Preliminary $^{40}Ar/^{39}Ar$ Laser Dating of Detrital Micas from Cenozoic Sandstones, Blacktail Mountains, SW Montana

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Abstract

Single detrital biotite crystals from two different sandstone units, the Teddy Creek Group and the Renova Formation were analyzed using $^{40}Ar/^{39}Ar$ laser age dating. The objective of this project was to determine the absolute age of the micas and provide information on: 1) the depositional age of the sandstones; 2) the provenance/unroofing history of their source region; and 3) speculate on the tectonic evolution of this region following the Laramide Orogeny.

Both the Teddy Creek and Renova lithologic units are mapped as one unit and considered to be the same age. Although, sandstone petrology indicates that the Teddy Creek and Renova formations are distinct mineralogically and texturally. The Teddy Creek Group consists of a basal pebble-conglomerate with distinctive black chert fragments overlain by interlayered sandstones and white-purple volcanic ash. All lithologies have experience an episode of post-deposition silicification. Petrographic analysis reveals sandstones are compositionally mature with high abundances of quartz and minor amounts of feldspar and muscovite mica. Most grains and lithic clasts are subrounded; however monocrystalline quartz grains are subangular. The TCG also preserve cross-bedded laminations indicating a fluvial depositional environment as well as fragments of petrified wood. In contrast, the Renova Formation consists mainly of tuffaceous sandstones containing muscovite and biotite micas. The presence of the micas is attributed to the unroofing of the Idaho batholith. However, the lack of micas, especially biotite, in the Teddy Creek sandstones suggests a different source than the Renova Formation.

This study will begin to address the debate of whether high standing topography existed during the time of deposition of the Teddy Creek and Renova Formations or whether a broad basin surrounded by low standing topography existed during these times. Current tectonic models suggest that sediment found in isolated basins in southwest Montana were derived from the ~ 80 million year old Idaho Batholith, located 100 km to the west and deposited in a fluvial system of braided rivers. An alternative model involves a locally derived sediment source possibly from the surrounding 1.8-2.7 billion year old metamorphic rocks of the Blacktail and Ruby mountains.

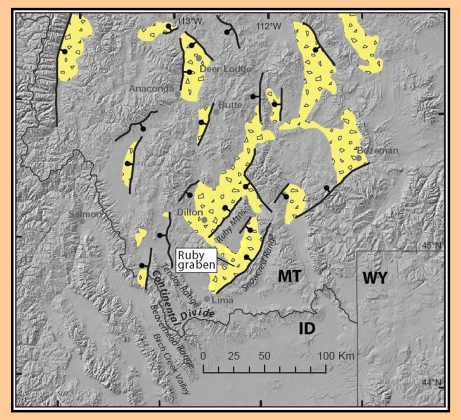
Project Objectives

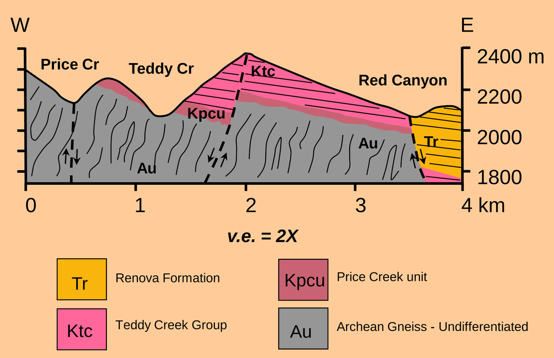
- Perform single crystal $^{40}Ar/^{39}Ar$ laser dating on detrital micas from the Teddy Creek and Renova Formation sandstones
- Establish minimum stratigraphic age for each lithologic unit
- Evaluate possible provenance sources for the detritus
- Integrate new age data into existing models for the tectonic evolution of SW Montana during Cenozoic time

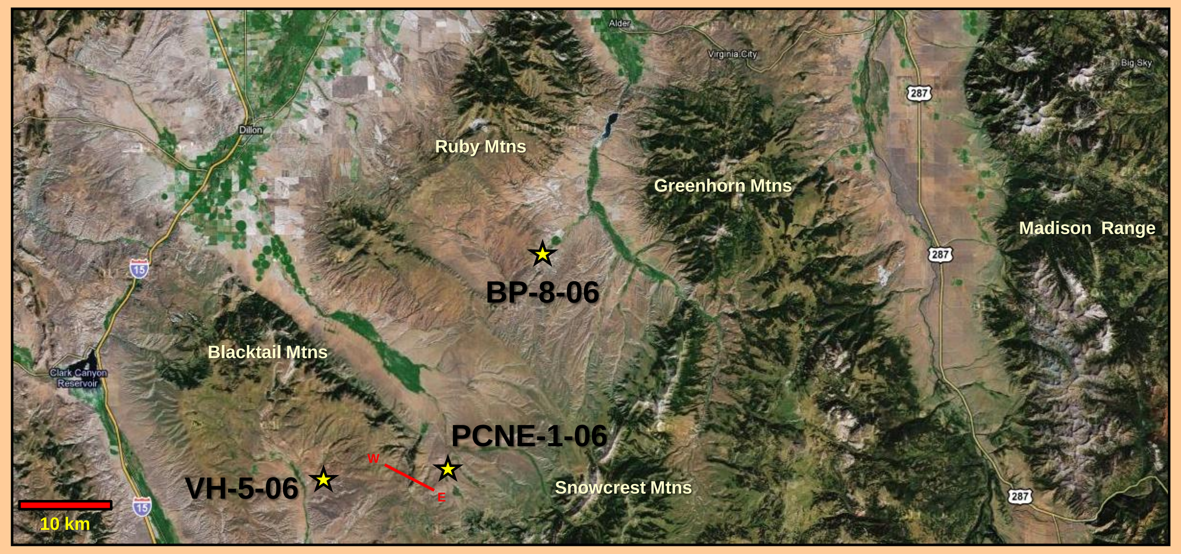
View looking north at tuffaceous Renova Formation, Tobacco Root Mountains in background

Geologic Setting

Sandstones present throughout the Basin and Range province of SW Montana record the geologic evolution of this region following late Mesozoic and early Cenozoic tectonism. The Basin and Range province consists of a series of fault bounded sedimentary basins as well as adjacent faulted bounded crystalline basement uplifts that developed during the Laramide Orogeny. Two of these uplifted blocks are the Blacktail and Ruby Mountains. Basement rocks consist of Archean-Proterozoic (2.7- 1.8 billion year old) metamorphic gneisses and Proterozoic (1.7-1.4 billion year old) mafic intrusions. Clastic sedimentary rocks occur within isolated valleys and grabens throughout the region and in places, unconformably on the metamorphic basement. The basal unit in the Blacktail-Ruby ranges is a maroon conglomeratic mudstone called the Price Creek unit (PCu). The TCG unconformably overlies the PCu and contains cobbles of the PCu within its basal unit (1, 2). The Renova Formation occurs as basin fill within the Ruby Valley and others valleys throughout the region. The base of the Renova Formation is not observed, but appears to overlie the TCG.







A) Map shows the location of the Ruby graben and other isolated basins of clastic sedimentary rocks. B) Schematic cross-section showing the geologic relations of TCG and Renova Formation. C) Satellite view of Blacktail and Ruby mountains. Location of cross-section shown as W-E red line. Sample locations shown by yellow stars (©googlemaps).

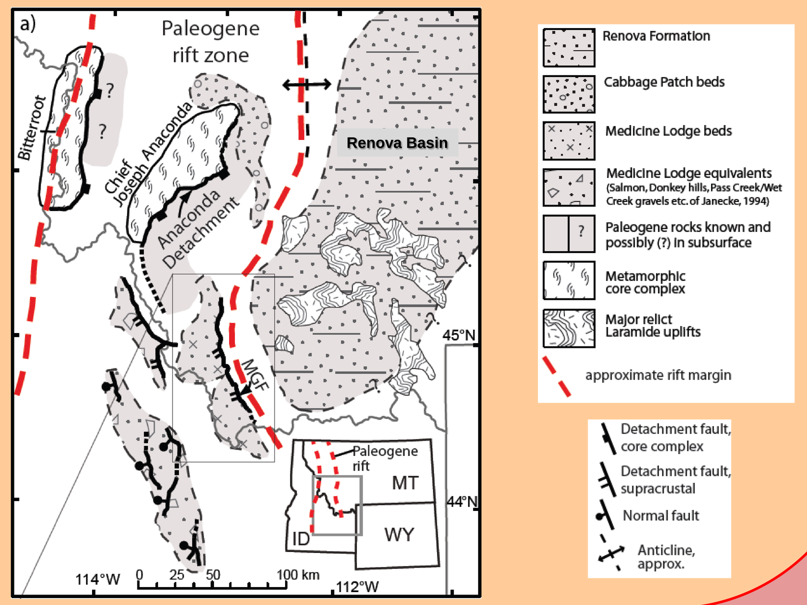
Background Tectonic Models

Recently, much work has been done concerning the provenance and tectonic setting of Cenozoic sedimentary rocks within southwestern Montana (3,4). Current tectonic models suggest extensional deformation, associated with low-angle subduction resulted in the development of the Basin and Range Province and subsequent topography during the Eocene time (5). Deposition of the regionally extensive Renova Formation occurred during this time within semi-isolated extensional rift grabens (5).

An alternative model suggests a single, large, broad basin extending from eastern Idaho beyond the Blacktail-Ruby mountains. Following Paleogene rifting a fluvial system developed during the unroofing and erosion of the Idaho Batholith. Throughout the Middle Eocene to Middle Miocene sediment was transported eastward and deposited in the Renova basin (3). Following development of the Pliocene Yellowstone hotspot, the region was dissected by a series of northwest-trending faults which disrupted the Renova basin into smaller grabens which remain preserved today (6). Prior to disruption, the provenance for the Renova sediment is thought to be derived from the Cretaceous-aged Idaho granite batholith (3). Much of the evidence for the Idaho Batholith as the source for the Renova sediment relies on the presence of two-mica (muscovite and biotite) sandstones (3).

An alternate model we are investigating is the existence of high standing topography prior to the deposition of the Renova or TCG sediments. Based on petrologic data and field relations (see below), we believe the TCG is a separate, distinct unit deposited prior to Renova deposition.

This study continues to address whether the TCG represents an older unit than the Renova Formation, or whether it is time-equivalent. Utilizing $^{40}Ar/^{39}Ar$ laser dating of detrital micas we will document the age of the source material providing a minimum stratigraphic age for these units.

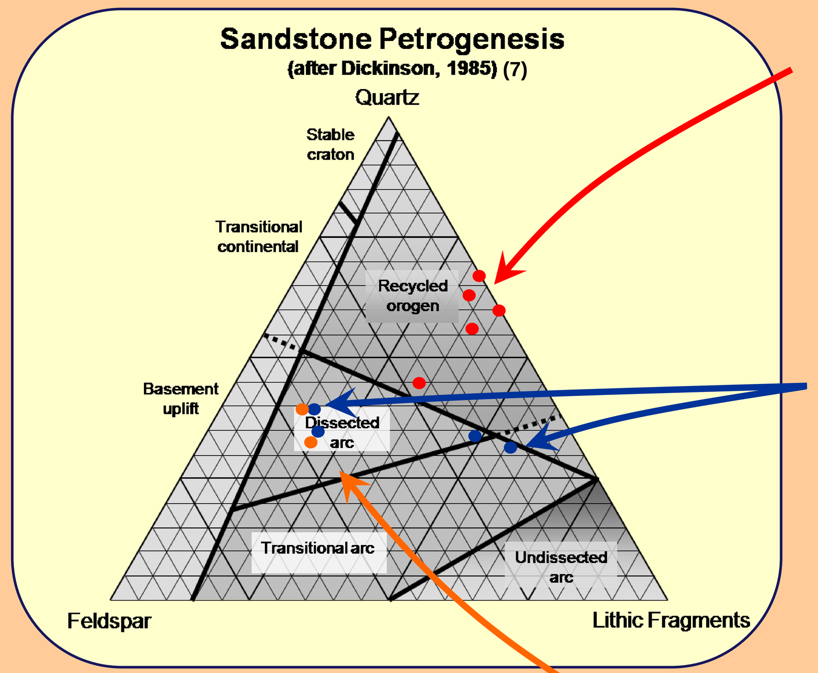


Conceptual model for the development and evolution of the Renova basin. Transport is predominantly from west to east.

Tectonic Setting of Source Material

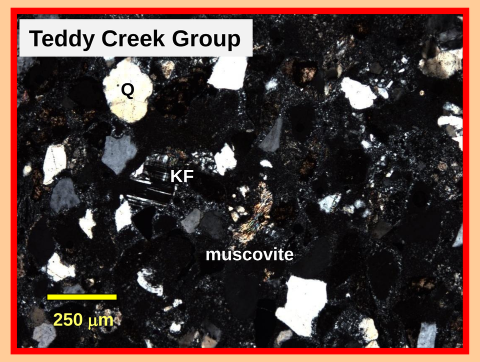
Sedimentary Petrology

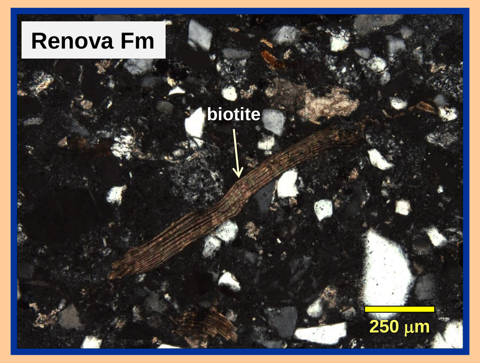
- Compositionally, Teddy Creek Group sandstones plot within the recycled orogen field implying derivation from pre- existing sedimentary and/or metasedimentary rocks.
- Texturally, the TCG sandstones are immature with subangular to subrounded clasts with silica cement.
- TCG sandstones contain minor or trace amounts of detrital muscovite mica with biotite largely absent.
- Renova sandstones compositionally plot within the magmatic arc field indicative a volcanic arc source which is in agreement with the composition data of the Idaho batholith.
- Renova sandstones are textually mature with subrounded to rounded clasts and calcite cemented.
- Detrital biotite & muscovite mica are abundant (3).
- Field relations, mineral compositions, and textures suggest the TCG is distinctive and older than the regionally extensive Renova Formation. Previous workers argue that the Renova sediment was derived from the unroofing of the 80 Ma Idaho Batholith into a broad, depositional basin flanked by low-standing topography.

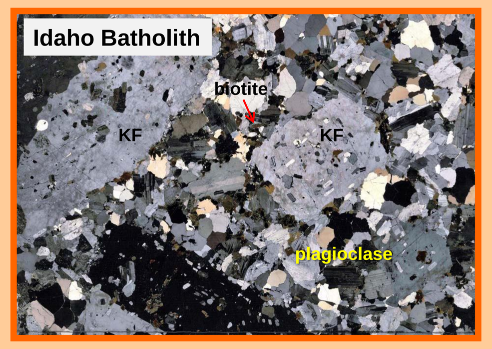


LEGEND

- *Teddy Creek Group data from (8)*
- *Renova Formation data from (4)*
- *Idaho Batholith data from (4)*

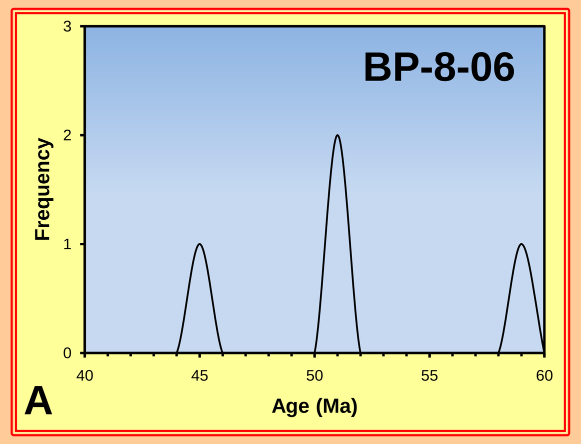


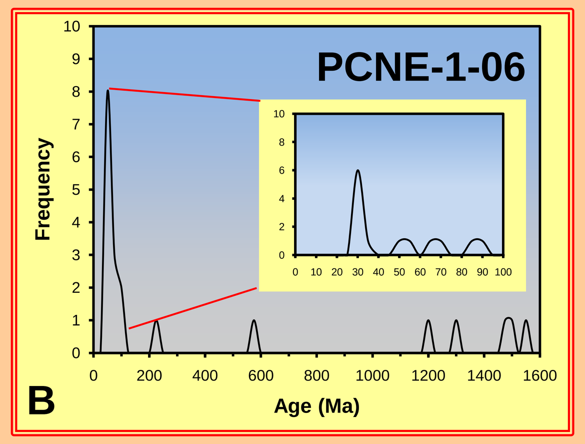


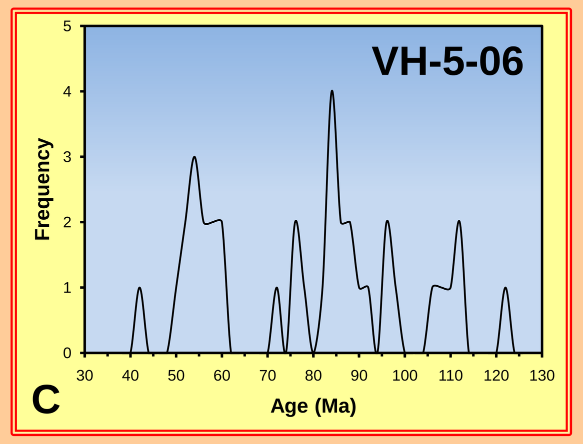


$^{40}Ar/^{39}Ar$ Dating Results

Samples were crushed, sieved and micas were handpicked for purity under petrographic and binocular microscopes. Only single, fresh and unaltered, micas were selected for $^{40}Ar/^{39}Ar$ laser analysis. Single crystals were packaged and sent to the McMaster University Research Nuclear Reactor in Hamilton, Ontario for irradiation. Samples were loaded in copper planchets and fused using a Lambda-Physik ArF Excimer laser. Liberated gas was analyzed using a MAP 215-50 Noble gas mass spectrometer with electron multiplier.



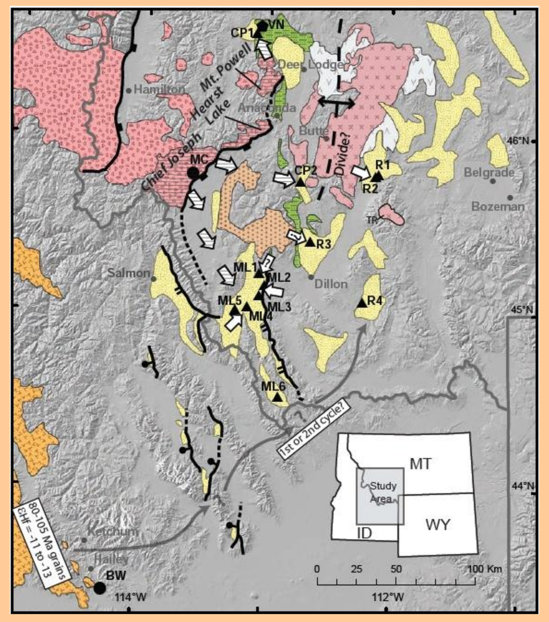




Frequency-age diagrams for detrital micas from the Renova Formation (A & B) and the Teddy Creek Group (C).

Data are inconclusive but several inferences can be made:

- $^{40}Ar/^{39}Ar$ ages from the Renova Fm. indicate significant input from a multiple of source regions.
- Sample BP-8-06 contained only 4 dateable grains ranging between 45 and 60 Ma, significantly younger than the age of the Idaho Batholith (A).
- PCNE-1-06 contains Precambrian through Cenozoic grains with a dominant peak at ~30 Ma (B).
- Nearby Dillon volcanics may have been the dominant contributor for 25-30 Ma grain population in the PCNE-1-06 sandstones.
- $^{40}Ar/^{39}Ar$ mica ages from TCG sandstone record a significant variation (C). Two predominant peaks are at 54 Ma & 84 Ma, respectively. Several peaks of older micas ages are also preserved.
- Ages are scattered and suggest multiple volcanic-plutonic sources or the reworking of older deposits.
- Precambrian ages are lacking which suggests crystalline basement may not have been significantly exposed at the time of deposition or did not provide detritus to the TCG.



Transport model for sediment of Renova and TCG sandstones (4).

Conclusions

1) On the basis of $^{40}Ar/^{39}Ar$ age dating of detrital micas from the TCG and Renova Fm. it is suggestive that the Idaho Batholith did not provide a significant amount of detritus to the Renova basin.
2) The youngest age of 42.6 provides a maximum minimum age for the deposition of the TCG.
3) Lack of Archean ages suggests metamorphic basement was not exposed at the time of deposition of the TCG.
4) Previous workers speculated that a quiet, broad, low-topography basin existed during the time of Renova deposition. Archean ages present in the Renova sandstones suggest either basement was exposed and high-standing topography existed or this detrital material was recycled from older, possibly multiple sources.
5) The youngest ages in the Renova samples are most likely derived from the nearby Dillon volcanic center rather than the Idaho Batholith.

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