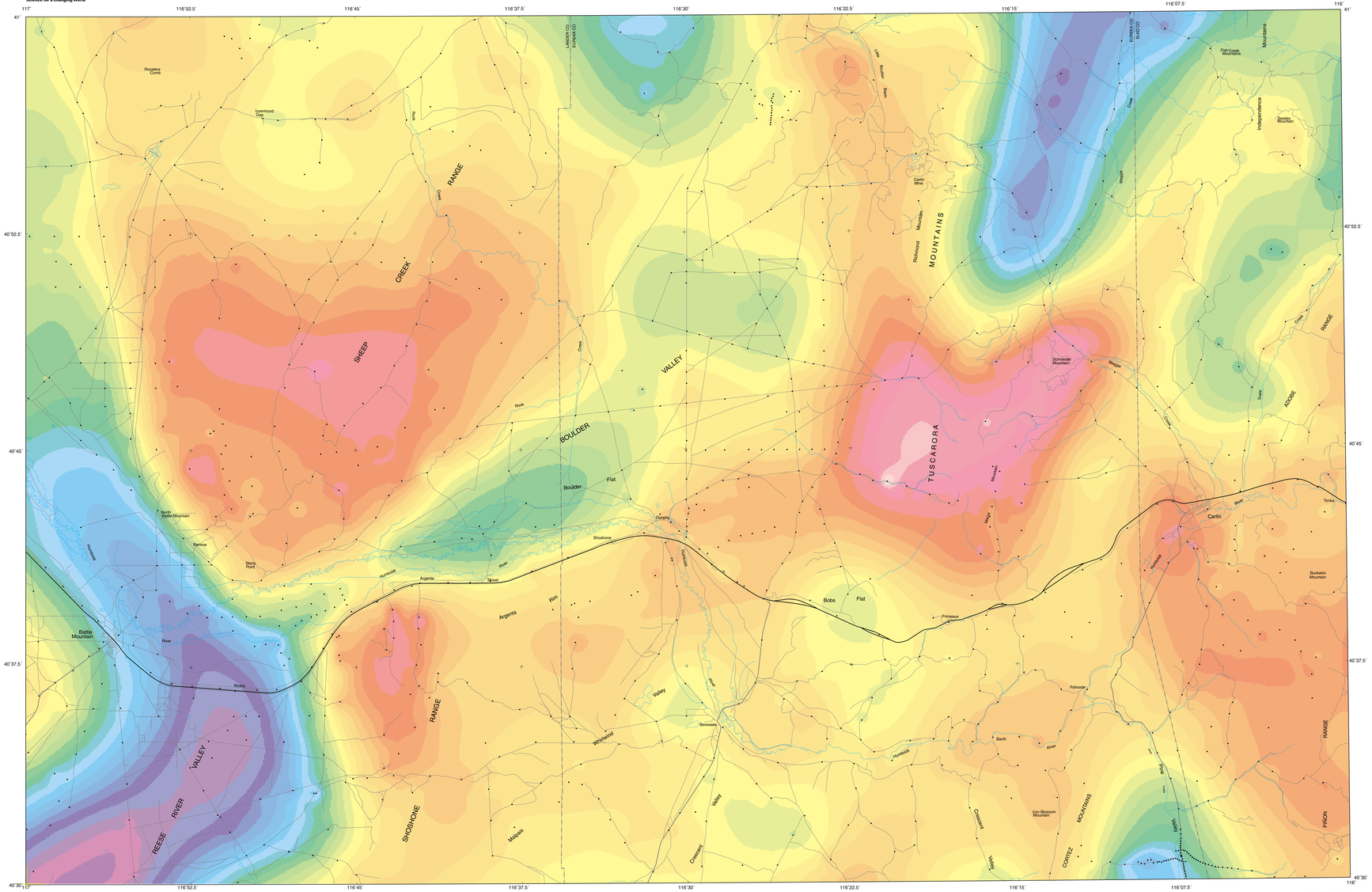
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



EXPLANATION

Gravity contours
milligals (mGal)

24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-14
-16
-18
-20
-22
-24
-26
-28
-30

Gravity station

Base from U.S. Geological Survey, 1988

UTM Projection, zone 11
Central Meridian 117°
1927 North American Datum

Data compiled in 1999
Edited by Jane S. Ciener
Cartographic preparation
by David Lanford
Manuscript approved for
publication on June 25, 1999

SCALE 1:100 000

1 0 1 2 3 4 5 6 7 8 MILES

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

CONVERSION FACTORS

Multiply	By	To obtain
centimeters (cm)	0.3937	inches (in)
meters (m)	3.281	feet (ft)
kilometers (km)	0.6214	miles (mi)

Figure 1. Index map of Nevada showing 1 by 2 degree quadrangles and location of study area.

ISOSTATIC GRAVITY MAP OF THE BATTLE MOUNTAIN 30 X 60 MINUTE QUADRANGLE, NORTH-CENTRAL NEVADA

By
D. A. Ponce and R.L. Morin
2000

INTRODUCTION

Gravity investigations of the Battle Mountain 30 x 60 minute quadrangle were begun as part of an interagency effort by the U.S. Geological Survey (USGS) and the Bureau of Land Management to help characterize the geology, mineral resources, hydrology, and ecology of the Humboldt River Basin in north-central Nevada. The Battle Mountain quadrangle is located between lat 40°30' and 41°N. and long 116° and 117°W (fig. 1).

This isostatic gravity map of the Battle Mountain quadrangle was prepared from data from about 1,180 gravity stations. Most of these data are publicly available on a CD-ROM of gravity data of Nevada (Ponce, 1997) and in a published report (Jewel and others, 1997). Data from about 780 gravity stations were collected by the U.S. Geological Survey since 1996; data from about 245 of these are unpublished (USGS, unpub. data, 1998). Data collected from the 400 gravity stations prior to 1996 are a subset of a gravity data compilation of the Winnemucca 1:250,000-scale quadrangle described in great detail by Wagini (1985) and Sikora (1991). This detailed information includes gravity meters used, dates of collection, sources, descriptions of base stations, plots of data, and a list of principal facts. A digital version of the entire data set for the Battle Mountain quadrangle is available on the World Wide Web at:

http://wrgis.wr.usgs.gov/docs/gump/gump.html

ACKNOWLEDGMENTS

Gravity data were collected or compiled by numerous persons over many years: T.V. Burt, P.E. Fabringer, J.M. Glen, E.B. Jewel, D.R. Mabey, R.L. Morin, D.A. Ponce, S.L. Robbins, C.W. Roberts, R.F. Sikora, and Alexander Wagini of the U.S. Geological Survey; J.W. Erwin of the Nevada Bureau of Mines and Geology; and the U.S. Department of Defense, Defense Mapping Agency.

GRAVITY DATUM AND REDUCTION

All gravity data were reduced using standard gravity corrections that include: (a) an Earth-tide correction, which corrects for tidal effects of the moon and sun; (b) instrument drift correction, which compensates for drift in the instrument's spring; (c) latitude correction, which incorporates the variation of the Earth's gravity with latitude; (d) free-air correction, which accounts for the difference in elevation between each station and sea-level; (e) Bouguer correction, which corrects for the attraction of material between the station and sea-level; (f) curvature correction, which corrects the Bouguer correction for the effect of the Earth's curvature to 166.7 km; (g) terrain correction, which removes the effect of topography to a radial distance of 166.7 km; and (h) an isostatic correction which removes long-wavelength variations in the gravity field inversely related to topography to a radial distance of 180°.

Observed gravity values are referenced to the International Gravity Standardization Net 1971 (IGSN 71) gravity datum (Morelli, 1974, p. 18). Free-air gravity anomalies were calculated using the Geodetic Reference System 1967 formula for theoretical gravity on the ellipsoid (International Union of Geodesy and Geophysics, 1971, p. 60) and Swick's formula (1942, p. 65) for the free-air correction. Bouguer, curvature, and terrain corrections were added to the free-air correction to determine the complete Bouguer anomaly at a standard reduction density of 2.67 g/cm^3. Finally, an Airy-Heiskanen model for isostatic compensation of topographic loads (Jachens and Roberts, 1981) with an assumed crustal thickness of 25 km, a crustal density of 2.67 g/cm^3, and a density contrast across the base of the model of 0.4 g/cm^3 was used to remove a regional isostatic gravity field from the Bouguer gravity field.

Terrain corrections, which account for the variation of topography surrounding a gravity station, were computed using a combination of manual and digital methods. Terrain corrections consist of a three-part process: the innermost or field terrain correction, inner-zone terrain correction, and outer-zone terrain correction. Terrain corrections were made using either Hayford and Bowie (1912) or Hammer (1939) systems, which divide the terrain surrounding a gravity station into zones and equal area compartments. Terrain corrections nearest the gravity station, the innermost or field terrain corrections, were estimated in the field and typically extend to a radial distance of 53 or 68 m (Hammer zone C or Hayford-Bowie zone B, respectively).

Until recently, terrain corrections were manually estimated by averaging compartment elevations from the largest scale topographic maps available, usually USGS 1:24,000-scale maps. With the increasing availability of detailed and large-scale digital elevation models (DEMs), modern day inner-zone terrain corrections are computed using USGS 7.5' DEMs with a resolution of 30 m derived from USGS 1:24,000-scale topographic maps. Inner-zone terrain corrections typically extend to a radial distance of 0.59 to 2.29 km (Hayford-Bowie zone D to F, respectively).

Outer-zone terrain corrections extend from the inner-zone radii to a standard radial distance of 166.7 km and were computed using a DEM derived from USGS 1:250,000-scale topographic maps and a procedure developed by Plouff (1966; Godson and Plouff, 1988). Digital terrain corrections were calculated by computing the gravity effect of each grid cell using the distance and difference in elevation of each grid cell from the gravity station. Beyond 166.7 km a combined topographic and isostatic correction based on maps developed by Karki and others (1961) was computed to 180° from the station.

DISCUSSION

GENERAL

In contrast to previous gravity studies in the area by Mabey (1964) and Erwin (1967, 1974), in this study terrain corrections were computed to a radial distance of 166.7 km, gravity station coverage and accuracy are greatly improved, and data have been reduced to isostatic anomalies. In general, isostatic gravity anomalies reflect lateral density variations in the middle to upper crust. Thus, gravity anomalies can be used to infer the subsurface geometry of known or unknown geologic features. North-central Nevada is characterized by gravity anomalies that reflect the distribution of pre-Cenozoic carbonate rocks, thick sequences of volcanic rocks, and moderately thick alluvial basins. In addition, regional gravity data reveal the presence of linear features that reflect Basin and Range faults whereas detailed gravity data can indicate the presence of smaller-scale faults.

As expected, regional gravity highs reflect exposed pre-Cenozoic rocks along the west margin of the Sheep Creek Range in the northwest part of the quadrangle, along the Shoshone Range in the southwest part, in the Tuscarora Mountains in the eastern part, in the Piñon Range in the southeast part, and in the Independence Mountains in the northeast part. Gravity highs also delineate other exposed or shallowly buried pre-Cenozoic rocks east of Dunphy in the central part of the quadrangle. In general, gravity lows reflect moderately thick alluvial basins in the Reese River Valley in the southwest part of the quadrangle, Boulder Valley in the central and north-central part, along Maggie Creek in the northeast part, in Crescent Valley in the south-central part, and in Pine Valley in the southeast part.

REESE RIVER VALLEY

One of the most prominent gravity anomalies within the study area is a gravity low centered over the Reese River Valley in the southwest part of the quadrangle. Steep gravity gradients along the margin of the gravity low reflect late Cenozoic Basin and Range faulting; where, on either side, Paleozoic rocks are exposed or buried at shallow depth. The asymmetry of the gravity anomaly along the Reese River Valley indicates that the basin is an eastward tilted block (Mabey, 1964). A gravity anomaly of about -30 mGal and a density contrast of 0.4 g/cm^3 between basin fill and basement suggests a basin fill thickness of about 2.3 km (7,000 ft). Range front faults are evident along the western edge of the Shoshone Range and along the northern edge of Argenta Rim, as well as along the western edge of the Sheep Creek Range. Offset gravity anomalies indicate a left-lateral offset of several kilometers between faults along the west edges of the Shoshone and Sheep Creek Ranges, where Boulder Valley joins Reese River Valley.

HUMBOLDT RIVER

Isostatic gravity anomalies along the Humboldt River indicate that at least part of the river's path may be structurally controlled. In particular, gravity anomalies near the intersection of Reese River Valley, Boulder Valley, and the Humboldt River Valley suggest that ENE-trending Basin and Range faulting controls the location of the Humboldt River. In other areas, the Humboldt River transects Basin and Range structure. The Humboldt River parallels the northern edge of Argenta Rim, but near Dunphy, the Humboldt bends nearly 90° to the south, cutting across a gravity high related to Paleozoic rocks exposed in the Dunphy area. Southwest of Carlin, the Humboldt River cuts across a gravity high that reflects exposed Paleozoic rocks over the Piñon Range.

BOULDER VALLEY

Boulder Valley, a northeast-trending, fault-bounded graben, is characterized by a gravity low that extends the entire length of the valley approximately along its topographic axis. The gravity low reaches an amplitude of about -12 mGal, which indicates a depth to basement of about 1 km (3,000 ft). Several local gravity highs cut across the valley: north of Dunphy, a prominent gravity high extends some 8 km northward to the center of Boulder Valley and probably reflects Paleozoic rocks at shallow depth. In the northern part of Boulder Valley, another gravity high extends across the valley and suggests that buried Paleozoic rocks form a structural ridge across the valley at shallow depth. These features indicate that Boulder Valley is composed of at least three sub-basins that may play an important role in the hydrology of the Rock Creek–Reese River–Humboldt River triple confluence within the Humboldt River basin.

MAGGIE CREEK AND SUSIE CREEK BASIN

Steep gravity gradients along the eastern margin of the Tuscarora Mountains and the western margin of the Independence Mountains define a well-developed Tertiary basin that underlies Maggie Creek in the northeast part of the Battle Mountain quadrangle. A gravity low of about -22 mGal indicates a depth to basement of about 1.7 km (5,200 ft) in the deepest part of the basin.

Another gravity low is located east of the Independence Mountains, west of the Adobe Range, and north of Carlin. Gravity data indicate that this basin is relatively shallow and has about 0.6 km (1,900 ft) of basin-fill material and that the margins of the basin are diffuse and not well defined.

CRESCENT AND PINE VALLEYS

In the south-central part of the quadrangle, gravity lows in the northern part of Crescent Valley indicate that the area is underlain by volcanic rocks. Just northeast of Beowawe, a gravity high indicates that Paleozoic rocks, exposed in some places, extend at shallow depth beneath adjacent areas of alluvial cover.

The northernmost part of Pine Valley extends into the Battle Mountain quadrangle in the southeast part of the study area. A gravity low of about -18 mGal indicates that basin fill material is about 1.4 km thick (4,300 ft).

SHEEP CREEK RANGE

Greatly improved gravity data coverage over the Sheep Creek Range reveal several geophysical features. Along the western edge of the range, a steep isostatic gravity gradient of about 6 mGal/km indicates the presence of a prominent Basin and Range fault striking about N. 10° W. along the northern part to about N. 30° W. along the southern part. The vertical displacement of this fault is about 2.5 km (7,500 ft). The displacement was determined from a depth-to-basement map of the Winnemucca quadrangle (Ponce, 1998) and the relief on exposed Paleozoic rocks. A gravity high along the western margin of the range is associated with exposed Paleozoic rocks, and a gravity high in the central part of the range probably indicates the presence of similar rocks at shallow depths. A part of these gravity highs may be related to an increase in density of the rock units due to the occurrence, locally, of barite in the Slaven Chert. A local 2-4 mGal gravity low extends across the southern third of the Sheep Creek Range and may reflect the presence of a thick section of lower density volcanic rocks or the presence of a buried intrusion. This gravity low is south of and not related to a dacitic intrusion mapped in the central part of the Sheep Creek Range by John and Wrucke (1999). The location of this feature is also distinct from a possible intrusion interpreted by Gott and Zablocki (1968) on the basis of geochemical and geophysical anomalies below a pediment at the southwestern end of the range near Rennox. The western margin of the Sheep Creek Range also correlates to one of the most prominent aeromagnetic anomalies in the state of Nevada: the northern Nevada rift (fig. 2), a linear feature about 500-km long that extends almost the entire length of Nevada (Blakely and Jachens, 1991) and is related to mid-Miocene mafic igneous rocks. Gravity data indicate that a left step occurs between the northern end of the Shoshone Range and the Sheep Creek Range and reflects a left-lateral fault that offsets the northern Nevada rift by about 3 km, similar to and coincident with an offset aeromagnetic anomaly described by Zoback and others (1994).

SHOSHONE RANGE

The western margin of the Shoshone Range is characterized by a gravity high that is related to exposed Paleozoic rocks. Gravity values are highest south of Argenta and may reflect an increase in density caused by massive sedimentary barite deposits. Some barite beds are up to 12-m (40-ft) thick, 305-m (1,000 ft) long, and 305-m (1,000 ft) wide (Stewart and McKee, 1977). Gravity data do not indicate the presence of pediments along the western margin of the Shoshone Range, whereas a steep gravity gradient of 7.2 mGal/km does indicate a prominent Basin and Range fault with possible vertical offset of about 4.3 km (13,000 ft).

The gravity high over the Shoshone Range continues, in a subdued fashion, to the east along Argenta Rim, where Miocene basaltic rocks crop out, and suggests that Paleozoic rocks are present at moderate depth. This may indicate that a thick section of lower density volcanic rocks or possibly plutonic rocks is present. At the eastern margin of the Argenta Rim and east of Dunphy, a broad, but low amplitude gravity high correlates to scattered Paleozoic outcrops, and indicates that the entire area is underlain by Paleozoic rocks at shallow depth. Although no gravity stations are on a small exposed granitic body in this area, surrounding gravity data suggest its areal extent is limited.

TUSCARORA MOUNTAINS

One of the most prominent gravity anomalies in the Battle Mountain quadrangle is a gravity high in the central part of the quadrangle over the Tuscarora Mountains. The anomaly bifurcates to the north along Richmond Mountain and to the northeast along Schroeder Mountain. Maximum isostatic gravity values of about 22-24 mGal are similar to the maximum values over exposed Paleozoic rocks along the western margin of the Shoshone and Sheep Creek Ranges. The western edge of the Tuscarora Mountains gravity high correlates with the north-northeast-trending Crescent Valley–Independence lineament (fig. 2), a crustal fault zone described by Peters (1998). The northern extension of the high along Richmond Mountain follows the western margin of a wide belt of Paleozoic sedimentary rocks, and is coincident with the Carlin trend (Roberts, 1960; 1985). Aeromagnetic data (Kirchoff-Stein, 1988) indicate that the gravity high correlates to a broad, circular magnetic high typical of intrusions. Several small exposed granitic bodies (Evans, 1980) occur along the flank of the gravity high and coincide with local aeromagnetic highs. Gravity and magnetic data indicate that this entire area is probably underlain by large intrusions.

Gravity data along the northeastern extension of the high indicates that intermittently exposed Paleozoic rocks are part of a continuous northeast-trending ridge that extends from Schroeder Mountain to Swales Mountain in the Independence Mountains. A gravity high overlies Swales Mountain and is coincident with a magnetic high associated with mapped Tertiary granitic rocks (fig. 2) (Stewart and Carlson, 1976).

CORTEZ MOUNTAINS AND PIÑON RANGE

The northern end of the Cortez Mountains correlates with a broad gravity high centered just north of Iron Blossom Mountain along the Humboldt River. Although the gravity high is underlain by Jurassic volcanic rhyolite and rhyodacite flows, the source of the anomaly is unknown. Along the northern margin of the high, exposed granitic rocks have do not appear to be related to the gravity anomaly.

The Piñon Range is characterized by a gravity high associated with exposed Paleozoic rocks. The northern extension of the high, near Carlin, indicates that Paleozoic rocks occur at shallow depth below the Humboldt River basin. The trend of the gravity high is coincident with the Carlin trend (Roberts, 1960; 1985) and may reflect doming of basement rocks or could be in part related to slightly higher density (Mabey, 1964) rock units of the lower plate of the Roberts Mountain thrust.

SUMMARY

Gravity anomalies in the Battle Mountain quadrangle reflect a suite of geologic features that include the structure and topography of pre-Cenozoic rocks, thick sequences of Tertiary volcanic rocks, buried intrusions, Basin and Range faults, other faults, and moderately deep late Cenozoic basins. These features play an important role in the geologic, mineral, and hydrologic setting and evolution of north-central Nevada.

REFERENCES CITED

Blakely, R.J., and Jachens, R.C., 1991, Regional study of mineral resources in Nevada: Insights from three-dimensional analysis of gravity and magnetic anomalies: Geological Society of America Bulletin, v. 103, p. 795-803.

Erwin, J.W., 1967, Gravity map of Battle Mountain and adjacent areas, Lander, Pershing, and Humboldt Counties, Nevada: Nevada Bureau of Mines and Geology Map 31, scale 1:125,000.

_____1974, Bouguer gravity map of Nevada, Winnemucca sheet: Nevada Bureau of Mines and Geology Map 47, 4 p., scale 1:250,000.

Evans, J.G., 1980, Geology of the Rodeo Creek NE and Welches Canyon quadrangles, Eureka County, Nevada: U.S. Geological Survey Bulletin 1473, 81 p., 2 pls., scale 1:24,000.

Godson, R.H., and Plouff, Donald, 1988, BOUGUER version 1.0, a microcomputer gravity-terrain-correction program: U.S. Geological Survey Open-File Report 88-644-A, Documentation, 22 p.; 88-644-B, Tables, 61 p.; 88-644-C, 5 1/4-inch diskette.

Gott, G.B., and Zablocki, C.J., 1968, Geochemical and geophysical anomalies in the western part of the Sheep Creek Range, Lander County, Nevada: U.S. Geological Survey Circular 595, 17 p.

Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, v. 4, p. 184-194.

Hayford, J.F., and Bowie, William, 1912, The effect of topography and isostatic compensation upon the intensity of gravity: U.S. Coast and Geodetic Survey Special Publication 10, 132 p.

International Union of Geodesy and Geophysics, 1971, Geodetic reference system 1967: International Association of Geodesy Special Publication 3, 116 p.

Jablonsky, H.M., 1974, World relative gravity reference network North America, Parts I and 2: U.S. Defense Mapping Agency Aerospace Center Reference Publication 25, 1261 p.

Jachens, R.C., and Roberts, C.W., 1981, Documentation of a FORTRAN program, 'isocomp', for computing isostatic residual gravity: U.S. Geological Open-File Report 81-574, 26 p.

Jewel, E.B., Ponce, D.A., and Morin, R.L., 1997, Principal facts for about 500 gravity stations in part of the Humboldt River basin, Lovelock and Winnemucca quadrangles, Nevada: U.S. Geological Survey Open-File Report 97-519, 17 p.

John, D.A., and Wrucke, C.T., 1999, Geologic map of the Izzenhood Spring quadrangle: U.S. Geological Survey Map I-2668, scale 1:24,000.

Karki, P., Kivioja, L., and Heiskanen, W.A., 1961, Topographic-isostatic reduction maps of the world for Hayford zones 18-1, Airy-Heiskanen system, T=30 km: Isostatic Institute of the International Association of Geodesy Special Publication 35, 23 p.

Kirchoff-Stein, K.S., 1988, Aeromagnetic map of Nevada, Winnemucca sheet: Nevada Bureau of Mines and Geology Map 92, scale 1:250,000.

Mabey, D.R., 1964, Gravity map of Eureka County and adjoining areas, Nevada: U.S. Geological Survey Geophysical Investigations Map GP-415, scale 1:250,000.

Morelli, Carlo, ed., 1974, The International Gravity Standardization Net 1971: International Association of Geodesy Special Publication 4, 194 p.

Peters, S.G., 1998, Evidence for Crescent Valley-Independence lineament, 305-m (1,000 ft) long, and 305-m (1,000 ft) wide (Stewart and McKee, 1977). Gravity data do not indicate the presence of pediments along the western margin of the Shoshone Range, whereas a steep gravity gradient of 7.2 mGal/km does indicate a prominent Basin and Range fault with possible vertical offset of about 4.3 km (13,000 ft).

Plouff, Donald, 1966, Digital terrain corrections based on geographic coordinates (abs.): Geophysics, v. 31, no. 6, p. 1208.

Ponce, D.A., 1997, Gravity data of Nevada: U.S. Geological Survey Digital Data Series DDS-42, CD-ROM, 27 p.

_____1998, Mapping the Humboldt River basin using gravity and magnetic methods, Winnemucca 1- by 2-degree quadrangle, northern Nevada (abs.): Geological Society of America, Abstracts with Programs, v. 29, no. 6, p. 304.

Roberts, R.J., 1960, Alignments of mineral districts in north-central Nevada: U.S. Geological Survey Professional Paper 400-B, p. B17-B19.

_____1985, The Carlin story, in Tingley, J.V., and Bonham, H.F., eds., Sediment-hosted precious-metal deposits of northern Nevada: Nevada Bureau of Mines and Geology Report 40, p. 71-79.

Sikora, R.F., 1991, Principal facts for 133 gravity stations, with color maps of Bouguer and isostatic residual gravity anomalies on the Winnemucca 10 x 20 quadrangle, Nevada: U.S. Geological Survey Open-File Report 91-256-A, documentation, 49 p.; 91-256-B diskette.

Stewart, J.H., and Carlson, J.E., 1976, Geologic map of north-central Nevada: Nevada Bureau of Mines and Geology Map 50, scale 1:250,000.

Stewart, J.H., and McKee, E.H., 1977, Geology and mineral deposits of Lander County: Nevada Bureau of Mines and Geology Bulletin 88, 106 p.

Swick, C.H., 1942, Pendulum gravity measurements and isostatic reductions: U.S. Coast and Geodetic Survey Special Publication no. 232, 82 p.

Wagini, Alexander, 1985, Principal facts, accuracies, and sources for 1951 gravity stations on the Winnemucca 10 x 20 quadrangle, Nevada: available from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, PB-85-235927/AS, 74 p.

Zoback, M.L., McKee, E.H., Blakely, R.J., and Thompson, G.A., 1994, The northern Nevada rift: Regional tectono-magmatic relations and middle Miocene stress direction: Geological Society of America Bulletin, v. 106, p. 371-382.

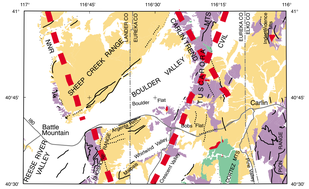


Figure 2. Index map of the Battle Mountain quadrangle showing generalized geology faults, and features described in text (modified from Stewart and Carlson, 1976; Peters, 1999). CVIL, Crescent Valley-Independence lineament; NNR, northern Nevada rift

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, or call 1-888-ASK-USGS
Available on World Wide Web at http://geopubs.wr.usgs.gov/data.html