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GEOPHYSICAL DATA ON THE CLIMAX STOCK, NEVADA TEST SITE, NYE COUNTY, NEVADA

By John W. Allingham and Isidore Zietz

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June 1961

Report TEI-794

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By

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ABSTRACT

A granitic stock at Oak Spring, Nevada, was selected in 1960 as a possible site by the Atomic Energy Commission to study the seismic effect of a deep nuclear shot contained in a large volume of rock. Geophysical surveys were conducted to determine the general configuration of the stock, particularly the thickness.

The stock intrudes a sequence of carbonate and siliceous sedimentary rocks of Paleozoic age, which, in turn, are overlain by Tertiary pyroclastic rocks consisting of tuff, welded tuff, and breccia.

A three-dimensional analysis of a detailed aeromagnetic survey indicates that the stock has a shape similar to a truncated cone, the diameter of which increases from about 1 mile at the surface to at least 6 miles near sea level. The stock therefore is much larger than indicated by the area of 1-1/3 square miles exposed at the surface. In addition, computations show that the intrusion has a thickness of at least 15,000 feet.

Much of the ambiguity of interpretation was removed from the analysis because susceptibility measurements of cores from recent drilling and remanent magnetization data from surface samples were available.

Interpretation of a gravity profile over the stock does not delineate the intrusive from the host rock. It does, however, give the thickness of the overlying alluvial fill.

GEOPHYSICAL DATA ON THE CLIMAX STOCK
NEVADA TEST SITE, NYE COUNTY, NEVADA

By John W. Allingham and Isidore Zietz

INTRODUCTION

As part of a program for detecting underground explosions, a small composite stock at Oak Spring, Nev., known as the Climax granite (fig. 1), was selected in 1960 as a possible site by the Atomic Energy Commission to study the seismic effect of a deep nuclear explosion contained in a large volume of unfractured rock. From their geologic studies Houser and Poole (1959, p. 21) postulated that the stock was a non-floored discordant intrusion. The subsurface configuration of the stock was investigated by geophysical means to assure the presence of a body of sufficient size to confine a nuclear explosion. This investigation was made on behalf of the Albuquerque Operations office, U. S. Atomic Energy Commission.

Cylindrical models were used in a three-dimensional analysis of the aeromagnetic anomaly associated with the stock. The analysis lacks much of the usual ambiguity of the magnetic method because of a reduction in the number of variables used in computing profiles, particularly the magnetic susceptibility. Interpretation of the geophysical data shows the general configuration of the stock to be similar to a truncated cone having a diameter increasing with depth to about 6 miles near sea level. The stock, exposed at an altitude of about 5,000 feet, has an inferred thickness of 15,000 feet. Interpretation of a gravity profile gives the thickness of the alluvium over the stock but does not delineate the intrusion from

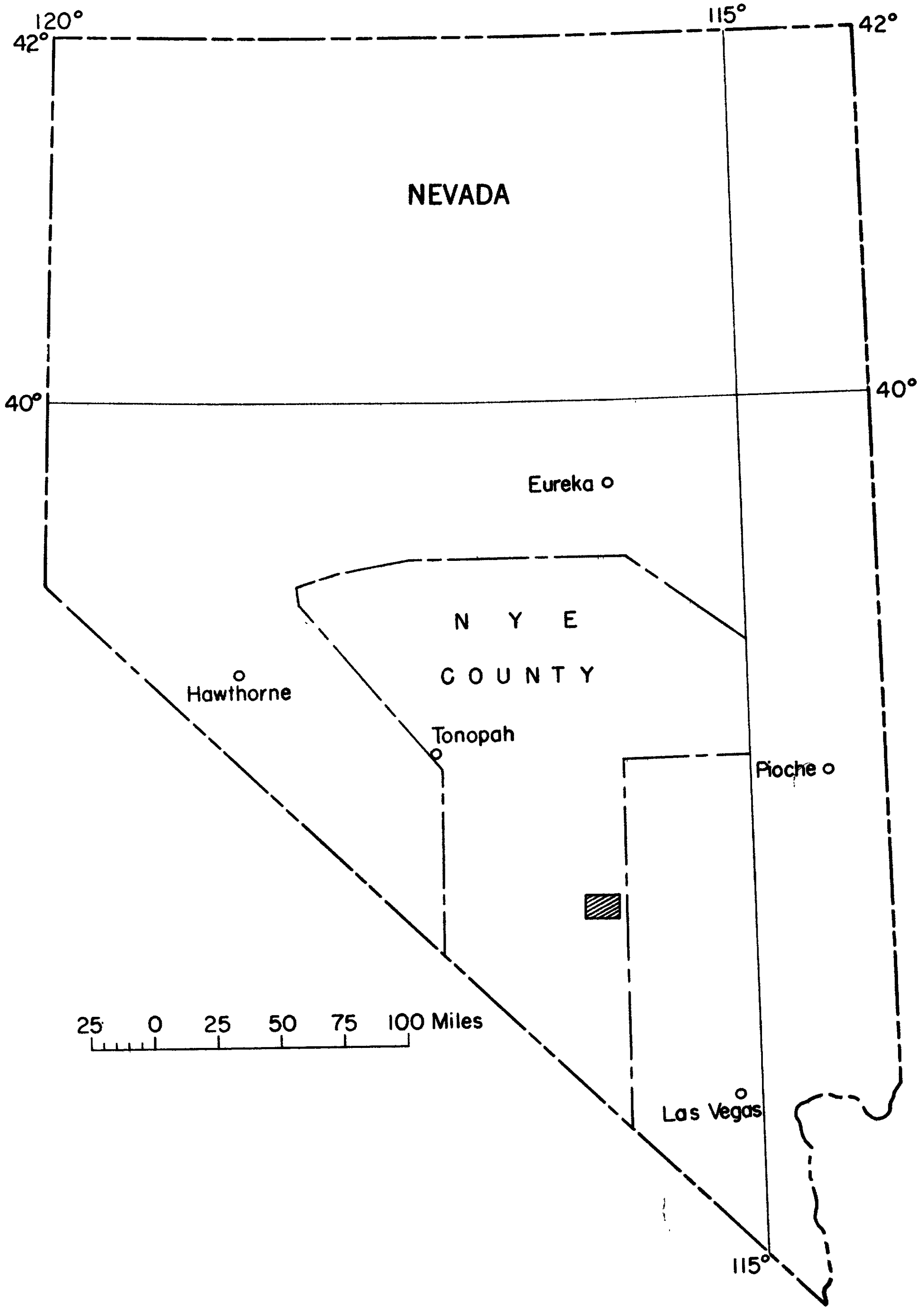

Figure 1. Index map showing the area of aeromagnetic survey of the Climax intrusion, Oak Spring Butte, Nye County, Nevada.

the Paleozoic host rock.

GEOLOGIC SETTING

The stock crops out over an area of 1-1/3 square miles at Oak Spring, near the northern end of Yucca Flat between 4900 and 6100 feet altitude, and intrudes a sequence of carbonate and siliceous rocks of Paleozoic age, mainly limestone, dolomite, quartzite, and shale (fig. 2). This sedimentary sequence is overlain by Tertiary pyroclastic rocks of the Oak Spring Formation, consisting of tuff, welded tuff, and breccia (Houser and Poole, 1960, pl. 1). At the contact of the intrusion, carbonate rocks are metamorphosed to marble and to a complex silicate mineral assemblage called tactite. The stream beds and valley floor are covered by unconsolidated alluvial deposits of gravel, sand, silt, and clay, which form the southeastern margin of the stock.

The major phases of the intrusion are granodiorite and quartz monzonite, which locally contain altered zones. Samples from the upper part of borehole U-15A (fig. 2) are quartz monzonite, whereas those from the lower part are predominantly granodiorite. Part of the contact between these two rocks dips steeply southward from the borehole. The southeast margin of the stock is bounded by a normal fault believed by Johnson and Hibbard (1957, p. 375) to have a displacement of 1200 feet.

VARIABLES IN COMPUTATIONS

Although the rocks of the intrusion range in composition from quartz monzonite to granodiorite, the magnetite content does not vary significantly (Izett, 1960, p. 18). The average susceptibility of samples from borehole

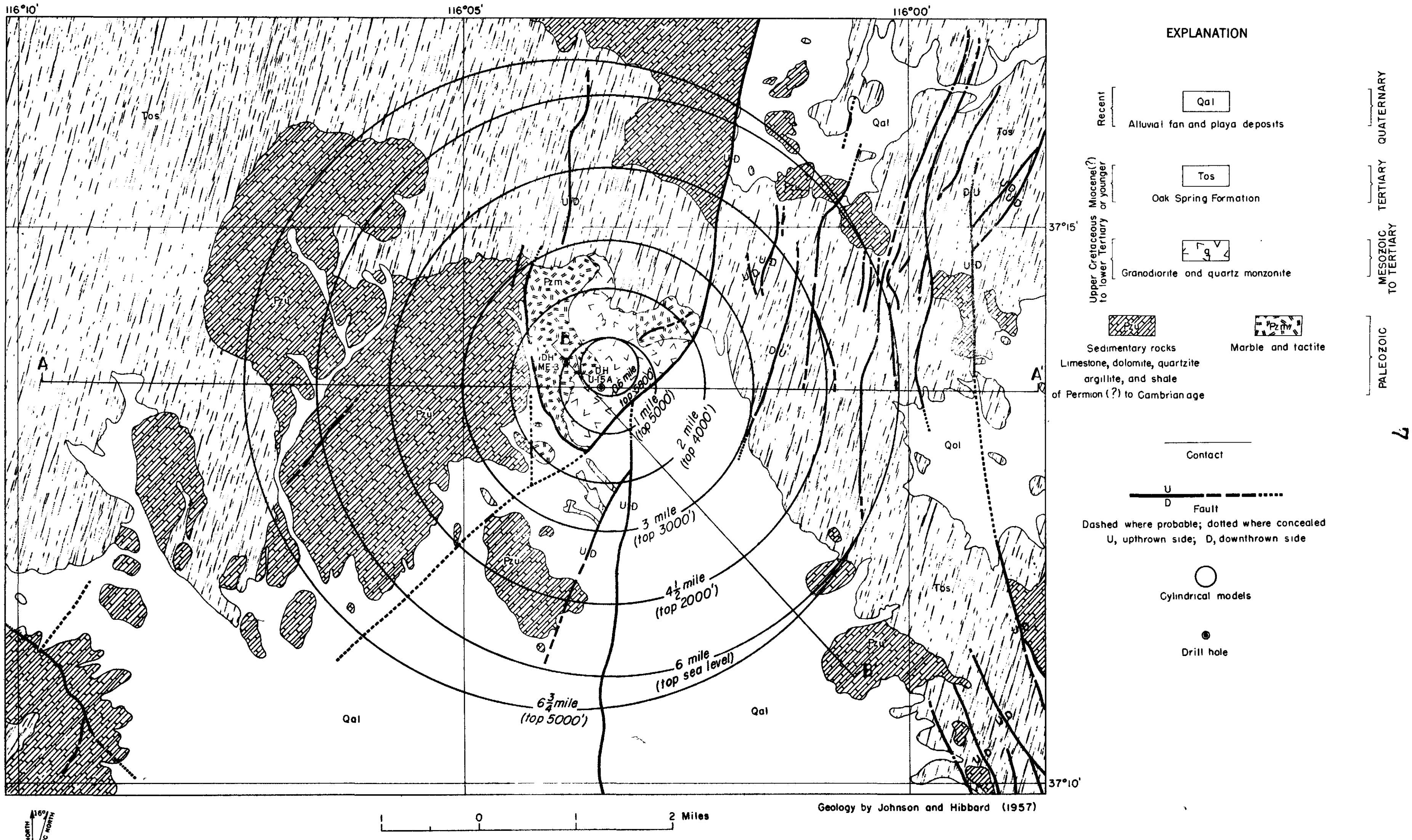

Figure 2. Geology of the Oak Spring Butte area and outline of cylinders used in computations

U-15A (fig. 3) is about 1.46 x 10^{-3} cgs units (0.8 percent magnetite by weight) for the upper 400 feet of rock and is 2.94 x 10^{-3} units (1.4 percent magnetite by weight) for the lower 800 feet. The difference in susceptibility is due to both near-surface alteration of the quartz monzonite and to a greater amount of magnetite in the granodiorite. The magnetic susceptibility of the granodiorite is uniform to the bottom of the bore hole and was extrapolated below this point for the purpose of computing the magnetic profile A-A' (fig. 4) from cylindrical models. Measurement of remanent magnetization of surface samples of quartz monzonite and granodiorite indicates that the magnetization is less than one-eighth of the induced magnetization (table 1), and that the direction of the remanent moment is random as shown in figure 5. The remanent magnetization of the stock can therefore be neglected in the magnetic interpretation.

The analysis approaches a unique solution. The distance from the magnetic detector to the outcrop or upper surface of the intrusion is known. A second variable, the contribution of the induced and remanent magnetizations, is known from laboratory measurements of the magnetic properties of the intrusive rocks obtained from surface samples (Doell, written communication, 1961) and drill core (Izett, 1960). Knowledge of these variables permits a significant limit to be placed on the depth and lateral extent of this three-dimensional feature; therefore, the size and shape of the intrusion are defined by the aeromagnetic data.

THE AEROMAGNETIC MAP

The total-intensity aeromagnetic map (fig. 4) covers about 94 square miles and was made in 1960 by the U. S. Geological Survey using a continuously recording fluxgate magnetometer installed in a twin-engine

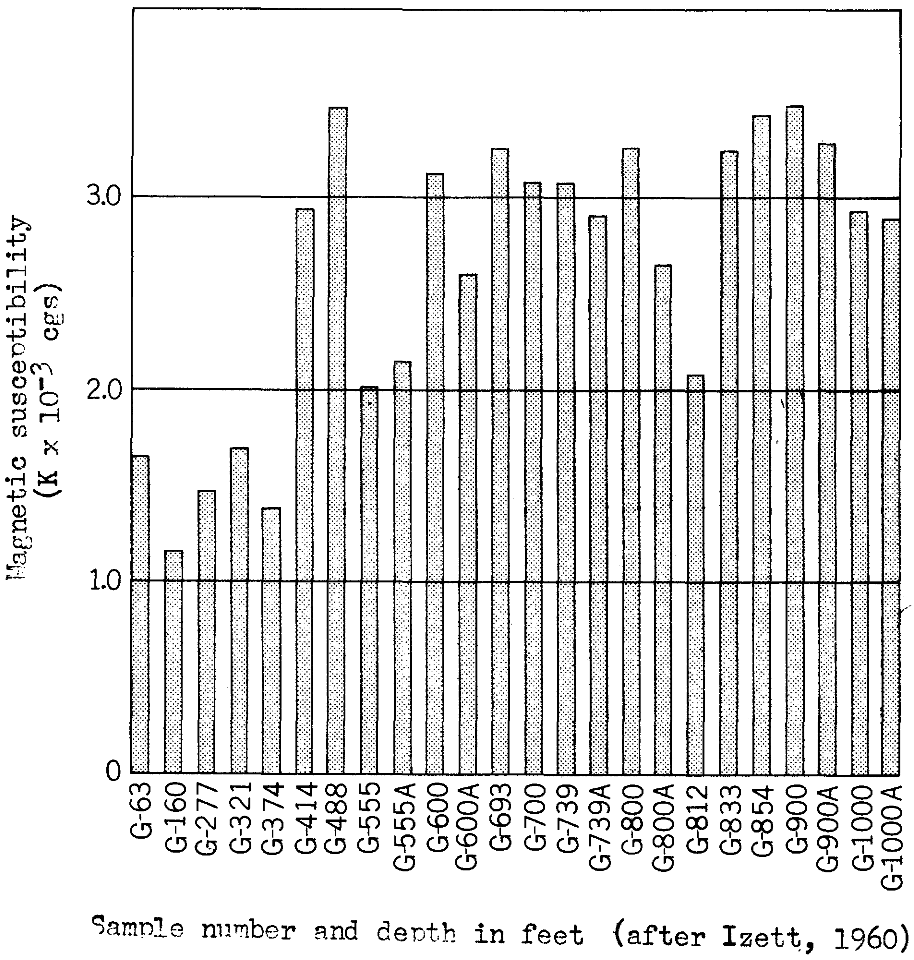

Figure 3. Magnetic susceptibility of samples from borehole U-15A

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GEOPHYSICAL INVESTIGATIONS
PRELIMINARY MAP

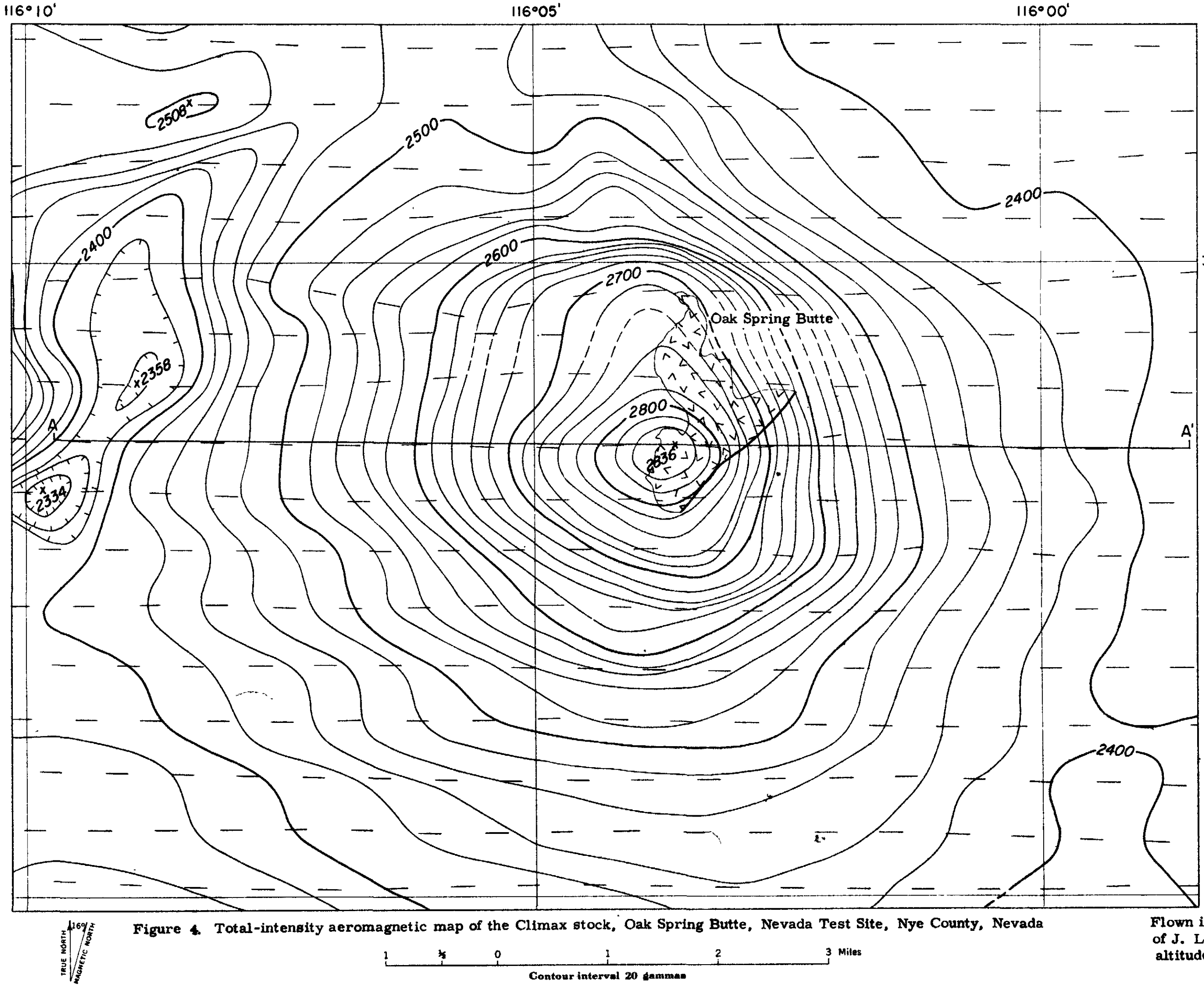
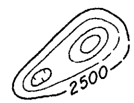


Figure 4. Total-intensity aeromagnetic map of the Climax stock, Oak Spring Butte, Nevada Test Site, Nye County, Nevada

EXPLANATION



Magnetic contours show total intensity magnetic field of the earth in gammas relative to arbitrary datum, hachured to indicate closed areas of lower magnetic intensity; dashed where data are incomplete

x 2836
Measured maximum or minimum intensity within closed high or closed low

Flight Path
shows location and spacing of data

Climax stock
Granodiorite and quartz monzonite

Flown in 1960 under the direction of J. L. Meuschke at a barometric altitude of 8000 feet.

Table 1. Remanent magnetization of samples from the Climax stock, measured by R. R. Doell, 1961.

Number	Intensity of magnetization	Inclination[1/]	Declination
	x 10^5		
1M-1	9.0	-64	322
1M-2	8.1	-70	86
1M-3	6.4	+ 4	126
1M-4	11.5	+74	139
1M-5	11.1	+16	54
1M-6	7.5	+16	98
1M-7	9.6	+12	191
1M-8	13.1	+38	40
1M-9	7.2	- 3	355
1M-10	8.8	-46	259
1M-11	7.4	- 3	303

1/ Positive where the north-seeking pole is downward and negative where the south-seeking pole is downward.

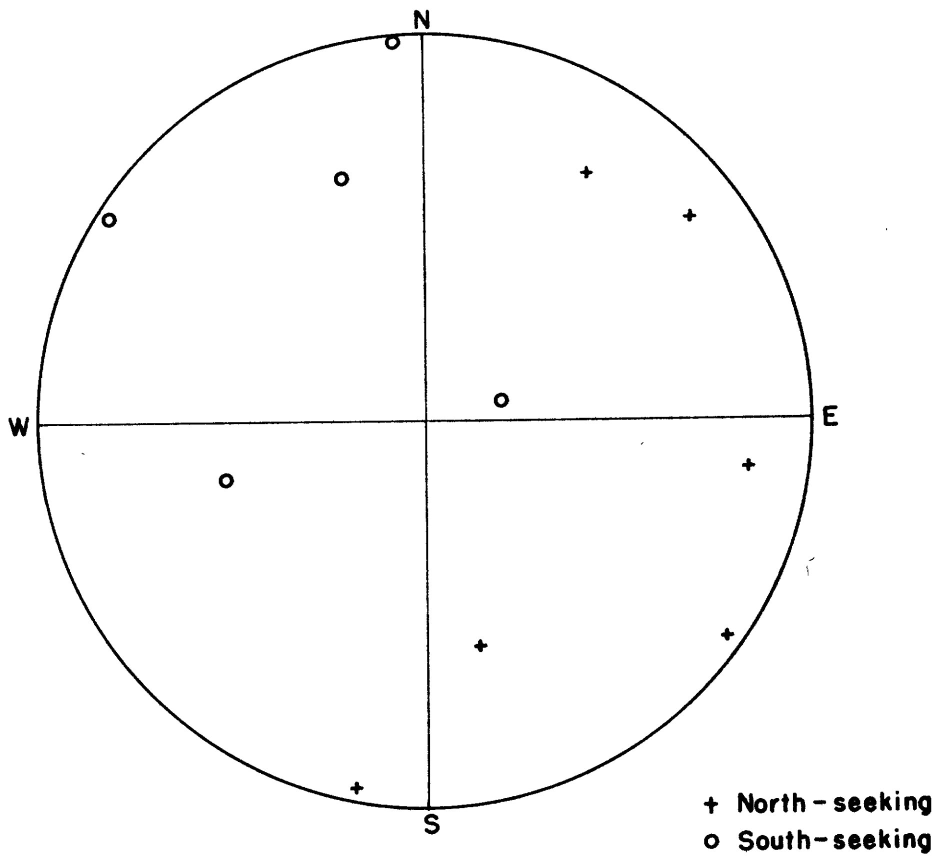


Figure 5. Remanent moment of rock samples from the Climax stock plotted on an equal area projection.

aircraft. The survey was flown with 1/2 mile spacing between flight lines and at a constant barometric altitude of 8,000 feet.

The nonmagnetic character of the sedimentary and pyroclastic rocks in the vicinity of the Climax stock are indicated by the flat magnetic field associated with them. The relative smoothness of the magnetic gradient further shows a lack of significant concentrations of magnetite in the tactite at the margin of the stock. Asymmetry in the observed profile (fig. 6) indicates that the walls of the stock are steeper on the east than on the west side. The effects of magnetic volcanic flows have altered the extreme western part of the anomaly, but for the purpose of this analysis, their effects can be ignored.

INTERPRETATION OF THE ANOMALY

Interpretation of the Climax stock is based on approximating its shape by a stack of cylinders having an areal extent as shown in figure 6. Magnetic total-intensity profiles in an east-west direction (A-A' figs. 4 and 6) were computed by use of polar charts for three-dimensional bodies (Henderson, 1960). Numerical integration of the cylindrical models was done by T. W. Case, D. S. Yanick, and R. H. Scantlebury of the Geological Survey. A model composed of superimposed discs was chosen to simulate the shape of the intrusion because of the circular symmetry of the observed magnetic anomaly (fig. 4). The net contributions of the discs were summed to give the computed total-intensity magnetic anomaly. The model giving the best fit between the computed and observed profiles is assumed to approximate the shape of the intrusive body.

As a first approximation, the minimum size of the stock was estimated by computing the fields of separate cylinders of infinite depth extent and

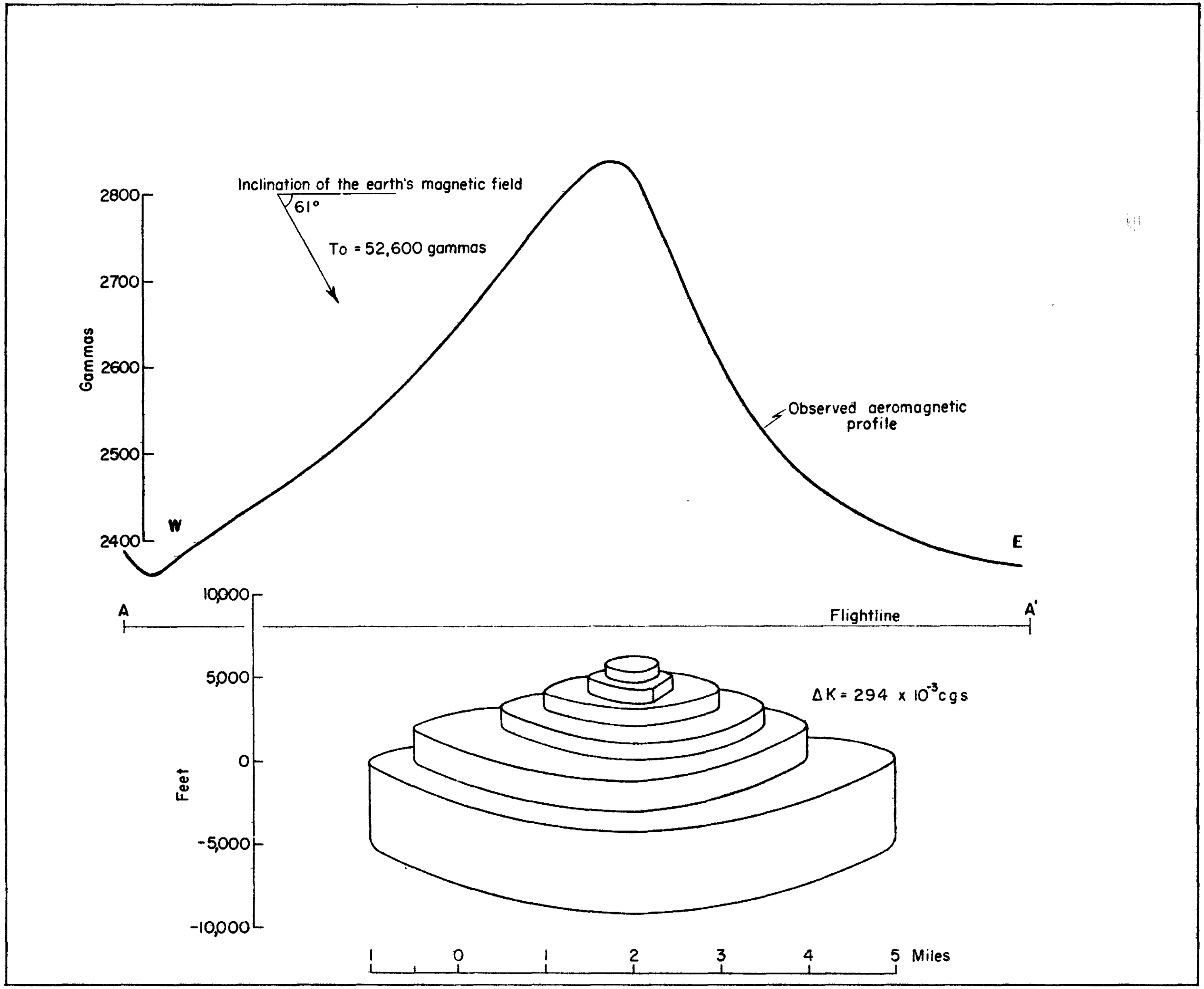


Figure 6. The total-intensity aeromagnetic profile over the preliminary model used to approximate the shape of the Climax stock

varying the diameters to 6 miles (figs. 7 and 8). The distance between the points of inflection on the profile (minimum curvature) also indicates the diameter of a body of infinite extent in depth. The lateral extent of the total-intensity aeromagnetic anomaly (fig. 4) shows that the subsurface size of the stock is much greater than the areal extent of the outcrop. A vertical cylinder of infinite depth extent having a cross-sectional area equal to that of the outcrop produced an anomaly (fig. 7) of only 160 gammas. A cylinder greater than 3 but less than 4 miles in diameter resulted in the best fit between computed and observed profiles (fig. 8). In estimating the depth extent of the stock, two assumptions regarding susceptibility contrast at the bottom of the model are postulated. First the susceptibility contrast between the granitic body and the basement is assumed to be negligible, that is, the roots of the intrusion and the crustal complex are magnetically indistinguishable. Secondly, if the susceptibility contrast is not negligible, the susceptibility of the substratum must be uniform over a large area, so that the induced field due to the substratum does not contribute to the magnetic field over the intursion.

The first estimated distance to the bottom of the stock and its shape was obtained by using a model of discs to approximate the postulated conical shape of the stock. According to Diment (oral communication, 1960) regional gravity information indicated basement at about 2,500 feet in the valley southeast of the stock; therefore, discs of increasing diameter were stacked from 5,800 feet to 2,500 feet and thence to 5,000 feet below mean sea level (fig. 9, curve 1). The computed field from this model accounted for four-fifths of the observed field. An additional disc 5,000 feet thick and 6 miles in diameter somewhat improved the fit to the observed field (curve 2). The poor fit of these curves indicates that the upper

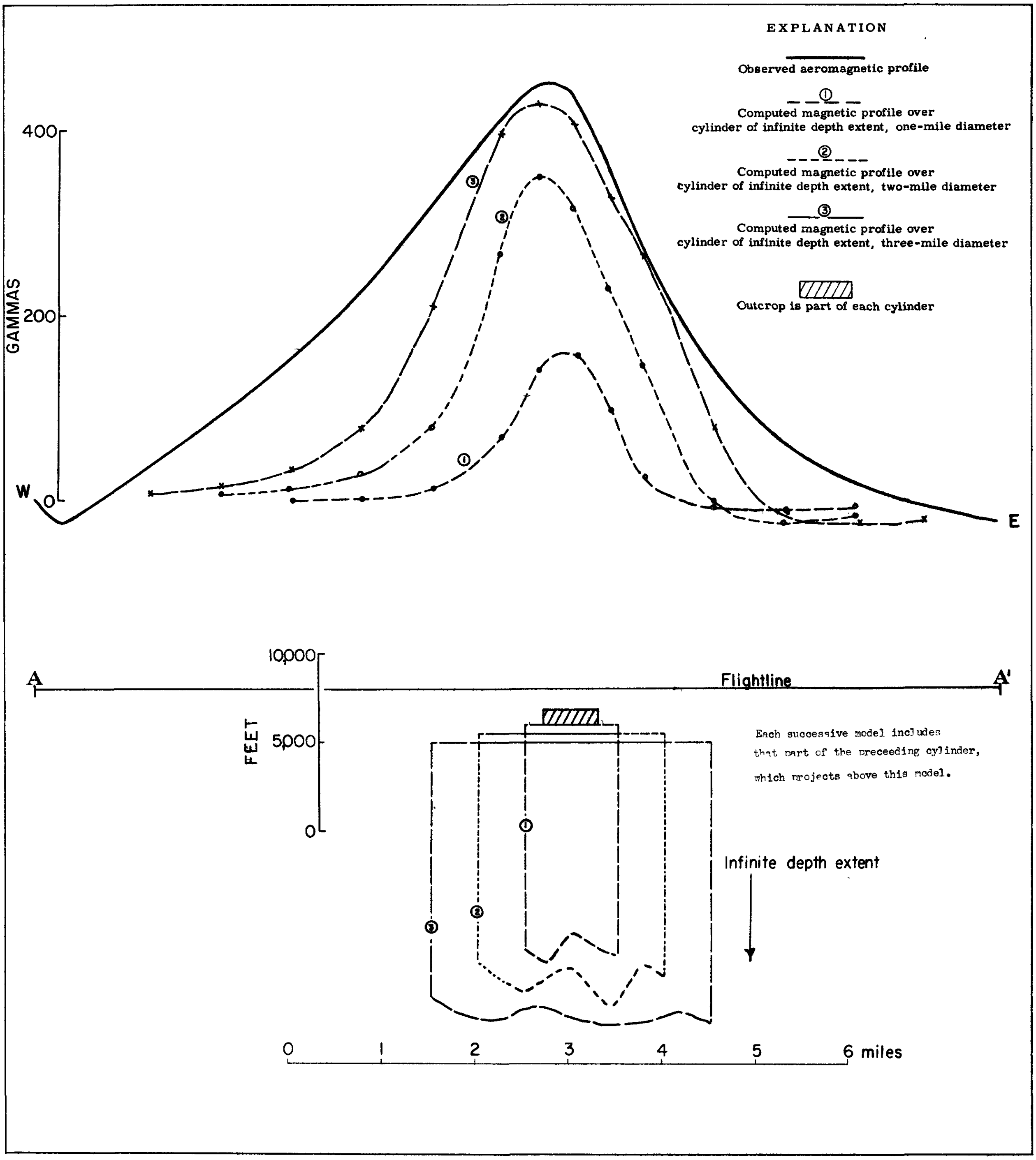


Figure 7 Computed magnetic profiles over cylinders of infinite depth extent

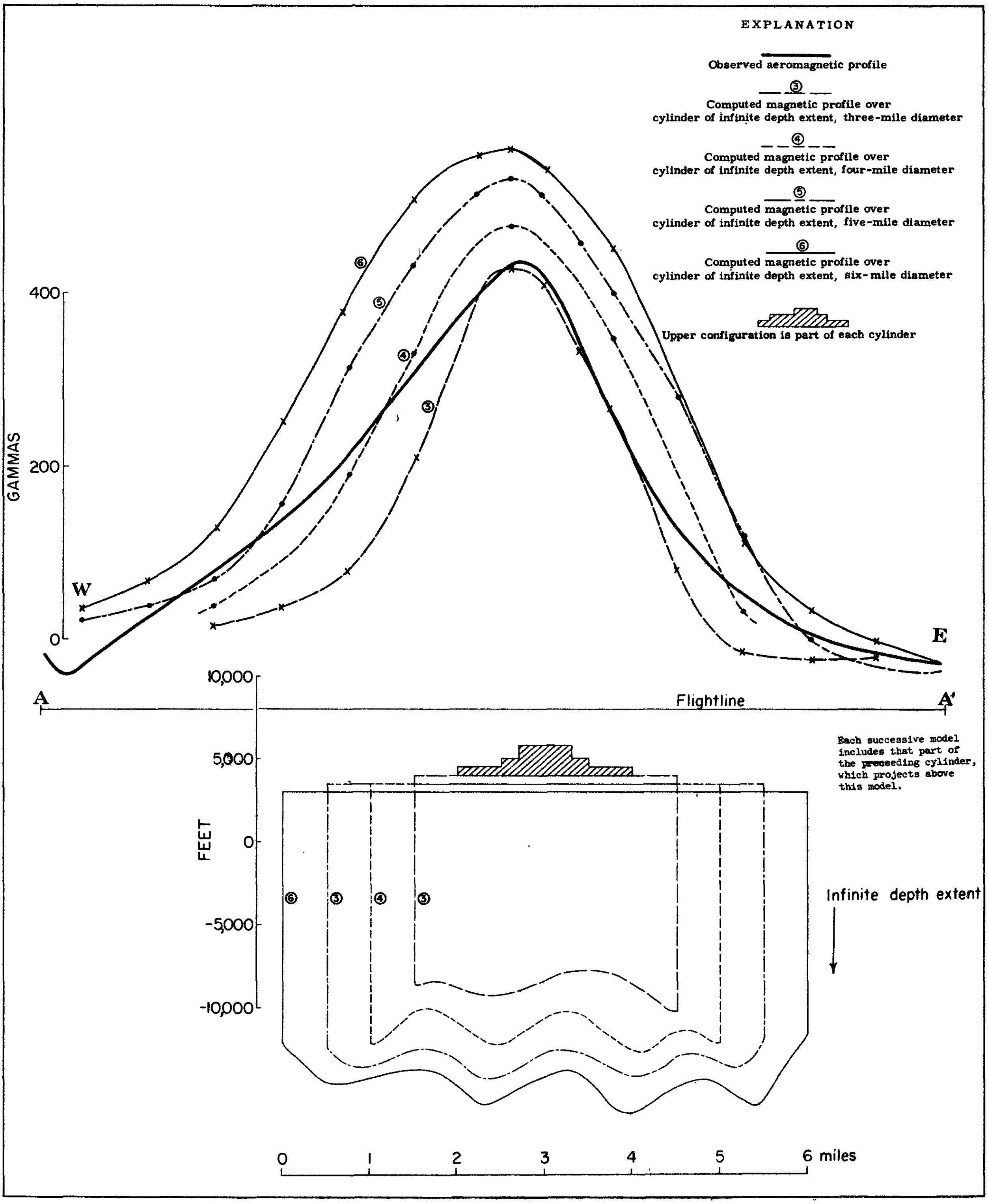


Figure 8 Computed magnetic profiles establishing the minimum diameter of the Climax stock

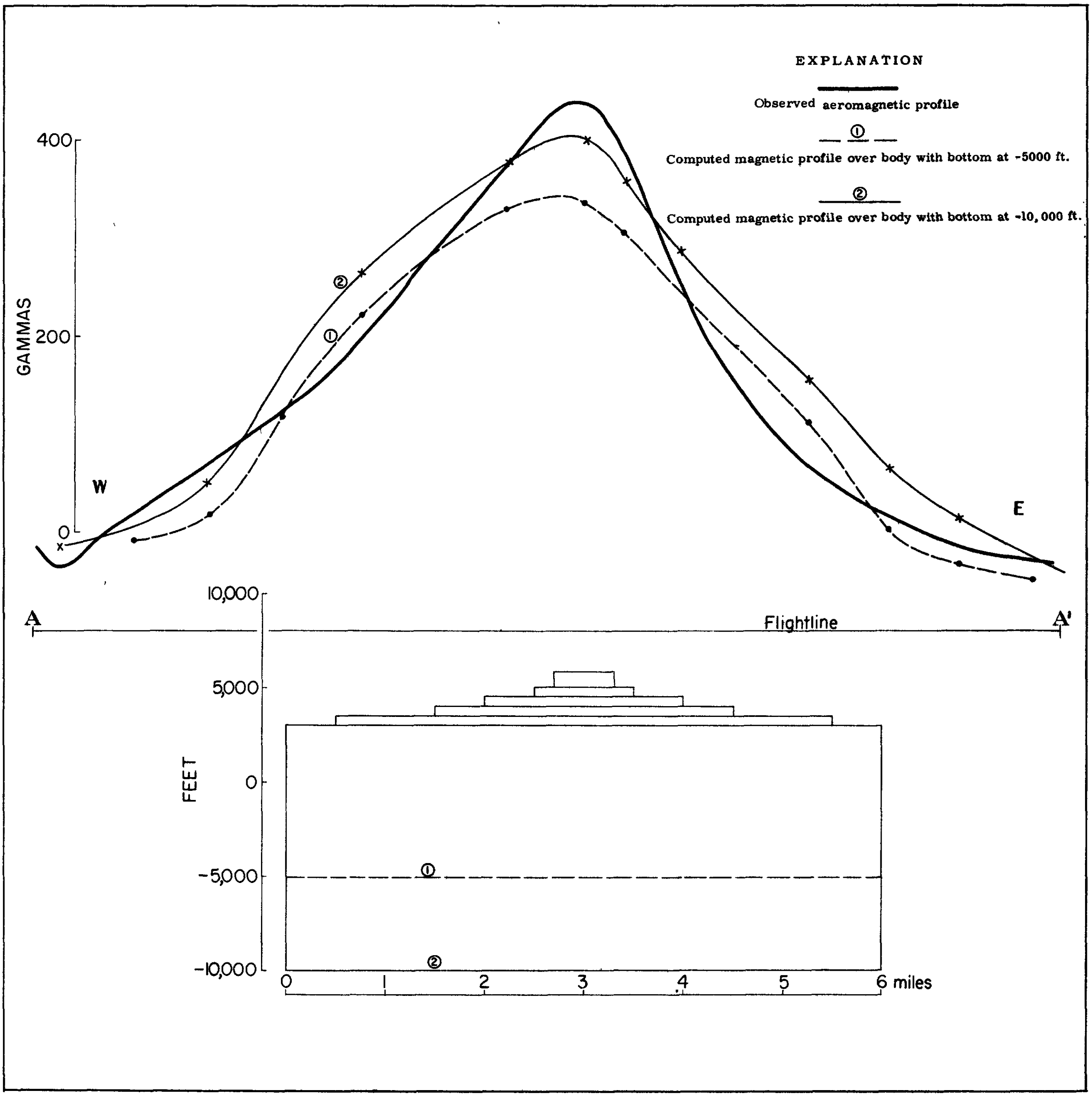


Figure 9 Computed profiles showing initial approximation of distance to bottom of intrusion

part of the intrusion is steeper than represented by this model. A model having a maximum total depth extent of about 15,000 feet and a maximum diameter of about 6 miles approximates the general size of the intrusion.

After the general limits were set, the shape of the model was modified by steepening the upper part, increasing thickness and decreasing diameter of each disc, and extending its bottom downward. A series of curves was computed showing the effect of depth extent (fig. 10). The model extending from the outcrop to an altitude of 10,000 feet below sea level produces most of the anomaly (curve 2) and defines the major part of the configuration of the intrusion. The broad, low-amplitude anomaly generated by a body extending from 10,000 feet below sea level to an infinite depth represents only a fraction of the observed anomaly. The body having infinite depth extent, for example, results in a total-intensity field of only slightly greater magnitude (curve 3) than the magnetic field over a body bottomed at 25,000 feet below sea level (curve 4).

INTERPRETATION OF THE GRAVITY DATA

A map of the regional gravity field presented by Diment and others (1960, p. B157) suggests a lack of density contrast between the granitic rock and carbonate rock. Two-dimensional interpretations of a detailed gravity profile (B-B' of fig. 2) by D. L. Healey, U. S. Geological Survey, across the southeastern border of the stock, where alluvium and tuff are faulted against the Climax intrusion (fig. 11), partly substantiates the aeromagnetic interpretation. A Bouguer anomaly of 12.5 milligals was obtained by standard reduction of gravity data from a survey having 1/2 to one-mile station spacing. Corrections for terrain were applied for a radial distance of nine miles and a regional gradient of one milligal per mile was

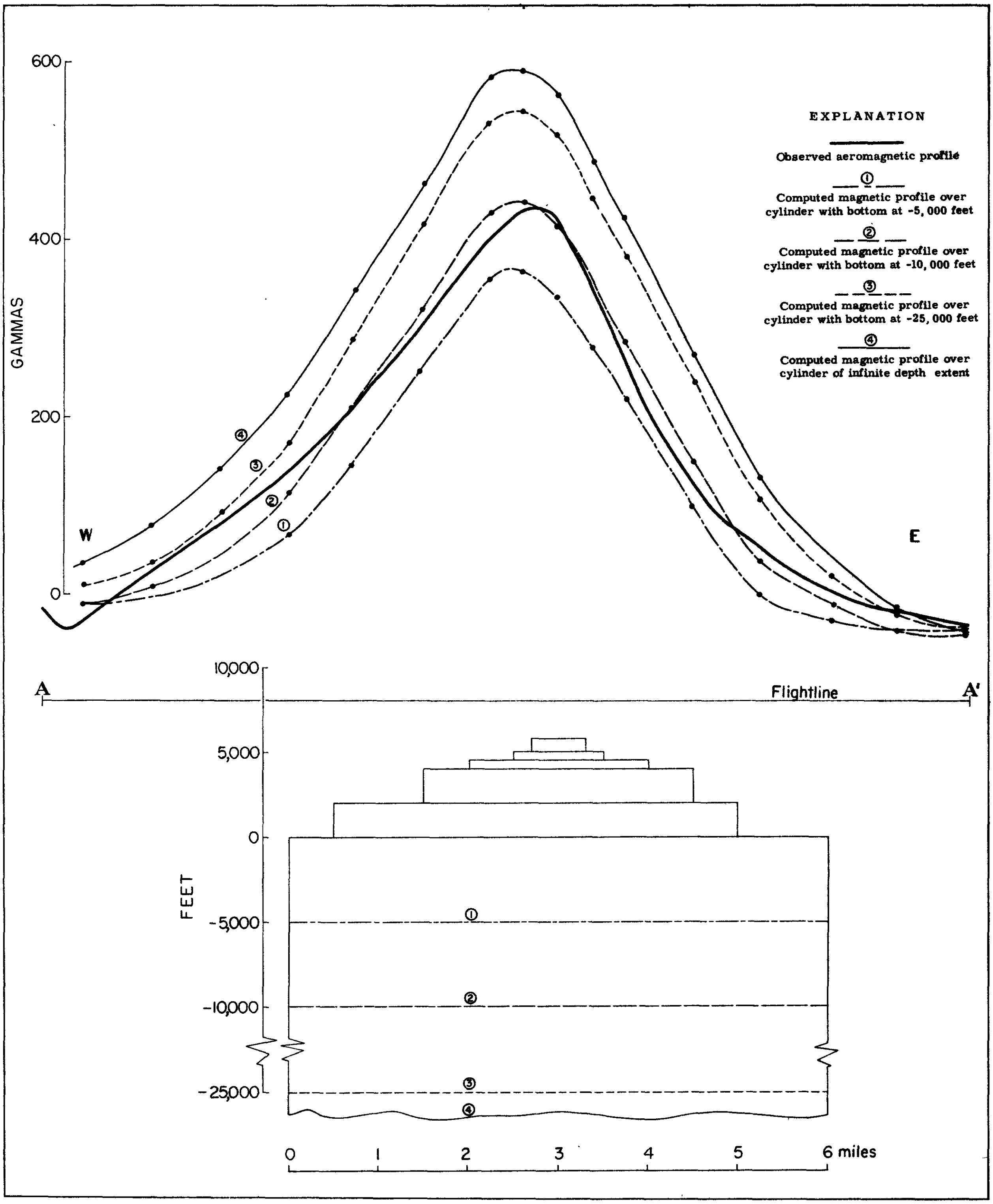
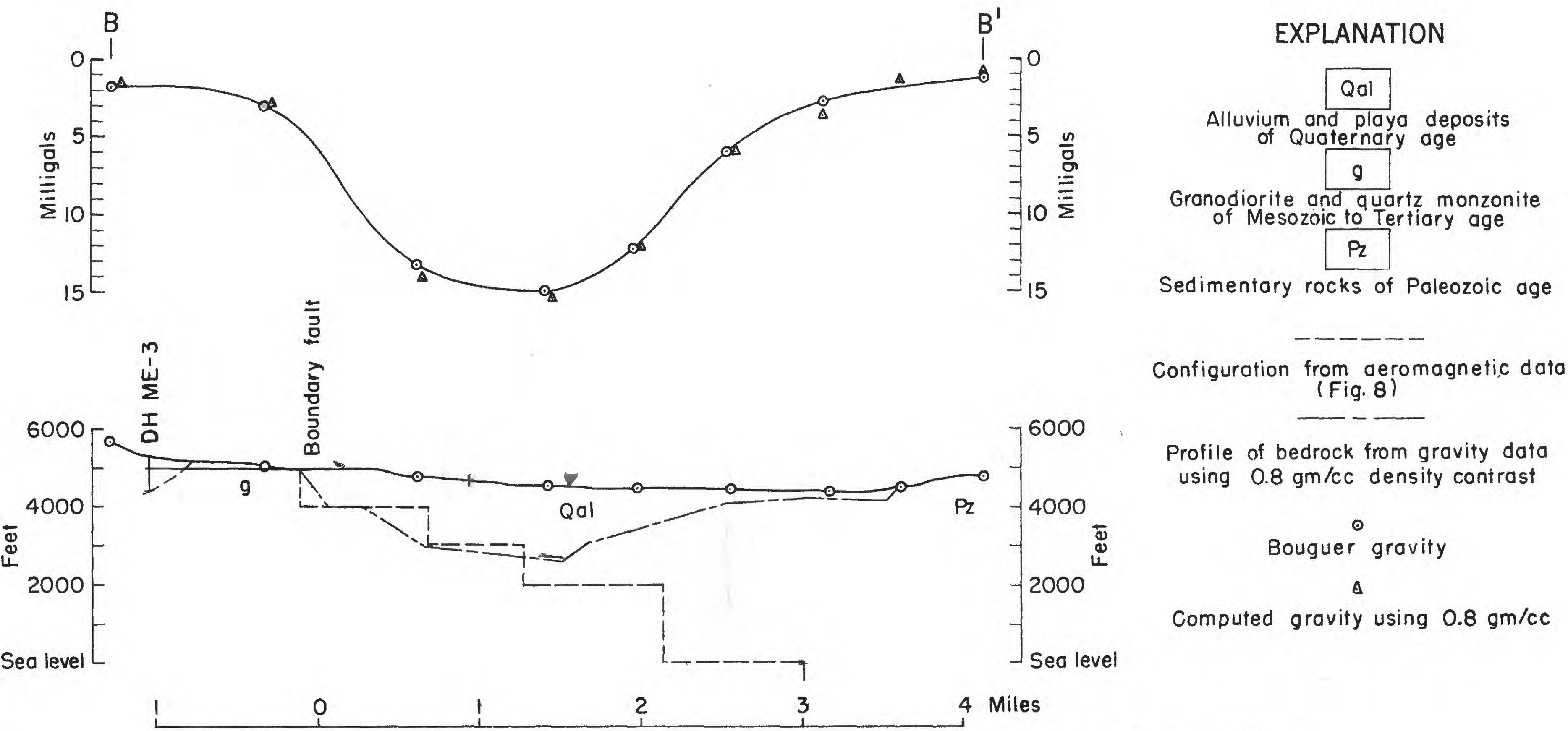


Figure 10 Computed magnetic profiles showing the influence of the depth extent of the stock



Gravity profiles by D. L. Healey, U. S. Geological Survey

Figure 11 Subsurface profiles of the Climax stock from gravity and magnetic data

removed before interpreting the profile. The tuff of the Oak Spring Formation and alluvium are combined in the gravity analysis, as their average density is about the same. A density contrast of about 0.8 g/cm^3, between tuff and granodiorite, was inferred from the weighted average density of the tuff of the Oak Spring Formation collected by Frank Byers, U. S. Geological Survey, in the vicinity of the boundary fault. The gravity minimum defines the near-surface configuration of the stock in an area where aeromagnetic data can only approximate its near-surface shape. More uniform density of intrusive rocks in contrast to less uniform magnetic properties favors a better gravity interpretation of the near-surface configuration. Drill hole ME-3 (fig. 2) which penetrated intrusive rock at 951 feet below its collar, shows further difficulty in approximating the near-surface intrusive boundary by aeromagnetic information. Magnetic data, however, define the gross subsurface configuration of the intrusion, width and depth extent, where gravity interpretation fails to distinguish between Paleozoic sedimentary rocks and intrusive rocks at depth. Curve fitting, that is, refining the shape by steepening the upper part and broadening the lower part of the magnetic model, improved the agreement between the configurations obtained from aeromagnetic and gravity information.

CONCLUSIONS

The best fit of a computed magnetic curve to the observed east-west profile across the igneous outcrop was obtained from a model having a total depth extent of about 15,000 feet (fig. 12). The upper part of the model was steepened and the lower part enlarged to a diameter of 6 3/4 miles. Interpretation of aeromagnetic information in the Oak Spring Butte area, Nev., not only gives the general size and shape of the Climax intrusive,

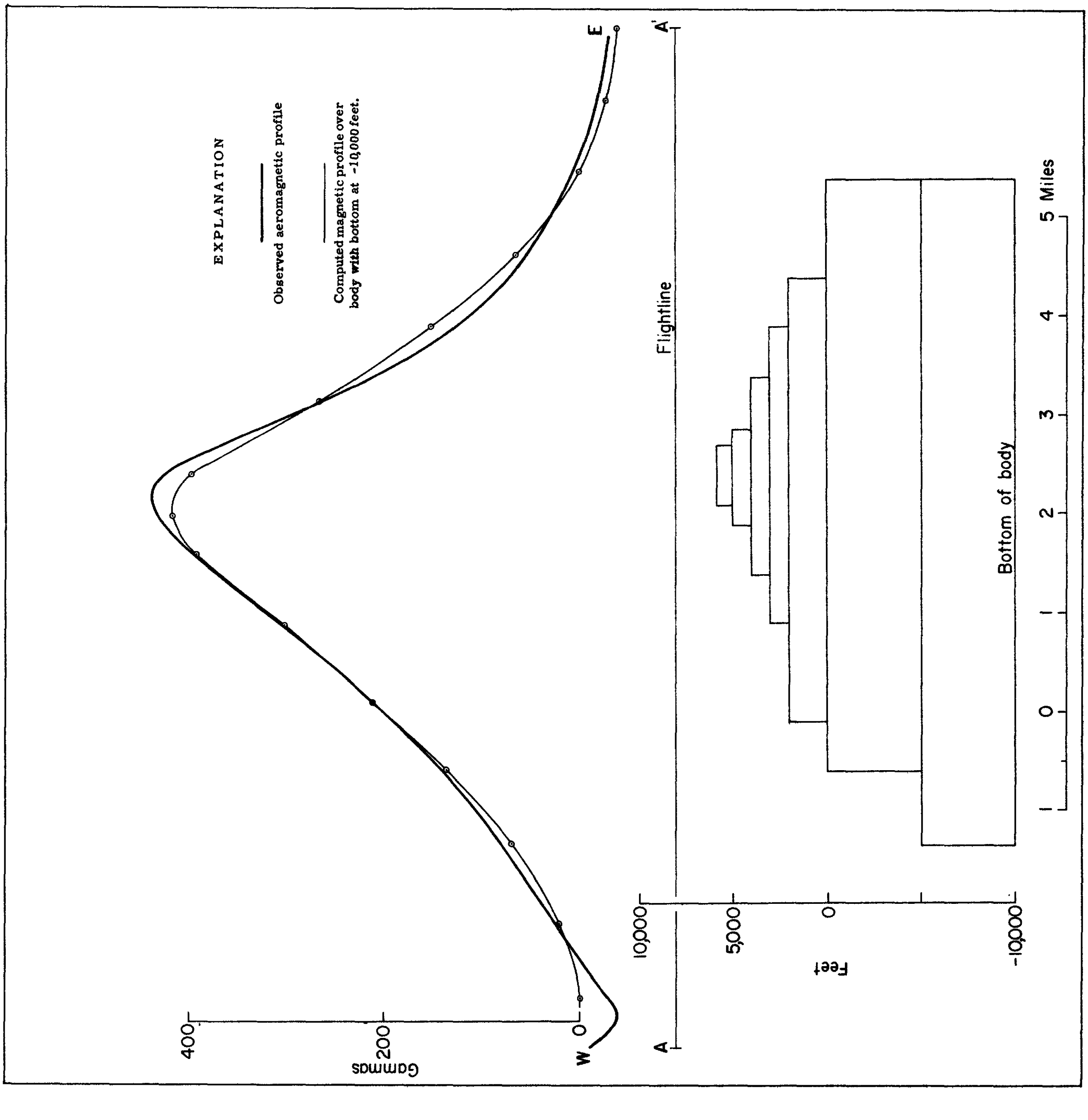


Figure 12 Final approximation of shape and depth extent of the Climax stock

particularly at depth, but also suggests a minimum depth extent for the intrusive of about 15,000 feet and a diameter that increases from about 1 mile at 5,000 feet above sea level to at least 6 miles near sea level.

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