

## Antarctic research: The role of the Earth Sciences

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Interest in Antarctic geology started during initial exploration of the continent. Pre-IGY (1957-1958) research involved mostly reconnaissance surveys resulting in rudimentary knowledge of the general geological structure of Antarctica. The establishment of SCAR in 1958, following the success of the IGY, initiated a new phase of coordinated international scientific research in Antarctica. SCAR's present science strategy emphasizes the understanding of the role of Antarctica in planet-wide systems and global change. The emergence of the mineral resources issue within the Antarctic Treaty System (ATS) in the 1970s influenced Earth sciences research by stimulating more economically-oriented activities, particularly marine seismic reflection surveys. In spite of speculations, no mineral deposits have yet been found in the Antarctic and most prospects for exploration or exploitation are pessimistic because of both technological problems and an unfavorable market situation. Stricter rules for the regulation of scientific and logistic activities in the Antarctic may impose some extra difficulty for the planning and conducting of science programs. Whatever the context, however, participation of Earth scientists will undoubtedly continue to be extremely relevant.

*O interesse pela geologia da Antártica surgiu durante a exploração inicial do continente. A pesquisa pré-IGY (1957-1958) envolveu, principalmente, trabalhos de reconhecimento que resultaram num conhecimento rudimentar da estrutura geológica geral da Antártica. O estabelecimento do SCAR em 1958, em consequência do sucesso do IGY, deu início a uma nova fase de pesquisa científica internacional coordenada. A atual estratégia científica do SCAR enfatiza o entendimento do papel da Antártica nos sistemas e mudanças globais. O surgimento da questão dos recursos minerais no seio do Sistema do Tratado da Antártica (STA), nos anos 70, influenciou a pesquisa em ciências da Terra, es-*

*timulando atividades de orientação mais econômica, particularmente levantamentos de reflexão sísmica marinha. A despeito de especulações, nenhum depósito mineral foi ainda detectado na região antártica e a maioria das previsões de exploração e extração é pessimista, em razão tanto de problemas tecnológicos quanto de condições de mercado desfavoráveis. Regras mais exigeantes para a regulamentação das atividades científicas e logísticas podem impor dificuldades adicionais para o planejamento e condução de programas científicos. Em qualquer contexto, entretanto, a participação dos geocientistas continuará, sem dúvida, a ser extremamente relevante.*

**A**ntarctic rocks attracted the attention of virtually every expedition to the continent since the pioneer days of the "heroic age" in the XIX century. The limited number of exposures (ice-free areas) which comprise about 1% of the continent are mainly situated near the coast. Therefore, they immediately drew the attention of expeditions seeking ice-free ground to establish bases (Fig. 1).

Despite this attention, the first century or so of Antarctic geology prior to the IGY (1847-1957/58) resulted mainly in scattered observations of small areas and provided only limited insight into a complex geological history. In the mid-1950s, knowledge of the geological composition, structure and evolution of Antarctica was rudimentary, and broad-ranging reconnaissance programs were predominant in the Earth sciences. By the end of 1950's, geological research had established that East Antarctica was a shield area with a basement complex of mainly Precambrian schists and gneisses overlain by Paleozoic and Mesozoic sediments, and that West Antarctica appeared to be composed of greatly deformed Mesozoic and Tertiary sediments fairly similar to the Andes. The structural relationships between East and West Antarctica were (and still are) a major geological question (Fig. 2).

**Post-IGY years: The role of SCAR**

Coordinated international scientific research in Antarctica, initiated during the IGY of 1957/58, provided geo-

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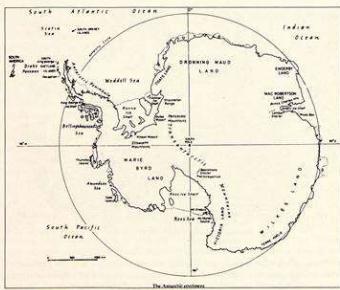


Figure 1 (above): Map of Antarctica with indication of localities of tectonic research.



Figure 2 (left): Geotectonic map of Antarctica with indication of its geological affinities with other Supercontinents (Fairbridge, 1949, in Walther, 1987).

## Main research themes

physical (seismic, gravimetric) data on the crustal structure of Antarctica. Research confirmed that thick crust (40–60 km) underlies East Antarctica and a thin (25 km) crust underlies the Ross Sea and Weddell Sea depressions (Fig. 3). The success of the IGY as a program of

international scientific cooperation and free exchange of scientific information provided the basis for the establishment of the Scientific Committee on Antarctic Research (SCAR) in 1958, a body of the International Council of Scientific Unions (ICSU) in charge of the initiation, promotion and coordination of scientific research in Antarctica.

Scientific activities in the Earth sciences are conducted through its permanent Working Groups on Palaeontology and on Solid Earth Geodynamics. Current research is aimed at some specific geological problems, including: Antarctica's geological composition, structure and evolution; the geological relationship between the continent and the surrounding continents; geological and palaeontological relationships with other continents and with the surrounding ocean basins; the history of the development of Antarctica's current glaciation and the consequences of glaciation; Earth processes in a polar, glaciated, continental environment; the relevance of Antarctica to global Earth sciences.

Antarctica has long been recognized as a key to Gondwana reconstructions and some of the geologic problems listed reflect this importance. Particularly relevant to attempt reconstruction of Gondwana is the understanding of the fit of the Antarctic Peninsula with the continents of South America, West Africa and Australia. The Antarctic Peninsula is a magmatic arc which has been active since the Triassic. The history of the other fragments is

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Figure 3: Major tectonic elements of the Scotia arc region (Doake, 1987).

less certain, and their affinities may be either with West or East Antarctica.

Intense marine geophysical investigation has revealed marine geological complexity in the tectonic region of the Scotia arc, which forms part of the boundary between the American and Antarctic plates, and different geotectonic models have been proposed. The evolution of the area, and the opening of the Drake Passage, have had major implications for continental and oceanic modeling, physical oceanography, paleogeography and geophysics. Worldwide modification in ocean circulation and climatic isolation of Antarctica are believed to have resulted in the onset of the Antarctic Ice Sheet.

Interpretation of the paleoclimatic changes recorded in Palaeozoic continental and marine rocks and sediments in Antarctica, and particularly the Cenozoic glacial history, is another example of Earth science research in the Antarctica with implications for understanding events beyond the boundaries of the continent.

One of the major research areas has been tackled by SCAR through the formation of Groups of Specialists to coordinate multidisciplinary, international research. Two of these include a group studying the Structure and Evolution of the Antarctic Lithosphere, and another the Biogeography and Conservation of Marine life in the High Southern Latitudes. The former group is presently coordinating the Antarctic contribution to the Global Geoscience Transects Project of the International Union Commission on the Lithosphere. It also intends to conduct a series of five major sub-ice seismic (Acoustic) transects (Antarctic) across the five major sub-ice physiognomies that lie along the 130°W to 60°E meridian, from the coast of Marie Byrd Land via the South Pole to the coast of Mac Robertson Land. The goal of the latter group is to integrate and correlate the Antarctic terrestrial and marine Cenozoic geological record with that of the Southern Hemisphere latitudes in terms of paleoclimatic, paleo-oceanographic and tectonic events. Research is now closely focused on the Antarctic terrestrial and marine history (glacial and interglacial) and global climate and sea-level fluctuations using offshore geophysical and geological data. The group is ac-

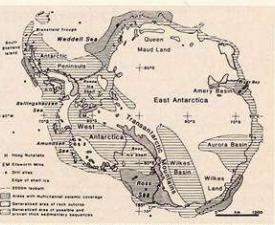


Figure 4: Major tectonic elements of the Scotia arc region (Doake, 1987).

tively developing the Antarctic project, the purpose of which is to study the problem of Cenozoic ice-volume changes and the effect of these changes on global sea-level and climatic variations.

The Earth sciences are, therefore, making an important contribution to the understanding of the role of Antarctica in natural systems of the Planet Earth and thus, as a critical area for global change studies such as those contemplated in the International Geosphere-Biosphere Program (IGBP). This approach now constitutes one of the main elements of SCAR's science strategy.

## Antarctic mineral resources

The emergence of the mineral resources issue in the Antarctic Treaty System (ATS) in the 1970's (a topic not dealt with in the Antarctic Treaty) has had profound influence on the conduct of Earth sciences activities in the southernmost continent.

Geophysical data mainly from aeromagnetic surveys conducted by radio sounding of bedrock topography had already furnished a very broad picture of the bedrock structure, revealing a number of features in the bedrock interpreted as reflecting crustal structures. This, plus seismic refraction and reflection data has shown that some of the depressions correspond to basins filled with continental and marine sediments both in the interior of Antarctica and at its continental margin, extending in fact, seaward of the 2,000 m bathymetric contour (Fig. 5). The only region for which adequate seismic data exist to establish sediment thicknesses and outline the general structure of the basins are the Ross Sea, part of the Wilkes Land Coast, Prydz Bay, Western Margin of

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Queen Maud Land and along the immediate front of the Ronne and Filchner Ice Shelves (Weddell Sea) (Fig. 6). Other area for which geophysical data exist is the continental shelf of the Antarctic Peninsula and Amundsen and Amundsen Seas, however, are little known.

Speculations on the probable presence of mineral deposits in the Antarctic grew out of an "area probabilistic approach" based on the numerous mineral occurrences in the continental shelf and marginal shelf deposits elsewhere, particularly those in the ice-drift adjacent Gondwana continents (Fig. 7). The large gabbroic Duffek intrusion in the Pensacola Mountains has been compared with the Bushveld complex in South Africa, rich in platinum group elements. Proximity to basins on formerly adjacent continents formed during rifting of Gondwana, which are oil and gas producers, led to estimates of the hydrocarbon potential of the Antarctic sedimentary basins.

Gaseous and heavy hydrocarbons have been detected in cores from the Deep Drilling Project (DDP), Ocean Drilling Project (ODP), and Cenozoic Investigation in the Ross Sea (CICOS) in sites in the Ross Sea, as well as in other places on the Antarctic continental shelf (Fig. 8), but their significance in terms of hydrocarbon assessment is questionable. Jurassic-Cretaceous sapropelic clays and mudstones in the northern Antarctic Peninsula and on the Western Queen Maud Land margin may constitute adequate source rocks (Fig. 7). Knowledge of the thermal and tectonic histories of the basins is

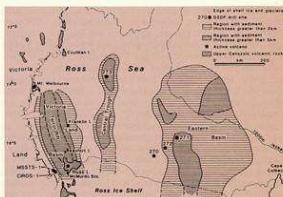


Figure 6: Delimitation of sedimentary basins in the Ross Sea area. This is the geophysically multi-channel seismic data known area on the Antarctic continental shelf. Note the Ross Ice Shelf.

in the SCAR Group of Specialists set up at the request of the ATCPs for studying the Antarctic Environmental Implications of Possible Mineral Exploration and Exploitation. They also take part in the present Group of Specialists on Environmental Management in the Antarctic. The establishment of these important multidisciplinary groups confirms SCAR's continuing commitment to sound and active scientific conservation and is part of a SCAR mechanism for complying with its role as the main scientific advisory body to the ATCPs.

The combination of external pressure (particularly due to the presence of a powerful environmental lobby against the threat posed by possible future exploration and exploitation of Antarctic minerals regulated by the Convention on the Regulation of Antarctic Mineral Resource Activities), and the fact that the ATCPs had to act in the context of the existing system of environmental protection of the Antarctic environment. The necessity of a comprehensive treatment of this question was recognized by the ATCPs at the XV ATCM (Antarctic Treaty Consultative Meeting) held in Paris in 1989, and resulted in the call for a Special Antarctic Treaty Consultative Meeting for the discussion of a more comprehensive arrangement.

The first session of the VI Special ATCM was held in Chile, November-December 1990, and discussions will continue in Madrid next year. For the moment, the Earth Sciences in particular the anticipated implications of the negotiation of a new international judicial instrument dealing with Antarctic environmental protection are ambiguous. On one hand, it is widely recognized that there is a need for a system of solid environmental and environmental protection rules and excessive regulation of activities (including increased requirements for science and operational logistics) to be subjected to environmental impacts (and vice versa) may impose difficulties for the planning and conducting of science and operational/logistic support. Concerns have been expressed, for instance, by Earth scientists with

SCAR and the ATCPs on possible restrictions to the utilization of explosives for seismic surveys or on drilling because of their possible environmental impacts.

From a more general perspective, the strengthening of the environmental management arrangements in the Antarctic probably have some influence on the conduct of National Antarctic programs, with substantial efforts being directed toward environmental matters and not always corresponding to true scientific research. Another broad implication of additional protective measures will be either a ban or a long term moratorium on mineral exploration and exploitation in the Antarctic. In other words, this means that the Wellington Convention will be either "frozen" or declared "dead".

Whatever the context, however, conservation and environmental protection in the Antarctic will certainly not preclude the continuing contribution of Earth scientists in Antarctic research.

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9. Acknowledgements. I thank Paulo R. dos Santos for critically reading this paper.

Figure 7: Reconstruction of Gondwana in the Cretaceous showing the proximity of Antarctic basins to basins in formerly adjacent continents. Some of them are oil and gas producers (Elliot, 1988).

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Earth sciences and the environment

Earth scientists have been also actively contributing to the improvement of the system of conservation and protection of the Antarctic environment and its ecosystems, which has always been a main concern within SCAR and the ATS. They have, for instance, participated

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