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The CRANDON Project

EXXON MINERALS COMPANY, U.S.A.

METALLIC MINING COUNCIL

Rhinelander Meeting
May 29, 1979

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METALLIC MINING COUNCIL

Rhinelander Meeting
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PRESENTATION BY THE CRANDON PROJECT TEAM

TO THE

METALLIC MINING COUNCIL

MAY 29, 1979

THE MINE DEVELOPMENT PROCESS

MADAM CHAIRMAN, MEMBERS OF THE COUNCIL, LADIES AND GENTLEMEN:

I WOULD LIKE TO THANK THE COUNCIL FOR INVITING EXXON TO PARTICIPATE IN THIS MEETING. WHILE THE COUNCIL HAS HEARD A GREAT DEAL ABOUT MANY OF THE FACETS OF THE DISPOSAL OF MINE WASTES AND OTHER SPECIFIC ISSUES RELATED TO MINING AND THE ENVIRONMENT, PERHAPS YOU HAVE NOT HAD THE OPPORTUNITY TO LEARN SOMETHING OF THE WHOLE PROCESS OF BRINGING A MINERAL DISCOVERY FROM ITS INCEPTION THROUGH MANY STEPS AND DECISION POINTS TO FINAL DEVELOPMENT. SEVERAL MEMBERS OF THE CRANDON PROJECT TEAM WILL, THIS AFTERNOON, ATTEMPT TO PROVIDE YOU WITH AN INSIGHT INTO THE APPROACH EXXON IS USING IN EVALUATING AND POTENTIALLY DEVELOPING THE CRANDON COPPER-ZINC DEPOSIT.

But, first I would like to introduce you to the various members of the Crandon Project Team:

(Introduce the Team)

From this, I think you can deduce that a wide variety of skills and experience are necessary. However, for a project the size of Crandon, there are, on any given day, a great many more people over and above the team which you see here who are working full-time for the benefit of the project. Within the Minerals Company in Houston, there are legal, environmental and various mine-related technically skilled engineers who provide assistance in specific areas. In engineering firms in the United States and Canada, there probably are somewhere in the neighborhood of 50 people who daily spend most of their efforts in one technical area or another in studying, engineering or designing for the Crandon Project. This number, of course, varies with each phase of the project, with the requirement being much smaller early in the life of the project, and much larger than we currently are experiencing down the road if the mine development and construction phase is reached.

First, let's talk about the basic elements of the mine building process, and this, of course, assumes that the process goes the full route from discovery to production. As you probably realize, for all mining projects, there is a final point of decision

WHERE ONE ELECTS EITHER TO PLACE THE PROPERTY BEING CONSIDERED INTO PRODUCTION, OR TO PUT IT ON THE SHELF, OR AS IS VERY OFTEN THE CASE, TO DROP FURTHER INTEREST IN PURSUING THE VENTURE. AS FOR ANY SIZEABLE PROJECT, THERE ARE MANY MILESTONES, OR INTERMEDIATE DECISION POINTS, AT WHICH THE QUESTION IS ASKED, "ARE WE OPTIMISTIC ENOUGH TO PROCEED TO THE NEXT MILESTONE?"

THE RISKS ASSOCIATED WITH DISCOVERY OF A DEPOSIT ARE PERHAPS WELL KNOWN, BUT THE FACT THAT MANY DISCOVERIES--IN FACT, A LARGE PERCENTAGE--NEVER MAKE IT TO THE PRODUCTION STAGE, IS NOT WELL KNOWN.

THE ELEMENTS OF MINE DEVELOPMENT OR MINE BUILDING PROCESS ARE SHOWN ON THIS SLIDE. THEY ARE BASICALLY SEQUENTIAL, AS YOU CAN SEE HERE, BUT OFTEN THERE ARE OVERLAPS AND OFTEN THE PROCESS HAS DISTINCT ITERATIVE QUALITIES WHERE IT IS OFTEN NECESSARY TO GO BACK AND RE-EVALUATE ALTERNATIVES, OR EVEN RE-DEFINE THE RESOURCE PRIOR TO PERMITTING AND FINAL ENGINEERING.

STARTING WITH THE DISCOVERY, WHICH AT CRANDON OCCURRED IN 1975, THE PROJECT QUICKLY BLOSSOMED INTO WHAT WE CALL THE PRE-DEVELOPMENT STAGE. THE INITIAL DISCOVERERS OF A DEPOSIT MAY BE SOMEWHAT FREE TO SPECULATE ON ITS SIZE AND EXTENT, (WHICH THEY OFTEN DO WITH CONSIDERABLE IMAGINATION AND BLISSFUL OPTIMISM). BUT THIS IN TURN IS FOLLOWED BY A PROGRAM OF DELINEATING THE DEPOSIT WHICH WE AT EXXON MINERALS TERM PRE-DEVELOPMENT. THIS OFTEN INVOLVES A DIAMOND DRILLING PROGRAM, AS WAS THE CASE AT CRANDON, WHERE 198 HOLES WERE DRILLED FROM 1975 THROUGH 1978.

THE OBJECTIVE OF THE PRE-DEVELOPMENT PHASE IS TO DETERMINE ITS LOCATION, ATTITUDES, BOUNDARIES, MINERALOGY, GEOLOGY, AND PERHAPS MOST IMPORTANT OF ALL, THE AMOUNT OF METAL (TONNAGE AND GRADE) AND THE METAL DISTRIBUTION WITHIN THE DEPOSIT. IN A VERY REAL SENSE WE CALL THIS "PROVING" THE ORE RESERVE. THE RESULT OF THIS PHASE, MORE OFTEN THAN NOT IS THAT THE BLISSFUL OPTIMISM FOLLOWING DISCOVERY TURNS TO THE STARK REALITY THAT THE DEPOSIT IS MUCH SMALLER OR MUCH LOWER GRADE OR MUCH MORE BROKEN UP, AND THUS MUCH MORE DIFFICULT TO MINE THAN HAD PREVIOUSLY BEEN THOUGHT.

IN CASE OF CRANDON, QUITE HAPPILY, THE DISCOVERERS HOPES PROVED TO BE PARTIALLY JUSTIFIED. WHILE AMONG THE TOP 10 DEPOSITS OF ITS TYPE IN NORTH AMERICA IN TERMS OF SIZE, THE CRANDON DEPOSIT GRADE IS ONLY AVERAGE.

GIVEN THE RUDIMENTARY INFORMATION AVAILABLE FROM EARLY DRILLINGS, THE PRELIMINARY EVALUATION PROCESS IS ONE OF CONCEPTUALIZING A MINE OPERATION AND DETERMINING WHAT THE UNIQUE OUTCOME MIGHT BE. THIS IS USUALLY BASED ON SOME REASONABLE ASSESSMENT OF WHAT THE ORE RESERVES ARE THOUGHT TO BE, THE SELECTION OF A BASIC MINING METHOD AND PROCESSING PLAN, AND THE DEVELOPMENT OF VERY PRELIMINARY ESTIMATES FOR METAL RECOVERIES, CAPITAL INVESTMENTS, AND OPERATING COSTS. OFTEN IN THIS STAGE, SEVERAL ALTERNATIVE SCENARIOS ARE SELECTED. THE FACTORS WHICH ARE ALSO INCLUDED IN DEVELOPING THESE ALTERNATIVE SCENARIOS ARE THE ENVIRONMENTAL AND REGULATORY ASSUMPTIONS. PERHAPS WE COULD COMPARE PRELIMINARY EVALUATION

TO PICKING VARIOUS HI-FI COMPONENTS OFF THE STORE SHELF OR SKETCHING A PICTURE PRIOR TO ACCOMPLISHING A MORE DETAILED ARTISTIC PRODUCT.

IN CRANDON, THE PRELIMINARY FEASIBILITY STUDIES TOOK PLACE BETWEEN JANUARY, 1977 AND AUGUST, 1977. THE STUDIES INVOLVED THREE TO FOUR EXXON PEOPLE, PLUS ABOUT THE SAME NUMBER OF PEOPLE FROM CONSULTING FIRMS. THE EVALUATION WAS BASED UPON 30 DIAMOND DRILL HOLES WHICH GAVE A CRUDE ESTIMATE OF THE DEPOSIT.

WE ALSO HAD THE BENEFIT OF 6 MONTHS OF BASELINE ENVIRONMENTAL STUDIES BY DAMES AND MOORE. THE ALTERNATIVE SCENARIOS DEVELOPED INCLUDED BOTH OPEN PIT AND UNDERGROUND OPTIONS, AS WELL AS VERY ROUGH ESTIMATES OF CAPITAL INVESTMENT AT SEVERAL RATES OF ANNUAL PRODUCTION. THE RESULTS OF THE STUDY INDICATED THAT FOR BOTH ENVIRONMENTAL AND ECONOMIC REASONS, THE CRANDON DEPOSIT SHOULD BE DEVELOPED AS A TOTALLY UNDERGROUND MINE, AND AT THE RATE OF 10,000 TONS PER DAY.

AS IN THE CASE OF ALL PRELIMINARY EVALUATION STUDIES, EACH OF THE ALTERNATIVES WHICH MAY BE CONSIDERED IS BASED UPON A "REAL WORLD" KNOWLEDGE OF EXISTING OPERATIONS WHICH ARE SIMILAR TO THE ALTERNATIVES BEING SELECTED. OUR MODELS WERE EXISTING MASSIVE SULPHIDE COPPER-ZINC OPERATIONS, PRINCIPALLY IN CANADA.

WERE IT NOT FOR THE BROAD EXPERIENCE OF THE PEOPLE CHARGED WITH ACCOMPLISHING THE PRELIMINARY EVALUATION AND THE FACT THAT THE MINING INDUSTRY ACTIVELY SHARES ITS TECHNOLOGY, THE PRELIMINARY EVALUATION PROCESS WOULD INDEED BE VERY DIFFICULT.

THIS BRINGS US TO THE CONSIDERATION OF UNIQUENESS WHICH IN ONE FACET OR ANOTHER IS CHARACTERISTIC OF EVERY MINERAL DEPOSIT, AND OF EVERY MINE. THE UNIQUENESS OF CRANDON WAS FOUND NOT SO MUCH TO BE IN THE TYPE OF OCCURRENCE OR SIZE OR ATTITUDE OR METALLURGY OF THE DEPOSIT, BUT IN ITS SENSITIVE ENVIRONMENTAL SETTING.

A PART OF THE PRELIMINARY EVALUATION STAGE OF THE PROJECT IS THE OBJECTIVE OF DETERMINING WHAT UNIQUE FEATURES EXIST AND WHAT TECHNICAL CHALLENGES WILL HAVE TO BE MET. CRANDON'S CHALLENGES, IT WAS FOUND, CENTERED UPON DEVELOPMENT OF TAILINGS DISPOSAL AND MINE BACKFILL ALTERNATIVES, IN VIEW OF THE HIGH PYRITE CONTENT OF THE ORES.

THE NEXT STAGE OF THE DEVELOPMENT PROCESS IS OFTEN TERMED THE DESIGN AND EVALUATION PHASE. AT CRANDON, WE TERM THIS THE INTERMEDIATE FEASIBILITY STAGE. IN ESSENCE, ITS OBJECTIVE IS, THROUGH CONSIDERING ALL DATA AND ALTERNATIVES, TO ASSEMBLE A DEFINITIVE PROJECT PLAN FOR BRINGING THE PROPERTY INTO PRODUCTION AND RECLAIMING THE SITE. AN IMPORTANT ASPECT OF THIS PHASE IS DATA GATHERING. THIS INCLUDES NOT ONLY DATA FROM PRE-DEVELOPMENT DRILLING, BUT ALSO METALLURGICAL TESTING, ENVIRONMENTAL STUDIES AND A WHOLE SERIES OF INVESTIGATIONS TO DETERMINE WHAT ALTERNATIVES EXIST IN SUCH DIVERSE AREAS AS MINING METHODS, PROCESS TECHNOLOGY, WATER TREATMENT TECHNOLOGY, TAILINGS DISPOSAL, MINE BACKFILLING, UTILITIES LOCATION AND PLANT SITING.

IT IS IMPORTANT HERE, ALSO, TO CONSIDER AND FULLY DEFINE THE OBJECTIVES OF THE PROJECT. SOME MIGHT SAY THE OBJECTIVES

OF SUCH A PROJECT ARE SIMPLY STATED--THAT IS, PRODUCE PROFIT FOR THE INVESTING FIRM. LET ME ASSURE YOU THAT, TODAY, THIS IS NOT THE CASE, FOR A GROUP SUCH AS THE CRANDON PROJECT TEAM NOT ONLY ENGINEERS FOR THE PROFIT OBJECTIVE, BUT ALSO FOR THE ENVIRONMENTAL AND SOCIAL OBJECTIVES OF SOCIETY. IN FACT, THE DELIBERATIONS OF THIS COUNCIL, I HAVE NO DOUBT, WILL CONTRIBUTE TOWARD DEFINING ENVIRONMENTAL DESIGN OBJECTIVES OF THE CRANDON PROJECT.

WORKABLE RULES AND REGULATIONS, WHICH HOPEFULLY WILL RESULT FROM THE EFFORTS OF THIS GROUP, WILL SET SPECIFIC GUIDELINES AND MANDATES TO ACHIEVE THE OBJECTIVES OF AN ENVIRONMENTALLY AWARE SOCIETY.

ONE THING THAT I WOULD LIKE TO POINT OUT, WHICH DEMONSTRATES THE MULTIPLICITY OF OBJECTIVES, IS THE THOUGHT THAT WE AT CRANDON, EVERY DAY, IN EVERY ISSUE, IN EVERY TECHNICAL PIECE OF THE PROJECT, HAVE FOUND THAT IT IS NOT POSSIBLE ANY LONGER TO SEPARATE ANY OF THE OBJECTIVES AND DEAL WITH THEM INDEPENDENTLY. ENVIRONMENTAL, SOCIAL, AND PROFIT GOALS ARE INTER-RELATED AND MUST BE WEIGHED AND CONSIDERED IN DECIDING THE MERITS OF EACH ALTERNATIVE BEING CONSIDERED.

THE END RESULT OF THE INTERMEDIATE FEASIBILITY STUDY OR EVALUATION PHASE IS A SERIES OF PRODUCTS WHICH IN TOTAL PROVIDE A COMPLETE PROJECT PLAN, WHICH IS WELL-BALANCED IN ALL RESPECTS--SOCIALLY, ENVIRONMENTALLY, AND OPERATIONALLY. IN THE CASE OF CRANDON, THE END PRODUCT OF THIS STUDY WILL BE AN ENVIRONMENTAL IMPACT REPORT.

This is a report, in effect, to the public and to the regulatory bodies, and describes in great detail the environment, the preferred action, and the environmental and social consequences.

In terms of the Candon Project, the evaluation phase or Intermediate Feasibility study began in earnest in mid-1977, following completion of the Preliminary Feasibility studies. To date the Crandon Project has cost in excess of 20 million dollars since 1975. We feel that the Intermediate Feasibility study will be completed mid to late 1980--a period of three years. When we first started, I estimated the effort required would be about 100 man-years. That was wrong. In this case it will be at least 200, with a large portion of that effort being put into environmental studies and studies that are related to the challenges of water management and waste disposal.

Following the completion of the Environmental Impact Report and the Intermediate Feasibility study, the basic decision must be made by the investor to determine whether or not the potential financial return for the project when considered in the light of political, technical and economic risks justifies the very large expenditures required to bring a sizeable discovery into production.

If management's decision is in the affirmative, the next phase, the Permitting Phase, is started. This phase of the project has as its objectives the obtaining of all necessary regulatory permits.

THE OBVIOUS QUESTION ARISES--WHAT IS A REASONABLE PERIOD OF TIME FOR THE PERMITTING OF A MINING PROJECT? I DON'T THINK THAT THIS CAN BE ANSWERED BY ME IN ANY SIMPLE WAY, EXCEPT TO POINT OUT SEVERAL IMPORTANT FACTORS.

IF THE PERMITTING AGENCIES HAVE BEEN DEALT WITH IN A FORTHRIGHT MANNER BY WAY OF WHAT HAS PERHAPS COME TO BE KNOWN AS THE "OPEN PLANNING CONCEPT," THEN THE TIME REQUIRED SHOULD QUITE LOGICALLY BE SHORTER. IT IS ALSO APPARENT THAT IF THE PUBLIC WHICH WILL BE AFFECTED BY MINE DEVELOPMENT HAS BEEN KEPT INFORMED AND THE MINING COMPANY HAS BEEN ATTUNED TO THEIR ENVIRONMENTAL AND SOCIAL SENSITIVITIES, THEN THE PERMITTING PERIOD SHOULD BE SHORTER THAN IT WOULD BE OTHERWISE.

DURING THIS STAGE, THE INVESTOR MAY, OR MAY NOT, ELECT TO PROCEED WITH FINAL DESIGN AND ENGINEERING OF THE PROJECT. BECAUSE OF THE FACT THIS PHASE OF ENGINEERING IS VERY EXPENSIVE, IT IS USUALLY ELECTED TO DEFER MAJOR FINAL DESIGN EXPENDITURES ON MOST ASPECTS OF THE PROJECT UNTIL THERE IS REASONABLE ASSURANCE THAT THE NECESSARY PERMITS WILL BE GRANTED.

AT THE END OF THE INTERMEDIATE FEASIBILITY STAGE, THE NUMBER OF DRAWINGS, FOR EXAMPLE, IS MEASURED IN THE HUNDREDS. JUST PRIOR TO CONSTRUCTION, THE NUMBER OF DESIGN DRAWINGS FOR A MAJOR PROJECT IS MEASURED IN THE THOUSANDS. THIS DETAILED DESIGN AND ENGINEERING DOES NOT CHANGE THE BASIS WHICH HAS BEEN SELECTED IN THE INTERMEDIATE FEASIBILITY STAGE. IT PROVIDES THE HOST OF DETAILS WHICH IS REQUIRED FOR THE CONSTRUCTOR AND HIS CRAFTSMEN TO BUILD EACH AND EVERY FACET OF THE PLANT.

SOME MENTION SHOULD BE MADE OF PROSPECTING. IN A SENSE IT PARALLELS PRE-DEVELOPMENT, BUT IT IS NOT SO MUCH A DATA GATHERING PHASE AS A CONFIRMATORY PROCESS.

AT CRANDON WE PROPOSE TO OBTAIN A BULK SAMPLE OF THE ORE BY SINKING A SMALL SHAFT ABOUT 700 FEET DEEP AND DRIVING ABOUT A MILE OF TUNNEL INTO THE OREBODY FROM NEAR THE BOTTOM OF THIS FACILITY. THIS WOULD BE PROCESSED THROUGH AN EXISTING CONCENTRATOR PILOT PLANT FOR THE PURPOSE OF CONFIRMING AND FINE-TUNING PLANT DESIGN PARAMETERS DERIVED FROM EARLIER LABORATORY BENCH SCALE TESTING. IN OUR CASE THE ACTUAL PROCESS IS WELL PROVEN SO WE CAN CONCENTRATE UPON REFINEMENTS SUCH AS VERIFYING SIZING OF KEY PIECES OF EQUIPMENT WHICH WOULD BE EXPENSIVE TO REPLACE ONCE SET IN PLACE FOR PRODUCTION.

OTHER OBJECTIVES ARE TO CONFIRM ORE RESOURCES BY DOING MORE DRILLING AND VERIFYING OUR CONCLUSIONS CONCERNING THE MINING METHODS WE HAVE SELECTED. HOWEVER, NO ACTUAL TEST OF MINING METHODS IS REQUIRED OR CONTEMPLATED AS A PART OF THE PROSPECTING EFFORT. THE PROGRAM WOULD TAKE ABOUT 2 YEARS TO FULLY COMPLETE AND WOULD EMPLOY ABOUT 50 PEOPLE. INTERESTINGLY ENOUGH, THE SAMPLE WOULD CONSTITUTE ABOUT 1 DAY'S PRODUCTION AND THE TOTAL PROGRAM WOULD COST ABOUT 15 MILLION DOLLARS.

THE RESULTS OF THIS PROGRAM ARE COMPARED WITH THE PLAN, AND THE EARLIER THIS CAN BE DONE THE EASIER IT IS TO REACT AND AVOID POTENTIALLY COSTLY RE-DESIGN EFFORT. THE TYPE OF PROSPECTING PROGRAM I HAVE DESCRIBED IS QUITE TYPICAL OF MOST MINING PROJECTS.

FINALLY, THE THOUGHT THAT WE LIVE IN A VERY DYNAMIC WORLD WHERE THE OUTLOOK FOR THE DEMAND FOR METAL PRODUCTS AND OTHER COMMODITIES CAN AND OFTEN DOES CHANGE RATHER ABRUPTLY. AS TIME AND THE MINE DEVELOPMENT PROCESS WHICH I DESCRIBE MOVE FORWARD, THE INVESTOR COULD POTENTIALLY BE FACED WITH CHANGING HIS MIND CONCERNING THE VIABILITY OF A PROJECT. FOR EXAMPLE, ENERGY CONCERNS HAVE DRASTICALLY CHANGED THE CONSUMPTION PATTERN FOR ZINC IN A VERY BRIEF SPAN OF TIME. IT HAS BECOME DESIRABLE TO MAKE AUTOMOBILES LIGHTER SO THAT WE SEE THE REPLACEMENT OF DIE CAST ZINC PARTS BY ALUMINUM AND PLASTIC. FORTUNATELY, CONSUMERS, DURING THIS SAME SHORT PERIOD, HAVE DEMANDED IMPROVEMENTS IN CORROSION RESISTANT QUALITIES OF AUTOMOBILES AND MANY SIMILAR PRODUCTS. HAD THE LATTER NOT OCCURRED IN SYNC WITH THE FORMER, ZINC CONSUMPTION OVERALL WOULD HAVE DECLINED. THE DECISION TO PROCEED WITH CONSTRUCTION OF THE MINE IS THE BIGGEST STEP OF ALL.

THE CONSTRUCTION PHASE OF THE PROJECT IS THE PERIOD WHERE THE INVESTOR SPENDS MONEY AT A VERY RAPID RATE. IN OUR CASE, IT WILL PROBABLY BE MORE THAN 350 MILLION DOLLARS OVER A 3 TO 4 YEAR PERIOD.

FINALLY, THE PRODUCTION PHASE IS REACHED, BUT IT SHOULD BE EMPHASIZED THAT ONE SIMPLY DOES NOT GO FROM PRODUCTION START-UP TO ACHIEVING FULL CAPACITY OF THE PLANT IN A BRIEF PERIOD OF TIME. WE ESTIMATE AT CRANDON, DEPENDING UPON AVAILABILITY OF PERSONNEL AND THE AMOUNT OF TRAINING REQUIRED, THAT IT IS REASONABLE TO ASSUME THAT FULL PRODUCTION WOULD NOT BE REACHED FOR SEVERAL YEARS.

To summarize the schedule: We discovered the deposit in 1975; we completed the preliminary evaluation in mid-1977; we expect to complete the Intermediate Feasibility study stage, which includes preparation of the EIR, by mid to late 1980. If we estimate that two years is a reasonable time for the permitting phase, then final engineering and construction would begin in the fall of 1982. Construction could require 4 years, so production then could really begin about 1987, and full production about 1989.

The period from discovery to the beginning of construction is about 7 years. The full process of mine building to the point of achieving full production then has spanned about 14 years, and the cost when including Pre-development, Evaluation, and Prospecting will approach 40 million dollars. Perhaps more significant is the very personal human endeavor required to achieve a 21st Century mine; and, after all, what is more basic and important than that--the people involved. Company--regulators--the local community.

CRANDON GEOLOGY

- Regional Geology

Northern Wisconsin is underlain by ancient, steeply dipping Precambrian aged rocks that consist of:

Granite Intrusive Rock
Sedimentary Rock
Volcanic Rock - "Greenstone Belts"

The Crandon deposit and other similiar, but smaller deposits, the Pelican and Flambeau, occur within a greenstone belt that stretches across Wisconsin from Ladysmith to the Michigan border.

- Discovery

The Crandon deposit was discovered in July of 1975 after five (5) years of intensive exploration . It was detected by an airborne electromagnetic survey.

- Functions of the Geology office are:

-- Delineation of the deposit.

-- Detailed examination of diamond drill cores

Visual observation (megascopic).
Assaying.
Microscopic observation using thin section, polished section and microprobe methods.

-- Preparation of plan, cross section and longitudinal maps to illustrate:

Rock types
Ore types
Distribution of metals

-- Identification and delineation of ore types.

-- Calculation of ore reserves and metal grades.

-- Determination of grain boundary relationships between one sulfide mineral grain with another sulfide grain or with waste mineral grains.

-- Identification and recording of waste rock types.

-- Notation of rock properties for waste and ore types.

- <u>The Crandon Deposit</u>

  The deposit is a tabular deposit having a length of 5000 feet, an average width of 125 feet, defined to a depth of 1500 feet. Ore reserves are 70 million tons of ore grading about 5% zinc and 1% copper. Additional ore potential is indicated.

  The deposit consists of nearly equal amounts of massive sulfide and stringer ore. Massive sulfide is a geologic term which refers to a high sulfide content and does not relate to the grade nor the size of the deposit.

- <u>Use of Geologic Data</u>

  Geologic data is used by Crandon engineers to assist with the design of underground facilities, prediction of metal values going into the mill, recovery of metal values, and the design of surface storage facilities of mine waste rock products.

MINING

- Four stages of planning:
  - -- Preliminary feasibility.
  - -- Intermediate feasibility.
  - -- Final feasibility.
  - -- Engineering construction.

- Method of study:
  - -- Determine mining method.
  - -- Develop production schedule.
  - -- Design materials handling system, including mine access, ventilation, and electrical requirements.
  - -- Determine stope and level development requirements as dictated by production schedule.
  - -- Develop stope blasthole drilling patterns, method of blasting and sequence.
  - -- Determine manpower and machinery requirements as dictated from all of the above.
  - -- Develop capital and operating costs.

- Mining method:
  - -- Blasthole open stoping with delayed backfilling.

- Mine access and materials hanlding:
  - -- A 24-foot diameter shaft sunk to a depth of 2922 feet will be the primary access with supplementary access via a 15% to 17% decline or ramp interconnecting all levels.

- Ventilation:
  - -- Intake - will be via the main shaft and a parallel fresh air raise.

-- Exhaust - will be via a system of four raises, two of which will extend to surface.

- Muck flow:

  -- The broken ore will be gravity fed via a system of ore passes from the producing levels to an electric haulage -- passes through the crusher to the loading pocket at the main shaft and hoisted to surface.

- Level development:

  -- Will utilize air powered and electric powered drill jumbos with mucking accomplished using a combination of diesel powered LHD units and trucks.

- Stope drilling:

  -- Will be accomplished using high pressure air, down-the-hole, crawler mounted drill rigs.

- Stope blasting:

  -- Will be accomplished using a combination of ammonium nitrate and water resistant explosive slurries with non-electric detonation.

- Communication:

  -- Will be via a system of dial telephones and mine page voice boxes.

- Backfilling:

  -- Utilizing tailings from the mill the backfill will be gravity fed via diamond drill holes and connected pipelines to stope voids.

- Mine drainage and pumping:

  -- Utilization will be made of a two-stage pumping system from main sumps located on the 340 meter level and the 840 meter level, plus a shaft bottom sump. Drainage from individual levels will be via overflow settling sumps gravity fed to the main pumping stations.

- Final product:

  -- Utilizing a contingent of approximately 450 men, including supervision, engineers, technicians and hourly paid employees, the mine will produce 14,000 tons per day from 10 operating stopes working 5 days per week, resulting in a yearly production of 3.5 million tons.

METALLURGICAL DEVELOPMENT

- In discussing the Metallurgical Development activities relating to the Crandon Project, we will consider the following questions:

  -- What is Metallurgical Development?

  -- Why is it done?

  -- How is it accomplished?

  -- What is the result?

- First of all, some basic definitions:

  -- Metallurgy is the art and science of extracting metals from their ores.

- Metallurgy is divided into:

  -- Mineral Dressing which is commonly regarded as the processing of raw minerals to yield marketable products, and waste, by means that do not destroy the physical and chemical identity of the minerals.

  -- Extractive Metallurgy is concerned with the production of metals in the pure state from ores and mineral concentrates. It always involves a chemical and physical change.

  -- Physical Metallurgy is concerned with the casting, machining, fabricating and alloying of metals.

- For our discussion today, we will concentrate on the development of the Mineral Dressing processes for the complex ores of the Crandon Deposit.

- Why is it necessary to develop specific processes for individual ores?

  Ores are like snowflakes. No two are exactly alike. But unlike snowflakes that are all simply frozen water, ores are complex mixtures of various minerals, intergrown in a completely unique fashion. The diversity and variety that makes nature so fascinating, presents interesting challenges to the metallurgist in developing the processes necessary to recover the maximum value from the ore while producing metal concentrates of acceptable purity.

- How is the Metallurgical Development accomplished?

  In developing the process flowsheet the following considerations are important:

  -- Location of the deposit.

  -- Nature of the deposit.

  -- Proposed mining method.

  -- Markets and product quality requirements.

  -- Environmental considerations.

  -- Samples of the ore for testing.

  -- Testing.

- Consultation with the project geologists, mining engineers, environmental engineers and marketing specialists is important in establishing the metallurgical concepts. As the project progresses and additional information becomes available, periodic reviews with these individuals insures that the most up to date thinking is incorporated in the metallurgical process design.

- Outside of the coordination with other project specialists, the project metallurgist performs a wide variety of investigations to satisfy the requirements for the processing of the ore. The techniques involved include:

  -- Literature review and plant visits.

  -- Chemical analyses.

  -- Mineralogical investigations.

  -- Laboratory testing.

  -- Pilot plant testing.

  -- Engineering studies.

- By taking advantage of the experience of others reported in the literature and visiting other mines and plants treating similar ores, the project metallurgist can expedite the development process and insure that no reasonable approach is overlooked.

- Chemical analyses are performed to establish as completely as possible the composition of the ore, including both metals of economic interest as well as impurities that might be important from a process or environmental standpoint.

- Detailed mineralogical investigations will reveal the minerals present, the degree of interlocking, extent of dissemination, size distribution of economic minerals and amount of alteration. All of these factors are important in the design of the flowsheet. The techniques utilized include optical microscopy, x-ray diffraction analysis, and electron microprobe analysis. Minerals having environmental consequences such as asbestos are searched for. No asbestos-like minerals have been detected in the Crandon ores.

- Laboratory testing is carried out on representative samples of ore to determine the requirements for:

  -- Crushing.

  -- Grinding and classification.

  -- Flotation.

  -- Water quality.

  -- Ore aging.

  -- Equipment sizing.

  -- Effluent treatment.

  -- Environmental control.

- For complex ores it may be necessary to perform pilot plant testing to confirm the results of the laboratory testing.

- Engineering design studies are performed based on the results of the testing, investigations and coordination activities. These studies include:

  -- Definition of the process flowsheet, including environmental control features.

  -- Sizing and layout of process equipment.

  -- Determination of plant inputs and outputs.

  -- Land requirements.

  -- Utilities requirements, such as water, fuel and power.

  -- Labor requirements.

  -- Reagent and supply requirements.

- Capital and operating cost estimates are prepared for feasibility studies.

- What is the result of the Metallurgical Development activities?

  The final product is a process that profitably recovers the desired metal concentrates with a high level of metal recovery and minimal environmental distrubance.

WASTE CHARACTERIZATION

- Mining waste characterization is a comprehensive program (not just a single test) including the following steps:

  -- Identification of waste products.

  -- Chemical analysis of the wastes.

  -- Mineralogic examination.

  -- Acid generation/leachability testing.

  -- Laboratory column leaching studies.

  -- Field testing.

  -- Design and monitoring.

- Identification of the mine waste products in terms of the type and quantity is absolutely necessary in order to provide the proper size and types of waste containment areas. The major wastes are:

  Concentrator Tailings

  Mine Waste Rock

  Water Treatment Sludges

  Sanitary Wastes.

  Refuse.

- Storage facilities must be provided for materials in process which cannot be considered wastes yet must be isolated from the environment. These include:

  -- Stockpiled development ore.

  -- Mine Backfill.

  -- Process water being recycled to the concentrator.

- Detailed chemical analyses of the wastes and materials in process are performed in order to aid in selecting the most appropriate and cost effective method of disposal which will provde adequate environmental protection.

- Detailed mineralogic examination of samples of the typical waste products to determine the nature and occurrence of the minerals and metals offers a great deal of guidance in selecting the proper waste handling procedures.

- Laboratory tests are run on samples of wastes to detemrine their tendency to produce sulfuric acid and heavy metal pollution. This information identifies those wastes which will require special handling.

- Laboratory column leaching tests are performed on samples of waste rock in order to confirm the acid generation tests and to gain information about the rate that the acid generation reactions take place and to better simulate the conditions to be encountered in stockpiling.

- Finally field testing and monitoring the test piles is carried out during prospecting and mine development in order to confirm the findings of the laboratory studies.

- The results of these studies are incorporated into the final design of the waste containment structures. Continuous monitoring of the performance of these facilities is carried on to insure that they are satisfactory and that the wastes are safely stored.

JH/lw
5/24/79

ENVIRONMENTAL CONCEPTS

A General Philosophy

Environmental efforts are project wide and are a totally integrated part of engineering planning. Environmental considerations extend much beyond the requirements of WEPA and the pursuit of permits. Mining project planning and engineering includes environmental engineering which is the responsibility of all the engineering design disciplines required to plan and develop a mining project. An important part of environmental engineering is the development and/or application of the most environmentally compatible systems through a design attitude that is constantly aware of environmental considerations. A requisite of design is a commitment to minimizing the potential of releasing a pollutant or creating an undesirable condition that must be secondarily controlled.

Environmental Studies

Baseline Studies

Since March 1977 we have been carrying out environmental baseline studies relative to the Crandon Project. The basic purposes of the environmental baseline (existing environmental conditions) study are to document existing conditions, provide basis for assessment of impacts associated with potential project development, facilitate mitigation measures, and provide a basis for design of future monitoring programs. The chemical, physical, biological, cultural, and economic studies include the following specific disciplines.

- Aquatic Ecology - water quality, plankton (swimming and floating plants and animals), fish, benthos (bottom dwellers), periphytic algae (attached organisms), macrophytes (water plants), sediments
- Terrestrial Ecology - soils, vegetation, birds, mammals, amphibians and reptiles, tissue chemistry
- Hydrology/Geology - surface water, ground water, physical and chemical surface and subsurface geology
- Land Use - recreational, farming, timbering, etc.
- History and Archaeology - historic and prehistoric resources, i.e., evidence of human activities of the past
- Socioeconomics - local and regional economy, public service needs, employment, income, etc.
- Meteorology and Air Quality - wind speed and direction, dust in air, rainfall, temperature, etc.
- Acoustics - sound levels

Site Identification/Selection Studies

- Identification of potentially suitable sites for the location of the concentrator/plant and the tailings disposal area, including preliminary evaluation of their suitability from the standpoint of hydrological, engineering, and environmental considerations.

- Selection of the most suitable concentrator and tailings disposal sites, along with identifying basic geotechnical and hydrological parameters to determine a conceptual design of these facilities at candidate sites in order to assess the acceptability of each site.

- The Phase I site identification process basically included field, laboratory, and office analyses required to:

  -- Develop exclusionarly criteria.

  -- Identify potential areas.

  -- Develop environmental evaluation criteria.

  -- Collect site-specific data.

  -- Screen potential sites through application of evaluation criteria.

  -- Identify a workable number of sites for further study and evaluation.

- The Phase II evaluation of most suitable sites involves intensive geological and hydrological studies, as well as carrying out complete environmental baseline studies for at least one year on the alternate sites.

Project Engineering Considerations

Environmental considerations extend beyond those incorporated into the planning stages of the project. As conceptual and preliminary engineering designs are produced, they are reviewed from an environmental engineering standpoint. This may be best described as an environmental quality assurance program.

Environmental Impact Report

The Environmental Impact Report (EIR) is considered the full disclosure document of a proposed project and is based on the Wisconsin Environmental Policy Act (WEPA) guidelines and our understanding of DNR Bureau of Environmental Impact needs for preparing their EIS. The EIR that will be prepared will go beyond fulfilling this statutory requirement in that extraordinary detail will be included so that this document will provide the necessary information to satisfy regulatory permit parameters. The general kinds of information in the EIR are organized as follows:

- Introduction.

- Description of the environment.

-- Physical environment.

-- Biological environment.

-- Social and cultural features.

-- Economic setting.

- Description of entire mining project:

  -- Description of physical parameters.

  -- Construction procedures and schedule.

  -- Operation of facilities.

  -- Economic aspects.

  -- Rehabilitation.

- Probable impacts on the environment - beneficial and adverse:

  -- Physical impacts.

  -- Biological impacts.

  -- Social and cultural impacts.

  -- Economic impacts.

- Alternatives considered.

- Environmental measurement and monitoring programs.

- Probable adverse environmental effects that cannot be avoided.

- Relationship between local short-term environmental use and the maintenance and enhancement of long-term productivity.

- Commitment of resources.

- Environmental approvals and permits required.

SITING/ENGINEERING

General

Some of the major facilities required for a mine/mill complex such as Exxon's Crandon Project are:

- Mine surface facilities.
- Mill/concentrator and ancillary facilities.
- Tailings disposal system.
- Reclaim water system.
- Mine waste rock disposal area.
- Railroad.
- Access highway.
- Electrical power transmission line.

Siting studies and/or route selection studies are required for each of these facilities to determine the best location or route from both the environmental and engineering standpoints, and from the standpoint of land use, political boundaries, and transportation facilities.

Once a potential site or route has been identified, preliminary engineering is performed to ensure that the facility can be engineered for the particular site or route.

Mine Surface Facilities

The mine and the associated surface facilities must be located at, or near, the ore body. This includes the production shaft, hoist headframe, and support facilities. The features of the ore body, as well as the envirnomental and natural features of the surface area over the ore body, dictate the location of the mine surface facilities. But, in the engineering work, the facilities are located and designed to minimize the environmental impact on the area.

Mill/Concentrator and Ancillary Facilities

While there is some flexibility in locating the mill, it is very desirable to keep the mill as close to the mine as possible:

o It minimizes long transport of ores from the mine to the mill.

o The mine and mill can share some common facilities, such as, sanitary treatment, potable water supply, shops, offices, warehouses, and electrical supply.

When looking for a mill site, we must consider:

- Land use requirements:

  -- This must be determined to some degree at a very early stage in order to know how large a site to look for.

  -- Good soil conditions are needed for the construction of the facilities.

  -- Must minimize environmental impacts.

  -- Need access by highway and railroad.

  -- Must be able to control surface water runoff and not be subject to flooding.

The preliminary engineering work will consider:

- How best to situate the facilities onto the site area from an operational standpoint, but with strong emphasis on environmental considerations.

- Some of the environmental considerations are location in relation to lakes, streams, wetlands, residences, municipalities, and endangered species.

- The engineering of the facilities will consider dust emissions, gas emissions, and noise and will determine methods or technology for controlling each of these.

- Strong emphasis is placed on the aesthetics of the facilities.

Tailings Disposal Site

It is desirable to keep the tailings disposal site close to the mill in order to keep the tailings slurry pump lines as short as possible.

When looking for a tailings disposal site, we must consider:

- Land use requirement:

  -- The volume of tailings which must be disposed of over the life of the mine must be determined at an early stage. It is desirable to have one disposal site large enough to dispose of all the tailings.

- Must minimize environmental impacts.

- Need construction materials for dams and embankments:

  -- It is desirable to get this material from within the disposal sites.

- Prefer an area with soils which have a low permeability.

- Topography with natural features which minimizes the construction of dams.

The preliminary engineering work will consider:

- How best to situate the disposal facilities in the land area and topography, yet have an operational and environmentally acceptable facility.
- How best to control seepage from the facilities so that the ground water, lakes, or streams are not contaminated.
- Ensure that the dams and embankments are "safe" from failure.
- The facilities should have low visual exposure.
- How will the facilities be reclaimed or abandoned.

Reclaim Water System

A facility is required to decant the water from the tailings disposal area into a reclaim water reservoir, and then return the water to the mill for re-use:

- The reservoir must be large enough to retain the required volume of water for a determined period of time to allow for "aging" before returning the water to the mill.
- It is desirable to have this reclaim water reservoir near the tailings disposal site.
- Seepage from the reservoir must be controlled the same as from the tailings disposal area.

Mine Waste Rock Disposal Area

An area is required for storing, handling, controlling, and reclaiming the mine waste rock:

- This area must be of sufficient size to handle all of the waste rock over the life of the mine.
- It is desirable to have this area near the mine so that long distance transportation of the rock is not required.
- This area may be incorporated into the same area as the tailings disposal site.

Railroad and Access Highway

Both railroad and highway facilities are required to the mine/mill site for the movement of people, supplies and materials, and for shipping of the concentrator products.

In selecting routes for these, we will consider:

- Determine the location of the nearest main railroad and major highway.
- Look at several alternate routes from both the environmental and engineering standpoints.

- Select routes that are the shortest possible, but consider the environmental impacts.
- Minimize cuts and grading.
- Minimize stream or wetland crossings.
- Maintain required distances from endangered species.
- The railroad must meet grade and curvature requirements.
- The highway must meet load and traffic requirements, and must be an all-weather road.

Preliminary engineering will be performed on selected routes to ensure that the railroad and highway can be designed on the identified route to meet requirements.

Electrical Power Transmission Line

Electrical power is required for the operation of the facilities, so early consideration must be given to the power requirements and to the source. This is done by:

- Determining the electrical power requirements for these facilities.
- By working with the utility company, which supplies the area, determine the source of adequate power.
- Have the utility company study and identify potential routes from the source to the mine/mill.

The utility company will usually select a preferred route, perform the preliminary engineering and environmental assessment, and then present this to the Wisconsin Public Service Commission for approval. However, the WPSC makes the final determination as to which route will be used.

APPENDIX I

UNITED STATES MINERAL INDUSTRY

UNITED STATES MINERAL INDUSTRY

- In 1976, domestic mineral raw material production was valued at $68 billion (B) -- $6B metals, $10B nonmetals, $52B fuels.

  Imports of mineral raw materials approximated $30 billion -- $28B crude oil and natural gas, $1B iron ore, $1B all other.

  Imports of processed energy and minerals totalled another $21B -- including $6B refined petroleum, $4.5B iron and steel, $4B chemicals, $2B major non-ferrous metals.

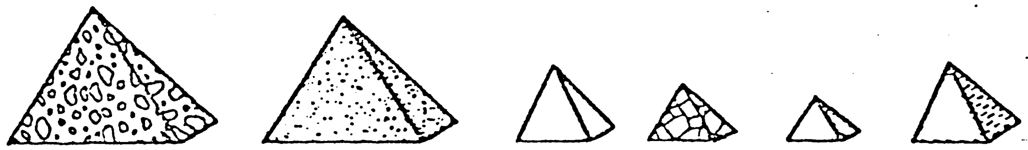
  Exports of both raw and processed mineral materials totalled $19 billion, principally chemicals, coal, iron and steel, plastics, petroleum products, and iron and steel scrap, with coal being the important mineral raw material export ($3B).

- With only 5% of world population and less than 7% of land area, the U.S. produces or imports a disproportionately large part of world mineral production:

- 1973 DATA -

Mineral	World Production (Millions)	U. S. as Percentage of World Production: Production	Imports
Ores & Concentrates			
Bauxite	70. l.t.	3%	16%
Copper (in conc.)	7.9 s.t.	22	2
Iron Ore	850. l.t.	10	5
Lead (in conc.)	3.9 s.t.	16	2
Molybdenum	181. lbs.	64	0
Nickel	1460. lbs.	2	26
Platinum - group	4.3 tr. oz.	1/2	54
Silver	307. tr. oz.	12	43
Zinc (in conc.)	6.4 s.t.	8	2
Metals			
Aluminum	13.3 s.t.	34%	5%
Copper	7.8 s.t.	22	3
Steel ingots/castings	766. s.t.	20	2
Lead	3.8 s.t.	18	5
Zinc	5.8 s.t.	9	10
Nonmetals			
Cement	764. s.t.	11%	1%
Fluorspar (marketable)	5. s.t.	5	24
Nitrogen (agricultural)	42. s.t.	31	2
Phosphate rock	108. s.t.	39	-
Potash (K_2O equiv.)	24. s.t.	11	15
Salt	166. s.t.	27	2
Sulfur (elemental)	32. s.t.	35	4
Mineral Energy			
Crude petroleum	20357 bbl.	16%	6%
Natural gas	45917032 cu. ft.	49	2
Coal & lignite	3480 s.t.	18	0

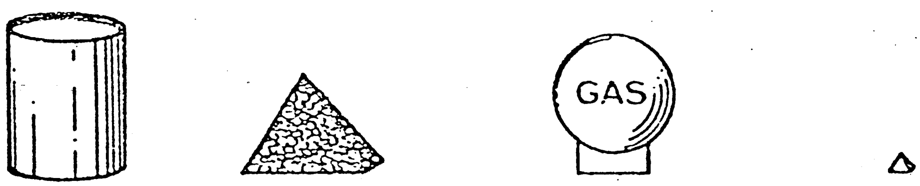
ABOUT 40,000 POUNDS OF NEW MINERAL MATERIALS ARE NOW REQUIRED ANNUALLY FOR EACH U.S. CITIZEN[1]



9310 LBS. STONE | 8740 LBS. SAND AND GRAVEL | 640 LBS. CEMENT | 480 LBS. CLAYS | 400 LBS. SALT | 1400 LBS. OTHER NONMETALS

990 LBS. IRON AND STEEL | 57 LBS. ALUMINUM | 20 LBS. COPPER | 14 LBS. ZINC | 13 LBS. LEAD | 31 LBS. OTHER METALS

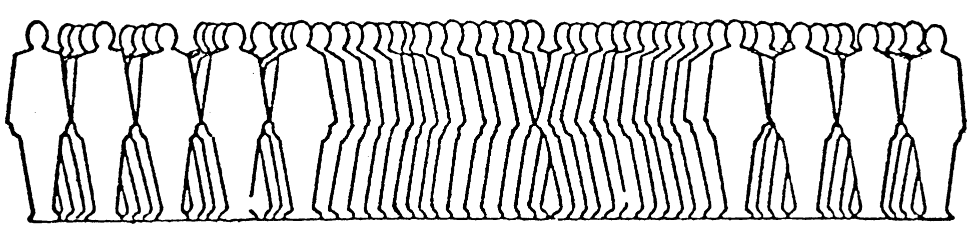
PLUS



7860 LBS. PETROLEUM | 5550 LBS. COAL | 4000 LBS. NATURAL GAS | 1/7 LB. URANIUM

TO GENERATE:

ENERGY EQUIVALENT TO 300 PERSONS WORKING ROUND THE CLOCK FOR EACH U.S. CITIZEN



U.S. TOTAL USE OF NEW MINERAL SUPPLIES IN 1976 WAS ABOUT 4 BILLION TONS !

[1] ESTIMATED SEPTEMBER 1, 1976

BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

NET IMPORT RELIANCE OF SELECTED MINERALS AND METALS AS A PERCENT OF CONSUMPTION IN 1976

MINERAL AND METALS	NET IMPORT RELIANCE* AS A PERCENT OF APPARENT CONSUMPTION**	MAJOR FOREIGN SOURCES (1972 - 1975)
COLUMBIUM	100	BRAZIL, THAILAND, NIGERIA
MICA (sheet)	100	INDIA, BRAZIL, MALAGASY
STRONTIUM	100	MEXICO, U.K., SPAIN
COBALT	98	ZAIRE, BELGIUM-LUXEMBOURG, FINLAND, NORWAY
MANGANESE	98	BRAZIL, GABON, AUSTRALIA, SOUTH AFRICA
TANTALUM	94	THAILAND, CANADA, AUSTRALIA, BRAZIL
TITANIUM (rutile)	93	AUSTRALIA, INDIA
PLATINUM GROUP METALS	92	U.K., U.S.S.R., SOUTH AFRICA
CHROMIUM	89	U.S.S.R., SOUTH AFRICA, PHILIPPINES, TURKEY
ALUMINUM (ores & metals)	87	JAMAICA, AUSTRALIA, SURINAM, CANADA
TIN	85	MALAYSIA, THAILAND, BOLIVIA
ASBESTOS	83	CANADA, SOUTH AFRICA
FLUORINE	79	MEXICO, SPAIN, ITALY
NICKEL	71	CANADA, NORWAY, NEW CALEDONIA
GOLD	70	CANADA, SWITZERLAND, U.S.S.R.
MERCURY	65	CANADA, ALGERIA, MEXICO, SPAIN
CADMIUM	64	CANADA, MEXICO, AUSTRALIA, BELGIUM-LUXEMBOURG
POTASSIUM	62	CANADA
ANTIMONY	61	SOUTH AFRICA, P.R. CHINA, BOLIVIA, MEXICO
SELENIUM	59	CANADA, JAPAN, MEXICO
TUNGSTEN	59	CANADA, BOLIVIA, PERU, THAILAND
ZINC	59	CANADA, MEXICO, AUSTRALIA, PERU, HONDURAS
TELLURIUM	57	PERU, CANADA
SILVER	47	CANADA, MEXICO, PERU
PETROLEUM (inc. Nat. Gas liq.)	39	CANADA, VENEZUELA, NIGERIA, SAUDI ARABIA
BARIUM	38	IRELAND, PERU, MEXICO
GYPSUM	38	CANADA, MEXICO, JAMAICA
TITANIUM (ilmenite)	37	CANADA, AUSTRALIA
VANADIUM	31	SOUTH AFRICA, CHILE, U.S.S.R.
IRON	27	CANADA, VENEZUELA, JAPAN, COMMON MARKET (EEC)
COPPER	15	CANADA, PERU, CHILE, SOUTH AFRICA
LEAD	15	CANADA, PERU, AUSTRALIA, MEXICO
SALT	7	MEXICO, CANADA, BAHAMAS, CHILE
NATURAL GAS	5	CANADA
CEMENT	3	CANADA, BAHAMAS, NORWAY, U.K.
PUMICE	2	GREECE, ITALY

0% 25% 50% 75% 100%

* NET IMPORT RELIANCE = IMPORTS-EXPORTS + ADJUSTMENTS FOR GOV'T AND INDUSTRY STOCK CHANGES

** APPARENT CONSUMPTION = U.S. PRIMARY + SECONDARY PRODUCTION + NET IMPORT RELIANCE

BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR (import-export data from Bureau of the Census)

U. S. ZINC INDUSTRY

- Statistics

	United States				Free World			
	1973	1974	1975	1976e	1973	1974	1975	1976e
Production/Consumption (Thousand tons zinc)								
Mine Production	479	500	469	477	4800	4760	4680	4610
Refinery Production	667	634	438	536	4690	4790	4150	4530
Slab Zinc Consumption	1509	1287	925	1127	5320	4950	3960	4560
Average Price (¢/lb.)								
U. S. Producer	20.7	35.9	38.9	37.0				
European Producer					24.0	35.3	36.9	36.1

- Mine Production

U. S. mine production has remained relatively stable the past five years, supplying 1/3 to 1/2 our needs. Production comes from 18 states, principally Tennessee, New York, and Missouri; also New Jersey, Pennsylvania, Illinois, Virginia, Maine, Wisconsin, Idaho, Colorado, New Mexico, Utah and Washington. Almost all production is from straight zinc ore, zinc-lead ore and lead ore. Current Wisconsin production is from straight zinc ores mined in the southwestern part of the state. Principal U.S. miners are St. Joe Minerals, New Jersey Zinc, ASARCO, AMAX, and Bunker Hill, which together account for 3/4 of mine production. (1975 Wisconsin mine production was 9M tons, by Eagle Picher Industries.)

- Reserves

U. S. zinc reserves apparently are large, about 30 million tons, but not high grade. The continuing discovery and development of large high grade Canadian orebodies the past 15 years has put great pressure on domestic miners. Central Tennessee-Kentucky is a potential major producing area.

- Refinery Production

The closing of about half of domestic refining capacity since the late 1960's has meant that we normally must import several hundred thousand tons of zinc metal a year to meet our industrial needs. (The old refineries which were closed could not meet environmental regulations.) There are 6 remaining zinc refiners, including the 5 principal miners (listed above) and National Zinc Co., owned by Philipp Brothers, a division of Engelhard Minerals and Chemicals Corp.

- Consumption

The three principal zinc metal uses are galvanizing (40%), diecasting (35%), and brass (14%). Normally, about 1/3 of zinc consumption ends up in cars and trucks in the form of zinc diecastings and galvanized sheet steel.

U. S. COPPER INDUSTRY

- Statistics

	United States				Free World			
	1973	1974	1975	1976e	1973	1974	1975	1976e
Production/Consumption (Million Tons Copper)								
Mine Production	1.72	1.60	1.41	1.61	6.70	6.88	6.26	6.66
Refinery Production	2.31	2.15	1.79	1.91	7.37	7.66	6.90	7.34
Refined Metal Consumption	2.45	2.19	1.53	1.96	7.65	7.13	6.04	7.20
Metal Stocks, e.o.y.		0.36	0.52	0.50	NA	1.20	2.02	2.16
Average Price (¢/lb.)	59.5	77.3	64.2	69.6	80.8	93.1	56.1	63.9

- Mine Production

About 58% of U.S. mine capacity is in Arizona, 36% in New Mexico, Utah, Nevada, and Montana, and 6% elsewhere (none in Wisconsin). Kennecott presently is developing a small copper mine (11 thousand tons/year) in Wisconsin. Principal domestic producers are Kennecott, Phelps Dodge, Anaconda, Duval (Pennzoil), Magma (Newmont), Cyprus, and Cities Service, which together account for about 3/4 of U.S. mine production.

Other principal Free World producers include the CIPEC countries -- Zambia, Zaire, Chile, Peru, and Indonesia -- also Canada, Philippines, Australia, Papua New Guinea, and South Africa.

- Reserves

U.S. copper reserves total some 93 million tons, most of it in the 5 principal producing states (Arizona, Utah, New Mexico, Nevada and Montana), in porphyry-type disseminated ore bodies. World resources also are large, with potential for continuing discoveries. Worldwide, only about 5% of copper resources are in massive sulfide type deposits.

- Consumption

Principal copper users are brass mills and wire mills which produce a wide variety of shapes for fabricators.

4/13/77

WISCONSIN'S MINERAL INDUSTRY

- In 1976 Wisconsin's mineral production was valued at $121.4 million, principally from sand and gravel, stone, iron ore, cement, lime, and zinc.

	No. Operations	Production	Value (Million $)
Sand/gravel	~ 400	27. million s.t.	36.4
Stone	~ 400	20.3 million s.t.	39.8
Iron ore (taconite pellets)	1	675 thousand l.t.	NA
Cement	1	NA	NA
Lime	5	327 thousand s.t.	9.5
Zinc/lead	2	NA	NA

Other minor production of clay, gem stones, abrasive stone, and peat. One of two cement plants in the state shut down in 1975.

- Forest County currently produces only sand and gravel, 60 thousand tons, valued at $77 thousand in 1975.

- Historically, Wisconsin has produced about 1.5 million tons of zinc, probably 0.5 million tons of lead, a few thousand tons of copper, and negligible gold and silver. Wisconsin formerly also produced iron ore from part of the Gogebic Range which extends from Michigan a short distance into Wisconsin. (Current iron ore production is from a different area.)

Source: Bureau of Mines

4/13/77

WISCONSIN COUNTIES INDEX

APPENDIX II

COMMON MINING TERMS

COMMON MINING TERMS

ACID ROCK--Usually refers to an igneous rock carrying a high proportion of silica.

ADIT--A passageway or opening driven horizontally into the side of a hill generally for the purpose of exploring or otherwise opening a mineral deposit. Strictly, an adit is open to the atmosphere at one end, a tunnel at both ends.

AERIAL SURVEY--A survey made from an airplane to obtain photographs, or measure magnetic properties, radioactivity, etc.

AGITATION--In metallurgy, the act or state of being stirred or shaken mechanically, sometimes accompanied by the introduction of compressed air.

ALLOY--A compound of two or metals, usually produced by fusion.

ALLUVIAL, ALLUVIUM--Deposits of sedimentary material laid down in river beds, flood plains, lakes, or at the foot of mountain slopes.

ALTERATION--Any physical or chemical change in a rock or mineral subsequent to its formation.

AMORPHOUS--A term applied to rocks or minerals that possess no definite crystal structure or form.

ANOMALY--A term applied to a departure from the normal or field characterists, commonly used in geophysical prospecting. Thus, in a magnetometer survey an area showing much higher (or much lower) readings of magnetic intensity than the surrounding area would be identified as an anomaly.

ANTICLINE--An arch or fold in the layers of rock shaped like the crest of a wave, as opposed to a syncline which is similar to the trough of a wave.

APEX--The top or terminal edge of a vein on surface or its nearest point to the surface.

ASSAY--To test ores or minerals by chemical or other methods for the purpose of determining the amount of valuable metals contained.

AUTOGENOUS GRINDING--The process of grinding in a rotating mill which uses as a grinding medium large pieces or pebbles of the ore being ground, instead of conventional steel balls.

BALL MILL--A cylindrical shaped steel container filled with steel balls into which crushed ore is fed. The ball mill is rotated, causing the balls to cascade, which in turn grinds the ore.

BANDED ORE (STRUCTURE)--Composed of bands or layers of minerals (rocks) differing in color and texture.

BASE METAL--A metal inferior in value to gold and silver, generally applied to the industrial metals such as copper, lead, etc.

BASIC ROCK--An igneous rock, relatively low in silica and composed mostly of dark-colored minerals.

BATHOLITH--A large mass of igneous rock extending to great depth and with its upper portion dome-like in shape. It has crystallized below surface, but may be exposed due to erosion of the overlying rock. Smaller masses of igneous rocks are known as bosses or plugs.

BEDROCK--Solid rock forming the earth's crust, frequently covered by soil or water.

BENEFICIATE--To concentrate or enrich; e.g., as applied to the preparation of iron ore for smelting, through such processes as sintering, magnetic concentration, washing, etc.

BIOLOGICAL LEACHING--A process for recovering metals from low grade ores by dissolving them in solution, the dissolution being aided by bacterial action.

BIT--The cutting end of a boring instrument. In rock drilling, it is frequently made with ultra-hard material such as diamonds or tungsten carbide.

BLAST HOLE--A hole drilled for the purposes of blasting rather than for exploration or geological information.

BREAST--A working face, usually restricted to a stope.

BRECCIA--A type of rock whose components are angular in shape, as distinguished from a conglomerate whose components are water-worn into a rounded shape.

BULK SAMPLE--A large sample, frequently involving many tons selected in such a manner as to be representative of the material being sampled.

BYPRODUCT--A secondary or additional mineral or mineral product.

CAGE--The conveyance used to transport men and equipment in a shaft.

CHALCOPYRITE--A sulphide mineral of copper and iron, being a common ore of copper.

CLOSED CIRCUIT--A loop in a process wherein a selected portion of the product of a machine is returned to the head of the machine for finishing to required specificiation; commonly used examples in milling plants include grinding mills in closed circuit with classifiers.

COLLAR--The term applied to the timbering or concrete around the mouth of a shaft; also used to describe the top of a drill hole.

COMPLEX ORE--An ore containing a number of minerals of economic value, usually implying difficulty to extract the valuable metals.

CONCENTRATE--A product containing the valuable metal and from which most of the waste material in the ore has been eliminated.

CONCENTRATOR--A milling plant that produces a concentrate of the valuable minerals or metals. Further treatment is required to recover the pure metal.

CONGLOMERATE--A sedimentary rock consisting of rounded, water-worn pebbles or boulders cemented into a solid mass.

CONTACT--The line or plane along which two different rocks come together.

CORE--The long cylinder of rock, about one inch or more in diameter, that is recovered by the diamond drill.

COUNTRY ROCK--A loose term to describe the general mass of rock adjacent to an orebody, as distinguished from the vein or ore deposit itself.

CROSSCUT--A horizontal opening driven across the course of a vein or structure, or in general across the strike of the rock formations; a connection from a shaft to an ore structure.

CRUSHER--A machine for crushing rock, such as a gyratory crusher, jaw crusher, stamp mill, etc.

CUT AND FILL--A method of stoping in which ore is removed in slices, or lifts, following which the excavation is filled with rock or other waste material known as backfill, before the subsequent slice is mined; the backfill supports the walls of the stope.

DEVELOPMENT--The underground work carried out for the purpose of opening up a mineral deposit. It includes shaft sinking, crosscutting, drifting and raising.

DIABASE--A common basic igneous rock usually occurring in dikes or sills.

DIAMOND DRILL--A rotary type of rock drill in which the cutting is done by abrasion rather than percussion. The cutting bit is set with diamonds and is attached to the end of a long hollow rods through which water is pumped to the cutting face. The drill cuts a core of rock which is recovered in long cylindrical sections, an inch or more in diameter.

DIFFERENTIAL FLOTATION--A milling process by which each of the valuable minerals is floated and separated from the waste constituents of the ore.

DIKE--A long and relatively thin body of igneous rock that, while in the molten state, has intruded a fissure in older rocks and solidified.

DILUTION--Waste or low grade rock which is unavoidably removed along with the ore in the mining process.

DIP--The angle at which a vein, structure or rock bed is inclined from the horizontal, measured at right angles to the strike.

DISSEMINATED ORE--Ore carrying small particles of valuable minerals, spread more or less uniformly through the gangue matter; distinct from massive ore wherein the valuable minerals occur in almost solid form with very little waste material included.

DRIFT (DRIVE)--A horizontal passage underground that follows along the length of a vein or rock formation as opposed to a crosscut which crosses the rock formation.

DUMP--A pile or heap of rock or ore on surface.

EM SURVEY--A geophysical survey which measures the electromagnet property of the rocks.

EXPLORATION--The prospecting, diamond drilling and other work involved in searching for ore.

FACE--The end of a drift, crosscut or stope in which work is progressing.

FAULT--A break in the earth's crust caused by forces which have moved the rock on one side with respect to the others; faults may extend for miles, or be only a few inches in length; similarly, the movement or displacement along the fault may vary widely.

FISSURE--An extensive crack, break or fracture in rocks.

FLOTATION--A milling process by which some mineral particles are induced to become attached to bubbles and float, and others to sink. In this way the valuable minerals are concentrated and separated from the worthless gangue.

FLOWSHEET--The sequence of operations,step by step, by which ore is treated in a milling, concentration, or smelting process.

FOLD--Any bending or wrinkling of a rock strata.

FOOTWALL--The wall or rock on the underside of a vein or ore structure.

FRACTURE--As the name implies, is a break in the rock. The opening affords the opportunity for entry of mineral bearing solutions. A cross-fracture is a minor break extending at more or less right angles to the direction of the principal fractures.

FRICTION HOIST--A mine hoist in which conveyances are suspended from both sides of a simple friction pulley which imparts the desired motion; it is distinct from a drum hoist in which the ropes are wound onto their individual drums.

GABRO--A coarse grained dark igneous rock.

GALENA--A sulphide mineral of lead, being a common lead ore.

GANGUE--The worthless minerals in an ore deposit.

GEOLOGY--The science concerned with the study of the rocks which compose the earth.

GEOPHYSICAL SURVEY--A scientific method of prospecting that measures the physical properties of rock formations. Common properties investigated include magnetism, specific gravity, electrical conductivity and radioactivity.

GLACIAL DRIFT--Sedimentary material consisting of clay and boulders which has been transported by glaciers.

GLACIAL STRIAE--Lines or scratches on a smooth rock surface caused by glacial abrasion.

GNEISS--A layered or banded crystalline metamorphic rock whose grains are aligned or elongated into a roughly parallel arrangement.

GOSSAN--The rust colored oxidized capping or staining of a mineral deposit, generally formed by the oxidation or alteration of iron sulphides.

GOUGE--Fine, putty-like material composed of ground-up rock found along a fault.

GRAB SAMPLE--A sample taken at random; it is assayed to determine if valuable elements are contained in the rock. A grab sample is not intended to be representative of the deposit, and usually the best looking material is selected.

GRAVITY METER, GRAVIMETER--An instrument for measuring the gravitational attraction of the earth which varies with the density of the rocks in the vicinity.

GREENSTONE--A convenient field term used to describe any fine-grained greenish volcanic rock, most often applied to andesite.

GRIZZLY--A grating (usually constructed of steel rails) placed over the top of a chute or ore pass for the purpose of stopping the larger pieces of rock or ore.

GROUTING--The process of sealing off a water flow in rocks by forcing thin cement slurry, or other chemicals into the crevices; usually done through a diamond drill hole.

HANGING WALL--The wall or rock on the upper side of a vein or ore deposit.

HIGH GRADE--Rich ore. As a verb, it refers to selective mining of the best ore in a deposit.

HOIST--The machine used for raising and lowering the cage or other conveyance in a shaft.

HOST ROCK--The rock surrounding an ore deposit.

IGNEOUS ROCKS--Rocks formed by the solidification of molten material that originated within the earth.

INDUCED POLARIZATION--A method of ground geophysical surveying employing an electrical current to determine indications of mineralization.

INTRUSIVE--A body of igneous rock formed by the consolidation of magma intruded into other rocks, in contrast to lavas, which are extruded upon the surface.

JAW CRUSHER--A machine in which the rock is broken by the action of moving steel jaws.

LAGGING--Planks or small timbers placed along the roof of a stope or drift to prevent rocks from falling, rather than to support the main weight of the overlying rocks.

LAUNDER--A chute or trough for conveying pulp, water or powdered ore in the milling process.

LEACHING--A chemical process for the extraction of valuable minerals from ore; also, the natural process by which ground waters dissolve minerals, thus leaving the rock with a smaller proporton of some of the minerals than it contained originally.

LEVEL--The horizontal passages on a working horizon in a mine; it is customary to work mines from a shaft, establishing levels at regular intervals, generally about 50 metres or more apart.

LIMESTONE--A bedded sedimentary deposit consisting chiefly of calcium carbonate.

LIMONITE--A brown hydrous iron oxide.

LODE--A mineral deposit in solid rock.

MAGMA--The molten material deep in the earth from which rocks are formed.

MAGNETITE--Magnetic iron ore, being a black iron oxide containing 72.4% iron when pure.

MARGINAL ORE DEPOSIT--An orebody of minimal profitability.

MATRIX--The rock or gangue material containing ore minerals.

METALLURGY--The process of extracting metals from their ores.

METAMORPHIC ROCKS--Rocks that have undergone a change in texture or composition from their original form through such agencies as heat, pressure.

MILL--(a) A plant in which ore is treated for the recovery of valuable metals, or concentration of the valuable minerals into a smaller bulk for shipment to a smelter or other reduction works; (b) A machine consisting of a revolving drum, for the fine grinding of ores as a preparation for treatment.

MINERAL--A naturally occurring homogeneous substance having definite physical properties and chemical composition, and if formed under favorable conditions, a definite crystal form.

MUCK--Ore or rock that has been broken by blasting.

ORE--A mixture of ore minerals and gangue from which at least one of the metals can be extracted at a profit.

ORE DRESSING--The treatment of ore by the removal of some of the waste materials.

ORE RESERVES--The prime measured assets of a mine as to tonnage and grade. They may be classified as <u>positive</u> or <u>proven</u>, <u>probable</u>, or <u>possible</u>, in decreasing degree of statistical confidence as to the accuracy of their expressed tonnage and grade; other terms frequently applied include, <u>measured</u>, <u>indicated</u>, <u>geological</u>, <u>broken</u> <u>reserves</u>, etc.

OUTCROP--An exposure of rock or a mineral deposit that can be seen on surface, i.e., it is not covered by overburden or water.

OXIDATION--A chemical reaction caused by natural forces that results in a change in the composition of a mineral.

PEGMATITE--A coarse grained igneous rock usually irregular in texture and composition, similar to a granite in composition; it usually occurs in dikes or veins and sometimes contains valuable minerals.

PILLAR--A block of solid ore or rock left in place for the purpose of supporting the saft, walls or roof in a mine.

PLANT--A group of buildings and their contained equipment, in which a process or function is carried out; on a mine it will include warehouse, hoisting equipment, compressors, repair ships, offices, mill or concentrator.

PORPHYRY--Any igneous rock in which relatively large, conspicuous crystals (called phenocrysts) are set in a fine grained groundmass.

PULP--Pulverized or ground ore in solution.

PYRITE--A common sulphide mineral, shiny and yellow in color, composed of sulphur and iron, sometimes known as "fool's gold."

PYRRHOTITE--An iron sulphide, less common than pyrite, bronze in color and magnetic; sometimes is associated with nickel, in which case it may be mined as a nickel ore.

RAISE--A verticle or inclined underground working that has been excavated from the bottom upward.

RECOVERY--The percentage of valuable metal in the ore that is recovered by metallurgical treatment.

REFRACTORY ORE--One that resists the action of chemical reagents in the normal treatment processes, and which may require roasting or other means to effect the full recovery of the valuable minerals.

REPLACEMENT ORE--Ore formed by a process during which certain minerals have passed into solution and have been carried away, while valuable minerals from the solution have been deposited in the place of those removed.

ROASTING--The treatment of ore by heat and air, or oxygen-enriched air, in order to burn off sulphur and arsenic.

ROCK--Any naturally formed combination of minerals forming an appreciable part of the earth's crust.

ROCKBOLTING--The act of consolidating roof strata by means of anchoring and tensioning steel bolts in holes especially drilled for the purpose.

ROCK MECHANICS--A study of stress conditions surrounding mine openings, and the ability of rocks and underground structures to withstand imposed stresses.

ROD MILL--A rotating cylindrical mill which employs steel rods as a grinding medium.

ROYALTY--The amount paid by the lessee or operator to the owner of the mineral land, generally based on a certain amount per ton or a percentage of the total production or profits. Also the fee paid for the right to use a patented process.

RUN OF MINE--A loose term sometimes used to describe ore of average grade.

SAMPLE--A small portion of rock or mineral deposit, usually taken for the purpose of being assayed to determine the content of valuable elements.

SCALING--The act of removing loose slabs of rock from roofs and walls.

SCHIST--A foliated metamorphic rock whose grains have a roughly parallel arrangement; it is generally developed by shearing.

SECONDARY ENRICHMENT--Enrichment of a vein or deposit by minerals which have been taken into solution from one part of the vein or adjacent rocks and redeposited in another.

SEDIMENTARY ROCKS--
Secondary rocks formed from material which is derived from other rocks and which is laid down under water, e. g., limestone, shale, sandstone. A characteristic feature of sedimentary deposits is a layered structure known as bedding or stratification.

SELECTIVE FLOTATION--See <u>differential flotation.</u>

SHAFT--A vertical or inclined excavation for the purpose of opening and servicing a mine. It is usually equipped with a hoist at the top, which lowers and raises a conveyance for handling men and material.

SHALE--Sedimentary rock formed by the consolidation of mud or silt.

SHORT TON--Contains 2,000 lbs. avoirdupois.

SHRINKAGE STOPE--A method of stoping which utilizes part of the broken ore as a working platform and as support for the walls.

SILICA--An oxide of silicon, of which quartz is a common example.

SILL--An instrusive sheet of igneous rock of approximately uniform thickness and generally extending over a considerable lateral extent; it has been forced between level, or gently-inclined beds.

SILT--A general name for the muddy deposits of fine sediment usually found on the bottom of lakes.

SKIP--A self-dumping type of bucket used in a shaft for hoisting ore or rock.

SLASH--Rock blasted from the side of a drift, resulting in the widening of the opening; it may be done to ascertain the width of the ore, or merely to make more working room.

SLICKENSIDE--The striated polished surface of a fault caused by one wall rubbing against the other.

SPHALERITE--A sulphide mineral of zinc, being a common zinc ore.

SQUARE SET--A set of timbers used for support in underground mining, consisting of cap, girt and post.

STATION--An enlargement of a shaft made at the level horizon used primarily for the storage and handling of equipment.

STOCK PILE--Broken ore accumulated in a heap on surface, pending treatment or shipment.

STOPE--An excavation in a mine from which ore is being or has been extracted.

STRIKE--The direction, that is the course or bearing, of a vein or rock formation measured on a horizontal surface.

STRINGER--A narrow vein or irregular filament of mineral traversing a rock mass.

STRIP--To remove the overburden or barren rock overlying an orebody.

SUBLEVEL--An intermediate level or working horizon in a mine opened between main working levels.

SULPHIDE--A compound of sulphur with another element.

SUMP--An excavation for the purpose of catching or storing water in an underground working or at the bottom of a shaft.

SYNCLINE--A downarched fold in bedded or stratified rocks.

TAILINGS--Material rejected from a mill after the recoverable valuable minerals have been extracted.

THICKENER--A large round tank in a mill for the separation of solids from a solution, the clear liquid overflowing the tank whereas the rock particles sink to the bottom.

TRAM--To haul cars of ore or waste in a mine.

TRENCH--A long, narrow excavation dug through overburden, or blasted out of rock, to expose a vein or ore structure.

TUBE MILL--An apparatus consisting of a revolving cylinder about half filled with steel rods or balls and into which crushed ore is fed for fine grinding.

TUFF--A rock composed of fine material such as ash that has been explosively ejected from a volcano.

VEIN--A fissure, fault or crack in a rock filled by minerals that have travelled upwards from some deep source.

VOLCANIC ROCKS--The class of igneous rocks that have been poured out or ejected at or near the earth's surface, as from a volcano.

VUG--A small cavity occurring in vein or ore deposit. It is frequently lined with well formed crystals, such as amethyst.

WALL ROCK--The rock forming the walls of a vein or ore deposit. Sometimes referred to as country rock.

WASTE--Barren rock in a mine, or a least material that is too low in grade to be of economic value.

WEATHERING--The chemical and mechanical breakdown of rocks and minerals under the action of atmospheric agencies. Eventually, surface rocks crumble into soil.

WEDGE--As used in diamond drilling, refers to the placing of a wedge at some point in the hole for the purpose of deflecting the bit in another direction.

WINZE--A vertical or inclined opening sunk from a point inside a mine. Similar to a shaft, but the latter starts at surface.

ZONE--Is an area or region which is distinct from the surrounding rock either because of a difference in the type or structure of rocks, or because of mineralization.

ZONE OF OXIDATION--The upper part of a mineral deposit that has become oxidized.

THE MINE DEVELOPMENT PROCESS