bentonitic clay matrix.
 - b) Member V, composed of unconsolidated quartzite, limestone, and volcanic boulders in a bentonitic clay matrix.
- 3) the Sage Valley Limestone Member, composed of limestone that contains twigs, leaves, and fresh-water snails. This unit does not occur in the Skinner Peaks quadrangle.

Meibos' stratigraphy is useful, but his definition of the Chicken Creek Tuff Member is too simplistic for southern Juab Valley, where it can be separated into four distinct, mappable units (Units I-IV, this study). The Hall Canyon Conglomerate (or its equivalent) was recognized in this area for the first time, and was mapped as Unit V. Descriptions of Units I-V (Figures 25 and 26), which are based on observations made while mapping, and on a measured section (Appendix, Painted Rocks Section) are presented below.

Unit I is an epiclastic conglomeratic sandstone. The thickness of this unit is variable, ranging from 100 to approximately 500 feet thick. The contact between it and the underlying Eocene Green River Formation is gradational wherever it is exposed, as in the NE 1/4 of section 27, T. 16 S., R. 1 W.

Unit I forms slopes, ledges, and cliffs, and is either blue, gray or green in color. It contains a variety of sedimentary structures,

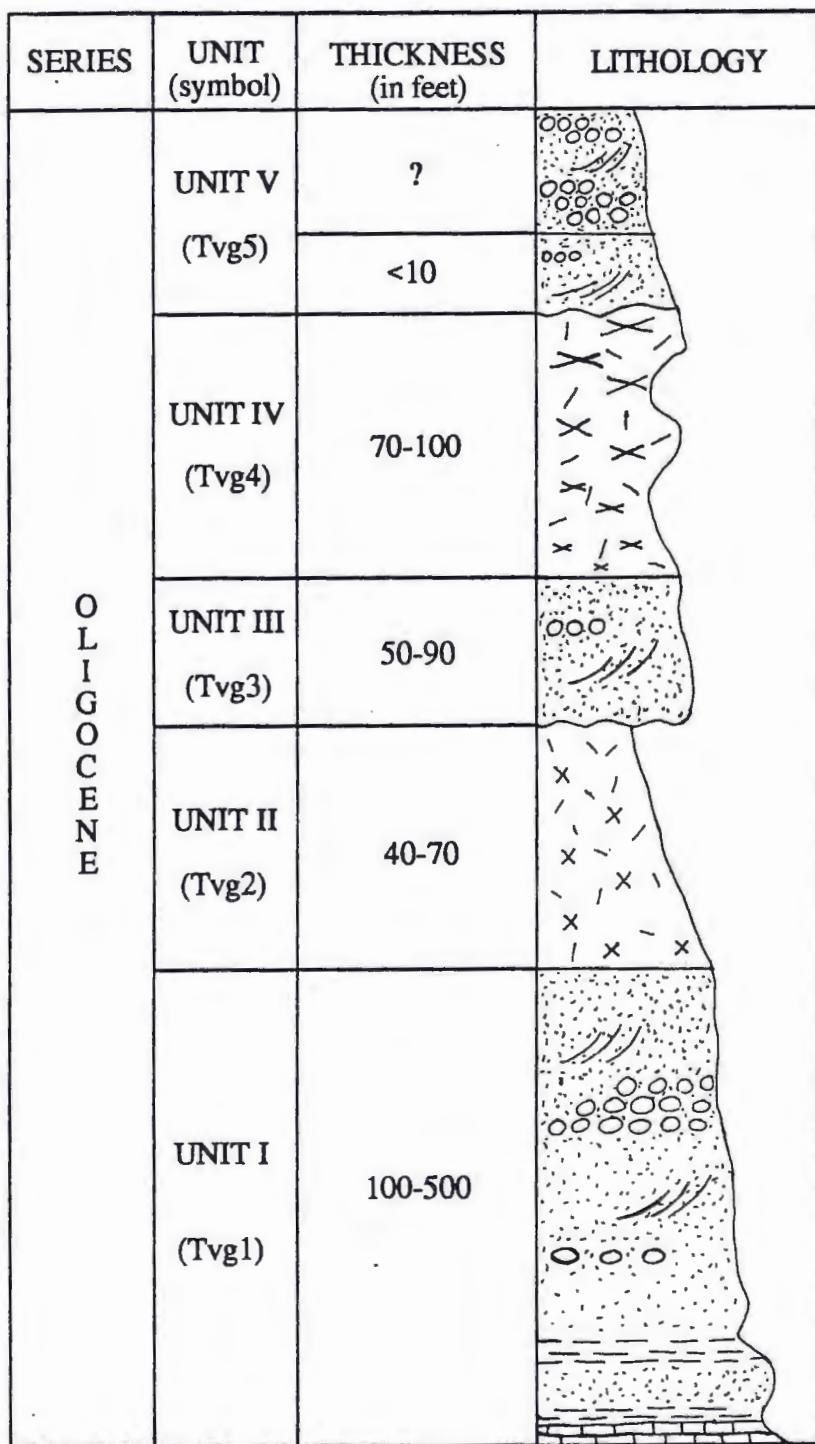


Figure 25: Stratigraphic column of the Goldens Ranch Formation in the Skinner Peaks quadrangle. \times = pumice; \gg = flattened pumice.

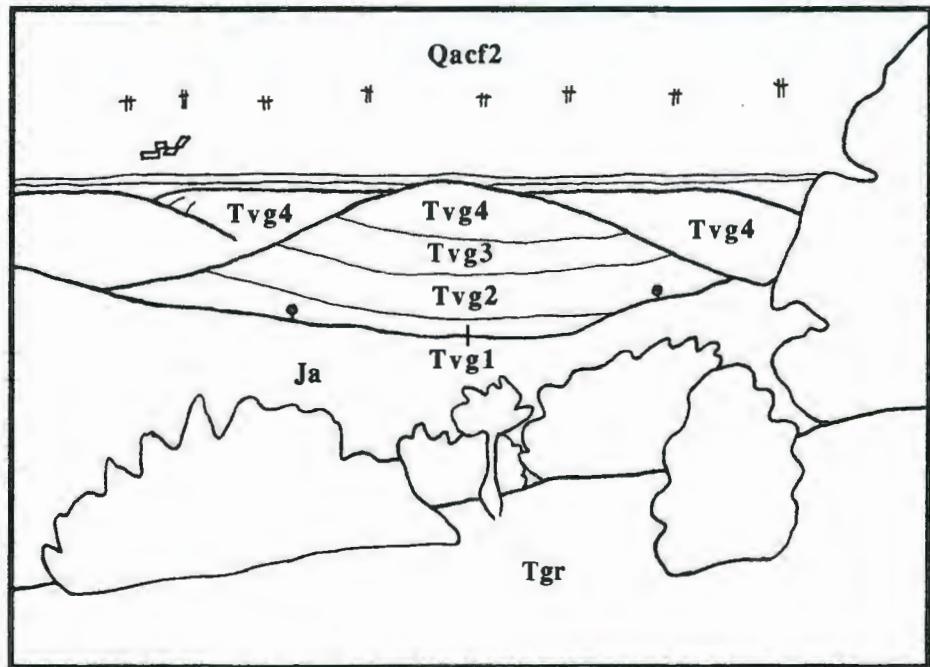


Figure 26: Units I-IV (Tvg1-4) of the Goldens Ranch Formation.
Photo taken looking west from Skinner Peaks. (Photo courtesy of S. R. Mattox.)

including laminae, trough and tabular cross-bedding, channels, pebble/cobble lenses, (Figure 27) scour-and-fill structures, and normally and reversely graded beds.

Just above the contact with the Green River Formation, Unit I is composed of bentonitic shales interbedded with thin, platy limestone. This unit grades upward into sandstone, and finally into conglomeratic sandstone, forming a coarsening-upward sequence.

The upper three-quarters of Unit I are composed of sandstone and conglomeratic sandstone. The sandstone and matrix of the conglomeratic sandstone is most commonly a poorly-sorted lithic or arkosic sandstone. Grains are subangular, and range in size from 0.5-10 mm, with an average of 1 mm. The cement is typically calcareous, and the rock is friable to moderately coherent.

Clasts in the conglomeratic sandstone are angular to subrounded, and poorly sorted, ranging in size from 1.5-7.0 cm, with an average size of 5 cm. Approximately 90% of these clasts are volcanic in origin, and were probably derived from ash and lava flows of the East Tintic District (Figure 2). The other 10% are quartzite clasts that were derived from the Precambrian Mutual Formation and the Cambrian Tintic Quartzite, or from pre-existing conglomerates.

The coarsening-upward sequence of Unit I represents a shallow lacustrine/marginal lacustrine/fluvial environment of deposition that marks the end of Lake Uinta (De Vries and others, 1988).



Figure 27: Outcrop of epiclastic conglomeratic sandstone of Unit I of the Goldens Ranch Formation. Note the cross-bedding, pebble lenses, and typical blue-gray color. Hammer for scale in center of photo. Photo taken in the Painted Rocks area. (Photo courtesy of S. R. Mattox.)

The best exposure of Unit I is in the Milky Wash area, section 27, T. 16 S., R. 1 W. (Plate 1).

Unit II is a crystal vitric tuff (Figure 28) that is 40-70 feet thick. The contact between Unit I and Unit II is concordant and sharp (Figure 26). This tuff is slightly welded, pink (weathered and fresh), and usually forms slopes. It is composed of 30-35% crystals and 65-70% glassy matrix. The crystals are euhedral and average 1 mm in size. Approximately 60% of these crystals are biotite, 40% are bipyramidal quartz, and sanidine occurs in trace amounts. The matrix is composed of pumice fragments (25%-30%), which range in size from 0.5-20 mm, and ash (70%-75%). Bubble wall shards are visible in thin section.

Unit III is coarse-grained epiclastic sandstone that is 50-90 feet thick. This unit is red or gray in color, forms resistant ledges and cliffs, and displays cross-bedding and channels (Figure 29). It is composed of approximately 60% bipyramidal quartz crystals, 5-15% lithic fragments, 15% sanidine, and traces of hematite. The lithic fragments are subrounded, and range in size from 2-15 mm. The quartz crystals, hematite, and sanidine are subhedral to euhedral, and average 2 mm in size. This unit is cemented by both silica and calcite, and is moderately to very coherent.

Unit II and Unit III are separated by an erosional contact. The nature of the contact and the presence of clasts of Unit II within Unit III suggest that Unit III was derived at least in part from the top of Unit II. Unit III represents a period of volcanic



Figure 28: Handsample of the crystal vitric tuff of Unit II of the Goldens Ranch Formation taken from an exposure in the Painted Rocks area. White spots are pumice, dark flecks are biotite. (Photo courtesy of S. R. Osterberg.)



Figure 29: Typical outcrop of the epiclastic sandstone of Unit III in the Painted Rocks area. Photo shows the bedded, ledge-forming character of this unit. Hammer for scale in center of the photo. (Photo courtesy of S. R. Mattox.)

quiescence that occurred between the eruptive episodes that deposited Unit II and Unit IV.

Unit IV is an orange- or tan-colored vitric lithic tuff that is approximately 70-100 feet thick (Figure 30). The contact between it and Unit III is sharp and concordant (Figure 26). This tuff is less welded at the base where it weathers to form slopes; the upper part of the unit is better welded and it weathers to form vertical cliffs that commonly are cavernous.

The tuff of Unit IV is composed of 75% matrix, 20% lithic fragments, and 5% crystals. The matrix is composed of 50% ash, and 50% pumice that ranges in size from 1-10 cm, and is commonly flattened in the bedding plane (Figure 30). The pumice forms a coarsening-upward sequence within the tuff. The lithic fragments are subangular to round, range in size from 0.5-2 cm, and are composed of volcanic rocks and quartzite. Biotite, bipyramidal quartz, and a trace of sanidine constitute the crystal fraction of the tuff. These crystals are euhedral, and range in size from 0.5-2 mm.

The best exposures of Units II-IV are found in the SW 1/4 of section 15, T. 16 S., R. 1 W., the NE 1/4 of section 34, T. 16 S., R. 1 W., and the Painted Rocks area, adjacent to the Sevier Bridge Reservoir.

Unit V is the Hall Canyon Conglomerate or its equivalent. It is an epiclastic sandstone/conglomeratic sandstone (Figure 31) of unknown thickness. In the Skinner Peaks quadrangle the base of the unit is exposed in only one place, the top is not exposed at all, due to erosion, and the section is further complicated by faulting.



Figure 30: This close-up photo of Unit IV (vitric lithic tuff) which was taken in the Painted Rocks area, shows the abundance of lithic fragments and flattened pumice that typify this unit. A large piece of pumice is visible in the upper right-hand corner of the photo. (Photo courtesy of S. R. Mattox.)



Figure 31: A typical outcrop of Hall Canyon Conglomerate (Unit V) NE of Skinner Peaks. The light-colored blocks at either end of the photo are clasts of underlying Unit IV. The presence of clasts of Unit IV distinguishes the Hall Canyon Conglomerate from Unit I. Hammer for scale in center of photo.

Clark (1987) reports that the thickness of the Hall Canyon Conglomerate varies from 0-400 feet in the Juab quadrangle (Figure 2). The contact between Unit V and Unit IV is erosional and sharp.

The basal part of Unit V is an epiclastic sandstone that is very similar to Unit III; however, it is thin (rarely greater than 10 feet thick), and contains sand-sized grains of Unit IV. The rest of Unit V is very similar to Unit I in terms of texture and composition. The principal difference between Units I and V is the presence of angular clasts of Unit IV within Unit V (Figure 31). Unit V also contains more sandstone and less conglomeratic sandstone than Unit I. The sandstone is relatively homogeneous in terms of grain-size and composition (medium- to coarse-grained lithic sandstone); it contains very large-scale, tabular cross-bedding. The sedimentary structures, thickness, and overall stratigraphy of this unit suggest that it is an alluvial fan or a fan-delta deposit. The best exposures of Unit V are in section 23, and in the S 1/2 of sections 14 and 15, T. 16 S., R. 1 W.

Age and Correlation

The age of the Goldens Ranch Formation has been the subject of much debate. Muessig (1951) assigned an age of Middle Eocene to the formation, based on the gradational contact with the underlying Eocene Green River Formation, and on plant fossils from the Sage Valley Limestone that were identified by Roland Brown (U.S. Geol. Survey). Evernden and James (1964), however, obtained

an Oligocene age (33.2 m.y.) when they used the potassium-argon method to date biotite from the Chicken Creek Tuff (one of the tuffs in Meibos' Chicken Creek Tuff Member). Because of the discrepancy between the radiometric age and the paleobotanical age, Everden and James (1964) submitted the original report by Brown to H. D. MacGinitie of the Carnegie Institution of Washington (Witkind and Marvin, 1989). MacGinitie (as cited by Everden and James, 1964, p.962) determined that the flora of the limestone is of indeterminate age, and could be anything from middle Eocene to Upper Oligocene; therefore, the radiometric ages are not inconsistent with the paleobotanical evidence. Potassium-argon dates of 38.5-29.9 m.y. obtained by Witkind and Marvin (1989) on samples collected from various units within the Chicken Creek Tuff Member further support an Oligocene age for at least units II-IV of the formation. Based on stratigraphic relationships, the lower part of Unit I may be Latest Eocene in age.

The Goldens Ranch Formation is thought to be correlative with the Fernow and Packard Quartz Latites of the East Tintics (Morris, 1975). Hintze (1988) correlates the Goldens Ranch Formation with the nearby Moroni Formation; however, recent work by De Vries (1990) indicates that this is erroneous, and that the Moroni is actually older than the Goldens Ranch. Further study of the volcanic units in the vicinity of the Skinner Peaks quadrangle would supplement the recent work by De Vries (1990), and possibly would answer questions related to age, correlation, and source.

TERTIARY-QUATERNARY SYSTEMS

A variety of alluvial, colluvial, and lacustrine deposits blanket extensive areas of the Skinner Peaks quadrangle (Plate 1). These sediments range in age from Late Tertiary to Recent. They were deposited in response to tectonic and climatic events such as the development of the Gunnison Plateau and West Gunnison Monocline, the onset and continuation of Basin and Range faulting, and the advance and retreat of Lake Bonneville. The following section provides a description of each unit that was mapped; the thickness, age and environment of deposition of each deposit also is discussed.

Older Alluvial Fans and Pediment Alluvium

The Gunnison Plateau and West Gunnison Monocline formed, and Basin and Range faulting began soon after the Goldens Ranch Formation was deposited. These tectonic events produced topographic highs from which sediment was eroded and subsequently deposited in the adjacent valleys. In the Skinner Peaks quadrangle these alluvial deposits are represented by the remnants of old alluvial fans and pediment alluvium.

Sediment that was eroded from the Gunnison Plateau and West Gunnison Monocline was shed off to the west in a series of alluvial fans much like those that have formed in present-day Juab Valley. The uplifted remnants of the old alluvial fans are exposed along the flank of the West Gunnison Monocline in an area that extends from Broad Canyon to the southern end of the quadrangle (Plate 1). The material that forms these deposits is

semiconsolidated, massive to poorly-stratified, poorly-sorted (ranging in size from sand to boulders), and yellowish-gray (5Y 7/2) in color (Figure 32). It is composed predominantly of sandstone, limestone, and conglomerate derived from the Green River Formation (Figure 33), and includes clasts of pebbly sandstone from the Crazy Hollow Formation, and volcanic clasts derived from the Goldens Ranch Formation.

The remnants of the old alluvial fans overlie the Goldens Ranch Formation (Figure 32), Green River Formation and Arapien Shale at various elevations, reflecting deposition over irregular paleotopography. This paleotopography may have been due in part to episodic Basin and Range faulting, which began in the Miocene shortly after development of the plateau and monocline. The thickness of these older alluvial fans varies from a few feet to 300 feet (Vogel, 1957). It is possible that these drastic thickness variations also reflect deposition over irregular paleotopography, with the thickest deposits representing paleo-lows and the thinner deposits representing paleo-highs.

Pediment alluvium, which caps the Goldens Ranch Formation in the South Hills (Plate 1), reflects an old erosional surface that developed during and after uplift of the South Hills area. The pediment alluvium, which is 0-20 feet thick, is very similar in texture and composition (Figure 33) to the material that forms the old alluvial fans to the east. The most noticeable difference is the increased abundance of volcanic clasts, and the local occurrence of red, semi- to moderately consolidated, pebbly sandstone and sandy



Figure 32: Remnants of an old alluvial fan form distinctive yellow caps on hills of Hall Canyon Conglomerate north of Skinner Peaks.



Figure 33: Poorly-sorted, unconsolidated material of an old alluvial fan caps a hill of Hall Canyon Conglomerate north of Skinner Peaks. Most of the boulders are sandstone from the Green River Formation.

limestone. The red, pebbly sandstone and sandy limestone, which occur locally as pods between the Goldens Ranch Formation and the poorly consolidated upper pediment alluvium, may represent local ponds that formed on the erosional surface (Oviatt, per. comm., 1989). Like the old alluvial fans, the pediment alluvium occurs at relatively high elevations, reflecting the uplift and dissection that occurred after deposition.

The distribution of the pediment alluvium and the alluvial fans reflects Lustig's (1969) prediction that areas with larger highlands favor alluvial fan development, and areas with lower highlands favor pediment development.

The age of the older alluvial fans and the pediment alluvium is not known for certain. They are no older than Early Miocene because they formed after the development of the plateau and the onset of Basin and Range faulting. They are no younger than Earliest Pleistocene because Lake Bonneville sediments locally surround the bases of hills that these old alluvial deposits cap.

A solitary alluvial fan (mapped as Qaf in this study) corresponding to Qaf₃ of Clark (1987) was mapped in the NW corner of the quadrangle (Plate 1). This fan is very dissected, faulted, and higher in elevation than a younger fan which surrounds it. It is composed of light-brown, poorly-sorted, clay- to boulder-size material that is subangular to subrounded. The poorly-sorted nature of the deposit, plus its proximity to the mouth of a deeply incised canyon that cuts through the Flagstaff Formation indicate that this fan is a debris flow as Clark (1987) suggested. Clark

(1987) estimates that the fan is at least 50 feet thick. Based on its relatively high elevation, and on the very dissected and faulted nature of the fan, it formed either in the Latest Tertiary or Earliest Quaternary.

QUATERNARY SYSTEM

Older Coalescing Alluvial Fans

Areas covered by old alluvial fans and pediment alluvium were differentially uplifted by Basin and Range faulting and then eroded, leaving only remnants of these old alluvial deposits capping the hills along the flank of the monocline (Figure 32) and in the South Hills (Plate 1). The material that was eroded from these uplifted areas was deposited as a series of coalescing alluvial fans that fill present-day Juab Valley. Material that was derived from the South and West Hills was shed primarily to the east, although some was deposited in the low spots to the west of the South Hills. Material derived from the Gunnison Plateau was shed into Juab Valley to the west. As Clark (1987) noted, the fans from the Gunnison Plateau are significantly larger than those emanating from the West and South Hills; consequently the convergence line of the two fan systems lies west of the center of Juab Valley.

Coalescing fan alluvium is reddish-brown to yellowish-gray, unconsolidated, poorly-sorted, and massive to crudely bedded; local channels suggest a fluvial environment of deposition. Material is clay- to boulder-size, although sand- and pebble-size material is most common; grain size decreases in a down-fan direction.

Quartzite, limestone, sandstone, and volcanic rocks form the majority of the pebble- and cobble-size clasts. Data from a gravity survey (Zoback, 1983) across northern Juab Valley indicates that alluvial fan deposits are approximately 3,900 feet thick in that portion of the valley. Since Juab valley shallows to the south, the equivalent deposits in the Skinner Peaks area to the south are probably thinner than those to the north.

The youngest sediment contained in the coalescing fans was deposited on the fan surfaces during Recent time; the oldest sediment contained in these fans was probably deposited in the Late Tertiary, although there is no observable evidence to confirm this. Lake Bonneville sediments overlap coalescing fan deposits in the southwest corner of the quadrangle (Plate 1), indicating that the deposits must be at least as old as Earliest Pleistocene.

Lake Bonneville Sediments

Lake Bonneville was the largest Late Pleistocene pluvial lake in the western United States (Benson and Thompson, 1987). In 1890 G. K. Gilbert produced the first comprehensive physiographic study of Lake Bonneville (Hunt, 1980), which consequently became the foundation for all subsequent studies. The most recent studies of the deposits and geomorphic features produced by Lake Bonneville are by Scott, McCoy, and Shroba (1983), Scott, McCoy, Shroba, and Rubin (1983), Scott and others (1980), Currey (1982), Currey and others (1984), Currey and others (1983a,b), Oviatt (1984), and McCoy (1987).

Lake Bonneville reached its highest level, known as the Bonneville Stage, approximately 16,000-17,000 yrs. B.P. (Scott and others, 1983a; Spencer and others, 1983). During this stage the lake was approximately 1,000 feet deep, covering an area of approximately 20,000 square miles (Smith and Street-Perrot, 1983; Benson and Thompson, 1987; Hintze, 1988) that included parts of northwestern Utah, southeastern Idaho, and northeastern Nevada (Figure 34).

As the lake rose to the Bonneville Stage, water spilled through Leamington Canyon (Figure 34), drowning the Sevier River and forming a fresh-water estuary (Oviatt, personal comm., 1989) that extended almost as far south as Redmond (Currey, 1982). The eastern shore of this estuary cut across the southwestern corner of the Skinner Peaks quadrangle (Figure 34). Sediments deposited in the estuary are exposed in the low, gently-sloping, dissected, fan-shaped patches in the Washboard and in wave-cut cliffs along the Sevier Bridge Reservoir (Plate 1). These sediments occur up to an elevation of 5,090 feet, which was the overflow elevation of the lake during the Bonneville Stage (Currey, 1982). A change in vegetation pattern that is best observed on aerial photos also occurs between 5,090-5,100 feet. It is presumed, based on this elevation, that this change in vegetation marks the shoreline of Lake Bonneville. It also is presumed, on the basis of elevation, that water from Lake Bonneville spilled through Mills Gap and flooded the Chicken Creek Reservoir area. There are no deposits or shoreline features to substantiate this, but it is possible that Lake Bonneville

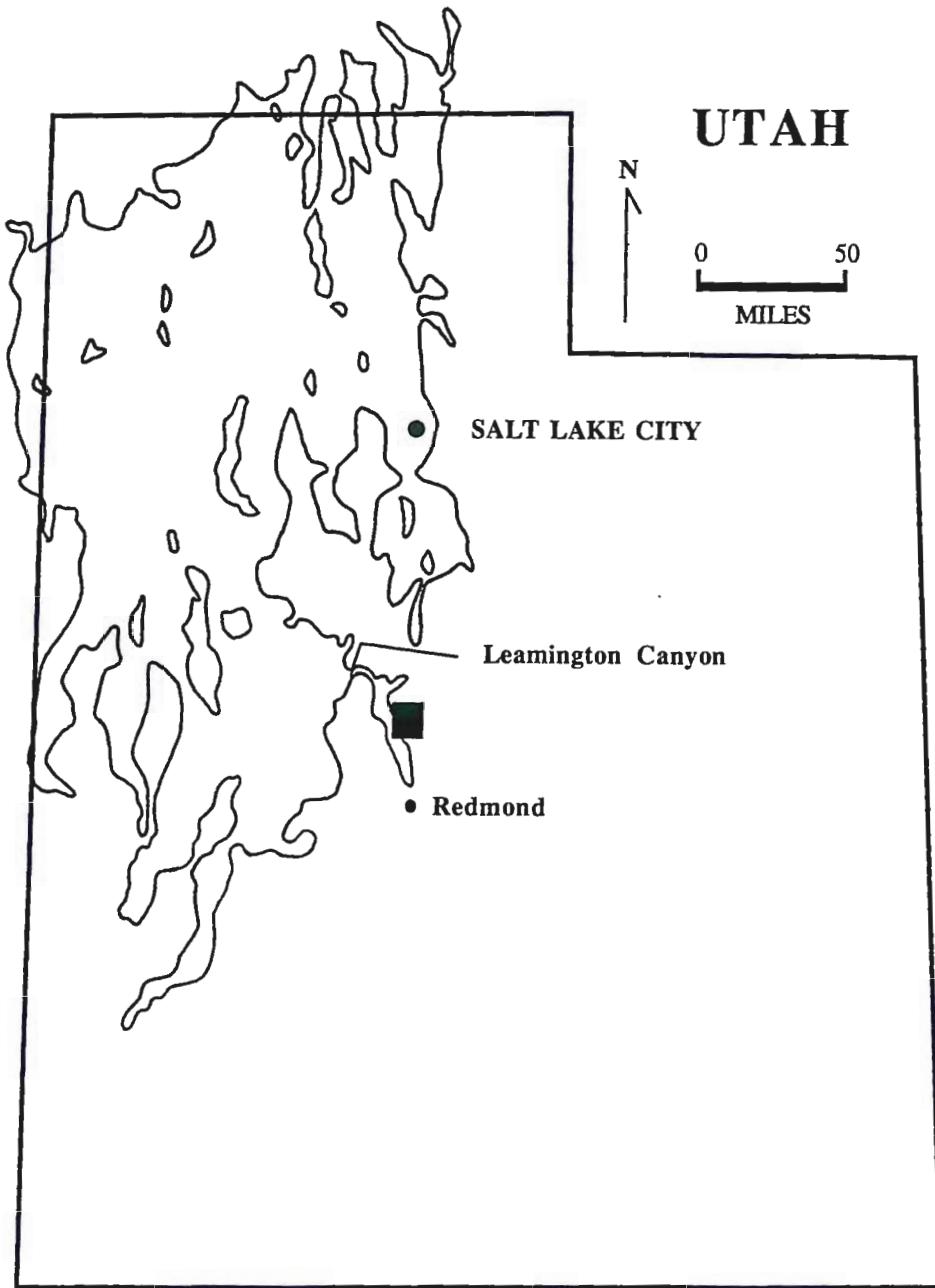


Figure 34: Map showing the extent of Lake Bonneville during the Bonneville Stage. The Skinner Peaks quadrangle is represented by the black rectangle. (Modified from Hintze, 1988.)

sediments and shoreline features were there once but have been obliterated since by present-day Chicken Creek Reservoir.

Lake Bonneville existed at the Bonneville Stage for approximately 2,000 years before it finally eroded through the Zenda Threshold at Red Rock Pass in southern Idaho. The resultant deluge of water, known as the Bonneville Flood, catastrophically lowered the level of the lake approximately 350 feet (Currey, 1982)--an amount that was sufficient to drain the estuary, leaving the sediments exposed.

When Vogel mapped the Skinner Peaks quadrangle in the mid-fifties, he acknowledged the presence of the Lake Bonneville sediments, but did not differentiate them from the rest of the Quaternary alluvium "due to lack of good exposure and contacts..." (Vogel, 1957, p. 106). Although exposures are poor except along the Sevier Bridge Reservoir, the sediments themselves are fairly distinctive (especially on aerial photos) and can be distinguished from the surrounding alluvium without much difficulty. Poor exposures obscure the nature of the contact between the Lake Bonneville sediments and the surrounding alluvium, but at one location (section 30, T. 16 S., R. 1 W.) the lake sediments clearly overlap the Quaternary-Tertiary pediment alluvium. Elsewhere (e.g., in the Washboard; Plate I), the Bonneville sediments are slightly higher than the adjacent alluvium which suggests deposition of the Lake Bonneville sediments on top of the adjacent alluvium. This observation is consistent with the relationships observed by Mattox

(1986) in the Hells Kitchen Canyon SE quadrangle, 10 miles southeast of the present study area (Figure 2).

The Bonneville sediments are light brown, unconsolidated, coarse- to fine-grained sand, silt, and mud. These sediments form a fining-upward sequence that is 30-60 feet thick, and composed mostly of silt and mud. Deposits are finely laminated and cross-laminated; soft-sediment deformation structures (Figure 35a) and ripple cross-lamination (Figure 35b) are common near the base of the exposed section. These characteristics, combined with the lack of foreset and bottomset beds, fit Oviatt's (1984) description of underflow fan deposits, which are similar to deltaic deposits.

Oviatt (1984) recognized from his work at the Old River Bed and Leamington Canyon, that even though a large portion of the sediments had accumulated under deltaic conditions, the deposits lacked many of the sedimentary structures and facies that are commonly associated with deltas. Gilbert-type deltas are characterized by topset, foreset, and bottomset beds. They are commonly gravelly, with the fluvial component present at the top of the sequence, and they grow by prograding into the lake (Oviatt, 1984). Based on the lack of these characteristic features, Oviatt (1984) concluded that the deposits he was studying more closely represented an underflow fan than a Gilbert-type delta. Underflow fans lack true foreset and bottomset beds, and the fluvial component is at the base of the sequence (Oviatt, 1984, p. 13). The deposits are characterized by finely cross-bedded and rippled sand, and massive to laminated silt and clay (Baker, 1967, p. 34; Brophy,



Figure 35A: Soft-sediment deformation structures in basal Lake Bonneville sediments exposed along the Sevier Bridge Reservoir.



Figure 35B: Lamination and ripple cross-lamination in basal Lake Bonneville sediments exposed along the Sevier Bridge Reservoir.

1967, p. 102); they generally form a fining-upward sequence (Oviatt, 1984). This type of fan is deposited by the turbid (and possibly cold) water of a tributary river that enters and flows along the bottom of a lake as a density current (Kehew and Clayton, 1983, p. 208).

Younger Coalescing Alluvial Fans

A series of younger coalescing alluvial fans rests on top of older coalescing alluvial fans north of Little Salt Creek Canyon (Plate 1). The younger fans are very similar to their older counterparts; however, they are considerably smaller in size, and they slope more steeply toward the valley. The composition of these younger fans is also different from their older counterparts; most of the material is angular, pebble-size fragments of limestone that were derived from the Arapien Shale. These deposits are only 50-100 feet thick.

Younger alluvial fans, such as those that are found north of Little Salt Creek Canyon, form in response to climatic or tectonic changes that lower base level (Pazzaglia and Wells, 1989; Bull, 1990). In the Skinner Peaks area base level could have been lowered by the retreat of Lake Bonneville, continued Basin and Range faulting or a combination of both of these events.

The very local occurrence of the younger alluvial fans suggests that they formed in response to renewed uplift along a fault segment and not in response to the regional lowering of base level that would have resulted from the retreat of Lake Bonneville. This hypothesis is supported by the presence of Recent fault scarps

that cut the older coalescing alluvial fans (Plate 1); however the older coalescing alluvial fans in Juab Valley and the Lake Bonneville sediments are incised by gullies that are as much as 15 feet deep, which suggests a regional lowering of base level. Perhaps the deep gullies are an expression of a regional lowering of base level that was due to the retreat of Lake Bonneville, and the younger alluvial fans reflect Recent Basin and Range activity on a local fault segment. Assuming that these younger alluvial fans are related to the Basin and Range faulting that produced the fault scarps, the age of these fans is Late Pleistocene to Recent.

Colluvium, Alluvium, and Landslide Deposits

The youngest sediments in the quadrangle are colluvium, alluvium, and landslide deposits, which are all Recent in age. The colluvium forms steeply-sloping, cone-shaped deposits along the base of the slopes from which it was derived (Plate 1). It is unconsolidated, very angular, very poorly-sorted, clay- to boulder-size material. The color and composition of these deposits reflect the formation or formations from which they were derived. These deposits are 0-15 feet thick.

The alluvium occurs along most drainages; at higher elevations, such as Flat Canyon and the South Hills, it forms broad, even surfaces of low relief. Like the colluvium, the composition and color of the alluvium reflect the local bedrock from which it was derived. In most cases it is unconsolidated, gray or brown in color, and massive to poorly stratified. Alluvial material is clay- to

cobble-size, subangular to subrounded, and poorly- to well-sorted. These deposits are generally less than 30 feet thick.

Two landslides are the only mass-movement deposits that were observed in the Skinner Peaks quadrangle (Plate 1). One of the landslides occurred on the north side of Chriss Canyon in the SE 1/4 of section 11, T. 16 S., R. 1 W., the other is located south of Skinner Peaks in the SE 1/4 of section 22, T. 16 S., R. 1 W.

(Figure 36). Both of these landslides occurred in strata of the Green River Formation and consequently are composed of very angular, poorly-sorted blocks of carbonate and sandstone in a matrix of mudstone. The Chriss Canyon landslide occurred in 1984 (Weiss, per. comm., 1989) after a period of heavy rain. Presumably the Skinner Peaks landslide, which is as fresh as the Chriss Canyon landslide, also occurred in 1984.

IGNEOUS INTRUSIONS

Two small intrusions of hornblende monzonite porphyry occur in the Arapien Shale. One is located in the NW 1/4, NE 1/4 of section 36, T. 15 S., R. 1 W., and the other is located in the SW 1/4, SE 1/4 of section 25, T. 15 S., R. 1 W. These intrusions are not very resistant, and they weather to a grus-like talus that is black or dark-gray due to the abundance of hornblende. These and other intrusions in the vicinity were classified as dikes by Vogel (1957), Zeller (1949) and Hunt (1950).

Two thin sections of the intrusions were examined under a petrographic microscope. Approximately 65% of the rock is



Figure 36: A landslide in the Green River Formation just south of Skinner Peaks. Note the headwall scar and the hummocky topography.

composed of phenocrysts, and the other 35% is a light-colored, aphanitic groundmass of highly altered plagioclase and orthoclase. Approximately 75% of the phenocrysts are hornblende; feldspar and magnetite make up the remaining 5%. The hornblende phenocrysts occur as euhedral to subhedral laths that range from 0.01 to 2.5 cm in length. Most feldspar phenocrysts are blocky, subhedral to euhedral, highly altered plagioclase crystals.

These intrusions are post-Jurassic in age based on the cross-cutting relationships in the Skinner Peaks quadrangle. Witkind and others (1987) cite an Oligocene(?) to Upper Eocene age for similar intrusions in the vicinity; however, the relationship of these intrusions to Tertiary units is not exposed in the Skinner Peaks quadrangle.

STRUCTURAL GEOLOGY

Introduction

The Skinner Peaks quadrangle lies in the transition zone between the Colorado Plateau and the Basin and Range provinces (Spieker, 1949; Figure 1, this study). The Southern Wasatch Mountains, which represent the southern end of the Middle Rocky Mountains, lie approximately 15 miles to the north (Figure 1). The quadrangle is also just west of the leading edge of the Sevier fold-and-thrust belt (Standlee, 1982; Lawton, 1985). Consequently, the structural geology of the quadrangle is complex, and consists of superposed tectonic events related to the leading edge of the Sevier fold and thrust belt, the formation of the Gunnison Plateau and West Gunnison monocline, and Basin and Range faulting; evidence indicates that local diapirism of the Arapien Shale also occurred throughout the structural development of central Utah (Stokes, 1952, 1982; Witkind, 1982, 1983).

The major structures which represent the Colorado Plateau and Basin and Range provinces in the Skinner Peaks quadrangle are the West Gunnison Monocline, Juab Valley Graben, Flat Canyon Graben, north-south trending normal faults, and east-west dipping fault blocks. Rootless fault-blocks of Green River Formation floating in Arapien Shale, and other evidence suggests that the structure of the area may have been modified locally by diapiric movement of the Arapien Shale.

A discussion of the tectonic processes that affected the study area is presented in the following section, along with a discussion of the resultant structures.

SEVIER OROGENY

The Sevier Orogeny, which began in the Late Jurassic and continued into the Paleocene (Armstrong, 1968), was characterized by eastward-directed thrusting which placed Precambrian, upper Paleozoic, and lower Mesozoic strata over strata as young as Middle Jurassic. Middle Jurassic marine shales such as the Arapien are structurally incompetent and consequently acted as glide planes for the thrusting that built the Sevier Highland.

Sevier-Related Structures in the Skinner Peaks Quadrangle

Recent studies based on subsurface data (Standley, 1982; Lawton, 1985) confirm Spieker's (1949) idea that deformation related to the Sevier Orogeny occurs as far east as the Wasatch Plateau (Standley, 1982; Lawton, 1985). Subsurface data collected from drill-holes in and adjacent to the study area (Figure 9, Table 2) reveal several thrust faults that are related to Sevier thrusting (Standley, 1982; Lawton, 1985; Clark, 1987). Standley (1982), and Lawton (1985) constructed several interpretive cross-sections (Figure 37a, b) across Juab Valley, the Gunnison Plateau, and Sanpete Valley based on subsurface data, and their interpretations are very similar.

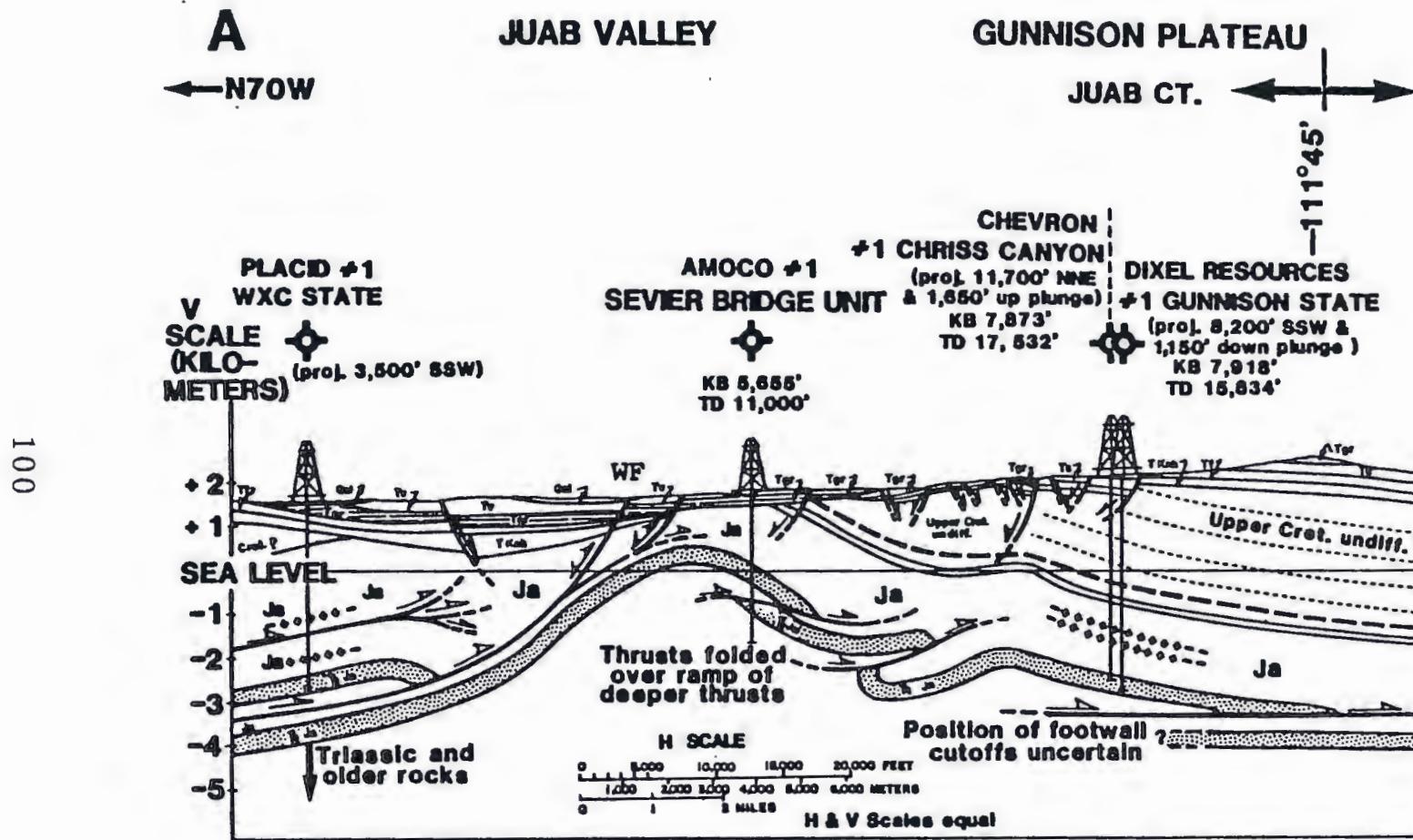


Figure 37A: Cross-section from the West Hills to the Gunnison Plateau. (See Figure 9, cross-section A-A'; From Standlee, 1982.)

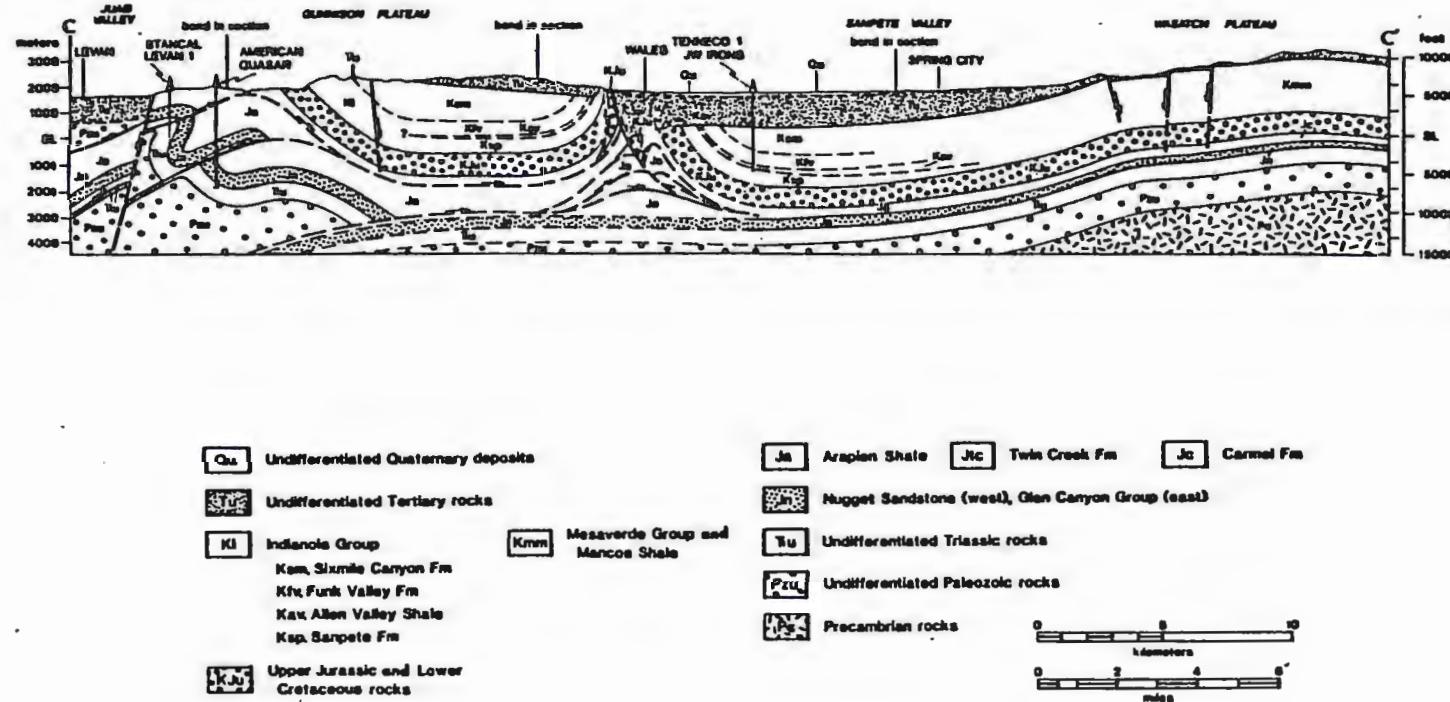


Figure 37B: Cross-section from Juab Valley to the Wasatch Plateau along approximately the same line as cross-section A-A' of Figure 9. (From Lawton, 1985.)

Despite the subsurface evidence for Sevier-related thrusting in the Skinner Peaks area, no direct evidence of thrusting was observed in outcrop. It is possible, however, that the highly deformed strata of the Arapien, and the unconformity that occurs between the Arapien and the North Horn(?), Green River, and Goldens Ranch Formations may be related to the Sevier orogenic event.

A recent study by Sims and Morris (1989) indicates that thrusting of a competent unit over an incompetent unit (e.g., the Sevier fold-and-thrust belt) will cause the incompetent unit to shorten and thicken close to the hinterland, and uplift will occur over the thickened region. As a result, the incompetent unit should be highly deformed, as is the Arapien Shale. Another possible result of this process is the formation of topographic highs in the area of thickening. Standlee (1985, per. comm. to S. Mattox) suggested that thrusting and folding indirectly may have caused the local Indianola highs observed by Weiss (1969) and Mattox (1986). It is also possible that the paleo-highs are the result of diapiric movement of the Arapien Shale. Differential loading or tectonic activity is often necessary to initiate diapirism (Lemon, 1985; Jackson and Talbot, 1986); the influx of coarse-grained clastics from the highland to the west, and the eastward directed thrusting that was occurring at this time would have provided both of these mechanisms. Regardless of which explanation is correct, the idea of local, thrust-related Arapien highs in the vicinity of Skinner Peaks and Little Salt Creek Canyon offers a reasonable explanation for the

unconformable contacts that occur between the Jurassic Arapien and strata of the North Horn(?), Green River, and Goldens Ranch Formations.

Thrusting versus Diapirism

Eastward-directed thrusting (Spieker, 1949; Standlee, 1982; Lawton, 1985) and large-scale evaporite diapirism (Stokes, 1952, 1982; Witkind, 1982; Baer, 1976) are the two mechanisms commonly employed to explain the post-Sevier structural development of central Utah. Both of these explanations involve the evaporite-rich Middle Jurassic Arapien Shale. Therefore, understanding the Arapien Shale is essential to understanding the structural history of central Utah.

Throughout central Utah the evaporite-rich Arapien Shale is commonly intensely deformed (Black, 1965; Hardy, 1952; Witkind, 1982), unlike adjacent units which are often only slightly deformed. The thickness of the Arapien is also quite variable (Eardley, 1933; Spieker, 1946; Hardy, 1952; Sprinkel, 1982), and numerous stratigraphic unconformities between younger strata and the Arapien have been documented (Zeller, 1949; Witkind, 1982; Standlee, 1982).

Stokes (1952, 1982) noted similarities between the monoclinal structures of the plateau region of central Utah and the salt dissolution structures of the Paradox Basin to the east. Stokes (1952, 1982) subsequently proposed that diapirism and collapse of the evaporite-rich Arapien Shale, which underlies much of central

Utah, may have produced the monoclinal structures of central Utah. Witkind (1982, 1983) supported Stokes' idea and noted that the chaotic structure, variable thickness, and numerous unconformities associated with the Arapien further substantiated the idea of diapirism and collapse as a mechanism for the formation of the central Utah monoclines. This idea of diapirism contradicts the ideas of Spieker (1949), who proposed that the unconformities and monoclines were the result of thrusting, monoclinal flexing, and normal faulting. Thrusting models that support and expand on Spieker's ideas have been proposed recently by Standlee (1982) and Lawton (1985). Mattox (1986) presents a thorough discussion of the various thrusting models, which he subsequently compares to the salt diapir model.

After critically evaluating the studies of Standlee (1982), Lawton, (1985), Stokes (1982), Witkind (1982, 1983), and the discussion outlined by Mattox (1986) I have concluded that large-scale diapirism of the Arapien Shale did not produce the major structures of central Utah because the geology does not reflect features that are characteristic of diapiric structures (Stokes, 1982; Witkind, 1982, 1983; Jackson, 1985; Lemon, 1985). It is certainly possible, however, that local diapirism of the Arapien was a significant factor in modifying the structure of the area. Evidence supporting this conclusion is presented in the section titled "Diapirism of the Arapien Shale".

DEVELOPMENT OF THE GUNNISON PLATEAU

In the Skinner Peaks quadrangle the Colorado Plateau Province is represented by the Gunnison Plateau, which terminates as the West Gunnison Monocline inside the east edge of the quadrangle. The West Gunnison Monocline is approximately 18 miles long, and it extends from Fayette Wash in the Hells Kitchen Canyon SE quadrangle (Figure 2) to Buck Canyon, north of Little Salt Creek Canyon (Mattox, 1986).

West Gunnison Monocline

The West Gunnison Monocline consists of Green River Formation and Goldens Ranch Formation strata which dip 25 to 30 degrees to the west or southwest (Plate 1). Dips of 55 degrees and greater were observed in Green River strata on Skinner Peaks, but these values are anomalously high and may reflect diapiric modification by the underlying Arapien Shale.

A thick section of Arapien Shale cores the monocline and extends eastward under the synclinal structure of the plateau. In general, the Arapien is highly deformed, and attitudes are quite variable (Plate 1). Vogel (1957) stated that the prevailing dip of the Arapien is to the west except near Skinner Peaks where attitudes represent an anticlinal flexure. Structural data collected from the Arapien in this study are extremely variable and do not support either of Vogel's (1957) statements. Attitudes measured in a relatively undeformed section below the Arapien-Green River unconformity south of Little Salt Creek Canyon dip consistently 40

to 45 degrees SE; these attitudes are consistent with those observed by Zeller (1949) in Arapien strata east of the Skinner Peaks quadrangle.

Based on the interpretations of Standlee (1982) and Lawton (1985), the Arapien core of the monocline represents a ramp structure that formed during Sevier thrusting; it is likely that the variable attitudes of the Arapien strata reflect deformation due to the thrusting event, as well as later modification by thrusting-induced diapirism.

The West Gunnison Monocline and the Gunnison Plateau formed in the Late Oligocene(?) shortly after deposition of the Goldens Ranch Formation. The timing of this event is constrained by the Oligocene Goldens Ranch Formation, which represents the youngest strata on the monocline. The conformable contact between the Green River Formation and overlying Goldens Ranch Formation indicates that monoclinal warping had not begun prior to deposition of the Goldens Ranch Formation.

The cause of the monoclinal warping that formed the Gunnison Plateau and West Gunnison Monocline is unclear. Vogel (1957) suggests that it is related to Basin and Range normal faulting, and Witkind (1982, 1983) attributes the deformation to the collapse of a salt diapir. If the formation of the monocline and plateau are related to Basin and Range extension, this indicates that the onset of Basin and Range faulting occurred in the Late Oligocene.

BASIN AND RANGE EXTENSION

Basin and Range extension produced north-south trending, high angle normal faults that dissected the landscape of Nevada and western Utah into a series of fault blocks that dip approximately 20 degrees (Stewart, 1980) in a general west or east direction. The faults are often nearly vertical, although in some cases they become listric or low-angle at depth. The major Basin and Range normal faults or fault zones in the Skinner Peaks quadrangle are the Sage Valley Fault, the Western Juab Valley Fault Zone (WJVZ), and the Wasatch Fault Zone (WFZ). Smaller normal faults also dissect the area (Plate 1).

The Sage Valley Fault is a high-angle, down-to-the-west fault which bounds the west side of the West Hills (Plate 1). This fault is discussed in detail by Clark (1987). The WFZ, (down-to-the-west) bounds the west edge of the West Gunnison monocline, and the east edge of Juab Valley; the west edge of Juab Valley is bounded by the WJVZ (down-to-the-east). The structure of Juab Valley is discussed below.

Juab Valley Graben

Recent gravity and seismic data presented by Zoback (1983) indicate that Juab Valley is an asymmetric graben that is bounded on the west by the Western Juab Valley Fault Zone (WJVZ) and on the east by the Wasatch Fault Zone (WFZ). These fault zones are characterized by down-to-the-east and down-to-the-west movement, respectively. Outcrop evidence for the existence of the

WJVFZ is sparse. A fault that offsets Goldens Ranch strata near the Chicken Creek Reservoir in section 19, T. 15 S., R. 1 W. may represent the WJVFZ. Outcrop evidence for the WFZ is more obvious, and is manifest as fault scarps in Pleistocene alluvial fans, and truncated or faceted spurs of Arapien south of Little Salt Creek Canyon (Plate 1).

Vogel (1957) suggested that Juab Valley was underlain by a broad syncline that had been modified extensively by Basin and Range normal faulting. In Vogel's model the west-dipping strata of the West Gunnison Monocline formed the east limb of the syncline, and the east-dipping strata of the West and South Hills formed the west limb.

Basin and Range normal faulting not only affected Juab Valley, but it also affected the structure of the West Gunnison Monocline by dissecting the west-dipping strata into a series of west-dipping fault-blocks that are bounded by north-south-trending normal faults. Strata in the southern end of the quadrangle have been affected most noticeably. Other Basin and Range related structures in the quadrangle include the Sage Valley Fault, which is the bounding fault on the west side of the West Hills, and numerous vertical joints in Green River and Goldens Ranch strata. The joints, which trend approximately 30 degrees west and east of north, probably represent shear fractures that formed due to east-west extension.

DIAPIRISM OF THE ARAPIEN SHALE

Although diapiric movement of the Arapien did not form the major structures of central Utah, evidence throughout the quadrangle indicates that diapiric movement of the Arapien did modify the structure of the area locally. This local, episodic diapirism was probably initiated by tectonic events such as Sevier thrusting, development of the West Gunnison Monocline, and Basin and Range extension. Structures that are related to diapirism are discussed below.

Flat Canyon Graben and Skinner Peaks

Flat Canyon Graben is an interesting structure that may represent an extensional graben that has been modified by diapiric collapse. This structure is approximately one mile wide. It begins near Timber Canyon in the Hells Kitchen Canyon SE quadrangle (Figure 2) and extends north to Chriss Creek, where it bends to the west (Plate 1). This graben is bounded on the east by the high-angle, down-to-the-west normal fault which parallels the southwest front of the Gunnison Plateau. This fault, termed the Valley fault by Mattox (1986), is thought to be the terminus of the Wasatch Fault Zone (Vogel, 1957; McKee and Arabasz, 1982). It down-drops Hall Canyon Conglomerate against Flagstaff and Green River strata (Plates 1 and 2). The west edge of the graben is bounded by a down-to-the-east normal fault which down-drops the Hall Canyon Conglomerate against Green River and Arapien strata (Plates 1 and 2).

The interesting point concerning this graben is the westward bend that it makes when it reaches Chriss Canyon (Plate 1). The bend in the graben parallels the northwest trend of Skinner Peaks, which cuts across the otherwise north-south trending structures that are related to the Basin and Range-Colorado Plateau provinces. The graben, like Skinner Peaks, is underlain by Arapien Shale. The presence of the Arapien in the subsurface beneath the Flat Canyon graben is manifest in salty well water and sink holes (W. Jay Dalley, landowner, per. comm., 1989). It seems reasonable to assume from this evidence that the structure of the Flat Canyon Graben is controlled in part by diapiric collapse of the Arapien. It also seems reasonable to assume, based on the timing of the event, that the mobility of the Arapien was triggered by Basin and Range faulting.

Rootless fault blocks of Green River formation can be observed "floating" in Arapien Shale on the flanks of Skinner Peaks in the NE 1/4 of section 22, and the SW 1/4 of section 15 T. 15 S., R. 1 W.. These blocks are similar to the detached blocks of Colton and Green River Formation described by Willis (1986) approximately 30 miles to the south in the Salina quadrangle. I concur with Willis' (1986) interpretation that these detached blocks are slump blocks which, in this case, slid off of the Skinner Peaks block.

A small syncline in Green River strata that unconformably overlie the Arapien Shale in the NE corner of the Skinner Peaks quadrangle is also thought to have formed by diapiric movement of the Arapien (Sprinkel, per. comm., 1989). Contacts between the Arapien and overlying units are often sheared, with slickensides

and well-foliated clays similar to those described by Willis (1986) in the Salina quadrangle. These contacts are also indicative of movement.

Other Structures

Other structures that occur throughout the quadrangle include high-angle cross-faults (Figure 38) such as those in the West Hills, and the scissors(?) fault which parallels Old Botham Road in the South Hills area (Plate 1). These structures are possibly related to local strain accomodation that occurred during Basin and Range extension.

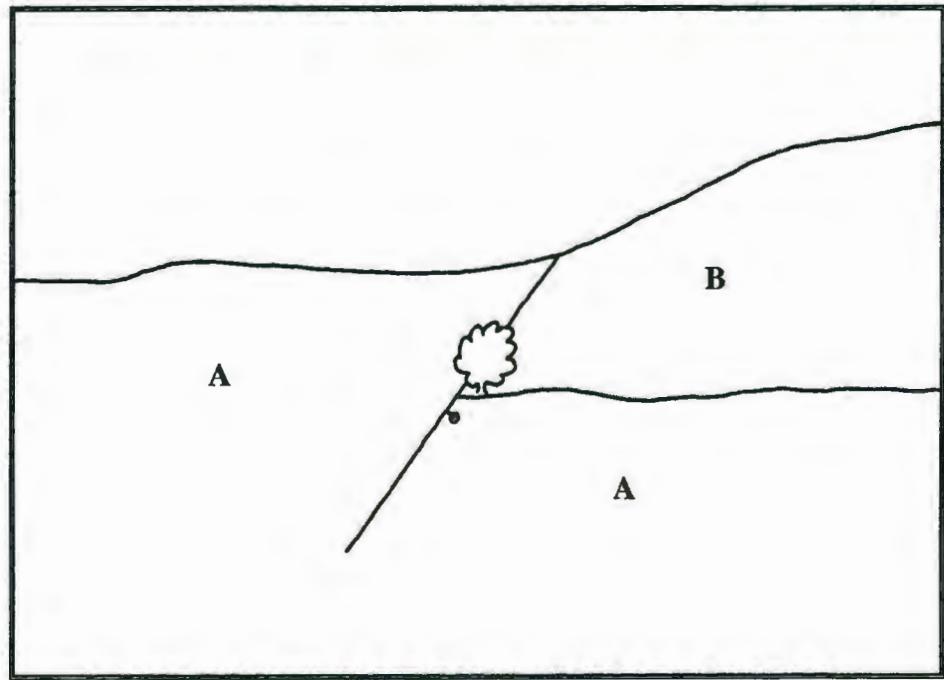


Figure 38: Green River Formation strata offset by a high-angle fault in the West Hills north of Mills Gap.

ECONOMIC GEOLOGY

Economic deposits in the Skinner Peaks quadrangle and vicinity include sand and gravel, gypsum, tuff, carbonate rock, manganese, petroleum products, and water. The sand and gravel occurs as alluvial, colluvial, and lacustrine deposits. Material ranges in size from clay to boulders; most material is sand and gravel composed of quartzite and carbonate clasts, with local concentrations of volcanic clasts. The sand and gravel, which is used primarily as road ballast, is quarried from numerous gravel pits throughout the quadrangle (Plate 1).

Active quarrying of gypsum from the Arapien Shale on the NE side of Skinner Peaks (Figure 10) began in (1989). This gypsum can be used in the production of dry-wall or as a bonding agent in cement.

Tuff from Unit IV (Tvg_4) of the Goldens Ranch Formation formerly was quarried south of Skinner Peaks and in the Painted Rocks area for use as poultry grits, and soil mineralizer and conditioner (Vogel, 1957). This operation was run by the Azome Utah Mining Company of Sterling, Utah, and the products were marketed under the trade name "Azomite" (Vogel, 1957).

Carbonate rock that is found in the Flagstaff Limestone and Green River Formation possibly could be used as building or dimension stone. Unfortunately, in the Skinner Peaks quadrangle neither of these formations contain sufficient amounts of limestone or dolomite to make quarrying a profitable economic venture

because both formations contain anomalously high amounts of coarse-grained clastic material.

Small amounts of manganese occur in fault zones within the volcaniclastic Goldens Ranch Formation. The manganese occurs as dendritic pyrolusite in a calcite matrix. Pyrolusite is a secondary mineral that results from the alteration of manganese minerals (Edwards and Atkinson, 1986) which are present in small amounts in most crystalline rocks (Hurlbut and Klein, 1971). The manganese that forms the pyrolusite was probably leached from the surrounding Goldens Ranch Formation and deposited with calcite along the fault zones.

Oil and gas exploration has taken place throughout central Utah because of the structural similarities between it and the producing overthrust belt of Wyoming (Clark, 1987). Several oil companies have drilled test wells in Juab Valley and on the Gunnison Plateau in SE Juab County; no productive reservoirs have been discovered to date.

Water resources are somewhat limited in the Skinner Peaks quadrangle. Surface water occurs in the Chicken Creek and Sevier Bridge Reservoirs, in Chicken Creek, and as small springs in the vicinity of the Skinner Peaks (Plate 1). Depth to the top of the water table is more than 100 feet (Bjorklund and Robinson, 1968) in the area of Juab Valley that lies between the South Hills and the west margin of the Gunnison Plateau (Plate 1).

GEOLOGIC HAZARDS

Earthquakes, mass movements, karst development, and groundwater contamination are the potential geologic hazards in the Skinner Peaks quadrangle and vicinity.

The Skinner Peaks quadrangle is centered roughly on the Wasatch Fault Zone, which is part of the Intermountain seismic belt (McKee and Arabasz, 1982); the potential for catastrophic earthquakes is high. Earthquakes may result in destructive ground shaking, surface rupture of alluvium, soil liquefaction, and differential settling (Clark, 1987); they also may trigger mass movements such as snow avalanches and landslides. Landslides also may occur simply because strata are incompetent or poorly consolidated. Heavy rain or large volumes of melt-water moving over steep, sparsely-vegetated mudstone slopes may result in mass wasting.

The development of karst topography and contamination of groundwater are both related to the Arapien Shale. The evaporite-rich Arapien underlies much of the Skinner Peaks quadrangle. Groundwater moving through the Arapien dissolves the evaporites, causing surface collapse and subsequent formation of sink-holes; evaporite dissolution also results in the contamination of the groundwater. Land-owner W. Jay Dalley reported the development of sink-holes and collapse structures in hay fields in Flat Canyon (Plate 1); he also reported salty water in a stock well in Flat Canyon. Vogel (1957) and Hunt (1950) cite similar reports from local residents concerning the quality of well water.

GEOLOGIC HISTORY AND INTERPRETATIONS

Aspects of the geologic history of the Skinner Peaks quadrangle were discussed throughout the stratigraphy and structural geology sections of this manuscript. A brief synopsis of the geological history is presented here along with interpretations concerning the structure and stratigraphy of the quadrangle.

The Precambrian through Early Jurassic interval was dominated by deposition of marine and continental sediments in the Cordilleran miogeocline. These rocks are not exposed as bedrock in the quadrangle, but they do occur in the subsurface, and as clasts in conglomerate of the North Horn, Flagstaff, Colton, Green River, and Goldens Ranch Formations. The oldest exposed strata are the marine shales of the Middle Jurassic Arapien Shale. The sediments that comprise these strata were deposited by a shallow arm of the sea which advanced from Canada, through central Utah and into northern Arizona. By the Late Jurassic this sea had retreated to the north. Compression caused by the subduction of the Pacific Plate under the North American Plate also started to affect central Utah around this time. Eastward-directed thrusting placed Precambrian, Paleozoic, and Mesozoic strata over the incompetent Arapien Shale which acted as a glide plane. This thrusting built the Sevier Highland and corresponding foreland basin.

In Middle and Late Cretaceous time, the Skinner Peaks quadrangle, which was located in the foreland basin just east of the Sevier Highland, began to receive sediment that was being eroded from the highland and deposited in the basin as alluvial fans.

Continued thrusting to the east, and the differential loading that was caused by the influx of sediment from the west, initiated diapiric movement of the evaporite-rich Arapien Shale. This local, episodic diapirism produced local topographic highs of Arapien Shale within the basin. Consequently, unconformities developed between the Arapien and various Cretaceous-Tertiary units that were being deposited in the foreland basin. Based on the stratigraphic relationships and the abundance of oncolitic limestone on Skinner Peaks, this area was the site of an actively rising topographic high of Arapien Shale.

The unconformity between the Arapien and the Green River Formation indicates that tectonically activated diapirism continued through the Early Tertiary, during which time the foreland basin was dominated by alternating lacustrine and fluvial conditions which produced the strata of the Flagstaff, Colton, and Green River formations. In the Skinner Peaks quadrangle these formations have an anomalously high clastic fraction because the quadrangle was located along the western margin of the basin.

Wide-spread volcanism dominated the landscape of central Utah in the Oligocene, producing formations such as the volcaniclastic Goldens Ranch Formation. Episodic diapirism was still occurring, based on the unconformable contact between the Arapien and the Goldens Ranch Formation.

The Gunnison Plateau and the West Gunnison Monocline formed in the Late Oligocene after deposition of the Goldens Ranch

Formation. Sediment was eroded from the plateau and monocline, and deposited into coalescing alluvial fans in the basin to the west.

Basin and Range extension began shortly after the formation of the monocline. The extension dissected the area with north-south trending normal faults such as the Sage Valley and Wasatch faults, and produced east- and west-dipping fault blocks. Uplifted areas were dissected and eroded, and the sediment was deposited as alluvial fans in present-day Juab Valley.

In the Pleistocene, Lake Bonneville reached the Bonneville Stage, flooding the Sevier River and depositing underflow fan sediments. Approximately 2,000 years later the lake retreated catastrophically, lowering the regional base level. Active down-cutting through the alluvial fans in Juab Valley, and in stream gullies attests to the change in base level; continued Basin and Range extension also steepened the average regional gradient. Fault scarps that cut alluvial fan deposits, and the formation of secondary alluvial fans are evidence of Recent Basin and Range faulting.

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APPENDIX

Stratigraphic Sections

<u>SECTION</u>	<u>FORMATION</u>	<u>IN FEET</u>	<u>PAGE</u>
Mills Gap	Green River	902.0	132
	Colton		
	Flagstaff		
Painted Rocks	Goldens Ranch	417.0	142
Skinner Peaks	Green River	745.0	148
	Cretaceous-		
	Tertiary undivided		
	Arapien Shale		

Note: Stratigraphic sections are described from top to bottom, and thicknesses were measured in feet.

MILLS GAP SECTION

FLASTAFF LIMESTONE, COLTON, AND GREEN RIVER FORMATIONS

This section was measured on a northeast traverse beginning at the bottom of the cuesta on the north side of the prominent drainage in the N 1/4 of section 13, T. 15 S., R. 1 1/2 W. in the Juab quadrangle. Strata dip 15 degrees SE.

UNIT# & <u>(SAMPLE#)</u>	UNIT <u>THICKNESS</u>	CUMULATIVE <u>THICKNESS</u>	<u>DESCRIPTION</u>
47	4.0	902.0	Stromatolitic limestone, grayish-green (5G 5/2), weathered and fresh; ledge-forming; algal heads up to 2 ft in diameter; contains brown and gray chert nodules; weathers to a hackly surface.
46	11.0	898.0	Sandy limestone, light-gray (N7), weathered; moderate-orange-pink (5YR 8/4), fresh; ledge-forming; sand is subrounded, medium-grained quartz and lithic fragments.

45	8.0	887.0	Conglomerate, grayish-yellow (5Y 8/4), weathered and fresh; ledge-forming; clasts are matrix- supported, rounded quartzite pebbles and cobbles up to 1 ft; matrix is fine- to medium- grained, limey sandstone.
44	52.0	879.0	Mudstone, grayish-yellow (5Y 8/4), weathered and fresh; slope- forming.

GREEN RIVER FORMATION

COLTON FORMATION

43	72.0	827.0	Mudstone, moderate-reddish- brown (10R 4/6), weathered and fresh; local limestone ledges and pebble/cobble lenses.
42	5.0	755.0	Limestone, finely crystalline, yellowish-gray (5Y 7/2), weathered and fresh; ledge- forming.

41	10.5	750.0	Sandstone, pale-red (10R 6/2), weathered; medium-light-gray (N6), fresh; sand is subrounded, medium- to coarse-grained quartz and lithic fragments cemented by calcite.
40	20.0	739.5	Mudstone; similar to unit 34.
39	2.0	719.5	Limestone; similar to unit 35.
38	73.0	717.5	Calcareous mudstone, moderate-reddish-orange (10R 6/6), weathered and fresh; slope-forming; contains pebble and sandstone lenses; sand is fine- to medium-grained quartz and lithic fragments.
37	4.0	644.5	Sandstone, grayish-red (5R 4/2), weathered; moderate-reddish-orange (10 6/6), fresh; ledge-forming, laterally discontinuous, massive; sand is very coarse-grained quartz and lithic fragments cemented by calcite.

36	58.0	640.5	Calcareous mudstone, moderate-reddish-orange (10R 6/6), weathered and fresh; slope-forming; contains a laterally discontinuous sandstone lense; sand is very coarse-grained quartz and lithic fragments; sequence coarsens to pebbles at the top of the lens.
35	5.0	582.5	Sandy limestone, grayish-orange (10YR 7/4), weathered; grayish-orange-yellow (5Y 8/4), fresh; ledge-forming; contains coarse-grained lithic sand and carbonate intraclasts.
34	26.0	577.5	Calcareous mudstone; similar to unit 32.
33	3.0	551.5	Limestone, dense, finely crystalline, medium-light-gray (N6), weathered; light-gray (N7), fresh; ledge-forming.

32 24.0 548.5 Sandstone, pale-brown (5YR
(MG-32) 5/2), weathered; reddish-brown
 (10R 5/4), fresh; muddy; forms
 slopes with local ledges; weathers
 into very friable plates; sand is
 fine- to medium-grained quartz,
 that is cemented by calcite.

COLTON FORMATION

FLAGSTAFF LIMESTONE

31 7.0 524.5 Limestone, finely crystalline,
 very-pale-orange (10YR 8/2),
 weathered and fresh; weathers
 into blocks that have a hackly
 surface.

30 3.5 517.5 Sandstone interbedded with
 calcareous mudstone, pale-red
 (10R 6/2), weathered; grayish-
 orange (10YR 7/4), fresh; ledge-
 forming; sand is fine- to very
 coarse-grained quartz and small
 amounts of lithic fragments.

29 16.0 514.0 Covered slope.

28 2.5 498.0 Sandstone; similar to unit 26.

27 20.0 495.5 Mudstone; similar to unit 3.

26	2.5	475.5	Sandstone; similar to unit 24.
(MG-26)			
25	15.5	473.0	Mudstone; similar to unit 3.
24	2.5	457.5	Sandstone, pale-red (10R 6/2), weathered; grayish-orange (10YR 7/4), fresh; ledge- forming; sand is fine- to medium-grained quartz.
23	26.5	455.0	Sandstone, pale-reddish-orange (10R 5/4), weathered; grayish- orange (10YR 7/4), fresh; slope- forming; weathers into very friable plates; sand is fine- to medium-grained quartz cemented by calcite.
22	4.0	428.5	Sandstone, pale-red (10R 6/2), weathered; grayish-orange (10YR 7/4), fresh; ledge- forming; laminated and cross- laminated; sand is fine- to very coarse-grained, subangular to subrounded quartz cemented by calcite.
(MG-22)			
21	5.5	424.5	Mudstone; similar to unit 3.

20	3.5	419.0	Sandstone with local pebbles; pale-reddish-orange (10R 5/4), weathered; grayish-orange (10YR 7/4), fresh; ledge-forming; laminated and cross-laminated; sand is fine- to very coarse-grained, subangular to subrounded quartz cemented by calcite.
19	53.5	415.5	Platy limestone; similar to unit 12.
18	4.0	362.0	Conglomerate, grayish-yellow (5Y 8/4), weathered and fresh; ledge-forming; clasts are subangular to subrounded pebbles of quartzite and sandstone.
17	9.5	358.0	Sandy dolomite, grayish-orange (10YR 7/4), weathered and fresh; cliff-forming; weathers to a hackly surface.

16	10.0	348.5	Pebbly sandstone, grayish-orange (10YR 7/4), weathered and fresh; cliff-forming; massive with shallow caves; grain size varies from fine sand to pebbles; grains are subangular to subrounded, and cemented by calcite.
15	21.0	338.5	Sandy limestone; similar to unit 12.
14	6.0	317.5	Sandy limestone; similar to unit 6.
13	24.5	311.5	Mudstone; similar to unit 3, except it is grayish-green (10G 4/2), weathered and fresh.
12	41.0	287.0	Sandy limestone, very-pale-orange (10YR 8/2), weathered and fresh; slope-forming; weathers into plates and locally into ledges.
11	4.5	246.0	Sandy limestone, pale-yellowish-orange (10YR 8/6), weathered and fresh; ledge-forming.
10	29.0	241.5	Mudstone; similar to unit 3.

9	4.5	212.5	Sandy limestone, grayish-orange (10YR 7/4), weathered; grayish-yellow (5Y 8/4), fresh; ledge-forming; sand is fine- to coarse-grained, subangular to subrounded quartz and small amounts of lithic sand.
8	10.0	208.0	Sandy limestone with local pebbles and cobbles in the upper 1 ft of the unit; sand is fine- to medium-grained, subangular to subrounded quartz; pebbles and cobbles are subangular to subrounded quartzite and sandstone; similar to unit 4.
7	81.5	198.0	Calcareous mudstone; similar to unit 3.
6	17.0	116.5	Sandy limestone, grayish-orange (10YR 7/4), weathered; grayish-yellow (5Y 8/4), fresh; ledge-forming.
5	19.0	99.5	Calcareous mudstone; similar to unit 3.

4	5.0	80.5	Sandy limestone; yellowish-gray (5Y 7/2), weathered; very-pale-orange (10YR 8/2), fresh; ledge-forming; sand is fine- to medium-grained, subangular to subrounded quartz.
3	31.5	75.5	Calcareous mudstone, yellowish-gray (5Y 7/2), weathered and fresh; slope-forming.
2	20.0	44.0	Mudstone, pale-red-brown (10R 5/4), weathered and fresh; slope-forming.
1	24.0	24.0	Calcareous mudstone, moderate-red-orange (10R 6/6), weathered and fresh.

PAINTED ROCKS SECTION
GOLDENS RANCH FORMATION

This section was measured on a southwest traverse beginning at the bottom of the eastern-most cuesta in the SE 1/4 of section 32, T. 16 S., R. 1 W. in the Hells Kitchen Canyon SE quadrangle. Strata dip 25 degrees w.

UNIT# & <u>(SAMPLE#)</u>	UNIT <u>THICKNESS</u>	CUMULATIVE <u>THICKNESS</u>	<u>DESCRIPTION</u>
14 (PR-14)	47.0	417.0	Vitric lithic tuff, orange to tan, moderately welded, cliff-forming; similar to unit 13, except with more lithic fragments and pumice; pumice clasts range in size from 1.0 inches to 1 ft, is reversely graded, and flattened.

13 45.0 370.0 Vitric lithic tuff, orange to tan,
(PR-13) poorly welded; forms slopes and
 rounded, knobby ledges; crystals,
 lithic fragments and pumice in
 an ash matrix; euhedral crystals
 of biotite, bipyramidal quartz,
 and sanidine; lithic fragments
 (up to 1 inch) of volcanic and
 sedimentary rocks; pumice
 ranges in size from 0.2-1.0
 inches.

UNIT IV

UNIT III

12 89.0 325.0 Epiclastic sandstone, gray,
(PR-12) quartz-rich; massive, with local
 cross-bedding and channels;
 quartz occurs as euhedral to
 subhedral, bipyramidal crystals
 (0.15 inches), and composes 85%
 of the rock; the other 15% is
 composed of lithic fragments (up
 to 1 inch) of varying
 composition.

UNIT III

UNIT II

11	125.0	236.0	Covered slope; float blocks of pink, crystal vitric tuff were observed.
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UNIT II

UNIT I

10 (PR-10)	4.0	111.0	Epiclastic sandstone, yellowish-white; similar to unit 8.
9	5.0	107.0	Covered slope
8 (PR-8)	34.0	102.0	Epiclastic conglomeratic sandstone, blue-gray, ledge-forming; similar to unit 6.
7	10.0	68.0	Epiclastic conglomerate, blue-gray, cliff-forming; grades vertically into epiclastic conglomeratic sandstone; matrix is lithic sandstone similar to unit 1; clasts are angular cobbles (up to 2 ft) of quartzite and volcanic rocks.

6	24.0	58.0	Epiclastic, conglomeratic sandstone, blue-gray, cliff-forming; sandstone is cross-bedded, and is similar to that of unit 1; clasts are subrounded to subangular pebbles and cobbles of volcanic rocks (50%) and quartzite (50%); clasts are concentrated in lenses as channel fill deposits; grades vertically into cross-bedded sandstone.
5	10.5	34.0	Epiclastic conglomerate, blue-gray, cliff-forming; matrix is lithic sandstone similar to unit 1; clasts are subrounded volcanic cobbles that range in size from 0.5-2.0 ft; forms a crude fining-upward sequence.
4	10.0	23.5	Covered slope.

3	5.0	13.5	Epiclastic sandstone, blue-gray, ledge-forming; laminated and cross-laminated; locally conglomeratic; calcite cement; fine- to medium-grained lithic fragments; similar to unit 1; locally it weathers into 1 inch spheres; clasts are angular to subrounded volcanic rocks, up to 5 inches in diameter.
2 (PR-2)	6.5	8.5	Epiclastic conglomerate, blue-gray, ledge-forming; matrix is a lithic sandstone, similar to unit 1; clasts are pebbles and cobbles (up to 7 inches in diameter); they are angular to rounded, and are dominantly composed of volcanic rocks and minor amounts of quartzite.

SKINNER PEAKS SECTION

This section was measured on a southwest traverse beginning on the 5700 ft contour, just south of the jeep trail in the SE 1/4 of section 15, T. 16 S., R. 1 W.; strata dip approximately 30 degrees SW.

UNIT# & <u>(SAMPLE3)</u>	UNIT <u>THICKNESS</u>	CUMULATIVE <u>THICKNESS</u>	<u>DESCRIPTION</u>
13	17.0	745.0	Sandy limestone, grayish-yellow (5Y 8/4); slope-forming.
12	15.0	728.0	Calcareous sandstone, pinkish-gray (5YR 8/1), weathered and fresh; massive, ledge-forming; sand is 80% quartz, subangular to subrounded, moderately-sorted.
11	95.0	713.0	Sandy limestone, variable color; weathers into plates; sand is medium-grained, subrounded quartz.

GREEN RIVER FORMATION

FLAGSTAFF LIMESTONE or NORTH HORN FORMATION

10	50.0	618.0	Interbedded pebble conglomerate and sandstone lenses; sandstone contains algal mat pieces (up to 5 inches) and oncolites; composed of medium-grained, well-sorted, subangular to subrounded quartz; conglomerate clasts are 50% quartzite (rounded tan and purple from the Cambrian Tintic Quartzite, and the Precambrian Mutual Formation) and 50% carbonate (Paleozoic).
9	60.0	568.0	Sandy limestone and sandstone, pale-reddish-brown (10R 5/4); forms a slope with local ledges; sand is medium-grained quartz.
8 (SK-8)	81.0	508.0	Oncolitic limestone, yellowish-gray (5Y 7/2); cliff-forming; oncolites up to 3 inches in diameter.
7	15.0	427.0	Covered slope.
6 (SK-6)	10.0	412.0	Limestone, finely-crystalline, light-gray (N7); massive, ledge-forming.

FLAGSTAFF LIMESTONE or NORTH HORN FORMATION

NORTH HORN FORMATION (?)

5 (SK-5)	55.0	402.0	Conglomerate interbedded with sandstone; cliff and ledge-forming; sandstone is light-gray (N7); composed of medium-grained, subangular to subrounded, well-sorted quartz; locally cross-bedded; conglomerate is clast-supported; 80% of the clasts are subangular to subrounded cobbles composed of Paleozoic carbonates (75%) and Precambrian/Cambrian quartzite (25%); matrix is medium-grained, well-sorted, rounded quartz sand.
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4	220.0	347.0	Conglomerate; cliff and ledge-forming; clasts are subangular to subrounded pebbles, cobbles, and boulders of purple and tan quartzite derived from the Precambrian Mutual Formation and Cambrian Tintic Quartzite respectively; matrix is coarse-grained quartz sand; unit is gray at base, and changes to red up-section.
3	90.0	127.0	Slope covered with rubble of quartzite boulders and cobbles; derived from the conglomerate that is up-slope.

NORTH HORN FORMATION (?)

ARAPIEN SHALE

2	2.0	37.0	Limestone, finely-crystalline, grayish-green (10GY 5/2); ledge-forming; separated from unit 3 by a fault.
1	35.0	35.0	Calcareous mudstone, grayish-green (10GY 5/2).