The Enigmatic Rattlesnake Knoll, Spring Valley, East-Central Nevada—A Geophysical Perspective

Open-File Report 2023–1002

U.S. Department of the Interior
U.S. Geological Survey

Cover: The igneous breccia at the top of Rattlesnake Knoll. View is looking north toward Wheeler Peak and into Spring Valley.

The Enigmatic Rattlesnake Knoll, Spring Valley, East-Central Nevada—A Geophysical Perspective

By Edward A. Mankinen, Peter D. Rowley, and Edwin H. McKee

Open-File Report 2023–1002

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2023

Suggested citation:
Mankinen, E.A., Rowley, P.D., and McKee, E.H., 2023, The enigmatic Rattlesnake Knoll, Spring Valley, east-central Nevada—A geophysical perspective: U.S. Geological Survey Open-File Report 2023–1002, 13 p., https://doi.org/10.3133/ofr20231002.

ISSN 2331-1258 (online)

Acknowledgments

The Southern Nevada Water Authority (SNWA) provided funding for this project and we appreciate their support. We also appreciate the able assistance with the field surveys provided by Bruce Chuchel, Robert Morin, Barry Moring, and Carter Roberts. Technical reviews by Jonathan Hagstrum and David Ponce were very helpful.

Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
metric ton (t)	1.102	ton, short [2,000 lb]
metric ton (t)	0.9842	ton, long [2,240 lb]
	Density	
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot (lb/ft^3)

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to the height of a point in the air above the land’s surface.

Elevation, as used in this report, refers to the height of a point on the land’s surface above the vertical datum.

Abbreviations

AMT	audiomagnetotelluric
Ma	million years old
NRM	natural remanent magnetization
GPS	Global Positioning System

The Enigmatic Rattlesnake Knoll, Spring Valley, East-Central Nevada—A Geophysical Perspective

By Edward A. Mankinen,[1] Peter D. Rowley,[2] and Edwin H. McKee[1]

Abstract

Rattlesnake Knoll is a small, 30-meter-high mound of igneous breccia in the center of Spring Valley, east-central Nevada. In the past, researchers have disagreed as to whether the unusual-looking outcrop is intrusive or volcanic. The breccia possesses a normal magnetic polarity, but this is not apparent in aeromagnetic survey data. These data instead show that the knoll lies within a small aeromagnetic low that partially overlaps the extent of a small gravity high. The small gravity anomaly associated with the knoll, combined with an initial, limited ground magnetic survey taken at the knoll, indicates that the knoll rocks extend northward in the subsurface. A second, more extensive ground magnetic traverse was also done north of the knoll. Taking into consideration these new survey data and preexisting data, a two and one-half dimensional modeling program based on Webring (1985) was used to produce a geophysical model that accounts for gravity and magnetic properties, satisfies available geologic information, and conforms to current estimates of basin thickness. This model and the field observations support the interpretation that the knoll consists of gently west-dipping beds of Tertiary volcanic flow breccia, mudflow breccia, and conglomerate.

Geologic Setting

Rattlesnake Knoll, also known as Rattlesnake Heaven Prospect, is a small outcrop of igneous breccia rising about 30 meters (m) above the floor of Spring Valley, south of U.S. Routes 6 and 50 in White Pine County, east-central Nevada (figs. 1, 2). The oblong hill measures 300 m across in its longest direction (north-south; Hose and Blake, 1976) and its breccia, described as a fragmental dacite vitrophyre (Drewes, 1967), contains many fragments of Paleozoic quartzite, limestone, and metamorphic rocks in addition to volcanic rocks. These fragments are roughly sorted into layers parallel to nearly horizontal partings, which led Drewes (1967) to suggest the vitrophyre could be a lava flow that picked up debris from the surface of an underlying alluvial fan. Later reports, in contrast, considered the knoll to be an intrusive breccia (for example, Hose and Blake, 1970; Hose and Blake, 1976; and Stewart and Carlson, 1978). Papke (1979), however, recognized the poorly developed bedding, and Smith (1976) also proposed a bedded volcanic origin.

Through a reconnaissance survey of the knoll, we recognized consistent, gently west-dipping bedding everywhere it could be measured (Mankinen and others, 2006), which argues against an intrusive origin. These beds comprise dacitic-to-rhyodacitic flow breccia and volcanic mudflow breccia, both of which locally contain Paleozoic sedimentary rock clasts, as well as minor volcanic conglomerate. Rowley and others (2017, p. 107) stated that this small fault block protruding through the sedimentary basin fill is part of a covered east-trending bedrock ridge that separates Spring Valley into deep geophysical basins to the north and south (see figure 4 of Mankinen and others, 2006). A 2-kilometer-long, east-west audiomagnetotelluric (AMT) profile, the west end of which is near the knoll, detects sedimentary basin fill and a central graben whose west edge is nearly 1 kilometer (km) east of the knoll (Rowley and others, 2017, p. 63).

Small bodies of dacite vitrophyre, similar to the one at Rattlesnake Knoll, underlie and are occasionally exposed within about 8 square kilometers of the southern Schell Creek Range, which bounds the west side of Spring Valley. Some of these bodies conformably overlie a localized latite tuff that differs from the extensive welded tuff sheets studied elsewhere in this part of the Great Basin (Drewes, 1967). Drewes (1967) reported unpublished ages of 38 million years old (Ma) and 36 Ma for the latite tuff and dacite vitrophyre, respectively. Although both ages have large uncertainties (±10 percent), the dacite vitrophyre is clearly Tertiary in age. Subsequent researchers have thus considered Rattlesnake Knoll to be Tertiary, perhaps Oligocene, in age.

Rattlesnake Knoll, along with prospects on the east slope of the Schell Creek Range, is part of the Cooper Mining District (White, 1871; Tingley, 1998). Prospects in the Schell Creek Range were discovered in 1869 and feature veins 1–2.5 meters wide that contain silver, galena, fluoride, and antimony (Hose and Blake, 1976; Wong, 1983). No precious metals have been reported at the knoll itself, but three vertical, fluorite-bearing veins striking east-west occur near its center. No production was ever reported at the knoll, though by the late 1970s, 30–50 tons of low-grade fluorspar ore were stockpiled there, indicating that the veins were mined (Hose and Blake, 1976; Papke, 1979).

---

[1] U.S. Geological Survey.

[2] Geologic Mapping, Inc.

Figure 1. Photograph of Rattlesnake Knoll, view facing east across Spring Valley, Nevada. The Snake Range is visible in the background; U.S. Routes 6 and 50 cross the valley on the left.

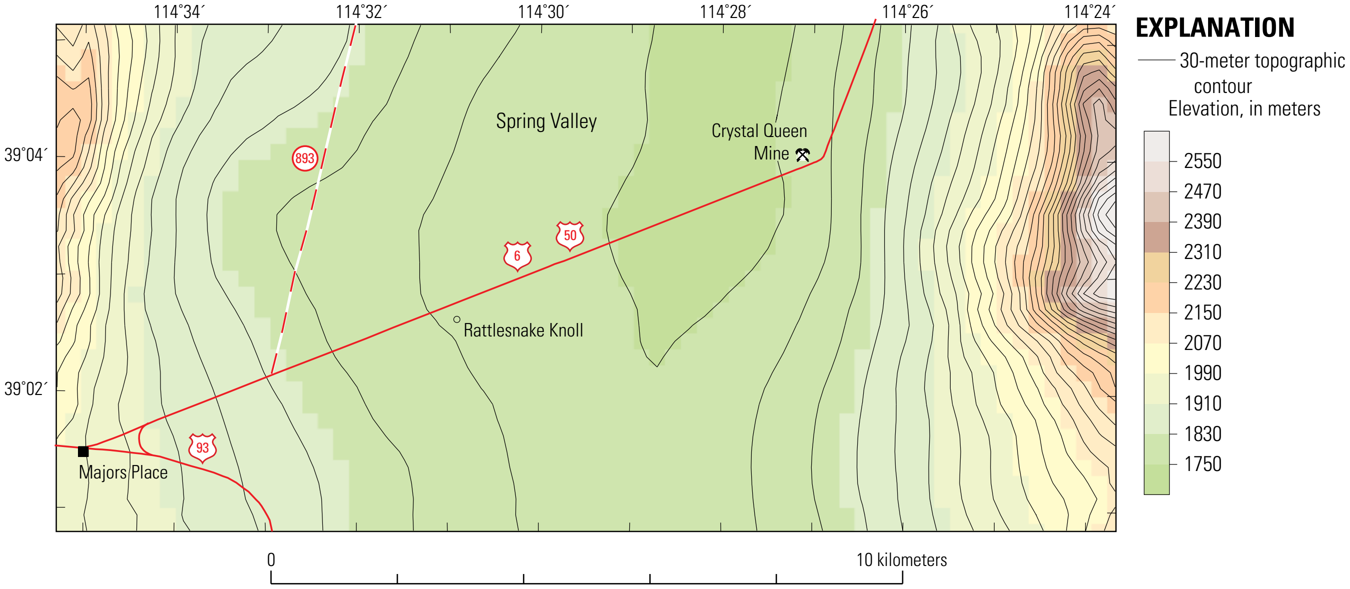

Figure 2. Map showing the location of Rattlesnake Knoll in Spring Valley, Nevada.

Geophysical Expression

Initial Findings

The geophysical characteristics of Rattlesnake Knoll were investigated contemporaneously to gravity investigations of Spring and Snake Valleys in 2004 and 2005 (Mankinen and others, 2006), during which an oriented hand sample was collected from a well-bedded section of volcanic breccia near the crest of the knoll. Two cores were then extracted from this hand sample and reoriented in the laboratory for paleomagnetic analysis. Their natural remanent magnetization (NRM) was measured using a superconducting magnetometer housed in a magnetically shielded room. The NRM intensities for the two cores were 0.7 and 1.3 amperes per meter (A/m), and when corrected for the strike and dip of the bedding (N. 23° W., 21° SW.), both cores had magnetization directions that were essentially horizontal toward the south. Upon alternating-field demagnetization of one of the cores, the magnetization direction became northeasterly and stabilized at a direction within 25° of that expected for Tertiary time at the site locality. Although a single hand sample is not necessarily representative of the entire knoll, this general consistency between the measured and expected directions indicates the knoll has not been substantially disrupted, other than a possible slight tilting, since it was emplaced.

During the same field seasons, magnetic data were obtained along a traverse stretching over and around Rattlesnake Knoll using a portable cesium-vapor magnetometer integrated with a differential Global Positioning System (GPS) receiver. Measurements were made at 1-second intervals while operating the instrument in continuous mode and walking at a normal pace. This survey showed the total magnetic variation was less than 20 nanoteslas across the entire length of the traverse. The magnetic character of the exposed part of Rattlesnake Knoll is indistinct from its immediate surroundings (Mankinen and others, 2006), which may indicate it is an exposed part of a much larger body.

Gravity Data

The processing of gravity data from the area around Rattlesnake Knoll was described in Mankinen and others (2006), a summary of which is provided here. The gravity data were reduced using standard gravity corrections (Blakely, 1995) to produce a complete Bouguer anomaly. A regional isostatic field was also calculated using an Airy-Heiskanen (Heiskanen and Vening Meinesz, 1958) model for local compensation of topographic loads (Jachens and Roberts, 1981; Simpson and others, 1986). This model assumes a crustal thickness of 25 km, a crustal density of 2,670 kilograms per cubic meter (kg/m^3), and a density contrast between the crust and mantle of 400 kg/m^3. The regional isostatic field was then subtracted from the Bouguer anomaly, removing long-wavelength variations in the gravity field that are inversely related to topography. The resulting isostatic gravity anomaly reflects local density distributions in the middle to upper crustal levels (about 10–15 km depth; Jachens and others, 1989). These data were combined with existing datasets for the region (Ponce, 1997; Bankey and others, 1998) and were gridded at a spacing of 0.5 km using the minimum curvature algorithm of Webring (1981) to produce the final isostatic gravity map presented in Mankinen and others (2006), which covers parts of eastern Nevada and western Utah. An examination of this gravity map near Rattlesnake Knoll revealed a small-magnitude anomaly encompassing an area substantially larger than the knoll itself (fig. 3).

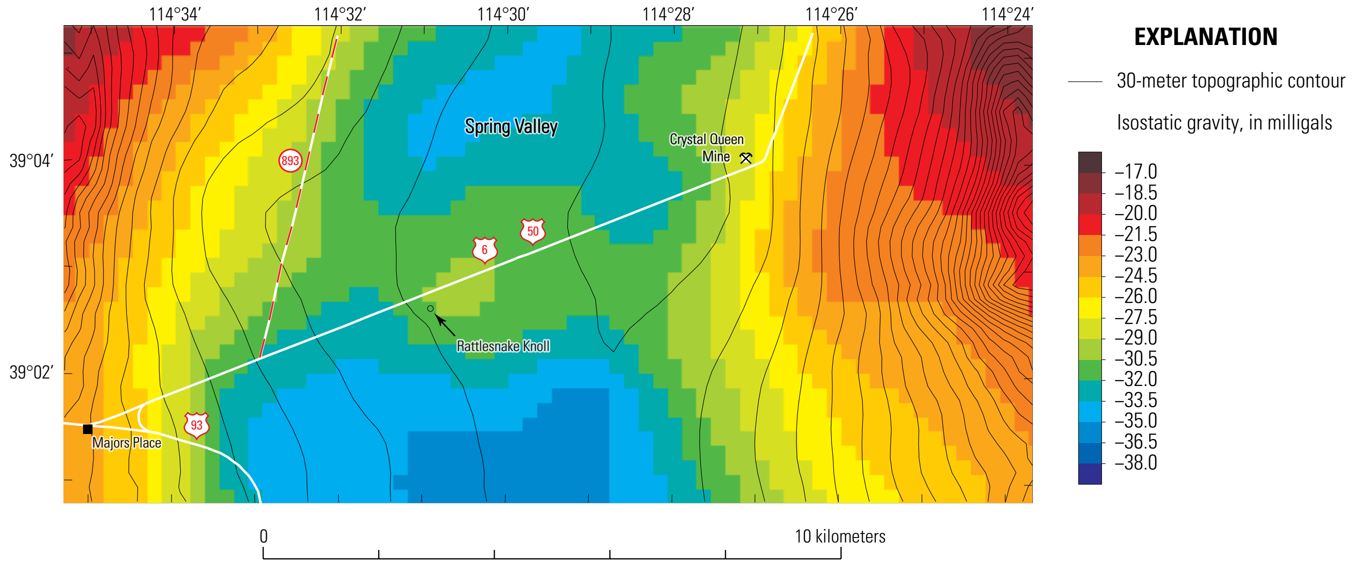

Figure 3. Gravity anomaly map of the area around Rattlesnake Knoll, in Spring Valley, Nevada.

Aeromagnetic Data

Aeromagnetic surveys of Nevada were presented by Zietz and others (1978), Mabey and others (1978), Hildenbrand and others (1983), Hildenbrand and Kucks (1988), and Kucks and others (2006). These 82 separate surveys of varying quality were used to construct the Nevada magnetic map used in this study (Kucks and others, 2006). The flight line spacing ranged from 1.5 to 5 km for most of the state; around Rattlesnake Knoll, the surveys were flown at a 5-kilometer spacing. Kucks and others (2006) merged every survey into a coherent data set as if all were flown at a constant altitude of 305 m above the ground surface, following the contours of the terrain.

For this study, the data near Rattlesnake Knoll were extracted from the Nevada magnetic map of Kucks and others (2006) and reduced to the magnetic pole (for example, Blakely, 1995), which is a technique that eliminates the asymmetry of most anomalies and shifts their positions laterally. This process makes the magnetic anomalies nearly centered over the bodies that cause them. The reduced-to-pole magnetic data were then re-gridded to a 0.2-kilometer spacing, producing the map shown in figure 4.

Ground Magnetic Data

The normally magnetized rocks associated with Rattlesnake Knoll are not obvious in figure 4, which may indicate that these rocks are limited in surface area, volume, both surface area and volume, or perhaps were not detected because of the low resolution of the aeromagnetic survey in this area. The knoll does, however, lie within a small low magnetic anomaly that partially overlaps the extent of the small low gravity anomaly shown in figure 3. To better identify the magnetic properties of Rattlesnake Knoll rocks and to expand the scope of the ground magnetic survey described in Mankinen and others (2006), the same magnetometer was mounted to a nonmagnetic aluminum frame (following the methodology of Tilden and others, 2006) and towed behind a vehicle in a separate survey (Mankinen and others, 2007). Measurements were taken at 1-second intervals over a 16-kilometer traverse along U.S. Routes 6 and 50. The GPS readings had a horizontal margin of error of about 1 m and a vertical margin of error of about 5 m, the latter of which was determined through a test of the unit over the gravity calibration loop at Mount Hamilton, California (Barnes and others, 1969; J.T. Watt, U.S. Geological Survey, written commun., 2004). Because of the short survey duration, we did not employ a stationary base-station magnetometer to record geomagnetic diurnal variations. The ground magnetic data of the survey from Mankinen and others (2007) are shown in figure 5, along with the reduced-to-pole aeromagnetic data along the same traverse. These ground magnetic data are available as a data release through ScienceBase (Mankinen, 2023).

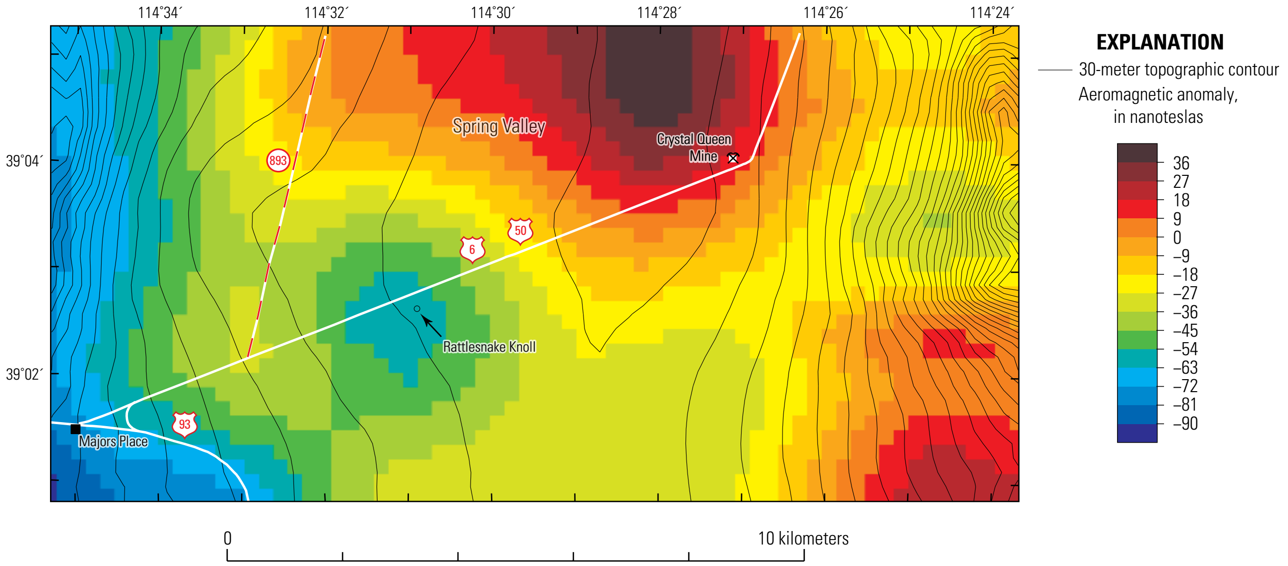

Figure 4. Reduced-to-pole aeromagnetic anomaly map of the area around Rattlesnake Knoll in Spring Valley, Nevada.

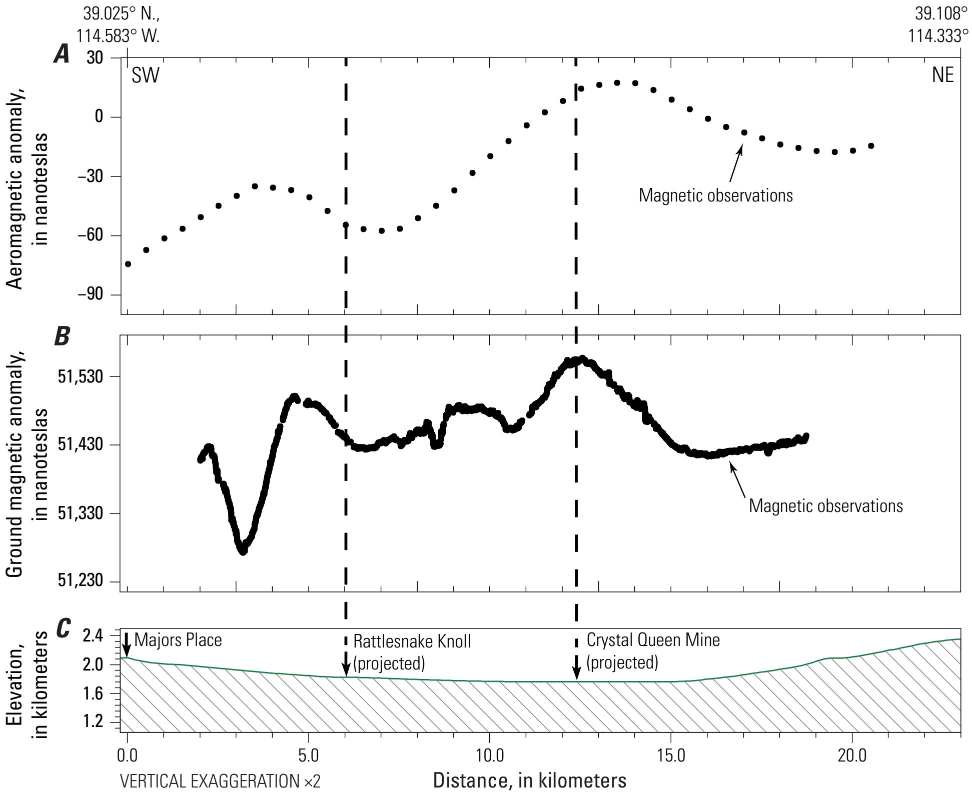

Figure 5. Graphs of reduced-to-pole aeromagnetic anomalies (*A*), ground magnetic anomalies (*B*), and topographic elevation (*C*) along the ground magnetic survey traverse in Spring Valley, Nevada. The ground magnetic data show the same magnetic low visible in the aeromagnetic data, although with much greater detail. These data also indicate the possibility of several distinct magnetic sources. Profiles extend from 39.025° N., 114.583° W. to 39.108° N., 114.333° W., largely following U.S. Routes 6 and 50. SW, southwest; NE, northeast.

Depth to Magnetic Source

Although different methods exist for estimating the depth to a magnetic source (Blakely, 1995), this study uses the graphical method described by Peters (1949). This method is built on the concept that the horizontal gradient of a magnetic anomaly is proportional to the depth of its source (that is, the steeper the gradient, the shallower the source). Peters' (1949) method also assumes that a magnetic anomaly is caused by a two-dimensional body with vertical sides and a uniform, nearly vertical magnetization. Such assumptions are not strictly applicable in many geologic situations, so these depth estimates should be considered approximate. The general practice with this method is to assume the two-dimensional body has an intermediate but unspecified thickness as a first approximation (for example, Blakely, 1995).

An inspection of the magnetic anomaly gradients along the traverse indicates that the magnetic source on the west end is considerably shallower than that on the east end. The Peters (1949) method provides an estimate of about 600 m depth to the top of the source on the west side and nearly 1 km to the top on the east side. Beneath the magnetic anomalies along this traverse, the pre-Cenozoic basement surface has estimated depths of 900 m or less (Mankinen and others, 2007). Thus, the magnetic source rocks at the west side of the traverse are probably within the basin fill, whereas toward the east, the source or sources seem to be within the basement and most likely represent a buried pluton. If true, this eastern magnetic source rock could be a very thick body. When applied to the Peters (1949) method, this increased thickness yields a revised estimate of about 800 m to the top of the magnetic body. This revised depth estimate may put the magnetic source rock very close to the basement surface in the area.

Potential Field Modeling

The gravity and magnetic anomalies recorded along the traverse were used to construct a geologic model of the subsurface. The two and one-half dimensional modeling program used for this modeling, which is based on the work of Webring (1985), requires an initial estimate of model parameters (table 1). The program then adjusts these parameters along the profile to reduce the weighted root-mean-square error between the recorded and calculated values for gravity and magnetism. It can produce a theoretically infinite number of geometric models

Table 1. Physical properties of rock units used in the geophysical model.

[Unit numbers correspond to those in figure 6. kg/m³, kilogram per cubic meter; A/m, ampere per meter; —, not applicable]

Unit number	Unit name	Density, in kg/m³	Magnetization, in A/m	Magnetic susceptibility, in A/m
1	Surficial sediment	1,900	—	—
2	Normal-polarity volcanic rock	2,100	0.8	—
3	Reversed-polarity volcanic rock	2,100	0.8	—
4	Intrusive igneous rock	2,670	0.2	0.6
5	Pre-Cenozoic basement rock	2,670	—	—

with associated fields that closely match a measured field, but incorporating available geologic maps, interpretive cross-sections, physical property data, and estimates of basin thickness can limit the number of possible solutions (Saltus and Blakely, 2011). To provide an additional constraint, the gravity profile along the traverse was also extrapolated to gravity stations established on basement rock outcrops. If the assumed unit densities and magnetizations are representative of the associated unit lithologies, the resulting geophysical model should reasonably approximate the actual geologic structure.

Density Distribution

The Cenozoic basin-fill deposits in the area are almost entirely volcanic. These deposits comprise welded and unwelded ash-flow tuffs (both primary and water-lain), shallow intrusions, sedimentary interbeds, brecciated material, and overlying unconsolidated Quaternary sediments. Density data for these deposits were obtained from borehole gravimeter studies and borehole density logs from throughout the region (see Jachens and Moring, 1990; Mankinen and others, 2003; and references therein). Because the basin within which the Rattlesnake Knoll rock erupted is shallow, a basin fill (unit 1) density of 1,900 kg/m³ was used for the model.

Volcanic rocks can be dense at an individual outcrop, but the average density of a volcanic unit can be considerably lower if it has interbeds of sediment or other poorly consolidated material, or if its rocks are highly fractured. Many valleys in this region contain volcanic rocks as part of their basin fill, and these rocks influence the average overall densities of the basins. For modeling purposes, units such as Rattlesnake Knoll should be denser than their sedimentary basin-fill counterparts, so the Rattlesnake Knoll rocks (unit 2) were separated from the basin fill unit and assigned a density of 2,100 kg/m³. This value is also applicable to some of the shallow volcanic rocks in the Pahute Mesa area in southern Nevada, an area which has a robust data set on the physical properties of various volcanic lithologies (Mankinen and others, 2003).

Along with the general basin-fill deposits and the Rattlesnake Knoll unit, a density was assigned to the pre-Cenozoic basement rocks. In this region, densities can differ considerably: sandstone and shale range from 2,330 to 2,410 kg/m³, limestone and quartzite from 2,600 to 2,620 kg/m³, granitic intrusions are about 2,660 kg/m³, and metamorphic rocks range from 2,740 to 2,750 kg/m³ (see, for example, Telford and others, 1976; Dobrin and Savit, 1988; Schön, 1996). A uniform density of 2,670 kg/m³ was assumed for the pre-Cenozoic basement rocks (unit 5) in this model. This value is a commonly used reduction density in geophysical studies (Simpson and Jachens, 1989).

Magnetic Property Data

The strong NRM intensities of the samples collected from Rattlesnake Knoll, coupled with their initial horizontal magnetization directions and a rapid loss of magnetic intensity during demagnetization (by 15 milliteslas, more than an order of magnitude), indicates that the hand sample was probably taken near the site of a previous lightning strike. NRM intensities for samples from a hornblende dacite intrusion in northern Snake Valley, located along the Nevada and Utah border just east of the study area, ranged from about 0.1 to 1.0 A/m (Hagstrum and Gans, 1989), similar to the range of 0.7 to 1.3 A/m measured in the Rattlesnake Knoll sample. Hagstrum and Gans (1989) also suggested that their samples with the strongest intensities and dispersed initial directions may be indicative of lightning-induced magnetization. Thus, a value closer to the middle of the range indicated by that study is probably more representative of Rattlesnake Knoll and is more appropriate for modeling the magnetic intensity at the knoll. A magnetization of 0.8 A/m was used for Rattlesnake Knoll in this model, a value which is among the strongest measured in Cenozoic volcanic rocks in the Pahute Mesa area (Mankinen and others, 2003).

The magnetic intensities of intrusive rocks in the basement are expected to be much weaker than those above the basement, so the intrusive basement rocks were assigned a value of 0.2 A/m. Basement rocks are also expected to have larger magnetic susceptibilities than remanent magnetizations. Because of this, a susceptibility value of 0.6 A/m was chosen. This value is typical of silicic igneous rocks (Telford and others, 1976) and of igneous rocks in general (Sanger and Glen, 2003). The magnetization direction used for both extrusive and intrusive rocks is one that would be produced by a middle Cenozoic geocentric axial dipole field (an inclination of about ±60° and a declination of 0° or 180°).

Model Results

The geophysical model, which incorporates the gravity and ground magnetic data along the traverse, is shown in figure 6. To account for both the ground magnetic data and aeromagnetic data, two volcanic units within the basin fill were defined. The most extensive unit (unit 3 of figure 6) has a reversed polarity corresponding to the magnetic low in the aeromagnetic data. The normal-polarity unit (unit 2 of figure 6), which is exposed on the knoll, is much smaller volumetrically; this at least partially accounts for its absence in the aeromagnetic data. A buried intrusion (unit 4 of figure 6) is likely the source for the normal-polarity Rattlesnake Knoll rocks and may be the source for both volcanic units.

Two reasonable interpretations exist for the volcanic units. The first interpretation is that both volcanic units are from the same source. If true, a substantial amount of time must have passed between eruptions, during which a polarity reversal took place. This time gap is likely on the order of at least a few thousand years. The second interpretation is that the volcanic units have different sources. The reversed-polarity unit may be part of the early latite tuff reported by Drewes (1967), or possibly one of the welded tuffs of the region. Although none of the regional tuffs are mapped in the immediate vicinity of the study area, four units are mapped sufficiently nearby to be considered candidates: the Cottonwood Wash Tuff and Wah Wah Springs Formation of the Needles Range Group, the Kalamazoo Tuff, and the Windous Butte Formation, all of which are shown to be near the study area in the compilation by Sweetkind and du Bray (2008). Only the Windous Butte Formation (Grommé and others, 1972) and the Wah Wah Springs Formation have reversed polarity, however (Grommé and others, 1972; Best and others, 2013). These tuffaceous formations are ~33 Ma and 30.1 Ma, respectively (Best and others, 2013), so if one is the reversed-polarity unit, the maximum age for Rattlesnake Knoll is middle Oligocene.

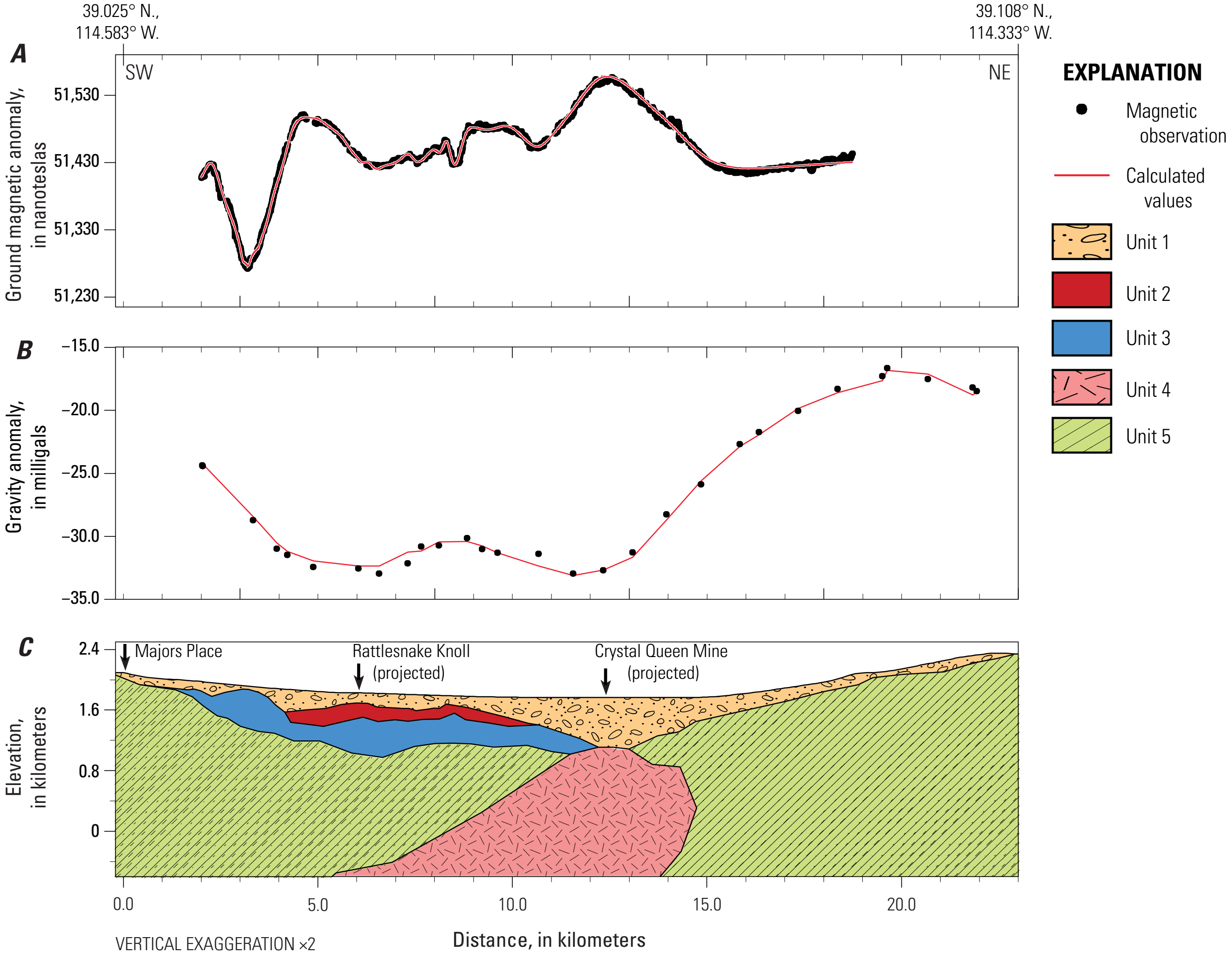

Figure 6. Graphs of ground magnetic anomalies (*A*) and gravity anomalies (*B*) compared to a cross sectional geophysical model (*C*) along the ground magnetic survey traverse located in Spring Valley, Nevada. Lithologic units are surficial sediment (1), normal-polarity volcanic rock (2), reversed-polarity volcanic rock (3), intrusive igneous rock (4), and pre-Cenozoic basement rock (5). See table 1 for physical properties of units. Profiles extend from 39.025° N., 114.583° W. to 39.108° N., 114.333° W., largely following U.S. Routes 6 and 50. SW, southwest; NE, northeast.

Conclusions

Past researchers have proposed different origins for a small outcrop of igneous breccia in the center of Spring Valley, Nevada. Our reconnaissance field examination of Rattlesnake Knoll recognized flow breccia, volcanic mudflow breccia, and conglomerate, all of which had consistent, gently west-dipping bedding wherever it was measured. On the basis of these field data, we agree with those who consider the knoll a volcanic breccia. The geophysical model shown in figure 6 is a straightforward interpretation of all available data. The simplest explanation for the magnetic data is that one igneous intrusion exists in the basement beneath the traverse and is overlain by basin fill containing two volcanic units. The more extensive volcanic unit has a reversed magnetic polarity, corresponding to the magnetic low in the aeromagnetic data. The other unit, which is exposed on the knoll, has a normal polarity and is much smaller volumetrically. Its small size can at least partially account for the fact that this normal-polarity unit is not visible in the aeromagnetic data.

References Cited

Bankey, V., Grauch, V.J.S., and Kucks, R.P., 1998, Utah aeromagnetic and gravity maps and data—A web site for distribution of data (on-line version): U.S. Geological Survey Open-File Report 98–761, https://doi.org/10.3133/ofr98761.

Barnes, D.F., Oliver, H.W., and Robbins, S.L., 1969, Standardization of gravimeter calibrations in the Geological Survey: Eos, Transactions of the American Geophysical Union, v. 50, no. 10, p. 526–527, https://doi.org/10.1029/EO050i010p00526

Best, M.G., Christiansen, E.H., Deino, A.L., Gromme, S., Hart, G.L., and Tingey, D.G., 2013, The 36–18 Ma Indian Peak–Caliente ignimbrite field and calderas, southeastern Great Basin, USA—Multicyclic super-eruptions: Geosphere, v. 9, no. 4, p. 864–950, https://doi.org/10.1130/GES00902.1.

Blakely, R.J., 1995, Potential Theory in Gravity and Magnetic Applications: New York, Cambridge University Press, 441 p., https://doi.org/10.1017/CBO9780511549816.

Dobrin, M.B., and Savit, C.H., 1988, Introduction to Geophysical Prospecting (4th ed.): New York, McGraw-Hill, 867 p.

Drewes, H., 1967, Geology of the Connors Pass quadrangle, Schell Creek Range, east-central Nevada: U.S. Geological Survey Professional Paper 557, 93 p., https://doi.org/10.3133/pp557.

Grommé, C.S., McKee, E.H., and Blake, M.C., Jr., 1972, Paleomagnetic correlations and potassium-argon dating of middle Tertiary ash-flow sheets in the eastern Great Basin, Nevada and Utah: Geological Society of America Bulletin, v. 83, no. 6, p. 1619–1638, https://doi.org/10.1130/0016-7606(1972)83[1619:PCAPDO]2.0.CO;2.

Hagstrum, J.T., and Gans, P.B., 1989, Paleomagnetism of the Oligocene Kalamazoo Tuff—Implications for middle Tertiary extension in east central Nevada: Journal of Geophysical Research, v. 94, no. B2, p. 1827–1842, https://doi.org/10.1029/JB094iB02p01827.

Heiskanen, W.A., and Vening Meinesz, F.A., 1958, The Earth and its Gravity Field: New York, McGraw-Hill, 470 p.

Hildenbrand, T.G., and Kucks, R.P., 1988, Total intensity magnetic anomaly map of Nevada: Nevada Bureau of Mines and Geology Map 93A, 1 sheet, scale 1:750,000.

Hildenbrand, T.G., Kucks, R.P., and Sweeney, R.E., 1983, Digital colored magnetic-anomaly map of the Basin and Range Province: U.S. Geological Survey Open-File Report 83–189, 11 p., https://doi.org/10.3133/ofr83189.

Hose, R.K. and Blake, M.C., Jr., 1970, Geologic map of White Pine County, Nevada: U.S. Geological Survey Open-File Report 70–166, 2 sheets, scale approximately 1:146,000, https://doi.org/10.3133/ofr70166.

Hose, R.K. and Blake, M.C., Jr., 1976, Part I, geology, *in* Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines and Geology Bulletin, v. 85, p. 1–35.

Jachens, R.C., Simpson, R.W., Blakely, R.J., and Saltus, R.W., 1989, Isostatic residual gravity and crustal geology of the United States, *in* Pakiser, L.C., and Mooney, W.D., eds., Geophysical Framework of the Continental United States: Geological Society of America Memoirs, v. 172, p. 405–424, https://doi.org/10.1130/MEM172-p405.

Jachens, R.C. and Moring, B.C., 1990, Maps of the thickness of Cenozoic deposits and the isostatic residual gravity over basement for Nevada: U.S. Geological Survey Open-File Report 90–404, 2 sheets, scale 1:1,000,000, 15-p. pamphlet, https://doi.org/10.3133/ofr90404.

Jachens, R.C., and Roberts, C.W., 1981, Documentation of a FORTRAN program, ‘isocomp’, for computing isostatic residual gravity: U.S. Geological Survey Open-File Report 81–574, 26 p., https://doi.org/10.3133/ofr81574.

Kucks, R.P., Hill, P.L., and Ponce, D.A., 2006, Nevada magnetic and gravity maps and data—A website for the distribution of data (ver. 1.0, December 2006): U.S. Geological Survey Data Series 234, https://doi.org/10.3133/ds234.

Mabey, D.R., Zietz, I., Eaton, G.P., and Kleinkopf, M.D., 1978, Regional magnetic patterns in part of the Cordillera in the western United States, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 93–105, https://doi.org/10.1130/MEM152-p93.

Mankinen, E.A., 2023, Ground magnetic data, Spring Valley, White Pine County, Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/P9WL97XY.

Mankinen, E.A., Hildenbrand, T.G., Fridrich, C.J., McKee, E.H., and Schenkel, C.J., 2003, Geophysical setting of the Pahute Mesa–Oasis Valley region, southern Nevada: Nevada Bureau of Mines and Geology Report 50, 1 CD–ROM, 45 p.

Mankinen, E.A., Roberts, C.W., McKee, E.H., Chuchel, B.A., and Moring, B.C., 2006, Geophysical data from the Spring and Snake Valleys area, Nevada and Utah: U.S. Geological Survey Open-File Report 2006–1160, 42 p., https://doi.org/10.3133/ofr20061160.

Mankinen, E.A., Roberts, C.W., McKee, E.H., Chuchel, B.A., and Morin, R.L., 2007, Geophysical data from Spring Valley to Delamar Valley, east-central Nevada: U.S. Geological Survey Open-File Report 2007–1190, 43 p., https://doi.org/10.3133/ofr20071190.

Papke, K.G., 1979, Fluorspar in Nevada: Nevada Bureau of Mines and Geology Bulletin, vol. 93, 77 p.

Peters, L.J., 1949, The direct approach to magnetic interpretation and its practical application: Geophysics, v. 14, no. 3, p. 290–320, https://doi.org/10.1190/1.1437537.

Ponce, D.A., 1997, Gravity data of Nevada: U.S. Geological Survey Digital Data Series 42, 1 CD–ROM, 27 p.

Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee, D.K., McKee, E.H., Burns, A.G., Watrus, J.M., Ekren, E.B., Patrick, W.G., and Brandt, J.M., 2017, Geology and geophysics of White Pine and Lincoln Counties, Nevada, and adjacent parts of Nevada and Utah—the geologic framework of regional groundwater flow systems: Nevada Bureau of Mines and Geology Report 56, 4 sheets, scale 1:250,000, 146 p., accessed September 12, 2022, at https://pubs.nbmg.unr.edu/Geol-geophys-White-Pine-Lincoln-p/r056.htm.

Saltus, R.W. and Blakely, R.J., 2011, Unique geologic insights from “non-unique” gravity and magnetic interpretation: GSA Today, v. 21, no. 12, p. 4–10, https://doi.org/10.1130/G136A.1.

Sanger, E.A. and Glen, J.M.G., 2003, Density and magnetic susceptibility values for rocks in the Talkeetna Mountains and adjacent region, south-central Alaska: U.S. Geological Survey Open-File Report 2003–268, 42 p., https://doi.org/10.3133/ofr03268.

Schön, J.H., 1996, Physical properties of rocks—Fundamentals and principles of petrophysics, *in* Helbig, K., and Treitel, S., eds., Handbook of Geophysical Exploration—Seismic Exploration, v. 18: New York, Pergamon Press, 583 p.

Simpson, R.W., and Jachens, R.C., 1989, Gravity methods in regional studies, *in* Pakiser, L.C., and Mooney, W.D., eds., Geophysical framework of the continental United States—Boulder, Colorado: Geological Society of America Memoir 172, p. 35–44, https://doi.org/10.1130/MEM172-p35.

Simpson, R.W., Jachens, R.C., Blakely, R.J., and Saltus, R.W., 1986, A new isostatic residual gravity map of the conterminous United States with a discussion on the significance of isostatic residual anomalies: Journal of Geophysical Research, v. 91, no. B8, p. 8348–8372, https://doi.org/10.1029/JB091iB08p08348.

Smith, R.M., 1976, Part II, mineral resources, in Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines and Geology Bulletin, v. 85, p. 36–105.

Stewart, J.H., and Carlson, J.E., 1978, Geologic map of Nevada: U.S. Geological Survey Unnumbered Series, scale 1:500,000.

Sweetkind, D.S., and du Bray, E.A., 2008, Compilation of stratigraphic thicknesses for caldera-related Tertiary volcanic rocks, east-central Nevada and west-central Utah: U.S. Geological Survey Data Series 271, 40 p., https://doi.org/10.3133/ds271.

Telford, W.M., Geldart, L.P., Sheriff, R.E., and Keys, D.A., 1976, Applied Geophysics: New York, Cambridge University Press, 860 p.

Tilden, J.E., Ponce, D.A., Glen, J.M.G., Chuchel, B.A., Tushman, K., and Duvall, A., 2006, Gravity, magnetic, and physical property data in the Smoke Creek Desert area, northwest Nevada: U.S. Geological Survey Open-File Report 2006–1197, 33 p., https://doi.org/10.3133/ofr20061197.

Tingley, J.V., 1998, Mining districts of Nevada: Nevada Bureau of Mines and Geology Report 47, 379 p.

Webring, M., 1981, MINC—A gridding program based on minimum curvature: U.S. Geological Survey Open-File Report 81–1224, 43 p., https://doi.org/10.3133/ofr811224.

Webring, M., 1985, SAKI—a Fortran program for generalized linear inversion of gravity and magnetic profiles: U.S. Geological Survey Open-File Report 85–122, 29 p., https://doi.org/10.3133/ofr85122.

White, A.F., 1871, Report of the Mineralogist of the State of Nevada for the Years 1869 and 1870: Carson City, Charles L. Perkins, State Printer, 128 p.

Wong, G., 1983, Preliminary map of the resource areas in the Basin and Range Provnce of Nevada: U.S. Geological Survey Open-File Report 83–721, 37 p., https://doi.org/10.3133/ofr83721.

Zietz, I., Gilbert, F.P., and Kirby, J.R., 1978, Aeromagnetic map of Nevada—Color coded intensities: U.S. Geological Survey Geophysical Investigations Map 922, 1 sheet, scale 1:1,000,000, https://doi.org/10.3133/gp922.

Moffett Field Service Center, California
Manuscript approved for publication Janurary 8, 2023
Edited by Claire E. Ashcraft

Mankinen and others—**The Enigmatic Rattlesnake Knoll, Spring Valley, East-Central Nevada**—OFR 2023–1002

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20231002