Submarine Slumps in Delta-Front Sandstones of the Upper Cretaceous Blair Formation Rock Springs Uplift, Wyoming

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By H. W. ROEHLER

Syndepositional slumps on
the western shores of the
interior Cretaceous sea

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Submarine Slumps in Delta-Front Sandstones of the Upper Cretaceous Blair Formation, Rock Springs Uplift, Wyoming

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Abstract

Submarine slumps are present in sandstone beds in the upper part of the Blair Formation on the southeast flank of the Rock Springs uplift in southwest Wyoming. The slumped beds are part of a lower delta-front lithofacies that was present on the submarine margins of an arcuate delta on the western shores of the interior Cretaceous sea. The slumped beds are as much as 13 ft thick, lenticular in cross section, convoluted, and intercalated with normally bedded sandstone and shale. The slumps resulted from slope failure and mass-gravity movement of sand along oversteepened, descending slopes of a prograding submarine terrace.

INTRODUCTION

Syndepositional slumps are present in sandstone beds on the submarine margin of an arcuate delta that occupied a segment of the western shore of the interior Cretaceous sea. The slumps occur as distinct beds as much as 13 ft thick that are situated within a 60-ft-thick, ledge-forming, shaly-sandstone sequence in the upper part of the Blair Formation of early Campanian age. The shaly-sandstone sequence crops out in a north-south trend across parts of sec. 32, T. 18 N., R. 102 W., and secs. 4, 5, 8, 9, 16, and 17, T. 17 N., R. 102 W., on the southeast flank of the Rock Springs uplift. Beds in the sequence are well exposed in the study area in sec. 9, T. 17 N., R. 102 W. The distinguishing features of the slumped beds are lenticularity, undulating upper and lower surfaces, and internal convolutions. The slumped beds are intercalated with normally bedded sandstone and shale.

The slumps in the Blair Formation are generally much smaller in scale than the mass-gravity flow deposits described by Coleman and Prior (1982) on the periphery of the Mississippi River delta. Similar submarine gravity-slide and slump deposits are well known in the geological record (Reineck and Singh, 1973), but they apparently have not been reported in delta-front sandstones along the western shores of the interior Cretaceous sea in the western United States.

Location and Accessibility of the Study Area

The study area is 20 mi southeast of Rock Springs, Wyo. (fig. 1). It is accessible by an improved gravel road that branches eastward from Highway 430 18 mi southeast of Rock Springs (fig. 2). This gravel road parallels the north edge of Cutthroat Draw and is the primary access route to Brady Gas Field. Approximately 1.7 mi east of Highway 430 on the gravel road to Brady Gas Field, an unimproved road branches northward, climbs a rocky slope, and continues northward along the crest of a low, cedar-covered ridge (fig. 2). The slumped beds are exposed along the lower west slopes of this ridge. The sandstone beds that form this ridge were mapped as marker bed UST in the Blair Formation on the Camel Rock quadrangle, GQ1521 (Roehler, 1979).

Geologic Setting

The upper part of the Blair Formation is exposed in the study area within a broad, deep, rectangular-shaped, alluvium-filled valley formed by Cutthroat Draw (fig. 2). The valley is open to the west but is bounded by high ridges and plateaus to the north, east, and south. The Blair Formation crops out in the valley walls and along low hills and ridges that rise above the valley floor. The formation is covered locally by slump material, sandy soil, and sand dunes. The beds containing the slumps crop out at elevations between 6,700 ft and 6,900 ft. Adjacent escarpments capped by the Chimney Rock Tongue of the Rock Springs Formation, also of Campanian age, rise to more than 7,500 ft (fig. 3). The area is hot and dry

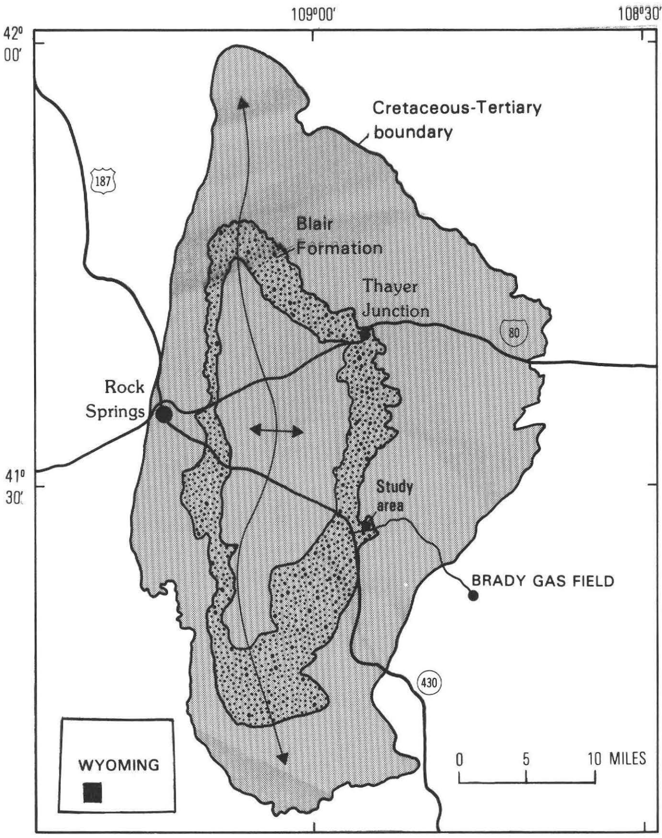

Figure 1. Index map showing the location of the study area on the southeast flank of the Rock Springs uplift in southwest Wyoming. Cretaceous rocks are shaded, the Blair Formation is stippled.

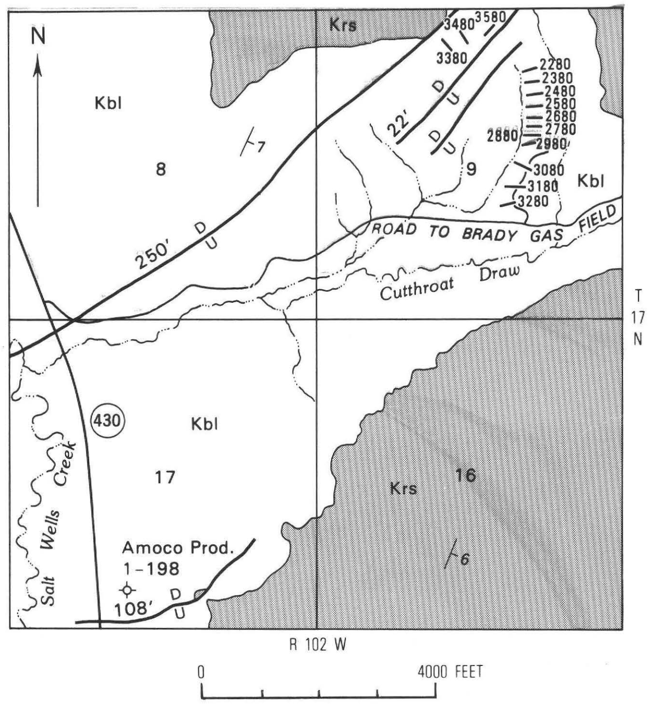

Figure 2. Geologic map of the study area in sec. 9, T. 17 N., R. 102 W., showing the locations of measured sections. **Kbl**, Blair Formation; **Krs**, Rock Springs Formation; **D**, downthrown side of fault; **U**, upthrown side of fault.

during summer months, and vegetation consists mostly of clumps of sagebrush and thin desert grasses. Groves of cedar trees are present along sandstone ridges at higher elevations.

The slumped beds dip 5°–6° southeast on the southeast flank of the Rock Springs uplift. The overall structure is locally homoclinal, but it is interrupted in the northern part of the study area by three southwest-trending, high-angle, normal faults (fig. 2). The largest of these faults crosses the northwest corner of sec. 9, T. 17 N., R. 102 W., is downthrown to the northwest, and has about 250 ft of displacement. Two minor faults, each having less than 25 ft of displacement, parallel the larger fault a few hundred feet to the southeast. The smaller faults offset the line of outcrops studied. The southwest trend of the faults in the study area is associated with a larger pattern of Paleocene and older faulting that crosses the Rock Springs uplift (Love and Christiansen, 1985).

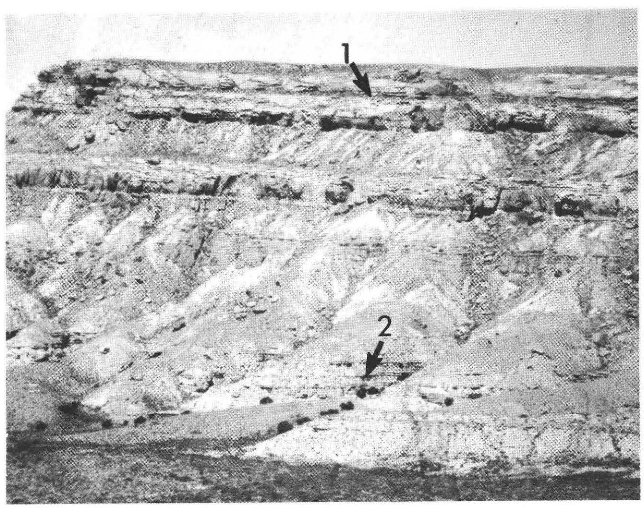

Figure 3. Outcrops near the northwest corner of sec. 9, T. 17 N., R. 102 W. 1, Sandstone beds composing the Chimney Rock Tongue at the base of the Rock Springs Formation; 2, Shaly sandstone in the upper part of the Blair Formation that contains slump structures. The outcrops shown are about 500 ft thick. View is northwest.

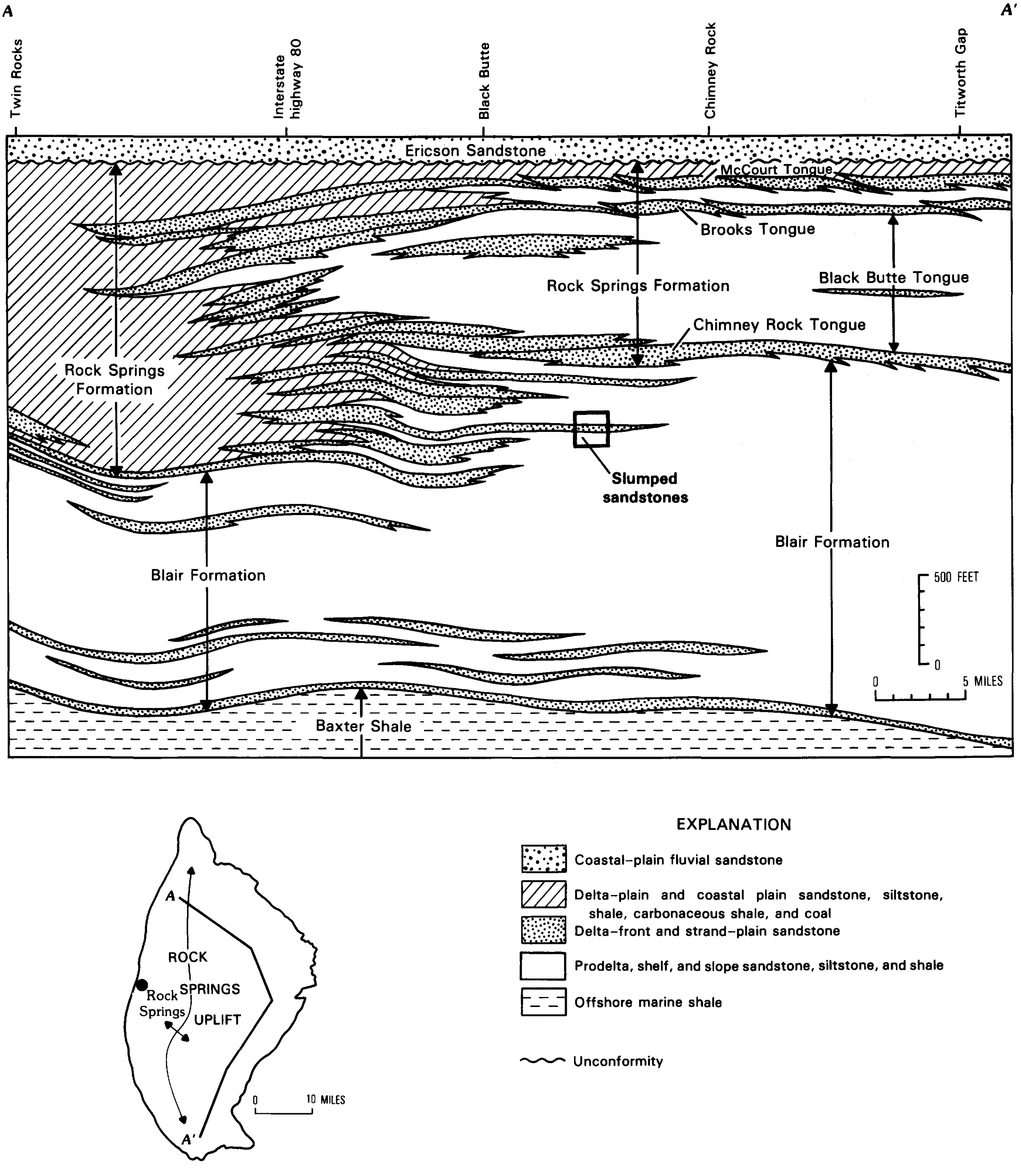

Figure 4. Regional stratigraphic cross section showing the nomenclature and intertonguing relationships of the Blair and Rock Springs Formations in the Rock Springs uplift, Wyo. (Roehler, 1983).

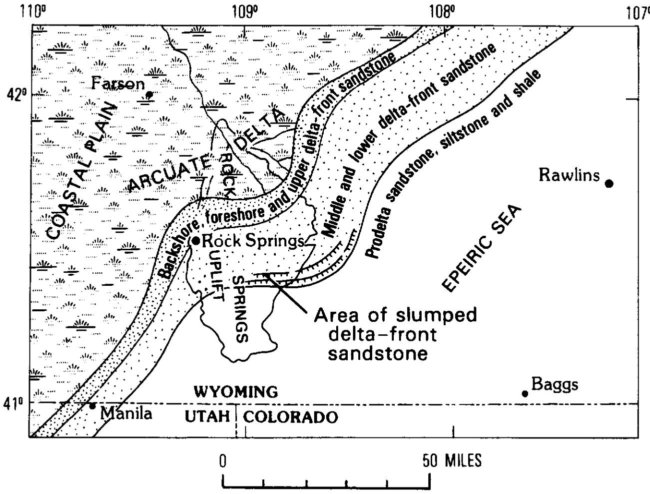

Figure 5. Regional early Campanian paleogeographic map showing depositional environments and the location of slumped, delta-front sandstones in the upper part of the Blair Formation.

STRATIGRAPHY

Nomenclature and Previous Investigations of the Blair Formation

The Blair Formation was named by Schultz (1920) for 1,000–1,200 ft of "sandstone and sandy shale which form the beds immediately below the Mesaverde." A geologic map published by Schultz (1920, pl. 1) shows that the outcrops of the formation are 1–7 mi wide and encircle the central basin of the Rock Springs uplift (fig. 1). The type area of the formation is on Blair Creek in sec. 4, T. 16 N., R. 103 W., 7 mi southwest of the study area. The Blair Formation conformably overlies the Baxter Shale of Coniacian-Campanian ages, but it intertongues with the overlying Rock Springs Formation.

Rocks that compose the Blair Formation consist of prodelta shelf and slope sandstone, siltstone, and shale that were deposited during regressive stages of the interior Cretaceous sea (Hale, 1950). Parts of the western shorelines of the sea during these regressions trended northeast across the Rock Springs uplift area. As a result, the lower 700 ft of the Rock Springs Formation—composed of delta-plain sandstone, siltstone, shale, carbonaceous shale and coal, and delta-front sandstone—intertongues with and grades laterally southeastward across the Rock Springs uplift into the upper part of the Blair Formation (fig. 4). The shaly-sandstone sequence that contains the slumped beds was deposited during one of these regressions. It is situated stratigraphically 320 ft below the base of the Chimney Rock Tongue of the Rock Springs Formation.

The age of the Blair Formation is early Campanian (~77 Ma) based on fossils collected by Smith (1961) at U.S.G.S. Mesozoic locality 2214 in NE1/4 sec. 26, T. 16 N., R. 103 W. These fossils include the ammonite *Scaphites hippocrepis* and several species of marine pelecypods, among them *Inoceramus subcompressus*. The fossil collection site is located near the top of the Blair Formation, 9 mi southwest of the study area (fig. 1).

Regional Correlations and Paleogeography

The 60-ft-thick, shaly-sandstone sequence that contains the slumped beds has been correlated for more than 25 mi along the east flank of the Rock Springs uplift in measured sections (Roehler, 1983). Within the study area the sequence is a lower delta-front lithofacies composed of thin, parallel-bedded to subparallel-bedded (and convoluted) sandstone with some thin, interbedded shale. The sequence weathers to tan-brown, ledge-forming, steplike slopes. North of the study area in sec. 14, T. 19 N., R. 102 W., the lower delta-front lithofacies grades in a landward direction into a middle delta-front lithofacies consisting of 90 ft of large-scale, low-angle, trough-crossbedded sandstone that weathers to a tan-brown, massive cliff. Farther north, in sec. 21, T. 20 N., R. 102 W., adjacent to Interstate Highway 80, a similar middle delta-front lithofacies is present at the base of the sequence, but it is capped there by 16 ft of white, small-scale, trough-crossbedded and tabular-bedded sandstone that comprises surf and forebeach lithofacies. The geographic location of the surf and forebeach lithofacies suggests that the delta strandlines were formerly located in the vicinity of what is now Interstate Highway 80 near Thayer Junction (fig. 1). The interpreted paleogeography of the area is shown on figure 5. Water depths for the various lithofacies are unknown, but the author speculates that the lower delta-front sandstones in the study area were deposited below normal wave base at depths between 50 ft and 150 ft.

Measured Sections and Restored Cross Section of the Study Area

Fourteen stratigraphic sections were measured and described at the locations indicated on the geologic map (fig. 2). The measured sections (fig. 6) show that the

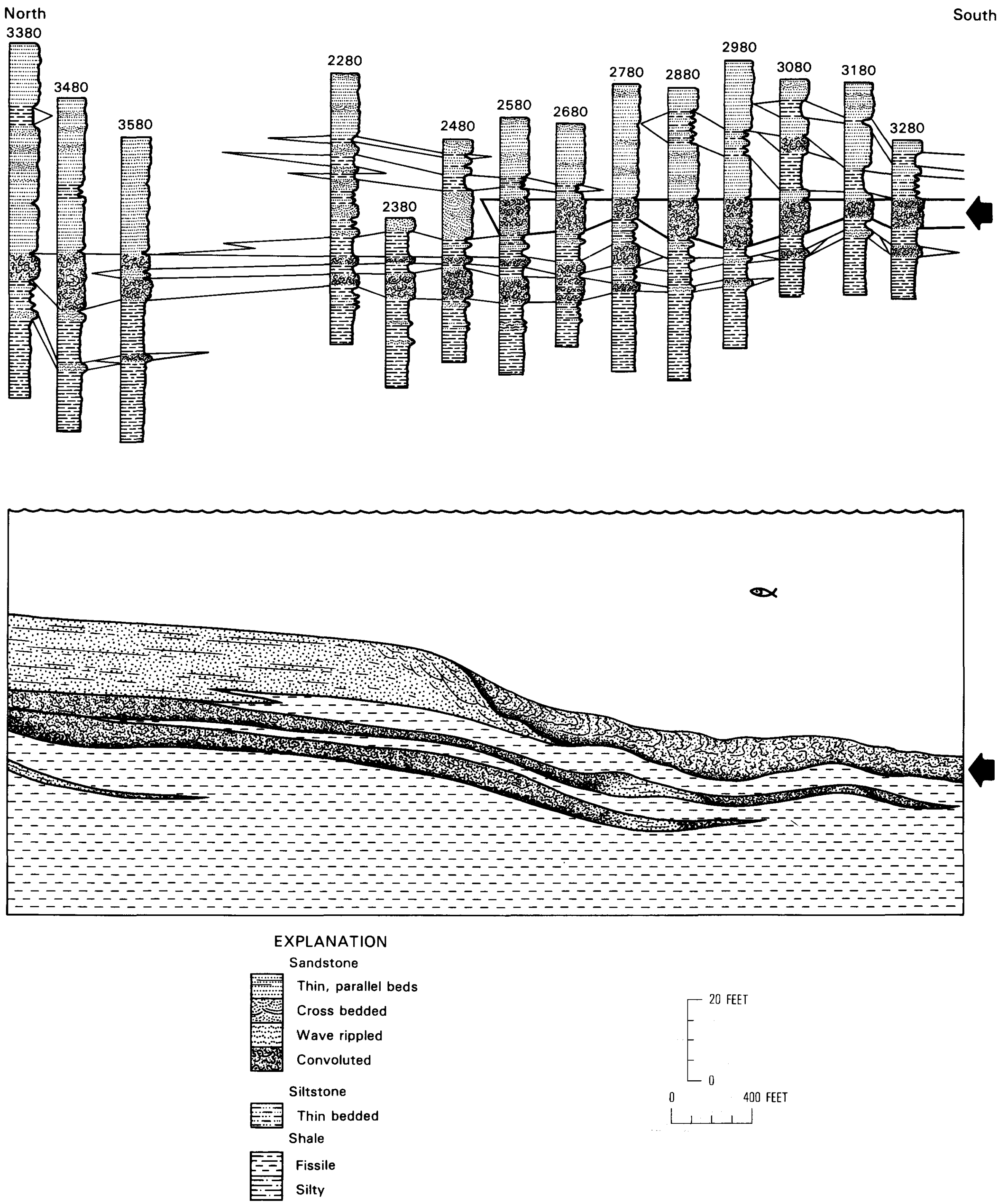

Figure 6. Measured stratigraphic sections (top) and restored cross section (bottom) showing the relationships of slump structures in the Blair Formation in the study area. Arrows identify the same bed in both illustrations.

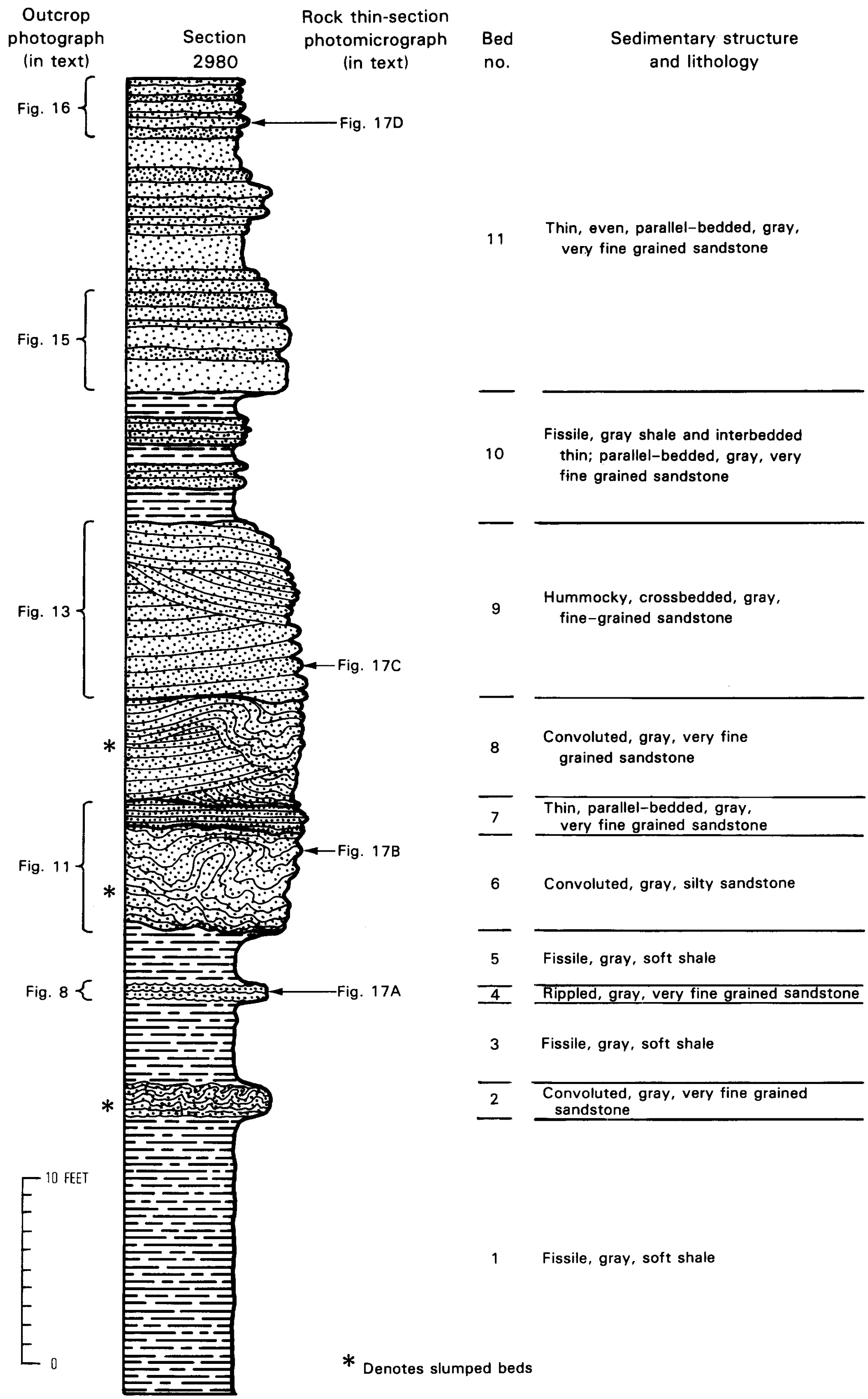

Figure 7. Measured section 2980 showing lithologies of the lower delta-front environment in the Blair Formation.

Figure 8. Wave-rippled upper surface of bed 4 in measured section 2980 (fig. 7). Pick handle is 17 in. long.

Figure 9. Fossil-crawling traces on wave-rippled upper surface of bed 4 in measured section 2980 (figs. 7, 8). Scale is in centimeters.

Figure 10. Trace fossils on wave-rippled upper surface of bed 4 in measured section 2980 (figs. 7, 8). Arrow points to probable feeding trace. Scale is in centimeters.

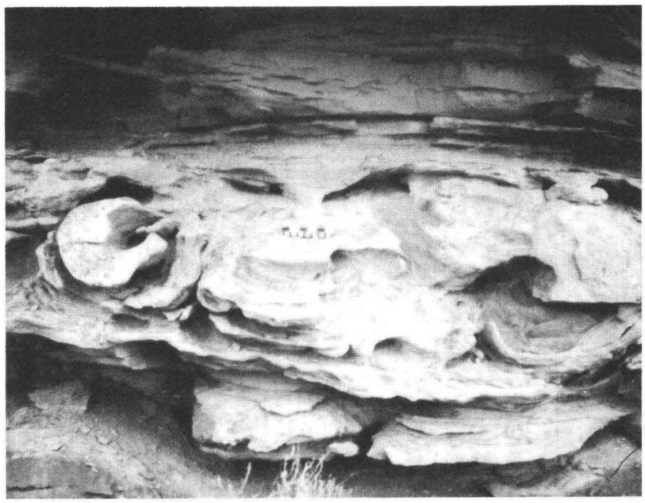

Figure 11. Convoluted sandstone in slumped bed 6 in measured section 2980. Black and white scale is in inches and centimeters.

slumped beds are lenticular in cross section and occur intermittently along outcrops. The slumped beds are recurrent and rise stratigraphically from north to south across the study area in the direction of the paleoslope. The restored cross section on figure 6 depicts the sea floor and bottom sediments as they may have appeared following the period of slumping that is identified by arrows.

SEDIMENTARY STRUCTURES AND LITHOLOGIES

Measured section 2980 (fig. 7) is typical of the stratigraphic sections in the study area and illustrates primary sedimentary structures and lithologies. The geographic location of the section is shown on figure 2 and the stratigraphic relationships are shown on figure 6.

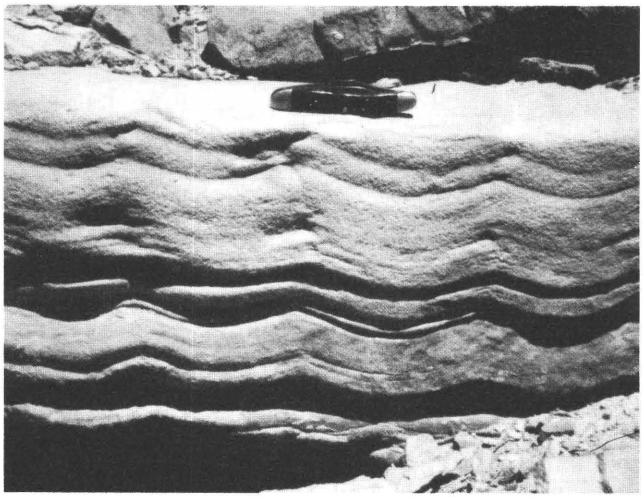

Figure 12. In-phase climbing ripples near the base of bed 6 in measured section 2580 (figs. 6, 7). Jackknife used for scale is 3 1/2 in. long.

Figure 14. Hummocky, parallel crossbeds in bed 9 in measured section 2980 (fig. 7).

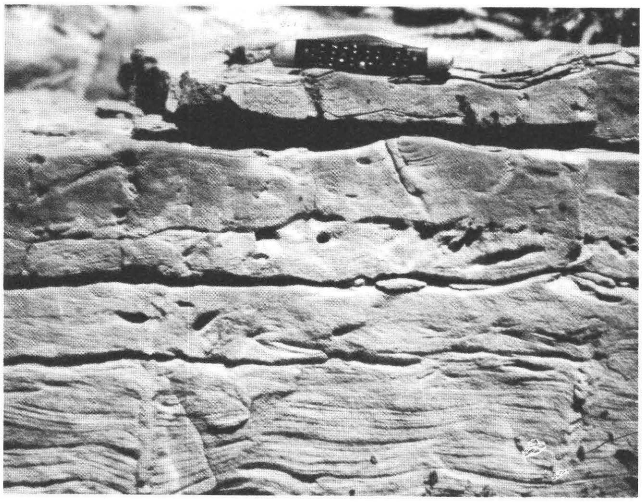

Figure 13. Trace fossils including *Ophiomorpha* near the base of bed 6 in measured section 2680 (figs. 6, 7).

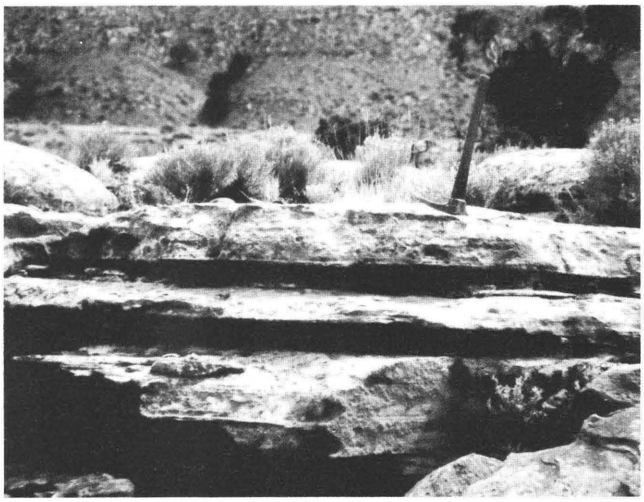

Figure 15. Thin, parallel-bedded sandstone at the base of bed 11 in measured section 2980 (fig. 7). Pick handle is 17 in. long.

Beds 2 and 4 near the base of measured section 2980 (fig. 7) are very fine grained, poorly sorted, angular sandstones that are interbedded with fissile gray shale. The sandstones are thin bedded and wave rippled. Bed 2 is convoluted in the upper part. The upper wave-rippled surface of bed 4 (fig. 8) has numerous small, fossil-crawling and feeding traces that include *Helminthoida* (figs. 9, 10). Bed no. 6 (fig. 7) is composed of sandy siltstone and has undulating upper and lower contacts with adjacent beds. It is entirely convoluted (fig. 11). The basal 3 ft of bed 6 has in-phase climbing ripples in section 2580 (fig. 12) and small, variously oriented trace fossils, including *Ophiomorpha*, in section 2680 (fig. 13). Bed 7 is very fine grained sandstone that exhibits thin, parallel bedding. It is visible above the convoluted beds on figure 11. Bed 8 (fig. 7) is very fine grained sandstone with convolutions similar to bed 6. Bed 9 (fig. 7) is very fine grained, poorly sorted, angular sandstone with hummocky, parallel crossbedding (fig. 14). The hummocky crossbedding probably resulted from storm-generated waves that reworked bottom sediments. Bed 10 (fig. 7) consists of gray shale and interbedded very thin to thin, parallel-bedded, very fine grained sandstone. Bed 11 (fig. 7) is poorly sorted, angular, very fine grained sandstone in even, parallel beds that thin upwards (figs. 15, 16).

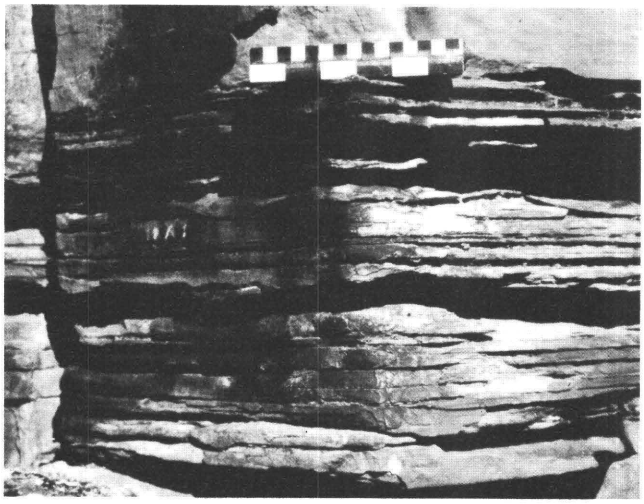

Figure 16. Very thin to thin, parallel-bedded sandstone at the top of bed 11 in measured section 2980 (fig. 7). Scale is in centimeters and inches.

SANDSTONE PETROLOGY

Four sandstone samples were collected for petrographic analysis at randomly selected stratigraphic intervals in section 2980, as indicated on figure 7. Photomicrographs of thin sections of the sandstone samples are shown on figure 17. The sandstones are light gray (unweathered) and tan brown (weathered) quartzose and range from sandy silt to fine grained. The grains are angular and poorly sorted, and cementing materials consist of clay and hematite. The sandstones are composed of 65–85 percent quartz grains, 10–25 percent rock fragments, and 5–8 percent miscellaneous mineral grains and cement. They contain about 2 percent heavy-mineral grains, mostly tourmaline, zircon, and garnet. The coarsest sandstones are present in the hummocky beds, where fine sand grains are mixed with interstitial silt and mud. The convoluted beds are composed of silty sand. The fine texture and poor sorting in these beds probably reflects random mixing of bottom sediments during slumping.

CONCLUSIONS

Syndepositional slumps in the Blair Formation are the products of submarine slope failure and mass movement of sand toward the periphery of an arcuate delta. The slump scarps were probably linear but did not form blocks and steps. The shear planes had high angles of seaward dip adjacent to the scarps but were otherwise nearly horizontal. All of the slumped sandstone beds are underlain by shale, which suggests that the semifluid muds from which the shale formed comprised soft, incompetent substrates for overlying, more-competent sands. The slumped sands were not confined to channels, but flowed downslope as sheetlike masses. The mechanics of slumping were probably similar to those of snow avalanches—where material suddenly detached at a scarp splits, separates, and moves rapidly downslope in an accelerating wave. The energy of the movement is dissipated at the base of the slope by loss of acceleration and increase in drag. Mechanisms that triggered the slumps are unknown, but they may have involved rapid sediment influx, severe storms, or earthquakes.

The superposition and lateral offset of the slump structures in a north-to-south direction across the study area are interpreted by the author as caused by oversteepened slopes that developed along a migrating submarine terrace. The terrace prograded, but its steep, descending-seaward slopes were periodically destroyed by slumping. The recurrent pattern of terrace sedimentation followed by slumping is depicted by block diagrams on figure 18.

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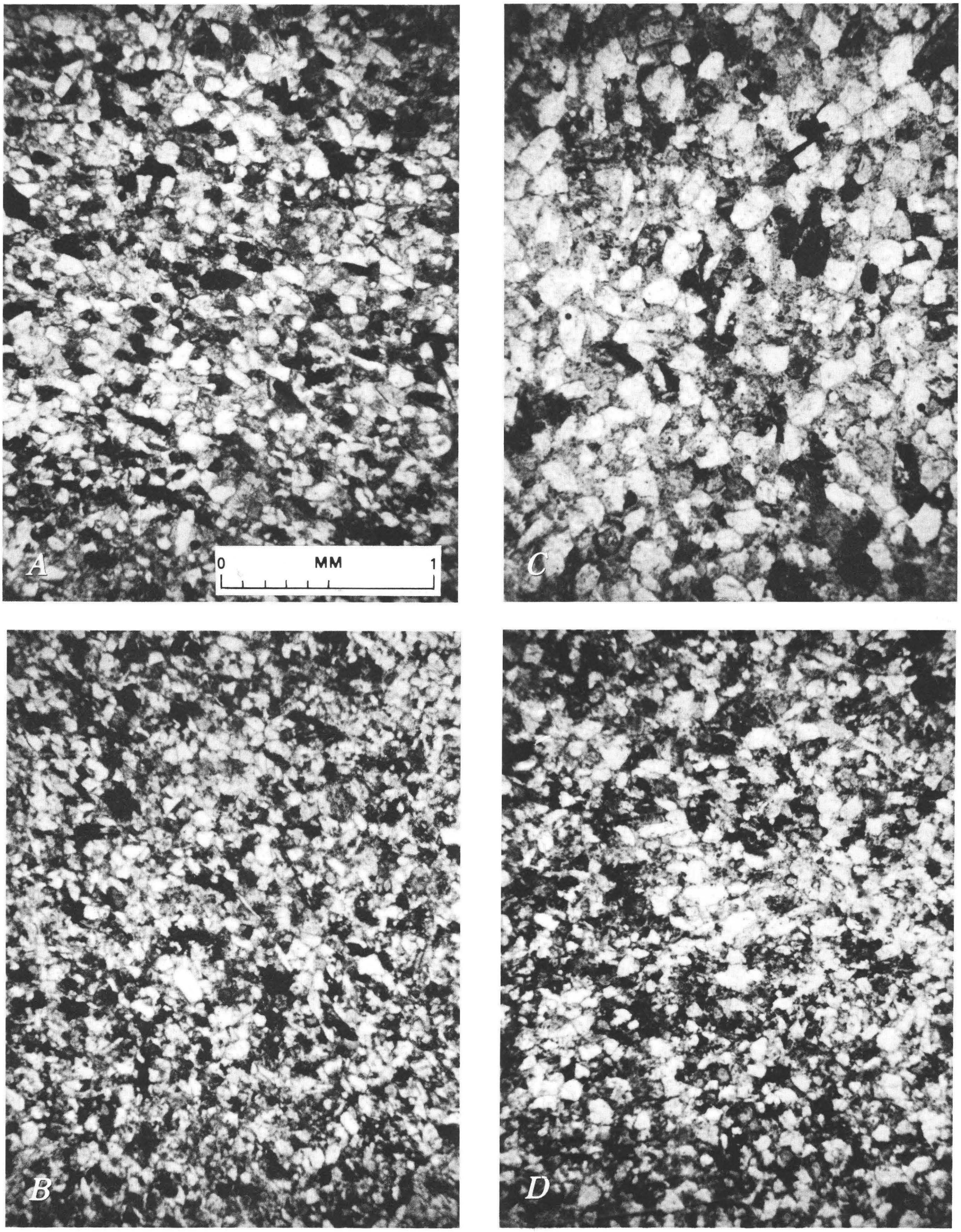

Figure 17. Photomicrographs of sandstone thin sections. Samples from measured section 2980: *A*, bed 4; *B*, bed 6; *C*, bed 13; *D*, bed 16. The stratigraphic positions of the beds are shown on figure 7.

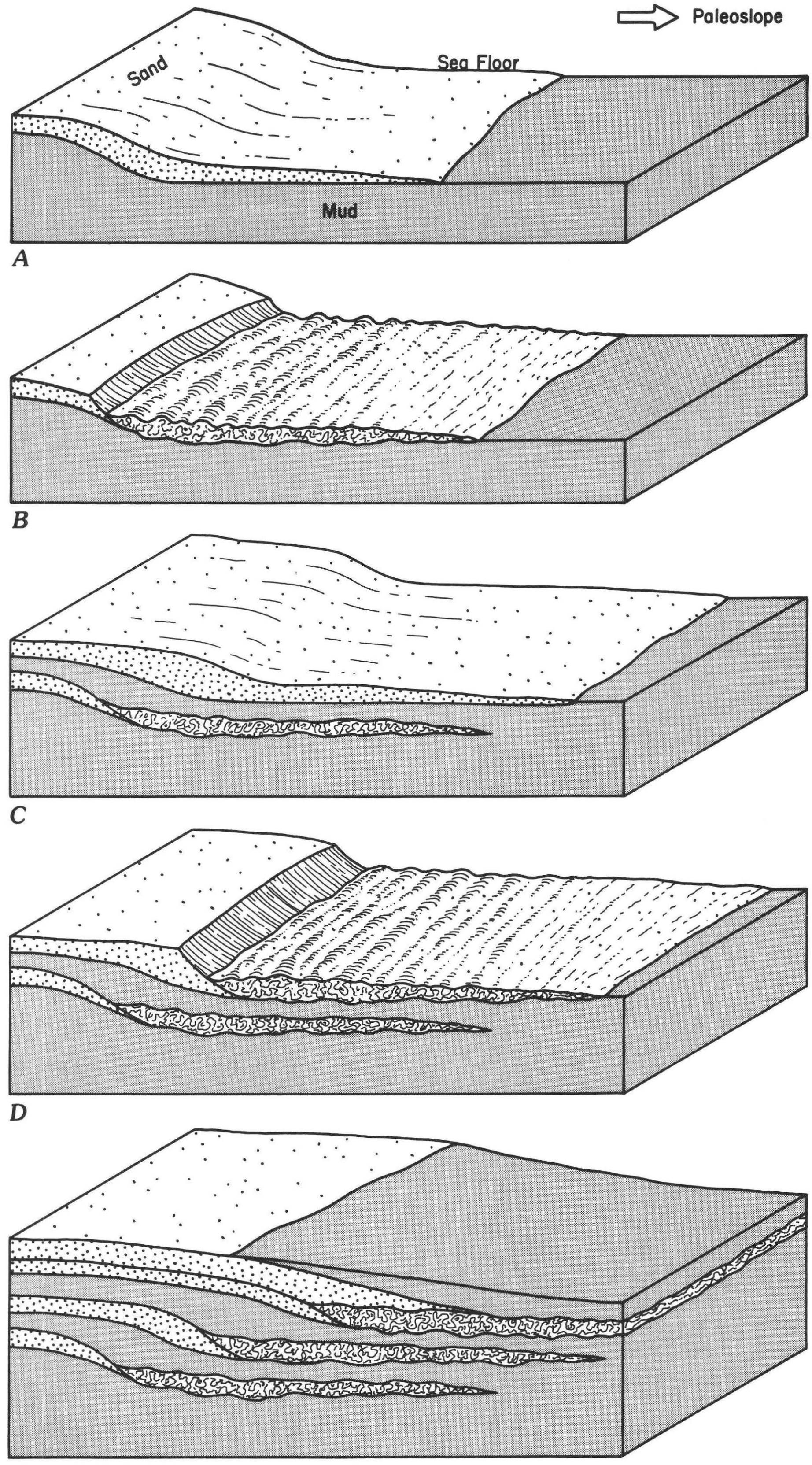

Figure 18. Block diagrams illustrating the superposition and lateral seaward movement of successive slumps along the descending slopes of lower delta-front terraces in the Blair Formation. *A*, early deposition prior to slumping, followed by periods of deposition and slumping, *B*, *C*, *D*, and *E*.

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