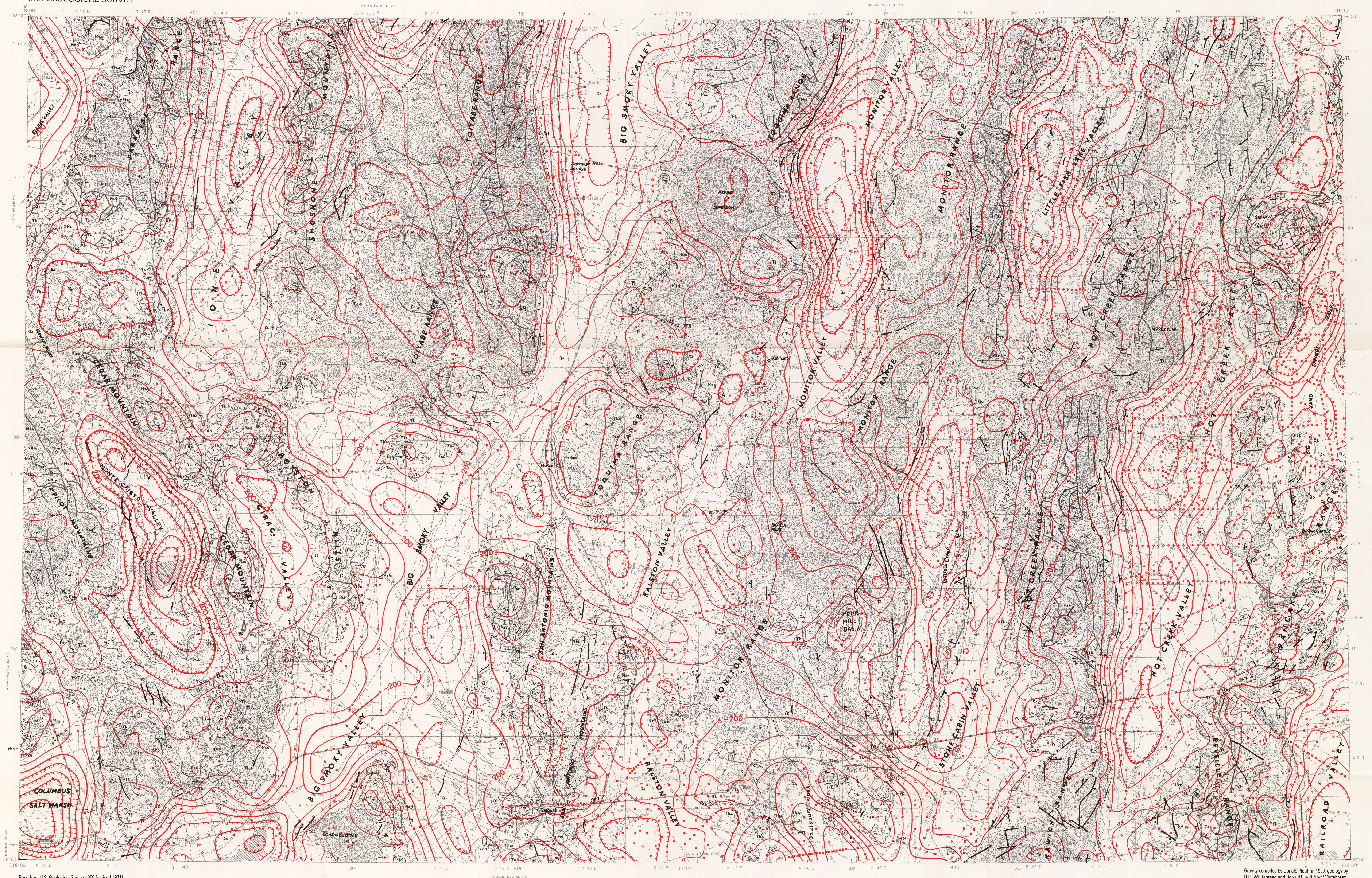
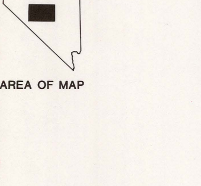


SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS



Bouguer gravity and anomaly map

EXPLANATION

Bouguer gravity anomaly contours—Reduction density 2.67 g/cm^3. Terrain corrections to 167 km. Hachures indicate closed gravity low. Contour interval 5 mGal. Grid interval for contouring, 800m

Gravity station—Diamond indicates location near bench mark, surveyed elevation, or spot elevation; square indicates location where elevation or location is less certain, for example, elevation established by altimetry or topographic contour interpolation

CORRELATION OF MAP UNITS

Qa, Ts; Qb, Tba, Ta; Tt, TMzt; Tr; Tg — QUATERNARY, TERTIARY — CENOZOIC
Mzg — MESOZOIC
MzPzm; Mzs, Pzs, Zs — MESOZOIC, PALEOZOIC, LATE PROTEROZOIC

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

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

INTRODUCTION

These gravity maps are 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 of the folio is designated by a different letter symbol, starting with A, in the MF-1877 folio. The quadrangle encompasses an area of about 19,500 km^2 in the west central part of Nevada.

The set of gravity data consists of 4,185 observation points. Plouff (1990b) described data sources, base stations, reduction and compilation methods, and the accuracy of the data. Principal facts for the gravity data are listed in tables and are in digital format on a magnetic diskette. That report incorporates and partly supersedes principal facts published by Healey and others (1980), Saltus and others (1981), and Bol and others (1983).

A 4-minute band of gravity data obtained from Plouff (1982) and Saltus (1988b) for the area surrounding the Tonopah quadrangle provided sufficient data coverage to contour Bouguer gravity anomalies to the edges of the Tonopah quadrangle (sheet 1). This map supersedes the gravity map published by Healey and others (1981). Values of observed gravity were tied to the International Gravity Standardization Network of 1971 (Morelli, 1974). Theoretical gravity at sea level was determined by using the Geodetic Reference System, 1967 formula (International Association of Geodesy, 1971, p. 60). The standard free-air formula (Swick, 1942, p. 65) and a standard reduction density of 2.67 g/cm^3 were used. Corrections for the Earth's curvature and terrain were calculated to a standard distance of 166.7 km. These parameters were selected so that the Bouguer gravity anomaly map merges with previously published gravity maps (Plouff, 1987; and Saltus, 1988a).

A residual isostatic gravity map (sheet 2) was prepared so that the regional effect of isostatic compensation present on the Bouguer gravity anomaly map (sheet 1) would be minimized. Isostatic corrections based on the Airy-Heiskanen system (Heiskanen and Vening Meinesz, 1958, p. 135-137) were estimated by using 3-minute topographic digitization and applying the method of Jachens and Roberts (1981). Parameters selected for the isostatic model were 25 km for the normal crustal thickness at sea level, 2.67 g/cm^3 for the density of the crust, and 0.4 g/cm^3 for the contrast in density between the crust and the upper mantle. These parameters were selected so that the isostatic residual gravity map would be consistent with isostatic residual gravity maps of the adjacent Walker Lake quadrangle (Plouff, 1987) and the state of Nevada (Saltus, 1988c).

DISCUSSION

GENERAL FEATURES

Previous interpretations of gravity surveys in the quadrangle were made by Erwin (1968), Ekren and others (1973; and 1974), and Brem and Snyder (1983). Although new stations were added and numerous revisions and deletions were made for the data shown on the Bouguer gravity anomaly map of Healey and others (1981), the approximate shapes of the principal anomalies are qualitatively similar to anomalies on the present gravity map (sheet 1). Therefore, the qualitative part of the interpretation of the Bouguer gravity anomaly map by Snyder and Healey (1983) is unchanged. Interpretation of gravity anomaly data is a standard method that was used to help to evaluate the mineral potential of localities in the Tonopah quadrangle (Diggles and others, 1986; Brooks and others, 1987; Hardyman and others, 1987; John and others, 1987; Brem and others, 1991). The present interpretation of the isostatic residual gravity map (sheet 2) refers to the accompanying simplified geologic base (from Whitebread, 1986).

The most conspicuous regional features on the gravity maps are broad gravity highs in mountain ranges and large gravity lows in basins. Gravity lows in basins mostly reflect the thickness and relatively low densities of sedimentary deposits, including interbedded volcanic rocks, in contrast to denser bedrock surrounding basins. Predominantly north-south elongation of gravity highs and lows along the strikes of ranges and valleys characterize the effect of basin-range faulting, which is generally interpreted to be an effect of regional east-west extension (for example, Stewart, 1978). Linear gravity contours that reflect locations of vertical offsets of basement along normal fault zones are conspicuous between the Paradise Range and Ione Valley, between the Toiyabe Range and Big Smoky Valley, between northern Cedar Mountain and Monte Cristo Valley, between Royston Hills and Big Smoky Valley, along the east edge of Lone Mountain, along the west edge of the San Antonio Mountains, along both edges of the central part of Monitor Valley, along the west edge of Little Fish Lake Valley, along the edges of west Stone Cabin Valley (Willow Creek), along the west edge of the southern part of Hot Creek Valley, along both edges of the north part of Big Sand Springs Valley, and along the west edge of Railroad Valley.

GRAVITY HIGHS OVER PRE-CENOZOIC ROCKS

Gravity highs conform to the extent of exposed Paleozoic rocks in the northeastern and southeastern parts of the Toiyabe Range, the northern and central parts of the Toquima Range, the east edge of the northern part of the Monitor Range, and most of the Hot Creek Range. Based on extents of gravity highs, subsurface continuations of mapped Paleozoic rocks at shallow depth are inferred beyond outcrops of Paleozoic rocks in the northern part of the Shoshone Mountains, along and to the southeast of the south edge of the Toiyabe Range, in the southern part of Cedar Mountain, in the Royston Hills, in the northern part of Lone Mountain, in the central and northeastern parts of the San Antonio Mountains, in the eastern part of the San Antonio Mountains, in the south and central parts of the Toquima Range, 8 km south of Belmont, 20 km east of Belmont in the central part of the Monitor Range, east of Saulsbury Wash, in the Reveille Range, and north of the Squaw Hills (northeast of the north edge of Hot Creek Valley). Alternatively, the gravity high east of Saulsbury Wash may reflect an underlying Tertiary intrusive center, inasmuch as Tertiary intrusive rocks (John, 1987) crop out near the crest of the gravity high. A narrow aeromagnetic high, which forms part of a northeast-trending, 5- by 10-km aeromagnetic high (Plouff, 1990a) over the northwest part of the gravity high, is associated with exposed Tertiary intrusive rocks.

Gravity highs are correlated with Mesozoic rocks in the Paradise Range, the northern part of Cedar Mountain, the Pilot Mountains, and the central part of the Shoshone Mountains. Interpreting ages and rock types for rocks concealed beneath surficial Cenozoic deposits is uncertain for gravity highs centered west of Four Mile Basin near the southern part of the Monitor Range, between the central parts of west Stone Cabin (Willow Creek) and east Stone Cabin Valleys, and between the Reveille and Pancake Ranges.

Spacings of observation points generally are too wide in mountainous areas, or the contacts have too shallow a dip, to determine depths to contacts between basement rocks and less dense Cenozoic rocks on the basis of gravity interpretation. Gravity data coverage, however, is sufficiently dense to reveal steeply dipping contacts between basement rocks and Cenozoic rocks at the following locations: near the west edge of basement rocks exposed along the east edge of the Toiyabe Range; over wall rocks at the periphery of the caldera near Mount Jefferson in the Toquima Range; at the edges of a gravity high near the south edge of the Toquima Range near Tonopah; along the northeast edge of a gravity low associated with a caldera in the Monitor Range to the northeast of Big Ten Peak; near Squaw Hills northeast of Hot Creek Valley; near the highway between the Hot Creek and Kawich Ranges; and near Nevada Highway 25 between the Reveille and Pancake Ranges.

CALDERAS

Snyder and Healey (1983, pl. 1) delineated calderas in the Tonopah quadrangle on the basis of geologic mapping and interpretation of gravity lows. Conspicuous gravity lows are found over areas covered by Tertiary tuff or rhyolite in the Toiyabe, Toquima, Monitor, and Kawich Ranges. A gravity low is present over a veneer of Quaternary basalt in the Pancake Range. Calderas can be formed by the collapse of roof rocks into underlying magma reservoirs, which were partly evacuated in response to an explosive eruption of pyroclastic rocks. Gravity lows are associated with calderas because the subsiding topographic depressions are filled by sedimentary deposits with lower average densities than the surrounding rocks. Although not marked by a closed gravity low, the caldera near Morey Peak (Ekren and others, 1974, fig. 2) is reflected by lower gravity values than adjacent parts of the Hot Creek Range. D.A. John (written commun., 1990) suggested that the presence of greater than 1,200 m of densely welded, propylitically altered, intracaldera, dacitic ash-flow tuff exposed at Morey Peak probably accounts for the lack of a local gravity low near Morey Peak.

Outer edges of calderas can be approximately delineated by a curved line drawn through the center of the steepest gravity gradients that mark edges of gravity lows associated with calderas. In places such as the Toquima and Monitor Ranges (Plouff, 1990a), correlation with clusters of intense magnetic highs and lows associated with intracaldera volcanic rocks help to delineate calderas that are indicated by gravity lows. In general, the greater the amplitude of the associated gravity low, the thicker are sedimentary deposits that fill a caldera. Quantitative modeling of suspected calderas is difficult, however, because densities of the enclosed sedimentary deposits and interbedded volcanic rocks are highly variable (for example, Healey, 1970), and their distribution is uncertain. Densities of subjacent and adjacent wall rocks, which can range in density from that of ash-flow tuff to pre-Cenozoic crystalline rocks, also are variable.

A standard rock density of 2.67 g/cm^3 was assumed for reducing gravity observations to Bouguer gravity anomalies. However, significantly less dense Tertiary volcanic rocks are exposed, for example, near Mount Jefferson. One would expect that the amplitude of the gravity low associated with the caldera centered near Mount Jefferson and the consequent estimated thickness would be reduced by using a lower reduction density appropriate for Tertiary volcanic rocks. Using a reduction density of 2.50 g/cm^3 resulted in values for Bouguer gravity that correlate least with elevations of 21 observation points and, therefore, 2.50 g/cm^3 statistically best represents the average near-surface density of the exposed tuffaceous rocks near Mount Jefferson. Although the observed gravity anomalies and consequent "best" reduction density also respond to density contrasts of rocks below and outside the topographic expression of Mount Jefferson, a density of 2.50 g/cm^3 is a more realistic estimate of the density of exposed volcanic rocks than the standard 2.67 g/cm^3 for crystalline rocks. The average density of volcanic rocks exposed near Mount Jefferson probably is not significantly less than 2.50 g/cm^3, inasmuch as about a 1-km thickness of densely welded tuff is exposed near Mount Jefferson (D.A. John, written commun., 1990). Using a reduction density of 2.50 g/cm^3, the amplitude associated with the local gravity low over the Mount Jefferson caldera was reduced by about 5 mGal, but the anomaly still forms a gravity saddle about 10 mGal lower than gravity highs to the southwest and northeast in the Toquima Range. Using a reduction density of 2.50 g/cm^3, the gravity low over the Meadow Canyon Caldera (Shawe and Snyder, 1988, pl. 2; Trail Canyon Caldera of Boden, 1986, fig. 2) still forms a prominent closed gravity low located about 10 km south-southeast of Mount Jefferson.

ORIGINS OF BASINS

The pattern of nearly parallel, fault-bounded basins generally is interpreted to be a result of extension of the underlying crust along a horizontal component approximately perpendicular to the strike of the basins. On the basis of rotations and net displacements of Cenozoic volcanic strata along normal faults, Proffett (1977, p. 258) estimated that more than 100% east-west late Cenozoic extension—lateral strain—has taken place in the Yerington mining district, which is located about 100 km west of the northwest corner of the Tonopah quadrangle. The thickness of basin deposits has been used as a measure of the near-surface strain attributed to extension. Models incorporating simple shear, pure shear, and a combination of anastomozing shear zones have been suggested to explain stretching and consequent thinning of underlying brittle and ductile parts of the crust to cause extension, but our "present knowledge of Basin and Range geology and geophysics does not allow us to state unequivocally which, if any, of these models is applicable to the province" (Thompson and others, 1989, p. 192-193). Upward bulges at the base of each model may reflect magmatic underplating and intrusion in the transition zone between the thinned crust and the mantle (Thompson and others, 1989, p. 199). Thompson and McCarthy (1990) stated that no prominent gravity highs are associated with the underplated material derived from the mantle nor the removal of as much as 10 km of upper crust (corresponding to about 100% extension) in highly extended terranes, because the mantle-derived material such as gabbro has a density about the same as the average density of the lower crust.

Zoback and Anderson (1983, p. 364) interpreted geologic and seismic reflection data for 10 major basins to conclude that three principal modes of basin-range faulting exist as end members in the uppermost part of the crust: (1) graben about 10 to 20 km in width, bounded by steeply inward-dipping normal faults that intersect at depths of 8 to 17 km; (2) domino-style tilted blocks bounded by planar normal faults; and (3) tilted blocks bounded by listric faults that sole into a detachment fault. Zoback and Anderson (1983) listed three types of accommodation that may tie basin-range fault models in the upper crust to lower-crustal models: (1) faults that penetrate the entire crust; (2) stretching and attenuation by creep; and (3) a combination of faults and intrusive dilation.

An alternative to the hypothesis that basins result from extension of the underlying crust is that pull-apart basins can be formed along strike-slip fault zones (for example, Crowell, 1974; Sylvester, 1988, p. 1683). Pakiser (1960) proposed that an en echelon strike-slip system near the eastern front of the Sierra Nevada could form shear zones of stress relief, in which Lassen Peak, Sierra Valley, Mono Lake, and Long Valley (east-central Calif.) were developed. On the basis of the pattern of historical surface faults and conspicuous structures in the Walker Lane (see Stewart, 1988 for discussion of Walker Lane belt), Shawe (1965) suggested that a conjugate strike-slip fault system, parallel to the San Andreas-Garlock Fault System, may be associated with the basin-range horst-and-graben system. Molinari (1984, fig. 2) suggested that trends of five short segments of late Cenozoic strike-slip faults and numerous minor fold axes in Stewart and Monte Cristo Valleys in the west-central part of the Tonopah quadrangle may be part of a wrench-fault system that incorporates major strike-slip displacements along faults mapped by Ekren and Byers (1984) and Hardyman (1984) in the Gabbs Valley (range that extends north-northwest from the Pilot Mountains in the west-central part of the Tonopah quadrangle) and northern Gillis (range located about 10 to 25 km southwest of the Gabbs Valley Range) Ranges. No major strike-slip faults with trends parallel or perpendicular to valleys have been reported, however, for locations in the Tonopah quadrangle except the postulated left-lateral Tybo Shear Zone in the southeast corner of the quadrangle (Feldman and Taranik, 1988, fig. 1).

RELATION OF CALDERAS TO BASIN FORMATION

[illegible]

MINERAL RESOURCE POTENTIAL

[illegible]

ACKNOWLEDGMENTS

[illegible]

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