What Happened to My Marine Reservoir?
Implications of Falling Stage and Lowstand Fluvial Sediment Storage
during “Sequence-Boundary” Scour for Sand Starvation of
Coastal Marine Reservoirs*

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Abstract

Recent flume and field studies show that sediment may be stored by fluvial aggradation and lateral migration during regression, resulting in sediment starvation in coeval marine environments. In extreme cases, this may result in storage of all sediment within the fluvial system and complete starvation, or “autodetachment,” of the contemporary marine shoreline. Complete sediment starvation of the shore is still theoretical, and likely rare. Several recent field studies, coupled with new ideas regarding the scour processes of sequence boundaries, however, suggest that significant falling and lowstand fluvial sand storage commonly results in diminished to near total reduction of marine reservoir sand.

Newer views on scour of the “subaerial unconformity” sequence boundary show that it does not actually record a surface of exposure and near-complete bypass of sediment at lowstand as originally presumed, but rather records a composite surface formed by lateral migration and incision of rivers that ‘carve-and-cover’ the subaerial unconformity throughout regression. This carve-and-cover process means that fluvial sediment is deposited above this surface throughout the regressive phase. Because transport of sand lags transport of suspended load, regressive fluvial sediments disproportionally sequester the sandy fraction. Coastal Quaternary systems and the Cretaceous of the Western Interior provide several examples where coastal systems were deprived of sandy sediment to varying degrees during regression. Sand starvation ranges from minimal, resulting in prominent regressive coastal sand reservoirs, to near-complete, in which case lowstand terminal estuaries with negligible coastal sand deposition result. Partial to near-complete "sand autodetachment", in which there is sand starvation of marine reservoirs, appears more pronounced where regressive slopes are low, compared to river profiles and where base-level remains relatively stable during regression. Such minimally incised systems are common where stable base-level promotes lateral migration of channels during falling and lowstand stage, enhancing fluvial sand storage.
Selected References

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Holbrook, J.M., and J.P. Bhattacharya, 2012, Reappraisal of the sequence boundary in time and space: Case and considerations for an SU (subaerial unconformity) that is not a sediment bypass surface, a time barrier, or an unconformity: Earth-Science Reviews, v. 113/3-4, p. 271-302.


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Sediment "Bypass"

"Back-Filling"

Lowstand Normal Regression and Sequence Boundary Burial

Back-filled Valley

Normal Regression

Lowstand Wedge

Sequence Boundary Formation and Lowstand Deposition

Lowstand Wedge

Lowstand Surface of Erosion

Correlative Conformity

Condensed Section

Lowstand Fan

(Van Wagoner et al., 1990)
Fluvial Sequence Stratigraphy

(Shanley & McCabe, 1994)
Maximum Lowstand and Significant Marine Deposition
(Marine Volume = Bypassed Hinterland Sediments + Incised Valley Volume)

Late Lowstand and Diminished Marine Deposition
(Marine Volume = Hinterland Sediments – Valley-fill Volume)
A Bypass Alternative

(Holbrook and Bhattacharya, 2012)
A Bypass Alternative

(Strong and Paola, 2008)

Sequence boundary formed over 75% of the entire sea level cycle!!!
Bypass

Highstand/Early Falling Stage

Advanced Falling Stage

Early Lowstand

Late Lowstand

Late Transgression

Cut-and-Cover

Highstand/Early Falling Stage

Advanced Falling Stage

Early Lowstand

Late Lowstand

Late Transgression

SU Unconformity?
Maximum Lowstand and Significant Marine Deposition
(Marine Volume = Bypassed Hinterland Sediments + Incised Valley Volume)

Late Lowstand and Diminished Marine Deposition
(Marine Volume = Hinterland Sediments – Valley-fill Volume)

Falling and Early Lowstand = Marine

Sediment Storage?
Sediment Storage?

Falling and Early Lowstand = Fluvial and Marine

Cut-and-Cover

Highstand/Early Falling Stage

Advanced Falling Stage

Early Lowstand

Late Lowstand

Late Transgression

Older Fluvial Mesa Rica Sandstone above Younger Glencairn/Mesa Rica Deltaic strata across SU/RCS/SB3.1
Narrow “Buttress” Valleys and Minimal Storage

“Buffer” Valleys with Lateral Planation and Significant Storage

(Holbrook and Bhattacharya, 2012)
Narrow “Buttress” Valleys and Minimal Storage

Q Gulf Coast

Falling Stage Fluvial

Regressive Composite Scour (RCS)/ Composite Valley-fill ‘Unconformity’
“Buffer” Valleys with Lateral Planation and Significant Storage

Falling Stage

Maximum Lowstand

B) Regression over Slope Approximating the Channel Equilibrium Profile

K Western Interior
Multistory incision and fill, south side of I-70. These incisions have historically been interpreted as distributary channels. Detailed analysis suggest that they are small, incised valleys.
The “LAB” Models (Leeder, Allen, Bridge) (Bridge and Leeder 1979)

(Catuneanu 2006)
Multistory incision and fill, south side of I-70. These incisions have historically been interpreted as distributary channels. Detailed analysis suggest that they are small, incised valleys.
Mesa Rica and Glencairn Fms

**Fluvial Volume**
14m x 37500km² = 500km³

**Marine Volume** at (50% sand)
150km³ (Falling) + 250km³ (Lowstand) = 400km³

If SU is Cut-and-Cover Diastem
Sand storage equal for Fluvial and Marine

If SU is Bypass Unconformity
Marine Sand, Minor Fluvial Sand Storage

(Holbrook and Bhattacharya, 2012)
Autodetachment?

(Petter and Muto, 2008)

Sand Autodetachment?

Valley incision and terrace formation

Low-sinuosity high gradient rivers

1-10's km

1-10's m
Terminal Estuaries in the K Clearwater Fm, Canada

(Feldman et al., 2008)
Mesa Rica Ss

Glencairn Fm

SU 3

Upper KMR Terminal Estuaries

(Holbrook, et al., 2006)
Variation in Shoreline Sand Preservation
K Dunvegan Fm, Alberta

(Holbrook and Bhattacharya, 2012)
(Holbrook and Bhattacharya, 2012)
Conclusions

SU is probably not a bypass surface or unconformity

Falling and lowstand fluvial sand storage can be high to the expense, and possible autodetachment, of marine reservoirs

MRS is probably a better correlation surface than given credit