

NEWS AND VIEWS

Icebergs: technology for the future

from Herbert E. Huppert

EVERY year some 5000 icebergs, totalling 10^{12} m³ of ice, are calved from Antarctic glaciers and ice shelves. Each iceberg consists of approximately 10^8 tons of pure fresh water. It drifts for a number of years under the influence of the currents and the winds, gradually breaking up and melting into the Southern Ocean. Occasionally, icebergs drift as far as 30°S, and may influence regional climate as well as local weather. At the time of calving each iceberg has a flat top and vertical sides which plunge some 200m into the water. After several years they may be worn into very convoluted shapes as can be seen in the cover illustration.

A recent conference on The Use of Icebergs* was mainly devoted to discussions of the physical characteristics of icebergs, including the way they break and roll over, their melt-rate, and the feasibility of capturing icebergs and towing them to Australia, South Africa, California or Saudi Arabia, where they could be used as a supply of fresh water.

Icebergs break due to the flexural strains induced by ocean swell and differential melting. Breaking can be enormously enhanced by the presence of flaws such as the cracks and deep crevasses that are frequently found in ice shelves. P. Wadhams (Cambridge University) presented calculations for the elastic response of a perfect, two-dimensional ice sheet to a given swell-induced pressure distribution at the base of the ice. The results yielded the maximum strain as a function of the amplitude of swell and size of the ice, the ice fracturing when the strain exceeds a postulated breaking strain. His calculations suggest that large ice sheets will not be broken up in seas which can destroy smaller sheets. Only very large icebergs would thus be expected to remain intact as they drift into regions far from the Antarctic coast. This fits well with the

observations that few medium-sized icebergs are seen in these areas. O. Orheim (Norsk Polarinstitut, Oslo) reported that the 1978/9 Norwegian Antarctic Research Expedition found very few crevasses at the base of the 24 tabular icebergs on which they landed. If this is generally true, it suggests that icebergs are calved from the ice shelf along every basal crevasse, although it is possible that the ice around each crevasse had melted since calving.

The processes of iceberg melting were surveyed by H. E. Huppert (Cambridge University), who argued that the base of an iceberg was likely to melt less than the vertical sides. Melting at the sides of an iceberg into an ocean of uniform density leads to a turbulent, entraining plume containing upwardly moving melt water mixed with oceanic salty water. In regions where the ocean is vertically stratified, the melt water largely flows out in a horizontal series of layers (Huppert & Turner, *Nature*, 271, 46; 1978 and *J. Fluid Mech.*, in press). There was evidence of both forms of convection in measurements taken around a grounded iceberg in Conception Bay, Newfoundland by E. G. Josberger (Oregon State University). An experiment in which a block of ice $1\text{m} \times 0.5\text{m} \times 0.25\text{m}$ was melted into water at approximately 20°C and 35‰ was described by D. S. Russell-Head (University of Melbourne). Under these conditions it appeared that the basal melt rate was comparable to that for the vertical walls. This is possibly due to melt water formed at the base being able to flow up the sides.

Calculations for the frequencies of oscillation of an iceberg of given shape, and the shapes which lead to instability and hence roll-over, were the subject of a number of presentations. J. F. Nye (University of Bristol) presented an analysis based on catastrophe theory. From Nye's results it can be inferred that if the melt-rate increases with increasing depth the iceberg remains stable and is unlikely to roll over. This melting pattern was noted in the experiments above but in the Antarctic the melt-rate may be sufficiently influenced by local variations

in temperature and current speed to alter the resultant geometrical shape. All the calculations neglected the induced motion in the water, although this has been found by naval architects to be important (J. N. Newman, *Marine Hydrodynamics*, M.I.T. Press).

A number of results are already available from the 1978/9 Norwegian Antarctic Research Expedition. This was one of the first expeditions to obtain field data from Antarctic icebergs rather than just ice shelves. South of about 66°S, the measured annual melting was less than a few centimeters. Measurements of the temperature of the upper 10m of the bergs indicated that the temperature rose above that of the -20°C of the ice shelf to -5°C and higher. The expedition employed a sidescanning sonar to determine the underwater shapes of icebergs and ice shelves. The most exciting result, reported by B. A. Fossum (Continental Shelf Institute, Trondheim), is the discovery of an underwater ram of ice protruding more than 180m at a depth of 100m from the ice wall at Kapp Norvegia. This contrasts with the completely vertical face mapped at Blåenga which is less than 100km away.

Iceberg Transport International have carried out a number of scaled towing tests and some of the results were reported by F. Mauviel (Iceberg Transport International, Paris). The tests consisted of towing a wooden 1/100 scaled model of a tabular iceberg in Brienz Lake, Switzerland, and a steel 1/60 model in St. Malo Harbour, France. Propulsion was provided by outboard motors, or by sails, or by hauling on lines attached to a very large parachute drogue ahead of the model. The last means of propulsion appears to be the most efficient. Extrapolating from the test results, Mauviel estimated that a reasonable efficiency could be achieved by using two drogues of 10^5 m² to propel an

*The conference, organized by The International Glaciological Society, was held at the Scott Polar Research Institute, Cambridge, UK from 1-3 April, 1980 and was sponsored by Iceberg Transport International, King Faisal Foundation and Abdul-Aziz University through the initiative of Prince Mohammed al Faisal al Saud. The proceedings are to appear in *Annals of Glaciology*, 1.

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iceberg through the water at a speed of 0.5 knots. The two drogues would be pulled alternately, operating, in principle, like the hands of a swimmer doing the Australian crawl. The drag acting on the models was noted to be a fairly strong function of shape and to be least for an "iceberg" whose maximum girth is amidships and whose vertical walls are tapered so that the bow and stern width are approximately 3/5 of the central width. It is envisaged that the next series of tests will involve an actual Arctic iceberg that is roughly 1/10 the size of an Antarctic berg.

A study by D. J. DeMarle (Rochester Institute of Technology, New York) focused on the feasibility of processing icebergs in Saldanha Bay, on the west coast of South Africa. The region has been listed as a future metropolitan growth area by the South African Department of

Environmental Planning. Instead of melting the iceberg on arrival, DeMarle proposed that it be mined using existing technology. A slurry of ice fragments and water would then be pumped ashore via an ocean pipeline. The operation might be powered by the waste heat of a nearby industrial complex, for which a large cold sink could help to increase efficiency.

M. W. Holdgate (Department of the Environment, UK) highlighted the audacious simplicity and social benefits of using icebergs as an inexhaustible source of water. However, such a scheme is not without dangers, not only because of accidents which could result from a stream of broken off icebergs being abandoned in shipping lanes but also because we have little idea of the environmental effects of moving icebergs around the world. □

of available SRS, so described because the bulk of the research over this period concentrated on material chemically released with the ionophore A23189, rather than the immunologically generated SRS-A.

In May 1979, at the international prostaglandin conference in Washington, Bengt Samuelsson of the Karakinska Institute in Stockholm, in collaboration with Borgeat, Hammarstrom and Murphy described the work which led to the characterization of the leukotriene (LT) structures LTA, LTB and LTC from a murine mastocytoma cell line and from rabbit polymorpho-nuclear leukocytes. LTA was shown to be 5.6 epoxyarachidonic acid, LTB a dihydroxyarachidonic acid and LTC as 5 hydroxy 6 cysteinyl arachidonic acid. His suggested name derived from the leucocytes which release the material and the conjugated triene system of double bonds in the structure. These double bonds were also responsible for the chromophore at around 280 nm, an observation made by both Piper's and Parker's groups.

A relationship was suggested between this chemically released SRS, now to be known as leukotriene C, and SRS-A but the picture was not yet complete. At the end of 1979, and in early 1980 Samuelsson, in collaboration with the chemical group of Corey at Harvard, described LTC as glutathionyl hydroxy arachidonate. Comparison of the biological activities of the natural with totally synthesized material showed them to be identical. It should be stressed, however, that this natural material was chemically released and so could not be correctly called SRS-A. Also, early in 1980, Piper and Morris characterized an SRS chemically released from guinea pig lung as glycy-cysteinyl hydroxy arachidonate, differing from the LTC described by Corey and Samuelsson by a glutamic acid residue.

In this issue of *Nature* (p. 104) Piper and Morris describe the first characterization of immunologically released SRS-A from guinea pig lung, achieved with a novel mass spectrometric procedure, and show that it is identical with the chemically released material released from this tissue.

Developments in this field are so rapid, however, that Samuelsson described the same compound at the Winter Prostaglandin Conference in Snowbird, Utah this April and showed that it was formed from leukotriene C by the enzyme A-glutamyltranspeptidase. He named it leukotriene D and described, in collaboration with a number of his colleagues, various aspects of the pharmacology of the leukotriene compounds: A, B, C and D.

It is pertinent to note that the majority of the data presented by the various groups is chemical in nature and the biological activity of these compounds will need to be clearly defined. No doubt in the ensuing months biological flesh will be put on these exciting chemical bones. □

SRS-A and the leukotrienes

from W. Dawson

The discovery of a new class of biologically active compounds is always exciting, even at the present time when knowledge is advancing so rapidly.

The leukotrienes are a new structural class deriving from arachidonic acid, a precursor which has already given us the prostaglandins, thromboxanes, prostacyclin and various hydroxy fatty acids. The systems from which the leukotrienes have been released and characterized are closely related to immediate hyper-sensitivity reactions and it has been proposed that SRS-A, slow reacting substance of anaphylaxis is a member of the leukotriene family.

Slow reacting substances (SRS) are so-called because of the characteristic slow contractile response they induce in smooth muscle preparations *in vitro*. The original SRS from lung tissue was described by Kellaway and Trethewie in 1940, being released from guinea pig lung by snake venom. In a series of papers in the early 1950's Brocklehurst isolated and characterized a similar substance released from guinea pig lung following anaphylactic challenge and named it SRS-A. He later identified a similar product released *in vitro* from human lung, derived from an asthmatic person in response to the specific allergen. This work clearly linked SRS-A with the long lasting bronchoconstriction experienced by asthmatics.

For the next 25 years many research groups attempted to identify the chemical structure of SRS-A, notably those of Brocklehurst himself in England and Austen with the late Robert Orange in the USA. Although advances were made, the structure remained elusive. Undoubtedly the extreme potency of SRS-A, the relatively small amounts of material available, and its unusual physico-chemical properties were the major causing slow progress of this research.

During the 1960's and early 1970's the prostaglandin (PG) family of structures were identified and their pharmacology described. It seemed natural that the analytical challenge of SRS-A should attract workers in the PG field and within a relatively short period of time publications from many research groups appeared in the literature. The independent work of Parker, Piper and Bach all suggested incorporation of radiolabelled arachidonate into SRS-A-like biological activity whilst two groups, at St. Louis and Lilly, showed incorporation of 35 sulphur. The Harvard group identified sulphur by spark emission spectroscopy in their SRS-A preparation and it seemed clear that it was only a matter of time before the structure was revealed.

During 1978 and early 1979, both Parker and Jakschik in St. Louis and Piper and Morris in London suggested various functional groupings which they felt were present in the molecule. In particular, the chromophore at 278-280 nm seemed a key to the purification of the minute amounts