ABANDONED MINE HAZARDS

A. **Oxygen (O_2) Deficiency (Anoxia)** - Oxygen deficiency may result from combustion (including blasting), oxidization of organic material (e.g., mine timbers, coal), respiration in confined spaces, or replacement by other gases.

TABLE I
OXYGEN THRESHOLD VALUES AND POTENTIAL SYMPTOMS

(These values are approximate and vary with the individual's state of health and degree of physical activity.)

Oxygen Content (% by Volume)	Effects and Symptoms (At Atmospheric Pressure)
20.95	Typical ambient air conditions.
19.5 *	Minimum permissible oxygen level.
15 - 19	Decreased ability to work strenuously. May impair coordination and can induce early symptoms in persons with coronary, pulmonary, or circulatory problems.
12 - 14	Respiration increases in rate; pulse up; impaired coordination, perception, and judgement.
10 - 12	Respiration further increases in rate and depth; poor judgement; lips blue.
8 - 10	Mental failure; ashen face; blue lips; nausea; vomiting; fainting; unconsciousness.
6 - 8	8 minutes: 100% fatal 6 minutes: 50% fatal 4-5 minutes: recovery with treatment
4 - 6	Convulsions; coma in 40 seconds; respiration ceases; death.

The area should be evacuated at oxygen concentrations of less than 19.5%.

B. Common Life-Threatening Gases

1. **Carbon Monoxide (CO)** - Carbon monoxide is an odorless, tasteless, colorless gas that may build up in a confined space, usually as a result of combustion or blasting. It can also be produced by certain coals at room temperature. CO is slightly lighter than air, so may tend to stratify toward the roof of a drift. CO inhibits the oxygen-carrying capacity of the blood by combining more readily with hemoglobin than oxygen. In high concentrations of carbon monoxide, a person may collapse with little or no warning and thus be unable to aid himself.

TABLE II
CARBON MONOXIDE THRESHOLD VALUES AND POTENTIAL SYMPTOMS

(These values are approximate and vary with the individual's state of health and degree of physical activity.)

ppm	Effects and Symptoms	Time
50 *	Permissible exposure level	8 hours
200	Slight headache; discomfort	3 hours
400	Headache; discomfort	2 hours
600	Headache; discomfort	1 hour
1000-2000	Slight heart palpitations	30 minutes
1000-2000	Tendency to stagger	1.5 hours
1000-2000	Confusion; headache; nausea	2 hours
2000-2500	Unconsciousness	30 minutes
4000	Fatal	Less than 1 hour

The area should be evacuated at carbon monoxide concentrations in excess of 50 ppm.

2. **Methane (CH_4)** - Methane is the most common flammable gas in mines, but other hydrocarbons such as ethane and propane may also be present in trace amounts. While hydrocarbon gases are most often associated with coal mines, they may also be found

in mines adjacent to oil and gas fields, or in strata which contain combustible materials. Methane is odorless, tasteless, and colorless, and stratifies along the ceiling of a drift since it is much lighter than air. Although it is not toxic, it acts as an asphyxiant by diluting oxygen concentration in the air. At a 5% concentration (by volume), methane in air will ignite. This is termed the "lower explosive limit," or "100% LEL." Methane also has an upper explosive limit at 300% LEL (15% by volume in air). Above this level, methane has displaced so much oxygen that there is no longer adequate oxygen to support combustion. These properties of methane are diagramed below:

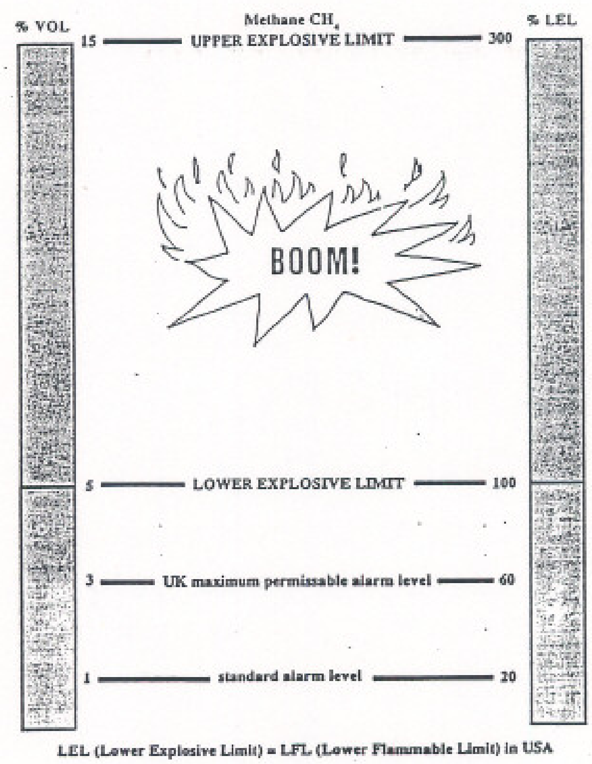

Figure 1. Methane Explosive Limits

The area should be evacuated at methane concentrations in excess of 20% LEL (1% by volume in air).

3. **Oxygen (O_2)** - Oxygen is potentially explosive in high concentrations. This would usually only be a problem where leaky oxygen tanks are stored.

The area should be evacuated at oxygen concentrations in excess of 23%.

4. **Carbon Dioxide (CO_2)** - Carbon dioxide is produced through respiration, combustion (including blasting), or it can exude naturally from coal seams, carbonate strata, and other rock types. It is colorless, much heavier than air, and has a slight acid taste when present in high concentrations.

While carbon dioxide is commonly present in the air (0.03%), it is hazardous in higher concentrations. The following chart demonstrates some of the effects of carbon monoxide.

TABLE III
CARBON DIOXIDE THRESHOLD VALUES AND POTENTIAL SYSMPTOMS

Concentration	Symptoms
5000 ppm (0.5%)	Breathing (ventilation) is deeper and faster than normal
3%	Ventilation doubles
10%	Tolerable only for several minutes at low activity (note: due to air displacement, 10% CO_2 concentration reduces oxygen content to 18.9%)

In typical respiration, we breath air at 20.95% O_2 and 0.03% CO_2, and exhale 16% O_2 and 4% CO_2. In confined spaces, therefore, oxygen can quickly be replaced by carbon dioxide.

Additionally, mining may intercept pressurized CO_2-bearing strata. Being much heavier than air, CO_2 stratifies along the floor of a drift and low-lying areas, displacing the air. This is why extreme caution, proper instrumentation, and approved procedures should be used when descending into a mine.

When entering a mine on a steady downgrade, a person may not be aware of elevated CO_2 until his mouth reaches the CO_2 level. By walking into the area, however, the person has mixed the stratified gas with the good air above. The resulting mixture may be incapable of supporting respiration, and the person may not be able to evacuate the mine.

The area should be evacuated at carbon dioxide concentrations in excess of 5000 ppm (0.5%).

5. **Hydrogen Sulfide (H_2S)** - Hydrogen Sulfide is a colorless, toxic, and flammable gas which can be formed when blasting in sulfide ores, or may occur in some natural gas, oil, and coal fields. Although its foul odor (like rotten eggs) is easily detected at low concentrations, exposure and higher concentrations quickly desensitize the olfactory nerves, leaving a person unaware of its presence. In high concentrations, a person may collapse with little or no warning.

TABLE IV
HYDROGEN SULFIDE THRESHOLD VALUES AND POTENTIAL SYMPTOMS

(These values are approximate and vary with the individual's state of health and degree of physical activity.)

ppm	Effects and Sypmtoms	Time
10	Permissible exposure level	8 hours
50 - 100	Mild eye irritation Mild respiratory irritation	1 hour
200 - 300	Marked eye irritation Marked respiratory irritation	1 hour
500 - 700	Unconscious; death	0.5 - 1 hour
> 1000	Unconscious; death	minutes

The area should be evacuated at hydrogen sulfide concentrations in excess of 10 ppm.

6. **Radon gas (Rn-222)** - Radioactive elements are unstable because, on the atomic level, their nuclei have more

protons and neutrons than they can hold. For instance, uranium-238 (U238) will decay through time to lead-206 (Pb206) in a defined sequence of steps. (See the Uranium Series chart below.) When an atom of a certain element "throws off" an **alpha particle** (composed of two neutrons and two protons, with an atomic mass of four) from its nucleus, it becomes a new element (**"daughter,"** or **"progeny"** in the plural form) with an atomic mass of four less than the original element (**"parent"**). Discharge of an alpha particle in this manner is called "alpha radiation." Due to their size and mass, alpha particles are very damaging to sensitive living tissues.

When the atomic nucleus discharges a **beta particle** (a massless particle similar to an electron, but found only in the nucleus), the atom becomes a new element of the same atomic mass, but different atomic number. Discharge of beta particles is called "beta radiation."

Gamma rays (non-particulate energy rays) may accompany either of these processes. The **half-life** of an element is the time it takes for half of all the atoms present to undergo radioactive decay.

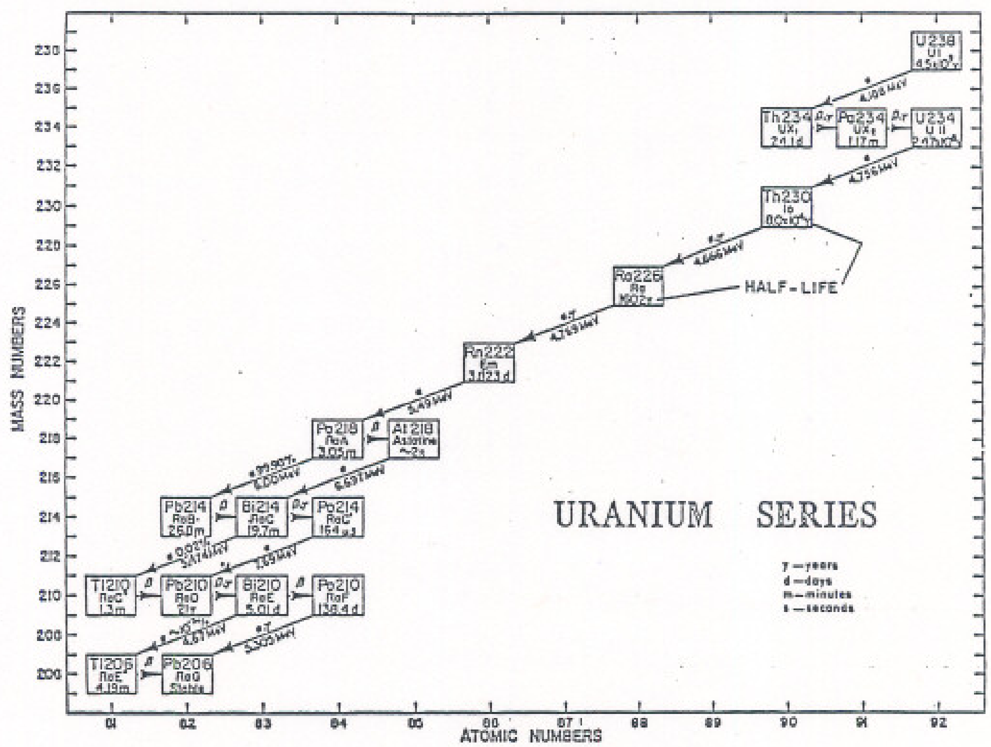

Figure 2. Uranium Series

Most health-threatening radiation problems in natural settings are caused by alpha radiation emitted in the decay of the immediate progeny of radon gas. In brief, three radon daughters [notably Radon-A (RaA), Radon-C (RaC), and Radon-C' (RaC')] are the most active and dangerous alpha-emitters in nature. This is due partially to their short half-lives. For instance, U238 has a half-life of 4.5×10^9 years, so at any given time, any U238 present is emitting little alpha radiation. RaC', however, has a half-life of 16.4 microseconds, so it decays as soon as it is formed, thereby emitting large quantities of alpha.

When an atom of radon gas undergoes radioactive decay, an alpha particle and a RaA atom are produced. RaA then decomposes to Radon-B (RaB) by emitting an alpha particle. Through beta particle emission, RaB decays to RaC and RaC', which in turn decay by giving off more alphas.

The other reason why radon daughters are dangerous has to do with their high affinity for particulates in the air. Radon daughters are solid at standard temperature and pressure, and immediately attach, or "plate out" on dust particles, which can get lodged in lung tissue when inhaled. When the attached daughter undergoes radioactive decay in the lungs, it emits a high-energy alpha particle which in turn collides with and damages cells of the lung tissue. Since there is no "trapping mechanism" for radon **gas** (i.e., radon gas which has not decayed is simply exhaled, and the half life of radon gas is 3.8 days, so it is not directly emitting much alpha radiation), it has relatively little effect on lung tissue.

With extreme or continued low-level exposure to radon progeny, lung tissue is scarred in such a manner that it cannot take oxygen into the bloodstream, thereby reducing breathing efficiency. Damage from this process is irreversible and cumulative through one's lifetime.

While radon progeny are certain to be present to some degree in abandoned uranium mines, they are not limited to this occurrence. Radioactive elements may be associated with other mineralization episodes, and occur in varying proportions throughout nature. Any confined airspace may host radiological activity.

Since radon progeny are airborne, they are controlled by ventilation and dust suppression. Personal protection is achieved through the use of a dust-filtering respirator in low concentrations, and an oxygen-supplied breathing apparatus in high concentrations. In AML situations, the primary radiological concern is damage to lung tissue. Human skin effectively stops alpha radiation. While skin cells may get damaged from alpha exposure, the effect is much less hazardous than typical sunburn damage, and the damaged cells are replaced with new, healthy cells.

Radon daughter concentrations are measured in **working levels (WL)**. Occupational (mining) standards require that respirators be worn in radon daughter concentrations in excess of one WL. Concentrations in excess of ten WL require a supplied-oxygen breathing device. Miners, furthermore, are only allowed to accumulate an exposure of 692 **working level hours** per year. (1 **WLH** is the equivalent of 1 WL exposure for 1 hour, 2 WL for 1/2-hour, etc.) It is important to note that EPA guidelines for the general public are 10% of occupational standards. Therefore, **the general public is allowed 69.2 WLH exposure per year.**

MMB has the instrumentation and expertise to monitor for radon contamination of mine air. Additionally, samples can be taken of soil and water around mines to check for radium-226 (Ra226) levels. (Ra226, a solid, is the direct "parent" of Ra222, and is therefore the best parameter on which to test soil and water contamination. Soil and water radiological pollution standards are therefore primarily based upon Ra226 concentration.) NPS samples are currently being analyzed by EPA through an informal interagency agreement.

For those interested in a detailed paper entitled Radioactivity and Abandoned Mineral Lands is available from MMB.

The area should be evacuated at radon daughter concentrations in excess of 10 WL.

Respirators should be worn in radon daughter concentrations in excess of 1 WL.

C. Falling Hazards

1. **Shafts (Winzes, Raises)** - Shafts are vertical or declined openings exposed on the ground's surface, whereas winzes and raises are declined or inclined openings (respectively) underground inside of a mine. The area around the top of these openings is called the "collar." One of the primary dangers of vertical

openings is when the collar has deteriorated through weathering and wear. Loose rock around a collar, which slopes gradually into a shaft, creates a slipping hazard that can draw its victim into the shaft. Inside a mine, raises and winzes often connect between different levels. An explorer with inadequate lighting could easily walk into a winze left open in the floor. Rotten boards or plywood may also conceal a winze or shaft, and should never be trusted. Always check under any covering in a mined area which looks like it could conceal a vertical opening. Falls could result in a serious injury or death by the following means:

a. Impact on the walls or at the bottom of the shaft during a fall could cause an injury or fatality.

b. The shaft may be a trap for contaminated or oxygen-deficient air, so that the victim who survives the fall may be asphyxiated.

c. The shaft may be flooded at depth, presenting the possibility of drowning.

d. The victim may be unable to climb out, especially if injured. If he were unaccompanied in a remote situation, the victim could starve to death.

2. **Glory Holes** - Many underground mines will follow a mineralized area upward near or to the ground's surface. When underground workings reach or collapse to the surface in this manner, a glory hole is the result. Quite often, the caved area underground is much larger than the hole at the surface, thereby causing the glory hole to collapse and enlarge through time.

3. **Stopes** - Underground stopes are large, often irregular mine openings where an entire zone of mineralization has been excavated. Generally, the larger the stope, the less stable it is. Stopes may reach the ground's surface in the form of a glory hole, or may connect between levels in a mine. With inadequate lighting inside the mine, a person may fall into a stope breaking into the floor from a lower level.

4. **Collapse Zones** - Underground mine workings of any type which are near to the ground's surface may be subject to subsidence or collapse at any time. Be particularly aware of surface depressions around mine sites. Avoid walking in these areas, and see if they may correlate to mapped underground workings in the area.

5. **Highwalls and Steep Pit Walls** - Although this presentation primarily addresses underground mine hazards, it is appropriate to mention these surface mining features briefly. A highwall is the vertical (or near-vertical) exposure of an open cut on its uphill side. Open pits may also have extremely steep walls on all sides, or at least on faces which are not "benched" with roadways. Any steep rock wall exposed by blasting will tend toward instability through time, especially in a surface location where the rock is fully exposed to the forces of weathering. As with shaft collars, erosion near the edges may lead to a decayed, loose surface which increases the possibility of slipping and falling over the edge. For this reason, do not approach the perimeter of a pit or highwall to look over the edge.

D. **Cave-ins** - Unlike caves, mines are artificial, temporary openings which are designed to last as long as it takes to extract the ore. Left untended, rock and ground-support measures deteriorate and become incompetent. Soft, stratified rock types such as shale tend to collapse more easily, but often in smaller pieces. Harder, more massive rock types such as granite or sandstone collapse less frequently, but often more catastrophically in large blocks. Cave-ins may be the result of:

1. **Weak Rock - The first way to assess rock stability is to look at the floor of the mine.** If the floor is covered with loose rock, the mine is most likely unstable. If the floor is clean, rock conditions are most likely fairly stable. Stratified or severely jointed rock types are most prone to collapse under the forces of gravity, or from the force of "overburden" (pressure exerted by overlying rock). An area which is "taking on weight" may make creaking and popping noises, and sometimes rock under stress can be seen to shoot off in splinters. Timbers under stress are also prone to splintering and emitting creaking noises. Other signs of weight stress are crushed timbers or bent support steel beams.

2. **Decayed Timbers** - Through time, timbers which once supported the rock above will oxidize and rot. Although they may remain in-place and appear to provide support, they could be totally ineffective.

3. **Ineffective Rock Bolts** - Rock bolts are used to stabilize weak areas in a mine. Sometimes an abandoned mine may have entire areas where numerous bolts are found dangling several feet below the roof. In these areas, the rock which these bolts once supported has since collapsed.

E. <u>Explosives</u> - It is not uncommon to find explosives in abandoned mines. **Under <u>no</u> circumstances should explosives be <u>handled</u> <u>or</u> <u>touched</u> by anyone other than a certified blaster.** When explosives are found, any distinguishing characteristics should be noted, such as the form of the explosive and any printing on cases or on the explosives themselves. If there is any doubt whether the material in question is an explosive, assume that it is. The chief safety officer and superintendent should be notified and a certified blaster should be contacted to arrange for disposal.

Explosives may be found in several different forms:

1. **Powder** - "Powder" is the miner's term for explosives. Miners will often store their supply of explosives at the end of a drift, or in a small side room off of a main drift in the mine. Explosives are also often stored in a separate cache, away and separate from the rest of the mine. Explosives come in many forms, some of which are listed below:

   Stick Dynamite - Dynamite is produced in various sizes, but basically looks like a paper-wrapped mixture of packed moist sawdust or powder. It may vary typically from 6 inches to 2 feet in length, from 1/2 to 1-1/2 inches in diameter, and is usually packed in 50-pound cases. If the sticks appear wet or have clear beads of moisture on the surface, this is most likely nitroglycerine which has "bled" out of the dynamite. Nitroglycerine is the explosive component of dynamite, and is highly unstable when separated from the matrix of the dynamite stick. Bleeding can occur with age or when dynamite is heated.

   Water Gels - Water gels are similar in shape and packaging to stick dynamite, but have a plastic wrapper enclosing a jelly-like or creamy mixture in any variety of colors.

   ANFO-Prill - Prill, small porous pellets, typically comes in 50-pound bags. Rather than being placed in blast holes by hand, it is typically blown into the holes using compressed air.

   Boosters - Supplement caps and detonating cord when using less sensitive explosives. Vary in size and diameter weighing from 1/3-1 pound. Packaging varies from cans to plastic tubes.

   Detonator Cord - "Det cord" is round, flexible, brightly-colored, hard nylon cord with a center core of high explosive. It is used to connect explosive charges together.

Detonators - Detonators, or blasting caps, are metallic cylinders about the size of a small cigarette with attached wires, plastic tubing, or cord. They may be found in storage caches, or, since they are easy to drop or misplace through carelessness, can be found laying about a mine site. They are very sensitive and are powerful enough to blow off a hand. Should be treated with the same respect as other explosives.

2. **Misfires** - Misfires are explosive charges which for some reason did not detonate with the rest of a blast. Miners check for misfires after each blast, but may sometimes overlook them. In entering a mine, an inspector watches the ribs (sides) back (roof, or ceiling), and faces (ends) of all drifts for misfires. If wires or dynamite can be seen protruding from a drill hole, it should be treated as a misfire. Misfires must be blasted in-place by a certified blaster. **No** attempt should be made to remove a misfire from the hole.

F. **Unsafe Structures and Ladders** - Due to rotting and desiccation, wooden headframes, platforms, ladders, etc. become weak and unstable. They should not be trusted to support your weight.

G. **Pools of Water** - Standing water may conceal flooded lower levels of a mine. Upon entering an abandoned mine, inspectors should probe any standing water in front of them with a bar or stick before proceeding.

H. **Disorientation** - In larger mines, it is easy to become disoriented. This can be quite unsettling, and may lead to panic. In a panic situation, all of the other underground hazards become that much more dangerous.

I. **Dangerous Animals** - An abandoned mine may serve as a refuge for poisonous snakes, disease-infested rats or bats, or to larger predatory mammals.

J. **Hazardous Materials** - Drums or other containers of unknown materials are often abandoned on a mine site or inside the mine itself. These containers should not be opened, and should only be handled by a hazard materials specialist.

K. <u>Danger to Rescue Teams</u> - Many people have lost their lives in attempting to rescue someone else. Parks with AML sites should contact State mine inspectors and safety officers at any nearby active mines. These people may have certified mine rescue teams at their disposal which could be used if a visitor or staff person required rescue from an abandoned mine. **The park dispatcher should have emergency phone numbers for any available certified mine rescue teams.**