REPORT 168

AFMAG Field Recording, 1968-1971

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Bureau of Mineral Resources, Geology and Geophysics

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AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1974

DEPARTMENT OF MINERALS AND ENERGY
MINISTER: THE HON. R. F. X. CONNOR, M.P.
SECRETARY: SIR LENOX HEWITT, O.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
DIRECTOR: N. H. FISHER
ASSISTANT DIRECTOR, GEOPHYSICAL BRANCH: N. G. CHAMBERLAIN

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

ISBN 642 00484 6

MANUSCRIPT RECEIVED: MARCH 1973
ISSUED: FEBRUARY 1974

Printed by Graphic Services Pty Ltd, 60 Wyatt Street, Adelaide 5000

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Relative AFMAG field strengths were recorded near Perth and Darwin between 1968 and 1971. The records obtained are discussed qualitatively and their relation to use of the AFMAG prospecting equipment is described. On the basis of experience with the prospecting equipment and the information gained from the recordings, it is concluded that AFMAG is not in general an efficient prospecting technique in Australia.

INTRODUCTION

The AFMAG method of prospecting was first introduced in 1958 (Ward et al., 1958; Ward, 1959). It is an inductive electromagnetic method in which the primary field is a natural audio-frequency magnetic field arising mainly from worldwide lightning discharges.

In January 1968 the Bureau of Mineral Resources (BMR) acquired a McPhar Ground AFMAG Unit (type A652, high sensitivity), shown in Figure 1, and this unit has been used in three test surveys in various parts of Australia

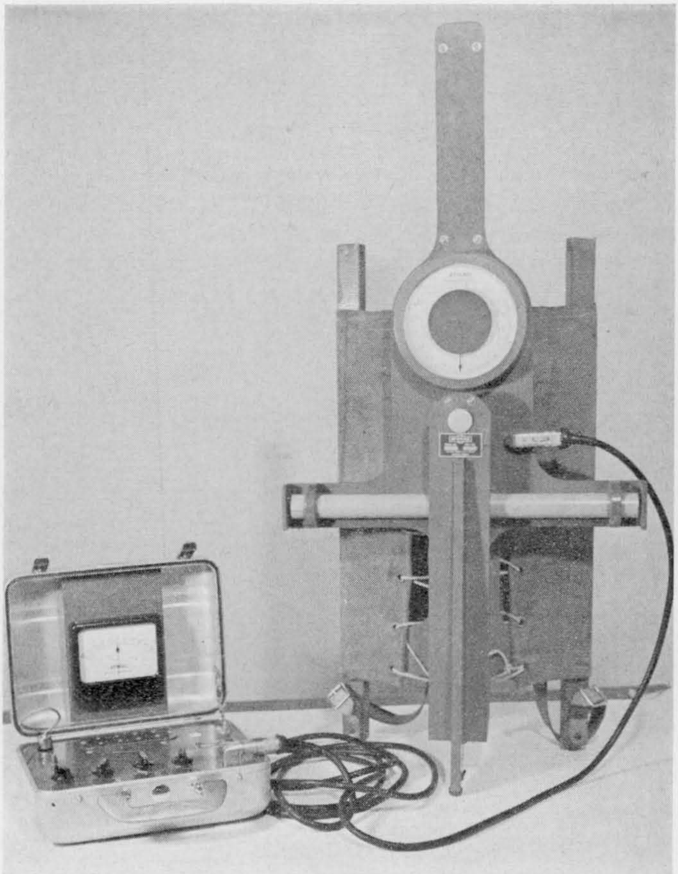

Fig. 1. The AFMAG Prospecting Equipment.

(Farrow, 1969, 1970a, 1970b). It was soon found that the efficiency of the method was strongly subject to vagaries in the natural AFMAG field. Therefore it was considered desirable to investigate the field more closely, and in October 1968 two AFMAG field strength recording units were obtained on loan from McPhar Geophysics Ltd. These recorders were operated intermittently at locations near Perth and Darwin from the summer of 1968-69 to 1971.

This Report is a short account of BMR experience with the AFMAG prospecting equipment, and includes a discussion of the AFMAG field variations measured by the recording units with reference to their effect on use of the prospecting equipment.

THE AFMAG FIELD

Nature of the field

The AFMAG field, as the name implies, is an audio-frequency magnetic field. It arises almost wholly from worldwide lightning discharges, though other sources —e.g. direct audio-frequency radiation from the sun, the gyromagnetic effect of charged particles in the Earth's magnetic field, and artificial noise such as that due to power and telegraph lines—make a minor contribution.

The undisturbed field consists of rapid and essentially random pulses with only a small vertical component. The pulses have a slightly preferred direction which gives an indistinct azimuth to the field when it is observed over an appreciable period of time (about half a minute). Over a period of time a quantity of energy can be measured in three orthogonal directions; therefore the field can be considered to have an 'average' or 'integration' ellipsoid of polarization with its major and minor axes along the directions of maximum and minimum field strength respectively, and the other axis perpendicular to both. This ellipsoid will be referred to simply as the 'integration ellipsoid', though the term should not be taken to imply any condition on the type of polarization possessed by the individual pulses. In an AFMAG field undisturbed by conductive inhomogeneities, the vertical component of each pulse is small and the major axis of the integration ellipsoid is almost horizontal. Ward et al. (1966) have made a detailed study of the integration ellipsoid. A summary of their findings is as follows:

(a) The ratios of the major, intermediate, and minor axes are usually about 1.0 : 0.6 : 0.2.

(b) The azimuth of the major axis may vary by up to 90° in a few days. There is a strong variation in the average azimuth from month to month due to successive build-up and decay of the various world thunderstorm centres.

(c) The dip of the major axis is relatively stable and seldom deviates by more than 5° from the mean. This dip is close to zero in the absence of any conductive inhomogeneities in the neighbourhood of the point of observation.

Propagation of the field

The AFMAG field is propagated in the spherical waveguide formed by the Earth's surface and the lower surface of the ionosphere. The efficiency of this waveguide is a function of the conductivities of the ground and of the ionosphere to audio-frequency waves. The conductivity of the ground is nearly always much greater than that of the ionosphere (Bleil, 1964), and for practical purposes attenuation in the Earth/ionosphere waveguide can be taken as a function only of the conductivity of the lower ionosphere. At night the lower surface of the ionosphere is the E-layer at a height of about 90 km. During the day ultraviolet radiation from the sun causes extra ionization and formation of the diffuse D-layer, which has a lower reflecting efficiency than the night-time E-layer. Therefore AFMAG fields during the day are weaker than those during the night owing to decreased efficiency of propagation.

The propagation of the field in the waveguide is also frequency dependent. Chapman & Macario (1956) showed a photograph of a model which illustrates the way in which the spectrum of the disturbance radiated by an average cloud-to-ground lightning stroke varies with the distance of propagation. At distances greater than about 500 km their curves showed marked peaks in intensity at 100 Hz and 7000 Hz. The frequency dependence of propagation was also illustrated by Aarons (1956), who recorded frequency sweeps between 10 Hz and 900 Hz at various times of day and observed a daytime peak in intensity at about 90 Hz. During the night intensities were found to be consistently high, with little frequency dependence.

THE AFMAG RECORDERS AND PRESENTATION OF RESULTS

The two recorders on loan from McPhar Geophysics each consisted of a coil and amplifier tuned to 340 Hz connected to a Rustrak recorder. The running speed was about 25 mm per hour and clocks were provided to put hourly timing marks on the records. The date and time were also marked off manually every few days to provide an accurate time-scale. The recorder was geared so that the pressure-sensitive chart paper was marked by a stylus every four seconds. Before being sent to their respective locations the two recorders were calibrated against each other and set to equal, though arbitrary, scales. Therefore the records provide a reasonable, semi-quantitative indication of variations in the field strength. Records are available from Darwin for about 50 percent of the time from November 1968, and from Mundaring (near Perth) for about 75 percent of the time from January 1969.

Records were cut into lengths of one day, running from 00 GMT to 2400 GMT. The records for one week, starting with Monday, were pasted to a large sheet of paper, labelled with dates, hours, etc., and then photographed and reduced to 36 x 28 cm prints for ease of handling. The records were cut and labelled according to Greenwich time in order to provide a common time base for Perth and Darwin, which otherwise would be $1\frac{1}{2}$ hours out of phase with each other, and to put the most disturbed night-time portion near the centre of the daily record. However, it was later found more convenient to display some results relative to local time, and this has been done in Figures 2 and 3. A week's set of records typical of those obtained during the Darwin wet season is shown in Figure 4.

Although the main diurnal variation was fairly constant over a month, records for different days differ in detail (e.g. Fig. 4). For this reason the daily activity has been averaged over each month by summing the field strengths at a particular time of day for each day of the month and averaging it over a number of days. This was done for each hour in order to obtain the average monthly field strength for each hour of the day. From these values of hourly average field strength an 'average AFMAG day' was plotted. This was done for each month and the results are shown in Figures 2 and 3. This averaging process was performed in order to obtain a better idea of the diurnal and seasonal variations of the AFMAG field. Individual records were still used to investigate the effect of local thunderstorms and of solar flares. Information on thunderstorm activity for 1968, 1969, and 1970 at Perth and Darwin Airports was provided by the Bureau of Meteorology, and each observation of thunder at these localities was marked on the respective recordings. The dates and times of solar flares as recorded by the BMR observatories at Port Moresby and Mundaring were also marked on the records.

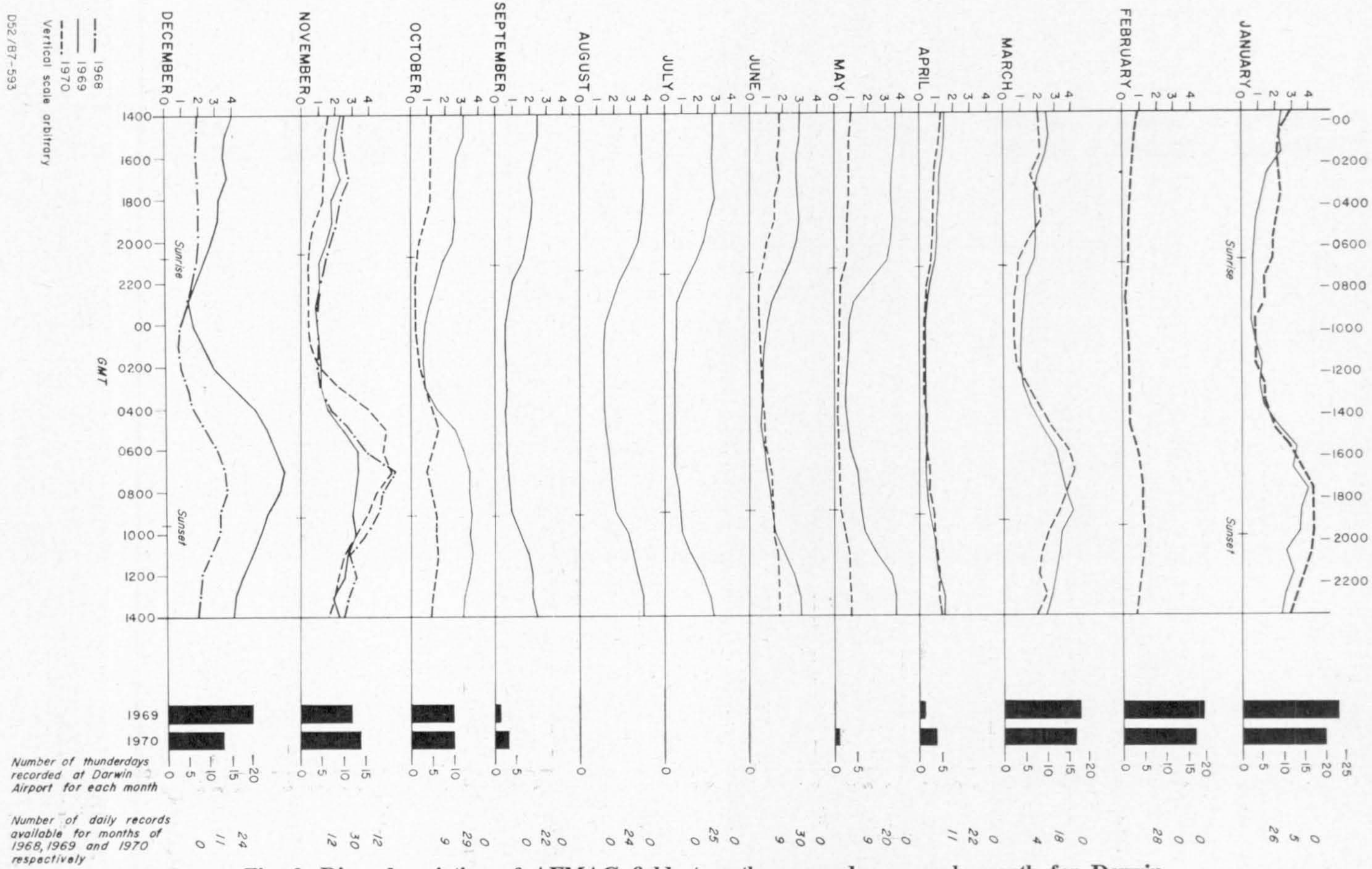

Fig. 2. Diurnal variation of AFMAG field strength averaged over each month for Darwin.

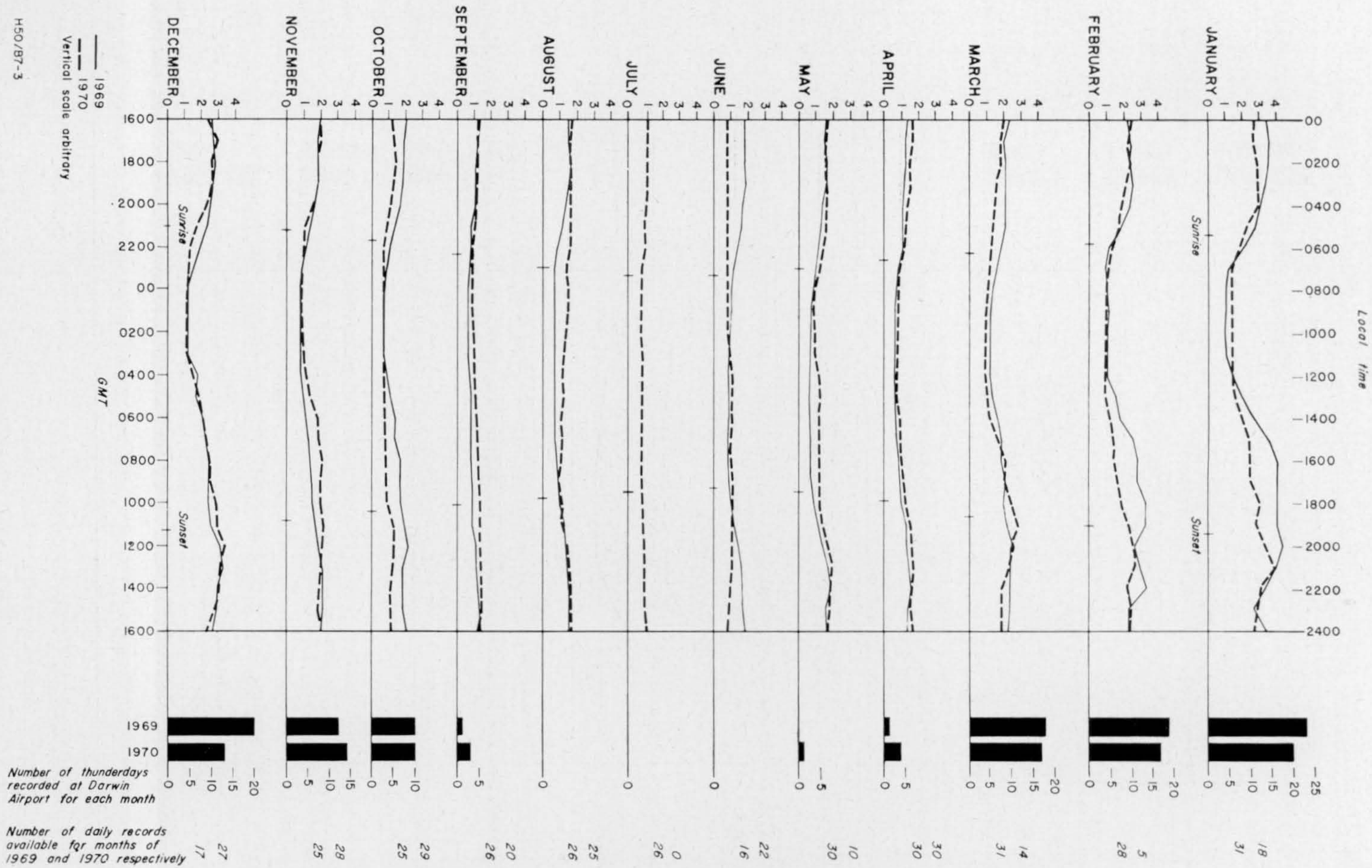

Fig. 3. Diurnal variation of AFMAG field strength averaged over each month for Perth.

DISCUSSION OF THE RECORDS

Diurnal variation

The diurnal variation can be seen clearly on the individual records (e.g. Figs 4 and 5) and on the average AFMAG days for each month (Figs 2 and 3). Occasionally the field strength drops to such a low level over an interval of several days that the diurnal variation is barely visible on the records. This can be seen in Figure 6, which shows a week of very low field strengths recorded at Darwin in the dry season. In the winter months fields start to increase to their night-time levels just before sunset and start to decrease back to their daytime levels just before sunrise. In the summer months afternoon thunderstorm activity in the Southeast Asia thunderstorm centre causes much earlier afternoon increases in field strength at both localities, although the morning decrease still commences shortly before sunrise.

Seasonal variation

The seasonal variation in the AFMAG field can be seen in Figures 2 and 3. There is obviously a marked increase in activity in the summer months during the afternoon and night. The morning level of activity remains remarkably constant throughout the year. The columns to the right of the average AFMAG day for each month give the number of thunder-days recorded for that month at Darwin Airport in 1969 and 1970. (A thunder-day is defined as a day on which thunder is heard.) It is apparent that the seasonal change in the AFMAG field at both Perth and Darwin is in phase with the changing level of thunderstorm activity at Darwin. Assuming that thunderstorm activity in the Perth area is negligible as regards the generation of AFMAG fields (only 14 thunder-days were recorded at Perth Airport in the two years 1969 and 1970), it has been concluded that the increase in the level of AFMAG activity at Perth is due to the increase in the level of thunderstorm activity in the Southeast Asia thunderstorm region, of which Darwin area is part. As Perth is distant from Darwin (about 2700 km) it would be expected that this conclusion would also apply to the rest of Australia; i.e. the afternoon and night-time AFMAG field strengths in Australia are roughly proportional to the level of thunderstorm activity in the Southeast Asia thunderstorm region.

Effect of individual thunderstorms and solar flares

As the gearing of each Rustrak recorder was such that the paper was marked only every four seconds, the records would not be expected to show the effects of individual local lightning discharges, but only to show the response to an increase in the general field strength.

The dates and times of thunder registered at Darwin and Perth Airports were marked on the respective sets of records. In general, thunderstorms recorded at the airports do not show up on the records, as would be expected from the argument above. Only very strong storms have a noticeable effect on the records, and good examples of this are shown in Figure 7. None of the storms registered at Perth Airport had any noticeable effect on the records. As the Darwin recorder was situated about 70 km south of the airport it is probable that storms would occur near the recorder without being registered at the airport. Therefore it is thought that some of the other peaks on the records shown in Figure 7 could also be the result of thunderstorms even though they were not registered at the airport.

The dates and times of solar flares observed at Mundaring and Port Moresby

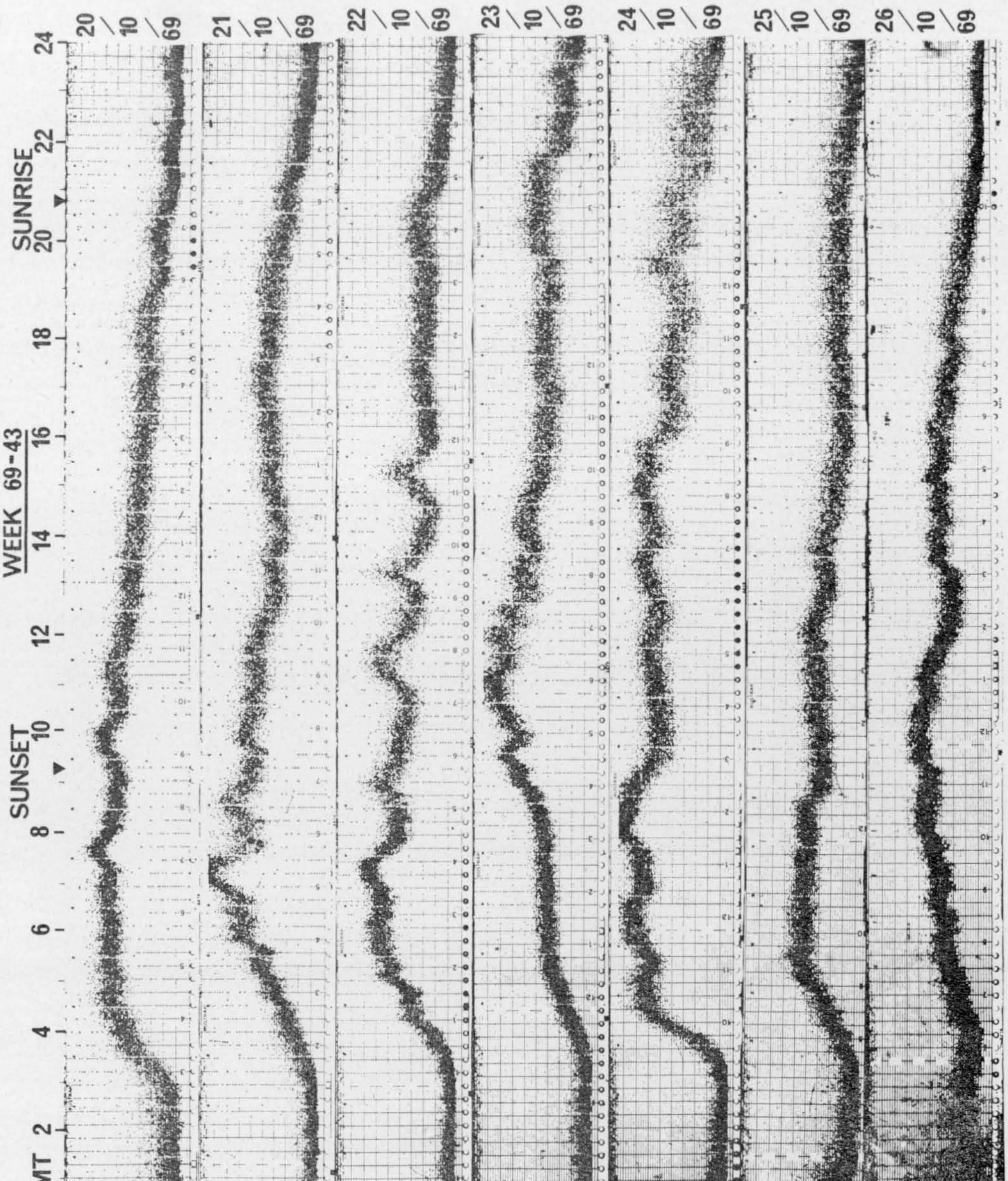

Fig. 4. AFMAG records, Darwin, 20-26 October 1969.

Geophysical Observatories were marked on the records. Mostly they had little or no effect on the general field strength, though it is possible that the effects of three of them can be seen in Figure 7. It is also possible that these peaks are the result of local thunderstorms that happened to coincide with the occurrence of solar flares, but this is considered unlikely in view of the fact that the times of occurrence of the solar flares coincide so exactly with the disturbances on the records.

Figure 8 shows another set of records on which the times of occurrence of a

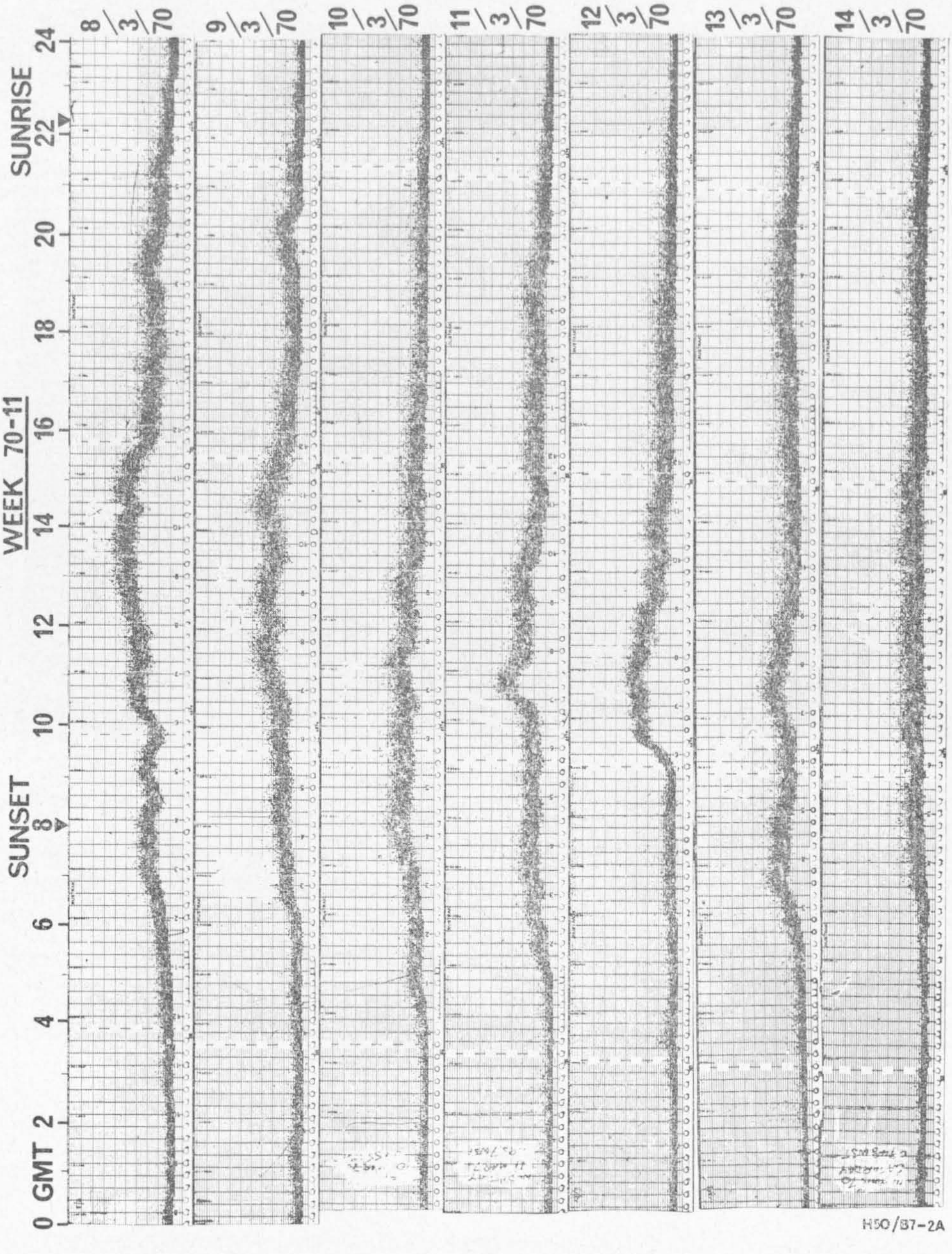

Fig. 5. AFMAG records, Perth, 8-14 March 1970.

solar flare and of several thunderstorms are marked. There is no definite correlation between the times of the thunderstorms and features on the records. The solar flare could be related to the slight peak in intensity occurring at the same time, though this is by no means certain.

On the basis of Figures 7 and 8 it is considered that solar flares can have an appreciable though short-lived effect on the field strength, but that this effect is of minor importance.

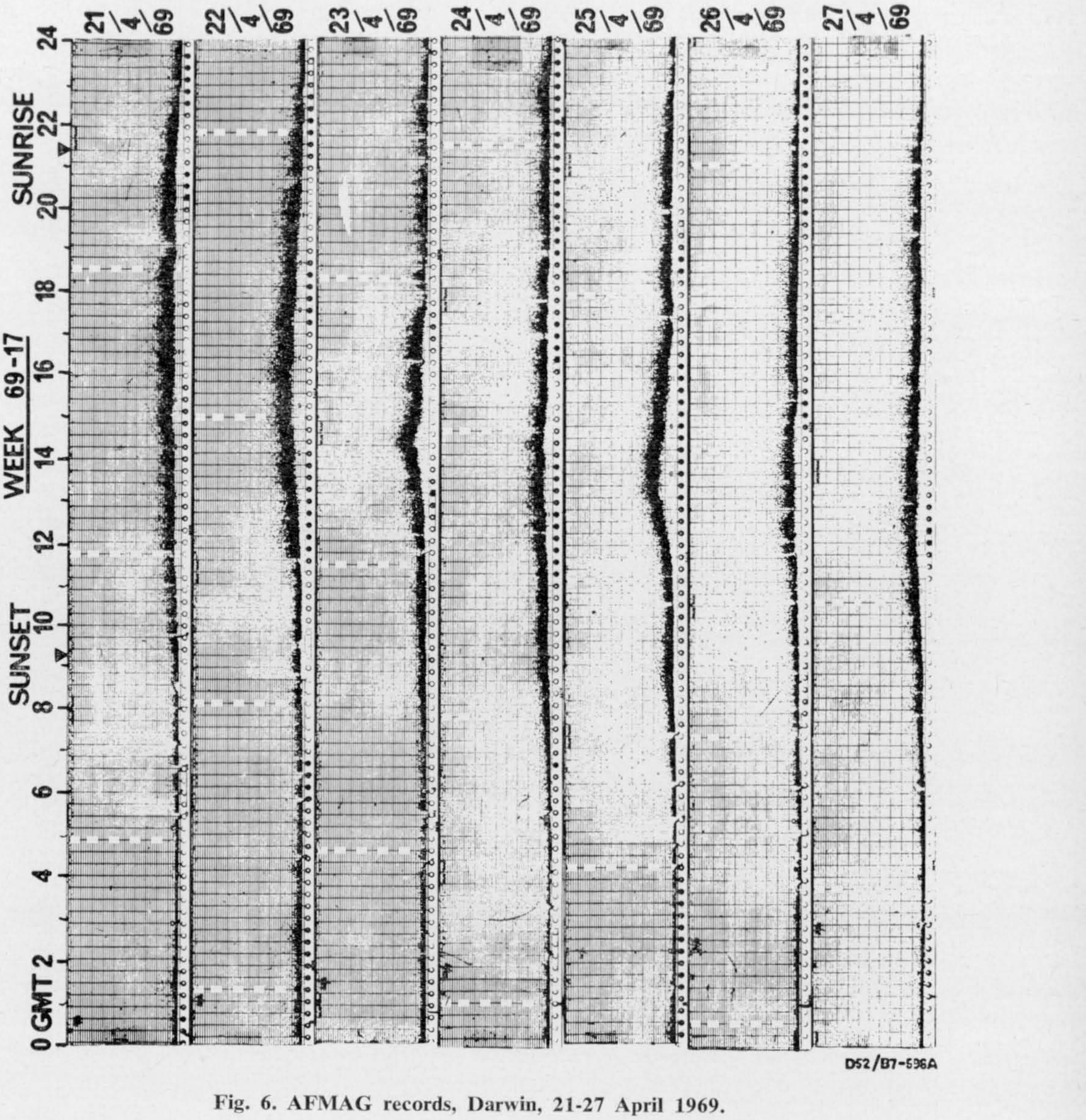

Fig. 6. AFMAG records, Darwin, 21-27 April 1969.

SUMMARY OF THE AFMAG PROSPECTING METHOD AND FIELD RESULTS

The effect of a conductor on the AFMAG field is to tilt the major axis of the integration ellipsoid out of its usually almost horizontal position and to rotate it in the horizontal plane towards the perpendicular to the conductor. This axis also becomes much more pronounced. The function of the AFMAG ground prospecting unit is to measure the dip and azimuth of the major axis of the integration ellipsoid, also called the 'field azimuth'. A description of the McPhar Ground AFMAG Unit and the way in which it is used has been given by Farrow (1969).

Three test surveys were conducted by BMR using the AFMAG ground unit (Farrow, 1969, 1970a, 1970b). Briefly, it was found that the method could delineate certain geological features, particularly major faults, good lithological conductors, and possibly lithological contacts. The method was usually slow owing to reading difficulties and was generally inconvenient because of lost time during intervals when the field was weak or erratic. It was not generally possible to repeat readings and obtain good agreement. Although none of the tests were carried out in the winter, it is thought that low field strengths at this time of the year would preclude efficient use of the equipment, except possibly in the north of the continent.

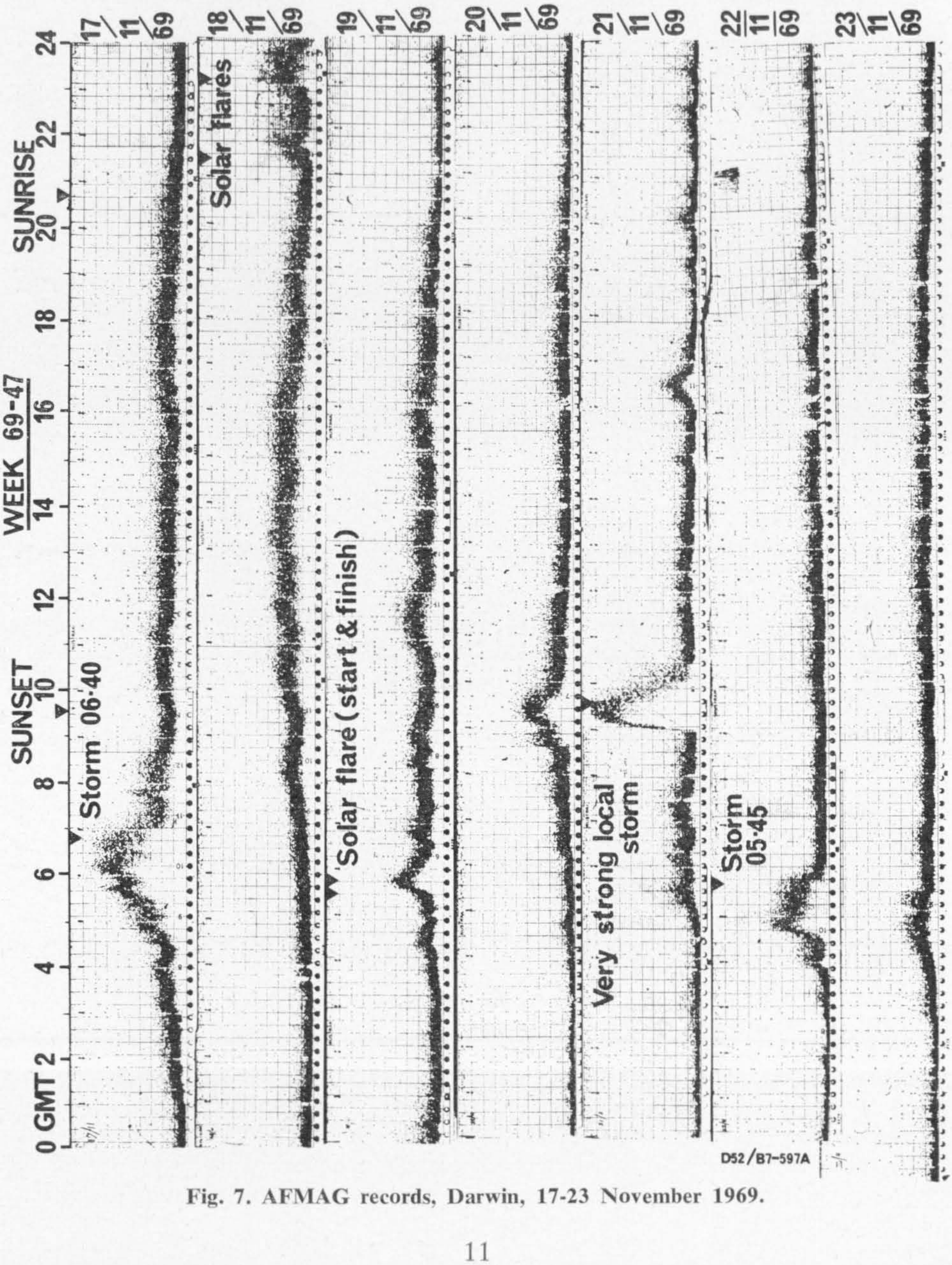

Fig. 7. AFMAG records, Darwin, 17-23 November 1969.

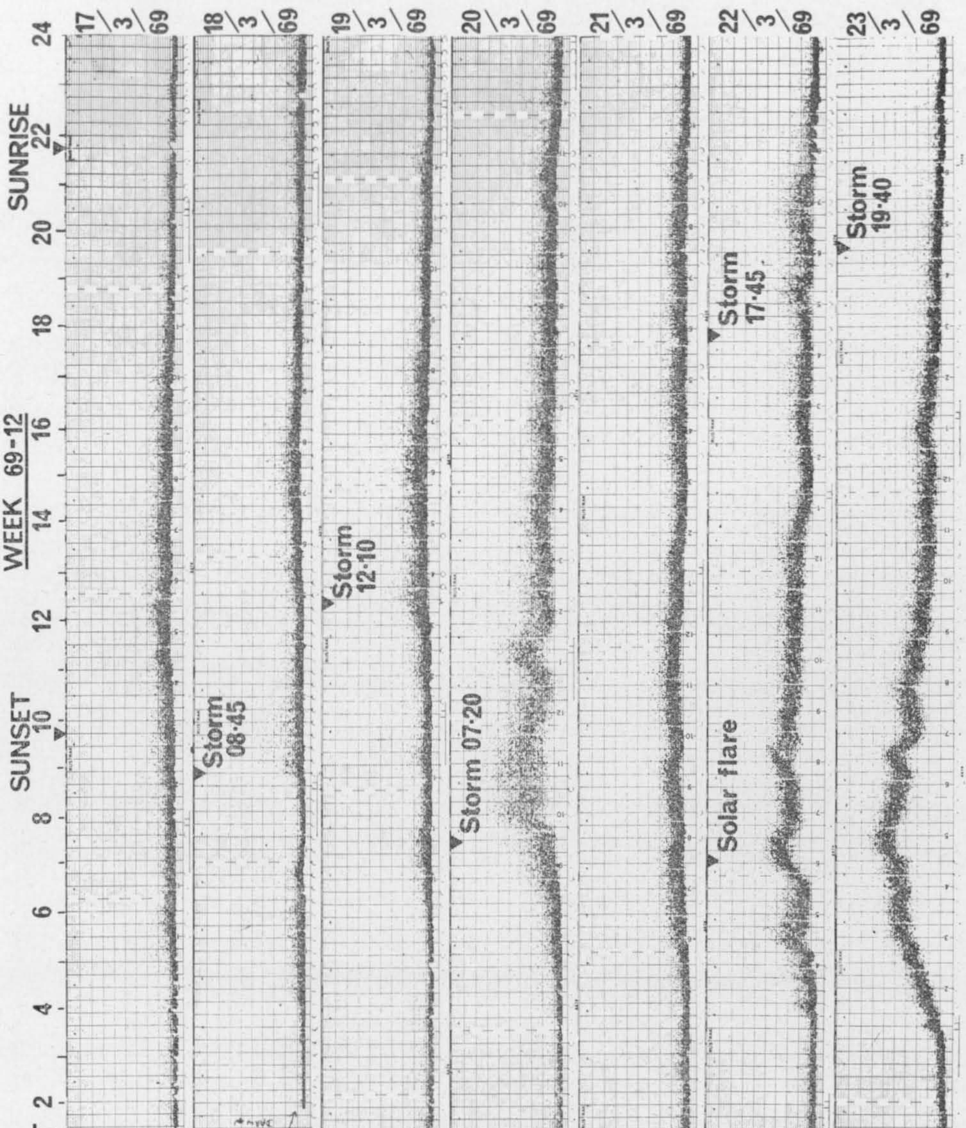

Fig. 8. AFMAG records, Darwin, 17-23 March 1969.

CONCLUSIONS

Although the AFMAG records made by BMR do not give a quantitative measure of the field, they show the relative daily and seasonal variations very clearly. They show that the field (considered only during the daytime) is strongest for an hour or two around dawn, or during the afternoons of the summer months. Thus these would probably be the most suitable times for field work with the AFMAG equipment, but operation even at times of high field strength might be prevented by large fluctuations in the field. As was mentioned earlier, such fluctuations would not be registered by the two recorders and so the results studied contain no information about them.

The main conclusion to be drawn from the AFMAG records is that the level of activity in Australia depends on the state of the Southeast Asia thunderstorm cycle. This was to be expected from results of similar recordings made in the Northern Hemisphere (e.g. Ward et al., 1966). As regards AFMAG as a geophysical tool, the conclusion reached is that it is not generally suitable for metalliferous prospecting, though it could be of use in certain geological investigations. A survey based on other methods might profitably make use of an AFMAG unit if it were used only when conditions were favourable. However, it is the opinion of the author that AFMAG as a geophysical tool has been superseded by more recent developments of methods based on artificial V.L.F. electromagnetic fields. These methods are more rapid, less costly, and more reliable than present methods using natural E.L.F. fields, and are capable of yielding the same or better information.

ACKNOWLEDGMENTS

Thanks are due to McPhar Geophysics Ltd for loan of the recorders, and to the Bureau of Meteorology for records of thunderstorm activity at Darwin and Perth for 1968, 1969, and 1970.

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