will yield valuable information about the distribution and state of matter in the most distant regions of the universe and perhaps help to answer the age-old question as to its origin.

For the new studies a very large radio telescope will be needed, far too large to be built in a completely steerable form, such as the large paraboloid being constructed by the Commonwealth Scientific and Industrial Research Organization at Parkes. The radio telescope needed for this work must have dimensions of about one mile, and the most suitable form for this is a cross-like structure invented by Dr. Mills and called a Mills cross. The cost of a radio telescope of this type and size will be about £300,000.

The Chatterton Astronomy Department, supported by the Nuclear Research Foundation, has set aside £100,000 for the first stage of this telescope. The rest of the cost to complete the instrument to its full size must be raised elsewhere by the Schools of Physics and Electrical Engineering of the University. During the next year, when the first stage of the telescope is being designed and construction commenced by Dr. Mills and his collaborators, Prof. Christiansen will be in Holland engaged in a design study for a similar instrument for a Benelux research foundation. Because of the different conditions it is probable that the details of the two instruments will be very different. This close international collaboration is typical of many astronomical projects and should be of great benefit to astronomy in both countries.

Although the design of the Sydney radio telescope has not been completed, the broad specifications are already decided (Fig. 1). It is intended to operate at two different wave-lengths, near 75 cm. and near 3 m. The shorter wave-length is the basic one, and will give the higher sensitivity and resolution; the beam-width will be less than 3 min. of arc with the planned size of 1 mile. The longer wave-length will

be used to obtain spectral information, particularly of optical emission nebulae for which observations in the neighbourhood of this wave-length are most important.

The arms of the cross will be in the form of cylindrical parabolas with 'line' feeds for the two wave-lengths at their foci. It will be possible to direct the instrument in the meridian plane, partly by mechanical and partly by electrical means, rotation of the Earth bringing all parts of the sky, within the coverage of the instrument, into view. Emphasis is being placed on rapid alteration of the setting of the radio telescope so that many selected objects can be studied in a single night's observation; at the same time a number of simultaneous records at closely spaced elevations produces the analogue of a photograph taken with an optical telescope. Because of the vast amount of data which will be produced by the instrument, the principal output will be in digital form on paper tape, and for analysis will be fed directly into *Silliac*, the electronic computer of the School of Physics.

This instrument will combine very well with the 210-ft. steerable radio telescope of the Division of Radiophysics, which is designed primarily for operation at shorter wave-lengths, down to 10 cm., including the *H*-line wave-length of 21 cm. The conjunction of these two very powerful instruments in studies of the southern skies, particularly of the central regions of the Milky Way and the closest of the external galaxies, the Clouds of Magellan, is an exciting prospect for Australian radio astronomers.

The joint effort of the Schools of Physics and Electrical Engineering in this ambitious undertaking is without parallel in the University of Sydney, or indeed in any Australian university, and may help substantially in setting a pattern for the more effective introduction of advanced research into the universities of Australia.

THE INTERNATIONAL GEOPHYSICAL YEAR

A SYMPOSIUM on the "International Geophysical Year", arranged by Section A (Mathematics and Physics) of the British Association, was held in Cardiff on September 1.

Dr. R. Stoneley opened the symposium with a reminder that the idea of international co-operation in scientific matters is by no means a modern one. Sir Graham Sutton has pointed out that in 1861 the American meteorologist Commander F. M. Maury, in an article in the *British Association Notices and Abstracts*, strongly advocated international co-operation in the scientific exploration of the Antarctic. However, the suggestion was not followed up, and it was not until 1882-83 that the First International Polar Year marked the commencement of scientific collaboration in polar research: observations were made in arctic regions of auroræ, geomagnetic and meteorological phenomena. Fifty years later, 1932-33, the Second International Polar Year included as new features the observation of weather conditions above ground-level by means of radio-balloons, and the investigation of the ionosphere by radio.

It was too much to expect scientists to wait until 1982 for another Polar Year, and in 1950, Louis V. Berkner and Sydney Chapman suggested to the

Mixed Commission on the Ionosphere that the Third International Polar Year be held only 25 years after the second, with the advantage that 1957-58 would coincide with the expected sunspot maximum. This project was recommended by that Commission to the three parent Unions (Union Géodésique et Géophysique Internationale, International Astronomical Union, Union Radio Scientifique Internationale) and was approved in 1951 by the International Council of Scientific Unions, which appointed a special committee, to be known later as the Comité Spécial de l'Année Géophysique Internationale, with Prof. S. Chapman as president; the name of the project was changed to 'International Geophysical Year', embracing the whole Earth, and not merely the polar regions. The duration of the International Geophysical Year was extended to the eighteen months July 1, 1957-December 31, 1958. By the commencement of the Year the number of nations participating had grown to 67.

The scientific activity was divided among 14 'disciplines': (1) World Days and Communications; (2) Meteorology; (3) Geomagnetism; (4) Aurora and Airglow; (5) Ionosphere; (6) Solar Activity; (7) Cosmic Rays; (8) Longitudes and Latitudes;

(9) Glaciology; (10) Oceanography; (11) Rockets and Satellites; (12) Seismology; (13) Gravity Measurements; (14) Nuclear Radiation. Each of these was represented on the Comité Spécial de l'Année Géophysique Internationale by a reporter. Correspondingly, national committees were set up in the participating countries, with reporters for each discipline. In all, five conferences of the Comité were held, in addition to conferences of special groups. The general plan was that all observational data were to be collected and sent as promptly as possible to the three appropriate World Data Centres, of which the first was in Washington, D.C., the second in Moscow, and the third in centres different for various disciplines. Thus, there should be in existence a triplicate centralized record of the observations relating to each discipline: notification of each despatch of data to the Centres was sent to the co-ordinator of the International Geophysical Year (Vice-Admiral Sir Archibald Day) at Brussels. To co-ordinate more efficiently the taking of observations a calendar of World-Days was drawn up, indicating the days on which there should be a special concentration of observational work. In addition, provision was made for a world-wide distribution of warnings of special events, such as outbreaks of solar activity.

All this central organization, however economically managed, involved considerable expenditure. The earlier expenses were borne by the International Council of Scientific Unions, which by the end of the International Geophysical Year contributed some £14,000 to the project. More than double this amount, about £30,000 was paid by Unesco during the same period, during which the participating nations themselves contributed some £60,000. But this total sum of about £100,000 is small compared with the total expenditure, principally by the participants, of a sum of the estimated order of £300,000,000—a tribute indeed to the efficiency of the central organization.

The task of publishing the results of the International Geophysical Year is an onerous one. A scheme of publication of the *Annals of the International Geophysical Year* was approved by the Comité Spécial de l'Année Géophysique Internationale with the help of an advisory committee presided over by Gen. Laclavère and later by Dr. D. C. Martin, with Sir Harold Spencer Jones as general editor until May 1958, when this task was transferred to the secretariat of the International Geophysical Year. To secure co-ordination of observational work, a series of four "Instruction Manuals" was published well ahead of the Year. The complete series of the *Annals* will deal with the history and planning, as well as national programmes, lists of International Geophysical Year stations, summaries of results with their analysis, interpretation and discussion, bibliographies and catalogues of material available at World Data Centres. Evidently some procedures, such as access to data at these Centres, will need to be developed or modified according to needs and experience. Analogous problems, such as publication and storage of data, will fall to the lot of individual countries. In Great Britain, for example, the Royal Society has well in hand the publication of the Halley Bay Observations, under the editorship of Dr. D. C. Martin.

Something should be said about the continuation of the International Geophysical Year effort after the end of 1958. The manifest success of the plan

led to the proposal at the fifth conference of the Comité Spécial de l'Année Géophysique Internationale at Moscow in the late summer of 1958 that the International Geophysical Year period should be extended to the end of 1959, making $2\frac{1}{2}$ years in all. Not all the nations involved could assent to this scheme, since in some cases the national commitment was explicitly limited to the original 18 months. It was, however, unanimously agreed that, so far as practicable, observations should be continued throughout 1959 under the title of "International Geophysical Co-operation", with the central organization bridging the gap until a smaller special committee could take over the functions of the Comité Spécial de l'Année Géophysique Internationale. Some of the International Geophysical Year disciplines that are otherwise catered for have been dropped, and two new disciplines, aeronomy and palaeogeophysics, have been included*.

The Antarctic claimed special attention. As H. Wexler pointed out, essentially for seven reasons: (1) It is a large part of our planet; (2) it contains 86 per cent of the world's glacial ice; (3) it is the most efficient cold air factory, and contains the South Pole; (4) the melting ice generates the antarctic bottom current; (5) it is the region of the aurora australis; (6) it contains the south magnetic pole; (7) it presents a stable platform for the investigation of the thermal and electrical properties of an atmosphere cut off from sunlight for many months of the year. Thus, it is not surprising that 12 nations sent expeditions to Antarctica.

During 1954 the Vahsel Bay region of the Weddell Sea was recommended by the Comité Spécial de l'Année Géophysique Internationale at a conference in Rome as a suitable place for a station on the Antarctic continent, and the Royal Society decided to send an expedition there. An advance party late in 1955 erected the base hut at Halley Bay; the main party arrived on January 4, 1957. The leader of the expedition was Col. R. A. Smart, who later was succeeded by Mr. J. MacDowall.

Taking part in the symposium held by the British Association were: Prof. W. J. G. Beynon, who was reporter for the ionosphere, both on the Comité Spécial de l'Année Géophysique Internationale and on the U.K. National Committee for the International Geophysical Year; Mr. J. MacDowall, who, as mentioned, had for part of the time the leadership of the Halley Bay Expedition, in addition to his heavy responsibilities for observations in meteorology, glaciology, seismology and geomagnetism; Dr. G. E. R. Deacon, chairman of the U.K. National Committee for Geodesy and Geophysics, and national correspondent for oceanography.

Ionospheric Observations

Ionospheric studies formed a major part of the overall programme of the International Geophysical Year, and some of the early results of these studies were described by Prof. W. J. G. Beynon of the University College of Wales, Aberystwyth. The most important type of study—vertical radio soundings—was carried out at more than 160 stations. Work on radio-wave absorption by the ionosphere was carried out at some 40 stations by the conventional ground-based method and at a further 30 stations by a method

* The writer wishes to express his indebtedness to Prof. S. Chapman's article, "The International Geophysical Year", published in Vol. 1 of the I.C.S.U. Review, January 1959.

which employs radiation from radio stars. Movements in the ionosphere formed a special investigation at a further 36 stations. This radio work on the ionosphere was supplemented by other investigations, including rocket and satellite experiments.

In siting the ground-based stations, high priority was given to the equatorial zone since earlier work had indicated that the ionosphere exhibits a number of anomalies in the locality of the magnetic equator. These investigations have confirmed that in the uppermost layer of the ionosphere (the *F*2 layer) there is a belt of low electron density centred on the magnetic equator, with maxima located some 15°–20° of latitude away on each side. At times the densities at these maxima are as much as three or four times that in the equatorial trough. Theoretical work suggests that these maxima north and south of the magnetic equator result from a movement of high-level equatorial ionization outwards along the magnetic field, and the results now available from the close network of ionospheric stations tend to confirm this suggestion.

A second equatorial problem, for which the results obtained during the International Geophysical Year have already been published, concerns the 'equatorial electro-jet'—an intense but narrow current system, postulated by magneticians to account for abnormally large magnetic variations observed at equatorial magnetic observatories and notably at Huancayo. A series of rockets launched during the International Geophysical Year by U.S. workers from a ship-borne launcher, at latitudes between 4° N. and 2½° S., show that the equatorial electro-jet is limited to a zone of only about 3–4 degrees of latitude around the magnetic equator, and that it flows in one or more current sheets of thickness about 10 km. at levels of 95–125 km. above the ground.

It has long been appreciated that disturbances in the Earth's magnetic field, and associated disturbances in high latitudes in the form of auroræ, are very probably caused by electrically charged particles entering the Earth's atmosphere from outside and being guided towards high latitudes by the terrestrial magnetic field. More than 50 years ago the Norwegian physicist Störmer made an extensive analysis of the trajectories of solar electrically charged particles as they approach the Earth, and published theoretical curves of particle precipitation in high latitudes. Investigations during the International Geophysical Year, by British workers, of two distinctive polar ionospheric phenomena (the 'radio black-out' and polar sporadic-*E* ionization) have shown that the incidence of these two phenomena and their variations with latitude are of the general form predicted by Störmer's 'precipitation curves'.

The incidence of streams of charged particles at high latitudes might be expected to give rise to an increase in the temperature of the upper atmosphere. Strong evidence that this is in fact the case has come from rocket soundings at Fort Churchill (latitude 59° N.) and at White Sands (latitude 33° N.). Above about 200 km. the average temperature at Churchill is some 1,200 degrees higher than at the lower-latitude station.

Geomagnetic and Seismic Observations

Mr. J. MacDowall gave an account of the Royal Society's expedition to Halley Bay. A suitable site 1½ miles from the sea on a floating ice-shelf had been

found by a ten-man advance party in January 1956, and a living hut 130-ft. long was erected. This was then the largest building in Antarctica, a record which will now undoubtedly be claimed elsewhere. With this advance party in the field during 1956 the main party in Great Britain were able to plan their preparations with a good appreciation of some of the practical problems facing the establishment of the scientific programme. One of the most serious problems was the mutual electrical interference; fortunately this did not greatly affect the carrying out of seismic and geomagnetic observations. The main problem was perhaps the situation of the observatory on what is now called the Brunt Ice-Shelf, which was about 50 km. long and 140 m. thick, floating in about 190 m. of sea water; the relative dimensions can be represented by a board of wood ½ in. thick and 10 ft. long overlying ¼ in. of water.

Such a situation was not considered ideal for seismic and geomagnetic recorders, which are ordinarily built on a firm subsoil-rock if possible. The advance party, the Building Research Station and the Scott Polar Research Institute contributed to the eventual solution of the problem of the geomagnetic instrument foundations, which were formed by driving 13 wooden telegraph-poles 20 ft. into the compacted snow of the ice-shelf; these reduced differential movement and formed a satisfactory vibration-free foundation. Snow accumulated on the flat upper surface of the ice-shelf at the average rate of 3 ft. per year (density 0.36 gm. cm.⁻³); it afterwards became compacted and spread out, with the result that the ice-front, or coast-line, moved outwards, taking the Base with it at about 400 m./year. At the same time the Base rotated by about 0.5° a year, so that regular astronomical observations were needed in order to find the true orientation of the recording magnets.

The seismic recorders were tried in several situations, and were eventually installed at the bottom of a 30-ft. pit, the floor of which was sufficiently firm, and free from local vibration due to the nearby Base: at that depth the compacted snow has the consistency of soft sandstone. In this site the arrivals of longitudinal waves originating in any part of the world were well recorded; secondary phases and shear waves, however, were not well recorded, even from nearby earthquakes in the South Shetland Islands about 1,200 km. away. In seismological work, the first arrivals are undoubtedly the most important and to this extent the seismological readings were quite satisfactory.

On the question of the continuation of observations at Halley Bay, Mr. MacDowall considered that on the observational side the issue is clear cut, as much is now known that was unknown in 1956. In view of the unique situation of the Base it would be highly desirable to bring the Base up to the ideal geomagnetic observatory standard by making quick-run recordings and measurements of space gradients; tests should be made of other and better types of seismic instruments.

Oceanography

Dr. G. E. R. Deacon remarked that the main idea of the International Geophysical Year was to co-operate in work that needs world-wide networks of observations. Oceanographers exploited the idea by studying changes in mean sea-level, long waves

propagated across the oceans, and the general circulation of the oceans.

Mean sea-level, he said, is not the unalterable datum often implied in everyday usage; at the very first meeting of the British Association, indeed, Sir John Lubbock emphasized the importance of studying the effect of barometric changes on the height of the tide. Sir James Clark Ross in the 1840's found that the ocean behaved like a vast water-barometer; variations of temperature and density of course have to be taken into account.

From data compiled by the International Association of Physical Oceanography it was shown by Patullo, Munk, Revelle and Strong that the sea-level is usually lower in spring than in autumn, the range varying from a few cm. at island stations in low latitudes to 165 cm. in the Bay of Bengal. Near the British Isles the mean sea-level is 15-20 cm. higher in autumn than in spring; most of this can be accounted for by differences of temperature and pressure, but part may be due to the storage of water on the land during the winter months. Some of the fluctuations from year to year are attributable to changes in climate, but the actual rise and fall of the land seems to play a part in it. Variations of mean sea-level become of practical importance in coastal defence against inundation.

Another matter of practical importance arises when a seismic surge or tsunami (popularly called a 'tidal wave') travels across an ocean from the seat of a submarine earthquake in the form of waves which cause considerable damage and loss of life when they impinge on the sea shore. Since the wavelength is in practice many times the depth of the ocean, the waves travel with speeds $(gh)^{1/2}$, corresponding to the usual theory of long waves in shallow water, where g is the acceleration due to gravity and h is the depth of the water. Thus, the ordinary speed of travel is 400-550 miles per hour. On April 1, 1946, for example, a submarine earthquake near the Aleutian Is. gave rise to waves which reached Hawaii 4½ hr. later, causing great loss of life and much damage. At Valparaiso these waves were still 5 ft. high, and in the Antarctic were large enough to wash away an old hut left by the British Graham Land Expedition. Since that disaster a warning system, based on the recordings of earthquakes, has been instituted in the Pacific; during the International Geophysical Year long-wave recorders were installed on many oceanic islands as well as on continental margins, and their records have added much to the knowledge and development of the subject.

After 150 years of ocean exploration there are sufficient observations of temperature and salinity at all depths to give a general idea of the large-scale movements of oceanic waters. Dr. Deacon gave as an example the deep current starting between Greenland and Labrador, where cold water with a fairly high content of salt sinks and spreads southwards at depths of 2,000-3,000 metres. The flow is continued, with a reinforcement of water of high salinity from the Mediterranean, as far south as 50° S., where it rises and forms a stratum between a large wedge of Antarctic bottom water and a shallow layer of Antarctic surface water. This current has been traced round the Cape of Good Hope into the Indian Ocean and south of Australia into the Pacific Ocean. These bodies of water, though moving slowly, transport large quantities of heat and considerably affect the mechanics and productivity of the oceans. During

the International Geophysical Year a notable advance was made in the direct determination of the velocity of flow by using a simple form of float devised by Dr. J. C. Swallow. This could be arranged to float at a predetermined depth and give out sound signals by means of a simple circuit and a magnetostriction oscillator. The results have been surprising: for example, a southward counter-current below the Gulf Stream was observed to flow at 1/3 knot, water at a depth of 2½ miles north-east of Bermuda moved northward for several days at nearly 1 knot, while U.S. scientists have found an equatorial subsurface current in the Pacific flowing at 2½ knots.

In all, Dr. Deacon considered the oceanographic work carried out during the International Geophysical Year to be an undoubted success. It brought to light more problems than it solved, and has led to other co-operative schemes.

Conclusions

Summing up the symposium, Dr. Stoneley remarked that while some of the discoveries have been spectacular, such as the van Allen belts, only the lapse of time will permit an adequate appraisal of all the results of the International Geophysical Year. The geophysical conclusions will gradually fall into their place in this rapidly developing science, but, as with the explosion of Krakatoa in 1883, some of the observations will undoubtedly be of value in lines of research as yet quite unforeseen. Many of the benefits are already clear, even if it is premature to assess their relative importance. However, Dr. Stoneley mentioned in particular the following:

(a) Support has been forthcoming for large-scale and expensive projects which, without the stimulus of the International Geophysical Year, would not have been undertaken. This is particularly true of Antarctic expeditions.

(b) There has been a great stimulus to research in geophysics. In seismology, for example, it has resulted in the setting-up of a number of new stations, of re-equipping and modernizing some of the older ones, and in planning new large-scale lines of research. Likewise, a new magnetic survey of the Earth has been planned.

(c) The general public has become much more aware of the background and the development of geophysics. Radio and television broadcasts have been extremely effective.

(d) The interrelationship of different disciplines has been emphasized. For example, the determination of the inertial constants of the Earth from observations of artificial satellites, linking up with the gravitational field of the Earth and its internal constitution; the world-wide programme of micro-seismic observations, linking oceanography, meteorology and seismology.

(e) The closer association of scientists, whether of the same or of different nationalities, by correspondence, interchange of publications and personal discussion.

Finally, Dr. Stoneley raised the question of the next International Geophysical Year. His own view was that the rapid advances in geophysics would call for another such project sooner than 1985. However, such occasions of international co-operation while stimulating are expensive. It is also conceivable that an overdose of stimulants may not be in the best interests of geophysics.

R. STONELEY