CENOZOIC TECTONIC SEQUENCES AND BASIN EVOLUTION IN WESTERN MONTANA

ABSTRACT

Cenozoic sedimentary and volcanic basin-fill in western Montana can be packaged into sequences related to regional tectonic events. We use interpreted seismic, borehole, and gravity data, regional mapping, and detailed age constraints on Cenozoic deposits, employing both fossil vertebrates and isotopic ages, to delineate sequences and to generate a more data-integrated paradigm for Cenozoic basin evolution.

The "Eocene unconformity" or Rocky Mountain erosion surface underlies the oldest sequence. This sequence, known as Cenozoic Sequence 1/Challis Sequence, ranges in age from ~50 to 44 Ma. It preserves a record of orogenic collapse and basin development related to metamorphic core complex formation in the Cordilleran hinterland and listric normal faulting in the fold and thrust foreland, as well as abundant arc-magmatism.

The overlying sequence, Cenozoic Sequence 2/lower Kittitas Sequence, spanning a time duration of ~38 to 30 Ma, documents a tectonic interval of extensional collapse that occurred throughout the entire Cordilleran orogen. Significantly, this sequence is bounded by the ~30 Ma unconformity which may be related to eustatic and/or climatic changes rather than to tectonic events.

The overlying ~27 to 21 Ma Cenozoic Sequence 3/upper Kittitas Sequence is bounded at its top by the Hemingfordian unconformity, which represents a hiatus from ~20 to 17 Ma. The Heminfordian unconformity is largely isochronous across the western U.S., and marks the change from orogenic collapse to backarc spreading of the Basin and Range event, the next major Cenozoic episode of crustal extension and magmatism.

Its overlying sequence, Cenozoic Sequence 4/lower Walpapi Sequence, ranges in age from ~16 to 4 Ma. This sequence records the development of the present topographic basins which includes reactivated Paleogene and newly defined basins. Some of these newly delineated basins contain only portions of the older Paleogene basins whereas others extend geographically beyond the original Paleogene basins.

The youngest sequence, Cenozoic Sequence 5/upper Walpapi Sequence ranges in age from ~ 2 Ma to the present. This sequence correlates to the tectonic pulse documented in the Yellowstone/Teton area and to the initiation of the Yellowstone Plateau volcanic field at ~ 2 Ma.



Sequence 1/Challis documents metamorphic core complex extension coupled with basin formation and widespread magmatism.





Sequence 1/Challis volcanics, Deer Lodge Valley.

> Sequence 1/Challis volcanic ash, Three Forks Valley.



Sequence 1/Challis conglomerates and red beds, Sage Creek Valley.





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CENOZOIC SEQUENCE STRATIGRAPHY OF SELECTED WESTERN MONTANA VALLEYS



interval of extension, as seen by the structural control of the Kishenehn Formation deposition.



Calcic paleosol atop Sequence 3/Upper Kittitas mudstone, Jefferson Valley.

Sequence 2/Lower Kittitas mudstone, Pipestone area, Jefferson Valley.



Sequence 2/Lower Kittitas mudstone and cryptic grus channels, Little Pipestone area, Jefferson Valley.



Sequence 3/Upper Kittitas lacustrine strata, Townsend Valley.

controlled eastern basin margin.



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INTERPRETATIONS



Sequence 3/Upper Kittitas alluvial fan strata, Toston Valley (Sixmile Creek type section).

A Townsend Valley Quaternary sediments/Glacier Peak-Mazama volcanic ash Sixmile Creek Formation: Early Barstovian - Hemphillian Canyon Ferry Beds: ?Late Chadronian,Orellan, Arikareean **B** Toston/Three Forks Valleys Quaternary sediments/Mazama volcanic ash Sixmile Creek Formation: Arikareean - Hemphillian Madison Valley Formation: Early Barstovian - Clarendonian Dunbar Creek Formation: Orellan/Whitneyan Climbing Arrow Formation/Milligan Creek Formation: Chadronian Sphinx Conglomerate - ? Red Mountain/Shoddy Springs volcanics: Early Eocene **C** Jefferson/Beaverhead/Melrose/Divide Valleys Quaternary sediments/Mazama volcanic ash Sixmile Creek Formation: Early Barstovian - Early Blancan Renova Formation: Dunbar Creek Member: Orellan/Whitneyan Climbing Arrow Member/Bone Basin Member: Chadronian Pioneer/Beaverhead volcanics: Early/Middle Eocene **D** Upper/Lower Ruby Valleys Quaternary sediments/Yellowstone Huckleberry Ridge Tuff Timber Hill Basalt: @ 4 Ma Sixmile Creek Formation: Early Barstovian - Hemphillian Renova Formation: Passamari Member: Whitneyan in lower Ruby; Late Arikareean in upper Ruby Dunbar Creek Member: Orellan/Whitneyan Climbing Arrow Member/Bone Basin Member: Late Unitan/ Duchesnean - Chadronian Virginia City/Ruby Dam volcanics: Early/Middle Eocene **E** Sage Creek/Blacktail Valleys Quaternary sediments/Yellowstone Huckleberry Ridge Tuff Sage Creek Basalt equivalent: @ 5 Ma Little Sage Creek beds: Early Barstovian Blacktail Deer Creek Formation: Late Arikareean White Hills Beds: ?Whitneyan Cook Ranch Formation: Late Chadronian - Late Orellan Dell Beds: Late Unitan Beaverhead Canyon/Hall Springs volcanics: Early/Middle Eocene ^C Grasshopper/Horse Prairie/Muddy Creek

ISOLATED VALLEY STRATIGRAPHIC

- Medicine Lodge Valleys Quaternary sediments
- Sixmile Creek Formation (Railroad Canyon beds): Early Barstovian

Medicine Lodge Beds: Chadronian - Late Arikareean (Renova Formation for all in Muddy Creek) Challis equivalent volcanics: Early/Middle Eocene



Sequence 4/Lower Walpapi tuffaceous sediments at Anceney in the Madison Valley.



Sequence 4/Lower Walpapi mudstone at Aelurodon locality, Jefferson Valley.



Sequence 5/Upper Walpapi unconformably overlies Sequence 3/Upper Kittitas, Grasshopper Valley.



Sequence 5/Upper Walpapi Yellowstone Event Tuff unconformably overlies Sequence 4/Lower Walpapi strata, Upper Ruby Valley.

