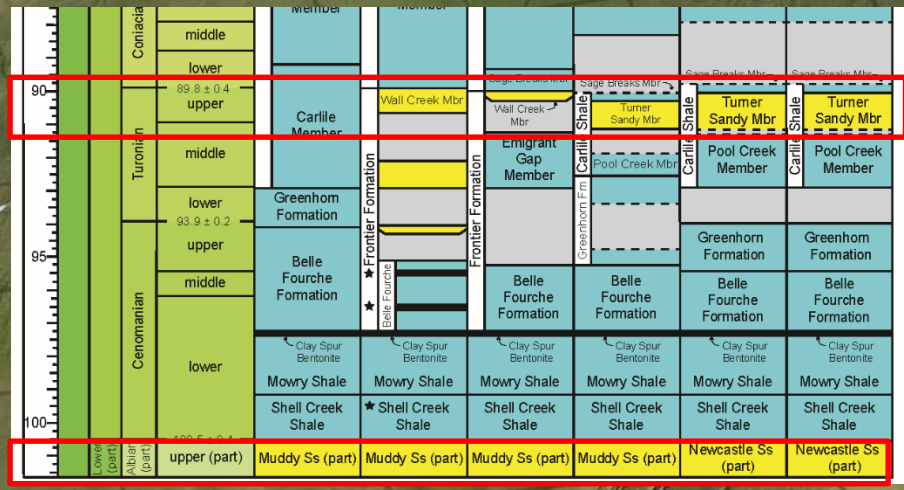
Origin and Stratigraphy of Enigmatic Sandstones of the Cretaceous Western Interior Seaway: The Late Turonian Wall Creek-Turner System, Powder River Basin, WY.

Patrick Sullivan
PhD. Student, anticipated S23

COLORADO SCHOOL OF MINES
MUDTOC

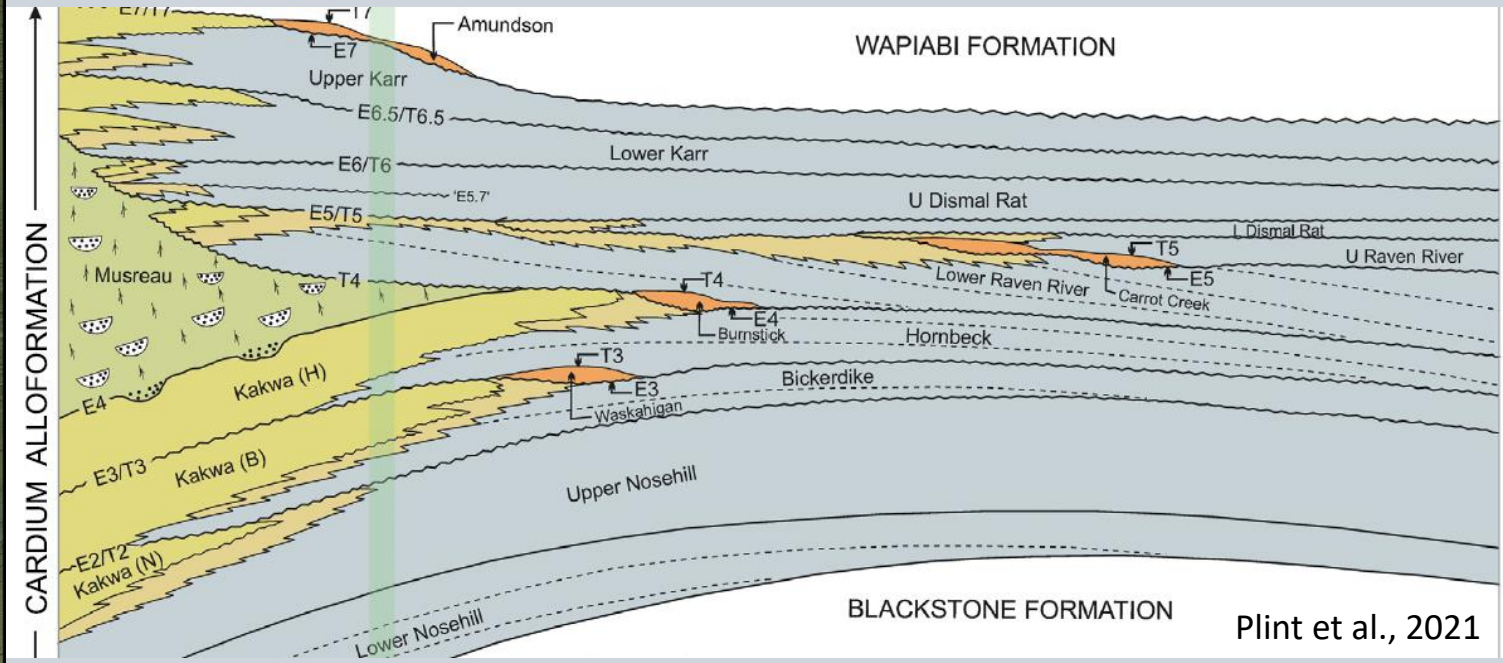
Still in the Seaway…



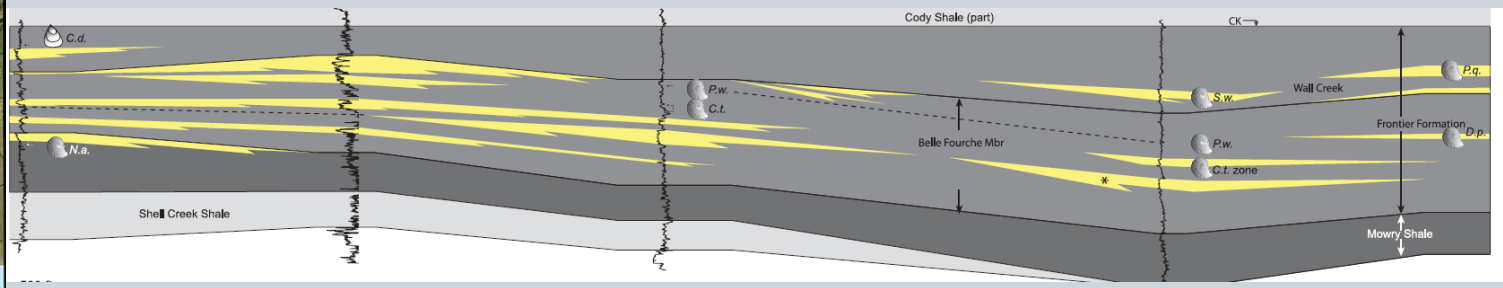
Blakey, 2019

The Turonian System

Blakey, 2019



Plint et al., 2021



Kirschbaum and Mercier, 2013

Outline

- **Introduction to the Wall Creek-Turner System**

- **How and when was the Wall Creek-Turner system deposited?**
  - Stratigraphy
  - Depositional models
  - Recent Work

- **Research Roadmap and Future Work**
  - Cores and Outcrops
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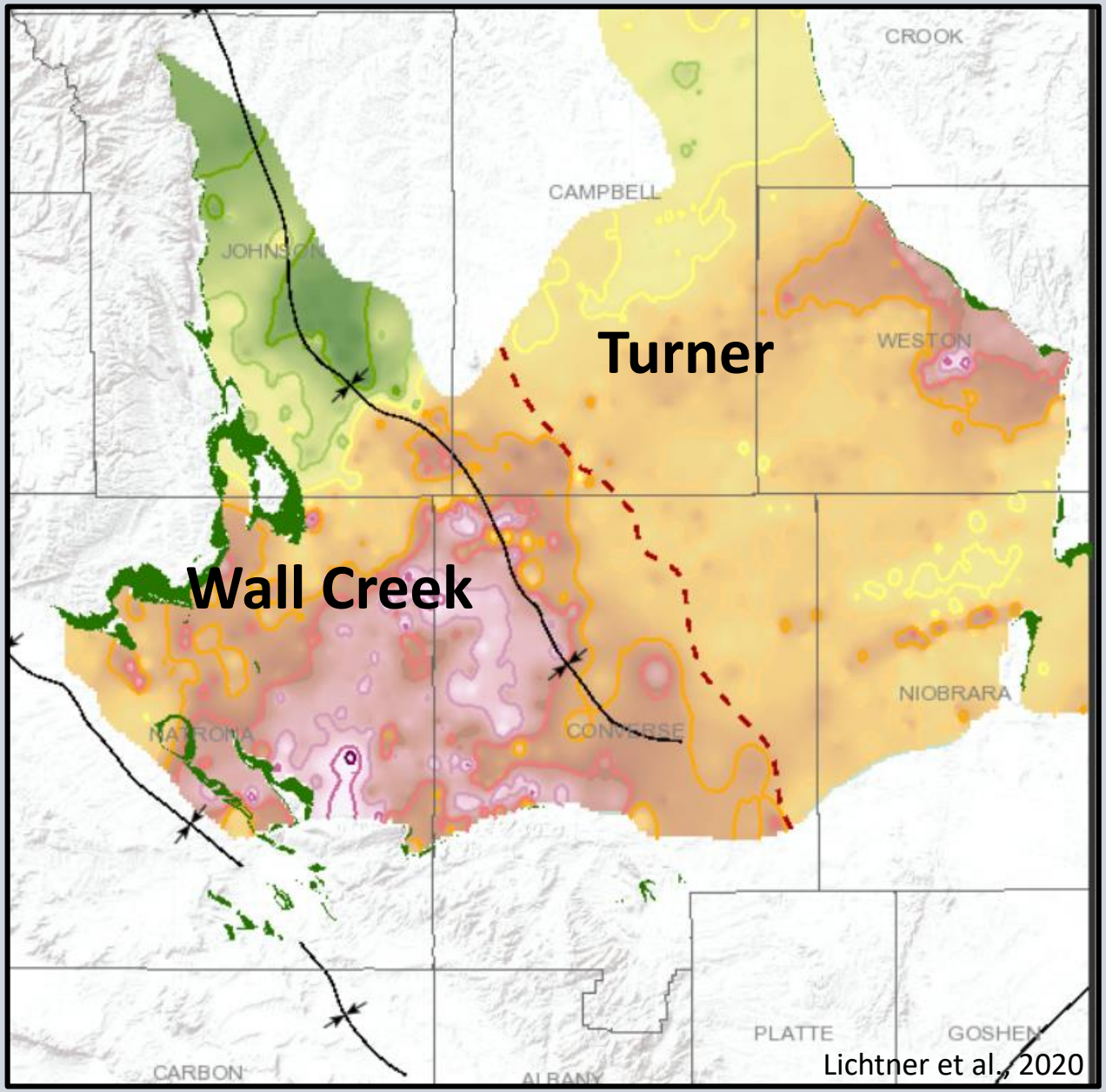
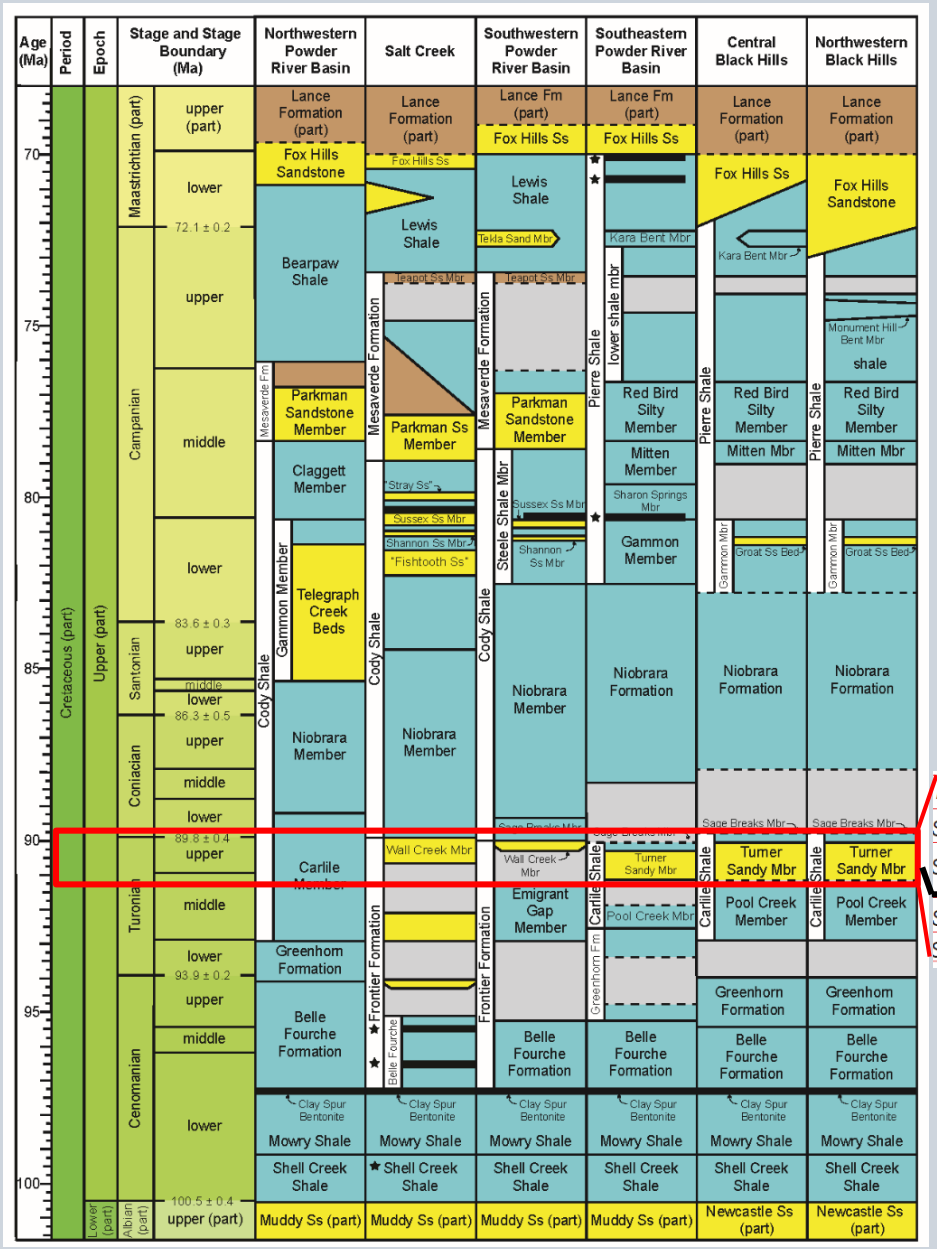
  - Paleogeography

Introduction



Lichtner et al., 2020



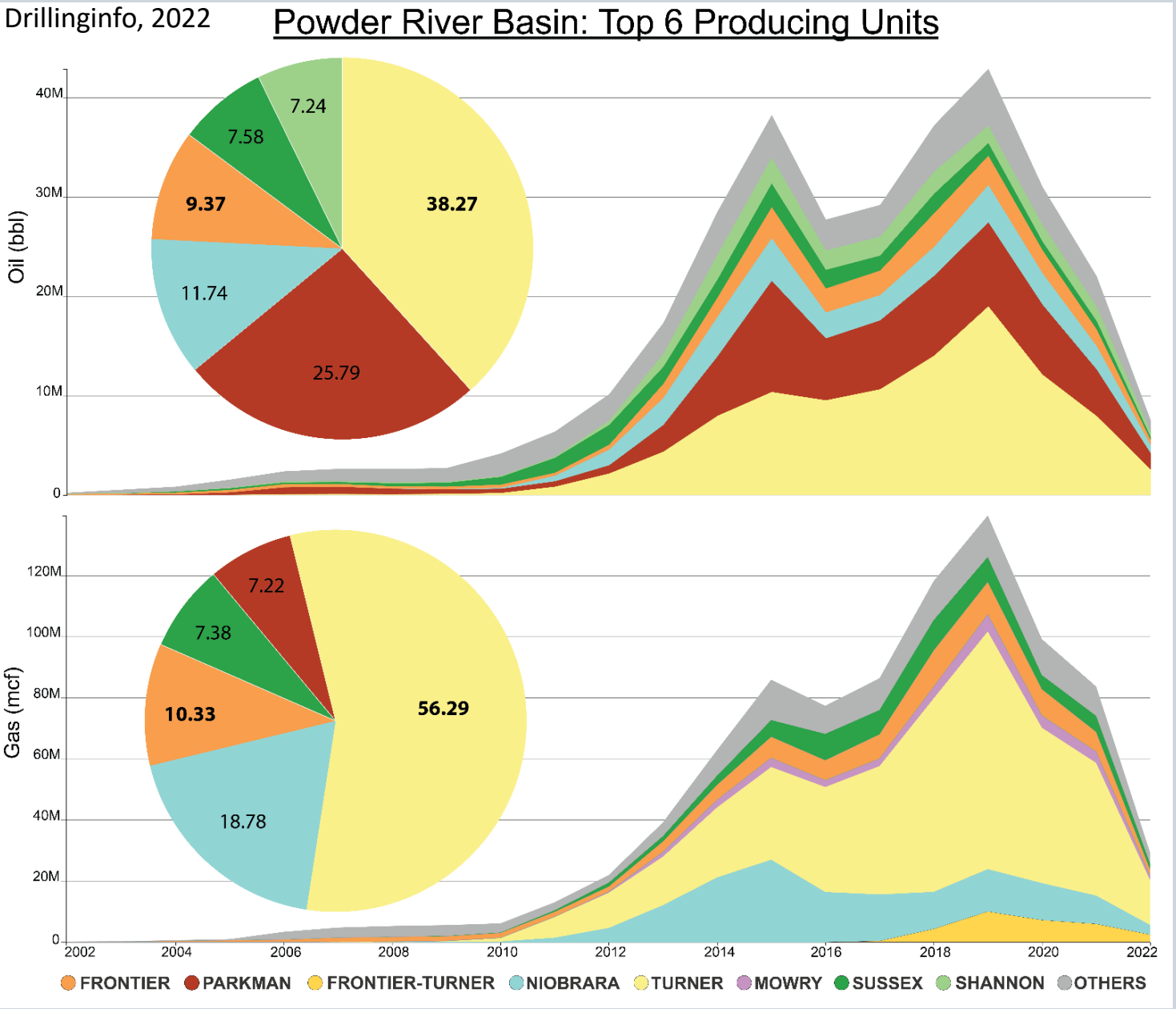
Prionocyclus germari
Scaphites nigricollensis
Scaphites whitfieldi
Scaphites ferronensis
Scaphites warreni

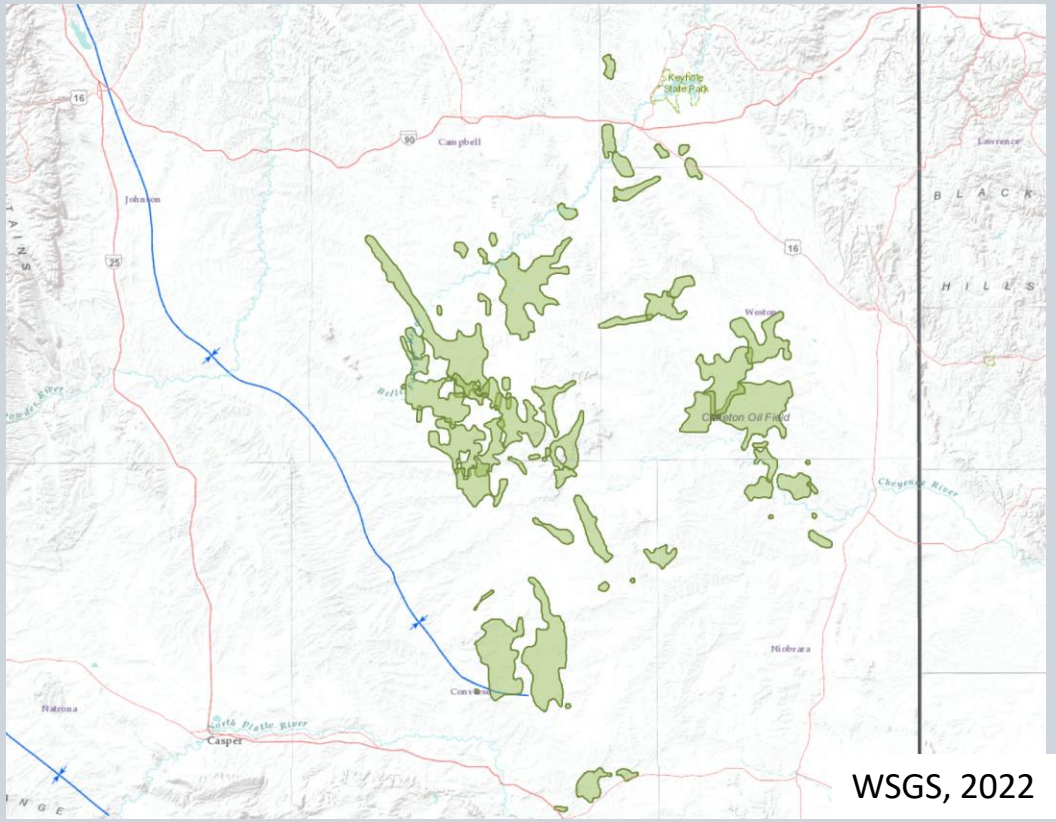
Upr Tur.
Mid Tur.

Merewether et al., 2007

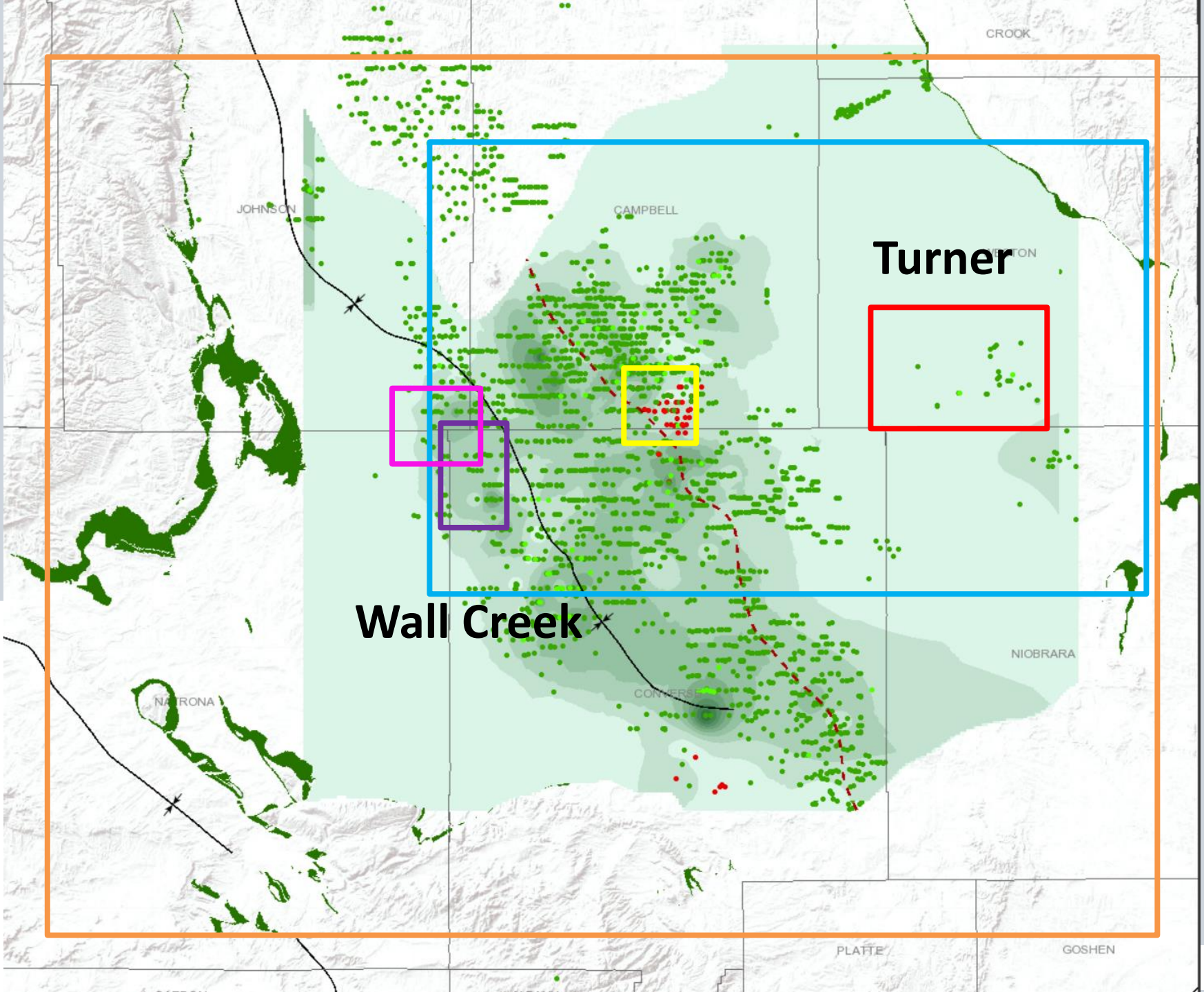
Introduction

Drillinginfo, 2022





WSGS, 2022



BBL (18 mo)

- < 42,000
- 42,000 - 84,000
- 84,000 - 126,000
- 126,000 - 168,000
- 168,000 - 210,000
- 210,000 - 252,000
- 252,000 - 294,000
- 294,000 - 336,000
- 336,000 - 378,000
- 378,000 - 420,000

Payne, 2017

Heger, 2017

Dellenbach, 2019

Bone, 2020

Milar, 2020

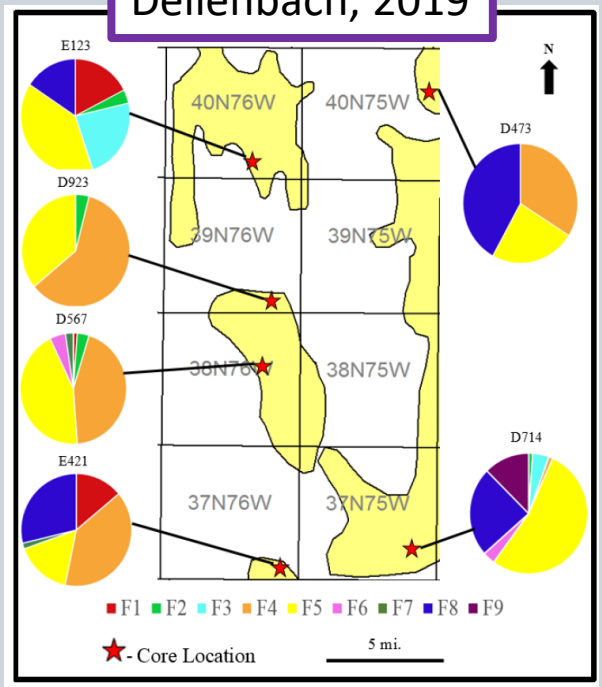
Sullivan (Proposed)

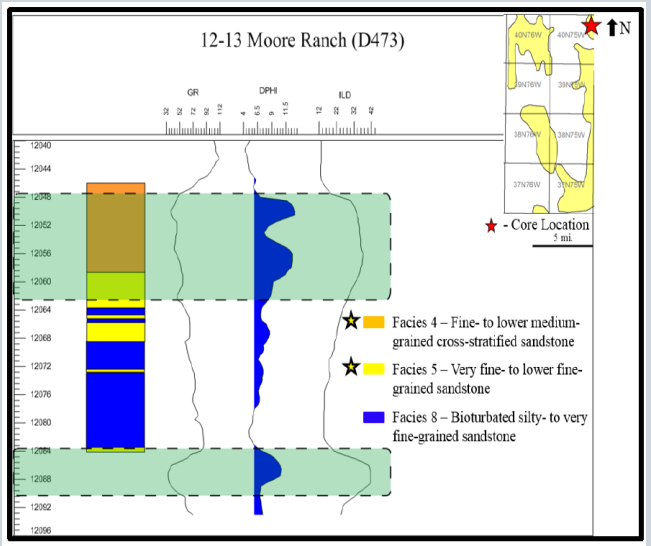
WSGS, 2019

WEST

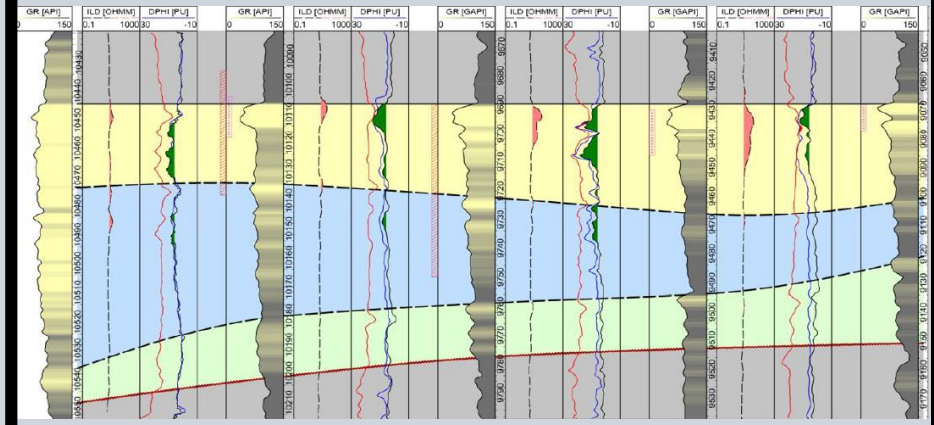
EAST

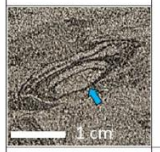
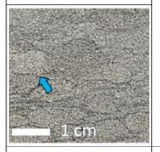
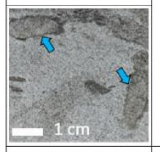
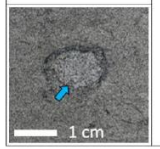
Dellenbach, 2019



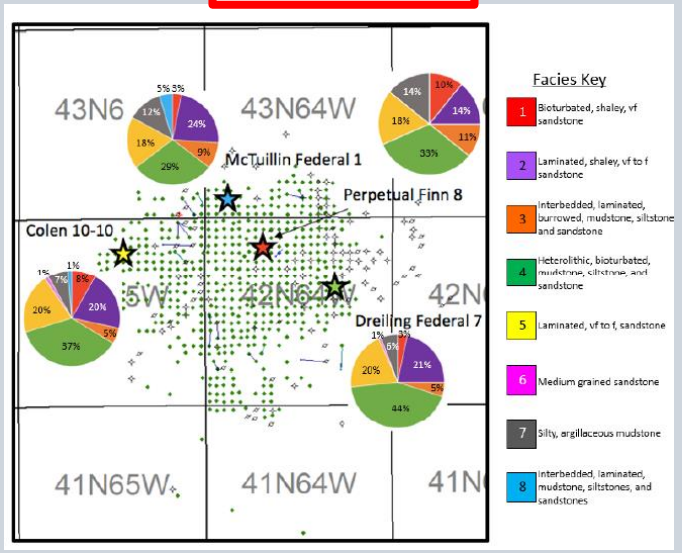


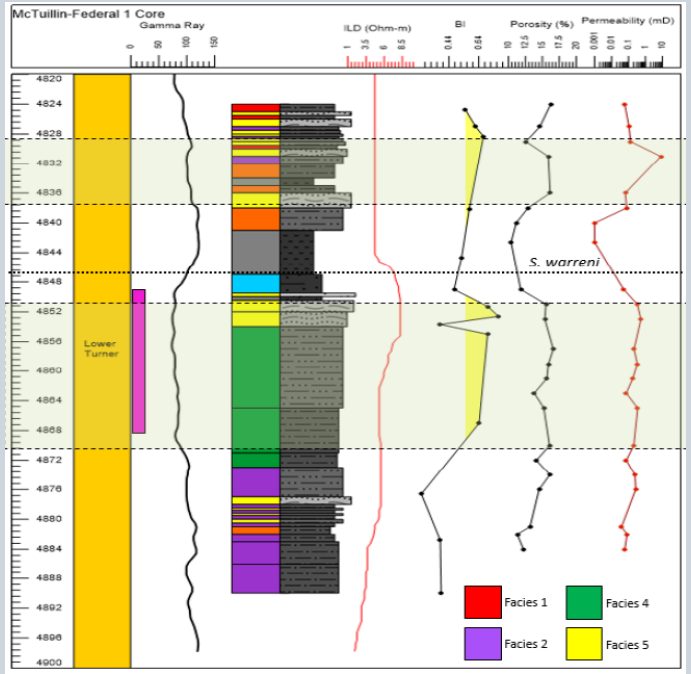
Milar, 2020



BURROW TYPE	LINING	FILL MATERIAL	IMPACT ON RESERVOIR
Asterosoma 	YES – linings packed with clay and/or fine organic matter	Actively filled with mud, silt and/or very fine sand	Negative
Macronichnus 	NO	Actively filled with sediment that contrasts with the host sediment	Positive
Ophiomorpha 	YES – linings packed with clay and/or fine organic matter	Passively filled – can be the same as the host strata or have an increased clay content	Positive/ negative
Paleophycus 	YES – margins lined with agglutinated sand, silt or organic matter	Passively filled with sediment that rarely contrast with the host sediment	Positive

Bone, 2020





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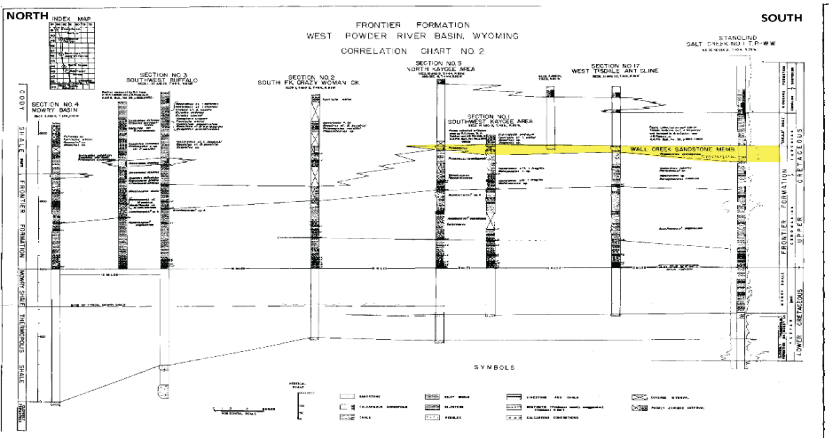
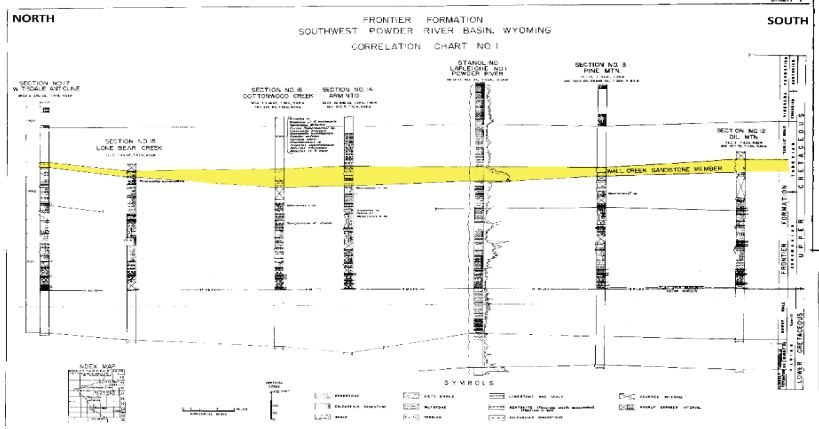
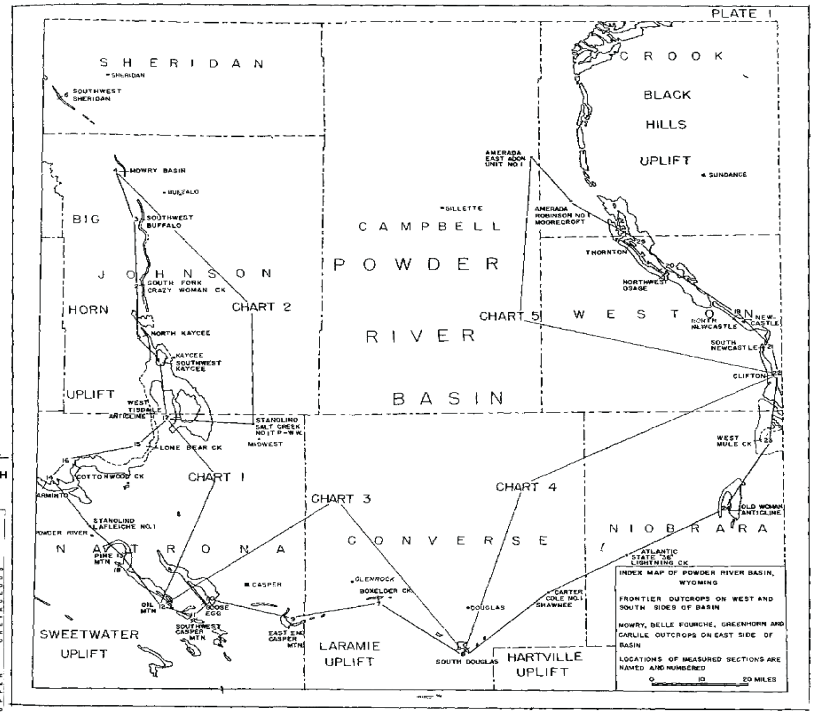
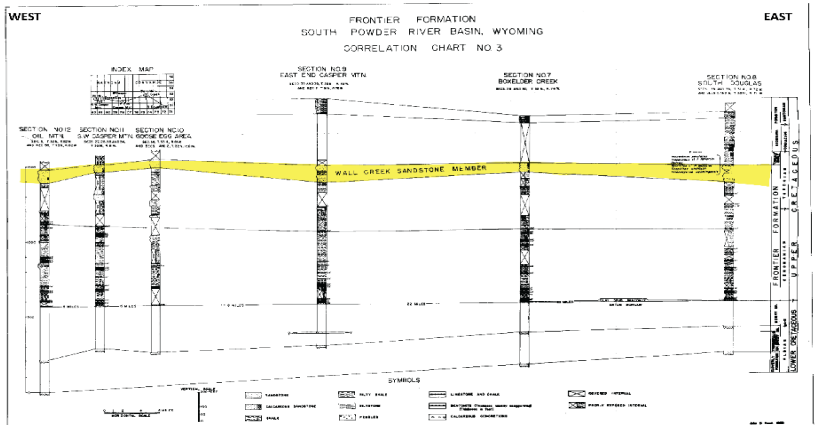
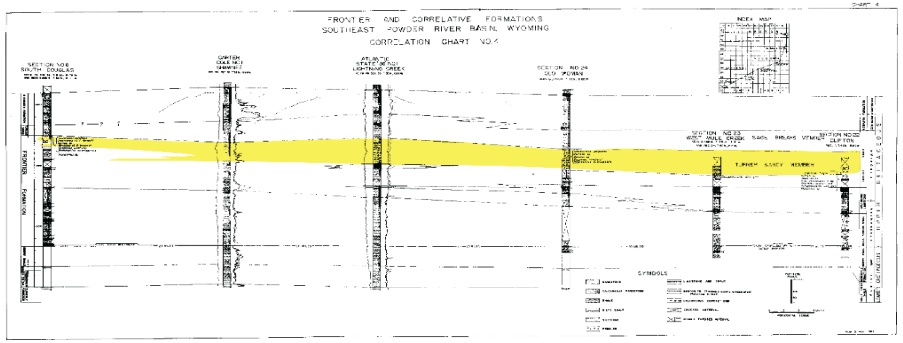
Regional Stratigraphy

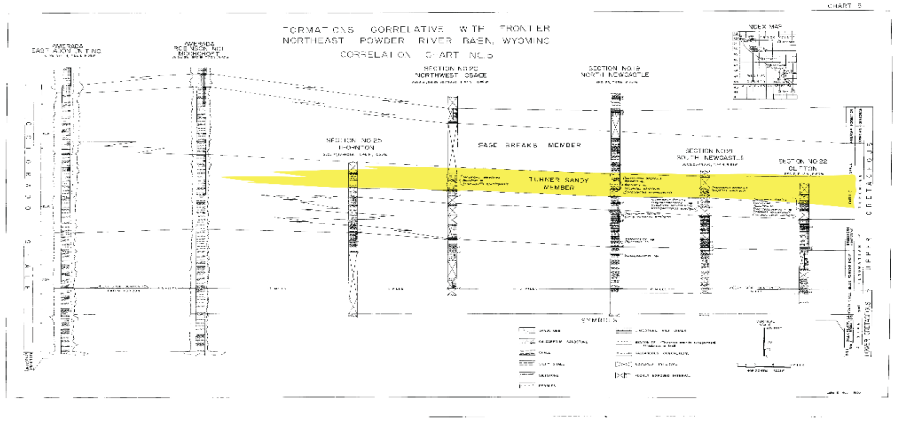






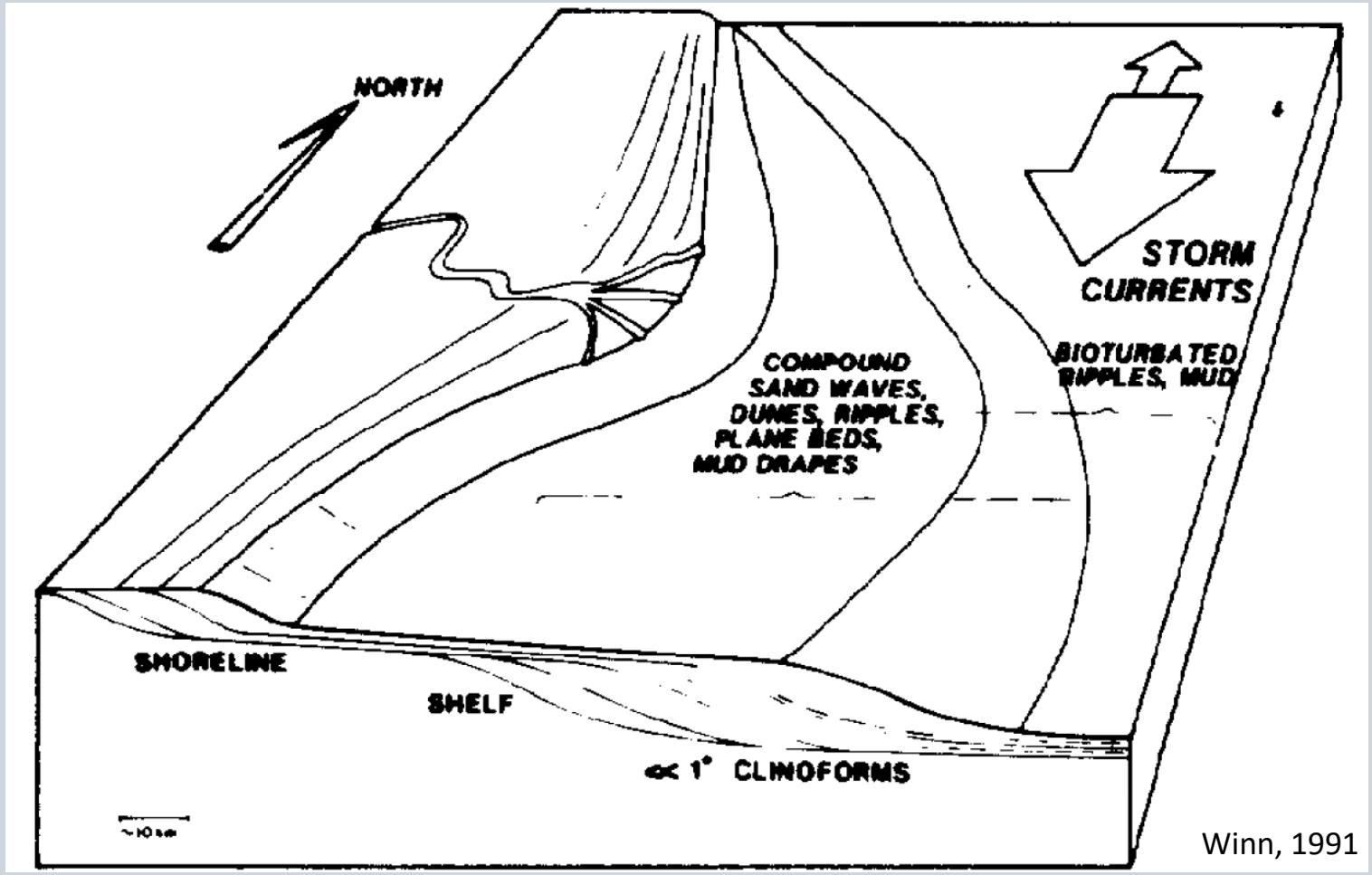




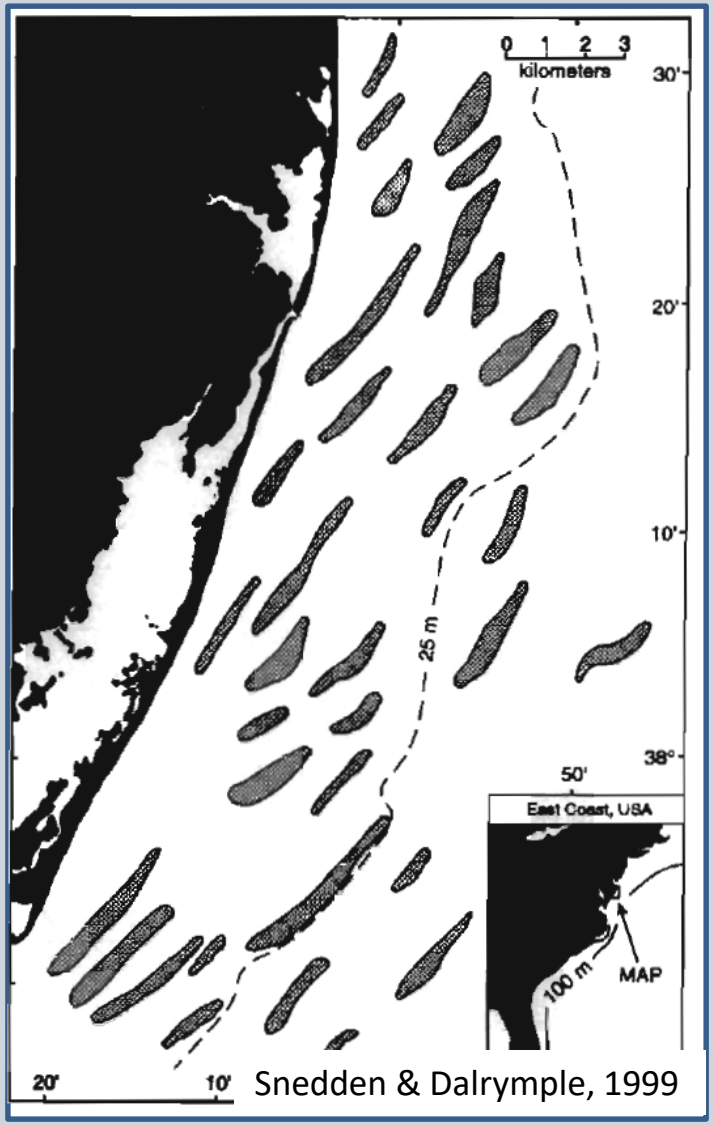


Haun, 1958

Depositional Models

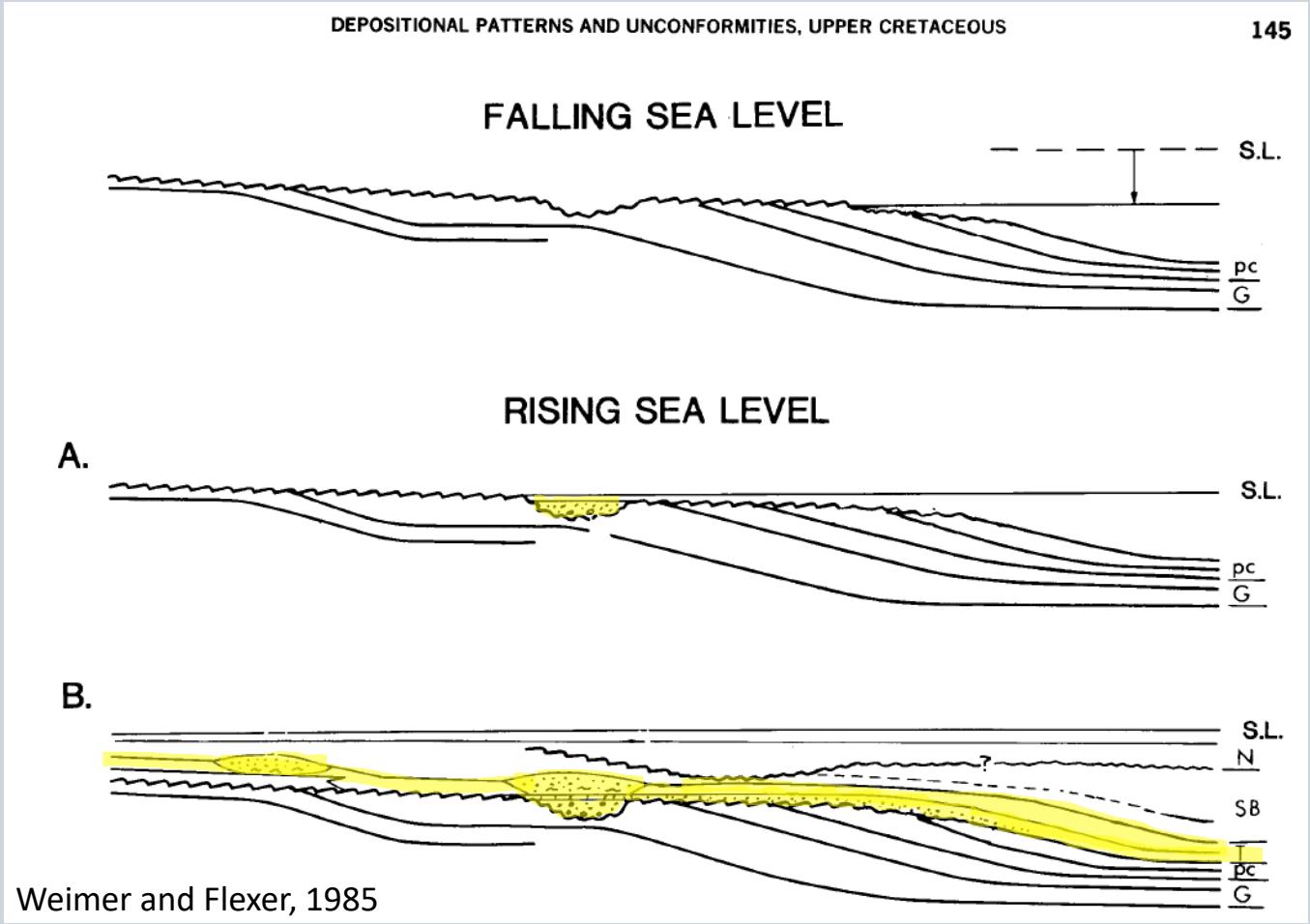


Winn, 1991

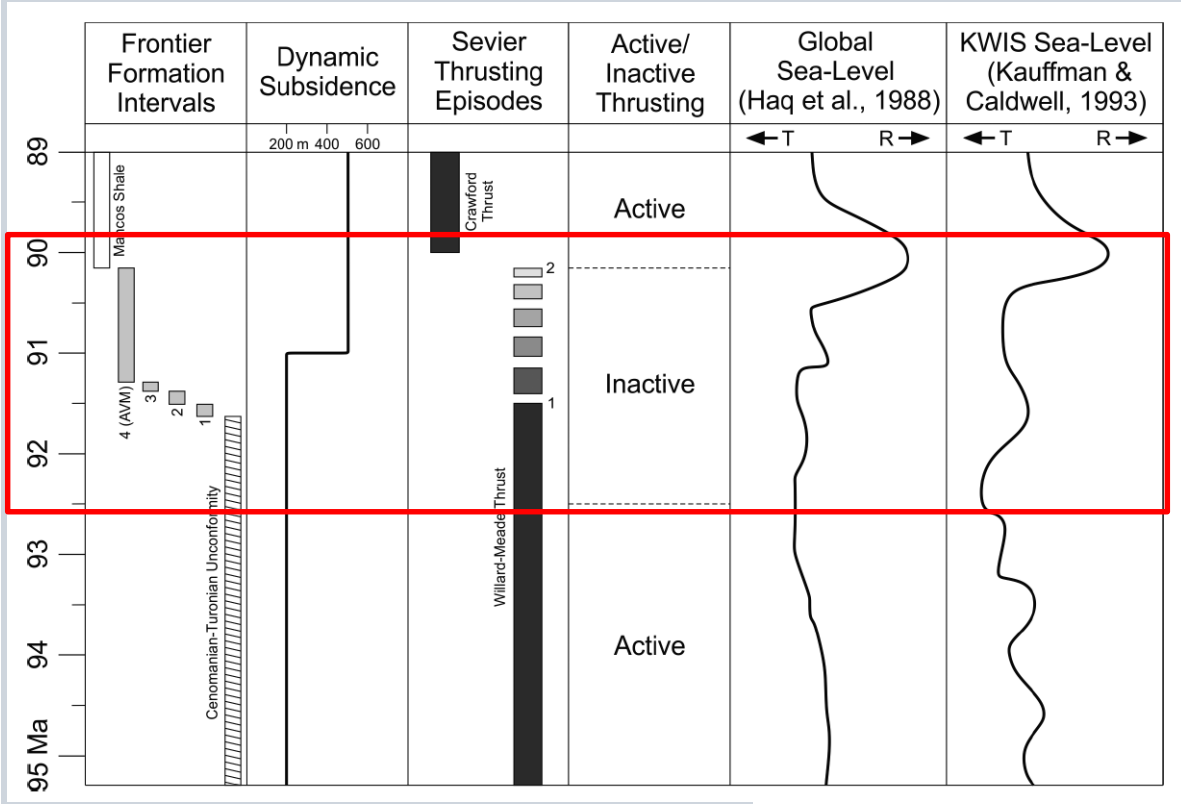


Snedden & Dalrymple, 1999

Depositional Models

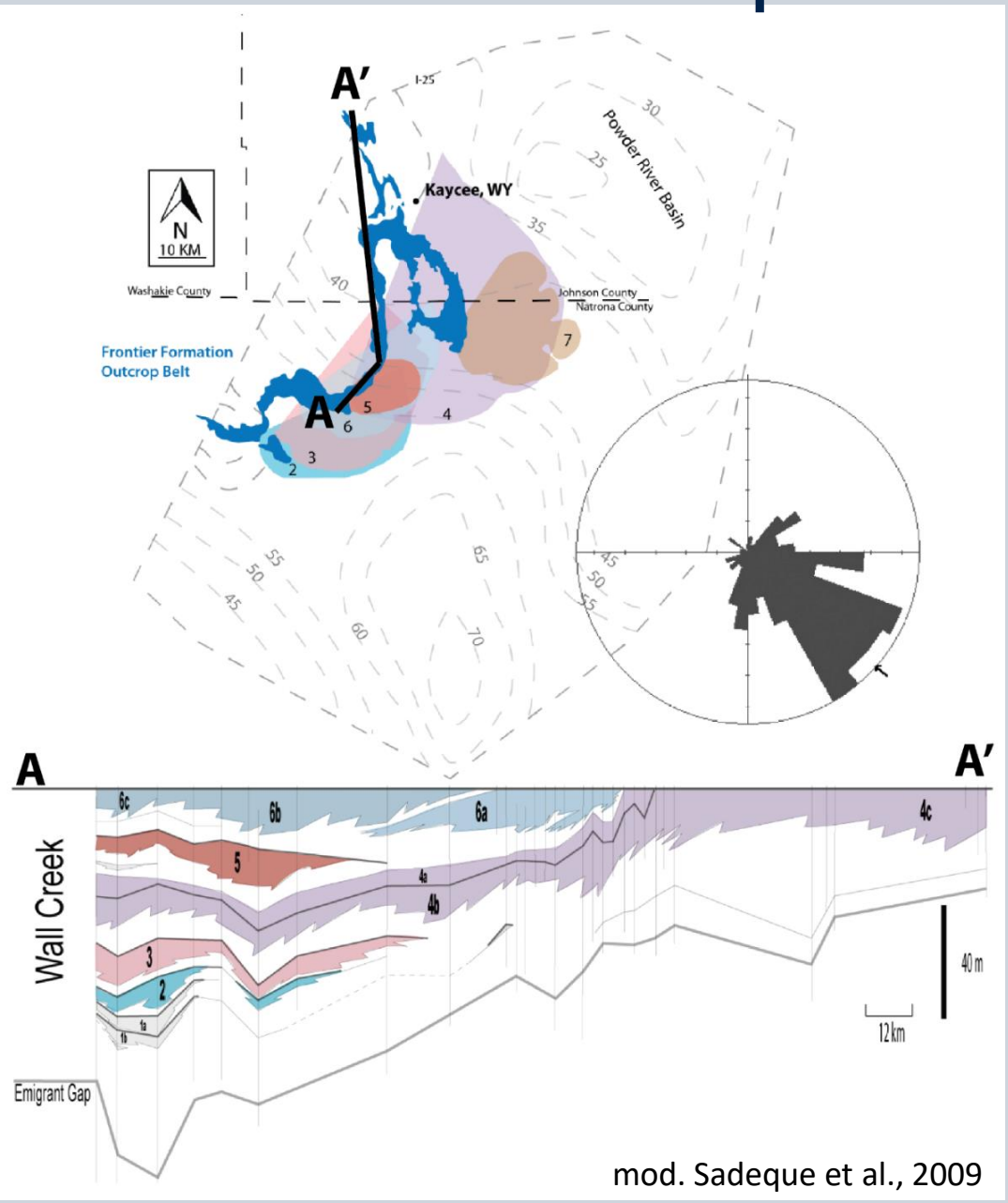


Weimer and Flexer, 1985

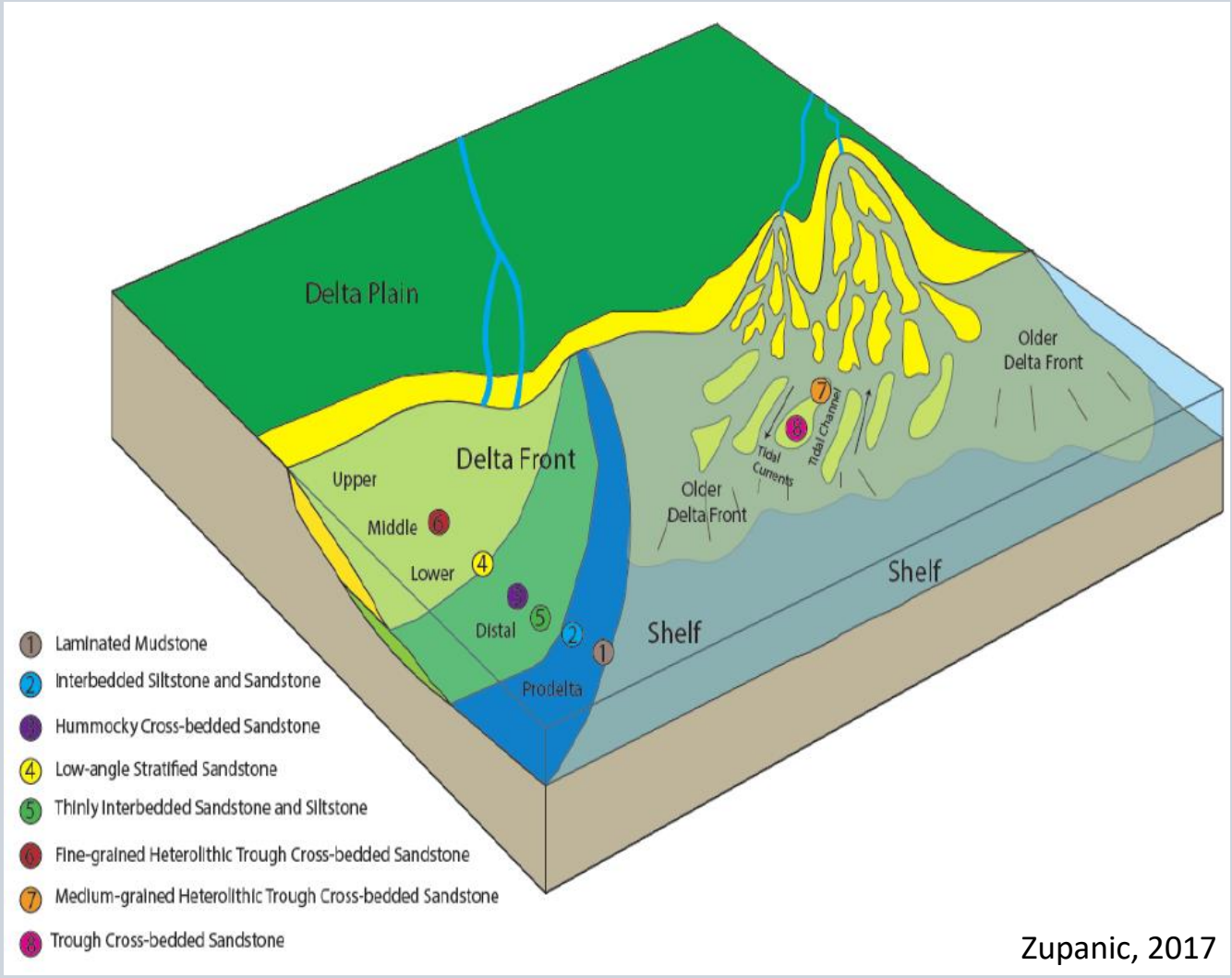


Hutsky and Fielding, 2017

Depositional Models



mod. Sadeque et al., 2009



Zupanic, 2017

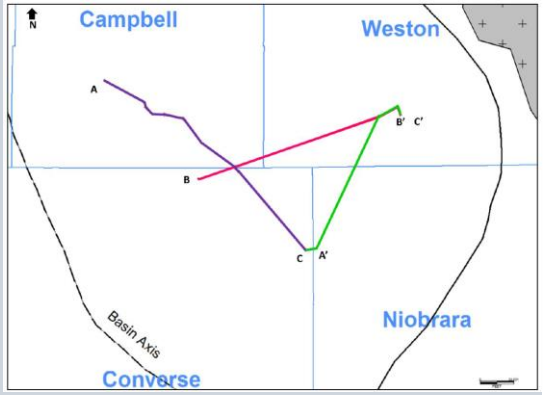
Depositional Models

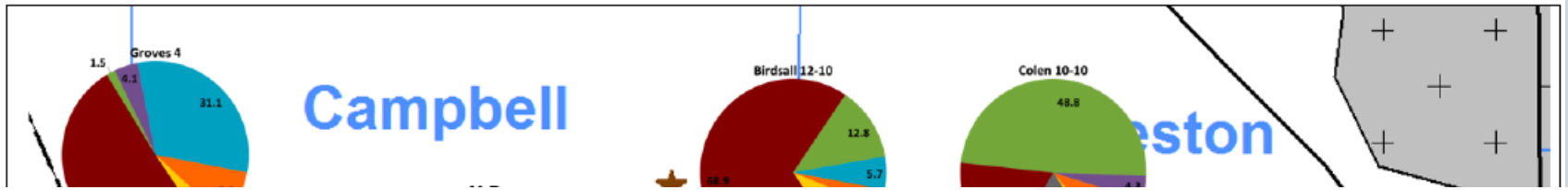
Table 3.1 Summary of the nomenclature and varying interpretations of depositional environment and sediment transport.

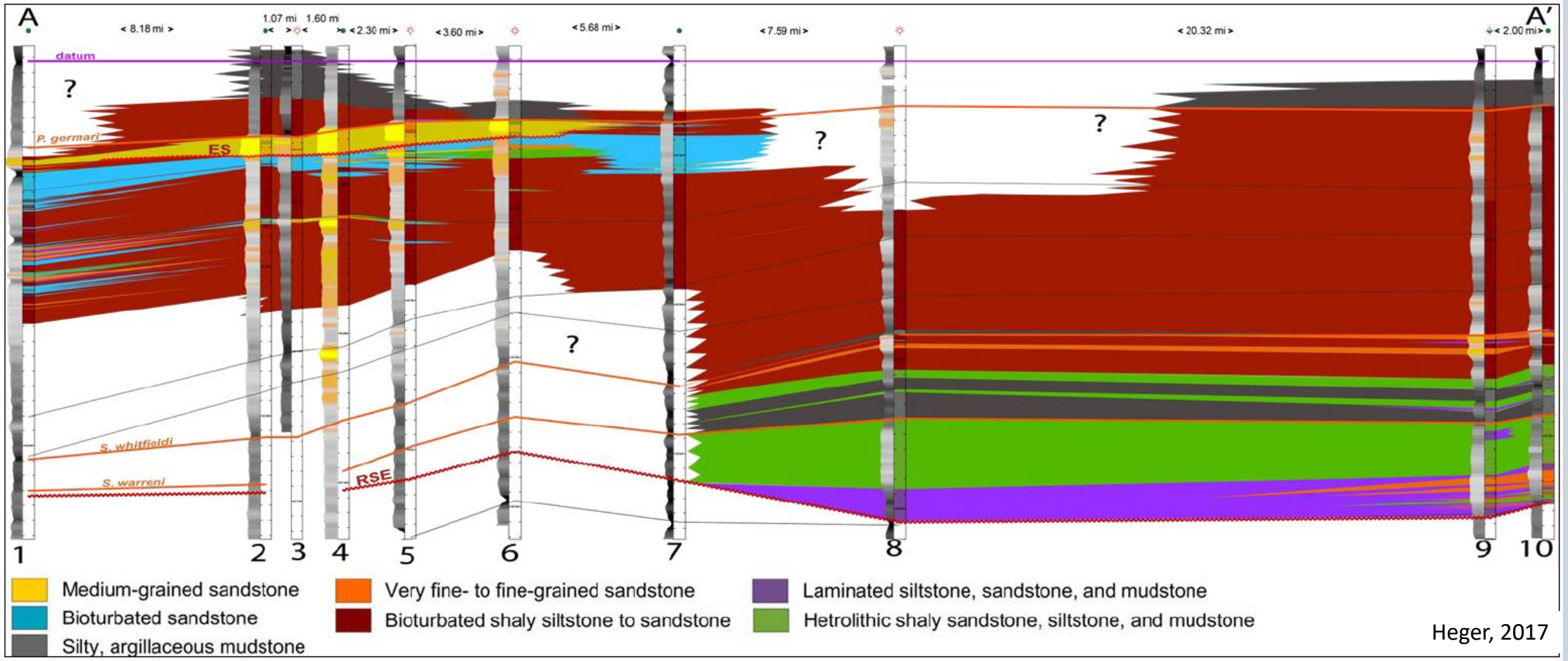
Nomenclature	Interpreted Depositional Environment	Sediment Transport Processes & Mechanism	Reference
Wall Creek-Turner: Unit VIII, Unit VII, Unit VI	Channels, nearshore bars, offshore bars	Destructive tide-dominated delta	Merewether et al.1979, p.68, 91
Turner: Type 1 SS	Lowstand shelf edge sands	Sea level drop	Weimer and Flexer 1985, p. 138, 144-145
Turner: Type 2 SS	Intertidal or estuarine valley fill	Sea level rise	
Turner: Type 3 SS	Valley fill, normal marine shelf sand	Sea level rise	
Lower Turner: Type 1 SS	Wave-dominated Shelf	Major river-dominated delta; minor storm influence	Rice and Gaskill 1988, p.69-70, 72
Lower Turner: Type 2 SS	Wave-dominated shelf	Offshore-flowing submarine channelized currents	
Upper Turner	Storm-dominated shelf, below fwwb	Storm currents	
Lower Turner	Wave-dominated, tide-influenced upper shoreface	Wave-generated currents, tidal currents, minor storm influence	Sawyer 1990, p. 198-202
Middle Turner	Lower shoreface to inner shelf	Reworking by storm currents	
Upper Turner	Lower shoreface to inner shelf	Reworking by storm currents	
Wall Creek-Turner: Unit VII	Middle to outer shelf sand sheet	Storm-generated currents, minor wave-generated currents	Winn 1991, p. 97-99
Turner	Shallow marine shelf, distal delta lobe, nearshore-marine close to lowland vegetation	Deltaic, transgressive onlap during early sea level rise	Merewether 1996, p. T33-34.
Wall Creek-Turner	Wall Creek: strand line, reworked shoreface Turner: proximal - distal shelf hyperpycnites	Wall Creek: long-shore currents, storm waves Turner: sediment gravity flows	Melick 2013, p. 156
Upper Turner-Wall Creek	Isolated shelf sand body, sand ridge	Storm-generated currents	Gustason 2015, abs.

Heger, 2017

Recent Work: Turner

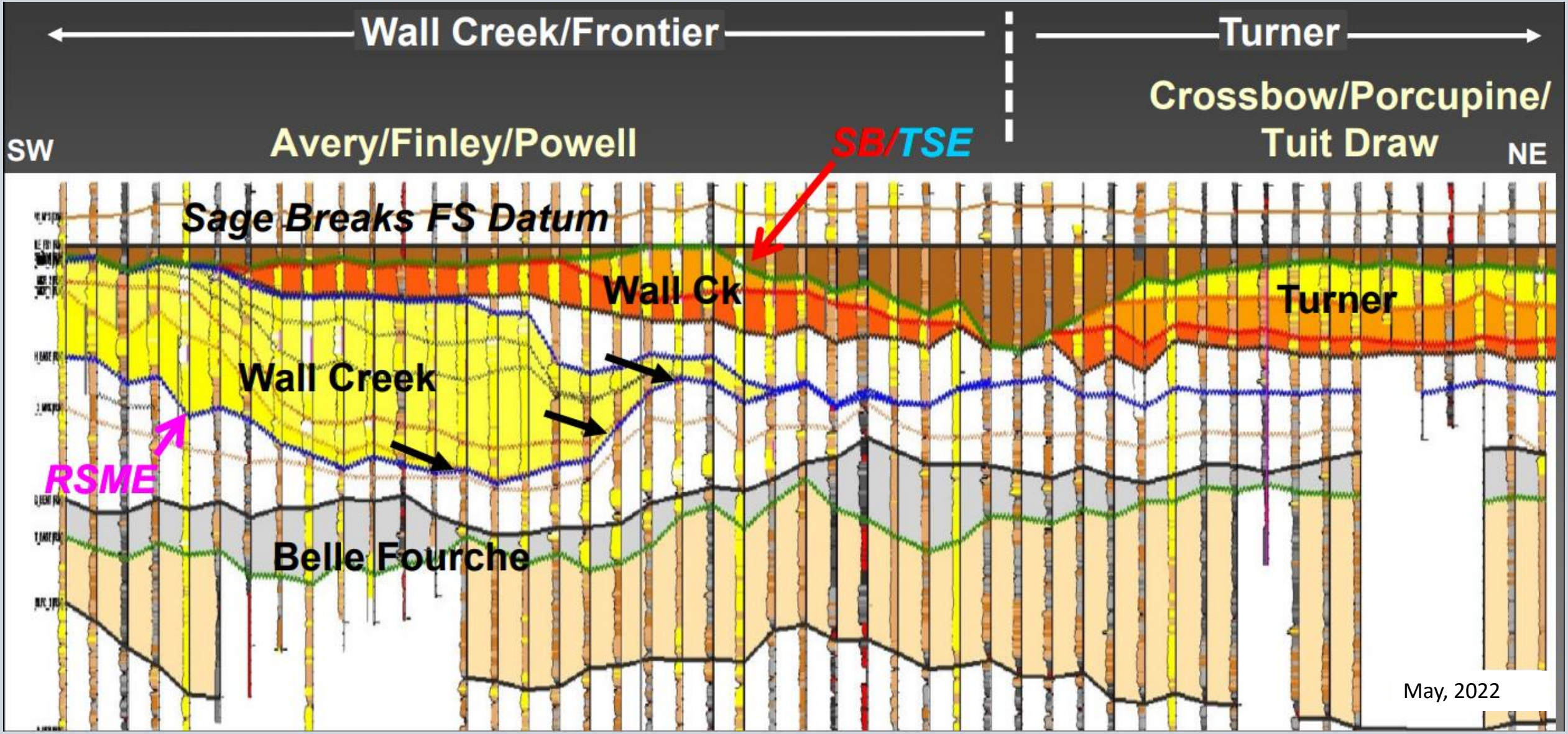






Heger, 2017

Recent Work: Wall Creek-Turner



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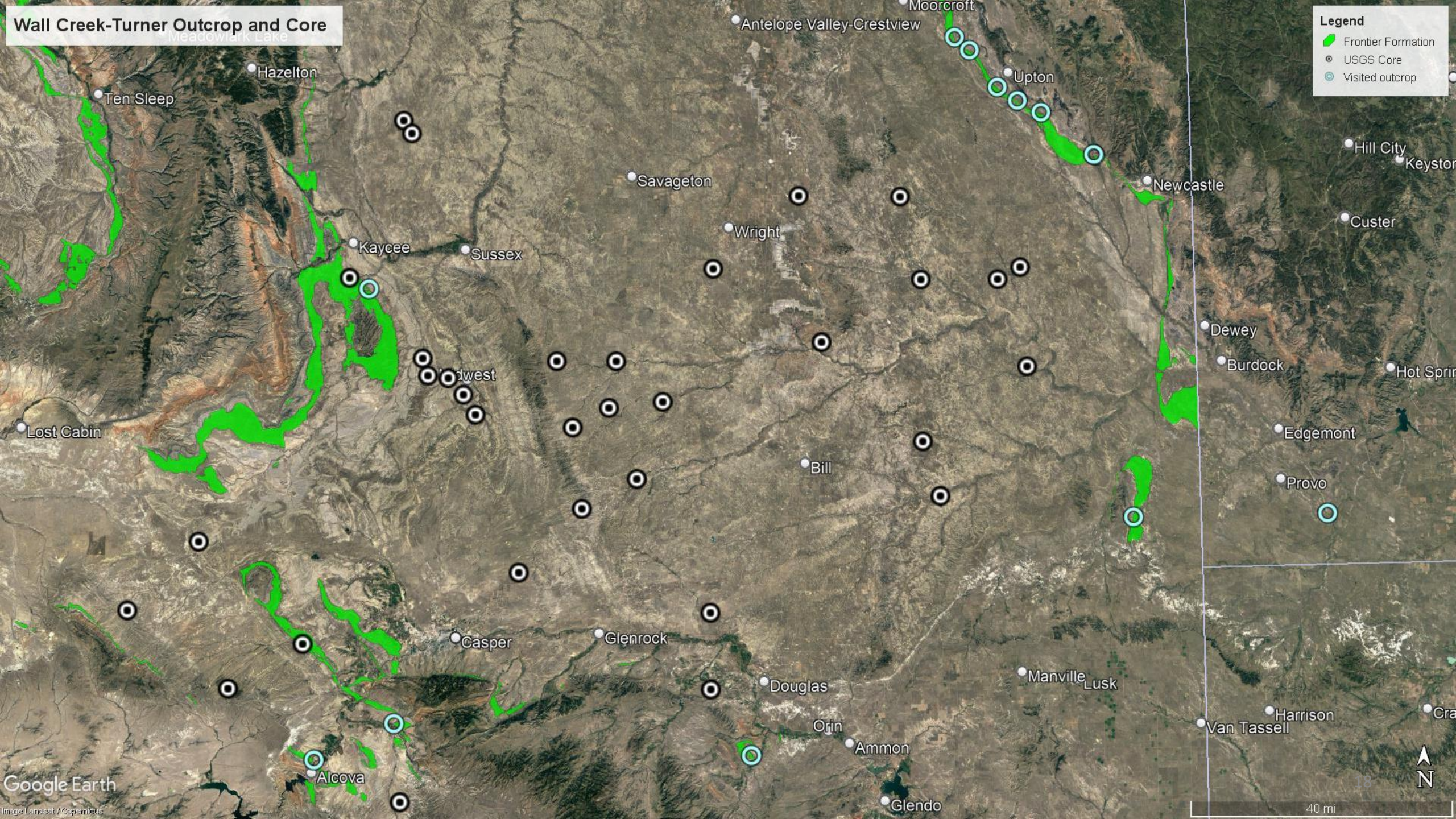
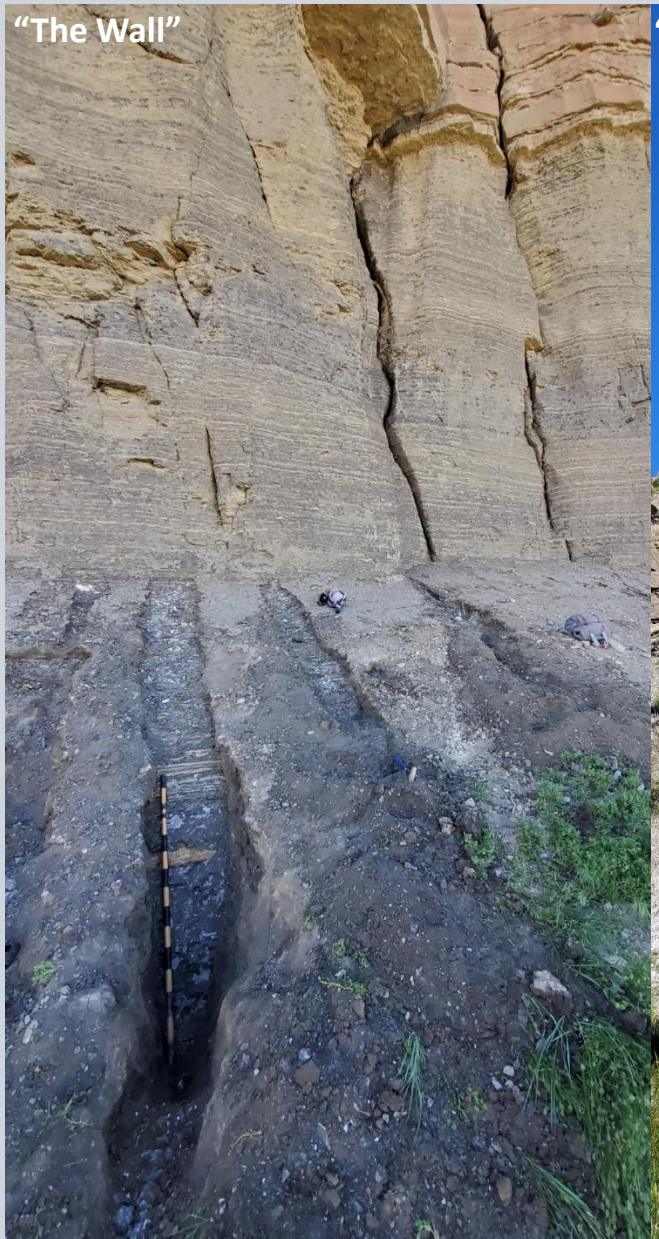
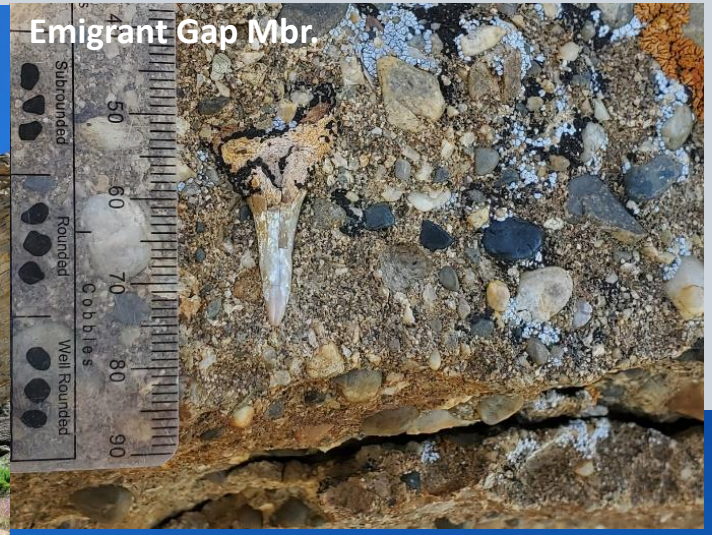
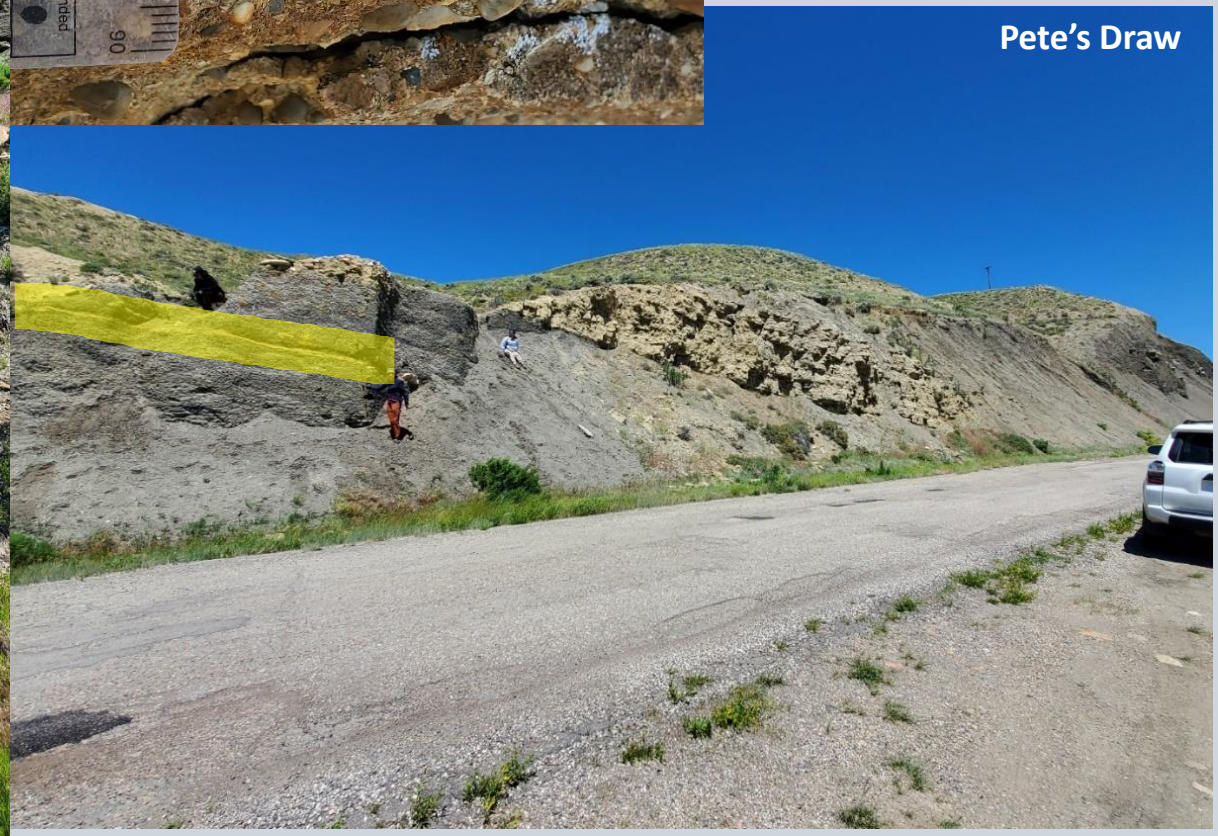

Wall Creek-Turner Outcrop and Core
Legend
Frontier Formation
USGS Core
Visited outcrop
Meadowlark Lake
Hazelton
Ten Sleep
Antelope Valley-Crestview
Moorcroft
Upton
Hill City
Keyston
Savageton
Newcastle
Wright
Custer
Kaycee
Sussex
Dewey
Burdock
Hot Sprin
Lost Cabin
Edgemont
Bill
Provo
Casper
Glenrock
Douglas
Manville
Lusk
Harrison
Van Tassell
Orin
Ammon
Alcova
Glendo
Google Earth
Image Landsat / Copernicus
40 mi
N

Wall Creek Outcrops

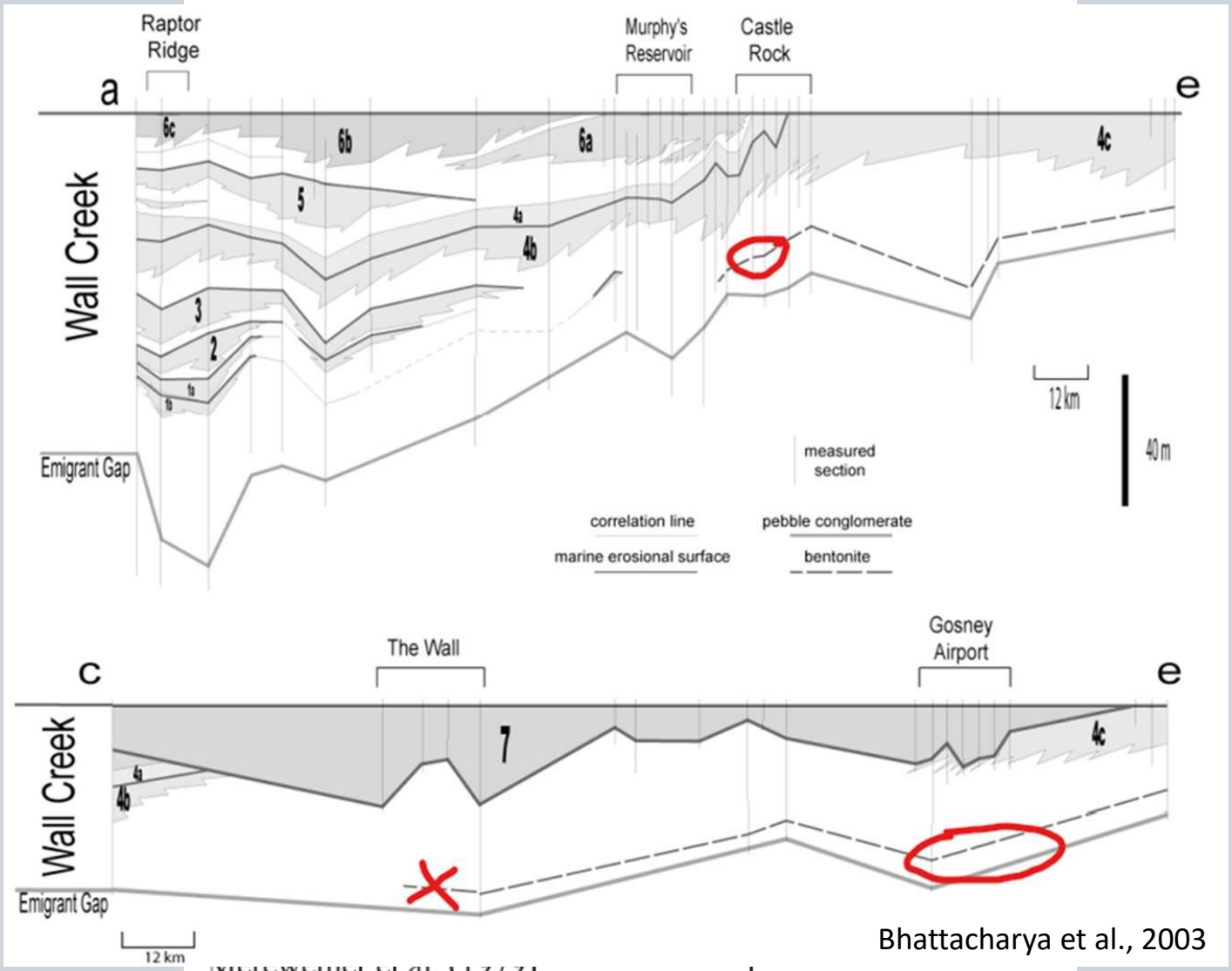






Turner Outcrops

Geochronology



Bhattacharya et al., 2003

Kirschbaum and Mercier, 2013

Cobban et al. (2006)

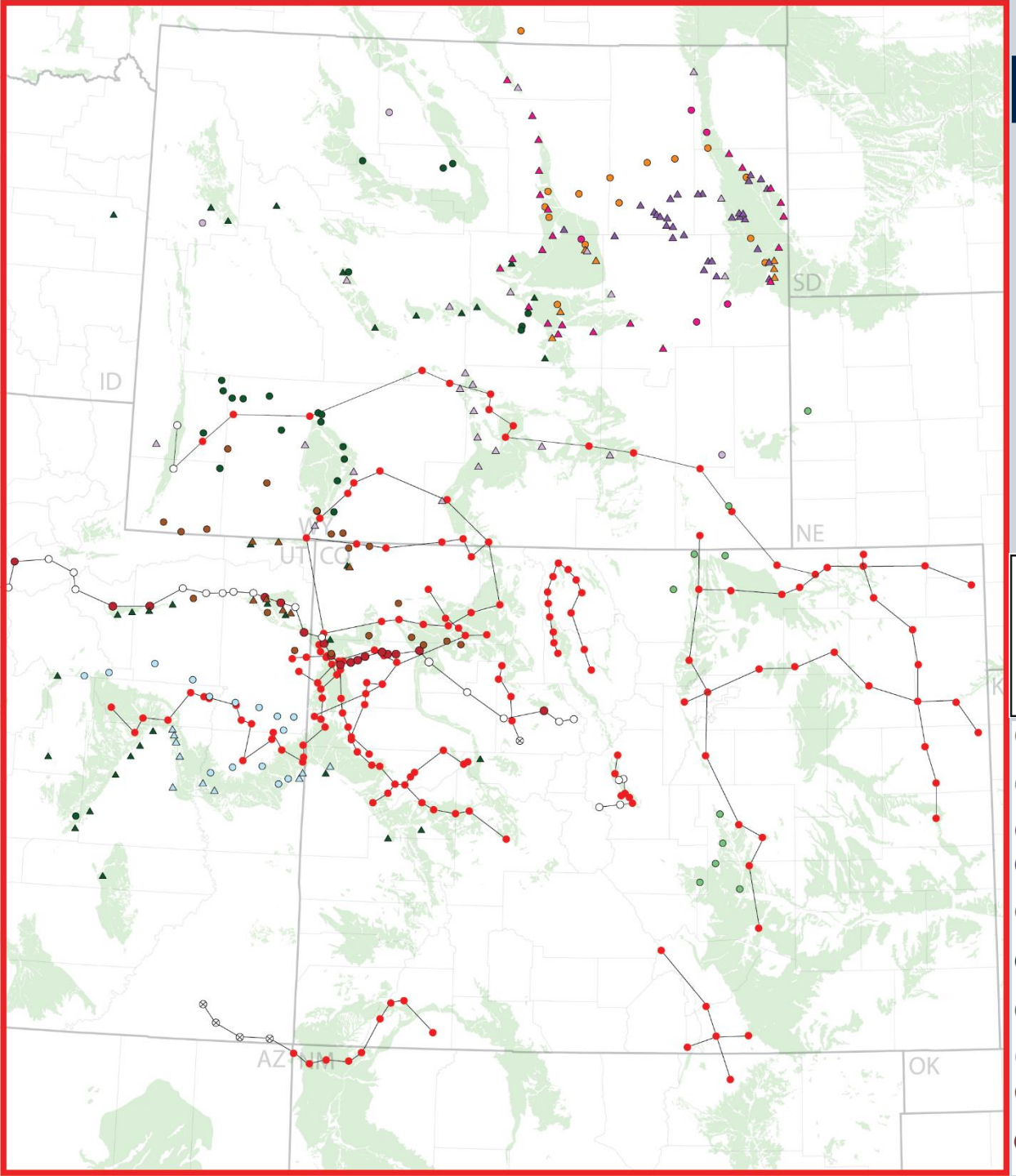
New, unpublished U-Pb CA-ID-TIMS dates, in stratigraphic order:

CO-BS-11140:	87.985 +/- 0.014 Ma	(Niobrara Channel – Powder R. Basin)
CO-BS-11177:	88.567 +/- 0.015 Ma	(Sage Breaks Sh – Powder River Basin)
CO-BS-11285.85:	90.645 +/- 0.016 Ma	(Turner Ss – Powder River Basin)
WY-TA-1 (Janok Section):	Waiting on collection…	(Wall Creek Ss: Powder River Basin)
CO-NC-1-130'	90.881 +/- 0.023 Ma	(Montezuma Valley Fm – Eagle Basin)
CO-TR-1:	91.008 +/- 0.014 Ma	(Juana Lopez Mbr– Eagle Basin)
HQ-CB1-191107:	91.639 +/- 0.024 Ma	(Codell Ss – Denver Basin)
CO-LP-1-U:	92.682 +/- 0.015 Ma	(Blue Hill Sh – Denver Basin)
HQ-CB2-191107:	93.513 +/- 0.021 Ma	(Fairport Chalky Sh – Denver Basin)

Sources of Detrital Zircons in the above rocks:

GEA-UBB1-2008-01	94.136 +/- 0.013 Ma	(UBB Bentonite – Bighorn Basin)
CRC E099 - 569'	96.004 +/- 0.016 Ma	("X" Bentonite – Denver Basin)
GEA-XB1-200801	96.010 +/- 0.017 Ma	("X" Bentonite – Bighorn Basin)
Case 11370'	97.841 +/- 0.021 Ma	(Clay Spur Bent. – Powder River Basin)
AA-CSB-1-200801	97.849 +/-0.019 Ma	(Clay Spur Bent. – Bighorn Basin)
GEA-ACB-2021	99.008 +/- 0.018 Ma	(Arrow Ck Bent. – Bighorn Basin)
Twig Fee 8790'	99.013 +/-0.013 Ma	(Arrow Ck Bent. – Powder River Basin)

Paleogeography



- Outcrop data
- Subsurface - not deposited or eroded
- Subsurface - not deposited
- Subsurface - present
- Subsurface - no data

Cobban, W. A., Merewether, E. A., Fouch, T. D., & Obradovich, J. D. (1994). Some Cretaceous shorelines in the western interior of the United States. Rocky Mountain Section (SEPM).

DeReuil, A. A., & Birgenheier, L. P. (2019). Sediment dispersal and organic carbon preservation in a dynamic mudstone-dominated system, Juana Lopez Member, Mancos Shale. Sedimentology, 66(3), 1002-1041.

Haun, J. D. (1958). Early Upper Cretaceous Stratigraphy, Powder River Basin, Wyoming.

Heger, A. W. (2016). Stratigraphy and reservoir characterization of the Turner sandstone, southern Powder River Basin, Wyoming. Colorado School of Mines.

Hutsky, A. J., & Fielding, C. R. (2017). Tectonic control on deltaic sediment dispersal in the middle to upper Turonian Western Cordilleran Foreland Basin, USA. Sedimentology, 64(6), 1540-1571.

Kirschbaum, M. A., & Mercier, T. J. (2013). Controls on the deposition and preservation of the Cretaceous Mowry Shale and Frontier Formation and equivalents, Rocky Mountain region, Colorado, Utah, and Wyoming. AAPG bulletin, 97(6), 899-921.

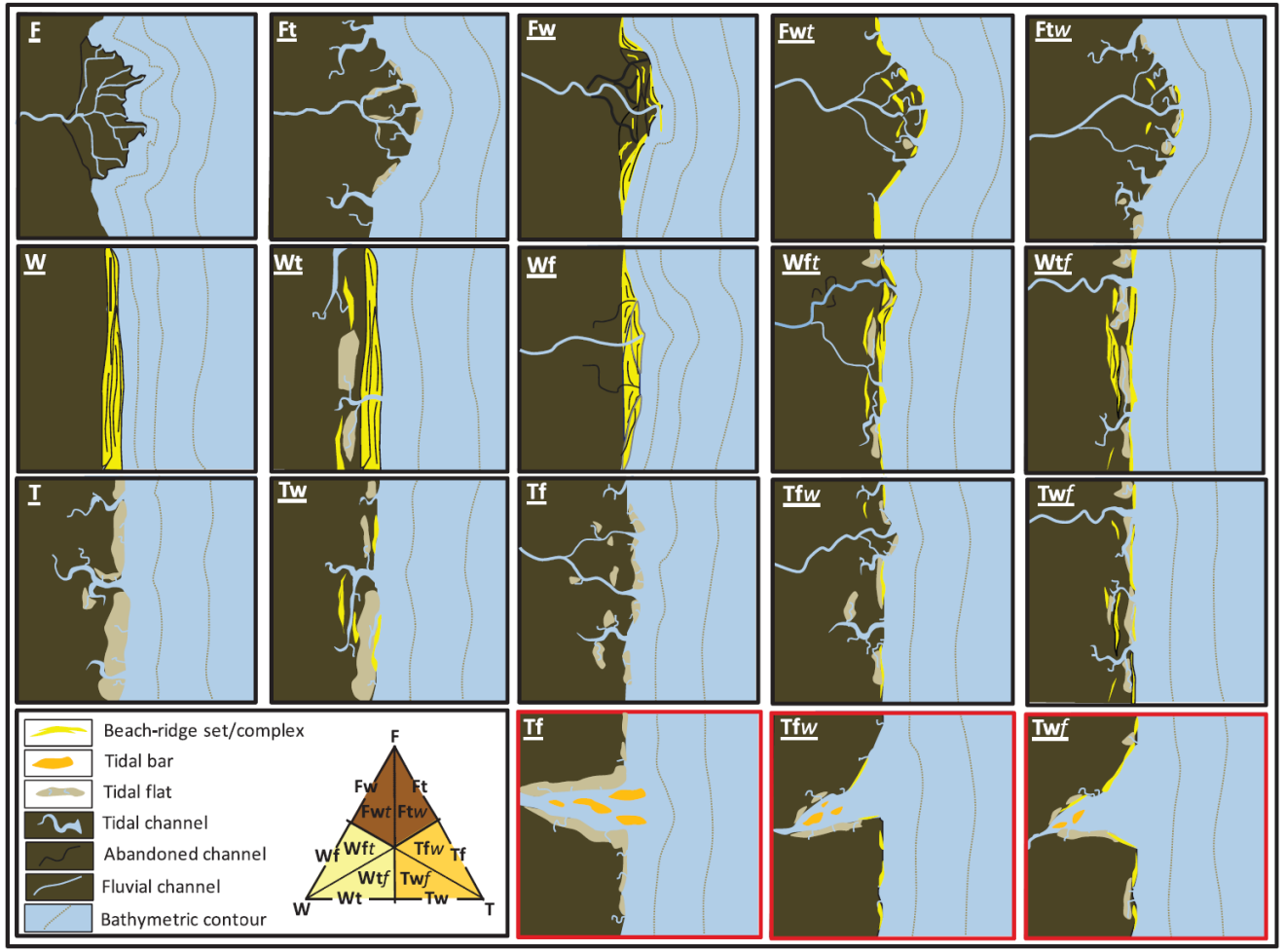
Longman, M. W., Hagadorn, J. W., & Gent, V. A. (2021). Sedimentology, petrography, and deposition of the Upper Cretaceous Codell Sandstone in the Denver Basin. The Mountain Geologist, 58(3), 249-303

Lynds, R. M., & Slattery, J. S. (2017). Correlation of the Upper Cretaceous strata of Wyoming. Wyoming Geological Survery.

Merewether, E. A. (1996). Stratigraphy and tectonic implications of Upper Cretaceous rocks in the Powder River Basin, northeastern Wyoming and southeastern Montana (No. 1917). US Government Printing Office.

Johnson, S. Y., & Johnson, R. C. (1991). Stratigraphic and time-stratigraphic cross sections of phanerozoic rocks along line AA', Uinta and Piceance basin area-Eagle basin, Colorado, to eastern basin and range area, Utah (No. 2184-A).

Paleogeography



Ainsworth et al., 2011

Kirschbaum and Mercier, 2013

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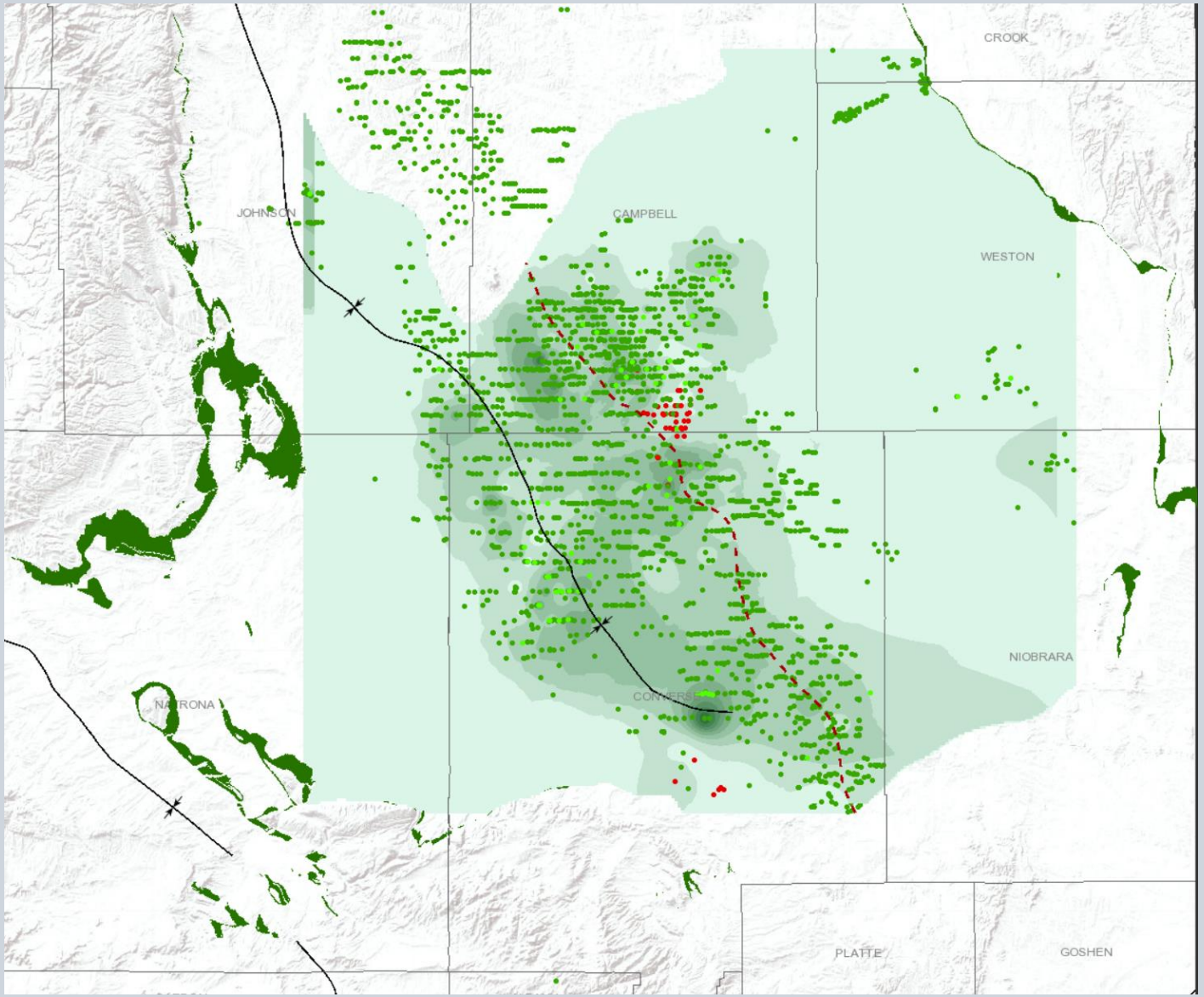
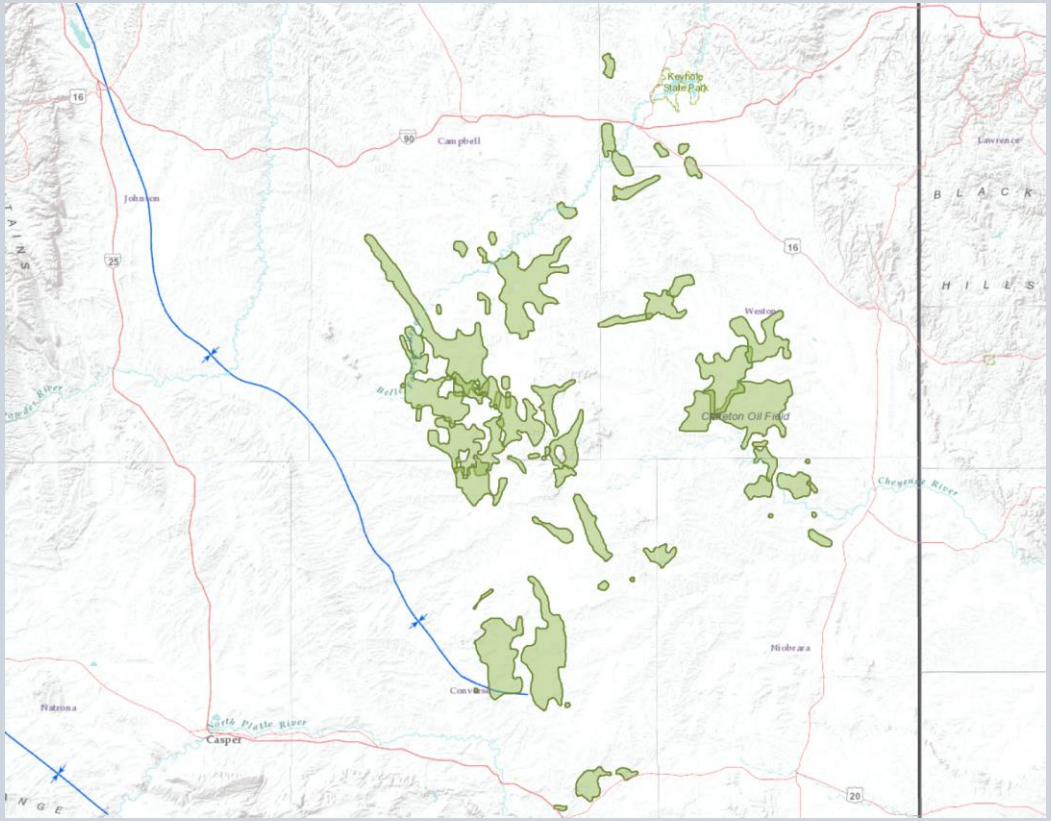
Enverus

COLORADO SCHOOL OF
MINES
MUDTOC

Predicting Reservoir Quality

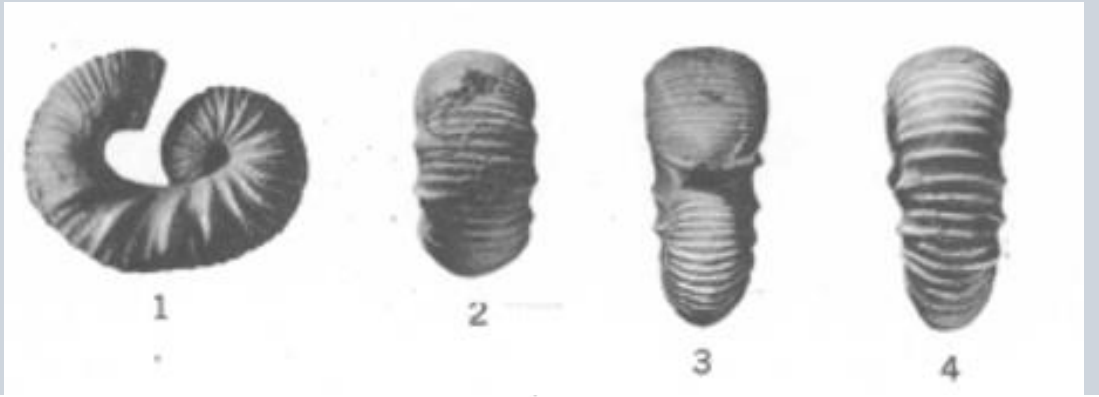




WSGS, 2019, 2022

Biostratigraphy

Western Interior inoceramid range zones	Intercalated radiometric ages (Ma)	2nd order sea-level fluctuations
adoceramus undulatoplicatus		Niobrara
agadiceramus crenelatus		
agadiceramus subquadratus		
lviceramus involutus	87.61	
lviceramus koeneni	88.08	
emnoceramus crassus crassus		
emnoceramus crassus inconstans	88.70	
emnoceramus deformis dobrogensis	88.85	
emnoceramus deformis erectus	89.00	
emnoceramus waltersdorfensis	89.15	
ytiloides scupini	89.30	
ytiloides incertus	89.45	
oceramus dakotensis	89.60	
oceramus perplexus	89.75	
	89.90	
oceramus dimidius	90.05	
oceramus aff. *dimidius*		
oceramus howelli		



FIGURES 1–15. *Scaphites warreni* var. *ubiquitosus* Cobban, n. var. 1–5, Side, rear, top, and bottom views, and second from last suture (composite) of holotype, an internal mold, U.S.N.M. 106751. From a thin sandstone bed in the Mancos shale about 150 feet below base of Tocito sandstone lentil at map locality 274. 6–11. Seventh from last suture, and top, bottom, rear, front, and side views of an internal mold, U.S.N.M. 106752, from same locality as figures 1–5. 12–15, Last suture, and bottom, rear, and side views of an internal mold of a small adult specimen, U.S.N.M. 106753. From the Mancos shale at map locality 273 (p. 23).

FIGURES 1–17. *Scaphites nigricollensis* Cobban, n. sp. From a bed of calcareous concretions 59 feet below top of Turner sandy member of Carlile shale at map locality 114. 1–6, Bottom, top, rear, front, and side views, and second from last suture of holotype, an internal mold, U.S.N.M. 106730. 7–12, Next to last suture, and front, rear, top, bottom, and side views of a paratype, an internal mold, U.S.N.M. 106731b. 13–17, Fifth from last suture, and side, rear, top and bottom views of a paratype, an internal mold, U.S.N.M. 106731a (p. 25).

30–40. *Scaphites whitfieldi* Cobban, n. sp. 30–34, Fifth from last suture, and side, rear, bottom, and top views of holotype, U.S.N.M. 106735. From a ferruginous concretion bed 251–264 feet above base of Carlile shale at map locality 112. 35–40, Side, front, rear, top, and bottom views and next to last suture of a specimen, an internal mold, U.S.N.M. 12258a, figured by Whitfield as *S. wyomingensis* Meek. From the Carlile shale on the western flank of the Black Hills (p. 24).

Cardium Fm.

A.G. Plint, D. Uličný, S. Čech et al.

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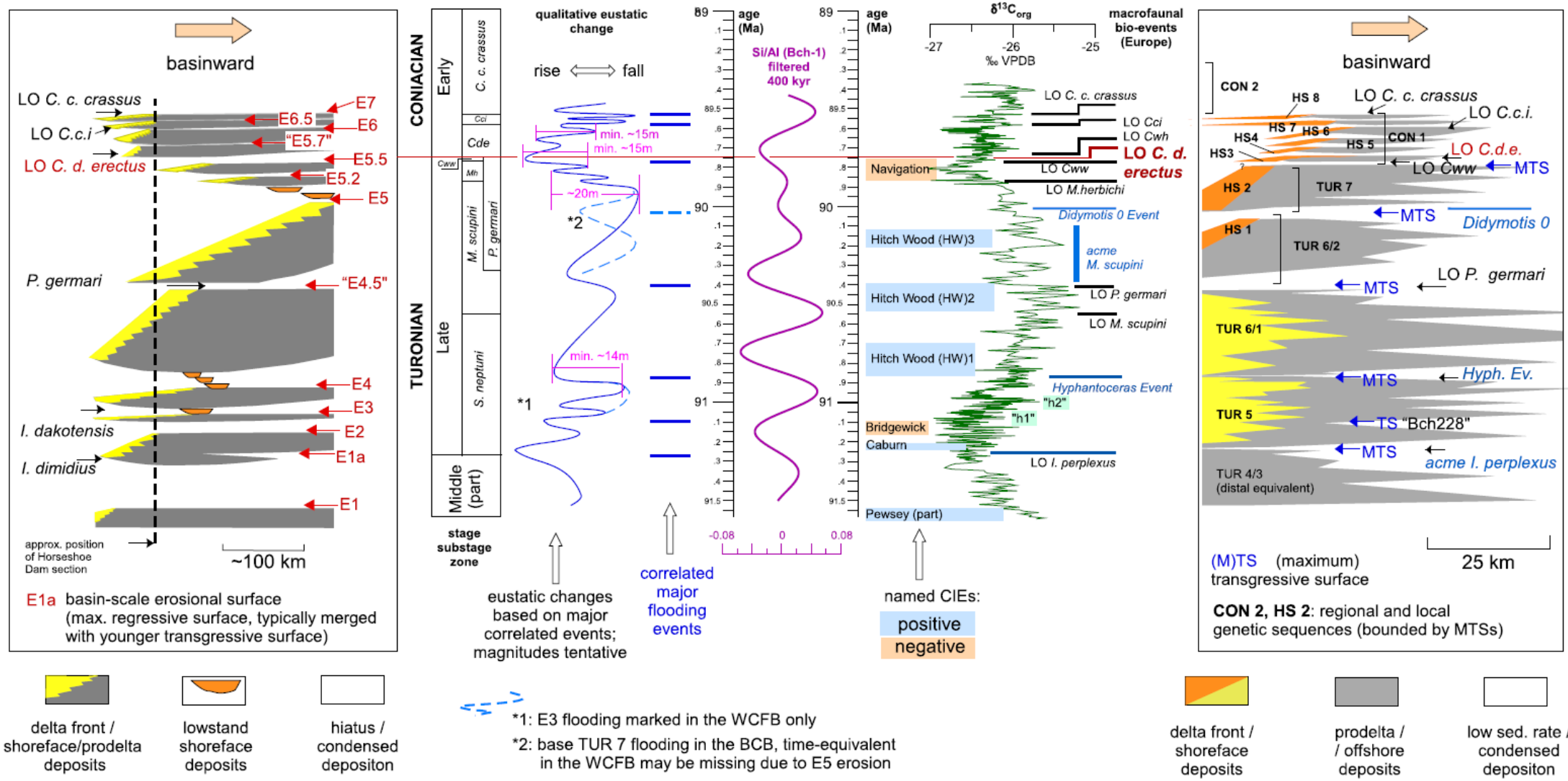
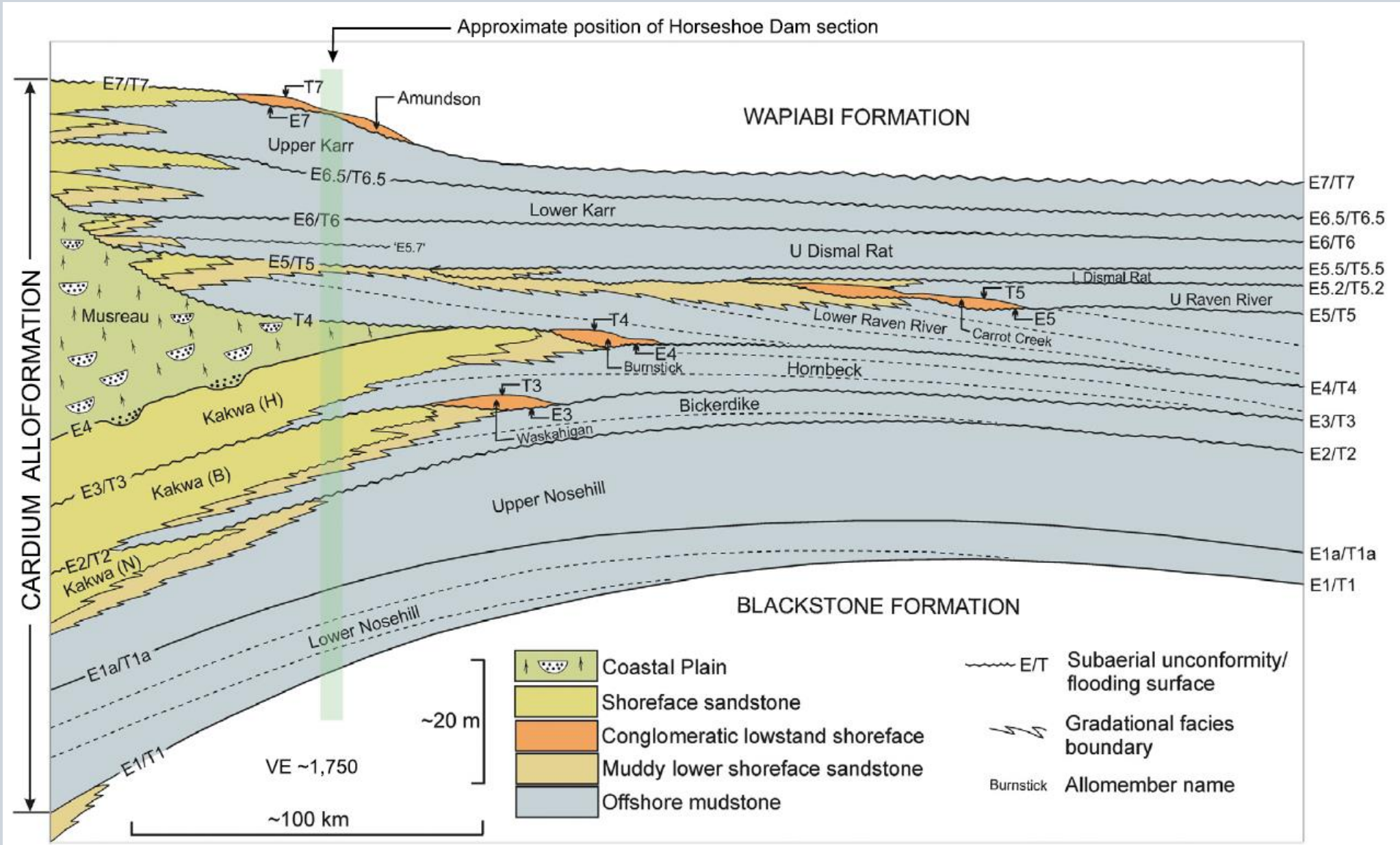
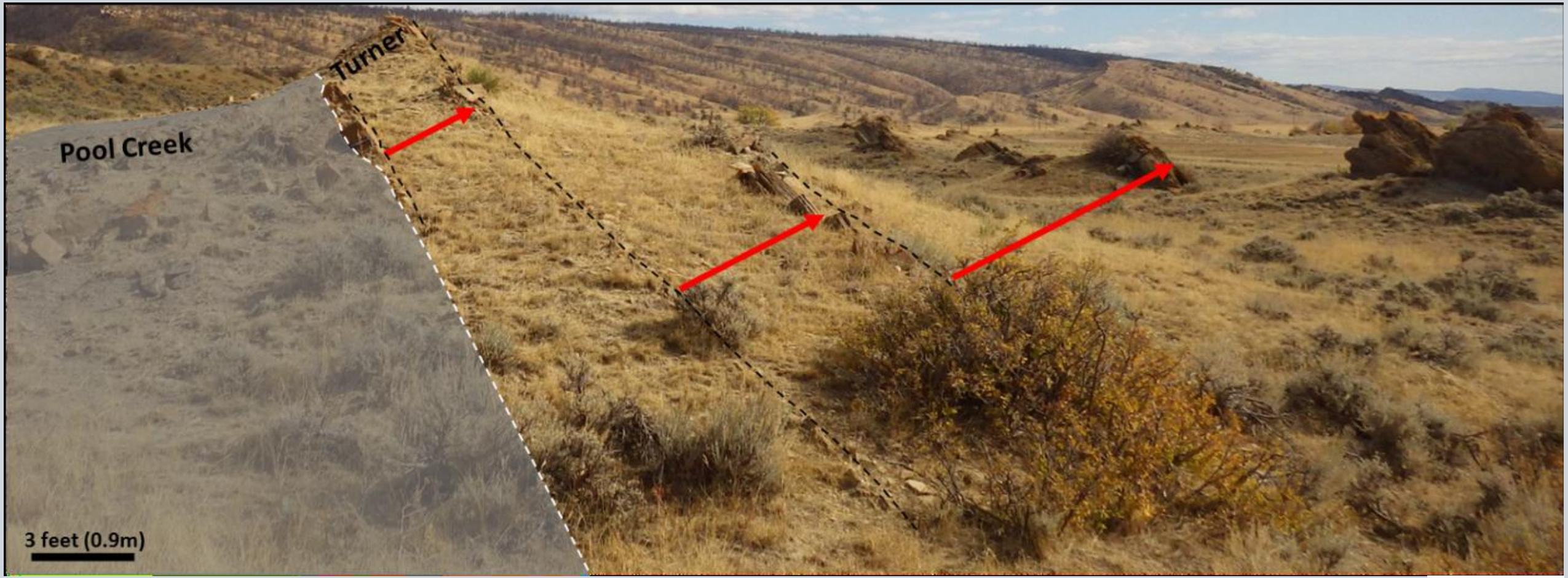


Cardium Fm.


Approximate position of Horseshoe Dam section
CARDIUM ALLOFORMATION
E7/T7
T7
E7
Amundson
Upper Karr
WAPIABI FORMATION
E6.5/T6.5
Lower Karr
E6/T6
'E5.7'
U Dismal Rat
E5/T5
L Dismal Rat
T5
E5
U Raven River
Lower Raven River
Carrot Creek
Musreau
T4
E4
Burnstick
Hornbeck
T3
E3
Bickerdike
Waskahigan
Kakwa (H)
E4
E3/T3
Kakwa (B)
Upper Nosehill
E2/T2
Kakwa (N)
E1a/T1a
Lower Nosehill
E1/T1
BLACKSTONE FORMATION
E7/T7
E6.5/T6.5
E6/T6
E5.5/T5.5
E5.2/T5.2
E5/T5
E4/T4
E3/T3
E2/T2
E1a/T1a
E1/T1
~20 m
VE ~1,750
~100 km
Coastal Plain
Shoreface sandstone
Conglomeratic lowstand shoreface
Muddy lower shoreface sandstone
Offshore mudstone
E/T
Subaerial unconformity/ flooding surface
Gradational facies boundary
Burnstick
Allomember name

Turner Outcrops



Heger, 2017