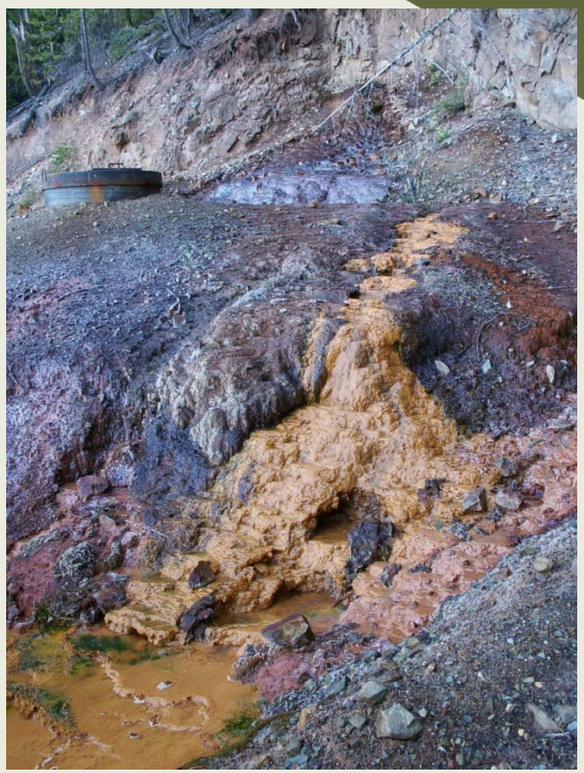
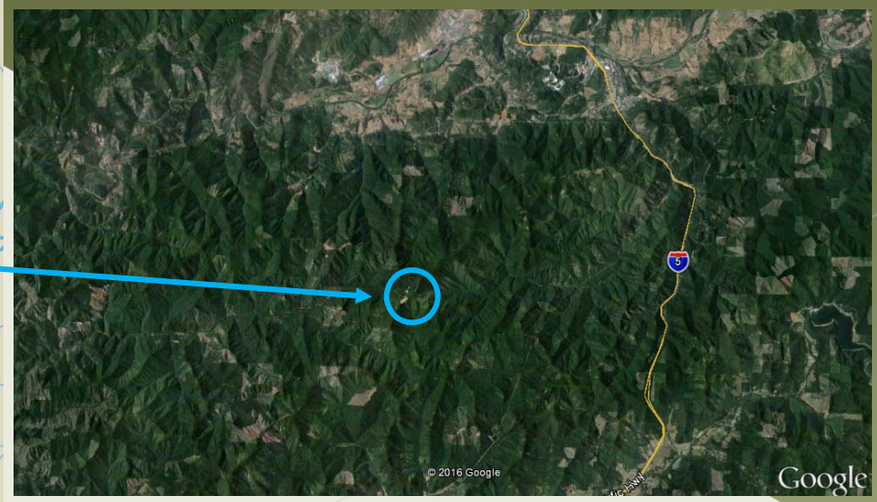
Formosa & Black Butte Mine Superfund Site

Methylation of Mercury at Mining Sites

March 29, 2016



Mine Locations



Black Butte Mine Site Characteristics

Deposit: primarily cinnabar

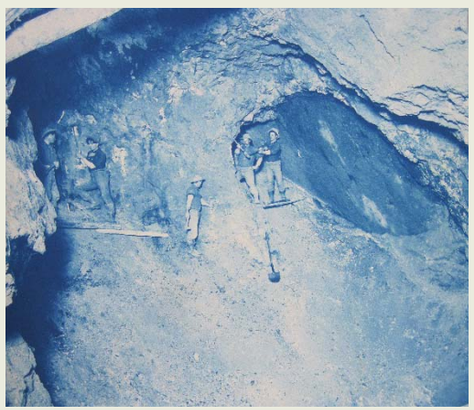
Operation timeframe: 1890 to late 1960s

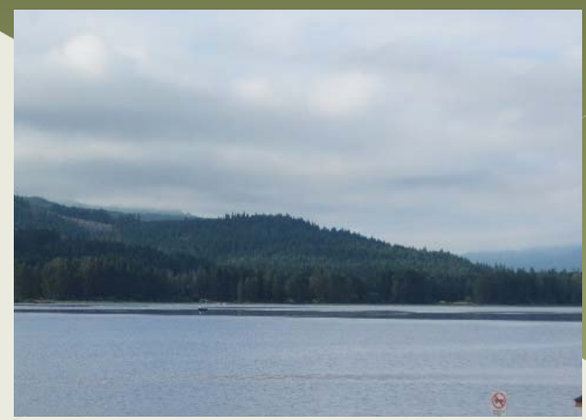
Mine: underground mine; surface waste rock & tailings

Ore Processing: elemental mercury was produced on the site by heating crushed ore in a furnace.

Production: ~635,000 kg of Hg

Environmental Issues: High Hg content tailings located in and near stream channels. Elevated methylmercury (MeHg) levels in fish in downstream reservoir.





Formosa Mine Site Characteristics

Mine type: Copper & Zinc

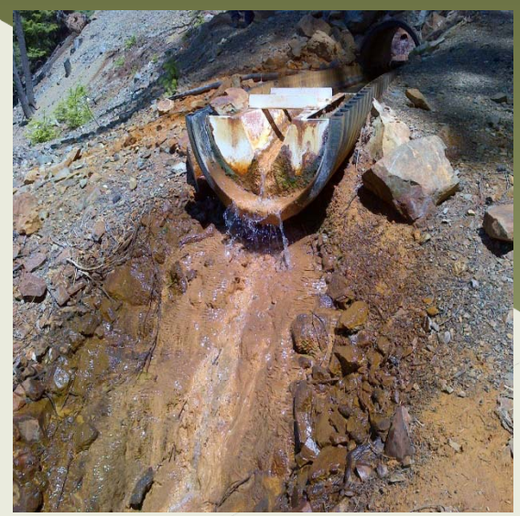
Operation timeframe: 1910 to1993

Mine: underground mine; surface waste rock & tailings

Environmental Issues:

- Release ~19,000 m^3/y of acid mine drainage to area streams, which contains up to 15 tons of dissolved copper, zinc, and other heavy metals

- Streambed sediment and precipitate



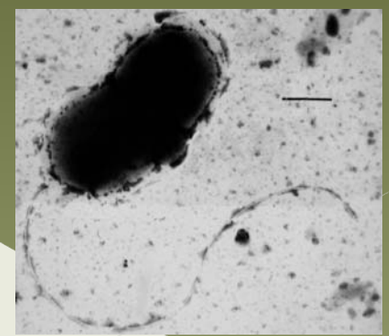
Introduction to Mercury Methylation

Methylmercury is of concern due to its increased toxicity and ability to bioaccumulate

Mercury is methylated by some anaerobic bacteria

Main Factors Necessary for Methylmercury Production:

1) **Source of bioavailable inorganic mercury**
2) **Microbial activity:**
   - **Anoxic conditions**
   - **Electron donors: organic carbon**
   - **Electron acceptors: sulfate, ferric iron, etc**



Site Aqueous Mercury Concentrations

Formosa Mine

Adit Water:

Low THg: 3.0± 0.7 ng/L

41 ± 11% dissolved-phase

Low MeHg: <0.03 ng/L

High Sulfate: 2,245 ± 500 mg/L

Low pH: 2-3 s.u.

Low organic carbon: 2.1 ± 1.1

Black Butte Mine

Furnace Creek Water:

High THg: 32,000 ± 36,000 ng/L

(Max: 93,000 ng/L during storm events)

17 ± 11% dissolved

Low MeHg: <0.001% MeHg

Low Sulfate: 3.1 ± 0.9 mg/L

Neutral pH: 6.8

Low organic carbon: 3.0 ± 1.4

Furnace Creek

Site Aqueous Mercury Concentrations

Formosa Mine

Adit Water:

Low THg: 3.0± 0.7 ng/L

Black Butte Mine

Furnace Creek Water:

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For comparison: USGS Mercury Streams Study (Scudder et al, 2009_

Parameter	Site grouping	Mean	Median	Std Dev	Min	Max	n	Units	Comparison
Methylmercury	All sites	0.19	0.11	0.35	<0.010	4.11	337	ng/L	No significant difference
	Sites in unmined basins	0.20	0.11	0.37	<0.010	4.11	257		
	Sites in mined basins	0.18	0.10	0.31	<0.010	2.02	80		
Total mercury	All sites	8.22	2.09	32.8	0.27	446	336	ng/L	Mined > Unmined ($p<0.0001$)
	Sites in unmined basins	2.96	1.90	5.29	0.27	75.1	250		
	Sites in mined basins	23.5	3.79	62.1	0.48	446	86		
Methyl/Total mercury	All sites	7.08	4.60	8.18	0.02	81.5	328	Percent	Unmined > Mined ($p<0.0001$)
	Sites in unmined basins	7.46	5.35	6.72	0.19	46.8	249		
	Sites in mined basins	5.87	2.37	11.6	0.02	81.5	79		

Downstream conditions

Formosa Mine

Relatively steep gradient stream systems

Well oxygenated; low potential for methylation

Black Butte Mine

Reservoir downstream of mine with wetlands

Conditions conducive to MeHg production