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# Australian magnetic observatories

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**Magnetic observatories capable of providing long-period results in absolute measures have been operated in Australia and its territories on and off since 1840. As the first such observatory (that at Gottingen, built by Gauss) was erected only eight years earlier, a long tradition has been established in the observational aspects of the science. In 1979 six observatories are operating: one in Papua New Guinea (recently transferred to that country's Geological Survey), three in Australia, one in the sub-Antarctic, and one in Antarctica. The number and disposition of continental observatories is inadequate. The factors which should be considered in planning any future network are outlined.**

## Introduction

'The function of a geomagnetic observatory is to record the short and long period variations of the geomagnetic field in such a way that the variations are representative of a large area' (Wienert, 1970, p. 15); which requires that vector components of the field are measured in absolute units.

Gauss erected the first such 'absolute' observatory at Gottingen in 1832 after discovering how to measure intensities, and only eight years later the first Australian observatory was recording. With only a few small breaks there has been one or more observatories operating in Australia ever since.

The main purpose of this paper is to briefly outline their histories. At present, all observatories are operated by the Federal Government, but this has been the situation only since 1947. Several other variation observatories, operated mainly by universities, are outside the scope of this paper because they cannot provide information on the long-term variations.

Table 1 gives details of the observatory sites, and recommendations are made for future developments. The localities of past, present and recommended observatories are shown in Figure 1.

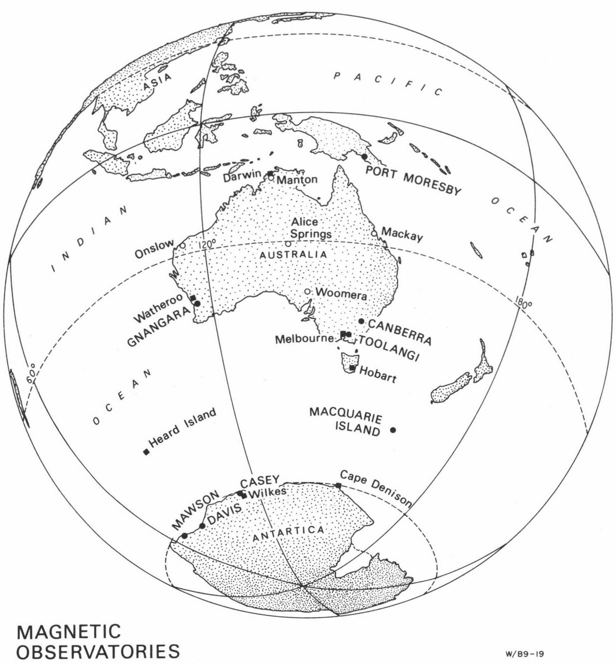


**Figure 1. Magnetic observatories, locality map.**

## Hobart Observatory, 1840-1854

The Royal Society of London established four 'colonial' observatories in the early 1840s. The initial objective was to support expeditions to investigate the Earth's magnetic field in high southern latitudes (this was probably a consequence of von Humboldt's plea to the Royal Geographical Society in 1838: '. . . I invite . . . your Society . . . to propagate Gauss's manner of observing . . . points in high latitudes in the southern hemisphere . . . would be most desirable . . . . .' (Chapman & Bartels, 1940 p. 931). The expeditions were led by Ross and Crozier in the 'Erebus' and 'Terror' of Antarctic fame, and one observatory was built at 'Hobarton' under the direction of Lieutenant Kay.

Self-recording instruments had not been then devised, and the observatory was equipped with three eye-reading variometers; and a declinometer, an inclinometer and a horizontal-intensity magnetometer for absolute measurements (Kay, 1842). Variometer readings were made hourly except on 'term-days': these were days specified by Gauss's 'Magnetic Union' (the first international geophysical association) and were the forerunners of the present Regular World Days. On term-days the variometers were read every 2.5 minutes throughout the 24 hours—the colony's Governor being one of the keenest observers.

Unfortunately the '. . . . Domain site employed by Lieutenant Kay is, from a geological point of view, by no means a good one . . .' (McAuley & Hogg, 1904 p. 40), and subsequent re-occupations of the site for the determination of secular change were not practicable.

Nevertheless, the program at Hobart yielded the first detailed data on geomagnetic variations in the Australian region. The data were obtained by arduous and tedious methods, and their volume and continuity are all the more remarkable for this. Amongst other things they helped lead to the discovery of the relations between magnetic disturbance and the sunspot cycle (Sabine, 1857).

## Melbourne/Toolangi Magnetic Observatory, 1858-

Geomagnetic observations began in Melbourne in 1858 and have been maintained there, and later at Toolangi, more or less continuously ever since (Dooley, 1958). The work was begun by the Victorian State Government which allocated a site on Flagstaff Hill. However, it was Dr. George Neumayer's initiative

| Name | Locality | Co-ordinates | | | | | Duration |
|---|---|---|---|---|---|---|---|
| | | Geographic | | Geomagnetic | | Dip(a) | |
| | | Lat°S | Long°E | Lat° | Long° | Lat° | |
| *Past and present* | | | | | | | |
| Canberra | A.C.T. | 35.32 | 149.36 | —44.0 | 224.7 | 48.6 | 1978- |
| Casey | Antarctica | 66.28 | 110.53 | —77.8 | 179.1 | 73.9 | (b) |
| Cape Denison | Antarctica | 67.00 | 142.67 | —75.5 | 235.3 | 88.0 | 1912-1913 |
| Darwin | Northern Territory | 12.45 | 130.83 | —23.2 | 201.1 | 22.8 | 1957-1959 |
| Davis | Antarctica | 68.58 | 77.97 | —76.7 | 119.9 | 57.8 | (c) |
| Gnangara | Western Australia | 31.78 | 115.95 | —43.2 | 185.8 | 48.6 | 1957- |
| Heard Island | Indian Ocean | 53.03 | 73.37 | —61.4 | 129.9 | 53.1 | 1952-1954 |
| Hobart | Tasmania | 42.90 | 147.50 | —51.7 | 224.6 | 59.5 | 1840-1854 |
| Macquarie Island | Southern Ocean | 54.50 | 158.95 | —61.1 | 243.1 | 68.2 | 1952- |
| Mawson | Antarctica | 67.60 | 62.88 | —73.2 | 103.1 | 44.0 | 1955- |
| Melbourne | Victoria | 37.83 | 144.97 | —47.0 | 220.1 | 52.5 | 1858-1919 |
| Port Moresby | Papua New Guinea | 9.40 | 147.15 | —18.6 | 217.9 | 18.0 | 1958- (d) |
| Toolangi | Victoria | 37.53 | 145.47 | —46.7 | 220.8 | 51.8 | 1919- |
| Watheroo | Western Australia | 30.32 | 115.88 | —41.8 | 185.6 | 47.0 | 1919-1958 |
| Wilkes | Antarctica | 66.25 | 110.58 | —77.2 | 179.2 | 73.9 | 1957-1967 |
| *Recommended* | | | | | | | |
| Alice Springs | Northern Territory | 23.7 | 133.9 | —34.2 | 205.5 | 36.5 | |
| Mackay | Queensland | 21.2 | 149.2 | —30.0 | 221.8 | 32.6 | |
| Manton | Northern Territory | 12.8 | 131.1 | —23.6 | 201.4 | 23.5 | |
| Onslow | Western Australia | 21.6 | 115.1 | —33.1 | 184.5 | 35.5 | |
| Woomera | South Australia | 31.1 | 136.8 | —41.3 | 209.7 | 44.5 | |

(a) Dip latitudes based on 1975.0 values of inclination.
(b) Regular absolute observations only since 1974.
(c) Regular absolute observations only since 1972.
(d) Transferred to Government of Papua New Guinea 1978.

**Table 1. Australian magnetic observatories.**

which made this happen: a student of Lamont's and an observer at Hobarton under Kay, he obtained funds for magnetic instruments from the Duke of Bavaria to outfit an observatory to replace Hobarton (Day, 1966). Neumayer remained in charge of the observatory until his return to Germany in 1864.

Initially, hourly readings of D, H and I were made by eye, but these were ended in 1863 pending receipt of photographic recording variometers (the new technique had been introduced at Greenwich in 1847). These recording variometers were not installed until 1867 and only absolute measurements were made during the hiatus. The observatory was shifted to the Botanical Gardens in 1862—the site originally chosen by Neumayer because of its freedom from local magnetic anomalies.

Until the move to Toolangi (enforced by the introduction of electric tramways and railways) the recording program was maintained continuously. On the other hand absolute measurements were made less regularly, at one period (1904 to 1906) being reduced for some mysterious reason to 2 sets each November; they were suspended completely between 1907 and 1911.

In 1919 the observatory was moved to its present site at Toolangi, about 50 km northeast of Melbourne (Baldwin, 1926). The station differences were measured in 1922 by making almost simultaneous absolute measurements at both sites; the second observer and instruments were provided by the Carnegie Institution of Washington's (CIW) magnetic survey party (D. G. Coleman *in* Fisk 1927, p. 131).

The variometer building and the Eschenhagen magnetograph were destroyed during the disastrous bush fires of January 1939. They were replaced by the present underground vault and La Cour magnetograph, and recording resumed in January 1940.

From 1943 to 1946 Toolangi Observatory was administered by the Commonwealth Solar Observatory (Mount Stromlo, ACT), but when the Bureau of Mineral Resources, Geology and Geophysics (BMR) was created in 1946 the observatory was transferred to it. Thus commenced BMR's programs in fundamental and regional geophysics.

Under BMR, operations have stabilised (absolute measurements have been made weekly since 1951), and some improvements have been made (modern absolute and semi-absolute magnetometers introduced, and a better observing building constructed). However, it is intended to reduce the program to variation recordings in 1979 and to close the observatory in the mid-1980's. It will be superseded by the modern Canberra Magnetic Observatory described later.

The series of recordings obtained at Melbourne/Toolangi since the end of 1857 is one of the longest available, and has enabled such extensive studies as that of Mayaud (1973). Figure 2 portrays the results of the work between 1858 and 1978, in the form of the direction of the Earth's field. The observatory has of course fulfilled its essential function as defined by

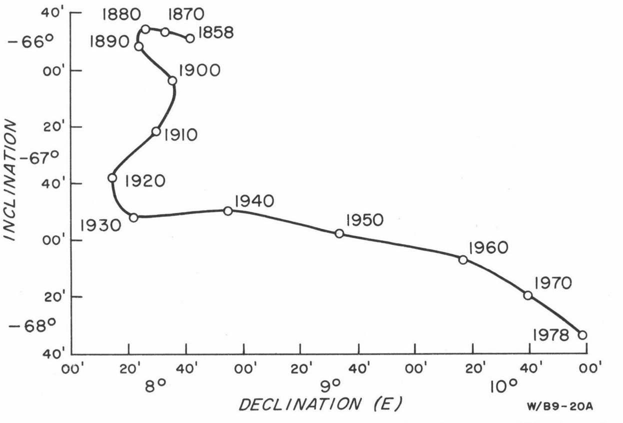


**Figure 2. Direction of the geomagnetic field at Toolangi 1858-1978.**

**Figure 3. Watheroo magnetic observatory, 1920: magnetograph house (top) and absolute house (bottom).**

Wienert, and served as a base for several surveys and expeditions; notably, Mawson's Australasian Antarctic Expedition of 1911-13, the CIW magnetic survey of Australia 1911-1923, and latterly BMR's periodic regional magnetic surveys.

## Watheroo Magnetic Observatory, 1919-1958

Since 1905 the CIW's Department of Terrestrial Magnetism (DTM) had carried out extensive magnetic surveys '. . . in the regions where most needed and where there (were) no organisations to undertake the work' (Bauer, 1912). These surveys provided widespread information on the geographical variability of the Earth's magnetic field, but to improve knowledge of its time-variability an Observatory Division was created in 1915. A main objective was to '. . . erect, man, and equip at least two magnetic observatories in the Southern Hemisphere where they were most needed . . . one observatory (to be established) in the general region between 28° to 36° south latitude and 114° to 118° east longtitude.' (Fleming & others, 1947).

Site requirements were stringent because the planned observatory was to undertake observations in geoelectricity and solar phenomena as well as geomagnetism. DTM officers W. F. Wallis (who was to become the observatory's inaugural Observer-in-Charge) and W. C. Parkinson (who was destined to spend 13 years in charge) examined several localities before selecting the final site in March 1917. The observatory was commissioned 21 months later on 1 January 1919. Considering the wartime circumstances and the difficult access by horse and cart across 20 km of sand from the nearest railroad station, the commissioning of the observatory in such a short time is remarkable (present-day comparisons would not be favourable). The absolute and variometer houses are shown as they appeared in 1920 in Figure 3.

Detailed descriptions of programs, instruments, methods, personnel and results are given in the three DTM Volumes VII listed in the references. We enumerate here simply the equipment which was operated by DTM at one time or another between 1919 and 1947: normal and rapid-run magnetographs, atmospheric potential gradient and conductivity recorders; telluric-current recorder; fixed-frequency and multi-frequency ionosondes; spectroheliosope; atmospherics recorder; and meterological instruments.

On 1 July 1947 the observatory was transferred by gift to the Australian Government and from then until its closure in March 1959 it was operated by BMR. The Observer-in-Charge at the time of the transfer was F. W. Wood who had been at the observatory from 1926-1932, and who later became an Assistant Chief Geophysicist in BMR.

Under BMR, emphasis in observatory operations was to be placed on solid-earth rather than upper-atmosphere geophysics and therefore planning in the newly-developing Observatories Section was directed towards this end. One of the main decisions of the early 1950s was to replace Watheroo Magnetic Observatory by a new geophysical observatory capable of and better placed to undertake the new role. However, commitment to the International Geophysical Year (IGY) 1957/58 governed the time-table, and Watheroo was maintained until early 1959 (McGregor, 1966a).

Notwithstanding, improvements were made in the geomagnetic program by the introduction of modern magnetometers and an ionospheric recorder, and two new projects were begun: cosmic-noise (ionospheric absorption) recording was made during the IGY (Kirton & McGregor, 1958) and a seismological program was begun (Everingham, 1958).

The Watheroo Magnetic Observatory had a profound influence on science in Western Australia, particularly in the pre-war years. A close association with the University's Physics Department developed through Professor A. D. Ross 'who from the beginning, showed a keen interest in the work and . . . . . . has given freely of his time to consult, confer and advise . . . on the many problems concerned with maintenance of a high standard of work' (Fleming & others, 1947). Ross even provided physical help when he stood in for the Observer-in-Charge during the University vacation of 1933-34.

Through this association several physics graduates and technicians obtained employment in the difficult pre-war years, some of whom were to later form the nucleus of BMR's Geophysical Branch. They were Messrs N. G. Chamberlain, R. G. Curedale, E. McCarthy, A. Parkes, L. S. Prior and F. W. Wood. Under BMR's aegis the observatory was the principal training centre in observatory geophysics and many of Australia's geophysicists gained their first practical experience at Watheroo (and later Mundaring) Observatory.

One name above all is inextricably linked with Watheroo, that of Parkinson: W. C. (father) and W. D. (son). The former helped in the site-selection surveys and spent a total of 15 years at the Observatory, 13 as Observer-in-Charge. During the war he and his son (part-time) were the only professional staff for almost 3 years. Later, after a stay as relief Observer-in-Charge, W. D. Parkinson began his well-known researches on induction effects: changes in declination and vertical intensity are strikingly correlated at Watheroo, where the 'Parkinson Plane' is tilted westerly at 40° (Parkinson, 1961).

## Gnangara Observatory, 1957-

The first unit of BMR's new geophysical establishment in Western Australia was a magnetic observatory erected near Lake Gnangara about 20 km north of Perth. Details of the site, buildings and equipment are given by McGregor (1966b).

A La Cour magnetograph began regular recording in June 1957, in time for the IGY. Records were changed by a local resident and weekly absolute and scale value observations were made by an observer from Watheroo.

Although the operations were hampered by the distance between the observatories (100 km), sufficient parallel recordings were obtained to determine the differences between the two localities before Watheroo was closed in March 1959.

Buildings for the other geophysical programs—ionospheric and seismological recordings—and offices and workshops were completed during 1958 and the new Mundaring Geophysical Observatory was commissioned on 18 March 1959. Gnangara magnetic observatory is part of that establishment.

The Gnangara site is on the Quaternary sands covering the Perth Basin, and is free of local magnetic anomalies. It is less than 30 minutes drive from Mundaring so it can be visited conveniently.

In May 1960 the re-furbished Eschenhagen magnetograph from Watheroo was brought into operation and the La Cour instrument dismantled. BMR-type scale value/orientation coils, temperature-compensating magnets, and auto-calibrator were fitted to simplify procedures and improve the characteristics. A proton vector magnetometer was introduced for absolute measurements of H and Z in 1974.

It is planned to install an automatic digital magnetograph during 1979; the equipment will be of the same type described under Canberra Magnetic Observatory.

## Darwin, 1957-1959

An Askania portable variograph recording D, H and Z was operated in the Botanical Gardens throughout the IGY and its extension, the International Geophysical Cooperation (IGC). Absolute measurements were made by a BMR geophysicist from the regional office in Darwin. None of the magnetograms have been reduced to hourly values.

## Port Moresby Geophysical Observatory, 1958-

A review of the geomagnetic program at this Observatory is included here for completeness, although the Observatory was transferred to the Government of Papua New Guinea in October 1978.

The Port Moresby Observatory was the second major observatory developed by BMR in the 1950s, and was sited specifically to fill a large gap in the regional distribution of permanent magnetic observatories, as well as to study local seismicity.

As with Mundaring the requirements were for magnetic, ionospheric and seismological recordings. A suitable site 15 km from Port Moresby was obtained and construction begun in 1956 with the aim of completing the magnetic observatory by the start of the IGY; unfortunately construction was delayed and recording did not begin until March 1958 (Observatory Staff, 1965).

A normal La Cour magnetograph has operated there ever since. It has been fitted with standard BMR devices: scale value-orientation coils, auto-calibrator, synchronous motor drive, and (in 1978) 20 mm/hr recording drum.

Collaboration with BMR will continue in the production and distribution of data and standardisation of magnetometers.

## Antarctic observatories

### *Commonwealth Bay (Cape Denison), 1912-1913*

Mawson's Australasian Antarctic Expedition (AAE) had aims which were almost entirely scientific, and the site of '. . . the Main Base (was to be) as nearly as circumstances would allow directly north of the Magnetic Polar Area. Here a magnetic observatory was to be established . . .' (Webb, 1925 p. 17).

The Australasian Association for the Advancement of Science (AAAS) provided much of the finance, and an Eschenhagen magnetograph was procured (it was subsequently returned to AAAS and later installed at Toolangi q.v.). The several magnetometers for the observatory and for the extensive field work were lent by the DTMCIW, which also trained the chief magnetician, E. N. Webb.

Owing to heavy pack-ice the base at Cape Denison was farther to the west than Mawson had planned, and the region turned out to be the '. . . kingdom of blizzards . . .' (Bickel, 1977, p. 65)—during the two years of occupation the wind speed averaged over 80 km/hr, and the volume of drift snow was '. . . altogether phenomenal . . . . . . Webb laboured under what were probably the most difficult conditions ever presented to any magnetician . . .' (Mawson, preface to Webb, 1925).

Regular absolute measurements began in the Absolute Hut on 20 February 1912, about six weeks after landing; recording started in April and continued until August 1913 (Fig. 4). Webb bore the brunt of the work until November 1912, when he left on the sledge journey to the magnetic polar area. The subsequent observatory work was done by Hannam, and later by Bage.

The thoroughness and energy of Webb and his colleagues is testified to by the fact that an ANARE party found the Magnetograph Hut still occupiable in 1978 (Brookes, 1978), no doubt because of the stacking of '. . . some thirty tons of rocks . . . round the outer walls as a breakwind' (Webb, 1925).

The magnetograms were reduced at Christchurch with funds provided by the Royal Society and by the NZ government (through representations of Professor C. Coleridge Farr, who had played a leading role from the outset in planning the magnetic work).

Although of short duration by comparison with those from present-day permanent Antarctic bases, the AAE records were the most comprehensive of their time and provided new information on the southern polar magnetic field. Combined with the observations made by other expeditions in the Ross Sea area, and by Mawson during Edgeworth David's 1908/1909 journey to the magnetic polar region, they confirmed and quantified the northwesterly motion of the dip pole.

The variation data were interesting: D daily ranges were large—commonly 2°-2.5°—as would be expected from the proximity of the magnetic pole. But ranges in hourly values of H and Z were relatively small, only once exceeding 500 nT. This was attributed to the sunspot minimum current at the time, but is now known to be characteristic of polar cap stations: the geomagnetic latitude of Commonwealth Bay is 75.5° which places it within the auroral oval.

The station provides important secular change data because magnetic measurements were made during visits by Mawson's British-Australian-New Zealand Expedition in January 1931; by parties from Expeditions Polaire Francaise in 1951 and 1959; and by ANARE, NZARE and USARP in 1962. Despite other subsequent visits no magnetic observations have been made since then, and a re-occupation at the next opportunity would be valuable. Steps should also be taken to preserve the magnetograph house for future re-occupation, and to determine the differences between it and the absolute house (which has disintegrated).

### *Australian National Antarctic Research Expeditions*

The Australian National Antarctic Research Expeditions (ANARE) are organised and operated by the Antarctic Division, which was established formally in January 1949 as part of the then Department of External Affairs (Law & Bechervaise, 1957); it is now in the Department of Science and the Environment. Several governmental agencies and universities provide personnel and equipment for the diverse scientific programs which are undertaken; BMR is responsible for standard magnetic and seismological observatory operations.

ANARE's operations began in 1947 with a reconnaissance cruise in Antarctic waters, and the establishment of stations on Heard Island and Macquarie Island. Since then ANARE stations have been established at Mawson (1954), Davis (1957) and Casey (1969); the US IGY station at Wilkes was transferred to ANARE in 1959, and subsequently replaced by Casey. The Heard Island station was succeeded by Mawson in 1955. Geomagnetic programs have been carried out in varying degrees at all stations.

### *Heard Island, 1952-54*

Magnetic observations were first made on the island in December 1947 during the first ANARE (Chamberlain, 1952) but observatory operations did not begin until 1952 (Ingall, 1955). In the previous year the observatory buildings had been erected, installation of the magnetograph almost completed, and some absolute observations made (Doyle, 1953).

A normal run La Cour magnetograph was operated until the end of October 1954, when the instruments and buildings were dismantled for use at Mawson, ANARE's first station on the Antarctic continent (Lodwick, 1957). The observing piers and reference marks were left undisturbed to enable exact reoccupation for determining secular change. This was wise, because the area of the ANARE station is disturbed by local basalt flows. (However, without the surrounding floor, the pier tops are high above the ground and this should be allowed for in future re-occupations).

### *Macquarie Island, 1952-*

Magnetic observations were made at a station on the northern isthmus of the island by members of Mawson's

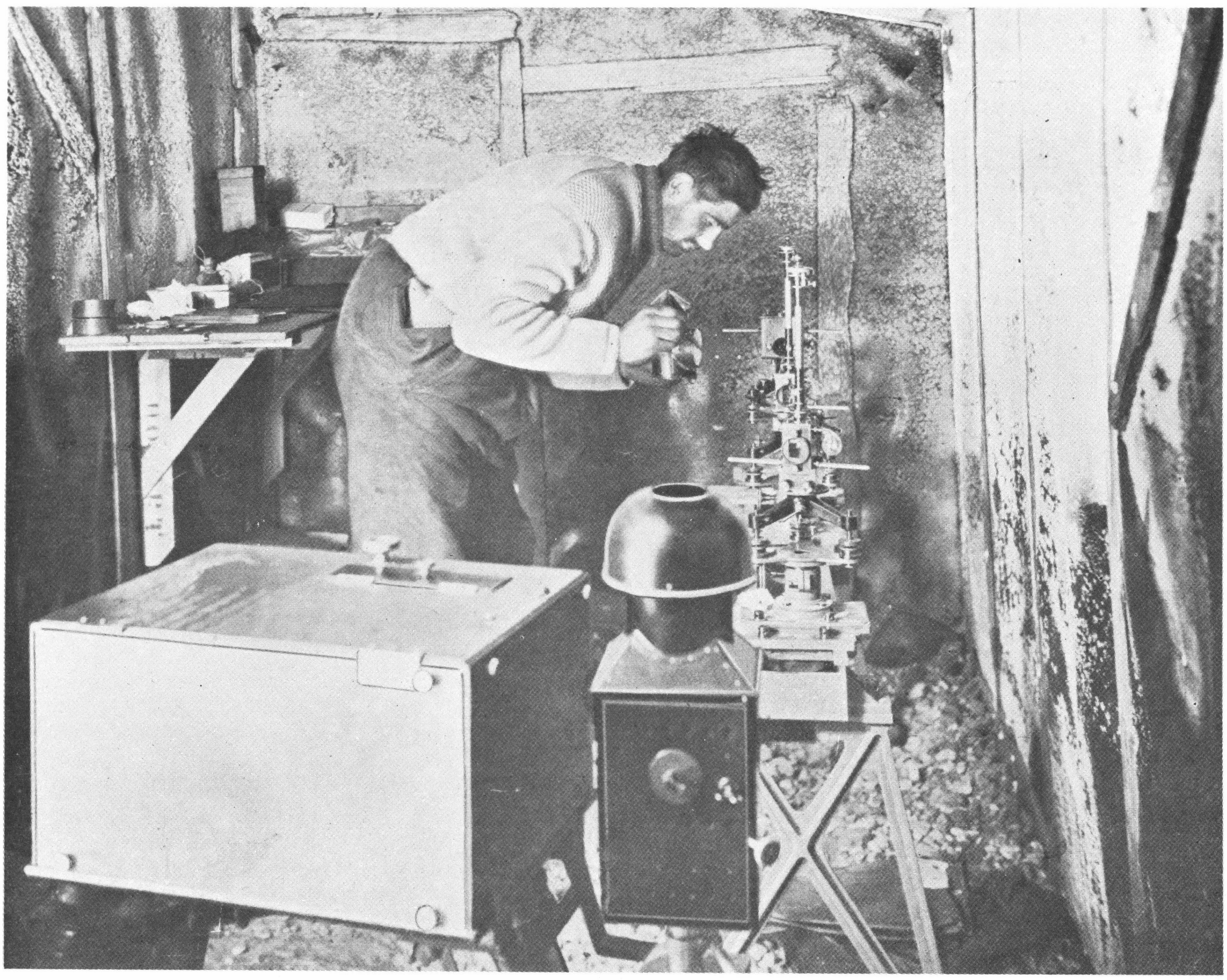

**Figure 4. Cape Denison King George V Land, 1912: magnetograph house (top) and Eschenhagen magnetograph (bottom).**

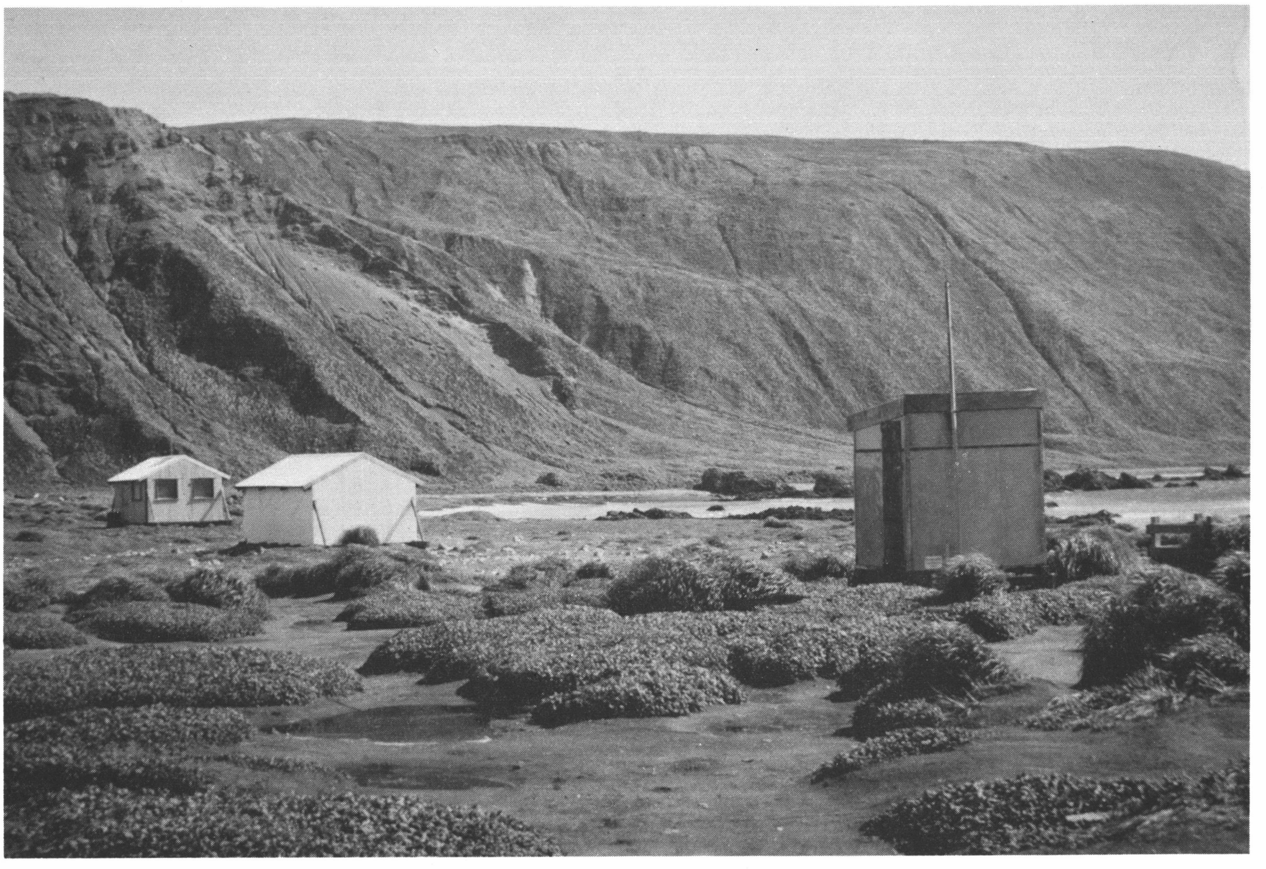

**Figure 5. Macquarie Island, 1972: view southwards of magnetograph hut (left foreground) and absolute hut.**

Australasian Antarctic Expedition in 1911 (Webb, 1925), and his British Australian New Zealand Antarctic Expedition in 1930 (Farr, 1944); and by Chamberlain (1952) during the 1947/48 ANARE. This repeat station was finally occupied in 1952 when it was tied to the absolute observatory pier (Ervin, 1952). As a result, knowledge of the secular variation extends back to 1911.

The observatory buildings (Fig. 5) were erected in 1950, and sporadic absolute measurements were made from July 1950 to April 1952 when regular recording began (McGregor, 1956). A recording H-variometer of the Schmidt balance type was operated in 1950, and a normal-run La Cour magnetograph was installed in 1951 (Oldham, 1953), but the recordings were not calibrated in absolute terms.

Subsequently the normal magnetograph was improved by reducing the sensitivity (Gregson, 1965); at the same time (1963) a rapid-run magnetograph, which had been in use at Watheroo from 1933-1958, was installed.

Macquarie Island is an important station magnetically: the long interval for which secular variation data are available has already been noted; although it is geographically sub-Antarctic, its high geomagnetic latitude (61°) makes it close to the auroral oval, and the series of magnetograms obtained since 1952 is the longest available from the southern auroral regions; and the island is roughly conjugate to College, Alaska (the reason for installing the rapid-run magnetograph —but that instrument has now been superseded by pulsations equipment provided by the Alaskan Geophysical Institute).

### *Mawson, 1955*

The ANARE station was established in 1954 and the magnetic observatory erected in 1955 using the buildings from Heard Island (Oldham, 1958; Fig. 6). Continuous recordings produced by a normal-run La Cour magnetograph date from August 1955.

A 'storm' (insensitive) magnetograph was added in 1961, but its sensitivity was increased in 1968, to make it the standard instrument (Smith, 1971). The original normal magnetograph had been too sensitive for the high average level of disturbance—Mawson is very close to the auroral electrojet and quiet days are rare.

From the outset, Mawson has been a base for extensive exploration of MacRobertson and Enderby Lands, and regional magnetic observations have been made wherever practicable. The magnetic observatory has provided the means for calibrating the field instruments, but it is of very limited use as a reference for field observations because of the highly localised and directional character of the auroral electrojet. For example, an extended series of readings taken by McGregor in 1956 (unpublished) at Amundsen Bay (in the western part of Enderby Land) showed little correspondence with the variations recorded at Mawson. The electrojet is orientated somewhat to the north of east, and it sometimes passes between Mawson and Amundsen Bay. In regions like this, observatories cannot meet Wienert's requirements of providing information 'representative of a large area', and, more so than elsewhere, field observations can be reliably reduced only by means of local recordings.

*Wilkes, 1957-1967*

The station was constructed late in 1957 as part of the USA's IGY program. A magnetic observatory was equipped and manned by the Coast and Geodetic Survey which at that time was the US agency responsible for magnetic observatories. At the end of 1958 the station was transferred to ANARE's administration, and BMR provided a geophysicist to man the magnetic and seismological observatories (Underwood, 1960).

The magnetic observatory was fitted out with modern Ruska magnetographs—a normal-run and a rapid-run; but the absolute instruments were a theodolite-magnetometer and earth-inductor of the CIW pattern. These were not well suited for high latitude measurements and were replaced in 1960 by QHMs and a BMZ.

Although these improved absolute results, calibration of the magnetograms never reached the standards achieved at the other BMR observatories. The variometers were supported on a wooden table which was subject to warping, and a pool of melt water under the building periodically froze and melted; both these caused frequent discontinuities and changes in baseline values. Also the Ruska Z variometer performed poorly, but this was largely overcome when it was replaced by a La Cour variometer in 1964 (Small, 1968).

The difficulty of providing three observers a year for Antarctic observatories, and the imminent abandonment of Wilkes station (for Casey) were factors in the decision to wind-up magnetic observatory operations at the end of 1967; all equipment was subsequently returned to the owners in USA (Taylor, 1968).

*Davis and Casey*

Although no full-scale magnetic observatory has been operated at these stations, regular absolute measurements have been made for BMR by Antarctic Division personnel since 1972 (Davis) and 1974 (Casey). These results suffice to give a reasonably good idea of the main field and secular change, because the rates generally are high ($\Delta F = 70 - 100$ nT/year); if substorm times are avoided, transient variations have a negligible effect in this context. The Davis station has added importance because regional magnetic measurements have been made there, albeit sporadically, since 1957.

## Canberra Magnetic Observatory, 1978-

In the early 1970s two decisions were made which profoundly affected BMR's magnetic observatory programs. The first was to transfer to Canberra the small observatory group which had been left in Melbourne when the Geophysical Branch joined the rest of BMR in Canberra in 1965; the second was to develop automatic recording magnetographs to produce data more rapidly and efficiently at more places.

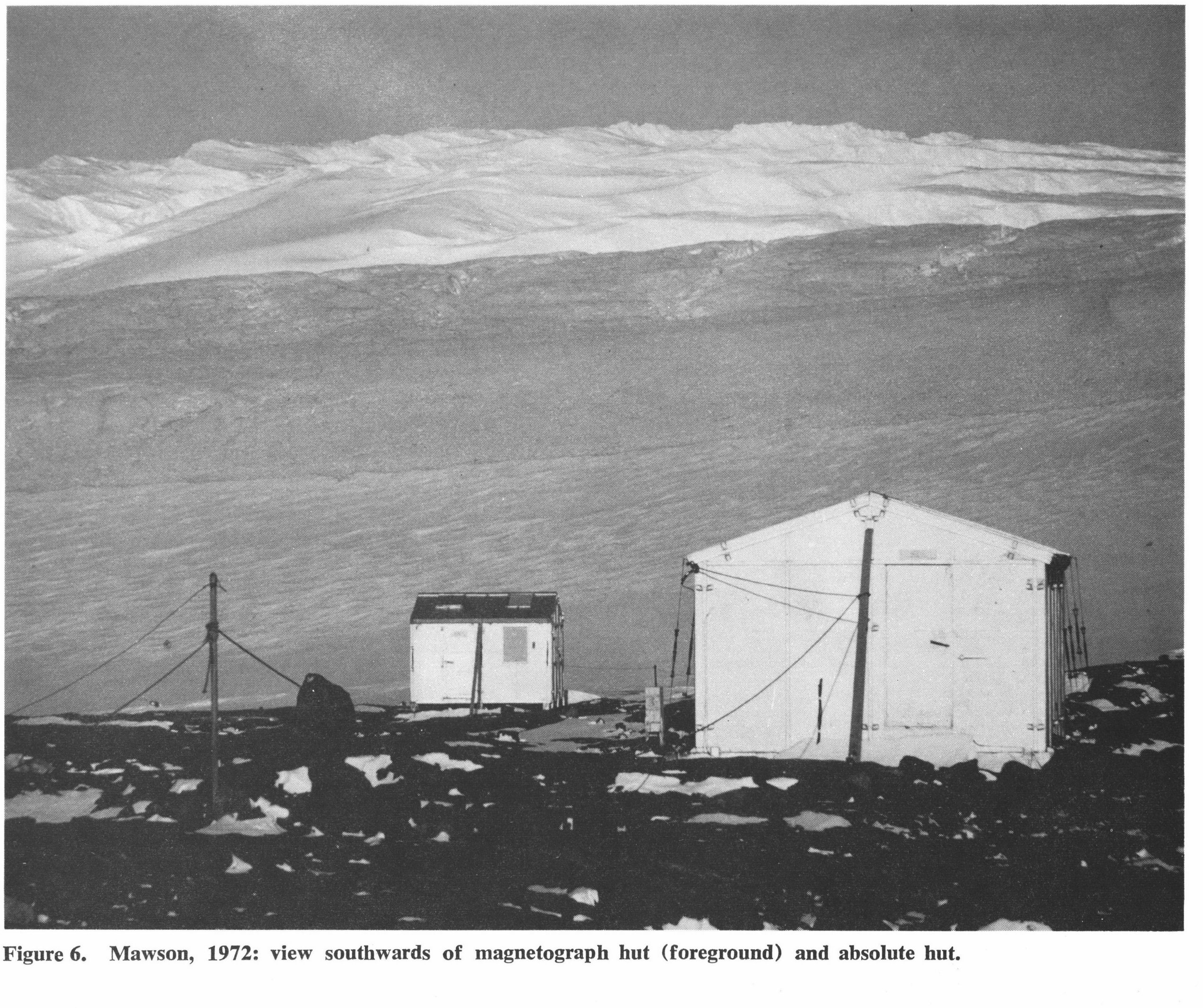

**Figure 6. Mawson, 1972: view southwards of magnetograph hut (foreground) and absolute hut.**

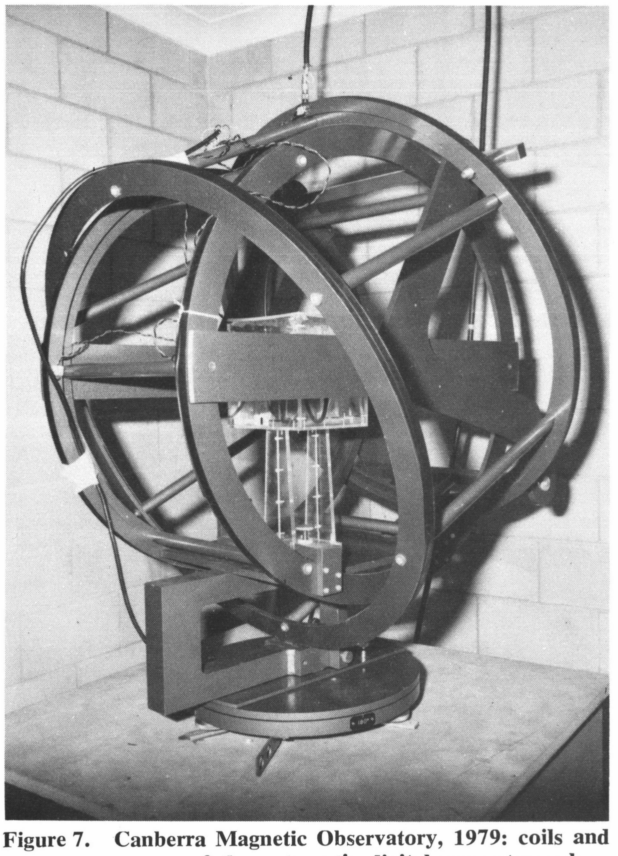

**Figure 7. Canberra Magnetic Observatory, 1979: coils and sensor of the automatic digital magnetograph.**

The immediate upshot of these two decisions was the need to establish a magnetic observatory close to BMR's central offices and workshops, where it would be practicable to develop and test the new automatic digital magnetographs(ADM). The resultant Canberra Magnetic Observatory is about 30 km east of the city.

Observatory buildings were completed in 1977 and installation, modification and proving of the first ADM proceeded during 1978. Although more-or-less continuous recording began in mid-year, reduced data are available only from 1 January 1979.

The Canberra ADM is a modified Elsec Type 6920. It uses a proton precession magnetometer (PPM) to measure total intensity and four resultant fields, produced by bias currents in two pairs of helmholtz coils. The bias fields are directed so as to give measures of changes in declination (D) and inclination (I) (Fig. 7). Data are produced once a minute on magnetic tape, and displayed on a monitor chart.

The ADM is calibrated from absolute measurements of D and I made by means of a standard declinometer, and a proton vector magnetometer. The I measurement is obtained by a unified procedure specified by McGregor (1976) which yields horizontal intensity (H) and vertical intensity (Z) simultaneously— the former by Nelson's (1958) method and the latter by Serson's (1962) method: this procedure requires only a single horizontal vector coil and single-valued bias fields.

ADM data are converted to mean hourly values of the standard elements (D, H and Z); 1-minute values of D and H are computer-plotted for displaying transient phenomena, and for deriving indices of disturbance. Figure 8 shows recordings of H made by the La Cour magnetograph at Toolangi and the synthesized H record derived from the Canberra ADM.

A 'photo-electronic magnetograph' is being developed to provide analogue back-up records to cover occasional failures of the AMO, and to give faithful recordings of rapid variations. This device is a variant of feedback magnetographs based on suspended-magnet variometers which others have operated successfully. Digital versions are planned to replace the traditional magnetographs in Antarctica, where the frequent large, rapid variations render PPM-based ADM data less reliable.

An objective is to make the ADM sufficiently stable to reduce the need for frequent calibrations. This requires principally that the orientations of the coil axes remain fixed: particular care was taken to provide a stable pier for the ADM; and allowance has been made to thermostat the sensor room if temperature changes produce coil movements.

The almost-continuous cycling of the PPM produced very high temperatures in the original sensor. The effects were dramatic: firstly the signal-to-noise ratio decreased markedly within a few hours: and secondly the sensor burst. The eventual solution was to immerse a hollow solenoidal sensor in a water bath; this allows convective flow through the solenoid and air cooling of the water. No problems have subsequently occurred, although the water temperature still reaches 15°C above ambient, i.e. up to 45°C, in summer.

Absolute measurements have been made weekly at Canberra since mid-1978 and also were continued at Toolangi until mid-1979. This 12-month period of parallel operation will suffice to determine the absolute differences between the two observatories. From mid-1979 Canberra replaced Toolangi as the reference observatory in southeastern Australia, although it is planned to continue variations recording at Toolangi for several years more, in order to define the variation-differences between the two.

## The future

Information on the Earth's magnetic field is needed for a number of practical reasons (as well as for the fundamental investigation of a geologically rapid phenomenon), including:

— The derivation of magnetic anomaly maps. The time-variability of the field requires the production of accurate charts and 'reference fields' at internationally agreed epochs so that surveys made at different times can be reduced to a common datum. Where surveys join or overlap, errors in reference fields may produce artificial anomalies, particularly offshore where anomalies may be much smaller than over land.

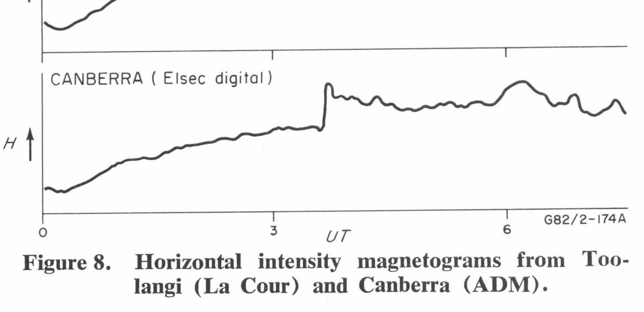


**Figure 8. Horizontal intensity magnetograms from Toolangi (La Cour) and Canberra (ADM).**

— For navigation. The magnetic compass, in its simple traditional form or its more elaborate modern versions, still has an important place in navigation over land, sea and in the air.

— For monitoring of magnetic disturbance and changes of field level. Results are applied in prospecting surveys; radio communications; induced telluric current effects on long, power and gas pipe-lines.

The requisite information can be supplied by a network of permanent observatories and supplementary magnetic 'stations'—places where repeat measurements are made to determine the secular change. In planning such a network the basic question to be answered is the essential number and spacing of the required observatories and 'first-order' (repeat) stations. By overseas standards the Australian region is poorly equipped with magnetic observatories, e.g. in North America there is one observatory for every $10^6$ km$^2$; in Australasia, one every 6 x $10^6$ km$^2$ (the disparity is even greater with respect to Europe and other places).

However, the region's small and generally sparse population, and large distances between centres limit the localities where observatories can be operated. Overseas densities will be unachievable until there are dramatic advances in the development of highly stable, low-powered automatic observatories which will utilise satellite data transmission and allow quasi-unmanned operation.

In these circumstances the design of the network should take into account:

• The scale of the features to be described. Isoporic cells may have dimensions of only one ore two thousand kilometres, so this suggests that measurements are needed farther apart than about 500 km. The BMR first-order stations have this average spacing.

• The area over which a station's recordings are representative. This depends mainly on the nature of the external (ionospheric and magnetospheric), and the internal (induction) components of the more rapid transient variations. In the Australian region, the focus of the solar quiet day (Sq) ionospheric current system crosses about the middle of the continent (dip latitude is a controlling factor in the Sq system, at least in middle latitudes, and the average focal path appears to follow dip latitude 40°S (Matsushita, 1967, fig. 7a): this runs from Grafton to Carnarvon). Hence variations in F and H are reversed in northern and southern Australia, and the present (southern) observatories cannot provide information for northern Australia. Moreover, the path of the focus is highly variable from day to day, e.g. McGregor (1966b) showed that Watheroo lies to the north of the focus about 30 percent of the time. The internal induced component of external fields gives significant effects near the coasts (Parkinson, 1961). Experience gained by BMR during a first-order regional survey in 1973 underlined the futility of attempting to apply measurements made near the coast to data recorded inland.

• The time-scale of secular changes. Observatory data clearly show that rates can alter quite sharply over a short time-interval, and ideally data should be produced continuously. It is equally clear that it is impracticable to operate 40 or more present-day observatories; but the re-occupation of 60 first-order stations more frequently than every five years is a costly venture in terms of money and manpower.

Taking these factors into account, most of the immediate deficiencies in the existing network could be overcome by establishing observatories, in order of priority, at or near Alice Springs, Mackay, Onslow, Woomera, and Darwin; they could reduce the number of first-order stations by 30-40 percent.

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