The Economic Potential of Alaska's Mining Industry

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Executive Summary

What will Alaska's mining industry look like in 20 years? How many people will it employ? What minerals will it produce?

Predictions about future events involve significant uncertainty, and the course of the mining industry will depend on mineral prices and a host of unpredictable events. Rather than trying to forecast these unpredictable events, this report constructs three possible futures: one with industry-favorable economic and policy conditions, one where status quo conditions prevail, and one with unfavorable conditions.

This report reviewed active mineral properties in Alaska: those operating, in permitting, and being explored. The report assigned probabilities that these would be operating in 20 years based on their exploration stage. The report assigned probabilities to each group of projects but does not venture an opinion about the prospects for any particular property. Probabilities for projects in the same exploration stage were assigned based on a review of probabilities in the academic literature, the exploration stage for that project group. Hard rock, coal, and placer mines were assigned probabilities separately. Different probabilities were assigned to a future with industry-favorable economic and policy conditions, to a status quo scenario, and to an unfavorable-condition scenario.

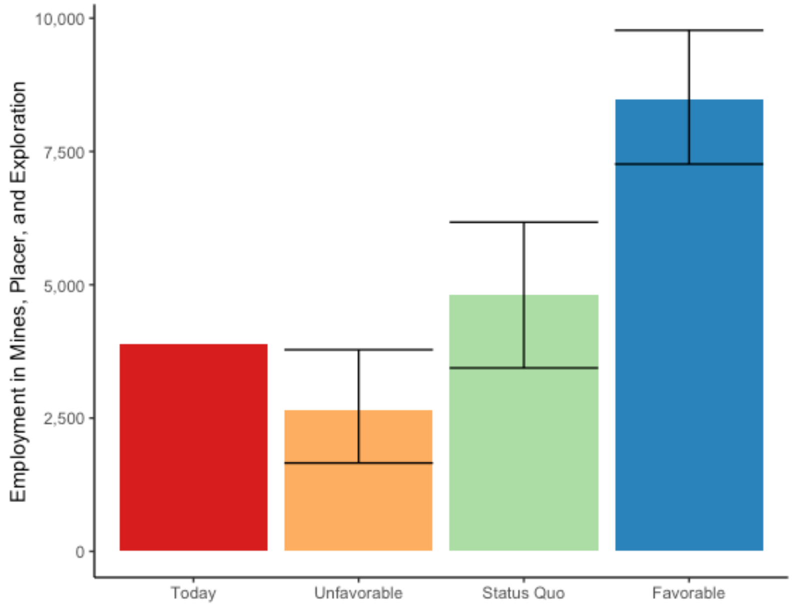
These three scenarios – favorable, status quo, and unfavorable – do not define the best or worst case. This report does not consider a zero-mining scenario, whereby an initiative or law makes it impossible to develop new mines and shuts down many or all existing ones. Such a scenario is not impossible but is not interesting for analysis. It is also possible that the industry could expand beyond our Favorable Scenario analysis. We have tried to describe reasonably likely, potentially achievable, descriptions of what may happen during the next two decades. Below are the results of our analysis.

Employment. In 2019, the mining industry provided approximately 3,900 direct jobs. In the favorable scenario, the number of mining jobs could more than double in 20 years to almost 8,500 jobs. Including indirect employment, the mineral industry could be responsible for almost 17,000 jobs in the favorable scenario. In our unfavorable scenario, employment would fall by approximately a third to 2,600 jobs.

Table ES-1. Mining Industry Potential in 20 Years by Scenario

		Unfavorable		Status Quo		Favorable	
	Today	Value	(Range)	Value	(Range)	Value	(Range)
Employment							
Direct	3,876	2,646	(1,657-3,782)	4,807	(3,440-6,174)	8,472	(7,263-9772)
Direct and Indirect	7,752	5,292	(3,300-7,600)	9,614	(6,900-12,300)	16,944	(14,500-19,500)
Direct Wages (Million $)	$428	$ 292	($166-$378)	$531	($340-$617)	$935	($726-$977)
Gross Value (Million $)	$2,626	$ 1,744	(1,069-2,506)	$3,196	(2,304-4,087)	$5,589	(4,841-6,341)

Figure ES-1. Potential Direct Employment in 20 Years, by Scenario



These are not precise estimates; there is some subjectivity in the probabilities they are based on. To show that, we assigned ranges on either side of the probability. These are the figures in parentheses in Table ES-1 and are represented by the bars in Figure ES-1. These ranges are not a statistical confidence interval. Rather, we more arbitrarily assigned a range around each probability to emphasize the inherent uncertainty of the method. We picked 10% on either side of the probability, or an obvious cut-off such as 50% or 75% to emphasize the potential uncertainty, or the order-of-magnitude nature of the analysis.

Production value and comparison with Alaska's economy. The gross value of production, using estimates of future production and today's prices, would increase also more than double under favorable conditions: from today's value of $2.6 billion to almost $5.6 billion. Of course, if prices increased, the value would increase as well. However, $5.6 billion is approximately 10% of Alaska's GDP in 2020, though it would be a smaller share in 20 years assuming the economy grows. In unfavorable conditions, the value of production would fall by approximately a third to $1.7 billion.

Basic industries bring money into Alaska from outside the state. Basic industries in Alaska – such as oil, fishing, tourism, mining, and federal spending – play a key role in our state's economy. Money from outside the state flows in and supports additional economic activity. We estimate that these basic industries today bring in approximately $19 billion to Alaska. The favorable scenario's value, $5.6 billion would be responsible for almost a quarter of what comes into Alaska today. Even in 20 years this would be a significant level of exports – more than the federal government brings into Alaska today and much more than any other industry except oil. It would raise the basic industries' input to Alaska's economy as it is sized today by 15%. This would bring an important statewide increase into the economy, even accounting for overall economic growth in 20 years.

Regional Effects. While mining is an important state-wide industry, it will not achieve the dominant status that the oil and gas industry has in today's Alaska economy. But for some of Alaska's rural regions, it has an important status. In these areas, a mine may be the only significant large private employer in the area. It can raise wages and create significant high-paying employment opportunities where few exist. Taxes from a large mine can also provide the funding for local government where none now exists. The Red Dog Mine creates this situation currently for the Northwest Arctic Borough. Donlin Gold project, should it begin production, may create similar benefits for a portion of the Kuskokwim. Smaller mines identified in this report may create employment and income benefits for rural communities.

State Government Revenue. The major sources of mining revenue to the state government come from rents, royalties, mining license tax, and corporate income taxes. These revenues are all based on net profits. This analysis has not attempted to estimate mining profits, which will heavily depend on mineral prices. Because we cannot predict profits, the best we can do is presume that state government revenue would increase (or decrease) proportionally to the industry size.

Over the four years from 2016 to 2019, the mineral industry paid $66.6 million per year, which is very similar to state revenues collected by the state from the commercial fishing industry and the tourism industry. This is the revenue which would presumably change proportionally with the mineral industry. However, this assumes that prices remain at today's levels. If prices increase, profits and state revenue would increase more than proportionally. However, no industry, including mining, replaces the oil industry in Alaska's economy, and this level of state revenue would not do so.

The mineral industry also paid another $27 million per year to independent state agencies: the Alaska Railroad and the Alaska Industrial Development and Export Authority. It annually paid another $36.8 million to municipalities.

An important aspect of the mineral revenue to state government is that it provides true net returns to the state budget. The industry pays more in royalties, taxes, and fees than the state expends on administration and enforcement. A 2022 ISER study estimated that the state government spends only a small amount regulating and promoting revenue from the mining industry, $6.7 million per year. This is less than a tenth of what the industry pays the state.[1]

Alaska Native Corporation Revenues. Through a provision of the Alaska Native Claims Settlement Act, 70% of revenue due to minerals on land owned by Alaska Native Regional Corporations is shared with all Alaska Native Regional Corporations, and half of that is re-shared to Alaska Native Village Corporations. Royalties paid to the NANA Corporation from the Red Dog Mine illustrate the impact of this provision. Since the mine was founded, NANA has received approximately $2.4 billion from the Red Dog Mine, of which $1.5 billion has been redistributed to other Alaska Native Regional Corporations. Between 2014-2020, NANA distributed over $126 million per year to Regional Corporations. This is 69% of all the distributions made by all Native Corporations during these years.

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[1] Information in this and the preceding paragraphs is from Fiscal Effects of Commercial Fishing, Mining and Tourism: Fiscal Years 2016-2019. Bob Loeffler and Steve Colt. Institute of Social and Economic Research. February 24, 2022.

Half of the shared amount is re-shared with Alaska Native Village Corporations. This is important income for those corporations. According to the Alaska Native Village Corporation Association (ANCVA), this income, "accounts for all or nearly all of the revenue collected by approximately two-thirds of the 177 village corporations that are ANVCA members."

Revenue from the Red Dog Mine source is expected to end in 2031 when mining at the Red Dog Mine ends on NANA's Native Corporation land. The mine is exploring other reserves to extend the mine's life, but they are on state land. Revenue from state land is not shared with other Alaska Native Corporations.

For this report's review of potential mineral properties, only the potential Donlin Gold project is close to production and is also on Native land, owned by the Calista Corporation (an Alaska Native Regional Corporation). If the Donlin Gold project goes into production, payments shared by Calista may make up part of the revenue lost when Red Dog ceases operation on Native land. If that project does not begin mining, Native Regional and Village Corporations are likely to lose significant funding shared from mining. This loss is likely to be especially consequential for the many Alaska Native Village Corporations without another source of funding.

Critical and Energy Minerals. Minerals are necessary for the U.S. economy. Today, Alaska provides:

- 80% of the U.S. production of zinc, mostly from the Red Dog Mine,
- 44% of the country's production of lead, and
- Approximately half of the country's production of silver.

The USGS ranks these minerals as important for the U.S. economy, but only zinc is described as "critical minerals" because these minerals have limited potential for disruption, largely because of domestic production, much of which is from Alaska.

In the Favorable Scenario, Alaska's mines can also produce several minerals that are listed as critical by the USGS for domestic manufacturing, and particularly for the deployment of clean energy technology. These minerals are critical for renewable energy and the increasingly electrified economy.

- Graphite. Alaska has the potential to produce more graphite than is currently produced in the country today. Graphite has important applications in lubricants and batteries for electric vehicles.
- Cobalt. Cobalt is another key input for electric vehicle batteries and is today mostly produced from the Democratic Republic of Congo by Chinese-owned companies. Alaska has the potential to more than double current domestic production of cobalt in the United States.
- Rare Earth Elements. The state also has an opportunity to produce some of the country's important rare earth elements, used in a variety of industrial processes,
- Barite. The mineral is used as weighting agent in oil drilling.

Most of these minerals are dependent on a single mine, such as Graphite Creek on the Seward Peninsula for graphite, and the Bornite project in the Ambler Mining District for cobalt.

Finally, Alaska can produce significant amounts of copper from several prospects, mostly those being explored in the Ambler Mining District. Copper is an important base metal used in electric wiring, power transmission and power generation, including many renewable energy applications. Our Favorable Scenario estimates production of around 110 thousand tons of copper per year, primarily from Ambler District mines in northwest Alaska. This level amounts to about 9% of United States' annual copper production, and about 1% of global production. As elsewhere in the report, we omit estimates of potential production from the Pebble Project, which on its own could produce more than double this quantity.

The Role of Large Projects. Two projects/mining districts play an outsized role in the potential Favorable Scenario; that is, in the potential growth of the mining industry. The properties that could develop in the Ambler Mining District could together employ around 900, as could the Donlin Gold project. Together, these 1,800 potential direct jobs represent around 40% of the new jobs that might be created in the Favorable Scenario. The projects share several other important features. They both are situated on land owned by Alaska Native Corporations, and they both require a significant infrastructure investment to operate. Donlin Gold requires a 315-mile natural gas pipeline, and Ambler requires a 200-mile access haul road.

The Role of Infrastructure. Mapping the projects this report's database illustrated the role of infrastructure in mineral exploration and development. Most exploration projects in this report are close to infrastructure: whether that is the limited road system in Alaska, or the ocean – which is a kind of transportation infrastructure. Despite the large area beyond reach of the ocean or the road system, there are many fewer projects in the large part of Alaska that is not near a road nor the ocean. The further from transportation (and the further from power), the large and richer a project must be to go into development. It appears that provision of new infrastructure is important for increasing mineral investment.

The Pebble Project. Our analysis has omitted the Pebble Project from the three scenarios, due in part to its exceptionally large size, its controversy, and the fact that the federal government has denied a key permit for the project. (Developers have appealed this denial.) The Pebble deposit is one of the largest copper deposits ever discovered. The developer's PEA indicates that mine's proposed 20-year mine plan would generate an average of $1.7B in annual revenue after an initial $6 billion in capital expenses. The U.S. Army Corps of Engineers Final Environmental Impact Statement stated the proposed mine would generate $84 million per year in state tax revenue annually and employ around 850 people. In other words, the Pebble Project alone might increase the gross value produced by the state's mining industry by 65%, more than double state government revenue from mining, and increase hard rock mining employment by one-third.

If you believe the project could be developed in 20 years, its effects may be added to any of the scenarios. This study takes no position on whether the project can or should be developed.

Chapter 1. The Question: What might Alaska's mining industry look like in two decades?

There is a value to discussing the potential futures of the mining industry. It is useful to think about the events which may affect the industry. Some of these, such as state policy or infrastructure investment, are under the state's control. If the benefits of the mining industry are valuable, the state may wish to address policy changes that may make industry growth likely. Or it may wish not to do so.

Alaska's economy is changing. While oil has driven the State's economy since the 1970s, the advent of shale oil production and depletion at the State's historic fields have put downward pressure on petroleum's employment and its role in government finance. In the future, non-petroleum industries may be more important to Alaska's economy than they are today. It is useful to think about the role that mining may plan in this new industry mix.

Alaska's government is addressing a budget deficit. It is useful understand the role that the mineral industry can play in supporting Alaska's budget solutions.

Finally, minerals provide the first link in many supply chains across the U.S. and global economy. Increasing interest has been paid to vulnerabilities in these supply chains, particularly for minerals in supply chains for clean energy technology. Minerals with important uses, but fragile supply chains are often defined as "critical minerals." It is useful to think about how Alaska can contribute to the country's economic security through the production of critical minerals or contribute to the country's response to climate change through the production of minerals needed for sustainable energy.

Forecasting what will happen to Alaska's mining industry is difficult. The industry's growth will depend on mineral prices, government policies, and a host of unpredictable events. Rather than trying to predict these events, the report addresses the question of the mineral industry's potential future in another way. This report constructs three scenarios that could represent a future for the mineral industry. What might the industry be like if conditions are improve? What happens if conditions do not change? What happens if conditions deteriorate?

This report uses five economic outcomes to describe Alaska's mineral industry: Production, value, employment, and state government revenue, and economic impact. It also looks at potential regional effects. The mining industry, while important, may not be Alaska's dominant industry even under favorable conditions. Our dominant industry is oil, or perhaps the federal government (if you wish to think of the government as an industry). Mining will not replace the role of either in our statewide economy in the next two decades, but it is the dominant industry in some of the regions in which it operates. Because regional effects are important, this report looks at regional potential.

A. Defining future scenarios for the mineral industry: What is a Favorable, Status Quo, or Unfavorable Scenario?

Favorable Scenario. What changes in Alaska might occur which would increase the ability of the mining industry to explore and develop mines? The Fraser Institute's Annual Survey of Mining Companies 2020 provides a partial answer to this question.[2]

The Fraser Institute is a Canadian Policy Institute. Each year it sends a questionnaire to mining industry representatives worldwide. It asked respondents' perception of the attractiveness of a location's mineral endowment, and their perception of 15 policy factors for that jurisdiction. Based on survey responses, the 2020 the report rated Alaska relative to 77 locations worldwide. Alaska is competing against 12 other U.S. States, 12 Canadian Provinces, 13 African countries, 10 European countries, and so forth.

In 2020, Alaska is ranked 13th out of 77 in the Policy Perception Index (a combination of the 15 policy-related questions). This ranking is relatively high but still lower than other mining states in the U.S. including Idaho, Wyoming, Nevada, Utah, Arizona, and New Mexico. For each of the 15 policy factors, the Fraser Institute asked respondents whether the location encouraged or discouraged investment. For five of those factors, at least a quarter of respondents noted that Alaska's situation presented either a mild or strong deterrent to investment. These are areas where there is room to improve government administration of the mining industry. Those five factors are below (numbers in parentheses note the percentage of survey respondents who indicated the factor, in Alaska, was a mild or strong deterrent to investment):

- Uncertainty Concerning the Administration, Interpretation and Enforcement of Existing Regulations (29%)
- Uncertainty Concerning Environmental Regulations (35%)
- Regulatory Duplication and Inconsistencies (40%)
- Uncertainty Concerning Protected Areas (45%)
- Quality of Infrastructure (59%)

A Favorable Scenario for mining would involve improvement in these issues. Note that not all the potential improvements are under state control. The problematic regulatory issues cited by the Fraser Institute report may be caused by the federal government rather than by the state. The Fraser Institute report did not discuss which government created the uncertainty. Further, the Fraser Institute reports industry perception of these issues, but takes no position about whether the perceptions are accurate. Therefore, improvement in these issues could involve actual substantive improvement or at least a change in perception.

To complete the Favorable Scenario, the authors added two more concepts:

- Sustained high mineral prices for gold or other minerals. The mineral industry, like other industries, is sensitive to the selling price for its products. High mineral prices make the industry more profitable, and the prices attract more investment and mining activity. The

[2] Fraser Institute Annual Survey of Mining Companies 2020. Jairo Yunis and Elmira Aliakbari. Fraser Institute. February 23, 2021.

Fraser Institute report does not address mineral prices, because prices affect all countries in the survey.

- Public support, or at least avoiding increased public opposition. In a democracy, public support for the industry allows stable and reasonable government tax, royalty, land use, and environmental policies.

We should note that a Favorable Scenario does not assume that Alaska relaxes its strict environmental standards.

In our Favorable Scenario, these conditions would exist:

- Stable, transparent system of administration and enforcement of regulations and environmental laws with a minimum of agency duplication or inconsistencies.
- A clear understanding of where mining is allowed to decrease industry's uncertainty about protected areas.
- Improved infrastructure, which could include additional roads, an expansion of the power grid, or similar improvements.
- Sustained high mineral prices.
- Public support, or at least non-opposition, in the areas where the industry operates.

In this scenario, companies would be more comfortable investing in Alaska. Alaska could attract more investment. If additional infrastructure exists, then in those locations, the cost of exploration and development costs would decrease.

Status Quo Scenario. The Status Quo Scenario is, not surprisingly, continuation of current trends. These trends include:

- Continuation of current enforcement and regulation trends, along with the industry perceptions documented in the Fraser Institute's Survey.
- No significant changes in infrastructure.
- Mineral prices that fluctuate, sometimes higher or lower than current prices.
- Variable public support and opposition, as occurs today. While the current state of public support/opposition makes for a long permit process, we are not assuming dramatic changes in tax and royalty rates.

Unfavorable Scenario. For this report, our Unfavorable Scenario for mining may involve the following events, not all of which would have to occur to create the Unfavorable Scenario:

- Less favorable regulatory or land-use policies by the state or federal government.
- No significant change in infrastructure.
- Sustained low mineral prices for gold or other minerals.
- Sustained public opposition to mining projects in general. This can make it more difficult to obtain favorable permits, increase permitting times, decrease the state's attractiveness for mineral investment, or result in government policies that make industry hesitant to invest.

For example, several recent state-wide elections have included citizen initiatives that would have had made it much harder, perhaps impossible, to develop a mine:

- 2018 Ballot Measure 1: Alaska Salmon Habitat Initiative (did not pass)
- 2014 Ballot Measure 4: Bristol Bay Fisheries Reserve Initiative (passed)
- 2008 Ballot Measure 4: Alaska Clean Water Initiative (did not pass)

The 2014 initiative would directly affect only the Pebble Mine. Industry spokesmen stated that if either the 2008 or 2018 initiatives had passed, it would have made it difficult or impossible to develop a new mine anywhere in Alaska.

These ballot initiatives provide examples of changes that could decrease the ability of Alaska to permit new mines or to attract mining investment. Additionally, direct changes by the legislature, future governor, or perhaps more likely by the federal government could create a similar situation.

While the Favorable Scenario would allow Alaska to attract more mineral investment, the Unfavorable Scenario would greatly decrease or eliminate the ability of a project in Alaska to attract investment.

Overall, these scenarios do not define the best or worst case. This report does not consider a zero-mining scenario, whereby an initiative or law makes it impossible to develop new mines and shuts down many or all existing ones. Such a scenario is not impossible but is not interesting for analysis. It is also possible that the industry could expand beyond our Favorable Scenario analysis. We have tried to describe reasonably likely, potentially achievable, descriptions of what may happen during the next two decades.

B. Why two decades? Why not three decades? Or a century? The answer involves the mine development process. Hard rock mines take a long time to develop from initial exploration to an operational mine. Most take at least two decades. The Pogo Mine was Alaska's fastest development process from discovery to production. It proceeded from claim staking to production in 15 years, 1991-2006,[3] though regional exploration occurred a decade earlier.

It is possible that some mine will be in production in 20 years from a prospect that is unknown today, but given historic timeframes, it is unlikely. Twenty years is close enough to the present that almost any mine that will exist in two decades is being explored today.

Two decades is sufficient time for a few early-stage projects to finish exploration activity, permitting, development, and to come into operation, but near-term enough to exclude the more speculative tier of mineral prospects whose quantity and size are all but unknown. Two decades also builds in enough time for a policy change to be implemented or for new infrastructure to be built and for the effects of these changes to start materializing.

[3] "Gold and other minerals were found through regional exploration near the present mine site in 1981. Claims were staked in these areas in 1991 and, by the late 1990s, drilling confirmed that the Pogo site contained major gold deposits. Soon thereafter, the extensive multi-year permitting process began and in January of 2005 underground mine development began, resulting in the first gold pour in February of 2006." Pogo Mine Alaska, Who we are. Website: https://pogominealaska.com/who-we-are/. Visited 12/17/21

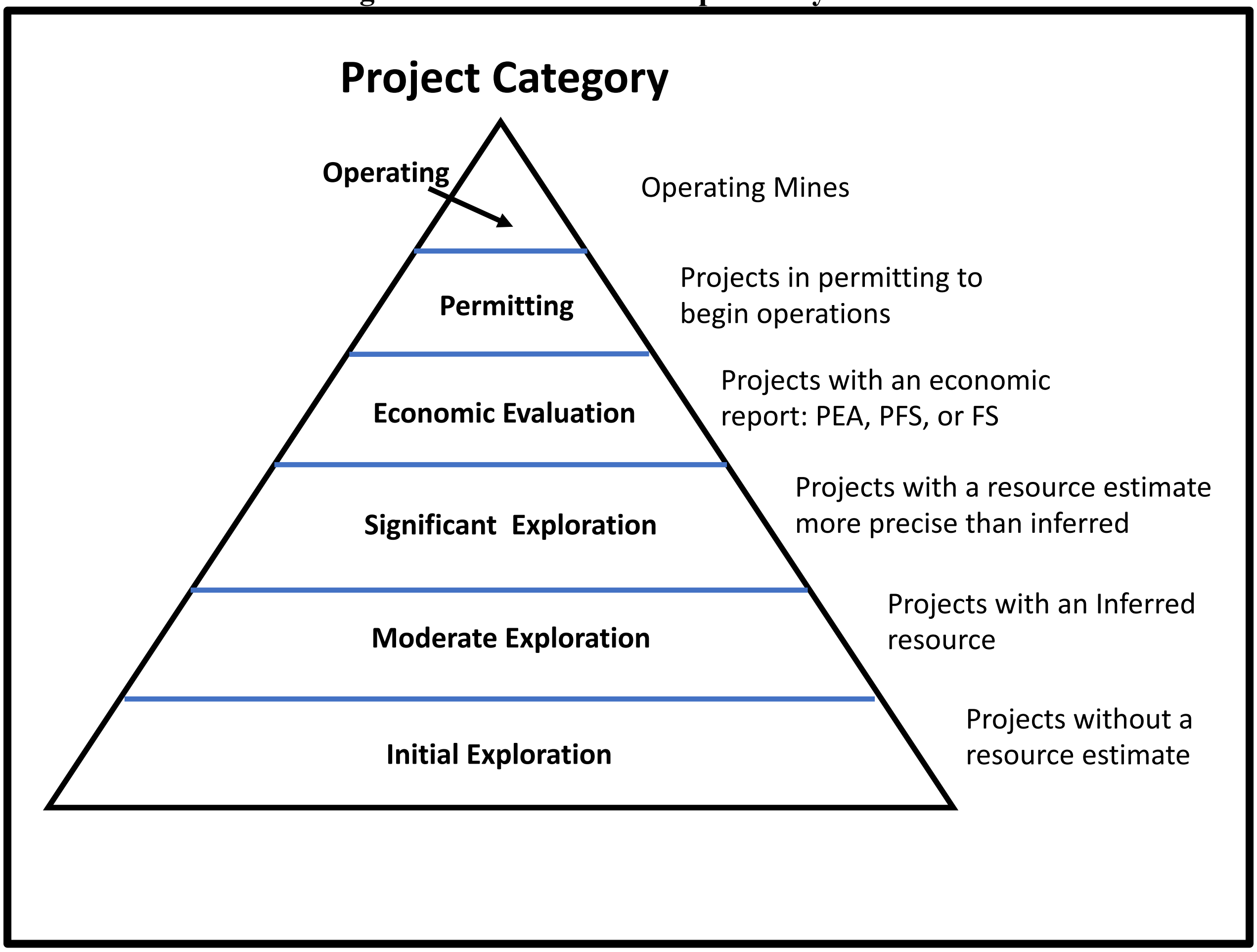
As in other aspects of this report, two decades should be taken as a rough approximation of timing. Our analysis is not precise enough to differentiate between an event occurring in 18 years versus 22 years but could likely exclude an event occurring within the next 10 years (given the lengthy development cycle).

Chapter 2. The Mine Development Pyramid

A. The Theoretical Pyramid. Developing an operating mine is a multistage process. When exploring a new prospect, it is unclear if it will meet all the conditions necessary to become a mine. This leads to mineral resource development to take a “stage-gate” process. Favorable results must be obtained from the one stage before a project can advance to the next intensive and more expensive round of exploration. The increased scrutiny provides additional confidence in the size and quality of the resource.

As a project moves from one stage to the next, the odds of it becoming a mine increase. Figure 1 shows the stages of mine development used in this project. Each stage can be assigned a different probability of becoming a mine within the 20-year period of this report, which we detail in Chapters 3 and 4.

Figure 1. The Mine Development Pyramid



Projects in the bottom tier of the pyramid, “Initial Exploration,” are in the earliest stage of exploration. Companies exploring these projects are looking for initial geologic indicators or are drilling the first exploration holes. A company’s geologic model may provide information to indicate a potential mineable deposit, but they do not have enough information to calculate the size and grade of the deposit.

A project may remain in the initial development stage for many years because of intermittent financing, or because the project requires multiple years of exploration (and millions of dollars of work) to develop enough information to estimate a resource. Many initial exploration projects never progress. If all exploration found enough minerals to justify a mine, mining would be an easy business. But it is not. Sometimes exploration does not find enough of a mineral concentration to be worth further exploration. That is why the development pyramid is a triangle. At each stage, some projects are not pursued further (though an increase in mineral price or new technology may revitalize interest in previously discarded projects).

After some initial drilling, or for some deposits multiple years of drilling and millions of dollars of work, a company may develop enough data to make an estimate of the potential size and grade of the deposit. The major stock exchanges, especially in Canada, Australia, and South Africa, established standards that companies must meet before they can publish a resource estimate.[4] These standards, based on available data, rank deposits from the lowest to a higher level of confidence: from inferred resource, to indicated resource, and then to a measured resource. Each of these provide an estimate of the total amount of the mineral resource, and an estimate of the grade. They differ in the amount of data needed. A measured resource requires more drilling and more data than the lower two ranks. This report classifies projects with an inferred resource as "moderate exploration," and those with an indicated or measured resource as "significant exploration."

Whether a deposit becomes a mine is not just a geologic question. It is an economic question as well. Further geologic investigation of a significant exploration project must be coupled with an economic evaluation to determine whether the deposit can be economically developed. The international stock exchanges have defined the level of engineering and economic analysis necessary to qualify for certain labels. From the most limited to increasing economic confidence, these are: Preliminary Economic Assessment (PEA), Pre-feasibility Study, (PFS) and Feasibility Study (FS).[5] Sometimes the economic evaluation determines that the project is unprofitable or not profitable enough for further work. Once this happens, the project may be put on hold or end entirely. Or the company may search for more concentrated ores within the original target or explore adjacent areas that might extend the deposit. The company may also refine projected mining methods to try to decrease the mining cost.

Even if the economics are favorable, it does not guarantee a project's successful development as a mine. In the United States, mining projects are subjected to an extensive process for environmental permitting. The permitting process is expensive and can take years, including multiple years of data-gathering. If a project is economic, and the company believes that a design

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[4] For reasons of historical development, most significant mining stock investment occurs via stock exchanges in Canada, Australia, South Africa, and England. These countries are the home of many of the world's major mining companies. Investment definitions and standards are more developed in these countries' stock exchanges than in the U.S., and U.S. companies tend to follow the regulatory investment standards there.

[5] The terms above are used in the Canadian system, outlined in Canadian Regulation NI 43-101. In Australia, the Preliminary Economic Assessment is termed a "Scoping Study." Occasionally a feasibility study will be described as a "bankable feasibility study" to differentiate from the pre-feasibility study.

will meet federal and state permitting standards, it may proceed from the economic evaluation into permitting.

Definitions for the six stages this report uses for the mine development pyramid:

- ***Initial Exploration.*** For purposes of this study, projects just beginning exploration, without enough data to calculate the lowest-rank estimate of a resource, are classified as "Initial Exploration."
- ***Moderate Exploration.*** Projects that have found enough minerals and developed enough exploration data to establish an *inferred resource* estimate, compliant with international stock exchange standards, are classified as "Moderate Exploration."
- ***Significant Exploration.*** If drilling a moderate exploration continues to identify a larger or higher quality mineral deposit, the property will eventually develop an *indicated* or *measured reserve* estimate. For purposes of this study, these are termed "Significant Exploration." Some projects in this category, upon further investigation, do not warrant further exploration, and the project stops. Others continue to the next stage.
- ***Economic Evaluation.*** Once a project publishes an economic evaluation (PEA, PFS or FS) consistent with international standards, this report classifies the property in the fourth stage.
- ***Permitting***. If the project proceeds into permitting, it is classified into the fifth stage. Alaska's mining history includes projects which have stopped during permitting, when the company determined it would not receive a permit. Others were denied permits, and still others received permits, but did not operate for other reasons, including underestimated development costs.[6]
- ***Operating.*** Some projects pass through permitting and become operational.

The six stages of the mine development pyramid were developed for this report. This report uses definitions that are useful for the calculations discussed in this report. However, the concepts are common and other studies have used similar figures.[7]

Note: The mine development pyramid is not useful for thinking about the future of the placer portion of the mining industry, Placer mines are typically located within established placer mining districts. They are frequently mined as a method of exploration, and the small, often family-owned businesses do not use the stock market to raise money. They do not complete formal economic evaluations such as a PEA or PFS. Permitting is less complex and is usually

[6] Examples include:

- Quartz Hill Mine – Granted a permit for a tailings location that was not economic and the project stopped in 1990.
- Wishbone Hill Coal – Operating permits for the project were authorized in 1991, though the mine has not gone into operation.
- Chuitna Coal Mine – Suspended permitting in 2017 part-way through its permit process.
- Lucky Shot Gold Mine – Permits were authorized in 2017 and the project began construction. The project was suspended in 2018 before it began operations or produced ore. It is currently being re-evaluated by a new company, and may resume construction or apply for new permits.
- Pebble Project – Denied a key federal permit in 2020. The denial is under appeal.

[7] For a similar pyramid, see for example John P Sykes, Allan Trench. University of Western Australia, Conference Paper August 2014. Resources versus Reserves - Towards a Systems-based Understanding of Exploration and Mine Project Development and the Role of the Mining Geologist. Figure 7

completed within a month or two. For these reasons, we used other methods to estimate potential scenarios for placer mines, as described in Chapter 3C.

B. Academic Literature: What's the shape of the pyramid? Or how many Initial Exploration Projects does it take to make a mine? If there were an established ratio of projects at each stage of the pyramid, this would be a short report. We could apply that ratio and calculate how many of the projects would become a mine. Unfortunately, it is not that simple, though a few academics and mining professionals have developed estimates.

Among these, there is broad agreement that it takes many initial exploration projects to make a mine. However, there is no agreement on the actual number, or ratios between pyramid stages. Studies are based in different locations, which maintain different records. Different times in history may give different results. Some studies begin with what this study terms Initial Exploration; others with Significant Exploration. The time frame each study considers matters as well. Some projects are suspended for years, perhaps decades, before prices rise or technology changes, and they are re-energized for further exploration and development. This gap can affect accurate estimation of the ratio of projects that get to each stage of the pyramid.

Despite the confusion, it is useful to consider the few estimates that exist. The limited literature on the subject can give us a sense of the type of concentration that occurs between stages of development, and of the diversity that exists in their results. We have included six studies in Table 1.

The studies are not directly comparable. Each uses different definitions for development stages, so we have reclassified them based on our best judgment. The studies cover different time frames, and the work occurred in different years. The longer the time frame covered in the study, the more likely a prospect will succeed in moving forward (i.e., some projects stall for years but are revitalized due to better understanding of the geology, different technology, higher prices, or some other reason). In addition, most of the studies are old, and exploration effectiveness has likely improved since these studies. Despite the differences between the studies and their age, they give a sense of the decrease in number of projects as one ascends the development pyramid.

Table 1. Exploration Projects to Operating Mines: Data from Literature

Original Data Source	BCMC[1]	Cominco[2]	RTZ[1]	SOQUEM[3]	Potter[4]	Sykes/Trench[5]
Time Frame of Study		**40 yrs.**		**10 yrs.**	**20 yrs.**	
Operating Mines	1	18*	1	3	6	66
Projects with Economic Evaluation	5		1		8	92
Significant/Moderate Exploration	60	78	10	192	67	664
Recon/Initial Exploration	1649	1000	3000		159	2870

[1] From a presentation by Hammond International Group. Note RTZ is taken from the RTZ website (2000). And BCMC is referenced as Peters 1967. (Primary sources unavailable).
[2] Cominco, 1982. Mining is a risky business, in Hoskins, J. R., ed., Mineral industry costs: Spokane, Northwest Mining Association. P. 241.
[3] Come Carbonneau, 1978. From Dream to Discovery – or From Resources to Reserves. CIM Bulletin January 1978
[4] Quoted in William C. Peters. Exploration and Mining Geology. 2nd Edition, 1987. P. 537. (Primary source unavailable).
[5] John P Sykes, Allan Trench. University of Western Australia, Conference Paper August 2014. Resources versus Reserves - Towards a Systems-based Understanding of Exploration and Mine Project Development and the Role of the Mining Geologist. Figure 7.
* The Cominco Ltd data noted that 18 mines were brought into production, but only 7 were profitable.

Most of the studies show a sharp decrease in projects between the Recon/Initial Exploration stage and the Significant/Moderate Exploration stage. BCMC shows a 92% drop between projects that were the subject of initial reconnaissance, and those which developed into the Significant/Moderate Exploration stage. RTZ showed a 99.7% drop, which presumably means they included properties that were briefly looked at but never drilled. The more optimistic study, Sykes/Trench, is based on copper projects in Australia and records only a 77% drop. However, this study may have included more advanced projects in the "Recon/Initial Exploration" category.

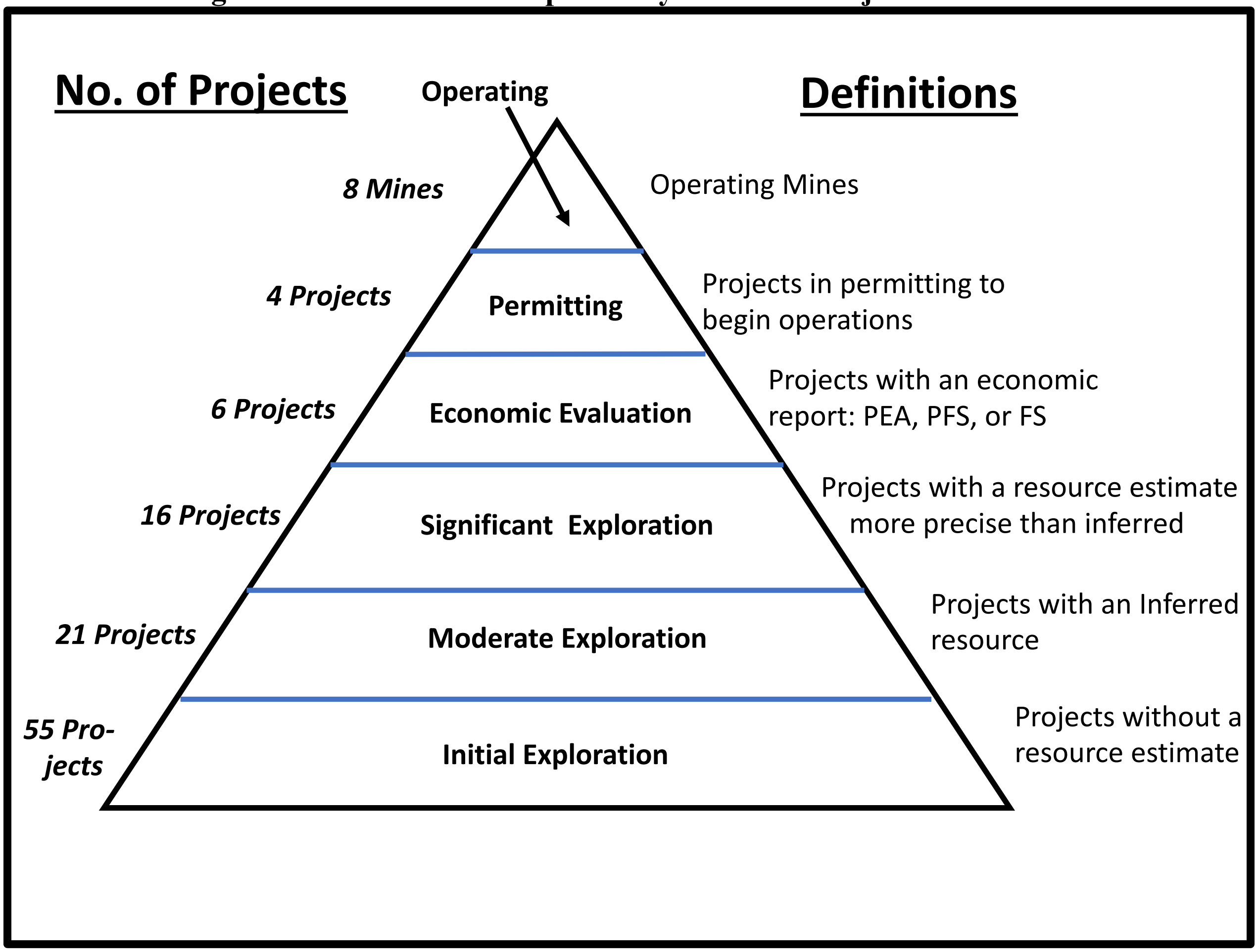
A more comparable series of statistics may be the difference between those with a substantial drilling program (Significant/Moderate Exploration) and those in production. BCMC records a 98% decrease; Cominco a 77% decrease; SOQUEM 98%; Potter 91%, and Sykes/Trench 90%.

The studies indicate that once a project has gotten to the point of an economic evaluation, the chances of it developing into a mine increase greatly. The BCMC study still records an 80% drop in projects, but three other studies show a drop of 25% or less.

There is only an order-of-magnitude agreement in the table. All studies show a significant drop in projects as the "pyramid" progresses upward, or as projects move through the stage-gate process of exploration and development. The exact percent of decrease varies widely. The studies consistently show that projects in the economic evaluation or permitting stage are much more likely to go into production than those in earlier stages.

C. Alaska's Mine Development Pyramid. Figure 2 provides the mine development pyramid as it exists in Alaska in 2021. This report reviewed all projects for which the Alaska's Mineral Industry Report 2019,[8] prepared by the Alaska Department of Natural Resources (DNR), discusses a reserve or resource estimate, and any hard-rock exploration project that has had a DNR permit over the five years between 2016-2020. DNR permits include all mining activities on state or private lands, and all active exploration projects on federal land, which use DNR's reclamation bond pool. The result is 110 projects, including Alaska's eight operating mines.

Figure 2: The Mine Development Pyramid for Projects in Alaska



This pyramid illustrates Alaska mines and projects as a snapshot in time, in 2021. It must be interpreted differently than the numbers shown in Table 1, which tracked projects over time as they moved between stages. In this figure, it would be incorrect to assume that the 21 Moderate Exploration Projects became the 16 Significant Exploration Projects: i.e., that 16 of 21 moved between stages. We do not know how many projects over the past 10-20 years were explored to get to the 16 projects. That would require a different set of data.

[8] Alaska's Mineral Industry 2019. Special Report 75. State of Alaska Department of Natural Resources, Division of Geologic and Geophysical Surveys. Jennifer Athey, Melanie Werdon, and Evan Twelker.

The next paragraphs list the mines and projects in the top three stages of the development pyramid. The remaining projects are in Appendix A.

Operating Mines. Alaska has six large operating mines, five hard rock and one coal mine. It also has two small operating mines. The list does not include placer mines, or gravel pits and construction material sites.

Table 2. Operating Mines

Mine	Primary Minerals	Resource *(in Short Tons)*	Employment
Red Dog	Zinc, Lead	75,397,000	700
Pogo	Gold	21,306,000	450
Kensington	Gold	6,465,000	383
Greens Creek	Zinc, Lead, Silver, Gold	21,213,000	426
Fort Knox	Gold	571,654,000	655
Usibelli	Coal	450,000,000	100
Dawson	Gold	1,000,000	50
Calder	Limestone	Unknown	12

Dawson and Calder mines are operating hard-rock mines, but we have separated them at the bottom, as they are much smaller than the six large mines above.[9]

Many of the operating mines conduct exploration at nearby ore bodies which, if permitted, would extend the life of the operating mine. These are listed in Appendix A. Some of the notable exploration projects are:

Fort Knox:
- Gil Exploration (Gold)
- Manh Choh (Gold)

Red Dog:
- Anarraaq (Zinc, Lead, Silver)
- Lik (Zinc, Lead, Silver)

Projects in Permitting. This category shows mines in permitting to begin construction plus those which are permitted but not in operation. We also include the smaller Nixon Fork and Lucky Shot Mines, both of which have operating permits that are voluntarily suspended while new owners re-evaluate the mine plans. Alaska has four projects in this category.[10]

[9] Information is from DNR's 2019 Mineral Industry Report, except for information from the Dawson Gold Mine, which was provided by the owner.
[10] Information from the reports of individual mines, except for Nixon Fork Employment which is from the 2005 BLM Environmental Assessment.

Table 3. Projects in Permitting, plus those Permitted but not Operating

Mine	Minerals	Resource Short Tons	Estimated Employment
Donlin	Gold	698,366,574	900
Lucky Shot	Gold	292,661	76
Nixon Fork	Gold	542,949	45
Wishbone Hill	Coal	14,000,000	100

Note: this Table does not include the Pebble Project, which is appealing a denied permit, and is discussed separately in Chapter 4F. It also does not include Quartz Hill or the Chuitna Coal Projects, which were abandoned by their respective companies. Finally, Tetlin (Manh Choh Project) is proposing to truck ore to Fort Knox for processing, rather than become a totally independent mine.

Projects in Economic Evaluation. This study uses the term "economic evaluation" to mean projects that have completed a reserve and economic analysis compliant with one of the major mining regulatory structures: a Preliminary Economic Assessment (PEA), Pre-feasibility Study (PFS), or Feasibility Study (FS), which are compliant with the Canadian regulations at 43-101; or similar studies compliant with the Australian Joint Committee on Ore Resources (JORC). The Australian economic reports are named in a similar, but not identical, fashion to those for Canada: Scoping Study, PFS, or FS.

Table 4. Projects with a PEA, PFS, or FS

Project	Status	Minerals	Resource Metric Tons	Expected Employment
Arctic (Upper Kobuk Projects)	Feasibility	Zinc, Copper, Lead, Gold	51,299,303	378
Bokan Mountain	PEA	Rare Earth	6,435,000	118
Golden Summit	PEA	Gold	146,561,808	299
Graphite Creek	PEA	Graphite	113,360,000	269
Money Knob (Livengood)	Pre-Feasibility	Gold	637,334,353	331
Palmer	PEA	Zinc, Copper, Gold	15,731,066	94

Note, the Lik project also has a PEA but it is not listed because it would not result in a separate mill. It is better understood as a project that could continue the life of the Red Dog Mine. Note, Graphite Creek has a PFS in progress.

Projects in the remaining pyramid stages are listed in Appendix A.

Chapter 3. Methodology: Calculating Three Development Scenarios

Previous chapters have explained the mine development pyramid and listed projects that exist in each development stage. To calculate the size of the industry in 20 years, the project assigns probability of development to projects in each stage for each scenario. Probabilities are not assigned to individual mines, but to stages in the development pyramid. For example, in the Favorable Scenario, if there is a two-thirds chance that projects in the economic evaluation will be in production in 20 years, then multiplying the total production and employment for the mines in economic evaluation by two-thirds will provide the expected value that mines in that category will contribute to the industry in 20 years. After making the same calculation for all stages of the development pyramid, the report describes the expected value of the mineral industry, for each scenario. An expected value is the probability that mine in each development stage comes into operation multiplied by the economic outcomes for the mines in that stage (employment, gross value, commodity production).[11]

These probabilities should be thought of in an abstract way. For instance, instead of representing the probability that each mine in the category is operating at full scale, they may represent the proportion of properties within a category operating at full scale. They may represent that all mines in a category are operating, but at some reduced scale relative to their full capacity; an interpretation that is useful for thinking of the operating mines. The probabilities may also represent some even more abstract combination of these three representations. We are not estimating the probability of a particular mine coming into production. Rather, we are looking at the probability for mines in each stage of the development pyramid.

Assigning probabilities is subjective. We used several principles and techniques to reduce the subjectivity.

- Probabilities in the Favorable Scenario are higher than in the Status Quo Scenario, which are higher than those in the Unfavorable Scenario.
- Projects currently in more advanced stages of development are more likely to come into operation in the next two decades than projects in early exploration. Also, based on the limited literature on the subject, movement up the development pyramid is non-linear. Projects with an economic evaluation (those with a PEA, PFS, or FS) are much more likely to become operating mines than projects in a lower exploration stage. There is only a small chance that a project that has not to date complete extensive drilling will become a large mine in the next two decades.
- The capital expenditures, project management expertise required, and regulatory and social issues make very large mines more difficult to bring into operation than smaller mines with equivalent rates of return.

[11] To use a simplified example: If there were 10 mines in one development stage and each employed an average of 100 people, and mines in that stage of development had a 50% chance of becoming a mine in 20 years, then the expected employment for that stage would be 10 x 100 x 0.5 = 500 employees. A sum of all the stages would give us estimated employment for that scenario in 20 years. A similar process can be done for the tonnage and value of minerals produced.

- We assigned probabilities for hard rock, coal, and placer/suction dredge projects separately.

We assigned probabilities using the information above, and after reviewing the limited literature on the subject. We then discussed these probabilities with Alaska mining industry experts. We selected five individuals with expertise in different areas of the state, from southeast to northwest Alaska, and individuals who focused on different stages of the development pyramid. The individuals are involved with projects from the initial exploration stages to operating mines. The probabilities assigned in this paper reflect the judgement of the authors and no one else. Nevertheless, these discussions gave us confidence that the probabilities used in this paper are reasonable. Given the constraints – that the Favorable Scenario has higher probabilities than less favorable scenarios, that the probabilities decrease as one descends the pyramid, and that probabilities at the economic development stage are much higher than at lower stages – it is possible for reasonable people to come up with different probabilities. But given the constraints, and being consistent with the literature, the probabilities would probably not be wildly different. In other words, the results of the analysis should be treated as a reasonable, order-of-magnitude, assessment of what events in these scenarios may produce.

A. Hard Rock Minerals. Table 5 shows the probability and probability range assigned to hard-rock projects in each scenario and at each development stage.

Table 5. Expected Probability of Operation in 20 years, by Scenario
Hard Rock Minerals

Development Stage	Unfavorable Probability	Unfavorable (Range)	Status Quo Probability	Status Quo (Range)	Favorable Probability	Favorable (Range)
Operating	**50%**	(40%-60%)	**70%**	(60%-80%)	**100%**	(100%-100%)
Permitting	**37.5%**	(25%-50%)	**62.5%**	(50%-75%)	**87.5%**	(75%-100%)
Economic Evaluation	**12.5%**	(0%-25%)	**37.5%**	(25%-50%)	**62.5%**	(50%-75%)
Significant Exploration	**0%**	(0%-10%)	**12.5%**	(0%-25%)	**33%**	(25%-40%)
Moderate Exploration	**0%**	(0%-5%)	**5%**	(0-10%)	**10%**	(0%-20%)
Initial Exploration						
Small Mines	**0%**	(0-0)	**1**	(1-1)	**2.5**	(2-3)
Medium Mines	**0%**	(0-0)	**-**	(0-0)	**0.025**	(0-0.05)
Large Mines	**0%**	(0-0)	**-**	(0-0)	**0.025**	(0-0.05)

For each scenario, the table shows the probability that projects at each stage of development may be operating in 20 years. The numbers in parenthesis to the right of the probability provide a potential range of values. They are not a statistical confidence interval. Rather, we more arbitrarily assigned a range around each probability to emphasize the inherent uncertainty of the method. We picked 10% on either side of the probability, or an obvious cut-off, such as 50% or 75% to emphasize the potential uncertainty, or the order-of-magnitude nature of the analysis. Nearly all probabilities are the just the midpoint value of the range, except for projects with significant or moderate exploration in the Unfavorable Scenario. Here we assume that no project that has not completed at least their preliminary economic assessment would be expected to overcome the scenario's assumptions of additional regulatory hurdles and a low mineral price environment to come into production in 20 years.

The table shows that mines which have gotten to the economic evaluation stage have a much higher chance of entering production than those in lower exploration stages.

For the Favorable Scenario, we assume that the operating mines continue as they are working today. While Alaska's hard rock mines do not have reserves which extend 20 years, most mines are exploring for additional reserves, and have been successful over the last few decades of replacing their reserves. If Alaska is fortunate, this will continue. As examples, Red Dog is exploring the Lik deposit, which would extend its life past 20 years. Fort Knox is extending the facility's life as a regional mill for reserves elsewhere in its region beginning with the Manh Choh project near Tetlin. Note: To avoid double counting, the report does not assign probabilities to Lik, Manh Choh, or other deposits associated with an operating mine. The potential production from these deposits is presumed to extend the life of the operating mine, and therefore is not considered an independent project for purposes of this report.

For the Favorable Scenario, we assume that most of the projects currently in permitting develop into a mine. This is consistent with the literature on the subject. Note that the expected value is the midpoint of the range. Therefore, we calculate that 87.5% of the projected employment and project from the mines in the permitting category will be part of Alaska's mineral industry in 20 years. The statistics of the permitting are dominated by the very large Donlin Gold project. Essentially, the Favorable Scenario assumes an 87.5% chance that Donlin Gold will be in production (and the upper limit of the range shows a probability up to 100%). The size of this project means that the fates of other projects in this category matter much less.

In the Favorable Scenario, the probability of a project continuing through permitting to reach operating in 20 years decreases as one goes further down the pyramid. We assume a two-thirds chance that projects with an economic evaluation will be in production in 20 years. This probability is consistent with the literature and with our informal review of the mines in this category. For projects in the initial stage of development, the literature and history indicate that few of these will be mines within 20 years, though some may achieve that status later.

Projects in the Initial Exploration category do not have a reserve estimate or estimated employment. Assigning them probabilities would not be useful, because there is no information with which to multiply the probabilities. Calculating these projects' potential contribution to the employment and production requires a different system. For this study, we estimate the number of mines at different stages that may come into production. While these decisions may be more subjective than other parts of the analysis, the consequences of this subjectivity are not large. The size of the mining industry in 20 years is dominated by the probabilities at the upper stages of development. Reasonable changes at the low-probability initial stage of the development pyramid do not have a large effect on the outcome.

The Unfavorable Scenario reflects a significantly less desirable mining regulatory climate. This could occur through an electoral initiative, or significant sustained public opposition along with lower prices. This scenario would greatly lessen, perhaps eliminate, the ability for early-stage exploration projects to attract investment. We assume that projects for which there is already a significant sunk cost – those which have reached the economic evaluation stage – may continue to attract some development dollars. But early-stage exploration will be much harder, perhaps impossible, to finance. For these reasons, we assigned a zero probability to the lowest three exploration stages. Further, in this scenario, we assumed that half of the production of today's operating mines has reached its economic limit and close. The production decrease could come from mines closing or from a decrease in production at some mines.

The Status Quo Scenario is a continuation of today's current trends.

B. Coal. The economics of the coal industry have changed notably in the last decade, as has public perception of its climate impact. This change raises questions about the demand for new coal mines over the next 20 years. We considered a few factors that could affect the outlook for coal. Metallurgical coal, coal needed to make steel, will likely maintain or grow demand in the next several decades. In addition, it may be possible that some coal mines develop a carbon sequestration strategy, or some countries may do so which would increase the demand for coal. Also, some countries also need low-sulfur coal that is abundant in Alaska as they develop other fuel sources. Even with these factors, it is difficult to imagine economic and social circumstances providing for a large amount of growth in Alaska coal markets. Therefore, the probabilities for coal are different from those of a hard rock explained in the previous table.

The Status Quo Scenario reflects some diminished demand in the future. The Favorable Scenario reflects continued operation by Alaska's existing coal mine, and some probability for a new mine due to metallurgical coal, carbon sequestration, higher demand for low-sulfur coal, or for another reason. Currently there are no Alaska coal mines in the Economic Evaluation or Initial Exploration stages, so we did not assign probabilities to those stages.

Table 6. Expected Probability of Operation in 20 years, by Scenario

Coal

Development Stage	Unfavorable Probability	Unfavorable (Range)	Status Quo Probability	Status Quo (Range)	Favorable Probability	Favorable (Range)
Operating	**50%**	(40%-60%)	**70%**	(60%-80%)	**100%**	(100%-100%)
Permitting	**0%**	(0%-0%)	**0%**	(0%-0%)	**20%**	(15%-25%)
Economic Evaluation	**N/A**		**N/A**		**N/A**	
Significant Exploration	**0%**	(0%-0%)	**0%**	(0%-0%)	**16%**	(12%-20%)
Moderate Exploration	**0%**	(0%-0%)	**0%**	(0%-0%)	**5%**	(0%-10%)
Initial Exploration	**N/A**		**N/A**		**N/A**	

C. Placer. Placer gold mines, including suction dredge operations, are a much different type of operation than the hard rock or coal projects examined above. According to a 2014 study of the industry,[12] the average placer mine had 4.1 employees. Approximately 27% were run by a single person, and only 4% of the industry had 10 or more workers. The placer industry also operates exclusively during the summer. Those mines with paid employees have an 86-day season; those without average a 58-day season.

For estimating the potential scenarios for placer employment, we look at historic employment figures from 2008-2019.[13] During that time, full-time equivalent employment in the industry ranged from 159 workers (2019) to 477 workers (2012). In 2019, placer mining employed approximately 160 people in full-time-equivalent positions. For the Status Quo Scenario, we assume placer mining maintains this scale over the next two decades. For the Favorable Scenario, we assume that placer employment, wages, and gross value double, which is slightly more than the average for the period. We also include a range (500 people), which is slightly more than the maximum employment during the period. Finally, we assume that for the Unfavorable Scenario, employment is around half of today's values.

[12] The Economic Impacts of Placer Mining in Alaska. October 2014. Prepared by McDowell Group for the Alaska Miners Association.

[13] Alaska's Mineral Industry 2019. Special Report 75. State of Alaska Department of Natural Resources, Division of Geologic and Geophysical Surveys. Jennifer Athey, Melanie Werdon, and Evan Twelker. Table 2, page 5.

Chapter 4. Results: Alaska's Mining Industry in 20 years, in Three Scenarios

A. Explanation of calculations. Chapter 2 explains the mine development pyramid. That chapter, along with Appendix A, lists the mineral projects in Alaska. Chapter 3 describes probabilities that can be applied to projects at each stage of the mine development pyramid, for each of three scenarios. This chapter explains the results: applying the probabilities of Chapter 3 to the information from the mines presented in Chapter 2.

Our analysis calculates several outcome measures to describe the potential impacts of the mineral industry to the Alaska economy in 20 years: employment, commodity production values, and total wages. First, employment captures the number of full-time-equivalent jobs associated with exploration, mining, and milling operations.[14] Second, we estimate the annual gross value of commodities contained in mined ore, an approximation of producer revenues before processing losses and smelter discounts are applied. Third, we estimate employee wages for the industry. We then use our estimates of gross value produced to calculate the potential fraction of total Alaskan exports that mining could represent. These estimates are used to inform a qualitative analysis of potential impacts to statewide government revenue and to Alaska Native Regional and Village Corporations. Finally, production by commodity estimates are used to understand the potential for Alaska to contribute to material supply chains in the United States and globally.

For operating mines, projects in permitting, and projects in the economic evaluation stage, employment figures are those reported by the project. For exploration projects without an economic evaluation (most properties considered in this report), employment is estimated, as indicated from below, from a project's resource estimate. Resource production is taken from the actual production values reported by operating mines. However, for other mines, the annual production is estimated from resource values using mine engineering guidelines.[15]

Mine engineering equations are drawn from the SME Mining Engineering Handbook, Chapter 6.3.[16] These equations start by estimating the optimal annual operating rate of the mine based on the resource size, denoted by the variable R. By assuming complete extraction of the resource, the resource size divided by this operating rate will equal its mine life. Once a rate of ore mining is calculated, employment can be estimated using the empirical relationship between personnel requirements and the daily ore mining rate. Milling employment can be similarly estimated.

First, we apply the Taylor rule (an empirical relationship between estimated resources and mine life) to calculate a rate of annually mined tonnage and associated mine life.

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[14] We do not include construction jobs that are needed during a mine's initial development.

[15] We do this so that the project has a consistent methodology across all projects with a resource estimate. It would have been possible to also use the company's projected production rates from projects in permitting and those with an economic evaluation. The difference produced by using a project's totals is not large.

[16] O'Hara, T. and Suboleski, S., 1992. Costs and Cost Estimation. In: *SME Mining Engineering Handbook Vol 1*. pp.405-424.

Mining Life = 0.2 $R^{0.25}$

Mining Rate = R/Mine Life

where R is the mineral property's resource estimate. To estimate the annual gross value of minerals produced at each property (i), we use the following formula:

$$\text{Gross value}_i = \sum P_j * \text{Mining Rate}_i * \text{Grade}_{ij}$$

where P_j is the price of a commodity j (dollars per ton), Mining Rate is the rate estimated using the Taylor rule (tons per year), and Grade_{ij} is the reported fraction of contained commodity in the resource (percent weight). All prices are from the USGS Series 140, most recently updated in 2017, and which measures the weighted average price of the contained metal of US imports.

Employment is estimated using a low-grade open pit prototype mine. This abstracts from the complexity of making assumptions about each mine's potential to develop as an above/below ground operation or making arbitrary determinations of resource grade. While we recognize deposit depths will vary widely, we assume a stripping ratio for all mines of 3:1.

Mine employment = 0.034 x 3 x Mining $\text{Rate}^{0.8}$

Mill employment = 5.9 x Mine $\text{Rate}^{0.3}$

These formulas for estimating employment tend to underestimate employment at the currently operating mines in Alaska but do well at matching the employment estimates found in PEAs, PFS, and FS studies. Adding together current employment from all operating mines and the employment projections reported in all current PEAs, PFS and FS studies yields a total of 6,280 jobs. Compare this to the total estimated employment of 5,410 from these same mines and projects using the formulas above, a difference of approximately 16%. We adjust our employment estimates upward by this amount. We make a similar adjustment to estimates of gross revenue to match them more closely to reported or projected revenue.

We use a different method to calculate these outcome measures for exploration activities and for placer mining. To estimate employment potential for exploration, we look at employment in exploration and development in Alaska from 2008-2019. Over this period, there have been between 2-4 employees at operating mines for every one person employed in exploration and development activities, with an average of 2.5 persons. We apply this ratio to the total employment for each scenario to estimate the number of potential employees in exploration and development.

B. Employment. With respect to employment, the results of the calculations, by scenario, are presented in Table 7.

Table 7. Mining Industry Employment in 20 years, by Scenario

	Today	Unfavorable		Status Quo		Favorable	
	Today	Emp.	(Range)	Emp.	(Range)	Emp.	(Range)
Hard Rock & Coal	**2,776**	**1,833**	(1,141-2,630)	**3,319**	(2,372-4,267)	**5,823**	(5017-6,623)
Exploration	**941**	**733**	(456-1,052)	**1,328**	(949-1,7707)	**2,329**	(2,007-2,649)
Placer Mines	**159**	**80**	(60-100)	**160**	(120-200)	**320**	(240-500)
Total	**3,876**	**2,646**	(1,657-3,782)	**4,807**	(3,440-6,174)	**8,472**	(7,263-9,772)

Employment from hard rock and coal mines "today" is as reported by the 6 operating mines. Exploration and placer mine employment comes from DNR Alaska Mineral Industry 2019.

The table shows that in the Favorable Scenario, employment in the mining industry goes up by 120%. Most of the increase comes from employment at Alaska's large mines which increases by over 3000. Exploration increases by almost 1,400, and placer mining by 160 people. The table shows much more modest growth in the Status Quo Scenario, which is expected. By our assumptions, employment in the Unfavorable Scenario falls by approximately one-third.

Average mining wages in 2019 were $110,434. Table 8 shows the total wages payment for each scenario. It is equal to the number of people employed (indicated in Table 7) times the 2019 average wage. The table shows that total wages to employees could range from $292 million in the Unfavorable Scenario to close to a billion dollars in the Favorable Scenario.

Table 8. Mineral Industry Wages, by Scenario in Millions of 2019 $

	Today	Unfavorable		Status Quo		Favorable	
	Today	Wages ($m)	(Range)	Wages ($m)	(Range)	Wages ($m)	(Range)
Large Mines		**$ 202**	($126-$290)	**$ 367**	($262-$471)	**$ 643**	($554-$731)
Mineral Exploration		**$ 81**	($50-$116)	**$ 147**	($105-$195)	**$ 257**	($222-$293)
Placer Mines		**$ 9**	($7-$11)	**$ 18**	($13-$22)	**$ 35**	($27-$55)
Total	**$ 428**	**$ 292**	($183-$418)	**$ 531**	($380-$689)	**$ 936**	($802-$1,079)

To this point, the analysis has focused on the direct effect of the scenarios in terms of gross value, employment, and wages only in the mining industry. However, economic activity from one industry spills over into other sectors of the economy. The mining industry contracts financial, consulting, geological, transportation, security, and construction services and purchases fuel, goods, and other raw materials from suppliers. Additionally, mining employees spend their earnings in the local economies where they work and live, generating further economic activity at retailers, grocers, and other establishments. The economic multiplier effect is the number of jobs across the economy for every one job in the mining industry.

McKinley Capital (formerly McDowell Group) estimates an economic multiplier effect[17] of the mining industry of around 2, meaning for every mining job, there's an additional job supported elsewhere. Across the industries that McKinley regularly reports, mining has the second largest multiplier (with only the petroleum industry being larger).

Considering a multiplier effect of 2 in the context of our employment scenarios, total employment from direct and indirect effects in the Favorable Scenario is estimated to range between 14,500-19,500 jobs. For context, Alaska had average employment of around 330,000 in 2019. In the Unfavorable Scenario, we estimate average total employment between 3,300-7,600.

Table 9. Direct and Multiplier Employment by Scenario

	Unfavorable		Status Quo		Favorable	
	Emp.	(Range)	Emp.	(Range)	Emp.	(Range)
Direct	2,646	(1,657-3,782)	4,807	(3,440-6,174)	8,472	(7,263-9,772)
Direct & Multiplier	5,292	(3,300-7,600)	9,614	(6,900-12,300)	16,944	(14,500-19,500)

Direct and Multiplier effects include direct, indirect, and induced effects.

Table 10 shows the gross value of production. This information multiplies the tonnage of production, by commodity, times the 2019 world price for that commodity. It does not consider smelter deductions, nor does it consider real price increases that are forecast for many metals, especially those needed for green energy.

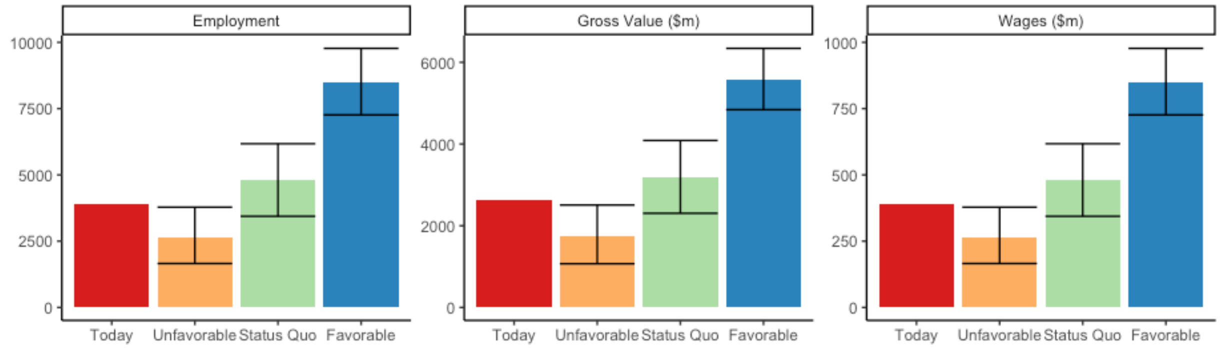
Table 10. Mining Industry Gross Value in Two Decades, by Scenario. Millions of 2019 $

		Unfavorable		Status Quo		Favorable	
	Today	Value	(Range)	Value	(Range)	Value	(Range)
Hard Rock & Coal	$ 2,559	$ 1,709	(1,043-2,462)	$ 3,126	(2,252-4,000)	$5,439	(4,729-6,123)
Placer Mines	$ 67	$ 35	(26-44)	$ 70	(53-88)	$ 150	(113-219)
Total	$ 2,626	$ 1,744	(1,069-2,506)	$ 3,196	(2,304-4,087)	$ 5,589	(4,841-6,341)

The information discussed above is provided in graphs below.

[17] McDowell Group. 2018. "The Economic Benefits of Alaska's Mining Industry" www.mcdowellgroup.net/wp-content/uploads/2021/01/2017-ama-ei-final-report.pdf

Figure 3: Mining Industry Outcomes in Two Decades, by Scenario



Employment is measured as full-time-equivalent jobs. Gross values and wages are in millions of 2019 dollars.

Overall, in the Status Quo Scenario, we project a modestly larger mining industry than exists today in terms of employment, gross value, and wages. Our Favorable Scenario sees an industry that is roughly larger than exists today. Our Unfavorable Scenario sees an industry that is one-third smaller than today's.

The Status Quo Scenario projects employment between 3,440-6,174 jobs, with 4,807 as the midpoint value. Two-fifths of these jobs come from currently operating mines where production is expected to decline over the next several decades. Another third come from exploration and development activities. The remainder are from currently-being-explored projects and placer mining. Operating mines provide a larger contribution to gross value (around two-thirds) than employment, mostly because exploration activities do not contribute to gross value of the industry.

In the Favorable Scenario, industry employment is between 7,260 and 9,720, with 8,470 as the midpoint value. Gross value is between $4.8B-$6.3B per year, with a midpoint value of $5.6B. In the Favorable Scenario, currently operating mines play a slightly smaller role in the size of the industry, as in this scenario their size is assumed fixed at today's levels, but a number of new mines would be expected to open.

In the Unfavorable Scenario, industry employment is between 1,660-3,780, with 2,650 as the midpoint value. Gross value is between $1.1B-$2.5B, with a midpoint value of $1.7B. Despite our assumption of a 33% decline from currently operating mines, in the Unfavorable Scenario, they still play an outsized role in the state's industry because of the low likelihood that any new projects come online over the next two decades.

C. Production, Gross Domestic Product (GDP), and Exports. Alaska's GDP between 2016-2020 (pre-covid) averaged approximately $48 billion in real 2012 dollars (U.S. Bureau of Economic Analysis). Export industries play a key role in regional development. Money from outside the state flows in and supports additional economic activity. One measure of export (or basic industry) activity is the gross value of these activities. Oil wellhead value over this period averaged around $8 billion per year. The next largest source of money from outside the state has been the federal government, including the US military, providing for around $4.1

billion of the state's GDP. Mining gross value averaged $2.3 billion per year. Visitor spending from the tourism economy was $2.2 billion. Fisheries ex-vessel values were approximately $2 billion in 2018, and fish processing value added of $2.45 billion, for a total of $4.45 billion. Other manufacturing industries account for $0.25 billion Combined, these basic sector industries which export nearly all of their products outside Alaska, account for $18.9 billion in value.[18]

This study estimates that the value of Alaska's mineral exports could decline in the Unfavorable Scenario to $1.7 billion, or it could increase in the Favorable Scenario to $5.6 billion. This latter amount would be a significant level of exports – more than the federal government brings into Alaska today and more than any other industry other than oil. It would raise the basic industries' input to Alaska by 30% of today's value. This would bring an important statewide increase into the economy, even accounting for overall economic growth in 20 years.

D. Statewide Government Revenues. The State of Alaska receives mining revenue from the industry in several ways: royalty, mining license tax, corporate income tax, rents, and fees. The significant majority of this revenue comes from the state's six large mines.

Projects on state land pay Alaska's government a net profits royalty. However, only the Pogo Gold Mine and the Usibelli Coal Mine are on state land. The ore deposit for the Fort Knox Gold Mine is owned by the Alaska Mental Health Trust Authority and is subject to state rent and royalty.

Each of the six large mines are subject to the state's net profits mining license tax and corporate income tax. The exploration sector does not pay royalty or production taxes, because the projects are not in production. The placer mining industry, while subject to these requirements, does not pay a large amount to the state due to the industry's small size and because most family and small businesses are not subject to a significant levy. All of the sectors pay claim rentals. Finally, the industry pays a variety of fees.

Between 2016 and 2019, the mineral industry paid approximately $66.6 million per year in revenue to the state government plus another $36.8 million to municipalities.[19] Given the state's general fund budget of around $4-5 billion, mining makes a relatively small contribution to state revenue today. Compare this to petroleum revenues, which over the same period contributed an average of $2.2 billion in general fund revenue to the State.[20] In the Favorable Scenario, the mining industry approximately doubles in size. However, this is partially based on our gross value calculation, for which we have assumed that prices are fixed at today's levels. This

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[18] Sources for this calculation are as follows. Oil wellhead value comes from the Alaska Deparment of Revenue Fall Revenue Sources Book, 2020. Federal government spending and other manufacturing industries come from the U.S. Bureau of Economic Analysis Regional Economic Accounts. Mining gross value comes from the Alaska DNR Mineral Industries Report, 2019. Visistor Spending is estimated by the McDowell Group from its 2016 Visitor Industry Impacts Report. Fishing industry numbers of from McDowell Group "The Economic Value of Alaska's Seafood Industry" January 2020 Report.

[19] Fiscal Effects of Commercial Fishing, Mining and Tourism: Fiscal Years 2016-2019. Bob Loeffler and Steve Colt. Institute of Social and Economic Research. February 24, 2022.

[20] Alaska Department of Revenue Source Book. Fall 2021. Appendix A, Table 3, p. 101. Includes restricted and unrestricted petroleum revenue averaged from 2015-2019.

assumption makes the comparison between scenarios more clear, but masks an important issue. If prices were to increase significantly, state tax revenue from mining would increase significantly, as net profits taxes are more sensitive to prices than quantities.

It is difficult to imagine contributions to state government revenue on the same order as those for petroleum today. However, Alaska faces a structural budget deficit of around $1 billion going into the future. A doubling of State revenues from mining (i.e. from $66.6 million to $133 million) would reduce the deficit by approximately 7%. Alaska's net profits tax and royalty mechanisms makes Alaska's government revenues sensitive to price changes. Therefore, if mineral prices rise moderately, the state would also see a corresponding increase in revenue, but that increase would still be a small part of Alaska's state government budget.

Another important aspect of the state fiscal effects of mining is that it provides true net returns to the state budget. The industry pays more in royalties, taxes, and fees than the state expends on administration and enforcement. A 2022 ISER study estimated that the state government spends less than $6.7 million per year regulating and promoting revenue from the mining industry. That study averaged both revenue and costs over four years, finding that state government revenue was ten times more than what it spent on regulating and promoting the industry.[21]

E. Alaska Native Corporation Revenue. Due to provisions in the Alaska Native Claims Settlement Act (ANCSA), mining has developed an unusual role for Alaska Natives through royalties paid to the NANA Corporation from the Red Dog Mine. The role is as a revenue source for all Alaska Native Regional Corporations, and through them to provide revenue to all Alaska Native Village Corporations. To an extent, those revenues are passed through to Native shareholders.

ANCSA Section 7(i) provides that 70% "of all revenues received by each Regional Corporation from…subsurface estate patented to it..." must be distributed to all 12 Alaska Native Regional Corporations on the basis of each corporation's Native population. Because the Red Dog Mine is on Native Land conveyed to the NANA Corporation, NANA must distribute 70% of the royalties among the 12 Alaska Native Regional Corporations.

NANA has received approximately $2.4 billion from the Red Dog Mine since its inception. Of that amount, $1.5 billion has been redistributed to other ANCSA regional corporations. This equaled over $126 million per year to Alaska's Regional Native Corporation, and equals approximately $1,120 per year for every Alaska Native living in the state.[22]

NANA's 7(i) distribution provides important income for other Alaska Native Regional Corporations, but also for Alaska Native Village Corporations. ANCSA Section 7(j) requires that half of the 7(i) income be redistributed to the Alaska Native Village Corporations.

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[21] See Fiscal Effects of Commercial Fishing, Mining and Tourism, Fiscal Years 2016-2019. Bob. Loeffler and Steve. Colt. February 24, 2022. Institute of Social and Economic Research.

[22] Information concerning NANA distributions from its inception are from Alaska Native Claims: Mining in Alaska, 50 years after ANCSA. Data Mine North. October 13, 2021. P. 76. Information for the period 2014-2020 provided by Lance Miller. Per capita information uses information from these sources divided by Alaska Native population from the U.S. Census website, visited January 2021.

According to the Alaska Native Village Corporation Association (ANVCA), "the 7(j) income accounts for all or nearly all of the revenue collected by approximately two-thirds of the 177 village corporations that are ANVCA members."[23]

This is an important revenue source for Alaska's unique regional and village corporations, and for Alaska Natives. Between 2014-2020, NANA's distributions from Red Dog constituted 69% of all distributions under 7(i) which is redistributed through 7(j). However, this significant revenue source could end in 2031, within the time frame of this report.

Current reserve for the Red Dog Mine is scheduled to be exhausted in 2031. The Lik deposit is the most likely next potential source to extend the mine's life. However, it is on state land. State land is not "subsurface estate patented to Native Corporations" and not subject to 7(i). Therefore, NANA's 7(i) payments may come to an end. This is likely to have a very significant effect on those Alaska Native Village Corporations that are dependent on the distribution.

Mineral properties associated with Alaska Native Corporations that are most likely to become operating mines are in the Ambler Mining District and the potential Donlin Gold Mine. NANA is involved in both the Bornite and Arctic properties in the Ambler Mining District. Arctic is on state land and Bornite is on land acquired by NANA outside of ANCSA. Therefore, neither are subject to 7(i) (with minor exceptions).[24]

The Donlin Gold prospect is owned by Calista Native Corporation. Royalties to Calista from mining at the site, if it comes into production, are subject to 7(i). The potential distribution is unknown, but Donlin Gold could make up at least part of what is lost when Red Dog's ANCSA ore is exhausted. However, if Donlin Gold does not go into production, the loss of NANA 7(i) revenues will be substantial, and will be especially hard on the Native Village Corporations.

F. The Pebble Project. Thus far, our analysis has omitted the Pebble Project, due in part to its exceptionally large size, its controversy, and the fact that the federal government has denied a permit for the project, though that denial is on appeal. The Pebble deposit is one of the largest copper deposits ever discovered. Using numbers from the developer's 2021 Preliminary Economic Assessment, the in-situ value of the contained copper alone might have a value of \$230B. the value of the gold, silver, and molybdenum is added, the total value of the deposit is estimated at close to \$400B. The developer's PEA indicates that mine's proposed 20-year plan would generate an average of \$1.7B in annual revenue after an initial \$6 billion in capital expenses. The U.S. Army Corps of Engineers Final Environmental Impact Statement stated the proposed mine would generate \$84 million in state tax revenue annually, \$27 million to local government, and employ around 850 people. In other words, the Pebble Project alone might increase the gross value produced by the state's mining industry by 65%, nearly double state government revenue from mining, and increase hard rock mining employment by one-third.[25]

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[23] Alaska Journal of Commerce, "Native corporations slowly approach state shared revenue 'cliff'." September 29, 2021.
[24] There are a few parcels of ANCSA land that could be a part of a mine at Bornite, but they are not the major part of the deposit.
[25] Employment and Tax figure from the Pebble Project final Environmental Impact Statement. July 2020. Page 4.3-2 and 4.3-3

If this project were added to any of the scenarios, its effect would greatly change the statistics of that scenario. Given its controversy, its size, and the fact that the permit has been denied, it seems more reasonable to describe the effect of this project individually. If you believe the project could be developed in 20 years, its effects may be added to any of the scenarios.

This study takes no position on whether the project can or should be developed.

Chapter 5. Alaska's Role in Supplying Energy and Critical Minerals

Engineered materials are becoming increasingly complex. An Intel computer chip in 1980 used 11 mineral-derived elements found on the periodic table. By the 1990s, it was 15 elements. In the future their chips may contain up to 60 elements. The inputs into more general household products are also growing in number. Just 30 years ago a typical household in the US might have owned products containing 20 chemical elements. Today, General Electric uses 70 chemical elements in its product lines.[26]

Similarly, many technologies in the renewable energy space are becoming more complex. They depend on chemical elements that have never had significant commercial demand, particularly at the scale that would be required for substantial proliferation of these technologies. For example, delivering reliable power through advanced, thin-film solar panels could require elements such as gallium, indium, and tellurium for the photovoltaic cells, and lithium, cobalt, and graphite for battery storage. Electric vehicles depend on these same battery materials, along with powerful and lightweight rare-earth element magnets.

A number of these mineral-derived elements have never had significant commercial demand, so their supply chains are not diversified and are vulnerable to disruption. Such minerals are sometimes described as "critical materials," because of the essential role they play in their end-use technology, along with the fragile supply chains that produce them.

Which materials are considered critical depends on one's perspective. A battery manufacturer in the United States is likely to face different supply chain risk than an electric vehicle engine manufacturer in China. This is because a mineral's supply chain risk is not just a function of how much is contained in the earth's crust. Instead, supply chain risk is a function of a broad set of factors that define a mineral's availability in a broader sense. These factors include economics (e.g., the cost of producing, refining, and transportation), social (e.g., local opposition to mining), political (e.g., environmental or trade policy), and technological.

Several organizations like the US Department of Energy, General Electric Corporation, or the European Commission,[27] have identified lists or rankings of critical materials reflecting their perspectives on supply chain risk. The United States Geological Survey has recently assembled a list of minerals critical to domestic manufactures, which provides a useful starting point in assessing how Alaska mineral production might play a role in supplying critical minerals for the US economy. [28]

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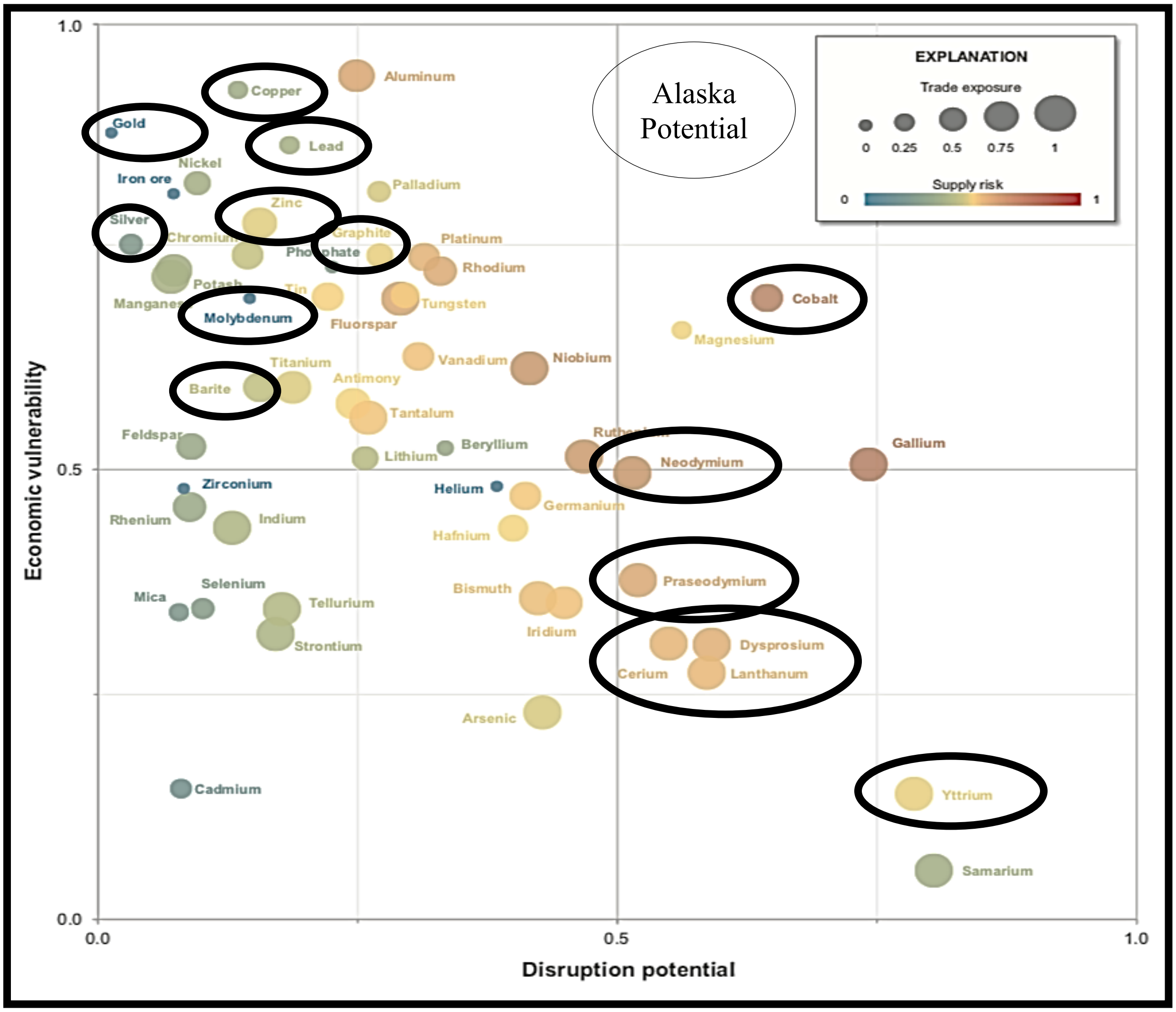
[26] Information in this paragraph taken from: Eggert, Rodrick. 2011. https://www.govinfo.gov/content/pkg/CHRG-112hhrg66649/html/CHRG-112hhrg66649.htm

[27] See US Department of Energy Critical Materials Strategy. Dec 2011; Duclos S., materials for manufacturing: GE risks and opportunities, paper presented at the GE Whitney Symposium, Niskayuna, New York, October 2011; Mathieux, Fabrice, et al. "Critical raw materials and the circular economy." *Publications Office of the European Union: Bruxelles, Belgium* (2017).

[28] Nassar, Nedal T., and Steven M. Fortier. Methodology and technical input for the 2021 review and revision of the US Critical Minerals List. No. 2021-1045. US Geological Survey, 2021. https://pubs.usgs.gov/of/2021/1045/ofr20211045.pdf

Figure 4 is the USGS's mineral criticality assessment. The horizontal axis "Disruption Potential" reflects the probability that a mineral might become unavailable to US manufacturers, while the vertical axis represents how consequential such a disruption would be. Minerals in the upper-righthand area of the figure are more "critical," as they have higher risk of a potential disruption, and the consequences of the disruption are very high. The circled elements in Figure 4 are those Alaska currently produces or has the potential to produce in the next two decades.

Figure 4. Economic Importance and Disruption Potential[29]



A. Alaska's current mineral products. Today, Alaska produces four metal commodities, almost all of which is exported out of state, and thermal coal, all of which is used within state for power generation. The four metal products of Alaska's mineral industry today are zinc, gold, silver, and lead.

[29] Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List. USGS Open-File Report 2021-1045. Nedal T. Nassar and Steven M. Fortier

Zinc (Zn). Zinc's primary use is in galvanizing steel to prevent rusting. Alaska is a major zinc producer. In 2019, the state produced more than 600 thousand tonnes of zinc (mostly from the Red Dog mine), accounting for nearly 80% of US primary production. While the USGS assessment of zinc ranks its potential for supply disruption as low, this is in part based on Alaska current production output. In other words, without Alaska zinc production, American production would be significantly more susceptible to disruption.

In our Status Quo Scenario, zinc production falls to around 500 thousand tonnes, as the Red Dog and Greens Creek mines are depleted. This level is around 70% of current domestic production and 4% world production. Our Favorable Scenario projects Alaska annual production of approximately 700 thousand tonnes per year. Most of this still is driven by the Red Dog mine, which under the Favorable Scenario is assumed to successfully develop adjacent properties sufficient to maintain today's production levels.

Gold (Au). Gold's primary use is as a financial asset, held by funds, individuals, and central banks. Use in jewelry accounts for around two-fifths of global demand, while industrial and technological applications make up a small fraction of demand. At less than 20 tonnes of gold per year, Alaska is the distant second gold producer in the US today (Nevada produces six times more). In our Favorable Scenario, gold production in Alaska might increase significantly to around 80 tonnes, as many development and advanced exploration projects are targeting gold.

Silver (Ag). Silver has several industrial and technological applications, including uses in alloys, solders, catalysts, electronic components, and film photography. Silver is also used in silverware, jewelry, and bullion directly as an investment asset. An emerging use for silver in the energy sector is in photovoltaic cells in silicon solar panels. Alaska is the largest silver producer in the United States, accounting for more than half of domestic production in 2019. Our Status Quo Scenario imagines that silver production expands by about 40%, whereas the Favorable Scenario finds potential for silver production to roughly double. At that level of production, silver production would be equivalent to all the country's 2019 production of silver.

Lead (Pb). Since its phase-out from paints and gasoline, lead's primary application (more than 90% of end-use) has been in lead-acid batteries, with only minor demand for solder, ammunition, and other uses. Alaska is a major lead producer in the US, accounting for 44% (121 thousand tonnes) of primary lead production in 2019. Our Status Quo Scenario projects a moderate increase in production (around 25% more), and our Favorable Scenario projects less than twice current production. As lead-acid batteries are being replaced by lithium batteries in many applications, prospects for long term demand growth are modest. Nevertheless, lead will remain an essential mineral for the economy, and Alaska's production could increase to 94% of the country's 2019 total production of lead.

Coal. Coal has two major applications. Thermal coal is burned for electricity generation and metallurgical coal is used to produce steel. Thermal and metallurgical coals are differentiated by their grade and the presence of ash and moisture contaminants. Currently, Alaska produces only thermal coal from the Usibelli mine for use in electricity generation in the Fairbanks area. Statewide, coal electricity accounts for about 12% of all electricity generation. Our Status Quo Scenario projects this situation remaining largely unchanged. Under the Favorable Scenario, we might see one additional thermal or metallurgical coal mine open, which would almost certainly supply out of state customers, likely international customers in the case of thermal coal.

B. Alaska's potential mineral products. In addition to the five important minerals discussed above, Alaska has the potential to contribute significant quantities of six other critical or energy minerals.

Copper (Cu). Copper is a major base metal. Its conductive properties make it well suited for use in electric wiring, power transmission and power generation. Such uses account for about three quarters of demand. Copper is quite important to the global economy. The USGS ranks copper number two of all metals in terms of how vulnerable the United States economy would be to a disruption. Demand for copper is expected to increase due to its use in renewable energy technology and general electrification. Our Favorable Scenario finds an expected production of around 110 thousand tons of copper per year, primarily from Ambler District mines in northwest Alaska. This level amounts to about 9% of United States' annual copper production, and about 1% of global production. As elsewhere in the report, we omit estimates of potential production from the Pebble Project, which on its own could produce more than double this quantity.

Molybdenum (Mo). Molybdenum's primary use is as a steel alloy. Alaska has three properties with molybdenum potential: Pyramid, Pebble, and Quartz Hill. While Pebble and Quartz Hill have reasonably large molybdenum resources, these projects have had permits denied. Pyramid's molybdenum resources are much smaller by comparison. As such, even in the Favorable Scenario, Alaska's potential to produce molybdenum in significant quantities is limited.

Barite. Barite's main application is as a weighting agent in oil drilling. Our Favorable Scenario finds Alaska could supply a significant amount of domestic barite production. Just two identified projects have identified barite resources: the Palmer project and the Lakeview project. Calculations based on their resource indicates that they could together produce 760,000 tons per year.

Rare earth elements (REEs). Rare earth elements are a group of 17 chemical elements that tend to concentrate together in mineral deposits. Applications of this group vary by element, but neodymium, praseodymium, samarium, and dysprosium are often used in powerful and lightweight rare earth magnets. These magnets have several important applications, including in clean energy technology (e.g., high efficiency direct drive wind turbines, electric vehicle motors). Rare earth elements also appear in energy efficient lighting technology. Their military applications often raise strategic questions about their supply.

The total global market for rare earth elements is relatively small; around 240 thousand tonnes of total rare earth oxide is produced annually. Most mining occurs in China, as does nearly all refining. Mineral deposits of these minerals are sometimes simply classified as being rich in the more abundant "light" rare earths (e.g., cerium, lanthanum, and neodymium) or the more scarce and valuable "heavy" rare earths. (e.g., dysprosium). Alaska's sole rare earth project, Bokan Mountain, is often classified as the latter. While a very small mine in terms of the total rare earth element production – the company's PEA indicates it could produce 1,828 metric tons of rare earth oxides per year – its concentration of heavy elements means it could play an important role in domestic production of these elements.

Graphite. Graphite has primary applications in lubricants and in battery technologies, particularly in electric vehicle batteries where demand is expected to grow significantly. The United States currently produces no natural graphite, so Alaska could represent the entirety of domestic supply in our scenarios. Currently, the only property being activity explored for graphite is the Graphite Creek project on the Seward Peninsula. The Graphite Creek PEA projects that the mine could produce 55,350 tons of graphite per year and be refined in the U.S. pacific northwest.

Cobalt (Co). Cobalt is a key mineral input in the production of lithium batteries for consumer electronics and particularly electric vehicles. Cobalt ranks third on the USGS's list of critical materials, due to the potential growth in these industries, and because nearly all global supply comes from Democratic Republic of the Congo where it is produced by Chinese-owned corporations as a byproduct of nickel and copper. Alaska has one identified mineral property with estimated cobalt resources, the Bornite project in the Ambler area. Bornite's currently reported resource and grade suggest it could meaningfully increase domestic cobalt primary production. Calculations based on resource size indicate that production could be on the order of 1,570 tons per year. While this is still a small volume, it is three times the 2019 U.S. production.

The potential production estimates of cobalt, graphite, and rare earth elements found in Table 11 involve an important additional element of uncertainty that is different than for other estimates in this report. Throughout the report, we have not made predictions for whether any one mine would come into production. Rather, we applied probabilities to classes of projects, based on their location in the development pyramid. When looking at Alaska's potential mineral products, these three commodities products are each associated with a single respective project. For example, in our analysis, all of Alaska's production of graphite would come from the Graphite Creek project, and all cobalt would come from the proposed Bornite project. In our analysis, the probability that these prospects will come into production is based on their place in the development pyramid and does not account for project-specific factors beyond this that might make their development more or less likely. Therefore, the production of these four commodities depends on the success of the individual projects for which they would be produced.

Table 11 provides Alaska's expected production by mineral and compares it with U.S and world production. Consistent with the methodology used in this report, it is calculated using the expected production for the mines in the report database times the probability of that mine producing based on its stage in the development scenario. The probability is much easier to understand when applied to minerals such as gold, which are produced by many mines: it provides the expected production from these multiple mines. For minerals potentially produced by only one or two mines – graphite, cobalt, rare earths, barite, and molybdenum – the uncertainty in the prediction is greater. Since Table 11 is based on probabilities, the production for these minerals will not match the production predicted for the individual mine.

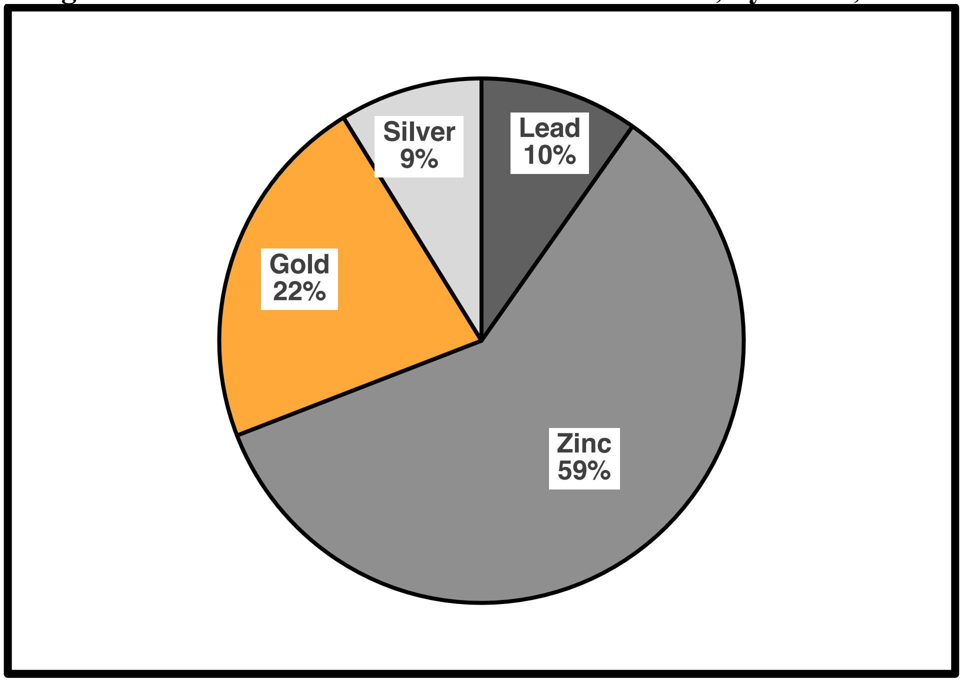
Table 11: Expected Value of Commodity Production by Scenario

	Today			Unfavorable				Status Quo				Favorable			
			% 2019 US			% 2019 US	% 2019 World			% 2019 US	% 2019 World			% 2019 US	% 2019 World
Cu				18	kt	1%	0%	54	kt	4%	0%	114	kt	9%	1%
Pb	121	kt	44%	97	kt	35%	2%	155	kt	57%	3%	215	kt	79%	5%
Zn	603	kt	80%	307	kt	41%	2%	504	kt	67%	4%	710	kt	94%	6%
Au	17	t	9%	22	t	11%	1%	45	t	22%	1%	80	t	40%	2%
Ag	501	t	51%	430	t	44%	2%	706	t	72%	3%	1,008	t	103%	4%
Mo[2]				-	t	0%	0%	69	t	0%	0%	138	t	0%	0%
Co[2]				78	t	16%	0%	196	t	39%	0%	518	t	104%	0%
Barite[2]				38	kt	9%	0%	138	kt	33%	2%	237	kt	57%	3%
TREO[1,2]				445	t	2%	0%	1,336	t	5%	1%	2,227	t	8%	1%
Graphite[2]				50	kt	100%	5%	149	kt	100%	14%	249	kt	100%	23%

The expected value of production for each mine is calculated as the ore mining rate of a given mine, times the grade of a given commodity at that mine, times the probability that the particular mine is operating in each scenario. These values are summed over all mines.
2019 US and World production numbers are from each commodity's respective USGS Mineral Commodity Summary report.
Production units are metric tons (t) or thousand metric tons (kt).
1 Total Rare Earth Oxide
2 Mo, Co, Barite, TREO, and Graphite only have a single associated project each. As the production estimates are expected values (probability of operation times production capacity), these will be smaller than the production capacity from these mines.

Today, Alaska produces sizable amounts of four mineral commodities (excluding coal and industrial minerals such as sand, gravel, or crushed granite). In both value and volume terms, zinc is the largest commodity. Alaska currently mines around 80% of the primary zinc production in the United States. Gold is the next largest commodity for the state in terms of gross value, followed by silver and lead. Alaska makes up around half of the United States's silver production, and just under half its production of primary lead. Table 6 shows that over half of the gross value produced by Alaska's hard rock mines is in the zinc production; roughly a quarter is gold, followed by lead and silver.

Figure 5. Percent of Alaska's Mineral Production, by Value, 2021



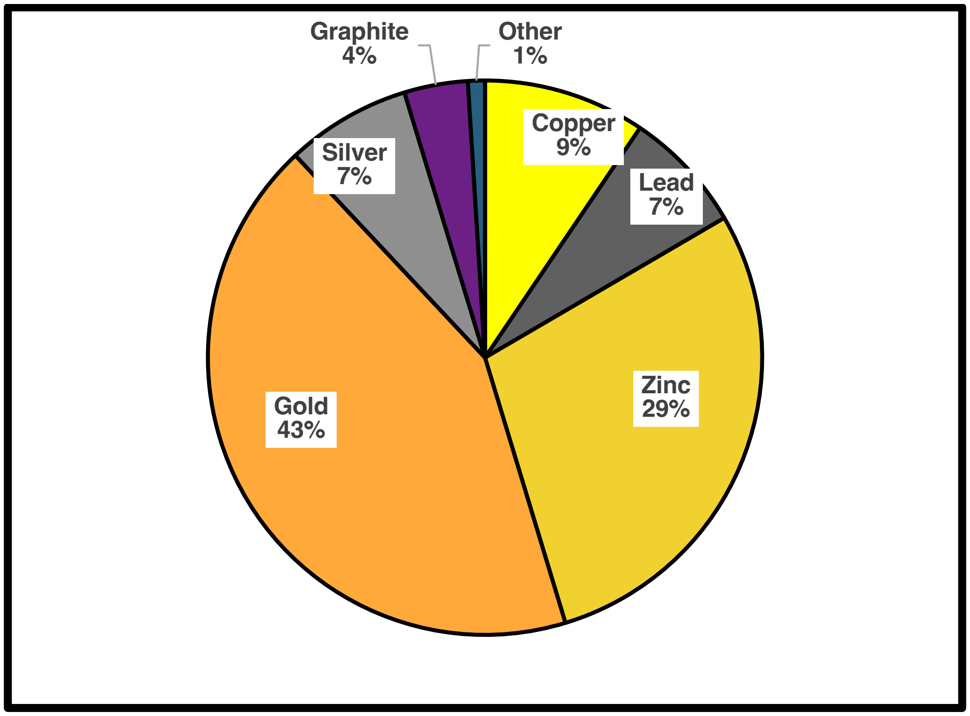
In our Favorable Scenario, Alaska could become a significant producer of several additional commodities and increase its position for the four it currently mines. Alaska could produce 100% or more of current US production of cobalt, silver, and graphite, and over 90% of current zinc production. Notably, in the Favorable Scenario, Alaska might produce significant amounts of several minerals identified as 'critical' to domestic industrial supply chains by the United States Geological Survey.[30] These include zinc, barite, rare earth elements, graphite, and cobalt. Cobalt ranks third on the USGS's list of critical materials. Many of the minerals produced in the Favorable Scenario have important clean energy applications.

One important issue we have not addressed yet is the refining of concentrated ore materials into metal products suitable for use in manufactured materials. Currently, Alaska ships much of its ore concentrate products outside the state for further processing and refining. Some of this ore is refined in other U.S. states or stable countries with good trade relations with the United States (e.g., Canada, South Korea, the European Union, Japan), posing little risk to domestic importers who look to purchase these refined mineral commodities. Some ore, however, is further processed in China, or other countries where trade relations have been more unstable in recent years. Domestic production of mineral ore is a necessary, but insufficient condition of securing critical material supply chains. Evaluating the locations of metals refining facilities over the next two decades is outside the scope of this report, but it is a key issue in a complete understanding of critical materials supply chains.

[30] Nassar, Nedal T., and Steven M. Fortier. *Methodology and technical input for the 2021 review and revision of the US Critical Minerals List*. No. 2021-1045. US Geological Survey, 2021.

Figure 6 shows the mineral production, by value, for the Favorable Scenario. In that scenario, gold provides the largest gross value, followed by Zinc. Graphite and the other critical and energy minerals are a small part of the gross value produced by Alaska, but these minerals are part of a value chain that produces a lot of value to the U.S. They are necessary for the U.S. economy and producing more of them in the country may be an important improvement to national security.

Figure 6, Potential Percent of Alaska's Mineral Production, by Value, in 20 years Favorable Scenario



Chapter 6. Regional Effects

A. Description of Potential Regional Effects. Mining is not the dominant employer or taxpayer for the State of Alaska, but it is an important, sometimes dominant, economic force for regions within Alaska. This chapter examines the potential regional effects of mineral development. Like the other sections of the report, it is not a prediction. It describes potential effects.

Alaska is a big state. Each region will see different impacts from economic development. Yet there are two prototype situations that illustrate potential effects. There are regions of Alaska that lack a private economic base. For these, money coming into the region is predominantly public money from outside the region. These predominantly rural areas are outside Alaska's boroughs. In these regions, a large mine can provide a private economic base, with important socioeconomic and fiscal effects. The Red Dog Mine's effect on the Northwest Arctic Borough area is Alaska's best example. A 2015 ISER study[31] reviewed the 20 largest employers in the borough and concluded that the mine is the only significant, non-publicly funded employer in the region.

There are other regions that already have a diverse private economy. The commercial fishing industry has large, local economic effects on southeast Alaska, southcentral Alaska, Bristol Bay, the Alaska Peninsula, and other locations. Tourism is important for much of the same areas, plus the railbelt from Homer to Fairbanks. Most, but not all, of these areas have borough governments. In these regions, the addition or expansion of a mining industry can be an important support and a diversifying economic addition, but it does not have the transformative effects that occur in regions without a private economic base.

In both situations, the effect depends on the size of the mine and its life. Longer-lived and larger mines have longer-lasting effects than smaller mines or those that last only a few years.

Rural regions with a limited economic base: the Red Dog example. The effect of the Red Dog Mine on the region of the Northwest Arctic Borough has been the subject of several academic studies. Some of the studies' conclusions are potentially applicable to other regions.

- ***Increase Employment and Income.*** Mining is known for its high wage scale. According to a 2021 study, the industry hosts some of Alaska's highest paying jobs with a pay rate that is more than twice Alaska's average wage.[32] The high wage is true of Red Dog. The average Red Dog employee earned almost twice the average wage elsewhere in the Borough. A 2015 ISER study found that the mine's total direct payroll was 40 percent of all private sector wages and 30 percent of all wages, including government.[33]

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[31] Mining and Sustainable Communities: *A case study of the Red Dog Mine.* Bob Loeffler. Economic Development Journal, Volume 14, No. 2, Spring 2015.
[32] The Economic Benefits of Alaska's Mining Industry. February 2021. Prepared by the McDowell Group for the Alaska Miners Association.
[33] Mining and Sustainable Communities (see footnote above).

- ***Local Government & Local Control of Decisions.*** Boroughs in Alaska cannot exist without a tax base. Alaska law requires that boroughs contribute to local school costs.[34] Before construction of the Red Dog Mine, the Northwest Arctic Borough lacked a tax base to form a borough. The Northwest Arctic Borough and the school district both formed in 1986 around the tax payments from the Red Dog Mine. Existence of a local government allows local populations to take control of decisions that were previously made hundreds or thousands of miles away in Juneau.
- ***Education.*** The period during which Red Dog Mine has been operating has been associated with an improvement in some educational outcomes in the Northwest Arctic Borough, though data are lacking to prove a direct causal link. However, the mine provides additional funds to the school district tax payments, works closely with the district to provide job shadow opportunities, internships, seasonal jobs, and scholarships, which may help motivate high school students to graduate. Further, it provides the opportunities and funding for a dormitory, vocational education, and other educational initiatives that benefit the community in addition to the mine.[35]

These effects could potentially occur in other rural regions if mining development occurred, though they would vary depending on the size of the mine, commitment to local benefits by the mine or the region, and the length of the mining operation. Large mines in rural regions tend to accomplish significant local hire, though this is not guaranteed. For example, the 200+ person Donlin Gold exploration camp was reported to achieve over 90% shareholder hire. Pebble exploration camp achieved over 80% Alaska hire and more than 43% from Bristol Bay communities.[36] The potential tax payments from a large mine, such as Donlin Gold, are large enough to support borough formation. Smaller and shorter-lived mines may not create these opportunities.

Some of the benefits associated with the Red Dog Mine are related to local government, it is possible that some regions where a mine may develop would vote down local government and may not capture many of the benefits. Representatives of the Pogo Mine and community of Delta negotiated a Payment in Lieu of Taxes to support a potential Delta Borough. However, the potential borough populace voted down the borough formation in 2007, and much of the benefits listed above failed to occur.

2. Fairbanks, Juneau and other communities and regions with a significant economic base. For communities with a significant economic base, the addition of another employer, especially a high-paying employer, adds to the diversity of the economy, results in well-paid employees and citizens, and can frequently be a large or the largest taxpayer in the

[34] Local governments must pay the equivalency of 2.65 mills of the full and true value of property within their respective boundaries, or 45% prior year basic need, whichever is less.
[35] Mining and Sustainable Communities: A Case Study of the Red Dog Mine. Bob Loeffler. Economic Development Journal, Volume 14, No. 2, Spring 2015.
[36] Local Jobs and Income from Mineral Exploration: A Case Study of the Pebble Exploration Project. Bob Loeffler and Jennifer Schmidt. January 2017. Institute of Social and Economic Research.

region. However, because of the size of the employment and tax base in the area, the addition of another tax and employment source is unlikely to transform the region.

Large mines are usually the largest local government taxpayer and a large employer within their local jurisdiction. In Alaska, the large mines usually pay property tax or an agreed payment-in-lieu-of property tax to local government. The Greens Creek Mine is the largest property taxpayer in southeast Alaska. The Kensington Mine pays the second-largest property tax. The Fort Knox Mine is the second largest property taxpayer in the Fairbanks North Star Borough, after the Trans-Alaska Pipeline. While these are important and welcome additions to each Borough's tax base, their tax payments are only a few percentage points of the total Borough budget.

The same is true with expectations for employment. The combined employment of Juneau's two mines was 826 employees in 2020. This is sizeable workforce, even for Juneau, and the pay is roughly double the city's wage. However, it constitutes approximately 2% of the city's total workforce. Similarly, the Fort Knox Mine pays much higher than the average wage of the Fairbanks North Star Borough but comprises roughly 2% of employment in the Borough.[37] Therefore, while these are important additions to tax payments and employment, they are not as transformative as they can be in the rural regions of Alaska.

B. Potential Regional Effects in Alaska. This portion of the study discusses potential regional effects in 10 regions of Alaska. It focuses on the regional effects of potential large mines, hard-rock and at least in the Denali Borough, coal.

Placer mining mostly occurs within established placer mining districts. The location of the productive mining districts has not changed a lot over the last few decades. Many of these mining districts have produced gold for more than 100 years. Today, Alaska's large mines provide most of the industry's total gross value, employment, income, and government revenue, but placer mines are important for the families that work them, and for communities near the mine

1. The Northwest Arctic Borough

The Northwest Arctic Borough has the same boundaries as the NANA Regional Corporation. The region hosts the multiple mineral properties of the Ambler Mining District.

As discussed earlier, the operating Red Dog Mine is the private economic driver of the Northwest Arctic Borough. The mine's current reserve is expected to last through 2031, though the mine is exploring reserves that would extend the mine life.

The Ambler Mining District within the borough has multiple properties and prospective drill targets. Table 12 lists only those which have been active within the last five years, though

[37] The workforce calculations are taken from two sources. The Juneau and Fairbanks employment is taken from the 2019 Quarterly Census of Employment and Wages (i.e., mostly pre-pandemic), while the mining project employment is taken from the February 2021 (i.e., 2020 data) McKinley Research Group, the Economic Benefits of Alaska's Mining Industry prepared for the Alaska Miners Association.

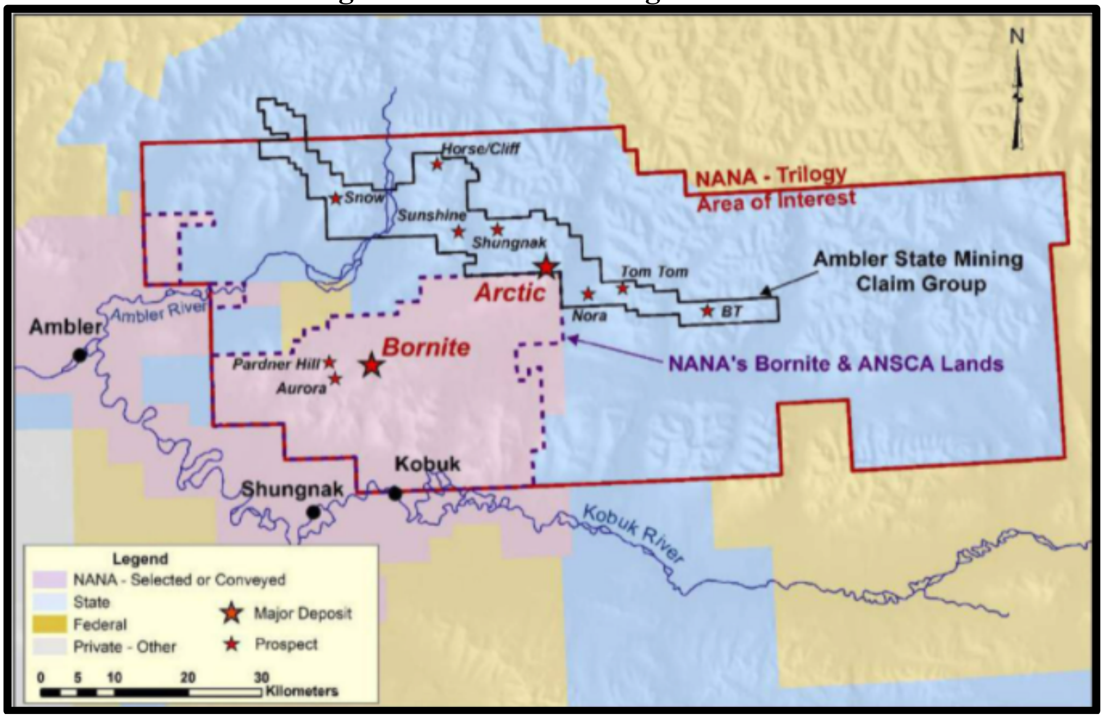
additional known prospects exist. Figure 5 shows a close-up of what is known as the Ambler Mining District. Prospects within the Ambler district have the potential to at least partially replace the Red Dog Mine as the Borough's economic engine if Red Dog Mine shuts down in 2031, or to significantly increase employment and tax payments to the Borough if it does not. The Red Dog Mine employs more people from villages closer to the mine than it does from most villages further away. If mines are built in the Ambler district, there would likely be greater employment from the nearby villages than from elsewhere in the Borough. Current exploration activities employ more from these local villages than from others further away.

Table 12 shows active mineral properties in the Northwest Arctic Borough. Employment information for operating mines for these properties is taken from the 2019 Mineral Industry Report. Employment for mines in permitting and those for which an economic evaluation is completed is taken from the mine's economic evaluation. For exploration properties, it is estimated from the reserve estimates using the calculation method explained in Chapter 3.

Table 12. Active Mineral Properties in the Northwest Arctic Borough

Mining Type	Project Name	Project Status	Estimated Employment
Hard Rock	Red Dog	Operating	700
Hard Rock	Arctic (Upper Kobuk)	Feasibility	207
Hard Rock	Bornite (Upper Kobuk)	Exploration: Significant	388
Hard Rock	Sun (Upper Kobuk)	Exploration: Significant	124
Hard Rock	Sunshine (Upper Kobuk)	Exploration: Moderate	144
Hard Rock	Smucker (Upper Kobuk)	Exploration: Moderate	116
Hard Rock	Horse Creek (Upper Kobuk)	Exploration: Moderate	110
Hard Rock	BT (Upper Kobuk)	Exploration: Moderate	75
Hard Rock	Shungnak (Upper Kobuk)	Exploration: Moderate	49
Hard Rock	Scout Claims Exploration (Upper Kobuk)	Exploration: Initial	Unknown
Hard Rock	Upper Kobuk Mineral Project	Exploration: Initial	Unknown
Hard Rock	Upper Kobuk Mineral Project	Exploration: Initial	Unknown
Placer	Eight placer mine permits in the region		

Figure 7. Ambler Mining District[38]



Red Dog has an unusual position of supporting statewide economic development for Alaska Native regional and village corporations. This support is discussed in more detail in Chapter 4E.

The proposed Ambler Road, currently undergoing permitting, is likely necessary for the development of mines in the Ambler Mining District. If the road is not authorized, it is unlikely that any mines in the region will be developed, other than potential extensions of the existing Red Dog deposit.

2. Southwest Alaska – Kuskokwim

The only project of significance in the Calista region is the Donlin Gold Project (Table 13). This is a huge project. It has received almost all its permits, though the company has not announced plans to build the mine. The project has a $7.4 billion development cost.[39] It requires a 315-mile natural gas mile pipeline from Cook Inlet. Higher end estimates suggest the mine could employ 1,400 people during peak operation,[40] though average employment from its latest technical document reports 725.[41]

[38] Alaska Journal of Commerce 8/28/19
[39] The capital cost estimate is from the Novagold NI 43-101 Technical Report on the Donlin Gold Project, Alaska USA. June 2021. The pipeline distance estimate is from the Donlin website.
[40] Donlin Gold, Planning Your Future. Retrieved from the NovaGold.com website 12/14/21.
[41] Hanson, Krik and Woloschuk, Michael. "NI 43-101 Technical Report on the Donlin Gold Project, Alaska, US". Prepared for: NovaGold Resources INC. June 1, 2021.

Table 13. Active Mineral Properties in the Southwest/Kuskokwim Region

Mining Type	Project Name	Project Status	Estimated Employment
Hard Rock	Donlin	Development	725
Placer	Eight placer permits		
Suction Dredge	One suction dredge permit		

This project has the potential to create regional benefits for the Calista Region similar to the benefits Red Dog created for the NANA Region. The project is on Alaska Native land and is likely to create a large opportunity for shareholder hire for Alaska Native shareholders in the region and possibly elsewhere. The ore body is owned by the regional Calista Corporation, and the land surface is owned by the Kuskokwim Corporation, a consolidation of eight Alaska Native Village Corporations. Both have private agreements with Donlin Gold concerning the potential mine. These agreements presumably require a shareholder hiring preference.

The mine's exploration camp has been one of the most successful Alaska Native-hire businesses in Alaska. Donlin Gold's multi-year, 200+-person exploration camp achieved over 90% shareholder hire. If the mine is built, the large number of high-paying mining jobs could have a significant impact on earnings in the region.

The project is also large enough to provide the foundation for local government in at least part of the large region, though whether locals would vote to establish a local government is uncertain.

The Red Dog Mine has provided significant 7(i) payments to other ANCSA Corporations. The 7(i) payments are not related directly to a mine's size, but rather to its profit. Profit is difficult to predict. Therefore, this study does not speculate on the size of Calista's payments and 7(i) distribution. However, the project is large enough to some extent offset the end of NANA's 7(i) and 7(j) distributions from Red Dog, projected to end in 2031.

3. Interior Alaska

The study divided Interior Alaska into three regions: 1) Fairbanks, 2) an area within 30 miles of a road system, and 3) areas more than 30 miles from a road system. The reason for this division is that the effects of access, power, and other infrastructure on mineral development is significant. There is much more exploration in areas easier to access than where access is difficult and expensive. It is much more expensive to develop a mine accessed only by airplane or by a long, expensive-to-build road, than it is to develop a mine close to an existing road and power. It requires a much larger or a more profitable deposit if access and power are not cl.

A. Fairbanks North Star Borough

The Fairbanks North Star Borough hosts the Fort Knox Gold Mine. It, along with the Trans-Alaska Pipeline, are the two largest taxpayers in Fairbanks. Active mining at Fort Knox is slated to end in 2027. However, Fort Knox is proposed to be the mill for the Manh Choh project near

Tetlin. That project is now beginning the permit process to truck ore to Fort Knox for processing. If Fort Knox succeeds in becoming a regional mill, it may decrease development costs for other prospects in the area, and extend the life of Fort Knox, possibly through the 20 years of this study. The only other project that has developed an economic reserve and finished a preliminary economic evaluation is Freegold Ventures Limited's Golden Summit Prospect just north of the Fort Knox Mine.

Other properties are in the early stages of exploration. If Fort Knox shuts down, there will be a significant decrease in employment and taxes to Fairbanks. However, there is significant exploration along the road system outside of the Borough, as we detail in the next section.

Table 14. Active Mineral Properties in the Fairbanks North Star Borough

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Fort Knox	Operating	655
Hard rock	Golden Summit	PEA	299
Hard rock	NAOSI	Exploration: Significant	107
Hard rock	Amanita	Exploration: Initial	Unknown
Hard rock	Ester Grant Mine	Exploration: Initial	Unknown
Hard rock	Ester Dome	Exploration: Initial	Unknown
Hard rock	Shamrock	Exploration: Initial	Unknown
Hard rock	Treasure Creek	Exploration: Initial	Unknown
Hard rock	True North Tailings (BJW)	Exploration: Initial	Unknown
Placer	There are 80 placer mine permits		
Suction Dredge	There is one suction dredge permit		

Note: Exploration near the operating Fort Knox Mine that would extend the life of that mine is not shown, such as the Manh Choh project near Tetlin. The projected employment and production are not added to the industry total to avoid double counting.

The 81 placer and suction dredge permits are important for the Fairbanks area.

A. Interior, within 30 miles of a road

Much of Alaska's mineral exploration occurs in the interior, near a road. This area is explored much more intensively than the much larger area discussed in the next section (Interior, greater than 30 miles of a road). This may reflect the mineral endowment of the area, but it certainly reflects the lower cost of developing a prospect in this area. This means that a smaller or lower-grade deposit is more likely to be developed here than in areas further from infrastructure. The use of Fort Knox as a regional mill could further decrease the development cost if ore from these deposits could be transported there.

Of these prospects, only International Tower Hill's deposit in Livengood is potentially close to entering permitting in the near term. Others, of course, could be proved up, permitted and developed within the 20-year time frame of this study.

Table 15. Active Interior Mineral Prospects within 30 miles of a road

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Tetlin (Peak, Manh Choh Project)	Permitting	130
Hard rock	Money Knob (Livengood)	Pre-Feasibility	331
Hard rock	DELTA	Exploration: Moderate	117
Hard rock	LMS	Exploration: Moderate	88
Hard rock	Elephant Mountain	Exploration: Initial	Unknown
Hard rock	Forbes - Emerick	Exploration: Initial	Unknown
Hard rock	Giles	Exploration: Initial	Unknown
Hard rock	GMAPA Chisna	Exploration: Initial	Unknown
Hard rock	Goodpaster	Exploration: Initial	Unknown
Hard rock	Healy	Exploration: Initial	Unknown
Hard rock	Hona	Exploration: Initial	Unknown
Hard rock	Liberty Bell	Exploration: Initial	Unknown
Hard rock	Livengood	Exploration: Initial	Unknown
Hard rock	McCord Exploration	Exploration: Initial	Unknown
Hard rock	Napolean	Exploration: Initial	Unknown
Hard rock	Northway	Exploration: Initial	Unknown
Hard rock	Oreo Mountain	Exploration: Initial	Unknown
Hard rock	Quartz Creek	Exploration: Initial	Unknown
Hard rock	Richardson Project	Exploration: Initial	Unknown
Hard rock	Seventymile	Exploration: Initial	Unknown
Hard rock	Shorty Creek	Exploration: Initial	Unknown
Hard rock	Sunny Side Up	Exploration: Initial	Unknown
Hard rock	Triple Z	Exploration: Initial	Unknown
Hard rock	Unknown	Exploration: Initial	Unknown
Hard rock	Victory Ridge	Exploration: Initial	Unknown
Hard rock	W. Fork, S. Fork, Goodpaster	Exploration: Initial	Unknown
Coal	Usibelli	Operating	100
Placer	There are 210 Placer Permits		
Suction Dredge	There are 29 Suction Dredge Permits		

The 239 placer and suction dredge permits make this portion of the industry important for the interior road-system towns.

C. Interior Alaska, more than 30 miles from a road

Interior Alaska is a very big place. The amount of exploration is relatively small, relative to its size. The lower level of exploration may reflect the difficulty of development far away from access or power. In addition, the Pogo prospect was large enough to afford to build a 48-mile to the Richardson Highway. The Stone Boy project is at least partially accessed from the Pogo Road. The Tanacross project is accessed cross-country from the Alaska Highway.

Nixon Fork is a small underground mine. It was previously in production, still has operating permits and is being re-examined with an intention to reopen.

Table 16. Active Interior Mineral Prospects more than 30 miles away from a road

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Pogo	Operating	450
Hard rock	Nixon Fork	Development (Previous Operation)	46
Hard rock	Vinasale	Exploration: Significant	255
Hard rock	Illinois Creek	Exploration: Significant	90
Hard rock	Red Mountain	Exploration: Moderate	91
Hard rock	Lakeview	Exploration: Moderate	70
Hard rock	Carrie Creek	Exploration: Initial	Unknown
Hard rock	Honker Project	Exploration: Initial	Unknown
Hard rock	Mt. Harper	Exploration: Initial	Unknown
Hard rock	Round Top	Exploration: Initial	Unknown
Hard rock	Stone Boy	Exploration: Initial	Unknown
Hard rock	Tanacross	Exploration: Initial	Unknown
Hard rock	Tibbs	Exploration: Initial	Unknown
Coal	Western Arctic	Exploration: Significant	532
Placer		There are 37 Placer Permits	
Suction Dredge		There are three Suction Dredge Permits	

Note: Exploration near the operating Pogo Mine that would extend the life of that mine is not shown.

6. Cook Inlet

This region includes the Kenai Peninsula and Matanuska-Susitna Boroughs. There are currently no hard-rock mineral mines operating in these Boroughs. Any of these projects would be a significant taxpayer. Any of the larger projects could become a large employer and one of the more significant taxpayers in either Borough. Given the size of these Boroughs' employment and tax bases, the projects would be important, but would not have the transformative effects that a large project could have in a rural location.

Most, but not all of these projects are accessible by road or from the ocean. However, the Whistler, Island Mountain, Estelle, and Canyon Creek projects would be accessible from the proposed West Susitna Access. That proposed access would significantly lower the cost of development for those projects.

The only projects not accessible by road, water, or the proposed West Susitna Access Project[42] are the Capps Coal Project, and the Terra Project.[43]

Table 17. Projects within the Kenai and Matanuska-Susitna Boroughs

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Lucky Shot (Willow)	Permitting	76
Hard rock	Whistler	Exploration: Significant	499
Hard rock	Island Mountain (Whistler)	Exploration: Significant	359
Hard rock	Golden Zone	Exploration: Significant	76
Hard rock	Caribou Dome (Stellar)	Exploration: Significant	59
Hard rock	Terra	Exploration: Significant	40
Hard rock	Estelle	Exploration: Moderate	536
Hard rock	Raintree West (Whistler)	Exploration: Moderate	231
Hard rock	Zackly (Stellar)	Exploration: Moderate	64
Hard rock	Johnson Tract	Exploration: Moderate	43
Hard rock	Gail Exploration (nr Lucky Shot)	Exploration: Initial	Unknown
Hard rock	Honolulu	Exploration: Initial	Unknown
Hard rock	Nr. Hatcher Pass	Exploration: Initial	Unknown
Hard rock	Valdez Creek	Exploration: Initial	Unknown
Coal	Wishbone Hill	Permitting	35
Coal	Beluga	Exploration: Significant	525
Coal	Capps	Exploration: Moderate	390
Coal	Canyon Creek	Exploration: Moderate	305
Coal	Castle Mtn	Exploration: Moderate	124
Placer	There are 81 Placer mine permits		
Dredge	There are 10 suction dredge permits		

The 91 placer and suction dredge permits are a small part of the large Anchorage-Matanuska-Susitna-Kenai economy. They remain important for some subareas and, of course, for the people who work them.

[42] The West Susitna Access project is a proposed road project that would begin near Point MacKenzie in the Matanuska Susitna Borough and would extend across the Susitna River along the western border of the Susitna Valley. It would cross the Skwentna River and extend up the Skwentna River to the Alaska Range. According to the AIDEA website (https://www.aidea.org/Programs/Project-Development/West-Susitna-Access), it would access a variety of resources.

[43] The Terra project is just outside the western border of the Matanuska Susitna Borough. It is included in this region, because its main access would be from the region.

7. Bristol Bay

The three projects in Table 18 are within the Bristol Bay watershed. The Pebble Project, about which much has been written, has been denied a permit by the U.S. Army Corps of Engineers. For more information about the Pebble Project and potential effects, see Section 4F.

Table 18. Projects with Bristol Bay

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Shotgun	Exploration: Moderate	126
Hard rock	Big Chunk	Exploration: Initial	Unknown
Hard rock	Pebble	Permit Denied*	1278
Placer		There are two placer permits	

Pebble's federal permit application was denied by the U.S. Army Corps of Engineers. The company is appealing the permit denial.

8. Alaska Peninsula, Aleutians East Borough, and Kodiak

The three hard-rock projects in Table 19 are within the Aleutians East borough. Should any of them be developed, they could potentially diversify the Borough's predominantly fishing-based economy, add regional jobs and significantly increase the tax base. While further away from the state's urban areas, access to each of these properties is from the ocean. The single placer permit is in the Kodiak Borough.

Table 19. Mineral Projects within the Aleutians East Borough

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Pyramid	Exploration: Moderate	308
Hard rock	Centennial (Unga Project)	Exploration: Moderate	69
Hard rock	Shumagin (Unga Project)	Exploration: Moderate	28
Placer		There is one placer permit	

9. Southeast Alaska

Southeast Alaska hosts four operating mines. Two of them are large and within the City and Borough of Juneau: The Greens Creek and Kensington Mines. As noted earlier in this paper, there are the first and second largest private taxpayers in Juneau, and in Southeast Alaska. They provide a significant tax base and high-paying jobs to the community. Given the size of Juneau's total employment and tax base, they are not transformative, as they would be in rural areas.

The Dawson and Calder Mines, on Prince of Wales Island, also provide good jobs in an area with many fewer jobs. Dawson's 50 jobs are a large economic force for the community of Hollis on Prince of Wales Island (2020 Census population = 65), and nearby small communities.

The most advanced exploration projects – Bokan Mountain, Palmer, and Niblack – are all in smaller communities. Bokan Mountain and Niblack are also on Prince of Wales Island, and Palmer is near Haines, Alaska. Most of these projects are relatively accessible by Alaska standards, and generally not far from either a road system or the ocean.

Table 20. Mineral Projects in Southeast Alaska

Mining Type	Project Name	Project Status	Estimated Employment
Hard rock	Greens Creek	Operating	426
Hard rock	Kensington	Operating	383
Hard rock	Dawson Mine	Operating	50
Hard rock	Calder	Operating	12
Hard rock	Bokan Mountain	PEA	118
Hard rock	Palmer	PEA	94
Hard rock	Niblack	Exploration: Significant	200
Hard rock	Herbert Gold	Exploration: Significant	57
Hard rock	Helm bay	Exploration: Initial	Unknown
Hard rock	Riverside	Exploration: Initial	Unknown
Hard rock	Snettisham Vanadium	Exploration: Initial	Unknown
Large Placer	Icy Cape (Placer)	Exploration: Initial	
Placer	Three are 11 placer permits (not including Icy Cape)		
Dredge	There is one suction dredge permit		

10. Seward Peninsula

Mining plays a large role in the history of the Seward Peninsula. It was the site of the 1899 Nome Gold Rush and is still the site of extensive placer mining and suction dredge operations. The Graphite Creek deposit is off the Nome-Teller Highway. It would be a medium-sized project, though it could have a significant employment effect on the nearby villages of Brevig Mission, Teller, and even on Nome.

Table 21. Mineral Projects on the Seward Peninsula

Mining Type	Project Name	Project Status	Estimated Employment
Hard Rock	Graphite Creek	PEA (PFS in prog)	269
Placer	There are 42 placer permits		
Dredge	There are 69 suction dredge permits		

The 111 placer and suction dredge operations are a remainder of the historic importance of mining on the Seward Peninsula. The off-shore and on-shore placer/suction dredge mining remains an important part of the Seward Peninsula economy.

Chapter 7. Conclusions

Given what is known about mineral projections currently under exploration and development, and given realistic assumptions about the future, this analysis finds a reasonable path for Alaska to double the size of its mineral industry in the next two decades. And a reasonable path to decrease the size by at least a third.

Doubling the size of the industry means roughly doubling the employment to approximately 8,500 direct jobs and 17,000 jobs including direct, indirect, and induced. It also means that the mineral industry's contribution to Alaska's exports would increase. In 2019, the export value of the industry was $2.6 billion, or 38% of Alaska's total exports. This figure could increase by more than double, to $5.6 billion, which brings it closer to the $8.5 billion wellhead value of today's oil industry (2019 data).[44] This is an important contribution to Alaska's economy, though it would not replace the oil industry. No industry can do that.[45] This path would require the state to make investments in infrastructure to support the industry, streamline permitting processes, and enjoy some luck that global mineral prices are robust.

On the other hand, if mineral prices fall and remain depressed, infrastructure quality degrades, or sweeping restrictions are enacted, Alaska might reasonably see an industry decline in size by half over the next twenty years.

The Role of Large Projects. Two projects/mining districts play an outsized role in the potential Favorable Scenario. The various properties that could develop in the Ambler Mining District could together employ around 900, as could the Donlin Gold project. Together, these 1,800 potential direct jobs represent around 40% of the new jobs that might be created in the Favorable Scenario. The projects share several other important features. They both are situated on land owned by Alaska Native Corporations, and they both require a significant infrastructure investment to operate. Donlin Gold requires a 315-mile natural gas pipeline, and Ambler requires a 200-mile access haul road

The Role of Infrastructure. In addition to the critical infrastructure element of the large projects described above, there are two other observations that indicate the crucial role of infrastructure to the industry's future. Most exploration projects are close to infrastructure: whether that is the limited road system in Alaska, or the ocean – which is a kind of transportation infrastructure. Despite the large area beyond reach of the ocean or the road system, there are many fewer projects in the large part of Alaska that is not near a road nor the ocean. The further from transportation (and the further from power), the large and richer a project must be to go into development.

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[44] This analysis does not include the potential contribution made by the Pebble Project. Because the project's permit was denied and for other reasons given in Chapter 4.F, that project is not included any of the Scenarios. If the project is eventually be developed, it would be a large addition to any scenario.

[45] The gross value of oil production is much larger than the production value of state industries. In addition, worldwide, the oil industry pays a much larger share of the revenue to the government or the royalty owner than do other industries. This is due to the structure of the industry. Costs are a much smaller percentage of the selling price for oil than for minerals or other commodities.

Finally, in the 2020 Fraser Institute Survey of the Mining Industry, the policy question that generated the most negative responses about Alaska was the question about infrastructure. Fifty-nine percent of respondents said that the quality of Alaska's infrastructure was a mild or strong deterrent to investment.

Government Revenue. Our analysis sheds light on the potential economic impacts of the mining industry under favorable and unfavorable conditions. While the industry has significant growth potential in terms of employment, wages, and gross value, doubling state revenue, while useful, will not solve Alaska's budget problems.

Regional Effects. The addition of a mine, even a large mine, within the part of Alaska with a diverse economy, will bring a significant addition of high-paying jobs and important local government tax revenues. This could occur in Southeast Alaska, the Matanuska-Susitna Borough, the Kenai Borough, Aleutians East borough, and elsewhere.

In rural areas without a robust private economy, the mining industry has large potential to increase local wages, spur local businesses, and provide the tax base for local government which gives local citizens control over decisions now made for them in Juneau. The Red Dog Mine has done this for the Northwest Arctic Borough. The addition of projects in the Ambler Mining District would continue this effect should the Red Dog Mine close. The Donlin Gold project has the potential to bring similar benefits to the middle Kuskokwim Region. Other projects are being explored that could bring similar benefits to the interior road system area outside Fairbanks. Further, even small mines can provide an important source of jobs for smaller communities, even if they do not create the opportunity for local government. The Dawson Mine on Prince of Wales Island is an example of this effect.

Critical and Energy Minerals. Another key finding of this analysis is that Alaska has the potential to produce significant amounts of some of the most critical minerals to the United States. Production of these minerals rests on the success of specific projects rather than from a diversified pool of properties. The only rare earth elements resources are from Bokan Mountain, the only graphite resources are from Graphite Creek, and the only cobalt resources are from Bornite.

Appendix A. Alaska's Mining Projects by Development Stage

This appendix lists Alaska's mining projects according to the mine development pyramid explained in this report. For projects in the operating stage, information is taken from the Alaska's Mineral Industry 2019 (Special Report 75. DNR. Jennifer Athey, Melanie Werdon, and Evan Twelker.). For projects in the permitting and economic evaluation stage, the employment is taken from project information. For projects in the significant and moderate exploration stage, employment is estimated from the resource using equations explained in Chapter 4. For consistency, all resource information is taken from Alaska's Mineral Industry 2019.

This appendix includes hard rock and coal projects, but not placer or suction dredge projects. As explained in Chapter 2, placer and suction dredge projects do not conform to the mine development pyramid for reasons explained in Chapter 2.

Table A1. Alaska Mining Projects by Development Stage

Material	Status	Name	Resource Short Tons	Employ-ment	Cu k lbs	Pb k lbs	Zn k lbs	Au k ox	Ag K oz	Mo k lbs	Co k lbs	Barite k lbs	TREO k lbs	Graphite k lbs
Metal	Operating	Fort Knox	571,654,000	655				5,601						
Metal	Operating	Red Dog	75,397,000	700		3,906,550	15,815,639		120,479					
Metal	Operating	Pogo	21,306,000	450				5,946						
Metal	Operating	Greens Creek	21,213,000	426		1,211,740	3,226,360	1,927	257,426					
Metal	Operating	Kensington	6,465,000	383				1,486						
Metal	Operating	Dawson Mine	1,000,000	50										
Metal	Operating	Calder		12										
Coal	Operating	Usibelli	450,000,000	100										
Metal	Permitting	Donlin	698,366,574	900				45,000						
Metal	Permitting	Tetlin (Peak, Manh Choh)*	11,623,859	400	62,000			1,324	4,893					
Metal	Permitting	Nixon Fork**	542,949	43				225						
Metal	Permitting	Lucky Shot (Willow)**	292,661	76				157	15					
Coal	Permitting	Wishbone Hill (Usibelli)	15,432,354	20-50										
Metal	Permitting	Pebble	12,026,093,000	1278	81,950,000			106,540	514,900	5,590,000				
Metal	Economic Evaluation (PFS)	Money Knob (Livengood)	637,334,353	331				12,588						
Metal	Economic Evaluation (PEA)	Golden Summit	146,561,808	299				2,947						
Metal	Economic Evaluation (PEA, PFS in prog)	Graphite Creek	113,360,000	269										18,063,372
Metal	Economic Evaluation (FS)	Arctic (Upper Kobuk)	51,299,303	378	2,332,273	587,830	3,284,191	719	52,870					
Metal	Economic Evaluation (PEA)	Lik (Red Dog)	25,850,000			1,403,000	4,251,000		35,820					
Metal	Economic Evaluation (PEA)	Palmer	15,731,066	94	278,000	90,000	1,586,000	166	26,000			8,315,827		
Metal	Economic Evaluation (PEA)	Bokan Mountain	6,435,000	118									77,503	
Metal	Exploration: Significant	Whistler	248,000,000	430	769,000			3,130	13,240					
Metal	Exploration: Significant	Bornite (Upper Kobuk)	201,061,344	388	6,364,000						77,000			
Metal	Exploration: Significant	Island Mountain (Whistler)	124,671,261	309	131,550			1,722	3,789					
Metal	Exploration: Significant	Vinasale	59,100,000	220				1,865						
Metal	Exploration: Significant	Gil (Ft Knox)	32,540,220	170				596						
Metal	Exploration: Significant	NAOSI	15,268,000	125				1,502	19,371					
Metal	Exploration: Significant	Sun	15,226,208	124	360,291	401,832	1,201,045	103	32,784					
Metal	Exploration: Significant	Niblack	9,955,000	200	178,780		311,354	384	5,843					
Metal	Exploration: Significant	Illinois Creek	9,690,000	104	36,676			296	10,000					
Metal	Exploration: Significant	Golden Zone	6,106,804	88				303	1,509					
Metal	Exploration: Significant	Caribou Dome (Stellar)	3,082,059	69	189,596									
Metal	Exploration: Significant	Herbert Gold	2,682,944	66				858						
Metal	Exploration: Significant	Terra	940,199	47				420	767					
Coal	Exploration: Significant	Western Arctic	283,293,926	#N/A										
Coal	Exploration: Significant	Beluga	275,577,749	453										

Information sources, other than that specified below, are on page 1 of the appendix

*Employment for Manh Choh project is from KUAC Public Radio: https://fm.kuac.org/2021-10-13/kinross-to-give-manh-choh-mine-progress-report-seek-public-input

**The Nixon Fork employment information is from the 2005 BLM Environmental Assessment for the mine. Both Nixon Fork and the Lucky Shot project have previously operated but have suspended operations.

Table A1. Alaska Mining Projects by Development Stage, page 2

Material	Status	Name	Resource Short Tons	Employ-ment	Cu k lbs	Pb k lbs	Zn k lbs	Au k ox	Ag K oz	Mo k lbs	Co k lbs	Barite k lbs	TREO k lbs k lbs	Graphite k lbs
Metal	Exploration: Moderate	Anarraaq (Red Dog) bedded barite	1,100,000,000	919										
Metal	Exploration: Moderate	Estellle	518,000,000	621				4,700						
Metal	Exploration: Moderate	Pyramid	169,094,354	357	1,262,000			456		70,000				
Metal	Exploration: Moderate	Raintree West (Whistler)	91,976,746	269	156,040			1,539	12,544					
Metal	Exploration: Moderate	Shotgun	22,860,000	147				706						
Metal	Exploration: Moderate	Sunshine (Upper Kobuk)	22,046,200	144	617,294	220,462	1,102,310		16,802					
Metal	Exploration: Moderate	Anarraaq (Red Dog) Massive sulfide	21,428,906	143		1,800,028	6,171,525		45,626					
Metal	Exploration: Moderate	DELTA	18,800,000	135	211,400	754,000	1,763,680	1,008	40,058					
Metal	Exploration: Moderate	Smucker	12,786,796	116	242,949	588,193	1,636,710	325	61,084					
Metal	Exploration: Moderate	Horse Creek (Upper Kobuk)	11,023,100	110	220,462	440,924	661,386		9,978					
Metal	Exploration: Moderate	Red Mountain	10,031,033	106	26,455	515,872	1,170,655	261	46,100					
Metal	Exploration: Moderate	LMS	9,170,000	102				267						
Metal	Exploration: Moderate	Lakeview	4,960,395	81								1,150,626		
Metal	Exploration: Moderate	Centennial (Unga Project)	4,780,000	80				200						
Metal	Exploration: Moderate	BT (Upper Kobuk)	3,858,085	75	131,175	69,446	200,620		4,551					
Metal	Exploration: Moderate	Zackly (Stellar)	3,747,854	74	90,900			213	1,500					
Metal	Exploration: Moderate	Johnson Tract	1,140,891	50	17,113	25,784	189,844	335	254					
Metal	Exploration: Moderate	Shungnak (Upper Kobuk)	1,102,310	49	66,139		44,092		2,002					
Metal	Exploration: Moderate	Shumagin (Unga Project)	280,335	33				224	1,025					
Coal	Exploration: Moderate	Capps	275,577,749	453										
Coal	Exploration: Moderate	Canyon Creek	165,346,649	353										
Coal	Exploration: Moderate	Castle Mtn	22,046,220	144										

The table below shows projects in the initial exploration stage; those without an inferred resource. The information includes all projects with a DNR exploration permit 2016-2020. The company information is that given the DNR permit analyzed for the project. Some company names may have changed since that time.

Table A2. Initial Exploration Projects

Project Name	Company	Borough Or Census Area
Centennial	Redstar Gold Inc. | John Gray	Aleutians East
Liberty Bell	Boot Hill Gold, Inc. | Millrock Resources Inc.	Denali
Red Mountain	White Rock (RM) Inc.	Denali
Amanita	Tonya Stolz | Avidian Gold US, Inc.	Fairbanks
Ester Dome	Range Minerals Corp. | Millrock Resources Inc.	Fairbanks
SAM Project	Stone Boy et. al. | Great American Minerals	Fairbanks
Shamrock	Bluestone Resource (Alaska), Inc.	Fairbanks
Treasure Creek	Treasure Creek Partnership	Fairbanks
Coffee Dome East	Wendell Zesiger	Fairbanks
Hilltop	Bluestone Resources, AK Inc.	Fairbanks
Kellcher	Kellcher Resources LLC	Fairbanks
Snettisham Vanadium	N23 LLC. | Northern Cobalt Ltd.	Juneau
Helm Bay	Agnico Eagle USA Ltd.	Ketchikan
Big Chunk	Chuchuna Minerals Co.	Lake and Pen
Gail Exploration	Alaska Hardrock Inc. | Gold Torrent Inc.	Mat-Su
Honolulu	Honolulu Prospect Corp.	Mat-Su
Nr. Hatcher Pass	High Grade Gold Mining Company	Mat-Su
Valdez Creek	World Class Mining Inc.	Mat-Su
Aubrey/Larson	Sharon Aubrey/Stella Larson	Mat-Su
Interior Mining	Interior Mining, Inc.	Mat-Su
Valdez Creek	World Class Mining, Inc.	Mat-Su
Divide	David & Daniel Lajack	Nome
Scout Claims	NANA Regional Corp | Alex Conn	Northwest Arctic
Upper Kobuk	Ambler Metals LLC	Northwest Arctic
Upper Kobuk	Ambler Metals	Northwest Arctic
Riverside	Roanan Corporation | Hyder Ventures Ltd.	POW/Hyder

Project Name	Company	Borough Or Census Area
Carrie Creek	Doyon LTD | Tectonic Metals	SE Fairbanks
Delta Project	Grayd Resource Corp. | Agnico Eagle	SE Fairbanks
–orbes - Emerick	David Johnson	SE Fairbanks
Giles	Millrock Alaska LLC	SE Fairbanks
Goodpaster	Aurora Resource Exploration / Millrock	SE Fairbanks
Healy	Newmont / Northway Resources Alaska	SE Fairbanks
Hona	Peak Gold, LLC	SE Fairbanks
Mt. Harper	Doyon LTD / Tectonic Metals / Northway	SE Fairbanks
Napolean	Northway Resources Alaska Corp.	SE Fairbanks
Northway	Doyon Ltd./ Northway Natives, Inc.	SE Fairbanks
Oreo Mountain	Tubutulik Mining / Kennecott Exploration	SE Fairbanks
Richardson Project	Richardson Exploration & Mining	SE Fairbanks
Seventymile	Doyon Limited/Tectonic Metals, LLC	SE Fairbanks
Stone Boy	Northern Star Resources LTD.	SE Fairbanks
Sunny Side Up	Woolly Mammoth Mining	SE Fairbanks
Tanacross	Kenorland Minerals Ltd.	SE Fairbanks
Tibbs	Tibbs Creek Gold | Tectonic Resources Inc.	SE Fairbanks
Triple Z	Peak Gold LLC | Mark Isto	SE Fairbanks
Unknown	Paxson Resources. | Northern Associates Inc.	SE Fairbanks
Icy Cape (Placer)	Alaska Mental Health Trust Authority TLO	Yakutat
Elephant Mountain	Frantz LLC | Endurance Gold Corporation	Yukon-Koyukuk
Honker Project	Western Alaska Copper & Gold	Yukon-Koyukuk
McCord Exploration	Andrew Ault	Yukon-Koyukuk
Quartz Creek	James M. McCann	Yukon-Koyukuk
Round Top	Western Alaska Copper & Gold Co.	Yukon-Koyukuk
Shorty Creek	Gold Range Ltd | Grizzly Bear Gold	Yukon-Koyukuk
Victory Ridge	Spectrum Resources | Great American Minerals	Yukon-Koyukuk
Copper Joe	Kiska Metals (Kennecott)	Yukon-Koyukuk
Kiska (Kiska)	Kiska Gold Mining	Yukon-Koyukuk

Appendix B. Maps: Projects by Region

This appendix maps the projects listed in Appendix A. It also includes the location, though not the names of the Placer Projects, including Suction Dredge Operations with DNR permits 2016-2020.

Figure B1: Mineral Properties in the Northwest Arctic Borough

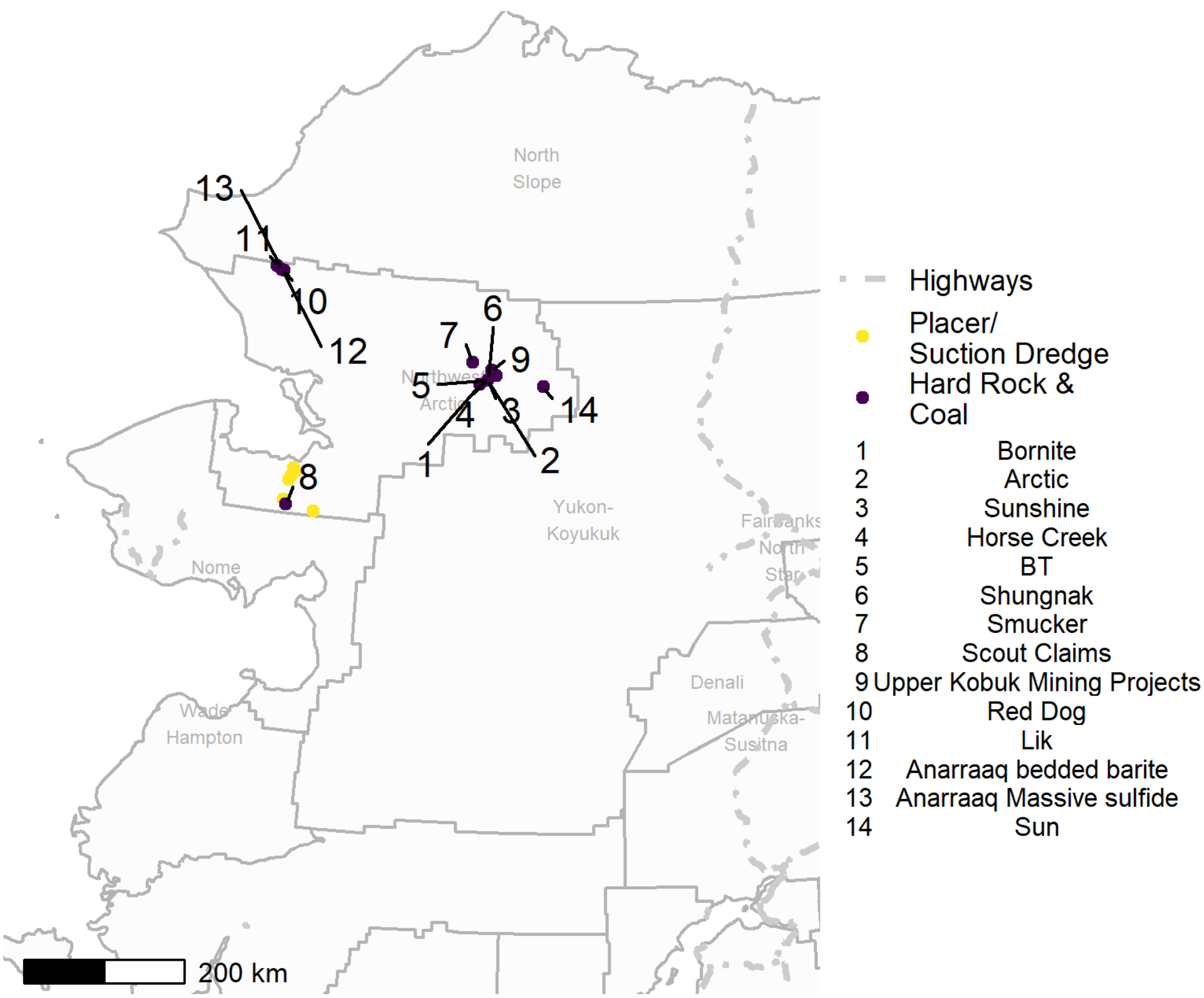


Figure B2: Mineral Properties in Southwest Alaska/Kuskokwim

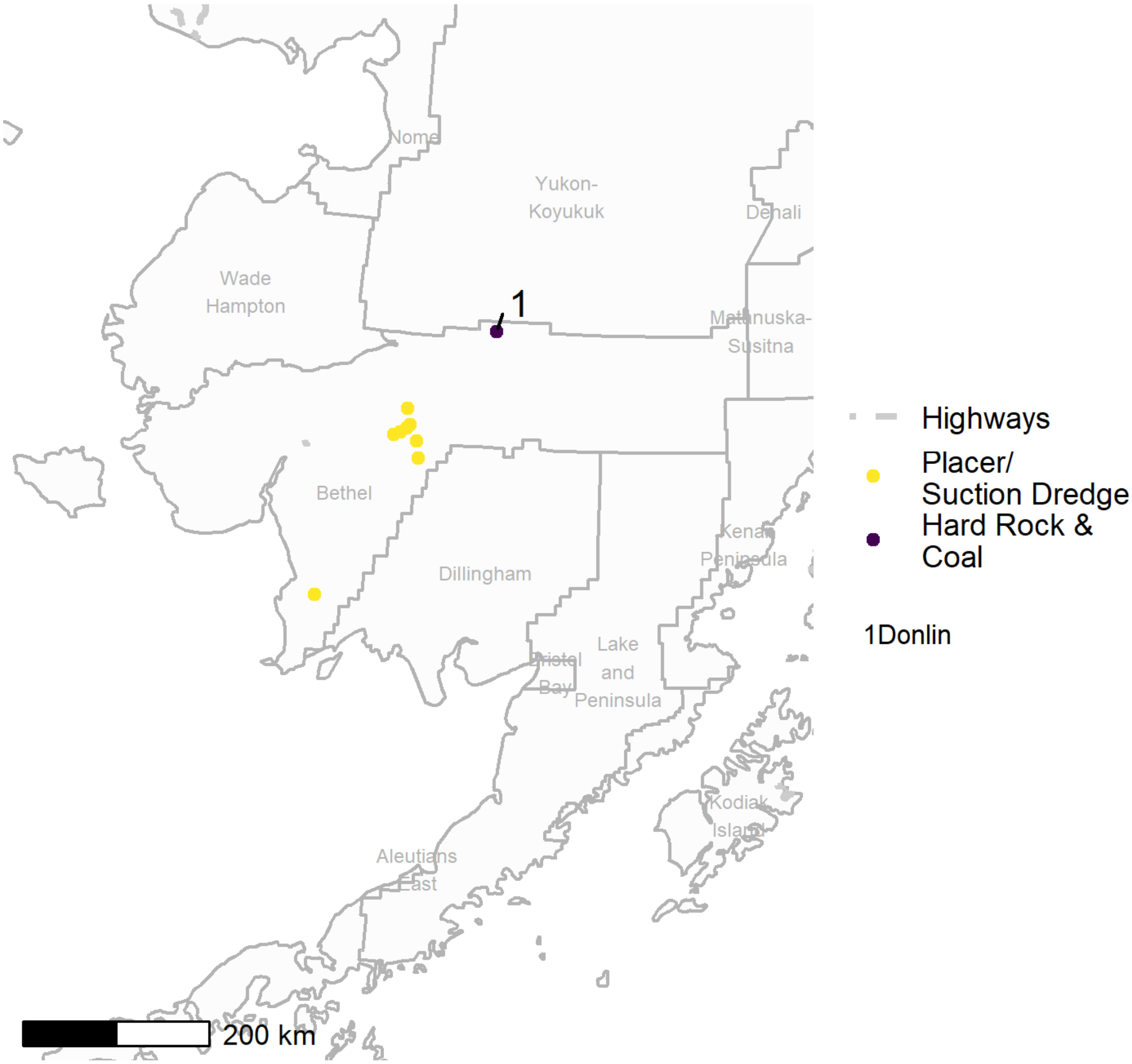


Figure B3: Mineral Properties in the Fairbanks North Star & Denali Boroughs

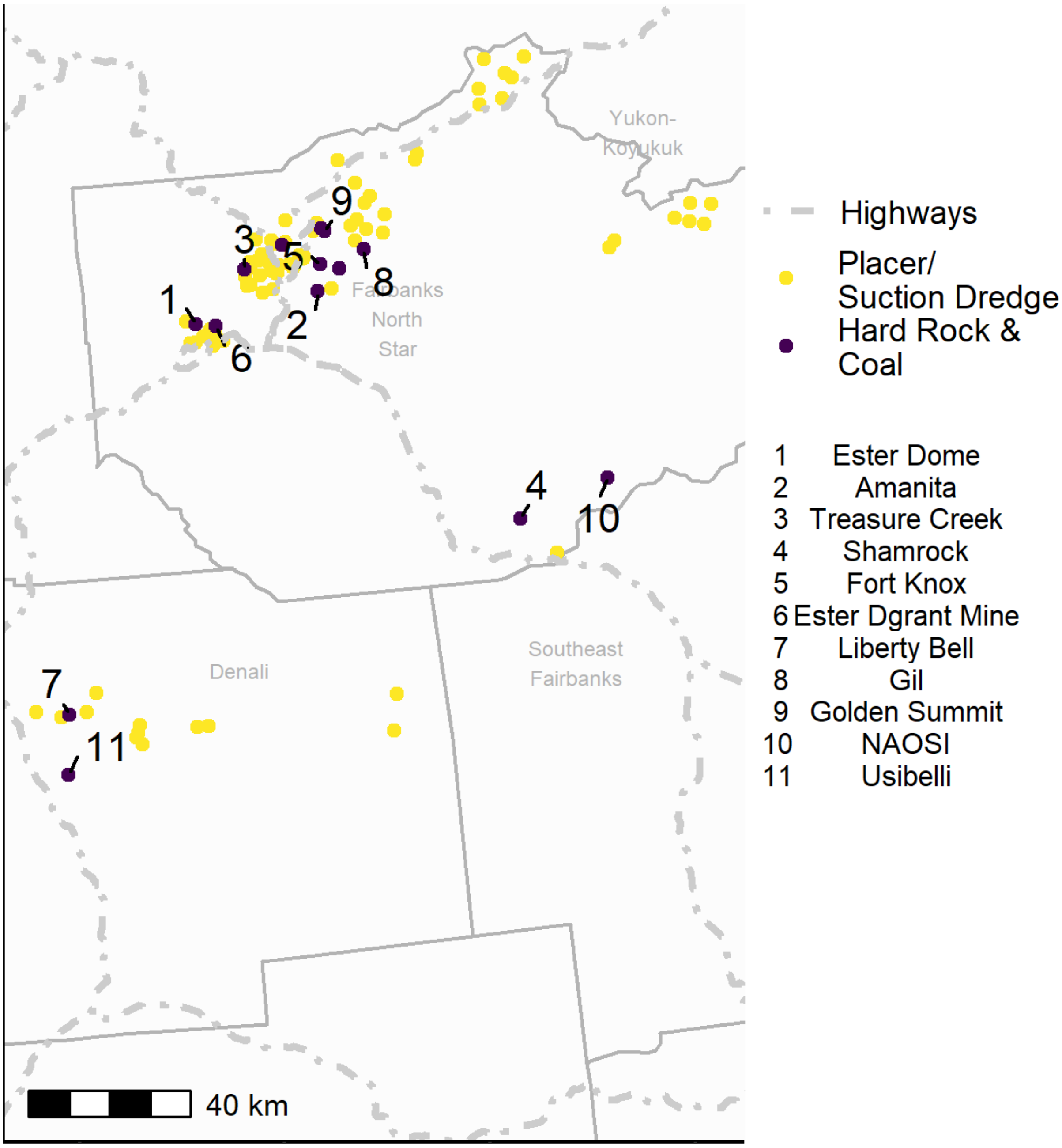


Figure B4: Mineral Properties in Interior Alaska, within 30 miles of Highway

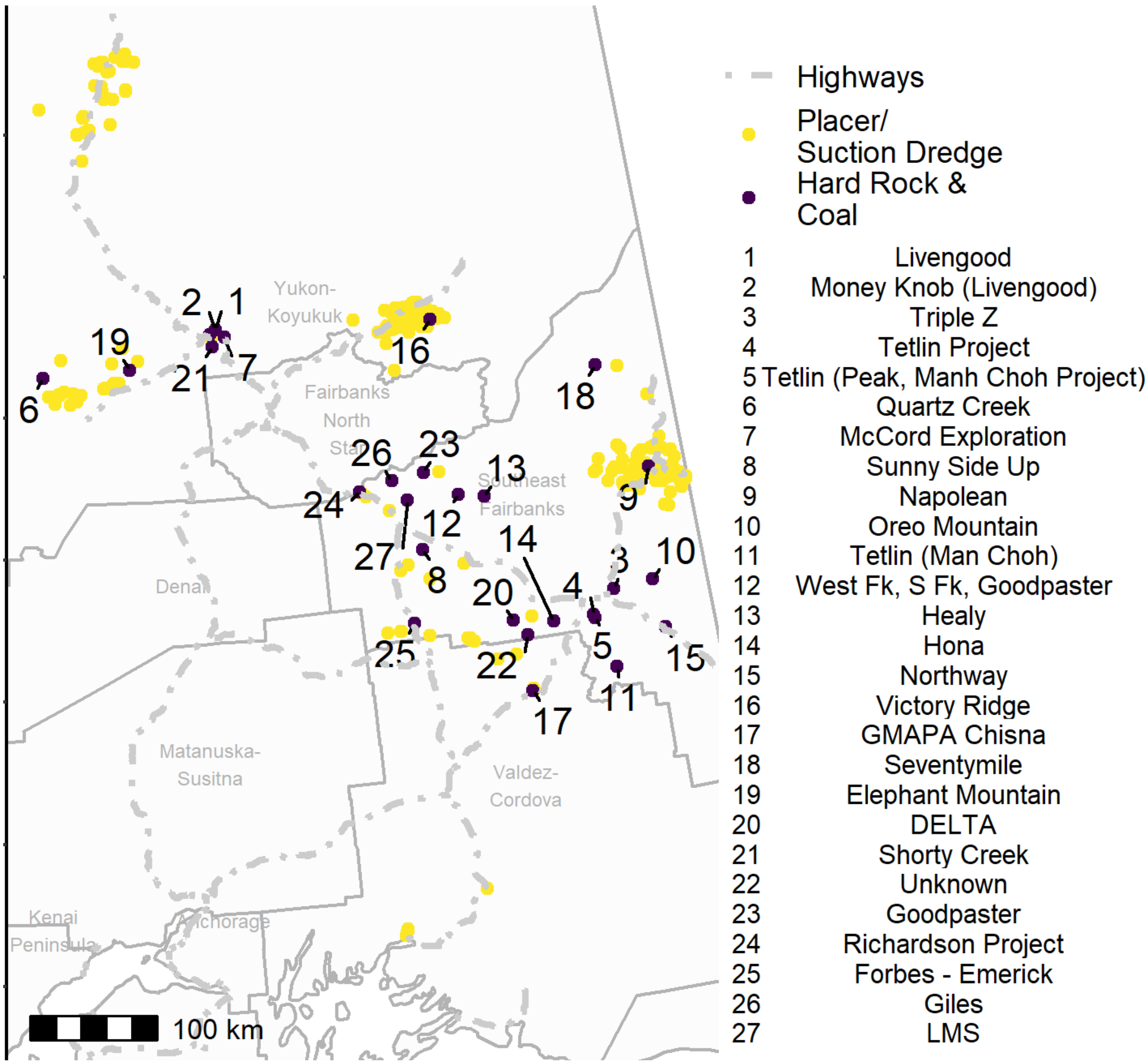


Figure B5: Mineral Properties in Interior Alaska, more than 30 miles from Highway

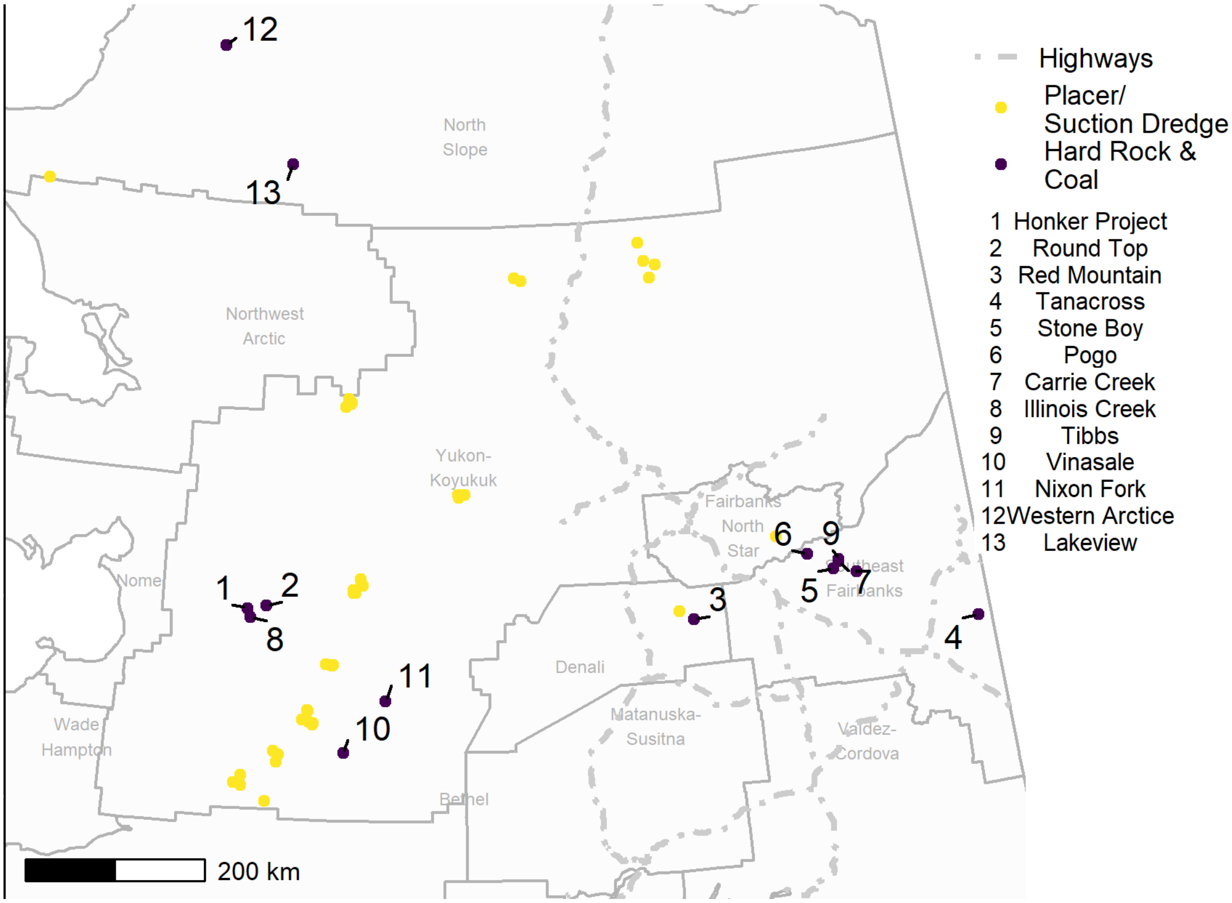


Figure B6: Mineral Properties in the Matanuska-Susitna and Kenai Boroughs

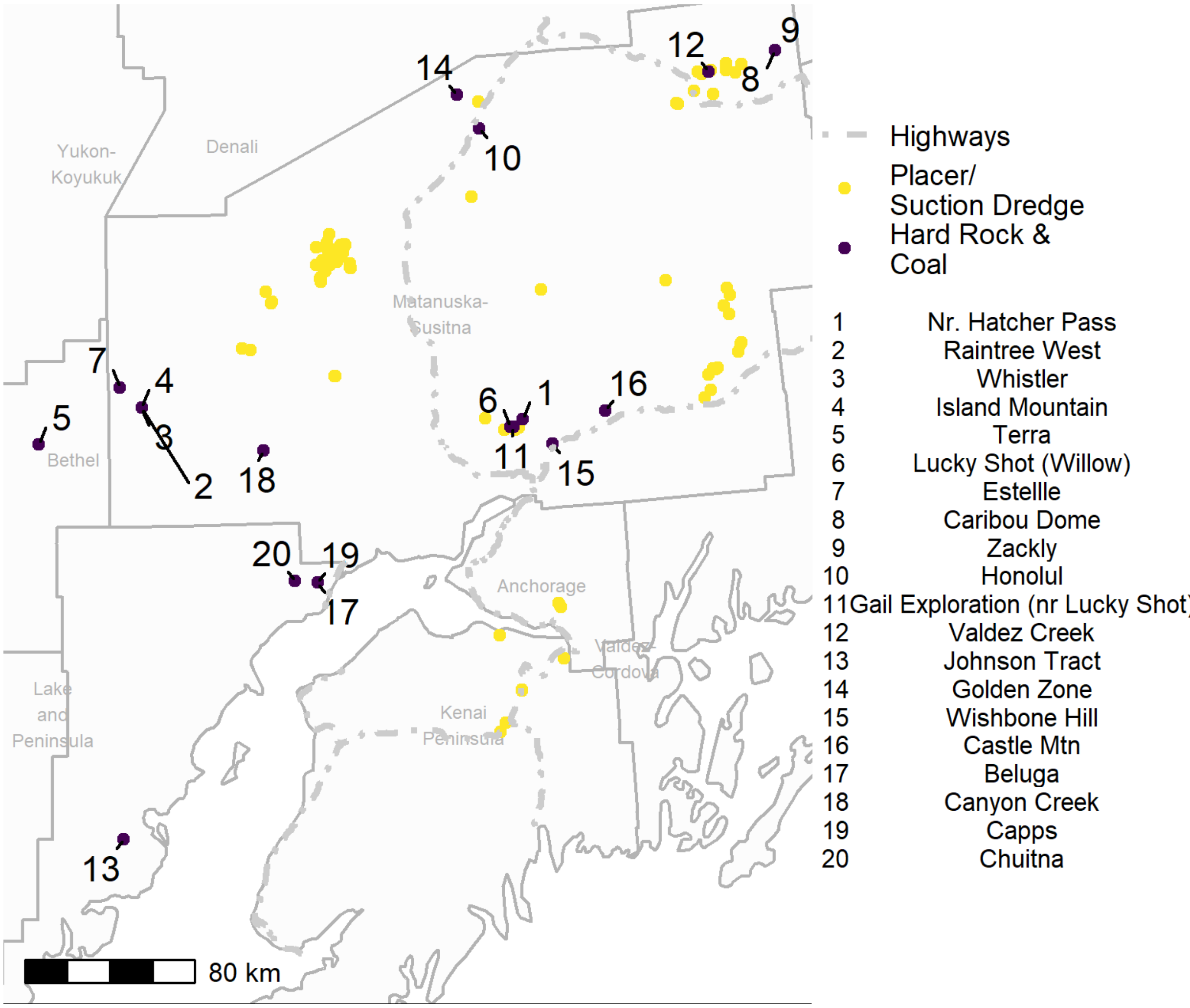


Figure B7: Mineral Properties in the Bristol Bay Region

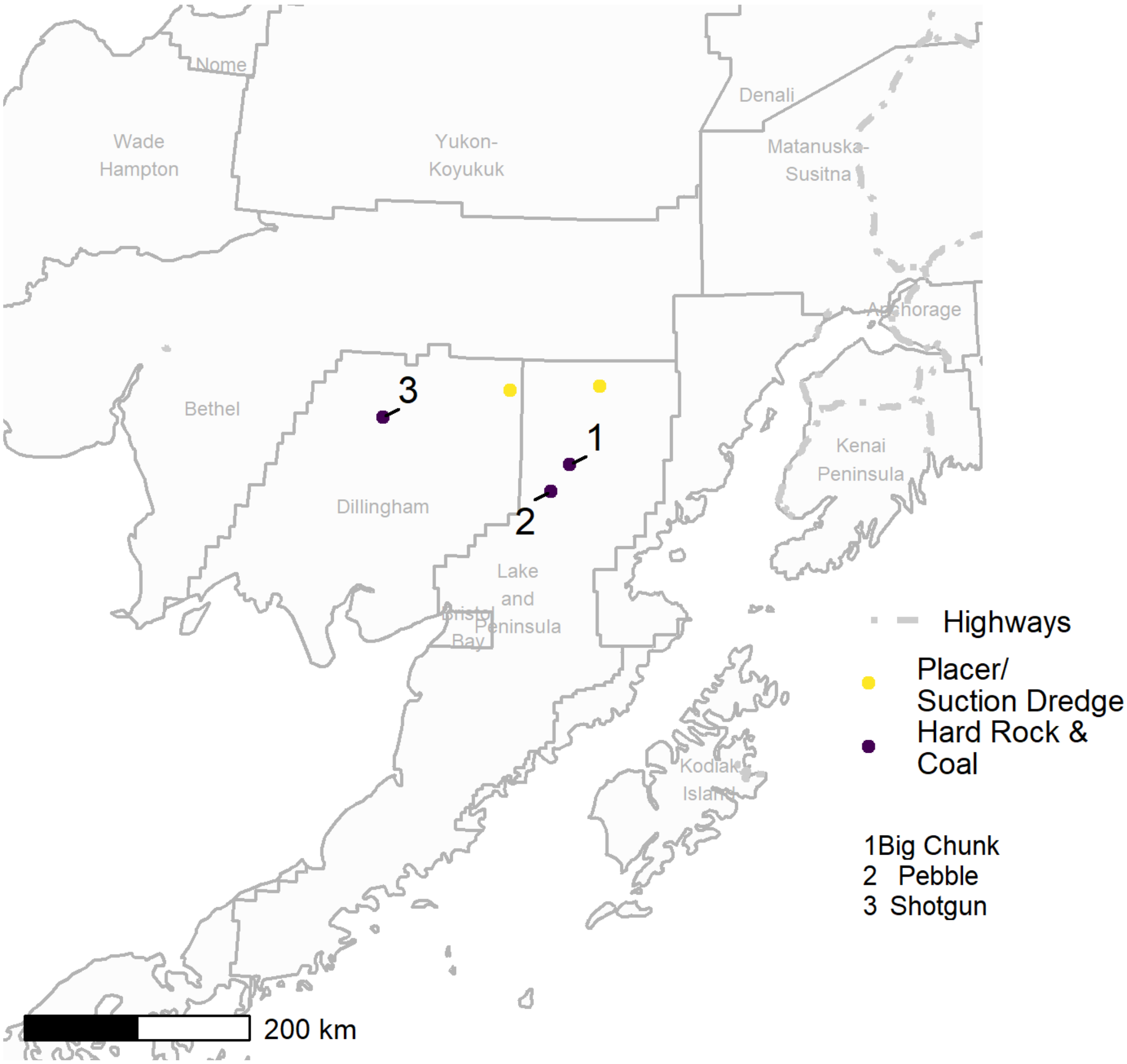


Figure B8: Mining Properties in the Aleutians East and Kodiak Boroughs

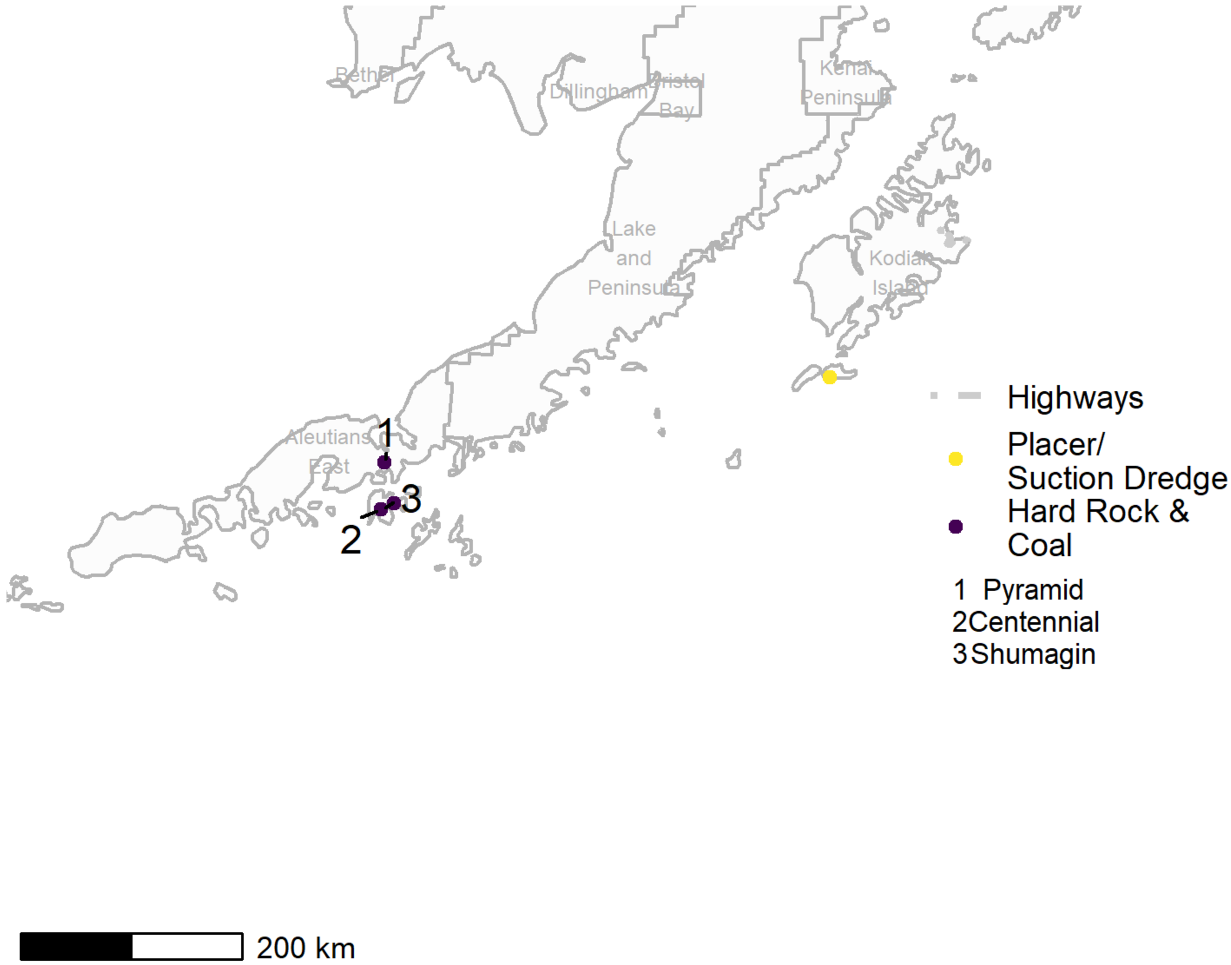


Figure B9: Mineral Properties in Southeast Alaska

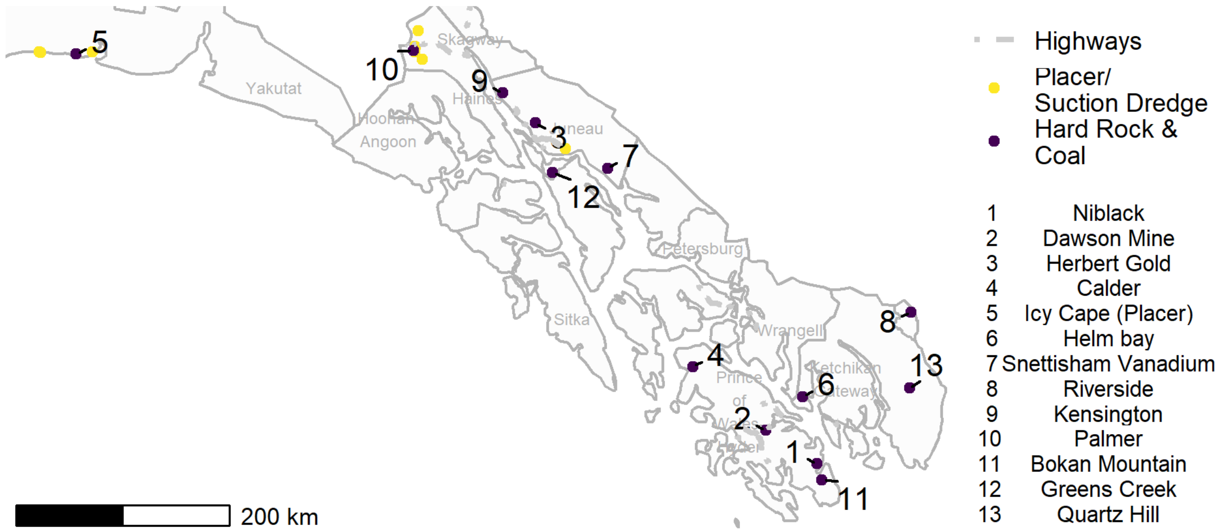
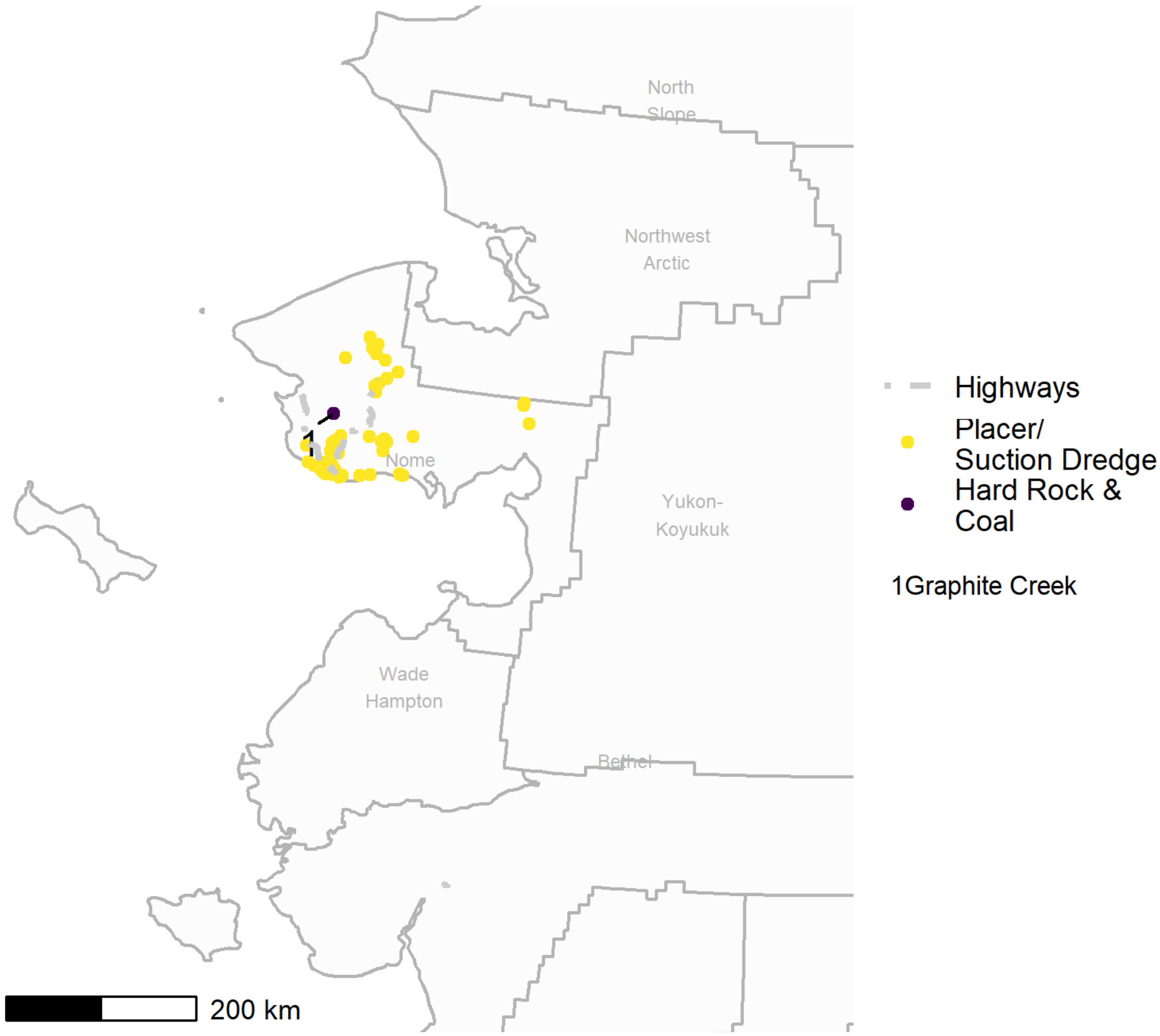

Highways
Placer/ Suction Dredge
Hard Rock & Coal
1 Niblack
2 Dawson Mine
3 Herbert Gold
4 Calder
5 Icy Cape (Placer)
6 Helm bay
7 Snettisham Vanadium
8 Riverside
9 Kensington
10 Palmer
11 Bokan Mountain
12 Greens Creek
13 Quartz Hill
200 km
Yakutat
Skagway
Haines
Hoonah
Angoon
Petersburg
Sitka
Wrangell
Ketchikan
Prince
of

Figure B10: Mineral Properties on the Seward Peninsula



Appendix C. Probabilities by Scenario and Development Stage

These tables provide more detail for table C1 and Table C2 in Chapter 4.

Table C-1. Hard Rock and Coal Employment by Scenario and Development Stage

	Unfavorable		Status Quo		Favorable	
	Employment	**(Range)**	**Employment**	**(Range)**	**Employment**	**(Range)**
Operating	**1,388**	(1,110-1,666)	**1,943**	(1,666-2,221)	**2,776**	(2,776-2,776)
Permitting	**158**	(30-286)	**414**	(286-541)	**901**	(766-1,022)
Economic Evaluation	**186**	(0-372)	**558**	(372-744)	**931**	(744-1,1170
Significant Exploration	**100**	(0-201)	**251**	(0-502)	**832**	(634-1,015)
Moderate Exploration	**-**	(0-105)	**105**	(0-211)	**252**	(0-534)
Initial Exploration	**-**	(0-0)	**48**	(48-48)	**131**	(96-159)
Total: All Hard rock and Coal	**1,832**	(1,141-2,630)	**3,319**	(2,372-4,267)	**5,823**	(7,263-9772)

Table C-2. Hard Rock and Coal Production Value by Scenario and Development Stage (Millions of 2019 $)

	Unfavorable		Status Quo		Favorable	
	Value	**(Range)**	**Value**	**(Range)**	**Value**	**(Range)**
Operating	**$ 1,285**	(1,028-1,542)	**$ 1,799**	(1,542-2,056)	**$ 2,571**	(2,571-2,571)
Permitting	**$ 151**	(15-288)	**$ 424**	(288-561)	**$ 957**	(818-1,091)
Economic Evaluation	**$ 192**	(0-383)	**$ 575**	(383-767)	**$ 958**	(767-1,150)
Significant Exploration	**$ 81**	(0-161)	**$ 201**	(0-403)	**$ 651**	(496-794)
Moderate Exploration	**$ -**	(0-87)	**$ 87**	(0-175)	**$ 193**	(0-385)
Initial Exploration	**$ -**	(0-0)	**$ 38**	(38-38)	**$ 108**	(77-132)
Total: Aall Hard rock and Coal	**$ 1,709**	(1,043-2,462)	**$ 3,124**	(2,252-4,000)	**$ 5,438**	(4,729-6,123)