# 3.6. GEOLOGY AND GEOCHEMISTRY

Geology is the primary framework for this environmental assessment, influencing the location of mineralization, proposed mining methods, environmental geochemistry, and contributions of constituents to water. Together, hydrology, geology, and mineralogy determine the potential impact of mining on water resources.

## 3.6.1. Analysis Methods

The geochemical analysis area encompasses the underground zones from which ore and waste rock would be mined and the surface locations on which waste rock or tailings would be placed. Much of the analysis and description of the geology of the proposed mine and tailings impoundment areas presented in this section is based on the 2017 Project MOP Application (Tintina 2017) submitted to DEQ. Elements of the geology that directly affect environmental geochemistry are emphasized within this description.

The following sections summarize the baseline information collected on environmental geochemistry and geology, the approaches used by DEQ in analyzing potential impacts, and the environmental consequences of the proposed Project.

## 3.6.2. Affected Environment

### *3.6.2.1. Geology*

Resource Modeling, Inc. summarized the geologic setting, deposit types, and mineralization in the Project area (Resource Modeling, Inc. 2010). The following subsections contain a modified summary, with the addition of more recent information. **Figure 3.6-1** shows a geologic map of the Project area, **Figure 3.6-2** includes a stratigraphic section, and **Figure 3.6-3** shows a geologic cross-section through the Project area. Topography in the Project area is from the USGS website: viewer.nationalmap.gov; 2011 Strawberry Butte 7.5 Minute Quadrangle.

**Regional Geologic Setting**

The copper deposits of the Project area (i.e., MOP Application Boundary) occur in middle Proterozoic (approximately 1.4 billion years old) sedimentary rocks of the Belt Supergroup (Zieg and Leitch 1993). During subsidence and filling of the Belt sedimentary basin, a deep-water calcareous shale facies (Newland Formation) was deposited in the Helena embayment, a trough-like seaway that extended eastward into the craton through central Montana (Godlewski and Zieg 1984). The northern depositional boundary of the deeper water sediments of the Helena embayment lay along the present-day southern flank of the Little Belt Mountains, north of White Sulphur Springs, Montana (**Figure 1.3-1**). During the Cretaceous Laramide orogeny (approximately 65 million years ago), renewed thrust faulting along the ancestral northern margin of the Helena embayment formed the VVF (Winston 1986). Tertiary igneous rocks intrude Paleozoic rocks and Belt Supergroup rocks in the region. Tertiary sedimentary rocks have also been identified. The Black Butte copper deposits lay along the northern margin of the Helena embayment, and along the reactivated VVF zone (**Figure 3.6-1**).

### Local Geologic Setting

The Newland Formation shale hosts the Black Butte copper deposits (**Figure 3.6-2**). Its evenly laminated shale formed from deposition of microturbidites (small-scale turbidity or density flow deposits) in a subwave base[1] depositional setting. Debris flow conglomerates occur in the sedimentary section (Resource Modeling, Inc. 2010) and record larger mass wasting events from a shallow water shelf in the Newland Formation along the northern margin of the embayment. Alluvial deposits lie beneath the modern stream channels and along the axis of larger drainages. The deposits rest on the thick sequence of dolomitic and silicic shales of the Proterozoic Newland Formation that dip gently to the southeast. The above-described prominent east-west-trending, southerly dipping low-angle VVF forms a northern boundary to Newland Formation exposures within the Project area (**Figure 3.6-1**). Paleozoic (Middle Cambrian) Flathead sandstone (**Figure 3.6-2**) outcrops at the surface on the north side of the VVF. The sandstone lays nonconformably over Proterozoic Newland Formation, Chamberlain Formation shales, Neihart Formation quartzite, and Precambrian crystalline basement rock (**Figure 3.6-3**).

The Newland Formation may be separated into upper (Ynu) and lower (Ynl) subunits (**Figure 3.6-2**) in the immediate deposit areas (north of the BBF). In addition, the lower Newland is further informally separated into Ynl A and Ynl B subunits (**Figure 3.6-2**) relative to their location above and below the USZ, respectively. The Ynl A and Ynl B units are largely used in the MOP Application (Tintina 2017) and its associated baseline studies to define portions of the geologic section based on geochemical subunits (see Section 2.4.2 of the MOP Application, **Table 3.6-1,** and **Figure 3.4-4**) and hydro-stratigraphic subunits (see Section 4.1.2 of the MOP Application, **Figure 3.4-5,** and **Figure 3.6-4**). The use of these units is a matter of convenience for topical studies, designed to be used only in the vicinity of the Johnny Lee Deposit zones, and is not intended to have any larger, regional-scale geologic significance. The Ynl B consists of interbedded dolomitic shale and shale-clast conglomerate and lies beneath the USZ, which consists of stratabound bedded pyrite and contains the UCZ. Undifferentiated dolomitic shale and shaley dolomites of the upper part of the Lower Newland Formation (Ynl A) overlie the USZ.

A separate northeast verging segment of the VVF called the BBF lies south of the Johnny Lee Deposit copper deposit (**Figure 3.6-1**). The area between the BBF and the VVF contains all the known copper resources within the Project area. Tertiary igneous rocks intrude the lower part of the Newland Formation mostly south of the BBF but have not been identified in the deposit areas.

The Buttress Fault likely has a Proterozoic age and carries both the Chamberlain and Newland Formation shales downward against Precambrian crystalline basement rocks (gneiss) on its south side and Neihart Formation quartzite on its north side (**Figure 3.6-3**). The VVF truncates the Buttress Fault, and Cambrian sedimentary rocks (e.g. Flathead sandstone and Wolsey Formation) cover it to the north such that it has no surface expression (**Figure 3.6-1**).

[1] Subwave base refers to below the wave base (i.e., the maximum depth at which a water wave's passage causes significant water motion. For water depths deeper than the wave base, bottom sediments and the seafloor are no longer stirred by the wave motion above).

## Mineralization

Geologists classify the Johnny Lee Deposit as a sediment-hosted deposit. Bedded pyrite shows higher concentrations in several discrete, semi-continuous, and laterally-extensive stratigraphic horizons or sulfide zones (**Figure 3.6-2**) that locally contain copper enrichments. The sulfide zones exposed in the near-surface environment as shown in **Figure 3.6-1** are typically altered to gossan (due to intense oxidation and leaching of former sulfide minerals) consisting of iron-oxide rich (i.e., goethite) and/or quartz minerals.

The Johnny Lee Deposit consists of two stratabound lenses of mineralization: a UCZ and LCZ, contained respectively within the upper and lower sulfide zones of the lower Newland Formation (**Figure 3.6-2** and **Figure 3.6-3**). The UCZ lies at a depth of approximately 90 to 625 feet bgs and occurs within shale and dolostone of the upper part of the lower Newland. The southward dipping VVF cuts through the entire Newland Formation. A thin slab of the lower Newland Formation lies below the VVF and contains the LCZ, which is at a depth of approximately 985 to 1,640 feet bgs (**Figure 3.6-3**). The LCZ and enclosed lower part of the Newland Formation shale lie on the Chamberlain Formation.

### *Johnny Lee Deposit Upper Sulfide Zone*

The Johnny Lee Deposit USZ consists of a lens of fine-grained bedded pyrite ($FeS_2$) as thick as 285 feet, and containing two or three chalcopyrite-bearing ($CuFeS_2$) horizons all capped by a barite ($BaSO_4$)-rich pyritic stratigraphy. Himes and Petersen (1990) describe microscopic textures and various sulfide minerals (primarily from copper-enriched horizons) and Graham et al. (2012) and White et al. (2013) have completed more recent work. Pyrite occurs as laminations and beds of very fine-grained pyrite, as micro-crystals, and spheroidal aggregates (1 to 25 microns in diameter). Pyrite and rarely marcasite aggregates contain rims, patches, and sometimes interior cores of chalcopyrite and tennantite ($Cu_{12}As_4S_{13}$), and in many cases amorphous copper (Cu), cobalt (Co), nickel (Ni), and arsenic (As)-rich material. Chalcopyrite occurs as coarser grained veinlets and clots, in parallel-bedded layers and bands, in quartz veinlets, and in barite veins and masses.

While local silicification occurs within the USZ, most of the copper mineralization occurs within unsilicified bedded pyrite. The USZ reaches its greatest thicknesses in the south-central portion of the Johnny Lee Deposit. Strontium-rich minerals celestine ($SrSO_4$) and strontianite ($SrCO_3$) occur in some places toward the base of the USZ and below the copper-enriched horizons. Barite concentrations cap the copper zone, and include a sulfide-free shale horizon called the “barite marker horizon.”

### *Johnny Lee Deposit Lower Sulfide Zone*

The Johnny Lee Deposit LSZ lies in the footwall (below) of the southward-dipping VVF (**Figure 3.6-2**). The LSZ mineralization consists of pyrite and rare marcasite, with high concentrations of chalcopyrite and local occurrences of siegenite ($[Ni,Co]_3S_4$) and cobaltite (CoAsS). The LSZ contains no identifiable barite or strontium-rich minerals. Coarse-grained dolomite alteration is abundant on the margins and above the pyritic zone. Silicification also overprints much of the Cu-mineralized area. A silicified debris flow conglomerate underlies the LSZ with disseminated chalcopyrite, and chalcopyrite also occurs in quartz veinlets. Most sulfide textures show replacement of both preexisting dolomite alteration and of earlier generations of sulfide mineralization. Some pyrite is bedded, even at the base of the LSZ.

The VVF dips more steeply south than the underlying LSZ and truncates the zone (**Figure 3.6-3**) to form its south boundary. The Buttress Fault truncates the LSZ on the north. Because of fault truncations on its north and south, the LSZ retains little evidence of its presumably broader scale mineralogical zoning patterns.

### Copper Deposit Geometry

The Johnny Lee Deposit UCZ constitutes 78 percent of the total tonnage of the Johnny Lee Deposit copper resource. The UCZ measures 3,280 feet in a north-south direction and approximately 2,165 feet in an east-west direction (**Figure 3.6-2**), and ranges in depth from 90 to 590 feet from the surface. The UCZ is a flat, tabular deposit that ranges in thickness from 10 to 85 feet. The deposit varies in dip from 0 degrees to 20 degrees to the west. In some areas, the mineralized zone consists of a single lens. In other areas, it consists of two sub-parallel lenses separated by 6 to 53 feet of lower grade material.

The LCZ constitutes 22 percent of the total tonnage of the Johnny Lee Deposit copper resource. It measures approximately 3,300 feet from west to east, and ranges from 160 to 660 feet from north to south (**Figure 3.6-2**). The LCZ dip varies from 20 degrees to 37 degrees to the south and ranges in depth from 985 to 1,640 feet from surface. The mineralized zones range in thickness from 8 to 57 feet.

### Mineral Resources

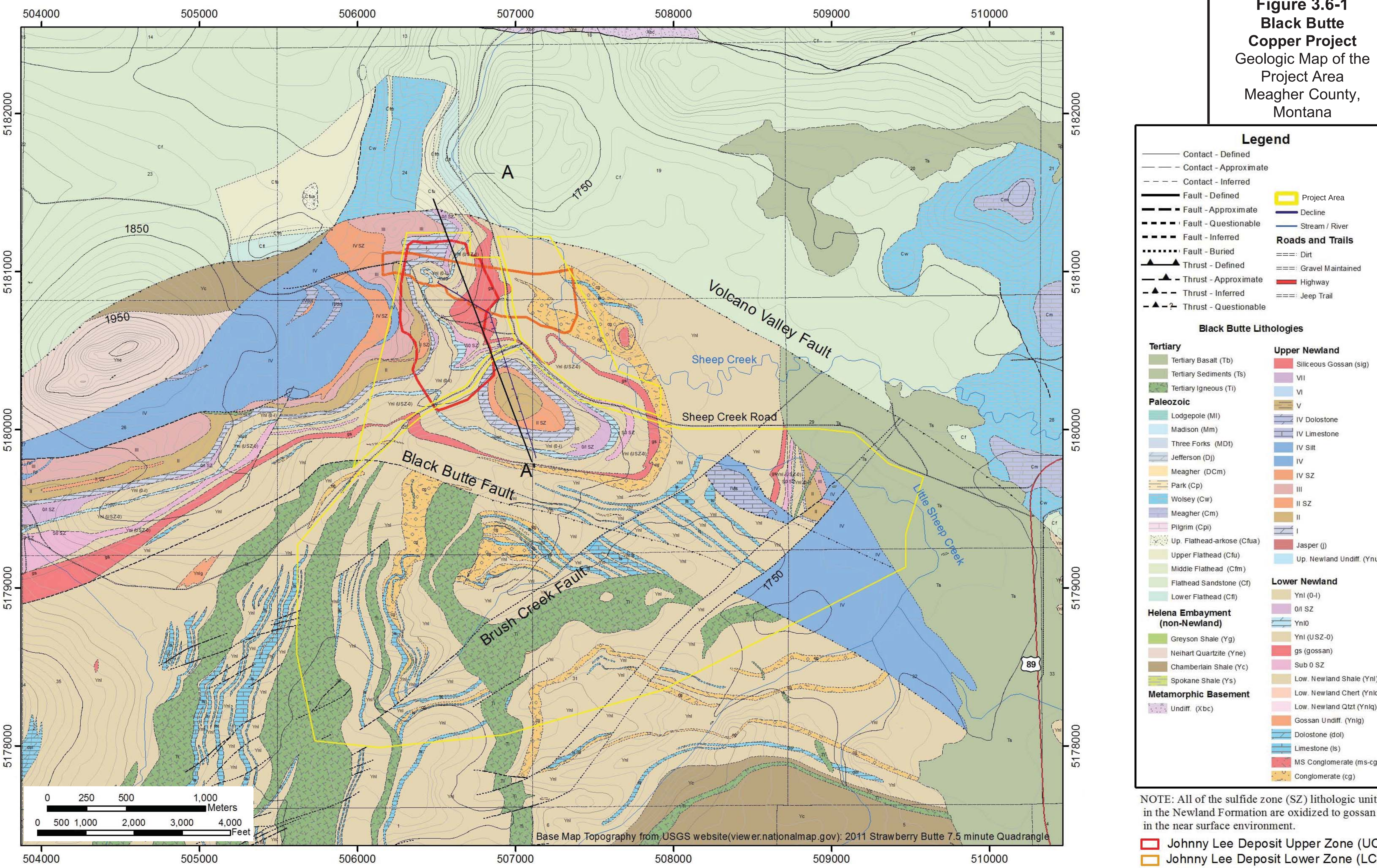
**Figure 3.6-2** and cross-section **Figure 3.6-3** illustrate the location of both the UCZ and the LCZ in the Johnny Lee Deposit. Mineral resources were recalculated in 2013 using data collected between 2010 and 2012, including drill hole logs, geologic correlations, and assays to create a block model of the deposit zones (Tetra Tech, 2013). See Table 1-2 of the MOP Application (Tintina 2017) for a summary of measured and indicated copper resources of the Johnny Lee Deposit.

#### *3.6.2.2. Environmental Geochemistry*

### Geochemical Assessment Methods and Criteria

The acid generation and metal release potential of waste rock, construction rock, and tailings to be produced by the Project have been characterized using static (acid-base accounting [ABA], multi-element analysis, net acid generation [NAG], and static leach tests) and kinetic methods. Mineralogical analyses of metal residence and asbestiform mineral analyses were also completed. Results of all geochemical tests reported in Appendix D of the MOP Application are summarized below. **Table 3.6-1** summarizes the number of tests completed by method, rock type, and tonnage for waste rock. **Table 3.6-2** provides a summary for tailings testing. These test methods are described and their results are also provided in detail in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) and are summarized below.

**Figure 3.6-1**
**Black Butte Copper Project**
Geologic Map of the Project Area
Meagher County, Montana




NOTE: All of the sulfide zone (SZ) lithologic units in the Newland Formation are oxidized to gossan in the near surface environment.

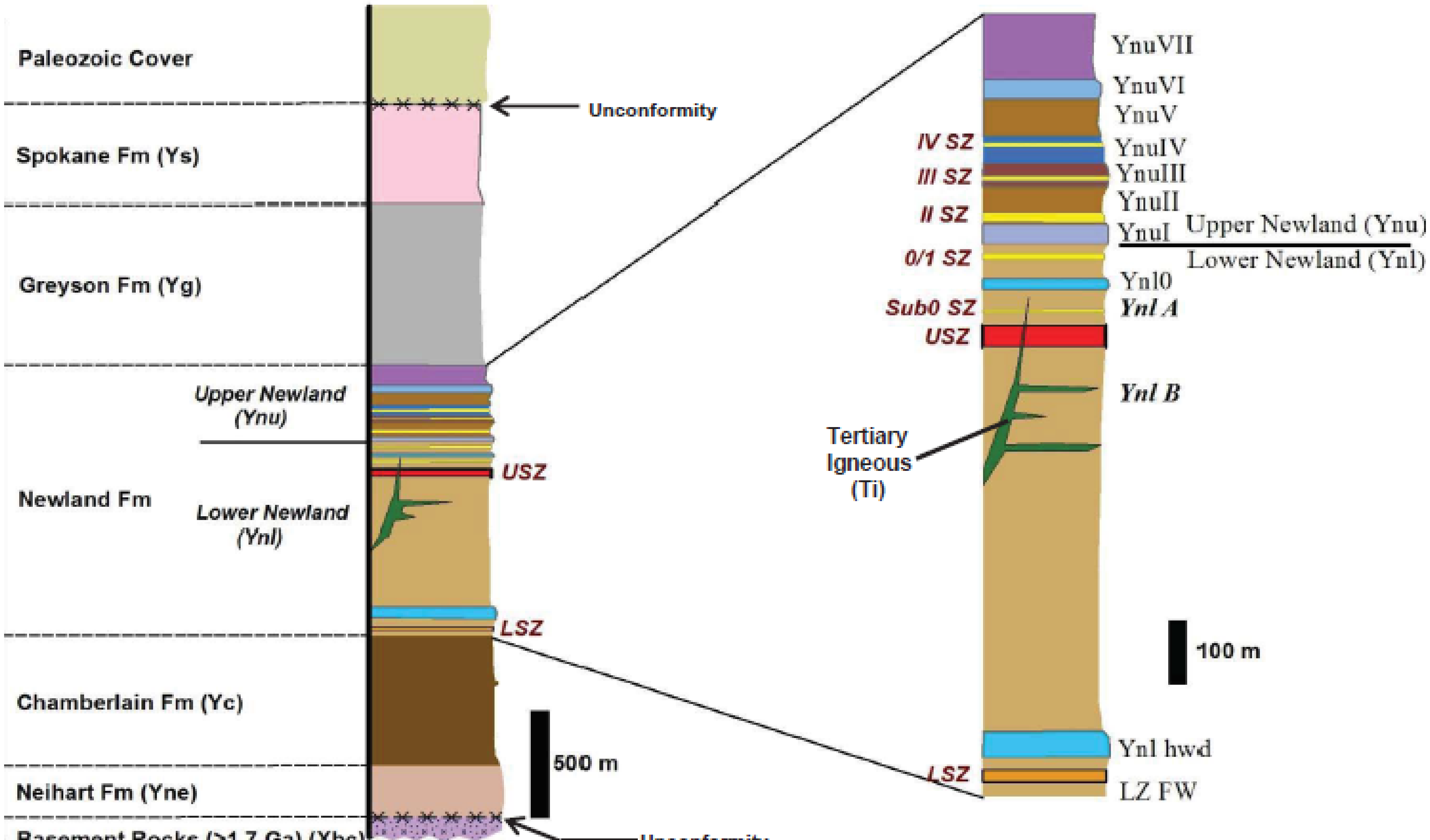
*This information is for environmental review purposes only.*

FILE: M:\Clients\M-O\MTDEQ_ArcGIS\2018\04\Geology_Geochem_MTDEQ_Geologic_Map.mxd | REVISED: 05/08/2018 | SCALE: 1:14,320 when printed at 11x17

DRAWN BY: MBG

Source: Tintina 2017

NOTES: (1) Geologic unit codes and colors used in Site Geologic Map in Figure 1.5
(2) Mining units UCZ and LCZ lie within the USZ and LSZ, respectively




Abbreviations: Fm = Formation; FW = Footwall; hwd = hanging wall dolomite; SZ = Sulfide Zone; LZFW = Lower Zone Footwall
Other geologic units not listed on this straigraphic section but that are included in Figure 1.5 site geologic map include:
Ts (Tertiary sediments) and Paleozoic cover units (Cw = Wolsey Formation; Cf = Flathead Sandstone;
cg = conglomerate interbeds in Ynu and Ynl; and ls = limestone interbeds in the Ynu and Ynl.
The Ynl unit is divided into tye Ynl A and the Ynl B subunits relative to the location above or below the USZ, respectively.

**Figure 3.6-2**
**Black Butte Copper Project**
Stratigraphic Section
Meagher County, Montana

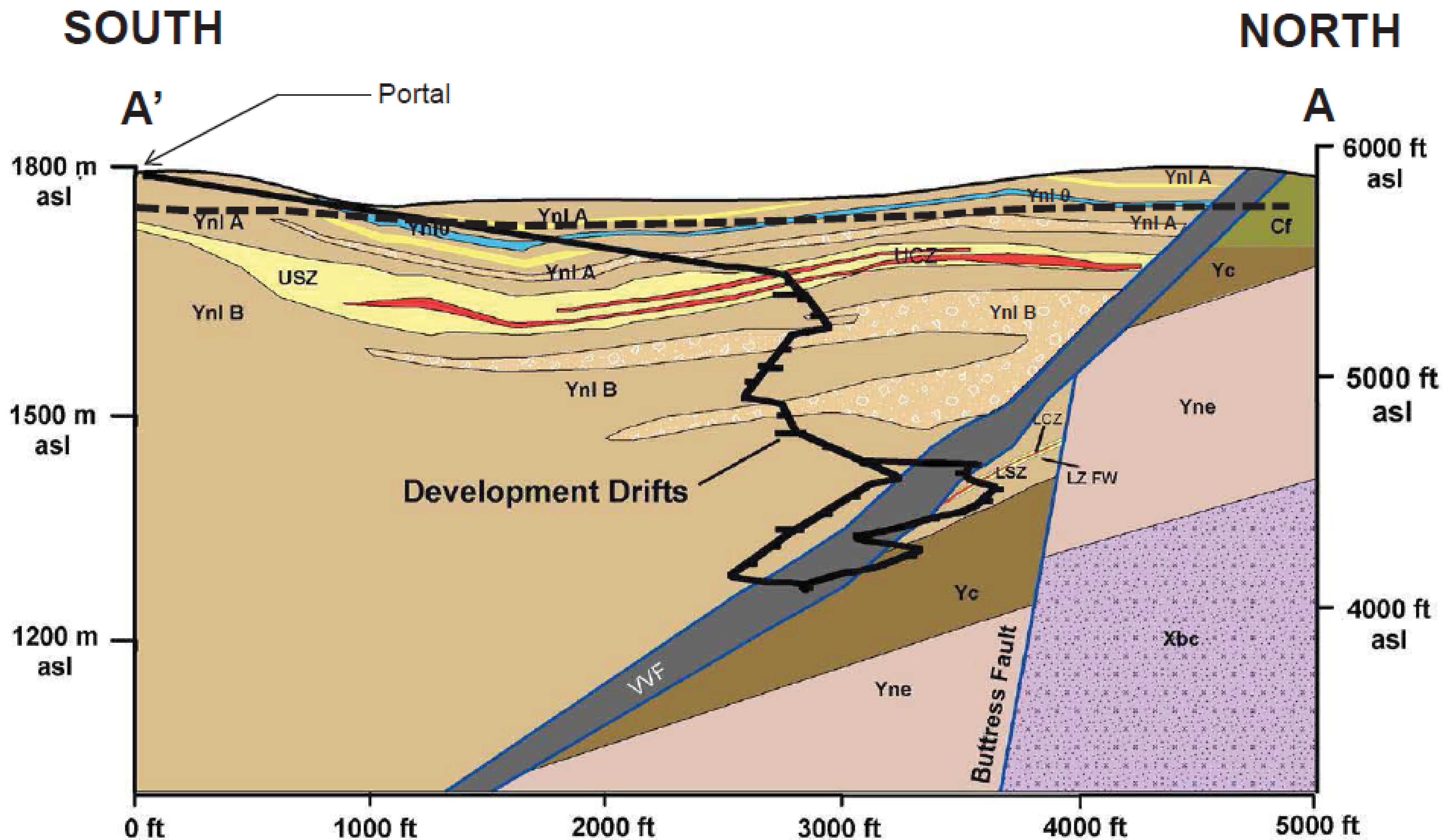
*This information is for environmental review purposes only.*

FILE: M:\Clients\M-O\MTDEQ_ArcGIS\2018\04\Geology_Geochem_MTDEQ_Stratigraphic_Section.mxd | REVISED: 05/01/2018 | SCALE: 1:14,320 when printed at 11x17

DRAWN BY: JPB

Source: Tintina 2017

**Figure 3.6-3**
**Black Butte Copper Project**
Generalized Geologic Cross-Section A-A' with Ore Deposits and Ramp Access
Meagher County, Montana




Notes: (1) See Figures 1.5 and 1.6 for lithology descriptions
(2) See Figure 1.5 for location of cross-section line A-A'

VVF = Volcano Valley Fault LZ FW = Lower Zone Footwall

Top of groundwater table surface as of November 2016

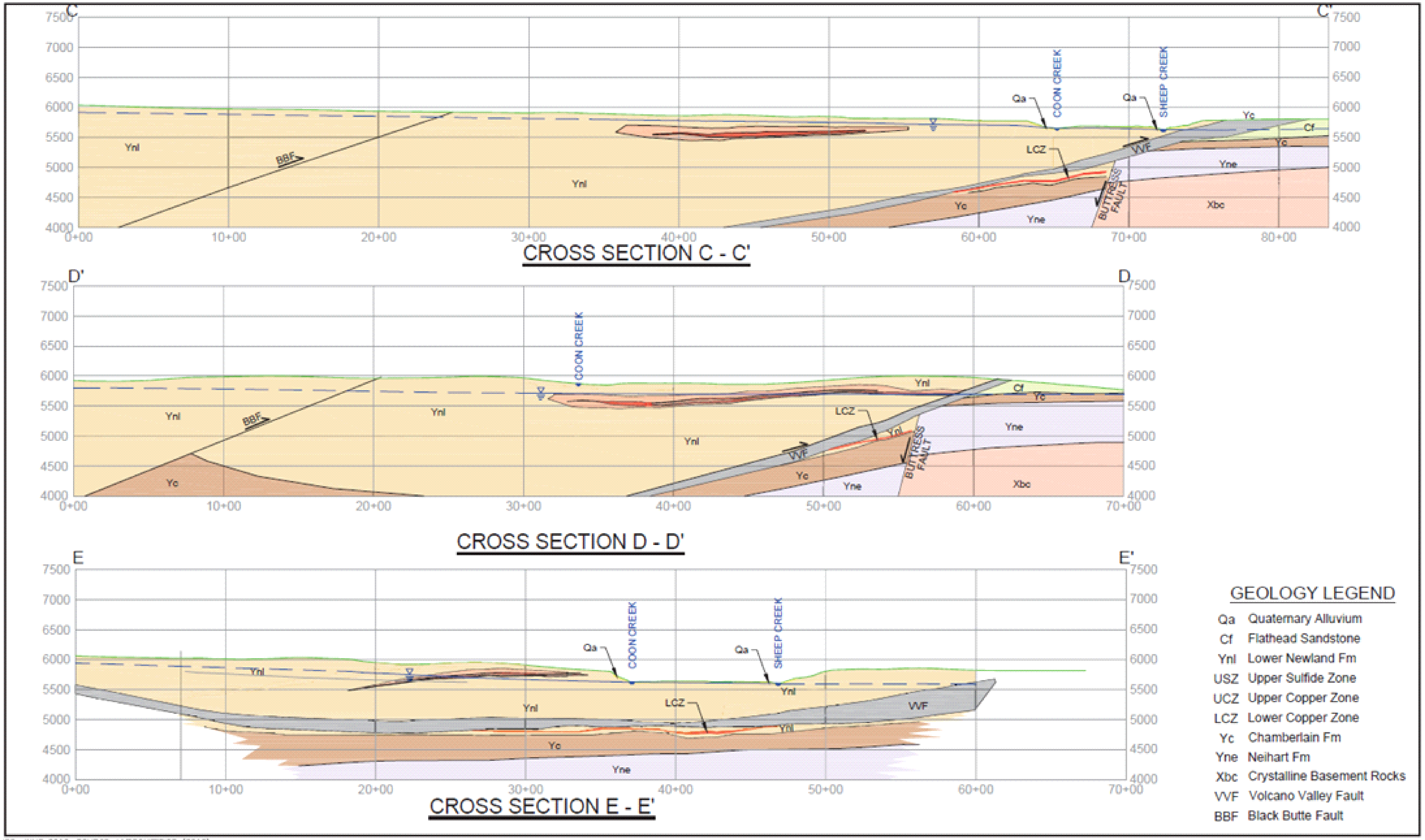
*This information is for environmental review purposes only.*

FILE: M:\Clients\M-O\MTDEQ_ArcGIS\2018\04\Geology_Geochem_MTDEQ_Geologic_Cross_Section_A_Aprime.mxd | REVISED: 05/01/2018 | SCALE: 1:14,320 when printed at 11x17

DRAWN BY: JPB

Source: Tintina 2017

**Figure 3.6-4**
**Black Butte Copper Project**
Schematic Cross-Sections
Meagher County, Montana




*This information is for environmental review purposes only.*

FILE: M:\Clients\M-O\MTDEQ_ArcGIS\2018\04\Geology_Geochem_MTDEQ_Schematic_Cross_Sections.mxd | REVISED: 05/01/2018 | SCALE: 1:14,320 when printed at 11x17

DRAWN BY: JPB

Source: Tintina 2017

## Table 3.6-1
## Geochemical Testing of Major Waste Rock and Near-surface Materials by Lithotype

| Material Type | Lithotypes | Description | Waste Rock % Tonnage | ICP | ABA/ NAG | SPLP | Mineralogy | Asbestos | HCT |
|---|---|---|---|---|---|---|---|---|---|
| Waste Rock Materials | LZ FW | Silicified shale and debris flow | 35 | 550 | 15 | 0 | 0 | 1 | 1 |
| | Ynl B | Lower Newland shale and conglomerates | 32 | 1,412 | 34 | 2 | 1 | 2 | 2 |
| | USZ | Lower Newland upper sulfide zone | 28 | 2,542 | 41 | 2 | 1 | 2 | 2 |
| | Ynl A | Undifferentiated Lower Newland | 4 | 1,138 | 48 | 2 | 1 | 2 | 1 |
| | **Total Dominant Waste Rock Samples**[a] | | 99 | 5,642 | 138 | 6 | 3 | 7 | 6 |
| | **Additional Waste Rock Samples**[b] | | <1 | 1,855 | 37 | 3 | 1 | 4 | 2 |
| | **All Waste Rock Samples**[c] | | 100 | 7,497 | 175 | 9 | 4 | 11 | 8 |
| Near-Surface Materials | Ynl Ex | Near-Surface Lower Newland shale | <1 | 108 | 10 | — | — | 1 | 1 |
| | Tgd | Tertiary Granodiorite | <1 | 76 | 8 | — | — | 1 | 1 |
| | **Total Excavation Tonnage** | | NA | 184 | 18 | — | — | 2 | 2 |

Source: Tintina 2017

ABA = acid-base accounting; HCT = Humidity Cell Test; ICP = inductively coupled plasma; LZ FW = lower sulfide zone footwall; NAG = net acid generation; SPLP = synthetic precipitation leachability procedure; Tgd = tertiary sill-form granodiorite intrusive rocks; USZ = upper sulfide zone; Ynl A= Lower Newland Formation subunit above the USZ; Ynl B = Lower Newland Formation subunit below the USZ; Ynl Ex = bedrock zones of the Lower Newland Formation

Notes:

[a] Total waste rock tonnage over the life of the mine equals 706,525 tonnes (778,810 tons). A total of 7,497 ICP analyses of waste rock were evaluated.

[b] Four waste rock types would be mined above 1 percent of total tonnage; 5,642 ICP analyses were evaluated for these units.

[c] Additional waste rock unites were characterized representing less than 1 percent of tonnage; 1,855 samples were evaluated for these units. All geochemical test results are presented in Appendices D and D-1 (Enviromin 2017a and 2017b).

**Table 3.6-2**
**Black Butte Copper Project Tailings Treatments and Related Testing**

| Tailing Test Table | ABA | NAG | ICP Metals | Saturated HCT | Unsaturated HCT | Diffusion Test |
|---|---|---|---|---|---|---|
| Raw Tailings | X | X | X | X | X | — |
| Paste Tailings 2% | X | X | X | — | X[a] | —[b] |
| Paste Tailings 4% | X | X | X | — | X[a] | X |
| Paste Tailings 4% and Waste Rock | — | — | — | — | X[a] | X |

Source: Tintina 2017

ABA = acid-base accounting; HCT = Humidity Cell Test; ICP = inductively coupled plasma; NAG = net acid generation
Notes:
[a] Unsaturated HCTs conducted on intact cement paste cylinders
[b] an attempted test of 2 percent cemented paste tailings could not be completed.

## Waste Rock Geochemistry

### *Static Testing of Waste Rock*

The metal contents of whole rock samples were quantified through four-acid digestions followed by inductively coupled plasma (ICP) atomic emission spectroscopy multi-element analyses (method ME- MS61). A total of 5,642 samples of the four dominant waste rock types were statistically analyzed to characterize overall geochemical variability within individual units and to identify representative sample subsets for static testing, as detailed in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017).

To evaluate acid generation potential, ABA, and NAG analyses were completed on 138 samples of the four dominant waste rock types and 37 samples of additional waste rock types, for a total of 175 samples. Comparison of neutralization potential (NP) and acid potential (AP) and NAG testing (Figure 2.11 of the MOP Application, Tintina 2017) indicate that the majority of Ynl B and Ynl A samples (90 percent) are unlikely to form acid, while many USZ and LZ FW samples have an uncertain potential or are likely to generate acid. A direct comparison of NP and AP in Figure 2.12 of the MOP Application (Tintina 2017) shows a similar relationship.

Static tests of metal mobility were completed for composites of the 2012 Ynl B, Ynl A, and USZ rock units using EPA Method 1312, the synthetic precipitation leaching procedure. Because these tests show elevated pH values (> pH 9.5, a result of carbonate mineralization reacting with acids used in the test), these results were considered an unrealistic prediction of pH-sensitive metal concentrations. While they are presented and discussed in Appendix A of the revised Baseline Environmental Geochemistry Evaluation of Waste Rock and Tailings report, which is included as Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017), they are not discussed further here. All estimates of metal mobility for this project rely on kinetic data from humidity cell tests.

Although asbestiform minerals are highly unlikely to occur in the rock units in the Project area, asbestiform mineral testing was included in the characterization work completed for all waste rock units. No asbestiform minerals were identified in any lithotype, and Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) provides detailed methods and results for these tests.

*Kinetic Testing of Waste Rock*

Kinetic tests of waste rock acid generation and metal release potential were conducted following ASTM International (ASTM) method D5744 for HCTs. This test exposes samples to alternating dry and humidified air, followed by weekly flushing to remove oxidation products. Parameters like pH, alkalinity, acidity, dissolved iron, and sulfate were measured weekly as indications of sulfide oxidation and acid generation potential. All waste rock kinetic tests were conducted on composites of subsamples from the individual lithologies, determined by a statistical analysis of static test results.

Kinetic test results for waste rock are discussed in greater detail in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) and are summarized as follows. Kinetic testing has shown evidence of sulfide oxidation in the four dominant waste rock units. However, consistent with the static test results and the presence of abundant carbonate mineralization, acid generation in waste rock HCTs was limited. Furthermore, metal release from waste rock HCTs was varied. The Ynl A and Ynl B released relatively low concentrations of a few metals (with nickel and thallium exceeding groundwater standards in the initial weeks of testing). In contrast, the USZ released strontium and thallium at concentrations exceeding groundwater standards throughout the test, with additional metals (notably copper, lead, and nickel) exceeding groundwater standards after the pH dropped in week 60. The LZ FW released a different suite of metals, with nickel exceeding groundwater standards in the early weeks of testing, and uranium and arsenic exceeding standards throughout the test.

*Total Organic Carbon Analysis*

The total organic carbon (TOC) content of several waste rock composites from the Johnny Lee Deposit were analyzed to support observations of organic carbon made in hand specimen, as seen in Appendix N-2 (Enviromin 2017d) of the MOP Application (Tintina 2017). Appendix N (Enviromin 2017c) of the MOP Application (Tintina 2017) identifies organic carbon as one of three possible oxygen sinks from infiltrating groundwater, which is likely consumed via (1) aerobic microbial metabolism, (2) oxidation of sulfide minerals, and (3) reaction with available organic carbon. Further, *in situ* measurements of dissolved oxygen in site groundwater support its depletion with depth. See Appendix B (Hydrometrics, Inc. 2017) of the MOP Application (Tintina 2017).

Results of Laboratory Equipment Corporation (LECO) analyses of TOC in waste rock (Price 2009) are compared with values from published literature (Lyons et al. 2000) in **Table 3.6-3**. The results reported by Lyons et al. (2000) are comparable to the values measured in the Project composites and support the hand specimen observations of organic carbon in these sediments.

**Table 3.6-3**
**Total Organic Carbon Content of Waste Rock Composite Samples**

| Sample ID | TOC (weight %) |
|---|---|
| 2012 Ynl A | 0.81 |
| 2015 USZ | 0.41 |
| 2015 Ynl B | 0.50 |
| 2015 LZ FW | 0.39 |
| 2016 Ynl Ex | 0.30 |
| Lyons et al. 2000[a] | 0.13-3.39 |

Source: Tintina 2017

LZ FW = lower sulfide zone footwall; TOC = total organic compound; USZ = upper sulfide zone; Ynl A= Lower Newland Formation subunit above the USZ; Ynl B = Lower Newland Formation subunit below the USZ; Ynl Ex = bedrock zones of the Lower Newland Formation.
Notes:
[a] Range of values for samples collected at the Project site, averaging 1.3 percent as reported by Lyons et al. (2000).

## Tailings Geochemistry

*Static Testing of Tailings*

Splits of homogenized tailings reject produced in bench-scale metallurgical testing were used for all tests. While there is some variation in AP and NP between subsamples (Table 2-23 of the MOP Application, Tintina 2017), ABA and NAG tests indicate that the tailings would have a strong potential to generate acid regardless of cement addition (Table 2-23 of the MOP Application, Tintina 2017). The NP resulting from the addition of 2 percent to 4 percent cement is not sufficient to neutralize the sulfide in the tailings; however, this was not the intent of cement addition. The addition of cement is considered to provide structural strength in support of drift and fill mining methods underground, and to change the physical properties of the material to a stable, non-flowable material with low hydraulic conductivities on the order of $10^{-9}$ meters per second in both surface and underground settings (see Appendix A of this EIS).

*Kinetic Testing of Tailings*

Kinetic tests of raw, non-amended tailings and cemented paste tailings were completed. **Table 3.6-4** summarizes the tailings characteristics, testing methods and conditions, and the various operational scenarios represented by each kinetic test. Cemented paste tailings cylinders were tested (without crushing) in conventional ASTM method D5744 HCTs to simulate subaerial weathering. They were also tested using ASTM C1308 diffusion tests to simulate diffusion through backfill in saturated underground workings. The ASTM C1308 diffusion test involves the submergence of paste tailings cylinders (height:diameter ratio of 2:1) in 14 sequential deionized water baths over a period of 11 days. The test is designed to predict sulfide reactivity and solute release as a result of diffusion. Raw, non-amended tailings were also tested using ASTM method D5744, both sub-aerially and in a modified, saturated test, to represent dry stack surface placement and subaqueous impoundment deposition scenarios, respectively.

**Table 3.6-4**
**Tailings Characteristics, Kinetic Test Methods, and Facility Scenarios**

| Action Scenarios | Facility Represented | Tailings Characteristics | Test Method |
|---|---|---|---|
| Proposed | Backfilled Paste in flooded workings | 4% binder | ASTM C1308 diffusion test |
| | Cement paste in CTF, subaerial weathering, routine operations | 2% binder | ASTM method D5744 (HCT) |
| | Cement paste in CTF, subaerial weathering, final closure lift | 4% binder | ASTM method D5744 (HCT) |
| Alternative | Saturated tailing, e.g., subaqueous impoundment | Raw | Modified ASTM method D5744 (saturated HCT) |
| | Subaerial weathering, e.g., dry stack tailing pile | Raw | ASTM method D5744 (HCT) |
| Additional[a] | Cement paste in CTF, subaerial weathering | 4% co-disposed with waste rock | ASTM method D5744 (HCT) |
| | Backfilled Paste in flooded workings | 4% co-disposed with waste rock | ASTM C1308 diffusion test |

Source: Tintina 2017

ASTM = ASTM International; CTF = Cemented Tailings Facility; HCT = Humidity Cell Test
Notes:
[a] Geochemical testing of paste tailings mixed with ROM was conducted to evaluate previously considered scenarios that are no longer pertinent to Tintina's operational plans. See Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) for data.

Kinetic test results for the tailings are discussed in greater detail in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) and are summarized as follows. The HCTs indicate that all of the cemented paste tailings samples had potential to oxidize and to release at least some sulfate, acidity, and metals if left exposed to air and water. Importantly, this was not observed immediately in test cells, and the rate of weathering in a humidity cell is recognized to be significantly greater than in the field. Increasing surface area and exposure to air/water drives the sample reactivity. The cement provides structural stability but does not completely neutralize sulfide oxidation.

### Near-Surface Materials Geochemistry

Figure 2.17 of the MOP Application (Tintina 2017) shows locations where the Ynl Ex and Tgd near-surface deposits (less than 65 feet depth) have been sampled extensively by geotechnical drilling and soil test pits, providing a population of samples that is representative of the shallow bedrock materials that would be excavated or disturbed by near surface facilities. **Figure 3.6-5** illustrates the proposed construction footprint for the mine facilities of interest along with these same drill holes and test pits. The final selection of samples for composite geochemical testing of Ynl Ex and Tgd is described in Appendix D-1 (Enviromin 2017b) of the MOP Application (Tintina 2017). Geochemical data described below indicate that these highly fractured rocks in the near-surface weathering zone were leached by infiltrating meteoric water, with resulting depletion of sulfide and metals.

A statistical review of select multi-element data as a function of depth was used to determine whether Ynl Ex and Tgd, were comparable to deeper Ynl B and Igneous Dike (IG) test units, respectively. Summary statistics, based on 10 elements from multi-element analyses, were used to test these relationships. Examples of these comparisons are presented in Figure 2.19 of the MOP Application (Tintina 2017). Results and summary statistics are included in Appendix D-1 (Enviromin 2017b) of the MOP Application (Tintina 2017).

Comparisons of the geochemistry as a function of depth demonstrate that weathered surface materials are relatively depleted in metals and sulfur, and are therefore distinct from the deeper materials. This is consistent with observations made while drilling, that the rocks are highly fractured with iron-oxide stained fractures (Knight Piésold Consulting 2017b). The near-surface deposits of Ynl Ex and Tgd are geochemically distinct from the deeper bedrock material; hence, they were tested independently to evaluate acid generation and metal release potential.

The near-surface bedrock excavated materials (Ynl Ex and Tgd) have been characterized using static (ABA, multi-element analysis, and NAG tests) and kinetic methods. Figure 2.20 through Figure 2.22 of the MOP application (Tintina 2017) summarize test results. Like the other rock types, composites of Tgd and Ynl Ex were tested for asbestiform minerals but none were identified. Kinetic tests were conducted as reported in Appendix D-1 (Enviromin 2017b) of the MOP Application (Tintina 2017).

Information provided by static test results and kinetic testing—full details provided in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017)—suggests that it is unlikely that either the Ynl Ex or Tgd material would produce acid or release elevated concentrations of metals. Static tests were confirmed by kinetic testing, and metal release was very low. As demonstrated in the MOP Application (Figure 2.23 and Figure 2.24, Tintina 2017), effluent from these HCTs met Montana groundwater quality standards in all weeks. These effluents also met surface water quality standards, except for selenium exceedances in weeks 0 through 4 in Ynl Ex. No metals were detected above surface water quality standards for the Tgd. Mineralogical analyses of asbestiform mineral content were also completed and no asbestiform minerals were identified.

## 3.6.3. Environmental Consequences

The predicted environmental impacts of rock geochemistry are discussed in water resources sections. The text below describes how mine materials are proposed to be mined, processed, and managed as a consequence of the localized geology and geochemical test results.

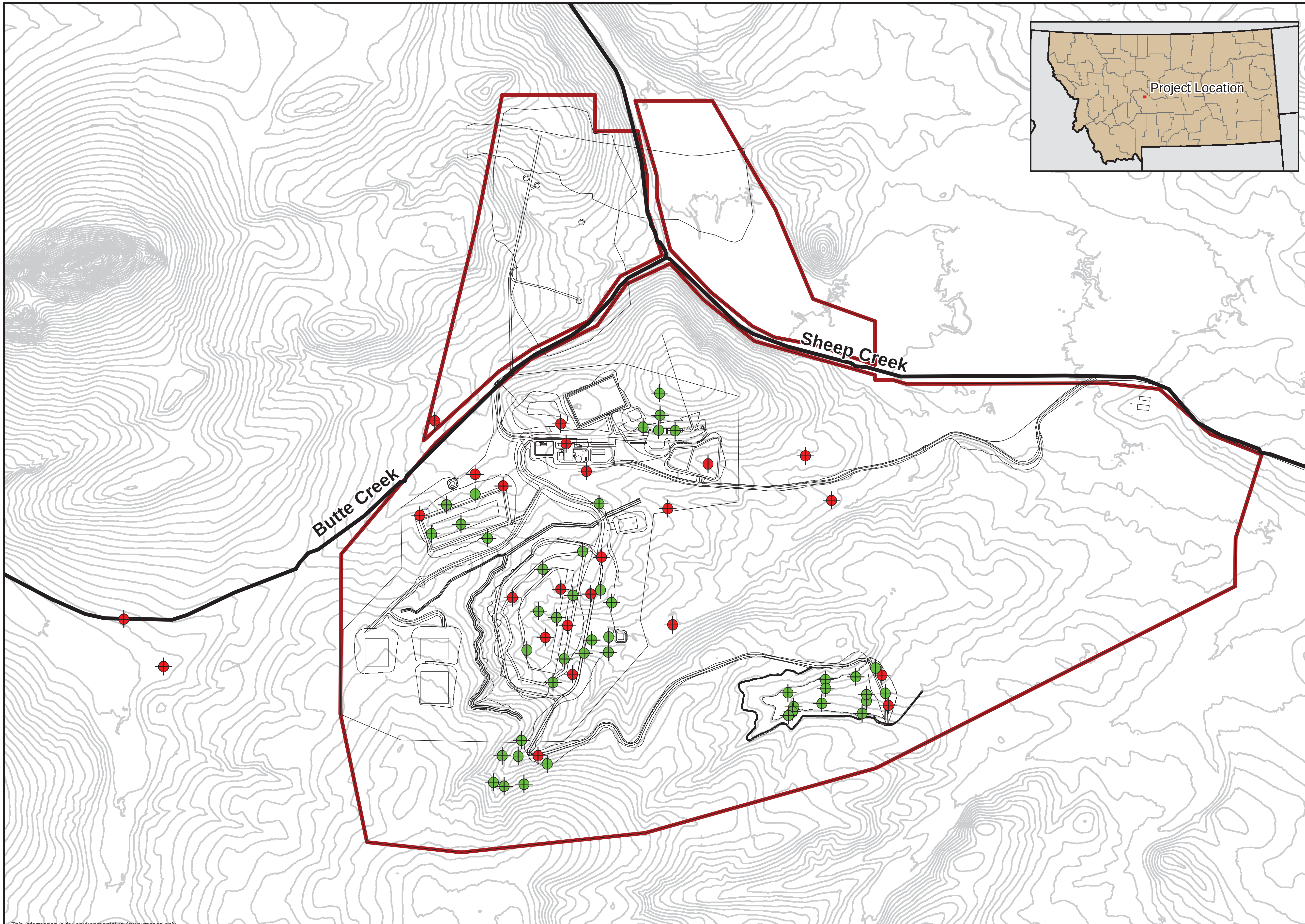



**Figure 3.6-5**
**Black Butte Copper Project**
Geotechnical Site Investigation Drill Hole and Test Pit Locations with Facilities
Meagher County, Montana

FILE: M:\Clients\M-O\MTDEQ_ArcGIS\2018\04\Geology_Geochem_MTDEQ_Drill_Holes_Test_Pits.mxd | REVISED: 05/04/2018 | SCALE: 1:16,000 when printed at 11x17

DRAWN BY: JPB

Source: Tintina 2017

#### *3.6.3.1. No Action Alternative*

The No Action Alternative would result in no change to geology when compared to baseline conditions. As such, this alternative would not have any impacts on geology resources and would not alter baseline conditions discussed in Section 3.6.2, Affected Environment.

#### *3.6.3.2. Proposed Action*

The Proponent proposes to mine waste rock from the Lower Newland Formation (Ynl), which contains copper enriched rock in both the USZ and the LSZ. The Proponent's consultant for geochemical services defined operational geochemical units for testing purposes based on mineralization and hydrogeology. The Proponent's proposal includes mining waste rock from the following units:

- Footwall of the LSZ (LZ FW); (35 percent of waste rock tonnage);
- Lower Newland Formation dolomitic shale and turbidite clay-clast conglomerate below the USZ and above the VVF in the Johnny Lee Deposit area (Ynl B, 32 percent);
- Portions of the USZ outside of the copper-enriched UCZ, (USZ, 28 percent); and
- Lower Newland Formation above the USZ (Ynl A, 4 percent).

The LZ FW represents a silicified conglomerate, stratigraphically below the LSZ, that consists of shale clasts from both the lowermost Newland Formation and the Chamberlain Formation.

Specific tonnages for each waste lithotype are listed in **Table 3.6-1**. This rock would be exposed in underground access workings and, temporarily, in active stopes. Some waste rock would also be stockpiled for approximately 2 years on a lined surface pad prior to being co-disposed with cemented tailings early in mine life. Once the temporary WRS pad is reclaimed, all of the waste rock, including the rock to be mined from the LZ FW during development, would report directly to the CTF for use in constructing the foundation drain and ramp. Waste rock produced after the CTF begins full operations would be end dumped from the ramp, where it would be subsequently buried by paste tailings. Additional waste rock units representing tonnages below 1 percent – including Igneous Dykes (IG), Dolomite, Neihart Quartzite, and Chamberlain Shale – have also been characterized in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017); those results are not discussed further here.

Operationally, tailings would be produced via flotation and blended with cement/binders to create cemented paste tailings. The Proponent proposes to use a drift and fill mining method, placing 45 percent of produced tailings mixed with 4 percent cement and binder as backfill into mined out underground stopes and access headings during operations. The remaining tailings (approximately 55 percent) would be amended with as much as 2 percent cement and binder, and transferred as paste into a double lined surface tailings impoundment (the CTF). The operational plan for the CTF is to utilize an internal sump to rapidly transfer any water from the CTF to the PWP, providing for little or no water storage on the facility. To provide information for this EIS, raw or non-amended tailings were tested along with cemented paste tailings with 2 percent and 4 percent binders. Both raw or non-amended tailings and cemented paste tailings were tested under subaerial weathering and saturated conditions. To date, the testing regimen supports the selected cement content levels of 2 percent for cemented tailings reporting to the CTF, and does not indicate a need for or benefit from increased cement contents (see Appendix A of this EIS). The one difference between the two paste tailings alternatives is that the 2 percent alternative has a lower operating cost than does the 4 percent alternative, while still providing sufficient structural integrity for the deposited cemented paste (Geomin Resources, Inc. 2016). Although a 4 percent cement binder mixed with 10 percent (by weight) waste rock (identified as "4%+ROM") was also tested to simulate disposal of blended materials, that option was eliminated. Those data are presented in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017) and are not considered further here.

Each of the waste rock units has some potential to generate acid or release concentrations of various metals in excess of groundwater quality standards at different times in the expected weathering process. Hence, all mined waste rock would be encapsulated in cemented paste tailings in the lined CTF impoundment to both minimize the amount of contact water and limit the influx of oxygen. This would delay the potential onset of acid generation in waste rock, as well as reduce the volume of water that might require treatment. Furthermore, the Proponent proposes to collect all seepage from the temporary WRS, the copper-enriched rock stockpile, the CTF, and the UG for treatment to meet non-degradation criteria prior to discharge via underground infiltration galleries. Impacts to surface water and groundwater are therefore not anticipated. Models of water quality for these facilities that incorporate these data are described in Section 4.2 and Appendix N (Enviromin 2017c) of the MOP Application (Tintina 2017).

Shallow, weathered, highly fractured and oxidized bedrock zones of the Ynl Ex and Tgd would be excavated and used for construction of Project mine facilities, such as embankments, protective layers for liners, and drain-rock.

Of the approximately 3.9 million cubic yards of bulked rock (20 percent after excavation) to be excavated during construction of the facilities listed in **Table 3.6-5a**, approximately half (or 2.0 million cubic yards) would be from each of the Ynl Ex and Tgd units. The Proponent proposes to use an estimated total of 241,343 cubic yards of the excavated Tgd as prepared sub-grade bedding and drainage gravel Project-wide (**Table 3.6-5b**).

**Table 3.6-5a**
**Project Cut and Fill Quantities**

| Facility | Bulked Volume Available (cubic yards) | Bulked Fill Required after Bulking (cubic yards) | Net (cubic yards) |
|---|---|---|---|
| Mill Pad | 64,090 | 40,546 | 23,543 |
| Portal Pad | 52,318 | 91,557 | -39,239 |
| Contact Water Pond and Brine Pond | 110,783 | 44,496 | 66,287 |
| Cemented Tailings Facility | 2,489,029 | 2,021,217 | 467,812 |
| Process Water Pond | 565,034 | 623,107 | -69,845 |
| Non-Contact Water Reservoir | -31,391 | 185,075 | -216,466 |
| Diversion (Channels and Ditches) | 22,235 | 28,775 | -6,540 |
| Temporary Waste Rock Pad | 180,497 | 44,470 | 136,027 |
| Copper-Enriched Rock Stockpile | 34,007 | 9,156 | 24,851 |
| Roads and Ditches | 419,852 | 419,852 | 0 |
| Underground Infiltration Galleries (UIGs) | 7,194 | 7,848 | -654 |
| Total | 3,901,876 | 3,516,099 | 385,777 |

Source: Adapted from Tintina 2017

Notes:
[a] This table only includes conceptual cut and fill bedrock material volumes (not development waste rock).
[b] All cut and fill volumes listed in this table exclude soils; however estimated topsoil and subsoil thicknesses from 2017 (see Table 7-4 in the MOP Application) have been subtracted from the initial total excavation volume.
[c] The CTF construction bulked rock fill includes 101,135 cubic yards (43 percent) of the excavation rock fill required to construct the CTF haul ramp as shown in Table 3-14b of the MOP Application. Other volume and material type details are also listed in Table 3-14b.
[d] This scenario utilizes 411,537 tonnes (269,134 cubic yards) of development waste rock to construct the following facilities: 31,390 cubic yards for the sub-grade bedding layers above the HDPE liner systems of the WRS pad and the copper-enriched rock stockpile; 104,636 cubic yards for the drainage layer of the CTF basin drain system; and 133,107 cubic yards for the CTF haul ramp. Any additional development waste would be placed on top of the drainage layer of the basin drain system.
[e] Most construction materials <1,000 cubic meters (<1,308 cubic yards) are not included in this table.
[f] Most volumes are rounded to the nearest 1,000 cubic meters (converted to 1,308 cubic yards).
[g] Volumes of cut (after excavation) and fill (after placement and compaction) materials include a 20 percent bulking factor.
[h] The cut and fill volumes from the ventilation raises are included in the waste rock plan presented in Table 3-5 and Table 3-6 of the MOP Application (Tintina 2017). All waste rock ultimate ends up in the CTF above the CTF HDPE liner system.
[i] The net excess 391,009 cubic yards of general rock fill would be placed on the two “reclamation material” stockpiles after construction: 174,307 cubic yards is placed on the northern stockpile whereas 211,469 cubic yards is placed on the southern stockpile located west of the CTF.

**Table 3.6-5b**
**Project Cut and Fill Quantities by Material Type and Source [a]**

| Development Waste Rock Use (tonnes)**** | Assigned Material Designation or Equation | Construction Material Type/Cut or Fill Volume | CTF | PWP | NCWR | Contact Water Pond & Brine Pond | Temporary Waste Rock Storage Pad | Copper-Enriched Rock Stockpile | Mill Pad | Portal Pad | Diversion Channels | UIGs | Roads and Ditches | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | **Total cut bulked volume available (cubic yards)** | 2,489,029 | 553,263 | -31,391 | 110,783 | 180,497 | 34,007 | 64,090 | 52,318 | 22,235 | 7,194 | 419,852 | **3,901,876** |
| | 1 | Embankment fill (cubic yards) | 1,748,729 | 588,578 | 180,497 | 34,922 | 31,391 | 6,540 | 40,546 | 91,557 | 28,775 | 1,962 | 0 | **2,753,496** |
| 48,000 | 2 | Sub-grade bedding placed above the HDPE liner system (cubic yards) * | 57,550 | 0 | 0 | 0 | 26,159 | 5,232 | 0 | 0 | 0 | 0 | 0 | **88,941** |
| | 3 | Sub-grade bedding placed below the HDPE liner system (cubic yards) * | 102,020 | 31,391 | 4,578 | 9,574 | 13,080 | 2,616 | 0 | 0 | 0 | 0 | 0 | **163,258** |
| | 4 | ***Total subgrade bedding (cubic yards)*** | ***159,570*** | ***31,391*** | ***4,578*** | ***9,574*** | ***39,239*** | ***7,848*** | 0 | 0 | 0 | 0 | 0 | **252,199** |
| | | Drainage gravel * (cubic yards) | 11,510 | 3,139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,886 | 0 | **20,535** |
| | 5 | Filter sand (cubic yards) | 392 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **392** |
| 160,000 | 6 | Waste rock forming the drainage layer of the CTF basin drain system (cubic yards)** | 104,636 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **104,636** |
| | 7 | CTF haul ramp (HR) (cubic yards) | 101,016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **101,016** |
| 203,537 | 8 | CTF haul ramp waste rock (cubic yards) | 133,107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **133,107** |
| | 9 | Other (cubic yards)*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **419,852** | **419,852** |
| | B – 1+3+4+5+7+9 | Total rock fill construction materials with HR and excluding all waste rock (cubic yards) | 2,021,217 | 623,107 | 185,075 | 44,496 | 44,470 | 9,156 | 40,546 | 91,557 | 28,775 | 7,848 | 419,852 | **3,516,099** |
| | A – B | **Net (cubic yards) only materials sourced from excavation cut (not waste rock)** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** | **357,668** |
| **411,537** | **Total WR tonnes** | | | | | | | | | | | | | |

Source: Tintina 2017

CTF = Cemented Tailings Facility; HR = CTF haul ramp; NCWR = Non-Contact Water Reservoir; PWP = Process Water Pond; UIG = Underground Infiltration Gallery; WR = development waste rock

Notes:

[a] The sources of the construction materials are listed below, and some are indicated by highlighted cells in the table. The primary source of the construction materials would be from fresh unweathered bedrock from each individual facility excavation footprint. Most of the construction materials would be sourced from the facility that they are excavated from (i.e., most of the mill pad would be constructed with materials sourced from the mill pad excavation). If there is a deficit of material listed in a facility (indicated by a negative volume value in the "Net" cells), then some construction material would be required to be sourced from another facility excavation that has excess fill material. For instance, there is excess material fill from the CTF excavation that would likely be used as construction material to construct the PWP, NCWR, UIG, and diversion channel facilities. The excess fill material from the temporary WRS pad would likely be used for some of the construction materials to construct the portal pad. The same notes included in Table 3-14a are applicable to Table 3-14b.

[b] * Most sub-grade bedding and all drainage gravel materials would be sourced from granodiorite (indicated in the table by volumes highlighted in the magenta color) excavated from the CTF and the PWP excavations. Sub-grade bedding material placed above the HDPE liner system at the WRS pad and the copper-enriched rock stockpile would consist of development waste rock (indicated in the table by volumes and tonnages highlighted in the light blue color) that is temporarily stored on the WRS pad. The sub-grade bedding material and the drainage gravel would require crushing and screening of the excavated bedrock. The crusher and screen plant would need to be located on the temporary WRS pad after the HDPE liner and overlying materials to the liner have been placed. After the development waste rock required for the sub-grade bedding required over the HDPE liner system for the WRS pad and the copper-enriched rock stockpile has been constructed, the crusher and screen plant may be moved to either the temporary construction stockpile or to the CTF excavation basin. The contractor would finalize these details prior to construction. Since excess fill materials from the facility construction would be stored on the northern and southern reclamation material stockpiles, some of the sub-grade bedding and drainage gravel materials could be sourced from these two reclamation material stockpiles too.

[c] ** The minimum volume of development waste rock forming the "drainage layer" in the upper part (minimum 1.0 meter thick) of the CTF basin drain system (see Drawing C2003 in Appendix J; Knight Piésold Consulting 2017a) would be sourced from the remaining unused development waste rock stored on the WRS pad (i.e. after some of the development waste rock has been used to help construct the WRS pad, the copper enriched rock stockpile, and the CTF haul ramp as listed in the table). The maximum volume of development waste rock forming the "drainage layer" is calculated by using the maximum design capacity of the WRS pad (which is 500,000 tonnes) and would be approximately 162,489 cubic yards (248,464 tonnes) making the layer 1.7 yards thick.

[d] *** Other materials refer to road construction materials that would be sourced from the individual road cuts.

[e] **** Development waste rock tonnes are calculated using 1.31 cubic yards = 2 tonnes. All development waste rock utilized for construction of the facilities would be end up at the end of the project (in closure) would be transported and placed in the CTF. The first 2 years of the mine life would produce 411,537 tonnes as stated in Table 3-6 of the MOP Application, which would be stored on the temporary WRS pad.

[f] Filter sand sourced from the CTF excavation cut

[g] All construction materials needed to construct the NCWR would be sourced from the CTF excavation.

[h] Approximately 69,845 cubic yards of the PWP construction materials and 216,466 cubic yards of the NCWR construction materials would be sourced from the CTF excavation.

[i] Construction material volumes <1,000 cubic meters are not included in the table.

[j] All cut and fill volumes listed in the table are conceptual and would be refined after a contractor has been awarded the construction project. However, the development waste rock volumes and tonnages correspond to a preliminary mine plan shown in Tables 3-5 and 3-6 of the MOP Application. All gradation specifications (and placement and compaction requirements) for the embankment fill, sub-grade bedding, and drainage gravel are shown in Drawing C0003 in Appendix J. The specifications for the development waste rock would approximate that for the embankment fill. The development waste rock used to construct the drainage layer of the CTF basin drain system would be required to be a free-draining material.

[k] Total rock fill to be stored in the northern and southern reclamation material stockpiles after the end of construction is 385,777 cubic yards (same as Table 3-14a). The facility names highlighted in the light green colored fill would have their excess general rock fill (totaling approximately 174,308 cubic yards) materials stored in the northern reclamation material stockpile whereas the facility names highlighted in the light orange colored cells would have their excess general rock fill (totaling approximately 211,469 cubic yards) stored on the southern reclamation material stockpile as shown in Figure 1.3 and Map Sheet 1. The excess rock fill volumes stored on the two reclamation material stockpiles in this table are conceptual and would be recalculated by a contractor prior to construction.

[l] Total net rock cut minus rock fill volume excluding materials not sourced from the facility excavation footprints (i.e., development waste rock).

[m] The development underground waste rock schedule for the first two years is 411,537 tonnes; the maximum storage capacity of the temporary WRS pad is 500,000 tonnes which indicates that the WRS pad may be used for more than two years. These tonnages include excavated tonnages from the two development ventilation raises (The waste rock tonnage difference between the first two years and the design capacity is equal to 88,463 tonnes, which could be added to the upper part of the drainage layer within the CTF basin drain system during construction).

[n] 241,343 cubic yards (or 369,040 tonnes) of combined sub-grade bedding and drainage gravel is required to construct the mine facilities (not including the sub-grade bedding placed above the HDPE liner system at the WRS pad and the copper-enriched rock stockpile). There is ample granodiorite expected from the CTF and PWP excavations to supply these sub-grade bedding and drainage gravel construction materials.

[o] See Table 3-14c for volume of reclamation materials required to close the following facilities: CTF, NCWR, PWP and NCWR diversion channels, the NCWR spillway, and backfilling of the portal (plug), the drift under the Coon Creek (approximately 200 feet length of workings), and the four ventilation raises.

[p] Diversion channels include: CTF (a permanent facility that would exist during construction, operations, closure, and after closure) and the PWP and NCWR which are not permanent facilities (i.e., would not exist after closure).

[q] These 57,550 cubic yards of material have been identified as Tgd; however, the Proponent may alternatively use Ynl Ex and/or preproduction waste rock for sub-grade bedding material to be placed above the double liner in the CTF. Please see Section 3.6.8.7 of the MOP Application for additional information on these alternative materials.

Given the proposed drift and fill method of mining, distinct surfaces of backfilled material would only be exposed to air for a short period of time, thus reducing the production of sulfate, acidity, and metals. At closure, the backfill material would be submerged by groundwater, reducing oxygen availability (the diffusivity of oxygen in water is 10,000 times less than in air) and reducing sulfide oxidation to negligible levels. Results of the kinetic diffusion tests indicate that the cemented paste tailings (4 percent binders) that are proposed for backfill is unlikely to become acidic and has potential to release only arsenic in concentrations above groundwater standards under saturated conditions at closure. Baseline groundwater monitoring documented that average pre-mining arsenic concentrations in groundwater in the area of the proposed mining stopes are greater than 6 times higher the groundwater standard. Due to the extremely low hydraulic conductivity of this material, interaction with groundwater would be limited. In addition, concrete blocks or plugs would be installed in post-mine tunnels and shafts, which would effectively seal mine workings that are otherwise open. Furthermore, post-closure underground arsenic concentrations were predicted to be non-detectable as a result of the precipitation of $Ba_3(AsO_4)_2$ and sorption to mineral surfaces.

In the CTF, each new lift of cemented paste tailings would behave as a massive block of material with low transmissivity, with a thin upper surface that would be exposed to some degree of oxidation before being covered by fresh cemented paste tailings within 30 days of placement. This is the longest duration of exposure that is anticipated; average exposure times are expected to be shorter, on the order of 7 to 15 days. The unsaturated kinetic tests of cemented paste tailings reflect the type of oxidation to be expected along this surface, while the diffusion tests better represent the majority of tailings placed in each lift. However, it is highly unlikely that the rate of disaggregation observed in the field would approach that observed in the laboratory test, which optimized sulfide oxidation and disaggregation of the small (and unconfined) test cylinders. Waste rock would be placed in lenses adjacent to the ramp in the CTF where it would be encapsulated by cemented paste tailings. The cemented paste tailings placed within the CTF are best represented by the 2 percent binder HCT data, while the final lift of paste tailings in the CTF is best represented by the 4 percent binder HCT data. If material is covered in a timely manner (on the scale of weeks and less than 30 days, average range expected to be 7 to 15 days), relatively less oxidation, acidity, and leaching of metals is expected to occur and it would be limited to the exposed surface of the cemented paste tailings. If operations were to be interrupted, as in the case of a temporary suspension in tailing production, or during early closure, the Proponent would increase the cement binder content to reduce weathering during the period of extended exposure. In addition, any water interacting with oxidized tailings would subsequently flow through and react with waste rock before being collected in a sump within a lined facility for treatment.

Although the CTF would store little to no water during operations, any water remaining in the CTF at closure (e.g., precipitation, runoff, tailings consolidation) would be removed from the facility via the seepage collection sump. At closure, the CTF would be covered with a geotextile membrane over a period of months, which would be welded to the lower liner, eliminating long-term exposure of the final lifts to oxygen and water. The double lined CTF with drainage collection is designed to prevent discharge to surface water and groundwater. Thus, any solutes resulting from oxidation and release of metals by cemented paste tailings within the CTF are unlikely to reach or affect surface water or groundwater.

The acid generation and metal release potential of near-surface rock to be excavated near the Project facilities was characterized. Results of static ABA indicate Tgd is net neutralizing, which was confirmed by kinetic testing – full details provided in Appendix D (Enviromin 2017a) of the MOP Application (Tintina 2017). No metals were detected above any relevant groundwater or surface water standard. Due to this material's lack of chemical reactivity and metals release, the Proponent plans to use it as protective sub-grade bedding below lined facilities, and as drainage rock in its facility foundation drains and underground infiltration galleries. The Ynl Ex also appears unlikely to produce acid, despite a temporary spike in sulfate concentrations. These rocks released low concentrations of selenium that exceeded surface water standards (but not groundwater) in early weeks of testing.

**Smith River Assessment**

The Project area is limited to the location described in Section 1.3, Project Location and History; therefore, the Proposed Action would have no direct impacts on the geologic resources along any reach of the Smith River. As discussed in previous sections, it is highly unlikely that chemical source water generated at the site (mine contact water and surface facility seepage) would lead to the concentration of any constituent exceeding its estimated groundwater non-degradation standards in shallow groundwater or surface water. The water collection systems within mine workings or surface facilities would convey water to the WTP, and the water released to the alluvial aquifer via the UIG would be treated to assure compliance with groundwater standards and non-degradation criteria per the MPDES permit (Hydrometrics, Inc. 2018; Tintina 2018).

There is no direct hydrogeological connection between groundwater in the Project area and the Smith River or its alluvium. The only geochemical pathway from the site to the Smith River is via Sheep Creek surface water, a river distance of 19 miles from the mine site. Because the proposed Project would not cause Sheep Creek surface water to exceed water quality standards, the mine would also not cause secondary impacts like exceeding standards in the Smith River (see discussion presented in Section 3.5, Subsection 3.5.3.2, Surface Water Quality and Temperature).

### *3.6.3.3. Agency Modified Alternative*

Under the AMA, the Project would include all the same components as the Proposed Action with one exception: backfilling additional mine workings, access ramps, and ventilation shafts. The additional backfill component would use low hydraulic conductivity material (i.e., cemented tailings generated from mill processing of the stockpiled ore and/or waste rock at the end of operations) as the backfill material. Approximately 106,971 cubic yards of cemented tailings would be needed to backfill portions of the mine workings, access tunnels, and ventilation shafts.

Cemented paste tailings would only be used to backfill certain mineralized mine voids to avoid the potential of degrading groundwater quality in non-mineralized geologic units (DEQ 2018). The upper section of the access decline (within the Ynl A geologic unit) and a lower section of the access tunnel (within the Ynl B geologic unit) would not be backfilled because these units are non-mineralized, and they have better baseline groundwater quality than the Upper Sulfide Zone (USZ) and the Lower Sulfide Zone (LSZ). All mine voids located within the USZ and the LSZ would be backfilled with cemented paste tailings. Hydraulic plugs would be used to separate the backfilled and open areas of the access decline. This proposed configuration of backfilling is aimed at more effectively separating rock zones that are: (1) mineralized vs. non-mineralized, and (2) more permeable vs. less permeable.

Compared to the Proposed Action, the actions taken under the AMA would decrease the load coming from the underground workings during closure, as mineralized zones with a higher potential for acid generation are backfilled with cemented tailings and plugged, while the non-mineralized zones are allowed to refill with groundwater.

**Smith River Assessment**

Similar to the Proposed Action, the location of the Project area under the AMA would have no direct impacts on the geologic resources along any reach of the Smith River. It is highly unlikely that chemical source water generated at the site (mine contact water and surface facility seepage) would lead to the concentration of any constituent exceeding its estimated groundwater non-degradation standards in shallow groundwater or surface water. The water collection, treatment, and discharge systems in the AMA would be the same as under the Proposed Action. The only geochemical pathway from the site to the Smith River is via Sheep Creek surface water, and because the proposed Project would not cause Sheep Creek surface water to exceed water quality standards, secondary impacts like exceeding standards in the Smith River would also not occur (see discussion presented in Section 3.5, Subsection 3.5.3.2, Surface Water Quality and Temperature).