To Eliot Porter
for comment, please
—Dave Brower 6/12/76 (en route Japan)

Not for Quotation

DRAFT MATERIAL
Relevant to a
Possible International Coordinated Program
for the Exploitation of Antarctic Resources

Preliminary

Most of this material was prepared for another purpose, and will require extensive reorganization before it can be made publicly available.

It is apparent however that at this time, when interests in Antarctic resources are increasing, there is no attempt to coordinate plans, or even research (or exploratory) programs among the signatory nations to the Antarctic Treaty. To some extent this is a reflection of the diverse resources involved. A Convention for Antarctic Sealing has discussed possible quotas or limits for the taking of seals on the pack ice. Whaling has long been a subject of international discussion, while the whale stocks have decreased almost to the vanishing point. There have been several experimental fisheries for krill and some Antarctic fishes; these exploratory efforts have been treated as samplings of the commons of the high seas. No one so far has suggested harvesting penguins. Exploratory drilling suggests there may be hydrocarbon resources in the shelf waters of Antarctica. The prospect of valuable minerals, especially in the Pensacola Mountain regions, may result in a sort of international prospecting race between the United States and Russia, reminiscent of a high seas fishery in that both nations would treat the Antarctic continent as a sort of sea or common resource. The various resources would bring very different kinds of experts and viewpoints to the conference tables, and it would appear that if any coordination or agreement is to be attained, these differences in resources and the approach to them must be considered and the natural divisions, possibly of land, shelf-pack

ice regions and the high seas, recognized. Certainly the problems of coordinating resource exploitation on land and sea must be approached in fundamentally different ways. The Antarctic is available to anyone who has the resources to get there and while at the present time the resources to get to Antarctica exceed the possible value of resources to be gained, in time this may not be so. What happens in Antarctica may depend in great part upon whether a Law of the Sea is eventually achieved.

Joel W. Hedgpeth

Concerns

Antarctica and its surrounding ocean is the most inhospitable environment to man on this planet: the land mass is covered by ice and snow, with a few mountain ranges projecting above the ice; air temperatures are seldom above zero over the land and there is no place where man may live without bringing everything with him that he needs to survive. Other than levying upon the populations of penguins and seals to extermination in limited regions, there would seem to be little that we could do that will leave a permanent trace; as Captain Robert Falcon Scott said of the expeditions of his era, "for one brief moment they settle, eat, sleep, trample and gaze, then they must be gone, and all must be surrendered again to the desolation of the ages".*

In recent years, however, our capacity to affect our environment has increased to such an extent that we can leave permanent traces on the Antarctic land, and we can trace some of the effects of our actions in other parts of the

*The Voyage of the Discovery.

globe in the ice and perhaps in the air of the Antarctic. Insofar as our interest in the Antarctic as a site for monitoring global aspects of our activity on earth and for the study of life processes at a simple and severe level uninfluenced by the presence of man is concerned, we have become aware that we must respect this environment for its potential value to scientific research and govern our actions so that we have as little impact upon it as possible. While we cannot control potential allochthonous pollution such as industrial wastes, pesticides or radioactive fallout so far from the source, we have become aware that we must reduce the potential impact of our own activities in Antarctica, or at least be certain that we do not confuse such matters as exhaust from aircraft and surface vehicles used in Antarctica with what may settle on the continent from elsewhere in the world, and that we severely limit introduction of alien organisms to Antarctica.

Our concern for the environment of Antarctica has frequently been expressed in articles in the Antarctic Journal of the United States, especially in the issue of May-June, 1971. These articles, which were prefatory to the Colloquim on Conservation Problems in Antarctica held in Blacksburg, Virginia, in September of that year, were reprinted in Frozen Future, A Prophetic Report from Antarctica (Quadrangle Books, 1973), somewhat cavalierly edited by Richard S. Lewis and Philip M. Smith. The proceedings of the Colloquim were published by Bruce C. Parker in 1972 (Blacksburg, Virginia, printed by Allen Press, Lawrence, Kansas). These references are valuable sources of information relevant to our impact upon the environment of Antarctica, as well as indications of our growing concern for preserving, insofar as possible, the integrity of the Antarctic environment.

Tourism

Under the category of allochthonous impacts, we must include tourism, primarily because it is a business operation at this time outside the influence of the deliberations of SCAR and the Recommendations of the Antarctic Treaty. Yet it is the only commercial business so far developed in Antarctica. It depends to a considerable extent on our scientific activity in Antarctica and, without the publicity of IGY and international research under the aegis of the Antarctic Treaty, tourism would probably not have got its start. Visiting research bases is part of the tour; to be sure, there is no other kind of settlement to visit in Antarctica. One recent TV program, shown over KTVU on October 26, featured a Lindblad tour of the Antarctic Peninsula. Most of the footage was of droves of penguins moving back and forth. A visit to the whalebone piles at Port Lockroy and a view of Palmer Station were included, with the strong implication that Palmer Station was a regular part of the tour. Although ostensibly a nature program, it seemed more like a half-hour commercial for the tour.

There is no international control of the routes and destinations of tour ships or of their frequency of visitation. In addition to visits to active bases to observe scientists in action, tour groups may visit abandoned bases or defunct whaling stations and, of course, penguin rookeries, wherever accessible. We do not have adequate information on the effect of repeated but short visits to penguin rookeries, although it has become apparent that continued activity by men near large penguin colonies may result in some decrease in populations as at Cape Hallet. This also seems to be the case with skuas.

In any event, it is undesirable to have groups of people tramping

around and among nesting birds anywhere in the world. When touring groups are supervised or chaperoned by a naturalist, disturbance of the birds and gathering of souvenirs is probably under reasonable control. Not all these tour groups provide naturalists, nor are all shore parties supervised. While we are not aware of any severe damage done to the penguins or the scenery from the present level of tourism, it seems bound to increase and may result in easily visible effects in those areas most easy of access. In this respect, the Antarctic and the Galapagos are remarkably similar, for, in the Galapagos, the places where one may land, especially if one is not too spry, are limited, and the pressure is building up in these few restricted areas.

The most serious aspect of tourism is the resultant litter, both from shore parties and from the sanitary practices on the ships. A tour ship proceeding down a restricted channel, such as the Gerlache Strait, may leave a trail of souvenirs along the shore: cans, bottles, package wrappers, and other detritus, as well as waste from the galley and heads. In time, such litter may become obvious enough to detract from the appearance of the environment where man's presence is minimally apparent. Another danger from intensive tourism is the possible destruction of abandoned bases. These bases are not simply historical relics of past explorations; the buildings are traditionally left standing and unlocked to provide shelter for explorers or scientists who may find themselves in difficulties. It is easy to start fires in Antarctica and almost impossible to stop them. Therefore, it is to the advantage of visitors of all nationalities to make every effort to leave these places as they found them.

In some ways, the ultimate in tourism was the visit of the Calypso to the Antarctic banana belt, a few years ago. Ostensibly a scientific visit,

the most tangible result was a film for TV viewing in which the personnel behaved like the ultimate tourists, arranging old whale bones, at an abandoned whaling station, in a vaguely anatomical order on the beach, and their leader consumed his prime time making out as if he were in instant touch with all the significant oceanographic happenings in Washington. While all this was going on, the ship's cook casually tossed his slops over the side as if he were in any other part of the world, despite the narrator's implication that the dauntless explorers were in territory seldom, if ever, seen by man before, and his well-known warnings that the oceans are dying from the thoughtless activities of man. Among the litter left behind by this expedition were 50-55 drums of bottles and trash.

Probably this business will be more difficult to control if it prospers in the future, yet some international accord on the management and conduct of these cruises would be desirable. Not only should there be an experienced naturalist or scientist aboard to impress upon the tourists the need for leaving things as they find them: the officers and crew must be willing to forego the convenient practice of throwing everything overboard, especially in small embayments and in channels, or it may not be long before the ships that follow may have a course well-marked by artifacts. Cruise ships to fragile environments should have litter receptacles on deck, especially for the rejects of photography, and waste disposal should be deferred until the ship is well out of sight of land. The charm of the Antarctic to visitors is that there is nothing but snow and ice and penguins and other birds, and continued littering and molestation of the penguins will make touring less attractive, in the long run. This is an environmental impact that could be avoided by care and appropriate indoctrination.

Tourism is growing both in magnitude and capacity. The first Lindblad Tour to Palmer Station in February of 1970 utilized a chartered vessel of no particular distinction; now, only five years later, a special ship, the Lindblad Explorer (built in 1969), conveys luxury cruises all over the world; during the Antarctic season of 1975-76, it will offer four cruises along the Antarctic peninsula to the Antarctic Circle. It may not be long before this enterprise musters enough logistics capacity to get along without the assistance of research stations and can convey its patrons to such potential tourist attractions as the Dry Valleys.

Exploratory Drilling and Oil

The proposal to drill through the Ross Ice Shelf some distance from the front was first discusses by Zumberge (1971); the project is now in its preparatory stages, although schedules have been upset by aircraft losses. From the scientific point of view, there are many interesting questions, and obviously we will not know enough about the nature of the ice-sea interface beneath the shelf, the fauna, nature of bottom sediment, or possible hydrocarbon deposits to predict possible impacts until a hole is actually drilled and samples taken. We are not even certain that there is any life far back beneath the ice at all. Hence, our initial concern is for possible accidents during the drilling process, such as leakage of oil used to lubricate the drill, loss of equipment, and the like. The surface base itself located remotely from land and sea (Figure A) is not expected to have much impact on the ice shelf, as the site will be covered with snow and ice within a year or so after completion of the project and will move toward the sea at the rate of approximately a meter a day. If such movement

is steady and in one direction (which it may not be), it is expected that the abandoned base and materials such as wastes and ashes would reach the ice front and calve off into the sea in about a thousand years.

The possibility, although considered remote, of striking a pocket of hydrocarbons and causing an uncontrolled release, has been considered the maximum possible impact. However, the magnitude and effect of the environmental impact, as contrasted with oil spills and outbreaks in warmer seas because of the expected low decomposition rate of hydrocarbons (oil) in the low temperatures of the Ross Sea, would be of less immediate significance.

Similar concern for a possible blowout has been expressed over the activities of the Glomar Challenger and other similar deep sea drilling projects, and for the inevitable leakage of oil from wells on the continental shelf, should oil ever be discovered in commercial quantities near Antarctica. The Glomar Challenger is not an oil-prospecting vessel, however, and at the first trace of hydrocarbons, a hole is immediately plugged and abandoned. Oil well technology has not yet reached the stage of coping with the problem of maintaining a well-head under the annual pack ice. Undoubtedly, such technology will be developed in time.

Discussion of possible production of oil also raises the matter of pollution from leaks, spills, runaway wells and tanker mishaps. With respect to the 70 million square kilometers of the Antarctic Ocean, it would take a rather large quantity of oil to have a noticable impact. A thousand cubic meters (about a thousand tons) of oil, if spread in a layer a millimeter thick, would cover a square kilometer. While the oil would probably not be spread evenly in a layer only a millimeter thick, it would take something like 500 billion tons of oil to

cover only 1% of the Antarctic Ocean to a thickness of a millimeter. Such a release seems highly unlikely, but a discharge of such magnitude would be necessary to have a noticable impact upon the sea-air interface in open water.

Spills or leaks of 1,000 tons are more possible, and the coincidence of such a small spill with a swarm of krill might cause some mortality. Where krill are abundant, irregular patches on or near the surface averaging perhaps 2500 square yards (about 2,000 square meters) may be distributed closely but not evenly over an area of 150 square miles or more than 380 square kilometers (Hardy, 1967). Complete blanketing of a massive krill swarm would require far more oil than is likely to be spilled by the largest modern tanker, and it is to be doubted that very large tankers can work safely in Antarctic waters in any event. A more serious danger to krill populations might arise from trapping of oil beneath the pack ice. We do not yet know all that we should about the life cycle of euphausiids, especially the spawning area of Euphausia superba, but it does appear that their early stages may be passed under the edge of the pack ice, and exposure of the larval stages to oil trapped beneath the ice may result in greater losses than to adults. It is safe to assume some loss of krill from oil pollution, but we lack at this time the necessary information to estimate the possible extent of such loss.

Penguins are very vulnerable to oil; perhaps because of their "porpoising" habit, they are most easily exposed to patches of oil on the surface and lose their insulation when fouled with any kind of oil, including the offal of a fish cannery (Anonymous, 1975). This suggests that a comparatively insignificant oil spill, should it occur along a shore near a penguin rookery, would result in severe losses. Also, a surface patch of only a few acres in an area where penguins are actively feeding would cause high mortality in a group of penguins. If

penguins are as gregarious at sea as on land, an entire colony could be wiped out by a minor oil spill.

Several studies are now in progress, most of them related to the impending production of massive quantities of oil in the Arctic (Hoult et al., 1975; Lewis, 1975), and degradation of petroleum in low temperatures (Traxler and Cundell, 1975). These studies indicate that it is possible for oil to be entrapped in the ice as lenses and carried some distance from the source without degradation, and that such degradation is not necessarily slowed down under very cold conditions. Although Traxler and his associates have not yet completed studies of oil degradation at Antarctic temperatures, they have found evidence of psychrophilic oil bacteria at winter temperatures in New England, and that "Hydrocarbon biodegradation was mot apparent during the winter months and at rates approximating 1 µg of hydrocarbon per g of dry sediment per day." The rate of solution of water soluble fractions from crude and diesel oils at Antarctic water temperatures does not seem to have been studied, but since it depends in part on agitation of surface water, it can be expected to be significant in open water surface conditions in the Antarctic Ocean.

We are only at the beginning of understanding the action of oil at the sea surface and at the water-ice interface, and its potential toxicity to marine life. It would not be surprising to find that toxicity under Antarctic conditions might be comparatively greater than in temperate seas, because of the lower level of pollution in general. For recent general statements of the nature and possible magnitude of oil pollution in the oceans of the world, refer to Wilson and Hunt (1975). We should not forget that the

life of Antarctic waters appears to be characterized by large swarms and populations of relatively few species, and that another characteristic of the pelagic life of the Antarctic Ocean in particular is its patchy occurrence. These circumstances may make the marine life of Antarctic waters more vulnerable to comparatively minor pollution episodes by northern hemisphere standards, especially when the episode coincides with patches or seasonal swarms.

Mineral Resources

With respect to the actual geological exploration for possible minerals, it must be pointed out that this is in one sense a form of prospecting. The effort to demonstrate the magnitude of the coal measures of the outcrop in the central Horlick Mountains resulted in a prospect hole known as the "Dirty Diamond Mine". (Potter, 1969). The quality of the coal revealed in this effort was not impressive, and it is obviously far below the economic value of even second-rate coal on other continents. As for prospect holes, they are found all over the world, and not much thought is given to them.

The discovery of a rich fossil outcrop, however, may result in a larger excavation, similar to a mine or quarry. When a valuable fossil deposit is discovered in a remote situation, there is the option of leaving it alone, or of trying to remove as much as possible for convenient study later. In the matter of the Jurassic fossils at Carapace Nunatak in South Victoria Land, it was decided that the best procedure would be to remove as much of the outcrop as possible, both to enable future study in less forbidding surroundings, but also to save the fossils from souvenir collectors. Accordingly, some 700 kilograms of fossiliferous rock was removed from Carapace Nunatak (Borns, et al., 1972). This must be

conceded as an insignificant environmental impact. One is entitled to wonder what may happen, however, if an entire mountainside rich in dinosaurs is discovered. Aircraft logistics will be taxed to their limit, at least.

Krill

Krill fishing and processing methods are rapidly being developed by both Soviet and Japanese fisheries interests, and the catch is now reaching significant proportions despite the difficulties involved in developing techniques in dangerous waters remote from their home bases. The economics of this operation are difficult to assess because the fishery, still in its experimental or exploratory stage, is conducted by state enterprises. In 1954, Jackson (1954) estimated that a krill fishery would be economically justifiable at a price of 50-100 pounds (ca $300) of raw product per ton. Undoubtedly the fishery will be developed, but it will depend in part on other resources between the home base and the Antarctic Ocean to justify the long voyages to the krill areas. In this respect, it should be remembered that the capture of a slow-moving, near-surface organism like Euphausia superba requires specialized gear and techniques that differ from techniques used for schooling fish such as clupeids and mid-water fish like hake. This implies more extensive and varied equipment on fisheries vessels to exploit varied, world-wide resources.

There are uncertainties in this situation that cannot be answered at this time. Were the great quantities of krill consumed by the blue whale a natural surplus whose removal had no significant impact upon the other organisms that depend on the krill? Or did this consumption of krill represent a food supply that could support other organisms? The apparent increase of chinstrap

penguins in particular suggests that these birds are now finding a more abundant food source as a result of the decrease of predation by the blue whale. Would it be more efficient, in view of the difficulties of processing krill, to consider whether penguins or crabeater seals might be a more economical way of utilizing this resource?

Another question is suggested by the obvious concentration of krill in the Scotia Sea region. Again, is this concentration a vast natural surplus or excess perhaps representing populations or stocks beyond the requirements of the rest of the ecosystem, or is this concentration more a function of the intensity of our research? Certainly, until the development of pelagic whaling in Antarctic waters, this region was the favored whaling ground because of its accessibility to British and Norwegian whalers and the availability of shore situations, especially the whaling factory on South Georgia. It appears that this fishery, before the development of pelagic whaling, was not a serious danger to the blue whale stocks. Can we say that developing an intensive krill fishery in this region in preference to other parts of Antarctica, will not endanger the other stocks, of fishes and crabeater seals and penguins as much as an ocean-wide fishery around all of Antarctica? We have made pretty diagrams of all these inter-relationships, many of them the mainstays of ecology lectures and texts (e.g., Figures B and C), but we still lack the essential dates and numbers to put these questions into economic perspective. The "externals", or the "rent" that is unpaid in exploitation of a commons are very difficult to evaluate, but the potential loss that man may incur if he completely changes his world is even greater.

It is certain that the concentration of whales in this part of

Antarctica was in response to these vast populations of krill, and, as the whaling developed it was expanded geographically to have a devastating impact upon the world population of the species. The krill, however, is restricted to waters south of the Antarctic Convergence, and has a much higher reproductive potential than the whales, and a life cycle that ensures the unavailability of large parts of the population to intensive fishery. While this may not mean that it is invulnerable, it is certainly less so than the whales. But it is the key species of this vast ecosystem of the Antarctic and we cannot assume that it is safe to replace the blue whale with potentially more efficient plankton collectors, for there can be many more artificial plankton collectors than there were blue whales.

What would be the effect on the Antarctic ecosystem of this massive removal of its principal herbivore? Euphausia superba feeds primarily on diatoms, and does not also feed on detritus, as some euphausiids do. If the diatoms are not eaten, what will happen? As the cells grow older, they will sink or "spill out" of the surface layers, and the krill moving into the surface layers later in the same season may find food less abundant or out of reach. If the krill fishery succeeds and attains a significant magnitude (whatever that might be), one possible effect could be a long term reduction of surface stocks in favor or those of deeper water which could be harder to catch. These complex relationships between exploited stocks in their ecological meshwork are still inadequately understood (Cushing, 1975).

These problems and speculations concerning the development of the krill fishery will be the subject of conferences and controversy in the years ahead. It is better, however, to be prepared for them and to encourage research

into the still uncertain aspects of the life history of the krill before the fishery gets out of hand. We have, as a species, given inadequate consideration of the potential impact of our development of fisheries on the high seas. With the sobering example of what we are doing to the whales in mind, we nevertheless have the opportunity to examine, to think, and to consider the impact of a developing fishery at the outset.

Penguins

It appears, interestingly enough, that the principle impact upon penguins may not be Antarctic explorers and scientific activity, but the decline of the whale fishery that has made the stocks of krill available to penguins. One species in particular, the chinstrap, is noticeably increasing in numbers. Another factor favoring the increase of penguins is climatic amelioration. Of course this may be a transient phenomenon. In any event, the interference or presence of man near penguin rookeries is only one of at least three possible impacts upon Antarctic penguins (Conroy, 1975).

Frequent visitation by ornithologists and others to the Ross Island rookeries have been associated with some shifting of Adelie and Emperor penguins' nesting sites. At Cape Hallett, the displacement has been conspicuously noticeable. At Palmer, most of the rookeries are on islands in Arthur Harbor, separated from the station itself; here, the chief impact may be from tour groups. In years past, penguins, and especially their eggs, were a mainstay in the explorer's diet, and nothing was thought of any possible effect on the populations levied upon. In view of the great numbers of penguins and the relatively high losses in recruitment in some years, it seems evident that scientists have been among

the least of the impacts upon penguins. While the taking of 4,000 eggs at Cape Adare by Borchgrevink's party may have cut down recruitment, the effect would have been slight if most of the eggs were the first eggs of the clutch. The Adelie penguin produces a clutch of two eggs; if the first is taken, it will lay a third. According to John R. Baker (pers. comm.), this occurred in 54% of the nests from which first eggs were taken at Cape Hallett in 1969 and 1970. Thus the actual loss or "cost" of eggs was reduced by half.

Radioactive Waste Contamination in Antarctica

Contamination from mid Pacific weapons tests has been detected in Antarctica; the fallout of Strontium 90 from the Castle series of tests in 1955 will be detectable for years and will serve as a convenient date. Some of this pollution may interfere with the use of natural isotopes for dating purposes.

Direct disposal of radioactive wastes in Antarctica is prohibited under the terms of the Antarctic Treaty, and the United States has made every effort to comply with the provisions of the Treaty in cleaning up the site of the experimental nuclear power plant at McMurdo Sound. This installation, known as PM3A, was a small pressurized water reactor of 1800 KW rated output installed on the side of Observation Hill at McMurdo in 1961-62. It first produced power in July, 1962. The plant was operated until September, 1972, when a leak was discovered in the shield. Determination of the extent of the damage would have required a very expensive inspection, and the possible costs of repairs indicated that the only feasible course was to remove the reactor and replace it with diesel powered generators.

Dismantling and removal began during the 1973-74 austral summer, and

the last parts of the plant, along with more than 365 metric tons of possible contaminated soil around the site were removed to the United States in 1975.

The elaborate and costly procedures to detect and remove the comparatively small amounts of radioactivity in the environment from the operation of PM3A would be pointless if the scheme proposed by Zeller, Saunders and Angino (1973) in the January 1973 issue of the Bulletin of Atomic Scientists were adopted. These authors proposed the Antarctic ice cap as the most suitable location for an international depository for the high level radioactive wastes from nuclear power plants. One possible way to place the material beneath the ice would be to let it sink into the ice by melting its way down from the internal heat of the radioactive package. Such a proposal, if taken seriously, would require revision of the Antarctic Treaty. It also appears to assume more immobility of the polar ice sheet than may exist, as the ice moves slowly away from the dome-like structure under gravitational forces (see e.g., de Robin, 1975).

The suggestion to use Antarctica as an international dumping area for radioactive wastes was discussed in SCAR Bulletin 50. It is considered that such massive disposal of radioactive material might trigger instability of the ice sheet, as well as impair the potential use of Antarctic ice as a source of water for desert areas in the future. In this context, we are reminded that one of the questions of universal interest to man is still open: are we at the beginning of a new ice age, or is our climate warming up? The state of the art of climatology is such that there are plausible predictions for both alternatives, but the general consensus seems to be that we are at present in a cooling period (Bryson, 1974; Lamb, 1973). Should this continue, we may expect more proposals to use radioactive waste to warm up the Antarctic region.

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nomic expansion will contribute. As a result of the controversy in Nova Scotia, questions have been asked in the New Brunswick house about the advisability of carrying on with the programme. In an article to be published in the June issue of *Science Forum*, Neal Benneworth and Chris Bailey contend that spraying should be prohibited because it is "an energy-intensive attempt to bend nature to conform with the forest industry's narrow concepts of how a forest should behave".

They say the operation only increases in the long term the chances of occurrence of what it was originally intended to prevent, because preservation of the host trees by spraying "simply improves the environment for the budworm and increases the likelihood of further population expansion." This is so because the forest and the budworm are a self-regulatory system: the budworm destroys the forest and ensures a new development of host species favourable for future budworm generations. The present composition of the forest, they say, has evolved as a result of budworm predation removing mature balsam fir preferentially, which allows less competitive species of trees to survive. Budworm spraying merely protects the host trees, which are economically significant to the forest industry, and this in turn improves the environment for the budworm, thus increasing the likelihood of further population expansion. □

USSR

One of the obstacles to communication between Soviet geologists and their foreign colleagues in recent years has been the unwillingness of Soviet geologists officially to admit the possibility of continental drift. This block was not due to any political considerations—unlike those imposed in Stalin's time on genetics and cybernetics—but seems to have been due to personal opposition from certain leading geologists, notably Professor V. V. Belousov of the Institute of Earth Physics in Moscow. Recently there has been a discernible relaxation in this attitude: the popular science magazine *Priroda* has carried an article dealing with this "hypothesis", and even Professor Belousov himself has somewhat half-heartedly discussed the subject in his latest book.

Now, however, a TASS radio bulletin, transmitted in English and hence clearly for international consumption, has given even greater approval to this concept, stating that Australian rock samples, collected by M. Ravich of the Institute of Arctic Geology in Leningrad, have proved to be "completely identical" to samples from the Antarctic opposite Australia, thereby giving added proof of the "so-called theory of Gondwanaland". According to Professor Ravich, the samples match not only in chemical composition and age (2,000 million years), but also in the size of the deposits, and give credence to predictions of mineral wealth in the Antarctic similar to deposits in Australia, South Africa and South America. A number of Soviet geologists have privately supported the concept of continental drift for some time. The TASS broadcast indicates a possible reversal of the official view of the Soviet geological establishment.

● The chance a private individual in the USSR has to participate in a major scientific research project nowadays is extremely limited. But it was granted to the citizens of Byelorussia, the Baltic States and the Leningrad-Novgorod region of the Russian Republic by the flight, on February 11 this year, of what has been named the "Baltic bolide".

This large meteorite, which appeared in the twilight over the Gulf of Finland, crossed the gulf moving in the general direction of Moscow before burning up. Its flight time of

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more than 100 seconds, instead of the normal one second or so, is a record for any meteor, and is attributed to a velocity comparable with that of the Earth and a trajectory virtually tangential to it. Before the bolide finally broke up with a fine display of natural pyrotechnics, some 600 people following it along its path had observed it closely enough for their letters and sketches to help astronomers at the Pulkovo observatory plot its course. According to V. Kratt, the observatory's Director, the bolide ceased glowing only at a height of 25 km, and there is reason to hope that some fragments may have penetrated the atmosphere to ground level. The Soviet Academy of Sciences has therefore appealed to all persons living along the route to survey the area for fragments.

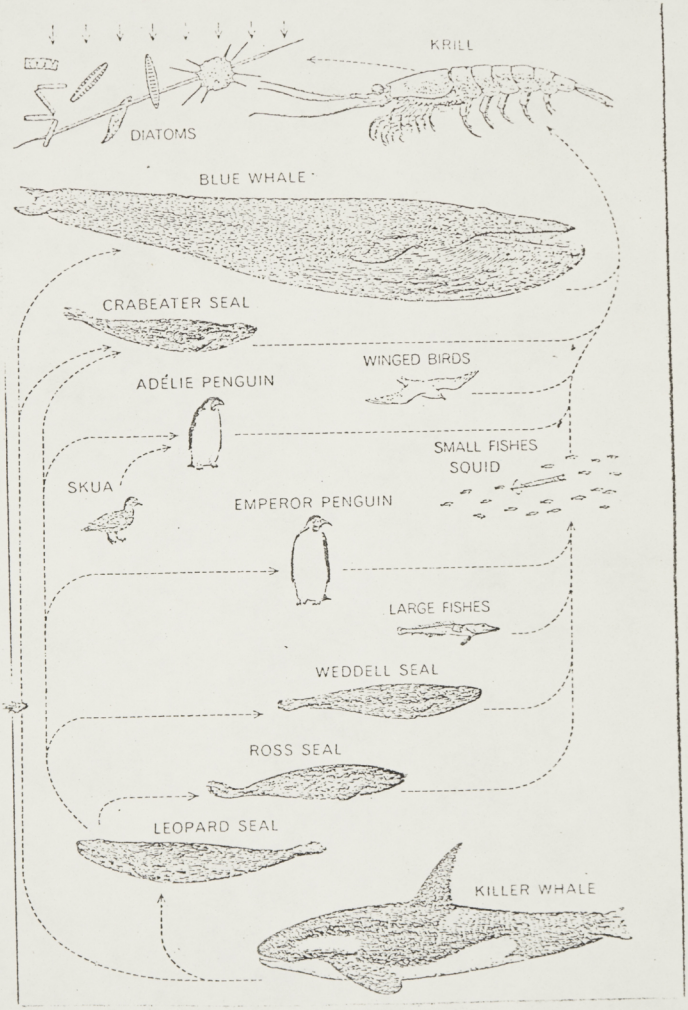
● The State Committee for Science and Technology of the USSR's Council of Ministers has signed an agreement on technical cooperation with British Petroleum, to run for an initial period of five years. It provides for broad-based reciprocal scientific and technical cooperation on a long term basis, and is the result of some two years of negotiation, since Academician Vladimir A. Kirillin, the committee's Chairman, visited Britain in 1974.

The agreement envisages exchanges of scientific and technical information and of specialist staff, joint research and development, the organisation of symposia on topics of mutual interest, and the joint implementation of research programmes and projects—on the production of unicellular proteins from petroleum wastes, for example. The State Committee has shown considerable interest in purchasing the expertise for deep-water drilling developed by BP in connection with the Forties field in the North Sea.

One new Soviet development in anti-pollution measures, however, is unlikely to form part of any exchange agreement. According to Moscow radio a new agent for cleaning up oil spills in the Caspian has been discovered: the cockle *Cerastoderma*, which, although only some 2.5 cm long, filters up to 15 litres of water through its body in its feeding process. Any oil contained in this water is coated with slime and eliminated, forming a sludge which falls to the sea-bed, where, it is thought, it is later rendered harmless biologically.

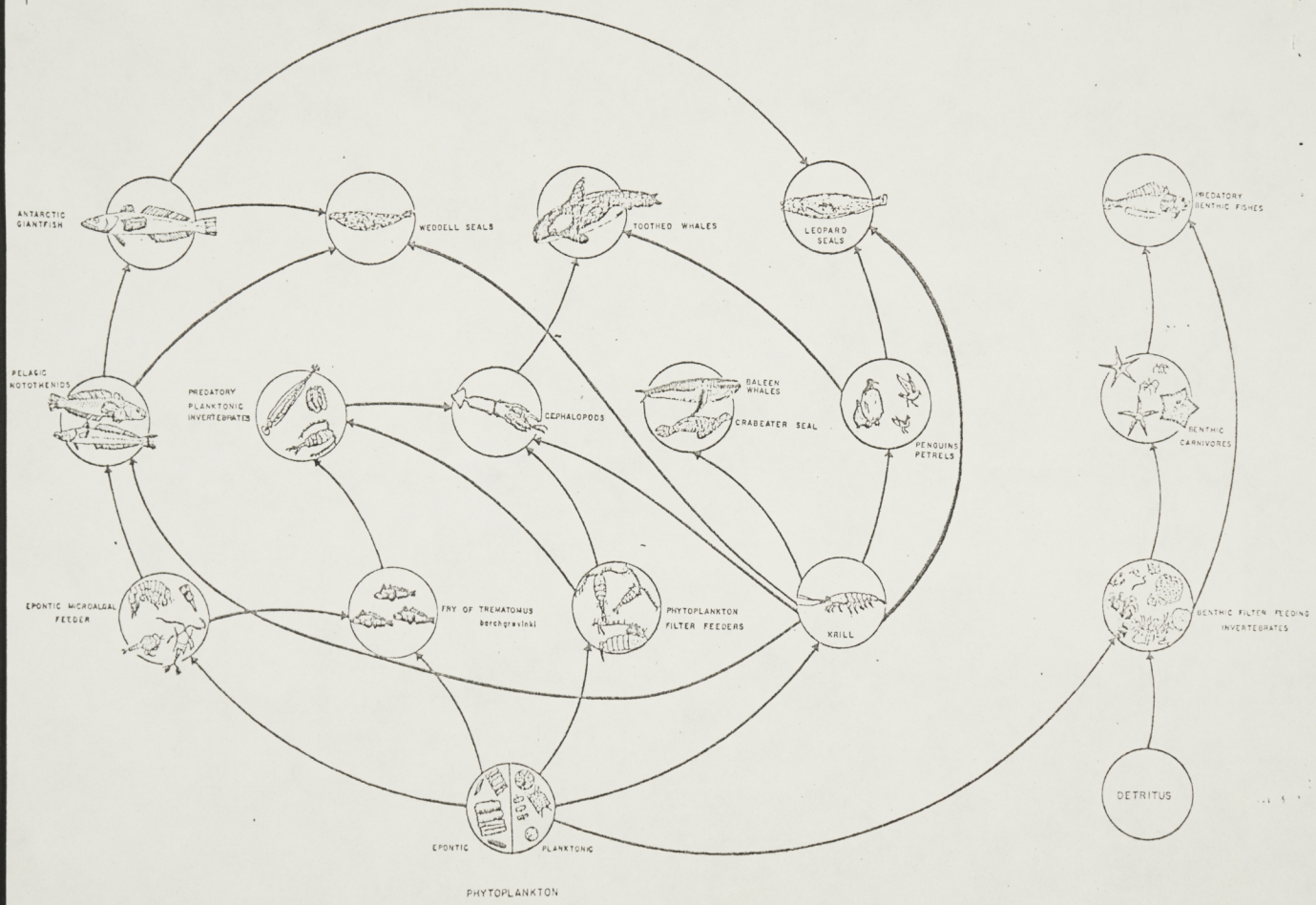
● The latest volume of the Large Soviet Encyclopedia carries a brief, 75-word biography of Andrei Sakharov, complete with photograph, describing him as a "Soviet physicist and Academician" and recording that he was thrice awarded the title of Hero of Socialist Labour (the highest Soviet civilian award). Sakharov's human rights work is nowhere mentioned; his recent activity is dismissed with the remark that "in recent years he departed from scientific activity". Sakharov himself commented that he was "very pleased" with the entry.

Vera Rich


KRILL
DIATOMS
BLUE WHALE
CRABEATER SEAL
WINGED BIRDS
ADÉLIE PENGUIN
SMALL FISHES
SQUID
SKUA
EMPEROR PENGUIN
LARGE FISHES
WEDDELL SEAL
ROSS SEAL
LEOPARD SEAL
KILLER WHALE

TO

14



B4 FOOD CHAIN RELATIONSHIPS IN THE PACK ICE ZONE

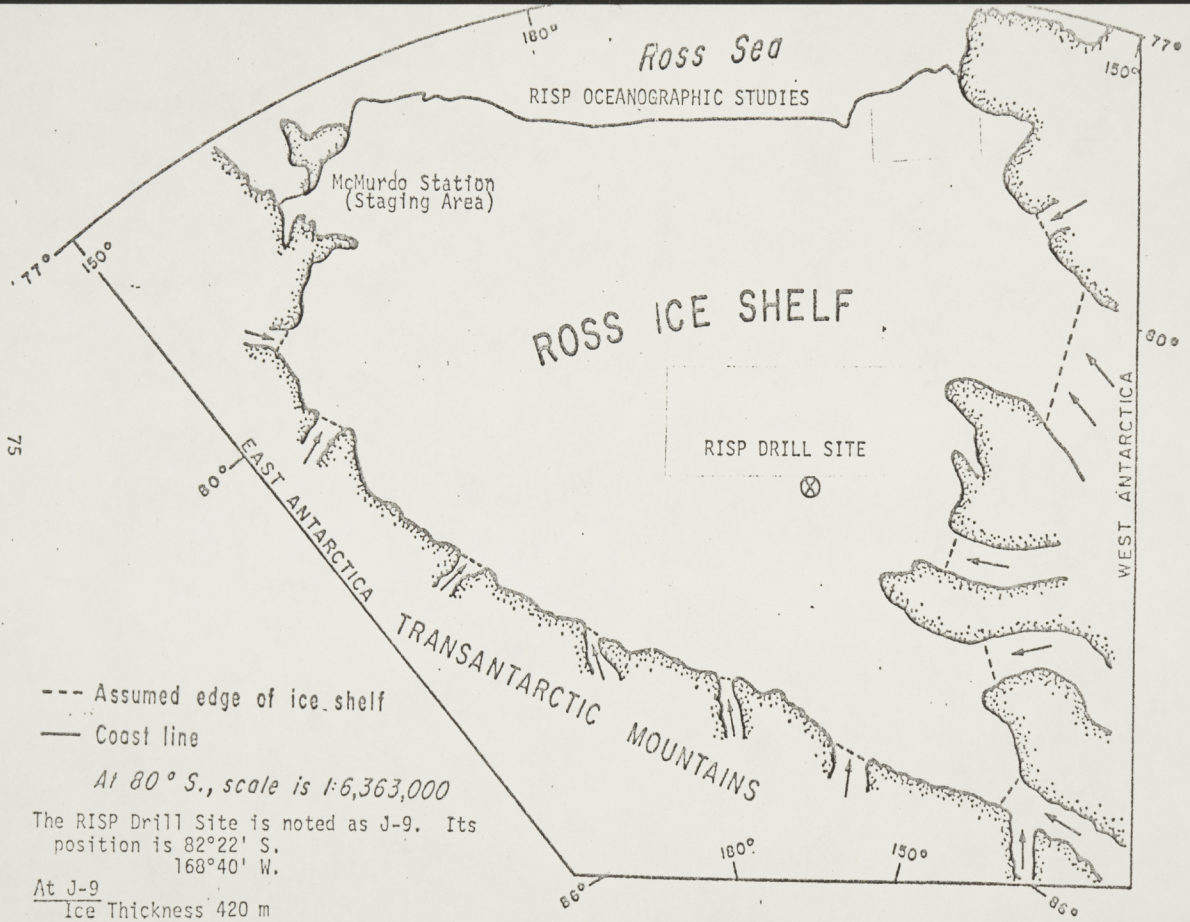


Figure 1. RISP Drill Site

A