### PSStrike Variability within a Wave-influuenced Delta, the Gallup Sandstone, Shiprock, New Mexico\*

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### **Abstract**

The Upper Cretaceous Gallup Sandstone Formation in the San Juan Basin, New Mexico, has been interpreted as an amalgamated wave-dominated barrier-shoreface, and strand-plain deposit. Reassessment of outcrops near Shiprock, New Mexico, shows elements of river and wave-influenced deposition varying laterally along depositional strike. River-influenced deposition is restricted to the west side of the area, which includes upward-coarsening heterolithic facies, with soft sediment deformation, allocthonous plant and coal fragments, Bouma sequences, and parallel-laminated to cross-bedded sandstones with scours. Rare burrows include *Arenicolites* and *Planolites*, suggesting a stressed environment. These coarsening-upward successions are interpreted as storm-influenced, river-dominated delta front and terminal distributary channel deposits. Wave-influenced deposition predominates on the east side of the area and comprises homogeneous sandy shoreface deposits, with alternating bioturbated to hummocky-cross-stratified sandstones that pass into dune-scale cross-bedded sandstones. Abundant *Asterosoma*, *Ophiomorpha*, and *Chondrites* suggest a wave-influenced shoreface.

Eight-hundred-twelve paleocurrent measurements were taken from the shoreface. Trough cross-beds indicate NW- to SE-longshore currents, which we interpret to represent the overall shoreline orientation. NNW to SSE wave-ripple crest orientation indicates wave approach was oblique to the shoreline. Dominant longshore drift direction appears to be to the southeast, which is the dominant direction of marine circulation currents in the Western Interior Seaway. However, there were a significant number of northwest directed currents that are more compatible with the oblique wave approach determined from wave-ripple crest measurements.

Petrographic analysis of the updrift and downdrift areas was conducted to determine relative textural maturity. Higher amounts of silt and sedimentary rock fragments were found in the downdrift facies in the west side, whereas higher porosity sandstones characterize the updrift facies. Grain size, roundness, and sorting show no distinct trends, which suggests some mixing of updrift and downdrift sediments.

We suggest the Gallup sandstone is an asymmetric, wave-inflenced delta. An asymmetric delta forms under the influence of oblique wave action, resulting in muddy river sediments being deposited downdrift of the river, while updrift sediments form the homogenous sandy shoreface.

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### Abstract

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812 paleocurrent measurements were taken from the shoreface. Trough cross-beds indicate NW to SE longshore currents, which we interpret to represent the overall shoreline orientation. NNW to SSE wave-ripple crest orientation indicates wave approach was oblique to the shoreline. Dominant longshore drift direction appears to be to the southeast, which is the dominant direction of marine circulation currents in the Western Interior Seaway. However, there were a significant number of northwest directed currents that are more compatible with the oblique wave approach determined from wave-ripple crest measurements.

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### . Introduction

An asymmetric delta is a wave-dominated delta that forms under the influence of a dominant direction of longshore sediment transport resulting in river discharge deflection (Fig. 1; Bhattacharya and Giosan, 2003). The asymmetric delta model predicts a laterally abrupt change in deposition facies. Heterogeneous river-dominated delta front and prodelta deposits are found downdrift of river input and homogenous wave-dominated shoreface deposits lie updrift. The updrift sandstones are hypothesized to form superior reservoirs compared to downdrift deposits due to higher textural maturity. Without lateral control, potential mixed-influenced deltaic reservoirs could be misclassified, resulting in poor estimation of reservior architecture (Fig. 2).

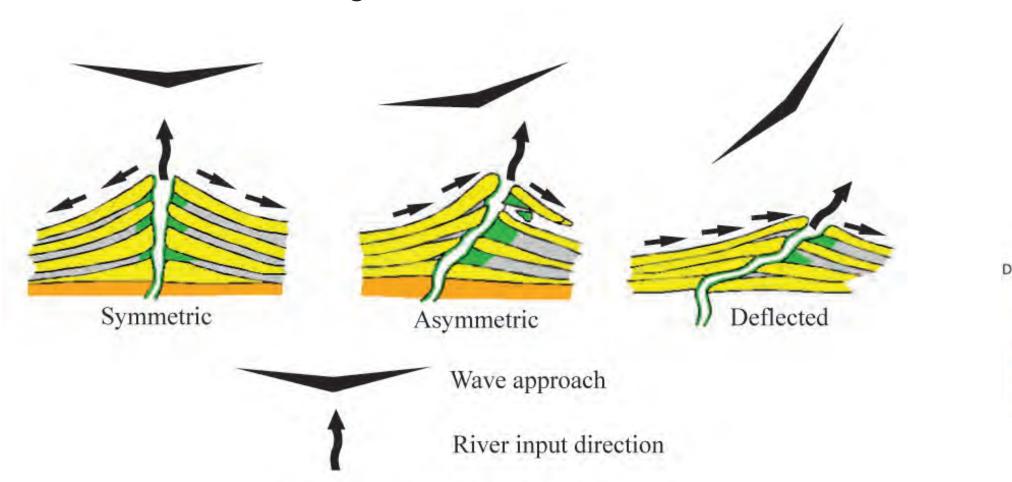


Figure 1. The relationship between wave approach direction, river input direction, and longshore current direction. Oblique wave approach results in deflection of river sediments downdrift of river input (modified from Bhattacharya and Giosan, 2003).

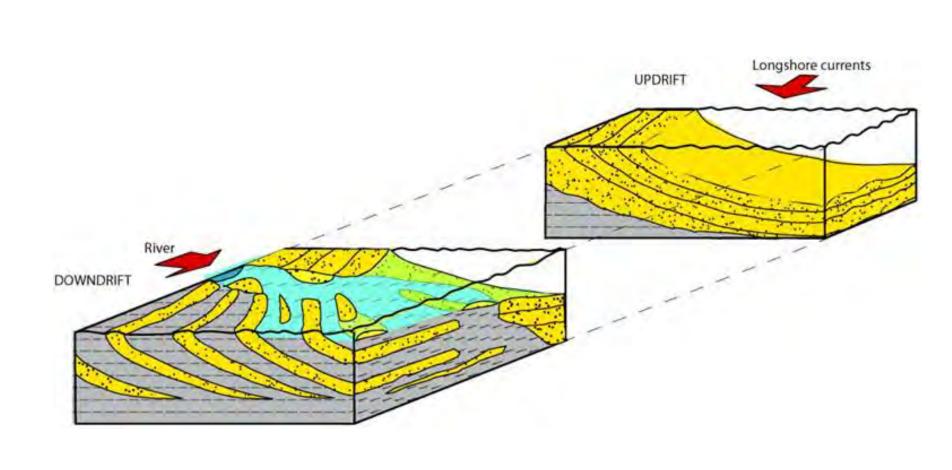


Figure 2. The lateral distribution of mud and sand expected in an asymmetric delta. Homogenous, wave-dominatead deposits updrift and heterogenous, river-dominated deposits downdrift (modified from Bhattacharya and Giosan, 2003).

Figure 4 (above). Lithostratigraphy of the Gallup Sandstone tongues within the

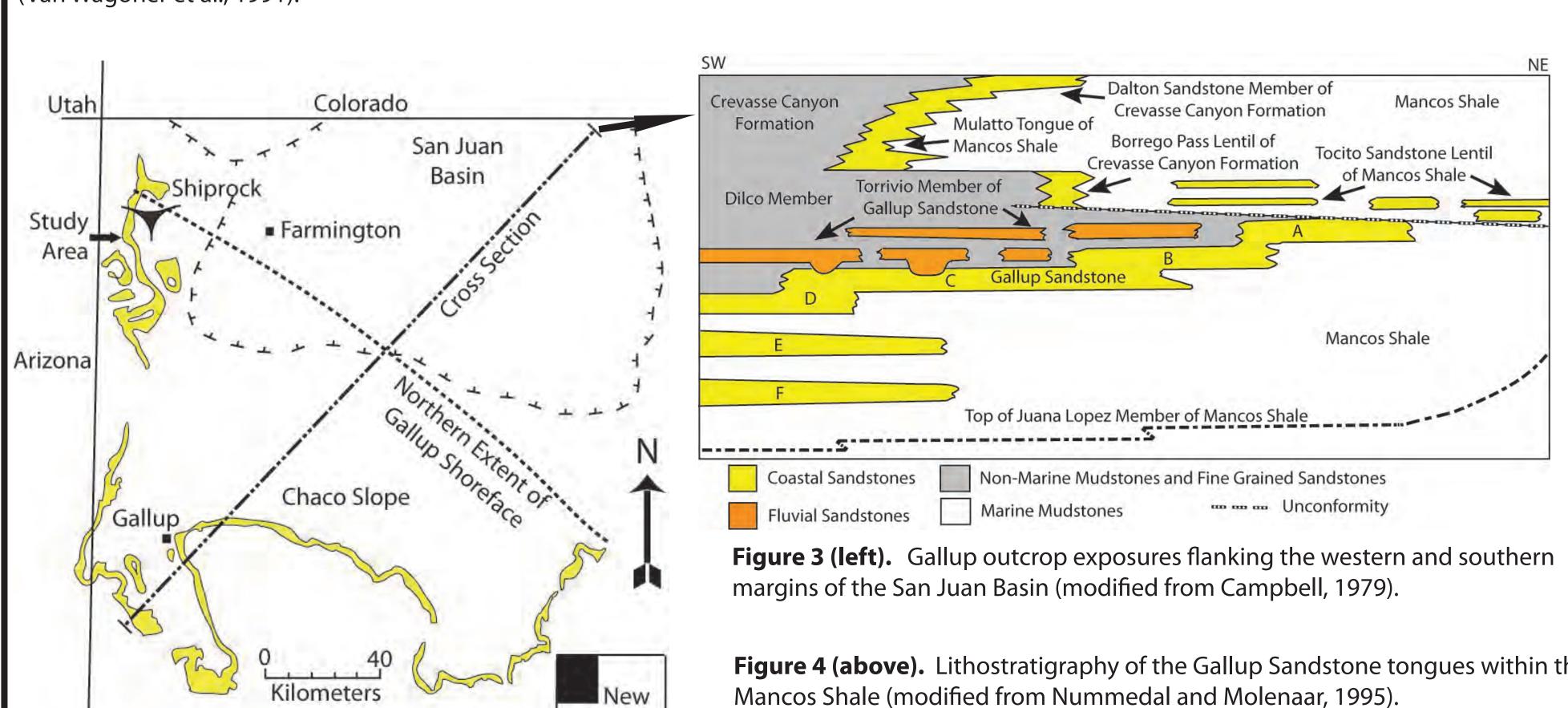
Mancos Shale (modified from Nummedal and Molenaar, 1995).

# 2. Geologic Setting

Outcrop of Gallup

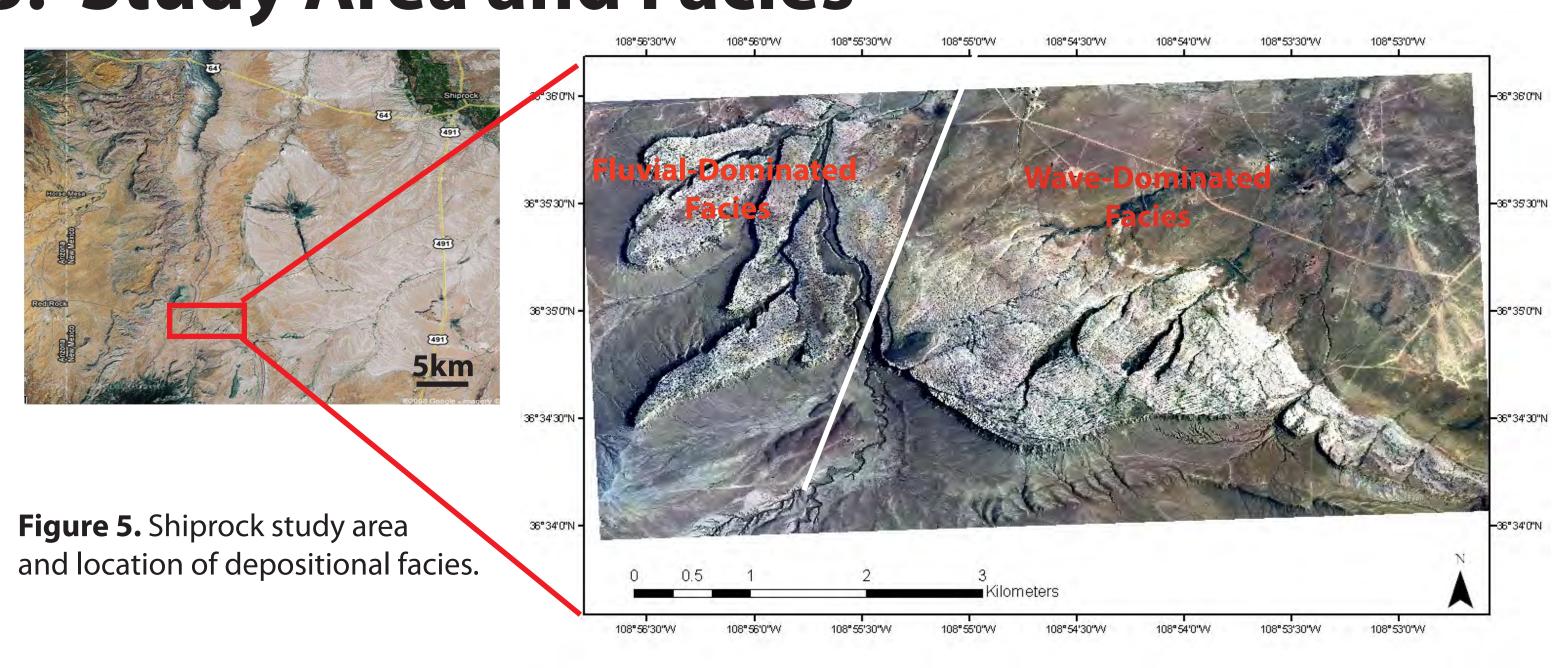
Border of Central San Juan Basin

The Gallup Sandstone was deposited on the western side of the Cretaceous Western Interior Seaway during the late Turonian (Fig. 3). The Gallup is a regressive deposit with a shoreline oriented NW-SE and prograded to the NE. Molenaar (1973) designated the Gallup into 6 tongues, F-A. The F tongue is the oldest and most proximal, and the A tongue is the youngest and most distal (Fig. 4). The focus of this research is on the A tongue (Van Wagoner et al., 1991).



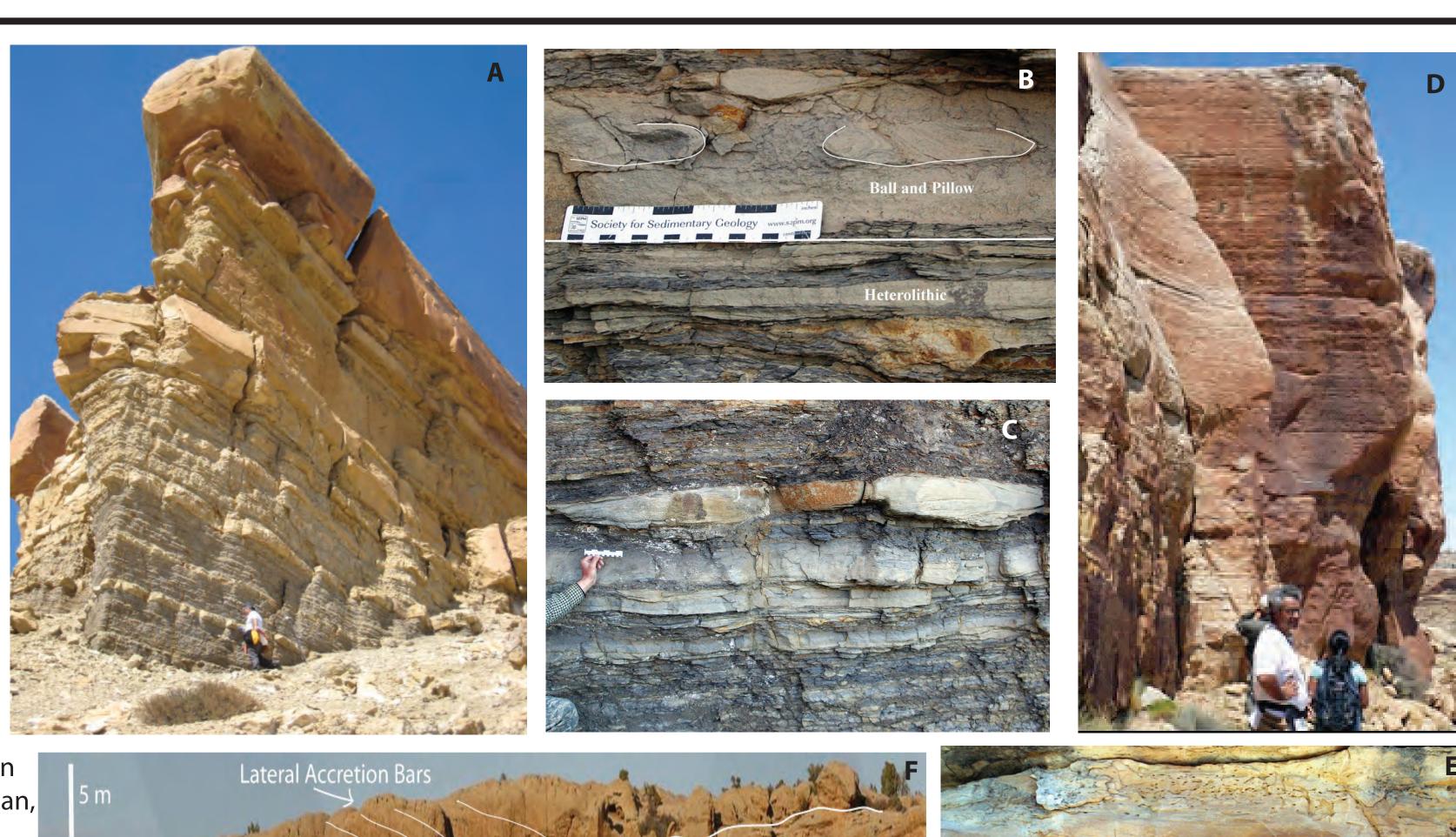
Mexico

## 3. Study Area and Facies



The Shiprock study location is located 35 km SW of the city of Shiprock, New Mexico (Fig. 5). This outcrop shows abrupt lateral changes in depositional facies. River-dominated delta deposits are found on the west side of the study area whereas wavedominated shoreface deposits are found on the east side of the study area. The west side deposits contain more interbedded mud than the east side deposits, terminal distributary channels, and soft sediment deformation features (Fig. 6A-C). The east side deposits are clean, homogenous sandstones with abundant bioturbation (Fig 6D-E). The fluvial Torrivio Member of the Gallup is present erosionally thoughout the west side of the study area (Fig. 6F).

Figure 6. Facies photographs of Gallup Sandstones near Shiprock. A) Heterolithic delta deposit on the west side of the study area. B) Interbedded sandstone and mudstone from the west side of the study area containing ball and pillow structures, lacks bioturbation. C) Hummocky cross-stratified sandstones interbedded with mudstones on the west side of the study area. D) Homogenous sandy shoreface on the east side of the study area. Trough cross-bedded upper shoreface sandstones transition into planar bedded swash zone sandstones. E) Clean, cross-bedded sandstone with abundant *Ophiomorpha* burrows from the east side of the study area. F) Fluvial Torrivio Member deposited erosionally in the Gallup delta front. Contains meter scale lateral accretion bars.



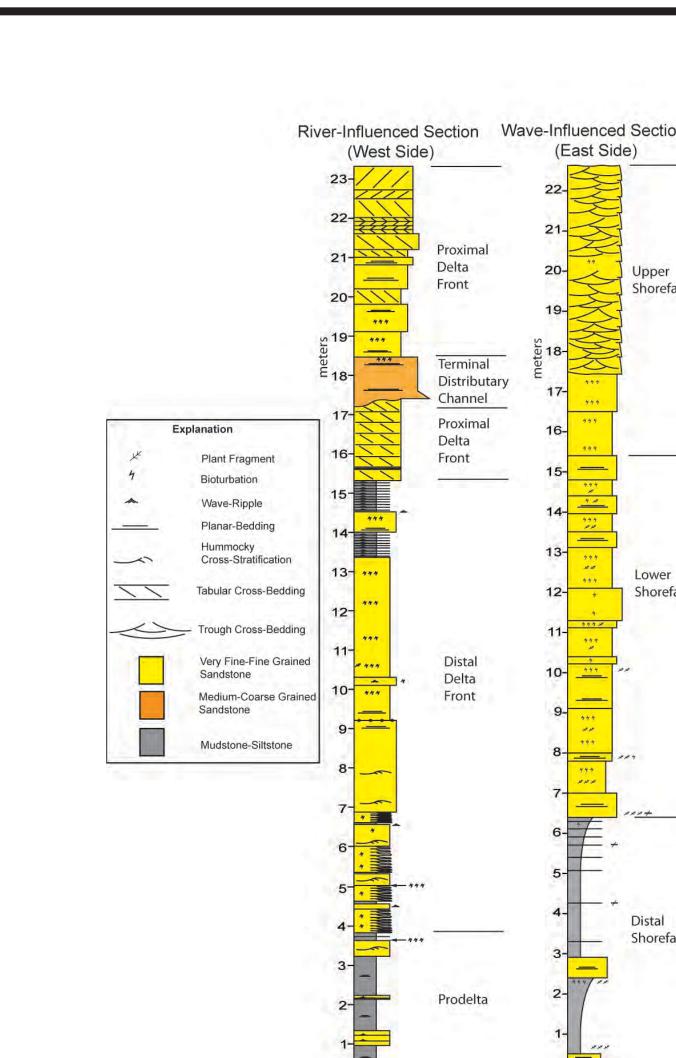


Figure 7. Comparison of measured sections from the east side and west side of the study area (LoParco in prep.).

### 4. Paleocurrent Data

Paleocurrent data were taken from the mesa top exposure sandstone of study area. In total, 871 measurements were taken. There are 786 trough cross-bedding measurements (Fig. 8A-D), 2 low angle swash zone measurements, 19 channel bar measurements (Fig. 8H), 27 channel cross-bedding measurements (Fig. 8G), 11 tidal inlet measurements (Fig. 8F), and 26 wave-ripple crest orientation measurements (Fig. 8E). 62% of the total trough cross-bedding measurements are to the SE and 38% are to the NW. Although there is a higher abundance of measurements to the SE, there is a significantly higher relative abundance of measurements to the NW in the study area than elsewhere in the Gallup (McCubbin, 1982). This is not what would be expected at this locality, considering the lateral position of depositional facies associated with the relationship of the shoreline orientation and wave approach direction. By using the shoreface trough cross-bedding direction as an estimation of shoreline orientation, the Gallup shoreline at this locality is NW-SE, 129-145 degrees (Fig. 9). The orientation of the wave-ripple crests is N NW-S SE, averaging 150 degrees which is oblique to shoreline orientation. Fluvial paleocurrents from the Torrivio are to the NE which is the direction of progradation (Fig. 10).

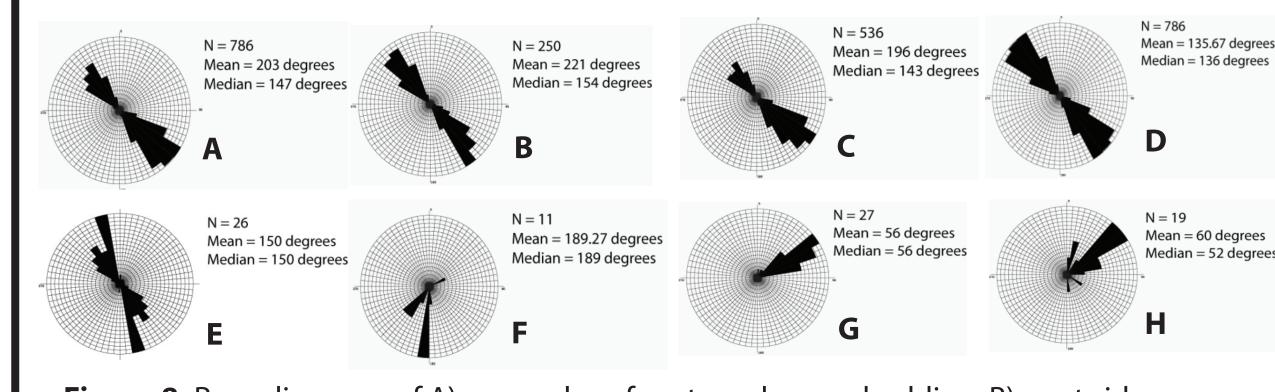


Figure 8. Rose diagrams of A) upper shoreface trough cross-bedding, B) west side upper shoreface trough cross-bedding, C) east side upper shoreface trough cross-bedding, D) normalized upper shoreface trough cross-bedding plotted as planes, E) wave-ripple crest orientation, F) tidal channel cross-bedding, G) Torrivio fluvial trough cross-bedding, H) Torrivio fluvial lateral accretion bar strike direction.

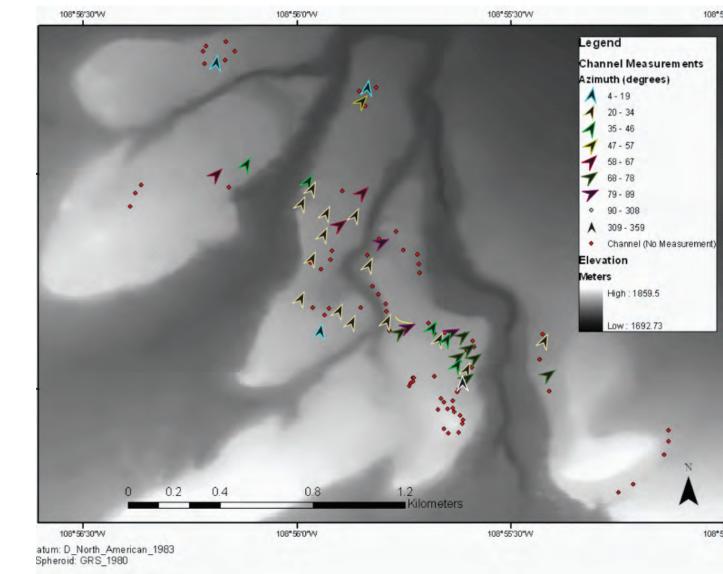
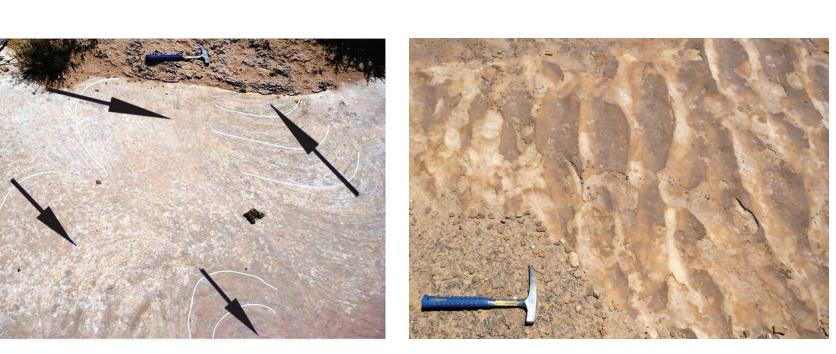


Figure 10 (left). Map of Torrivio exposure and associated paleocurrent measurements

> Figure 11 (right). A) Bedding plane view of trough cross-bedding of the upper shoreface. Most measurements taken of these exposures on mesa tops. B) Wave-ripple crests.

# Measurement Location

Figure 9. Approximate shoreline orientation by upper shoreface trough cross-bedding dip direction.



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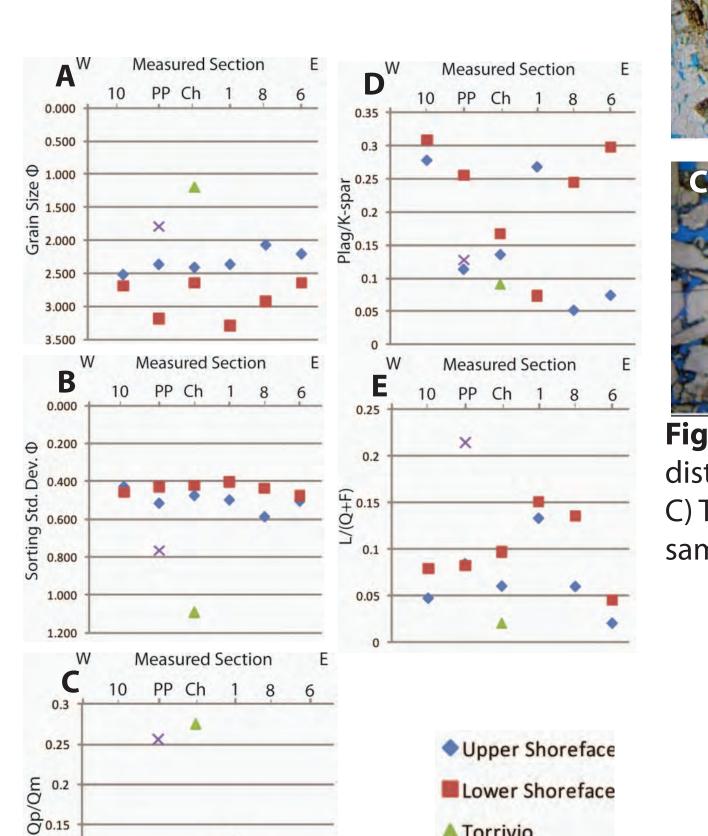
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# 5. Petrography



**Figure 12.** Trends of A) grain size, B) sorting, C) polycrystalline relative to monocrystalline quartz, D) plagioclase relative to K-feldspar, E) lithics relative to quartz and feldspar.

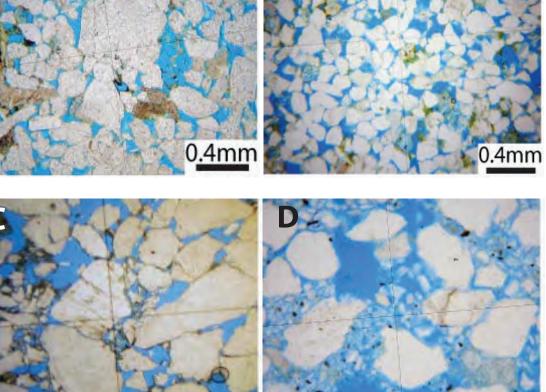
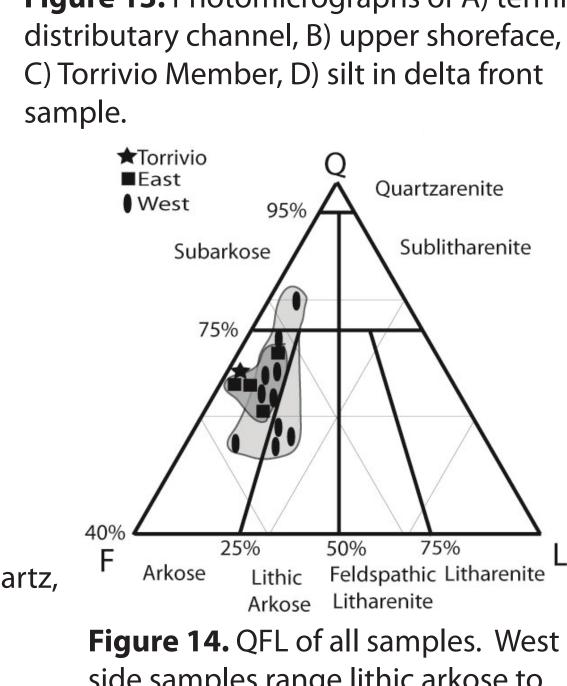
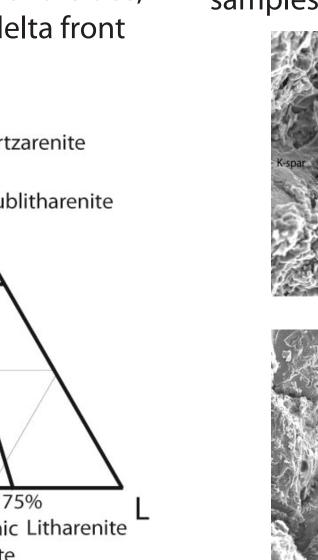


Figure 13. Photomicrographs of A) terminal C) Torrivio Member, D) silt in delta front



side samples range lithic arkose to arkose whereas east side samples

Sorting and grain size values show no distinct trend from east to west (Fig. 12A-B). However, silt content which was not included in the grain size analysis is higher in the west side samples (Fig. 13D). Terminal distributary channel and Torrivio samples are significantly coarser and more poorly sorted than the delta front and shoreface samples (Fig. 13A-C). Higher relative abundances of polycrystalline quartz, sedimentary rock fragments, and plagioclase are found in the delta sandstones on the west side of the study area (Fig. 12C-E). Clay minerals were analyzed by SEM. West side samples contain irregular, structureless occurences of illite, whereas authigenic kaolinite is more common in east side samples (Fig 15). Porosity values are similar due to compaction, but east side samples have minus-cement porosity ranging 11-13% and west side samples range 8-10%.



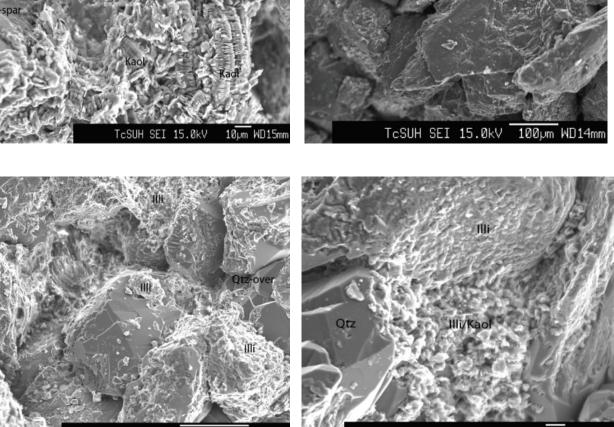


Figure 15. SEM images of A) authigenic kaolinite (east), B) clean grains lacking mud (east), C) detrital illite (west), D) detrital illite with minor authigenic kaolinite (west).

# 6. Conclusions

-The Gallup Sandstone near Shiprock, New Mexico has an abrupt lateral change from wave-dominated deposits in the east to river-dominated deposits to the west.

-Trough cross-bedding direction and wave-ripple crest orientation suggests wave approach was oblique to the shoreline. However, there is a higher abundance of measurements to the SE than NW, which is the opposite of what was expected. -Textural petrographic trends are not distinct; this may be the result of significant sediment mixing. The relatively higher abundance of less resistant grains and detrital mud in the delta deposits on the west side suggests a lesser degree of reworking than the shoreface deposits on the east side (Mack and Suttner, 1977).

-Sediment mixing, the lack of significant trends in the petrography, and the paleocurrent data abundances contradicting facies locations, as would be predicted by the asymmetric delta model, suggests this is a weakly asymmetric delta rather than an end member example.