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MINING IN ALASKA-  
ENVIRONMENTAL IMPACT AND POLLUTION  
CONTROL

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Draft - Final Report

Submitted to the U.S. Bureau of Mines

by

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June 1975

The opinions expressed are those of the author and not necessarily those of the U.S. Bureau of Mines, M.I.R.L. or the University of Alaska.

No patents were applied for or inventions made during this study.

## ABSTRACT

Environmental factors affecting mining are difficult to establish in Alaska due to the absence of large scale hard rock mining activities at the present time. Currently, experience is gathered from (and to a large degree based on) construction of above ground facilities such as roads, pipelines and buildings.

Past mining activities appear to have had little lasting effect on the natural environment, the exceptions being mine tailings and surface structures.

This report, sponsored by the U.S. Bureau of Mines, present general engineering activities, considers the interaction of permafrost and underground mining, summarizes available literature and indicates possible environmental problems that might be encountered in Alaska based on Scandinavian experiences in large-scale northern mining operations. How the Scandinavians are solving their problems is also discussed.

#### ACKNOWLEDGEMENTS

This paper was sponsored by the U.S. Bureau of Mines, Contract No. 0133059. Mr. Bruce I. Thomas, U.S. Bureau of Mines, Technical Project Officer in Fairbanks, has been very helpful, and his wise comments based on his extensive Alaskan mining experience was greatly appreciated.

A thanks also goes to the Director, Associate Director and Staff of the Mineral Industry Research Laboratory, University of Alaska, for their support.

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## INTRODUCTION

The Mineral Industry Research Laboratory was awarded the U.S. Bureau of Mines Contract S 0133059, Mining in Alaska - Environmental Impact and Pollution Control, on the 8th of June, 1973. The Laboratory was charged with analyzing selected mineral deposits in Alaska that may be brought into production in the near future. Environmental problems associated with developing these deposits under Alaskan climatic conditions were to be investigated and solutions suggested. Lost River and Bornite were specifically mentioned as two such possible areas. However, it would appear at the present time that neither prospect is likely to be brought into production in the immediate or near future.

At present, the Alaska hardrock mining industry is quiescent because of the current land situation. Until the status of the land under the Native Land Claims Settlement Act has been clearly established, there is little evidence that any new large-scale mining operation will take place. Many of these factors are currently being studied by others (22). Questions of access across federal and native selected land are also under debate at the present time, as is the question of taxation of mineral and petroleum resources in the ground.

For these reasons, it is difficult to specify specifically the effect of the environment on mining operations and the impact of mining per se on the environment under Alaskan conditions. This study, therefore, has concentrated on a literature search and on the more general possible relationships between climate and permafrost on the one hand and mining practices under northern conditions on the other. The study also addresses revegetation of mine tailings, construction practices, environmental considerations, mining and exploration parameters with specific reference to Lost River and Bornite.

The issue of environmental protection versus mining is an old one (an example is found in Appendix C) which revolves around conflicting human values. For Alaska, the issue appears at the present time to be somewhat ephemeral, since there is very little evidence of environmental damage caused by mining operations; even the dredge tailings from the gold mining in the Interior of Alaska are becoming revegetated, the impact of current placer operations on stream water quality may be debatable. Scandinavian experiences suggest that large scale mining operations can be compatible with protection of the environment, including factors such as vegetation, animal life and water quality.

The issue quite often breaks down into individual value judgement. An abandoned mining operation can be looked upon as a historical monument or an eye sore depending on the person looking.

As a final note, it is likely that mining activity in Alaska will increase over the next decade, when the land status has been decided and the mineral deposits and reserves are better known. It is possible that the energy and mineral shortage facing the United States will be an added incentive developing oil, coal and mineral deposits. In the Yukon Territory in Canada, mining is taking place on a fairly large scale, and Alaska will probably also see increased mining activity. The oil and gas development in Alaska may be of added help to further mining activities; the haulroads related to the pipeline construction may in time provide better access to known mineralized areas and may also open other areas to more thorough exploration efforts.

Mining in the North faces problems not found at lower (and milder) latitudes. This report points out some specific solutions based on the experience gained by companies and individuals engaged in mining in the far North, both in Europe and North America.



## CLIMATIC PARAMETERS

Alaska spans several different climatic zones, ranging from the mild, rainy southeast to the cold and windy North Slope. Any mining operation will be affected by climate to some degree, and the following is a very brief description of the climate in the various parts of Alaska. The information is largely from the Environmental Atlas of Alaska by Johnson and Hartman (11). In addition to pure climatic data, the Atlas also contains engineering design data and as such is a valuable research tool for anyone interested in engineering activity in Alaska.

From an engineering viewpoint Alaska may be divided into several regions based largely on climatic factors. Variations within each region due to topography may be of course expected. It must be emphasized that the data presented herein must be taken as guidelines only, guidelines that generalize the region, rather than pointing out variations that may occur within any region.

The regions considered in this section are listed below and shown on Figure 1.

- A. Southeastern Alaska
- B. Southcentral coastal areas
- C. Aleutian Islands
- D. Alaska Range and Coast Range Mountain Systems
- E. Yukon - Kuskokwim Delta
- F. Interior Alaska
- G. Brooks Range
- H. North Slope

The impact of climate on a mining operation depends on the type of operation; i.e. surface mining versus underground, and the ore handling system employed at the mine. Climate may also affect personnel working at a mine. The effect of the winter darkness in the north, the total darkness for varying lengths of time north of the Arctic Circle, affects people to varying degrees. The effect is often magnified by the remoteness of the mine or the settlement. The principal investigator of this study had the opportunity to observe this over a winter in a small community in Europe at about 70°N and found that the darkness made some people less productive in their work, sometimes to the point that they had to be transferred to the south because they posed a physical threat to their fellow workers. Communication with mine managers in North Norway and North Sweden points out similar experiences with a small portion of the transient work force, while people who permanently reside in the region are less affected if at all. The latter is especially true of people born and raised in the region.

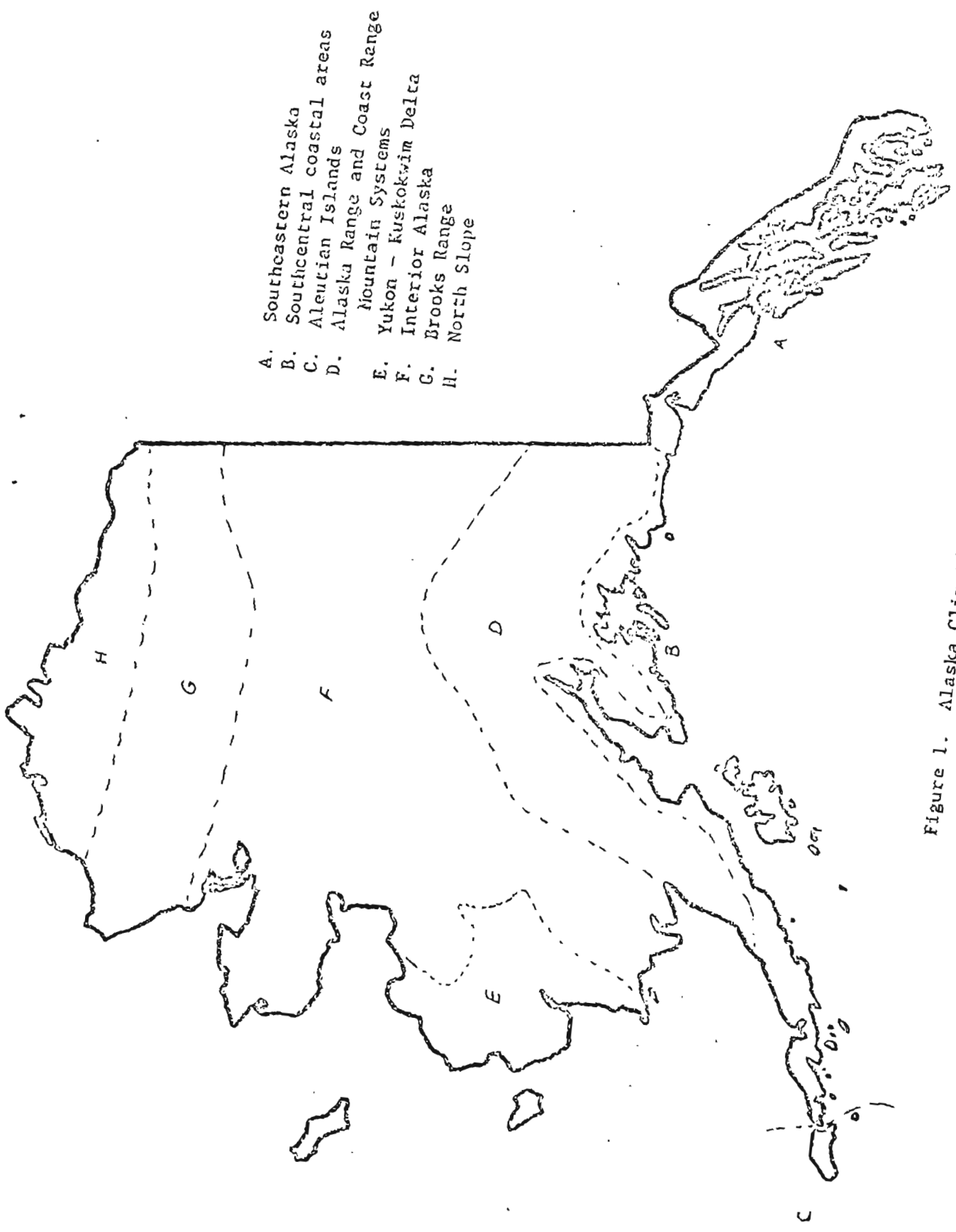


Figure 1. Alaska Climatic Regions.  
 Modified for Engineering Purposes.

Another climatic factor affecting Alaska is the time of freeze-up and break-up of the Bering and Chukchi Seas. The north coast of Alaska is accessible only by ocean-going vessels about two months out of the year, and even then, the Arctic Pack-ice may prohibit ship movement for periods of time. Table 1 is reproduced from Clark (3) and gives a summary of the ice conditions around Alaska.

As an example of the impact the ice conditions have on shipping, a comparison between Svalbard and North Alaska may be useful. Svalbard has a much longer shipping season, and coals from Svalbard are shipped to the European market for about 75 years, subjected to and limited by the non-climatic conditions on the high seas such as wars.

The effect of this lack of easy access to ocean shipping necessitates overland transportation of the minerals, coals and oil of North Alaska. The impact of these transportation modes are discussed in two MIREL reports: Clark's (3) as mentioned and also one by Wolff et. al. (18).

## Alaska Climatic Regions

### A. Southeastern Alaska

This area, sometimes referred to as the "panhandle", is characterized by a mild, maritime climate. Mean annual precipitation can be in excess of 220 inches per year in some places in the southern parts. The winters are mild, at least at lower elevations, mean annual temperatures range from about 45°F in the south to about 35°F in the north. January temperatures at places near sea level may go as low as 0°F, but this is a rare occurrence. At higher elevations, glaciers are present and a correspondingly cool climate exists. High winds may create problems at exposed locations. The problems experienced with icing and the blowing down of transmission towers on the power line from Snettisham to Juneau verified this.

### B. Southcentral Coastal Areas

The area has a maritime climate, similar to that of Southeastern Alaska. Mean temperatures are slightly lower, the January means range from about 34°F to about 0°F and July means range from 46°F to 64°F. The colder January and warmer July temperatures occur inland, away from the moderating influence of the ocean. The mean annual temperature for Anchorage is about 35°F. Permafrost is absent with these temperatures. Relict ice may, however, be found. In the Anchorage area, masses of ice, possibly of glacial origin, may be found buried in the morainal soil. Houses built on such ice masses have experienced severe settlement, and in some cases necessitated moving the structure to a new location.

### C. Aleutian Islands

The Aleutian Islands have a cool, maritime climate. High winds and fog are common. Permafrost is absent.

Table 1<sup>†</sup>

## Dates of Ice Break-Up and Freeze-Up

Location	<u>Ice Break-Up</u>			<u>Ice Freeze-Up</u>			<u>Ice Free Months</u>		
	<u>Ave.</u>	<u>Earliest</u>	<u>Latest</u>	<u>Ave.</u>	<u>Earliest</u>	<u>Latest</u>	<u>Ice Free</u>	<u>Light Ice</u>	<u>Heavy Ice</u>
Golovin Bay	May 23	May 13	June 14	Nov. 2	Oct. 8	Nov 19			
Teller-Port Clarence	June 7	May 12	June 18	Nov. 10	Nov. 13	Dec 26	*3	*4	*5
Kotzebue	May 31	May 17	June 8	Oct. 23	Oct. 2	Nov 5			
Point Hope	June 20	May 30	July 8	Nov. 11	Oct. 6	Dec 19	**3	**4	**6
Point Lay	June 24	June 1	July 10	Nov. 4	Oct. 12	Nov 27	**2.5	**3	**6.5
Wainwright	June 29	June 7	July 26	Oct. 2	Sept. 26	Oct 9	*2	*3	*7
Point Barrow	July 22	June 15	Aug 22	Oct. 3	Sept. 31	Dec 19	*2	**3	**7

\*Source - U.S. Coast Guard, Polar Transportation Requirements

Source - U.S. Coast Pilot No. 9, 1964

\*\*Estimated from above sources

<sup>†</sup>After Clark (3) M.I.R.L. Report No. 31, May 1973.

#### D. The Alaska Range and the Coast Range

Climatic data for the higher elevations in these mountain systems are sparse. With elevations ranging from sea level to that of Mt. McKinley, changes towards progressively more Arctic conditions takes place with increase in elevation. The area, especially in the south has significant rainfall, glaciers are common at higher elevations throughout the mountain ranges. In the Copper River Basin, permafrost is present, while in the more open Matanuska Valley, permafrost is generally absent. At higher elevations and northward permafrost is more and more extensive.

#### E. Yukon - Kuskokwim Delta

This large portion of Alaska is generally underlain by continuous or discontinuous permafrost. A large portion of the region is wet tundra, low lying and marshy with numerous lakes.

#### F. Interior Alaska

The Interior is characterized by extreme temperatures; a typical continental climate. Winter temperatures may go down to  $-60^{\circ}\text{F}$  or less and cold spells where the maximum temperature may be  $-40^{\circ}\text{F}$  may last for weeks. Summer temperatures on the other hand may go up to in the 90's. Permafrost underlies most of the area, but may be absent at favorably located southfacing slopes. The mean annual temperature for Fairbanks is about  $25.8^{\circ}\text{F}$ . This creates the additional problem of "warm" permafrost in places. The permafrost is close to melting and only a minor surface disturbance may trigger a thaw condition. The Fairbanks area has several such areas where farming or small mining operations have changed the soil temperature and induced melting of ice-rich permafrost producing often spectacular thermokarst features.

#### G. Brooks Range

The elevations in the Brooks Range are lower than those of the Alaska Range. The amount of precipitation is much less. The Brooks Range has as a result few glaciers, although the winter temperatures are quite low. Valleys in the Brooks Range, especially to the south, do support timber, but the climate may be more severe than Interior Alaska. The Range is north of the Arctic Circle with midnight sun during part of the summer and perpetual darkness in part of the winter.

#### H. North Slope

The climate of the North Slope is well known from the publicity given the oil development in Prudhoe Bay. High winds, drifting snow and low temperatures along with perpetual darkness characterize much of the winter. The summers are cool and short. Mean annual temperature is about  $10^{\circ}\text{F}$  with  $45-52^{\circ}\text{F}$  being the mean July maximum temperature. The annual precipitation is low, less than 20 inches per year.

This brief discussion of the climate in various parts of Alaska shows indirectly how climate may affect an operation. The added cost of keeping machines running under extremely cold conditions is one of the many well known problems of Northern operations.

## CONSTRUCTION AND MINING ACTIVITIES IN THE ARCTIC

### General

Most construction or mining activity in the Arctic and Subarctic regions will be influenced to some degree by permafrost, seasonal frost, and other climatic parameters. In addition, the remoteness of the location found at most such activities raises other problems. These include personnel problems, high turnover rates and also local access to needed labor and supervisory personnel, cost of living problems to the higher capital costs and the inventory costs of maintaining an operation in the North. Wolff and Johansen (20) have outlined the differential in some of these parameters. For inventory and capital costs over those in western U.S., the percentage will be about 400% and 2-300% respectively. In addition to this, there is also the added cost of transporting the commodities to market. The long transportation adds to the cost which will have to be discounted somehow; the world price of a commodity is the governing price or value for that commodity.

This particular problem is taken up in two MIREL reports: one by Wolff et. al. (18), the other by Clark (3). Implied in both of these reports is the thought that commodities with a low value per unit weight, such as coal will not be mined at a profit because the transportation costs are so large. With the current world price of coal at the present level, coal mining in the Brooks Range may not be economically feasible, unless a government subsidized operation were to take place.

The picture for metals is better in that here the end product may be a concentrate or pure metal, the latter necessitating a smelter at or near the mine. With an integrated approach to mineral development, such an effort could indeed be feasible. Rhoads (21) in his paper discusses the feasibility of using local fuel for smelter operations in the Brooks Range, thus producing blister copper at or near the mine for shipment to tidewater.

### Cold Weather Construction Practices

There is substantial literature available regarding cold weather construction practices. For true Arctic conditions, there is less written information readily available, much exists as in-house information in agencies, public and private, engaged in engineering in the Arctic.

Such information may be well known locally, but is not always known outside the area. An example of this is reflected in the licensing of registered professional mining and civil engineers in Alaska where passing a University of Alaska course in Arctic Engineering or writing an acceptable paper about permafrost engineering to the Board's satisfaction is required

before obtaining an Alaska license, either by examination or by reciprocity from another state.

The United States Army Cold Regions Research and Engineering Laboratory (USA CRREL) publishes numerous reports and papers related to cold and Arctic conditions. Anybody considering working in the Arctic ought to study a bibliography of available CRREL publications; chances are that some helpful information regarding a specific (or general) problem is available.

Havers and Morgan (8) in a study undertaken for CRREL discuss cold weather practices in some detail. This particular publication is also of value because of the extensive bibliography it contains. The authors discuss the effect of cold and Arctic conditions on men, materials, equipment planning, earthwork, concreting, masonry, structural steel erection, timber construction, plastering, exterior painting, roofing, waterproofing as well as economic feasibilities. Environmental considerations are implied throughout the report. Parts of several of the sections are directly concerned with mining activities, especially the section related to the operation of equipment under severe weather conditions and also earth moving of frozen rock or soil, either in permafrost or seasonally frozen

Another good source of information is the National Research Council of Canada, Division of Building Research. The Division has published numerous papers dealing with the interaction of building and construction in general and permafrost.

Another U.S. source is the Environmental Protection Agency (E.P.A.).

The Alaska Water Laboratory has put out several reports regarding environmental impact on river and waters from construction and other activities. One paper by Lotspeich (14) considers the impact of road construction. The reports states as its purposes to:

Compile and describe the best practical measures required to assure environmental protection during road construction under cold climate conditions. The report is intended to aid the road construction agency and highway engineer in establishing and meeting environmental protection requirements. In addition, the report will inform the general public, resource managers, and equipment operators of the impact of road construction on water quality and the means available to lessen this impact.

Professional journals are another source of information. A paper by Li (13) focuses on general principles of Arctic Construction, especially the permafrost regions. He lists:

1. A knowledge of genesis, historical evolution and physical revelations of the composition and structure of permafrost, ground ice, and terrestrial and marine glacial aspects.
2. A knowledge of the physics, physical chemistry, geomechanics

properties, their mechanical properties, the state of unfrozen water, water migration, ice lensing and diffusion.

3. A knowledge of surface and ground water flow patterns, recharge and discharge phenomena, salt water intrusion and salt-fresh water interphase, as well as activity of layered ground water, water occurrence and quality, waste-water disposal and recycling and tracer techniques.
4. A knowledge of the energy exchange, heat flow, the geothermal properties of permafrost formations, as well as their thermal response to natural and man-modified environmental changes, and the thermodynamics of phase change.
5. A knowledge of regional and local occurrence distribution, and variation of permafrost, both areally and vertically, and its terrestrial, marine, climatic and terrain aspects.
6. A knowledge of photogrammetric, remote-sensing, and geophysical surveys and mapping of the surface and subsurface of permafrost regions and their responses to such geodetic techniques.

These points, although written with the construction man in mind, are equally applicable to mining operations in the Arctic. Changes in the thermal regime, for instance, will yield the same result whether caused by mining operations or construction. For mining operations in the Arctic, a thorough knowledge of the conditions as outlined above is an absolute necessity. Li's paper is also of value in that he lists several what he terms "group references" of recent dates dealing with Arctic construction.

#### Permafrost and Underground Mining Operations

The areas of Bornite and Lost River both lie within the continuous permafrost zone in Alaska. Sainsbury (26) reports the permafrost at Lost River to be to at least 200 feet below the surface. Any underground mining operations will hence be affected by permafrost to some degree. The Society of Mining Engineers' Mining Engineering Handbook gives some general information (19) (20). Specific information is currently gathered by the Mineral Industry Research Laboratory. A M.I.R.L. team (consisting of Drs. Lambert and Lynch) visited the coal mines at Svalbard in the summer of 1974. Their findings are included in another study (27). However, some of Lynch's observations of mining practices are of interest here (Lynch, personal communication).

Problems with underground mining in permafrost will fall in several categories, some of the more typical ones, especially related to permafrost are:

- a. Loss of strength of the rock upon thawing.
- b. Discontinuities in the permafrost especially those containing



water or pockets of thawed ground within the permafrost.

- c. Change in ground strength parameters upon penetration of the permafrost layer and entering the thawed ground below.
- d. Dust suppression.
- e. Ventilation.
- f. Handling of frozen ore.
- g. Filling of old works with ice.

The coal mines operated by Store Norske Spitzbergen Kulkompani A/S at Svalbard may serve as an example on some of the problems in Arctic underground mining, although coal mining will also have other problems (gas) that metals mines may not have.

With one exception, the Norwegians mine coal within the permafrost zone. The roof support problems are thus minimized as long as the roof stays frozen. The major roof support problems are related to degradation of the permafrost. This degradation takes place from two sources. The mine opening penetrates the shallow, active layer where annual freeze-thaw conditions and associated roof support problems exist. Further in the mine, possible thaw conditions exist until the surrounding permafrost rock (at about  $-4^{\circ}\text{C}$ ) cools the air to below freezing temperatures.

In another mine, now closed, a portion underneath a glacier was outside the permafrost zone and water problems existed here, but this was handled by normal pumping. In permafrost, dust suppression may be a problem. Water is of limited value and the ice formed if water was to be used may do more harm than good. The Russians did use water for dust suppression, their argument being that freezing problems in the mined coal would not be of any magnitude as long as the moisture content was below about 7%; the mining operation is not a high speed cutting operation. If the mining methods were changed, some new problems involving frozen moisture may occur.

When the permafrost coal is mined out, the Norwegians have traditionally abandoned the mine. The Soviet mining operations by Arctic Ugol' at Svalbard are below the permafrost, one mine being below sea level and another being in the sub-permafrost layers. Again, according to Lynch, the mines seemed to have no typical problems due to ground temperature.

The area of ventilation has two schools at Svalbard, the Soviets in winter blow heated air into the mines, the Norwegians exhaust air. Again, national mining practices as well as peculiarities with the depoists are probably the reasons for these diametrically opposite ways of ventilating the mines. The Norwegians using their method for mining permafrost coal are thus minimizing the thaw by introducing warm air into the mines, the Russians being out of the permafrost may be less affected by the warmer air entering the mine.

Another problem in permafrost, as well as in areas of seasonal frost, is refreezing of broken ore. Controlled use of water and circulation of hot air may solve this problem for each individual mine in operation. In North Central Norway at Rana Gruber, at the Arctic Circle and in an area of heavy snowfall, this problem has largely been solved in the design of the ore bins. In Svalbard, the problem is handled in the stock piling process. The frozen pile is exposed to the summer thaw, successive layers "shaved" off and shipped out.

A final problem with permafrost mines is water or rather ice development in the mine. Abandoned works get filled with ice making reopening of the mine a difficult and time consuming task.

This same phenomenon may be used to an advantage in Arctic Mining Operations. Fangel (24) in a paper outlines a method whereby ice would support the walls and make the roof thus turning an open pit operation into an underground operation. The downward mining progress kept ahead of the ice creep. By adjusting the underground openings to adjust the ice flow Fangel maintains that variations in progress rate could be accounted for and material brought to the surface at acceptable rates. The method, he suggests, may be of value in areas close to permafrost or colder, where natural cooling would form and maintain the ice rather than relying on refrigeration to obtain and maintain the ice.

#### Environmental Consideration

The conservation and preservation of the Alaskan environment, especially the tundra has received considerable publicity since the Prudhoe Bay oil discovery. This publicity has served to focus public attention to some of the problems of the North, especially biological aspects such as revegetation, disruption of migratory routes for caribou and also the slow rate of waste decay. This public attention has often lead to pressure of non-development and especially an anti-mining and petroleum development. This is further discussed in Appendix C, a historical footnote to our current dilemma.

Research on the mining and exploration activities in Alaska are being carried out more or less continuously. A quote from a report by Grybeck, Peek and Robinson (6) is of interest. The quote is a comment from a participant in their investigations regarding a study of the cost of exploration for metallic minerals in Alaska. The participant states:

More consideration needs to be given to preserving the environment during exploration such as:

- a. Hauling out old gas cans and not leaving them sprinkled over the countryside.
- b. Leaving clean camp sites; hauling in (sic) all leftover gear and debris.
- c. Not leaving debris at remote sites where helicopters land.

Crews need to respect the property of local miners, prospectors, residents, etc. They should not disturb cabins and equipment around them, even if they appear abandoned.

There is no question that the Arctic environment is sensitive to pollution. The problem is compounded by two factors:

1. The often one-way type of operation, and as already stated,
2. The slow degradation of materials in the north.

An extreme example of the latter may be the preservation of Pleistocene Mammal remains in the permanently frozen silt (locally termed muck) in the Interior Alaska. The pollution problem is circumpolar; a discussion of European Arctic experiences is found in Appendix B of this report.

Another of the problems of the Arctic is the availability of water. The Arctic regions have low precipitation and reliable sources of water for a year-round operation may be difficult to obtain in many instances. MIREL Report 31 by Clark (3) makes a brief outline of the problem (3, p. 15):

Rivers east of the Colville River in the Arctic Coastal Plain have numerous braided channels, whereas rivers west of the Colville meander sluggishly in valleys 50-400 feet deep (Wahraftig, 1965). Most streams in the Arctic Foothills have swift braided courses across broad gravel flats. The major rivers of the Brooks Range flow north to the Arctic Ocean, and south to the Kobuk, Koyukuk and Yukon Rivers.

The many small lakes on the Arctic Coastal Plain are limited to low volume utilization because low annual precipitation results in slow replenishment rates. In most areas, permafrost to depths of over 1000 feet prevents the formation of any subsurface water (Parker, 1972).

In winter, ice cover of approximately 6 feet builds up on all surface water bodies. Many streams are locally covered in winter with extensive sheets of anchor ice. Even in the largest rivers, flow in winter is approximately 5 per cent of the summer flow (see Fig. 8).

Water is available from lakes which do not freeze to the bottom and from unfrozen aquifers beneath the rivers. Williams (1970) reported that aquifers in the Colville River yield from several hundred gallons per minute from alluvium to less than ten gallons per minute from bedrock.

Mining operations in the Arctic will be of several kinds: open pit, underground or placer operations. Each of these operations will have a potentially added impact in the Arctic. Placer mining operations have been a source of discontent for decades. Much of Alaska's early mining industry was placer mining and the impact of placer mining on the aquatic environments is a source of several papers.

The Alaska Water Laboratory published in 1969(2) a report regarding the effects of placer mining on water quality in Alaska. The report limits its discussions to placer operations in the interior of Alaska. Six representative districts were considered, namely:

1. Fairbanks District
2. Tolovana District
3. Iditarod District
4. Seward Peninsula District
5. Koyukuk District
6. Wiseman District

These areas are shown in Figure 2. The findings of the report is as follows:

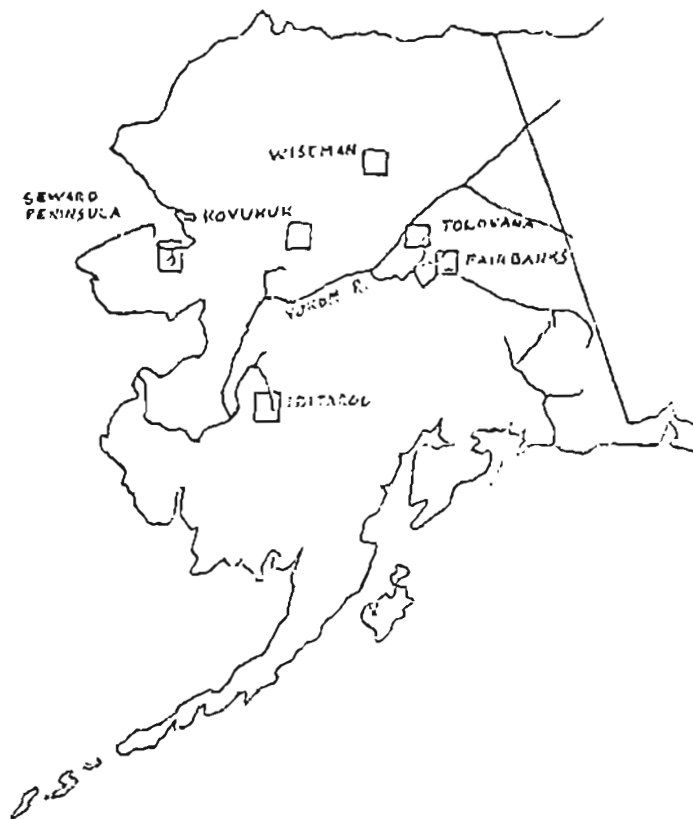


Figure 2. Index map showing mining district examined (2).

1. Clear, clean and biologically productive water of excellent quality was found in most streams above the influence of mining operations and in streams where there were no mining operations.
2. Significant populations of fish and/or fish-food organisms were found associated with the clean water above mining operations, but were absent or found in significantly reduced numbers in the highly turbid and silt-laden stream below mining operations.
3. Mines and mining operations can produce physical and water quality barriers that prevent the upstream migration of fish.
4. The sediment load from one mine can interfere with the utility of the water supply for downstream mining.
5. Hydraulic stripping operations greatly increase the loading of suspended material as measured by turbidity, and can reduce the oxygen level in a stream to zero.
6. When the overburden is mechanically stripped and stockpiled, less water quality degradation results than from hydraulic stripping operations.
7. The number of mines and total gold production in Alaska has been declining for many years, and in 1967, the income from gold mining in Alaska accounted for less than one percent of the value of total mineral products, and less than 0.3 percent of the value of total resource products.
8. A substantial rise in the price of gold would increase the number of placer mines in Alaska.
9. Few, if any, mines provide treatment for the wastes generated from their stripping and sluicing operation.
10. Settling ponds can be effective in improving water quality by reducing turbidity.
11. The distribution of sluice box effluent over old placer mine workings via numerous small streams reduces the turbidity of the waste through the process of sedimentation and filtration.
12. Changes in stream gradients resulting from mining operations have in some cases caused erosion to exist for many years.

The reports presented four general conclusions. They are as follows:

1. Placer mining operations degrade downstream water quality as evidenced by an increase in turbidity, a reduction in dissolved oxygen (D.O.), and a resulting significant reduction of fish and fishfood organisms.

2. The major impact on water quality from placer mining comes from the hydraulic stripping operation.
3. The termination of mining operations do not necessarily eliminate water quality degradation.
4. Techniques for the control of sediments from mining operations are available but are generally not being employed at the present time.

Pollution in the form of silting has been and is a source of studies in Alaska. Many streams are glacier-fed and hence naturally will carry a heavy load of silt.

A study by Guymon (7) focuses on the natural sediment yield of Alaskan streams. Such data is of value in evaluating the environmental impact of engineering works on rivers, lakes or coastal areas. The study also looked at the water supply potential of sediment laden streams and the sedimentation in lakes, either natural or man-made reservoirs. In an unpublished paper, Forrest (4) looks in detail at some parameters, especially their application to the Interior Alaska. He looked at:

- Topsoil disturbance or removal
- Subsoil disturbance or removal
- Relocation of soils
- Silting in streams
- Effects of removal of vegetation (especially surface vegetation)
- Changes in pH and/or hardness of water
- Effect upon ground water level
- Effect upon stream water level
- Changes in stream and lake geography
- Possible pollutants introduced due to mining activity

Forrest points out that the major source of stream pollution is caused by the removal of the muck, the organic silt that typically overlies the gold bearing gravels in the Interior of Alaska. By hydraulic removal of the muck, both turbidity (silt) and B.O.D. are introduced into the stream. The result is a reduction in the D.O. of the stream, values of zero have been reported (4). In addition, the high turbidity reduced the amount of light that would benefit aquatic plants in their photosynthesis.

The silt itself also has a detrimental effect on the fish life, reducing the fish population by blanketing spawning grounds and interfering with the operation of the gills. In Alaska, there is a well known fact among sports fishermen that the clear streams support fish (grayling). The silt laden, glacier fed streams do not support fish to the same degree. Streams carrying the effluent from placer mining operations can be compared with these glacier fed streams.

Personal communication (in 1974) with local placer miners, however, brought out disagreement with the statement that the high turbidity downstream from placer operations is detrimental to fish life to the same extent.

Although there is some siltation the levels were compatible to the normal load carried by many streams and as such no significant environmental impact from the placer operation occurs.

Quite often miners would point out the benefits from a placer operation in changing the environment. The dredge tailings around Fairbanks may be used as a case-in-point.

The washed gravels left by the placer mining operations are now a source of construction material. The tailings further present a better foundation material for structures than does the ice rich organic silts formerly forming the upper portion of the unconsolidated deposits filling the river valleys in the Interior of Alaska. In the natural stage, the permafrost level in these mucks may be just a few feet below the surface.

The increase price of land and the increased building activity in the Fairbanks area in connection with construction of the Trans-Alaska Pipeline shows the new use of the tailings. The ice rich permafrost valleys are still undeveloped while substantial use is being made of the tailings area, both as sources of construction materials and as homesites as well.

Greenwalt (5) wrote a short paper regarding the environmental changes caused by the dredging operations in the Fairbanks area. He used the tailings at Fox as an example. Before onset of the dredging operations, the terrain was like that which can be observed along the unmined areas of Coldstream, just north of Fairbanks. The area is characterized by permafrost, muck, black spruce type vegetation. The animals living here were moose, squirrels and carnivores like fox, lynx, wolf and blackbear. Human activities have had the most marked effect on the carnivores. Lynx and wolf are essentially missing, these animals being the most sensitive to human occupation. An occasional blackbear can still be found. Fox is less affected by human occupation and the tailings support a fox population similar to what existed before the onset of the mining operation and subsequent human influx in the area.

The moose population is favored by the mining operation. The change in vegetation to deciduous trees from evergreens and the occurrence of the many ponds with associated aquatic plants favor the moose. Squirrels, on the other hand, experience some decline by the change in vegetation and topography.

Similar observations can probably be made for other mined-out areas in the Interior.

In other parts of Alaska, the picture may be different due to a different climate and topography.

The mine tailings in the Juneau, Alaska, area were the subject of a brief paper by MacKinnon (16). This area is outside the permafrost area of Alaska and is located just outside Juneau along the Gastineau Channel. The tailings are unvegetated, sandy, and present a poor foundation material.

When the Alaska-Juneau Company was operating, they experienced problems with their stackers sliding into the Channel as the rock pile failed due to the added weight. In the early twenties, a Standard Oil bulk plant on the shoreline slid into the channel with the loss of one life. Currently the mine tailing delta is used for a golf course, the world's largest sandtrap some local people call it. Additional use is oil storage tanks and a radio tower. Some efforts have been made trying to revegetate the area, but the combination of climate and type of tailings make this difficult.

Open pit operations may impose other problems. The only major open-pit operation in Alaska at present (1975) is the Usibelli Coal Mines at Healy. This operation is probably not typical with respect to problems with mining in the far North. The coal mining operations at Svalbard (Appendix B) cannot be termed typical either, they are underground and as far as the Norwegian mines are concerned, mostly within the permafrost layer.

In an unpublished paper, Jirik (10) points out some considerations for coal mining in a permafrost region. He admits that the available information is meagre, but nevertheless, his observations are interesting, and should be given consideration. Jirik is concerned with the coals in the Cape Beaufort area. This is an area where continuous permafrost is present. It is likely that the North Slope coals will be mined at some future date, at least, there is some exploration activity at the present time and also consideration of mining for domestic purpose by local villages in the area. Jirik's list of potential problems include:

1. Change in the thermal regime by changing of the topography by piling of cast overburden.
2. Change in the surface by changing (stripping) of vegetation and subjecting areas to possible thawing, subsidence and/or erosion.
3. Generation of acid mine waters. This may or may not be a problem, he states, because the coals are low sulphur coals and the amount of precipitation is low. But, ironstones have been reported and the possibility of some acid mine drainage does exist.
4. Slope stability is another concern. Permafrost may be a help or a hindrance here. This very subject is currently investigated by the Mineral Industry Research Laboratory, University of Alaska (26).

Jirik did not consider management decisions regarding mining operations. Proper understanding of the interactions between the mining operations and the environment may significantly reduce the environmental impact of some or all of the factors he mentions. An example is the mining method proposed by Fangel (24) using ice for wall support and mine roof as well.

Both underground and open-pit operations may have a tailings disposal problem. The interactions between tailings and permafrost are not fully understood, but research (25) is going on to find solutions. Some of the construction problems on the Trans-Alaska Pipeline can be correlated to a



similar problem, the interaction between a fill (tailing) and the permafrost ground (ice rich or dry).

The final solution to the mining vs. environment question is in part legal.

Lenarz (12) in a short paper dealing with his own opinions regarding the present mining laws presents several points that are well worth considering.

He points out that on the State (Alaska) level there are only two restrictions which a miner must follow:

1. A miner is not allowed to damage any stream or lake important to the spawning of anadromous fishes, and
2. If the claim is located in a watershed above an inhabited area, he (the miner) must comply with the guidelines set down by the Alaska Water Pollution Control Act.

This is an oversimplification, but the points may be well taken if one looks at the problem like Lenarz from a preservation point of view.

These laws have some effects on operating mines, but they are ineffective in dealing with abandoned mines. Lenarz writes that evidence of former mining operations will remain for a long time and as such the "wilderness" aspect of the area is ruined. He further suggests that wilderness itself has a value, maybe higher than that of the minerals contained in that area. He suggests setting areas aside for wilderness areas and periodically review these areas in light of the national needs for minerals. The sentiment he expresses have been voiced by Agricola (1) in 1556, but the conflict is intensified by the population increase. A more complete summary of Agricola's views are found in Appendix C. Lenarz and many with him claim that wilderness is a natural resource all by itself and ought to be considered as such. The way human population patterns emerge in the U.S. with the significant increase in urbanization, wilderness areas where one can "get away from it all" may be one of the many prices one has to pay for this change in population patterns.

## MINING AND EXPLORATION PARAMETERS

With the need for new materials, fuels and better use of existing materials, all putting pressure on the known, often limited non-renewable natural resources, the world is headed toward a major conflict. If the developing nations were to develop a similar material standard as the western world enjoys today, the pressure on development of natural resources will be incredible. This conflict is expressed in a paper by Park (17). He states:

p. 1. According to the United States Bureau of Mines we now import some of 90 mineral commodities that we consume. The country depends entirely upon imports for several of these critically needed commodities, for example, manganese, tin, and chromium. Others, such as nickel, titanium in rutile, and fluorite are produced in part domestically, while a few such as molybdenum, phosphate rock, and sulfur are in surplus and available for export. Imports of many mineral commodities have been increasing at the rate of about 1% a year; domestic production is unable to keep up with growing demands. The dependence of the United States on foreign sources for both metallic and nonmetallic thus is slowly increasing and gives cause for considerable thought and concern. Not only are we importing more; we are also curtailing our domestic output by restricting areas where prospecting and mining are permitted and by causing smelters to close. For example, at least 5 zinc smelters have closed in recent years and no new ones have been built. Growing imports contribute appreciably to an already serious adverse balance of payments and hence to the problems of inflation. Is the United States sure enough of its import sources so that it can afford to penalize or discourage production from its domestic deposits?

p. 8. People in recent years have rediscovered the environment and, without studied consideration of the consequences, have decided that things must change, not at a reasonable rate but at once under a crash program. Many well meaning organizations, commonly made up of reasonably affluent educated middle class people, have formed highly vocal and effective lobbies aimed in part at establishing clean air and clean water, but also at preserving in primitive condition for posterity, very large areas of government owned lands. How far toward "preservationism" can the United States afford to go? Our standard of living require that our resources be used. What is wrong with the concept of multiple use of land?

Certainly mining has made thoughtless mistakes in judgement in the past and is now being forced to correct these past errors. Industry can no longer allow sulfur smoke to escape unhindered into the atmosphere, "acid mine waters" to drain into the waterways, nor dusty tailings to blow around. It is being pressured to landscape in an acceptable manner such things as abandoned open pits and tailing dumps. Bulldozer cuts and other ways of defacing the countryside must be

avoided as far as possible. These corrections make good sense from a national standpoint but the cost of the changes and the time involved in their implementation must be taken into consideration. We cannot afford to shut down the mineral industries and must remember that when the final products are sold they must still be competitive with foreign products. To clean up the environment takes time, is going to be very expensive, and is bound to divert funds from badly needed exploration and research. It should also be pointed out that some of the techniques necessary to attain the desired environmental standards are as yet imperfectly developed.

This pressure has brought new interest in the Arctic and Northern Regions as one of the two remaining terrestrial frontiers (the other being the tropics) for minerals and fuels to be exploited while hopefully other methods for a more equitable distribution of natural resources will take place over the next decades, as well as bringing new technology into the picture thus relieving the enormous pressure on natural resources utilized in the conventional manner.

But development of Arctic resources is not easy. Large areas are only known on a reconnaissance basis, mineral deposits that may be mineable are probably still waiting to be found. An indication is the current U.S. Bureau of Mines sponsored research on mineral evaluation of the southern Brooks Range.

This area of the Brooks Range has also been investigated in the past. One of the earliest accounts dates from 1902 and is written by Walter C. Mendenhall (25). M.I.R.L. Report No. 16 (9) is one of the newer references to the mineralization of the region.

In this report there are references to the copper mineralization along the southern flank of the Brooks Range:

p. 11. The major interest in this mining region at the present time is the development of a copper deposit in the Ruby Creek area at the west end of the proposed railroad route. This is the largest known Alaskan Copper Reserve. After more than ten years of exploration and testing of this deposit, the Kennecott Copper Corporation has purchased the property and established a division to plan for production. Access roads and camp facilities have been built. Underground exploration is underway (Kennecott Ann. Rept., 1966).

The Kobuk region that contains the deposit at Bornite is the scene of much prospecting and exploration for copper. Reconnaissance and drilling over an east-west distance of more than 200 miles is currently in progress.

Later in the report, p. 274, there is another brief mention of some background regarding the copper mineralization around Bornite.

On the Alatna River, within the schist belt, copper sulfides were noted by the U.S. Geological Survey (Bull. 815, p. 117) but the occurrence

does not seem to have been important. In the 1940's, Ernest Johnson of Bettles found what he described as a fairly large deposit of copper ore but he did not consider that any copper deposit in that remote area had any prospective value.

It may be argued that the indications of base metal ore bodies along the southern flank of the Brooks Range are indefinite and remarkably few in number for a supposedly favorable belt some 500 miles long. The argument would seem to be strengthened by the fact that the belt has had its share of prospectors - in 1893 there were about 800 prospectors in the Kobuk Valley (USGS Bull. 815, p. 321) and an estimated 1,000 men in the Koyukuk Valley (USGS Bull. 442, p. 238). Of approximately 55 placer deposits with recorded production of gold, nearly all were discovered before 1905.

However, this argument fails when consideration is given to the history of Kennecott's copper mine at Boronite. That deposit was discovered about 1900 but it was well over sixty years after the original discovery before a prospector (Reinhardt Berg) realized a reward for his stamina, skill and persistence in demonstrating the value of the discovery. Obviously, there was no incentive to develop base metals during the short lived waves of prospecting around the beginning of this century when men were searching for the rich, shallow gold placers that had made poor men wealthy in the Klondike and on the Seward Peninsula. There was no market for a base metal mine; a market for gold was no farther than the nearest trading post.

Kennecott's purchase of Berg's prospect is the first sign that a market for mines in the more remote parts of Alaska is finally being realized. That the market will grow and grow rapidly is evident from all forecasts of the future mineral requirements of the United States. For example, Secretary of the Interior Stewart L. Udall noted that the people of the United States in the last thirty years had used more minerals and fuels than all of the people of the entire world had used previously - and that our requirements for the next thirty years will likely be double those of the past thirty years (Wash. D.C., Jan. 10, 1966, Address to American Mining Congress).

To meet the national need, the less accessible parts of the United States must be made accessible, and the nearly forgotten prospector must be induced to return to the hills. These must be done before a mineral shortage begins to cripple the nation's economy. Provision of reliable transportation to potentially productive but as yet unproven areas of Alaska may be less of a gamble than the failure to do so; incentives for prospectors are a worthwhile governmental investment (as has been proven in Canada).

Here it is interesting also to note the warning regarding a potential mineral shortage, a theme repeated in Park's (17) paper and currently (1974) considered by the U.S. government. Two of M.I.R.L.'s more recent reports deal with other aspects of Alaskan mining. In Report No. 29, Wolff et. al. (18) mentions the copper deposits and devotes a short section to this deposit.

p.9

## Copper

Since the early 1950's, the area north of Shungnak, on the Kobuk River in the Baird Mountains, has been under exploration and development for copper. This area probably has the greatest potential for copper at present of any in Alaska, and no doubt would be further advanced towards production if transportation was available. At present, numbers cannot be assigned to grade or reserves, but indications are that it will become a major producer of copper. There is little doubt that the area is a prime target of a transportation system.

Copper mineralization extends eastward from the Bornite area all the way into the Koyukuk and Chandalar districts. For the purposes of this study, it is assumed that there is a 75% chance that a major copper deposit will be discovered somewhere near the headwaters of the eastern Koyukuk or western Chandalar drainage.

In trying to assess the need for power from a dam across the Yukon at Rampart, it was postulated that mines in the Tindir group near the Canadian Border north of Eagle could be to little justification for this statement. Equipment and supplies for exploration in this area would probably be moved at first by river and tractor train, later by a road north from Eagle.

The Fluorite deposit at Lost River has received considerable publicity over the last several years, but currently, not much is being written about the mine. The following is a summary of M.I.R.L. Reports regarding the mineralization in the western part of the Seward Peninsula, the Peninsula made famous by the Nome goldrush.

## M.I.R.L. Report No. 18 (15):

This report was written before the Lost River fluorite deposits were considered for mining. The report states (p. 32):

Known Alaska tin resources (Figure 3) are not large but they constitute the only significant tin resource known in the United States. The Seward Peninsula contains the only known lode tin deposits in Alaska; Lost River, Potato Mountain, and Ear Mountain. Cassiterite is the principal tin-bearing mineral in the lodes and placer deposits of the region. Tungsten, fluorite, and many other minerals are associated with lode tin in the western part of the Seward Peninsula.

It was also reported (Sainsbury, 1964, p. 50) that all inferred ore reserves at the Lost River mine of more than one percent combined tin and  $WO_3$  are in the Cassiterite and the Ida Bell dikes. If the ore shoot continues from the mine's 195 foot level to the 265 foot level at a projected rake, it may contain as much as 80,000 tons of inferred ore that will average about 1.5 percent tin. However, no operation depending upon inferred ore should be undertaken until sufficient exploration and development is done to verify this tonnage estimate. The inferred ore in the extension to the east, according to Sainsbury (1964, p. 51) is approximately

430,000 tons.

Potential tin-tungsten resources in the Lost River Mine area are resources whose average assay value is below one percent tin or combined tin and tungstic oxide. Under favorable economic conditions and technological advance or in the event of strategic necessity, these tin-tungsten resources together with other metal by-products might be exploited.

Further on p. 18 it refers to the Seward Peninsula mineralization:

Reserves are estimated at 36,750 tons of metal at 0.2% to 1.3% at Lost River and only a few thousand tons at Ear Mountain, Cape Mountain, and Potato Mountain. If mining is resumed and continued there should be a good chance of extending the reserves.

At the Lost River tin mine, significant amounts of commercial fluorite and beryllium were discovered. Total estimated resources are about two million tons of 50% fluorite, most, if not all of which could be economically recovered as byproducts of the tin mining.

A reference to the fluorite is found in M.I.R.L. Report 29 (18):

The Lost River area on the Seward Peninsula has long been known to contain tin, but recently other associated minerals have come to the fore. The Lost River Mining Company has announced plans for developing its fluorite deposits at Lost River. According to its annual report (McQuat, 1972) they now have 28 million tons of ore with an average grade of 18.6%  $\text{CaF}_2$ . The Company expects to upgrade this ore to a concentrate containing about 85%  $\text{CaF}_2$ . The mining rate is expected to be about 2,000 tons per day of ore, producing about 300,000 t.p.y. of concentrates. It is expected that the above reserves will last 20 years. According to the annual report of the Company, there is an excellent chance of increasing reserves. Preliminary plans call for building a port at Lost River and using a 30,000 ton semi-icebreaker ship making one trip per month for up to 10 months. Tin, tungsten and beryllium would be produced as a by-product; tin and tungsten ore estimated to make up one half of the value.

The Lost River activity has subsided the last several years, and this year (1975) no activity at the site is reported. The finalization of the plans listed above seem to have been postponed to some future, yet unspecified time.

Of the two properties of specific interest in this report, it would seem, at least from the news releases in the press, that the copper in the Brooks Range may be brought into production before the fluorite in the Seward Peninsula.

## CONCLUSIONS

To be able to specifically pinpoint potential pollution problems related to mining activities, the specific mining and ore processing methods employed at the mine site will have to be known. In the cases of Lost River and Bornite, it is yet too early to tell what the final decisions regarding these parameters might be.

For Lost River, one of the constraints on the development is the amount of water available. This potential problem may be more severe should a major development take place at the site; however, these plans seem to have been shelved, at least for the time being. Should a major community be developed in conjunction with the Lost River mine, the associated pollution potential, especially to the marine environment, should be considered. The developments at Prudhoe Bay, however, show that preservation of the environment can be carried out even with a major development such as the North Slope oil fields. The expense is great, and the cost of the environmental protection is one that will have to be balanced against the value of the deposit; the revenue created by the operation of the mine or petroleum resource. At the present time, there is no activity at the Lost River site.

Bornite is in a somewhat more favorable position as far as the availability of water is concerned. Also from the environmental point of view, since no major development as originally envisioned at Lost River, the Bornite is in a more favorable condition. The reserves at Bornite are probably large, the mine may cover a large area. However, by using modern reclamation techniques, the environmental impact should be kept to a minimum.

Another factor which complicates the issue of the environmental impact of mining, especially in Alaska, is the intimate relationship between the mine operation and the access to the mine. The environmental impact of the access may be more objectionable than that caused by the mine itself, although the impact is often blamed on the mine. The environmental impact of the mining operation per se is usually small. The amount of land involved in the mining operation is usually quite small, environmental impact often relate to the disposal methods of waste from the mining and milling operations.

Some environmental damage or degradation from mining operation is probably unavoidable. The conflict has been with us for hundreds of years, and it is not likely that the arguments will quiet down over the next decades. With the pressure on development of natural resources on one hand and the need to preserve a quality environment for future generations we will see more arguments from both camps. Maybe Agricola said it best when he wrote "...it is not metals that are to be condemned, but our vices..."

## RECOMMENDATIONS

This paper has pointed out several general features of Alaskan mining. Some specific points to keep in mind are the following:

- A. Revegetation following the mining operation takes place, even if the reclamation efforts done by the mining company has been minimal. This is clearly seen in the Fairbanks area where the old dredge tailings support heavy growth of willow and birch in many places. If conscientious reclamation efforts are carried out, the regrowth is quite good. The present coal operations near Healy have carried out a highly successful revegetation project on their tailings.
- B. The total land area disturbed by mining operations is quite small in acres, however, the mining area, including access roads, may be eyesores, especially if the road has been cleared without regard to the ground conditions, i.e. permafrost, and littering has been taking place. But, like shown for the Trans-Alaska Pipeline road, controlled access and a dedicated effort to minimize environmental impact, have created a road that does not unduely disrupt the natural environment.
- C. A negative impact created by roads, is one of providing easier access to the land. Increased hunting and fishing pressures may follow, the results are seen around Fairbanks where increased population and increased hunting pressure have combined with natural causes created a significant decrease in certain species; moose being one such example, caribou another.
- D. Water quality is being affected by placer mining operation; however, the impact on clear water streams can be reduced using practices reducing the silt released into the waterway. Quite often the natural runoff is silty and mining operations do not really affect the stream. The latter is evident in glacier fed streams which naturally carry a heavy silt load.



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## APPENDICES

Appendix A: Bibliography - Lost River Area

Appendix B: Mining and Environmental Considerations  
as Practiced in Norway and Sweden

Appendix C: Mining vs. the Environment - A Historical  
Note

## APPENDIX A

### Bibliography - Lost River Area

This bibliography was in part compiled by a graduate student originally working on this project. Special attention should be focused on the work by Robinson and Patton, this being the most recent reference regarding the geology and environmental setting of the Lost River Area.

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permits (konsesjon) to operate a mine and the rules governing that particular mine (Bergverkskonsesjon). These two basically different types of regulations will be discussed in some detail below.

### Environmental Regulations

With the tremendous interest sparked by the North Sea oil development, there has been considerable pressure put on the Norwegian Government to open vast areas of the Norwegian Continental Shelf and the Continental Shelf off Svalbard as well as on Svalbard. This has resulted in regulations published by the Norwegian Government [8] and [9].

The booklet containing the environmental regulations for Svalbard is interesting in that it points out special features of the Arctic environment, features that are not commonly known (or anticipated) by people in milder climates. The regulations surrounding the Trans-Alaska Pipeline can serve as a U.S. counterpart.

The Norwegian booklet states in the general introduction, "Experience shows that violation of regulations and damage to the environment on Svalbard occur most frequently due to inadequate knowledge of the regulations and the special conditions in the Arctic". The book also contains several "do and don'ts":

9. The winter in the arctic attracts special attention. Food is limited and energy costs are high for mammals and birds. Do not chase them with snowmachines, aircrafts or helicopters because this may upset the energy balance of the animals and increase mortality.
10. It is normally no use burying garbage because the frost soon brings it to the surface again. Burn what is possible and bring the rest back or bury it in scree. Broken glass, can, wires and cables, etc. must not be left behind. Such waste is a continual threat to birds and mammals. Do not consider the sea as a garbage can. It will soon return the waste to the beaches.
11. If you come across a deserted camp which has not been cleaned up, please devote some time to cleaning it up.
12. Pay attention to the arctic environment. It is extremely vulnerable. Respect for the environment costs little and means much.

The booklet also contains general (and practical) information concerning Svalbard, population, administration, accommodations (there are none) and supplies among others. Other regulations specifically govern the exploration and drilling for petroleum and other resources on Svalbard [8]. These regulations are specific in outlining restraints to assure a safe exploration program. If, for example, petroleum is found, Section 50 is specific as to what to do:



## APPENDIX B

### Mining and Environmental Considerations As Practiced in Norway and Sweden

The summer of 1974, a three-man team from the Mineral Industry Research Laboratory had the opportunity to visit mines in Norway, Sweden and Svalbard to observe mining practices. This work was part of two contracts with the United States Bureau of Mines (S 0133057[1])<sup>1</sup> (S 0144117[2]). In addition to the primary objectives of the two projects, the trip also gave insight into the Scandinavian practices of environmental conservation vs. mining operations.

#### General

There are two departments of the Norwegian Government generally involved in the aspects of Mining and Environmental considerations. These departments are the Royal Ministry of Industry and Handicraft and the Royal Ministry of Environment. The legal basis for their operation is found in the Norwegian laws. The bulk of the laws pertaining to the mineral industries are contained in the following Acts, the Norwegian Mining Law [7] and the law regarding Protection of Nature [5]. Portions of other laws also influence the relationship between mining and environmental concerns. The National Building Law [4] and the law concerning Outdoor Life and Recreation [3] are two very important ones.

Other laws with bearing on the environmental aspects of mining are found in the law concerning relationships between neighbors and several laws dealing with air and water pollution [6], both from domestic and industrial sources. Another basis for regulations regarding mining and environmental issues are Royal Decrees (executive order). These are regulations established by the King (i.e. Executive Branch).

Based on these laws, the appropriate Ministry will issue regulations (Forskrifter) on how the law is to be implemented. These regulations are often quite detailed and points out how operations are to be carried out and also spells out appropriate safeguards and, of course, fines for not following the regulations. In addition to the general regulations, the Ministry of Industry through Office of Mines and Petroleum will issue the

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<sup>1</sup>Number in brackets refer to references listed in the attached bibliography to this Appendix.

The finding of petroleum shall promptly be reported to the Ministry together with the licensee's evaluation of it.

Complete information relating to the nature of the finding and what further steps the licensee has taken to determine the extent of the deposits and the results thereof shall be submitted in writing to the Ministry as soon as possible. Furthermore, information shall be given as to whether the deposits are considered commercially exploitable. As soon as a plan for the exploitation has been completed, it shall be submitted to the Ministry for approval.

Section 51. Wells where petroleum finds have been made shall be secured in a proper manner according to good oilfield practice, so as to facilitate production, to protect the well against penetration of water or other alien matter into the well, to prevent the escape of petroleum from the well, and to protect the surroundings and air against pollution.

#### Mining Concessions

The mining laws for Svalbard and Norway are quite different. The discussion below applies to Norway only.

The Ministry of Industry and Handicraft issues a concession which permits a company to operate a mine for a certain period of time, usually 50 years. After that, the concession goes back to the government free of charge. The basis for the concession is the Mining Law [7] and the detailed interpretations and rules based on the Mining Law.

The Mining Concession defines the company structure to some degree: "the head office shall be in Norway", "the board shall consist of Norwegian citizens," the company stock: "80% shall be in Norwegian hands". The document also specifies some of the key personnel needed to operate the mine (i.e. registered mining engineer, a mine foreman, etc.).

One section is devoted to the interaction between mining operations and environmental conservation. A typical concession may state that the company will, as far as possible and at company expense, protect plant and animals, geologic and mineralogical formations and other environmental assets. If the work unduely damages the environment for scientific studies, damage historical sites, the cost of exploring such sites are carried by the company. The company is also charged with making sure that the works are the least possible eyesore, this goes for the physical plant as well as the tailings disposal areas. At the close of the mining operation, the company has the responsibility of cleaning the area and of making openings safe for people and animals. The results of these regulations is a cooperative effort to preserve the environment, carried out by the mining company and the appropriate government agencies. This in turn has resulted in modern efficient mines

where concern and preservation of a quality environment has a high priority.

#### Examples

The copper mine at Repparfjord may serve as an example. Copper mineralization around the Repparfjord in North Norway has been known for centuries. In 1758, 60 pounds of "pure copper" were shipped out through Hammerfest customs office. The source of this copper must have been one of the many small high grade deposits in the area. The ore body which is mined at the Repparfjord mine was discovered about 1900 and was mined intermittently until 1913. Further exploration was carried out, but the results of these efforts were inconclusive and the operations were suspended. Eventually by the 1960's 10 million tons (metric) reserves at 0.72% Cu were delineated and this led to Follidal Verk A/S developing the present mine. The first construction work started in 1970 and in June, 1972, the mine was in full production. Design production is 600,000 tons (metric) ore per year or about 8-13,000 tons (metric) annually of copper concentrate with a copper content of 45 to 50%.

The mine lies at tidewater, about a mile from the head of the fjord. At this location a salmon river, Repparfjordelva, empties into the fjord. During our visit to the mine we saw several 15 lbs. salmon that had been taken out of the river. The mill tailings are being deposited in the fjord about one mile further out from the mine or two miles from the mouth of Repparfjordelva. In addition to the salmon fishing, commercial fishing is also taking place in the fjord. The tailings are deposited at about 60 m depth. An underwater pipeline carried the effluent from the mill to the site. The pipeline is about 20 m above the bottom and is arranged so that the disposal takes place over a 600 m length. To assure a fast settlement, a flocculating agent is added to the tailings. Reports from a diving bell at the disposal site verify the effectiveness of the method; there is essentially no turbidity at the site. Reports from people observing from the diving bell also indicate that the fish may even be attracted to the disposal area.

One of the iron mines visited, Sydvaranger, also disposes of tailings from the mill by depositing it in the fjord. In the case of this mine, no flocculating agents are needed, the tailing material is essentially all quartz, the magnetite ore is separated from the quartz magnetically.

In other mines in the interior of the Scandinavian Peninsula, tailings disposal using tailings ponds were utilized. The ponds were quite long downstream thus making the effluent clear and the water could either be reused in the mill or discharged into existing streams to maintain low flow or both. From an environmental and engineering standpoint, these solutions were adequate, any inadequacy would hinge on the "visual pollution" aspects. The aesthetics of an in part dry and dusty, in part wet and muddy tailing area are somewhat questionable. However, mine operation includes these aspects. (Some people would probably be equally or more distressed by an

open pit mine.) The local population accepts the mine and of course the associated tailing disposal area. The objections to it were raised by environmental groups from other parts of the country. As far as Alaska is concerned, the parallel is striking.

The big difference is the local attitude. The Northern parts of the Scandinavian Peninsula have been a source of raw materials and of trade in natural resources for more than a millenium. The Lapps with their reindeer herding also have the old hunting and fishing rights in the Interior, thus trading in fur and meat. The coast people traded in fish. Since the Thirty Year War (1618-1648) there has been an increasing interest in the mineral resources of the region. The Mineral Industry has a natural place in the economy and what may be considered environmental damage by certain groups is a way of life and an economic base for large segments of the local population.

There is a minor conflict between reindeer herding and mining. The mining operations sometimes occupy land used for grazing or the mine and associated road systems present an obstacle to the annual moving of reindeer from the interior to the coast, or winter grazing to summer grazing areas. These conflicts are settled in or out of court. (A small never-ending problem remains in trying to keep the reindeer out of a mine. Fences are set up with some success, but fences do not work if people forget to shut the gates.)

Bibliography - Appendix B

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## APPENDIX C

### Mining vs. the Environment

#### A Historical Note

The current energy and mineral shortages experienced in the United States the last few years and the opposition by environmental groups to resource development have served to focus public attention on what in fact is an ancient conflict between establishing a certain standard of living, and utilizing the earth's resources to maintain this standard. Quite often the two are viewed separately and as a result, people often lose sight of the interdependence of the two.

In our modern society where the service oriented functions employ the majority of people, it is not strange that our need for and dependence on minerals are often overlooked. The very small percents of the population engaged in agriculture and mining, the two basic industries, makes these industries very natural ones to overlook or downgrade in importance. The fear of developing is also fueled by the current discrepancy in resource utilization between the developed and the developing world.

This limited and often confused outlook is not new. In his book, De Re Metallica, published in 1556, Georgius Agricola devotes one "book", or chapter, to the subject of the importance of mining. The quotes from this "book" are taken from the 1912 translation by Herbert and Lou Henry Hoover (1).

Agricola first opens the "book" describing the knowledge needed to be a miner:

For a miner must have the greatest skill in his work, that he may know first of all what mountain or hill, what valley or plain, can be prospected most profitably, or what he should leave alone; moreover, he must understand the veins, stringers and seams in the rock. Then he must be thoroughly familiar with the many and varied species of earths, juices, gems, stones, marbles, rocks, metals, and compounds. He must also have a complete knowledge of the method of making all underground works. Lastly, there are the various systems of assaying substances and of preparing them for smelting; and here again there are many diverse methods.

And he continues:

Furthermore, there are many arts and sciences of which a miner should not be ignorant. First there is Philosophy, that he may discern the origin, cause, and nature of subterranean things; for then will he be able to dig out the veins easily and advantageously, and to obtain

more abundant results of his mining. Secondly, there is Medicine, that he may be able to look after his diggers and other workmen, that they do not meet with those diseases to which they are more liable than workmen in other occupations, or if they do meet with them, that he himself may be able to heal them or may see that the doctors do so. Thirdly follows Astronomy, that he may know the divisions of the heavens and from then judge the direction of the veins. Fourthly, there is the science of Surveying that he may be able to estimate how deep a shaft should be sunk to reach the tunnel which is being driven to it, and to determine the limits and boundaries in these working, especially in depth. Fifthly, his knowledge of Arithmetical Science should be such that he may calculate the cost to be incurred in the machinery and the working of the mine. Sixthly, his learnings must comprise Architecture, that he himself may construct the various machines and timber work required underground, or that he may be able to explain the method of the construction to others. Next he must have knowledge of Drawing, that he can draw plans of his machinery. Lastly, there is the Law, especially in dealing with metals, that he may claim his own rights, that he may undertake the duty of giving others his opinion on legal matters, that he may not take another man's property and so make trouble for himself, and that he may fulfill his obligations to others according to the law.

As a sideline, we can see that the philosophy of mining engineering education has not changed much over the last several centuries. But back again to the issue of conflict created by mining:

Since there has always been the greatest disagreement amongst men concerning metal and mining, some praising, others utterly condemning them, therefore I have decided that before imparting my instruction, I should carefully weigh the facts with the view to discovering the truth in this matter.

Agricola then proceeds to cover aspects of the conflicts raised by mining, but also defends the mining industry. Discussing the various examples, he also expresses a very "modern" way of thinking, showing also how much we, the Western civilization, indeed owe the great people of the Renaissance. The following quotes are of interest:

Again, those who condemn the mining industry say that it is not in the least stable, and they glorify agriculture beyond measure. But I do not see how they can say this with truth, for the silver-mines at Freiburg in Meissen remain still unexhausted after 400 years and the lead mines of Goslar after 600 years. The proof of this can be found in the monuments of history. The gold and silver mines belonging to the communities of Schemnitz and Grossnitz have been worked for 800 years, and these latter are said to be the most ancient privileges of the inhabitants.

Agricola also has comments on mine safety:

The critics say further that mining is a perilous occupation to pursue, because the miners are sometimes killed by the pestilential air which they breathe; sometimes their lungs rot away; sometimes the men perish by being crushed in masses of rock; sometimes, falling from the ladders into the shafts, they break their arms, legs, or necks; and it is added there is no compensation which should be thought great enough to equalize the extreme dangers to safety and life. These occurrences, I confess, are of exceeding gravity, and moreover, fraught with terror and peril, so that I should consider that the metals should not be dug up at all, if such things were to happen very frequently to the miners, or if they could not safely guard against such risks by any means. Who would not prefer to live rather than to possess all things, even the metals? For he who thus perishes possesses nothing, but relinquishes all to his heirs. But since things like this rarely happen, and only in so far as workmen are careless, they do not deter miners from carrying on their trade anymore than it would deter a carpenter from his, because one of his mates has acted incautiously and lost his life by falling from a tall building.

Considerable thought is spent on the philosophy of the advantages of metals to mankind.

Another of their arguments is this: Metals offer to men no advantages, therefore we ought not to search them out. For whereas man is composed of soul and body, neither is in want of minerals. The sweetest food of the soul is the contemplation of nature, a knowledge of the finest arts and sciences, and understanding of virtue; and if he interests his mind in excellent things, if he exercises his body, he will be satisfied with this feast of noble thoughts and knowledge, and have no desire for other things. Now although the human body may be content with necessary food and clothing, yet the fruits of the earth and the animals of different kinds supply him in wonderful abundance with food and drink from which the body may be suitably nourished and strengthened and life prolonged to old age. Flax, wool, and the skins of many animals provide plentiful clothing low in price while a luxurious kind, not hard to produce - that is the so called seric material is furnished by the down of trees and the webs of the silk worm. So that the body has absolutely no need of the metals, so hidden in the depths of the earth and for the greater part very expensive.

And further, he gives this example:

But besides this, the strongest argument of the detractors is that the fields are devastated by mining operations, for which reason formerly Italians were warned by law that no one should dig the earth for metals and so injure their very fertile fields, their vineyards, and their olive groves. Also they argue that the woods and groves are cut down, for there is a need of an endless amount of wood for timbers, machines, and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds very much of which furnish



a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away. Therefore, the inhabitants of these regions, on account of the devastation of their fields, woods, groves, brooks and rivers, find great difficulty in procuring the necessaries of life, and by reason of the destruction of the timber they are forced to greater expense in erecting buildings. Thus it is said, it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces.

So in fierce contention they clamour, showing by such examples as follow that every great man has been content with virtue, and despised metals.

Evil of the metals, especially gold and silver are shown in the many stories where people have betrayed their families, cities or countries for the love of gold. The base metals also got theirs. Agricola cites examples exposing the evils of copper, lead and iron. Lead, for instance, "...is a pestilential and noxious metal, for men are punished by means of molten lead..." Concerning iron, Agricola quotes Pliny: "'Iron is used not only in hand to hand fighting, but also to form the winged missiles of war, sometimes for hurling engines, sometimes for lances, sometimes even for arrows. I look upon it as the most deadly fruit of human ingenuity. For to bring death to men more quickly we have given wings to iron and taught it to fly.'"

In summarizing the statements of people who attack mining, Agricola adds also a defense of the mining industry. The reference to God is not at all out of place. Agricola was a devoted Christian all his life.<sup>1</sup>

They contend that, inasmuch as nature has concealed metals far within the depths of earth, and because they are not necessary to human life, they are therefore despised and repudiated by the noblest, and should not be mined, and seeing that when brought to light they have always proved the cause of very great evils, it follows that mining is not useful to mankind, but on the contrary harmful and destructive. Several good men have been so perturbed by these tragedies that they conceive an intensely bitter hatred towards metals, and they wish absolutely that

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<sup>1</sup> This was during these first years of the Lutheran Reformation. A measure of Georgius Agricola's standing can be deduced from the fact that all his life he remained a Catholic. The princes and dukes who called upon him and his services were Protestants. A Protestant prince, Duke Maurice of Saxon, made Agricola Burgomaster of Chemnitz and also presented him with a house and plot. In addition to duties as Burgomaster, Agricola was used for diplomatic mission. In 1547, Duke Maurice addressed the Chemnitz Council: "'We hereby make known to you that we are in urgent need of your Burgomaster, Dr. Georgius Agricola, with us. It is therefore, our will that you should yield him up and forward him that he should with the utmost haste set forth to us here near Fricberg.'"

metals had never been created, that no one had ever dug them out. The more I commend the singular honesty, innocence, and goodness of such men, the more anxious shall I be to remove utterly and eradicate all error from their minds and to reveal the sound view, which is that the metals are most useful to mankind.

In the first place then, those who speak will of the metals and refuse to make use of them, do not see that they accuse and condemn as wicked by the Creator Himself, when they assert that He fashioned some things vainly and without good cause, and thus they regard Him as the Author of evils, which opinion is certainly not worthy of pious and sensible men.

In the next place, the earth does not conceal metals in her depths because she does not wish that men should dig them out, but because provident and sagacious nature has appointed for each thing its place...

And,

Seeing then that metals have their proper abiding place in the bowels of the earth, who does not see that these men (detractors of mining) do not reach their conclusions by good logic?

They say, 'Although metals are in the earth, each located in its own proper place where it originated, yet because they lie thus enclosed and hidden from sight, they should not be taken out.' But in refutation of these attacks, which are so annoying, I will on behalf of the metals instance the fish, which we catch, hidden and concealed though they be in the water, even in the sea. Indeed, it is far stranger that man, a terrestrial animal should search the interior of the sea than the bowels of the earth. For as birds are born to fly freely through the air, so are fishes born to swim through the waters, while to other creatures nature has given the earth that they might live in it, and particularly to man that he may cultivate it and draw out of its caverns metals and other mineral products. On the other hand, they say that we eat fish, but neither hunger nor thirst is dispelled by minerals, nor are they useful in clothing the body, which is another argument by which these people strive to prove that metals should not be taken out. But man without metals cannot provide these things which he needs for food and clothing. For, though the produce of the land furnishes the greatest abundance of food for the nourishment of our bodies, no labour can be carried on and completed without tools.

Agricola then goes into some detail discussing the various kinds of tools and their uses; ploughs to till the soil are made from iron, the tailors needle, the fisherman's hook, the carpenter's tools to make houses. He summarizes his defense in the following manner:

But what need of more words? If we remove metals from the service of man, all methods of protecting and sustaining health and more carefully preserving the course of life are done away with. If there were no metals, men would pass a horrible and wretched existence in the midst of wild beasts; they would return to the acorns and fruits and

berries of the forest. These would feed upon the herbs and roots which they plucked up with their nails. They would dig out caves in which to lie down at night, and by day they would rove in the woods and plains at random like beasts, and inasmuch as this condition is utterly unworthy of humanity, with its splendid and glorious natural endowment, will anyone be so foolish or obstinate as not to allow that metals are necessary for food and clothing and that they tend to preserve life?

Moreover, as the miners dig almost exclusively in mountains otherwise unproductive, and in valleys invested in gloom, they do either slight damage to the fields or none at all. Lastly, where woods and glades are cut down, they may be sown with grain after they have been cleared from the roots of shrubs and trees. These new fields soon produce rich crops, so that they repair the losses which the inhabitants suffer from increased cost of timber. Moreover, with the metals which are melted from the ore, birds without number, edible beast and fish can be purchased elsewhere and brought to these mountainous regions.

The final part of the "book" deals with human nature and the minerals, especially gold and silver. Agricola writes that greed for gold is a function of human nature, not of the gold itself. He states:

From these examples we see that it is not metals that are to be condemned, but our vices, such as anger, cruelty, discord, passion for power, avarice, and lust.

Human nature seems to have changed very little throughout the centuries; although today we often think ourselves as far removed from the Renaissance, as a thought it would be interesting to know what people 419 years from now will think about our present day environmental conflict and also the people of the future's thoughts on the changes in (or stability of) human nature.