Coastal Sedimentation Along a Segment of the Interior Seaway of North America, Upper Cretaceous Baxter Shale, and Blair and Rock Springs Formations, Rock Springs Uplift, Southwest Wyoming

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Coastal Sedimentation Along a Segment of the Interior Seaway of North America, Upper Cretaceous Baxter Shale, and Blair and Rock Springs Formations, Rock Springs Uplift, Southwest Wyoming

By HENRY W. ROEHLER

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Location and description of outcrops of paralic and marine delta, shelf, slope, and basin deposits

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CONVERSION FACTORS

U.S. customary unit	Multiply by	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometers (km^2)
inch (in.)	2.54	centimeters (cm)

COASTAL SEDIMENTATION ALONG A SEGMENT OF THE INTERIOR SEAWAY OF NORTH AMERICA, UPPER CRETACEOUS BAXTER SHALE, AND BLAIR AND ROCK SPRINGS FORMATIONS, ROCK SPRINGS UPLIFT, SOUTHWEST WYOMING

By Henry W. Roehler

ABSTRACT

Outcrops of the Baxter Shale and the Blair and Rock Springs Formations in the Rock Springs uplift comprise rocks of paralic and marine delta, shelf, slope, and basin origins. When their depositional environments are synthesized, the rocks reveal the pattern of sedimentation along part of the west coast of the Late Cretaceous interior seaway of North America. The rocks investigated crop out in nine easily accessible geographic areas that are located in the report by detailed topographic maps. Columnar sections, photographs, and sketches illustrate and integrate the observations of the report, which contributes to studies of the sedimentology and to the understanding of the origin and location of mineral deposits in the Rock Springs uplift area.

INTRODUCTION

PURPOSE AND METHODOLOGY

This study examines the sedimentary rocks deposited along a segment of the west coast of the interior seaway of North America in southwest Wyoming during the late Santonian and early Campanian subages of the Late Cretaceous Epoch. Sedimentologic data are presented in ascending paleoenvironmental sequence, beginning with descriptions of marine basin, slope, and shelf deposits in the Baxter Shale and Blair Formation and ending with descriptions of paralic delta-front and delta-plain deposits in the Rock Springs Formation. The study focuses on the geographic location of rocks deposited in selected depositional environments. It emphasizes the sedimentology of sandstone beds, but does not dwell on the origin of sedimentary structures, on paleogeography, or on paleontology.

Rock outcrops were studied in nine geographic areas located between Tps. 16–21 N., and Rs. 101–105 W. in the central and southern parts of the Rock Springs uplift. The geographic interrelation of the nine study areas is shown in figure 1, which locates figures 5, 10, 17, 21, 29, 38, 45, 48, and 52. When combined, the outcrop areas total about 75 mi^2. They are mostly located along paved highways, but a few are located adjacent to improved gravel roads. All the outcrops are easily accessible by automobile.

The sedimentologic data used in preparing this report were acquired by me during field investigations that began in 1952 and continued intermittently through 1989. The data were derived primarily from hundreds of stratigraphic sections measured on the flanks of the uplift. Parts of nine of these sections are illustrated in the report by columnar sections. The stratigraphic sections were measured using a 5-ft Jacob staff with attached Abney level to compensate for the dip of strata; a pocket engineering tape measure was used to measure beds less than 5 ft thick. Detailed lithologic descriptions of the stratigraphic sections are on file at the Wyoming Geological Survey, Laramie, Wyo. Sediment transport directions for some sandstone beds were recorded using a Brunton compass; several measurements appear in the report in a rose diagram. During these investigations, eighteen 7½′ geologic quadrangles were mapped along the southeast part of the Rock Springs uplift and a reconnaissance geologic map of the uplift was published at the scale of 1 in. = 2 mi (Roehler, 1977).

GEOLOGIC SETTING

The Rock Springs uplift area is a windy desert with cold winters and warm to hot summers. The general

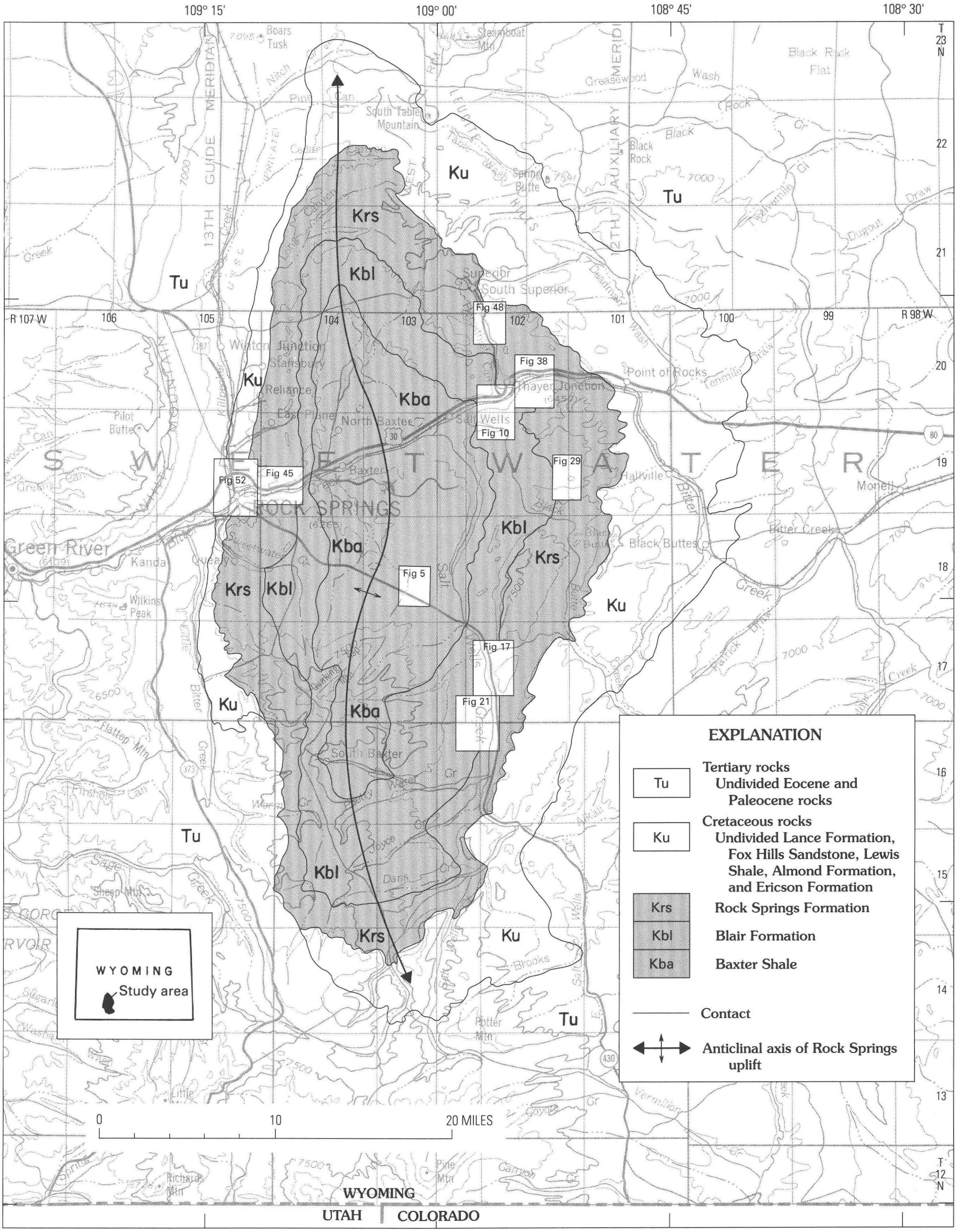

Figure 1. Index map of the Rock Springs uplift showing formations studied (shaded). Outlines and figure numbers locate and designate detailed maps of outcrop areas studied. Base from U.S. Geological Survey 1:500,000 topographic map of Wyoming; contour interval 500 ft.

range of altitude is from 6,000 to 8,000 ft. Vegetation is sparse. Cedar trees are present on a few high-standing ridges, but most of the area is characterized by sage, greasewood, rabbit brush, cactus, lichens, and a variety of desert flowers. The major drainage is Bitter Creek, which flows perennially from east to west across the center of the uplift and whose valley the Union Pacific Railroad follows (fig. 1). Major intermittent tributaries of Bitter Creek include Salt Wells Creek and Little Bitter Creek. A number of villages and small towns are present in the uplift area, but the only sizable city is Rock Springs, whose population is about 25,000. The main industries are cattle and sheep ranching, oil and gas exploration and production, and coal mining.

The structure of the Rock Springs uplift consists of a north-south-trending, doubly plunging, asymmetric anticline about 70 mi long and 40 mi wide located near the center of the greater Green River basin north of the common boundary of Wyoming, Utah, and Colorado (fig. 1). Dips in Cretaceous, Paleocene, and Eocene rocks exposed on the flanks of the uplift range from 3° to 35° on the west flank and from 3° to 8° on the east flank. The center of the uplift is composed of deeply eroded, soft shale, which is surrounded by numerous resistant sandstone ridges separated by shale valleys. The uplift is a Laramide structure that was uplifted at least twice during the Late Cretaceous and at least three times during the Paleocene and Eocene (Roehler and others, 1977). The uplift was extensively faulted during the Paleocene, eroded to a peneplain during the Oligocene and Miocene, and the site of intensive volcanic activity during the Pliocene and Pleistocene.

SEDIMENTOLOGY

The sedimentary rocks of paralic and marine origins investigated in this report were deposited in subtropical to warm temperate climates that prevailed along the west coast of the interior seaway during the Late Cretaceous (Kauffman, 1977). The interior seaway at that time extended in a north-south direction across central North America from southern Alaska and Canada southward to the Gulf of Mexico (Gill and Cobban, 1966). The rocks investigated were deposited when the seaway was nearly 1,000 mi wide east of the study area (fig. 2). The basin of the seaway was asymmetric, with the area of maximum subsidence and thickest sediment accumulation located along its western margins (King, 1959).

Upper Cretaceous rocks exposed in the Rock Springs uplift, in ascending sequence, are the Baxter Shale of marine origin, the Mesaverde Group (consisting of the Blair and Rock Springs Formations, Ericson Sandstone, and Almond Formation) of shallow marine and continental origins, the Lewis Shale of marine origin, and the Fox Hills Sandstone and Lance Formation of shallow marine and continental origins. The stratigraphic positions and intertonguing relationships of these and other formations of Late Cretaceous age are illustrated in a restored regional west-east cross section across the study area (fig. 3).

The formations studied are of Santonian and Campanian Ages. These ages have been determined by the Late Santonian ammonite index fossil *Desmoscaphites bassleri* collected at the top of the Airport Sandstone Tongue of the Baxter Shale by Hale (1950) and the early Campanian ammonite index fossil *Scaphites hippocrepis* collected at several stratigraphic levels in the Blair Formation by Smith (1961). Regional correlations of stratigraphic units containing these and other Late Cretaceous index fossils were discussed by Roehler (1990).

The environmental relationships and types of paralic and marine deposits discussed in this report are illustrated by a block diagram in figure 4. Figure 4 is a cross-sectional view of the onshore, nearshore, and offshore parts of an arcuate delta, a type that is generally wave dominated. These features are characteristic of all the delta systems present in Upper Cretaceous rocks in the Rock Springs uplift area. The following discussion identifies, locates, and describes deposits that correspond to the features illustrated in figure 4.

MARINE BASIN DEPOSITS

The Airport Sandstone Tongue in the Baxter Shale is a marine basin deposit. It takes its name from the Rock Springs airport in sec. 30, T. 19 N., R. 103 W., where it forms a broad, flat bench on which the runways are located. The upper exposed part of the sandstone locally stands more than 75 ft high; along its north edge, it arcs in an east-west direction across the axis of the Rock Springs uplift. This arcing is visible across the southeastern part of T. 19 N., R. 104 W., 1–2 mi south of and parallel to Interstate Highway 80. The Airport Sandstone Tongue is generally 400–550 ft thick and consists of a "sandy" interval of thin interbedded and interlaminated sandstone, siltstone, and shale situated about 1,300 ft below the top and 2,500 ft above the base of the Baxter Shale. The lithology of the tongue coarsens upward, and thin beds of very fine grained, limy sandstone are abundant near the top.

The Airport Sandstone Tongue is well exposed in a roadcut of Wyoming Highway 430, 10 mi southeast of Rock Springs, Wyo., in SW1/4NE1/4 sec. 28, T. 18 N., R. 103 W. (fig 5). At this locality, it trends north-northeast, dips about 3° SE., and weathers to an extensive round-topped ridge (fig. 6). The lithology of the upper 40 ft of the unit was examined on the east side of the highway roadcut and is illustrated in measured section 7585, figure 7. As indicated in figure 7, the beds are extensively

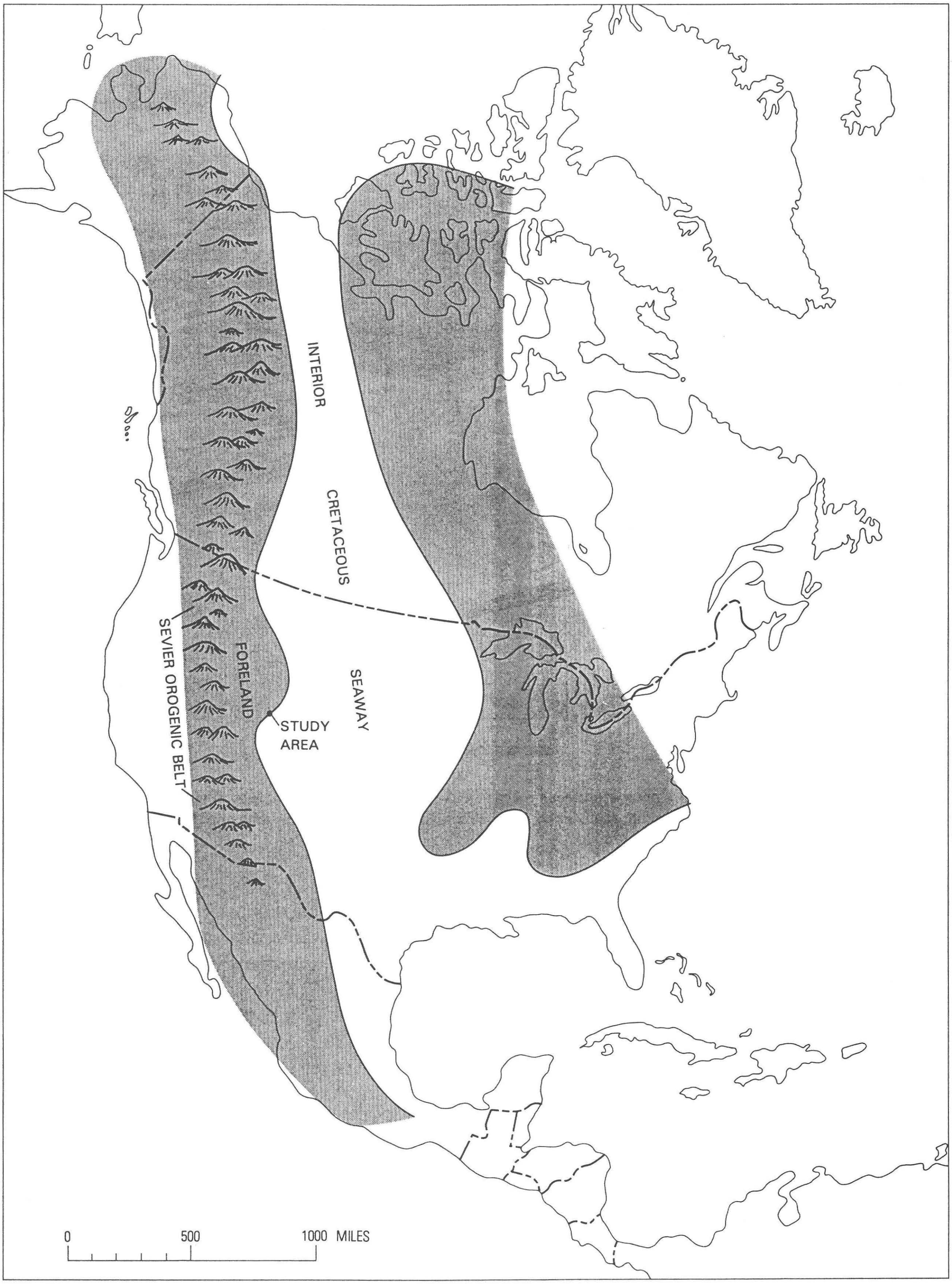

Figure 2. Map of interior seaway of North America during Campanian Age of Cretaceous Period. Modified from Gill and Cobban (1966).

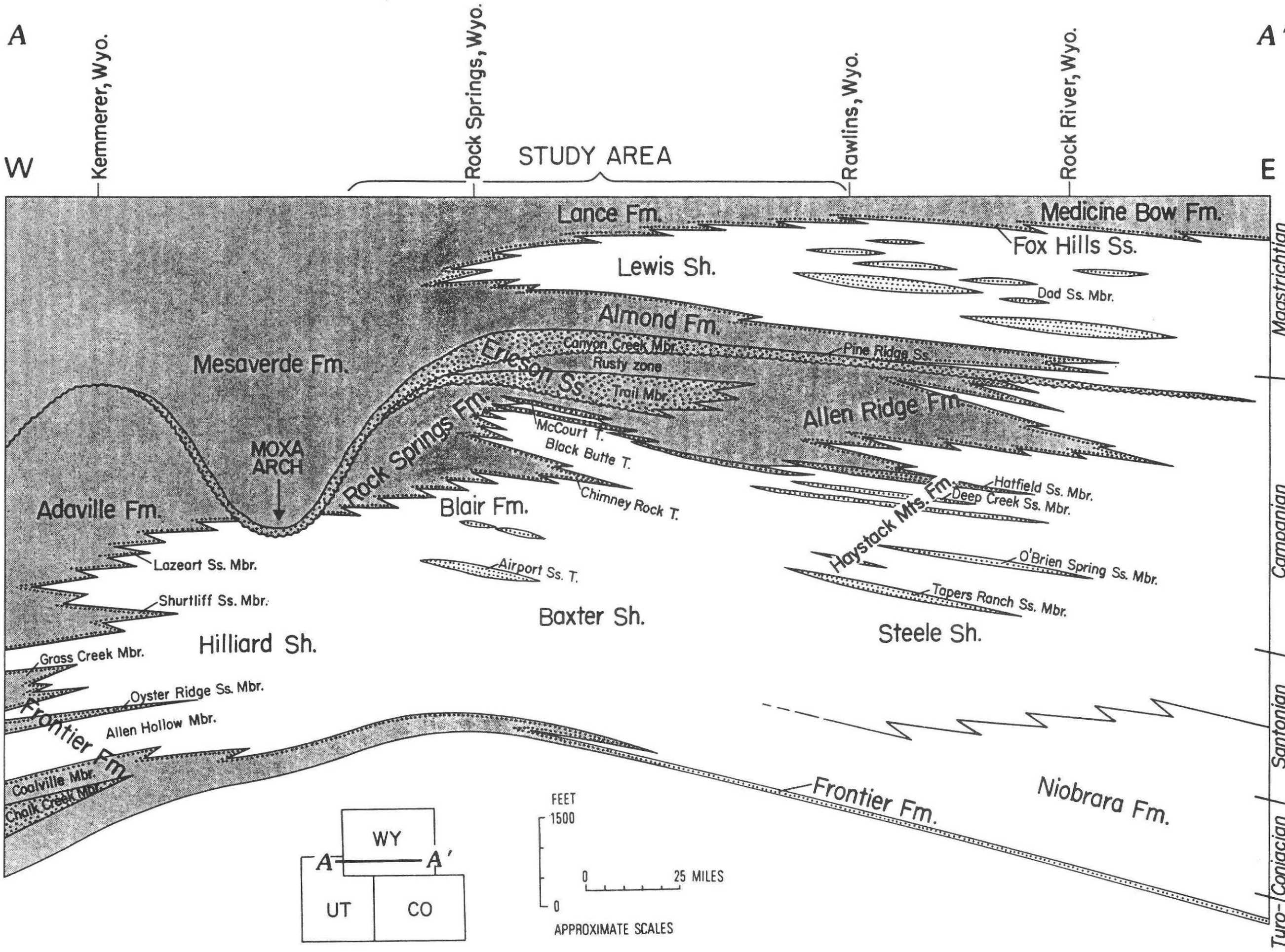

Figure 3. Restored regional cross section of Cretaceous rocks from northeast Utah to southeast Wyoming. Shaded formations are continental in origin; unshaded formations are marine in origin. From Roehler (1990).

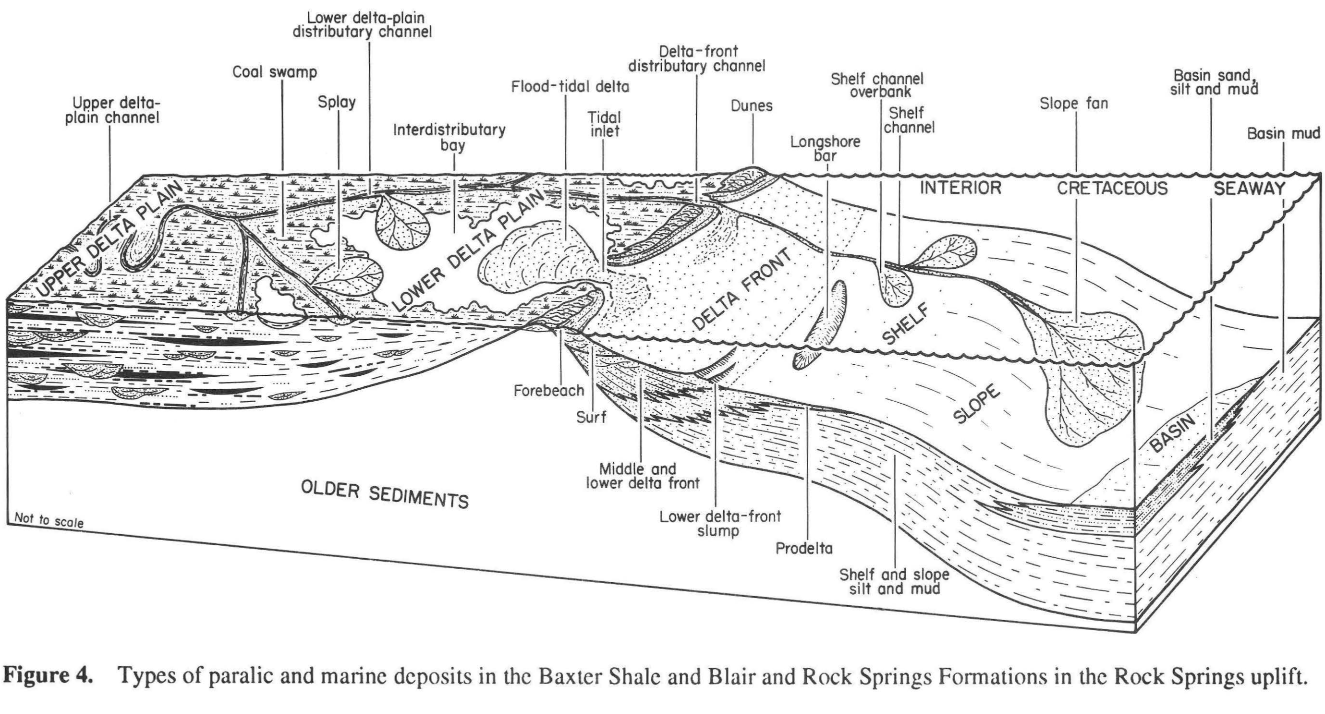

Figure 4. Types of paralic and marine deposits in the Baxter Shale and Blair and Rock Springs Formations in the Rock Springs uplift.

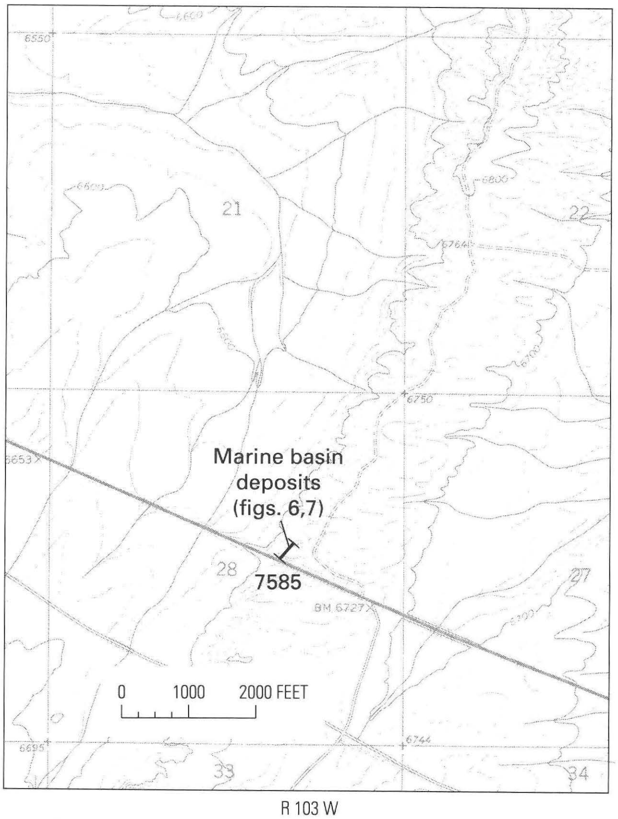

Figure 5. Location of marine basin deposits (measured section 7585, fig. 7) in Airport Sandstone Tongue in the Baxter Shale, in roadcut of Wyoming Highway 430. Base from U.S. Geological Survey 1:24,000 Baxter, Wyo.; contour interval 20 ft.

Figure 6. Outcrop of Airport Sandstone Tongue in the Baxter Shale in roadcut of Wyoming Highway 430 in SW1/4NE1/4 sec. 28, T. 18 N., R. 103 W. Outcrop location shown in figure 5.

current rippled. Deposition probably took place under more than 300 ft of water, and a possible explanation for the presence of the current ripples is the activity of turbidity currents.

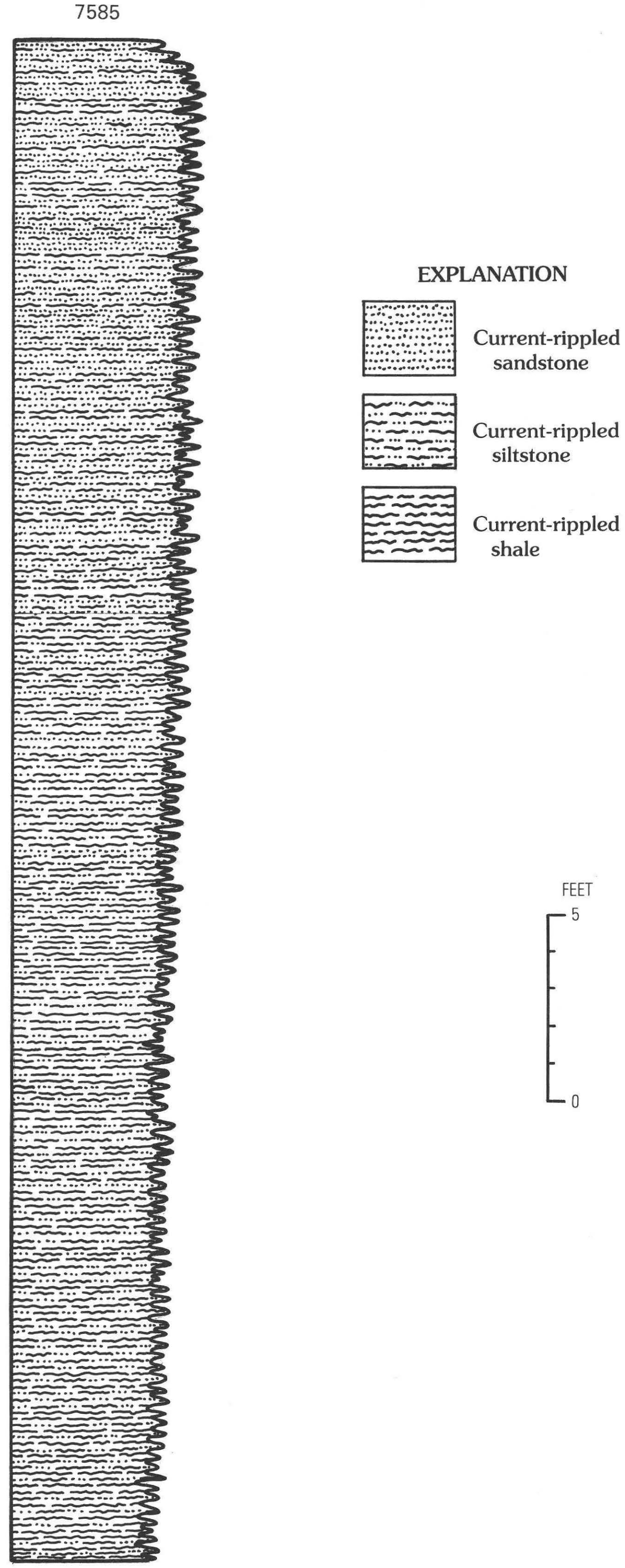

Figure 7. Measured section 7585 of Airport Sandstone Tongue in the Baxter Shale in roadcut of Wyoming Highway 430, 11 mi southeast of Rock Springs, Wyo. Section location shown in figure 5.

SUBMARINE FAN DEPOSITS

The basal part of the Blair Formation exposes parts of 12 submarine fans. These fans compose what is commonly called the "basal Blair sandstones." The fans were deposited on submarine slopes (or coastal rises) that were located between the shelf and basin of the interior seaway (fig. 4). The fans are lenticular in cross section, as much as 100 ft thick, and 3–10 mi wide. They occasionally overlap each other, but have never been observed to coalesce. That some of the fans have upper and lower benches indicates the presence of superposed fan lobes. Most of the fans fine upward from sharply defined bases (fig. 8), but a few coarsen upward to sharply defined tops (fig. 9).

Good exposures of one of these fans are present in a roadcut on the north side of Interstate Highway 80 in SE1/4NW1/4 sec. 32, T. 20 N., R. 102 W., 16 mi east of Rock Springs, Wyo. (location shown in fig. 10). Parts of the same fan are exposed 1–1½ mi south of this roadcut in secs. 5 and 6, T. 19 N., R. 102 W. The highway roadcut exposures (figs. 11–14) are situated 2,000 ft west of an overpass on Interstate Highway 80 at the exit of Wyoming Highway 371 to Superior, Wyo.

The fan exposed in the Interstate Highway 80 roadcut consists of three fining-upward lithologic sequences. (1) The entire fan fines upwards from a sharp base; (2) internal parts of the fan are composed of fining-upward units 3.0–4.5 ft thick that comprise multiple beds of alternating sandstone and shale; and (3) the individual sandstone and shale beds form couplets 4–8 in. thick that are composed of very fine grained, silty sandstone at the base and silty shale or shale at the top. Interbedded in these sequences are a few channel deposits composed mostly of sandstone. The overall fining-upward relationships of these lithologic units suggest that the fan was retrogradational.

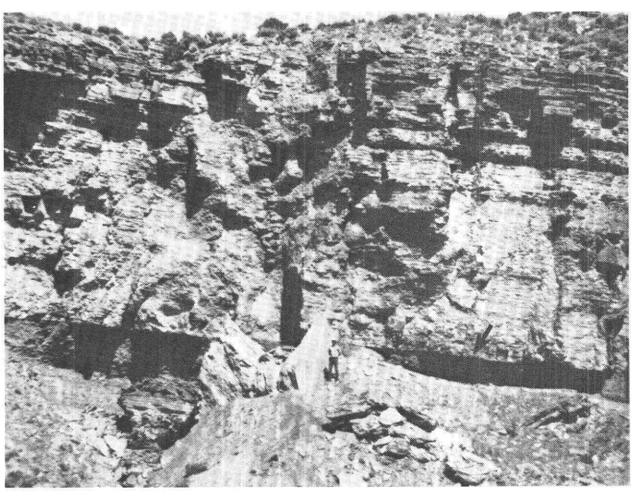

Figure 8. Sharp basal contact (arrow) and fining-upward sandstone in submarine fan in basal Blair Formation on north slopes of Black Butte Creek in NE1/4SE1/4 sec. 6, T. 19 N., R. 102 W. Outcrop location shown in figure 10. Scale indicated by person standing in lower part of view.

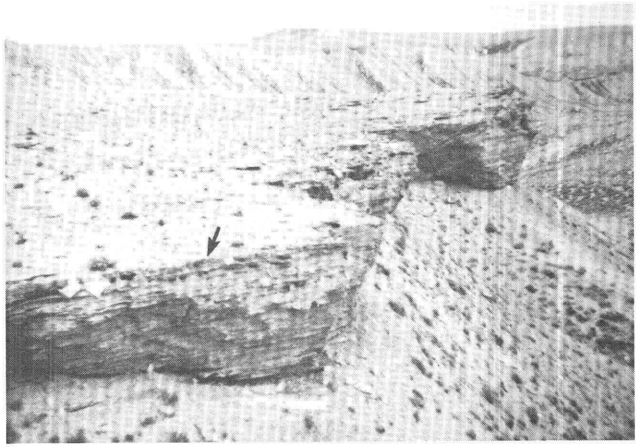

Figure 9. Sharp upper contact (arrow) and coarsening-upward sandstone in submarine fan in basal Blair Formation in NW1/4 sec. 23, T. 17 N., R. 103 W. Bench-forming outcrop is about 40 ft thick.

The beds exposed in the highway roadcut are current rippled and contain numerous trace fossils. The trace fossils consist of variously oriented burrows, crawling trails, and feeding traces (fig. 15), and possible marine reptile tracks (fig. 16). Flute casts, oriented in east-southeast directions, are present on the lower surfaces of some sandstone beds. The sedimentary structures and fossil data suggest that the fan was deposited under as much as 250 ft of water.

The channel deposits in the roadcut section have erosional bases and contain deformed and convoluted beds. Slumping was apparently initiated within the channels by the seaward flow of soft sediments to where the channels filled and overflowed and the channel sediments spread outward onto gently seaward sloping adjacent parts of the fan.

The fan in the roadcut section is similar to turbidite facies described by Mutti and Lucchi (1978). The turbidite facies described by these authors contains isolated channel sandstones interbedded in sandstone and shale couplets in the middle and outer parts of fans. The section primarily consists of sandstone and shale couplets at the outer margins of the fans. The coarse material (sandstone) was deposited by traction and the fine material (shale) settled out of suspension. The fans in the Blair Formation are composed of very finely textured sediments and bear little resemblance to the "Bouma sequence" (Bouma, 1962).

I have reached a number of conclusions concerning the submarine fans in the basal Blair Formation. Among them are: (1) The source of the sandstone was probably distant beaches located northwest of the Rock Springs uplift; (2) as most of the fans fine upwards, they were

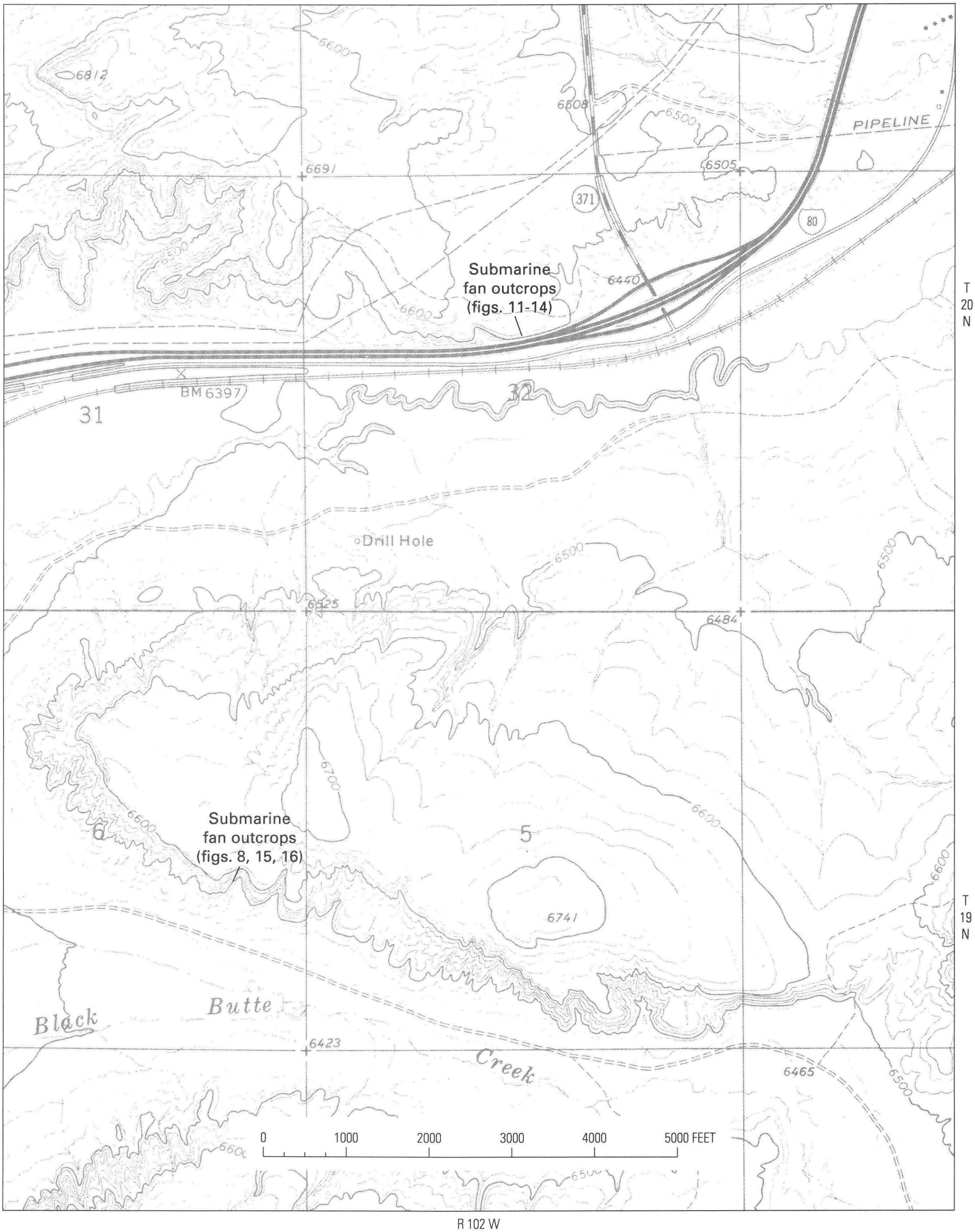

Figure 10. Location of submarine fan outcrops in basal Blair Formation, east flank of Rock Springs uplift. Base from U.S. Geological Survey 1:24,000 Thayer Junction, Wyo.; contour interval 20 ft.

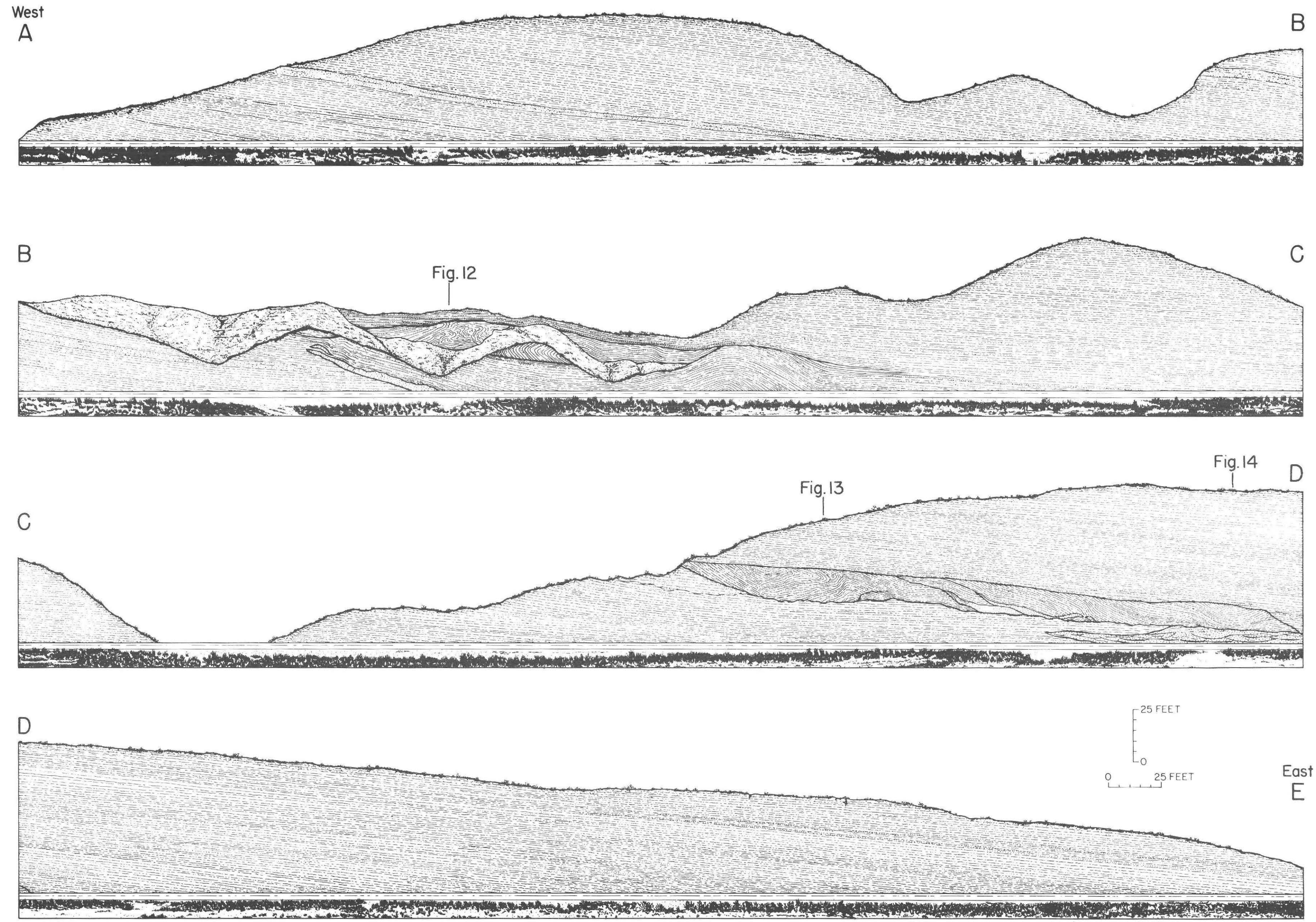

Figure 11. Pen sketches illustrate a cross-sectional view of part of the peripheral submarine fan in basal Blair Formation in roadcut of Interstate Highway 80, 16 mi east of Rock Springs, Wyo. Sedimentary structures and fossils are described and illustrated in figures 12–14. Fan location shown in figure 10.

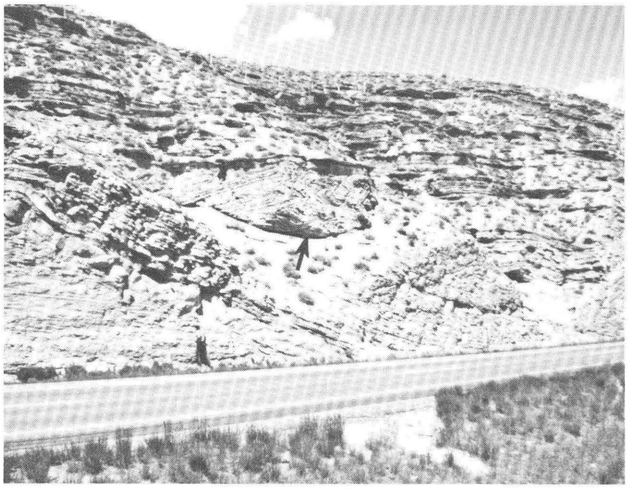

Figure 12. Convoluted bedding (arrow) in channel sandstone in submarine fan in basal Blair Formation in roadcut on north side of Interstate Highway 80, 16 mi east of Rock Springs, Wyo. Outcrop location shown in figures 10 and 11.

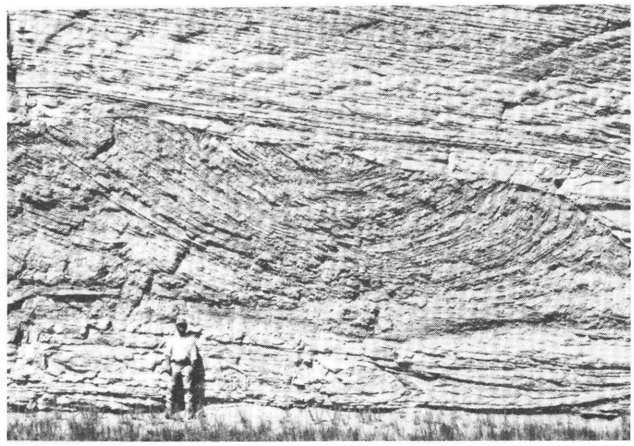

Figure 14. Syncline in deformed bedding in channel of submarine fan in basal Blair Formation in roadcut on north side of Interstate Highway 80, 16 mi east of Rock Springs, Wyo. Outcrop location shown in figures 10 and 11.

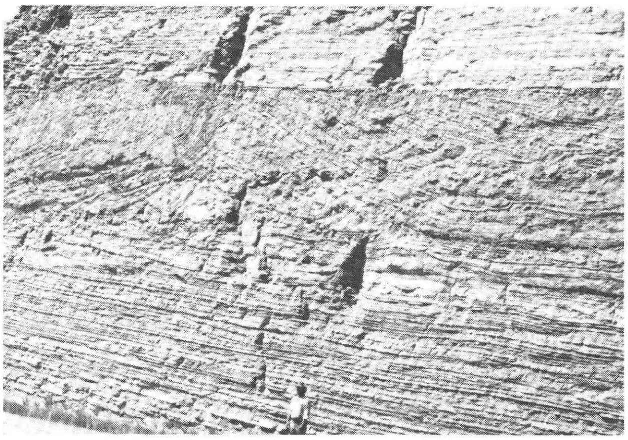

Figure 13. Anticlinal distortion in channel deposits in submarine fan in basal Blair formation in roadcut on north side of Interstate Highway 80, 16 mi east of Rock Springs, Wyo. Outcrop location shown in figures 10 and 11.

probably deposited as a result of either tectonic disturbances or repetitious climate changes, which occurred suddenly and then moderated; and (3) the geographic distribution of the fans suggests that they are not part of a single river system, unless they are associated with distributary streams of a very large delta.

MARINE SHELF DEPOSITS

Two types of linear, shelf sandstone deposits have been identified in marine shale in the middle part of the Blair Formation in Tps. 16–17 N., Rs. 102–103 W., on the

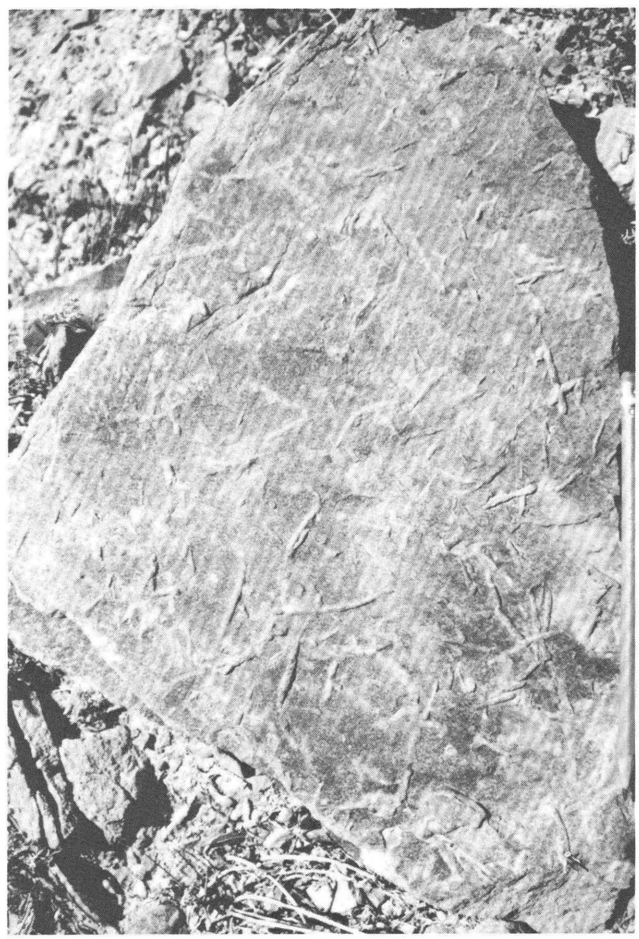

Figure 15. Trace fossils at base of submarine fan in basal Blair Formation in NE¼SE¼ sec. 6, T. 19 N., R. 102 W. Outcrop location shown in figure 10.

Figure 16. Trace fossils including possible reptile tracks (arrow) at base of submarine fan in basal Blair Formation in NE1/4SE1/4 sec. 6, T. 19 N., R. 102 W. The animal that made the tracks appears to have had three toes and webbed feet. Outcrop location shown in figure 10.

southeast flank of the Rock Springs uplift. The first type comprises a longshore bar that paralleled the northeast trend of the Blair Formation shorelines. The second type consists of submarine channel and overbank deposits that are perpendicular to the trend of the Blair Formation shorelines.

LONGSHORE BAR

The longshore bar identified in the Blair Formation crops out as isolated knobs along the tops of ridges located in secs. 7 and 18, T. 17 N., R. 102 W. The bar is particularly well exposed in SE1/4NW1/4 sec. 18, T. 17 N., R. 102 W., where eroded remnants cap a low ridge (fig. 17). The bar there is composed mostly of sandstone (section 7785, fig. 18), which exhibits southeast-dipping, planar crossbeds in the direction of prevailing longshore currents (fig. 19). Some of the foreset laminae in these beds dip as much as 20°, which, in places, resulted in avalanche slope failure and bed convolutions (fig. 20).

SUBMARINE CHANNEL AND OVERBANK

A submarine channel sandstone is exposed in a thick section of marine shale in the middle part of the Blair Formation in SW1/4SW1/4SE1/4 sec. 36, T. 17 N., R. 103 W. (fig. 21). The channel trends about S. 18° E., is lenticular and about 400 ft wide in cross section, and has a maximum recorded thickness of about 18 ft (section 9882, fig. 22). The channel is a coarsening-upward sequence. The lower 8 ft is transitional with underlying marine shale and consists of thin, parallel beds of gray siltstone and interbedded gray, sandy shale. The upper 10 ft is composed of tan, very fine grained to fine-grained sandstone in low-angle, canoe-shaped trough crossbeds that are 12–15 ft wide and as much as 75 ft long (figs. 23, 24).

A few limy layers in the channel sandstone, composed of mostly lag material, contain small, flat, rounded, gray clay pebbles and abundant marine fossils. Fossil mollusks include *Nucula* sp., *Inoceramus balticus*, and unidentified small gastropods. Ammonite fossils were identified as *Baculites* sp., *Scaphites hippocrepis*, and *Glyptoxoceras rubeyi* (USGS Mesozoic locality D11913). Trace fossils are present in thin beds of shale near the base of the channel, and small black shark teeth were collected from adjacent ant hills. Similar but smaller shelf channels are present in outcrops a few hundred feet north and south of this channel.

Marine channel and overbank deposits are exposed in SE1/4 sec. 2, T. 16 N., R. 103 W. (fig. 21). The contact of one of these overbank deposits with underlying marine shale is a sharply defined scoured surface (fig. 25). Above this sharply defined basal contact, the overbank deposit consists of current-rippled, parallel to subparallel beds of dark-gray, silty shale, and interlaminated gray siltstone. These beds coarsen upward into parallel to subparallel beds, as much as 0.2 ft thick, consisting of gray, very fine grained to fine-grained sandstone (fig. 26). The channel deposit shown in figures 25 and 26 is part of an isolated outcrop, which makes the overall size and geometry of the deposit impossible to determine. One overbank deposit in the area, however, is more than 7 ft thick and at least 300 ft wide.

PRODELTA DEPOSITS

Prodelta deposits are exposed in a roadcut and in outcrops above the roadcut along the east side of Wyoming Highway 430 in NW1/4NE1/4 sec. 29, T. 17 N., R. 102 W., 19 mi southeast of Rock Springs, Wyo. (figs. 17, 27). The prodelta deposits consist of more than 120 ft of mostly

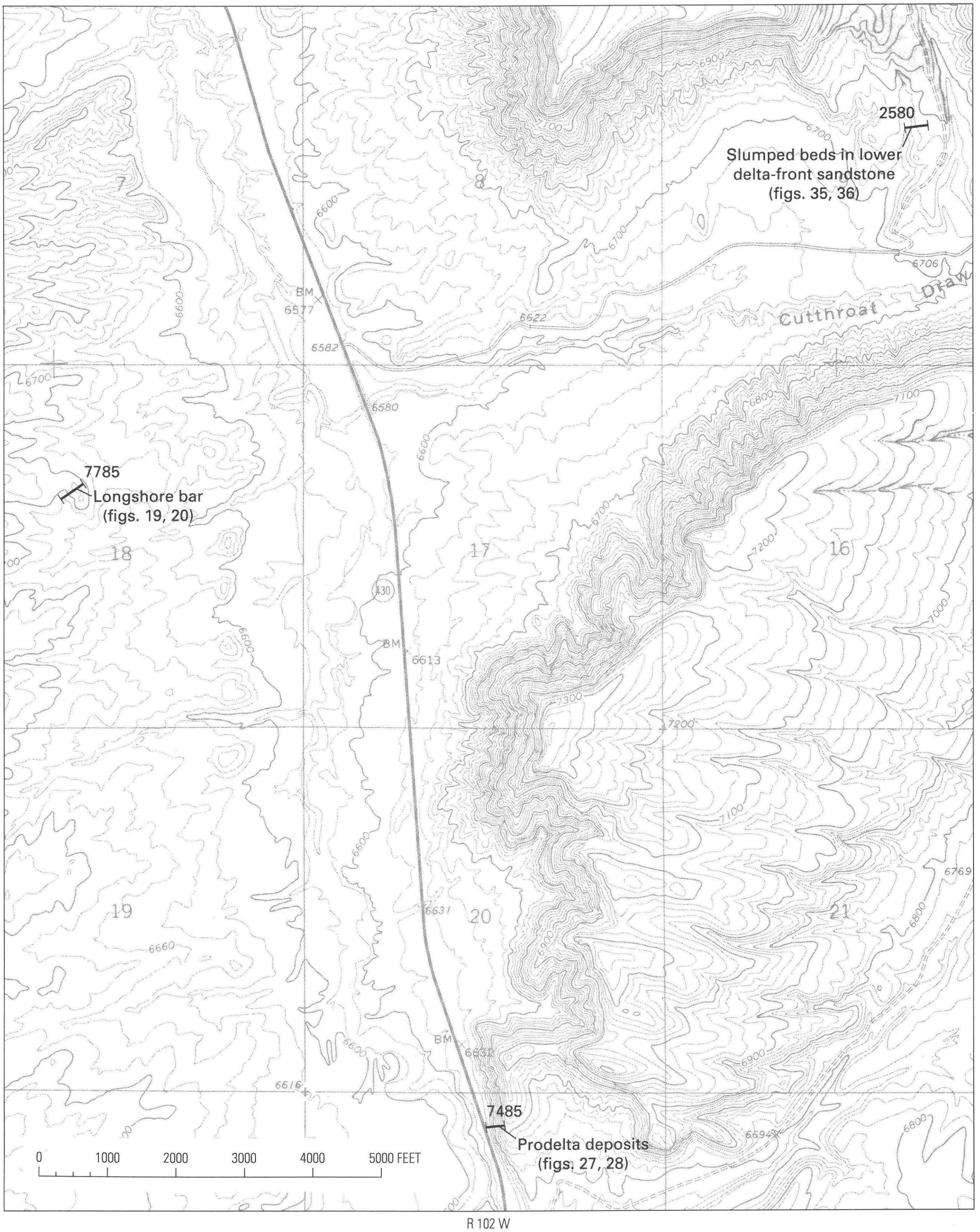

Figure 17. Location of measured sections 7485 (prodelta deposits), 7785 (longshore bar), and 2580 (slumped delta-front deposits) in the Blair Formation, and figures 18, 19, 20, 27, 28, 35, and 36. Base from U.S. Geological Survey 1:24,000 Camel Rock, Wyo.; contour interval 20 ft.

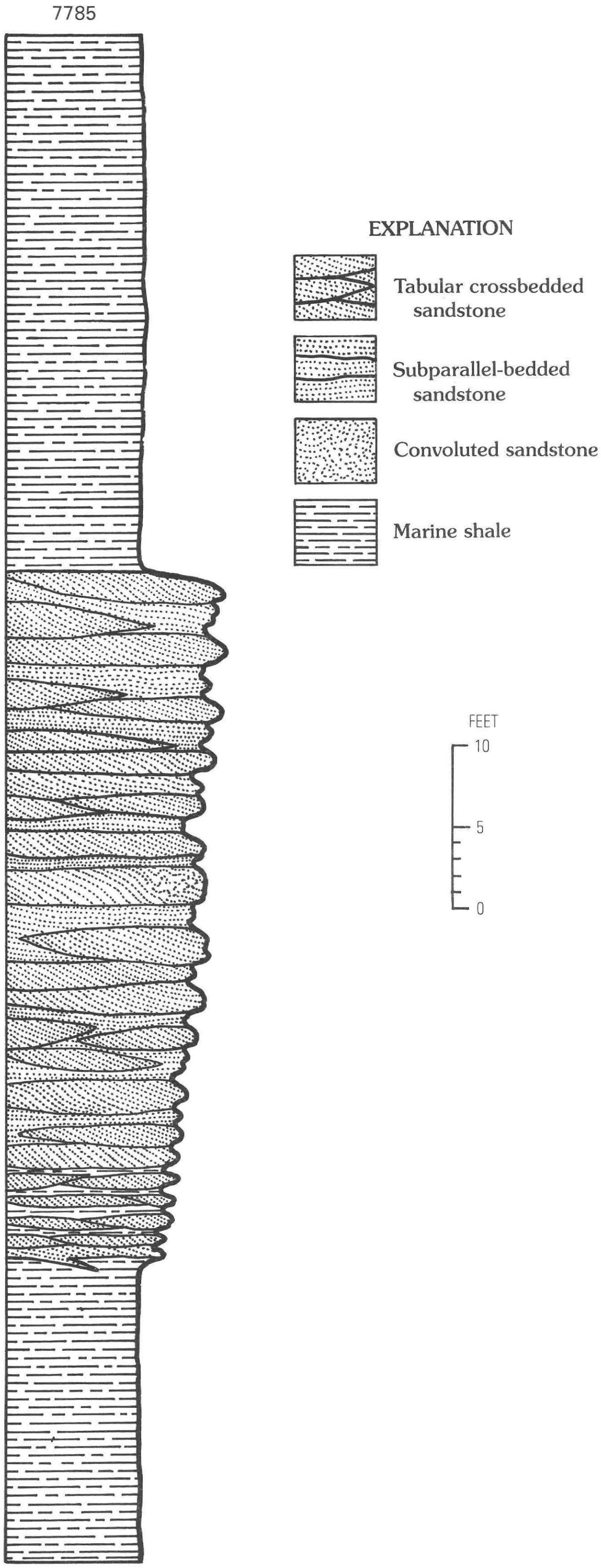

Figure 18. Measured section 7785 of longshore bar in Blair Formation on southeast flank of Rock Springs uplift. Section location shown in figure 17.

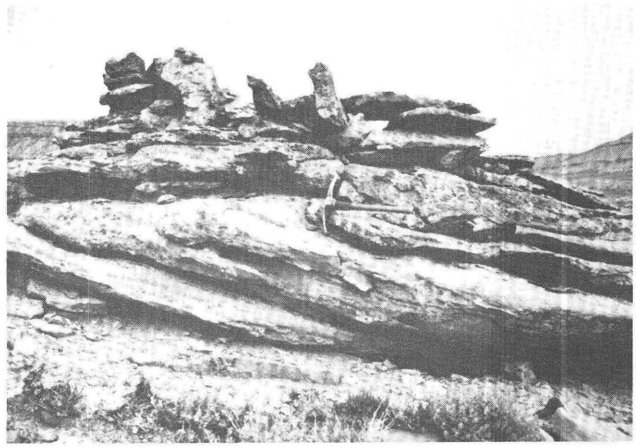

Figure 19. Large sand wave with southeast-dipping foreset laminae in longshore bar in Blair Formation on southeast flank of Rock Springs uplift. Outcrop location shown in figure 17. Pick handle is 1.5 ft long.

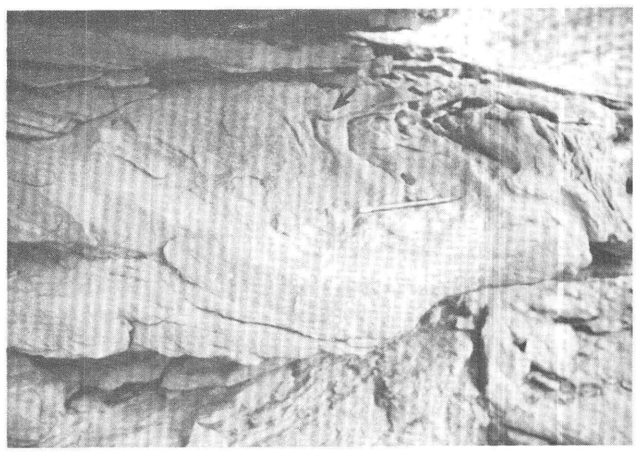

Figure 20. Convoluted bedding (arrow) on avalanche slope of sand wave in longshore bar in Blair Formation on southeast flank of Rock Springs uplift. Outcrop location shown in figure 17.

dark gray, silty shale that is interbedded with numerous very thin beds of gray, sandy siltstone and some gray, very fine grained sandstone (section 7485, fig. 28). The siltstone and sandstone occur in parallel, partly wave rippled beds and laminae containing abundant *Ophiomorpha, Skolithus,* and worm borings and trails. The prodelta deposits thicken and coarsen upward in the outcrops to where they merge imperceptibly with still thicker beds of sandstone and shale that cap the slopes on the east side of Highway 430. The cap rocks are part of a lower delta-plain sequence in the overlying Chimney Rock Tongue of the Rock Springs Formation (fig. 3).

DELTA-FRONT DEPOSITS

Outcrops of delta-front deposits are ubiquitous in the basal part of the Rock Springs Formation on the east and

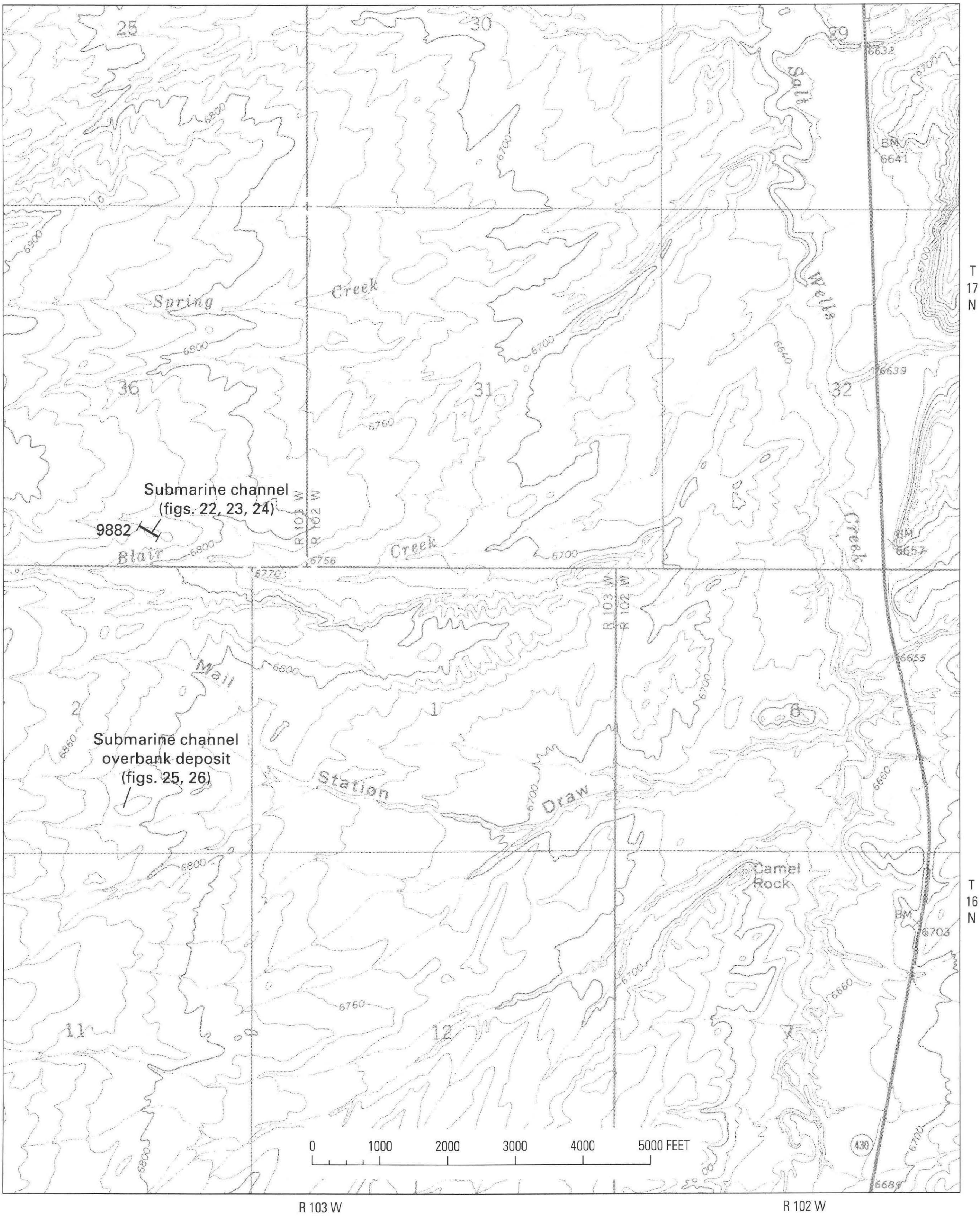

Figure 21. Location of submarine channel and overbank deposits in measured section 9882 and in figures 23–26, Blair Formation on southeast flank of Rock Springs uplift. Base from U.S. Geological Survey 1:24,000 Camel Rock, Wyo.; contour interval 20 ft.

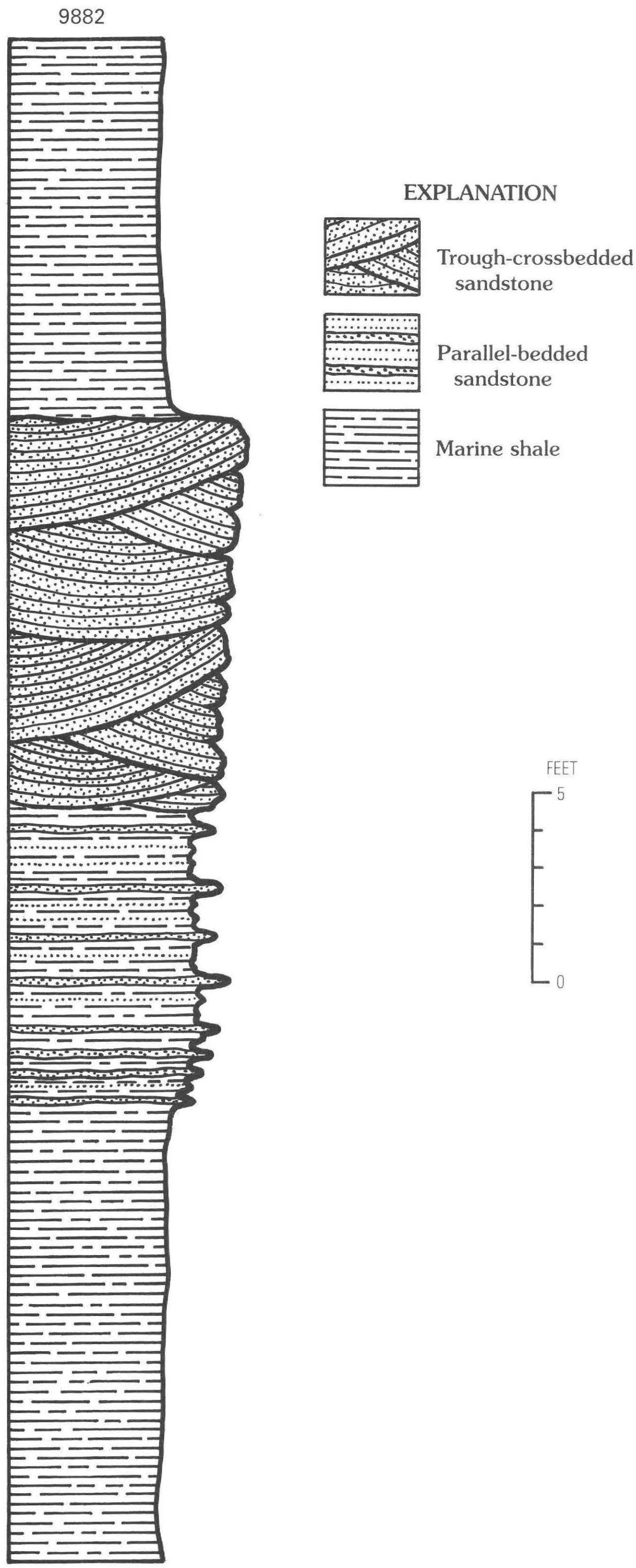

Figure 22. Measured section 9882 of submarine channel sandstone in Blair Formation on southeast flank of Rock Springs uplift. Section location shown in figure 21.

Figure 23. View to north of trough-crossbedded submarine channel sandstone (arrow) in Blair Formation on southeast flank of Rock Springs uplift. Jacob staff near center of photograph is 5 ft long. Outcrop location shown in figure 21.

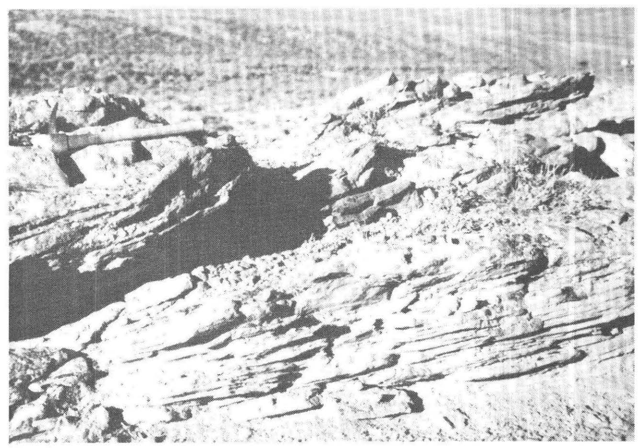

Figure 24. Closeup view of submarine channel sandstone in Blair Formation shown in figure 23. Pick handle is 1.5 ft long. Outcrop location shown in figure 21.

west flanks of the Rock Springs uplift. They are conspicuous along Interstate Highway 80 a few miles west of Point of Rocks, Wyo., and a few miles east of Rock Springs, Wyo., where they crop out as stacked beds of tan and light-gray sandstone that generally weather to cliffs.

SHORELINE SANDSTONES

Seven delta-front shoreline sandstones are superposed in outcrops that dip about 5° E. along an east-west-trending ridge near the center of sec. 24, T. 19 N., R. 102 W., on the east flank of the Rock Springs uplift. One of these delta-front sandstones, well exposed near the east end of the ridge in NE¼NE¼SE¼ sec. 24 (fig. 29), displays the

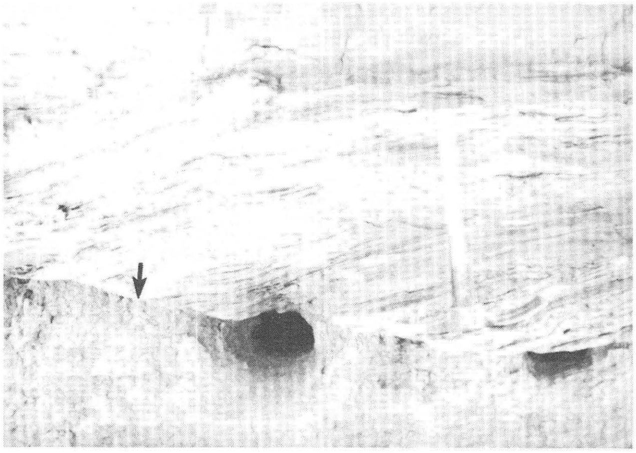

Figure 25. Scoured, sharp basal contact (arrow) of submarine channel overbank siltstone and very fine grained sandstone overlying marine shale in Blair Formation on southeast flank of Rock Springs uplift. Pick handle is 1.5 ft long. Outcrop location in figure 21.

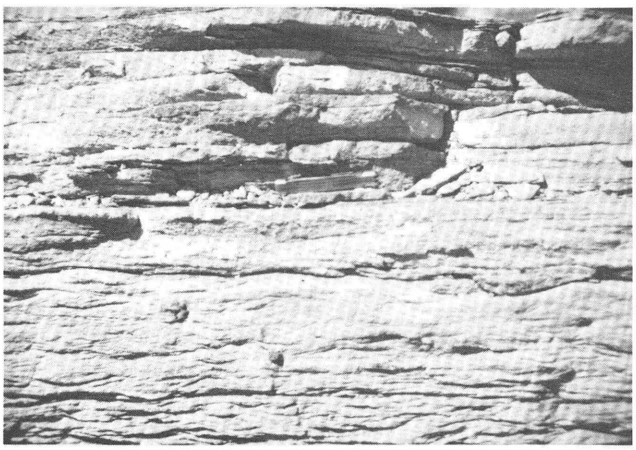

Figure 26. Coarsening-upward, current-rippled, very fine grained sandstone in submarine channel overbank deposit in Blair Formation on southeast flank of Rock Springs uplift. Pocket knife is 3.3 in. long. Outcrop location shown in figure 21.

three characteristic lithofacies of delta-front deposits in the uplift area (figs. 30, 31). The three lithofacies are (1) the lower delta front consisting of tan, very fine grained to fine-grained sandstone and some interbedded gray, silty shale, deposited distances offshore (fig. 32); (2) the middle delta front consisting of massive or thick, subparallel beds of tan, fine-grained sandstone, deposited in shallow, nearshore water (fig. 33); and (3) the upper delta front consisting of variously bedded, light-gray, fine- to medium-grained sandstone deposited inshore and onshore (fig. 34). The upper delta-front sandstone can be further subdivided into small-scale trough crossbeds that comprise a surf zone at the base (fig. 34, No. 1), thin, parallel, tabular beds that comprise a forebeach zone in the middle (fig.

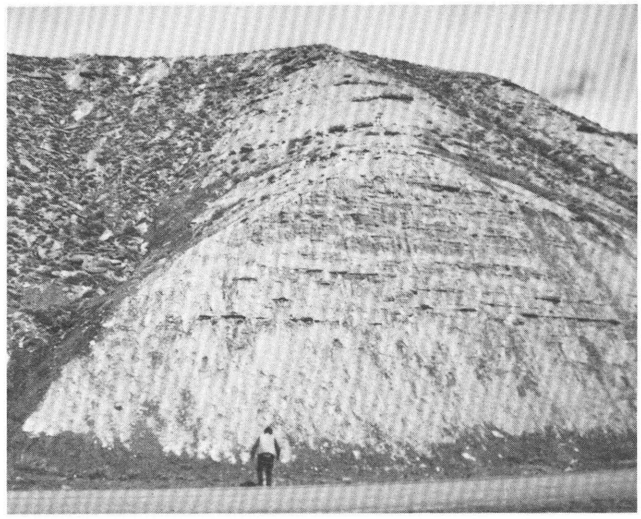

Figure 27. Prodelta deposits in upper part of Blair Formation in roadcut of Wyoming Highway 430, 20 mi southeast of Rock Springs, Wyo. Outcrop location shown in figure 17.

34, No. 2), and deeply weathered, faintly crossbedded remnants of eolian dunes at the top (fig. 34, No. 3).

SUBMARINE SLUMPS

Submarine slumps are present in lower delta-front sandstones in measured section 2580 in the Blair Formation in Cutthroat Draw in sec. 9, T. 17 N., R. 102 W. on the southeast flank of the Rock Springs uplift (figs. 17, 35). The slumped beds are as much as 13 ft thick and partly convoluted (fig. 36), and they are interbedded with shale and uncontorted parallel-bedded and hummocky-crossbedded sandstone. The slumped beds are believed to be the product of submarine slope failure and the mass movement of unconsolidated sand toward the periphery of an arcuate delta (Roehler, 1988). The sand bodies were not confined to channels, but flowed downslope (marineward) in sheetlike masses. The mechanics of the slumping are analogous to those of snow avalanches.

HEAVY-MINERAL BEACH PLACER

A heavy-mineral beach sandstone placer deposit is present in S½N½NW¼SW¼ sec. 19, T. 19 N., R. 101 W., 1,000 ft east of the previously described delta-front sandstone deposit in section 3776 (fig. 29). The placer deposit is located along the top of an upper delta-front sandstone that overlies section 3776 (fig. 37). The placer deposit, in turn, is overlain by a thick section of interbedded sandstone, shale, and carbonaceous shale of lagoon origin. The mineralized zone is nearly 2,000 ft wide, about 3 ft thick, and trends northeast parallel to the strike of the delta-front shoreline. An erosional remnant of the placer is

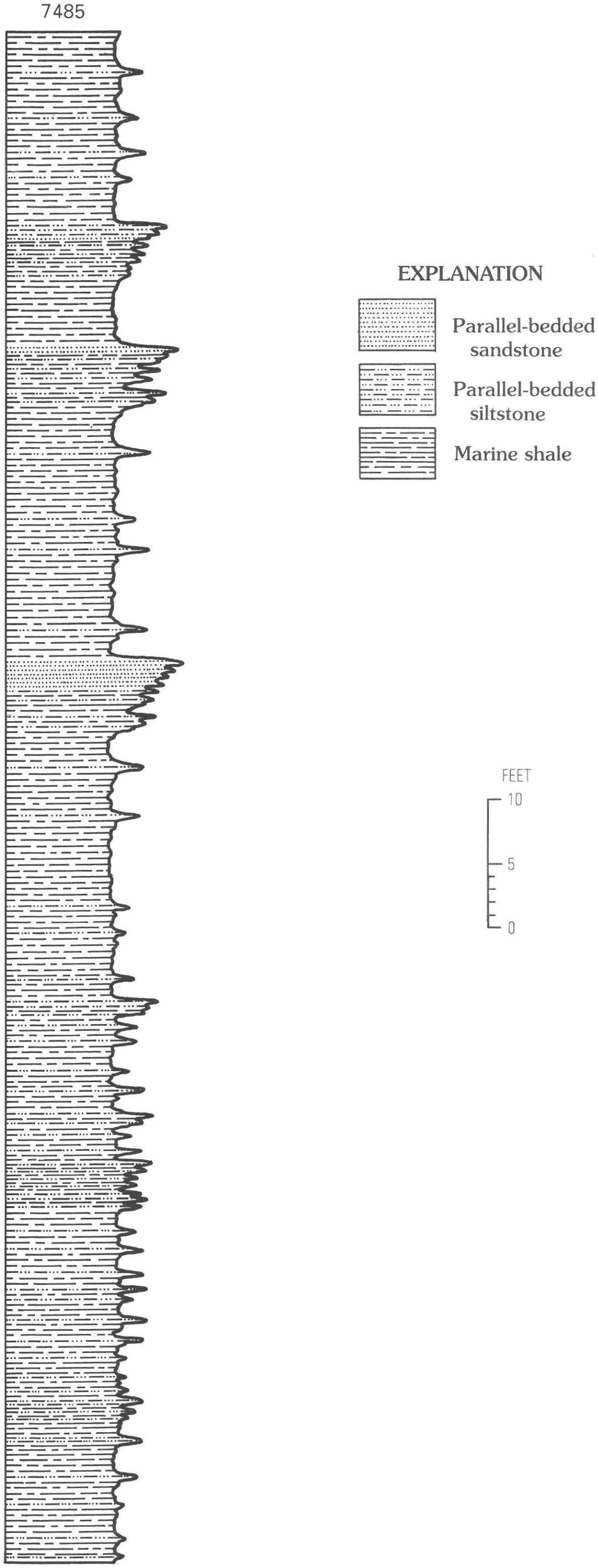

Figure 28. Measured section 7485 of prodelta deposits in Blair Formation in roadcut of Wyoming Highway 430, 19 mi southeast of Rock Springs, Wyo. Section location shown in figure 17.

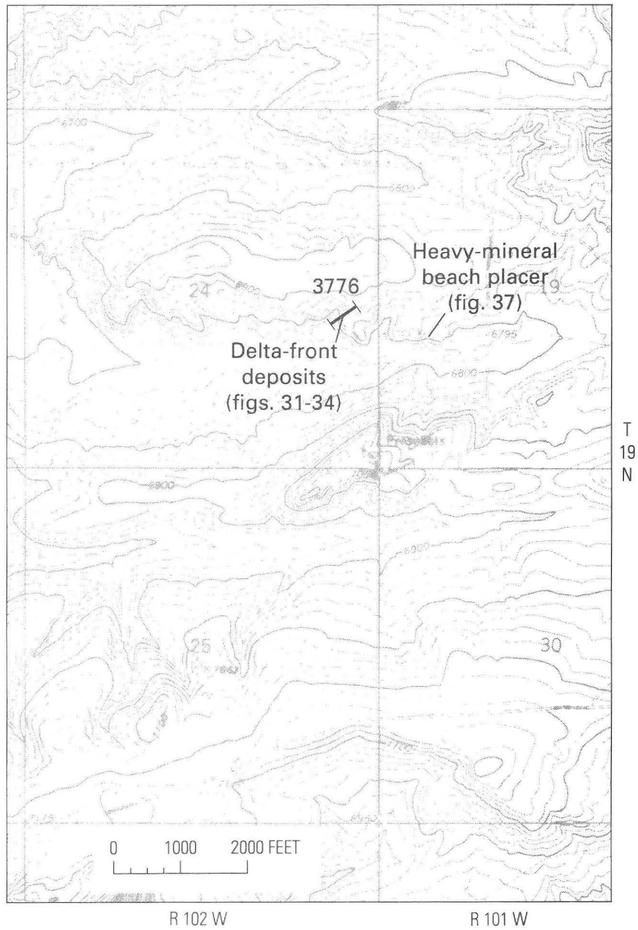

Figure 29. Location of delta-front deposits and heavy-mineral beach placer in measured section 3776 and in figures 31–34 and 37, Rock Springs Formation on tributary of Black Butte Creek on east flank of Rock Springs uplift. Base from U.S. Geological Survey 1:24,000 Point of Rocks SE, Wyo.; contour interval 20 ft.

Figure 30. Outcrops of 1, lower, 2, middle, and 3, upper delta-front sandstone and shale in Rock Springs Formation on tributary of Black Butte Creek on east flank of Rock Springs uplift. Outcrops are 185 ft thick.

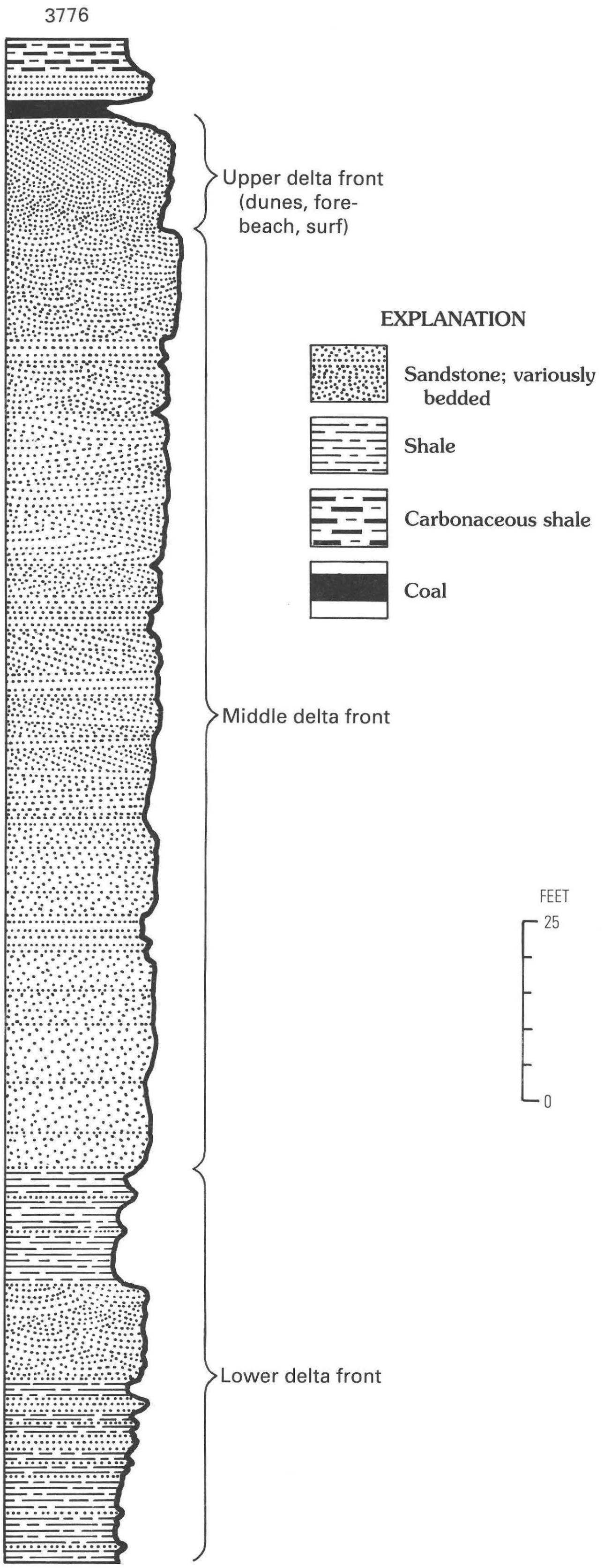

Figure 31. Measured section 3776 of delta-front sandstones in Rock Springs Formation on tributary of Black Butte Creek on east flank of Rock Springs uplift. Section shown in figure 29.

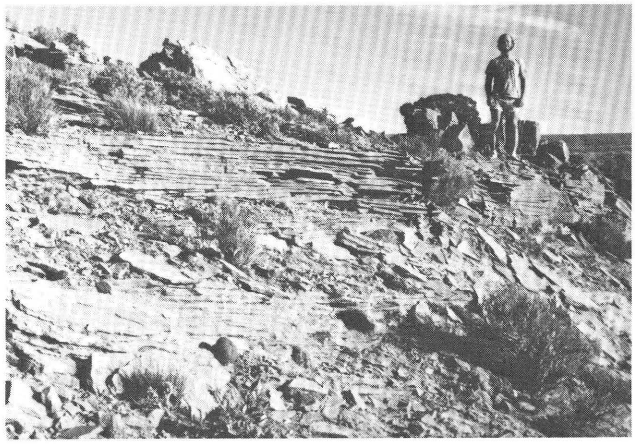

Figure 32. Parallel-bedded lower delta-front sandstone and shale in Rock Springs Formation on tributary of Black Butte Creek, illustrated in measured section, figure 31.

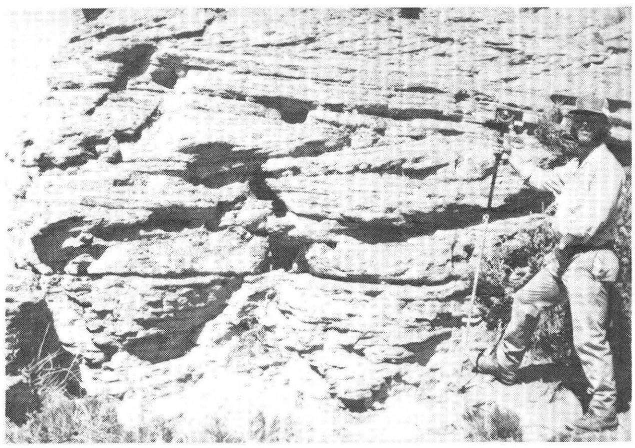

Figure 33. Subparallel-bedded, middle delta-front sandstone in Rock Springs Formation on tributary of Black Butte Creek, illustrated in measured section, figure 31. Note that some foreset laminae dip to the left in a southeast (seaward) direction.

separated from the main part of the deposit on the upthrown side of a west-northwest-trending, high-angle normal fault. The erosional remnant surrounds the common corner of secs. 24 and 25, T. 19 N., R. 102 W. and secs. 19 and 30, T. 19 N., R. 101 W. (fig. 29). Examination of a channel sandstone that is the stratigraphic equivalent of the placer, in outcrops 500 ft northeast of the placer, indicates that the placer formed at the mouth of a small distributary stream that flowed southeast from an adjacent delta plain. *Ophiomorpha, Arenicolites,* and other trace fossils are abundant in the placer deposit, and *Corbula undifera* and *Thalassinoides* were identified in nearby outcrops.

The heavy-mineral placer deposit weathers dark red brown and contains radioactive zircon. Because of this radioactivity, the deposit was claimed by uranium

Figure 34. Upper delta-front sandstone in Rock Springs Formation on tributary of Black Butte Creek, illustrated in measured section, figure 31. 1, Small-scale, trough-crossbedded surf sandstone; 2, parallel, tabular-bedded forebeach sandstone; 3, deeply weathered dune(?) sandstone.

prospectors in the 1950's, who dug several exploratory pits and trenches along the outcrops. The grain-size distribution of the deposit is about 15 percent coarse, 30 percent medium, 20 percent fine, 20 percent very fine, and 15 percent silt and clay (Roehler, unpub. data, 1978). Magnetic heavy-mineral fractions consisting of ilmenite and magnetite compose 50–55 percent. The nonmagnetic heavy-mineral fraction is composed of more than 95 percent zircon, with the remaining fractions composed of mostly garnet and rutile. The composition is similar to six other beach placer deposits described by Roehler (1989) in Upper Cretaceous rocks in the Rock Springs uplift area. The placer deposit has proven to be uneconomic as a source for uranium, but it remains a possible source for titanium. The titanium is present in the ilmenite, which is composed 52–68 percent of titanium dioxide.

FLOOD-TIDAL DELTA AND TIDAL INLET

The lower part of the Rock Springs Formation exposes several delta-front sandstones along Interstate Highway 80 in secs. 21, 22, 27, and 28, T. 20 N., R. 102 W., on the east flank of the Rock Springs uplift. These sandstones weather to tan benches. Some are stacked one upon the other and many have white sandstone cap rocks. At the top of one of these delta-front sandstones, where it crosses Interstate Highway 80 near Thayer Junction in the south-center of sec. 22, T. 20 N., R. 102 W. (fig. 38), is a tidal-inlet sandstone. The tidal-inlet deposits (section 7582, fig. 39) comprise 12 ft of tan-gray fine- to medium-grained sandstone in thick, planar crossbeds having bidirectional (northwest- and southeast-dipping) foreset

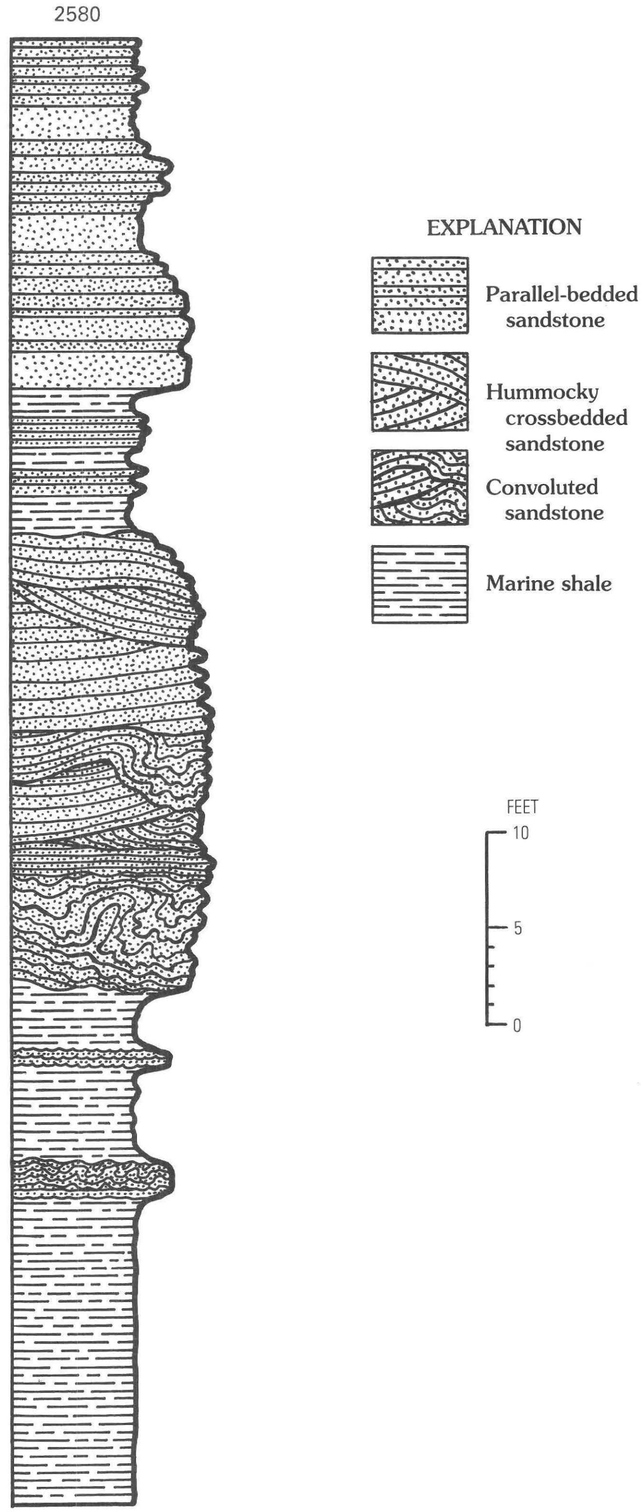

Figure 35. Measured section 2580 of slumped lower delta-front sandstone in Blair Formation in Cutthroat Draw on southeast flank of Rock Springs uplift. Section location shown in figure 17.

laminae (fig. 40). The bidirectional bedding is the result of the landward flow of flood tides and the seaward flow of ebb tides near a flood ramp at the head of the flood-tidal

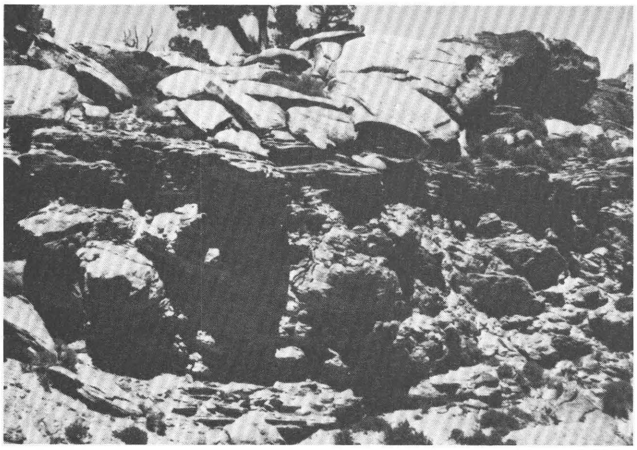

Figure 36. Submarine slump of lower delta-front sandstone in Blair Formation in Cutthroat Draw on southeast flank of Rock Springs uplift. Convoluted interval is 7.5 ft thick. Outcrop location shown in figure 17.

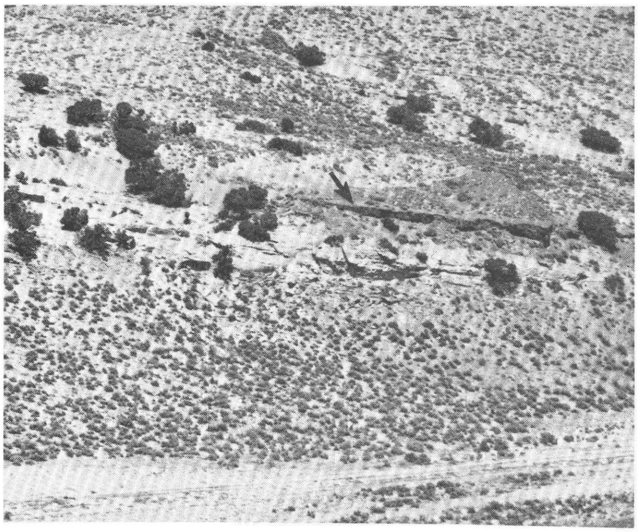

Figure 37. Heavy-mineral beach placer (arrow) in delta-front sandstone in Rock Springs Formation on tributary of Black Butte Creek, southeast flank of Rock Springs uplift. The placer deposit has a maximum thickness of about 3 ft. Outcrop location shown in figure 29.

delta (fig. 41). The flood-tidal delta was aligned southeast and opened in a landward direction into a large, brackish, open-water lagoon located to the northwest. The sandstone that makes up the flood-tidal delta thins in outcrops for about 4,000 ft in a northwest direction from where it crosses Interstate Highway 80. It wedges out in gray, slightly carbonaceous shale of lagoon origin in the east-center of NE1/4NW1/4SE1/4 sec. 21, T. 20 N., R. 102 W., near measured section 10482 (figs. 38, 42). The flood-tidal delta sandstone consists of parallel to subparallel beds with mostly landward dipping foreset laminae across the middle and distal parts of the delta (fig. 43).

Eroded remnants of the seaward part of the tidal-inlet sandstone associated with the flood-tidal delta are present in measured section 7682 in W1/2SE1/4NE1/4 sec. 27, T. 20 N., R. 102 W., on the south slopes of Bitter Creek, 3,000 ft south-southeast of where the flood-tidal delta sandstone crosses Interstate Highway 80 (fig. 38). The upper part of the inlet there is composed of 12 ft of light-gray, fine- to medium-grained sandstone in parallel beds with bidirectional (landward- and seaward-dipping) foreset laminae. These beds are underlain by 14 ft of tan, fine- to medium-grained, partly shaly sandstone beds that occur in lenses up to 4 ft thick made up of broad, low-angle trough crossbeds having scoured bases (fig. 44).

DELTA-PLAIN DEPOSITS

Delta-plain deposits are divided into lower delta plain and upper delta plain, based on their paleogeographic location and lithology. The lower delta plain consisted of the seaward parts of deltas, where large, open-water bays were present. The lower delta plain is composed mostly of thick beds of bay-fill shale and thin interbedded splay sandstone, carbonaceous shale, and coal (fig. 4). The upper delta plain consisted of the landward parts of deltas, where large swamps and coal bogs were present. The upper delta plain is composed of thick interbedded carbonaceous shale, coal, splay sandstone, stream-channel sandstone, and thin interbedded bay-fill shale (fig. 4). The dividing line between the lower delta plain and the upper delta plain in modern deltas is generally placed at the uppermost limit of salt water (tidal) influence. The dividing line is easily recognized in modern deltas by distinct changes of freshwater to saltwater vegetation, but it is generally vague in rock outcrops of ancient deltas.

DISTRIBUTARY STREAM CHANNEL

A distributary stream channel sandstone rests upon a delta-front sandstone in outcrops of the Rock Springs Formation in NW1/4 sec. 29, T. 19 N., R. 104 W., about 1,000 ft north of Interstate Highway 80, 1½ mi east of Rock Springs, Wyo. (figs. 45, 46). The channel sandstone is about 26 ft thick and lenticular in cross section, and it has a scoured base. It is composed of mostly gray, very fine grained to fine-grained sandstone in large-scale trough crossbeds.

LOWER DELTA PLAIN

The lower part of a lower delta-plain deposit is exposed in the Rock Springs Formation in measured section 10482 located in NW1/4SW1/4 sec. 22, T. 20 N., R. 102 W., overlying the previously described flood-tidal

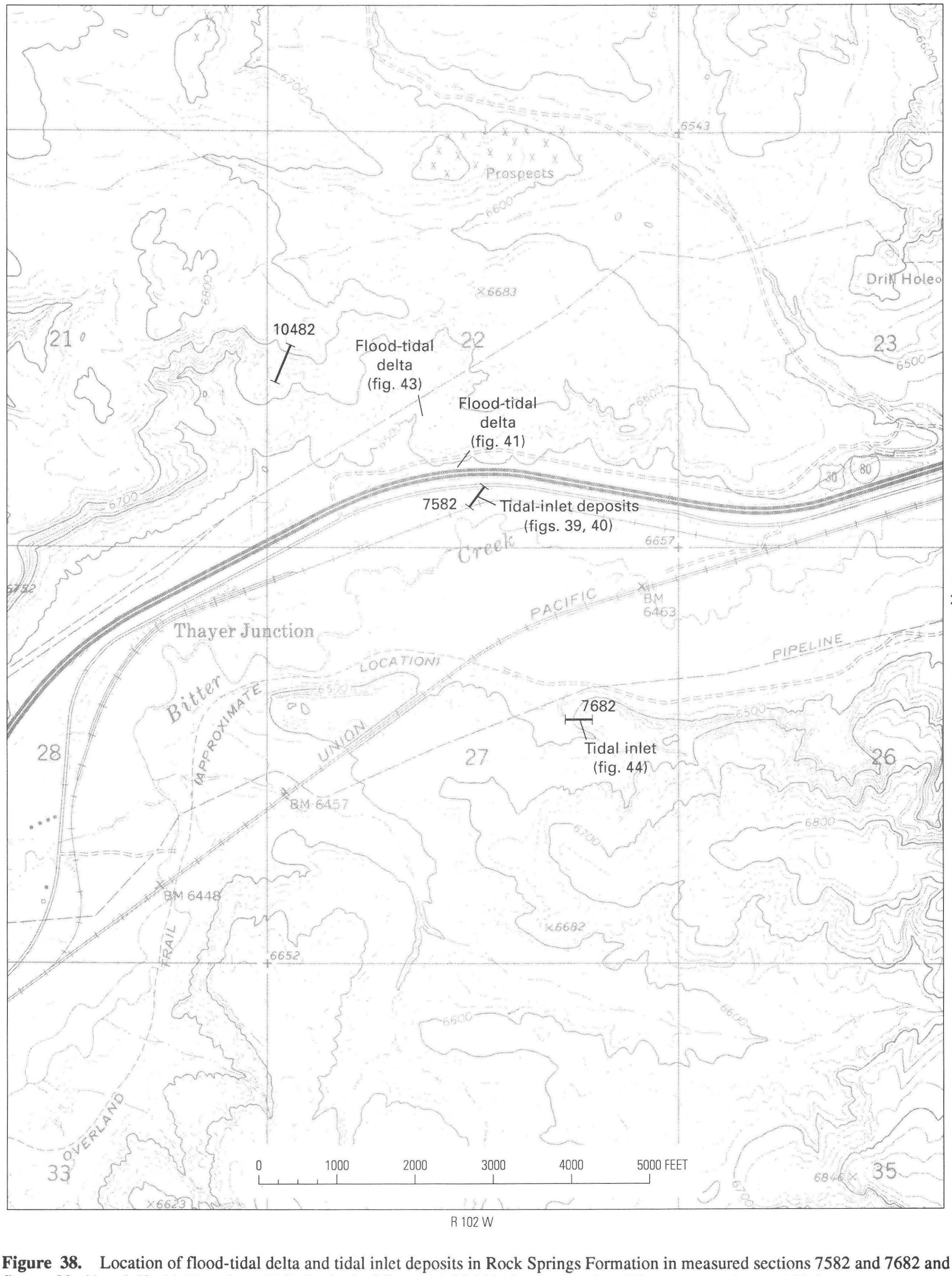

Figure 38. Location of flood-tidal delta and tidal inlet deposits in Rock Springs Formation in measured sections 7582 and 7682 and in figures 39–41 and 43–44. Base from U.S. Geological Survey 1:24,000 Thayer Junction, Wyo.; contour interval 20 ft.

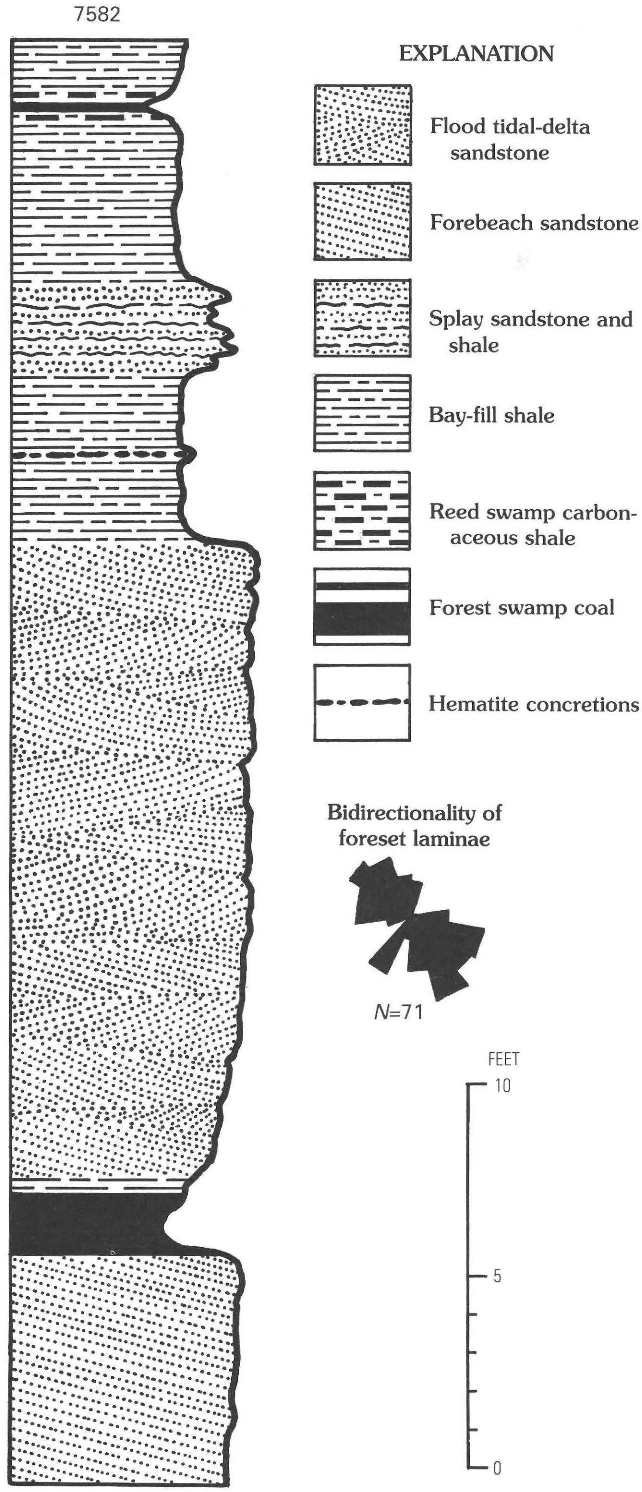

Figure 39. Measured section 7582 of flood-tidal delta sandstone in Rock Springs Formation near Thayer Junction, Wyo., on east flank of Rock Springs uplift. Section location shown in figure 38.

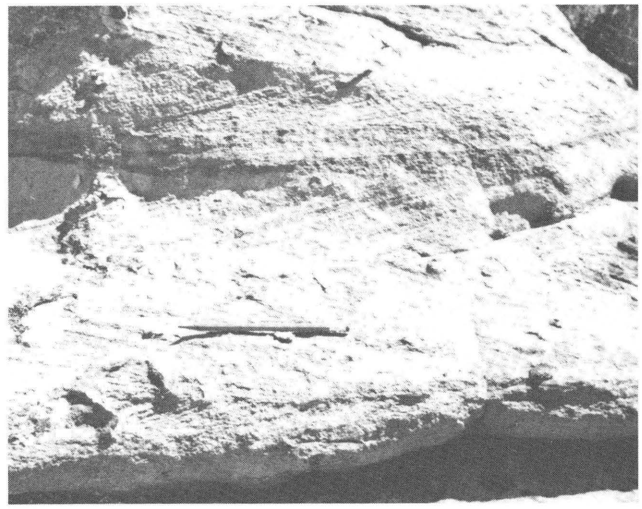

Figure 40. Bidirectional crossbeds in tidal inlet associated with delta-front sandstone in Rock Springs Formation near Thayer Junction, Wyo. Crossbeds are shown in measured section 7582, figure 39. Outcrop location shown in figure 38.

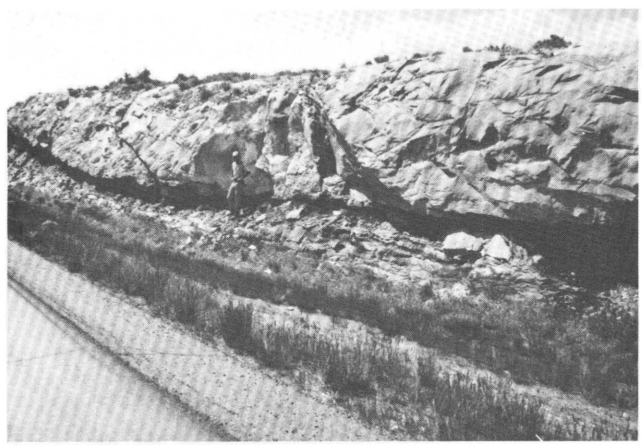

Figure 41. Crossbedded flood-ramp sandstone in flood-tidal delta in Rock Springs Formation on north side of Interstate Highway 80 near Thayer Junction, Wyo. The sandstone is underlain by the No. 15 coal bed. Outcrop location shown in figure 38.

delta near Thayer Junction, Wyo. (fig. 38). Measured section 10482 is composed mostly of gray shale of bay-fill origin, and thin interbedded sandstone and siltstone of splay origin, carbonaceous shale of reed swamp origin, and coal of forest swamp origin (figs. 42, 47). Thin beds of dolomite and hematite concretions are also present at several stratigraphic levels. Sandstone beds of distributary stream channel origin are widely spaced in the lower part of the lower delta plain, but in this section they are missing.

The sediments deposited across the lower delta plain undergo subtle changes from its lower (seaward) part to its upper (landward) part, as shown by a comparison of measured sections 10482 and 680 (fig. 47). Measured section 680 illustrates the type of rocks deposited in the upper part of a lower delta plain in the Rock Springs Formation. Section 680 was measured in a roadcut of Wyoming

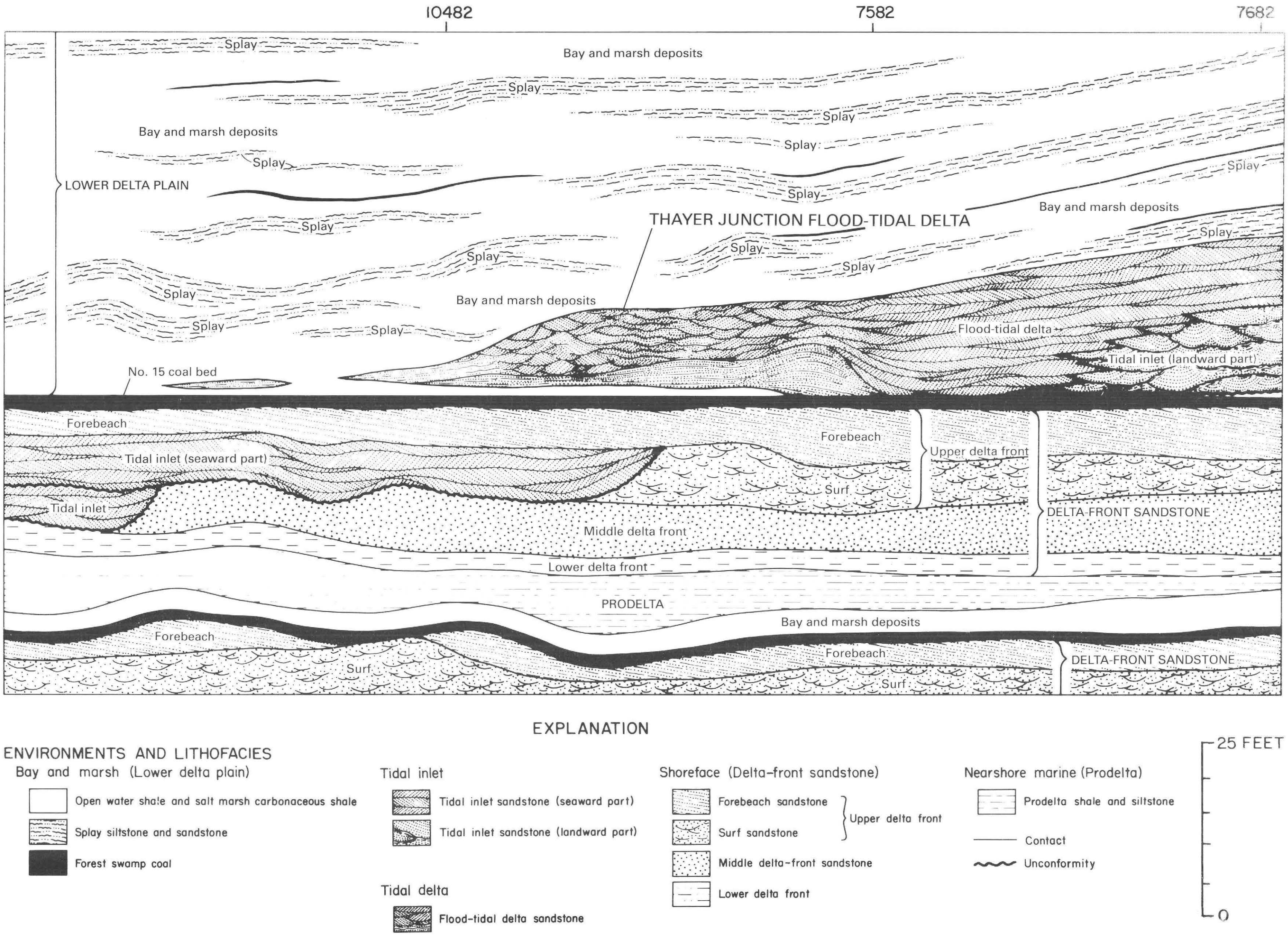

Figure 42. Restored cross section of flood-tidal delta deposits in Rock Springs Formation near Thayer Junction, Wyo. Locations of measured sections 10482 (fig. 47) and 7582 (figs. 39, 40) and of figure 44 are shown in figure 38.

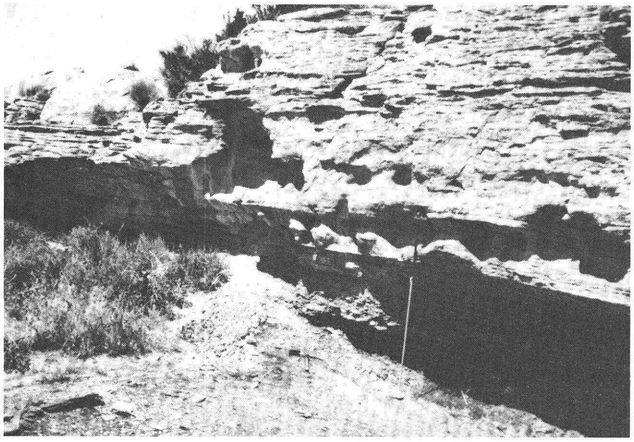

Figure 43. Flood-tidal delta sandstone in Rock Springs Formation near Thayer Junction, Wyo. Note very low angle left- (landward-) dipping foreset laminae. Jacob staff in lower right is 5 ft long. Outcrop location shown in figure 38.

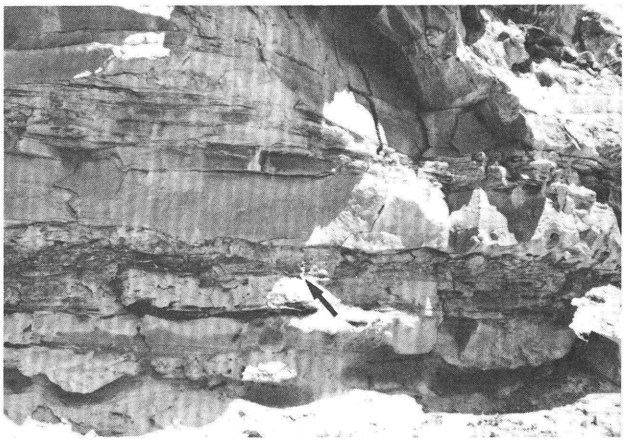

Figure 44. Sandstone beds near mouth of tidal inlet near measured section 7682 in Rock Springs Formation near Thayer Junction, Wyo. Scale (arrow) near center of photograph is in inches. Outcrop location shown in figure 38.

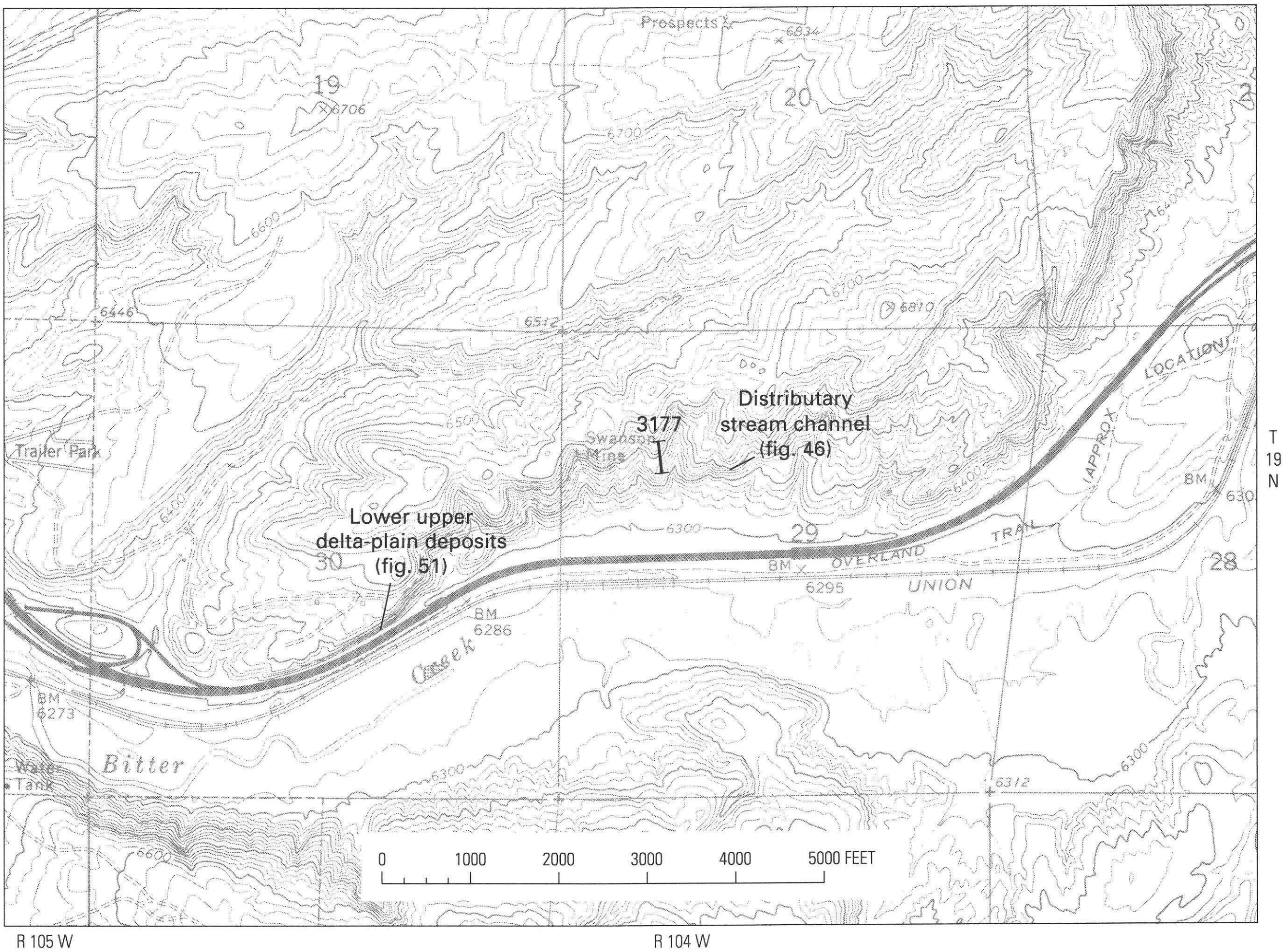

Figure 45. Location of distributary stream channel and lower upper delta-plain deposits in Rock Springs Formation in measured section 3177 (1½ mi east of Rock Springs) and in figures 46 and 52. Base from U.S. Geological Survey 1:24,000 Rock Springs, Wyo.; contour interval 20 ft.

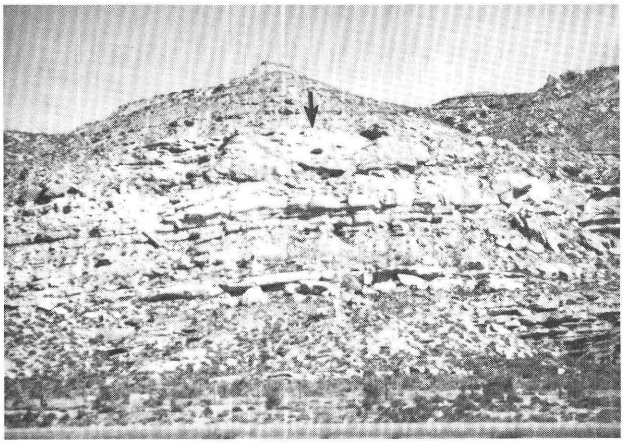

Figure 46. Distributary stream channel sandstone (arrow) overlying delta-front sandstones in Rock Springs Formation north of Interstate Highway 80, 1½ mi east of Rock Springs, Wyo. Channel sandstone is about 26 ft thick. Outcrop location shown in figure 45.

Highway 371, 2 mi south of Superior, Wyo., near the center of NE¼ sec. 6, T. 20 N., R. 102 W. (figs. 48, 49). From comparison of measured sections 10482 and 680, it is obvious that the upper part of the lower delta plain contains thicker and more numerous beds of sandstone and siltstone of splay origin, carbonaceous shale of reed swamp origin, and coal of forest swamp origin than does the lower part of the lower delta plain.

UPPER DELTA PLAIN

A segment of the lower part of an upper delta-plain deposit in the Rock Springs Formation is illustrated in measured section 3177 (fig. 50). Measured section 3177 is located north of Interstate Highway 80, 1½ mi east of Rock Springs, Wyo. (fig. 45). A section similar to measured section 3177 is exposed in a roadcut along the north side of Interstate Highway 80, 1 mi to the west of the measured section, in NW¼SE¼ sec. 30, T. 19 N., R. 104 W. (fig. 51). The lower part of the upper delta-plain deposit consists of interbedded dark-gray to dark-brown carbonaceous shale of reed swamp origin, coal of forest swamp origin, gray, partly current rippled sandstone and siltstone of splay origin, gray shale of bay-fill origin, and tan, fine-grained, trough-crossbedded sandstone of distributary stream channel origin. The beds are generally less than 5 ft thick and rarely exceed 10 ft in thickness. Beds of coal, stream channel sandstone, and splay sandstone and siltstone are thicker and more numerous, and beds of bay-fill shale are thinner and less numerous than in the previously discussed lower delta-plain deposits. (Compare figures 47 and 50.)

The upper part of an upper delta plain is exposed in measured section 181 located on the west slopes of Killpecker Creek near its confluence with Bitter Creek, in the city of Rock Springs, in W½SW¼ sec. 26, T. 19 N., R. 105 W. (fig. 52). The upper delta plain in measured section 181 is composed of thick beds of sandstone of stream channel and splay origins, thick interbedded carbonaceous shale of reed swamp origin, and coal of forest swamp origin (figs. 53, 54). Beds of shale of bay-fill origin are sparse and thin. The splay sandstones are composed of mostly thin subparallel beds of current-rippled silty sandstone and interbedded gray silty shale (fig. 55). A few thin beds of tuff (tonstein) are present in and overlying the Rock Springs coal bed No. 5 (fig. 50).

Beds of stream sandstone in the delta-plain sequence in the Rock Springs Formation were mostly deposited in channels having straight or nearly straight stream courses. These sandstone beds are linear but generally lenticular and symmetrical in cross section. They are thick in relation to their width, exhibit large-scale trough crossbedding, and have convex, scoured lower surfaces. Near the top of the upper delta-plain deposits in the Rock Springs Formation, immediately underlying the Ericson Sandstone of alluvial plain origin, the stream channel courses become sinuous and large meander loops are exposed in cliff-forming outcrops along Dewar Drive in the western part of the city of Rock Springs in NW¼SE¼SE¼ sec. 34, T. 19 N., R. 105 W. (figs. 52, 56). The meander loops are lenticular in cross section but are wide in relation to their thickness. The meander loops are wedge shaped and have convex upper surfaces; well-developed point bars are visible in long, low-angle accretionary beds that are present at the outer margins of the channels (fig. 56).

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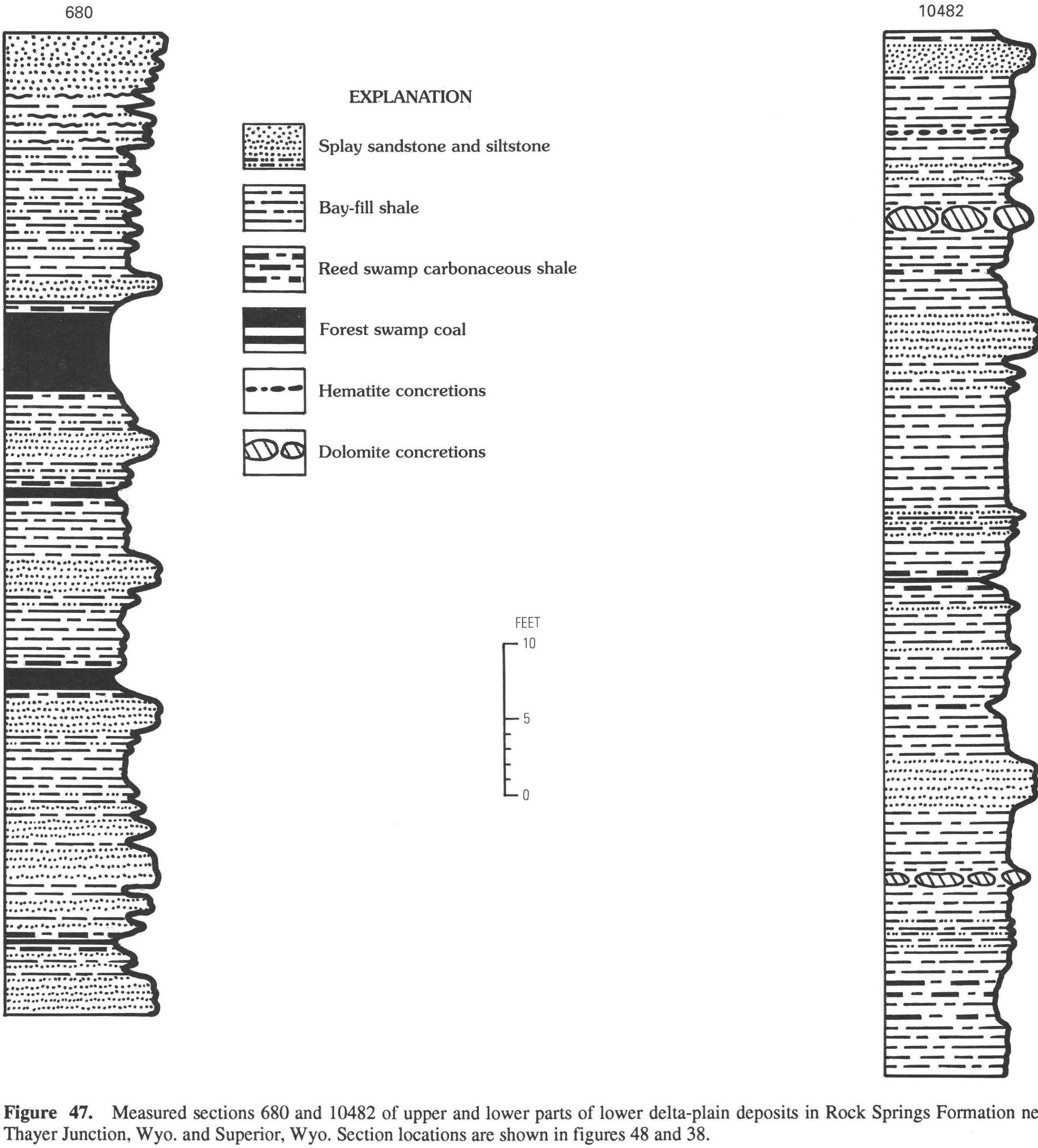

Figure 47. Measured sections 680 and 10482 of upper and lower parts of lower delta-plain deposits in Rock Springs Formation near Thayer Junction, Wyo. and Superior, Wyo. Section locations are shown in figures 48 and 38.

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———1989, Origin and distribution of six heavy-mineral placer deposits in coastal-marine sandstones in the Upper Cretaceous McCourt Sandstone Tongue of the Rock Springs Formation, southwest Wyoming: U.S. Geological Survey Bulletin 1867, 34 p.

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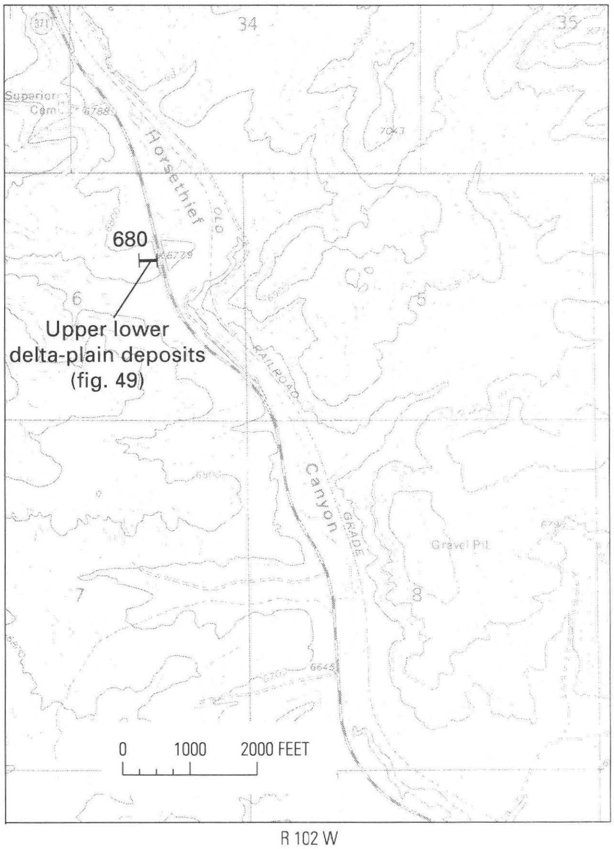

Figure 48. Location of upper lower delta-plain deposits in Rock Springs Formation in measured section 680 along Highway 371 near Superior, Wyo. Base from U.S. Geological Survey 1:24,000 Thayer Junction, Wyo.; contour interval 20 ft.

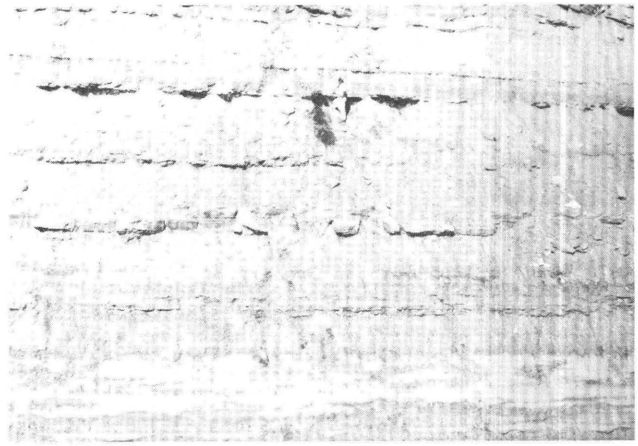

Figure 49. Upper lower delta-plain deposits in Rock Springs Formation in roadcut of Wyoming Highway 371, 2 mi south of Superior, Wyo. Outcrop location shown in figure 48. Person in upper middle gives scale.

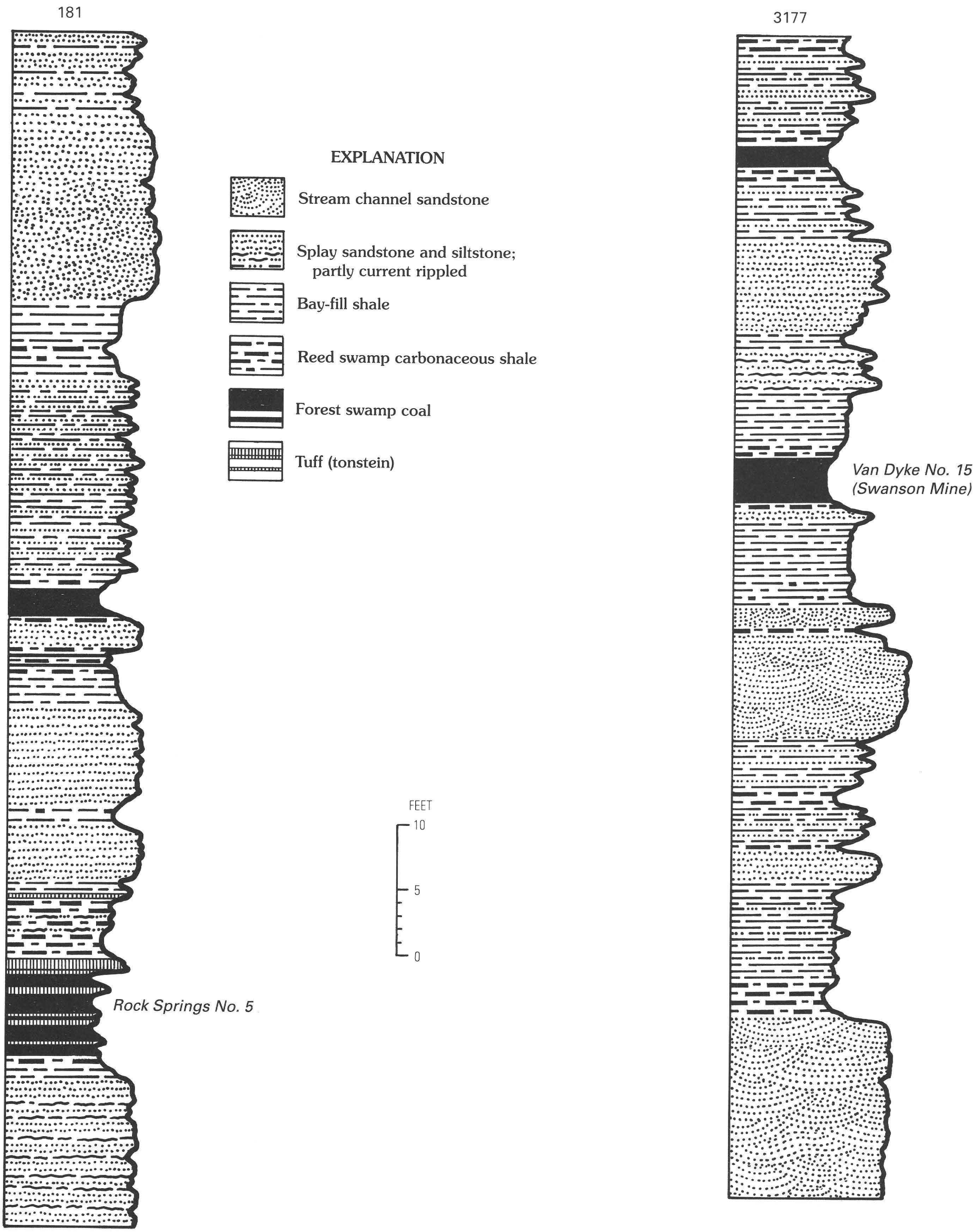

Figure 50. Measured sections 3177 and 181 of lower and upper parts, respectively, of upper delta-plain deposits in Rock Springs Formation on west flank of Rock Springs uplift, in Rock Springs, Wyo. Section locations shown in figures 45 and 52.

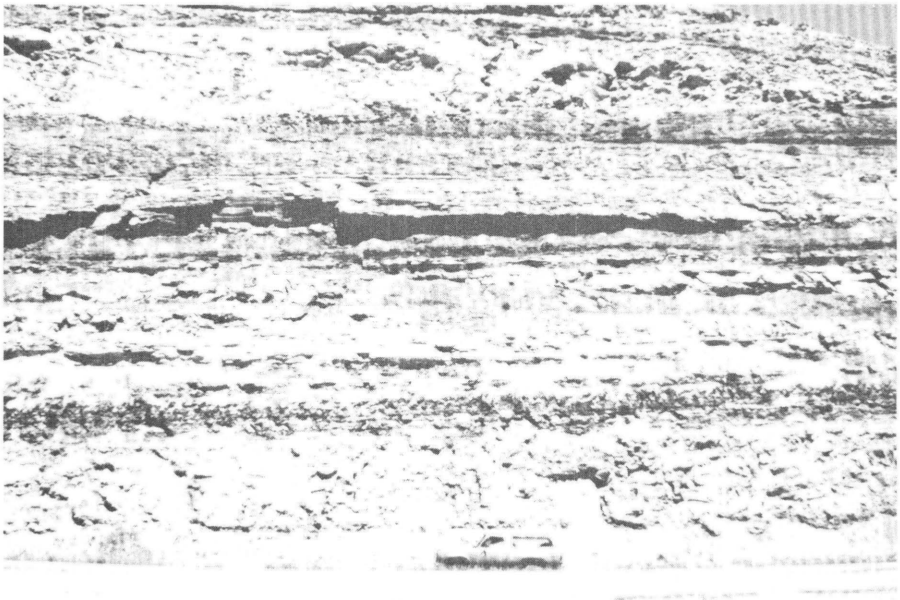

Figure 51. Lower upper delta-plain deposits in Rock Springs Formation along north side of Interstate Highway 80, $^1/_2$ mi east of Rock Springs, Wyo. Outcrop location shown in figure 45.

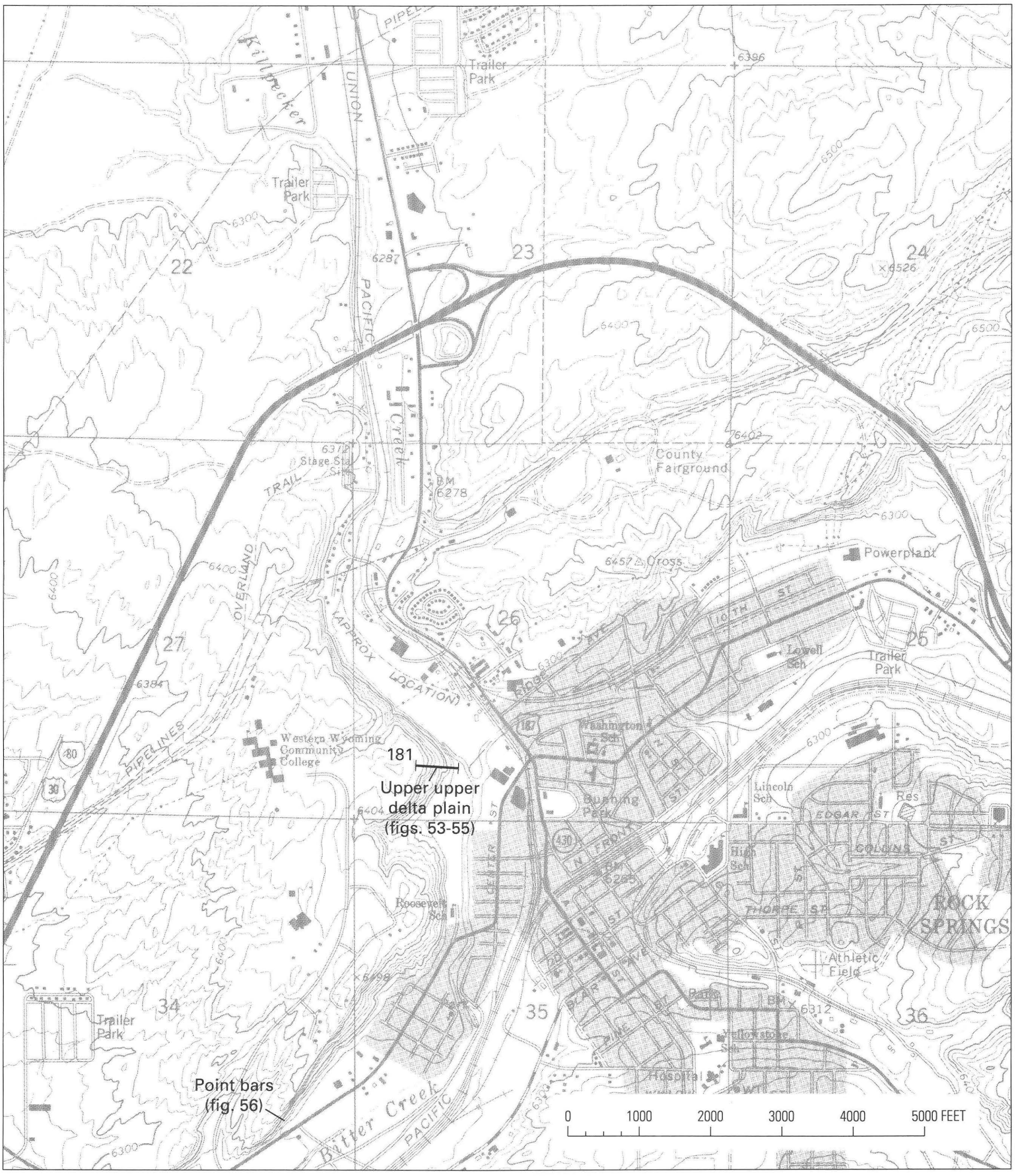

Figure 52. Location of upper delta-plain deposits in Rock Springs Formation in measured section 181 and in figures 53–56, in Rock Springs, Wyo. Base from U.S. Geological Survey 1:24,000 Rock Springs, Wyo.; contour interval 20 ft.

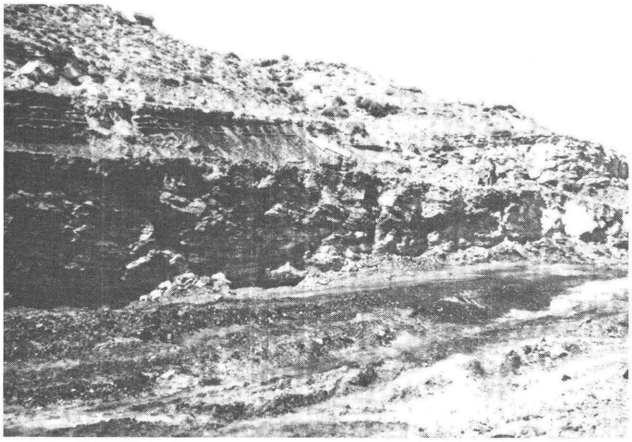

Figure 53. View to northwest of upper upper delta-plain deposits in Rock Springs Formation along Killpecker Creek in Rock Springs, Wyo. Coal (arrow) is Rock Springs No. 5 bed. Scale indicated by person standing in upper right. Outcrop location shown in figure 52.

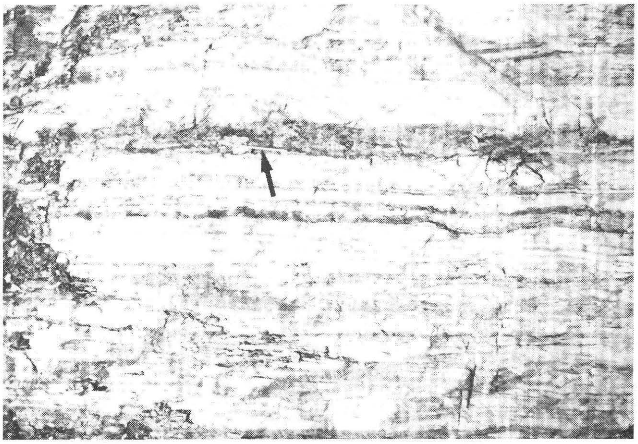

Figure 55. Upper upper delta-plain current-rippled sandstone and silty shale of splay origin in Rock Springs Formation along Killpecker Creek in Rock Springs, Wyo. Outcrop location shown in figure 52. Pencil (arrow) gives scale.

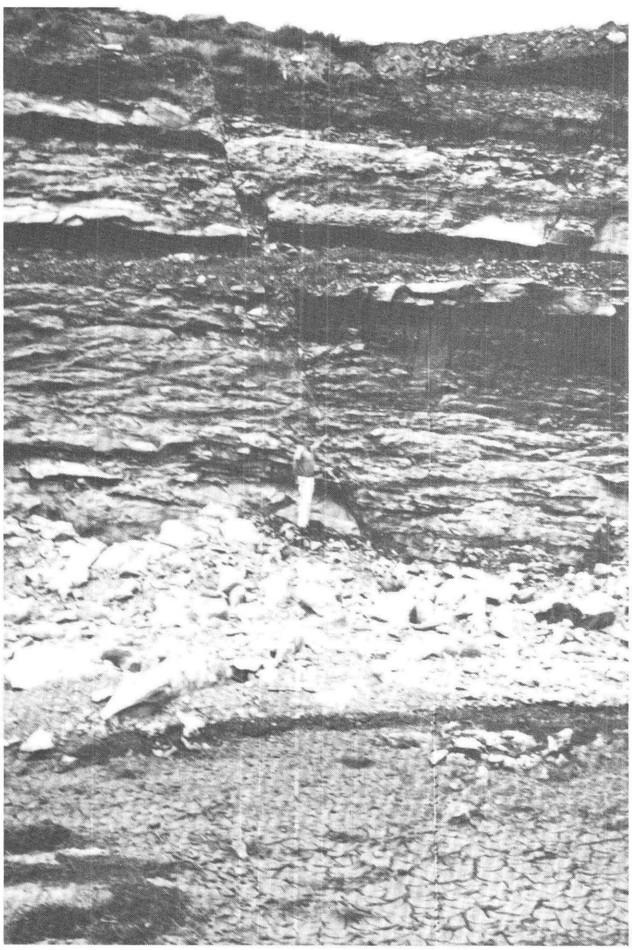

Figure 54. View to west of faulted upper upper delta-plain sandstone, carbonaceous shale, and coal deposits in Rock Springs Formation in Rock Springs, Wyo. Man gives scale. Outcrop location shown in figure 52.

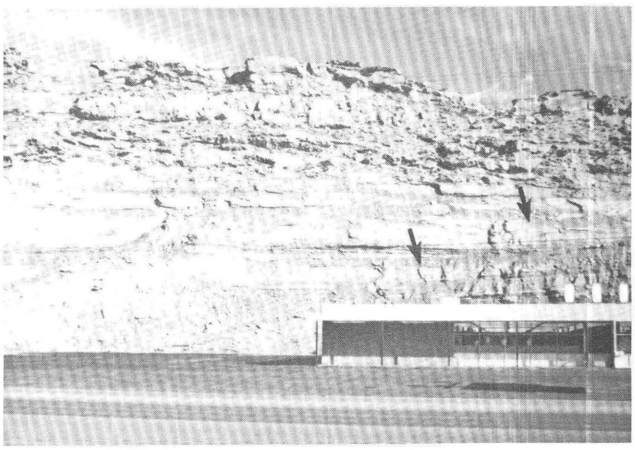

Figure 56. View to northwest of sandstone point bars (arrows) on meander loops of stream channels in the upper upper delta-plain deposits in Rock Springs Formation in Rock Springs, Wyo. Outcrop location shown in figure 52.

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