APPENDIX W: Quaternary Faulting in the Proposed Cemented Tailings Facility Area

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June 22, 2017

Mr. Jerry Zieg, Senior Vice President
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Dear Mr. Zieg:

The attached report was done to determine if there are Quaternary faults in the general area of a planned cement tailings facility at the proposed Black Butte Copper Mine. Previous workers have mapped faults in this area that offset Mesoproterozoic to earliest Eocene rocks, but the youngest documented activity on these faults occurred during the late Cretaceous and early Eocene. Geologic mapping done by others and in this study indicates that there is no evidence of these older faults or any new faults being active during the Quaternary. This conclusion is supported by geologic field evidence of the area's Cenozoic deposits which demonstrates that these deposits are not disrupted by faulting. It is also supported by LiDAR data from which a hillshade image was generated. Northeast-trending features can be identified on the hillshade image, but these features do not offset mapped Quaternary deposits. Additionally, no other fault-like features were observed cutting through Cenozoic units on the hillshade image.

Sincerely,

Digitally signed by Debra L Hanneman
DN: cn=Debra L Hanneman, o=Whitehall Geogroup, Inc., ou=President, email=whgeol@gmail.com, c=US

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EXECUTIVE SUMMARY

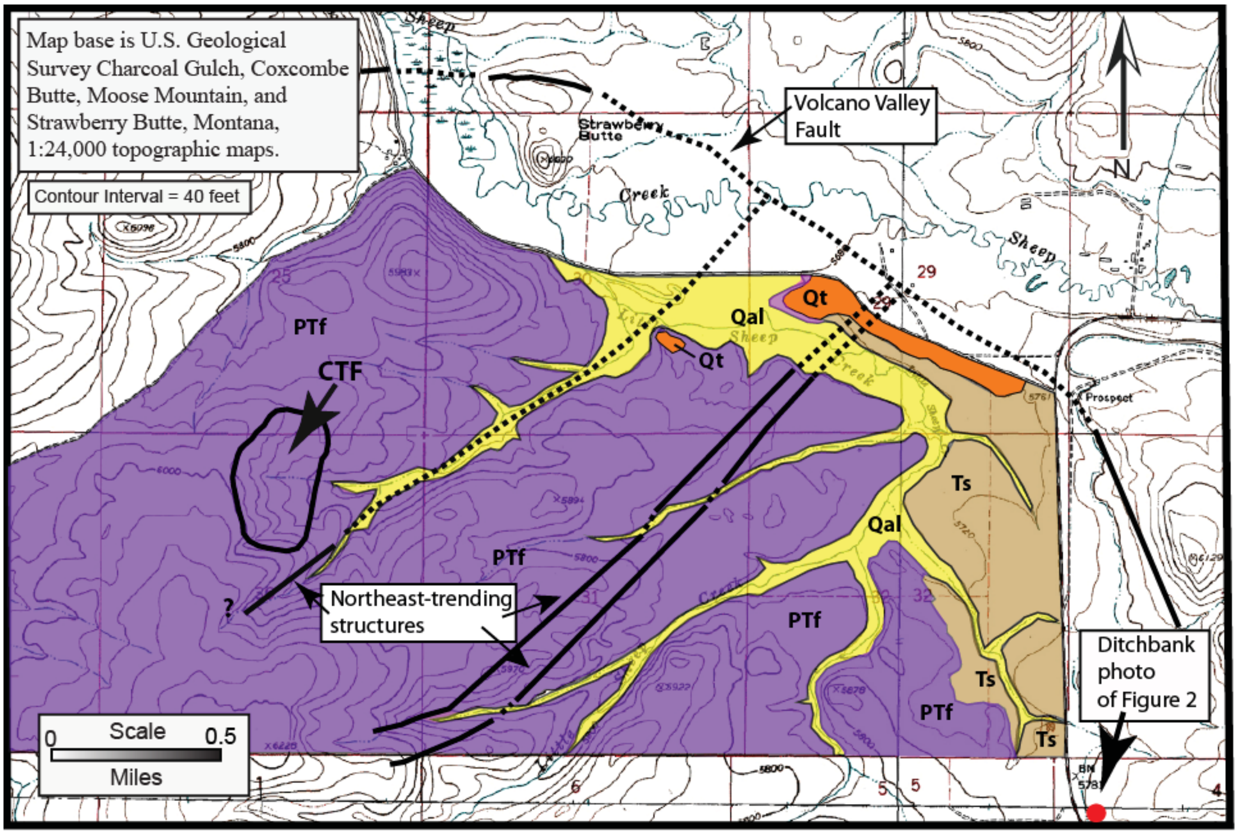
This project was done to determine if there is Quaternary faulting activity in the general area of the cement tailings facility at the proposed Black Butte Copper Mine. Previous workers have mapped faults in this area that offset Mesoproterozoic to earliest Eocene rocks, but the youngest documented activity on these faults occurred during the late Cretaceous and early Eocene. Geologic mapping done by others and in this study indicates that there is no evidence of these older faults or any new faults being active during the Quaternary. This conclusion is supported by geologic field evidence of Cenozoic deposits which demonstrates that these deposits are not disrupted by faulting. It is also supported by LiDAR data from which a hillshade image was generated. Northeast-trending features can be seen on the hillshade image, but these features do not offset mapped Quaternary deposits. Additionally, no other fault-like features crossing the Cenozoic units were identified on the hillshade image.

INTRODUCTION

This project is focused on the question of whether Quaternary faulting is present in the area of the cement tailings facility (CTF) location that will be part of the proposed Black Butte Copper Mine. The CTF's planned location is in section 36, T12N, R6E (Figure 1), atop Mesoproterozoic bedrock of the Newland Formation. Additionally, Eocene age intrusive rocks mapped as biotite-hornblende dacite (Reynolds and Brandt, 2007) cut the Newland Formation in the area of the proposed CTF.

Geologic structures that fault pre-Quaternary deposits mapped in the general vicinity of the proposed CTF include the Volcano Valley fault (Reynolds and Brandt, 2007) and three northeast-trending faults (Tintina Resources, 2016 Geologic Map) (Figure 1). The Volcano Valley fault lies about 1.5 miles north of the proposed CTF, and is a reverse fault with its south side up. The reverse fault movement is Late Cretaceous-pre Eocene in age. The only documented younger activity on this fault is that it is intruded by a hornblende biotite dacite body that has a $^{40}Ar/^{39}Ar$ isotopic age of 54.4±0.2 Ma, which places these rocks in the earliest Eocene. This intruded part of the Volcano Valley fault lies approximately 8 miles west of the CTF (Reynolds and Brandt, 2005).

The three north-east-trending faults that are mapped approximately 0.08 to 0.8 miles to the southeast and east of the CTF (Figure 1) offset Mesoproterozoic and earliest Eocene intrusive rocks that occur as sills and larger intrusive bodies (Tintina



Map Legend for the Geology in the Area of the Proposed Cement Tailings Facility

- Qal — Qal - Quaternary alluvium
- Qt — Qt - Quaternary terrace deposit
- Ts — Ts - Tertiary strata
- PTf — PTf - Pre-Tertiary fill (this unit includes rocks from Mesoproterozoic to 54.2 Ma in age)
- Fault, dotted where concealed
- CTF — Outline of cement tailings facility

Figure 1. Geology in the area of the proposed cement tailings facility (mapped geology based on Reynolds and Brandt, 2007; Tintina Resources, 2016 Geologic Map; and mapping by D.L. Hanneman, 6/14/2017-6/16/2017).

Resources, 2016 Geologic Map). The compositions of the intrusive rocks in this area are hornblende biotite dacite, and as such, I assume them to have an age similar to the 54.4±0.2 Ma hornblende biotite dacite that intruded the Volcano Valley fault.

DO QUATERNARY FAULTS EXIST NEAR THE CTF?

Based on the geologic structural setting and previous geologic mapping outlined above, the determination of whether Quaternary faulting exists near the CTF should be made by initially examining where already identified faults project through Quaternary deposits. These faults are of particular interest because they are zones of previous weakness and could therefore reactivate through time. Both the mapped Volcano Valley fault trace and the northeast-trending fault traces can be projected into an area that, using available previous geologic mapping and my geologic mapping done for this project, contains Cenozoic deposits (Reynolds and Brandt, 2007;Tintina Resources, 2016 Geologic Map; Hanneman, 6/14/2017-6/15/2017) (Figure 1). This area is located approximately 1.5 miles north and northwest of the CTF, mainly in sections 29, 30, and 32, T12N, R7E. And finally, the CTF area was investigated during this project to determine if any unidentified faults offset the area's Cenozoic deposits.

Cenozoic Deposits Used For Age Constraints

In order to better age constrain the question of Quaternary faulting for this area, it is critical to age constrain the local Cenozoic deposits. The oldest unit in this area is Tertiary in age, and more specifically probably late Eocene to early Oligocene. The maximum age determination is based upon the strata containing hornblende biotite dacite clasts, and thus the strata are younger than earliest Eocene, specifically younger than 54.4±0.2 Ma. The minimum age constraint is based upon mapped Tertiary strata north of the proposed mine site being overlain by basalt flows that have whole rock $^{40}Ar/^{39}Ar$ isotopic ages ranging from 32.8 to 30.4 Ma (Reynolds and others, 2002). The lithologies present in the late Eocene to early Oligocene unit include smectitic mudstone, sandstone, conglomerate, and volcanic tuff beds (based upon my geologic field work and core samples provided by Tintina Resources, 6/14/2017-6/16/2017). The age range and lithologies of this Tertiary unit are consistent with those described for the Beaver Creek area by Runkel (1986) in his work on the Tertiary geology and vertebrate paleontology of the Smith River Valley.

The next younger geologic unit is an unconsolidated gravel deposit that caps the Tertiary strata. Reynolds and Brandt (2007) mapped this unit on the north side of Sheep Creek, immediately north of the proposed mine area, and labeled it a terrace gravel with a Pleistocene to Holocene age. I matched the gravel cap I found on the proposed mine property with what Reynolds and Brandt mapped as a terrace gravel and I believe they are the same unit. However, I disagree with the time range that those authors placed on the unit. The terrace gravel is likely only Pleistocene, and probably falls more into the 200,000 years old to 220,000 years old age range. This age designation is based upon the weathering rind thicknesses of basalt clasts that I sampled (sample number=67 clasts) from the gravel as compared with basalt clast weathering rind thicknesses from a study done by Coleman and Pierce (1981) in the western United States. I give an age range for the basalt clast weathering rinds on the proposed mine property because, unlike the Coleman and Pierce study samples that came from a soil B horizon, there is little to no soil B horizon in my sample area. I also measured the clast rind thickness in the field using a portable millimeter scaler. Hence, the basalt clast weathering rinds may indicate an inflated older age for the deposit, but even the minimum rind thickness suggests an age older than Holocene. The gravel unit includes unconsolidated rounded small boulders to pebbles of quartzite, fossiliferous limestone, basalt, dacite, and sandstone clasts. Clast bases have calcium carbonate coatings with some coatings (particularly on the limestone) up to three cm in thickness.

The current drainage system is incised into all older geologic units, including the Quaternary terrace gravel described above. The sediments associated with the current drainage system are unconsolidated and include clay to boulders that comprise the current floodplains and active channels of Sheep Creek and its tributaries. As these sediments are a part of the present drainage system, I have grouped them into Quaternary alluvium and into the one age unit of Holocene. A water well log from an adjoining property to the proposed mine ($SE_{1/4}SW_{1/4}NW_{1/4}$, section 28, T12N, R7E) indicates 17 feet of clay, sand, pebbles, and cobbles of what I interpret as Quaternary alluvium, so there may well be late Pleistocene sediment contained within this unit. But for the purposes of this project, Holocene is sufficient for an upper Quaternary age constraint.

Do Any Structures Offset the Cenozoic Deposits?

I assessed both geologic field evidence and airborne LiDAR (Light Detection and Ranging) data in determining if there is evidence for Quaternary faulting in and around the CTF. The field evidence is taken from the Cenozoic deposits on the proposed mine property and from Tertiary strata exposures in the Holstrom ditch walls located in section 4, T11N, R7E, approximately 0.5 miles southeast of proposed mine property.

Geologic Field Work Observations and Interpretations. The Quaternary terrace gravel provides a reasonable basis for determining if the surface in sections 29 and 30, T12N, R7E has been cut by Quaternary faulting. I walked the old terrace surface and found that where the clasts aren’t disturbed by human-caused workings, the clasts are in their original positions with calcium carbonate coatings on the clasts' undersides (that calcium carbonate occurs on the undersides of clasts in semi-arid to arid areas is well documented: Machette, 1985; Pustovoytov, 2003; Scott and Moore, 2007). Thus, because clasts on the terrace surface (where not disturbed by human-caused workings) are undercoated by calcium carbonate, I interpret this occurrence to indicate that surface is not disrupted.

There is a noticeable gully developing in section 29, beneath the terrace gravels (Figure1 and Figure 3). My mapping of this area shows that the gully is the likely result of the boundary between softer Tertiary mudstone and much more resistant Mesoproterozoic Newland Formation rock. The lithologic boundary can be more readily explained as an erosional edge rather than as an older fault. This explanation arises because the overall Tertiary strata distribution mapped by myself and more extensively by Reynolds and Brandt (2007) appears to be that of a Tertiary erosional paleovalley such as those described for age-equivalent strata in the Laramie Range (Evanoff, 1990, 2016).

That this area represents a Tertiary erosional paleovalley is further supported by Tertiary exposures in the Holstrum ditch. Figure 2 shows a ditch bank where thin white layers at the ditch bank's top are horizontal. These thin white layers occur at the top of

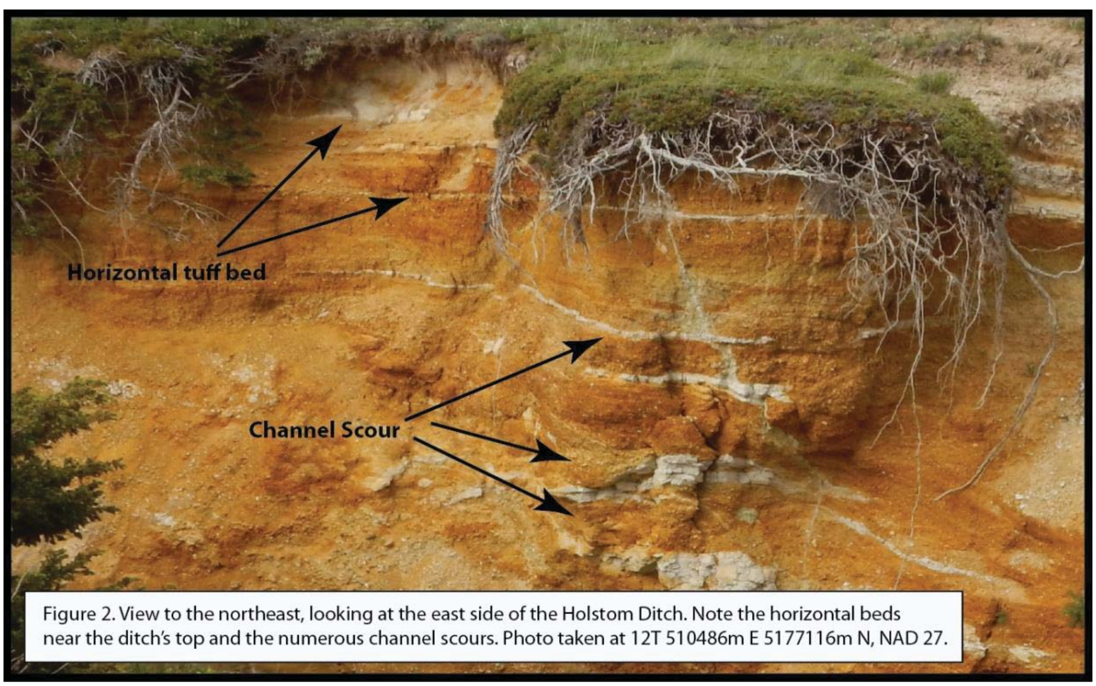


Figure 2. View to the northeast, looking at the east side of the Holstom Ditch. Note the horizontal beds near the ditch's top and the numerous channel scours. Photo taken at 12T 510486m E 5177116m N, NAD 27.

a cut-and-fill channel, and thus are within that part of the channel fill where original sedimentation events aggrade to form horizontal units. This ditch bank is approximately 0.5 miles west of the mapped Volcano Valley fault (Reynolds and Brandt, 2007). If the

Volcano Valley fault system was active during or after deposition of the channel fill and the contained thin white layers, the white layers should probably be tilted away from horizontal as a result of faulting activity.

LiDAR Data Observations. High resolution, 16 points/m2, airborne LiDAR flown by Sands Surveying, Kalispell, Montana (2012), was used to provide a detailed digital terrain model (DTM) of the proposed mine and CTF area. DTMs developed from airborne LiDAR surveys are increasingly used to identify and characterize surface faults (Haugerud et al., 2003; Hilley and Arrowsmith, 2008; Zielke and others, 2010; Stumpf and others, 2013; Tortini and others, 2015). The technique of hillshading was applied to the DTM that encompassed the proposed mine and CTF area using Golden Software Surfer version 12 (Figure 3). This technique illuminates the surface of the DTM from a

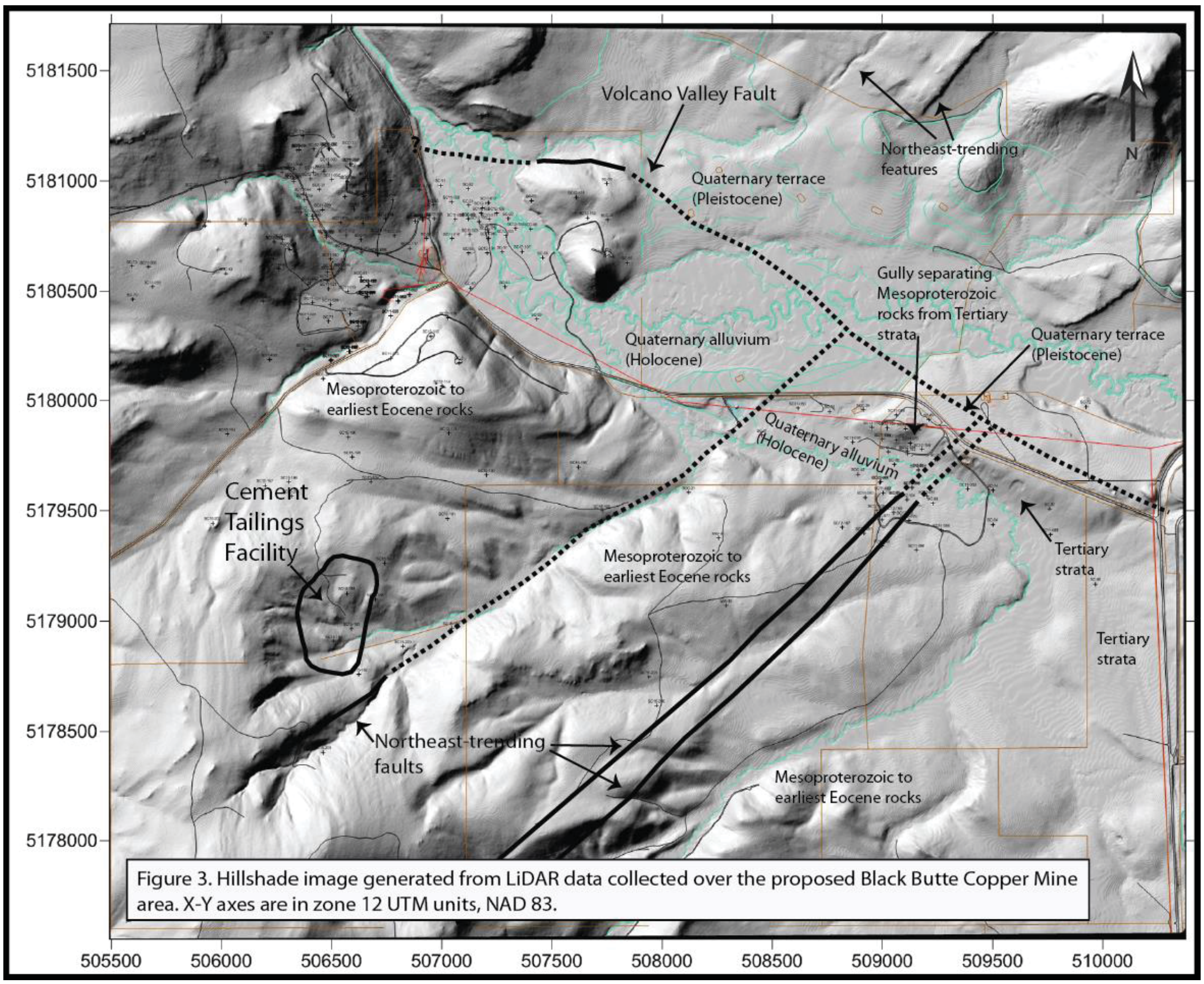


Figure 3. Hillshade image generated from LiDAR data collected over the proposed Black Butte Copper Mine area. X-Y axes are in zone 12 UTM units, NAD 83.

particular sun angle and has proven effective for visualizing surface faults (Ganas et al., 2005; Engelkemeir and Khan, 2008; Tortini and others, 2015; Morell and others, 2017).

As shown in the hillshade image of Figure 3, there are no obvious disruptions on the older Quaternary terrace surfaces or in the Quaternary alluvium of the current floodplains. The northeast-trending structures noted earlier in the *Introduction* section of this report and indicated by arrows in Figure 3 do not cut through Cenozoic deposits. The gully that is the boundary of Mesoproterozoic Newland Formation rocks and Tertiary strata can be seen in Figure 3, but again as discussed above, is more likely an erosional boundary. Furthermore, no other fault-like features that cut through Cenozoic units were observed on the hillshade image.

The present channels of Sheep Creek and its tributaries are also depicted on the hillshade image. None of the meanders in either Sheep Creek or Little Sheep Creek line up with projected northeast-trending faults. The non-alignment of channel segments suggests that there is no channel control by Quaternary faulting.

As depicted in both Figures 1 and 3, the tributary of Little Sheep Creek immediately east-southeast of the CTF appears to conform to topography rather than follow a northeast trend where it merges with the main Little Sheep Creek drainage. The uppermost channel of Little Sheep Creek also appears to be curving to the northwest in response to butting up against the older Tertiary strata that are flanked by Cambrian rock. Both these geomorphic features lead me to believe that they are also not controlled by Quaternary faulting, but rather they are controlled by topographic features of the landscape.

DISCUSSION

Prior to the late Eocene, faulting did occur in the general area of the CFT. However, there is no geologic evidence found by previous mapping in this area and in the geologic mapping done for this project that indicates Quaternary faulting activity.

The geological field work that I did for this project supports a conclusion that the surface covered by an older Quaternary terrace deposit is not disrupted by faulting. The in-situ position of clasts within the terrace gravel, with calcium carbonate coatings on their undersides, is the main basis for this deduction. This deposit also matches up with other Quaternary terrace deposits mapped by Reynolds and Brandt (2007) on the north side of Sheep Creek that are not cut by northeast-trending lineaments which can be readily observed in the hillshade image of Figure 3. It should also be noted that Reynolds and Brandt (2007) show the faulting that they mapped in this same area as concealed beneath Cenozoic deposits, thus also indicating that there is no evidence for Quaternary faulting.

The Tertiary deposits in the proposed mine area appear to be deposits within erosional paleovalleys rather than fault controlled depocenters. Topographic relief was considerable in the northern Rockies during the Eocene (Constenius, 1996; Fan and others, 2017), and resulted in numerous Eocene-Oligocene paleovalleys that extended into the core of areal mountain ranges. As noted by Evanoff (1990) for the Eocene paleovalleys in the Laramie Mountains of Wyoming, "the local relief indicated by the paleovalleys was ample for erosion to provide coarse gravel for fluvial systems, without requiring episodes of repeated uplift" (p.446). Similarly, the sediments within the Tertiary units in and near the proposed mine site indicate local fluvial systems with very localized clast input. These same sediments also contain a high percentage of volcanic ash. The ash was probably originally an aeolian component to the depositional system, being derived from the nearby Helena Volcanic field which was active from about 39-36 Ma (Chadwick, 1985; Schmidt and others, 1994). Volcanic ash as an aeolian deposit is a common component of erosional paleovalleys, although in the area of the proposed mine, the volcanic ash appears to be mostly reworked by fluvial processes in cut-and-fill channels. However, the erosional paleovalley interpretation for the Tertiary deposits in the project area is a viable interpretation for the Tertiary fill and is supported by the Tertiary deposits extending into the Little Belt Mountains (Reynolds and Brandt, 2007), horizontal bedding observed in Tertiary strata within a nearby irrigation ditch (Figure 2), and the documentation of high relief in the northern Rocky Mountain during the Eocene.

The hillshade image generated from LiDAR data shows no evidence for faults that cut Cenozoic deposits. Northeast-trending structures that can be clearly seen on the image do not cross either the older Quaternary terrace gravel surface or the current floodplain that contains Holocene sediment. Even the meander segments of Little Sheep Creek and Sheep Creek show no alignment with the projected trends of mapped area faults. Typically stream channels do reflect fault control by a change in their direction that parallels a fault's trend, but again this aspect of stream channel geomorphology cannot be seen on the LiDAR hillshade image in Figure 3.

The present drainage system within the area of the proposed Black Butte Copper Mine has down-cut into pre-existing rock, and this indicates a change in base level for the system. However, the down-cutting may have more to do with glacial melt-outs that affect the entire Smith River drainage system rather than local tectonism.

Lastly, the conclusion of no evidence for Quaternary faulting in the immediate area of the CTF is also supported by historical seismicity data. Wong and others (2005) place the area of the proposed mine in the Northern Great Plains, which is part of the stable continental U.S. interior. These authors state that "tectonism associated with plate boundary interactions probably ceased about 100 Ma, so zones of major recent deformation area generally absent (Dewey and others, 1989). Earthquake epicenters are scattered and form isolated clusters with no apparent spatial relationship to geologic structures" (p. 6). Indeed, in the very general area of the proposed mine, there are only two 1.5-2 magnitude earthquakes found in the historic seismicity data base for years 1809-2001. Wong and others work (2005) also indicates low probability for significant seismic events in this area over the next 5,000 years.

SUMMARY

Faults mapped in the area of the proposed Black Butte Copper Mine and its contained CTF offset Mesoproterozoic to earliest Eocene rocks. The youngest documented activity on these faults occurred during the late Cretaceous and early Eocene. Geologic mapping done by previous workers and in this study indicates that there is no evidence of these older faults or any new faults being active during the Quaternary. This conclusion is supported by geologic field evidence of Cenozoic deposits showing that these deposits are not disrupted by faulting. It is also supported by LiDAR data from which a hillshade image was generated. Northeast-trending features can be seen on the hillshade image, but these features do not offset mapped Quaternary deposits. Additionally, no other fault-like features within the Cenozoic units were observed on the hillshade image.

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Curriculum Vitae

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Education

1989 - Ph.D., Geology, University of Montana, Missoula, Montana; Study focus – Continental stratigraphy/sedimentology/paleontology.
1977 - MSc., Geology, University of Calgary, Calgary, Alberta; Study focus – Paleozoic invertebrate paleontology.
1975 - BS., Natural History, University of Toledo, Toledo, Ohio.

Professional Experience

1990 – present: President and Principal Owner, Whitehall GeoGroup, Inc.,

Whitehall, Montana.

- Consulting projects include:
  - Paleosol and Cenozoic basin development research.
  - GIS paleontological database developed for U.S. Bureau of Land Management, southwestern Montana lands.
  - Vertebrate fossil inventory for U.S. Bureau of Land Management lands acquisitions.
  - Webb Schools/Raymond A. Alf Museum of Cenozoic geologic history/paleontology fossil vertebrate research in Gravelly Range, southwest Montana.
  - Hydrogeological research for high-volume water wells.
  - Near-surface geophysical survey/interpretation for Cenozoic Florissant Fossil Beds National Monument, U.S. National Park Service.
  - Near-surface geophysical surveys/interpretations for groundwater contamination and industrial development projects.
  - Geologic mapping for geologic resources.
  - Keck Geology Consortium, Co-leader for Cenozoic basin geology and geophysics, southwestern Montana.
  - Gravity/seismic interpretation of Montana basins.
  - Adjunct Assistant Professor – Earth Science Department, Montana State University.

- Over 250 mineral assessments done for conservation easements throughout Montana, Idaho, and North Dakota.
- Geologic resource due diligence work for various law firms.
- Registered lobbyist for the Montana 63rd /2013 Session – lobbying focus on energy and eminent domain issues.
- CO2 offset in Borden Hotel Renovation –Jefferson County, Montana, Local Development Corporation.
- Southwestern Montana geology CD development, now marketed by AAPG and Earthmaps.

1986/1989: Assistant Professor, Earth Science Department, Montana State University, Bozeman, Montana.

- Instructed geology field camps

1983-1988: Instructor, Geological Engineering Department, Montana College of Mineral Science and Technology, Butte, Montana.

- Instructed undergraduate courses in physical, historical, and structural geology, hydrogeology, presentation media, and graduate level stratigraphy.

1982-1983: Hydrogeologist, Department of Natural Resources and Conservation, Water Resources Division, Helena, Montana.

- Researched Montana groundwater availability in numerous locales state-wide.

1979-1982: Geologist, U.S. Geological Survey, Geologic Division, Denver, Colorado.

- Collected data for mineral evaluations of proposed wilderness areas; conducted research on southwestern Montana Cenozoic basins.

1978: Geologist, U.S. Forest Service, Beaverhead National Forest, Wisdom, Montana.

- Evaluated Wisdom District mining claims.

1977: Instructor, Earth Sciences Department, Mount Royal University, Calgary, Alberta, Canada.

- Instructed undergraduate courses in historical geology and stratigraphy.

Professional Affiliations

Association of American Petroleum Geologists
Association for Women Geoscientists

- Board of Directors, Rocky Mountain delegate: 2007-2013
- International Member Liaison: 2010 – 2016
- Committees served on: Professional Excellence Award, the Sand Travel Grant Award, the Takken Travel Grant Award, and the Gaea Editorial Board

Geological Society of America
Montana Geological Society
SEPM - Society for Sedimentary Geology

Publications

Geologic Maps : Peer-Reviewed

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