Minerals Under Ice

How far do we go to utilize Antarctic resources?

by

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ABSTRACT

Speculation about future mining in Antarctica is increasing. This unique, untouched continent is dominated by its severe climate and inaccessibility. Its rich mineral deposits are expected due to its geological history, yet exact amounts and quality of the minerals are unknown. This syndicate report focuses on current concerns about mining in Antarctica. A fictitious, yet possible scenario of uranium mining in the future is presented in detail, to underline the feasibility of mining in Antarctica. The report also discusses coal and oil and a less well known "mineral" in Antarctica, icebergs. The debate about environmental concerns is outlined using current case studies of Arctic mines, and Canadian and Australian uranium mines. Although it has never been ratified, the regulation of Antarctic mining is covered by CRAMRA and is discussed as a likely outline of legal and political issues. Our predictions about future development of mining on this continent are made, with the focus on how far we should go to utilize Antarctica’s minerals.
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1. Introduction

Mining in Antarctica is a contentious issue caused by the juxtaposition of mining with severe environmental impacts, in this pristine environment. Antarctica is known as one of the last great wildernesses of the world, causing more attention to be focused on maintaining it as a world nature reserve, devoted to peace and science under the Antarctic Treaty System. However, as minerals and hydrocarbons become scarce in other locations around the world, it is predicted that the focus will shift to Antarctica and the exploitation of its resources. Due to the logistics involved in working in a polar environment with limited accessibility and extreme weather, this is likely to occur only when it becomes more profitable to mine in this remote location than other places.

Mining and prospecting is currently banned under the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol). The protocol prohibits “any activity related to mineral resources” in the Antarctic, with the exception of approved scientific research. All mineral activities have an indefinite ban. However, this ban can be reviewed after 50 years in 2041 if more than ¾ of the current Antarctic Treaty Consultative Parties (ATCP’s) agree for the review to take place. This allows modifications to the ban as future changes in resource availability, mining technology and economic viability increases (Roper-Gee, 2003). Interest in exploiting Antarctica’s natural resources surfaced during the late 1970s to early 1980s after power shortages. The Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) was initiated as a response. During the 8 years of negotiation from 1981 to 1988, restrictions on prospecting and mining activities were created within a binding legal document. This included objectives such as strict technological procedures to minimise any environmental impact. CRAMRA was never ratified, as France, Australia and New Zealand stated they wanted no mining to take place in Antarctica and for it to remain a natural reserve. However, CRAMRA could be important in the future if the ban on mining is lifted, and should therefore not be discarded (Scott, 2003).
Mineral resources are defined by CRAMRA as “all non-living natural non-renewable resources, including fossil fuels, metallic and non-metallic minerals” (1988) and this is the definition that will be used throughout this report. It is important to note that CRAMRA excludes icebergs, as they are a water source and are renewable. Many minerals are known to occur in Antarctica including coal, iron ore, chromium, copper, manganese, uranium, and hydrocarbons such as oil and gas. There are many other known minerals but concentrations are small and are almost negligible such as gold, nickel, cobalt and platinum (Wright and Williams, 1974). There was significant interest in Antarctic minerals in the 1970’s due to the geological history of the continent, and its position in Gondwanaland. Antarctica was situated in the centre of Africa and Australia, which are both known to have high quality mineral resources. It is therefore expected that the minerals through the Trans Antarctic Mountains and other Antarctic areas would be of similar quantity and quality.

The following report looks at mining in Antarctica. There are a number of issues such as whether the resources are commercially significant in both quantity and quality, and if they can be mined in an efficient way with minimal environmental impact. Mining will be viewed from different angles including the geological history of the area, environmental impacts of mining, issues in current law and how documents such as CRAMRA would need to be changed to ensure sufficient regulation. Associated economic costs and benefits of mining in the Antarctic environment are likely to be the determining factor as to whether mining is worth undertaking or not.

As economic forces are often very powerful in the area of natural resources exploitation, a future scenario of mining uranium in Enderby Land in East Antarctica is used to predict, demonstrate and emphasize how mining could occur. Currently there are a number of known uranium deposits in this area, but exact locations and quantities are unpublished. The fictional company called ERRORES Inc. (Extracting Refining and Reprocessing Of Remaining Energy Sources Incorporated), is an Australian company with a history of uranium mining in Australia. Uranium has the potential to be a mineral with high demand, as energy use moves towards alternatives to petroleum and gas such as nuclear technology. Many minerals are known to have poor quality in Antarctica and can be found in plentiful amounts.
elsewhere, while uranium is predicted to have high quality in Antarctica due to its historical position in Gondwanaland.

This uranium mine scenario is used only in section 2 of this report. The scenario is fictional, but current theories and data have been applied as much as possible. Potential issues and technology are based on a number of current case studies, such as Canadian and Australian uranium mines, polar mining in Alaska and a proposed Antarctic mine.

In section 3, other mines including oil drilling in the Ross Sea Region, and coal mining in the Prince Charles Mountains are discussed. Coal is relatively easy to access due to the terrestrial nature, however issues of poor quality and increased quantities in areas of greater convenience and accessibility, makes it currently uneconomical. Oil drilling is offshore and poses different environmental and technological challenges and requirements on extraction processes when compared to uranium mining.
2. Case Study: Uranium Mining in Antarctica

2.1 The Current Situation

The end of the last millennium has often been regarded as the end of nuclear power, where political resistance in the United States, parts of Europe and New Zealand were proving successful. However, intensive research investments into improvements and new technologies have continued to be undertaken by most countries. While renewable energies cannot provide power to today's constantly growing population at a realistic cost, nuclear power prevails over the failed fusion technologies to meet those demands. Oil can no longer be used as fuel, as it is required for producing plastics and other materials that cannot be made with alternative energy sources. Owing to the most recent research outcomes on nuclear power, safer and more efficient reactors with a significantly lower hazardous waste output could be developed and constructed. Employing modern methods, the nuclear fuel cycle is not adding to the greenhouse effect caused by common fossil fuels. Uranium is now one of the last remaining natural resources found quantities significant enough to be suitable as a major energy source. Antarctica, bearing one of the largest bodies of relatively high quality ore, is now the challenge to meet.

ERRORES Inc. (Extracting, Refining and Reprocessing Of Remaining Energy Sources Incorporated), the most successful and experienced mining company of Australia, has produced this report. Our aim is to target and emphasize the feasibility and the economical value of mining uranium in Enderby Land, East Antarctica.
2.2 Earth’s History as an Indicator for Potential Uranium Deposits

Enderby Land is located on the East Antarctic Ice Sheet, within the Antarctic Circle and 70° South between 40° and 70° East. Geologists proposed this site as a possible deposit for uranium long before ERRORES Inc. started prospecting in Antarctica. This was reinforced by geological theories regarding the former super continent Gondwanaland. These are based on evidence of matching coastlines and similar fossils and mineral abundances found in overlapping break-up zones of Gondwanaland. Consequently, Antarctic rocks were formed in the same geological processes as rocks of other mineral rich Southern Hemisphere landmasses. The potential of a geological reconstruction provides the opportunity of a pre-selection of profitable mineral deposits and reserves in Antarctica. Figure 1 illustrates the geological connection of East Antarctica with India and Australia. Uranium occurrences of high natural densities have been found in West India and in the South-West of Australia (AMDER and SEA-US). These rich deposits led to the prediction of additional reserves at the former contact zone of these landmasses in Enderby Land.

Figure 1: Historical Position of continents before the break up of Gondwanaland

Source: National Geographic Map Supplement, 1988
Led by the geological predictions, ERRORES Inc. launched a massive prospecting campaign for lucrative uranium reserves in Enderby Land. In consideration of the environmental issues, the detection method of choice was advanced airborne gamma-ray spectroscopy. As a result of this survey, ERRORES Inc. found rich deposits in the Napier Mountains, in an area located approx. 100 meters below the ice cover. An independent SCAR (J.H. Zumberge 1979) group proposed back in 1980 that out of 900 possible mineral deposits most likely, only 20 are not completely buried under kilometres of Antarctic ice sheet. Hence, the ice coverage of only 100 meters in this area of the Napier Mountains makes this a highly accessible location for a uranium mine. Having in mind the high unit-value of concentrated uranium oxide U₃O₈ (also known as ‘yellowcake’), leading engineers of ERRORES Inc. have developed the following feasible layout for a uranium mine in Antarctica.
2.3 Details of the Planned Uranium Mine and Main Supportive Structures

As the targeted body of uranium ore lies below 100 meters of glacial ice and another 200 meters of waste rock, open pit mining is not feasible. Equally, in situ leaching (ISL), or solution mining, is not a valid option. Antarctic permafrost depths can reach 1000 meters (Elliot, 1977), which is why any acidic or alkaline leaching fluid would freeze under the given conditions. Therefore, underground mining techniques that are common practice in the Arctic will be implemented.

2.3.1 Mine Layout

First, the glacial ice cover needs to be penetrated. Due to the slow, but constant motion of the ice sheet, the preferred approach is an incline tunnel. Using advanced hot-water-drilling methods, an arched tunnel of approximately five meters in diameter will be created to access the underlying rock. The motion of the ice sheet can then be compensated by extending the end of the tunnel in the appropriate direction over time. The incline will be such that large (rail based) support vehicles and/or pipeline and conveyor-belt installations can be used for haulage of uranium oxide or pre-processed ore to the surface.

Once solid ground is reached, a box cut will serve as portal followed by a large cave used as rock-drilling base, 15-20 meters underground. From here, access to the ore horizon will be gained by excavation of a circular vertical shaft rather than an incline, as this allows faster vertical approach to the ore body, is easier to maintain, better for ventilation and minimizes waste-rock production. The shaft will descend to a depth within a few meters of the ore horizon and have main crosscuts\(^1\) every 30 to 40 meters. From there, a 'conveyor incline-decline crosscut system' will be used. The central conveyor incline tunnel will penetrate most of the ore body and serve as the main tunnel from which the ore access tunnels ("Footwall Haulage drives") branch of horizontally (see Figure 2 for draft of the layout and Appendix 1 for a detailed plan).\(^2\)

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1 Horizontal tunnels that extended outward from the main shaft and are interconnected in order to facilitate access for machinery, personnel and improve ventilation.
2 The basis and reasoning for this general layout is the hypothetical platinum mine in (Daly, 1989).
Following the continuing success of the first highly automated uranium mine at McArthur River, Saskatchewan, Canada, ERRORES Inc. will employ similar automated stoping\(^3\) procedures and underground pre-processing techniques in order to minimize health and safety hazards to personnel. Following blasting with conventional explosives, the ore rubble is transported with remote controlled scoop trams to a series of crushers. These grind the ore to a sand-like consistency. During this process the ore is heated to temperatures above 0°C, which causes the permafrost to liquefy. If necessary, the resulting ‘mud’ is further diluted with water, until it can be pumped up into the initial drilling cave through a pipeline. This facilitates the transport of ore and reduces the potential for hazardous radioactive dust-concentrations in the air.

2.3.2 Milling and Other Support Facilities

The initial main drilling cave will be extended horizontally by tunnels in several directions. There further shafts will be drilled to guarantee sufficient air-circulation as the mine expands. Potentially, some of the tunnels will be extended to accommodate additional processing facilities. Depending on the exact properties of the surrounding rock such as temperature and water content, which have yet to be determined, milling facilities will be located in this area. If milling cannot be conducted

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\(^3\) "Stoping is defined as the process whereby ore rock is extracted for removal to the surface for metal recovery." (Daly, 1989, Vol.2, p.183)
underground, numerous transport vehicles, conveyor-systems and/or a long, heated pipeline along the access-incline will be required to transport the slurry to the surface and return waste-rock to the mine. Especially over longer periods of time, this would be a highly energy-consuming process, which is why ERRORES favours an underground infrastructure for the leaching, separation and precipitation procedures. The resulting yellowcake (tri-uranium-octo-oxide, U₃O₈) can then be immediately packaged into steel barrels for evacuation. The rock-residuals, also known as ‘tailings’, will eventually be returned into the mine for refilling. An overview of the ore-processing procedures is given in Figure 5 in Appendix 2.

The packaged yellowcake can be easily stored underground and transported to an Australian refinery by plane for further processing*. The exact location for the airfield still needs to be determined, but will most likely be within 50 km of the mine site, as a preliminary survey of ice sheet topology of the area has identified a number of sites flat enough to serve as landing areas if they prove crevasse free. Transport from the ice-tunnel to the airfield will be conducted with hovercrafts, similar to the ones that have been used in the Arctic in the last few decades.

To minimize exposure of personnel to increased terrestrial radiation, the support village will be located on the ice sheet, close to the entrance of the incline ice-tunnel. Due to its practicality and flexibility, modular design is favoured for the village.

A nuclear power plant will provide the significant amounts of electricity required for the planned operations. This will be built either close to the support village on the ice-sheet, or, if possible, on ice-free ground. While the costs of building this plant are likely to exceed the costs of the actual mining operations, the logistical and environmental advantages are significant. Once the power plant is operating, less than 100 tonnes of fuel are required per year, as opposed to 1 million tonnes of coal required for a similar-output, high-efficiency coal plant. Other than the spent fuel rods, no further emissions except water vapour will be produced. Even the outer cooling cycle, which commonly employs local lake water, will be replaced by a closed,
external pipeline system, as the ambient conditions provide sufficient cooling. During power plant construction and the beginning of the ice drilling phase, energy demands will be satisfied with two portable nuclear power plants (PE-10A and PE-11A), the improved successor models of the US prototype PM-3A (also known as “Nukey Poo”) of 1962. An overview of the mine layout and support facilities is given in Figure 6 in Appendix 2.

2.4 Estimated Costs

A detailed cost-benefit-analysis has been conducted and ERRORES has concluded that mining for uranium in Antarctica is profitable at this stage. Approximate costs have been calculated to be as follows (in SPD\textsuperscript{5}):

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<thead>
<tr>
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<th>600,000,000 SPD</th>
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<tr>
<td>Underground Mine</td>
<td></td>
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<tr>
<td>Mill</td>
<td>200,000,000 SPD</td>
</tr>
<tr>
<td>Nuclear Power Plant</td>
<td>1,500,000,000 SPD</td>
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<tr>
<td>Logistics</td>
<td>300,000,000 SPD</td>
</tr>
<tr>
<td>Other Structures (Airfield, support village, etc.)</td>
<td>250,000,000 SPD</td>
</tr>
<tr>
<td>Potential additional clean-up costs</td>
<td>100,000,000 SPD</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>2,950,000,000 SPD</strong></td>
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These estimates are very conservative and will most likely be undercut. In the context of developments on the energy market, with a strong tendency of increasing prices for fossil fuels compared to a much slower increase in the nuclear sector, an expense-recovery-time for this undertaking of about 10 ± 2 years was calculated. As the discovered ore deposits allow for a minimum of 20 years of mining activities, ERRORES believes this to be a lucrative project.

\textsuperscript{5} South Pacific Dollars, common currency of Australia, New Zealand and all Pacific Islands, except the Great Tongan Empire - approximately equal to the original Australian Dollar.

\textsuperscript{6} The estimates for the mine and mill are based on actual costs of similar facilities built recently, while the costs for the power plant are estimated to be lower in the future than a current estimate. Other costs are estimates that the authors believe to be reasonable, but not based on any official figures.
2.5 Environmental Considerations

Every possible effort will be made to keep the environmental damage as low as possible. After intensive studies concerning the local ecosystem during the exploration stage, ERRORES Inc. has concluded that there is no significant wildlife or vegetation that could be disrupted.

An environmental impact statement that analyses if the mine can cause any damage to nature has been presented to the CRAMRA Regulatory Committee. Depending on the results of these studies, further work will proceed only after all the required permits under which an environmentally responsible mine may be developed, have been obtained. ERRORES Inc. is positive that the employed mining methods will guarantee minimal possible pollution (Nash, 2006).

2.5.1 Tailings & Radon

When naturally occurring radium undergoes radioactive decay, one of the products is radon gas. Radon and its decay products are radioactive. While the tailings are at the surface, measures are taken to minimise the emission of radon gas. During the operational life of the mine, material in the tailings dam will be covered by water to reduce surface radioactivity and radon emission. Ultimately, all tailings will be refilled into the mine.

2.5.2 Water

Water used or created in the mining process and waste liquors from the milling operation are collected in secure retention ponds for isolation and recovery of any heavy metals or other contaminants. Process water, containing traces of radium and some other metals, is evaporated and the contained metals are retained in secure storage.
A main environmental issue addressed by ERRORES is to avoid release of any water that could pollute the environment, most importantly during above ground operations. Underground, the potential effect of minor spills is strongly reduced by the fact that operations occur under permafrost conditions. Therefore, most liquid wastes will not permeate throughout the soil, but freeze into the ground without causing any further damage (Hore-Lacy, 2006).

2.5.3 General Wastes

All other kinds of waste, including domestic and industrial wastes are collected at a secure disposal location to make sure that no environmental hazards are created. Eventually, all wastes will be taken to Australia for recycling and processing.

2.5.4 Health of Workers

All Australian uranium mining and milling operations are controlled under the Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores. This was created by the Commonwealth in line with recommendations of the International Commission on Radiological Protection (ICRP) and is administered by state health and mines departments. This Health Code, common practice in today’s mining activity, was updated in 1995 and again in 2002-05, and sets strict health standards for radiation and radon gas exposure for both workers and members of the public.

Precautions that will be taken during the mining and milling of uranium ores to protect the health of the workers include:

- Ventilation systems in the mine to ensure that exposure to radon gas and its radioactive daughter products is as low as possible and does not exceed established safety levels.
- Efficient dust control, because the dust may contain radioactive constituents and emit radon gas. Dust occurrence is reduced to a minimum due to immediate processing of the ore into slurry.
• The radiation exposure of workers in the mine, mill and tailing areas is further reduced, by using remote controlled processing as much as possible. Therefore, exposure levels will be as low as possible, and will not exceed the allowable dose limits set by the authorities.

• Radiation detection equipment for constant monitoring of terrestrial radiation levels will be installed.

• Strict personal hygiene standards for workers handling uranium will be enforced.

At any mine, the employees who are exposed to radiation or radioactive materials will be monitored for alpha radiation contamination and personal dosimeters will be worn to measure exposure to gamma radiation. Routine monitoring of air, dust and surface contamination will be undertaken (Hore-Lacy, 2006).
2.6 Legal Issues with Mining in Antarctica

Due to the increasing world energy demands, the 1988 Convention on the Regulation of Antarctic Mineral Resources Activities (CRAMRA) has now been re-introduced and successfully ratified into the Antarctic Treaty System. Already a number of companies have applied for mining permits through the CRAMRA system. Mining in the Antarctic is now an accepted activity due* to strict environmental, social and economic guidelines based on the precautionary principle. National and international legal ambiguities have largely been resolved, allowing nationally funded private companies to extract and utilise Antarctic mineral resources.*

Appendix 3 and 4 illustrate the CRAMRA application process. Australia, with reference to the operator ERRORES, has been thorough the majority of the application process. They have successfully made it to the final stages of the permit process, almost completing the CRAMRA requirements ensuring all legal parameters involved in Antarctic mining have been covered.*

2.6.1 Case Issues under CRAMRA

The ‘aim’ of CRAMRA set out in Article 1 is that Antarctic mineral resource activities are to be undertaken in the interest of the international community as a whole. Such activities are prohibited without permission from CRAMRA, which regulates all Antarctic mineral resource activities taking place in Antarctica. Article 5 defines the area in question to be within the ‘Antarctic Treaty area’ referring to all land including Antarctic islands south of sixty degrees South Latitude (Cook, 1990). The ERRORES application lies within the geographical area of Antarctica, and within the Australian dependency. ERRORES undertakes this project at a time when any form of high-grade energy such as nuclear is welcomed by an energy-deprived world. The uranium in question will be used in accordance with pre-negotiated agreements

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7 Please note any actions undertaken by ERRORES or the Australian government are fictional.
8 Mining is currently prohibited under section 7 of the Protocol of Antarctic Protection to the Antarctic Treaty (Madrid Protocol)
9 Many issues under international law have not been resolved and it remains a contentious issue under the Antarctic Treaty System.
10 The CRAMRA process was researched and the diagram shown is thought to be the actual proposed relationship between the CRAMRA Commission and working parties.
with International Energy Distribution Companies and the CRAMRA Regulatory Committee on Profit Dispersal (RCPD)\textsuperscript{11} to ensure that a portion of the profit from the mined uranium is used in the "interest of the international community as a whole" and "for the greater good of mankind". \textsuperscript{12}

Historically, a major point of opposition for Antarctic mining was the economic turmoil that would be created by an influx of exported Antarctic minerals flooding the world markets. Competing exporting nations would loose out on domestic product export due to the deflation of price in accordance to overall quantity (Nansen report, 1973).

Australia is the 'sponsoring state' of the discussed development, as required by Article 1(12) of CRAMRA. Australia is required to show a 'genuine link' with ERRORES and provide national laws to regulate for mining in Antarctica. Australia has recently amended the federal Australian Radiation Protection and Safety Act 1998 (Australian Federal Law, 2007)\textsuperscript{13} to include activity based in Antarctica. In turn, this ensures Australia is answerable for the actions of its nationals because, as an Australian company, ERRORES must comply with national law. Under article 1(12) a 'sponsoring state' is:

(i) Whose law that juridical person is established and to whose law it is subject, without prejudice to any other law which might be applicable, and
(ii) In whose territory the management of the juridical person is located, and
(iii) To whose effect control that juridical person is subject.

The liability issues for Australia in relation to the ERRORES application as the sponsoring state are discussed in section 2.6.2 below.

Prospecting provisions are sourced in Chapter III of CRAMRA. Prospecting, unlike exploration and development, may proceed without explicit authorization by

\textsuperscript{11} There is no such Regulatory Committee. In CRAMRA negotiations, there was talk of the use of Regulatory Committees to enhance bargaining power for compensation for export looses.
\textsuperscript{12} There are a number of highly contentious social issues surrounding the export and use of Antarctic minerals. These issues will be discussed further in Section 3 of this report.
\textsuperscript{13} There is currently no mention of Antarctica in this Australian legislation.
the institutions established by CRAMRA, as long as such prospecting does not violate CRAMRA. As Sponsoring State, Australia provided notification prior to prospecting along with the assessments of environmental affects that could have resulted from their activity (Francioni, 1986). Although historical prospecting by ERRORES using ‘airborne gamma-ray spectrometry’ was found to be within the CRAMRA guidelines, the completion of the prospecting stages of the ERRORES project does not retain any certainty that there is a right to mine and extract these resources. The information found due to prospecting is to be kept confidential for a certain period, in this case 10 years\textsuperscript{14}, to ensure ERRORES’s intellectual property is safe, until such time as the CRAMRA permit requirements can be fulfilled before mining takes place.

CRAMRA requires that appropriate procedures, comprehensive information and technologies be in place to ensure that a strict environmental code is adhered to (Antarctica NZ, 2003). Before any area can be opened for development a Comprehensive Environmental Evaluation (CEE)\textsuperscript{15} is required by the CRAMRA Regulatory Committee. It must include a monitoring program to avoid potentially harmful environmental consequences “or undue interference with other established uses of Antarctica” (CRAMRA, Article 4). The review of the last permit application for ERRORES activities has been evaluated. The regulatory committee is satisfied that measures have been put in place to ensure ERRORES activities are of no risk.

2.6.2 Liability and Compliance Issues

As the Sponsoring State and a member of CRAMRA, Australia must fulfil a number of duties to ensure that the operator under which they sponsor, follows all regulations and procedures set out in CRAMRA. Australian federal law must ensure that it governs all of the operator’s activities. The Sponsoring State needs to provide details on the operator, such as certifying that the Operator has “a substantial and genuine link with” the Sponsoring State and that the Operator is qualified financially and technically to execute the proposed prospecting in accordance with the

\textsuperscript{14} This figure can vary due to the decision being made within the CRAMRA decision process.

\textsuperscript{15} The CEE process under CRAMRA has not been decided on. However it is likely to go through the same comprehensive environmental evaluation (CEE) within the Madrid Protocol and handled by the Committee on Environmental Protection (CEP).
CRAMRA). Article 8 of the Minerals Convention addresses the problem of compliance with the Convention. Rather than prescribing the basis upon which jurisdiction should be exercised Article 7 leaves it to Sponsoring State.

The factors controlling a “substantial and genuine link” between the state and operator are numerous. Over the last decade, Australia has incorporated a highly efficient national legal structure to handle these measures*16. All companies must have ‘efficient’ historical ties with Australia according to the Australia Tax Bureau.*17

Concerning the current case, mineral extraction anywhere on the Antarctic continent by an Australian national is regulated under current Australian mining legislation. In addition, all sponsored operators have had an ‘environmental competence audit’ carried out on their operations by Australian officials. ERRORES came out as having the best environmental stewardship in the country and therefore have full Australian government support*18. After a lengthy permit process, ERRORES, backed by the Australian Government, will have completed the CRAMRA procedure and will be granted a Development Permit (Appendix 3 and 4).

The legal issues concerned with mining in Antarctica have been largely rectified in the last few years of discussion under CRAMRA. It has been agreed by all CRAMRA members that the impacts of mining in Antarctica are trivial compared to the problems the world faces due to energy shortages. With the continually increasing need for a high performance, low cost and flexible energy source, such as nuclear, it is unlikely that the Regulatory Committee will find any local environmental or social impacts that outweigh the world wide benefits created by the type of uranium mining being undertaken by ERRORES within the Australian Dependency.

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16 These amendments have not been made under Australian Federal Law.
17 The position Australia currently takes on foreign investment and corporate responsibility is unknown to the authors.
18 The previous paragraph was fictional.
3. Discussion

3.1 Minerals in Antarctica

As discussed above in the uranium case study, the argument suggesting Antarctica is rich in mineral resources is based on the geological history of Gondwanaland and limited research done before the Protocol was signed in 1991. There has been no recent research into the minerals present, as prospecting is banned under the Protocol. Information is still being collected as a byproduct of geological research within Antarctica, but is not the main focus and is therefore not published. There are many minerals known to occur in Antarctica, usually around the edge of the continent (Figure 3).

![Diagram of mineral deposits in Antarctica]

**Figure 3:** Known locations of significant mineral deposits in Antarctica.

It is important to note the difference between mineral reserves, deposits and occurrences. Mineral occurrences are very small in size or quantity and usually not of commercial interest; deposits are quantities large enough to be commercially exploited; and reserves have been measured and the size is known to be of commercial value (Holdgate and Tinker, 1979).
Iron ore, chromium, manganese, coal and hydrocarbons including oil and gas, have been described as being possible minerals to be exploited in the future (AAD, 2006). Iron ore is found under the ice in boulders of banded iron formation in East Antarctica around Mt Ruker in the Prince Charles Mountains. This source is substantial with thicknesses of up to 70 kilometres, and exposed in cliffs up to 3.5 kilometres in width (Daly, 1989). However, it is found only in remote locations, and analysis has shown the concentration to be almost half (35%) of the lowest concentration currently mined in Pilabara, Western Australia, which is 60%. A smaller deposit was described in 1977 by Lovering and Prescott at Newman Nunatuks in Enderby Land. The area of this deposit is 750 metres wide, 150 metres across and 20 metres thick with an iron content of 34 percent on average (Rowley et al, 1983). As the iron ore content is so low in this area, it is unlikely to be mined as the extraction costs are high, and the logistics of extracting it are considerable.

Chromium is thought to be found in the Dufek Massif in East Antarctica but has not been seen or drilled to prove its existence. Minimal research indicated the concentration would be very weak. There is currently little demand for chromium so this is also unlikely to be mined in the near future. Seafloor nodules of manganese have also been found, but as tropical nodules are known to be more valuable than polar nodules with easier access, no further analysis has been undertaken.

Hydrocarbons including oil, gas, and coal are more economically viable options for being mined here. Hydrocarbons are a product of maturation of organic material and are generally found in younger rocks. The hydrocarbons in Antarctica have usually been exposed to heat and folding and are of poorer quality, particularly for onshore regions. Hydrocarbons will be the main focus of a comparison to the uranium case study above.
3.2 Site Choice and Accessibility

Accessibility will play a major role in deciding where mining operations will occur. The location of mineral deposits will be the initial factor in determining where to mine, because if the region is inaccessible the economic viability will be reduced. Therefore, it is important that the deposits are in a relatively accessible area to minimize costs of transport and reduce the potential for environmental problems such as spills and contamination to occur. The majority of the known deposits are at the periphery of the continent. It seems impractical to explore and prospect for minerals further inland when logistically it is much more difficult to transport equipment and supplies in, and all extracted products out. Coal deposits in the Prince Charles Mountains are likely to be favored over other coal deposits due to proximity to the coast (Rowley et al, 1983), and this is likely to be true for all other minerals. It is highly probable that minerals around the Antarctic Peninsula such as chromium, nickel, cobalt and gold may become the focus in the future as it is more accessible to ships and has a milder climate.

Another accessibility issue is where the minerals are located in terms of depth. Most geological research has looked at minerals within rocks that are already exposed including dry valleys and nunatuks (Wright and Williams, 1974). If the minerals were situated in the base rock under the ice sheet, then an ice drilling system is required. The East Antarctic Ice Sheet has thicknesses up to 4 km showing this is not feasible, but it may be possible in areas with decreased thicknesses such as glaciers and mountain ranges close to the coast. If there is continued warming of the West Antarctic Ice Sheet, it may become considerably thinner and easier to mine.
3.3 Coal Mining in the Prince Charles Mountains

Coal deposits have been found in Antarctica particularly within the Prince Charles Mountains and the Trans Antarctic Mountains (Figure 4). These two deposits were formed separately, most likely in the Permian Age. The deposits are scattered within a sandstone layer around 500 metres thick, in a vertical arrangement around three to four metres high and one kilometre in width (Wright and Williams, 1974). Very few samples have been taken from unweathered rock, and samples of the weathered material have shown the coal to be of poor quality and not suitable for mining. However, the Prince Charles Mountain coal is thought to be of a better quality than the Trans Antarctic Mountain coal, based on the limited analysis that has been undertaken. It shows more continuous seams that are thicker in width. These widths were up to 14 metres thick in the Beaver Lake Area of the Prince Charles Mountains, measured by Mulligan in 1963 (Daly, 1989). When one Antarctic Treaty nation sent a representative down to analyse the coal in the Trans Antarctic Mountains, the advice was the coal was of poor quality with high moisture and high ash, was thin and discontinuous and it was not worth having an appraisal undertaken. Whether this coal is of sufficient quality to be mined commercially is unknown at present (AAD, 2006). There has been no analysis of the quality of the Prince Charles Mountains coal. Daly also states that the information regarding the quality and distribution of coal is inadequate to make sufficient conclusions about Antarctic coalfields, except that they are generally poor in quality (1989).
Figure 4: Map of Antarctic Coal Deposits.

Source: Mulligan et al., 1963, p.6

A list on the processes and components needed for hard rock mining on land in Antarctica was published by SCAR for a workshop on the environmental implications of possible mineral exploration and exploitation in Antarctica (Appendix 5). This should be used as a guide of what would need to be assessed before a mining operation begins. Operations would need to be ensured to operate with minimal environmental impact in a safe, yet efficient way.

Coal is likely to be looked at as a potential resource for large tonnage but low quality products, and only when all other options have been exhausted (Rowley et al, 1983). Wright and Williams suggest that although the coal may not be valuable enough to be exported, its quality may be suitable for heating on a local scale (1974), and is supported by Rowley et al (1983). Due to the conclusions made from earlier research, it seems unlikely that the coalfields in Antarctica are of significant quality and quantity with ease of access to be mined in a profitable way using current technology. On the other hand, it will certainly be investigated in the future if the ban on mining is lifted and as other global coal sources become depleted.
3.4 Oil Drilling and Extraction in the Ross Sea Region

Offshore oil drilling is used as a comparison to onshore mines such as uranium and coal mining, by being an offshore example. Known onshore oil sources are generally older and are more deformed, making it harder to drill and therefore not suitable for commercial use. There are known areas of oil in the Ross Sea Region, and deep sea drilling projects and ocean drilling programs have avoided these areas to prevent drilling into oil reserves and creating environmental issues from releasing oil (AAD, 2006). Global oil production is becoming depleted and is a focus in the media due to rising petrol prices. Theories predict “the remaining Middle East oil reserves were about half the amount publicly claimed by resource interests and that oil production has peaked and will decline sharply” prevail (Sandilands, 2006). Oil barrel prices have risen dramatically in the last two years from $US28 a barrel in 2004 to just under $US75 today. As the prices continue to increase, it may be comparatively cheaper to use oil from the Arctic and Antarctic than other locations. It is estimated that the Arctic and Antarctic have two years worth of oil combined (Paine, July 14 2006).

The Ross Sea region has a known oil deposit (Figure 3, page 21) and some investigation has been done looking at the feasibility of drilling here. Potential impacts of drilling here include drilling muds and minor pollutants being released, shipping wastes and effluent released, impacts on land from support people and equipment, and oil the major concern is that oil will be released into the marine environment. The drill platform is likely to be a “very large floating structure with icebreaking and maneuvering capability, held on a station by a combination of moorings and self propulsion” (Holdgate and Tinker, 1979, page 29). Once extraction begins, this could also involve pumping oil into storage and then super tankers, or flow through pipes in the sea bed to shore. There are many variables with significant costs and risks, and these would need to be addressed. Some of these include impact on the ocean and its inhabitants, particularly for marine species critically important in the Southern Ocean food web such as krill Euphausia superba.

Oil drilling is a four stage process. For oil drilling to begin in Antarctica the initial stages of a regional scientific survey and an intensive local survey will need to
be done. This will be followed by exploratory drilling and lastly production. A list similar to the one explained above for land mining has been created for oil drilling in Antarctic Seas and again should be used as a checklist before oil drilling and extraction operations begin (Appendix 6).
3.5 ‘Mining’ Icebergs from Antarctica

There are major doubts about the traditional valuable minerals like hydrocarbons, oil and gas, being the most demanded in several decades. All prognoses regard water, the essential source of all life, as the most required resource in the future. Freshwater or icebergs are conservatively not regarded as a mineral and are therefore excluded by CRAMRA as icebergs are seen as a water source and a renewable resource in contrast to minerals and hydrocarbons. (Australian Government Antarctic Division 2006)

It is not yet known whether the towing of Antarctic icebergs to augment water supplies in such dry regions as Australia, Saudi Arabia or the Gulf will prove technically feasible, but it is already being seriously discussed and investigated. Each year, there are enough new icebergs formed in Antarctica to supply freshwater to the world’s six billion inhabitants and every industry on our planet for four months. (HowStuffWorks Express 2006) Remote sensing and the utilisation of GPS would achieve detection and selection of icebergs. Ice strengthened vessels, like the USS Polar Star, or nuclear powered aircraft carriers as the USS Enterprise, would tow the selected icebergs northwards into coastal areas for their final disposal. During their difficult voyage into constantly warmer waters, the icebergs would be protected and insulated by skirts or floating foams. These provisions would prevent the ice from splitting, melting and erosion as well as from tumbling. Biggest concerns arise regarding the steering and its natural antagonists, ocean currents and winds. The only environmental impact, which would cool air and sea locally, are rated as minor concerning the vastness of oceans. If the delivery of 10% of the annual Antarctic ice yield could be transported without severe melting losses, the operation could satisfy the water demands of an urban population of 500 million. The costs for this economical production of freshwater are estimated (Hult & Ostrander 1973) at U.S. $ 10 billion. This comes down to only U.S. $ 20 per person, which might be a cost effective alternative for freshwater production in the future.
3.6 Cost Comparison for Mining Different Minerals and Hydrocarbons

When thinking about how far to go to exploit Antarctic resources, the severity of the demand is one of the most important aspects. In the future, continued increase in the demand for electricity is almost certain. While this can be compensated by the use of fossil fuels, this is not going to be possible for a long period of time. Already, it is becoming increasingly difficult and expensive to establish new sources for oil, such as the recent Hibernia oil platform offshore Newfoundland, which was a 6 – 7 billion US$ project (Myers, 2005). Furthermore, use of oil and coal is under more pressure by environmental lobbyists, as awareness of the causes of global warming increases. If alternative energies continue to be as expensive and impracticable for major power generation as they currently are, and seemingly promising new methods such as nuclear fusion or geothermal plants\(^{19}\) fail to deliver, fission reactors might experience a renaissance.

But even today, the costs of energy production with fossil fuels are considerably higher, and statistics are in favour of nuclear electricity. Table 2 summarizes the development of the direct costs for electricity production from different sources in the US (in US$ per kWh). Nuclear and coal have not change much over the last few decades. Oil costs have significantly increased. Natural gas is also relatively high priced.

<table>
<thead>
<tr>
<th></th>
<th>Nuclear</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>1.03</td>
<td>1.22</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>1.74</td>
<td>2.17</td>
<td>3.10</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>1.72</td>
<td>2.21</td>
<td>8.09</td>
<td>7.51</td>
</tr>
</tbody>
</table>


These figures show that nuclear electricity production is the cheapest available option and is already more economic than electricity from oil or natural gas. While coal continues to be competitive, this is likely change in the future, as coal supplies are depleted and less accessible deposits have to be developed. Even if

\(^{19}\) Recently, a major pilot project in Basel, Switzerland suffered a serious drawback as operations had to be halted due to a series of earthquakes, probably caused by the water pumped into the ground for power generation (Swissinfo, 06.01.2007).
uranium prices increase significantly in the next few decades, this will not have very strong effect on the price of electricity production, as only 6-26 per cent (country dependent) of the costs are for fuel (IEA and NEA, 1998). Additionally, coal burning continues to be subject to strong criticism because of its strong contribution to CO₂ emissions worldwide.

Of course, currently there are many more readily accessible uranium deposits to be exploited before the ones in Antarctica become of interest. Low-quantity, high-value minerals seem to be the only natural resource in Antarctica that has the potential to become of economical interest, and uranium may well be one of them.
3.7 Environmental Impacts of Mining

The exploitation of minerals in Antarctica could, depending on the scale of the operation and the techniques that are used, have severe effects on the environment. There could be a significant and widespread impact on the environment from the passage of vehicles, exploratory drilling and the disposal of wastes (Rutford, 1986). Nearly all types of mining, like coal and oil or other minerals, cause similar impacts. They are explained in particular, using the example of uranium mining.

3.7.1 Environmental risks from a uranium mine

The greatest risk to the environment from a uranium mine is the contamination of water with dissolved radioactive materials. Radioactive dust could find its way into water, plants, animals and humans. Radon gas is a radioactive noble gas formed by the decay of radium. If this gas gets into the air, it can spread contaminants for hundreds of miles. The chemical pollutants in tailings (waste materials left over after removing the minerals from the ore) can also contaminate soil and water with heavy metals, acids, ammonia and salts (Edwards, 2006).

In the short term, chemical pollution can cause by far the most damage. Whole groups of organisms could disappear in uranium tailings areas. Radiation hazards will take longer to be manifested. Unless the tailings are properly disposed, these hazards will continue for thousands of years. Tailings hazards will also get worse as time goes on because of erosion, neglect and climatic change (Edwards, 2006).

3.7.2 Water pollution

During routine mine and milling operations, radioactive substances and other chemical contaminants (including sulphuric acid) can escape into melt water. For example in Ontario, by the late 70s the entire Serpent River system - including more than a dozen lakes - were heavily contaminated for 55 miles downstream from
the uranium mines in the Elliot Lake area. At that time, the International Joint Commission identified the Serpent River system as the largest single contributor of radium contamination to the Great Lakes.

If there is a failure of the containment system for tailings, rivers and lakes can be ruined completely as a source of water for humans and animals. In the Elliot Lake area, there have been over thirty tailings dam failures. In 1979, a new tailings dam built with the latest technology suddenly collapsed in Churchrock, New Mexico; the resulting spill was the greatest accidental release of radioactive material into the environment prior to the Chernobyl nuclear disaster (Edwards, 2006). Although there are no rivers in Antarctica, contamination of melt water ponds or the sea is still possible.

3.7.3 Radioactivity of tailings

After uranium is extracted, the portion that is used represents only about one seventh of the total radioactivity in the rock. The rest will be left in the tailings, which will remain dangerously radioactive for hundreds of thousands of years. The amount of radium in the tailings, and the amount of radon gas given off by the tailings, will not diminish much for the first 5,000 or 10,000 years. Even after 80,000 years, these quantities will have diminished by only one-half. Therefore, it is extremely important that all the tailings are refilled into the mine as fast as possible. Unless a great amount of money is spent on deep storage of the mine tailings, they will be left at the mine site. No mine or mill site has yet been cleaned up in a permanently satisfactory way anywhere in the world.

New stringent laws for covering (but not burying) mill and mine tailings in the U.S. have made mining companies move away to other countries where there are no such detailed laws. In most cases, the radioactive material is not even fenced in or signs posted to warn people that it is dangerous. Modern science has no way to eliminate this radiation. There is no practical way to neutralize radioactive materials, to destroy them or to render them harmless (Edwards, 2006). A uranium mine in Antarctica would cause the same environmental problems as we have seen them in other countries.
3.7.4 The dangers of tailings to humans and wildlife

Unless uranium tailings are safely contained in a storage system, whole areas and multiple generations of humans and animals can become contaminated. Living organisms that come close to the tailings will ingest or inhale some of this radioactive material which seeps into the air, the food and the water. Irreversible damage can be done to the lungs, skin, kidneys, blood, bones and reproductive organs. Over a period of years, that damage can lead to many types of illnesses, including cancers and leukaemia. It can also lead to diseases and malformations in unborn children.
Radioactive materials in the tailings can be carried by animals such as fish or birds and accumulate in the food chain. Anybody eating the meat from these contaminated animals will get the radioactive material inside his own body (Edwards, 2006).

3.7.5 Other dangers to wildlife

Contamination by the uranium tailings is not the only danger to wildlife. The increased human presence adds to the risk of any operation. Infrastructure, noise and the possibility for spills could endanger both, human lives and the natural environment.

The necessary infrastructure (buildings, roads, etc.) would also be a threat for much of the wildlife. Air pollution and the accumulation of waste would be inevitable in large-scale projects. The dramatically increased human presence that is required to support mineral activities would increase competition for the limited ice-free land and would lead to habitat destruction. Noise from seismic blasting could interfere with the ability of whales and seals to communicate and locate food, and shock waves can cause damage to their eardrums. Migration patterns of whales could be impacted when the number of vessels operating in the Southern Ocean increases with the commencement of mining operations (Wilson, 1998).

Regarding oil mining, it is obvious that the necessary presence of vessels would also lead to an increased risk of accidents, and therefore a higher potential for oil spills. It could take some time to return Antarctic waters to their natural state after
a major spill and animal mortality in turn could be high. The logistics of a clean-up would create difficulties because of the large area, its remoteness and the severity of the weather. Bad weather could also delay clean up and further disperse the oil slicks. An oil spill could be a biological hazard for years, as oil would become trapped in the ice as it froze and would be released during thaws in summer (Wilson, 1998).

The potential of spills and contamination are not the only dangerous. Antarctica's unpredictable weather and unique geography make mineral resource extraction dangerous. If an oil spill was to occur it could destroy Antarctica's fragile food chain. Oil would coat the krill and phytoplankton, the base of the food chain. It would collect in their tissues and concentrate as it moved up the food chain. The low metabolic rates of the fish would not allow them to excrete the oil from their bodies. Seabirds would get soaked with oil; the feather structure that keeps the plumage waterproof would break down and they would lose body heat and die of hypothermia. Oil is toxic to marine mammals causing abortions, and possibly death (Rutford, 1986).

When it is no longer economically viable to run the mine, it is rare that the mining company invests a sufficient amount of time and money necessary for a complete clean up. The destruction of the site is irreversible.

An increasing number of people working in Antarctica would seriously threaten both the terrestrial and ocean ecosystems. The infrastructure necessary to support mineral resource activities would have severe negative impacts. There is no way to exploit Antarctica's resources without permanently damaging the fragile environment and ecosystems. We should preserve this unique place on earth for science (Wilson, 1998).
3.8 The Legal and Political Issues of Mining in Antarctica

The major issues surrounding mining in the Antarctic were discussed over seven meetings from 1982 to 1988 (Bastmeijer, 2003). Throughout the 6-year regime, a number of issues were debated repeatedly with little satisfaction for either side of the table. But how far would we actually go to utilise Antarctic minerals for use in our home lands? The Antarctic Treaty refers to the area south of 60° and south recognised inter alia20, "that it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord". The possibility of political conflict in Antarctica has never entirely disappeared. This international debate over the presumed resources of Antarctica were testing whether the continent will continue to be a model of multinational co-operation in a world where such co-operation is rare (Francioni, 1986). The following is an account of legal and political issues that arise with the proposition of mining in the Antarctic and as to how far these issues have been resolved.

3.8.1 The Antarctic Treaty

One view is that proposed mining in Antarctica would violate the Antarctic Treaty. It would do so because of its alleged prejudice to pure scientific research and the inescapable contamination of the environment. On the other hand, it has been maintained that the "peaceful purpose" clause in Article I(1) must be understood to include mineral activities within the sphere of permissible uses of Antarctica – as they are neither hostile nor military in nature (Francioni, 1986).

3.8.2 Competing Views and Interests

Within the Treaty framework, the real issue with respect to mineral activities in Antarctica is that of agreeing upon the modalities of mineral exploration and development and setting up appropriate safeguards for other competing interests. In particular, these interests include the protection of the environment, the position of the so-called claimant states, and non-militarization (Francioni, 1986).

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20 The Latin term "inter alia" means, in a UK legal context: "amongst other things."
A number of states during CRAMRA negotiations showed signs of compromising environmental protection in favour of claimant interests on some issues. Claimant states however do mostly share an interest in environmental protection of “their” patch (Wallace, 1988). It is true that the group of industrialised states may favour more strongly a rapid development of mineral activities, while the Antarctic Treaty developing countries, especially the Latin America group, may place paramount interest in the protection of the Antarctic environment. However, all Consultative Parties agree that the establishment of environmental safeguards is an imperative deriving from the trust accepted under the Antarctic Treaty (Francioni, 1986).

3.8.3 Sovereignty

Perhaps the most contentious issue surrounding the development of a legal regime for mineral activities is the special territorial status of Antarctica. Article IV of the Antarctic Treaty temporarily freezes existing claims by claimant states. Future activities connected to the exploration and development of mineral resources will obviously affect this situation (Wallace, 1988).

If mining were to go ahead, the Consultative Parties would be likely to administer their claims on territory, to equate to the state having mineral rights. A claim of this sort could prompt claimant states to protect their territories by prohibiting other states access to minerals or putting a levy on minerals extracted from the territory. These actions would cause huge controversy as a number of non-consultative parties that claim their right to Antarctica through a status of ‘common heritage’.

3.8.4 Common Heritage

The Antarctic Treaty does not contain a specific reference to the common heritage principle, and it could not have done so because in 1959, the expression was not yet part of international vocabulary. Some states have gone as far as to suggest that any work on a mineral regime undertaken by the Consultative Parties should cease until an international administration is established (Wallace, 1988).
Despite internal disagreement over sovereignty, as a group the Antarctic Treaty Consultative Parties claim the right to administer Antarctica. They firmly reject the view of Malaysia and others outside the Treaty, that Antarctica is the "Common Heritage of Mankind" meaning that all nations would share the wealth, regardless of whether they have activities in Antarctica (Wallace, 1988).

The United Nations General Assembly believe that they should govern Antarctica. They commented that the existing treaty allows a "club" of developed nations to make decisions about the future of Antarctica (Cook, 1990).

If the principle of common heritage were to be applied to Antarctica, it would firstly require all states to abstain from asserting their claims to exclusive control or appropriation over areas in which mineral activities will be carried out. In addition, an allocation system could be established to share the mineral resource revenues for the benefit of the international community (Francioni, 1986).

The sovereignty issues in Antarctica are a somewhat ‘taboo’ topic. Although the Treaty freezes these claims, it is obvious that both claimant and non-claimant states see this as a major issue, particularly in the issue of mineral rights and the profits from those minerals. The assertion of the mineral rights and economic issues surrounding East vs. West nations could become issues of international discord between those parties who believe they have rights to Antarctic minerals.

3.8.5 International Economic Order

This is the requirement that the inequalities between industrialised states and less-developed countries are not worsened by the unregulated introduction of Antarctic minerals. Introducing raw materials and commodities from new sources onto the world market could cause a collapse in prices and a crisis for the economy of less developed producing countries (Francioni, 1986).

3.8.6 Third Parties

International law does not require third parties, or non-signatories, to abide by any agreement that they have not signed.
The obligation to refrain from mineral activities in Antarctica flows from the 1977 Consultative Parties Recommendation establishing a moratorium on resource exploration and exploitation. This recommendation was adopted at the Ninth Consultative Meeting and is addressed to both parties to and third parties to the Treaty.

Paragraph 8 of CRAMRA recommends that governments

"... Urge their nationals and other states to refrain from all exploration and exploitation of Antarctic mineral resources while making progress toward the timely adoption of an agreed regime concerning Antarctic mineral resources activities."

This recommendation is only intended to implement a policy of voluntary restraint that might become legally binding only upon its incorporation in international or national instruments imposing unambiguous legal obligations on states and their nationals (Francioni, 1986).

Therefore there is currently no legal constraints on third parties to the Antarctic Treaty System for mining in the Antarctic. There is however a number of political influences that can be employed to make it difficult for third parties to undertake unsupported actions.

3.8.7 Compliance

Third party actions a unable to be controlled by an agreement such as CRAMRA. On the other hand, those states that have signed up to the convention can be held liable for non-compliance to set regulations under the agreement.

The likelihood of compliance with set conditions will depend on the likeliness of detection of non-compliance, the successful prosecution in this event, and the size of the penalty imposed. There is lengthy record of the Treaty Parties over the flagrant breaches of the 1964 Agreed Environmental Measures by France at Dumont d'Urville during airstrip construction, or more recently the controversy around the drilling of
Lake Vostok by the Russians. Neither imparts confidence that there will be any strong deterrence to non-compliance (Francioni, 1986).

The biggest issue with compliance on the Antarctic continent is the continued policing of such a large area. Currently states agree to comply with certain standards and report on whether the operations were complied with. Neighbouring members have few other options than to take their word on it. Observers of operations have been used in the past but as of late, this practice seems to have been discontinued.

If there is non-compliance by a CRAMRA signatory, firstly action must be taken against the non-complying state and to be effective, liability must then be able to be imposed under national law.

3.8.8 Liability

The mineral regime negotiations account for the need to establish a state-operated link by requiring every operator to have a "substantial and genuine link" with a state that is party to the Treaty and by requiring every operator to have a sponsoring state (Francioni, 1986). Under Article 1(12) a 'sponsoring state' is

(i) Whose law that juridical person is established and to whose law it is subject, without prejudice to any other law which might be applicable, and
(ii) In whose territory the management of the juridical person is located, and
(iii) To whose effect control that juridical person is subject.

This ensures that the operator is then is answerable under the sponsoring state legal system.

This situation poses no threat to uninational companies with strong ties to states. On the other hand, large corporations with a multinational base could be seen to have a 'substantial and genuine link' with a number of equally preferable sponsoring state. This issue is crucial if there is any chance of ensuring that liability laws can be applied to a company under national law.
Liability issues are covered under Article 10, in association with Article 1(16) and 35. Environmentalists advocated for absolute liability rules on a no-fault basis with no defences. All risks borne by operators or in default by their sponsoring state or others who expect to benefit would see that there is also no limit to liability. Absolute and unlimited liability is believed to give an operator (or its user) a strong incentive to accurately judge the risks they are taking. Any diminution of full liability diminishes also the incentive to minimise or avoid risks and shift to outsiders.

However, the opposing view held by the potential miners and their sponsoring states who wanted limits to liability and a substantial array of defences was the position laid out in CRAMRA. The definition of “damage” in Article 10(4) of CRAMRA is designed to afford a broad sweep of defences to operators on the grounds that damage had been predicted and judged acceptable. The other usual defences such as a natural disaster - that could not reasonably have been foreseen and a violent act of a third party, other than another operator are also suggested (Wallace, 1988).

On the other hand, a relevant argument to liability is that there is little point in extracting liability payments from operators when the damage to the natural world is irrecoverable. The latter may well be true but enforced liability rules should act as a disincentive to excessive risk taking (Wallace, 1988).

3.8.9 Resource Rivalry and Militarisation

There is also concern, with the introduction of mining in Antarctica, that commercial minerals activity in the Antarctic could generate jealousies and set up rivalries and strategic targets in the Antarctic.

The construction of oil and other facilities in Antarctica will require a great deal of money and the maintenance of extended supply and product lines in difficult circumstances. This could lead to nations wishing to defend their installations and lines and to these becoming targets of hostile actions (Wallace, 1988)
4. Our opinion

Mining is a contentious issue with no correct answer. Every person has a different view on whether mining in Antarctica should occur and the extent to which the minerals should be utilised. There is little current information of what minerals are present and what quality and quantity they are after the Protocol prohibited prospecting. It is almost certainly going on, most likely as a by product of geological research, but is not being published. This makes it harder to form an opinion due to lack of knowledge.

In our opinion, mining in Antarctica will definitely be looked at as an option when other global resources become depleted and alternative energy sources and reserves are explored, especially with a focus to reduce the effects of greenhouse gases and global warming. However, perceptions of society would need to change dramatically and shift from Antarctica being viewed as one of the last wildernesses of the world, to a land of resources able to sustain their energy uses. Or global links would need to break down for countries to mine, against the political agreements such as the Protocol and CRAMRA they have signed.

We believe the more readily accessible mineral deposits will be exploited before the ones in Antarctica become of interest, with Antarctica only seen when desperation sets in. Due to the logistics involved in working in a polar environment, mining is likely to occur only when it becomes more profitable to mine in this remote location, than other places. Most of the minerals looked at in Antarctica are poor in quality and not readily accessible, and we expect only low-quantity, high-value minerals have the potential to become of economical interest in Antarctica, such as uranium. We feel it is important that Antarctica should not be seen as the solution to solving energy problems caused by depletion of global resources, although mining may still occur for minerals to support new technologies.

Demands may change in the future as resource availability and technology including mining technologies change. We cannot predict what the future will bring, but we hope that Antarctica remains a world natural reserve with minimal human impact, and believe no commercial mining is how this is best achieved.
5. Conclusion

It is impossible to anticipate the development of the energy market. However, there is no doubt that profit and the increasing demand for minerals will be one of the main drivers in the future. Therefore, predictions and forecasts of what minerals will be of most value in years to come are uncertain. Our uranium case study was chosen to emphasize the likelihood of a future mining-scenario. Uranium was selected as the mineral for the future because it does not enhance the Greenhouse effect, has been successfully utilized as an energy source for decades and has a high-unit value unlike traditional hydrocarbons and renewable energy. The legal issues within the Antarctic Treaty System and environmental impacts have both been stated and analyzed but in spite of either of these issues, the main factor for deciding whether mining becomes feasible in Antarctica will be cost effectiveness.

We think that the best indicator for the future of Antarctica is found in the Arctic. Even today mining is common procedure in the Arctic. We think further progress in Antarctica will be influenced by the impacts and progress the Arctic experiences in the next few decades.
References


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Appendices

Appendix 1: Detailed layout for an Antarctic mine.

Conveyor Incline-decline Crosscut System

Source: Daly, 1989, Vol.2, Backpocket, Plan 1
Appendix 2: Ore-extraction procedures and facilities overview

Figure 5: The ore is extracted, ground and diluted. The resulting slurry is then pumped to the milling facilities. After leaching, separation and precipitation, the resulting yellowcake can be flown to Australia.

Figure 6: Overview of the mine layout and supporting facilities (excluding Airfield).
Appendix 3: Flow Diagram of CRAMRA Application Process

NB: The CRAMRA process was researched and the diagram shown is thought to be the actual proposed relationship between the CRAMRA Commission and working parties.

1. Notification Request
   Party identifies an area of possible exploration and development

2. CRAMRA Commission
   Review procedures and actions instituted by the Advisory Committee.

3. Special Meeting of Parties
   Addressing the minerals and the particular area specified in the request
   Commission may amend area

4. Regulatory Committee
   Established to promulgate and implement rules and regulations
   Party may submit an application for an Exploration Permit for an Operator sponsored by that Party (see below)
   May decline, suspend, modify or cancel permits or application at any time if proposed activities cannot meet requirements of CRAMRA.

5. Exploration Permit
   Conveys to an Operator the exclusive right to explore and to develop the specified mineral resources.
   Application for a Development Permit on behalf of the Operator

6. Management Scheme
   A contract that prescribes the terms and conditions of the operation.
   Must update information to reflect Management Scheme
   Modified, suspended or cancelled if:
   1. Not modified to avoid unacceptable impacts
   2. Operator has failed to comply with the CRAMRA
   3. The Operator ceases to have a substantial and genuine link with its Sponsoring State.

7. Development Permit
   1. Development activities
   2. Planned development
   3. Mitigation measures for Operators
   Committee to examine application for any:
   a. Modifications to the development activities envisioned at the time of application for an Exploration Permit
   b. Check to see whether the planned development would cause previously unforeseen impacts on the Antarctic environment or dependent and associated ecosystems.
   Committee can require any modification to application before issuing the development permit.

Once the review has been finalised, a development permit allows the operation to go ahead.

NB: This permit may be terminated at any time.
Appendix 4: CRAMRA Process

(1) **Notification Request**

The initial step in the application process requires a State (applicant) to submit a notification request for possible exploration and development of a particular mineral resource or resources in an area. Any applicant that is a Party to the CRAMRA may submit a notification request to the Commission. This notification must contain:

a) A precise delineation and physical and environmental description of the requested area;

b) The resources of interest;

c) A characterization of the scale of exploration and development;

d) The methods likely to be employed; and

e) A detailed assessment of the environmental and other impacts of possible exploration and development for the resource or resources involved.

This notification is then submitted to all Parties and observers attending the Commission.

(2) **Advisory Committees**

There are review procedures and actions instituted by the various CRAMRA institutions, particularly the Commission, and the Scientific, Technical and Environmental Advisory Committee (Advisory Committee).

(3) **Special meeting of Parties**

A Special Meeting of Parties must be held. The Commission's decision addresses only the minerals and the particular area specified in the request. The Commission has authority, however, to amend the area delineated by the request for the purpose of resource management or to revise the scope of an identified area by incorporating additional mineral resources and geographic areas. In addition, the Commission must consider whether exploration and development should be prohibited or restricted in any areas within the requested area.

(4) **Regulatory Committee**

Once the Commission identifies an area, an Antarctic Mineral Resources Regulatory Committee (Regulatory Committee) is established to promulgate and implement rules and regulations. Specifically, the Regulatory Committee handles applications to conduct minerals exploration and development, establishes application fees and procedures for handling applications, establishes periods within which applications received will be considered simultaneous, and determines a method for resolving competing applications.

(5) **Exploration Permit**

After the Regulatory Committee develops and implements regulations, an applicant party (Party) may submit an application for an Exploration Permit for an Operator sponsored by that Party. The application must contain detailed information concerning the Operator, as well as a detailed description of proposed exploration activities and of later development activities. Additionally, the application must identify the mineral resources applied for, assess the environmental and other impacts of the proposed activities and describe the capacity of the Operator to respond effectively to accidents, particularly those with possible environmental effects. Similar to the prospecting requirement, the application also requires a certification by the Sponsoring State that the Operator has both technical competence and financial capacity, and that the Operator has a "substantial and genuine link with" the
The permit application above must update the information provided in the application for the Exploration Permit, assess the environmental and other impacts of the proposed development and contain a re-certification by the Sponsoring State of the technical competence and financial capacity of the Operator as well as a re-certification of a

(6) Management Scheme

After the application for the Exploration Permit is received but before issuing of the permit, the Regulatory Committee examines the application and elaborates a Management Scheme. The Management Scheme is a form of contract that prescribes the terms and conditions of the operation. If approved, the Management Scheme would result in the issuance of an Exploration Permit that conveys to an Operator the exclusive right to explore and, subject to re-examination and potential modification, to develop the specified mineral resources. At any time during the consideration of an application, the Regulatory Committee may decline the application if it determines that the proposed activities cannot meet the

(7) Development Permit

The CRAMRA also includes provisions governing application for a Development Permit. If the Operator holds a valid Exploration Permit, the Sponsoring State may file an application with the Regulatory Committee for a Development Permit on behalf of the Operator.

The Regulatory Committee will examine an application for any modifications to the development activities envisioned at the time of application for an Exploration Permit, and will check to see whether the planned development would cause previously unforeseen impacts on the Antarctic environment or dependent and associated ecosystems. If the Regulatory Committee members approve the application, a Development Permit will be issued to the Operator. However, the Regulatory Committee might also require modification of the application before agreeing to issue a permit.

CRAMRA also contains provisions, applicable to both Exploration Permits and Development Permits, authorizing the Regulatory Committee to suspend, modify, or cancel a Management Scheme, or to impose monetary penalties. Any or all of these sanctions may be imposed when a Regulatory Committee determines that exploration or development authorized by a Management Scheme has resulted, or is about to result, in unacceptable impacts on the Antarctic environment or dependent or associated ecosystems.

If the Regulatory Committee determines that an Operator has failed to comply with CRAMRA, it may modify, suspend, or cancel the Management Scheme and associated permit, or the Committee may impose a monetary penalty. Additionally, the Management Scheme and associated permit must be cancelled if the Operator ceases to have a substantial and genuine link with its Sponsoring State. Lastly, when appropriate, the Commission may be required to adopt mitigation measures for Operators.

(Sourced: Wallace, 1988)
Appendix 5: Some Components of the System Involved in Hard Rock Mining on Land

1. **Factors affecting scale of development** include ore quality; size of ore body; availability of water and energy; and location of suitable sites and construction materials, including harbours and overland transportation.

2. **Development features affecting scale of environmental impacts** include location of development; size of mining installation (land required); volume of waste and spoil generated, and location of dumping area; volume of ice / freshwater required; nature of energy source used; nature of transportation system used for mineral concentrate; and nature and volume of chemical pollution released to air and water.

3. **Environmental features affecting scale of impacts** include landscape features at site of development (including dumping and shipping); biological characteristics of site of development (pattern and rarity of soil, vegetation, fauna); and biological characteristics (sensitivity) of plant and animal communities exposed to development.

4. **Environmental management affecting development impacts** include constraints on location to avoid impact on ecologically or geomorphologically valued sites; grading, stabilization of dumped spoil to facilitate recolonisation by vegetation; direct re-establishment of vegetation on bared ground or spoil (very difficult in the Antarctic); removal of chemical pollutants in emissions to air and water; removal of installations one no longer required; and costs of all these measures.

Source: Holdgate and Tinker, 1979, page 35
Appendix 6: Some Components of the System Affecting Oil Exploration and Exploitation in Antarctic Seas

1. **Factors influencing site selection** are geological indicators of oil potential; bathymetry and structure of seabed; iceberg and pack ice condition; currents (surface and deep); climate; special biological features of the site and its alternatives; and costs of operation.

2. **Technological factors influencing impacts** include use of seismic explosives; drilling processes; nature of rigs and platforms; nature of wellhead completion structure; nature of oil storage system, nature of transport system; nature of pollution control system (including management); and nature of emergency procedures (including training).

3. **Environmental factors affecting impacts** include types and concentrations of pollutants, especially oil, released; rates of physical and biological degradation of oil and other pollutants; rates and directions of dispersion of oil and pollutants; relative location of emissions and living targets (benthos, phytoplankton, krill and other zooplankton, fish, seabirds, seals, whales etc); and sensitivity of living targets to oil and other pollutants and to substances used in clean up.

Source: Holdgate and Tinker, 1979, page 25