A Source-to-Sink Approach to Drainage and Sediment Flux in Thrust and Foreland Systems – Utah-Wyoming-Colorado, US Rockies*

Ole J. Martinsen[1]

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Abstract

Fold and thrust belts and adjacent foreland basins at first appear as relatively simple source-to-sink systems in terms of drainage and temporary storage and ultimate permanent sediment deposition in the foreland basin. Sediment routing from the hinterland should in principle be directed in a relatively predictive manner to the foreland basin albeit through one or more piggyback basins. Key learnings from application of source-to-sink methodology to various other tectonic settings suggest there are semi-quantitative relationships between for example areal size of the catchment and the area and volume of marine deposits. This relationship implies only limited permanent storage of sediment in route to the ultimate sink, and insignificant loss of sediment out of the source-to-sink system. Several challenges exist to establish a reliable source-to-sink methodology in thrust and foreland systems: (i) Catchments and antecedent drainage systems are not commonly preserved or easily observable in thrust and fold belts because of cannibalization of these areas during continued thrusting. (ii) Where significant piggyback basins are formed, lateral drainage out of the system is likely as well as permanent sediment storage in the piggyback basins. (iii) In thrust and foreland systems with significant foreland deformation, sediments can be sourced from foreland uplift areas thus adding sediment volumes from other sources than the thrust belt itself. (iv) Extensional collapse of the thrust belt itself may form drainage in alternate directions to from the thrust belt to the foreland. The Utah-Idaho-Wyoming thrust belt in the western USA formed largely from the early Cretaceous to the early Paleogene. It shows prominent examples of the complexities of the thrust belt to foreland basin source-to-sink systems, and offers unresolved challenges in terms of correlating between thrust belt and foreland. A source-to-sink approach offers at least a qualitative framework for understanding drainage, transport/bypass and intermediate and permanent sediment storage despite that various parts of the source-to-sink system are not preserved, such as the catchment. Modern and Recent systems in the area yield substantial information about the antecedent development of the Utah-Wyoming thrust system and can offer proxy data for establishment of at least a semi-quantitative relationships between various source-to-sink segments in the Utah-Idaho-Wyoming thrust and foreland system.

Selected References

Allen, P.A., J.J. Armitage, A. Carter, R.A. Duller, N.A. Michael, H.D. Sinclair, A.L. Whitchurch, and A.C. Whittaker, 2013, The *Q*s Problem: Sediment Volumetric Balance of Proximal Foreland Basin Systems: Sedimentology, v. 60, p. 102-130.

Aschoff, J.L., and R.J. Steel, 2011, Anatomy and Development of a Low-accommodation Clastic Wedge, Upper Cretaceous, Cordilleran Foreland Basin, USA: Sedimentary Geology, v. 236/1-2, p. 1-24.

Aschoff, J., and R. Steel, 2011, Anomalous Clastic Wedge Development during the Sevier-Laramide Transition, North American Cordilleran Foreland Basin, USA: Geological Society of America Bulletin, v. 123/9-10, p. 1822-1835.

Blakey, R.C., 2014, Paleogeography: Colorado Plateau Geosystems, Phoenix, AZ.

DeCelles, P.G., 1994, Late Cretaceous-Paleocene Synorogenic Sedimentation and Kinematic History of the Sevier Thrust Belt, Northeast Utah and Southwest Wyoming: Geological Society of America Bulletin, v. 106, p. 32-56.

DeCelles, P.G., and W. Cavazza, 1999, A Comparison of Fluvial Megafans in the Cordilleran (Upper Cretaceous) and Modern Himalayan Foreland Basin Systems: Geological Society of America Bulletin, v. 111, p. 1315-1334.

DeCelles, P.G., and K.A. Giles, 1996, Foreland Basin Systems: Basin Research, v. 8, p. 105-123.

Dickinson, W.R., M.A. Klute, M.J. Hayes, S.U. Janecke, E.R. Lundin, M.A. McKittrick, and M.D. Olivares, 1988, Paleogeographic and Paleotectonic Setting of Laramide Sedimentary Basins in the Central Rocky Mountain Region: Geological Society of America Bulletin, v. 100, p. 1023-1039.

Gomez-Veroiza, C.A., and R.J. Steel, 2010, Iles Clastic Wedge Development and Sediment Partitioning within a 300-km Fluvial to Marine Campanian Transect (3 m.y.), Western Interior Seaway, Southwestern Wyoming and Northern Colorado: American Association of Petroleum Geologists Bulletin, v. 94/9, p. 1349-1377.

Helland-Hansen, W., T.O. Sømme, O.J. Martinsen, I. Lunt, and J. Thurmond, 2016, Deciphering Earth's Natural Hourglasses: Perspectives on Source-to-Sink Analysis: Journal of Sedimentary Research, v. 86/9, p. 1008-1033.

Helland-Hansen, W., and O.J. Martinsen, 1996, Shoreline Trajectories and Sequences: Description of Variable Depositional-Dip Scenarios: Journal of Sedimentary Research, v. 66/4, p. 670-688.

Martinsen, O.J., R.S. Martinsen, and J.R. Steidtmann, 1993, Mesaverde Group (Upper Cretaceous), Southeastern Wyoming: Allostratigraphy Versus Sequence Stratigraphy in a Tectonically Active Area: American Association of Petroleum Geologists Bulletin, v. 77/8, p. 1351-1373.

Rudolph, K.W., W.J. Devlin, and J.P. Crabaugh, 2015, Upper Cretaceous Sequence Stratigraphy of the Rock Springs Uplift, Wyoming: The Mountain Geologist, v. 52/3, p. 13-157.

Sømme, T.O., W. Helland-Hansen, O.J. Martinsen, and J.B. Thurmond, 2009, Relationships between Morphological and Sedimentological Parameters in Source-to-Sink Systems: A Basis for Predicting Semi-quantitative Characteristics in Subsurface Systems: Basin Research, v. 21/4, p. 361-387.

Steidtmann, J.R., and J.G. Schmitt, 1988, Provenance and Dispersal of Tectogenic Sediments in Thin-Skinned, Thrusted Terrains: New Perspectives in Basin Analysis, Springer, New York, p. 353-366.

Yonkee, A., and A.B. Weil, 2010, Reconstructing the Kinematic Evolution of Curved Mountain Belts: Internal Strain Patterns in the Wyoming Salient, Sevier Thrust Belt, U.S.A.: Geological Society of America Bulletin, v. 122/1-2, p. 3-23.

A Source-to-Sink approach to drainage and sediment flux in thrust and foreland systems – Utah-Wyoming-Colorado, US Rockies

Ole J. Martinsen, Statoil

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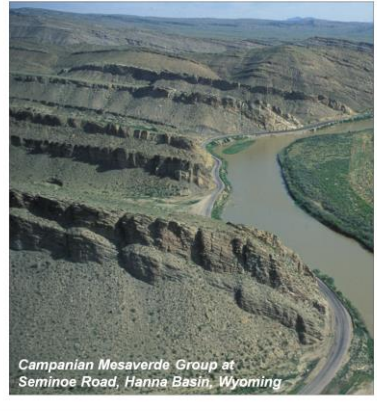
Classification: Open 13 juni 2016

Key challenge

- Do established Source-to-Sink (S2S) concepts work in thrust belt and foreland systems?
- Use Utah-Wyoming thrust belt and related Upper Cretaceous Mesaverde Group foreland basin stratigraphy as example
  - >600 km transect
  - 1st order principles for sediment supply and storage



Campanian Mesaverde Group at Seminoe Road, Hanna Basin, Wyoming

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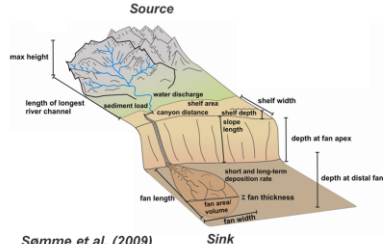
Presenter's notes: Thrust to foreland link never made confidently in Utah-Wyoming

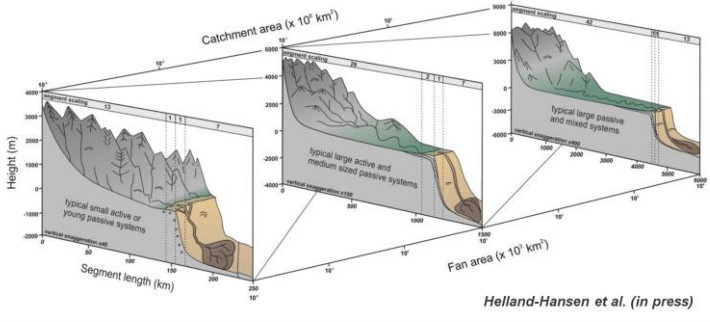
S2S: current concept

- Holistic way of thinking at basin and play scale
- Segments: predictive relationships
- Complements sequence stratigraphy
- Exploration at basin and play scale
- Semi-quantitative for good reasons
- Societal, academic, industrial use

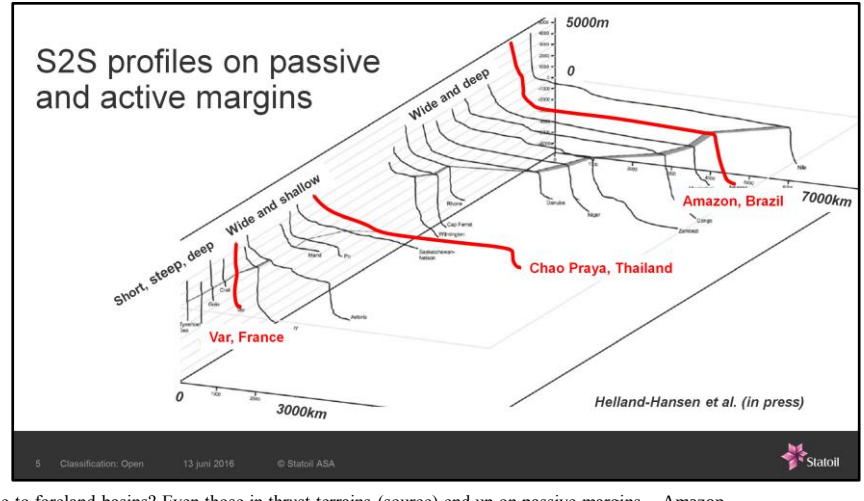
- *Erosion and bypass, sediment transport, intermediate and final storage*



S2S variability – thrust belt and foreland fit?



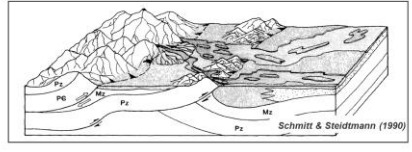
Presenter's notes: Challenge: basinal part-often continental margin



Presenter's notes: Resemblance to foreland basins? Even those in thrust terrains (source) end up on passive margins – Amazon.

Thrust and foreland systems sediment dispersal

- Tectonic and sediment supply complexity
  - Particularly where foreland uplifts
  - Many sediment sources: volume?
- Source-to-sink challenges
  - Segment definition
  - Catchment longevity and preservation
  - Intermediate and permanent storage areas en route to ultimate sink
  - Axial vs transverse vs landward transport



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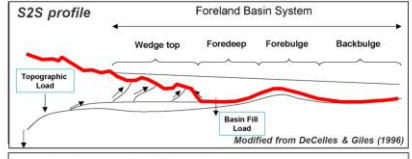
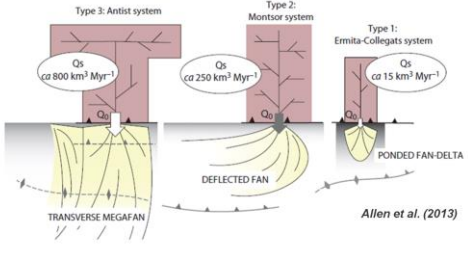
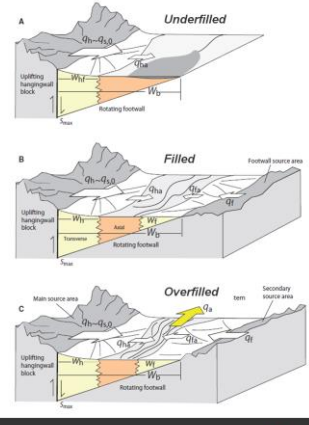


Thrust belt sediment routing





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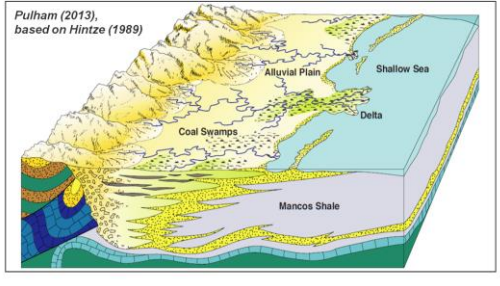
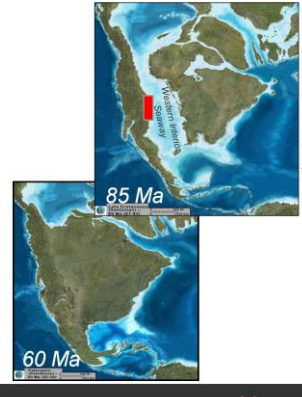
Presenter's notes: Alternating periods of deposition and incision upstream of topography, incision through uplift, local drainages oriented other directions, local storage

The Sevier thrust belt and foreland





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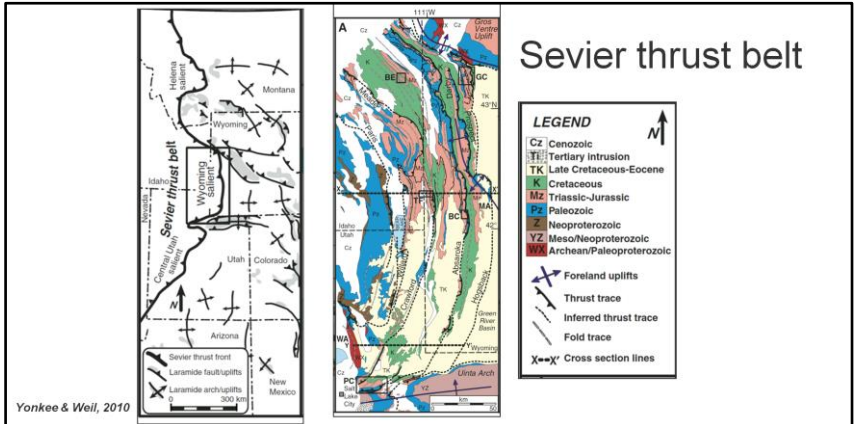
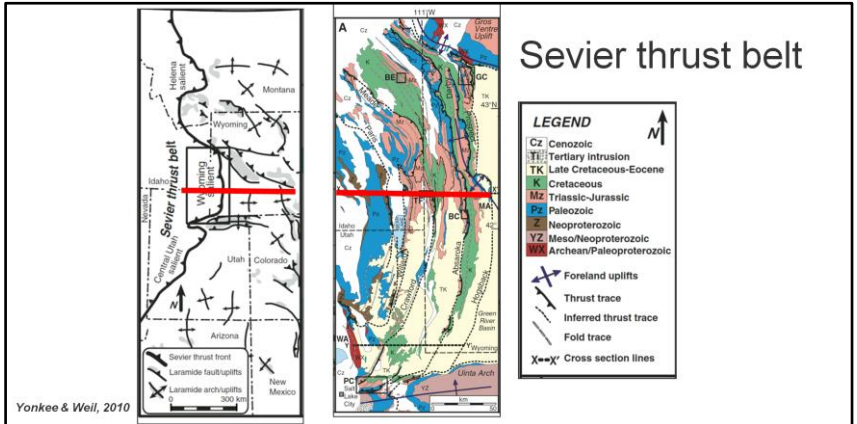


Presenter's notes: Piggyback fashion, piggyback basins, topography- highest topography sediment source moving basinwards
Cenozoic grabens, extensional collapse



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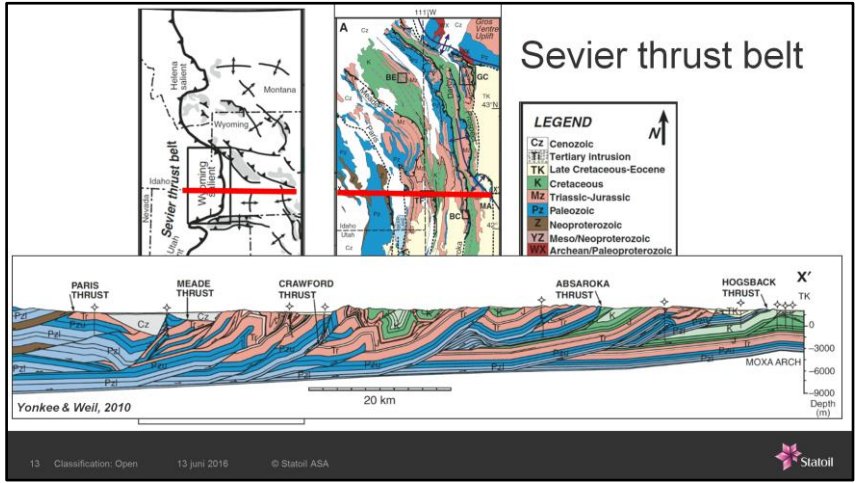

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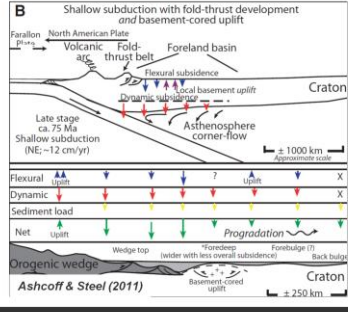
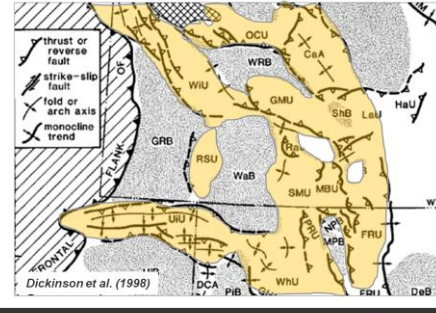
Cenozoic grabens, extensional collapse

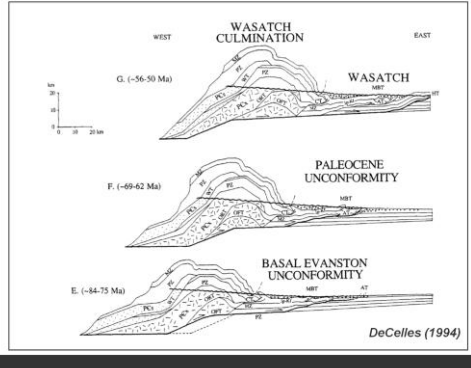
Foreland uplifts – related to shallow slab



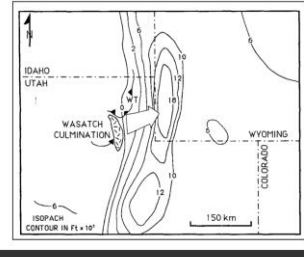
- Local sources and barriers to dispersal



Sevier thrust belt as sediment source - challenges



- Catchment volumes and rejuvenation
- Point-sourced supply
- Deposition in immediate foredeep



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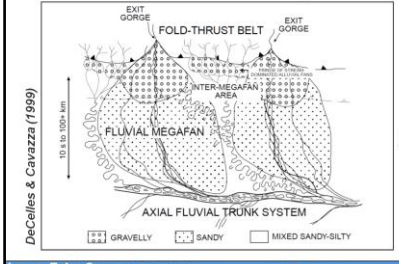
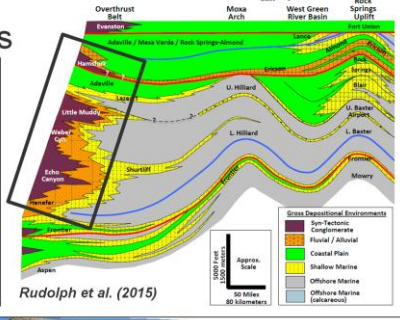
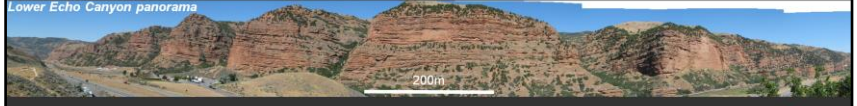
Presenter's notes: Local culmination, «local» sediment supply, elongate foredeep – how well do sediments bypass?

Sevier thrust belt systems







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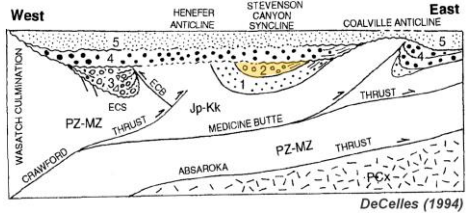
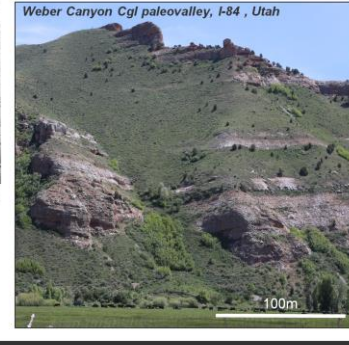
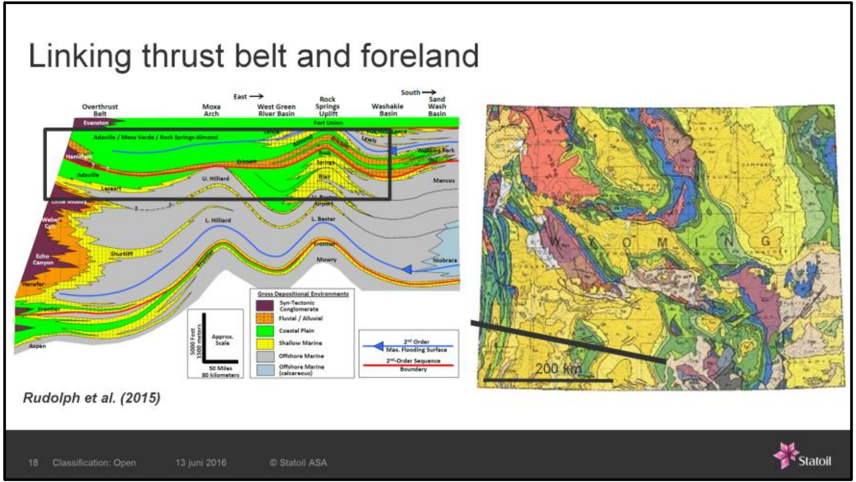
Sediment storage in thrust belt



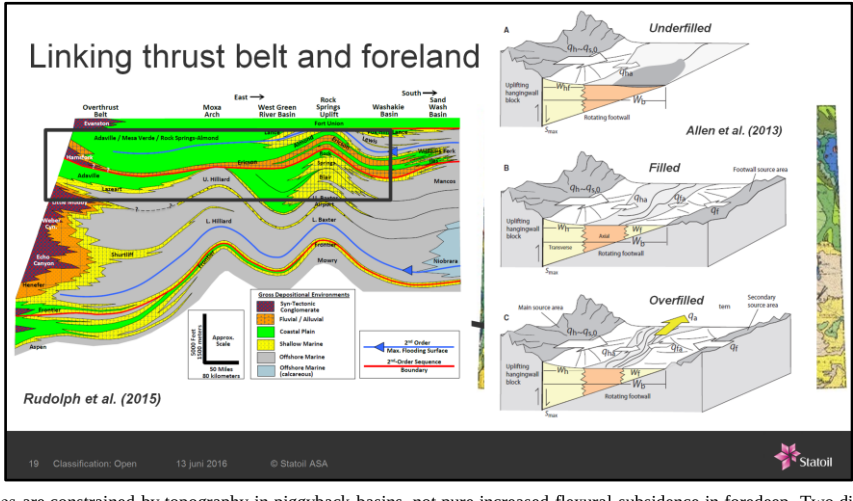
DeCelles (1994)



- Piggy-back basins with paleovalleys and transverse sediment supply
- Do these sediments reach the sink?



Presenter’s notes: Conglomerates are constrained by topography in piggyback basins, not pure increased flexural subsidence in foredeep. Two different systems.



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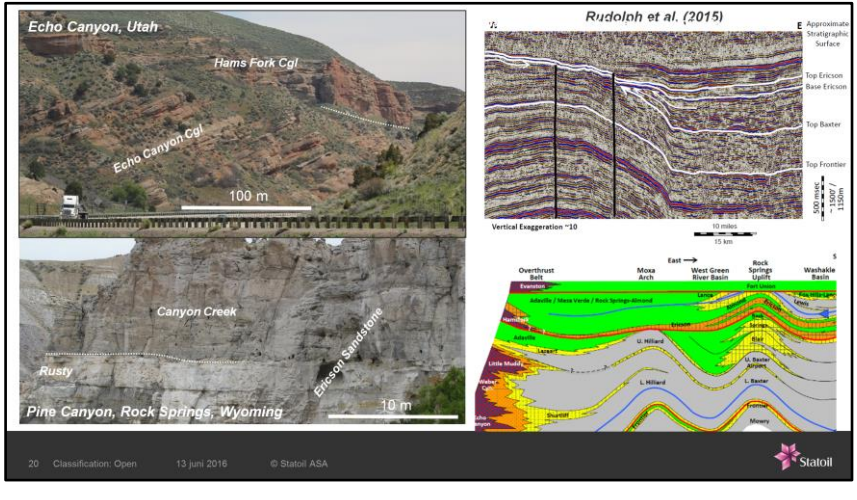
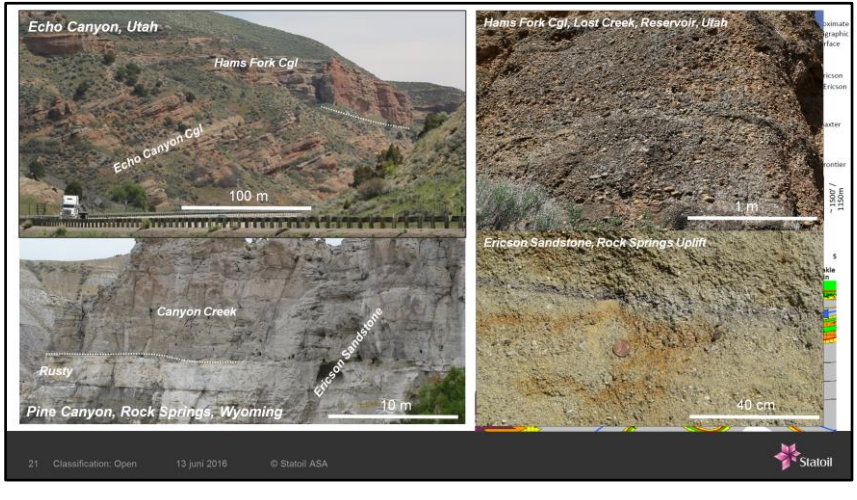

Echo Canyon, Utah
Hams Fork Cgl
Echo Canyon Cgl
100 m
Canyon Creek
Ericson Sandstone
Rusty
Pine Canyon, Rock Springs, Wyoming
10 m
Rudolph et al. (2015)
Approximate Stratigraphic Surface
Top Ericson
Base Ericson
Top Baxter
Top Frontier
500 msec
~ 1,500'
1150m
Vertical Exaggeration ~10
10 miles
15 km
East
Overthrust Belt
Moxa Arch
West Green River Basin
Rock Springs Uplift
Washakie Basin
Evanston
Fort Union
Adaville / Mesa Verde / Rock Springs-Almond
Hilliard
Ericson
Adaville
Lazeart
U. Hilliard
Little Muddy
Shurtliff
L. Hilliard
Frontier
Mowry
Statoil


Echo Canyon, Utah
Hams Fork Cgl
Echo Canyon Cgl
100 m
Canyon Creek
Rusty
Ericson Sandstone
10 m
Pine Canyon, Rock Springs, Wyoming
Hams Fork Cgl, Lost Creek, Reservoir, Utah
1 m
Ericson Sandstone, Rock Springs Uplift
40 cm
21 Classification: Open 13 juni 2016 © Statoil ASA
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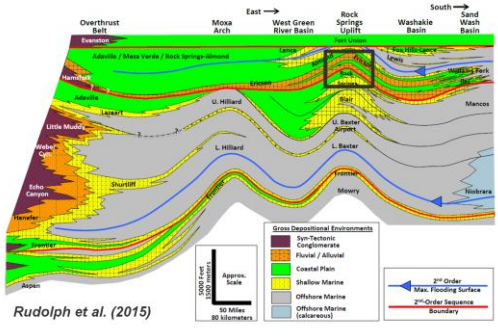
Shoreline and shelf, Rock Springs



Rudolph et al. (2015)

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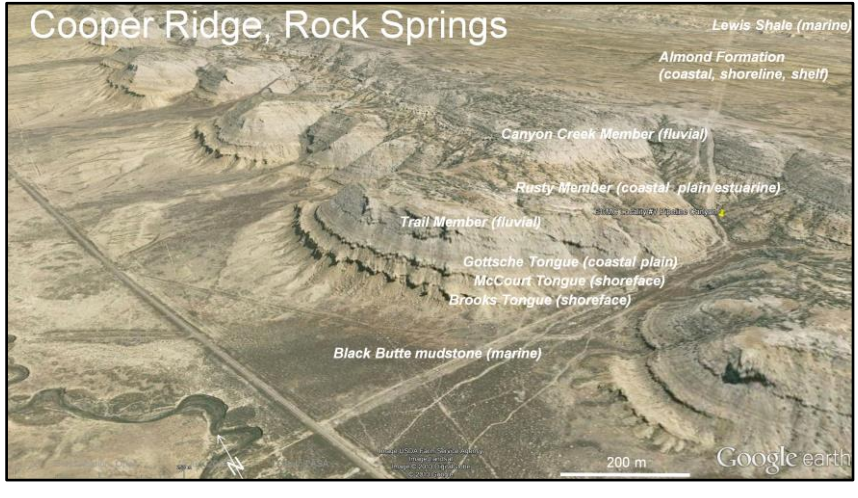
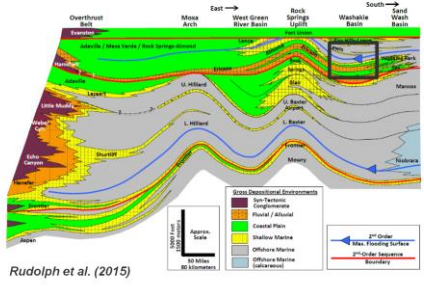

Cooper Ridge, Rock Springs
Lewis Shale (marine)
Almond Formation
(coastal, shoreline, shelf)
Canyon Creek Member (fluvial)
Rusty Member (coastal plain/estuarine)
Trail Member (fluvial)
Gottsche Tongue (coastal plain)
McCourt Tongue (shoreface)
Brooks Tongue (shoreface)
Black Butte mudstone (marine)
200 m
Google earth

Foreland uplifts



Rudolph et al. (2015)

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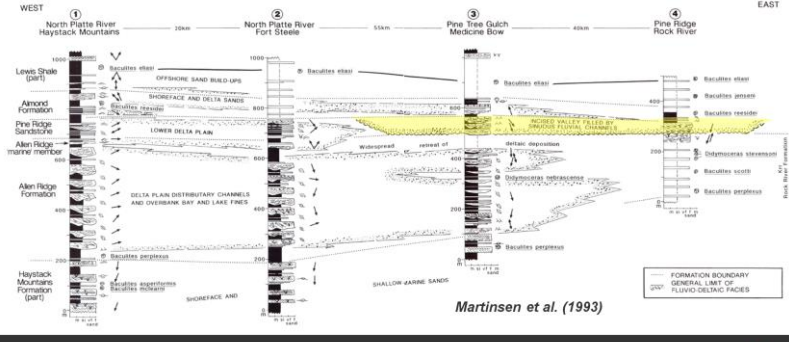
Foreland uplifts and local sediment sources



Martinsen et al. (1993)

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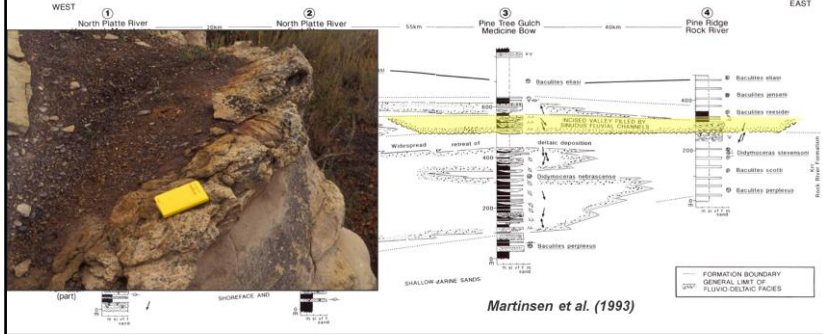

Martinsen et al. (1993)

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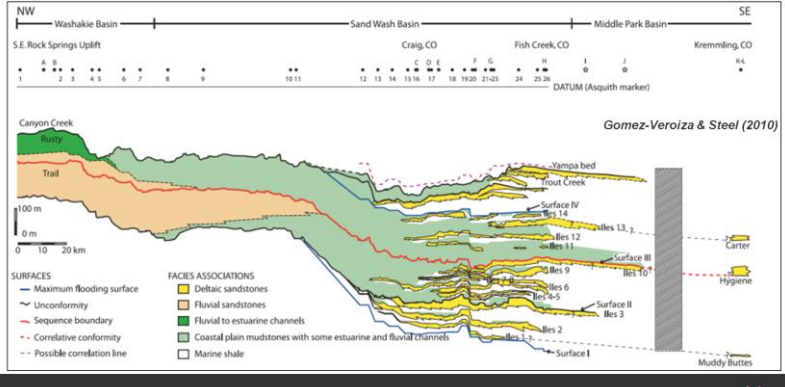
Basin pinchout



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Ultimate pinchout: Kremmling Sandstone

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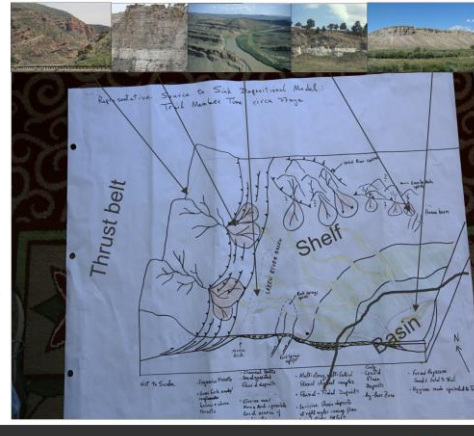
Summary

- S2S concept made up of
  5 previously unlinked subsystems
- 3 segments – 600 km scale
  - Thrust belt
  - Extended shelf
    - Basinward supply
    - Local uplifts-lateral supply
  - Basin
- Linkage between segments?
  - At least qualitatively



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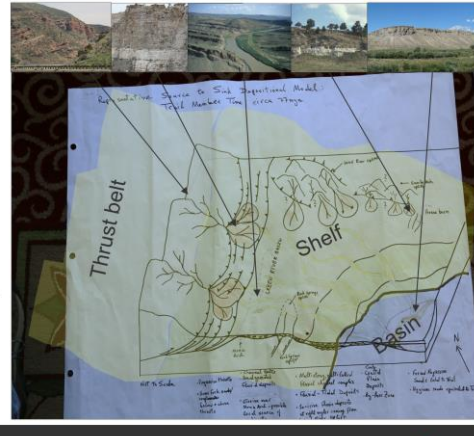

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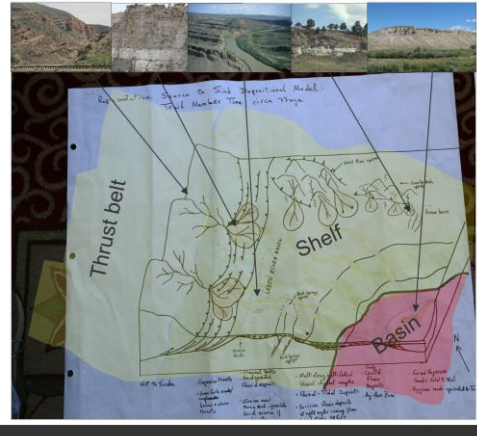

Statoil. The Power of Possible

An S2S approach to drainage and sediment flux in thrust and foreland systems

Ole J. Martinsen, Chief Geologist

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