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Soft-Sediment Structures

Microscale (mms-cms)

Zones of Abundant Microstructures (ZAMs)

A zone of abundant microstructures (ZAM) is a body of rock that contains up to four types of soft-sediment deformation features: 1) normal microfaults (NMF), 2) microboudins (MB), 3) reverse microfaults (RMF), and 4) microfolds (MF). Faults die out vertically within beds or sole into a hemipelagic layer. NMFs are generally listric. Fault length is limited by bed thickness (generally < 10 cm). Fold amplitudes are generally less than 1 cm.

NMF and MB are usually overprinted by MF and/or RMF. This suggests that the slump was overprinted by contractional features when the downslope end of the body came to rest before the upslope end (Farrell, 1984).

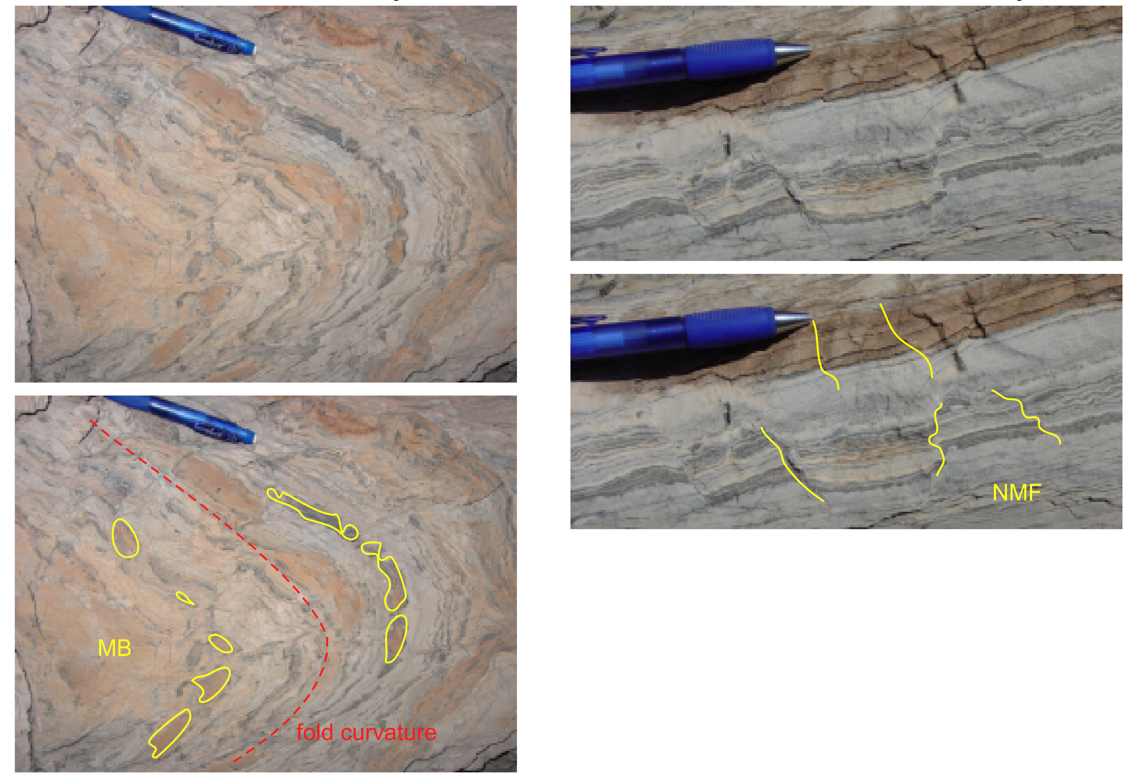
ZAMs are bounded on the top and bottom by truncation surfaces (TS) and may contain internal truncation surfaces as well. The vertical distance between bounding TS is no more than a few meters (the thickest ZAM observed is 6.5 m in height).

ZAMs appear locally within Unit 7 and comprise most of the observed portion of Unit 9 in the Delaware Mountains. Bounding TS in Unit 9 are generally planar and have a shallow dip or are horizontal. Bounding TS within Unit 7 are often deformed themselves and may be part of larger mesoscopic folds or complex deformation zones (CDZ) that contain rocks without ZAMs. These relationships, and the relative thinness of Unit 9 and other ZAMs, suggest that: 1) ZAMs in Unit 7 were later transported piggyback style within larger slump bodies, and 2) Unit 9 represents a slump (or package of slumps) that was not later transported.

Contractional Overprint of Extensional Microstructures

Folded Microboudins (MB)
Location: Black Canyon

Folded Normal Microfaults (NMF)
Location: Dance Hall Canyon



Mesoscale (ms)

Complex Deformation Zones (CDZs)

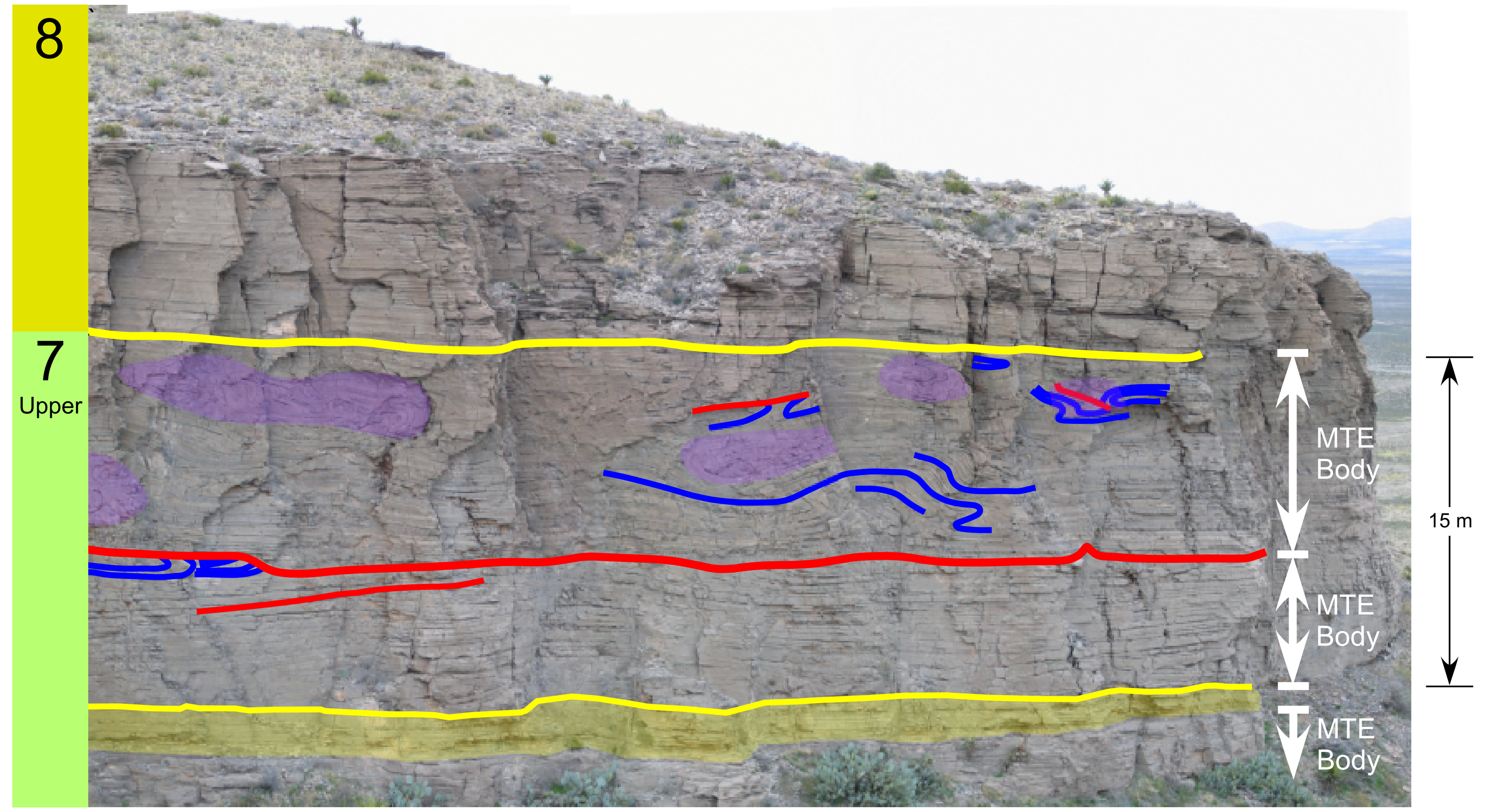
Complex deformation zones are local 3D regions within a slump body that are 1) characterized by a set of fold segments that have axial surfaces with similar strikes and differing dips, and 2) roughly cylindrical in shape with the long axis generally horizontal. They occur within Units 7 and 8.

Field evidence suggests that CDZs are concentrated within locally thicker zones within an MTE body and may indicate a soft-sediment "pile-up."

Two Views of a Complex Deformation Zone (CDZ)
That Contains a ZAM Block
Looking north and south from canyon cut
Location: Rolling Rock Canyon

Looking north — Looking south

CDZs and Other Structural Features Within MTE Bodies
Location: Side canyon on south side of Rock Art Canyon, facing west



- Unit boundary
- Internal truncation surface
- Selected bedding surface showing soft-sediment fold structure
- CDZ, trend is east-west (out of the plane of the photograph)
- Drape interval

Structural Trends

The orientation of fold axes in an MTE body may be an indicator of transport direction (roughly perpendicular to the fold axis), although there may be local variation within the body, and fold axes may rotate from the transport direction at body margins (Hansen, 1971). Lineations resulting from the intersection of normal microfaults and microfolds with bedding planes may also indicate transport direction at the times that extension and contraction were taking place, respectively.

· Fold axis orientations in the Cutoff Formation show variation by location and by correlation unit.

· The primary trend is N-S with a secondary trend of ENE-WSW. These two trends may represent: 1) differences in transport vectors among separate MTE bodies, or 2) deflection by underlying topography.

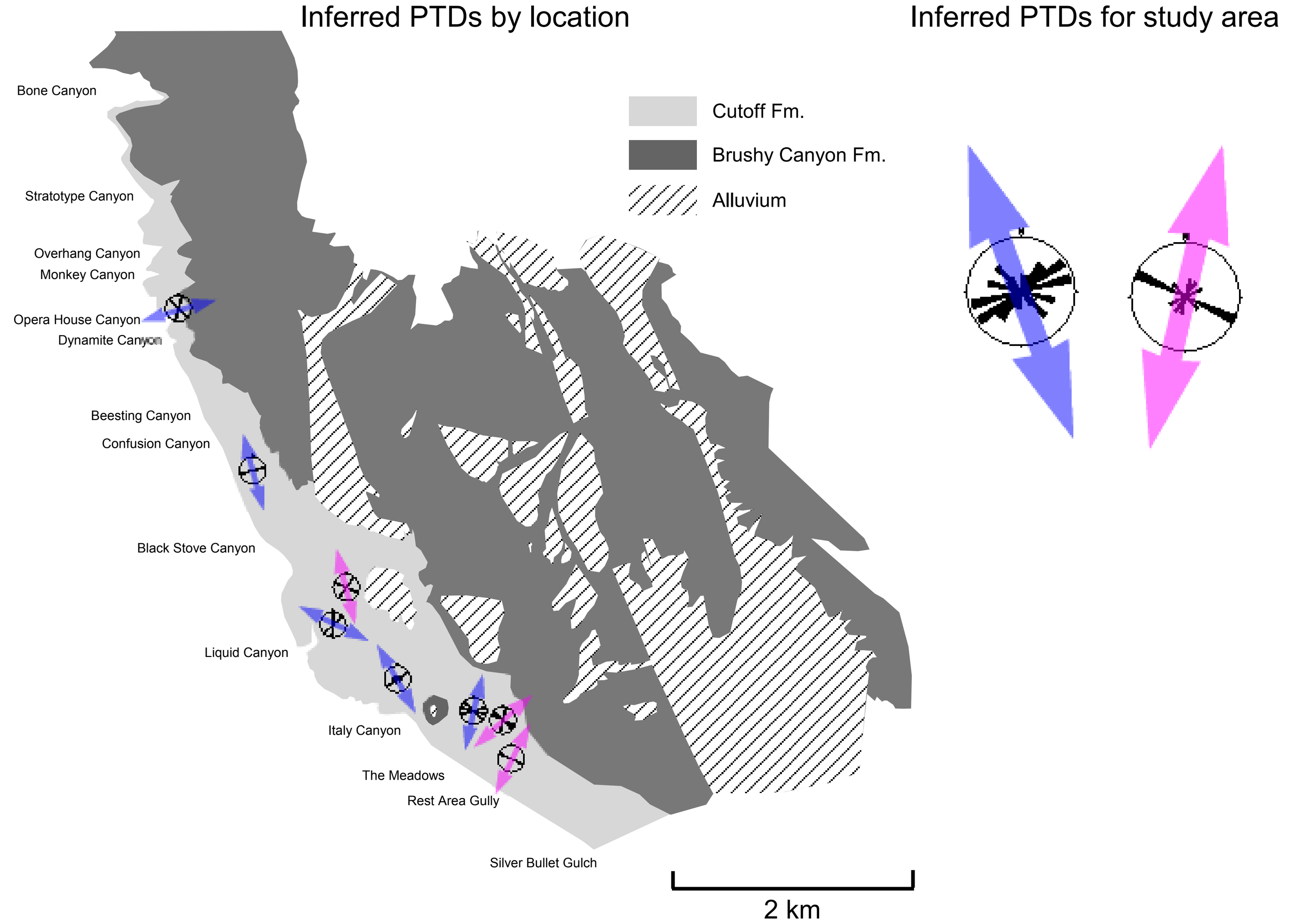
· Fold asymmetry may indicate the transport direction; however, relatively few measurable asymmetric folds were observed. The primary inferred direction from these folds is north to south, although some folds indicate the reverse.

· Unit 6 is excluded from this analysis as its nature in the Delaware Mountains is unclear.

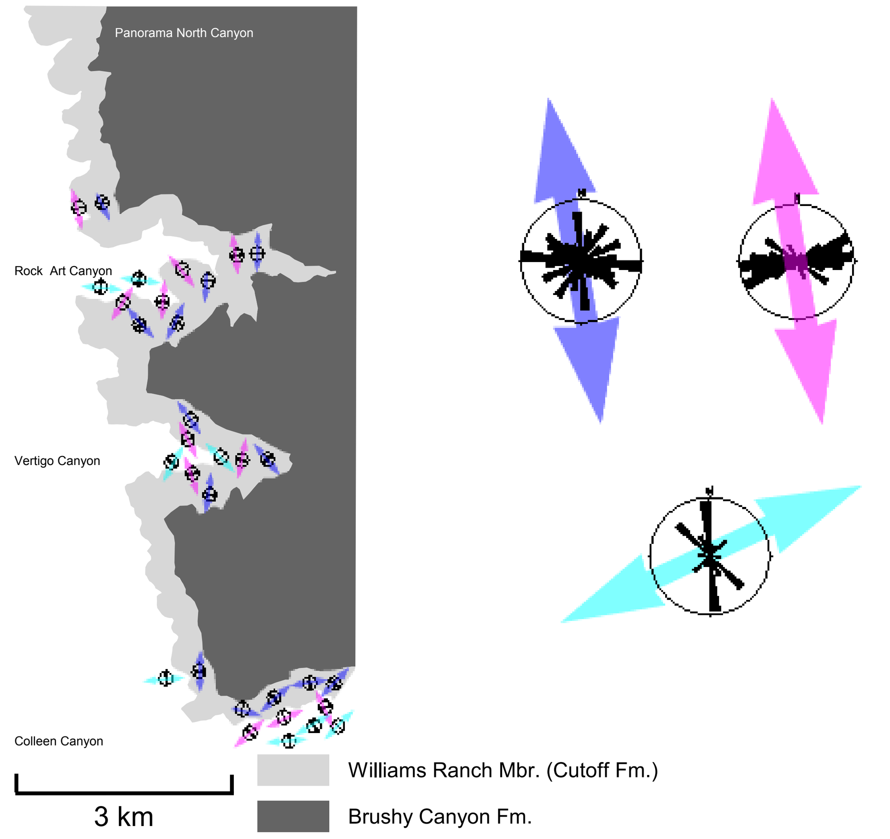
Paleo-Transport Directions (PTD), Williams Ranch Member (Excluding Correlation Unit 6) as Suggested by Fold Axis and Lineation Trends

Dark blue arrows: Average PTD based on fold axes
Violet arrows: Average PTD based on contractional lineations
Light blue arrows: Average PTD based on extensional lineations

Guadalupe Mountains Study Area

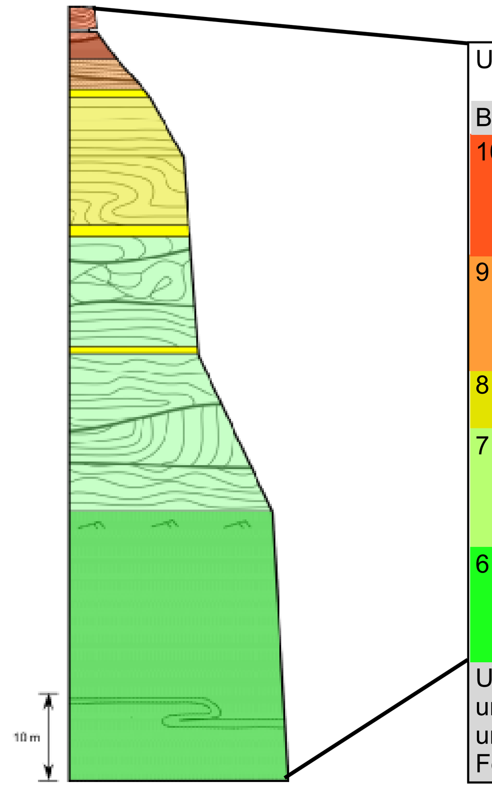


Delaware Mountains Study Area

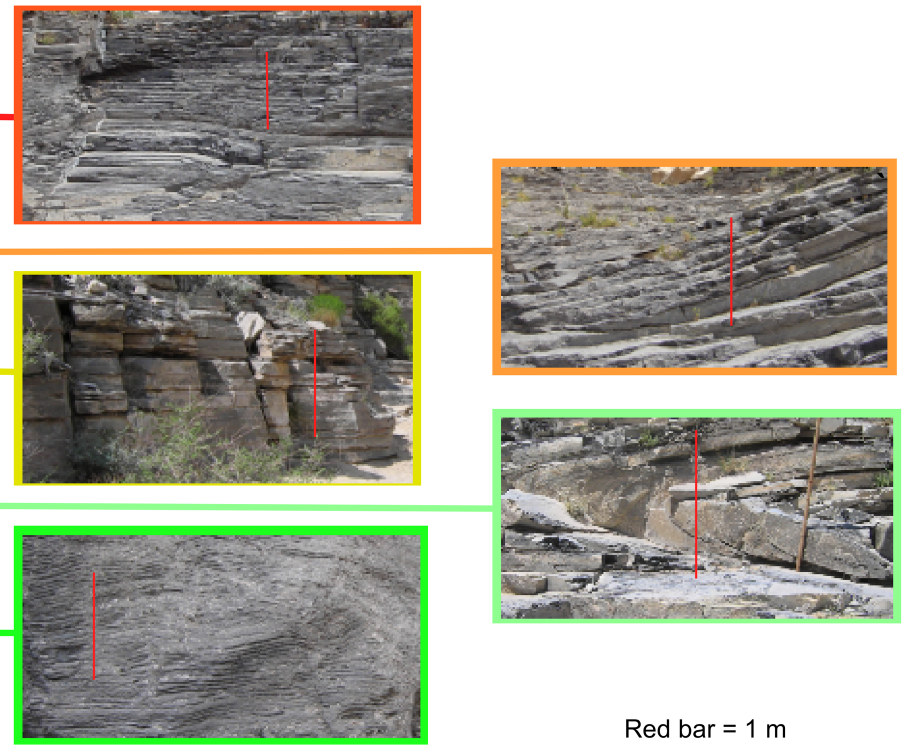


Correlation Units, Williams Ranch Member, Delaware Mountains Study Area

At left: Generalized stratigraphic column based on thicknesses at head of Rock Art Canyon. Yellow lines represent drapes (undeformed turbidites)
At center: Lithologic and structural comparison of units
At right: Representative photographs of units



Unit	Weathered Appearance	Mesostructures	Microstructures	Upper Boundary	Rhythmic Bedding	Relative Abundance of Carbonate Grains
Brushy Canyon Fm.						
10	Dark gray-brown, upper portion is locally resistant	Isoclinal recumbent folds in upper section, none in lower section	Tension gashes and normal faults in upper section, none in lower section	Submarine disconformity with chert nodules and ammonoids	< 1 cm, 2–10 cm in upper 1 m	Very low
9	Medium gray with local rusty zones	Isolated folds	ZAMs pervasive throughout unit	Graded turbidite/lenses of angular clasts in deformed matrix and/or truncation surface	2–10 cm	Low
8	Dark gray-brown with polygonal cliff faces	Highly deformed locally, but planar elsewhere	Local ZAMs at top of unit	Drape or truncation surface	2–10 cm	Low
7	Medium gray-blue with local rusty zones	Highly deformed: gentle upright to isoclinal recumbent folds, faults, CDZs	Isolated ZAMs	Drape or truncation surface	2–10 cm	High
6	Medium gray-blue with local rusty zones	Isolated gentle to isoclinal folds, less than 1 m in height	Undulating bedding planes throughout with wavy lineations near top of unit	Truncation surface	1–2 cm	Very low with rare, isolated, thin packstone layers
Undifferentiated underlying correlation units of the Cutoff Formation						



Red bar = 1 m

ZAM = Zone of abundant microstructures
CDZ = Complex deformation zone