Structural and environmental controls on groundwater flow and the potential for contamination: Warm Springs Creek Valley, Anaconda, Montana.

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INTRODUCTION

Southwestern Montana has a rich history of orogenic activity and related sedimentation events. Most notably, this area was recently affected by Laramide tectonism. As a result of the mountain building events, there are a series of ridges and valleys that, though not necessarily parallel or orderly, have a certain homogeneity about them. The valleys have a commonality that arises from the widespread deposition of Tertiary sands and gravels, while the mountains' similarities are erosional features from Pleistocene glaciation. Nestled between gaciated peaks in one of these Tertiary-fill valleys lies the city of Anaconda, Montana.

Surficial Hydrology. In the Anaconda area, the Warm Springs and Silver Bow Creeks come together to form the Clarks Fork River. Warm Springs Creek flows east from the Georgetown Lake area, through downtown Anaconda, and northeast toward the town of Warm Springs. The Silver Bow Creek flows west through Butte and Rocker, MT, and joins the Warm Springs Creek ten miles east of Anaconda in Warm Springs, MT (figure 1). The Warm Springs Creek watershed covers 425 square kilometers and receives approximately 25 cm of rainfall annually. Total vertical relief in the watershed is over 1.5 km, approximately half of which lies within the lowest tenth.

Purpose. Locally, the city of Anaconda is known for its former glory days in the mining industry, the most prominent of which was the operation of a smelting facility that processed the rock excavated from the Berkeley Pit in neighboring Butte, Montana. Mine and smelter wastes still piled on the valley floor threaten local surface and groundwater quality. A four square-mile area on the north bank of Warm Springs Creek, northeast of downtown Anaconda, was studied to: 1.) determine the extent to which local sedimentary structure controls the flow of groundwater in the valley, 2.) characterize the soils in order to make assessments of infiltration and percolation rates, and 3.) evaluate the potential for contamination of local water resources resulting from the presence of the mine and smelter waste.

GEOLOGIC UNITS

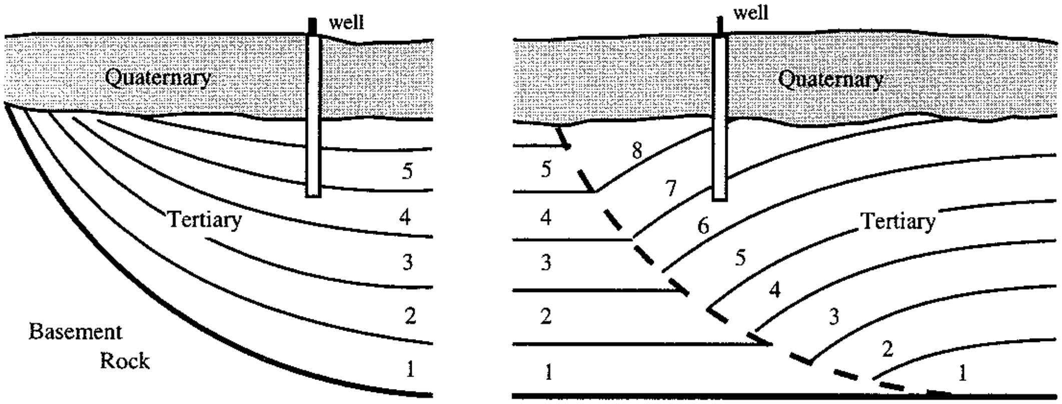
The land surrounding the lower half of Warm Springs Creek is geologically diverse and raises some important and difficult questions about the emplacement and deposition history. The volcanic, metamorphic, and sedimentary units in the region are all noticeably deformed: there is evidence of folding, faulting and tilting in each unit. Because of the diversity of the geologic units, the contacts are distinct, yet because of the short time span for their emplacement and deposition, the processes involved in their deformation are somewhat difficult to interpret.

There are six distinct units in this area (figure 2). The southern half of the watershed is composed of massive fine- to medium-grained Tertiary sandstones. These units are considered to be part of the Bozeman Group–Renova Formation's fine-grained strata deposited in low-energy flood plain and pond environments (Kuenzi & Fields, 1971) and are early- to mid-Oligocene in age (37 Ma). The beds are tilted and have an average NE 040 strike and dip 25°SE. The units range in thickness from 3 to 45 m. There is evidence of faulting on this southern slope of the watershed, including offset beds and modern hydrothermal activity. Two steep-sided travertine domes appear on this southern slope of the watershed and stand 3-4 m taller than the ground around them. The more northerly of the two is still overflowing with lukewarm water, while the other has a water level approximately 1.5 m below the rim of the dome. Further south and past the watershed boundary lie two more domes, one fairly new (little build up of dome sides) while another is quite a bit older: railroad tracks were cut through the dome approximately 80 years ago and there has been no more recent evidence of hydrothermal activity at this locale.

The next unit overlying the Tertiary beds is a massive volcanic breccia unit, and is part of the Lowland Creek Volcaniclastic series. This light to medium grey rock has a fine-grained matrix that supports a pebble- to cobble-sized angular breccia of similar composition. There are rims of mineralogic alteration around the edges of the breccia.

Finally, the age distribution for the Tertiary deposits seen in and around Rocker are not consistent with what would be expected in a listric fault system. A normal fault in the Tertiary deposits would likely be listric, as is nearly every fault in the region associated with the extensional episodes of the middle Eocene to early Miocene (Constenius, 1996). In a listric fault system, bedding within the hanging wall are dipped down toward the footwall as the hanging wall subsides—which in the case of Rocker would mean a down—dipping to the East of the younger Tertiary—aged sediments. With the presence of a listric fault just east of Rocker, younger—aged Tertiary material should have appeared in the well—drillings below the Quaternary sediments (fig. 3). The Tertiary material taken from the core samples in Rocker are Eocene in age—older than the Tertiary deposits outcropping to the West and in the foothills surrounding the site (Debra Hanneman, 1997, personal communication).

Figure 3: (Tertiary Sediments labelled oldest to youngest 1 - 8)



a) In the case that the Tertiary sediments represent undisturbed basin-fill deposits, well-cores will reach only the older sediments that have not been down-cut by the Quaternary.

b) In the case that the Tertiary sediments have been offset by listric faulting, sediments of younger age should appear within the well-logs. On the Rocker site they do not — indicating that listric faulting has probably not occured.

CONCLUSION

Though it is impossible to say with certainty that the Rocker Fault does not exist with the information available, data acquired in this study suggests that it does not. Given the well—log data, seismic reflection evidence for structurally undisturbed basin—fill sediments above the basement rock, and sediment age distributions inconsistent with a listric faulting zone, it seems unlikely that the Tertiary sediments have been offset by a major fault.

ACKNOWLEDGMENTS

I thank B. Haileab and T. Vick for technical support at Carleton, and J. Conaway, E. Hammar—Klose, and J. Sneeringer for the field work and seismic surveying done in Rocker. I especially thank D. Hanneman for her invaluable assistance throughout the course of this project.

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On the north side of the Creek, there are two volcanic members I believe to be part of the Elkhorn Volcaniclastic Unit, with an age of ≈40 Ma. The first, a more reddish-brown, micro-crystalline mafic unit, is most likely the remnant of the neck of a small volcano, while the second is a coarse, white ash/tuff unit. There are slickenlines on the exposed surfaces of the mafic unit at the very top of the volcanic neck, indicating a possible fault in the area. An closer look at the geomorphology of this volcanic peak supports the fault theory: a drainage runs southeast from the top of the peak and is very straight. A continuation of the theoretical fault plane coincides with the previously mapped faults planes on the south side of the creek.

The fifth unit is another Tertiary sandstone of the Bozeman Group: the Six Mile Creek formation is stratigraphically above the Renova formation and is described as being deposited in high energy channel settings (Kuenzi & Fields, 1971). The grains are rounded, well sorted pebbles and are primarily milky quartzite in mineralogy. These beds are also tilted and have an average NE strike of 100 and dip 40°SE.

The final rock unit is rather enigmatic. It is a cryptically sorted, unconsolidated, organic- and clay-rich diamicton. Most of the rounded pebble-to cobble-sized clasts are hematitic quartzite, probably derived from a Paleozoic quartzite unit 325 km to the south. This diamicton was interpreted by Wanek (1989) as a Pleistocene glacial moraine. I do not agree with this interpretation based on the evidence of ribbon channels I found and on the rounded-ness of the clasts. In my opinion, it is a low-energy channel/braided stream deposit that is likely the reworking of the glacial sediments that stopped Georgetown Lake from draining into Warm Springs Creek in the Pleistocene epoch.

GROUNDWATER AND AQUIFERS

There are two possible aquifers that are contributing to the presence of groundwater in the area. The first is the Six Mile Creek Sandstone with its recharge area likely in the mountains to the north and west of Anaconda at an unconformable contact between Tertiary and Mesozoic strata. The aquifer is confined by the Lowland Creek Tuff that lies to the north and west and also by the Elkhorn Basalt to the south and west. There are four "seeps" in the diamicton unit that can be associated with this aquifer: the seeps are expressed in the form of standing water (even after weeks without rain) in gulches and pits across the study area. The four seeps dot the west, south, and east portions of the perimeter of the principle hill in the study area are an expression of the confined-to-unconfined delineation of the aquifer (figure 3). This aquifer is also responsible for the high moisture content and resulting slumping of the deeply incised eastern slope of the study area. Just below the slump's head scarp, slump scars are filled with standing water and hydrophilic vegetation is abundant. The slumping problem is exacerbated by, if not solely caused by, a contracting company's removal of 40,000 cubic meters of material from the base of the slope for use in capping the nearby smelter waste.

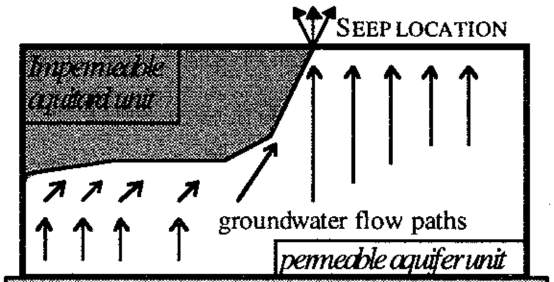

Figure 3: schematic diagram of the delineation of confined-unconfined boundary of an aquifer

The second aquifer lies in the bottom of the Warm Springs Creek valley in the Renova Sandstone and is the drinking water supply for the city of Anaconda. It is confined only by modern alluvium and smelter waste in the valley. The creek is a losing stream as indicated by nearby monitoring wells drilled a minimum of 100 m deep that all have water levels at 10-15 m below surface—even wells that are located 10 m to either bank of the creek. I also observed completely dry ground 3 m away from the creek bed...the dry ground was at least 2 m lower than the creek bed. The recharge area for this aquifer is also to the west, but in the Silver Lake area of the watershed.

QUARTZITE DIAMICTON CHARACTERIZATION

Field Methods. A contracting company was digging test pits in the quartzite diamicton on the east side of the study area to analyze its rock content and thus the potential for use in capping the smelter waste. I was able to make close visual inspections of 20 of the test pits they dug, each pit being 2-4 m deep and spaced 15-20 m apart. It was from these that I found evidence for ribbon channels and lenses of coarser material in the subsurface by correlating the layers I saw in adjacent pits. For seven of the pits, I made a stratigraphic columns and collected 0.5-1 kg of sediment with a garden trowel, storing the samples in Ziploc freezer bags.

Laboratory Methods. In the lab, I mixed a portion of each of the samples with deionized water, sonified each sample for 1-2 minutes to break up dirt clumps, then placed each sample in a centrifuge to separate the layers of solution (clay would be in the middle layer, silt and sand in the bottom) and filtered them through a 0.45 µm filter. I then placed the material that remained on the filter onto a glass slide and air dried the slide for approximately a week to 10 days in a vacuum hood. Once dry, I put them in the x-ray diffractometer and x-rayed each to determine clay mineral presence. After being x-rayed once, each sample was placed in an ethylene glycol atmosphere for 24 hours then x-rayed again. The ethylene glycol was used to make the layers of the semectite minerals expand. The trends in the expansion of the semectite gives information on the maturity and weathering history of the material. Conclusions drawn from these data are preliminary and unavailable at presstime.

CONCLUSION

Although Cordilleran uplift and erosion, Tertiary volcanism and tectonism, and Quaternary glaciation have contributed to the development of the complex Cenozoic stratigraphy, investigation revealed that groundwater flow is primarily controlled by 1.) Miocene sandstone bedding planes, and 2.) subsurface contacts with Eocene basalt intrusions and volcanic tuff layers. Soils had varying carbonate horizon development: thin development nearer to a groundwater seep, and thicker development with increased distance from a groundwater seep. From this, one can conclude that percolation prevents infiltration and impedes carbonate horizon development. Low annual precipitation in the area (and subsequently low infiltration rates) along with the deep water table in the valley's subsurface have helped to maintain groundwater quality thus far. Any significant increase in precipitation-infiltration in the watershed or increase in irrigation for local agricultural activity could lead to heavy metal, sulfate, and/or chlorine contamination of local water resources.

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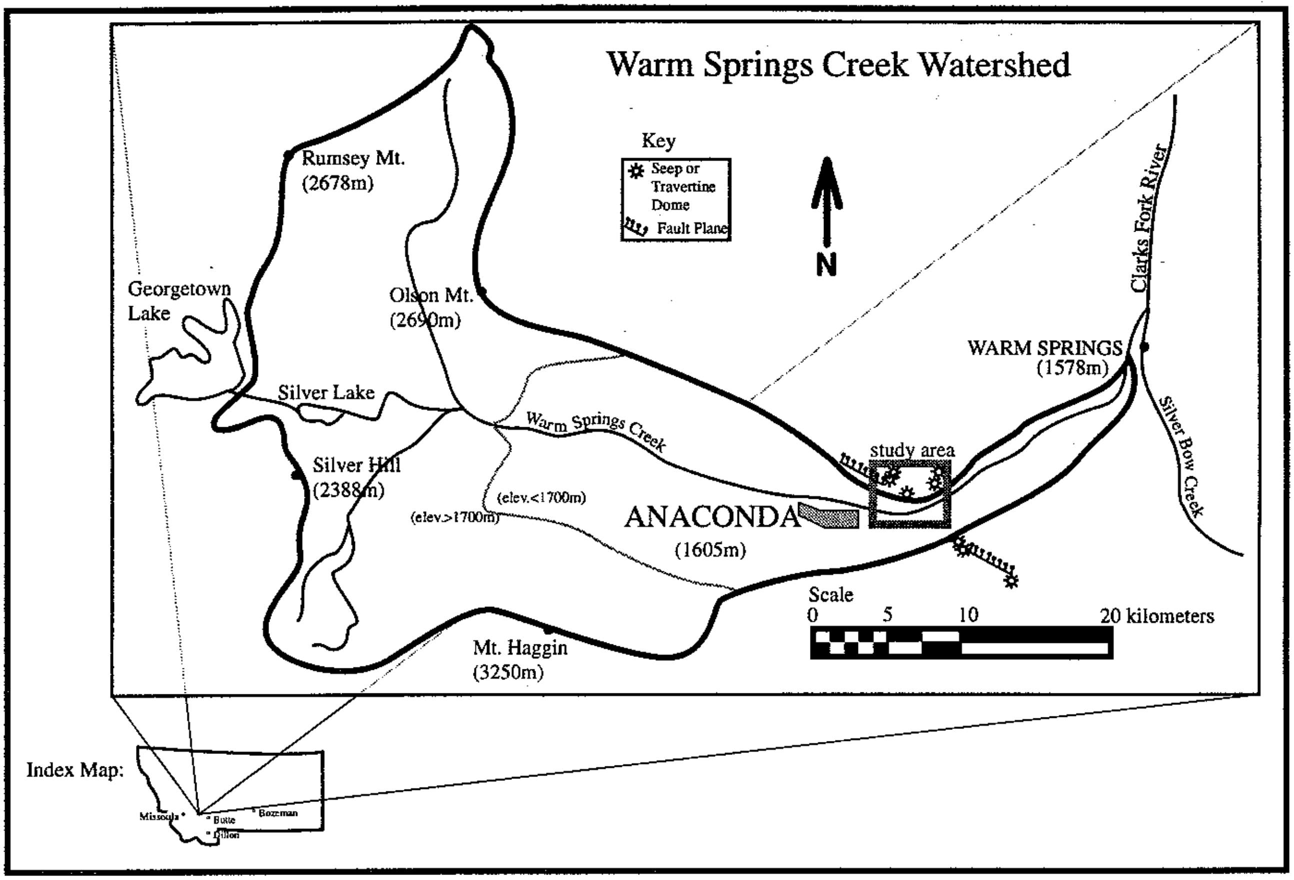

figure 1: map of study area

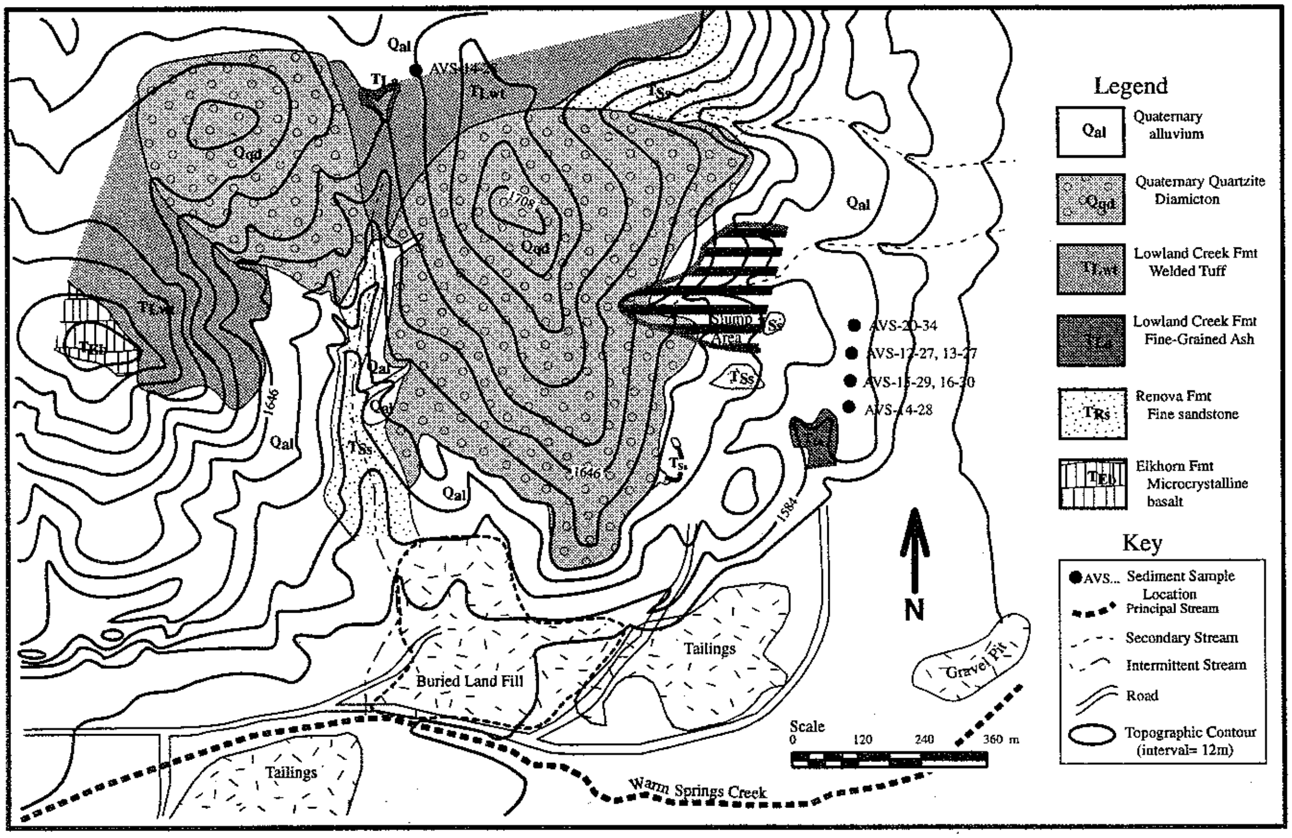

figure 2: geologic map of study area and sediment sample locations

Interpretation of a Tertiary-fill basin in southwestern Montana through the use of geophysical techniques

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INTRODUCTION

Willow Creek valley is located approximately 40 miles east-southeast of Butte, MT and surrounds the town of Harrison (Figure 1). Late Tertiary sediments overlaid by Quaternary alluvium fill the valley and rest unconformably against Archean basement rocks on the walls of the valley. Such an unconformity has two plausible interpretations: 1) The valley was originally a paleovalley and the basin margins are related to onlap processes, or 2) The valley is fault bounded. High density difference between Tertiary fill and Archean metamorphic rock (0.5-0.8 g/cc) is ideal for both gravity and seismic refraction investigation. The purpose of this investigation is to determine the nature of the unconformity using gravity methods constrained by seismic refraction data and to develop feasible models for the shallow subsurface geometry of the basin based on geophysical data.

BACKGROUND GEOLOGY

Willow Creek valley lies south of the Three Forks Basin and north of the Madison Basin in southwestern Montana (see Figure 1). Just to the north lies the southwest Montana transverse zone (SWMTZ), a major structural boundary marking the northern-most region of Archean basement rocks and the southern-most region of Paleozoic Belt Supergroup rocks in Montana (Schmidt and O'Neill, 1982). To the south of the SWMTZ lies Rocky Mountain foreland structures created during a period of uplift during Late Cretaceous and Paleocene time (ca. 95-55 Ma.) and exemplified by a set of northwest-trending faults. The valley of interest lies within this zone of NW-trending faults. The valley is also part of a regional intermontane basin system separating mountain ranges throughout western Montana and eastern Idaho (Fields, et al, 1985). Throughout its history, this system of valleys and mountains experienced similar orogenic developments to the traditional Basin and Range tectonics, including a distinct period of Cenozoic extension. Schmidt and Garihan (1986) suggested Neogene extension reactivated northwest-trending faults in the proximity of the Willow Creek watershed and produced half-graben structures that form the corners of several mountain ranges. Constenius (1996) related this Neogene event of normal faulting and basin-fill sedimentation to Basin and Range tectonism. However, Ruppel (1993) has argued that lateral motion along these faults created the existing basins.

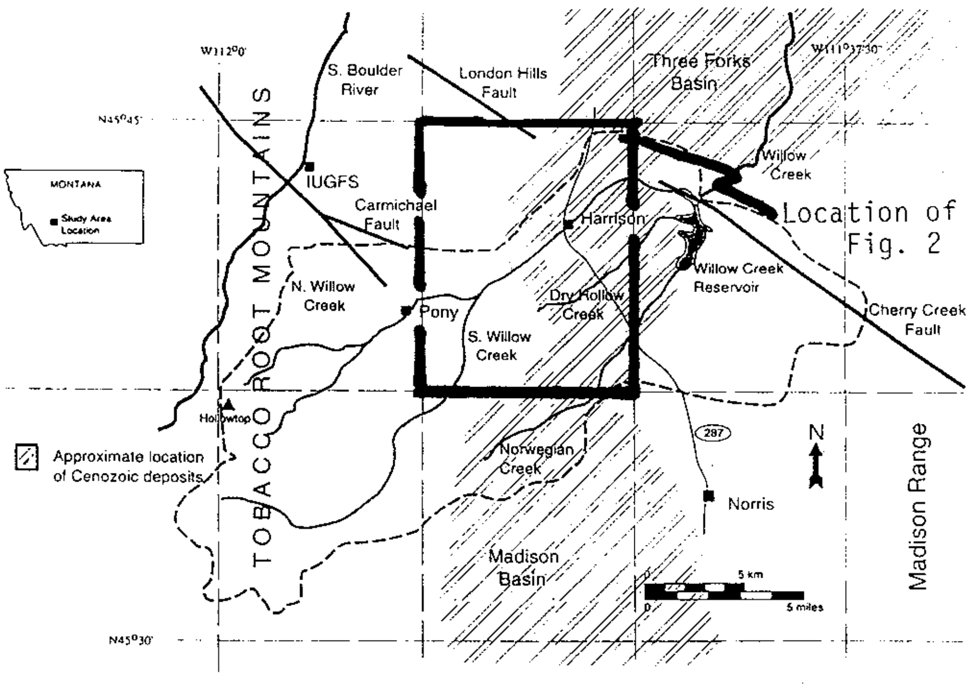

Figure 1. Map showing location of study area