Sequence Stratigraphy of the Albian-Cennomanian Naturita Formation and Lower Mancos Shale, Eastern Utah and Western Colorado

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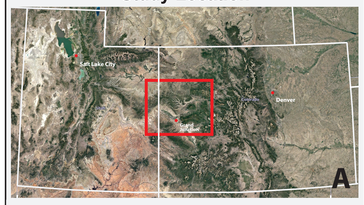
Abstract

The late Albian-Cenomanian Naturita Fm. and lower Mancos Shale in eastern Utah and western Colorado are interpreted as containing three unconformity-bound depositional sequences. The first Naturita sequence (Kn1) consists of fluvial channel conglomerates/sandstones and overbank mudstones deposited above a regional erosion surface above the Albian Ruby Ranch Member of the Cedar Mountain Fm. The second sequence (Kn2) contains lithologies similar to the Kn1. The Kn2 was deposited above an unconformity surface that was incised into the underlying Kn1 during latest Albian time. In places, this unconformity eroded most of the Kn1 interval and Kn2 deposits rest directly on the Cedar Mountain Fm. Above the Kn2 unconformity, the interval consists of fluvial and tidally-influenced sandstones, mudstone, coal, and bentonites. These non- and marginal-marine strata can be correlated with coeval shelf and shoreface deposits of the early Cenomanian Mowry Shale in the subsurface of Uinta and Piceance basins to the north. This same marine interval outcrops in western Colorado where Kn2 deposits are overlain by a transgressive surface of erosion and upward-coarsening beds of mudstone-sandstone in the lower Mancos Shale that are interpreted as Kn2 marine TST and HST deposits. Near Delta, Colorado this interval is overlain by pebbly, medium-coarse grained, trough cross-stratified, tidal-channel sandstones. The erosion surface at the base these deposits is interpreted as sequence-bounding unconformity that corresponds to the base of fluvial-channel sandstones that are erosionally incised into the top of Kn2 sequence fluvial deposits in eastern Utah. These fluvial/tidal-channel deposits represent LST and TST deposits of the third Naturita depositional sequence (Kn3). A transgressive surface of erosion and TST/HST marine shelf deposits of the Kn3 sequence overlies the basal interval. Palynomorphs, U-Pb zircon and 40Ar/39Ar sanidine ages of intercalated bentonite deposits, and age-diagnostic marine mollusks from the study interval indicate a late Albian depositional age for the Kn1 sequence, a latest Albian-early Cenomanian age for the Kn2 sequence, and a middle to late Cenomanian age for the Kn3 sequence.

Paleogeographic Setting

Figure 3. Middle Cenomanian (~96 Ma) paleogeographic map of the Western Interior Seaway.. Location of the study area outlined in red. Modified from Blakey (2014).

Study Location



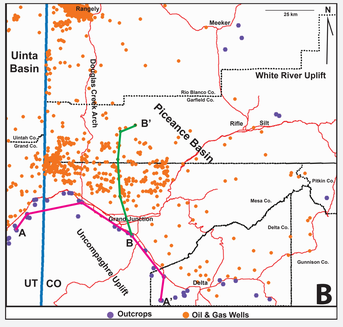


Figure 1. Maps of the study area. A) Satellite image of Utah and Colorado with the study area outlined in red. B) Well and outcrop locations within the study area. The orange dots are oil and gas wells and the purple dots are outcrops. The magenta line is a cross-section A-A'(Figure 4A)which runs approximately parallel to depositional strike. The green line is cross-section B-B' (Figure 4B) which is roughly perpendicular to depositional strike.

Time Stratigraphic Chart

Stage	Selected Index Fossils	Southern Uinta Basin	Piceance Basin
Coniacian	Forresteria sp.	Mancos Sh. (Main Body)	Mancos Sh. (Niobrara)
Turonian	P. wyomingensis C. woolgari M. endosoides W. coloradoense	Ferron Ss. (Frontier)	Juana Lopez Mbr. (Frontier)
Cenomanian	N. juddi S. gracile A. amphibolum C. gilberti	Tununk Shale Lower Mancos Sh. Naturita Fm.	Mancos Shale Graneros Sh.
Albian	N. cornutus N. haasi	Dakota Naturita Dakota Fm. Naturita Fm. Dakota Cedar Mtn Fm. (Ruby Ranch Mbr.)	Mowry Sh. Naturita Fm. Burro Canyon Fm.

-89.3 Ma, -93.5 Ma, -95 Ma, -95 Ma, -96 Ma, -99.6 Ma

Interpreted Depositional Environments: Fluvial, Fluvial/Tidal, Marine Shoreface, Marine Shelf

Figure 2. Time-stratigraphic chart with generalized depositional environments for the mid-Cretaceous deposits of the southern Uinta and Piceance basins. Modified from Molenaar and Cobban (1991)Currie et al. (2008), , and Pierson (2009).

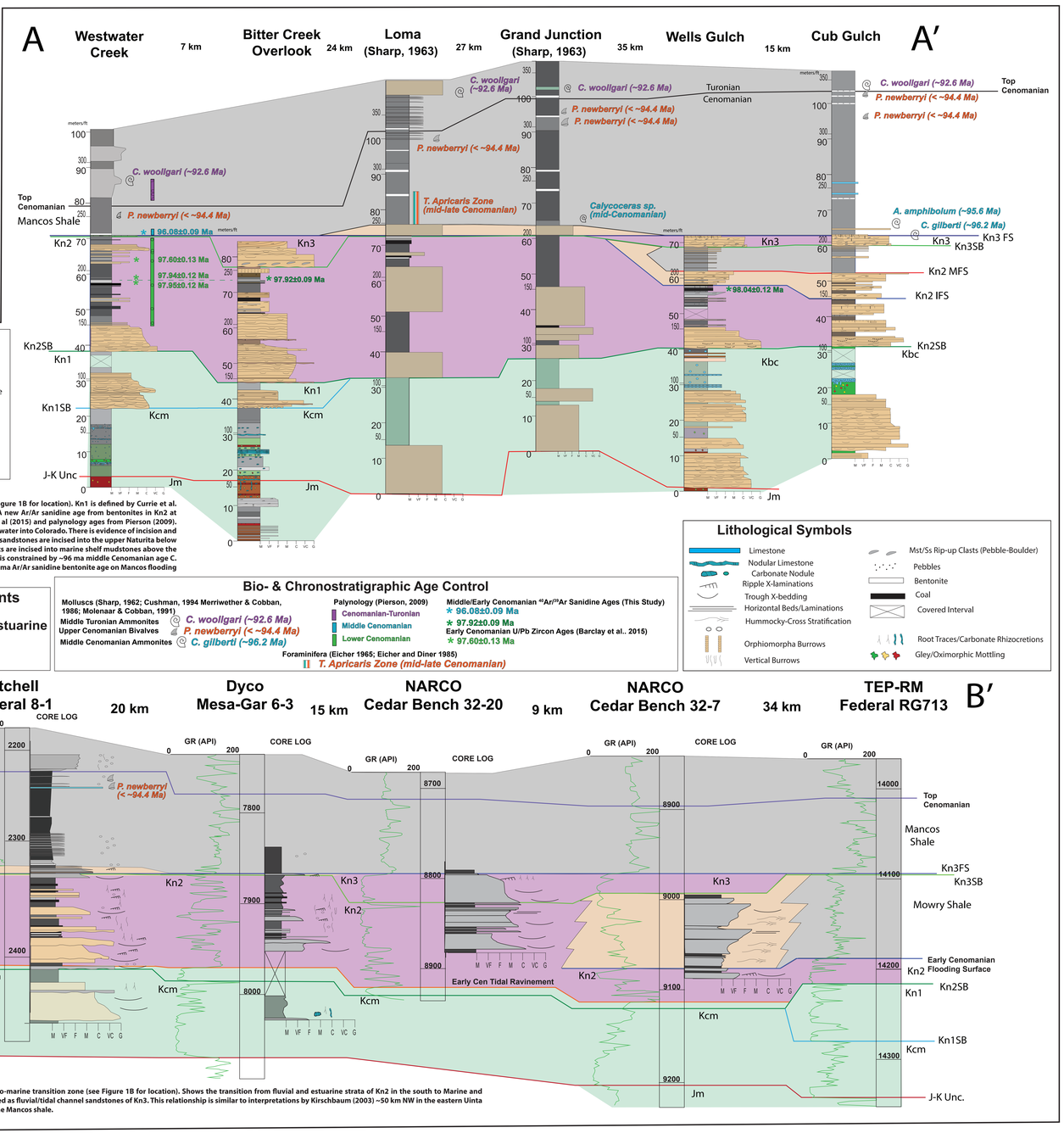


Figure 4A. Cross-section of A-A' approximately along depositional strike (see Figure 1B for location). Kn1 is defined by Currie et al. (2008) in the west as Late Albian age and pinches out into western Colorado. A new Ar/Ar sanidine age from bentonites in Kn2 at Westwater date as early Cenomanian and are similar to U/Pb ages of Barclay et al (2015) and palynology ages from Pierson (2009). Another new Ar/Ar age from the interval near Delta correlates Naturita from Westwater into Colorado. There is evidence of incision and sequence boundary unconformities in eastern Utah where isolated channel form sandstones are incised into the upper Naturita below its Mancos Shale contact. This corresponds to the SE where tidal channel deposits are incised into marine shelf mudstones above the Naturita interval. This represents the third Naturita sequence Kn3. Kn3 max-age is constrained by ~96 ma middle Cenomanian age C. gilberti ammonites in basal Mancos shale near Grand Junction and Delta and ~96 ma Ar/Ar sanidine bentonite age on Mancos flooding surface at Westwater.

Stratigraphic Markers/Symbols Symbols

- Top Cenomanian Strata
- Kn3 FS: Third Naturita Sequence Marine Flooding Surface
- Kn3: Third Naturita Sequence
- Kn3SB: Third Naturita Sequence-Bounding Unconformity
- Kn2 MFS: Second Naturita Sequence MaximumMarine Flooding Surface
- Kn2 IFS: Second Naturita Sequence Initial Marine Flooding Surface
- Kn2: Second Naturita Sequence
- Kn2SB: Second Naturita Sequence Bounding Unconformity
- Kn1: First Naturita Sequence
- Kn1SB: First Naturita Sequence Bounding Unconformity
- Kcm/Kbc: Cedar Mountain/Burro Canyon formations
- J/K Unc: Jurassic-Cretaceous Unconformity
- Jm: Jurassic Morrison Formation

Interpreted Depositional Environments

Shelf, Shoreface, Fluvial/Estuarine, Fluvial

Bio- & Chronostratigraphic Age Control

Molluscs (Sharp, 1962; Cushman, 1994 Merriwether & Cobban, 1986; Molenaar & Cobban, 1991)
- Middle Turonian Ammonites
- Upper Cenomanian Bivalves
- Middle Cenomanian Ammonites

C. woolgari (~92.6 Ma)
P. newberryi (< ~94.4 Ma)
C. gilberti (~96.2 Ma)

Palynology (Pierson, 2009)
- Cenomanian-Turonian
- Middle Cenomanian
- Lower Cenomanian

Middle/Early Cenomanian $^{40}Ar/^{39}Ar$ Sanidine Ages (This Study)
- ✶ 96.08±0.09 Ma
- ✶ 97.92±0.09 Ma

Early Cenomanian U/Pb Zircon Ages (Barclay et al.. 2015)
- ✶ 97.60±0.13 Ma

Foraminifera (Eicher 1965; Eicher and Diner 1985)
T. Apricaris Zone (mid-late Cenomanian)

Lithological Symbols

Limestone, Nodular Limestone, Carbonate Nodule, Ripple X-laminations, Trough X-bedding, Horizontal Beds/Laminations, Hummocky-Cross Stratification, Orphiomorpha Burrows, Vertical Burrows

Mst/Ss Rip-up Clasts (Pebble-Boulder), Pebbles, Bentonite, Coal, Covered Interval, Root Traces/Carbonate Rhizocretions, Gley/Oximorphic Mottling

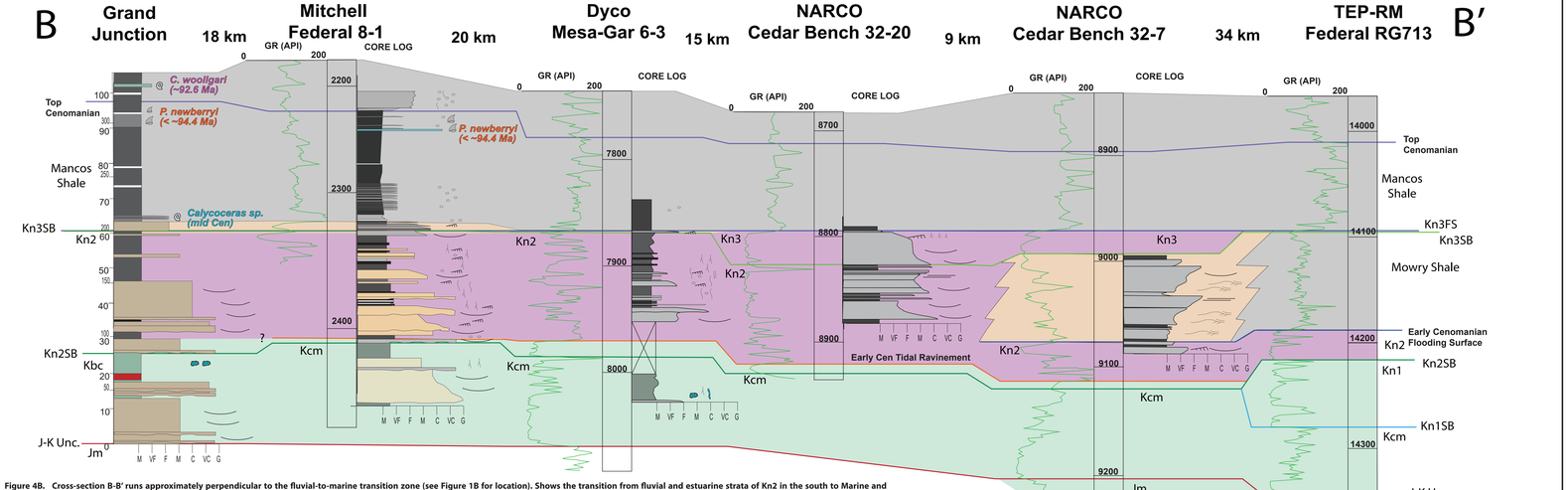


Figure 4B. Cross-section B-B' runs approximately perpendicular to the fluvial-to-marine transition zone (see Figure 1B for location). Shows the transition from fluvial and estuarine strata of Kn2 in the south to Marine and shoreface deposits of Mowry shale to the North. This marine interval is interpreted as fluvial/tidal channel sandstones of Kn3. This relationship is similar to interpretations by Kirschbaum (2003) ~50 km NW in the eastern Uinta basin. The middle Cenomanian flooding surface overlies the Kn3 at the base of the Mancos shale.

Sequence-Stratigraphic Diagram

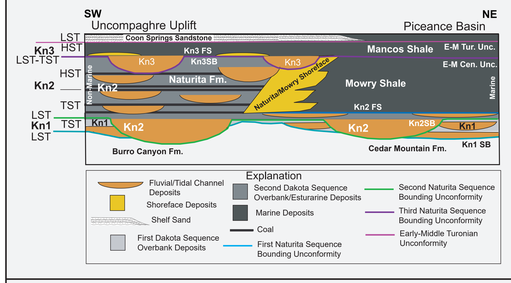


Figure 5. Schematic sequence-stratigraphic diagram of the Naturita-Mowry-Lower Mancos interval between the Uncompahgre Uplift and central parts of the Piceance basin to the northeast. Diagram is roughly parallel to Cross SEction B-B' (Figure 1; Figure 4B). Systems tract framework (LST: Lowstand Systems Tract, TST: Transgressive Systems Tract; HST: Highstand Systems Tract) is shown for the Kn1, Kn2, and Kn3 depositional sequences.

Regional Correlations

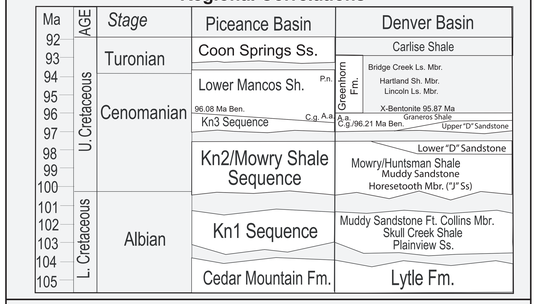


Figure 6. Regional stratigraphic correlation diagram of the Lower-Upper Cretaceous strata in the Piceance Basin in western Colorado and corresponding units in the Denver Basin ~200 km to the east. A.a.: Acanthoceras amphibolum; C.g.:Calycoceras gilberti; P.n.:Pycnodonte newberryi. Ages are based on sequence stratigraphic interpretations of Sonnenberg (1987), Sonnenberg et al. (1989), Dolsen et al. (1991), and Weimer et al. (1998), and chrono/biostratigraphic data from Barker et al. (2011), Meyer et al. (2012), Joo and Sageman (2014), Batenburg et al. (2016), and Scott et al. (2018).

Acknoledgements

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