FIELD OPERATIONS AND COMPILATION PROCEDURE INCIDENTAL TO THE PREPARATION OF ISOMAGNETIC MAPS*

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THE adaptation by the U. S. Geological Survey, in cooperation with the Naval Ordnance Laboratory, of the AN/ASQ-3A Magnetic Airborne Detector to problems of geophysical exploration has made it possible to produce maps of large areas showing total intensity variations of the earth's magnetic field with greater accuracy and speed, and less expense than by ground measurements.

Since 1943 the Geological Survey, largely in cooperation with the Naval Ordnance Laboratory, the Office of Naval Petroleum and Oil Shale Reserves, several state geological surveys, and more recently the Office of Naval Research, has surveyed more than 200,000 square miles from the Artic Ocean to the Gulf of Mexico. During these projects, flights were made at altitudes of 150 to 14,000 feet above ground, and a wide variety of magnetic and geologic environments was covered, from low magnetic gradients associated with oil structures to high gradients over magentic iron deposits. Aeromagnetic surveys are now being conducted on a routine basis by the Geological Survey and magnetic maps of comparatively large areas are being produced with a high degree of accuracy.

To produce such maps it is necessary to (1) plan the traverses so the airborne equipment will be used most efficiently, (2) keep all traverses in a plane which is compatible with the geologic environment, (3) record the location of the airplane so that magnetic values may be plotted in their true positions, (4) eliminate effects of magnetic diurnal variation and instrumental drift, (5) record the magnetic information in a form which can be used to make the magnetic contour map.

Traverse lines to be flown are drawn on topographic sheets and on aerial photographs at intervals determined by the detail desired in the finished map. The direction of the lines is usually normal to the grain of the area in order to obtain maximum detail in the profiles. The usual flight-line spacing is one-quarter mile. For reconnaissance of large areas, spacings of one to four miles have been used.

The altitude at which a project is flown depends upon the nature of the geology. For shallow highly magnetic ore deposits, it is ordinarily preferable to fly the profiles at a constant altitude above ground, so that the effect of ore bodies in valleys will be comparable with those in hills. For oil prospecting where the sources of the anomalies lie in the relatively deep basement rocks, it is better to fly the profiles at a constant barometric altitude, the effect of sedimentary topography being negligible.

The Geological Survey uses a crew of four in conducting aeromagnetic surveys. These are a pilot, a navigator, and two geophysicists. The pilot flies the plane along a ground path which is indicated to him by the navigator who has strips of aerial photographs on which the flight lines have been plotted.

The geophysicist in the plexiglass nose of the plane (See Fig. 1) has the topographic maps with the flight lines drawn on them. These maps are the base

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maps on which the magnetic data will be plotted. When the plane passes over recognizable check points on the ground this observer closes a switch which actuates four number counters, two edge markers, and a camera shutter. The forward number counter is advanced to the next number, and the observer notes it on the base map. The master counter, magnetometer E-A meter counter, camera counter, the edge markers on the magnetometer and altimeter recorders, and the camera shutter are actuated simultaneously with the forward switch.

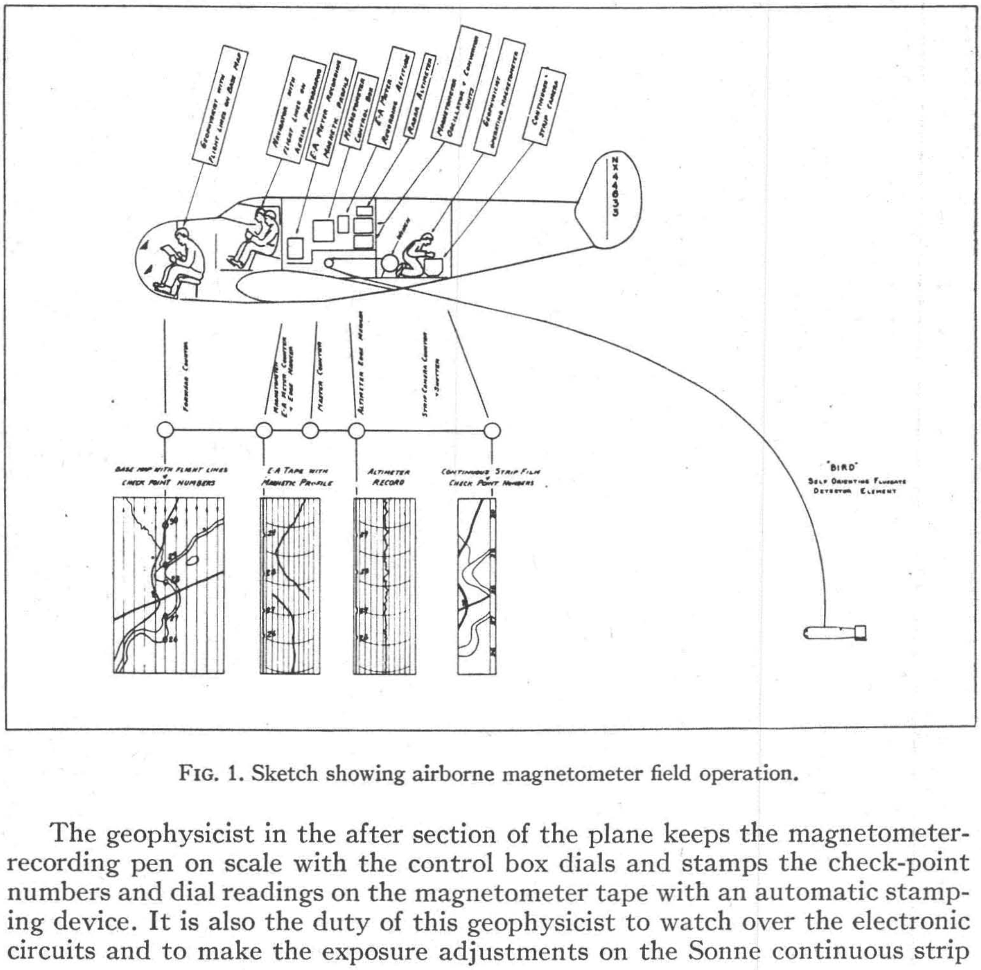
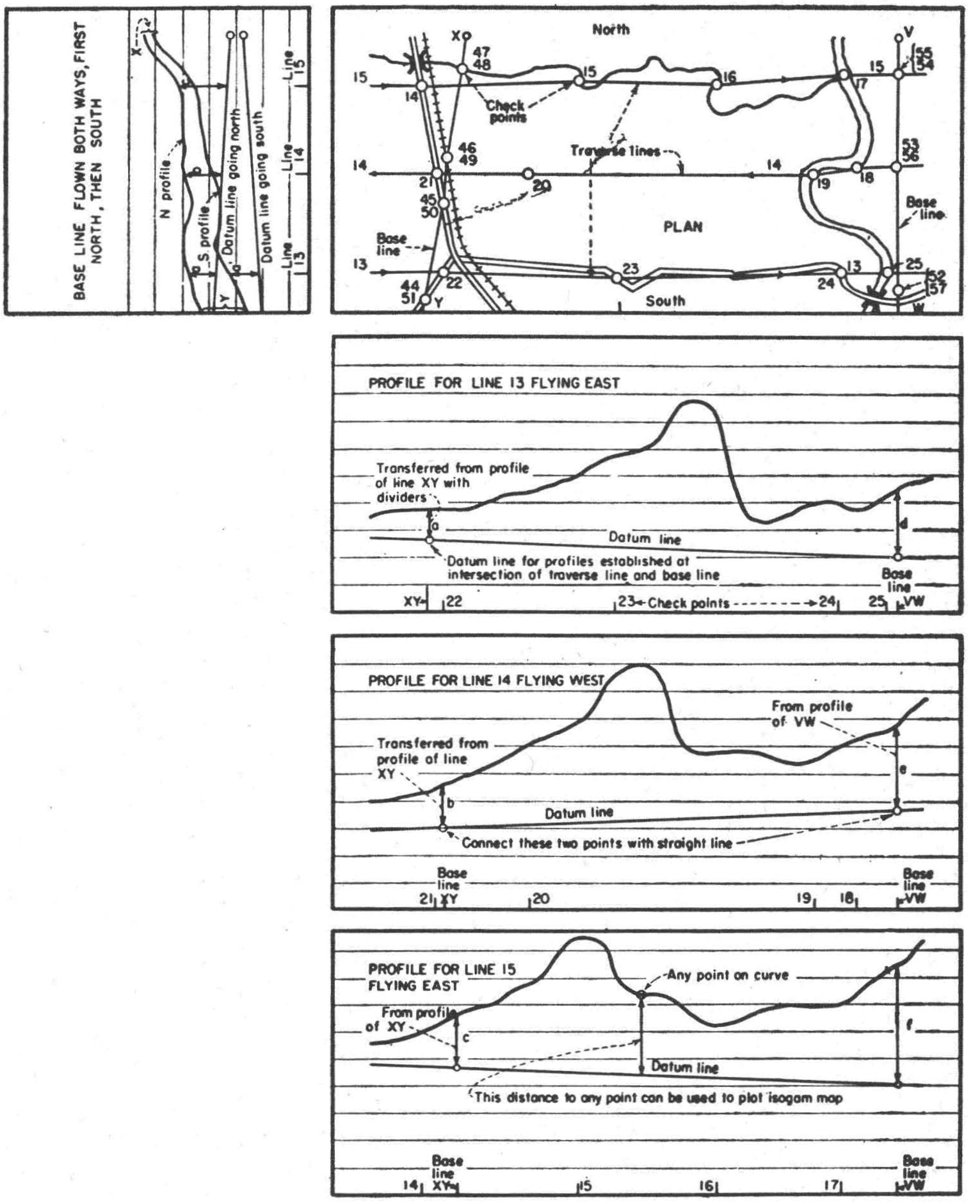


FIG. 1. Sketch showing airborne magnetometer field operation.

The geophysicist in the after section of the plane keeps the magnetometer-recording pen on scale with the control box dials and stamps the check-point numbers and dial readings on the magnetometer tape with an automatic stamping device. It is also the duty of this geophysicist to watch over the electronic circuits and to make the exposure adjustments on the Sonne continuous strip camera.

The records obtained during the flights are: (1) the base map on which approximate check-point locations are noted; (2) the E-A recorder tape with the edge marks and check-point numbers, instrument dial readings and total intensity profile on it; (3) the Radar altimeter record and edge marks on another E-A tape; (4) a continuous strip film of the terrain below the plane's flight path with photographs of check-point numbers superimposed over the terrain; and (5) the forward observer's log containing the direction of flight for each line, with the time and check-point numbers for the beginning and end of the line.

In the office, check points on the base map are located precisely by means of the continuous strip film, and the flight path of the plane is plotted between check points. Distances between check points are transferred to profile paper to form a straight line, and the magnetic curve is drawn in true relation to the



(*Illustration, Courtesy of Engineering and Mining Journal, McGraw-Hill*)

FIG. 2. Method of tying parallel magnetic traverses to common magnetic datum plane.

numbered edge marks and check points. A mechanical device was designed and built by the Naval Ordnance Laboratory and U. S. Geological Survey to transform E-A magnetic curves to orthogonal co-ordinates, adjust the vertical or magnetic scale to any desired value, correct discontinuities in recording, and correct the distance scale to that of the check points plotted on the maps.

The magnetic traverses are controlled by a base-line system transverse to the flight lines (See Fig. 2). These base lines are flown twice in opposite directions and, when plotted, the magnetic values will diverge slightly on the end where the flight is started and finished. The amount of divergence is the diurnal variation and drift for the total time of the forward and reverse flight. One line of the pair is chosen as a base line, and the diurnal variation and drift correction are applied to this line linearly in an amount proportionate to the time required to fly the line. This combined correction is accomplished by tilting the datum line of the profile, and values scaled from the corrected datum are considered true values.

The base lines then control the position of the datum for the traverses where they intersect the base-line profiles. Contours may be obtained by drawing lines parallel to the datum line with the isogam interval chosen and projecting the isogam intersections down to the line of ground points. These isogam points are then transferred to the base map, again using check points, and the isogams are drawn by connecting points of equal magnetic intensity.

Under ideal conditions, when vertical photographs and good topographic maps are available, the flight path of the plane can be plotted within 50 feet. The sensitivity of the magnetometer is such that in areas of low magnetic gradients total intensity variations as small as two gammas may be scaled; however, magnetic precision is probably best illustrated by closure errors. Base lines are usually flown to form a reference net. Closure on a 200-mile closed traverse is usually from one to ten gammas. In most work contour intervals of ten gammas may be used with the assurance that at any point the map is correct within the contour interval.

Aeromagnetic maps have yielded valuable information about subsurface geology in petroleum and mining areas. In the Project Volcano, sponsored by the Office of Naval Research and conducted by the U. S. Geological Survey in cooperation with the Naval Ordnance Laboratory, aeromagnetic studies were made of volcanoes, atolls, and a submarine deep. In Antarctica the airborne magnetometer was used to differentiate islands of igneous and sedimentary rocks which were covered with ice. A magnetic profile or map is useful in almost any geological exploration problem where anomalies can be shown to exist, because anomalies represent variations in underlying rocks.

The advent of the airborne magnetometer has opened up vast areas for geophysical exploration which were previously unexplored because of the tremendous expense and difficulty in making ground measurements over inaccessible terrain. The greatest use of this instrument should be for reconnaissance of areas which may be measured in terms of thousands of square miles.