



Pennsylvanian coarse-grained fan δ s associated with the Uncompahgre uplift, Talpa, New Mexico

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PENNSYLVANIAN COARSE-GRAINED FAN DELTAS ASSOCIATED WITH THE UNCOMPAHGRE UPLIFT, TALPA, NEW MEXICO

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INTRODUCTION

Pennsylvanian sedimentary rocks exposed in the Sangre de Cristo Mountains of northern New Mexico represent a series of clastic wedges deposited along the eastern margin of the ancestral Uncompahgre uplift. These wedges record an Atokan to early Desmoinesian episode of uplift that resulted in the eastward and southeastward progradation of coarse fan-delta lobes into the adjacent Taos trough. Rapid shifting of these small deltas during basin subsidence resulted in a vertical stacking of complex interbedded sequences of coarse elastics alternating with marine limestone and mudstone. Similar facies assemblages are characteristic of the many cratonic basins associated with the ancestral Rocky Mountains.

Exceptional examples of these complex cycles crop out in the vicinity of Rancho de Taos, New Mexico (fig. 1). This study focuses on exposures along the east side of state highway 3 and in adjoining east-trending canyons 4 to 4.5 kilometers south of Talpa, New Mexico. Five progradational sequences were recognized in the lower 105 meters of section measured in the area (fig. 2). Two sequences (3 and 4) were chosen for discussion.

Twenty-six measured sections and several outcrop sketches detail lateral and vertical variations in lithology, stratification type and fossil content. Environmental conditions have been interpreted from these relationships. Inferred processes combined with directional features, lithofacies geometry and stratigraphic successions have been integrated into a depositional model.

DEPOSITIONAL FACIES

Seven lithofacies are recognized in the study interval. These are:

- (a) Coarsening-upward interbedded siltstone and sandstone
- (b) Contorted sandstone
- (c) Conglomeratic sandstone with erosional base
- (d) Foreset-bedded sandstone
- (e) Burrowed calcareous sandstone
- (f) Siltstone and shale with marine fossils
- (g) Marine limestone

Facies a-d are associated with the two progradational sequences, with facies a and c the most important volumetrically. The contorted lenses of pebbly sandstone (facies b) are relatively uncommon but add significantly to the understanding of depositional processes of the fan deltas. The two fossiliferous units (facies f and g) represent environments prevalent at times or in sites not affected by active clastic sedimentation. Facies e is a transitional unit, which if present, always overlies a progradational sequence. The lower progradational sequence is exposed well along state highway 3 (fig. 3). Contorted sandstone lenses are present at the north end of a prominent roadcut near the base of this cycle (fig. 4). These folded units (facies g) represent several overlapping,

southeast-trending sandstone ribbons which were deformed by soft-sediment loading during or soon after deposition.

Overlying the contorted intervals is a thin unit of fossiliferous siltstone (facies f) which grades upward into interbedded siltstone and thin, sharp-based sandstone beds (facies a). The sandstone beds become both more numerous and thicker higher in the section. This fairly abrupt coarsening-upward trend is characteristic of most clastic cycles exposed in this area. Capping this sequence are two trough-crossbedded conglomeratic sandstones (facies c) separated by a thin fossiliferous, marine limestone (facies g). The conglomerates are channel-like with erosional bases and large internal scour-and-fill surfaces. The upper surfaces of these coarse units are burrowed sandstones (facies e).

Sequence 3 is overlain by a 9m-thick interval of fossiliferous siltstone and shale (facies f). A diverse brachiopod-molluscan fossil assemblage represents fairly shallow, open-marine conditions. Above this marine interval is a 4-to-10m-thick coarse sandstone (Unit 4 in Figure 2) with large-scale (0.5-to-3.5m-thick) foreset beds (facies d). These crossbeds have maximum dips of 27° and tangential basal contacts. Individual beds making up the foresets average about 25 cm in thickness, thin towards their toes, show faint bedding parallel to the bed boundaries, and often are texturally graded.

LATERAL FACIES RELATIONS

Exposures along state highway 3 form an oblique slice through the progradational units, thus revealing paleodip facies relationships. Sandstones of the lower sequence are laterally continuous in these exposures. However, because of the obliquity of the view, the channel-like geometry of the coarser units becomes obvious.

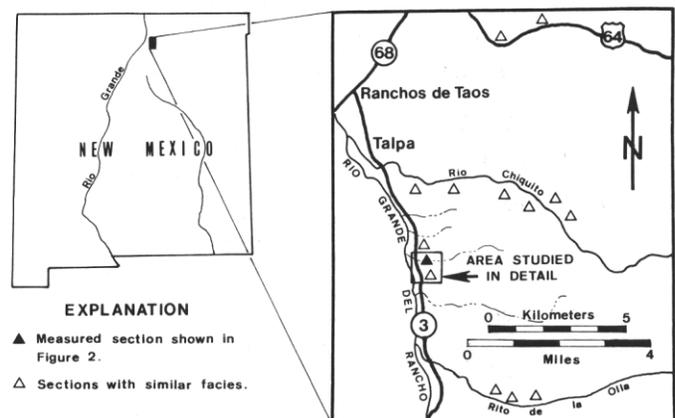


Figure 1. Location of study area and measured sections with Pennsylvanian coarse-grained fan-delta deposits.

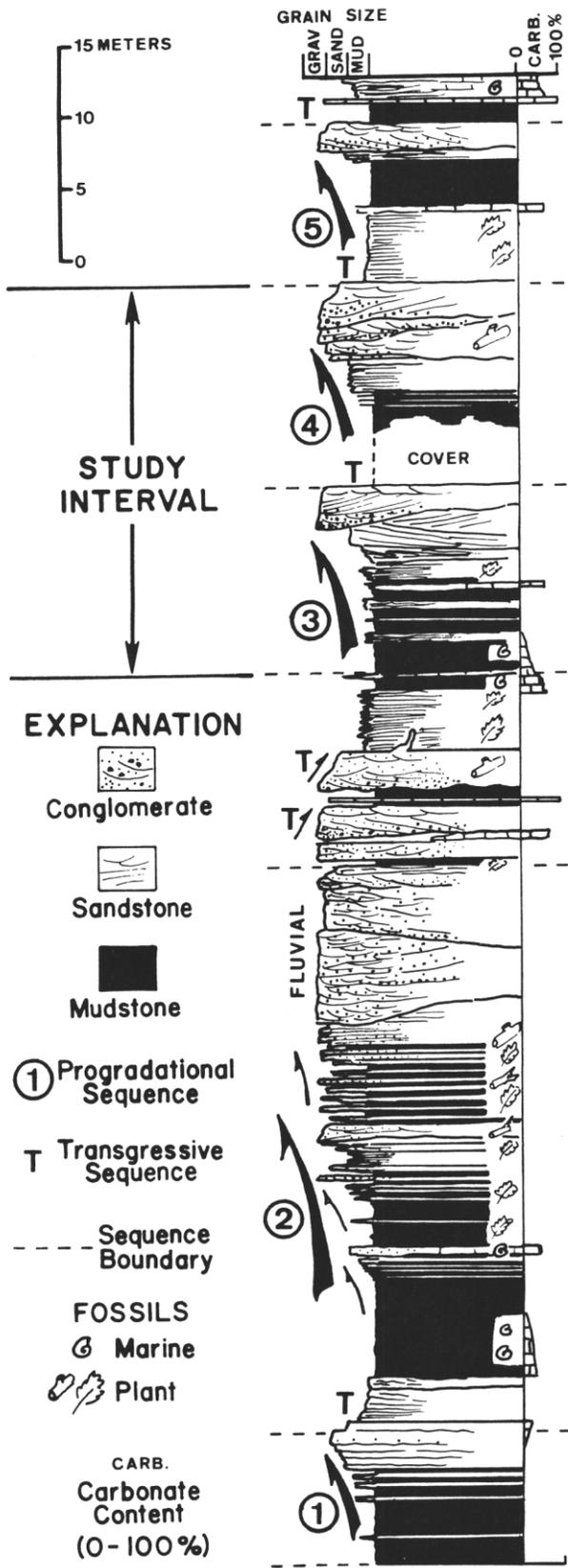


Figure 2. Stratigraphic section of study area.

The dip relations of the upper foreset-bedded sandstone unit are particularly interesting. Figure 5 is a sketch of part of this sandstone unit. Four individual foreset subunits can be distinguished, each with a slightly different dip orientation. Crossbeds within each subunit have strongly tangential basal contacts, giving rise to steep foresets and nearly horizontal bottomsets. The bottomsets are finer-grained and commonly burrowed. The uppermost foreset unit is capped by a trough crossbedded topset unit.

Approximately 400 meters north of the roadcut exposures, a small east-trending valley provides an oblique, paleostrike cross section of the study interval. A steep bluff on the south side of the valley reveals details of the lower coarsening-upward sequence not apparent in sections along the highway. This lower sequence actually is composed of several inclined low-angle (maximum dip of 12°), wedge-shaped sedimentation units which are cut at the top by a fairly broad channel sandstone (fig. 6). Individual sandstone beds within these wedges thin toward the toes of the wedges and grade into the surrounding mudstone facies. Thus, these wedges may be considered a second type of large-scale foreset bedding, which is broader and lower-angle than those described earlier.

On the opposite side of the valley, several large southeast-trending channels can be seen cutting into the lower sequence (fig. 7). Bedding within these channels varies from large-scale trough crossbeds to large sigmoidal crossbeds which dip perpendicularly to the channel axis. These sigmoidal crossbeds probably represent side filling of the channel or lateral accretion on small point bars.

The foreset beds of the upper sandstone in Figure 7 are similar to the large-scale foresets described earlier, except that they have more angular basal contacts, and individual foreset beds are more uniform in thickness. These crossbeds dip to the southwest, perpendicular to most other directional features in this area, and are overlain by trough-crossbedded sandstone.

FAN-DELTA MODEL

Delta Progradation

Following uplift of the Uncompahgre highland, small, coarse-grained delta lobes prograded eastward and southeastward into the adjacent Taos trough. These delta lobes were fed by fairly straight, symmetrical channels which graded landward into laterally more extensive braided stream systems (Casey, in prep.). Stream discharge was flashy due to the proximity of the highlands, small drainage areas, and a climate dominated by seasonal, or at least very sporadic rainfall. During periods of little or no discharge, bed-load sediment was stored in the distributary channels, whereas during flood discharge, this stored sediment was entrained and rapid progradation occurred. This alternating sediment storage and transport gave rise to channel deposits dominated by large-scale trough crossbeds and numerous internal erosion surfaces. Variations in delta-front sedimentation were dependent on many factors, including channel size, amount and caliber of sediment, discharge characteristics, and wave energy. Sediment influx to the delta front occurred only during high-discharge periods. If progradation was into areas with water depths greater than 4 meters, bed-load sediment would fan out on the delta slope, forming fairly extensive fan-shaped frontal splays. Individual splays thinned and fined away from the distributary mouth. During low discharge, very little sediment was deposited and marine organisms re-

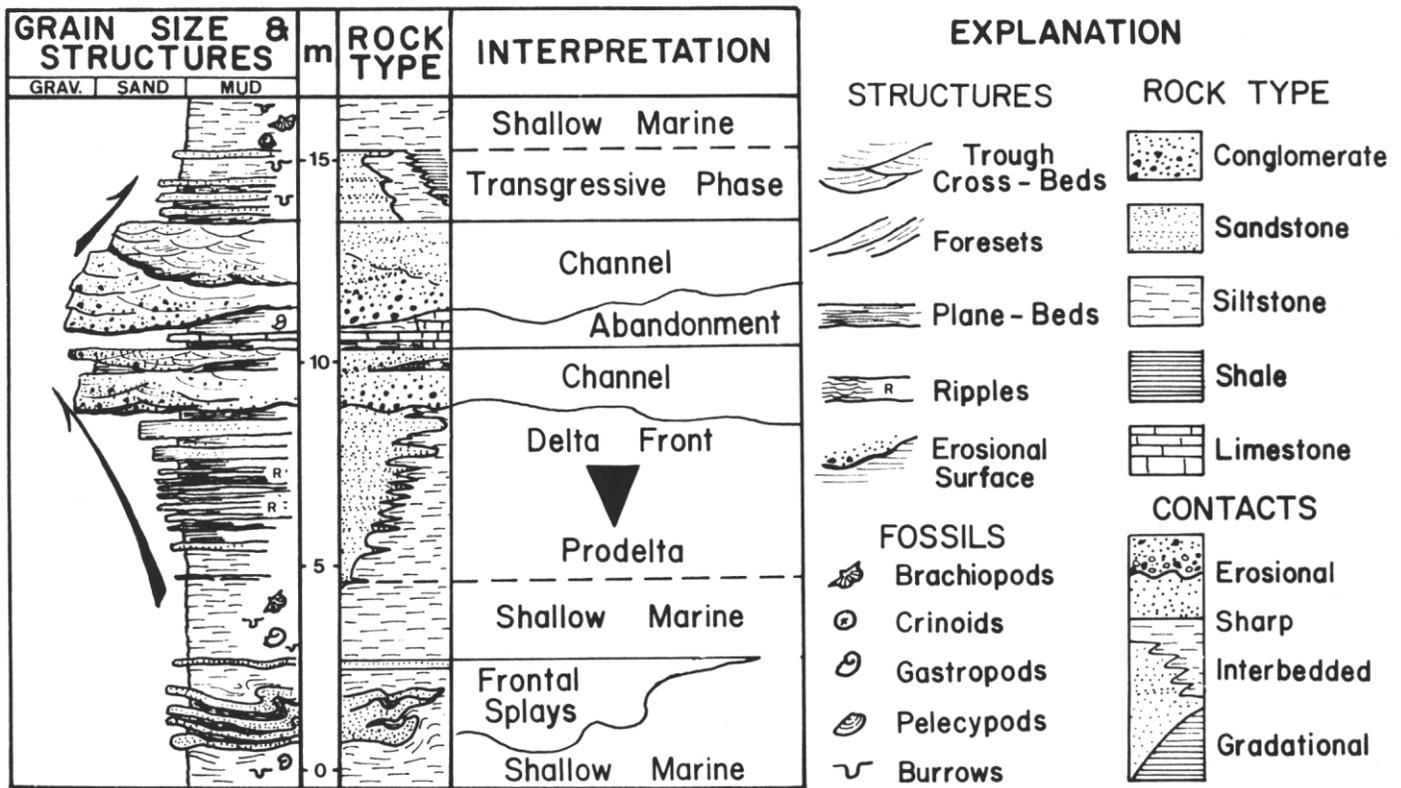


Figure 3. Representative measured section of lower progradational sequence (unit 3 of fig. 2).

established themselves on the distal parts of the delta front. The fact that marine fossils occur interbedded with the frontal splay sands is further evidence for flashy discharge and intermittent sedimentation. With successive flood events, these frontal splays prograded to form coarsening-upward wedges. Sandstone geometry suggests that lateral reworking by waves and other marine processes was minimal. The shape of the prograding wedges was elongate with beds dipping basinward and toward the flanks. The axis of successive splays varied, causing shifts in loci of deposition. Imbrication of several overlapping frontal splay wedges resulted (fig. 6). Internally, these wedges are made up of seaward-dipping-and-thinning sandstone beds which are low-angle delta foresets. As progradation continued, the distributary channel extended over these delta-front sediments, forming an overall coarsening-upward sequence capped by conglomerates with erosional bases (fig. 3).

Occasionally, during extremely high discharge, gravel frontal splays would develop. These formed narrow, ribbon-shaped deposits possibly with scoured bases. These coarser splays overloaded the underlying sediments, thus deforming both the substrate and the newly deposited splay. This deformation formed a depression which tended to localize subsequent splays, giving rise to several overlapping, contorted, coarse-grained splays (fig. 4). It should be noted that the contorted splays in Figures 3 and 4 are not related to the overlying coarsening-upward sequence but rather to an earlier episode of delta progradation.

Distributary Shifting

Another characteristic feature of these coarse delta lobes was a rapid shifting of distributaries, producing a complex of

overlapping delta sublobes. Figure 8 shows the inferred sequence of events which produced the lateral facies relation shown in Figure 7.

The upper sandstone in Figure 7 is thought to represent a small subdelta or crevasse splay which prograded into an interdistributary embayment (fig. 8c1). Because of the low mud content of these deltas, channel levees were poorly developed and easily breached by crevasse channels. Water and sediment would be diverted into adjacent low-lying areas. During floods, the saline water would be displaced from these shallow embayments, resulting in homopycnal flow (axial jet flow). Rapid

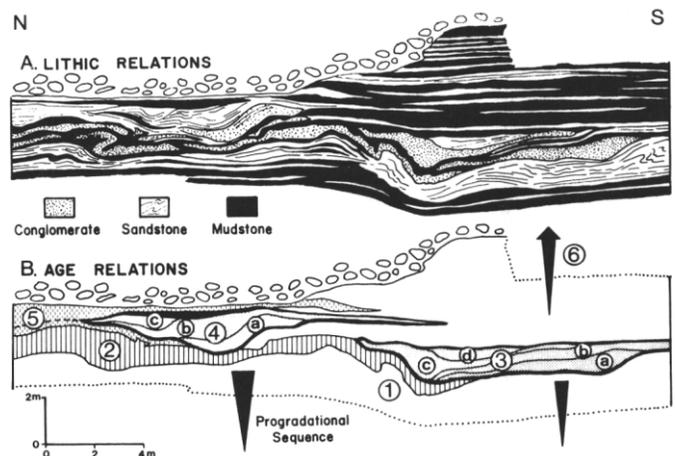


Figure 4. Sketch of contorted coarse sandstone lenses associated with progradational sequences. Gravel at top is included with the Tertiary Picuris Formation.

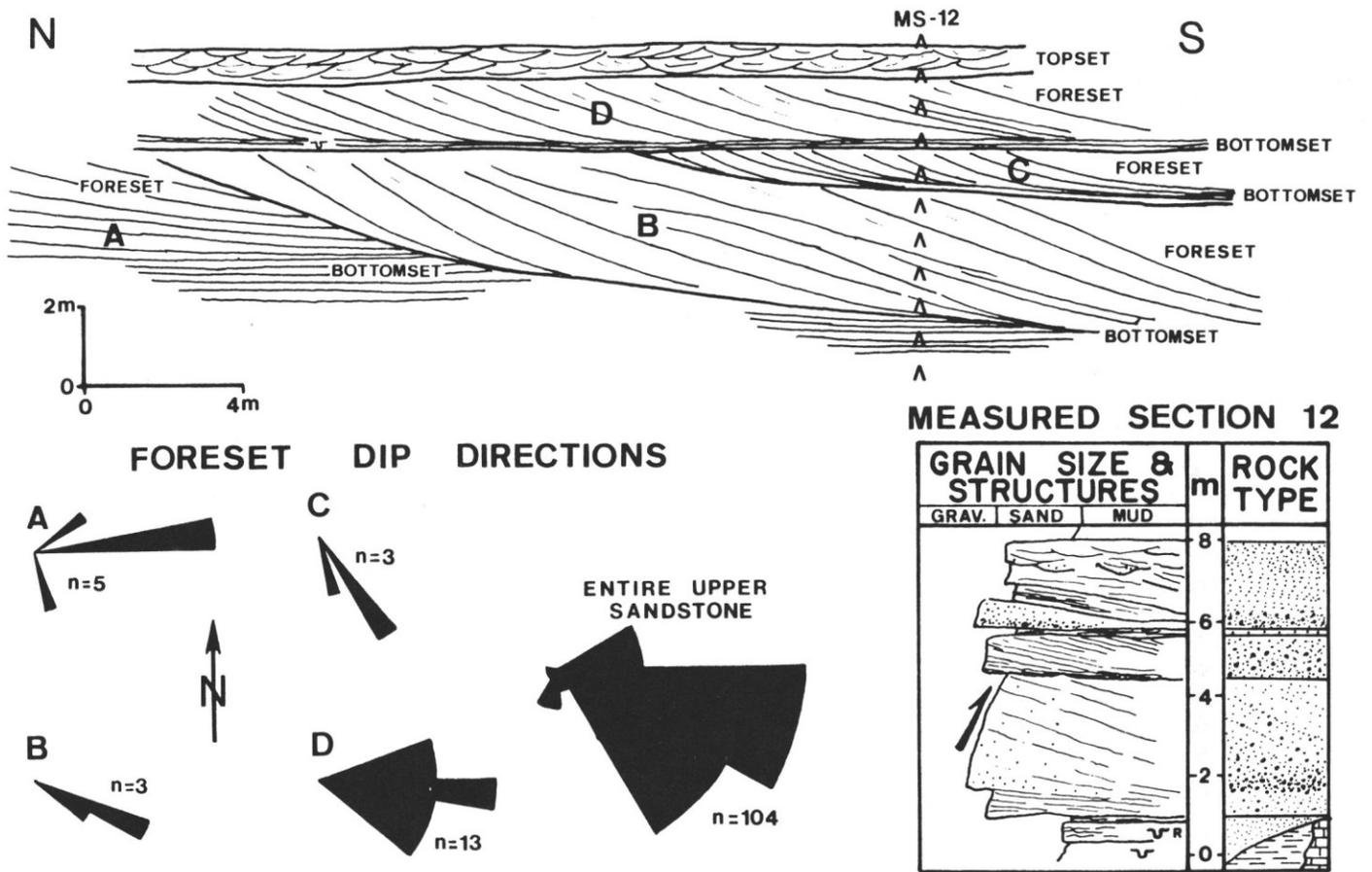


Figure 5. Large-scale foresets of upper progradational sequence exposed along state highway 3. See Figure 3 for explanation of structures and rock type.

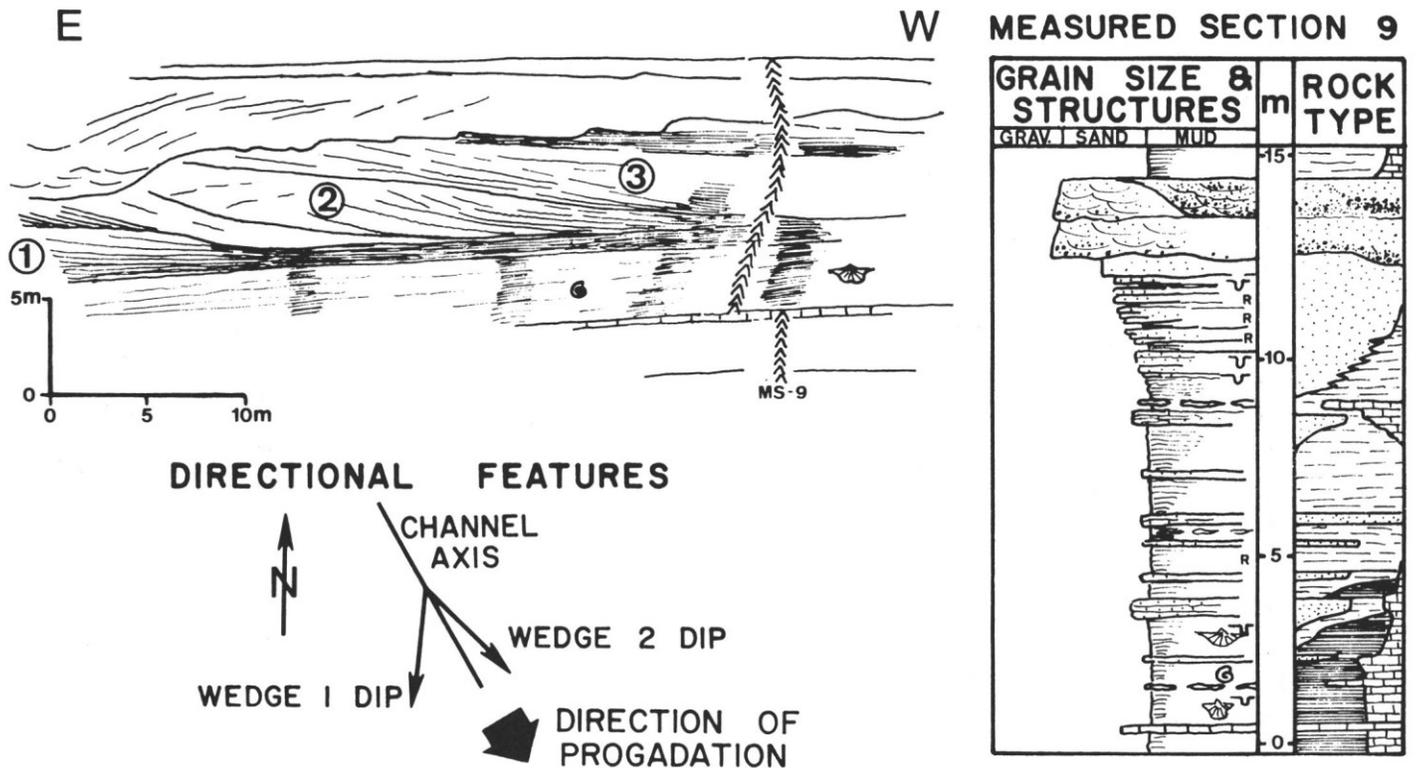


Figure 6. Low-angle progradational wedges exposed on south side of valley. See Figure 3 for explanation of structures and rock type.

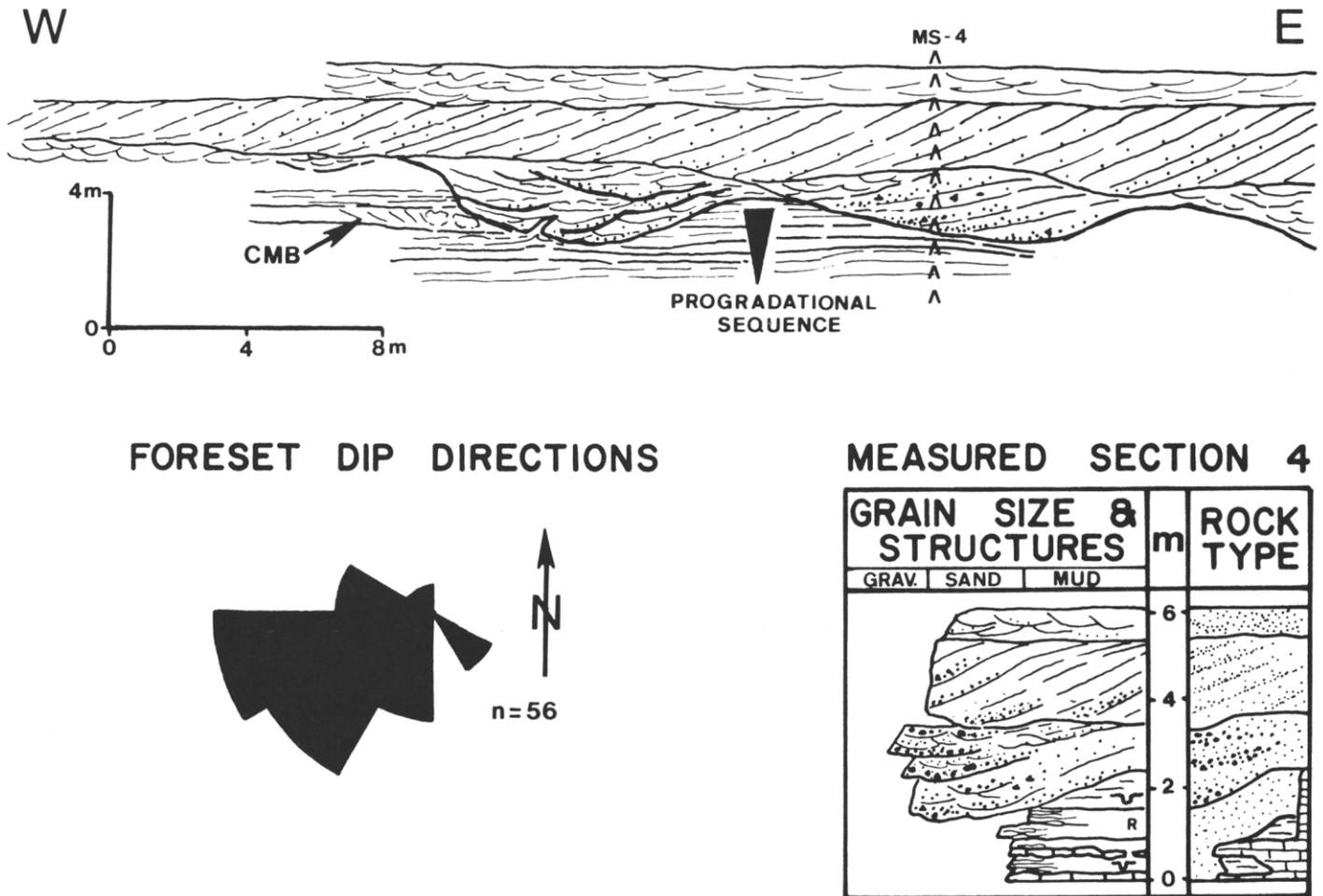


Figure 7. Channel and foreset-bedded sandstones exposed at top of lower progradational sequence along north side of valley. Note that dip directions of foresets are perpendicular to those of Figure 5. Sandstone labeled C.M.B. is interpreted as a channel-mouth bar deposit. See Figure 3 for explanation of structures and rock type.

deposition of sediment would form delta foresets characteristic of classical fresh-water "Gilbert" deltas (Bates, 1953). Such thin foreset-bedded crevasse splays prograded very rapidly and were relatively short-lived features. The unit in Figure 7 is relatively uniform along the entire length of its exposure. No evidence of reactivation was observed, suggesting that the sand was deposited during a single depositional event. A similar feature formed on Gum Hollow fan delta along the Texas coast as a result of Hurricane Beulah in 1967 (McGowen, 1970; Scott and others, 1969).

Distributaries may be abandoned or become inactive long enough for the establishment of benthic organisms on the delta front. The benthos also may colonize floors of inactive channels. Later reactivation of the channel or progradation of a delta sublobe over the same area can result in a thin marine limestone sandwiched between two channel deposits (fig. 3). In contrast, thick fossiliferous siltstone deposits, such as the one developed between progradational units 3 and 4, represent major lateral shifts in deltaic depocenters.

Shallow Water Delta Foresets

The upper foreset-bedded sandstone represents a reestablishment of deltaic sedimentation in the area (fig. 5). However, the water was shallow and delta progradation during periods of high rainfall produced small delta foresets. Unlike the lower

delta sequence, flow was unconfined and occurred as sheet-flood radiating out across the delta lobe. Sediment was transported across the lobes and deposited on steep, advancing frontal slopes, forming high-angle delta foresets. During sequential floods, these delta foreset lobes reactivated and advanced further. However, each extension had a slightly different orientation, giving rise to a composite of foreset subunits, each with slightly different dip directions and thicknesses. The length and magnitude of individual floods control led the characteristics of the resulting depositional subunits. Upper surfaces of the foreset subunits are truncated. Bottomset beds of subsequent reactivation units are subparallel to these surfaces. Erosion probably was the result of waves during periods of low sediment input.

In many respects, this upper sandstone resembles the small crevasse subdelta discussed earlier, with water depth probably playing a similar role in the origin of the foreset-bedding. These steeply dipping foresets are always less than 4 m thick, implying comparable water depths. In contrast, coarsening-upward sequences similar to the lower progradational unit (fig. 3) may be 20 m thick and average about 10 m in thickness. Foreset-bedded sandstones usually occur stratigraphically a few meters above a coarsening-upward deltaic sequence. This

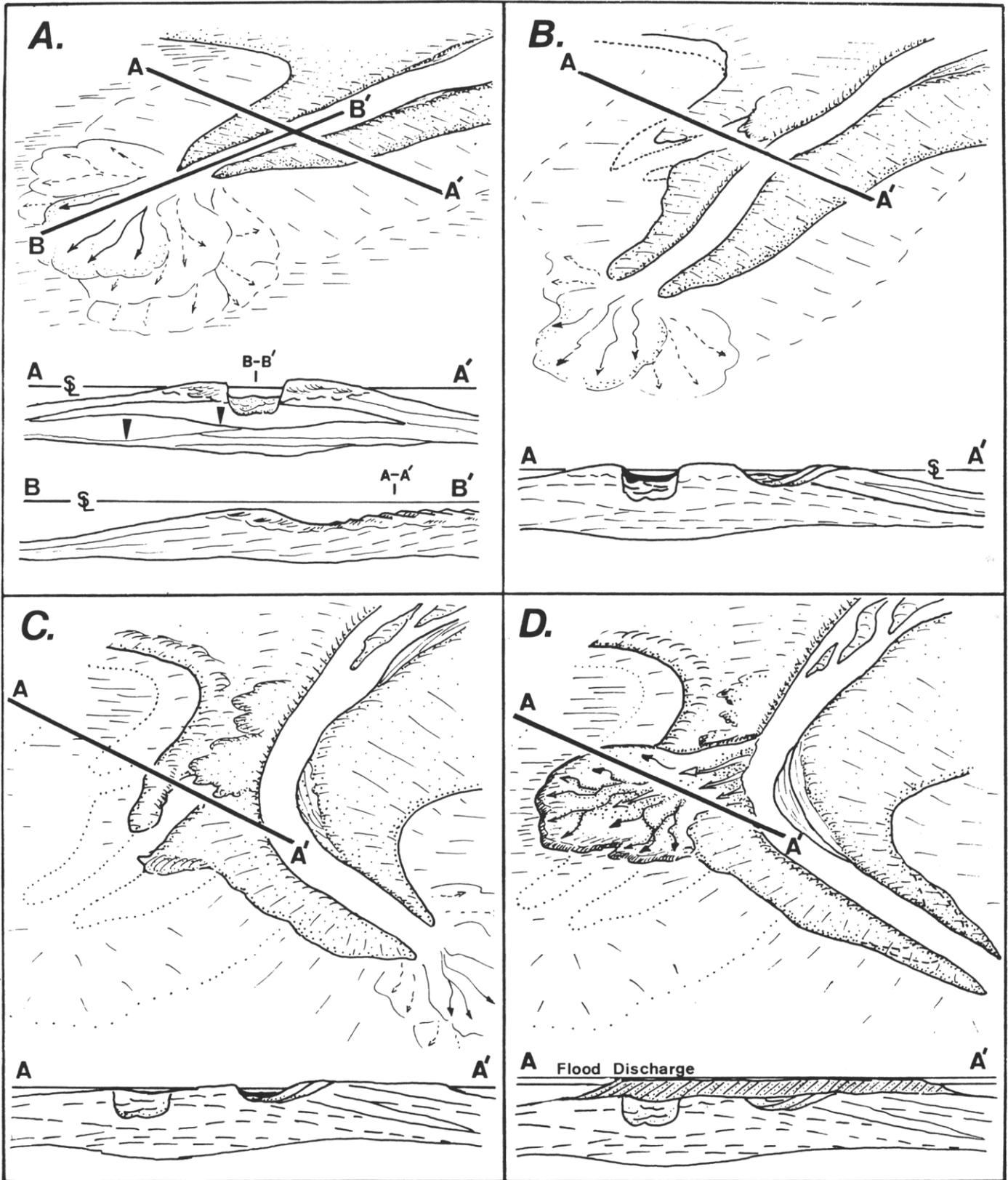


Figure 8. Fan-delta model. (A) Initial progradation of fan-delta lobe. Shifts in loci of deposition at delta front result in an imbrication of several frontal splay wedges. (B-C) Lateral shifts of distributaries. (D) Channel breaching and rapid progradation of small crevasse splay into shallow embayment on abandoned delta platform.

suggests that the initial delta progradation followed by a temporary abandonment produces a distinct shallow-water delta platform on which the later foreset-bedded deltas form. Fresh-water flushing and homopycnal flow probably are responsible for the delta foresets, similar to the crevasse subdelta processes.

There are significant differences in the foresets of the upper sandstone and the crevasse subdelta. Foresets of the upper sandstone have tangential bases and individual beds thin toward their toes, whereas the foresets of the crevasse splay are planar and have angular basal contacts. This difference may be related to relative discharge and the percentage of fine sediment being transported. Jopling (1965) demonstrated that for laboratory micro-deltas, the frontal profile evolves from angular to tangential and eventually low-angle concave as discharge velocity increases. He also showed that this same succession occurs as the amount of suspended-load increases. Assuming this also applies to somewhat larger deltas, the planar foresets of the crevasse subdelta indicate the splay was deposited by bed-load transport under relatively low velocities. This agrees with Russell's (1967) finding that the amount of bed-load sediment diverted through a crevasse channel is disproportionately large in respect to its relative discharge (bed load tends to move from areas of high velocity and turbulence to areas of lower turbulence). In contrast, the strongly tangential nature of the foresets of the upper sandstone (fig. 5) indicates higher velocities and a higher percentage of fines. These foresets dip parallel to the orientation of the lower channel, indicating progradation was in the same direction as the lower delta complex. Thus, these upper foresets were deposited by a major southeast-flowing stream system, and therefore, would be expected to have a higher discharge and percentage of fines than the subdelta fed by a crevasse breach. It also should be noted that the dip directions of the foreset beds in the upper sandstone (fig. 5) are almost perpendicular to those of the splay unit (fig. 7).

DISCUSSION OF MODEL

There are few published studies of modern fan deltas building into shallow-marine settings. The most comprehensive study was on the Gum Hollow fan delta of Nueces Bay, Texas by McGowen (1970). This delta is a relatively small feature strongly influenced by the activities of man. It is located in a tectonically stable area, but perhaps due to the scarcity of described examples, it often is cited as an analogue for deltas in tectonically active basins. Since McGowen's study, several authors have applied fan-delta models to interbedded marine and coarse-grained clastic sequences (Dutton, 1979; Flores, 1978; Spoelhof, 1976; Surlyk, 1975; Sykes and Brand, 1976). Sykes and Brand (1976), however, make a distinction between fan-delta deposits dominated by sheetflood and streamflood processes, and short-headed stream delta deposits in which flow is confined to stable channels. They feel that the term fan delta should be limited to deposits for which an alluvial fan nature can be documented with sheetflood the dominant process. The delta deposits described in this study provide evidence of both sheetflood and confined channel processes. Many of the delta lobes in the Talpa area are associated with narrow, fairly straight channels which rapidly shifted position. However, even these lobes commonly grade laterally into more extensive braided-stream deposits. Thus, it appears that the distal reaches of these braided streams became more confined and took on the attributes of more normal, straight delta dis-

tributaries, possibly due to the extremely low gradient of the lower-delta-plain environment.

Whether the delta sands develop high-angle foreset beds with sheet-flood topsets or coarsening-upward progradational sequences with lenticular channel deposits is a function of many variables, with water depth particularly important. In the Talpa study area, distinct channels are associated with progradational sequences greater than 4 m thick. Flow generally was confined as a series of frontal splays radiating from the channel mouth. When progradation occurred in very shallow water, delta foresets developed and sheetflood was common. Foreset bedding also developed when small subdeltas built into shallow, interdeltaic embayments.

The complex interrelationships of thin, laterally discontinuous depositional units described in the Talpa fan deltas are typical of many coarse clastic wedges occurring along margins of fault-bounded basins. Several such basins are associated with the ancestral Rocky Mountains. Fault-bounded basins also form in conjunction with a broad spectrum of other tectonic settings.

The thin nature of genetic units suggests rapid changes in depositional conditions and loci. Generalized measured sections lacking information as to variations in sedimentary structures and textural sequences are of little use in determining depositional history. Measurement of crossbedding dip directions, even within the same stratigraphic unit can provide confusing and spurious information regarding regional sediment dispersal patterns.

The significant lateral variations in the clastic wedges pose serious problems for mapping traditional rock-stratigraphic units. However, detailed study of these variations yields a wealth of information essential for an understanding of genetic stratigraphy and basin analysis.

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