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What is in Mount Polley Tailings?

Tailings are the leftover material after the minerals that contain the elements of interest have been removed. At Mount Polley (MP), the valuable elements are copper (Cu), gold (Au) and silver (Ag) and they are found most commonly in the sulphide minerals, chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4). These minerals are liberated by crushing and grinding the mined rock down to sand and silt sized particles. A process known as flotation is then used to separate the chalcopyrite and bornite from the rest of the crushed rock. The rest of the crushed rock is considered gange (waste) and is what makes up the tailings. The leftover minerals found in the gange are piped as a slurry with water to the tailings storage facility (presently Springer Pit).

The rocks that are mined at Mount Polley are around 200 million years old and represent ancient volcanic rocks and magma that intruded into these rocks. The intrusive rocks host the copper, gold and silver mineralization. The rocks which host most of the ore are made up primarily of the minerals orthoclase (potassium feldspar), albite (sodium plagioclase), magnetite (iron oxide), plagioclase (calcium plagioclase) diopside (pyroxene), garnet, biotite (mica), epidote and calcite (calcium carbonate). These minerals represent 90% of what ends up in the tailings (see Table 1). Of the other 10 percent, most are also common minerals, with a minor amount of sulphide minerals, including a little bit of chalcopyrite (0.17%) that didn't get captured in the mill, and a small amount of pyrite (0.04%). Another copper mineral, chrysocolla, a copper silicate, is also found in the tailings in very small amounts (0.03%).

What is unusual about the Mount Polley tailings is that when compared to other copper deposits, (and the reason why these tailings are considered by geochemists to be quite benign), is that there is very little pyrite (iron sulphide), and a fair amount of calcite (calcium carbonate) in the tailings. Due to this, Mount Polley's tailings do not generate "acid rock drainage" (ARD). This is the process that happens when sulphide minerals, especially pyrite, are exposed to the atmosphere and react to form sulphuric acid, which then can leach metals out of tailings and lead to metal contamination. Mount Polley's tailings do not have this problem, as there is very little pyrite, and calcite acts as a neutralizing agent if any of the minor amount of sulphide in the tailings breaks down. The rest of the minerals in Mount Polley's tailings are very stable (ie. do not react easily with air or water).

Average Mineral Grade in BC Tails from 29 Jan to 30 May 2014				
	Mineral Name	**mineral %**	**cumulative %**	**Representative Mineral Forumla (webmineral.com)**
	Orthoclase	36.95%	36.95%	$KAlSi_3O_8$
	Albite	24.38%	61.33%	$NaAlSi_3O_8$
	Fe-oxide (magnetite)	7.38%	68.71%	Fe_2O_3
	Plagioclase	7.12%	75.84%	$CaAlSi_3O_8$
	Diopside	4.48%	80.32%	$CaMgSi_2O_6$
	Grossular (garnet)	3.33%	83.65%	$Ca_3Al(Al, Fe++, Mn, Cr)_2Si_3O_{12}$
	Biotite (mica)	3.04%	86.69%	$K(Mg,Fe++)_3(Al,Fe+++)Si_3O_{10}(OH,F)_2$
	Epidote	2.12%	88.81%	$Ca_2(Al,Fe)_2(SiO_4)_3(OH)$
	Calcite	2.01%	90.82%	$CaCO_3$
	Clinochlore (chlorite)	1.44%	92.26%	$(Mg,Fe++)_5Al_2Si_3O_{10}(OH)_8$
	Chlorite	1.03%	93.29%	$(Mg,Fe++,Li)_6AlSi_3O_{10}(OH)_8$
	Zeolite (group)	0.97%	94.26%	$Na_2Al_2Si_3O_{10}{\cdot}2H_2O$
	Titanite	0.92%	95.18%	$CaTiSiO_5$ $Ca_{0.95}REE_{0.05}Ti_{0.75}Al_{0.2}Fe^{3+}{}_{0.05}SiO_{4.9}F_{0.1}$
	Clay	0.80%	95.98%	complicated group of phyllosilicate minerals
	Augite	0.67%	96.64%	$(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2$
	Apatite	0.65%	97.29%	$Ca5(PO_4)_3(OH,F,Cl)$
	Muscovite	0.51%	97.80%	$KAl_2(AlSi_3O_{10})(F,OH)_2$, or $(KF)_2(Al_2O_3)_3(SiO_2)_6(H_2O)$.
	Grossular with Fe	0.31%	98.11%	$Ca_3Al(Al, Fe++, Mn, Cr)_2Si_3O_{12}$
	Actinolite	0.28%	98.39%	$Ca_2(Mg,Fe++)_5Si_8O_{22}(OH)_2$
	Chamosite	0.24%	98.63%	$(Fe++,Mg,Fe+++)_5Al(Si_3Al)$
	Quartz	0.23%	98.86%	SiO_2
	Unknown	0.22%	99.08%	?
	Hydrogrossular	0.18%	99.26%	$Ca_3Al_2(SiO_4)_3$-x$(OH)_4$x
	Andradite	0.18%	99.44%	$Ca_3Fe+++_2(SiO4)_3$
	Chalcopyrite	0.17%	99.61%	$CuFeS_2$
	Grunerite	0.08%	99.69%	$[Fe++]_7Si_8O_{22}(OH)_2$
	Ilmenite	0.07%	99.75%	$Fe++TiO_3$
	MnTi-oxide	0.04%	99.79%	Mn,TiO_2?
	Aluminium	0.04%	99.84%	Al?O?H?
	Pyrite	0.04%	99.87%	FeS_2
	Chrysocolla	0.03%	99.90%	$(Cu,Al)_2H_2Si_2O_5(OH)_4nH_2O$ (Hydrous copper silicate)

Table 1. List of minerals in Mount Polley tailings from January to May 2014 with their representative mineral formula. Note that over 90% of Mount Polley's tailings are common rock forming minerals and the two highlighted minerals chalcopyrite and chrysocolla are copper bearing minerals.

What is a Mineral?

A mineral is defined as a naturally occurring inorganic solid with a definite chemical composition and an ordered atomic arrangement. So each mineral is made up of a particular mix of chemical elements and these chemical elements are arranged in a particular way which is why most minerals grow as crystals and reflect the ordered atomic arrangement. For example:

Quartz is made up of a silica atom plus two oxygen atoms (Figure 1).

The most common feldspar mineral is orthoclase, which is made up of potassium, aluminum, silicon and oxygen (Figure 2).

If you took a handful of sand from another creek around Quesnel Lake, you would probably find that it is made up of many of the same minerals as you find at Mount Polley. There is one exception; the sediment in most of the other creeks around Quesnel Lake will have a lot of quartz in it. Quartz (silicon dioxide) is one of the most common rock-forming minerals in the earth's crust; but you will find very, very little quartz in the Mount Polley tailings, less than 0.25%. This is because of the unusual composition of the intrusive rocks that host the mineralization at Mount Polley, that are very feldspar rich, but quartz poor.

Another way to look at the Mount Polley tailings is to compare the chemical composition of a bulk sample (a mixture of all the minerals dissolved in the lab to represent the whole sample) with an analysis of a local rock, in this case, the rock in the parking lot at the Likely Community Hall (see Table 2).

As you can see, the arsenic (As), and vanadium (V) concentrations are about the same in the MP tailings as in the rock found at the Hall. Copper (Cu) and Iron (Fe) are found to be higher in MP tailings. While cadmium (Cd), antimony (Sb), selenium, (Se), lead (Pb), zinc (Zn) and silver (Ag) are all significantly higher in the parking lot rock than in the tailings.

Sample	As ppm	Cd ppm	Cu ppm	Fe %	Hg ppm	Sb ppm	Se ppm	V ppm	Pb ppm	Zn ppm	Ag ppm
TSF average (2013)	10.63	0.13	810.91	5.14	0.07	0.46	1.14	197.6	4.85	51.13	.31
C. Hall avg	10.5	1.75	94.7	4.73	NA	2.98	1.9	194	16.7	204.2	.44

Table 2. Selected trace element concentrations found in the Mount Polley tailings (TSF average value for 2013) and a sample of the black crumbly rock from the parking lot at the Likely Community Hall (C. Hall avg, sampled in October, 2014).

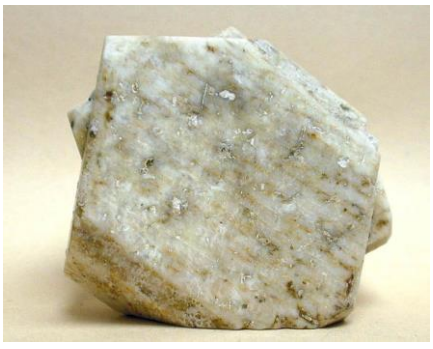

Figure 1. Orthoclase (Feldspar) example

Figure 2. Quartz example

http://webmineral.com/specimens/picshow.php?id=1005&target=Quartz#.VvwHufkrLic
http://webmineral.com/specimens/picshow.php?id=868&target=Orthoclase#.VvwIhvkrLic