# Sedimentology of Freshwater Lacustrine Shorelines in the Eocene Scheggs Bed of the Tipton Tongue of the Green River Formation, Sand Wash Basin, Northwest Colorado

U.S. GEOLOGICAL SURVEY BULLETIN 1911

# Sedimentology of Freshwater Lacustrine Shorelines in the Eocene Scheggs Bed of the Tipton Tongue of the Green River Formation, Sand Wash Basin, Northwest Colorado

By HENRY W. ROEHLER

Wave-dominated shorelines of Lake Gosiute are investigated
along Hardgrove Rim, 8 miles north of Maybell, Colorado

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## PLATE

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## FIGURES

# Sedimentology of Freshwater Lacustrine Shorelines in the Eocene Scheggs Bed of the Tipton Tongue of the Green River Formation, Sand Wash Basin, Northwest Colorado

*By* Henry W. Roehler

**Abstract**

Two freshwater shorelines are present in the Scheggs Bed of the Tipton Tongue of the Green River Formation along Hardgrove Rim in the Sand Wash basin. The shorelines are part of Lake Gosiute, which occupied southwest Wyoming, northeast Utah, and northwest Colorado during the Eocene Epoch. The rocks comprising the shorelines range in thickness from about 40 feet to 275 feet. They are composed of thick beds of resistant quartzose sandstone, and interbedded thin, less resistant conglomerate, siltstone, shale, oil shale, carbonaceous shale, and coal. The shorelines are vertically and horizontally divisible into fluvial channel, mudflat, swamp, strandline, nearshore, and offshore lithofacies, which are defined by their characteristic lithologies, their sedimentary structures, or both. Each lithofacies can be identified and correlated in the outcrops along Hardgrove Rim.

The term shoreline in this report refers to all of the subaerial and subaqueous margins of a lake. The investigations have revealed that the shorelines of the Scheggs Bed prograded extensively and that they were entirely wave dominated. They had maximum widths of about 10 miles and probably sloped less than 1° from backshore areas lakeward to water depths below wave base. Three different environments were present along the shorelines at the land-water interface: (1) strandlines, where there were sand beaches with swash zones; (2) swamps, where vegetation grew in backshore areas out into the lake; and (3) mudflats, where wave erosion caused flooding of parts of the backshore. A columnar section illustrates freshwater lacustrine shoreline deposits that are typical of the Scheggs Bed of the Tipton Tongue and of other tongues and members of the Green River Formation.

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## INTRODUCTION

### Purpose of Investigation

This report describes the stratigraphic relationships, depositional environments, and lithofacies of freshwater lacustrine shoreline sandstones and associated rocks in the Eocene Scheggs Bed (Roehler, 1990) of the Tipton Tongue of the Green River Formation in the Sand Wash basin in northwest Colorado. The investigation was undertaken because (1) rare, complete lacustrine shoreline sections are exposed, and (2) shoreline sedimentology of the Green River Formation is not well understood.

### Location and Accessibility of the Study Area

The study area is located on Hardgrove Rim in the south-central part of the Sand Wash basin in T. 8 N., Rs. 95–96 W., Moffat County, Colo. Hardgrove Rim is a prominent northeast-trending, cedar-covered sandstone ridge located 8 mi north of U.S. Highway 40 at Maybell, Colo. (fig. 1). The area is accessible from Maybell by Moffat County road 19 that trends north from U.S. Highway 40 and crosses Hardgrove Rim near the east edge of the study area. The outcrops investigated on the southeast face of Hardgrove Rim are about 3 mi long and less than ½ mi wide. They are accessible from Moffat County road 19 by way of unimproved roads and trails shown on figure 2. Hardgrove Rim continues for several miles to the northeast and southwest of the study area, but the shoreline sequences in the Scheggs Bed of the Tipton Tongue are not as well exposed in those areas.

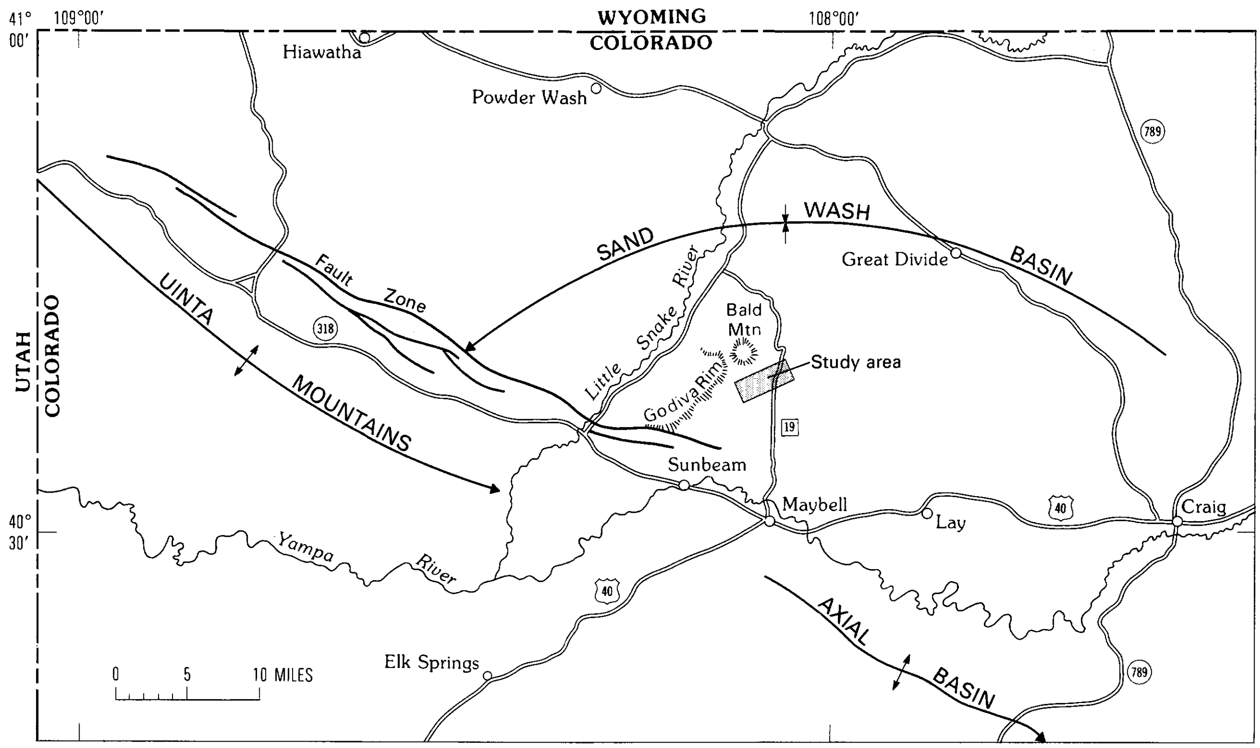


**Figure 1.** Index map showing location of the study area in the Sand Wash basin in northwest Colorado.

## Geographic Setting

The Sand Wash basin occupies the southeast corner of a larger intermontane basinal area called the greater Green River basin. The greater Green River basin encompasses nearly 20,000 mi$^2$ and includes the Green River basin, Rock Springs uplift, Great Divide basin, Washakie basin, and Sand Wash basin in southwest Wyoming, northeast Utah, and northwest Colorado as indicated on figure 3. Eocene Lake Gosiute was restricted to the greater Green River basin, where its maximum areal extent was about 15,000 mi$^2$ during deposition of the Scheggs Bed of the Tipton Tongue.

The Sand Wash basin is a structural and topographic basin about 75 mi long and 25 mi wide. It is elongated in an east-west direction between the Uinta Mountains on the west and the Sierra Madre on the east (fig. 3). The lowest structural part of the basin is located along its western margin near the faulted northeast flank of the Uinta Mountains. The eastern part of the basin consists of a gently plunging syncline, the axis of which trends westward past the settlement of Great Divide before crossing the Little Snake River about 10 mi north of the study area (fig. 1). Eocene rocks usually dip from 2° to 8° toward the structural axis. The primary drainage system is the Little Snake River and its tributaries.

The desert landscape of the study area in the south-central part of the Sand Wash basin consists of major and minor ridges and valleys that are interspersed with small areas of badlands. The most prominent landmarks are Godiva Rim and Bald Mountain, which parallel the northeast trend of Hardgrove Rim about 2 mi northwest of Hardgrove Rim (fig. 1). The crest of Hardgrove Rim has surface elevations about 200 ft higher than adjacent ridges and valleys, but Godiva Rim and Bald Mountain rise as much as 1,000 ft above the surrounding terrain. The crests of most of the higher ridges in the vicinity of the study area expose bare caprock, whereas the flanks of the ridges are mostly covered by cedar trees and sagebrush. The southeast face of Hardgrove Rim mostly consists of cliffs and ledges. The valleys at lower elevations are dissected by networks of dry drainages between which are scattered patches of sagebrush, shrubs, grasses, and wildflowers. Antelope, deer, coyote, and other wildlife abound in the area and the rocky ledges are home to numerous rattlesnakes. The geographic setting of Hardgrove Rim is discernible in photographic panoramas on plate 1.

## Field Work and Methodology

Field work in the study area began in July 1986, when two stratigraphic sections (nos. 2286 and 2386, pl. 1) were measured adjacent to Sand Creek where it crosses Hardgrove Rim (fig. 2). In July and August 1988, 14 additional sections (nos. 188–1488, pl. 1) were

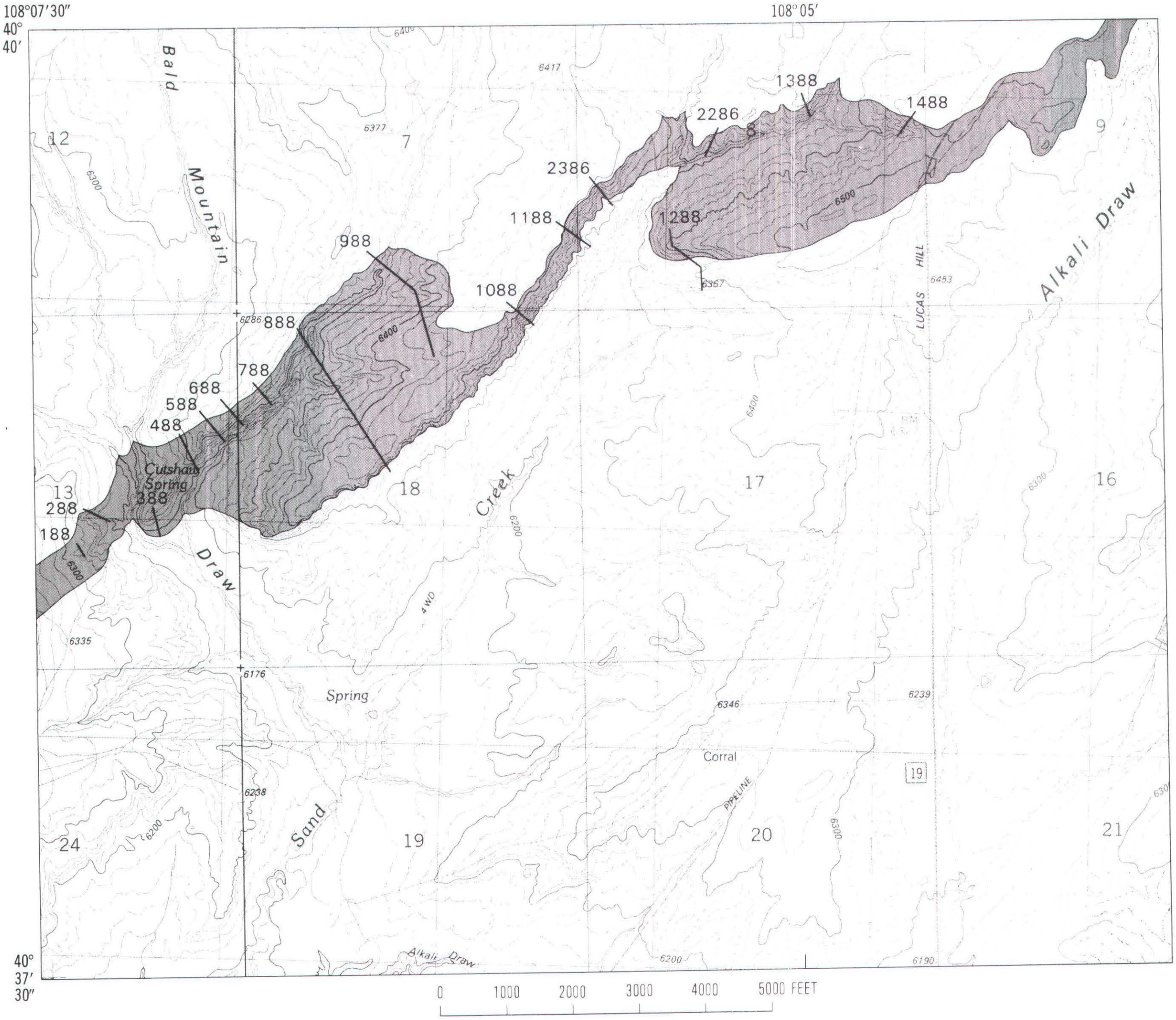


**Figure 2.** Locations of measured sections along Hardgrove Rim. Outcrops of the Scheggs Bed of the Tipton Tongue are shaded. The Scheggs Bed dips 6°–8° NW. Base from Bald Mountain 7½-minute quadrangle.

measured. The sections were measured using a 5 ft Jacob staff with attached Abney level to compensate for 6°–8° dips. All stratigraphic and sedimentologic data are field observations. Rose diagrams were not prepared to illustrate sandstone transport directions because most outcrops occur as vertical faces from which statistically valid numbers of dip direction readings could not be taken.

## Previous Investigations

The first detailed geologic investigations in the study area were undertaken by J.D. Sears and W.H. Bradley in 1921 and 1922. In a resultant report (Sears and Bradley, 1924, fig. 10), they constructed a regional stratigraphic cross section of Eocene rocks that extended from near the study area northwestward into southwest Wyoming. One of the measured outcrop sections used to construct the cross section was located in the vicinity of the Little Snake River a few miles west of the study area. In this section, and on an accompanying geologic map (Sears and Bradley, 1924, pl. 24), the Tipton Tongue is shown to be missing across the south-central and eastern parts of the Sand Wash basin, which includes the study area. Bradley also failed to identify the Tipton Tongue in those areas on later maps (1931, pl. 1; 1945; 1964, pl. 1) and in the 1964 text (1964, p. A32).

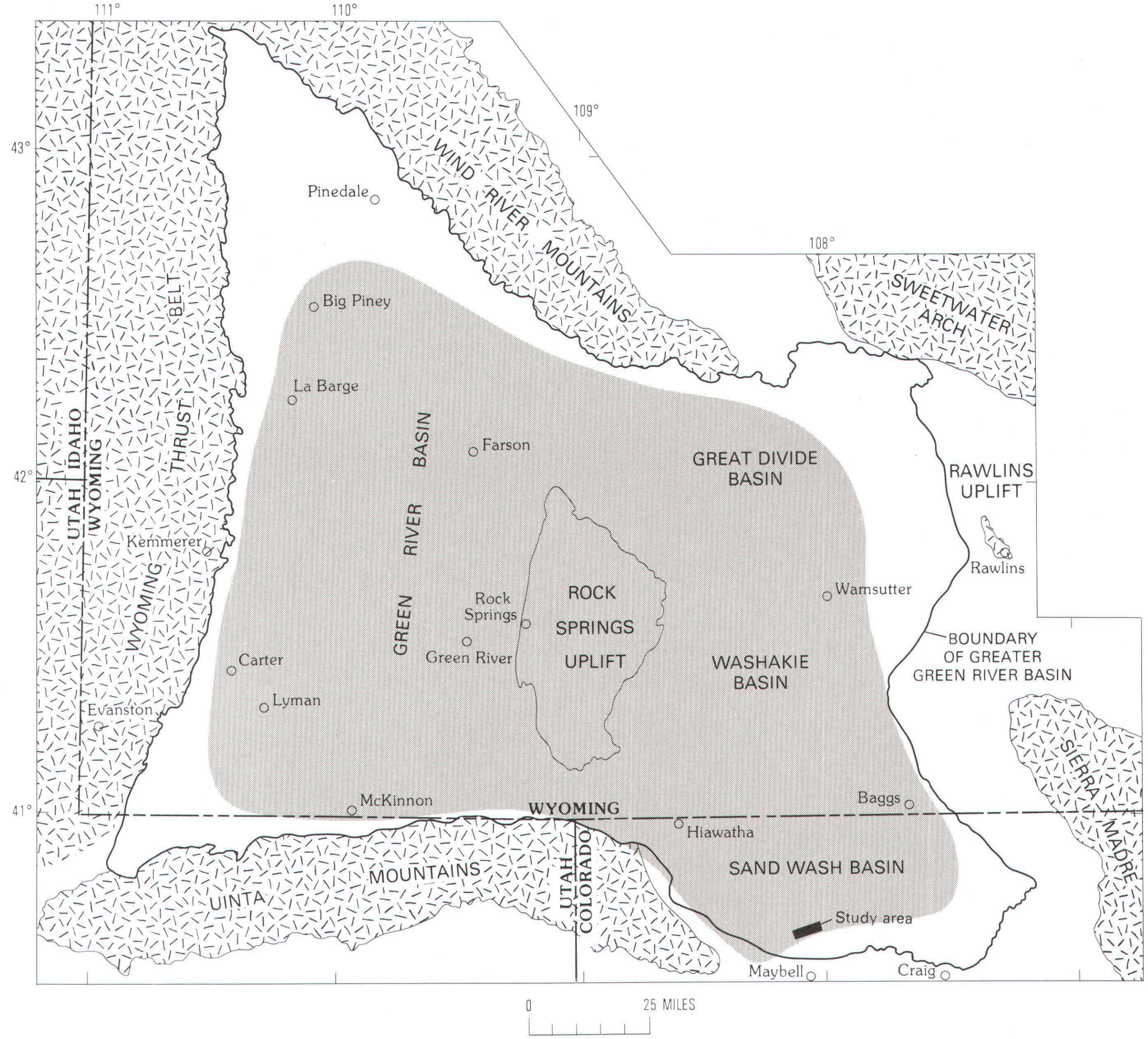


**Figure 3.** Greater Green River basin area showing the Eocene areal extent of Lake Gosiute (shaded) during deposition of the Scheggs Bed of the Tipton Tongue of the Green River Formation.

The sandstone beds that crop out along Hardgrove Rim in the study area were identified by the author (Roehler, 1968) as shorelines of the Tipton Tongue during investigations into the oil-shale resources of the Washakie and Sand Wash basins. The geology of the Hardgrove Rim area was included on a map published by the author (Roehler, 1973, fig. 1, p. 48). The formation contacts shown on this map were later used on a map of parts of the Vernal, Utah–Colorado 1°×2° quadrangle compiled by P.D. Rowley (Tweto, 1975). Tweto (1979) also used these contacts when he compiled the geologic map of Colorado.

The geology of the Hardgrove Rim study area is also shown on a map of the Maybell quadrangle, Colorado, compiled by McKay and Bergin (1974). The Tipton Tongue on this map is explained as consisting of about 200 ft of drab-gray claystone and siltstone, brown oil shale, and light-gray lenticular sandstone. The geographic locations and stratigraphic positions of the contacts of the tongue mapped by McKay and Bergin (1974) along the slopes of Hardgrove Rim do not agree with those shown on figure 2.

The geology and paleontology of a fan delta in the Tipton Tongue (assigned to the Scheggs Bed of the

Tipton Tongue in this report) on Cottonwood Creek in the southeast part of the Washakie basin were studied by Roehler, Hanley, and Honey (1988). This delta is located in Tps. 13–14 N., Rs. 91–92 W., 4 mi north of Baggs, Wyo., about 38 mi northeast of Hardgrove Rim. The investigations indicated that the delta is lenticular, 2 mi long, and 80 ft thick. It is composed mostly of quartzose sandstone intertonguing with oil shale that was deposited along the eastern shores of Lake Gosiute. Although the delta on Cottonwood Creek is contemporary with the shorelines along Hardgrove Rim, the delta displays distinct lithofacies that are missing along the shorelines.

# STRATIGRAPHY

## Formation Nomenclature, Thickness, and Lithology

Eocene rocks in the Sand Wash basin are about 7,800 ft thick. In ascending stratigraphic sequence they comprise the main body of the Wasatch Formation (3,000 ft), the Scheggs Bed of the Tipton Tongue of the Green River Formation (250 ft), the Cathedral Bluffs Tongue of the Wasatch Formation (1,950 ft), the Godiva Rim Member of the Wasatch Formation (300 ft), the Laney Member of the Green River Formation (900 ft), and the Bridger Formation (1,400 ft). The tongues and members of the Green River Formation were deposited in freshwater, brackish-water, saltwater, and evaporite stages of Lake Gosiute. These salinity changes correspond to lake expansions and contractions that were caused by Laramide tectonism and by climate changes over a 6 million year period. The Wasatch, Washakie, and Bridger Formations were deposited on flood plains and in swamps, in strata that overlie, underlie, or are laterally equivalent to the Green River Formation. The nomenclature and intertonguing relationships of Eocene stratigraphic units in the greater Green River basin are shown on a northwest-southeast cross section, figure 4.

The Tipton Tongue (or Tipton Shale Member where it is overlain or underlain by other members of the Green River Formation) was named by Schultz (1920, p. 30) for lacustrine shales, clays, and sandstones that crop out near Tipton Station on the Union Pacific Railroad 15 mi west of Wamsutter, Wyo., in the northern part of the Washakie basin (fig. 3). The Tipton Shale Member was redefined by Roehler (1968) in a principal reference section measured near Tipton Station. The principal reference section excludes equivalents of the Wilkins Peak Member of the Green River Formation that had previously been included in the upper part of the Tipton in the Washakie and Great Divide basins. The redefined Tipton Tongue (or Shale Member) has since been divided into an upper saltwater part (Rife Bed) and a lower freshwater part (Scheggs Bed) by Roehler (1990). Outcrops of the Scheggs Bed of the Tipton can be mapped continuously around the eastern margins of the Washakie and Sand Wash basins into the study area, but they are offset by numerous faults west of Baggs, Wyo., and they are locally covered by soil and vegetation in the eastern Sand Wash basin.

The thickness of the Scheggs Bed in most places ranges from less than 10 ft to about 200 ft, but it is a little thicker in a few places near the former depositional center of the lake basin. In hundreds of stratigraphic sections measured by the author, the thickness of the bed has never exceeded 275 ft. The bed is mostly composed of brown, laminated, sometimes papery, low-grade oil shale and thin interbedded tan or white tuff across the central parts of the lake basin. Ostracodes are ubiquitous in the oil shale. Toward shoreline areas the oil-shale beds intertongue with and are gradually replaced by barren shale, carbonaceous shale, siltstone, sandstone, and oolitic, ostracodal or algal limestone. A mollusk-bearing limy sandstone, 1 ft to 3 ft thick, is present at the base of outcrops of the Scheggs Bed in central parts of the lake basin. This sandstone characteristically contains large numbers of the turreted gastropod, *Goniobasis tenera*, and lesser numbers of a large, thick-spired gastropod, either *Viviparus trochiformis* or *Viviparus paludinaeformis*. In places a few large unionid clams, either *Plesielliptio* sp. or *Lampsilis* sp., are associated with the gastropods. The mollusk-bearing sandstone at the base of the bed comprises a series of ephemeral beaches deposited in step fashion as the lake enlarged and expanded across the floor of the greater Green River basin.

## Nomenclature and Definition of Lithofacies

The term shoreline in this report includes both the subaerial and subaqueous margins of a lake. The lithofacies that compose the shorelines of Eocene Lake Gosiute consist of distinct rock units that are easily identified and correlated in outcrops. These lithofacies are fluvial channel, mudflat, swamp, strandline, nearshore, and offshore. The distribution and relationships of these lithofacies to the paleogeography of the lake shorelines are shown in a block diagram, figure 5.

### Fluvial Channel

Three fluvial channels are present within the shorelines investigated (see sections 888, 1388, and 1488, pl. 1). The channels consist of 0–36 ft of trough-

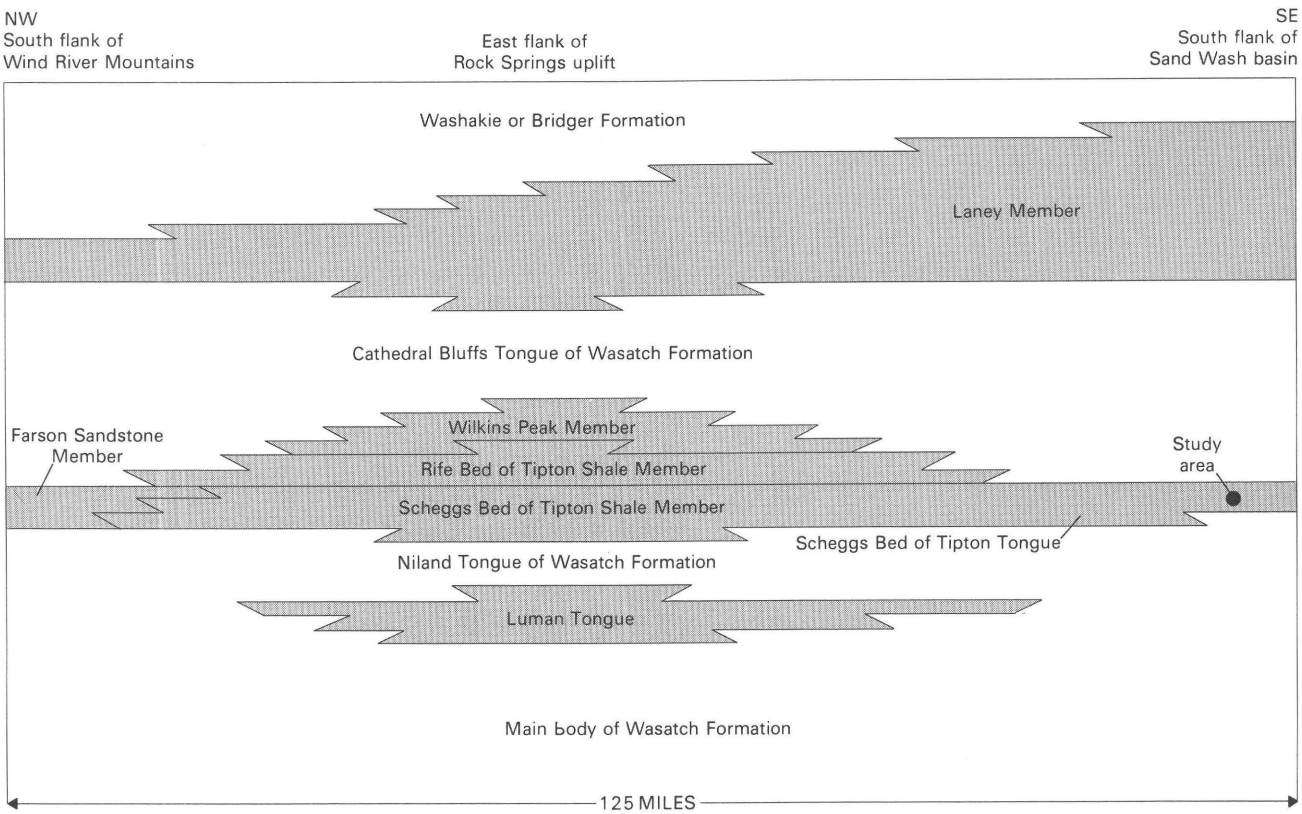


**Figure 4.** Generalized cross section of greater Green River basin showing Eocene stratigraphic nomenclature. The Green River Formation is shaded.

crossbedded, fine to very coarse grained sandstone. The channel in section 1388 (pl. 1) also contains interbedded lenses of conglomerate composed of gray quartzite and chert pebbles. The three channels are lenticular and nearly symmetrical in cross section; the basal contacts exhibit scouring into underlying rocks; and no large point bars were observed. These facts suggest that the channel configurations were straight or nearly straight where the streams entered the lake. Part of a fluvial channel that is present in section 888 (pl. 1) is shown in figure 6.

Deltas were not found in association with the channels, but the largest channel (at top of section 1388, pl. 1) has two types of delta-like distributary bars associated with it. The most distinctive of these are the linear bars that bordered the channel at the point where it entered the lake (fig. 5). These channel margin linear bars consist of massive, medium- to coarse-grained sandstones, as much as 15 ft thick, that exhibit long foreset laminae that dip at low angles away from the channel. The sands composing these bars accreted lakeward and were probably deposited during periods of flood at the place where the stream current velocity and sediment-carrying capacity abruptly decreased upon entering the standing body of lake water. Adjacent to the channel margin linear bars, and forming a fan configuration around them, is a second delta-like distributary bar, the channel mouth bar. The channel mouth bar consists of as much as 25 ft of fine- to medium-grained sandstone in lenticular, planar cross-beds that have foreset laminae that dip in various landward and lakeward directions. This polymodal cross-bedding resulted from the interaction of fluvial and lacustrine currents.

## Mudflat

The mudflat lithofacies consists mostly of thin, parallel-bedded, very fine grained splay sandstone and interbedded gray flood-basin mudstone or shale. Locally it contains minor thin beds of carbonaceous shale that were deposited in marshes. The beds composing the lithofacies were deposited in low-topographic, poorly drained areas between swampy parts of the lake margin and peripheral inland flood plains (fig. 5). The mudflat lithofacies, seldom more than a few feet thick, in outcrops usually weathers to benches and nonresistant grooves between thicker and more resistant strandline and nearshore sandstone lithofacies.

## Swamp

The swamp lithofacies is composed of very fine grained splay sandstone, overbank mudstone,

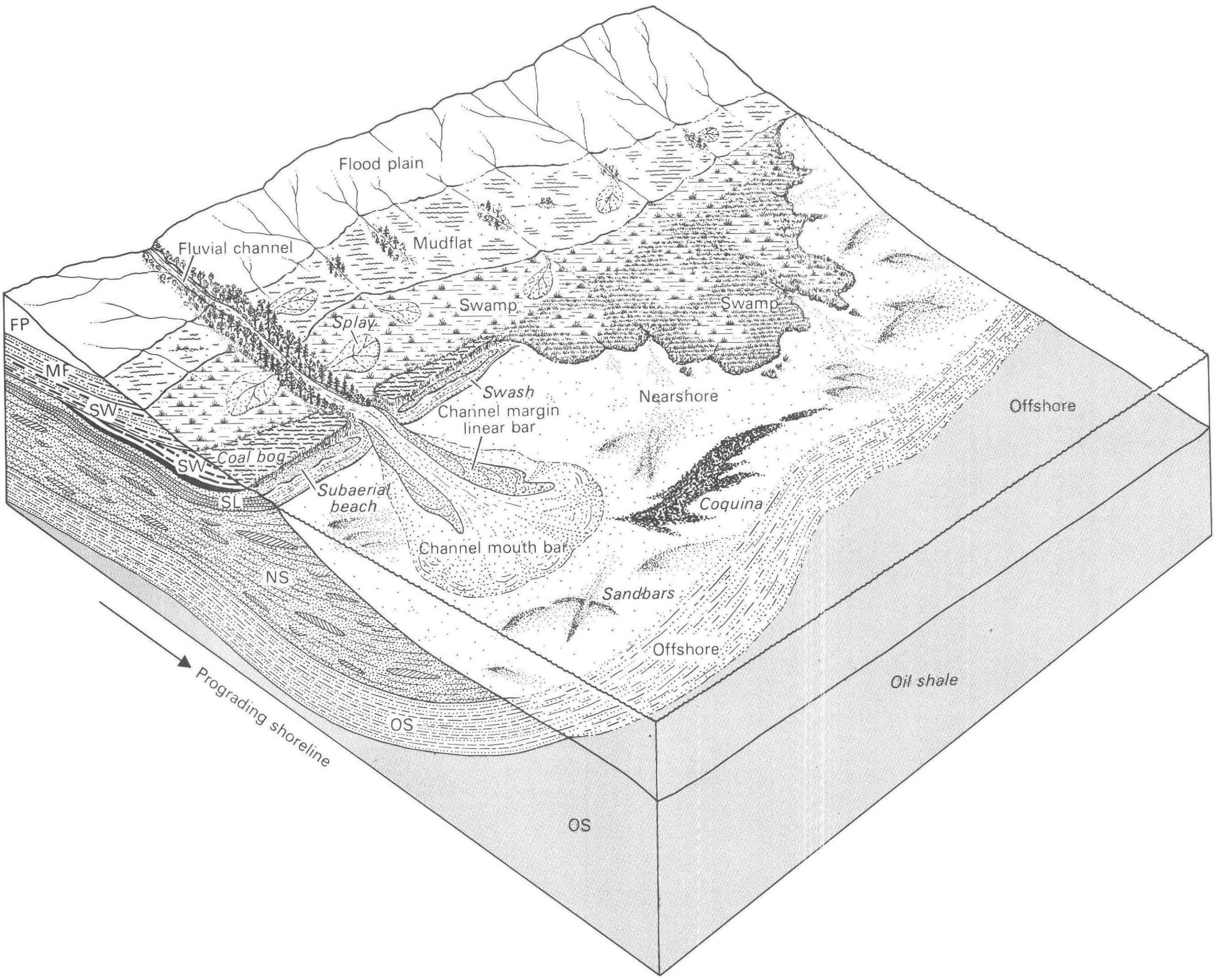


**Figure 5.** Block diagram illustrating shoreline lithofacies of the Scheggs Bed of the Tipton Tongue along Hardgrove Rim. FP, flood plain; MF, mudflat; SW, swamp; SL, strandline; NS, nearshore; OS, offshore.

carbonaceous shale, and coal that were deposited in standing water in backshore areas. It incorporates peat bogs that were dominated by trees, mosses, and other aquatic vegetation that formed coal, and marshes that were dominated by reeds and grass-like vegetation that formed carbonaceous shale. The peat bogs appear to have been restricted to lagoon-like areas parallel to the beaches, whereas the marshes were more widespread and in places spread from backbeach areas into shallow waters of the lake (fig. 5). The carbonaceous shale deposits range in thickness from 0 to 25 ft. The coals are never more than 2 ft thick, are soft and crumbly, and probably very low rank.

### Strandline

The strandline lithofacies combines the swash zone and subaerial parts of beaches. The swash zone consists of 0–38 ft of tan, fine- to medium-grained, micaceous sandstone in parallel, wave-rippled or tabular beds that are seldom more than 0.2 ft thick. The sandstones composing the swash zone were deposited by waves as they washed upward from the lake onto exposed parts of beaches. Overlying the swash zones in some sections, such as 1488 (pl. 1), are remnants, a few feet thick, of subaerial parts of beaches. These beds are usually massive, gray, calcareous, fine to very coarse grained sandstone containing widely scattered very small pebbles of subrounded gray quartzite and chert. They were deposited either by storms as washover, or by winds as dunes. In outcrops the subaerial parts of beaches are easily distinguished from the swash zones by their stratigraphic position, color, texture, and bed forms.

### Nearshore

The bulk of the sandstone outcrops comprising the shorelines of the Scheggs Bed of the Tipton Tongue in

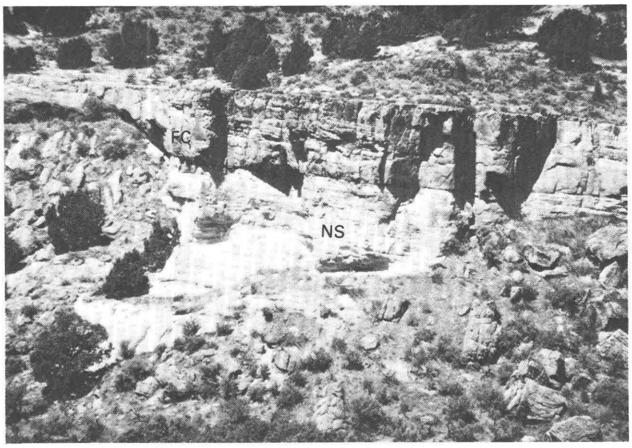


Figure 6. Fluvial channel (FC) sandstone overlying nearshore lacustrine (NS) sandstone in the Scheggs Bed of the Tipton Tongue in measured section 888 in NW¼NW¼ sec. 18, T. 8 N., R. 95 W. The fluvial channel has a maximum thickness of 21 ft in the photograph.

the study area were deposited in the nearshore lithofacies. The nearshore lithofacies normally ranges from 20 ft to 70 ft in thickness and weathers to massive cliffs (pl. 1). It is composed of tan, fine- to medium-grained, micaceous sandstone deposited in parallel to subparallel beds mostly less than 2 ft thick. Many of these beds consist of intercalated sandstone lenses from 50 ft to 100 ft long that exhibit east- and west-dipping foreset laminae (fig. 7). Where the lenses are concentrated in vertical section, the beds generally have the appearance of herringbone crossbeds. The beds were deposited as a result of onshore winds and longshore currents in subaqueous sand waves that formed bars oriented at oblique angles to the beach (fig. 5). One of these sand bars in section 688 is nearly 6 ft thick (fig. 8). As most of the foreset laminae in the lenses in the nearshore lithofacies dip in westward directions, the water circulation patterns were probably also east to west. Interbedded with the sand waves (or dunes) are segments of small troughs (probably remnants of swales between dune ridges) and beds that are massive or have parallel laminae (deposited in quiet nearshore waters, fig. 9).

Coquinas are present at two levels in the lower part of the nearshore lithofacies. A coquina present from section 388 through section 788 (pl. 1) is less than 3 ft thick and is composed more than 80 percent of *Viviparus* sp. with lesser percentages of *Goniobasis* sp. and *Lampsilis* sp. that exhibit sand abrasion and removal of shell ornamentation. A similar coquina is present at the base of the nearshore lithofacies in section 1088 (pl. 1). It is 2.5 ft thick and is composed of about 75 percent *Goniobasis* sp. and 25 percent *Viviparus* sp. These shell concentrations were probably located near the mouths of rivers as shown on figure 5.

### Offshore

The offshore lithofacies is composed mostly of thin, parallel-bedded, gray, very fine grained sandstone and interbedded gray sandy shale and brown oil shale. It ranges in thickness from 25 ft to 85 ft. These beds were deposited below normal wave base (fig. 5). The oil-shale beds are in many places silty and in some places contain disseminated, small, black, carbonaceous plant fragments. The oil yield was visually estimated to be less than 10 gallons of oil per ton of shale rock. A thin sandy coquina of poorly preserved *Goniobasis* sp., *Viviparus* sp., and *Lampsilis* sp. shells is present near the base of section 388 (pl. 1).

## Paleogeography

Lake Gosiute occupied about 15,000 mi$^2$ of southwest Wyoming and northwest Colorado during deposition of the Scheggs Bed. Shorelines of the lake probably also extended for short distances into northeast Utah (fig. 3). During this period the lake consisted of a body of open freshwater generally surrounded by sand shorelines and deltas which gave way inland to swamps, mudflats, and flood plains toward surrounding mountains. The climate of the early part of the Eocene Epoch during deposition of the Scheggs Bed was humid, warm temperate with little or no frost. Annual rainfall was between 38 and 50 inches and average annual temperatures were between 72 °F and 82 °F, based on plant megafossils collected by H.D. MacGinitie (written commun., 1972). The landscape surrounding the lake was characterized by hardwood forests. The lake

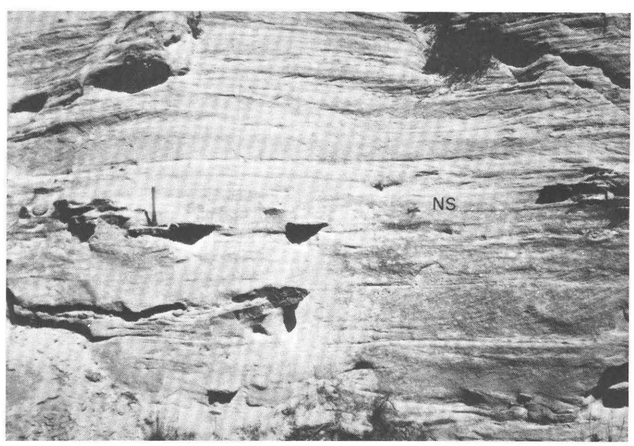


Figure 7. Nearshore lacustrine (NS) sandstone in the Scheggs Bed of the Tipton Tongue of the Green River Formation near base of measured section 588 in SW¼NE¼ sec. 13, T. 8 N., R. 96 W. Note that parallel beds have foreset laminae that dip west (left) and east (right). Pick handle in left center of photograph is 1.5 ft long.

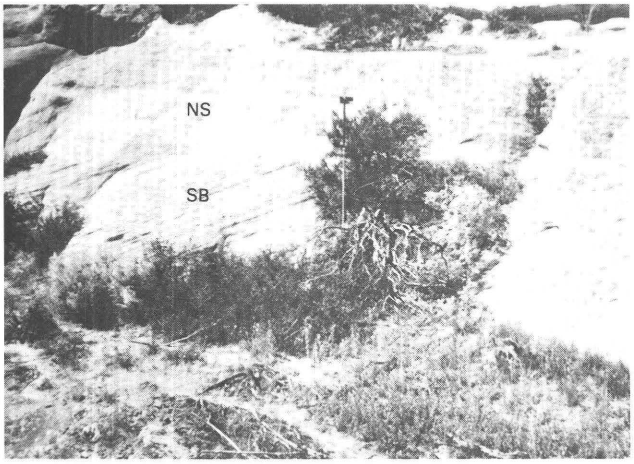


**Figure 8.** Bar (SB) sandstone underlying parallel-bedded nearshore (NS) sandstone in the Scheggs Bed of the Tipton Tongue in section 688 in SE¼NE¼ sec. 13, T. 8 N., R. 96 W. Foresets in the bar sandstone dip southeast. Jacob staff near center of photograph is 5 ft long.

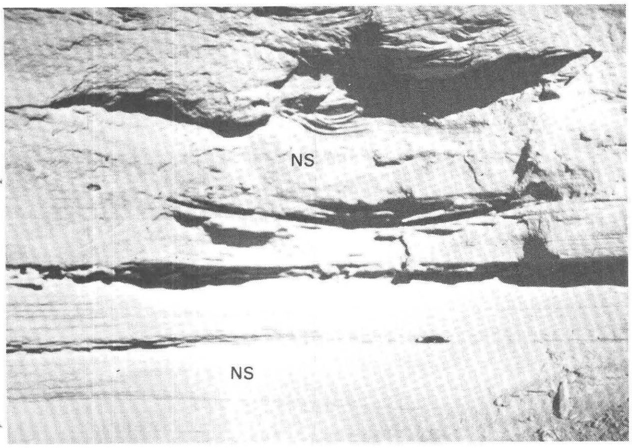


**Figure 9.** Small trough crossbeds and beds with parallel laminae in a nearshore (NS) sandstone in the Scheggs Bed of the Tipton Tongue near section 788 in SW¼NW¼ sec. 18, T. 8 N., R. 95 W. Pocket knife at lower right is 0.3 ft long.

originated at the beginning of deposition of the Scheggs Bed in an east-west-trending trough located directly north of the Uinta Mountains. From this trough it expanded northeastward across the Washakie basin and then northward into the Great Divide basin. Eventually, it expanded across the Rock Springs uplift, inundated most of the floor of the greater Green River basin, and reached its maximum size, shown on figure 3. Prevailing winds across the lake were from the northwest, and water circulation in the lake appears to have been clockwise (Roehler, Hanley, and Honey, 1988). During deposition of the Scheggs Bed, the lake was undoubtedly meromictic. The sedimentary structures of sandstones indicate that shorelines of the lake were totally wave dominated.

Depth of the lake waters during the Scheggs Bed stage of Lake Gosiute can be estimated from the composition and structure of bottom sediments. The transition area of shoreline sand to organic mud (oil shale) in nearshore to offshore parts of the lake exhibits very thin parallel beds and laminae that reflect neither a mixing of lake waters by turnover nor a churning of bottom sediments by the action of waves or organisms. As the lake had a maximum northwest-southeast length of more than 185 miles, the height of waves probably reached 5 ft and normal wave base was probably below 50 ft. Thus water depths within a few miles of the lake shorelines at the nearshore-offshore transition probably exceeded 50 ft. Varved oil-shale beds were deposited in deeper waters across the center of the lake where water depths may have exceeded 300 ft. The location of the outlet of the lake has not been determined, but it was probably located east of the Uinta Mountains and west of the town of Maybell, Colo. (fig. 3). Because the Scheggs Bed of the Tipton Tongue is deeply buried below younger Eocene rocks in that area, positive evidence for an outlet there is impossible to document.

The landward-lakeward width of the sandstones comprising the shorelines of Lake Gosiute in the vicinity of Hardgrove Rim during deposition of the Scheggs Bed is approximately 10 miles. The width was determined by examining geophysical and lithologic logs of dry oil and gas wells drilled in the southern part of the Sand Wash basin. In the C and K Petroleum No. 1–19 Well in sec. 19, T. 9 N., R. 96 W., 8 mi northwest of Hardgrove Rim, the Scheggs Bed consists of about 250 ft of oil shale and very thin interbedded sandstone that are interpreted to be parts of an offshore lithofacies. In the Polumbus Corporation Government No. 1 Well in sec. 17, T. 9 N., R. 97 W., 12 mi northwest of Hardgrove Rim, the Scheggs Bed is composed of 200 ft of oil shale. The homogeneous oil-shale section in this well is indicative of deep-water deposition in central parts of the lake. Hence the wedgeout of the shoreline sandstone occurs between 8 mi and 12 mi ( or approximately 10 mi) northwest of Hardgrove Rim. A width of about 6 mi for similar shoreline sandstone of Lake Gosiute was recorded in measured sections of the Scheggs Bed in Tps. 12–13 N., Rs. 103–104 W., near the convergence of the Wyoming, Utah, and Colorado State lines, 55 mi northwest of Hardgrove Rim (Roehler, 1981, sheet 1).

The lake bottom in the study area sloped very gently from the beaches toward the offshore areas. Considering that the width of the shoreline was about 10 mi and that only the offshore lithofacies was deposited below normal wave base (≈50 ft), the slope of the shoreline must have been less than 1° and was certainly less than 2°.

## SANDSTONE COMPOSITION AND PROVENANCE

The paleogeographic location of the Hardgrove Rim study area in the greater Green River basin indicates that the primary source areas for the sediments comprising the shorelines of the Scheggs Bed were the Uinta Mountains to the west and the Sierra Madre to the east (fig. 3). The sand grains that make up the shoreline sandstones are composed 80–90 percent of gray and milky quartz, 1–15 percent of feldspar and varicolored rock fragments, 2–5 percent of muscovite and biotite, and 1–2 percent of heavy minerals. The heavy minerals are mostly magnetite, garnet, and zircon, with traces of epidote and rutile. The sand grains are subangular and cemented by tan or white clay, probably illite. The composition suggests that the bulk of the source rocks were plutonic.

The exposed core of the Sierra Madre is composed of Precambrian granitic rocks, whereas the exposed core of the Uinta Mountains is composed of Precambrian quartzites. Most of the quartz and zircon grains in the shoreline sandstones were probably derived from the Uinta Mountains, and most of the feldspar and mica grains were probably derived from the Sierra Madre. The varicolored rock fragments, including the quartzite and chert pebbles in conglomerates, were derived from Paleozoic, Mesozoic, and older Cenozoic sedimentary rocks that crop out on the flanks of both the nearby mountain ranges.

## DEPOSITIONAL HISTORY

### Shoreline No. 1

At the beginning of the deposition of the Scheggs Bed of the Tipton Tongue (the base of shoreline No. 1, pl. 1), Lake Gosiute appears to have expanded rapidly southward across flood plains that occupied the study area during the period of deposition of the main body of the Wasatch Formation. Following this rapid expansion the lake slowly retreated in the opposite direction (northward) as a result of sediment infilling of the lake margins. This retreat and infilling continued until the sandstone shorelines of the lake were situated north of the study area and the study area was the site of a large swamp (the top of shoreline No. 1, pl. 1).

The retreat of shoreline No. 1 across the study area left a rock record of a complete shoreline succession consisting in descending order of fluvial channel, mudflat, swamp, strandline, nearshore, and offshore lithofacies. The presence of a complete lithofacies succession suggests that lake water levels were relatively stable and that rates of sedimentation along the shoreline remained fairly constant. The only disruption in the succession occurs in the upper 30 ft of shoreline No. 1 between sections 188 and 688 (pl. 1). The section there consists of thin beds of coal and carbonaceous shale comprising a swamp lithofacies that is situated within thicker sandstones comprising swash zones of strandline lithofacies. The irregular stacking of these lithofacies provides evidence that marshes and peat bogs that were present landward of a swash sandstone during early stages of shoreline deposition were later filled in and covered by a second swash sandstone. Numerous reasons can be offered to explain the swamp infilling, but the obvious result was a change in the linear configuration of the shoreline.

The lithofacies strike or direction of the trend of the strandline of shoreline No. 1 along Hardgrove Rim was about N. 80° E. The lake bottom across the nearshore part of the shoreline was hummocky in areas where wave-generated sand bars formed at oblique angles to the beach. In the shallow waters near the beach the largest of these sand bars may have been emergent. In distal, more level parts of the nearshore, coquinas formed from mollusks washed lakeward from beaches and river mouths by fluvial and longshore currents. The offshore lithofacies in shoreline No. 1 shows a predictable decrease in coarse clastics (sandstone and sandy shale) and an increase in the number and thickness of oil-shale beds from the nearshore-offshore interface toward deeper waters of the lake (from left to right across the restored section, pl. 1). The only anomaly in the offshore lithofacies is the presence of a trough-crossbedded sandstone in section 1088 (pl. 1). This sandstone is coarser grained than surrounding rocks and was probably deposited during a severe storm by large waves that disturbed the lake bottom and carried sediments from the nearshore lakeward into the offshore.

### Shoreline No. 2

Thick intervals of the normal shoreline lithofacies succession that are present in shoreline No. 1 are missing in shoreline No. 2. The basal offshore lithofacies of shoreline No. 2 is missing and the nearshore lithofacies is in disconformable contact with swamp lithofacies at the top of shoreline No. 1. The absence of the offshore lithofacies is not abnormal for a retreating lake where the shorelines offlap and are stacked in imbricate fashion. The top of shoreline No. 2 has been eroded and the strandline, swamp, and mudflat lithofacies are missing between sections 188 and 1188 (pl. 1). The nearshore lithofacies in that area is in disconformable contact with red flood-plain deposits of the overlying Cathedral Bluffs Tongue.

The lithofacies strike or direction of the trend of the strandline of shoreline No. 2 was approximately east-west. The lithofacies succession in shoreline No. 2 is in places out of sequence. It is interrupted twice by large fluvial channels that are present in sections 888 and 1388 (pl. 1). The relationships of the channel margin linear bar and channel mouth bar to the fluvial channel in section 1388 have been explained previously and are illustrated on figure 5. In the upper 25–55 ft of sections 588 through 1188 (pl. 1), the nearshore lithofacies is interrupted by two thin intervals of mudflat and swamp lithofacies. Where the swamp lithofacies is in contact with the nearshore lithofacies, the land-water interface consisted of marsh and bog vegetation that grew from the

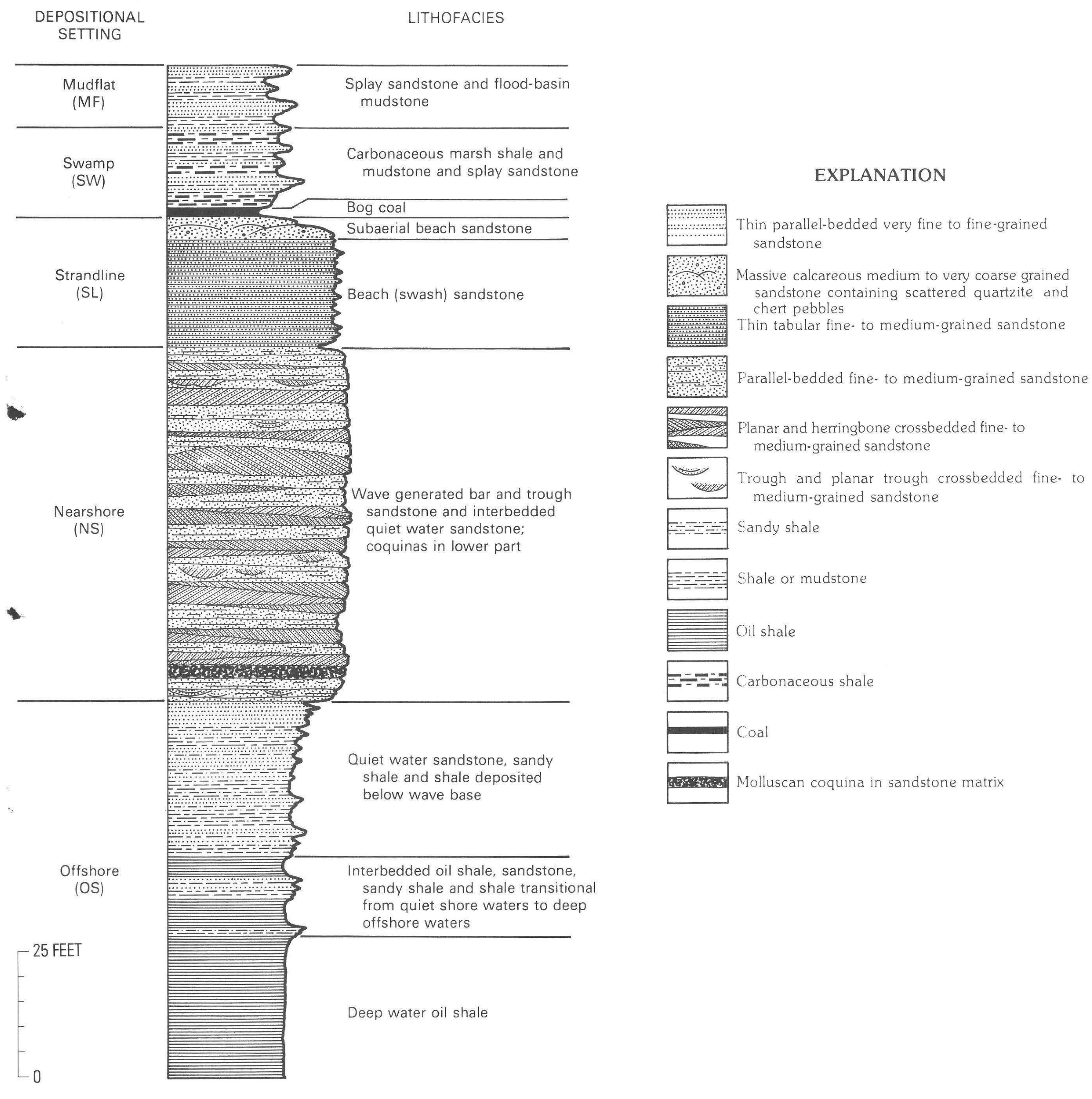


**Figure 10.** Generalized columnar section comprising a model for freshwater lacustrine shoreline lithofacies in the Scheggs Bed of the Tipton Tongue and throughout the Green River Formation.

backshore out into the lake (fig. 5). In other places the mudflat lithofacies is in contact with the nearshore lithofacies, and there the backshore areas were probably undergoing erosion by waves and were inundated by lake water. Erosion of this sort could occur locally for one of several reasons: (1) a rise in lake water levels; (2) severe storms that destroyed the beaches and washed the beach sands outward into the lake; (3) shoreline subsidence, which caused minor shoreline retrogression and beach erosion; and (4) sediment starvation, possibly caused by stream avulsion or other changes in drainage patterns, whereby beach sedimentation stopped and erosion started.

Shoreline deposition in the Scheggs Bed along Hardgrove Rim appears to have ended almost as abruptly as it began. The lake rapidly retreated from the study area northward toward the basin center and a long period of flood-plain deposition in the Cathedral Bluffs Tongue followed. Remnants of Lake Gosiute (the Rife Bed of the Tipton Shale Member and Wilkins Peak Member of the Green River Formation, fig. 4) persisted contemporaneously with the Cathedral Bluffs Tongue in central parts of the greater Green River basin, but the water salinities increased and the shoreline sands disappeared.

## CONCLUSIONS

Two freshwater lacustrine shorelines of Eocene Lake Gosiute are well exposed in the Scheggs Bed of the Tipton Tongue of the Green River Formation along Hardgrove Rim in the Sand Wash basin. The lowermost of these shorelines, designated shoreline No. 1, exposes all the components of a complete shoreline lithofacies succession consisting in descending and lateral order of fluvial channel, mudflat, swamp, strandline, nearshore, and offshore. The lithologies and sedimentary structures that characterize these lithofacies are described in a columnar section, figure 10, which comprises a model for freshwater lacustrine shorelines in the Scheggs Bed of the Tipton Tongue along Hardgrove Rim and for similar shorelines throughout the Green River Formation.

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