ORE PROCESSING
MILLING AND SMELTING
KEY

Terminology
Define the following terms as they relate to mining.

Mill - A plant in which ore is treated and metals are recovered or prepared for smelting; also a revolving drum used for the grinding of ores in preparation for treatment.

Beneficiation – The processing of ores for the purpose of regulating the size of a desired product, removing unwanted constituents; and improving the quality, purity, or assay grade of a desired product. Concentration or other preparation of ores can be for smelting by screening, drying, flotation, or gravity or magnetic separation. Improvement of the grade of ores can be by milling, screening, flotation, sintering, gravity concentration, or other chemical and mechanical processes.

Concentration – The mechanical process, often involving flotation or gravity separation, by which the valuable part of an ore is separated from the gangue, or non-economical rock minerals, to be further treated or disposed of as tailings.

Flotation – The method of mineral separation in which a froth, created in water by a variety of reagents, floats some finely ground minerals while other minerals sink.

Magnetic separation – A process in which a magnetically susceptible mineral is separated from gangue minerals by applying a strong magnetic field; ores of iron are commonly treated in this way.

Extractive Metallurgy – the methods employed to clean, process, and prepare metallic ores for the final marketable product.

Smelting (Pyrometallurgy) – the chemical reduction of a metal from its ore or concentrate by a process usually involving fusion, so that earthly and other impurities separate as lighter and more fusible slags and can readily be removed from the reduced metal. The process commonly involves addition of reagents (fluxes) that facilitate chemical reactions and the separation of metals from impurities.

Hydrometallurgy – The treatment of ore by wet processes, such as leaching, resulting in the solution of a metal and its subsequent recovery.

Cyanidation – A method of extracting exposed gold or silver grains from crushed or ground ore by dissolving it in a weak cyanide solution. May be carried out in tanks inside a mill or in heaps of ore out of doors.

Sodium cyanide – A chemical used in the milling of gold ores to dissolve gold and silver.

Heap leaching – A process whereby valuable metals, usually gold and silver, are leached from a heap, or pad, of crushed ore by leaching solutions percolating down through the heap and collected from a sloping, impermeable liner below the pad.

Slag – The vitreous mass separated from the fused metals in the smelting process.

Gangue – The valueless minerals in an ore; that part of an ore that is not economically desirable but cannot be avoided when mining the deposit. It is separated from the ore during beneficiation.

Tailings – The solid waste product (gangue and other material) resulting from the milling and mineral concentration process applied to ground ore. This term is usually used for sand to clay-sized refuse that is considered too low in mineral value to be treated further, as opposed to the concentrates that contain the valuable metals.

Questions
Answer the following questions related to ore processing, milling, and smelting.

1) Describe the beneficiation process. (i.e. gravity concentration, smelting, etc.)
After a mineral deposit is mined it must be processed to get the valuable metal or element out of the ore; this is done by beneficiation. Beneficiation is the processing of ores for the purpose of regulating the size of a desired product, removing unwanted constituents, and improving the quality, purity, or assay grade of a desired product. Concentration or other preparation of ores can be for smelting by screening, drying, flotation, or gravity or magnetic separation. Improvement of the grade of ores can be by milling, screening, flotation, sintering, gravity concentration, or other chemical and mechanical processes. (See page 67 of Anatomy of a Mine USFS publication, also see Figure 2.2, pg 10 in *Basics of Metal Mining Influenced Water* book).

2) Where were smelters and stamp mills located in Park County and how does a stamp mill work?
The Paris Mill is located in Buckskin Gulch and Magnolia Mill is located behind Montgomery Reservoir. There were smelters in Alma (Boston and Colorado) and Dudley (see chapter 7 of *Mining Among the Clouds*). North London Mill and the Leavick Mill are good examples of what the students should find in *Bayou Salado* or *Mining Among the Clouds*. The very basic stamp mill is described in the *Life of a Miner* book. Students should elaborate on what is in that book.

3) How is water used in the beneficiation process?
Water is used in almost all phases of the beneficiation process, as the medium for chemical extraction or gravity separation. It is used as the medium that cyanide is dissolved in when using cyanide heap leach processes (i.e. baron and pregnant ponds).
(See page 67 of Anatomy of a Mine USFS publication)

4) How are chemicals used in the beneficiation process (i.e. hydrometallurgy)?
Hydrometallurgical processes selectively dissolve metals from ores and concentrates, resulting in recovery of relatively pure metal. Various acids, such as sulfuric acid, and alkaline solvents, such as the hydroxides and carbonates of sodium or ammonium, are popular in leaching ores. Sodium and calcium cyanide solutions are widely used in extracting gold and silver from precious metal ores. The usual technique is to agitate finely ground ore or concentrate in open vessels at atmospheric pressure. Vat leaching percolates crushed ore bedded in large, stationary, rectangular, or circular containers. There is presently much interest in these processes, because many ores that were formerly smelted may

be treated by hydrometallurgy with far less air pollution and consumption of energy (Anatomy of a Mine USFS publication, pg 69).

5) What are the environmental impacts of milling and smelting?
Mine wastes produced during processing include but are not limited to: tailings – a residual slurry of ground-up ore that remains after minerals have been largely extracted; heap leach spent ore- the rock remaining in a heap leach facility after the recovery of the minerals. Tailings can be kept in large storage facilities, which have a large environmental footprints and potential drainage and stability issues. Metallurgical processing can affect air quality due to emissions from smelters, sprayers, crushers, ore roasters, autoclaves, refining operations and tailings facilities. Before the modern use of scrubbers and stacks, significant amounts of sulfur were released to the atmosphere, creating sulfuric acid.

6) What are the water quality impacts of milling and smelting?
A waste material is generally produced at each step in the process from the mine to the mill, contractor, smelter, and refinery. Tailings, smelter slag, and processing solutions can be sources of acid drainage and other drainage quality impacts. (see pg 22 in *Basics of Metal Mining Influenced Water*)

There are four major types of potential impacts from mining and metallurgical processing on water quality including 1) acid drainage, 2) metal leaching and resultant contamination, 3) release of processing chemicals and 4) increased erosion and sedimentation.

7) What is the Hg amalgamation process and where is Hg mined? (BONUS)
See this video: http://www.youtube.com/watch?v=jjJg_NWty74
Amalgamation is blending of mercury with another metal to produce an amalgam.
Some metals are soluble in mercury, such as gold. This process is used in both dentistry and gold mining.

The students may have to search in the Colorado Geological Survey publication to find where Cinnabar is mined, this mercury sulfide (HgS) is the primary mercury ore.