Depositional Conditions Associated with Bank-attached Separation Bars, Brushy Canyon Formation*

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Abstract

The Brushy Canyon Formation, a predominantly fine-grained turbidite system, was deposited on the slope and basin floor of the late Paleozoic Delaware Basin. Our project focuses on resolving intra-channel sediment sorting within upper-slope channel deposits, and comparing these deposits to channel fills on the proximal basin floor.

The depositional facies on the upper slope fall into two broad classes: A) open-channel facies associated with bypass of sediment to deeper water; and B) channel-filling facies associated with bed aggradation and significant loss of channel relief. Deposits accumulating during bypass are interpreted to be eddy bars located in bank-attached zones of flow separation. These deposits are characterized by packages of steeply inclined beds composed of planar-stratified, trough cross-stratified or sub- to super-critically climbing rippled deposits, with abundant mud drapes (D50=110µm). The channel-filling deposits form thick-bedded, sometimes gravel-rich, sandstone bodies which are structureless or which possess stratification associated with migrating dunes and intra-channel barforms (D50=156µm). On the proximal basin floor, the channel-filling sandstones (D50=110µm) are dominated by stratification associated with trains of dunes climbing at sub- to super-critical angles, indicating high rates of deposition from suspension.

Grain-size analyses show that particles in the 200-400µm range are common in the channel-filling deposits of upper-slope channels, but are poorly represented in the upper-slope eddy bars and the channel fills on the proximal basin floor. The eddy bars and basin-floor channel fills primarily consist of particles finer than 200µm, which we interpret as the size fraction that was fully-suspended on the upper slope. This size fraction dominates the eddy-bar deposits because only fully suspended particles can be advected into the bank-attached zones of flow separation in significant volumes. We will synthesize depositional styles and grain-size data in order to:

1) produce a facies model for thick bank-attached bar deposits built in zones of flow separation associated with planform irregularity in submarine channels, 2) estimate flow velocities and current thicknesses; and 3) assess sediment sorting and storage between channels on the upper slope and the proximal basin floor.

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Turbidity currents in submarine channel bends

T1

FLOW

T2

FLOW

T3
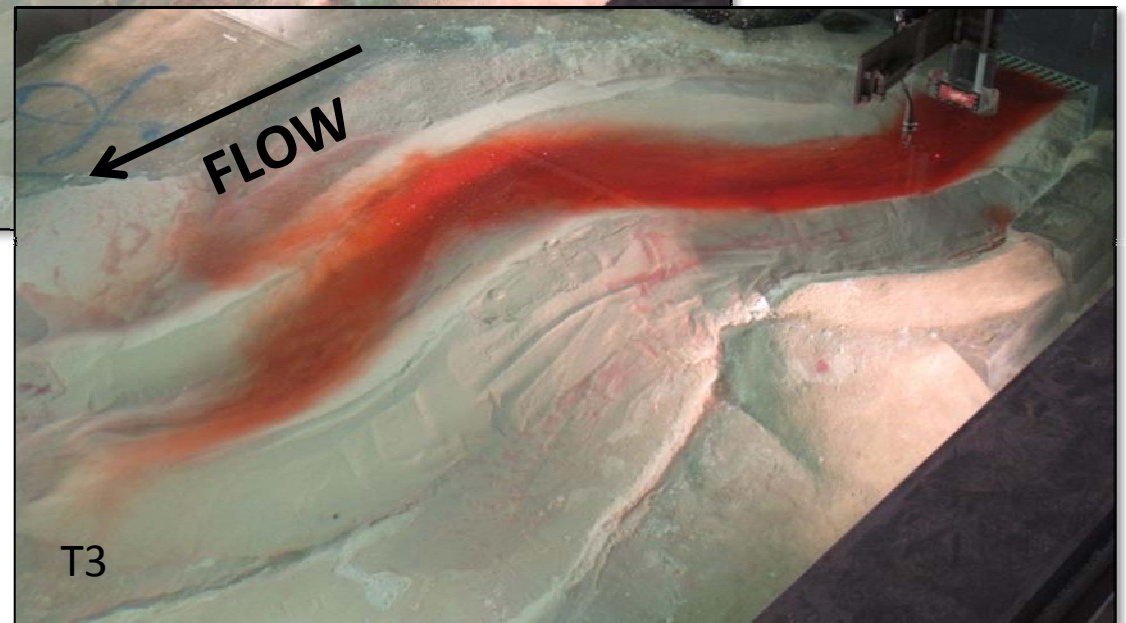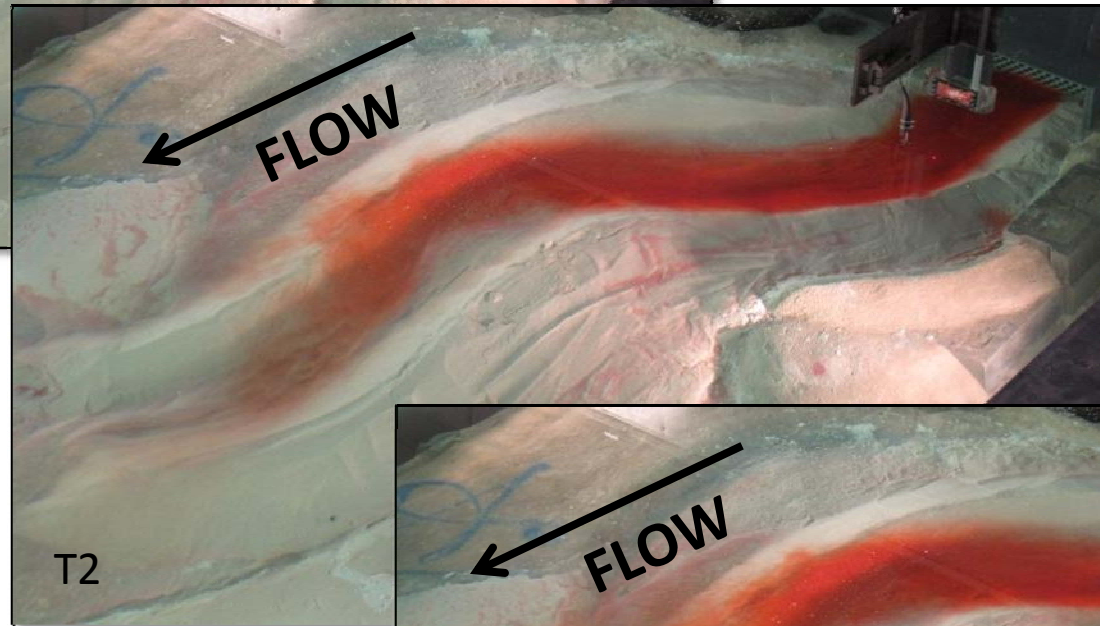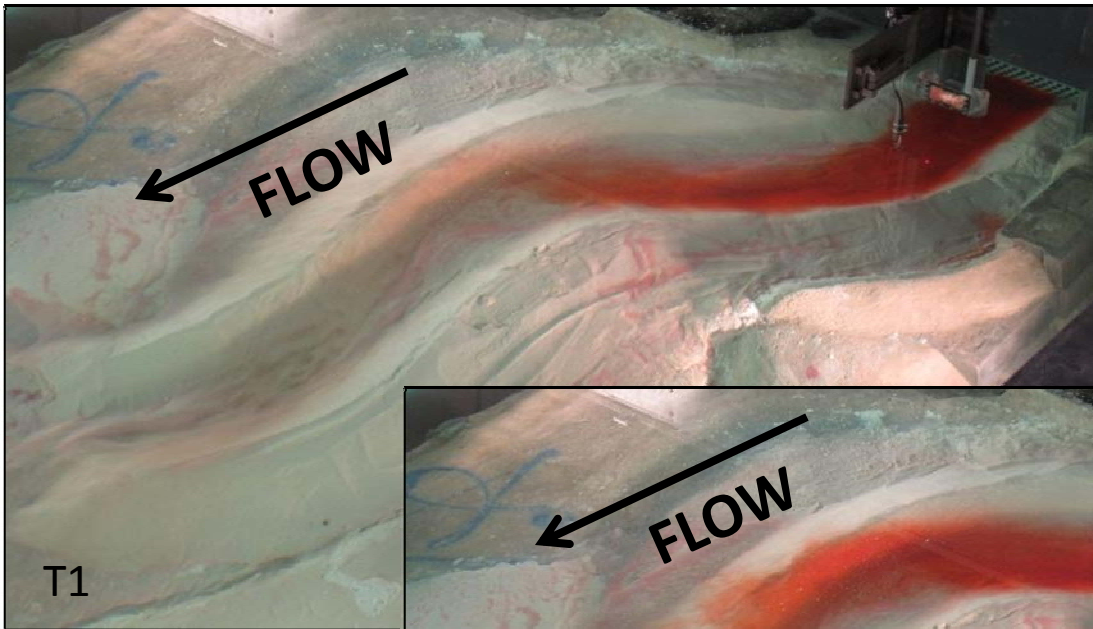
FLOW

Run-up at the outer banks of bends contributes to extreme flow separation from the inner banks

Flow separation at channel bends

Pure bedload is restricted to the path of the high-velocity core
Only suspended sediment enters the low velocity zone
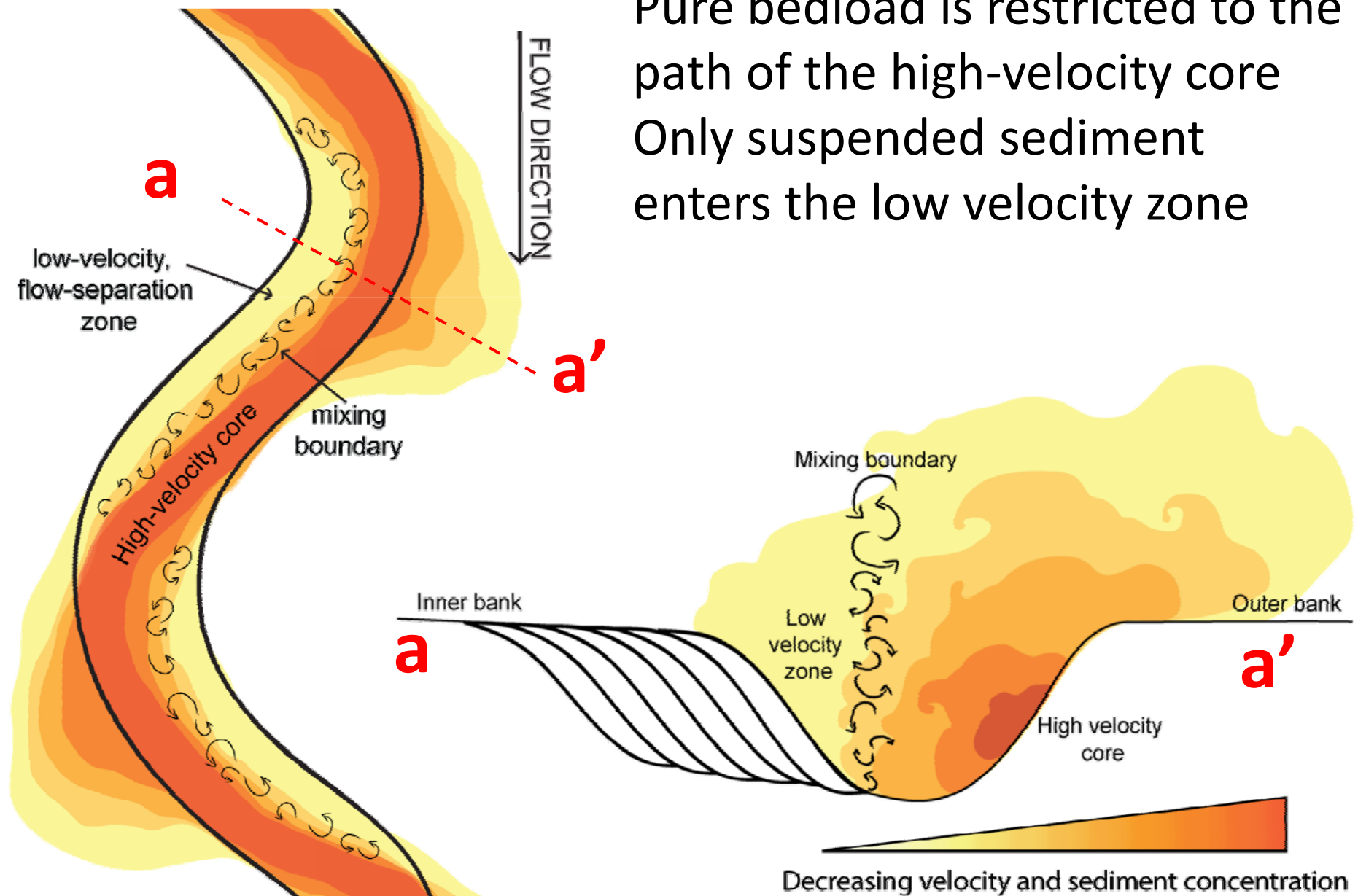
3-D geometries to processes of bar construction

Sinuous slope channel, Oligocene continental slope, Angola

A'

A

BARS   CHANNEL

40m

300m

A

A'
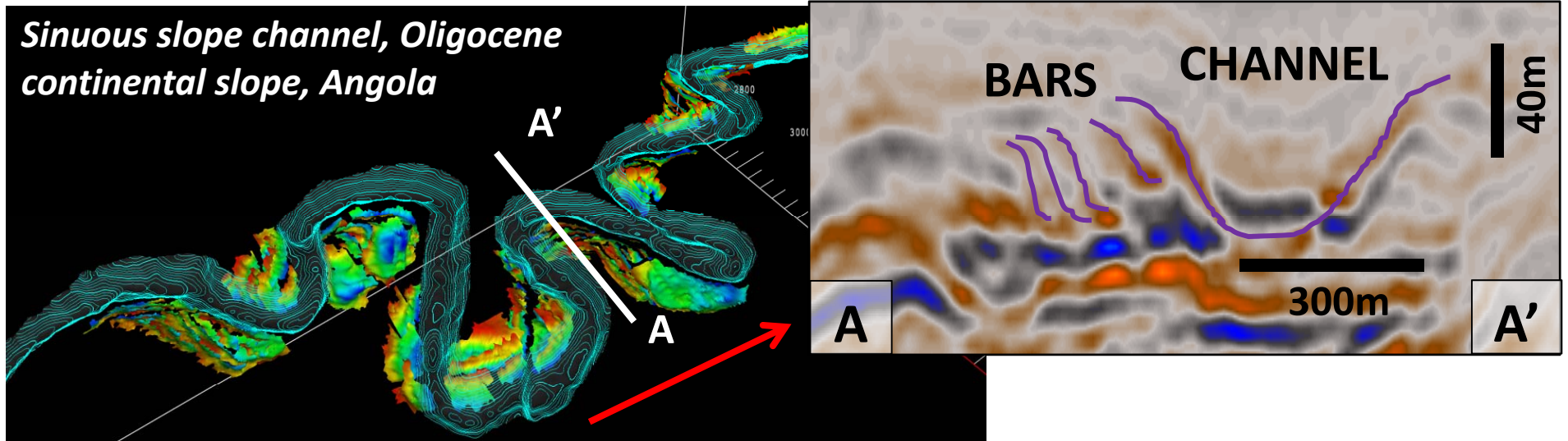
- Constructed in inferred flow separation zones

- Median slopes = 10°

- Narrow relative width

- Associated with weak incision (20-40% depth)

Mixing boundary

Inner bank

Low velocity zone

Outer bank

High velocity core

Decreasing velocity and sediment concentration
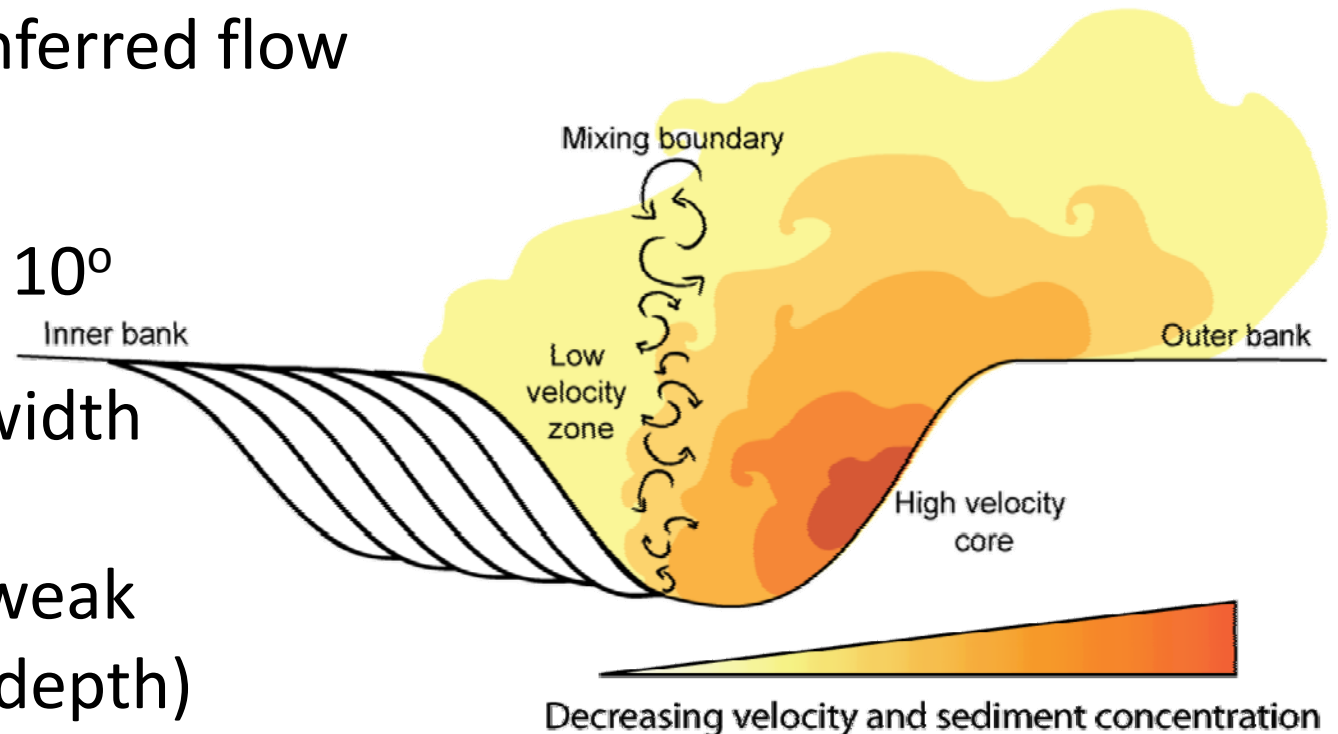
Concave Benches

- Pure suspension deposition in separation zones
  (Woodyer, 1975; Hickin, 1979; Smith et al., 2009)
- Hitherto under-recognized in submarine channels
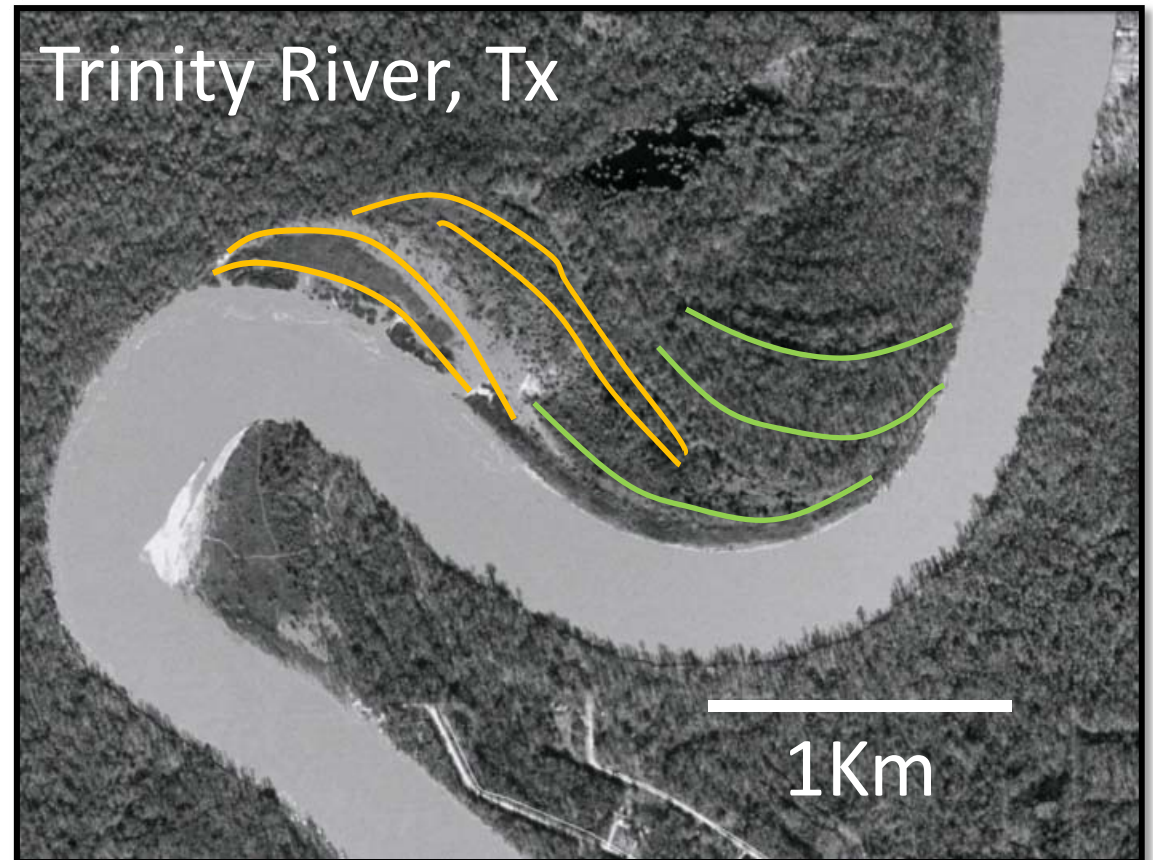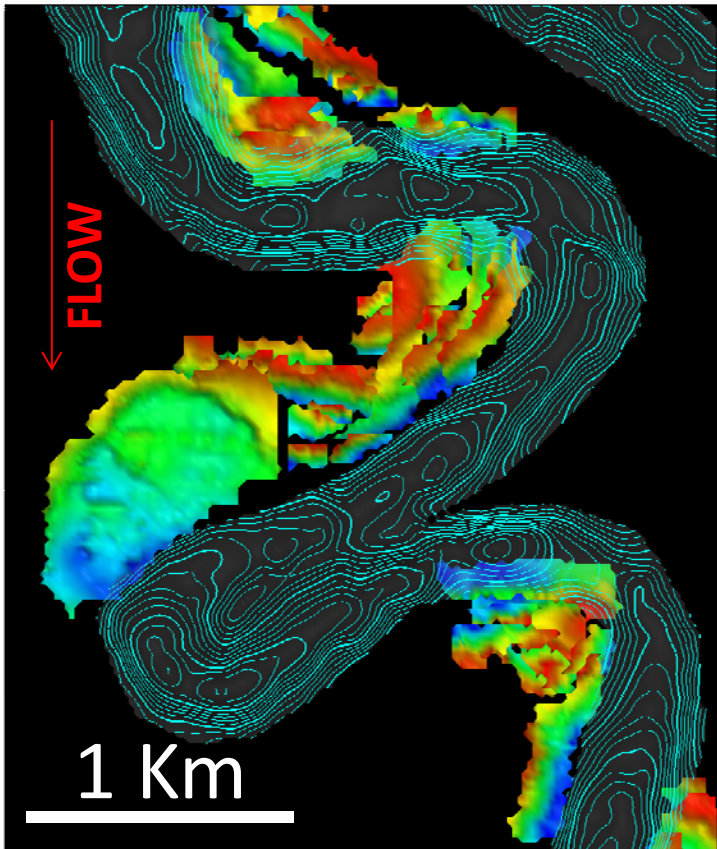
Upper slope channels in the Brushy Canyon Fm.
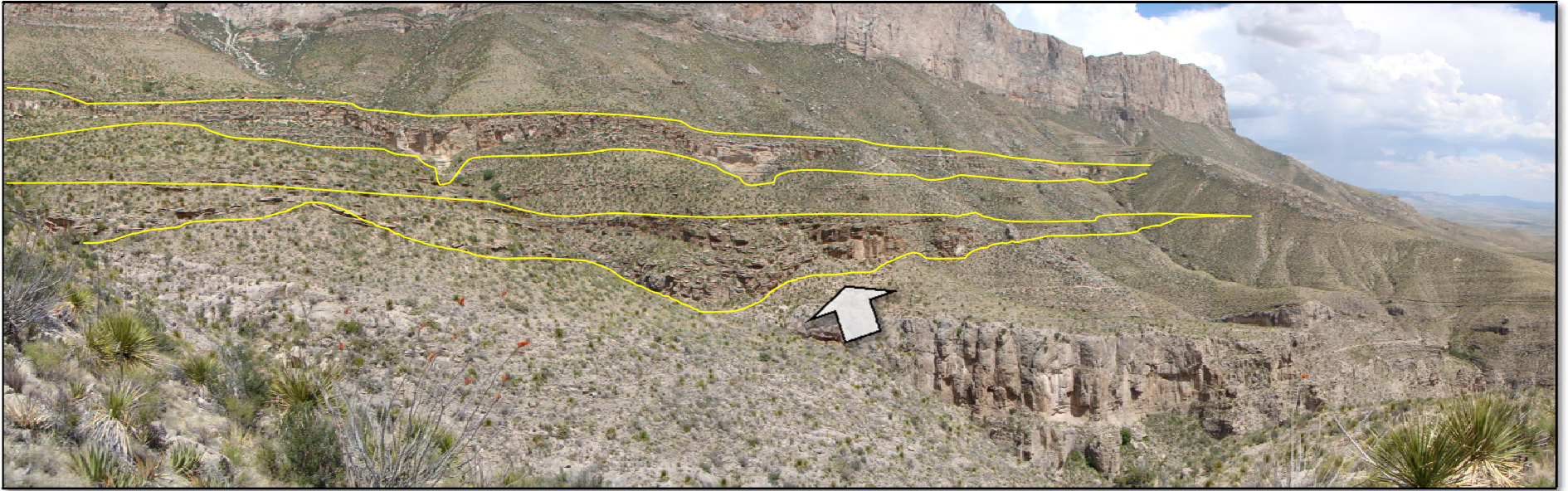
Thick submarine slope channel fills exposed in dip-oblique section, in Shumard Canyon in the Guadalupe Mountains

Study locations on slope and basin floor

Modified from Beaubouef et al., (1999)

Presented data from two locations
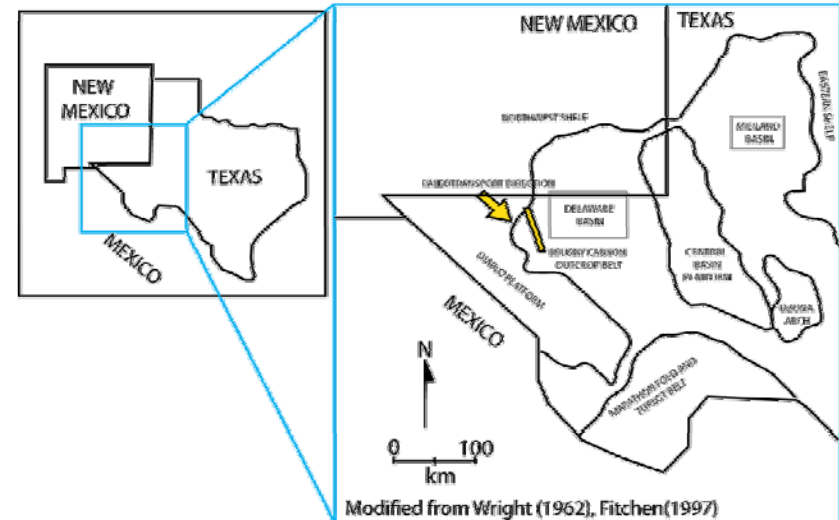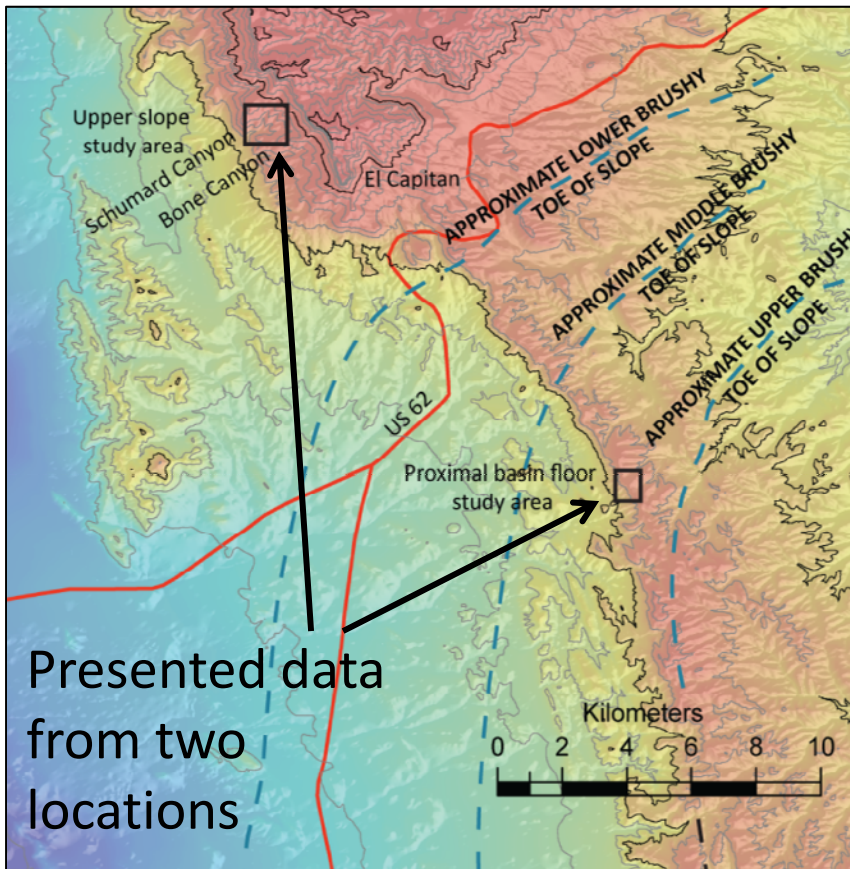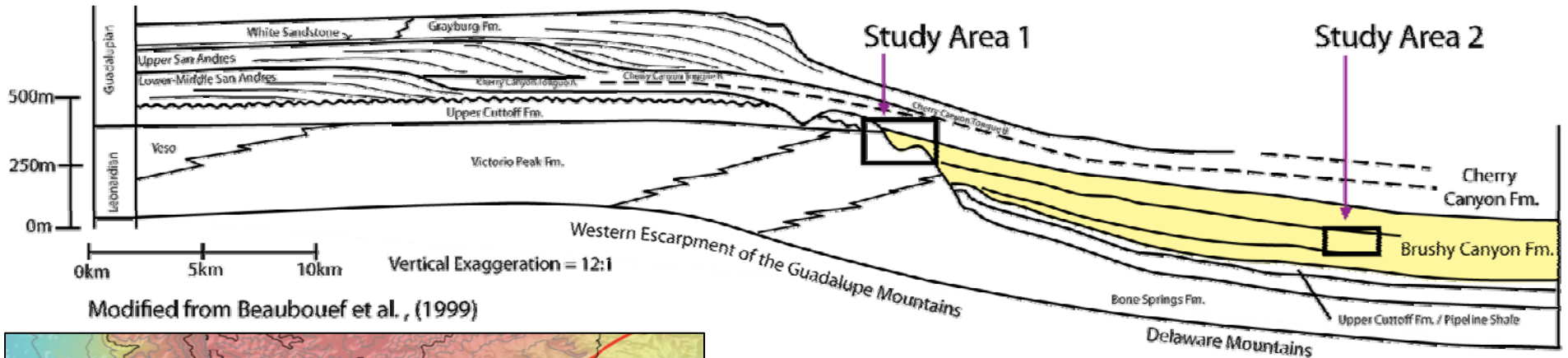
Clastic sediments deposited on a carbonate margin during low sea level and sub-aerial exposure of carbonate shelf

Deposit styles

1. **Channel filling deposits:** Thickly-bedded, relatively coarse, bedload filling in topography

2. **A bank-attached bar:** Finer grained sediment settling from suspension in low-velocity zones along channel margins, while channel relief is maintained
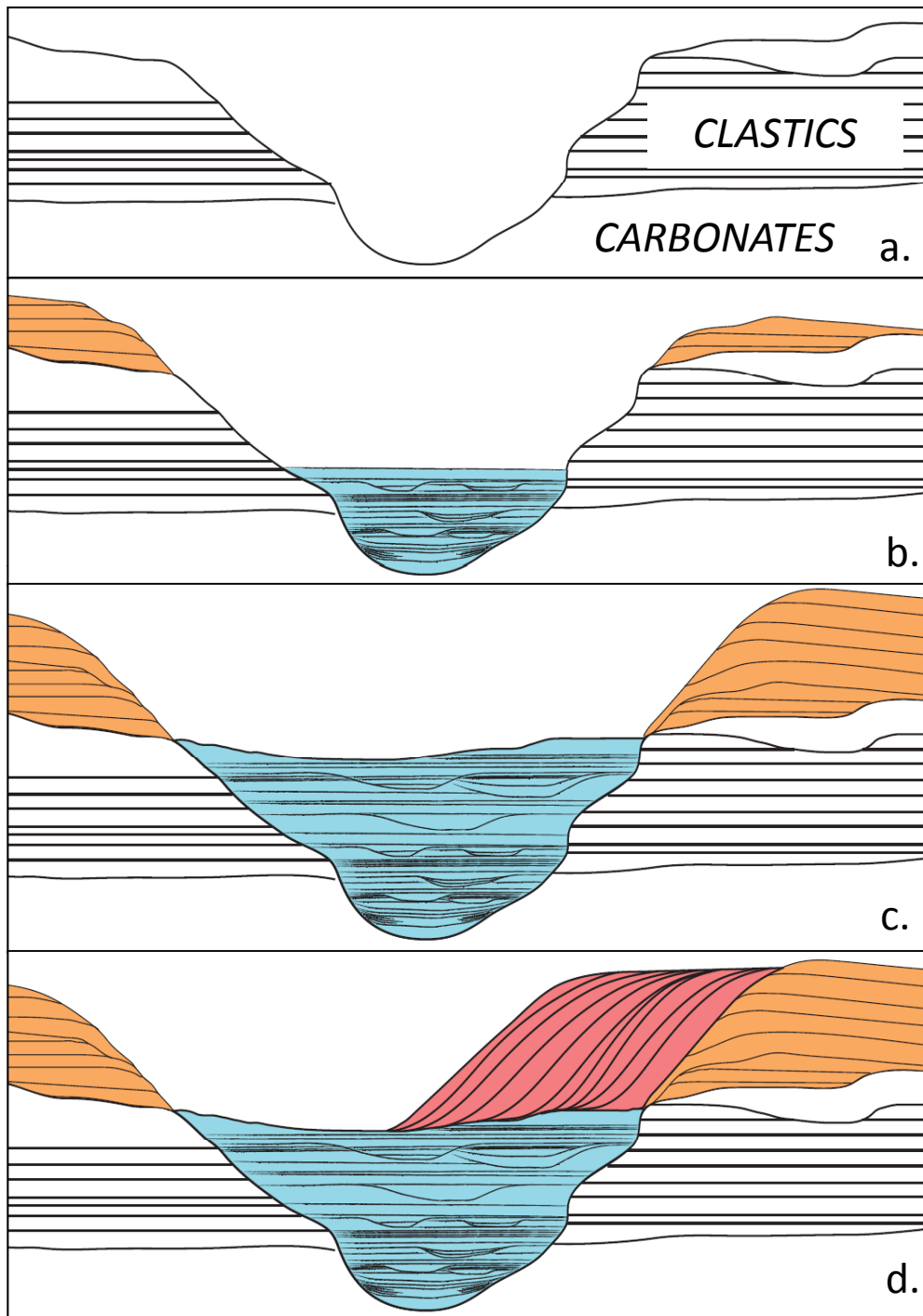
Deposit styles
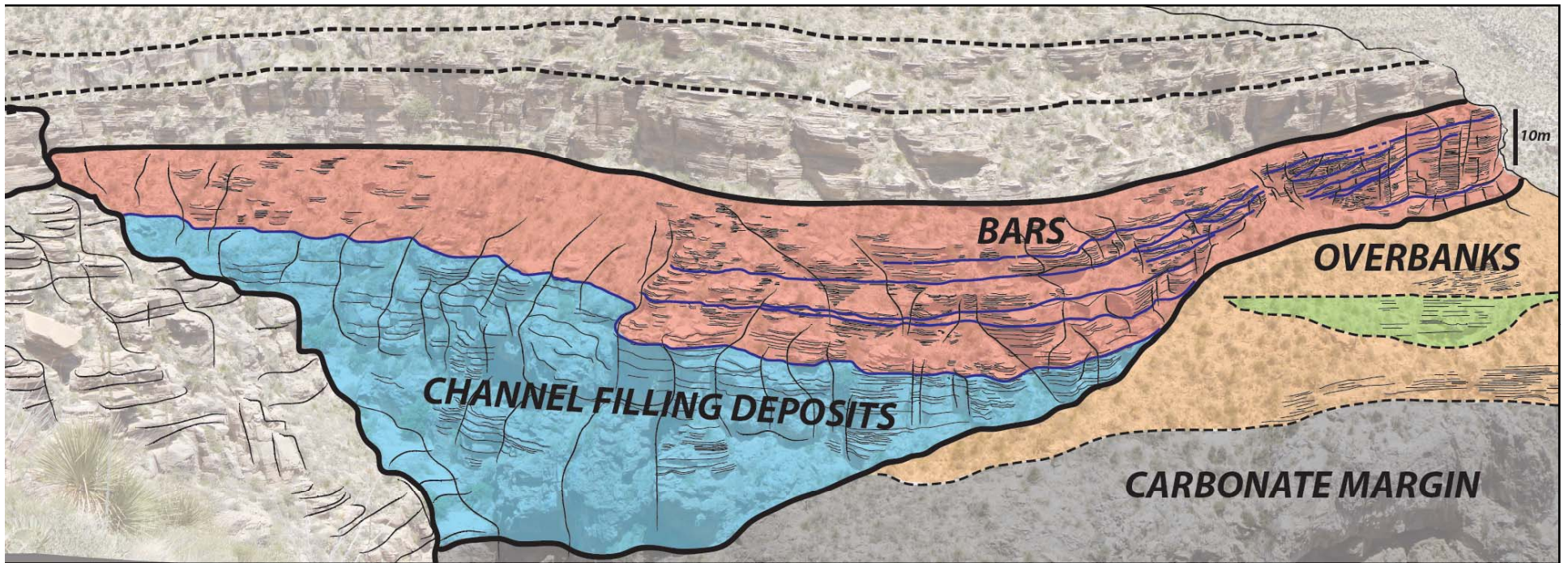
1. **Channel filling deposits:** Thickly-bedded, relatively coarse, bedload filling in topography

2. **A bank-attached bar:** Finer grained sediment settling from suspension in low-velocity zones along channel margins, while channel relief is maintained

CLASTICS

CARBONATES a.

Interpreted stages of studied channel fill

CLASTICS

CARBONATES

a.

b.

c.
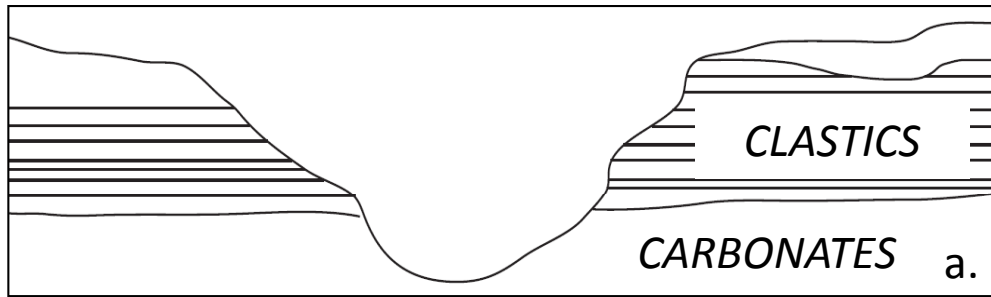
Interpreted stages of studied channel fill
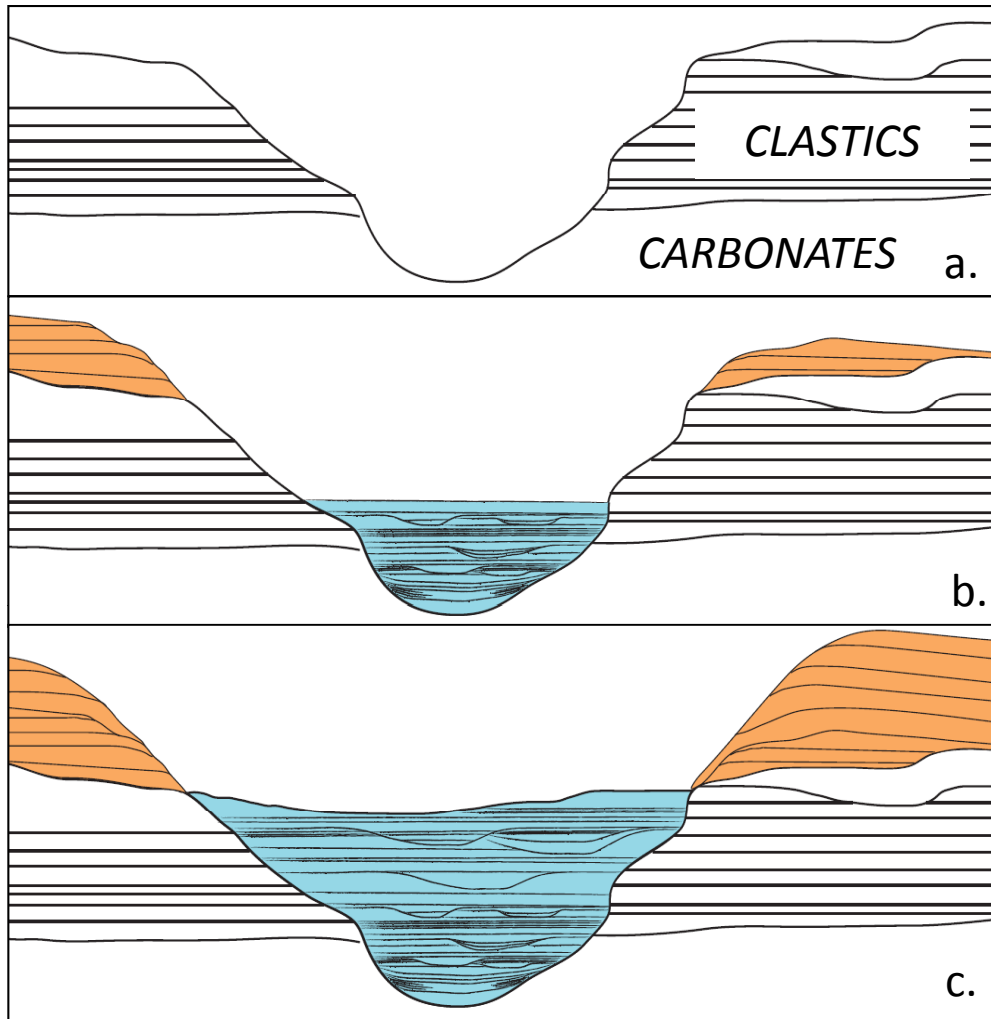
Stage 1: Channel bed aggradation reduces channel relief

Interpreted stages of studied channel fill

CLASTICS

CARBONATES

a.

b.

c.

d.

Stage 1: Channel bed aggradation reduces channel relief

Stage 2: A bar is constructed at the channel margin while channel relief is maintained

Channel filling deposits

Gravel-rich deposits

Thickly-bedded, structureless, planar-stratified and dune cross-stratified sands stones. Occasionally gravel-rich.
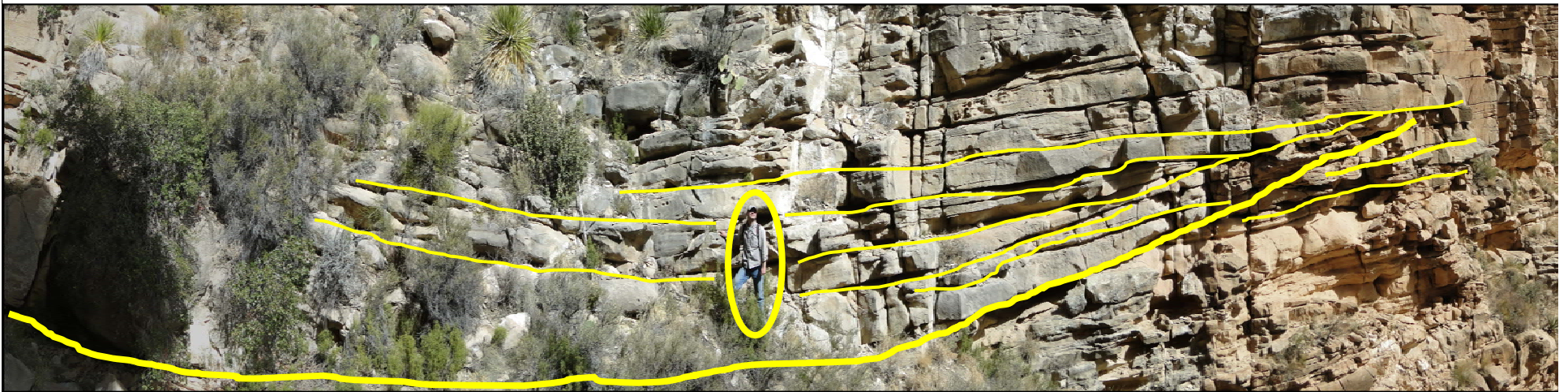
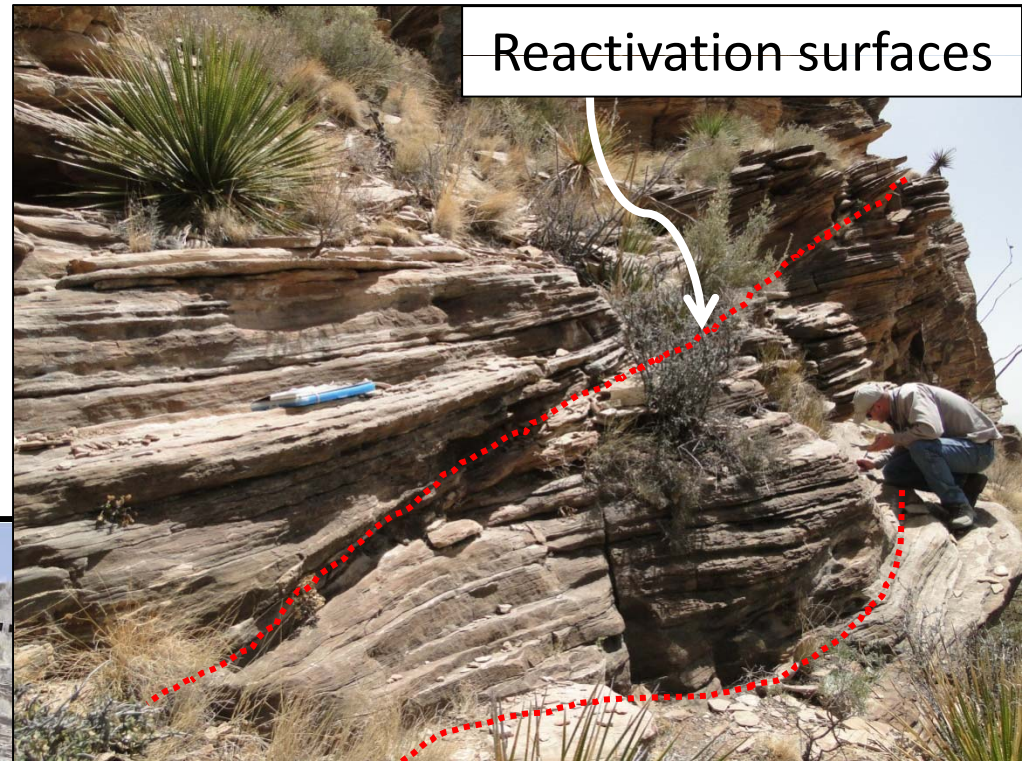Filling topographic lows
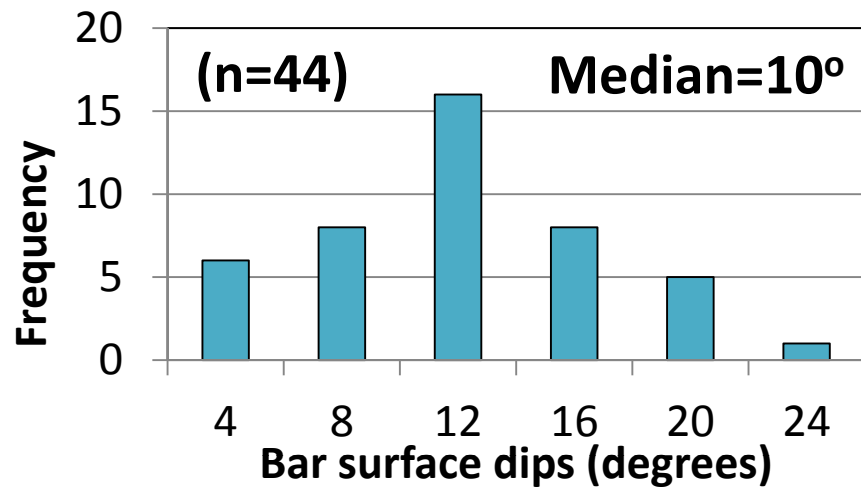
Bank-attached separation bar

~9m

Formed at channel margin.

Bank-attached separation bar

~9m

Organic rich siltstone interval

No erosion along top of bar. Bar thickness provides an estimate of minimum flow thickness.

Bank-attached separation bar

(n=44)   Median=10°

Frequency

Bar surface dips (degrees)

Reactivation surfaces

~9m
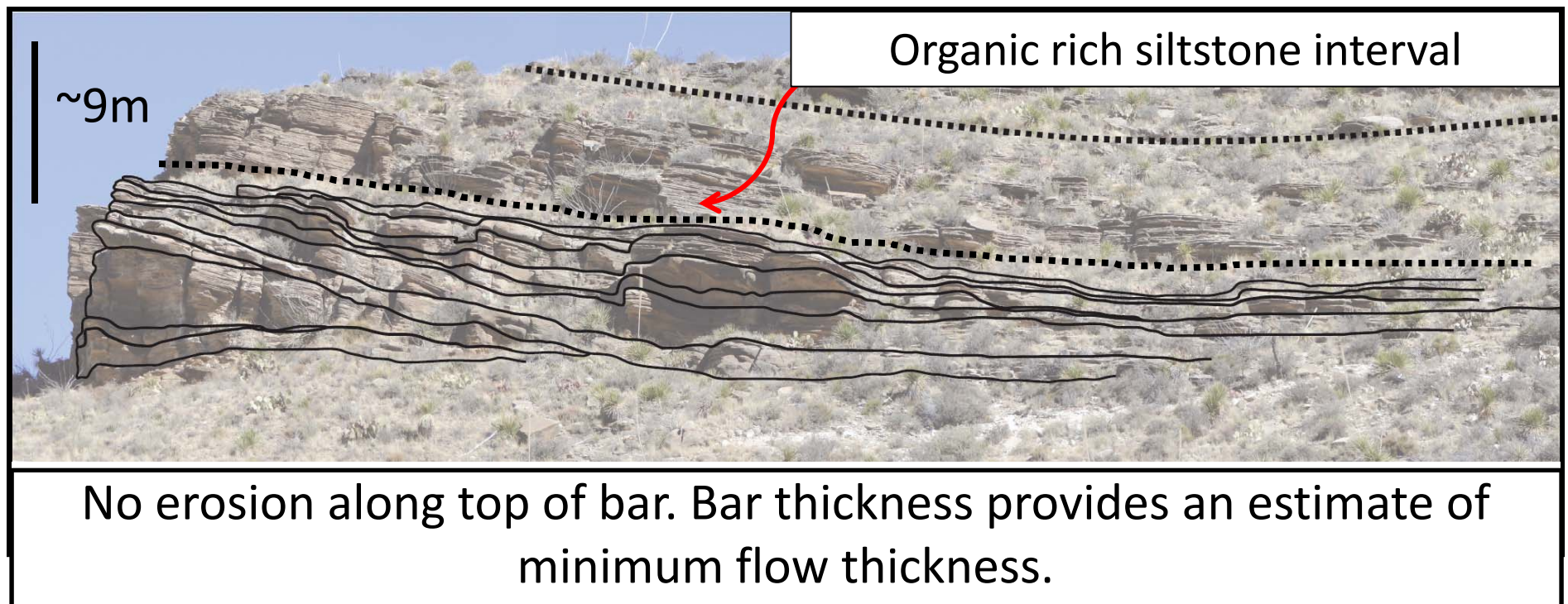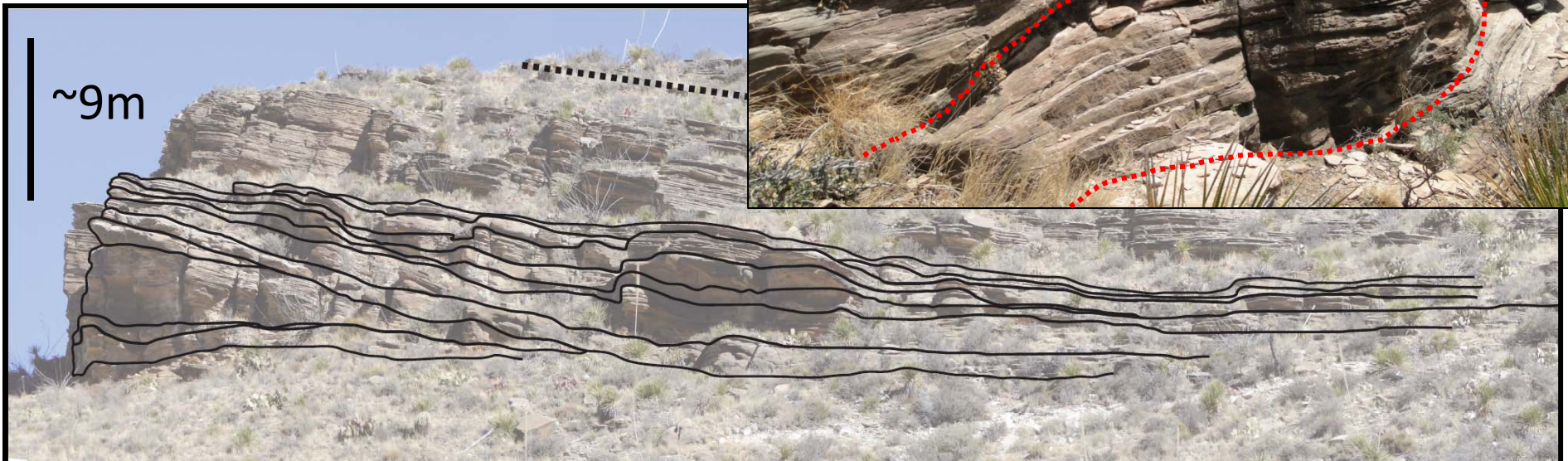
High bedding dips.

Reactivation surfaces associated with the changing shape of the bar.
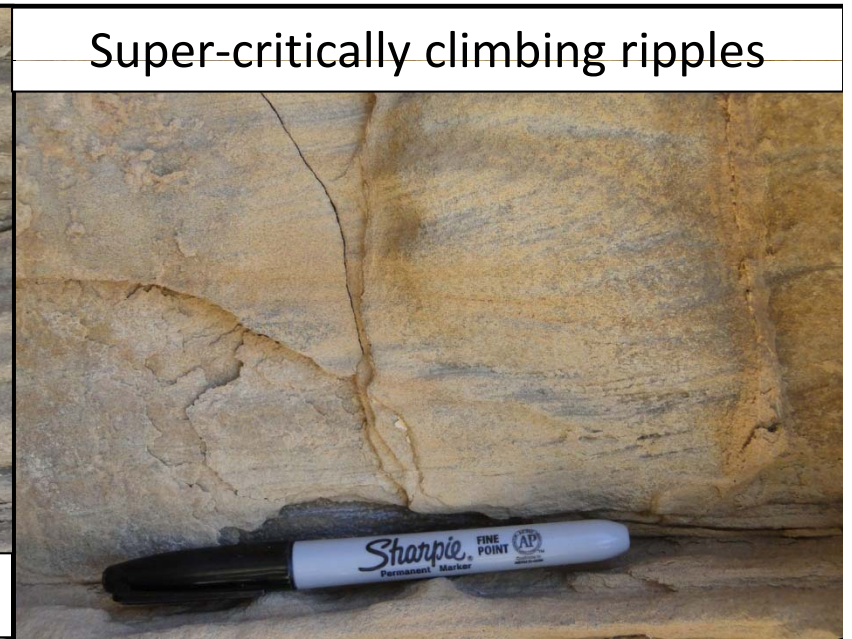
Bank-attached separation bar

Ripple transport

Dip direction

Reactivation surfaces

~9m
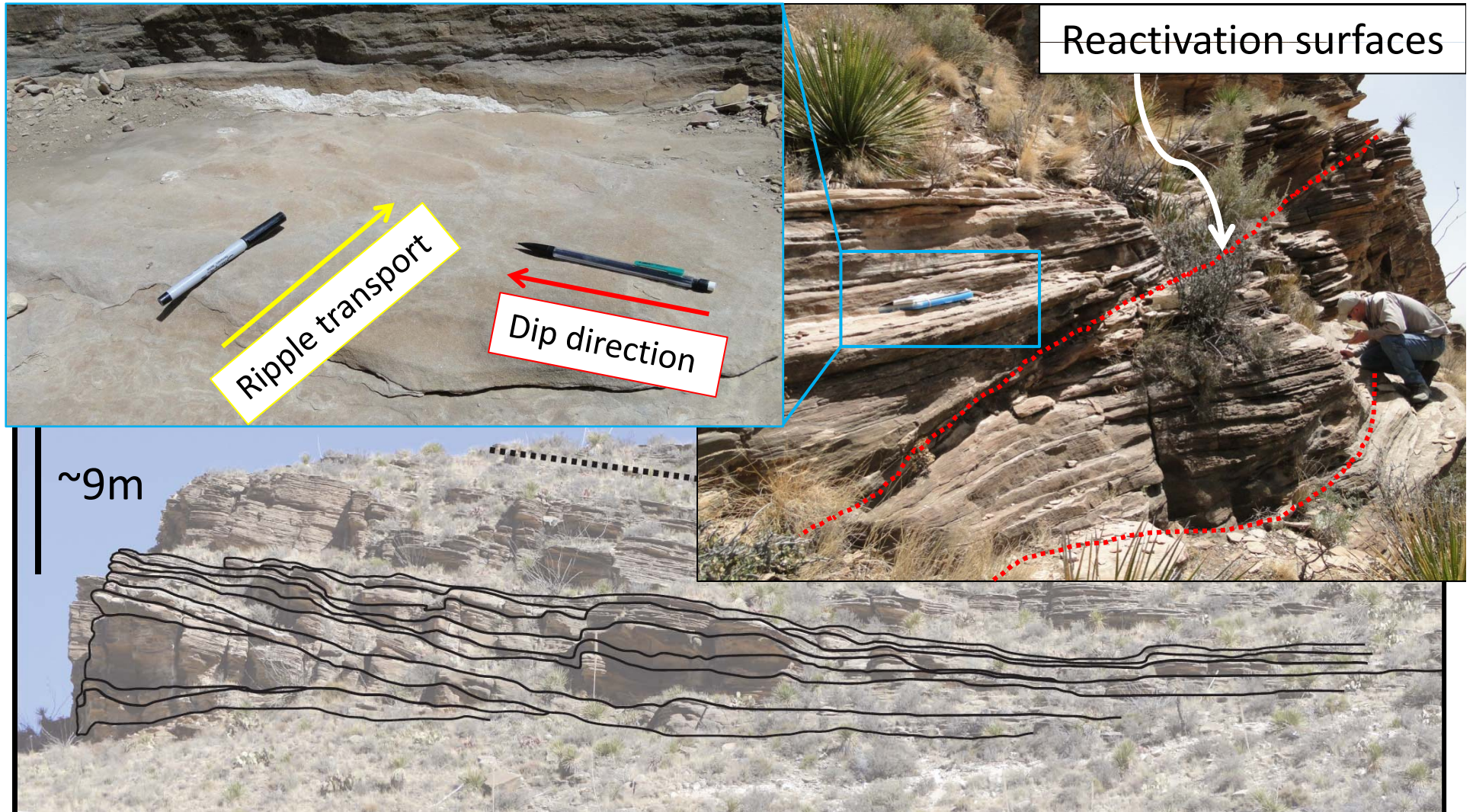
Ripple transport at high angles relative to azimuth of bedding dips.

Bank-attached separation bar

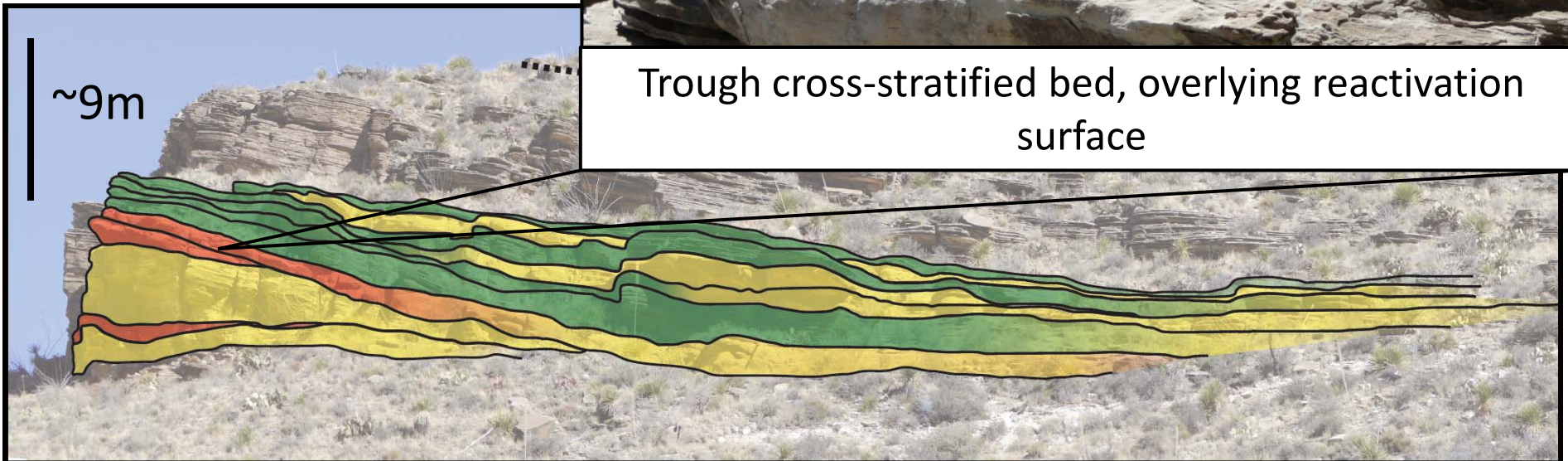Super-critically climbing ripples
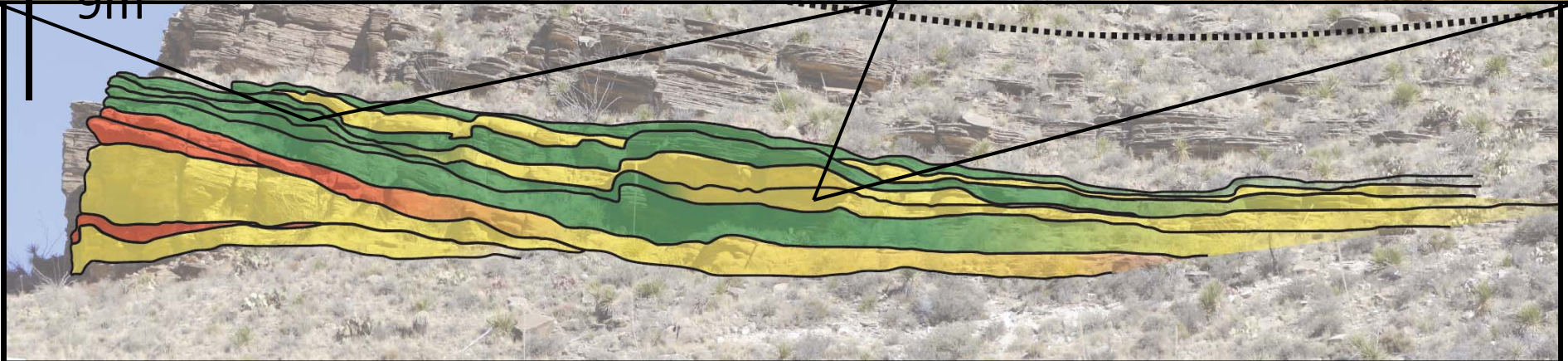
Mud-draped, poorly defined ripples

9m

RIPPLED SANDS

TROUGH CROSS-STRATIFIED SANDS

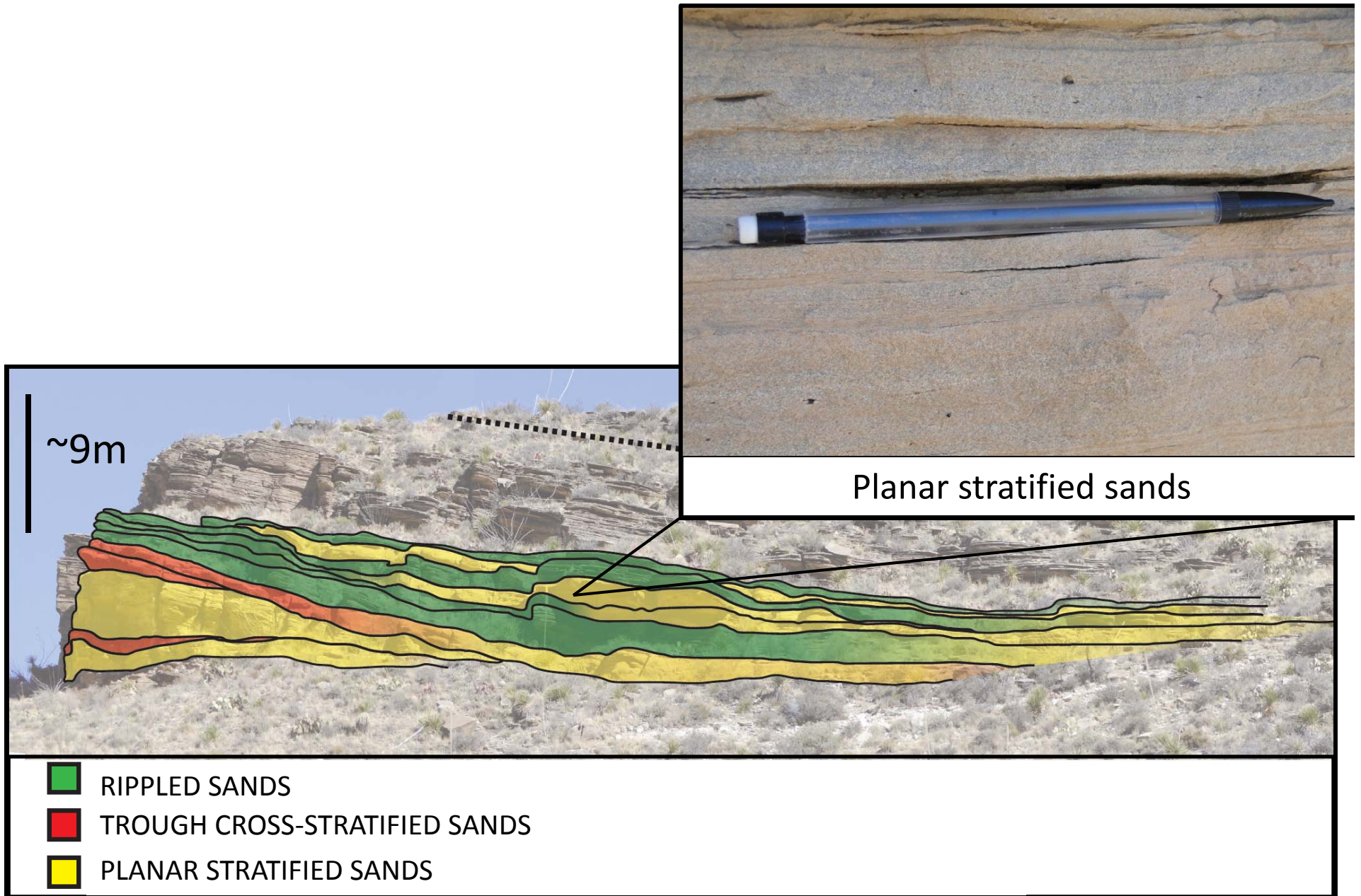PLANAR STRATIFIED SANDS

Bank-attached separation bar

Trough cross-stratified bed, overlying reactivation surface

~9m

RIPPLED SANDS
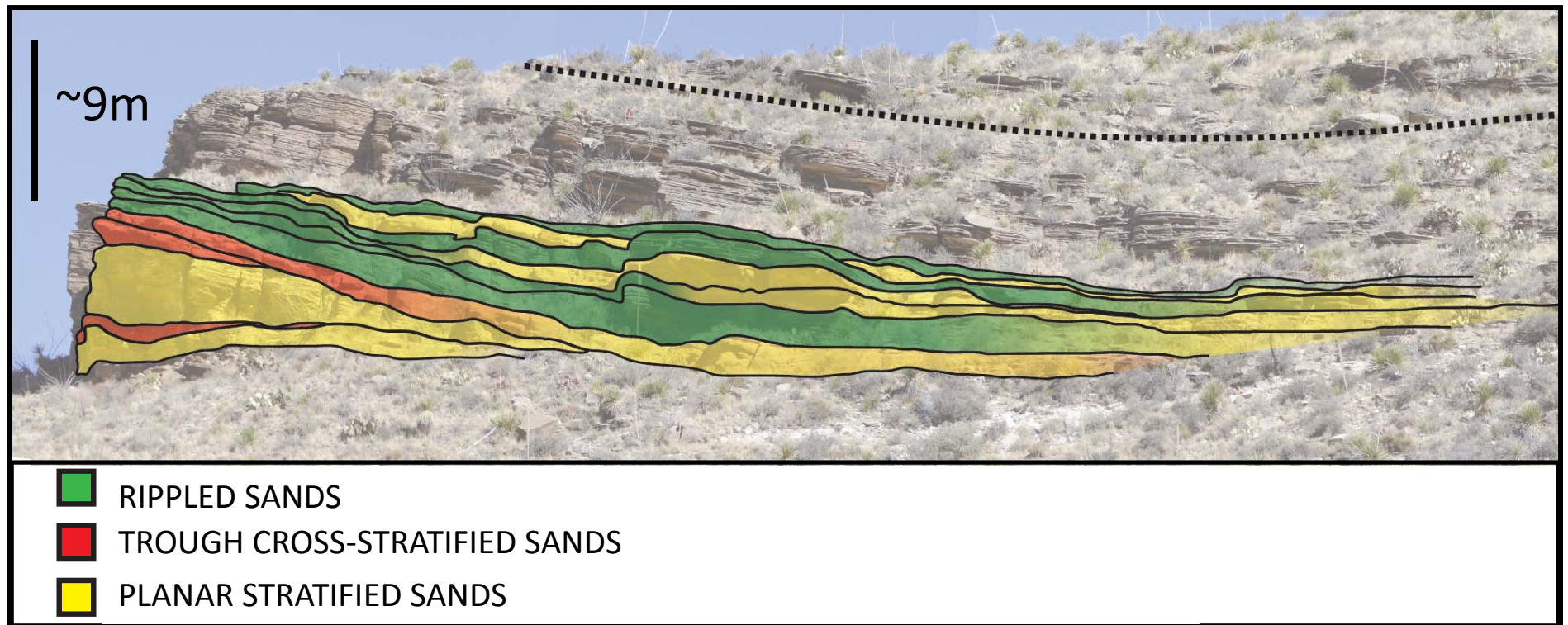
TROUGH CROSS-STRATIFIED SANDS
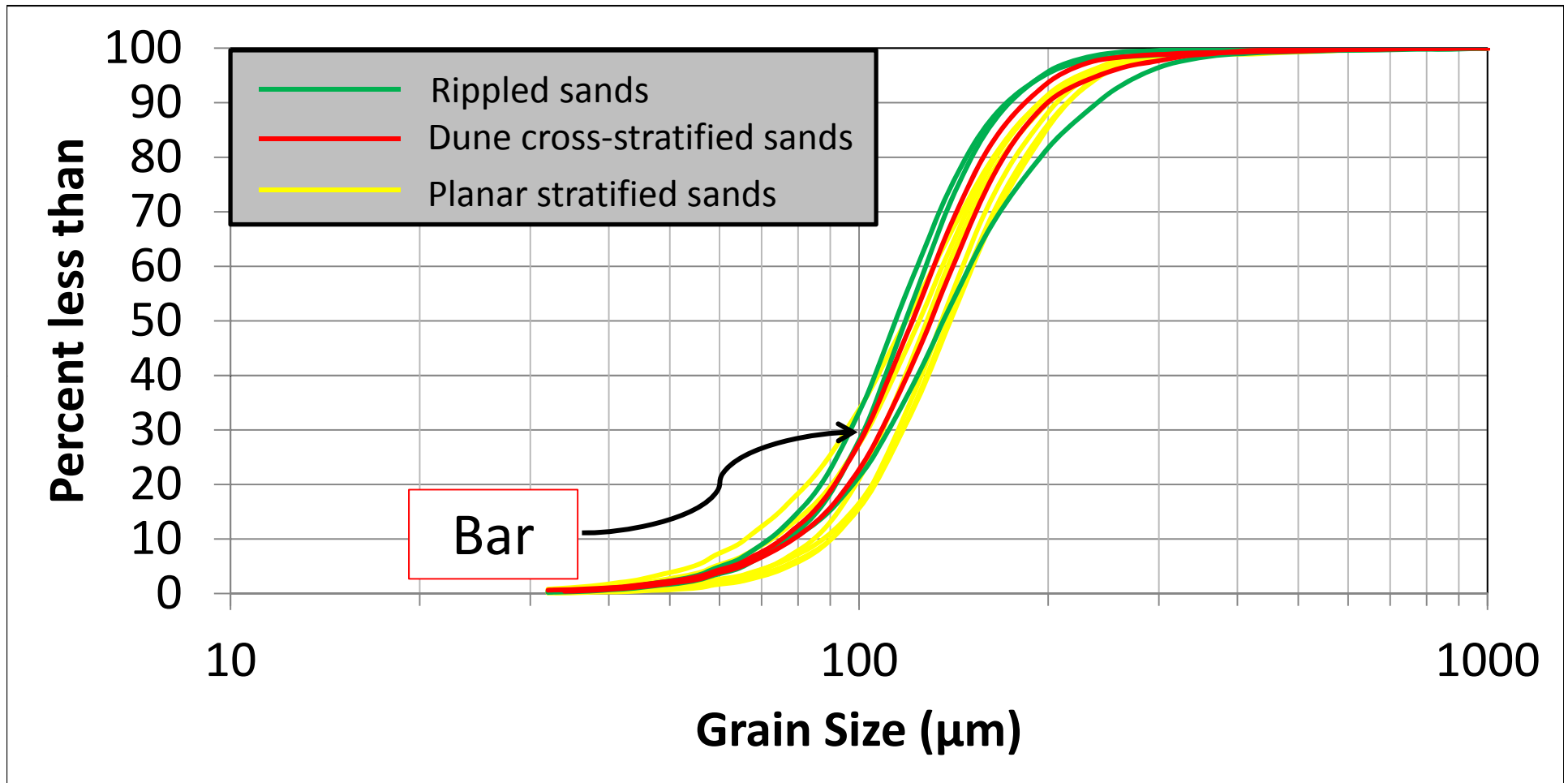
PLANAR STRATIFIED SANDS

Bank-attached separation bar

~9m

Planar stratified sands

RIPPLED SANDS
TROUGH CROSS-STRATIFIED SANDS
PLANAR STRATIFIED SANDS

Bank-attached separation bar

Lateral transitions between facies over small distances

~9m

RIPPLED SANDS

TROUGH CROSS-STRATIFIED SANDS

PLANAR STRATIFIED SANDS
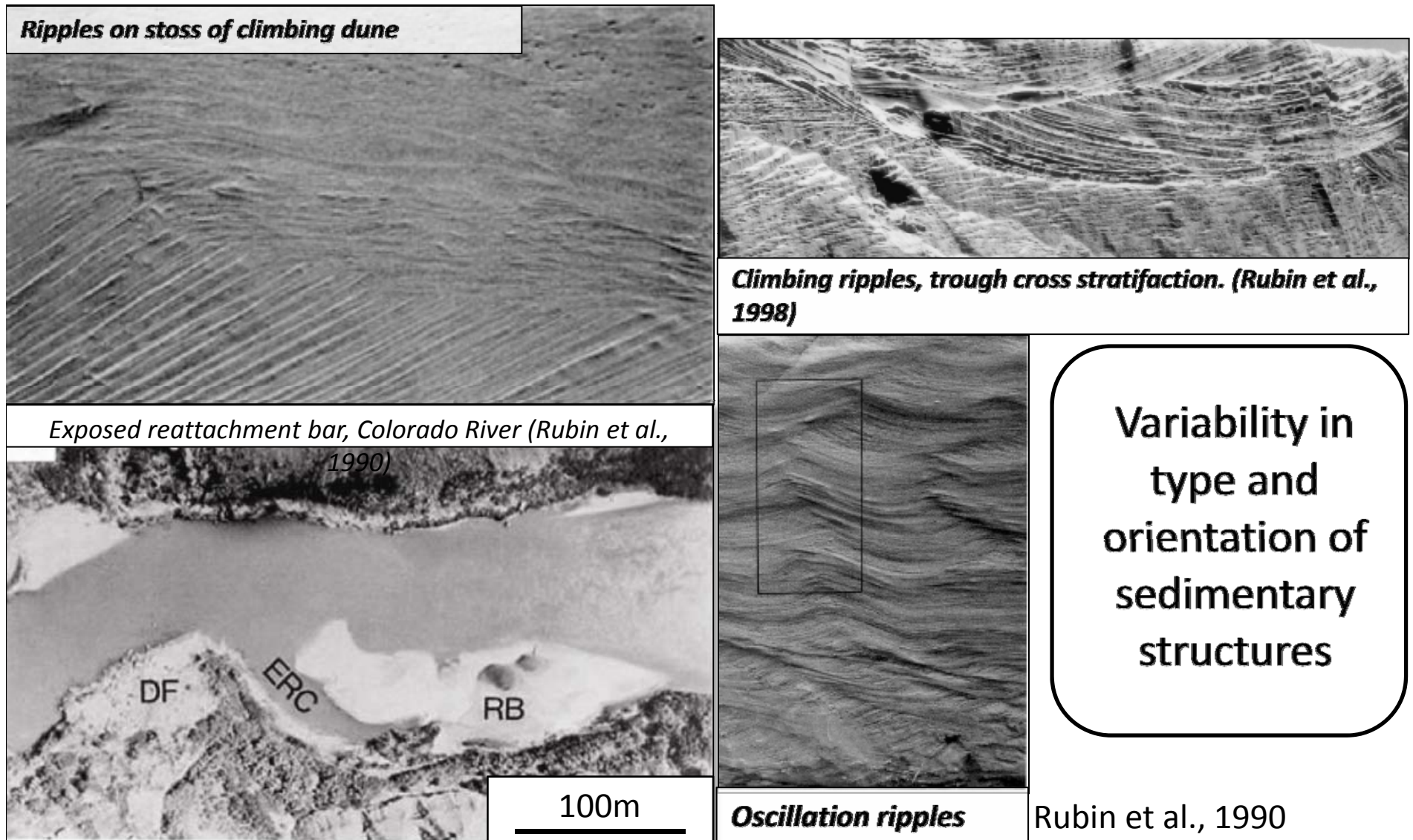
Bank-attached separation bar

Grain size distributions show **similar composition.**

Abundance of climbing rippled deposits suggest common source from **suspended load.**
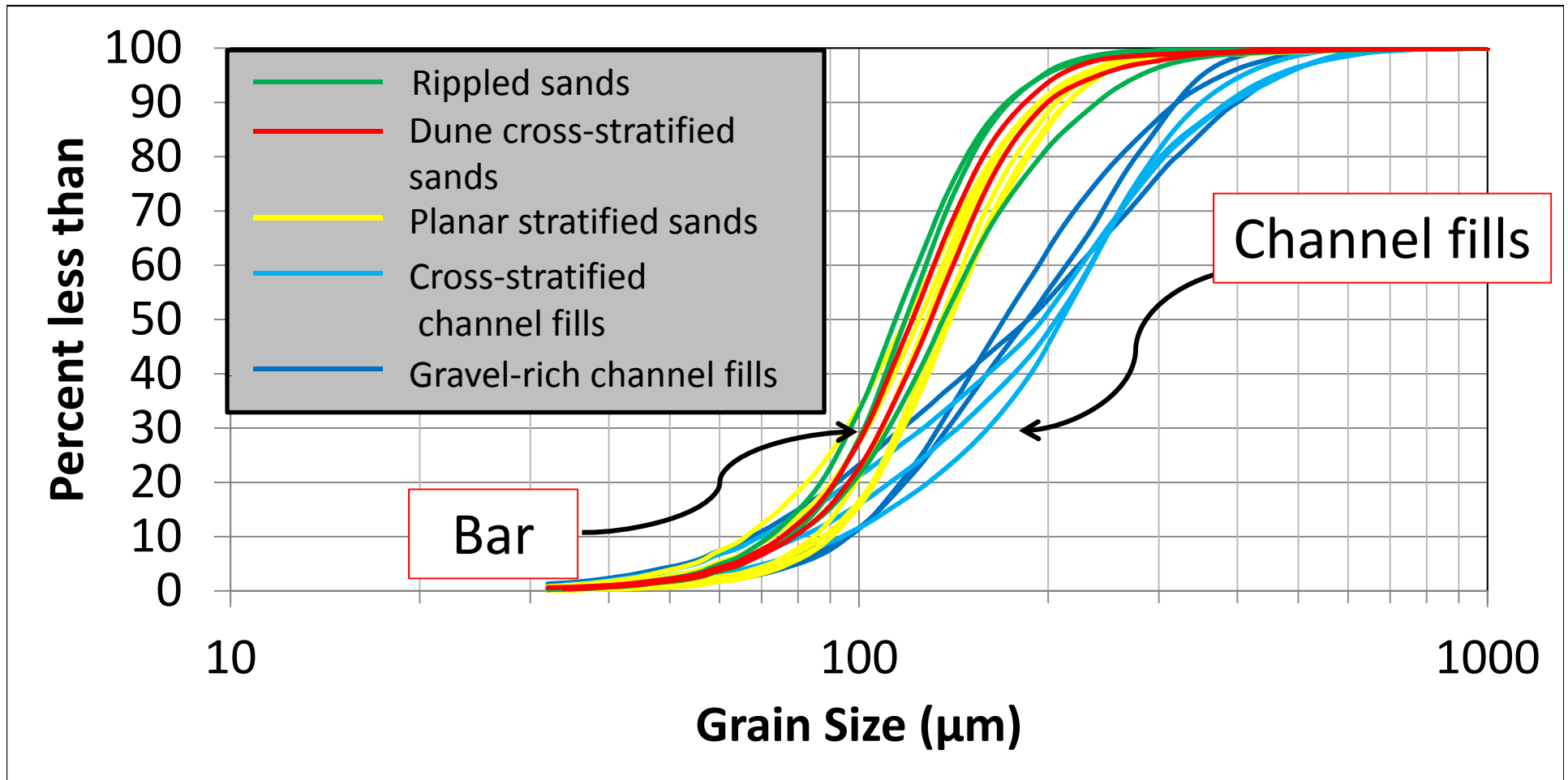
Re-attachment bar on Colorado river

Similar facies associations in a separation zone bar

Ripples on stoss of climbing dune

Exposed reattachment bar, Colorado River (Rubin et al., 1990)

DF   ERC   RB

100m

Climbing ripples, trough cross stratifaction. (Rubin et al., 1998)

Oscillation ripples

Variability in type and orientation of sedimentary structures

Rubin et al., 1990

Bars versus channel fills: Grain-sizes of sand

Legend:
- Rippled sands
- Dune cross-stratified sands
- Planar stratified sands
- Cross-stratified channel fills
- Gravel-rich channel fills

Y-axis: **Percent less than**
X-axis: **Grain Size (µm)**

Bar

Channel fills

Coarser particles in **channel filling** deposits.

Interpreted as bedload or incipiently suspended load (travelling near the bed)

Internal consistency in interpreted transport of sediment

1. Estimate settling velocity w_s of median clast size of gravels *(Dietrich, 1982)*

2. Estimate shear velocity u_* of transporting current *(Wiberg & Smith, 1987)*
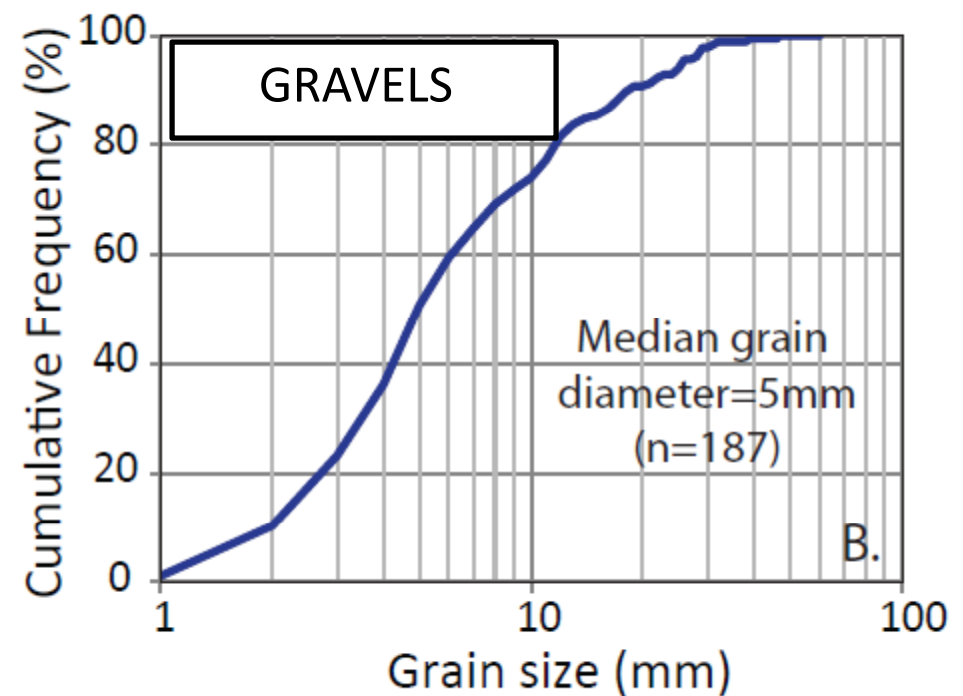
3. Determine fully suspended particle sizes

$$\frac{w_s}{u_*} \leq 0.33 \quad \textit{(Smith, 1977)}$$

Estimated particle sizes in full suspension **≤ 231µm**

Actual D_{95} in bars = **250µm**

Gravel clast clusters

Society for Sedimentary Geology www.sepm.org

GRAVELS

Median grain diameter=5mm (n=187)

B.

Cumulative Frequency (%)

Grain size (mm)

Bimodality in bar deposits

Distributions **usually unimodal** (peak at 120µm)

Occasionally bimodal

Second sediment source from **closer to the thalweg** (second peak at 210µm)

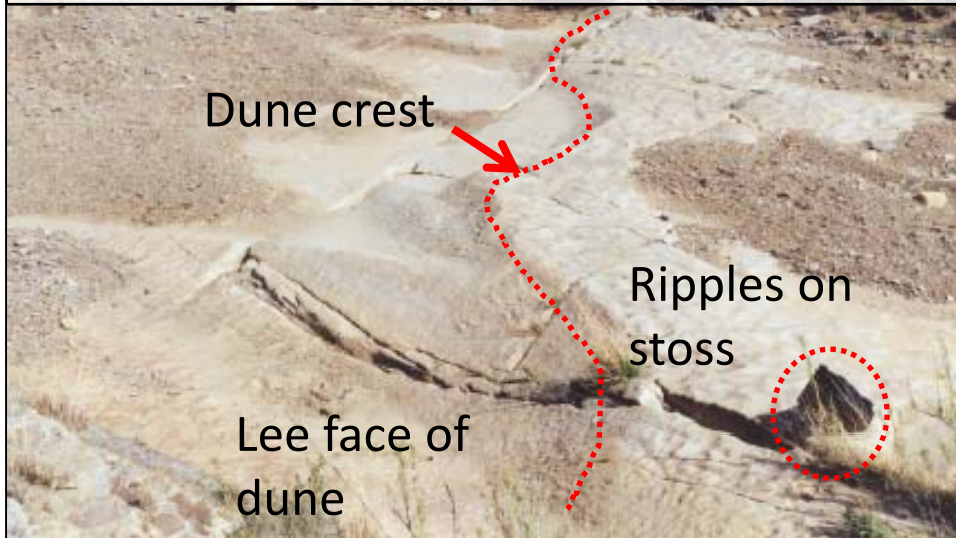*Lower fine sand*
Upper fine sand
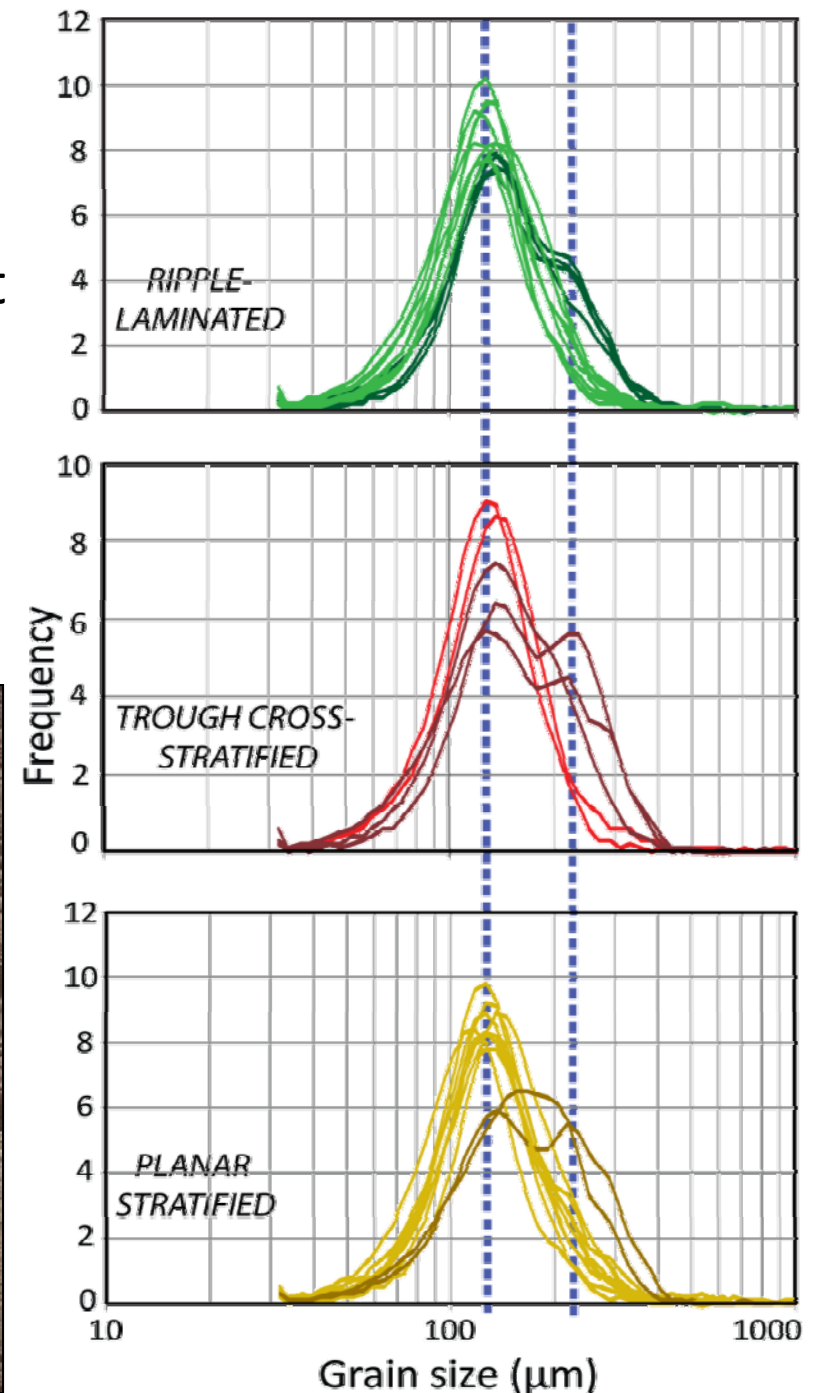
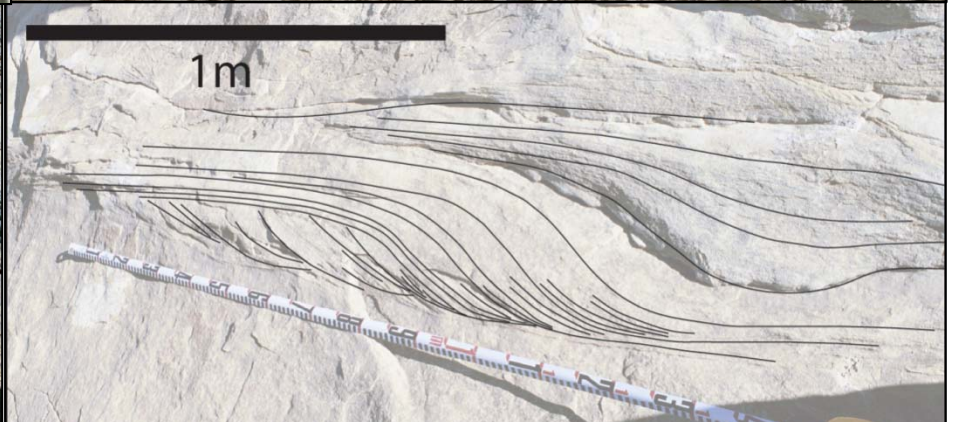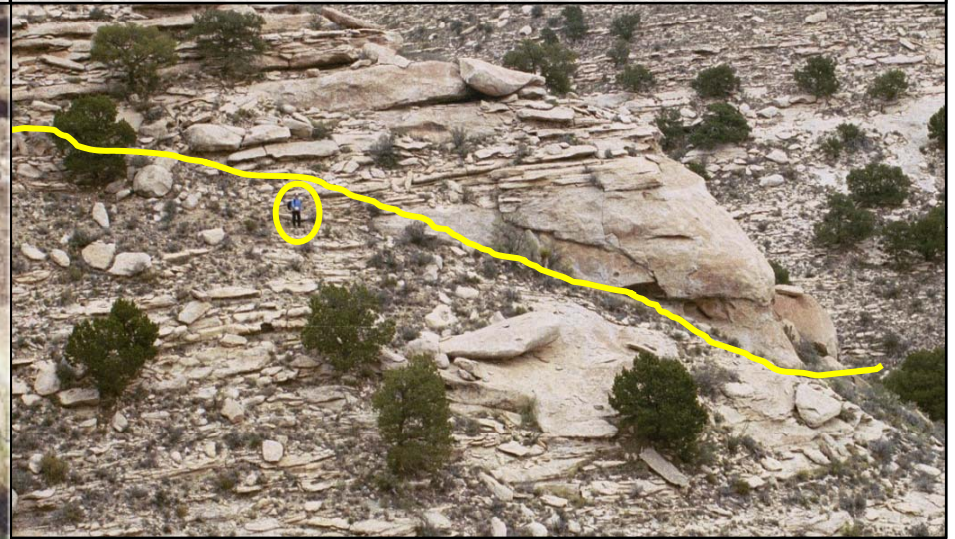# Basin floor channel fills

Sub- to super-critically **climbing 3-D dunes** in channel fills.

Requires sediment sourced from **suspended load.**

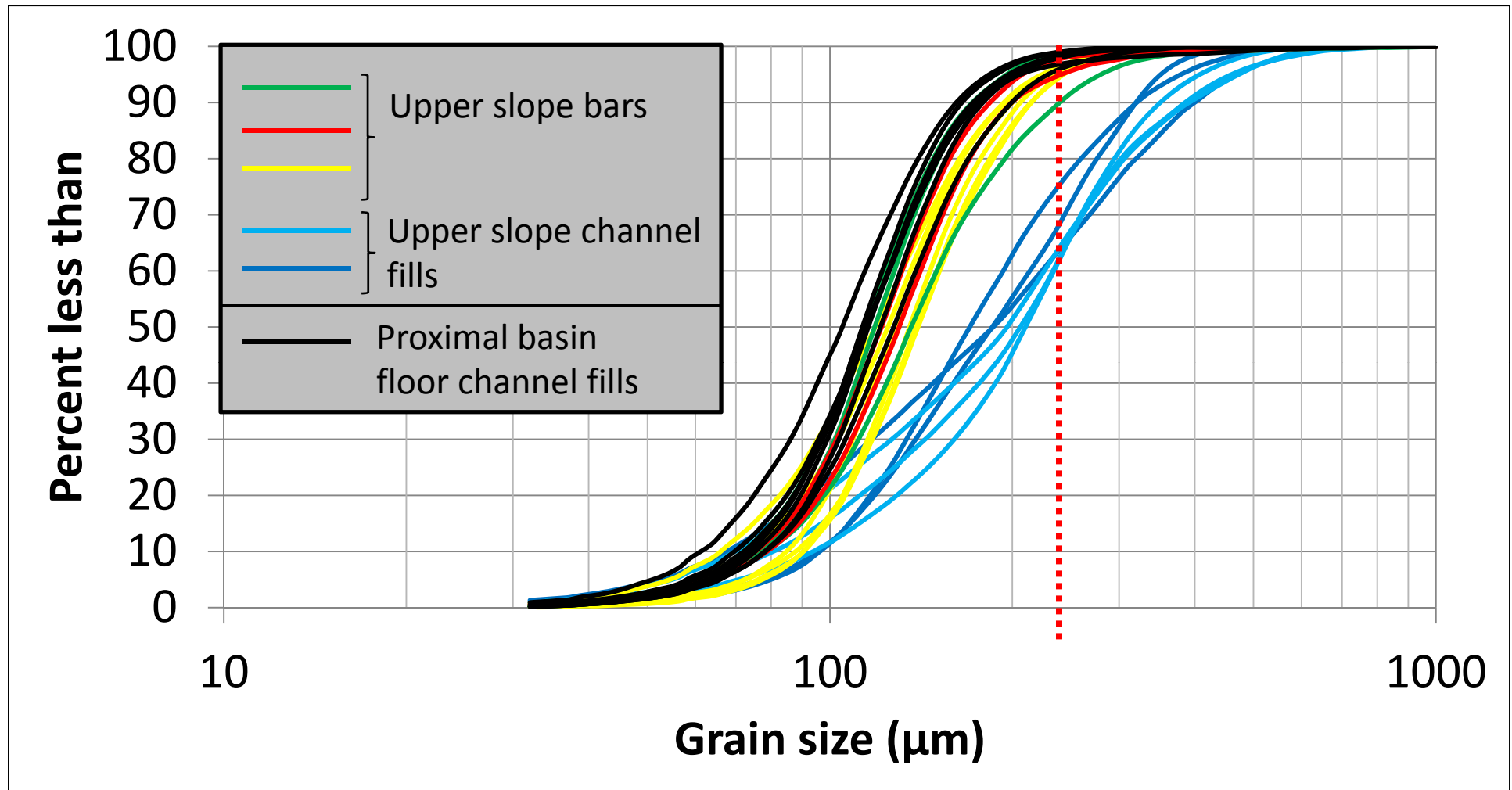*Exposed 3-D dune, basin floor channel fill*

Dune crest

Ripples on stoss

Lee face of dune

Channel plug: Proximal basin floor

1m

Climbing dunes, basin floor channel fills

Linking bars to channel fills on the basin floor

Legend:
- Upper slope bars (green, red, yellow)
- Upper slope channel fills (light blue, blue)
- Proximal basin floor channel fills (black)

Y-axis: Percent less than (0 to 100)
X-axis: Grain size (μm) (10, 100, 1000)

D_{50} (basin floor)=110-150μm, D_{50} (upper slope bar)=130-160 μm

Particle sizes <220μm bypassed to basin floor

Particle sizes >220μm selectively removed via deposition on slope

Summary: Facies Model
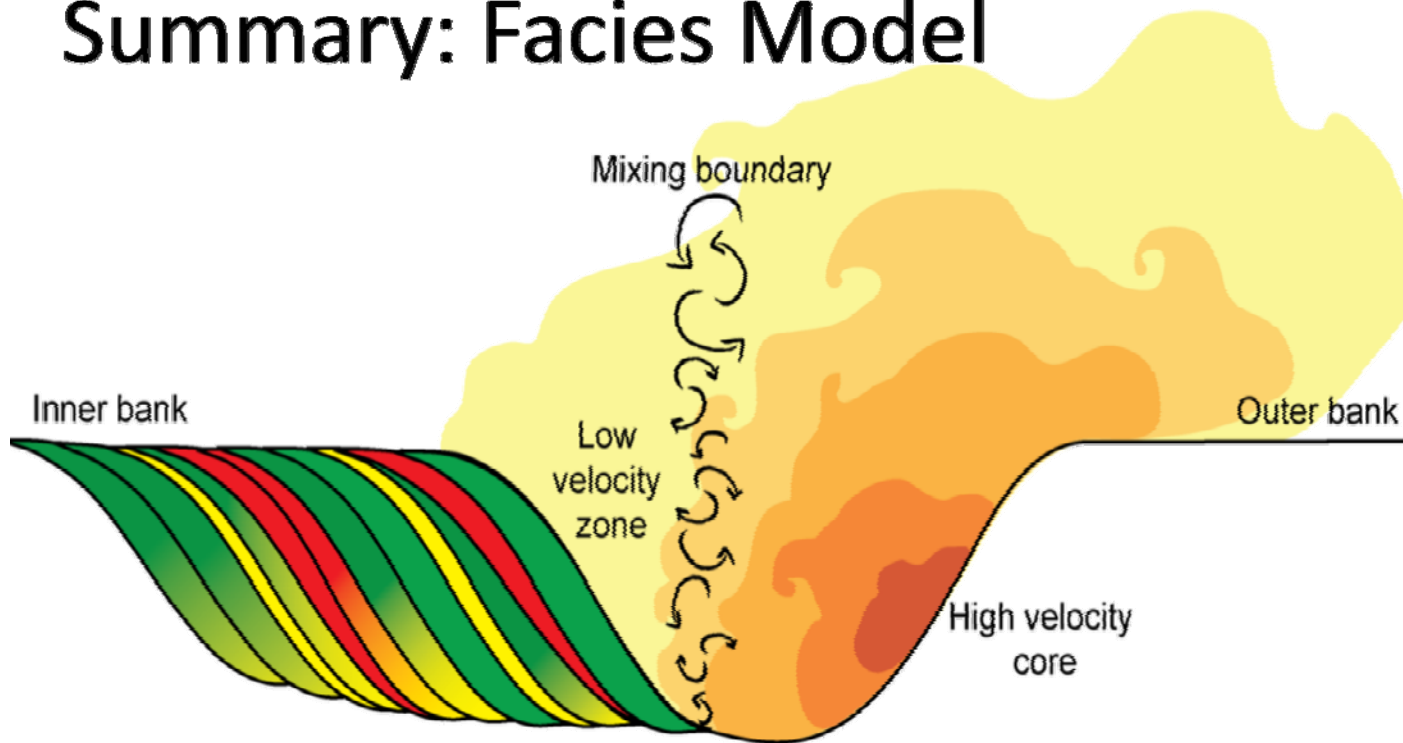
Constructed chiefly from **fully suspended** sediment

Reworked to varying degrees on the bed.

Proximity to the high-velocity core dictates degree of reworking and bar composition.

Small amounts of fully suspended sediment are **trapped in low velocity zones** on the slope, the rest is **bypassed to the basin floor.**

Acknowledgements