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Sequence Stratigraphic Expression of an Evolving Experimental Fluvial-to-Marine Depositional Profile*

By
John Martin[1], Chris Paola[1], Vitor Abreu[2], Jack Neal[2], and Ben Sheets[3]

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[1]St. Anthony Falls Laboratory, Minneapolis, MN (jmartin@umn.edu)
[2]ExxonMobil Exploration Company, Houston, TX
[3]ExxonMobil Upstream Research Company, Houston, TX

Abstract

Sequence stratigraphy is founded on identifying stratal discordances, a geometrically scale-independent procedure amenable to experimental stratigraphy. Here we perform a sequence stratigraphic analysis on an experimental fluvio-marine deposit for which the boundary conditions and depositional history are known. Our goals are to (1) evaluate when sequence stratigraphic markers are created and how they are structured, and (2) quantify the extent to which the bounded strata honor the known basinal sedimentation patterns. The generation of sequence stratigraphic surfaces is through shifts in sediment mass balance, which is expressed at the surface as an evolving fluvio-marine surface profile. By direct comparison of measured surface topography with preserved stratal surfaces, we show that marine disconformities are especially robust indicators of relative base-level fall. These surfaces, along with maximum flooding surfaces, correlate closely with specific geomorphic surfaces and thus are nearly time synchronous. Erosional surfaces, however, are diachronous and not associated with any instantaneous topographic surface.

Although sequence stratigraphic surfaces are recurrent features in the experimental deposit, their areal correlation and properties are closely related to the shape of the associated stratigraphic cycle, erosion from subsequent cycles, and autogenic overprinting. These effects prohibit a basin-wide correlation of any one horizon. However, by mapping the stacking arrangement of the bounded strata and applying time constraints on the stratigraphic surfaces, we find remarkable agreement between the stratigraphic and known depositional history. This demonstrates sequence stratigraphic horizons accurately capture shifts in the basinal mass balance, and form largely independently of the speed and manner of the changing depositional profile.

Sequence stratigraphic expression of an evolving fluvial-to-marine depositional profile

John Martin[1,2], Chris Paola[1], Vitor Abreu[3], Jack Neal [3], and Ben Sheets [2]

[1] St. Anthony Falls Laboratory, University of Minnesota

[2] ExxonMobil Upstream Research Company

[3] ExxonMobil Exploration Company

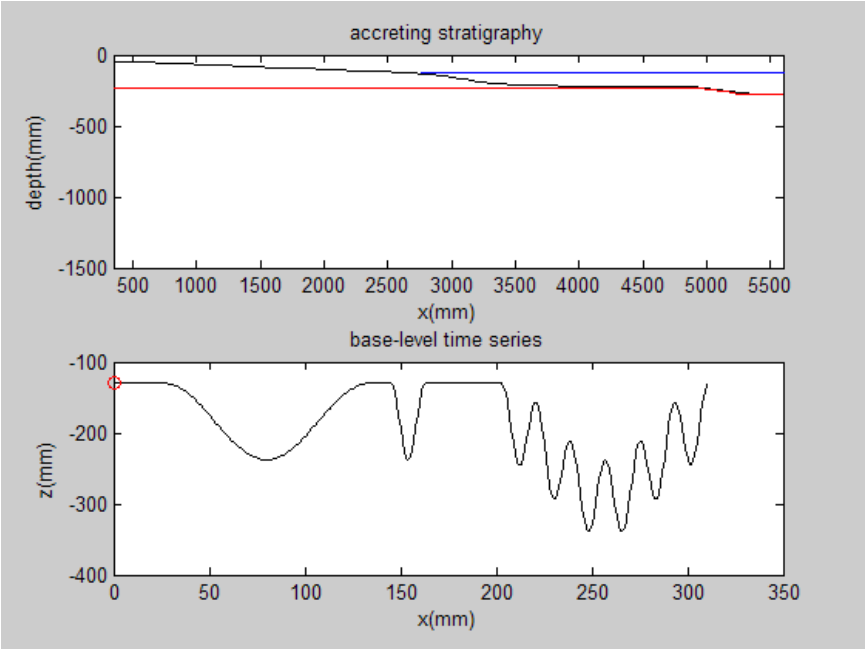
ExxonMobil
Upstream Research

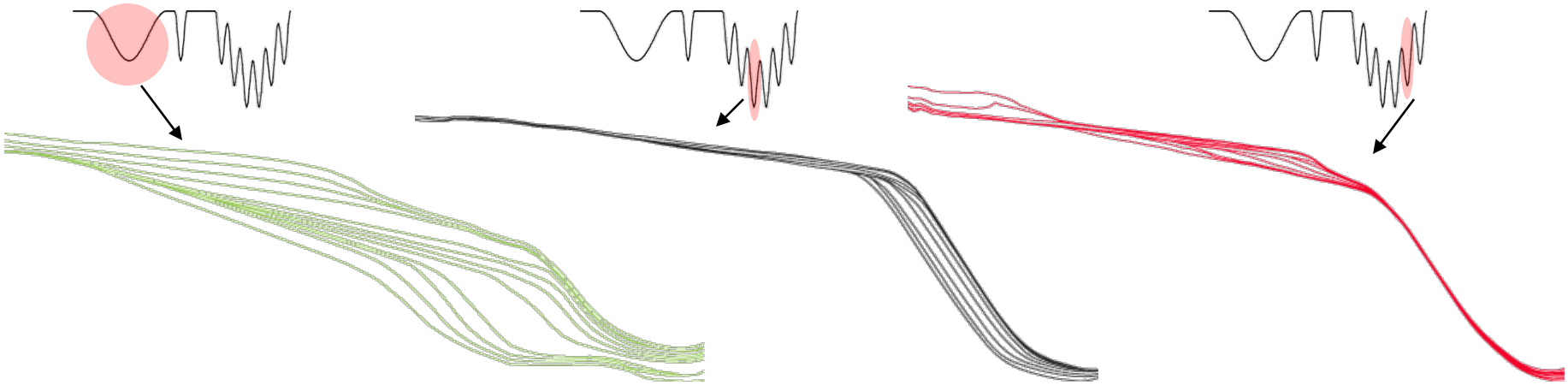
Sequence stratigraphic (time-integrated) imprint of an evolving depositional profile

Creation of stratigraphic disconformities
(i.e. time domain of key stratal surfaces)

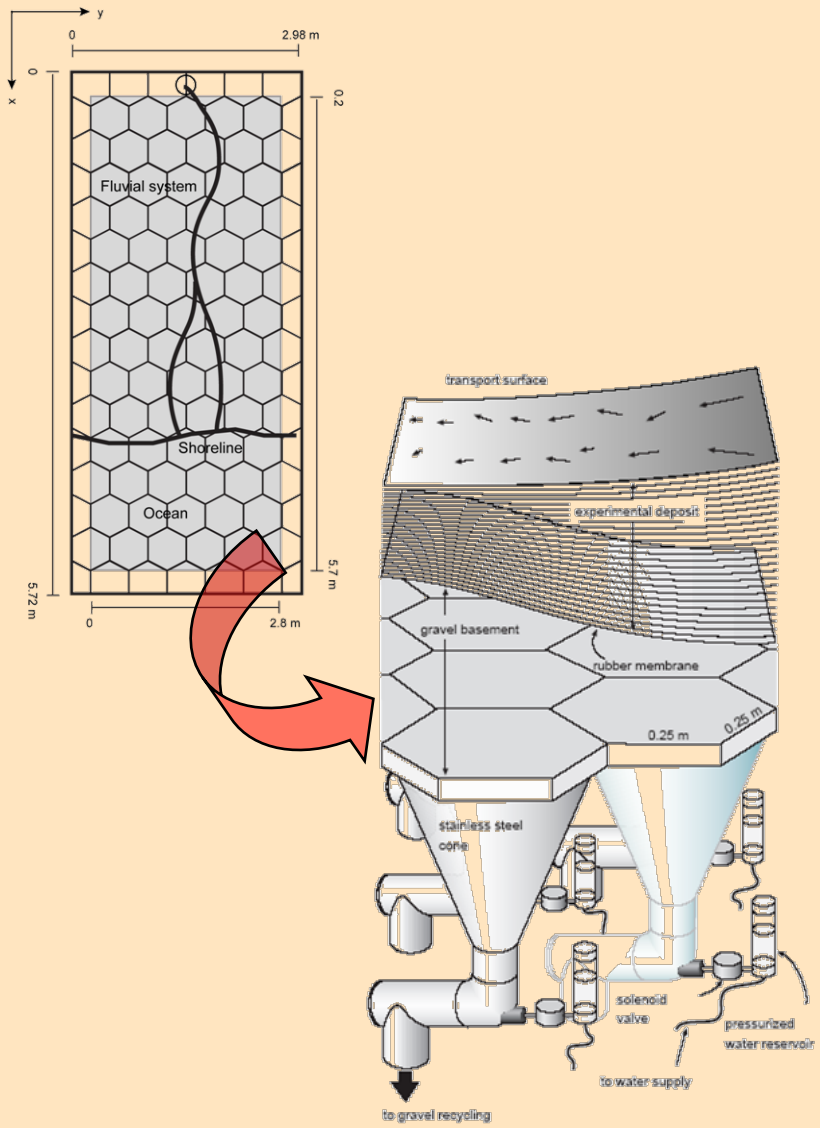
Spatial association between disconformities and paleo-topographic surfaces

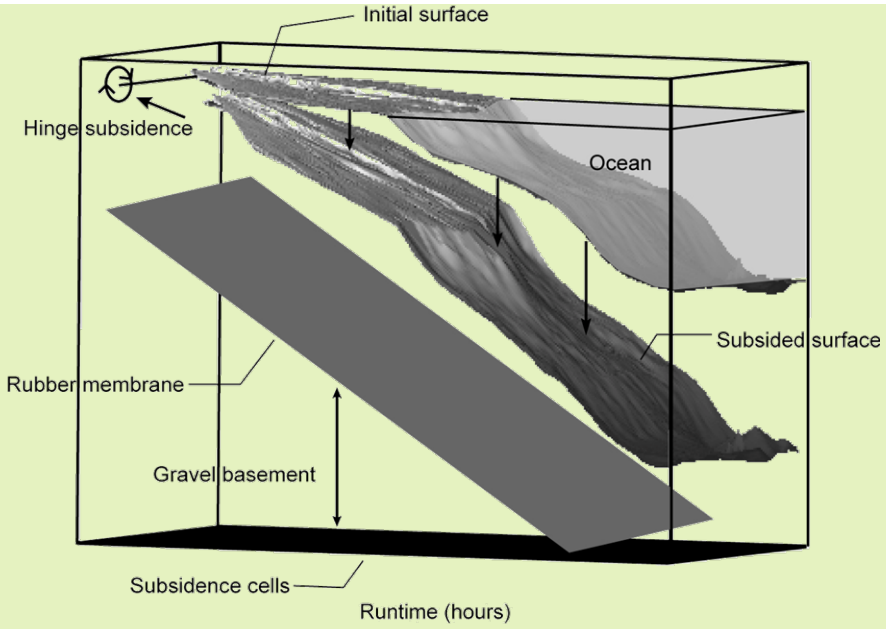
The degree to which the arrangement of sequence stratigraphic surfaces capture the depositional history

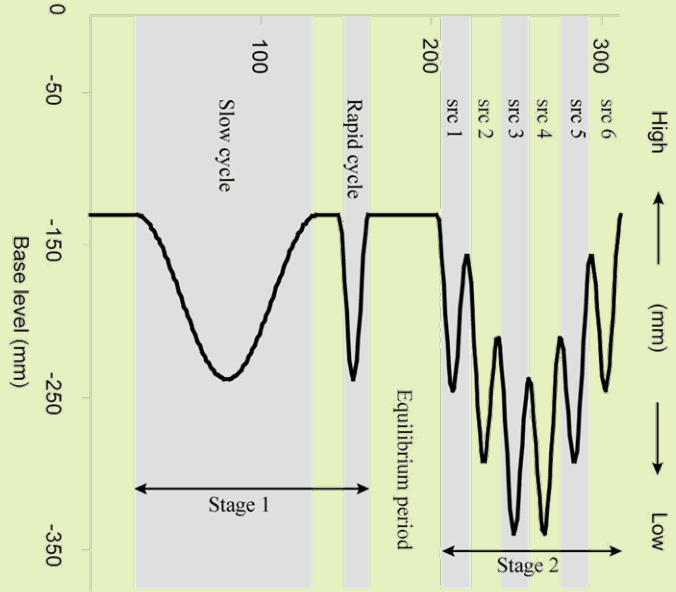




XES Basin and XES 02 experiment design







Stratigraphic methods: data integration

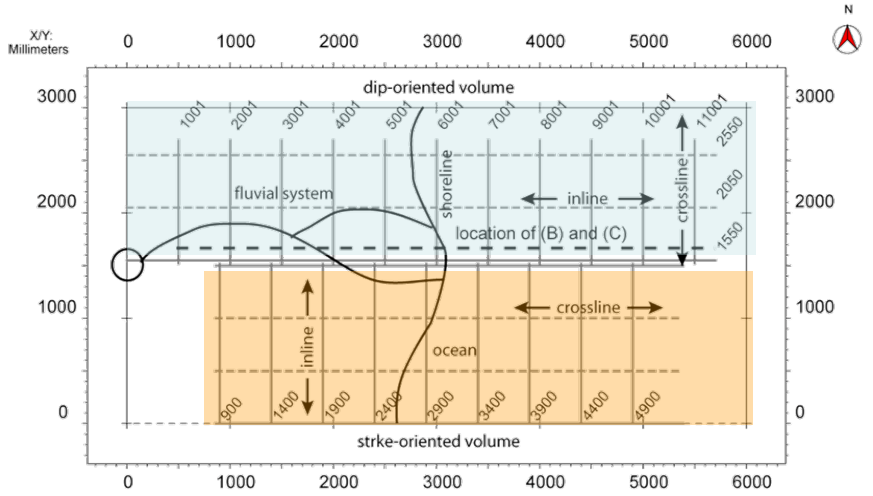
Dip –oriented survey

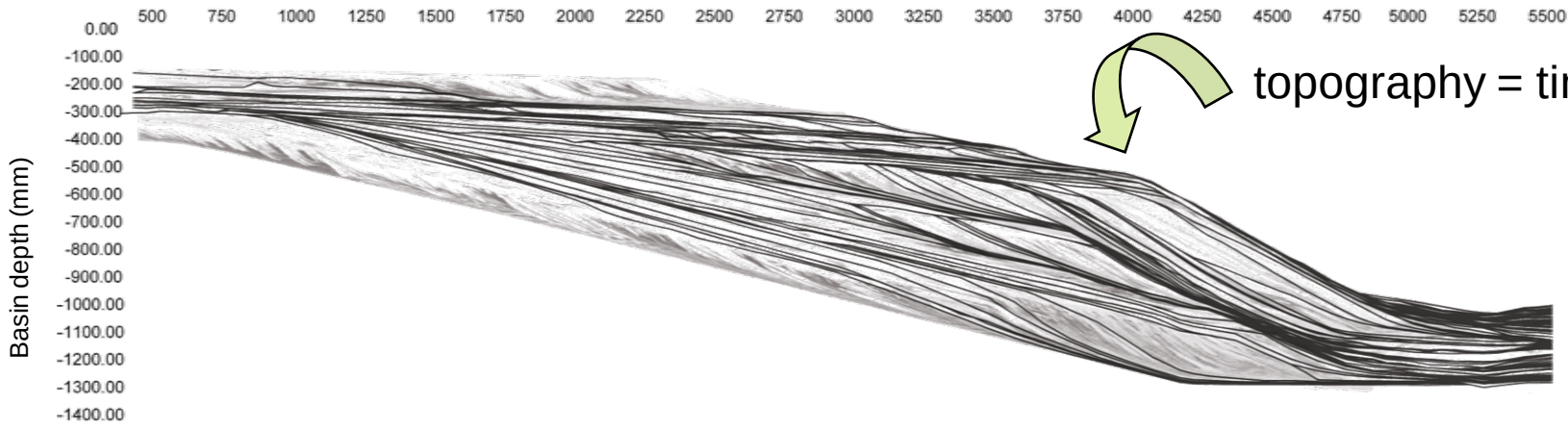
Inlines = images that parallel flow direction

Strike –oriented survey

Inlines = images that are perpendicular to flow direction

XES basin seismic survey grids

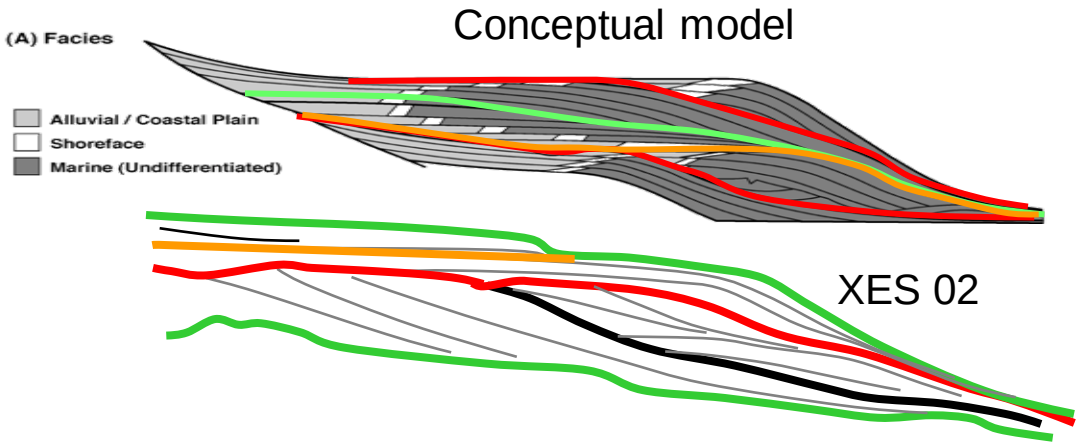




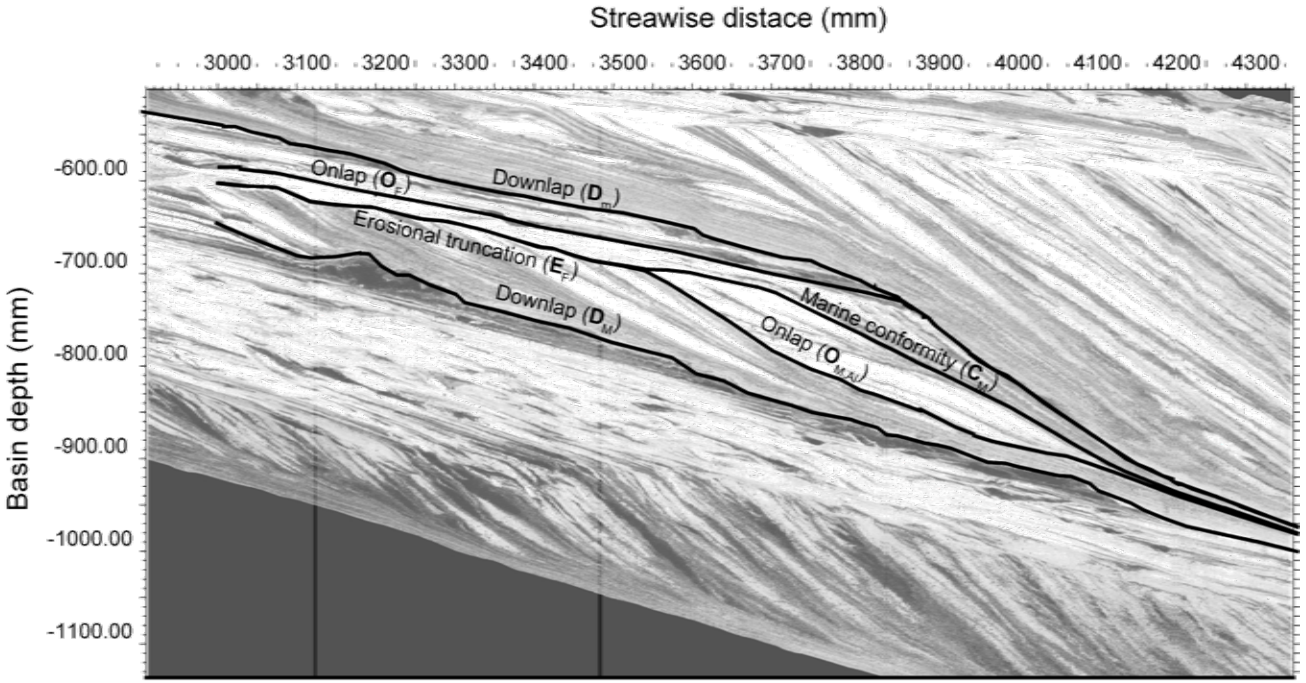
topography = time

Clipped and migrated topography data (black lines) layered on pseudo-seismic dip section (actual stratigraphy)

Stratigraphic methods: horizon interpretation

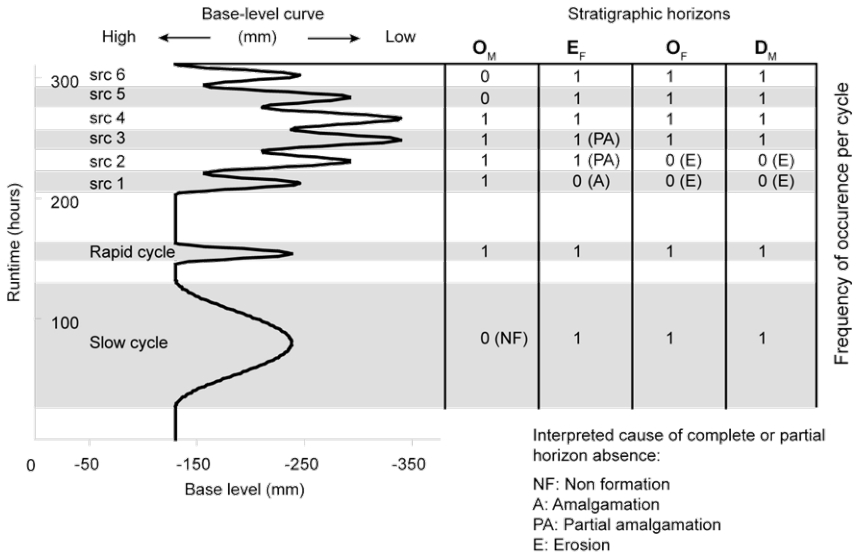


- $\mathbf{E_F}$ + $\mathbf{C_M}$ ~= sequence boundary
- $\mathbf{D_M}$ ~= maximum flooding surface
- $\mathbf{O_M}$ ~= no general equivalency
- $\mathbf{O_F}$ ~= transgressive surface



Stratigraphic methods: horizon interpretation

Full suite of stratigraphic horizons is not always present for each cycle

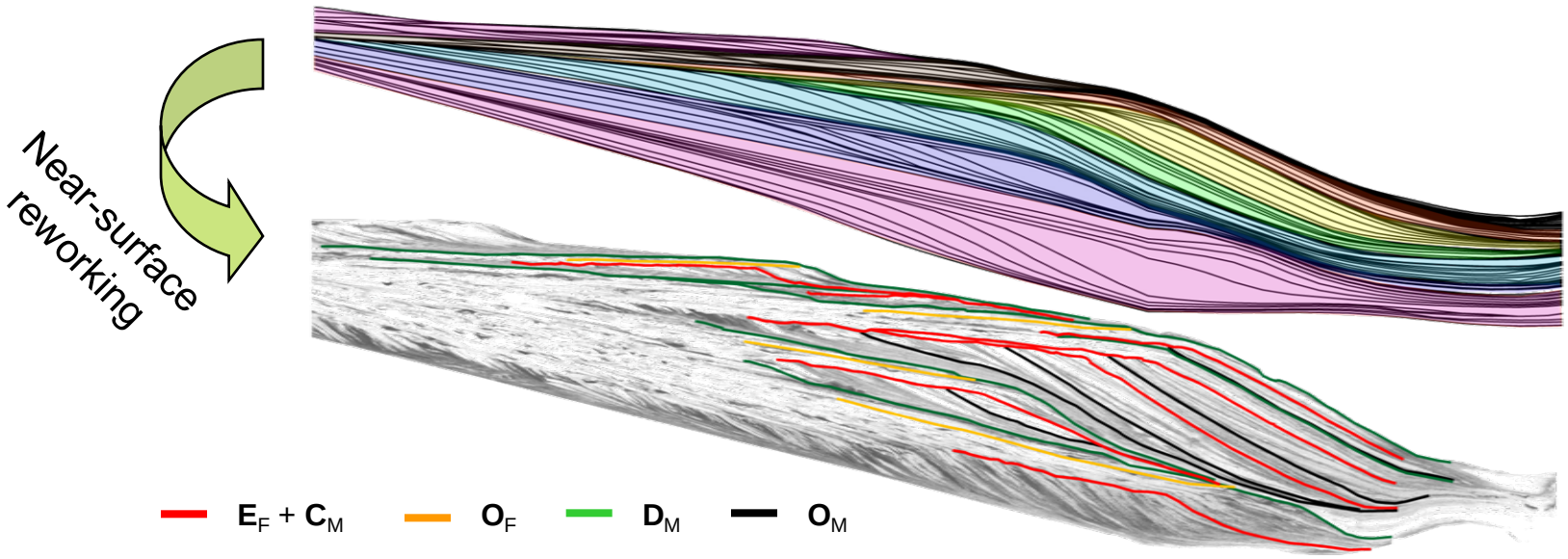


Destruction of original topography:

Difficult to state unequivocally that 8 stratigraphic cycles are present

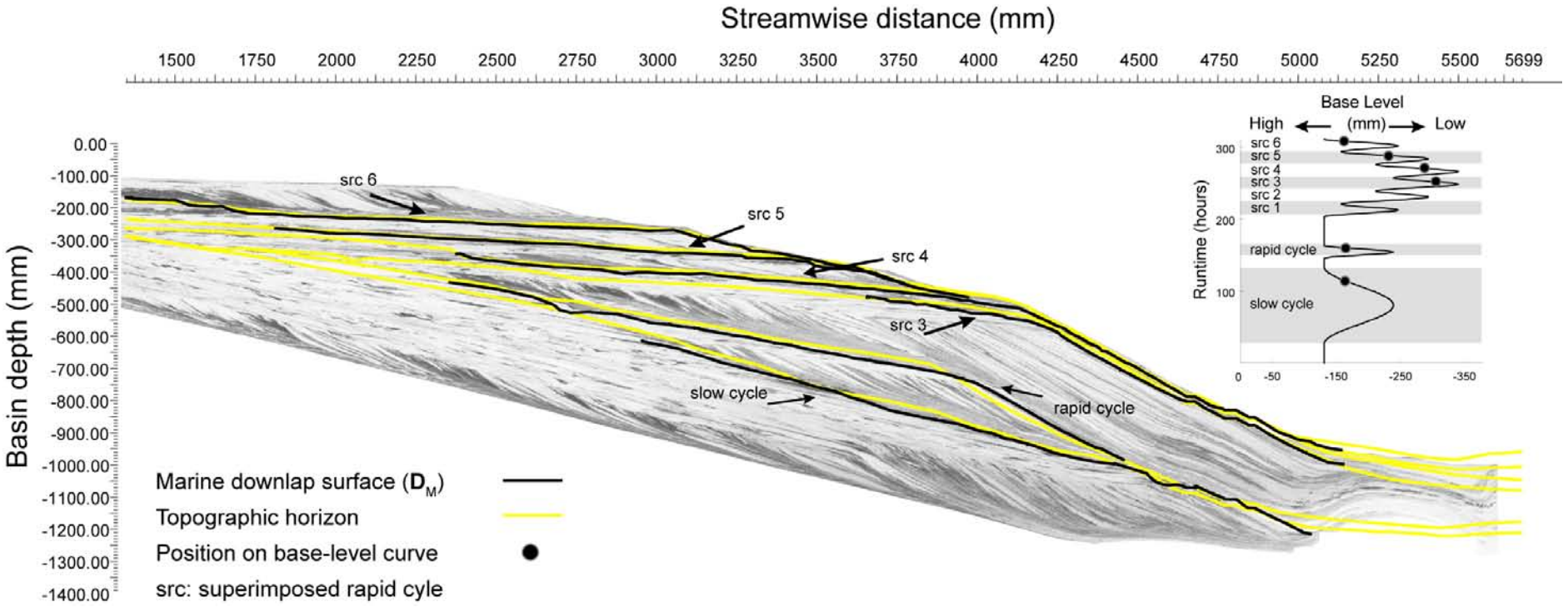
Scale independent form of complexity:

Inevitably, the stratigraphy is an incomplete and composite record of deposition



Stratigraphic surfaces: time significance: $\mathbf{D}_M$

(Chronostratigraphic significance is proportional to geomorphic significance)

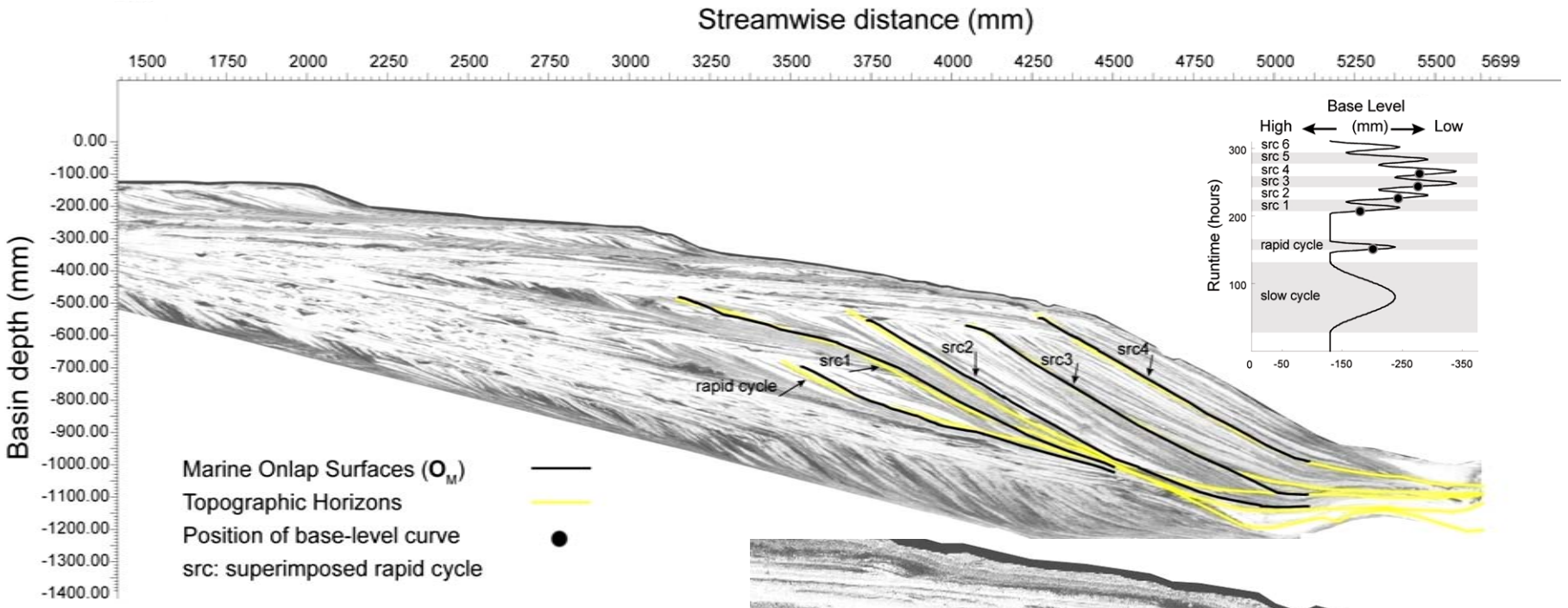


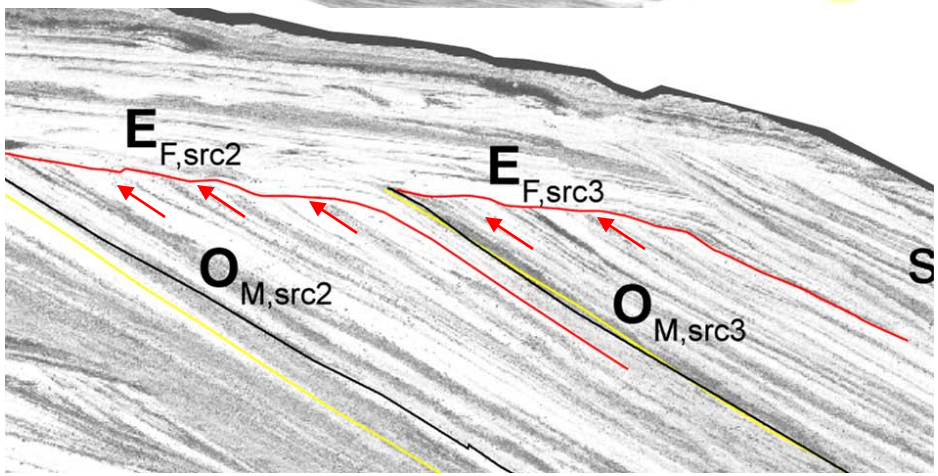
Closely correlate with topography around inflection point of base-level rise

Consistent despite unique base-level forcing scenarios

Stratigraphic surfaces: time significance: O_M

(Chronostratigraphic significance is proportional to geomorphic significance)





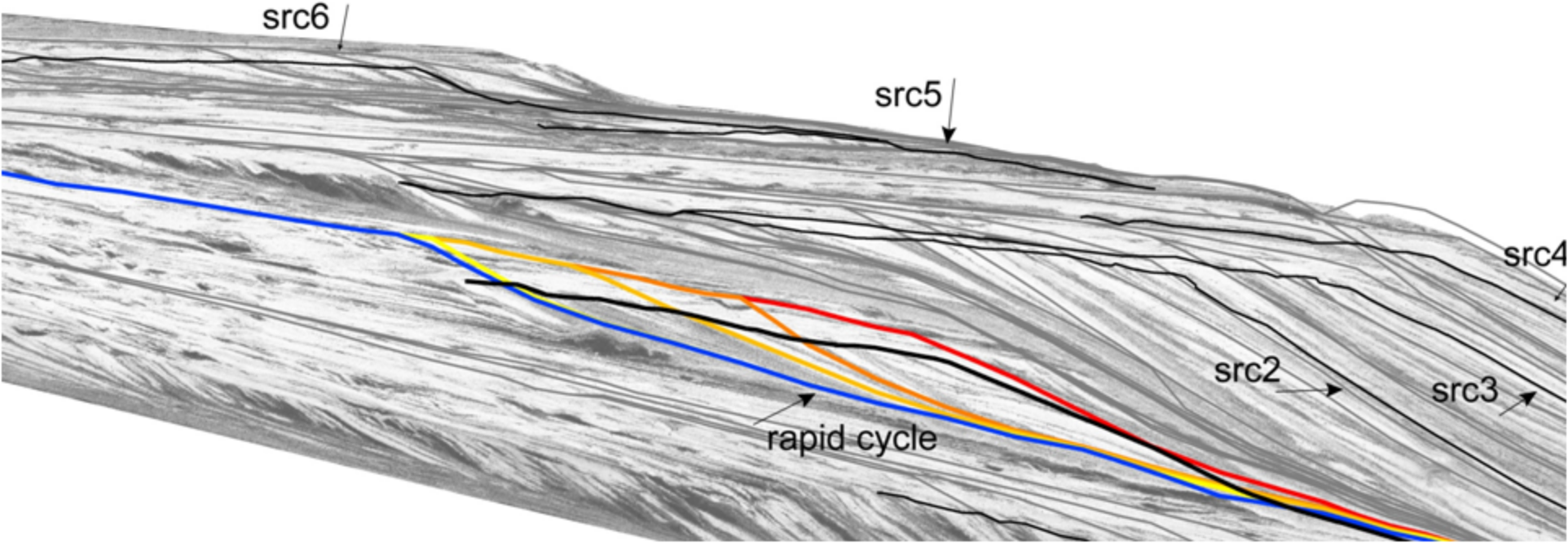
Best preservation potential

Break out cycles amidst cryptic foresets

Reveal multiple E_F

Stratigraphic surfaces: time significance: E_F

(Chronostratigraphic significance is proportional to geomorphic significance)



To topographic resolution, E_F spans the base-level fall period

At base-level minimum E_F below topography (by up to 3 channel depths!)

Deep erosion etches E_F locally

No clear geomorphic equivalency

Stratigraphic surfaces: time significance: $\mathbf{E}_F$

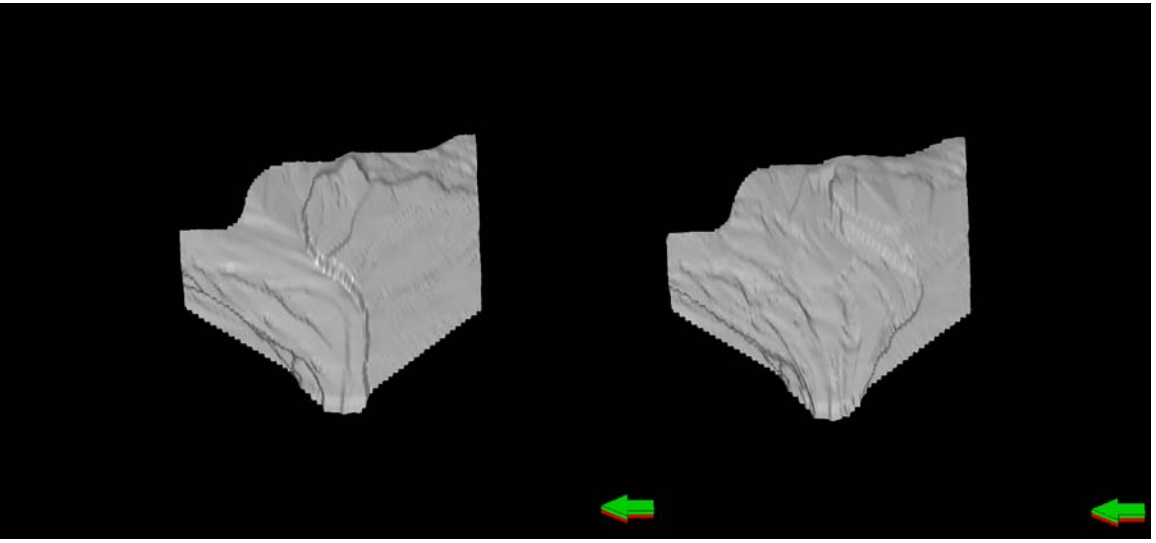
Quantify geomorphic significance of $\mathbf{E}_F$ using topography data

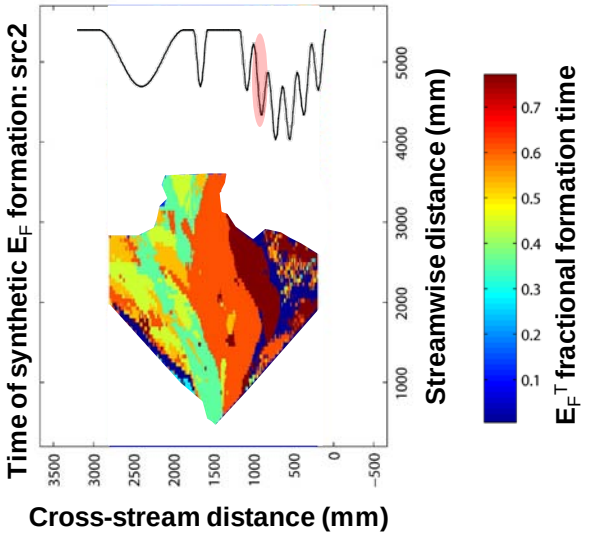
$\mathbf{E}_F{}^T(t) \neq$ topography (t)

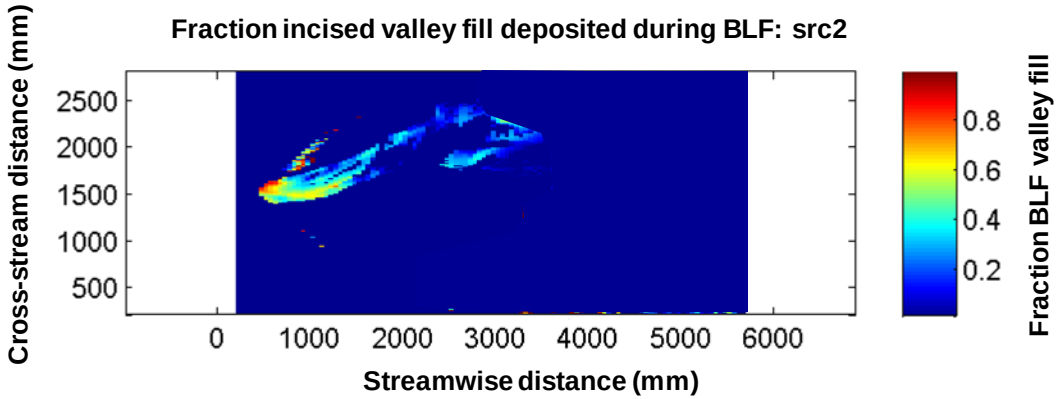
$\mathbf{E}_F{}^T$ forms over entire base-level cycle

Evolving topography: src2

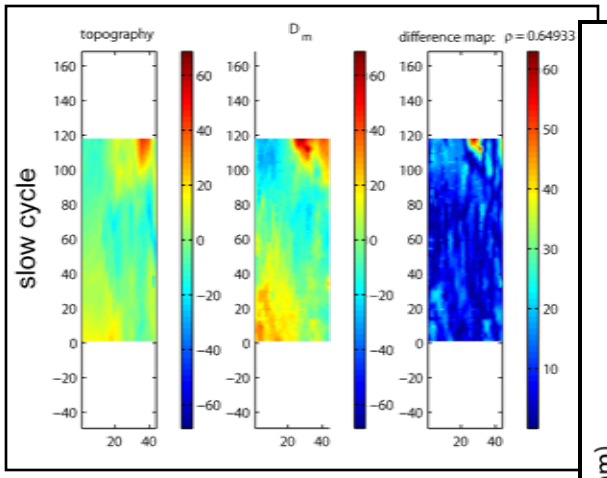
Evolving $E_F{}^T$: src2

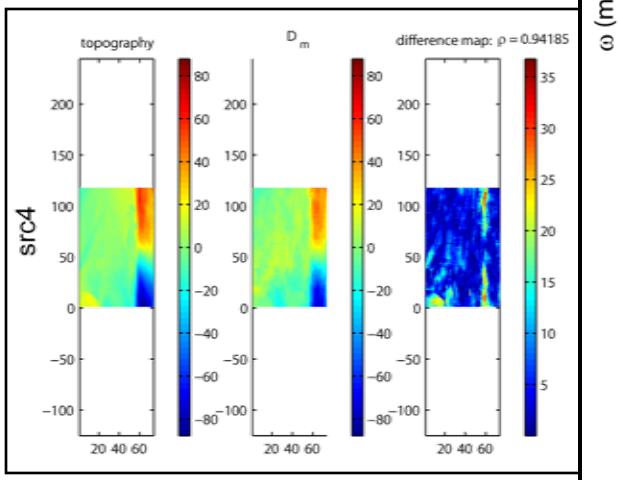


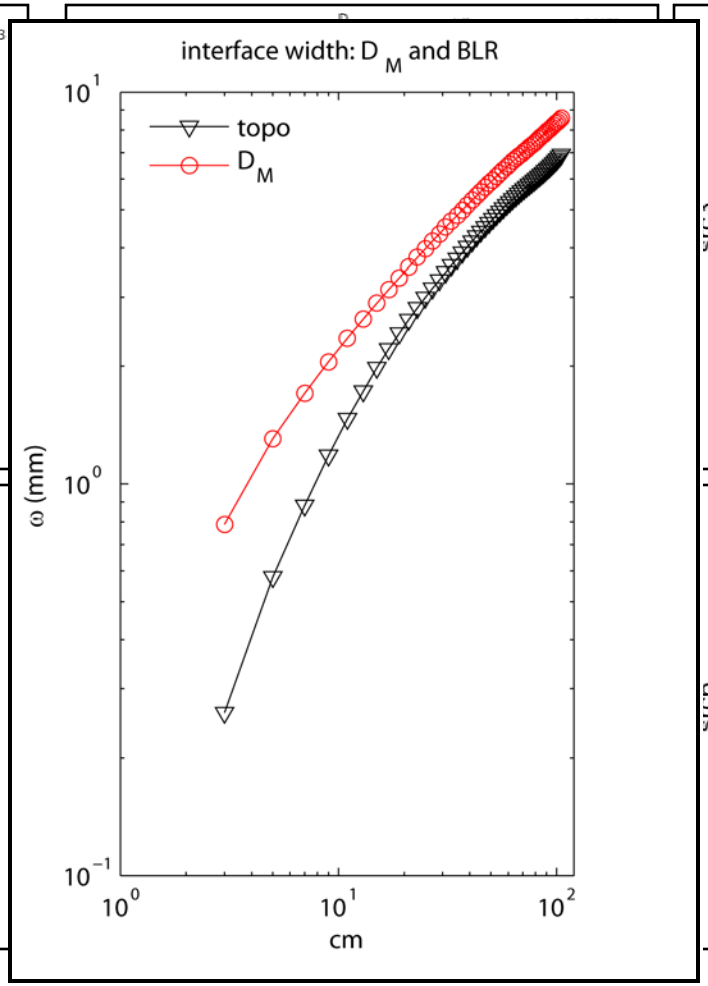


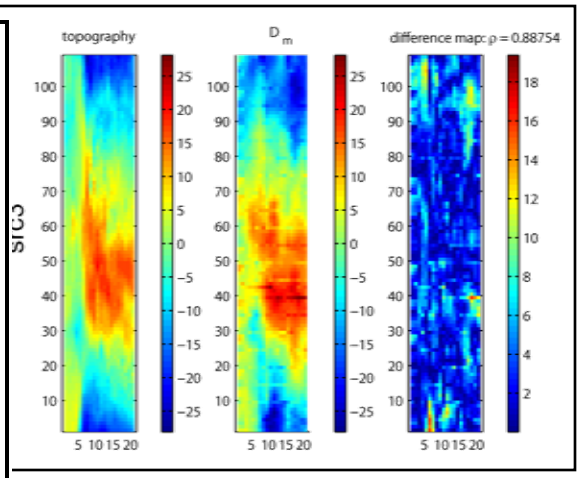


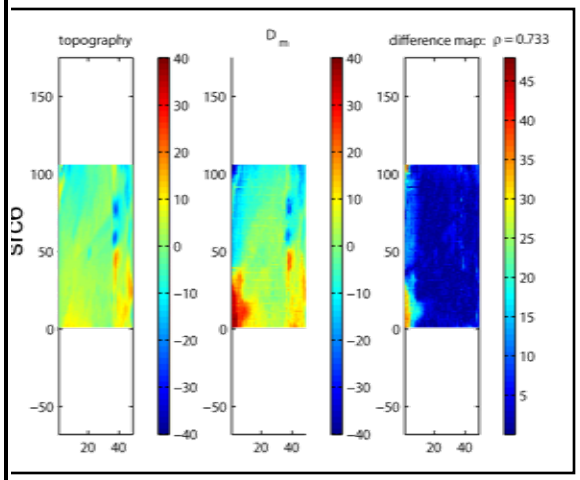
Stratigraphic surfaces: spatial structure: $\mathbf{D_M}$









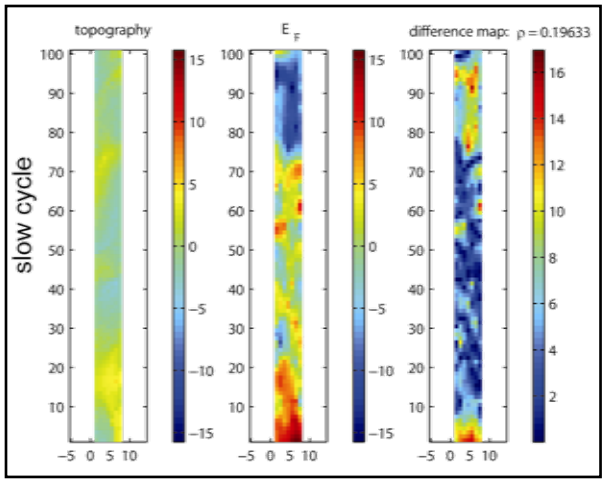


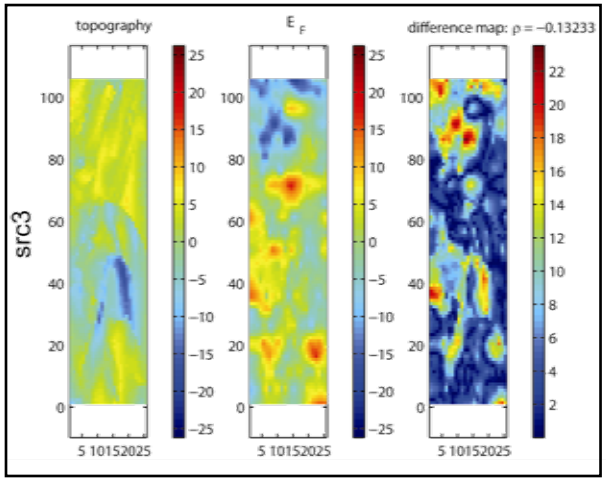
cross stream

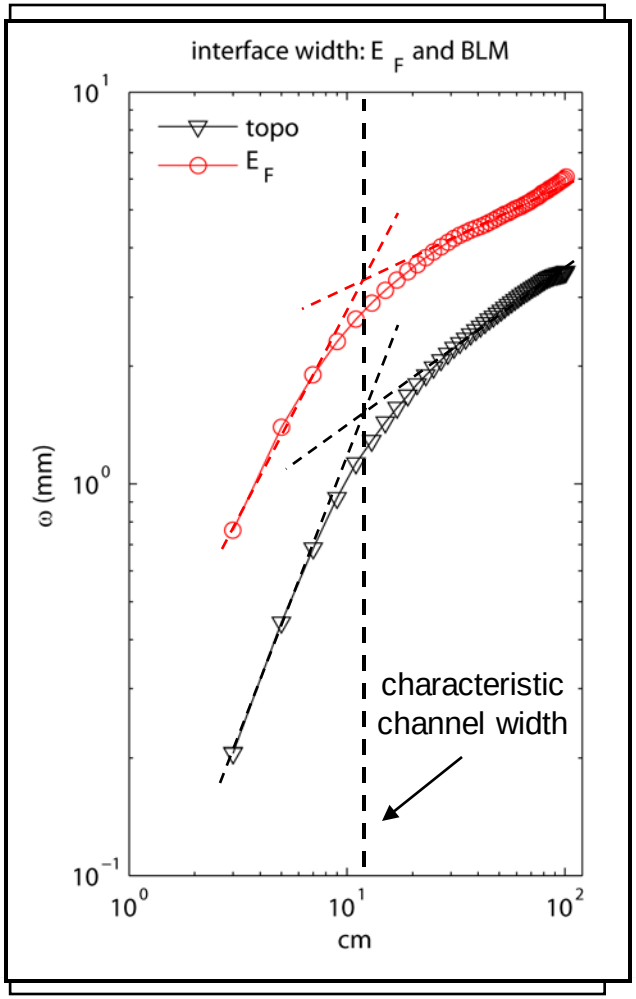
streamwise

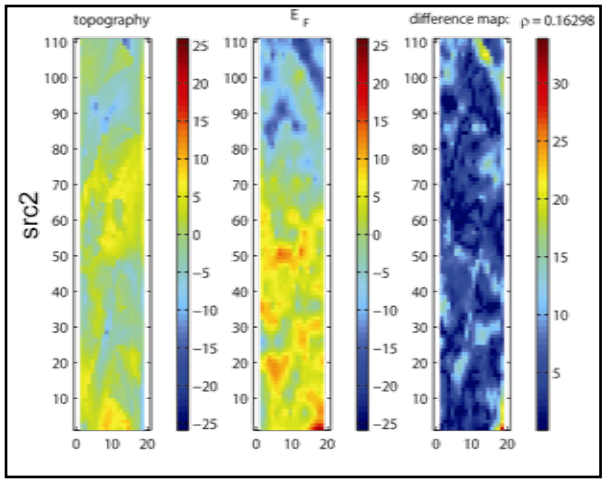
$\mathbf{D_M}$ ~= topography

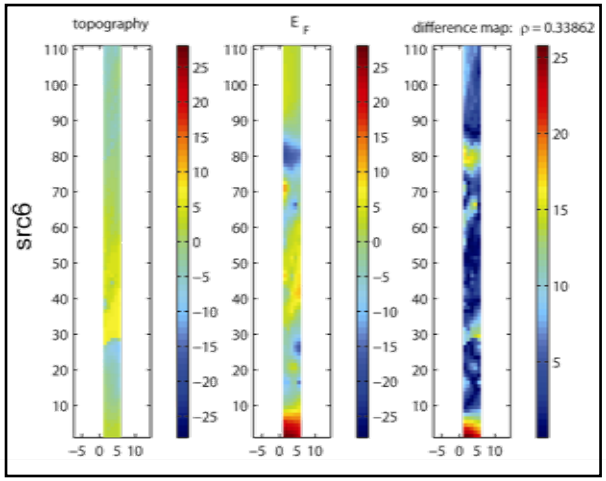
Stratigraphic surfaces: spatial structure: $\mathbf{E}_F$











cross stream

streamwise

$\mathbf{E}_F \neq$ topography

Sediment mass migration

XES02 stratigraphic surfaces result from and are primary indicators of shifts in the basinal mass balance

How well does the bounding strata stacking arrangement honor the known depositional history?

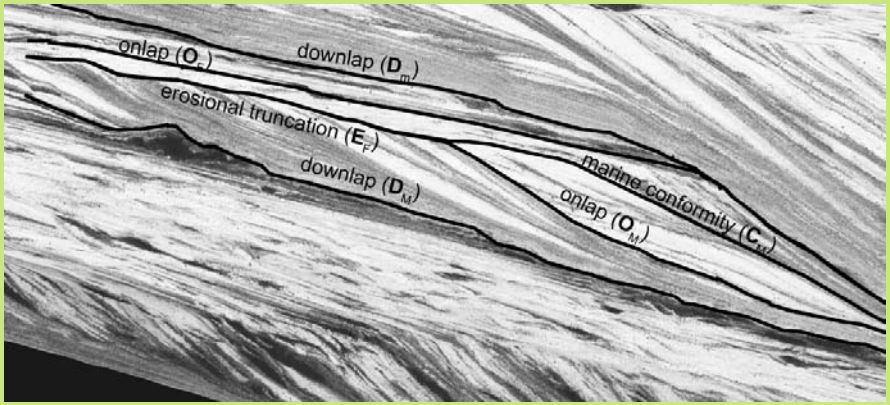
$D(s)$, $D(t)$ = centroid =

$$\bar{x} = \frac{1}{v}\int_R x\delta(x,y)dA$$

$$\bar{y} = \frac{1}{v}\int_R y\delta(x,y)dA$$

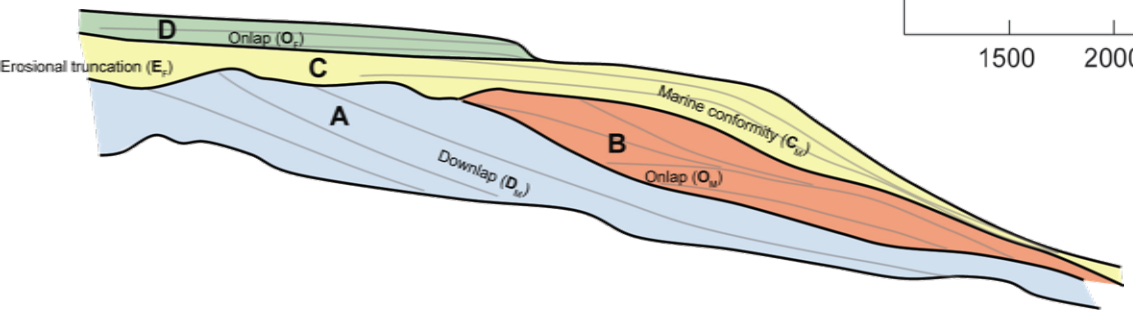
Average depositional position

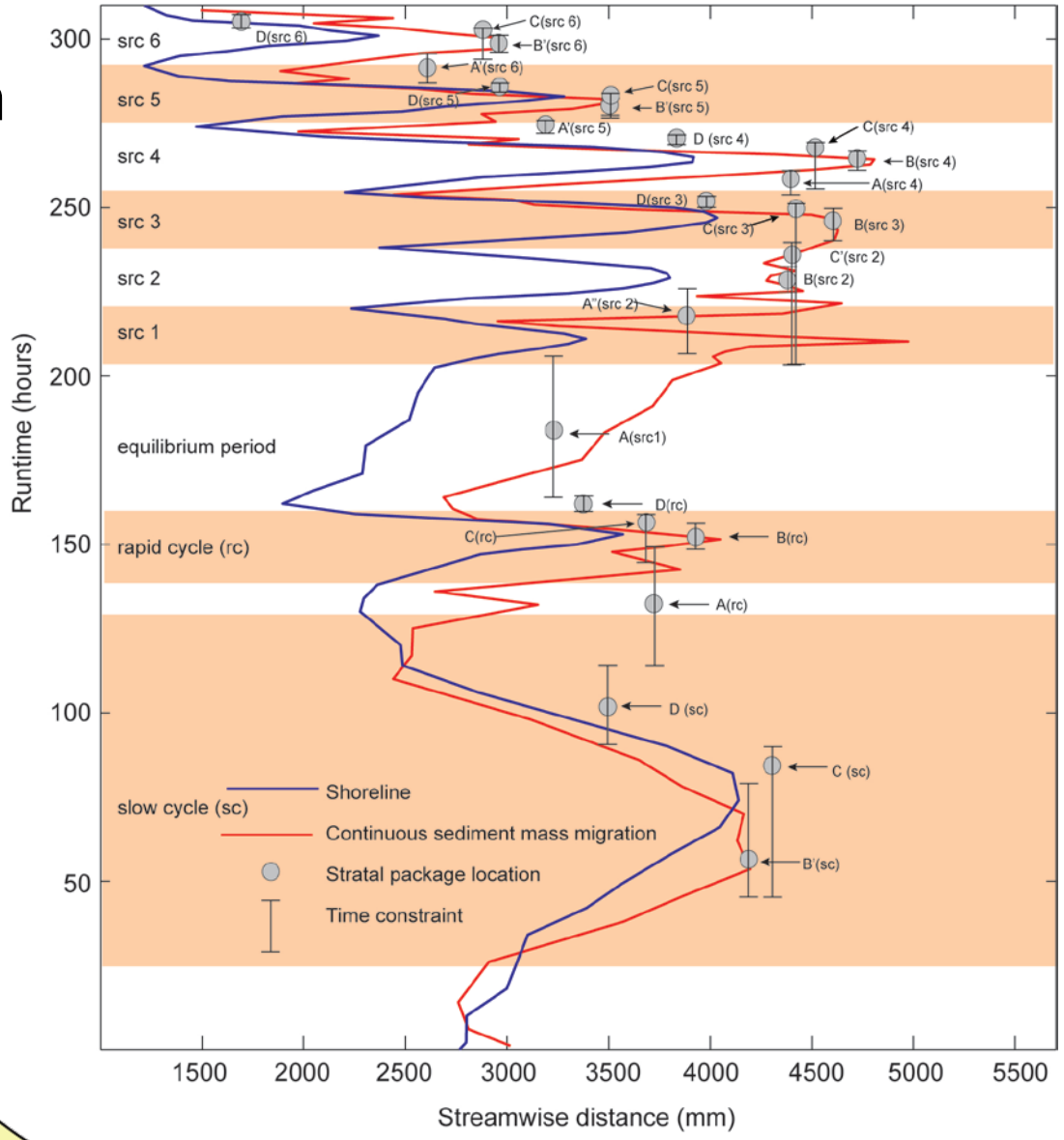
$D(s)$



$D(t)$

Sediment mass migration





Key results

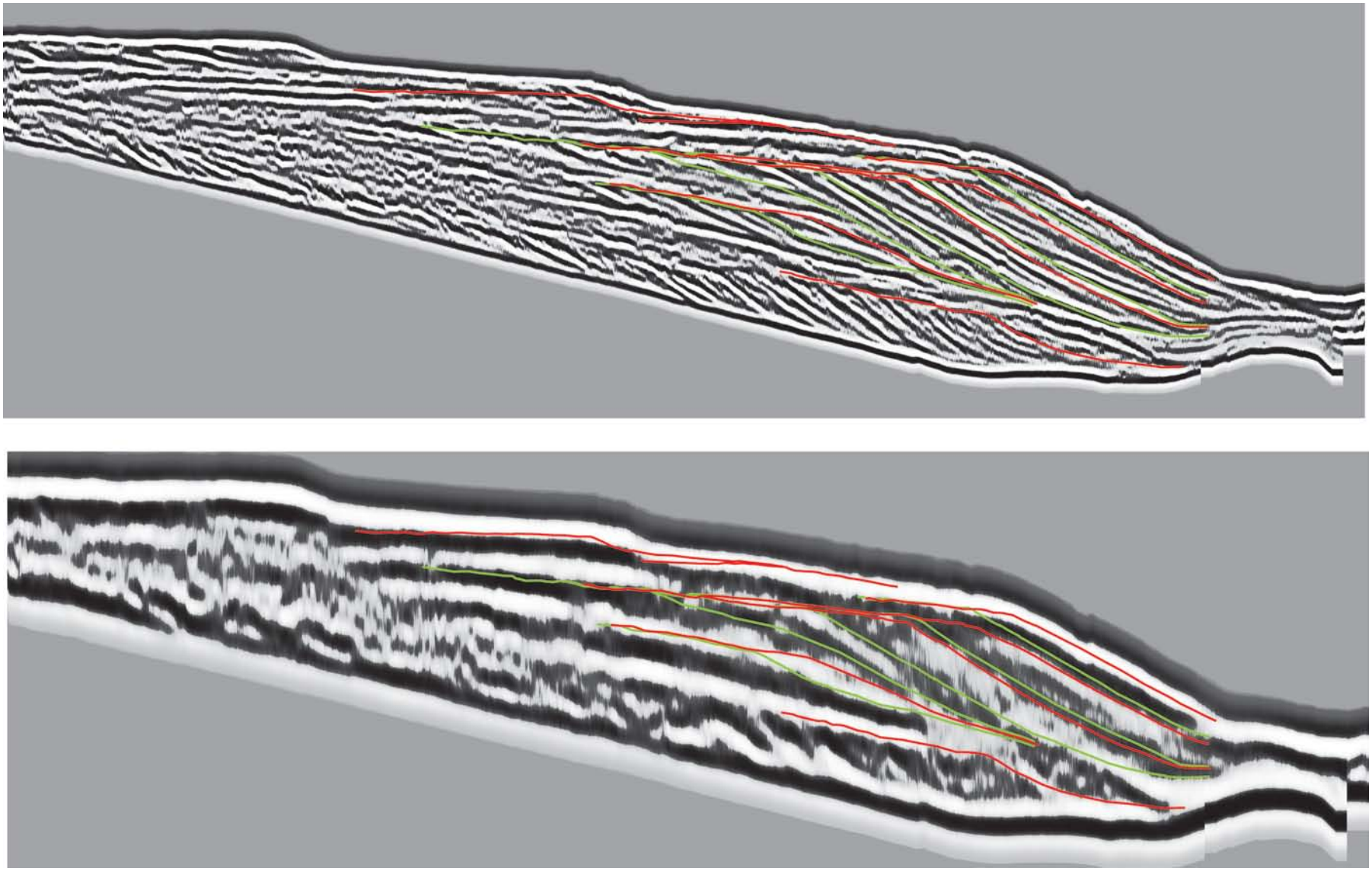
Mass balance effects from variable base level produce similar stratigraphic discordances at field and experimental scales that permit discretization of deposition

O_M and **D_M** demonstrate closest time equivalence with the deposit surface

O_M and **D_M** Are robust indicators of base-level fall and rise, respectively

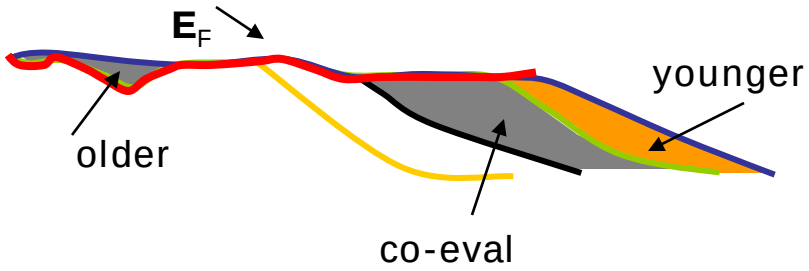
E_F has no clear geomorphic or absolute chronostratigraphic significance

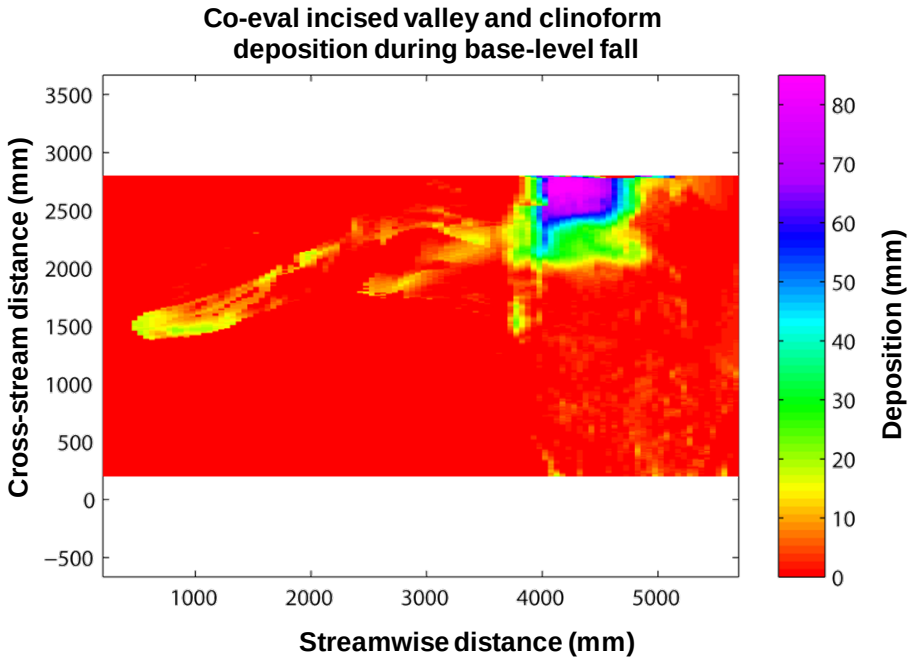
Stacking arrangement of strata honors the known preserved depositional history



Stratigraphic surfaces: time significance: $\mathbf{E}_F$

(Chronostratigraphic significance is proportional to geomorphic significance)





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