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Antarctic Science and its Likely Directions

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The Madrid Protocol to the Antarctic Treaty, for which Australia was one of the prime movers, has designated Antarctica as a 'natural reserve devoted to peace and science'. These are interesting words. No one could have any quibble about the word 'peace', but why 'science'? Certainly it is an acceptable activity from an ethical point of view, and a contrast is probably intended between the exploratory and conservatory nature of science and the exploitative activities of economics, commerce, industry and technology, but it immediately begs the questions 'Why science in Antarctica?' and 'What science in Antarctica?' In this chapter I shall try to provide answers to both these questions.

WHY SCIENCE IN ANTARCTICA?

Few governments, if any, are willing to provide more than limited support for science simply on the basis that it is a noble intellectual activity. The political rhetoric and the funding policy, in Australia as well as in most other countries in these financially difficult times, is that science is supported largely because of its potential economic payoff. Of course the payoff may be indirect, and that it must be in the case of Antarctica, where commercial activities apart from fishing and tourism are virtually forbidden. What then is the payoff, from a government point of view, for an expenditure that is really very large in the overall context of Australian research funding?

Australian government policy in relation to Antarctica lists several objectives, as set out in Chapter 1. Several of these are unarguably admirable, but certainly indequate as a reason for large expenditure, given that there are similar and more pressing problems and opportunities within Australia itself. The objective of 'deriving any reasonable economic benefits' from the non-mineral resources of the area is, as yet, something for the future, even in relation to fishing. The prime political objective is 'to preserve our sovereignty over the Australian Antarctic Territory', even though recognising that claims of national sovereignty are at least temporarily in abeyance under the Antarctic Treaty, and it is towards this objective that most Australian Antarctic activity is ultimately directed.

The principal way in which such a potential claim can be maintained is by carrying out activities in Antarctica that are of the sort that a sovereign nation might be expected to undertake in its own territories, having regard to the restrictions imposed by the Treaty. This basically means carrying out scientific activities, including environmental management, that are recognised internationally as being of importance. Only in this way can Australia maintain its influence among the nations party to the Antarctic Treaty. From a government point of view, this is the main payoff, although we shall see that there are a few more direct advantages because of Australia's relative proximity to the Antarctic continent. It is difficult to think of any activity other than scientific research that would suffice in this context.

WHAT SCIENCE IN ANTARCTICA?

So then, what type of scientific activity should be carried out in Antarctica? If the money is to be expended in pursuit of Government objectives, then we should certainly aim to achieve a maximal return, in scientific and other terms, for the investment. The choice depends upon a number of criteria. To undertake any sort of scientific research activity in Antarctica costs about ten times as much as doing the same sort of research in mainland Australia. The reason, of course, is the need to maintain well equipped base stations from which to work, the costs of inter and intracontinental transport, and the limitations imposed by difficult working conditions. This immediately makes it clear that we should not attempt to do in Antarctica research that could possibly be carried out as effectively somewhere else, unless the only other possible site is even more expensive, such as in space.

The second criterion relates to the value of the contemplated research, and is rather more difficult because several factors need to be considered. All scientific research should be thought of in terms of posing and answering questions, and much of the art of scientific research lies in asking the right questions. It then makes sense to ask, assuming that the research leads to an answer to the question, 'Who will be interested in the answer?' and 'Will the knowledge contained in the answer help anyone?' The first criterion is primarily a matter of scientific quality, the second of practical utility. There are many possible scientific programs of high quality and very significant interest that have no obvious short-term practical consequences, while many routine monitoring programs seem dull and boring but provide valuable data that can be used to help the general community, and may unexpectedly turn up something exciting. Clearly, wise decisions are necessary, and an appropriate balance must be struck. Australia's policy interests in Antarctica could be advanced by good programs of either type.

The Antarctic Science Advisory Committee (ASAC), in its 1992 report *Antarctic Science: The Way Forward* (ASAC 1992:37), recommended that the allocation of resources to science projects be based upon the following criteria:

- *first priority* should be given to research that has both scientific and practical importance and that can only be conducted in Antarctica, the sub-Antarctic or the Southern Ocean; it primarily relates to studies of global and regional change (particularly climatic change), the management of the marine ecosystem, and associated data gathering and monitoring.
- *second priority* should be given to:
  - research on uniquely Antarctic, sub-Antarctic or Southern Ocean topics which supports the areas of first priority research (such as biology of Antarctic plants and animals); or to
  - research which supports management strategies for the region (such as those aimed at protection of the Antarctic environment).
- *third priority* should be given to other scientific studies for which the Antarctic is an essential or particularly convenient location.

In order that decisions can be made on the basis of these priorities, it is necessary that research programs should be well defined, in terms of their scientific objectives. Careful planning of the programs themselves is also necessary if they are to be carried out effectively in the difficult Antarctic environment.

While these remarks are directed specifically at Australia's activities in the Antarctic, they apply quite closely to the activities of other nations working in the area. There is, indeed, a good measure of agreement about what programs should be developed and undertaken, and there are several major international programs to which Australian scientists contribute.

AUSTRALIA'S ANTARCTIC SCIENCE PROGRAM

Australia's Antarctic Research is carried out by a large and mixed community of scientists. The Australian Antarctic Division of the Department of the Arts, Sport, the Environment and Territories is responsible for operating all Australia's Antarctic stations, and for all aspects of Antarctic transport and logistics, and also conducts scientific research programs in marine, terrestrial and human biology, in glaciology and in upper-atmosphere physics. The Bureau of Meteorology operates an extensive Antarctic meteorological data program and uses these data in its Australian and global forecasts, as well as in specific forecasts for Antarctic regions. The Australian Geological Survey Organisation also operates a geophysical data gathering service in Antarctica. These three organisations have joined with the University of Tasmania and the CSIRO Division of Oceanography in a Cooperative Research Centre, funded by the Australian Government, to undertake research in Antarctica and the Southern Ocean. In addition, a large number of researchers from universities, together with a few from other government agencies and research organisations, between them contribute more than half of Australia's total research effort in Antarctica.

To give some idea of the high cost of supporting this research, the 1991-92 budget of the Antarctic Division was about $68 million, much of which went to provide logistic support for scientists from the Division and other organisations working in Antarctica. Counting contributions from other organisations, total Australian expenditure in the 1991-92 financial year was about $74 million. Australia's Antarctic stations have been substantially rebuilt over the past ten years at a cost of about $100 million, and now have a replacement value of around $200 million (see Chapter 8). This expenditure supported about 400 personnel travelling to Antarctica during the year, of whom about 170 were scientists or scientific support staff. The general scale of this program is comparable with the Antarctic activities of Britain and of Germany, though some aspects of their operations are rather different. Despite its magnitude, however, the budget is a fragile one because of the large infrastructure component - a reduction in funding by $10 million, for example, would effectively halve the amount of science that could be done.

Over recent years, the emphasis in the research program has tended to be on biological sciences and glaciology, with programs in earth sciences and physics also making substantial contributions. In the past two years, following the formation of the Cooperative Research Centre, there has been increased activity in oceanography and marine science, with a large increase in the amount of sea-time available on the research and supply vessel Aurora Australis for marine research.

DETERMINING FUTURE RESEARCH DIRECTIONS

Up to the present time, the direction of much of Australia's Antarctic research has been determined by the general community of Antarctic researchers on what might be described as an opportunistic basis. Each year ASAC calls for applications from scientists and others wishing to undertake Antarctic research, including scientists proposing programs from within the Antarctic Division itself. These proposals are evaluated by specialist Antarctic Research Evaluation Groups with independent chairpersons and either approved or not approved, largely on the ground of scientific quality. In the case of researchers from universities, approval generally carries with it a small research grant, typically around $10,000, but this grant pales into insignificance beside the logistic support of around $100,000 typically involved in a single-person project in Antarctica. This procedure is thus essentially a passive selection of the most promising projects from those put forward by the researchers concerned, bearing in mind the rather general set of priority areas defined by ASAC in an earlier report (ASAC 1991).

Under the proposals made in the ASAC report *Antarctic Science: The Way Forward*, a more disciplined approach will be adopted for the future. Program leaders will be nominated for each of the major branches of Antarctic science, and it will be a first-priority task of these program leaders, in consultation with the scientific community in their research areas, to develop a strategic science plan for that area. This recognises, of course, that strategic plans are not immutable, but must be continually revised in the light of new scientific information. For Antarctic science, however, even the logistic arrangements must be made more than twelve months in advance - some plans as long as five years in advance - and it is imperative that probable scientific directions are known over a very much longer time scale. Only in this way can the scientific objectives determine the logistics, rather than vice versa.

The Minister has not yet finalised her response to the recommendations of the ASAC report. These scientific plans are therefore still in the early stages of development, and I cannot report on their content. In some areas, researchers already have coherent objectives and research plans extending for many years into the future, but research in other areas has been simply the sum of individual ideas and opportunities, put together without the aid of a coherent set of scientific objectives for the area as a whole. Of course not all scientific advance can be planned and coordinated, and arrangements must be made to allow the support of bright short-term projects and to provide for rapid response to scientific opportunities, but these should be seen against a background of planned objectives and operations. An individual scientist requiring little in the way of equipment and operating expenses can allow himself or herself the luxury of simply following research leads as they occur. But when even a single project involves a share of the massive costs necessarily associated with Antarctic science, common sense demands coordinated forward planning.

The major areas of research interest that I see being pursued under Australia's Antarctic science program for the next decade or so are outlined below. This is done under a rather broader set of headings than were used in the ASAC report for simplicity of presentation, recognising that one must really consider research in a matrix with the columns representing the scientific and practical problems to be solved and the rows representing the scientific disciplines that contribute to finding the solutions.

THE PHYSICAL ENVIRONMENT

It is a perceptive statement that 'Everybody talks about the weather, but nobody does anything about it!' Weather and climate provide the background against which we live out our lives, and in our developed countries we scarcely give them the attention they deserve.

It is in the nature of weather and climate to change in a complex way, and the changes may even be chaotic in the technical sense, implying that while we may be able to make accurate predictions on a short time-scale, on a longer time-scale only certain global averages and fluctuations around them can be calculated. Certainly that seems to be the situation at present. Against this backdrop, Antarctica has an important role, both as a repository of the climate record back through hundreds of thousand of years, and as an active participant in influencing future climates. Only if we understand enough about climatic history and present climate dymanics will we have a chance of making useful predictions.

The Antarctic climate record is contained in annual layers in the ice cap and in the offshore sediments, both of which can be explored only by deep drilling to recover cores. Many of these drilling efforts are international, but Australia has contributed and Antarctic Division scientists are currently engaged in a drilling program in the high ice-accumulation area of Law Dome to retrieve a high-resolution record of climate over about the past 30,000 years. It is in the nature of this sort of work that drilling extends over several years, so that the program must be carefully planned. Similar remarks apply to ocean sediment studies.

The claim that nobody does anything about the weather is, however, not strictly true, at least when applied to the long-term aspects of weather that are more properly described as climate. Maintenance of the earth's present average temperature depends critically upon the presence of so-called greenhouse gases, principally methane and carbon dioxide, in the atmosphere. The concentration of both of these, but particularly carbon dioxide, is rising steadily because of our consumption of fossil fuels, and will probably have doubled by the middle of next century. At the same time, industrial processes have released fluorocarbon componds into the upper atmosphere which deplete the protective ozone layer. It would be surprising if these changes had no effect on average climate, and indeed our best current predictions suggest a rise in global mean temperature of nearly two degrees. This does not sound much, perhaps, though even in the last ice-age the mean temperature fell by only about six degrees. What may be much more important than temperature itself, however, may be the redistribution of rainfall. Australia is perhaps large enough in geographic extent that negative effects in some areas will be balanced by beneficial effects in others but, on a world scale, huge disruptions may be caused.

It is important to know as much as we can about the dynamics of weather and climate, and Antarctica may contribute quite significantly because of its large area and reflective ice coating. The sea ice, which almost doubles the white area in winter, may be particularly important and, of course, if there is any change in the amount of ice in the Antarctic cap this will also have a great effect, though probably only on a very long timescale. We must try, therefore, to find out as much as we can about the dynamics of the ice cap, the dynamics of sea ice, the characteristics of Southern ocean currents, and the way these things couple to the global ocean and atmospheric systems. The program is, of course, international, but Australian scientists are making notable contributions in all these areas, as well as in southern hemisphere meteorology and studies of the upper atmosphere. Much of this work has direct practical application because of our proximity to Antarctica and the influence of the Southern Ocean on our weather.

The areas of study that I have outlined here are all accorded first priority in the ASAC proposals for future research programs. The general thrust of the programs in the physical environment should be to know as much as we can about the processes influencing climatic stability and climatic change, both by uncovering and studying the historical record and by examining the dynamics of the ice, ocean, and atmospheric systems involved. We are not likely to be able to prevent these changes, though we can mitigate those caused by greenhouse gases, but at least we may be able to prepare for the necessary adaptations in our lifestyle.

BIOLOGICAL SCIENCES

The Antarctic is a varied region from a biological point of view. The interior of the continent is virtually devoid of any form of life. Exposed rocky shores and nearby lakes support a limited number of bird and animal species such as penguins and seals, together with small forms of plant life, while the sea is rich in plankton, krill, and many species of marine animals. In comparison with, for example, rainforests, the Antarctic marine ecosystem is simple and robust. Only the inhabitants of the small regions of exposed rock around the edge of the continent suffer appreciable environmental stress, but it is with these that there is most concern.

From a scientific point of view, all plants and animals are interesting and worthy of study, but this interest intensifies when the physiology of the plant or animal is unusual, as exemplified by deep-diving seals, or plants and animals living in extremely cold conditions. This basic information is really needed for scientific understanding of the working of the ecosystem, which could at a more practical level be documented by study of food chains and reproductive life cycles. We must beware, however, of giving excessive attention to those species, such as penguins and seals, that have caught the popular imagination, at the expense of the more important but less glamorous micro-organisms, lichens and krill.

All this is, however, really background information for our main concerns in relation to the biology of the Antarctic. Another long-term objective of Australia and other nations in this area is to be in a position to achieve maximal economic return from harvesting the biological resources of the area, without at the same time damaging the ecology irreparably. At an even more enlightened level, a subsidiary aim is to maintain the biological diversity of the area as insurance against the possibility of future needs. To accomplish either of these objectives, sustained scientific research over many years will be necessary.

ASAC places this ecosystem/bioresource-management program among its first priorities for several reasons. The first is that, in this area, humanity already has the ability to effect drastic changes in a short time through over-harvesting of particular species or through inadvertent damage to the food chain by pollution or other human activities. We can only make what appear to be rational decisions on the basis of existing knowledge, and if that knowledge base is inadequate then the decisions may well be wrong, and could cause immense damage before they can be reversed. The importance of this research is recognised in the international program under the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), to which Australian scientists make a major contribution.

The second reason is that, as the world continues to make such lamentably slow progress in reducing birthrates, though the means have been provided by natural scientists, the increasing world population is moving us ever closer to major disaster. In the long term we may perhaps be able to arrest the human plague before we destroy ourselves, or nature may restore a reasonable balance through spread of new virus strains, but it is most likely that there will be considerable pressure on available food resources. The Southern Ocean may perhaps provide a source of protein that becomes essential.

Planning of coordinated research in this biological area is important but difficult. There is a long tradition of simply studying particular biological species for their own intrinsic interest, and no doubt a wealth of information can be amassed in this way. Because of the cost of Antarctic research however, and the scarcity of information about some of the more important populations, it will be necessary to focus attention on those populations that are really significant, such as krill, rather than on those that are merely popular, such as seals and penguins.

Let me also mention here Antarctic medicine, which is in a special category. Clearly each Antarctic station requires the presence of a doctor throughout the whole year on grounds of safety. The presence of these people is often critical to life, but at other times their duties may occupy a relatively small amount of time. This has presented the opportunity for mounting, at little expense, a program of research into human adaptation to the remote and hostile environment of Antarctica. The results of this research have have benefited not only the Antarctic operation itself but have provided valuable data in preparation for missions in space. In this latter case, research in the Antarctic is more realistic and less expensive than most conceivable alternatives.

EARTH SCIENCES

The Madrid Protocol rather explicitly rules out development of mineral deposits in Antarctica, or drilling for oil around its continental margins. Even though such commercial mining or drilling was not really being considered seriously, for reasons of difficulty and cost, this Protocol removes much of the practical impetus for work in the earth sciences in Antarctica, and justification for support of the research must rest upon more general grounds. We have already noted the relevance of the record contained in certain marine sediments to the climate-variation program, and the same is true of glacial deposits that document aspects of the history of ice-sheet movements. There are also certain geophysical observatory functions that are clearly valuable in a global sense and that can be carried out only in Antarctica. But what are these more general grounds for undertaking research in the earth sciences?

In my introduction I noted that the Australian government is interested in maintaining its international influence in Antarctic matters and in similarly maintaining Australian claims to sovereignty over the Australian Antarctic Territory. One of the major ways in which this latter claim can be maintained is by carrying out in the AAT the sort of work that a sovereign nation would normally carry out in its acknowledged territories. One of the principal activities of this sort is mapping, of both topography and geology. A topographic map can be drawn, to a large extent, on the basis of remote sensing from appropriately equipped satellites, but for a geological map there is at present no substitute for trained geologists on the spot. Unfortunately, perhaps, nearly all of Antarctica is covered by a thick ice cap, so that rock outcrops are rare, but there is good justification for finding out all we can about what is exposed. The same goes for geophysical work and drilling offshore. The aim is simply to find out what is there, to map it appropriately, and to relate what is discovered to the geological history of Antarctica and its once neighbouring tectonic plates in the great continent of Gondwana. One of these was, of course, Australia, so that discoveries about the continental margins of Antarctica help inform us about some aspects of the geology of Australia.

SCIENCE OF OPPORTUNITY

Finally I come to those scientific programs which are in a sense peripheral to Australia's major research interests in Antarctica, but are nevertheless of considerable scientific merit on their own account. For these programs, in most cases, Antarctica is a convenient or even essential place in which to conduct the work. The work itself is not directly concerned with Antarctica. In many cases these programs are of the highest scientific merit and interest to the international scientific community. ASAC has decided to place these programs, for the most part, at third priority for funding from currently available Antarctic research funds, but has suggested that every assistance should be given to such projects provided that they have received their major funding from other sources.

The other major class of activities for which Antarctica is an excellent platform is that concerned with space science and astronomy. Let me discuss astronomy first. The major problems with earth-based optical telescopes are the fluctuations in seeing caused by atmospheric turbulence and nonuniformity, and the loss of information by absorption in the atmosphere, particularly at infrared frequencies. These problems have been overcome, at immense expense, by deployment of the Hubble telescope in space. It has been proposed, however, that the high Antarctic plateau is, from these points of view, an ideal location for large telescopes, particularly in the infrared and millimetre bands, because there is little wind or cloud, and the high altitude and extreme cold makes the residual concentration of water vapour above the site very small. Certainly the site is remote and inhospitable, at an altitude of 3000 metres and with a winter temperature of -80°C, and the observatory will be immensely expensive to construct and operate - perhaps ten times as expensive as at a more conventional site. But this still makes it ten times cheaper and much more convenient than a telescope in space. If the astronomical community can find the funding for this exciting endeavour, then it will certainly be considered for logistic support in the exploratory and operational stages, though special arrangements will probably have to be made during the construction stage.

More modestly, the Australian Antarctic program has, in the past, supported a considerable amount of research in ionospheric and space physics, and in cosmic ray physics. For both these fields a location close to the South Pole is ideal, since many of the phenomena are closely linked to magnetic lines of force that cut the earth's surface around the South Magnetic Pole. Again, it is the view of ASAC that these studies are scientifically very valuable, but generally do not relate directly to first or second priority programs in Antarctica. For this reason ASAC has recommended that these programs should seek their major funding from sources other than the Antarctic program. In many cases, the Antarctic component of the research simply involves the operation of more-or-less automatic equipment at selected sites in Antarctica, and it is reasonable that technical staff in Antarctica primarily for other reasons should assist by checking and maintaining this equipment. In this way, the valuable series of observations that have been built up over the years will be maintained, but the main tasks of interpretation will be carried out under other funding.

OTHER PROGRAM AREAS

Finally, let me not omit mention of programs in the social sciences and humanities, for these too have a place in Antarctic research. They often receive little attention because their needs for funds and facilities are small in comparison with scientific programs, and because most of the work can be carried out in Australia, with little or no need to visit Antarctica at all. Programs in this area include those related to the history of Australian activities in Antarctica, and to the legal regimes and management strategies that should be applied to the area. These are important matters and will occupy much of our attention at this conference, but because they are not included in the natural sciences they do not fall within the area of this paper.

CONCLUSION

The devising of a conservation strategy for the Australian Antarctic Territory is an important venture and one that will depend for its success upon the availability of reliable scientific information and understanding about the physical environment and ecology of the Antarctic continent and its coastal waters. I believe that the program of scientific priorities that has been established by ASAC and the strategic science plans that are now being devised by program leaders in consultation with the scientific communities in their areas will provide the necessary basis for establishing a realistic strategy. The presence of an ASAC representative on the Antarctic Conservation Strategy Steering Committee should ensure that there is a close and significant link between the conservation strategy that is developed and the objectives, strategies and programs of the Australian Antarctic science program.

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