Correlation, Composition, Areal Distribution, and Thickness of Eocene Stratigraphic Units, Greater Green River Basin, Wyoming, Utah, and Colorado

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1506-E

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By HENRY W. ROEHLER

GEOLOGY OF THE EOCENE WASATCH, GREEN RIVER, AND BRIDGER (WASHAKIE) FORMATIONS, GREATER GREEN RIVER BASIN, WYOMING, UTAH, AND COLORADO

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CORRELATION, COMPOSITION, AREAL DISTRIBUTION, AND THICKNESS OF EOCENE STRATIGRAPHIC UNITS, GREATER GREEN RIVER BASIN, WYOMING, UTAH, AND COLORADO

By HENRY W. ROEHLER

ABSTRACT

The correlation, composition, areal distribution, and thickness of tongues and members of Eocene formations in the greater Green River basin are shown by 11 transbasin stratigraphic correlation diagrams and 15 basinwide isopach maps. The data indicate that the composition and areal distribution of the various stratigraphic units are mostly related to Eocene tectonism and climate changes. Rocks that were deposited in Lake Gosiute in the Green River and Washakie basins in southwest Wyoming are correlated with rocks of similar age and origin that were deposited in Lake Uinta in the Piceance Creek basin in northwest Colorado and in the Uinta basin in northeast Utah.

INTRODUCTION

Stratigraphic investigations of Eocene rocks in the greater Green River basin are complicated by (1) intertonguing of stratigraphic units, (2) abrupt thickness and lithofacies changes, (3) transitional contacts, and (4) intraformational unconformities. In general, stratigraphic units cannot be stereotyped as to thickness, color, or composition. Rocks of predominantly lacustrine origin are normally assigned to the Green River Formation, whereas rocks of predominantly fluvial origin are normally assigned to the Wasatch, Bridger (Washakie), or Battle Spring Formations. The nomenclature and stratigraphic relationships of Eocene rocks are shown on a generalized west-east cross section of the greater Green River basin (fig. 1).

The correlation, composition, areal distribution, and thickness of Eocene stratigraphic units are discussed in ascending sequence and are illustrated by 11 transbasin stratigraphic correlation diagrams and 15 basinwide isopach maps. The data used to construct the correlation diagrams and isopach maps were primarily derived from 126 measured sections, lithologic logs of 16 holes cored for oil shale or trona, and geophysical logs of 18 holes drilled for oil and gas (pl. 1). The geographic locations of stratigraphic correlation lines *A–A′* to *K–K′* are shown in figure 2 and on plate 1. The intertonguing relationships and boundaries of the 15 stratigraphic units isopached are shown in figure 3.

An evaluation of the stratigraphy of Eocene rocks in the greater Green River basin was published by Sullivan (1980). He examined most of the stratigraphic relationships that are covered in this chapter; however, his paper is primarily a synthesis of previously published information, and it does not include several new stratigraphic units and stratigraphic revisions that have been introduced since 1980. Numerous papers have been published by other authors on the results of topical studies of small geographic areas or of specific stratigraphic intervals in the basin. In contrast, this report encompasses the entire greater Green River basin and the entire Eocene section.

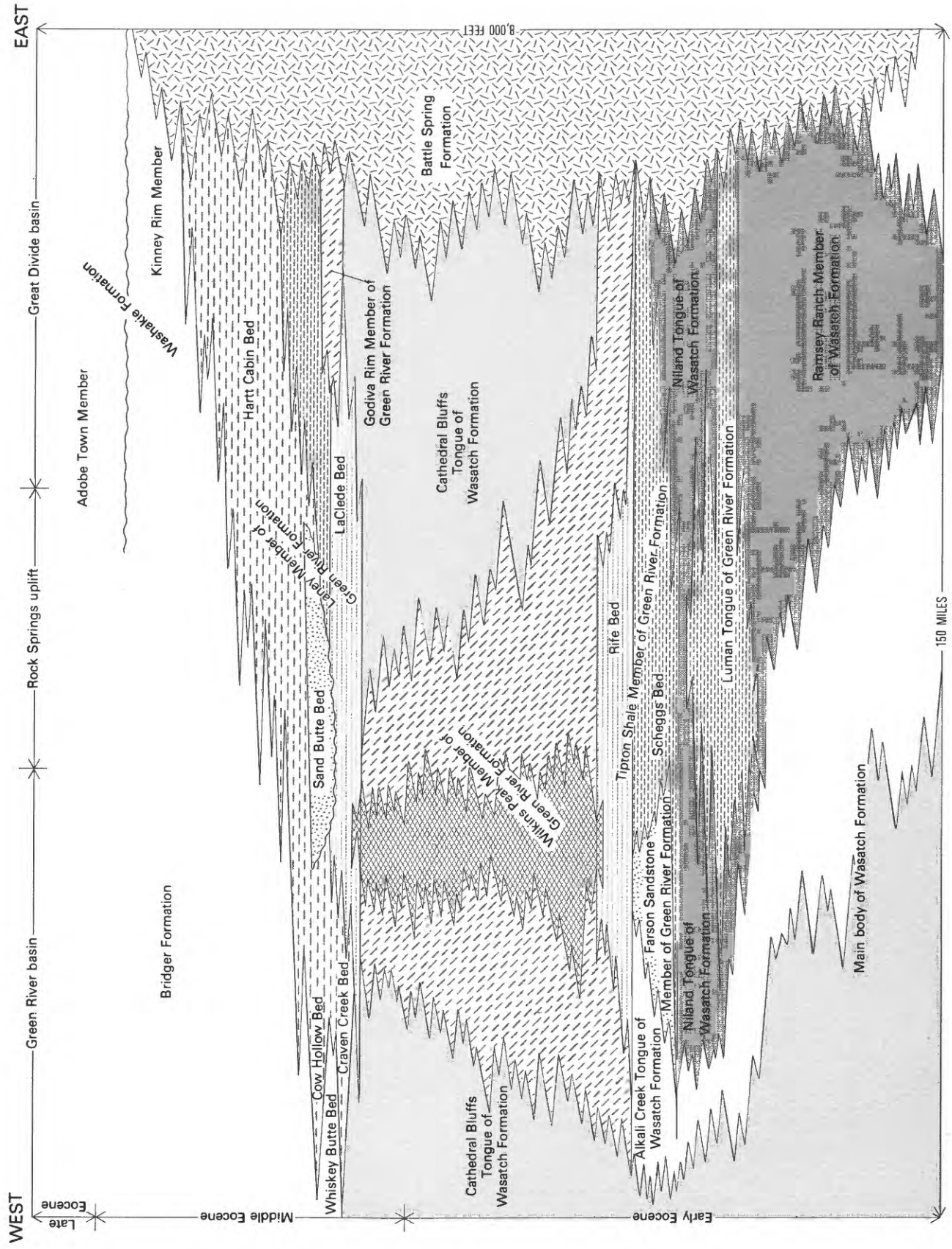
The drainages and topographic features mentioned in this chapter are located geographically on plate 1 of Chapter A, this volume.

CORRELATION AND COMPOSITION OF STRATIGRAPHIC UNITS

WESTERN MARGINS OF GREEN RIVER BASIN

Eocene rocks measured in outcrops along the western margins of the Green River basin are illustrated

Manuscript approved for publication July 12, 1991.


WEST
EAST
8,000 FEET
150 MILES
Late Eocene
Middle Eocene
Early Eocene
Green River basin
Rock Springs uplift
Great Divide basin
Bridger Formation
Adobe Town Member
Washakie Formation
Kinney Rim Member
Battle Spring Formation
Hartt Cabin Bed
Godiva Rim Member of Green River Formation
Cathedral Bluffs Tongue of Wasatch Formation
Laney Member of Green River Formation
LaClede Bed
Sand Butte Bed
Cow Hollow Bed
Whiskey Butte Bed
Craven Creek Bed
Wilkins Peak Member of Green River Formation
Tipton Shale Member of Green River Formation
Rife Bed
Scheggs Bed
Farson Sandstone Member of Green River Formation
Alkali Creek Tongue of Wasatch Formation
Niland Tongue of Wasatch Formation
Luman Tongue of Green River Formation
Ramsey Ranch Member of Wasatch Formation
Main body of Wasatch Formation

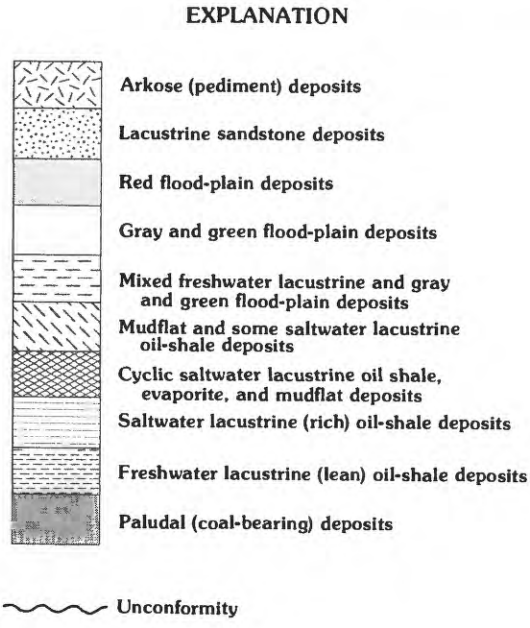


FIGURE 1 (above and facing page).—Generalized cross section of Eocene rocks in greater Green River basin showing stratigraphic nomenclature and depositional environments.

in correlation diagram *A–A′* (fig. 4). Correlation diagram *A–A′* begins at the south in T. 14 N., R. 118 W., continues northward through sections measured near Carter, Kemmerer, and La Barge, Wyo., and ends 10 mi northeast of Big Piney, Wyo., in T. 30 N., R. 110 W. (fig. 2). Eocene stratigraphic units exposed along the line of correlation are the main body of the Wasatch Formation, Scheggs Bed of the Tipton Shale Member and Farson Sandstone Member of the Green River Formation, Alkali Creek Tongue of the Wasatch Formation, Wilkins Peak Member of the Green River Formation, Cathedral Bluffs Tongue of the Wasatch Formation, and Laney Member of the Green River Formation (fig. 4). Their combined total thickness is more than 3,000 ft.

The Scheggs Bed of the Tipton Shale Member, Farson Sandstone Member, and Wilkins Peak Member of the Green River Formation intertongue with and are replaced southward along the line of correlation *A–A′* by the main body of the Wasatch Formation. The Alkali Creek Tongue and Cathedral Bluffs Tongue of the Wasatch Formation merge with the main body south of or approximately coincident with where these members of the Green River Formation are replaced. By the point of the localities of measured sections 2886 and 2986 (fig. 4), the main body has replaced all these units, and between sections 2486 and 2986 the top of the main body rises more than 1,000 ft stratigraphically to the base of the Laney Member of the Green River Formation.

The Cathedral Bluffs Tongue of the Wasatch Formation ranges from 0 to 550 ft in thickness. From north to south along correlation *A–A′*, it changes from variegated (mostly red) sandstone and mudstone to gray and green sandstone and mudstone and then back to variegated (mostly red) sandstone and mudstone. The Cathedral Bluffs Tongue is truncated by erosion near La Barge, Wyo. (measured section 1886, fig. 4), by what is called the La Barge unconformity. The Alkali Creek Tongue of the Wasatch Formation consists of 110–230 ft of brown-weathered, fine- to coarse-grained sandstone, and interbedded gray siltstone and bright-green and gray mudstone mostly of flood-plain origin.

The Scheggs Bed of the Tipton Shale Member of the Green River Formation, 10–60 ft thick, is composed of tan, fine-grained sandstone that crops out as parallel ledges or benches. The sandstone is commonly interbedded with and underlain by brown, low-grade oil shale. In places the sandstone contains the gastropod *Goniobasis tenera*, and the oil shale usually contains abundant ostracodes. The overlying Farson Sandstone Member of the Green River, 15–135 ft thick, is also mostly composed of tan, fine- to medium-grained sandstone that weathers to parallel benches but also to massive cliffs. It is usually interbedded or interlaminated with gray siltstone or gray, very sandy shale.

The Wilkins Peak Member of the Green River Formation weathers drab chalky gray and is about 175 ft thick. It is composed of interbedded brown to black oil shale, gray or green dolomitic mudstone, and gray sandstone and limestone, with minor thin beds of tan or gray algal limestone, siltstone, tuff, and conglomerate. Non-red parts of the overlying Cathedral Bluffs Tongue of the Wasatch Formation also may contain beds of algal limestone and low-grade oil shale, which makes it similar in appearance and composition to the Wilkins Peak Member. The two units are distinguishable, however, because the Cathedral Bluffs Tongue weathers to darker shades of gray and is predominantly of flood-plain origin, whereas the Wilkins Peak Member is lighter gray and predominantly of lacustrine and mudflat origins.

The Laney Member of the Green River Formation is 300–500 ft thick. It weathers to a series of tan-brown and gray, gently basinward dipping benches composed of gray or green mudstone and sandstone, and some interbedded brown oil shale, gray limestone, and gray algal limestone. Mollusks and ostracodes are fairly abundant. The member is partly lacustrine and partly fluvial in origin. The upper part of the Laney Member and the overlying Bridger Formation are not included in correlation *A–A′*, as these units are located basinward of the outcrops measured. Along these unmeasured outcrops, Sullivan (1980) separated two

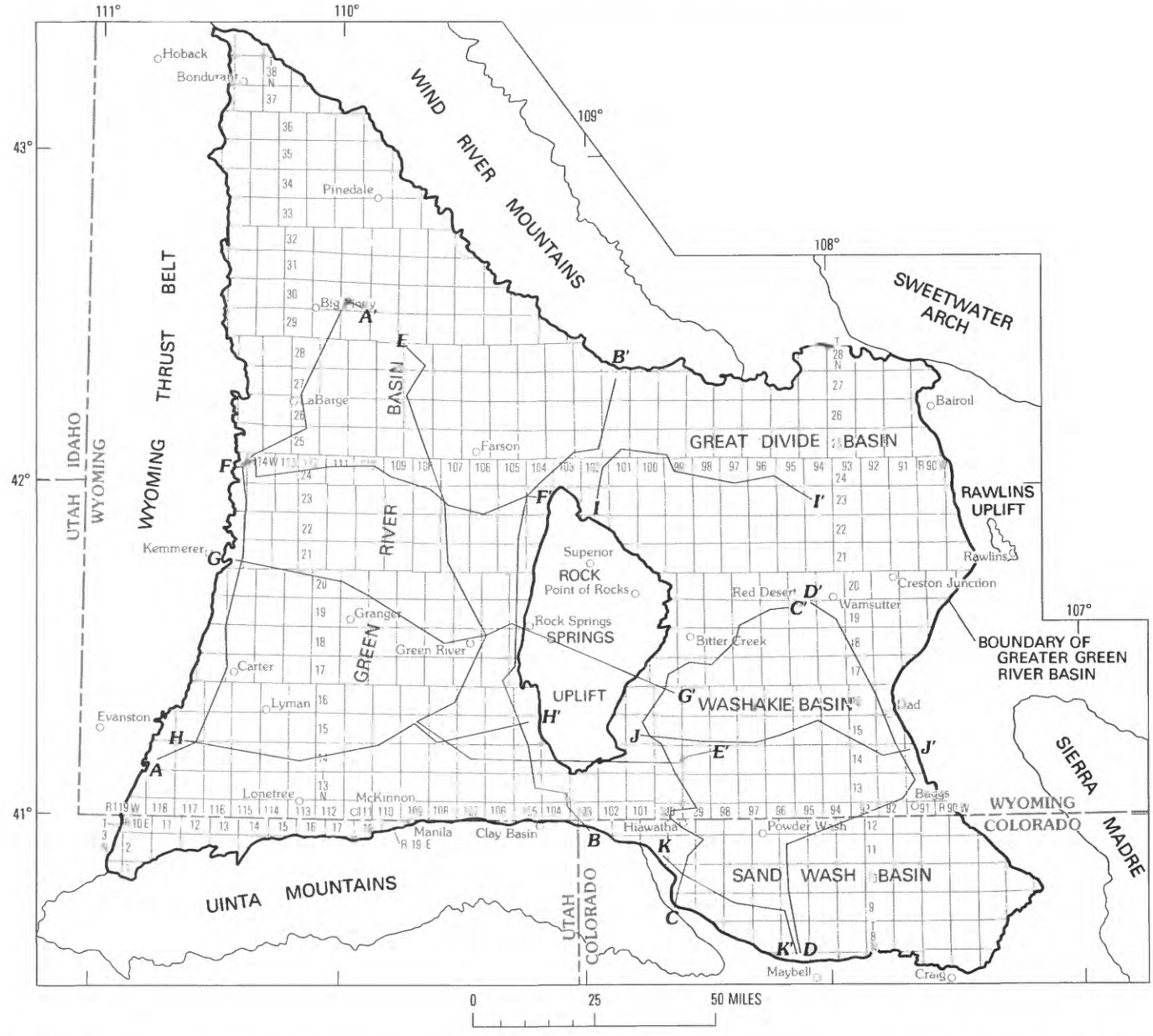


FIGURE 2.—Index map showing location of lines of stratigraphic correlation *A–A'* to *K–K'* of Eocene rocks in greater Green River basin.

persistent lacustrine tongues of the Laney Member from an intervening fluvial tongue of the Bridger Formation in Ts. 17–21 N., Rs. 114–115 W., north of Carter, Wyo. (fig. 1). The lower lacustrine tongue, 60–110 ft thick, was named the Craven Creek Bed, and the upper lacustrine tongue, 40–120 ft thick, was named the Cow Hollow Bed. The intervening fluvial tongue of the Bridger Formation, as much as 230 ft thick, was named the Whiskey Butte Bed. The overlying parts of the lower Bridger Formation that are preserved basinward and downdip of correlation line *A–A'* are more than 500 ft thick and are composed of soft, drab-gray-weathered tuffaceous mudstone, sandstone, and siltstone, and thin interbedded hard, ledge- or bench-forming limestone. Vertebrate, invertebrate, and plant fossils are locally abundant along the outcrops, especially where the Bridger Formation weathers to drab-gray badlands.

WEST FLANK OF ROCK SPRINGS UPLIFT

Correlation diagram *B–B'* (fig. 5) was constructed from surface sections measured along the west flank of the Rock Springs uplift beginning at the south near the juncture of the State boundaries of Wyoming, Utah, and Colorado in T. 12 N., R. 104 W., and continuing northward to near Oregon Buttes, south of the Wind

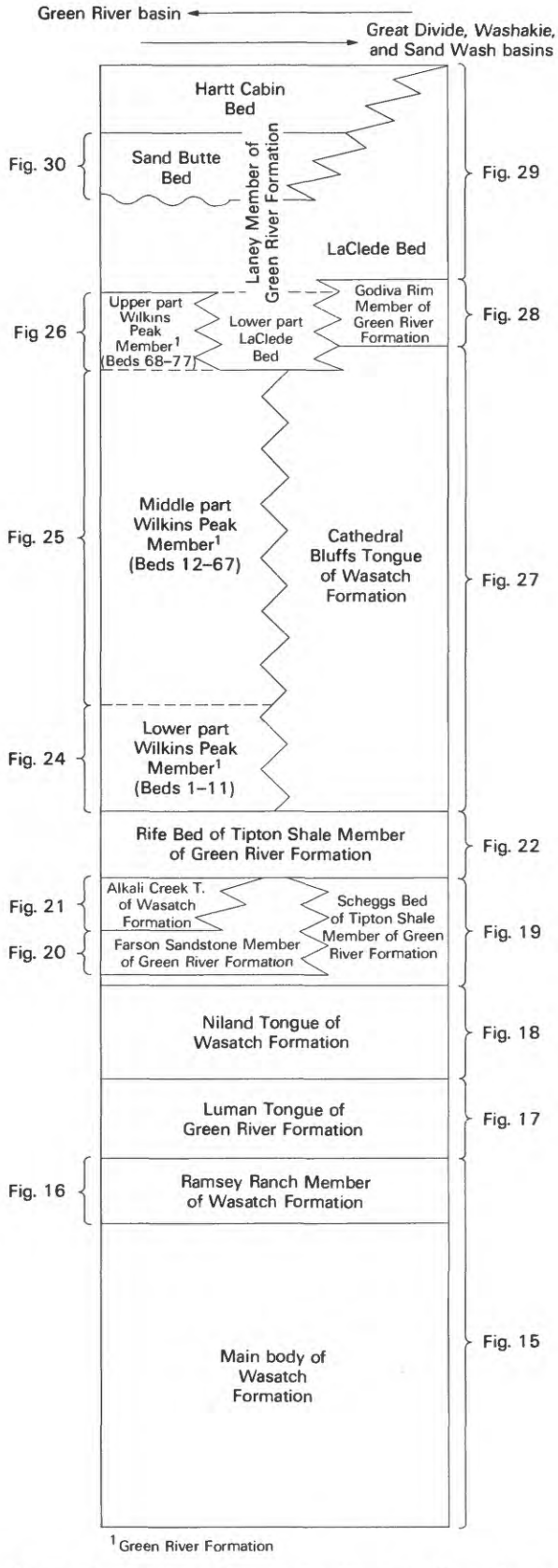


FIGURE 3.—Stratigraphic relationships of Wasatch and Green River Formations showing figure numbers of units isopached.

River Mountains in T. 27 N., R. 107 W. (fig. 2). Eocene stratigraphic units along the line of correlation intertongue extensively, generally thicken southward, and partly wedge out. The overall thickness of the Eocene outcrops ranges between 4,000 and 5,000 ft.

Stratigraphic units along correlation *B–B′*, in ascending order, are the main body of the Wasatch Formation, Luman Tongue of the Green River Formation, Niland Tongue of the Wasatch Formation, Scheggs Bed of the Tipton Shale Member of the Green River Formation, Farson Sandstone Member of the Green River Formation, Rife Bed of the Tipton Shale Member of the Green River Formation, Wilkins Peak Member of the Green River Formation, Cathedral Bluffs Tongue of the Wasatch Formation, and LaClede, Hartt Cabin, and Sand Butte Beds of the Laney Member of the Green River Formation. Depositional environments and intertonguing relationships are shown in figure 5.

The main body of the Wasatch Formation, 1,000–4,000 ft thick, consists of mostly red or variegated sandstone and mudstone of flood-plain origin, which usually weather to ridges and valleys having low topographic relief. Parts of the main body of the formation that underlie the Luman Tongue and Scheggs Bed of the Tipton Shale Member consist of gray and green sandstone and mudstone also of flood-plain origin.

The upper 400–800 ft of the main body of the Wasatch Formation grades laterally southward along correlation *B–B′* into the Ramsey Ranch Member of the Wasatch Formation, Luman Tongue of the Green River Formation, and Niland Tongue of the Wasatch Formation. North of measured section X8–1079, X1979 (fig. 5), the Niland Tongue consists of red flood-plain deposits that resemble the main body of the Wasatch. Between measured sections X8–1079, X1979 and 1569 (fig. 5), these red flood-plain deposits change lithology to gray shale, brown or black carbonaceous shale, and coal, and thin interbedded gray fossiliferous limestone, and brown oil shale, of mostly paludal and lacustrine origins. These beds make up the Ramsey Ranch Member and the Niland Tongue of the Wasatch Formation. The Ramsey Ranch Member and Niland Tongue closely resemble the Luman Tongue of the Green River Formation in weathering characteristics and composition, but the Luman Tongue contains more beds of oil shale and is more lacustrine in origin. South of measured section 1569 (fig. 5), the paludal and lacustrine deposits of the Ramsey Ranch Member and Luman and Niland Tongues merge with typical main body of the Wasatch, which is composed of mostly red flood-plain deposits.

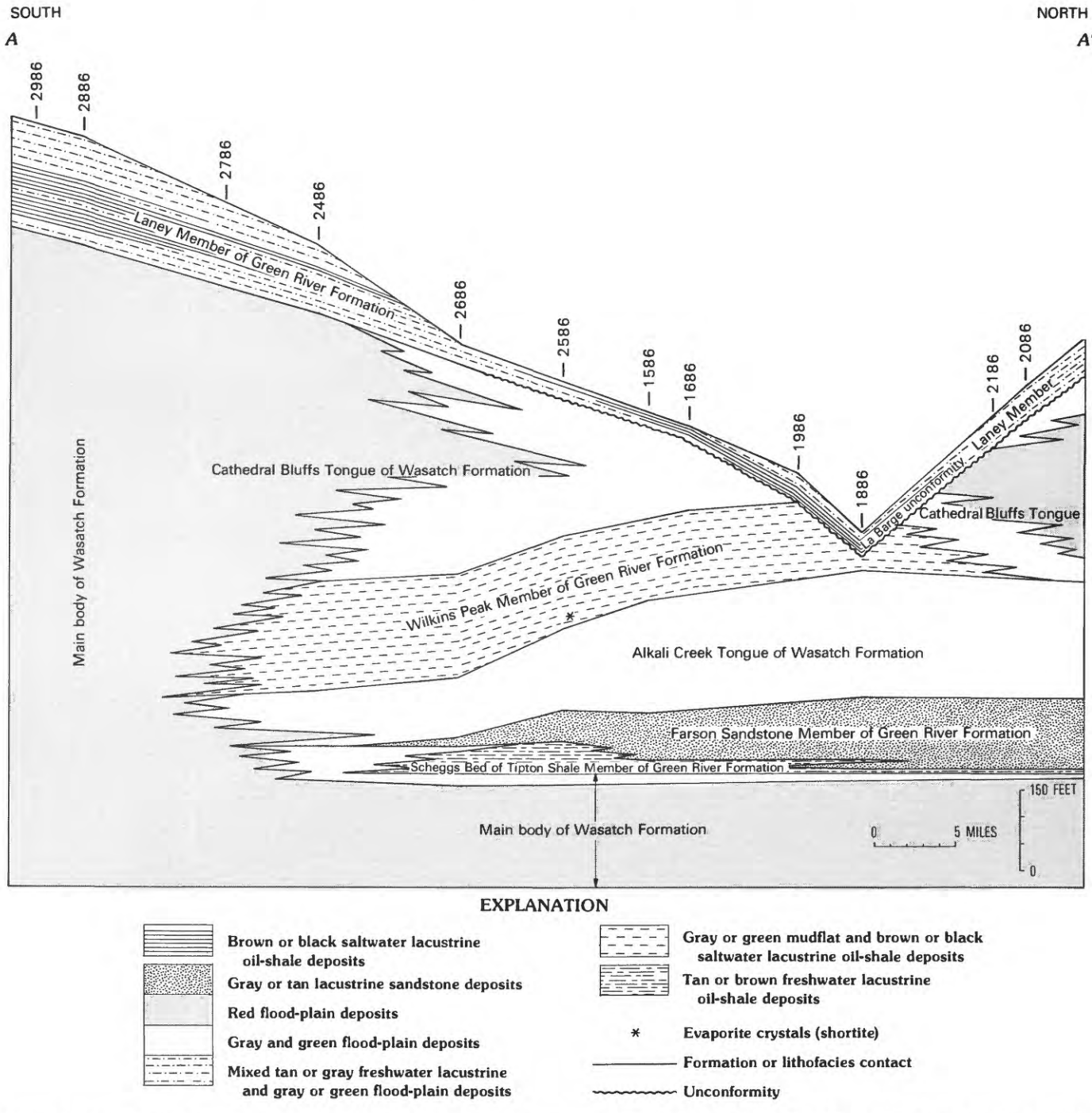


FIGURE 4.—South-north stratigraphic correlation diagram *A–A'* of intertongued Wasatch and Green River Formations along western margins of Green River basin. Numbered measured sections are located and identified on plate 1. Modified from Roehler (1989b).

The Scheggs Bed of the Tipton Shale Member has an average thickness of about 75 ft along correlation *B–B'*. It is composed mostly of oil shale and some thin interbedded sandstone and limestone, all of freshwater lacustrine origin. The oil shale commonly weathers to drab-brown, smooth slopes, which are sometimes interrupted by small ledges. The base of the Scheggs Bed is generally placed at the base of thin sandstone ledges that contain the mollusks *Goniobasis tenera*, *Viviparus* sp., and *Lampsilis* sp.

The Farson Sandstone Member of the Green River Formation is composed of mostly parallel bedded, gray, fine-grained sandstone of freshwater lacustrine origin that weathers to tan or gray ledges and cliffs. It

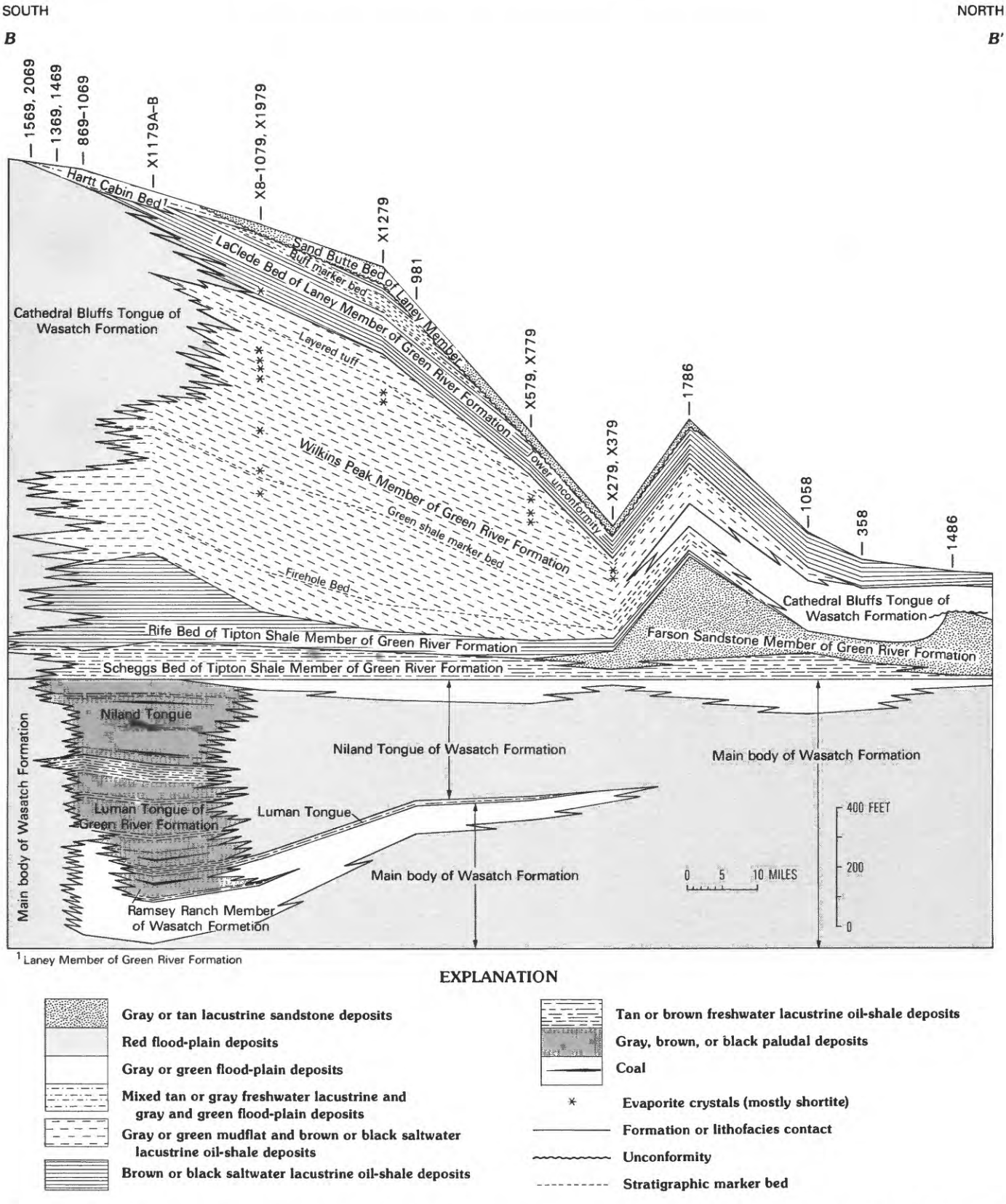


FIGURE 5.—South-north stratigraphic correlation diagram *B–B'* of intertongued Wasatch and Green River Formations along west flank of Rock Springs uplift. Numbered measured sections are located and identified on plate 1. Modified from Roehler (1989c).

thickens and thins from 45 to 260 ft across the northern part of correlation *B–B′* and wedges out toward the south near measured section X579, X779 (fig. 5). The Farson Sandstone Member intertongues with and is laterally equivalent to the middle and upper parts of the Scheggs Bed of the Tipton Shale Member. In measured section 1486, near the north end of correlation *B–B′* (fig. 5), the upper part of the Farson Sandstone Member is eroded across the crest of a monocline that formed along the surface trace of the Wind River thrust fault.

The Rife Bed of the Tipton Shale Member is more than 225 ft thick in measured section X1179A–B near the south end of correlation *B–B′* (fig. 5). The bed gradually thins northward from measured section X1179A–B and wedges out between measured sections 1786 and 1058 (fig. 5). Near measured section 1569 (fig. 5), the Rife Bed intertongues with and is replaced by the Cathedral Bluffs Tongue of the Wasatch Formation. The Rife Bed is composed of chalky-gray-weathered, brown to black, bench-forming oil shale, and some thin interbedded gray or tan sandstone, mudstone, tuff, limestone, and algal limestone, all of saltwater lacustrine origin.

The Wilkins Peak Member consists of 185–800 ft of gray-weathered, green and gray mudstone, brown to black oil shale, light-gray sandstone and siltstone, and some thin interbedded gray tuff, limestone, and algal limestone. The member thins abruptly from south to north (fig. 5). Mudstone of mudflat origin locally contains salt crystals or crystal molds of evaporite minerals (mostly shortite, $Na_2CO_3 \cdot 2CaCO_3$). Several persistent tuff and mudstone beds have been identified in the member, and these include the Firehole Bed, green shale marker bed, and layered tuff (fig. 5). The Wilkins Peak Member intertongues with and grades into red flood-plain deposits of the Cathedral Bluffs Tongue southward near the Uinta Mountains and into gray and green flood-plain deposits of the Cathedral Bluffs Tongue northward near the Wind River Mountains.

The Laney Member of the Green River Formation in correlation *B–B′* is divided into the LaClede, Hartt Cabin, and Sand Butte Beds. The LaClede Bed is the basal oil shale unit of the Laney Member. It thins northward along the line of correlation from more than 170 ft at measured section X8–1079, X1979 (fig. 5) to less than 40 ft at measured section X279, X379 (fig. 5). The upper part of the LaClede Bed was eroded by the Tower unconformity following a middle Eocene uplift of the Rock Springs anticline. A thick and persistent tuff in the upper part of the LaClede Bed is called the buff marker bed. The Hartt Cabin Bed is present only along the southern part of correlation *B–B′* where it is less than 100 ft thick. It is composed of mostly interbedded tan, gray, green, and brown sandstone, mudstone, oil shale, and limestone of mixed freshwater lacustrine and flood-plain origins. The Sand Butte Bed thins irregularly, but is generally 50–250 ft thick in correlation *B–B′*. It is composed of mostly tan and gray tuffaceous sandstone, siltstone, and mudstone of freshwater lacustrine origin. It caps the scenic cliffs, buttes, and pinnacles along Interstate Highway 80 near the town of Green River, Wyo.

WESTERN MARGINS OF SAND WASH AND WASHAKIE BASINS

Correlation diagram *C–C′* (fig. 6) is constructed from surface sections that were measured in a southwest to northeast direction from the north flank of the Uinta Mountains near Irish Canyon, Colo., in T. 9 N., R. 100 W. at the southwest to near Red Desert, Wyo., in T. 19 N., R. 96 W. at the northeast (fig. 2). In ascending stratigraphic sequence, the outcropping units are the main body of the Wasatch Formation, Ramsey Ranch Member of the Wasatch Formation, Luman Tongue of the Green River Formation, Niland Tongue of the Wasatch Formation, Scheggs and Rife Beds of the Tipton Shale Member of the Green River Formation, Wilkins Peak Member of the Green River Formation, LaClede and Sand Butte Beds of the Laney Member of the Green River Formation, Cathedral Bluffs Tongue of the Wasatch Formation, Godiva Rim Member of the Green River Formation, and Bridger Formation. The total thickness of the units measured is about 3,600 ft. The stratigraphic relationships are illustrated in figure 6.

The main body of the Wasatch Formation is composed of conglomerate, sandstone, and mudstone of interbedded red flood-plain and gray and green flood-plain origins along the southwestern part of correlation *C–C′* (between measured sections 5573 and 5073, fig. 6). Northeast of measured section 5073 (fig. 6), the main body is mostly gray and green sandstone and mudstone of flood-plain origin. The upper 200–300 ft of the main body between measured sections 5073 and 2369 (fig. 6) compose the Ramsey Ranch Member of the Wasatch Formation that were deposited in the hereinnamed "Uinta Mountain trough." These rocks consist of interbedded gray, brown, and black shale, carbonaceous shale, coal, oil shale, sandstone, siltstone, and limestone of predominantly paludal origin.

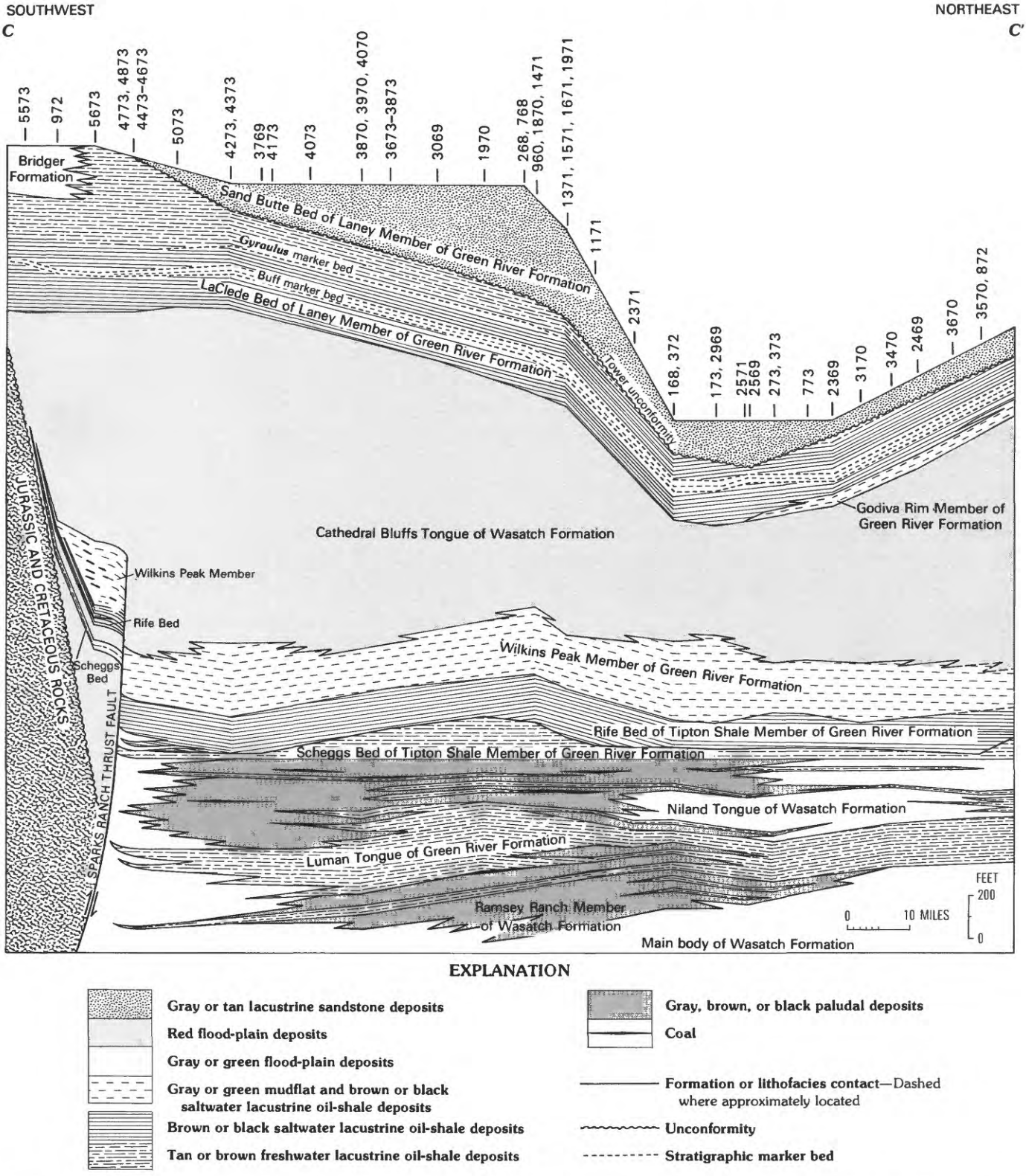


FIGURE 6.—Southwest-northeast stratigraphic correlation diagram *C–C'* of intertongued Wasatch and Green River Formations along western margins of Sand Wash basin in northwest Colorado and Washakie basin in southwest Wyoming. Numbered measured sections are located and identified on plate 1. Modified from Roehler (1989d). Barbs show direction of movement on Sparks Ranch thrust fault.

The Uinta Mountain trough was a structural and topographic depression that persisted during most of the Eocene Epoch along the northern flank of the Uinta Mountains, then northeastward across the Washakie basin, and from there northward into the Great Divide basin (location of the trough is illustrated in fig. 16). The Ramsey Ranch Member intertongues with and grades laterally from the Uinta Mountain trough into normal gray and green flood-plain deposits that characterize the main body of the Wasatch Formation. The overall thickness of the main body of the formation along correlation *C–C′* ranges between 1,000 and 2,500 ft. Disarticulated vertebrate remains, including mammal bone fragments and teeth, are abundant locally.

The Luman Tongue of the Green River Formation was deposited in and adjacent to the Uinta Mountain trough. The freshwater lake in which most of the tongue was deposited migrated back and forth along the length of the trough. As a result of these migrations, the lacustrine oil shale that composes much of the Luman Tongue intertongues extensively with carbonaceous rocks of paludal origin (fig. 6). The Luman Tongue is generally 200–300 ft thick, but the thicknesses change abruptly due to intertonguing with underlying and overlying parts of the Wasatch Formation.

The Niland Tongue of the Wasatch Formation is composed mostly of 200–400 ft of interbedded gray shale, brown and black carbonaceous shale, brown oil shale, coal, and gray sandstone, siltstone, and limestone, of predominantly paludal origin. These rocks were deposited in the Uinta Mountain trough. Adjacent to the trough, remnants of the Niland Tongue consist of gray and green mudstone and sandstone of flood-plain origin (fig. 6). Some oil-shale beds in the Niland Tongue are correlatable in outcrops for more than 50 mi.

The Scheggs Bed of the Tipton Shale Member consists of 25–200 ft of brown, flaky oil shale, and some thinly interbedded gray sandstone, siltstone, and limestone. The unit normally weathers to drab-brown smooth slopes. The thickest part of the Scheggs Bed is located along the depositional axis of the Uinta Mountain trough (measured section 1970, fig. 6). The bed is displaced about 400 ft by the Sparks Ranch thrust fault near the east end of the Uinta Mountains (measured section 5673, fig. 6). It thins southwestward on the upthrown block of the thrust fault and wedges out near measured section 5573. In the vicinity of the thrust fault, the Scheggs Bed is separated from the overlying Rife Bed by a thin, unnamed tongue of the Wasatch Formation. Mollusks, ostracodes, and fish fossils are abundant along most outcrops.

The Rife Bed of the Tipton Shale Member ranges in thickness from 120 to 250 ft and is composed of mostly dark brown to black oil shale that weathers drab gray. Interbedded with the oil shale are a few thin beds of gray sandstone, siltstone, and limestone, and tan algal limestone. Most exposures of the algal limestone are resistant, and they commonly cap ledges and benches along outcrops. In the vicinity of the Sparks Ranch thrust fault (between measured sections 5573 and 4773, 4873, fig. 6), the oil shale in the Rife Bed intertongues with gray and green mudstone and sandstone of mudflat origin. Fossils are not common in the Rife Bed, but thin layers containing ostracodes are present locally.

The Wilkins Peak Member of the Green River Formation rests conformably on the Rife Bed of the Tipton Shale Member. The contact between these units is not readily discernible in outcrops because both units weather drab gray. The upper part of the Wilkins Peak Member intertongues extensively with the Cathedral Bluffs Tongue of the Wasatch Formation. This contact is arbitrary, but it is usually placed at the base of the lowermost red bed in the section. The Wilkins Peak Member along correlation *C–C′* comprises from 0 to about 400 ft of gray and green mudstone and sandstone, and thin interbedded brown oil shale and carbonaceous shale, and gray siltstone, limestone, algal limestone, shale, and flat-pebble conglomerate, mostly of saltwater lacustrine and mudflat origins. The member thins and wedges out on the upthrown block of the Sparks Ranch thrust fault (measured sections 5573, 972, 5673, fig. 6). Ostracode and fish fossils are abundant locally in the member in limestone and sandstone beds.

The Cathedral Bluffs Tongue of the Wasatch Formation is recognized in outcrops along correlation *C–C′* by its variegation and dominant brick-red color. It is composed of mostly red mudstone and some interbedded gray or tan sandstone, and a few thin interbeds of brown carbonaceous shale, gray shale, siltstone, limestone, algal limestone, and tuff. Beds of conglomerate are fairly common near the northeastern flank of the Uinta Mountains (measured sections 5573, 972, 5673, fig. 6). The thickness of the Cathedral Bluffs Tongue generally ranges between 800 and 1,500 ft, but the unit thins to about 500 ft along part of the western margins of the Washakie basin (measured sections 168, 372 and 173, 2969, fig. 6). It is less than 200 ft thick on part of the upthrown block of the Sparks Ranch thrust fault (measured section 5573, fig. 6). The Cathedral Bluffs Tongue thins by about 500 ft across the plane of the thrust fault (between measured sections 5673 and 4773, 4873, fig. 6). This abrupt thinning provides evidence that the last movement of

the Sparks Ranch thrust fault took place during deposition of the Cathedral Bluffs Tongue, near the end of the early Eocene.

The Godiva Rim Member is laterally equivalent to the basal part of the LaClede Bed of the Laney Member of the Green River Formation in correlation *C–C′*. The Godiva Rim Member is present only in outcrops along the northern part of the Washakie basin, where it consists of 160–375 ft of gray mudstone, shale, sandstone, siltstone, and limestone, and brown oil shale that were deposited in shallow saltwater or brackish-water lakes and on mudflats.

The LaClede Bed of the Laney Member of the Green River Formation is composed more than 75 percent of brown oil shale. Interbedded with the oil shale are thin beds of gray sandstone, siltstone, shale, mudstone, limestone, algal limestone, and flat-pebble conglomerate, and tan or gray zeolitic tuff. The buff marker bed, a few feet to more than 50 ft thick, is a distinctive tan-brown-weathered tuff or tuffaceous siltstone in outcrops along Kinney Rim on the western margins of the Washakie basin. A persistent gray, limy siltstone, less than 1 ft thick, called the *Gyraulus* marker bed, contains numerous *Gyraulus militaris*, a small planorbid snail. The LaClede Bed is more than 800 ft thick in the western part of the Sand Wash basin (measured section 5673, fig. 6), but it thins by intraformational erosion to less than 250 ft in places along the western margins of the Washakie basin (measured section 2569, fig. 6). Ostracodes are abundant throughout the LaClede Bed, and mollusks are present at several stratigraphic levels in its upper part.

The Sand Butte Bed is the uppermost unit measured along the line of correlation *C–C′*. It forms the cap rocks on most of Kinney Rim in the Washakie basin (Chapter A, fig. 7, this volume). The Sand Butte Bed is composed of tan tuff, tuffaceous sandstone, and siltstone, and some thin interbedded brown oil shale and gray limestone of mostly freshwater lacustrine origin. Fish, mollusk, and ostracode fossils are occasionally found at various stratigraphic levels at widely separated localities.

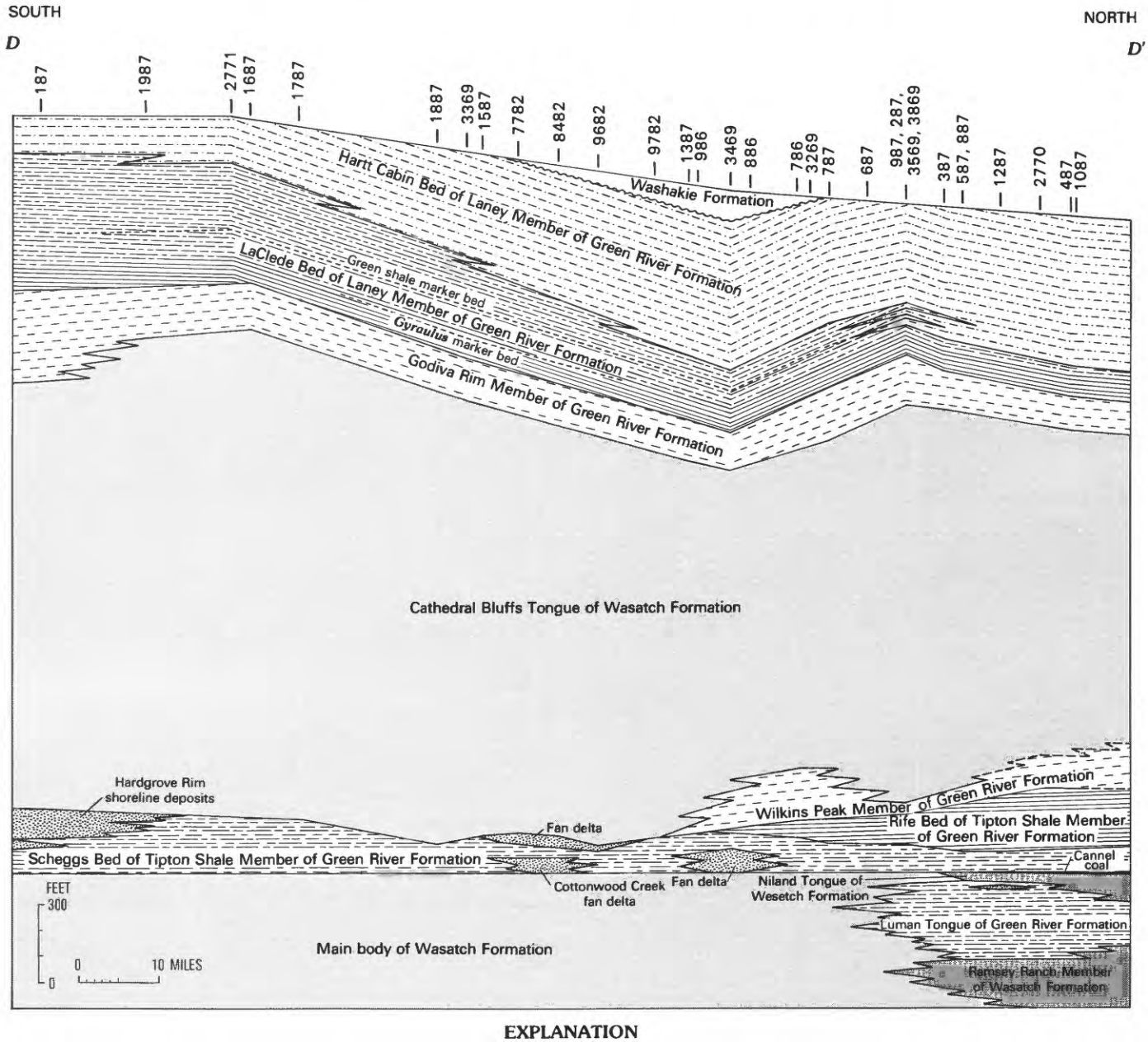
CENTRAL SAND WASH AND EASTERN WASHAKIE BASINS

Correlation diagram *D–D′* (fig. 7) begins at Godiva Rim, Colo., in T. 8 N., R. 96 W. at the south, trends northward across the central part of the Sand Wash basin to near the Colorado-Wyoming State line, and then eastward toward Baggs, Wyo., before again turning northward along the eastern margins of the Washakie basin. The correlation ends at the north in T. 19 N., R. 94 W., a few miles southwest of Wamsutter, Wyo. (pl. 1). Eocene rocks exposed in correlation *D–D′* are the main body of the Wasatch Formation, Luman Tongue of the Green River Formation, Niland Tongue of the Wasatch Formation, Scheggs and Rife Beds of the Tipton Shale Member of the Green River Formation, Wilkins Peak Member of the Green River Formation, Cathedral Bluffs Tongue of the Wasatch Formation, Godiva Rim Member of the Green River Formation, LaClede and Hartt Cabin Beds of the Laney Member of the Green River Formation, and the overlying Washakie Formation. The total thickness of Eocene rocks along the line of correlation ranges from about 3,500 to 4,500 ft.

The main body of the Wasatch Formation thins irregularly north of Godiva Rim along the length of correlation *D–D′* (thinning not shown in fig. 7). The main body is composed of red or variegated mudstone and gray sandstone of flood-plain origin along most of the outcrops, except in the northeastern part of the Washakie basin. In that area, laterally equivalent rocks of paludal and lacustrine origins were deposited across a segment of the Uinta Mountain trough (fig. 7). These rocks form the Ramsey Ranch Member of the Wasatch Formation, Luman Tongue of the Green River Formation, and Niland Tongue of the Wasatch Formation.

The Tipton Shale Member, here as in most other parts of the greater Green River basin, is divided into the Scheggs and Rife Beds. The Scheggs Bed consists of 75–250 ft of mostly drab-brown-weathered, flaky oil shale, and interbedded tan to gray, fine-grained sandstone, with sparse thin interbeds of gray shale, limestone, algal limestone, and siltstone. Several thick sandstones in the bed were deposited as shorelines and deltas. Two of these sandstones have been informally named the Hardgrove Rim shoreline deposits (Roehler, 1990b) and the Cottonwood Creek fan delta (Roehler and others, 1988). Mollusk, ostracode, and fish fossils are abundant, especially in the shoreline sandstones. The Rife Bed consists of 0–225 ft of gray-weathered, brown to black oil shale, and very thinly interbedded gray limestone, algal limestone, siltstone, sandstone, and tuff. Fish fossils are concentrated in the Rife Bed in a few widely spaced strata.

The Wilkins Peak Member ranges in thickness from 0 to about 200 ft. It thickens and thins along outcrops, mostly as a result of intertonguing with the overlying Cathedral Bluffs Tongue of the Wasatch Formation. The member is poorly exposed but consists of mostly interbedded dark-brown oil shale, gray and green mudstone, and gray sandstone, siltstone, and algal limestone of mixed saltwater lacustrine and mudflat origins.



EXPLANATION

- Gray or tan lacustrine sandstone deposits
- Red flood-plain deposits
- Gray or green flood-plain deposits
- Mixed tan or gray freshwater lacustrine and gray or green flood-plain deposits
- Gray or green mudflat and brown or black saltwater lacustrine oil-shale deposits
- Brown or black saltwater lacustrine oil-shale deposits
- Tan or brown freshwater lacustrine oil-shale deposits
- Gray, brown, or black paludal deposits
- Coal
- Formation or lithofacies contact—Dashed where approximately located
- Unconformity
- Stratigraphic marker bed

FIGURE 7.—South-north stratigraphic correlation diagram *D–D'* of Eocene rocks across central Sand Wash basin in northwest Colorado and eastern Washakie basin in southwest Wyoming. Numbered measured sections are located and identified on plate 1. Modified from Roehler (1989e).

The Cathedral Bluffs Tongue of the Wasatch Formation intertongues with the overlying Godiva Rim Member of the Green River Formation. The tongue is 1,500–1,800 ft thick across the central part of the Sand Wash basin (between measured sections 187 and 1687, fig. 7), but it thins to between 1,100 and 1,500 ft along the eastern margins of the Washakie basin (between measured sections 3469 and 1087, fig. 7). The tongue is composed of variegated (mostly red) flood-plain deposits consisting of thick lenticular channel sandstone, thin parallel-bedded splay sandstone, and interbedded basin-fill mudstone. The tongue is nonresistant and extensive areas are covered by Quaternary alluvium. Trace and vertebrate fossils are found in local concentrations.

The Godiva Rim Member of the Green River Formation thickens southward along correlation *D–D′*. It is 125 ft thick in measured section 487 (fig. 7), and 340 ft thick in measured section 187 (fig. 7). Near measured section 187, it intertongues with the underlying Cathedral Bluffs Tongue of the Wasatch Formation. The Godiva Rim Member is composed of interbedded mostly gray and green mudstone, tan and gray sandstone and siltstone, brown oil shale, and sparse thin beds of gray limestone, algal limestone, and carbonaceous shale. Ostracode and fish fossils are fairly common along outcrops.

The LaClede Bed of the Laney Member is nearly 500 ft thick in measured section 187 (fig. 7), but thins north of there along correlation *D–D′*, mostly by intertonguing and replacement by the Hartt Cabin Bed of the Laney Member. At measured section 487 (fig. 7), in the northeastern part of the Washakie basin, the LaClede Bed is less than 150 ft thick. More than 80 percent of the LaClede Bed is brown oil shale. The remaining parts are mostly gray shale, mudstone, siltstone, sandstone, and limestone. A few beds of algal limestone are present near the base. The LaClede Bed commonly weathers to smooth, gray-brown slopes, which are interrupted by tan or gray ledges and benches. Freshwater pelecypod, gastropod, ostracode, and fish fossils are abundant.

The Hartt Cabin Bed of the Laney Member is composed of rocks that were deposited during the drying-up stages of Lake Gosiute. The bed is about 500 ft thick and is composed of mostly gray and green mudstone, shale, sandstone, and siltstone, and some thin interbedded brown oil shale and carbonaceous shale, and gray limestone and tuff. The bed weathers to drab-tan and gray slopes and ledges. Gastropod, pelecypod, ostracode, fish, and turtle fossils are locally abundant. Silicified *Goniobasis tenera* shells, commonly called *Turritella* agate, are present in outcrops at the base of the bed in measured section 3569, 3869 (fig. 7).

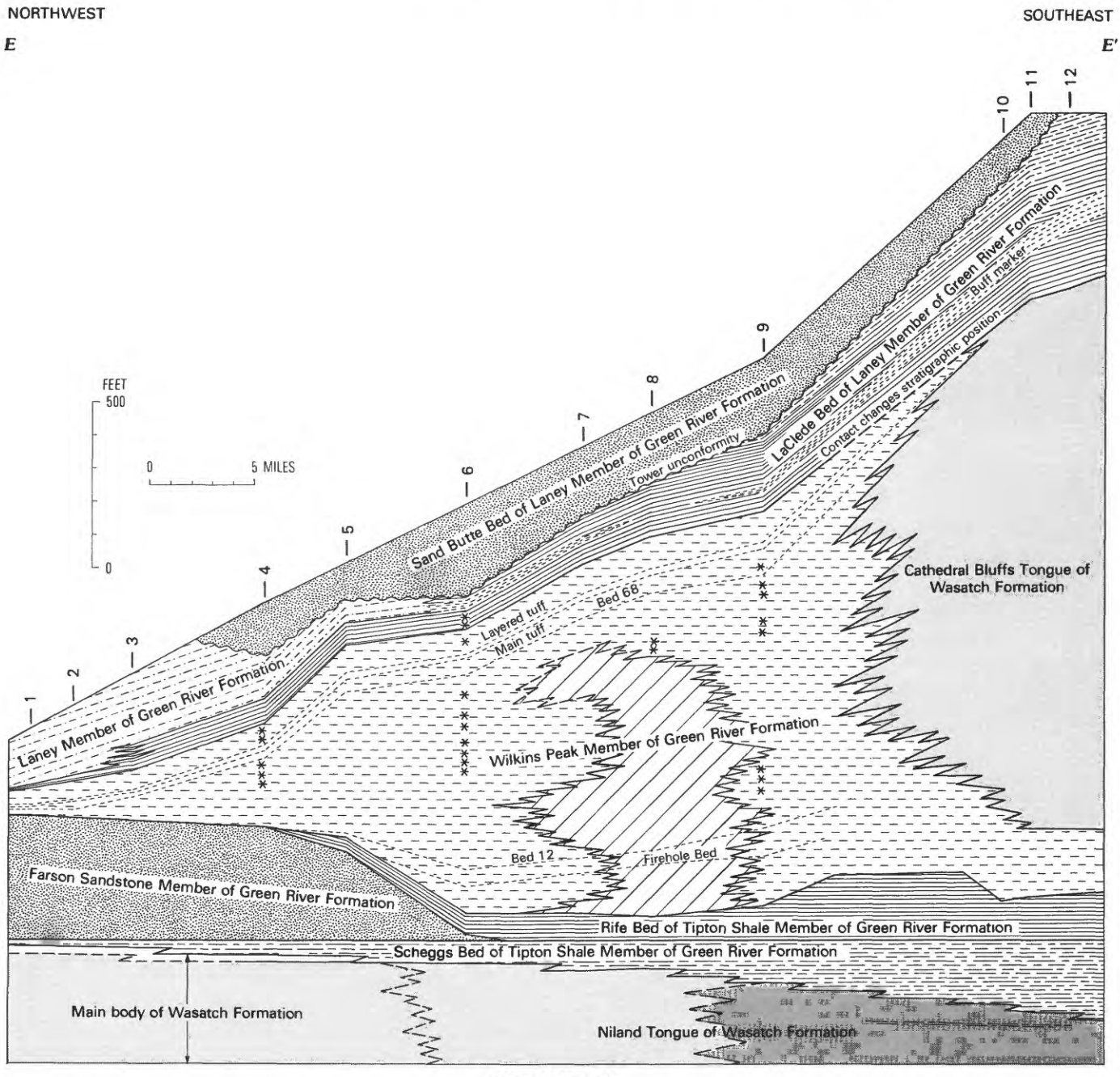
A basal 105-ft interval of the Washakie Formation was measured along correlation *D–D′* (between measured sections 7782 and 3269, fig. 7). The basal part of the formation there is composed of gray, tuffaceous siltstone and sandstone. These beds are ledge forming and constitute bed 569, the lower brown sandstone, in the Eocene reference section for the Washakie basin (Chapter D, this volume).

CENTRAL (NORTH-SOUTH) GREEN RIVER BASIN, SOUTHERN ROCK SPRINGS UPLIFT, AND SOUTHWESTERN WASHAKIE BASIN

Correlation diagram *E–E′* (fig. 8) was constructed from holes cored for trona and oil shale by various chemical companies and government agencies. The correlation begins in T. 27 N., R. 108 W., 22 mi northwest of Farson, Wyo., trends southeastward to the east side of Flaming Gorge Reservoir in T. 14 N., R. 107 W., and then runs eastward across the southern part of the Rock Springs uplift into the southwest part of the Washakie basin in T. 14 N., R. 98 W. (fig. 2, pl. 1). The Wasatch and Green River Formations intertongue extensively along the line of correlation, and most units thicken abruptly southward and southeastward. The total thickness of Eocene rocks along the correlation ranges from about 5,000 to 9,500 ft.

Eocene rocks in correlation *E–E′* consists of the main body and Niland Tongue of the Wasatch Formation, Scheggs Bed of the Tipton Shale Member of the Green River Formation, Farson Sandstone Member of the Green River Formation, Rife Bed of the Tipton Shale Member of the Green River Formation, Wilkins Peak Member of the Green River Formation, Cathedral Bluffs Tongue of the Wasatch Formation, and Laney Member of the Green River Formation. The Laney Member is partly subdivided into the LaClede and Sand Butte Beds, which are separated by the Tower unconformity. The Laney Member is overlain by the Bridger Formation in the Green River basin and by the Washakie Formation in the Washakie basin, but these relationships are not shown in figure 8.

Although its total thickness is not shown in figure 8, the main body of the Wasatch Formation is 1,500–3,000 ft thick along the line of correlation *E–E′*; and the Niland Tongue of the Wasatch Formation is as much as 400 ft thick. Both units are composed of mostly red, variegated, or gray and green flood-plain deposits, which grade southward into rocks in the Uinta



EXPLANATION

- Gray or tan lacustrine sandstone deposits
- Red flood-plain deposits
- Gray or green flood-plain deposits
- Mixed tan or gray freshwater lacustrine and gray or green flood-plain deposits
- Gray or green mudflat and brown or black saltwater lacustrine oil-shale deposits
- Gray or green mudflat, brown or black saltwater lacustrine oil-shale, and bedded evaporite (trona, halite) deposits; abundant salt crystals
- Brown or black saltwater lacustrine oil-shale deposits
- Tan or brown freshwater lacustrine oil-shale deposits
- Gray, brown, or black paludal deposits
- * Evaporite crystals (mostly shortite)
- Formation or lithofacies contact—Dashed where approximately located
- Unconformity
- Stratigraphic marker bed

Mountain trough that are mostly shale, carbonaceous shale, coal, limestone, and oil shale of paludal and freshwater lacustrine origins. This lithologic change takes place between drill hole 8 and corehole 9 (fig. 8).

The Scheggs Bed of the Tipton Shale Member is composed of mostly tan to brown oil shale, and the Rife Bed of the Tipton Shale Member is composed of mostly dark brown to black oil shale. Both beds thicken southward, and between coreholes 9 and 12 (fig. 8) each is as much as 225 ft thick. Between coreholes 4 and 7 (fig. 8), the Scheggs Bed is separated from the overlying Rife Bed by the Farson Sandstone Member of the Green River Formation. The Farson Sandstone Member is composed of mostly sandstone and is nearly 400 ft thick in corehole 1 (fig. 8). From corehole 4 it thins abruptly southward and wedges out between coreholes 6 and 7 (fig. 8).

The Wilkins Peak Member of the Green River Formation is 80–1,200 ft thick. It is composed mostly of gray, green, or brown sandstone, mudstone, oil shale, and salt of mudflat, saltwater lacustrine, and evaporite origins. Between coreholes 6 and 9 (fig. 8) the member contains several beds of the evaporite mineral trona ($Na_2CO_3 \cdot NaHCO_3 \cdot H_2O$). The Cathedral Bluffs Tongue is nearly 1,600 ft thick where it intertongues with and laterally replaces most of the Wilkins Peak Member in the Washakie basin (coreholes 10–12, fig. 8). The Cathedral Bluffs Tongue is composed of variegated (mostly red) mudstone and interbedded red and gray sandstone.

The Laney Member of the Green River Formation is not divided into beds along the northern part of the Green River basin (coreholes 1–5, fig. 8), but it is divided into the Sand Butte and LaClede Beds in the southern Green River basin (coreholes 6–9, fig. 8) and southwestern Washakie basin (coreholes 10–12, fig. 8). Where the Laney Member is undivided, it consists of interbedded mostly gray mudstone, sandstone, siltstone, and limestone, and some brown oil shale of mixed fluvial and freshwater lacustrine origins. The LaClede Bed is composed mostly of brown, flaky oil shale. The buff marker bed is recognizable within the LaClede Bed along most of correlation *E–E′*. The Sand Butte Bed is composed of mostly tan and gray tuffaceous sandstone and siltstone. The upper 100 ft of the Wilkins Peak Member in the central Green River basin has been previously mapped as basal Laney Member in outcrops along the northern part of the Green River basin and western part of the Washakie basin (Roehler, 1990c). The change in the stratigraphic position of the Wilkins Peak–Laney contact along correlation *E–E′* occurs between coreholes 9 and 10 (fig. 8).

FIGURE 8 (facing page).—Northwest-southeast stratigraphic correlation diagram *E–E′* of intertongued Wasatch and Green River Formations across central Green River basin, southern Rock Springs uplift, and southwestern Washakie basin. Beds 12 and 68 are oil-shale beds identified in figure 23. Numbered coreholes are located and identified on plate 1. Modified from Roehler (1990a).

NORTHERN GREEN RIVER BASIN

The stratigraphic relationships of Eocene rocks across the northern part of the Green River basin from the vicinity of Fontenelle Creek in T. 24 N., R. 115 W. on the west to the northern Rock Springs uplift in T. 23 N., R. 104 W. on the east are shown in correlation diagram *F–F′* (fig. 9). The Luman Tongue of the Green River Formation and the Niland Tongue of the Wasatch Formation are not shown on the diagram, because they were not deposited in this part of the Green River basin. The rocks shown on the diagram also exclude the Bridger Formation and the basal part of the main body of the Wasatch Formation. The maximum thickness of Eocene rocks along the line of correlation is about 3,500 ft. The La Barge unconformity is present at the top of the Cathedral Bluffs Tongue of the Wasatch Formation (between section 1586 and drill hole 14, fig. 9), and the Tower unconformity is present at the base of the Sand Butte Bed of the Laney Member of the Green River Formation (between corehole 4 and measured section 1786, fig. 9). The contact of the Wilkins Peak and Laney Members changes stratigraphic position near drill hole 17 (fig. 9). Along correlation *F–F′*, the stratigraphic position of the layered tuff is located 100 ft below the top of the Wilkins Peak Member in drill holes near the center of the basin (drill holes 17 and 18, fig. 9). It is located near the base of the Laney Member in outcrops along the western margins of the basin (drill hole 13, fig. 9).

The main body of the Wasatch Formation, about 2,500–3,000 ft thick, forms the base of the Eocene section. The upper 15–20 ft of the main body of the formation is chiefly gray or green mudstone and sandstone (fig. 9). The remaining parts of the formation are variegated (mostly red) mudstone and interbedded gray sandstone.

The Rife and Scheggs Beds of the Tipton Shale Member of the Green River Formation are composed of mostly tan, brown, or black oil shale. The Scheggs Bed has a fairly uniform thickness of between 25 and 50 ft across correlation *F–F′*, but the Rife Bed is less than 15 ft thick and wedges out in a westward direction in the eastern part of the correlation (between measured section 1786 and drill hole 19 (fig. 9)). Some algal limestone is present at various stratigraphic levels in

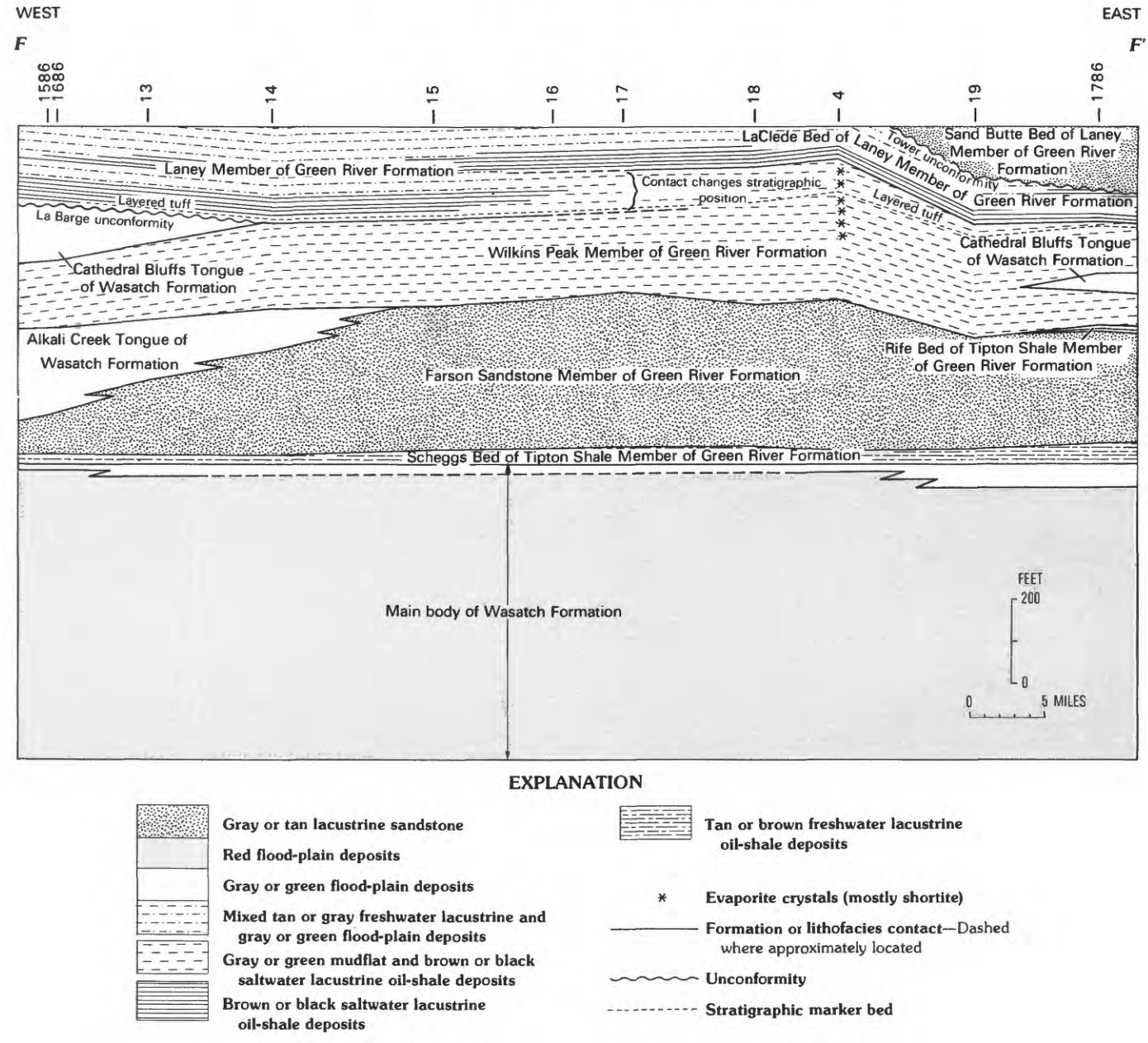


FIGURE 9.—West-east stratigraphic correlation diagram *F–F'* of intertongued Wasatch and Green River Formations across northern Green River basin. Numbered measured sections, drill holes, and coreholes are located and identified on plate 1. Modified from Roehler (1990c).

both the Rife and Scheggs Beds, and ostracodal siltstone is a common constituent of the Scheggs Bed along the western margins of the northern Green River basin (measured section 1586, fig. 9).

The Scheggs and Rife Beds are separated along correlation *F–F'* by as much as 250 ft of lacustrine delta and shoreline sandstone comprising the Farson Sandstone Member of the Green River Formation. The Alkali Creek Tongue of the Wasatch Formation, composed of green mudstone and sandstone of fluvial origin, intertongues with and replaces the upper part of the Farson Sandstone Member along the western part of the basin. The Alkali Creek Tongue thins abruptly basinward (eastward) from about 200 ft in outcrops along the western margin of the basin at measured sections 1586 and 1686 (fig. 9) to where it wedges out in the subsurface near drill hole 15 (fig. 9).

The Wilkins Peak Member of the Green River Formation is composed of 150–325 ft of mostly brown or black oil shale and interbedded gray or green mudstone. The evaporite mineral shortite was identified in corehole 4 (fig. 9). The member intertongues along the

eastern and western margins of the northern Green River basin with gray or green mudstone and sandstone composing the Cathedral Bluffs Tongue of the Wasatch Formation.

The Laney Member of the Green River Formation is only locally more than 400 ft thick in correlation *F–F′*. It intertongues extensively with the overlying Bridger Formation (not illustrated) across the center of the basin. The Laney Member, here as in other correlations, consists of a basal oil-shale unit, the LaClede Bed, and an overlying tuffaceous sandstone-siltstone unit, the Sand Butte Bed. These units intertongue westward across the northern Green River basin with gray, tan, or green sandstone and mudstone that compose the undivided Laney Member (between measured section 1586 and drill hole 15, fig. 9).

CENTRAL (EAST-WEST) GREEN RIVER BASIN, ROCK SPRINGS UPLIFT, AND WESTERN WASHAKIE BASIN

Correlation diagram *G–G′* (fig. 10) begins at the western margin of the Green River basin in T. 21 N., R. 115 W., a few miles east of Kemmerer, Wyo. It continues in an east-southeast direction across the center of the Green River basin to White Mountain in T. 19 N., R. 105 W., near Rock Springs, Wyo., and then crosses the Rock Springs uplift to where it ends at the west end of Laney Rim in the Washakie basin in T. 16 N., R. 100 W. (fig. 2, pl. 1). A normal succession of Eocene rocks generally thickens from west to east along the line of correlation *G–G′* and is more than 5,000 ft thick near the center of the Green River basin (between drill holes 21 and 22, fig. 10). Correlation *G–G′* excludes the Bridger Formation, lower part of the Niland Tongue of the Wasatch Formation, the Luman Tongue of the Green River Formation, and lower part of the main body of the Wasatch Formation.

The main body of the Wasatch Formation consists of 800–3,500 ft of mostly variegated mudstone and sandstone. The upper 600–800 ft grades laterally southeastward across the Rock Springs uplift area (corehole 6 and measured section X679, 2969, fig. 10) into the Luman Tongue of the Green River Formation and the Niland Tongue of the Wasatch Formation that occupied part of the Uinta Mountain trough. The Luman Tongue (not illustrated) is composed of mostly oil shale, and the Niland Tongue is composed mostly of interbedded sandstone, mudstone, carbonaceous shale, and oil shale. The Niland Tongue consists of mostly gray or green flood-plain deposits between corehole 22 and measured section X679, but it changes facies to mostly paludal deposits at measured section 2969.

The Rife and Scheggs Beds of the Tipton Shale Member of the Green River Formation are in contact across the eastern part of the Rock Springs uplift and western Washakie basin, but they are separated in the Green River basin by thin remnants of the Farson Sandstone Member of the Green River Formation. On the western margins of the Green River basin they are also separated by an unnamed tongue of the Wasatch Formation (fig. 10). The Scheggs Bed is 30–85 ft thick. The Rife Bed is 0–120 ft thick; it wedges out in the Green River basin near drill hole 21 (fig. 10), but thickens progressively east of there across the Rock Springs uplift and into the Washakie basin.

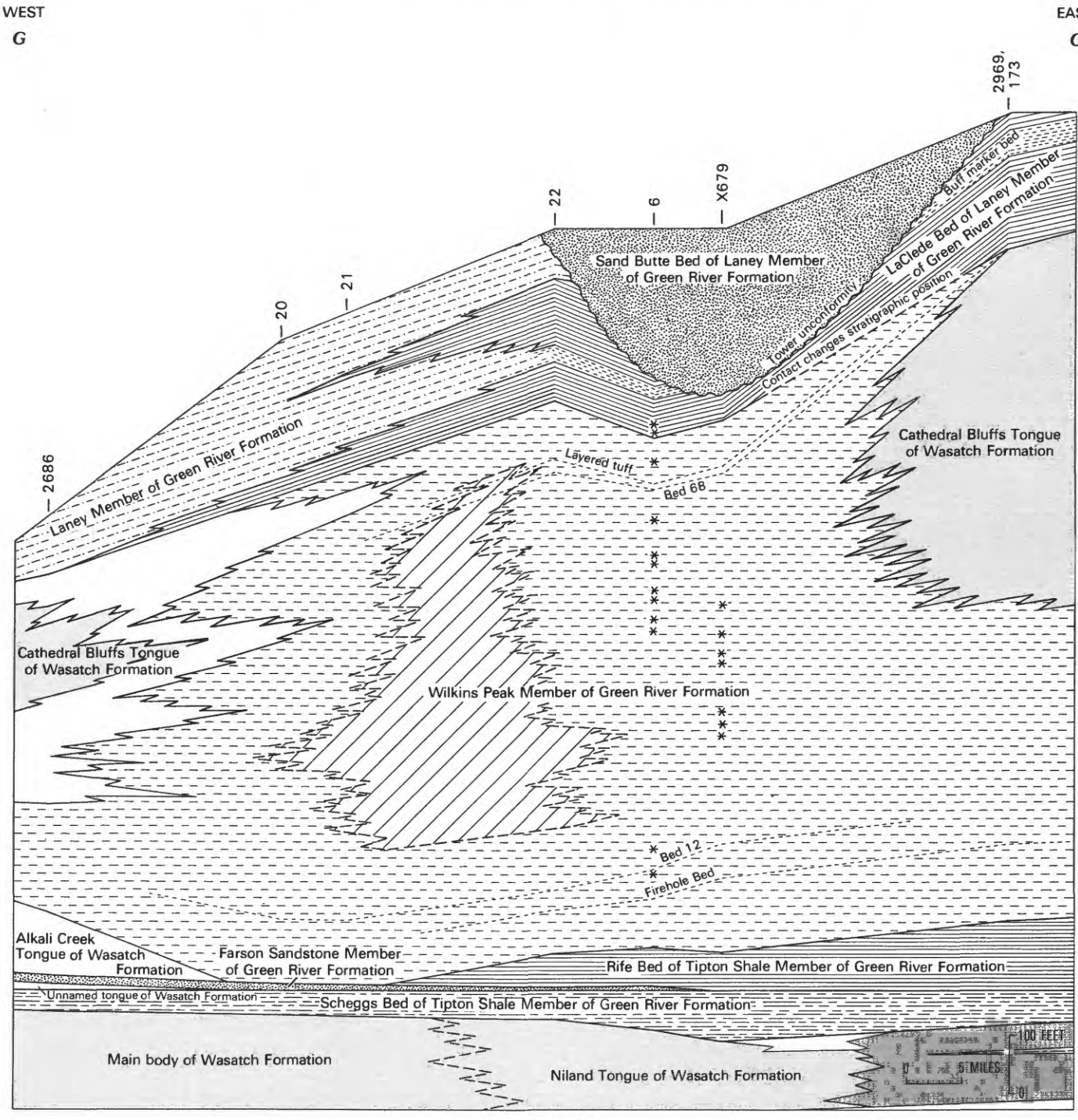
The Alkali Creek Tongue of the Wasatch Formation overlies the Farson Sandstone Member of the Green River Formation along the western margins of the Green River basin. In outcrops at measured section 2686 (fig. 10), the tongue is about 100 ft thick, but it thins rapidly eastward and is missing in the subsurface at drill hole 20 (fig. 10). The Alkali Creek Tongue is composed of mostly light to medium-gray-green mudstone and interbedded gray and brown sandstone and siltstone in outcrops at measured section 2686 (fig. 10).

The Wilkins Peak Member of the Green River Formation, including its intertongued lateral equivalents in the Cathedral Bluffs Tongue of the Wasatch Formation, thickens southeastward across correlation *G–G′* from about 570 ft along the western margins of the Green River basin (measured section 2686, fig. 10) to more than 1,000 ft along the western margins of the Washakie basin (measured section 2969, fig. 10).

The Laney Member of the Green River Formation is divided into the LaClede and Sand Butte Beds along the eastern Green River basin, Rock Springs uplift, and western Washakie basin (fig. 10, pl. 1). In other parts of the Green River basin the member remains undivided. The composition and stratigraphic relationships of the member have been discussed previously. Note, however, that the contact of the Laney and Wilkins Peak Members again changes stratigraphic position (between sections X679 and 2969, fig. 10). This contact change duplicates similar changes that occur between these units along correlations *E–E′* and *F–F′* (figs. 8 and 9).

SOUTHERN GREEN RIVER BASIN

Eocene rocks in the southern part of the Green River basin along correlation diagram *H–H′* (fig. 11) are similar in thickness and composition to those described in correlation diagram *G–G′* (fig. 10). The only major differences are the number and thickness of trona and



EXPLANATION

- Gray or tan lacustrine sandstone deposits
- Red flood-plain deposits
- Gray or green flood-plain deposits
- Mixed tan or gray freshwater lacustrine and gray or green flood-plain deposits
- Gray or green mudflat and brown or black saltwater lacustrine oil-shale deposits
- Gray or green mudflat, brown or black saltwater lacustrine oil-shale, and bedded evaporite (trona, halite) deposits; abundant salt crystals
- Brown or black saltwater lacustrine oil-shale deposits
- Tan or brown freshwater lacustrine oil-shale deposits
- Gray, brown, or black paludal deposits
- * Evaporite crystals (mostly shortite)
- Formation or lithofacies contact—Dashed where approximately located
- Unconformity
- Stratigraphic marker bed

halite beds in the evaporite section, the appearance of paludal rocks in the Ramsey Ranch Member of the Wasatch Formation in the Uinta Mountain trough (corehole 8 and drill holes and coreholes 24–27, fig. 11), and the absence by nondeposition of the Alkali Creek Tongue of the Wasatch Formation and the Farson Sandstone Member of the Green River Formation.

GREAT DIVIDE BASIN

Correlation diagram *I–I'* begins at the west on the east slopes of Steamboat Mountain in T. 23 N., R. 102 W. (measured section 2087, fig. 12), trends northward and includes parts of Bush Rim, Oregon Buttes, and Continental Peak (measured sections 2287, 958, and 3086, fig. 12), and then southeastward past the Luman Ranch (measured section 1086, fig. 12) and Niland basin (measured section 1286, fig. 12) to Lost Creek Butte in T. 23 N., R. 94 W. (measured section 2487, fig. 12). Eocene rocks along correlation *I–I'* are in places more than 5,000 ft thick. They comprise a normal Eocene stratigraphic succession, with a few exceptions. Mesas in the western part of the basin are capped by leucite lavas, the Battle Spring Formation replaces most of the Wasatch and Green River Formations along the eastern part of the basin, and cyclically deposited coal beds are present in the Niland Tongue of the Wasatch Formation.

The main body of the Wasatch Formation (only partly illustrated in fig. 12) thickens eastward across the Great Divide basin from less than 1,000 ft near measured section 2087 to more than 2,500 ft near measured section 2487 (fig. 12). The main body consists of gray and green mudstone and sandstone of flood-plain origin across the western part of the basin. Disarticulated mammal teeth and bone fragments are abundant in stream-channel sandstones. These rocks intertongue eastward with brown oil shale, gray sandstone and siltstone, dark-gray carbonaceous shale, and coal of lacustrine and paludal origins that compose the Ramsey Ranch Member, Luman Tongue, and Niland Tongue, which were deposited in the northern part of the Uinta Mountain trough (fig. 12). Arkosic sediments comprising the Battle Spring Formation entered the Great Divide basin from the Sweetwater arch located near the northeast corner of the basin (pl. 1). These sediments intertongued with the lacustrine and paludal sediments that were deposited in the Uinta Mountain trough.

FIGURE 10 (facing page).—West-east stratigraphic correlation diagram *G–G'* of intertongued Wasatch and Green River Formations across central Green River basin, Rock Springs uplift, and western Washakie basin. Numbered measured sections, drill holes, and coreholes are located and identified on plate 1. Modified from Roehler (1990a).

The Scheggs Bed of the Tipton Shale Member of the Green River Formation is consistently between 15 and 20 ft thick in outcrops along correlation *I–I'*. The bed is composed of nonresistant tan to brown oil shale, and sparse, very thin interbedded gray sandstone, siltstone, limestone, algal limestone, and tuff. A ledge-forming, limy sandstone, 1–3 ft thick, containing the mollusks *Goniobasis tenera*, *Viviparus* sp., and *Lampsilis* sp., is present at the base of the bed, and ostracodes and disarticulated fish remains are present at various stratigraphic levels.

The Rife Bed of the Tipton Shale Member of the Green River Formation is 60 ft thick at Steamboat Mountain (section 2087, fig. 12). It thickens eastward across the Great Divide basin along correlation *I–I'* to 125 ft in the Niland basin (measured section 1286, fig. 12). East of the Niland basin the Rife Bed intertongues with and is replaced by arkoses composing the Battle Spring Formation. The Rife Bed comprises mostly gray weathered, dolomitic oil shale, and some thinly interbedded gray or green mudstone, gray sandstone and siltstone, and tan tuff and algal limestone. Fossils are rare, except for a few ostracodes.

The Wilkins Peak Member of the Green River Formation is less than 60 ft thick at Steamboat Mountain in measured section 2087 (fig. 12) in the western part of the Great Divide basin. The member thickens abruptly east of Steamboat Mountain and is probably more than 250 ft thick across the central and eastern parts of the Great Divide basin, where the outcrops are covered by Quaternary alluvium. The Wilkins Peak Member weathers gray and is composed of interbedded gray or green mudstone, brown to black oil shale, and tan or gray limestone, algal limestone, sandstone, and tuff. A few thin beds in the member contain fish and ostracode fossils.

The Cathedral Bluffs Tongue of the Wasatch Formation ranges in thickness from less than 100 ft to about 700 ft from west to east across the Great Divide basin. The tongue is mostly gray or green mudstone in the Steamboat Mountain area (measured section 2087, fig. 12), but becomes variegated (mostly red) mudstone in a northeast direction along Bush Rim between measured sections 2187 and 2287 (fig. 12). This color change occurs within flood-plain deposits at the place where red, well-drained (oxidized) soils that were deposited at high topographic elevations along the basin margins graded basinward into poorly drained or water-saturated, gray and green (reduced) soils that were deposited at low topographic elevations toward the basin center. Interbedded in these mudstone deposits of the Cathedral Bluffs Tongue are some gray sandstone, siltstone, conglomerate, and reworked tuff beds, and a few very thin beds of tan or gray limestone and algal limestone of lacustrine origin. Unusual, very

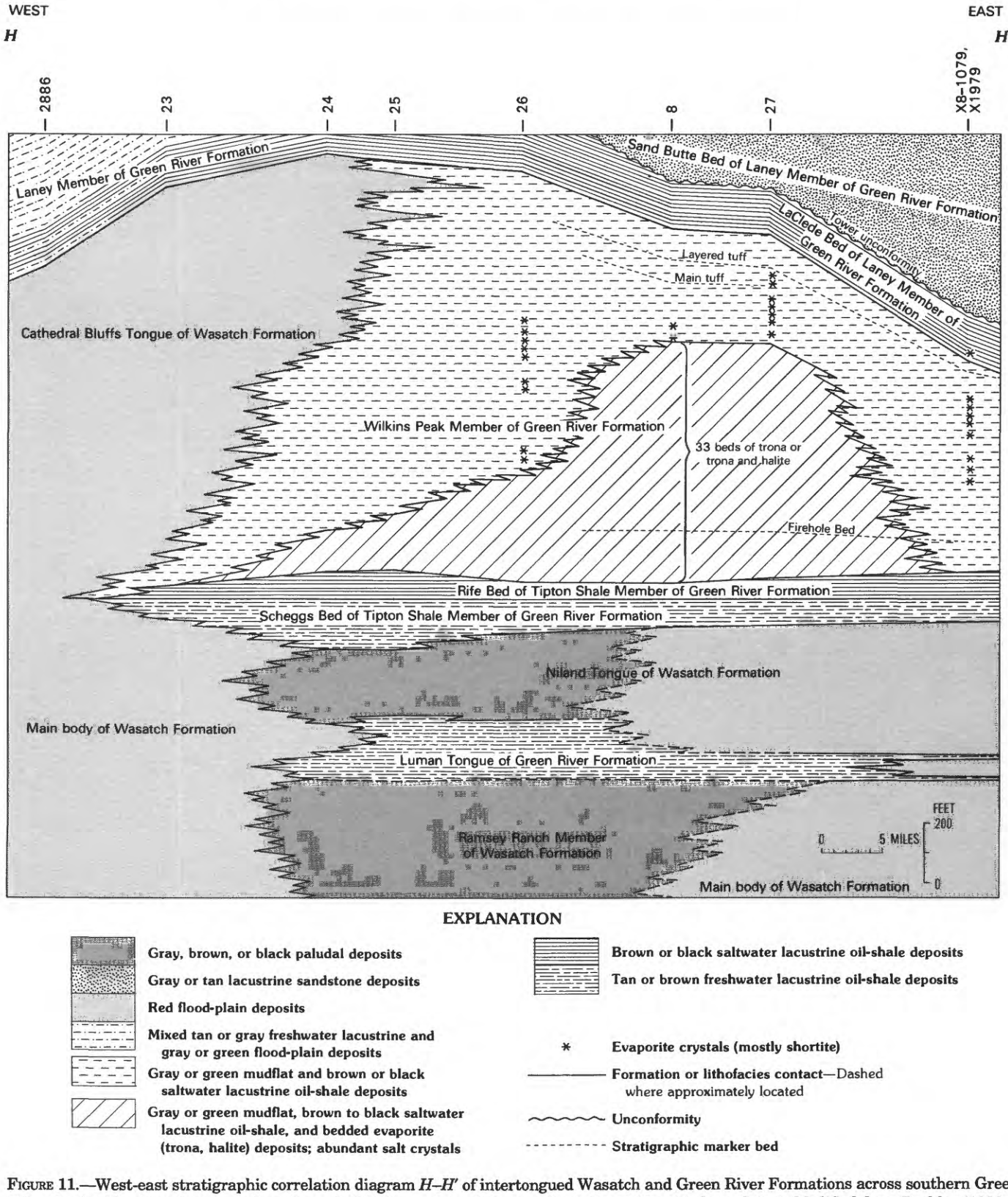


FIGURE 11.—West-east stratigraphic correlation diagram *H–H'* of intertongued Wasatch and Green River Formations across southern Green River basin. Numbered measured sections, drill holes, and coreholes are located and identified on plate 1. Modified from Roehler (1990c).

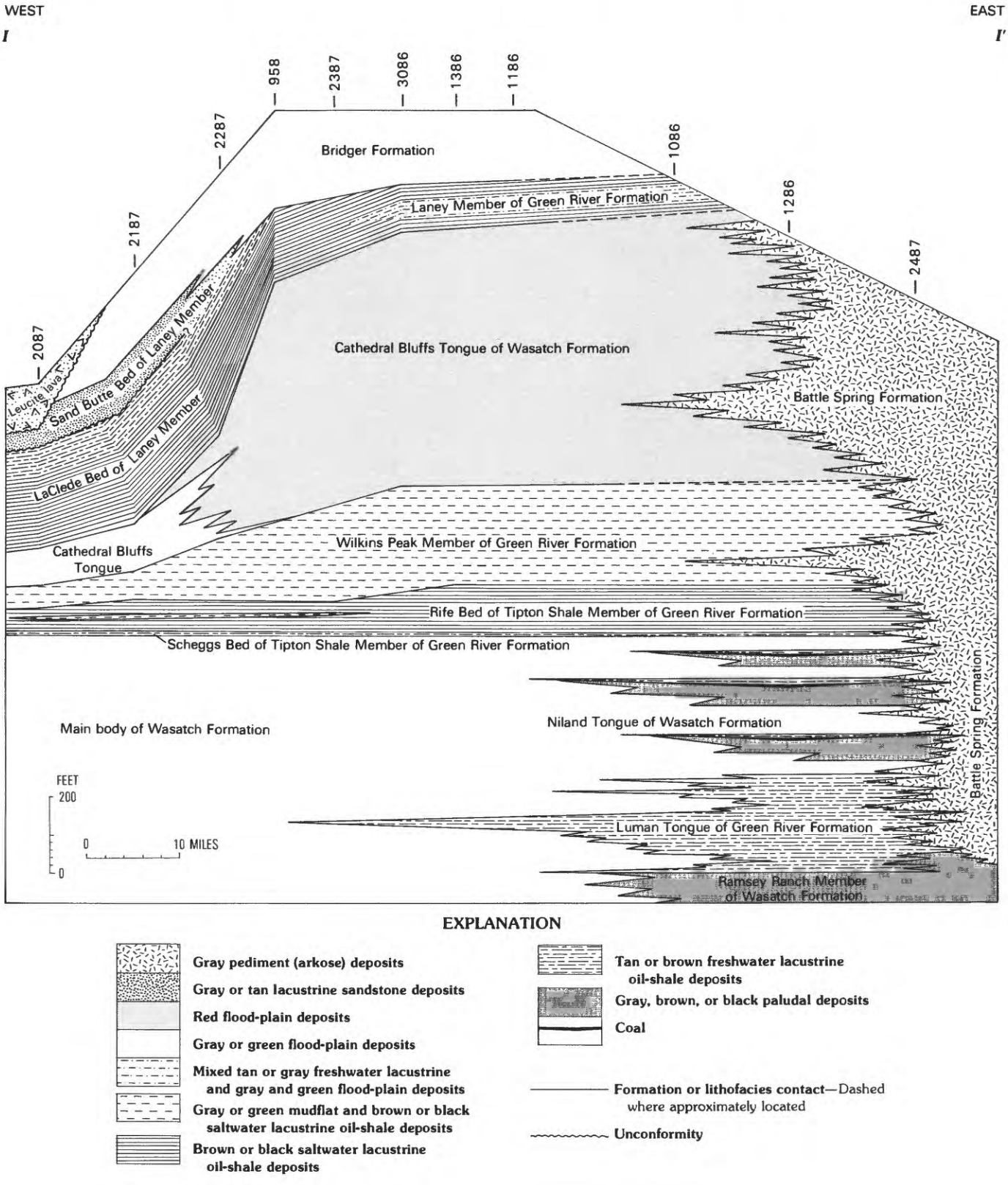


FIGURE 12.—West-east stratigraphic correlation diagram *I–I'* of Eocene rocks across Great Divide basin. Numbered measured sections are located and identified on plate 1. Modified from Roehler (1989f).

thin beds of dark-gray, carbonaceous shale of paludal origin, and brown, flaky oil shale of lacustrine origin interbedded with red mudstone of flood-plain origin are present at Bush Rim in measured section 2287 (fig. 12). Disarticulated turtle bones and scutes are abundant along outcrops of the Cathedral Bluffs Tongue. Mammal fossils are present locally.

Between measured sections 958 and 1086 (fig. 12), the undivided Laney Member of the Green River Formation weathers to nonresistant, smooth slopes composed of brown oil shale or gray mudstone that are interrupted by ledges formed by tan or gray sandstone, siltstone, limestone, and algal limestone. Beds of tan dolomitic claystone and tan or gray tuff are also present in some of the Laney measured sections. Ostracode, fish, mollusk, and turtle fossils are fairly abundant locally. The LaClede and Sand Butte Beds of the Laney Member are recognizable at Steamboat Mountain (measured section 2087, fig. 12), but between there and Oregon Buttes (measured section 958, fig. 12) the Sand Butte Bed thins and wedges out. At Steamboat Mountain the LaClede Bed is about 275 ft thick. It thins in a northeast direction to about 200 ft at Oregon Buttes (measured section 958, fig. 12) and to about 135 ft at Continental Peak (measured section 3086, fig. 12). The Sand Butte Bed is 50 ft thick at Steamboat Mountain (measured section 2087, fig. 12), where it unconformably overlies the LaClede Bed and is unconformably overlain by leucite lavas of late Tertiary age, which are part of the Leucite Hills volcanic field.

The Bridger Formation is more than 500 ft thick at Oregon Buttes (measured section 958, fig. 12) and at Continental Peak (measured section 3086, fig. 12). It is composed of drab-gray mudstone and thinly interbedded gray sandstone, siltstone, and limestone. Turtle and wood fossils are abundant and are often found concentrated on ledges at the base of mudstone slopes.

WASHAKIE BASIN

Correlation diagram *J–J′* (fig. 13) begins at outcrops along the west slopes of Kinney Rim near the west edge of the Washakie basin in T. 15 N., R. 101 W. (measured section 1171, fig. 13). It continues eastward in subsurface rocks across the center of the basin and ends at outcrops measured a few miles east of Flattop Mountain, in T. 14 N., R. 92 W., at the east edge of the basin (measured section 9782, fig. 13). Eocene rocks in the Washakie basin comprise a typical stratigraphic succession and are about 8,000 ft thick.

The main body of the Wasatch Formation, only partly illustrated in correlation *J–J′*, ranges from 1,500 to 4,500 ft in thickness. Along outcrops in the eastern part of the Washakie basin, the main body is composed of variegated mudstone and sandstone (between drill hole 31 and measured section 9782, fig. 13). These flood-plain deposits intertongue westward in the subsurface with mostly gray carbonaceous shale, coal, and brown oil shale that compose the Ramsey Ranch Member, Luman Tongue, and Niland Tongue, which were deposited in the Uinta Mountain trough (between measured section 1171 and drill hole 30, fig. 13). The Ramsey Ranch Member is as much as 800 ft thick, and the Luman Tongue and Niland Tongue are each 300–400 ft thick. The thickest parts of these units are near the center of the Uinta Mountain trough (drill holes 28 and 29, fig. 13).

The Scheggs Bed of the Tipton Shale Member of the Green River Formation is composed of mostly brown oil shale, with a few thin interbeds of gray sandstone, siltstone, algal limestone, and tuff. The Scheggs Bed is generally 75–130 ft thick in outcrops along the margins of the basin, but it also thickens in the subsurface to about 350 ft near the center of the Uinta Mountain trough.

The Rife Bed of the Tipton Shale Member is present only across the western and northern parts of the Washakie Basin. It is composed of dark-brown to black oil shale, and a few thin interbeds of tan algal limestone. The bed is 225 ft thick in outcrops at the west edge of Washakie basin (measured section 1171, fig. 13); it thickens slightly eastward in the subsurface to 290 ft in the Uinta Mountain trough (drill hole 28, fig. 13), but thins again farther eastward by intertonguing with the Wilkins Peak Member of the Green River Formation. The Rife Bed is entirely replaced by the Wilkins Peak Member in subsurface rocks near the center of the basin (drill hole 31, fig. 13).

The Wilkins Peak Member of the Green River Formation ranges in thickness from 0 to 300 ft, but it is missing by nondeposition in the southeastern part of the Washakie basin. The member is composed of gray and green mudstone, siltstone, sandstone, clay-pebble conglomerate, and brown oil shale, and tan algal limestone. It thins eastward across the basin by intertonguing with the Cathedral Bluffs Tongue of the Wasatch Formation, and it wedges out near measured section 9782 (fig. 13).

The Cathedral Bluffs Tongue, 1,000–2,000 ft thick, is composed mostly of variegated mudstone, gray siltstone and arkose, and sparse, thinly interbedded tan algal limestone. It intertongues at its top with the LaClede Bed of the Laney Member or is overlain by the Godiva Rim Member of the Green River Formation.

The Godiva Rim Member of the Green River Formation in correlation *J–J′* intertongues westward

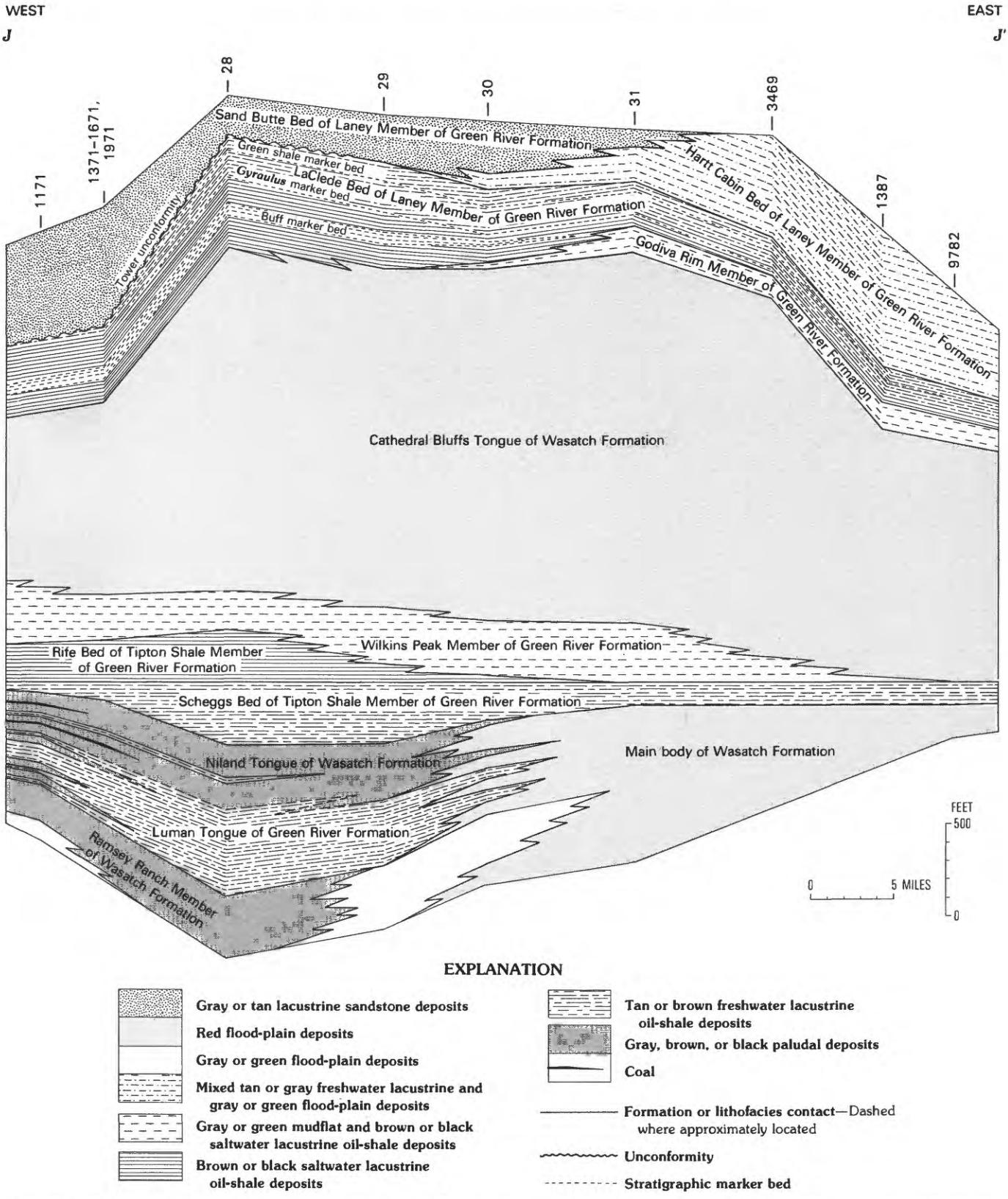


FIGURE 13.—West-east stratigraphic correlation diagram *J*–*J'* of intertongued Wasatch and Green River Formations across Washakie basin. Numbered measured sections and drill holes are located and identified on plate 1. Modified from Roehler (1991a).

with and is replaced by the lower part of the LaClede Bed of the Laney Member of the Green River Formation. In outcrops along the eastern margins of the Washakie basin, it is 150–200 ft thick, and is composed of brown oil shale, gray-brown, silty kerogenaceous shale, gray or tan sandstone, siltstone, and limestone, and brown algal limestone. Outcrops of the member generally weather drab gray.

The type sections of the LaClede, Hartt Cabin, and Sand Butte Beds of the Laney Member of the Green River Formation are located in the Washakie basin (Roehler, 1973). As discussed previously, the LaClede Bed is the basal lacustrine oil shale unit of the Laney Member, the Hartt Cabin Bed is a mixed lacustrine and fluvial unit of the Laney Member, and the Sand Butte Bed comprises a mostly lacustrine tuffaceous sandstone and siltstone lens in the Laney Member. The Sand Butte Bed unconformably overlies the LaClede Bed in the western part of the Washakie basin, and it intertongues with the Hartt Cabin Bed in the eastern part of the basin. The thicknesses of the LaClede, Hartt Cabin, and Sand Butte Beds are varied, but their combined thickness may exceed 1,500 ft.

The Washakie Formation overlies the Sand Butte and Hartt Cabin Beds of the Laney Member. The formation is mostly fluvial in origin and more than 3,100 ft thick. It is not included in correlation *J–J'* (fig. 13), but is described in detail in Chapter D of this volume.

WESTERN SAND WASH BASIN

Correlation diagram *K–K'* (fig. 14) begins near the west edge of the Sand Wash basin at Vermillion Creek in T. 11 N., R. 101 W. (measured sections 4773, 4873, fig. 14), continues southeastward across the basin in the subsurface in oil and gas drill holes (drill holes 32–34, fig. 14), and emerges at outcrops on Godiva Rim at the south edge of the basin in T. 8 N., R. 96 W. (measured section 187, fig. 14). The combined total thickness of Eocene rocks along correlation *K–K'* exceeds 9,500 ft.

The main body of the Wasatch Formation is locally as much as 6,000 ft thick at the west edge of the Sand Wash basin adjacent to the Sparks Ranch thrust fault, where it is composed of mostly gray and green or variegated mudstone and sandstone. Southeastward along correlation *K–K'*, between measured sections 4773, 4873 and drill hole 32 (fig. 14), the upper 1,000 ft of the main body changes lithology to mostly gray shale, carbonaceous shale, and limestone, brown oil shale, and coal, which were deposited in the arm or lobe of the Uinta Mountain trough that projected southeastward around the east end of the Uinta Mountains. These rocks are assigned to the Ramsey Ranch Member of the Wasatch Formation, Luman Tongue of the Green River Formation, and Niland Tongue of the Wasatch Formation. Mammal, fish, and reptile fossils are locally abundant in all of these units.

The Scheggs Bed of the Tipton Shale Member of the Green River Formation is more than 300 ft thick in most of the western part of the Sand Wash basin, where it is composed of mostly brown oil shale. The oil shale intertongues in places with sandstone and siltstone that are located along former shorelines of the lake. One of these shoreline sandstones is present at Hardgrove Rim (measured section 187, fig. 14). *Goniobasis tenera*, *Viviparus* sp., and *Lampsilis* sp. are locally abundant at several stratigraphic levels in the Scheggs Bed, particularly along shorelines.

The Rife Bed of the Tipton Shale Member is present in an arm or lobe of the Uinta Mountain trough that was located along the east end of the Uinta Mountains. In outcrops there, the bed is 230 ft thick and is composed mostly of dark-brown to black oil shale (measured sections 4773, 4873, fig. 14). Interbedded with the oil shale are a few beds of tan algal limestone, and gray sandstone, siltstone, shale, and mudstone. The Rife Bed thins southeastward across the western part of the Sand Wash basin by intertonguing with and replacement by the Wilkins Peak Member of the Green River Formation (fig. 14).

The Wilkins Peak Member of the Green River Formation is also present in the arm or lobe of the Uinta Mountain trough at the east end of the Uinta Mountains. In outcrops there (measured sections 4773, 4873, fig. 14), the member is composed of 225 ft of gray and green mudstone and thin interbedded brown oil shale, tan algal limestone, and gray shale, sandstone, and siltstone. Southeast of measured section 4773, 4873 or basinward along correlation *K–K'*, it intertongues with the overlying Cathedral Bluffs Tongue. The Wilkins Peak Member wedges out in the subsurface near drill hole 34 (fig. 14).

The Cathedral Bluffs Tongue of the Wasatch Formation is 1,600–1,900 ft thick. It is composed of variegated (mostly red) mudstone and gray sandstone and siltstone, and a few very thin interbeds of tan algal limestone and gray carbonaceous shale. Disarticulated vertebrate remains are fairly abundant along outcrops.

The type section of the Godiva Rim Member of the Green River Formation is located near measured section 187 on Godiva Rim (fig. 14). The member is about 300 ft thick in exposures along Godiva Rim, but it thins in the subsurface northwest of the rim by intertonguing with and replacement by the Cathedral

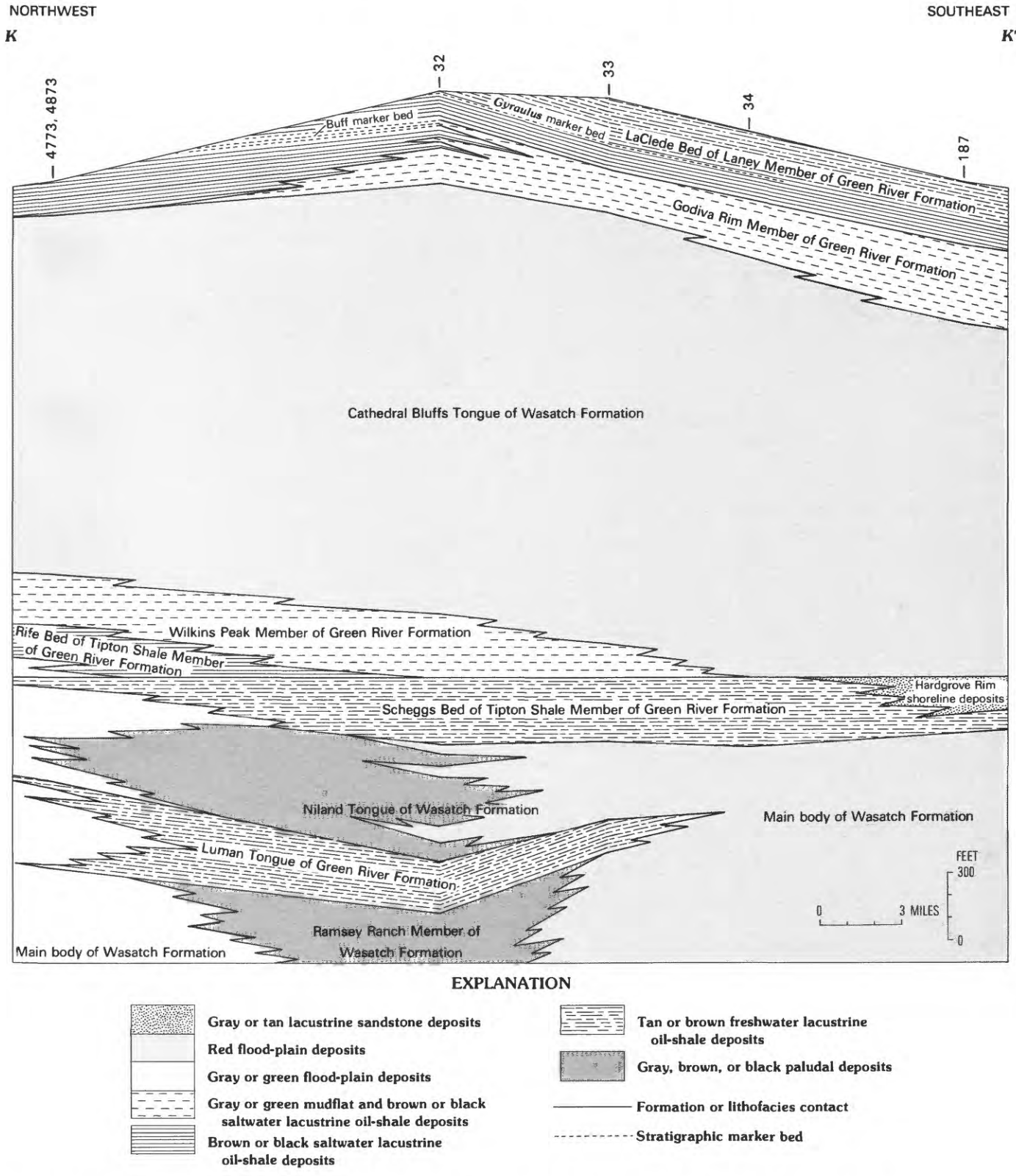


FIGURE 14.—Northwest-southeast stratigraphic correlation diagram *K–K'* of intertongued Wasatch and Green River Formations across western part of Sand Wash basin. Numbered measured sections and drill holes are located and identified on plate 1. Modified from Roehler (1991b).

Bluffs Tongue of the Wasatch Formation and the LaClede Bed of the Laney Member of the Green River Formation. The Godiva Rim Member is composed of mostly gray mudstone and thinly interbedded brown oil shale and gray sandstone.

The LaClede Bed of the Laney Member of the Green River Formation ranges in thickness from about 400 to 800 ft along correlation *K–K'*. It is composed of brown oil shale and some thinly interbedded gray sandstone, siltstone, mudstone, limestone, and algal limestone. The buff marker bed and *Gyraulus* marker bed are present in outcrops along the western margins of the Sand Wash basin. Mollusks are present in many of the sandstone and limestone beds.

The Bridger (Washakie) Formation (not shown in correlation *K–K'*) intertongues with the upper part of the Laney Member of the Green River Formation. The formation is hundreds of feet thick and composes the uppermost Eocene rocks exposed in the Sand Wash basin. The name Bridger Formation is used in the basin, but the rocks more closely resemble the Washakie Formation in color and composition. Many of the stratigraphic marker beds that are present in the Washakie basin, such as the robins-egg-blue bed (Chapter D, this volume), are also present in the Sand Wash basin. The entire Bridger Formation was examined during field investigations in the Sand Wash basin, but only parts of it were measured and described.

AREAL DISTRIBUTION AND THICKNESS OF STRATIGRAPHIC UNITS

The paleogeographic distribution of Eocene stratigraphic units in the greater Green River basin is shown on isopach maps (figs. 15–22 and 24–30). The maximum areal extent of the stratigraphic units on these maps is indicated either by the geographic locations of zero thickness lines, or by contacts with laterally equivalent stratigraphic units or thrust faults. It is apparent from the isopach maps that depositional centers (areas of maximum sediment accumulation) frequently shifted geographic locations within the greater Green River basin during the Eocene Epoch. Most of this depositional shifting was in response to contemporaneous tectonic activity in the mountains surrounding the basin. During the Eocene Epoch, the Rock Springs uplift was rarely a barrier to sedimentation between the eastern and western parts of the greater Green River basin, and thus the greater Green River basin was not divisible into equivalents of its Holocene subbasins, namely the Green River, Great Divide, Washakie, and Sand Wash basins.

MAIN BODY OF WASATCH FORMATION

The main body of the Wasatch Formation was deposited throughout the greater Green River basin during the Eocene Epoch. It has irregular thicknesses largely because it intertongues in its upper part with tongues and members of the Green River Formation. Where the Luman Tongue, Tipton Shale Member, Farson Sandstone Member, and Wilkins Peak Member of the Green River Formation wedge out toward the margins of the basin, the main body of the Wasatch Formation replaces them by expanding vertically in section and merging with equivalents of the Niland Tongue, Alkali Creek Tongue, and Cathedral Bluffs Tongue of the Wasatch Formation. Near tectonically active margins of the basin, the main body of the Wasatch grades laterally into the Hoback, Pass Peak, or Battle Spring Formations, or into unnamed fanglomerates. The main body is thin or missing on the upthrown sides of the Wind River, Darby, and Sparks Ranch thrust faults, which were active during the early Eocene.

The thickness of the main body of the Wasatch Formation ranges from less than 1,000 ft across the northern and middle parts of the Rock Springs uplift, and about the same thickness in places along the margins of the greater Green River basin, to more than 9,000 ft in the northern part of the basin on the southwest flank of the Wind River Mountains adjacent to the Wind River thrust fault. The main body of the formation is more than 6,000 ft thick in the Sand Wash basin near the east end of the Uinta Mountains, where it is truncated by the Sparks Ranch thrust fault, and more than 4,000 ft thick in southern parts of the Green River and Washakie basins. The main body thickened in the Uinta Mountain trough (fig. 15). The isopach configurations in figure 15 reveal the presence of several other structural irregularities where the main body thins across saddles and around basinward-plunging anticlines.

RAMSEY RANCH MEMBER OF WASATCH FORMATION

The Ramsey Ranch Member was deposited in the Uinta Mountain trough and in an arm or lobe of the trough that projected southeastward from the trough around the east end of the Uinta Mountains (fig. 16). During this period of deposition, swamps and shallow freshwater lakes were present along the Uinta Mountain trough, and between these swamps and lakes and in the areas surrounding the trough were extensive flood plains.

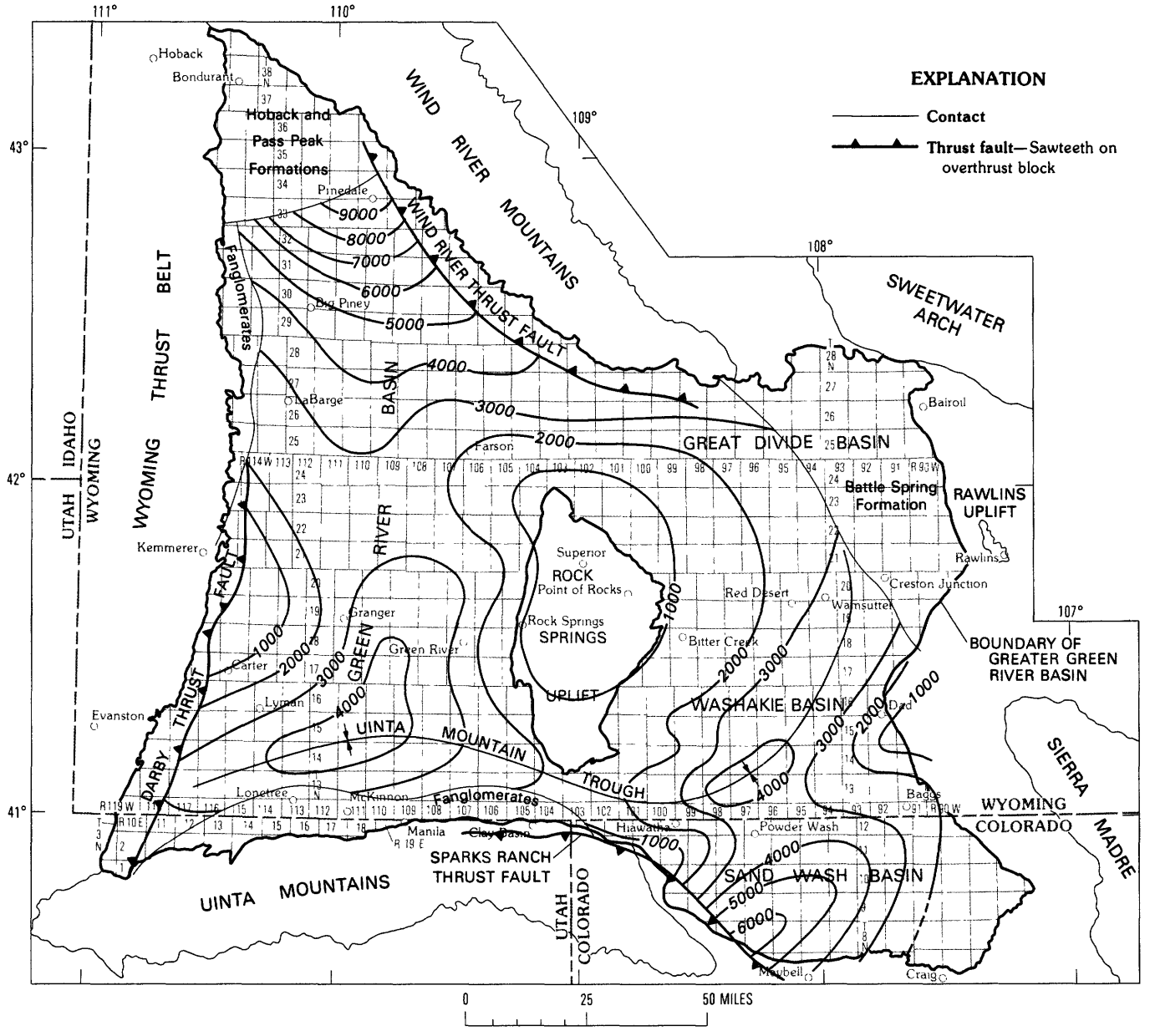


FIGURE 15.—Isopach map of main body of Wasatch Formation. Isopach interval 1,000 ft; dashed where inferred.

The lakes that were present in the Uinta Mountain trough during deposition of the Ramsey Ranch Member represent the embryonic stages of deposition of the Green River Formation in Eocene Lake Gosiute. I proposed (Roehler, 1965) that these beds be named the Ramsey Ranch Member of the Green River Formation. The proposal was made because a similar section of rocks of mixed lacustrine, paludal, and fluvial origins that is present in the terminal, drying-up stages of Lake Gosiute historically has been included in the Laney Member of the Green River Formation. Some geologists disagreed with my stratigraphic interpretations, because they believed that the Ramsey Ranch does not contain sufficient numbers and thicknesses of lacustrine rocks for the member to be included in the Green River Formation. As a result of these disagreements, the name Ramsey Ranch was never formally adopted as a member of the Green River Formation, but it is herein formally redesignated a member of the Wasatch Formation. The Ramsey Ranch Member is a mixture of rocks that are not characteristic of either the Wasatch or Green River Formations. The member, nonetheless, whether assigned either to the Wasatch or to the Green River Formation,

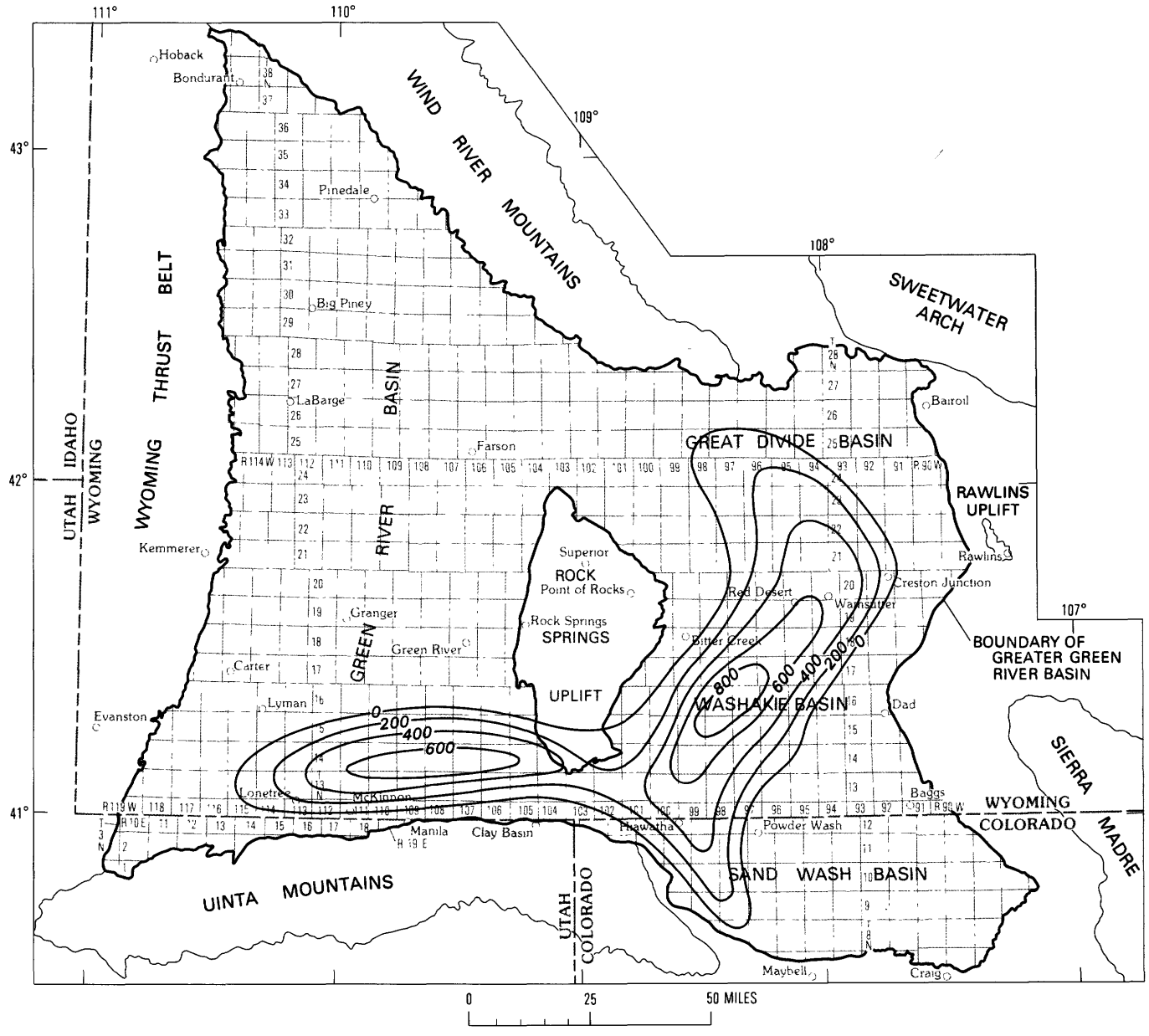


FIGURE 16.—Isopach map of Ramsey Ranch Member of Wasatch Formation deposited in Uinta Mountain trough. Isopach interval 200 ft.

is a distinct stratigraphic unit that requires special recognition because it contains important deposits of oil shale, uranium, and coal. The uranium and coal deposits in the member in the Great Divide basin were investigated in detail by Pipiringos (1961) and Masursky (1962). Five measured sections of the member were published by Roehler (1991c).

The Ramsey Ranch Member has a maximum thickness of about 800 ft near the center of the Washakie basin (fig. 16). It thins west of the Washakie basin to less than 400 ft across the southern plunge of the axis of the Rock Springs uplift, but thickens again to more than 600 ft along the northern flank of the Uinta Mountains.

LUMAN TONGUE OF GREEN RIVER FORMATION

The sediments composing the Luman Tongue of the Green River Formation were deposited mostly in freshwater lakes that occupied an enlarged Uinta Mountain trough (fig. 17). The lakes that had formerly occupied the trough during deposition of the Ramsey Ranch Member were shallow and dispersed, but during

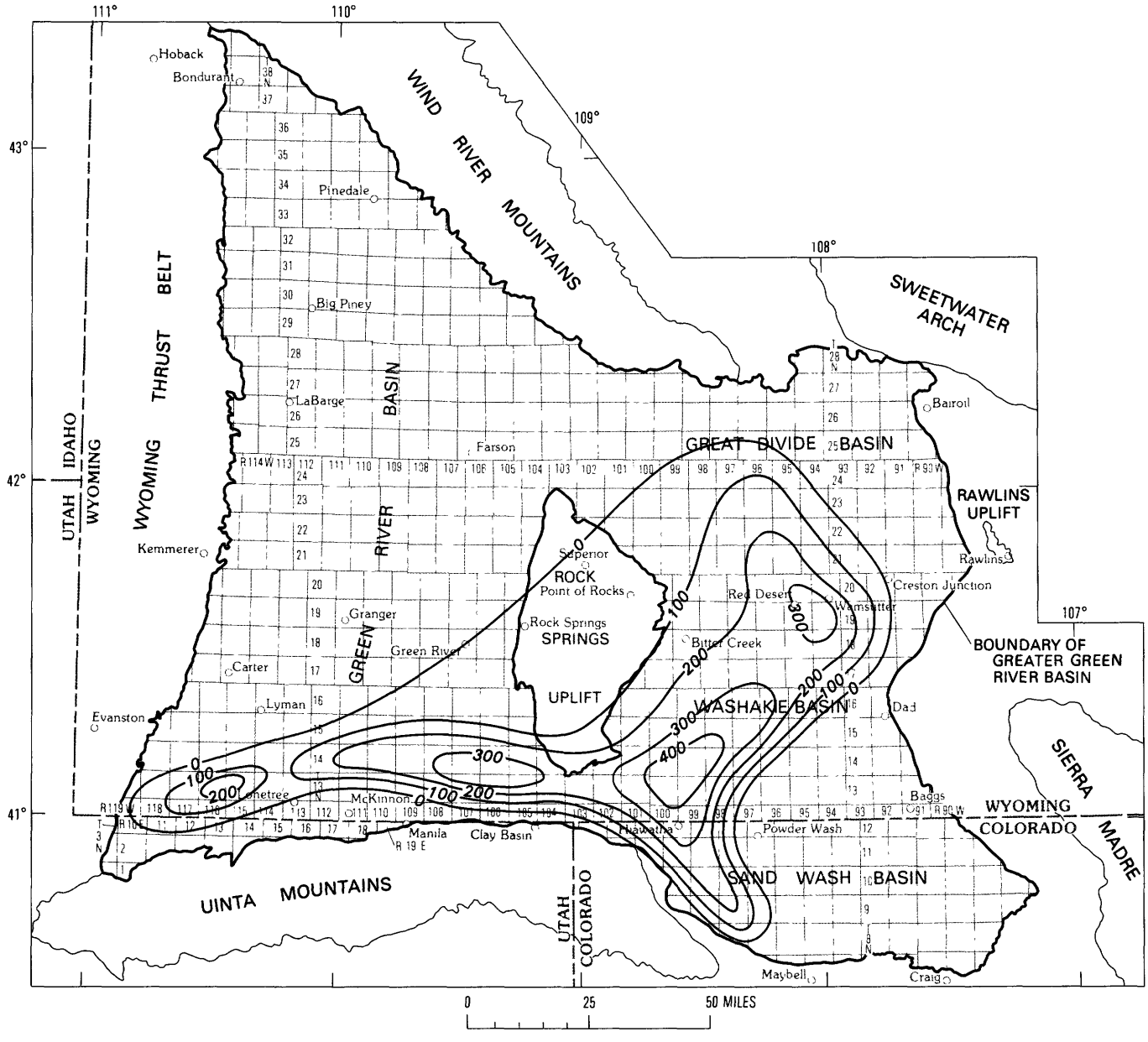


FIGURE 17.—Isopach map of Luman Tongue of Green River Formation. Isopach interval 100 ft.

the deposition of the Luman Tongue they expanded, filled the trough, and eventually became a single, large, deep, freshwater lake, fringed by extensive swamps. At its maximum development the lake was more than 175 mi long. Relative to its length, the lake was narrow, from only 13 to 40 mi wide along the north flank of the Uinta Mountains, but it expanded in an eastward direction across the Rock Springs uplift area, and was more than 60 mi wide in the Washakie and Great Divide basins. An arm of the lake was present in the Sand Wash basin near the east end of the Uinta Mountains in a similar geographic location to that of the lake, swamp, and flood-plain sediments that were present in the underlying Ramsey Ranch Member (compare figs. 16 and 17).

The Luman Tongue has a maximum recorded thickness of 455 ft in T. 13 N., R. 100 W. in outcrops that were measured in the southwestern part of the Washakie basin. It is more than 300 ft thick in two other places—north of the Uinta Mountains in the Green River basin, and near Wamsutter, Wyo., in the northern part of the Washakie basin.

NILAND TONGUE OF WASATCH FORMATION

The Niland Tongue of the Wasatch Formation has the same areal distribution as the Luman Tongue of the Green River Formation, for where the Luman Tongue is missing, the name Niland Tongue is discarded and the Niland Tongue becomes an undivided part of the underlying main body of the Wasatch Formation. The Niland Tongue was deposited during a less humid period of the early Eocene, when the preceding, large Luman lake had retreated and was replaced by small, freshwater lakes, swamps, and flood plains. The resulting environments were similar in type and location to those of the earlier deposited Ramsey Ranch Member.

The Niland Tongue is more than 400 ft thick in the southeastern part of the Green River basin, in the southwestern part of the Washakie basin, and in the western part of the Sand Wash basin (fig. 18). It thins irregularly from those areas. Structurally related thinning is present in large areas of the northeastern Washakie and southeastern Great Divide basins and in small areas in the southwestern Washakie basin, where the tongue is less than 100 ft thick.

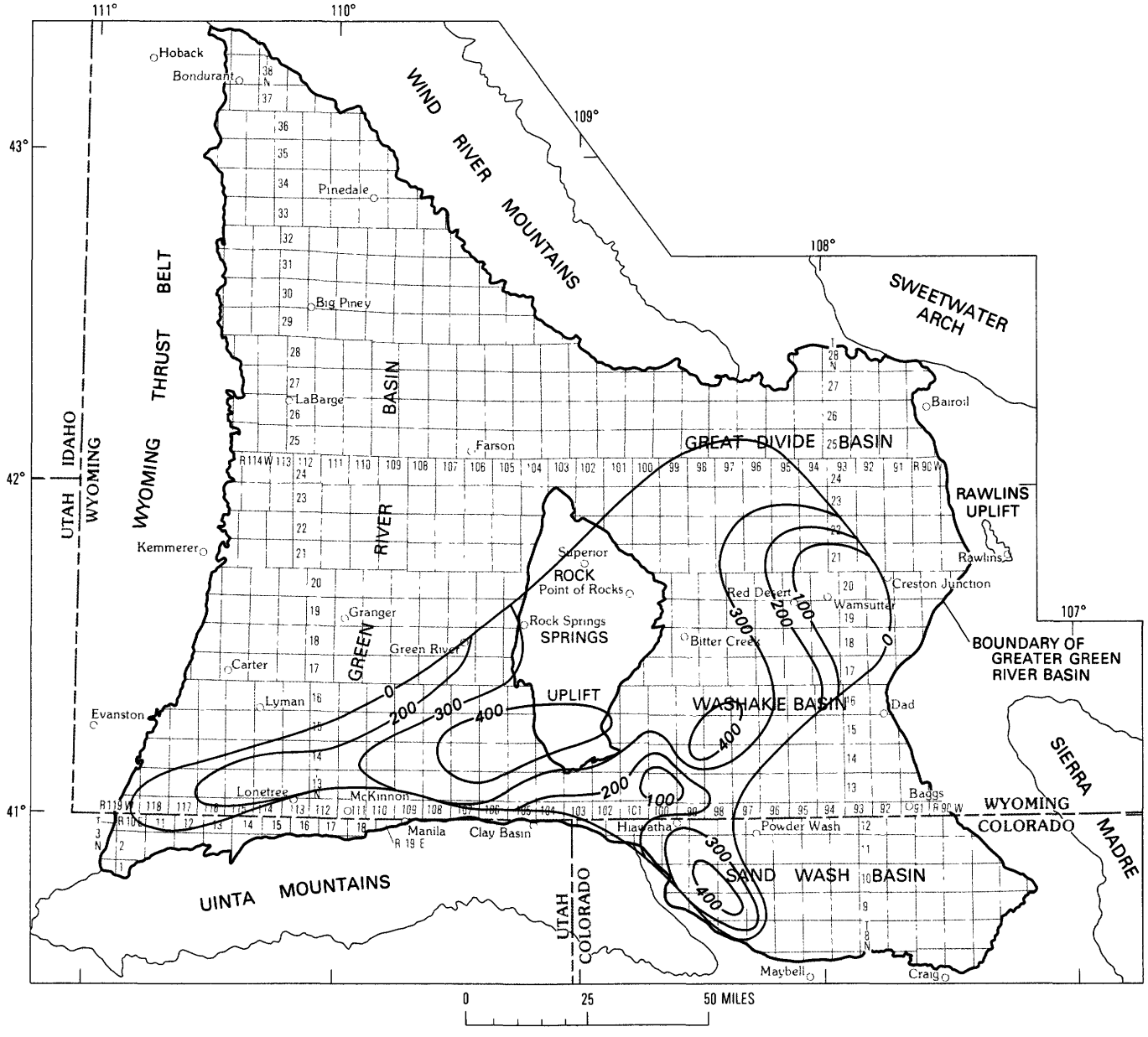


FIGURE 18.—Isopach map of Niland Tongue of Wasatch Formation. Isopach interval 100 ft.

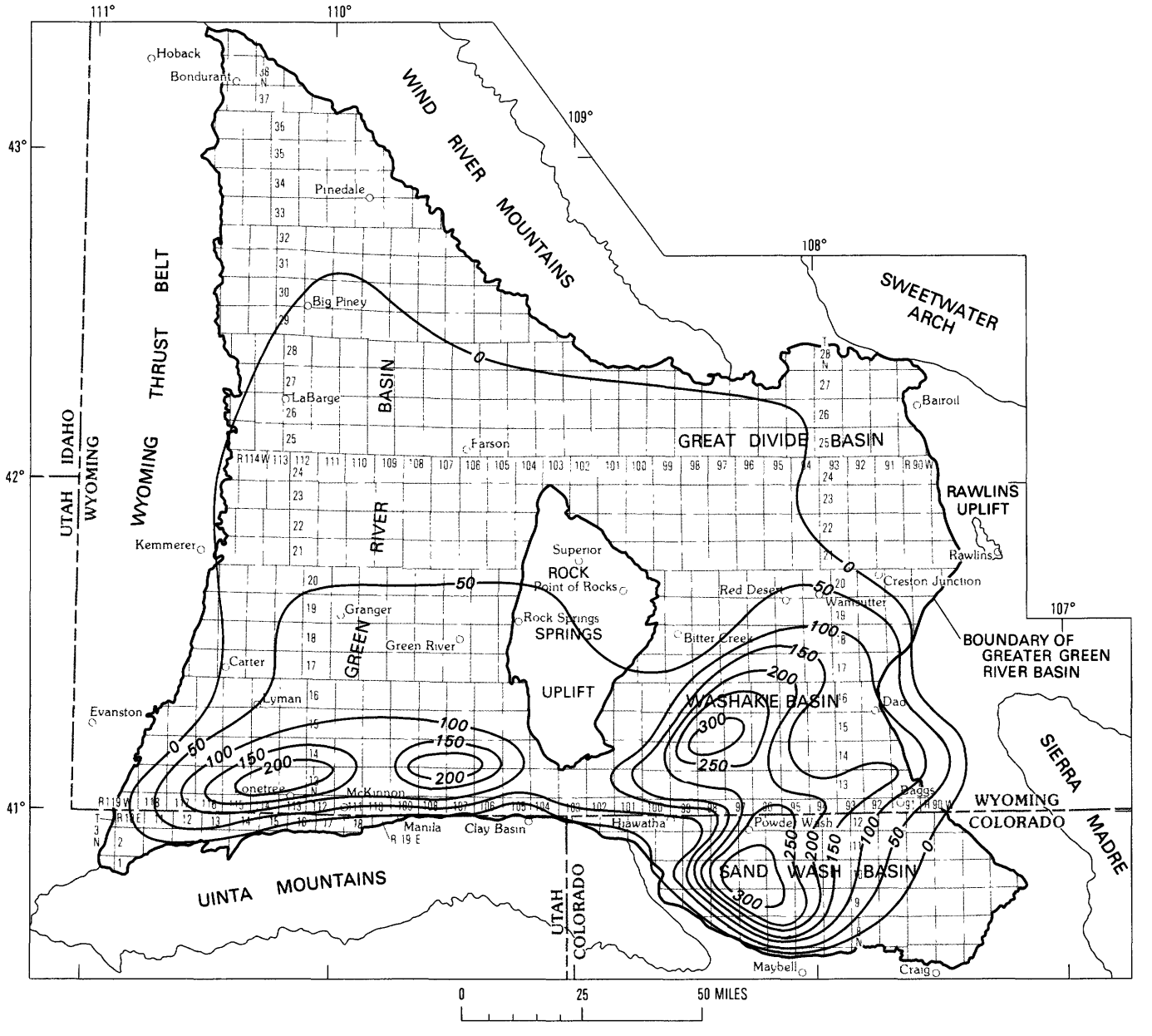


FIGURE 19.—Isopach map of Scheggs Bed of Tipton Shale Member of Green River Formation. Isopach interval 50 ft.

SCHEGGS BED OF TIPTON SHALE MEMBER OF GREEN RIVER FORMATION

Sediments composing the Scheggs Bed were deposited in a large freshwater lake that expanded from the reestablished Uinta Mountain trough and eventually nearly inundated the greater Green River basin area. At its maximum development the lake was irregularly rectangular in shape, more than 180 mi long, and about 100 mi wide (fig. 19). Lake Gosiute retreated from the central and northern parts of the Green River basin during the middle and late stages of deposition of the Scheggs Bed. In those areas the lake was filled in by coarse delta and shoreline sand that composes the Farson Sandstone Member of the Green River Formation and by mud and sand deposited on flood plains that formed the Alkali Creek Tongue of the Wasatch Formation (fig. 1).

Trends of thickening in the Scheggs Bed suggest that the basin of Lake Gosiute at this time was asymmetric—deep to the south and very shallow to the north. The bed is more than 300 ft thick in the southwestern part of the Washakie basin and in the western part of the Sand Wash basin (fig. 19). It is more than 200 ft thick in two areas located along the trend of the Uinta Mountain trough north of the

Uinta Mountains, and less than 50 ft thick in a broad area that encompasses the Great Divide basin, northern Rock Springs uplift, and central and northern Green River basin. Northeast-trending structural thinning is apparent in the isopach configurations across the eastern Washakie and western Sand Wash basins.

FARSON SANDSTONE MEMBER OF GREEN RIVER FORMATION

The Farson Sandstone Member of the Green River Formation, named in Chapter B of this volume, consists of mainly sandstone of lacustrine delta and shoreline origins. The sandstone was derived from rocks exposed in the Wind River Mountains following a period of late early Eocene tectonic activity. As previously mentioned, the delta and shoreline sands contemporaneously filled in the northwest part of Lake Gosiute, while oil-shale-forming muds were being deposited in most other parts of the lake basin as the Scheggs Bed. The delta and shoreline infilling across the northern and central parts of the Green River basin eventually reduced the size of the lake by about 45 percent.

The Farson Sandstone Member is more than 400 ft thick in the vicinity of Farson, Wyo., in T. 25 N., R. 104 W., but it thins laterally from there to the west, south, and east (fig. 20). The member is missing in the southern part of the Green River basin, but thin remnants are present along the western margins of the Great Divide basin, across the northern tip of the Rock Springs uplift, and along part of the east edge of the Wyoming thrust belt.

ALKALI CREEK TONGUE OF WASATCH FORMATION

The Alkali Creek Tongue of the Wasatch Formation is named and described in Chapter B of this volume. The tongue has small areal extent but is a prominent lithologic unit in outcrops in the northwestern part of the Green River basin, from a few miles south of La Barge, Wyo., northward to near Big Piney, Wyo. The outcrops of the tongue are mostly mudstone that weathers bright green and interbedded sandstone that weathers dark brown. These contrasting colors distinguish it from overlying rocks in the Wilkins Peak Member that weather light to medium gray and from underlying rocks in the Farson Sandstone Member that weather drab tan and gray.

A maximum recorded thickness for the Alkali Creek Tongue, 232 ft, was in a stratigraphic section measured in sec. 4, T. 26 N., R. 112 W., about 1½ mi northeast of La Barge, Wyo. (fig. 21). The tongue, however, probably thickens to more than 300 ft west of there. The tongue thins and merges with the main body of the Wasatch Formation southward along the western margins of the Green River basin. This merging is discernible in outcrops by a conspicuous color change that takes place about 12 mi north of Carter, Wyo. There, the bright-green and dark-brown colors that characterize the Alkali Creek Tongue change southward into variegated (mostly red) colors that characterize the main body of the Wasatch Formation.

The Alkali Creek Tongue is missing as a result of Tertiary and Quaternary erosion north of Big Piney, Wyo., and along eastern parts of the Wyoming thrust belt. Consequently, the original northern and western boundaries of the tongue are unknown. The tongue intertongues with and is replaced by the Farson Sandstone Member of the Green River Formation in subsurface rocks in southeastward, downdip directions from where it crops out (figs. 1, 21).

RIFE BED OF TIPTON SHALE MEMBER OF GREEN RIVER FORMATION

The Rife Bed of the Tipton Shale Member of the Green River Formation was deposited in a saltwater stage of Lake Gosiute, in a large lake that had no outlet. The lake occupied a basin which was more than 150 mi long and as much as 100 mi wide (fig. 22). The deepest parts of the lake, indicated by the areas of thick sediment accumulations, were located along the Uinta Mountain trough.

The Rife Bed is locally more than 200 ft thick in three places: (1) in the southeastern part of the Green River basin in Ts. 13–14 N., Rs. 105–111 W.; (2) in the southwestern part of the Washakie basin in Ts. 12–16 N., Rs. 98–101 W.; and (3) in the south-central part of the Great Divide basin in Ts. 19–21 N., Rs. 94–96 W. It is less than 100 ft thick across most of the Rock Springs uplift and southern Green River basin, and is missing by nondeposition in the northern and central parts of the Green River basin, in the southeastern part of the Washakie basin, and in most of the Sand Wash basin. Embayments along the southern margins of the lake were present at the east end of the Uinta Mountains and along the eastern part of the Washakie basin (fig. 22).

WILKINS PEAK MEMBER OF GREEN RIVER FORMATION

The Wilkins Peak Member of the Green River Formation was deposited cyclically during saltwater

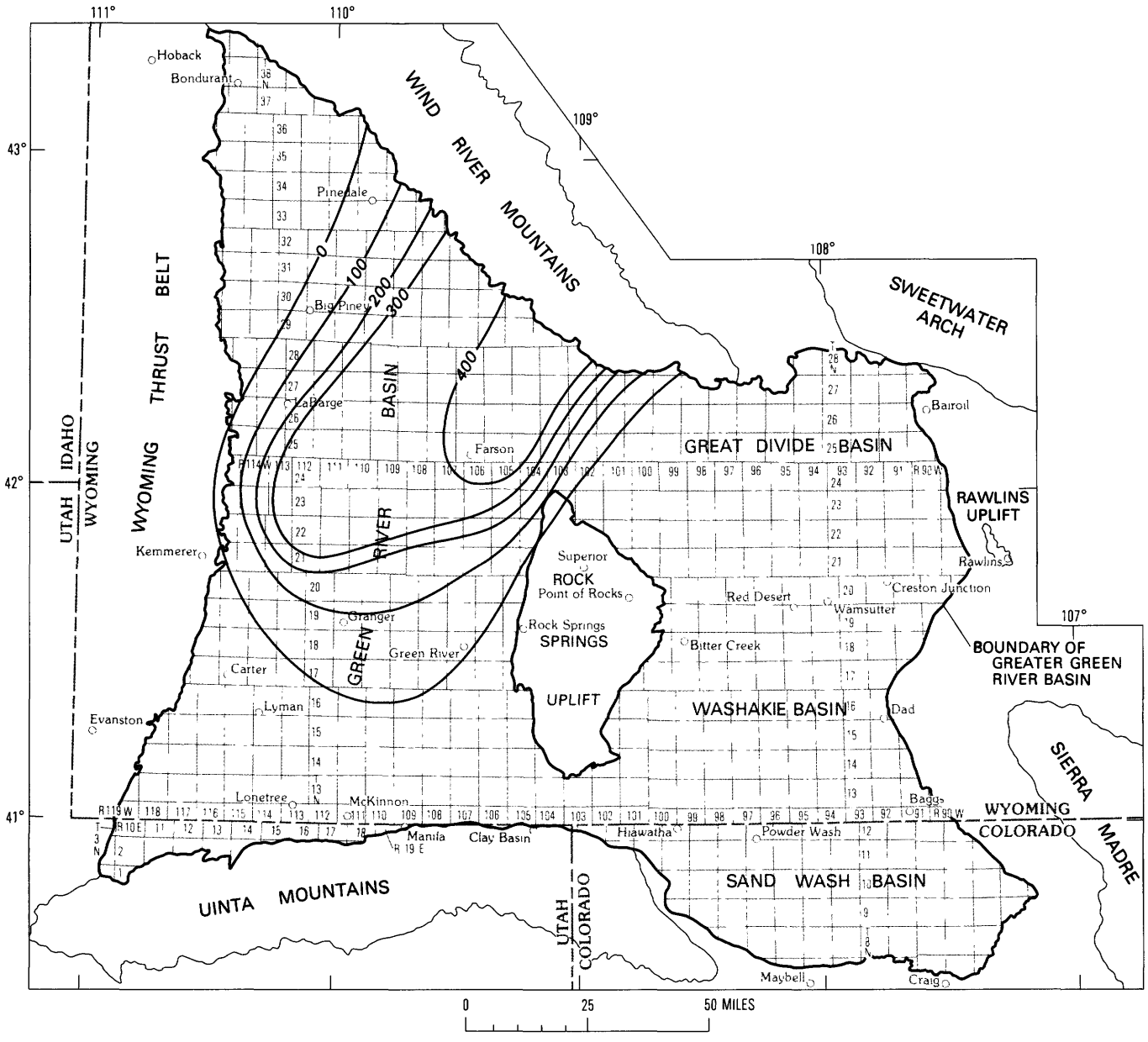


FIGURE 20.—Isopach map of Farson Sandstone Member of Green River Formation. Isopach interval 100 ft.

stages of Lake Gosiute that alternated with periods when the lake retreated to salt pans and dried up. A north-south correlation across the Green River basin (fig. 23) locates the stratigraphic positions of 77 beds of oil shale, which were deposited during expanded salt-water stages of the lake. Mudflat mudstones, playa-lake dolomites, and bedded evaporites are present between the numbered oil-shale beds. Beds 1–11 in figure 23 are defined in this report as "lower part of the Wilkins Peak Member," beds 12–67 are defined as "middle part of the Wilkins Peak Member," and beds 68–77 are defined as "upper part of the Wilkins Peak Member."

The Wilkins Peak is divided into lower, middle, and upper parts because of changing paleogeographies and changing salinities of the waters of Lake Gosiute. The lower part of the Wilkins Peak Member (fig. 24) includes rocks that were deposited along a generally east-west-trending depression that conforms to the Uinta Mountain trough, in geographic locations very similar to those of the preceding Rife Bed (fig. 22). The sediments that formed the middle part of the Wilkins Peak Member (fig. 25) were generally restricted to the Green River basin and Rock Springs uplift areas, after the lake had retreated from the Great Divide, Washakie, and Sand Wash basin areas. The upper part of

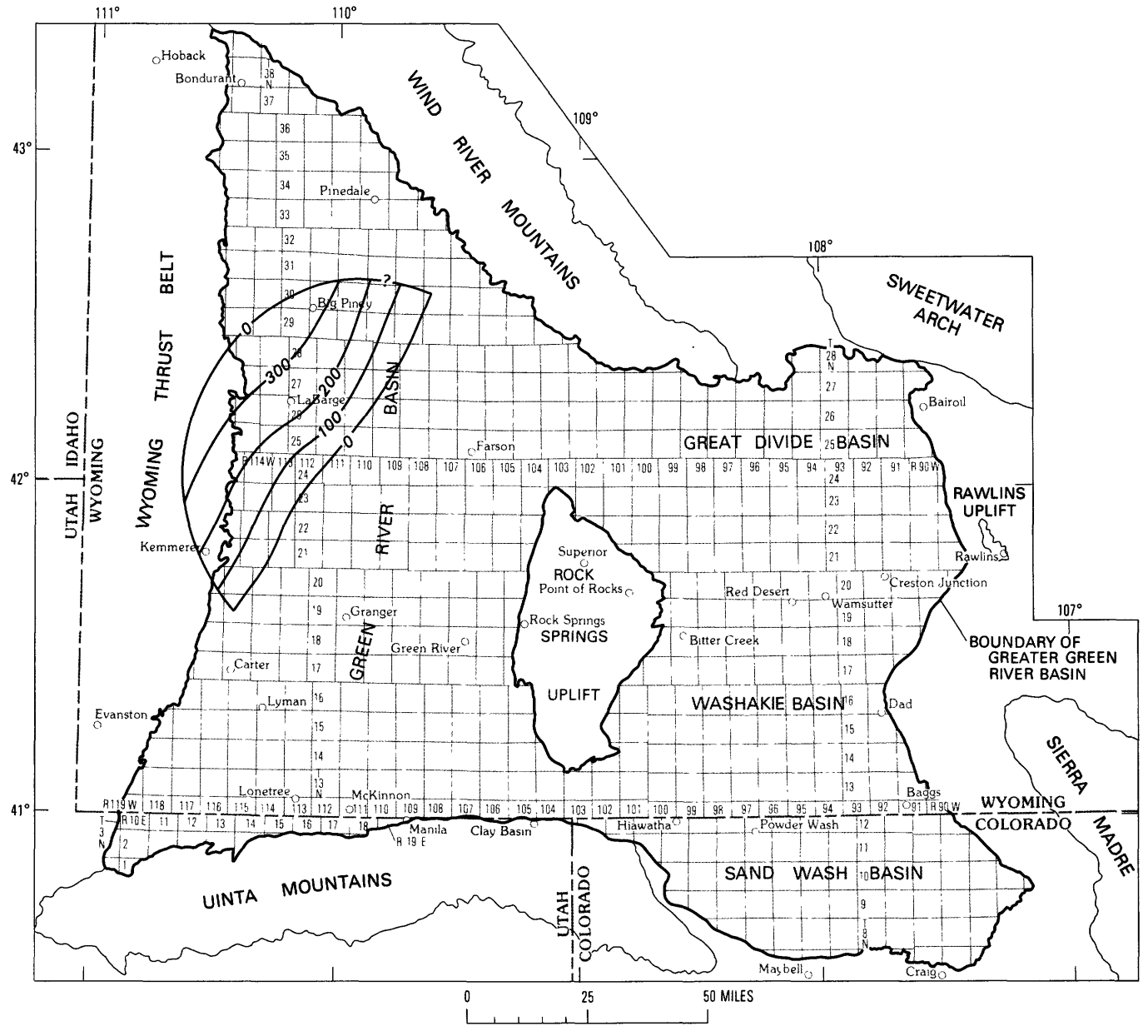


FIGURE 21.—Isopach map of Alkali Creek Tongue of Wasatch Formation. Isopach interval 100 ft; queried where eroded and extent uncertain.

the Wilkins Peak Member (fig. 26) was deposited as the lake increased in size and changed configurations a second time, and as the waters began to freshen after an outlet opened near the east end of the Uinta Mountains.

LOWER PART OF WILKINS PEAK MEMBER

The lower part of the Wilkins Peak Member (beds 1–11, fig. 24) was deposited in a closed lake basin that was approximately 135 mi long (east-west) and 75 mi wide (north-south). The saltwater lakes that occupied the basin contracted periodically to salt pans that were located in the southern part of the Green River basin. Ten beds of trona or trona and halite were deposited in these salt pans in Ts. 13–18 N., Rs. 109–113 W.

More than 200 ft of sediments was deposited in the lower part of the Wilkins Peak Member in local areas in Ts. 14–15 N., Rs. 108–110 W. in the southern part of the Green River basin and in Ts. 13–16 N., Rs. 98–101 W. in the southwestern part of the Washakie basin. The thick sediment accumulations in the southwestern

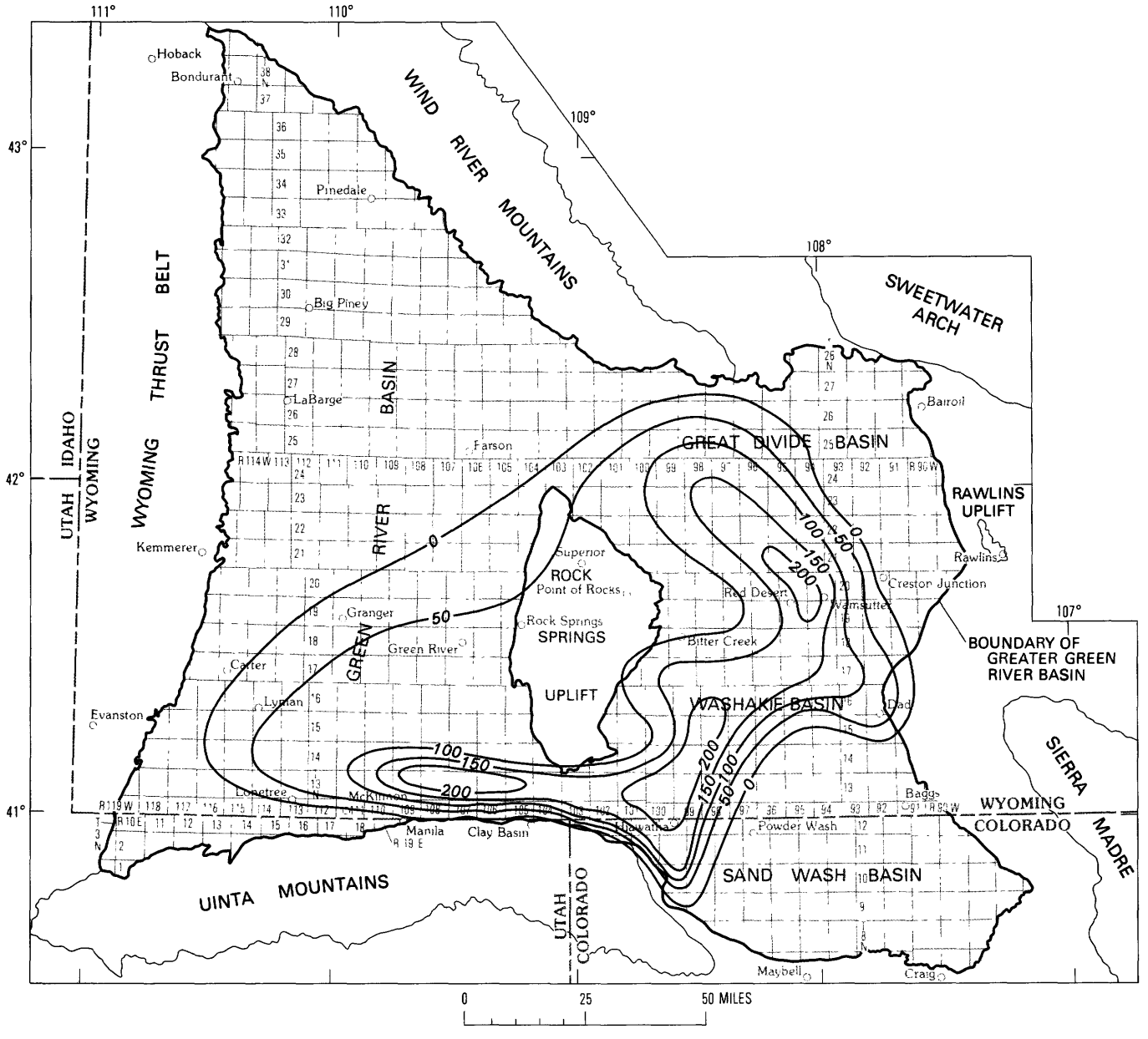


FIGURE 22.—Isopach map of Rife Bed of Tipton Shale Member of Green River Formation. Isopach interval 50 ft.

part of the Washakie basin were located in an area of active basin subsidence and rapid sediment infilling, but where no bedded evaporites were deposited. An embayment along the south margin of the lake basin was again present near the east end of the Uinta Mountains (fig. 24).

MIDDLE PART OF WILKINS PEAK MEMBER

The greater Green River basin was tilted from east to west at the beginning of deposition of the middle part of the Wilkins Peak Member (beds 12–68, fig. 23) in response to tectonic activity in the mountains located along the eastern margins of the basin (fig. 25). As the lake retreated from the Great Divide, Washakie, and Sand Wash basin areas in response to this tilting, the saltwater lacustrine and mudflat sediments that had been deposited in those areas in the lower part of the Wilkins Peak Member were subsequently replaced by fluvial (flood-plain) sediments that make up the Cathedral Bluffs Tongue of the Wasatch Formation (fig. 1).

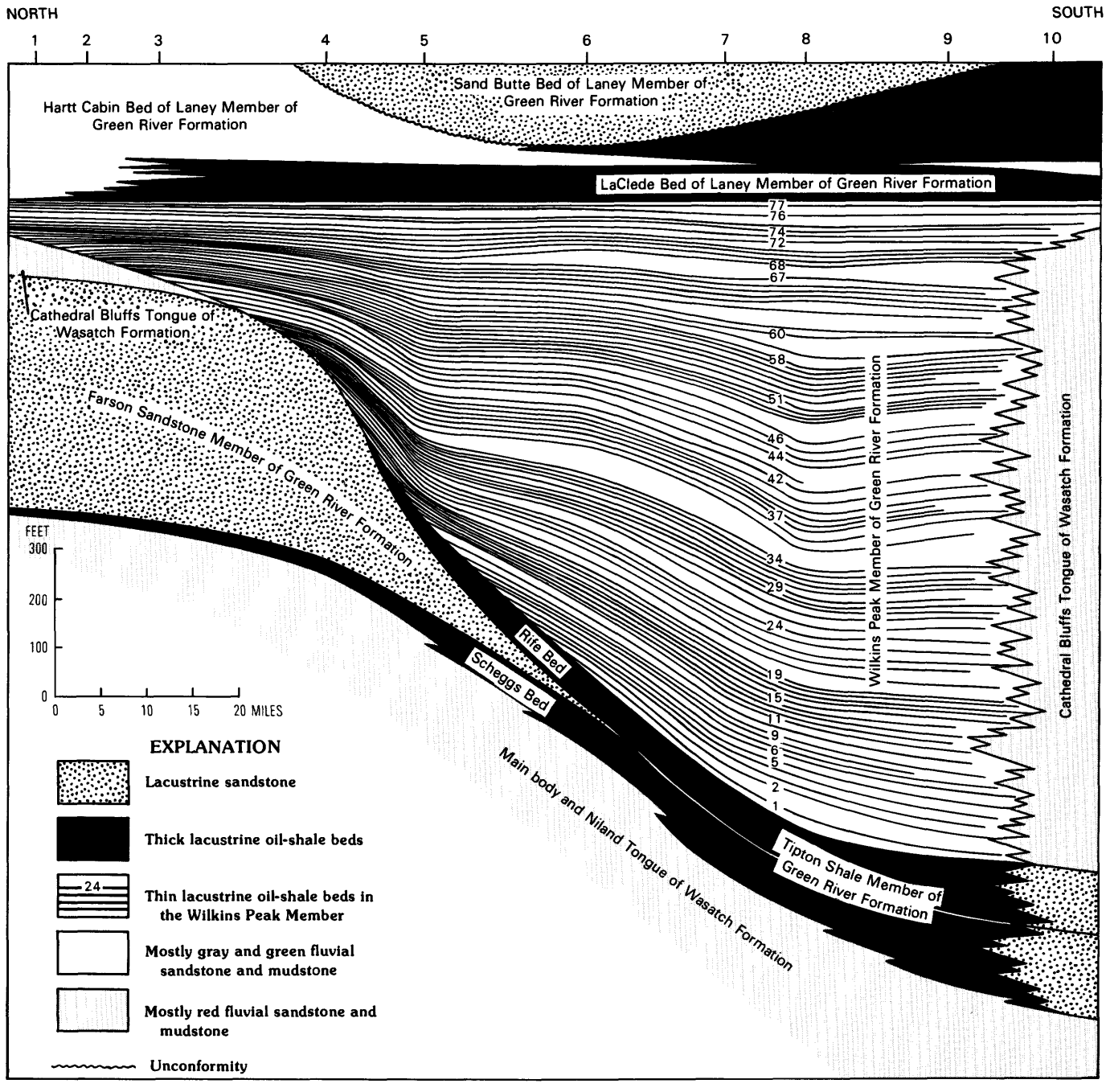
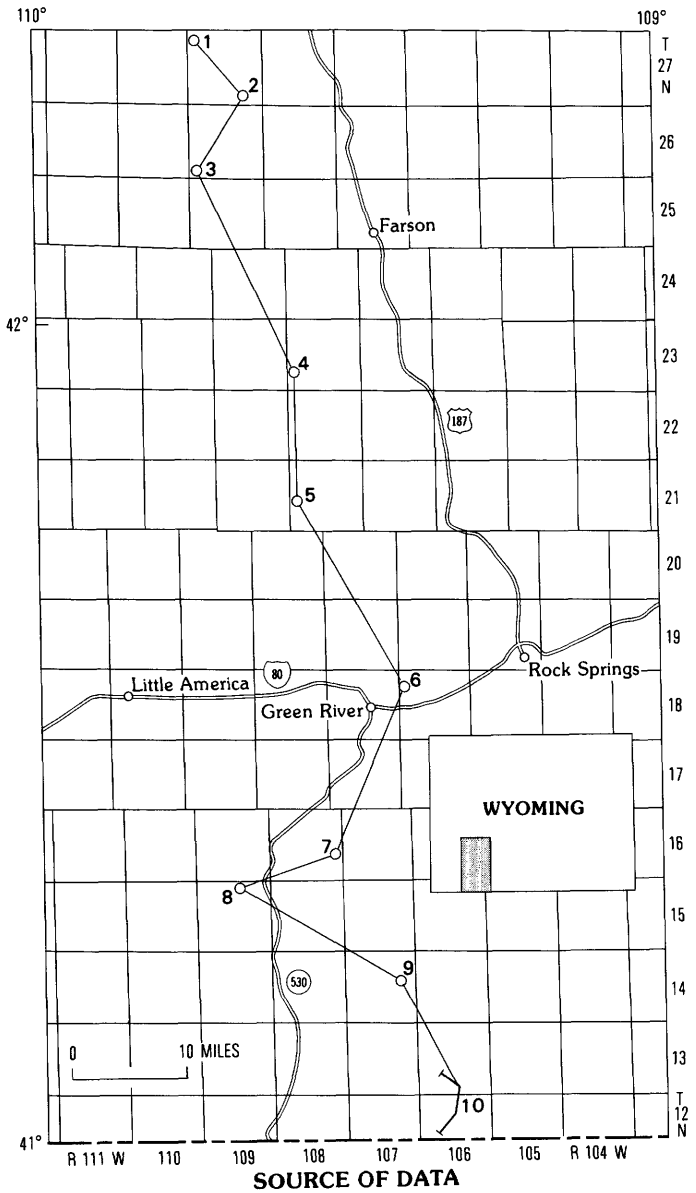


FIGURE 23 (above and facing page).—North-south restored stratigraphic correlation of Wilkins Peak Member of Green River Formation and adjacent formations in greater Green River basin. Oil-shale beds in Wilkins Peak Member are numbered 1–77. Modified from Roehler (1990a).

The basin of Lake Gosiute during deposition of the middle part of the Wilkins Peak Member was irregularly circular in shape and from 85 to 100 mi wide (fig. 25). Saltwater lakes expanded and contracted across this closed lake basin in similar cyclic fashion as those in which the lower part of the Wilkins Peak Member was deposited. Following lake contractions to salt pans, at least 28 beds of trona or trona and halite were deposited in Ts. 13–21 N., Rs. 106–113 W.

The middle part of the Wilkins Peak Member is more than 900 ft thick in Ts. 14–16 N., Rs. 107–112 W., along an east-west-trending remnant of the Uinta



SOURCE OF DATA

1. U.S. Department of Energy, Wyoming No. 13, sec. 6, T. 27 N., R. 108 W.
2. U.S. Department of Energy, Wyoming No. 12, sec. 35, T. 27 N., R. 108 W.
3. U.S. Department of Energy, Wyoming No. 11, sec. 31, T. 26 N., R. 108 W.
4. U.S. Bureau of Mines, Wyoming No. 1, sec. 30, T. 23 N., R. 107 W.
5. Union Pacific Railroad Company, Blue Rim 44–19, sec. 19, T. 21 N., R. 107 W.
6. Energy Research and Development Administration, White Mountain No. 1, sec. 7, T. 18 N., R. 106 W.
7. Energy Research and Development Administration, Blacks Fork No. 1, sec. 24, T. 16 N., R. 108 W.
8. Union Pacific Railroad Company, El Paso No. 44–3, sec. 3, T. 15 N., R. 109 W.
9. U.S. Department of Energy, Currant Creek Ridge No. 1, sec. 14, T. 14 N., R. 107 W.
10. U.S. Geological Survey, Measured section No. 1 (Roehler, 1981), T. 12–13 N., R. 106 W.

Mountain trough. The middle part thins abruptly southward from this area toward the Uinta Mountains and less abruptly to the north, east, and west across the Green River basin, Rock Springs uplift, and eastern part of the Wyoming thrust belt.

UPPER PART OF WILKINS PEAK MEMBER AND STRATIGRAPHIC EQUIVALENTS

Lake Gosiute expanded southeastward into the western parts of the Washakie and Sand Wash basins (fig. 26) during deposition of the upper part of the Wilkins Peak Member (beds 68–77, fig. 23). During this expansion an outlet of the lake opened east of the Uinta Mountains (Chapter C, this volume). Evaporite deposition gradually ended following the opening of the outlet as the lake waters began to freshen.

Stratigraphic correlations (Roehler, 1990b) indicate that the basal part of the LaClede Bed of the Laney Member in the northern Green River basin and western Washakie and Sand Wash basins is the stratigraphic equivalent of the upper part of the Wilkins Peak Member in the central and southern parts of the Green River basin (shaded areas in fig. 26). The units are mapped this way on the State geologic map of Wyoming (Love and Christiansen, 1985). The change in the stratigraphic position of the contacts of these units is made apparent by the presence of the layered tuff, which is less than 0.5 ft thick and consists of seven uniform layers of tuff. The layered tuff forms a remarkable time-stratigraphic marker bed across the entire Green River basin between beds 69 and 70 (fig. 23).

The upper part of the Wilkins Peak Member (and its LaClede Bed equivalents) has a maximum thickness of slightly more than 100 ft in the central and southern Green River basin and in the southwest Washakie and western Sand Wash basins (fig. 26). It was not deposited in the Great Divide basin.

CATHEDRAL BLUFFS TONGUE OF WASATCH FORMATION

The Cathedral Bluffs Tongue of the Wasatch Formation is composed of variegated (mostly red) fluvial rocks that intertongue with and are replaced from the margins toward the center of the greater Green River basin by rocks of mostly lacustrine origin that constitute the Wilkins Peak Member (fig. 1). The basal part of the Cathedral Bluffs Tongue also intertongues with the underlying Tipton Shale Member, and the upper part intertongues with the overlying Laney and Godiva Rim Members. In the northeastern part of the greater Green River basin, the Cathedral Bluffs Tongue intertongues with and is replaced by white and tan arkose composing the Battle Spring Formation. In

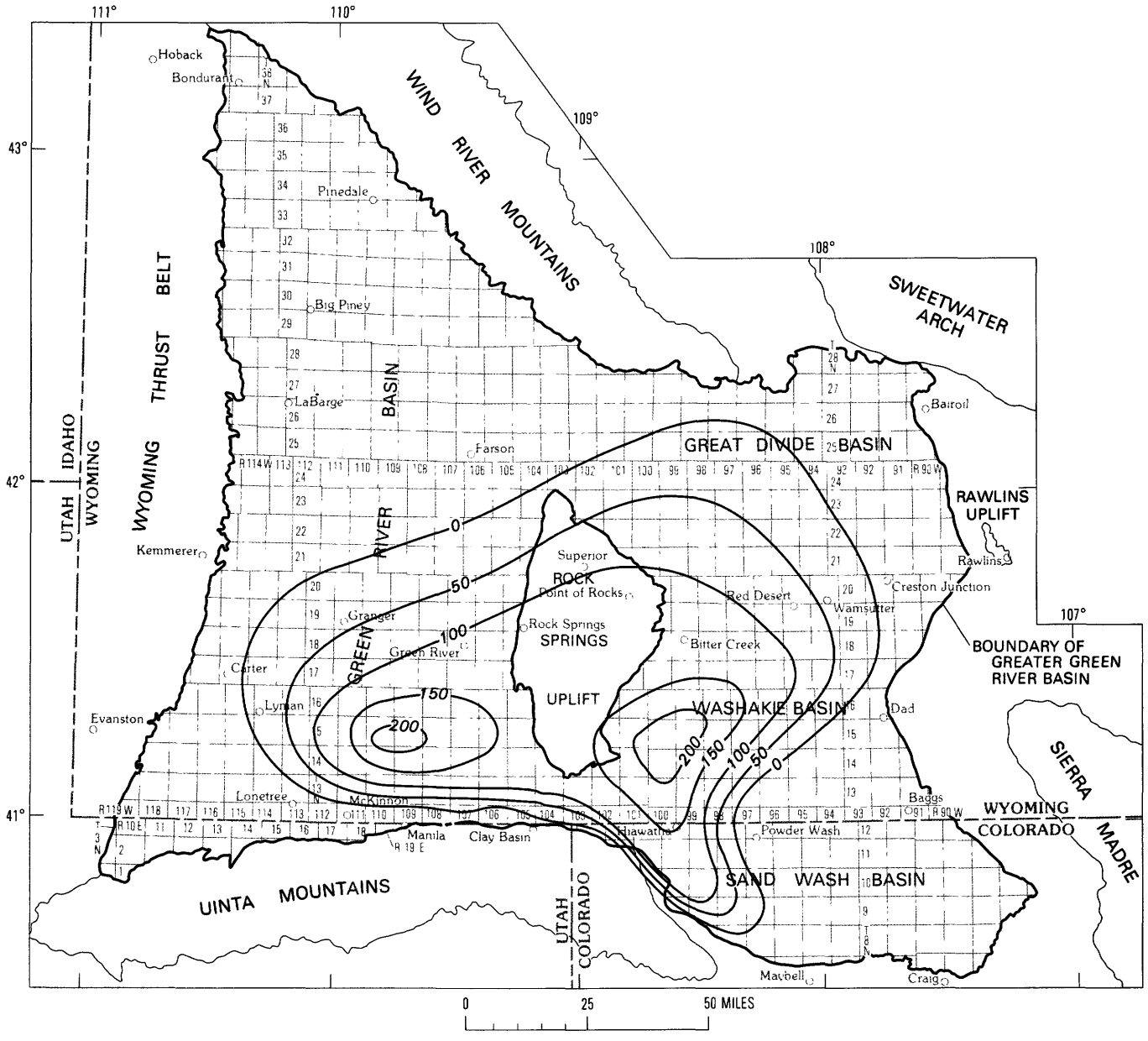


FIGURE 24.—Isopach map of lower part of the Wilkins Peak Member (beds 1–11) of Green River Formation. Isopach interval 50 ft.

the southeastern and southwestern parts of the greater Green River basin, where intervening tongues and members of the Green River Formation are missing by nondeposition, the Cathedral Bluffs Tongue merges with the main body of the Wasatch Formation. This relationship is shown by zero thickness lines in figure 27. Parts of the Cathedral Bluffs Tongue were removed by penecontemporaneous, pre-Laney Member erosion in the northern and northwestern parts of the greater Green River basin (shaded area in fig. 27). Across the western part of the Rock Springs uplift and the central and southern parts of the Green River basin, the tongue is entirely replaced by the Wilkins Peak Member (closed zero line in fig. 27). The tongue grades laterally into fanglomerates along the lower slopes of the Uinta Mountains along the southern margin of the Green River basin.

The Cathedral Bluffs Tongue ranges in thickness from 0 to more than 2,000 ft. Areas of maximum accumulation, in excess of 2,000 ft, are present near the center of the Washakie basin and in the western Sand Wash basin adjacent to the Sparks Ranch thrust fault.

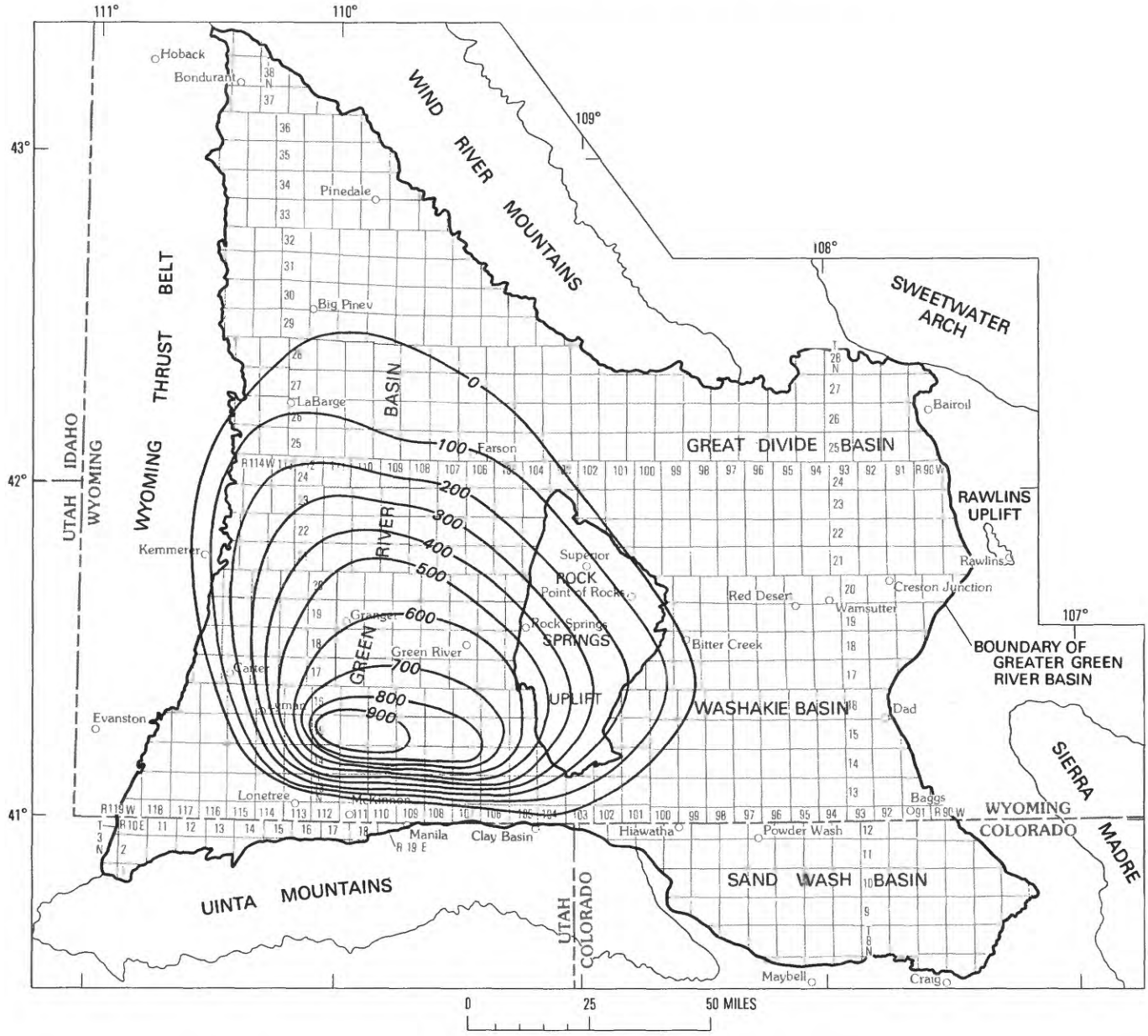


FIGURE 25.—Isopach map of middle part of the Wilkins Peak Member (beds 12–67) of Green River Formation. Isopach interval 100 ft.

GODIVA RIM MEMBER OF GREEN RIVER FORMATION

The Godiva Rim Member is named and described in Chapter C of this volume. The member was deposited mostly on mudflats that were located along the southeast margins of Lake Gosiute during deposition of the lower part of the LaClede Bed of the Laney Member (fig. 1). The areal distribution of the member is restricted to parts of the Great Divide, Washakie, and Sand Wash basins (fig. 28). The Godiva Rim Member intertongues with and is gradually replaced by the upper part of the Cathedral Bluffs Tongue of the Wasatch Formation northward in outcrops across the central part of the Sand Wash basin and along the eastern margins of the Washakie basin.

The Godiva Rim Member is 350 ft thick in a section that was measured in outcrops on Godiva Rim in T. 8 N., R. 96 W. in the southern part of the Sand Wash basin, but it thins northward to less than 125 ft in a section that was measured in outcrops in the northern part of the Washakie basin in sec. 4, T. 18 N., R. 95 W. Where the member intertongues with and is laterally replaced by the LaClede Bed in subsurface rocks in the

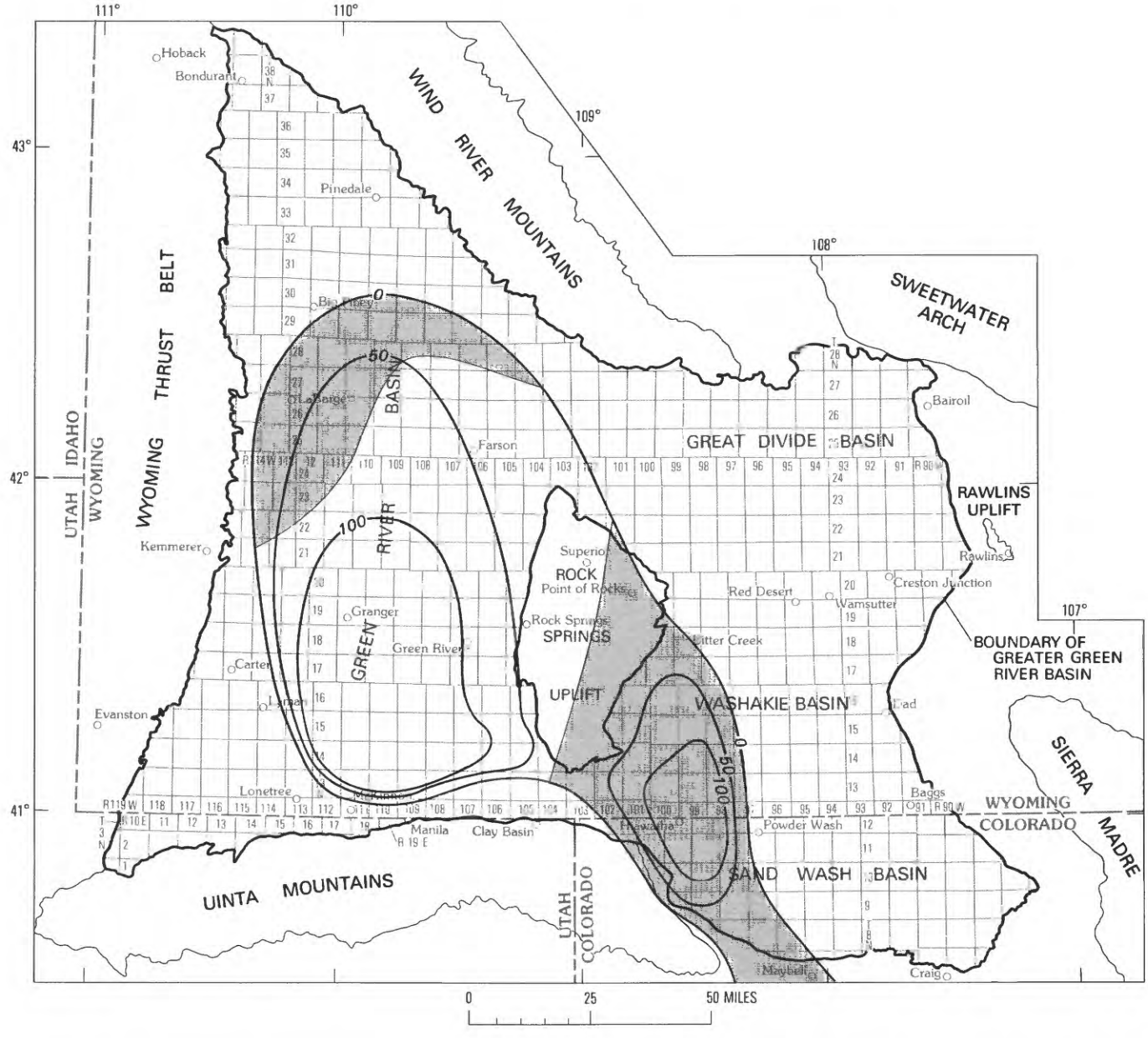


FIGURE 26.—Isopach map of upper part of the Wilkins Peak Member (beds 68–77) of Green River Formation. Isopach interval 50 ft. Shaded areas have been previously mapped as basal LaClede Bed of Laney Member of Green River Formation.

Sand Wash and Washakie basins, the contact is arbitrary, but is approximately located near the zero line shown at the left in the isopachs in figure 28. The location of the eastern and northern boundaries of the member with the Wasatch Formation has been removed by Tertiary and Quaternary erosion. The estimated position of this boundary is indicated by a queried zero thickness line shown at the right in the isopachs in figure 28.

LACLEDE BED OF LANEY MEMBER OF GREEN RIVER FORMATION

Lake Gosiute was irregularly shaped, but about 160 mi long (east-west) and 125 mi wide (north-south) during deposition of the LaClede Bed of the Laney Member (fig. 29). At its maximum development, shown in figure 29, this deep-water lake occupied more than 75 percent of the greater Green River basin. The depositional axis of the lake basin paralleled the north

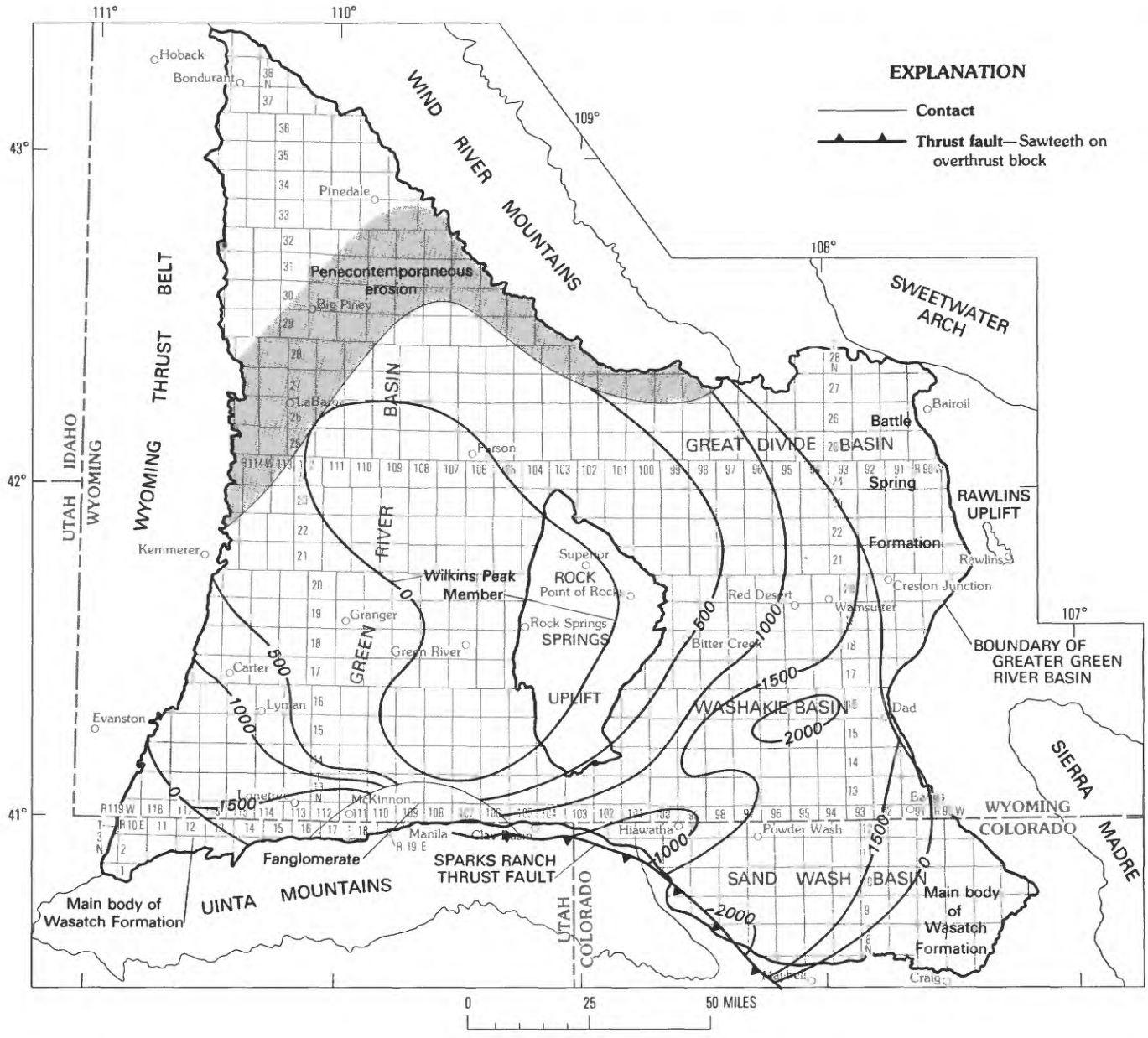


FIGURE 27.—Isopach map of Cathedral Bluffs Tongue of Wasatch Formation. Isopach interval 500 ft. Shading indicates areas where part of tongue was removed by penecontemporaneous erosion.

flank of the Uinta Mountains, and the thickest sediment accumulations (more than 800 ft) were near the east end of the mountains. Following its maximum development, the lake shallowed, slowly retreated to the southeast across the greater Green River basin, and began to dry up. During its final stages, it was restricted to the southern Washakie and western Sand Wash basin areas. Toward the end of deposition of the LaClede Bed, the Rock Springs anticline was uplifted and as much as 400 ft of the bed was eroded from the crest and flanks of the uplift (shaded area in fig. 29).

The LaClede Bed represents the longest period of sustained lacustrine deposition in Eocene Lake Gosiute (more than 2.5 million years). The bed contains the thickest oil-shale accumulation in the Green River Formation. The lower 350 ft of the bed was deposited in saltwater stages of the lake and contains at least 20 beds of oil shale that average more than 25 gallons of

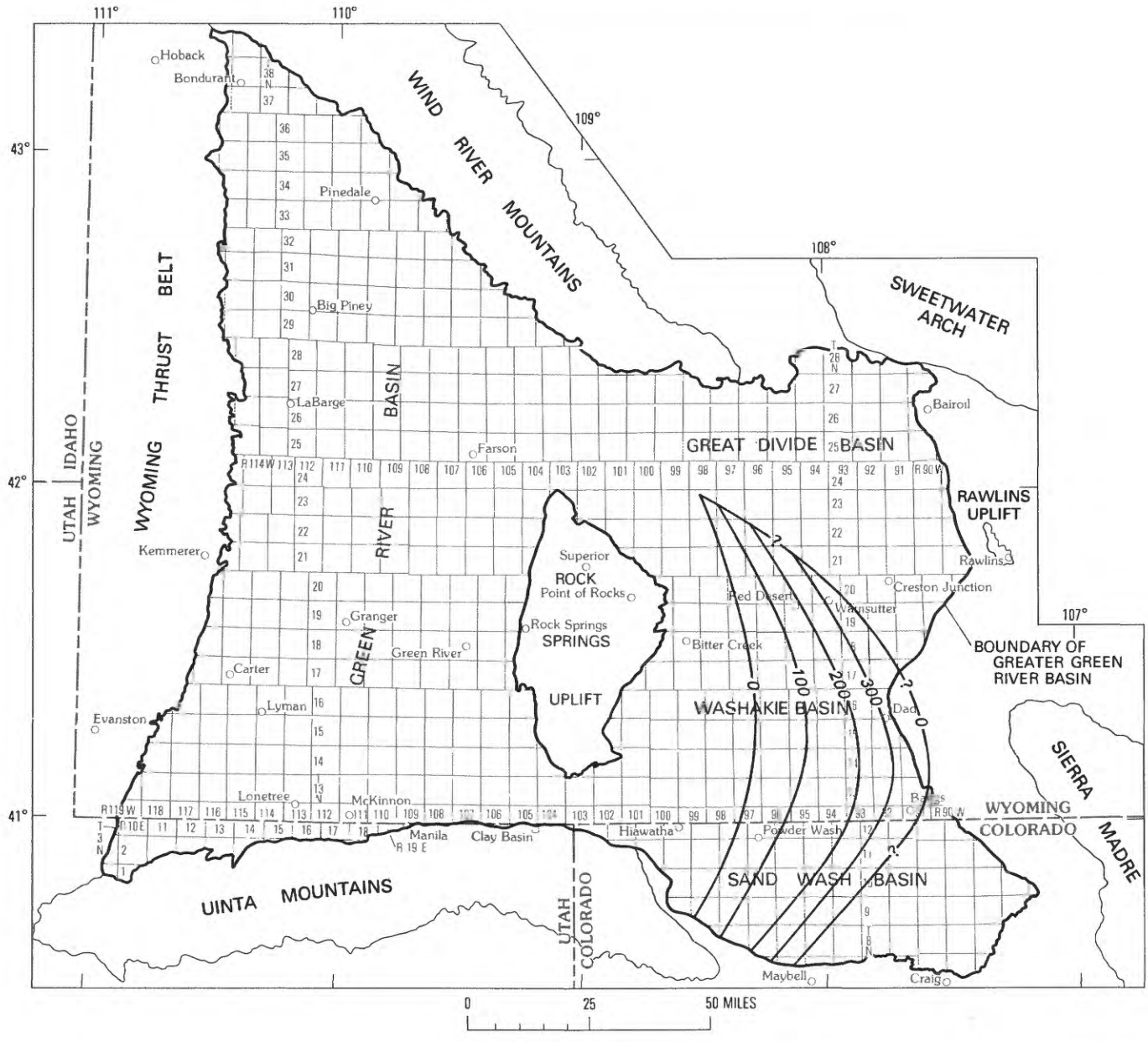


FIGURE 28.—Isopach map of Godiva Rim Member of Green River Formation. Isopach interval 100 ft; queried where eroded and extent uncertain.

oil per ton of rock by Fischer assay; the upper part of the bed was deposited in freshwater stages of the lake and is composed mostly of lean oil shale that rarely averages more than 15 gallons of oil per ton of rock by Fischer assay (Roehler, 1990a).

SAND BUTTE BED OF LANEY MEMBER OF GREEN RIVER FORMATION

The Sand Butte Bed of the Laney Member has variable thicknesses because (1) it was mostly deposited on erosional topography across the crest and flanks of the Rock Springs uplift, (2) it is largely composed of reworked beds of airfall volcanic ash (tuff) that sporadically entered the greater Green River basin from the Absaroka volcanic field located in northwestern Wyoming, and (3) it intertongues with or wedges out in the laterally equivalent Hartt Cabin and LaClede Beds of the Laney Member.

The areal distribution of the Sand Butte Bed is presently restricted to the flanks of the Rock Springs uplift and parts of adjacent basins, where it ranges in

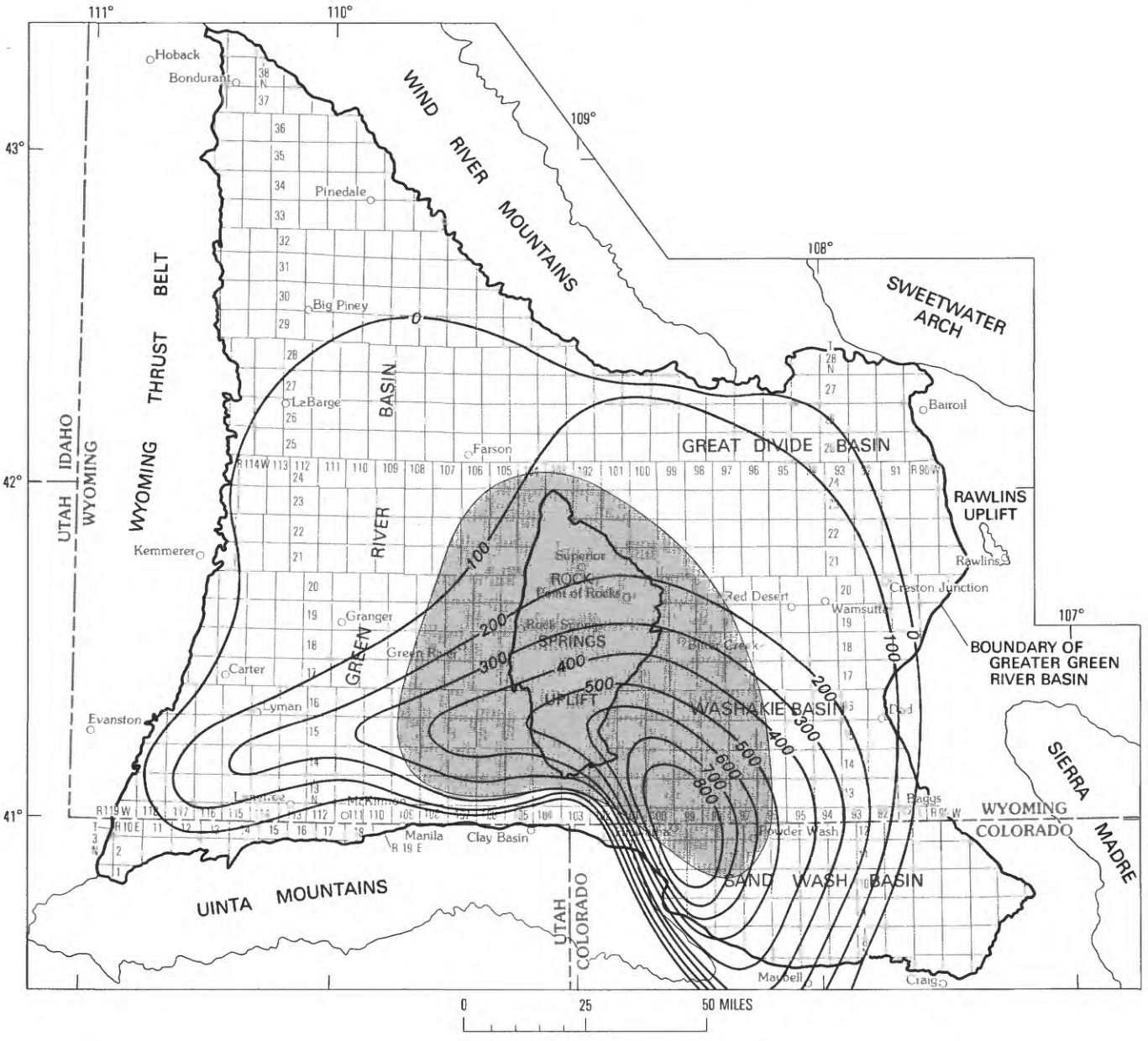


FIGURE 29.—Isopach map of LaClede Bed of Laney Member of Green River Formation (excluding stratigraphic equivalents of the Wilkins Peak Member). Isopach interval 100 ft. Shading indicates area where parts of LaClede Bed of Laney Member were eroded prior to deposition of Sand Butte Bed of Laney Member.

thickness from 0 to about 850 ft. Because the bed thickens and thins irregularly, the dashed isopach lines in figure 30 are approximately located.

HARTT CABIN BED OF LANEY MEMBER OF GREEN RIVER FORMATION AND BRIDGER (WASHAKIE) FORMATION

The Hartt Cabin Bed is about 800 ft thick in outcrops measured in the central part of the Washakie basin. It is generally less than 400 ft thick in other parts of the greater Green River basin. The bed intertongues extensively with the Bridger and Washakie Formations, which makes its contact with these formations arbitrary. In addition, large intervals of the bed are missing as a result of Tertiary and Quaternary erosion around the uplifted margins of the Green River, Great Divide, Washakie, and Sand Wash basins. Consequently, it is not possible to establish accurate basin-wide thicknesses for the bed, and an isopach map was not prepared.

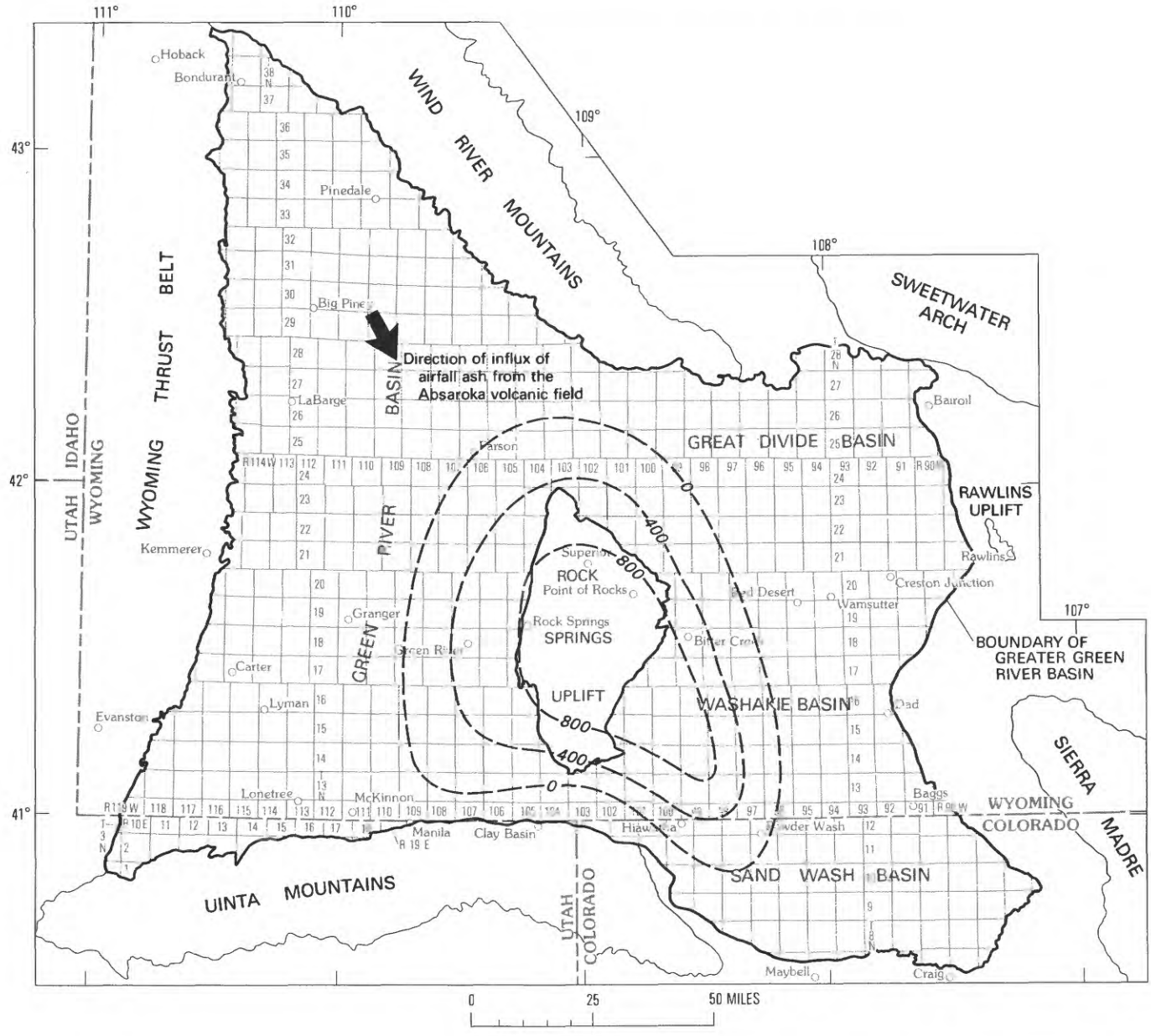


FIGURE 30.—Isopach map of Sand Butte Bed of Laney Member of Green River Formation. Isopach interval 400 ft. Isopach lines are approximately located.

The Bridger Formation is 2,106 ft thick in the Eocene reference section for the Green River basin that is described and illustrated in Chapter D of this volume. The reference section was measured in outcrops at Twin Buttes in Ts. 13–14 N., Rs. 109–110 W. in the southeastern part of the Green River basin, where the most complete section of the formation is preserved. At Twin Buttes the upper part of the Bridger Formation is, nonetheless, eroded and unconformably overlain by the Oligocene Bishop Conglomerate. The eroded Bridger interval above the unconformity may have been several hundred feet thick. As no complete section exists, in the basin, the formation was not isopached.

The Washakie Formation is 3,177 ft thick in the Washakie basin Eocene reference section that is described and illustrated in Chapter D of this volume. The top of the formation in the Washakie basin has been removed by Tertiary and Quaternary erosion. The formation was not isopached.

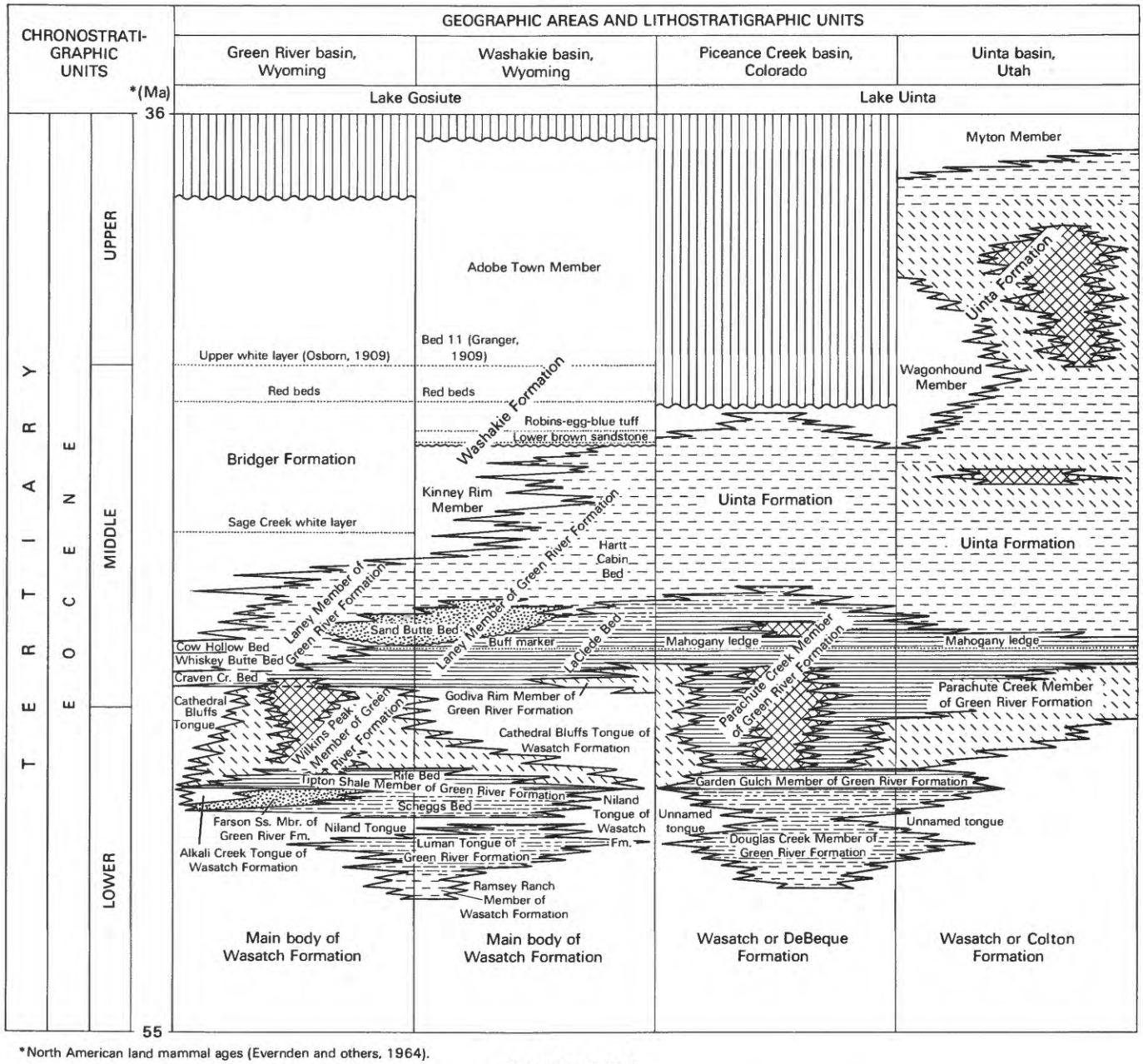
CORRELATION OF EOCENE ROCKS IN THE GREEN RIVER, WASHAKIE, PICEANCE CREEK, AND UINTA BASINS

The interbasin stratigraphic correlations shown in figure 31 are primarily based upon (1) similar depositional environments and lithologies of stratigraphic units, (2) chronostratigraphic ages determined by fossil mammals and K-Ar analyses of tuff beds, (3) climate and salinity changes indicated by fossil plants and mollusks, and (4) distinct and repetitive responses on geophysical logs of oil and gas drill holes.

Lakes Gosiute and Uinta were contemporaneous, were located on opposite sides of the Uinta Mountains, and at times joined around the east end of the Uinta Mountains (index map, fig. 32). Consequently, the depositional environments and composition of the stratigraphic units that were deposited in these lake basins, especially their color and weathering characteristics, are similar and correlatable. Rocks of fluvial origin are mostly red or variegated in the Wasatch Formation and are mostly drab gray in the Bridger, Washakie, and Uinta Formations. In the Green River Formation, rocks of freshwater lacustrine origin, which include the Luman Tongue, Scheggs Bed of the Tipton Shale Member, Douglas Creek Member, upper part of the LaClede Bed of the Laney Member, upper part of the Parachute Creek Member, and parts of the Uinta Formation, are composed mostly of soft, kerogenaceous shale that weathers to tan or tan-gray, smooth, nonresistant slopes. Rocks of saltwater lacustrine origin in the Green River Formation, including the Rife Bed of the Tipton Shale Member, Wilkins Peak Member, Garden Gulch Member, and most of the Parachute Creek Member, are mostly hard, kerogenaceous dolomite that generally weathers to light-gray or white, steep slopes and ledges. Saline minerals, including the bedded evaporites trona, nahcolite, and halite, and the richest oil-shale beds in the Green River Formation, are found in or associated with the rocks of saltwater lacustrine origin. These rocks form the distinctive light-gray and white escarpments at White Mountain along the east edge of the Green River basin near Rock Springs, Wyo., and along the Roan cliffs in the southern part of the Piceance Creek basin north of Grand Valley and Debeque, Colo.

Fossil mammals and their time-related evolutionary changes during the Eocene Epoch have been studied by vertebrate paleontologists since the 1860's (Chapter D, this volume). These studies, combined with K-Ar ages determined for tuff beds in the rocks, have provided chronological data for correlating stratigraphic units between the Eocene lake basins (Wood and others, 1941; Evernden and others, 1964; Mauger, 1977; O'Neill, 1980; Krishtalka and others, 1987). The chronological data indicate that the boundary between the lower and middle Eocene occurs in the upper part of the Cathedral Bluffs Tongue of the Wasatch Formation or upper part of the Wilkins Peak Member of the Green River Formation in Wyoming, and in the upper part of the Parachute Creek Member of the Green River Formation in Colorado and Utah. The boundary between the middle and upper Eocene is not precisely located stratigraphically, but occurs within the Bridger and Washakie Formations in Wyoming and within the Uinta Formation in Utah (fig. 31). The Eocene-Oligocene boundary is also not precisely located and may include the Duchesne River Formation in the Uinta basin (Krishtalka and others, 1987). The Paleocene-Eocene boundary is generally located at the base of the Wasatch Formation. The base of the Wasatch, however, includes rocks of Paleocene age in the southern part of the Piceance Creek basin (Donnell, 1969) and in the western part of the Green River basin (Oriel, 1962).

The depositional environments and composition of stratigraphic units in the basins of Lake Gosiute and Lake Uinta appear to be directly related to regional Eocene climate changes. The Eocene climates, based on paleoecological interpretations of fossil plants, were moist and warm (warm temperate) during the early Eocene, moist and hot (semiarid) and then dry and hot (arid) during the late early and very early middle Eocene, wet and hot (subtropical) during the middle Eocene, and dry and cool (cool temperate) during the late middle and late Eocene (Chapters D and F, this volume). The composition of stratigraphic units in the Green River and Uinta Formations reflects most of these climate changes synchronously in both lake basins. Sediments of freshwater origin were deposited as the Luman Tongue, Scheggs Bed of the Tipton Shale Member, and Douglas Creek Member, when the climate was moist and warm. Sediments of saltwater origin were deposited as the Rife Bed of the Tipton Shale Member and Garden Gulch Member, when the climate was moist and hot. Evaporites and sediments of saltwater origin were deposited as the Wilkins Peak Member, lower part of the LaClede Bed of the Laney Member, and Parachute Creek Member, when the climate was dry and hot. Sediments of saltwater and freshwater origins were deposited as the LaClede Bed of the Laney Member and lower lower part of the Uinta Formation, when the climate was wet and hot. The



*North American land mammal ages (Evernden and others, 1964).

EXPLANATION

- Freshwater lacustrine sandstone
- Freshwater lacustrine mudstone, oil shale, shale, sandstone, siltstone, and limestone; some carbonaceous shale and coal
- Saltwater lacustrine (rich) oil shale
- Freshwater lacustrine (lean) oil shale
- Saltwater lacustrine and mudflat mudstone, siltstone, algal limestone, oil shale, and sandstone
- Evaporites (trona, halite, nahcolite, or shortite)
- Fluvial mudstone, sandstone, and siltstone (partly red beds; some paludal deposits)
- Section missing by erosion or nondeposition
- Unconformity
- Intertongued contact
- Marker bed

FIGURE 31.—Stratigraphic correlation of Eocene rocks in Green River and Washakie basins, Wyoming, Piceance Creek basin, Colorado, and Uinta basin, Utah. Modified from Roehler (1974).

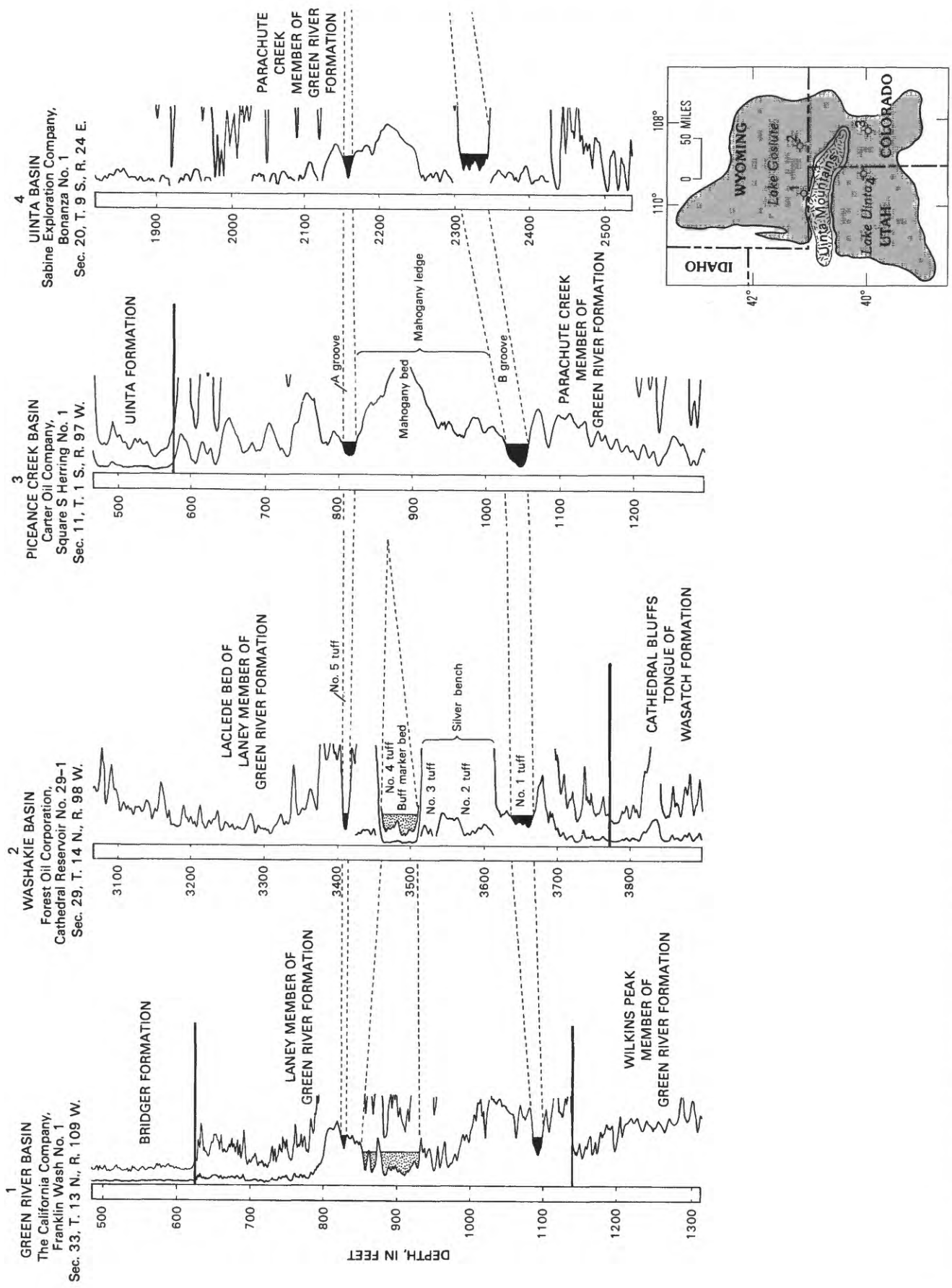


FIGURE 32.—Correlation of resistivity curves of electric logs of Mahogany ledge in Parachute Creek Member of Green River Formation in Piceance Creek and Uinta basins with stratigraphic equivalents in Laney Member of Green River Formation in Green River and Washakie basins.

climate was mostly dry and cool during the late middle and late Eocene, but evaporite beds were deposited in the middle and upper parts of the Uinta Formation in the Uinta basin (fig. 31).

Eocene molluscan assemblages, as well as their absence, provide important clues to the paleoecology, namely the water depth, temperature, and salinity, of Lakes Gosiute and Uinta. The large, ovoid, pulmonate gastropod *Physa pleromatis* characterizes a large molluscan assemblage found in marshy shoreline areas of the lakes, especially in basal parts of the Luman Tongue and Douglas Creek Member. The turreted gastropod *Goniobasis tenera*, the thick-spired gastropod *Viviparus* sp., and the unionid pelecypods *Lampsilis* sp. and *Plesielliptio* sp. were present in large numbers in open, freshwater parts of the lakes, especially along shorelines (Hanley, 1974). These large gastropods and pelecypods commonly form coquinas in the upper part of the Luman Tongue, in the Scheggs Bed of the Tipton Shale Member, and in the upper part of the LaClede and Hartt Cabin Beds of the Laney Member in Wyoming, and in the Douglas Creek Member, upper part of the Parachute Creek Member, and in various parts of the Uinta Formation in Colorado and Utah. As the freshwaters of the lakes became saline, the large freshwater mollusks quickly disappeared, but the small planorbid gastropod *Gyraulus militaris* survived for short periods of time in the environment of the Wilkins Peak and Parachute Creek Members. During periods of evaporite deposition the saltwater lakes were devoid of mollusks.

The responses of various lithologies on geophysical logs of oil and gas drill holes are generally distinct and correlatable in the Eocene lake basins. The resistivity curves of oil-shale and tuff beds on electric logs are especially useful for correlating certain stratigraphic intervals. An example of one of these intervals is shown in figure 32, where log segments of the Mahogany ledge in the Parachute Creek Member in the Piceance Creek and Uinta basins are correlated with the lower part of the Laney Member in the Green River and Washakie basins. The Mahogany ledge in the Carter Oil Company Square S Herring No. 1 Well in the Piceance Creek basin (No. 3, fig. 32) is about 200 ft thick, is composed mostly of rich oil shale, and is bounded above by a tuff bed called A groove and below by a tuff bed called B groove. The Mahogany ledge and its bounding tuffs are easily correlated from the Piceance Creek basin into the Uinta basin, but are less easily correlated from the Piceance Creek basin into the Washakie and Green River basins (fig. 32). Equivalents of the Mahogany ledge in the Washakie and Green River basins are split by the No. 4 tuff, or buff marker bed, but thin tuff bed equivalents of A and B grooves (the No. 1 and No. 5 tuff beds in the Washakie basin) are, nevertheless, correlatable.

REFERENCES CITED

Donnell, J.R., 1969, Paleocene and lower Eocene units in the southern part of the Piceance Creek Basin, Colorado *in* Contributions to Stratigraphy: U.S. Geological Survey Bulletin 1274–M, p. M1–M18.

Evernden, J.F., Savage, D.E., Curtis, G.H., and James, G.T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: American Journal of Science, v. 262, p. 145–198.

Granger, Walter, 1909, Faunal horizons of the Washakie Formation of southern Wyoming: American Museum of Natural History Bulletin, v. 26, art. 3, p. 13–23.

Hanley, J.H., 1974, Systematics, paleoecology, and biostratigraphy of nonmarine Mollusca from the Green River and Wasatch Formations (Eocene), southwestern Wyoming and northwestern Colorado: Laramie, Wyo., University of Wyoming Ph. D. thesis, 285 p.

Krishtalka, Leonard, West, R.M., Black, C.C., Dawson, M.R., Flynn, J.J., Turnbull, W.D., Stucky, R.K., McKenna, M.C., Bown, T.M., Golz, D.J., and Lillegraven, J.A., 1987, Eocene (Wasatchian through Duchesnean) biochronology of North America, *in* Woodburne, M.O., Cenozoic mammals of North America: Berkeley, Calif., University of California Press, p. 77–117.

Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000, 2 sheets.

Masursky, Harold, 1962, Uranium-bearing coal in the eastern part of the Red Desert area, Wyoming: U.S. Geological Survey Bulletin 1099–B, 152 p.

Mauger, R.I., 1977, K-Ar ages of biotites from tuffs in Eocene rocks of the Green River, Washakie, and Uinta Basins, Utah, Wyoming, and Colorado: University of Wyoming Contributions to Geology, v. 15, no. 1, p. 17–41.

O'Neill, W.A., 1980, $^{40}Ar^{39}Ar$ ages of selected tuffs of the Green River Formation—Wyoming, Colorado, and Utah: Columbus, Ohio, The Ohio State University M.S. thesis, 142 p.

Oriel, S.S., 1962, Main body of Wasatch Formation near LaBarge, Wyoming: American Association of Petroleum Geologists Bulletin, v. 46, no. 12, p. 2161–2173.

Osborn, H.F., 1929, The titanotheres of ancient Wyoming, Dakota, and Nebraska: U.S. Geological Survey Monograph 55, v. 1, 701 p.

Pipiringos, G.N., 1961, Uranium-bearing coal in the central part of the Great Divide Basin: U.S. Geological Survey Bulletin 1099–A, 104 p.

Roehler, H.W., 1965, Early Tertiary depositional environments in the Rock Springs uplift area, *in* DeVoto, R.H., and Bitter, R.K., eds., Sedimentation of Late Cretaceous and Tertiary outcrops, Rock Springs uplift: Wyoming Geological Association Guidebook, 19th Field Conference, Casper, Wyoming, p. 140–150.

———1973, Stratigraphic divisions and geologic history of the Laney Member of the Green River Formation in the Washakie Basin in southwestern Wyoming: U.S. Geological Survey Bulletin 1372–E, 28 p.

———1974, Depositional environments of Eocene rocks in the Piceance Creek basin, Colorado, *in* Murray, D.K., ed., Energy resources of the Piceance Creek basin, Colorado: Rocky Mountain Association of Geologists Guidebook, 25th Field Conference, Denver, Colorado, p. 57–64.

_____ 1989a, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations across the central part of the Sand Wash basin, northwest Colorado, and eastern part of the Washakie basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2106.

_____ 1989b, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations along the western margins of the Greater Green River basin in southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2103.

_____ 1989c, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations along the west flank of the Rock Springs uplift in southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2104.

_____ 1989d, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations along the western margins of the Sand Wash basin, northwest Colorado, and Washakie basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2105.

_____ 1989e, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations across the central part of the Sand Wash basin, northwest Colorado, and eastern part of the Washakie basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2106.

_____ 1989f, Correlation of surface sections of the intertongued Eocene Wasatch and Green River Formations, Great Divide basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2102.

_____ 1990a, Correlation and depositional analysis of oil-shale and associated rocks in the Eocene Green River Formation, greater Green River basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I–2226.

_____ 1990b, 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, 12 p.

_____ 1990c, West-east correlation of surface and subsurface stratigraphic sections of the intertongued Eocene Wasatch and Green River Formations, northern Green River basin, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2149.

_____ 1990d, West-east correlation of surface and subsurface stratigraphic sections of the intertongued Eocene Wasatch and Green River Formations, southern Green River basin, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2159.

_____ 1991a, East-west surface and subsurface correlation of the intertongued Eocene Wasatch and Green River Formations, Washakie basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2164.

_____ 1991b, Northwest-southeast surface and subsurface correlation of the intertongued Wasatch and Green River Formations, Sand Wash basin, northwest Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF–2166.

_____ 1991c, Measured sections of Ramsey Ranch Member of Wasatch Formation, greater Green River basin, southwest Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–2185.

Roehler, H.W., Hanley, J.H., and Honey, J.G., 1988, Geology and paleoecology of the Cottonwood Creek Delta in the Eocene Tipton Tongue of the Green River Formation and a mammalian fauna from the Eocene Cathedral Bluffs Tongue of the Wasatch Formation, southeast Washakie basin, northwest Colorado: U.S. Geological Survey Bulletin 1669, 52 p.

Sullivan, Raymond, 1980, A stratigraphic evaluation of the Eocene rocks of southwestern Wyoming: The Geological Survey of Wyoming Report of Investigations 2, 50 p.

Wood, H.E., 2nd, Chaney, R.W., Clark, John, Colbert, E.H., Jepsen, G.L, Reeside, J.B., Jr., and Strock, Chester, 1941, Nomenclature and correlation of North American continental Tertiary: Geological Society of America Bulletin, v. 52, no. 1, p. 1–48.

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