Paleogeography and Paleotectonics of the Western Interior Seaway, Jurassic-Cretaceous of North America*

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Abstract

The Western Interior Seaway dominated North American paleogeography during much of the Mesozoic. Beginning as a narrow body in a back arc basin along the British Columbia-Alberta border the Early Jurassic, the seaway expanded and contracted numerous times during the remaining Mesozoic. From the Cenomanian through most of the Campanian, the seaway extended from the Arctic to the Gulf of Mexico, at times covering nearly half of North America. An extensive volcanic signature in the rock record including ash beds (bentonites), detrital zircons, and local volcanic flows coupled with a robust fossil record, excellent, widespread outcrops, and voluminous subsurface data have provided the basis for basin-wide, detailed correlation.

From the Middle Jurassic through the Coniacian, Cordilleran subduction, magmatism, and thrusting generated a classic retro-arc foreland basin that orchestrated subsidence and sedimentation patterns in the Western Interior Basin that in turn controlled the geometry of the Western Interior Seaway. However, from the Santonian through the Maastrichtian, subsidence and sedimentation patterns changed in response to shallowing subduction angles and subduction of a thick oceanic slab. The subducted slab eventually caused regional uplift, partitioning of the Western Interior Basin into Laramide uplifts and basins, and withdrawal of the Western Interior Seaway.

The rock record of these events contains some of the greatest paleontologic and economic resources on Earth – dinosaurs, hydrocarbons, and coal. Paleogeographic maps prepared over tightly spaced time slices provide a basis for presenting this complex geologic history in an easily understood manner.

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Cretaceous Seas and Shores -- Western Interior Seaway

Tectonic Setting and Paleogeography of Widespread Sedimentary Rocks, West-central North America

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cpgeosystems.com/index.html

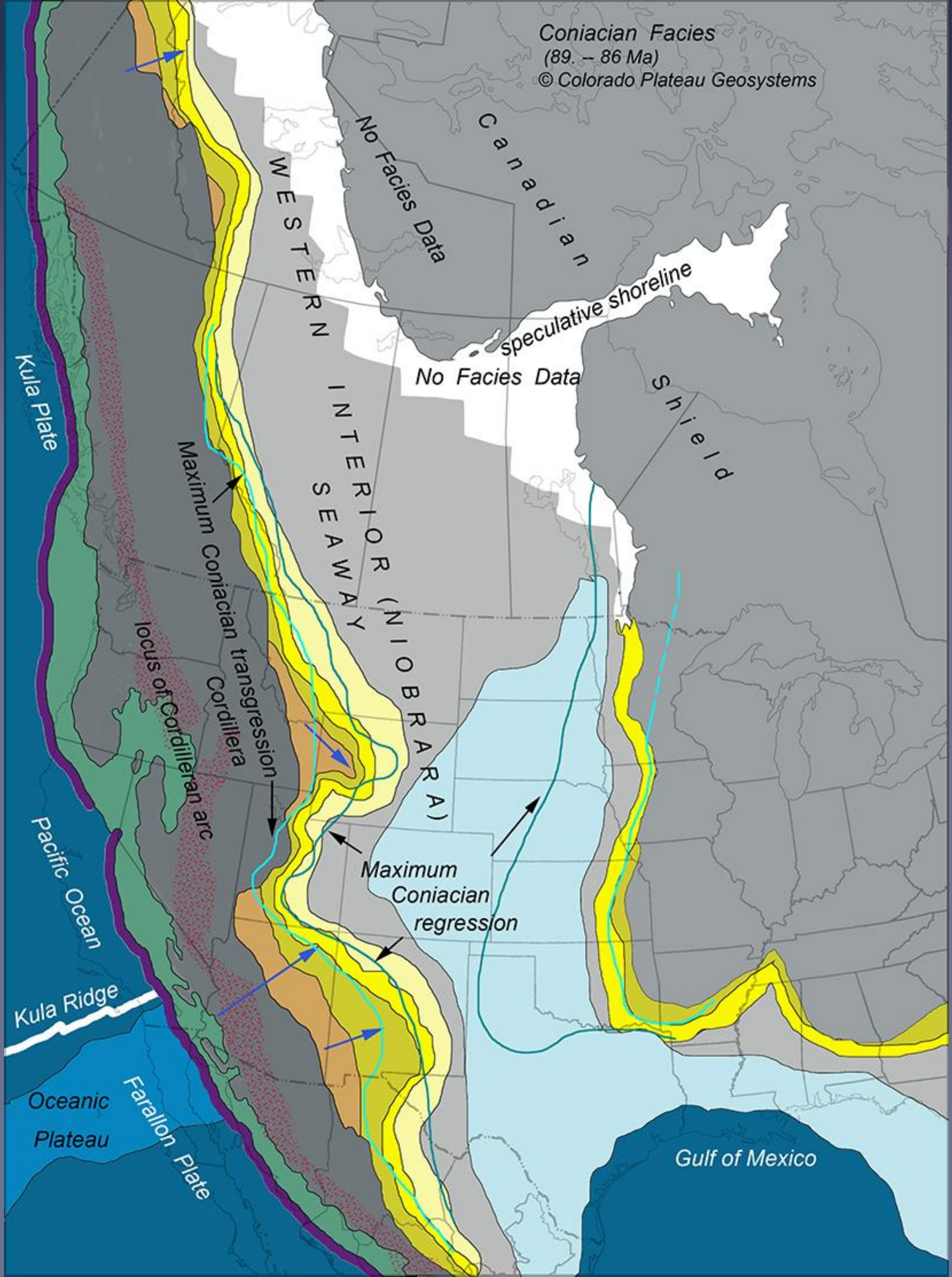
Outline of Presentation

- Geologic Setting
- Brief Overview of History of Western Interior Basin
- Paleogeographic Maps
- Example of Transgressive-regressive History – Detailed Paleogeography

General Geologic Setting Western Interior

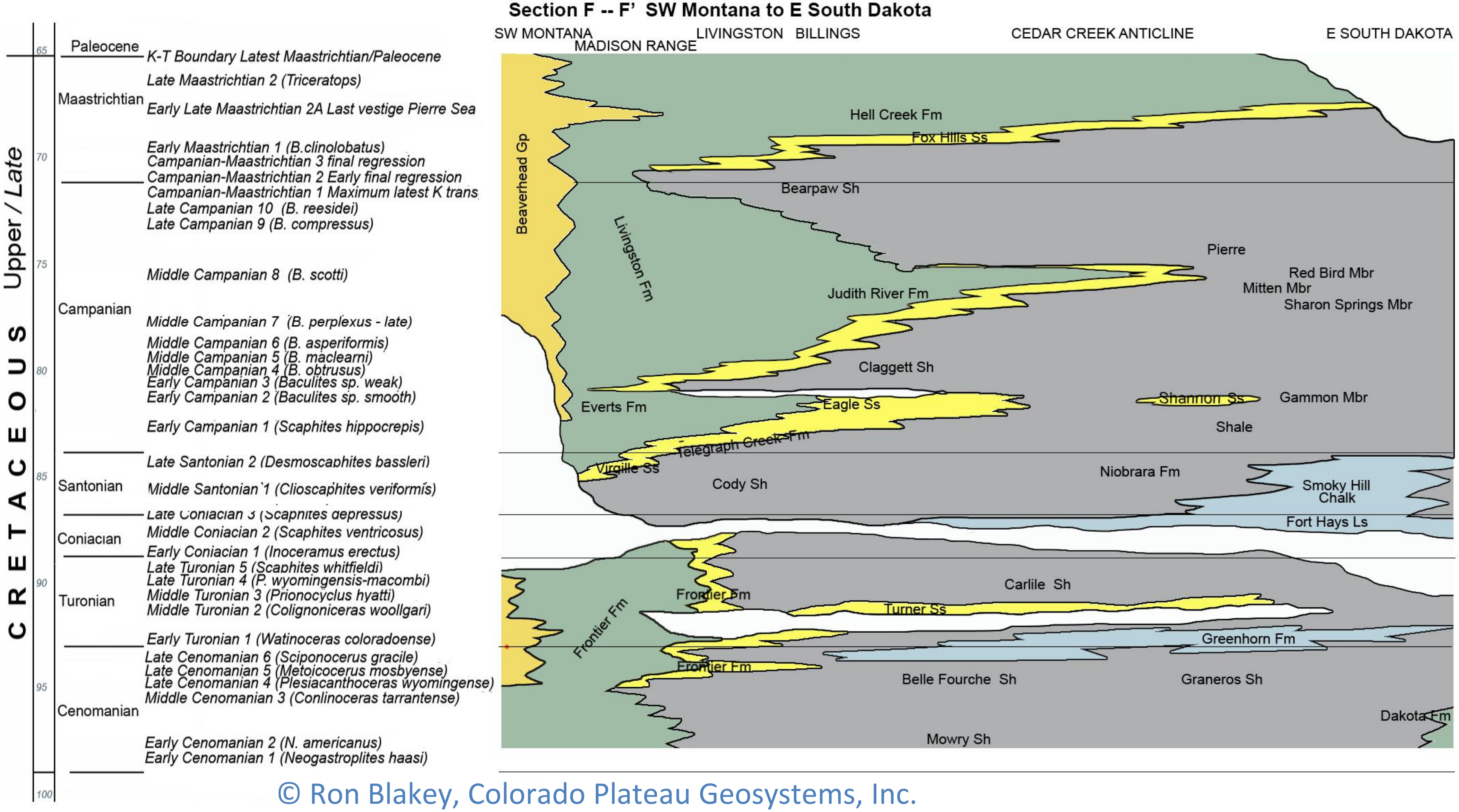
- Classic foreland basin adjacent to Sevier orogeny
- Coarse to fine sediment supplied by Sevier highlands to west
- Sand and mud supplied by NA Craton
- Limestone deposited in clear, offshore settings
- Well developed asymmetric transgressive-regressive sedimentary cycles; overall regressive sequence through Late Cretaceous

Coniacian Facies/ Tectonic map

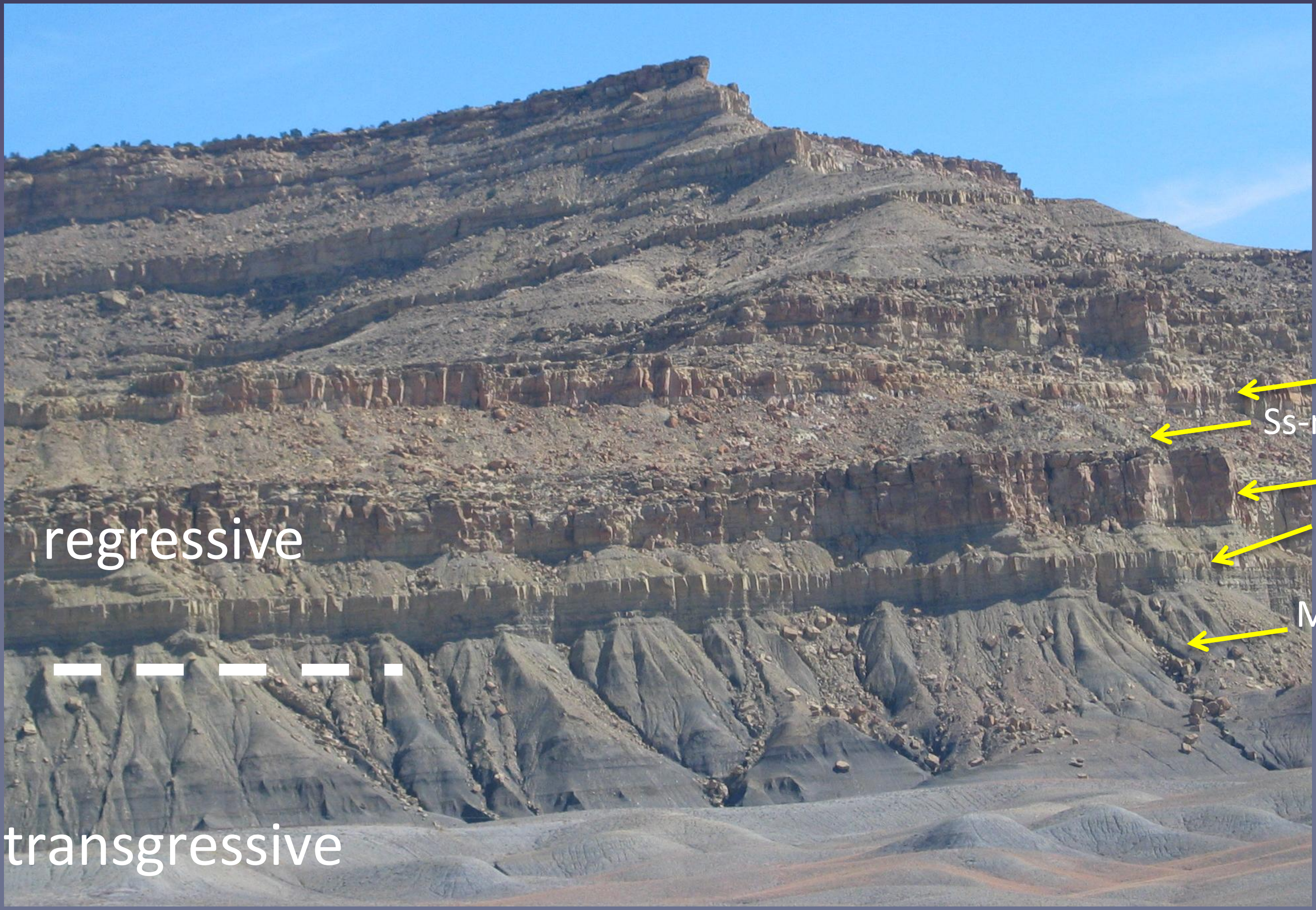


Late Cretaceous Chronostratigraphic Section

White areas represent missing rocks



Example of well-exposed Cretaceous section



Cse ss, cong

Ss-ms-coal – coastal plain

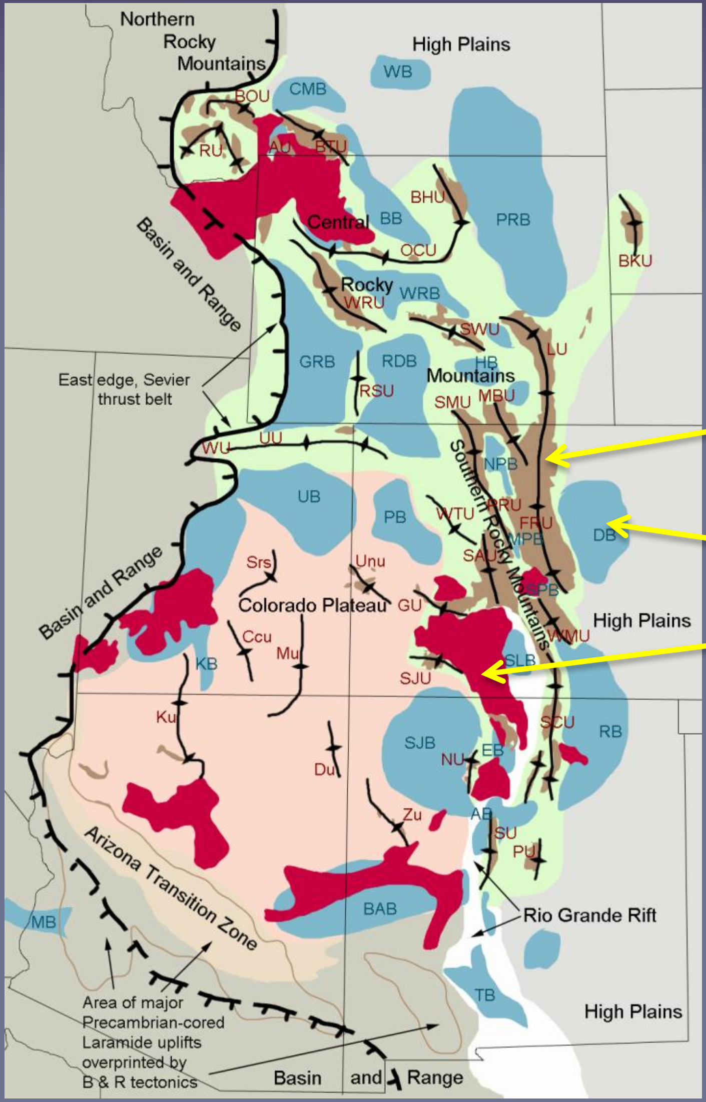
Ss – shoreline

Ss-ms – shoreface

Ms – offshore marine

Tropic Shale and Straight Cliffs Formation,
Brigham Plains, Kaiparowits Plateau, Utah

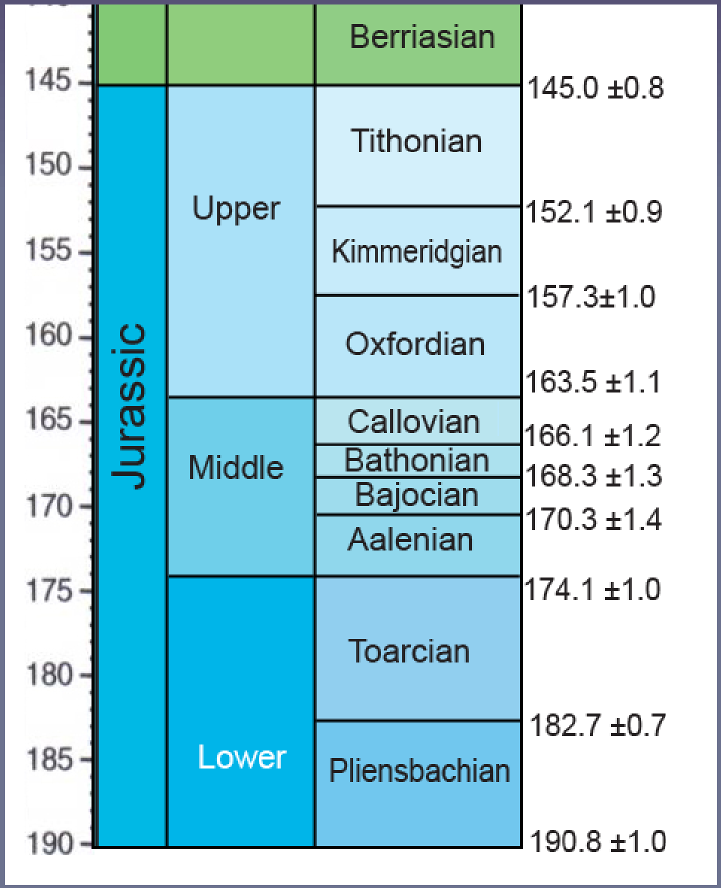
Western Interior Seaway terminated by Laramide tectonics

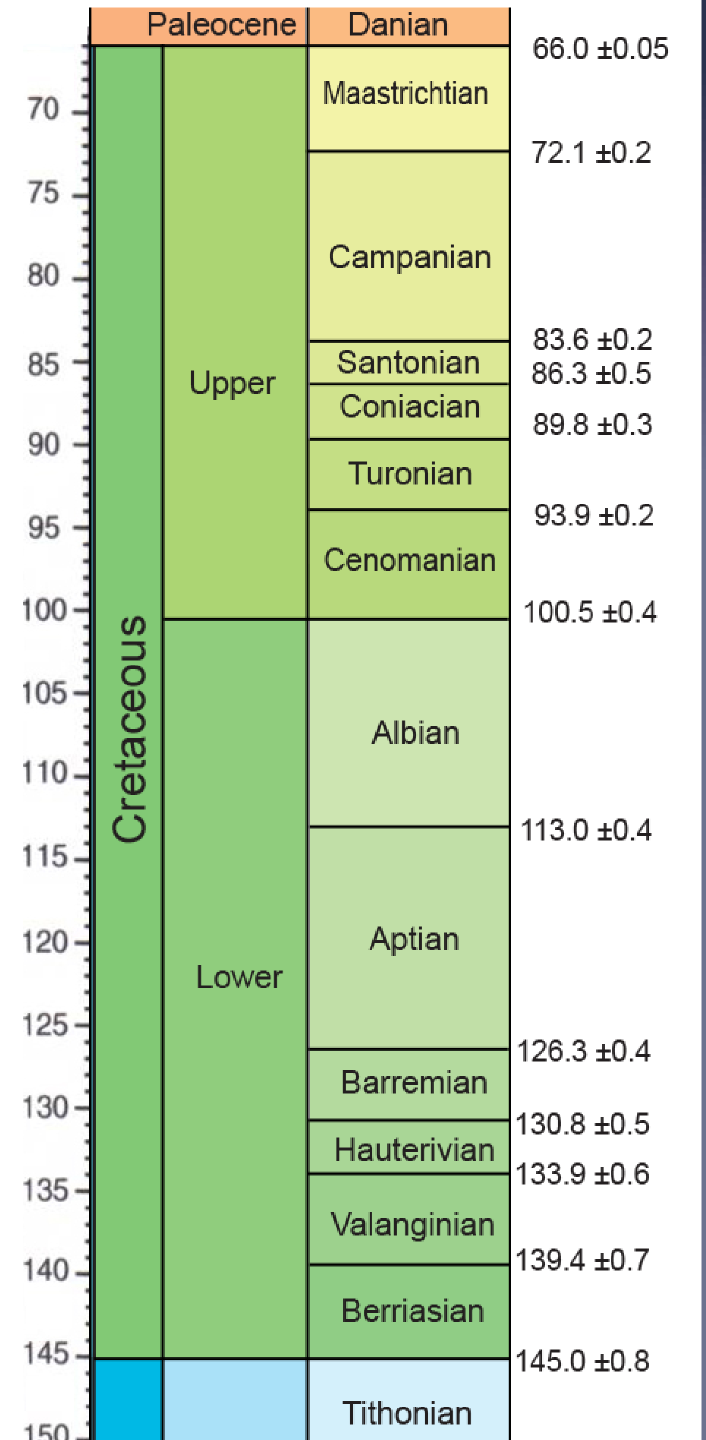


Correlating Major Events

- Radiometric dating
  - Plutonic-volcanic events – internal and external
  - Metamorphic events – external
  - Structural events – internal and external
  - Bentonites – internal
- Biostratigraphic dating (coupled with dating techniques above)
  - Marine record
  - Terrestrial record

Geologic Time Scale (part), Gradstein et al.,2004





Brief History of Western Interior Seas

Jurassic – Seas expand in Middle Jurassic with repeated T/R events; fluvial deposits close Jurassic sedimentation

Early Cretaceous – Narrow seas restricted to NW Canada early; sea expands to south and east during Aptian; late Albian Skull Creek Seaway bisects NA from Arctic to Gulf

Cenomanian-Turonian – major regression at Albian/Cenomanian boundary followed by major transgression that culminated with extensive Greenhorn Seaway in early Turonian; major deltaic progradation in Late Turonian

Coniacian-Santonian – repeated T/R events but seaway remains continuous from Arctic to Gulf

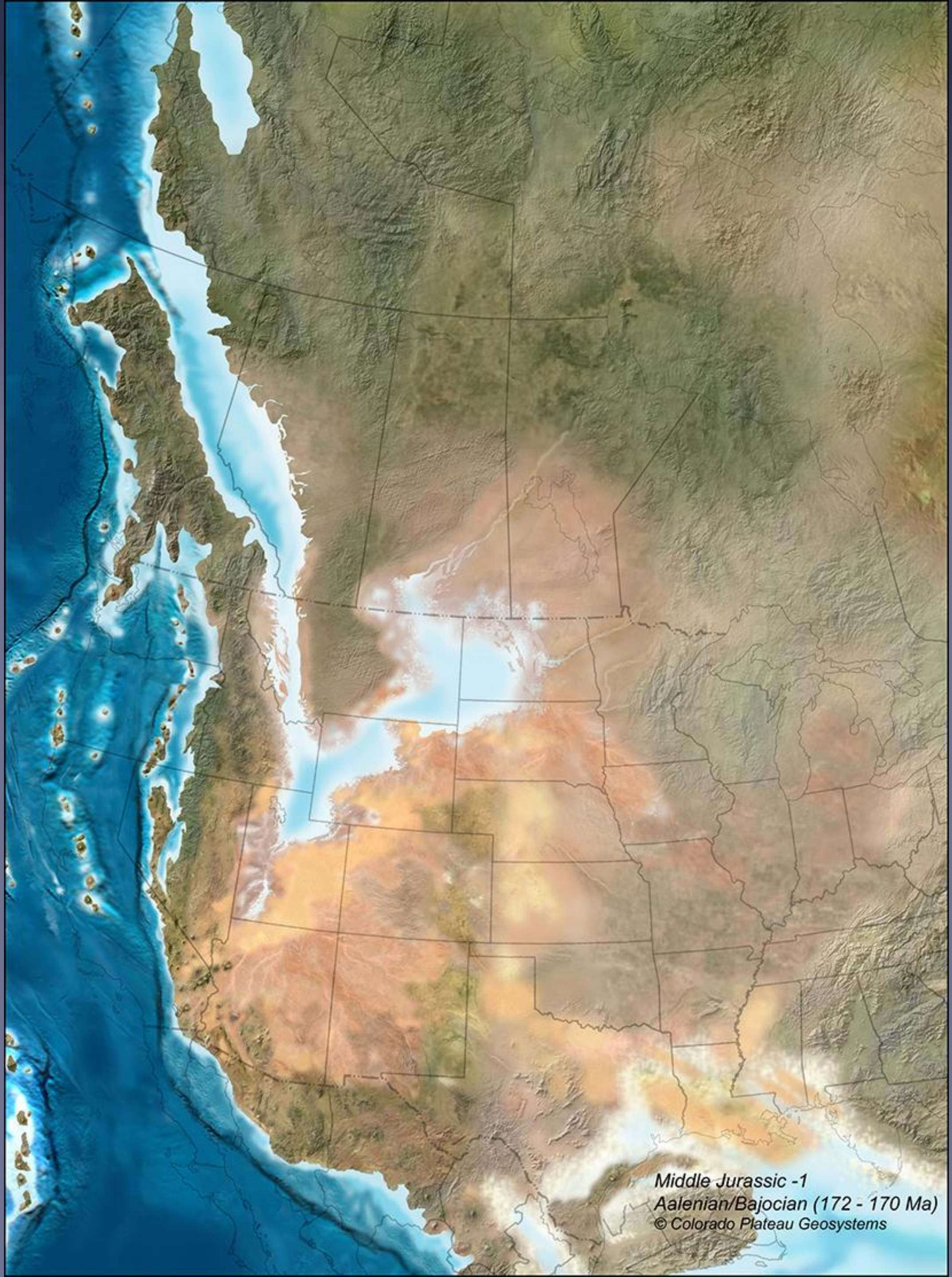
Campanian – major swings in shoreline during several T/R events; seaway closed in late Campanian north of Gulf region

Maastrichtian – early transgression followed by protracted regressive event that filled basins and ended reign of seaway; Western Interior Basin partitioned into basins and uplifts during late Maastrichtian-Paleocene Laramide Orogeny

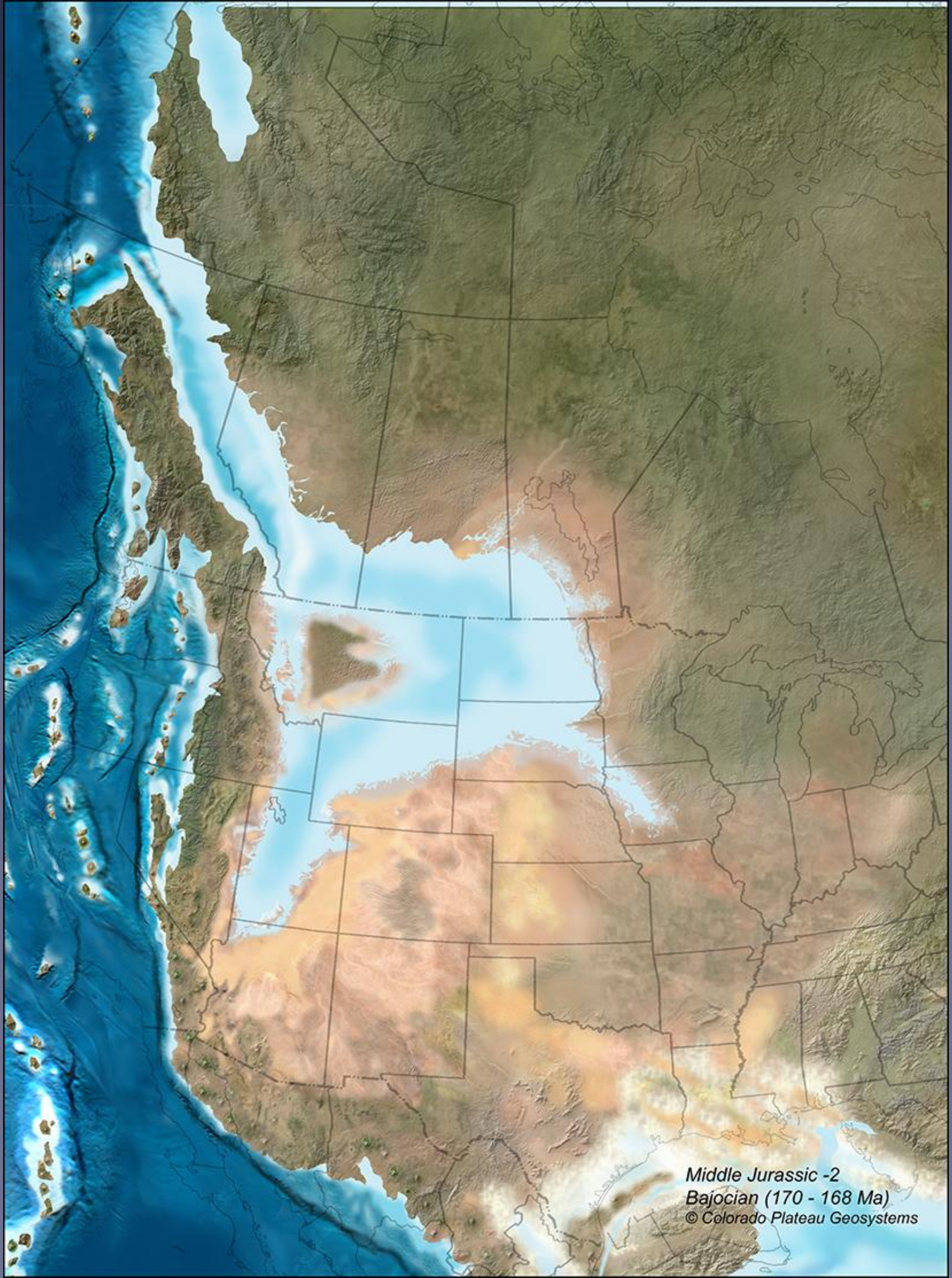
The following 26 maps portray the overall history of the Western Interior Seaway

All maps ©Ron Blakey, Colorado Plateau Geosystems, Inc.

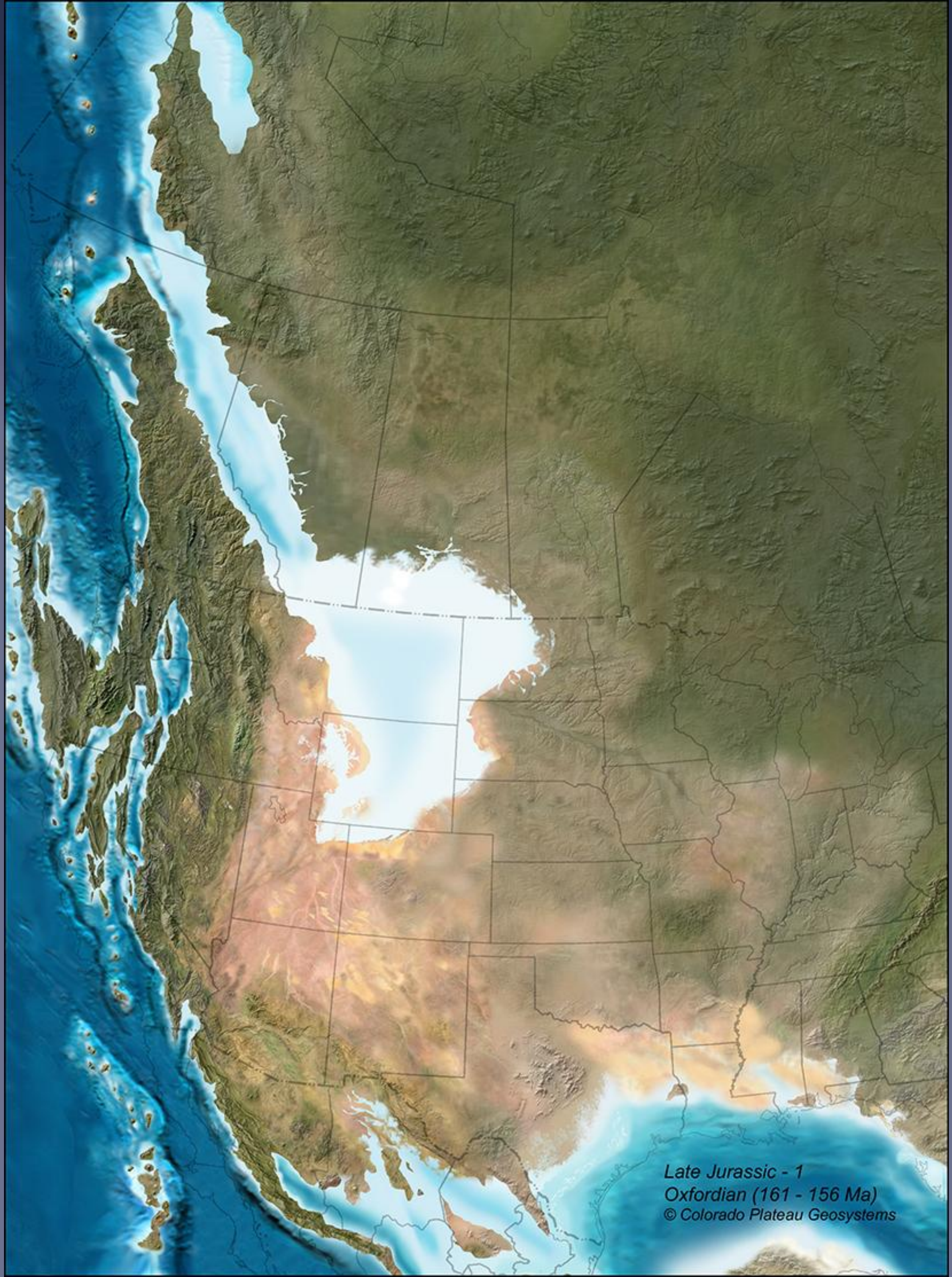
Middle Jurassic – Gypsum Springs Seaway



Middle Jurassic – Carmel-Twin Creek Seaway



Late Jurassic –
Swift-Upper
Sundance Seaway



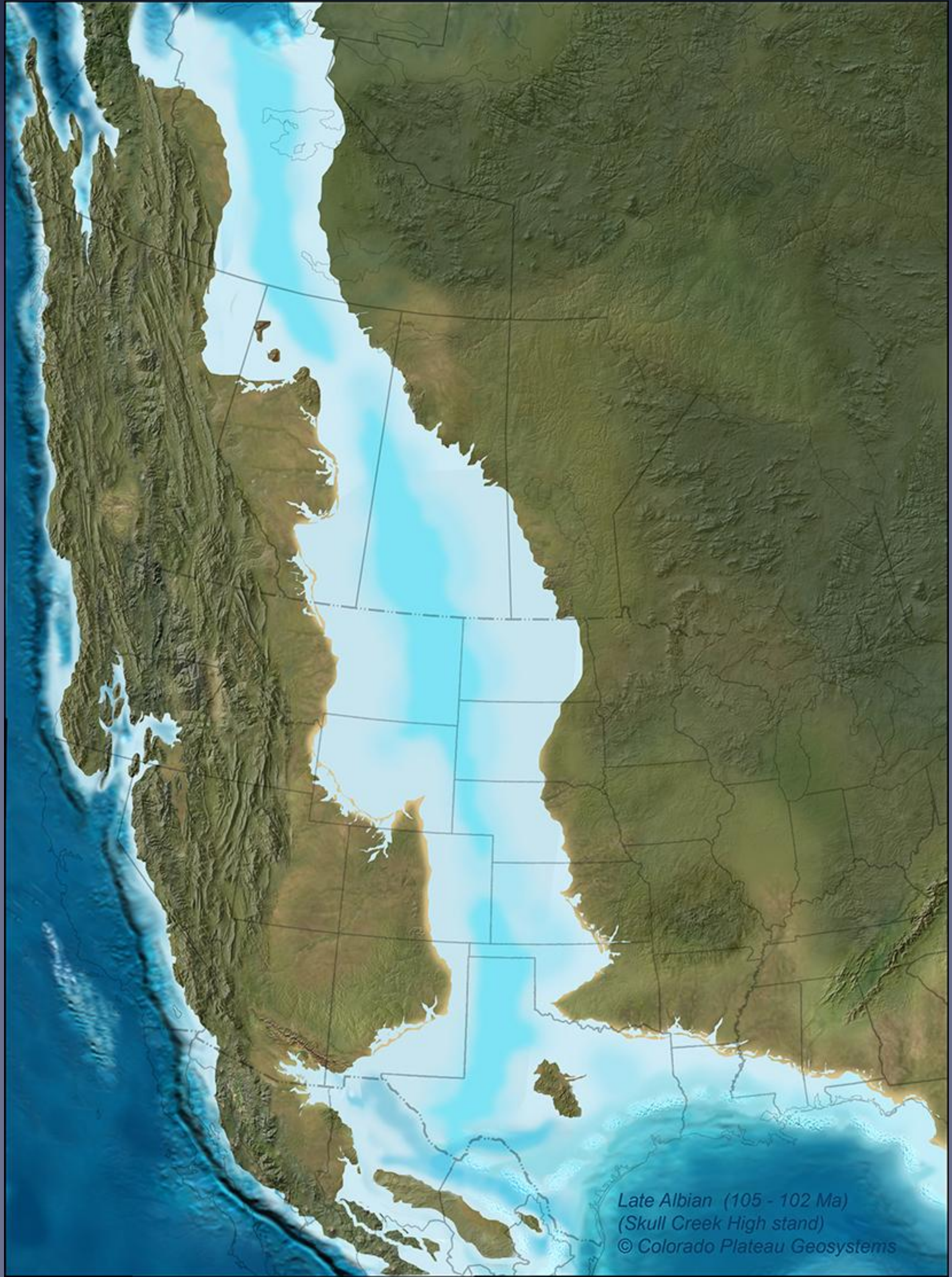
Late Jurassic – Morrison fluvial system

Early Cretaceous –
Berriasian

Early Cretaceous –
Aptian

Early Cretaceous –
Albian Fall
River Seaway

Early Cretaceous – Albian Skull Creek Seaway



“Mid” Cretaceous – Mowry Seaway

“Mid” Cretaceous – Mowry-Graneros Seaway

Late Cretaceous – Turonian Greenhorn Seaway

Late Cretaceous – Turonian Frontier/ Ferron regression

Late Cretaceous –
Coniacian
Mancos Seaway

Late Cretaceous –
Coniacian
Mancos Seaway –
Gallup regression

Late Cretaceous – Santonian Pierre-Mancos Seaway

Campanian regressive sequence,
Book Cliffs, UT

Campanian regressive sequence,
Mesa Verde, CO

Late Cretaceous – Campanian


Middle Campanian (B. maclearni) – 80.4 Ma
© Colorado Plateau Geosystems


Middle Campanian (B. asperiformis) -- 80.0 Ma
© Colorado Plateau Geosystems


Late Campanian (B. compressus) -- 73.5 Ma
© Colorado Plateau Geosystems


Campanian/ Maastrichtian - 1
~70.8 Ma max transgression
© Colorado Plateau Geosystems


Campanian/ Maastrichtian - 3
~70.0 Ma regression 2
© Colorado Plateau Geosystems

Late Cretaceous – Maastrichtian


Maastrichtian - 2A early Late
~68 Ma regression (final)
© Colorado Plateau Geosystems


Late Maastrichtian
(Triceratops) -- 67.0 Ma
© Colorado Plateau Geosystems

K-T Boundary


K - T Boundary -- 65 Ma
Latest Cret/earliest Paleocene
© Colorado Plateau Geosystems

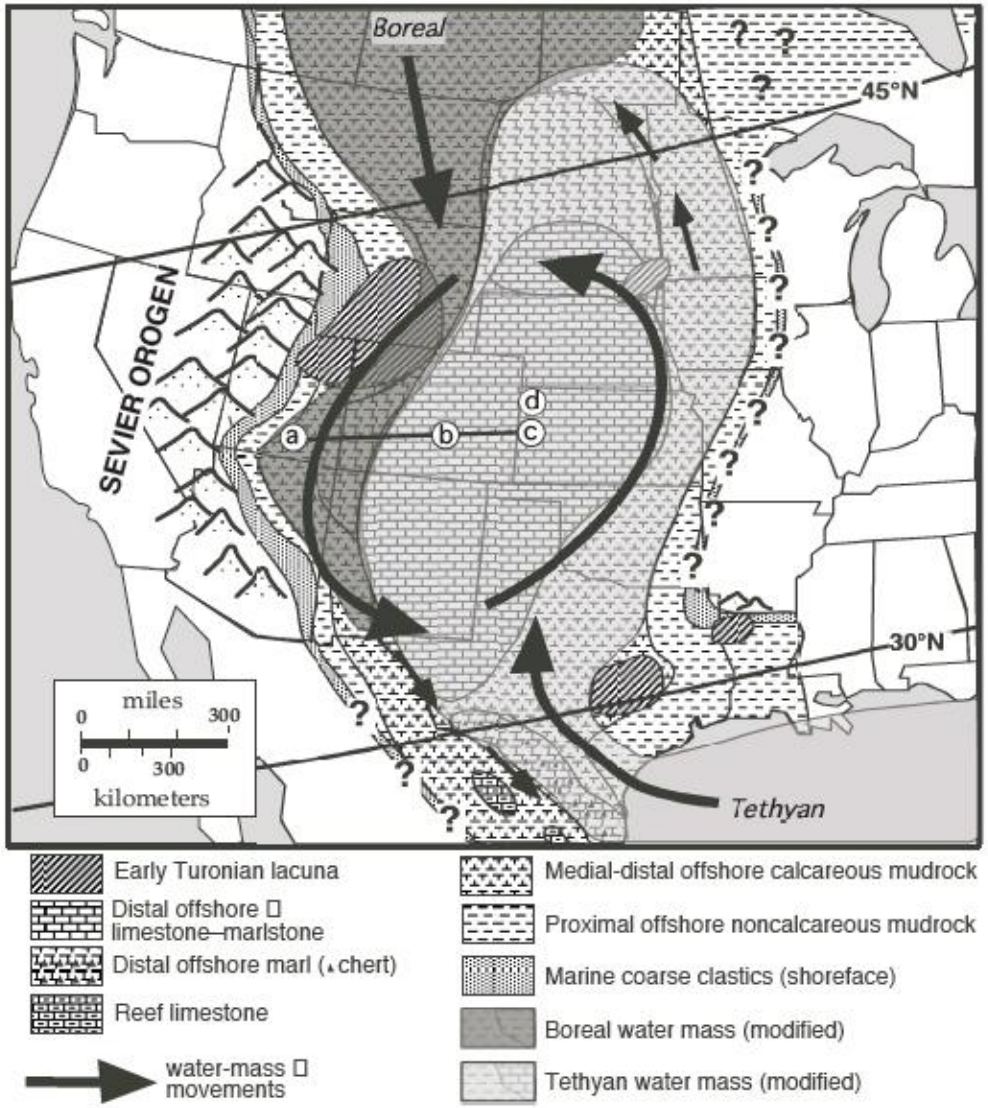
Paleocene


Paleocene -- 60 Ma
Laramide uplifts and basins
© Colorado Plateau Geosystems

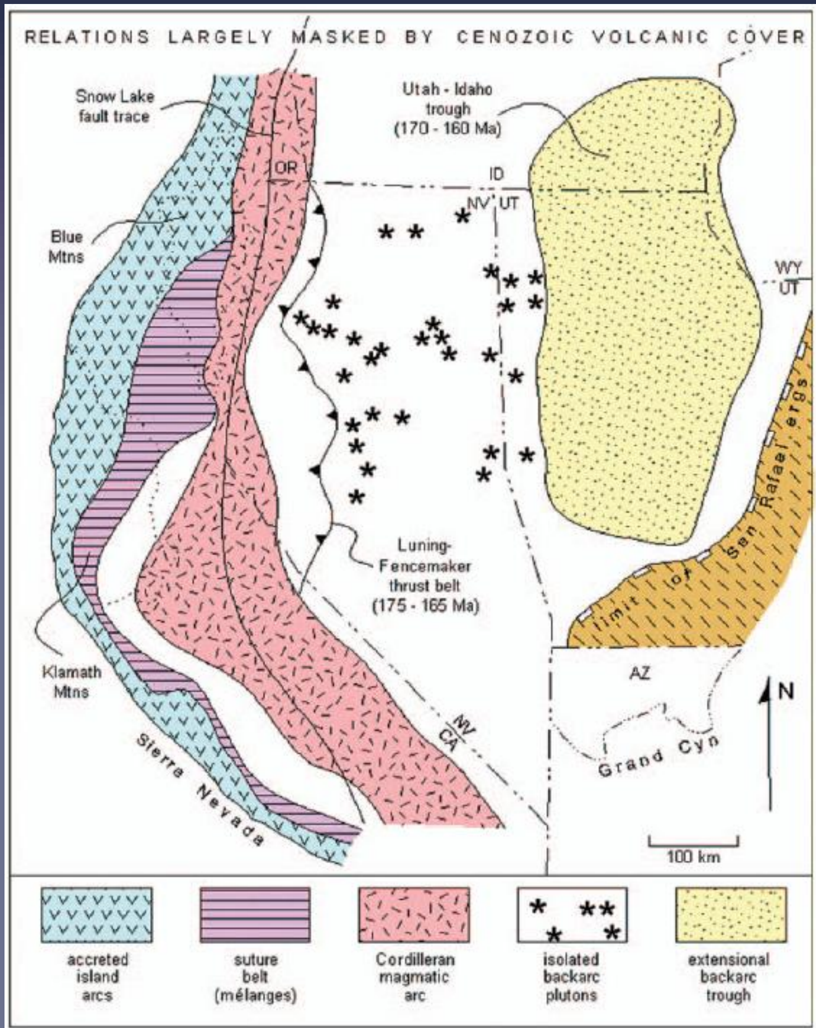
Paleogeographic Maps -- Sources of Data

- Excellent, widespread outcrops
- Robust subsurface data
- Voluminous radiometric data
- Unequalled biostratigraphic data
- The above have yielded a rich collection of publications and other types of shared information

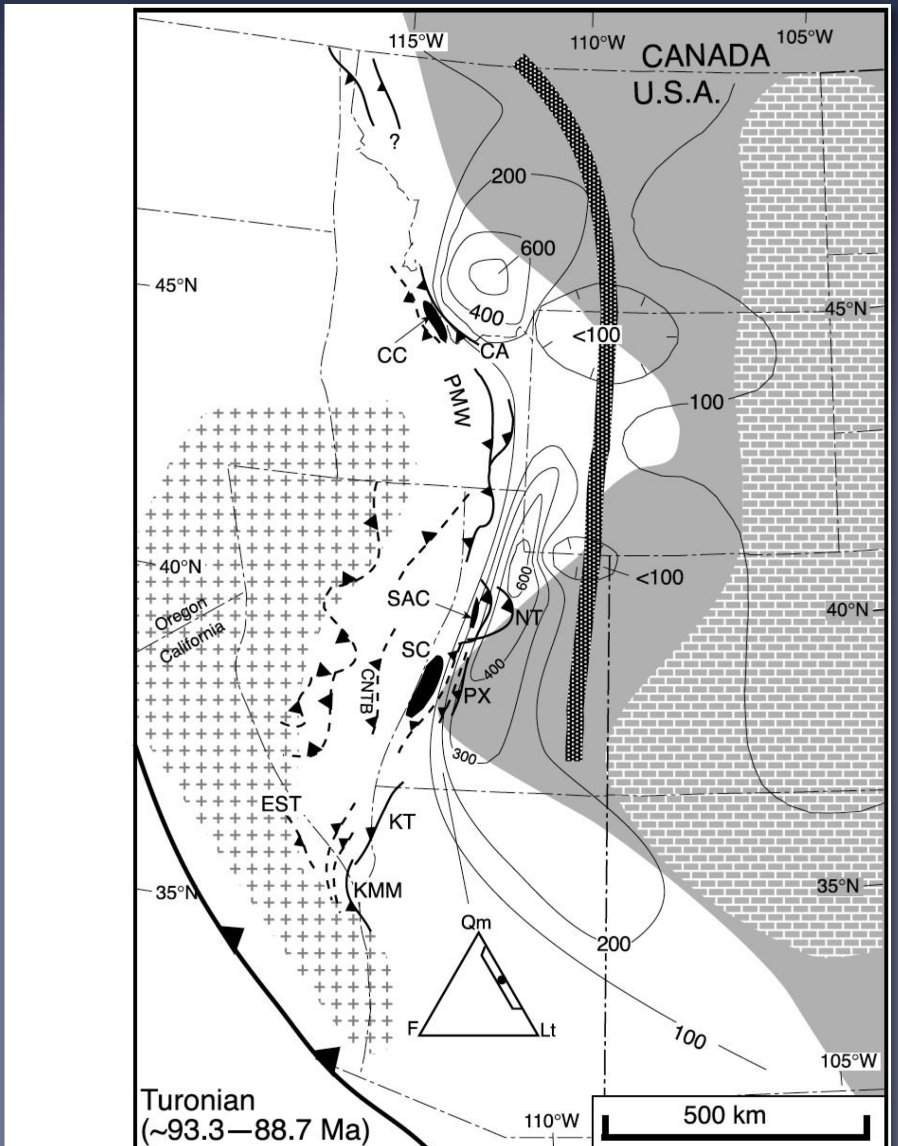
Cretaceous Turonian facies, Paleo-oceanography



Arthur and Sageman, 2004, SEPM Sp Pub 82



Palinspastic restoration,
175-125 Ma,
Dickinson, 2011,
Geol Soc Nev Symp vol.



Palinspastic-structural restoration,
Turonian,
DeCelles, 2004,
Am Jour Sci

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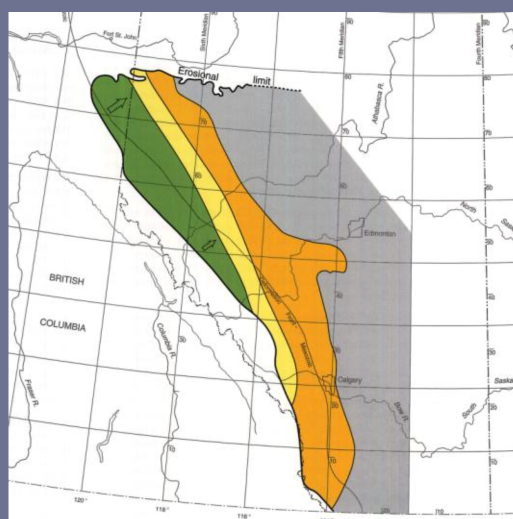
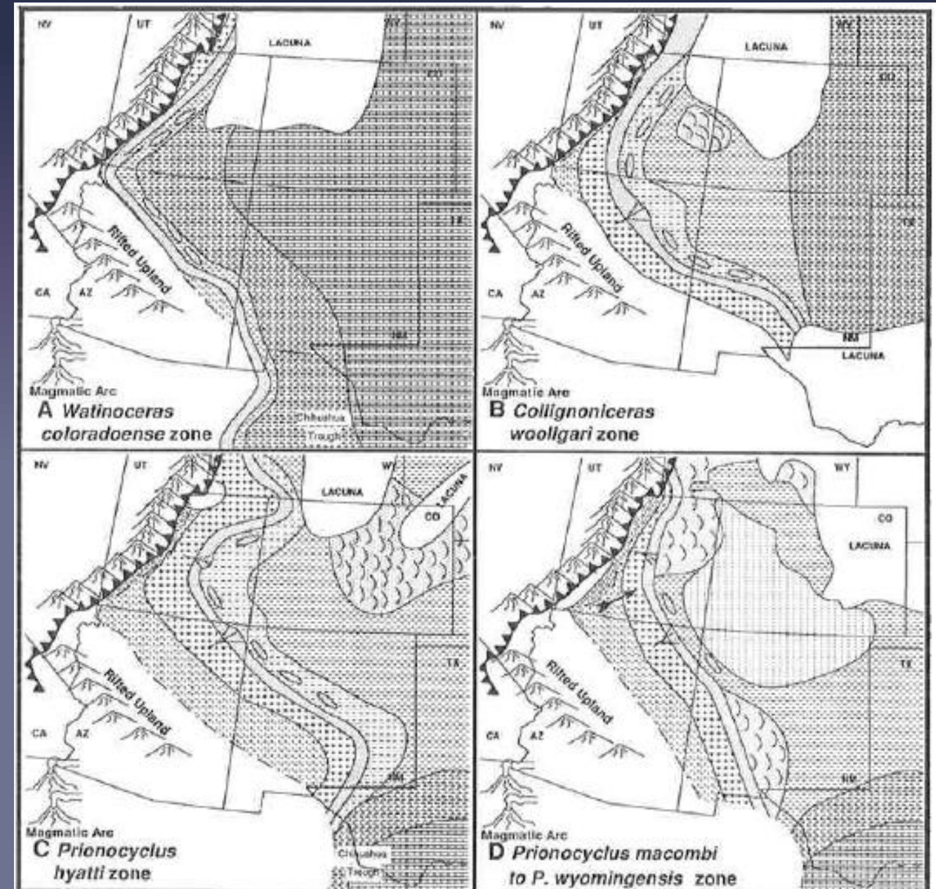
Cretaceous paleogeography, Western Canada Strat Atlas





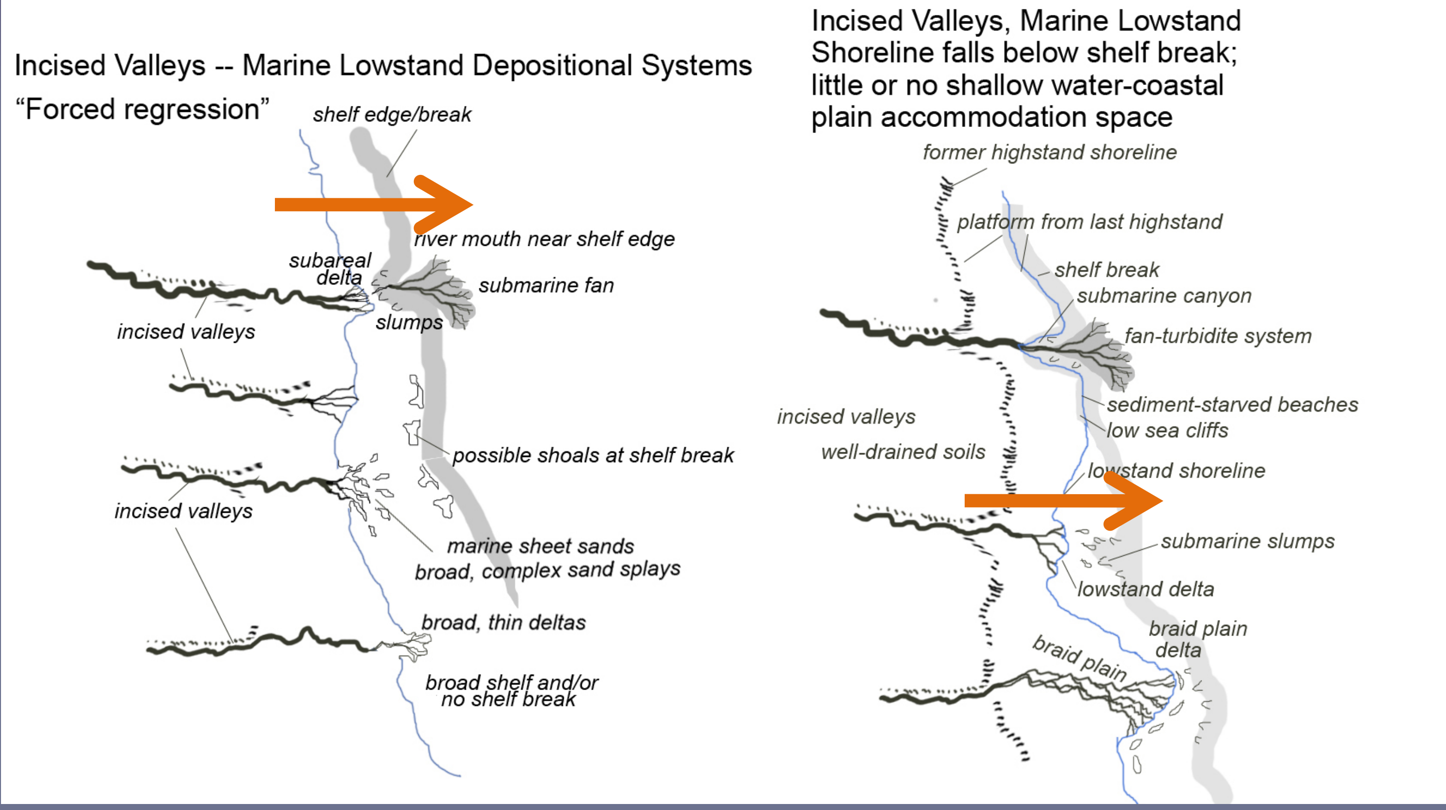
A -- 93 - Tropic-Dakota-Greenhorn-Frontier
B -- 91 - Tropic-Greenhorn-Frontier
C -- 90 Ma - Tropic-Mncos-Ferron-Juana Lopez-Tibbit Canyon
D -- 90-89 - Juana Lopez-Mancos-Smoky Hollow-Carlile-Gallup

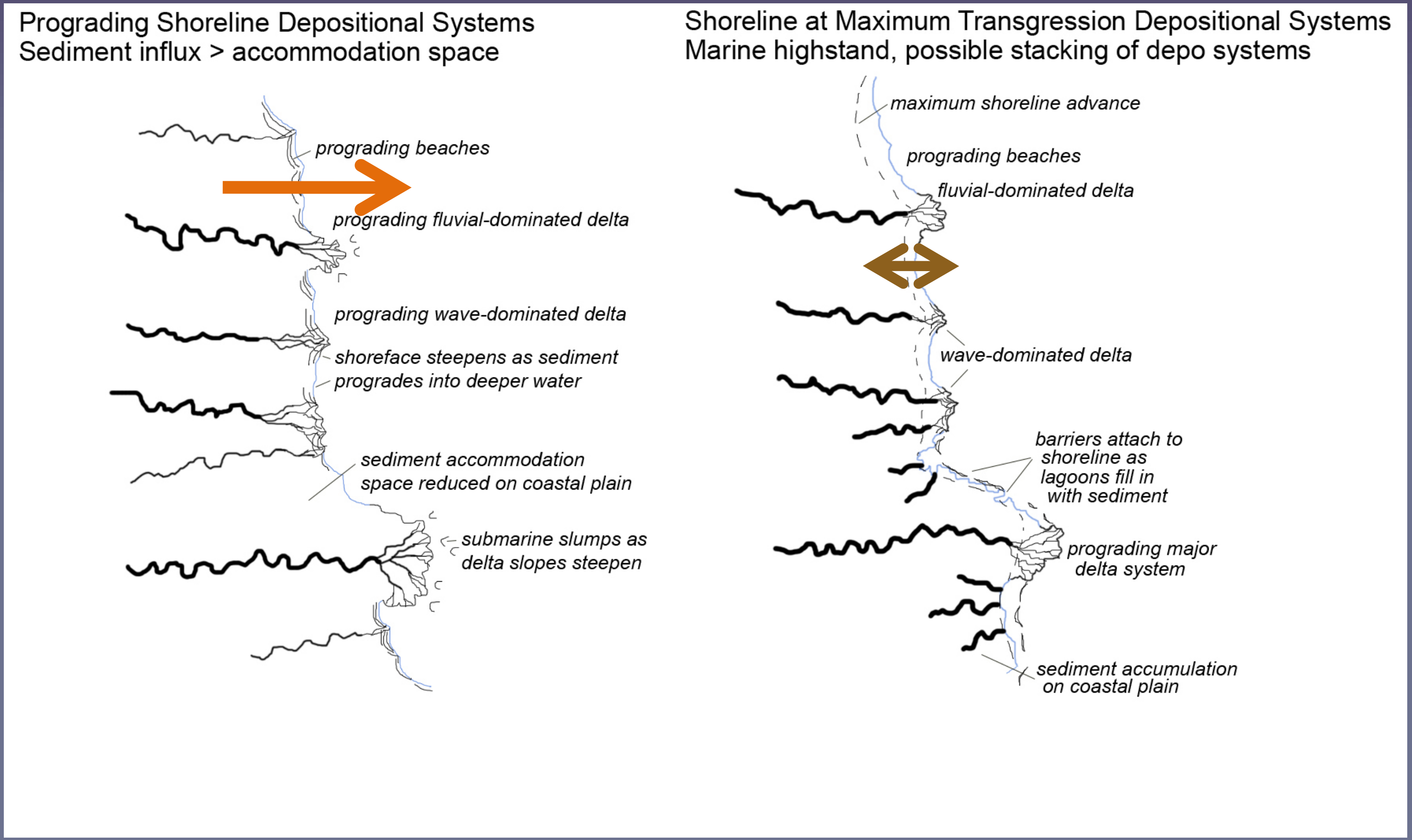
Cretaceous paleogeography, Elder and Kirkland, 1994, RMS -- SEPM Palgeog vol.

Example of Detailed Paleogeography

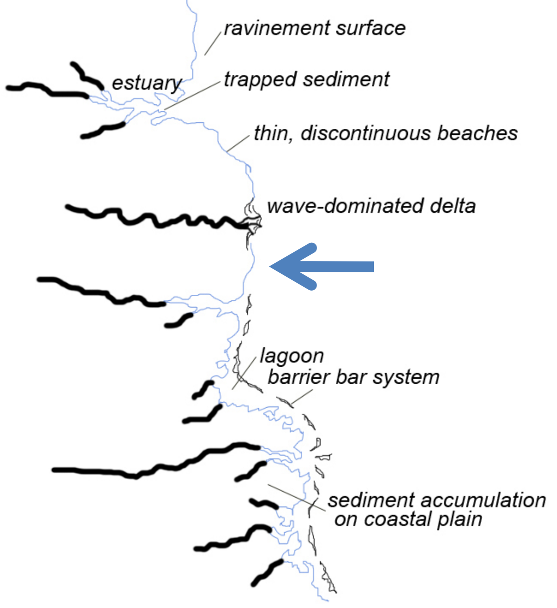
Cenomanian-Turonian transgression

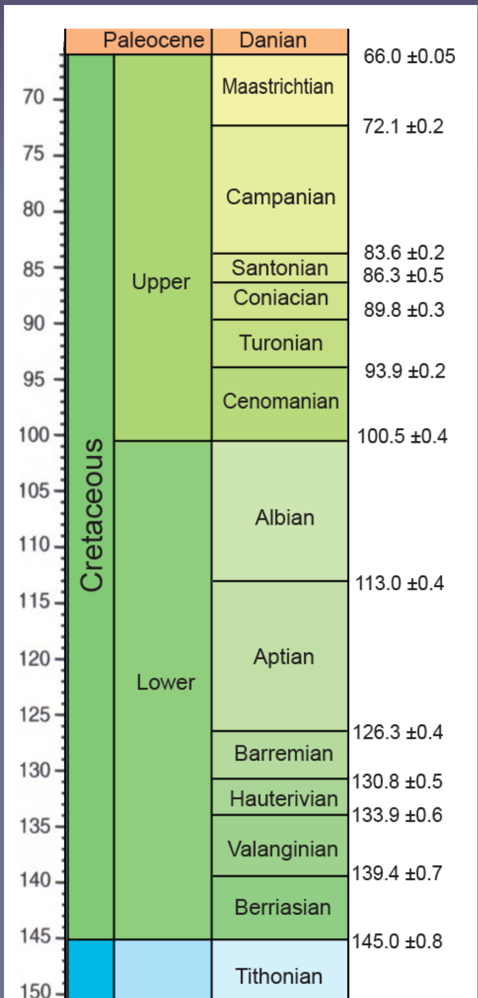
Variations in Shoreline Depositional Systems, Cretaceous Western Interior Seaway




Prograding Shoreline Depositional Systems
Sediment influx > accommodation space
prograding beaches
prograding fluvial-dominated delta
prograding wave-dominated delta
shoreface steepens as sediment progrades into deeper water
sediment accommodation space reduced on coastal plain
submarine slumps as delta slopes steepen
Shoreline at Maximum Transgression Depositional Systems
Marine highstand, possible stacking of depo systems
maximum shoreline advance
prograding beaches
fluvial-dominated delta
wave-dominated delta
barriers attach to shoreline as lagoons fill in with sediment
prograding major delta system
sediment accumulation on coastal plain

Transgressive Depositional Systems
Thin shoreline sands; sed trapped in estuaries; mud near shoreline; clear water promotes limestone depo; Accommodation space > sed rate





TIME SCALE *PALEOGEOGRAPHIC MAPS*

CRETACEOUS

Upper / Late

Ma *Gradstein et al., 2004 (2012)*

60

Paleocene Laramide Uplifts and Basins (ca. 60 Ma)

65 — 65.0 (66.0) — Paleocene

K-T Boundary Latest Maastrichtian/Paleocene (ca. 65 Ma)

Late Maastrichtian 2 (Triceratops) -- 67.0 Ma

Early Late Maastrichtian 2A Last vestige Pierre Seaway (ca 68 Ma)

Maastrichtian

Early Maastrichtian 1 (B.clinolobatus) -- 69.7 Ma

70 — 70.6 (72.1)

Campanian-Maastrichtian 3 final regression (ca. 70.0 Ma)
Campanian-Maastrichtian 2 Early final regression (ca. 70.4 Ma)
Campanian-Maastrichtian 1 Maximum latest K transgression (ca. 70.8 Ma)
Late Campanian 10 (B. reesidei) -- 72.1 Ma
Late Campanian 9 (B. compressus) -- 73.5 Ma

75

Campanian

Middle Campanian 8 (B. scotti) -- 77.0 Ma
Middle Campanian 7 (B. perplexus - late) -- 78.2 Ma

80

Middle Campanian 6 (B. asperiformis) -- 80.0 Ma
Middle Campanian 5 (B. maclearni) -- 80.4 Ma
Middle Campanian 4 (B. obtrusus) -- 80.6 Ma
Early Campanian 3 (Baculites sp. weak) -- 80.9 Ma
Early Campanian 2 (Baculites sp. smooth) -- 81.2 Ma
Early Campanian 1 (Scaphites hippocrepis) -- 82.9 Ma

83.5 (83.6)

Santonian

Late Santonian 2 (Desmoscaphites bassleri) -- 84.0 Ma
Middle Santonian 1 (Clioscaphites veriformis) -- 84.9 Ma

85 — 85.8 (86.3)

Coniacian

Late Coniacian 3 (Scaphites depressus) -- 87.0 Ma
Middle Coniacian 2 (Scaphites ventricosus) -- 87.9 Ma
Early Coniacian 1 (Inoceramus erectus) -- 89.0 Ma

89.3 (89.8)

Late Turonian 5 (Scaphites whitfieldi) -- 89.8 Ma

90

Turonian

Late Turonian 4 (P. wyomingensis-macombi) -- 90.5 Ma
Middle Turonian 3 (Prionocyclus hyatti) -- 90.9 Ma
Middle Turonian 2 (Collignoniceras woollgari) -- 92.1 Ma
Early Turonian 1 (Watinoceras coloradoense) -- 93.2 Ma

93.5 (93.9)

95

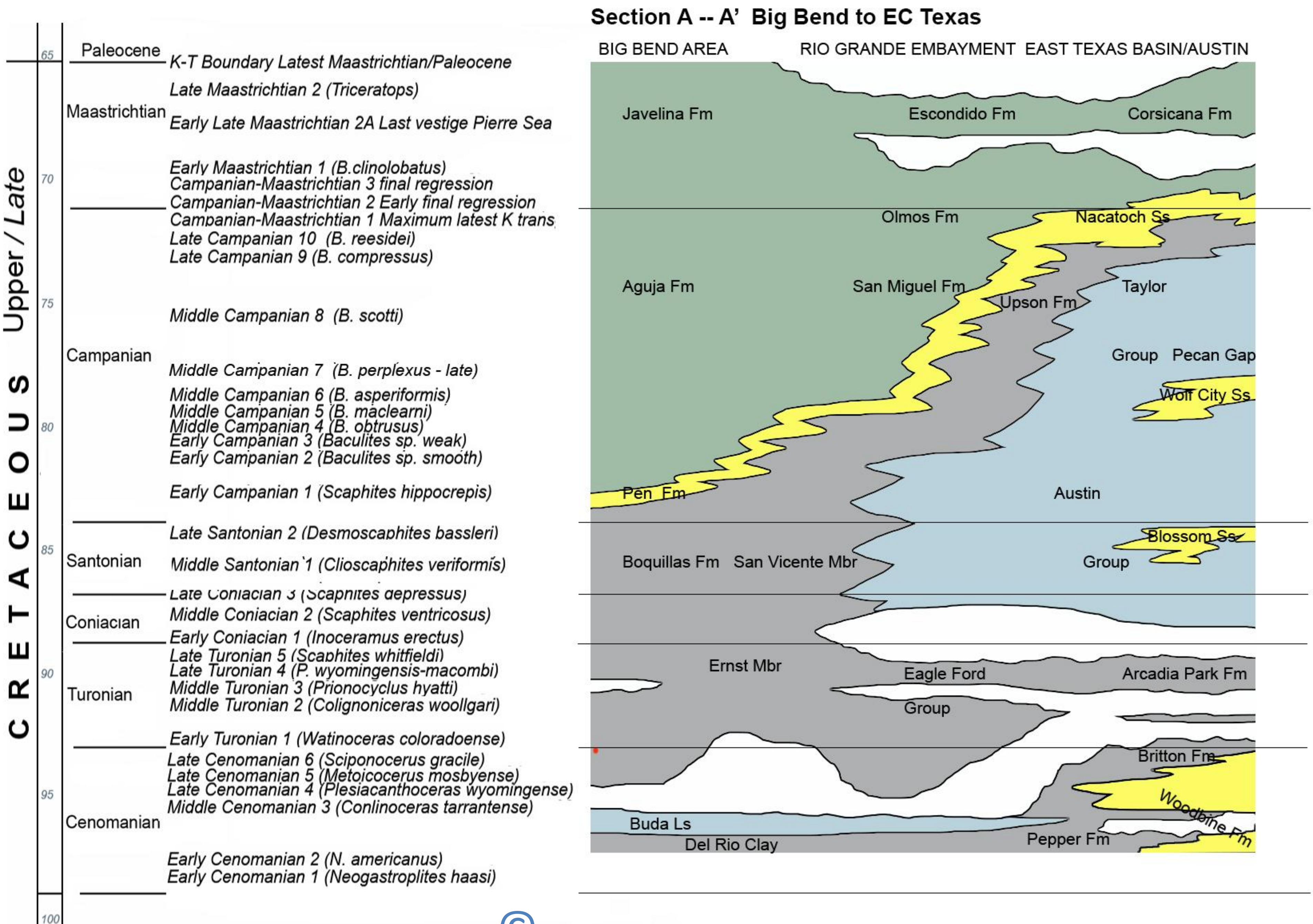
Cenomanian

Late Cenomanian 6 (Sciponocerus gracile) -- 94.0 Ma
Late Cenomanian 5 (Metoicocerus mosbyense) -- 94.3 Ma
Late Cenomanian 4 (Plesiacanthoceras wyomingense) -- 94.9 Ma
Middle Cenomanian 3 (Conlinoceras tarrantense) -- 96.0 Ma
Early Cenomanian 2 (N. americanus) -- 98.1 Ma
Early Cenomanian 1 (Neogastroplites haasi) -- 98.3 Ma

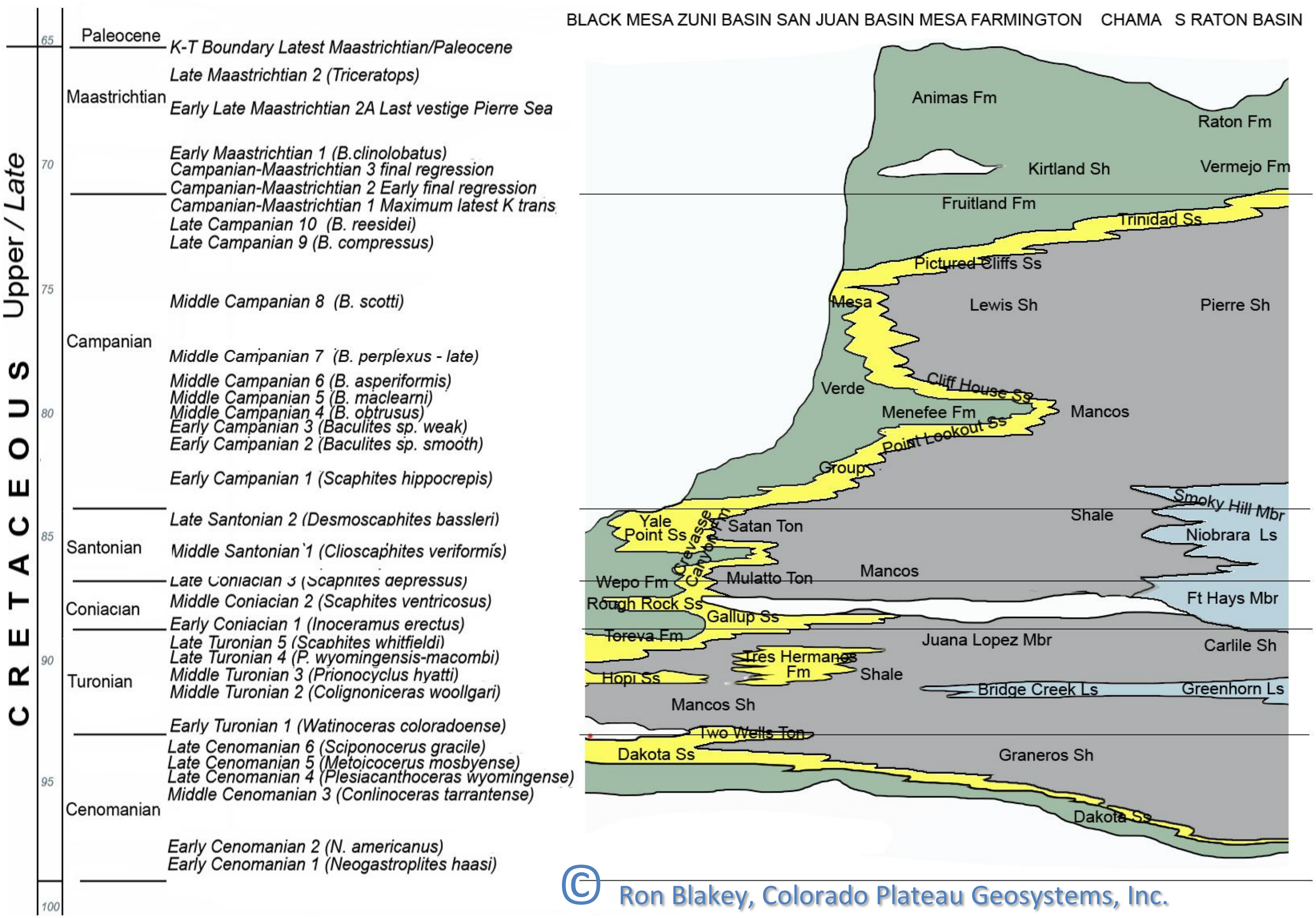
99.6 (100.5)

Late Albian 6 Muddy Low stand (ca. 100 – 99 Ma)

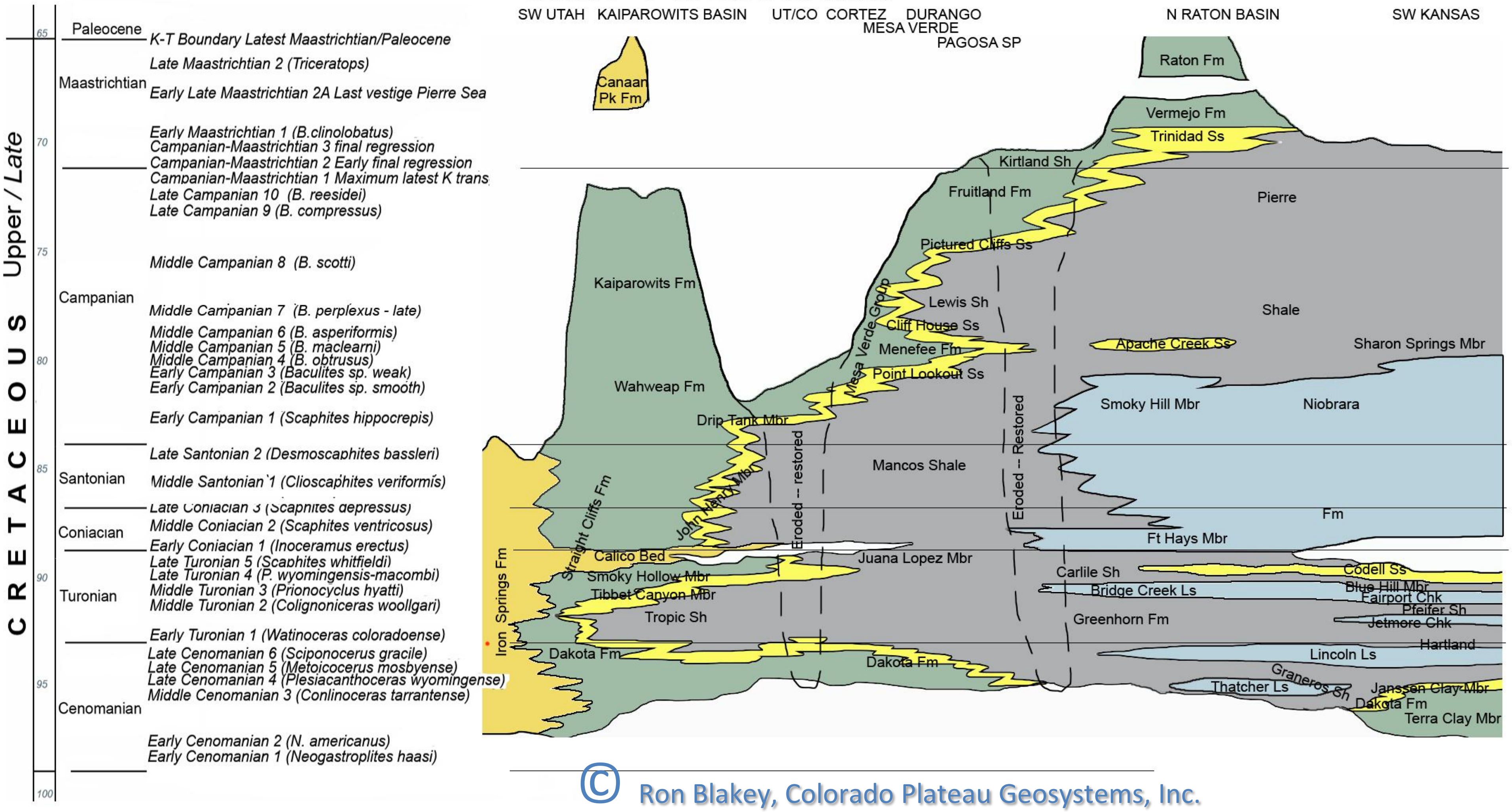
100


Section A -- A' Big Bend to EC Texas
BIG BEND AREA
RIO GRANDE EMBAYMENT
EAST TEXAS BASIN/AUSTIN
CRETACEOUS Upper / Late
65
70
75
80
85
90
95
100
Paleocene
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
K-T Boundary Latest Maastrichtian/Paleocene
Late Maastrichtian 2 (Triceratops)
Early Late Maastrichtian 2A Last vestige Pierre Sea
Early Maastrichtian 1 (B.clinolobatus)
Campanian-Maastrichtian 3 final regression
Campanian-Maastrichtian 2 Early final regression
Campanian-Maastrichtian 1 Maximum latest K trans
Late Campanian 10 (B. reesidei)
Late Campanian 9 (B. compressus)
Middle Campanian 8 (B. scotti)
Middle Campanian 7 (B. perplexus - late)
Middle Campanian 6 (B. asperiformis)
Middle Campanian 5 (B. maclearni)
Middle Campanian 4 (B. obtrusus)
Early Campanian 3 (Baculites sp. weak)
Early Campanian 2 (Baculites sp. smooth)
Early Campanian 1 (Scaphites hippocrepis)
Late Santonian 2 (Desmoscaphites bassleri)
Middle Santonian 1 (Clioscaphites veriformis)
Late Coniacian 3 (Scaphites depressus)
Middle Coniacian 2 (Scaphites ventricosus)
Early Coniacian 1 (Inoceramus erectus)
Late Turonian 5 (Scaphites whitfieldi)
Late Turonian 4 (P. wyomingensis-macombi)
Middle Turonian 3 (Prionocyclus hyatti)
Middle Turonian 2 (Collignoniceras woollgari)
Early Turonian 1 (Watinoceras coloradoense)
Late Cenomanian 6 (Sciponocerus gracile)
Late Cenomanian 5 (Metoicocerus mosbyense)
Late Cenomanian 4 (Plesiacanthoceras wyomingense)
Middle Cenomanian 3 (Conlinoceras tarrantense)
Early Cenomanian 2 (N. americanus)
Early Cenomanian 1 (Neogastroplites haasi)
Javelina Fm
Escondido Fm
Corsicana Fm
Olmos Fm
Nacatoch Ss
Aguja Fm
San Miguel Fm
Upson Fm
Taylor
Group
Pecan Gap
Wolf City Ss
Pen Fm
Austin
Blossom Ss
Boquillas Fm
San Vicente Mbr
Group
Ernst Mbr
Eagle Ford
Arcadia Park Fm
Group
Britton Fm
Woodbine Fm
Buda Ls
Del Rio Clay
Pepper Fm

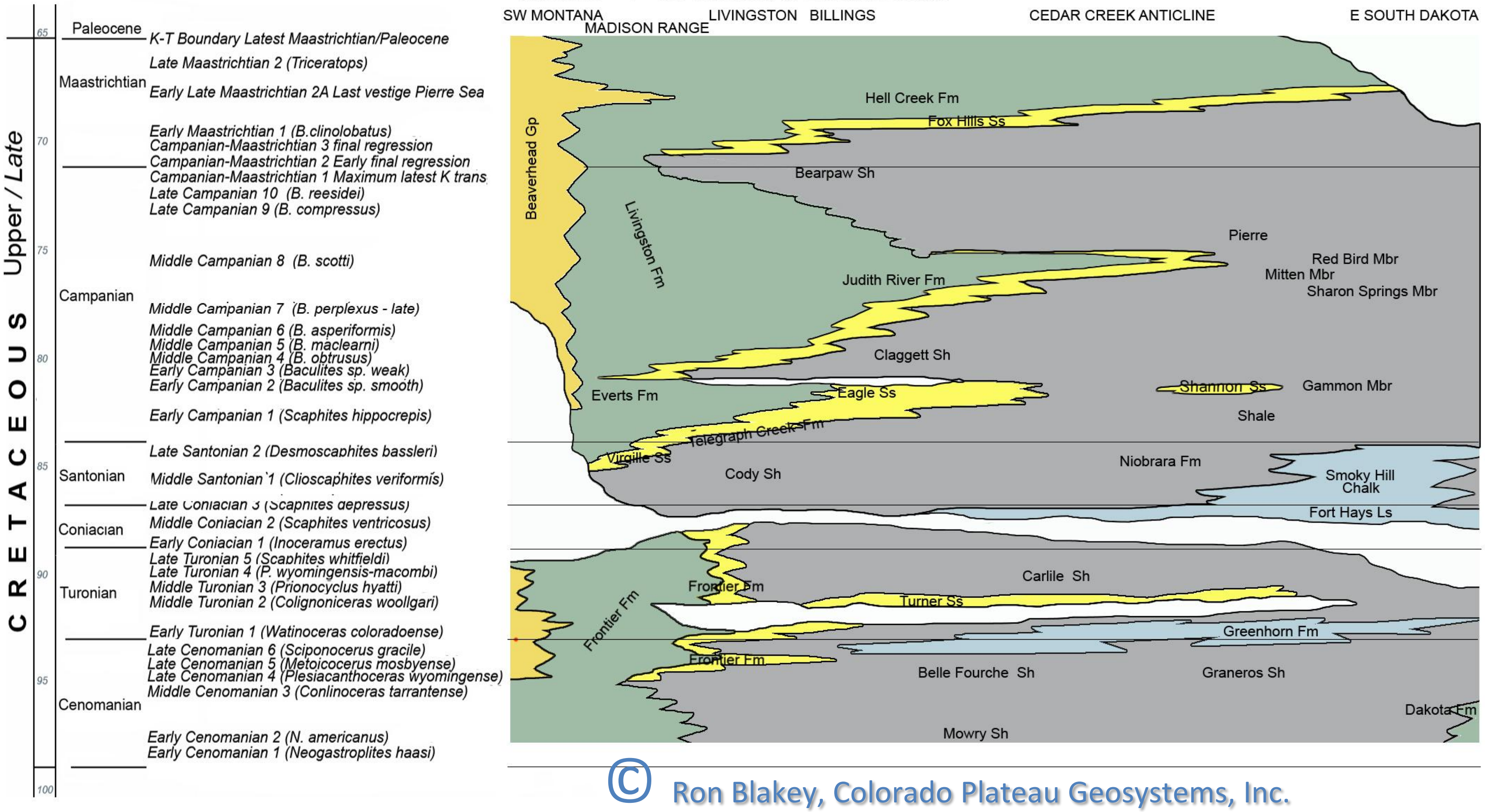
SECTION B -- B' NC Arizona to NE New Mexico



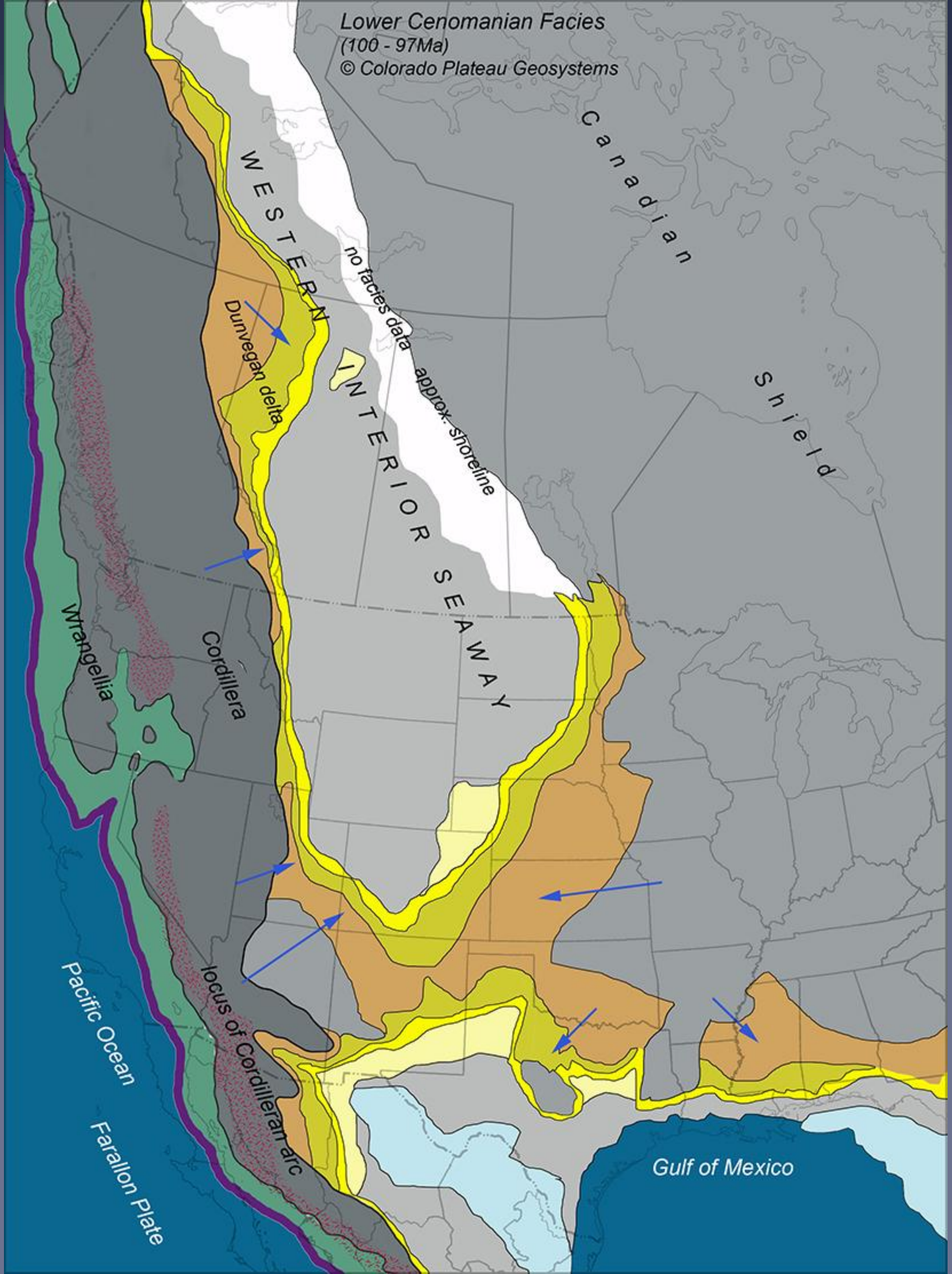
Section C -- C' SW Utah to SW Kansas



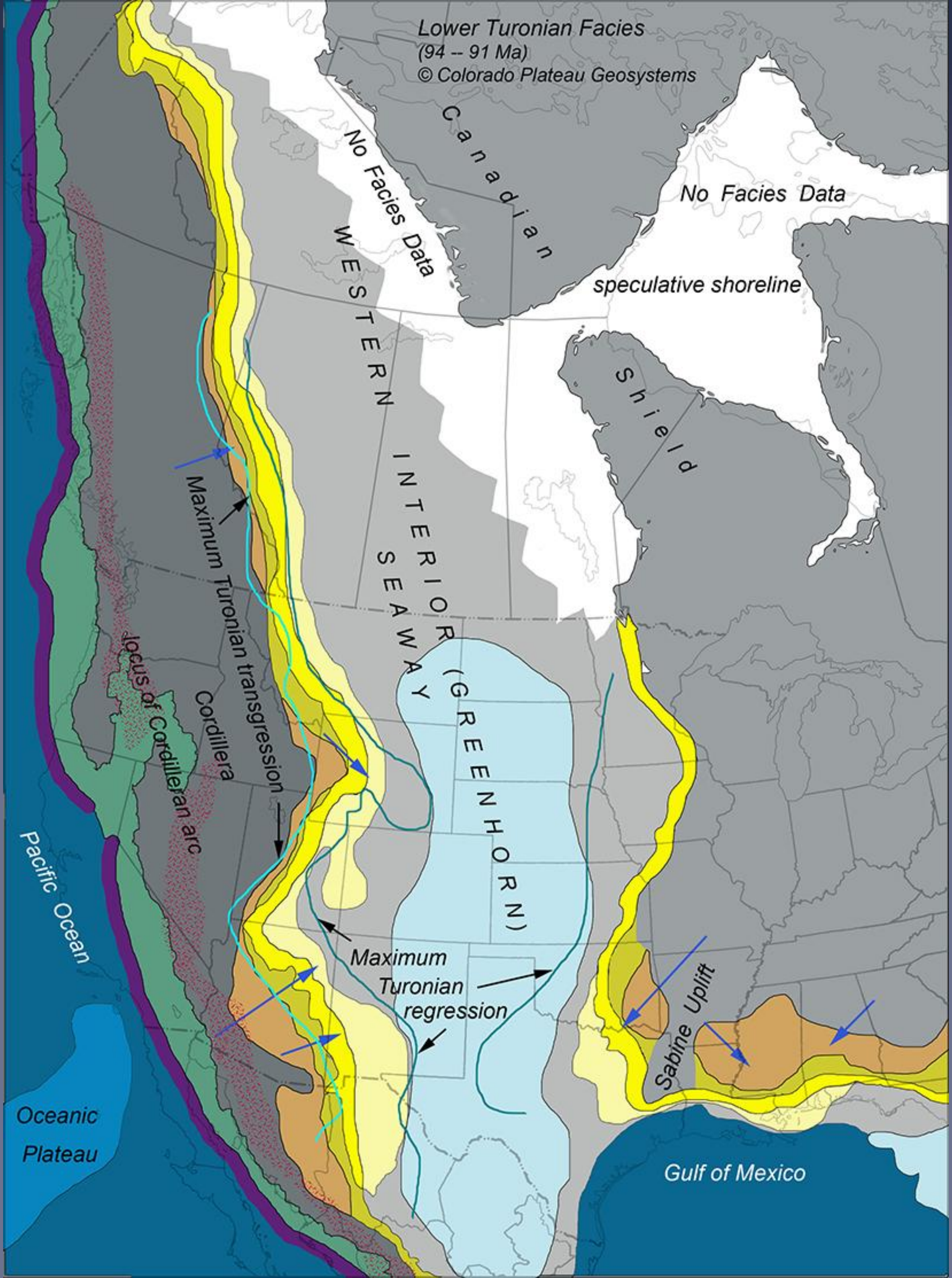
Section F -- F' SW Montana to E South Dakota



Lower Cenomanian Facies



Lower Turonian Facies



The following 12 maps detail the Cenomanian-Turonian transgressions and regressions across the Western Interior. Note tight spacing of time slices.

Late Albian
Muddy Ss lowstand

Albian-Cenomanian transgression – Mowry Seaway

Early Cenomanian
Mowry Seaway

Middle Cenomanian Graneros Seaway; AOE event

Middle Cenomanian Graneros Seaway; AOE event

Late Cenomanian Transgression; AOE event

Late Cenomanian transgression

Early Turonian maximum Transgression (Cretaceous global Highstand)

Middle Turonian maximum Transgression (Cretaceous global Highstand)

Middle Turonian regression

Late Turonian transgression

Late Turonian Regression – delta progradation

Significance

- Vast resources – petroleum, coal
- Significant fossil resources – dinosaurs, ammonites, forams
- Critical academic studies – principles of transgression/regression, sequence stratigraphy, principles of biostratigraphy
- Hydrologic resources
- Scenic resources – many National Parks and other scenic areas

Summary

- A huge stratigraphic, paleobiologic, and structure-tectonic database has generated vast knowledge of Cretaceous rocks deposited in and around the Western Interior Seaway.
- Paleogeographic maps are a powerful tool for displaying this information in a clear, concise, readily understood manner.
- For list of References as downloadable PDF, go to: http://cpgeosystems.com/wispaleogeography.html

Oyster bed, Dakota Ss, Cenomanian transgression near Paria, Utah