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U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

GRAVITY AND MAGNETIC ANOMALIES IN THE VICINITY OF YUCCA MOUNTAIN AND THEIR GEOLOGIC IMPLICATIONS

By

D.A. Ponce and H.W. Oliver

Open-File Report 96-662

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ABSTRACT

Gravity and magnetic maps compiled for southwest Nevada reveal important geologic features of an area that includes a potential nuclear waste disposal site at Yucca Mountain. High-amplitude gravity lows characterize major valleys and nonresurgent calderas in the study area, whereas gravity highs reflect Paleozoic rocks at or near the surface. Short-wavelength magnetic anomalies reflect volcanic rocks in the study area, and high-amplitude magnetic highs are associated with known or inferred plutonic rocks. Magnetic anomalies also correlate with cinder cones in Crater Flat and northwest of the town of Amargosa Valley. Isolated magnetic anomalies south of the town of Amargosa Valley may reveal the presence of buried volcanic centers.

INTRODUCTION

The study area, about 110 km northwest of Las Vegas, includes a potential nuclear waste disposal site at Yucca Mountain (fig. 1). Surface outcrops consist predominantly of Tertiary silicic volcanic and intrusive rocks (fig. 2). Precambrian rocks, consisting of the Johnnie Formation and Stirling Quartzite primarily crop out in the easternmost part of the study area in the Halfpint Range. Paleozoic rocks crop out near the central part of the study area in an arcuate band in the Eleana Range, at Syncline Ridge, and at Mine Mountain. Paleozoic rocks also occur in the Striped Hills, Specter Range, and northeast of Mercury. At the southwest edge of the map, Paleozoic rocks crop out at Bare Mountain. Rocks of Mesozoic age are represented by scattered granitic plutons that include quartz monzonite stocks in the northern end of Yucca Flat. Rocks of Tertiary age mostly consist of voluminous ash-flow tuffs that range in age from about 26 to 7 Ma (Ekren, 1968). Two small exposures of Tertiary granitic rocks occur northwest of Wahmonie.

GRAVITY AND MAGNETIC MAPS

Isostatic gravity (Ponce and others, 1988) and aeromagnetic maps (Kirchoff-Stein and others, 1989) of the study area (fig. 1) have been compiled at a scale of 1:100,000. The isostatic gravity map (fig 3) is controlled by about 16,000 gravity stations reduced using a Bouguer reduction density of 2.67 g/cm^3. A regional isostatic gravity field was removed from the gravity anomalies by assuming an Airy-Heiskanen model for isostatic compensation of topographic loads (Simpson and others, 1983). On the basis of seismic refraction data, this model assumed a crustal density of 2.67 g/cm^3, a normal crustal thickness at sea-level of 25 km, and a density contrast across the base of the model crust of 0.4 g/cm^3. In addition, an isostatic gravity map reduced using a Bouguer reduction density of 2.20 g/cm^3 (fig 4) was compiled to aid in the interpretation of areas covered by relatively lower-density volcanic rocks. An aeromagnetic map of the study area was compiled by merging eight separate aeromagnetic surveys (fig 5). Each survey was compiled and merged by Kucks and Hildenbrand (1987), as part of a statewide aeromagnetic data compilation of Nevada (Hildenbrand and Kucks, 1988). Each data set was gridded at a 1-km interval, and either upward or downward continued to 305 m above the ground. Because of the large grid interval and the merging and continuation processes, caution was exercised in interpreting local anomalies and anomalies that cross survey boundaries.

GRAVITY ANOMALIES

The isostatic gravity map (fig 3) shows a range of values from -65 mGal over Silent Canyon caldera, the lowest value in Nevada, to +14 mGal over Bare Mountain in the southwest corner of the study area. Major negative gravity values occur over the Timber Mountain caldera moat (-42 mGal), Yucca Mountain (-38 mGal), and Emigrant Valley (-40 mGal). Significant gravity highs with amplitudes of +6 to +10 mGal are associated with Paleozoic argillites and carbonate rocks.

Major valleys in the study area, which include Emigrant Valley, Yucca Flat, and Frenchman Flat, are characterized by high-amplitude gravity lows that reflect thick alluvial basins. These gravity lows are caused by large density contrasts between basement rocks and lower-density basin fill. In addition, calderas are characterized by moderate- to large-amplitude gravity lows that reflect lower-density volcanic rocks, or superimposed local gravity highs that reflect higher-density resurgent domes.

The gravity low associated with the Silent Canyon caldera is one of the most conspicuous gravity features in Nevada. A large-amplitude elliptical gravity low trending N. 35° E. is associated with the caldera. The gravity low over Silent Canyon caldera extends southward into the northern part of the younger Timber Mountain caldera, suggesting that the Timber Mountain caldera overlies the southern part of the Silent Canyon caldera. In contrast to the major low over the Silent Canyon caldera, a nonresurgent caldera, a local gravity high of about 8 mGal in amplitude occurs over a resurgent dome in the central part of the Timber Mountain caldera (fig. 4) (Kane and others, 1981). A gravity high dominates the Black Mountain caldera in the northwest corner of the study area (fig. 3) and has an amplitude of about 6 mGal. The Oasis Valley and Sleeping Butte caldera segments are characterized by gravity gradients with lows to the east, and the Claim Canyon caldron segment (fig. 1) is overlain by a local gravity high.

South of Timber Mountain, a local gravity low with an amplitude of about 30 mGal occurs over Crater Flat. Gravity data indicate that Tertiary volcanic rocks thicken toward Crater Flat, to a depth of about 3,000 to 4,000 m. A part of the gravity low extends east to Yucca Mountain in a narrow east-west zone near Drill Hole Wash indicating the presence of a structural basement low. This structural low may influence ground-water movement within the Yucca Mountain area. Along the east edge of Yucca Mountain, a gravity high reflects pre-Cenozoic rocks near the surface at a depth of about 1,100 to 1,400 m. Drilling confirmed the presence of Paleozoic rocks at a depth of 1,244 m (Carr and others, 1986).

MAGNETIC ANOMALIES

Aeromagnetic data are useful for estimating depth to magnetic basement and locating and delimiting plutons, calderas, and faults. One of the most conspicuous aeromagnetic anomalies is a large amplitude magnetic high over Climax stock in the northeastern part of the area (fig. 5). This magnetic high is part of a regional magnetic trend in the northern part of the study area that includes magnetic highs over intrusive rocks at Gold Meadows and Twinridge stocks, Pahute Mesa, and Black Mountain (Bath and others, 1983).

In the northern part of Timber Mountain, aeromagnetic highs are associated with upper parts of the Ammonia Tanks Member of the Timber Mountain Tuff. In the southern part of Timber Mountain, magnetic anomalies are of lower amplitude, and negative or no anomalies occur over the lower parts of the Ammonia Tanks Member. In the central part of the Timber Mountain caldera and along the southeastern part of Timber Mountain, the magnetic relationship of the upper and lower parts of the Ammonia Tanks Member appears to be reversed, indicating that the magnetic properties of these rocks have been altered by heating (see Kane and others, 1981).

Another conspicuous feature of the aeromagnetic map is a large amplitude high at Calico Hills, in the south-central part of the study area (fig. 5). Although a part of the anomaly probably reflects a pluton at depth, strongly magnetized argillite of the Eleana Formation is the principal cause of the anomaly (Snyder and Oliver, 1981). Farther east, at Wahmonie, a relatively large amplitude magnetic high occurs south of two exposures of granitic rocks, each of which are locally associated with magnetic anomalies. This indicates that the larger anomaly is also related to a granitic intrusion (Ponce, 1984). An aeromagnetic survey flown at a barometric elevation of 2,450 m (Boynton and Vargo, 1963a,b) shows that magnetic anomalies at Calico Hills and Wahmonie occur along the distal eastern parts of a southeast-trending magnetic high across the study area.

Circular magnetic anomalies in Crater Flat and northwest of the town of Amargosa Valley (formerly Lathrop Wells) correlate to known cinder cones. In addition, similarly shaped anomalies occur over alluvium in the Amargosa Valley, including an anomaly just south of the town of Amargosa Valley. These anomalies may be related to buried basaltic volcanic centers.

In summary, gravity and magnetic studies in southwest Nevada reveal important geologic features of an area that includes a potential nuclear waste disposal site at Yucca Mountian. These studies are particularly useful for delineating calderas, volcanic centers, granitic intrusions, and basement rocks. In addition, these studies show that the eastern part of Yucca Mountain is located at the east edge of a large depression in the pre-Tertiary basement rocks.

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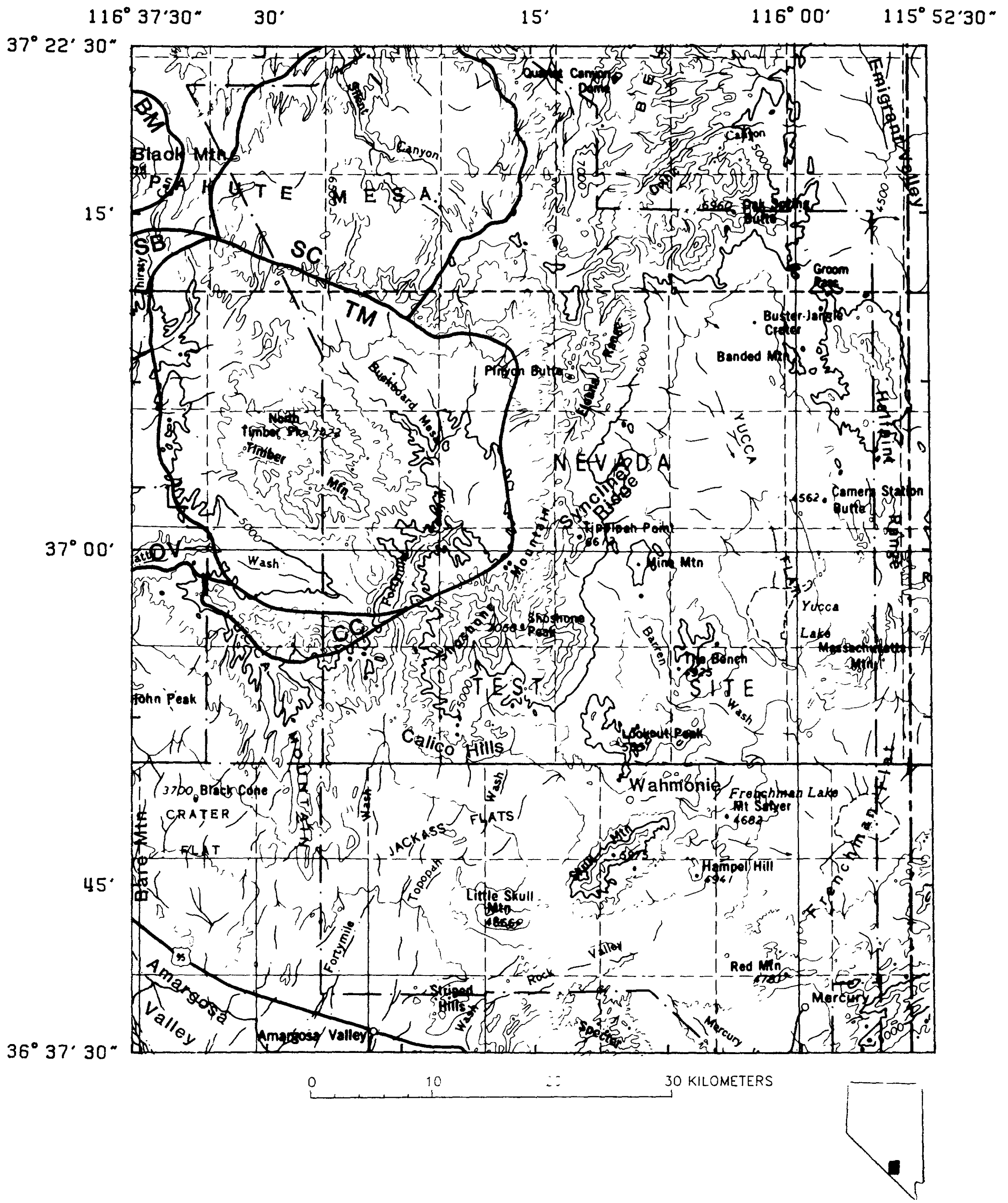

Figure 1. Index map of study area showing approximate boundaries of calderas (after Byers and others, 1976, fig. 1). BM, Black Mountain caldera; CC, Claim Canyon caldron segment; OV, Oasis Valley caldera segment; SB, Sleeping Butte caldera segment; SC, Silent Canyon caldera; TM, Timber Mountain caldera.

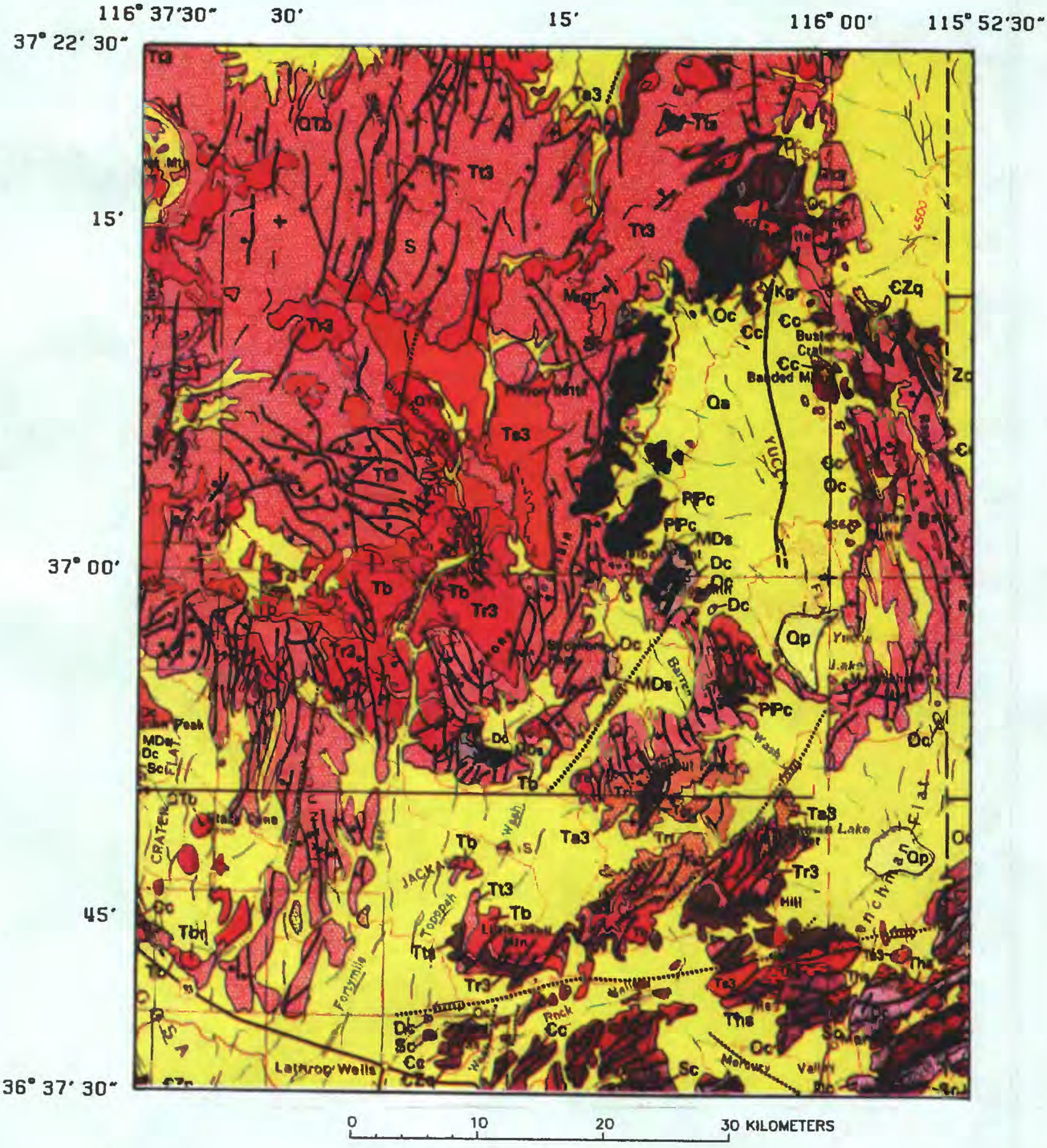

Figure 2. Geologic map of study area. Modified from Stewart and Carlson (1978).

DESCRIPTION OF MAP UNITS

- **Qa** ALLUVIAL DEPOSITS—Locally includes beach and sand dune deposits
- **Qp** PLAYA, MARSH, AND ALLUVIAL-FLAT DEPOSITS, LOCALLY ERODED
- **QTb** BASALT FLOWS—Locally includes maar deposits
- **Tri** RHYOLITIC INTRUSIVE ROCKS
- **Tr3** RHYOLITIC FLOWS AND SHALLOW INTRUSIVE ROCKS
- **Ta3** ANDESITE AND RELATED ROCKS OF INTERMEDIATE COMPOSITION—Flows and breccias
- **Tba** ANDESITE AND BASALT FLOWS—Mostly in ~17 to ~6 m.y. age range. In Humboldt County, locally includes rocks as old as 21 m.y. May include rocks younger than 6 m.y. in places
- **Tb** BASALT FLOWS
- **Tbr** BRECCIA—Volcanic, thrust, and jasperoid breccia and landslide megabreccia
- **Tt3** WELDED AND NONWELDED SILICIC ASH-FLOW TUFFS—Locally includes thin units of air-fall tuff and sedimentary rock
- ASH-FLOW TUFFS, RHYOLITIC FLOWS, AND SHALLOW INTRUSIVE ROCKS
- **Tr3** RHYOLITIC FLOWS AND SHALLOW INTRUSIVE ROCKS
- **Ta3** ANDESITE AND RELATED ROCKS OF INTERMEDIATE COMPOSITION—Flows and breccias
- ASH-FLOW TUFFS AND TUFFACEOUS SEDIMENTARY ROCKS
- **Ts3** TUFFACEOUS SEDIMENTARY ROCKS—Locally includes minor amounts of tuff
- **Ths** HORSE SPRING FORMATION—Tuffaceous sedimentary rocks, southern Nevada

PLUTONIC ROCKS

- **Tgr** GRANITIC ROCKS—Mostly quartz monzonite and granodiorite
- **Mgr** GRANITIC ROCKS, WESTERN NEVADA (Mesozoic)—Mostly quartz monzonite and granodiorite. Inconclusively dated or not dated radiometrically.
- **Kgr** GRANITIC ROCKS—Mostly quartz monzonite and granodiorite

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- LIMESTONE AND SPARSE DOLOMITE, SILTSTONE, AND SANDSTONE (Lower Pennsylvanian to Lower Permian)—Includes units such as undivided Riepe Spring Limestone of Steele (1960) and Ely Limestone or their equivalent in Elko, White Pine, and northern Lincoln Counties and most of the Bird Spring Formation and Callville Limestone in Clark and southern Lincoln Counties. Includes some stratigraphically higher Permian rocks in Leppy Peak, easternmost Elko County
- SHALE, SILTSTONE, SANDSTONE, CHERT-PEBBLE CONGLOMERATE, AND LIMESTONE—Includes units such as Pilot Shale, Joana Limestone, Chainman Shale, and Diamond Peak Formation in northern and eastern Nevada and Narrow Canyon Limestone, Mercury Limestone, and Eleana Formation in southern Nevada
- **Dc** DOLOMITE, LIMESTONE, AND MINOR AMOUNTS OF SANDSTONE AND QUARTZITE—Includes units such as Sevy and Simonson Dolomites, Guilmette and Nevada Formations, and Devils Gate Limestone
- DOLOMITE—Includes units such as Laketown and Lone Mountain Dolomites. Locally includes rocks of Early Devonian age at top
- **Oc** LIMESTONE, DOLOMITE, SHALE, AND QUARTZITE—Includes units such as Pogonip Group, Eureka Quartzite, and Ely Springs Dolomite. Where Ely Springs Dolomite or equivalent rocks are included in SOc unit, this unit includes only the Pogonip Group and Eureka Quartzite or their equivalents
- **Ꞓc** LIMESTONE AND DOLOMITE, LOCALLY THICK SEQUENCES OF SHALE AND SILTSTONE—Includes units such as Pioche Shale, Eldorado Dolomite, Geddes Limestone, Secret Canyon Shale, Hamburg Dolomite, Dunderberg Shale, and Windfall Formation of northern Nevada and Carrara, Bonanza King, and Ñopah Formations of southern Nevada
- QUARTZITE AND MINOR AMOUNTS OF CONGLOMERATE, PHYLLITIC SILTSTONE, LIMESTONE, AND DOLOMITE—Includes Prospect Mountain Quartzite, Osgood Mountain Quartzite, and Gold Hill Formation in northern Nevada and Stirling Quartzite, Wood Canyon Formation, and Zabriskie Quartzite in southern Nevada
- **Zqs** QUARTZITE, PHYLLITIC SILTSTONE, CONGLOMERATE, LIMESTONE, AND DOLOMITE—Includes McCoy Creek Group (excluding Stella Lake Quartzite) of Misch and Hazzard (1962) in east-central Nevada and Johnnie Formation in southern Nevada

- Contact
- High-angle fault—Dashed where inferred or uncertain; dotted where concealed. Bar and ball on downthrown side
- Low-angle fault—Dashed where inferred or uncertain; dotted where concealed. Sawteeth on upper plate
- Strike-slip fault—Dashed where inferred or uncertain; dotted where concealed. Arrows indicate relative movement

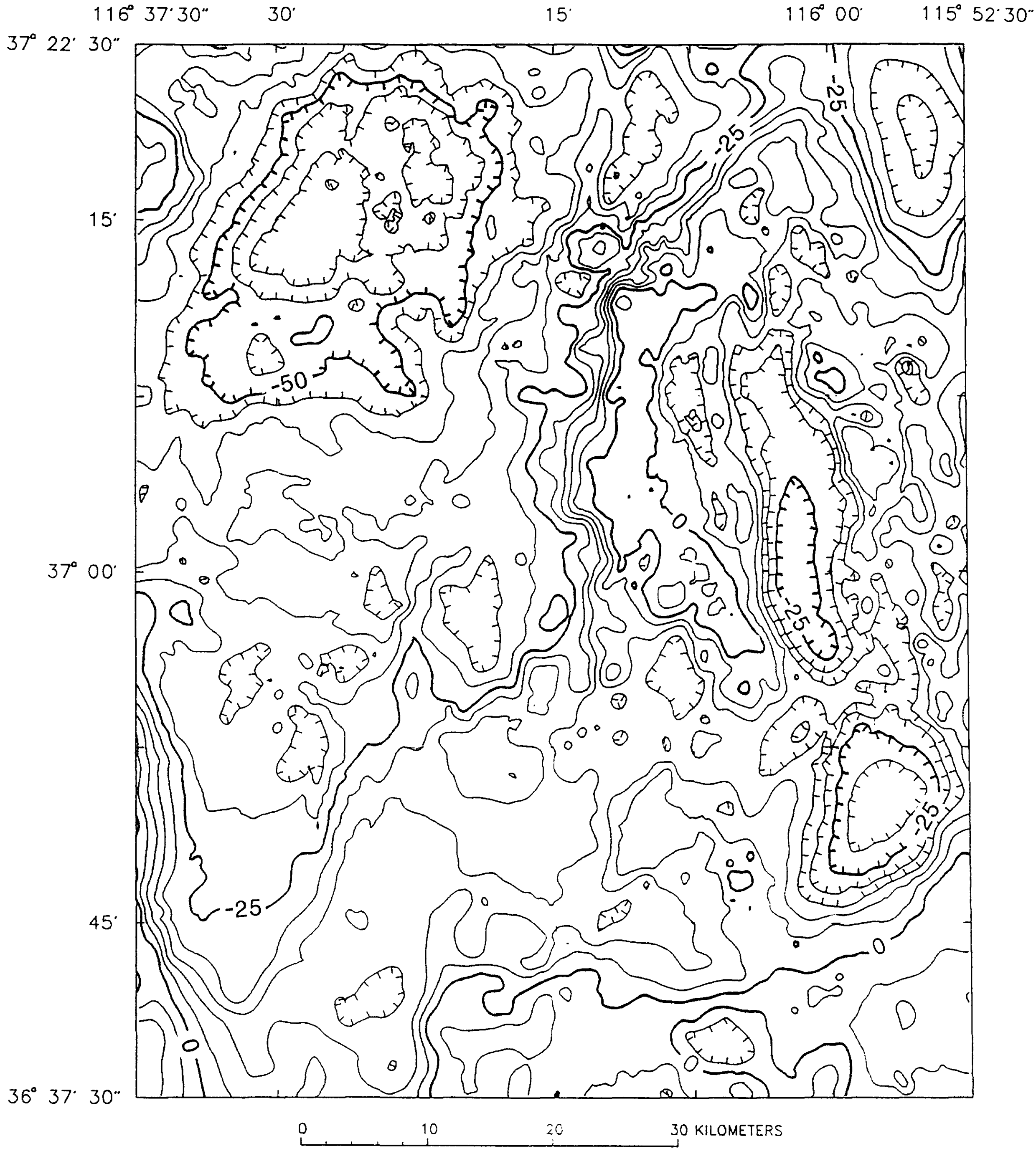

Figure 3. Isostatic gravity map. Isostatic corrections are based on an Airy-Heiskanen model of isostatic compensation, with an assumed crustal density of 2.67 g/cm^3, a crustal thickness at sea level of 25 km, and a density contrast across the base of the model crust of 0.4 g/cm^3. Contour interval 5 mGal.

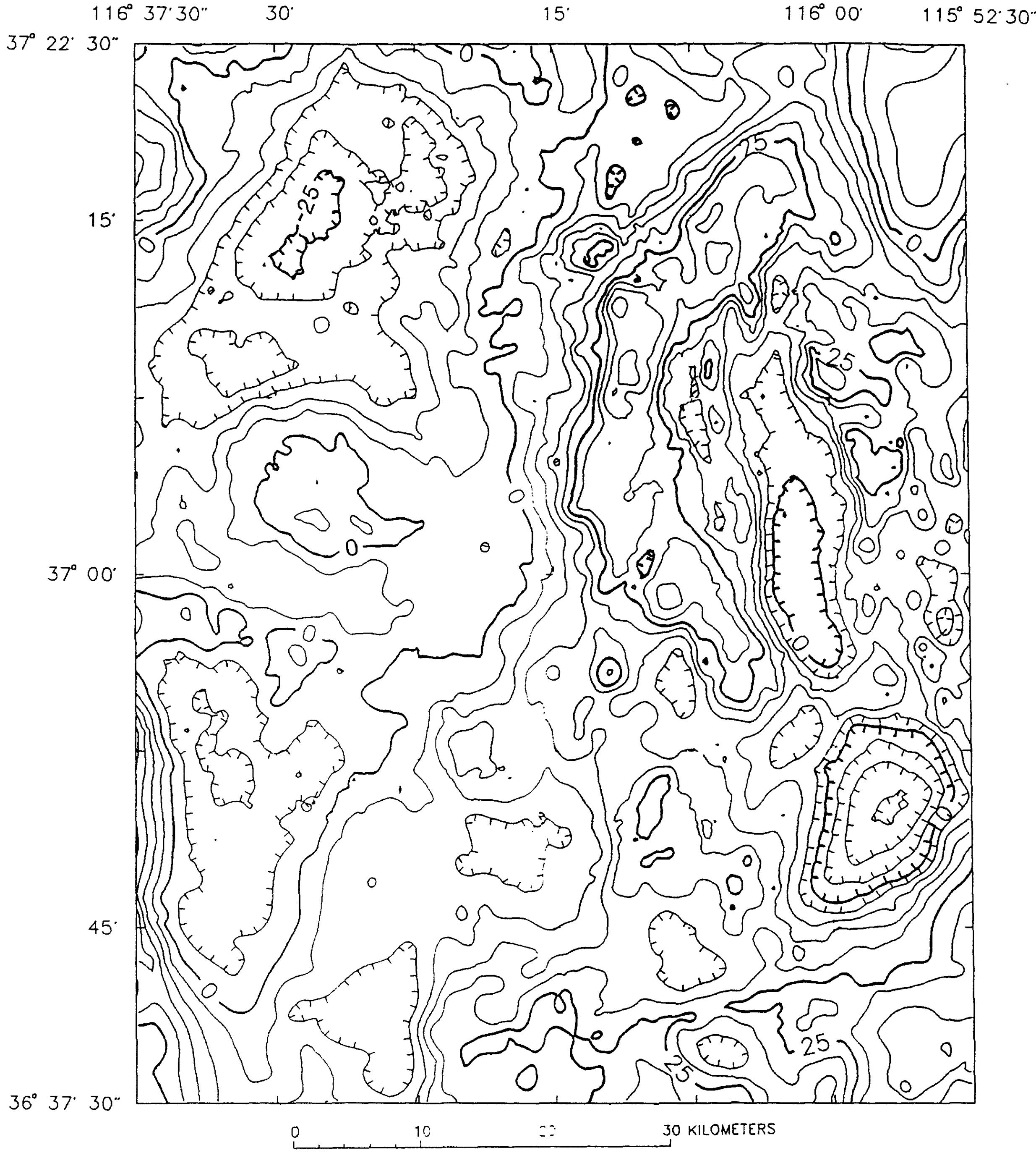

Figure 4. Isostatic gravity map reduced for a density of 2.20 g/cm^3. Contour interval 5 mGal.

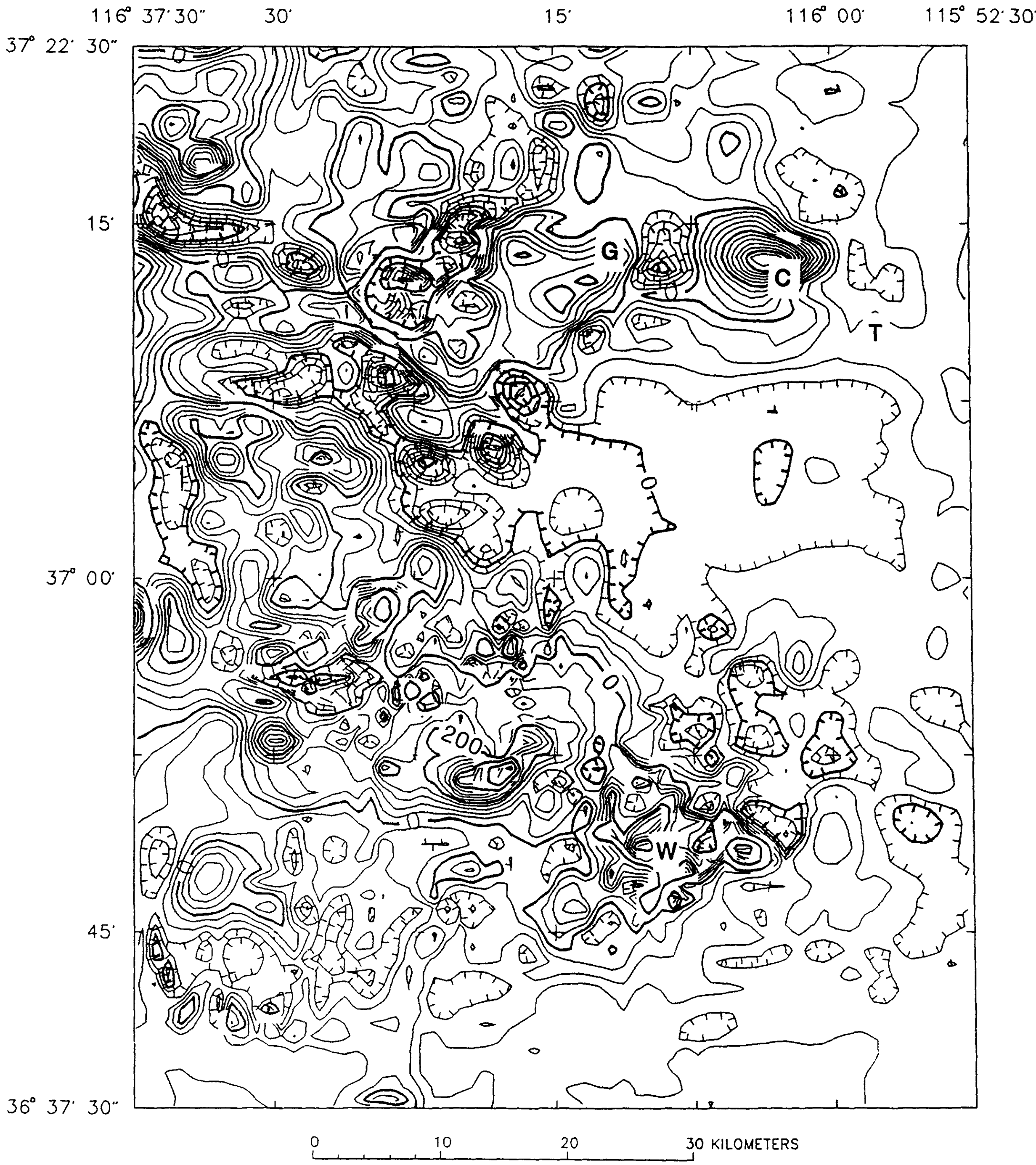

Figure 5. Aeromagnetic map. Contour interval 40 nT (1 nT = 1 gamma). C, Climax stock; G, Gold Meadows stock; T, Twinridge stock; W, Wahmonie.