Base from U.S. Geological Survey Freel Peak, Markleeville, Topaz Lake, 1956

APPROXIMATE MEAN DECLINATION, 1983

SCALE 1:62500

CONTOUR INTERVAL 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Magnetic map modified from U.S. Geological Survey (1981); geology from Armin and others (1982) and John and others (1981)

AEROMAGNETIC AND GRAVITY MAPS OF THE EAST PART OF THE RAYMOND PEAK ROADLESS AREA, ALPINE COUNTY, CALIFORNIA

By
Donald Plouff
1983

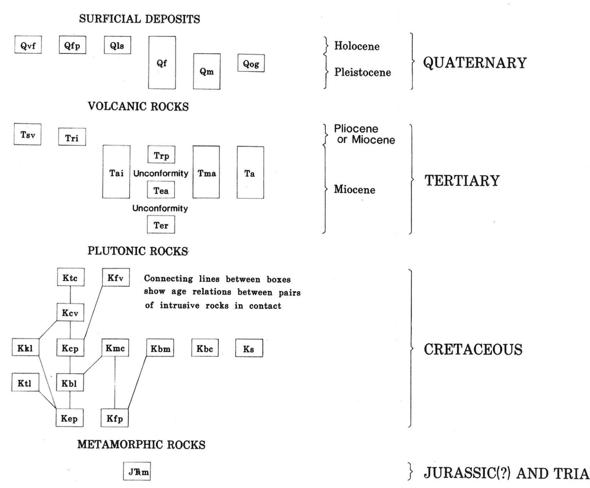
EXPLANATION

MAGNETIC CONTOURS--Showing residual intensity of Earth's magnetic field in nanoteslas (nT) (1 nT = 1 gamma). International Geomagnetic Reference Field updated to the month flown is removed. Arbitrary datum of 5,000 nT is added. Hachured to indicate closed areas of lower magnetic intensity. Contour intervals 20 and 100 nT

FLIGHT PATH--Showing location and spacing of data. Flight elevation 1,000 ft (300 m) mean terrain clearance

MAGNETIC SAMPLE LOCATION--Number refers to data in table 1. Open circle for uncertain location

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Geology from Armin and others (1982)

SURFICIAL DEPOSITS

- Qvf VALLEY-FILL DEPOSITS (HOLOCENE)
- Qfp FLOOD-PLAIN ALLUVIUM (HOLOCENE)
- Qls LANDSLIDE DEPOSITS (HOLOCENE)
- Qf ALLUVIAL FAN DEPOSITS (HOLOCENE AND PLEISTOCENE)
- Qm GLACIAL MORAINE DEPOSITS (PLEISTOCENE)
- Qog OUTWASH GRAVEL DEPOSITS (PLEISTOCENE)

VOLCANIC ROCKS

- Tsv SILICIFIED VOLCANIC ROCKS (EARLY PLIOCENE?)
- Tri INTRUSIVE RHYOLITE, UNDIVIDED (EARLY PLIOCENE OR LATE MIOCENE)
- Tai INTRUSIVE ANDESITE, UNDIVIDED (LATE TO MIDDLE? MIOCENE)
- Trp RAYMOND PEAK ANDESITES OF WILSHIRE (1957) (MIOCENE)
- Tma AUTOBRECCIATED ANDESITE FLOWS OF MARKLEVILLE (MIOCENE)
- Ta ANDESITE, UNDIVIDED (MIOCENE)
- Tea EARLY ANDESITE (MIOCENE)
- Ter EARLY RHYOLITE (MIOCENE)

GRANITIC ROCKS

- Ktc GRANODIORITE OF THORNBURG CANYON (CRETACEOUS)
- Kfv GRANODIORITE OF FAITH VALLEY (CRETACEOUS)
- Kcv GRANODIORITE OF CHARITY VALLEY (CRETACEOUS)
- Kkl GRANODIORITE OF KINNEY LAKES (CRETACEOUS)
- Kcp CARSON PASS TONALITE OF PARKER (1961) (CRETACEOUS)
- Kmc GRANODIORITE OF MILLBERRY CANYON (CRETACEOUS)
- Kbm BRYAN MEADOW GRANODIORITE (CRETACEOUS)
- Kbc GRANODIORITE OF BUCK CREEK (CRETACEOUS)
- Ks ALASKITE OF SILVER CREEK (CRETACEOUS)
- Ktl TAMARACK LEUCO-ADAMELLITE OF PARKER (1961)(CRETACEOUS)
- Kbl BURNSIDE LAKE ADAMELLITE OF PARKER (1961)(CRETACEOUS)
- Kep EBBETTS PASS GRANODIORITE OF PARKER (1961) (CRETACEOUS)
- Kfp GRANODIORITE OF FREEL PEAK (CRETACEOUS)

METAMORPHIC ROCKS

- JTRm METASEDIMENTARY ROCKS (JURASSIC? AND TRIASSIC?)

CONTACT

FAULT--Dashed where inferred or approximately located, dotted where concealed. Bar and ball on downthrown side

AREAS OF MODERATELY TO INTENSELY PROPYLITIZED VOLCANIC ROCKS

STRIKE AND DIP OF BEDS
- Inclined
- Vertical

STRIKE AND DIP OF FOLIATION
- Inclined--Metamorphic and plutonic rocks
- Vertical--Metamorphic and plutonic rocks
- Inclined--Flow foliation in volcanic rocks

APPROXIMATE BOUNDARY OF ROADLESS AREA

STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. 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 President and Congress. This report presents the results of a geophysical survey of the east part of the Raymond Peak Roadless Area (4-985) in the Toiyabe National Forest, Alpine County, California. The west part of the Raymond Peak Roadless Area is included in Plouff and McKee (1981). The Raymond Peak Roadless Area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

INTRODUCTION

The Raymond Peak Roadless Area, 60 mi^2 (153 km^2) in area, is located at the crest of the Sierra Nevada approximately 13 mi (21 km) south-southeast of Lake Tahoe. Markleeville, the seat of Alpine County, lies about 1.5 mi (2 km) outside the northeast boundary of the area. The rugged topography of this area is dominated by Raymond and Reynolds Peaks at the south end, and Hawkins Peak at the north end.

Two kinds of geophysical maps were prepared to aid geologic mapping and mineral appraisal in the area of study. The Bouguer gravity anomaly map and the associated isostatic residual gravity map reflect lateral changes in density of the underlying rocks (fig. 1). The aeromagnetic map reflects lateral changes in magnetization of the underlying rocks. Densities and magnetizations of rock samples from the collection of R. A. Armin and D. A. John were measured for the principal rock types of the area (table 1). Changes of these physical properties are related to changes in rock type, and, consequently, the geophysical maps can be used to aid geologic mapping at the surface and to infer rock types and contacts between rock units beneath the surface. The geologic base shown on the aeromagnetic map is from Armin and others (1982) and John and others (1981), where expanded descriptions of the geologic units are included. Data on the geophysical maps extend beyond the border of the roadless area and beyond the indicated mapped geology, so that the geophysical anomalies in the area of study can be interpreted in relation to the surrounding regional framework.

GRAVITY MAP

Donald Plouff and D. G. Evans established 31 gravity stations in 1979 in the area of study to supplement the existing regional gravity coverage compiled by Robbins and Oliver (1976). The datum of observed gravity for the Bouguer anomaly and isostatic residual gravity maps (fig. 1) is that of the International Gravity Standardization Net of 1971 (IGSN-71) (Morelli, 1974). The theoretical value of gravity at sea level for each station was determined from the Geodetic Reference System formula of 1967 (GRS67) (International Association of Geodesy, 1971). Methods used to obtain the Bouguer and isostatic anomalies and lists of anomalies at gravity stations are in Plouff (1982a).

The regional Bouguer gravity anomaly map (fig. 1A) is dominated within the roadless area by fairly closely-spaced, north-trending contours that generally reflect the distribution of major crustal units associated with the Sierra Nevada batholith. An approximate isostatic correction was subtracted from the Bouguer gravity anomaly at each station in an attempt to reduce the gravity gradients associated with deeper crustal changes so that perception of local gravity anomalies related to upper crustal geology and mineral deposits would be improved. The computer program of Jachens and Roberts (1981) was used to calculate the gravity effect of the mass deficiency within a hypothetical, complexly-shaped crustal downwarp ("root") that compensates for the mass above sea level. Parameters assumed for this isostatic model are a normal crustal thickness at sea level of 15.5 mi (25 km), a topographic density of 2.67 g/cm^3, and a density contrast of 0.4 g/cm^3 at the base of the crust. Elevations for the ground surface were obtained from the same geographic 3- by 3-minute grid used for digital terrain corrections (Plouff, 1977) in the region. The digital portion of the isostatic correction was carried to a distance of 103.6 mi (166.7 km) from each station and the remaining correction to the antipodes was interpolated by the computer program from the worldwide chart of Karki and others (1961).

The magnitude of the isostatic correction is illustrated by an increase in gravity level of 170 to 180 mGal from the Bouguer anomaly to the isostatic residual gravity map (fig. 1). The interfering regional gradient was reduced, as evidenced by a decrease of the anomaly range from about 36 mGal on the Bouguer gravity anomaly map to 28 mGal on the isostatic residual gravity map. Fairly strong regional gradients still persist along the west edge of the roadless area, however. These gradients mostly reflect major intra-crustal density contrasts associated with the Sierra Nevada batholith.

The most prominent anomaly on the isostatic residual gravity map is an east-west trending gravity low centered to the east of the northernmost part of the Raymond Peak Roadless Area (fig. 1B). The gravity low could reflect the density contrast between a basin of volcanic rocks and the surrounding, denser plutonic rocks. The occurrence of prominent north-south trending normal faults (with the down-dropped side toward the east) near the east edge of the roadless area suggests this relationship. The densities for 17 samples of Tertiary rocks collected in the area average of 2.59±0.14 g/cm^3 compared to an average of 2.68±0.03 g/cm^3 for 16 plutonic rock samples (table 1). The measured density contrast of 0.09 g/cm^3 between the two types of rocks, however, is reduced to 0.05 g/cm^3 if the densities of the three rhyolites, which are representative of less than 5 percent of the Tertiary rocks (D. A. John, oral commun., 1982), are omitted from the average.

No tuffs or tuffaceous sediments are present at the surface (Armin and others, 1981; John and others, 1981) to suggest the possibility of an underlying caldera similar to the Little Walker caldera (Noble and others, 1974), which causes a pronounced 15-mGal gravity low located about 20 mi southeast of the area of study (Plouff, 1982b). Though the exact shape of the gravity low is ill-defined because of sparse coverage and uncertain elevation and terrain correction accuracy, the western part of the gravity low apparently extends over plutonic rocks in the roadless area. This relation suggests that the gravity low is not wholly an effect of thickened Tertiary section of extrusive rocks. The low, for example, also may reflect a cupola of an underlying Tertiary batholith concealed beneath a roof of older plutonic rocks and Tertiary volcanic rocks. Part of the density contrast that causes the gravity low then would be the contrast between the Tertiary batholithic rock and denser wallrock.

Two small gravity highs occur to the south of the prominent gravity low (fig. 1B). The western high probably is underlain by a relatively dense pluton such as the nearby granodiorite of Millberry Canyon (table 1), which crops out just north of Grovers Hot Springs. The eastern high is centered just northwest of Colorado Hill. It is inferred that a concealed intrusive body of Tertiary age causes this gravity high. The rocks that compose Colorado Hill are Tertiary intrusive rhyolites (John and others, 1981), but they are intensely altered, have a relatively low density (table 1, samples 9 and 10), and hence are not the source of the gravity high nor an associated magnetic high. A broad but weak gravity low of no particular significance covers the southern half of the Raymond Peak Roadless Area.

AEROMAGNETIC MAP

The aeromagnetic survey was flown at an altitude of 1,000 ft (300 m) above the average terrain along northeast-trending flight lines spaced at intervals of 0.5 mi (0.8 km) (U.S. Geological Survey, 1981). A residual magnetic intensity map was prepared by subtracting the Earth's regional magnetic field at each observation point from the observed magnetic field and then adding an arbitrary constant of 5,000 nT.

Magnetic susceptibilities and remanent magnetizations were measured for one-inch cores from some of the principal Tertiary volcanic and older plutonic rocks of the area (table 1) in order to provide a basis for interpretation of the aeromagnetic map. The data were supplemented by measurements of the physical properties of metamorphic rocks from the Dardanelles Roadless Area to the northwest. Quaternary deposits were not sampled, because they are thin, unconsolidated, and essentially nonmagnetic.

The sample measurements indicate that most of the volcanic and plutonic rocks in the area of study are moderately to strongly magnetic, a conclusion that can also be inferred from the complexity of the aeromagnetic map. The total magnetizations without regard to algebraic sign for 17 samples of Tertiary volcanic rocks average 8±18 A/m (table 1). This average and its large standard deviation were strongly influenced by a value of 75 A/m for an intrusive rock sample and four samples with negligible magnetization. If these samples are omitted, the average total magnetization of 5.5±5.2 A/m still exhibits wide scatter. The direction of magnetization for one of two oriented samples indicated that its direction is reversed relative to the present Earth's field, suggesting the possibility of negative magnetic anomalies caused by underlying rocks with reversed magnetization.

The total magnetizations for 16 samples of plutonic rock average 1.2±1.0 A/m (table 1) and average 1.6±0.5 A/m for 12 samples collected to the northwest in the area of study associated with the Freel and Dardanelles Roadless Areas (Plouff, 1983). (John and others, 1981a). Hence, the magnetizations for plutonic rocks are generally lower and, for a given rock thickness the anomalies associated with plutonic rocks are not expected to be as intense as those related to volcanic rocks. The total magnetization for each of two samples of metamorphic rocks collected by D. A. John in the adjacent area is 3 A/m in directions reversed from that of the present Earth's field. Two other samples of metamorphic rocks have total magnetizations of 0.3 and 0.5 A/m. Qualitative fluxgate magnetometer measurements for 6 samples of metamorphic rock from the adjacent area indicated negligible to weakly normal magnetizations. Hence, the anomalies associated with metamorphic rocks are expected to be magnetic lows.

The aeromagnetic map reflects the diversity in the magnetization of the surface and underlying rocks. Moderate to strong magnetization of most volcanic and plutonic rocks exposed at the surface is exemplified by the ubiquity of strong topographic effects. That is, magnetic maxima ("highs") tend to occur over ridges and hilltops, and minima ("lows") occur over canyons and depressions. The topographic effect is especially strong because a constant ground clearance of 1,000 ft (300 m) could not be safely maintained at normal aircraft speeds in this area of rugged topographic relief. Therefore, the aircraft pilot tended to fly closer to the ground over hilltops than over valleys. The radar altimeter records indicate that the flight level ranged from less than 650 ft (200 m) to greater than 2,450 ft (750 m) above ground level (R. H. Godson, written commun., 1981).

Tertiary andesites have a relatively high magnetization and, hence, underlie narrow magnetic highs of high amplitude over steep hilltops such as Hawkins, Markleeville, and Raymond Peaks. A prominent magnetic low to the northeast of Markleeville Peak suggests that some of the underlying volcanic rocks may be reversely magnetized. This effect may be accentuated, however, because the low appears to be superimposed on a larger, southeast-trending regional magnetic low. Another example of possible reverse magnetization of volcanic rocks occurs 2 mi south of Markleeville at a summit (marked 7070 ft), which has an associated magnetic low and the topographic saddle to the south, which has an associated magnetic high.

It is difficult to identify sites of alteration based on associations with magnetic lows, because the effects of topography and variations in magnetization of the surrounding and deeper-lying rocks tend to conceal the lows. For example, samples 9 and 10 from Colorado Hill 1 mi east of the roadless area typify the intensely altered rocks in the vicinity at the surface and in the Zaca mine (D. A. John, oral commun., 1982). The rock samples are nonmagnetic (table 1). Nevertheless, the effect of an expected magnetic low is masked at Colorado Hill by a magnetic high centered less than 1 mi to the northwest. The magnetic high and a nearly-coincident, previously-mentioned gravity high may reflect the location of an unaltered Tertiary intrusive body at relatively shallow depth beneath Colorado Hill.

The magnetic anomalies over the areas of propylitized volcanic rocks in the southeast part of the Raymond Peak Roadless Area are generally more subdued than over volcanic rocks in other parts of the area. A pronounced magnetic low occurs between the site of Silver Mountain and IXL mine in an area of intense alteration (D. A. John, oral commun., 1982). The low is strongly accentuated, however, by the effect of topography along Silver Creek and IXL Canyon. The magnetic low continues northward from IXL mine along Indian Creek for about 3 mi and more than 1 mi southward from Silver Mountain.

Two magnetic lows about 1.5 mi north of Grovers Hot Springs and near the heads of the Buck Creek and Millberry Canyon drainages may partly be caused by hydrothermal alteration associated with the hydrothermal system that feeds Grovers Hot Springs. Other factors that may produce the complex pattern of magnetic highs and lows in this vicinity are topography, prominent block-faulting, and variations of magnetization including possible reversed magnetization among mapped and underlying plutons. The granodiorite of Millberry Canyon and the granodiorite of Buck Creek are relatively mafic plutons and hence would tend to cause magnetic highs where they are in contact with the less mafic (or more leucocratic) Burnside Lake Adamellite of Parker (1961) or the granodiorite of Freel Peak (D. A. John, oral commun., 1982).

Small magnetic highs are associated with the Carson Pass Tonalite of Parker (1961) about 1 mi southwest of Brewers mine and with the Ebbetts Pass Granodiorite of Parker (1961) near Border Ruffian Flat. A magnetic low is associated with the Tamarack Leuco-adamellite of Parker (1961) near Tamarack Lake. A large, complex magnetic low that extends for about 9 mi northwestward between Raymond Peak and Brewers mine seems to be associated with the underlying granodiorite of Charity Valley, the granodiorite of Kinney Lakes, the granodiorite of Thornburg Canyon, and the Burnside Lake Adamellite of Parker (1961).

The northwestmost part of the complex magnetic low is closely associated with outcrops of metamorphic rocks shown on the geologic map of Armin and others (1981). Therefore, substantial bodies of metamorphic rock with low or possibly reversed magnetization as revealed by the location of the prominent magnetic low, also may underlie thin or weakly magnetized Tertiary and Cretaceous rocks to the southeast in the roadless area. The largest body of metamorphic rock mapped in the area of study is located northeast of a line between the Burnside and Cal-Pine mines. The low magnetizations of the metamorphic rocks and the adjacent Burnside Lake Adamellite of Parker (1961) to the south of this line combine to form a closed magnetic low over and along the northwest extension of that line. The magnetic low is masked at the southeast end of the body of metamorphic rock by a magnetic high to the east that possibly reflects a mafic Tertiary pluton that may underlie Hawkins Peak.

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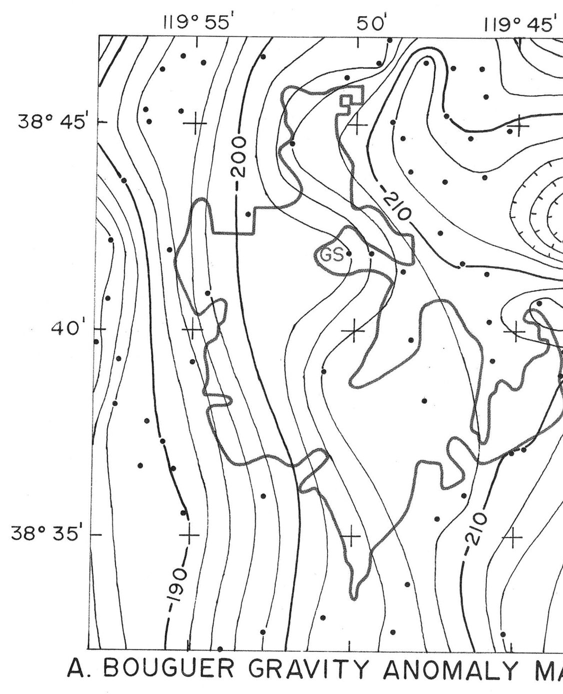
Table 1.--Densities and magnetizations of rock samples

[NC, number of cores from sample. DEN, bulk density in g/cm^3. K, magnetic susceptibility in Standard International Units (siu) times 1,000. S, standard deviation of preceding number. J_i (=KH), induced magnetization in amperes per meter (A/m), assuming that H, the Earth's normal magnetic field, is 41.5 A/m (equivalent to 0.522 oersted). J_r, remanent magnetization in A/m. $J_t = J_i + J_r$, total magnetization in A/m, assuming J_r is parallel to the Earth's magnetic field. $Q = J_r/J_i$. D, declination of magnetization. I, inclination of magnetization. Remanent magnetization measurements by R. F. Sikora and K. S. Grafft.]

Sample locality on map	Geologic map unit	NC	DEN	K	S	J_i	S	J_r	S	J_t	Q
				Volcanic rocks							
1	Tai	2	2.68	24.9	0.6	1.03	0.02	73.8	5.9	74.8	72.
2	Tai	1	2.74	27.1		1.12		4.37		5.5	3.9
3	Ta	2	2.69	22.3	0.6	0.93	0.02	7.12	0.36	8.0	7.7
4A	Ta	1	2.68	17.8		0.74		2.48		3.2	3.3
4B	Ta	1	2.66	17.2		0.72		0.55		1.3	0.8
5	Tea	2	2.74	39.5	1.3	1.64	0.05	1.53	0.55	3.2	0.9
6	Tea	2	2.57	26.4	0.8	1.09	0.03	1.53	0.26	2.6	1.4
7	Tea	2	2.54	0.0	0.0	0.00	0.00	0.00	0.00	0.0	
8	Tea	2	2.67	39.7	1.4	1.65	0.06	0.52	0.00	2.2	0.3
9	Tri	1	2.24	0.0		0.00		0.00		0.0	
10	Tri	1	2.31	0.0		0.00		0.00		0.0	
11A	Tea	2	2.54	16.3	0.1	0.68	0.01	-5.88	3.14	-5.2	8.7
								(D = 128°±19°; I = -30°±5°)			
11B	Tea	1	2.55	12.0		0.50		0.08		12.0	0.2
			(I = -9°, approximately because only top of sample identified)								
12	Tea	1	2.50	27.2		1.13		17.6		18.7	16.
13A	Tea	2	2.71	30.8	0.7	1.28	0.03	0.78	0.02	2.1	0.6
								(D = 212°±2°; I = 62°±1°)			
13B	Tea	1	2.68	33.3		1.38		0.86		2.2	0.6
14	Ter	2	2.55	0.0	0.0	0.00	0.00	0.00	0.00	0.0	
				pre-Tertiary plutonic rocks							
15	Ktc	1	2.66	22.0		0.91		0.12		1.0	0.1
16	Ktc	2	2.66	17.2	0.3	0.71	0.01	0.15	0.03	0.9	0.2
17	Ktc	2	2.65	14.9	0.3	0.62	0.01	3.67	0.05	4.3	5.9
18	Ktc	2	2.65	16.9	0.6	0.70	0.02	0.07	0.00	0.8	0.1
19	Kfv	2	2.70	17.6	1.1	0.73	0.04	0.51	0.04	1.2	0.7
20	Kcv	2	2.64	0.3	0.1	0.00	0.00	0.00	0.00	0.0	0.2
21	Kcv	2	2.68	26.7	1.7	1.11	0.07	0.19	0.03	1.3	0.2
22	Kcv	2	2.66	17.1	2.1	0.71	0.09	0.12	0.04	0.8	0.2
23	Kcv	2	2.66	19.6	1.6	0.81	0.07	0.08	0.02	0.9	0.1
24	Kkl	2	2.69	26.1	2.8	1.08	0.12	0.21	0.01	1.3	0.2
25	Kkl	1	2.71	28.8		1.20		0.14		1.3	0.1
26	Kcp	1	2.71	41.5		1.72		0.28		2.0	0.2
27	Kcp	2	2.72	24.0	4.6	1.00	0.19	0.43	0.07	1.4	0.4
28	Kmc	2	2.73	28.1	2.3	1.17	0.10	0.21	0.05	1.4	0.2
29	Kmc	2	2.72	20.7	0.9	0.86	0.04	0.13	0.03	1.0	0.1
30	Kep	2	2.65	0.2	0.0	0.01	0.00	0.05	0.00	0.1	5.4



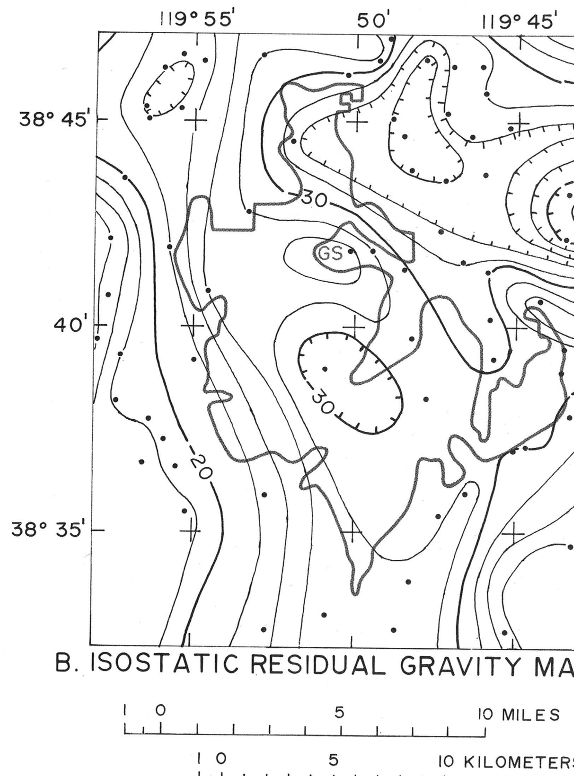
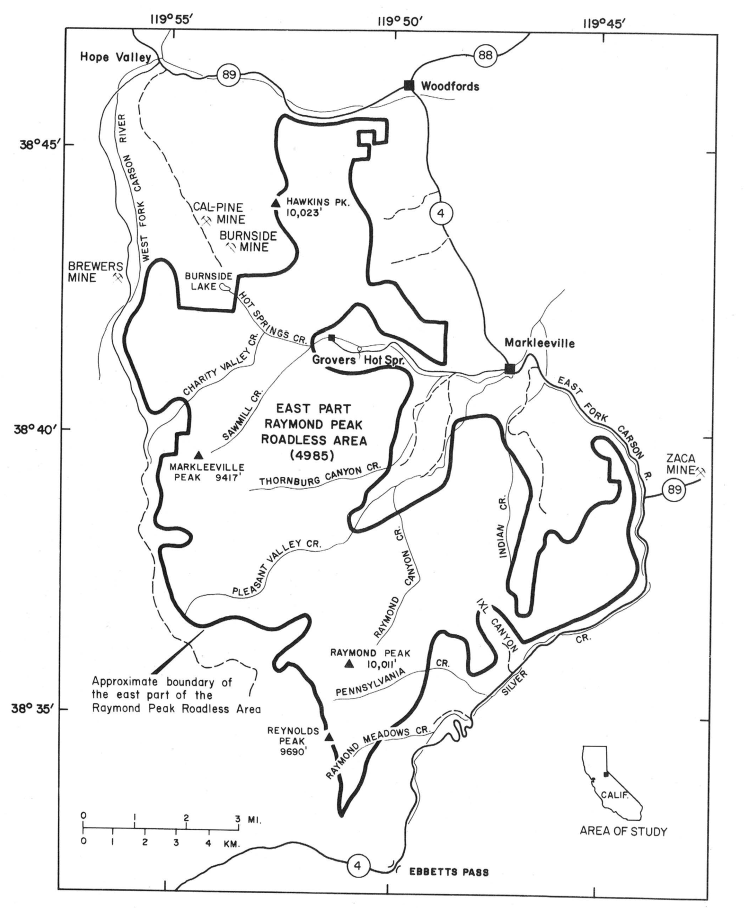


Figure 1.--Regional gravity maps. A. Bouguer gravity anomaly map. B. Isostatic residual gravity map. CH, Colorado Hill. GS, Grover Hot Springs. Heavy line, approximate boundary of roadless area. Dots indicate locations of gravity observations. Reduction density, 2.67 g/cm^3. Hachures indicate closed gravity lows. Contour interval, 2 mGal.



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Interior—Geological Survey, Reston, Va.—1983

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