Planetary science

Ices in the Solar System

from I. P. Wright

THE growth of interest in Solar System ices has been generated, in part, by visually spectacular data from the Voyager encounters with the rings and satellites of Jupiter and Saturn. At the same time, substantial advances have been made with threoretical modelling and observational measurements of dirty ices, long thought to be the primary constituents of cometary nuclei, and there is intensive laboratory study of the physical properties of ice. These and other topics were the subject of a meeting recently held in Nice*.

Water ice is thought to be prevalent in certain satellites of Jupiter and Saturn as well as in comets. E. Whalley (National Research Council, Ottawa) reviewed those properties of water ice (or the 'fundamentals of planetary glaciology' as he preferred to call it) that are pertinent to the study of large icy bodies. The phase diagram of water over temperatures between 0 and -120°C and pressures up to 25 kbar shows nine different polymorphs of ice (called ice I_h, ice II, ice III and so on), some of which are ordered structures, others disordered. A novel ordering transformation identified in ice I_h at low temperatures could possibly occur in an icy Solar System body, catalysed by such substances as ammonia. If so, since the transformation liberates heat, it would have a number of implications for the physical states of planetary bodies.

The water ice deep in the interiors of the satellites of Jupiter and Saturn may be the high-pressure forms, ice VI and VII. J. Poirier (Institut de Physique du Globe de Paris) described the use of a sapphire-anvil squeezer cell to study the laboratory deformation of these forms. By measuring the displacement of markers within the ice crystals it was possible to compute the creep rates of ice as a function of shear stress, temperature and pressure; preliminary measurements of ice VII show it to be extremely hard. Experimental deformation of ice I_h demonstrates that it can exhibit both brittle and ductile behaviour (S. Kirby, US Geological Survey, Menlo Park; W. Durham and H. Heard, Lawrence Livermore National Laboratory). Its brittle character is similar to that of rocks; measurements of ductile strengths, however, indicate that the ice I_h layer on icy Solar System bodies is much weaker than generally thought.

Of relevance to studies of ice accumulation was the report by E. Mayer and R. Pletzer (Universitat Innsbruck, Austria) that the properties of amorphous ice are dependent upon the method of production. In one of their methods, water vapour is leaked through a nozzle into a high-vacuum chamber and deposited as amorphous ice on a cryoplate. The ice, formed in supersonic flow conditions, is found to have a very rough surface; upon warming it shows a number of exothermic peaks. In their alternative method, the water flow is broken up by the introduction of a baffle, whereupon a glass-like ice with a very small surface area is formed. This ice produces only one exothermic peak when warmed. The interesting question that remains is what form of ice might be produced when a solid target travels at high velocity through water vapour, the probable situation in certain Solar System environments.

M. Nicol and co-workers (University of California, Los Angeles) have investigated ice formation in an ammonia–water system at low ammonia concentrations (0–30 per cent) and high pressures (up to 40 kbar), using a diamond-anvil squeezer cell. Microscopy showed that whereas the $NH_3.2H_2O$ phase is characterized by strong anisotropy, smaller refractive index than ice VII and the tendency to form cracks, the $NH_3.H_2O$ phase, which forms at higher pressures, has a refractive index close to that of ice VII and does not form cracks. The outcome of the work has been the production of a preliminary phase diagram for the ammonia–water system. The importance of this system was outlined by S. Miller (University of California, San Diego) who believes that hydrates of ammonia are likely to occur on Uranus and Neptune as well as on the satellites of Jupiter and Saturn.

Accompanying the ammonia hydrates on icy Solar System bodies might be methane hydrate, a substance known to occur on Earth in certain deep-sea sediments. Furthermore, by analogy with the air hydrates found in the terrestrial Antarctic ice cap, it is thought that CO_2 hydrates should be present in the polar regions of Mars (and may also exist in comets). Clathrate hydrates are thus thought to be important and widespread constitutents of Solar System ices and now appear in theoretical models of the physical and chemical states of the saturnian satellite Titan and the neptunian satellite Triton (J. Lunine, Caltech). T. Owen (Stony Brook, State University of New York) demonstrated that the atmospheres of icy bodies are composed of gases which probably result from the dissociation of clathrates. Unfortunately clathrate hydrates have observational characteristics which are indistinguishable from water ice and so, without an actual excursion to one of the icy Solar System bodies, it will not be possible to verify their existence anywhere other than on Earth.

An important constituent of bodies such as Pluto, Titan and Triton is methane ice. Indeed, on Triton there is evidence of islands of solid methane floating on a sea of liquid nitrogen (D. Cruikshank, University of Hawaii). By way of complimenting the observational work, N. Trappeniers (University of Amsterdam) reported that pressures of up to 60 kbar, attained in a diamond-anvil cell, produce evidence of a new phase of methane (phase IV).

All told, the meeting demonstrated that definite progress is being made towards the ultimate goal — a full understanding of the evolution of ices in the Solar System and the construction of consistent models which relate the nature and characteristics of the ices to the materials from which they are formed. It was easy to sense the impatient expectation of many participants for the unique measurements that should come from fly-by missions to Halley's comet when it makes its closest approach to Earth in 1985–6. □

I. P. Wright is in the Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA.

*'Ices in the Solar System', a NATO-sponsored Advanced Research Workshop, was held in Nice from 16 to 19 January.

NATURE

100 years ago

AMONG the superabundant "Universities" of the United States Harvard is unquestionably taking its place as a national institution on a par with British establishments which hold a similar designation. The last quarterly *Bulletin* of its proceedings is before us, which has to acknowledge during that short time nine legacies or donations in money, varying from 200 to 100,000 dollars, and amounting to 168,000 dollars. One of these is 10,000 dollars subscribed for the purchase of meteorites, and another is 2000 dollars from the Massachusetts Society for Promoting Agriculture, to assist in the establishment of a veterinary hospital, to which institution also a collection of pathological models is presented.

THE last number of the *Transactions of the Seismological Society of Japan* (Yokohama, 1884) contains various papers on seismology. The first is by Prof. Milne, on earth pulsations; the next is by Mr. Alexander, on the interpretation of a diagram described by a particular form of earthquake instrument. The object of the writer is to calculate not only the maximum velocity, but also the maximum rate at which the velocity changes, "which is a measure of the effect which an earthquake exerts in overturning and fracturing bodies placed on the earth's surface." Prof. Ewing describes the construction of a pendulum which shall be without a tendency to swing when the point from which it is suspended suffers displacement. Mr. Gergens gives a note on ripple-like marks found on the surface of an iron casting supposed to have been shaken while solidifying, which marks are picturesquely described as "a note in a congealed eathquake." The remainder of the volume contains suggestions for new types of seismographs.

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