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THE THICK-SPLAY DEPOSITIONAL STYLE OF THE CREVASSE CANYON FORMATION CRETACEOUS OF WEST-CENTRAL NEW MEXICO

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INTRODUCTION

An understanding of the genesis and geometry of alluvial units is useful or necessary for the development of their water and mineral resources (Galloway, 1981). The resources of the Crevasse Canyon Formation, a unit of Late Cretaceous age in west-central New Mexico, have attracted interest, yet little is known of its internal stratigraphy or genesis. This is a description of some deposits in the Crevasse Canyon Formation that represent diverse depositional settings but record similar depositional processes. Because these processes produced thick crevasse-splay sandstone bodies, I refer to these processes and their products as the thick-splay depositional style. This style is initimately associated with other fluvial and deltaic depositional styles, but here I only discuss the thick-splay style. Illustrated outcrops are in La Jara Canyon, Socorro County, and Third Canyon Mesa, Catron County (fig. 1).

Allen and Balk (1954) defined the Crevasse Canyon Formation in their study of the southwestern margin of the San Juan basin. There the unit conformably overlies the Gallup Sandstone of Sears (1925). The top of the Gallup in that area is a lithologically distinct unit known informally as the Torrivio sandstone. It is of probable fluvial origin, in contrast to the delta-front and littoral origin of the major underlying Gallup sandstone bodies (Molenaar, 1974). No widespread lithologic units in the Rio Salado drainage are comparable to the Torrivio sandstone. For this area, I have followed the usage of Molenaar (1974) and have picked the top of the Gallup, and hence the base of the Crevasse Canyon, as the upper surface of the littoral sandstone unit.

The Gallup and Crevas,se Canyon Formations comprise a wedge of coastal plain and littoral sediments which prograded northeastward into the western interior seaway beginning in latest Turonian time (Molenaar, 1974; Peterson and Kirk, 1977). McGookey (1972) suggested that the climate was probably humid and warm, similar to the present southeastern coast of the United States. Lloyd (1982), who modeled world paleogeography for a mid-Cretaceous time interval 10 million years prior to the latest Turonian, concluded that southern North America was then subjected to a greater seasonality in wind patterns with possibly a monsoonal climatic regime.

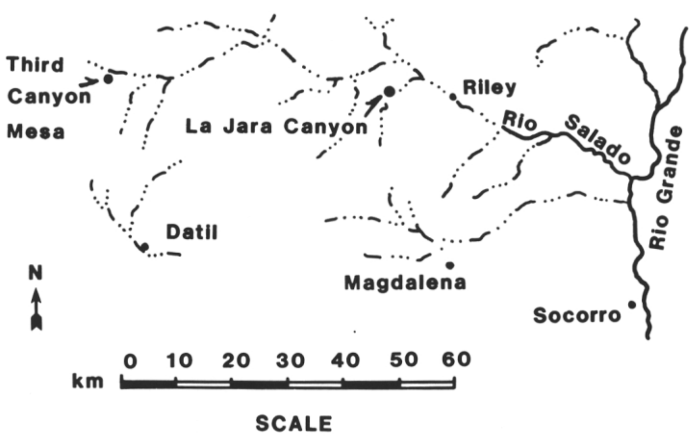

Figure 1. Index map showing location of outcrops.

Three facies are present in outcrops representing the thick-splay style. The mudstone facies, although volumetrically the most important, is poorly exposed. It serves as a matrix for the two sandstone facies. The splay sandstone facies is composed of laterally continuous, sheet-like bodies of sandstone. These commonly are stacked and pinch out laterally; they are the principle repositories for sand in the thick-splay style. The channel sandstone facies is composed of shoestring-shaped bodies, commonly within the stacked splay sandstone packet and separated from underlying sediments by a prominent scoured base. They are a volumetrically small part of the total sediment packet.

MUDSTONE FACIES

The covered slopes which develop upon the mudstone facies obscure a potpourri of lithologies. Thinly bedded, laterally continuous units of mudstone, claystone, shale, very fine-grained sandstone, siltstone, iron claystone, and lignite are common. These were deposited in paludal, lagoonal, lacustrine, and floodplain settings by settling from suspension or by rapidly waning flows. Time intervals between major sedimentation events often were long, allowing the chemical and organic processes in the depositional site to leave a strong impression on the sedimentary record.

In the La Jara Canyon area, clayshale, carbonaceous mudstone and mudshale, and lignite abruptly overlie the Gallup littoral sandstone and are the dominant lithologies in the lowest 30 m of the Crevasse Canyon Formation (fig. 2). Associated iron claystone may have originated as siderite-cemented clay, silt, or organic sediment. Its presence and association with lignite suggests a reducing, low sulfide-activity setting (Berner, 1971). Chapin and others (1979) report that brackish-water algal palynomorphs are present in this facies. A paludal or lagoonal setting seems likely.

Thin sandstone and siltstone sheets are locally prominent. These are homogeneous or ripple cross-laminated, very thinly to thinly bedded, and horizontal or slightly inclined. Small-scale trough crossbedding is common in thicker units. Individual units commonly fine upward, while packets of several units commonly illustrate upward-fining or upward-coarsening trends. Unit bases are abrupt and rarely are scoured. Fossil leaves, fossil wood, and organic debris are abundant, and rip-up clasts of clay and iron claystone are common. Root traces and burrowing are also common in some units. Some sandstone beds, when traced laterally, thicken to form the distal members of the splay facies. These interbedded siltstones and sandstones record the intermittent flushing of coarser material from the fluvial and splay settings into the lagoons or swamps.

Most mudstones higher in the Crevasse Canyon Formation contain fewer iron claystones and less organic matter. Horizons of very pale

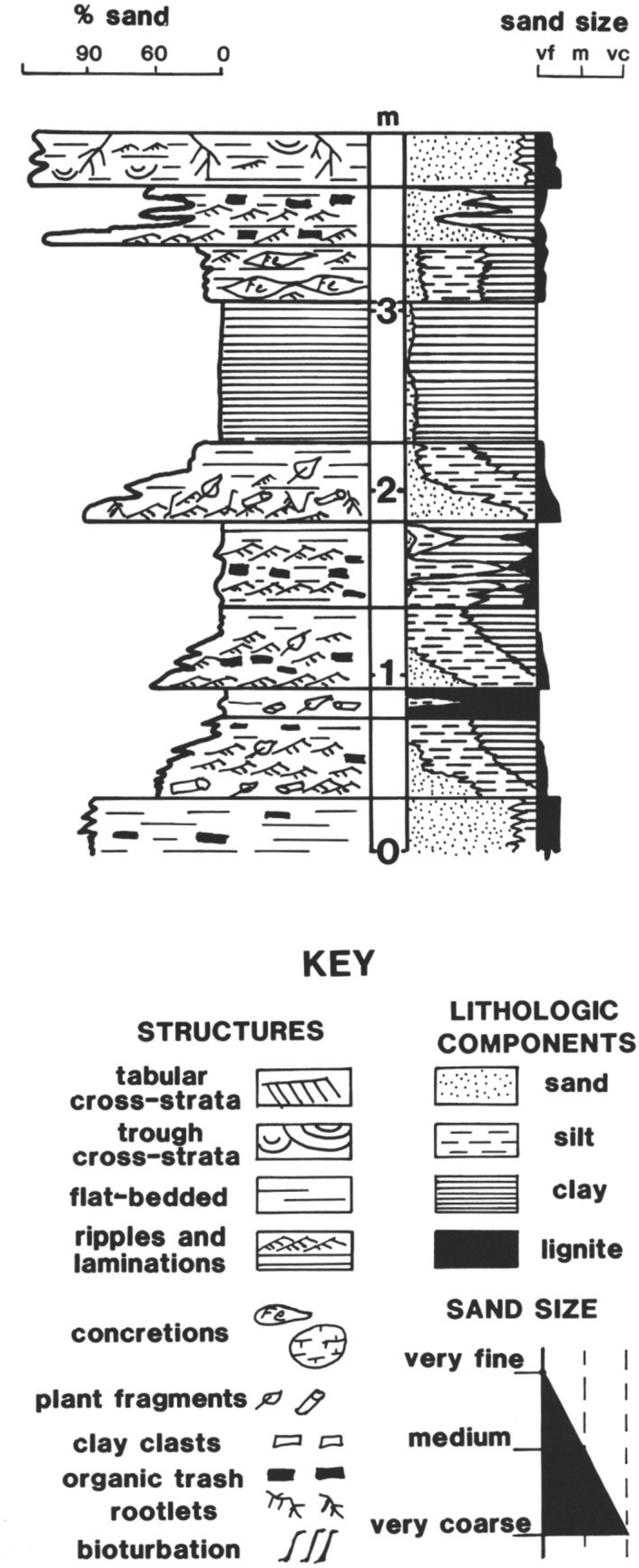

Figure 2. Graphic section of a mudstone facies outcrop. This interval is sandier than most of the facies, but sandier intervals are better exposed. Lower Crevasse Canyon Formation, La Jara Canyon. NE1/4 NE1/4 sec. 16, T2N, R5W, Socorro County.

blue to very pale green, very clayey siltstone or sandy mudstone are also present higher in the section. These may show crudely prismatic or blocky textures; abundant root traces may also be present. They probably represent clayey, water-logged, highly reduced soils, which commonly exhibit gley colors and prismatic textures (White, 1979).

SPLAY FACIES

A crevasse is a breach in the confining levee of a fluvial or distributary channel. This allows sediment-laden water to leave the confined channel and to spread into adjacent quiet-water settings. A splay is the fan-shaped deposit of rapidly deposited sand and silt which results. A crevasse may be reactivated by subsequent flood events; this is recorded in the splay by the intercalation of little or no-flow bedforms and high- flow bedforms and by the preservation of reactivation features. As the splay grows, small channels develop on its upper surface to carry newly arrived waters across the splay to its distal margins. Analogous processes occur at the mouth of a deltaic distributary channel; the resultant deposits are called delta-front bars and frontal splays. Crevasse splays occur in both delta-plain and fluvial-floodplain settings (Coleman and Gagliano, 1964; Coleman, 1969). Elliot (1978) reviews the formation and ge- ometry of splays in deltaic settings. Galloway (1981) and Payne (1982) discuss splays in fluvial settings.

Both crevasse and frontal splays are preserved in the Crevasse Canyon Formation, and the assignment of sand bodies to either environment is at times difficult. Individual splays can be thick and the structures they contain in their proximal parts are similar to structures preserved in many fluvial-channel sand bodies. When a number of splays are su- perimposed upon one another, the resultant thick body can be readily misinterpreted as a channel sand body if lateral relationships are not considered.

Figure 3 illustrates a splay sand body in the uppermost Crevasse Canyon Formation of Third Canyon Mesa. The thicker part of the deposit, which was proximal to the splay source, contains thick sets of gently inclined, thinly bedded, structureless or faintly ripple-bedded strata and thinly bedded cross-strata. Simple, planar, and trough cross-strata occur. Simple cross-strata may climb down in the direction of current flow (fig. 4) while planar and trough sets commonly do not climb or climb up in the direction of current flow. Small channels filled

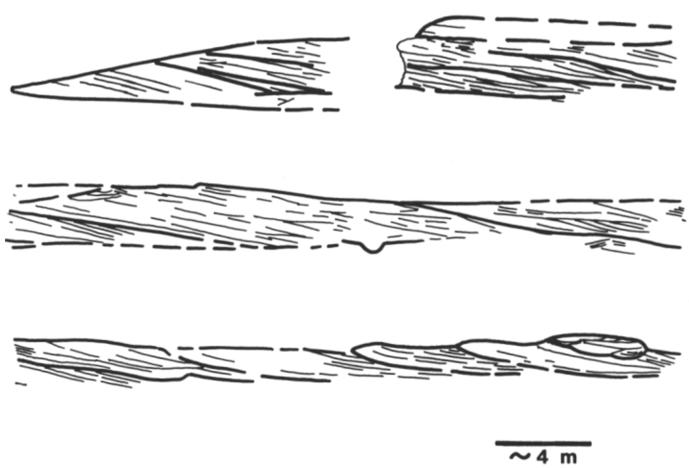

Figure 3. From top to bottom, the proximal, medial, and distal portions of a small crevasse-splay sand body. Flow is from left to right. Proximal deposits abruptly terminate against mudstones on the up-current side. Individual sandstone units within the splay, when traced in the direction of flow, move down-section. Some pass gradationally into the underlying mudstone facies. Tracing of a photomosaic. SW1/4 SW1/4 sec. 5, T2N, R10W, Catron County.

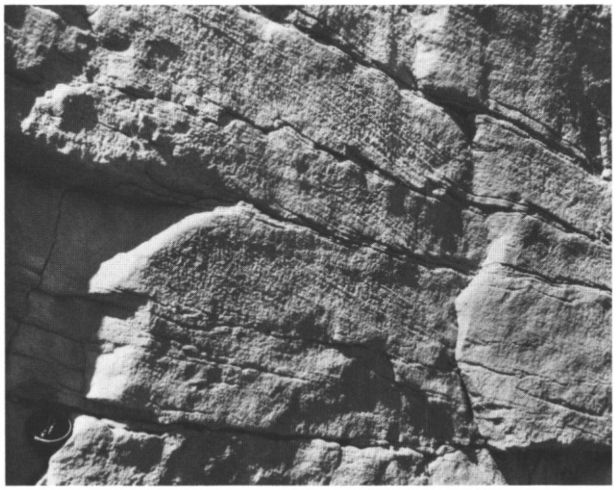

Figure 4. Proximal deposits of the splay illustrated in Figure 3. Lens cap in lower left corner is about 5 cm in diameter.

with trough cross-strata and very thinly to thinly bedded, horizontal or slightly inclined, homogeneous sandstone are common in the proximal part of the splay. Soft-sediment deformation also is common. The base of the proximal deposits may be abrupt and planar or scoured.

The distal areas of the splay in Figure 3 illustrate the episodic nature of flow in the splay system. Initial flow of a flood event is recorded by thick, gently inclined, structureless beds of clay-clast conglomerate and sandstone. As flow waned, the beds assumed a more laminated and horizontal aspect. Clay clasts became less common, and evenly laminated and climbing-ripple sandstone was deposited (fig. 5). Clay clasts represent rip-up material that was first deposited in quiet-water conditions upon the splay's surface. Distal splay deposits commonly have non-erosive bases and may grade into upward-coarsening units of the underlying mudstone facies.

Figure 6B is a large splay from the top of the Crevasse Canyon in Third Canyon Mesa. The lower part of the preserved splay consists of

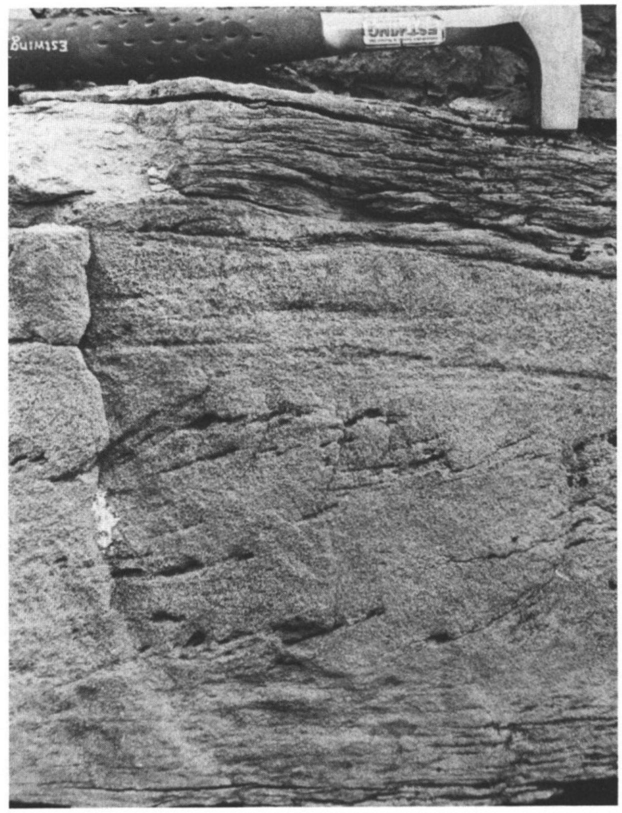

Figure 5. One flood event left this record in the distal part of a splay. Lower Crevasse Canyon Formation at La Jara Canyon, NW1/4 SE1/4 sec. 9, T2N, R5W, Socorro County. Hammer is 30 cm long.

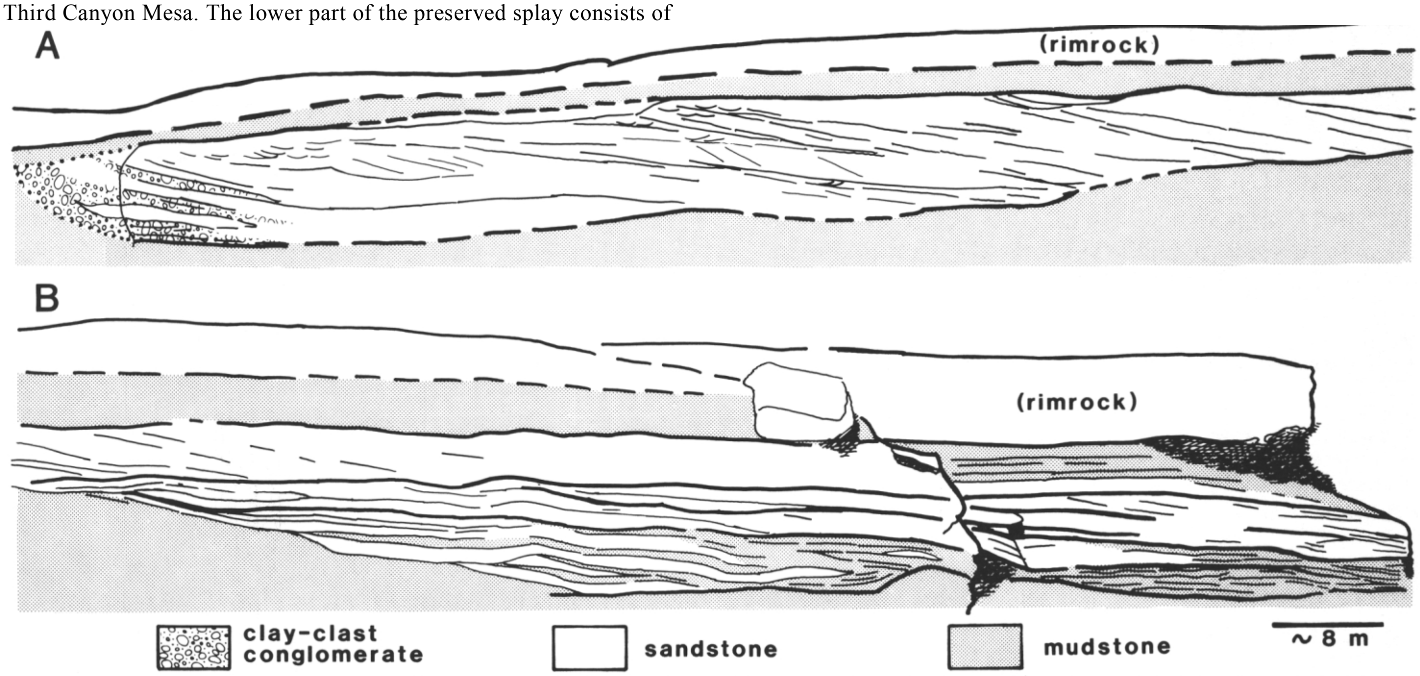

Figure 6. **A.** *Large channel preserved below the rimrock of Third Canyon Mesa. The channel migrated from left to right. The channel abandonment record is hidden by a covered slope, immediately to the right of this illustration. Tracing of a photograph.*

B. *This thick splay body emerges from the right side of the covered slope which obscures the abandonment record of the channel in A. Tracings from photographs. Eastern end of Third Canyon Mesa, SE1/4 SE1/4 sec. 6, T2N, R10W, Catron County.*

gently inclined interbeds of structureless, thinly to thickly bedded sandstone, ripple-laminated sandstone, and sandy mudshale. The sequence coarsens upward to a well-sorted sandstone. The upward-coarsening, inclined lower sequence is common in splays of the thick-splay depositional style. This suggests that the splays prograded into floodplain depressions or lagoonal areas from adjacent fluvial or distributary channels. Payne and Scott (in preparation) have proposed the name "Gilbert splay" for similar thick splays in a fluvial setting.

The lowest parts of the Crevasse Canyon Formation in La Jara Canyon contain thick stacks of splay sandstones. In the outcrop illustrated in Figure 7, individual splay sandstones are separated by muddy and silty interbeds, allowing individual splays to be delineated. Such is not always the case. Individual splay sandbodies in the lowest Crevasse Canyon commonly move downsection laterally, suggesting significant relief between the distributary channels and the floor of the surrounding lagoon.

In summary, splay sandstones of the Crevasse Canyon Formation are not always the thin packets of flat-bedded and rippled sediment which many associate with the word "splay." Individual splays can be several meters thick, with abundant trough and planar crossbeds and channelized flow in their proximal parts. Splays may be stacked to make thick sandstone sequences. Many of the thick splays represent small deltas which prograded into quiet water in a fluvial or lower-coastal-plain setting.

CHANNEL FACIES

Channels associated with the thick splays had small width-to-depth ratios and lateral migration was minor. Sand moved in bedload transport as dunes and sand waves, while finer elastics were transported in suspension. Some channels were preserved by their gradual filling with bedload as flow waned, but most were abandoned abruptly and later filled with mud and fine sand. Most channels also left a minor record

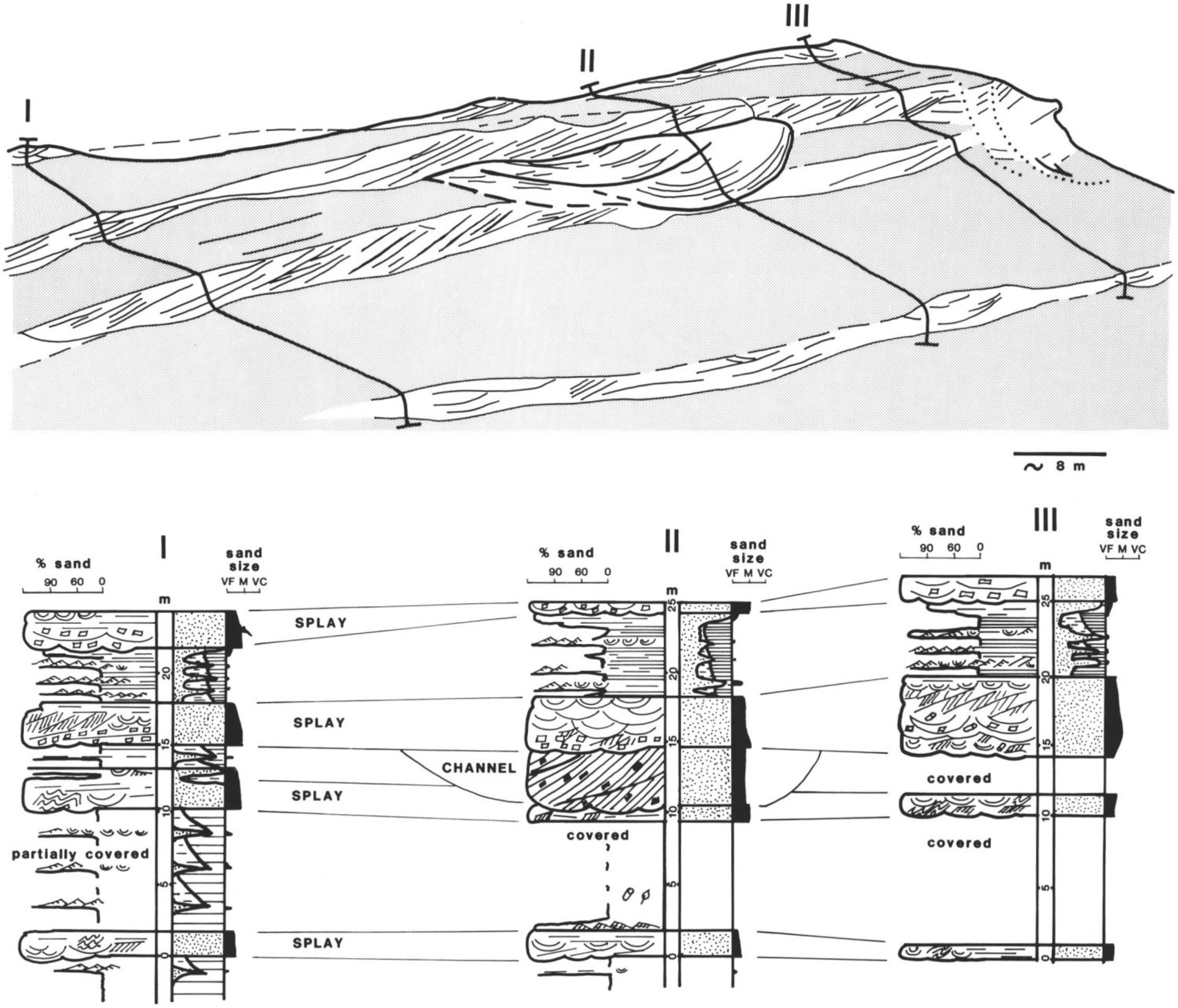

Figure 7. Oblique view of a hillside containing several splays and a distributary channel. Channel flow was toward the viewer. In the lowest splay, flow was toward the right; in the upper splays, flow was toward the left. Photo tracing keyed as in Figure 6; graphic sections keyed as in Figure 2. SW¼ SE¼ sec 9, T2N, R5W, Socorro County.

of lateral accretion sets. Vertical accretion within these channels was not a major sedimentary process.

Channels preserved in the lowest part of the Crevasse Canyon Formation in La Jara Canyon are distinctly lenticular in cross section (fig. 7). Medium-scale planar and trough cross-strata are common; these may be oversteepened (fig. 8) and may have superimposed ripple cross-strata on their cross-set surfaces (fig. 9). As channel deposits subsided into surrounding mud and splay sand, deformational structures formed on their margins. Intrachannel paleoflow was unimodal, but different channels show widely divergent paleocurrent directions. Channels filled with sand in a crudely symmetric fashion during waning flow stages. If later flows followed the same channel route, they commonly scoured a new channel slightly offset from the axis of the old channel.

Channels higher in the section at La Jara Canyon are larger and display evidence for orderly lateral migration (fig. 10). Lateral accretion sets are composed of medium- and small-scale trough cross-strata and slightly inclined, structureless, thin beds. Channel abandonment was abrupt and abandoned channels filled with contorted claystone, mud-shale, and muddy sandstone.

Channels preserved in the uppermost Crevasse Canyon at Third Canyon Mesa are among the largest I've seen in the Crevasse Canyon Formation of central New Mexico (fig. 6A). They also record more lateral migration of the channel than in many other thick-splay depositional settings. The initial channel was deep, and initial accretion sets contain much clay-clast conglomerate. As the channel migrated laterally, clay-clast content and depth of channel scour both decreased.

DEPOSITIONAL SETTING

The described outcrops might be considered members of a spectrum of depositional style. One end of the spectrum is represented by the lowest Crevasse Canyon exposures in La Jara Canyon (fig. 7). These deposits record the progradation of a fluvial-dominated deltaic system into a lagoonal setting. Frontal and crevasse splay deposits, supplied by small, straight distributary channels, prograded across the lagoon. This style is present in the lowest Crevasse Canyon Formation of So- corro County and also may occur in the highest Crevasse Canyon outcrops of the southern Acoma Basin.

The other end of the spectrum is represented by the large channel found in Third Canyon Mesa (fig. 6A). Preserved splays are less commonly encountered below the channels, but are located on channel flanks. The ratio of sandstone to mudstone is greater and soil zones are preserved. This end of the spectrum merges with a meanderbelt style which is also present in the Crevasse Canyon Formation and its equivalents, especially in exposures west of this study area and in the middle of the Crevasse Canyon Formation.

Most aggradation of the coastal plain by the thick-splay depositional style was not accomplished by deposition in the fluvial channels, but by deposition in surrounding, often topographically lower, subaqueous environments. The stabilization of banks by vegetation may have made lateral migration of channels difficult, or perhaps most deposition occurred during wet-season flood events when most of the landscape was inundated, and the preserved channels largely reflect dry-season flow conditions. However, I suspect a major factor contributing to the thick-splay depositional style was the imposition, by other processes, of very low gradients upon the fluvial systems.

Consider the lowest Crevasse Canyon Formation of the La Jara Canyon area. Molenaar (1974) recognized that a major fluvial axis in the area of the present western margin of the San Juan basin was supplying sand to the delta front and littoral deposits of the Gallup Sandstone. Sand supplied to that coastline probably was transported southeastward in a barrier island system; the thinning of the Gallup toward the southeast and paleocurrent data collected by Robinson (1981) and myself support this hypothesis. Therefore, the position of the Gallup shoreline in the La Jara Canyon area may have been controlled by the rate that sediment was supplied by a remote fluvial axis, the interplay of wave and tidal forces, and relative basin subsidence and sea level changes. The small

Figure 8. Oversteepened, tabular planar cross-strata in the base of a distributary channel. Soft-sediment deformation structures are common in distributary channel deposits. Lowest part of Crevasse Canyon Formation in La Jara Canyon near exposure illustrated in Figure 7. Pen is about 13 cm long.

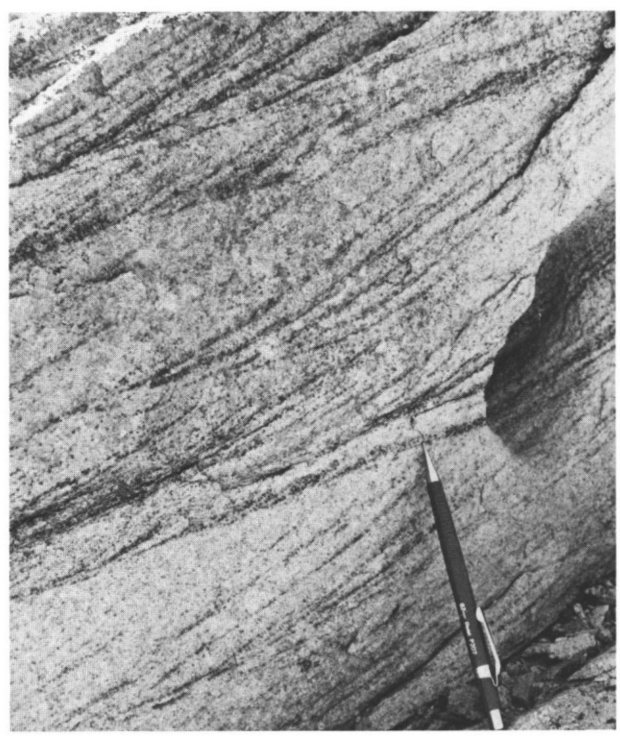

Figure 9. Ripples or small dunes migrated down the lee side of a larger bedform to produce these superimposed cross-strata. From the channel illustrated in Figure 7. Pen is 14 cm long.

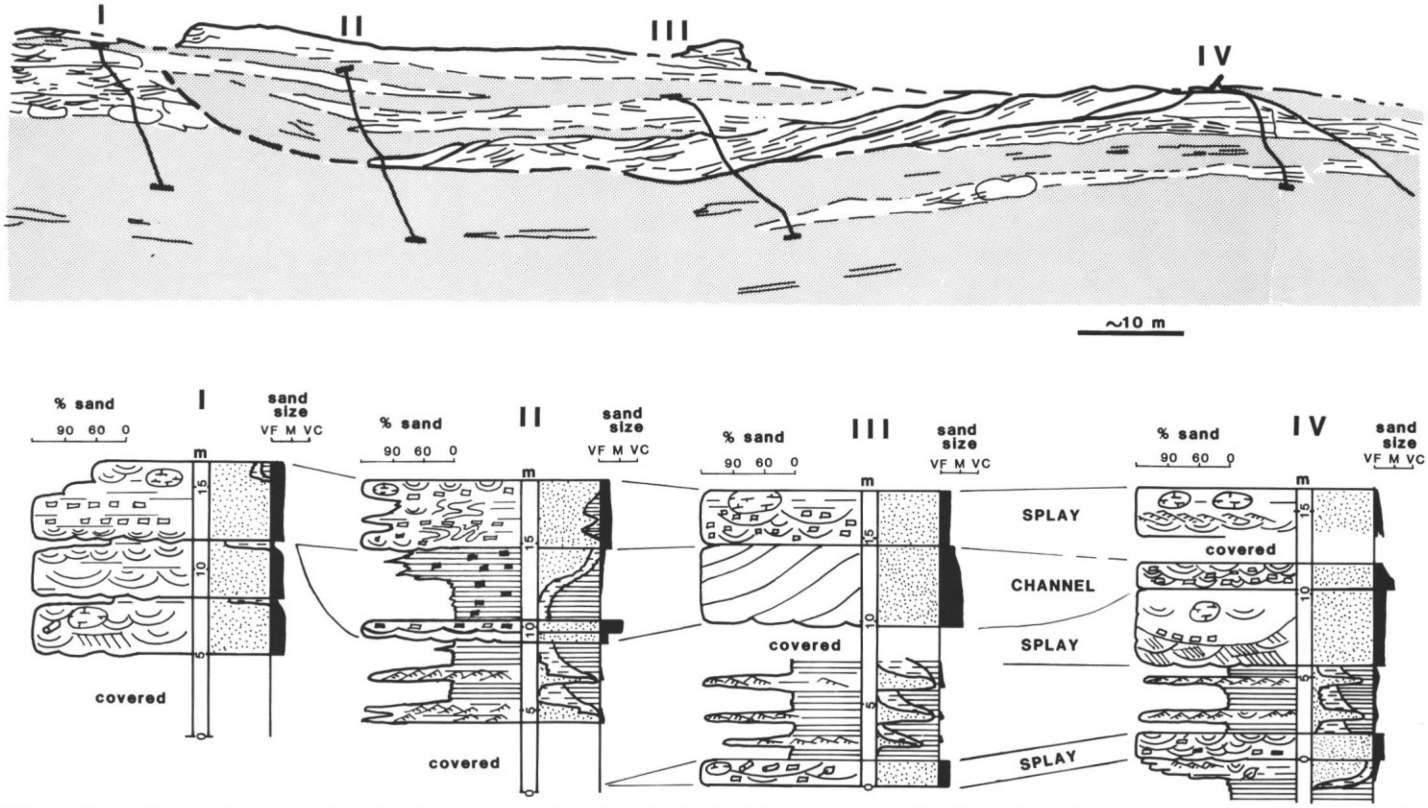

Figure 10. A fluvial channel with a few lateral accretion deposits incised into two stacked splays. Paleoflow was approximately towards the viewer. The dissected splays can be traced laterally for more than half a kilometer; the fluvial channel incised into their thickest accumulation. Perhaps the channel location was controlled by a previous crevasse. Photomosaic tracing keyed as in Figure 6; graphic sections keyed as in Figure 2. Middle Crevasse Canyon Formation, La Jara Canyon. SE¼ SW¼ sec. 9, T2N, R5W, Socorro County.

fluvial systems preserved in the lowest Crevasse Canyon Formation of western Socorro County probably could not aggrade the coastal plain fast enough to keep pace with this superimposed shoreline progradation. Very low fluvial gradients and abundant lagoonal and lacustrine deposits resulted.

The development of the thick-splay facies throughout the Crevasse Canyon Formation may reflect, in part, shoreline positions and processes farther to the north. It may be possible to recognize and delineate major genetic packets within the Crevasse Canyon Formation and relate them to the better-understood shoreline transgressions and regressions of the southern San Juan basin.

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