TRANSECT ACROSS AN ESTUARY FACIES COMPLEX IN THE EARLY CRETACEOUS FORELAND BASIN OF WESTERN MONTANA: SUNBURST MEMBER OF THE KOOTENAI FORMATION

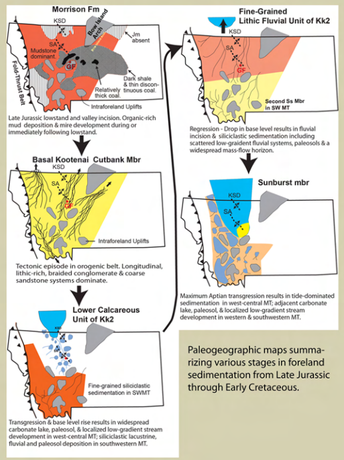
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ABSTRACT

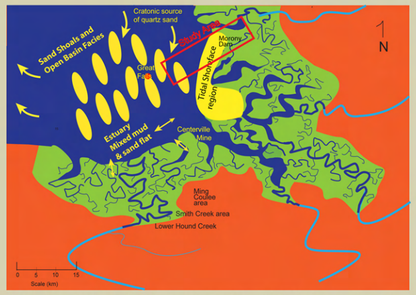
The lower Kootenai Formation in the subsurface of northern Montana and the correlative lower Mannville Group in the subsurface of southern Alberta serve as major oil and gas reservoirs. Exposures of the marine-influenced Sunburst member limited to the Great Falls area provide an unusual opportunity to observe tidal facies in outcrop that are recognized in the subsurface to the north. Overall, the exposed Sunburst facies define a lobate estuarine complex that lies at the southern end of the pre-Kootenai Whitlash paleovalley. High-resolution panoramic photography and facies analysis were conducted along the Missouri River Gorge in order to demonstrate stratigraphic relationships and facies change along a transect oriented at a high angle to the paleobasin and paleovalley axes.

Near the basin center, a 10-15 km wide, <1-28 m thick, estuary kaolinite-mudstone/sandstone complex disconformably overlies the basal Kootenai lithic-fluvial sandstone (Cutbank Member) and remnants of reddish Kootenai paleosols. This is overlain by a 5 to 15 m-thick, quartzose, upward-fining, estuary mouth (linear-bar) facies with a concavo-convex erosional (tidal ravinement) base. The estuary mouth-bar facies is superposed by a > 5 km-wide x <40 m thick tract of regressive estuary channel facies which, in turn, is overlain by regionally widespread nonmarine coastal plain facies. Laterally, toward the eastern basin margin, the estuary channel facies is absent and coastal plain facies directly overlie the estuary mouth-bar facies. Here, an incised upper-Kootenai paleovalley with coarse fluvial fill fully truncates the Sunburst member. Laterally, the mouth-bar facies pinches out where it is flanked by an ~ 3.5 km-wide tract of stacked upward coarsening tidal shoreface units within which an incised late-Sunburst paleovalley with estuarine mudstone fill fully truncates the shoreface succession. The tidal shoreface lithosome then undergoes a lateral transition into gray estuarine mudstone containing scattered upward coarsening tidal bar(?) units followed laterally by thin tidal flat units encased in reddish paleosols. Overall, the transect demonstrates change from high to low energy tide-dominated settings across an estuary and compounding preservational effects due to subsequent base fluctuation and paleovalley development.

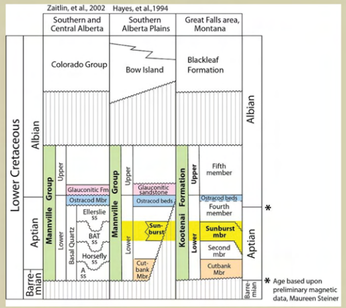
BACKGROUND



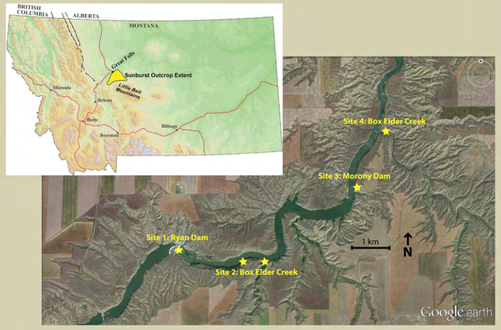
Paleogeographic maps summarizing various stages in foreland sedimentation from Late Jurassic through Early Cretaceous.



Schematic map of tide-dominated estuary-like terminus of the Aptian transgression in west-central Montana. Arrows depict general circulation pattern. Outline of study area is highlighted in red.



Stratigraphic section highlighting the Sunburst Member of the Kootenai Formation in the Great Falls, Montana area, and its correlative member of the Mannville Group in Alberta, Canada.



The study area is in the Great Falls region of western Montana. Locations studied consist of five sites along the Missouri River Gorge. For convenience, the two Box Elder sites are grouped together as one.

SUNBURST FACIES CHARACTERISTICS

estuary channel
- ~40 m-thick assemblage of laterally and vertically stacked channel bodies
- rhythmic bedding of bioturbated mud and clean, well-sorted sand
- bundled parallel laminations
- flaser bedding
- increase in bioturbation from the bottom to the top of the facies
- 2D and 3D dunes
- Upward fining and upward thinning of channel bodies

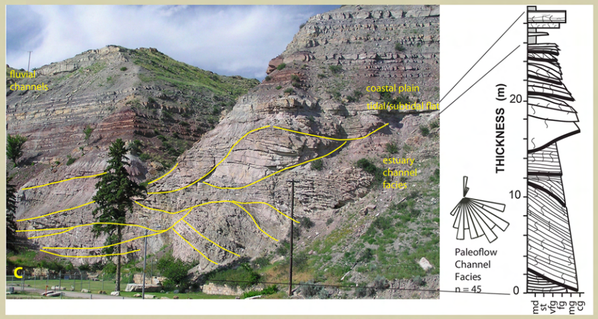
estuary mouth bar
- net upward fining and thinning
- abundant tidal structures
- rare presence of wave-formed structures
- high energy current dominated system
  - o evidenced by scarcity of mud and poorly developed reactivation surfaces
- low trace fossil abundance and diversity
- abundance of erosional surfaces and giant- to large-scale, 3D dune-related structures in the lower part of the facies

estuary basin mudstone
- exceptionally pure kaolinite mudstone
- also present in coastal plain and paleosol facies that directly underlie and/or are later ally adjacent to the Sunburst estuary facies

tidal shoreface
- widespread, tabular, sandstone dominated units and scattered heterolithic channel bodies
- shoreface units
  - o upward coarsening with erosional cap
  - o amalgamated thicker sandstone beds with uniform grain size separated by an erosional surface
- ~90-95% quartz
- abundance of tidal structures, minor wave associated structures
- scattered heterolithic channel bodies (50-100's m wide, 5-10 m thick)

tidal flat
- tabular units
- sandstone- or mudstone-dominated
- occurs as single or vertically stacked units, typically characterized by an erosional base and an upward-fining succession of beds
- sandstone-dominated units
  - o contain thicker amalgamated sandstone beds and larger-scale cross-stratification
  - o undulating and channel-like scour surfaces below the thicker and coarser beds in the sandstone
- minor amounts of wave-ripple bedforms and wave-ripple cross-lamination
- abundance of bioturbation, low diversity of ichnogenera, and absence of body fossils

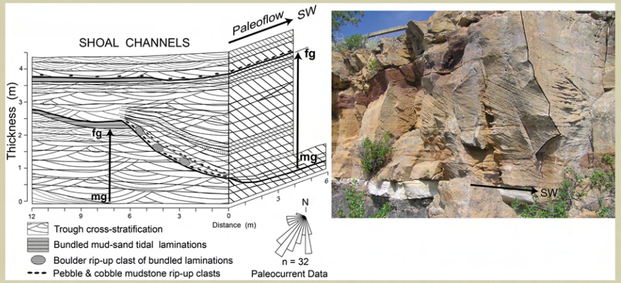
SITE 1: RYAN DAM - BASIN CENTER BAR TO COASTAL PLAIN SUCCESSION



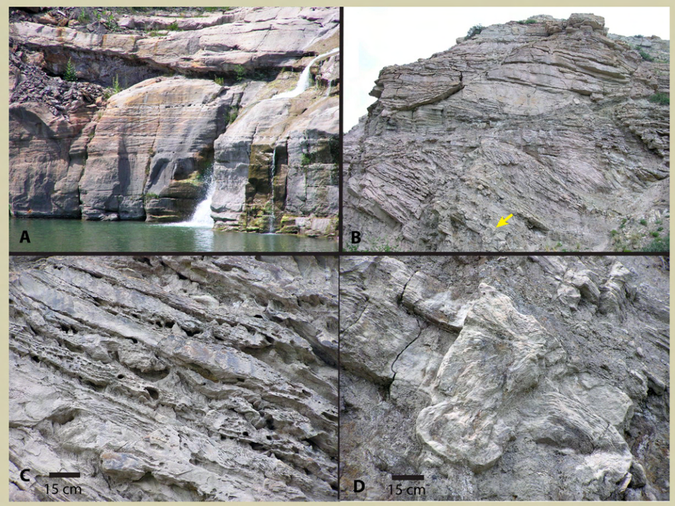
Upper part of the estuary channel succession overlain by tidal flat and coastal plain facies of the Kk4.



Estuary channel sandstone bodies erosionally overlying the estuary mouth bar facies.



Block diagram of channel fill within estuary mouth bar facies at Ryan Island. Based upon exposure seen in photograph to the right. Estuary mudstone is visible below the bar facies (bottom of photograph).

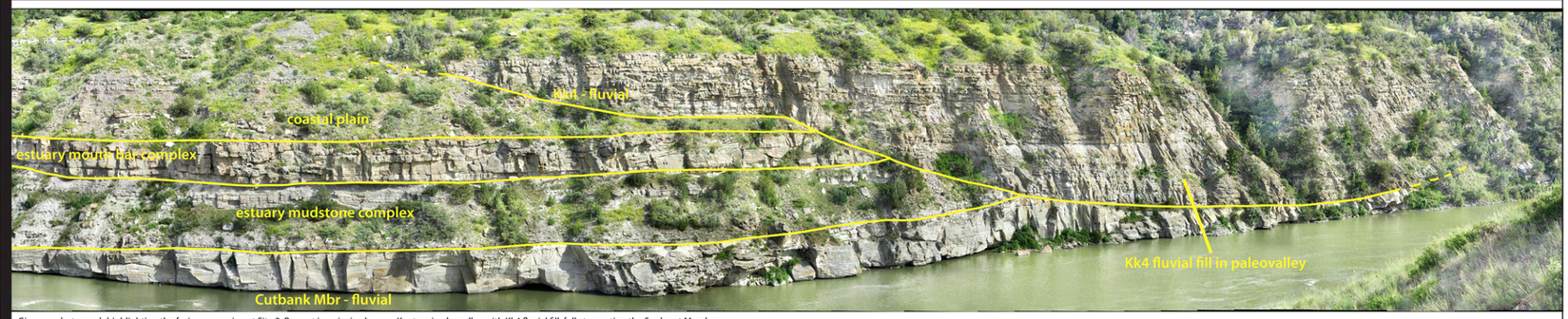


Estuary channel facies exposed at Ryan Dam site.
A) Close-up of the concave base of an estuary channel body erosionally overlying stacked cross-stratified sets of the bar (shoal) facies.
B) Stacked estuary channel bodies including inclined heterolithic strata.
C) Close-up of Figure 5-2B showing extensively bioturbated inclined heterolithic strata.
D) Soft-sediment fold near the base of inclined heterolithic strata.

Facies Succession:
- -Kk4 - fluvial
- -coastal plain
- **-tidal flat**
- **-estuary channel**
- **-estuary mouth bar**
- **-estuary basin mudstone**
- ~~~ disconformity
- -Kkc - fluvial

Sunburst Member

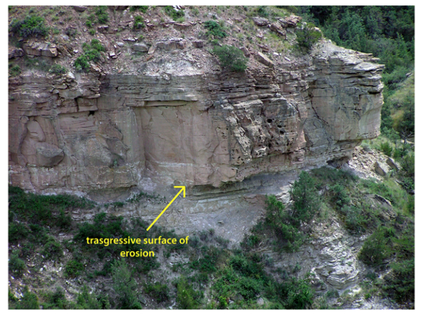
SITE 2: BOX ELDER CREEK - BASIN CENTER ESTUARY MOUTH BAR & INCISED VALLEY



Gigapan photograph highlighting the facies succession at Site 2. Present is an incised upper-Kootenai paleovalley with Kk4 fluvial fill, fully truncating the Sunburst Member.

Facies Succession:
- -Kk4 - fluvial
- -coastal plain
- **-estuary mouth bar complex**
- **-estuary basin mudstone**
- ~~~ disconformity
- -Kkc - fluvial

Sunburst Member



Photograph showing upward-fining estuary mouth bar facies erosionally overlying kaolinite rich, heterolithic estuary facies.