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PRELIMINARY GEOPHYSICAL REPORT ON SELECTED GEOLOGIC TEST SITES

By

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The U. S. Geological Survey is releasing in open file the following reports. Copies are available for consultation in the Geological Survey libraries, 1033 GSA Bldg., Washington, D. C. 20242; Bldg. 25, Federal Center, Denver, Colo. 80225; 345 Middlefield Rd., Menlo Park, Calif. 94025; and in other offices as listed:

1. Preliminary geophysical report on selected geologic test sites, by R. D. Regan. 21 p., 14 figs. 601 E. Cedar Ave., Flagstaff, Ariz. 86001.

2. A survey of lunar geology, 10 January 1966 through 10 June 1966, by Jerald J. Cook. 71 p., 28 figs., 3 tables. 601 E. Cedar Ave., Flagstaff, Ariz. 86001.

3. Availability of palynological material from Naval Petroleum Reserve No. 4, II: Kaolak Test Well No. 1, by Richard A. Scott. 2 p.

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In a press release dated December 20, 1967, eight maps were placed in open file showing compilation of metallic mineral resources for certain quadrangles in Alaska. Authorship for the last-listed one (Seward and Blying Sound quadrangles) should be shown as "compiled by Edward H. Cobb and Donald H. Richter." Depositories for all eight maps should include: 678 U. S. Court House Bldg., West 920 Riverside Ave., Spokane, Wash. 99201; 504 Custom House, San Francisco, Calif. 94111; 7638 Federal Bldg., Los Angeles, Calif. 90012; and 1012 Federal Bldg., Denver, Colo. 80202.

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ON SELECTED GEOLOGIC TEST SITES

By R. D. Regan

ABSTRACT

Geophysical surveys conducted at Zuni Salt Lake, Hopi Buttes, and Meteor Crater show anomalies that are representative of the varied geologic history of these test areas.

INTRODUCTION

A part of the Branch of Astrogeology program has been to provide complete geophysical documentation of selected geologic test sites. The sites are of varied geologic complexity and are chosen as being representative of possible lunar geologic conditions. They were investigated geophysically in order that we might have a basis for comparison of mission test results and to obtain data on geophysical properties.

This report presents only a qualitative representation of results obtained at the three major test sites: Zuni Salt Lake, Hopi Buttes, and Meteor Crater.

METHODS AND INSTRUMENTATION

Magnetic, gravity, and seismic surveys were conducted in each area. This report presents mainly the results of the magnetic and gravity surveys and some preliminary seismic interpretations.

Magnetic

Two types of magnetic surveys were conducted.

Vertical field

A Sharpe Instruments model MF-100 fluxgate magnetometer was used to measure the vertical component of the field. It is a standard saturable core of fluxgate magnetometer with a readout directly in gammas (10^{-5} oersted, 10^{-5} lines of force per cm^2). One of the greatest problems with fluxgate probes is proper orientation; a change in probe orientation of 1° will result in a magnetic field error of 30 gammas. The Sharpe magnetometer with internal self-leveling requires only coarse leveling and is capable of an accuracy of 5 gammas. The instrument is hand-held, with a battery pack carried around the operator's waist.

All the survey points were occupied three times with this magnetometer, and all readings were taken with the operator facing north. All three instrument readings at a particular station were usually within 5-10 gammas of each other, and the mean was used in the data reduction.

Total field

A Varian rubidium vapor magnetometer was used to measure the total magnetic field. The instrument operates on the principle of optical pumping and monitoring. The sensor, which operates on an atomic process, contains no moving parts and is virtually drift-free. The standard instrument is equipped with a strip chart recorder and is stated to be an absolute instrument with an accuracy of 0.01 gamma. It was found to be unsatisfactory for field use; without the addition of a digital frequency meter and oscilloscope the absolute magnetic field could not be determined within an accuracy of 5 gammas.

The instrument was used with an oscilloscope, which monitored the sensor output in order to determine optimum orientation, and with a digital frequency meter to read out the Larmor frequency. The sensor produces a radio frequency signal (Larmor frequency) directly proportional to the total magnetic field intensity. The constant of proportionality for our rubidium vapor magnetometer is 4.667 cycles per gamma. The digital frequency meter was accurate to ± 1 cycle per second or ± 0.22 gamma. This accuracy is considered sufficient for field operation. The instrumental accuracy of 0.01 gamma could be achieved by monitoring the strip chart recorder with the digital frequency meter, but this would also necessitate the use of another oscilloscope to monitor crystal selection to determine whether or not the proper crystal was being used for heterodyning. The instrument itself will yield false readings on several crystals.

The electronics for the system employed in the field survey were housed in an equipment truck that provided ac power for the electronics by means of a solid-state inverter. The sensor was carried on top of a wooden pole 100 feet behind the instrument truck. All the survey points were occupied twice. The truck was always parked north of the instrument so that the same orientation was maintained throughout the survey.

In the field, a primary base station was established at each site and occupied every 90 minutes. Daily magnetograms recorded at our magnetic observatory enabled us to determine days of magnetic activity.

Gravity

A Worden master gravimeter with a scale constant of 0.088 milligals was used for the entire survey. The instrument is temperature controlled, and the temperature was maintained at 80° F.

The gravimeter was read three times at each station, and all survey stations were occupied twice with several random surveys conducted to pinpoint any possible reading errors. The base station was occupied every 90 minutes to correct for tidal effects and possible instrument drift. A primary base station was established at each site and tied to an absolute gravity base station.

TEST SITES

Zuni Salt Lake, N. Mex.

Zuni Salt Lake is a circular depression about 1 mile in diameter with a cinder cone in it. It is an isolated maarlike structure of volcanic origin. The surrounding rock consists of Cretaceous limestone and shale. Volcanic features, all basaltic in composition, consist of bedded rim deposits, dikes or flows, and cinder cones.

Survey.--A station spacing of 300 feet was used over the Zuni Salt Lake area. The location of stations relative to the crater rim is shown in figure 1. The stations were placed to sample the regional gradient and several anomalies that appeared during the course of our survey. The first two lines were east-west and north-south; they intersected near the cinder cone.

Gravity.--The greatest problem in gravity data reduction was the choice of density. The terrain correction had to compensate for nearby relief of dense sedimentary rocks and also of the nearby relatively less dense cinder cone. A density of 2.30 grams per cm^3 was used for our data reduction.

Figure 2 shows the Bouguer anomaly map that was made. A highly anomalous area near the cinder cone and several anomalies in the northern part of the crater are evident, as well as a fairly strong northwest-southeast gradient.

The large anomaly near the cinder cone can be attributed in part to an improper density choice for the cinder cone. The program for our data reduction only accepts one density as being representative of an area; it will have to be altered to compensate for this large low-density cinder cone. Even so, a large positive anomaly still exists. The size of the body that causes this anomaly can be roughly estimated. A sphere at a depth of 500 feet with a radius of 300 feet would yield an anomaly of this magnitude.

The anomalies in the northern part of the crater have not been studied.

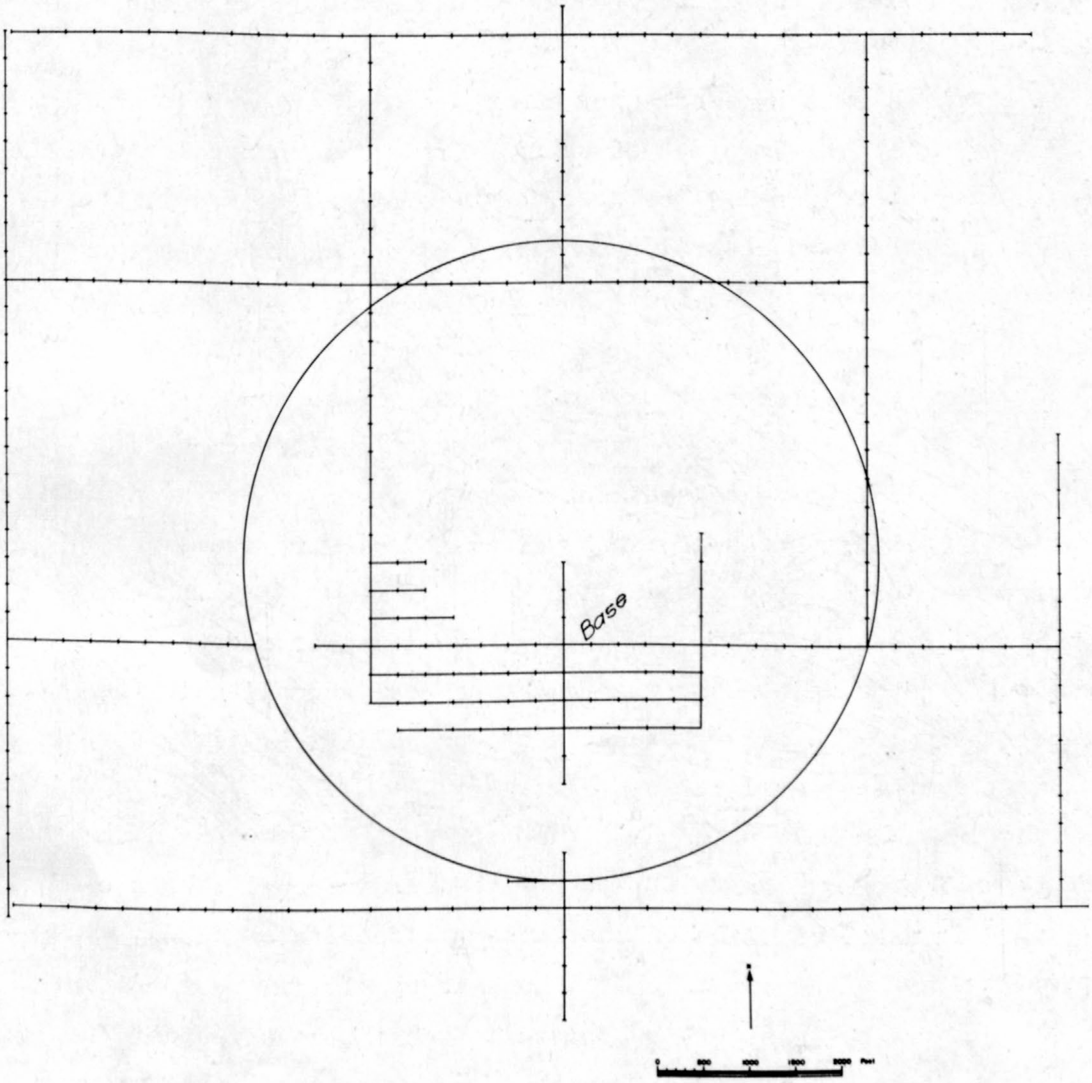

Figure 1.--Station locations at Zuni Salt Lake, N. Mex.

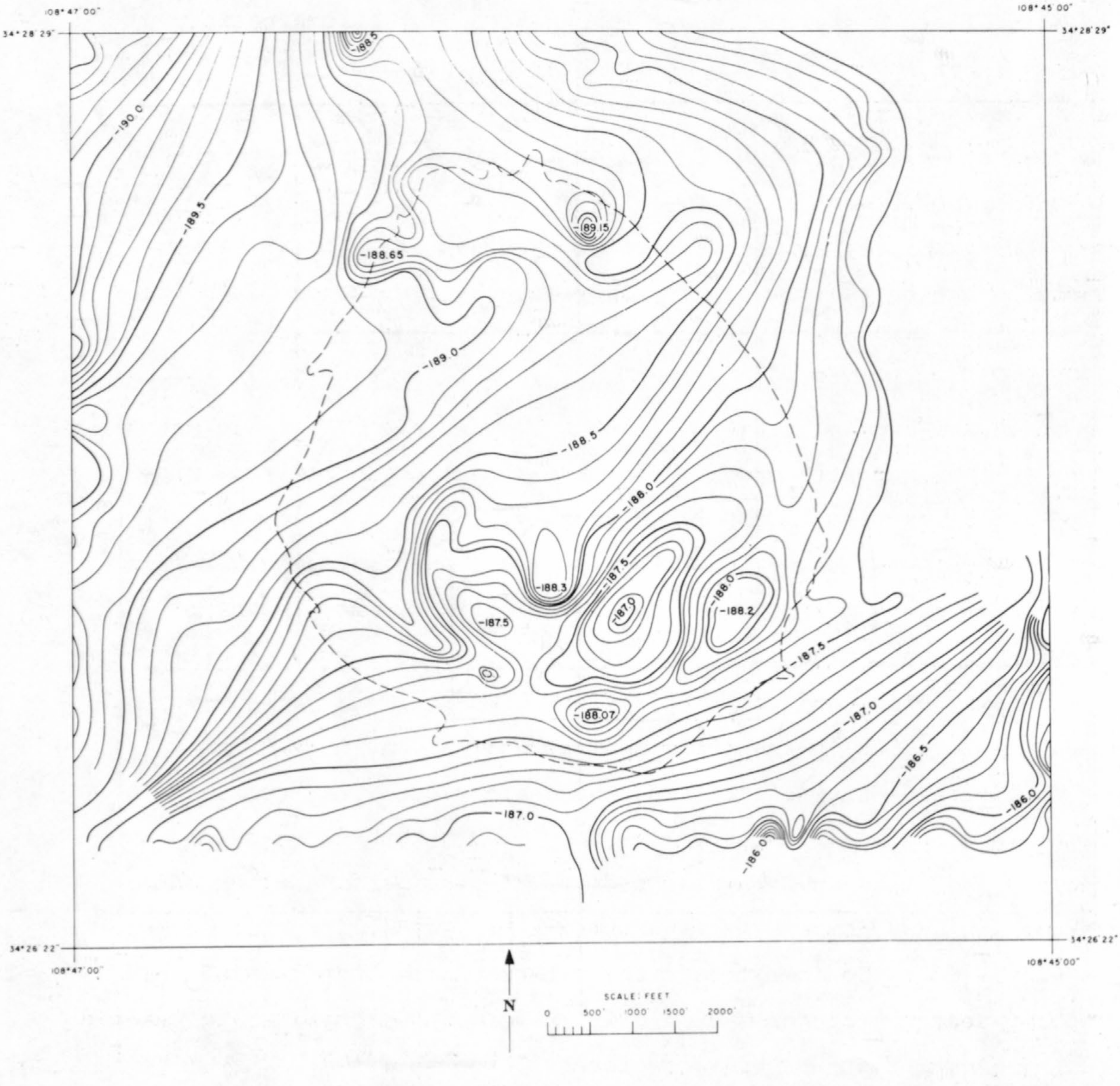

Figure 2.--Complete Bouguer anomaly map, Zuni Salt Lake, N. Mex. Contour interval 0.1 milligal. Crater outline dashed.

Magnetic.--A vertical intensity magnetic survey was conducted over the crater; figure 3 shows the results.

Much interpolation between points was necessary, and the map should only be considered as an estimate of the actual vertical magnetic field distribution over the crater. An aeromagnetic survey is planned to obtain a more complete picture.

The map shows a large magnetic anomaly near the cinder cone, several anomalies around the edge of the crater, and a strong northwest-southeast gradient.

The anomalies around the crater that appear as localized features are quite misleading. They are due to station location and the presence of a ring dike of variable magnetic intensity.

The magnetic investigations suggest that the crater is surrounded by an inward-dipping ring dike (not a flow as others had suggested).

A large magnetic body is also present at depth near the cinder cone and gives rise to the large anomaly.

An east-west magnetic profile is shown in figure 4. Readings were taken every 5 feet. The base station is just southeast of the cinder cone. The large anomaly near the cone shows up as a 7,000 gamma high, and the very intense erratic readings between E 2400 and E 3300 indicate a dike (probably a double dike).

Seismic.--Seismic data have not been reduced yet; however, lines shot in the vicinity of the intense gravity and magnetic anomaly indicated an irregular body of limited horizontal extent through which seismic P-waves propagate at >20,000 feet per second.

Drilling.--To investigate the nature of the body causing the anomaly near the cinder cone, a drill hole was sunk near where seismic data indicate that the body is closest to the surface. The drill penetrated cinders to a depth of 254 feet, then entered a very dense magnetic body. Laboratory measurements are now being conducted on the drill core.

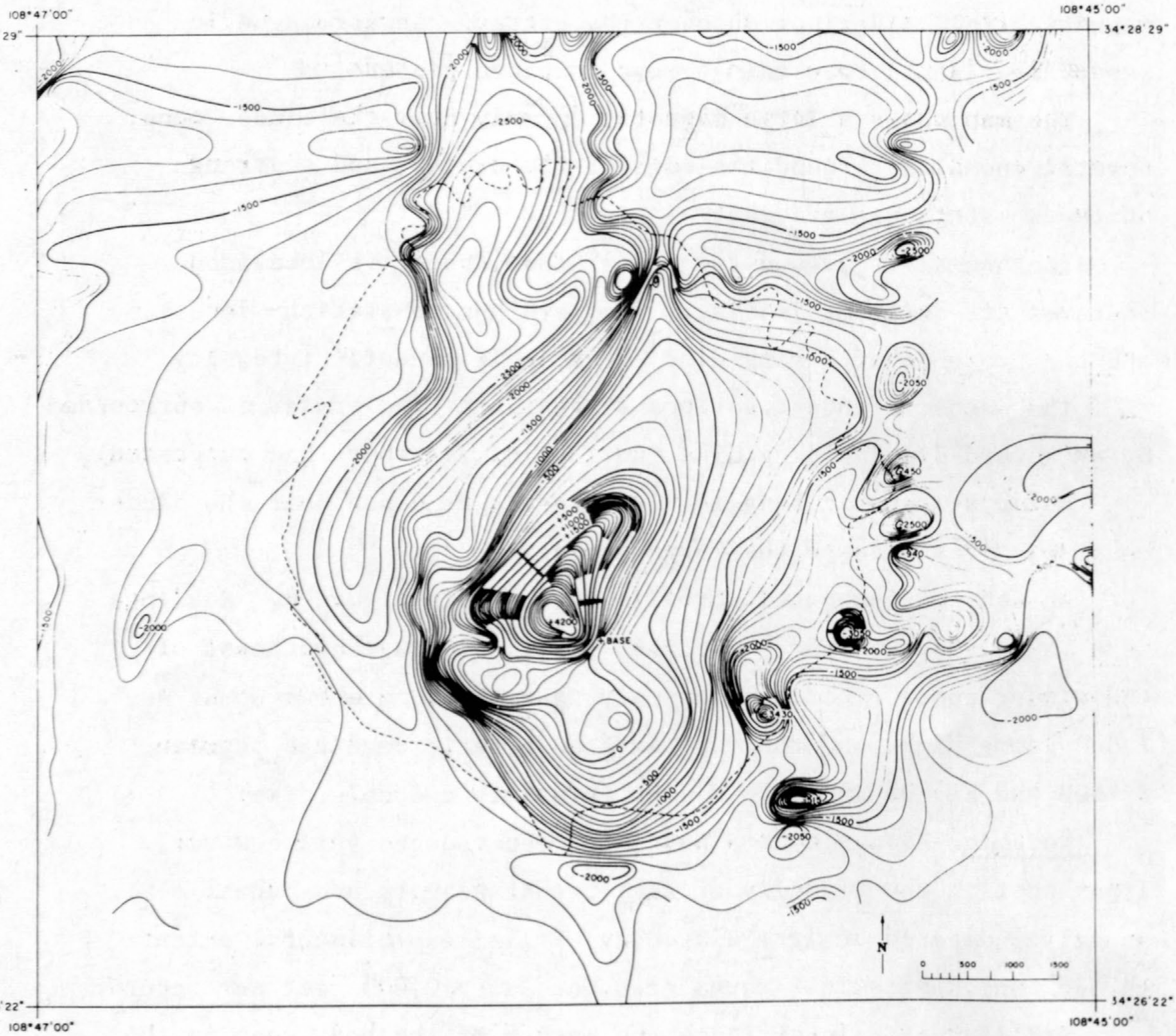

Figure 3.--Vertical magnetic intensity relative to base, Zuni Salt Lake, N. Mex. Contour interval 100 gammas. Crater outline dashed.

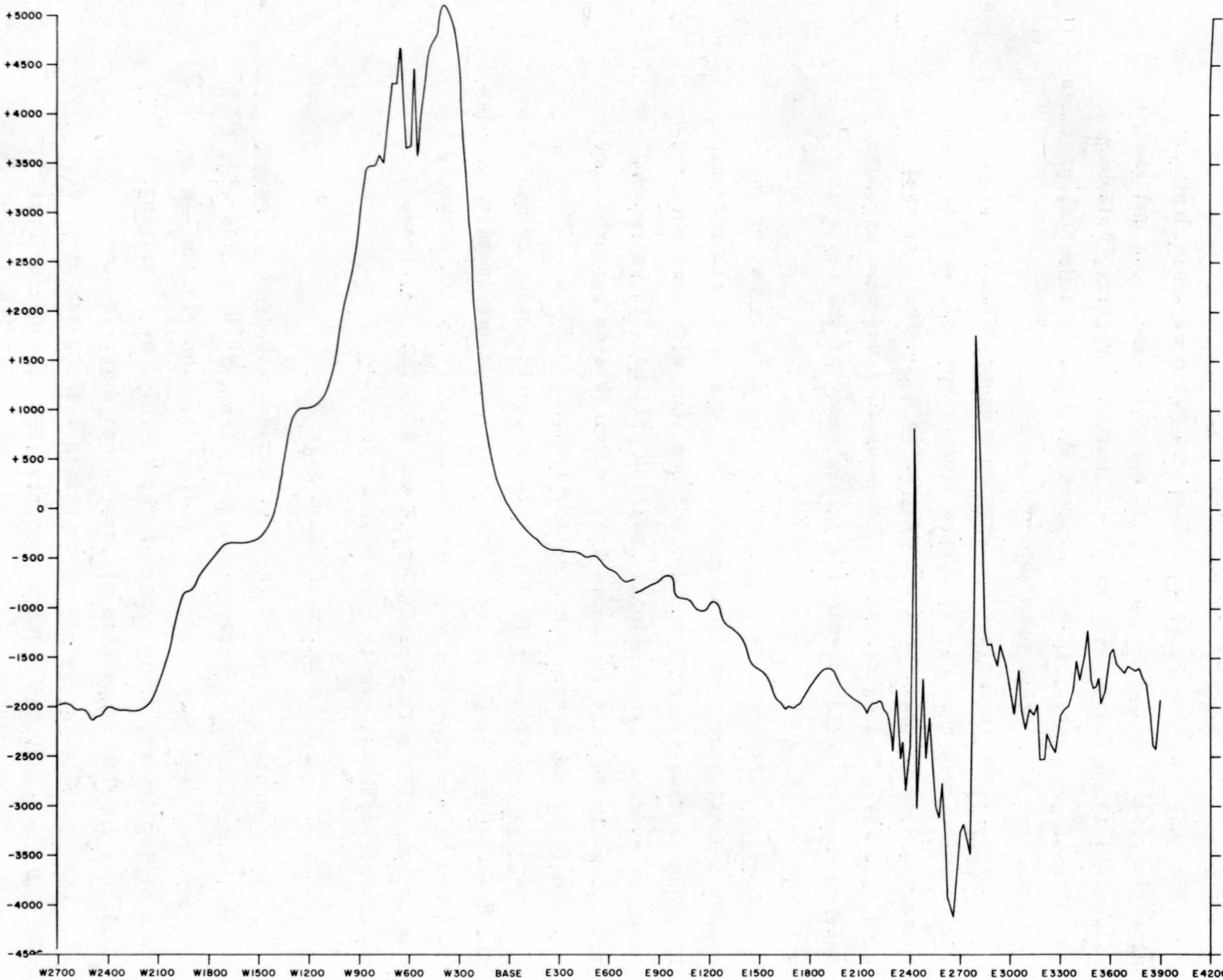

Figure 4.--Vertical magnetic intensity relative to base, east-west profile, Zuni Salt Lake, N. Mex.

Hopi Buttes, Ariz.

The Hopi Buttes area is in a Tertiary basin of sedimentation and volcanism. Bedrock, consisting of Mesozoic sandstones and shales, is exposed in the faces of many of the buttes. Tertiary volcanics cap many of the buttes, form widespread pyroclastic deposits, protrude as dikes, and form other prominent outcrops.

Survey.--The investigation began on a broad, flat alluvium-filled valley south of Castle Buttes Trading Post and west of French Butte. A 4-square-mile area was divided on a 500-foot interval grid (fig. 5). The east-west and north-south lines were extended farther than the grid coverage to enable sampling the regional gradient.

Gravity.--Figure 6 is a Bouguer gravity anomaly map of the area. A density of 2.40 grams per cm^3 was used for data reduction. A strong southwest-northeast regional gradient with some perturbations is evident. The regional gradient will have to be removed from this map so that the anomalies, now visible as perturbations, stand out and can be treated quantitatively.

Magnetics.--Figure 7 is a vertical magnetic intensity map of the area. The geology of the alluvium-filled valley is quite complex, as shown by the number of magnetic anomalies. They are probably due to volcanic vents buried beneath the alluvium. A strong southwest-northeast gradient is also evident.

Meteor Crater, Ariz.

Meteor Crater is one of the most unusual topographic features of northern Arizona. Nearly circular in form, it is a mile wide and over 600 feet deep. Situated on the Colorado Plateau, in an area of low relief, it is underlain by a series of flat-lying sandstone and limestone beds of Permian and Triassic age.

Survey.--The survey was conducted in a 16-square-mile area centered on the crater. Station separations of 100 feet were used from the center to a distance of 3,000 feet; 500-foot spacings were used from 3,000 to 5,000 feet; and 1,000-foot spacings were used from 5,000 to 10,000 feet.

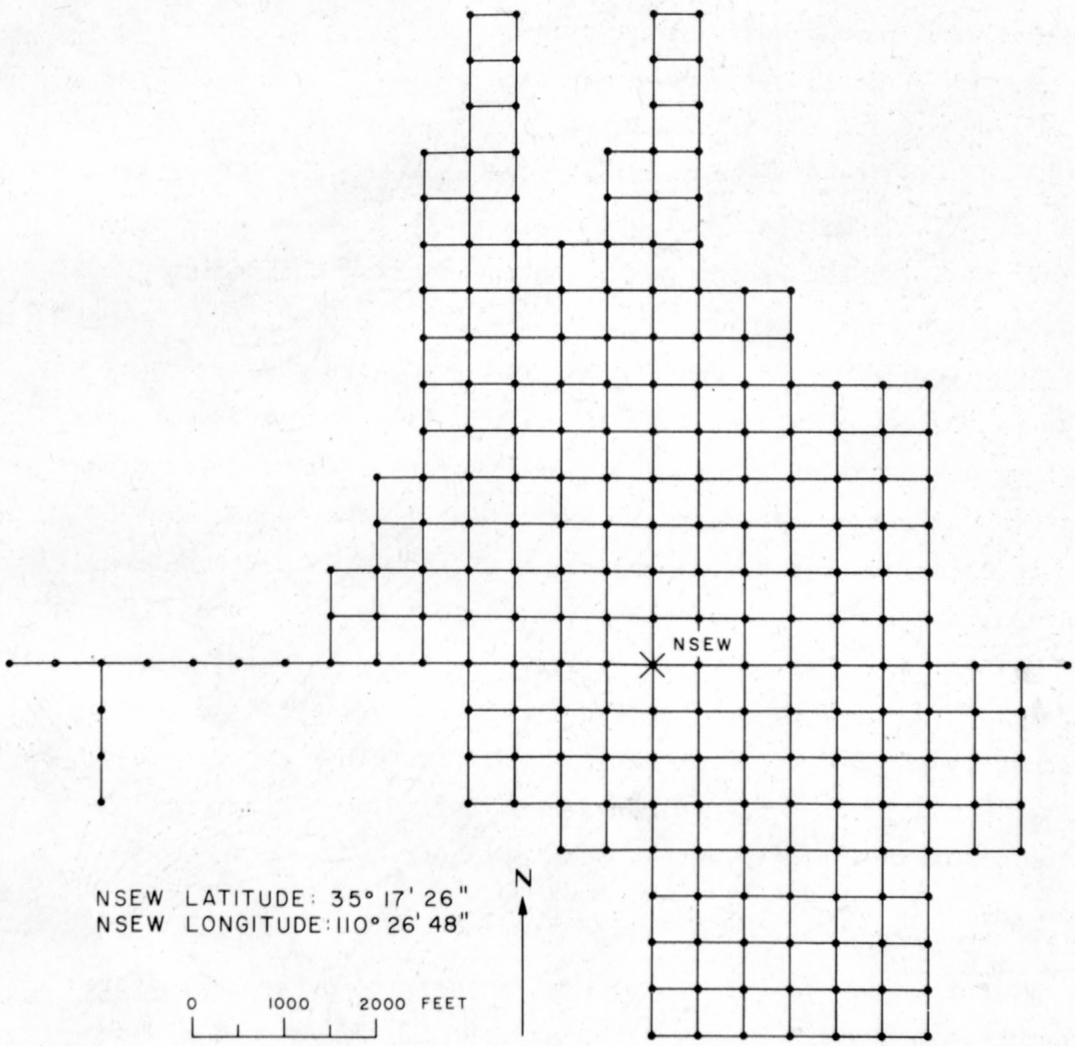

Figure 5.--Station locations at Hopi Buttes, Ariz.

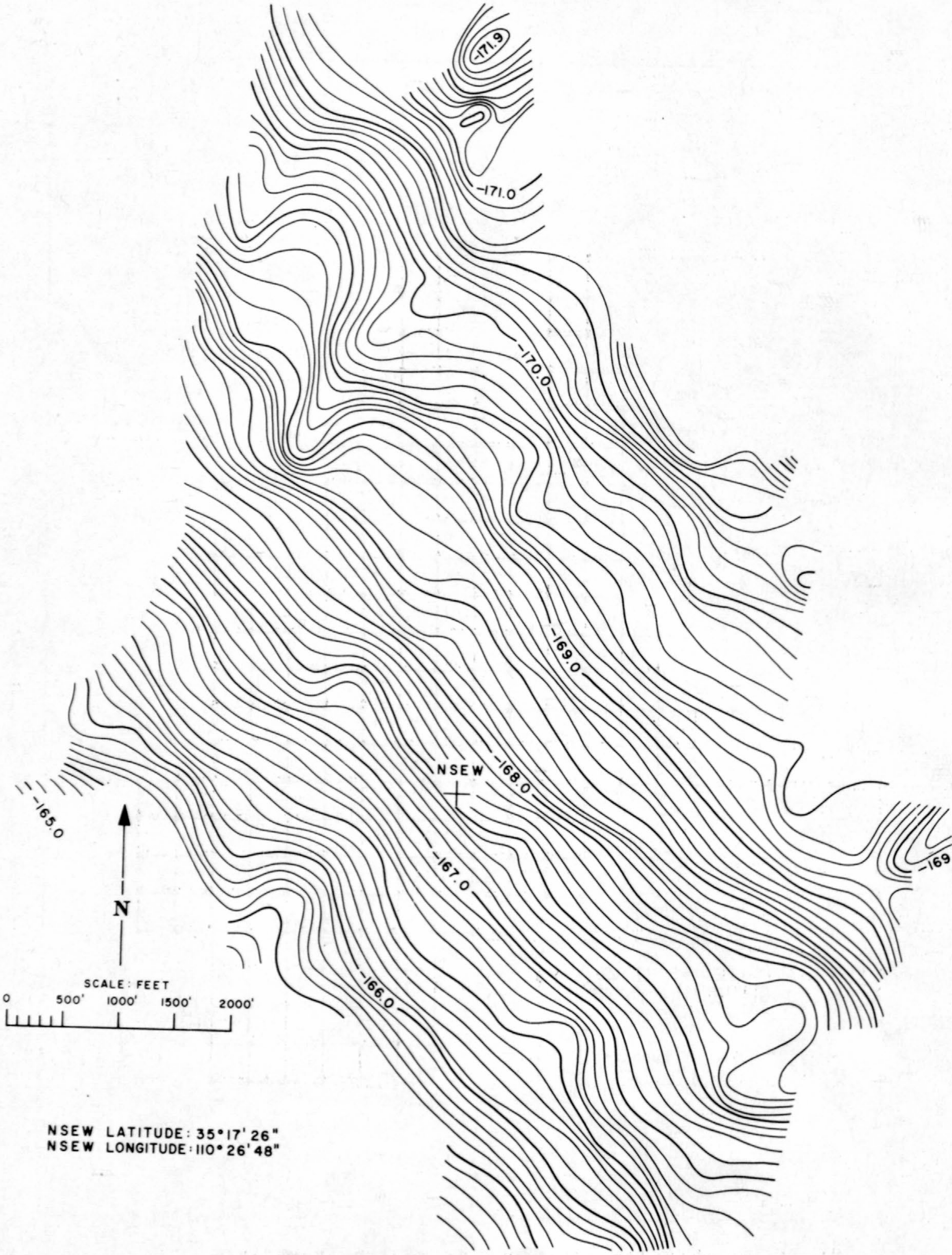

Figure 6.--Complete Bouguer anomaly map, Hopi Buttes, Ariz. Contour interval 0.1 milligal.

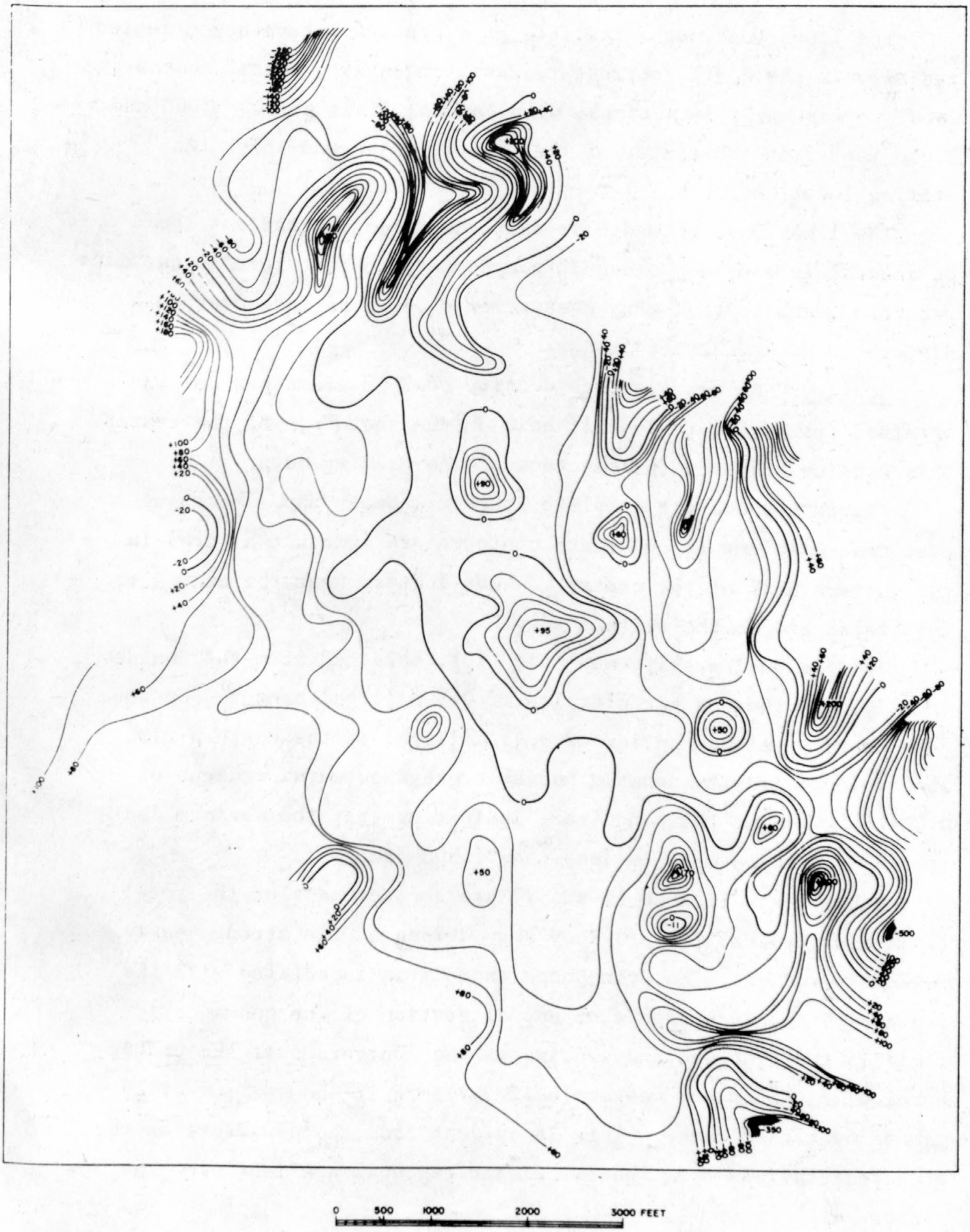

Figure 7.--Vertical magnetic intensity relative to base, Castle Butte area, Hopi Buttes, Ariz. Contour interval 20 gammas.

The lines were not a complete grid pattern but rather oriented radially in the north, northeast, east, southeast, south, southwest, west and northwest directions, with control lines at 500, 2,000 and 3,000 feet from the center of the crater. Figure 8 shows the station locations.

The lines were extended so that the regional gradient could be accurately sampled, since it played an important role in our data reduction, and so that many measurements could be made over both disturbed and undisturbed rock.

Gravity.--An average rock density of 2.28 grams per cm^3 was obtained from a 130-foot drill hole on the south rim of the crater. This density was used in reduction of the gravity data.

Figure 9 shows the complete Bouguer anomaly map. A strong east-west gradient is apparent; contours are somewhat altered in the western half of the crater. A low appears near the center of the crater and on the western edge.

The residual gravity map (fig. 10), obtained from the Bouguer anomaly map, shows a circular low of 0.8 milligal centered on the crater and an elongated low of 0.45 milligal on the western rim. The residual gravity anomaly has an average outward gradient of 0.4 milligal per thousand feet, indicating that the maximum depth to the disturbing mass is less than 1,500 feet.

Magnetics.--Figures 11 and 12 are contour maps of the total field and vertical field. They show evidence of a strong east-west regional gradient. No pronounced anomaly is associated with the crater. The only evidence of any alteration of the geomagnetic field is the widening and bending of the contours over the crater, particularly over the western half. Figure 13 shows a low of 20 gammas over the crater. This is evident from the departure of the measured stations from the calculated regional gradient over the crater.

The regional-residual separation, shown in figure 14, yielded no gross anomaly associated with the crater. The residual contours on the bottom are due to manmade objects--a great deal of iron

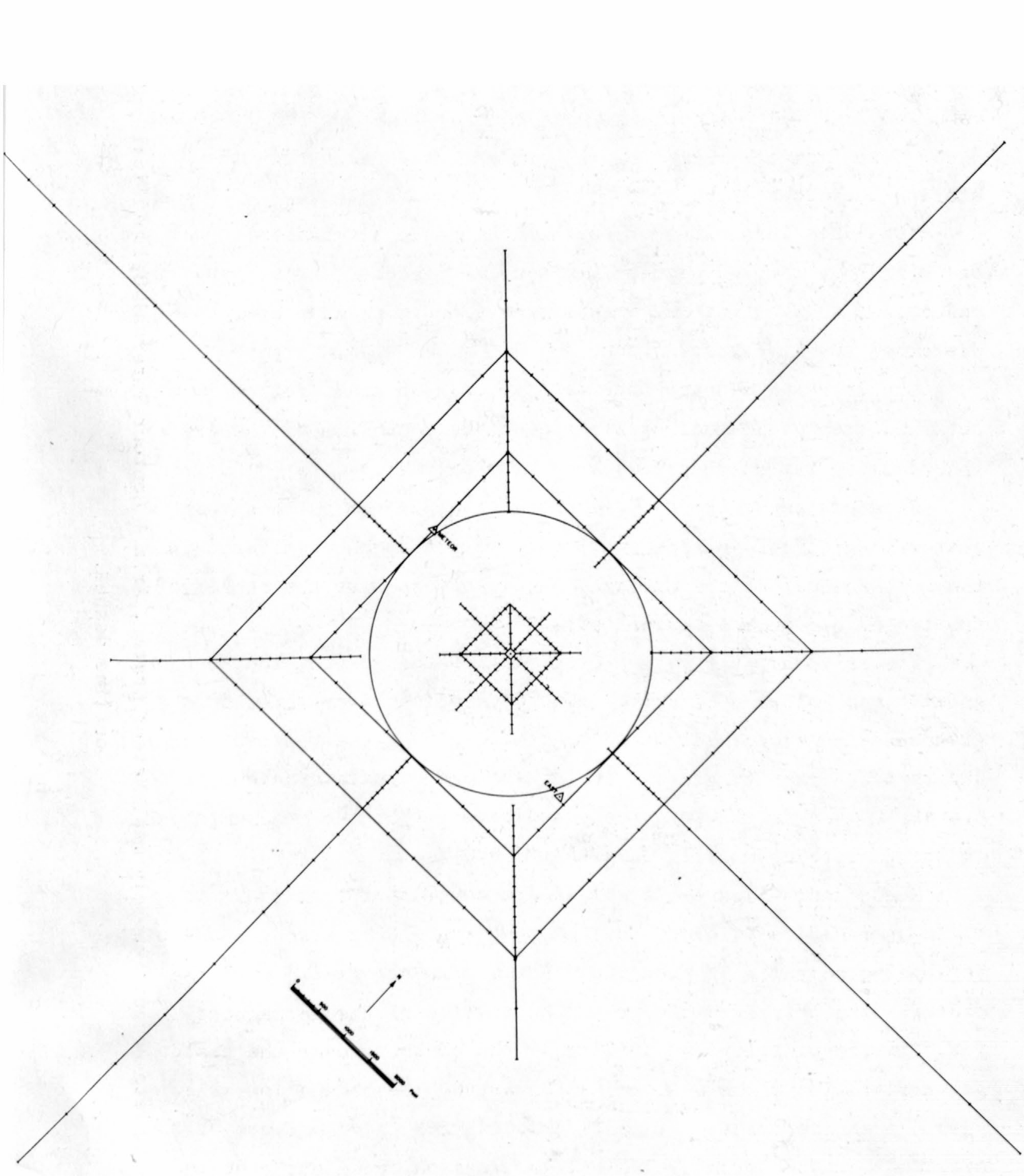

Figure 8.--Station locations at Meteor Crater, Ariz.

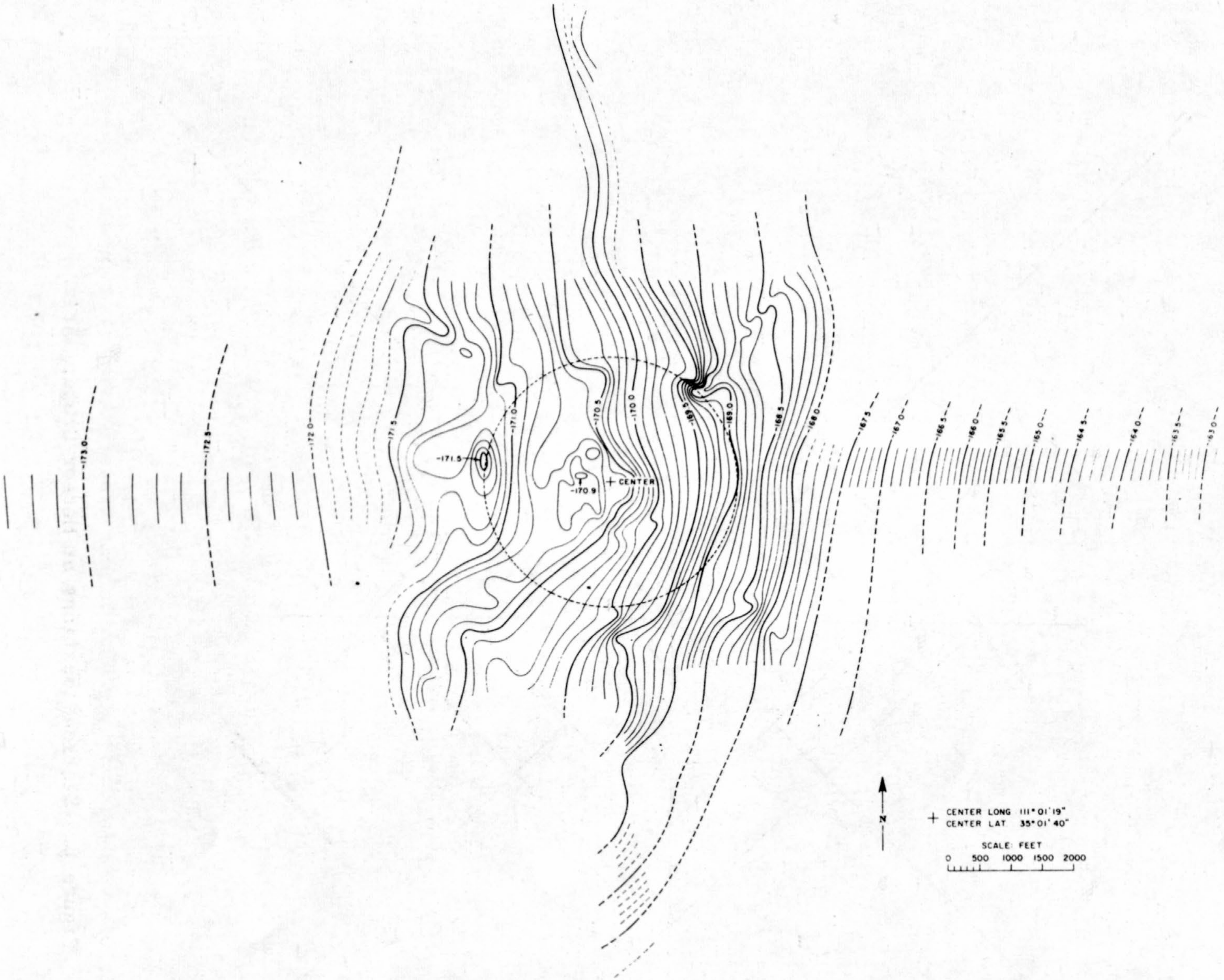

Figure 9.--Complete Bouguer anomaly map, Meteor Crater, Ariz. Contour interval 0.1 milligal. Crater outline dashed.

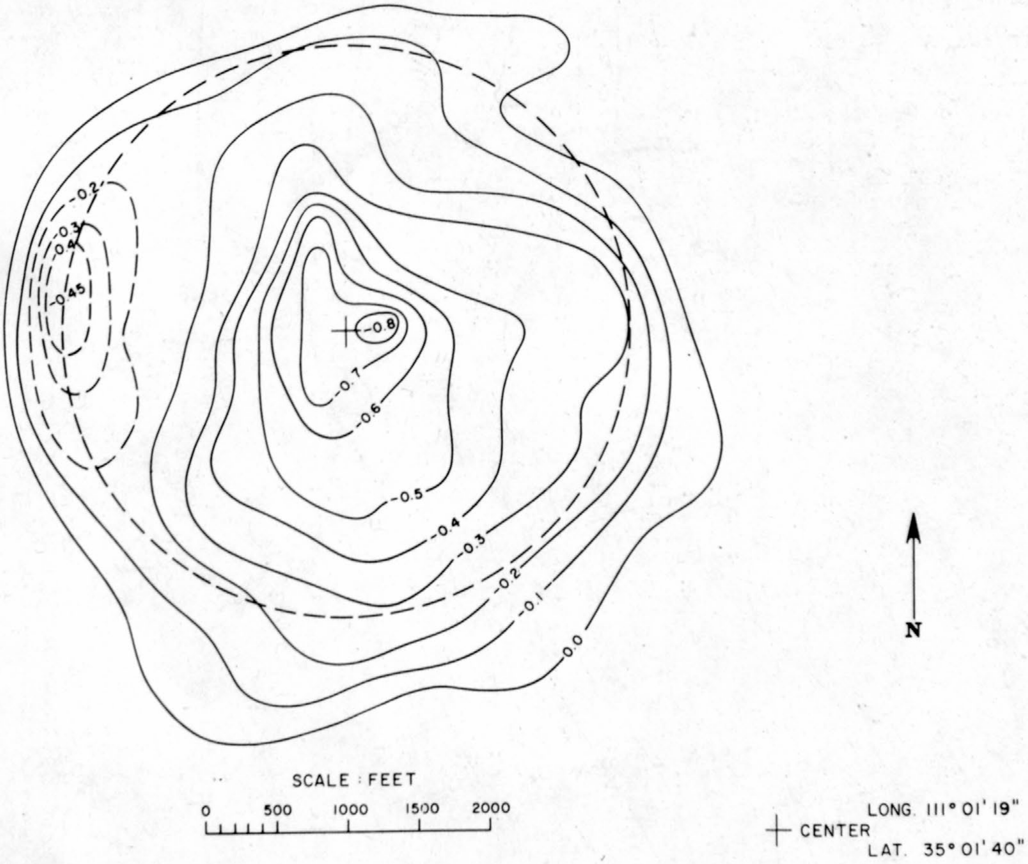

Figure 10.--Residual gravity map, Meteor Crater, Ariz. Contour interval 0.1 milligal. Crater outline dashed.

Figure 11.--Total field magnetic intensity, Meteor Crater, Ariz. Contour interval 10 gammas. Crater outline dashed.

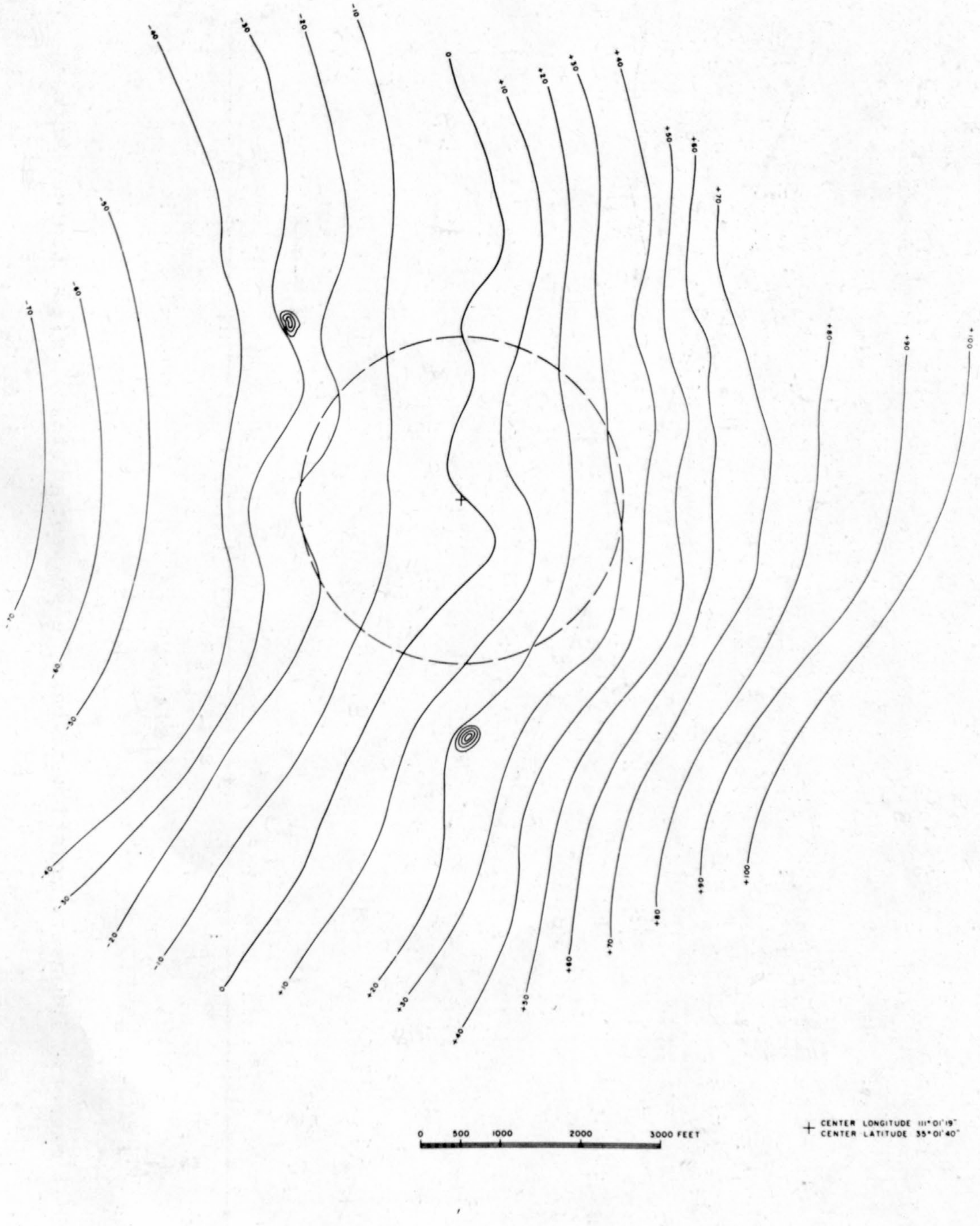

Figure 12.--Vertical magnetic intensity relative to base, Meteor Crater, Ariz. Contour interval 10 gammas. Crater outline dashed.

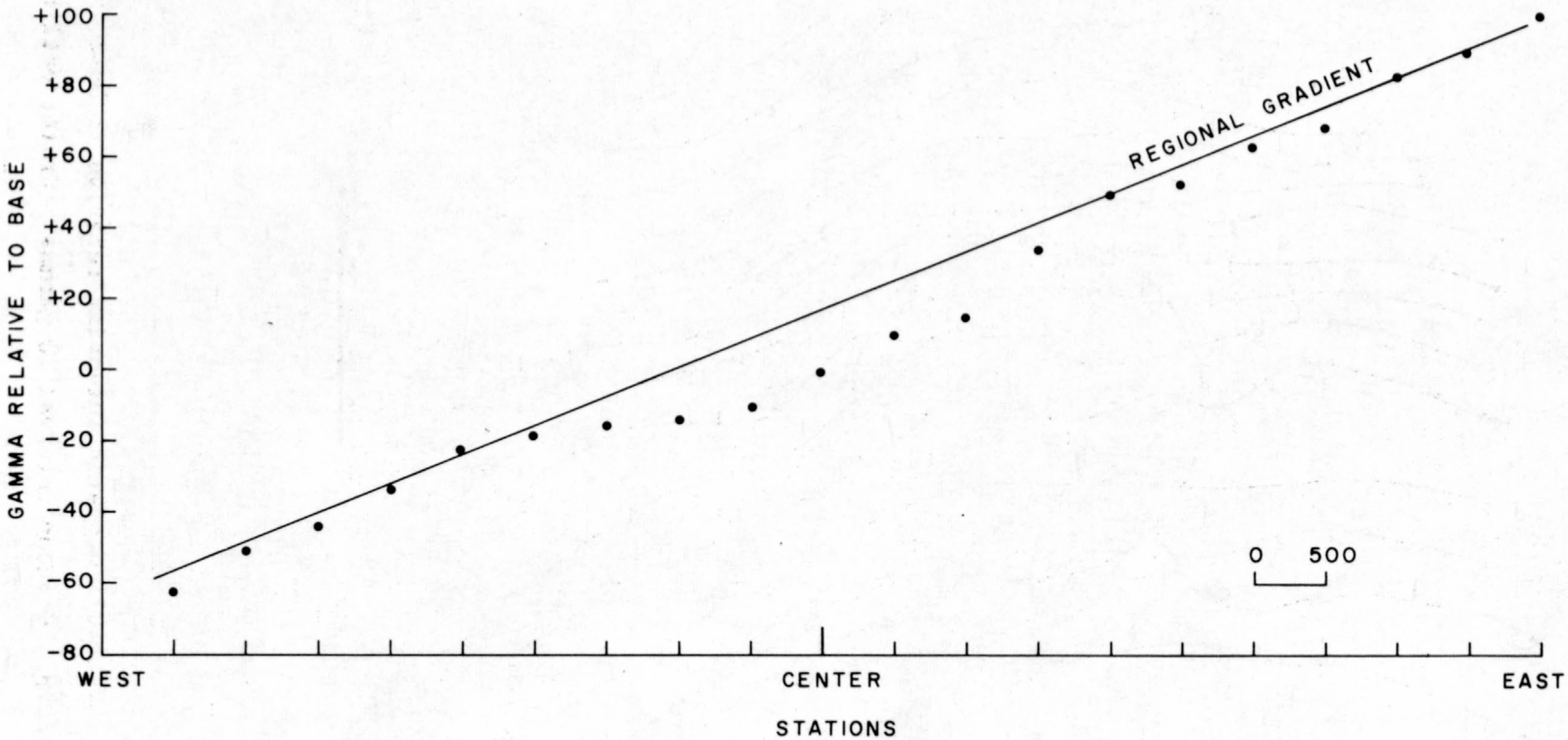

Figure 13.--Vertical magnetic intensity relative to base, east-west profile, Meteor Crater, Ariz.

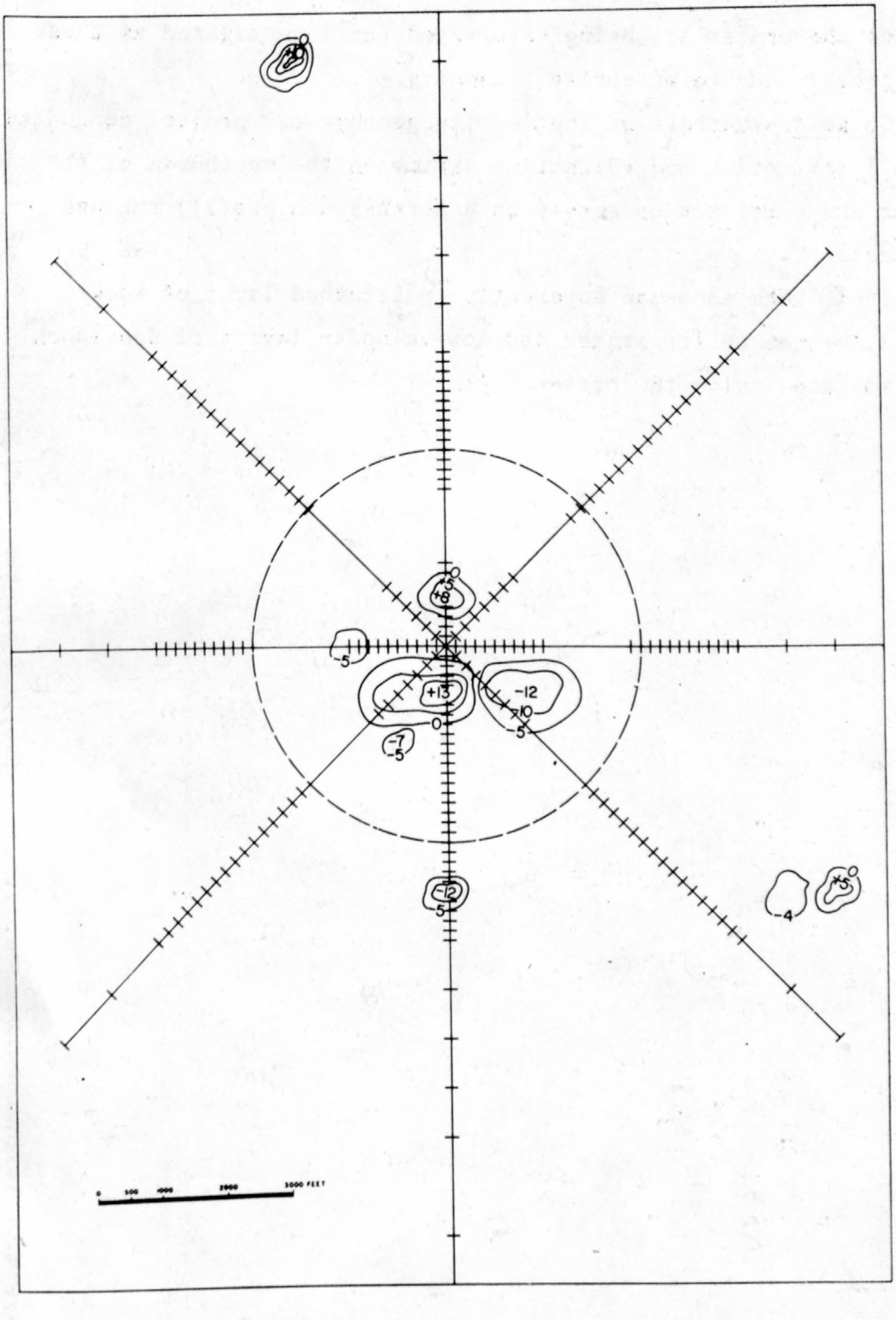

Figure 14.--Residual total field magnetic intensity map, Meteor Crater, Ariz. Contour interval 5 gammas. Sample density 500 ft.

machinery and drilling equipment. The two prominent anomalies outside the crater are being resurveyed and investigated as these are probably due to meteorite fragments.

Seismic.--Members of the in situ geophysical project conducted a small reflection and refraction survey on the south rim of the crater and a refraction survey on a north-south profile through the crater.

Their work shows an apparently undisturbed layer of rock underlying the entire crater and low-velocity layers of debris on the rims and inside the crater.