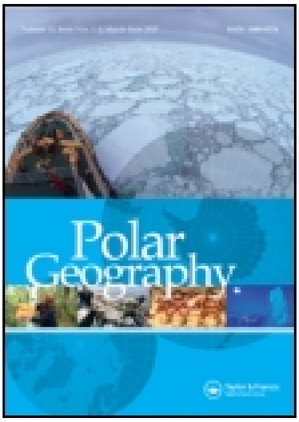

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Observing trends and assessing data for Arctic mining

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Observing trends and assessing data for Arctic mining

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This paper reviews and assesses the state of data to describe and monitor mining trends in the pan-Arctic and their social effects, and discusses drivers of change in Arctic mining. Trends in mining activity can be characterized as stasis or decline in mature regions of the Arctic, with strong growth in the frontier regions. World prices and the availability of large, undiscovered and untapped resources with favorable access and low political risk are the biggest drivers for Arctic mining, while climate change is a minor and locally variable factor. The widely available measures of mineral production and value are poor proxies for social and economic effects on Arctic communities. Historical data on mineral production and value are unavailable in electronic format for much of the Arctic, specifically Scandinavia and Russia; completing the historical record back to 1980 will require work with paper archives. The most critically needed improvement in data collection and reporting is to develop comparable measures of employment. The eight Arctic countries each use different definitions of employment and different methodologies to collect the data. Furthermore, many countries do not report employment by county and industry, so the Arctic share of mining employment cannot be identified.

Introduction

This analysis is a component of a larger project known as the Arctic Observing Network Social Indicators Project (AON-SIP), which in turn is part of a science initiative known as the Study of Environmental Arctic Change (SEARCH) (see Kruse this volume). This paper reports AON-SIP project results for one arena of Arctic change, specifically the mining component. (see http://www.iser.uaa.alaska.edu/projects/search-hd/index.htm.)

Arctic oil and gas prospects, and the ensuing, contentious diplomatic relations that have resulted between circumpolar countries, have received widespread attention in recent years. By contrast, the expansion of Arctic mining has proceeded with little fanfare. Employment growth in Alaska's mining sector grew at six times the pace of the petroleum sector's employment growth since 1990. In Canada, the value of diamond mining has outstripped oil and gas extraction in the Northwest Territories (NWT) for the past decade (McDonald *et al.* 2006). In Alaska, Canada, and Greenland, recent regulatory changes and policies have encouraged the development of new mines (Borell 2004; Carter 2007; Cope 2004). And Russian mega-companies like Norilsk have extended their global reach, buying into operations in Finland and Arctic Canada (*Mining Exploration News*, 2008).

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Mining, like oil and gas, has not only the potential to spur economic development and create wealth, but also harm the environment and irrevocably shape the social dynamics of Arctic communities and indigenous ways of life. Mining development in the Arctic can be further complicated by an extreme environment, remote locations, and a limited labor supply. Mining's uncertain socio-economic impact is also of concern in regions where an *informal* economy – particularly subsistence hunting and herding – is a critical cultural component and essential to the quality of life of local inhabitants (AHDR 2004).

Within the Arctic, mining regions can be categorized as either 'resource frontier regions,' or 'mature' regions (also known as 'downward transitional areas') (Duhaime 2004; Sugden 1982). Arctic Scandinavia is a mature region. Mines in Scandinavia have operated since the 1950s and are well integrated into a national transportation network. They have generated widespread economic spin-offs and are central to local and regional economies.

In frontier regions like Alaska, the Canadian Territories, Nunavut, and potentially Greenland, 'economic decoupling' is more characteristic: the economic benefits of mining are largely exported, and the control of resources is dictated from afar (Duhaime 2004). Value-added industries, like the refining and industrial application of minerals, remain largely undeveloped. Most North West Territories diamonds, for example, are exported out of Canada as rough or uncut. Exploration in Greenland has jumped in recent years, and new mines have opened, but are under pressure from falling prices (McDonald *et al.* 2006; Sørensen 2008). Mining in frontier regions, where costs are high, is particularly sensitive to price fluctuations (Duhaime 2004). Developments in 'benefit sharing agreements' and 'corporate social responsibility' are securing regional benefits and mitigating negative impacts to a certain degree, though the threat of resource dependency remains, sewing vulnerability into a fledgling frontier economy.

Mining does not exist in Iceland or the Faeroe Islands (except sand and gravel), though large smelting operations, supplied by Scandinavian ore, contribute significantly to Iceland's economy.

Mine production is classified as mineral fuels (mostly coal), iron, ferro-alloy and non-ferrous minerals (with myriad industrial applications), precious metal ores (mostly gold and silver), or industrial minerals including diamonds. Oil and gas, sand, gravel and quarry stone are also classified as mining, though they are not considered here.

The Arctic contributes a small share of global production of minerals like titanium (0.3%) and bauxite (1.9%), but contributes as much as 40% to the global production of palladium (used by the auto and electronics industries, among others), 26% of diamond gem stones, and 23% of industrial diamonds (Lindholdt 2006).

Arctic Russia with abundant reserves and large-scale production accounts for the largest share of Arctic mining (Lindholdt 2006), but other regions are increasingly important, including one of the world's largest zinc mines in remote Alaska, and the world's second largest underground mine in Kiruna, Sweden. Greenland's rapid movement towards exploration and production marks a new era in Arctic mining, and therefore a new era in Arctic economics and society. It is unclear how recent volatility and price fluctuations will shape current developments, however, and what the implications are for countries and communities dependant on resources with notoriously volatile prices. Data for mining in the Arctic have been irregular and inconsistent—either because of its proprietary nature, different reporting standards, or their inclusion into greater numbers for the country at large. Mining's contribution to Arctic economies therefore remains unclear.

This paper describes trends in mining across the circumpolar north and highlights systemic shortcomings in information that make comparisons and evaluation difficult.

Methodology

The focus of this paper is specific to the role of mining in Arctic regions, with a goal of better contextualizing mining's contribution to social and economic development by comparing data across regions and across time. It therefore necessitated, first and foremost, an extensive gathering of mining and mining–related data. This information was pursued for each Arctic country, with the goal of isolating data for the Arctic share of mining, and even further, for the individual sub-regions of the Arctic as defined by the Arctic Human Development Report (AHDR). In Norway, for example, data were isolated for the counties of Nordland, Troms, Finnmark, and Svalbard, while in Canada data were sought for the Yukon Territories, Northwest Territories, and Nunavut.

Data were sought on mineral production including industrial minerals (specifically diamonds and olivine), metal ores, and energy minerals (coal). Gravel and stone operations, which generally contribute more to local construction supplies than to exports, were omitted in this study. Oil and gas data were compiled separately. Published information on mining value, employment, exploration expenditures, and claims data was also collected. These categories are defined and reported differently by different agencies across the Arctic, necessitating further research to understand discrepancies and make appropriate corrections when comparing between countries. Our transformation of the data to facilitate comparison of the mining sector in different countries and identify trends is discussed further below.

We attempted to construct a time series of mining data from 1980 to the present day. The availability of historical data varies, and missing data are noted. In some instances, data available online were supplemented by research *in situ* at agency vaults or libraries (in Greenland, Alaska, Norway and Russia), as well as personal contact with statistical, geological, or mining personnel (in Alaska, Canada, Sweden, and Norway).

The AON-SIP conceptual model explicitly identifies two pathways of interactions between development activities and social outcomes: economic effects and ecosystem services, with institutions as a mediating layer. In this project, our emphasis on currently available, time series data has led us to an almost exclusive focus on economic and production data. The complete dataset and detailed documentation are available at www.search-hd.net.

Economic effects and potential indicators

We evaluated four types of measures for monitoring economic effects: local mine-related spending, mine-related employment, mining production measured in physical quantities, and mining production measured by market value. To identify pan-Arctic patterns and monitor trends over time, a good indicator must meet four criteria: first, it should be a meaningful measure of local socio-economic impacts.

Second, it should be available for each mine in each Arctic region. Third, it should be comparable between different regions and minerals. And fourth, it should be comparable over time. Each of the potential measures we identified failed to meet at least one of these criteria (see Haley *et al.* 2011).

Information on local mine-related spending is proprietary and not generally available. Mine-related employment is a key indicator, but unfortunately, employment data are collected and reported in different manners in different Arctic regions (e.g. reporting total employees vs. full-time equivalent employment, reporting employees by place of work vs. place of residence). And some countries only report employment-by-industry data at the national level, lumping Arctic and non-Arctic employment together.

Mining production has potential to be used as an indicator of mining's social impact because the inputs to mining production – employment, payments to local governments, payments to landowners, and environmental impacts – have direct social impacts on a region. An increase in a region's mine production increases local spending and therefore mining's social impact on the region.

Measuring mining production in physical units allows us to compare the year-to-year change in the level of mining activity one mineral at a time, but not to compare the social impacts of mining different products. Measuring mining production by market value allows us to aggregate and compare production across different minerals, but has two inherent problems. First, a short-term increase or decrease in market price will change the market value of production but have little effect on the volume of production or the social impact of mining. Second, it is an imprecise measure because the relationship between mining value and social impact differs between mines: each mining operation has different production costs, local value-added and labor characteristics.

To solve the problem of short-term price fluctuations which affect value but do not affect mining activity or social impacts, we created an index of mining production, constructed as the physical production of a mineral multiplied by its 28-year (1980–2007) average price. This creates a reliable measure of production over time that can be aggregated across minerals, weighted by their relative values. The prices used are from the US Geological Survey mineral commodity statistics (Kelly and Matos, 2005), except coal prices which are from IMF commodity data for Australian thermal coal (EIA 2009). For diamonds we used a 10-year average price (1997–2007) to avoid the price discontinuity due to the break-up of the De Beers diamond cartel. The index includes metallic minerals, diamonds, and coal; most other industrial minerals are excluded due to a lack of developed and consistent global market prices. Industrial minerals are important in some regions and are briefly discussed in that context.

As Figure 1 shows, mineral prices are volatile, but real (inflation adjusted) prices tend to hover around their long-term average with occasional temporary price spikes. Figure 2 shows the normalized global market price of the minerals used in this analysis and indicates the level of price volatility that exists.[1] Prices here are normalized with their 28-year (1980–2007) annual average price equal to 1.00.

The mining production index is a better indicator of social impacts than mining's market value because the index evens out short-term price fluctuations. A mining company's decision whether, and on what scale, to develop and operate a mine determines the level of mining activity and spending in a region. Mining companies use long-term expected prices, not current, short-term prices when making these

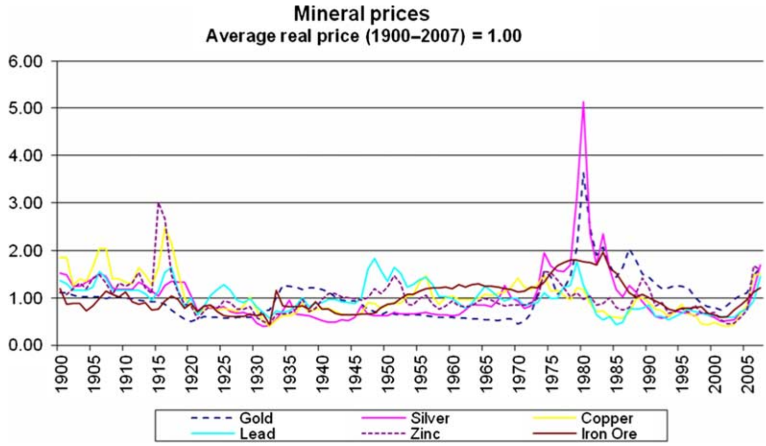

Figure 1. Normalized real mineral prices, 1900–2007.
Source: US Geological Survey, mineral commodity statistics, in Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States: US Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2005/140/ (Accessed 2009).

decisions. The level of mining activity and spending and associated social impacts are based on long-term price expectations and do not fluctuate with market prices.

The mining production index is inferior to employment as an indicator of mining's economic impact: employment is a direct measure of impact, while the index is an indirect measure with more confounding factors. But as noted above, employment cannot currently be used as a pan-Arctic comparative measure because it is

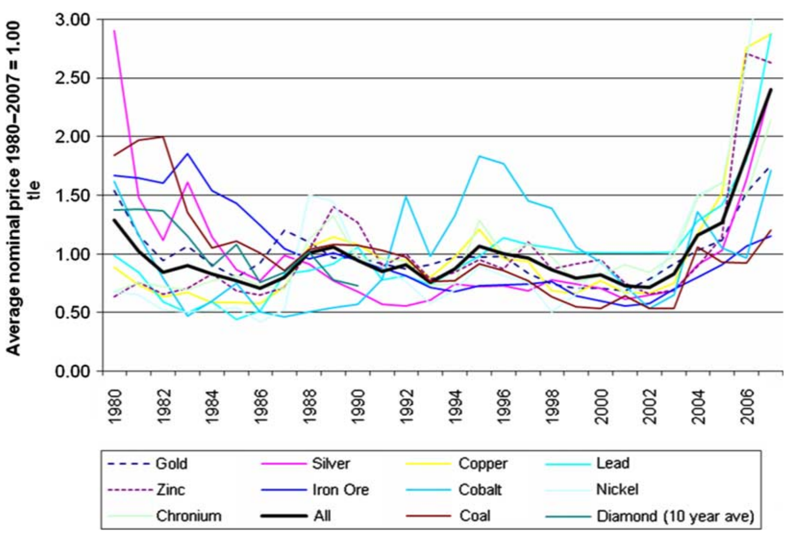

Figure 2. Monthly mineral price index, 1980–2007.
Note: Calculated from US Geological Survey mineral commodity statistics, in Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States: US Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2005/140/ (Accessed 2009).

inconsistently defined and measured across countries, and in some countries cannot be broken out for the Arctic counties. The positive relationship between mining employment and the mining production index is illustrated for Alaska in Figure 3.

There are four inherent sources of error in the mining production index as a measure of economic impact. First, it does not account for the variability of economic rent between mines and how much of that rent remains within the region. Second, the production costs and the composition of production costs required to produce one unit of mineral production vary between different mines. Third, the amount of local value-added varies between mines. Fourth, the labor characteristics and labor's regional impact vary between mines. The exact relationship between mining production and social impacts cannot be fully understood without itemized cost data of individual mines and detailed analysis of the impact of those costs. Nevertheless, the mining production index is the best available generic indicator of the social impact of mining because, unlike other potential indicators, it is able to measure and compare the level of mining activity over time, for different minerals and for different locations. A more detailed assessment of the mining production index is provided in Haley *et al*. (2011).

Trends in Arctic mining

The Arctic Human Development Report (2004) divided Arctic countries along the lines of their economic development, characterizing each half as either a 'mature,' or 'resource frontier' region. The differences between the two types are represented by trends in mining. Mature regions have integrated mining operations into a broader, more diverse economy, and are well connected to a national transportation and power grid. Frontier regions, on the other hand, are just beginning to develop new mining operations, operate in remote, challenging locations, and usually draw labor, supplies, and contractors from distant hubs. The mature regions in the Arctic are principally the Scandinavian countries – Norway, Sweden, and Finland – while Alaska, Greenland and Arctic Canada are characteristically frontier regions.

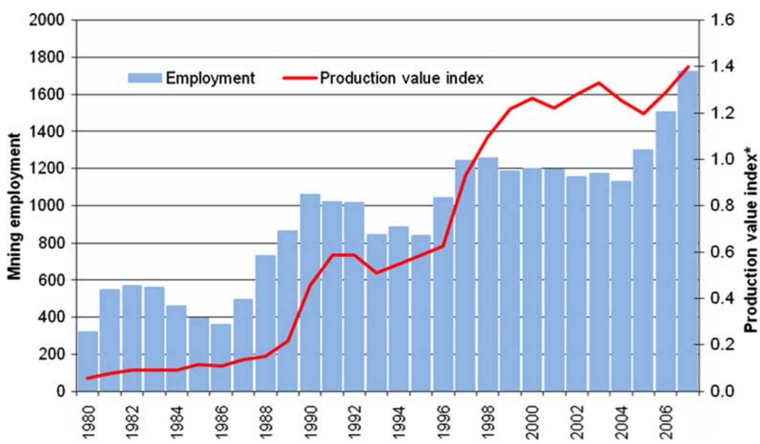

Figure 3. Alaska mining employment and production index, 1980–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

Northwestern Russia is a mature mining region, while central and eastern Siberia are frontier. Iceland and the Faeroe islands have no mining.

Mature regions

The Scandinavian countries continue to host several large, productive mines, but new developments, exploration, and growth (through 2008) have been minimal.[2] High prices encouraged some investment, but largely at preexisting mines. The overall value of mining in mature regions of the Arctic has increased modestly over time. The following country narratives discuss developments in each country since 1980, or the years for which data were available.

Finland (Arctic provinces: Lapland and Oulu, including Kainuu and North Ostrobothnia)

Mining records in Finland date back to 1530, and Oulu in the Arctic region hosts the third largest stainless steel plant in the world (Outokumpu Chrome), supplied by a Lapland chromite mine. Domestic iron ore deposits once fed the Raahe carbon steel processing plant, but the last mine shut down in 1988 and the plant now relies on imports from Sweden and Russia – a telling indicator of Finnish mining itself.

Besides a historic mining legacy, Finland's northern economy is well-integrated into the larger national economy, and *not* wholly dependant on resource extraction. Much of the minerals extracted there are processed locally. Manufacturing in other industries, including telecommunications, outstrip mining's contribution to the economy of Arctic Finland. Even the household incomes in Arctic Finland are only marginally lower than those of southern counterparts (McDonald *et al.* 2006, p. 52), distinguishing it from other Arctic regions in this respect. Arctic Finland is therefore not dependent on mining, even if it remains an important component of the overall economy. Mining faces an uncertain future in places like Finland, where old mines yield fewer new discoveries, but where easy transportation exists, and new investment continues. Figure 4 shows the value-weighted index of mining production

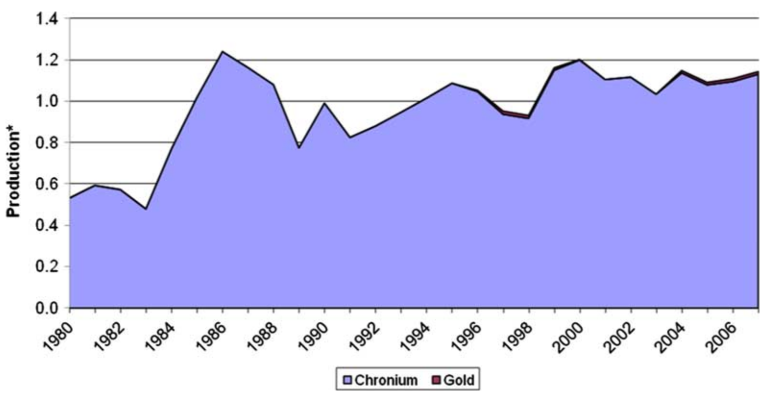

Figure 4. Arctic Finland mining production, 1980–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

in Finland. It demonstrates the relatively constant level of production in Arctic Finland, with some normal fluctuations.

Sweden (Arctic Counties: Västerbotten and Norbotten)

Swedish mining is composed of a handful of long-producing mines located in Norbotten County. Like in Finland, Swedish mining regions are well-integrated into the greater transportation and overall economic network. Within the Swedish Arctic, mining contributes a mere 2.5% to the economy (compared to 45% from services, 2002). Historic data for Sweden are absent prior to 1992, but Figure 5 nonetheless illustrates relatively steady mining production values over recent years in Arctic Sweden. Employment, however, has steadily declined over the decades – raising new questions about the contribution of mining to the economy as a whole.

Norway (Arctic Counties: Finnmark, Troms, Nordland, and the territory of Svalbard)

Mainland Arctic Norway is well-served by road, air, and sea, including deep-water ports and sleek, new airports. In spite of important hubs, including Bodø, Tromsø, Alta, Hammerfest, and Kirkenes, and important Sámi centers like Kautokeino and Karasjok, the north is rural, somewhat remote, and largely dependant on natural resources, such as reindeer herding and especially fish. Mining's contribution to the regional economy, and to that of Norway as a whole, is small. Mining comprised a mere 0.4% of Arctic employment and only 0.8% of regional GDP in 2002. The Arctic share of total mine output for metal ores and industrial minerals, however, is relatively large, approximately 40% of Norway's total.

Mining in mainland Norway is currently not very dynamic. Figure 6 shows the steadily declining iron ore production of the only remaining metal mine in the Arctic region; three other metal mines closed between 1991 and 2003. Locals have pinned their hopes on oil and gas development instead, anxiously awaiting

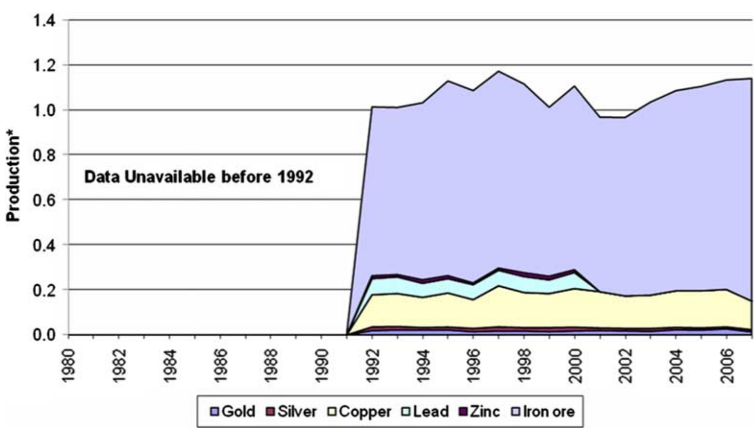

Figure 5. Arctic Sweden mining production.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

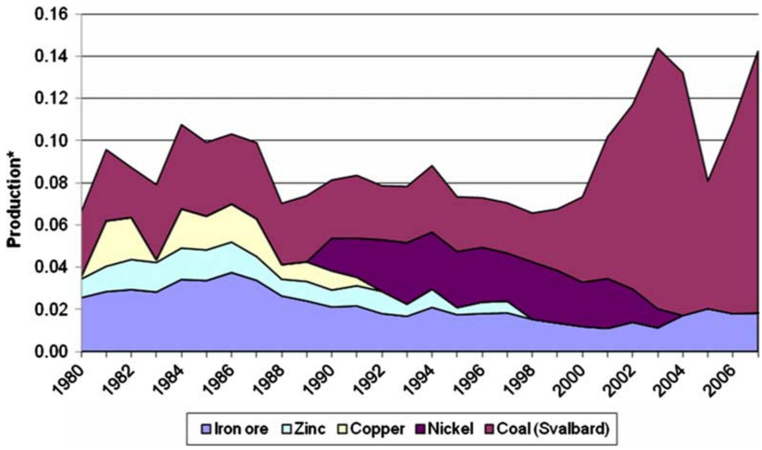

Figure 6. Arctic Norway mining production, 1980–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

trouble-free production from *Snøhvit* – the much-watched, expensive, and contentious Liquefied Natural Gas facility in Hammerfest. Other communities are hoping for their share in Barents Sea oil and gas development, including impending developments in Russia. The Norwegian government's High North Strategy (2006) dedicates a brief passage to mining, acknowledging a desire for increased development under a regulated framework. This is merely a token compared to the attention devoted to marine resources and petroleum activities in the same document.

On Svalbard, however, coal mining is both an important employer and the only source of coal in Norway. Its production has wavered, but has increased dramatically since 2000.

Frontier regions

Frontier regions, including Alaska, Canada and Greenland, differ dramatically in comparison to mature regions. Mining values have increased steeply, in line with new developments, dramatic increases in exploration development, and recent high commodity prices. Unlike the mature regions, new mines have come online since 1980, and undeveloped resources are plentiful. On the other hand, environmental obstacles and lack of infrastructure continue to make development challenging. These areas also continue to struggle to retain added value from mining operations and generate more sustainable local economic development and employment.

Alaska

Alaska is a prototypical frontier economy. In mining, much of the product, along with its value, is exported out of state. Remote, roadless regions and frozen shipping lanes make construction, transportation, and exploration both demanding and expensive. But this has not deterred an explosion in exploration and development in recent years: record high prices generated a total mineral industry value of over

$4 billion in 2007. This was a 100% increase in value compared to 2005, a then record-setting year itself. Exploration expenditure increased three-fold between 2005 and 2007, marking the fourth consecutive year of dramatically increased exploration expenditures (Figure 7). New gold mines throughout the state spurred increases in development spending as well. Unlike the trends in mature regions, Alaska's production index trends steadily upwards (Figure 8). As Figure 9 shows, Alaska's share of total US mineral production by value has increased dramatically, from less than 1% in 1980 to nearly 13% by 2006. Only very recently have prices for zinc, lead, and other minerals retreated, if not collapsed, and it remains unclear how mining operations will respond. Gold prices have remained relatively stable, however, and mines from Southeastern Alaska, Nome, and the interior are moving forward with development and production.

Teck Cominco's Red Dog mine is of particular importance. Located near Kotzebue in northwestern Alaska, it is responsible for over 72% of the value of production in Alaska in 2006, and two-thirds of US zinc reserves are located at Red Dog. Its ore grade is considered of extremely high quality, yielding as much as 480 pounds of valuable lead and zinc (combined) for every ton milled – a combined concentration of 24%. This compares to 0.023 ounces of gold per ton at the Fort Knox gold mine. One negative effect of Red Dog's extremely high ore content is that its waste tailings still contain relatively high concentrations of metals and will require active containment and monitoring in perpetuity.[3]

The joint venture operating agreement between the NANA Regional Corporation – a native-owned regional corporation organized under the Alaska Native Claims Settlement Act (ANCSA) which owns the land and mineral rights – is a model for increasing local benefits and regional development in the Arctic.

Environmental concerns persist in Alaska, however, and challenge development. The proposed Pebble Creek copper, gold, and molybdenum mine in Southwest Alaska has fostered a contentious public debate about the safety of waste ponds. And currently, the fate of potential Kensington mine tailings (in Southeast Alaska) is being decided by the US Supreme Court.

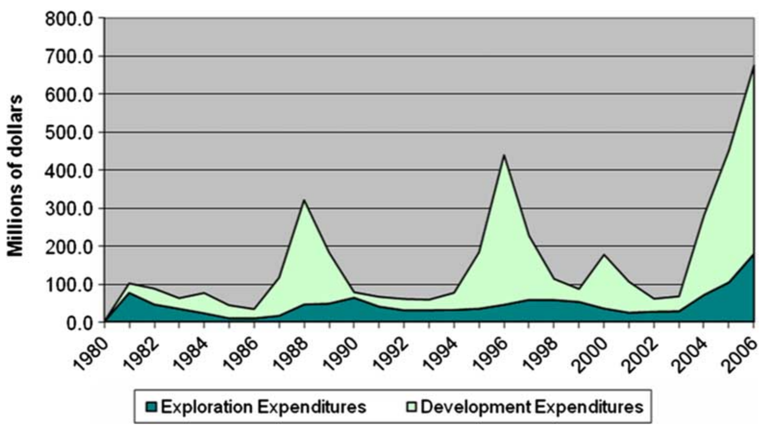

Figure 7. Alaska mining expenditures, 1980–2006.

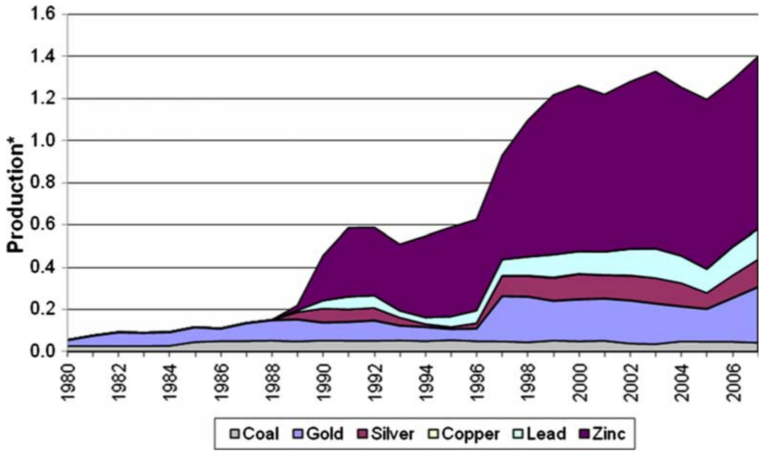

Figure 8. Alaska mineral production, 1980–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

Canada (Arctic Territories: Northwest Territories, Yukon Territory and Nunavut)

Canada exemplifies the changes in Arctic economic systems. It is an advanced country with a highly developed southern tier, but resource development dominates the rural economy of the north – a prototypical resource frontier region. Oil, gas, and other types of mining – particularly diamonds – have spurred industrial development by Canadian and foreign multinational firms in remote areas with difficult climates. Revenues have benefited the central government, and to some degree local communities, but much of the profit has flowed to the southern tier and distant financial capitals. Effective indigenous self-organization, and increased autonomy in Nunavut, has begun to reverse the outward flow of profits and stimulate local development.

For the territories and Nunavut combined, mining and oil and gas accounted for 36.4% of total economic activity in the region in 2004 (Glomsrød and Aslaksen 2006). High-quality diamonds have established Canada as a major global supplier of

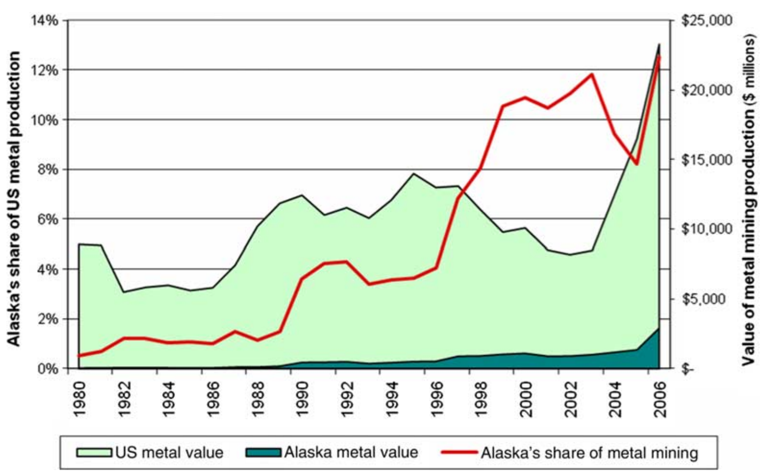

Figure 9. Alaska's share of US mineral production and value, 1980–2006.

the precious mineral. Some small companies process diamonds in the Northwest Territories, though the majority is exported for processing elsewhere. Nonetheless, the value of diamond mining – mostly from NWT mines, and recent additions from Nunavut – rose from $791 million in 2002 to $2.1 billion in 2004, then backtracked to $1.4 billion in 2007. Diamond mining has spurred economic development by stimulating exploration in the north, and through capital expenditures resulting from the expense of building and maintaining the mines (Santarossa 2004).

Although mining remains largely undeveloped throughout the Canadian Arctic, with only small contributions to the production of minerals other than diamonds and trace amounts of gold, its overall share of mining expenditure has grown dramatically (Figure 10). In 1990, For example, the Arctic share of mining expenditure in Canada was a respectable 7%. It rose dramatically in the early 1990s and now hovers around 25%. Figure 11 shows a corresponding increase in Arctic mine production.

Greenland

Greenland is a compelling example of heightened search for Arctic non-renewable resources. Like Arctic Canada, it is a frontier region with little infrastructure and obvious physical barriers to exploration. Exports are 90% based on fish – especially shrimp. But exploration for petroleum and minerals has recently boomed (Figures 12 and 13). The first gold mine started production in 2003 and an olivine (an industrial mineral) mine opened in 2004.

Greenland does, however, have a historical legacy of mining, including a now-depleted cryolite mine near Ivigtut that was a major contributor to Greenland's economy before 1973 (Lycke and Taagholt 1987); 3.5 million tons of cryolite, which aids in aluminum production, was extracted before depletion. Between 1956 and 1962, 130,000 tons of lead and zinc were extracted from the Mesters Vig site in East Greenland; 600,000 tons of coal was mined at Qutdliqssad on the island of Disko between 1924 and 1972. There have also been reserves identified for Iron, Chromium, Molybdenum, Tungsten, Anorthosite, and Uranium. None of these were deemed economically viable, but this could change (Lycke and Taagholt 1987).

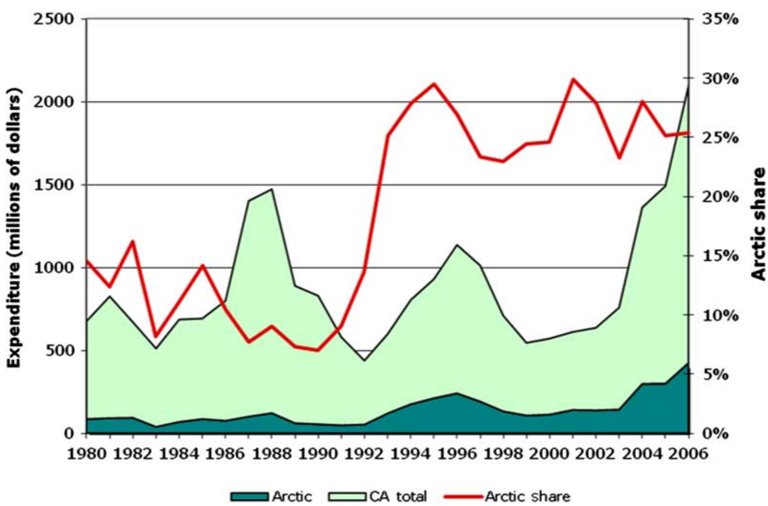

Figure 10. Canadian exploration expenditures and the Arctic share, 1980–2006.

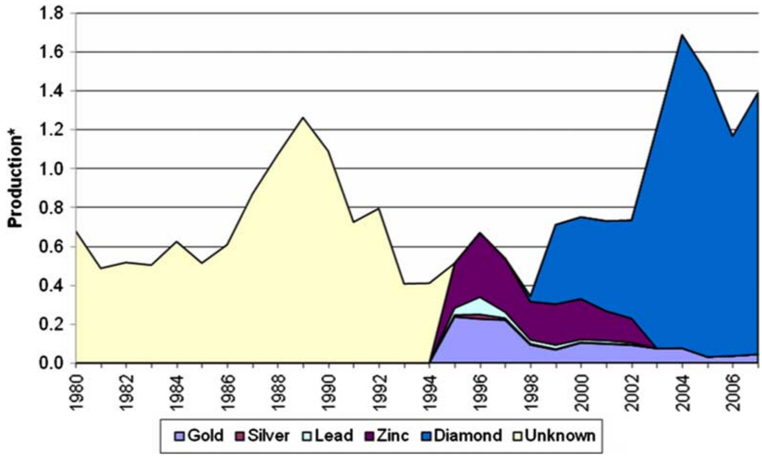

Figure 11. Arctic Canada mining production, 1980–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

Complicating the current and future development of resources in Greenland is the relationship between Greenland Home Rule Authorities and the Danish government. Greenlanders recently voted for increased autonomy and are counting on mineral royalties to help finance their home-rule government. Minerals, including oil and gas, are being heavily explored for their economic potential. Recent political and institutional developments are discussed in greater detail below.

Other regions

Russia (Arctic regions: The Republics of Karelia, Komi, the Oblasts of Archangelsk, Murmansk, and the Autonomous Okrugs of Khanty-Mansi and Yamalo-Nenets, Taymir, Evenks, Sakha, Chukotka, Magadan, Koryakia)

The Russian Arctic blends characteristics of the resource frontier with those of mature regions. Northwestern Russia has a long history of large-scale mining and well-developed infrastructure that class it with the mature regions. The central and

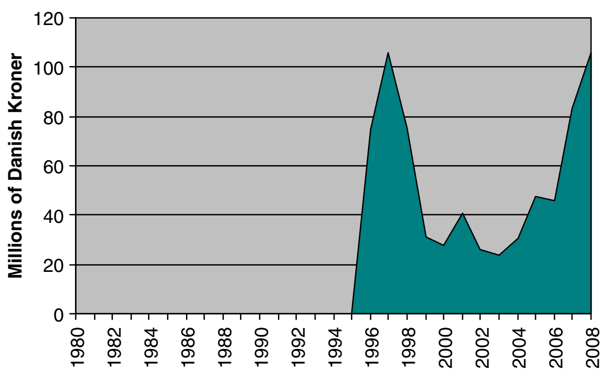

Figure 12. Mineral exploration commitments in Greenland.

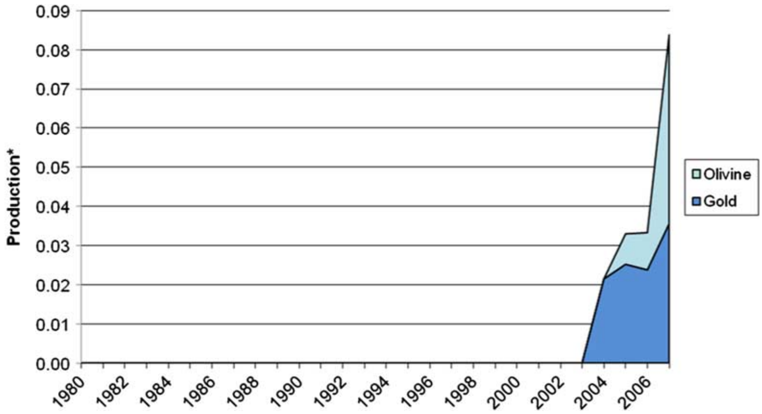

Figure 13. Greenland mining production.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

eastern Arctic also have a long history of mining, but because of the vast, remote, and largely unexplored territory and limited infrastructure, these regions would be classed as frontier. The region holds substantial resources and is of increasing interest to Russian officials and companies alike.

Russian statistics are difficult to obtain, assess, and compare with other Arctic regions. Data are complicated by different reporting standards and methodologies. Mining statistics are neither centralized nor available electronically. Our project personnel traveled to Anadyr, Chukotka, to gather data from paper archives for that region since 1991, but we found it to be of limited value for our database. Our discussion below is based on secondary sources.

Northwestern Russia: Murmanskaya Oblast

Mining in the Murmansk Oblast is supported by a well-developed transportation and energy infrastructure. From 2000 to 2006 minerals accounted for 32–21% of Murmanskaya Oblast's exports (London Metal Exchange 2010). Its mineral exports include iron ore, apatite, nickel, copper, and cobalt. Murmansk accounts for nearly 100% of Russia's production of apatite. It also produces 12% of Russia's iron ore and iron ore concentrates, 43% of Russia's nickel, and as a byproduct of nickel mining produces 15% of Russia's copper and 40% of its cobalt.

In the last decade Murmansk's iron mines have been integrated into Severstal, a vertically integrated, international steel producer (Olenegorsky GOK 2010). The Oblast's nickel mines are now part of Norilsk Nickel, Russia's largest nickel producer (Norilsk Nickel 2010). Despite the large role that mining plays in Murmansk, the Oblast's future seems more tied to the development of the Shtokman gas fields in the Barents Sea. Of the ten investment priorities listed in the Oblast development plan, only one, the Fedorov Tundra enrichment plant, involves mining (Ministry of Economic Development of the Murmansk Region 2010).

Northeastern Russia

Northeastern Russia, which includes the Republic of Sakha (Yakutia), Magadanskaya Oblast, and the Chukotka Autonomous Okrug, holds a large portion of Russia's untapped mineral wealth. It has an underdeveloped transportation and power infrastructure, and very low population density. These factors all raise the cost of mining operations and have focused production on high value minerals. Russia produces about 20% of the world's diamonds and nearly 100% of Russia's production comes from four mines in the Western portion of the Republic of Sakha. In 2008 Russia accounted for approximately 7% of the world's gold production, at 163.9 metric tons (Goldsheet Mining Directory 2010), and nearly a quarter of Russia's production came from the Northeast. Similarly, in 2009 Russia produced 42.2 million tons of silver or around 6% of the world's production, (The Silver Institute 2010), and Northeast Russia accounted for more than 30% of Russia's silver production. Most of the silver produced in this area is a byproduct of gold mining (Far Eastern Okrug Natural Resources Report 2010).

Mining plays a significant role in the economy of this region. In 2006 the Republic of Sakha had more than 22 mining companies operating, while Magadanskaya Oblast had 118 and Chukotka had 9 mining enterprises. Since the collapse of the Soviet Union there have been significant foreign investments in gold mining in this area. Large Russian mining conglomerates, like Russia's largest gold mining company Poly-metal, have significant investments and production in Russia's Northeast (Bloomberg BusinessWeek 2010).

This area began intensive gold production in the 1930s under the Soviet's first five-year plan. Production focused on the exploitation of extremely rich placer gold deposits, primarily in the Kolyma, Aldan, and Lena river systems (Jensen *et al.* 1983). These placer deposits are being depleted, and a significant portion of the remaining reserves are now ore deposits (Far Eastern Okrug Natural Resources Report 2010). The move toward increased production from ore deposits can be seen in the jump in Figure 14.

A similar trend can be observed in the production statistics for the Republic of Sakha (Yakutia), Magadanskaya Oblast, and especially for the Chukotka AO where the start of production at the Kubaka mine, an ore-based deposit, increased the Okrug's total gold production nine-fold in one year (Far Eastern Okrug Natural

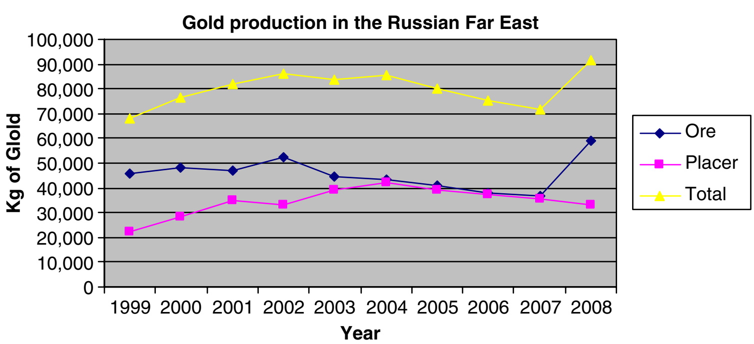

Figure 14. Gold production in the Russian Far East.
Source: http://www.tfidvfo.ru/msb/m3.htm (Natural resources report of the Far Eastern Okrug).

Resources Report 2010). This shift to ore deposits explains not only the increase in gold and silver production, but also the influx of new capital into the area. Ore deposits require greater capital investment to exploit than placer deposits. In Chukotka, Western capital financed two large gold mining projects, Kupol and Maisekoe. The Kupol project, owned by Kinross Gold of Canada, produced its first gold in June 2008. (Shalaginov 2009). In the first half of 2009, Kupol had delivered more than 15 tons of gold to the Kolyma Refinery and made Chukotka Russia's largest gold producer (Paxton 2009). The Maiskoe deposit, which is estimated to be larger than Kupol and be one of the five largest gold deposits in Russia, is expected to start producing gold in 2012 (Polymetall 2008). Since 2000 the Russian government has intensified geological work in Chukotka including new work on uranium deposits near Provideniya (Vasilev 2008).

While this area saw some mining of less valuable minerals like coal, tungsten, and tin during the Soviet era, the only mines which have survived are those that produce coal for local consumption, or have access to developed infrastructure (Vasilev 2008). The large coal field at Neryungri Yaktutia, for example, is linked to Russian and international markets with a spur from the Baikal-Amur Railroad (Russia Channel 2010).

Iceland

Iceland has no significant mining industry and is not included in this report. It does, however, has a growing aluminum smelting industry fueled by cheap geothermal electricity, and supplied by year–round ore shipments from Norway.

Faeroe Islands

The Faeroe Islands currently have no commercial production of mining resources, although there are coal reserves on the island of Suuroy that were exploited in from about 1770 through World War II. The Faeroe Islands may confront difficult decisions with respect to oil and gas development, however, particularly with how new developments might mesh with the economic mainstay of fishing.

Pan-Arctic summary

Figures 15 and 16 summarize the preceding discussion. Production is increasing rapidly in the frontier regions of Greenland, Svalbard, Arctic Canada, and Alaska, while growth is modest in the mature regions of Arctic Finland and Sweden, and showing modest decline in mainland Norway. Although data are not available for Russia, reports indicate recent growth in mining in the eastern Arctic, and stable production in the Kola Peninsula in the mature west.

Assessing data

As noted earlier, each country reports mining statistics differently, and data vary in its availability or level of detail. Information is usually divided, or sometimes reported using different criteria, between a national mining bureau and a national statistics bureau. Canada is particularly thorough in its reporting, with annual

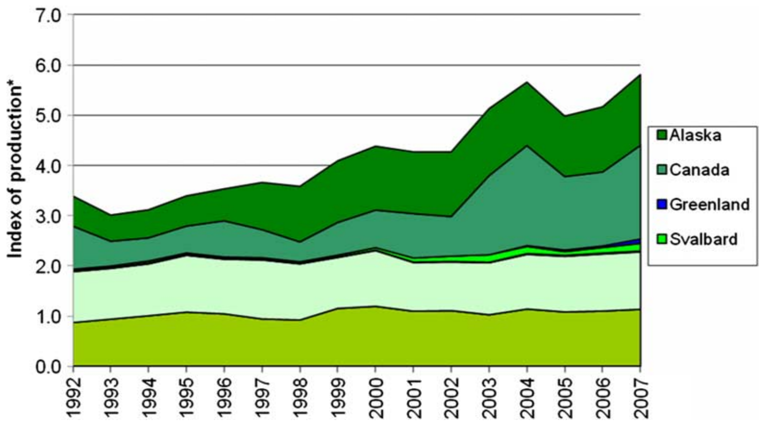

Figure 15. Mining production index for Arctic regions, 1992–2007.
*Production valued at long term average US price (1980–2007), by mineral, in billions of dollars.

reports available online including production levels and values divided by mineral, and further reported by province, facilitating the isolation of Arctic regions there.

In spite of the recent developments that have improved reporting standards and availability in Norway, historical data are largely unavailable online. Historical mining data are likewise unavailable in Sweden and Finland in electronic format prior to 1991 and 1997, respectively. For this project we were able to obtain some data electronically from NGU staff and compiled other data from paper reports in the NGU archives. Unfortunately, Norway reports mining data in aggregations that preclude cross-country comparisons for Arctic regions. When Norway reports data

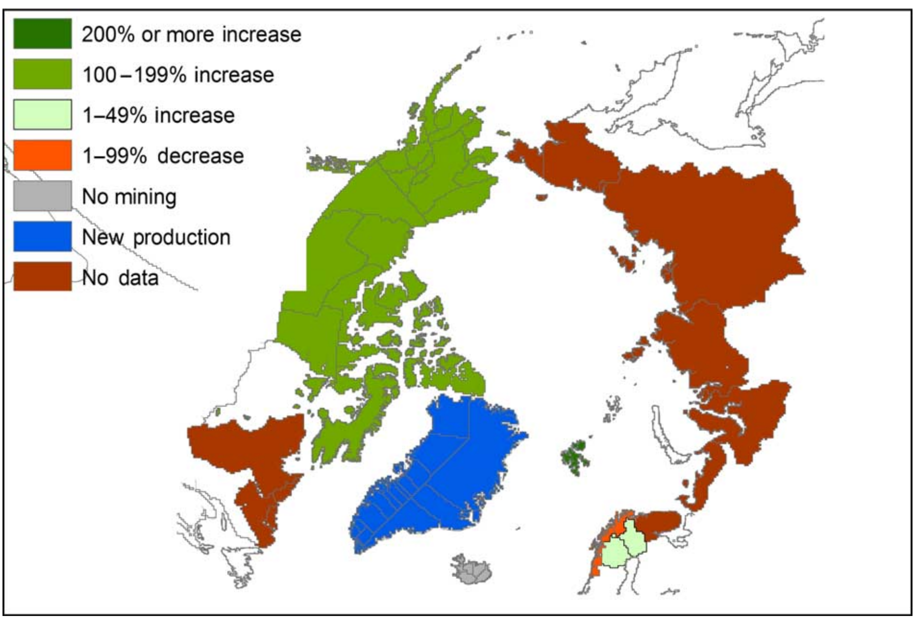

Figure 16. Changes in mining activity, 1992–2007.

by mineral, it is aggregated nationwide and not broken out by county. When Norway reports production by county, it is aggregated in broad categories: energy minerals, metal minerals, and industrial minerals. This frustrated efforts to distinguish trends, isolate the added value of specific minerals, or construct a pan-Arctic index. Detailed geographic knowledge is required to disaggregate statistics for the Arctic counties from reported national data by mineral.

Employment data are also reported disparately between countries and agencies. Historical data are regularly unavailable, and reporting standards differ between 'full time equivalency' (FTE) versus the number of employees, or wage and salary employment. Some countries collect employment data by place of residence, while others collect it by place of work, or even by the location of the company headquarters. Different reporting standards result in very different numbers for the same location, distorting trends over time. It is sometimes unclear whether the underlying methodology includes the self-employed or small-scale mining operations. Again, Canada and Alaska are particularly thorough in their reporting, and methodologies were recorded and noted.

In a similar manner, methods for calculating and reporting value of production may vary, and may or may not include costs associated with exploration, mining, transportation, or refining. In most cases, however, it is clear that 'value' reflects the value of the final, refined product at its global market price.

Russia poses the greatest logistical challenge for non-local researchers. A combination of a lack of centralized data, limited online reporting, a major regime change in the early 1990s, and language barriers make a comprehensive review of mining statistics especially challenging.

Drivers of change in the Arctic

Mining is a global industry driven by global markets and global players. Mining activities in the Arctic are driven by the same forces and factors as mining in any other region. First and foremost is geology: the presence or prospect of major ore deposits is the first determinant of industry interest. Available information concerning the geology of a region helps a firm decide where to explore, and more information makes a region relatively more attractive because it lowers the uncertainty. A second threshold factor is access to the land, which is a function of government policies and current land use: an ore deposit under a city will not be developed or considered. Other factors that play include expected economic viability, assessment of political risks, and firm-specific strategy relative to global markets and supply. Each firm has a portfolio of exploration and development options to consider, and a given prospect must compete against others both internally and externally to make the cut. And the different lifecycle stages of mining activities – exploration, pre-development permitting, development, operations, expansion, temporary shutdown, and decommissioning and reclamation – each have somewhat different drivers.

The Arctic is one of the largest remaining frontier regions on the globe, and as such is regarded as a vast storehouse of potential resources (AHDR, 2004). Known deposits include Red Dog's world-class lead and zinc mine, Canadian diamond mines like Ekati and Diavik, Russia's Norilsk Nickel, and huge gold deposits in the Russian Far East. But the Arctic remains relatively unexplored, so the potential for major new finds is high. In this respect, the Arctic will continue to be a region of particular industry interest for the long term. The Arctic also has vast tracts of undeveloped land, so in jurisdictions with favorable government policies, access to the resource is relatively attractive. But remote regions of the Arctic with no existing infrastructure have the countervailing challenge of high costs of development and operations.

In the sections below, we discuss four drivers of particular interest for understanding mining trends in the Arctic: market price, technological change, policy changes, and climate change. Although we have not attempted to quantify their relative contributions, price is clearly the most important and climate change the least important.

The effects of short- and long-term price

The evolution of an undiscovered ore body into an operating mine has three distinct phases of capital investment: exploration, predevelopment, and development. Short-term price increases temporarily increase profits and available funds for exploration and predevelopment activity in the mining industry, but do not increase investment in mine development. The development phase of a mine is expensive and must be debt financed. Mines are long-term investments and can take up to 12 years to develop and can last for more than 50 years. Mining companies use long-term price expectations for evaluating these investments. While there are no futures markets to track long-term price expectations, the long-term prices that firms use internally for investment planning are relatively stable, corresponding to the historical record for real prices shown in Figure 1.

Technological changes in mining and shipping

Technological developments have turned previously unfeasible, or economically marginal mining deposits into potential investments. Some of these developments are specific to the mining industry itself, including improved materials and equipment, while some affect exploration or transportation of mineral ore.

Examples of general technological improvements instituted in the Arctic include new developments in seismic exploration and mapping technology which have improved the overall understanding of potential deposits in frontier regions and result in more efficient exploration. Nunavut Tunngavik Incorporated, for example, promoted improved mapping and knowledge through the Canada-Nunavut Geoscience Office.

Other technological processes that are specific to the Arctic include methods to mine in permafrost or unstable and melting permafrost. The Diavik diamond mine in Northwest Territories is actively freezing existing permafrost to prevent surrounding lake waters from inundating the mine. An incident at Red Dog mine in Alaska where a miscalculation of permafrost led to release of contaminated waters from its waste pond and killed fish motivated the search for new techniques for building in discontinuous permafrost.

In the realm of Arctic shipping, Norilsk Nickel has built a fleet of double-ended, ice-protected vessels that can transport ore year-around across the Barents Sea. Operating without ice-breaker assistance cuts shipping costs by about 30%.

Mining policies and the effects of devolution in governance

A number of important political developments, as well as the advent of innovative policy making, have increased the autonomy of indigenous peoples in resource frontier regions, and therefore their ability to influence the nature and scope of new mining operations (Grover *et al* 2008).

Nunavut

Nunavut was born out of the Nunavut Act of 1993 and was made official in 1999. Its creation was in part driven by increased natural resource development, and a need to better define property rights and regulatory regimes on Aboriginal land. Like Greenland's Home Rule (see below), Nunavut's government is public and therefore serves all inhabitants, not distinguishing between Aboriginals and other Canadians. In both jurisdictions the overwhelming majority of citizens are indigenous.

Important developments regarding mineral rights include provisions under the Nunavut Land Claims Agreement (NLCA) for Inuit Owned Lands (IOL) – a portion of which includes surface and sub-surface property rights (~2%) and a portion of which includes only surface rights (~16%). The remainder is Crown administered. The NLCA states that IOLs are intended to 'provide Inuit with rights in land that promote economic self-sufficiency through time, in a manner consistent with Inuit social and cultural needs and aspirations' (Hardin and Donihee 1998). No development can take place on IOL without an Inuit Impact and Benefit Agreement in place (see section below), partly negotiated by the Nunavut Impact Review Board.

Dispelling any notions that self-determination in Nunavut means a reduction in resource extraction, James Eetoolook, first Vice-President of Nunavut Tanngavik Incorporated (NTI) which holds title to the mineral rights, told an audience at the Nunavut Mining Symposium in 2000 that 'NTI has clearly committed itself to *supporting and promoting* mining. We want the opportunities that mining can bring. There should be no doubt that we support mining and we want it' (speaker's emphasis).

Greenland home rule

Greenland achieved home rule in 1979. Section 8 of the Home Rule Act of 1978 provides that 'the resident population of Greenland has fundamental rights in respect of Greenland's natural resources.' While Greenlanders have assumed autonomy with respect to natural resource management in fisheries and agriculture, they continue to share control of mineral resources with the Danish government. The Home Rule Government's Bureau of Minerals and Petroleum grants many of the permits, while a joint committee between the Danish and Home Rule governments makes the leasing decisions. Different Danish bureaucracies house important data, further limiting Greenland's control.

While Greenland is moving towards self-determination and total independence from Denmark, the government and economy still rely on annual subsidies and money transfers from Denmark. The Annex to the *Programming for the Sustainable Development of Greenland* (2007) states: 'Greenland's long-term political goal is a more independent economy based on its own resources and greater integration into the world economy' (p. 8). Mineral resources are a potential gateway to greater economic development and a means to fund increased autonomy.

Public policy developments and stakeholder involvement

It is well understood that large-scale resource extraction in remote areas has caused social disruption in communities and cultures adjacent to the new developments (O'Faircheallaigh 1991; Gibson and Klink 2005; Hipwell *et al*. 2002; Brubacher and Associates 2002; Tatz *et al*. 2006; North Slave Metis Association 2002). Economic benefits – the only allure of mining to a potential host community – can and have many times escaped the local region. Labor and technical expertise may be hired from outside the region, royalties may go to a central government, and supply purchases may benefit businesses based far outside the local region.

Recent policy developments aiming to increase local benefits and mitigate the potential harm to local communities in frontier regions are being institutionalized and normalized in business practice. Natural Resources Canada identifies agreements between mining companies and Aboriginal communities or governments as signs of progress in the area of improved outcomes from mining. These include

- Memorandums of Understanding between a community and company during the exploration phase.
- Socio-Economic Agreements as required in the Northwest Territories and used also in the Yukon Territories.
- Joint Venture Agreements between communities and mining companies that address employment and training and profit sharing.
- Impact and Benefit Agreements (IBA) have become particularly important, and almost *de rigeur* practice for companies operating in Canada. These include agreements regarding funding, training, employment preferences for local residents, revenue sharing, and environmental concerns.

Where not required through a land claims agreement, or by First Nations, government might demand that an IBA be negotiated for a specific project, on an ad hoc basis. Sosa and Keenan (2001) explain further:

> Such a requirement may be part of an overall social policy to benefit Aboriginal communities or may result because the mine is predicted to have a significant social and/or environmental impact. In the case of the Ekati mine in the Northwest Territories, the mining company BHP and aboriginal organizations voluntarily entered into IBA negotiations. During the approval process for a water license, when an agreement was not yet forthcoming, the Minister of the Department of Indian Affairs and Northern Development (DIAND) made the granting of the license conditional on there being 'satisfactory progress' in the negotiations during a 60 day period. The negotiation of IBAs is now considered to be a de facto, albeit unwritten, regulatory requirement in the North. (Sosa and Keenan 2001: 7–8)

IBAs have caused some discontent in communities where some regard them with skepticism regarding effectiveness and enforcement, or as capitulation that ultimately permits development, in spite of ongoing opposition.

A complete list of known IBAs in Canada can be reviewed at the IBA Research Network's website: http://www.impactandbenefit.com/IBA_Database_List.html

Climate change

Climate change concerns all parties involved in mining operations in the Arctic and has local effects, but it is not an important driver of increased mining overall.

In Greenland, longer operating seasons and retreating ice are cited by the Bureau of Minerals and Petroleum as cause for high expectations of mining exploration and development. But climate change also creates new hazards and costs for industry in the Arctic. As the Greenland Ice Sheet breaks up, some coastal areas are experiencing increases in large ice bergs which create serious hazards for shipping, particularly with rapid and unpredictable changes in weather and currents.

In other regions, infrastructure is threatened by soil instability due to melting permafrost, exemplified by the incident with the tailings ponds at Red Dog Mine in Alaska and the open pit diamond mines in Northwest Territories, Canada.

Ice roads are possibly the most integral infrastructure in the Arctic directly impacted by climate change. In 1970, temperatures were cold enough to allow safe tundra travel on ice roads for more than 200 days of the year, according to the Alaska Department of Natural Resources (DNR). DNR statistics now show that period has shrunk to about 100 days (Muse 2008). In 2006, the Tibitt-Contwoyto Winter Road north of Yellowknife, which services several diamond mines, was closed weeks earlier than normal because of mild temperatures, reducing scheduled shipments to mines by 40%. Remaining supplies were airlifted at great expense (Katz 2007). Ice road construction costs as much as $100,000/mile, according to the North Slope Borough's Transportation Plan in Alaska (2005). Given the great expense of ice road construction, and dwindling seasons, their cost-effectiveness might ultimately be reconsidered.

Ultimately, the effects of climate change vary greatly, and local effects determine its influence on mining operations and exploration.

Conclusion

In this paper we have sought to review and assess the state of data to describe and monitor mining trends in the pan-Arctic and their social effects. The most universal measures we found address mineral production and value. We found these to be imperfect proxies for economic effects. Furthermore, we found that historical data on mineral production and value are unavailable in electronic format for much of the Arctic, specifically for Scandinavia and Russia. Completing the historical record back to 1980 will require work with paper archives.

The trends in mining activity that we found includes stasis or decline in mature regions of the Arctic, and strong growth in the frontier regions. The biggest driver in the Arctic frontier is the availability of large, undiscovered and untapped resources with favorable access and low political risk. The most critically needed improvement in data collection and reporting is to develop comparable measures of employment.

Acknowledgments

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Notes

1. Canadian diamond price, as deduced from Canadian mining data are only reported for the last 10 years. Prior to this time diamond prices were determined in a monopolistic market and were not representative of production costs and social impacts.
2. This analysis was prepared in early 2010. We note that recently there has been large growth in mining in Northern Finland and Sweden during the 2010s. New mines opened in Finland in Kainuu and Lappi area in the late 2000s, and new mines will be introduced in the early 2010s in arctic Sweden and Finland. See e.g. *Mining Journal*, November 19, 2010.
3. Based on information presented by Alaska Department of Natural Resources officials during the Western Alaska Interdisciplinary Science Conference in Nome, Alaska, April 9, 2009.

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