AN EXPERIMENTAL DETAILED MAGNETIC SURVEY BY LIGHT AIRCRAFT

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ABSTRACT

From March to May of 1963, the Bureau of Mineral Resources carried out an experimental aeromagnetic survey at Cobar, New South Wales, to field test a proton-precession magnetometer installation in the Cessna aircraft VH-GEO. The Cobar area was chosen as considerable information was already held on the Earth's magnetic field there, which was known to provide a range of anomalous areas that are not excessively disturbed.

A procedure for survey flying and methods for processing data were developed during the survey. Contour maps of the aeromagnetic results were produced in the field. The experimental survey was successful in outlining magnetic anomalies in detail.

INTRODUCTION

Since 1951 the Bureau of Mineral Resources, Geology and Geophysics (B.M.R.) has carried out an airborne magnetometer exploration programme with DC.3 aircraft carrying fluxgate magnetometer equipment. Recently a proton-precession magnetometer was developed by the Design and Development Group of the B.M.R. for observatory use. One unit modified for airborne use was installed in the Cessna light aircraft, VH-GEO. The Cessna was modified structurally to take the magnetometer, associated bird, and winch gear.

The proton-precession magnetometer has many good features.

1. It utilises the transistor and associated solid-state devices in its electronics, and hence is light and small. This is the basic feature allowing its installation in a light aircraft. The transistor circuits have a high reliability factor, and owing to the card sub-unit

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construction, the magnetometer is easily serviced in the event of breakdown.

2. Although the proton-precession magnetometer produces a step record of discrete readings, which is not as comprehensive as the continuous record of a fluxgate magnetometer, it has three advantages over the latter.
   (a) It makes absolute measurements of field, and hence is 'drift-free'. This considerably eases reduction of data.
   (b) The detecting unit requires no particular orientation with respect to the direction of the Earth's field, apart from the easily satisfied condition that the axis of the polarising field must not be parallel to the direction of the Earth's field. (This is easily achieved by maintaining the axis of the coil in a horizontal plane.)
   (c) The detecting unit is of simple construction and is easily fitted in a small bird, enabling it to be towed remote from the disturbing magnetic effects of the aircraft.

Compared with survey by ground party, the Cessna survey offers the advantages of being more rapid, cheaper, and incidentally more accurate in not recording near-surface 'false' anomalies such as those caused by iron drainage pipes.

Light-aircraft manoeuvrability allows the Cessna to fly short lines close to each other, and hence an area may be surveyed in considerable detail. This gives good resolution of an anomaly.

The Cobar area was selected to test the Cessna-borne proton-precession magnetometer because previous detailed ground magnetic and regional airborne magnetic (using a DC.3 aircraft and a fluxgate-type magnetometer) surveys showed that it contains a range of anomalous areas that are not excessively disturbed. The Cessna survey was made from March to May 1963. A small portion only of the total area covered is illustrated in Fig. 1.

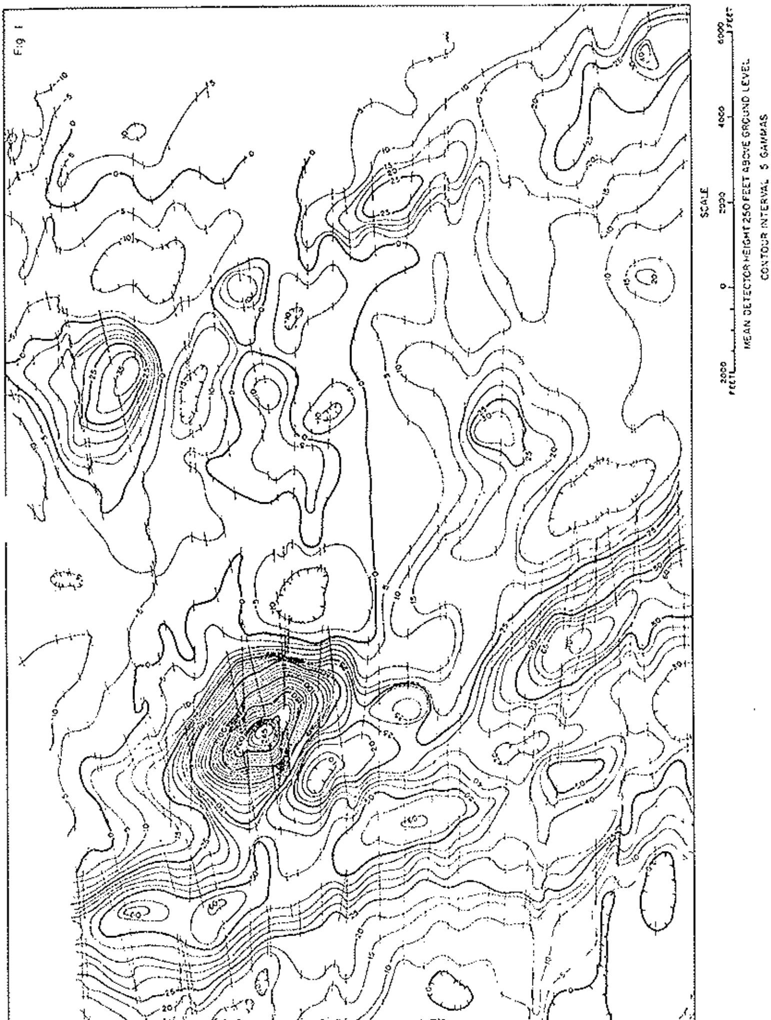

FIG. 1—Light-Aircraft Detailed Aeromagnetic Survey, 1963, Cobar, N.S.W. Total Magnetic Force.

EQUIPMENT

Cessna Aircraft VH-GEO

The aircraft VH-GEO is a Cessna 180-B, single engine, high-wing monoplane, to which the following structural modifications have been made for airborne survey purposes.

1. removal of the rear seat and installation of a rack to hold chart recorders and electronic units
2. alteration of the aircraft electrical system to 28 V d.c.
3. installation of the bird cradle and the cable winch
4. installation of a camera hatch, through the cockpit floor and the external skin, to hold the navigation camera
5. removal of the starboard set of dual controls to give the observer more space
6. installation of magnetometer assembly, power and timing unit, radio-altimeter, and navigation camera.

Magnetometer Assembly

The primary unit installed in the aircraft is the magnetometer. This consists of a bird, cable, MNZ1 electronic unit, and Westronic chart recorder.

The bird is streamed on 60 ft of coaxial cable where it is clear of the disturbing effects of the magnetic field associated with the aircraft. The bird consists of a fibreglass aerodynamic shell holding a coil of aluminium wire wound around a perspex bottle filled with kerosene.

The MNZ1 unit controls the electronic operation of the bird. The full cycle takes 2 seconds and comprises

1. a polarising period of 1 sec, during which a strong current (approximately 4A) is fed through the bird coil, causing a strong axial magnetic field which polarises protons in the kerosene, and
2. a period of 1 sec, for which the polarising current is removed, the protons precess around the Earth's field, and the frequency of precession is measured. This measurement normally occupies about the initial 0.6 sec of the 'counting' period.

The chart-recorder is fed by the memory unit of the MNZ1, which 'remembers' the value of a precession frequency estimation until it is reset by the next estimation 2 sec later. Hence the chart trace is in the form of steps, each lasting for 2 sec. At Cobar, the recorder was calibrated to 100 gamma full scale deflection. As the aircraft surveys at speeds of about 110 knots, a reading every 2 sec gives a station separation of about 370 ft.

Power and Timing Unit

The power and timing unit is fed by the aircraft 28 V d.c. supply. It produces the correct sequence of co-ordinating timing pulses for the system, and the variety of power supplies needed.

Radio-Altimeter

An APN1 radio-altimeter records on chart during survey flying. It also controls limit lights on the pilot's instrument panel.

Navigation Camera

A Vinten Camera, fitted with a 187° field-of-view lens, is employed to record the flight paths of the aircraft, 35-mm film being used and a frame exposed every 4 sec.

Magnetic Storm Warning Device (S.W.D.)

The Cobar party was equipped with a fluxgate magnetometer model MFD 3 for monitoring magnetic storms (which would interfere with the collection of magnetic data) and for correcting magnetic data for the diurnal changes in the Earth's magnetic field. The MFD 3, which was still in the developmental stage, was found to drift with ambient temperature and thus could not record diurnal magnetic changes accurately.

SURVEY FLIGHT PROCEDURE

Rectangular areas of interest were chosen, normally several square miles in extent. Standard aerial photographs enlarged to a scale of approximately 2000 ft to 1 in. were used as a basis for navigation. The line starting points for an ideal grid were marked on these at a separation equivalent to 10 lines per mile. The aircraft was then flown to cover this grid.

During a survey flight, the aircraft crew comprised pilot and operator-observer. The duties of the latter consisted of switching all equipment on before survey started, and then navigating for the pilot in directing him to the starting points of lines. The pilot would fly each line straight from the start by 'dead-reckoning', i.e. maintaining a constant bearing on the directional-gyro instrument and a constant height on his radio-altimeter.

Before starting on the grid, it became practice for the pilot to first carry out a 'dummy run' to estimate drift correction. For each flight it was also practice to fly a short traverse at the start of surveying that could be repeated at the end of surveying. Comparison of the 'before' and 'after' magnetic profiles gave an estimate, in the reduction process, of diurnal change in magnetic field during survey.

DATA PROCESSING METHODS

Film Processing

The navigation film (Ilford HP 3 and FP 3) was processed in a Microrecord tank. Both normal developing chemicals and a combination developer-fixer were tried. It was found that the combination developer-fixer gave excellent results with much greater simplicity of operation.

Plotting

The path of the aircraft was plotted on the navigation photos by the vertical camera record, which exposed one frame every 4 sec, i.e. at approximately 730 ft intervals. It was found sufficiently accurate at Cobar to plot only every fifth or tenth frame, interpolating a straight line in between. Maximum error introduced in this way is estimated to be 50 ft.

Correction for Diurnal Change

Because the S.W.D. drifted with temperature, an estimation of the diurnal change in the magnetic field during a survey flight was made by comparison of the records for the traverse flown at the beginning and repeated at the end. The change measured in this way was treated as if linear, unless the S.W.D. record showed a magnetic storm pattern superimposed upon the smooth curve due to temperature drift and normal diurnal change.

The absence of an accurate continuous record of diurnal change introduced the greatest error into the reduction of data and contour map compilation.

Contour Cut Determination

The trace on the magnetometer chart was in 2 sec steps, which were not smoothed for reduction purposes except in the case of very obvious noise spikes. For each area surveyed an arbitrary baseline value of magnetic field was selected. For each flight line this was adjusted for diurnal variations, and contour levels marked on the chart at 5 gamma intervals. The fiducial numbers of the trace cuts with these contour levels were then listed, and marked on a transparency overlying the flight path pattern. Contour lines joining points of equal strength were then drawn on the overlay. In some cases it was more convenient to draw the contours at 10 gamma intervals, rather than at 5 gamma intervals.

RESULTS

The maximum amplitude of noise on the magnetometer chart trace during flight was estimated to be ± 2 gammas, both when the aircraft was at survey altitude of 280 ft above ground level and during a test run at 5000 ft. Hence although anomalies of roughly 3 and 4 gammas were sometimes found to repeat, they could not be relied upon individually as being true. From this estimate, and the estimated error in the plotting procedure, the maximum error of a plotted contour cut is considered to be ± 2 gammas with

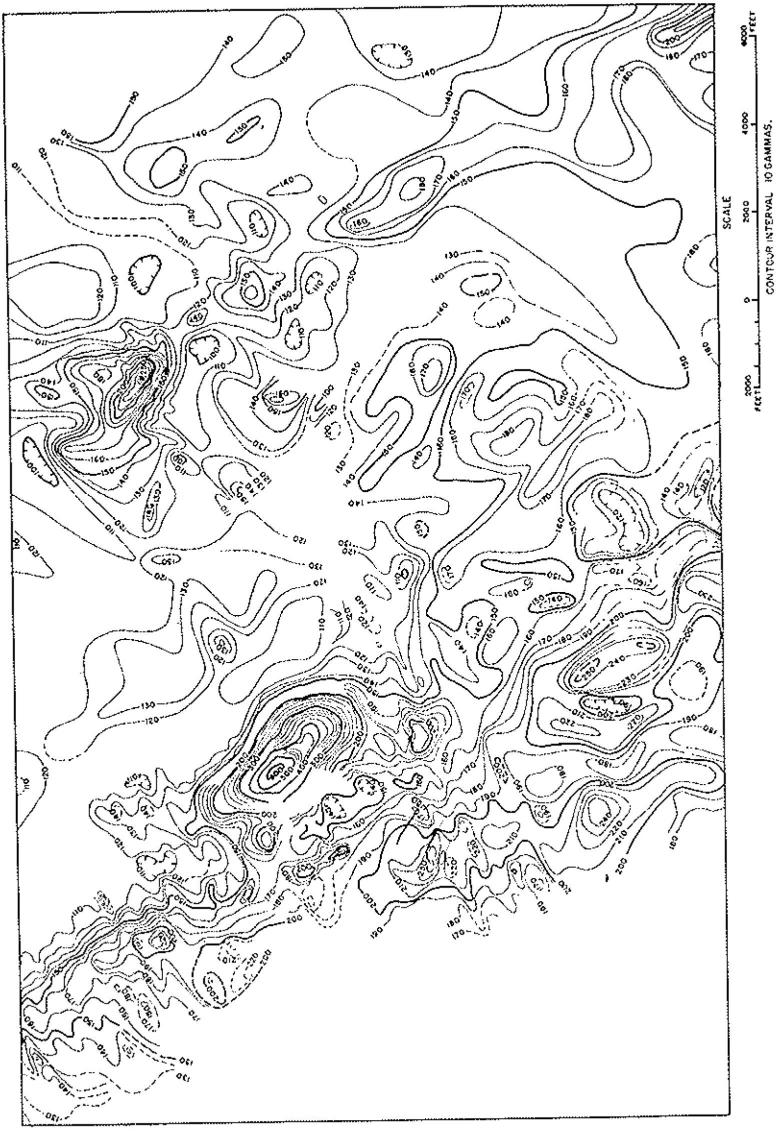

FIG. 2—Geophysical Ground Survey, Cobar, N.S.W. Geomagnetic Vertical Force Contours Prepared From Smoothed Profiles.

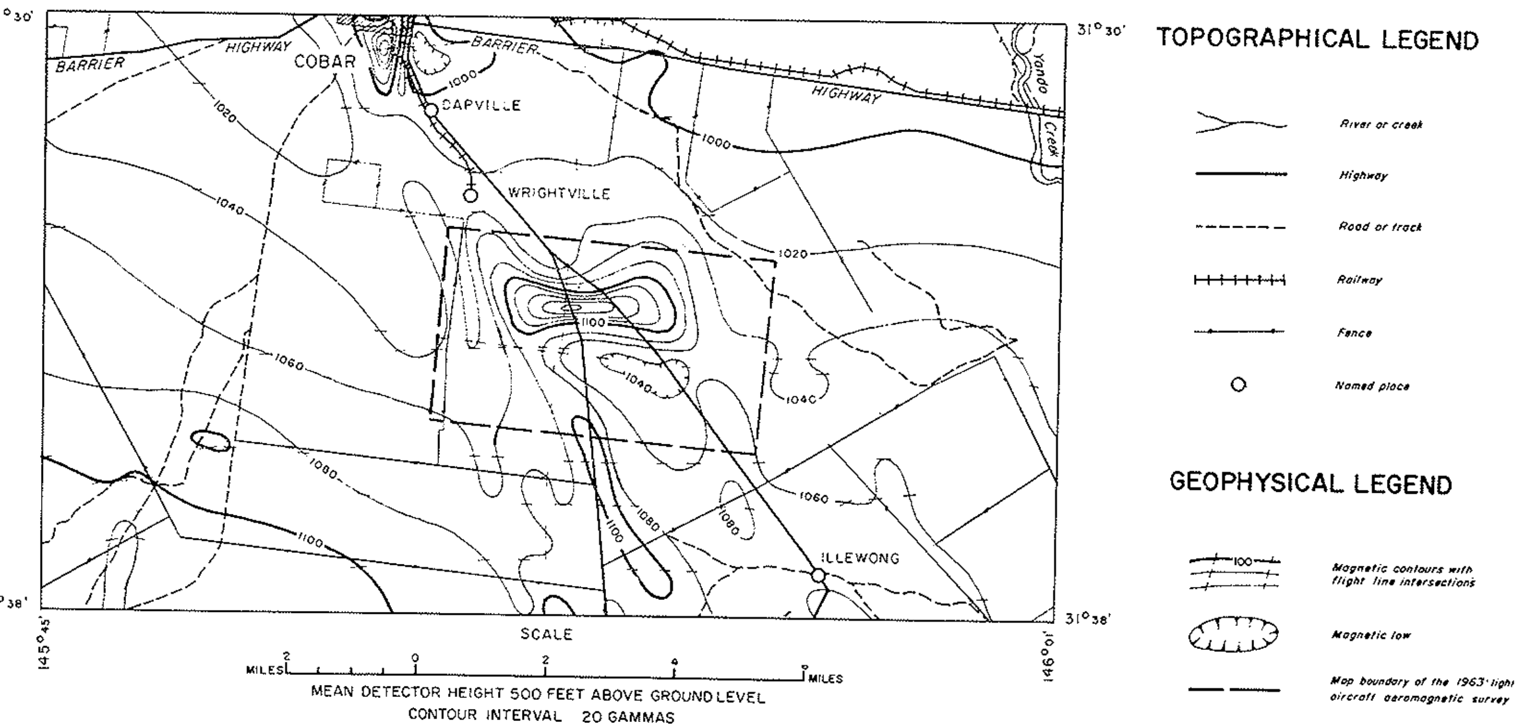

FIG. 3—DC3. aeromagnetic survey 1957, Cobar, N.S.W. Total magnetic force. Area bounded by broken line is same area as Figs. 1 and 2.

respect to the strength of magnetic intensity and ± 50 ft with respect to position.

The magnetic contour map produced by the Cessna survey of the Peak area is shown in Fig. 1. The area had been covered previously by a ground survey using vertical force magnetometers (Fig. 2) and a DC.3 regional aeromagnetic survey (Fig. 3). When compared with the map produced by the ground survey it can be seen that the anomaly features are well reproduced. The ground survey was carried out taking readings at 100 ft intervals along parallel grid lines spaced 200 ft apart, and it is significant to note that whereas the ground survey of the area shown in Fig. 2 took several weeks, the Cessna collected the survey data over the area shown in Fig. 1 in a few hours.

CONCLUSION

The proton-precession magnetometer installation in the Cessna is basically successful in performing detailed aeromagnetic surveys. Inspection of the maps for the Peak area shows that the contour map drawn from the results of a previous DC.3 regional survey (Fig. 3) is very considerably resolved by the Cessna survey (Fig. 1), even to the extent where the ground survey (Fig. 2) can add little or no useful detail to the Cessna survey map.

The MNZ1 installation in the Cessna is temporary, and in the future two factors will further increase the accuracy of the Cessna detailed survey. A non-drift S.W.D. (another proton-precession model) will enable accurate reduction for diurnal change, and magnetic recording at intervals less than the present 2-sec interval. The Bureau of Mineral Resources Laboratories are now developing a precession magnetometer that may record at intervals as short as 0·5 sec. This will be installed for future surveys.

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