

FROZEN CONTINENT

Antarctica: Endless Snow

to the continent, it can be said
of the continent, it can be said
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ANTARCTICA is a circumpolar continent occupying 13.5 million sq km area or about nine per cent of the Earth's land surface. It is surrounded by the Southern Ocean which is about 36 million sq km or about 10 per cent of the world's oceans. Ice covers 98 per cent of the continent, but the rest (about 260,000 sq km) is a non-glacial terrain. The average thickness of the ice sheet is about 2,300 m, but its maximum is known to be around 4,000 m. The volume of this ice is so enormous that, if melted, the water released would raise the sea level by about 60 m. The continental ice of the interior spreads to the coastal regions, giving rise to icebergs in the surrounding ocean. The Ross Ice Shelf and the Ronne Ice Shelf, which are the largest, also release icebergs into the ocean. The glacial history of Antarctica dates to several million years back†

The ice-free areas of Antarctica are the Transantarctic Mountains,

Ellsworth Mountains, the Antarctic Peninsula, and a few small tracts along the coastal regions.

Broadly speaking, the continent can be divided into East Antarctica, West Antarctica and the Antarctic Peninsula. The Transantarctic Mountains of East Antarctica rise above 4,000 m, but the highest peak, Vinson Massif (5,140 m), is in the Ellsworth Mountains of West Antarctica. The mountains are generally rugged and are 2,000-3,500 m in height.

Temperature

Temperatures on Antarctica are extremely low. The mean annual temperature on the polar plateau of East Antarctica is about -50°C but in the coastal regions it is about -15°C . During the coldest months on the plateau, temperatures are commonly not below -70°C . The world record for the coldest temperature was -86°C ; recorded recently at the South Pole; while on the coastal areas it is in the

-20°C to -30°C range. On the west and north sides of the Antarctic Peninsula it is about -10°C during winter. During the warmest summer months the mean temperature is about -35°C on the plateaus, but around 0°C on the coasts and on the Peninsula.

Antarctica has been described as the windiest continent on Earth. Winds of high intensity blowing for long durations are very common in the coastal regions. These winds blow from the interior toward the coasts. At high velocities, they produce blizzards, but on the northern and western sides of the Peninsula the winds are less intense, therefore, blizzards also are less frequent.

Southern Ocean

The Southern Ocean separates the Antarctic continent from the Southern Hemisphere, and from the other southern extremities of the Atlantic, Pacific and Indian Oceans. The nearest continent is South America whose southern

tip lies 880 km across the Drake Passage from the Antarctic Peninsula. The southern tip of New Zealand is 2,240 km from the Antarctic coast.

The continental shelf is very narrow but deep. It is about 4 million sq km in area and about 900 m deep. It is less than 200 km wide around East Antarctica, while it is 300-400 km wide around West Antarctica with an average depth of 500 m. Sea ice covers the entire shelf for nine or ten months of the year. During the austral summers, much of this ice breaks down to pack ice which moves northward leaving the open sea above the shelf. The thick ice of several years accumulation in the Amundsen, Bellingshausen and Weddell Seas makes ship movements very difficult. Two major circumpolar currents called the West Wind Drift (easterly) and the East Wind Drift (westerly) maintain the surface circulation of the waters of the Southern Ocean. Vertical movement of water masses also takes place and is caused by differences in salinities. The temperature of the cold, low salinity coastal waters of lower latitudes interact with the warm, high salinity waters of low latitudes at the Antarctic Convergence Zone or



Dr. S. Z. Qasim unfurls the Indian flag on Antarctica

Polar Front Zone which lies between 50°-60°S latitude.

A temperature of 0.3° to 0.6° C. at 2,973 m depth (35 m above the surface of the sea floor) and an average current speed of 65 m per second was observed

in the Scotia Sea bottom water (a mixture of Weddell Sea and eastern Pacific bottom waters) in the Fracture Zone between Falkland Islands and South Georgia.

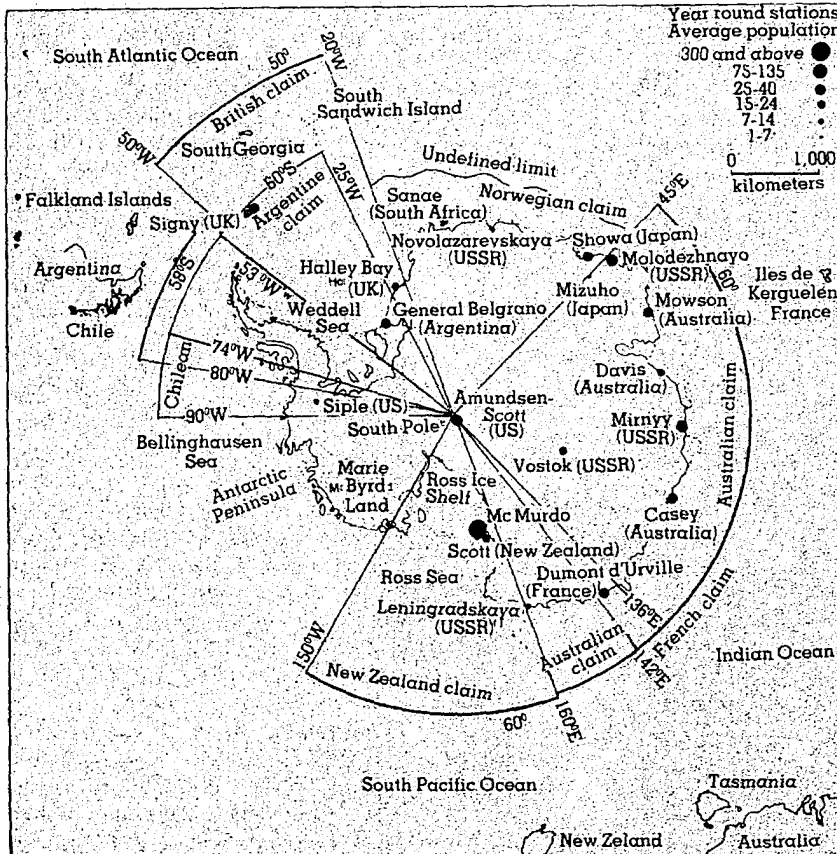
Geology

Systematic geological exploration of Antarctica is rendered very difficult because of the ice cover of most of the continent, paucity of outcrops, lack of topographic base maps, hostile environment and other logistic problems. However, in recent years some geologic maps of Antarctica have been published in the USA and the Soviet Union.

The Antarctic continent consists of two major geological provinces—East Antarctica and West Antarctica. East Antarctica is composed of a Precambrian shield of igneous and metamorphic rocks which are overlaid by undeformed sedimentary strata at certain regions. West Antarctica is characterised by highly deformed, younger metamorphosed strata which are intruded by igneous rocks. In addition, some volcanic deposits are also found. Some volcanic activity persists even today. Submarine volcanism was reported recently and its relation to seafloor spreading and plate tectonics discussed. The geological history of Antarctica is closely related to the geological evolution of South America, Southern Africa and Australia from the former super-continent—the Gondwana Land. Thus, the mineral deposits of value of these continents are common to all. The major geologic components of the Southern Hemisphere which includes India (Fig. 2).

Recently, fossils of a squirrel-like (marsupial) mammal of temperate climate have been reported in the sedimentary strata of the Antarctic Peninsula. Setty had recorded the distribution, ecology and the causative factors affecting the diversity, variation in foraminiferal assemblages of Deep Lake terraces, Vestfold Hills, Antarctica. Ostracods (a subclass of crustaceans) are very rare; he suggested the reasons for their paucity or even absence as mainly due to dissolution effect, wind erosion and transport after ablation of ice of the former ice-sheet or ice-sheet.

The mineral resource potential of Antarctica is only speculative as the detailed geological information available is not exhaustive. But it is known that this continent is geologically related to other continents of the South-



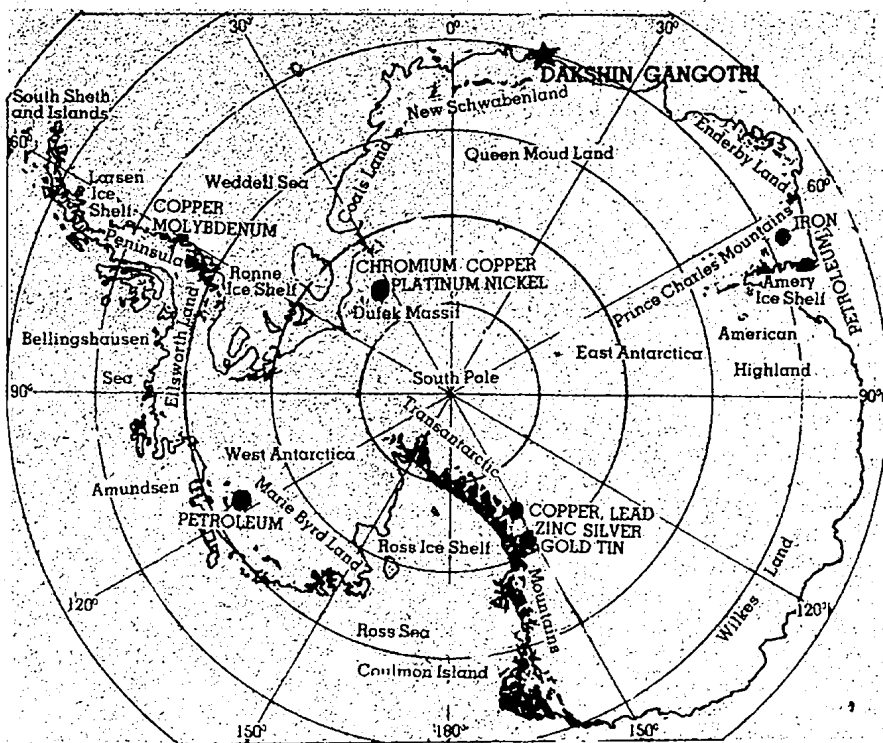
Territorial claims made by various countries on Antarctica

ern Hemisphere and consequently may have similar deposits of minerals and ores. Thus it goes without saying that Antarctica is the only continental platform on which mineral exploration has not been done so far; however, some information is available.

The Antarctic Peninsula is the extension of Andean Orogen of South America. Thus the copper deposits of Peru and Chile may be considered to have their extension into the Antarctic Peninsula. Copper mineralisation in the Peninsula is too low in grade, but it could be a target area for any future exploitation.

The Dufek Massif of Pensacola Mountains, having a total extent of 34,000 sq km consists of stratiform igneous complex of gabbro (rock with granular texture). It is 7 km thick and is covered by glacier ice. This can be another target area of ores of copper, chromium, nickel, platinum and molybdenum. The Sudbury nickel deposits of Ontario, Canada and Bushveld complex of South Africa produce such ores from similar rocks.

The Transantarctic Mountains composed of crystalline rocks of Precambrian and Paleozoic to Mesozoic strata contain coal beds of Permian age. Some of these coal beds are thick enough and mineable. The Gondwana Land relationship of Tasmania and Eastern Australia with the Transantarctic Mountains indicates continuity. The former indicates deposits of commercial grades of lead, zinc, copper, tin and



Antarctica: the mineral resources are presumptive, for little mineral exploration has been done so far

tungsten, while the latter contains economic ores of copper, lead, zinc, silver and gold. Sporadic occurrences of these are known from the Transantarctic Mountains.

Banded iron ore formations from Prince Charles Mountains, near Amery Ice Shelf, and magnetite-bearing rocks in Queen Maud Land have been reported. This banded iron ore formation may be similar to rocks

of the Precambrian Lake Superior Iron District in the US.

The Scientific Committee on Antarctic Research (SCAR) identified several geographic areas on the continent and its continental shelf as possible areas for future exploration.

The deep ocean around Antarctica contains ferromanganese/polymetallic nodules. Since these nodules and encrustations are associated with sea-floor volcanism and their proximity to the mid-ocean ridges is known, further exploration in Antarctic waters may hopefully uncover nodules of more desirable mineral content.

Oil and gas

The SCAR group of specialists suggested that the continental shelf on either side of the Antarctic Peninsula and beneath the Ross and Weddel Seas could attract exploration activities for hydrocarbons sometime in the future. The observations made are based more on inference than on factual evidence. This evidence may be very scanty and circumstantial, but is nonetheless very impressive. Some geophysical data is available for this region.

Exploration for hydrocarbons (oil and gas) is active in the offshore regions of southern Argentina, South Africa, Australia and New Zealand. These discoveries offer hopes for possible exploration, since the existence of similar hydrocarbon-bearing strata are



Instruments put up at Dakshin Gangotri by the first Indian expedition to study the weather



This time-exposure photograph, taken at Japan's Showa Base in Antarctica shows the up-and-down movement of the never-setting mid-summer Sun at the South Pole

found along Antarctica also. This is further proof that these were juxtaposed during the time of Gondwana Land. Franklin and Clifton (1971) found that the shelf beneath the Ross Sea is contiguous with that of Kind fish, Barra Couta, and Halibut oil fields in the region between Tasmania and Australia. Methane and ethylene gases (indicators of petroleum) were reported from the Miocene deposits of Ross Sea.

Prospecting for oil in these waters presents very special problems, such as pack ice, difficulty in the mobility of exploratory and drill ships and ice breakers, presence of icebergs of enormous draft and size. The combined hazards of pack ice, bottom scouring icebergs, prolonged storms of high intensity and heavy winds present technological difficulties of immense proportions.

Ice and icebergs

There are enormous quantities of fresh water ice in the Southern Ocean. In fact, icebergs can be considered as of great economic value. Icebergs of up to 70 × 100 km size have been documented. The larger icebergs even scour the seabed at depths of 200 m. Icebergs have been seen as far north as 35°S latitude in the Atlantic, and 40°—45°S latitude in the Pacific and Indian Oceans.

The idea of transporting icebergs to water deficient parts of the world was examined at the First International Conference held at Iowa State University in 1978. Saudi Arabia, which participated through the King Faisal Foundation of Saudi Arabia, was very much interested in the outcome of this Conference. Iceberg harvesting is a distinct possibility in the near future.

A great deal of geological data is needed before exploitable resources of Antarctica can be evaluated. But before

it can become a bonanza for any country, the political framework of Antarctica has to be settled.

Extensive research in Antarctica has been conducted by some nations for long, but in recent years 12 countries have been engaged in research in complete harmony, co-operation, and freedom of access to each other. India initiated Antarctic Studies in 1981-82 through its first expedition and established a station at Dakshin Gangotri.

An agreement was drawn up by the 12 countries at the conclusion of the International Geophysical Year (IGY), 1957-58. The IGY agreement through the Antarctic Treaty in 1961 made the 12 countries suspend all further territorial claims and hold in abeyance all earlier claims. Seven of the coun-



A member of a rescue team scales the wall of a crevasse at New Zealand's Scott Base. Scaling techniques are perfected in case someone crashes through the ice—an ever-present danger with crevasses in Antarctica

tries—Argentina, Australia, Chile, France, New Zealand, Norway and Great Britain—had laid claims to vast territories prior to the Treaty of IGY, but five countries (signatories)—Belgium, Japan, Soviet Union, South Africa and the United States had not made any territorial claims and also did not recognise the claims of the other seven. It is to be noted that Argentina, Chile and Great Britain had overlapping territorial claims which included the Antarctic Peninsula (p.58). Though Poland joined the Treaty in 1961, it became a full member only in 1977. At the twelfth consultative committee meeting held in Canberra (Australia) in September 1983, India, along with Brazil, were admitted as consultative members of the Treaty under article IX relating to scientific research, establishment of a station and scientific expeditions.

Even though territorial claims on large areas of Antarctic land were made by several countries and some having overlapping claims, sovereignty was not exercised by any country since all of Antarctica and the territory lying south of 60°S latitude are controlled by the terms of Antarctic Treaty which is in force from 23 June 1961.

The Treaty stipulated that any nation can call for a General Conference of the signatories to review the functioning in 1991. Otherwise, the Treaty can run for an indefinite period. When such a General Conference is convened, and any amendment to the Treaty proposed by any nation and agreed to by a majority, but not ratified within two years by any nation, then such nations would be free to withdraw from the Treaty and the nation/s will no longer be bound by the Treaty. But if an amendment has been agreed to *unanimously* by the Treaty countries and the government of any country fails to ratify it within two years then that country may withdraw from the Treaty even before 1991. So far the Treaty has worked well. But what will happen after 1991 nobody can predict, because any amendment after 1991 needs only a majority vote, which enables any country to withdraw.

Territorial claims

Regarding territorial claims in Antarctica, Section 2 of Article IV of the Treaty (SCAR Manual 1972) states:

"No acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to

territorial sovereignty in Antarctica or create any rights of sovereignty in Antarctica. No new claims or enlargement of an existing claim to territorial sovereignty in Antarctica shall be asserted while the present Treaty is in force".

Provision for free exchange of scientific information, scientific personnel, freedom of access to any part of Antarctica and right of inspection by observers of the Treaty countries to all stations located, their equipment, and other installations, are made in the Treaty. The Treaty is emphatic about prohibition of military activities other than support for expedition logistics, ban on nuclear explosions and ban on nuclear waste disposal. Further, the Treaty endorses the preservation of living resources, including flora and fauna, conservation of Antarctic seals, and designates some regions as specially protected areas.

Strangely, the Treaty was silent on mineral resources of the Continent. The question was raised in 1972, but only in 1977 at the Ninth Consultative Meeting of the Treaty, the contracting parties adopted "Recommendations IX-1—Antarctica Mineral Resources" which states:

"(1) The Consultative Parties agree to play an active and responsible role in dealing with the question of mineral resources in Antarctica; (2) the Antarctic Treaty must be maintained in its entirety; (3) protection of the unique Antarctic environment and of its dependent ecosystems should be a basic consideration; and (4) the Consultative Parties, in dealing with the question of mineral resources in Antarctica should not prejudice the interest of all mankind in Antarctica".

The Tenth Consultative Meeting hosted by the US was to consider as per Recommendation IX-1 the various legal and political aspects concerning all issues of mineral resources. Further, the above recommendation IX-1 also urged all nationals and other States to refrain from all exploration and exploitation of mineral resources during the time the Treaty nations are attempting to make progress towards the adoption of an agreed regime concerning Antarctic mineral resource activity. The subject of "Antarctic Resources, the Question of Mineral Exploration and Exploitation" was placed as an item on the Agenda of the Tenth Consulta-

tive Meeting of the Treaty for discussion.

In July 1983, the Treaty countries met at Bonn (West Germany) to devise new guidelines on future exploration of oil and other mineral resources on the continent. Several European countries, Australia, India and other developing countries desire that Antarctica should be treated as the common heritage of mankind.

The contracting countries of the Treaty, however, have agreed to an interim agreement on the protection of the Antarctic Marine Living Resources

It is felt that no mineral resources of the Antarctic continent nor the biological resources of the Antarctic waters and not even the iceberg harvesting will be exploited by any country until the Antarctic Treaty comes up for review in 1991.



Recommended reading: 1. Hunter, D. "The Bushveld complex and its remarkable rocks. *Amer. Scient.* 66: 551-559 (1978); 2. Zumberge, J.H. "Mineral resources and geopolitics in Antarctica. *Amer. Scient.* 67: 68-77.

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Scientifically Speaking



Vidya Dhar

YOU are all familiar with the term "meter" which denotes a device used to measure something. Thus, the speedometer in your vehicle measures its speed and the thermometer measures temperature. The word which precedes "meter" indicates the entity being measured. But these prefixes are not always simple nor as easy as the examples cited above. A dozen such "meters" are listed below. What are they used for? Go ahead and "meter" the limits of your vocabulary. Answers on pages 71, 72.

1. ANEMOMETER

is used to measure

- A: Degree of anaemia
- B: Wind speed
- C: Magnitude of electric current

2. BAROMETER

is used to measure

- A: Tensile strength of steel bars
- B: Height of a potential barrier
- C: Atmospheric pressure

3. DENSITOMETER

is used to measure

- A: Density of liquids or solids
- B: Optical density of photographic spots
- C: Population density of cells in a tissue

4. INTERFEROMETER

is used to measure

- A: Thickness of thin films

B: Extent of interference in radio transmission

C: Relative concentration of iron in alloys

5. LACTOMETER

is used to measure

- A: Melting point of resins
- B: Specific gravity of milk
- C: Level of lactic acid in blood

6. MANOMETER

is used to measure

- A: Basal metabolic rate of man
- B: Concentration of manose in starchy foods
- C: Pressure of a gas

7. MICROMETER

is used to measure

- A: Very small distances
- B: Magnification of a microscope
- C: Length of a chromosome

8. POLARIMETER

is used to measure

- A: Thickness of the polar ice cap
- B: Optical rotation caused by a substance
- C: Electric or magnetic polarity

9. POTENTIOMETER

is used to measure

- A: Potency of a drug
- B: Tension in a stretched wire
- C: Electromotive force

10. PLANIMETER

is used to measure

- A: Surface area of a plane
- B: Altitude of an aeroplane
- C: Topographic uniformity of planes

11. POTOMETER

is used to measure

- A: Intensity or flux of light
- B: Strength of ceramic materials
- C: Transpiration from leaves

12. TACHOMETER

is used to measure

- A: Engine speed in terms of revolutions
- B: Severity of body ache
- C: Strength of a sound echo