Crandon Project: progress report. 1981

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The CRANDON Project

EXXON MINERALS COMPANY

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CRANDON PROJECT

PROGRESS REPORT

October, 1980

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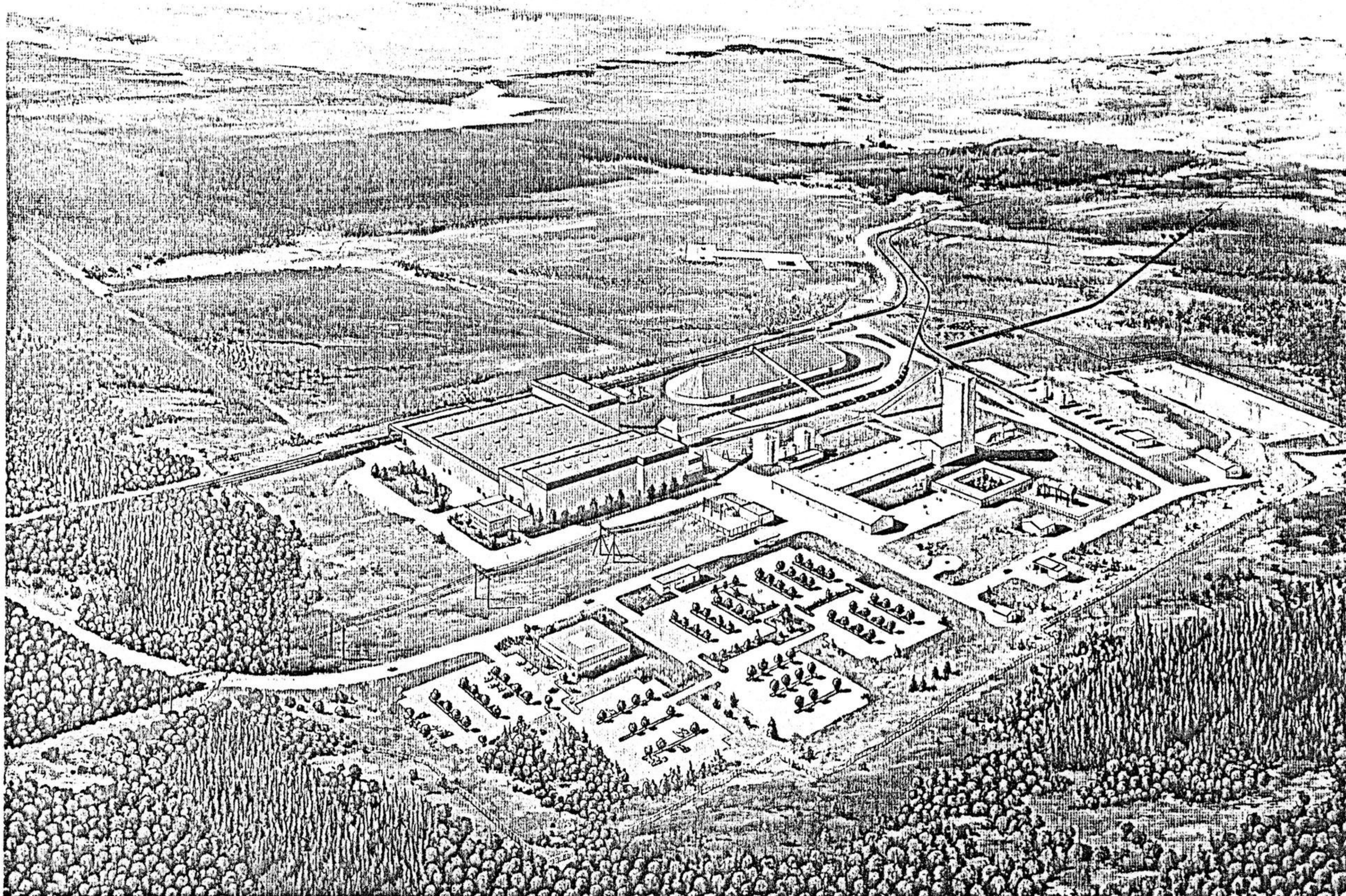


Surface Facilities - Crandon Project
Exxon Minerals Company, U.S.A.
Crandon, Wisconsin

The Ralph M. Parsons Company
Engineers/Constructors
Pasadena, California

TABLE OF CONTENTS

SCHEDULE OF FIGURES

SCHEDULE OF FIGURES (Continued)

LIST OF APPENDICES

PREFACE

The following summary progress report has been developed by the Crandon Project team of Exxon Minerals Company to provide general information concerning the Crandon Project to a wide audience. The Crandon Project team sincerely hopes that this will be of value in acquainting the people and organizations within the local communities in the Northwoods and other interested parties within the state with project activities and the status of the project.

Most of this material has been updated to reflect the September 15 and 16, 1980, communications relative to our decision not to seek prospecting permits. A great many questions asking clarification of the status of the project and the work which we have completed have resulted. Although the information contained herein is of a preliminary nature, and is subject to change and revision, we believe answers to the numerous inquiries can be found in this report.

It should be emphasized that many documents and specific reports concerning the Crandon Project are already within the public domain. A complete set of these public submittals, including this one, can be found in any of the following libraries:

- Crandon Public Library
- Rhinelander Public Library

- Antigo Public Library
- Nicolet College Library.

Single copies of this report are available on request from Exxon Minerals Company, Crandon Project, P.O. Box 813, Rhinelander, Wisconsin, 54501.

INTRODUCTION

The process of finding a commercial deposit and developing a mine is a long, arduous, and expensive process. After nearly a decade of persistence, Kennecott Copper Company discovered the Flambeau deposit in northern Wisconsin in 1969. This discovery attracted other mining companies, but despite a relatively high level of exploration effort, a second deposit was not found until 1974 when Noranda discovered the Pelican deposit in Oneida County. Finally, in 1975, a five year aerial geophysical survey search and subsequent drilling of 25 electro-magnetic anomalies by Exxon resulted in the discovery of the Crandon deposit.

Since that time, Exxon has pursued a vigorous program of delineating the deposit by diamond drilling and evaluating the potential of bringing the deposit into production. Since discovery of the Crandon deposit, some $30 million and hundreds of man-years of work have been expended in this effort. The Crandon Project team, which began in mid-1977, has grown to some 38 people which includes metallurgists, mining engineers, plant design engineers, environmental professionals, and support personnel. Other technical and staff support is also provided by personnel from Exxon Minerals Houston office. Numerous mining industry contractors are also employed to provide specific studies and perform specific tasks. Over the last three years contractor personnel working the the project have aggregated as many as 50 people at any given time. The project team, aided by these others, has been assigned the task, not only of determining the feasibility of bringing the mine into production, but of providing a definitive project design which would emphasize the companion goals of mine profitability and environmental sensitivity.

The Crandon Project team and other professionals within the Exxon Minerals Company have now worked for over three years toward accomplishing these objectives. Additionally, the same group has been working with the state and other interested parties toward the development of a comprehensive set of laws and regulations to effectively regulate and protect the environment.

While there is still considerable work to be done, particularly in the area of design of water management and waste management facilities, work has progresseed far enough with the project to be able to provide a general perspective of what the Crandon mine and mill would look like and the process to be employed. We also have, at this time, a relatively specific knowledge of the jobs and employment that would result. We would expect to have resolutions to these within a year's time.

At this point, we are confident that the mine can be developed in a fashion which would provide a high degree of sensitivity and protection to the physical environment. It is also apparent at this time that bringing the Crandon mine into production would result in material economic benefits to the three-county local area, as well as the state as a whole.

With one year's work yet to be accomplished, we still do not have all the answers. However, we believe that communicating those which we do have will contribute to a better understanding of Exxon's Crandon Project by the interested publics.

MINE DEVELOPMENT PROCESS

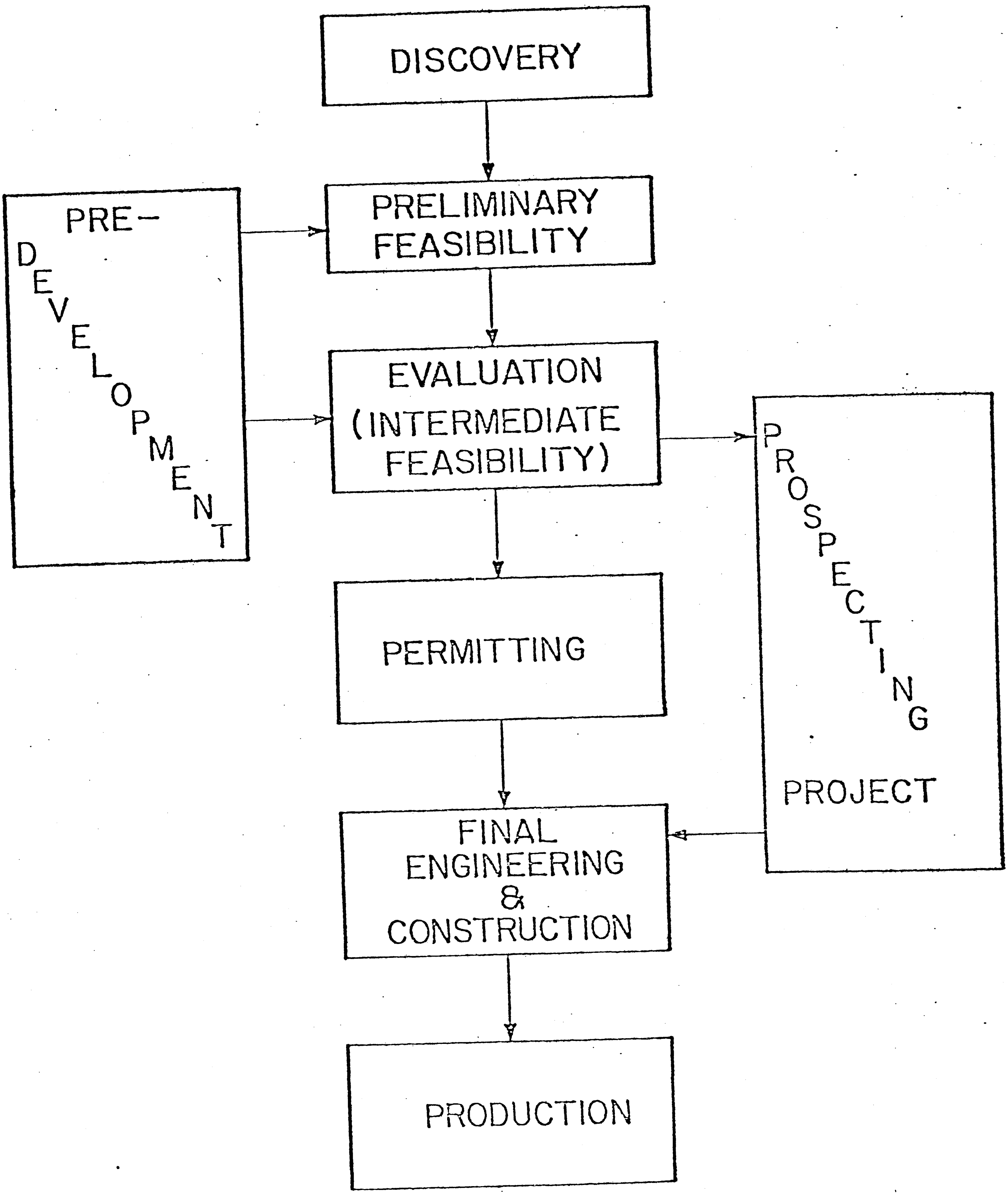
Generic Overview

General

The elements of mine development of the mine building process are discovery, preliminary feasibility, intermediate feasibility, permitting, final engineering and construction, and finally production. These steps are basically sequential as you can see by the acompanying chart. All of these steps are, or will be, present at Crandon. It should be emphasized, however, that the process has distinct iterative qualities where it is often necessary to go back and re-evaluate alternatives or even redefine the orebody prior to permitting and final engineering.

A very distinct activity, pre-development, usually takes place during preliminary feasibility and intermediate feasibility phase of the project. This is principally geological in nature and provides the basic information and facts concerning the ore deposit. A second activity, equally as important, termed "prospecting" in Wisconsin, is usually accomplished as early as possible following preliminary feasibility. In the case of Crandon, this was to consist of sinking a small diameter shaft and accomplishing about one-half mile of tunneling (drifting) to confirm the exact nature and characteristics of the deposit. A second phase of the prospecting would have been to obtain a bulk sample for confirmatory metallurgical testing. The prospecting project was cancelled September 15, 1980.

THE MINE DEVELOPMENT PROCESS



Specifically, the objective of the pre-development phase is to determine the location, attitudes, boundaries, mineralogy, geology, and perhaps the 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 and much lower grade or much more broken up, and thus much more difficult to mine, than had previously been thought.

In the case of Crandon, quite happily, the discoverers' intial assessments proved to be reasonably accurate. While among the top 10 deposits of its type in North America in terms of size, the Crandon deposit's 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 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. Also included are assessments of environmental and community needs and sensitivities. Often in this stage, several alternative approaches are selected. 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.

Preliminary Feasibility

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 drillholes into the deposit which gave a crude estimate of the size and metal grades.

The preliminary feasibility effort had the benefit of 6 months of baseline environmental studies by Dames & Moore, our environmental consultant. The alternative concepts 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 a production 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 sulfide 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.

Intermediate Feasibility

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. 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 environmental and social objectives of society.

The Crandon Project team has consistently found that it has not been possible 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 findings which in total provides a complete project plan, which is well balanced in all respects--socially, environmentally, and operationally. In the case of Crandon, the findings of our numerous work efforts will be an Environmental Impact Report. This is a report to the public and to the regulatory bodies, and describes in great detail the environment, the preferred action, alternative approaches, the environmental and social consequences of each, and steps to mitigate activities that might be deemed to be adverse.

In terms of the Crandon Project, the evaluation phase or intermediate feasibility study began in earnest in mid-1977, following completion of the preliminary feasibility studies. It is planned that the intermediate feasibility studies phase, including the Environmental Impact Report, will be completed in late 1981. This phase of the Crandon Project has taken much longer to complete, about three times as long, as we had planned when it was initiated. Similarly, the effort required has been about three times that of past industry experience. These several hundred man-years of effort required have emphasized siting and environmental considerations, with very thorough attention being given to the challenges of water management and waste management, as well as reclamation. Additionally, Exxon has chosen to accomplish a very detailed socioeconomic study so the local communities will have clear insight into the impact the mine will bring and thus we can assist them in any mitigation efforts that may be needed.

Management Decisions

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 sizable discovery into production.

If management's decision following completion of the intermediate feasibility phase is in the affirmative, the next phase, the permitting phase, of the project is started. This phase of the project has as its objective the obtaining of all necessary permits to allow construction to proceed. For Crandon, this will include zoning permits and all state required permits, with the Department of Natural Resources being the lead permitting agency. The local zoning permit decision will have the benefit of being accomplished following the completion of the DNR "master hearing."

The obvious question arises--what is a reasonable period of time for the permitting of a mining project in Wisconsin? Exxon's review of the procedures and requirements suggest that the minimum time required under existing and expected regulations would be about two to two and one-half years.

It has been Exxon's intention since the Crandon Project team was formed in mid-1977 to be as open and communicative as possible with all agencies of government. Exxon is hopeful that if the public which will be affected by mining development has been kept informed and the mining company in turn has been attuned to their environmental and social concerns, that the permitting period should be shorter than it would be otherwise. Exxon believes, also, that the Crandon Project team follows through with the above general commitment and provides specific information required by the state DNR for verification purposes, the permitting period should be shorter than it would be otherwise.

It is Exxon's intent to conclude with deliberate speed the engineering and environmental studies associated with the intermediate feasibility phase of the Crandon Project. The feasibility of the project design studies being conducted by the 38 people of the Crandon Project team will continue until they are completed in late 1981. Specifically, the Crandon Project team will continue with water management and waste management studies, and metallurgical testing associated with the present large hole core drilling program. They will also continue and complete the socioeconomic studies, environmental assessment and completion of the Environmental Impact Report. After having completed three years' worth of effort, the plan, thus, is to complete the fourth and final year of effort.

Final Engineering and Construction

Because of the fact that final engineering is very expensive and a significant portion of the total capital costs (typically, it can involve 10 to 13 percent of project capital), it is usually elected to defer these major final engineering expenditures until there is reasonable assurance that the necessary permits will be granted. At the end of the intermediate feasibilty stage (the beginning of permitting), the number of design drawings, for example, is measured in the hundreds. Just prior to construction, with a great deal of the final engineering complete, the number of design drawings for a major project such as Crandon is measured in the thousands. This detailed design and engineering does not change the basis which has been selected in the intermediate feasibilty 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.

The final engineering and construction phase of the project will require approximately 4 1/2 years to complete, with the controlling time factor being the miles of shaft, tunnel, and other excavations required to reach production. Usually, construction of a project such as Crandon is segregated into two major components--surface facilities construction and mine construction. As per our present plans, should Exxon proceed, we would elect to segregate the project into three major components:

1. Surface construction to be accomplished by a major contractor, with a number of subcontractors.

2. Sinking of the main shaft and excavation of related shaft facilities to be completed by a major underground excavation contractor; again, with a relatively large number of subcontractors.
3. Underground level development of the mine. This to be completed largely by permanent Exxon employees following the sinking of a fresh air shaft.

Production Phase

It should be emphasized the one simply does not go from production start-up to achieving full plant capacity in a brief period of time. We estimate that the Crandon mine could take three to five years to reach full capacity. The principal consideration here is the time required to build a high quality and well-trained Exxon work force. Most of the approximately 800-900 jobs associated with the Project are of a highly skilled nature, involving the use and operation of large and expensive mechanized equipment and a relatively sophisticated metallurgical process. The fact that a million dollars of capital is required per employee suggests the training and skill required by the operation.

The Production Decision and the World Metal Markets

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 move forward, the investor could, because of his assessment of the market and the costs to be incurred, potentially be faced with changing his mind concerning the viability of the project. For example, energy considerations have drastically changed the consumption pattern for zinc in a very brief span of time. They have also impacted significantly on projected operating costs. The decision to proceed with construction of the mine is the biggest step of all, for with that step assessments of price and cost projections reaching ten, twenty years into the future are the basis upon which you go forward. That is why the minerals business is known as a high risk activity.

The competitiveness of potential new ore deposits, such as Crandon, compared to those which are currently in production and those which will continue to produce during the next several decades is a crucial factor in making the new-mine investment decision.

PROJECT HISTORY

In the course of exploration for base metal deposits in northern Wisconsin, an aerial electro-magnetic geophysical anomaly was found near Crandon in Forest County during 1974. This was verified by collecting and interpreting ground survey data. Exxon began drilling this anomaly in the summer of 1975. The first diamond drill hole returned significant mineralization containing zinc and copper. Subsequent drilling confirmed the discovery of a sizable zinc-copper deposit.

From 1975 until 1978, about 200 diamond drill holes were completed, some as deep as 760 meters (2,500 feet). This drilling effort basically outlined the physical limits and determined the quality of the zinc-copper mineralization. An aggressive program of pre-development and mine planning activities has been conducted by Exxon Minerals Company since mid-1976.

The following summarizes the chronology of events and activities since Exxon Minerals Company began exploring for base mineral deposits in northern Wisconsin.

CHRONOLOGY

1970	Exploration program initiated in Wisconsin by Exxon Minerals Company. Selection of project areas from literature study, reconnaissance magnetic surveying, and initial airborne electromagnetic (AEM) surveys.
1971	Mapping of project areas and prospects, drilling of prospects initiated, AEM surveys continued.
1972	Regional AEM survey of greenstone belt, mapping, and AEM surveys of project areas continued.
1973	Drilling of prospects and AEM surveys of selected areas continued.
1974	Drilling of prospects continued, AEM survey identified Skunk Lake Crandon anomaly.
1975	Ground follow-up of Skunk Lake anomaly, electromagnetic, magnetic, gravity and induced polarization surveys. Discovery hole collared on June 22, massive sulfide encountered on July 4.
1976	Public announcement of discovery on May 13. Ten drill rigs were operating by July. Sixty holes were drilled by the Exploration group by the end of 1976.
1977	Crandon becomes a Project. Turned over to Pre-Development and Mine Evaluation and Development groups for evaluation. The environmental studies by the contractor, Dames & Moore, were started. Preliminary feasibility study completed by mid-1977 in Houston. Crandon Project team relocated to office in Crandon in mid-1977. Intermediate feasibility phase started mid-1977.
1978	Continuation of diamond drilling brought the total number of holes to 198. Intermediate feasibility environmental studies continued, with emphasis upon facility siting.
1979	Intermediate feasibility studies continued with emphasis upon conceptual design of the mine and surface facilities, also the siting of waste disposal facilities. Environmental studies continued. A major effort was directed towards cooperating with state and other interested groups in the development of environmental regulatory framework for metallic mining.
1980	Intermediate feasibility phase continued with emphasis upon the design of water management and waste management facilities. Environmental studies emphasized compilation of environmental baseline chapters, hydrological studies, and evaluation of waste disposal facilities. Prospecting project was cancelled September 15. Major effort continued toward development of state environmental regulations.

LOCATION AND ENVIRONMENTAL SETTING

The deposit is located in the Northern Highlands region of northeastern Wisconsin. Crandon, the county seat of Forest County, is located 5 miles due north of the deposit and the proposed Project site. Other communities in the area include Rhinelander, 28 miles west, Antigo, 45 miles south, and Iron Mountain and Iron River, in Michigan, 75 miles and 44 miles east and north of Crandon respectively. The Project site is located 2 miles east of State Highway 55 on Sand Lake Road.

The east-west striking deposit occurs in Section 25, Township 35 North, Range 12 East, Nashville Township, and in Section 30, Township 35 North, Range 13 East, Lincoln Township. Physiographically, the deposit lies one-quarter mile north of Little Sand Lake, and 1 mile south of Swamp Creek.

The Project area is in the region of rolling terrain that reflects its glacial origin. The ground surface elevation ranges from 1,520 feet to nearly 1,880 feet. The ground surface generally slopes away from the orebody toward Swamp Creek to the north and northeast, and toward Little Sand Lake to the south.

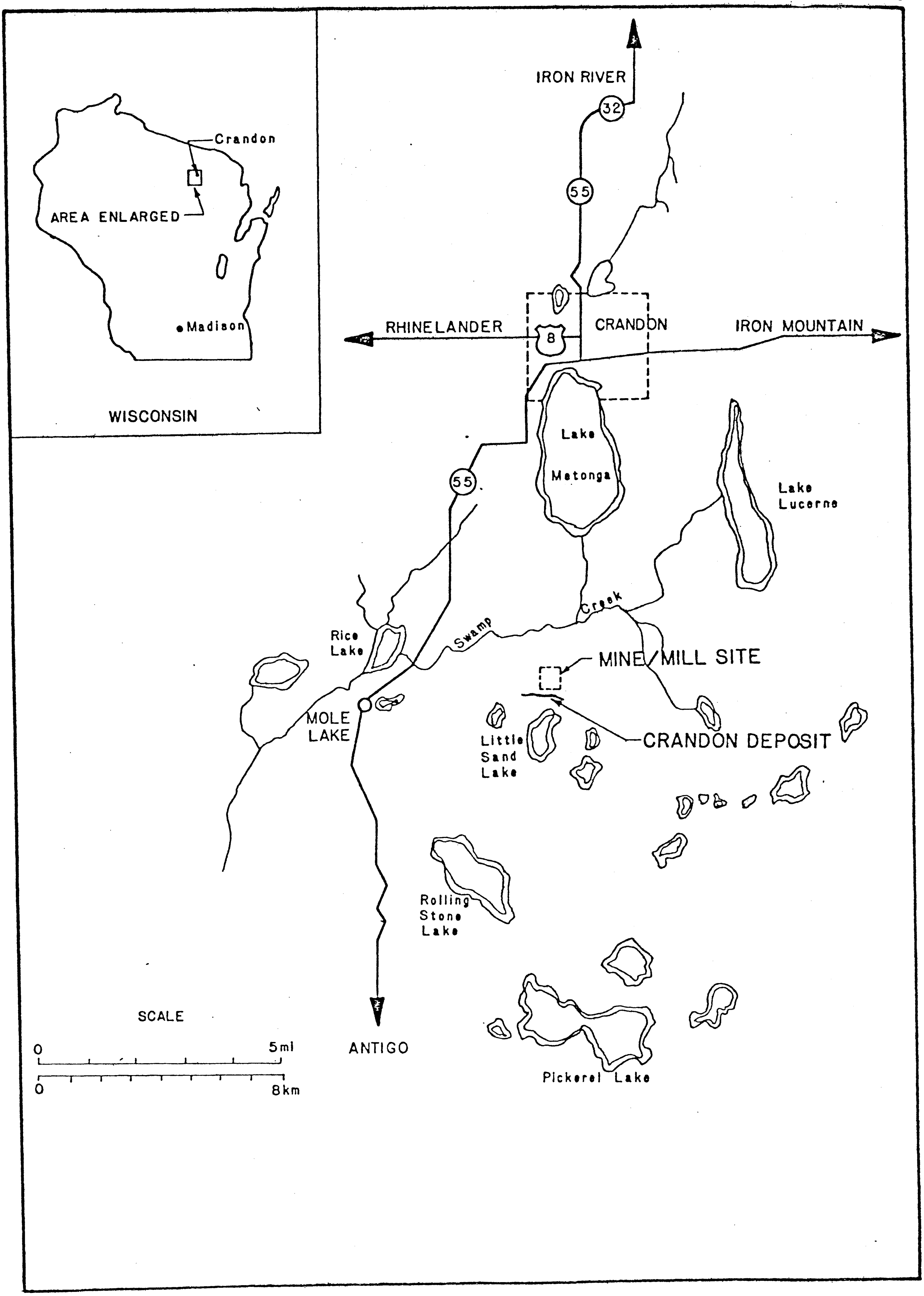
The area can be characterized hydrologically as an area of abundant lakes, ponds, streams, and wetlands. The orebody and candidate waste disposal facilities are in the headwaters of the Wolf River basin. Surface water drainage of this area moves toward the Wolf by migrating to Hemlock and Swamp Creeks to the east and north, and also by moving through wetlands and lake systems to the south.

Part of the Swamp Creek system originates on the eastern edge of one of our selected tailings disposal areas, flowing north and then west just to the north of the orebody. Swamp Creek flows through the Mole Lake Indian Reservation by way of Rice Lake, which is used by the tribe for wild rice production. The water quality and flow of Swamp Creek is of particular concern to the Sokaogon Tribe at Mole Lake.

Swamp Creek joins the Wolf River approximately 10 miles southwest of the Project area and flows through the Menominee Indian Reservation, approximately 30 miles southeast of the Project area. The quality of the Wolf River is of particular concern to tribal members, as well as numerous environmental groups.

Of the approximately 30 inches of total rainfall on this area, about 18 inches are lost to evaporation and transpiration, and the remaining 12 inches recharge the groundwater, streams and water bodies. The direction of groundwater movement is generally away from topographic highs toward low-lying areas. Lakes and wetlands at the higher elevations are not directly connected to the groundwater system, but are low contributors.

The area is in a natural setting of northern hardwoods and swamp conifers and is scenic and rustic, which spawns recreational use. The area has a number of designated trout streams, particularly Swamp Creek and some of its tributaries, and many of the lakes provide sport fishing. There are a number of game species in the area, i.e., deer, bear, grouse, etc. The osprey and bald eagle also occur and are designated as endangered species in Wisconsin.



Geographic location of the proposed Crandon Mine/Mill site and ore deposit.

DESCRIPTION OF THE DEPOSIT

The Crandon deposit is the result of volcanic activity that took place on the floor of an ocean approximately 1.8 billion years ago. The first volcanic activity began as ash and mud debris flows. Cool marine waters fractured the rock, and as volcanic activity increased, gas and fluid at depth exploded upward through the weak rock zone, causing more fracturing and brecciation.

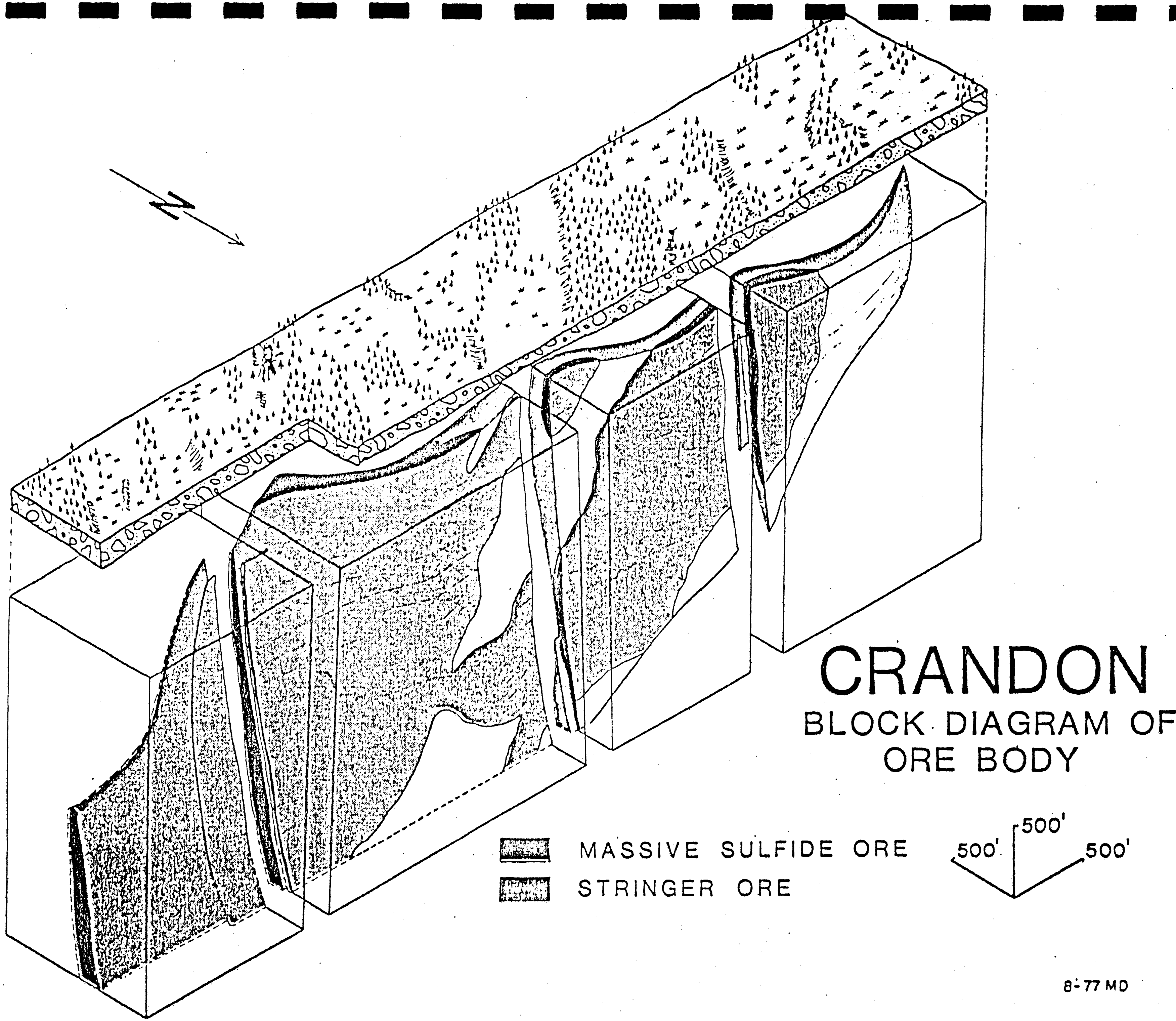
The ascending volcanic fluids were rich in silica, iron, calcium, sulfur, and metals, including zinc, copper, and lead. These reached the sea floor through the weakened rock fractures. Deposition of this material took place in a roughly layered fashion, along with cherty muds and fine volcanic ash. The metal sulfides formed were relatively fine-grained, and include sphalerite (zinc sulfide), chalcopyrite (iron-copper sulfide), galena (lead sulfide), and other ore minerals.

Renewed volcanic activity then deposited a thick layer of ash, with occasional pods of ore minerals and chert. This was followed by thick volcanic ash flows, along with volcanic debris. Some marine sediments, including sandstones and conglomerates, were deposited on top of the volcanics.

Then at some time during the Precambrian period, extensive folding of the strata tipped this rather stratagraphically flat sequence approximately 80 degrees. Accordingly, the deposit is now almost on end or vertical. Later there was some faulting in the area, along with intrusion of a basic granitic (gabbro) dike along a major east-west fault. Finally, recent glaciation (Quaternary) deposited 75 to 200 feet of sand and gravel over the deposit.

The 200 diamond drill holes which have been completed indicate that the orebody is very steep to vertical, and trends in an almost east/west direction. The mineralized zone can perhaps best be characterized as being tabular with an average width of 125 feet. The tabular, almost vertical ore zone is roughly wedge shaped, being about 5,000 feet long immediately below the glacial gravels, wedging down to a length of less than 1,000 feet at a depth of 2,300 feet below the surface. Current estimates of the probable tonnage and grade of the deposit are 85 million tons, which contain an average of 5 percent zinc, 1.1 percent copper, 0.4 percent lead, and minor quantities of silver and gold. This estimate, based on the 200 diamond drill holes completed to date, is subject to future change as new geological and economic data become available.

The deposit contains about equal amounts of two major ore types. The first ore type consists of copper mineralization, containing minor amounts of zinc. This copper-zinc ore has been designated "stringer ore" because of the occurrence of stringers or veinlets which fill fractures in the original rock. The second type of ore which occurs, mostly in the eastern and central portions of the ore deposit is termed "massive ore." Massive ore is principally a zinc sulfide ore with lesser amounts of copper and lead sulfide. In this type, the ore minerals occur within a matrix that is mostly pyrite (iron sulfide). Both the massive and stringer ore types are often separated from one another by zones of waste rock.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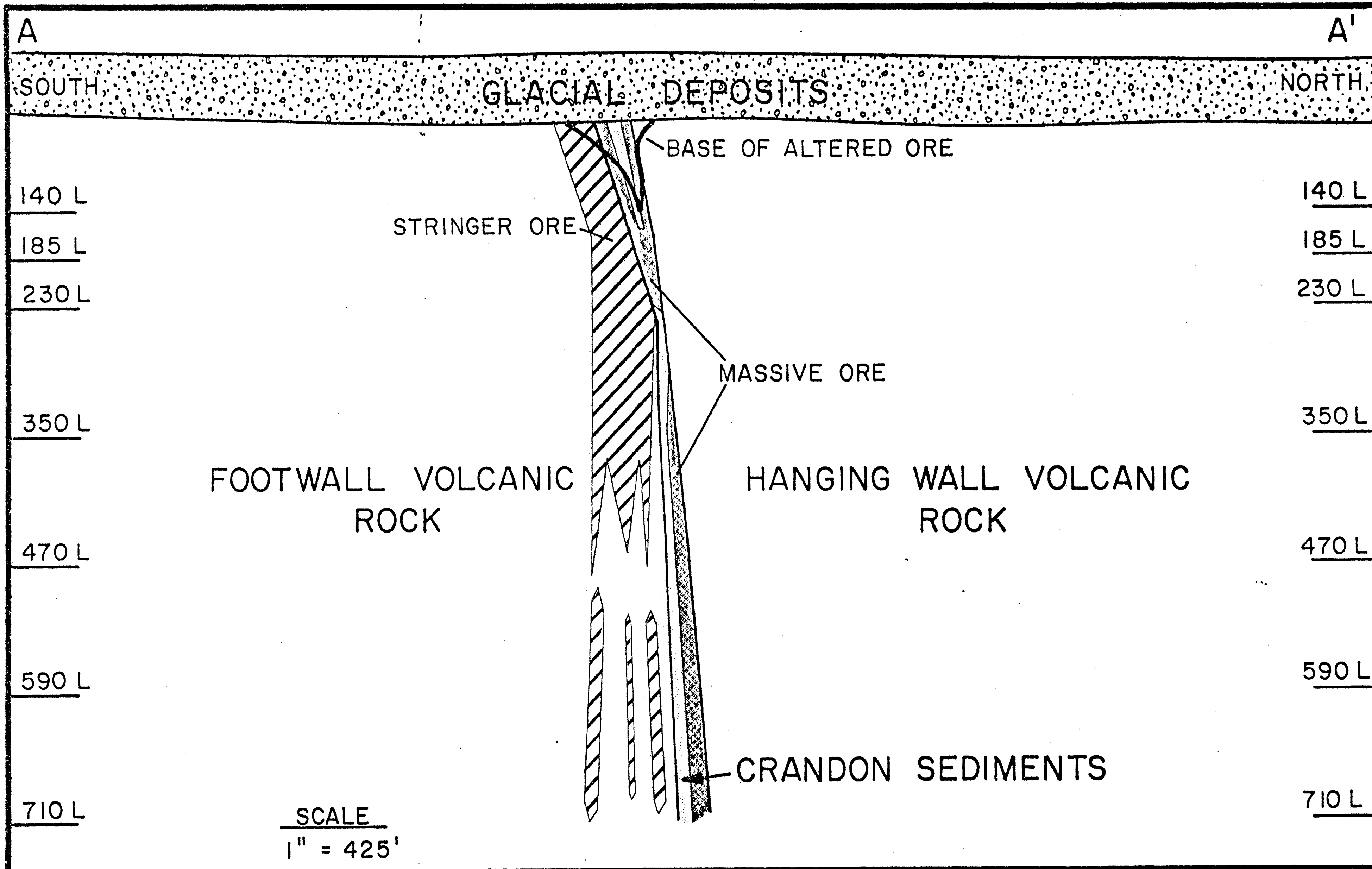
CRANDON
BLOCK DIAGRAM OF
ORE BODY
MASSIVE SULFIDE ORE
STRINGER ORE
500'
500'
500'
8-77 MD



GENERALIZED CROSS SECTION
CRANDON, WISCONSIN

TENTATIVE PROJECT SCHEDULE

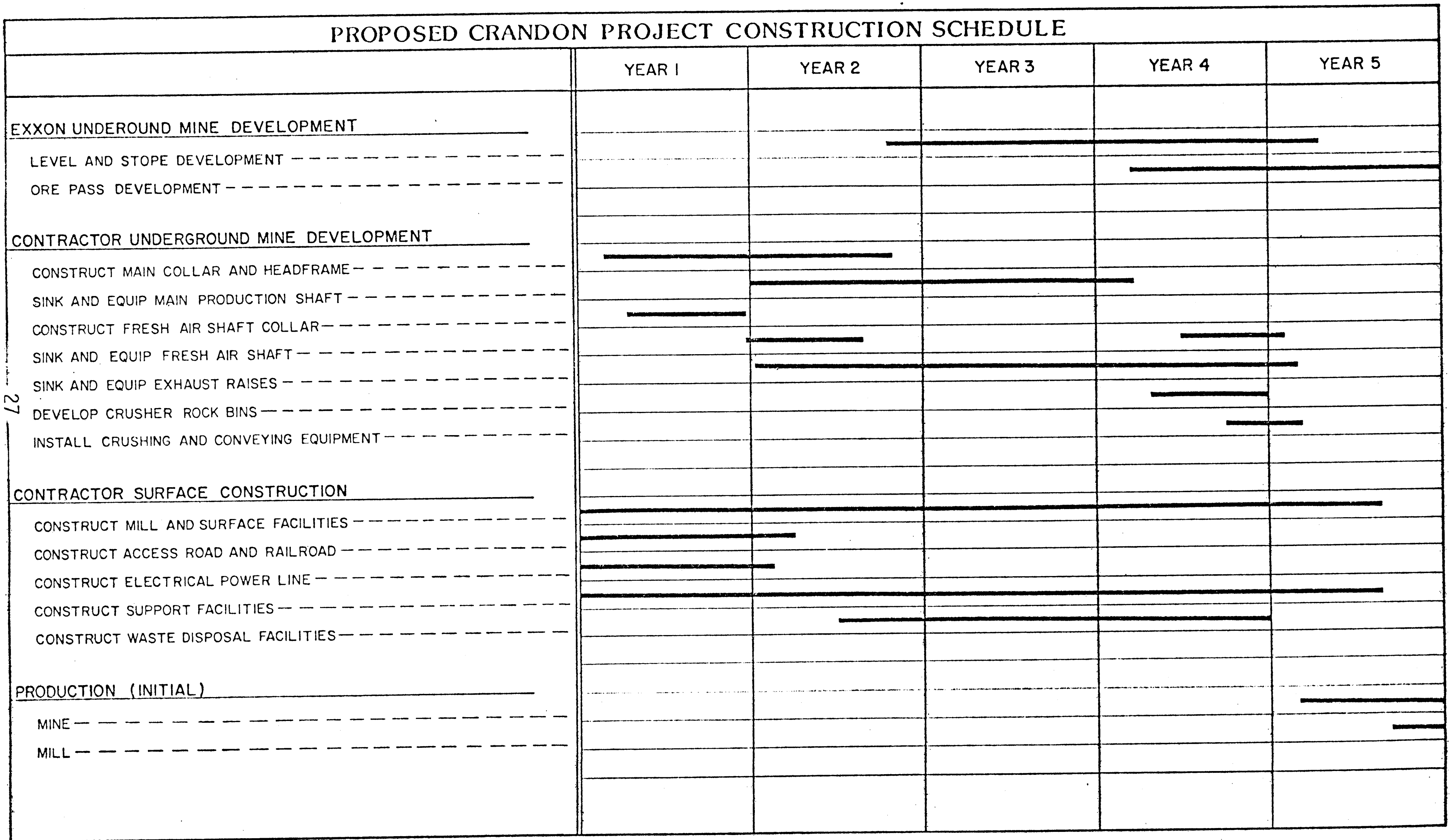
If Exxon elected to proceed with final engineering and construction, the project schedule would then depend upon the date when Exxon receives all required government permits and corporate approval to commence construction. Assuming favorable resolution to the decisions facing us during the next year, the following schedule could result, depending upon the time required for permitting:

Submittal of the Environmental Impact Report and permit applications	Early 1982
Receipt of all permits to allow construction	Mid to late 1984
Final decision by Exxon management to provide Project funding; beginning of construction	Late 1984, or early 1985
Begin production	Early to mid-1989
Full production	1992 to 1994.

A simplified construction schedule for the proposed Crandon Project is shown on the following diagram.

Site preparation and construction of the access road, railroad, electrical power line, and the surface facilities for support of the underground mine development would be started first. Shortly thereafter, work would start on sinking of the main production and ventilation shafts, followed by erection of the mine hoist headframe and installation of shaft equipment and facilities.

On the surface, work will commence on constructing the mine/mill and ancillary facilities, and the waste disposal facilities. As the buildings are constructed, equipment will be installed, tested, and prepared for production of concentrates. Exxon would begin sinking a 16 foot diameter fresh air shaft. This would be followed by level development by Exxon crews beginning early in the second year of construction.



Simplified construction schedule for the proposed Crandon mine and mill project.

PRELIMINARY PRODUCTION PLAN--CRANDON

Current tonnage estimates indicate that the orebody would sustain a mine life of about 25 years at a yearly production rate of 3.5 million tons. Mine construction to be done by Exxon crews would add another 4 years. Typically, additional ore reserves are proven during the life of such an operation, although at this time it is not possible to fully quantify projections.

Ore would be mined underground and hoisted to the surface at a rate of approximately 14,000 tons per day, five days per week. Processing of the ore would take place in the mill which would operate at a capacity of 10,000 tons per day, maintaining a 24-hour, seven day week schedule.

Typically, approximately 12 to 15 percent of the material ends up as saleable concentrates. Zinc concentrates ordinarily contain about 50 percent zinc with minor amounts of copper and precious metals. Copper concentrates typically contain 25 to 30 percent copper, with some zinc. In the case of Crandon, the lead concentrates contain only 30 to 40 percent lead, but do, however, contain most of the precious metals which would be recovered. Precious metals, silver and gold, occur less abundantly at Crandon than in most similar deposits.

Three concentrates will be produced at the mill--zinc, copper, and lead. These will be shipped by rail to a zinc refinery, copper smelter, and lead smelter. The specific destinations are as yet undetermined.

Mill tailings generated by the concentrator will be separated into coarse and fine fractions. The coarse fraction, which represents about 50 percent of the total material mined, would be returned to the mine as backfill to fill the voids created by mining. The remaining fine mill tailings would be deposited on the surface in a waste disposal facility.

MINE/MILL SURFACE FACILITIES

The mine/mill surface facilities will include those required on the surface for support of the underground mine; those for handling, storing, and crushing the ores on the surface; and concentrator where the minerals will be separated from the ores to produce the zinc, copper, and lead concentrates; and the ancillary facilities and utilities required to support the mine/mill operations. All of the surface facilities will be located within an area of about 100 acres. About one-third of this area will be covered by buildings, roadways, parking lots, and a railroad spur, an electrical power line, and a possible gas line will be provided into the mine/mill site.

Surface Facilities, View 1 (Page 33)

The mine surface facilities support the underground mine operations, Included are the collar house, mine operations building and change area, shaft access tunnel, mine air heaters, mine backfill preparation facilities, and air compressors. The mine hoist headframe is included as part of the mine.

Surface Facilities, View 2 (Page 34)

These facilities will include conveyors for moving the ore from the headframe to storage, the coarse ore storage building, ore reclaim feeders, conveyors for moving the ore from the building to the mill building, the fine crushing facility and conveyors, and the fine ore storage bins. Equipment for handling and disposing of mine waste rock brought to the surface also will be included. On the surface, the ore will be covered at all times as protection from precipitation and for dust control.

Surface Facilities, View 3 (Page)

The concentrator will include primary grinding; flotation; concentrate dewatering and drying; concentrate handling, storage, and shipping; reagent storage, mixing, and handling; the milk-of-lime facility; and office, laboratory, and change area.

The purpose of the concentrator facilities will be to further reduce the particle size of the ores by grinding; to separate the minerals from the ores to produce separate concentrates of zinc, copper, and lead; and to dewater and dry the concentrates for shipment.

Surface Facilities, View 4 (Page)

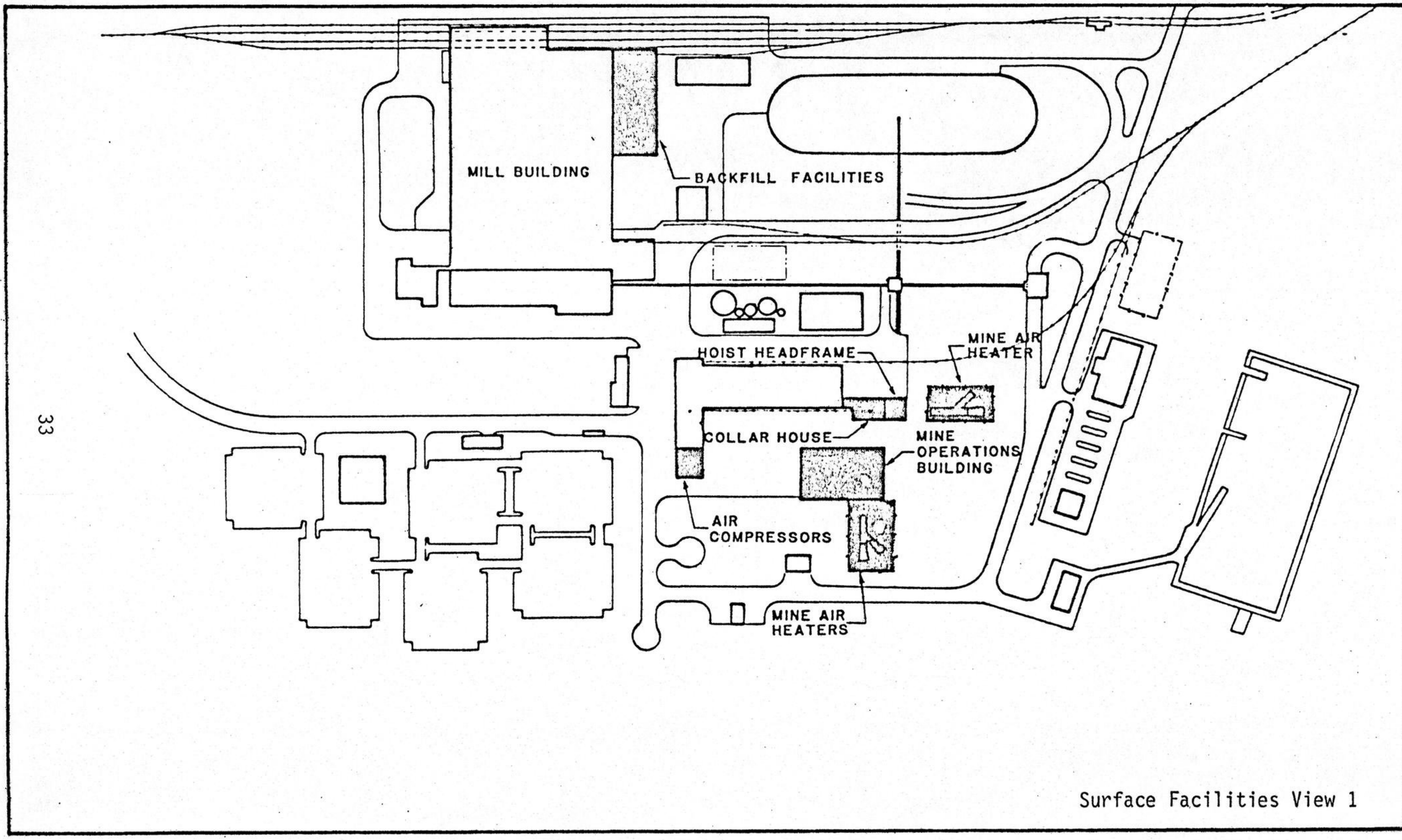
The ancillary facilities are those offices, warehouses, shops, service building, fuel and explosives storage, water systems, and sewage treatment required to support the operation of the mine/mill process facilities. The general design objective will be to unify as many of these facilities as practical, and to locate them close around and between the mine and mill. Also, because of the winter conditions, an effort will be made to combine as many facilities as practical under one roof, or into one building.

Surface Facilities, View 5 (Page)

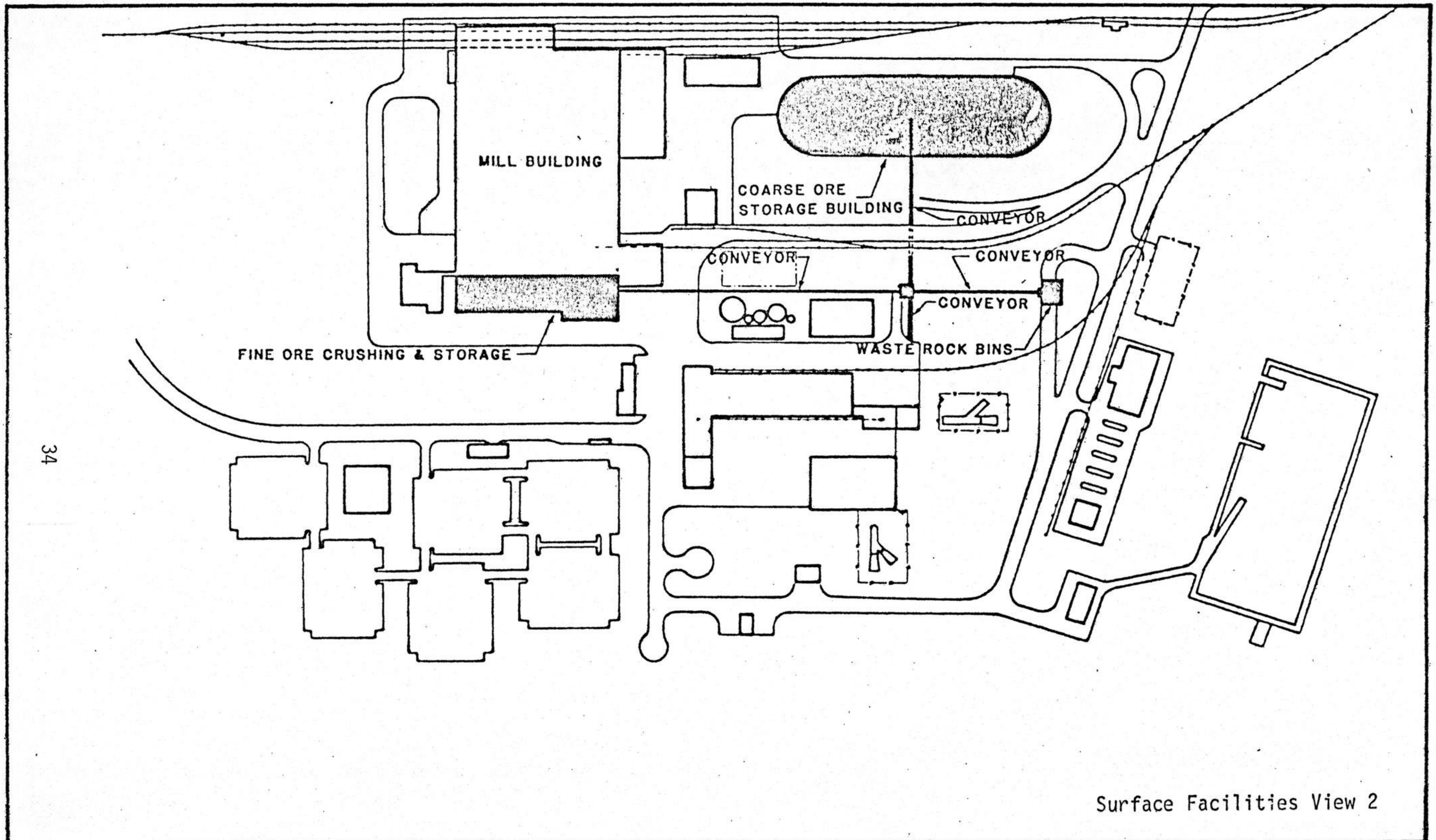
A railroad spur will be required for shipping concentrates and bringing in supplies, and an access road will be needed for auto and truck traffic. The railroad spur will be routed into the site from the Soo Line main line at a point about 2 miles northeast of the site. The access road will be routed into the site from northwest of the site. It is envisioned at this time that the main electrical power line and possible gas line will share the same corridor as the access road.

The facilities will be designed to produce concentrates in the most efficient manner possible, based on proven and established technology and will be consistent with environmental and regulatory requirements. Some of the primary considerations in the development of the overall mine/mill surface facilities are:

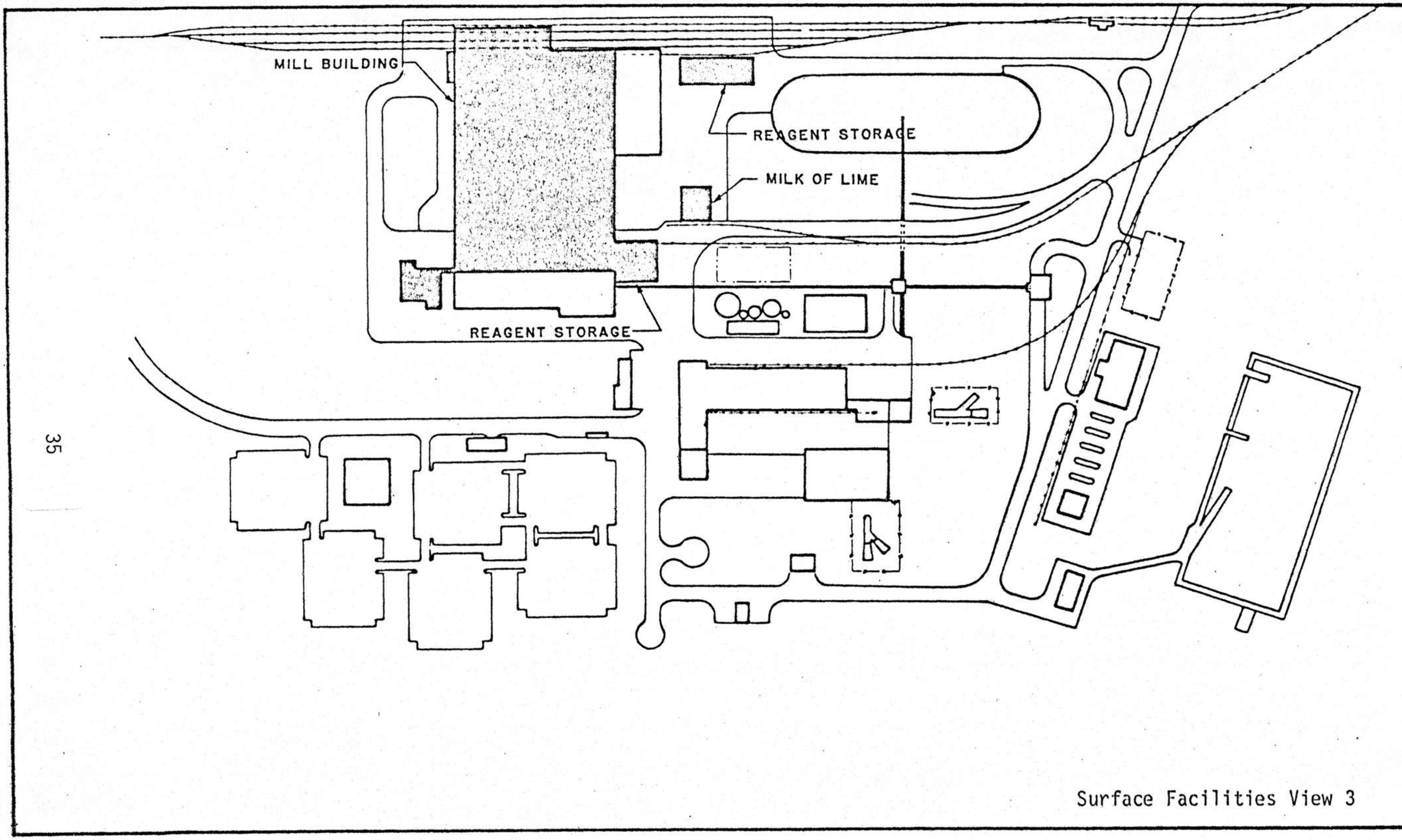
1. The facilities will be located as close as possible to the mine hoist headframe to minimize area impact and ore transport systems;
2. Advantage will be taken of topography in order to facilitate gravity flow of materials;
3. The surface area will be graded such that all operations will be in the same surface watershed;
4. Mine/mill surface drainage will be collected for possible treatment;
5. In consideration of local climatic conditions, as many installations as possible will be combined under one roof. The major buildings will be connected by tunnels;
6. All buildings and equipment layouts will be arranged to achieve a healthy and safe environment for the operating personnel;
7. Equipment selection and layout will meet federal noise regulations. Noise abatement procedures will be incorporated where necessary; and;
8. All buildings and structures will be designed to achieve the best overall visual aesthetics consistent with the local area.



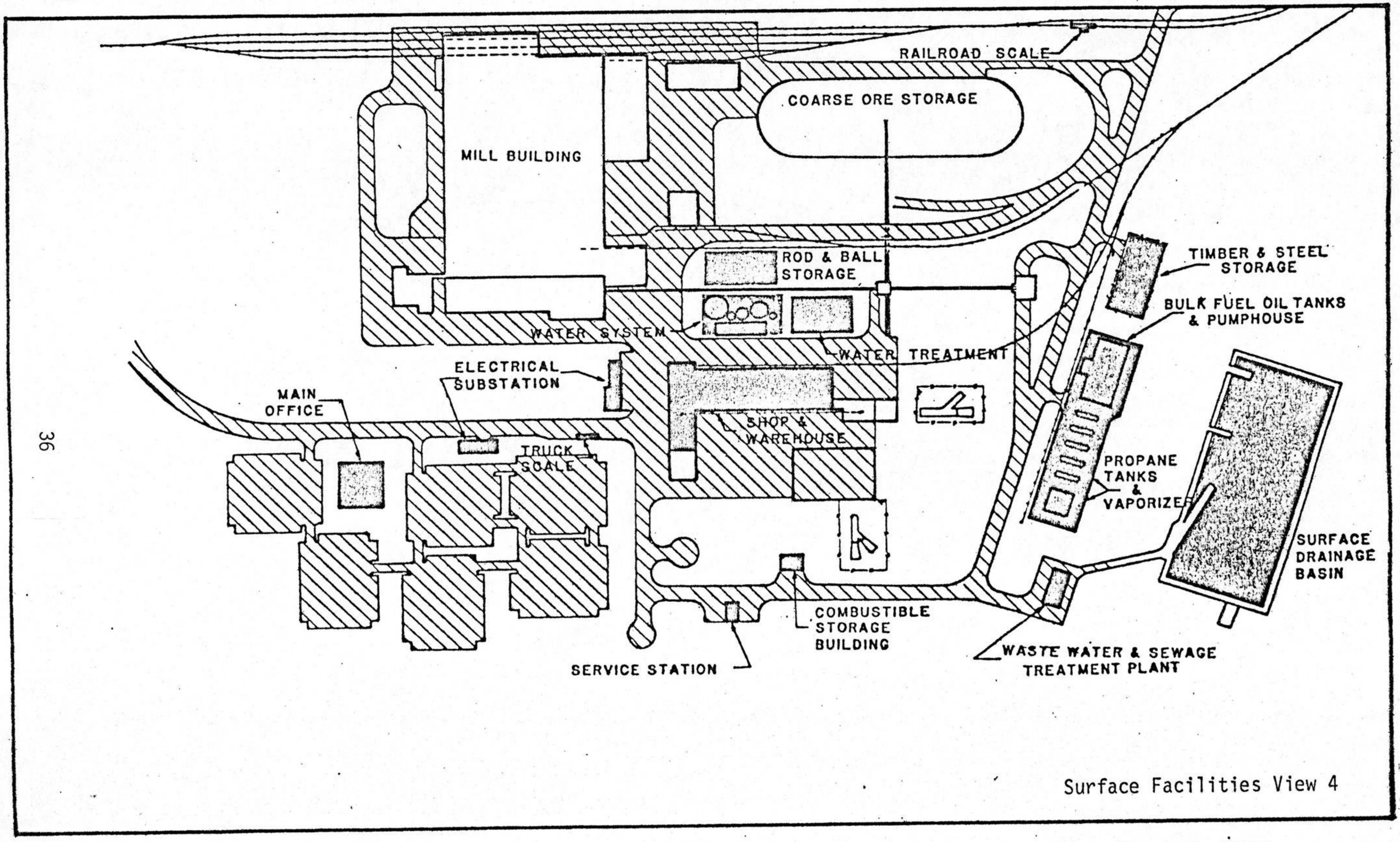
Plot plan of the proposed Crandon Mine/Mill Facilities showing the mine surface facilities as shaded areas.



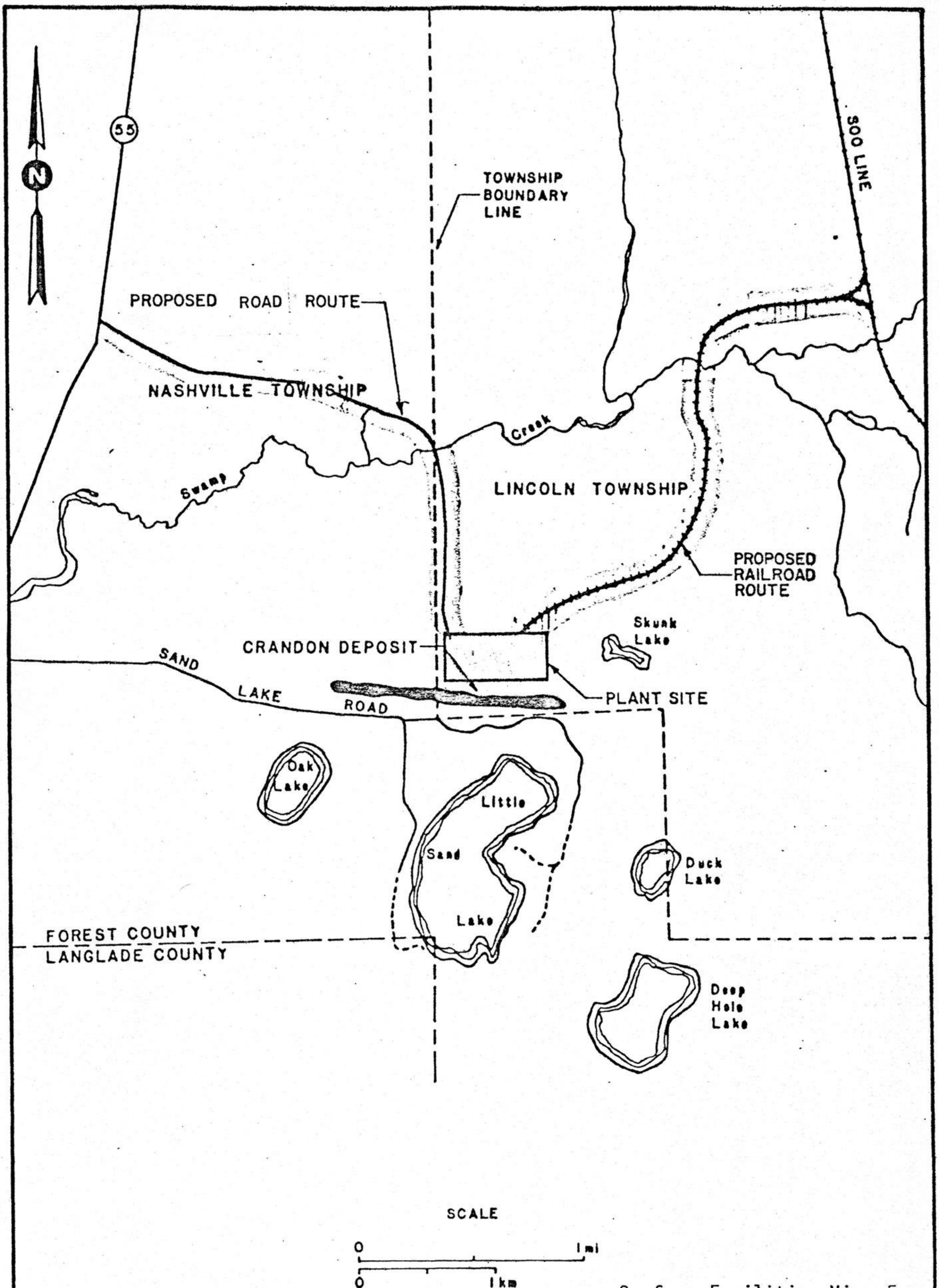
Plot plan of the proposed Crandon Mine/Mill Facilities showing the ore handling, storage, and crushing facilities as shaded areas.



Plot plan of the proposed Crandon Mine/Mill Facilities showing the concentrator facilities as shaded areas.



Plot plan of the proposed Crandon Mine/Mill facilities showing the ancillary facilities as shaded areas, and roads and parking lots, as cross-hatched areas.



Surface Facilities View 5

A location map of the Crandon ore deposit and proposed mine/mill location showing possible routes for the access road and railroad spur.

THE CRANDON MINE--THE MINING METHOD

The Crandon orebody lends itself to the utilization of safe, highly productive, mechanized, underground mining methods. The strong rock conditions and almost vertical attitude of the orebody will allow the use of a mining method termed "sublevel blasthole stoping." This basic method is now being employed in similar mines principally in Canada, Australia, and Africa. Like some of these mines, Crandon would employ the additional aspect of delayed backfilling.

For Crandon, the basic method involves doing a large amount of development work. To reach production, miles of tunnel, shaft, ore passes, and ventilation drifts are required, as well as installation of a number of major service facilities. This would allow five large blocks of ore to be mined simultaneously. Over the life of the mine, the entire orebody would be divided into several hundred blocks of ore, approximately 400 feet high and 150 feet along the horizontal strike of the orebody. The width of each block would be the distance from the hanging wall to the footwall, that is, the full width of the ore which can range from 10 feet to 270 feet.

Each ore block, termed a "stope," would require blasting in segments using large diameter (6") blastholes. These would be drilled from sublevels and main levels driven within the ore block. The broken rock is excavated from openings at the base of each block or stope. Exxon's plan would be to use 8 cubic yard diesel powered front-end loaders specially equipped for underground use. These vehicles would draw the broken ore from the base of each stope, and transport it a horizontal distance of up to 600 feet for transfer into steeply inclined ore passes, gravity feeding an electrical rail haulage system located below, near the bottom of the mine.

The electric rail haulage system will be utilized to collect ore from the ore passes for delivery to a large gyratory crusher where it is crushed and stored temporarily in silos. Transfer is then made from the storage silos via a hoist to the surface through a large production shaft. The production shaft accommodates balanced ore skips which hold approximately 32 tons of ore each. The skips are hoisted and lowered alternately by means of a 6,700 h.p. hoist motor located in a concrete tower, or headframe, above the top of the shaft. The multiple level concrete headframe at the top of the main shaft will be approximately 250 feet in height and will be one of the most prominent structures on the surface.

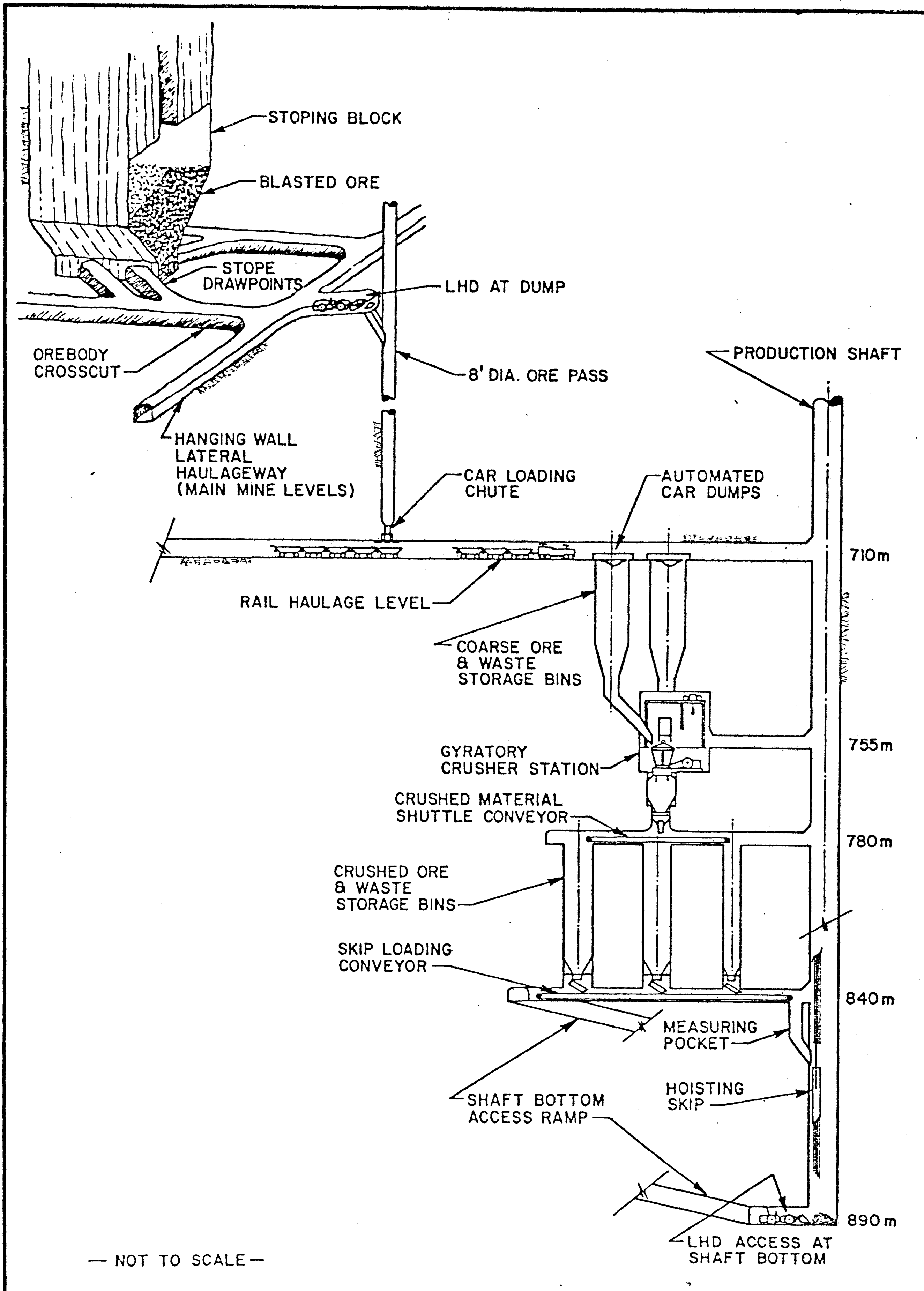
The shaft itself would be a 24 foot diameter structure lined with concrete. Additional facilities will be provided in the shaft to accommodate conveyances for handling men and materials. Underground supplementary access will be provided by a tunnel, termed a ramp or decline, which progressively winds downward at a grade of 15 to 17 percent (about 8 degrees). This ramp serves to interconnect all of the mining levels.

Fresh air, at the rate of 1.2 million cubic feet per minute will enter the mine through both the production shaft and a 16 foot diameter fresh air intake shaft. Fresh air will be routed across the various mine levels and the spent air finally will be collected and ultimately discharged to surface by a series of four exhaust raises. Two of these exhaust raises would be located at opposite extremes of the mine. The Crandon mine plan calls for the exhaust fans to be installed on the uppermost level rather than on the surface so as to elmininate surface noise.

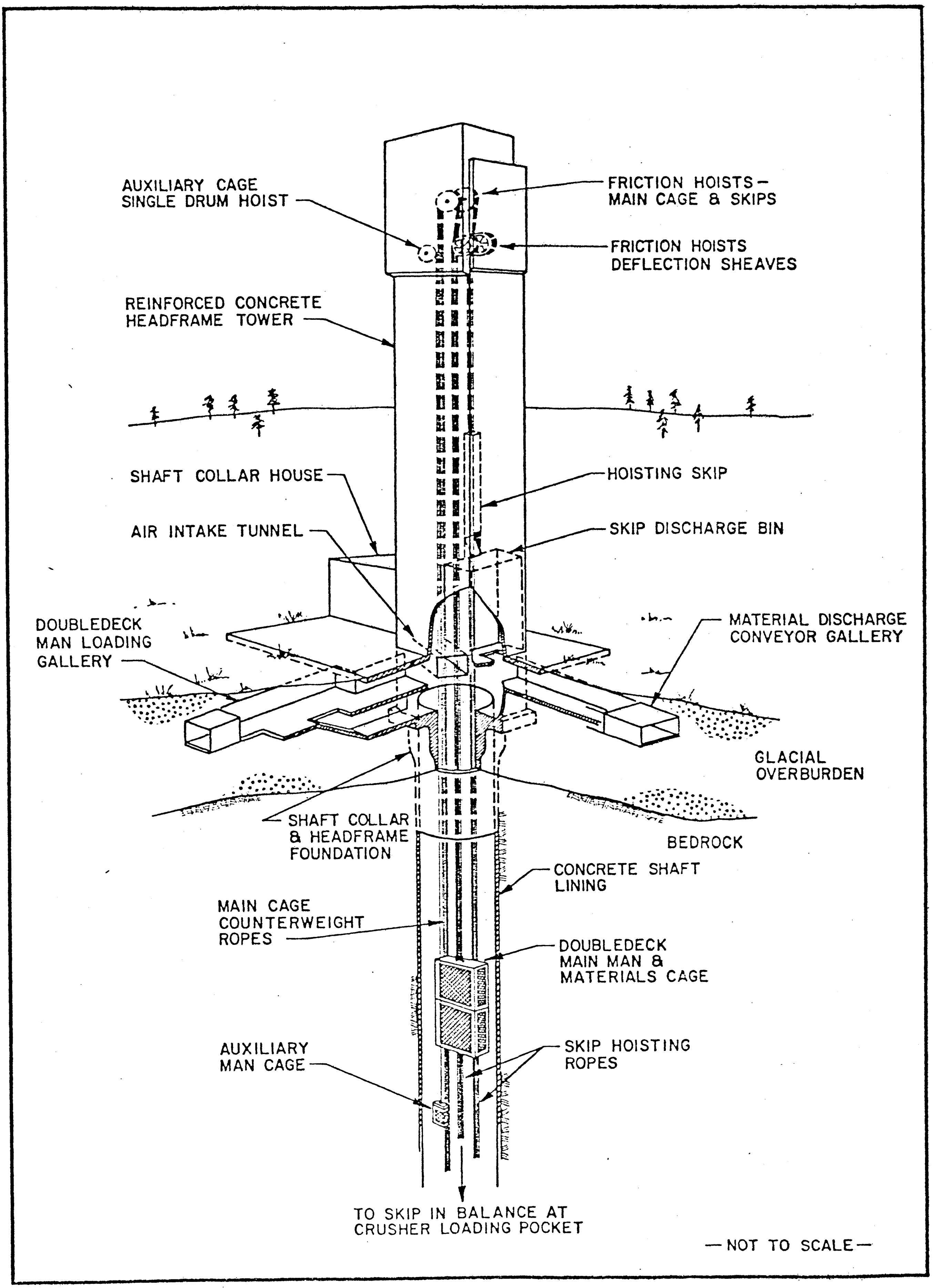
Development, that is, driving of all underground excavations in the mine, will be accomplished using large electric/hydraulic powered "drill jumbos." These will be used in conjunction with large diesel powered front-end loaders and trucks which will remove the rock broken for tunneling after each blast. As a matter of interest, most of the tunnel headings will be on the order of 12 feet high by 17 feet wide. During the life of the mine, several miles of tunnel would be excavated each year to bring into production additional blocks or stopes as others are mined out.

Backfilling of each mined out stope is required to preserve the integrity of the mine. The stopes are filled with classified mill tailings generated at the concentrator. Filling is by means of a slurry utilizing a pipeline system interconnecting the underground workings with the mill. As this backfilling proceeds, decanted water as well as drill water are collected in a mine drainage network. This water as well as original water within the mine area will be pumped to the surface and collected in the holding pond system.

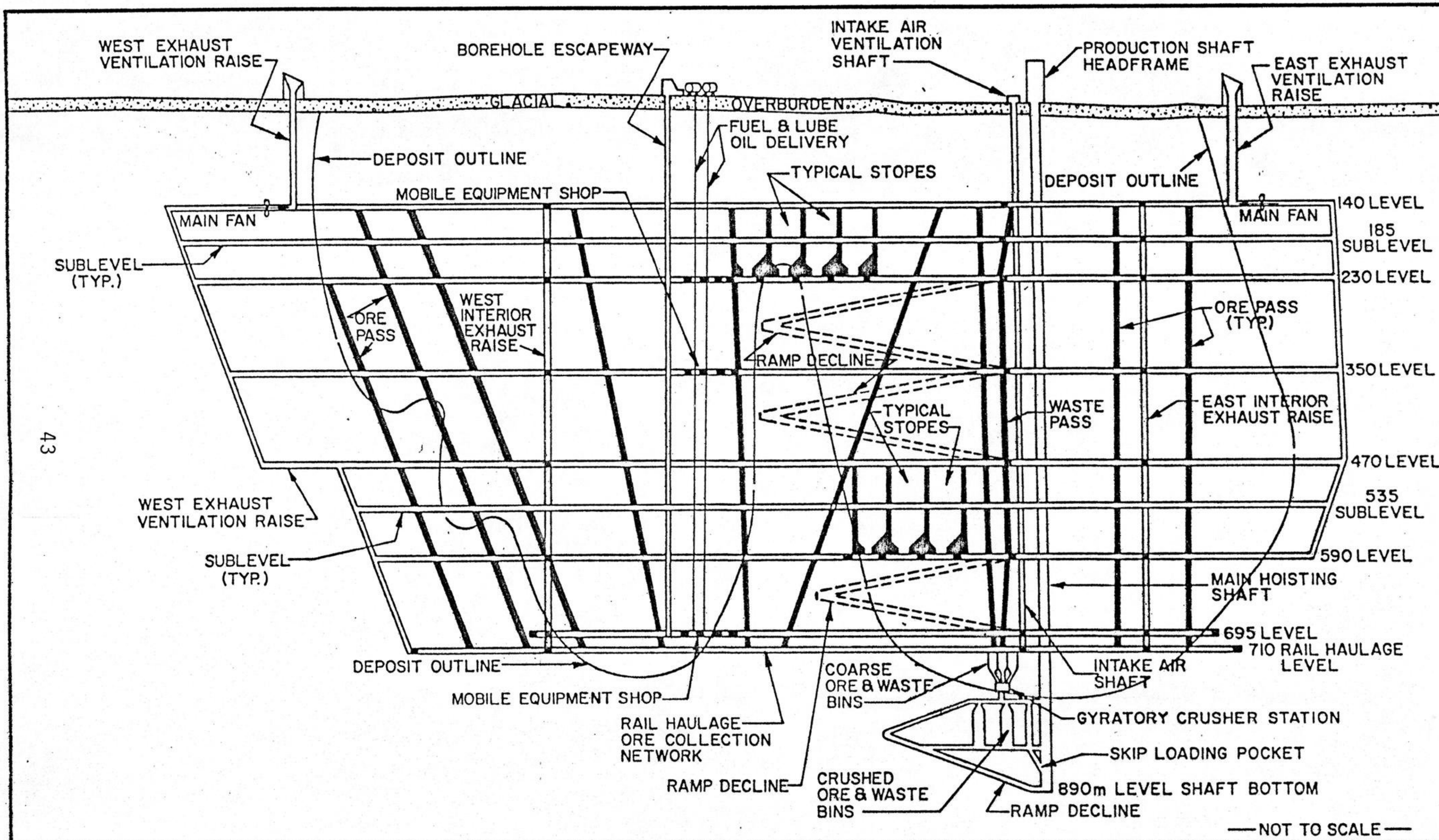
A mine such as Crandon requires large amounts of electric power. The mine will utilize a dual 13,800 volt system to supply power to underground pumps, underground fans, crusher, conveying equipment, and rock drills, as well as for lighting and general communications system.



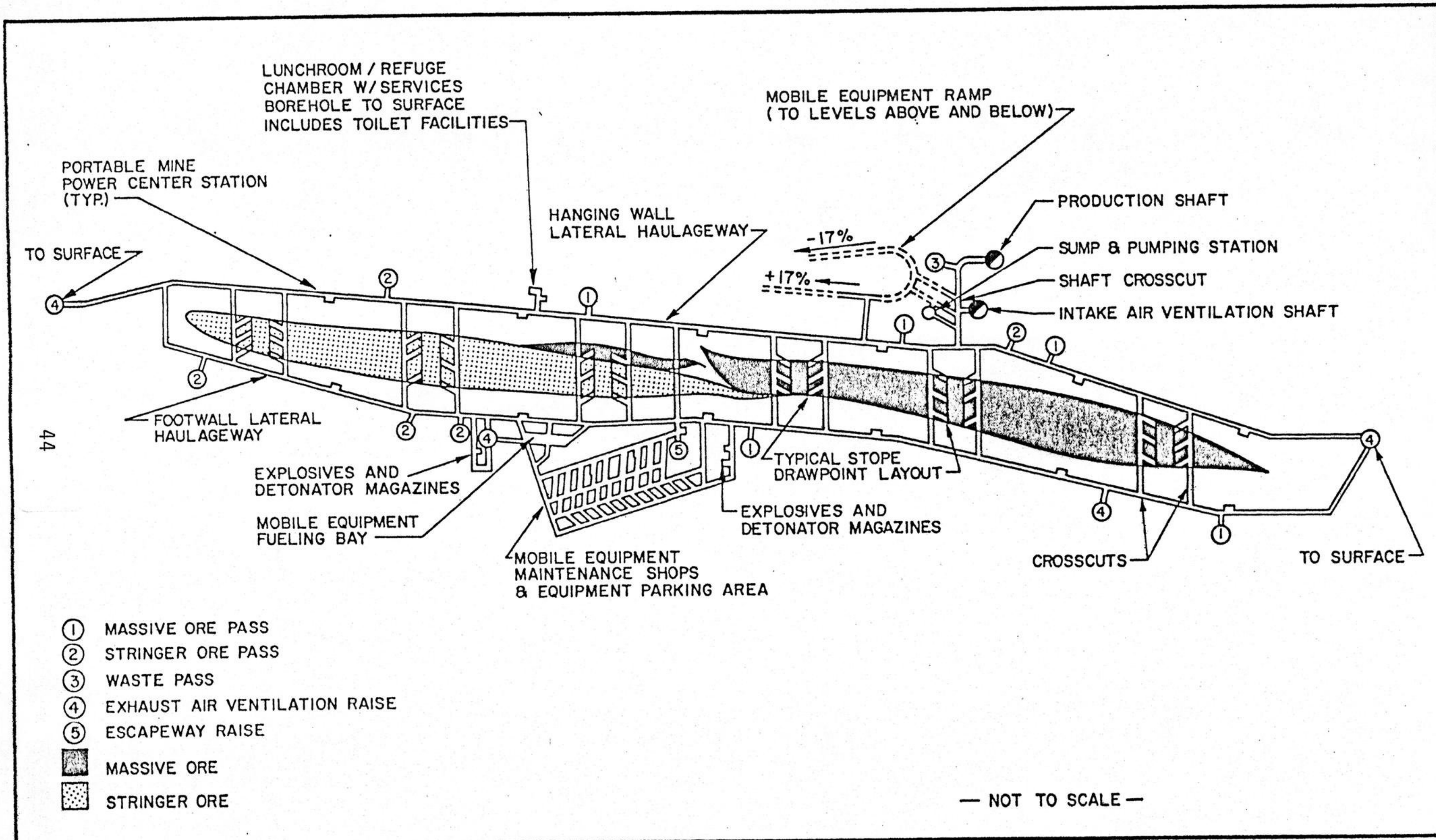
Underground ore handling schematic developed for the proposed Crandon Mine.



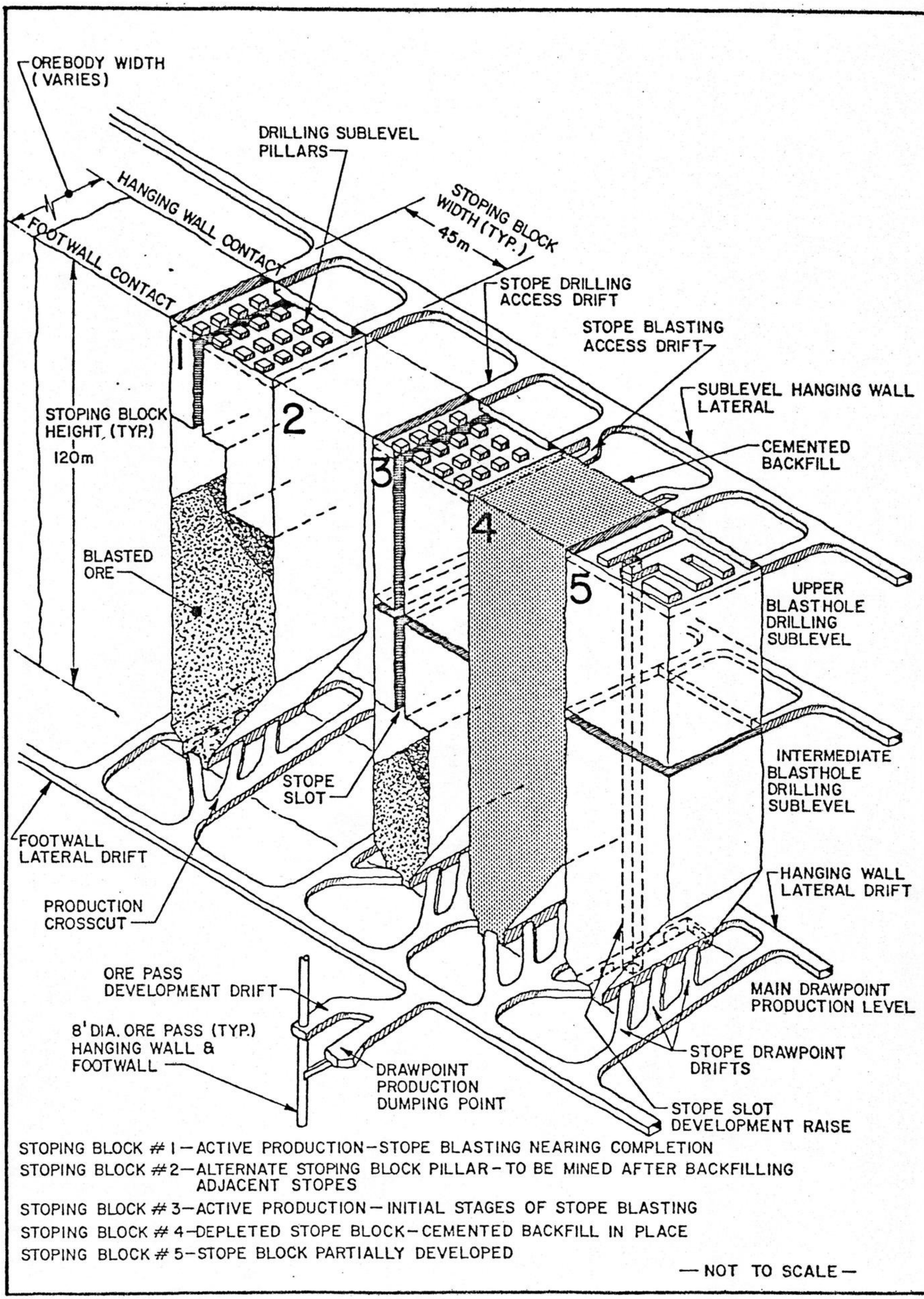
Production shaft headframe collar and shaft conveyance schematic developed for the proposed Crandon Mine.



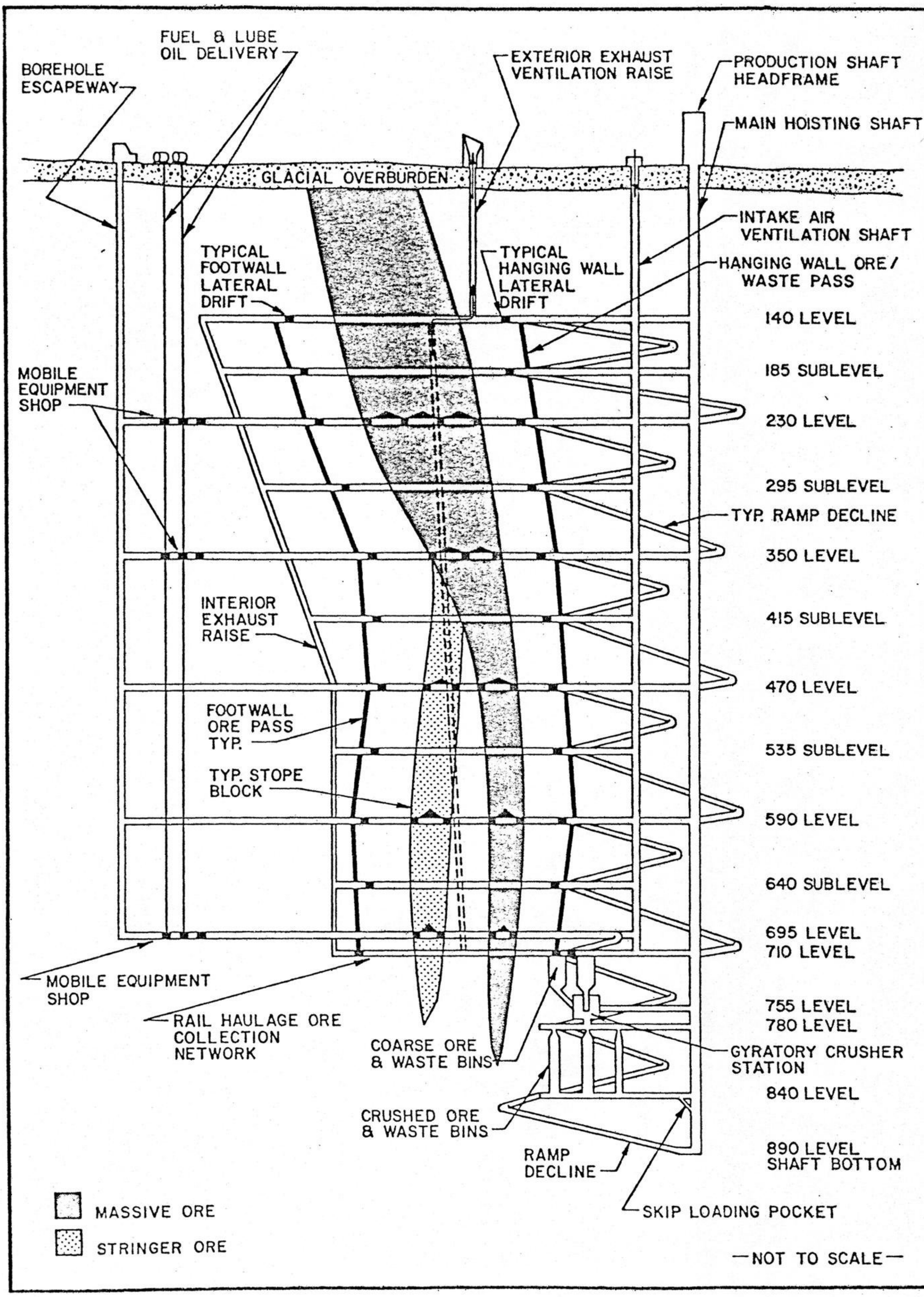
Longitudinal section illustrating primary development and major facilities developed for the proposed Crandon Mine.



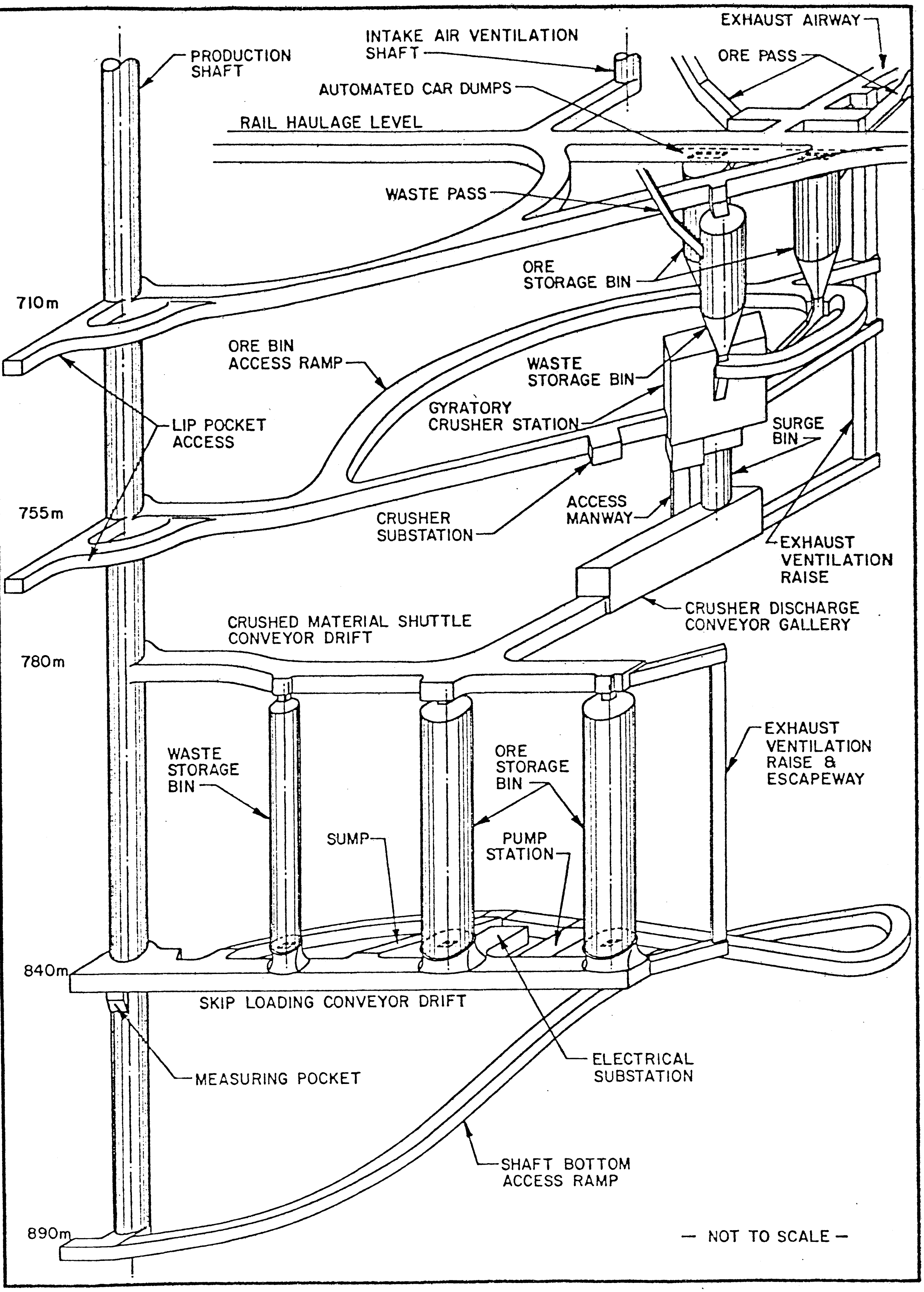
General arrangement of a typical underground main level developed for the proposed Crandon Mine (Plan View).



Conceptual stope dimensions and sequence of ore extraction proposed for the Crandon Mine.



Generalized cross-section illustrating primary development and major facilities developed for the proposed Crandon Mine.



Conceptual diagram of shaft, crusher, ore and waste bins, and transfer conveyor system including ancillary facilities for the proposed Crandon Mine.

THE CONCENTRATOR

The ores of the Crandon deposit are of economic interest because they contain metals--about 1 percent copper, 5 percent zinc, a small amount of lead, and microscopic quantities of silver and gold. For these metals to be useful and valuable, they must be separated and recovered in a pure form so that they might be fabricated into the useful objects that are used in our daily lives. Copper as a pure metal is fabricated into electrical wire, motors and copper pipe. Zinc as a metal is used in galvanizing and die casting such things as carburetors and fuel pumps, and as a chemical in anti-corrosion paints and primers. Lead as a metal finds its main use in electrical storage batteries.

All of the applications of metals mentioned above require metals in their pure state. But metals occur in the pure state only rarely in nature. Most of the deposits containing pure metals were discovered and mined ages ago. The remaining ore deposits are similar to Crandon in that the metals occur as minerals, that is, chemical compounds of the metals and some other element. For sulfide deposits such as Crandon, the other element is sulfur. Furthermore, the valuable metals in the Crandon ores represent only a small percentage of the ore. The remainder consists of worthless minerals that are usually referred to as "gangue." When finally discarded, the gangue forms mill tailings, a large part of which in the case of Crandon will be used to fill the voids created by underground mining. The remaining mill tailings will be disposed of in tailings ponds on the surface.

From the above you can see that there are two steps in the production of the pure metals required for our modern society. The first is the separation and recovery of the metallic minerals into concentrates of copper, lead, and zinc. These concentrates are produced in the concentrator. They derive their name from the fact that they contain a much higher percentage of metal than the ore. Most of the worthless minerals are discarded as tailings.

The next step in the production of pure metals is the separation of the metal from the sulfur and its purification. This process is the smelting and refining process that you have probably heard of before.

The Concentrator

In order to concentrate the metals in the Crandon ore it is necessary to:

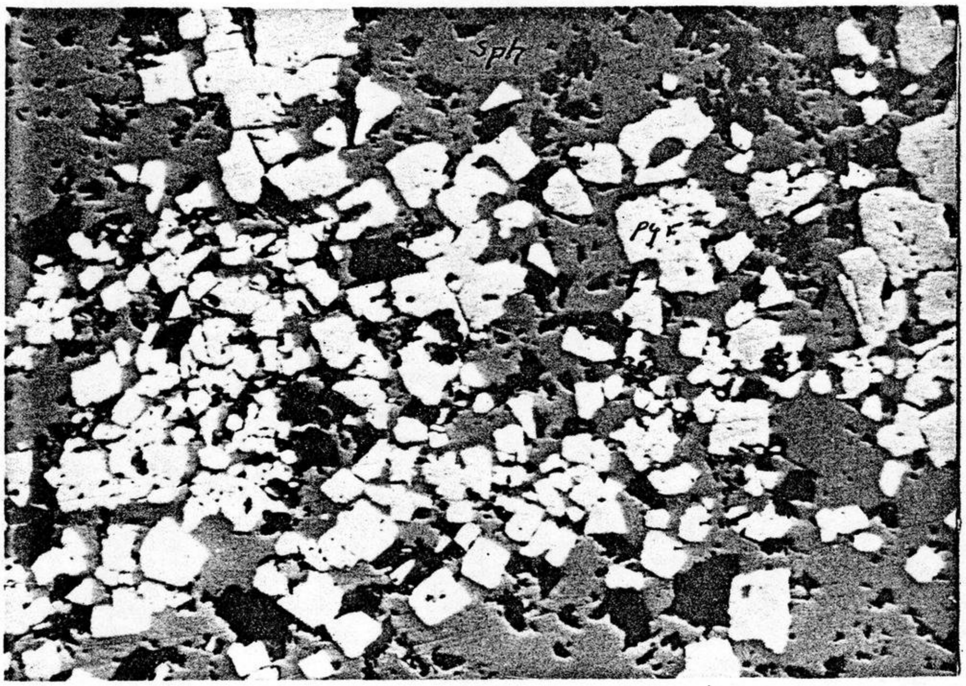
- Liberate the various minerals from the worthless gangue and from each other,
- Separate and recover the valuable minerals of copper, lead, and zinc from the worthless gangue.

To perform these two primary tasks a concentrator must include the necessary support facilities such as maintenance shops, laboratory, reagent storage and mixing facilities, tailings disposal and water management system, monitoring system, change house, offices, and other ancillary operations.

Liberation

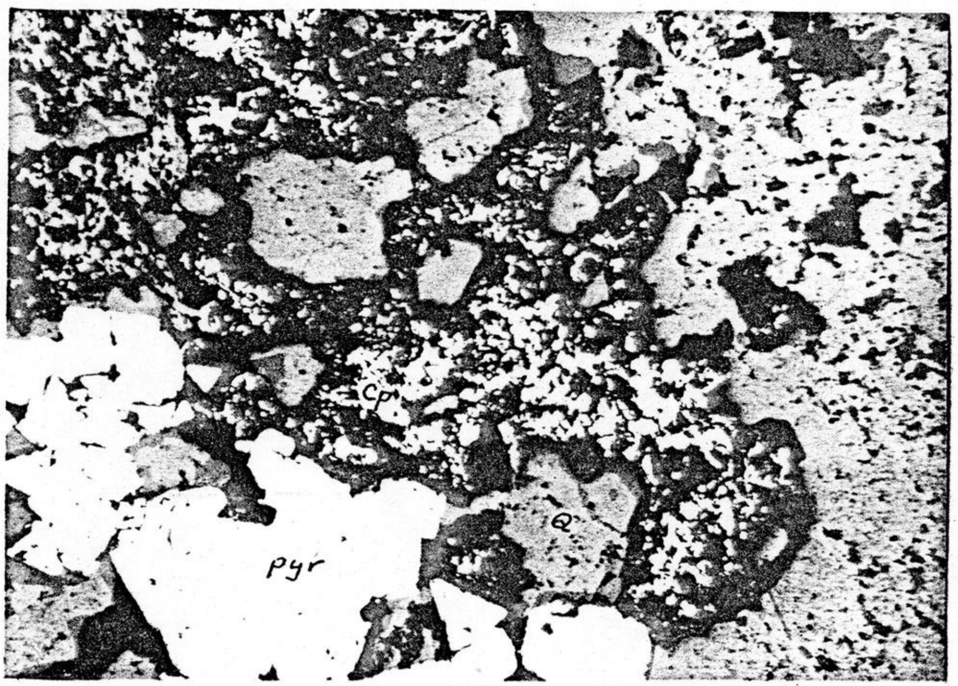
The following diagram sketch, Figures 1 and 2, developed from a photograph taken of the ore at a magnification of 170x, illustrates the separation challenge. This shows the Crandon massive ore (a complex mixture of copper, lead and zinc

FIGURE NO. 1



Massive Ore 170x

FIGURE NO. 2



Stringer Ore 170x

sulfide minerals occuring in pyrite [iron sulfide]), and the stringer ore (a simpler mixture of copper and zinc sulfide occuring in quartz). Referring to the diagram, you can see the individual minerals are very small and very finely intergrown. In order to achieve the necessary liberation, the ores must be crushed and ground very finely to a consistency of fine sand.

Crushing and grinding of 10,000 tons of hard ore per day to the necessary fineness for liberation is a difficult task. It requires very large and strong equipment which uses a considerable amount of electrical energy. Crushing and grinding account for one of the major operating costs of a modern concentrator. At Crandon, it is most likely that the ores will first be crushed and then ground, although several other alternatives have been investigated. The process selected requires first crushing the ores in cone crushers and then grinding in large rod mills and ball mills such as those manufactured by several firms in the Milwaukee area.

Crushing normally takes place in several stages. Each stage is equipped with a machine suitable for crushing a particular size rock. The first stage, as described earlier, will take place underground in a "gyratory" crusher. Gyratory crushers are quite effective in crushing ore several feet in diameter to approximately 6 inches or less. The next stage, which is the first process to begin on the surface, crushes the ore further in a "cone crusher," which crushes the 6" rock down to a size of 1½ inches. The final stage of crushing, commonly called the "tertiary" stage, follows and would involve crushing the 1½ inch material to about 3/8" size in a "short head" cone crusher. Each stage of the crushing is equipped with some type of screen device to remove the fine ore ahead of the crusher, thus allowing the crusher to operate more efficiently.

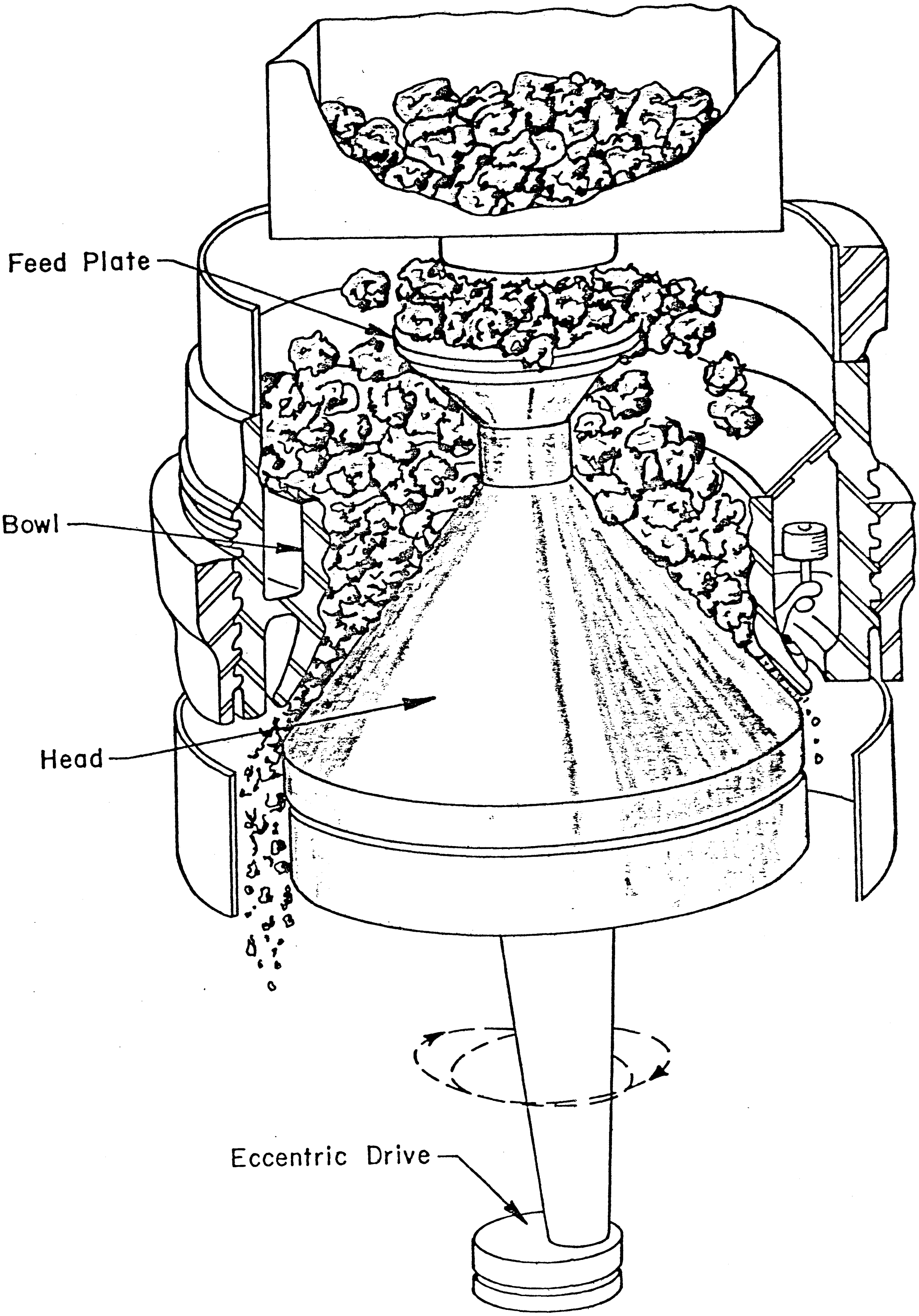
All crushers work in a similar manner. They all crush ore by squeezing it between the crushing surfaces of the machine. Figure No. 3 is a cutaway drawing of a cone crusher. The cone shaped head rotates in an eccentric manner within the bowl of the machine. As the dry ore passes through the machine, it is squeezed between the head and bowl and is broken. While gyratory and short head crushers differ in detail of design, they operate in the same way.

The next step in the liberation process is that of grinding. Grinding, like crushing, at Crandon will probably take place in several stages. The first stage of grinding is undertaken in a machine called a rod mill. A rod mill is a large horizontal cylinder equipped with heavy steel liners and filled with heavy steel grinding rods 2 to 3 inches in diameter. The mill is rotated by means of an electric motor, and the rods tumble as the mill turns.

The crushed ore is introduced into the feed end of the mill with a stream of water. As the ore and water pass through the mill, the ore is crushed between the tumbling rods. The product from a rod mill is the consistency of coarse sand, which is not fine enough for liberation so another stage of grinding is necessary.

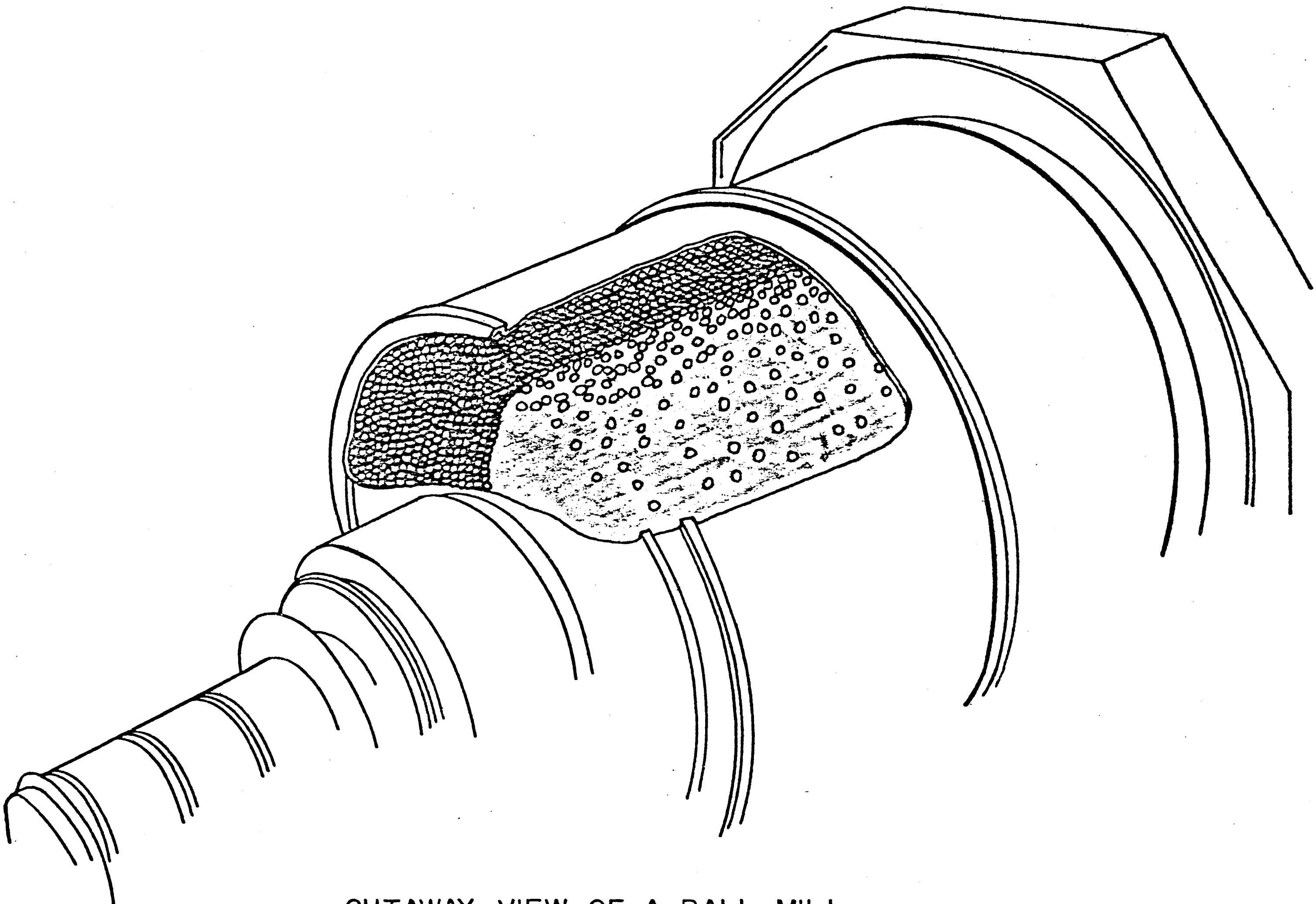
The next stage in the grinding process takes place in a ball mill. A ball mill is very much like a rod mill, in that it is a horizontal rotating cylinder. As the name implies, a ball mill is filled with alloy steel balls, which range in size from about 1/4 inch in diameter to about 2½ inches. As the mill rotates and the slurry (mixture) of ore and water passes through the mill, the impact of the balls on the ore particles cause them to break, and results in the size reduction and liberation. Figure No. 4 is a cutaway view of a ball mill.

FIGURE NO. 3



CUTAWAY VIEW OF CONE CRUSHER

FIGURE NO. 4



CUTAWAY VIEW OF A BALL MILL

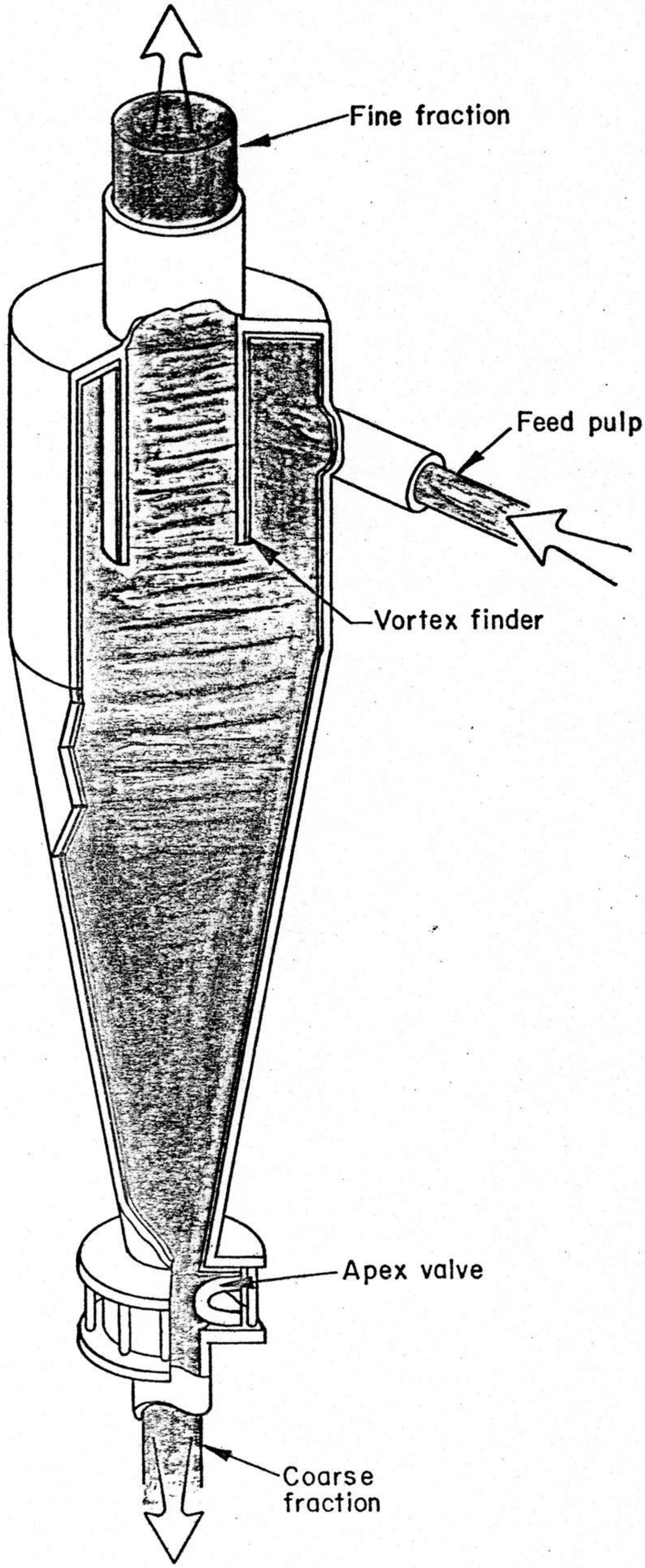
Grinding is an expensive operation requiring a considerable amount of electrical power to rotate the heavy mill and the heavy ball charges. It is inefficient to grind the ore any finer than is required for liberation. Excessive grinding results in wasting of energy and grinding material. But it also can result in excessive losses of valuable minerals.

Because of this, all grinding circuits are equipped with classifying devices. A classifier is a machine that separates particles on the basis of their size. One of the most common classifiers is a cyclone. As you can see in Figure 5, a cyclone is a conical machine in which a slurry of particles is pumped under pressure. As the name implies, the cyclone causes the mineral slurry to rotate; the coarse particles pass to the outside of the cyclone, and are collected down at the bottom while the finer particles tend to collect toward the center, and pass out through the top of the cyclone. The ground product from a ball mill is pumped to a cyclone classifier, and the cyclone overflow product is directed to the next stage in the operation (the separation). The coarser particles coming from the cyclone are directed back into the ball mill for further grinding. In this manner, the grinding energy is concentrated on those particles that require further grinding, and the fine particles are removed and sent on for further processing. This type of classifier results in important savings in energy and in grinding efficiency.

Separation and Recovery

Now that the ores have been ground to a very fine size and the various minerals have been liberated, the separation step can begin. Several separations must be made. The valuable sulfide minerals must be separated from the worthless gangue minerals, which will be disposed as tailings. At Crandon, the separation and

FIGURE NO. 5



CUTAWAY VIEW OF CYCLONE CLASSIFIER

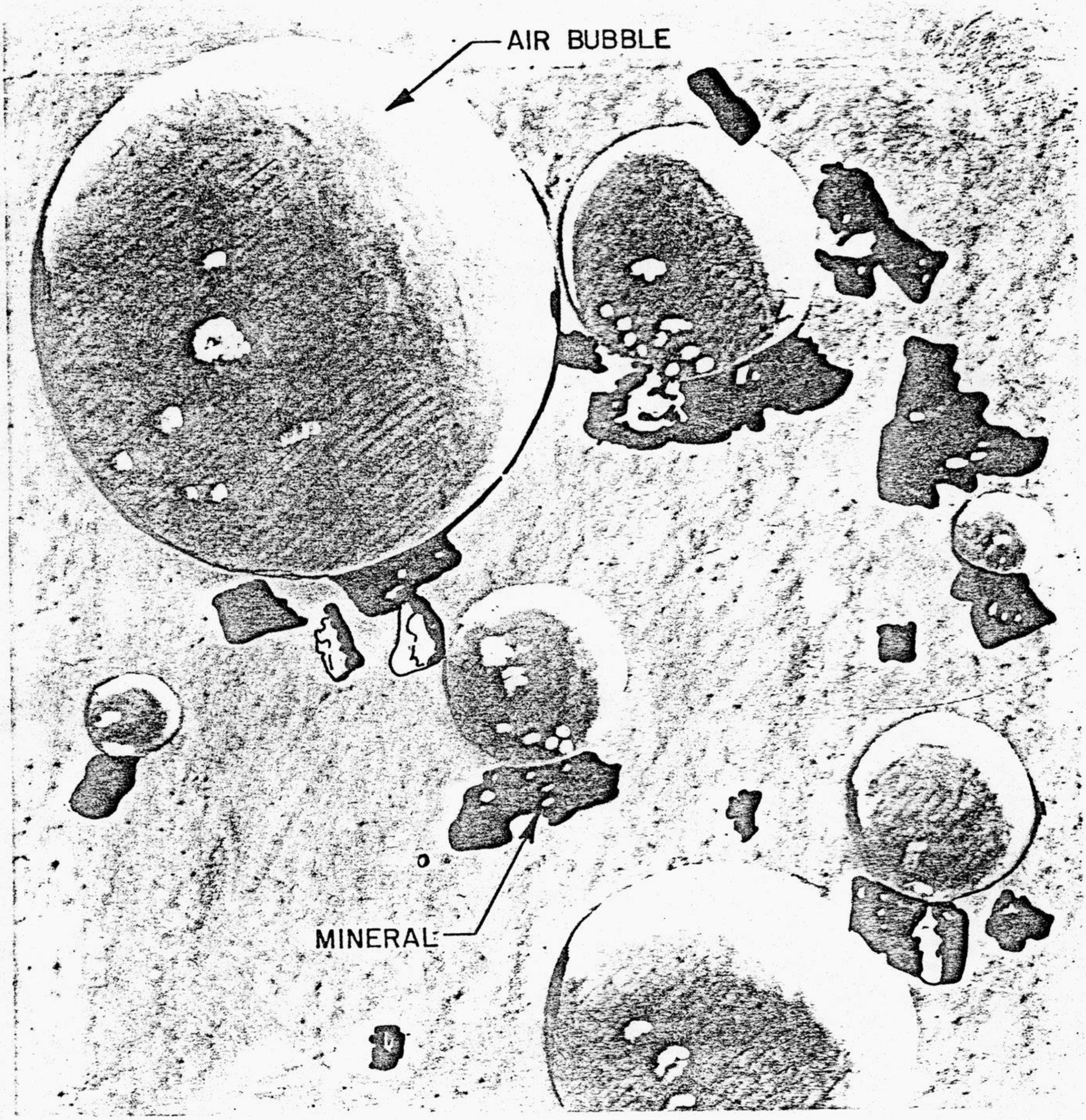
recovery process would result in the production of three different concentrates: copper, containing about 25 percent copper; lead, containing about 40 percent lead; and zinc, containing about 55 percent zinc. Our objective is, not only to separate the metals, but also to route them into the appropriate product. Quite simply, one attempts to get the appropriate metal into the appropriate smelter or refinery product, since all three concentrates will go to different locations. The second objective, and equally important, is to achieve a high recovery of all metals from the ore.

For the Crandon ores, the separation process to be utilized is "flotation." Flotation is the process in which the minerals can be made to adhere to either the water in which they are immersed or to air bubbles. The minerals are collected in either a froth or remain in the slurry, depending on whether they stick to the air or to the water.

By the use of various chemicals a mineral may be made to adhere to either an air bubble or to the water. The use of these chemical reagents permits the separation and recovery of the copper, lead and zinc sulfides from the gangue.

Figure No. 6 is an illustration derived from a high-speed photograph showing minerals adhering to air bubbles. The process works very much like that of a balloon raising a gondola up into the air. It may be easier to understand if thought of in terms of washing dishes after dinner. The detergent creates suds in the dishpan in the same fashion as the reagents create a froth in the flotation process. As the detergent causes the grease and food particles to adhere to the suds, so do the reagents cause the minerals to adhere to the air bubbles.

FIGURE NO. 6



FLOTATION

Flotation is carried out in practice in flotation machines similar to that shown in Figure No. 7. The ground ore in a slurry with water comes from the cyclone classifier of the ball mill circuit. Reagents are added and the ore slurry passes into the first cell of the flotation machine.

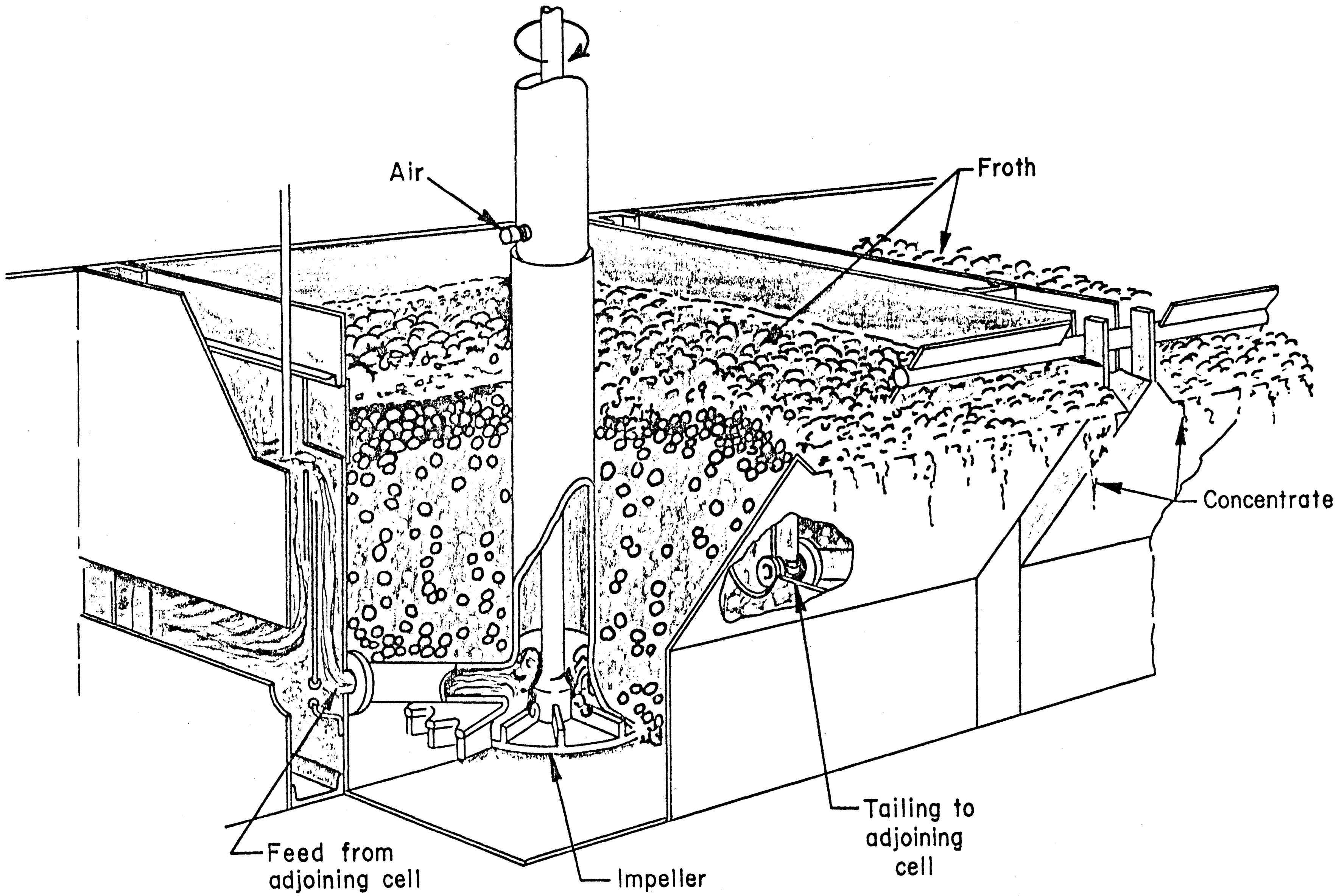
In the flotation machine, air is introduced into the bottom of the machine through the impeller (mixer). The air bubbles are distributed very finely and thoroughly through the slurry of ore and water. When an air bubble encounters a mineral particle that has been treated with the proper reagent, that particle adheres to the bubble and it is carried up into the forth that is established at the top of the machine. A particle that has not adsorbed the proper reagent will not adhere to an air bubble. This particle then remains in the water and is carried out with the water and forms the tailing. The minerals collecting in the froth make up the concentrate.

By proper combination of reagents and the arrangement of the flotation machines, it is possible to make separations between the various sulfide minerals and the gangue. This results in the production of high grade concentrates of copper, lead and zinc with good levels of recovery.

Process

The process for the Crandon ores could look very much like the schematic process flowsheet contained in Figure No. 8. This process flowsheet shows the two ores (massive and stringer) being ground separately.

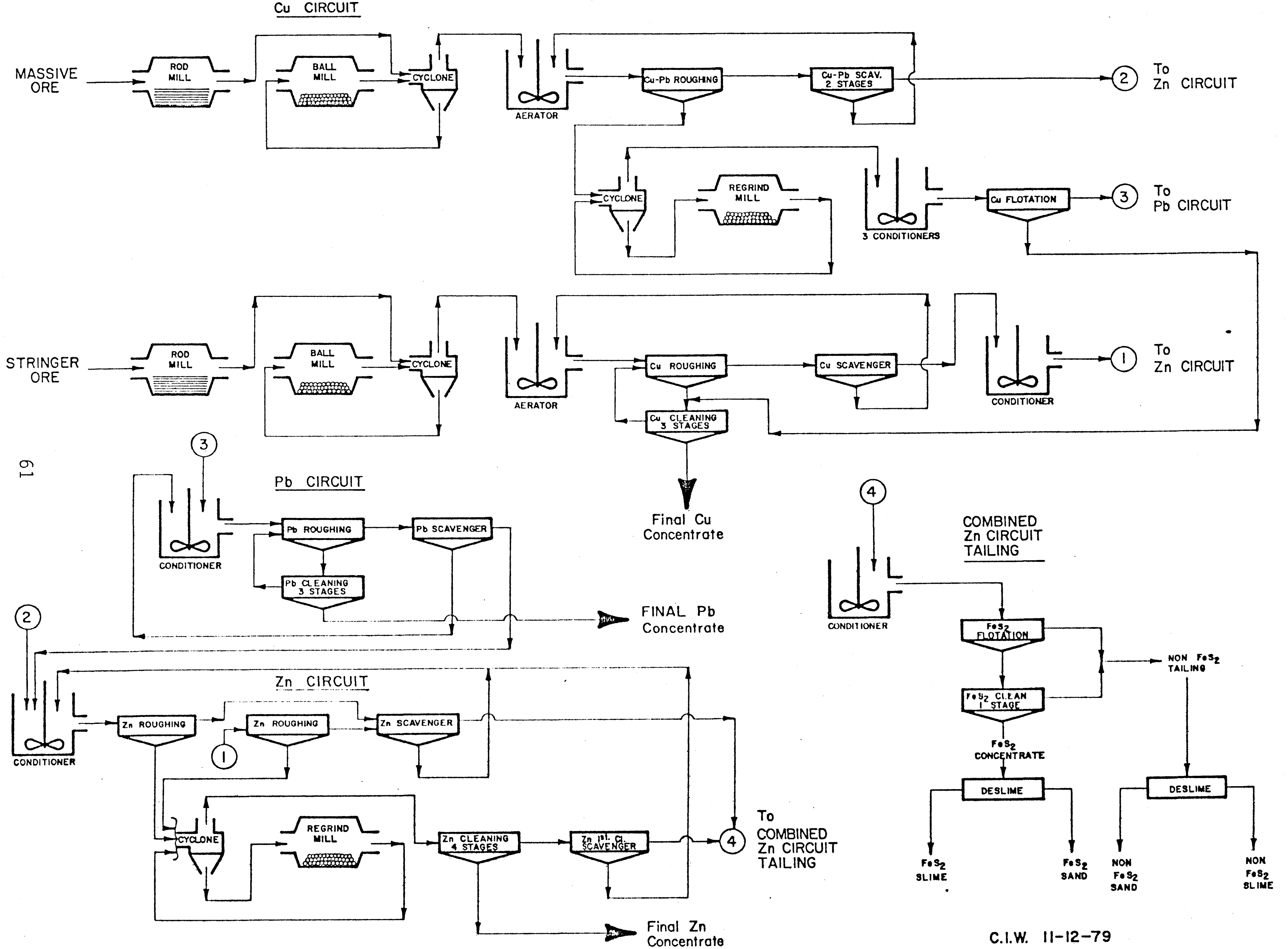
FIGURE NO. 7



CUTAWAY VIEW OF FLOTATION CELL

FIGURE NO. 8

CRANDON CONCENTRATOR PROCESS FLOWSHEET



A first rough copper concentrate is produced from the stringer ore. Then a similar rough zinc concentrate is produced from the stringer copper tailings. A copper-lead rough concentrate is produced from the massive ore. Then a separation is made between copper and lead and a final lead concentrate is produced. A rough zinc concentrate is produced from the copper-lead tailings. The rough copper concentrates from both ores are combined and cleaned by flotation to produce a final copper concentrate. A final zinc concentrate is produced in a similar fashion. Regrinding of the copper-lead concentrates and the zinc concentrate is necessary to complete the liberation necessary to produce high grade concentrates.

The tailings from both ores are combined and pyrite (iron sulfide) is recovered by flotation. The fines are removed from both the pyrite concentrates and tailings by the use of cyclones. These fines are pumped in separate pipelines to separate compartments (cells) to the tailings storage. At that point, the solids settle out and are stored in the pond area.

Exxon has accomplished a considerable amount of testing over the last three years using "bench" or laboratory scale procedures. Fortunately, the processes which we have selected are, in general, used in many concentrators where similar type of copper-zinc ores are processed. Each, however, has its own unique characteristics which slightly modify the process, the reagents used, or the equipment selected.

WASTE DISPOSAL AND WATER MANAGEMENT

Exxon is studying a broad range of alternatives for the handling of the wastes and managing the water for the Crandon Project. We are studying the potential sale or utilization of pyrite, as well as the long term storage and reclamation of these wastes. While these studies have not been completed as yet, we, quite frankly, do not feel that they will show it to be economic to utilize pyrite.

Approximately a year ago, Exxon engaged the engineering firm of CH2M-Hill to make a complete study of the problems associated with water management. In the process, this firm has considered more than two dozen individual processes or combinations of processes. Our policy here is to apply innovative and creative thinking so that the final system will provide maximum protection to the environment and result in compliance with the stringent federal and state water regulations. The water management program will account for all of the water entering and leaving the project site. We have progressed far enough with our studies to be able to determine that the technology exists to treat and discharge water to meet all applicable standards.

The sands (coarser material) recovered from the pyrite concentrates and tailings are recombined and pumped to the mine to be placed underground in the mined out areas (empty stopes) of the orebody. About 50 percent of the tailings will be returned underground to fill the voids created by mining. Most of this material will be cemented into a solid mass.

The present estimate of proven reserves for the Crandon orebody is about 83 million tons. In consideration of the possibility that more ore might exist over and above that amount, the capacity of the waste disposal facilities is being sized and designed to handle approximately 112 million tons. This represents a safety factor of approximately 25 percent above known ore reserves. This is a prudent approach to planning for the future.

In the design of waste disposal facilities, Exxon has had to consider all individual products requiring disposal. We estimate that disposal of the sulfide tailings, non-sulfide tailings, and sludge from water treatment, as well as waste rock would require approximately 600 to 700 acres of land. Additional acreage, however, for dikes and safety buffer around these ponds is also required. As per our present plans, which are not yet complete, we estimate about half of this acreage would be in use at any given time, in that the ponds would be divided into a number of cells.

Reclamation of the surface could take place in some areas of the waste disposal site relatively early in the life of the operation. Reclamation considerations are a vital part of planning a waste disposal facility. We have found in our investigations to date that effective means are available to provide for secure reclamation of the entire facility, but studies on reclamation are not complete at this time. Recent experience in Canada in providing for reclamation and vegetation growth over sulfide tailings has proven to be very successful. We feel that similar methods can be applied here. Toward that end, we have now reached the point where we are engaging the services of those most successful in bringing this about.

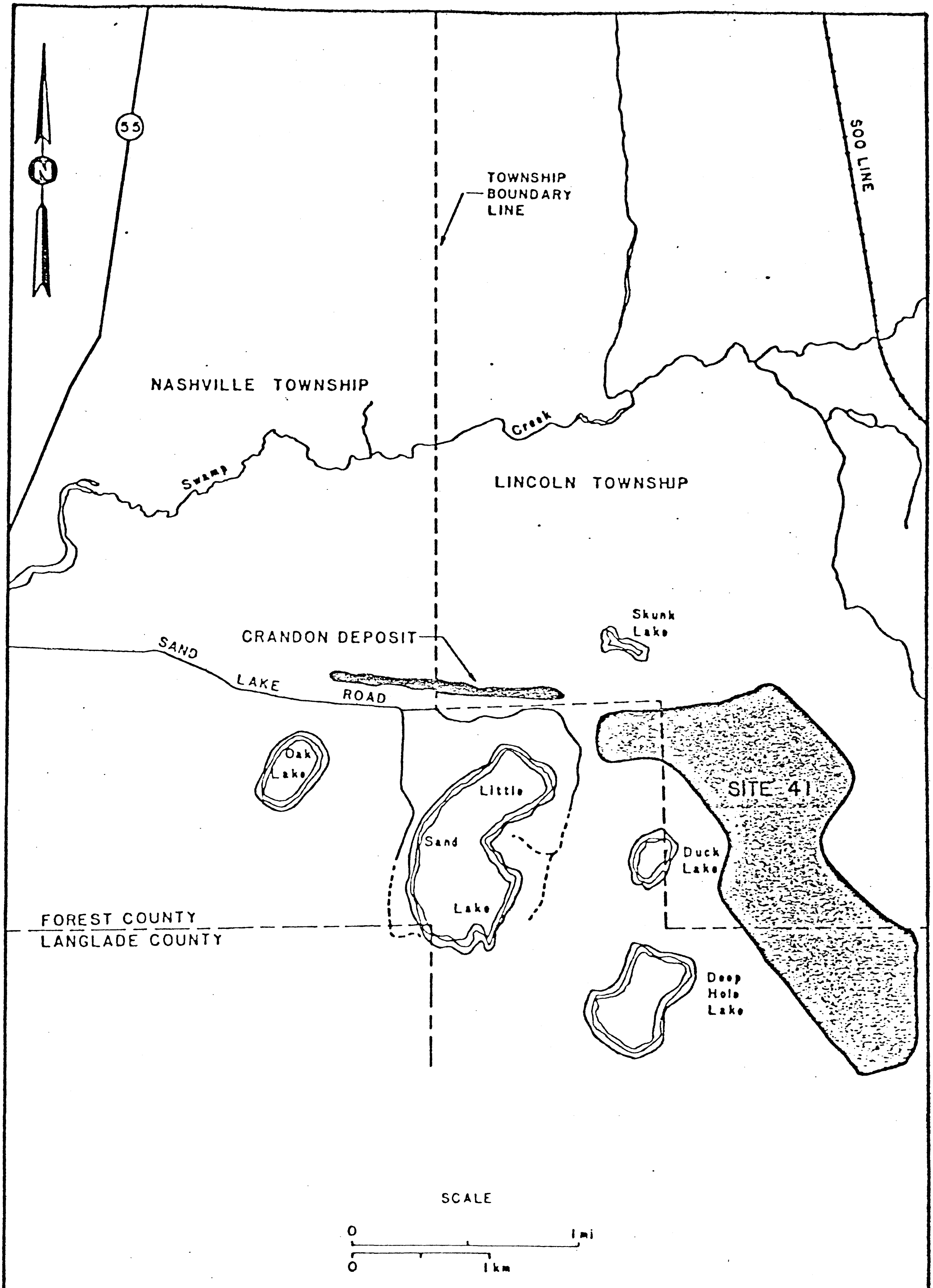
An additional factor of the water management and waste management program will be the reclaim water pond. This is not considered a waste material for permanent disposal since as much of this water as possible will be reused in the milling process. The basic purpose of this pond is to provide sufficient retention time for the water in the pond to undergo natural biological oxidation of the chemical process reagents. This may allow most of the water to be recycled to the concentrator. If there is surplus water, it will be run through a water treatment plant.

Finally, it should be emphasized that while our contractor for the waste disposal system, Golder Associates, has at this time completed all of the siting studies, the final designs are still in progress. As a result of these siting studies, three potential disposal sites were identified for further detailed study and evaluation. They are as follows:

1. Site 41 located east and southeast of the mine site;
2. Site 40 located southwest of the mine site; and
3. Site 50 which incorporated parts of both Site 40 and 41.

Most of the siting work completed has been made available to the public. As we finalize our basic design, we will similarly communicate this information to interested parties.

The combined backfill sand will be pumped from the mill as a slurry. Depending on the need for backfill in the mine, the sand will either be pumped directly to the mine or to a pond at the waste disposal facilities for temporary storage. As the need requires, those sands stored in the pond will be reslurried and pumped to the mine for backfill. It is estimated that after about 15 years of operation



A map of the area around the Crandon ore deposit showing the general location of waste disposal site 41.

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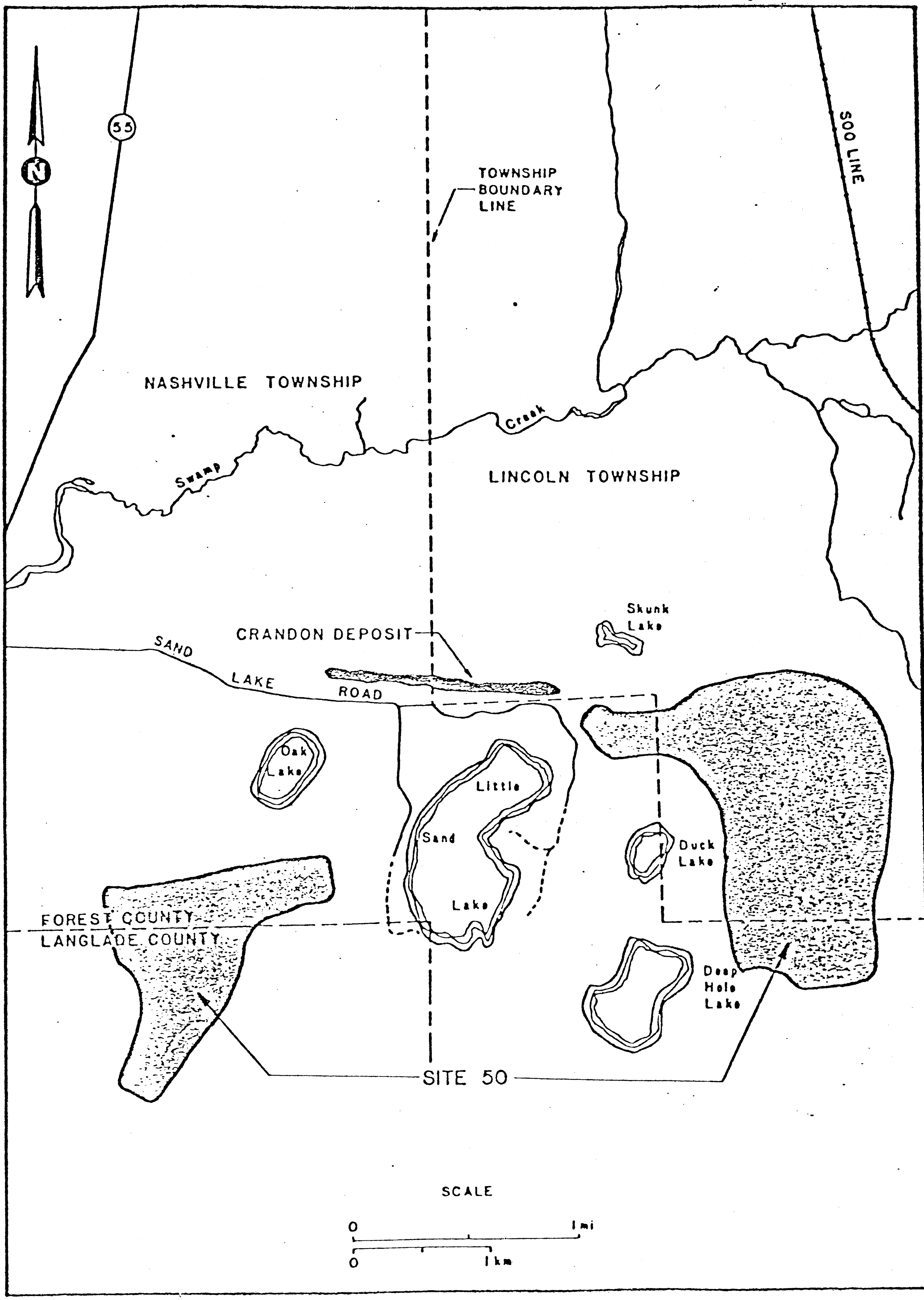


A map of the area around the Crandon ore deposit showing the general location of waste disposal site 50.

this storage pond will not be required for backfill sands and will be available for disposal of sulfide tailings.

The sulfide and non-sulfide tailings will be pumped from the mill as a slurry to the respective disposal ponds. In these ponds the ground rock solids will settle out and the clarified water will be continuously removed for recycle and reuse in the mill to the greatest extent possible.

It is anticipated at this time that the tailings will be stored under water in the disposal ponds to minimize oxidation of the sulfide materials. Any excess water over that needed to maintain the cover over the tailings will be removed by decant systems and piped to the reclaimed water storage pond. From the reclaim pond, the water will be pumped back to the mill for reuse to the greatest extent possible. However, because of rainfall on the disposal ponds and requirements for fresh makeup water in part of the milling process, it is anticipated there will be a surplus of water over what can be recycled in the mill. In anticipation that there might be a surplus of water, we have planned for treatment of any such surplus. The reject sludge from this water treatment will be placed in a separate pond in the waste disposal facility.

ENVIRONMENTAL STUDIES

Environmental baseline studies were carried out by our environmental consultant, Dames & Moore, from March, 1977, through 1978. The basic purposes of these studies were to document existing conditions, provide bases for assessment of impacts associated with potential project development, facilitate mitigation measures, and provide a basis for the design of future monitoring programs. The chemical, physical, biological, and cultural studies include the following special disciplines.

-- Aquatic Ecology

These studies were designed to describe and document surface water quality, fish, plants and organisms, and sediments in and adjacent to the project area. This required the establishment of approximately 34 water quality stations. At least one year of baseline sampling was taken from these stations--monthly for water quality, and quarterly to monthly during open weather on the biological samplings.

-- Terrestrial Ecology

The terrestrial baseline studies were designed to describe the soils, vegetation, and wildlife in and around the area of potential project development. This program included soil mapping, vegetation studies, songbird and waterfowl surveys, small mammal sampling, etc.

-- Hydrology/Geology

The hydrology and geology studies were designed to investigate the physical and chemical aspects of surface and groundwater resources and the glacial geology of the area. This program included extensive surface water data collection on streams and lakes for levels, flows, and suspended sediments. Geohydrological and geotechnical studies were conducted after drilling in excess of 100 boreholes and in existing water wells in the area. The quarterly water samples were analyzed for 30 parameters. Over 800 soil samples were collected from the boreholes for laboratory testing.

-- History and Archaeology

Dr. Robert Salzer, Director of the Logan Museum of Anthropology at Beloit College, directed an archaeological survey team from the College in an investigation of approximately 4,000 acres of the project area. Actual shovel testings at 15 meter intervals were made over the area. Some minor excavation work was carried out where warranted. No findings of potential archaeological significance were discovered. Additional field work will be necessary to complete the studies on access corridors.

-- Meteorology, Air Quality, and Noise

Suspended particulate sampling, wind speed and direction, temperature, and rainfall data were collected for approximately one and one-half years in the project area. Baseline sulfur dioxide measurements also were obtained for a one year period. Existing sound level readings were taken at six locations around and in the area of potential development. These measurements were taken for both day and night periods in summer and winter.

From the extensive collections, draft baseline reports have been written by Dames & Moore and are now being reviewed by Exxon. In addition to the environmental baseline studies, many special studies have been performed by the contractor, Dames & Moore. Among the special studies conducted were siting programs and attendant environmental evaluations for the surface plant and waste disposal facilities. Also extensive studies related to groundwater hydrology have been completed, including large scale pumping tests from deep wells to test the groundwater aquifers. This contractor continues monitoring activities to maintain environmental data continuity.

During the remainder of 1980 and 1981, additional environmental studies are planned, but the main emphasis of Exxon's environmental professionals will be to prepare the Environmental Impact Report (EIR). In essence, the applicant for mining permits must provide the following:

- Description of the proposed action.
- Description of affected environment, including physical, chemical, geological, social, cultural, and economic.
- Assessment of environmental consequences, including all forecast impacts.
- A description of alternatives to the proposed action.
- Disclosure of the rationale and methodology used for accomplishing the baseline studies.

If Exxon elects to proceed with the project, they will also prepare permit applications for submittal to the regulatory agencies.

A major task within the EIR will be the writing of a detailed project description. This compilation of project specific technical information will describe in considerable detail the final proposed preferred action plan which Exxon would propose. This constitutes the culmination of all of the mining, metallurgical, and surface project engineering to be included in the plan. As a matter of interest, Exxon has recently completed and will submit to the DNR a "Preliminary Project Description" which is intended to aid the Department in understanding the Crandon Project in the accomplishment of specific verification studies.

SOCIOECONOMIC STUDIES FOR THE CRANDON PROJECT

After extensive evaluation, Exxon Minerals Company selected RPC, Inc. of Austin, Texas, in late 1979 as its principal socioeconomic consultant. Exxon commissioned RPC, Inc. to accomplish a major part of its effort to provide socio-economic information and analyses necessary for effective company and community planning. This effort also was found to be a necessary part of providing information for regulatory approvals for the Crandon Project. The assessment resulting from this study will be incorporated into the Environmental Impact Report (EIR) required by WEPA, and into supporting documentation for other regulatory approvals.

The first step was started in January, 1980, by circulating a Draft Study Plan to state officials, local officials, tribal officers, and numerous other interested individuals and parties. This was done so as to:

1. Let all interested parties know what work Exxon considers adequate to describe the possible socioeconomic effects of the Crandon Project to provide for company planning and to satisfy regulatory requirements.
2. Hear from all interested parties on the adequacy of the scope and methods in this draft in light of regulatory requirements.
3. Find out what modifications may be necessary to compile a final study plan that describes an adequate socioeconomic assessment in the opinion of state officials, local offícals, tribal officers, and other interested parties.

Comments on the study plan were received through June, 1980, and the the Study Plan accordingly was revised. Baseline socioeconomic data collection began early in 1980. This effort will continue through the year, with final analysis is being concluded during the first half of 1981.

The Crandon project is a large one, both on its own terms and in comparison to the economy of the local study area, and could be of long duration. The socioeconomic study will forecast the effects of the project so Exxon, state government, local governments, and project neighbors will have the necessary information to react and respond to them.

The basic philosophy of this prediction process is to describe the differences in the local study area as it is most likely to be in future years without the project (without-project future) and as it will be if the project goes ahead (with-project future). The study will compare the without-project and with-project futures to determine what changes result from the project and what changes would occur anyway over the course of time.

For a project of this size, analysts typically use several different analytic techniques for different parts of the prediction. The prediction problem is further complicated by the fact that different aspects of the quality of life interact: the state of the housing market in Crandon in 1985 will affect the population and the decisions made by local governments in 1987. This study plan describes a rather complicated process of predicting many different dimensions of the quality of life in the local study area and their interactions in great detail. However, the basic approach is fairly simple:

1. Identify the important social and economic aspects of the local study area that the project may affect, and carefully describe current conditions.
2. Carefully describe mechanisms by which actions by Exxon, governments, or individuals will affect these values in subsequent years. Summarize those descriptions in models.

3. Each of these models will allow inclusion of different assumptions and possible actions by the important parties.
4. These predictive models will describe several different futures the local study area can expect, depending on decisions made by Exxon, state and local governments, and the project neighbors, not only at the beginning of the project, but in subsequent years as development proceeds.
5. The most important difference is the difference between the future without the mine development and with the development. "The development" or "the project" can mean several different things depending on the way both Exxon and local governments respond to events. Many of these responses are currently planned or under consideration, and it is the scenarios that result from these plans that will be evaluated first. Part of this evaluation will be a comparison of scenarios to a projection of what the area would be like without the project. All of the changes that may occur with development of the project are not necessarily attributable to the project. Change is inevitable with time.
6. An important part of the study plan is to categorize the impacts of development relative to the without-project future on different people and groups in the local study area. Not all of these impacts will be positive; one of the principal reasons for doing this socioeconomic study is to discover the negative impacts that would occur if everyone went ahead as planned. Thus, we will be able to discuss changing the plans to mitigate or avoid undesirable impacts.
7. In the final part of this study, the combination of scenario elements and mitigation strategies that make the development project as nearly as possible beneficial to everyone concerned will be selected.

We will use this information as a basis for cooperation between Exxon, local governments, and interest groups in dealing with the effects of the project.

We must point to some general qualities of this process at the outset. First of all, any predictive process, especially one running more than a decade into the future, is approximate and includes important uncertainties. There is simply no way to predict the future with great precision. Therefore, we will often have to state our forecasts as ranges covering probable variations. We have chosen elements of the study described above to allow us to predict the future as accurately as possible. These elements represent the state-of-the-art in prediction and forecasting of socioeconomic effects. We will highlight and explain the uncertainties that remain as the analysis proceeds.

Second, the study plan includes not only research, but also important components of planning and decision making. We have designed the study plan to encourage feedback for the communication and balancing of interests among the parties involved in the proposed Crandon Project.

All interim and final reports of the study are being made available for professional and public review as the work progresses. A number of senior social science professionals have been retained to review each step of the research and analysis. These professionals will examine the completeness and validity of the work and will suggest revisions to the study plan as circumstances dictate. We selected the study team members because of the their national reputations in their fields; in addition, many are residents of Wisconsin.

Interim results of the study are being distributed to government officials and the interested public through a series of technical papers and discussion papers. Technical papers will describe the methodology used to perform a certain analysis, the data used, and full reference to the authorities consulted. Discussion papers will present the results of the analyses organized by jurisdiction and economic sector. In addition, as we complete portions of the EIR, we will distribute them for public review. We are circulating these documents so we can find how those affecting and affected by the project feel about the study as it progresses. If we are told of gaps or inaccuracies in the work as the study progresses, we can make the final document a better guide to planning and decision making by state and local governments.

The effects of the Crandon Project are not preordained. They will depend on decisions made by Exxon, state and local governments, and by residents of the area. This study will be one of the most complete bodies of facts and projections ever assembled on a similar local study area. Because of this, the study will be an important resource for those in both public and private sectors. We intend to make the study and its supporting documentation available to the people of Wisconsin to enable them to better manage growth of the area.

EXXON EMPLOYMENT AND TRAINING--CRANDON PROJECT

While the Crandon Project team now consists of 38 Exxon employees located at the Crandon and Rhinelander offices, it is forecast that, if a favorable decision is made to proceed with development, the work force would grow to a total of about 800-900 employees. This employment forecast is based upon the present project plan and could change to a slight extent as the plans are finalized.

Exxon's basic hiring policy has been communicated by letter to those who would most reasonably be affected in northern Wisconsin. It is Exxon's intention to utilize local people in filling its manpower needs to the maximum possible extent. To the extent that local people are available and to the extent allowed by law, it will be Exxon's practice to preferentially hire local individuals among equally qualified candidates. Employment of Native Americans is also an important aspect of our employment policy.

A successful mine operation to a large extent requires that Exxon have a proper number of employees in the right jobs at the right time. Our employment philosophy is to provide all employees with an opportunity to use their abilities to the fullest. They will be compensated on a fair and equitable basis and provided with healthful and safe working conditions. Further, it is Exxon's philosophy to recognize individual contributions to the company's progress. Our business will be conducted in an atmosphere of consideration for the individual employee. In return, Exxon expects each employee to do his or her best to meet our high standards of performance.

Exxon is a career oriented employer. With the exception of professional employees where we manage a nation-wide college recruitment program, we would prefer to fill most of our positions with applicants from the local area. We find that employees from the surrounding area are usually more stable and are interested in helping the community grow and prosper.

With regard to training, Exxon believes that a well-trained work force will perform in a safer and more productive manner, and accordingly places high emphasis upon training. It is our practice that each job that we have in our operations today has a program of skills training. This is usually taught by a company training instructor or alternately by the trainee's supervisor if the training program is based upon standard operating procedures for the job as developed by the particular operations group. Operations people, as a matter of fact, work very closely with the training supervisors in developing not only operating procedures, but also the training programs. The length of training programs depends upon the skill that is needed for each particular job. Each specific program has classroom lecture sessions as well as the important aspect of hands-on training. For example, the operator of an underground front-end loader may take up to 40 hours of both classroom and hands-on training before he is allowed to operate the piece of equipment in an actual production circumstance.

Miners, for example, are taught how to drill, the safe use of explosives, safe methods for ground support, and the safe operation of different types of loading equipment. In our operations, miner trainees work with the instructor for about eight weeks in classroom and underground, with about 80 percent of the time being spent underground with hands-on training. Upon successful completion of the miner course, the trainee is then assigned as a partner to an experienced miner, where they then work together as a team, under the guidance of the section supervisor.

Exxon believes that mining must be done productively and safely; and we believe that the hands-on section of our training is very important for each worker.

Each of Exxon's underground personnel receives a minimum of 40 hours of safety instruction before beginning the training associated with specific skills. Each of our concentrator and surface plant personnel receives a minimum of 24 hours of safety training prior to beginning their skills training. Additionally, each person receives a minimum of 8 hours of refresher safety training each year after he is hired, and is expected additionally to attend safety meetings in which all personnel participate. These programs are fully approved Mine Safety and Health Administration training programs, conducted by certified instructors. An additional aspect of the safety training involves emergency programs.

Exxon would also train and maintain underground mine rescue teams which are fully knowledgeable and trained in rescue and fire fighting procedures. Additionally, these teams compete in local and national competitions with other mine rescue teams--an effective method of demonstrating proficiency.

Historically, Exxon gives high priority to training. At Crandon we plan to have a group of nine instructors who are scheduled just to train underground miners in their skills. The plant will also have a training coordinator and an assistant.

A recent study conducted by Exxon indicates that 73 percent of the 800-900 jobs can be filled by people with high school or high school equivalent education. Eleven percent of the work force would be college degreed manager-professional-technical employees. Finally, approximately 16 percent of the employees would have either community college or vocational/technical training or the equivalent.

It would be Exxon's intention to build the work force methodically and carefully to accomplish the goals and objectives outlined. By the time construction would begin, less than 10 percent of the work force would be on hand. As per the present schedule 80-85 percent of the permanent Exxon employees would be hired at a relatively uniform rate between 1985 and 1989. This relatively long period of time will not only allow us to acquire better quality employees, but also to train them in an effective manner. The employment schedule also will allow the community to grow as uniformly as possible over approximately one-half decade.

The attached schedules both categorize Exxon's needs and provide information concerning employment growth with time. The largest group of the positions will be in the areas of underground operations. It is in this employment area that Exxon must begin with a number of experienced people. About 25 percent of those employed will have to be experienced. Roughly the same ratio of experienced to non-experienced people is expected to be applied to the surface plant. The Crandon operation would need approximately 180 maintenance personnel, and we will be hiring both apprentice level and journeymen to fill these positions.

The mine and the concentrator will be very modern and technically sophisticated. The positions should be exciting and challenging in both areas.

The present forecasts indicate that about 120 positions of a clerical and technician nature will have to be filled. It is expected that many of these people, as well as a substantial percentage of the maintenance personnel would be products of Wisconsin state vocational schools, particularly Nicolet College and Technical Institute in Rhinelander, and North Central Technical Institute at Antigo. We would anticipate working closely with these schools as we progress. Additionally, Exxon would fill approximately 60 front-line supervisor positions--35 for the underground operations, 15 for the maintenance operations, and 10 for the mill operations. For the most part, these would have a high school education or equivalent, and, of course, they would have to be experienced or familiar with the jobs which they would supervise. To the extent possible, it will be Exxon's policy to develop supervisors from within the working force.

Exxon is justifiably proud of its employee benefits program. This includes--

- A savings and investment program,
- Disability income protection program,
- Family income protection program,
- Retirement income program.

The present Exxon Crandon Project team payroll approximates $1,000,000 annually. In terms of 1980 dollars, the payroll associated with the contemplated full work force would be $25 to $30 million.

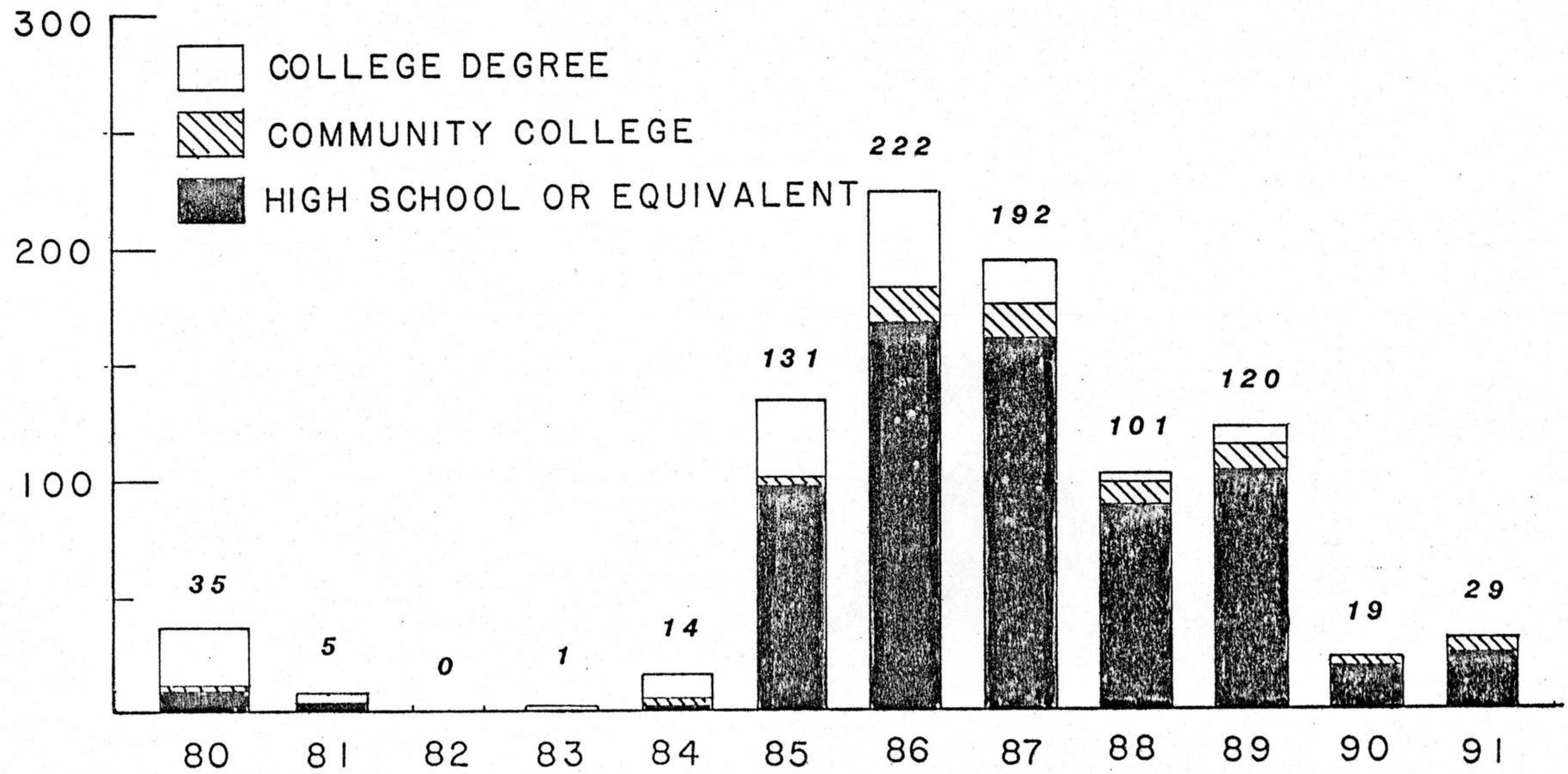
	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
MGMT./ PROF. / TECH.	25	3	0	1	10	32	41	18	2*	24*	0	0	104
CLERICAL	7	1	0	0	1	3	6	17	8	6	0	0	49
TECHNICIAN	3	1	0	0	3	6	15	14	9	13	2	6	72
OPERATIONS SUPERVISION	0	0	0	0	0	4	6	20	18	12	2	0	52
MAINTENANCE	0	0	0	0	0	18	38	51	36	31	3	4	181
MINE OPERATORS	0	0	0	0	0	68	116	72	42	26	12	0	336
MILL OPERATORS	0	0	0	0	0	0	0	0	0	56	0	19	75
NET ADDED POSITIONS	35	5	0	1	14	131	222	192	101	120	19	29	869

*PROFESSIONAL CONSTRUCTION MANAGEMENT PERSONNEL - CORPORATE TRANSFER.

EMPLOYMENT CATEGORIES **
CRANDON PROJECT

**Permanent Exxon employees only

PROBABLE HIRING TREND FOR CRANDON PROJECT



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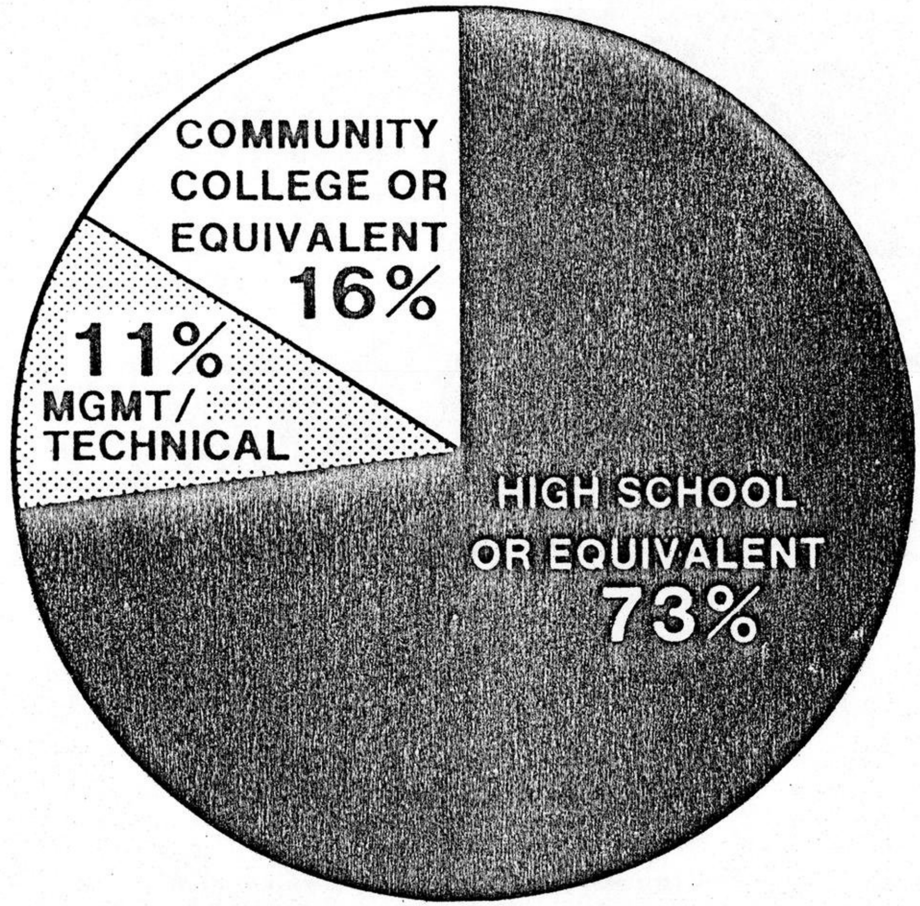
PROBABLE COMPOSITION OF WORK FORCE
CRANDON PROJECT



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CONSTRUCTION MANPOWER REQUIREMENTS

A project of the size and type of the proposed Crandon Project normally requires four to five years to develop the underground mine and to construct all of the surface facilities. As planned at this time, three general categories of manpower will be used to accomplish the development and construction. Exxon permanent employees will be used for a major portion of the mine level and stope development. Two groups of specialized contractors will be employed to perform the remainder of the mine development and the surface facilities construction.

One group of these specialized contractors using their employees will be used for mine development work. This will include sinking of shafts and exhaust air raises, hoist headframe construction, and installation of major underground equipment such as the primary crusher and conveying system. This work will cover about four years and will require about 1.1 million manhours, with a peak workforce of about 160. In addition Exxon crews, primarily locally hired, will require 2.2 million manhours to bring the mine into production. Much of this labor force will continue to operate the mine.

The other group of specialized contractors will be employed to construct all of the surface facilities. This will include facilities required for mine support, mill and concentrator, ancillary, transportation, and waste disposal.

This work will cover more than four years and will require 3.1 million manhours, with a peak workforce of about 585.

Total construction manpower requirements directly site-related will be about 6.4 million manhours over the four year construction period.

APPENDIX I

MINERALS AVAILABILITY--THE MINERAL POSITION OF THE UNITED STATES

By John D. Morgan, Jr.
Chief Staff Officer, U.S. Bureau of Mines

As Published in

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February, 1980

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Chief Staff Officer, U.S. Bureau of Mines

Minerals Availability—The Mineral Position of the United States

Mining and agriculture are the primary sources of new wealth and the foundations for national security. Modern agriculture would be impossible without mining, for mining provides metals for farm equipment, mineral fertilizers and mineral fuels. Of the U.S. population of 222 million, close to 4 million are employed in the mineral industry, including about 1 million in mining. Domestically produced materials of mineral origin are currently valued at over $225 billion annually, contributing importantly to our over $2 trillion economy (fig. 1). Domestic sources account for the major part of our total mineral materials supplies but imports also supply significant quantities of a broad spectrum of mineral materials (fig. 2), causing in 1979 a nonfuel mineral trade imbalance of $2 billion (fig. 3).

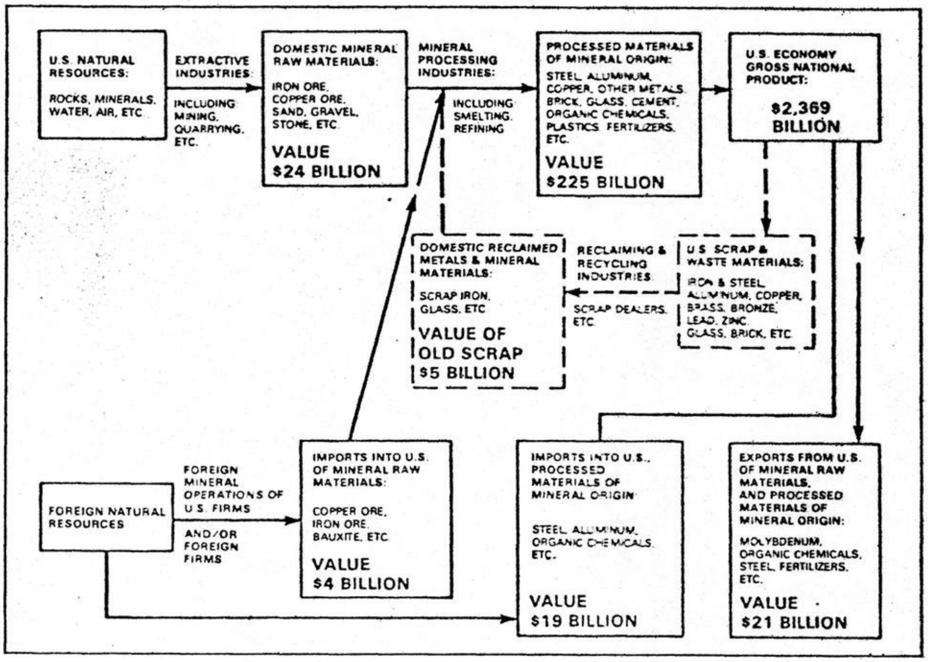

Fig. 1. Role of nonfuel minerals in the U.S. economy (estimated values for 1979—based on statistics for first 11 months of 1979 only)

"That it is the continuing policy of the federal government in the national interest to foster and encourage private enterprise in the development of economically sound and stable domestic mining, minerals, metal and mineral reclamation industries, . . ." was specified by the Mining and Minerals Policy Act of 1970, PL 91-631, Dec. 30, 1970.

Strategic stockpiling critical element of mineral policy

Strategic stockpiling has long been an important element of U.S. mineral policy. The Strategic and Critical Materials Stock Piling Revision Act of 1979, PL 96-41, July 30, 1979, reaffirmed the need for stockpiling, conservation and the development of domestic sources. It specified that "the purpose of the stockpile is to serve the interest of national defense only and is not to be used for economic or budgetary purposes" and that "the quantities of the materials stockpiled should be sufficient to sustain the United States for a period of not less than three years in the event of a national emergency.

Under the prior 1946 Stock Piling Act, administration policy in the period from 1946 to 1958 based stockpile planning on a 5-year emergency, from 1958 to 1973 on a 3-year emergency, from 1973 to 1976 on a 1-year emergency, and from 1976 to the present on a 3-year emergency. Ninety-three materials have been designated as basic stockpile materials, including 79 metals and minerals. Stockpiled materials are valued at more than $12 billion, by far the greatest part attributable to metals and minerals (see table 1).

Another recent major piece of legislation closely related to mineral policy was the Trade Agreements Act of 1979, PL 96-39, July 26, 1979, which included among its purposes "to foster the growth and maintenance of an open world trading system; to expand opportunities for the commerce of the United States in international trade: and to improve the rules of international trade and to provide for the enforcement of such rules." In this connection it is important to note that most metals and minerals are international commodities in that only a few cents per pound can move them physically in the major markets of the world while ownership can often be changed by mail, telephone, or telex for even less.

Mineral trade immediately affected by world events

Fig. 4 shows the growth of world production over the last three decades for four of the world's most important nonfuel mineral materials: steel, cement, copper and aluminum. In recent years about two-

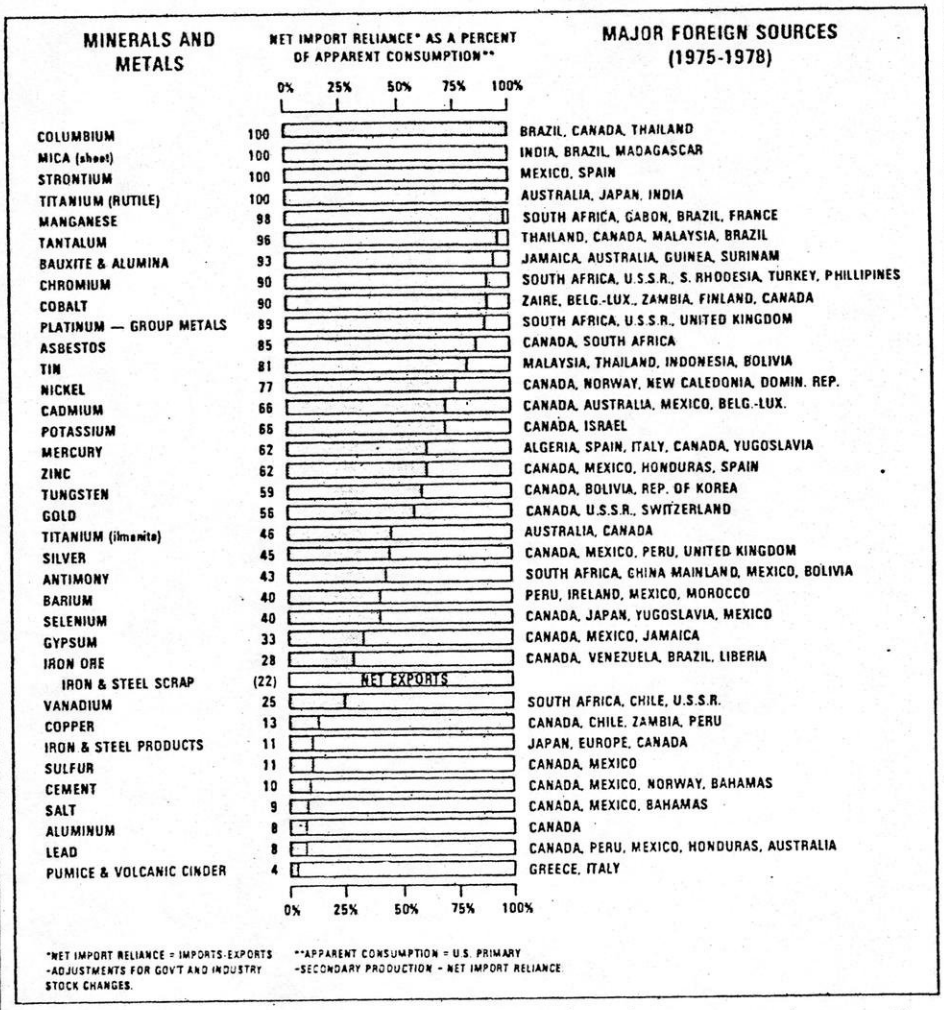

Fig. 2. U.S. net import reliance of selected minerals and metals as a percent of consumption in 1979 (estimated Dec. 12, 1979)

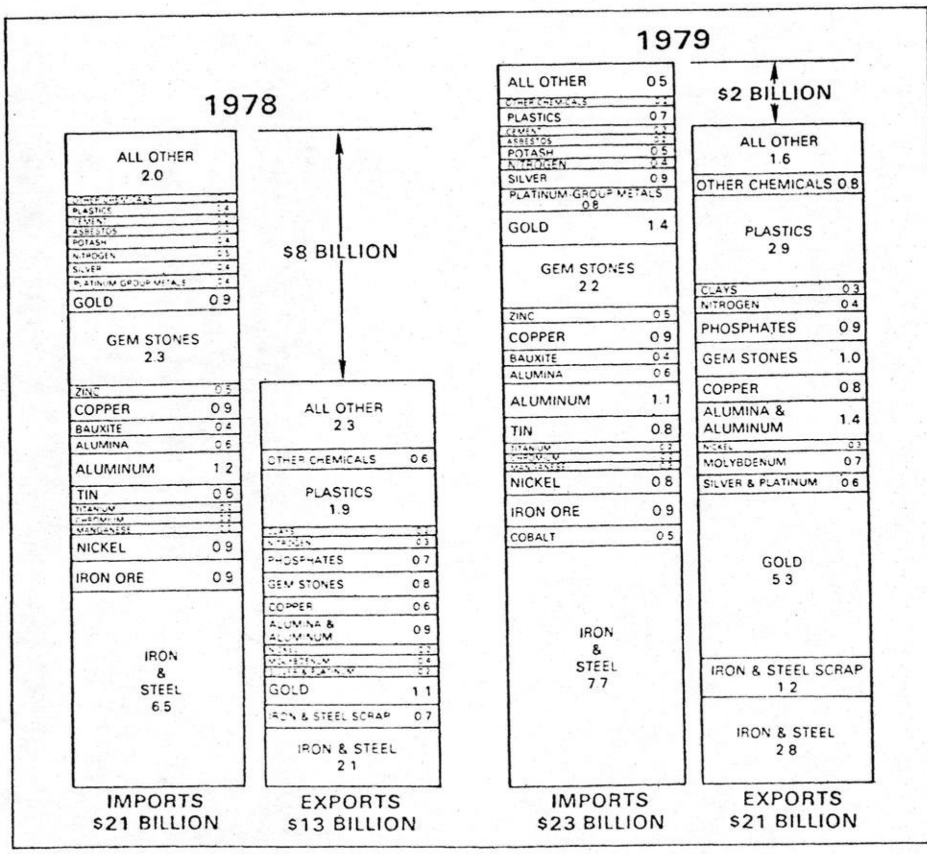

Fig. 3. U.S. imports and exports of raw and processed nonfuel minerals—1979 (based on statistics for first 11 months of 1979 only)

fifths of the world's iron ore, bauxite, alumina, and copper and about one-fifth of the world's steel and aluminum moved in world trade. Many other mineral materials from diverse geographic sources are used in more or less direct proportion to these major mineral materials; for example, the ferroalloys: manganese, chromium, nickel, molybdenum, tungsten and vanadium used in steel. Therefore, politico-economic developments anywhere in the world are likely to have almost immediate effect upon both producers and consumers of mineral materials wherever they may be located.

In periods of lessened demand, the efforts of some less-developed or developing countries to acquire foreign currencies and to maintain employment in the mineral producing sectors of their economies impact on employment in similar industries in the developed nations. The growth of mining in a number of less-developed or developing nations is illustrated by world copper mine production (table 2). Centrally planned economies may have somewhat more success in isolating themselves from the world trading system, but they too are not immune from the repercussions of world developments.

Markets are increasingly competitive

The United States now produces only about one-fifth of the world's steel and copper, and only about one-third of the world's aluminium. Consequently, we find greater competitive pressures in world markets, not only in the acquisition of mineral raw materials but also in the sale of manufactured articles. Foreign suppliers desire to realize the value added by manufacture. Hence, future imports are likely to include more of the costly upgraded forms. In assessing our position with respect to any particular material we must consider not just import dependence but also many other factors.

Materials on hand in the strategic stockpile, other government stocks and industry stocks are often significant. For example: our present posture in several important materials such as tin, tungsten, manganese and chromium would be quite different were it not for the strategic stockpile, which, however, can only be called upon for defense purposes.

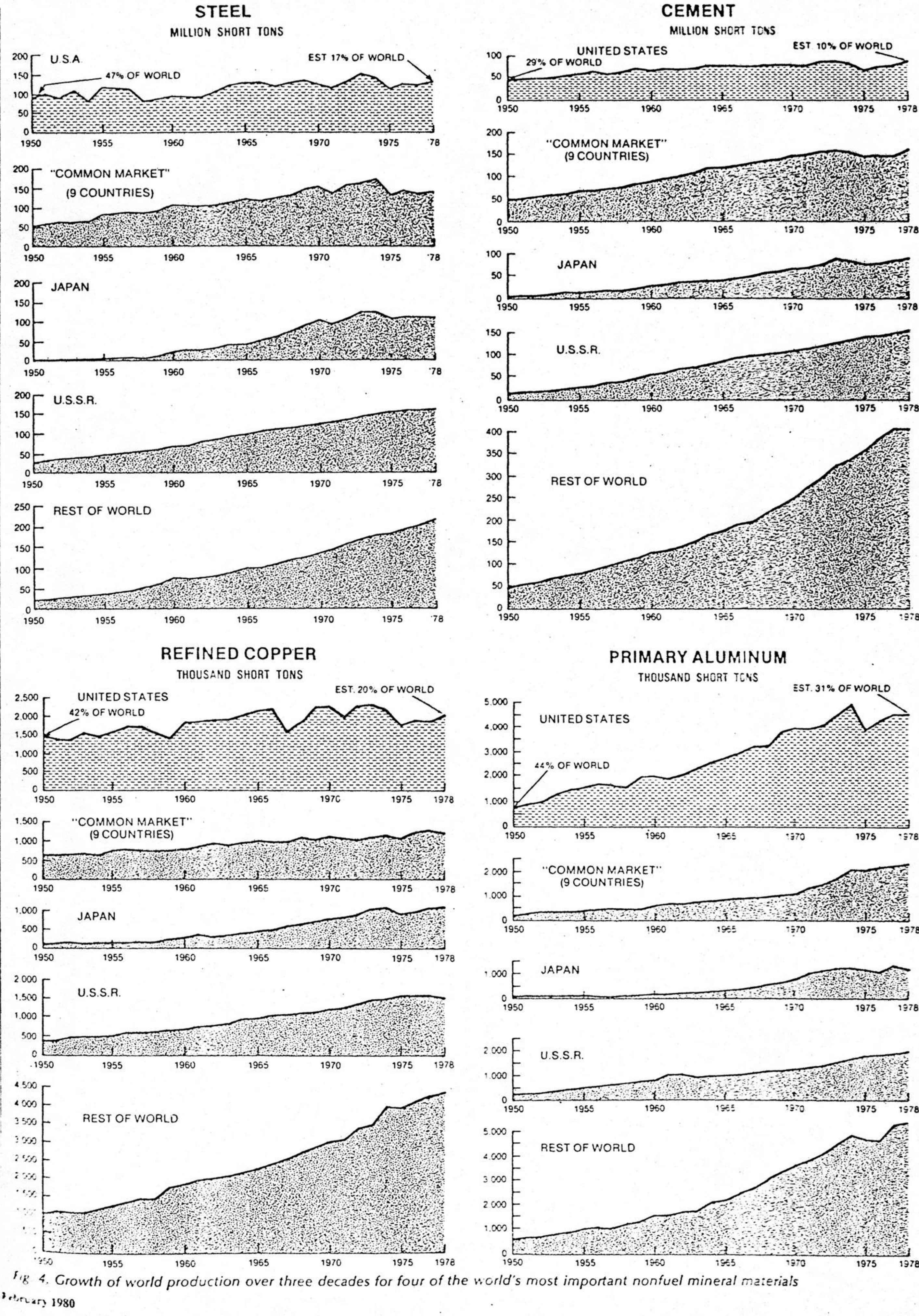

Fig. 4. Growth of world production over three decades for four of the world's most important nonfuel mineral materials

A. Materials with current stockpile goals Unit	Goal	Inventory	Excess	Sold during 1978
Alumina (tons)	11,532,000	0	0	0
Aluminum oxide, grain (tons)	75,000	50,904	0	0
Aluminum oxide, crude (tons)	147,615	249,388	73,426*	0
Antimony (tons)	20,130	40,730	20,599	0
Asbestos, amosite (tons)	26,291	42,533	16,243	0
Bauxite, Jamaica (long tons, dry)	523,000	8,858,881	0*	0
Bauxite, refractory (long tons, calcined)	2,083,000	174,599	0	0
Beryllium copper (lb)	33,420,000	14,733,731	0	0
Beryllium metal (tons)	895	299	0	0
Bismuth (lb)	771,000	2,081,298	1,310,255	0
Cadmium (lb)	24,701,000	6,328,622	0	0
Chromite, chemical (tons, dry)	734,000	242,414	0	0
Chromite, metallurgical (tons, dry)	2,550,000	2,488,043	531,219	0
Chromite, refractory (tons, dry)	642,000	391,414	0	0
Chromium, ferro HC (tons)	236,000	402,696	0*	0
Chromium, ferro LC (tons)	124,000	318,892	124,316*	0
Chromium, ferro silicon (tons)	69,000	58,355	0	0
Chromium metal (tons)	10,000	3,763	0	0
Cobalt (lb)	85,415,000	40,802,421	0	0
Columbium concentrates (lb)	3,131,000	1,781,481	0	0
Copper (tons)	1,299,000	22,859	0	0
Diamond, industrial bort (kt)	14,974,000	25,959,493	10,984,594	2,452,053
Diamond, industrial stones (kt)	5,559,000	20,007,991	14,447,289	0
Fluorspar, acid grade (tons, dry)	1,594,000	895,983	0	0
Fluorspar, metallurgical (tons, dry)	1,914,000	411,738	0	0
Graphite, Ceylon (tons)	6,271	5,498	0	0
Graphite, Malagasy (tons)	20,472	17,911	0	0
Graphite, other (tons)	34,748	2,802	0	0
Iodine (lb)	3,333,000	8,013,448	4,680,492	0
Jewel bearings (pieces)	224,623,000	66,999,769	0	0
Lead (tons)	865,000	601,067	0	0
Manganese, battery, natural (tons, dry)	12,736	262,828	233,994*	0
Manganese, battery, synthetic (tons, dry)	19,105	3,011	0	0
Manganese, chemical (tons, dry)	247,136	217,105	0	0
Manganese, metallurgical (tons, dry)	2,052,000	3,382,373	1,084,670*	206,690
Manganese, ferro HC (tons)	439,000	599,763	160,764	0
Manganese, ferro MC (tons)	99,000	28,920	0	0
Manganese, silicon (tons)	81,000	23,574	0	0
Manganese, metal (tons)	15,000	14,171	0	0
Mercury (flasks)	54,004	191,587	137,583	0
Mica, muscovite block (lb)	6,188,000	5,204,024	0	0
Mica, muscovite film (lb)	90,000	1,274,145	1,182,545	0
Mica, muscovite splittings (lb)	12,631,000	21,655,028	9,154,746	503,157
Mica, phlogopite block (lb)	206,064	130,745	0	0
Mica, phlogopite splittings (lb)	932,000	2,818,361	1,931,341	104,026
Nickel (tons)	204,335	0	0	0
Iridium (troy oz)	97,761	16,990	0	0
Palladium (troy oz)	2,450,000	1,252,789	0	0
Platinum (troy oz)	1,314,000	452,642	0	0
Rutile (tons, dry)	173,928	39,185	0	0
Silicon carbide, crude (tons)	306,628	89,538	0	0
Talc steatite, block & lump (tons)	104	976	883	21
Tantalum carbide (lb)	889,000	28,688	0	0
Tantalum metal (lb)	1,650,000	201,133	0	0
Tantalum minerals (lb)	5,452,000	2,551,456	0	0
Thorium nitrate (lb)	1,800,000	7,205,337	5,386,996	19,215
Tin (long tons)	32,499	200,473	167,974	325
Titanium sponge (tons)	131,503	32,331	0	0
Tungsten carbide (lb)	12,845,000	2,032,833	0	0
Tungsten, ferro (lb)	17,769,000	2,025,491	0	0
Tungsten, metal (lb)	3,290,000	1,898,814	0	0
Tungsten ores & concentrates (lb)	8,823,000	97,583,091	56,988,517*	5,372,823
Vanadium, ferro (tons)	10,095	0	0	0
Vanadium pentoxide (V content) (tons)	2,576	540	0	0
Zinc (tons)	1,313,000	373,051	0	0
B. Materials with former objectives but zero current goals				
Aluminum (tons)	0	1,732	0*	0
Asbestos, chrysotile (tons)	0	10,957	10,957	0
Bauxite, Surinam (long tons, dry)	0	5,299,596	0*	0
Beryl Ore (tons)	0	17,987	0*	0
Columbium carbide (lb)	0	21,372	0*	0
Columbium, ferro (lb)	0	930,911	0*	0
Columbium, metal (lb)	0	44,851	0*	0
Diamond dies, small (pieces)	0	25,473	25,473	0
Quartz crystals (lb)	0	2,693,744	2,693,744	63,492
Sapphire & ruby (kt)	0	16,305,502	16,305,502	0
Silver fine (troy oz)	0	139,500,000	139,500,000	0
C. Other inventories				
Asbestos, crocidolite (tons)	—	2,384	2,384	0
Celestite (tons, dry)	—	14,408	14,408	0
Diamond tools (pieces)	—	113	113	22,312
Kyanite mullite (tons, dry)	—	2,658	2,658	0
Lithium hydroxide (lb)	—	0	0	190,000
Magnesium (tons)		362	362	500
Mercury (flasks)	—	6,655	6,655a/	5,700
Mica, muscovite block (lb)	—	177,746	177,746	0
Mica, muscovite splittings (lb)	—	141,224	141,224	0
Rare earths (tons, dry)	—	1,775	1,775	2,973
Talc, steatite ground (tons)	—	2,389	2,389	0
Yttrium oxide (lb)	—	237	237	0

*Part or all of apparent excess held to offset shortfall of other grade or form of same commodity

a/ Department of Energy Surplus

Table 1. Status of U.S. government inventories of minerals and materials as of Dec. 31, 1978

And, while gold is not in our strategic stockpiles per se, the large gold reserves held by the Treasury provide a degree of assurance of supply in an emergency.

Possibilities of substitutes and alternates must also be considered, as must the possible use of low-grade presently noncommercial domestic mineral deposits. For example, chromium has been recognized as an important strategic material ever since World War I. Over many years, the U.S. Geological Survey and the U.S. Bureau of Mines have helped to discover and to assess numerous domestic chromium deposits. The Bureau produced acceptable chrome concentrates from domestic deposits as well as acceptable ferrochromium, chromite refractories, chromium metal and chromium chemicals. Consequently, presently submarginal deposits could become sources of supply at some future time. Current Bureau research includes recovering chromium, nickel and cobalt from laterite deposits and also from flue dusts, plating wastes and other residues.

World mineral supply adequate for two decades

The dynamic supply/demand situation for over 100 mineral materials is monitored regularly by the Bureau of Mines. Detailed Bureau supply/demand forecasts to the year 2000 (table 3) show that world reserves of most mineral materials should be adequate to meet world demands over the next two decades and that for many minerals the United States itself is in a favorable position. However, changing patterns of both supplies and uses can be expected in many cases.

While many presently industrialized nations are experiencing energy shocks caused by escalating prices for fuels, they should not overlook that the cost of producing petroleum in Arabia is reportedly only about 50¢ per barrel and that such petroleum production is accompanied by major quantities of natural gas currently being flared. Consequently, in the Middle East there are prospects of greatly increased materials production, including direct reduction of metals, electrodeposition using electricity generated by gas engines, and petrochemicals and plastics. Further, there are still many favorable sites in the world for both high-head and low-head hydroelectric development where, if political stability could be ensured, there could be created major mineral material producing complexes.

As an illustration of possible changes in use, consider the U.S. automotive industry which now consumes about 26 percent of iron and steel, 16 percent of aluminum, 12 percent of copper, 69 percent of lead (15 percent in gasoline and 54 percent in other uses), 34 percent of zinc, and 40 percent of platinum-group metals. In recent years automobile weights have been reduced by as much as 1000 lb to improve fuel efficiency, and further reductions are in prospect. A leading auto-

Table 2. World mine production of copper (thousand metric tons)

	1960	1978 (prelim.)
United States	980	1,358
Canada	398	647
Latin America:		
Bolivia	2	3
Brazil	1	
Chile	536	1,036
Cuba	12	6
Ecuador		1
Guatemala		2
Haiti	1	
Mexico	60	83
Nicaragua	5	
Peru	182	354
Africa:		
Angola	2	
Botswana		15
Congo		1
Mauritania		8
Morocco	1	5
Mozambique		3
Namibia (Ter. S.W. Africa)	21	43
South Africa, Rep. of	46	194
Tanzania	1	
Uganda	15	3
Zaire	302	423
Zambia	576	643
Zimbabwe-Rhodesia	14	34
Asia:		
China:		
Mainland	70	105
Taiwan	2	2
Cyprus	35	7
India	9	25
Indonesia		59
Iran		6
Israel	6	
Japan	89	72
Korea, North	6	18
Korea, Rep. of		1
Malaysia		25
Philippines	44	263
Turkey	27	22
Europe:		
European Economic Community:		
Fed. Rep. of Germany	2	1
Greece		4
Ireland	6	5
Italy	3	1
Other Europe:		
Albania	2	10
Austria	2	
Bulgaria	11	57
Czechoslovakia		9
Finland	28	47
German Dem. Rep.	24	17
Norway	15	28
Poland	11	290
Portugal	1	2
Romania		50
Spain	8	45
Sweden	17	48
U.S.S.R.	499	825
Yugoslavia	33	113
Oceania:		
Australia	111	220
Papua New Guinea		198
World total (rounded)	4,200	7,400

Commodity (Units)	Primary mineral demand 1976–2000			Mineral reserves 1976		
	United States	Rest of World	World	United States	Rest of World	World
Metals and mineral forming elements						
Aluminum (million tons)	275	682	958	10	5,600	5,610
Antimony (thousand tons)	907	1,669	2,576	120	4,620	4,740
Arsenic (thousand tons)	W	720	W	400	2,700	3,100
Beryllium (thousand tons)	9	6	15	28	391	419
Bismuth (million lb)	80	203	283	20	164	184
Boron (million tons)	5	11	16	22	67	89
Bromine (million lb)	9,296	9,699	18,995	A	A	A
Cadmium (thousand tons)	216	477	693	220	540	760
Cesium (thousand lb)	1,780	1,950	3,730	—	218,000	218,000
Chlorine (million tons)	419	722	1,141	A	A	A
Chromium (million tons)	18	69	87	1	829	829
Cobalt (million lb)	698	2,030	2,728	—	3,300	3,300
Columbium (million lb)	322	972	1,294	—	22,000	22,000
Copper (million tons)	62	256	318	93	410	503
Fluorine (million tons)	26	69	95	3	34	37
Gallium (thousand kg)	450	230	680	1,000	A	A
Germanium (thousand lb)	1,517	3,920	5,437	900	3,100	4,000
Gold (million troy oz)	200	954	1,154	110	1,105	1,215
Hafnium (tons)	1,220	1,090	2,310	A	A	A
Indium (million troy oz)	23	32	56	10	41	51
Iodine (million lb)	280	660	940	530	5,220	5,750
Iron in ore (billion tons)	3	18	20	4	99	103
Lead (million tons)	28	99	127	28	108	136
Lithium (thousand tons)	153	107	260	410	NA	NA
Magnesium (million tons)	44	158	202	A	A	A
Manganese (million tons)	42	348	390	—	1,800	1,800
Mercury (thousand flasks)	1,330	4,740	6,070	410	4,800	5,210
Molybdenum (billion lb)	3	7	10	8	12	20
Nickel (million tons)	7	20	27	1	60	60
Nitrogen fixed (million tons)	500	1,540	2,040	A	A	A
Nitrogen-elemental (million tons)	608	720	1,328	A	A	A
Palladium (million troy oz)	20	65	85	1	194	194
Platinum (million troy oz)	22	66	88	1	297	297
Rare earths and yttrium (thousand tons)	541	425	966	5,050	2,680	7,730
Rhenium (thousand lb)	193	113	306	2,600	4,400	7,000
Rhodium (million troy oz)	2	3	5	1	17	17
Rubidium (thousand lb)	61	45	106	—	2,100	2,100
Scandium (kg)	258	238	496	A	A	A
Selenium (million lb)	40	67	107	74	298	372
Silicon (thousand tons)	21,000	76,000	97,000	A	A	A
Silver (million troy oz)	4,200	7,216	11,416	1,510	4,590	6,100
Strontium (thousand tons)	439	239	678	—	1,155	1,155
Sulfur (million long tons)	400	1,460	1,860	205	1,495	1,700
Tantalum (thousand lb)	64	45	109	—	130	130
Tellurium (million lb)	10	6	15	19	82	101
Thallium (thousand lb)	39	73	112	192	1,008	1,200
Thorium (thousand tons)	2	3	5	140	640	780
Tin (thousand metric tons)	1,160	5,440	6,600	40	9,960	10,000
Titanium (million tons)[1]	22	59	81	31	303	334
Tungsten (million lb)	721	2,210	2,931	275	3,925	4,200
Vanadium (thousand tons)	470	890	1,360	115	10,500	10,600
Zinc (million tons)	39	162	201	24	142	166
Zirconium (million tons)[1]	3	7	11	6	16	22
Nonmetallic minerals						
Asbestos (million tons)	17	184	201	4	92	96
Barite (million tons)	50	99	149	65	135	200
Clays (billion tons)	3	15	18	A	A	A
Corundum (thousand tons)	24	361	385		A	A
Diatomite (million tons)	19	50	70	600	1,400	2,000
Feldspar (million tons)	31	103	134	600	400	1,000
Garnet (thousand tons)	613	418	1,031	700	1,540	2,240
Graphite (million tons)	2	11	13		10	10
Gypsum (million tons)	636	1,072	2,338	500	1,780	2,280
Kyanite (million tons)	W	15	W	30	70	100
Lime (million tons)	646	3,011	3,657	A	A	A
Mica-scrap and flake (thousand tons)	4,000	3,500	7,500	A	A	A
Mica-sheet (thousand lb)	70,200	429,000	499,200	1	365,000	365,000
Peat (million tons)	55	7,300	7,355	10,000	40,000	50,000
Perlite (million tons)	22	51	73	200	810	1,010
Phosphate rock (million tons)	966	2,971	3,937	3,500	22,232	25,732
Potash (million tons)	213	827	1,039	200	13,030	12,230
Pumice (million tons)	169	545	714	1,250	815	2,065
Salt (million tons)	1,460	4,170	5,630	A	A	A
Sand and gravel (billion tons)	25	NA	NA	A	A	A
Soda ash (million tons)	230	605	835	A	A	A
Stone-crushed (billion tons)	29	225	254	A	A	A
Stone dimension (million tons)	27	1,025	1,052	A	A	A
Talc (million tons)	35	190	225	150	180	330
Vermiculite (million tons)	10	9	19	100	90	190
Commercial gases						
Argon (million tons)	14	10	24	A	A	A
Helium (billion cu ft)	23	NA	NA	149	NA	NA
Oxygen (million tons)	800	1,500	2,300	A	A	A

A Adequate NA not available W withheld because of individual company confidentiality. Totals may not add due to rounding

[1] Data includes metal content in metallic and nonmetallic commodities

Table 3. Comparison of world cumulative primary mineral demand forecasts, 1976–2000, with world identified mineral reserves

motive manufacturer has predicted that by 1985 net weights could be in the area of 2700 to 2800 lb—a reduction of about 15 percent from 1978 weights. Aluminum, magnesium, plastics and fiberglass are being given increasing attention as substitutes for the traditional 2500 lb of steel in an automobile. Special steel products such as coated and high-strength low-alloy steels also are expected to be used increasingly in motor vehicles in the next few years.

Volume of plastic usage near that of steel

Escalating growth in the use of plastics illustrates how a new mineral-based material can limit use of more traditional ones. Plastics are largely mineral-based materials in that about 2 lb of petroleum yield 1 lb of plastics. In 1978, 17 million tons of plastics were used in the United States, up from only 1 million tons three decades ago. This 17 million tons of plastics is approaching twice the combined tonnages of aluminum, copper, lead and zinc. With a specific gravity in the vicinity of 1, the annual volume of new plastics consumed is approaching the volume of steel. No wonder that major metal firms are diversifying not only into other metals but also into plastics.

Programs to improve energy supplies and utilization can be expected to have major impacts upon such materials as chromium, cobalt, columbium, molybdenum, nickel, platinum, tantalum and titanium. Resistance to high temperatures, corrosion and erosion is of particular importance in energy related applications. The efficiency of thermodynamic processes is enhanced by increased temperature differentials and the number of elements with high melting points is very limited. Coal gasification, coal liquefaction, magnetohydrodynamics, nuclear fission and fusion can be expected to make unprecedented demands upon special property mineral materials.

Even electric power generation in conventional steam powerplants will make unprecedented demands upon special property materials if air quality regulations are to be realized. At the present time in the United States more than 500 million tons of coal are being burned annually by electric utilities and about 43 percent of our electricity is derived from coal. At least 15 tons of air are required to burn a ton of coal. If vigorous stack gas cleanup is to become a reality, 8 billion tons of hot corrosive gases will have to be handled in the process. While the major constituents in powerplant stack gases are well known, mineral fuels contain many more elements when analyzed at the parts-per-million range and many of these trace elements will also be present in some form in stack gases.

Increased understanding of the role of trace elements in many other industrial processes will also be required in view of increasing concerns with the role of trace or fugitive elements, compounds and particulates in possible air, water and land pollution and the possible synergistic effects thereof.

Declining productivity expected to continue

As the world's need for food, energy and improved materials increase, the mineral sector of the U.S. economy is experiencing some difficulties in keeping pace. The 1979 Annual Report of the Council of Economic Advisors decried "the productivity slowdown" in the United States. This report included data showing that mining, which accounted for 1.5 percent of U.S. 1977 output, had experienced a productivity decline of 6.1 percent per year in the period 1973–1977, compared to a prior modest increase of 1.9 percent per year in 1965–1973, and an earlier increase of 4.3 percent per year in 1960–1965.

At the direction of the President, a review of federal policies related to nonfuel minerals is currently under way. A product thereof is the August 1979 draft "Report on the Issues Identified in the Nonfuel Minerals Policy Review." The first "principal issue" stated is that "The future supplies of several imported minerals critical to the United States and its allies are becoming less secure," with chromium, manganese, cobalt and platinum group metals cited as being of greatest concern. Other "principal issues" include: expected declining production by the year 2000 of several domestic mineral industry segments and possible loss of shares in both the U.S. and world markets; major shortcomings in the federal nonfuel mineral policy-making process and the supporting policy analyses and data capabilities; lack of effective tools for managing the mineral resources potentially found on the public lands; and, for several minerals, the high costs of limiting some pollutants, with potentially significant price increases, capacity decreases, job losses and the possibility of increased import reliance. ◆

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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 differential flotation.

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.

APPENDIX III

GEOLOGISTS BLOCK OUT EXXON'S BIG FIND OF ZN-CU AT CRANDON

By P. G. Schmidt, J. D. Dolence
M. R. Lluria, and G. Parsons III

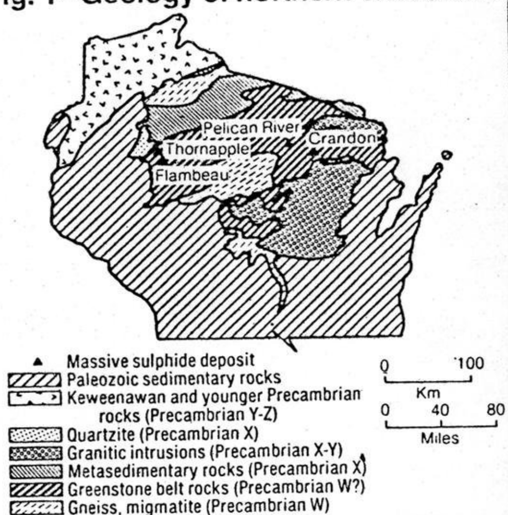
Exxon Minerals Comapny

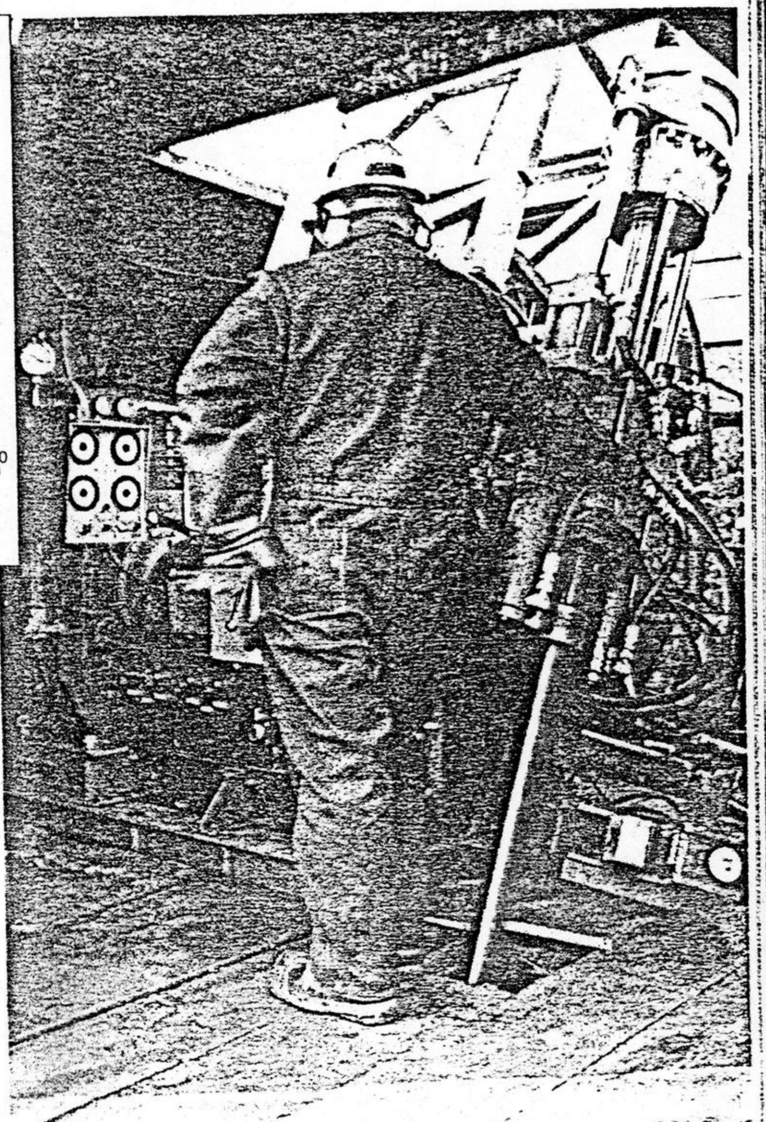
As Published in

E/MJ

July, 1978

Fig. 1—Geology of northern Wisconsin





Diamond drilling on the Crandon zinc-copper deposit.

Geologists block out Exxon's big find of Zn-Cu at Crandon

P. G. Schmidt, J. D. Dolence, M. R. Lluria, and **G. Parsons III,**
Exxon Minerals Co. USA

A MAJOR ZINC-COPPER FIND—the Crandon massive sulphide deposit in Forest County, Wis.—is undergoing in-depth examination by Exxon Minerals Co. USA, which made the discovery in 1975. So far, announced in-place reserves total 62 million mt grading approximately 5% zinc and 1% copper, with substantially lesser values of silver, gold, and lead.

The Crandon reserves are evenly divided between massive sulphide ore and stringer sulphide ore. The body is associated with Precambrian felsic pyroclastic rocks and is overlain by intermediate volcanic rocks, which were subjected to greenschist facies metamorphism and tilted to a near-vertical attitude.

The Crandon deposit is not the only massive sulphide occurrence in this area. Others are the Flambeau and Thornapple deposits of Kennecott Copper Corp. near Ladysmith, and the Pelican River deposit of Noranda Exploration Inc., situated immediately east of Rhinelander, Wis. (Fig. 1).

This paper was originally presented at the 107th annual meeting of AIME, Denver, Colo., Feb. 27, 1978.

These massive sulphide deposits occur in Precambrian volcanic rocks of the "Rhinelander-Ladysmith greenstone belt," which strikes easterly across the northern part of the state. This belt is about 100 km wide and 240 km long. The lithologies of the greenstone belt are dominantly mafic and intermediate flows, pyroclastic rocks, and tuffaceous sedimentary units. Felsic volcanic rocks are present locally. The metamorphic grade within the greenstone belt varies from low greenschist to granulite facies.

The Precambrian geology of the region is very similar to the 2.5- to 2.7-billion-year old (Precambrian W) Superior Province volcanic belts in Canada. Greenstones and older gneisses in northern Wisconsin and the Upper Peninsula of Michigan are dated as Archean (Precambrian W).[1] However, model lead dates from Flambeau and Pelican River galena samples indicate that the age of these deposits is 1.8 billion years.[2] Numerous large intrusions, such as the Wolf River batholith, were emplaced 1.4 to 1.8 billion years ago (Precambrian X and Y), with attendant regional metamorphism.[3,4] These

Fig. 2—Schematic columnar section, Crandon deposit

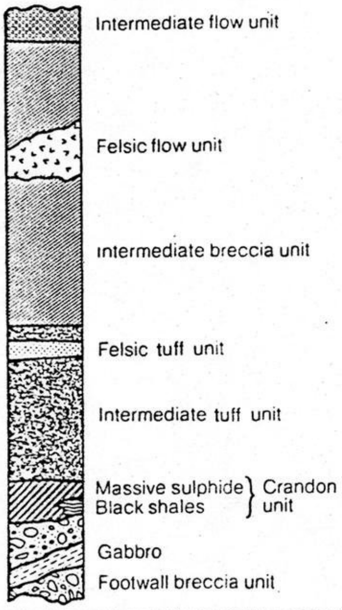
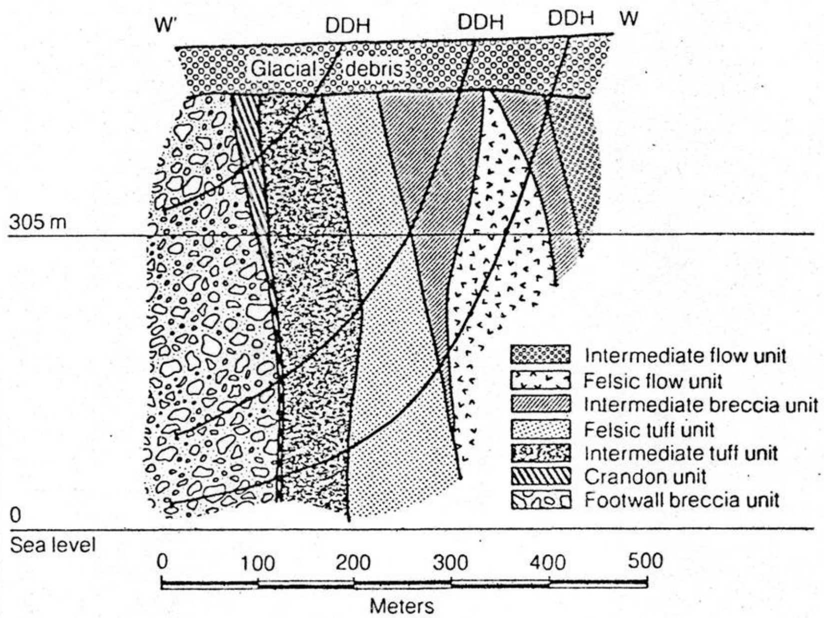


Fig. 3—Geologic cross section W-W' looking west



rocks, with complementary granitic and mafic intrusions, gneisses, and sedimentary rocks are surrounded by younger Precambrian and Paleozoic rocks. Exposures of these rocks are sparse because most of northern Wisconsin is mantled by glacial drift.

Mapping the geology of Crandon

Exxon began exploration in Wisconsin in 1970 and drilled 24 prospects before discovering the Crandon deposit in July 1975. The deposit is a near-vertical tabular body striking N85°W, consisting of a strata-bound massive zone and a stratigraphically underlying stringer zone. It occurs within a sequence of predominantly intermediate and felsic volcanic rocks and their sedimentary derivatives. Relict depositional features indicate stratigraphic tops to the north. Glacial drift over the sulphide body ranges from 30 to 60 m thick, and the nearest known outcrop is granite, about 10 km west.

Within the area of drill information, stratigraphic relationships appear to be disarmingly simple (Figs. 3, 4, and 5). The massive sulphide body is underlain by felsic pyroclastic rocks and overlain by intermediate volcanic rocks and their derived sedimentary rocks (Fig. 2).

Lithology comprised of eight major units

The **footwall breccia unit** is predominantly pyroclastic rhyolitic breccia and subordinate tuff beds. It occurs across the entire drill area; the thickness is unknown. Felsic breccia fragments up to 0.5 m in size are angular to subrounded in a rhyolite matrix of the same composition. Exotic fragments occur sparsely throughout the unit. The breccia zones are apparently conformable, but bedding is apparent only in tuff beds.

The **Crandon unit** includes the massive sulphide and its equivalent facies. This unit is readily identifiable for a distance of 1,500 m along strike (Fig. 4) and 730 m below bedrock surface. The thickness varies from 0.3 m on the west to 80 m near the center of the deposit. Three major lithologies dominate: massive sulphide, sulphide-rich rhyolite lapilli tuff, and black shale.

The massive sulphide facies is predominantly pyrite, with variable amounts of sphalerite and chalcopyrite and minor amounts of galena, quartz, chlorite, and sericite. Grain size in the massive sulphide varies from very fine to coarse. The massive sulphide is commonly banded. In places, sulphide clasts, graded bedding, and slump features are observed. Total sulphide content is commonly greater than 65% by volume.

Sulphide-rich rhyolite lapilli tuff, generally less than 10 m thick, occurs near the base of the Crandon unit. It is a coarse-grained pyroclastic rock with clasts of rhyolite, cherty rhyolite, and pyrite in a matrix of pyrite, sphalerite, and quartz. Total sulphide content varies widely, ranging from 10% to 40% by volume.

The black shale facies occurs throughout the Crandon unit as thin, discontinuous lenses above, within, or below massive sulphide or sulphide-rich rhyolite tuff. On the east end at depth, the Crandon unit is 90% black shale. The shale is laminated to thinly bedded, chlorite-rich with minor carbonaceous material, and 3-15% pyrite.

The **intermediate tuff unit** directly overlies the Crandon unit in most of the drill area (Figs. 4 and 5). These rocks are fine- to medium-grained, thin-bedded tuffs and tuffaceous sedimentary rocks of dacitic to andesitic composition. Subordinate lithologies include lapilli-rich tuff, crystal tuff, cherty tuff, shale, graywacke, and local calcareous tuff. Graded bedding, flame structures, slump structures, and other primary features are present. In

Fig. 4—Geologic plan map
(elevation 305 m)

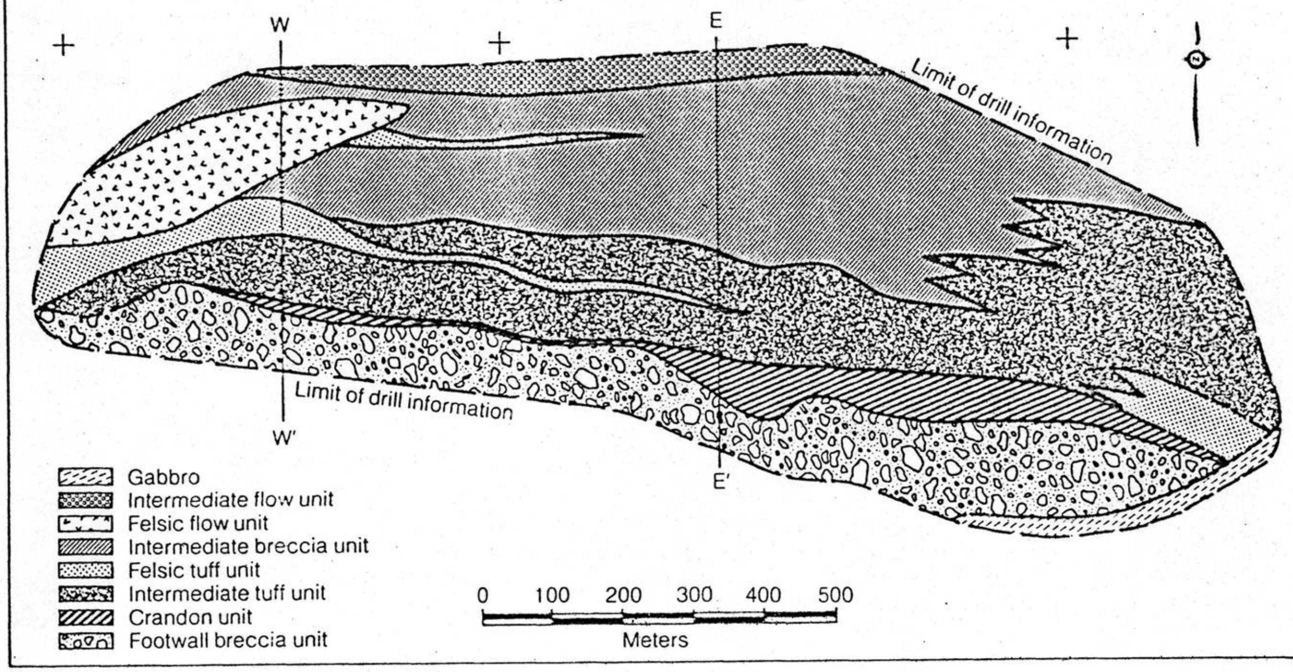


Fig. 5—Geologic cross section E-E' looking west

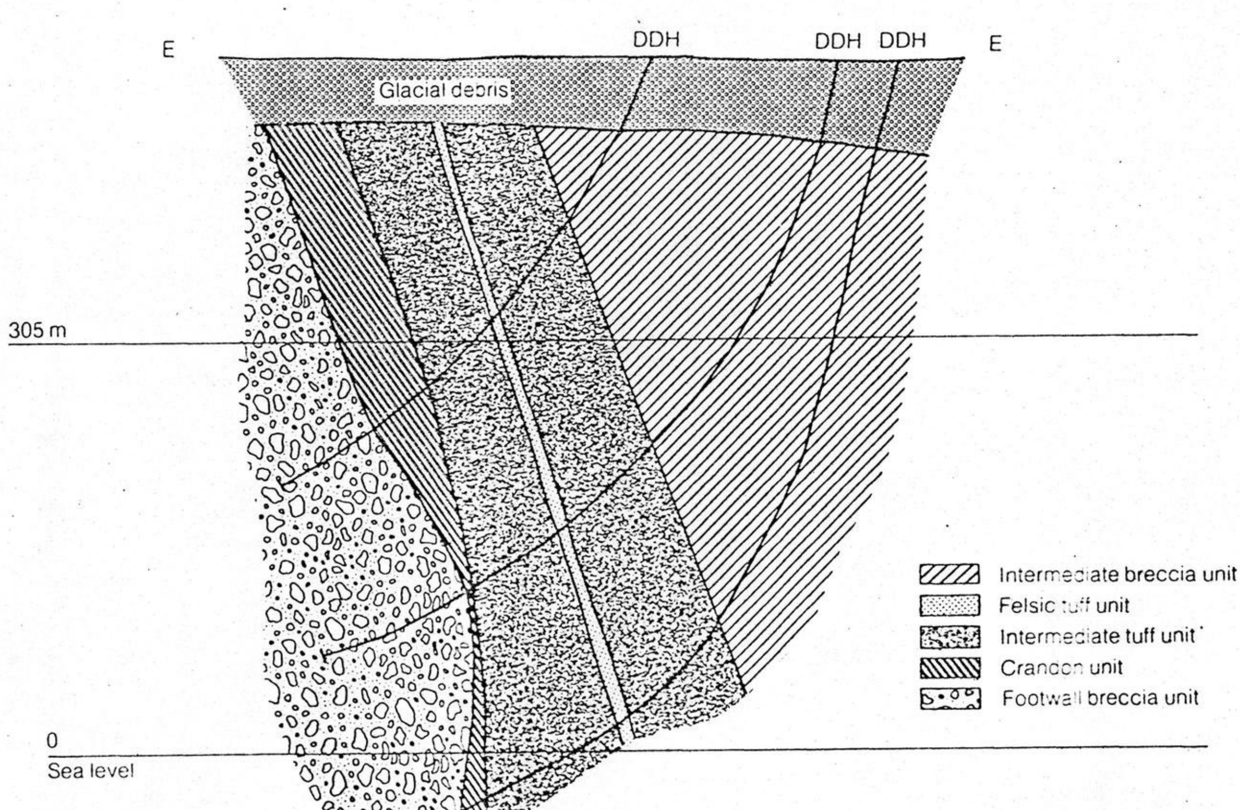
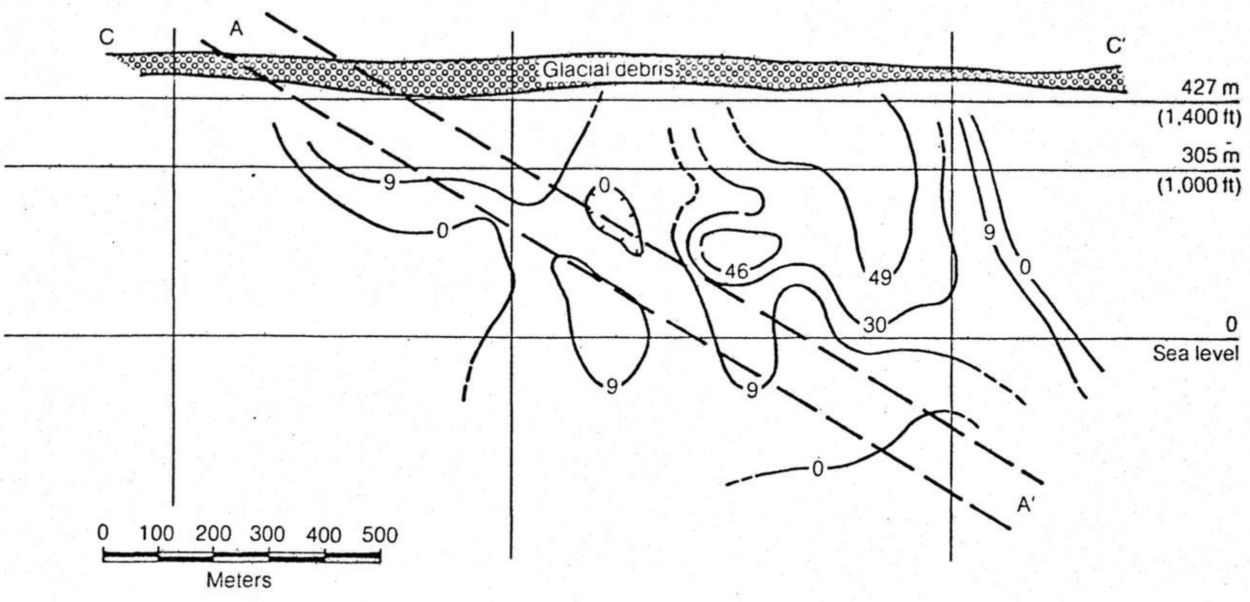


Fig. 6—Massive sulphide ore isopach (meters)

(longitudinal vertical section looking north)



lapilli-rich beds, clast size decreases to the east and with depth. The whole unit also becomes more sedimentary in character to the east and with depth. This unit varies in thickness from 0 to more than 300 m.

Several **felsic tuff and lapilli tuff beds** are interbedded with the intermediate tuff unit and the overlying intermediate breccia unit. The rocks vary from 0 to 90 m thick and are best developed on the western end of the deposit (Figs. 3 and 4). Toward the east, they become thinner, more cherty, and more sedimentary in character and usually contain 2-5% pyrite by volume.

The **felsic flow unit** is a porphyritic dacite occurring at the western end of the drill area (Figs. 2 and 4). The dacite is believed to be an extrusive unit, as it contains beds of sedimentary rock up to 1 m thick.

The **intermediate breccia unit** is composed of andesite to dacite and may be a coarse facies of the intermediate tuff unit (Fig. 4). These rocks are characterized by highly contorted, thin, alternating silica-rich and chlorite-rich bands.

The **intermediate flow unit** is composed of fine-grained, massive andesite flows that are stratigraphically the highest rocks intercepted in the drilling and are known from only a few of the drillholes.

Gabbroic intrusions have been intercepted in the eastern part of the drill area (Fig. 4). They range up to 40 m thick and commonly have chilled margins and a diabasic texture in the centers. Contact metamorphic effects are limited to 3-6 m in the intruded rocks. The intrusions are interpreted as being post-metamorphic bodies.

Fig. 7—Plan of massive and stringer ore

(elevation 427 m)

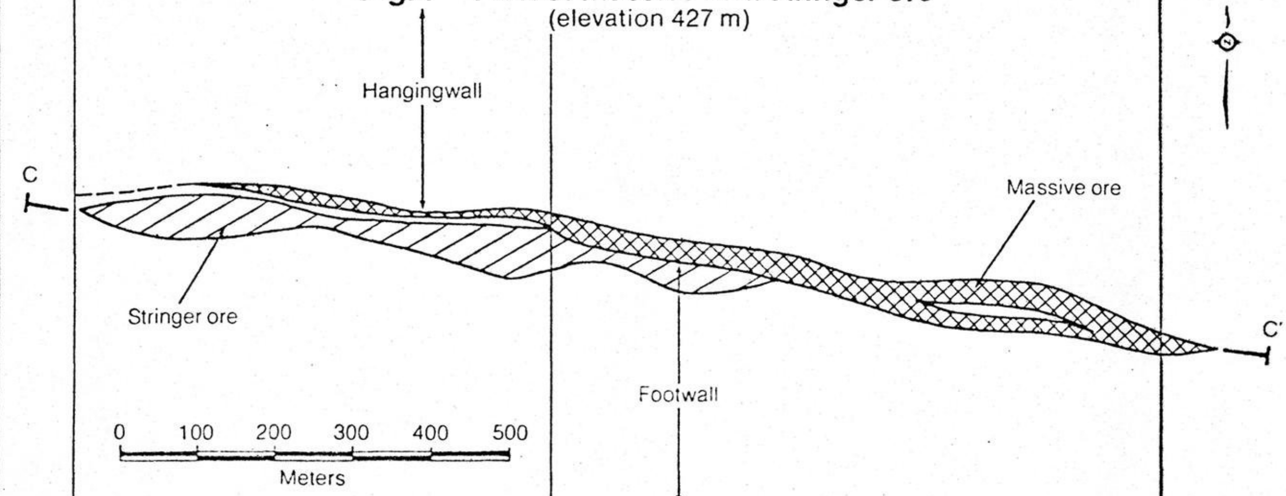


Fig. 8—Stringer sulphide ore isopach (meters)
(longitudinal vertical section looking north)

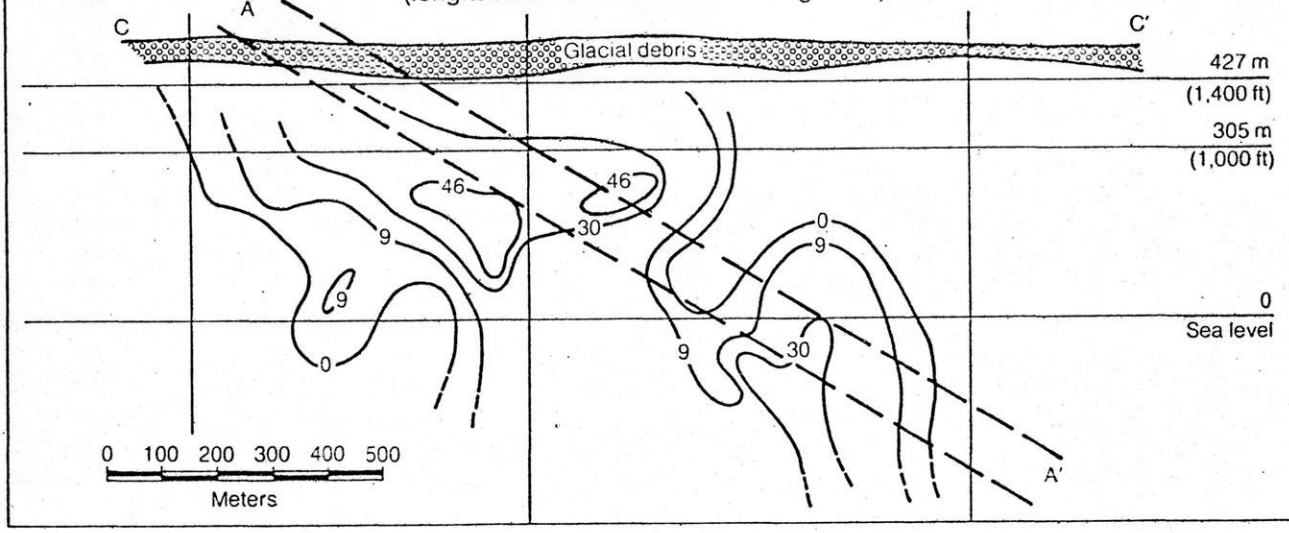


Fig. 9—Massive sulphide ore, zinc:copper ratio
(longitudinal vertical section looking north)

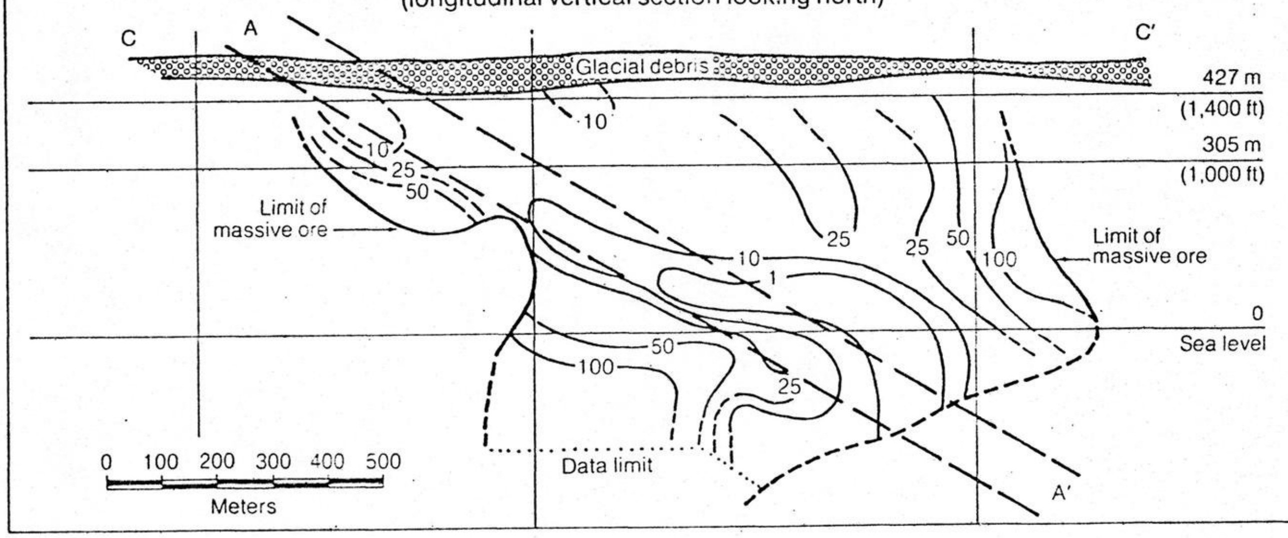
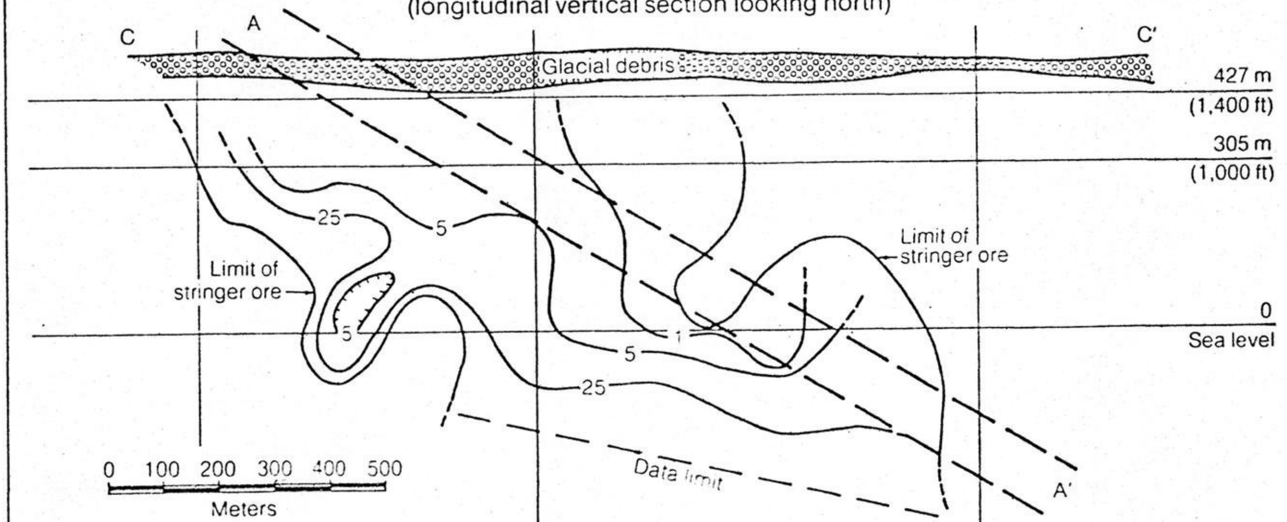


Fig. 10—Stringer ore, copper:zinc ratio
(longitudinal vertical section looking north)



Metamorphism and the ore zone

Low greenschist facies metamorphism has affected all rocks except the gabbro. Mineral assemblages are typical of the quartz-albite-muscovite-chlorite subfacies. Deformation associated with regional metamorphism is expressed in core as stretched clasts and small-scale folds.

The stringer sulphide zone contains evidence of hydrothermal alteration, which is expressed by silica flooding, quartz-siderite-sulphide veining, chlorite-pyrite rims around rhyolite clasts, and patchy zones of very fine-grained sericite alteration of rhyolite. Areal extent of the alteration has not yet been defined.

The Crandon orebody, as defined by an assay boundary, is an elliptical lens 1,500 m long, averaging 30 m thick and extending at least 500 m below surface. It strikes N85°W, dips 85°N, and rakes 50°E. The orebody consists of a conformable and continuous massive sulphide layer partly underlain by a stringer zone.

The massive ore (Fig. 6) averages 20 m thick and is 60-90% sulphide minerals, primarily pyrite, sphalerite, chalcopyrite, and galena. The massive sulphide zone is irregularly weathered down to 45 m below the bedrock surface. This zone contains minor amounts of supergene minerals, such as chalcocite, covellite, bornite, native copper, and native silver. Aside from iron, metal in the massive ore is predominantly zinc, with lesser values of copper, lead, silver, and gold. The stratigraphic top of the massive sulphide body is sharply defined and closely corresponds to the top of the ore. However, the base of the ore zone is irregular.

Zinc-rich portions of the massive ore are laminated to thinly bedded sphalerite and pyrite. Some of the pyrite in the laminae has a colloform or botryoidal texture. Color of the sphalerite varies between amber and dark reddish-brown. Chalcopyrite is usually coarse-grained and preferentially associated with pyrite.

The western half of the massive sulphide lens is underlain by stringer sulphide ore (Fig. 7), containing both contorted and planar quartz-sericite-chlorite-sulphide veins. About half of the tonnage in the Crandon orebody is stringer ore. Most stringer ore is in apparently conformable breccia units, commonly adjacent to or within 30 m of the bottom of the massive sulphide layer. However, stringer ore may be separated from the massive sulphide unit by as much as 120 m of footwall felsic rocks. The combined stringer ore intervals average 23 m thick (Fig. 8). Aside from iron, the metal content is predominantly copper, with lesser zinc, lead, silver, and gold. Sulphide minerals in the stringer ore are pyrite, chalcopyrite, sphalerite, and minor galena, pyrrhotite, and arsenopyrite.

The orebody is distinctly zoned. The massive ore contains more zinc and lead and less copper than does the stringer ore. Within the massive ore zone, there is no apparent systematic variation of zinc-to-copper ratios normal to stratigraphy. But in cross section the zinc-to-copper ratio increases laterally away from zone A-A′ (Fig. 9).

In the stringer ore zone (Fig. 10), the copper-to-zinc ratio decreases as zone A-A′ is approached. The metal zoning in both stringer and massive ore suggests an elongate plumbing system coinciding with zone A-A′.

Genesis of the deposit

The geologic history, as interpreted from the stratigraphy, suggests the following sequence of events:

1) Explosive rhyolitic volcanism depositing what is now the footwall breccia unit.

2) Cessation of local explosive volcanism, deposition of black shale, and development of local submarine fumarolic activity, causing hydrothermal alteration of footwall breccia rocks and deposition of stringer and massive sulphide mineralization.

3) Deposition of the intermediate tuff unit, indicating continuing, more distant volcanic activity.

4) Increasing nearby volcanism, expressed by the felsic units, the intermediate breccia unit, and the intermediate flow unit.

5) Dynamic metamorphism, which tilted the rocks to their present near-vertical position.

6) Intrusion of gabbro.

7) Erosion, weathering, and glaciation.

Geologic observations indicate a submarine-volcanic-exhalative origin for the Crandon ore deposit. Some of these observations:

- The association of ore with felsic and intermediate volcanic products.
- The strata-bound nature of the massive sulphide body.
- The presence of a hydrothermally altered and mineralized zone beneath the massive sulphide body.
- Simple ore mineralogy, which is zoned.

These are characteristics common to volcanogenic massive sulphide deposits in the Canadian Shield and elsewhere. □

Acknowledgement

The authors wish to thank the management of Exxon Minerals Co. USA for encouragement and support and for permission to publish this report. We also wish to thank the many colleagues who helped in the effort that led to the discovery of the Crandon deposit.

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2) Sims, P. K., "Middle Precambrian Age of Volcanogenic Massive Sulfide Deposits in Northern Wisconsin," 22nd Annual Meeting, Institute on Lake Superior Geology, 1976 (abstract).

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EXXON MINERALS COMPANY

CRANDON PROJECT

LEGISLATIVE COUNCIL COMMITTEE ON MINING

January 11, 1981

AGENDA

Welcome and Introduction	R. L. Russell Project Manager
Geology and Mine Engineering	J. E. Grimes Senior Mining Engineer
Surface Plant Engineering	B. J. Hansen Technical Services Manager
Environmental Affairs	J. A. DeMarte Chief, Environmental Affairs
Socioeconomics	D. J. Derfus Socioeconomic Study Supervisor

Questions and Answers

Tour of Office

Showing of "To Protect Tomorrow"

REPORTS SUBMITTED TO THE DNR

EXXON MINERALS COMPANY, U.S.A.

CRANDON PROJECT

August 5, 1977	DAMES & MOORE PERSONNEL BIOGRAPHICAL DATA
	DAMES & MOORE FIELD NOTES
	AIR DATA REPORT
	DAMES & MOORE AIR QUALITY TESTING PROCEDURES
November 4, 1977	SUGGESTED AIR QUALITY MONITORING LOCATIONS
November 21, 1977	TECHNICAL PROJECT PLAN FOR ENVIRONMENTAL STUDIES FOR THE CRANDON PROJECT DATED NOVEMBER 14, 1977
February 7, 1978	ENVIRONMENTAL CRITERIA AND METALLURGIES ON TAILINGS DISPOSAL SITE SELECTION
March 20, 1978	INTERIM REPORT ON PHYTOPLANKTON AND ZOOPLANKTON
May 5, 1978	SURFACE WATER QUALITY DATA SHEETS FOR STATIONS E, G-1, H, M-2, AND S
June 16, 1978	DEVELOPMENT OF IDAHO GUIDELINES FOR MINE AND MILL WASTE DISPOSAL THROUGH 208 PLANNING--A CASE STUDY
August 9, 1978	INVENTORY OF ENVIRONMENTAL DATA COLLECTED PRIOR TO JULY 1, 1978
September 18, 1978	INFRARED AERIAL PHOTOS COVERING PRIMARY AREA OF ENVIRONMENTAL INVESTIGATION
December 18, 1978	"MASTER SCHEDULE" FOR EXXON'S CRANDON PROJECT
January 22, 1979	SITE AREA SELECTION FOR CONCENTRATOR FACILITIES
January 22, 1979	SCOPE OF WORK: LAKEFIELD RESEARCH OF CANADA--FOR VARIOUS METALLURGICAL TESTING AND DEVELOPMENT WORK
	GOLDER ASSOCIATES INC.--FOR PRELIMINARY ENGINEERING TAILINGS DISPOSAL
	RALPH M. PARSONS CO.--PHASE II ENGINEERING SURFACE FACILITIES

REPORTS SUBMITTED TO THE DNR

EXXON MINERALS COMPANY, U.S.A.

CRANDON PROJECT

	KILBOURN ENGINEERING LTD.--PHASE I, WATER MANAGEMENT STUDY
February 28, 1979	SITE IDENTIFICATION FOR DISPOSAL OF TAILINGS, PHASE I
	CONCENTRATOR SITING STUDY REPORT
	SCOPE OF WORK: FOR ENVIRONMENTAL RELATED CONTRACTS
March 15, 1979	RESULTS OF SPLIT GROUND SAMPLES TAKEN AT WELLS DMB 1A 4-78 AND 18
March 23, 1979	LIST OF BORINGS RE: WATER LEVELS AND/OR QUALITY
April 9, 1979	1' = 1000' SCALE MAP OF DMA DMB SERIES OF BORE HOLES IN THE ORE BODY
May 1, 1979	SITING REPORT FOR DISPOSAL OF TAILINGS
May 7, 1979	LETTER TO ROY TULL RE: CRANDON ORE BODY AND PROCESSING METHODS DATED MARCH 16, 1979
May 14, 1979	ENVIRONMENTAL MOVIE
June 17, 1979	DRAFT TECHNICAL PLAN
June 19, 1979	ANALYTICAL DATA FOR SPLIT GROUND QATER
June 28, 1979	MINE AND CONCENTRATOR WASTE CHARACTERIZATION STUDIES FOR THE CRANDON PROJECT
July 9, 1979	ORTHOPHOTO-TOPOGRAPHIC MAPS AND AERIAL COLOR INFRARED PHOTOGRAPHS OF THE CRANDON PROJECT REGION
July 12, 1979	DATA ON OPTICAL CHARACTERIZATION AIRBORNE PARTICULATES
July 17, 1979	AERIAL PHOTO LEGEND MAPS OF CRANDON PROJECT REGION
July 17, 1979	ORTHOPHOTO-TOPOGRAPHIC MAPS AND AERIAL PHOTO LEGEND MAPS OF THE CRANDON PROJECT REGION
July 20, 1979	PRELIMINARY COMMON NAME SPECIES D & M LISTS FROM ENVIRONMENTAL BASELINE DATA FOR THE CRANDON PROJECT STUDY AREA

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REPORTS SUBMITTED TO THE DNR

EXXON MINERALS COMPANY, U.S.A.

CRANDON PROJECT

August 14, 1979	PRELIMINARY SCIENTIFIC NAME SPECIES D & M LISTS FROM ENVIRONMENTAL BASELINE DATA FOR THE CRANDON PROJECT STUDY AREA
August 31, 1979	BIOLOGICAL LEACHING OF SULFIDE ORES
	PRATICAL ASPECTS OF BIOLOGICAL LEACHING STUDIES
	PREDICTION OF ACID GENERATION POTENTIAL
	B.C. RESEARCH BROCHURE
September 6, 1979	HOUSING STUDY OUTLINES
November 7, 1979	ARCHAEOLOGICAL RESEARCH IN THE POTENTIAL EXXON MINERALS COMPANY, U.S.A. MINING AREA, FOREST AND LANGLADE COUNTIES, WISCONSIN
	ADDENDUM TO DAMES & MOORE TECHNICAL PROJECT WORK PLAN
	SCOPE OF WORK - PHASE II WATER MANAGEMENT STUDY (CH2M HILL CONTRACT)
January 17, 1980	ORTHO-TOPOGRAPHIC (OTM) MAPS OF CRANE, LILY, JUNGLE AND BRADLEY LAKES
	ENTIRE EXXON OTM SEPIAS
	WETLANDS MAP (1' = 1000')
	WETLANDS MAP (1' = 400')
November 6, 1980	PRELIMINARY PROJECT DESCRIPTION-VOLUME I

1/12/81 jq

REPORTS SUBMITTED TO THE GENERAL PUBLIC

EXXON MINERALS COMPANY, U.S.A.

CRANDON PROJECT

November, 1977	040-1-C	SITE SELECTION STUDIES FOR DISPOSAL OF TAILINGS PHASE I
November 18, 1977	040-2-C	SITE AREA SELECTION STUDY FOR CONCENTRATOR FACILITIES
April 13, 1978	048-3-E	TECHNICAL PROJECT PLAN, ENVIRONMENTAL STUDIES
July 3, 1978	043-2-A	PRELIMINARY DRAFT REPORT OF SOCIOECONONMIC STUDIES
July 28, 1978	048-4-A	DATA INVENTORY
August 10, 1978	048-2-A	ENVIRONMENTAL BASELINE STUDIES
September 1, 1978	043-4-B	ARCHAEOLOGICAL RESEARCH IN THE EXXON MINERALS COMPANY, U.S.A. MINING AREA OF FOREST AND LANGLADE COUNTIES, WISCONSIN
September 14, 1978	043-3-A	SOCIOCULTURAL STUDIES, A SUPPLEMENTAL REPORT TO THE PRELIMINARY DRAFT REPORT OF SOCIOECONOMIC STUDIES
September 15, 1978	043-1-A	PRELIMINARY DRAFT REPORT OF LAND USE BASELINE STUDIES
January 1979	040-1-D	SITE IDENTIFICATION STUDIES FOR DISPOSAL OF TAILINGS - PHASE I
April 1979		DRAFT TECHNICAL PLAN--CRANDON PROSPECTING PROJECT EXXON MINERALS COMPANY, U.S.A. CRANDON, WISCONSIN
December 1979		DRAFT STUDY PLAN
September 1980		DEFINITION OF LOCAL STUDY AREA
September 1980		REVISED STUDY PLAN
October 1980		SURVEY RESEARCH METHODOLOGY
November 1980		SOCIOCULTURAL METHODOLOGY
		PRELIMINARY PROJECT DESCRIPTION-VOLUME I
		SITING REPORT FOR DISPOSAL OF TAILINGS--CRANDON PROJECT

1/12/81 jq

REPORTS SUBMITTED TO THE GENERAL PUBLIC

EXXON MINERALS COMPANY, U.S.A.

CRANDON PROJECT

DRAFT STUDY PLAN SOCIOECONOMIC ASSESSMENT

MINE AND CONCENTRATOR WASTE CHARACTERIZATION STUDIES FOR THE CRANDON PROJECT

PHASE I PILOT PLANT PROGRAM--CRANDON PROJECT

NATIVE AMERICAN METHODOLOGY

FISCAL METHODOLOGY

DEMOGRAPHIC METHOLDOLOGY

SURVEY RESEARCH RESULTS

METALLIC MINING COUNCIL MEETING BOOK
MEETING MAY 29, 1979

MICHIGAN TECHNOLOGICAL INSTITUTE, SEMINAR ON MINE PLANNING, VOLUME I AND II, FEBRUARY 12, 1980

CRANDON PROJECT GREEN BOOK, UPDATED NOVEMBER 26 1980 AND JANUARY 8, 1981

SOCIOECONOMIC REPORT STATUS
January 9, 1981

NAME	DATE RELEASED	STATUS
Draft Study Plan	December 1979	Available
Definition of Local Study Area	September 1980	Available
Revised Study Plan	September 1980	Available
Survey Research Methodology	October 1980	Available
Sociocultural Methodology	November 1980	Available
Native American Methodology	--	Given to DNR-Will Be Released in 1 week
Fiscal Methodology	--	In Review-Expected in 3 weeks
Demographic Methodology	--	In Review-Expected in 5 weeks
Survey Research Results	--	Being Prepared by RPC, Inc. Expected in 6 weeks

o Other Methodologies, Baseline Data Report, reports of results, and community reports will be out later.

o All reports expected to be published by the autumn of 1981.

DJD:eaf