University of Saskatchewan

Geological Engineering
GEOE 498.3

Introduction to Mineral Engineering
Trevor Eagles
Mine Manager
Colonsay Mine
Mosaic
◆ **Course Structure**

- Part A (7 Lectures) Mine Engineering
- Part B (7 Lectures) Metallurgical Engineering

- Term Project
GeoE 315.3 - 2009
Rock Mechanics

This course includes an introduction to mining and mineral processing. This course provides the student with a basic understanding of mining engineering and the mining industry. The mining component of the course will introduce the drill and blast cycle, mining methods and the economic evaluation of mineral properties. The mineral process engineering component will introduce mineral separation processes including gravity, electrostatic and flotation separation.

Marking Scheme

<table>
<thead>
<tr>
<th>Assignments</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-term</td>
<td>35%</td>
</tr>
<tr>
<td>Final</td>
<td>45%</td>
</tr>
</tbody>
</table>

Assignments

Group assignments will be given to help explain the different factors considered in the development of a mine.
GeoE 498 - 2010
Introduction to Mining and Mineral Processing Engineering

Note - You must receive a grade of 50% or higher in at least one of the midterm or final exams in order to achieve a passing grade in this course.
- All assigned work is mandatory. Failure to attend or complete any of the assignments will result in a final grade of less than 50% for the course unless alternate arrangements are specifically approved by the instructor.
- Alternate times to write midterm examinations will not be considered except in the case of illness or a conflict with other university related activities.
- Alternate times to write final examinations cannot be accommodated. If a student misses a final exam, application must be made to the Dean's office to write a deferred exam.
- Students planning on registering with the office for Disability Services for Students (DSS) must do so by January 30.

Academic Honesty Expectations:
This course will conform to the academic requirements and standards for undergraduate courses, including:

- Rules of Student Appeals in Academic Matters (see http://www.usask.ca/university_council/reports/12-06-99.shtml), and
- Academic Honesty (see http://www.usask.ca/honesty/).

For further information, see the attached information sheet on Guidelines for Academic Honesty entitled “Writing it Right”.
GeoE 498
Introduction to Mining and Mineral Processing Engineering

These course notes are a compilation of work conducted by many people. Some of the notes have been taken from the Laurentian University course notes on “Introduction to Mineral Resources Engineering developed by Dr. Amaratunga and Dr Hudyma as well as the notes from the University of Western Australia developed by Chris Langille. Notes have also been taken from the following text books:


Mine Engineering Outline

◆ Mining Terms and Definitions
◆ Geology
◆ Project / Operation Management
◆ U/G Mining Methods
◆ Infrastructure
◆ Open Pit Mining Methods

◆ Term Project – Mine Evaluation
◆ Mining Terms
  ● Sustainable Development
  ● Common Mining Terms
  ● Mining Methods – O/P vs. U/G; Hard Rock vs. Soft Rock

◆ Mineral Economics
Underground Mining Methods

- Bulk vs. Selective
- Reasons for Selection (Geotechnical, Geometry, Value, Grade, Dilution Control, Skill of work force, health and safety, etc)
- Mining Equipment (mobile)
- Tunneling Methods
◆ **U/G Infrastructure**
  ● Shafts (production and Service)
  ● Ore Flow
  ● Air/Water
  ● Ventilation
  ● Maintenance
  ● Warehousing and Supplies
  ● Electrical and Communications

◆ **Drilling / Blasting**
Project and Operations Management

- Scope
- Schedule
- Cost
- Stagegate
- WBS (Work Breakdown Structures)
- Project Charters
- Economics
- Differential NPV
Open Pit Mining

- Types of o/p
- Selection criteria
- Strip Ratio (geotechnical, safety factor, ore/waste)
- Pit Geometry, push backs and bench heights
- Equipment
- Waste dumps and Stock piles
- Infrastructure
Assignment / Tutorial # 6

◆ Tutorial
  ● Guest Lecture (Coal)

◆ Assignment
  ● Strip Ratio Exercise
  ● Equipment Selection
  ● NPV
Introduction to Mining
Mining companies recognize that in order to be successful, they need a good corporate image.

- Many large pension funds will only invest in corporately responsible companies.
- Companies do business in many regions of the world and deal with many levels of government. In most cases, their reputation proceeds them.

Mining companies want to be welcomed by the communities they do business in and the governments they deal with.
Sustainable Development

An example of a sustainable development statement is:

“This meeting the needs of our stakeholders today, while preserving choices for future generations to meet their needs.”

Four typical key measures of success are:

• A safe, healthy and rewarding workplace
• A clean environment
• Supportive communities
• Outstanding financial performance
Sustainable Development

• **Injuries cost money**
  - Increased insurance
  - Increased WSIB fees
  - Risk of fines
  - Increased presence of Gov. inspectors
  - Reduced productivity

**Environmental non performance cost money**

- Risk of fines
- Increased presence of Gov. inspectors
- Clean up costs
Sustainable Development

- **Supporting Communities Pays**

  Fund hospitals, Education, non-profit organizations, parks, Hire locals, Support local businesses, etc.

  Communities are more likely to welcome companies with a positive history.

  Miners and Mining professionals are more likely to work for a safe, responsible company.
Is mining dangerous?

A danger is an unmanaged hazard. If a hazard is understood and managed, the Risk is significantly reduced.

Risk = Impact x Probability

Mining has many potential hazards, but with proper controls in place, it is a safe occupation.
Work-related injuries, by industry, 2007
(per 1,000 employed workers)

- Financial: 0.8
- Private Households: 2.7
- Real Estate and Business Activity: 5.0
- Education: 7.1
- Mining and Quarrying: 12.9
- Agriculture, Hunting and Forestry: 14.2
- Community, Social and Personal Services: 14.8
- Hotels and Restaurants: 16.7
- Electricity, Gas and Water: 14.0
- Wholesale/retail trade, Vehicle repair: 18.1
- Health and Social Work: 22.4
- Public Administration and Defence: 24.2
- Transport, Storage and Communications: 24.4
- Fishing: 22.1
- Construction: 30.0
- Manufacturing: 32.0

Source: International Labour Organization (ILO) LABORSTA Internet. Table 8B - Rate of occupational injuries, by economic activity, Canada, 2007. Available from: Laborsta Internet. Rates are calculated by ILO using data compiled from Human Resources and Social Development Canada, Statistics Canada and Association of Workers' Compensation Board of Canada.
2010 Preliminary Premium Rate Consultation

D71 – Open Pit Mining
D72 – Underground Softrock Mining
D73 – Underground Hardrock Mining
M31 – Manufacturing, Pipeline Operations

October 2009
Injury Rate: D71, D72, D73, M31

Time Loss Claims per 100 Workers

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Class</td>
<td>4.40%</td>
<td>4.25%</td>
<td>4.05%</td>
<td>3.80%</td>
<td>3.70%</td>
<td>3.39%</td>
</tr>
<tr>
<td>D71</td>
<td>0.84%</td>
<td>0.94%</td>
<td>0.68%</td>
<td>1.08%</td>
<td>0.93%</td>
<td>0.54%</td>
</tr>
<tr>
<td>D72</td>
<td>1.58%</td>
<td>1.32%</td>
<td>1.22%</td>
<td>1.39%</td>
<td>2.05%</td>
<td>1.27%</td>
</tr>
<tr>
<td>D73</td>
<td>2.02%</td>
<td>2.15%</td>
<td>3.17%</td>
<td>2.79%</td>
<td>2.38%</td>
<td>1.23%</td>
</tr>
<tr>
<td>M31</td>
<td>1.38%</td>
<td>1.20%</td>
<td>1.36%</td>
<td>1.47%</td>
<td>1.95%</td>
<td>1.13%</td>
</tr>
</tbody>
</table>

*Projected*
## Annual Program Costs

<table>
<thead>
<tr>
<th></th>
<th>2004 ($000)</th>
<th>2005 ($000)</th>
<th>2006 ($000)</th>
<th>2007 ($000)</th>
<th>2008 ($000)</th>
<th>2009* ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Care</td>
<td>46,039</td>
<td>44,950</td>
<td>49,910</td>
<td>52,418</td>
<td>57,090</td>
<td>59,622</td>
</tr>
<tr>
<td>Earnings Replacement</td>
<td>40,406</td>
<td>42,783</td>
<td>44,765</td>
<td>44,015</td>
<td>46,607</td>
<td>48,527</td>
</tr>
<tr>
<td>Wage Loss</td>
<td>75,538</td>
<td>70,166</td>
<td>70,677</td>
<td>69,952</td>
<td>73,745</td>
<td>71,229</td>
</tr>
<tr>
<td>Vocational Rehab</td>
<td>5,108</td>
<td>4,345</td>
<td>4,721</td>
<td>3,963</td>
<td>3,846</td>
<td>5,134</td>
</tr>
</tbody>
</table>

*Projected*
The following are the 2008 SMA injury statistics.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number</th>
<th>Frequency Rate</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Aid</td>
<td>523</td>
<td>8.86</td>
<td>60.1%</td>
</tr>
<tr>
<td>Medical Consultation</td>
<td>120</td>
<td>2.03</td>
<td>14%</td>
</tr>
<tr>
<td>Medical Incident</td>
<td>91</td>
<td>1.54</td>
<td>10.6%</td>
</tr>
<tr>
<td>Modified Work Injury</td>
<td>84</td>
<td>1.42</td>
<td>9.8%</td>
</tr>
<tr>
<td>Lost Time Injury</td>
<td>41</td>
<td>.69</td>
<td>5%</td>
</tr>
<tr>
<td>Total Injuries</td>
<td>859</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body Parts</th>
<th>Number</th>
<th>Frequency Rate</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>79</td>
<td>1.34</td>
<td>9.2%</td>
</tr>
<tr>
<td>Eye</td>
<td>87</td>
<td>1.47</td>
<td>10.1%</td>
</tr>
<tr>
<td>Upper Limb</td>
<td>319</td>
<td>5.4</td>
<td>37.2%</td>
</tr>
<tr>
<td>Torso</td>
<td>46</td>
<td>0.78</td>
<td>5.4%</td>
</tr>
<tr>
<td>Back</td>
<td>136</td>
<td>2.3</td>
<td>15.8%</td>
</tr>
<tr>
<td>Lower Limb</td>
<td>192</td>
<td>3.25</td>
<td>22.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accident Sources</th>
<th>Number</th>
<th>Frequency Rate</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls of Ground</td>
<td>25</td>
<td>0.4</td>
<td>3.0%</td>
</tr>
<tr>
<td>Slips and Falls</td>
<td>138</td>
<td>2.3</td>
<td>16.3%</td>
</tr>
<tr>
<td>Working in/Between</td>
<td>69</td>
<td>1.2</td>
<td>8.1%</td>
</tr>
<tr>
<td>Machinery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling Material</td>
<td>240</td>
<td>4.1</td>
<td>26.3%</td>
</tr>
<tr>
<td>Hand Tools</td>
<td>96</td>
<td>1.6</td>
<td>11.3%</td>
</tr>
<tr>
<td>Toxic or Corrosive</td>
<td>26</td>
<td>0.4</td>
<td>3.1%</td>
</tr>
<tr>
<td>Temperature Extreme</td>
<td>12</td>
<td>0.2</td>
<td>1.4%</td>
</tr>
<tr>
<td>Electrical</td>
<td>3</td>
<td>0.1</td>
<td>0.3%</td>
</tr>
<tr>
<td>Mobile Equipment</td>
<td>61</td>
<td>1.0</td>
<td>7.2%</td>
</tr>
<tr>
<td>Scaling</td>
<td>10</td>
<td>0.2</td>
<td>1.2%</td>
</tr>
<tr>
<td>Other</td>
<td>167</td>
<td>2.8</td>
<td>19.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days Lost</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Work Days</td>
<td>2693</td>
<td>44.49</td>
<td></td>
</tr>
<tr>
<td>Days Lost</td>
<td>7685.5</td>
<td>133.60</td>
<td></td>
</tr>
</tbody>
</table>
Why do we Mine?

◆ If it can’t be grown, it has to be mined.
  ● Base Metals
  ● Precious Metals and Gems
  ● Fuel
  ● Industrial Materials

◆ Mining is the only source for the minerals and materials that are required to maintain the high quality of life we enjoy in the modern high–tech world in which we live.
How many Minerals are there in a typical Computer???
# Minerals In Typical Computers

<table>
<thead>
<tr>
<th>Computer Component</th>
<th>Element/Compound</th>
<th>Mineral Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monitor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorescent Coating - Transition Metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZnS - Zinc Sulfide</td>
<td>Zn, S</td>
<td>Sulfur, Hemimorphite, Zincite, Smithsonite, Franklenite</td>
</tr>
<tr>
<td>Ag - Silver</td>
<td>Ag</td>
<td>Ag, Pyrargyrite, Cerargyrite</td>
</tr>
<tr>
<td>Cl - Chlorine</td>
<td>Cl</td>
<td>Halite</td>
</tr>
<tr>
<td>Al - Aluminum</td>
<td>Al</td>
<td>Bauxite</td>
</tr>
<tr>
<td>Cu - Copper</td>
<td>Cu</td>
<td>Chalcopyrite, Boronite, Enargite, cuprite, malachite, azurite, chrysocolla, chalcocite</td>
</tr>
<tr>
<td>Au - Gold</td>
<td>Au</td>
<td>Au</td>
</tr>
<tr>
<td>Y2O2S - Yttrium Sulfate</td>
<td>Y</td>
<td>Alunite, Orthoclase, Nephelite, Leucite, Apophyllite; Fluorite, cryolite, vesuvianite, lepidolite: Dolomite, magnesite, espomite, spinel, olivine, pyrope, biotite, talc, pyroxenes</td>
</tr>
<tr>
<td>Eu - Europium</td>
<td>Eu</td>
<td></td>
</tr>
<tr>
<td>KF,MgF2):Mn Potassium-Magnesium Fluorite: Manganese</td>
<td>K, F, Mg, Mn</td>
<td>Realgar, Orpiment, Niccolite, Cobalite, Arsenopyrite, Tetrahedrite</td>
</tr>
<tr>
<td>(Zn,Cd)S - Zinc Cadmium Sulfide</td>
<td>Cd</td>
<td></td>
</tr>
<tr>
<td>Zn2SiO4:Mn, As - ZincSilicate, Manganese, Arsenic</td>
<td>As</td>
<td>Realgar, Orpiment, Niccolite, Cobalite, Arsenopyrite, Tetrahedrite</td>
</tr>
<tr>
<td>Gd2O2S:Tb - Gadolinium Sulfate: Tebrium</td>
<td>Gd, Tb</td>
<td>Monzanite, Orthite</td>
</tr>
<tr>
<td>Y2SiO12:Ce - Yttrium Silicate: Cerium</td>
<td>Ce</td>
<td></td>
</tr>
<tr>
<td><strong>CRT Glass</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Pb - Lead</td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
</tr>
<tr>
<td>SiO2</td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td><strong>Plastic Case, Keyboard</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermoplastic - Polypropylene, PVC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaCO2 _additive</td>
<td>Ca</td>
<td>Calcite, gypsum, apatite, aragonite</td>
</tr>
<tr>
<td>TiO2 - White Pigment</td>
<td>Ti</td>
<td>Rutile, Ilmenite, Titanite</td>
</tr>
<tr>
<td>Amonium Polyphosphate</td>
<td>P</td>
<td>Apetite, Pyromorphite, Wavellite</td>
</tr>
<tr>
<td>LCD, Liquid Crystal Display Monitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb - Lead</td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
</tr>
<tr>
<td>Thin Film Transistors</td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td>Ferro Electric Liquid Crystal</td>
<td>Fe</td>
<td>Hematite</td>
</tr>
<tr>
<td>Indium Tin Oxide</td>
<td>Sn</td>
<td>Cassiterite, Sphalerite (Commonly found with Zinc)</td>
</tr>
<tr>
<td><strong>Metal Case</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>Magnetite, Limonite</td>
</tr>
<tr>
<td><strong>Flat Screen Plasma Display Monitors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass</td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td>Pb - Lead</td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
</tr>
<tr>
<td>ZnS - Zinc Sulfide</td>
<td>Zn, S</td>
<td>Sulfur, Hemimorphite, Zincite, Smithsonite, Franklenite</td>
</tr>
<tr>
<td>Ag - Silver</td>
<td>Ag</td>
<td>Ag, Pyrargyrite, Cerargyrite</td>
</tr>
<tr>
<td>Cl - Chlorine</td>
<td>Cl</td>
<td>Halite</td>
</tr>
<tr>
<td>Al - Aluminum</td>
<td>Al</td>
<td>Bauxite</td>
</tr>
<tr>
<td>Cu - Copper</td>
<td>Cu</td>
<td>Chalcocytite, Boronite, Enargite, cuprite, malachite, azurite, chrysocolla, chalcocite</td>
</tr>
<tr>
<td>Au - Gold</td>
<td>Au</td>
<td>Au</td>
</tr>
</tbody>
</table>
Y2O2S - Yttrium Sulfate
Eu - Europium

Eu - Europium
Alumite, Orthoclase, Nephelite, Leucite, Apophyllite; Fluorite, cryolite, vesuvianite, lepidolite: Dolomite, magnesite, espeomite, spinel, olivine, pyrope, biotite, talc, pyroxenes

KF,MgF2):Mn Potassium-Magnesium Fluorite: Manganese
K, F, Mg, Mn

(Zn,Cd)S - Zinc Cadmium Sulfide
Cd

Zn2SiO4:Mn, As - ZincSilicate, Manganese, Arsenic
As

Realgar, Orpiment, Niccolite, Cobaltite, Arsenopyrite, Tetrahedrite

Gd2O2S:Tb - Gadolinium Sulfate:Tebrium
Gd, Tb

Monzonite, Orthite

Y2SiO12:Ce - Yttrium Silicate: Cerium
Ce

Printed Circuit Boards, Computer Chips

Si - Silicon

Cu - Copper

Si - Silicon

Au - Gold
Ag - Silver
Sn - Tin
Al - Aluminum

Cu - Copper

Au - Gold
Ag, Pyrargyrite, Cerargyrite

Sn - Tin

Al - Aluminum

Bauxite
There are 66 individual minerals that contribute to the typical computer that are identified above. There are others in addition to those above, but it should be evident that without many minerals, there would be no computers, or televisions, for that matter.
Mining Terminology

- **Open Pit Mine** – Bench Mining, Strip Mine or Quarry
  - Overburden, Ore and Waste need to be Mined

- **Underground Mine** – Bulk or Selective.
  - Significantly less waste needs to be excavated.
  - More expensive/challenging
  - Numerous mining methods

- **Hard Rock** - Requires Drilling and Blasting.
- **Soft Rock** – Use of continuous mining machines or free dig.

- In 2002 there were 365 underground mines in the Western world\(^1\).
- In 2002 around 4,100 Mt of ore was mined of which 615 Mt (16\%) was mined via underground\(^1\).
Ore production from open pits (green), underground (red), and alluvial/recycling (white).
Mining Terminology

◆ **Mineral**: Inorganic substance that are extracted from the earth for use by man.

◆ **Ore**: Rock that contains a mineral or minerals in sufficient quantities as to make commercial extraction (mining – milling) profitable.

◆ **Grade**: A measure of a mineral contained rock (or ore). Gold and other precious metals – g/t or oz/t, base metals - %, rare earth elements – ppm…

◆ **Cut off Grade**: The minimum concentration or grade of mineral that is required for rock to be considered ore.

◆ **Waste**: Not Ore.

◆ **Ore Body**: A mineralized deposit (resource) whose characteristics have been examined and found to be commercially viable. The extents of the ore body are determined by the cut-off grade.

◆ **Host Rock**: The rock containing an ore deposit.
**Mining Terminology**

- **Vein**: A narrow zone, or belt, of mineralized rock.
- **Seam**: A horizontal or sub horizontal bed of mineral, usually associated with coal.
- **Strike**: The angle at which a vein, structure or rock is located with respect to North Line.
- **Dip**: The angle at which a vein, structure or rock bed is inclined from the horizontal, measured at right angles to the strike.
- **Plunge**: The angle at which a vein, structure or rock bed is inclined from the horizontal, measured parallel to the strike.
Mining Terminology

- **HANGING WALL**: An underground mining term describing the interface between the orebody and the host rock, on the upper side of the mining excavation (stope).

- **FOOT WALL**: An underground mining term to describe the interface between the orebody and the host rock, on the lower side of the mining excavation (stope).
Basic infrastructure required for a typical underground mine.
**DEVELOPMENT:** Is the underground work carried out for the purpose of reaching and opening up a mineral deposit. It includes shaft sinking, cross-cutting, drifting and raising.

**SHAFT:** A vertical or steeply inclined excavation used for moving workers and materials, hoisting ore and waste, providing ventilation and provides access for services such as compressed air, water, power and communications.

- **Cage:** The conveyance used to transport men and equipment in a shaft.
- **Skip:** A container used for hoisting material up a shaft.
- **Hoist:** The machine used for raising and lowering the cage or other conveyance in a shaft.
- **Guides:** The steel girders/timber along the sides of a shaft for the purpose of steadying, or guiding, the cage or conveyance.
- **Galloway:** Machine used for sinking (or excavating a Shaft)
- **Head frame:** Building that covers shaft and may also contain the hoist room.
- **Collar:** The mouth or uppermost entrance to a shaft; also used to describe the top of a drill hole.
- **Shaft Station:** Underground access point to a shaft, typically located at the “Main Levels”.
- **Loading Pocket:** Location where ore is loaded into a skip for hoisting.

**Winze:** A shaft collared (or started) below surface.
Surface Infrastructure

#2 Shaft

#1 Shaft

Portal

NVS Exhaust Fans

Open Pit
Decline or Ramp: A large inclined tunnel driven from the surface to an underground ore body/coal seam. Provides access for men, equipment, material, ventilation and services. Typically driven at a size and angle which allows mobile equipment access.

Adit: Horizontal tunnel driven into the side of a mountain to access an orebody.

Portal: The surface entrance to a Decline or Adit.

Drift - A horizontal underground passage or tunnel.

Crosscut - A horizontal opening driven across the course of a vein or structure, or in general perpendicular to main access drifts.

Draw point – Access drift into the ore body from which ore is extracted or “Mucked”.

Mining Terminology
Shaft
Collar
Cross Cut

Basic infrastructure required for a typical underground mine.
Mining Terminology

- **Raise**: A vertical or sub-vertical excavation, excavated from the bottom up.
- **Manway**: An access raise with a ladder installed.
- **Orepass / Waste pass**: Raise used to transport ore or waste.
- **Bin**: Large diameter raise used to store ore or waste.
- **Chute**: An inclined opening, usually constructed of concrete and steel and equipped with a gate, through which ore is drawn from an orepass or bin.
- **Ventilation Raise**: Intake (fresh air) and Exhaust (used air)
form the basis of the next generation of mining techniques.

Kemi underground mine simplified long section.
Mining Terminology

- **Stope** - An excavation in a mine from which ore is being or has been extracted.
- **Slot**: The initial opening of a stope.
- **Backfill**: Material used to fill a stope, once the ore has been extracted. Waste rock, cemented waste rock, hydraulic fill and paste are example of back fill.
- **Sublevel** - An intermediate level opened a short distance below the main level for drilling or for caving the ore body in the caving system of mining.
- **Face** - As applied to a drift, crosscut or stope, is the end in which work is progressing.
- **Undercut**: To remove the underlying ground. Also used to describe the lower level of a stope. Typically the mucking horizon.
- **Overcut**: The upper level of a stope. Typically the drilling horizon.
- **Powder**: Explosives
- **Caps**: Detonators
- **Sump** - An excavation underground for the purpose of catching or storing water; the bottom of a shaft is commonly used for this purpose.
Stope General Arrangement
Production LHD – Toro 0011
Mining Terminology

- **Pillar**: Rock, typically ore, that is left in place to act as support.
- **Crown pillar**: A body of rock located above underground operations that supports the surface above the underground openings (stopes) and aims to minimize subsidence.
- **Sill Pillar**: A body of rock left in situ to separate between two levels or to support un cemented or low cement content backfill.
- **Rib Pillar**: A body of rock left in situ to separate and act as support between two stopes or mine areas.
Basic infrastructure required for a typical underground mine.
Mining Terminology
(Ground Support)

- **ROCK BOLTING** - The act of consolidating roof strata by means of anchoring and tensioning steel bolts in holes especially drilled for the purpose.
  - Rock bolts come in many types: Mechanical Bolts, Rebar, Split Sets, Swellex, Cable Bolts, Cont Bolts...

- **SHOTCRETE**: A type of ground control used in underground mines, where concrete, often with steel or synthetic fibres added for extra strength, is sprayed at high pressure on to the walls of an opening to prevent rocks from falling.

- **TAILINGS** - Material rejected from a mill after the recoverable valuable minerals have been extracted.
Figure 8.1: Rockbolting alternatives involving individual judgement. (Drawings based upon a cartoon in a brochure on rockfalls published by the Department of Mines of Western Australia.)
Introduction to Underground Mining

- Resource and Reserve Estimation
- Ore dilution and its effects
Resource and Reserve Estimation

- **Ore:** A mineralised deposit whose characteristics have been examined and found to be *commercially viable*. The extents of the ore body are determined by the cut-off grade.

- **Mineral Resource:**

  A Mineral Resource is a concentration or occurrence of diamonds, natural solid inorganic material, or natural solid fossilized organic material including base and precious metals, coal, and industrial minerals in or on the Earth’s crust in such form and quantity and of such a grade or quality that it has reasonable prospects for economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge.

Prepared by the *CIM Standing Committee on Reserve Definitions*
Adopted by CIM Council on December 11, 2005
Resource and Reserve Estimation

◆ Mineral Reserve:

A Mineral Reserve is the economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a Preliminary Feasibility Study. This Study must include adequate information on mining, processing, metallurgical, economic and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined.

Prepared by the CIM Standing Committee on Reserve Definitions
Adopted by CIM Council on December 11, 2005
Figure 1
Relationship between Mineral Resources and Mineral Reserves

Prepared by the CIM Standing Committee on Reserve Definitions
Adopted by CIM Council on December 11, 2005
Resource and Reserve Estimation

◆ Qualified Person (QP):

Qualified Person

Mineral Resource and Mineral Reserve estimates and resulting Technical Reports must be prepared by or under the direction of, and dated and signed by, a Qualified Person.

A “Qualified Person” means an individual who is an engineer or geoscientist with at least five years of experience in mineral exploration, mine development or operation or mineral project assessment, or any combination of these; has experience relevant to the subject matter of the mineral project and the technical report; and is a member or licensee in good standing of a professional association.

Prepared by the CIM Standing Committee on Reserve Definitions
Adopted by CIM Council on December 11, 2005
The ultimate objective of all exploration is to predict, with the greatest accuracy possible, the shape, distribution, and concentration of mineralization.

Create a geologic model to look at the three dimensional perspective of an mineralization deposit. Purpose of ore deposit modeling is to predict the geology.

Use this three dimensional model to calculate the quantity and quality of the ore deposit.

The information is examined along both horizontal slices (plan maps) and vertical cross sections (drill sections).
Resource and Reserve Estimation
Tonnage Estimation of Ore

- Based on a large amount of information (drill data, chip samples, bulk samples, geophysical).

- Drill holes are generally placed along a parallel drill lines, to make the calculation of the volume easier. A square grid is convenient, but not essential.

- Increased confidence is achieved by more drilling followed by trenching at the surface or drifting underground and bulk sampling (test stopes).

- Tonnage and grade calculations are done using geostatistical methods using 3D geometries, 3D block models and specialized software (Datamine, Vulcan, Surpac, MedSystem etc.).

- After the volume calculation is complete, the volume is converted to weight by multiplying the volume by the “tonnage factor”. The tonnage factor states the density of the ore and host rock, in terms of cubic feet/ton or cubic meters/tonne.
Volume Estimation of Mineralization

A) Drill intercepts interpreted to represent large, laterally continuous ore bodies. B) Same drill intercepts interpreted to represent discontinuous, small scale ore bodies
FIGURE 17-2 CROSS SECTION OF CONTACT STYLE MINERALIZATION PORTION OF WIREFRAME
Diamond Drilling
Diamond Drilling
Cross Section Showing Drill hole and Block Model – Grade and Tonnage Estimate
Mining Dilution and Recovery

- Dilution is defined as material that is mined in the process of ore extraction. Typically a contamination of ore with below cut off grade material or with barren waste wall rock.
- Recovery is defined as the percent of valuable material or ore that is extracted relative to the total amount of Ore.
- Why does it occur?
- Primary dilution and recovery (Planned)
- Secondary dilution and recovery (Unplanned)
Mining Dilution

- Why does it occur?
  - Narrow or varying Ore Body widths;
  - Structures in the Hanging Wall;
  - Poor mining practices (blasting, bore hole);
  - Poorly understood Ore Body. Not enough drill information ("nugget" Ore Body)
- Primary dilution - Planned Dilution - minimum mining width required to extract. 2 m ore width and 4 m wide drifts.
- Secondary dilution - Unplanned Dilution – Overbreak (too much extracted) or Underbreak (less extraction). Failure in the Hanging Wall due to poor ground conditions (rock bursting, fault zones)
Mining Dilution - Control

◆ Planned Dilution Control:
  ● More data collected by diamond drilling, chip sampling, mapping, sampling of blast holes
  ● Use different mining equipment or appropriate mining methods. Right size equipment for proper widths.

◆ Unplanned Dilution Control:
  ● More data collected by diamond drilling, chip sampling, mapping, sampling of blast holes;
  ● Different blasting techniques;
  ● Surveying of pre and post stope blasting;
  ● Support Hanging Wall, backfill open stopes

◆ Unplanned Dilution After Blasted:
  ● Grade control procedures – sort waste and ore (difficult)
  ● Move waste to empty stopes or bring to surface, secondary blast large waste rocks
  ● Mine the waste and lower the grade leaving the mine
Mineral Economics

◆ Discounted Cash Flow
  ● NPV (net present value) is a means of comparing a dollar today to the value of the same dollar in the future. For mining projects, we apply NPV to determine if a project is worth more than it costs.
  ● Free Cash Flow is the operating cash flow minus capital includes Taxes, Dividends, Royalties, Depreciation and Amortization. I.e. the amount of money left after the bills are paid
  ● Discount Rate is rate that future cash flows are discounted to determine present value. This is different than interest.
  ● IRR (internal rate of return) is the discount rate that results in an NPV of 0.
\[ \text{NPV} = \sum_{i=1}^{n} \frac{\text{values}_i}{(1 + \text{rate})^i} \]

- Value = Free Cash Flow
- Rate = Discount Rate
- n=Total number of periods
- i=Period
Mine XYZ

Discount Rate = 10%

Value of Uranium ($/lb) 50

Annual Production t/year 100000

Average Grade 3.5%

Operating Cost ($/lb) 30

Capital Cost ($000,000) 500

Construction Period (years) 3

Mine Life (years) 5

Capital - Operating Overlap (years) 1
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Mining Information

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- Saskmining.ca
- IR.GOV.SK.CA
- CIM.org
- SME
- Northern miner
- KITCO