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Early Work in Australia, New Zealand and at the Halley Stewart Laboratory, London

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Early work in Australia, New Zealand and at the Halley Stewart Laboratory, London

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Ionospheric research began in Australia in 1927 after the formation of the Radio Research Board. A. L. Green, by measuring polarization of downcoming waves travelling in the opposite direction to the Earth's magnetic field confirmed that electrons were the effective particles. Builder, Pulley and Wood designed equipment for the automatic recording of critical frequencies. Martyn & Pulley found evidence for high temperatures at F region levels. Munro discovered travelling ionospheric disturbances.

In New Zealand the earliest measurements were made by Munro in 1927–8. The New Zealand Radio Research Board later supported the measurement of critical frequencies, absorption and collisional frequency of Peddie, White, Banwell and Straker.

Australian and New Zealand postgraduate students contributed to Appleton's group at King's College and at the Halley Stewart Laboratory, London. Builder introduced the pulse technique and took part in the Polar Year (1932–3) expedition to Tromsø. Pulley designed the first manual ionogram equipment. Both returned to work in Sydney. White measured reflexion coefficients and collisional frequencies of electrons and later returned to Canterbury University, New Zealand.

The early ionospheric researches sponsored by the Australian and New Zealand Research Boards had a profound influence by expanding university research and the training of many postgraduate students.

1. Introduction

My contribution to this early history of the ionosphere links the Australian and New Zealand activity with that in London, particularly during the last few years before Appleton left the Wheatstone Chair at King's College to return to Cambridge. This association is natural. It began with the event we are celebrating, Miles Barnett, the New Zealander, and Appleton being together in the direct discovery of the ionosphere.

During the years of which I speak many young scientists came to England from Australia and New Zealand to London or to Cambridge to take part in this work. You will see from my later remarks that many returned and with English recruits became the principal investigators in their own countries.

I propose to speak first about the work in Australia, then about the Halley Stewart Laboratory of King's College, London, when I was there during 1931 to 1936 and finally about the work in New Zealand.

2. Australia

The formation in 1927 of the Australian Radio Research Board by the Council for Scientific and Industrial Research (C.S.I.R.) marked the beginning of extensive and successful university research on the ionized regions of the upper atmosphere with the aid of radio techniques.

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Australian scientists and engineers had become aware of or involved with radio – or wireless – communications or broadcasting from early in the century.

The development of radio for all purposes in Australia followed much the same course as it did elsewhere. Wireless telegraphic communications grew vigorously after World War I, stimulated by actions of the Commonwealth Government. This Government had, in 1905, passed the Wireless Telegraphy Act bringing all wireless under the control of the Postmaster-General. Australian and British interests bought out the rights of the Marconi and Telefunken organizations to form Amalgmated Wireless (Australia) Ltd, the first Australian company with large manufacturing and communications interests. A.W.A. was to be a major factor in the growth of radio technology. Its well-known Managing Director, Sir Ernest Fisk, a Marconi Company man, personally played an important role in receiving signals from England for the first time and in the development of radio telephony and broadcasting.

Radio broadcasting for entertainment began in 1923 and rapidly developed; there were 25 stations by 1925.

In 1922 the Government provided A.W.A. with funds to install international beam wireless at Ballan (Victoria) and Rockbank (N.S.W.), at the same time becoming a major shareholder in the venture.

Some of us will recall too the major success of amateur radio in proving the effective use of short waves for long distance communications.

The rapid development of practical radio communication and broadcasting undoubtedly stimulated interest in the universities but I would guess that it was the publications in *Nature*, the *Proceedings of the Royal Society* and other scientific journals that caught the attention of two men – Madsen and Laby, the university professors who initiated scientific radio research in Australia.

Although I had met Madsen briefly previously, I did not get to know him well until I came to Australia in 1941. Madsen was then 62 years old but a vigorous man fully in command of the activities he had promoted and developed since 1927.

At the age of 48 in the year 1926, he had many friends, particularly among the engineering colleagues he met or trained as the first Professor of Electrical Engineering in an Australian university. His appreciation of research was more that of a physicist than an engineer. This was certainly due to his apprenticeship with the older Bragg – W. H. Bragg in Adelaide.

It was in that university that Bragg began his researches in radioactivity during the years from 1901 to 1909 when Madsen was his close collaborator. Madsen's own work on the scattering of electrons interested Rutherford who was at that time evolving his theory of the structure of the atom.

Apart from that period in his early career Madsen spent the whole of his life in the University of Sydney where he originally graduated, doing no more original research but exercising a great influence on the teaching of electrical engineers and on the growth of research in physics, particularly that sponsored by the C.S.I.R.

Laby, only one year younger than Madsen, and also a graduate of Sydney, went to Emmanuel College, Cambridge, as an 1851 Exhibition scholar and worker on the ionization of gases with J. J. Thomson. Laby was appointed Professor of Physics at Victoria University in New Zealand in 1909 and came back to Australia in 1915 to the Chair of Natural Philosophy in Melbourne. There with colleagues and students he published precise measurements of the mechanical equivalent of heat, studied X-ray spectroscopy and chemical analysis and with

Kaye published with well-known Tables of Physical Constants. Laby was to become a Fellow of the Royal Society in 1931.

In 1926 Laby had obtained for his department a grant of £500 for research from the local broadcasting station in Melbourne. Madsen, the entrepreneur of science, was after something bigger and more lasting; he made the running but Laby and he certainly collaborated in the future years of the new Radio Research Board.

The Council for Scientific and Industrial Research (C.S.I.R.) was formed by Act of the Commonwealth Parliament in 1926 with power to undertake or support scientific research for the benefit of primary or secondary industry. Madsen saw in the C.S.I.R. the sponsor he needed to support his plans for radio research in the universities.

C.S.I.R. was not easily persuaded, for the Executive Committee had already decided to devote their limited funds to the obvious problems of a mainly agricultural economy. In September 1926 Madsen approached the Chairman of C.S.I.R., George Julius, his friend and fellow engineer, with the vigour of argument and indication of wide support which are clear from his letter.

He referred to Laby's support and to that of the Post Office. The two broadcasting stations in Sydney and Melbourne, both commerically owned, and Ernest Fisk, Managing Director of A.W.A., offered support and help. The Wireless Institute of Australia and the military authorities were prepared to cooperate.

In addition the Australian National Research Council, then responsible for liaison with I.C.S.U., stated it was in favour of the proposal and had already formed an Australian National Committee for liaison with U.R.S.I.

The formation of the Board was approved and it was able to hold its first meeting in June 1927 with Madsen as its chairman. The members were Professor T. H. Laby, Mr H. P. Brown, Director of the Post Office, Electrical Commander F. G. Cresswell of the Defence Department, with G. A. Cook as Secretary.

The influence of H. P. Brown, Director of the Post Office, was important to its success. His organization had wide responsibilities for the progress of radio and particularly for the development of the new venture of broadcast entertainment. The early investigations of the field strength distribution of signals from the existing broadcasting stations and the study of atmospherics were both to him of very direct interest. Madsen's insistence that the Board's investigations should be allowed scientific freedom met a sympathetic response from the Post Office but this was certainly made easier by the choice being directed to problems which concerned the practical interest of the Post Office.

In the event the P.M.G.'s Department from 1929–30 onwards until 1942–3 found some 70 % of the total annual budget of around £5000.

Until about 1945 only two university groups shared the grants from the Board. Laby's group in Melbourne chose the study of field strength distribution, fading and atmospherics. Those who remember the early work in these fields may recall the names of R. O. Cherry, Leonard Huxley and George Munro. D. F. Martyn when he first came to Australia joined this team but later transferred to Sydney.

It was decided in 1939 to discontinue the atmospherics work but by then it had contributed substantially to the knowledge of interference with radio reception and to the understanding of the meteorology of thunderstorms.

A series of good scientific papers had resulted and a succession of notable graduates – Pawsey, Wark, McNeill, Boswell, Nicholls, Nickson and Kerr – had gained postgraduate degrees through this programme.

My attention must on this occasion be focused particularly on the ionospheric work chosen by the Sydney group.

Madsen, I know, felt in later years personal gratification at having made a wiser choice than Laby in picking for his people the investigation of the ionosphere.

It was not in Madsen's nature to allow the Australian effort to suffer the isolation of distance from the active centres of science, particularly that of England. No sooner had the first meeting of his Board ended than he was off to England. He spent time at the D.S.I.R. Radio Research Station and attended the fifty-first meeting of the British Radio Research Board on 12 December 1927. He was given the British programme for 1928–9 and suggestions on researches where collaboration between Australia and Britain might be desirable.

Perhaps of equal importance in the long term was the friendship he formed with Henry Tizard, then Secretary, D.S.I.R., and with Edward Appleton, then at King's College, London.

His reception on that occasion was typical of the generosity that continued to be shown to Australian radio scientists by Britain.

The research of the Sydney group was lifted into the limelight of World scrutiny by the earliest investigations of A. L. Green.

Not long after the direct confirmation of the presence of ionized regions in the upper atmosphere, Appleton & Ratcliffe (1928) measured the state of polarization of downcoming wireless waves. Transmitting from the National Physical Laboratory, Teddington, to a receiving station to the north at Peterborough the polarization was found to be predominantly circular and of left-handed rotation. The waves leaving the ionosphere were in this experiment travelling downwards in the same direction as the Earth's magnetic field and at a small angle to it. The authors stated:

'It is shown that, according to the magnetoionic theory of atmospheric deflexion of wireless waves in which the influence of the Earth's magnetic field is recognized, such left handed elliptical polarization might be expected if the electrical carriers in the ionized layer are of electronic mass, but that similar measurements made in the southern hemisphere would yield evidence which would materially confirm or disprove such an interpretation.'

In 1929 the Australian Radio Research Board decided to appoint experienced research scientists to assist in the development of the Australian programme. Dr A. L. Green, an English student who at King's College, London, had, with Appleton, proved the existence of the F as well as the E-region, (1930) joined Madsen's group in December 1929. He immediately began planning a polarization experiment using the broadcasting transmitter 2BL, Sydney, with his own receiving equipment at the Naval College at Jervis Bay, south of Sydney. On 25 June 1930 he telegraphed Madsen announcing his first measurements in the southern hemisphere of the height of the Heaviside layer. On 1 September he again telegraphed confirming the prediction of Appleton & Ratcliffe that the polarization of downcoming waves in the hemisphere would be right handed when the downcoming waves travelled in the opposite direction to the Earth's field.

This was a major success for the young R.R.B. and it was unfortunate that Green's work failed to be published by the Royal Society. Appleton published in *Nature, Lond.* (1931) a brief account of Green's work, but the complete work did not appear until it was published by the

Institution of Radio Engineers in the U.S.A. (Green 1934) after already having been published by C.S.I.R. (Green 1932, pp. 11–36).

Green's observations (1932, pp. 37–80) of the height of reflexion also clearly showed the existence of both E and F-layers in the southern hemisphere at levels of the same order as those found in England.

Green continued his interest in polarization and propagation, working with Baker, Builder and Martyn, until he retired from the R.R.B. service in 1935 to join Amalgamated Wireless (Australia) Limited. In 1946 he wrote an excellent early history of the ionosphere (Green 1946).

Although the frequency change method had served Appleton and his colleagues well, by the 1930s the greater versatility of the pulse technique was appreciated. Appleton was fortunate that Geoffrey Builder arrived at King's College at precisely the right time, 1930, to design and build pulse equipment and demonstrate its utility (Appleton & Builder 1932).

Builder, a graduate of the University of Western Australia, had spent some time at the Watheroo Magnetic Observatory of the Carnegie Institution of Washington, D.C., and had gone to London for postgraduate training. He was appointed to the Sydney R.R.B. group in 1933 but stayed only one year before joining A.W.A.

It will be recalled that Builder, while still a research student at King's College, took part with Appleton and Naismith in the extensive observations made at Tromsø during the Polar Year 1932–3. His experience with Appleton gave him a better appreciation than that of any of the Australian group in Sydney of the importance of the equivalent height against frequency plot, over a wide range of frequencies.

Writing to the secretary of the Australian Board in June 1933 he emphasized the virtues of the *P′f* approach; Appleton in writing to Laby suggested that Builder make equipment to bring back to Australia. Financial difficulty prevented the Board from agreeing and the use of this important advance in Australia was thus delayed for some years.

Builder on his return to Sydney constructed a pulse transmitter (80 m) which was installed at the University and a receiver at Liverpool to the south of Sydney; *P′t* recording began in October 1934.

O. O. Pulley, a graduate of Madsen's school, followed Builder at King's College and there built the first manual *P′f* set to be used in London. He returned to Sydney as Walter and Eliza Hall Fellow in the Department of Electrical Engineering and again built similar equipment for the Australian Board which, functioning by June 1935, provided the first routine ionograms for the Sydney workers (Pulley 1934).

H. B. Wood, another graduate of Sydney in Electrical Engineering and Physics, designed and built the first fully automatic frequency sweep recorder covering the range from 1.6 to 10 MHz in 5 min (Wood 1936). Continuous recording of *P′f* ionograms began in May 1936.

A second Wood recorder was later installed with A. J. Higgs at Mt Stromlo Observatory.

About 1943, during the war, the needs of the ionosphere prediction service required an expansion of the network of recorders. New instruments were made to performance requirements specified by the Board and their construction was supervised by A. J. Higgs.

The coastal fringe of Western Australia, north of Perth, is for some 80 km from the sea a sandy waste with a characteristic desert vegetation.

It was here, at Watheroo, that the Carnegie Institution of Washington established its Magnetic Observatory – one of a chain of such stations designed to provide information on the Earth's magnetism and electricity. When the Department of Terrestrial Magnetism of that

Institution became interested in the ionosphere, this Western Australian observatory, with Washington and Huancayo, was made one of their three major ionospheric observatories.

Dr L. V. Berkner designed for these stations automatic ionosonde equipment and in 1938 he installed this equipment at Watheroo and spent six months visiting in Sydney and Melborune with the R.R.B. scientific teams.

In Western Australia in pre-war days, the Watheroo Magnetic Observatory was in fact the only scientific institution interested in physics outside the University of Western Australia itself. It thus naturally attracted graduates in physics, many of whom worked there for a period.

This valuable scientific asset continued to be operated for many years by the Carnegie Institution of Washington; it was, after the war, handed over to the Commonwealth Government and the activity continued at different sites by the Bureau of Mineral Resources, Geology and Geophysics.

The Australians from 1927 until the outbreak of war in 1939 were becoming familar with the general characteristics of the ionosphere and their variations, particularly as regards vertical distribution of ionization. Many interesting and important studies were published.

David F. Martyn, originally from Scotland, began his scientific career at the Royal College of Science in London. In 1929 he accepted an appointment to the Australian Radio Research Board, going first to Laby's group in Melbourne. With R. O. Cherry he made extensive studies of the fading of signals from broadcasting stations at night and was able to deduce values for the equivalent height of the ionized regions. Martyn moved to the Sydney group in April 1932 and continued the interest in the upper atmosphere which distinguished his whole subsequent career.

A stream of publications flowed thereafter from Sydney; some personal contributions from Martyn alone, but frequently from Martyn in collaboration with other members of the group. Martyn was to lead the thinking of his colleagues towards fresh physical ideas of the structure of the ionosphere which their experimental investigations revealed. Between 1927 and 1940 (when the war prevented further research) there were 21 publications on a variety of subjects. Some will be recalled as unusual and interesting.

Victor Bailey, Professor of Physics at Sydney, collaborated with Martyn in examining what was called the 'Luxemburg effect', the modulation of one wave travelling through the ionosphere by another due to the non-linear effects of the medium (Bailey & Martyn 1934).

In a paper with O. O. Pulley (Martyn & Pulley 1936), remarkable deductions were made from very limited observations of the heights and ionization densities during July, August and September 1935. Absolute temperatures between E and F-regions were estimated from electron collision frequencies to be of the order 1000 K with high temperatures in both summer and winter attributed to absorption of solar radiation by ozone, and because of this it was believed that the ionization densities in E and F-regions were correlated with barometric pressure at the ground. Martyn showed for the first time in this paper his remarkable acquaintance with the possible physical mechanisms in the upper atmosphere. Some of the deductions, for example the high temperatures at the F-region heights, have turned out to be true but not for the reasons given in this paper.

By 1937 Martyn and his colleagues were discussing ionospheric disturbances, fade-outs and solar eruptions and writing on the supposed association of meteorological changes with variations in F-region ionization (Bannon, Higgs, Martyn & Munro 1940).

George Munro, who came from New Zealand, was working at the Radio Research Station, Slough, when he was appointed to the Melbourne group in 1929. When he transferred to

Sydney in 1935 he took over from A. L. Green the frequency change recording equipment and was probably the last to use this system. After pulse recording began Munro provided the major part of the observational material and assisted in its interpretation, thus giving Martyn and others the data for their work.

It was Munro's experimental skill that produced the experiment for the observation of the polarization of reflected pulse signals reported by Martyn, Piddington & Munro (1937). These authors deduced from magnetoionic effects that electrons were the effective charges in E-region.

Collaboration with the Commonwealth Solar Observatory, Mount Stromlo, Canberra (its name had since been changed) gave the Sydney group an excellent opportunity to observe the effect on the ionosphere of disturbances on the Sun.

In 1937 Martyn and Munro together with Higgs and Williams of Mount Stromlo (1937), reported observations that bright hydrogen eruptions on the solar disk occurred almost simultaneously with a change in the ionosphere characterized principally by a marked increase in D-region absorption. These were sudden ionospheric disturbances described by Dellinger (1937) in the U.S.A. The Australians claimed that every solar eruption observed at Mount Stromlo was accompanied by an ionospheric disturbance, although only some were large enough to cause a 'fade-out'.

Munro's research work was interrupted in 1939 when he went overseas as the first Scientific Liaison Officer on radar and later on ionospheric propagation. Before he left Australia he made a particularly significant observation which was the beginning of his later major work.

Following up the observation of the effects of solar eruptions he noticed, in collaboration with Higgs at Mount Stromlo, that some ionospheric disturbances occurred more frequently than solar flares and that there was an appreciable time lag between their appearance over Canberra and Sydney. Munro's post-war work fully described these quasi-periodic changes in the vertical distribution of F-region ionization lasting from 10 to 60 min and travelling horizontally at about 5–10 km/h. They are of terrestrial origin and not caused by solar disturbances (Munro 1950).

George Munro, although nominally retired, is the only member of the original group appointed before the war to the R.R.B. who is still working in the Electrical Engineering Department in Sydney University.

3. The Halley Stewart Laboratory, King's College, London

In 1931 I left Cambridge to take up an appointment in Appleton's Department of Physics at King's College in London. This was for me a very fortunate appointment. I was able to take part in the ionospheric work of Appleton's group while learning the profession of university teaching. Also, in those days of the depression, it gave me a job which lasted until I went back to New Zealand in December 1936.

That Appleton was able to devote much of his time to research and his many outside interests was due to the support he had from an excellent staff. The names of the H. T. Flint and B. L. Worsnop, well known to physicists for their textbooks as well as for their research, took considerable responsibility for teaching both senior and junior classes. Indeed this was equally true of Williams, Oatley, Champion, Chapman and others.

King's College in the Strand did not, in those days, provide spacious accommodation for research. The teaching laboratories were of reasonable size and had a scientifically romantic air; the large glass cupboards around the walls of the junior practical laboratory held a large collection of unusual musical instruments devised by Wheatstone. Numbers of Wheatstone's early telegraph equipment were there too and at the far end of the laboratory was a miniature figure of George III in marble.

Research and the Department's workshop were relegated to the basement, where, in winter, fog obscured the view along the corridor which seemed to stretch the whole length of the College from the Strand to the Embankment. At the Strand end were the workshops and several rooms where E. G. Bowen, D. B. Boohariwalla, Geoffrey Builder and I did our work. There was also a small hut on the roof of the Strand annexe from which we could look down on the Roman baths in the lane next door.

We succeeded in making King's the regular meeting place for the groups interested in upper atmosphere. Our Maxwell Society had no constitution, charged no fees and kept no minutes but it served this purpose; Ratcliffe's group in Cambridge, the people from Slough where R. Naismith was the principal worker at the time, Sydney Chapman and his colleagues from Imperial College, E. B. Moullin from Oxford and others all came frequently. Someone would read a paper, there would be discussion and then most of us went off to dinner at Slater's, a few doors down the Strand.

S. K. Mitra from Calcatta at one meeting told us of his work and the discovery of D-region over India. I remember it was after Chapman had described his theory (with Ferraro) of magnetic storms and aurorae that he confessed never having seen the aurora – he must certainly have seen plenty later in Alaska.

It was probably early in 1932 that we began to hear news of the possible gift to the College of the house in Hampstead that became the Halley Stewart Laboratory. This large house owned by Halley Stewart, a wealthy builder, had already been used for medical research; Halley Stewart, we learned, was looking for a new occupant likely to bring distinction to his generosity.

The Halley Stewart Laboratory, 30 Chesterford Gardens, became the venue of all the ionospheric research after it was opened by Rutherford in May 1933. Appleton with his wife and two young children moved into the flat on the upper floor in the late summer of 1932. The ground floor and basement were available for research. Appleton enjoyed these facilities for nearly four years until he moved back to Cambridge early in 1936 to be succeeded at King's and the Halley Stewart by C. D. Ellis.

When I went to King's A. L. Green had already gone to Australia; Geoffrey Builder arrived from Western Australia in 1930.

Appleton was singularly fortunate in having Builder with him at the crucial change-over to the pulse technique, for Builder was a very able experimentalist with a good knowledge of radio techniques.

I remember how he attacked the problems of these researches with a vigour characteristic of his personality and, as was often the case with Australian students in England, was restless and rebellious at the restraints of King's College management. Appleton with Builder at King's and with Naismith at Slough introduced at this time the notion of measuring height as a function of frequency, leading to the measurement of maximum density of ionization and all the other qualities that can be deduced from the ionogram.

E. G. Bowen, who came to King's from Swansea, published a paper in 1933 with Appleton on sources of atmospherics and penetrating radiation. He joined Watson-Watt and Wilkins to undertake a major role in the early days of the secret investigations of radar.

The Polar Year (1932–3) expedition to Tromsø occupied Appleton, Builder and Naismith and it was on his return that Appleton moved into the Halley Stewart Laboratories. A stream of research students came and went over the next few years. After this period of time I confess an inability to remember the work of each in detail.

Owen Pulley, a graduate in physics and engineering from Sydney University, made a distinguished contribution by building the first manual *P'f* equipment for Appleton's group. This covered the range 2.5–7 MHz; the transmitter was on the roof at King's and the receiver at the Halley Stewart (Pulley 1934).

Two other Australians came to the Halley Stewart: F. W. Wood and Poole, both from Western Australia. Both went later to R.A.E., Farnborough. Frank Wood returned to Sydney in 1937 and played a noted role in the early ionospheric prediction work.

Halliday from South Africa made, I believe, a short study of tidal movements in E-region.

During my period at King's College before I left for New Zealand in December 1936, I was interested in the attentuation of radio waves in the ionosphere. With L. W. Brown reflexion coefficients were measured and values of the collisional frequency of electrons deduced (White & Brown 1936).

Boohariwalla, Biggs, Hutchinson and Williams were some of our colleagues, not forgetting Piggott, who was with us then and who stayed with Appleton in Cambridge and later.

Compared with the facilities available to research people today or indeed even with those in Sydney at that time, our workshop and other technical facilities were only just adequate. Gander and Roberts were the only technicians to help us but we managed somehow.

Appleton took with him to Cambridge all the ionospheric research with which he was personally associated and this interesting phase in King's College, London, came to an end in 1936.

4. New Zealand

It was George Munro who made the first ionospheric observations in New Zealand. As a research student in Auckland before he went to the British Radio Research Station at Slough he published an interesting study of the height of the reflecting layer of the upper atmosphere calculated from the height at which incident sunlight caused in the morning a sharp increase in attenuation (Munro 1928).

M. A. F. Barnett returned to New Zealand from Cambridge in time to take part in the first Radio Research Committee set up by the New Zealand D.S.I.R. in 1929. Various researches were sponsored in the universities and in 1934 Barnett was able to write to the Australian R.R.B. to tell of the first attempt to measure heights of the ionized layers over New Zealand. This was the work of a former colleague of mine, G. A. Peddie, of Victoria University College (now called Victoria University).

At the A.N.Z.A.A.S. Congress for 1937 held in January in Auckland, Peddie made a summary report on his work in Wellington from its beginning in June 1935 until the end of 1936. It is stated that in addition to E, F_1 and F_2 definite reflexions were obtained from a D-layer (50 km) and from an intermediate layer between E and F_1 (150 km); also from a G-layer above F_2 (600 km but variable). The change in the ionosphere during the eclipse of the Sun of 14 December 1935 showed that the ionizing agency for E and F_1-region was ultraviolet light. K. Kreielsheimer and D. Brown of Auckland University reported fixed frequency observations and that an attempt to correlate E-region ionization with barometric pressure had failed.

The substantial Australian delegation to the Congress included Madsen, Martyn and G. H. Munro. As President of Section A, Maden's address was entitled 'Radio Research'.

Madsen, with his intense interest in promoting research activity, emphasized, in disussion with Ernest Marsden (Secretary, D.S.I.R.) and others, the importance of reviving and extending the radio researches in New Zealand. As a result a new arrangement was approved by the New Zealand Government for a Radio Research Board. I arrived in New Zealand in January 1937 to take up the Chair of Physics at Canterbury University College in Christchurch. The new Board was under the Chairmanship of Professor James Shelley, Director of Broadcasting, and had as members the four Professors of Physics, including myself. There were also representatives from the fighting services and Miles Barnett representing D.S.I.R. Attention was to be confined to ionospheric investigations, reception of signals from distant stations and propagation of signals over the Earth of interest to the broadcasting and post office people.

In Christchurch, J. C. Banwell was appointed as full-time assistant and with his help a $P'f$ instrument was built and operating by October 1937. The first heights and critical frequency data were reported to the U.R.S.I. meeting in Rome (White & Banwell 1938). Further early information from White, Banwell & Peddie (1940) covered the period October 1937 until April 1939. The anomalous diurnal and seasonal variation of F-region ionization was immediately apparent. T. W. Straker (White & Straker 1939) completed a study of the diurnal variation of absorption. Since Christchurch is relatively near the zone of maximum auroral frequency in the Southern Hemisphere, workers in that area had a natural interest in auroral observations. Moreover, the New Zealand Magnetic Observatory was situated in the vicinity of Canterbury College and could report days of magnetic disturbance.

The World-wide radio fade-out and magnetic storminess accompanied by auroral displays in January 1938 was observed in New Zealand and interesting features were reported (White, Skey & Geddes 1938), particularly the coincidence in time of the aurorae and the magnetic storm with an interval of 30 h between the beginning of the fade-out and that of the magnetic storm.

In 1939 Ernest Marsden returned from Britain with news of the radar enterprise. Then came the decision of the New Zealand Government to develop radar research and equipment and the request to me to become involved in this in Christchurch and at the same time train potential radar scientists. This, in addition to university teaching, occupied me until I went to Australia in January 1941.

Ionospheric and other forms of radio geophysical research were later carried on very successfully in New Zealand by others.

5. War intervenes

The formative phase of upper atmospheric research by means of radio in Australia and New Zealand started in June 1927 with the first meeting of the Australian R.R.B. and the similar Committee in New Zealand.

The outbreak of the war in 1939, bringing as it did the diversion of attention of many of the ionospheric researchers to radar, terminated the first successful period.

By then the possibility of ionospheric data being used to forecast the propagation conditions for communications by radio was known but not widely appreciated. The U.S. National Bureau of Standards was already, in May 1937, publishing weekly forecasts of radio transmission conditions.

So urgent was the demand of scientific personnel for the new Radiophysics Laboratory of C.S.I.R. that the majority of those previously working for the R.R.B. became absorbed in this new activity.

F. W. Wood, who had been with Appleton at the Halley Stewart Laboratory, returned to Australia in August 1937 to join the Sydney R.R.B. group. Originally from Western Australia and with experience first at Watheroo and later at the Royal Aircraft Establishment at Farnborough, Frank Wood was to develop a unique understanding of the analysis of ionospheric data for use by the fighting services.

Left almost alone in Madsen's department, but later joined by L. S. Prior, also from Watheroo, Wood began to develop methods of data analysis and prediction. Primary data were, at the outbreak of the war, available only from Sydney, Mount Stromlo, Watheroo and Christchurch.

Stimulated by service interest, money became available to premit the building of additional recorders for Brisbane, Cape York Charters Towers, Hobart and Admiralty Island. New Zealand extended its circuit to include Fiji, Campbell Island and the Kermadec Islands. Under the auspices of the Australian Radio Propagation Committee, the Sydney Laboratory became one of the three allied centres for the collection and analysis of data from these stations and from the many others established by Great Britain, Canada and the United States of America.

Frank Wood initiated this effort in Australia and was responsible throughout the war for its scientific development and management.

The great increase in the number of automatic ionospheric recorders due to the efforts of those countries interested in war-time prediction provided much information on the temporal and geographic variations in upper-atmospheric ionization. For the first time the 'longitude effect' became noticed as well as the daily and seasonal anomalies of F-region. The effect of magnetic storms and solar eruptions causing radio fade-outs could be more easily interpreted.

6. Retrospect

As a concluding note let me reflect on the influence of the Board's work on Australian physics. When the war ended many of those previously associated with the Board were dispersed to other interests.

But Madsen resumed the Chairmanship and held it for many more years. D. F. Martyn returned to ionospheric research and became the principal leader in this field in Australia; he was elected, for his work, to the Fellowship of the Royal Society in 1950 and was President of the Australian Academy of Science from 1969 to 1971. G. H. Munro returned to Sydney to continue his successful researches. Frank Wood became the Director of the Watheroo Observatory and A. L. Green the head of the Ionospheric Prediction Service. The Physics Departments of Queensland and Adelaide became prominent centres of research after Webster and Huxley were appointed to the Chairs of those Universities.

The war-time radar research and development of the Radiophysics Laboratory in Sydney was made possible by the recruitment of the staff of the Board and the many students who had worked on the ionosphere.

Among the Australians who returned from overseas to help was J. L. Pawsey. Many of you will remember him and recall that, with the vigorous support of E. G. Bowen, then Chief of the Radiophysics Laboratory, Joe Pawsey led the subsequent major Australian work in radio astronomy.

The influence of the Radio Research Board was profound.

The decision to hold the meeting of U.R.S.I. in Australia in 1952 with Appleton as President was an indication of the regard in which the Australian work on the ionosphere and in radio astronomy was held.

This was the first time an International Union had held a meeting in Australia and this was greatly appreciated.

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