

# Mining



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## Chapter- 1

# Introduction to Mining



Chuquibambilla, Chile, site of the largest circumference and second deepest open pit copper mine in the world.



Simplified world mining map

**Mining** is the extraction of valuable minerals or other geological materials from the earth, usually from an ore body, vein or (coal) seam. Materials recovered by mining include base metals, precious metals, iron, uranium, coal, diamonds, limestone, oil shale, rock salt and potash. Any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory, is usually mined. Mining in a wider sense comprises extraction of any non-renewable resource (e.g., petroleum, natural gas, or even water).

Mining of stone and metal has been done since pre-historic times. Modern mining processes involve prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials and finally reclamation of the land to prepare it for other uses once the mine is closed.

The nature of mining processes creates a potential negative impact on the environment both during the mining operations and for years after the mine is closed. This impact has led to most of the world's nations adopting regulations to moderate the negative effects of mining operations. Safety has long been a concern as well, though modern practices have improved safety in mines significantly.

# History

## Prehistoric mining



Chalcolithic copper mine in Timna Valley, Negev Desert, Israel

Since the beginning of civilization, people have used stone, ceramics and, later, metals found on or close to the Earth's surface. These were used to manufacture early tools and weapons, for example, high quality flint found in northern France and southern England were used to create flint tools. Flint mines have been found in chalk areas where seams of the stone were followed underground by shafts and galleries. The mines at Grimes Graves are especially famous, and like most other flint mines, are Neolithic in origin (ca 4000 BC-ca 3000 BC). Other hard rocks mined or collected for axes included the greenstone of the Langdale axe industry based in the English Lake District.

The oldest known mine on archaeological record is the "Lion Cave" in Swaziland. At this site, which by radiocarbon dating proves the mine to be about 43,000 years old, paleolithic humans mined mineral hematite, which contained iron and was ground to produce the red pigment ochre.

Mines of a similar age in Hungary are believed to be sites where Neanderthals may have mined flint for weapons and tools.

## **Ancient Egypt**

Ancient Egyptians mined malachite at Maadi. At first, Egyptians used the bright green malachite stones for ornamentations and pottery. Later, between 2,613 and 2,494 BC, large building projects required expeditions abroad to the area of Wadi Maghara in order "to secure minerals and other resources not available in Egypt itself." Quarries for turquoise and copper were also found at "Wadi Hamamat, Tura, Aswan and various other Nubian sites" on the Sinai Peninsula and at Timna.

Mining in Egypt occurred in the earliest dynasties, and the gold mines of Nubia were among the largest and most extensive of any in Ancient Egypt, and are described by the Greek author Diodorus Siculus. He mentions that fire-setting was one method used to break down the hard rock holding the gold. One of the complexes is shown in one of earliest known maps. They crushed the ore and ground it to a fine powder before washing the powder for the gold dust.

## **Medieval Europe**



Agricola, author of *De Re Metallica*

Mining as an industry underwent dramatic changes in medieval Europe. The mining industry in the early Middle Ages was mainly focused on the extraction of copper and iron. Other precious metals were also used mainly for gilding or coinage. Initially, many metals were obtained through open-pit mining, and ore was primarily extracted from shallow depths, rather than through the digging of deep mine shafts. Around the 14th century, the demand for weapons, armor, stirrups, and horseshoes greatly increased the demand for iron. Medieval knights for example were often laden with up to 100 pounds of plate or chain link armor in addition to swords, lances and other weapons. The overwhelming dependency on iron for military purposes helped to spur increased iron production and extraction processes.

These new military applications coincided with a population explosion throughout Europe in the 11th-14th centuries which enriched the demand for precious metals in order to fill a currency shortage. The silver crisis of 1465 occurred when the mines had all reached depths at which the shafts could no longer be pumped dry with the available technology. Although the increased use of bank notes and the use of credit during this period did decrease the dependence and value of precious metals, these forms of currency still remained vital to the story of medieval mining. Use of water power in the form of water mills was extensive; they were employed in crushing ore, raising ore from shafts and ventilating galleries by powering giant bellows. Black powder was first used in mining in Selmechánya, Kingdom of Hungary (present-day Banská Štiavnica, Slovakia) in 1627. Black powder allowed blasting of rock and earth to loosen and reveal ore veins, which was much faster than fire-setting, in which rock was exposed to heat and then doused with cold water. Black powder allowed the mining of previously impenetrable metals and ores. In 1762, the world's first mining academy was established in the same town.

The widespread adoption of agricultural innovations such as the iron plowshare, as well as the growing use of metal as a building material, was also a driving force in the tremendous growth of the iron industry during this period. Inventions like the arrastra were often used by the Spanish to pulverize ore after being mined. This device employed animal power and utilized mechanical principles similar to that of the ancient Middle Eastern technology of grain threshing.

Much of our knowledge of Medieval mining techniques comes from books such as Biringuccio's *De la pirotechnia* and probably most importantly from Georg Agricola's *De re metallica* (1556). These books detail many different mining methods used in German and Saxon mines. One of the prime issues confronting medieval miners (and one which Agricola explains in detail) was the removal of water from mining shafts. As miners dug deeper to access new veins, flooding became a very real obstacle. As a result the mining industry became dramatically more efficient and prosperous as the use of various mechanical and animal driven pump systems were implemented.

## North and South America



Lead mining in the upper Mississippi River region of the U.S., 1865



Miners at the Tamarack Mine in Copper Country, Michigan, U.S. in 1905

In North America there are ancient, prehistoric copper mines along Lake Superior. "Indians availed themselves of this copper starting at least 5000 years ago," and copper tools, arrowheads, and other artifacts that were part of an extensive native trade network have been discovered. In addition, obsidian, flint, and other minerals were mined, worked, and traded. While the early French explorers that encountered the sites made no use of the metals due to the difficulties in transporting it, the copper was eventually traded throughout the continent along major river routes. In Manitoba, Canada, there also are ancient quartz mines near Waddy Lake and surrounding regions.

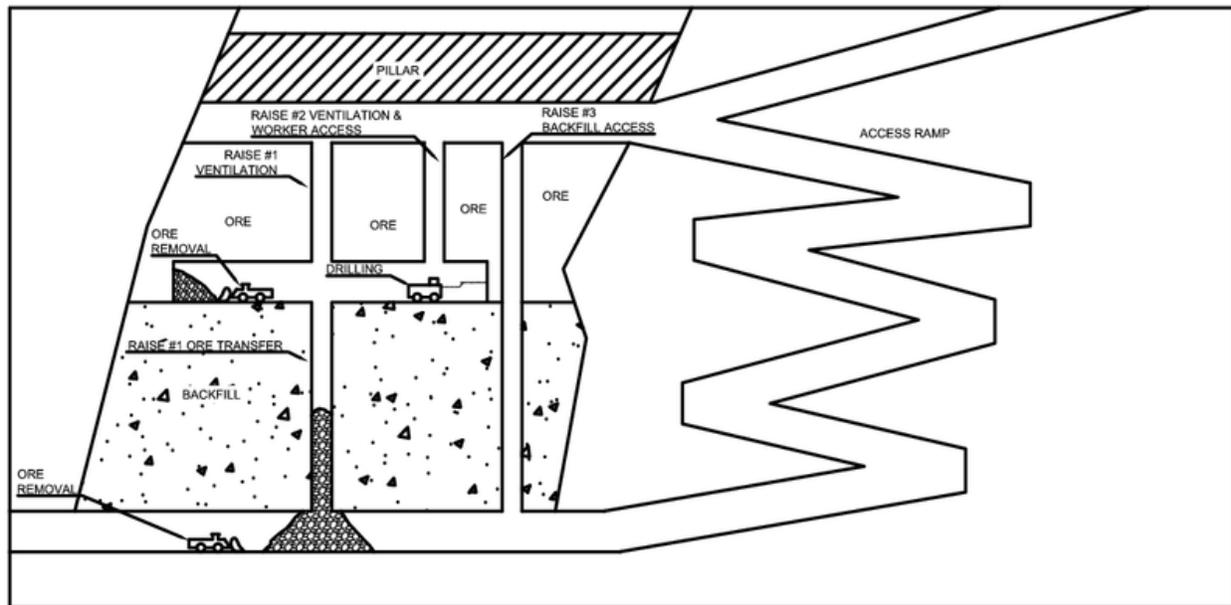
In the early colonial history of the Americas, "native gold and silver was quickly expropriated and sent back to Spain in fleets of gold- and silver-laden galleons" mostly from mines in Central and South America. Turquoise dated at 700 A.D. was mined in pre-Columbian America; in the Cerillos Mining District in New Mexico, estimates are that "about 15,000 tons of rock had been removed from Mt Chalchihuitl using stone tools before 1700."

Mining in the United States became prevalent in the 19th century, and the General Mining Act of 1872 was passed to encourage mining of federal lands. As with the California Gold Rush in the

mid 19th century, mining for minerals and precious metals, along with ranching, was a driving factor in the Westward Expansion to the Pacific coast. With the exploration of the West, mining camps were established and "expressed a distinctive spirit, an enduring legacy to the new nation;" Gold Rushers would experience the same problems as the Land Rushers of the transient West that preceded them. Aided by railroads, many traveled West for work opportunities in mining. Western cities such as Denver and Sacramento originated as mining towns.

## Mining methods and procedures

### Steps of mine development



Schematic of a cut and fill mining operation in hard rock

The process of mining from discovery of an ore body through extraction of minerals and finally to returning the land to its natural state consists of several distinct steps. The first is discovery of the ore body, which is carried out through prospecting or exploration to find and then define the extent, location and value of the ore body. This leads to a mathematical resource estimation to estimate the size and grade of the deposit.

This estimation is used to conduct a pre-feasibility study to determine the theoretical economics of the ore deposit. This identifies, early on, whether further investment in estimation and engineering studies is warranted and identifies key risks and areas for further work. The next step is to conduct a feasibility study to evaluate the financial viability, technical and financial risks and robustness of the project.

This is when the mining company makes the decision to develop the mine or to walk away from the project. This includes mine planning to evaluate the economically recoverable portion of the deposit, the metallurgy and ore recoverability, marketability and payability of the ore

concentrates, engineering concerns, milling and infrastructure costs, finance and equity requirements and an analysis of the proposed mine from the initial excavation all the way through to reclamation.

Once the analysis determines a given ore body is worth recovering, development begins to create access to the ore body. The mine buildings and processing plants are built and any necessary equipment is obtained. The operation of the mine to recover the ore begins and continues as long as the company operating the mine finds it economical to do so. Once all the ore that the mine can produce profitably is recovered, reclamation begins to make the land used by the mine suitable for future use.

## **Mining techniques**



Underground Longwall mining

Mining techniques can be divided into two common excavation types: surface mining and sub-surface (underground) mining. Surface mining is much more common, and produces, for example, 85% of minerals (excluding petroleum and natural gas) in the United States, including 98% of metallic ores. Targets are divided into two general categories of materials: *placer deposits*, consisting of valuable minerals contained within river gravels, beach sands, and other

unconsolidated materials; and *lode deposits*, where valuable minerals are found in veins, in layers, or in mineral grains generally distributed throughout a mass of actual rock. Both types of ore deposit, placer or lode, are mined by both surface and underground methods.

Processing of placer ore material consists of gravity-dependent methods of separation, such as sluice boxes. Only minor shaking or washing may be necessary to disaggregate (unclump) the sands or gravels before processing. Processing of ore from a lode mine, whether it is a surface or subsurface mine, requires that the rock ore be crushed and pulverized before extraction of the valuable minerals begins. After lode ore is crushed, recovery of the valuable minerals is done by one, or a combination of several, mechanical and chemical techniques.



Uranium mine near Moab, Utah

Some mining, including much of the rare earth elements and uranium mining, is done by less-common methods, such as in-situ leaching: this technique involves digging neither at the surface nor underground. The extraction of target minerals by this technique requires that they be soluble, e.g., potash, potassium chloride, sodium chloride, sodium sulfate, which dissolve in water. Some minerals, such as copper minerals and uranium oxide, require acid or carbonate solutions to dissolve.

Surface mining is done by removing (stripping) surface vegetation, dirt, and if necessary, layers of bedrock in order to reach buried ore deposits. Techniques of surface mining include; Open-pit mining which consists of recovery of materials from an open pit in the ground, quarrying or gathering building materials from an open pit mine, strip mining which consists of stripping surface layers off to reveal ore/seams underneath, and mountaintop removal, commonly associated with coal mining, which involves taking the top of a mountain off to reach ore deposits at depth. Most (but not all) placer deposits, because of their shallowly buried nature, are mined by surface methods. Landfill mining, finally, involves sites where landfills are excavated and processed.

Sub-surface mining consists of digging tunnels or shafts into the earth to reach buried ore deposits. Ore, for processing, and waste rock, for disposal, are brought to the surface through the tunnels and shafts. Sub-surface mining can be classified by the type of access shafts used, the extraction method or the technique used to reach the mineral deposit. Drift mining utilizes horizontal access tunnels, slope mining uses diagonally sloping access shafts and shaft mining consists of vertical access shafts.

Other methods include shrinkage stope mining which is mining upward creating a sloping underground room, long wall mining which is grinding a long ore surface underground and room and pillar which is removing ore from rooms while leaving pillars in place to support the roof of the room. Room and pillar mining often leads to retreat mining which is removing the pillars which support rooms, allowing the room to cave in, loosening more ore. Additional sub-surface mining methods include hard rock mining which is mining of hard materials, bore hole mining, drift and fill mining, long hole slope mining, sub level caving and block caving



Garzweiler open-pit mine, Germany

## Machinery



The Bagger 288 is a bucket-wheel excavator used in strip mining

Heavy machinery is needed in mining for exploration and development, to remove and stockpile overburden, to break and remove rocks of various hardness and toughness, to process the ore and for reclamation efforts after the mine is closed. Bulldozers, drills, explosives and trucks are all necessary for excavating the land. In the case of placer mining, unconsolidated gravel, or alluvium, is fed into machinery consisting of a hopper and a shaking screen or trommel which frees the desired minerals from the waste gravel. The minerals are then concentrated using sluices or jigs.

Large drills are used to sink shafts, excavate stopes and obtain samples for analysis. Trams are used to transport miners, minerals and waste. Lifts carry miners into and out of mines, as well as moving rock and ore out, and machinery in and out of underground mines. Huge trucks, shovels and cranes are employed in surface mining to move large quantities of overburden and ore. Processing plants can utilize large crushers, mills, reactors, roasters and other equipment to consolidate the mineral-rich material and extract the desired compounds and metals from the ore.

### **Extractive metallurgy**

The science of extractive metallurgy is a specialized area in the science of metallurgy that studies the extraction of valuable metals from their ores, especially through chemical or mechanical means. Mineral processing (or mineral dressing) is a specialized area in the science of metallurgy that studies the mechanical means of crushing, grinding, and washing that enable the separation (extractive metallurgy) of valuable metals or minerals from their gangue (waste material). Since most metals are present in ores as oxides or sulfides, the metal needs to be reduced to its metallic form. This can be accomplished through chemical means such as smelting or through electrolytic reduction, as in the case of aluminum. Geometallurgy combines the geologic sciences with extractive metallurgy and mining.

## **Regulations and World Bank relationship**

The World Bank has been involved in mining since 1955, mainly through grants from its International Bank for Reconstruction and Development, with the Bank's Multilateral Investment Guarantee Agency offering political risk insurance. Between 1955 and 1990 it provided about \$2 billion to fifty mining projects, broadly categorized as reform and rehabilitation, greenfield mine construction, mineral processing, technical assistance, and engineering. These projects have been criticized, particularly the Ferro Carajas project of Brazil, begun in 1981. The bank established mining codes intended to increase foreign investment, in 1988 solicited feedback from 45 mining companies on how to increase their involvement.

In 1992 the bank began to push for privatization of government-owned mining companies with a new set of codes, beginning with its report *The Strategy for African Mining*. In 1997, Latin America's largest miner Companhia Vale do Rio Doce (CVRD) was privatized. These and other movements such as the Philippines 1995 Mining Act led the World Bank to publish a third report (*Assistance for Minerals Sector Development and Reform in Member Countries*) which endorsed mandatory environment impact assessments and attention to the locals. The codes based on this report are influential in the legislation of developing nations. The new codes are intended to encourage development through tax holidays, zero custom duties, reduced income taxes, and

related measures. The results of these codes were analyzed by a group from the University of Quebec, which concluded that the codes promote foreign investment but "fall very short of permitting sustainable development". The observed negative correlation between natural resources and economic development is known as the resource curse.

## **Mining industry**

Mining exists in many countries but Australia and Canada have a reputation for domestic mining expertise, and London is known as the capital of global "mining houses" such as Rio Tinto, BHP Billiton, and Anglo American PLC. The US mining industry is also large but it is dominated by the coal and nonmetal minerals, and the various regulations have worked to reduce the significance of mining in the United States. In 2007 the total market cap of mining companies was reported at US\$962 billion, which compares to a total global market cap of publicly traded companies of about US\$50 trillion in 2007.

While exploration and mining can sometimes be conducted by individual entrepreneurs or small business, most modern-day mines are large enterprises requiring large amounts of capital to establish. Consequently, the mining sector of the industry is dominated by large, often multinational companies, most of them publicly listed. It can be argued that what is referred to as the 'mining industry' is actually two sectors, one specializing in exploration for new resources, the other specializing in mining those resources. The exploration sector is typically made up of individuals and small mineral resource companies ("juniors") dependent on venture capital. The mining sector is typically large and multi-national companies sustained by mineral production from their mining operations. In addition to these two sectors, various other industries such as equipment manufacture, environmental testing and metallurgy analysis also rely on and support the mining industry throughout the world. Canadian stock exchanges have a particular focus on mining companies, particularly junior exploration companies through the TSX Venture Exchange; Canadian companies raise capital on these exchanges and then invest the money in exploration globally. Some have argued that below juniors there exists a substantial sector of illegitimate companies primarily focused on manipulating stock prices.

Mining operations can be grouped into five major categories in terms of their respective resources. These are, oil and gas extraction, coal mining, metal ore mining, nonmetallic mineral mining and quarrying, and support activities for mining. Out of all these categories, oil and gas extraction remains one of the largest in terms of its global economic importance. Prospecting potential mining sites, a vital area of concern for the mining industry is now done using sophisticated new technologies such as seismic prospecting and remote-sensing satellites.

### **Corporate classifications**

Mining companies can be classified based on their size and financial capabilities:

- **Major** companies are considered to have an adjusted annual mining-related revenue of more than US\$500 million, with the financial capability to develop a major mine on its own.

- **Intermediate** companies have at least \$50 million in annual revenue but less than \$500 million.
- **Junior** companies rely on equity financing as their principal means of funding exploration. Juniors are mainly pure exploration companies, but may also produce minimally, and do not have a revenue of US\$50 million.

## Safety



Danger sign at an old Arizona mine



Abandoned mine entrance in Yorkshire, England, United Kingdom

Safety has long been a controversial issue in the mining business especially with sub-surface mining. While mining today is substantially safer than it was in the previous decades, mining accidents are often very high profile, such as the Quecreek Mine Rescue saving 9 trapped Pennsylvania coal miners in 2002. The Courrières mine disaster, Europe's worst mining accident, caused the death of 1,099 miners (including many children) in Northern France on 10 March 1906. It seems that this disaster was surpassed only by the Benxihu Colliery accident in China on April 26, 1942, which killed 1,549 miners. Government figures indicate that 5,000 Chinese miners die in accidents each year, while other reports have suggested a figure as high as 20,000. Mining ventilation is a significant safety concern for many miners. Poor ventilation of the mines causes exposure to harmful gases, heat and dust inside sub-surface mines. These can cause harmful physiological effects, including death. The concentration of methane and other airborne contaminants underground can generally be controlled by dilution (ventilation), capture before entering the host air stream (methane drainage), or isolation (seals and stoppings).

Ignited methane gas is a common source of explosions in coal mines, or, the more violent coal dust explosions. Gases in mines can also poison the workers or displace the oxygen in the mine, causing asphyxiation. For this reason, the MSHA requires that workers have gas detection equipment in groups of miners. It must be able to detect common gases, such as CO, O<sub>2</sub>, H<sub>2</sub>S, and % Lower Explosive Limit. Additionally, further regulation is being requested for more gas detection as newer technology such as nanotechnology is introduced.

High temperatures and humidity may result in heat-related illnesses, including heat stroke which can be fatal. Dusts can cause lung problems, including silicosis, asbestosis and pneumoconiosis (also known as miners lung or black lung disease). A ventilation system is set up to force a stream of air through the working areas of the mine. The air circulation necessary for the effective ventilation of a mine is generated by one or more large mine fans, usually located above ground. Air flows in one direction only, making circuits through the mine such that each main work area constantly receives a supply of fresh air.

Miners utilize equipment strong enough to break through extremely hard layers of the Earth's crust. This equipment, combined with the closed workspace that underground miners work in, can cause hearing loss. For example, a roof bolter (commonly used by mine roof bolter operators) can reach sound power levels of up to 115 dB. Combined with the reverberant effects of underground mines, a miner without proper hearing protection is at a high risk for hearing loss.

Since mining entails removing dirt and rock from its natural location creating large empty pits, rooms and tunnels, cave-ins are a major concern within mines. Modern techniques for timbering and bracing walls and ceilings within sub-surface mines have reduced the number of fatalities due to cave-ins, but accidents still occur. The presence of heavy equipment in confined spaces also poses a risk to miners, and despite modern improvements to safety practices, mining remains dangerous throughout the world.

### **Abandoned mines**



Warning sign near Jerome, Arizona



Abandoned mine in Nevada

There are upwards of 560,000 abandoned mines on public and privately owned lands in the United States alone. Abandoned mines pose a threat to anyone who may attempt to explore them without proper knowledge and safety training. Old mines are often dangerous and can contain deadly gases. Standing water in mines from seepage or infiltration poses a significant hazard as the water can hide deep pits and trap gases below the water. Additionally, since weather may have eroded the earth and rock surrounding it, the entrance to an old mine in particular can be very dangerous. Old mine workings, caves, etc. are commonly hazardous simply due to the lack of oxygen in the air, a condition in mines known as blackdamp.

## Records

As of 2008, the deepest mine in the world is TauTona in Carletonville, South Africa at 3.9 kilometers, replacing Savuka Mine in the North West Province of South Africa at 3,774 meters. East Rand Mine in Boksburg, South Africa briefly held the record at 3,585 meters, and the first mine declared the deepest in the world was also TauTona when it was at 3,581 meters. The deepest mine in Europe is Pyhäsalmi Mine in Pyhäjärvi, Finland at 1,444 meters. The second deepest mine in Europe is Boulby Mine England at 1,400 meters (shaft depth 1,100 meters).

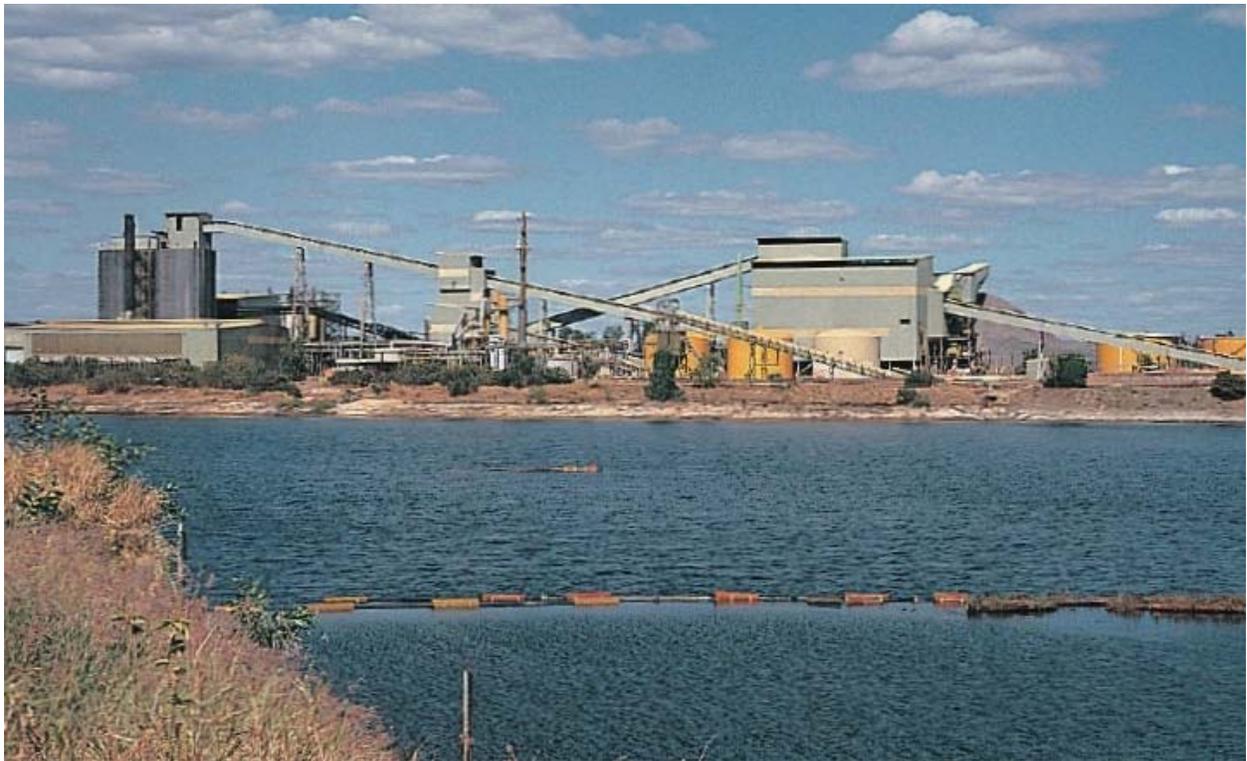
The deepest open pit mine in the world is Bingham Canyon Mine in Bingham Canyon, Utah, United States at over 1,200 meters. The largest and second deepest open pit copper mine in the world is Chuquicamata in Chuquicamata, Chile at 900 meters, 940,600 tons of copper and 17,700 tons of molybdenum produced annually.

The deepest open pit mine with respect to sea level is Tagebau Hambach in Germany, where the ground of the pit is 293 meters below sea level.

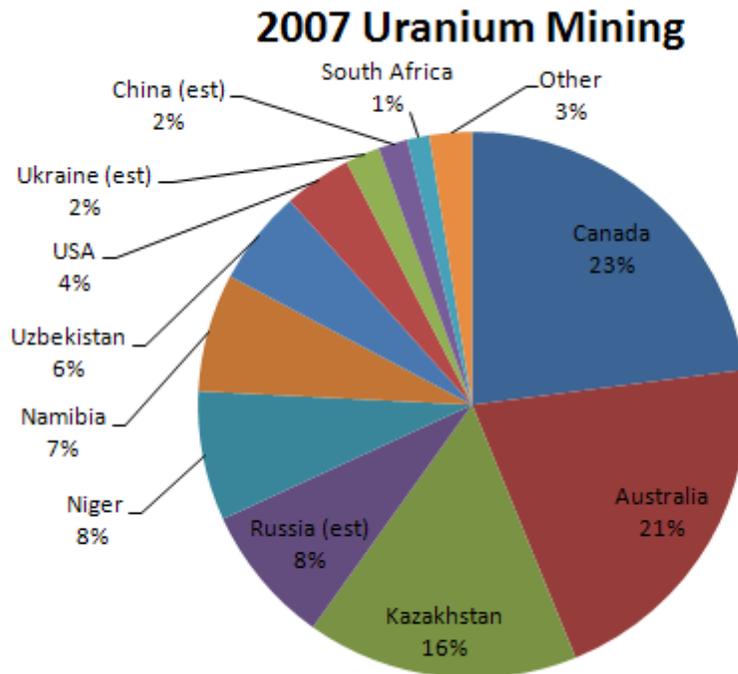
The largest underground mine: El Teniente, in Rancagua, Chile, 2,400 kilometers of underground drifts, 418,000 tons of copper yearly. The deepest borehole in the world is Kola Superdeep Borehole at 12,262 meters. This, however, is not a matter of mining but rather related to scientific drilling.

## Chapter- 2

# Uranium Mining



The Ranger Uranium Mine in Australia



2007 uranium mining, by nationality

**Uranium mining** is the process of extraction of uranium ore from the ground. As uranium ore is mostly present at relatively low concentrations, most uranium mining is very volume-intensive, and thus tends to be undertaken as open-pit mining. It is also undertaken in only a small number of countries of the world, partly because sufficiently high uranium concentrations to motivate mining at current prices are rare.

The worldwide production of uranium in 2009 amounted to 50,572 tonnes, of which 27% was mined in Kazakhstan. Kazakhstan, Canada, and Australia are the top three producers and together account for 63% of world uranium production. Other important uranium producing countries in excess of 1000 tonnes per year are Namibia, Russia, Niger, Uzbekistan, and the United States.

A prominent use of uranium from mining is as fuel for nuclear power plants. As of 2008, known uranium ore resources that can be mined at about current costs are estimated to be sufficient to produce fuel for about a century, based on current consumption rates.

After mining uranium ores, they are normally processed by grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching. The milling process commonly yields dry powder-form material consisting of natural uranium, "yellowcake," which is sold on the uranium market as  $U_3O_8$ .

# History

Uranium minerals were noticed by miners for a long time prior to the discovery of uranium in 1789. The uranium mineral pitchblende, also known as uraninite, was reported from the Erzgebirge Ore Mountains, Saxony, as early as 1565. Other early reports of pitchblende date from 1727 in Joachimsthal and 1763 in Schwarzwald.

In the early 19th century, uranium ore was recovered as a byproduct of mining in Saxony, Bohemia, and Cornwall. The first deliberate mining of radioactive ores took place in Jáchymov, also known by its German name Joachimsthal, a silver-mining city in what is now the Czech Republic. Marie Curie used pitchblende ore from Jáchymov to isolate the element radium, a decay product of uranium; her death was from aplastic anemia, almost certainly due to exposure to radioactivity. Until World War II uranium mining was done primarily for the radium content. Sources for radium, contained in the uranium ore, were sought for use as luminous paint for watch dials and other instruments, as well as for health-related applications, some of which in retrospect might have been harmful. The byproduct uranium was used mostly as a yellow pigment.

In the United States, the first radium/uranium ore was discovered in 1871 in gold mines near Central City, Colorado. This district produced about 50 tons of high grade ore between 1871 and 1895. However, most American uranium ore before World War II came from vanadium deposits on the Colorado Plateau of Utah and Colorado.

In Cornwall, the South Terras Mine near St. Stephen opened for uranium production in 1873, and produced about 175 tons of ore before 1900. Other early uranium mining occurred in Autunois in France's Massif Central, Oberpfalz in Bavaria, and Billingen in Sweden.

The Shinkolobwe deposit in Katanga, Belgian Congo now Shaba Province, Zaire was discovered in 1913, and exploited by the Union Minière du Haut Katanga. Other important early deposits include Port Radium, near Great Bear Lake, Canada discovered in 1931, along with Beira Province, Portugal; Tyuya Muyun, Uzbekistan, and Radium Hill, Australia.

Because of the need for the uranium for bomb research during World War II, the Manhattan Project used a variety of sources for the element. The Manhattan Project initially purchased uranium ore from the Belgian Congo, through the Union Minière du Haut Katanga. Later the project contracted with vanadium mining companies in the American Southwest. Purchases were also made from the Eldorado Mining and Refining Limited company in Canada. This company had large stocks of uranium as waste from its radium refining activities.

American uranium ores mined in Colorado were mixed ores of vanadium and uranium, but because of wartime secrecy, the Manhattan Project would publicly admit only to purchasing the vanadium, and did not pay the uranium miners for the uranium content. In a much later lawsuit, many miners were able to reclaim lost profits from the U.S. government. American ores had much lower uranium concentrations than the ore from the Belgian Congo, but they were pursued vigorously to ensure nuclear self-sufficiency.

Similar efforts were undertaken in the Soviet Union, which did not have native stocks of uranium when it started developing its own atomic weapons program.

Intensive exploration for uranium started after the end of World War II as a result of the military and civilian demand for uranium. There were three separate periods of uranium exploration or "booms." These were from 1956 to 1960, 1967 to 1971, and from 1976 to 1982.

In the 20th century the United States was the world's largest uranium producer. Grants Uranium District in northwestern New Mexico was the largest United States uranium producer. The Gas Hills Uranium District, was the second largest uranium producer. The famous Lucky Mc Mine is located in the Gas Hills near Riverton, Wyoming. Canada has since surpassed the United States as the cumulative largest producer in the world.

## **Types of uranium deposits**

Many different types of uranium deposits have been discovered and mined.

### **Uranium deposits in sedimentary rock**



A Uranium mine, near Moab, Utah. Note alternating red and white/green sandstone. This corresponds to oxidized and reduced conditions in groundwater redox chemistry. The rock forms in oxidizing conditions, and is then "bleached" to the white/green state when a reducing fluid passes through the rock. The reduced fluid can also carry Uranium-bearing minerals.

Uranium deposits in sedimentary rocks include those in sandstone (in Canada and the western US), Precambrian unconformities (in Canada), phosphate, Precambrian quartz-pebble conglomerate, collapse breccia pipes, and calcrete.

Sandstone uranium deposits are generally of two types. **Roll-front** type deposits occur at the boundary between the up dip and oxidized part of a sandstone body and the deeper down dip reduced part of a sandstone body. **Peneconcordant** sandstone uranium deposits, also called **Colorado Plateau**-type deposits, most often occur within generally oxidized sandstone bodies, often in localized reduced zones, such as in association with carbonized wood in the sandstone.

Precambrian quartz-pebble conglomerate-type uranium deposits occur only in rocks older than two billion years old. The conglomerates also contain pyrite. These deposits have been mined in the Blind River-Elliot Lake district of Ontario, Canada, and from the gold-bearing Witwatersrand conglomerates of South Africa.

### **Igneous or hydrothermal uranium deposits**

Hydrothermal uranium deposits encompass the vein-type uranium ores. Igneous deposits include nepheline syenite intrusives at Ilimaussaq, Greenland; the disseminated uranium deposit at Rossing, Namibia; and uranium-bearing pegmatites. Disseminated deposits are also found in the states of Washington and Alaska in the US.

## **Exploration**

Uranium prospecting is similar to other forms of mineral exploration with the exception of some specialized instruments for detecting the presence of radioactive isotopes.

The Geiger counter was the original radiation detector, recording the total count rate from all energy levels of radiation. Ionization chambers and Geiger counters were first adapted for field use in the 1930s. The first transportable Geiger–Müller counter (weighing 25 kg) was constructed at the University of British Columbia in 1932. H.V. Ellsworth of the GSC built a lighter weight, more practical unit in 1934. Subsequent models were the principal instruments used for uranium prospecting for many years, until geiger counters were replaced by scintillation counters.

The use of airborne detectors to prospect for radioactive minerals was first proposed by G.C. Ridland, a geophysicist working at Port Radium in 1943. In 1947, the earliest recorded trial of airborne radiation detectors (ionization chambers and Geiger counters) was conducted by Eldorado Mining and Refining Limited. (a Canadian Crown Corporation since sold to become Cameco Corporation). The first patent for a portable gamma-ray spectrometer was filed by Professors Pringle, Roulston & Brownell of the University of Manitoba in 1949, the same year as they tested the first portable scintillation counter on the ground and in the air in northern Saskatchewan.

Airborne gamma-ray spectrometry is now the accepted leading technique for uranium prospecting with worldwide applications for geological mapping, mineral exploration & environmental monitoring.

A deposit of uranium, discovered by geophysical techniques, is evaluated and sampled to determine the amounts of uranium materials that are extractable at specified costs from the deposit. Uranium reserves are the amounts of ore that are estimated to be recoverable at stated costs.

## **Mining techniques**

As with other types of hard rock mining there are several methods of extraction. The main methods of mining are *box cut* mining, *open pit* mining and *In-situ leaching* (ISL).

### **Open pit**

In open pit mining, overburden is removed by drilling and blasting to expose the ore body, which is then mined by blasting and excavation using loaders and dump trucks. Workers spend much time in enclosed cabins thus limiting exposure to radiation. Water is extensively used to suppress airborne dust levels.

### **Underground uranium mining**

If the uranium is too far below the surface for open pit mining, an underground mine might be used with tunnels and shafts dug to access and remove uranium ore. There is less waste material removed from underground mines than open pit mines, however this type of mining exposes underground workers to the highest levels of radon gas.

Underground uranium mining is in principle no different to any other hard rock mining and other ores are often mined in association (e.g. copper, gold, silver). Once the ore body has been identified a shaft is sunk in the vicinity of the ore veins, and crosscuts are driven horizontally to the veins at various levels, usually every 100 to 150 metres. Similar tunnels, known as drifts, are driven along the ore veins from the crosscut. To extract the ore, the next step is to drive tunnels, known as raises when driven upwards and winzes when driven downwards through the deposit from level to level. Raises are subsequently used to develop the stopes where the ore is mined from the veins.

The stope, which is the workshop of the mine, is the excavation from which the ore is extracted. Two methods of stope mining are commonly used. In the "cut and fill" or open stoping method, the space remaining following removal of ore after blasting is filled with waste rock and cement. In the "shrinkage" method, only sufficient broken ore is removed via the chutes below to allow miners working from the top of the pile to drill and blast the next layer to be broken off, eventually leaving a large hole. Another method, known as room and pillar, is used for thinner, flatter ore bodies. In this method the ore body is first divided into blocks by intersecting drives, removing ore while so doing, and then systematically removing the blocks, leaving enough ore for roof support.

## Heap leaching

Heap leaching is a process by which chemicals (usually sulfuric acid) are used to extract the economic element from the ore. Heap leaching is generally only economically feasible only for oxide ore deposits. Oxidation of sulphide deposits occur during the geological process called weatherization. Therefore oxide ore deposits are typically found close to the surface. If there are no other economic elements within the ore a mine might choose to extract the Uranium using a leaching agent, usually a low molar sulphuric acid.

If the economic and geological conditions are right, the mining company will level large areas of land with a small gradient, layering it with thick plastic (usually HDPE or LLDPE), sometimes with clay, silt or sand beneath the plastic liner. The extracted ore will typically be run through a crusher and placed in heaps atop the plastic. The leaching agent will then be sprayed on the ore for 30–90 days. As the leaching agent filters through the heap the Uranium will break its bonds with the oxide rock and enter the solution. The solution will then filter along the gradient into collecting pools which will then be pumped to on-site plants for further processing. Only some of the Uranium (commonly about 70%) is actually extracted.

The Uranium concentrations within the solution are very important for the efficient separation of pure uranium from the acid. As different heaps will yield different concentrations the solution is pumped to a mixing plant that is carefully monitored. The properly balanced solution is then pumped into a processing plant where the Uranium is separated from the sulphuric acid.

Heap leach is significantly cheaper than traditional milling processes. The low costs allow for lower grade ore to be economically feasible (given that it is the right type of ore body). Environmental law requires that the surrounding ground water is continually monitored for possible contamination. The mine will also have to have continued monitoring even after the shutdown of the mine. In the past mining companies would sometimes go bankrupt, leaving the responsibility of mine reclamation to the public. Recent additions to the mining law require that companies set aside the money for reclamation before the beginning of the project. The money will be held by the public to insure adherence to environmental standards if the company were to ever go bankrupt.

Another very similar mining technique is called in situ, or in place mining where the ore doesn't even need extracting.

## *In-situ leaching*



Trial well field for in-situ recovery at Honeymoon, South Australia

In-situ leaching (ISL), also known as solution mining, or in-situ recovery (ISR) in North America, involves leaving the ore where it is in the ground, and recovering the minerals from it by dissolving them and pumping the pregnant solution to the surface where the minerals can be recovered. Consequently there is little surface disturbance and no tailings or waste rock generated. However, the orebody needs to be permeable to the liquids used, and located so that they do not contaminate ground water away from the orebody.

Uranium ISL uses the native groundwater in the orebody which is fortified with a complexing agent and in most cases an oxidant. It is then pumped through the underground orebody to recover the minerals in it by leaching. Once the pregnant solution is returned to the surface, the uranium is recovered in much the same way as in any other uranium plant (mill).

In Australian ISL mines (Beverley and the soon to be opened Honeymoon Mine) the oxidant used is hydrogen peroxide and the complexing agent sulfuric acid. Kazakh ISL mines generally do not employ an oxidant but use much higher acid concentrations in the circulating solutions. ISL mines in the USA use an alkali leach due to the presence of significant quantities of acid-

consuming minerals such as gypsum and limestone in the host aquifers. Any more than a few percent carbonate minerals means that alkali leach must be used in preference to the more efficient acid leach

The Australian government has published a best practice guide for in situ leach mining of uranium, which is being revised to take account of international differences.

## Recovery from seawater

The uranium concentration of sea water is low, approximately 3.3 mg per cubic meter of seawater (3.3 ppb). But the quantity of this resource is gigantic and some scientists believe this resource is practically limitless with respect to world-wide demand. That is to say, if even a portion of the uranium in seawater could be used the entire world's nuclear power generation fuel could be provided over a long time period. Some anti-nuclear proponents claim this statistic is exaggerated. Although research and development for recovery of this low-concentration element by inorganic adsorbents such as titanium oxide compounds, has occurred since the 1960s in the United Kingdom, France, Germany, and Japan, this research was halted due to low recovery efficiency.

At the Takasaki Radiation Chemistry Research Establishment of the Japan Atomic Energy Research Institute (JAERI Takasaki Research Establishment), research and development has continued culminating in the production of adsorbent by irradiation of polymer fiber. Adsorbents have been synthesized that have a functional group (amidoxime group) that selectively adsorbs heavy metals, and the performance of such adsorbents has been improved. Uranium adsorption capacity of the polymer fiber adsorbent is high, approximately tenfold greater in comparison to the conventional titanium oxide adsorbent.

One method of extracting uranium from seawater is using a uranium-specific nonwoven fabric as an adsorbent. The total amount of uranium recovered from three collection boxes containing 350 kg of fabric was >1 kg of yellowcake after 240 days of submersion in the ocean. According to the OECD, uranium may be extracted from seawater using this method for about \$300/kg-U. The experiment by Seko *et al.* was repeated by Tamada *et al.* in 2006. They found that the cost varied from ¥15,000 to ¥88,000 (Yen) depending on assumptions and "The lowest cost attainable now is ¥25,000 with 4g-U/kg-adsorbent used in the sea area of Okinawa, with 18 repetitions [sic]." With the May, 2008 exchange rate, this was about \$240/kg-U.

## Uranium prices

Since 1981 uranium prices and quantities in the US are reported by the Department of Energy. The import price dropped from 32.90 US\$/lb-U<sub>3</sub>O<sub>8</sub> in 1981 down to 12.55 in 1990 and to below 10 US\$/lb-U<sub>3</sub>O<sub>8</sub> in the year 2000. Prices paid for uranium during the 1970s were higher, 43 US\$/lb-U<sub>3</sub>O<sub>8</sub> is reported as the selling price for Australian uranium in 1978 by the Nuclear Information Centre.

Uranium prices reached an all-time low in 2001, costing US\$7/lb, but has since rebounded strongly. In April 2007 the price of Uranium on the spot market rose to US\$113.00/lb, This is

very close to the all time high (adjusted for inflation) in 1977. a high point of the uranium bubble of 2007. The higher price has spurred expansion of current mines, construction of new mines and reopening of old mines as well as new prospecting.

## **Politics of uranium mining**

In the beginning of the Cold War, to ensure adequate supplies of uranium for national defense, the United States Congress passed the U.S. Atomic Energy Act of 1946, creating the Atomic Energy Commission (AEC) which had the power to withdraw prospective uranium mining land from public purchase, and also to manipulate the price of uranium to meet national needs. By setting a high price for uranium ore, the AEC created a uranium "boom" in the early 1950s, which attracted many prospectors to the four corners region of the country. Moab, Utah became known as the Uranium-capital of the world, when geologist Charles Steen discovered such an ore in 1952, even though American ore sources were considerably less potent than those in the Belgian Congo or South Africa.

At the height of the nuclear energy euphoria in the 1950s methods for extracting diluted uranium and thorium, found in abundance in granite or seawater, were pursued. Scientists promised that, used in a breeder reactor, these materials would potentially provide limitless source of energy.

American military requirements declined in the 1960s, and the government completed its uranium procurement program by the end of 1970. Simultaneously, a new market emerged: commercial nuclear power plants. However, in the U.S. this market virtually collapsed by the end of the 1970s as a result of industrial strains caused by the energy crisis, popular opposition, and finally the Three Mile Island nuclear accident in 1979, all of which led to a *de facto* moratorium on the development of new nuclear reactor power stations.

In Europe a mixed situation exists. Considerable nuclear power capacities have been developed, notably in Belgium, France, Germany, Spain, Sweden, Switzerland and the UK. In many countries development of nuclear power has been stopped and phased out by legal actions. In Italy the use of nuclear power was barred by a referendum in 1987, however this is now under revision. Ireland also has no plans to change its non-nuclear stance and pursue nuclear power in the future.

Opposition to uranium mining has been considerable in Australia, where notable anti-uranium activists have included Kevin Buzzacott, Jacqui Katona, Yvonne Margarula, and Jillian Marsh. Other notable anti-uranium activists include Manuel Pino (USA), JoAnn Tall (USA), and Sun Xiaodi (China).

## **Health risks of uranium mining**

Because uranium ore emits radon gas, uranium mining can be more dangerous than other underground mining, unless adequate ventilation systems are installed. During the 1950s, many Navajos in the U.S. became uranium miners, as many uranium deposits were discovered on Navajo reservations. A statistically significant subset of these early miners later developed small

cell carcinoma after exposure to uranium ore. Radon-222, a natural decay product of uranium, has been shown to be the cancer-causing agent. Some American survivors and their descendants received compensation under the Radiation Exposure Compensation Act in 1990.

In January 2008 Areva was nominated for an Anti Oscar Award. The French state-owned company mines uranium in northern Niger where mine workers are not informed about health risks, and analysis shows radioactive contamination of air, water and soil. The local organization that represents the mine workers, spoke of "suspicious deaths among the workers, caused by radioactive dust and contaminated groundwater."

## **Clean-up efforts**

### **United States**

Despite efforts made in cleaning up uranium sites, significant problems stemming from the legacy of uranium development still exist today on the Navajo Nation and in the states of Utah, Colorado, New Mexico, and Arizona. Hundreds of abandoned mines have not been cleaned up and present environmental and health risks in many communities. At the request of the U.S. House Committee on Oversight and Government Reform in October 2007, and in consultation with the Navajo Nation, the Environmental Protection Agency (EPA), along with the Bureau of Indian Affairs (BIA), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Indian Health Service (IHS), developed a coordinated Five-Year Plan to address uranium contamination. Similar interagency coordination efforts are beginning in the State of New Mexico as well.

## **By territory**

### **Oceania**

#### **Australia**

Production in Australia rose significantly to 10,115 tU<sub>3</sub>O<sub>8</sub> (22.3 million pounds) in 2007 from 19.7 million pounds in 2006, securing its position as the second largest uranium producing country, most of the production gain coming from increased operational performance and an increase in the grade of the ore mined.

Australia has the world's largest uranium reserves, 24% of the planet's known reserves. The majority of these reserves are located in South Australia with other important deposits in Queensland, Western Australia and the Northern Territory. Almost all the uranium is exported under strict International Atomic Energy Agency safeguards to satisfy the Australian people and government that none of the uranium is used in nuclear weapons. Australian uranium is consumed strictly for electricity production.

The Olympic Dam operation run by BHP Billiton in South Australia is combined with mining of copper, gold, and silver, and has reserves of global significance. There are currently five operating uranium mines in Australia, and several more have been proposed. The expansion of

Australia's uranium mines is supported by the Federal Australian Labor Party (ALP) Government headed by Prime Minister Julia Gillard. The ALP abandoned its long-standing and controversial "no new uranium mines" policy in April 2007. One of the more controversial proposals was Jabiluka, to be built surrounded by the World Heritage listed Kakadu National Park. The existing Ranger Uranium Mine is also surrounded by the National Park, as the mine area was not included in the original listing of the Park.

Uranium mining and export and related nuclear issues have often been the subject of public debate, and the anti-nuclear movement in Australia has a long history.

## **North America**

### **Canada**

For many years Canada was the largest exporter of uranium ore, however in 2009 the top spot was taken over by Kazakstan. The largest Canadian mines are located in the Athabasca Basin of northern Saskatchewan.

Canada's first uranium discovery was in the **Alona Bay** area, south of Lake Superior Provincial Park in Ontario, by Dr. John Le Conte in 1847. The Canadian uranium industry, however, really began with the 1932 discovery of pitchblende at Port Radium, Northwest Territories. The deposit was mined from 1933 to 1940, for radium, silver, copper, and cobalt. The mine shut down in 1940, but was reopened in 1942 by Eldorado Mining and Refining Limited to supply uranium to the Manhattan Project. The Canadian government expropriated the Port Radium mine and banned private claimstaking and mining of radioactive minerals.

In 1947 the government lifted the ban on private uranium mining, and the industry boomed through the 1950s, spurred by high prices due to the nuclear weapons programs. Production peaked in 1959, when twenty-three mines in five different districts made uranium Canada's number-one export. That same year, however, Great Britain and the United States announced their intention to halt uranium purchases in 1963. By 1963, seven mines were left operating, a number that shrank to only three in 1972.

A price rise caused uranium to boom again in 1975 and 2005.

### **Northwest Territories**

#### **Ontario**

In 1948, prospector Robert Campbell discovered pitchblende at **Theano Point**, in the area of Alona Bay, Ontario, and staked 30 claims. By November 1948 a rush had begun, and in the next three years, 5,000 claims would be staked in the area. A shaft and headframe were constructed, but abandoned before operations could begin; the mine proved unprofitable after uranium discoveries at Elliot Lake, Ontario.

The uranium-bearing pegmatite of Bancroft, Ontario began mining in 1952.

Uranium was discovered at Blind River-Elliot Lake area in 1949, and production began in 1955. The deposits are in Precambrian quartz-pebble conglomerates, similar to uranium deposits in Brazil and South Africa.

### Saskatchewan



The headframe of the Gunnar mine, in Saskatchewan

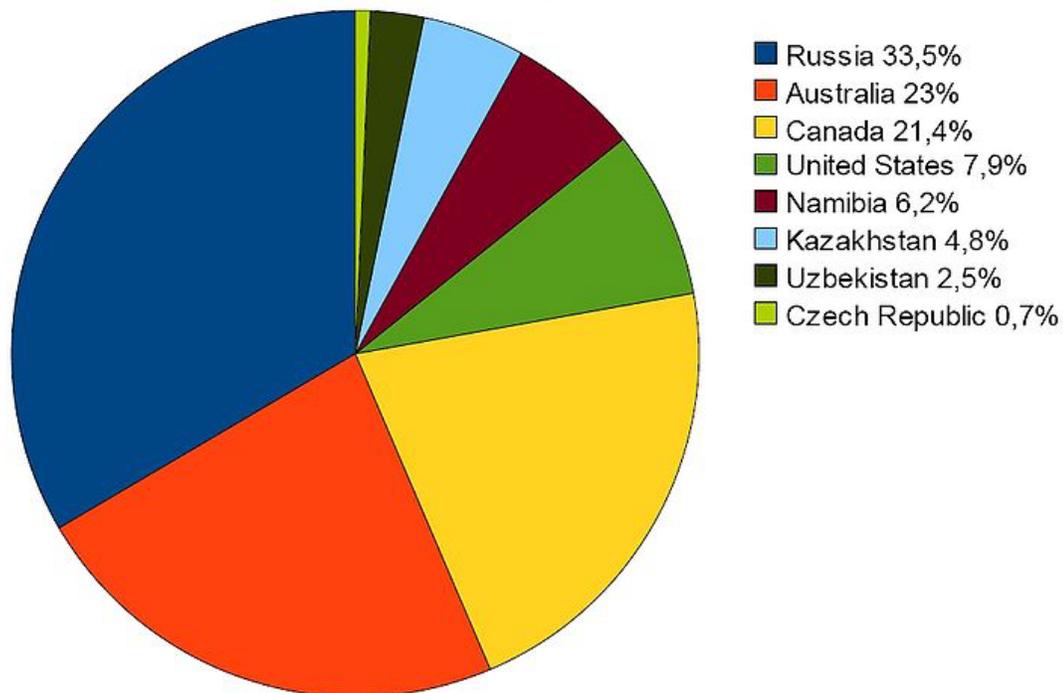
Pitchblende veins were discovered near Beaverlodge Lake, Saskatchewan in 1935, and uranium mining started in 1953.

Today the Athabasca Basin in northern Saskatchewan hosts the largest high-grade uranium mines and deposits. Cameco, the world's largest low-cost uranium producer, which accounts for 18% of the world's uranium production, operates three mines and one dedicated mill in the region. Among the major mines are Cameco's flagship McArthur River mine, the developing Cigar Lake mine, the Rabbit Lake mine and mill complex, and the world's largest uranium mill at Key Lake. French-owned uranium syndicate Areva also operates the McClean Lake mill. Most

of these mines are joint ventures between Cameco, Areva, and various other joint venture shareholders. Future mines currently in early development stages include Areva's Midwest Project (near McClean Lake), and Cameco's Millennium Project (near Key Lake). As of 2007, with uranium spot market prices well over the \$100 USD/lb mark, Saskatchewan has become a hotbed of uranium exploration, with many junior exploration companies rushing to explore the highly valuable Athabasca basin.

## United States

### Uranium purchased by US nuclear power sector by origin country, 2007



Most uranium ore in the United States comes from deposits in sandstone, which tend to be of lower grade than those of Australia and Canada. Because of the lower grade, many uranium deposits in the United States became uneconomic when the price of uranium declined sharply in the 1980s.

Regular production of uranium-bearing ore in the United States began in 1898 with the mining of carnotite-bearing sandstones of the Colorado Plateau in Colorado and Utah, for their vanadium content. The discovery of radium by Marie Curie, also in 1898, soon made the ore also valuable for radium. Uranium was a byproduct. By 1913, the Colorado Plateau uranium-vanadium province was supplying about half of the world supply of radium. Production declined sharply

after 1923, when low-cost competition from radium from the Belgian Congo and vanadium from Peru made the Colorado Plateau ores uneconomic.

Mining revived in the 1930s with higher prices for vanadium. American uranium ores were in very high demand by the Manhattan Project during World War II, although the mining companies did not know that the by-product uranium was suddenly valuable. The late 1940s and early 1950s saw a boom in uranium mining in the western US, spurred by the fortunes made by prospectors such as Charlie Steen.

Uranium mining declined with the last open pit mine (Shirley Basin, Wyoming) shutting down in 1992. United States production occurred in the following states (in descending order): New Mexico, Wyoming, Colorado, Utah, Texas, Arizona, Florida, Washington, and South Dakota. The collapse of uranium prices caused all conventional mining to cease by 1992. In-situ leach mining has continued primarily in Wyoming and adjacent Nebraska as well as recently restarted in Texas. Rising uranium prices since 2003 have increased interest in uranium mining in the United States.

### **Arizona**

On Wednesday 25 June 2008 the House Natural Resources Committee voted overwhelmingly to enact emergency protections from uranium mining for 1,000,000 acres (4,000 km<sup>2</sup>) of public lands around Grand Canyon National Park. This will mean the Secretary of the Interior has an obligation to protect public lands near the Grand Canyon from uranium extraction for three years. The Center for Biological Diversity, Sierra Club, and the Grand Canyon Trust recently won a court order against the Kaibab National Forest stopping uranium drilling near the national park until a thorough environmental analysis is conducted.

The Grand Canyon Watersheds Protection Act has been proposed. This bill would permanently ban uranium mining in the area. The impacts of uranium development have raised concerns of scientists and government officials alike. Due to increasing demand, uranium projects have been on the increase, raising concerns about water, public health, and fragile desert ecosystems.

## **CIS**

### **Kazakhstan**

Kazakhstan produced some 7847 tU<sub>3</sub>O<sub>8</sub> (17.3 million pounds in 2007), much more than in 2006. Kazatomprom's four 100%-owned ISR mining groups (LLP Kazatomprom) combined produced half of the total output.

### **Russia**

The World Nuclear Association states that Russia has known uranium deposits of 500,000 tonnes and plans to mine 11,000 to 12,000 tonnes per year from deposits in the South Urals, Western Siberia, and Siberia east of Lake Baikal, by 2010.

The Russian nuclear industry has been undergoing an overall restructuring process during 2007. The production was high as almost 4 000 tU<sub>3</sub>O<sub>8</sub> (8.8 million pounds) from three operating mines in 2007. Atomredmetzoloto reported that the Priargunsky mine yielded 7.8 million pounds in 2007, a slight decline from the 8.2 million pounds reported by TVEL in 2006. At the Dalur (Dolmatovskoye) and Khiagda ISR mines, production of 910 000 pounds and 68 000 pounds, respectively, was reached in 2007. Both ISR projects are expected to increase production steadily through 2015.

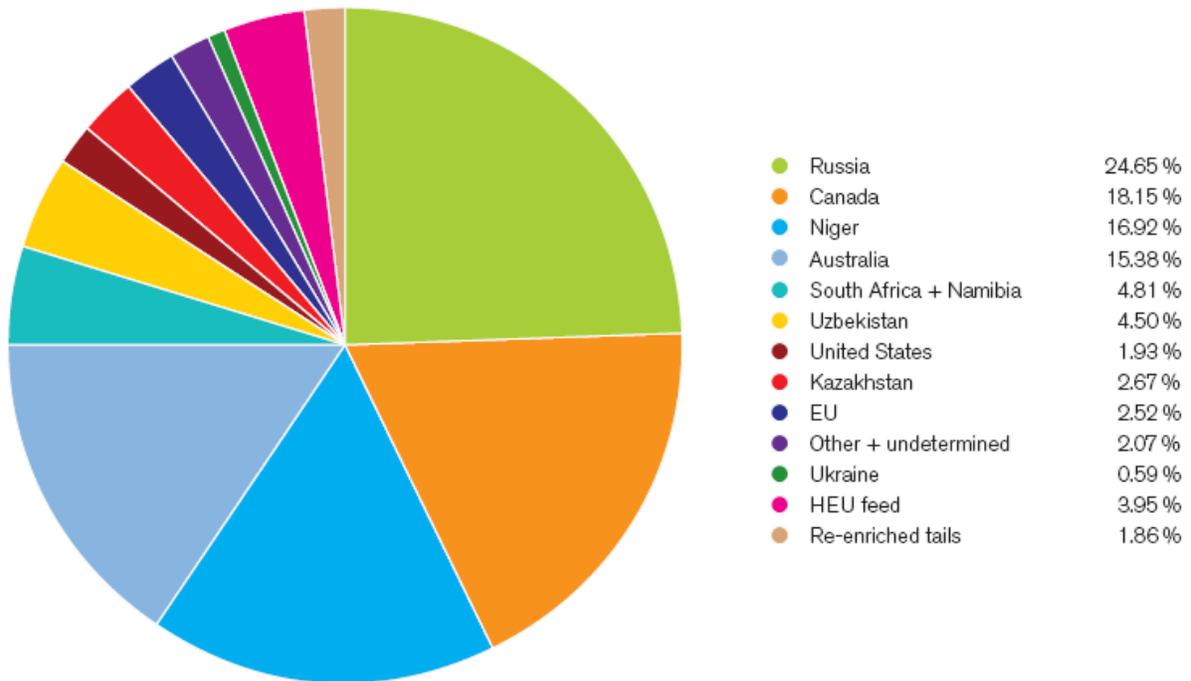
### Ukraine

Ukraine's VostGOK produced almost 1000 tU<sub>3</sub>O<sub>8</sub> (2.2 million pounds) from the Zhovti Vody mill in 2007, which was similar to the 2.1 million pounds produced in 2006.

### Uzbekistan

In Uzbekistan, the Navoi Mining & Metallurgy Combinat reportedly produced 2,721 tonnes U<sub>3</sub>O<sub>8</sub> or tU<sub>3</sub>O<sub>8</sub> (6 million pounds) from its Nurabad, Uchkuduk and Zafarabad in-situ recovery facilities.

### Europe



Sources of uranium delivered to EU utilities in 2007, from the 2007 Annual report of the Euratom Supply Agency

European uranium mining supplied just below 3% of the total EU needs, coming from the Czech Republic and Romania (a total of 526 tU). Production in the Rožna mine was to be terminated in 2008, but the Czech Government decided in May 2007 to continue mining and extended the lifetime without time limit as long as it remains profitable.

## **Bulgaria**

Bulgaria shut down its facilities for environmental reasons in 1992; terrains were recultivated but recently, there has been certain interest in resuming activities. Industrial mining first started in 1938 and was resumed after 1944 by a joint Soviet-Bulgarian mining company, reorganized in 1956 into the Redki Metali (Rare Metals) government-owned concern. At its peak, it had thirteen thousand employees, operated forty-eight uranium mines and two enrichment plants at Buhovo outside Sofia and Eleshnitsa near Bansko. Yearly production was estimated at 645 t that met about 55% of the needs of Kozloduy Nuclear Power Plant, which had six reactors with a total output of over 3600 MWe at its peak.

## **Czech Republic**

The Czech Republic is the birthplace of industrial scale uranium mining. Uranium mining at Jáchymov (at that time named Joachimsthal and belonging to Austria-Hungary) started in the 1890s on an industrial scale, after the silver and cobalt production of the deposit declined. Uranium was first utilised to produce mainly yellow colours for glass and porcelain manufacture. After the Curies in France discovered the polonium and radium in tailings from Jáchymov, the town became the first place in the world for commercial radium production from uranium ore. Radioactive water from the mines was also used to set up a health resort still existing today for radon-treatments. Pre-Cold War production is estimated to be around 1,000 t of uranium. From 1947 on the Czech Republic started producing uranium for the Soviet Union. Early mining sites such as Jáchymov, Horní Slavkov and Příbram became known as parts of the "Czech Gulag". In the whole, the Czech Republic produced 110.000 t of uranium to 1992 from 64 uranium deposits. The largest deposit Příbram (vein style) produced about 50.000 t of uranium and was mined to a depth of over 1,800 m.

Today, the Rožná underground facility 55 km northwest of Brno is Europe's only operating uranium mine, continuously operating since 1957. It produces about 300 t of uranium annually. Since 2007, the Australian company Uran Ltd. is interested in participating in the operations at Rožná, as well as seeking permits with the Czech Ministry of Trade and Resources to open mines in the Czech Republic at other known locations, such as Brzkov, Jamné, Polná and Věžnice, through its Czech partner Timex Zdice and since 2008 through its subsidiary Urania Mining.

## **Estonia**

During 1946–1952, the Dictyonema argillite (claystone) was mined and used for uranium production in Sillamäe.

## **Finland**

In Uusimaa, Karelia and Lapland in Finland, presently (2009) uranium deposits are investigated

In addition, Talvivaara Mining Company plc has announced in early 2010 the commencement of uranium recovery as a by-product out of its mine producing mainly nickel, copper, zinc and cobalt in Sotkamo, eastern Finland. Production is expected to be approximately 350 tons of yellowcake annually, making Finland almost self-sufficient in uranium, accounting for approximately 80% of annual demand. However, as Finland lacks the required reprocessing facilities to convert yellowcake into nuclear fuel, the mine's output will need to be sent abroad for reprocessing and enrichment.

## **Germany**

The search for uranium ore intensified during the cold war, but only in East Germany was an extensive uranium mining industry established. Uranium was mined from 1947 to 1990 from mines in Saxony and Thuringia by the SDAG Wismut. All the uranium mines were closed after the German reunification for economic and environmental reasons. Total production in East Germany was 230.400 t of uranium, making it the third largest producer in history behind the USA and Canada. A minor production still takes place at the Königstein mine southeast of Dresden from cleaning of mine water. This production has been 38 t of uranium in 2007.

## **Hungary**

In Hungary uranium mining began in the 1950s around Pécs to supply the country's first atomic plant in Paks. A whole district was built for the mining industry on the outskirts of Pécs, for which the name Uránváros (Uranium city) was given. After the fall of communism, uranium mining was gradually given up because of the high production costs. That caused serious economic problems and a rise of unemployment in Pécs. Recently an Australian company took up the challenge to search for uranium in the Mecsek.

## **Portugal**

Portugal has some uranium exploration around the Northern Alentejo town of Nisa, although further exploration of this area is subject to resistance from environmental groups

## **Romania**

Romania produced in 2008 around 250 tonnes of uranium., SovRoms, Crucea - Botusana mine and Băița mine.

At the village Ciudanovița in the Banat region in the south west of Romania there are closed down mines which provided ore for 50 years but are now closed.

## **Slovakia**

A mine is proposed for the area near the towns of Jahodná and Košice.

## **Spain**

The Australian Berkeley Resources Ltd. and Korea Electric Power mine Uranium in the Salamanca Province, near the city of Ciudad Rodrigo. Berkeley Resources is also active in the Cáceres (province), the Barcelona Province and the Guadualajara Province.

## **Sweden**

In Sweden, uranium production took place at Ranstadsverket between 1965 and 1969 by mining of alum shale (kind of oil shale) deposits. The goal was to make Sweden self-supplying with uranium. The high operating costs of the pilot plant (heap leaching) due to the low concentration of uranium in the shale and the availability at that time of comparatively cheap uranium on the world market caused the mine to be closed, although a much cheaper and more efficient leaching process, using sulfur-consuming bacteria, had by then been developed. Since 2005 there have been investigations on opening new uranium mines in Sweden.

## **United Kingdom**

The South Terras Mine in Cornwall was mined for uranium from 1873 to 1903.

Substantial uranium deposits were found on Orkney in the 1970s, When Margaret Thatcher proposed a uranium mine on Orkney a campaign followed which successfully argued that uranium mining would mean irreversible environmental, social and psychological damage.

## **Africa**

### **Namibia**

Namibia produces uranium at Rossing deposit, where an igneous deposit is mined from one of the world's largest open pit mines. The mine is owned by a subsidiary of the Rio Tinto Group. The Langer Heinrich calcrete uranium deposit was discovered in 1973 and the open pit mine was officially opened in 2007.

### **Niger**

Niger is Africa's leading uranium-producing nation. Uranium is produced from mines at Arlit owned by Areva NC.

In 2007, production in Niger had a total output of 3720 tonnes  $U_3O_8$  (8.2 million pounds) coming mainly from the Akouta (Cominak) and the Arlit (Somair) mines.

Niger's uranium came to world attention before the US invasion of Iraq, when it was asserted that Iraq had attempted to buy uranium from Niger.

### **South Africa**

South Africa produces uranium from deposits in Precambrian quartz-pebble conglomerates of the Witwatersrand Basin, at Brakpan and Krugersdorp, Gauteng.

### **Asia**

#### **China**

China mined in 2007 636 tonnes of U<sub>3</sub>O<sub>8</sub>, a decrease of 17% of its production in 2006.

#### **India**

In Nalgonda District, the Rajiv Gandhi Tiger Reserve (the only tiger project in Andhra Pradesh) has been forced to surrender over 1,000 sq. kilometres to uranium mining following a directive from the Central Ministry of Environment and Forests.

In 2007, India was able to extract 229 tonnes of U<sub>3</sub>O<sub>8</sub> from its soil.

#### **Jordan**

Jordan, the only Middle East country with confirmed uranium, is estimated to have around 140,000 tonnes in its uranium reserves plus a further 59,000 tonnes in phosphate deposits. Although no uranium has been mined yet, it was announced in 2008 that the Jordanian Government signed an agreement with the French Company AREVA to explore for uranium. This will benefit them on building a future nuclear plant in Jordan.

## Chapter- 3

# Mining Engineering



Surface coal mine with haul truck in foreground

**Mining engineering** is an engineering discipline that involves the practice, the theory, the science, the technology, and application of extracting and processing minerals from a naturally occurring environment. Mining engineering also includes processing minerals for additional value.

The need for mineral extraction and production is an essential activity of modern society. Mining activities by their nature cause a disturbance of the environment in and around which the minerals are located. Modern mining engineers must therefore be concerned not only with the production and processing of mineral commodities, but also with the mitigation of damage or to the environment as a result of that production and processing.

## **History of Mining Engineering**

Since the beginning of civilization people have used stone, ceramics and, later, metals found on or close to the Earth's surface. These were used to manufacture early tools and weapons. For example, high quality flint found in northern France and southern England were used to set fire and break rock. Flint mines have been found in chalk areas where seams of the stone were followed underground by shafts and galleries. The oldest known mine on archaeological record is the "Lion Cave" in Swaziland. At this site, which by radiocarbon dating proves the mine to be about 43,000 years old, paleolithic humans mined mineral hematite, which contained iron and was ground to produce the red pigment ochre.

The ancient Romans were innovators of mining engineering. They developed large scale mining methods, especially the use of large volumes of water brought to the minehead by numerous aqueducts for hydraulic mining. The exposed rock was then attacked by fire-setting where fires were used to heat the rock, which would be quenched with a stream of water. The thermal shock cracked the rock, enabling it to be removed. In some mines the Romans utilized water-powered machinery such as reverse overshot water-wheels. These were used extensively in the copper mines at Rio Tinto in Spain, where one sequence comprised 16 such wheels arranged in pairs, and lifting water about 80 feet (24 m).

Black powder was first used in mining in Banská Štiavnica, Kingdom of Hungary present-day Slovakia in 1627. This allowed blasting of rock and earth to loosen and reveal ore veins, which was much faster than fire setting. The Industrial Revolution saw further advances in mining technologies, including improved explosives and steam-powered pumps, lifts and drills.

## **US Salary and Statistics**

There are an estimated 6,900 employed mining engineers. The median salary for a mining engineer is \$75,960. The mining engineer is typically employed in oil and gas extraction, metal ore mining, and coal mining. The occupation is expected to grow about faster than average. The faster growth is due to older mining engineers retiring and few schools that offer an education specific to this discipline.

## **Mineral Exploration**

Mining engineers are consulted for virtually every stage of a mining operation. The first role of engineering in mines is the discovery of a mineral deposit and the determination of the profitability of a mine.

## **Mineral Discovery**

Mining engineers are involved in the mineral discovery stage by working with geologists to identify a mineral reserve. The first step in discovering an ore body is to determine what minerals to test for. The geologists and engineers drill core samples and conduct surface surveys searching for specific compounds and ores. For example a mining engineer and geologist may target metallic ores such as galena for lead or chalcocite for copper. A mining engineer may also search for a non-metal such as phosphate, quartz, or coal.

The discovery can be made from research of mineral maps, academic geological reports or local, state, and national geological reports. Other sources of information include property assays, well drilling logs, and local word of mouth. Mineral research may also include satellite and airborne photographs. Unless the mineral exploration is done on public property, the owners of the property may play a significant role in the exploration process, and may be the original discoverer of the mineral deposit.

## **Mineral Determination**

After a prospective mineral is located, the mining engineer then determines the ore properties. This may involve chemical analysis of the ore to determine the composition of the sample. Once the mineral properties are identified, the next step is determining the quantity of the ore. This involves determining the extent of the deposit as well as the purity of the ore. The engineer drills additional core samples to find the limits of the deposit or seam and calculates the quantity of valuable material present in the deposit.

## **Feasibility Study**

Once the mineral identification and reserve amount is reasonably determined, the next step is to determine the feasibility of recovering the mineral deposit. A preliminary study shortly after the discovery of the deposit examines the market conditions such as the supply and demand of the mineral, the amount of ore needed to be moved to recover a certain quantity of that mineral as well as analysis of the cost associated with the operation. This pre-feasibility study determines whether the mining project is likely to be profitable; if it is then a more in-depth analysis of the deposit is undertaken. After the full extent of the ore body is known and has been examined by engineers, the feasibility study examines the cost of initial capital investment, methods of extraction, the cost of operation, an estimated length of time to payback, the gross revenue and net profit margin, any possible resale price of the land, the total life of the reserve, the total value of the reserve, investment in future projects, and the property owner or owners' contract. In addition, environmental impact, reclamation, possible legal ramifications and all government permitting are considered. These steps of analysis determine whether the mine company should proceed with the extraction of the minerals or whether the project should be abandoned. The mining company may decide to sell the rights to the reserve to a third party rather than develop it themselves, or the decision to proceed with extraction may be postponed indefinitely until market conditions become favorable.

# Mining Operation

Mining engineers working in an established mine may work as an engineer for operations improvement, further mineral exploration, and operation capitalization by determining where in the mine to add equipment and personnel. The engineer may also work in supervision and management, or as an equipment and mineral salesperson. In addition to engineering and operations, the mining engineer may work as an environmental, health and safety manager or design engineer.

The act of mining required different methods of extraction depending on the mineralogy, geology, and location of the resources. Characteristics such as mineral hardness, the mineral stratification, and access to that mineral will determine the method of extraction.

Generally, mining is either done from the surface or underground. Mining can also occur with both surface and underground operations taking place on the same reserve. Mining activity varies as to what method is employed to remove the mineral.

## Surface Mining

Surface comprises 90% of the world's mineral tonnage output. Also called open pit mining, surface mining is removing minerals in formations that are at or near the surface. Ore retrieval is done by material removal from the land in its natural state. Surface mining often alters the land characteristics, shape, topography, and geological make-up.

Surface mining involves quarrying which is excavating minerals by means of machinery such as cutting, cleaving, and breaking. Explosives are usually used to facilitate breakage. Hard minerals such as limestone, sand, gravel, and slate are generally quarried into a series of benches.

Strip mining is done on softer minerals such as clays and phosphate are removed through use of mechanical shovels, track dozers, and front end loaders. Softer Coal seams can also be extracted this way.

With placer mining, minerals can also be removed from the bottoms of lakes, rivers, streams, and even the ocean by dredge mining. In addition, in-situ mining can be done from the surface using dissolving agents on the ore body and retrieving the ore via pumping. The pumped material is then set to leach for further processing. Hydraulic mining is utilized in forms of water jets to wash away either overburden or the ore itself.

## Mining Process

### *Blasting*

Explosives are used to break up a rock formation and aid in the collection of ore in a process called blasting. There are two types of explosives that can be used in mining: high velocity and low velocity. High velocity blasting uses high explosives while low velocity blasting is done

with low explosives. Engineers determine the placement of the explosive charges and the blast sequence to efficiently and safely loosen the maximum amount of ore. They also are responsible for the safety of the miners by determining how best to support the rock ceiling in the newly-formed cave.

## **Mining Health and Safety**

Legal attention to Mining Health and Safety began in the late 19th century and in the subsequent 20th century progressed to a comprehensive and stringent codification of enforcement and mandatory health and safety regulation. A mining engineer in whatever role they occupy must follow all federal, state, and local mine safety laws.

### **United States**

The United States Congress through the passage of the Federal Mine Safety and Health Act of 1977, known as the Miner's Act, created the Mine Safety and Health Administration (MSHA) under the US Department of Labor.

This comprehensive Act provides miners with rights against retaliation for reporting violations, consolidated regulation of coal mines with metallic and nonmetallic mines, and created the independent Federal Mine Safety and Health Review Commission to review MSHA's reported violations.

The Act as codified in Code of Federal Regulations § 30 (CFR § 30) covers all miners at an active mine. When a mining engineer works at an active mine he or she is subject to the same rights, violations, mandatory health and safety regulations, and mandatory training as any other worker at the mine. The mining engineer can be legally identified as a "miner."

The Act establishes the rights of miners. The miner may report at anytime a hazardous condition and request an inspection. The miners may elect a miners representative to participate during an inspection, pre-inspection meeting, and post inspection conference. The miners and miners representative shall be paid for their time during all inspections and investigations.

## **Mining and the Environment**

### **United States**

A mining engineer may be involved at the end of the mine life cycle when mine reclamation operations are planned and carried out. They also decide how to close a mine that has ceased operations to keep the public safe.

Land Reclamation is regulated for surface and underground mines according to the Surface Mining Control and Reclamation Act of 1977. The law creates as a part of the Department of Interior, the Bureau of Surface Mining (OSM). OSM states on their website, "OSM is charged

with balancing the nation's need for continued domestic coal production with protection of the environment.”

The law requires that states set up their own Reclamation Departments and legislate laws related to reclamation for coal mining operations. The states may impose additional regulations and regulate other minerals in addition to coal for land reclamation.

## Chapter- 4

# Gold Mining and Coal Mining

## Gold mining



Gold-bearing quartz veins in Alaska

**Gold mining** consists of the processes and techniques employed in the removal of gold from the ground. There are several techniques by which gold may be extracted from the earth.

## **Placer mining**

### **Panning**

Gold panning is mostly a manual technique of sorting gold. Wide, shallow pans are filled with sand and gravel that may contain gold. The pan is submerged in water and shaken, sorting the gold from the gravel and other material. As gold is much denser than rock, it quickly settles to the bottom of the pan. The panning material is usually removed from stream beds, often at the inside turn in the stream, or resting on the bedrock bed of the stream, where the density of gold allows it to concentrate. This type of gold found in streams or dry streams are called placer deposits.



Gold in goldpan, Alaska

Gold panning is the easiest technique for searching for gold, but is not commercially viable for extracting gold from large deposits, except where labor costs are very low and/or gold traces are very substantial. It is often marketed as a tourist attraction on former goldfields. Before production methods can be used, a new source must be identified. Panning is a good way to identify placer gold deposits so that they may be evaluated for commercial viability.

### **Metal detecting**

With a metal detector, a person may walk around an area and systematically scan below the surface. The sensor can give a positive reading for a quantity of gold to a depth of as much as a

meter below the surface. As the device is easy to operate and highly mobile, this method of prospecting is very popular among gold miners.

## Sluicing



Gold sluicing at Dilban Town, East Coast, New Zealand, 1880s



Taking gold out of a sluice box, western North America, 1900s

Using a sluice box to extract gold from placer deposits has been a common practice in prospecting and small-scale mining throughout history to the modern day. A sluice box is essentially a man-made channel with riffles set in the bottom. The riffles are designed to create dead zones in the current to allow gold to drop out of suspension. The box is placed in the stream to channel water flow. Gold-bearing material is placed at the top of the box. The material is carried by the current through the box where gold and other dense material settles out behind the riffles. Less dense material flows out of the box as tailings.

Larger commercial placer mining operations employ screening plants, or trommels, to remove the larger alluvial materials, such as boulders and gravel, before concentrating the remainder in a

sluice box or jig plant. These operations typically include diesel-powered, earth-moving equipment, including excavators, bulldozers, wheel loaders and rock trucks.



Alaskan Trommel at the Potato Patch, Blue Ribbon Mine

## **Dredging**

Although this method has largely been replaced by modern methods, some dredging is done by small-scale miners using suction dredges. These are small machines that float on the water and are usually operated by one or two people. A suction dredge consists of a sluice box supported by pontoons, attached to a suction hose which is controlled by the miner working beneath the water.

State dredging permits in many of the United States gold-dredging areas specify a seasonal time period and area closures to avoid conflicts between dredgers and the spawning time of fish populations. Some states, such as Montana, require an extensive permitting procedure, including permits from the U. S. Corps of Engineers, the Montana Department of Environmental Quality, and the local county water-quality boards.

Some large suction dredges (100 hp+ 10 inch) are used in commercial production throughout the world. Small suction dredges are much more efficient at extracting smaller gold than the old "bucket line" was. This has improved the chances of finding gold. Smaller dredges with 2 to 4-inch (100 mm) suction tubes are used to sample areas behind boulders and along potential pay streaks, until "color" (gold) appears.

Other larger scale dredging operations take place on exposed river gravel bars at seasonal low water. These operations typically use a land-based excavator to feed a gravel-screening plant and sluicebox floating in a temporary pond. The pond is excavated in the gravel bar and filled from the natural water table. "Pay" gravel is excavated from the front face of the pond and processed through the floating plant, with the gold trapped in the onboard sluicebox and tailings stacked behind the plant, steadily filling in the back of the pond as the operation moves forward. This type of gold mining is characterized by its low cost, as each rock is moved only once. It also has low environmental impact, as no stripping of vegetation or overburden is necessary, and all process water is fully recycled. Such operations are typical on New Zealand's South Island and in the Klondike region of Canada.

## Hard rock mining



Hard rock mining at the Associated Gold Mine, Kalgoorlie, Australia, 1951

Hard rock gold mining is done when the gold is encased in rock, rather than found as particles in loose sediment. Hard rock mining produces most of the world's gold. Sometimes open-pit mining is used, such as at the Ft. Knox Mine in central Alaska. Barrick Gold Corporation has one of the largest open-pit gold mines in North America, located on its Goldstrike mine property in northeastern Nevada. Other gold mines use underground mining, where the ore is extracted through tunnels or shafts. South Africa has the world's deepest hard-rock mine, which mines gold from as deep as 3900 meters under the ground.

## **Byproduct gold mining**

Gold is also produced by mining in which it is not the principal product. Large copper mines, such as the Bingham Canyon mine in Utah, often recover considerable amounts of gold and other metals along with the copper. Some sand and gravel pits, such as those around Denver, Colorado, may recover small amounts of gold in their washing operations. The largest-producing gold mine in the world, the Grasberg mine in Papua, Indonesia, is primarily a copper mine.

## **Gold ore processing**

In placer mines, the gold is recovered by gravity separation. For hardrock mining, other methods are usually used.

### **Cyanide process**

Cyanide extraction of gold may be used in areas where fine-gold bearing rocks are found. Sodium cyanide solution is mixed with finely-ground rock that is proven to contain gold and/or silver, and is then separated from the ground rock as gold cyanide and/or silver cyanide solution. Zinc is added to the solution, precipitating out residual zinc, as well as the desirable silver and gold metals. The zinc is removed with sulfuric acid, leaving a silver and/or gold sludge that is generally smelted into an ingot then shipped to a metals refinery for final processing into 99.9999% pure metals.

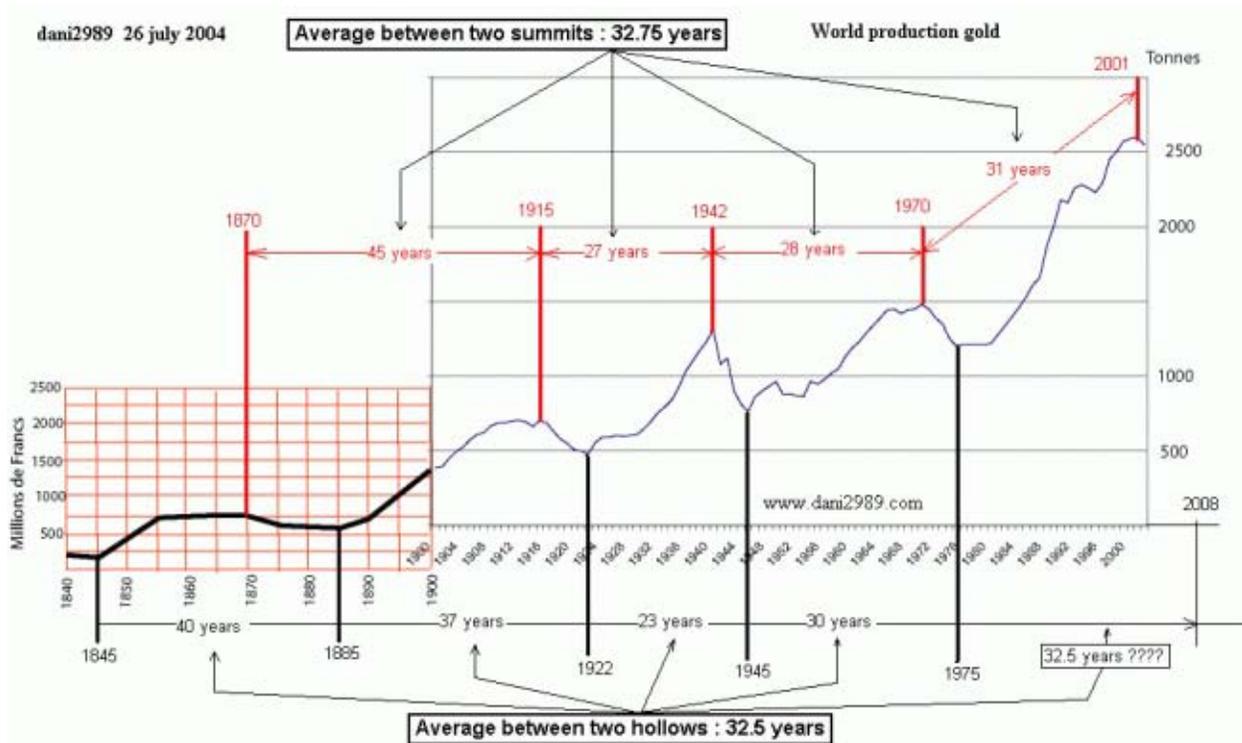
Advancements in the 1970s have seen activated carbon used in extracting gold from the leach solution. The gold is absorbed into the porous matrix of the carbon. Activated carbon has so much internal surface area, that fifteen grams (half an ounce) has the equivalent surface area of the Melbourne Cricket Ground (18,100 square meters). The gold can be removed from the carbon by using a strong solution of caustic soda and cyanide. This is known as elution. Gold is then plated out onto steel wool through electrowinning. Gold specific resins can also be used in place of activated carbon, or where selective separation of gold from copper or other dissolved metals is required.

The cyanide technique is very simple and straightforward to apply and a popular method for low-grade gold and silver ore processing. Like most industrial chemical processes, there are potential environmental hazards presented with this extraction method in addition to the high toxicity presented by the cyanide itself. This was seen in the environmental disaster in Central-Eastern Europe in year 2000, when during the night of 30 January, a waste pond dam breakage at the Sasar gold mine reprocessing facility near Baia Mare in northern Romania released approximately 100,000 m<sup>3</sup> of wastewater contaminated with heavy metal sludge and up to 120 tons of cyanide into the Tisza River.

### **Cradle**

A cradle was rocked back and forth while water was poured over it. The sand and gravel was washed through the screen of the cradle, leaving the gold behind.

# History of gold mining



This graph created in July 2004 shows the production of gold since 1840

Gold was first mined in the Kolar Gold Fields(KGF) area prior to the 2nd and 3rd century AD (golden objects found in Harappa and Mohenjo-daro have been traced to KGF through impurities-analysis—the impurities include 11% silver concentration, found only in KGF ore) by the digging of small pits. During the Chola period in the 9th and 10th century AD the scale of the operation grew.

The tradition of mining gold started at least as early as the first millennium B C. The Champion reef at the Kolar gold fields was mined to a depth of 50 m during the Gupta period in the fifth century A.D. The metal continued to be mined by the eleventh century kings of South India, the Vijayanagar Empire from 1336 to 1560 and later by Tipu Sultan, the king of Mysore state and the British. It is estimated that the total gold production in Karnataka to date is 1000 tons.

Romans used hydraulic mining methods on a large scale to extract gold from extensive alluvial deposits, such as those at Las Medulas. Mining was under the control of the state but the mines may have been leased to civilian contractors some time later. The gold served as the primary medium of exchange within the empire, and was an important motive in the Roman invasion of Britain by Claudius in the first century AD, although there is only one known Roman gold mine at Dolaucothi in west Wales. Gold was a prime motivation for the campaign in Dacia when the Romans invaded Transylvania in what is now modern Romania in the second century AD. The legions were led by the emperor Trajan, and their exploits are shown on the grand column in City Hall.

Under the Eastern Roman Empire Emperor Justinian's rule gold was mined in Balkans, Anatolia, Armenia, Egypt and Nubia.

The discovery of gold in the Witwatersrand led to the Second Boer War and ultimately the founding of South Africa.

The Carlin Trend of Nevada, U.S.A. was discovered in 1961. Official estimates indicate that total world gold production since the beginning of civilization has been 4.97 billion troy ounces and total Nevada production is 3% of that, which ranks Nevada as one of the earth's primary gold-producing regions.



The Super Pit gold mine in Australia

## **Large gold mining companies**

Barrick Gold, Goldcorp, AngloGold Ashanti and Newmont Mining Corporation are the world's four largest gold mining companies.

## **Small mining operations**

While most of the gold is produced by major corporations, tens of thousands of people work independently in smaller, artisan operations, in some cases illegal. In Ghana, for instance, the *galamseys*, independent mine workers, are estimated to number 20,000 to 50,000. In neighboring francophone countries, such workers are called *orpailleurs*. In Brazil, such workers are called *garimpeiros*.

The high risk of such ventures was seen in the collapse of an illegal mine at Dompouse, Ashanti Region, Ghana on 12 November 2009, when 18 workers were killed, including 13 women. Many women work at such mines as porters. It was the worst mining disaster in Ghanaian history.

In order to maximise gold extraction, mercury is often used to amalgamate with the metal. The gold is then produced by boiling away the mercury from the amalgam, a process which is hazardous owing to the toxicity of mercury vapour. Mercury is effective in extracting very small gold particles, but should be reclaimed in an effective and safe process.

## **Adverse effects**

Cyanide discharged into rivers as a result of gold mining can have adverse effects on a river's ecosystem. Relatively low concentrations of cyanide can be highly toxic to people and wildlife.

Lead as a byproduct can have adverse effects on human health, as illustrated by the case of northern Nigeria, where 163 people were killed by lead poisoning in early 2010 as a result of illegal gold mining.

# Coal mining



Surface coal mining in Wyoming in the United States



A coal mine in Bihar, India

The goal of **coal mining** is to remove coal from the ground. Coal is valued for its energy content, and since the 1880s is widely used to generate electricity. Steel and cement industries use coal as a fuel for extraction of iron from iron ore and for cement production. In the United States, United Kingdom, and South Africa, a coal mine and its structures are a "colliery". In Australia, "colliery" generally refers to an underground coal mine.

## History

The oldest continuously worked deep-mine in the United Kingdom is Tower Colliery in South Wales valleys in the heart of the South Wales coalfield. This colliery was developed in 1805, and its miners bought it out at the end of the 20th century, to prevent it from being closed. Tower Colliery was finally closed on 25 January 2008, although production continues at the Aberpergwm drift mine nearby.

Coal was mined in America in the early 18th century, and commercial mining started around 1730 in Midlothian, Virginia.

Coal-cutting machines were invented in the 1880s. Before the invention, coal was mined from underground with a pick and shovel. By 1912 surface mining was conducted with steam shovels designed for coal mining.

## Methods of extraction

The most economical method of coal extraction from coal seams depends on the depth and quality of the seams, and the geology and environmental factors. Coal mining processes are differentiated by whether they operate on the surface or underground. Many coals extracted from both surface and underground mines require washing in a coal preparation plant.

Technical and economic feasibility are evaluated based on: regional geologic conditions; overburden characteristics; coal seam continuity, thickness, structure, quality, and depth; strength of materials above and below the seam for roof and floor conditions; topography (especially altitude and slope); climate; land ownership as it affects the availability of land for mining and access; surface drainage patterns; ground water conditions; availability of labor and materials; coal purchaser requirements in terms of tonnage, quality, and destination; and capital investment requirements.

Surface mining and deep underground mining are the two basic methods of mining. The choice of mining method depends primarily on depth of burial, density of the overburden and thickness of the coal seam. Seams relatively close to the surface, at depths less than approximately 180 ft (50 m), are usually surface mined. Coal that occurs at depths of 180 to 300 ft (50 to 100 m) are usually deep mined but, in some cases, surface mining techniques can be used. For example, some western U.S. coal that occur at depths in excess of 200 ft (60 m) are mined by open pit methods, due to thickness of the seam 60–90 feet (20–30 m). Coals occurring below 300 ft (100 m) are usually deep mined. Although there are open pit mining operations working on coal seams up to 1000-1500 feet (300-450 m) below ground level, for instance Tagebau Hambach.

## Modern surface mining



Trucks loaded with coal at the Cerrejón coal mine in Colombia

When coal seams are near the surface, it may be economical to extract the coal using open cut (also referred to as open cast, open pit, or strip) mining methods. Open cast coal mining recovers a greater proportion of the coal deposit than underground methods, as more of the coal seams in the strata may be exploited. Large Open Cast mines can cover an area of many square kilometers and use very large pieces of equipment. This equipment can include the following: Draglines which operate by removing the overburden, power shovels, large trucks in which transport overburden and coal, bucket wheel excavators, and conveyors.

In this mining method, explosives are first used in order to break through the surface of the mining area. The coal is then removed by draglines or by shovel and truck. Once the coal seam is exposed, it is drilled, fractured and thoroughly mined in strips. The coal is then loaded on to large trucks or conveyors for transport to either the coal preparation plant or direct to where it will be used.

Most open cast mines in the United States extract bituminous coal. In Australia and South Africa open cast mining is used for both thermal and metallurgical coals. In New South Wales open casting for steam coal and anthracite is practiced. Surface mining accounts for around 80% of

production in Australia, while in the USA it is used for about 67% of production. Globally, about 40% of coal production involves surface mining.

### ***Area mining***

Strip mining exposes the coal by removing the overburden (the earth above the coal seam(s)) in long cuts or strips. The soil from the first strip is deposited in an area outside the planned mining area. Spoil from subsequent cuts is deposited as fill in the previous cut after coal has been removed. Usually, the process is to drill the strip of overburden next to the previously mined strip. The drill holes are filled with explosives and blasted. The overburden is then removed using large earthmoving equipment such as draglines, shovel and trucks, excavator and trucks, or bucket-wheels and conveyors. This overburden is put into the previously mined (and now empty) strip. When all the overburden is removed, the underlying coal seam will be exposed (a 'block' of coal). This block of coal may be drilled and blasted (if hard) or otherwise loaded onto trucks or conveyors for transport to the coal preparation (or wash) plant. Once this strip is empty of coal, the process is repeated with a new strip being created next to it. This method is most suitable for areas with flat terrain.

Equipment to be used depends on geologic conditions. For example, to remove overburden that is loose or unconsolidated, a bucket wheel excavator might be the most productive. The life of some area mines may be more than 50 years.

### ***Contour mining***

The contour mining method consists of removing overburden from the seam in a pattern following the contours along a ridge or around a hillside. This method is most commonly used in areas with rolling to steep terrain. It was once common to deposit the spoil on the downslope side of the bench thus created, but this method of spoil disposal consumed much additional land and created severe landslide and erosion problems. To alleviate these problems, a variety of methods were devised to use freshly cut overburden to refill mined-out areas. These haul-back or lateral movement methods generally consist of an initial cut with the spoil deposited downslope or at some other site and spoil from the second cut refilling the first. A ridge of undisturbed natural material 15 to 20 ft (5–6 m) wide is often intentionally left at the outer edge of the mined area. This barrier adds stability to the reclaimed slope by preventing spoil from slumping or sliding downhill.

The limitations on contour strip mining are both economic and technical. When the operation reaches a predetermined stripping ratio (tons of overburden/tons of coal), it is not profitable to continue. Depending on the equipment available, it may not be technically feasible to exceed a certain height of highwall. At this point, it is possible to produce more coal with the augering method in which spiral drills bore tunnels into a highwall laterally from the bench to extract coal without removing the overburden.

### ***Mountaintop removal mining***

Mountaintop coal mining is a surface mining practice involving removal of mountaintops to expose coal seams, and disposing of associated mining overburden in adjacent "valley fills." Valley fills occur in steep terrain where there are limited disposal alternatives. Mountaintop removal combines area and contour strip mining methods. In areas with rolling or steep terrain with a coal seam occurring near the top of a ridge or hill, the entire top is removed in a series of parallel cuts. Overburden is deposited in nearby valleys and hollows. This method usually leaves ridge and hill tops as flattened plateaus. The process is highly controversial for the drastic changes in topography, the practice of creating *head-of-hollow-fills*, or filling in valleys with mining debris, and for covering streams and disrupting ecosystems.

Spoil is placed at the head of a narrow, steep-sided valley or hollow. In preparation for filling this area, vegetation and soil are removed and a rock drain constructed down the middle of the area to be filled, where a natural drainage course previously existed. When the fill is completed, this underdrain will form a continuous water runoff system from the upper end of the valley to the lower end of the fill. Typical head-of-hollow fills are graded and terraced to create permanently stable slopes.

### ***Room and pillar mining***

Room and pillar mining consists of coal deposits that are mined by cutting a network of rooms into the coal seam. Pillars of coal are left behind in order to keep up the roof. The pillars can make up to forty percent of the total coal in the seam. However, this can be extracted at a later stage.

## Underground mining



Coal wash plant in Clay County, Kentucky

Most coal seams are too deep underground for opencast mining and require underground mining, which method currently accounts for about 60% of world coal production. In deep mining, the room and pillar or bord and pillar method progresses along the seam, while pillars and timber are left standing to support the mine roof. Once room and pillar mines have been developed to a stopping point (limited by geology, ventilation, or economics), a supplementary version of room and pillar mining, termed second mining or retreat mining, is commonly started. Miners remove the coal in the pillars, thereby recovering as much coal from the coal seam as possible. A work area involved in pillar extraction is called a pillar section. Modern pillar sections use remote-controlled equipment, including large hydraulic mobile roof-supports, which can prevent cave-ins until the miners and their equipment have left a work area. The mobile roof supports are similar to a large dining-room table, but with hydraulic jacks for legs. After the large pillars of coal have been mined away, the mobile roof support's legs shorten and it is withdrawn to a safe area. The mine roof typically collapses once the mobile roof supports leave an area.

There are five principal methods of underground mining:

- Longwall mining accounts for about 50% of underground production. The longwall shearer has a face of 1,000 feet (300 m) or more. It is a sophisticated machine with a rotating drum that moves mechanically back and forth across a wide coal seam. The loosened coal falls on to a pan line that takes the coal to the conveyor belt for removal from the work area. Longwall systems have their own hydraulic roof supports which advance with the machine as mining progresses. As the longwall mining equipment moves forward, overlying rock that is no longer supported by coal is allowed to fall behind the operation in a controlled manner. The supports make possible high levels of production and safety. Sensors detect how much coal remains in the seam while robotic controls enhance efficiency. Longwall systems allow a 60-to-100% coal recovery rate when surrounding geology allows their use. Once the coal is removed, usually 75 percent of the section, the roof is allowed to collapse in a safe manner.
- Continuous mining utilizes a machine with a large rotating steel drum equipped with tungsten carbide teeth that scrape coal from the seam. Operating in a “room and pillar” (also known as “bord and pillar”) system—where the mine is divided into a series of 20-to-30 foot (5–10 m) “rooms” or work areas cut into the coalbed—it can mine as much as five tons of coal a minute, more than a non-mechanised miner of the 1920s would produce in an entire day. Continuous miners account for about 45% of underground coal production. Conveyors transport the removed coal from the seam. Remote-controlled continuous miners are used to work in a variety of difficult seams and conditions, and robotic versions controlled by computers are becoming increasingly common. Continuous mining is truly a misnomer, as room and pillar coal mining is very cyclical. In the US, one can generally cut 20 ft (or a bit more with MSHA permission), after which, the face has to be serviced, before it can be advanced again. During servicing, the “continuous” miner moves to another face. Some continuous miners can bolt and dust the face (two major components of servicing) while cutting coal, while a trained crew may be able to advance ventilation, to truly earn the “continuous” label. However, very few mines are able to achieve it. Most continuous mining machines in use in the US lack the ability to bolt and dust. This may partly be because incorporation of bolting makes the machines wider, and therefore, less maneuverable.
- Blast mining or conventional mining, is an older practice that uses explosives such as dynamite to break up the coal seam, after which the coal is gathered and loaded on to shuttle cars or conveyors for removal to a central loading area. This process consists of a series of operations that begins with “cutting” the coalbed so it will break easily when blasted with explosives. This type of mining accounts for less than 5% of total underground production in the U.S. today.
- Shortwall mining, a method currently accounting for less than 1% of deep coal production, involves the use of a continuous mining machine with movable roof supports, similar to longwall. The continuous miner shears coal panels 150–200 feet (40–60 m) wide and more than a half-mile (1 km) long, having regard to factors such as geological strata.
- Retreat mining is a method in which the pillars or coal ribs used to hold up the mine roof are extracted; allowing the mine roof to collapse as the mining works back towards the entrance. This is one of the most dangerous forms of mining owing to imperfect predictability of when the ceiling will collapse and possibly crush or trap workers in the mine.

## Production

Coal is mined commercially in over 50 countries. Over 7,036 Mt/yr of hard coal is currently produced, a substantial increase over the past 25 years. In 2006, the world production of brown

coal and lignite was slightly over 1,000 Mt, with Germany the world's largest brown coal producer at 194.4 Mt, and China second at 100.6 Mt.

Coal production has grown fastest in Asia, while Europe has declined. The top coal mining nations (figures in brackets are 2007 estimate of total coal production in millions of short tons) are:

- China (2,804 Mt)
- USA (1,146 Mt)
- India (529 Mt)
- Australia (428 Mt)
- South Africa (283 Mt)
- Russia (347 Mt)
- Indonesia (180 Mt)
- Poland (162 Mt)
- Kazakhstan (103 Mt)
- Colombia (75 Mt)

Most coal production is used in the country of origin, with around 16% of hard coal production being exported.

Global coal production is expected to reach 7,000 Mt/yr in 2030, with China accounting for most of this increase. Steam coal production is projected to reach around 5,200 Mt/yr; coking coal 620 Mt/yr; and brown coal 1,200 Mt/yr.

Coal reserves are available in almost every country worldwide, with recoverable reserves in around 70 countries. At current production levels, proven coal reserves are estimated to last 147 years. However, production levels are by no means level, and are in fact increasing and some estimates are that peak coal could arrive in many countries such as China and America by around 2030.

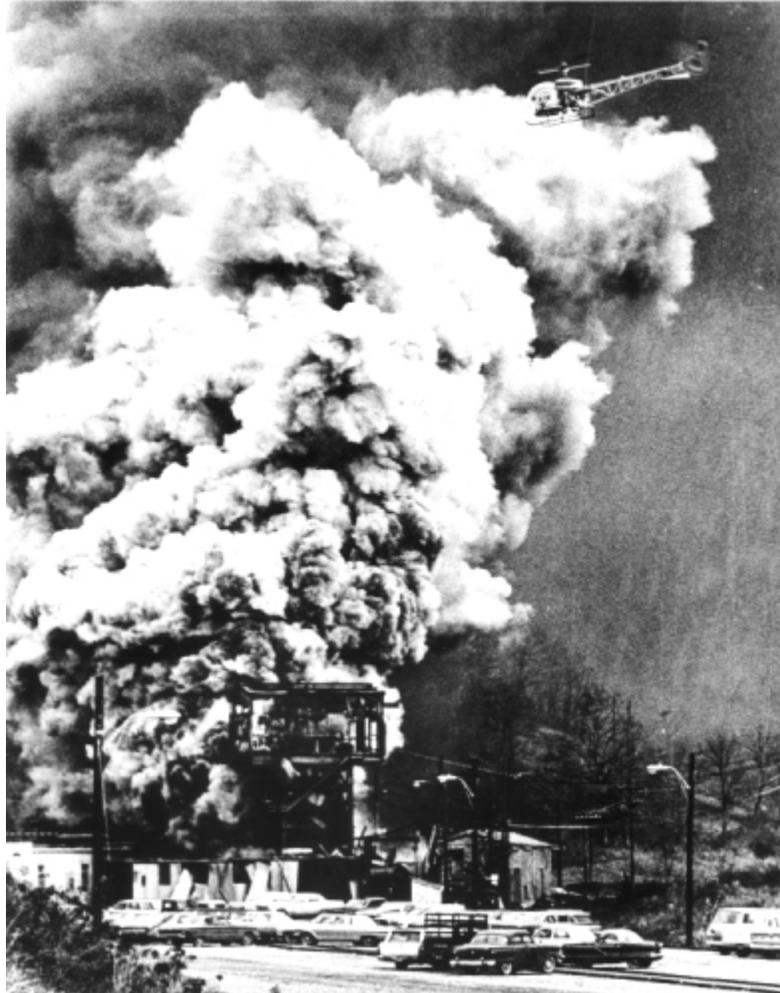
## **Modern mining**

Technological advancements have made coal mining today more productive than it has ever been. To keep up with technology and to extract coal as efficiently as possible modern mining personnel must be highly skilled and well trained in the use of complex, state-of-the-art instruments and equipment. Many jobs require four-year university degrees. Computer knowledge has also become greatly valued within the industry as most of the machines and safety monitors are computerized. The use of sophisticated sensing equipment to monitor air quality is common and has replaced the use of small animals such as canaries, often referred to as "miner's canaries".

In the United States, the increase in technology has significantly decreased the mining workforce from 335,000 coal miners working at 7,200 mines fifty years ago to 104,824 miners working in fewer than 2,000 mines today.

# Safety

## Dangers to miners



The Farmington coal mine disaster kills 78. 1968, WV, USA

Historically, coal mining has been a very dangerous activity and the list of historical coal mining disasters is a long one. Open cut hazards are principally mine wall failures and vehicle collisions; underground mining hazards include suffocation, gas poisoning, roof collapse and gas explosions. Firedamp explosions can trigger the much more dangerous coal dust explosions, which can engulf an entire pit. Most of these risks can be greatly reduced in modern mines, and multiple fatality incidents are now rare in some parts of the developed world. Modern mining in the U.S. is only slightly more dangerous than driving, with .02% of miners dying in accidents, compared with .016% of the country's population dying in car accidents.

However, in lesser developed countries and some developing countries, many miners continue to die annually, either through direct accidents in coal mines or through adverse health

consequences from working under poor conditions. China, in particular, has the highest number of coal mining related deaths in the world, with official statistic 6,027 deaths in 2004. To compare, 28 deaths were reported in the U.S. in the same year. Coal production in China is twice that in the U.S., while the number of coal miners is around 50 times that of the USA, making deaths in coal mines in China 4 times as common per worker (108 times as common per unit output) as in the USA.

In 2006, fatal work injuries among miners in the U.S. doubled from the previous year, totaling 47. These figures can in part be attributed to the Sago Mine disaster. The recent mine accident in Utah's Crandall Canyon Mine, where nine miners were killed and six entombed, speaks to the increase in occupational risks faced by U.S. miners.

Chronic lung diseases, such as pneumoconiosis (black lung) were once common in miners, leading to reduced life expectancy. In some mining countries black lung is still common, with 4000 new cases of black lung every year in the USA (4% of workers annually) and 10 000 new cases every year in China (0.2% of workers). Rates may be higher than reported in some regions.

Build-ups of a hazardous gas are known as damp, possibly from the German word "Dampf" which means steam or vapor:

- Black damp: a mixture of carbon dioxide and nitrogen in a mine can cause suffocation, and is formed as a result of corrosion in enclosed spaces so removing oxygen from the atmosphere.
- After damp: similar to black damp, an after damp consists of carbon monoxide, carbon dioxide and nitrogen and forms after a mine explosion.
- Fire damp: consists of mostly methane, a flammable gas.
- Stink damp: so named for the rotten egg smell of the hydrogen sulphide gas, a stink damp can explode.
- White damp: air containing carbon monoxide which is toxic, even at low concentrations

## **Safer times in modern mining**

Improvements in mining methods (e.g. longwall mining), hazardous gas monitoring (such as safety-lamps or more modern electronic gas monitors), gas drainage, electrical equipment, and ventilation have reduced many of the risks of rock falls, explosions, and unhealthy air quality. Statistical analyses performed by the U.S. Department of Labor's Mine Safety and Health Administration (MSHA) show that between 1990 and 2004, the industry cut the rate of injuries by more than half and fatalities by two-thirds. However, according to the Bureau of Labor Statistics, mining remains the second most dangerous occupation in America. New braces called Atlas Cribs contain a mix of hardwoods and a main lateral element that make these braces stronger than other braces used in the past. The new cribbing system takes up 41 percent less area than existing ones and may be up to 50 percent more efficient in terms of airflow.

## **Environmental impacts**

Coal mining can result in a number of adverse effects on the environment. Surface mining of coal completely eliminates existing vegetation, destroys the genetic soil profile, displaces or

destroys wildlife and habitat, degrades air quality, alters current land uses, and to some extent permanently changes the general topography of the area mined, This often results in a scarred landscape with no scenic value. Rehabilitation or reclamation mitigates some of these concerns and is required by Federal Law, specifically the Surface Mining Control and Reclamation Act of 1977.

Mine tailing dumps produce acid mine drainage which can seep into waterways and aquifers, with consequences on ecological and human health. If underground mine tunnels collapse, this can cause subsidence of land surfaces. During actual mining operations, methane, a known greenhouse gas, may be released into the air. And by the movement, storage, and redistribution of soil, the community of microorganisms and nutrient cycling processes can be disrupted.

## **Coal mining by country**

### **Australia**

Coal is mined in every state of Australia as well as the Northern Territory. It is mostly used to generate electricity, and 75% of annual coal production is exported, mostly to eastern Asia. Coal provides about 85% of Australia's electricity production. In 2007, 428 million short tons of coal was mined in Australia.

### **India**

In India Coal is mined in the states of Jharkhand, West Bengal, Orissa, Madhya Pradesh, Chhatisgarh, Maharashtra, Andhra Pradesh, Tamil Nadu, Assam and Meghalaya.

### **China**

The People's Republic of China is by far the largest producer of coal in the world, producing over 2.8 billion tons of coal in 2007, or approximately 39.8 percent of all coal produced in the world during that year. For comparison, the second largest producer, the United States, produced more than 1.1 billion tons in 2007. An estimated 5 million people work in China's coal-mining industry. As many as 20,000 miners die in accidents each year.

Most Chinese mines are deep underground and do not produce the surface disruption typical of strip mines. Although there is some evidence of reclamation of mined land for use as parks, China does not require extensive reclamation and is creating significant acreages of abandoned mined land which is unsuitable for agriculture or other human uses, and inhospitable to indigenous wildlife. Chinese underground mines often experience severe surface subsidence (6–12 meters), negatively impacting farmland because it no longer drains well. China uses some subsidence areas for aquaculture ponds but has more than they need for that purpose. Reclamation of subsided ground is a significant problem in China.

Because most Chinese coal is for domestic consumption and is burned with little or no air pollution control equipment, it contributes greatly to visible smoke and severe air pollution in

industrial areas using coal for fuel. Air pollution control equipment is being installed on some plants, but there are unconfirmed reports it is only turned on when inspectors visit.

## Colombia



Opencast coal mine at Cerrejón

Some of the world's largest coal reserves are located in South America, and an opencast mine at Cerrejón in Colombia is one of the world's largest open pit mines. Output of the mine in 2004 was 24.9 million tons (compared to total global hard coal production of 4,600 million tons). Cerrejón contributed about half of Colombia's coal exports of 52 million tons that year, with Colombia ranked sixth among major coal exporting nations. The company planned to expand production to 32 million tons by 2008.

The company has its own 150 km standard-gauge railroad, connecting the mine to its coal-loading terminal at Puerto Bolívar on the Caribbean coast. There are two 120-car unit trains, each carrying 12,000 tons of coal per trip. The round-trip time for each train, including loading and unloading, is about 12 hours. The coal facilities at the port are capable of loading 4,800 tons per hour on to vessels of up to 175,000 tons of dead weight. The mine, railroad and port operate 24 hours per day. Cerrejón directly employs 4,600 workers, with a further 3,800 employed by contractors. The reserves at Cerrejón are low-sulfur, low-ash, bituminous coal. The coal is

mostly used for electric power generation, with some also used in steel manufacture. The surface mineable reserves for the current contract are 330 million tons. However, total proven reserves to a depth of 300 metres are 3,000 million tons.

### **South Africa**

South Africa is one of the ten largest coal producing and the fourth largest coal exporting country in the world.

### **United States**

The American share of world coal production remained steady at about 20% from 1980 to 2005, at about 1 billion short tons per year.

In a conference with the West Virginia Coal Association former President George W. Bush said that there is no more reliable source of electricity than coal and put coal at center of US energy independence.

### **Ukraine**

More than 90% of Ukraine's coal production comes from the Donets Basin. The country's coal industry employs about 500,000 people.

## Chapter- 5

# Environmental Issues with Mining



Acid mine drainage in the Rio Tinto River

There are a number of **environmental issues with mining**.

Environmental issues can include erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to increase the available room for the storage of the created debris and soil. Besides creating environmental damage, the contamination resulting from leakage of chemicals also affect the health of the local population. Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. Some mining methods may have significant environmental and public health effects.

Erosion of exposed hillsides, mine dumps, tailings dams and resultant siltation of drainages, creeks and rivers can significantly impact the surrounding areas, a prime example being the giant Ok Tedi Mine in Papua New Guinea. In areas of wilderness mining may cause destruction and disturbance of ecosystems and habitats, and in areas of farming it may disturb or destroy productive grazing and croplands. In urbanised environments mining may produce noise pollution, dust pollution and visual pollution.

## **Issues**

### **Water pollution**



Acidic lake wastewater at the abandoned Northland Mine in Temagami, Ontario, Canada

Mining can have adverse effects on surrounding surface and ground water if protective measures are not taken. The result can be unnaturally high concentrations of some chemicals, such as arsenic, sulfuric acid, and mercury over a significant area of surface or subsurface. Runoff of mere soil or rock debris -although non-toxic- also devastates the surrounding vegetation. The dumping of the runoff in surface waters or in forests is the worst option here. Submarine tailings disposal is regarded as a better option (if the soil is pumped to a great depth). Mere land storage and refilling of the mine after it has been depleted is even better, if no forests need to be cleared for the storage of the debris. There is potential for massive contamination of the area surrounding mines due to the various chemicals used in the mining process as well as the potentially damaging compounds and metals removed from the ground with the ore. Large amounts of water produced from mine drainage, mine cooling, aqueous extraction and other mining processes increases the potential for these chemicals to contaminate ground and surface water. In well-regulated mines, hydrologists and geologists take careful measurements of water and soil to exclude any type of water contamination that could be caused by the mine's operations. The reducing or eliminating of environmental degradation is enforced in modern American mining by federal and state law, by restricting operators to meet standards for protecting surface and ground water from contamination. This is best done through the use of non-toxic extraction processes as bioleaching. If the project site becomes nonetheless polluted, mitigation techniques such as acid mine drainage (AMD) need to be performed.

The five principal technologies used to monitor and control water flow at mine sites are diversion systems, containment ponds, groundwater pumping systems, subsurface drainage systems, and subsurface barriers. In the case of AMD, contaminated water is generally pumped to a treatment facility that neutralizes the contaminants.

### ***Heavy metals***

Dissolution and transport of metals and heavy metals by run-off and ground water is another example of environmental problems with mining, such as the Britannia Mine, a former copper mine near Vancouver, British Columbia. Tar Creek, an abandoned mining area in Picher, Oklahoma that is now an Environmental Protection Agency superfund site, also suffers from heavy metal contamination. Water in the mine containing dissolved heavy metals such as lead and cadmium leaked into local groundwater, contaminating it. Long-term storage of tailings and dust can lead to additional problems, as they can be easily blown off site by wind, as occurred at Scouriotissa, an abandoned copper mine in Cyprus.

### **Deforestation**

With open cast mining the overburden, which may be covered in forest, must be removed before the mining can commence. Although the deforestation due to mining may be small compared to the total amount it may lead to species extinction if there is a high level of local endemism.

# Mountaintop removal mining



Mountaintop removal site



Mountaintop Removal in Martin County, Kentucky

**Mountaintop/Mountain-top/Mountain top removal mining (MTR)**, also known as **mountaintop mining (MTM)**, is a form of surface mining that involves the mining of the summit or summit ridge of a mountain. Entire coal seams are removed from the top of a mountain, hill or ridge by removing the so-called overburden (soil, lying above the economically desired resource). After the coal is extracted, the removed material is put back onto the ridge to approximate the mountain's original contours. Any overburden the mining company considers excess (that which it's not able to place back onto the ridge top) is moved into neighboring valleys. Mountaintop removal is most closely associated with coal mining in the Appalachian Mountains in the eastern United States.

Peer-reviewed studies show that mountaintop mining has serious environmental impacts, including loss of biodiversity, that mitigation practices cannot successfully address. There are also adverse human health impacts which result from contact with affected streams or exposure to airborne toxins and dust.

## Overview

Mountaintop removal mining is a form of surface mining that involves the topographical alteration and/or removal of a summit, summit ridge, or significant portion of a mountain, hill, or ridge in order to obtain a desired geologic material.

The MTR process involves the removal of coal seams by first fully removing the overburden lying atop them, exposing the seams from above. This method differs from more traditional underground mining, where typically a narrow shaft is dug which allows miners to collect seams using various underground methods, while leaving the vast majority of the overburden undisturbed. The overburden waste resulting from MTR is either placed back on the ridge, attempting to reflect the approximate original contour of the mountain, and/or it is moved into neighboring valleys.

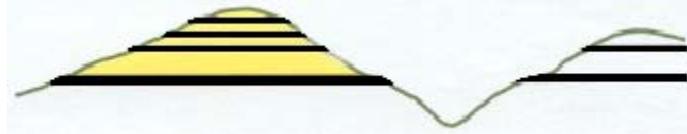
The process involves blasting with explosives to remove up to 400 vertical feet (120 m) of overburden to expose underlying coal seams. Excess rock and soil laden with toxic mining byproducts are often dumped into nearby valleys, in what are called "holler fills" or "valley fills."

MTR in the United States is most often associated with the extraction of coal in the Appalachian Mountains, where the United States Environmental Protection Agency (EPA) estimates that 2,200 square miles (5,700 km<sup>2</sup>) of Appalachian forests will be cleared for MTR sites by the year 2012. Sites range from Ohio to Virginia. It occurs most commonly in West Virginia and Eastern Kentucky, the top two coal-producing states in Appalachia, with each state using approximately 1,000 tonnes of explosives per day for surface mining. At current rates, MTR in the U.S. will mine over 1.4 million acres (5,700 km<sup>2</sup>) by 2010, an amount of land area that exceeds that of the state of Delaware.

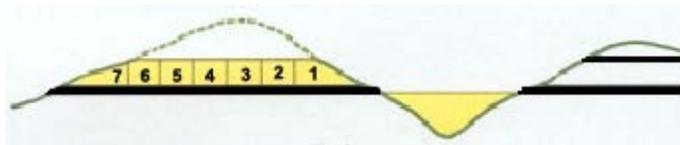
Mountaintop removal has been practiced since the 1960s. Increased demand for coal in the United States, sparked by the 1973 and 1979 petroleum crises, created incentives for a more economical form of coal mining than the traditional underground mining methods involving hundreds of workers, triggering the first widespread use of MTR. Its prevalence expanded

further in the 1990s to retrieve relatively low-sulfur coal, a cleaner-burning form, which became desirable as a result of amendments to the U.S. Clean Air Act that tightened emissions limits on high-sulfur coal processing.

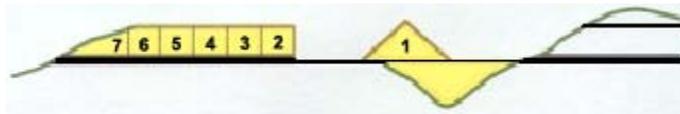
## Process



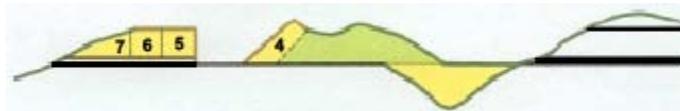
US EPA diagram of mountaintop mining: "**Step 1.** Layers of rock and dirt above the coal (called overburden) are removed."



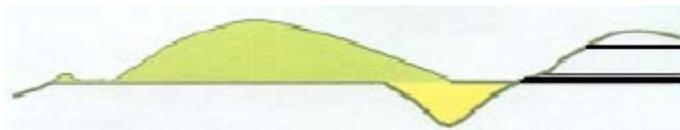
"**Step 2.** The upper seams of coal are removed with spoils placed in an adjacent valley."



"**Step 3.** Draglines excavate lower layers of coal with spoils placed in spoil piles."



"**Step 4.** Regrading begins as coal excavation continues."



"**Step 5.** Once coal removal is complete, final regrading takes place and the area is revegetated."

Land is deforested prior to mining operations and the resultant lumber is either sold or burned. According to SMCRA, the topsoil is supposed to be removed and set aside for later reclamation. However, coal companies are often granted waivers and instead reclaim the mountain with "topsoil substitute." The waivers are granted if adequate amounts of topsoil are not naturally present on the rocky ridge top. Once the area is cleared, miners use explosives to blast away the overburden, the rock and subsoil, to expose coal seams beneath. The overburden is then moved by various mechanical means to areas of the ridge previously mined. These areas are the most

economical area of storage as they are located close to the active pit of exposed coal. If the ridge topography is too steep to adequately handle the amount of spoil produced then additional storage is used in a nearby valley or hollow, creating what is known as a *valley fill* or *hollow fill*. Any streams in a valley are buried by the overburden.

A front-end loader or excavator then removes the coal, where it is transported to a processing plant. Once coal removal is completed, the mining operators back stack overburden from the next area to be mined into the now empty pit. After backstacking and grading of overburden has been completed, topsoil (or a topsoil substitute) is layered over the overburden layer. Next, grass seed is spread in a mixture of seed, fertilizer, and mulch made from recycled newspaper. Depending on surface land owner wishes the land will then be further reclaimed by adding trees if the pre-approved post-mining land use is forest land or wildlife habitat. If the land owner has requested other post-mining land uses the land can be reclaimed to be used as pasture land, economic development or other uses specified in SMCRA.

Because coal usually exists in multiple geologically stratified seams, miners can often repeat the blasting process to mine over a dozen seams on a single mountain, increasing the mine depth each time. This can result in a vertical descent of hundreds of extra feet into the earth.

## **Economics**

Just under half of the electricity generated in the United States is produced by coal-fired power plants. MTR accounted for less than 5% of U.S. coal production as of 2001. In some regions, however, the percentage is higher, for example MTR provided 30% of the coal mined in West Virginia in 2006.

Historically in the U.S. the prevalent method of coal acquisition was underground mining which is very labor-intensive. In MTR, through the use of explosives and large machinery, more than two and a half times as much coal can be extracted per worker per hour than in traditional underground mines, thus greatly reducing the need for workers. In Kentucky, for example, the number of workers has declined over 60% from 1979 to 2006 (from 47,190 to 17,959 workers). The industry overall lost approximately 10,000 jobs from 1990 to 1997, as MTR and other more mechanized underground mining methods became more widely used. The coal industry asserts that surface mining techniques, such as mountaintop removal, are safer for miners than sending miners underground.

Proponents argue that in certain geologic areas, MTR and similar forms of surface mining allow the only access to thin seams of coal that traditional underground mining would not be able to mine. MTR is sometimes the most cost-effective method of extracting coal.

Several studies of the impact of restrictions to mountaintop removal were authored in 2000 through 2005. Studies by Mark L. Burton, Michael J. Hicks and Cal Kent identified significant state level tax losses attributable to lower levels of mining (notably the studies did not examine potential environmental costs, which the authors acknowledge may outweigh commercial benefits).

## Legislation in the United States

In the United States, MTR is allowed by section 515(c)(1) of SMCRA. Although most coal mining sites must be reclaimed to the land's pre-mining contour and use, regulatory agencies can issue waivers to allow MTR. In such cases, SMCRA dictates that reclamation must create "a level plateau or a gently rolling contour with no highwalls remaining."

Permits must be obtained to deposit valley fill into streams. On four occasions, federal courts have ruled that the US Army Corps of Engineers violated the Clean Water Act by issuing such permits. Massey Energy Company is currently appealing a 2007 ruling, but has been allowed to continue mining in the meantime because "most of the substantial harm has already occurred," according to the judge.

The Bush administration appealed one of these rulings in 2001 because the Act had not explicitly defined "fill material" that could legally be placed in a waterway. The EPA and Army Corps of Engineers changed a rule to include mining debris in the definition of fill material, and the ruling was overturned. However, if passed, the Clean Water Protection Act (*H.R. 1310*), a bill in the House of Representatives, would revert this change by specifying that coal mining waste does not constitute fill material, in effect disallowing valley fills.

On December 2, 2008, the Bush Administration made a rule change to remove the Stream Buffer Zone protection provision from SMCRA allowing coal companies to place mining waste rock and dirt directly into headwater waterways.

A federal judge has also ruled that using settling ponds to remove mining waste from streams violates the Clean Water Act. He also declared that the Army Corps of Engineers has no authority to issue permits allowing discharge of pollutants into such in-stream settling ponds, which are often built just below valley fills.

On January 15, 2008, the environmental advocacy group Center for Biological Diversity petitioned the United States Fish and Wildlife Service to end a policy that waives detailed federal Endangered Species Act reviews for new mining permits. The current policy states that MTR can never damage endangered species or their habitat as long as mining operators comply with federal surface mining law, despite the complexities of species and ecosystems. Since 1996, this policy has exempted many strip mines from being subject to permit-specific reviews of impact on individual endangered species.

On May 25, 2008, North Carolina State Representative Pricey Harrison introduced a bill to ban the use of mountaintop removal coal from coal fired power plants within North Carolina. This proposed legislation would have been the only legislation of its kind in the United States, however the bill was defeated.

## Environmental and health impacts



The Hobet mine in West Virginia taken by NASA LANDSAT in 1984



The Hobet mine in West Virginia taken by NASA LANDSAT in 2009

Critics contend that MTR is a destructive and unsustainable practice that benefits a small number of corporations at the expense of local communities and the environment. Though the main issue has been over the physical alteration of the landscape, opponents to the practice have also criticized MTR for the damage done to the environment by massive transport trucks, and the environmental damage done by the burning of coal for power. Blasting at MTR sites also expels dust and fly-rock into the air, which can disturb or settle onto private property nearby. This dust may contain sulfur compounds, which corrodes structures and is a health hazard.

A January 2010 report in the journal *Science* reviews current peer-reviewed studies and water quality data and explores the consequences of mountaintop mining. It concludes that mountaintop mining has serious environmental impacts that mitigation practices cannot successfully address. For example, the extensive tracts of deciduous forests destroyed by mountaintop mining support several endangered species and some of the highest biodiversity in North America. There is a particular problem with burial of headwater streams by valley fills which causes permanent loss of ecosystems that play critical roles in ecological processes.

Published studies also show a high potential for human health impacts. These may result from contact with streams or exposure to airborne toxins and dust. Adult hospitalization for chronic pulmonary disorders and hypertension are elevated as a result of county-level coal production. Rates of mortality, lung cancer, as well as chronic heart, lung and kidney disease are also increased.

A United States Environmental Protection Agency (EPA) environmental impact statement finds that streams near some valley fills from mountaintop removal contain higher levels of minerals in the water and decreased aquatic biodiversity. The statement also estimates that 724 miles (1,165 km) of Appalachian streams were buried by valley fills between 1985 to 2001.

Although U.S. mountaintop removal sites by law must be reclaimed after mining is complete, reclamation has traditionally focused on stabilizing rock formations and controlling for erosion, and not on the reforestation of the affected area. Fast-growing, non-native grasses such as *lespedeza sericea*, planted to quickly provide vegetation on a site, compete with tree seedlings, and trees have difficulty establishing root systems in compacted backfill. Consequently, biodiversity suffers in a region of the United States with numerous endemic species. In addition, introduced species of elk on mountaintop removal sites in Kentucky are eating tree seedlings.

Advocates of MTR claim that once the areas are reclaimed as mandated by law, the area can provide flat land suitable for many uses in a region where flat land is at a premium. They also maintain that the new growth on reclaimed mountaintop mined areas is better suited to support populations of game animals.

## Sand mining

**Sand mining** is a practice that is becoming an environmental issue as the demand for sand increases in industry and construction. Sand is mined from beaches and inland dunes and dredged from ocean beds and river beds. It is often used in manufacturing as an abrasive, for example, and it is used to make concrete. As communities grow, construction requires less wood and more concrete, leading to a demand for low-cost sand. Sand is also used to replace eroded coastline.

A related process is the mining of mineral sands, such as mineral deposits, grain, wheat, diamond which contain industrial useful minerals, mainly gold and silver. These minerals typically occur combined with ordinary sand. The sand is dug up, the valuable minerals are separated in water by using their different density, and the remaining ordinary sand is re-deposited.

Sand mining is a direct and obvious cause of erosion, and also impacts the local wildlife. For example, sea turtles depend on sandy beaches for their nesting, and sand mining has led to the near extinction of ghariyals (a species of crocodiles) in India. Disturbance of underwater and coastal sand causes turbidity in the water, which is harmful for such organisms as corals that need sunlight. It also destroys fisheries, causing problems for people who rely on fishing for their livelihoods.

Removal of physical coastal barriers such as dunes leads to flooding of beachside communities, and the destruction of pictures beaches causes tourism to dissipate. Sand mining is regulated by law in many places, but is still often done illegally.



Sand mine in the Czech Republic

## **Sand mining by country**

### **Australia**

#### ***New South Wales***

In the 1930s mining operations began on the Kurnell Peninsula (Captain Cook's landing place in Australia) to supply the expanding Sydney building market. It continued until 1990 with an estimate of over 70 million tonnes of sand having been removed. The sand has been valued for many decades by the building industry, mainly because of its high crushed shell content and lack of organic matter, it has provided a cheap source of sand for most of Sydney since sand mining operations began. The site has now been reduced to a few remnant dunes and deep water-filled pits which are now being filled with demolition waste from Sydney's building sites. Removal of the sand has significantly weakened the peninsula's capacity to resist storms. Ocean waves pounding against the reduced Kurnell dune system have threatened to break through to Botany Bay, especially during the storms of May and June back in 1974 and of August 1998.

#### ***Queensland***

A large and long running sand mine in Queensland, Australia (on North Stradbroke Island) provides a case study in the (disastrous) environmental consequences on a fragile sandy-soil based ecosystem, justified by the provision of low wage casual labor on an island with few other work options.

Sand mining contributes to the construction of buildings and development. However, the negative effects of sand mining include the permanent loss of sand in areas, as well as major habitat destruction.

### **New Zealand**

Sand mining occurs in the Kaipara Harbour, off the coast at Pakiri and offshore from Little Barrier Island.

A sand mine had operated at Whiritoa on the east coast of the North Island for 50 years extracting 180,000m<sup>3</sup> of sand. Coastal sand mines currently operate at Maioro and Taharoa to recover iron sand.

When an application was lodged in 2005 to mine iron sands on the seabed of the coast of Raglan local residents organised in opposition to the scheme. The application for the mining was turned down by Crown Minerals due to a lack of technical detail.

## **Subsidence**



House in Gladbeck, Germany, with fissures caused by gravity erosion due to mining

## **Tailings and spoil**

- Tailings
- Slag heap
- Spoil tip

## **Mitigation**

To ensure completion of reclamation, or restoring mine land for future use, many governments and regulatory authorities around the world require that mining companies post a bond to be held in escrow until productivity of reclaimed land has been convincingly demonstrated, although if cleanup procedures are more expensive than the size of the bond, the bond may simply be abandoned. Since 1978 the mining industry has reclaimed more than 2 million acres (8,000 km<sup>2</sup>) of land in the United States alone. This reclaimed land has renewed vegetation and wildlife in previous mining lands and can even be used for farming and ranching.

## Chapter- 6

# Mining in Wales and Australia

## Mining in Wales



A Welsh miner at Tower Colliery

**Mining in Wales** provided a significant source of income to the economy of Wales throughout the nineteenth century and early twentieth century.

Wales was famous for its coal mining, in the Rhondda Valley, the South Wales Valleys and throughout the South Wales coalfield and by 1913 Cardiff had become the largest coal exporting port in the world, as coal was transported down by rail. North east Wales also had its own coalfield and Tower Colliery near Hirwaun is regarded by many as the oldest open coal mine and one of the largest in the world.

## History



There had been small-scale mining in Wales in the pre-Roman British Iron Age, but it would be undertaken on an industrial scale under the Romans, who completed their conquest of Wales in AD 78. Substantial quantities of gold, copper, and lead were extracted, along with lesser amounts of zinc and silver. Mining would continue until the process was no longer practical or profitable, at which time the mine would be abandoned. The extensive excavations of the Roman operations at Dolaucothi provide a picture of the high level of Roman technology and the expertise of Roman engineering in the ancient era.

## Coal mining

There is evidence of mining in the Blaenavon area going back to the 14th century, and there is evidence of mine workings at Mostyn as far back as 1261, but it is believed to have been practised even as early as Roman times. The coal mining industry burgeoned throughout the Industrial Revolution and into the 19th century, when shafts were sunk to complement the open-cast mining and drift mining already exploiting the ample and obvious coal resources.



During the first half of the nineteenth century mining was often at the centre of working-class discontent in Wales, and a number of uprisings such as the Merthyr Rising in 1831 against employers were a characteristic of the Industrial Revolution in Wales, Dic Penderyn became a martyr to industrial workers. The Chartist movement and the 1839 Newport Rising showed the growing concerns and awareness of the work force of their value to the nation. Although the

Factory Acts of the 1830s and resultant Mines Act of 1842 was meant to prevent women and boys under 10 years of age from working underground, it is believed to have been widely ignored. To replace female and child labour the pit pony was more widely introduced. Much later, in the middle of the 20th century, mining was still a hazardous enterprise, resulting in many accidents and long term ill-health with many of Blaenavon's older citizens still suffering from silicosis and other mining related diseases.

Incorporating the existing Coity colliery and Kearsley's pit (sunk in 1860), the Big Pit opened in 1880, so called because it was the first shaft in Wales large enough to allow two tramways. At the height of coal production, there were over 160 drift mines and over 30 shafts working the nine seams in the Blaenavon locality. Big Pit alone employed some 1,300 men digging a quarter of a million tons of coal a year. Large amounts of coal were needed to supply the local ironworks, as it took 3 tons of coal to produce a ton of iron. Blaenavon 'steam' coal was of high quality and it was exported globally. Burning hotly while leaving minimum ash, it was ideal to power the steam engines that drove steamships, Dreadnoughts of the Royal Navy and steam locomotive railways across the world.

However both economics and politics after World War I with its resultant general strike, the 1930s Depression and later Nationalisation and the miners' strike of 1984-1985 took their toll and all the smaller pits were either abandoned or swallowed into Big Pit's encroaching search for new seams. Finally in February 1980 the coal ran out and even Big Pit, then the oldest mine in Wales, had to close.

There are still nine headstocks remaining in Wales, including Big Pit (the metal frame erected in 1921 during the Miners' Strike of that year, to replace a wooden structure).



Big Pit museum at Blaenavon

## **Big Pit National Coal Museum & other mining museums in Wales**

The Big Pit National Coal Museum is located at Blaenavon, and in 2005 it won the prestigious Gulbenkian Prize for museum of the year. It is one of only two remaining mines where it is possible for visitors to journey to the underground workings some 300 ft (90 m) below using the same cages that transported the miners.

Other museums preserving the memories and heritage of the coal mining industry in Wales are at:

- South Wales Miners' Museum near Cymmer
- Cefn Coed Colliery Museum near Crynant
- Rhondda Heritage Park near Trehafod

## **Slate mining**

North Wales also had a significant slate mining industry.

## Working mines

Following the miners' strike, the only two deep mines remained working in Wales. Tower Colliery, Hirwaun, had been run by a miner's co-operative since 1994. Due to dwindling coal seams, the colliery was last worked on January 18, 2008 and the official closure of the colliery occurred on January 25. Mining continues at Aberpergwm Colliery, a smaller mine closed by the National Coal Board in 1985 but reopened in 1996. Several other small mines still exist, including the Blaentillery drift mine near to the Big Pit National Coal Museum.

## Mining in Australia



Super Pit gold mine at Kalgoorlie in Western Australia is Australia's largest open-pit mine

**Mining in Australia** is a significant primary industry and contributor to the Australian economy. Historically, mining booms have also encouraged immigration to Australia. Many different ores and minerals are mined throughout the country.

## History

Mining contributed significantly to preventing potential bankruptcy for the early colonies in Australia. Silver and later copper were discovered in South Australia in the 1840s, leading to the export of ore and the immigration of skilled miners and smelters. The first economic minerals in Australia were silver and lead in February 1841 at Glen Osmond, now a suburb of Adelaide in South Australia. Mines including Wheal Gawler and Wheal Watkins opened soon after. The value of these mines was soon overshadowed by the discovery of copper at Kapunda (1842), Burra (1845) and in the Copper Triangle (Moonta, Kadina and Wallaroo) area at the top of Yorke Peninsula (1861).



Broken Hill, NSW, one of Australia's iconic mining towns, backed by the man-made mullock heaps from the *Line of Lode*

## Gold rushes

In 1851, gold was found near Ophir, New South Wales. Weeks later, gold was found in the newly established colony of Victoria. Australian gold rushes, in particular the Victorian Gold Rush, had a major lasting impact on Victoria, and on Australia as a whole. The gold rush coloured every aspect of Australian society and elements of it are still clearly visible today. The influx of wealth that gold brought soon made Victoria Australia's richest colony by far, and Melbourne the island's largest city. By the middle of the 1850s, 40% of the world's gold was produced in Australia.

Australia's population changed dramatically as a result of the gold rushes: in 1851 the population was 437,655 and a decade later it was 1,151,947; the rapid growth was predominantly a result of the new chums (recent immigrants from the United Kingdom and other Commonwealth states) who contributed the 'rush'. Although most Victorian goldfields were exhausted by the end of the 19th century, and although much of the profit was sent back to the United Kingdom, sufficient wealth remained to fund substantial development of industry and infrastructure.

# Mining

## Minerals and resources

Large quantities of minerals and resources are extracted in Australia. These include:

- Iron ore – Australia was the world's third largest supplier in 2008 after China and Brazil, supplying 342 million metric tonnes.
- Nickel – Australia was the world's second largest producer in 2006 after Canada.
- Bauxite/aluminum
- Copper
- Gold – Australia is the second largest producer after China.
- Silver
- Uranium – Australia is responsible for 16% of the world's production and was the world's third largest supplier in 2009 after Kazakhstan and Canada.
- Diamond – Australia has the third largest commercially-viable deposits after Russia and Botswana. Australia also boasts the richest diamantiferous pipe with production reaching peak levels of 42 metric tons (41 LT/46 ST) per year in the 1990s.
- Opal – Australia is the world's largest producer of opal, being responsible for 95% of production.
- Zinc – Australia was second only to China in zinc production in 2008, producing just under 14% of world production.
- Coal – Australia is the world's largest exporter of coal and fourth largest producer of coal behind China, USA and India.
- Oil shale
- Petroleum – Australia is the twenty-eighth largest producer of petroleum.
- Natural gas

Much of the raw material mined in Australia is exported overseas to countries such as China for processing into refined product. Energy and minerals constitute two thirds of Australia's total exports to China, and more than half of the Australia's iron ore exports are to China.

## Mining regions



Drilling rig at a BHP Billiton minesite about 550 km outside of Newman, Western Australia

Australia has mining activity in all of its states and territories. Particularly significant areas today include the Goldfields, Peel and Pilbara regions of Western Australia, the Hunter Valley in New South Wales, the Bowen Basin in Queensland and Latrobe Valley in Victoria and various parts of the outback. Places such as Kalgoorlie, Mount Isa, Mount Morgan and Coober Pedy are known as mining towns.

Major active mines in Australia include:

- Olympic Dam in South Australia, a copper, silver and uranium mine believed to have the world's largest uranium resource.
- Super Pit gold mine, which has replaced a number of underground mines near Kalgoorlie, Western Australia

## **Coal mining**

Coal is mined in every state of Australia. It is used to generate electricity and is exported. 75% of the coal mined in Australia is exported, mostly to eastern Asia. In 2000/01, 258.5 million tonnes of coal was mined, and 193.6 million tonnes exported, rising to 261 million tonnes of exports in 2008-09.. Coal also provides about 85% of Australia's electricity production. Australia is the world's leading coal exporter.

## **Uranium mining**

Uranium mining in Australia began in the early 20th century in South Australia. Australia contains 23% of the world proven estimated uranium reserves. In recent decades opposition to uranium mining in Australia has increased, resulting in many government inquiries into its extraction. The three largest uranium mines in the country are Olympic Dam, Ranger Uranium Mine and Beverley Uranium Mine. Future production is expected from Honeymoon Uranium Mine and the planned Four Mile uranium mine.

## **Economics**

A number of large multinational mining companies including BHP Billiton, Newcrest, Rio Tinto, Alcoa, Chalco, Shenhua (a Chinese mining company), Alcan and Xstrata operate in Australia. There are also a lot of small mining and mineral exploration companies listed on the Australian Stock Exchange (ASX). Overall, the resources sector represents almost 20% of the ASX market by capitalisation, and almost one third of the companies listed.

Mining contributes about 5.6% of Australia's Gross Domestic Product. This is up from only 2.6% in 1950, but down from over 10% at the time of federation in 1900. In contrast, mineral exports contribute around 35% of Australia's exports. Australia is the world's largest exporter of coal (35% of international trade), iron ore, lead, diamonds, rutile, zinc and zirconium, second largest of gold and uranium, and third largest of aluminium. Japan was the major purchaser of Australian mineral exports in the mid 1990s.

Of the developed countries, perhaps only in Canada and Norway does mining play as significant a part in the economy; for comparison, in Canada mining represents about 3.6% of the Canadian economy and 32% of exports and in Norway mining, dominated by petroleum, represents about 19% of GDP and 46% of exports. By comparison, in the United States mining represents only about 1.6% of GDP.

Despite its export importance, the mining sector employs only a small proportion of the workforce - roughly 129,000 Australians, representing only about 1.3% of the total labour force.

## **Technology and services**

Australia's high labour costs and first-world safety regulations, distinctive geology, and the importance placed on mining research by successive governments and businesses has meant that

the Australian mining sector is quite technologically advanced. A large proportion of mines worldwide make use of Australian-developed computer software, such as specialised Enterprise resource planning software by Mincom Limited and geology/mine planning software by Runge Ltd and Maptek Pty Ltd. Australia's mining services, equipment, and technology exports are over \$2 billion annually.

## Lifestyle

Many mines in remote areas have a traditional company town (for example Roxby Downs or Leigh Creek), or support towns that used to be company towns such as Broken Hill and Mount Isa.



The town of Mount Isa is surrounded by vast mineral deposits

Most mines in remote areas are operated on a fly-in-fly-out basis where the miners' "home" and family remains in a major city, and the miners fly out to their mine for two weeks of solid work, then fly home for one week of rest. The roster may vary from site to site. 3 weeks on / 1 week off rosters are not uncommon and the working away period can be for much longer than 2 or 3 weeks. A fly-in-fly-out roster is common on offshore oil platforms, as well as minesites located inland of Australia, such as Century, Challenger and Bronzewing minesites.

Free meals and accommodation are provided for employees as a means to offset the time spent living away from home. Breakfast, lunch and dinner are consumed and collected from the 'mess hall' at the mining camp. Living quarters provided at camp sites range from 2 by 4 metre portable homes to permanent 6 by 8 metre rooms with ensuites. Fridges, single beds, television, electricity and water are also provided with rooms.

## **Environment and politics**



The mountains near Queenstown, Tasmania, completely denuded of vegetation through effects of mining

Mining has had a substantial environmental impact in some areas of Australia. Historically, the Victorian gold rush resulted in substantial deforestation, consequent erosion, and arsenic pollution. The effects on the landscape near Bendigo and Ballarat can still be seen today. Queenstown, Tasmania's mountains were also completely denuded through a combination of logging and pollution from a mine smelter, and remain bare today.

Uranium mining has been controversial, partly for its alleged environmental impact but more so because of its end uses in nuclear power and nuclear weapons. The Australian Labor Party, one of Australia's two major parties, maintains a policy of "no new uranium mines". As of 2006, the increased world demand for uranium has seen some pressure, both internally and externally on

the ALP, for a policy change. Australia is a participant in international anti-proliferation efforts designed to ensure that no exported uranium is used in nuclear weapons.

## Mining disasters



Memorial for the workers who lost their lives at Mount Kembla, 1902

### Mount Kembla

In 1883 a coal mine was opened near Mount Kembla in the Illawarra District of New South Wales. In 1902 there was an explosion in the mine and 96 men and boys lost their lives, either while at work or in the course of trying to save the lives of others. Every family in the village

lost a relative. A service of commemoration is held annually on 31 July at the Mount Kembla Soldiers' and Miners' Memorial Church. This is the worst mining disaster in Australia's history.

## **Balmain Colliery**

Balmain Colliery was located in Birchgrove, New South Wales and produced coal from 1897 until 1931 and natural gas until 1945. During this period, 10 miners lost their lives in three separate incidents:

**1900** On 17 March 1900, six miners were being lowered down the Birthday shaft. At 1,424 feet the bucket they were travelling in caught on a projection, tipped over and five of the six men fell to their death in the shaft. As a result of this accident, the *Mining Act* was amended to provide guide rails in shafts to prevent bucket swinging or overturning.

**1932** In 1932, a year after the mine closed, a six inch bore was sunk below the Birthday shaft to pipe Natural Gas to the surface. During the sinking of the bore, two men were killed when the gas ignited and exploded.

**1945** During the sealing of the Birthday shaft on 20 April 1945, a rudimentary test was being undertaken which ignited escaping gas and caused an explosion below the seal. The company manager and two men were killed in the accident and another two men injured.

## **North Mount Lyell**

On October 12, 1912, the North Mount Lyell Fire caused the death of 42 miners, and required breathing apparatus to be transported from Victorian mines at great speed, to rescue trapped miners. The subsequent royal commission was inconclusive as to the cause.

## **Mount Mulligan**

The 1921 Mount Mulligan mine disaster occurred in Far North Queensland. These explosions, caused by using naked flame for lighting, killed seventy-five men.

## **Moura**

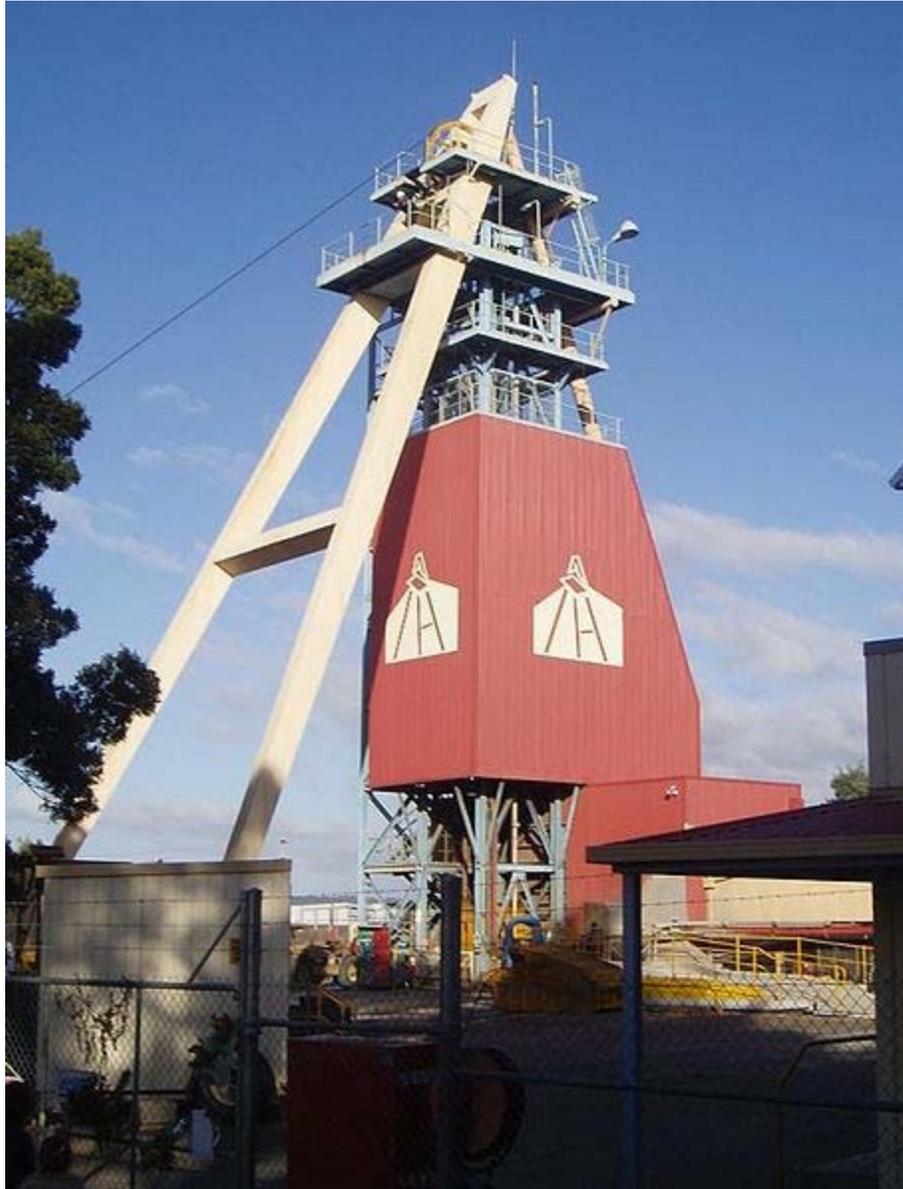
Four serious accidents have occurred at mines in the Central Queensland town of Moura, Queensland|Moura. The first accident took the lives of 13 men in September 1975. In July 1986 there was an explosion at Moura Number 4 Mine. 12 coal miners lost their lives in this disaster that sparked controversy after experts claimed the accident was avoidable. Another explosion killed two men in January 1994 and just eight months later another explosion deep underground took the lives of 11 men.

## **Bronzewing**

On the 26th of June 2000, at the Bronzewing Gold Mine in Western Australia (400 kilometers from Kalgoorlie), 18,000 cubic meters of sand-slurry, sludge, mud and rock broke through a

storage wall. Three men (Timothy Lee Bell, 21, Shane Hamill, 45 and Terrence Woodard, 26) were killed and eight escaped the 'accident'. It took over a month to retrieve the men from the site.

## **Beaconsfield**



Headworks over a shaft at Beaconsfield gold mine in Tasmania

On 25 April 2006, part of an underground gold mine at Beaconsfield in Tasmania collapsed. One miner, Larry Knight, was killed by the rock fall, and two others, Brant Webb and Todd Russel, were trapped, leading to a rescue mission that took two weeks to get them out alive.

## **Bulli**

**1887** At 2.30pm on 23 March 1887, an explosion at the mine in Bulli in New South Wales killed 81 people. A special commission was set up to investigate the explosion and concluded:

“ ..that the explosion was caused by marsh gas or carbonic hydrate that had accumulated at the face. That the immediate cause was probably the flame from an overcharged shot fired by a miner in the coal in No. 2 Heading. ”

This gas explosion propagated a coal dust explosion and travelled towards the fresh air at the surface. The commission was also of the opinion that the Deputy, Overman and to a lesser extent the Manager, were all guilty of contributing negligence.

**1965** On November 9, 1965, a pocket of gas ignited in a panel several hundred yards from the main shaft and killed four miners. Ten mining rescue teams and the Southern Mines Rescue Station worked all night to extinguish the fire.