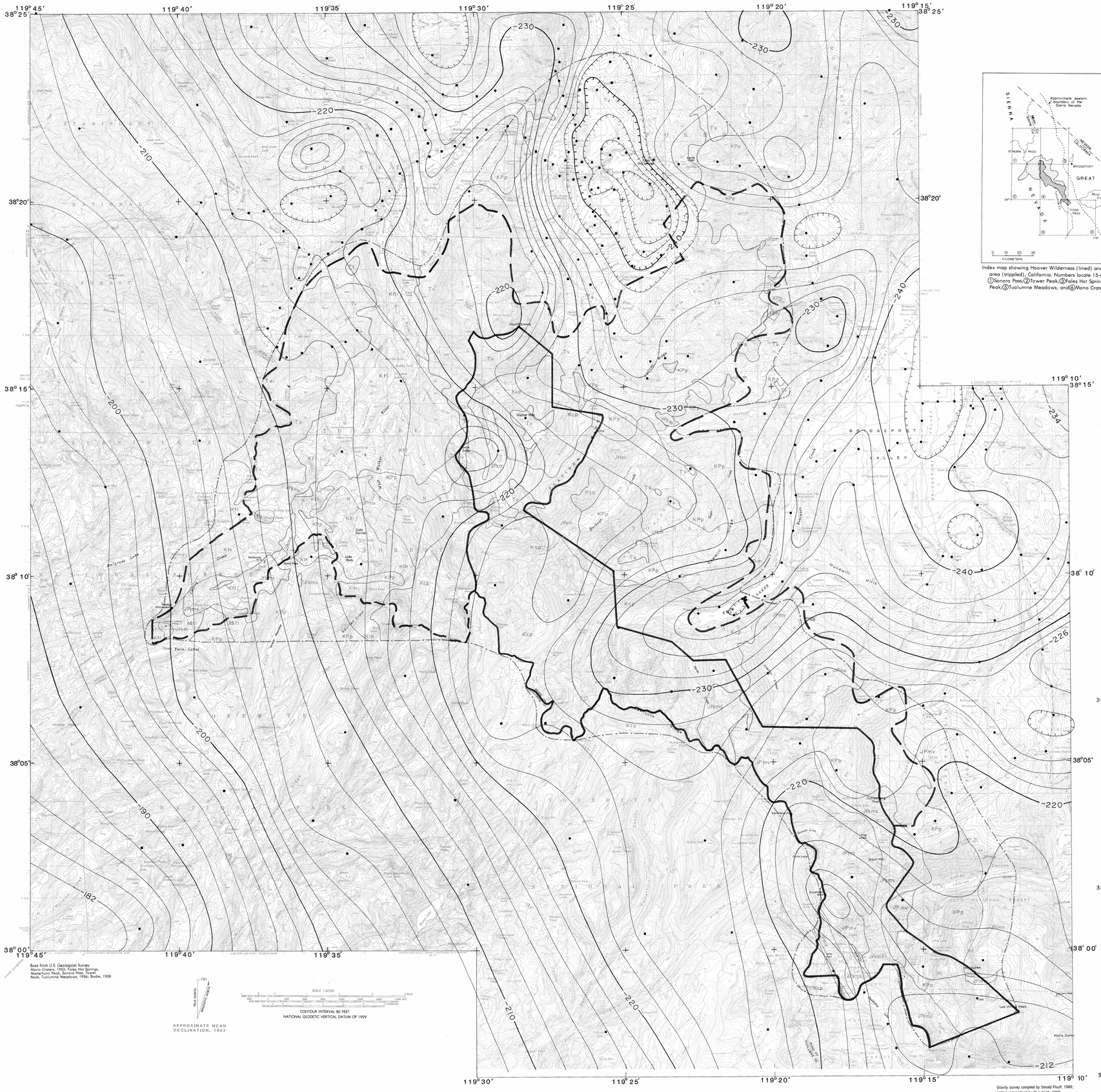
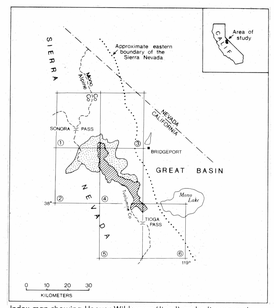


Gravity survey compiled by Donald Plouff, 1960; geology generalized by W.J. Keith, 1980



Index map showing Hoover Wilderness (lined) and adjacent study area (stippled), California. Numbers locate 15-minute quadrangles: (1)Sonora Pass, (2)Tower Peak, (3)Frales Hot Springs, (4)Matterhorn Peak, (5)Tuolumne Meadows; and (6)Mono Craters.

EXPLANATION

GRAVITY STATION—Not indicates location near bench mark or spot elevation; recent, location where elevation was determined by altimetry or topographic contour interpolation

GRAVITY CONTOUR—Reduction density 2.67 g/cm³. Terrain correction density 2.67 g/cm³. Interpretive contours indicate closed gravity lows. Contour interval 2 mGal

EXPLANATION OF MAP UNITS

Generalized geology from Keith and Bateman (1981)

CORRELATION OF MAP UNITS

DICTIONARY OF MAP UNITS

Tv VOLCANIC ROCKS (TERTIARY)

Kcp CATHEDRAL PEAK GRANODIORITE (CRETACEOUS)

Kti GRANODIORITE OF TIOGA LAKE (CRETACEOUS)

Kfl GRANODIORITE OF FREMONT LAKE (CRETACEOUS)

Kin GRANODIORITE OF LAKE NANKITE (CRETACEOUS)

KPp PLUTONIC ROCKS (CRETACEOUS to PERMIAN)—Locally includes granodiorite of Mount Lola, granite of Dana Plain, granite of Twin Lakes, granite of Cony Creek, granodiorite of Bond Pass, granite of Dorothy Lake, gabbro of Mount Warren, granodiorite of Log Cabin Creek, granite of Devils Gate, granodiorite of Sonora Pass, granodiorite of Leavitt Meadows, granodiorite of Buckeye Creek, granodiorite of Mono Dome, and quartz diorite of Obsidian Dome

Mzgb GABBRO OF TWIN LAKES (MESOZOIC)

JPzmv METAVOLCANIC ROCKS (JURASSIC TO PALEOZOIC)

JPzms METASEDIMENTARY ROCK (JURASSIC TO PALEOZOIC)—Includes metaconglomerate of Conway Lake

JPzm METAMORPHIC ROCKS (JURASSIC TO PALEOZOIC)

APPROXIMATE CONTACT

LIMIT OF GEOLOGIC MAPPING

BOUNDARY OF HOOVER WILDERNESS

BOUNDARY OF STUDY AREA

Studies Related to Wilderness

The Wilderness Act (Public Law 88-577, September 3, 1964) and related Acts require the Geological Survey and the Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the Administration and the Congress. This report presents the results of a geophysical survey of the Hoover Wilderness and adjacent study area, Mono and Tuolumne Counties, Calif.

DISCUSSION

INTRODUCTION

Two geophysical maps were prepared to aid in the study of the Hoover Wilderness and adjacent study area, California. The Bouguer gravity anomaly map (sheet 1) shows the distribution of rocks of different densities, which may reflect (sheet 2) reflects lateral changes in magnetics of the underlying rock. Changes of these physical properties are related to changes in rock type, and consequently, the geophysical maps can be used to aid mapping of rocks and geologic structures at the surface and to infer rock types and boundaries between rocks beneath the ground surface. The study area is in the Sierra Nevada, a physiographic province that is distinct from the more detailed geologic map of the study area (W. J. Keith, written commun., 1980; and Keith and Bateman, 1981). Data on the geophysical maps extend beyond the border of the study area, so that the geophysical anomalies in the study area can be interpreted with regard to the surrounding regional framework.

COLLECTION AND REDUCTION METHODS FOR GRAVITY DATA

The contours on the Bouguer gravity anomaly map (sheet 1) are defined by interpolation among 234 previously established gravity stations (Robbins and others, 1975; and Robbins and Oliver, 1976) and 86 stations established in 1978 by Donald Plouff, David W. Jeffrey, and Robert F. Sikora. Where feasible, the gravity stations were located near bench marks or spot elevations shown on topographic maps (U.S. Geological Survey, 7.5-minute series, 1:24,000 scale). Because some sites were difficult to reach, elevations were estimated at 18 stations by using altimetry or topographic contour interpolation. The elevation error at these 56 stations—most of which are in the gravity depressions—approaches 12 m (half a contour interval) or more, which contributes to a gravity anomaly error of 2.4 mGal or more at the 2.67 g/cm³ reduction density.

Standard methods were used to convert the gravity observations to Bouguer gravity anomalies. To be consistent with previously published gravity maps in the Sierra Nevada, the Bouguer gravity anomaly was calculated using a reduction density (Chapman, 1984; Beiswenger and Moolard, 1981), and the theoretical value of gravity at each station was derived from the International Formula of 1930 (Lambert and Darling, 1937). Most of the gravity stations were tied to a base station near the Bridgeport courthouse (Robbins and Oliver, 1976, p. 12).

The terrain correction was estimated out to a distance of 166.7 km from each station. The inner terrain correction was estimated by subdividing the topography into cylindrical sectors (Hammer, 1939) to distances of 0.9 or 1.3 km from each station. The outer terrain correction was estimated by subdividing the surrounding topography into rectangular prisms with dimensions 30 arcseconds (Plouff, 1977). The gravity anomaly error resulting from the error of the terrain correction can be large in a mountainous area such as the Hoover Wilderness. The terrain corrections for 27 stations exceed 20 mGal, ranging up to 45 mGal at Dunnwalds Peak. An estimated error of 10 percent for the terrain correction performed in areas for the gravity anomaly that range from 2.0 to 4.5 mGal for these stations.

AEROMAGNETIC DATA

The aeromagnetic survey (U.S. Geol. Survey, 1979) was flown at an altitude of approximately 300 m above the average ground surface. The flight lines were flown in east-west directions at intervals of 800 m in most of the area and 1,600 m near the border. A residual magnetic map was prepared by subtracting the Earth's magnetic field from the data. The Earth's magnetic field was calculated for an arbitrary constant. The dimensions of the grid used for computer-contouring the residual magnetic field was 300 m northwest-to-south by 150 m east-west.

INTERPRETATION OF GRAVITY MAP

The most prominent feature of the gravity map (sheet 1 and fig. 1) is the contrast in gravity between the southwest third of the map and the rest of the area. The gravity decreases by 30 mGal in the southwest corner, and the gradient decreases in Bouguer gravity anomaly of about 150 mGal in 25 km to the southeast. This rather uniform gravity gradient for the most part reflects a regional zone of northeastward thickening of the crust and the effect of a deeper root beneath the Sierra Nevada (Oliver, 1977, fig. 4). The gradient persists nearly to the Sierran crest, where it steepens in response to the rapid decrease in crustal thickness (Ryberg and others, 1981). The gradient associated with crustal thickening is so large that a near-surface body of anomalous density would require an exceptionally large volume or density contrast with the surrounding rock to cause more than a minor deflection of the gravity anomaly contours.

The gravity pattern is more complex northeast of the Sierran crest where anomalies from near-surface sources are not masked by the effect of underlying changes in crustal thickness. Here gravity anomalies are caused mostly by lateral density contrasts of three types: (1) the contrast between plutonic rocks of the Sierra Nevada batholith and the generally denser rocks of the metamorphic wallrocks and roof pendants (Oliver, 1977, p. 448); (2) the contrast between young sediments and the denser bedrock; and (3) the contrast between the volcanic rocks and the denser plutonic or metamorphic rocks.

The most prominent feature of the prominent gravity low at Twin Lakes seems mostly to reflect the contrast between the relatively plutonic rocks (Cathedral Peak Granodiorite) and the denser metamorphic rocks to the south and north. Gravity stations observed near the level of Twin Lakes are 5 mm closer than the surrounding hilltop stations to the mass deficiency of the batholitic root beneath the Sierra Nevada, and this spatial relation accounts for 2 to 3 mGal of the 13-mGal anomaly. Low-density glacial sediments beneath Twin Lakes probably account for less than 2 mGal of the anomaly, because the gravity effect of the sediments is offset by the elevation of stations between the lakes. The boundary between the western part of the gravity low, which is presumed to reflect the density contrast between plutonic rocks and surrounding metamorphic rocks, and the eastern part of the gravity low, which seems to reflect thickened low-density sediments and volcanic rocks beneath Robinson Creek and Buckeye Creek, is indistinct.

The small gravity high east of Jeno Lake in the central part of the area seems to reflect the density contrast between underlying metamorphic rocks and less dense, plutonic rocks of the Sierra Nevada batholith. The gravity high near Mount Dana in the southeast part of the area, reflects the contrast in density between the underlying north-northwest-elongated band of steeply dipping metamorphic rocks and the surrounding plutonic rocks. Oliver (1977, fig. 5 and p. 454) interprets the southeast extension of this anomaly as the effect of a high-density (2.86 g/cm³) roof pendant.

Many of the outcrops of volcanic rocks occur on relatively thin layers deposited on crystalline rock and, hence, have an insufficient volume to appear as distinct gravity lows. The gravity anomalies in the northwestern part of the area are related to volcanic rocks. The gravity high near Mount Dana mostly reflects the absence of the low-density volcanic rocks that are present elsewhere (W. J. Keith, oral commun., 1980) and the surrounding, less dense volcanic rocks. The major gravity low further to the northeast overlies the Little Walker caldera, which is believed to have collapsed in response to the eruption of the Minaret Eureka Valley Tuff (Bailey and others, 1976).

Gravity data were first obtained near the Little Walker caldera between 1968 and 1970 by students of Stanford University under the direction of N. B. Hinshaw (A. A. Oliver III, unpublished report, 1970). A 16- to 18-mGal gravity low with a steep gradient on its south flank was revealed in the resulting gravity map. A. A. Oliver III reported that the gravity low was caused by a subsurface caldera and implied that the location of Paleo Hot Springs is consistent with the fault at the west edge of the caldera. His two-dimensional models of the gravity anomaly suggested that volcanic rocks with an average density of 2.45 g/cm³ extend to a depth of 1.5 km below the caldera floor.

A minimum thickness of the caldera fill can be estimated by assuming that the caldera is filled with a combination of tuff and sediments with an average density of 2.2 g/cm³. A simple Dietzgarten model (Plouff, 1976) with a composite thickness of 1.4 km nearly can account for the gravity anomaly associated with the Little Walker caldera. The fit of the model to the observed data is not unique, but the depth of the model was selected at 2,200 m (6,562 ft) above sea level so that the tuffs and sediments would nearly reach the surface beneath the Little Walker River. The mass deficiency associated with volcanic rocks or sediments above that elevation are not considered in the model.

INTERPRETATION OF AEROMAGNETIC MAP

General characteristics of map

The residual magnetic map (sheet 2) shows great diversity in the magnetism of rocks underlying the Hoover Wilderness and adjacent study area. The magnetic pattern is further complicated by strong topographic effects. That is, magnetic anomalies that are caused by rocks near the ground surface are commonly strong depressions. The topographic effect exists mostly because a constant ground clearance could not be maintained at normal aircraft speeds in this area of rugged topography. The intense occurrence of pronounced magnetic lows over topographic highs indicates that some of the underlying igneous rocks could with strong remanent magnetization during a time in which the Earth's main magnetic field was reversed.

Some of the following generalizations regarding the relative magnetizations of the plutonic rocks are based on comparisons of the magnetic map with petrographic data by sample data in the Bridgeport Basin and adjacent areas of the Sierra Nevada. Heterolithic rocks are variable in magnetization but usually have a higher magnetization than adjacent metasedimentary rocks or plutonic rocks. Plutonic rocks have greater magnetizations than metasedimentary rocks. More mafic plutonic rocks have greater magnetizations than felsic plutonic rocks. Felsic plutonic rocks have widely varying magnetizations. Magnetization also varies within mapped geologic units in response to local changes of the initial chemical composition and magnetization and of later rock alteration.

Unless otherwise stated, descriptions of specific rock units in the following discussion are provided by Bateman and Wahrhaftig (1966). The locations of principal features discussed are shown on sheet 2 and summarized in figure 1.

Magnetic anomalies southeast of Twin Lakes

The location of the western part of a prominent 3- by 15-km magnetic low near Twin Lakes generally agrees with the location of the western part of a prominent gravity low discussed earlier (compare figs. 1 and 3). The western part of the magnetic low is centered on the contact between the Cathedral Peak Granodiorite and Granodiorite. The east edge of the magnetic low outside the study area reflects the low magnetization of underlying metasedimentary rocks and glacial till (Chesterman, 1973) near the Tamarack sites. Though the metavolcanic rocks along the west edge of Oroter Crest and along the crest of Monument Ridge clearly are magnetic, as indicated by a prominent magnetic high, the magnetic anomaly associated with the part of the large magnetic low occurs over metavolcanic rocks to the north of the local highs. The underlying metavolcanic rocks may form a relatively thin cover over plutonic rocks or metasedimentary rocks, or local rock alteration may have destroyed much of the original magnetite, or, as indicated by the occurrence of the magnetic lows over topographic moats, the rocks may be reversely magnetized.

An apparent southeastward extension of the large magnetic low overlies metasedimentary rocks and glacial till (Chesterman, 1973) and probably reflects metavolcanic rocks in the northeast and rocks beneath Dunnwalds Ridge. The low magnetic trend continues southeastward for several kilometers to a closed magnetic low in the north of Gentoo Peak. The low is bounded to the southeast by a 3-km-diameter magnetic high associated with the granodiorite of Schlitz Lake (plutonic rocks). The magnetic high continues southeastward to a closed magnetic low (which reflect underlying reversely magnetized rocks, is centered along the creekline between Summit Lake and Union Lake. Although this low and a magnetic low centered 3 km to the east-southeast between Rock Mountain and Frog Lakes are formed partly by topographic effects and partly as polarization lows associated with magnetic highs (see discussion of magnetic anomalies in the Hoover Wilderness), they are real and not a result of topography. The location and trend of this belt of magnetic lows along the east margin of the Sierra Nevada batholith generally agree with the location and trend of a gravity high (compare figs. 1 and 3) and with the trend of the Sierra Nevada batholith. Magnetic lows also occur near Mount Warren near the southwest corner of the study area and over the long Cathedral Peak Granodiorite. The rocks at Mount Warren are metasedimentary rocks of low magnetization. Both magnetic lows are mostly polarization lows associated with the large magnetic high to the south, but magnetic lows near Cathedral Peak are probably caused by reversely magnetized rocks.

The magnetization of the plutonic rocks that underlie the gravity and magnetic highs centered south of Lake Vining Peak contrasts sharply with magnetization of the rocks to the north. A 2.5- by 1.5-km northwest-trending outcrop of the gabbro of Mount Warren (Smith and Ockerman, 1981) near the northwest end of the magnetic high may be the source of the magnetic high. Rock samples from the gabbro (collected by the author in 1982) located 1.4 km south of Mount Warren has a measured remanent magnetization of 0.5 A/m, suggesting that the outer part of the gabbro adjacent to the rocks with the large magnetic high also may reflect a greater than normal magnetization of part of the underlying granodiorite of Mono Dome that nearly surrounds the gabbro of Mount Warren, as shown by Smith and Ockerman (1981).

Magnetic anomalies northwest of Twin Lakes

The prominent magnetic gradient generally to the north of Twin Lakes delineates the boundary between a plutonic (Cathedral Peak Granodiorite) with low magnetization to the south and a combination of more magnetic rocks to the north. This gradient forms part of the south edge of a 5-km-diameter magnetic high centered at the north end of Dowdill Ridge. The occurrence of the crest of the magnetic high over the contact between the metamorphic rocks to the south and the plutonic rocks of the granite of Eagle Creek (Keith and Bateman, 1981) indicates that both rocks have about the same magnetization. The magnetic high is bounded on the north by a magnetic low northwest of the Dowdill Ridge magnetic high generally is caused by the topographic effect of increased flight altitude above the valley floor. Therefore, the metamorphic rocks along Platform Ridge to the northwest of Buckeye Creek are associated with magnetic and topographic highs.

The magnetic high at Platform Ridge (Keith and Bateman, 1981) at the northeast end of the southeast segment of Platform Ridge and the Cathedral Peak Granodiorite surrounding Walker Mountain to the west are plutonic rocks of low magnetization, as indicated by associated magnetic lows (fig. 3). A sample of the granite of Devils Gate collected near the hilltop labeled 10413 on Platform Ridge has a moderate measured remanent magnetization of 1.0 A/m, suggesting that the outer part of the pluton adjacent to the metamorphic rocks to the south is more mafic than the rest of the pluton. The magnetic gradient also is steep along the south flank.

The magnetic pattern associated with the granodiorite of Fremont Lake, which covers an extensive part of the study area along Cherry Creek and West Walker River, is characterized by the absence of prominent magnetic highs and by generally lower magnetic intensities compared to the surrounding rocks. Magnetic lows, and hence low magnetizations, are associated with the granite of Upper Twin Lakes and the alaskite of Grace Meadow (Keith and Bateman, 1981) in the westernmost part of the study area. The granodiorite of Bond Pass and the granodiorite of Lake Barrett, however, have relatively high magnetizations between Beatrice Crest and Lake Ruth, as indicated by a prominent magnetic high.

The gabbro of Twin Lakes near the west corner of the study area apparently has reversed magnetization, as indicated by the occurrence of two closed magnetic lows and relatively topographic highs (fig. 3). The Cherry Creek also occurs in metamorphic rocks, which a magnetic gradient along the northwest flank of these magnetic lows. Magnetic anomalies also occur along the contact between the northwest flank of a magnetic low associated with the alaskite of Grace Meadow. The Montenema mine and a prospect 1 km to the south also occur within the magnetic gradient, which therefore northwestward over local magnetic highs along the contact between the granodiorite of Fremont Lake and the metaconglomerate of Conway Lake (Keith and Bateman, 1981).

The heterogeneous magnetic pattern in the northern part of the study area mostly reflects variations in thickness and magnetization of underlying Tertiary volcanic rocks. The most prominent magnetic anomaly in the northern part of the study area is a 900-nanotesla magnetic high about 6 km in diameter, which reaches a peak amplitude near the crest of Mount Dana, and an associated polarization low to the north. A large part of the anomaly is caused by the thick section of volcanic rocks that underlie the Bridgeport Basin (Bateman and Wahrhaftig, 1966); substantial part of the anomaly probably reflects deeper lying igneous rocks beneath this major volcanic center.

The location of the prominent magnetic low centered to the southwest of Paleo Hot Springs agrees with the location of the gravity low (compare figs. 1 and 3) that is caused in part by the low-density fill in the subsurface caldera of Little Walker caldera. C. C. F. Wan (oral commun., 1981) stated that the location of the intense faults mapped along the edge of the caldera agree with the locations of gradients along the edges of the gravity and magnetic anomalies. Wan also stated that the observed occurrence of strongly reversed magnetization in the intracaldera tuff explains the occurrence of the intense central magnetic low. Small magnetic lows in the south and southeast of the caldera also may reflect reversely magnetized volcanic rocks (sheet 2 and fig. 3).

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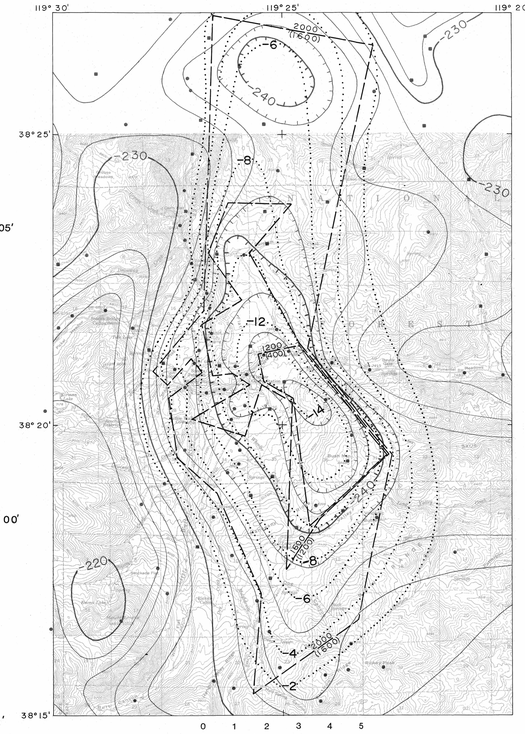

Figure 3.—Gravity effect of caldera model. Light solid lines are Bouguer gravity anomaly contours from sheet 1 supplemented by data from Robbins and Oliver (1976). Darkness indicate closed gravity lows. Dashed lines indicate boundary of model layers. Elevations of top of layers are shown in hundreds of meters. Elevations are meters relative to sea level. Density contrast 0.8 g/cm³. Dotted lines indicate gravity anomaly caused by model of caldera. Contour interval 2 mGal. Dots and squares indicate gravity stations from sheet 1.

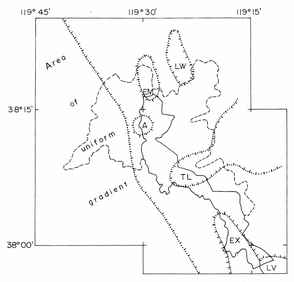

Figure 1.—Localities and gravity anomalies discussed in text. A, Anne Lake; EX, Mount Emma; EX, Excelsior Mountain; LV, Lee Vining Peak; LW, Little Walker caldera; and TL, Twin Lakes. Heavy line indicates Hoover Wilderness boundary; dashed line, boundary of study area. Dotted lines indicate approximate boundaries of gravity anomaly; hachured on side of lower gravity anomaly.

BOUGUER GRAVITY ANOMALY MAP

MAPS SHOWING GRAVITY AND MAGNETIC SURVEYS OF THE HOOVER WILDERNESS AND ADJACENT STUDY AREA, MONO AND TUOLUMNE COUNTIES, CALIFORNIA

By
Donald Plouff

1982

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