Resources in Antarctica:
With the World's dwindling natural resources, is there a chance for exploitation in Antarctica?

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Abstract

Pressure on global resources increases daily as the worlds human population and its demand for energy, raw materials, food, water and health care increases almost exponentially. Naturally such growth puts pressure on resources and is therefore inevitable that relatively untouched areas of the world such as Antarctica come under the spotlight.

From an almost unlimited number of potential resources for exploitation, the syndicate chose to concentrate on five areas considered to be the most significant in terms of their current and future relevance.

Whilst the pressure to exploit some resources seems distant in terms of time and economic viability, exploitation has already begun in the Southern Ocean and coastal waters of Antarctica.

Fishing, bioprospecting and the potential of iceberg utilisation are all activities which can occur with minimal environmental impact if they are well managed. Prospecting and extraction of oil and mineral resources are likely to cause significant problems for otherwise pristine areas. Above all, the exploitation of Antarctic resources poses the greatest threat to the current stability of the ATS and the wider Antarctic political framework.

The increasing global pressure to use resources of any kind from Antarctica, underlines the need to strengthen existing Treaty and Protocol statements and intentions, in order to provide the world with a single Antarctic voice with which to guide its future approach to this unique region of the planet.

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List of Abbreviations

ATCPs	Antarctic Treaty Consultative Parties
ATS	Antarctic Treaty System
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
CBD	Convention on Biological Diversity
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CCAS	Convention for the Conservation of Antarctic Seals
CDS	Catch Documentation Scheme
CRAMRA	Convention on the Regulation of Antarctic Mineral Resource Activities
DSDP	Deep Sea Drilling Project
EEZ	Exclusive Economic Zone
IEE	Initial Environmental Evaluation
IUU	Illegal Unreported and Unregulated
MYO	Million Years Ago
NGO	Non-Governmental Organisation
PAH	Polycyclic aromatic hydrocarbons
UK	United Kingdom
U.N.	United Nations
VMS	Vessel Monitoring System

1. Introduction

Pressure on global resources increases daily as the worlds human population and its demand for energy, raw materials, food, water and health care increases almost exponentially. When the ATC first began to meet in the 1960s, there were only 3 billion people on the planet. At the end of 2003 that number had grown to 6.3 billion. Naturally such growth puts pressure on resources and is therefore inevitable that relatively untouched areas of the world such as Antarctica come under the spotlight.

Energy production in most developed countries relies heavily on non-renewable resources in the form of fossil fuels. For example, 86% of the energy produced in the United States is based on fossil fuels, 54% of which is imported. Globally the world consumes 80 million barrels of crude oil per day, with the U.S. alone using more than one quarter of that total. Currently more than 2 billion people, almost 1/3 of the world's population, don't have access to modern energy. However, with improving standards of living, especially in highly-populated countries such as China, the pressure on these non-renewable resources is expected to increase drastically.

To date, no effective alternative to these diminishing resources has been found. Increasing pressure prevails on the exploitation of already existing reserves and potential new reserves. Antarctica, being a large unexplored and unexploited continent, could perhaps be one solution to the existing pressure on resources. It is not out of the question, that this large continent, one and a half times the size of Australia, holds vast resources. Beyond historical (sealing, whaling) and present resources (fish), Antarctica has the potential to provide freshwater; cures for diseases; hydrocarbons; minerals; alternative energy sources such as geothermal, wind and solar; sand, gravel and other extractable building materials. Many of these are of minor importance, as there is little or no immediate pressure to use them today or in the foreseeable future. Renewable energy in Antarctica may well become important, but mainly for the continent itself, rather than globally. Thus, for the scope of this research, the report deals with five major globally important resources: water, oil, minerals, fish and bioprospecting.

Antarctica was once attached to the super continent Gondwanaland, which also included mineral rich landmasses such as Australia and South Africa. As major ore processes evolved during the time of the super continent, Antarctica is likely to hold similar mineral deposits. The geological nature of the seabed is similar to many of the oil bearing fields around the World. This raises the possibility of vast oil fields in the Southern Ocean, which perhaps could be an answer to the diminishing oil reserves around the world. In addition, oil reserves in Antarctica may be powerful tool against the dominance of current oil countries, as Antarctica is not owned by one single nation.

The Southern Ocean itself holds an enormous amount of marine life, and to date, it is a comparatively unexploited area. With a growing world's population, the Southern Ocean may well be a potential resource to satisfy the increasing demands for food.

The continent of Antarctica is to 98% covered in ice, and holds more than 90% of the world's fresh-water. In the light of the UN predicting that the future wars are likely to be fought over the access to, and demand for, fresh-water (rather than oil) Antarctica could be a major contributor to a solution for this issue.

Beyond that, Antarctica is the coldest, highest, windiest, driest and most remote continent on Earth. It thus holds a high potential for undiscovered and unusual species. The potential for commercial gain from products developed from these organisms has led to increased interest in bioprospecting in Antarctica and the Southern Ocean.

Thus, with an emphasis these five potential resources from Antarctica - minerals, hydrocarbons, water, fish and bioprospecting - the report investigates the following question:

Aim

With increasing pressure on the world's dwindling resources, is there a case for the exploitation in Antarctica?

Objective

- What is known about these resources in Antarctica?
- Is it at present possible to extract this resource?
- What are the political, economic, environmental, social and technological difficulties in using these resources?
- Bearing the difficulties in mind, is there a case for exploiting these resource in Antarctica

2. Resources

2.1. Fishery

2.1.1. Introduction

The exploitation of the Southern Ocean has received increasing amounts of attention from a range of groups over the last decade. The commercial collapse of several northern hemisphere fisheries has meant that fishing nations have had to seek their livelihoods from other areas. At the same time, countries with Exclusive Economic Zones within the region have recognised the value of the marine resources within their sovereign territory and are taking significant steps to protect their territory. Despite the significant steps taken by states to protect their 'turf', marine resources within the Southern Ocean have increasingly become subject to incidents of Illegal, Unregulated and Unreported (IUU) fishing.

CCAMLR is the body which regulates the harvesting of marine resources within the Southern Ocean. Established in 1982, CCAMLR has had a great deal of success in the conservation and management of a range of marine resources, however it is now facing some major challenges.

With the use of strong management and systematic controls, the Southern Ocean will remain a sustainable resource.

2.1.2. Fishery in Antarctica

The first form of exploitation of the Southern Ocean took place in the nineteenth century with the advent of sealing in the area. Initial efforts concentrated on Antarctic and Sub-Antarctic fur seals. Later efforts were directed towards hunting Elephant seals. This trade effectively ceased at the start of the twentieth century as seal numbers had been reduced to a level that were no longer commercially profitable. Additionally, the 1972 International Convention for the Conservation of Antarctic Fur Seals has provided legal protection to the species. The success of this convention is evident by the dramatic increase in Antarctic fur seal populations. (Burke, 2001)

The second form of exploitation of the Southern Ocean commenced at the start of the twentieth century with the building of the first whaling station in South Georgia. During the peak trading years in 1910 - 1911 over 1500 Humpback whales were caught at an individual station. This initial intensity was unsustainable and within five years, the Humpback numbers had reduced to levels that were no longer commercially viable. Each time this occurred a new species of whale was sought for commercial gain. The arrival of the first factory ship in the

Southern Ocean dramatically increased the pressure on whaling stock and resulted in over 37,500 whales being processed by factory ships during the 1930-1931 season. Large-scale commercial whaling continued through to the late 1960's when it became increasingly obvious that significant damage had been done to the entire whale population. (Burke, 2001)

As whaling declined as a commercial enterprise, attention was diverted to the development of fin-fishing. Early fishing interest was mostly confined to the Antarctic Peninsula and centred on N.rossii and Champsocephalus gunnari. Levels of fishing increased over a number of seasons as fishing techniques and the design of vessels evolved. The Soviet catch during the 1976/77 season totalled 124,611 tons which was four times greater than the previous season. (Burke, 2001)

Less than a decade later, the Soviets commenced experimental long-line fishing of the Patagonian Toothfish and by the late eighties, had commenced commercial fishing of the species. Other species that have been commercially important to varying degrees include lanternfish, mackerel, marbled rockcod, Patagonian rockcod and Krill. In many respects, the depletion of these fish stocks paralleled that of the whaling industry in the successive discovery, exploitation and depletion of each new stock. (Lack, 2001)

Krill is notably significant, having been commercially fished since 1972 with annual catches exceeding 300 000 throughout the 1980s but decreasing to around 100, 000 tonnes in the 1990s. This decrease reflects a decrease in the worldwide demand for krill rather than the possible over-fishing of the species. Commercial fishing for krill occurs mainly in the South Atlantic near the South Shetland Islands and South Orkney Islands in summer and adjacent to South Georgia in winter. The interest in Krill has increased in recent years with new advances in harvesting and processing technology having eventuated alongside the development of pharmaceutical products based on krill. This has resulted in a rise in the number if states harvesting krill, with the United States indicating that it may soon be a participant in the krill fishery for the first time. (Burke, 2001)

The most topical and important fishery in the Southern Ocean at present is that of the Patagonian and Antarctic Toothfish. Both of these species have attracted significant interest in the last decade. The increase in their demand arose because of the commercial collapse of many northern hemisphere fisheries and the collapse of the Austral Hake and Golden Kingclip fisheries in Chilean waters. Most reported catch of Patagonian Toothfish occurs in waters around the islands of Kerguelen and Crozet (France), South Georgia (UK) and Heard and McDonald Islands (Australia) whilst Antarctic Toothfish is now being caught in the CCAMLR managed area in the Ross Sea region. Although the Ross Sea area is still considered an exploratory fishery, New Zealand has been harvesting Antarctic Toothfish for a number of seasons with varying degrees of success. Catch figures indicate the area to be commercially viable and industry expectations are that the exploratory fishery will become a commercial fishery managed by CCAMLR in the coming seasons (Johansson, 2004).

2.1.3. Environmental Impact

A number of countries have now raised the issue of the long-term sustainability of the Patagonian Toothfish Fishery. There are indications that catches of the Patagonian Toothfish around the Prince Edward Islands have fallen to about 10% of their initial levels and biomass estimates around the Crozet Islands have declined to between 25 and 30% of their original levels. Although these figures provide some indication of the gravity of the situation, accurate data is hard to obtain, as data availability for stock assessment is dependent largely on the level of reported fishing in each area. As there are some areas within CCAMLR's jurisdiction that have been largely untouched by legal commercial fishing, knowledge of stocks within these areas remains limited.

IUU fishing continues to be the greatest challenge to the conservation of Toothfish stocks. IUU fishing operations use longline-fishing methods with little attention given to avoiding seabird bycatch. This has had a devastating effect on a number of seabird populations, some of which are endangered species (AAD, 2003)

Whilst the accuracy of data concerning IUU activity is not entirely reliable it has been estimated that the total IUU catch of Toothfish over the past six years is almost equal to the total catch by legal fishers, and is worth about A$1 billion in wholesale value. (AAD, 2003). The high incidence of IUU fishing in the Southern Ocean commenced in the mid 1990s largely due to the collapse of northern hemisphere fisheries, overcapacity in the global fishing fleet and the introduction of larger maritime jurisdictions for coastal states. (AAD, 2003)

An increased global effort to stop IUU fishing has slowed the upward trend in IUU incidents. There are indications however, which suggest that the nature of IUU fishing has changed from the hit and miss styles of the mid-1990s to a highly sophisticated form of transnational organised crime.(Johansson, 2004) New IUU methods now include the sophisticated control of vessel movements; refuelling at sea; and the active intelligence gathering of enforcement efforts. (AAD, 2003)

Catching and prosecuting perpetrators is extremely difficult as most participants use complex corporate arrangements and law to disguise the real owners and beneficiaries of IUU fishing. Additionally some operators exploit weak State regulatory regimes to flag vessels and fraudulently obtain validation of catch documents needed for market access. There are also indications that IUU operators are supported by the corrupt conduct of some State's officials. (AAD, 2003)

At present, there are between twenty and thirty vessels involved in IUU fishing for Toothfish. The main ports for landing IUU caught Toothfish are all located in States that are not CCAMLR Members, including Tanjong Priok in Indonesia, Hong Kong and Singapore. These ports are used for ease of logistical convenience and to minimise risk of being caught participating in illegal trade. These ports have yet to implement the CCAMLR Catch Documentation Scheme (CDS), which aims to prevent IUU catches entering the market. (Lack, 2001)

CCAMLR regulates fishing in the Southern Ocean by controlling access to fisheries, determining which countries may access fisheries as well as determining the number of vessels that are given access to a specific area. CCAMLR is also responsible for the licensing and inspection of fishing operators and their vessels, ensuring sea-bird bycatch is mitigated, monitoring marine pollution and placing independent observers on fishing vessels to ensure that correct procedures are followed. (CCAMLR, 2004)

In response to the significant threat of IUU activity, CCAMLR has instituted a number of measures. The first of these measures adopted in 1998 required the inspection by Contracting Parties on all their vessels licensed to fish in the CCAMLR area; the compulsory identification markings on vessels and fishing gear; the promotion of compliance by non-Contracting Parties; and the mandated use of vessel monitoring system (VMS) in Toothfish fisheries. (CCAMLR, 2004)

During the following year, CCAMLR introduced the Catch Documentation Scheme (CDS). The implementation of this scheme, and the passing of further resolutions over the following years to strengthen and support the CDS has been a significant step towards the conservation and management of the species. The CDS is designed to track the landings and trade flow of Toothfish caught in the CCAMLR Area by requiring landings of Toothfish at participants' ports, or transhipments to participants vessels, to be accompanied by a valid CCAMLR Catch Document. This effectively identifies the origins of Toothfish catches, gathers statistics on total catches and identifies catches harvested in a manner consistent with CCAMLR requirements. Principally, the CDS aims to prevent IUU catches from entering the territories and markets of CCAMLR parties. (AAD, 2003)

The final measure of current interest taken by CCAMLR in response to IUU fishing for Patagonian Toothfish was the resolution urging Members to blacklist known IUU vessels. CCAMLR will maintain the list of IUU vessels. Of note however, is the fact that this is only a resolution and not a binding Conservation Measure. (Lack, 2001)

2.1.4. Legal and Political matters

Most States that wish to fish in the Southern Ocean are faced with either the prospect of applying to CCAMLR for a permit, or seeking a permit from a country such as Australia or France that have an EEZ within the area. Either way, most countries are forced to operate in accordance with the CCAMLR guidelines if they wish to offload their catch at nearby ports, as all of the countries bordering the Southern Ocean are CCAMLR members, and are active participants of the CDS regulating the trade of fish.

Those states that engage in IUU activity and do not participate in the conservation measures instituted by CCAMLR are finding a decreasing market for their catch. Increasing numbers of States are recognising the range of benefits that flow from a regulated industry and are actively seeking ways to support the trade in legal fish.

As more buyers make the choice of only purchasing legal fish, IUU suppliers will find themselves forced out of the illegal market. This may prompt some operators to participate in the legal market and adopt the appropriate conservation measures.

2.1.5. Summary

The exploration and hence the exploitation of the Southern Ocean has only eventuated over the last two centuries. Despite this, seal, whale and finfish were all seriously affected by harvesting until international regulations, put an end to most of this activity.

The formation of CCMALR in 1982 has had a significant effect in the conservation and management of various marine resources since its inception. Whilst CCAMLR faces a number of challenges based on the fact the organisation represents both conservationists and those that wish to harvest fish stock, it is still seen as a successful body that is able to form and institute conservation measures to protect a varied range of resources.

CCAMLR's future success is principle to the management of the Southern Ocean's resources. CCAMLR is currently tackling the problem of IUU activity in a vigorous manner. Whilst is not able to eradicate all IUU activity in one season, it has instituted a number of Conservation Measures which will have a significant impact on IUU operations.

It is clear that the Southern Ocean's marine resources are openly available to all fishing nations that choose to venture south. Given strong management and appropriate controls, the Southern Ocean can be a sustainable resource open to all.

2.2. Minerals

2.2.1. Introduction

Discussion around the mineral potential and mineral exploitation in Antarctica has a long history. It reached its peak during the early eighties, when the consultative parties agreed on establishing a minerals convention called "Convention on the Regulation of Antarctic Mineral Resource Activities" (CRAMRA) (Elliot, 1994). Due to lacking consensus on this issue, the minerals convention failed (Joyner, 1995). Instead an environmental protocol, was established, the 1991 Madrid Protocol, which forbids any mineral exploration or exploitation in Antarctica for 50 years (Elliot, 1994, Joyner, 1995). For that reason literature on the mineral potential in Antarctica can only be found during that time. Any mineral resource knowledge at present is due to political motives not published. Nevertheless, the following section is going to explore the mineral resource potential of Antarctica based on 1980's knowledge and hypothetical determination of its significance for exploitation.

2.2.2. Mineral Resources in Antarctica

Among scientists, there exists a strong belief that Antarctica could be an area with high mineral potential. The major reason for this belief is that Antarctica was once part of the super-continent Gondwanaland and was joined to mineral rich land masses such as Australia, Africa and South America (figure 2.1)[1] (Behrendt, 1983, Wright, 1974, Zumberge, 1979). As major ore creating processes occurred about 800–150 million years ago (MYO), at the time of the super-continent, Antarctica has a high potential for large mineral occurrences (Wit, 1985). The fact that the continent is large in terms of its size - one and a half times the size of Australia – speaks for itself, the mineral resource potential. Thus, there is not the question if minerals exist in Antarctica at all, but if they are viable to extract on economic, social and political grounds.

[1] Exposed rocks in Antarctica are comparable to those found in these continents. For example, rocks in the Antarctic Peninsula are comparable in type and association to those that constitute the Andes in South America (Wit, 1985)

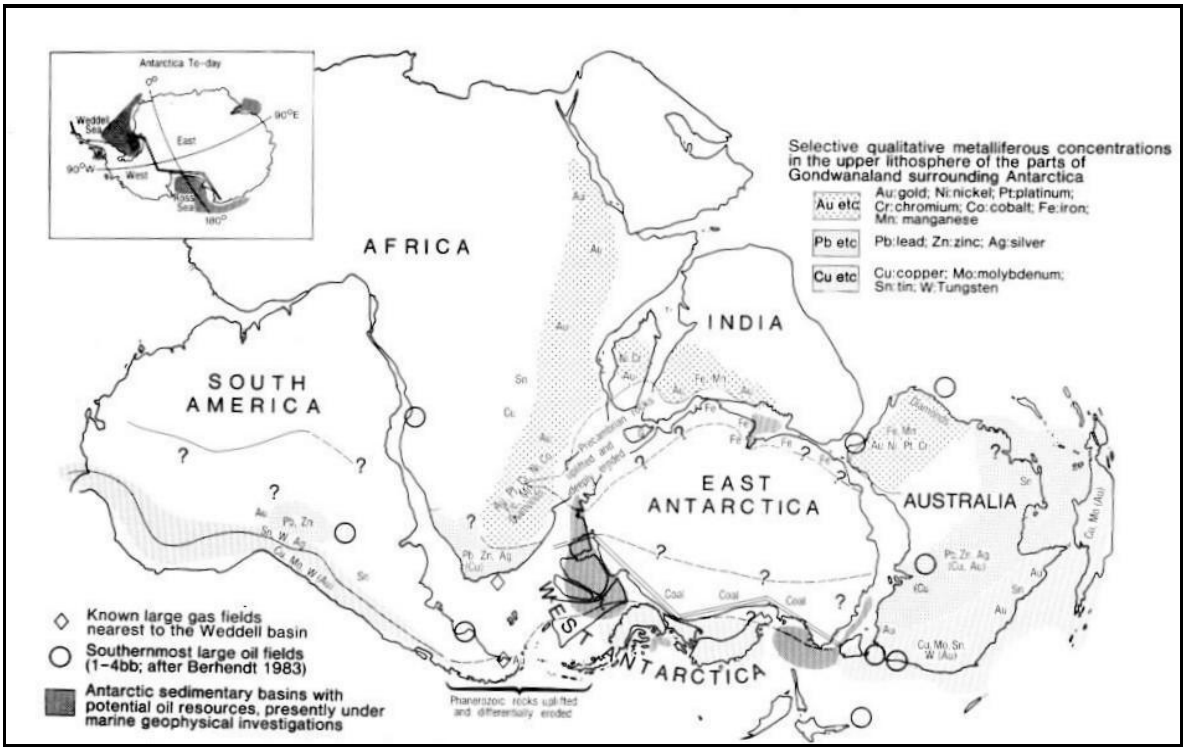

Figure 2:1 The super-continent Gondwanaland, reconstructed as it was about 180 million years ago

Apart from large coal reserves along the Trans-Antarctic Mountains and iron ore in East Antarctica, no economically significant mineral reserves have yet been found (Behrendt, 1983, Witt, 1985, Wright, 1974, Zumberge, 1979). Nevertheless, numerous traces of minerals, supporting the theoretical belief of Antarctica's resource potential, were identified in various places around the continent (Behrendt, 1983, Wit, 1985).

Area	**Minerals**
Antarctic Peninsula	copper, molybdenum
Dufek Massif	chromium, platinum, copper, nickel
TransAntarctic Mountain	copper, lead, zinc, silver, tin, gold
Prince Charles Mountains	iron

Table 2:1 Areas of Antarctica with potential mineral resources

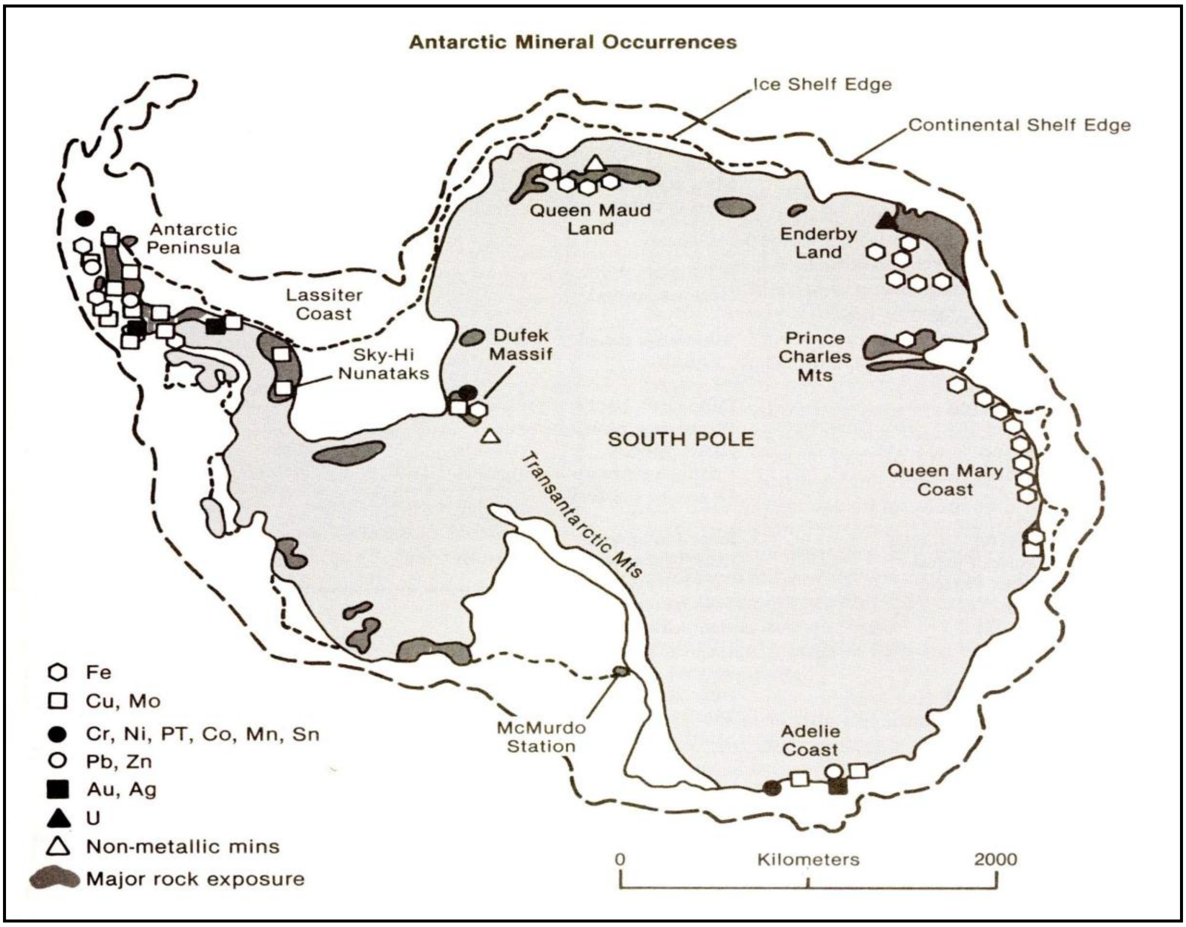

Figure 2:2 Mineral Resources in Antarctica

As seen in Table 2.1 and Figure 2.2, copper, molybdenum (occasionally with gold), lead and zinc have been found in the Antarctic Peninsula. On the opposite side of the Antarctic Peninsula, rocks deriving from the Archaean area (>2500 MYO), known as Archaean cratons were identified. In the Southern Hemisphere, these cratons are known to contain valuable gold and diamond deposits e.g. 65% of the 1982 world diamond production was derived from Australian and South African rocks (Wit, 1985). Thus, it can be expected that similar deposits exists in Antarctica, but no proof has yet been found. On the opposite side of East Antarctica, a potential mineral rich belt exists, which once connected to the mid-Proterozoic (2000-1000 MYO) lead-zinc-silver belt of Australia and South Africa. However, due to its inaccessibility and limited rock exposure in this area, little is known about the actual geology of this part of Antarctica (Behrendt, 1983, Zumberge, 1979).

The TransAntarctic Mountains in the centre of Antarctica are well studied. They are built up of dark igneous rock (Ferrar dolerites) and Kirkpatrick basalts. At the northern end a mafic[2] igneous intrusive complex, known as the Dufek Massif is located (Behrendt, 1983). The United States, Russia and former German Democratic Republic have extensively studied this

[2] The term mafic is used to describe a silicate minerals, magmas, and rocks which have relatively high concentrations of the heavier elements.

geological anomaly for its potential deposits. According to Wit (1985) this area, which is claimed by the U.K., Chile and Argentina, posses the most significant potential mineral reserve of Antarctica. The main mineral found, platinum, is according to him economically profitable to mine. However, he also points out, that these assumptions have only been theoretically proven[3] and that unless exploration in form of drilling is undertaken, nothing can be stated for certain.

2.2.3. Difficulties in mineral resource extraction

As the previous section demonstrated, the predicted vast mineral resource potential of Antarctica remains hypothetical. Apart from the ban on exploration, many constraints existed, and still exist to establish a detailed map of Antarctica's resources. These are as follows: (Behrendt, 1983, Elliot, 1994, Witt, 1985, Wright, 1974, Zumberge, 1979):

- *Physical constraints:* To identify the resources precisely, exploratory drilling is necessary. This however, is only possible in ice-free areas, which are merely 2% in Antarctica. Therefore, there is an extremely limited geological study potential.
- *Accessibility:* The continent is far away from potential mineral markets, surrounded by stormy waters, filled with pack ice. Ports, and areas where ports could be built are rare; few of these are usable for more than 2 months a year. Transport methods to prospecting sites, which are environmental friendly and economical have not yet been found. Beyond that, land transport to the potential location is made difficult by often heavily crevassed glaciers. Reaching the interior is only possible by expensive aircraft transport, yet due to darkness and weather conditions, air transport during winter would be dangerous.
- *Climatic Constraints:* 6 months of low or no sunlight, high wind velocity accompanied by complicated weather forecasting makes mining difficult.
- *Technological Constraints:* Currently lack of suitable mining technology for the Antarctic environment
- *Environmental Constraints*: see section 2.3.3
- *Profit sharing:* see section 2.3.4
- *Social Constraints:* Public awareness of the impact of mining on the environment is strong. During the 1980s, they pushed with the aid of NGOs for a ban on mining. It is doubtful that in future their position will dramatically change.

[3] Geological and Mineralogical comparison of rocks found in the Dufek Intrusion with rocks of the Bushveld complex (biggest intrusion on earth, located in South Africa) have been undertaken and found similar (Wit, 1985).

- *Resource Constraints:* A large energy supply is necessary for mining. At present no studies have been compiled which deal with where and how to get the energy for any mineral activity. Next to energy, mining requires vast amount of water, yet water can also be a limiting factor in Antarctica

2.2.4. Environmental Impact

Any mineral activity in Antarctica will have negative environmental effects, whether it is exploratory drilling or exploitation. The detrimental effect of mineral extraction will be mainly on the land and in the atmosphere, but it could extend on to the oceans when the area open for exploitation is adjacent to the coast (Joyner, 1988). Any impact of mineral activities can be divided into to two major stages:

- setting up an area for mining,
- operation

Setting Up an area for mining:

The extraction of minerals requires the area around it to be accessible or to be made accessible e.g. roads. For the construction of roads, sand and gravel is needed, which most likely comes from localised sources rather than from beaches (SCAR, 1979). Hence, the impact of the ore extraction process reaches far beyond the actual pit.

In addition to the provision of access, mining facilities have to be established such as conveyer belt systems, power generation and transmission installations, sewage and water distillation plants, aircraft with necessary airport or over-snow vehicle. Despite potential strict environmental regulations, it cannot be guarantied that these facilities and machineries are 100% clean. Beyond potential fuel spillage, they increase the localised aerosol concentration. Increased dust particles in the air accompanied by a darker surface (facilities) compared to the surrounding areas, decreases the albedo4 of this area (SCAR, 1979). The albedo in Antarctic snowfields is about 0.85. If it decreases to 0.82, the intensity of solar heating is assessed to increase by 20% (SCAR, 1979)). This change in the solar heat budget could in the long-term have an effect on the present climate equilibrium. (Fastook and Hughes 1982 (in Wit, 1985))

Operation:

The types of deposits found in Antarctica are of low grade (Behrendt, 1983) and dispersed through vast rock volumes. Consequently, they have to be mined open-cut, leading to large-

[4] NASA defines the albedo as: "the fraction of solar energy (shortwave radiation) reflected from the Earth back into space" (NASA, 2004). The lighter the surface, the higher the albedo.

scale rock excavation (Wit, 1985). The result is a change in the drainage pattern5, affecting vegetation and soil fauna.

The removal of the waste material through mostly crushing, grinding and screening as well as the extraction of the valuable material by magnetic, chemical or flotation methods require extensive amount of water and energy (SCAR, 1979). To some extend water may have to be heated to prevent freezing of materials. Likewise, stockpiles have to be kept in heated shelters, requiring vast amount of energy.

Both the removal of the waste material and the processing of the valuable matter create emissions of chemicals (e.g. SO_2, mercury, cadmium) and aerosols, which can disperse over large areas. Upon settling, these chemicals can affect the subsurface environment.

Depending on the proximity to wildlife, opencast mining can also have adverse effects on birds and seals due to increased localised noise levels (SCAR, 1979).

The extraction of minerals in an area cannot proceed without human presence. Human activity, where there has been none before can cause further disturbance to the ecosystem, localised pollution and waste disposal (Elliot, 1994). This can have an impact on the subsurface environment through the release of liquid effluent or the accumulation of litter.

Despite these numerous effects, perhaps the largest impact of mining in Antarctica is the 'unknown' effect. Due to the constraints mentioned in the previous section, limited knowledge about potential environmental effects exists in Antarctica. These range from the effect of air pollution on the ice sheet, landform and soil patterns, long-term effects of chemical emission on terrestrial biota, rate of biodegradation under different environmental conditions to the indirect effect of dust on the radiation budget and on long-term climatic conditions in the Southern Hemisphere (SCAR, 1979). The full external costs (indirect costs) of mining are basically difficult to measure, especially in Antarctica.

2.2.5. Future significance

The viability of Antarctic minerals for future exploitation depends whether or not economic and political obstacles can overwhelm the current regulation on mineral exploitation and exploration, in other words, the Madrid Protocol. This section outlines these obstacles and assesses their significance for future exploitation.

Economic:

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[5] For example, coal mining requires a groundwater free environment.

The economic viability of Antarctic mineral reserves is difficult to assess. Up to now, no economically viable reserves have been found in Antarctica. This does not imply they don't exist, but due to the constraints mentioned before, they are hard to estimate. Generally, the literature suggests, that with current mineral prices, minerals in Antarctica seem not viable to mine at present and in future unless a sharp increase of the unit price of these minerals occurs. (Wit, 1985). It is suggested for example, that if the gold price continued to rise, the likelihood of profitable exploitation of gold deposits would increase. (Behrendt, 1983). However, this has to occur in conjunction with good accessibility of these deposits. Platinum for example is said to be a potential economically viable reserve. The deposit however is located in the interior, which makes it only economically viable, if there is a major disruption of supply from South Africa (U. S. Congress, 1989). Thus, in addition to a price increase, the potential reserves have to be located in an accessible area, preferably in the Antarctic Peninsula.

Therefore, despite many speculations of potential economically viable reserves such as coal, platinum, gold and iron reserves, the economic viability of these reserves remains hypothetical. Even if exploitable resources are found, political restrictions remain, and remain (at present) stronger than the economic output of these resources.

<u>Political:</u>

Assuming that one day economically viable resources and appropriate technology are found, there are still numerous obstacles which have to be overcome in order to undertake mining. (Figure 2:3).

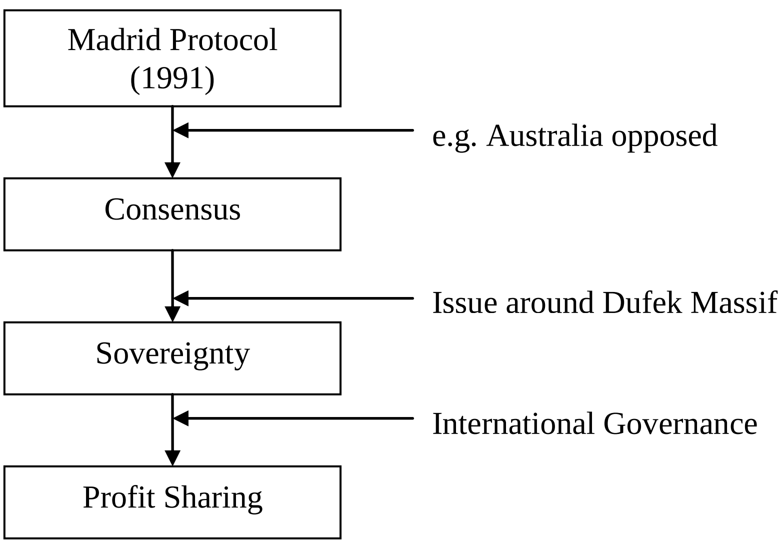

Figure 2:3 Political Obstacles necessary to overcome for peaceful exploitation

At present mineral resources are regulated under the 1991 Environmental Protocol, which puts a ban on development and exploration in Antarctica (Elliot, 1994, Joyner, 1995). Thus, only a consensus from all Consultative Parties can change current mineral policy. A consensus however seems unlikely to happen in the near future. Australia, who blocked the minerals convention in 1988 (Elliot, 1994), still has vast resources and hence due to potential competition is still likely to remain opposed to minerals exploitation in Antarctica.

Nevertheless, if consensus is reached, the mineral issue will bring up the dispute about sovereignty, which has successfully been avoided. The most economically viable zone is the Dufek Massif. However, this area is claimed by three nations and thus would put Antarctic sovereignty issue under a severe test (Wit, 1985). The sovereignty conflict between Argentina and the U.K. over Sub-Antarctic islands has shown the extent of this issue. A similar clash again would have serious consequences, which far outweigh the actual economic benefits of mineral exploitation in Antarctica. To keep Antarctica from major political confrontation is in the interest of the ATCP members (Elliot, 1994). Currently, this is more important than resource exploitation.

Should sovereignty issues be overcome, there remains the question of profit sharing, which already under CRAMRA is heavily disputed (Elliot, 1994). There is no agreement among the nations as to whom, if anybody, owns the resources in Antarctica. Developed countries will be the ones that are able to undertake the highly expensive exploitation. However, the United Nations (U.N.), and many developing countries see Antarctica as a common heritage of mankind (Joyner, 1995), hence demanding a 'piece of the pie'. As the number of Antarctic Treaty Consultative Parties (ATCPs) has increased since the time of CRAMRA, the issue is expected to be more contentious now and in future. A way to control profit sharing is by placing Antarctica's mineral resources under international governance like the U.N. However, this has been, and still is heavily objected to by members of the Antarctic Treaty System (Elliot, 1994). New Zealand for example would see its importance, which it has in Antarctica as being a claimant states, diminished under U.N. governance, where it plays comparatively a minor role. International control in a continent that has succeeded without a central organisation for almost 50 years seems unlikely.

Political obstacles remain at present stronger than the economic need to exploit resources in Antarctica. In future, these obstacles are unlikely to diminish, but rather increase. Economic pressure overwhelming political obstacles will only happen when worldwide mineral resources have depleted. Once we are at this point, exploitation of minerals in Antarctica is going to happen, but it is unlikely to be a peaceful process.

2.2.6. Summary

Despite many reported mineral occurrences, to date no economic reserves have been shown to exist in Antarctica (Behrendt, 1983, U.S. Congress, 1989, Witt, 1985, Wright, 1974, Zumberge, 1979) In addition, the cost of exploration and exploitation is unknown, which is closely related to technical problems. Even if technological issues are solved, exploitation still faces major social, environmental and political obstacles. At present, conflicts evolving from these issues seem (even in the future) unlikely to be solved by peaceful means.

Economically, Antarctic minerals are only viable to be mined, if the price of minerals increases dramatically. Even if that is the case and overcoming environmental, social and political obstacles, Antarctic resources will only temporarily solve the diminishing resource problem. Ultimately, they will deplete, and what happens then remains questionable.

Antarctic minerals are not a solution to the diminishing non-renewable resources worldwide. They might at best extend the time of complete resource depletion, given that major aforementioned obstacles are overcome, which remains doubtful.

'There is no justification for the exploitation of Antarctica, except in terms of human greed. For we do not need Antarctica's supposed resources – we merely desire them to prolong a way of life which must, ultimately, come to terms with its own bankruptcy' (Friends of the Earth, 1982 (In Wit, 1985))

Instead, it is recommended that the resource utilisation worldwide is optimised, which includes above all, intensified recycling of non-renewable materials. At the same time, increased funding ought to be given to scientific research to find alternatives to these non-renewable minerals. However, these solutions are only viable, if we simultaneously attack the basic problem, which is a reduction in the world wide population growth, while increasing education.

2.3. Hydrocarbons – Oil and Gas

2.3.1. Introduction

Since the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA, Wellington 1988; has never been ratified by any state) was abandoned in 1989, and the Protocol on Environmental Protection to the Antarctic Treaty (The Protocol, Madrid 1991) entered into force in 1998, with a provision (Article VII) for prohibiting "all mineral resources activities in Antarctica" for the next 50 years, (Berkman, 2002, Cohen, 2002), no further declared exploration of the potential oil and gas reserves in the Antarctic has been performed. However, the mounting pressure on available resources and a seemingly insatiable appetite coupled with national self-interest and changes in the political landscape will undoubtedly, in the not too distant future, force Antarctica's exploitable resources to the forefront of Antarctic issues. Additionally, it should be kept in mind that non-treaty parties are not bound by the Protocol. In the following sections the information available on potential hydrocarbon (essentially oil and gas) resources in the Antarctic, their exploration and exploitation, are reviewed and discussed.

2.3.2. The hydrocarbon potential of the Antarctic

As there has been little direct drilling, speculation on the location of hydrocarbon reservoirs in Antarctica has largely been based on extrapolations made from the neighbouring continents, marine geophysical surveys including seismic profiling, information gained from geological studies of Antarctica's coastal regions, and theoretical models of hydrocarbon formation and accumulation (Anderson, 1990, Cripps & Priddle, 1991). In the 1970s and 1980s it was generally agreed that deposits of hydrocarbons were likely to occur in some of the sedimentary basins both onshore and offshore from Antarctica (e.g. Anderson, 1990, Mitchell, 1983). In addition, there was a consensus that Antarctic offshore oil was likely to be concentrated in West Antarctica (the Ross, Weddell, Amundsen and Bellinghausen Seas), and that the Amery Ice Shelf areas in East Antarctica could contain oil reserves (Behrendt, 1983, Cooper et al., 1990, Cripps & Priddle, 1991, Holdgate & Tinker, 1979, Mitchell, 1983).

Gross comparisons and analogies with other continents and continental margins show that continental shelves throughout the world are proving to be rich sites for oil and gas (Mitchell, 1983). It is generally accepted that Antarctica was once joined to nearby continents in the super-continent of Gondwana, which then, during the past 180 million years, was torn apart in the process of continental drift (BAS, 2004). Antarctica would therefore undoubtedly have undergone the same processes that have produced minerals in neighbouring continents. Oil exploration is under way on the shelves attached to many of the countries that make up these continents, and oil and gas are already being extracted from the shelves of New Zealand, Australia and South Africa and from the southern tip of South America (Gregory, 1982, Mitchell, 1983). The sediments found in the Antarctic continental shelf provide further indirect evidence. Surveys have revealed thick layers of unmetamorphosed tertiary sediments in the Weddell and Ross Seas; such sediments are frequently associated with oil (Mitchell, 1983).

During exploratory drilling for research purposes by the Deep Sea Drilling Project (DSDP; drilling vessel Glomar Challenger) in the Ross Sea in 1972/73 hydrocarbon gases were detected (compare Behrendt, 1983, Cripps & Priddle, 1991, Mitchell, 1983, Rapp, 1987). Trace amounts of methane and ethane were detected in three of four holes drilled on the continental shelf. While methane is fairly common, ethane is held as an indicator of possible hydrocarbon reservoirs (Mitchell, 1983). Following Holdgate & Tinker (1979), the sites chosen were located so as to avoid the most likely oil-bearing structures, and even though such occurrences of gas in themselves established nothing, the components, source rocks and general geological conditions confirmed the Ross Sea as one of the more likely areas for the exploration for hydrocarbons.

In the past, various projects on practical exploration, ranging from marine geophysical studies to remote sensing, have been performed (Behrendt, 1983, Mitchell, 1983). For example, the Federal Institute for Geosciences and Natural Resources (BGR, Germany) performed seismic surveys in the Weddell Sea (1977/78) and in the Ross Sea (1980); Starting in 1980/81, Japan conducted a three-year geological survey, including seismic work, of the Bellinghausen, Weddell and Ross Seas, under the auspices of the semi-official Japan National Oil Corporation; New Zealand chartered the polar vessel Benjamin Bowring from the UK to undertake geophysical and oceanographic work (1981), and also had been involved in a drilling programme in McMurdo Sound "which may have commercial undertones" (Mitchell, 1983). In this context, Mitchell (1983) remarked that "it is not always easy to differentiate the early stages of oil exploration from scientific research activities and the Antarctic Treaty countries are reluctant to admit that they are engaged in exploratory work because they have endorsed a gentleman's agreement to refrain from mineral exploration or exploitation". It does seem suspicious that that since the Protocol has been adopted the exploration of Antarctica's oil and gas resources is no longer discussed openly. Instead, nowadays gas hydrate volume estimations are carried out "because of the vast amounts of methane that may be stored in gas hydrates, their potential role in climate change, and their possible interaction with seafloor stability" (Jin et al., 2003; compare e.g. with Kvenvolden et al., 1987, and Rapp et al., 1987).

Direct geological observations of the rocks in the basins of greatest interest have not been possible because these basins are located either on the continent beneath the ice or on the continental margin beneath the water (Kvenvolden et al., 1987). Also, controversy arises over the matter of estimates concerning the discoverable and recoverable oil reserves. For example, in 1976 the U.S. Government mentioned an estimate "in the order of magnitude of tens of billions of barrels" for potentially recoverable oil in the Antarctic continental shelf (Mitchell, 1983).

Whereas speculations on offshore hydrocarbons are discussed manifold, information and opinions on potential onshore hydrocarbons are very limited. Mitchell (1983) comments that "oil and gas are almost certain to be found, but the technological difficulties of locating and exploiting it are such as to make it essentially irretrievable in the near future". Consequently, the following discussion will be mostly concerned with offshore hydrocarbon resources.

2.3.3. Difficulties in extracting oil and gas in the Antarctic

The obstacles and hazards that must be overcome, when exploiting potential oil and gas resources are immense. The Antarctic continental shelf is one of the most unsuitable regions of the world for hydrocarbon exploitation (Anderson, 1990, Mitchell, 1983; compare Poland et al., 2003). Its average water depth ranges between 400 and 800 m and is covered by sea ice most of the year. Huge icebergs with drafts of several hundred meters drift freely over the shelf, and the seas that surround the continent are among the roughest in the world. The shelf itself is rugged and is floored by Quaternary glacial and glacial-marine deposits whose geotechnical properties vary widely over relatively short distances (Anderson, 1990). The weather is severe and changeable. Fog, wind, ice and snow can severely disrupt human activity, often bringing it to a complete stop for many days. Ships may become icebound for weeks, and aircraft may be unable to land or take-off for days or weeks. Also, as one of the most remote and isolated areas in the world, the logistics, including all forms of transport from and to Antarctica, would require an enormous amount of time, effort and expenses.

Notwithstanding the known difficulties, the vast continental margin of Antarctica has long been considered a suitable location for large oil fields, and interest in possible exploitation of the continent's predicted hydrocarbon reservoirs continued to grow (Anderson, 1990, Mitchell, 1983) before the Protocol brought open discussion of the subject to an end. In 1979, Holdgate & Tinker draw a quite optimistic picture concerning the feasibility of exploration and exploitation of oil in the Antarctic, and pointed out that on land, the necessary technology had already been largely developed and was functioning in the Arctic, and that at sea, the technology, e.g. drilling platforms and vessels, had been advancing rapidly. The authors also posed the question how far Antarctic's climate and ice conditions would impose either an absolute constraint or an unbearable cost on oil exploration and exploitation, and argued that climate would probably not be a major limitation, although it could prevent some types of sea-surface equipment from operating continuously for long periods. Mitchell (1983) asserted that the depth of the Antarctic continental shelf may prove to be the least of the problems as drilling is taking place in deeper waters in other parts of the world, and that experience with hazardous ice conditions, like icebergs, were growing as a result of activities in the high latitudes of the Northern Hemisphere. However, the author also acknowledged that along with issues like icebergs, ice shelves and pack ice, the lack of suitable terrain to build back-up facilities, like ports, airstrips, bases, recreation and medical installations was a major problem facing Antarctic oil exploration. Holdgate & Tinker (1979) considered logistics the main problem for onshore exploitation, and maintained that the costs of operation in the Antarctic will be such that only very large oilfields are likely to be considered for development. Mitchell (1983) assumed that even though oil and gas are most certain to be found onshore, the technical difficulties of locating and exploiting it are such as to make it essentially irretrievable in the near future. In addition, any attempt at onshore exploration is likely to be complicated enormously by the huge ice sheets covering the Antarctic continent.

When discussing the difficulties of exploiting Antarctica's oil and gas, it is self-evident that the complex equipment required, including tankers and platforms suitable for the Antarctic, will pose a considerably financial hurdle. A crucial technological question concerns the ability of vessels and platforms to avoid causing pollution (Holdgate & Tinker, 1979). In case of any oil spill, complicated remediation would be required. The clean up of contaminated sites in the Antarctic would involve well above average hazards, and can expected to be very costly (compare Poland et al., 2003). Additionally, as there is little doubt that commercial production would generate huge amounts of waste and physical debris, the question of waste disposal needs careful consideration. In Antarctica, burial of waste is not permitted; so all waste must either be shipped north or incinerated (Cohen, 2002, Poland et al., 2003). As the Protocol seeks to have as much waste as possible returned to the country of origin, guidelines are given for the minimum levels of waste treatment and the disposal of combustible and liquid wastes on the continent or at sea. Some products are specifically prohibited from the Antarctic, such as polystyrene beads, chips or similar forms of packaging (Cohen, 2002, Poland et at., 2003).

2.3.4. Potential impact on the environment

The exploration and exploitation of potential oil and gas reserves in the Antarctic are likely to have considerable environmental impacts (Holdgate & Tinker, 1979, Mitchell, 1983, Poland et al., 2003). The severity of local conditions such as the cold and presence of ice and icebergs increase the likelihood of accidents, and would complicate remedial measures (Mitchell, 1983). As the comparison with the Arctic shows, the exploration for petroleum products has had profound effects on the environment; catastrophic large-scale oil spills occur even with the use of modern utilities, and accidental spills due to human error and technology failure are still commonplace. In Canada an average of 12 spills per day were being reported in 1995, although the majority were too small to attract media attention (Poland et al., 2003). In 1989 the Bahia Paraiso oil spill in the Antarctic Peninsula Region (near the U.S.A. Palmer research station, Anvers Island) caused the Antarctic Treaty nations to abandon CRAMRA (Berkman, 2002). About 300 seabirds died as a direct consequence of oil fouling, and reproductive failure of the local population of south polar skua was also attributed to the spill, although alternative hypotheses for this have been proposed (compare Poland et al., 2003). In this context, it also should be pointed out that danger for the wildlife also can derive from the fact that Antarctic marine life such as penguins and seals tend to congregate so that the local effects of even a small spill could be quite severe (Mitchell, 1983). The most contaminated marine site in Antarctica is Winter Quarters Bay, at McMurdo Station on Ross Island, where about 80,000 m^2 of seabed is contaminated with polychlorinated biphenyls and hydrocarbons, resulting in reduced faunal diversity and the presence of a few opportunistic species (compare Poland et al., 2003). A further impact on the Antarctic ecosystem is caused by large discharges of organic contaminants and heavy metals from the petroleum industry (Poland et al., 2003). Especially polycyclic aromatic hydrocarbons (PAHs) are of greatest environmental concern, as crude oils are composed of up to 10 % PAHs and shale oils and coal products can have PAH contents as high as 15 %. PAHs are also introduced into the environment from the large volume of water produced by oil and gas platforms, by the incomplete combustion of wood and fossil fuels, and the incineration of garbage, steel and coal (Poland et al., 2003).

The above mentioned potential and actual environmental impacts are of even greater concern as the rate of biological productivity is limited under polar conditions, affecting attenuation processes such as microbial degradation (Delille et al., 2003, Poland et al., 2003). Unfortunately, relatively little research (even though contamination in the Antarctic is in the order of 1 to 10 million m^3 of abandoned waste with possibly a similar volume of petroleum-contaminated soil (Snape, 2003) has been conducted in relation to contamination issues in cold climates and the unique situation that exist in the polar regions (Delille et al., 2003, Snape, 2003, Snape et al., 2003, Poland et al., 2003). There is an obvious need to develop new technologies to address the problem of soil remediation in high-latitude regions (Delille et al., 2003). Information gaps exist in such areas as bioaccumulation in polar species and the toxicity of contaminants to polar species (Poland et al., 2003). For example, there is little data available to determine whether polar species are more or less sensitive than temperate species and, consequently, whether the relationship between concentration and impacts derived from temperate species can be applied at higher latitudes. Also, even if a contaminant is present at concentrations below the threshold for toxic effects (on the biota), it may still have unforeseen impacts in the context of the Antarctic. For example, the burning of fuel, production of waste and dispersal of aerosols in the context of oil and minerals exploitation would interfere with the monitoring of global pollution and the detection of global background levels that is currently conducted on the continent (Holdgate & Tinker, 1979, Mitchell, 1983, Poland et al., 2003). Hence, even in the ideal case of an accident free progression of exploration and exploitation activities, the impacts on the Antarctic and its intrinsic values could be considerable.

Even though Antarctic Treaty contains provisions dealing with environmental matters, there are currently no legislated clean-up regulations or guidelines with respect to e.g. contaminated soil in the Antarctic (Cohen, 2002, Poland et al., 2003). With respect to waste disposal and environmental management, the Protocol on Environmental Protection generally obliges member countries to minimise waste production and to clean-up past and present waste-disposal sites on the continent. This clean-up is a matter of discretion; if the process is likely to cause more damage than leaving the site as it is, the parties are not required to carry out this action (Poland et al., 2003, Snape, 2003). Also, there are no universally accepted guidelines and no binding process for assigning liability for environmental damage in the Antarctic (Snape, 2003). Consequently, at present the legal framework is not suitable for holding potential oil explorers to account for their acts in Antarctica.

2.3.5. Outlook

In a speech, given at the 2nd International Oil Summit in Paris in 2001 (Sandal, 2001), Bjørn Sandal, the former Norwegian State Secretary of Oil and Energy, concluded that oil is the most important energy source in the world economy. She stated that oil's share of total energy consumption is expected to stay around 40 % and its importance is unlikely to diminish in the next 10–20 years. Commenting on whether oil resources would be a constraint on supply she observed that this should not be a problem for many years as there is a reserve/production ratio for oil of more than 40 years. Although, from the perspectives of today's consumers and multinationals this might be welcomed news, a window of some 40 years seems scant time for Antarctica's environmental issues to be explored and discussed let alone resolved.

At the present time the existing agreements are politically acceptable and expedient. Although this situation is likely to continue for the lifetime of the Protocol, it should be viewed in the light of the actions taken in certain troubled parts of the world, where industrial countries have shown willingness to take military action to safeguard oil supplies. As the world resources of oil and gas diminish, the point will be reached where political agreements and environmental conservation will become secondary to national interests. Given recent history, there is no reason to believe that Antarctica's oil and gas will be left unexploited. Hence, the environmental security of Antarctica will in no small part depend on there being a considerable reduction in the world's reliance on oil over the next few decades. Advances in technology, energy savings and greater use of existing and alternative energy supplies and materials could conceivably achieve this. However, the best and most realistic hope for the preservation of Antarctica could be the maintenance and fostering of the unique position it has already gained in our collective conscience.

2.3.6. Summary

Speculation about the existence and location of hydrocarbon reservoirs in Antarctica, as drilling activities have been limited, are mainly based on assumptions, extrapolations and theoretical modelling. Nevertheless, the consensus view of oil experts and geologists is that when taken together the circumstantial evidence points to there being a high likelihood that there are substantial deposits of hydrocarbons in some of the sedimentary basins both onshore and offshore from Antarctica. Exploring for and exploiting potential hydrocarbon resources in the Antarctic would be logistically time-consuming and complex, requiring an enormous technological and financial effort. Justifiably, Antarctica's continental shelf can be referred to as one of the most unsuitable regions in the world for the exploitation of oil and gas. However, examples from around the world show that difficult terrain and extreme environments can be overcome if rewards are considered great enough. The exploration and exploitation of potential oil and gas reserves in the Antarctic are certain to have considerable environmental impacts. And this is one door that once open will never be able to be closed again. At the present time, the legal and political regime of the Antarctic does not allow any mineral resource activities, but also does not provide guidelines and regulations for e.g. clean-up and remediation management, and to assign liability for environmental damage. However, for the lifetime of the Protocol exploitation of oil and gas reserves seems unlikely.

2.4. Water

2.4.1. Introduction

The concept of iceberg utilisation has been present for many years, yet no attempts have been made to utilize this resource. This is primarily due to two reasons, proximity (in principle economics and logistics) and politics. Economics has also limited the use, but this is a direct consequence of transport costs. The economic use of natural ice has been ongoing for centuries (Reynolds, 1983). The Romans used alpine lake ice and transported it in straw to Rome, and in the early 19th century, Norway had become a significant ice supplier to Britain, France and Germany. Glacier ice exploitation was also present, and when calving rates were low, explosives were often used. The cessation of the glacier ice industry came abruptly when the economics of ice manufacture were more attractive than ice mining.

There are four main areas of concern with respect to the exploitation of Antarctic ice, and it is almost certain that they all will have to be resolved before the exploitation of icebergs will occur. These are the economic feasibility, the environmental factors, the legal/political issues and technological ability for the transportation and utilisation. The last of these will not be discussed in this report, as modelling has proven it capable, and with current advances in technology, if we are not yet logistically able, there is no doubt we soon will be.

2.4.2. Freshwater Resources in Antarctica

Iceberg utilisation was first conceived by John Isaacs in 1972, who calculated that, with the use of six powerful tugboats there was feasibility for a three month haul across the southern ocean (Stockinger, 2003). This concept was considered with great speculation, however, the initial convergence of this developing science occurred at the First International Conference on the use of Icebergs (1979), Ames, Iowa. The conference was strongly supported by Prince Mohammed al Faisal, who in 1977, created an organisation delegated to study the feasibility of towing an iceberg (of 100million tons) to the port of Jeddah, Saudi Arabia. The dedication to this concept has been long lived and the annual continuation of the international conference until 1996 indicates the dedicated scientific support that has followed. The development of the Iceberg Research Journal in 1980 also supports this.

Research focussed on the physical uncertainties that are abundant with the challenge of such a large scale operation. Weeks and Campbell (1973) investigated towing 'bergs to areas in the southern hemisphere (primarily Australia and Southern Africa), they concluded that economically, large scale operations were much more desirable. Proposals for transportation to the northern hemisphere were soon ruled out due to the loss of volume due to melting in the equatorial regions (Weeks, 1980). A primary area of concern is the uncertainty as to how an iceberg will behave under tow. The potential for break-up, melt and over turning have all been thoroughly considered and many designs have been developed to mitigate these problems. However, until the theory is put into practise, there will inevitably be unknowns.

2.4.3. Environmental impacts

The global iceberg supply strongly outweighs the human demand. Antarctic iceberg production is estimated at 1250 km^3 per year. (Quilty, 2003). This is equivalent to 1250 billon m^3 of water per year (~200 m^3 per person). The extent to which natural processes would be affected due to the removal of icebergs (proposed in an area 60-65º south) is minimal.

Interestingly, environmental concern has been focused on the subsequent development of localized weather patterns that may develop due to thermal exchange and albedo. The concept of cloud seeding (atmospheric modification) using icebergs has been developed (Simpson, 1977), though the thought of iceberg towing for this cause alone must be abandoned on an economical basis. Shapiro (1995) rationalized the expense of towing arctic icebergs to warm hurricane catalysing waters, to reduce their intensity and save millions of dollars of annual damage. Transport of significant ice mass towards the equator is inevitably going to influence global weather systems, as they are driven solely on temperature imbalance. The potential modification of weather systems is a large concern, though little is known about the relative effects. Another cause for concern is the oceanic impacts and long term global impacts of the affected (diluted and cooled) water trail, which could considerably affect the marine biological systems. There is also concern that the icebergs path will inevitably entail 'bergy bits' (Holdgate, 1980). The largest concern here is the effects once 'landed', as for example, a large frozen mass of water positioned in the shallow continental waters of Africa (~few hundred meters) is something that history has surpassed for many millennia. To assume adaptation could occur to any of the abundant marine life would be ridiculous and significant consequences would have to be expected (Holdgate, 1980). Though the environmental effects on Antarctica are thought to be rather small, it would be in best interest, to have an ongoing monitoring of environmental effects throughout the procedure so early detection of unforeseen circumstances could occur.

2.4.4. Legal matters

There are a number of legal problems that could arise with the development of iceberg utilisation. Although with little reference to the topic and with the degree of ambiguity involved, it may prove less of a challenge to overcome legal boundaries. "(Neither) the 1959 Antarctic treaty or any other international instrument with interest in the Antarctic environment contains any specific reference to 'ice bergs'" (Trombetta-Panigadi, 1996). The 1959 Treaty applies to all areas below that of '60º south and ice shelves' but again has no reference to 'icebergs', suggesting the potential to 'capture bergs' outside of 60º south. The Final act of the 11th Antarctic Treaty Consultative Meeting has significant relevance to the use of icebergs and states 'the harvesting of ice was not considered to be an Antarctic mineral resource activity', it was therefore discussed and agreed that the harvesting of ice would be possible in the future.

Following this, developments of the 1991 Madrid protocol specify the need for Initial Environmental Evaluation (IEE), to identify any possible environmental impacts. These must be completed for all Antarctic activities. A further provision is the requirement for protocol party consensus (agreement) for any activity that is considered to have more than minor or transitory impacts. Trombetta-Panigadi (1996), however, suggests that iceberg exploitation would have only minor and transitory impacts. A further problem is the unknown effects of iceberg exploitation, and if the potential for significant irreversible damage is present, the 'precautionary principle' may apply.

The 1982 Convention on the Law of the Sea is of significance due to the nature of transport. The towage of icebergs will certainly interact with international freight paths and possibly travel within some States EEZs (Exclusive Economic Zone) en route. Though these problems are not directly related to Antarctica, they will still remain an issue.

Problems stem from the issue of ownership. Where an iceberg is captured, it is probably appropriate to treat it as a ship, registered under the same flag of the ship that tows. 'Ownership' therefore produces the liability of that country, in the case of any pollution or collision. Furthermore, who owns an iceberg?, if it calves off a Greenland glacier then is it still part of Greenland? And if it then drifts into the Canadian EEZ, for example, is Greenland liable? This problem develops, when considering Antarctic icebergs, as they are not owned, a problem being the unrecognised claims to sovereignty in Antarctica (Burton, 1978). The first attempt on iceberg towage will create interesting debate and the evolution of global hydro-politics will be inevitable. Unfortunately there is potential that economic interests and global water tension demands could undermine the resolution and agreement of legal concerns (Chamoux, 1978), leading to further international tension and a potential war of the water (Jones, 1997).

2.4.5. Future significance

As the world divides increasingly into water rich and water poor regions, and with the projected population growth estimates and proportional demand for resource (primarily water) use, there is no doubt that supply costs and user prices will rise significantly (Quilty, 2003). This reinforces the fact that alternative sources may have to be pursued, to enable international access to fresh water.

The modelled economics of iceberg utilisation indicate a surprisingly cheap method of water supply. Though there is some variation in the literature. Victor (1979) suggests the price of 60 (US) cents per cubic metre of water delivered to Los Angeles, U.S.A., is only slightly cheaper than desalinisation. Where Jones (1997) discusses prices one-quarter that of desalinisation costs. Though water supply would be considered as the primary use, power from icebergs can be harnessed using 'Ice Tec' a recently developed method of energy utilization. In theory a million ton ice berg would be able to support a 100MW station for three years (worth over £100 million) and supply water worth about £75 million (Jones, 1997). The value of energy potential definitely makes this concept more economically attractive.

Desalinisation lacks the ability to produce large quantities of water and the initial costs of setup are large. Though currently there are few countries or organisations with significant interest in iceberg utilization. For example, a recent North American company has just patented a new method of ice berg capture (Johnston, 2001). The future demands for water will grow and inevitably iceberg exploitation will become a reality unless there are new developments in water production. Inevitably it will be the rich nations or large companies that will be the first to begin, which is ironic as these are generally the countries that need water the least.

2.4.6. Summary

Iceberg utilisation may well be the next step in the exploitation of Antarctic resources, however the environmental effects will be minor. The global water demand is rising steadily with population, and water security (being essential for survival) is high up on the agenda for all countries. Although research on iceberg utilisation began over 30 years ago and has been thoroughly investigated, no attempts have been made to capture this potential resource. It is most likely that the western demand for water resources will be the catalyst for the beginning of a new age of hydro-politics. The extent of exploitation will be dependent on two important factors, the relative cost in comparison to other methods of water production but primarily, the demand quantity.

2.5. Bioprospecting

2.5.1. Introduction

'Rich harvest from the ice land, but profits melt away'

This was the international news headline that greeted the readers of the Sydney Morning Herald on the morning of April 12th 2003. (Unknown author) Why would such a story make the lead in a section of one of Australia's premier newspapers? The story referred to bioprospecting, one of the five key areas of resource exploitation we have chosen to explore.

Unlike the mineral, petrochemical and freshwater (ice) resources that may face future exploitation pressures in Antarctica, the marine environment is already being exploited. The level of fishing in the Southern Ocean has increased significantly in recent years, and is discussed elsewhere in this report. Bioprospecting of the marine Antarctic environment is also a current issue. Bioprospecting undoubtedly occurred somewhere in Antarctica yesterday and today. It will almost certainly continue into at least the near future, unless there is a significant change in Antarctic policy and law that is accepted internationally.

But what exactly is bioprospecting? A synthesis of the many definitions that exist suggests that bioprospecting could be simply defined as 'the purposeful evaluation of biological material in search of valuable new products'. Such an activity is certainly not new. The use of biological substances, (sometimes referred to as 'bioactives') which have some form of effect on living organisms has been around since the development of the earliest societies. In its modern form, bioprospecting involves the application of advanced technologies to develop new pharmaceuticals, agrochemicals, industrial enzymes, cosmetics, flavourings, fragrances, and many other products from global biodiversity.

2.5.2. Bioprospecting in Antarctica

The isolated and extreme nature of Antarctica has tempted some bioprospectors away from the already heavily plundered tropical areas that characteristically have a high level of diversity in all categories of terrestrial and aquatic life. The reasons are obvious; the unique environment of Antarctica and the ocean that surrounds it, is home to a large number of organisms adapted to 'life in the freezer'. These 'extremophiles' exhibit physical and chemical adaptations not found elsewhere on the planet. These unique properties make them a good bet as a source of novel bioactives that have the potential for commercial development in fields as diverse as ice-cream production and heart disease prevention.

2.5.3. Environmental, Political and Economic Problems

The very nature of Antarctica has limited terrestrial life to a relatively small number of species, which exist on a tiny fraction of the available environment. Indeed, until relatively recently, Antarctica was considered to have a very low diversity of life. The exploration of the Southern Ocean, and particularly the inshore waters, has led to the discovery of a far greater species diversity. Whilst this low in comparison to many tropical areas, it is the unique nature of many of these organisms which makes them worthy of commercial investigation. Antarctic bioprospecting has concentrated on marine species.

Traditionally, medicines or other organic derivatives have been obtained by a significant harvesting of the source organism. Frequently, this has caused harm to populations, on at least a local scale. Recent developments in biotechnology and genetic engineering mean that very low quantities of original material is needed, as both the process and the eventual goal requires artificial synthesis of the bioactive ingredient.

Modern Antarctic bioprospecting certainly does not seem to be a huge environmental threat. Whilst any human activity in the area has the potential for unintentional damage through pollution etc, the removal of organisms in any quantity (likely to cause harm to either the population or the ecosystem) is no longer a necessary part of the search for bioactives. Of particular commercial interest are marine micro-organisms such as algae and bacteria. Because of their small size and high rate of reproduction, low-volume sampling can provide literally millions of organisms from the sea-water or from marine sediments, and yet at the same time, be virtually undetectable. (Hemmings, 2003)

So, although bioprospecting could arguably lead to depletion of Antarctic species, and could indirectly damage the environment, the reality at the present moment in time is that this is not happening. Nor, is it likely to in the foreseeable future. Why then is such activity an issue at all?

The legal status of bioprospecting, and the complications which follow are the main cause for concern. Potentially lucrative organisms are being patented from a place where no royalties are payable. There is a threat to what is meant to be the common heritage of mankind. Antarctica is a unique place in many ways, not least of which is its legal status, and the fact that it has no native (indigenous) population.

Until recently, organizations engaged in bioprospecting were under no obligation to compensate countries from which biological material had been collected. With the entry into force of the U.N. Convention on Biological Diversity (CBD) (1992), open access to biological resources was replaced by the recognition of the sovereign rights of each country to control access to the biodiversity existing within its borders. In accordance with the CBD, bioprospecting organizations are now expected to share benefits (profits) and transfer technology in exchange for access to biochemical resources. THE CBD however, does not apply to areas that lack national sovereignty. All territorial claims in Antarctica (including New Zealand's Ross Dependency) are held in abeyance under the terms of the Antarctic Treaty. (the Treaty) (Gilbert, N. 2003)

The Treaty, which entered into force in 1961, was originally signed by 12 nations including New Zealand. The original countries have been joined by a further 14 consultative parties, and 18 non-voting nations. The treaty is the core policy document for Antarctica, and to this day guides the majority of Antarctic activities. Importantly, Article VI states that the treaty applies to the area south of 60^0 south. The treaty therefore includes the ice shelves and coastal waters which have been amongst the target areas of bioprospectors. Of particular relevance to the issue of bioprospecting, is Article III, the Free exchange of scientific results. It is this free exchange that is the crux of the current argument against bioprospecting activities within territory covered by the Antarctic Treaty. I will return to this later.

The Treaty, whilst still central to Antarctic policy has been added to by a number of other agreements to form a collective legal framework often referred to as the Antarctic Treaty System (ATS). The ATS currently comprises of the original treaty plus the Convention for the Conservation of Antarctic Seals (CCAS) (1972) and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (1980). The Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) (1988), although produced by Parties to the Antarctic Treaty, has never been ratified. In essence, CRAMRA was superseded by the Protocol on Environmental Protection to the Antarctic Treaty (1991) (The Protocol).

Of these later additions, The Protocol (which although agreed in 1991, did not enter into force until 1998) has potentially the greatest control on future bioprospecting in the area. Significantly, it requires that an Environmental Impact Assessment is completed for every activity likely to have an environmental impact. Annex II of The Protocol requires a permit for the 'taking of, or harmful interference of native fauna & flora'. Fortunately for bioprospectors, the wording (if not the intent) of Annex II currently applies only to birds, mammals and plants, leaving the removal of micro-organisms effectively unregulated.

It appears then, that whilst the intent of many of the framing documents that exist for the legal status of Antarctic activities is to protect and preserve the resources of the area in perpetuity, the reality is that no legal challenge is currently being enforced to prevent the removal of the material targeted by bioprospectors.

What has started to raise the eyebrows of the world with respect to Antarctic bioprospecting, are the concepts of patents and intellectual property rights. To be more specific, the profits that can be made which follow on from these. Bioprospecting institutions, companies or even governments can again thank the wording of international patent law, which actually secures only the 'commercial use' of information and does not prevent the information being freely available to other interested parties. Because of this, patenting does not actually breach the wording of the Treaty. Indeed, because bioprospecting is at least the beginnings of a scientific investigation, it is in some ways supported by Article III of the Treaty!

2.5.4. Future significance

Bioprospectors themselves would of course argue that there is a case for the exploitation of Antarctic resources. Those arguing against this type of exploitation have a strong case when it comes to harvesting or removal of significant quantity of an organism with respect to its population or community. As this appears NOT to be the case with the current approach to sample acquisition, it is difficult to argue that Antarctic bioprospecting is damaging the environment or ecosystem.

With regards to the financial and intellectual sides of the process, the former could be debated ad-nauseum, but in essence, the actual bio-sample itself is so far removed from the processes and costs involved in developing a useful end-product, that any profits derived from it could quite legitimately be attributed almost wholly to the company/group/country that has put in the work.

If current practice continues, then perhaps the most controversial issue is the sharing of information. Because the Treaty does not specify any timeframe for which the reporting of scientific results should occur, it could be argued that information disclosed post-patent is perfectly legitimate. Many would argue that this is not in the spirit of the Treaty, but as it stands, it is certainly within its legal boundaries.

The benefits of bioprospecting in terms of potential to create effective new drugs, useful chemical products, and for profits in a number of other areas are undoubtedly large. The threats to the Antarctic environment at present, are minimal, if not completely insignificant. The threat to the political stability of the Treaty and its membership is however a completely different story!

To avoid a political meltdown, and to avoid current levels of bioprospecting escalating to a level where damage to the environment becomes a reality, it will be necessary to modify (or introduce new) Antarctic legislation.

2.5.5. Summary

Bioprospecting, which can be simply defined as 'the purposeful evaluation of biological material in search of valuable new products', has huge potential for commercial gain. Under increasing pressure as a source of novel 'bioactives', the Antarctic region is likely succumb to a significant increase in this type of activity over the next few years.

Currently, Antarctic bioprospecting does not seem to present a significant environmental threat. Whilst any human activity in the area has the potential for unintentional damage through pollution etc, the removal of organisms in any quantity (likely to cause harm to either the population or the ecosystem) is no longer a necessary part of the search for bioactives.
The legal status of bioprospecting, and the activities which rely upon it, are the main cause for concern. Potentially lucrative organisms are being patented from a place where no royalties are payable.

The threat to the political stability of the Treaty and its membership is perhaps the greatest imminent problem of Antarctic bioprospecting. To avoid a political meltdown, and to avoid current levels of bioprospecting escalating to a level where damage to the environment becomes a reality, it will be necessary to modify (or introduce new) Antarctic legislation.

3. Discussion and Conclusion

The resources of Antarctica present both great opportunity and great difficulty for the global community. International views on access to the section of our planet south of 60^0 South differ as widely as political, moral and social views differ within any given group of people.

The ATS has to a large extent managed to control both activity and cooperation within the largest unspoiled wilderness left on Earth. The very nature of a system that chooses to ignore individual territorial claims as a key part of its structure runs into difficulty when global social and economic pressures create the type of situations that historically have led nations to dissent or even war.

It is unlikely, that a consensus opinion could ever be reached from the global community as a whole. What is important then, is that future regulation of the activities we have discussed earlier in this report, (along with any other activities currently or potentially possible in the Antarctic region) is made in such a way that it is both functional and acceptable to all concerned. Member states of the ATS as well as other nations likely to have an interest in Antarctica, need to reach a stable consensus to avoid existing and future legislation being broken or ignored. If this does not happen, the potential for irreversible damage to the Antarctic environment and/or political stability could occur.

Antarctica remains unique in the need to manage an area that is at the same time without nationality and yet subject to the claims of many nations that are currently held in abeyance. To move forward in many areas we are going to have to seriously address the issue of territory. Global regulations already exist which effectively and successfully control access to resources and profits made from those resources when they fall within national territory. Similarly, global commons such as the high seas are managed by regulations that have been universally accepted. The key issue is that Antarctic policy and politics currently spans both of these worlds, and it is difficult to see how this will ever be resolved.

Clearly activities such as fishing in the Southern Ocean, and limited (predominantly oceanic) bioprospecting are likely to continue into the foreseeable future. Appropriate control and management of these activities may well allow them to continue in an effective yet essentially benign manner. Similarly, whilst the removal of icebergs as a source of water appears at the present time to be an economic and logistical minefield, iceberg utilisation may well be the next step in the exploitation of Antarctic resources. The environmental effects (at least to Antarctica) will be minor, with the caveat that any increased activity carries with it the risk of pollution and associated environmental degradation. The Western demand for water resources will almost certainly be the catalyst for the beginning of a new age of resource use, and a large step in the evolution of hydro-politics, which will face the same problems as any other resource needing a single Antarctic voice to guide its development.

We have already mentioned that Antarctica's continental shelf can be referred to as one of the most unsuitable regions in the world for the exploitation of oil and gas. This applies equally to the exploitation of non-organic minerals. History reveals that difficult terrain and extreme environments can, and have been exploited if the rewards are considered great enough. Unlike current bioprospecting practices, regulated fishing and the possible use of icebergs to quench a global thirst, the exploration and exploitation of potential oil and gas and other mineral reserves in the Antarctic are certain to have considerable environmental impact; the type of impact that would be irreversible.

It is hoped that before the pressure to exploit the short-term economic gains of Antarctica's geological resources becomes insurmountable, there will be a political consensus to ensure that resource utilisation worldwide is optimised. This should include intensified recycling of all non-renewable materials, as well as extensive research towards providing alternatives to non-renewable resources.

In the spirit of these remarks, we would like to conclude our report by 'recycling' a quote we used earlier.

'There is no justification for the exploitation of Antarctica, except in terms of human greed. For we do not need Antarctica's supposed resources – we merely desire them to prolong a way of life which must, ultimately, come to terms with its own bankruptcy' (Friends of the Earth, 1982 (In Wit, 1985))

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