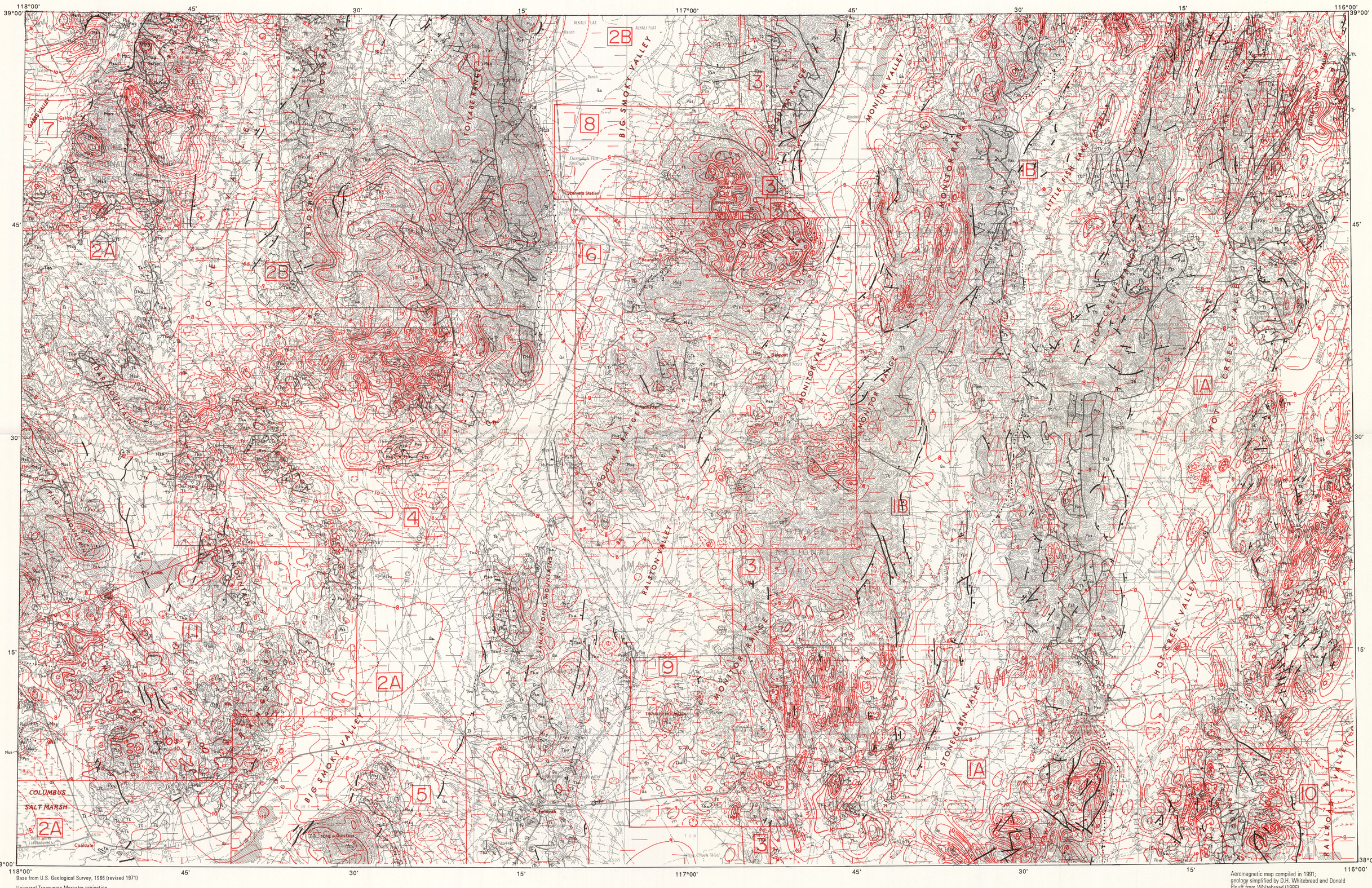



Base from U.S. Geological Survey, 1966 (revised 1971)

Universal Transverse Mercator projection

SCALE 1:250 000

5 0 5 10 15 20 MILES

5 0 5 10 15 20 25 30 KILOMETERS

CONTOUR INTERVAL 200 FEET

SUPPLEMENTARY CONTOURS AT 100-FOOT INTERVAL

NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEVADA

AREA OF MAP

Aeromagnetic map compiled in 1991; geology simplified by D.H. Whitebread and Donald Plouff from Whitebread (1986)

Edited by Dale Russell, prepared by Lori Moore

Manuscript approved for publication on February 26, 1992

## EXPLANATION

**Magnetic contours**—Showing residual magnetic field in nanoteslas (nT) (1 nT = 1 gamma). Contour interval 100 nT. Supplementary 50-nT contours are dashed. Hachures indicate closed magnetic lows. Contour labels are in units of 100 nT

**Flight path**—Showing location and spacing of data

**Survey boundary**—See table 1 for sources and specifications of data

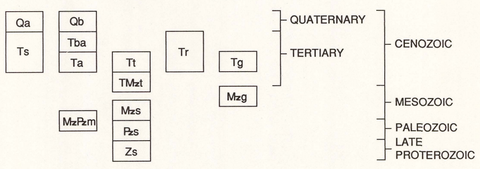
**Approximate contact**

**High-angle fault**—Dotted where concealed. Bar and ball on downthrown side

**Low-angle fault**—Sawteeth on upper plate

**Thrust fault**—Sawteeth on upper plate

### CORRELATION OF MAP UNITS




### DESCRIPTION OF MAP UNITS

Qa — **Alluvial, lacustrine, eolian, and landslide deposits (Quaternary)**—As mapped, includes Tertiary gravel

Qb — **Basalt (Quaternary)**—Lava flows and cinders

Tba — **Basalt and andesite (Quaternary and Tertiary)**—Flows, breccia, and shallow intrusive rocks. As mapped, may include Quaternary lava flows in Pancake Range

Ts — **Sedimentary rocks (Tertiary)**—Tuffaceous sandstone, siltstone, conglomerate, and gravel. Locally includes tuff

Tr — **Rhyolite to dacite (Tertiary)**—Flows and shallow intrusive rocks. Minor ash-flow tuffs and sedimentary rocks

Ta — **Andesite to latite (Tertiary)**—Intermediate flows and intrusive rocks

Tt — **Tuff (Tertiary)**—Welded and nonwelded ash-flow tuff. Minor rhyolite to andesite flows and sedimentary rocks.

Tg — **Granitic rocks (Tertiary)**—Granite to granodiorite stocks, dikes, and sills

TMzt — **Ash-flow tuff and volcaniclastic sedimentary rocks (Tertiary and Mesozoic)**—Tuffs are silicified and variably metamorphosed

Mzg — **Granitic rocks (Mesozoic)**—Granite to diorite

Mzs — **Sedimentary and volcanic rocks (Mesozoic)**—Limestone, dolomite, marble, argillite, sandstone, quartzite, conglomerate, and greenstone

MzPzm — **Mafic and ultramafic rocks (Mesozoic and Paleozoic)**—Includes volcaniclastic sedimentary rocks and serpentine

Pzs — **Sedimentary and volcanic rocks (Paleozoic)**—Mostly chert, argillite, schist, greenstone, quartzite, and limestone in western part of quadrangle. Mostly limestone, dolomite, siltstone, sandstone, and conglomerate in eastern part of quadrangle

Zs — **Sedimentary rocks (Late Proterozoic)**—Schist, phyllite, dolomite, limestone, and quartzite

## INTRODUCTION

This aeromagnetic map is part of a folio of maps of the Tonopah 1° by 2° quadrangle, Nevada, prepared under the Conterminous United States Mineral Assessment Program. Each product is designated by a different letter symbol, starting with A, in the U.S. Geological Survey Miscellaneous Field Studies map series MF-1877 folio. The quadrangle encompasses an area of about 19,500 $km^2$ in the central part of Nevada.

## METHODS OF COMPILATION

The aeromagnetic map is a compilation of 11 aeromagnetic surveys (fig. 1; and table 1). Values of the International Geomagnetic Reference Field (IGRF) (Peddie, 1982) were graphically subtracted by the author from magnetic intensities published for the earliest three surveys (table 1, 1A, 1B, 2A, 2B, 3) as part of this compilation. Values of IGRF had been already subtracted for the later surveys. For the later surveys, data including dates flown, flightline numbers, locations, magnetic intensities, and elevations are available in digital format from the National Geophysical Data Center (table 1). For consistency of display, contour maps of the 11 aeromagnetic surveys then were adjusted nearly to the same datum by adding or subtracting constant values obtained from average differences of magnetic intensities near places with low magnetic gradients along common borders. Datum differences were averaged from 4 to 58 points along all combinations of adjacent or overlapping borders. Although flight altitudes were different along common borders between aeromagnetic surveys, the standard deviation of datum shifts did not exceed 50 nanoteslas (nT). Datums initially were adjusted to fit the adjacent east edge of the previously published Walker Lake quadrangle (Plouff, 1987).

The first seven surveys (table 1) were merged by Kucks and Hildenbrand (1987) into gridded format —with grid intersections spaced at 1000-m — for contouring at a scale of 1:750,000 (Hildenbrand and Kucks, 1988). Merging without conspicuous discontinuities near boundaries between surveys and abrupt changes of flight elevations within surveys was accomplished by best-fitting magnetic datums of adjacent surveys after continuing upward and downward by mathematical filtering to simulate flight altitudes of 300 m above the ground. Inasmuch as mathematical filtering to some extent distorts locations and magnetic intensities, especially near boundaries between surveys, the purpose of the present compilation was to display the original observations with changes only for arbitrary shifts of magnetic datum and corrections for the effect of the Earth's regional magnetic field. Use of the magnetic intensities and elevations for the original aeromagnetic surveys, however, are recommended for quantitative analysis by modeling.

The present map differs slightly from a previously published aeromagnetic map of the Tonopah quadrangle (Plouff, 1990), because analysis of the digital data for the Mount Jefferson survey (table 1, survey 8; U.S. Geological Survey, 1984a) indicated that maximum radar altitudes (700 m) were exceeded for 75 percent of the data points (about 78 percent of the area). An apparent recording limit of 3,048 m also was reached for the barometric elevations of 25 percent of the data points. Approximate radar altitudes can be recovered for about 63 percent of survey 8 by using an approach of best fits among recorded barometric elevations, digital topographic elevations, and the accepted 25 percent of the radar altitudes, leaving 15 percent of the original area uncovered by radar altitudes or barometric elevations. A best fit can be achieved by adding about 480 m to barometric elevations recorded on July 11, 1983, and adding about 100 m to barometric elevations recorded on July 12, 1983.

In addition to the above-mentioned surveys, the U.S. Department of Energy contracted for airborne radioactivity and aeromagnetic surveys of the Tonopah quadrangle (Geodata International, Inc., 1979) as part of the National Uranium Resource Evaluation program (NURE). The flight altitude for the survey was 120 m above the average terrain, which provided greater sensitivity to variations in rock magnetization than aeromagnetic surveys of the present compilation. The average flightline spacing of 5 km, however, was too wide to infer values of the magnetic field between flightlines except at wavelengths longer than about 5 km. Therefore, the NURE survey could not be merged with the present compilation.

## GENERAL FEATURES OF AEROMAGNETIC MAP

The following generalized interpretation of the aeromagnetic map is based on comparison of aeromagnetic anomalies with topography and the accompanying geologic base (from Whitebread, 1986). Interpretation of the aeromagnetic map was one of the standard methods used to evaluate the mineral potential of specific localities in the Tonopah quadrangle (Diggles and others, 1986; Brooks and others, 1987; Hardyman and others, 1987; John and others, 1987). Previous interpretations of aeromagnetic surveys in the quadrangle with emphases on mineral potential were made by Davis and others (1971; 1979).

Anomalies on the aeromagnetic map reflect the diversity in magnetization of surficial and underlying rocks. Magnetizations of rocks near the surface cause conspicuous topographic effects on the aeromagnetic map. That is, maxima of magnetic intensities (highs) associated with induced magnetization and normal remanent magnetization occur over ridges and hilltops, and magnetic minima (lows) occur over canyons and valleys. Except for flightlines over the highest crests, surveys flown at constant barometric elevation (numbers 2 and 3 in table 1) are flown higher above the ground surface than surveys flown at nominally constant heights above the ground (draped). Therefore, parts of the quadrangle covered by draped surveys generally are closer to underlying magnetic sources and, consequently, have more magnetic anomalies detected with steeper magnetic gradients and curvatures than parts covered by surveys flown at constant barometric elevation. Steep magnetic gradients observed between flightlines can be caused by location errors and significant differences of altitudes between adjacent flightlines over underlying rocks with high magnetization.

## DISCUSSION OF AEROMAGNETIC ANOMALIES

### PRE-TERTIARY PLUTONIC ROCKS

Conspicuous magnetic highs that extend to 10 km in size and 600 nT in magnetic intensity closely correlate with outcrops of pre-Tertiary plutonic rocks in the Paradise Range, Cedar Mountain, Lone Mountain, the southern part of the San Antonio Mountains, the southern part of the Toquima Range, and the northern part of the Toiyabe Range (John, 1987). Shawe and Snyder (1988, pl. 2) show close correlations between magnetic highs and exposures of intrusive stocks centered about 4 km east of the town of Round Mountain and about 4 km northeast of Manhattan. Although only small outcrops of pre-Tertiary plutonic rocks are present, concealed large plutons may be inferred beneath conspicuous magnetic highs near the Pilot Mountains, the northwest edge of the San Antonio Mountains, the northern end of the Royston Hills, and the southern end of the Toiyabe Range. Davis and others (1971) suggested that the magnetic high near the northwest edge of the San Antonio Mountains may be underlain by a mass of Tertiary intrusive andesite extending northeastward in the subsurface from the southwestern part of the anomaly, which encloses outcrops of Tertiary intrusive rocks. The presence of outcrops of plutonic rocks in the adjacent hills suggests that large plutons are present beneath sediments at the north end of Gabbs Valley (Davis and others, 1979) and the north end of Ione Valley.

Other concealed plutons may be inferred beneath magnetic anomalies located near the northwest edge of the Monte Cristo Range, at the west edge of Cedar Mountain near Dry Lake, to the west of the northwest end of the Royston Hills, and at the southeast end of the Paradise Range. A 6-by-6-km, 300-nT magnetic high east of the center of the Paradise Range may indicate concealed plutonic rocks, but Davis and others (1979) suggested that an accumulation of Tertiary welded tuff with relatively high measured magnetization may be the source of the anomaly.

Sizes and intensities of magnetic highs in the central part of the Toiyabe Range are comparable to previously discussed anomalies associated with underlying plutons, but the crests of the magnetic highs nearly coincide with topographic crests of Tertiary tuff. Although these magnetic highs appear to reflect deep, coherent bodies, as viewed from the higher constant-level aeromagnetic survey, instead they probably reflect the cumulative effect of near-surface Tertiary volcanic rocks with moderate to intense magnetization.

No magnetic highs are associated with large exposures of pre-Tertiary plutonic rocks in the central and the southeastern parts of the Toquima Range except for a narrow magnetic high that extends about 13 km west-northwest from Belmont. The lack of magnetic anomalies indicate that the plutonic rocks have low magnetization. Therefore, Grauch and others (1988, sheet 2), in their statewide compilation of inferred plutonic rocks, classified this area as having "no geophysical expression of mapped granitic rocks." Local rock alteration has been reported (D.A. John, written commun., 1984), which indicates that primary magnetite may have been substantially altered to nonmagnetic minerals.

### PRE-TERTIARY SEDIMENTARY AND VOLCANIC ROCKS

Iron-bearing metavolcanic rocks cause local magnetic anomalies in the Paradise Range (Davis and others, 1979, locality F2). The lack of magnetic anomalies associated with most other pre-Tertiary sedimentary and volcanic rocks indicates that these rocks generally have low magnetization in the Tonopah quadrangle. The occurrence of a conspicuous, elongated magnetic low over Late Proterozoic and adjacent Paleozoic rocks at Lone Mountain indicates that these rocks have low magnetization and extend to moderate depth between normally magnetized pre-Tertiary plutonic rocks to the southwest and Tertiary volcanic rocks to the northeast. The lack of magnetic anomalies over exposures of pre-Tertiary sedimentary and volcanic rocks adjacent to pre-Tertiary plutonic rocks with associated magnetic anomalies in the San Antonio Mountains, the Toquima Range, the Toiyabe Range, Shoshone Mountains, Paradise Range, Cedar Mountain, Royston Hills, and Pilot Mountains indicates that these rocks have low magnetization. Magnetic anomalies generally do not occur over large exposures of Paleozoic sedimentary and volcanic rocks in the northern part of the Monitor Range, throughout the Hot Creek Range, and in the Reveille Range. The occurrence of a magnetic high over Paleozoic rocks to the west of the south edge of Stone Cabin Valley indicates that those rocks have a substantially greater magnetization than other Paleozoic nonplutonic rocks in the quadrangle, or a pluton may underlie extensive exposures of altered rocks (G.J. Orris, written commun., 1986).

### CENOZOIC VOLCANIC AND INTRUSIVE ROCKS

Irregularly spaced, short-wavelength anomalies typify the magnetic pattern for draped surveys over Cenozoic volcanic terrane of the Tonopah quadrangle. This pattern reflects the irregular nature of the topography and large variations in the direction and intensity of rock magnetization. Intensities and directions of remanent magnetization have sufficiently small ranges for some volcanic rocks, so that qualitative field estimates of remanent magnetization and categorization of aeromagnetic anomalies were used as supplementary geologic mapping tools in the Tonopah quadrangle (for example, Ekren and others, 1972; 1974). Remanent magnetization is sufficiently high for some reversely magnetized volcanic rocks that associated magnetic lows are observed. Reversed magnetization of exposed volcanic rocks is suspected if aeromagnetic lows overlie topographic highs, for example, at Thunder Mountain. Extensive magnetic lows on the east flank of the San Antonio Mountains over flows of basaltic andesite (Davis and others, 1971) demonstrate that reversed remanent magnetization also can be detected in areas with constant-level aeromagnetic surveys.

Magnetic highs also may be associated with Tertiary plutons. For example, the 300-nT crest of a 5-by-10-km, 750-nT aeromagnetic high coincides with a small outcrop of Tertiary intrusive rocks (John, 1987) to the east of Saulsbury Wash located about 35 km east of Tonopah. The anomaly apparently delineates a subjacent Tertiary pluton. A 100-nT magnetic high with an associated polarization low to the north overlies a small outcrop of Tertiary intrusive rocks located about 10 km southwest of Mount Jefferson in the Toquima Range. There is no similar association between aeromagnetic highs and other exposures of Tertiary intrusive rocks along the east flank of the Toiyabe Range, because magnetizations of the rocks presumably are too low or the intrusive rocks are too thin to be detected at the high altitude of the constant-elevation survey. A cluster of Tertiary intrusive rocks to the southeast of Carvers Station, however, is located along the south and east edges of a broad magnetic high. A large magnetic high with an amplitude of about 700 nT, which is located in Little Smoky Valley (northeast corner of quadrangle), may reveal the extent of an underlying intrusive body.

## OTHER FEATURES OF AEROMAGNETIC MAP

Short-wavelength magnetic anomalies are generally absent in basins and valleys because sediments generally have negligible magnetization. Volcanic flows interfingered with sediments or bedrock at shallow depth are revealed at many locations in the quadrangle where magnetic anomalies occur within valleys or over Tertiary sedimentary rocks.

Clusters of intense anomalies are present over exposures of Tertiary rhyolite in the southern and central parts of the Monitor Range. Similar clusters are found over presumably thick accumulations of Tertiary tuff in the southern part of the Toiyabe Range, near Mount Jefferson in the Toquima Range, in the Monitor Range to the east of Mount Jefferson, in the southern part of the Monitor Range, and in the Kawich Range. Wavelengths associated with magnetic anomalies over Tertiary tuff in the northern part of the Toiyabe Range are long because the accumulative effects of variable thicknesses and magnetizations of volcanic rocks are merged at typically high altitudes of the constant-elevation survey. Clusters of intense anomalies are found over Tertiary andesitic to basaltic rocks in the Reveille Range, but magnetic anomalies are more subdued over andesitic to basaltic rocks in other parts of the quadrangle.

Extensive areas of the Toquima, Monitor, and Hot Creek Ranges, where volcanic rocks are prevalent at the surface, lack associated magnetic anomalies. Three conditions may contribute to the lack of anomalies. First, the volcanic rocks may inherently have a low concentration of magnetite. Second, the volcanic rocks may be thin and overlie pre-Tertiary basement rocks with low magnetization concealed at shallow depth. Third, the volcanic and underlying rocks may be hydrothermally altered. Areas with pervasive rock alteration, however, may be difficult to detect at the altitudes and flightline spacings of the aeromagnetic surveys.

Except for basin-range faults, the most prominent magnetic gradients are not generally associated with faults or fault zones. A conspicuous magnetic gradient between the northern part of the Toiyabe Range and Big Smoky Valley probably reflects a basin-range fault. Rather linear magnetic contours, suggesting fault-bounded blocks, enclose magnetic highs near the northwest edge of the northern part of Cedar Mountain and near the inferred fault to the east of the Toiyabe Range. Arcuate contours and steep magnetic gradients may overlie a ring fracture zone at the south and southeast edges of the caldera suggested by the cluster of intense magnetic anomalies centered near Mount Jefferson in the Toquima Range. The caldera near Mount Jefferson is reflected as a gravity low (Healey and others, 1981; Snyder and Healey, 1983).

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**Table 1.** *Sources of aeromagnetic data for Tonopah 1° by 2° quadrangle, Nevada*

[SUR, symbol of survey on the accompanying map. YEAR, year of U.S. Geological Survey publication; parentheses indicate unpublished survey of U.S. Geological Survey. DIR, direction of flight lines; E, east-west; N, north-south. SPACE, specified spacing between flightlines. HEIGHT, specified elevation or altitude of survey in meters; B, barometric elevation above sea level; G, nominal altitude above the ground surface. AVG, average altitude recorded; STD, standard deviation of recorded altitude. NUM, associated number; and NAME, name of digital magnetic tape available from the National Geophysical Data Center (NOAA), 325 Broadway, Boulder, Colorado, 80303-3328. —, data not available]

| SUR | YEAR | DIR | SPACE (km) | HEIGHT (m) | AVG (m) | STD (m) | NUM | NAME |
|---|---|---|---|---|---|---|---|---|
| 1A | 1968 | E | 1.6 | 150G | — | — | — | — |
| 1B | 1968 | E | 1.6 | 300G | — | — | — | — |
| 2A | 1971 | E | 1.6 | 2,740B | — | — | — | — |
| 2B | 1971 | E | 1.6 | 3,660B | — | — | — | — |
| 3 | (1974) | N | 1.6 | 3,660B | — | — | — | — |
| 4 | 1979a | E | 0.8 | 300G | 300 | 34 | 3171 | Cedar Mountain |
| 5 | 1979b | E | 0.8 | 300G | 309 | 48 | 3170 | Lone Mountain |
| 6 | 1979c | E | 0.8 | 300G | 303 | 55 | 3172 | Manhattan |
| 7 | 1979d | E | 0.8 | 300G | 303 | 33 | 3173 | Paradise Peak |
| 8 | 1984a | E | 0.8 | 300G | 483 | 148 | 4121 | Mount Jefferson |
| 9 | 1984b | E | 0.8 | 300G | 330 | 50 | 4120 | Thunder Mountain |
| 10 | 1985a | N | 0.8 | 300G | 300 | 43 | 4133 | South Reveille Range |
| 11 | 1985b | E | 0.8 | 300G | 297 | 30 | 4135 | Monte Cristo Range |

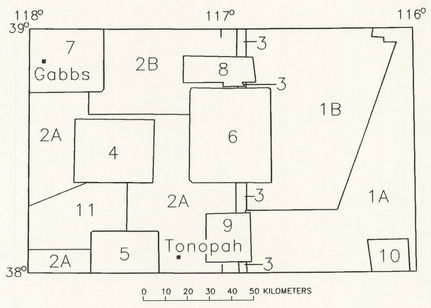


**Figure 1.** Index map of aeromagnetic surveys for the Tonopah 1° by 2° quadrangle, central Nevada. See table 1 for sources of data.

# AEROMAGNETIC MAP OF THE TONOPAH 1° BY 2° QUADRANGLE, CENTRAL NEVADA

By
Donald Plouff

1992

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1992

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225