Humans' Dependence on Earth's Mineral Resources
Unit 3
Mining and Mining Impacts

Part II: Ore Grades, Waste, and Remediation

Learning objectives

- Use spatial and quantitative skills to interpret geological information.
- Calculate the amount of metals obtained and the amounts of waste created through mining.
- Evaluate the impacts of various factors on an ore's cut-off grade.
- Compare the pros and cons of continuing mining in an area and weigh different remediation approaches.

Assignment Directions

The class will divide into small groups. Each group will work on a different section of this assignment. There are three different sections.

Once your group completes a section of the assignment, please see me for the next section.

You will have a total of 20 minutes to complete this activity.

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Section I: Mining and Waste

Golden Sunlight Mine (GSM), near Whitehall, Montana, opened in 1983 and is still open today. It is one of the properties owned by the Canadian company Barrick Gold Corp. Take a look at the attached satellite image of Golden Sunlight Mine. Some remediation (slope stabilization) has been done by planting and growing vegetation on the west side of the West Waste Rock Dump Complex and on the northeast side of the East Waste Rock Dump Complex.

1) On the attached satellite image, use a marker to denote the boundaries of mining areas (e.g., draw a line around the Mineral Hill Open Pit Mine area, etc.) and a different color marker to denote the boundaries of waste areas (e.g., draw a line around the West Waste Rock Dump Complex, etc.).

2) Use the boundaries you created to estimate the approximate percentage of land surface area that is used for actual pit mining as opposed to the storage of mining waste products (including both waste rock and tailings). The approximate percentage of land surface used for pit mining as compared to that used in mine waste storage is:
    a. 90–100%
    b. 70–85%
    c. 45–55%
    d. 15–30%

3) For a sense of scale:
    a. Estimate the number of acres inside Tailings Impoundment #2 using the scale box (100 acres) on the map.

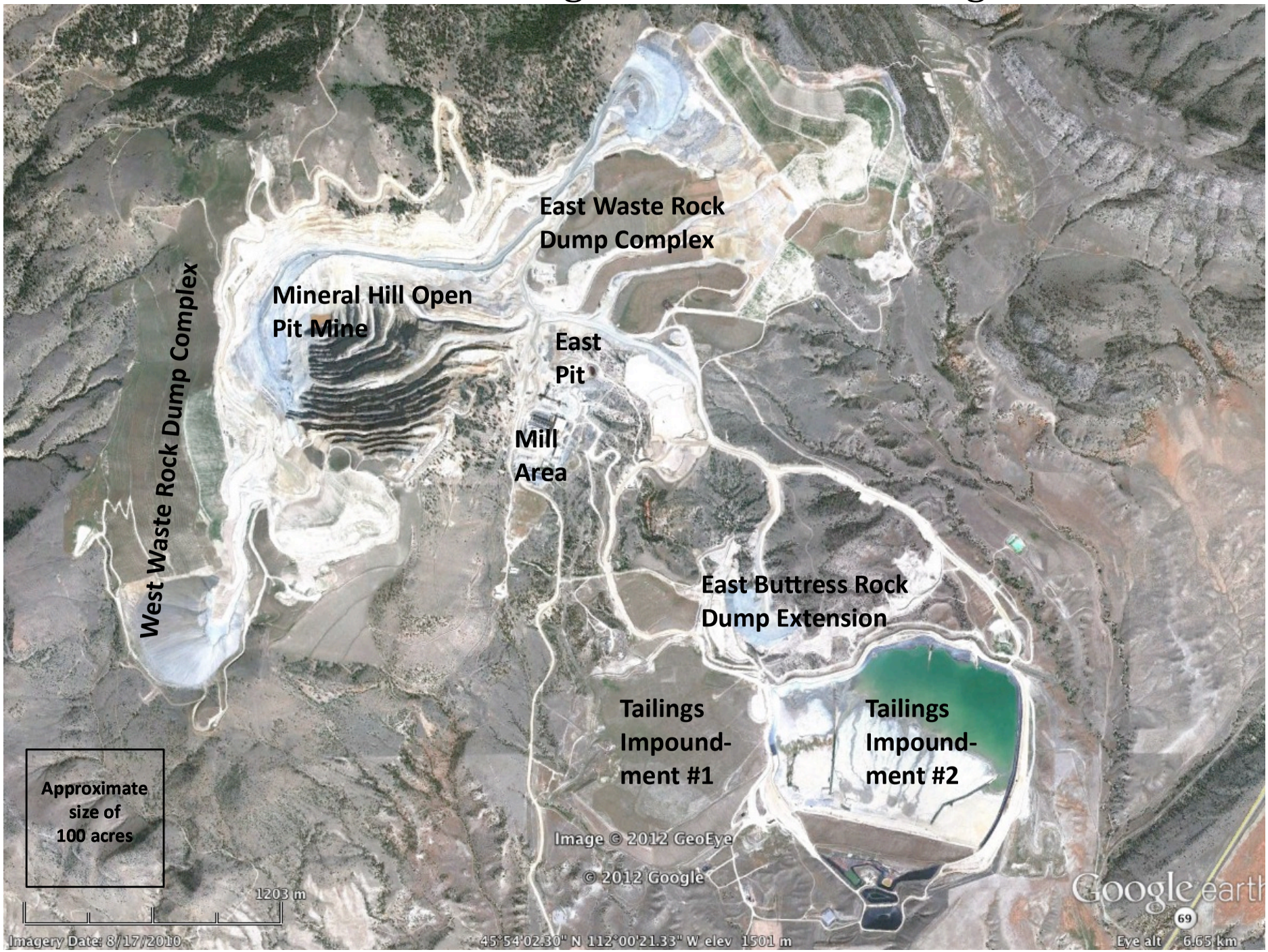
    b. If an American football field, including the end zones, is about 1.32 acres, approximately (mathematically) how many football fields would fit inside Tailing Impoundment #2? Show your calculations here.

4) Why might Tailings Impoundment #1 look different than Tailings Impoundment #2?

5) The Montana Department of Environmental Quality (DEQ) has recently received an application from GSM to amend their operating permit. This would include adding one new pit northeast of the mine and extending the larger Mineral Hill pit, although within the previous permit boundary. This additional mine area would extend the life of the mine for two years to 2017, allowing the company to continue to explore the area without closing. The additional mining would result in an estimated 4.2 million tons of ore and 52.6 million tons of non-ore rock (waste).
    a. What is the percentage of ore to waste (by weight) for these new sections? Show your calculations here.

    b. What might be some incentives of the DEQ and the community to approve the permit? What might be some incentives not to approve the permit?

Golden Sunlight Mine Satellite Image



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Section II: Ore Grades and Mining

The **grade** of an ore is the concentration of the desired material within the rock. There is more metal (a higher concentration) in higher grade metal ores. Ore grades are often given in percentages or in units of ppm (defined below).

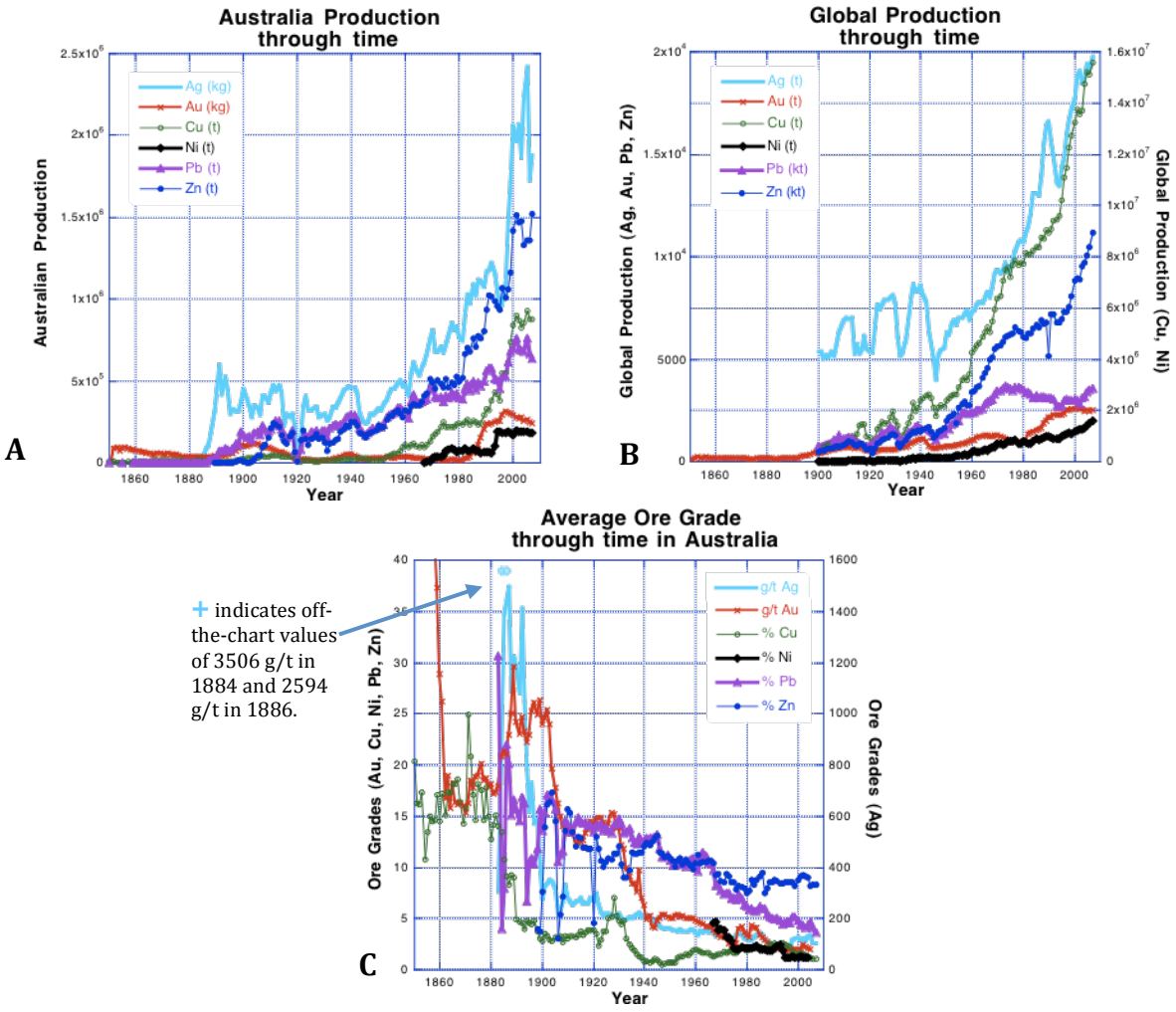
Percentages, which most of us are familiar with through our class grades, are actually a measurement of "parts per total parts." In the case of grades on an exam, if you received a 92% on your 100-point exam, you received 92 points out of a possible 100 points. This is similar to ores: If a nickel ore has a grade of 2%, it means there are 2 pounds of nickel for every 100 pounds of ore. It also means that there are 2 grams of nickel for every 100 grams of ore, etc., so long as the unit of comparison remains the same within the percentage calculation (pounds to pounds or grams to grams or ounces to ounces, etc.).

1) Some sources say that the average single family home in the United States uses about 420 pounds of copper within the plumbing, appliances, building wire, and more. In the twenty-first century, an average copper grade ore might be ~0.6%.
    a. How many pounds of 0.6% grade copper ore needs to be mined in order to obtain 420 pounds of copper? Show your work here.

Another frequently used unit of measurement for ore grades is "parts per million" or ppm. Instead of finding the concentration per 100 parts, like the percentage, ppm finds concentration out of one million parts. This unit is used to represent metals that often occur in smaller concentrations. A gold ore with a 2 ppm ore grade would have 2 pounds of gold for every 1,000,000 pounds of ore. An equivalent unit is grams/ton (since there are 1,000,000 grams, or 10^6 grams, in a metric ton). Thus a 2 ppm grade gold ore would also have 2 grams of gold for every ton of ore.

1) A gold coin called a Krugerrand has approximately 31.1035 grams of gold in it.
    a. How many metric tons of 15 ppm grade gold ore need to be mined in order to get enough gold for a *single* Krugerrand? Show your work here. Remember that 1 metric ton = $1x10^6$ grams.

    b. How much waste product (in metric tons) is created? Show your work here.



The plots A and B above indicate the production of certain metals (Ag, Au, Cu, Ni, Pb, and Zn) in Australia (A) and globally (B) over the period from ca. 1850 to 2007 (where data is available). Plot C shows the average ore grade mined in Australia for these same metals over the same period.

2) Draw an arrow on each of the three plots above to indicate the general trend of the amount of production (A & B) and the grade of the ore (C).

3) If ore grades (the concentration of the metal within the ore) have decreased toward more recent times, yet production of the metal has increased, then what are the implications for:
   a. The amount of ore that must be mined to allow production of the metal to stay the same or to increase?

   b. The amount of waste rock and tailings produced from the processing of that ore?

4) List/explain at least three possible reasons why the ores grades have trended toward lower grade ores in more recent times.

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Section III: Cut-off Grade, Mine Productivity, and Legacy Mines

Many aspects influence the financial productivity of any mine. Obviously the presence of the desired material is key, but both geological and nongeological elements influence the overall success of the mine. Some important factors, in addition to the strategy of the company and their management, include:

Resource Quality: Ease with which the ore can be mined, the type of mineral resource, the size of the ore deposit, ore grade (concentration of desired material within the rock)

Input Costs: Labor, energy, and water use; infrastructure and services; other materials used in the mining process

Macroeconomic Factors: Metal prices, ability to obtain credit and interest rates, exchange rates

Other Factors: Governmental permitting rules, financial resources, social and political factors

Together these factors determine whether a site is worth mining and/or whether a mine will stay open and, if so, for how long. They will also influence the extensiveness of the mine (how much land is mined), the amount of waste products created, the number of jobs maintained, and more. A mining company has some control over only some of these factors.

The **grade** of an ore is the concentration of the desired material within the rock. There is more metal (a higher concentration) in higher grade metal ores. Ore grades are often given in percentages or in units of ppm.

The **cut-off grade** of an ore is essentially the lowest grade of an ore that is worth mining. If the ore grade is less than the cut-off grade, then a mining company will not make money mining that ore. According to Fellows (2010), the cut-off grade of an ore is one of the main factors in determining the economics of the mine.

It might seem as if the cut-off grade of an ore is determined permanently at the time of exploration and mine opening, but actually the cut-off grade changes throughout the lifetime of the mine (and thus, changes the estimates of the amount of ore in a reserve). For example, if cut-off grade drops, the mine is now able to profitably extract metal from an ore with a lower ore grade (a lower concentration of metal in the ore).

1) For the factors listed below, note whether the cut-off grade would likely rise or fall ***and explain why***. The first one (a) is an example:

   a. Increased market price of the metal? Rise or **Fall**
   Explain:
   If the mine can receive more money for each ounce that they produce, then the extra costs of processing more lower concentration ore are worthwhile. Therefore an increased market price could lead to a lower cut-off ore grade.

   b. New beneficiation technologies? Rise or Fall
   Explain:

c. Better (more equitable) labor agreements? Rise or Fall
Explain:

d. Rising energy costs? Rise or Fall
Explain:

e. More stringent environmental regulations? Rise or Fall
Explain:

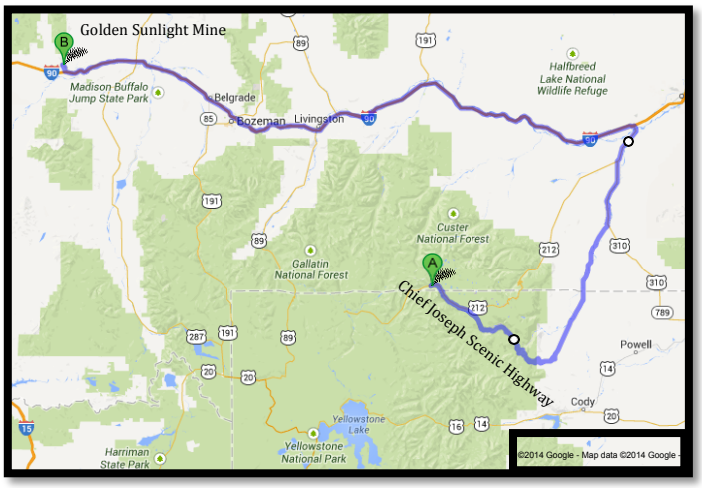
2) Many closed mines exist throughout the United States (and other countries). If the cut-off grade drops for ores once extracted from these legacy mines, what might happen to these old mines?

The Golden Sunlight Mine (GSM) near Whitehall, Montana, is relatively close to dozens of legacy mining operations. In the fall of 2012, GSM won an award from the U.S. Bureau of Land Management for helping to reuse materials from legacy silver and gold mines. The GSM partnered with other groups to remove and process the tailings from the legacy mines, deposit the reprocessed tailings into a more modern, lined, tailings pond, and reclaim the old site (all with proper permitting). The partners and related contractors benefit financially, the historic sites are cleaned up with a reduced amount of federal/state (taxpayer) expense, and new jobs are provided. In 2011–2012, GSM had at least 10 different contracts to bring in historic mine materials for processing, including from sites on public lands.

3) These same legacy tailings have been around for a long time and remained untouched for years. What factors might have changed to allow this type of "ore processing" partnership to exist today?

In 2010, the Montana Department of Environmental Quality (DEQ) proposed a plan for the cleanup of the McLaren Tailings Abandoned Mine Site just outside of Yellowstone National Park near Cooke City ("A" on map below). This area was noted to be contributing acid mine drainage to the Soda Butte Creek, which runs through a portion of Yellowstone National Park, and there were concerns about a possible failure of the tailings dam. As proposed in 2010, the plan was to remove approximately one-half million tons of mine waste from the site, most to be placed in a repository near the site, but of which about 20% (~68,700

tons) would be transported for gold processing at GSM. It was believed that for the DEQ/State of Montana, this would break even monetarily; the cost of hauling on this 640-mile round-trip route through both Montana and Wyoming (see highlighted highway section on map) to the Golden Sunlight Mine ("B" on map) would approximately equal the money made by selling the gold tailings, estimated to be $25–30 million.



The plan would require approximately 120 loads to be transported each week (Monday through Friday), averaging 24 round trips each day using double belly haul trucks with a capacity of about 40 tons for one summer (~14 weeks). As commercial hauling vehicles are not allowed in Yellowstone National Park, the trucks must take the longer route noted in the map above.

The tailings contain some substances that can be dangerous to humans or other organisms. Laboratory testing of the tailings (stabilized for easier hauling) indicated that values of cadmium, copper, iron, mercury, and silver were significantly above background levels; in particular, concentrations of iron and copper were above the target concentrations for residential exposure. However, the tailings were below the limits established by the Toxicity Characteristic Leaching Procedure and therefore not classified by the Environmental Protection Agency (EPA) as Hazardous Material.

In the end, this plan to transport the tailings to GSM was nixed based particularly on voiced concerns from Wyoming about the intense use of the Chief Joseph Scenic Highway (see on map above), which has very curvy sections and is one of the steepest roads in the area (up to 7% slope), to transport the tailings. Instead, the new plan calls for all the tailings material to be placed in the nearby repository, which was deepened in design in order to accommodate the total amount from the McLaren site.

4) Please explain some potential positive aspects of the proposal to haul the legacy tailings to GSM to extract the gold. In what ways would this have been a good plan?

5) Please explain some potential negative aspects of the proposal to haul the legacy tailings to GSM to extract the gold. In what ways might this not have been a good plan?

6) If you were a resident of Wyoming near this area, what concerns might you have had about this proposal to haul to GSM?

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Plots and Figures

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Section II:

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