Sedimentary Petrology and Provenance of the Teddy Creek Group SW Montana

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Renee conducted this research in southwest Montana, an area that has been the region of study for several geologic endeavors at Bridgewater State through the Adrian Tinsley Program. Her undergraduate research experience led to a poster presentation at the Geological Society of America conference, a national geology conference. Attending this conference exposed her to graduate research possibilities such as the hydrogeology research she is currently involved with as a graduate in a fellowship program at Central Washington University. Renee hopes to enter a career in hydrogeology after completion of her masters degree program in June of 2012.

A previously undocumented sequence of sedimentary rocks has been identified within SW Montana and informally named the Teddy Creek Group (TCG). This project focuses on the field relations, mineral compositions, and textures of these rocks to determine their origin and relationship to the more regionally extensive Cenozoic Renova Formation.

The TCG consists of a basal pebble-conglomerate with distinctive black chert clasts overlain by sandstones interlayered with 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 or biotite 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 abundant muscovite and biotite micas. The presence of the micas is attributed to the unroofing of the Idaho batholith. However, the general lack of micas, especially biotite, in the TCG suggests a different source than that of the Renova Formation.

Compositional analysis documents distinct differences between the TCG and Renova Formation. Sandstones of the TCG plot within the field of recycled orogen implying they were derived from pre-existing sedimentary and/or metasedimentary rocks at a convergent plate margin. Renova sandstones plot within the dissected arc field indicative a volcanic arc source which is in agreement with the composition of the Late Cretaceous Idaho batholith.

Introduction

Recently, much work has been done concerning the provenance and tectonic setting of Cenozoic sedimentary rocks within southwestern Montana (Thomas, 1995; Thomas et al., 1995; Stroup et al., 2008). Current tectonic models suggest extensional deformation, associated with low-angle subduction of the Farallon plate beneath the North American resulted in the development of the Basin and Range Province and subsequent topography during the Eocene time (Fields et al., 1985). Deposition of the regionally extensive Renova Formation occurred during this time within semi-isolated extensional rift grabens (Fields et al., 1985). An alternative model proposed

Regional Location Map

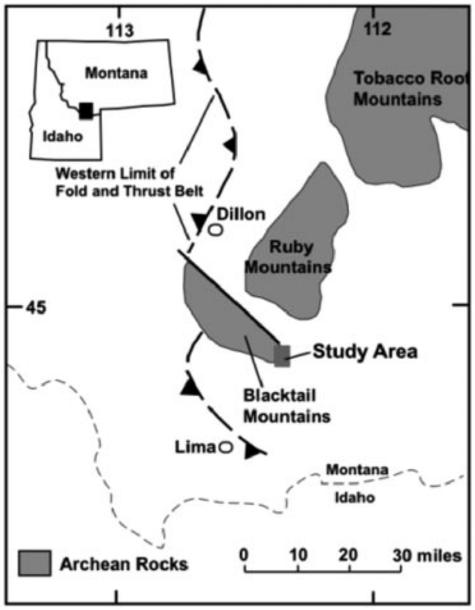

Figure 1. Map of southwest Montana along the Montana-Idaho border. The study area is located in the southern portion of the Blacktail Mountains as indicated by the red box.

for this region suggests a single, large, broad basin extending from central Idaho in the west to an area east of the Ruby Mountains (Figure 1). Within this basin deposition of the fluvial Renova Formation occurred from Middle Eocene to Middle Miocene time (Thomas, 1995). As a consequence of the development of the Pliocene Yellowstone hotspot, the region was dissected by a series of northwest-trending faults which dissected the broad Renova basin into smaller grabens which remain preserved today (Fritz & Sears, 1993; Sears, 1993). However, prior to the disruption of this regionally extensive board basin, the provenance of the Renova sediment is believed to be derived from the Cretaceous-aged Idaho granite batholith with material being transported eastward within an intricate system of braided streams (Thomas, 1995; Thomas et al., 1995). 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 (Thomas, 1995; Thomas et al., 1995).

Recent work in the Blacktail Mountains approximate 50 km east of Dillon reveal the presence of a previously undocumented package of sedimentary rocks informally termed the Teddy Creek Group (Muller & Krol, 2004). This project documents the mineralogy and textures of sandstones from the Teddy Creek Group (TCG) which are used to unravel the provenance and transport history of this unit. A major question that is addressed is whether the TCG represents a lithologic unit older than the Renova Formation, or whether it is time-equivalent and thus part of the Renova sequence. Modal analyses of sandstones from the TCG are compared to the Renova sandstones in an effort to document the tectonic setting of the source material that supplied the detritus to the TCG.

Geologic Setting

The Teddy Creek Group (TCG) occurs within the Rocky Mountain Basin and Range province of the western U.S. Cordillera predominately within the Blacktail Mountains and also within the Ruby Mountains (Figure 1). The TCG is disrupted by several normal faults resulting from extension and rifting. The Blacktail Mountains are one of numerous basement-cored uplifted blocks that occur throughout SW Montana. Basement rocks consist of Archean metamorphic gneisses and Proterozoic mafic intrusions. In the northern portion of the Blacktail Mountains, the basement rocks are overlain by a sequence of Paleozoic and Mesozoic sedimentary rocks. However, in the southern portion of the mountain range, these rocks have been eroded away, and sedimentary rocks unconformably lie on metamorphic basement. The basal unit is a maroon conglomeratic mudstone called the Price Creek unit (PCu). Within the Blacktail Mountains the TCG unconformably overlies the PCu with cobbles of PCu within the basal unit of the TCG (Figure 2).

Results

Mesoscopic and Microscopic Characteristics

Teddy Creek Group

The TCG is a siliciclastic unit consisting of chert pebble conglomerates, medium-grained quartz sandstones and very fine-grained volcanic ash. Sandstone units commonly

Figure 2. Field photograph showing contact between Price Creek unit (bottom) and the Teddy Creek Group (top). Notice the rip up clasts of the Price Creek within the overlying Teddy Creek unit. Pencil for scale.

Figure 3. Field photograph of cross-bedding sedimentary structure within TCG sandstone. Quarter for scale.

exhibit cross-bedding indicating a fluvial environment during deposition (Figure 3). Rocks of the TCG are silica-cemented producing highly resistant rock outcrops resulting in high standing topography. Conglomerate layers occur near the base of the TCG and contain clasts that range in composition from chert to granite gneiss, with the gneiss clasts being subordinate. The size of the clasts varies from 1 to 15 cm (Figure 4). Rock fragments are primarily metamorphic in nature, although minor amounts of volcanic detritus is also present. The basal

Figure 4. Silica-cemented basal conglomerate of the TCG. Conglomerate layers repeatedly throughout the stratigraphic column. Note presence of rounded black chert pebbles. Quarter for scale.

TCG contains rounded-subangular clasts of the underlying Price Creek unit. The quartz-rich sandstones are texturally sub-mature with quartz grains being chiefly subangular to

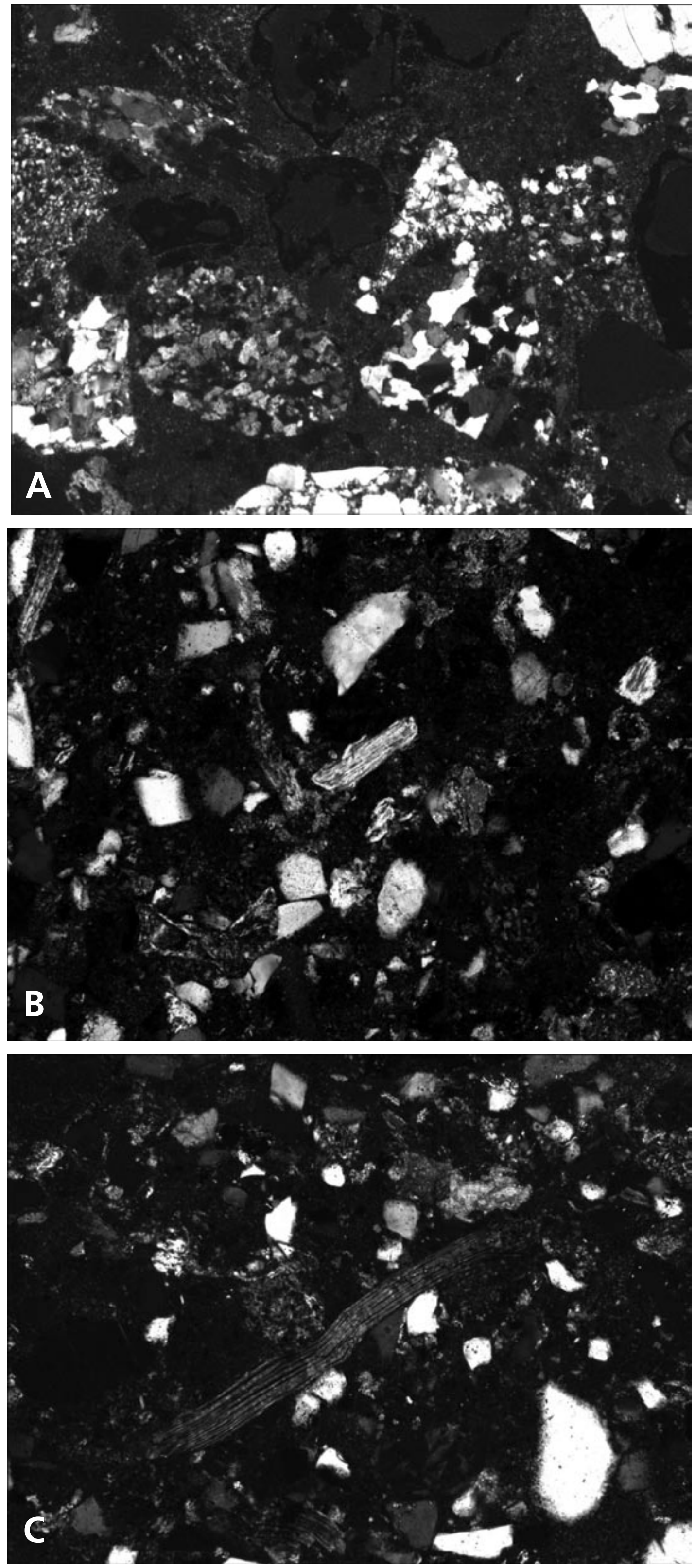

Figure 5. Photomicrographs of clastic units of the TCG. (A) Pebbly sandstone with lithic fragments, chert and chalcedonic quartz clasts in a fine-grained silica matrix. (B) Minor muscovite and subangular to subrounded quartz grains. (C) Kinked biotite grain with subangular quartz grains. Field of view is 2.5 mm.

subrounded. Quartz and lithic clasts are the most abundant with feldspar and kinked micas occurring in minor amounts (Figure 5). Quartz commonly occurs as 0.25 to 2.0 mm grains. Hematite occurs in and around many grains and is found within pore spaces. Very fine grained polycrystalline to cryptocrystalline forms of quartz are abundant although monocrystaline quartz is also present. Distinctive black chert and chalcedonic quartz pebbles are abundant in the conglomerate units and absent in the more uniform sandstone layers.

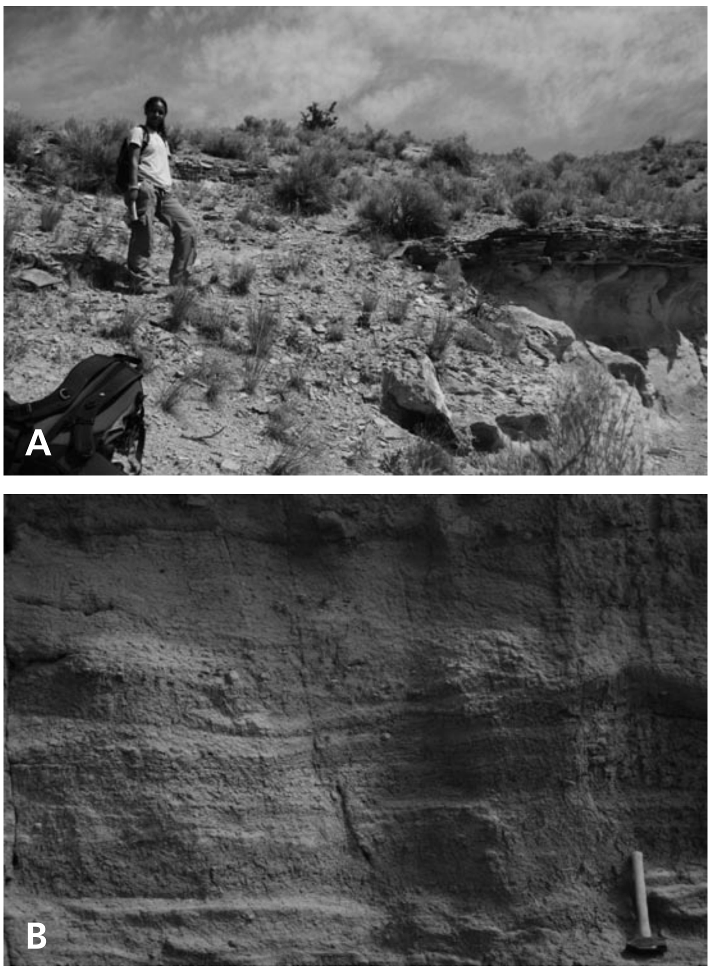

Figure 6. Field photographs of the typical Renova Formation tuffaceous sandstones. Note the poorly lithified nature relative to the sandstones in the Teddy Creek Group. (A) Outcrop of typical interbedded Renova Formation. Reneé Holt for scale. (B) Close-up of tuffaceous Renova Formation. Hammer for scale.

Renova Formation

In contrast, the Renova Formation occupies lower elevations and consists predominantly of interbedded tuffaceous siltstone and quartz-mica sandstones. Layers are significantly less lithified and outcrops are typically friable and crumbly (Figure 6). Sandstones are calcite-cemented with biotite and abundant muscovite. Grains are subrounded and show a higher degree of textural maturity than those found in the TCG. Quartz and mica grains range in size from 50 μm to 550 μm. Micas tend to be larger than those of the TCG with some biotite crystals as large as 2.0 mm. The Renova Formation also displays cross-bedded sandstones in places and may contain petrified wood fragments, as well as mammal fossils (Thomas, 1995).

Modal Analysis & Provenance

Point counting analysis was performed on five samples of TCG sandstones in order to compare them with results obtained from the Renova Formation. The objective was to see if we could distinguish the provenance or source terrains between these different clastic units. Point counting is a statistical measure of the mineral components within the sandstones. Results are plotted on a ternary QFL composition diagrams (Q: quartz; F: Feldspar; L: lithic fragments) with superimposed fields of tectonic environments (Dickinson, 1983). Two to three hundred mineral counts were made for each of the five representative TCG samples (Table 1). Figure 8 shows the results of the TCG data along with data reported from the Renova Formation. Results for the TCG sandstones indicate high amounts of quartz and lithic fragments and with the exception of one sample (PC-28b) very little feldspar is present. Four of the five samples plot in a tight cluster within the field of recycled orogen terrain (Figure 7). By definition this indicates sediment derived from pre-existing sedimentary and/or metasedimentary rocks at a convergent plate margins (Dickinson 1983). The source

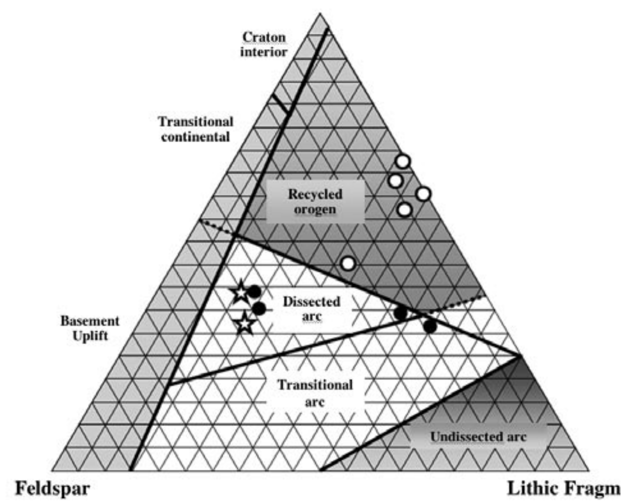

Figure 7. Triangular QFL composition diagram subdivided based upon provenance type (Dickinson 1983; 1985). White circles are TCG sandstone samples (n=5); data points in black are Renova Formation samples (n=4); and white stars represent the Idaho Batholith (n=2). The Renova Formation and Idaho Batholith data are from Stoup et al. (2008).

sediments are exposed to erosion via tectonic uplift of fold belts and thrust sheets. Tectonic settings center on convergence and include subduction complexes, sutured belts of collisional orogens and along thin-skinned foreland fold-thrust belts adjacent to margins of collision orogens (Dickenson 1983). Low amounts of feldspar within the TCG further exclude a significant contribution from an igneous parental.

For comparison modal analysis data from Stroup et al. (2008) for the Renova Formation and the Idaho granite batholiths are also plotted on the QFL diagram (Figure 7). The Renova/Idaho batholiths data plot within the dissected and transitional arc terrains. Both terrains are variations of magmatic volcanic arc settings indicative of igneous source sediment. These plots provide further support the idea that the Idaho batholith was the source of Renova Formation sediment. The compositional diagram highlights the differences between the TCG and Renova Formation sandstones.

Discussion

Compositional QFL diagrams, field relations, mineral compositions, and textures all suggest the TCG is distinctive and older than the regionally extensive Renova Formation. The abundance of two micas in the Renova and the absence of this component in the TCG is a major discriminatory feature. The source rocks for the TCG may have been derived from the recycling of older material eroded from tectonically uplifted areas in the hinterland of the Cordilleran Mountains. This region was shaped by tectonism associated with the Mesozoic Sevier, the Mesozoic-Cenozoic Laramide, and the Cenozoic Basin and Range orogenies. Whereas the Sevier Orogeny was predominantly "thin-skinned" in nature and affected mainly Paleozoic and Mesozoic sedimentary rocks, the Laramide Orogeny was "thick-skinned" and involved significant uplift of Precambrian metamorphic basement and overlying sedimentary cover rocks. During the waning stage of the Laramide and onset of Basin and Range extension, southwest Montana experienced a prolonged phase of magmatic activity.

On the basis of field relations, the TCG appears older than the Renova Formation. If so, then it is most likely that the source of sediment found in the TCG is most likely derived from the regions of basement rocks exposed during the Laramide Orogeny. The material for the Renova Formation appears to be related to the emplacement and subsequent unroofing of the 75 Ma Idaho granite batholith. U-Pb zircon ages from sandstones in the Renova Formation yield dates around 75 Ma, supporting the batholith as the probable source. However, there have been no attempts to date detrital minerals from the TCG. Work in progress at Bridgewater State will shed new insight into the origin and provenance of the TCG sediment with more confidence.

Two questions remain concerning the origin and provenance of the rocks in the TCG. First, although we know that the source of the TCG is distinct from that of the Renova Formation, it remains unclear what the source region was that provided this detritus. The TCG does not contain a compositional signature similar to the Renova so we can rule out the Idaho batholith. Second, micas contained within the TCG and Renova sandstones are kinked and bent suggesting they were derived not from an igneous source, but from a deformed metamorphic source. If so, this would indicate that the surrounding Archean basement gneisses may have been exposed as high-standing topography during a time that was supposed to be characterized by a low-lying broad basin with no significant relief. Understanding the dates of these micas could shed new light on the ultimate source rocks with implications for the topographic and landscape evolution during Late Cretaceous-Early Cenozoic time.

Future Work

In an effort to answer the questions stated above, we plan to date single crystals of muscovite crystals within the sandstones using the $^{40}Ar/^{39}Ar$ laser dating technique. The dates obtained will provide additional constraints on the source rocks for the Teddy Creek sandstones as well as providing a minimum age of deposition. Ages will help confirm or refute the relationship between the Teddy Creek Group and the Renova Formation. Detrital mica ages may shed new information on the possibility that the modern landscape may have existed prior to 4 million years ago as proposed by several workers in the last few years, and may have existed 50-60 million years ago.

Table 1. Compositional and modal analyses (in %) of Teddy Creek Group sandstones. n represents the number of point counts.

Sample #	Quartz	Lithic Fragments	Feldspar	n
PC-28b	43.0	33.6	21.9	234
PC-25A-03	67.1	32.9	0.0	240
PC-18A-03	59.4	39.7	0.1	308
PC-5-02	62.7	32.9	4.4	203
PC-6B-02	55.8	37.4	6.8	333

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References Cited

Dickinson, W., 1983, Provenance of North American Phanerozoic sandstones in relation to tectonic setting, Geological Society of America Bulletin, v. 94, p. 222-235.

Dickinson, W., 1985, Interpreting provenance relations from detrital modes of sandstone, in Zuffa, G.G. (ed.), Provenance of Arenites, Reidel Dordrecht, p. 333-361.

Fields, R.W., Tabrum, A. R., Rasmussen, D.L., & Nichols, R., 1985, Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho, in Flores, R.M. and Kaplan, S.S., eds., Cenozoic paleogeography of the west central United States, Denver, CO, Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, p. 9-36.

Fritz, W. J. & Sears, J.W., 1993, Tectonics of the Yellowstone hotspot wake in southwestern Montana, Geology, v. 21, p. 427-430.

Muller, P.D. & Krol, M.A., 2004, Early Cenozoic volcanism, sedimentation, and faulting, southeast Blacktail Mountains, Montana, Geological Society of America Abstracts with Programs, v. 36, no. 5, p. 510.

Rofe, N.Q. & Krol, M.A., 2004, Geologic mapping of volcanic rocks in the Blacktail Mountains, Montana, 18th National Conference for Undergraduate Research, Abstracts with Programs, p. 157.

Sears, J.W., 1995, Middle Miocene rift system in SW Montana: Implications for the initial outbreak of the Yellowstone hotspot, Northwest Geology, v. 25, p. 43-46.

Stroup, C.N., Link, P.K., Janecke, S.U., Fanning, C.M., Yaxley, G., and Beranek, L.P., 2008, Eocene to Oligocene provenance and drainage in extensional basins of southwest Montana and east-central Idaho: Evidence from detrital zircon populations in the Renova Formation and equivalent strata, *in* Spencer, J.E., and Titley, S.R., eds., Ores and Orogenesis: Circum-Pacific Tectonics, Geologic Evolution, and Ore Deposits: Arizona Geological Society Digest 22.

Thomas, R.C., 1995, Tectonic significance of Paleogene sandstone deposits in southwestern Montana, Northwest Geology, v. 24, p. 237-244.

Thomas, R.C., Sears, J.W., Ripley, A. A., & Berg, R.B., 1995, Tertiary extensional history of southwestern Montana: Field trip guide for the Sweetwater and Upper Ruby valleys, Montana, Northwest Geology, v. 25, p. 5-25.