UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

LITHOSTRATIGRAPHIC RELATIONS, NONMARINE MOLLUSCA, AND DEPOSITIONAL ENVIRONMENTS OF A PORTION OF THE GREEN RIVER AND WASATCH FORMATIONS SOUTH OF THE ROCK SPRINGS UPLIFT, SWEETWATER COUNTY, WYOMING, WITH APPENDICES OF MEASURED STRATIGRAPHIC SECTIONS

BY

John H. Hanley

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CONTENTS

TABLES

FIGURES

PLATES

METRIC - ENGLISH EQUIVALENTS

1	millimeter	= 0.03937	inch
1	meter	= 3.28	feet
1	kilometer	= 0.62	mile

INTRODUCTION

This report discusses lithostratigraphic relations, distribution of nonmarine Mollusca, and depositional environments within the Luman Tongue, Tipton Shale Member, and Wilkins Peak Member of the Green River Formation and the main body and Niland Tongue of the Wasatch Formation (all early Eocene) in a 250 square mile area in southwestern Wyoming (index map, Pl. 1). However, interpretations are based on observations in a much larger area that extends from the western Washakie Basin to the southeastern Green River Basin and from the southern margin of the Rock Springs uplift to northern Colorado (Fig. 1).

The purpose of this report is to present and interpret stratigraphic data that were, in part, the basis for an earlier detailed analysis of molluscan paleoecology (Hanley, 1976). The distribution, thickness, lithologies, and stratigraphic relations of the Green River and Wasatch Formations are discussed. Based on the paleoecology and distribution of mollusk associations (Hanley, 1976) relative to complex lithostratigraphy of the Green River and Wasatch, seven facies are defined; the distribution of these facies documents the lacustrine-alluvial depositional history of the formations (Pl. 1).

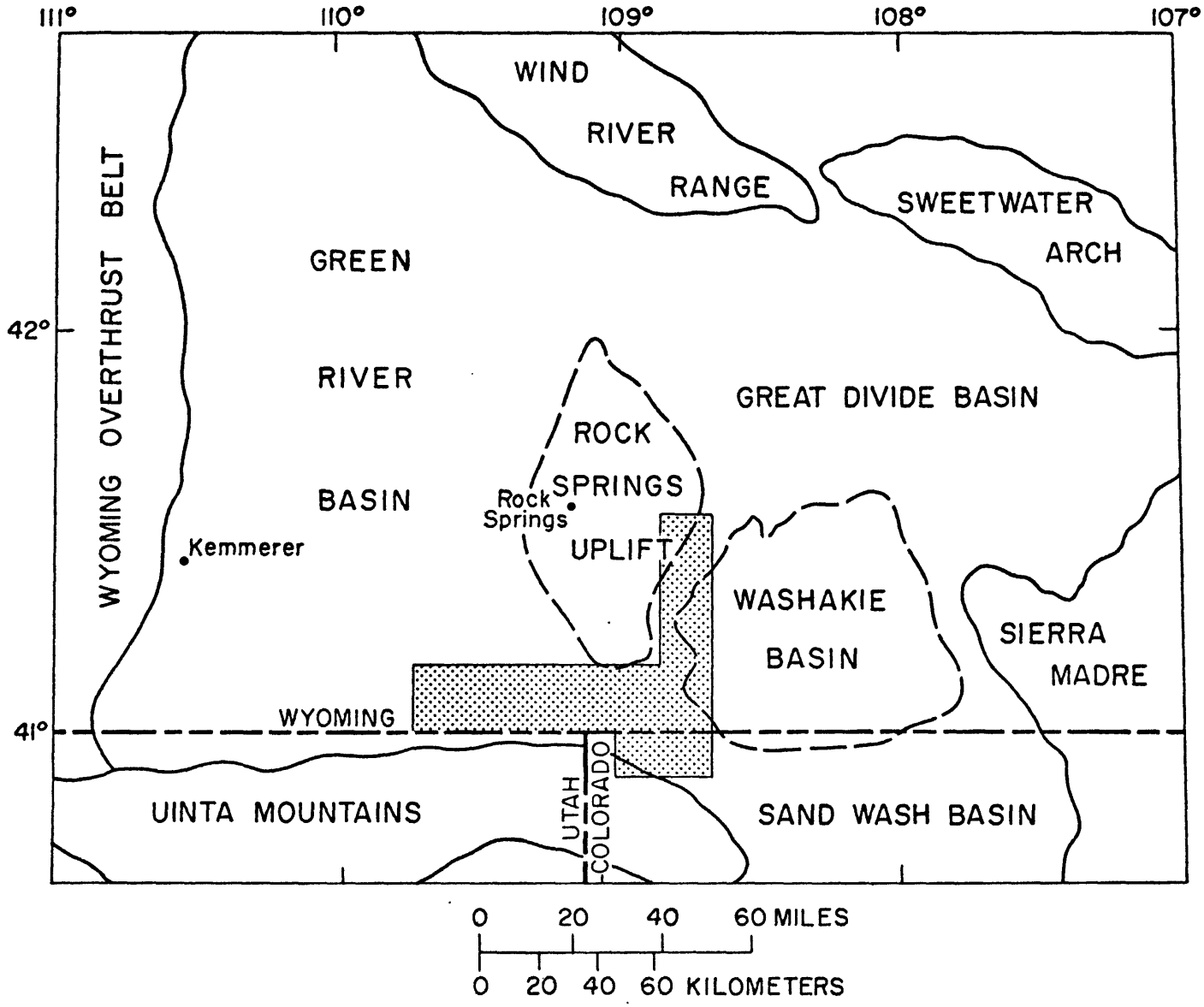

Figure 1. Geologic Setting of Principal Study Area (stippled). (Base from Roehler, 1973f.)

PURPOSES OF LITHOSTRATIGRAPHIC INVESTIGATION

Detailed lithostratigraphic work had four objectives: (1) description of lithologies; (2) documentation of stratigraphic relations and lithofacies distribution within the complexly intertonguing Green River and Wasatch Formations; (3) recognition of principal environments of deposition; and (4) documentation of distribution of mollusk associations. The ultimate purpose of this research was to provide a detailed stratigraphic framework in which to consider the paleoecology of nonmarine mollusks (Hanley, 1974 and 1976).

METHODS OF STRATIGRAPHIC ANALYSIS

Twenty-one detailed stratigraphic sections of parts of the Green River and Wasatch Formations were measured with a Brunton compass, tape, and jacob's staff. Composite sections, section numbers, locations, stratigraphic intervals, and thicknesses are listed in Table 1. Lithologic descriptions were made in the field with 10X and 50X hand magnifiers. A standard rock color chart (Goddard and others, 1963) was used in stratigraphic section 1-70. Invertebrate, and plant fossils were collected or described from all fossiliferous strata. Field collecting localities and their mollusk faunas are cited in the appendices of measured stratigraphic sections; the stratigraphic position and geographic location of each field locality is given by Hanley (1974). Table 2 summarizes the taxonomy of mollusks from the Green River and Wasatch. Lithostratigraphic and paleontologic data are synthesized in a detailed stratigraphic correlation diagram (pl. 1). An understanding of data presented herein will be greatly facilitated by repeated reference to plate 1.

Table 1.--Register of measured stratigraphic sections

[Individual sections are grouped into composite sections on plate 1. Descriptions of stratigraphic sections are given in appendices as indicated.]

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Telephone Canyon Overlook (Appendix A)	1-70	SE1/4SW1/4 sec. 24, T. 13 N., R., R. 104 W.	Wilkins Peak Member (approximately lower 2/3)	387
			Tipton Shale Member	116
			Niland Tongue	304
			Luman Tongue	255
			main body of Wasatch Formation (uppermost part)	54
Vermillion Creek (Appendix B)	1-71	NW1/4NW1/4 sec. 22, T. 12 N., R. 100 W.	Luman Tongue (lower part)	239
			main body of Wasatch Formation (uppermost part)	11
	2-71	NE1/4NE1/4NE1/4 sec. 21, T. 12 N., R. 100 W.	Luman Tongue (middle part)	98

Table 1.--Register of measured stratigraphic sections--continued

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Vermillion Creek (Appendix B)--- continued	3-71	NE1/4SW1/4 sec. 15, T. 12 N., R. 100 W.	Niland Tongue (lower part)	132
			Luman Tongue (upper part)	89
	4-71	SE1/4 sec. 10, T. 12 N., R. 100 W.	Tipton Shale Member (lower part)	52
			Niland Tongue (upper part)	91
	5-71	NW1/4SW1/4SE1/4 sec. 10, T. 12 N., R. 100 W.	Tipton Shale Member (middle part)	75
	6-71	NE1/4SW1/4 sec. 10, T. 12 N., R. 100 W.	Wilkins Peak Member (lower most part)	59
			Tipton Shale Member (upper part)	36

Table 1.--Register of measured stratigraphic sections--continued

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Canyon Creek (Appendix C)	7-71	S1/2NW1/4SW1/4 sec. 16, T. 12 N., R 101 W.	Luman Tongue (lower part)	194
	8-71	SE1/4SE1/4 sec. 17, T. 12 N., R. 101 W.	Niland Tongue (lower part)	26
			Luman Tongue (upper part)	55
	9-71	W1/2NW1/4 sec. 17, T. 12 N., R. 101 W.	Niland Tongue (middle part)	114
	10-71	NW1/4NW1/4NW1/4 sec. 17, SW1/4SW1/4SW1/4 sec. 8, and SE1/4SE1/4 SE1/4 sec 7, T. 12 N., R. 101 W.	Wilkins Peak Member (lower part)	351
			Tipton Shale Member	118
			Niland Tongue (upper part)	140

Table 1.--Register of measured stratigraphic sections--continued

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Rife Ranch (Appendix D)	11-71	SE1/4NE1/4NE1/4 sec. 6, and W1/2 NW1/4 sec. 5, T. 13 N., R. 101 W.	Luman Tongue (lower part)	272
			main body of Wasatch Formation (uppermost part)	37
	12-71	S1/2SE1/4 sec. 11, and S1/2SW1/4 sec. 12, T. 13 N., R. 102 W.	Niland Tongue (lower part)	154
			Luman Tongue (upper part)	79
	13-71	SE1/4NW1/4 and SW1/4 NE1/4 sec. 12, T. 13N., R. 102 W.	Tipton Shale Member (lower part)	42
			Niland Tongue (upper part)	31
	14-71	NE1/4NW1/4NW1/4 and SW1/4NE1/4NW1/4 sec. 18, T. 13 N., R. 101 W.	Wilkins Peak Member (lower part)	46
			Tipton Shale Member (upper part)	72

Table 1.--Register of measured stratigraphic sections--Continued

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Rifes Rim (Appendix E)	1-72	SE1/4SE1/4 sec. 29, SW1/4SW1/4SW1/4 and SE1/4SE1/4SW1/4 sec. 28, and NE1/4NW1/4 sec. 33, T. 14 N., R. 101 W.	Luman Tongue (lower part)	27
			main body of Wasatch Formation (approximately upper 1/4)	554
Four J Basin (Appendix F)	2-72	E1/2NE1/4 sec. 7, T. 12 N., R. 102 W.	Tipton Shale Member (lower part)	67
			main body of Wasatch Formation (upper part)	209
	3-72	NE1/4NE1/4NW1/4 sec. 7, and S1/2SE1/4 SW1/4, sec. 6, T. 12 N., R. 102 W.	Wilkins Peak Member (approximately lower 1/2)	311
			Tipton Shale Member (upper part)	58

Table 1.--Register of measured stratigraphic sections--continued

Composite section	Section number	Location	Stratigraphic interval	Thickness (feet)
Red Creek (Appendix G)	4-72	N1/2SE1/4SW1/4 sec. 25, T. 13 N., R. 104 W.	Luman Tongue (part of upper unnamed tongue)	123
			main body of Wasatch Formation (part)	53
			Luman Tongue (lower unnamed tongue)	77
			main body of Wasatch Formation (part)	50
	5-72	SW1/4SW1/4NE1/4 sec. 25, T. 13 N., R. 104 W.	Niland Tongue (lower part)	69
			Luman Tongue (part of upper unnamed tongue)	15
	6-72	SE1/4NE1/4NW1/4 and SW1/4NW1/4NE1/4 sec. 25, T. 13 N., R. 104W.	Tipton Shale Member (lower part)	18
			Niland Tongue (upper part)	190

Table 2.--*Mollusca of the Green River and Wasatch Formations, southwestern Wyoming*

Class Bivalvia
- Subclass Palaeoheterodonta
  - Order Unionoida
    - Superfamily Unionacea
      - Family Unionidae
        - Genus *Plesiellipti*o Russell, 1934
          - *Plesiellipti*o *priscus* (Meek and Hayden)
          - *Plesiellipti*o n. sp. A
        - Genus Indeterminant
          - Species A
          - Species B
  - Order Veneroida
    - Superfamily Corbiculacea
      - Family Pisidiidae
        - Genus *Sphaerium* Scopoli, 1777
          - *Sphaerium* sp.
        - Gen. ex gr. *Eupera*-*Pisidium*
          - Species A

Class Gastropoda
- Order Mesogastropoda
  - Superfamily Cerithiacea
    - Family Pleuroceridae
      - Genus *Goniobasis* Lea, 1862
        - *Goniobasis tenera* (Hall)

Table 2.--*Mollusca of the Green River and Wasatch Formations, southwestern Wyoming*--continued

Class Gastropoda--continued

Order Mesogastropoda--Continued

Superfamily Rissoacea

Family Hydrobiidae

Genus Hydrobia Hartmann, 1821

Hydrobia aff. *H. utahensis* White

Hydrobia sp. A

Superfamily Valvatacea

Family Valvatidae

Genus Valvata Muller, 1774

Valvata subumbilicata (Meek and Hayden)

Valvata cf. *V. filosa* Whiteaves

Superfamily Viviparacea

Family Viviparidae

Genus *Viviparus* Montfort, 1810

Viviparus trochiformis (Meek and Hayden)

Viviparus paludinaeformis (Hall)

Order Basommatophora

Superfamily Ancylacea

Family Physidae

Genus *Physa* Draparnaud, 1801

Physa bridgerensis Meek

Physa longiuscula? Meek and Hayden

Physa pleromatis White

Physa sp. A.

Table 2.--Mollusca of the Green River and Wasatch Formations, southwestern Wyoming--continued

Class Gastropoda--continued

Order Basommatophora--continued

Superfamily Ancylacea--continued

Family Physidae--continued

Genus *Aplexa* Fleming, 1820

Aplexa? sp. A

Aplexa? sp. B

Family Planorbidae

Genus *Biomphalaria* Preston, 1910

Biomphalaria aequalis (White)

Biomphalaria storchi (Russell)

Biomphalaria pseudoammonius (Schlotheim)

Genus *Drepanotrema* Fischer and Crosse, 1880

Drepanotrema? sp.

Genus *Gyraulus* Charpenteir, 1837

Gyraulus militaris (White)

Genus *Omalodiscus* Benson, 1855

Omalodiscus cirrus (White)

Genus *Promenetus* F. C. Baker, 1945

Promenetus sp. A.

Superfamily Acroloxacea

Family Acroloxidae

Genus *Acroloxus* Beck, 1937

Acroloxus minutus (Meek and Hayden)

Acroloxus sp. A

Table 2.--*Mollusca of the Green River and Wasatch Formations, southwestern Wyoming*--continued

Class Gastropoda--continued

Order Basommatophora--continued

Superfamily Lymnaeacea

Family Lymnaeidae

Genus *Lymnaea* *Lamarck*, 1799

Lymnaea cf. *L. minuscula* White

Lymnaea similis Meek

Lymnaea sp. A.

Lymnaea sp. B.

Genus *Pleurolimnaea* Meek, 1866

Pleurolimnaea tenuicosta (Meek and Hayden)

Order Stylommatophora

Suborder Sigmurethra

Superfamily Bulimulacea

Family Bulimulidae

Genus *Oreoconus* Taylor, 1962

Oreoconus n. sp. A

Oreoconus n. sp. A "form A"

Oreoconus n. sp. A "form B"

Table 2.--*Mollusca of the Green River and Wasatch Formations, southwestern Wyoming*--continued

Class Gastropoda--continued
  Order Stylommatophora--continued
    Suborder Sigmurethra--continued
      Superfamily Bulimulacea--continued
        Family Urocoptidae
          Subfamily Holospirinae
            Genus *Holospira* Von Martens, 1860
              Holospira n. sp. A
      Superfamily Endodontacea
        Family Endodontidae
            Genus *Discus* Fitzinger, 1833
              Discus ralstonensis (Cockerell)
      Superfamily Helicacea
        Family Oreohelicidae
            Genus *Oreohelix* Pilsbry, 1904
              Oreohelix grangeri Cockerell and Henderson
      Superfamily Polygyracea
        Family Polygyridae
            Genus *Mesodon*? Rafinesque, 1821
              Mesodon? sp.

Table 2.--*Mollusca of the Green River and Wasatch Formations, southwestern Wyoming*--continued

Class Gastropoda--continued

Order Stylommatophora--continued

Suborder Orthurethra

Superfamily Pupillacea

Family Pupillidae

Genus *Vertigo* Muller, 1774

Vertigo arenula (White)

Genus *Albertanella*? Russell, 1931

?Albertanella minuta Russell

Order Archaeogastropoda

Superfamily Neritacea

Family Helicinidae

Subfamily Helicininae

Genus *Schasicheila* Shuttleworth, 1852

Schasicheila n. sp. A

Family Grangerellidae

Genus *Grangerella* Cockerell, 1915

Grangerella mcleodensis (Russell)

Incertae Sedis

Genus *Pseudocolumna* Wenz, 1920

Pseudocolumna vermicula (Cockerell)

TERMINOLOGY

Descriptive terms applied to sedimentary rocks may have several meanings. The following terms are briefly defined to provide a more precise interpretation of their use in this report.

Facies

This term is used in a lithogenetic sense: "The sum of all the primary lithologic and paleontologic characteristics exhibited by a sedimentary rock and from which its origin and environment of formation may be inferred ..." (Gary and others, 1972, p. 249).

Shale

"A fine-grained, indurated, detrital sedimentary rock formed by the consolidation ... of clay, silt, or mud, and characterized by a finely stratified ... structure and/or fissility ..." (Gary and others, 1972, p. 649). The adjective "shaly" is applied to rocks exhibiting fissility.

Oil Shale

The term refers to all kerogenaceous rocks regardless of the amount of oil yield by Fischer assay. This definition is the same as that of Roehler (1969, p. 204).

Dolomitic

The modifier "dolomitic" is applied to rocks which exhibit the following characteristics: (1) crystalline texture at 50X magnification; (2) very slight, delayed effervescence with dilute hydrochloric acid applied to a fresh surface; and (3) strong, immediate effervescence with dilute hydrochloric acid on a fresh surface which has been scratched with a knife.

Mudstone

This term is applied to a blocky or massive rock composed of clay- and silt size grains. Because the ratio of silt and clay fractions could not be discerned in the field, rocks that lacked a "gritty feel" when placed between my teeth were termed mudstones. This term is less specific in meaning than "claystone", but in view of the informal method of field identification, use of "mudstone" is warranted.

Coquinal

The modifier "coquinal" is applied to rocks containing abundant, abraded fossils.

Sandstone and Siltstone

The distinctions between sandstone, siltstone, and all modifiers applied to sandstone (medium grained, very fine grained, etc.) are based on differences in grain size as presented in the Wentworth grain size classification (Wentworth, 1922).

Roundness and Sorting

Description of the roundness and sorting of sedimentary grains is based on Powers (1953) and Compton (1962, p. 214), respectively.

Irregular Fragments, Platy, Papery, Blocky

These terms refer to the physical character of a rock when struck with a hammer. Unless specifically stated in the appendices of lithologic descriptions, these terms do not refer to the weathering character of a rock.

ACKNOWLEDGEMENTS

I have greatly profited from numerous field trips and discussions with Henry W. Roehler, U.S. Geological Survey, concerning stratigraphy and depositional environments of the Green River and Wasatch Formations, and the Cretaceous and Tertiary geologic history of southwestern Wyoming.

Emmett Evanoff, Michael Elwood, and Steven Sloan served as field assistants during this investigation. Lynn Keller drafted the stratigraphic correlation diagram (pl. 1).

This research represents a portion of my Ph.D. dissertation in the Department of Geology, University of Wyoming. I especially thank Donald W. Boyd, University of Wyoming, for his outstanding counseling as my primary dissertation director.

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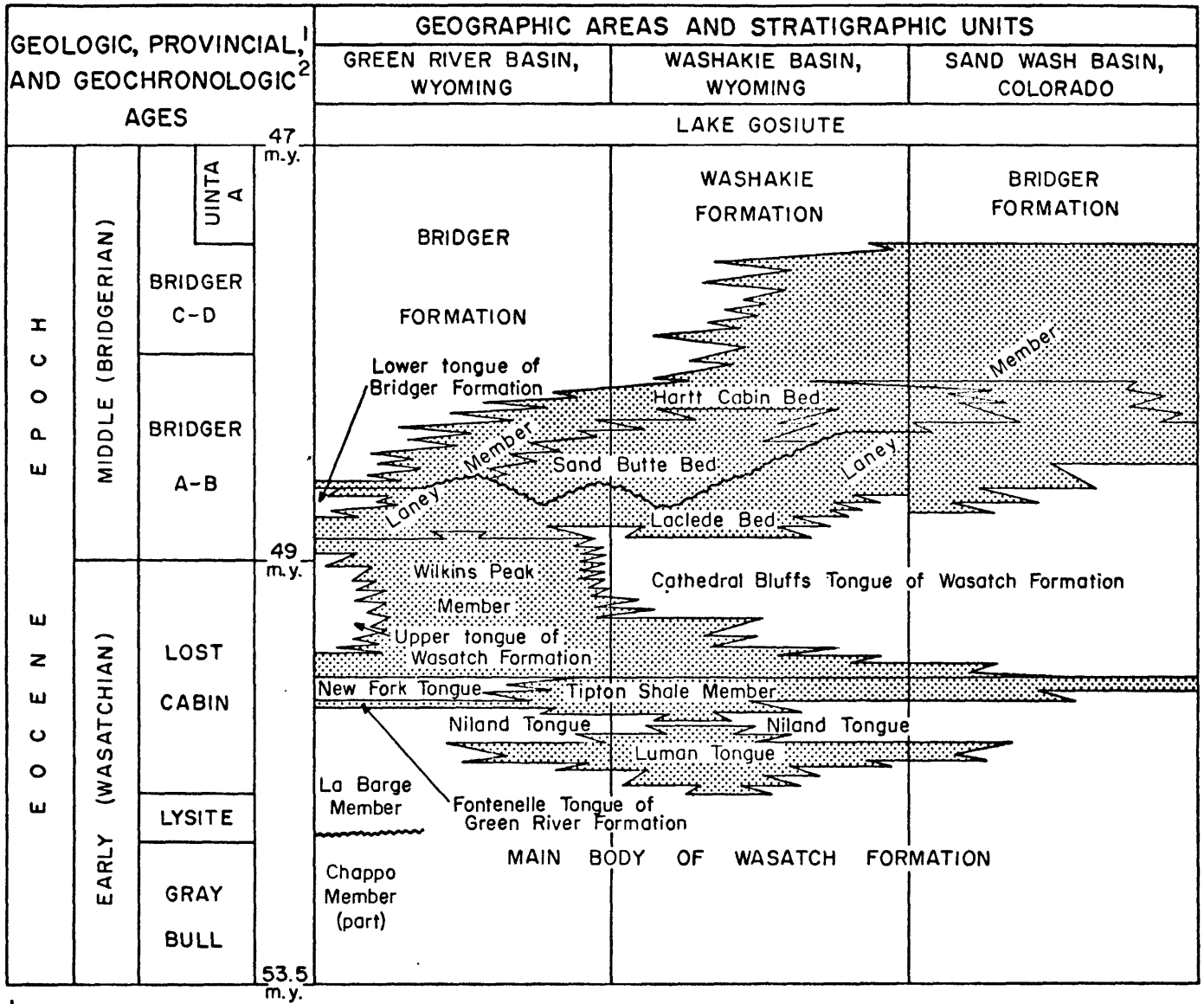
PREVIOUS WORK

Although the principal study area is south of the Rock Springs uplift (pl. 1), and understanding of this area's stratigraphic relations and paleoenvironments is facilitated by examination of geologic data from a much larger area including the eastern margin of the Green River Basin, and the western margin of the Washakie Basin (fig. 1). The stratigraphy of the eastern margin of the Green River Basin has been investigated by Culbertson (1961, 1962, 1965, 1969), Deardorff (1959), Millice (1959), Roehler (1961, 1965), Stuart (1963, 1965), Textoris (1960, 1963), and Wiegman (1964). The Eocene stratigraphy of the Washakie Basin has been studied extensively by Roehler (1968, 1969, 1972c, 1972d, 1973e, 1973f, 1974b, 1975). The geology and general stratigraphic relations in the study area are documented by Roehler (1972a; 1972b; 1973a, b, c, d; 1974a,c). Regional stratigraphic relations of the Wasatch and Green River Formations are summarized in Bradley (1964), Love (1964), McDonald (1972), Robinson (1972), Roehler (1965, 1972c), and Wolfbauer (1972).

The evolution of stratigraphic nomenclature of the Green River and Wasatch Formations is complex, and it will not be recounted here. Nomenclatural history was summarized by Bradley (1964), Roehler (1965), and Textoris (1963). Stratigraphic nomenclature of the Green River and Wasatch Formations in the study area was illustrated by Roehler (1972c, Fig. 5). A portion of Roehler's stratigraphic correlation chart, which is reproduced in Figure 2, illustrates the complex regional stratigraphic relations.



[1] Wood and others (1941)
[2] McKenna and others (1973)

Figure 2.-Stratigraphic relations of the Green River (stippled) and Wasatch Formations, southwestern Wyoming. (From Roehler, 1972c.)

Paleogeography of four intervals of lacustrine deposition in southwestern Wyoming and adjacent Utah and Colorado (Roehler, 1965 and 1973f) delineates the general paleoenvironmental setting of the study area. During the Eocene, the east-west-trending Uinta Mountains formed a southern barrier to expansion of Lake Gosiute in this region. Roehler's reconstructions indicate that the Pine Mountain area was repeatedly the site of nearshore shallow water lacustrine deposition. Thus this area is ideal for delineating and studying the distribution of adjacent lacustrine and alluvial environments and associated molluscan faunas.

CHARACTERISTICS, DISTRIBUTION, AND INTERPRETATION OF FACIES

The seven facies recognized in the study area closely correspond to Roehler's (1965) environments of deposition in this region. Definition of facies is based on the paleoecology and distribution of mollusk associations (Hanley, 1976) relative to the complex lithostratigraphy of the Green River and Wasatch Formations; the distribution of these facies documents the lacustrine-alluvial depositional history of the formations (pl. 1).

Paleoecology of mollusks has been discussed in detail by Hanley (1976), and will only be summarized here. Similarly, dominant taxa of the mollusk associations have been illustrated (Hanley, 1976, pls. 1-3). The schematic distribution of facies and mollusk associations proximal to Lake Gosiute is shown in figure 3 (upland-fluviatile facies not shown). These facies and associations are typical of deposition of the Luman Tongue and Tipton Shale Member of the Green River Formation and the main body and Niland Tongue of the Wasatch Formation. Precise distribution of facies within this stratigraphic interval is shown in plate 1.

UPLAND-FLUVIATILE FACIES

Red-brown mudstone, generally coarse-grained sandstone, and fanglomerate of the upland-fluviatile facies were deposited in well drained upland areas adjacent to mountain fronts or local topographic highs (Roehler, 1965, p. 141). Roehler's interpretation that the red color of these strata indicates <u>in situ</u> oxidation of iron-rich sediments is supported by local and regional lithostratigraphic relations and the paleontologic character of the facies.

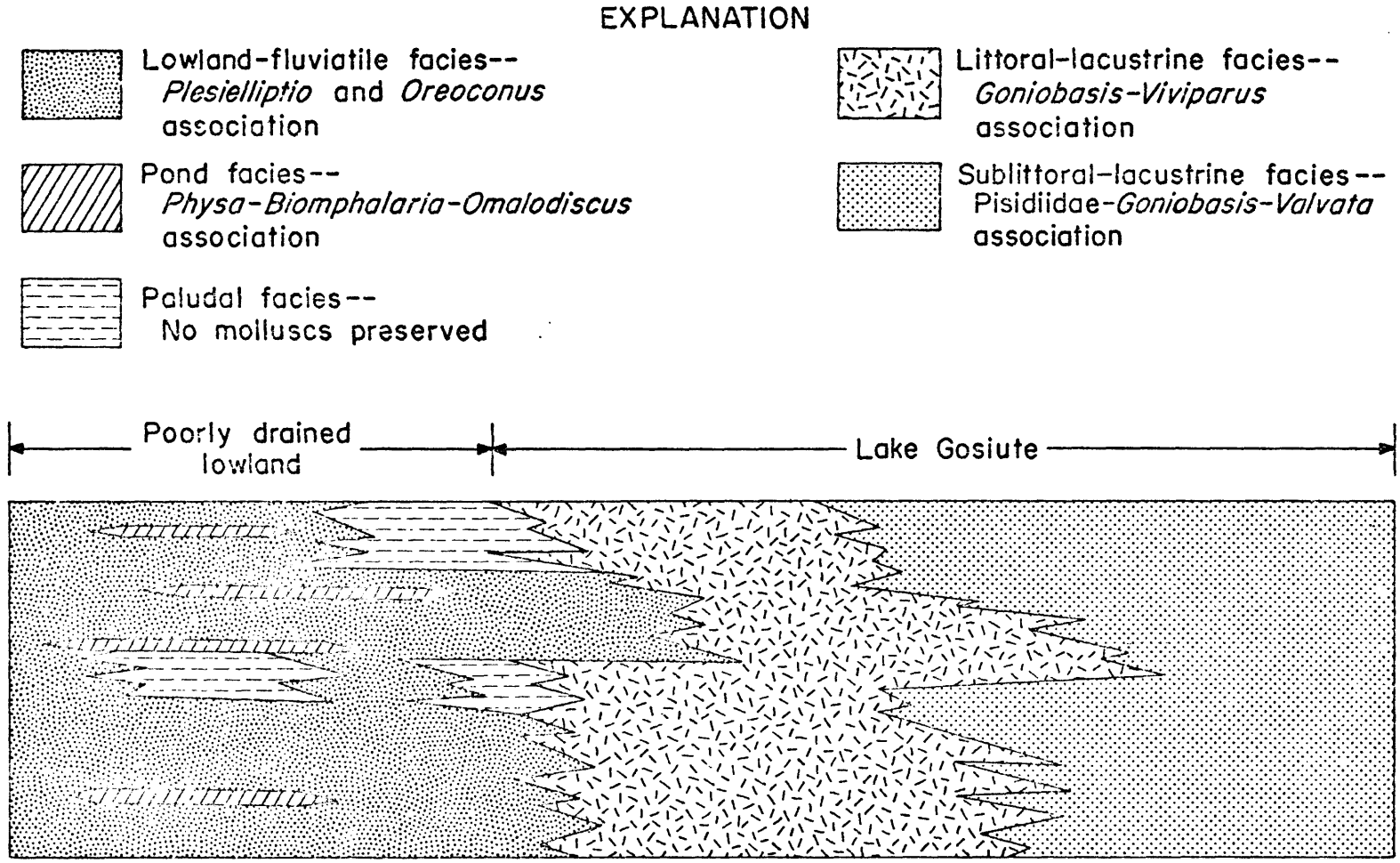


Figure 3. Schematic distribution of (1) mollusk associations; (2) the lowland-fluviatile, pond, and paludal facies typical of the main body and Niland tongue of the Wasatch Formation; and (3) the littoral-lacustrine and sublittoral-lacustrine facies typical of the Luman Tongue and Tipton Shale Member of the Green River Formation, as deposited in Lake Gosiute and adjacent environments south of the Rock Springs uplift.

Regional lithostratigraphic relations (Roehler, 1965, Fig. 1) demonstrate that the gray-green mudstone, interbedded limestone, and carbonaceous shale of the problematic lacustrine facies of the main body of the Wasatch Formation intertongue toward the basin margin with red beds of the upland-fluviatile facies. The red beds increase in grain size and locally grade into fanglomerates which may contain clasts derived from the Uinta Mountains to the south. Both grain size and composition of the sandstone and fanglomerate suggest proximity of the red beds to the basin margin and adjacent sediment source areas.

Similar lithostratigraphic relations accompany the transition from inferred lowland to upland paleoenvironments in the western Green River Basin.

> "From north to south, the subtongues and the upper tongue of the Wasatch Formation change from drab-green beds with some faint light-red bands to distinctively red and light-green banded beds and finally to brilliant red beds which become increasingly thick and coarse conglomeratic ..." (Lawrence, 1962, p. 42)

These regional stratigraphic relations in the southeastern and western Green River Basin demonstrate that the red beds intertongue laterally with the limestone, carbonaceous shale, and drab mudstone of the pond, paludal, and lowland-fluviatile facies, respectively. These facies collectively characterize lowland areas adjacent to Lake Gosiute.

The paleoecology of mollusks preserved in the upland-fluviatile facies supports the interpretation that this facies formed in a well drained, upland paleoenvironment. Only rare terrestrial-pulmonate gastropods occur in the red beds; This fauna reflects the absence of extensive moist or ponded water habitats in which terrestrial- and aquatic-pulmonate gastropods flourished in adjacent lowland areas.

LOWLAND-FLUVIATILE FACIES

Regional stratigraphic relations suggest that gray-green mudstone and buff fine-grained sandstone, the dominant rock types of the lowland-fluviatile facies, were deposited in lowland areas under poorly drained conditions. As Roehler (1965, p. 141) has observed, red colors of rocks at the edge of the basin uniformly change to drab gray and green colors basinward. This intertonguing relationship is spectacularly shown in the west slopes of Telephone Canyon (secs. 23 and 26, T. 13 N., R. 104 W.). I agree with his opinion that the color change reflects reduction of ferric iron to ferrous iron in poorly drained low topographic areas toward the basin center. Roehler also noted that channel-form sandstones within the lowland facies locally contain red material derived from the adjacent upland-fluviatile facies (as in bed 42 in strat. sect. 1-72). He suggested that streams carried red pigments basinward from the red beds into environments otherwise characterized by drab fluviatile sediment.

Oriel (1961, p. B-152) also noted that because of poor drainage and reducing conditions, sediments deposited close to Lake Gosiute lack the red color of sediments in well-drained alluvial soils of higher elevations.

In the western Green River Basin, Lawrence (1962, p. 23) noted that the contact between the main body of the Wasatch Formation and the overlying Fontenelle Tongue of the Green River Formation is marked by a persistent light-green calcareous mudstone and siltstone bed, which he termed the "green marker." A similar drab marker is present near Red Creek Ranch (secs. 24 and 25, T. 13 N., R. 104 W.), where deposition of gray-green mudstone preceded lacustrine deposition of the Luman Tongue during the local transgressions and regressions of Lake Gosiute (strat. sects. 1-70 and 4-72). Walther's law of facies as summarized by Middleton (1973, p. 982) states:

> "Only those facies and facies-areas can be superimposed primarily which can be observed beside each other at the present time."

This relationship further suggests that the drab fluviatile facies was deposited in a lowland area adjacent to Lake Gosiute.

The typical interbedding of the lowland-fluviatile facies with the limestone of the pond facies and with carbonaceous shale of the paludal facies indicates the poorly drained character of this lowland region.

The lowland-fluviatile facies is characterized by two molluscan habitats (Hanley, 1976): (1) rivers and streams inhabited by unionid bivalves such as Plesielliptio priscus of the low-diversity Plesielliptio association; and (2) the moist and dry, vegetated, calcium-rich alluvial plain inhabited by the more diverse terrestrial gastropods of the Oreoconus association.

PALUDAL FACIES

Strata representing the paludal environment are proximally associated with marginal lacustrine, floodplain, and pond deposits. Deposits of carbonaceous shale and sandstone, or coal, often underlie or occur adjacent to lacustrine deposits. Carbonaceous strata are also more frequently interbedded with lowland-fluviatile and pond facies than with the upland-fluviatile facies (Niland Tongue in strat. secs. 1-70; 3-, 4-, 9-, 10-, 12-, and 13-71; 5-, and 6-72). These relations indicate that swamps were common in poorly drained lowland areas, particularly adjacent to Lake Gosiute. This relationship is logical inasmuch as swamps are often distributed along the margins of lakes today. Transgressio of Lake Gosiute is typically reflected by littoral lacustrine deposits overlying paludal strata (contact of main body of Wasatch and Luman Tongue in strat. secs. 1-70, 11-71; contact of Niland Tongue and Tipton Shale Member in strat. secs. 1-70, 10-71, 13-71, 6-72).

Mollusks have not been collected from the paludal facies. Either mollusks lived in this habitat and were not preserved or they found conditions inequitable. I favor the former hypothesis for several reasons. Standing-water areas rich in aquatic vegetation are ideal habitats for aquatic-pulmonate gastropods and pisidiid bivalves. In such environments, acidic conditions develop in association with decomposition and incomplete oxidation of organic material; this can be particularly true in the substrate, where the shells of mollusks can undergo post-mortem dissolution.

POND FACIES

The pond facies is composed of limestone and marlstone interbedded with the paludal and lowland-fluviatile facies of the main body and Niland Tongue of the Wasatch Formation.

Regional stratigraphic relations (fig. 2) provide additional data regarding the paleoenvironmental setting of the limestone lithosomes that contain the very diverse Physa-Biompholaria-Omalodiscus association (Hanley, 1976). Lacustrine deposition of the Luman Tongue of the Green River Formation began in the Washakie Basin and spread westward into the Green River Basin. The many limestone beds in the main body of the Wasatch Formation (strat. sect. 1-72), therefore, formed adjacent to Lake Gosiute. Similarly, thin limestone beds containing the Physa-Biomphalaria-Omalodiscus association originated adjacent to lacustrine deposits of the Niland Tongue of the Wasatch Formation (strat. secs. 1-70 and 12-71).

These local and regional stratigraphic relations suggest that the lenses represent a local, ephemeral, recurring environment in the lowland area adjacent to Lake Gosiute. Paleosynecology of the Physa-Biomphalaria-Omalodiscus association supports the interpretation that deposition occured a pond environment. Because aquatic pulmonate gastropods and pisidiid bivalves are ideally adapted for existence in and dispersal into shallow, ephemeral ponds, this unstable environment is characterized by a very diverse molluscan association (Hanley, 1976, p. 251).

LITTORAL-LACUSTRINE FACIES

The littoral-lacustrine facies is characterized by coquinal limestone and siltstone, and it locally contains richly-fossiliferous sandstone and shale, all of beach and shallow nearshore, open lacustrine origin. In the Luman Tongue of the Green River Formation, the facies complexly intertongues with the lowland-fluviatile facies of the main body of the Wasatch Formation (strat. secs. 1-70, 4-72), and the sublittoral-lacustrine facies of the Luman Tongue (strat. sec. 11-71).

The facies is readily distinguished in the field by the presence of the Goniobasis-Viviparus mollusk association (Hanley, 1976). The three dominant mollusks of this association (Goniobasis tenera, Viviparus trochiformis, and Plesielliptio n. sp.A) are consistent indicators of shallow, nearshore, open lacustrine conditions in the Luman Tongue of the Green River Formation, and their distribution traces many complex shoreline fluctuations of Lake Gosiute during deposition of the Luman. The presence of this mollusk association in numerous layers interbedded with strata of fluviatile and paludal origin in the Niland Tongue of the Wasatch Formation clearly documents successive shorelines of several lacustrine transgressions (localities GR 75-70, 91-70, 98-70, 101-70, and 19-71 of Hanley, 1974; strat. secs. 1-70, 3-71, 9-71, 10-71, and 6-72). The association also reflects transgression of Lake Gosiute in the widespread, time-transgressive "Goniobasis marker" at the base of the Tipton Shale Member of the Green River Formation.

SUBLITTORAL-LACUSTRINE FACIES

This facies is characterized by drab shale and oil shale that typically contain the low-diversity Pisidiidae-Goniobasis-Valvata mollusk association (Hanley, 1976). The facies intertongues with the littoral-lacustrine facies (strat. sec. 11-71), represents and offshore lacustrine environment, and reflects maximum lacustrine transgression in the study area. The inferred increase in water depth from the littoral to sublittoral facies is reflected by the transition from sandstone, siltstone, and local conglomerate to shale.

Formation of oil shale has been attributed to several environments of deposition. Bradley (1948) proposed that oil shale formed in the deep, oxygen-poor hypolimnion of Lake Gosiute. Recently, Bradley (1973), Eugster and Surdam (1973), and Surdam and Wolfbauer (1973) suggested that oil shale formed in a shallow, oxygenated lacustrine environment. The presence of the Pisidiidae-Goniobasis-Valvata association in beds of low-grade oil shale supports the latter hypotheses.

Mollusks are extremely rare in the sublittoral-lacustrine facies of the Wilkins Peak Member. During deposition of this member, Lake Gosiute decreased notably in size and became saline. Since nonmarine mollusks are typically stenohaline, their absence is easily explained because of the elevated salinity. Mollusks undoubtedly flourished locally near the shoreline where inflowing streams lowered the salinity. Nine gastropods were collected from the sublittoral facies of the Wilkins Peak Member (locality GR 18-72 of Hanley, 1974). One specimen is questionably assigned to cf. Drepanotrema (an aquatic pulmonate gastropod); the others are too poorly preserved to be identified.

MUD FLAT FACIES

Thick intervals of dolomitic mudstone and thin beds of dolomite in the Wilkins Peak Member probably originated on mudflats adjacent to Lake Gosiute as discussed by Eugster and Hardie (1975). On the basis of sedimentary structures and textures, and diagenetic features, Eugster and Hardie delineated seven lithofacies that represent six saline-lacustrine, mudflat, or alluvial environments. Several of their lithofacies are probably represented in the Wilkins Peak in the study area (e.g. flat-pebble conglomerate, mudstone, oil shale, and siliciclastic sandstone lithofacies). They interpret the flat-pebble and mudstone lithofacies to be of mudflat-lacustrine shoreline and mudflat origin, respectively. Because mollusks are extremely rare in the Wilkins Peak Member, sedimentary structures and textures, diagenetic features, and depositional cycles were not studied in sufficient detail to permit environmental interpretations as precise as those of Eugster and Hardie (1975).

One specimen of Biomphalaria sp. and one of Holospira sp. (aquatic-pulmonate and terrestrial gastropods, respectively) were collected in dolomitic mudstone (locality GR 11-71 of Hanley, 1974). Is is probable that they were washed onto the mudflat from adjacent aquatic and terrestrial habitats.

LITHOSTRATIGRAPHY

GREEN RIVER FORMATION

The Green River Formation (early and middle Eocene) is a large lens of lacustrine strata enclosed within generally fine-grained alluvial sediments of the Wasatch Formation below and the Bridger Formation above. The complex stratigraphic relations of these formations (fig. 2) reflect climatic and tectonically induced changes in the size and paleogeography of Lake Gosiute during its four-million-year history.

In the study area, the Green River Formation is divided into the Luman Tongue, and the Tipton Shale Member, and the Wilkins Peak Member.

Luman Tongue

Name, Definition, and Age.-The Luman Tongue of the Green River Formation was named by Pipiringos (1962, p. A14) for excellent exposures of oil shale; fossiliferous, muscovitic, calcareous sandstone; varved siltstone; clay shale; and a few thin coal beds on the south slope of Luman Butte (sec. 34, T. 24 N., R. 97 W.). Photographs of the Luman at its type locality (Pipiringos, 1962, fig. 11) indicate it contains the common lacustrine mollusk assemblage of Goniobasis sp., Viviparus sp., and unionid bivalves.

Based on vertebrate fossils, the Luman Tongue is considered to be early Lost Cabinian (late-early Eocene) (Roehler, 1972c, fig. 13).

Distribution and Thickness.-The Luman Tongue ranges from 0 to 426 feet thick in the study area. Northwest of Pine Mountain the Luman is 255 feet thick (strat. sec. 1-70), but in outcrops to the south and in the subsurface to the southeast it disappears by intertonguing with the main body of the Wasatch Formation. Although the Luman Tongue is not present southeast of Pine Mountain in Four J Basin, fourteen miles to the east near Hiawatha, Colo., the tongue is 426 feet thick (strat. secs. 1-, 2-, and 3-71). The Luman thickens to 400-500 feet along its depositional axis approximately six miles north of these stratigraphic sections (Roehler, 1969, Fig. 4; 1972c). The Luman forms a low ridge, Rifes Rim, northeast of Pine Mountain; and it is 351 feet thick at that locality near Wyoming State Highway 430. The Luman Tongue is also exposed at the Canyon Creek gas field. (T. 12 N., R. 101 W.)

Lithology and Stratigraphic Relations.-In the study area, the Luman Tongue is dominantly low-grade, olive-brown oil shale; drab-brown shale; and very fine to fine-grained, buff, quartz sandstone. Minor beds include buff to brown limestone, buff marlstone and siltstone, dark-brown to black carbonaceous shale, and thin beds of coal. Except for carbonaceous strata, the sediments are typically calcareous and may contain ostracodes and the Goniobasis-Viviparus and Pisidiidae-Goniobasis-Valvata mollusk associations.

Near Hiawatha, Colo., the Luman Tongue contains 300 feet of low-grade oil shale with numerous, thin (1-2 inch) interbeds of coquinal siltstone and rare sandstone (strat. secs. 1-, 2-, and 3-71). The oil shale locally contains mollusks of the Pisidiidae-Goniobasis-Valvata association, and coquinal siltstone contains mollusks of the Goniobasis-Viviparus association. Near the contact with the overlying Niland Tongue of the Wasatch Formation at this location, the rocks grade to calcareous sandstone, siltstone, and drab shale with locally abundant mollusks (strat. sec. 3-71) A similar lithologic succession occurs at the Luman-Niland transition at the Canyon Creek gas field, seven miles west of Hiawatha (strat. secs. 7-71, 8-71).

Along Rifes Rim at Wyoming State Highway 430 and near the Rife Ranch, the oil-shale sequence of the Luman in stratigraphic sections 1-, 2-, and 3-71 is largely replaced by a sequence of calcareous sandstone and drab shale, with calcareous siltstone, carbonaceous shale, and thin beds of limestone (strat. sec. 11-71). Oil shale constitutes approximately 29 percent of the Luman Tongue in the latter section, compared to 64 percent near Hiawatha, Colorado. This notable decrease in oil shale from Hiawatha to the Rifes Rim-Highway 430 area reflects a transition to a nearshore lacustrine environment that existed in the latter area during much of Luman deposition. Two tongues of oil shale (strat. sec. 11-71) in the Rifes Rim-Highway 430 area, which correlate with more continuous oil shale deposits to the south and east (strat. secs. 1-, and 2-71), characterize an offshore, sublittoral-lacustrine facies of Lake Gosiute during deposition of the Luman Tongue.

Northwest of Pine Mountain, the Luman is dominantly composed of low-grade oil shale, drab-brown shale, carbonaceous shale, and minor sandstone (strat. sec. 1-70). Less than one mile to the south, the Luman thins and intertongues with the main body of the Wasatch Formation, and consists of several tongues of calcareous sandstone, siltstone, and drab-brown shale (strat. sec. 4-72). This north-south lithologic and lithostratigraphic change reflects a transition from dominantly offshore, sublittoral, open-lacustrine deposition to shallower, nearshore littoral-lacustrine deposition, and finally to alluvial sediments of the Wasatch. As each tongue of the Luman thins, sandstone becomes the dominant rock type and grain size gradually increases. Sediments of the littoral-lacustrine facies of the Luman that represent a lacustrine shoreline environment are very coarse and conglomeratic sandstone, with clasts of quartz sandstone, and locally abundant Goniobasis tenera. Multiple tongues of the Luman (strat. sec. 4-72) reflect transgressions and regressions of Lake Gosiute. The distribution of the Goniobasis-Viviparus association delineates these complex shoreline fluctuations.

The Luman Tongue overlies and laterally intertongues with the main body of the Wasatch Formation northwest of Pine Mountain (strat. secs. 1-70, and 4-72). In the subsurface, the Luman pinches out by intertonguing with the Wasatch Formation southeast of stratigraphic sections 1-70 and 4-72, south of outcrops along Salt Wells Creek, southeast of outcrops along Rifes Rim (strat. secs. 11-, and 12-71), and west of outcrops near the Canyon Creek gas field (strat. secs. 7-, and 8-71). The distribution of the depositional edge of the Luman Tongue delineates an upland peninsula in the Pine Mountain-Four J Basin area, that was not transgressed by Lake Gosiute during deposition of the Luman Tongue.

The basal contact of the Luman Tongue with the main body of the Wasatch Formation is distinct, and it is typically marked by a change from sandstone, gray mudstone, and carbonaceous shale of the Wasatch to fossiliferous lacustrine oil shale and drab shale (locally containing the Pisidiidae-Goniobasis-Valvata association) or limestone (containing the Goniobasis-Viviparus association). The upper contact of the Luman is locally irregular (strat. secs. 1-70, and 4-72), and is marked by interfingering of mollusk-bearing sandstone, marlstone, and shale of lacustrine origin with unfossiliferous sandstone and carbonaceous shale of the Niland Tongue of the Wasatch Formation. Near the Rife Ranch, Canyon Creek gas field, and Hiawatha, Colo., (strat. secs. 12-71, 8-71, and 3-71, respectively), the upper contact of the Luman is distinct.

Tipton Shale Member

Name, Definition, and Age.-The Tipton Shale Member of the Green River Formation was named by Schultz (1920, p. 30) for 200-250 feet of fissile shale, oolitic limestone, conglomerate, and sandstone exposed in the vicinity of Tipton, a station on the Union Pacific Railroad (sec. 18,T. 19 N., R. 96 W.). Because of inconsistencies in the recognition of the upper and lower contacts of the member, Roehler (1968, p. 2252) redefined the Tipton near its type locality as 163 feet of brown, fissile, low-grade oil shale. The contacts of the Tipton Member were defined by Roehler (1968, p. 2252 and 2254):

> "Two thin sandstone ledges (contain) the gastropods Goniobasis sp., and Viviparus sp., and the pelecypod Lampsilis sp. One or more of these 'Goniobasis beds' defines the Tipton-Wasatch contact nearly everywhere in the Rock Springs Uplift area. The contact of the Tipton Shale Member and the Wilkins Peak Member is well marked by an abrupt color and lithologic change from fissile, brown, low-grade oil shale to blocky, gray, and green dolomitic mudstone."

The Tipton Shale Member is middle Lost Cabinian (late-early Eocene) (Roehler, 1972c, Fig. 13).

Distribution and Thickness.-Gently dipping strata of the Tipton Shale Member are exposed in Red Creek syncline north and east of Pine Mountain. South and east of Pine Mountain, the Tipton crops out along the margin of Four J Basin. Scattered outcrops of the Tipton extend from the Canyon Creek gas field to Hiawatha, Colorado. The Tipton is relatively uniform in thickness ranging from 114 feet near the Rife Ranch (strat. secs. 3-, and 4-71) to 147 feet near Hiawatha, Colo. (strat. secs. 4-, 5-, and 6-71).

Lithology and Stratigraphic Relations.-The Tipton Shale Member is dominantly composed of olive-brown oil shale; drab-brown calcareous shale; very fine to fine-grained, buff, quartz sandstone; and minor beds of limestone, siltstone, and dark-brown to black carbonaceous shale. The Tipton contains many beds with mollusks and (or) ostracodes.

Northwest of Pine Mountain, above a basal coquinal limestone (the "Goniobasis marker"), the Tipton is entirely oil shale (strat. sec. 1-70) with locally abundant ostracodes. East of Pine Mountain, the oil shale contains an interval of sandstone and carbonaceous shale near the middle of the member. At Canyon Creek (strat. sec 10-71), this interval consists of 37 feet of interbedded siltstone and carbonaceous shale. Near Hiawatha, Colo. (strat. secs. 4-, and 5-71), the interval of the interbedded sandstone and carbonaceous shale reaches a maximum thickness of 61 feet. These lithologic and lithostratigraphic relations were produced by regression of Lake Gosiute and by the consequent deposition of thin beds of shallow-water lacustrine sand, alluvial sand, and carbonaceous mud of the adjacent paludal (swamp) environment. Although this interval is dominantly nonlacustrine and it is herein considered a local tongue of the Wasatch Formation.

The lateral lithologic transition discussed above, from oil shale and sandstone of lacustrine origin to sandstone, siltstone, and carbonaceous shale of alluvial and paludal origin, is duplicated in the vertical succession of beds at the Wasatch-Tipton transition in Four J Basin (strat. sec. 2-72). The transition is marked by a change from unfossiliferous siltstone of the Wasatch to an 18-foot-thick ripple-marked bed of sandstone containing mollusks of the Goniobasis-Viviparus association. This bed probably represents a lacustrine shoreline environment. The sandstone is overlain by a thin bed of low-grade oil shale. This transgressive sandstone-shale sequence is overlain by a regressive sequence of unfossiliferous sandstone, siltstone, carbonaceous shale, and drab mudstone. The latter sequence suggests lacustrine deposition was succeeded by alluvial and padual deposition. Renewed lacustrine transgression is represented by a coquinal limestone, the "Goniobasis marker," which is overlain by oil shale.

Throughout much of southwestern Wyoming, the base of the Tipton Shale is marked by a coquinal limestone or richly fossiliferous sandstone (the "Goniobasis marker") containing the Goniobasis-Viviparus association. The diachronous marker documents transgression of Lake Gosiute.

The upper contact of the Tipton Shale with the Wilkins Peak Member of the Green River Formation is marked by a change from oil shale to a thin bed of dolomite or yellow-brown, gray-weathering, platy, locally dolomitic or calcareous shale. This lithologic transition reflects a major environmental change during which Lake Gosiute lost its outlet, began to shrink, and increased in salinity in response to more arid climatic conditions (H. W. Roehler, oral commun., 1972). The Tipton-Wilkins Peak contact serves as a datum for the correlation of strata in the Pine Mountain area (plate 1). The upper contact of the Tipton is often difficult to recognize, because of poor exposures in the slope-forming shales. At Four J Basin and near Red Creek Ranch (strat. secs. 3-72 and 1-70, respectively) the transition from oil shale to gray-weathering platy shale is obscured by slumping, but it can be approximated in a stratigraphic interval of 25-30 feet. The transition between these superficially similar rocks is also difficult to discern in unweathered samples. However, error in the placement of the contact is insignificant, and does not affect correlation of strata in the study area.

Wilkins Peak Member

Name, Definition, and Age.-

> "The Wilkins Peak Member consists predominantly of gray to greenish-gray dolomitic and somewhat tuffaceous marlstone, mudstone, muddy sandstone, moderate number of lean to rich beds of oil shale, and considerable number of rather thin volcanic ash beds." (Bradley and Eugster, 1969, p. B7)

Some intervals of the Wilkins Peak are characterized by abundant saline minerals, such as halite and trona. The Wilkins Peak Member was defined by Bradley (1959) from exposures on the slopes of Wilkins Peak, six miles southeast of Green River, Wyoming. The Wilkins Peak was first recognized outside the Green River Basin by Roehler (oral commun., 1963, cited in Bradley and Eugster, 1969).

Bradley (1964, p. A36) discussed the contacts of the Wilkins Peak near its type locality.

> "The base of the Wilkins Peak is marked by a group of sandy, dolomitic, crudely bedded layers of marlstone ... that caps the cliff of oil shale in the uppermost Tipton Shale Member. The top of the Wilkins Peak Member was taken as the change from light-gray or white dolomitic marlstone and chippy shale to chalky buff laminated and varved marlstone (of the Laney Member), because the latter represents a deepening and expansion of the lake."

The Wilkins Peak Member is Lost Cabinian to earliest Bridgerian (Bridger A-B equivalent) in age, corresponding to the late-early to early-middle Eocene (Roehler, 1972c, Fig. 5).

Distribution and Thickness.-The Wilkins Peak Member is exposed on all flanks of Pine Mountain, as well as to the east in Red Creek syncline. The Wilkins Peak also crops out east of Four J Basin along Canyon Creek, and between the Canyon Creek gas field and Hiawatha, Colorado.

Because nomarine Mollusca are extremely rare in the Wilkins Peak, only incomplete stratigraphic sections of the member were measured. The maximum measured thickness (incomplete) is 387 feet near Red Creek Ranch (strat. sec. 1-70). The Wilkins Peak is 400 and 547 feet thick on the northwest and southeast flanks of Pine Mountain, respectively (Roehler, 1972a and b).

Lithology and Stratigraphic Relations.-The Wilkins Peak Member is dominantly composed of yellow and brown, gray weathering shale; olive-brown oil shale; and light-olive to gray, dolomitic mudstone. Minor beds include light-orange and gray dolomite; siltstone; and very fine and fine grained, buff, quartz sandstone.

The basal Wilkins Peak northwest and southeast of Pine Mountain is characterized by locally calcareous or dolomitic shale with thin interbeds of dolomite (strat. sec. 1-70, 3-72). Oil shale occurs in the basal Wilkins Peak near Canyon Creek and near Hiawatha, Colo. (strat. secs. 10-71 and 6-71, respectively).

The lower portion of the Wilkins Peak contains a tongue of oil shale which overlies the basal shale and dolomite, and thins southeastward from 94 feet near Red Creek Ranch (strat. sec. 1-70) to 35 feet near Canyon Creek (strat. sec. 10-71) The oil shale contains rare gastropods (locality GR 74-71 of Hanley, 1974) and ostracodes.

Above the oil shale tongue, the middle and upper Wilkins Peak are characterized by locally calcareous, light-gray weathering shale that is 150 and 100 feet thick in sections 1-70 and 10-71, respectively. The shale contains very rare gastropods (locality GR 18-72 of Hanley, 1974), Fish bones, ostracodes, and fragments of plants and insects. In these stratigraphic sections, the shale then grades to a thick sequence of gray, calcareous and dolomitic mudstone of inferred mudflat origin. The mudstone locally contains thin interbeds of stromatolites, sandstone, conglomeratic sandstone, intraformational conglomerate (containing clasts of dolomitic mudstone), and limy concretions (strat. sec. 1-70). This interval also exhibits linear shrinkage cracks (as illustrated by Picard and High, 1972, Fig. 23), polygonal shrinkage cracks, contorted bedding, load casts, and current and oscillation ripple marks.

Along the northeastern rim of Four J Basin (strat. sec. 3-72), the shale and overlying dolomitic mudstone sequence of sections 1-70 and 10-71 is largely replaced by tongues of the Canyon Creek sandstone lithofacies of the Wilkins Peak (terminology of H. W. Roehler, oral commun., 1972). The sandstone tongues are interbedded with dolomitic mudstone, which contains a thin bed of analcime and rare fish fragments. The sandstone lithofacies thickens in outcrops to the southeast, and forms prominent cliffs along Four J Rim and Canyon Creek. Although the Canyon Creek sandstone lithofacies is composed of fine- to medium-grained sandstone in stratigraphic section 3-72, to the southeast it contains coarse limestone, sandstone, and chert detritus (Roehler, 1968, p. 2254).

The Wilkins Peak Member overlies the Tipton Shale Member of the Green River Formation . On Pine Mountain, the Wilkins Peak is overlain by and intertongues with the Cathedral Bluffs Tongue of the Wasatch Formation. Because mollusks are extremely rare in the Cathedral Bluffs, the contact between these units was not studied in detail in the field. This transition is marked by a change from dark-gray-green dolomititic mudstone to maroon-red, gray, and green variegated mudstone and sandstone of the Cathedral Bluffs (Roehler, 1972a).

WASATCH FORMATION

The Wasatch Formation is typically composed of fine-grained sediment that complexly intertongues with lacustrine strata of the Green River Formation (fig. 2 and pl. 1). In the study area, the Wasatch is subdivided into the main body, Niland Tongue, and Cathedral Bluffs Tongue. The latter tongue was not studied in measured stratigraphic sections.

The Wasatch Formation is early Eocene (Wasatchian) to earliest-middle Eocene (Bridger A-B equivalent).

Main Body of the Wasatch Formation

Name, Definition, and Age.-The Wasatch Formation was named by Hayden (1869) for conglomeratic sediments in Echo and Weber Canyons, Utah, which grade eastward into variegated sandy clays and sandstones.

The term "main body" refers to strata of the Wasatch Formation that are not bounded both above and below by tongues or members of the Green River Formation. This definition is the same as that of Oriel (1961) in the western Green River Basin.

The main body of the Wasatch Formation is early Eocene (Wasatchian equivalent: Graybullian through mid-Lost Cabinian) (Roehler, 1972c, Fig. 5).

Distribution and Thickness.-The main body of the Wasatch Formation is exposed in Four J Basin southeast of Pine Mountain. Extensive red beds of the main body crop out in the Red Creek Badlands between Pine Mountain and Little Mountain. Strata of the main body also crop out in a two-mile-wide band from the Red Creek Badlands to east of Wyoming State Highway 430, a distance of over 18 miles.

Lithology and Stratigraphic Relations.-The Main body of the Wasatch is dominantly gray and red-brown mudstone, and very fine to fine-grained, buff and red-brown quartz sandstone. Minor rock types include gray and red-brown siltstone; thin, blocky, dark-gray limestone (containing mollusks of the Physa-Biomphalaria-Omalodiscus association); gray to black carbonaceous shale; dense gray marlstone; and coarse-grained and conglomeratic quartz sandstone containing clasts of quartz sandstone and quartzite.

Roehler (1965, p. 145) designated a thick sequence of strata in the main body of the Wasatch Formation as the Ramsey Ranch Member of the Green River Formation. The Ramsey Ranch Member is a lens that extends within 70 feet of the underlying Fort Union Formation to the overlying Luman Tongue of the Green River Formation (Roehler, 1965). The member consists of gray to black shale and coquinal limestone, chocolate-brown fissile shale, green mudstone, and gray fine-grained sandstone (Roehler, 1965, p. 145). Carbonaceous shale and lignite are also present. The Ramsey Ranch Member thickens north of its type locality and intertongues with red beds of the Fire Hole Sandstone lithofacies of the Wasatch Formation (terminology of Roehler, 1965). The member thickens in the subsurface west of the type locality; it also thins south of that locality and intertongues with red beds of the main body of the Wasatch Formation. Deposition of the member was restricted to a structural and topographic basin north of the Uinta Mountains, including portions of the Rock Springs Uplift, Washakie Basin, and Great Divide Basin (Roehler, 1965).

The Ramsey Ranch has not gained acceptance as a member of the Green River Formation. For example, McDonald (1972, Fig. 4a) recognized an unamed lacustrine facies equivalent to the Ramsey Ranch within the main body of the Wasatch Formation. Roehler (1972c, Fig. 5) did not recognize the Ramsey Ranch Member in regional correlation of Eocene strata in portions of Wyoming, Colorado, and Utah.

I examined the Ramsey Ranch Member at its type locality north of Little Mountain (secs. 13, 14, 22, and 23, T. 14 N., R. 105 W.) where it is 920 feet thick. The member is composed of strata representing shallow-water lacustrine (localities GR 95- and 96-71 of Hanley, 1974; and unpublishe Hanley field locality GR 3-75) and pond environments (localities 97- and 98-71 of Hanley, 1974) interbedded with strata of inferred fluviatile and paludal origin. Interpretation of paleoenvironments is difficult, because many beds lack nonmarine mollusks. I support informal recognition of a problematic lacustrine facies within the main body of the Wasatch Formation corresponding to portions of Roehler's Ramsey Ranch Member of the Green River Formation. The distribution of this facies delineates the embryonic development of lakes that preceded major transgression of Lake Gosiute during deposition of the Luman Tongue. Strata of the problematic lacustrine facies were not studied in measured stratigraphic sections.

Niland Tongue

Name, Definition, and Age.-The Niland Tongue was named by Pipiringos (1962, p. A24) for beds of coal, clay shale, siltstone, sandstone, and low-grade oil shale which crop out at the southern margin of the Niland Basin (central Great Divide Basin). The name is applied to strata of the Wasatch Formation stratigraphically between the Luman Tongue and Tipton Shale Member of the Green River Formation.

On the basis of vertebrate fossils, Roehler (1972c, Fig. 5) considers the Niland Tongue to be late-early Eocene (Lost Cabinian).

Distribution and Thickness.-The Niland Tongue crops out on the west and north slopes of Pine Mountain, and in an extensive area surrounding the Canyon Creek gas field and Hiawatha, Colorado. Because the Luman Tongue of the Green River Formation was not deposited in the Four J Basin region, the Niland Tongue is not distinguishable from the main body of the Wasatch Formation in that area.

The Niland varies from 0 to 304 feet thick in the study area.

Lithology and Stratigraphic Relations.-The Niland is composed of dark-brown and black carbonaceous shale, thin beds of lignite and gypsum, and buff, very fine grained quartz sandstone. Minor beds include gray and brown shale, thin gray fossiliferous limestone, siltstone, marlstone, and mudstone. Although the Niland is lithologically diverse, interbedded quartz sandstone and carbonaceous shale dominate throughout the study area. Thin lenses of limestone dominated by aquatic pulmonate gastropods of the Physa-Biomphalaria-Omalodiscus association are lithologically and paleontologically identical to those found in the main body of the Wasatch Formation.

Lacustrine facies are present in the Niland Tongue near Red Creek Ranch and Canyon Creek, and near Hiawatha, Colo. (strat. secs. 1-70 and 6-72; 9- and 10-71; and 3-71, respectively). These facies are not present near Rife Ranch (strat. secs. 12- and 13-71). Regional stratigraphic relations suggest that these facies probably represent lacustrine transgressions from north and east of the study area.

The upper portion of the main body of the Wasatch in Four J Basin (strat. sec. 2-72) is the rock-stratigraphic equivalent of the Niland Tongue. Strata of the main body differ markedly from the Niland in the paucity of carbonaceous shale and dominance of gray mudstone and some red-brown mudstone. The lithologic differences reflect the absence of ponded water and swamp environments that typified deposition of the Niland Tongue throughout the study area.

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APPENDIX A

TELEPHONE CANYON OVERLOOK COMPOSITE SECTION

TELEPHONE CANYON OVERLOOK (#1-70)

Measured at three locations in T. 13 N., R. 104 W.: in SE1/4SW1/4 sec. 24, east of the Telephone Canyon dry wash tributary to Red Creek, along the northern margin of the Red Creek Basin; in steep slopes on a spur below dirt road level in N1/2SE1/4SW1/4 sec. 24; and up to crest of hill (elev. 8263 ft) above dirt road along the boundary between sections 24 and 25.

Bed No.	Thickness (feet)	LITHOLOGY
		WILKINS PEAK MEMBER OF GREEN RIVER FORMATION (approximately lower two thirds)
133	0.50	Sandstone, light gray on fresh surface, weathers buff, minor limonitic staining, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous; top of unit not noted.
132	2.25	Siltstone, dusky-yellow (5Y 6-4), calcareous, irregular fragments.
131	0.20	Sandstone, weathers grayish orange (10YR 7-4), very fine sand, moderately sorted to moderately well sorted, subangular, calcareous.
130	2.25	Mudstone, pale-olive on fresh surface (10Y 6-2), blocky, slightly silty; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
129	0.33	Sandstone, light-gray on fresh surface, weathers buff, fine sand, subangular to subrounded, poorly sorted; parts along ripple-marked surface; upper portion is ledge former.
128	2.00	Mudstone, identical in all respects with bed 130.
127	2.00	Siltstone, identical in all respects with bed 132, gradational with bed 128.
126	3.00	Shale, grayish-olive (10Y4-2), mildly calcareous.
125	0.04	Quartz pebble conglomerate, weathers buff, very poorly sorted, composed of subangular to subrounded clasts of quartz sandstone, fine sand, clasts as large as 1.25-in., in maximum dimension.
124	19.50	Mudstone, light-olive on fresh surface, weathers gray, white, or grayish orange (10YR-4), dolomitic, crystalline, platy; contains rounded limy concretions; polygonal cracks infilled by buff siltstone at top.
123	0.40	Conglomeratic sandstone, gray on fresh surface, weathers buff to brown, medium to very coarse sand. (mode is coarse sand), angular to rounded, (mode is subrounded), poorly sorted, mildly calcareous; contains flat pebble clasts and disseminated grains of mudstone, gray, dolomitic, clasts as large as 2- to 3-in. in dimension, very midly calcareous; unit exhibits rare ripple marks.

Bed No.	Thickness (feet)	LITHOLOGY
122	13.50	Mudstone, light olive gray (5Y5-2), weathers to gray plates, dolomitic, crystalline, contains rare unidentifiable organic fragments, slope former; grades to siltstone at top, gradational with bed 123.
121	1.50	Sandstone, buff on fresh surface, weathers red-brown with minor hematitic bands, very fine sand, subrounded, moderately sorted, greater than 90 percent quartz, hematite coating on quartz grains, calcareous; minor ledge former.
120	0.10	Conglomeratic sandstone, gray on fresh surface, weathers buff to brown, fine to coarse sand, subangular to subrounded, poorly sorted, greater than 90 percent quartz, rare hematite coating on quartz grains, calcareous; contains clasts of light gray to buff siltstone, up to 1.25-in. in maximum dimension.
119	1.00	Sandstone, yellow-gray on fresh surface (5Y 7-2), weathers grayish orange (10YR 7-4), very fine sand, subangular, moderately well sorted, greater than 90 percent quartz; at top sandstone exhibits load casts of fine to medium sand with wavy bedding.
118	1.50	Mudstone, light-gray, dolomitic, thin bedded, poorly indurated.

Bed No.	Thickness (feet)	LITHOLOGY
117	0.20	Sandstone, light-gray on fresh surface, weathers buff, very fine to fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous.
116	6.00	Shale, light-olive on fresh surface, weathers light gray, thin plates; grades to mudstone, gray, dolomitic; silty at top of unit; gradational with bed 117.
115	30.00	Mudstone, light-olive on fresh surface, weathers light gray to white and grayish orange (10YR 7-4), dolomitic crystalline, mildly calcareous, platy, massive, ledge former; numerous layers exhibit shrinkage (synerisis?) cracks; unit contains rare layers of ellipsoidal, limy concretions; one thin (1/2 in.) stromatolite layer.
114	6.25	Shale, yellow-gray on fresh surface (5Y 7-2), weathers light gray, mildly calcareous; slope former.
113	0.25	Sandstone, weathers very pale orange (10YR 8-2), very fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, calcareous.
112	4.50	Shale, identical in all respects with bed 114.
111	7.25	Mudstone, yellow-gray (5Y 7-2), calcareous, platy.
110	0.50	Sandstone, yellow gray on fresh surface (5YR 7-2), weathers grayish orange (10YR 7-4), very fine sand, subrounded, moderately well sorted, calcareous, greater than 90 percent quartz.

Bed No.	Thickness (feet)	LITHOLOGY
109	129.50	Shale, pale yellow brown (5Y 5-2), fissile, platy, locally blocky, locally calcareous, locally contains ostracodes and fish bones; insect larvae, leaves, and unidentified organic fragments at 75-ft level; cf. Drepanotrema sp., and Planorbidae: indet. at 15- to 20-ft level, GR18-72; thin (2- to 4-in.) sandstone interbeds, weathers grayish-orange (10YR 7-4), yellow-gray (5Y 7-2) on fresh surface, very fine sand, sub-rounded, moderately well sorted, well indurated, calcareous; local calcite cavity filling.
108	7.50	Mudstone, pale-olive (10Y 6-2), calcareous, irregular fragments.
107	4.00	Shale, dark-yellow-brown (10YR 4-2), poor oil shale, calcareous; locally contains ostracodes.
106	0.25	Dolomite, pale-yellow-orange (10YR 8-6), crystalline, mildly calcareous, dense, brittle; locally slumped out of place; ledge former.
105	80.00	Oil shale, dark-yellow-brown (10YR 4-2), and light-olive-gray (5Y 5-2), locally calcareous, locally contains ostracodes; unit contains one thin (2-in.) sandstone at 2-ft level, weathers pale-yellow-orange (10YR 8-6), calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
104	1.00	Sandstone, weathers pale-yellow-orange (10YR 8-6), light olive gray (5Y 6-1) on fresh surface, very fine grained, calcareous; forms knob-like resistant blocks locally offset by small faults, calcite filling of fault planes and fractures, slickensides.
103	9.75	Oil shale, moderate-olive-brown (5Y 4-4), calcareous, unfossiliferous.
102	0.25	Marlstone, buff, calcareous, blocky; gradational with bed 101.
101	2.75	Mudstone, dusky-yellow-green (5GY 5-2), calcareous, irregular fragments.
100	0.50	Marlstone, white (N9) on fresh surface, weathers buff, calcareous, blocky, unfossiliferous; offset by small faults.
99	6.75	Shale, yellow-gray (5Y 7-2); becomes blocky claystone at top; locally slumped.
98	0.60	Sandstone, weathers yellow gray (5Y 7-2), very fine sand, subrounded, moderately well sorted, greater than 90 percent, very calcareous; poorly resistant.
97	3.50	Shale, weathers yellow gray (5Y 7-2), rare ostracode molds; locally slumped.

Bed No.	Thickness (feet)	LITHOLOGY
96	0.40	Dolomite, grayish orange (10YR 7-4), dense, very resistant, crystalline, very mildly calcareous; locally offset by small faults and fractures filled with calcite; upper surface exhibits ridges 1/2- to 1-in. high inferred to have formed by movement of dolomite into overlying shale of bed 97.
95	35.00	Shale, light-olive-gray (5Y 5-2) and brown, weathers light gray (N7), platy, brittle, fissile.
	386.77	Total measured stratigraphic section of a part of Wilkins Peak Member of Green River Formation at this locality.
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION
94	115.00	Oil shale, light-olive-gray (5Y 5-2) and olive-brown, locally calcareous, locally contains ostracodes, fissile, locally papery and slightly platy; slope former.
93	1.25	Coquinal limestone, brown and light-gray, contains poorly preserved Goniobasis sp. and Unionidae: indet.; poorly resistant.
	116.25	Total measured stratigraphic section of Tipton Shale Member of Green River Formation at this locality.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION
92	4.75	Shale, dark-dusky-red and black, at top shale becomes dark-yellow-brown (10YR 4-2), carbonaceous, sulphurous stringers, thin (less than 1-in.) coal beds, local gypsiferous layers near top.
91	3.50	Sandstone, light-yellow-brown, very fine sand, subangular, moderately well sorted, greater than 90 percent quartz, noncalcareous; minor hematitic staining.
90	7.00	Interbedded mudstone and siltstone, light-gray (N7) to buff, blocky, locally poorly indurated, locally calcareous; gradational with bed 91.
89	3.00	Shale, red-brown and black, carbonaceous, sulphurous stringers, coal bed in middle of unit, disseminated gypsum at top of bed.
88	2.75	Sandstone, light-yellow-brown, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, noncalcareous, minor limonitic staining near top; poorly indurated at bottom.
87	3.25	Mudstone, light-gray (N7), blocky to irregular fragments; contains interbeds of medium gray, poorly indurated siltstone; gradational with bed 88.

Bed No.	Thickness (feet)	LITHOLOGY
86	7.25	Oil shale, dark-yellow-brown (10YR 4-2), calcareous, fissile; contains Goniobasis tenera, Unionidae: indet., Valvata sp., and ostracodes; at top shale becomes carbonaceous, red brown and black, with disseminated gypsum and 1-in. gypsiferous bed at top.
85	3.25	Mudstone, light-gray (N7), calcareous, somewhat blocky: contains thin (4-in.) fissile, light-olive gray (5Y 5-2) shale interbed in middle of unit.
84	0.20	Gypsum, red-brown, resistant, persistant minor ledge former.
83	0.75	Coquinal limestone, light-gray and white, poorly indurated, contains Goniobasis sp. and fragments of Unionidae: indet.
82	7.70	Shale, red-brown and black, carbonaceous, gypsiferous stringers; two thin resistant gypsum beds, few thin coal interbeds, grades to coal at top.
81	1.25	Sandstone, yellow-brown with minor limonitic staining, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, noncalcareous; locally poorly indurated.
80	1.00	Siltstone, light-gray (N7), noncalcareous, blocky to irregular fragments.

Bed No.	Thickness-(feet)	LITHOLOGY
79	4.00	Sandstone, light-olive-gray on fresh surface, weathers buff, very fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz; poorly to moderately indurated, calcareous; thinly laminated.
78	2.00	Siltstone, light-olive-gray (5Y5-2), somewhat blocky, calcareous; gradational with bed 79.
77	1.00	Mudstone, brownish-gray, mildly calcareous, irregular fragments; minor unidentifiable organic fragments.
76	2.00	Shale, light-olive-brown, dark-brown, and black, becomes carbonaceous above base with plant fragments, sulphurous stringers, and one thin bed of coal.
75	0.50	Mudstone, light-gray (N7), noncalcareous, locally slightly silty, irregular fragments.
74	20.25	Sandstone, light-yellow-brown on fresh surface, weathers moderate yellow brown (10YR 5-4), very fine sand, subangular, moderately sorted to moderately-well sorted, greater than 90 percent quartz, calcareous, locally unindurated, typically well indurated; sedimentary structures include convoluted bedding, cross stratification, locally massive, laminated; weathers along laminations into flagstone-like blocks; in lower 1-ft sandstone contains few thin light-olive-gray (5Y 5-2) siltstone interbeds.

Bed No.	Thickness (feet)	LITHOLOGY
73	29.00	Shale, grayish-brown (5YR 3-2), dark-yellow-brown (10YR 4-2) between 10-ft and 24-ft levels, locally calcareous, papery, fissile, contains ostracodes and Valvata? sp , GR42-70; at top shale is yellow-brown, and is slightly silty.
72	3.50	Shale, yellow-brown, red-brown, and black, carbonaceous, sulphurous stringers, contains few thin coal interbeds; capped by 3-in. bed of poorly resistant gypsum.
71	0.30	Limestone, white to light-gray, platy; contains poorly preserved assemblage of aquatic pulmonate gastropods.
70	11.00	Shale, red-brown to black, carbonaceous, sulphurous and gypsiferous stringers, few thin interbeds of coal.
69	1.50	Limestone, light-brown to white, blocky, slightly platy, slightly brittle; contains the aquatic pulmonate gastropods Physa pleromatis, Biomphalaria sp., and Gyraulus sp.; 2-in. interbed of carbonaceous shale at 9-in. level.
68	1.75	Carbonaceous shale identical in all respects with bed 70.
67	0.40	Limestone, lithologically and paleontologically identical with bed 69.
66	3.25	Shale, red-brown and black, carbonaceous, rarely grades to coal.

Bed No.	Thickness (feet)	LITHOLOGY
65	0.80	Limestone, yellow-gray (5Y 8-1) on weathered surface, slightly darker on fresh surface, contains Gyraulus sp. and Hydrobia sp.; weathers into thin plates.
64	2.75	Shale, dark-brown and black, carbonaceous, sulfurous stringers and disseminated gypsum, grades to coal in upper 1-ft.
63	0.90	Mudstone, light-gray (N7), blocky, locally slightly silty, minor sulfurous stringers, gradational with bed 64.
62	2.00	Sandstone, very light gray (N8) on fresh surface, weathers buff with minor limonitic staining, very fine sand, subangular, moderate sorting, greater than 90 percent quartz, massive.
61	4.50	Siltstone, olive-gray (5Y 4-1), locally slightly calcareous, moderately indurated; contains thin (4-in.) interbed of sandstone.
60	6.40	Sandstone, dark-yellow-orange (10YR 6-6) on weathered surface, light gray (N7) on fresh surface, very fine sand, subangular, rarely subrounded, moderately sorted, greater than 90 percent quartz with minor fraction of unidentifiable dark grains; massive and cross-stratified; markedly thickens to southeast, interpreted to be portion of channel-form sandstone.

Bed No.	Thickness (feet)	LITHOLOGY
59	3.50	Siltstone, olive-gray (5Y 4-1), locally slightly calcareous, moderately indurated; contains thin interbed of sandstone in middle of unit.
58	2.50	Mudstone, light-gray (N7), blocky, noncalcareous, minor sulfurous stringers; near top grades to pale red carbonaceous shale with thin bed of coal.
57	9.00	Shale, brown, red-brown, and black, carbonaceous, sulfurous stringers, grades to coal in upper 4-ft.
56	6.00	Siltstone, dark-olive-gray (5Y 3-2), noncalcareous, moderately to poorly indurated; grades to sandstone at top of unit.
55	0.75	Shale, red-brown and black, carbonaceous, sulfurous stringers, locally slightly silty, disseminated gypsum.
54	1.00	Interbedded carbonaceous shale, siltstone, and sandstone; shale same as bed 55; siltstone is olive gray (5Y 3-2), slightly blocky, noncalcareous; sandstone is light gray (N6) on fresh surface, very fine sand, subangular, moderately sorted to poorly sorted, calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
53	2.20	Sandstone, weathers pale yellow orange (10YR 8-6), very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous, poo indurated, friable; contains thin (4-in.) siltstone interbed.
52	6.50	Siltstone, olive-gray (5Y 3-2), noncalcareous, moderately to poorly indurated; contains thin (4- to 5-in.) sandstone interbed near base.
51	9.25	Sandstone, medium-light-gray (N6) on fresh surface, very fine sand, subangular, moderate sorting, greater than 90 percent quartz, poorly indurated, friable; massive, cross-stratified on large scale at base, gr. to small scale cross stratification in lower 5-ft; minor hematitic staining on weathered surfaces; contains thin olive-gray (5Y 3-2) siltstone interbed near middle of unit.
50	6.40	Interbedded sandstone and carbonaceous shale, sandstone is very fine sand, subangular, moderate sorting, friable, poorly indurated, minor limonitic staining on weathered surface; shale is brown to black, carbonaceous, one thin coal interbed, at top shale grades to less carbonaceous, pale olive (10Y 6-2).

Bed No.	Thickness (feet)	LITHOLOGY
49	4.75	Sandstone, buff, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, poorly indurated to unindurated; contains thin (7-in.) dark-olive-brown shale bed in upper 1.5-ft of unit.
48	2.50	Shale, olive-brown, carbonaceous, sulfurous stringers, thin beds of coal.
47	0.30	Limestone, olive-brown on fresh surface, weathers light gray, dense, blocky; contains Pisidiidae: indet., Hydrobia aff. H. utahensis, Hydrobia cf. H. utahensis, Valvata? sp., Physa? sp., Biomphalaria aequalis, Biomphalaria sp., cf. Drepanotrema? sp., Acroloxus minutus, Acroloxus cf. A. minutus, and Acroloxus sp., GR31-70.
46	3.75	Shale, dark brown to black, and olive-brown, thin coal interbeds at base; grades to less carbonaceous olive-brown shale above base and contains mollusks.
45	4.75	Sandstone, buff, very fine sand, subangular to subrounded, moderately sorted to poorly sorted; poorly indurated to unindurated.

Bed No.	Thickness (feet)	LITHOLOGY
44	16.75	Shale, brown, red-brown, and black, carbonaceous, minor sulfurous stringers, locally slightly silty; rare thin interbeds of coal; grades to less carbonaceo brown shale at top.
43	13.50	Sandstone, weathers yellow gray (5Y 7-2), very fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, friable, poorly indurated, thi bedded, massive; slope former, minor ledge former at 4-ft and 8-ft levels.
42	6.00	Shale, olive-gray (5Y 4-1), irregular fragments, slightly silty; one thin (1-in.) sandstone interbed in upper 2-ft.
41	2.50	Sandstone, light-gray (N7) on fresh surface, weathers with minor hematitic staining, very fine sand, subangular, moderate sorting, greater than 90 percent quartz, alternately indurated and unindurated, indurat sand is calcareous; thinly bedded at top.
40	3.70	Shale, dark-reddish-brown and black, carbonaceous, sulfurous stringers; grades to less carbonaceous shale at top.
39	2.50	Sandstone, weathers buff, very fine sand, subangular, moderately sorted to moderately well sorted, greater than 90 percent quartz, noncalcareous, poorly indurate massive.

Bed No.	Thickness (feet)	LITHOLOGY
38	3.00	Shale, dark-red-brown to black, carbonaceous, sulfurous stringers, 8-in. coal bed at base; grades to less carbonaceous olive shale with minor organic fragments at top.
37	6.50	Covered interval where dirt road intersects transect of measured stratigraphic section.
36	8.00	Shale, light-olive-gray (5Y 5-2), very poor oil shale, papery, irregular fragments, contains rare beds with abundant fragments of Goniobasis tenera and Unionidae: indet.; top contact of unit covered by road fill.
35	0.40	Coquinal marlstone, brown to gray, poorly indurated, contains abundant shell fragments of Goniobasis tenera and Unionidae: indet.
34	29.00	Shale, red-brown, black, carbonaceous, sulfurous stringers, locally slightly silty, disseminated gypsum throughout; gypsum beds near base; shale becomes less carbonaceous at top; contains few thin (6-in.) sandstone interbeds, light gray, very fine sand, porous, noncalcareous, poorly indurated.

Bed No.	Thickness (feet)	LITHOLOGY
33	2.00	Sandstone, weathers buff, very fine sand, subangular, rarely subrounded, moderately sorted, greater than 90 percent quartz, moderately indurated to poorly indurated, noncalcareous.
32	0.25	Mudstone, light-gray, slightly blocky, irregular fragments, noncalcareous.
31	0.10	Shale, dark-brown and black, carbonaceous, locally slightly silty, slightly blocky.
30	1.50	Shale, light-olive gray (5Y 5-2), fissile.
29	1.00	Sandstone, weathers grayish orange (10YR 7-4), light gray on fresh surface, very fine sand, subangular, moderate sorting, greater than 90 percent quartz, poorly indurated, porous, noncalcareo extremely variable in thickness laterally, interprete to be portion of channel form sandstone; locally exhibits cross stratification and ripple marks.
	303.70	Total measured stratigraphic section of the Niland Tongue of the Wasatch Formation at this locality.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION
28	130.75	Shale, dusky-yellowish-brown (10YR 2-2), in part poor oil shale, fissile, papery, irregular fragments, calcareous, contains Pisidiidae: indet., Valvata sp., GR22-70; at top the shale becomes slightly blocky and slightly silty, gradational with bed 29; unit contains several thin 1- to 3-in. sandstone interbeds between 32-ft and 57-ft levels, pale yellow brown (10YR 6-2), dark yellow brown (10YR 4-2), yellow-gray (5Y- 8-1), very fine sand, subangular to rarely subrounded, moderately sorted, greater than 90 percent quartz, calcareous, locally slightly carbonaceous, moderately thin bedded, minor ledge formers, moderately to well indurated.
27	2.00	Coquinal marlstone, light-brown, composed of Goniobasis tenera (very prominent nodes), Viviparus trochiformis, cf. Plesielliptio priscus, and well preserved Plesielliptio n. sp. A, GR20-70; forms minor bench and litters slope with gastropods and bivalves.
26	18.00	Shale, moderate-yellow-brown (10YR 5-4), papery, flaky, mildly calcareous, contains ostracodes.

Bed No.	Thickness (feet)	LITHOLOGY
25	0.40	Sandstone, moderate-yellow-brown on weathered surface, very fine sand, subangular, moderately well sorted, greater than 90 percent quartz, calcareous; thinly bedded.
24	19.00	Shale, moderate-brown (5YR 4-4), flaky, locally with muscovite along bedding surfaces, locally with ostracodes and very poorly preserved gastropods.
23	0.25	Sandstone, yellowish-gray (5Y 7-2), very fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, calcareous; thinly bedded.
22	3.75	Coquinal marlstone, brown, blocky, moderately to poorly indurated, contains very poorly preserved Goniobasis sp. and Unionidae: indet.
21	22.50	Shale, dusky-yellowish-brown (10YR 2-2) to black, carbonaceous, noncalcareous, sulfurous stringers throughout unit; silty in basal two feet; 2-in. gypsum bed at top.

Bed No.	Thickness (feet)	LITHOLOGY
20	2.00	Sandstone, very light gray on fresh surface (N8), pale-yellowish-orange (10YR 8-6) on weathered surface, very fine sand, subangular to subrounded, moderately sorted, calcareous, at least 80 percent quartz with minor unidentified black grains; generally thin bedded, few 2-in.-thick intervals with small-scale cross stratification.
19	1.00	Shale, gray to light-brown, fissile, sandy; gradational with bed 20.
18	5.00	Coquinal limestone, light-yellowish-brown, composed of Goniobasis tenera, Viviparus trochiformis, and Unionidae: indet; moderately resistant, forms minor bench.
17	3.50	Shale, dark-yellow-brown (10YR 4-2), poor oil shale, locally contains ostracodes, flaky; becomes sandy at top.
16	0.75	Sandstone, pale-yellow-brown (10YR 6-2), very fine sand, subangular, moderately well sorted, greater than 90 percent quartz; thinly bedded, small-scale cross stratification.
15	17.90	Oil shale, dark-yellow-brown (10YR 4-2), calcareous, fissile, flaky, locally contains ostracodes and mollusks.

Bed No.	Thickness (feet)	LITHOLOGY
14	2.50	Interbedded sandstone and shale, sandstone is pale yellow-brown (10YR 6-2) and light brownish-gray (5YR 6-1), very fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz, calcareous, thinly bedded, small-scale cross stratification, locally weathers into thin slabs; shale is identical in all respects with bed 15, and is locally slightly silty.
13	23.10	Shale, identical in all respects with bed 15; mollusks and ostracodes in basal 7-ft of unit.
12	2.50	Mudstone, dark-yellow-brown (10YR 4-2), blocky, silty, fragments of Unionidae: indet. along laminations in lower part.
11	0.40	Coquinal limestone, light brown, contains *Goniobasis tenera*, and fragments of Unionidae: indet.; gradational with bed 12.
	255.30	Total measured stratigraphic section of Luman Tongue of Green River Formation at this locality.
		MAIN BODY OF WASATCH FORMATION (uppermost part)
10	7.50	Shale, gray on weathered surface, brownish-gray (5YR 4-1) on fresh surface, carbonaceous, local sulfurous stringers; 9-in. coal bed near base; thin interbeds of less carbonaceous shale at top of unit.

No.	Thickness (feet)	LITHOLOGY
9	3.00	Interbedded mudstone and carbonaceous shale, mudstone is light olive gray (5Y 5-2) with yellow mottling, silty, blocky; carbonaceous shale is dark brown and black, sulfurous stringers, rare thin coal interbeds.
8	8.00	Mudstone, identical in all respects with mudstone in bed 9.
7	2.20	Gypsum, red-brown, poorly indurated.
6	3.00	Mudstone, light olive gray with yellow mottling, blocky, locally slightly silty.
5	2.00	Shale, red-brown and black, carbonaceous, sulfurous stringers, rare thin interbeds of coal; 5-in.-thick gypsum bed at top.
4	3.00	Mudstone, identical in all respects with bed 6.
3	5.25	Shale, identical in all respects with bed 5; 1.25-ft-thick gypsum bed in middle of unit, red-brown, poorly indurated.
2	3.00	Mudstone, identical in all respects with bed 6; gradational with bed 3.
1	17.00	Mudstone, very dusky red (10R 2-2), slightly silty, rare light green mottles, blocky and irregular fragments, noncalcareous; bottom contact not noted.

Bed No.	Thickness (feet)	LITHOLOGY
	53.95	Total measured stratigraphic section of main body of Wasatch Formation (uppermost part) at this locality.

APPENDIX B

TELEPHONE CANYON OVERLOOK COMPOSITE SECTION

HORSESHOE HILL (#1-71)

Measured on slopes northwest of confluence of Horseshoe Wash and Vermillion Creek, north of a curve in Wyoming State Highway 430 in NW1/4NW1/4 sec. 22, T. 12 N., R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (lower part)
		Bed 104 of this section is the same as bed 1 of section #2-71.
104	1.30	Coquinal siltstone, hard, weathers crumbly; contains thin shale interbeds; abundant Goniobasis tenera (well developed ribs and good spiral ornamentation with small nodes), rare fragments of Unionidae: indet., and rare Viviparus sp.; caps prominent bench.
103	2.25	Shale, red-brown, silty, noncalcareous, somewhat carbonaceous; one external mold of Goniobasis tenera (well developed ribs and moderate spiral ornamentation); in upper one foot the shale is yellow-brown with less organic material and abundant Goniobasis tenera (well developed ribs, moderate spiral ornamentation, and no nodes).
102	2.00	Sandstone, same as Bed 100 but without cross stratificatic silty at base.
101	1.75	Shale, yellow-brown to dark-gray, silty, flaky, noncalcareous; grades into bed 102.

Bed No.	Thickness (feet)	LITHOLOGY
100	0.60	Sandstone, gray on fresh surface, weathers buff, very fine sand, subangular, well sorted, calcareous, minor limonitic layers; cross stratified.
99	0.90	Shale, yellow-brown to dark-gray, flaky, silty, with minor organic material, noncalcareous; grades into bed 100.
98	1.75	Sandstone, same as bed 96; organic material along laminations, moderately to poorly indurated; few interbeds of siltstone.
97	0.75	Shale, gray to light-yellow-brown with thin rusty-yellow-brown layers, flaky, noncalcareous; rare ostracodes; gradational with bed 98.
96	2.75	Sandstone, buff, very fine sand, greater than 90 percent quartz, massive; few interbeds of siltstone.
95	2.25	Siltstone, rusty-yellow-brown, calcareous, minor organic material, ostracodes; interbedded with thin beds of shale, gray, silty, noncalcareous.
94	3.25	Oil shale, yellow-brown to dark-olive-brown, flaky noncalcareous; sparse to abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Valvata sp., Viviparus trochiformis, Sphaerium sp., Pisidiidae: indet., Unionidae: indet. and ostracodes.
93	0.50	Coquinal siltstone, hard, crumbly; Goniobasis tenera as in bed 94; thin (less than 1/2-in. mudstone interbeds.

Bed No.	Thickness (feet)	LITHOLOGY
92	2.30	Mudstone, rusty-yellow-brown with white to dark-gray mottling, silty, blocky, calcareous; well preserved Goniobasis tenera with ornamentation as in bed 94, and Unionidae: indet.; GR88-71.
91	12.00	Oil shale, dark-olive-brown, noncalcareous; sparse to abundant Goniobasis tenera, Valvata sp., Sphaerium sp., Pisidiidae: indet..
90	0.30	Coquinal, siltstone, hard, crumbly; abundant shell fragments of unidentifiable mollusks.
89	0.75	Shale, light- to dark-brown and black, carbonaceous; sulfurous and gypsiferous stringers; 2-in. coal bed at top.
88	0.80	Coquinal siltstone, crumbly; minor ledge former; poorly preserved Goniobasis tenera (ribs, moderate spiral ornamentation, and no nodes), rare, Unionidae: indet., and rare Viviparus trochiformis.
87	1.50	Oil shale, dark-olive-brown, silty, noncalcareous; at top Unionidae: indet., Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and Viviparus trochiformis?; GR87-71.
86	1.00	Coquinal siltstone, hard, crumbly; abundant shell fragments, few Goniobasis tenera (well developed ribs and minor spiral ornamentation), rare Unionidae: indet., and rare Viviparus trochiformis.

Bed No.	Thickness (feet)	LITHOLOGY
85	2.75	Shale, light- to dark-brown and black, carbonaceous interbedded sulfurous stringers and thin gypsiferous layers; 3-in. coal bed at top.
84	0.75	Coquinal siltstone, hard, crumbly; minor ledge former; abundant shell fragments, few Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and rare Viviparus trochiformis.
83	6.00	Oil shale, yellow-brown, flaky, slightly silty; few Goniobasis tenera, and ostracodes.
82	0.75	Coquinal siltstone, hard, crumbly, ledge former; abundant shell fragments, few Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and rare Viviparus trochiformis.
81	1.80	Oil shale, dark-olive-brown, flaky, silty, noncalcareous; ostracodes; few thin coquinal layers, hard, crumbly; abundant shell fragments, fauna same as bed 84.
80	0.30	Coquinal siltstone, hard, crumbly, minor ledge former; abundant shell fragments, few Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), rare Unionidae: indet., and rare Viviparus trochiformis.
79	2.00	Oil shale and interbedded thin coquinal layers, same as bed 81.

Bed No.	Thickness (feet)	LITHOLOGY
78	0.25	Coquinal siltstone, hard, crumbly, minor ledge former; abundant shell fragments, few Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), rare Unionidae: indet., and rare Viviparus trochiformis.
77	0.60	Oil shale, yellow-brown, noncalcareous; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), ostracodes, rare Unionidae: indet.
76	0.70	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), rare Viviparus trochiformis.
75	1.25	Oil shale, yellow-brown, soft, flaky; ostracodes.
74	0.08	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes); GR86-71.
73	0.75	Oil shale, dark-olive-brown, soft, flaky, noncalcareous
72	0.60	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Unionidae: indet.; GR85-71.

Bed No.	Thickness (feet)	LITHOLOGY
71	1.00	Oil shale, yellow-brown to dark-olive-brown, noncalcareous, slightly silty at top; yellow-brown shale contains rare Goniobasis tenera and ostracodes; gradational with bed 72.
70	0.25	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Viviparus trochiformis, and rare Unionidae: indet..
69	1.00	Oil shale, rusty-yellow-brown to light-yellow-brown, flaky to somewhat blocky, slightly silty, noncalcareous, Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and ostracodes; one thin (1-in.) coquinal siltstone with ostracodes and Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and rare Viviparus trochiformis.
68	0.30	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Viviparus trochiformis, and rare Unionidae: indet..
67	0.90	Oil shale, rusty-yellow-brown to light-yellow-brown, flaky to somewhat blocky, slightly silty, noncalcareous, Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and ostracodes; one thin coquinal siltstone with ostracodes and Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and Viviparus trochiformis.

Bed No.	Thickness (feet)	LITHOLOGY
66	0.25	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and rare Unionidae: indet.; GR84-71.
65	0.75	Oil shale, rusty-yellow-brown to light-yellow-brown flaky to somewhat blocky, slightly silty, noncalcareous, contains ostracodes and Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes); one thin coquinal siltstone with Goniobasis tenera (ornamentation as in associated shale), and rare Viviparus trochiformis.
64	0.42	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Viviparus sp., and Unionidae: indet.; contains two thin (less than 1-in.) oil shale interbeds with Goniobasis tenera; GR83-71.
63	1.60	Oil shale, same as bed 65; several thin coquinal siltston beds with Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and Viviparus trochiformis.

Bed No.	Thickness (feet)	LITHOLOGY
62	0.40	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), and Viviparus trochiformis; GR82-71.
61	2.25	Oil shale and interbedded coquinal siltstone as in bed 63.
60	0.50	Coquinal siltstone, same as bed 62, Goniobasis tenera (nodes moderately developed), Viviparus trochiformis, and Unionidae: indet.; GR81-71.
59	2.50	Oil shale, light-yellow-brown, slightly silty, noncalcareous; contains Goniobasis tenera (well developed ribs and spiral ornamentation and small nodes), Pisidiidae: indet. and ostracodes; few thin (less than 1-in.) coquinal siltstone layers as in bed 63.
58	0.20	Coquinal siltstone, same as bed 62, Goniobasis tenera (well developed ribs, spiral ornamentation with small nodes), Viviparus trochiformis?; GR80-71.
57	26.80	Oil shale, yellow to dark-olive-brown, calcareous; ostracodes throughout, upper 5-ft contains abundant Pisidiidae: indet., Sphaerium sp., Valvata sp., and few Goniobasis tenera (well developed ribs and minor spiral ornamentation).

Bed No.	Thickness (feet)	LITHOLOGY
56	1.20	Coquinal siltstone, hard, crumbly, minor ledge former; Goniobasis tenera (well developed ribs, and spiral ornamentation with small nodes), Viviparidae?: indet., abundant shell fragments; GR79-71.
55	16.75	Oil shale, yellow to dark-olive-brown; upper 3- to 4-ft is ledge former with Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes) sampled as GR21-71, contains several thin coquinal siltstone layers sampled as GR78-71 consisting of Goniobasis tenera (ornamentation as in GR21-71) and rare Viviparus sp.; entire oil shale unit contains sparse to abundant ostracodes, Goniobasis tenera (well developed ribs and spiral ornamentation and small nodes), Valvata sp., Unionidae: indet., Sphaerium sp., and Pisidiidae: indet.; oil shale in lower 12-ft sampled as GR77-71.
54	0.30	Coquinal siltstone, hard, crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation with poor nodes), Viviparus trochiformis, rare Unionidae: indet., and abundant shell fragments.
53	2.25	Oil shale, dark-yellow-brown; contains Goniobasis tenera (well developed ribs and spiral ornamentation), ostracodes, Valvata sp., and Pisidiidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
52	0.10	Coquinal siltstone, same as bed 54; but with poorly preserved Goniobasis tenera (well developed ribs only).
51	0.50	Oil shale, dark-yellow-brown, calcareous; contains Goniobasis tenera (well developed ribs and spiral ornamentation), Pisidiidae: indet., Valvata sp., and ostracodes.
50	0.10	Coquinal siltstone, identical in all respects with bed 52.
49	4.20	Oil shale, dark-olive-brown, noncalcareous, soft, flaky; Goniobasis tenera, Valvata sp., and ostracodes.
48	0.50	Coquinal siltstone, identical in all respects with bed 52.
47	4.00	Oil shale, dark-olive-brown, soft, flaky, noncalcareous; Goniobasis tenera, and ostracodes at top.
46	0.30	Coquinal siltstone, identical in all respects with bed 52.
45	0.70	Oil shale, light-yellow-brown to olive-brown, soft, flaky, both calcareous and noncalcareous; basal portion contains Goniobasis tenera (well developed ribs, spiral ornamentation and poor nodes), and ostracodes.

Bed No.	Thickness (feet)	LITHOLOGY
44	1.40	Coquinal siltstone, identical in all respects with bed 52.
43	18.00	Oil shale, light-yellow-brown to dark olive-brown, soft, flaky, calcareous, carbonaceous at 5- to 7-ft level; sparse to abundant Goniobasis tenera (well developed ribs and moderately developed spiral ornamentation), Pisidiidae: indet., Sphaerium sp., Valvata sp., few fragments of Viviparus? sp., Unionidae: indet., and ostracodes.
42	0.50	Coquinal siltstone, identical in all respects with bed 54.
41	0.70	Oil shale, yellow-brown, soft, flaky, calcareous; locally abundant Valvata sp., and ostracodes.
40	0.10	Coquinal siltstone, identical in all respects with bed 54.
39	0.70	Oil shale, identical in all respects with bed 41.
38	0.40	Coquinal siltstone, identical in all respects with bed 54.

Bed No.	Thickness (feet)	LITHOLOGY
37	17.75	Oil shale; at base: yellow-brown, soft, flaky, calcareous, abundant ostracodes and Goniobasis tenera (well developed ribs), minor organic fragments; at 0.75-ft and 1.75-ft levels: thin coquinal siltstone beds with abundant shell fragments of what appear to be Goniobasis sp., and Unionidae: indet.; above 2-ft level: shale is light- to dark-yellow-brown, sparse to abundant ostracodes with rare Sphaerium sp.; in upper 1-ft shale contains abundant ostracodes, Pisidiidae: indet., Sphaerium sp., Valvata sp., and rare Unionidae: indet.; GR76-71.
36	0.50	Coal
35	1.20	Siltstone, reddish-yellow-brown, calcareous; contains Goniobasis (well developed ribs and spiral ornamentation), ostracodes, and Sphaerium sp.; shaly at base with fauna as above, but without Sphaerium sp.
34	0.70	Marlstone, buff; contains organic fragments, abundant ostracodes, Unionidae: indet.
33	0.30	Oil shale, yellow-brown, calcareous; contains abundant ostracodes, Unionidae: indet., and rare Goniobasis tenera.
32	3.00	Shale, light- to dark-brown and black, carbonaceous, sulfurous stringers; two 1-in. gypsiferous beds at top.

Bed No.	Thickness (feet)	LITHOLOGY
31	0.70	Sandstone, buff, very fine sand, subangular to subrounded, somewhat poorly sorted; contains minor organic fragments.
30	1.40	Shale, light- to dark-brown to black, highly carbonaceous above base, sulfurous stringers througho
29	1.00	Mudstone, gray, slightly silty, noncalcareous, organi material at base.
28	1.30	Siltstone, yellow-brown, mildly calcareous.
27	2.25	Mudstone, very dark yellow-brown becoming lighter toward top, blocky, noncalcareous; somewhat fissile with organic fragments at top.
26	3.75	Shale, light- to dark-brown and black, carbonaceous; thin gypsiferous and coal layers; capped by thin (1-in.) gypsiferous layer.
25	0.75	Mudstone, light-gray, blocky, with sulfurous stringers.
24	.90	Shale, light- to dark-brown and black, carbonaceous; few 1.5-in. gypsiferous layers; 3-in. coal bed in middle of unit.

Bed No.	Thickness (feet)	LITHOLOGY
23	2.50	Oil shale, dark-yellow-brown, noncalcareous, flaky, contains sparse Goniobasis tenera, Unionidae: indet., and ostracodes; 1-in. thin coquinal siltstone in middle of unit with abundant shell fragments of Goniobasis sp., and Unionidae?: indet.
22	1.00	Coquinal siltstone, hard crumbly, minor ledge former; abundant Goniobasis tenera (well developed ribs and spiral ornamentation), rare Viviparus trochiformis, and Unionidae: indet., all mollusks poorly preserved.
21	2.25	Shale, yellow-brown, carbonaceous, silty, slightly gypsiferous in middle of unit.
20	0.10	Coquinal siltstone, hard, crumbly, poorly preserved Goniobasis sp., Unionidae: indet., and abundant shell fragments.
19	0.75	Shale, dark-brown to black, carbonaceous; thin gypsiferous layer at base; thin coal bed at top.
18	1.00	Mudstone, dark-gray, blocky, noncalcareous, contains minor sulfurous stringers; gradational with bed 19.
17	2.50	Shale, dark-brown, carbonaceous, sulfurous stringers, gradational with bed 18.
16	0.50	Sandstone, light-gray, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, noncalcareous, minor sulfurous stringers.

Bed No.	Thickness (feet)	LITHOLOGY
15	3.50	Shale, dark-gray, noncalcareous, rare sulfurous stringers; interbedded with shale are thin (1/2-in.) rusty-yellow-brown siltstone layers.
14	6.00	Shale, light- to dark-brown to black, carbonaceous, noncalcareous, sulfurous stringers; thin interbeds of coal.
13	0.20	Mudstone, buff, very calcareous, blocky.
12	0.80	Shale, dark-gray to yellow-brown, slightly silty, yellow-brown shale is calcareous, contains rare poorly preserved ostracodes and Valvata sp.; dark-gray shale is unfossiliferous.
11	0.10	Mudstone, buff, calcareous.
10	1.25	Shale dark-yellow-brown, silty, carbonaceous, noncalcareous.
9	0.70	Mudstone, dark-brown, carbonaceous, noncalcareous, sulfurous stringers.
8	1.00	Oil shale, yellow-brown, noncalcareous, flaky, few ostracodes.
7	0.20	Siltstone, buff, calcareous, contains Goniobasis tenera (well developed ribs and spiral ornamentation), rare Viviparus trochiformis and Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
6	1.40	Oil shale, dark-yellow-brown, mildly calcareous, minor organic material, rare Goniobasis tenera (moderately well developed ribs).
5	0.90	Siltstone, yellow-brown, calcareous, organic fragments, rare poorly preserved ostracodes, Sphaerium sp., Goniobasis tenera, rare Viviparus trochiformis and Unionidae: indet.
4	1.75	Oil shale, brown, flaky, calcareous, rare ostracodes and Goniobasis tenera.
3	0.10	Coquinal siltstone, hard, crumbly, abundant shell fragments of very poorly preserved Goniobasis tenera (two specimens with spiral ornamentation), rare Viviparus trochiformis and Unionidae: indet.
2	26.25	Oil shale, brown, flaky, calcareous; abundant ostracodes, rare Goniobasis tenera (well developed ribs) and Valvata sp.
	239.35	Total measured stratigraphic section of lower part of Luman Tongue of Green River Formation at this locality.
		MAIN BODY OF WASATCH FORMATION (uppermost part)
1	11.00	Sandstone, buff to white, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, ripple lamination; bottom contact not noted.

Bed No.	Thickness (feet)	LITHOLOGY
	11.00	Total measured stratigraphic section of uppermost part of main body of Wasatch Formation at this locality.

HIGHWAY 430 CLIFF (#2-71)

Measured northwest of the confluence of Horseshoe Wash and Vermillion Creek on steep slopes NNW of Wyoming State Highway 430 in NE1/4NE1/4/NE1/4 sec. 21, T. 12 N., R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (middle part)
		Bed 10 of this section is same as bed 1 of section #3-71.
10	4.00	Sandstone, weathers buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz with minor biotite and muscovite, calcareous, ripple marks, local through cross-stratification; rare Goniobasis tenera and Unionidae: indet.
9	12.50	Oil shale, dark-olive-brown, flaky, silty, noncalcareous; few thin beds of yellow-brown fissile siltstone.
8	1.25	Coquinal siltstone, hard, crumbly; abundant poorly preserved Goniobasis sp., rare Viviparus sp., and Unionidae: indet.
7	9.00	Sandstone, weathers buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, thinly laminated, cross stratified, ripple marks.

Bed No.	Thickness (feet)	LITHOLOGY
6	7.25	Oil shale, dark-olive -brown, irregular plates, silty; contains thin interbeds of sandstone, weathers buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, thinly laminated.
5	0.50	Sandstone, weathers buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, thinly laminated.
4	34.75	Oil shale, dark-olive-brown, soft, flaky, papery when weathered, noncalcareous; contains Goniobasis tenera (well developed ribs and spiral ornamentation with small nodes), Viviparus trochiformis, Valvata sp., Pisidiidae: indet., Sphaerium sp., Unionidae: indet., and ostracodes; in top 1- to 3-ft shale is interbedded with thin (less than 1/2-in. siltstone beds with rare organic fragments.
3	0.90	Coquinal siltstone, hard, crumbly, very poorly preserved Goniobasis tenera, Viviparus trochiformis, and rare Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
2	26.25	Oil shale, dark-olive-brown, soft, flaky when weathered; contains Goniobasis tenera (well developed ribs and sprial ornamentation with small nodes), Valvata sp. Sphaerium sp., Pisidiidae: indet., and ostracodes; interbedded with shale are thin (1/2- to 2-in. coquinal siltstone beds containing abundant poorly preserved Goniobasis tenera (ornamentation as in associated shale), rare Viviparus trochiformis and rare Unionidae: indet.; coquinal beds mainly near top and bottom of unit.
1	1.30	Coquinal siltstone, hard, crumbly; contains thin shale interbeds; abundant Goniobasis tenera (well developed ribs and good spiral ornamentation with small nodes), rare fragments of Unionidae: indet., and Viviparus sp.; this unit traced laterally from top of bench into adjacent cliff face. Bed 1 of this section is the same as bed 104 in section #1-71.
	97.70	Total measured stratigraphic section of middle part of the Luman Tongue of Green River Formation at this locality.

HIAWATHA CLIFF (#3-71)

Measured directly north of confluence of Horseshoe Wash and Vermillion Creek NNW of a curve in Wyoming State Highway 430 in NE1/4SW1/4 sec. 15, T. 12 N, R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (lower part)
		Bed #34 of this section is bed 1 in section #4-71.
34	5.50	Sandstone, buff, fine sand, subangular, moderately sorted, greater than 90 percent quartz, very calcareous, large-scale cross stratification; ledge former.
33	12.50	Shale, light-yellow-brown and gray, silty, noncalcareous; interbedded in middle of unit with carbonaceous shale, silty, brown to black with sulfurous stringers and gypsiferous layers.
32	2.50	Sandstone, very fine sand, subangular, well sorted, greater than 90 percent quartz with minor muscovite and organic material, porous, noncalcareous; muscovite and organic material concentrated along bedding surfaces; grades to siltstone at top, gradational with bed 33.
31	15.50	Shale, brown, silty, calcareous; abundant ostracodes, Goniobasis tenera, Valvata sp., Viviparus trochiformis, Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
30	4.75	Sandstone, brown, very fine sand, subangular, moderately sorted to well sorted, porous, noncalcareous, moderately indurated to well indurated.
29	12.75	Shale, brown,; interbedded with light- to dark-gray silty shale and brown to black silty, carbonaceous shale with sulfurous stringers and gypsiferous layers; at base of unit is a 2-in. thick sandstone interbed, light gray on fresh surface, very fine sand, subrounded, well sorted, noncalcareous, porous.
28	13.25	Sandstone, light-yellowish-gray, very fine sand, subangular, moderately sorted to well sorted, porous, noncalcareous, minor organic material; contains thin interbeds of fissile, carbonaceous siltstone with sulfurous stringers and thin, silty, dark-gray shale or silty, carbonaceous shale.
27	4.75	Shale, light-gray to dark-reddish-brown, carbonaceous, silty, with sulfurous stringers and gypsiferous layers.

Bed No.	Thickness (feet)	LITHOLOGY
26	4.0	Sandstone, weathers light-reddish-brown, light brown on fresh surface, medium sand, subangular, moderately sorted, greater than 90 percent quartz with minor biotite?, calcareous; cross stratified; ledge former capping bench below main ridge.
25	34.75	Siltstone, weathers buff, light gray on fresh surface, very calcareous, slope former and ledge former, gradational with bed 26; interbedded with siltstone are 3 minor sandstone ledge formers, very fine sand, subrounded, well sorted, calcareous, with rare Goniobasis tenera (one specimen with well developed spiral ornamentation and no ribs), Viviparus trochiformis? and V. paludinaeformis?, Unionidae: indet.; siltstone also contains thin interbeds of silty dark gray and silty carbonaceous shale.
24	2.25	Shale, dark-reddish-brown to black, carbonaceous, silty, grades into bed 25.

Bed No.	Thickness (feet)	LITHOLOGY
23	3.00	Sandstone, at base brown, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, minor muscovite along bedding surfaces, noncalcareous, porous; at top sandstone is light gray, very fine sand, subrounded, moderately sorted, greater than 90 percent quartz with minor muscovite and biotite, very calcareous and nonporous.
22	4.25	Shale, gray to reddish-brown, silty, carbonaceous above base.
21	1.00	Sandstone, buff, very fine sand, subangular, well sorted, noncalcareous, porous, poorly indurated.
20	3.50	Shale, light- to dark-brown and black, carbonaceous, silty, noncalcareous, sulfurous stringers.
19	2.50	Sandstone, brown, very fine sand, subangular, moderately sorted at base, well sorted at top, noncalcareous, very porous; near base of unit is thin (4-in.) interbedded siltstone, buff to gray, somewhat fissile, minor muscovite flakes, noncalcareous, porous, small-scale cross stratification.
18	4.00	Siltstone, buff to gray, somewhat fissile, minor muscovite flakes, noncalcareous porous.

Bed No.	Thickness (feet)	LITHOLOGY
17	6.75	Sandstone, weathers buff, light gray on fresh surface, very fine sand, subrounded with few well rounded grains, moderately sorted, greater than 90 percent quartz, calcareous, well developed cross stratification, at top of unit sandstone is ledge former; interbedded with sandstone is siltstone yellow-brown, fissile, calcareous, minor muscovite flakes, rare ostracodes.
	132.00	Total measured stratigraphic section of lower part of Niland Tongue of Wasatch Formation at this locality.
		LUMAN TONGUE OF GREEN RIVER FORMATION (upper part)
16	2.50	Siltstone, yellow-brown, fissile, calcareous, minor muscovite flakes, rare ostracodes.
15	13.75	Shale, light gray to light-yellow-brown, flaky, weathers into irregular plates, silty, calcareous, abundant ostracodes, gradational with bed 16.
14	0.75	Limestone, blocky, very calcareous, slightly silty, aphanitic.
13	1.25	Shale, yellow-brown, flaky, weathers into irregular plates, silty, calcareous, abundant ostracodes.

Bed No.	Thickness (feet)	LITHOLOGY
12	3.00	Siltstone, light-yellow-brown, calcareous, ostracodes; upper 1.5-ft of siltstone unit contains three 1-in. sandstone interbeds, very fine sand, well sorted, subrounded, greater than 90 percent quartz, calcareous, thinly laminated, ostracodes.
11	2.00	Shale, identical in all respects with bed 15.
10	0.50	Sandstone, light gray, very fine sand, subrounded, well sorted, greater than 90 percent quartz, calcareous.
9	3.00	Shale, identical in all respects with bed 15.
8	0.90	Sandstone, buff, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous, numerous molds and steinkerns of elongate Uniondae: indet.
7	7.00	Siltstone, gray, fissile, rarely blocky, muscovite along bedding surfaces, ostracodes and Unionidae: indet.; contains thin, gray, silty shale interbed.
6	5.00	Sandstone, buff, very fine sand, subrounded, moderately sorted, greater than 90 percent quartz with muscovite along bedding surfaces, calcareous; ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
5	9.80	Interbedded siltstone, shale, and sandstone; siltstone is fissile; shale, is gray, silty, blocky, mildly calcareous; sandstone is very fine sand, predominately quartz, grades into siltstone, calcareous.
4	6.25	Mudstone, yellow-brown to dark brown, greenish-gray, silty, noncalcareous, ostracodes; gradational with bed 5.
3	27.75	Oil shale, dark-olive-brown, soft, flaky, noncalcareous contains ostracodes; blocky at top, gradational with bed 4.
2	2.00	Coquinal siltstone, hard, crumbly; abundant shell fragments, poorly preserved common Goniobasis tenera (well developed ribs, spiral ornamentation and faint nodes), abundant Viviparus trochiformis, rare Unionidae: indet.
1	4.00	Sandstone, buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz with minor biotite and muscovite, calcareous; ripple marks, local trough cross stratification; sparse Goniobasis tenera and Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
		Bed 1 of this section is same as bed 10 in section #2-71.
	89.45	Total measured stratigraphic section of upper part of Luman tongue of Green River Formation at this locality.

MOUNTAIN FUEL DUGWAY (#4-71)

Measured on steep slopes immediately north of Mountain Fuel Supply Company pipeline road dugway on west slopes of Vermillion Creek in SE1/4 sec. 10, T. 12 R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (lower part)
		Bed 20 is same as bed 1 in section #5-71.
20	16.50	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, cross stratified, basal 8-in. is very fine sand to siltstone with poorly preserved Goniobasis tenera, Gyraulus sp., and Physa pleromatis.
19	3.00	Siltstone, gray, blocky, calcareous; blocky, silty mudstone at base with ostracodes.
18	18.00	Oil shale, dark-yellow-brown, calcareous, silty at top; contains abundant ostracodes, Goniobasis tenera (well developed ribs), Unionidae: indet., Pisidiidae: indet., Sphaerium sp., Valvata sp., Viviparus sp.; shale contains one thin interbed of calcareous siltstone with abundant very poorly preserved Goniobasis tenera.

Bed No.	Thickness (feet)	LITHOLOGY
17	4.50	Siltstone, basal 2.5-ft is carbonaceous, fissile, abundant Goniobasis tenera (well developed ribs), Viviparus trochiformis, Valvata sp., and ostracodes; upper 2-ft is coquinal siltstone, abundant shell fragments of poorly preserved Goniobasis sp., and Unionidae: indet.
16	0.10	Coquinal siltstone, abundant shell fragments of Goniobasis tenera, Viviparus trochiformis, Valvata sp., and Unionidae: indet.; GR92-71.
15	1.50	Siltstone, yellow-brown, fissile, slightly carbonaceous, gypsiferous at base; contains ostracodes, Goniobasis tenera (well developed ribs), Gyraulus? sp., Unionidae: indet.
14	8.75	Mudstone, gray to brown, silty, blocky, gray is noncalcareous, brown is calcareous; 1 thin gypsiferous interbed with rare Unionidae: indet.
	52.35	Total measured stratigraphic section in lower part of Tipton Shale Member of Green River Formation at this locality.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (upper part)
13	1.30	Sandstone, weathers reddish-brown, gray on fresh surface, very fine sand to siltstone, well sorted, predominately quartz; blocky, minor ledge former.
12	1.20	Mudstone, gray to brown, silty, blocky, gray is noncalcareous, brown is calcareous.
11	1.00	Sandstone, identical in all respects with bed 13.
10	3.70	Mudstone, identical in all respects with bed 12.
9	1.25	Sandstone, buff, very fine sand, subrounded, few subangular, well sorted, greater than 90 percent quartz, calcareous; ledge former.
8	6.75	Mudstone, identical in all respects with bed 12.
7	7.75	Shale, brown to black, carbonaceous, silty with sulfurous stringers.
6	9.50	Sandstone, buff, very fine sand, subrounded, well sorted, greater than 90 percent quartz, noncalcareous porous, limonitic stains; ledge former with gypsiferc fillings of fractures? in lower part.
5	4.75	Mudstone, identical in all respects with bed 12.
4	1.00	Limestone, dense, strongly calcareous, aphanitic; weathers into irregular blocks.

Bed No.	Thickness (feet)	LITHOLOGY
3	21.00	Mudstone, identical in all respects with bed 12.
2	18.25	Shale, reddish-brown to black, carbonaceous, sulfurous stringers; few thin rusty-yellow layers; few thin, dense, hard, slightly calcareous, brown siltstone interbeds.
1	13.50	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, mildly calcareous, well indurated; few thin interbeds of fissile siltstone; in lower 5.50-ft sandstone exhibits large-scale cross stratification, ledge former.
		Bed 1 of this section is same as bed 34 in section #3-71.
	90.95	Total measured stratigraphic section of upper part of Niland Tongue of Wasatch Formation at this locality.

VERMILLION DRY WASH (#5-71)

Measured on northwest slopes of deep dry wash tributary to Vermillion Creek (west of Vermillion Creek) in NW1/4SW1/4SE1/4 sec. 10, T. 12 N, R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (middle part)
		Bed 12 is same as bed 1 in section #6-71.
12	0.75	Oolite-ostracode grainstone, brown; caps ridge and forms westward dip slope; contains Goniobasis tenera (well developed ribs, rare poorly developed nodes, and faint spiral ornamentation), Viviparus trochiformis, and Unionidae: indet.; GR94-71.
11	2.50	Siltstone, buff, blocky, calcareous; contains Viviparus sp., Goniobasis tenera (faint ribs), and Plesielliptio? sp.; GR93-71.

Bed No.	Thickness (feet)	LITHOLOGY
10	23.75	Shale, lower 5-ft is brown to black, carbonaceous, silty, sulfurous stringers, 1.5-ft sandstone interbed is very fine sand, subangular to subrounded, well sorted, noncalcareous, organic material along laminations; at 5-ft level shale becomes slightly blocky and silty bordering on mudstone and siltstone; at 12-ft level, shale is carbonaceous as at base; at 13-ft level, oil shale, light- to dark-yellow-brown, flaky, silty, calcareous, contains abundant ostracodes, Goniobasis tenera (ribs), and locally abundant Unionidae: indet., and Valvata sp. in near coquinal layers.
9	7.75	Sandstone, buff, light gray on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous, minor muscovite along bedding planes, small-scale cross stratification, ledge former; above 2-ft level sandstone is more poorly indurated; limonitic stained ledge former at top.
8	2.00	Oil shale, light- to dark-yellow-brown, silty, calcareous, contains ostracodes and Goniobasis tenera (ribs).

Bed No.	Thickness (feet)	LITHOLOGY
7	0.50	Sandstone, weathers buff, light gray on fresh surface, very fine sand, subrounded to subangular, moderately sorted, very calcareous, greater than 90 percent quartz with minor muscovite; contains Goniobasis tenera and Unionidae: indet.
6	5.00	Interbedded siltstone and shale, siltstone is rusty-yellow-brown to gray, noncalcareous; shale is brown to black, carbonaceous, silty.
5	0.75	Sandstone, weathers buff, light gray on fresh surface, very fine sand, subangular, poorly sorted greater than 90 percent quartz, minor muscovite along bedding surfaces; small-scale cross stratificatic minor ledge former.
4	2.50	Shale, brown to black, carbonaceous, silty sulfurous stringers, gypsiferous layers, and coal.
3	1.10	Sandstone, buff, light gray on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz with minor muscovite along bedding surfaces; small-scale cross stratification; ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
2	12.00	Interbedded shale, siltstone, and mudstone; shale is brown to black, with sulfurous stringers and gypsiferous layers; siltstone is buff, noncalcareous, slightly carbonaceous; mudstone is gray to brown, silty, blocky, gray is noncalcareous, brown is calcareous.
1	16.50	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, cross bedded; basal 8-in. is very fine sand to siltstone with poorly preserved Goniobasis tenera, Gyraulus sp., and Physa pleromatis.
		Bed 1 is same as bed 20 in section #4-71.
	75.10	Total measured stratigraphic section of middle part of Tipton Shale Member of Green River Formation at this locality.

VERMILLION HILL (#6-71)

Measured near crest of gentle slopes west of Vermillion creek in NE1/4SW1/4 sec. 10, T. 12 N., R. 100 W.

Bed No.	Thickness (feet)	LITHOLOGY
		WILKINS PEAK MEMBER OF GREEN RIVER FORMATION (lowermost part)
6	55.00	Oil shale, dark-olive-brown, weathers gray, noncalcareous, platy and papery; between 23-ft and 38-ft levels shale is light-yellow-brown poor oil shale; shale contains interbeds of dolomite, buff, blocky, aphanitic, dense, hard, mildly calcareous at following levels: 7.75-ft 2-in.-thick; 44.50-ft 2-in.-thick 12.25-ft 1-in.-thick; 55.00-ft 2-in.-thick 23.00-ft 1-in.-thick 38.00-ft 4-in.-thick; with 1-in. stromatolite layer
5	0.70	Dolomite, buff, blocky, dense, hard, aphanitic, mildly calcareous.
4	2.00	Oil shale, dark-olive-brown, noncalcareous; carbonaceous at base.
3	1.00	Dolomite, identical in all respects with bed 5.
	58.70	Total measured stratigraphic section of Wilkins Peak Member (lowermost part) of Green River Formation at this locality.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (upper part)
2	35.00	Oil shale, yellow-brown and dark-olive-brown, calcareous and noncalcareous (respectively), papery and flaky, abundant ostracodes in yellow-brown shale at base.
1	0.75	Oolite-ostracode grainstone, brown; caps ridge and forms westward dip slope; contains Goniobasis tenera (well developed ribs, rare poorly developed nodes, and faint spiral ornamentation), Viviparus trochiformis, and Unionidae: indet.; GR94-71.
	35.75	Total measured stratigraphic section of uppermost part of Tipton Shale Member of Green River Formation at this locality.
		Bed 1 of this section is same as bed 12 in stratigraphic section #5-71.

APPENDIX C

CANYON CREEK COMPOSITE SECTION

CANYON CREEK GAS FIELD (#7-71)

Measured in the banks of a dry wash tributary to Canyon Creek and in the slopes of a hill west of the improved dirt road to Maybell, Colorado, in S1/2NW1/4SW1/4, sec. 16, T. 12 N., R. 101W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (lower part)
		Bed 4 in this section is same as bed 1 in section #8-71.
4	3.90	Sandstone, weathers buff, light gray on fresh surface, fine sand, angular, moderately sorted, very calcareous, greater than 90 percent quartz; contains rare Viviparus paludinaeformis, Goniobasis sp. (faint ribs), and Unionidae: indet.; small-scale cross stratification, ripple marks; ledge former capping shale slope.

Bed No.	Thickness (feet)	LITHOLOGY
3	145.0	Oil shale, light- to dark-yellow-brown, calcareous and noncalcareous, platy and papery; in lower 20-ft of unit yellow-brown shale is typically calcareous and contains rare to locally abundant Valvata sp., Goniobasis tenera, Viviparus trochiformis, Unionidae: indet., Sphaerium sp., Pisidiidae: indet., and ostracodes, GR68-71; also in lower 20-ft are thin (1/4-in.) blocky siltstone beds, and thin (1- to 3-in.) coquinal siltstone beds containing Goniobasis tenera (ribs and rare small nodes), Viviparus trochiformis, and very poorly preserved Unionidae: indet.; upper 115-ft of unit is noncalcareous dark-yellow-brown oil shale with only rare ostracodes.
2	3.0	Shale, dark-brown to black, carbonaceous with coal bed; thin (6-in.) interbed of yellow-brown oil shale at base with rare Valvata sp., and Goniobasis tenera.

Bed No.	Thickness (feet)	LITHOLOGY
1	42.25	Oil shale, light- to dark-yellow-brown, calcareous and noncalcareous, platy and papery; shale contains abundant ostracodes and Valvata sp., with Goniobasis tenera (well developed ribs and rare distinct nodes), Plesielliptio? sp., Unionidae: indet., Sphaerium sp., and Pisidiidae: indet.; contains thin (1/2- to 2-in.) coquinal siltstone beds with Goniobasis tenera (moderately to well developed ribs), rare Viviparus trochiformis, and Unionidae: indet.; basal contact of bed 1 covered.
	194.15	Total measured stratigraphic section of lower part of Luman Tongue of Green River Formation at this locality.

CANYON CREEK FIELD WEST (#8-71)

Measured in the gentle slopes along an unmapped dirt road to an oil well west of road to Maybell, Colorado, WSW of Bench Mark 7084 in SE1/4SE1/4 sec. 17, T. 12 N. R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (lower part)
		Bed 26 of this section is same as bed 1 in Section #9-71.
26	5.00	Sandstone, weathers reddish brown, light gray on fresh surface, very fine sand, subangular, moderately sorted, calcareous, somewhat porous; well indurated in upper 3.5-ft of unit, small-scale cross stratification, ledge former; gradational with overlying carbonaceous shale.
25	1.00	Shale, light-gray, silty, noncalcareous, tiny irregular plates, gradational with bed #26.
24	3.00	Shale, dark-brown and reddish-brown to black, carbonaceous, sulfurous stringers, and gypsiferous layers.
23	3.25	Shale, rusty-yellow-brown, gray, noncalcareous, minor sulfurous staining, gradational with bed #24.
22	1.25	Shale, dark-brown to black, carbonaceous, silty.

Bed No.	Thickness (feet)	LITHOLOGY
21	1.50	Shale, light- to dark-gray, irregular plates, noncalcareous, gradational with bed #22.
20	1.75	Sandstone, yellow-brown, fine sand, subangular, moderately sorted, noncalcareous, porous, greater than 90 percent quartz.
19	2.50	Shale, identical in all respects with bed #21.
18	1.00	Shale, dark-brown to black, carbonaceous, sulfurous stringers.
17	0.75	Sandstone, light-yellow, fine sand, subangular to subrounded, moderately sorted, noncalcareous, porous, approximately 90 percent quartz with minor biotite and organic fragments.
16	1.00	Siltstone, yellow-brown, somewhat fissile, noncalcareous, porous.
15	1.25	Shale, dark-brown to black, carbonaceous, noncalcareous,
14	2.50	Sandstone, weathers buff, light gray on fresh surface, fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous, porous; small-scale cross stratification; sandstone is slumped into blocks resembling large-scale trough cross stratification.

Bed No.	Thickness (feet)	LITHOLOGY
	25.75	Total measured stratigraphic section of Niland Tongue of Wasatch Formation (lower part) at this locality.
		LUMAN TONGUE OF GREEN RIVER FORMATION (upper part)
13	6.00	Shale, yellow-brown to gray, calcareous and noncalcareous respectively, contains rare to abundant ostracodes; silty in upper 2-ft and gradational with bed #14.
12	0.30	Limestone, contains abundant shell fragments of Unionidae: indet. and Goniobasis sp. (one noted with faint ribs).
11	2.75	Shale, dark-brown to black, carbonaceous; yellow brown at base with rare to abundant ostracodes.
10	8.00	Shale, identical in all respects with bed #13; contains thin (1- to 2-in.) siltstone interbeds with Goniobasis tenera, Viviparus trochiformis, and Unionidae: indet.
9	0.75	Siltstone, yellow-brown, calcareous, contains very poorly preserved ostracodes, Goniobasis tenera, Viviparus sp., and Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
8	12.50	Shale, yellow-brown and gray, calcareous and noncalcareous respectively, weathers to small irregular plates, contains abundant ostracodes and poorly preserved Goniobasis sp. and Unionidae: indet.; in upper 2-ft the shale contains thin (1- to 2-in.) siltstone interbeds containing poorly preserved Goniobasis sp., Viviparus trochiformis, Unionidae: indet.
7	2.75	Siltstone, light-gray, very calcareous, contains Unionidae: indet., Viviparus sp., Goniobasis tenera (spiral ornamentation and faint ribs), and one Biomphalaria sp.
6	2.75	Shale, dark-brown, carbonaceous, noncalcareous, minor sulfurous stringers.
5	2.50	Sandstone, light-gray, fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous, porous, minor muscovite.
4	2.25	Shale, identical in all respects with bed #6.
3	6.25	Sandstone, identical in all respects with bed #5, but with locally abundant muscovite.
2	4.25	Shale, identical in all respects with bed #6.

Bed No.	Thickness (feet)	LITHOLOGY
1	3.90	Sandstone, light gray on fresh surface, weathers buff, fine sand, angular, moderately sorted, very calcareous, greater than 90 percent quartz; contains rare Viviparus paludinaeformis, Unionidae: indet., and Goniobasis sp. (faint ribs); small-scale cross stratification and ripple marks; ledge former.
		Bed 1 of this section is same as bed 4 in Canyon Creek Gas Field section #7-71.
	54.95	Total measured stratigraphic section of Luman Tongue of Green River Formation (upper part) at this locality.

CANYON CREEK DRY WASH (#9-71)

Measured in steep slopes near the head of a south flowing dry wash tributary to Canyon Creek in the W1/2NW1/4 sec. 17, T. 12 N., R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (middle part)
		Bed 12 of this section is same as bed 1 in Section #10-71.
12	10.00	Sandstone, buff, very fine, subangular to subrounded, moderately sorted to well sorted, greater than 90 percent quartz, matrix of calcium carbonate makes up approximately 40 percent of rock; lower 5-ft of unit contains rare Viviparus trochiformis, Unionidae: indet., Goniobasis sp. and 1 Physa sp.; upper 5-ft of unit is unfossiliferous; medium-scale cross stratification.
11	2.00	Shale, dark-brown to black, carbonaceous, minor sulfurous stringers, upper and lower contacts gradational.
10	15.00	Sandstone, weathers buff, white on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous; massive in lower 7.50-ft, contorted bedding in upper 7.50-ft; major cliff former.

Bed No.	Thickness (feet)	LITHOLOGY
9	27.75	Oil shale, light- to dark-yellow-brown, calcareous and noncalcareous respectively, contains Goniobasis tenera (faintly to moderately developed ribs), Valvata sp., Viviparus trochiformis, Hydrobia aff. H. utahensis, Hydrobia sp. A, Unionidae: indet., and ostracodes, GR69-71; shale contains thin (1/4- to 1-in.) interbeds of coquinal siltstone, hard, crumbly, abundant shell fragments of Goniobasis tenera, Viviparus trochiformis, Unionidae: indet., and ostracodes; in upper 2-ft shale becomes slightly carbonaceous and gypsiferous, mollusks much less abundant.
8	0.50	Marlstone, yellow-brown, contains abundant shell fragments of Goniobasis sp. and Unionidae: indet.; basal contact gradational.
7	6.00	Shale, dark-brown to black, carbonaceous, thin gypsiferous layers throughout, gradational upper and basal contacts.
6	18.60	Sandstone, buff, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous, porous, poorly to well indurated; upper contact gradational; prominent ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
5	15.50	Shale, light-brown to black, carbonaceous, thin coal beds, thin (1/2- to 2-in.) gypsiferous layers, sulfurous stringers common throughout unit; rare beds of gray shale.
4	6.50	Siltstone, buff, slightly calcareous, thinly bedded with carbonaceous material and muscovite along bedding surfaces; grades into thin (6-in.) sandstone at top, light brown, very fine sand, subangular, moderately sorted, noncalcareous.
3	1.25	Interbedded siltstone and shale, brown, carbonaceous, top contact marked by gypsiferous layer and thin coal; less carbonaceous parts of unit are very calcareous and contain very poorly preserved internal and external molds of Gyraulus sp., Lymnaea sp., and Biomphalaria sp., ostracodes.
2	5.90	Shale, dark-brown to black, carbonaceous, sulfurous stringers, coal beds, gypsiferous at base; basal and top contacts gradational, ostracodes at top in less-carbonaceous silty shale.
1	5.00	Sandstone, weathers reddish brown, light gray on fresh surface, very fine sand, subangular, moderately sorted, calcareous, somewhat porous, well indurated in upper two-thirds of unit; small-scale cross stratification, ledge former; gradational contact with bed 2.

Bed No.	Thick-ness (feet)	LITHOLOGY
		Bed 1 of this section is same as bed 26 in section #8-71.
1	114.00	Total measured stratigraphic section of middle part of Niland Tongue of Wasatch Formation at this locality.

CANYON CREEK MINE (#10-71)

Measured from vicinity of Canyon Creek Mine northwestward up slopes to top of cliffs overlooking Canyon Creek in NW1/4NW1/4NW1/4 sec. 17, SW1/4SW1/4SW1/4 sec. 8, and SE1/4SE1/4SE1/4 sec. 7, T. 12 N., R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		WILKINS PEAK MEMBER (lower part)
78	15.00	Siltstone, interlayered red-brown, buff, and gray, composed predominantly of quartz, calcareous, well indurated, faint ripple marks; thin beds of sandstone, very fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous; major cliff former.
77	116.00	Interbedded light gray to light brown, very calcareous, platy mudstone; and buff, dolomitic, blocky and platy mudstone.
76	35.00	Shale, light-gray to light-brown, very calcareous, tiny irregular plates; becomes platy and silty at 30-ft level.
75	0.20	Mudstone, buff, platy, dolomitic.
74	25.25	Shale, light-gray to light-brown, tiny irregular plates, slightly silty, calcareous.
73	0.25	Mudstone, buff, dolomitic, blocky.

Bed No.	Thickness (feet)	LITHOLOGY
72	10.60	Shale, weathers gray, dark-yellow-brown on fresh surface, possibly poor oil shale, thin plates, calcareous.
71	0.75	Mudstone, buff, dolomitic, blocky.
70	9.20	Shale, light-gray with minor yellow-brown, very calcareous, thin plates.
69	0.60	Mudstone, buff, dolomitic, blocky.
68	5.75	Shale, yellow-brown, mildly calcareous, thin plates.
67	1.00	Mudstone, buff, dolomitic platy.
66	71.00	Shale, light-yellow-gray, slightly silty, calcareous; at 25-ft oil shale, dark-brown, papery, noncalcareous, articulated incomplete fish skeletons at 25-ft level, includes thin (3-in.) interbed of buff marlston at 31.75-ft level; at 60-ft shale, yellow-brown, very calcareous, contains ostracodes and Gastropoda: indet. (GR74-71); near top poor oil shale contains locally abundant ostracodes.
65	0.50	Mudstone, white to light-gray, dolomitic, blocky.
64	9.00	Shale, light-gray to orange-brown, slightly calcareous, silty, papery toward top.

Bed No.	Thick-ness (feet)	LITHOLOGY
63	0.10	Mudstone, buff, dolomitic, platy.
62	5.00	Shale, light-gray, calcareous, weathers to small irregular plates.
61	0.50	Mudstone, buff, dolomitic, platy.
60	2.50	Shale, light-gray, calcareous, weathers to small irregular plates.
59	0.75	Mudstone, buff, dolomitic, blocky.
58	2.25	Shale, light-gray, calcareous, weathers to small irregular plates.
57	0.30	Mudstone, buff, dolomitic, blocky.
56	1.50	Shale, light-gray, calcareous, weathers to small irregular plates.
55	0.75	Mudstone, buff, dolomitic, blocky.
54	2.00	Shale, light-gray, orange at top, calcareous, weathers to small irregular plates.
53	0.25	Mudstone, buff, dolomitic, blocky.
52	6.5	Shale, yellow-brown and papery, rarely greenish-brown and platy, calcareous.
51	0.40	Mudstone, buff, dolomitic, platy, crystalline.

Bed No.	Thickness (feet)	LITHOLOGY
50	23.75	Shale, light-gray, orange-brown, dark-olive-brown (oil shale), slightly calcareous, platy.
49	0.40	Marlstone, buff, platy, crystalline.
48	3.60	Shale, weathers light gray, brown on fresh surface, platy, slightly calcareous.
	350.65	Total measured stratigraphic section of lower part of Wilkins Peak Member of Green River Formation at this locality.
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION
47	0.25	Limestone, buff, dense, crystalline, weathers to small irregular blocks.
46	17.75	Oil Shale, dark-olive-brown, noncalcareous, papery; rare thin layers of brown, slightly calcareous shale.
45	0.30	Marlstone, buff, contains ostracodes, weathers into irregular blocks and plates; caps minor bench.
44	11.25	Oil Shale, yellow-brown, papery, calcareous, contains ostracodes, Goniobasis tenera; rare thin (1-in.) coquinal layers with abundant shell fragments and very poorly preserved Goniobasis tenera (moderately developed ribs); beds of dark olive-brown, papery shale occur sporadically through unit.

Bed No.	Thickness (feet)	LITHOLOGY
43	1.00	Limestone, brown, crystalline, contains *Goniobasis tenera* (well developed ribs and poor nodes), *Valvata* sp., and *Hydrobia* sp., GR7-75; caps minor bench.
42	21.50	Shale, interbedded gray, yellow-brown and dark-brown (oil shale); gray shale is silty, noncalcareous, and weathers into tiny irregular plates; yellow-brown shale is calcareous and contains ostracodes, *Valvata*? sp., *Goniobasis tenera* (well developed ribs and poor nodes), and Unionidae: indet., GR73-71; gradational with bed 41.
41	8.00	Sandstone, weathers buff, light-gray on fresh surface, fine sand, moderately sorted, subangular with few rounded grains; medium-scale, low-angle planar cross stratification, small-scale ripple marks; forms a series of sandstone steps on a minor bench.
40	5.75	Shale, gray to brown, noncalcareous, silty, minor organic material.
39	2.25	Sandstone, buff, very fine sand, moderately sorted, subangular, greater than 90 percent quartz with minor biotite? flakes, calcareous, somewhat porous, contains fragments of organic material; forms small bench.

Bed No.	Thickness (feet)	LITHOLOGY
38	2.00	Shale, gray, noncalcareous, silty, tiny irregular plates, gradational with bed 39.
37	0.80	Sandstone, red-brown, very fine sand, moderately sorted, subangular, slightly calcareous, porous, moderately indurated, contains Goniobasis tenera and Physa pleromatis.
36	1.90	Siltstone, red-brown, calcareous, contains ostracodes, charophytes, Goniobasis tenera, and Unionidae: indet.
35	4.50	Shale, light- and dark-brown to black, carbonaceous, silty, 1-ft coal bed at top of unit.
34	0.40	Siltstone, gray, noncalcareous.
33	4.25	Shale, gray, noncalcareous, tiny irregular plates, very gentle slope former.
32	7.25	Sandstone, weathers buff, light-gray on fresh surface moderately sorted, subangular, poorly indurated to moderately indurated, minor organic material in lower portion, small- and medium-scale planar cross stratification; ledge former at top and bottom.

Bed No.	Thickness (feet)	LITHOLOGY
31	13.00	Oil shale, olive-brown, calcareous, contains Goniobasis tenera (well developed ribs), Viviparus trochiformis, Valvata sp., ostracodes, Unionidae: indet., Pisidiidae?: indet.; rare thin layers of silty shale; unit is carbonaceous at top.
30	1.00	Siltstone, light-gray, calcareous, weathers to irregular plates.
29	14.75	Shale, gray, carbonaceous at base; yellow-brown oil shale above base, calcareous, contains Goniobasis tenera (moderately developed ribs), Hydrobia sp., Valvata sp., Pisidiidae: indet., Unionidae: indet., GR72-71; at top shale is rusty yellow brown, silty, and calcareous.
	117.90	Total measured stratigraphic section of Tipton Shale Member of Green River Formation at this locality.
		NILAND TONGUE OF WASATCH FORMATION (upper part)
28	1.00	Siltstone, light-red-brown, calcareous, weathers to irregular plates; minor ledge former.
27	4.75	Shale, dark-brown to black, carbonaceous.
26	6.25	Shale, light- to dark-gray, silty, noncalcareous.
25	1.50	Sandstone, red-brown, very fine sand to siltstone, well sorted, at least 90 percent quartz, calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
24	11.20	Siltstone, light- to dark-gray, brown, calcareous, weathers to irregular blocks and tiny flakes; gentle slope former.
23	0.20	Sandstone, buff to white, very fine sand, moderately sorted, subangular, greater than 90 percent quartz, calcareous; minor ledge former.
22	2.25	Siltstone, light-gray, slightly calcareous, moderately indurated, thin (2-in.) carbonaceous interval in middle of unit.
21	6.00	Sandstone, buff, fine sand, moderately sorted, subangular to subrounded, slightly calcareous, porous, moderately indurated, greater than 90 percent quartz; locally major ledge former.
20	15.00	Shale, light- to dark-brown, black, noncalcareous; slightly carbonaceous at base grading to carbonaceous shale with sulfurous stringers in lower 5-ft; at 10.5-ft and 13.75-ft shale contains two thin siltstone interbeds (4-in. and 2-in. respectively), buff noncalcareous, contains organic material.
19	4.50	Sandstone, weathers light brown to dark red brown, fine sand, moderately sorted, subangular, very calcareous, some minor poorly indurated layers.

Bed No.	Thickness (feet)	LITHOLOGY
18	7.75	Shale, rusty-yellow-brown at base grading to yellow-brown, calcareous; upper 7-ft contains locally abundant ostracodes and organic fragments; upper 4- to 5-ft contains interbeds of gray shale up to 6-in. thick which contain poorly preserved Goniobasis tenera (moderately developed ribs) and rare Unionidae: indet.; at 4.5-ft shale contains an 8- in. limestone bed, dense, fractures irregularly, contains abundant Goniobasis tenera (well developed ribs), GR71-71.
17	4.25	Mudstone, light- to dark-gray, silty, noncalcareous, block, rarely somewhat fissile.
16	4.00	Sandstone, buff, very fine sand, moderately sorted, subangular, greater than 90 percent quartz with minor biotite? flakes, small-scale cross stratification, minor ledge former; sandstone fills horizontal and vertical cracks in underlying shale, longest infilling is 2-ft, infilling sand texturally identical to overlying sandstone; sandstone bed, infilling sandstone, and underlying shale are cross-cut by secondary gypsiferous stringers; sandstone is minor ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
15	7.50	Shale, light-gray at base, grades to light- and dark-brown and black carbonaceous shale with sulfurous stringers, minor resistant ledges; at top shale grades back to light gray, silty, with thin (1-in.) yellow-brown mudstone beds in upper 1-ft; upper portion of shale infilled from above by bed 16.
14	2.00	Sandstone, buff, very fine sand, moderately sorted to well sorted, subrounded, noncalcareous, porous, greate than 90 percent quartz.
13	5.00	Shale, light-gray to dark-brown, noncalcareous; darker shale contains organic fragments, minor sulfurous stringers.
12	0.70	Siltstone, red-brown, slightly calcareous, weathers to small irregular blocks.
11	11.50	Shale, light- and dark-brown to black, carbonaceous, sulfurous stringers, organic content varies from slight to high, silty, gypsiferous in lower portion; upper 2-ft of unit is less carbonaceous and is gradational with overlying bed #12.
10	1.75	Mudstone, olive-brown to light-yellow-brown, mildly calcareous to noncalcareous, gradational with bed #11.

Bed No.	Thickness (feet)	LITHOLOGY
9	4.75	Oil Shale, olive-brown, mildly calcareous, contains Goniobasis tenera (moderately developed ribs), Viviparus trochiformis, and Unionidae: indet.
8	1.50	Marlstone, buff to yellow-brown, platy and massive, contains Goniobasis tenera (moderately to well developed ribs), Unionidae: indet., abundant ostracodes, minor organic fragments.
7	1.00	Shale, dark-brown to black, carbonaceous, coal beds in lower half of unit with sulfurous stringers, gypsiferous at top.
6	2.25	Shale, dark-gray, minor organic material, gradational with bed #7.
5	5.70	Shale, light- to dark-brown, carbonaceous, sulfurous stringers, gradational with bed #6.
4	13.00	Shale, dark-brown to black, carbonaceous, sulfurous stringers, thin (1-in.) gysiferous layers, thin coal beds in lower 7-ft of unit; upper 6-ft of unit consists of coal with thin gypsiferous interbeds.

Bed No.	Thickness (feet)	LITHOLOGY
3	0.80	Marlstone, white to light-gray, platy, contains Physa pleromatis. P. bridgerensis, Gyraulus sp., Biomphalaria sp. Hydrobia? sp., ostracodes; thin (1/2-in.) gypsiferous layer in middle of unit.
2	2.50	Shale, dark-brown to black, sulfurous stringers, grades immediately into coal bed, upper 5-in. is gypsiferous.
1	11.50	Sandstone, buff, very fine sand, moderately sorted, subangular, greater than 90 percent quartz, porous, moderately indurated; lower one-half of unit contains rare Viviparus trochiformis, Unionida indet., Goniobasis sp. and 1 Physa sp.; upper 5.75-ft of unit is unfossiliferous; medium-scale cross stratification.
		Bed 1 of this stratigraphic section is same as bed 12 in section #9-71.
	140.10	Total measured stratigraphic section of upper part of Niland Tongue of Wasatch Formation at this locality.

APPENDIX D

RIFES RANCH COMPOSITE SECTION

RIFES RIM (#11-71)

Measured on slopes of Rifes Rim just east of Wyoming State highway 430 in SE1/4 NE1/4NE1/4 sec. 6 and W1/2NW1/4 sec. 5, T. 13 N., R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (lower part)
		Bed 37 of this section is the same as bed 1 of section #12-71.
		Bed 38 of this section is the same as bed 2 of section #12-71.
38	7.00	Sandstone, buff, fine sand, subangular, poorly sorted to moderately sorted, calcareous, greater than 90 percent percent quartz, small-scale cross stratification, caps prominent ridge; grades to silty shale at top.
37	54.50	Oil shale, dark-yellow-brown, papery, locally calcareous, locally contains ostracodes; at 32.75-ft shale becomes blocky and contains very poorly preserved Goniobasis tenera, Viviparus trochiformis, and Unionidae: indet.; at top shale becomes silty and gradational with bed 38.

Bed No.	Thickness (feet)	LITHOLOGY
36	25.00	Interval covered by alluvium and colluvium.
35	12.25	Sandstone, buff, very fine sand, subangular, moderately sorted to well sorted, greater than 90 percent quartz, calcareous, fissile through most of unit; ledge former at top with ripple marks and small-scale cross stratification.
34	0.50	Shale, light- to dark-yellow-brown, calcareous, papery, rare organic fragments, locally contains ostracodes.
33	0.25	Coquinal limestone, dense, contains Goniobasis tenera and Viviparus trochiformis, GR102-70.
32	2.40	Shale, light-gray, mildly calcareous, platy; in top 5-in. becomes brown and silty, contains Goniobasis tenera (well developed ribs and faint spiral ornamentation) and Unionidae: indet.
31	1.40	Marlstone, yellow-brown, contains abundant shell fragments of Goniobasis tenera (well developed ribs and moderately developed spiral ornamentation), Viviparus trochiformis, and Unionidae: indet.
30	29.50	Shale, dark-gray to dark-yellow-brown, papery, calcareous; at top contains shell fragments of Goniobasis tenera (moderately developed ribs and faint spiral ornamentation).

Bed No.	Thickness (feet)	LITHOLOGY
29	26.00	Interval covered by alluvium and colluvium.
28	0.40	Sandstone, buff to brown, very fine sand, subangular, moderately well sorted, calcareous, greater than 90 percent quartz: contains Goniobasis tenera (moderately developed ribs and faint spiral ornamentation), Viviparus trochiformis, and Unionidae: indet.
27	7.00	Sandstone, buff, very fine sand, angular, moderately sorted, approximately 90 percent quartz with minor biotite, calcareous, poorly indurated except for ledge former at top.
26	1.00	Shale, brown to black, carbonaceous, blocky, gypsiferous at base.
25	0.20	Sandstone, brown, very fine sand, subangular, moderately sorted, greater than 90 percent quartz.
24	0.50	Coquinal limestone, light-brown, contains Goniobasis tenera (well developed ribs), and Viviparus trochiformis, and Unionidae: indet.
23	15.00	Shale, yellow-brown, papery, calcareous, silty at top.
22	0.20	Coquinal limestone, light-brown, contains Goniobasis tenera (well developed ribs), and Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
21	0.75	Sandstone, buff, very fine sand, subangular, moderately sorted, calcareous, slope former; contains shell fragments of Goniobasis tenera and Unionidae: indet.
20	0.33	Shale, yellow-brown, noncalcareous, silty at top.
19	2.50	Sandstone, buff, very fine sand, subrounded, moderately sorted to well sorted, calcareous, poorly indurated, greater than 90 percent quartz; at top sand becomes better indurated and subangular, contains Goniobasis tenera (well developed ribs and faint spiral ornamentation), Viviparus trochiformis, and Unionidae: indet.
18	1.00	Shale, dark-brown, noncalcareous, very silty.
17	8.50	Sandstone, buff, fine sand, angular to subangular, moderately sorted, calcareous, minor ledge forming intervals, otherwise poorly indurated; exhibits ripple marks and cross stratification.
16	7.75	Shale, light-gray, brown and black, carbonaceous, noncalcareous, sulfurous stringers and coal in middle of unit.
15	7.25	Sandstone, buff, very fine to fine sand, moderately sorted to poorly sorted, ledge former, exhibits ripple marks; interbedded with buff siltstone.

Bed No.	Thickness (feet)	LITHOLOGY
14	4.00	Shale, olive-brown, mildly calcareous, contains ostracodes; becomes silty and buff toward top.
13	1.00	Coquinal limestone, light-olive-brown, shaly as base, contains abundant shell fragments of Goniobasis tenera, and Unionidae: indet.
12	0.42	Shale, dark-brown and black, carbonaceous, coal near top.
11	2.00	Siltstone, buff, calcareous.
10	17.75	Oil shale, light-olive-brown, calcareous, contains Goniobasis tenera, Valvata? sp., and ostracodes; contains thin siltstone near base with Goniobasis tenera and Unionidae: indet.; shale rarely grades to marlstone containing Goniobasis tenera (well developed ribs and faint spiral ornamentation), Viviparus sp., Plesiellipti o sp., Pisidiidae: indet., GR34-71; near top of unit shale becomes carbonaceous with sulfurous and gypsiferous stringers; gradational with bed 11.
9	3.00	Limestone, weathers buff at bottom and light red at top, contains Goniobasis tenera, Viviparus trochiformis, and Plesiellipti o cf. P. priscus, Planorbidae?: indet., Plesiellipti o n. sp. A, GR90-70.

Bed No.	Thickness (feet)	LITHOLOGY
8	29.00	Oil shale, olive-brown, mildly calcareous, contains ostracodes, Goniobasis tenera, (strongly developed ribs) Viviparus trochiformis, Valvata? sp., and Unionidae: indet.
7	3.25	Siltstone, buff, calcareous, contains poorly preserved Goniobasis tenera (moderately developed ribs), Viviparus trochiformis, and Unionidae: indet.
	271.60	Total measured stratigraphic section of the lower part of Luman Tongue of the Green River Formation at this locality.
		MAIN BODY OF WASATCH FORMATION (uppermost part)
6	15.00	Shale, brown and black, carbonaceous, sulfurous stringers, rare coal beds; interbedded with siltstone, weathers light gray, brown on fresh surface, noncalcareous, contains numerous small-scale gypsiferous stringers.
5	4.75	Sandstone, light-gray, fine sand, subangular, moderately sorted, greater than 90 percent quartz, noncalcareous, porous, ledge former in upper part; contains plant fragments along bedding planes.
4	3.00	Shale, brown and black, carbonaceous, coal at base, contains gypsiferous stringers, and plant fragments.

Bed No.	Thickness (feet)	LITHOLOGY
3	7.25	Sandstone, light-gray, fine sand, subangular, moderately sorted, calcareous, mainly quartz with minor biotite; slope former.
2	5.00	Shale, black to brown, carbonaceous, sulfurous stringers; at top grades to mudstone, light-gray, noncalcareous.
1	2.25	Sandstone, buff, very fine sand, subangular moderately well sorted, greater than 90 percent quartz, calcareous, porous; bottom contact not noted.
	37.25	Total measured stratigraphic section of the uppermost part of Main Body of Wasatch Formation at this locality.

RIFES RIM SOUTHWEST (#12-71)

Measured in an ESE direction in a series of dry washes on the dip slope of Rifes Rim, NNE of an unnamed intermittent stream which flows into the North Fork of Vermillion Creek.

Location: S1/2SE1/4 sec. 11, and S1/2SW1/4 sec. 12, T. 13 N., R 102 W.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (lower part)
		Bed 60 of this section is the same as bed 1 of section #13-71.
60	2.00	Sandstone, buff, light-gray on fresh surface, very fine sand, subangular, poorly sorted, greater than 90 percent quartz with minor biotite, calcareous, ledge former, exhibits large-scale cross stratification.
59	2.75	Shale, light-gray, noncalcareous, tiny irregular flakes.
58	1.00	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz with muscovite along bedding planes; ledge former, weathers into plates.
57	5.30	Shale, light-gray to dark-brown, locally carbonaceous with sulfurous stringers, locally silty and calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
56	0.70	Siltstone, weathers buff, light-gray on fresh surface, calcareous; weathers into plates.
55	1.75	Shale, light-gray, noncalcareous, weathers to tiny irregular plates; interbedded with thin siltstone beds, buff, calcareous.
54	0.30	Sandstone, weathers buff, light-gray on fresh surface, very fine sand, subangular, moderately well sorted, calcareous, contains organic fragments; ledge former.
53	10.00	Shale, yellow-brown, tiny irregular plates, locally papery, calcareous, contains ostracodes; grades to gray and slightly silty at top.
52	2.75	Limestone, buff, platy, dense, contains Goniobasis tenera and Unionidae: Gen. indet. sp. A, GR100-70.
51	0.40	Shale, dark-brown and black, thin coal stringers highly gypsiferous, locally red and yellow klinker.
50	0.40	Limestone, white and gray, contains poorly preserved ostracodes and unidentifiable mollusk shell fragments.
49	3.00	Shale, black, thin coal stringers; interbedded with gypsiferous bed, red, yellow, and black; sulfurous stringers; locally klinker.

Bed No.	Thickness (feet)	LITHOLOGY
48	7.00	Shale, gray, yellow-brown, locally red-brown, silty.
47	3.10	Sandstone, buff, very fine sand, angular, moderately sorted, calcareous; ledge former, locally poorly indurated; small-scale cross stratification.
46	2.00	Shale, gray, tiny irregular plates, becomes silty at top; gradational with bed 47.
45	0.60	Shale, dark-brown and black, carbonaceous, sulfurous stringers and one coal bed.
44	0.75	Siltstone, light-gray, calcareous, fissile.
43	0.30	Shale, dark-brown to black, carbonaceous, sulfurous stringers, thin coal stringers.
42	0.70	Shale, gray, tiny irregular plates, noncalcareous.
41	8.75	Sandstone, buff, very fine sand, subangular, fair sorting, greater than 90 percent quartz, poorly indurated; locally interbedded with carbonaceous, fissile siltstone.
40	0.40	Shale, dark-brown to black, carbonaceous, coal beds, weathers to small irregular plates.

Bed No.	Thickness (feet)	LITHOLOGY
39	6.00	Sandstone, buff, fine sand, angular, moderately sorted, porous, noncalcareous, poorly indurated; slope former.
38	1.25	Shale, dark-brown, carbonaceous, noncalcareous, slightly silty; slope former.
37	0.75	Sandstone, buff, very fine sand, angular, moderately sorted, calcareous; minor ledge former; small-scale cross stratification.
36	7.75	Shale, dark-olive-brown, carbonaceous, papery, noncalcareous, rare ostracodes?; gentle slope former.
35	1.25	Sandstone, weathers red brown, buff on fresh surface, very fine sand, subangular, moderately sorted, greater than 90 percent quartz; minor ledge former; small-scale cross stratification.
34	4.40	Shale, brown and gray, calcareous, slightly silty, weathers to tiny flakes; slope former.
33	3.00	Sandstone, buff, very fine sand, subangular, moderately sorted, calcareous; ledge former at top; poorly indurated with abundant muscovite below top; small- and medium-scale cross stratificatio and ripple marks.

Bed No.	Thickness (feet)	LITHOLOGY
32	13.70	Shale, red-brown to black, carbonaceous, sulfurous stringers; lower and upper portions of unit contain thin (1- to 3-in.) gypsiferous and coal interbeds, unidentifiable mollusks collected from lowermost gypsiferous layer in unit; middle part of unit is gray, silty shale which weathers to irregular plates; gradational with bed 33.
31	0.60	Marlstone, buff, locally slightly carbonaceous, ledge former; contains Physa pleromatis, Gyraulus sp., and ostracodes.
30	16.00	Shale, red-brown to black, carbonaceous, interbedded with thin (1- to 2-in.) gypsiferous layers, upper one half of unit contains thin beds of coal, sulfurous stringers.
29	1.00	Limestone, buff, platy, contains Pisidiidae: indet., Physa bridgerensis?, Biomphalaria aequalis and Acroloxus minutus, GR38-71.
28	0.60	Shale, dark-brown to black, carbonaceous, sulfurous stringers.
27	7.00	Sandstone, buff, very fine sand, subangular, moderately sorted, noncalcareous, porous; poorly indurated below top, ledge former at top with small-scale cross stratification.

Bed No.	Thickness (feet)	LITHOLOGY
26	4.25	Shale, gray, calcareous, slightly silty, tiny irregular plates.
25	1.00	Shale, dark brown to black, carbonaceous, sulfurous stringers; coal in lower 8-in. of unit, gypsiferous at top; gradational with bed 25.
24	1.00	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, minor biotite, noncalcareous, poorly indurated.
23	2.50	Shale, dark-brown to black, carbonaceous, thin beds of coal in lower 20-in.
22	2.50	Siltstone, buff, porous, noncalcareous, gypsiferous stringers near base; slope former.
21	3.75	Shale, light-gray, slightly silty, calcareous, tiny irregular plates.
20	2.25	Shale, red-brown to black, carbonaceous, coal layers in upper part of unit.
19	5.25	Shale, light-gray to red-brown, silty, noncalcareous, muscovite in lower portion; gradational with bed 20.
18	0.40	Shale, dark-brown to black, carbonaceous, silty, contains muscovite.

Bed No.	Thickness (feet)	LITHOLOGY
17	10.75	Sandstone, buff to white, very fine to fine sand, angular to subangular, poorly sorted, greater than 90 percent quartz with muscovite, noncalcareous, poorly indurated; local large-scale cross stratification; locally grades to light brown, poorly indurated siltstone.
16	3.00	Shale, dark-brown and gray, calcareous; contains thin (2-in.) interbed of siltstone, light-brown, calcareous.
	153.90	Total measured stratigraphic section of the lower part of Niland Tongue of Wasatch Formation at this locality.
		LUMAN TONGUE OF GREEN RIVER FORMATION (upper part)
15	1.00	Limestone, dense, ledge former; contains abundant poorly preserved fragments of Goniobasis tenera, Viviparus? sp., and Unionidae: indet.
14	2.25	Oil shale, brown, platy, calcareous; contains layers of abundant crushed Goniobasis tenera, Hydrobiidae: indet., Valvata sp., Viviparus cf. V. trochiformis, Viviparus sp., Plesiellipti o sp., Unionidae: indet., and Sphaerium sp., GR37-71.
13	5.00	Covered interval of colluvium.

Bed No.	Thickness (feet)	LITHOLOGY
12	17.75	Shale, red-brown to black, carbonaceous, few thin coal layers.
11	5.00	Sandstone, buff, very fine to fine sand, angular to subangular, moderately sorted to poorly sorted, gr than 90 percent quartz with minor biotite, calcareous; ledge former at top and bottom of unit; lower ledge former contains locally abundant internal molds of Unionidae: indet.
10	0.20	Coquinal limestone, abundant shell fragments of Goniobasis tenera (moderately developed ribs), Viviparus trochiformis, and Unionidae: indet.
9	0.66	Sandstone, white to buff, very fine sand, subangular, moderately well sorted, greater than 90 percent quartz, calcareous, porous, poorly indurated.
8	0.80	Coquinal limestone, weathers platy; contains abundant shell fragments of Goniobasis tenera, Viviparus? sp., and Unionidae: indet.
7	7.00	Shale, brown, slightly papery, calcareous, contains ostracodes.

Bed No.	Thickness (feet)	LITHOLOGY
6	9.75	Sandstone, buff, very fine to fine sand, subangular, poorly sorted, greater than 90 percent quartz; ledge former at bottom and top exhibiting ripple marks, large-scale cross stratification at top; sandstone caps ridge above dry spring and old broken windmill.
5	1.00	Shale, red-brown to black, carbonaceous, silty at base.
4	0.25	Coquinal limestone, light-brown, contains Goniobasis tenera, Viviparus sp., and Unionidae: indet.,
3	4.00	Shale, yellow-brown, somewhat papery, contains poorly preserved Goniobasis tenera, Viviparus sp., and Unionidae: indet.
2	14.75	Sandstone, very fine sand, angular, moderately sorted to poorly sorted, greater than 90 percent quartz with minor biotite; ledge former in upper 5-ft of unit; lower portion of ledge former contains locally abundant poorly preserved Goniobasis tenera, Viviparus trochiformis, and Unionidae: indet., and exhibits small-scale cross stratification.
1	10.00	Oil shale, dark-yellow-brown, calcareous, platy. Bed 1 of this section is the same as bed 37 in section #11-71.

Bed No.	Thick-ness (feet)	LITHOLOGY
		Bed 2 of this section is the same a bed 38 in section #11-71.
	79.41	Total measured stratigraphic section of the upper part of Luman Tongue of Green River Formation at this locality.

RIFES DRY WASH (#13-71)

Measured across a dry wash tributary to the North Fork of Vermillion Creek northwest of Rifes Ranch in SE1/4NW1/4 and SW1/4NE1/4 sec. 12, T. 13 N., R. 102 W.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (lower part)
		Bed 13 of this section is the same as bed 1 of section #14-71.
13	0.50	Sandstone, buff, very fine sand, angular, poorly sorted to moderately sorted, greater than 90 percent quartz with minor biotite; minor ledge former at top and bottom.
12	7.50	Siltstone, buff to light gray, calcareous, poorly indurated; slope former.
11	3.25	Sandstone, buff, very fine sand, subangular to subrounded, poorly sorted, calcareous; medium-scale planar cross stratification and horizontal laminations; ledge former.
10	5.00	Siltstone, light-yellow-brown to gray, calcareous, fissile; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
9	0.40	Sandstone, buff, very fine sand, angular, moderately sorted, greater than 90 percent quartz, calcareous; thin, horizontal laminations at base; upper 2-in. exhibits small-scale ripple lamination and poorly preserved questionable climbing ripple lamination; ledge former.
8	18.25	Oil shale, dark-yellow-brown to reddish-brown, calcareous, papery and irregular flakes, contains abundant ostracodes and few poorly preserved Goniobasis tenera (ribs); becomes buff and silty at top.
7	0.60	Coquinal limestone; contains few Goniobasis tenera (well developed ribs), Viviparus paludinaeformis?, and Unionidae: indet.; forms low bench.
6	5.75	Shale, yellow-brown, tiny irregular plates; becomes silty and carbonaceous at top.
5	0.40	Limestone, gray to white, platy, minor ledge former; contains abundant Goniobasis tenera (moderately developed nodes and well developed ribs), cf. Plesielliptio priscus, and Plesielliptio n. sp. A, GR6-75.

Bed No.	Thickness (feet)	LITHOLOGY
	41.65	Total measured stratigraphic section of lower part of Tipton Shale Member of Green River Formation at this locality.
		NILAND TONGUE OF WASATCH FORMATION (upper part)
4	9.75	Shale, gray at base, grades to dark brown and black, carbonaceous, calcareous, platy and tiny irregular plates, slightly silty, 1 external mold of Biomphalaria sp.; coal bed near top.
3	3.00	Siltstone, light-gray, slightly fissile, calcareous; slope former.
2	16.25	Shale, brown, red-brown, and black, carbonaceous, sulfurous stringers; rare intervals of brown, calcareous shale with ostracodes.
1	2.00	Sandstone, weathers buff, light-gray on fresh surface, very fine sand, subangular, poorly sorted, greater than 90 percent quartz with minor biotite, calcareous; ledge former; exhibits large-scale cross stratification.
		Bed 1 of this section is same as bed 60 in section #12-71.
	31.00	Total measured stratigraphic section of upper part of Niland Tongue of Wasatch Formation at this locality.

RIFE RANCH (#14-71)

Measured in slopes northeast of Rife Ranch buildings in NE1/4NW1/4 NW1/4 and SW1/4NE1/4NW1/4 of sec. 18, T. 13 N., R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		WILKINS PEAK MEMBER OF GREEN RIVER FORMATION (lower part)
8	45.00	Shale, weathers gray, light- to dark-yellow-brown on fresh surface, platy, unfossiliferous, dolomitic, secondary gypsum between some shale layers; interbedded with dolomitic shale are thin (1- to 6-in.) beds of dolomite, buff to orange, dense, crystalline , mildly calcareous on scratched surface.
7	0.50	Dolomite, buff, dense, crystalline, minor ledge former; locally with ostracodes on lower surface.
	45.50	Total measured stratigraphic section of lower part of Wilkins Peak Member of Green River Formation at this locality.
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (upper part)
6	24.00	Oil shale, light-yellow-brown to dark-brown, papery, calcareous, contains ostracodes, Valvata sp., and Pisidiidae: indet., GR47-71.

Bed No.	Thickness (feet)	LITHOLOGY
5	0.50	Ostracodal limestone, weathers to 1-in. thick slabs, contains abundant ostracodes, with Goniobasis tenera (strongly developed ribs and moderately developed nodes), Valvata of V. filosa, Valvata cf. V. subumbilicata and Viviparus sp., GR46-71; limestone is overlain and underlain by thin, fissile siltstone, light-yellow-brown, calcareous, with ostracodes.
4	28.00	Oil shale, light- to dark-brown, calcareous, platy and papery, contains locally abundant ostracodes; better indurated layers contain Unionidae: indet. and Goniobasis tenera; at top shale contains abundant G. tenera (well developed ribs), Valvata sp., and Unionidae: indet,; unit contains one 2.25-ft red-brown to black carbonaceous shale bed with coal and gypsiferous interbeds.
3	3.00	Coquinal limestone, light-gray to buff, contains abundant shell fragments of Goniobasis tenera (well developed ribs) and Unionidae: indet.; mollusks litter low knoll between shale slopes; gradational with bed 4.

Bed No.	Thickness (feet)	LITHOLOGY
2	16.75	Oil shale, dark-yellow-brown, papery, calcareous, rarely carbonaceous near base; contains locally abundant Goniobasis tenera, Viviparus sp., Valvata cf. V. filosa, Hydrobia sp., Pisidiidae: indet., and ostracodes, GR43-71.
1	0.50	Sandstone, buff, very fine sand, angular, poorly sort to moderately sorted, greater than 90 percent quartz with minor biotite; minor ledge former at top and bottom.
		Bed 1 of this section is same as bed 13 of section #13-71.
	72.75	Total measured stratigraphic section of upper part of Tipton Shale Member of Green River Formation at this locality.

APPENDIX E

RIFES RIM COMPOSITE SECTION

RIFES RIM (#1-72)

Measured in a generally southeastern direction in gullies and on slopes north of, and at the base of Rifes Rim in the SE1/4SE1/4 sec. 29, SW1/4 SW1/4SW1/4 sec. 28, SE1/4SE1/4SW1/4 sec. 28, NE1/4NW1/4 sec. 33, T. 14 N., R. 101 W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (lower part)
114	1.50	Limestone, brown, blocky, contains abundant Goniobasis tenera, and Unionidae: indet.; probably equivalent to GR90-70 in bed 9 of stratigraph section #11-71.
113	2.75	Shale, brown to black, carbonaceous, coal at top.
112	22.50	Oil shale, olive-brown, papery, calcareous, abundant ostracodes.
	26.75	Total measured stratigraphic section of lower part of Luman Tongue of Green River Formation at this locality.
		MAIN BODY OF WASATCH FORMATION (approximately upper one fourth)
111	1.00	Shale, red-brown, carbonaceous, gypsiferous layer at top.

Bed No.	Thickness (feet)	LITHOLOGY
110	10.33	Sandstone, buff, fine sand, subangular, moderately sorted, calcareous, greater than 90 percent quartz; ledge former, contorted bedding above base.
109	3.00	Siltstone, light-olive to gray, calcareous, argillaceous at base, flaky.
108	3.00	Shale, light-olive, noncalcareous, rarely slightly blocky.
107	0.33	Shale, dark-red-brown to black, carbonaceous, one coal interbed.
106	0.60	Siltstone, gray, irregular fragments; slope former.
105	0.60	Sandstone, rusty-yellow-brown, very fine sand to siltstone; slope former.
104	4.40	Mudstone, olive, irregular fragments; slope former.
103	4.80	Sandstone, buff, very fine sand to siltstone, well sorted, composed mainly of quartz, somewhat platy; minor ledge former.
102	0.75	Mudstone, olive, flaky, slightly silty; slope former.
101	0.50	Shale, dark-red-brown to black, carbonaceous.

Bed No.	Thickness (feet)	LITHOLOGY
100	20.00	Sandstone, rusty-yellow-brown, very fine sand to siltstone, noncalcareous, porous; slope former.
99	2.50	Shale, dark-brown to black, carbonaceous, coal beds, red-brown gypsiferous layers.
98	4.00	Siltstone, gray, flaky, noncalcareous; slope former.
97	0.90	Marlstone, light-gray, very dense, calcareous, weathers to irregular fragments.
96	2.00	Mudstone, olive to gray, irregular fragments.
95	5.00	Sandstone, gray to light-red-brown, very fine to fine sand, subangular, moderately well sorted, calcareous, rare muscovite; thin argillaceous siltstone beds near top; platy at top; minor ledge former.
94	3.00	Mudstone, gray, flaky; slope former.
93	0.75	Marlstone, identical in all respects with bed 97; one specimen each of Gyraulus sp., Physa pleromatis, and Biomphalaria sp.
92	5.20	Sandstone, light-red-brown to gray, very fine sand, subrounded, moderately well sorted, calcareous; minor ledge former near top.

Bed No.	Thickness (feet)	LITHOLOGY
91	8.00	Mudstone, light- to dark-gray, flaky; slope former.
90	2.00	Siltstone, black, carbonaceous, noncalcareous, thin coal layer.
89	1.75	Siltstone, gray, flaky, slope former.
88	0.90	Marlstone, identical in all respects with bed 97.
87	9.50	Sandstone, buff, very fine sand, subangular, moderately well sorted, calcareous, moderately indurated to well indurated; ledge former at top.
86	0.75	Mudstone, gray, flaky, slope former.
85	0.50	Siltstone, black, carbonaceous, blocky, noncalcareous, thin coal layer.
84	0.90	Sandstone, rusty-yellow-brown, very fine sand to siltstone, calcareous, poorly indurated to moderately indurated.
83	1.50	Mudstone, light- to dark-gray, flaky and irregular fragments, rarely slightly silty.
82	1.40	Marlstone, identical in all respects with bed 97.

Bed No.	Thickness (feet)	LITHOLOGY
81	7.50	Sandstone, buff to gray, very fine sand, subangular, moderately sorted, calcareous, greater than 90 percent quartz; slope former in lower part, ledge former at top; exhibits small-scale cross stratification.
80	1.75	Mudstone, light- to dark-gray, irregular fragments, slope former.
79	1.80	Siltstone, gray and brown, calcareous, flaky and irregular fragments.
78	1.00	Marlstone, identical in all respects with bed 97.
77	12.75	Sandstone, buff and gray, very fine to fine sand, subangular, moderately sorted, poorly indurated to w indurated, mainly quartz with biotite, calcareous; ledge former in upper part.
76	1.00	Mudstone, gray, flaky, noncalcareous; slope former.
75	4.50	Sandstone, buff and rusty-yellow-brown, very fine sand, subangular, moderately sorted, slightly calcareous, poorly indurated; slope former.
74	4.00	Mudstone, gray, slightly silty, flaky, somewhat fissile.

Bed No.	Thickness (feet)	LITHOLOGY
73	0.75	Shale, black, carbonaceous, silty; contains 1/2-in. marlstone interbed, identical in all respects with bed 97.
72	1.25	Sandstone, buff to rusty-yellow-brown, very fine sand, subangular, moderately sorted, calcareous, porous; slope former.
71	0.60	Marlstone, identical in all respects with bed 97.
70	2.25	Mudstone, light- to dark-gray, irregular fragments, rarely slightly silty.
69	5.66	Sandstone, weathers light red brown, light gray on fresh surface, very fine sand, subangular, moderately sorted, calcareous; ledge former near top.
68	2.75	Mudstone, light- to dark-gray, irregular fragments, silty at base; slope former.
67	2.75	Sandstone, weathers red brown, light-gray on fresh surface, very fine sand to siltstone, mainly quartz, calcareous, dense; minor ledge former.
66	5.00	Mudstone, gray and light-olive, irregular fragments, gradational with bed 65; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
65	19.25	Sandstone, light-gray, buff, and red-brown, very fine to fine sand, subangular, moderately sorted, calcareous, poorly indurated to moderately indurated; major ledge former; local small-scale cross stratification; in lower 2-ft sand is interbedded wit gray siltstone and silty mudstone.
64	0.66	Marlstone, identical in all respects with bed 97.
63	16.25	Mudstone, light- to dark-gray, locally brown and red-brown, irregular fragments; one thin (1-in.) siltstone interbed.
62	6.25	Sandstone, rusty-yellow-brown, fine sand, subangular, moderately sorted, greater than 90 percent quartz, poorly indurated to unindurated; slope former.
61	12.50	Mudstone, light- to dark-gray, locally red-brown, silty, flaky, irregular fragments.
60	0.75	Sandstone, rusty-yellow-brown, very fine sand, subangular, moderately well sorted, poorly indurated to unindurated.
59	3.50	Mudstone, light- to dark-gray, silty; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
58	1.50	Shale, dark-red-brown to black, carbonaceous, minor sulfurous stringers.
57	5.00	Mudstone, gray, locally brown, flaky, silty.
56	1.10	Marlstone, identical in all respects with bed 97.
55	2.25	Siltstone, greenish-gray, argillaceous, platy; slope former.
54	3.25	Sandstone, light-gray, very fine sand, subangular, moderately sorted, calcareous, abundant coarse biotite flakes, greater than 90 percent quartz; local ledge former.
53	3.50	Mudstone, dark- to light-gray, silty, rarely slightly fissile, irregular fragments; grades to siltstone at top.
52	11.50	Sandstone, buff to gray, very fine to fine sand, subangular, moderately sorted to moderately well sorted, calcareous, greater than 90 percent quartz with locally abundant biotite and muscovite; ledge former at bottom, minor ledge former at top; interbedded with siltstone, gray, calcareous, irregular fragments, slope former.

Bed No.	Thickness (feet)	LITHOLOGY
51	3.50	Mudstone, light-red to dark-gray, slightly silty, rarely fissile.
50	0.33	Limestone, dark-gray, dense, poorly exposed; contains few Physa pleromatis.
49	5.33	Siltstone, gray and locally red-brown, argillaceous, irregular fragments.
48	1.20	Sandstone, buff, very fine sand to siltstone; minor ledge former.
47	9.50	Mudstone, red-brown, slightly silty, irregular fragments.
46	0.50	Sandstone, light-gray, fine sand, subrounded, well sorted, greater than 90 percent quartz with abundant biotite and muscovite, calcareous.
45	5.00	Mudstone, red-brown, silty, flaky, tiny irregular fragments; interbedded with gray siltstone.
44	0.60	Sandstone, weathers buff, gray, light-gray on fresh surface, very fine sand, subangular to subrounded, moderately well sorted, mainly quartz with rare biotite and muscovite, calcareous; minor ledge former.
43	11.00	Interbedded mudstone and siltstone, identical in all respects with bed 45.

Bed No.	Thickness (feet)	LITHOLOGY
42	20.00	Sandstone, weathers brown to light red-brown, gray on fresh surface, very fine to fine sand, subrounded, moderately well sorted to well sorted, mainly quartz with rare unidentified red grains; locally contains clasts of poorly indurated siltstone and mudstone up to 1-in. in diameter; exhibits large-scale cross stratification and local contorted bedding; prominent ledge former; large channelform sandstone.
41	1.25	Mudstone, gray to light-red, flaky, silty at top.
40	0.50	Limestone, gray, platy, dense; contains poorly preserved Gyraulus sp., Biomphalaria sp., Omalodiscus sp., Physa pleromatis, and Lymnaeidae: indet.; locally covered.
39	2.50	Mudstone, light-red-brown, silty, flaky.
38	1.20	Marlstone, identical in all respects with bed 97.
37	0.50	Mudstone, light-red, silty, flaky.

Bed No.	Thickness (feet)	LITHOLOGY
36	8.80	Sandstone, light-red-brown, fine sand, subrounded, moderately well sorted, mainly quartz with common to abundant muscovite, hematite staining on some quartz grains; rare contorted bedding, small-scale cross stratification; minor ledge former at base, major ledge former at top; few thin siltstone interbeds at base.
35	12.75	Siltstone, red and gray, calcareous, irregular fragments; slope former.
34	0.60	Sandstone, light-gray to red-brown, very fine sand to siltstone, calcareous; exhibits few questional burrows.
33	4.00	Siltstone, gray, calcareous, irregular fragments; slope former.
32	0.50	Sandstone, light-gray on fresh surface, weathers red-brown, fine sand, subangular, poorly sorted, mainly quartz with abundant biotite; minor ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
31	10.50	Siltstone, gray, calcareous, irregular fragments, slope former; at 3-ft level siltstone contains a thin sandstone interbed which appears to be extensively burrowed, identical with bed 32; at 7.5-ft level siltstone contains thin 2-in. marlstone interbeds identical in all respects with bed 97.
30	1.00	Sandstone, buff, fine sand, subangular to subrounded, moderately sorted, calcareous, greater than 90 percent quartz; minor ledge former.
29	7.50	Siltstone, gray, calcareous, irregular fragments, slope former.
28	3.00	Sandstone, buff, fine sand, subangular to subrounded, well sorted, greater than 90 percent quartz, rare unidentified black grains; ledge forming channelform sandstone.
27	16.00	Siltstone, light- to dark-gray, argillaceous at base; gradational with bed 28.
26	17.50	Sandstone, buff, very fine sand, subangular, moderately sorted; medium-scale cross stratification; ledge former in lower and upper 5-ft, middle part of unit contains thin siltstone interbeds.

Bed No.	Thickness (feet)	LITHOLOGY
25	0.50	Limestone, dark-gray, platy, dense; contains Gyraulus sp., Valvata? sp., Omalodiscus sp., Physa pleromatis, Lymnaeidae: indet., Pisidiidae: indet., and ostracodes.
24	10.33	Siltstone, gray, flaky, irregular fragments.
23	16.50	Mudstone, gray, maroon, and brown, noncalcareous, irregular fragments.
22	1.50	Shale, red-brown to black, carbonaceous, sulfurous stringers, silty.
21	4.75	Sandstone, buff, very fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz with rare unidentified black grains; poorly indurated; grades to siltstone at top.
20	2.00	Shale, red-brown to black, carbonaceous, sulfurous stringers; less carbonaceous at top.
19	1.50	Limestone, light-red-brown, very platy, plates litter a bench; Hydrobia sp., Physa bridgerensis, P. longiuscula?, P. pleromatis, Physa? sp., Biomphalaria aequalis, B. storchi, Biomphalaria? sp., ?Gyraulus militaris, Omalodiscus cirrus, Lymnaea cf. L. minuscula, and ostracodes; GR110-70.

Bed No.	Thickness (feet)	LITHOLOGY
18	37.75	Sandstone, buff to red-brown, very fine to fine sand, moderately sorted to well sorted, subangular to subrounded; major ledge former at base with contorted bedding, minor ledge former above base; contains buff to gray siltstone interbeds.
17	0.75	Mudstone, olive-green, irregular fragments, slightly blocky; contains excellently preserved Plesielliptio priscus; GR109-70.
16	0.25	Limestone, gray to black, platy, dense; Goniobasis? sp., Hydrobia aff. H. utahensis, Hydrobia sp., Valvata cf. V. filosa, Valvata sp., Physa bridgerensis, P. cf. P. longiuscula, P. cf. P. pleromatis, Omalodiscus cirrus, Lymnaea? sp., cf. Pleurolimnaea tenuicosta, and Albertanella? sp.; GR3-71.
15	18.00	Mudstone, light-gray to red-brown, locally silty, contains thin (1-in.) carbonaceous layer with sulfurous stringers; interbedded with siltstone, gray, irregular fragments, slope former.
14	1.75	Shale, dark-red-brown to black, carbonaceous; contains coal layers, sulfurous stringers; red-brown gypsiferous layer at base.

Bed No.	Thickness (feet)	LITHOLOGY
13	7.25	Sandstone, buff, very fine sand, subangular, moderately well sorted, calcareous, greater than 90 percent quartz, minor ledge former; interbedded with siltstone, gray and buff, irregular fragments, locally argillaceous.
12	0.33	Limestone, gray, platy, dense; *Valvata*? sp., *Gyraulus*? sp., *Physa* sp., *Biomphalaria*? sp., *Omalodiscus*? sp., Unionidae: indet.
11	4.50	Siltstone, gray, irregular fragments, argillaceous.
10	0.75	Shale, red-brown to black, carbonaceous, contains thin coal beds.
9	17.50	Mudstone, gray and brown, locally silty and fissile; slope former.
8	0.75	Limestone, gray to black, dense, platy; *Plesiellipti*o cf. *P. priscus*, *Hydrobia* aff. *H. utahensis*, *Hydrobia* sp., *Valvata* cf. *V. subumbilicata*, *Valvata* sp., *Physa bridgerensis*, *P. longiuscula*?, *P. pleromatis*, *Physa* sp., *Biomphalaria aequalis*, *B. storchi*, ?*Gyraulus militaris*, *Omalodiscus cirrus*, and *Albertanella minuta*; GR2-71.
7	3.50	Mudstone, gray to brown, silty, noncalcareous; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
6	8.00	Sandstone, buff, very fine sand, subrounded, moderately well sorted, greater than 90 percent quartz; small-scale cross stratification, minor contorted bedding; ledge former.
5	8.50	Siltstone, gray, rarely reddish-gray, irregular fragments; slope former.
4	1.50	Sandstone, gray on fresh surface, weathers red brown, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous; local ledge former.
3	7.75	Siltstone, identical in all respects with bed 5.
2	0.50	Limestone, gray, platy, dense; Pisidiidae: indet., *Hydrobia* aff. *H. utahensis*, *Hydrobia* sp. A, *Hydrobia* sp., *Physa bridgerensis*, *P.* cf. *P. bridgerensis*, P. *longiuscula*?, *P. pleromatis*, *Physa* sp., *Physa*? sp., *Biomphalaria aequalis*, *B. storchi*, *Biomphalaria*? sp., *Omalodiscus cirrus*, *Promenetus* sp. A, *Acroloxus* sp., *Lymnaea* cf. *L. minuscula*, *Lymnaea* sp. A. *Lymnaea* sp. B?, *Pleurolimnaea tenuicosta*, *Oreoconus* sp., and *Pseudocolumna vermicula*; GR108-70.

Bed No.	Thickness (feet)	LITHOLOGY
1	10.00	Siltstone, gray, irregular fragments, noncalcareous.
	553.90	Total measured stratigraphic section of the main body of the Wasatch Formation (approximately upper one fourth) at this locality.

APPENDIX F

FOUR J BASIN COMPOSITE SECTION

FOUR J BASIN (#2-72)

Measured along the north edge of Four J Basin in the lower slopes of a prominent spur extending from Four J rim into the basin in E1/2NE1/4 sec. 7, T. 12 N., R. 102W.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (lower part)
		Bed 39 of this section is the same as bed 1 in section #3-72.
39	0.33	Ostracodal limestone, buff.
38	24.00	Oil shale, dark-olive-brown, noncalcareous, papery, rare ostracodes.
37	3.50	Sandstone, buff, very fine to fine sand, angular to subangular, moderately sorted, calcareous; contains abundant Viviparus paludinaeformis, and Goniobasis tenera; minor ledge former.
36	2.00	Oil shale, olive-brown, noncalcareous, contains ostracodes.
35	0.33	Coquinal limestone, red-brown, moderately dense; contains abundant shell fragments of Goniobasis tenera (well developed ribs), Unionidae: indet. and ostracodes.

Bed No.	Thickness (feet)	LITHOLOGY
34	5.00	Sandstone, buff, fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous; locally consists of very coarse sand, small- and medium-scale cross stratification; ledge former.
33	10.00	Oil shale, dark-olive-brown, calcareous, ostracodes; partially covered by colluvium.
32	5.00	Shale, dark-brown and light-red-brown, carbonaceous, silty, sulfurous stringers; covered by considerable colluvium.
31	5.00	Oil shale, light-olive-brown, contains Goniobasis tenera; covered by considerable colluvium.
30	3.50	Sandstone, buff, fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous; contains very abundant Goniobasis tenera, fragments of Unionidae: indet.; ledge former.
29	7.00	Oil shale, dark-olive-brown, calcareous, fissile; contains Goniobasis tenera (well developed ribs), Valvata sp., and fragments of Unionidae: indet.; unit includes a thin (1- to 3-in.) red-brown siltstone interbed which contains Goniobasis tenera.
28	0.90	Coquinal limestone, dense; contains abundant shell fragments of Goniobasis tenera.

Bed No.	Thickness (feet)	LITHOLOGY
	66.56	Total measured stratigraphic section of lower part of Tipton Shale Member of Green River Formation at this locality.
		MAIN BODY OF WASATCH FORMATION (upper part)
27	1.75	Mudstone, gray, slightly silty, noncalcareous, tiny irregular fragments.
26	0.80	Siltstone, red-brown, well indurated, noncalcareous; contains Goniobasis tenera (well developed ribs), Viviparus trochiformis, Unionidae: indet., and ostracodes.
25	0.75	Mudstone, identical with bed 27.
24	1.25	Siltstone, identical in all respects with bed 26.
23	3.50	Mudstone, identical with bed 27.
22	2.75	Sandstone, rusty-yellow-brown, very fine sand and siltstone, moderately well sorted, noncalcareous, minor organic fragments.
21	0.66	Shale, dark-brown, carbonaceous; interbedded with siltstone, fissile and blocky.
20	1.00	Sandstone, red-brown, very fine sand and siltstone, noncalcareous.

Bed No.	Thickness (feet)	LITHOLOGY
19	3.50	Siltstone, gray, blocky, noncalcareous, slightly fissile.
18	0.50	Oil shale, dark-olive-brown, platy; contains *Goniobasis tenera* (moderately developed ribs) *Valvata* sp., and ostracodes.
17	17.75	Sandstone, brown, medium sand, subrounded to rounded, moderately well sorted to well sorted, greater than 90 percent quartz, calcareous; contains beds with *Goniobasis tenera*, *Viviparus* sp. and *Physa pleromatis*, GR68-70; small-scale cross stratification, ripple marks; major ledge former; lower contact gradational with bed 16.
16	22.00	Siltstone, gray, brown, red-brown, irregular fragments, covered by considerable colluvium; in lower 5-ft of unit is thin (1-ft) interbed of sandstone, buff, fine sand, subrounded, moderately well sorted, calcareous.
15	2.25	Sandstone, rusty-brown, fine to medium sand, subangular to subrounded, poorly sorted, greater than 90 percent quartz, calcareous; local minor ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
14	19.00	Siltstone, gray, red-brown, one thin (1-in.) carbonaceous layer; interbedded with few gray mudstone layers.
13	19.00	Sandstone, light-gray, very fine sand, subangular, well sorted, greater than 90 percent quartz, poorly indurated, local ledge former; basal portion of unit is red-brown siltstone.
12	4.75	Shale, dark-brown to black, carbonaceous, sulfurous stringers, gypsiferous beds and coal beds; interbedded with yellow-gray carbonaceous mudstone.
11	7.75	Siltstone, buff, gray and red-brown, minor sulfurous staining, gypsiferous stringers in lower part.
10	23.00	Sandstone, red-brown, buff, fine to medium sand, subangular to subrounded, poorly sorted, greater than 90 percent quartz, calcareous; ledge former in upper part is locally conglomeratic with rounded and subrounded quartz sandstone clasts as large as 1/2-in. in diameter; at 14-ft level is 4-ft interval of conglomerate with sandstone and quartzite clasts up to 2-in. in diameter, conglomeratic interval local in distribution.

Bed No.	Thickness (feet)	LITHOLOGY
9	6.50	Mudstone, gray, silty, noncalcareous, blocky, tiny irregular fragments; interval contains thin better indurated interbeds of mudstone and siltstone.
8	29.75	Mudstone, red, noncalcareous, tiny irregular fragments, silty at top.
7	8.50	Mudstone, gray, noncalcareous, tiny irregular fragments.
6	16.33	Sandstone, buff with thin red-brown layers, medium to coarse sand, subangular to subrounded, poorly sorted, calcareous; gradational with bed 5; ledge former, locally forms benches.
5	6.75	Mudstone, gray, silty, noncalcareous, tiny irregular fragments; in center of unit is 1-ft of interbedded sandstone and siltstone, sandstone is buff, very fine to fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, calcareous, siltstone is red-brown and blocky.
4	8.50	Sandstone, red-brown, fine to medium sand, calcareous, greater than 90 percent quartz; locally coarse sand and conglomeratic layers 4- to 5-in. thick with subrounded to rounded clasts of quartz sandstone and quartzite as large as 4-in. in diameter.

Bed No.	Thickness (feet)	LITHOLOGY
3	16.00	Mudstone, gray, silty, mildly calcareous, tiny irregular fragments.
2	6.50	Sandstone, red-brown, very fine to fine sand, greater than 90 percent quartz, few siltstone interbeds, poorly indurated; above basal 18-in. sandstone is very well indurated, medium to coarse sand, subangular to subrounded, moderately sor to locally very poorly sorted, greater than 90 percent quartz with minor biotite flakes; locally very coarse grained and conglomeratic with quartz sandstone and quartzite clasts as large as 2-in. in diameter; ledge former.
1	1.00	Conglomerate, red-brown, very poorly sorted, composed of subrounded to rounded clasts of quartz sandstone and quartzite as large as 4-in. in diameter; irregular bottom contact.
	209.02	Total measured stratigraphic section of upper part of Main Body of Wasatch Formation at this locality.

FOUR J RIM (#3-72)

Measured on the north edge of Four J Basin in the upper slopes of a prominent spur that extends from Four J Rim into the basin, below the intersection of a dirt road and the edge of Four J Rim in NE1/4NE1/4 NW1/4 sec. 7, and S1/2SE1/4SW1/4 sec. 6, T. 12 N., R. 102 W.

Bed No.	Thickness (feet)	LITHOLOGY
		WILKINS PEAK MEMBER OF GREEN RIVER FORMATION (approximately lower one half)
59	1.50	Sandstone, light-gray and buff, very fine sand, subangular to subrounded, well sorted, porous, noncalcareous.
58	0.75	Dolomite, gray, dense, crystalline, blocky, mildly calcareous; grades to less blocky dolomitic mudstone.
57	2.75	Sandstone, light-gray, very fine sand and siltstone, well sorted, porous, noncalcareous.
56	2.75	Dolomite, identical in all respects with bed 58.
55	9.00	Sandstone, buff, fine sand, subangular to subrounded, well sorted, locally poorly sorted, porous, noncalcareous; poorly indurated; locally better indurated, calcareous, and a ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
54	2.00	Mudstone, light- to dark-gray, dolomitic, crystalline, brittle, contains plant fragments and analcime.
53	0.40	Sandstone, buff, very fine sand, angular to subangular, calcareous, dense; minor ledge former.
52	4.00	Dolomitic mudstone, identical in all respects with bed 54.
51	11.50	Sandstone, buff, fine sand, subrounded, moderately sorted, porous, noncalcareous, poorly indurated to moderately indurated; better indurated layers are calcareous; exhibits medium-scale cross stratification; ledge former.
50	1.75	Dolomitic mudstone, identical in all respects with bed 54.
49	4.00	Sandstone, buff, fine sand, subrounded, moderately sorted, greater than 90 percent quartz, porous, noncalcareous; well indurated layers are calcareous; exhibits ripple marks; ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
48	7.20	Mudstone, buff to gray, dolomitic, dense, blocky, crystalline, contains poorly preserved fish bones; interbedded in middle one third of unit with shale, dark-brown, dolomitic, brittle, fissile, crystalline; at 5.40-ft level in unit is 1.5-in. layer of analcime.
47	0.25	Sandstone, buff, very fine sand, subangular, well sorted, greater than 90 percent quartz, mildly calcareous, dense; minor ledge former; locally interbedded with dolomitic mudstone.
46	30.00	Interbedded dolomitic mudstone and dolomitic shale, identical in all respects with bed 48; mudstone contains leaves as well as fragments of fish bones; at 2-ft level of unit is 1-in. layer of very dense dolomite; dolomitic mudstone occurs at the following levels within the dolomitic shale: a. 5.5-ft level; 1.00-ft thick b. 10.5-ft level; .90-ft thick c. 15.0-ft level; 0.33-ft thick d. 20.0-ft level; 0.33-ft thick e. 23.0-ft level; 2.00-ft thick f. 29.0-ft level; 0.10-ft thick

Bed No.	Thickness (feet)	LITHOLOGY
45	6.25	Sandstone, buff, medium sand, subrounded, poorly sorted to moderately sorted, greater than 90 percent quartz, thin layers with very coarse sand, mildly calcareous; ledge former.
44	2.50	Mudstone, dark-brown to dark-gray, dolomitic, crystalline, blocky.
43	6.25	Sandstone, buff, fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, massive, calcareous; major ledge former.
42	2.50	Mudstone, dark-brown to dark-gray, dolomitic, blocky, crystalline.
41	2.75	Sandstone, buff and rusty-yellow-brown, fine sand, subrounded, moderately sorted to poorly sorted, greater than 90 percent quartz, mildly calcareous, poorly indurated to well indurated; grades to siltstone at top.
40	5.40	Dolomitic mudstone, identical in all respects with bed 42; contains thin interbed of siltstone near top.
39	0.33	Siltstone, buff, mildly calcareous, organic fragments along laminations; exhibits small-scale sole markings.

Bed No.	Thickness (feet)	LITHOLOGY
38	12.50	Shale, dark-brown and black, dolomitic, some layers slightly carbonaceous, crystalline, slightly blocky.
37	1.20	Siltstone, rusty-yellow-brown, blocky, poorly indurated.
36	2.50	Dolomitic mudstone identical in all respects with bed 42; also platy and brittle.
35	4.00	Siltstone, identical in all respects with bed 37.
34	2.00	Dolomitic mudstone, identical in all respects with bed 42; also platy and brittle.
33	6.00	Sandstone, rusty-yellow-brown, fine sand, subrounded, moderately well sorted, greater than 90 percent quartz, calcareous, poorly indurated; contains thin (4-in.) interbed of gray siltstone.
32	4.00	Dolomitic mudstone, identical in all respects with bed 42; also platy and brittle; contains few thin (2-in.) sandstone interbeds, rusty yellow-brown, very fine sand, rare organic fragments.
31	2.50	Sandstone, rusty-yellow-brown, very fine sand to siltstone, well sorted, calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
30	11.00	Dolomitic mudstone, identical in all respects bed 42; also platy and brittle.
29	23.00	Interval covered by colluvium.
28	5.00	Oil shale, dark-brown, papery, noncalcareous; one thin (1-in.) rusty-yellow-brown siltstone near base; top contact not noted.
27	10.00	Interval covered by colluvium.
26	1.75	Sandstone, rusty-yellow-brown, fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz, calcareous, poorly indurated to well indurated; minor ledge former in upper part.
25	2.40	Siltstone, green and gray, locally slightly fissile and argillaceous.
24	0.50	Marlstone, light-gray, dense, mildly calcareous, crystalline.
23	0.66	Shale, dark-brown, noncalcareous.
22	3.50	Siltstone, gray and yellow-brown, locally slightly fissile and argillaceous; contains interbeds of sandstone, rusty-yellow-brown, very fine sand, well sorted, calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
21	0.20	Dolomite, gray and light-orange, very dense, crystalline, very mildly calcareous, readily calcareous if scratched.
20	1.50	Oil shale, dark-olive-brown, noncalcareous, contains few ostracodes; grades to silty shale at top.
19	4.75	Siltstone, gray, slightly argillaceous; contains thin interbeds of sandstone, very fine sand, well sorted, calcareous.
18	0.25	Sandstone, buff, very fine sand, well sorted, slightly calcareous, well indurated; minor ledge former.
17	11.25	Oil shale, dark-olive-brown, noncalcareous, papery.
16	1.10	Sandstone, buff, very fine sand, subangular, moderately sorted, greater than 90 percent quartz, calcareous.
15	18.50	Oil shale, dark-olive-brown, noncalcareous, papery; rare ostracodes.
14	30.00	Interval covered by colluvium.

Bed No.	Thickness (feet)	LITHOLOGY
13	0.75	Sandstone, rusty-yellow-brown, very fine sand, subrounded, well sorted, greater than 90 percent quartz, calcareous.
12	6.25	Siltstone, gray calcareous, irregular fragments, slightly fissile.
11	0.20	Sandstone, identical in all respects with bed 13.
10	10.50	Siltstone, identical in all respects with bed 12.
9	0.20	Stromatolite, buff to orange, gray, dense, dolomitic, irregular upper surface.
8	4.00	Shale, dark-gray, silty, fissile, calcareous, tiny plates.
7	11.75	Interbedded sandstone and siltstone; sandstone is buff to gray, fine sand, subangular to subrounded, moderately sorted, greater than 90 percent quartz, calcareous, poorly indurated to moderately indurated; siltstone is gray, argillaceous, calcareous; these two lithologies are thinly interbedded throughout unit; at top siltstone becomes fissile contains ostracodes and is gradational with bed 8.

Bed No.	Thickness (feet)	LITHOLOGY
6	0.40	Sandstone, rusty-yellow-brown and red-brown, fine to medium sand, subangular, poorly sorted, greater than 90 percent quartz, calcareous; minor ledge former.
5	1.00	Mudstone, buff, silty.
4	11.00	Shale, brown, weathers gray, slightly crystalline, mildly calcareous, readily calcareous if scratched, slightly brittle, platy; much of slope is covered by colluvium.
3	1.00	Dolomite, buff, dense, brittle, thick plates, crystalline, mildly calcareous, readily calcareous if scratched.
	310.94	Total measured stratigraphic section of Wilkins Peak Member of Green River Formation (approximately lower one half) at this locality.
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (upper part)
2	57.50	Shale, brown, slightly calcareous, oil shale at base, platy and possibly dolomitic toward top; much of slope is covered by collovium; above base shale weathers gray.

Bed No.	Thickness (feet)	LITHOLOGY
1	0.33	Ostracodal limestone, buff.
		Bed 1 of this section is the same as bed 39 in #2-72.
	57.83	Total measured stratigraphic section of upper part of Tipton Shale Member of Green River Formation at this locality.

APPENDIX G

RED CREEK COMPOSITE SECTION

RED CREEK BASIN (#4-72)

Measured in steep slopes on the northern margin of Red Creek Basin, north of Red Creek in N1/2SE1/4SW1/4 sec. 25, T. 13 N., R. 104 W.

Bed No.	Thickness (feet)	LITHOLOGY
		LUMAN TONGUE OF GREEN RIVER FORMATION (part of upper unnamed tongue)
		Bed 33 of this section is the same as bed 1 of section #5-72.
33	25.00	Sandstone, weathers buff and red brown, very fine sand, subrounded, well sorted, calcareous, contains Goniobasis tenera, Viviparus cf. V. paludinaeformis, Viviparus trochiformis, and Unionidae: indet., GR3-70; ledge former.
32	7.33	Mudstone, gray, noncalcareous, irregular fragments.
31	43.50	Shale, brown, silty, irregular papery fragments, calcareous and noncalcareous, locally abundant ostracodes.
30	2.75	Coquinal limestone, light-brown, dense, contains Goniobasis tenera, Viviparus trochiformis, and Unionidae: indet.; locally caps small bench and litters slopes below bench with mollusks.

Bed No.	Thickness (feet)	LITHOLOGY
29	25.00	Shale, brown and red-brown, calcareous and noncalcareous, papery, rarely irregular silty fragments, contains locally abundant ostracodes; rare thin interbeds of siltstone, weathers red brown, dense, calcareous.
28	0.90	Coquinal limestone, brown, dense, contains Goniobasis tenera (well developed ribs and nodes), Viviparus trochiformis, and Unionidae: indet.
27	6.75	Sandstone, weathers buff and red brown, very fine sand, subangular, poorly sorted, calcareous, platy, grades to siltstone at top; one Pisidiidae: indet. collected from upper 2-ft of unit; minor ledge former.
26	6.75	Shale, brown, tiny irregular flakes, slightly silty, noncalcareous, contains ostracodes; gradational with bed 27, very silty at top.
25	5.00	Mudstone, gray, blocky, slightly fissile and silty, locally contains Goniobasis tenera (well developed ribs and nodes), Viviparus trochiformis, and Unionidae: indet.; unit contains rare thin 1- to 2-in.) red-brown siltstone with same fauna as mudstone, GR17-72.
24	0.50	Coquinal limestone, dense, composed of abundant shell fragments of Goniobasis tenera, Viviparus trochiformis and Unionidae: indet.

Bed No.	Thickness (feet)	LITHOLOGY
	123.48	Total measured stratigraphic section of Luman Tongue of Green River Formation (part of upper unnamed tongue) at this locality.
		MAIN BODY OF WASATCH FORMATION (part)
23	1.00	Siltstone, weathers red brown and blocky at base, grades to gray irregular fragments.
22	5.00	Mudstone, gray, tiny irregular fragments, silty, very silty at top.
21	0.66	Limestone, white, dense, crystalline.
20	4.80	Siltstone, weathers gray, irregular fragments.
19	3.75	Sandstone, weathers buff to brown, fine sand, subrounded, moderately sorted, calcareous, poorly indurated; slope former.
18	23.75	Mudstone, red-brown and gray, silty, slope former; gradational with bed 19.
17	3.50	Sandstone, weathers buff, fine sand, subangular, moderately sorted, calcareous, porous, silty at top; slope former.
16	1.75	Sandstone, white to light-gray, fine sand, subangular to subrounded, moderately sorted, calcareous, poorly indurated; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
15	8.75	Mudstone, identical in all respects with bed 22.
	52.96	Total measured stratigraphic section of main body of Wasatch Formation (part) at this locality.
		LUMAN TONGUE OF GREEN RIVER FORMATION (lower unnamed tongue)
14	9.00	Sandstone, weathers buff, medium to coarse sand, subangular, poorly sorted, calcareous, contains Goniobasis tenera (well developed spiral ornamentation and moderately developed ribs), ledge former; in upper five feet sandstone is fine sand, slope former, and gradational with bed 15.
13	18.00	Mudstone, gray, irregular fragments, slightly silty, noncalcareous; gradational with beds 12 and 14.
12	3.75	Sandstone, weathers buff to red brown, fine sand, subangular, poorly sorted, calcareous, greater than 90 percent quartz, contains Goniobasis tenera, Viviparus trochiformis?, and Unionidae: indet.; ledge former.
11	1.75	Mudstone, identical in all respects with bed 13.

Bed No.	Thickness (feet)	LITHOLOGY
10	14.75	Sandstone, weathers light gray to red brown, fine sand, subangular, moderately sorted to poorly sorted, calcareous, porous, greater than 90 percent quartz, contains few Goniobasis tenera, ledge former; unit is locally conglomeratic with clasts of quartz and quartz sandstone as large as 1/4-in. in diameter, subrounded to rounded; basal 1-ft of unit is siltstone yellow-brown, contains ostracodes; upper 5-ft of unit is slope former.
9	0.20	Coquinal limestone, yellow-brown on fresh surface, weathers gray and black, dense, composed of abundant shell fragments of Goniobasis tenera, GR82-70.
8	7.75	Siltstone, weathers gray and yellow brown, calcareous, contains Goniobasis tenera (well developed spiral ornamentation), Viviparus trochiformis, Pisidiidae: indet., and ostracodes.
7	9.00	Sandstone, weathers buff, very fine to fine sand, subangular to subrounded, poorly sorted, porous, calcareous, local limonitic staining, laminated; ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
6	0.75	Mudstone, yellow-brown, slightly silty, noncalcareous, contains ostracodes, gradational with bed 7; abundant secondary gypsiferous stringers throughout unit.
5	10.00	Interbedded shale and mudstone, weathers yellow brown, fissile, blocky, silty; contains abundant shell fragments of Goniobasis tenera, Viviparus sp., and Unionidae: indet., unit locally capped by gray marlstone; secondary gypsiferous stringers throughout unit.
4	2.00	Siltstone, weathers rusty yellow brown, noncalcareous, unfossiliferous; grades to brown siltstone containing abundant shell fragments of Goniobasis tenera (well developed ribs); gradational with bed 5.
	76.95	Total measured stratigraphic section of Luman Tongue of Green River Formation (lower unnamed tongue) at this locality.

Bed No.	Thickness (feet)	LITHOLOGY
		MAIN BODY OF WASATCH FORMATION (part)
3	11.50	Interbedded shale and mudstone, red-brown, fissile, blocky, silty, locally carbonaceous; blocky and silty mudstone at top.
2	4.25	Mudstone, gray, slightly silty, blocky, irregular fragments, noncalcareous.
1	34.00	Mudstone, red-brown, slightly silty, blocky, irregular fragments, noncalcareous.
	49.75	Total measured stratigraphic section of main body of Wasatch Formation (part) at this locality.

RED CREEK DRY WASH (#5-72)

Measured at the head of a deep dry wash tributary to Red Creek along the northern margin of Red Creek Basin in SW1/4SW1/4NE1/4 sec. 25, T. 13 N., R. 104 W.

Bed No.	Thickness (feet)	LITHOLOGY
		NILAND TONGUE OF WASATCH FORMATION (lower part)
		Bed 17 of this section is the same as bed 1 in section 6-72.
17	1.00	Limestone, weathers tan, crystalline, platy, dense, contains Gen. ex gr. Eupera-Pisidium sp. A, Hydrobia aff. H. utahensis, Physa cf. P. pleromatis, Physa sp., Biomphalaria aequalis, Biomphalaria sp., Gyraulus militaris, cf. Promenetus sp. and Acroloxus cf. A. sp. A. GR84-70.
16	2.00	Shale, dark-brown to black, carbonaceous, silty, gypsiferous in upper half.
15	5.25	Sandstone, weathers buff with limonitic staining, very fine to fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz, with minor muscovite, porous, noncalcareous, poorly indurated; slope former.
14	4.50	Shale, red-brown to black, carbonaceous, silty, sulfurous stringers, few thin coal beds.

Bed No.	Thickness (feet)	LITHOLOGY
13	0.20	Marlstone, weathers light brown and white, platy, contains *Physa* sp., *Gyraulus* sp., and *Biomphalaria*? sp.
12	1.75	Shale, identical in all respects with bed 16.
11	9.00	Sandstone, weathers white to buff with limonitic staining, very fine sand, subangular, moderately well sorted, greater than 90 percent quartz, porous, noncalcareous, poorly indurated; unit contains few thin gray, silty mudstone and brown to black, silty, carbonaceous shale interbeds.
10	14.75	Shale, red brown to black, carbonaceous, silty; rare interbeds of blocky carbonaceous mudstone; basal one foot of unit is red-brown gypsum, gradational with shale; one thin (4-in.) sandstone interbed, weathers buff with limonitic staining, fine sand, subrounded, well sorted, greater than 90 percent quartz, porous, noncalcareous, poorly indurated.
9	6.75	Shale, light brown, slightly silty, contains poorly preserved *Goniobasis tenera* and Unionidae: indet., rare thin (1-in.) indurated layers of abundant shell fragments.

Bed No.	Thickness (feet)	LITHOLOGY
8	2.25	Shale, dark-brown, red-brown, and black, carbonaceous, sulfurous stringers, silty at base; rarely grades to carbonaceous mudstone.
7	4.25	Sandstone, weathers buff with minor limonitic staining, very fine sand, subrounded, moderately sorted, calcareous, porous, poorly indurated; slope former.
6	2.75	Siltstone, weathers gray, noncalcareous, tiny irregular fragments.
5	2.50	Sandstone, weathers rusty yellow brown, fine to medium sand, subangular, moderately sorted to poorly sorted, greater than 90 percent quartz, calcareous, porous; slope former.
4	5.00	Shale, dark-brown and black, carbonaceous, sulfurous stringers, rarely slightly silty; grades to carbonaceous mudstone at top; gradational with bed 5.
3	7.50	Sandstone, weathers buff, very fine sand, subangular, moderately sorted, calcareous, minor ledge former; unit contains few thin siltstone interbeds, weathers buff, calcareous.

Bed No.	Thickness (feet)	LITHOLOGY
	69.45	Total measured stratigraphic section of Niland Tongue of Wasatch Formation (lower part) at this locality.
		LUMAN TONGUE OF GREEN RIVER FORMATION (part of upper unnamed tongue)
2	3.75	Shale, brown, papery, noncalcareous, contains locally abundant ostracodes, one Pisidiidae: indet.; rare indurated layers with abundant shell fragments of Goniobasis tenera, Viviparus trochiformi and Unionidae: indet.
1	11.00	Sandstone, weathers red brown, very fine sand, subrounded, well sorted, greater than 90 percent quartz, calcareous; contains Goniobasis tenera, Viviparus cf. V. paludinaeformis, Viviparus trochiformis, and Unionidae: indet., GR3-70; ledge former; bottom contact covered.
		Bed 1 of this section is the same as bed 33 of Red Creek Basin Section #4-72.
	14.75	Total measured stratigraphic section of Luman Tongue (part of upper unnamed tongue) of Green River Formation at this locality.

RED CREEK BADLANDS OVERLOOK (#6-72)

Measured in the slopes above dirt road beginning at bench marker and continuing east in locally poorly exposed outcrops in SE1/4NE1/4NW1/4 and SW1/4NW1/4NE1/4 sec. 25, T. 13 N., R. 104 W.

Bed No.	Thickness (feet)	LITHOLOGY
		TIPTON SHALE MEMBER OF GREEN RIVER FORMATION (lower part)
24	15.00	Oil shale, light-olive-brown, papery, calcareous, contains locally abundant ostracodes; Goniobasis tenera (moderately developed ribs), and Valvata sp.; unit only locally exposed, top contact covered by colluvium.
23	3.00	Coquinal limestone, weathers gray to white, contains abundant shell fragments of poorly preserved Goniobasis tenera, Viviparus sp., and Unionidae: indet.; unit is shaly at base and gradational with bed 24.
	18.00	Total measured stratigraphic section of Tipton Shale Member (lower part) of Green River Formation at this locality.
		NILAND TONGUE OF WASATCH FORMATION (upper part)
22	2.75	Shale, dark-brown and black, carbonaceous, sulfurous stringers, thin coal layers.

Bed No.	Thickness (feet)	LITHOLOGY
21	14.00	Sandstone, weathers buff, fine sand, subangular, well sorted, noncalcareous, poorly indurated to unindurated; slope former.
20	2.00	Shale, carbonaceous, identical in all respects with bed 22.
19	7.75	Siltstone, weathers gray, locally slightly carbonaceous, irregular fragments, calcareous; slope former.
18	2.75	Shale, carbonaceous, identical in all respects with bed 22.
17	5.00	Oil shale, light-olive-brown, papery, calcareous, locally abundant ostracodes and shell fragments of Goniobasis tenera, Viviparus sp., and Unionidae: indet.
16	0.90	Coquinal limestone, weathers rusty yellow brown and brown, contains abundant shell fragments of Goniobasis tenera and Unionidae: indet.
15	6.50	Shale, carbonaceous, identical in all respects with bed 22.
14	9.75	Interval covered by colluvium.
13	2.50	Sandstone, weathers red brown, very fine sand to siltstone, silty at base; local ledge former.

Bed No.	Thickness (feet)	LITHOLOGY
12	10.50	Siltstone, gray, calcareous, irregular fragments, contains few thin interbeds of very fine sandstone; slope former.
11	2.50	Sandstone, weathers red brown, identical in all respects with bed 13.
10	1.50	Shale, gray; noncalcareous, irregular fragments, contains few ostracodes and unidentifiable organic fragments.
9	2.00	Shale, carbonaceous, identical in all respects with bed 22.
8	14.50	Oil shale, brown, papery, calcareous; contains poorly preserved locally abundant ostracodes, Goniobasis tenera, Valvata sp., and Unionidae: indet.
7	2.75	Shale, carbonaceous, identical in all respects with bed 22, contains gypsiferous beds.
6	3.50	Siltstone, gray, noncalcareous, irregular fragments; slope former.

Bed No.	Thickness (feet)	LITHOLOGY
5	83.50	Sandstone, weathers red brown, white and buff, very fine sand and siltstone, calcareous and noncalcareous, generally massive; few thin interbeds of carbonaceous shale and coal as well as carbonaceous laminae within sand; few thin, gray and brown siltstone interbeds; unit forms ledges and steep slopes above bench marker 7658; laterally discontinuous.
4	1.25	Shale, carbonaceous, identical in all respects with bed 22.
3	3.75	Mudstone, gray, irregular fragments, noncalcareous; contains few thin gray siltstone interbeds; becomes more silty toward top.
2	9.00	Shale, dark-red-brown and black, carbonaceous, contains sulfurous stringers and coal layers, locally silty; upper portion of unit contains one 6-in. sandstone, interbed, weathers buff, very fine sand, subangular to subrounded, moderately well sorted, greater than 90 percent quartz with minor muscovite, contains organic fragments.

Bed No.	Thickness (feet)	LITHOLOGY
1	1.00	Limestone, weathers tan, crystalline, platy, dense, contains Gen. ex gr. Eupera-Pisidium sp. A, Hydrobia aff. H. utahensis, Physa cf. P. pleromatis, Physa sp., Biomphalaria aequalis, Biomphalaria sp., Gyraulus militaris, cf. Promenetus sp. and Acroloxus cf. A. sp. A, GR84-70.
		Bed 1 of this section is the same as bed 17 of section #5-72.
	189.65	Total measured stratigraphic section of Niland Tongue (upper part) of Wasatch Formation at this locality.