

Dangerous and Beneficial Minerals

Several years ago, Gordon Brown decided to add a top ten list to his mineralogy course. Since presenting this at a workshop for science journalists, many others have asked to have these lists. Here, we share the lists to help everyone understand the importance of minerals in our lives.

The list has been presented in several ways on the following pages. The first is the list with a short reason why the minerals are beneficial or dangerous to humans. The second set is the long descriptions of why. The last page is has the names and the reasons separately.

Teachers: we have not developed an activity or lesson to use this information, yet we invite you to use this with your students. The last page of this document could be used to make a matching activity. . We have also provided a powerpoint slide show with images of the minerals. Please let us know if you actually teach a lesson using these materials. – Jennifer (saltzman@stanford.edu) and Gordon (gordon@pangea.stanford.edu)

The Ten Most Dangerous Minerals and Why (from the perspective of human health) (Gordon Brown's opinion)

10. **Cinnabar** (HgS) Main source of mercury
9. **Galena** (PbS) Main source of lead
8. **Pyrite** (FeS₂) Main source of acid mine waters associated with sulfide mine tailings. As-containing pyrite
7. **Fluorite** (CaF₂) major fluorine-containing mineral
6. **(tie) Quartz** (SiO₂) Quartz in fine particulate form causes respiratory effects (silicosis or silicotuberculosis).
6. **(tie) Chrysotile** (Mg₃Si₂O₅(OH)₄) Known as white asbestos. Chronic exposure can cause a progressive lung disease
5. **K-Feldspar** (KAlSi₃O₈) contains small quantities of radioactive uranium, a major source of Pb
4. **Phenacite** (BeSiO₄) Beryllium (Be)-containing dust is highly poisonous.
3. **Erionite** (NaK₂MgCa_{1.5})[Al₈Si₂₈]O₇₂·28H₂O) A fibrous zeolite (sometimes referred to as a molecular sieve). Known to induce malignant mesotheliomas in humans
2. **Hydroxyapatite** (Ca₅(PO₄)₃(OH)) form deposits in human heart valves and arteries
1. **Crocidolite** (Na₂(Fe₂₋₃Mg)₃Fe₃₋₂Si₈O₂₂(OH)₂) Known as blue asbestos. Lung diseases, including lung and mesothelial cancer

The Ten Most Beneficial Minerals and Why

(from the perspective of human usage) (Gordon Brown's opinion)

10. **Bauxite and Al-hydroxides** Major sources of aluminum
9. **(tie) Iron oxides** Major source of iron for steel-making
9. **(tie) Copper minerals** Major source of copper
8. **Ferrihydrite** ($\approx\text{Fe}(\text{OH})_3$) Sorbers of toxic heavy metals and metalloids such as As, Se, Pb, etc.
7. **Zeolites** Known as molecular sieves, zeolites are commonly used in the cracking of petroleum to make gasoline, in chemical catalysis, and as cation exchangers in softening H_2O .
6. **Gypsum** ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) An important component of cements.
5. **Salt** (NaCl) An essential nutrient.
4. **Quartz** (SiO_2) cutting tools and weapons (producing sharp edges), semiconductors (Silicon Valley).
3. **(tie) Calcite** (CaCO_3) Calcite sequesters CO_2 in the lithosphere
3. **(tie) Phosphates** Essential plant nutrient used in fertilizers.
2. **Hydroxyapatite** ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$) bones and teeth
1. **Clay minerals** holding nutrient elements, which are necessary for plant growth

The Ten Most Dangerous Minerals and Why

(from the perspective of human health) (Gordon Brown's opinion)

10. **Cinnabar** (HgS) Main source of mercury; Very insoluble ($K_{\text{sp}} = 10^{-53.3}$) However, when oxidized, can be methylated by sulfate-reducing bacteria, producing methyl mercury and dimethyl mercury, two of the most toxic compounds known to humans. Causes developmental and nervous system disorders in fetuses and children. These two compounds can kill at low concentration levels!
9. **Galena** (PbS) Main source of lead. Relatively insoluble ($K_{\text{sp}} = 10^{-27.5}$). When released into the environment in various forms, can cause developmental and nervous system disorders in fetuses and children. Implicated in cardiovascular disease in adults. The common weathering products of galena – cerussite and anglesite – are much more soluble than galena (as discussed earlier), resulting in much more rapid dissolution of these two minerals and quicker release of Pb into the environment.
8. **Pyrite** (FeS_2) Main source of acid mine waters associated with sulfide mine tailings. Oxidation of pyrite, which is catalyzed by certain types of bacteria and archaea (see next slide), releases trace quantities of toxic metals and metalloids like As. Microbial oxidation rates of aqueous ferrous iron (see box below) are about 5 orders of magnitude faster ($5 \times 10^{-7} \text{ mol L}^{-1}\text{s}^{-1}$) than abiotic oxidation rates ($3 \times 10^{-12} \text{ mol L}^{-1}\text{s}^{-1}$) at pH 2 and 25°C . Acid waters associated with pyrite oxidation cause solubilization of toxic heavy metals, resulting in their dispersal in the environment. As-containing pyrite in coals is a major health problem in the Guizhou province in southwest China, affecting millions of people.
7. **Fluorite** (CaF_2) The major fluorine-containing mineral in the Earth's crust, although there are a number of other minerals that contain fluorine as well, and these others are probably more important in an environmental context. Fluorite is relatively soluble ($K_{\text{sp}} = 10^{-10.4}$). Too much fluorine in human diets can cause a very severe bone disorder, resulting in an irreversible disease referred to as skeletal fluorosis. Various forms of fluorosis affect more than 10 million people in the Guizhou province of China. There it is present in coal, ranging in concentration from 200 to 1500 ppm; however, its exact form is not known.
6. **(tie) Quartz** (SiO_2) Quartz in fine particulate form has been known since Biblical times to cause respiratory effects (silicosis or silicotuberculosis). Workers in the "dusty trades" – mining, sand blasting, quarrying, metallurgy, construction – suffer from these diseases. There is also concern about the potential of silica in other areas, including lung cancer and other cancers, kidney disease, and immunological problems. Quartz is relatively soluble ($K_{\text{sp}} = 10^{-4}$)
6. **(tie) Chrysotile** ($\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$) Known as white asbestos. Chronic exposure (chrysotile mine workers, insulation workers,

etc.) can cause asbestosis, a progressive lung disease that causes hardening of lung tissue resulting in loss of elasticity and difficulty in breathing. Epidemiological studies do not suggest high risk of lung and mesothelial cancers among chrysotile mine workers, however (see Ross, 1984). Chrysotile is relatively soluble in human lung fluids. The study by Hume and Rimstidt (1992) predicted that a chrysotile fiber 1 μm in diameter would dissolve completely in the human lung in 9 (± 4.5) months ($T = 37^\circ\text{C}$, $\text{pH } 6$).

5. K-Feldspar (KAlSi_3O_8) This is one of the most common minerals in the Earth's continental crust, comprising about 22% by volume of crustal rocks. K-feldspar has made my ten most dangerous minerals list because it contains small quantities of radioactive uranium, which decays to form radon gas, which has been implicated by the EPA as potentially responsible for about one-third of all lung cancer deaths in the U.S. among non-smokers. K-feldspar is also a major source of Pb in the environment. Although the average Pb concentration in typical K-feldspars in granites is only about 20 ppm, this mineral is very abundant and weathers easily (relatively soluble), thus releases more Pb into the environment naturally than most other Pb-containing minerals.

4. Phenacite (BeSiO_4) Fortunately, this is not a very common mineral and is no longer commonly used in technological products. However, in the past it was the major phosphor used in fluorescent lights (when I was a kid). When one of these fluorescent light tubes broke, the common warning was not to take a breath for fear of breathing in some of the Be-containing dust, which is highly poisonous.

3. Erionite ($\text{NaK}_2\text{MgCa}_{1.5}[\text{Al}_8\text{Si}_{28}]\text{O}_{72} \cdot 28\text{H}_2\text{O}$) A fibrous zeolite (sometimes referred to as a molecular sieve). Known to induce malignant mesotheliomas in humans, based on epidemiological studies on the Cappadocian plateau of Turkey.

2. Hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$) Apatite is a serious health threat because it can form deposits in human heart valves and arteries, resulting in restricted flow of blood or complete blockage. Many people die each year because of such blockages.

1. Crocidolite ($\text{Na}_2(\text{Fe}_2, \text{Mg})_3\text{Fe}_{3-2}\text{Si}_8\text{O}_{22}(\text{OH})_2$) Known as blue asbestos. Chronic exposure to this mineral results in lung diseases, including lung and mesothelial cancer. Even casual (one-time) exposure to this mineral may be dangerous. Thus, it takes the number one ranking on my list of dangerous minerals.

The Ten Most Beneficial Minerals and Why (from the perspective of human usage) (Gordon Brown's opinion)

10. Bauxite and Al-hydroxides Major sources of aluminum.

9. (tie) Iron oxides Major source of iron for steel-making.

9. (tie) Copper minerals Major source of copper, which is used as an electrical conductor in all sorts of applications.

8. Ferrihydrite ($\approx \text{Fe}(\text{OH})_3$) Common natural sorbers of toxic heavy metals and metalloids such as As, Se, Pb, etc. (hydrous manganese oxides have a similar importance and are probably more important than iron hydroxides in the marine environment).

7. Zeolites Known as molecular sieves, zeolites are commonly used in the cracking of petroleum to make gasoline, in chemical catalysis, and as cation exchangers in softening H_2O

6. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) An important component of cements.

5. Salt (NaCl) An essential nutrient. Are you worth your salt?

4. Quartz (SiO_2) Essential in the early development of civilization because of its use in cutting tools and weapons (hardness of 7 and conchoidal fracture, producing sharp edges). It is also the primary source of silicon, which is the major chemical component of modern semiconductors (Silicon Valley).

3. (tie) Calcite (CaCO_3) Calcite sequesters CO_2 in the lithosphere. Without calcite or some other carbonate mineral that was equally effective at sequestering CO_2 , we would live on a much warmer planet.

3. **(tie) Phosphates** Essential plant nutrient used in fertilizers.

2. **Hydroxyapatite** ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$) Without hydroxyapatite, we would not have bones or teeth (or at least they would be made of a different mineral).

1. **Clay minerals** Without clay minerals, we would have very poor soils that would be incapable of holding nutrient elements like K, nitrogen, and phosphorous, which are necessary for plant growth. Without plants and soils, we wouldn't be here!

The Eleven Most Dangerous Minerals

Cinnabar (HgS)

Galena (PbS)

Pyrite (FeS_2)

Fluorite (CaF_2)

Quartz (SiO_2)

Chrysotile ($\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$)

K-Feldspar (KAlSi_3O_8)

Phenacite (BeSiO_4)

Erionite ($\text{NaK}_2\text{MgCa}_{1.5}[\text{Al}_8\text{Si}_{28}]\text{O}_{72} \cdot 28\text{H}_2\text{O}$)

Hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$)

Crocidolite ($\text{Na}_2(\text{Fe}_{2+}, \text{Mg})_3\text{Fe}_{3+} \cdot 2\text{Si}_8\text{O}_{22}(\text{OH})_2$)

The Twelve Most Beneficial Minerals

Bauxite and Al-hydroxides

Iron oxides

Copper minerals

Ferrihydrite ($\approx \text{Fe}(\text{OH})_3$)

Zeolites

Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

Salt (NaCl)

Quartz (SiO_2)

Calcite (CaCO_3)

Phosphates

Hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_3(\text{OH})$)

Clay minerals

Dangerous Reasons

- A fibrous zeolite (a molecular sieve). Known to induce malignant mesotheliomas.
- Main source of acid mine waters associated with sulfide tailings. Contains arsenic.
- Major fluorine-containing mineral
- Beryllium containing dust is highly poisonous
- Form deposits in human heart valves and arteries
- Fine particulate form causes respiratory effects (silicosis or silicotuberculosis).

- Known as white asbestos. Chronic exposure can cause a progressive lung disease. Contains small quantities of radioactive uranium, a major source of Pb
- Known as blue asbestos. Lung diseases, including lung and mesothelial cancer
- Main source of mercury
- Main source of lead

Beneficial Reasons

- Holds nutrient elements in soils, which are necessary for plant growth
- Sorbers of toxic heavy metals and metalloids such as As, Se, Pb, etc.
Known as molecular sieves, commonly used in the cracking of petroleum to make gasoline, in chemical catalysis, and as cation exchangers in softening H₂O.
- An essential nutrient
- Major source of iron for steel-making
- Major source of copper
- Essential plant nutrient used in fertilizers
- Bones and teeth are made of this mineral
- Cutting tools and weapons (producing sharp edges), semiconductors (Silicon Valley).
- Sequesters CO₂ in the lithosphere which helps reduce atmospheric carbon dioxide
- An important component of cements
- Major sources of aluminum

(These lists are G. Brown's opinion)