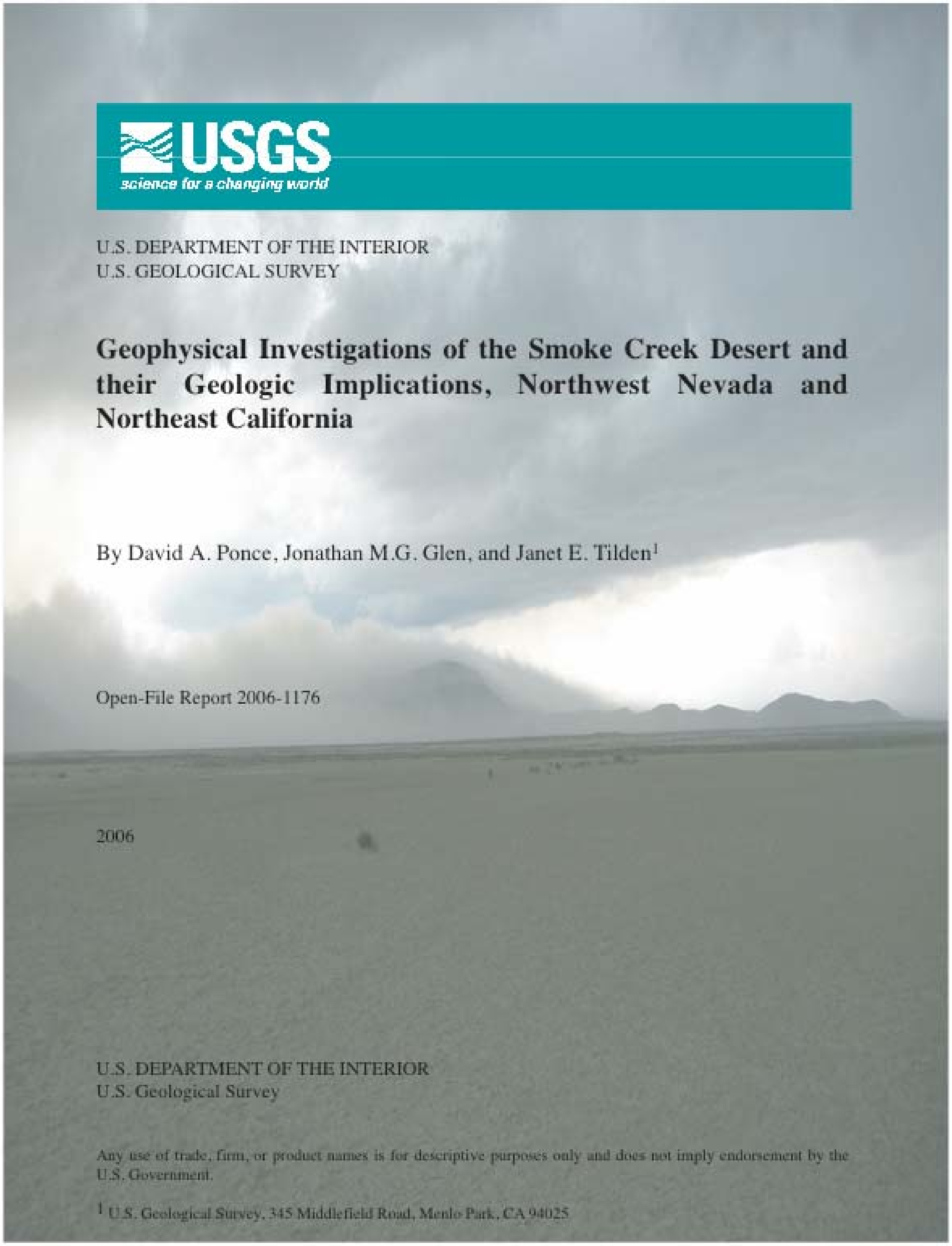

U.S. DEPARTMENT OF THE INTERIOR
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Geophysical Investigations of the Smoke Creek Desert and their Geologic Implications, Northwest Nevada and Northeast California

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Cover photo: View looking SE across the Smoke Creek Desert.

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ABSTRACT

The Smoke Creek Desert is a large basin about 100 km (60 mi) north of Reno near the California-Nevada border (fig. 1), situated along the northernmost parts of the Walker Lane Belt, a physiographic region defined by diverse topographic expression consisting of northwest-striking topographic features and strike-slip faulting. Because geologic and geophysical framework studies play an important role in understanding the hydrogeology of the Smoke Creek Desert, a geophysical effort was undertaken to help determine basin geometry, infer structural features, and estimate depth to basement.

In the northernmost parts of the Smoke Creek Desert basin, along Squaw Creek Valley, geophysical data indicate that the basin is shallow and that granitic rocks are buried at shallow depths throughout the valley. These granitic rocks are faulted and fractured and presumably permeable, and thus may influence ground-water resources in this area.

The Smoke Creek Desert basin itself is composed of three large oval sub-basins, all of which reach depths to basement of up to about 2 km (1.2 mi). In the central and southern parts of the Smoke Creek Desert basin, magnetic anomalies form three separate and narrow EW-striking features. These features consist of high-amplitude short-wavelength magnetic anomalies and probably reflect Tertiary basalt buried at shallow depth. In the central part of the Smoke Creek Desert basin a prominent EW-striking gravity and magnetic prominence extends from the western margin of the basin to the central part of the basin. Along this ridge, probably composed of Tertiary basalt, overlying unconsolidated basin-fill deposits are relatively thin (< 400 m).

The central part of the Smoke Creek Desert basin is also characterized by the Mid-valley fault, a continuous geologic and geophysical feature striking NS and at least 18-km long, possibly connecting with faults mapped in the Terraced Hills and continuing southward to Pyramid Lake. The Mid-valley fault may represent a lateral (east-west) barrier to ground-water flow. In addition, the Mid-valley fault may also be a conduit for along-strike (north-south) ground-water flow, channeling flow to the southernmost parts of the basin and the discharge areas north of Sand Pass.

INTRODUCTION

The Smoke Creek Desert, located approximately 100 km (60 mi) north of Reno near the California-Nevada border (fig. 1), is a large basin situated along the northernmost parts of the Walker Lane Belt (Stewart, 1988), a part of the Basin and Range physiographic province defined by diverse topographic expression and strike-slip faulting. Because geologic framework studies play an important role in understanding the hydrology of the Smoke Creek Desert, a geophysical effort was undertaken to help determine basin geometry, infer structural features, and estimate depth to basement.

The study area (fig. 1) is bounded by Permian and Triassic metavolcanic rocks and Cretaceous granitic rocks along the western margin of the Smoke Creek Desert, Triassic and Jurassic metasedimentary rocks and Cretaceous granitic rocks in the Fox and parts of the Granite Ranges along the eastern and northeastern margin of the Smoke Creek Desert (fig. 2). Tertiary basalts are mapped to the north, west, and south of the Smoke Creek Desert playa in the Buffalo Hills, Skedaddle Range, and Terraced Hills, respectively (fig. 2). (See Stewart and Carlson, 1978; G.L. Dixon and others, written commun., 2005; Faulds and Ramelli, in press). Metavolcanic and metasedimentary rocks, granitic rocks, volcanic rocks, and unconsolidated alluvial deposits exhibit densities and magnetic properties that create a distinguishable pattern of gravity and magnetic anomalies that can be used to infer subsurface structure and determine the geologic and geophysical framework of the area.

ACKNOWLEDGMENTS

We would like to thank Bruce Chuchel, Alison Duvall, and Kira Tushman of the U.S. Geological Survey for their assistance in collecting the geophysical data and Tom Hildenbrand and Gary Dixon for their review comments and suggestions.

GRAVITY AND MAGNETIC METHODOLOGY

General

Gravity data for northwest Nevada and northeast California were derived from statewide compilations of Nevada (Ponce, 1997) and California (Snyder and others, 1986) and supplemented with over 587 gravity stations collected as part of the Smoke Creek Desert investigations (Tilden and others, 2005). The study area includes 1,642 gravity stations that were reduced to a common datum using standard reduction methods that included terrain and isostatic gravity corrections (Dobrin and Savat, 1988; Blakely, 1995). The isostatic gravity corrections were based on an Airy-Heiskanen model of local isostatic compensation that enhances sources within the shallow- to mid-crust by removing long-wavelength variations in the gravity field inversely related to topography (Jachens and Roberts, 1981; Simpson and others, 1986). Gravity values are expressed in milligals (mGal), a unit of acceleration or gravitational force per mass equal to 10^{-5} m/s^2. Gravity data were gridded at an interval of 400 m (1/4 mi) using a computer program (Webring, 1981) based on a minimum curvature algorithm by Briggs (1974) and displayed as a color-contoured map (fig. 3).

A regional aeromagnetic map of northwest Nevada and northeastern California (fig. 4) was derived from statewide compilations of Nevada (Hildenbrand and Kucks, 1988) and California (Roberts and Jachens, 1999). Aeromagnetic survey specifications in this compilation vary, but within the study area most surveys were flown at a flight-line spacing of 1.6-3.2 km (1-2 mi) and a barometric flight-line altitude of 2,700 m (9,000 ft) with varying flight directions. Magnetic anomalies were calculated by subtracting an International Geomagnetic Reference Field (IGRF) (Langel, 1992) appropriate for the year of the survey. Individual aeromagnetic surveys were normalized (upward or downward continued), if necessary, to a flight-line elevation of 305 m (1,000 ft) above ground, adjusted to a common datum, and merged to produce a uniform map that allows interpretations across survey boundaries.

In addition, a detailed aeromagnetic survey of the Smoke Creek Desert was collected by Sander Geophysics Ltd., Ottawa, Canada, a geophysical company that specializes in high-precision airborne surveys. The airborne survey was flown at a fight-line spacing of 0.2 km (1/8 mi) over the Smoke Creek Desert and 0.4 km (1/4 mi) over the Squaw Creek Valley, at a nominal flight elevation above the ground of 150 m (500 ft), and in an EW flight-line direction. Aeromagnetic data were reduced to total intensity magnetic field and include corrections for the diurnal variations of the Earth's magnetic field, despiking, leveling, and removal of a regional magnetic field of the Earth (IGRF). Aeromagnetic data were gridded at an interval of 50 m (165 ft) using a computer program (Webring, 1981) based on a minimum curvature algorithm by Briggs (1974) and displayed as a color-contoured map (fig. 4).

Density and magnetic properties of over a hundred rock samples (table 1) were collected throughout the study area and used as an aid to the geophysical interpretations. In particular, physical property measurements were especially valuable for gravity and magnetic modeling as well as the gravity inversion calculations. A more detailed description of the density and magnetic physical property data, as well as the gravity and magnetic data, are contained in a companion report by Tilden and others (2005).

Because many of the features on the geophysical maps can be obscured by the superposition of anomalies from a variety of sources, which can produce ambiguous interpretations, a number of geophysical filtering and processing techniques have been utilized to enhance interpretations and are described below. Our interpretive approach includes: (1) a gravity inversion technique to determine the thickness of Cenozoic deposits (or depth to basement), (2) determination of maximum horizontal gradients to better define lateral changes in the rock properties, (3) a filtering technique to isolate near-surface magnetic features, and (4) two-dimensional modeling to estimate source geometries and properties.

Gravity Inversion—Depth to Basement

The thickness of Cenozoic deposits beneath Smoke Creek Desert was determined utilizing a modified version (Chuchel, oral commun., 2005) of an iterative gravity inversion method originally developed by Jachens and Moring (1990) that allows for the inclusion of independent constraints, such as drill-hole information as well as minimum depths to basement (e.g., drill holes that do not reach basement). The inversion method separates the isostatic gravity field into two components: the gravity field generated by pre-Cenozoic basement and the gravity field generated by less-dense overlying Cenozoic deposits.

The inversion process begins by using an initial *basement* gravity field determined from the isostatic gravity data collected solely on outcrops of pre-Cenozoic basement rocks or in areas where the gravity field represents a value determined for basement rocks. This initial basement gravity field is only a first approximation because gravity stations measured on basement outcrops are influenced by the gravity effect of low-density deposits in adjacent basins, especially for those measurements nearest the edge of the basin. The arithmetic difference between the isostatic and basement gravity fields represents the initial estimate of the *basin* gravity field. The gravitational effects of this basin gravity field are removed from each gravity measurement made on basement rock, essentially removing gravity effects caused by low-density basin-fill material, thus creating an improved measure of the basement gravity field. This process is repeated until successive iterations produce little or no changes in the basement gravity field. Inversion of the final basin gravity field yields the final estimate of the depth to pre-Cenozoic basement (fig. 5).

The inversion process is partly based on the density contrasts between Cenozoic alluvial deposits, Cenozoic volcanic deposits, and pre-Cenozoic basement. The density of basement rocks were allowed to vary horizontally, whereas, the density of Cenozoic deposits vary according to a density-depth function (table 2). In addition to these geologic and density constraints, the inversion process was constrained by limited drill-hole information. The density-depth function used in this process is similar to that used for the entire state of Nevada (Jachens and Moring, 1990) that was based on rock sampling, geophysical logs, and borehole gravity measurements throughout the state. Geologic data are from Bonham (1969), Jennings and others (1977), Stewart and Carlson (1978), G.L. Dixon and others (written commun., 2005), and Faulds and Ramelli (in press).

The inversion process used to determine the thickness of Cenozoic deposits is subject to a number of limitations, including: (1) gravity data coverage, especially for stations on basement outcrops; (2) accuracy of the density-depth function; (3) accuracy or scale of geologic mapping; and (4) simplifying assumptions regarding concealed geology. A more detailed discussion of the accuracy and limitations of the inversion method were provided by Jachens and Moring (1990). Because of limitations mentioned above and the inherent ambiguity in the gravity method, caution should be exercised when thickness values are interpolated below about 250 to 500 m (800 to 1600 ft).

Maximum Horizontal Gradients

To better define the edges of geophysical sources and to help derive geophysical lineaments and terranes, the maximum horizontal gradients of both gravity and magnetic data were computer generated. A technique described by Blakely and Simpson (1986) was used to calculate the maximum horizontal gradients which reflect abrupt lateral changes in the density or magnetization of the underlying geology, especially were the sources are shallow. Alignment of maximum horizontal gradient locations can be used to define lineaments, faults, and boundaries of geologic features.

Shallow Source Magnetic Map

In order to enhance magnetic anomalies caused by near surface sources, a filtering technique was used to separate short-wavelength (shallow) from long-wavelength (deeper) anomalies. This process highlights near-surface geologic boundaries by the removal of a smooth regional field. To accomplish this, the magnetic data were upward continued a small distance (50 m) to approximate the regional magnetic field. Upward continuation tends to remove shorter wavelengths produced by near-surface sources. This regional field was then subtracted from the original data to derive a residual field consisting of shorter wavelengths that reflects near-surface sources. The resulting residual magnetic map (fig. 6) illustrates the effectiveness of this approach to highlight boundaries of subtle magnetic sources that, in this case, are within about 500 m (1,600 ft) of the surface.

Two-dimensional Modeling

To supplement geophysical interpretations, selected geologic profiles were modeled (fig. 7) using a two-dimensional gravity and magnetic modeling program (GMSYS, Northwest Geophysical Associates, Inc., http://www.nga.com). These models are based on gravity and magnetic data, mapped surface geology, geologic cross sections (G.L. Dixon and others, written commun., 2005), and physical property measurements on rock samples throughout the study area. Note that geophysical models are limited by the non-uniqueness theorem of potential field modeling, where, an infinite number of mass (density) or magnetic property distributions can account for an observed anomaly. However, utilizing independent constraints such as surface geology, seismic reflection or refraction data, drill-holes, physical property data, and the simultaneous inversion of gravity and magnetic data, possible solutions converge to a family of similar geologic models.

DISCUSSION

General

In general, isostatic gravity anomalies reflect lateral (horizontal) density variations in the middle to upper crust and similarly, magnetic anomalies reflect lateral variations in rock magnetic properties. Thus, gravity and magnetic anomalies can be used to infer the three-dimensional subsurface geologic structure. Gravity anomalies often reveal dense basement rocks, calderas, deep sedimentary basins, faults, and other geologic features. Whereas, magnetic anomalies may reflect granitic rocks, volcanic rocks, faults, and other magnetic geologic features. Cretaceous granitic rocks and Mesozoic and Paleozoic metamorphic rocks in the Buffalo Hills, Fox Range, and Granite Range, may extend beneath the Smoke Creek Desert basin and their structure and degree of fracturing may play a role in the region's hydrology. Tertiary basaltic rocks probably underlie most of the Smoke Creek Desert basin, and their subsurface distribution, thickness, and structure are important in evaluating the hydrogeology of Smoke Creek Desert basin. Quaternary alluvial deposits and their three-dimensional distribution also plays an important role in the hydrology of the Smoke Creek Desert basin.

In the Smoke Creek Desert study area, gravity highs occur over the Skedaddle Mountains, Fox Range, Granite Range, and over portions of Tertiary volcanic rocks in the Buffalo Hills (fig. 3). These gravity highs likely reflect basement rocks, either exposed at the surface or buried at shallow depths. Average saturated bulk density for basement rocks is 2.65 g/cm^3 for grantic rocks, 2.52 g/cm^3 for metasedimentry rocks, and 2.84 g/cm^3 for metavolcanic rocks (table 1). Gravity lows occur over the Smoke Creek Desert basin, Buffalo and Squaw Creek Valleys, the

San Emidio Desert, and in the low-lying area northwest of Smoke Creek Valley. These lows reflect sedimentary basins filled with lower-density alluvial and volcanic deposits. Isostatic gravity data indicate that the southern Smoke Creek Desert basin corresponds to a 25-mGal gravity low, and assuming a density contrast of 0.4 g/cm^3, a simple infinite slab approximation yields a basin depth of approximately 2 km (1.2 mi).

Magnetic anomalies represent changes in the Earth's magnetic field and are generally used to infer lateral variations in the magnetization of rocks. These anomalies can be explained by the variations in rock type across the region. Magnetic highs are likely due to granitic and mafic volcanic rocks that have average magnetic susceptibilities of 0.75 x 10^{-3} and 0.55 x 10^{-3} cgs units, respectively, whereas magnetic lows are probably associated with less magnetic felsic volcanic rocks and sedimentary rocks (table 1). Magnetic highs occur in the study area over portions of Squaw Creek Valley, the northeastern Smoke Creek Desert, and the central and southern Smoke Creek Desert (fig. 4). Areas where the magnetic field is lower include parts of the central Smoke Creek Desert, the southern Smoke Creek Desert, and an area just southwest of Gerlach along latitude 40º 40'.

The diverse physical properties of rock units that underlie this region are well suited to geophysical investigations. The contrast in density and magnetic properties between Mesozoic and Paleozoic crystalline basement and overlying Tertiary volcanic rocks and unconsolidated alluvium, for example, produces a distinctive pattern of gravity and magnetic anomalies that can be used to infer geologic structure and determine the depth to pre-Cenozoic basement. Basement topography, which in places may correspond to the top of buried granitic or metamorphic rocks, probably plays an important role in the hydrogeologic framework of the area.

Surrounding Ranges—Buffalo Hills, Granite Range, Fox Range, and Terraced Hills

A prominent and circular magnetic low (M1, fig. 4), coincident with a gravity high (fig. 2), in the northwest part of the study area, overlies a small granitic outcrop and a small basin filled with older alluvial fan deposits (G.L. Dixon and others, written commun., 2005). This feature could represent a relatively weakly- to non-magnetic pluton, a resurgent volcanic center (rhyolitic), weakly- to non-magnetic basement rocks, or a zone of magnetically altered rocks. The surrounding magnetic highs correlate to exposed moderately magnetic Tertiary basalt.

Gravity and magnetic anomalies in the Granite Range reflect dense and moderately magnetic granitic rocks exposed along the range and Permian and Triassic metavolcanic rocks (Stewart and Carlson, 1978; Faulds and Ramelli, in press) exposed along the northern and northeastern parts of the range. The maximum gravity anomaly is displaced east of the Granite Range and over scattered outcrops of metavolcanic rocks (Stewart and Carlson, 1978), which suggests that these dense rocks are extensive in the subsurface and, where not exposed, occur at shallow depth. In the northern part of the Granite Range, a large amplitude magnetic anomaly (M2, fig. 4) indicates that Cretaceous granitic rocks extend in the subsurface across Squaw Creek Valley, essentially coincident with profile line AA'. The steep gravity gradient on the western flank of the Granite Range reflects a range bounding fault with significant vertical relief that has been mapped in more detail by Faulds and Ramelli (in press).

In the Fox Range, gravity and magnetic anomalies reflect basement rocks composed of Triassic and Jurassic metasedimentary rocks and Cretaceous granitic rocks (Stewart and Carlson, 1978; G.L. Dixon and others, written commun., 2005) exposed along the range. These anomalies are somewhat subdued as compared to the anomalies along the Granite Range, with the exception of a magnetic anomaly along the northernmost part of the Fox Range that probably reflects moderately magnetic granitic rocks. Gravity and especially magnetic data indicate that these rocks extend north and west beneath the Smoke Creek Desert basin (M3, fig. 4).

Immediately south of the Smoke Creek desert, subdued gravity anomalies over the Terraced Hills indicate that basement rocks are at greater depths in this region and suggest that this area is composed of a thick section of volcanic rocks. Although the detailed aeromagnetic survey did not extend over the Terraced Hills, magnetic features projected into the Terraced Hills area suggest that this area is extensively fractured or faulted, as shown on the geologic map (fig. 2) by G.L. Dixon and others (written commun., 2005).

Squaw Creek Valley

The pattern of magnetic highs and weak magnetic lows (fig. 6) in Squaw Creek Valley likely corresponds to the juxtaposition of weakly- to moderately-magnetic granitic rocks of the Granite Range with weakly-magnetic Tertiary volcanic rocks along a zone of intense faulting and fracturing (G.L. Dixon and others, written commun., 2005; Faulds and Ramelli, in press) (fig. 2).

Geophysical data indicate that Squaw Creek Valley is a shallow basin with a depth to basement that reaches about 500 to 750 m (1,600 to 2,500 ft). Gravity and magnetic modeling across Squaw Creek Valley (fig. 7a) also suggests that granitic rocks are buried at shallow depths. As inferred from the geologic cross sections (G.L. Dixon and others, written commun., 2005; Faulds and Ramelli, in press) and geophysical modeling, these granitic rocks may be fractured and faulted and thus highly permeable.

Smoke Creek Desert

Gravity data indicate that the Smoke Creek Desert is composed of three large oval sub-basins, all of which reach depths up to about 2 km (1.2 mi) (figs. 3 and 5). The resulting three-dimensional geometry of the Smoke Creek Desert basin, derived from the gravity inversion, is important for estimating the volume of basin-fill material and the interconnectivity of the sub-basins. Two-dimensional geophysical modeling of the Smoke Creek Desert basin indicates that the northern part of the basin is symmetric and U-shaped (profile DD', Fig. 7b), whereas the southern part of the basin is asymmetric with a central high along the Mid-valley fault (profile EE', fig. 7c).

In some areas, magnetic anomalies can be used to infer the presence of moderately-magnetic granitic rocks below the Smoke Creek Desert basin. In particular, granitic rocks are probably present at depth below the northeastern part of the Smoke Creek Desert basin and are defined by a broad long-wavelength magnetic anomaly (M3, fig. 4). However, gravity and magnetic data alone may not be able to adequately distinguish metamorphic and granitic rocks throughout other parts of the Smoke Creek Desert basin. These Permian to Triassic metavolcanic and Triassic to Jurassic metasedimentary rocks (Stewart and Carlson, 1978), units that have been subject to considerable geologic deformation and attenuation, may not have a constant thickness or be continuous across the entire basin. In addition, granitic plutons in the area may have widely varying magnetic properties and those that are essentially non-magnetic would be difficult to detect.

In the central and southern parts of the Smoke Creek Desert basin, magnetic anomalies form three separate and narrow (7-km wide) EW-striking features (M4, M5, and M6, fig. 4). These features consist of high-amplitude short-wavelength magnetic anomalies and probably reflect Tertiary basalt buried at shallow depths. In the central part of the basin, a prominent NNEstriking magnetic lineament (M4, fig. 4) is along strike with exposures of metavolcanic rocks (fig. 2) along the northwestern margin of the basin and may indicate that they are present here as well. In the central part of the Smoke Creek Desert basin, at the location of the Mid-valley basalt outcrop, a prominent EW-striking gravity anomaly (fig. 3) extends from the western margin to the central part of the basin and correlates with a an EW-striking magnetic ridge associated with feature M5 (fig. 4). Along this gravity ridge, probably composed of Tertiary basalt and underlying basement rocks, overlying unconsolidated basin-fill deposits are relatively thin. Similarly, in the southern part of Smoke Creek Desert basin (M6, fig. 4), moderately magnetic Tertiary volcanic rocks are probably present, however, the absence of an associated gravity high (fig. 3) indicates that these rocks are likely at greater depth or less dense.

The broad, longer-wavelength gravity and magnetic anomalies throughout the basin reflect dense metamorphic and granitic rocks buried at relatively shallow depths. Because of their fine-grained nature and inferred impermeability, metavolcanic rocks exposed along the western margin of the basin may impede the flow of ground water and represent a ground-water barrier to the deeper flow system. However, where fractured, metavolcanic rocks may have increased permeability. Granitic rocks, inferred to be present beneath Squaw Creek Valley and the northeastern part of the Smoke Creek Desert basin, may also influence ground-water resources of the region. Granitic rocks may have increased permeability where fractured, as suggested in the northernmost parts of the study area (G.L. Dixon and others, written commun., 2005; Faulds and Ramelli, in press).

Mid-valley Fault

Based on gravity and magnetic data, the central parts of the Smoke Creek Desert basin are characterized by the Mid-valley fault (MVF, figs. 3 and 4) and a prominent ridge that extends from the western margin to the eastern part of the basin (M5, fig 3). This ridge separates the central and southern Smoke Creek Desert into two sub-basins. High-precision aeromagnetic data suggest that the Mid-valley fault is a continuous NS-striking feature at least 18-km long, possibly connecting with faults mapped in the Terraced Hills and continuing southward to Pyramid Lake. Although physical property constraints on these volcanic rocks at depth, which may consist of multiple cooling geologic units and have variable magnetic properties, are limited, gravity and magnetic modeling suggest that there may be about 500 m (1,600 ft) of vertical relief on the Tertiary mid-valley basalt outcrop (profile EE', fig. 7c). Geophysical modeling also indicates that the Mid-valley fault probably penetrates the underlying basement rocks of the Smoke Creek Desert basin. Based on gravity and magnetic data, the Mid-valley fault, may represent a lateral (east-west) barrier to ground-water flow. In addition, the Mid-valley fault may also be a conduit for along-strike (north-south) ground-water flow, channeling flow to the southernmost parts of the basin.

CONCLUSIONS

Geophysical data define a number of major basin and basement geologic features that play an important role in determining the hydrogeologic framework of the Smoke Creek Desert and vicinity. An important part of the basin analysis is the separation of the isostatic gravity field into that caused by lower-density basin-fill material and that caused by higher-density crystalline basement rocks. Based on the inversion of gravity data, the Smoke Creek Desert basin itself consists of three sub-basins, all of which reach depths up to about 2 km (1.2 mi). The southernmost sub-basin is separated from the central sub-basin by a prominent ridge of volcanic rocks buried at shallow depth.

The NS-striking Mid-valley fault, a prominent geophysical feature, and the EW-trending geophysical feature associated with the Mid-valley basalt outcrop that reflects Tertiary volcanic rocks at shallow depth, may represent lateral barriers to ground-water flow. In addition, the Mid-valley fault may also be a conduit for along-strike ground-water flow, channeling flow to the southernmost parts of the basin.

Granitic and metamorphic basement rocks may form much of the floor of the Smoke Creek Desert basin. In the northern part of the basin (Squaw Creek Valley), fractured or faulted granitic rocks probably comprise the valley floor. In the northeastern part of the Smoke Creek basin, granitic rocks are present at depth, as indicated by the broad long-wavelength magnetic anomaly in the northeast part of the basin. However, gravity and magnetic data alone, cannot adequately distinguish between the metamorphic and granitic rocks that may occur below the central and southern parts of the Smoke Creek Desert basin and these basement rocks may not be everywhere continuous across the basin.

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Table 1. Average physical property data of selected rock types.

Rock Type	No. of samples	Density (g/cm^3) Grain	Saturated bulk	Dry bulk	Susceptibility (10^{-3} cgs units)
Andesite	11	2.59	2.51	2.46	0.88
Basalt	56	2.64	2.60	2.57	0.55
Diorite	6	2.76	2.72	2.70	0.54
Granitic rocks	13	2.68	2.65	2.63	0.75
Metamorphic					
Gneiss	2	2.72	2.66	2.62	0.01
Metasedimentary	7	2.65	2.52	2.43	0.12
Metavolcanic	11	2.86	2.84	2.83	0.77

Table 2. Density-depth function for Cenozoic basin fill material and Cenozoic volcanic rocks used in the depth to basement process and relative to basement rocks (2.67 g/cm^3).

Depth range (m)	Cenozoic basin fill Contrast (g/cm^3)	Density (g/cm^3)	Cenozoic volcanic rocks Contrast (g/cm^3)	Density (g/cm^3)
0 - 200	-0.65	2.02	-0.45	2.22
200 - 600	-0.55	2.12	-0.40	2.27
600 - 1200	-0.47	2.20	-0.35	2.32
> 1200	-0.37	2.30	-0.25	2.42

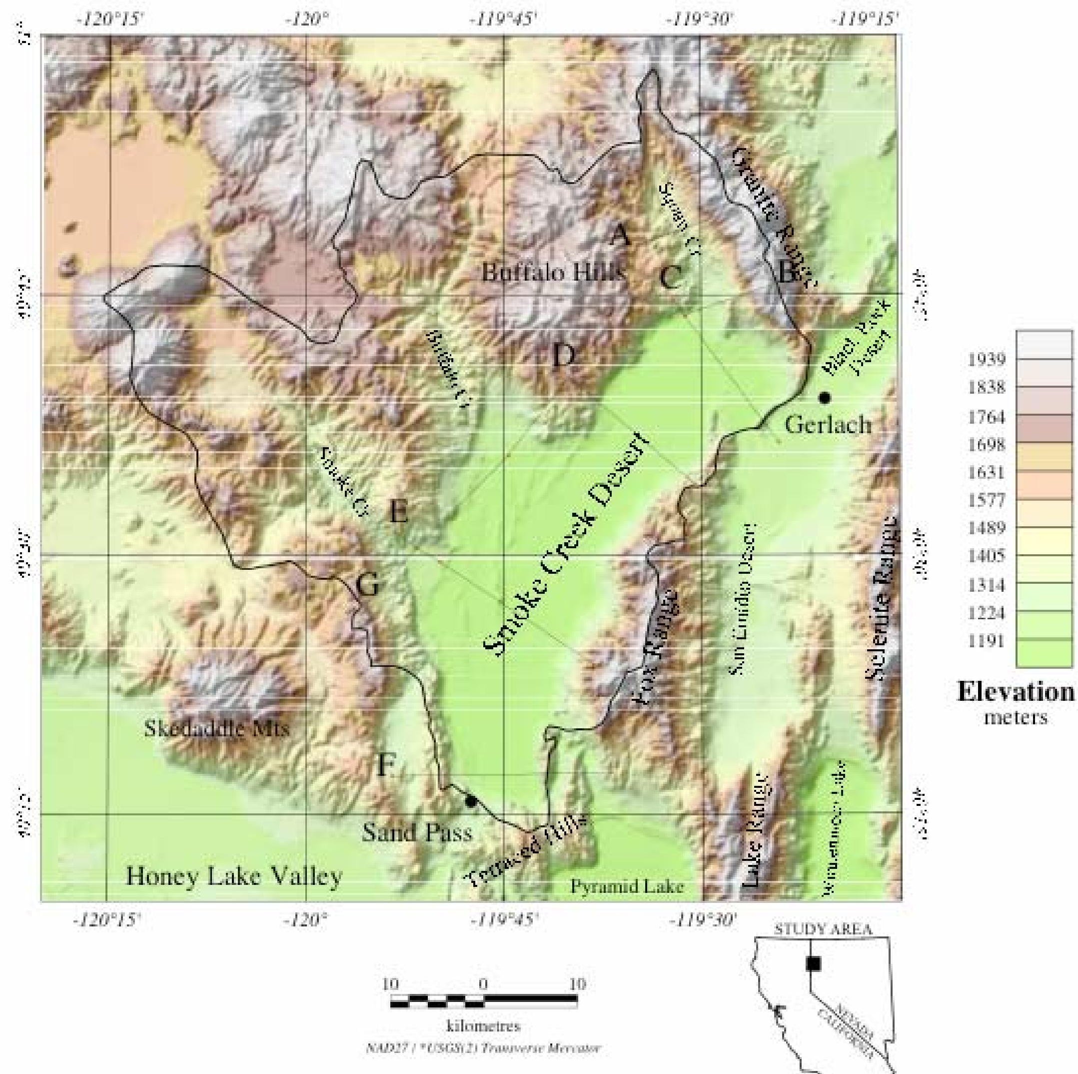

Figure 1. Shaded-relief topographic map of the Smoke Creek Desert and vicinity derived from a 15' (about 450 m) digital elevation model. Black lines (labeled A-G), location of geologic cross sections (G.L. Dixon and others, written commun., 2005). Bold black line, approximate outline of the Smoke Creek Desert study area.

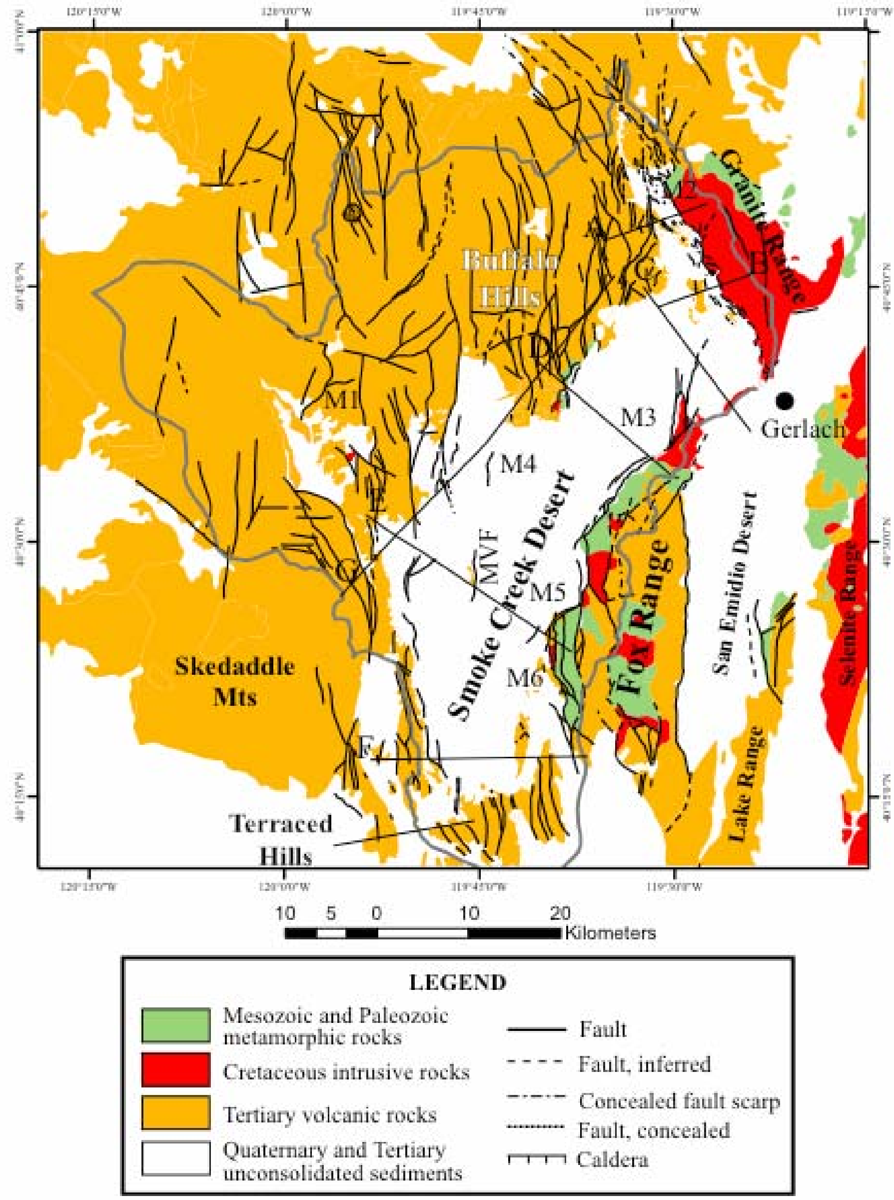

Figure 2. Simplified geologic map of the Smoke Creek Desert and vicinity (modified after Bonham, 1969; Jennings et al., 1977; Stewart and Carlson, 1978; G.L. Dixon and others, written commun., 2005; and Faulds and Ramelli, in press). MVF, Mid-valley fault; M1-M6, magnetic features discussed in the text.

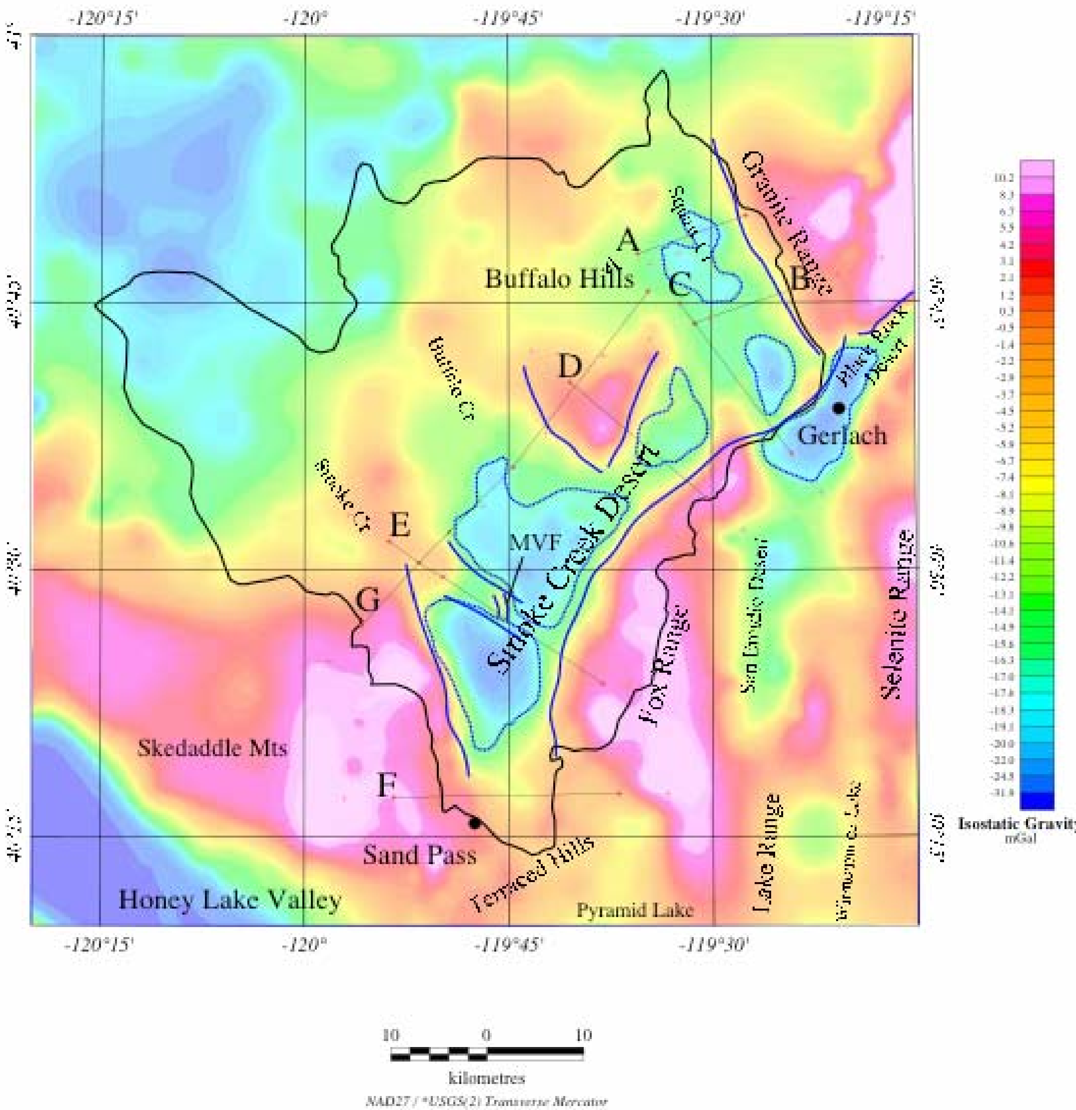

Figure 3. Isostatic gravity map of the Smoke Creek Desert and vicinity. Bold blue lines, lineaments (or faults) inferred from the gravity data; dotted blue lines, gravity features; MVF, Mid-valley fault.

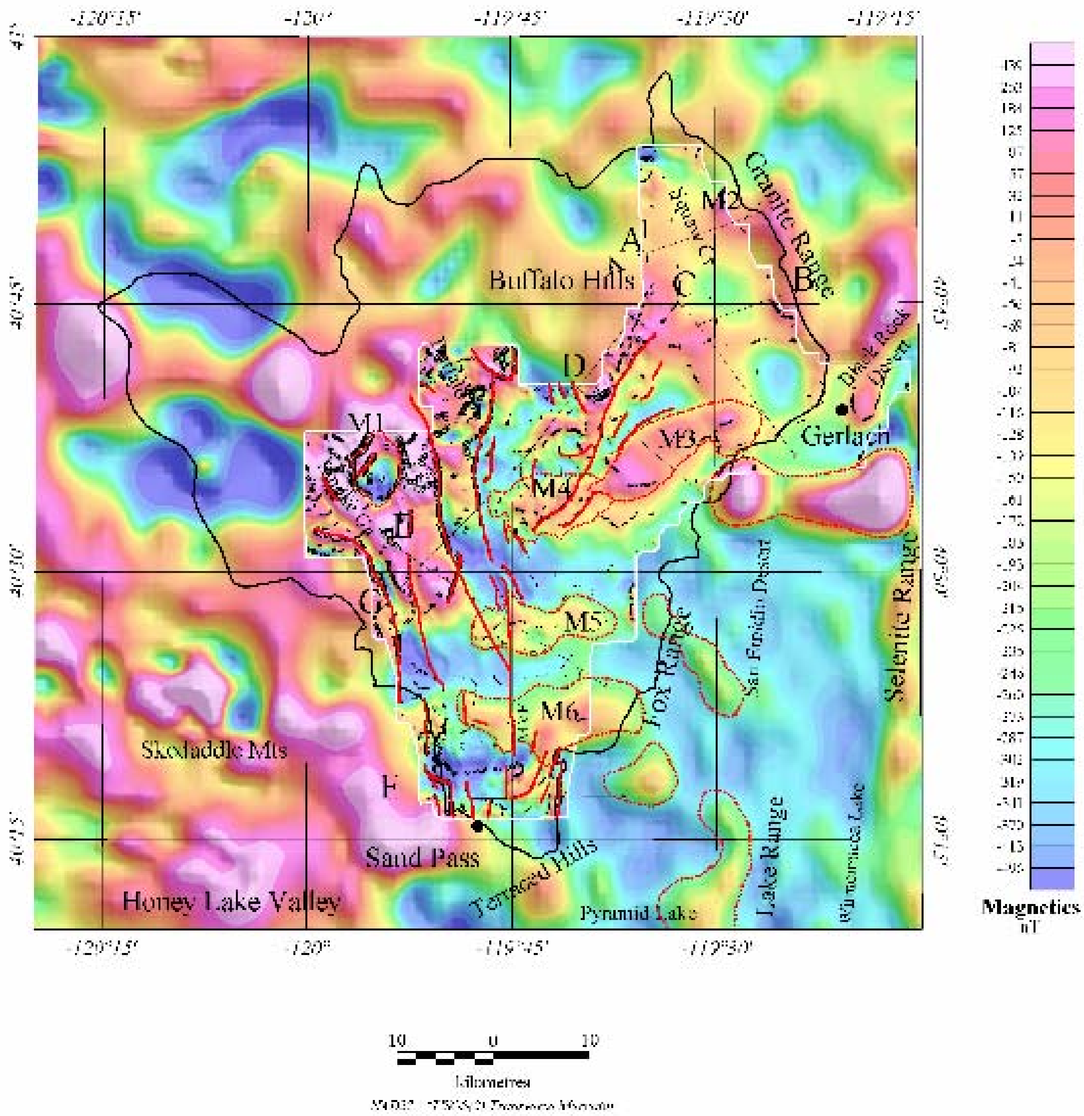

Figure 4. Detailed aeromagnetic map of the Smoke Creek Desert and vicinity (inset) superimposed on a regional aeromagnetic map of the state of Nevada (Hildenbrand and Kucks, 1988) and California (Roberts and Jachens, 1999). Black open circles, maximum horizontal gradients (symbol size is proportional to the magnitude of the gradient); bold red lines, lineaments (or faults) inferred from the magnetic data; dotted red lines, magnetic features (only those labeled are discussed in the text); MVF, Mid-valley fault.

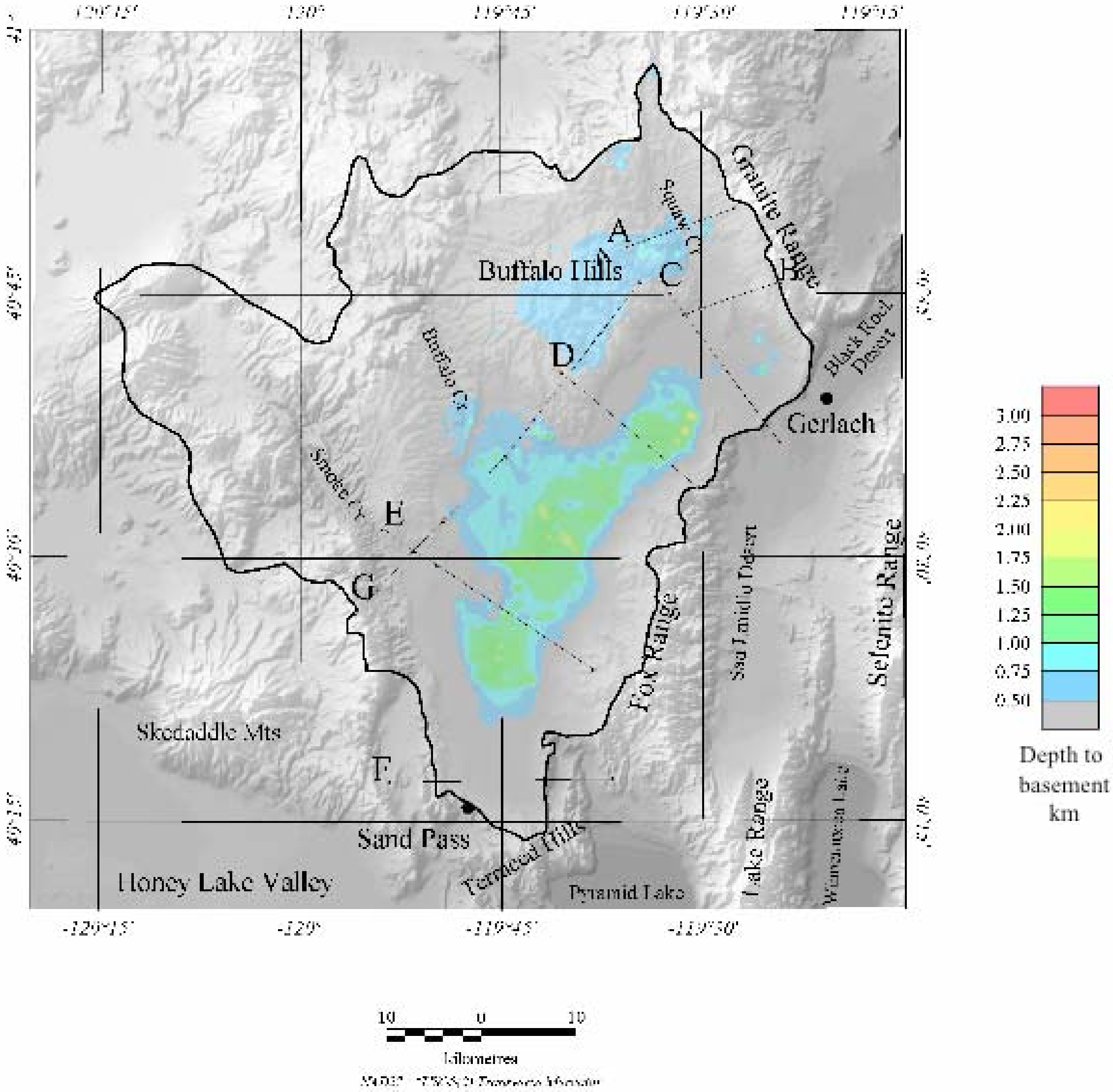

Figure 5. Depth to basement map of the Smoke Creek Desert and vicinity superimposed on a topographic map of the area.

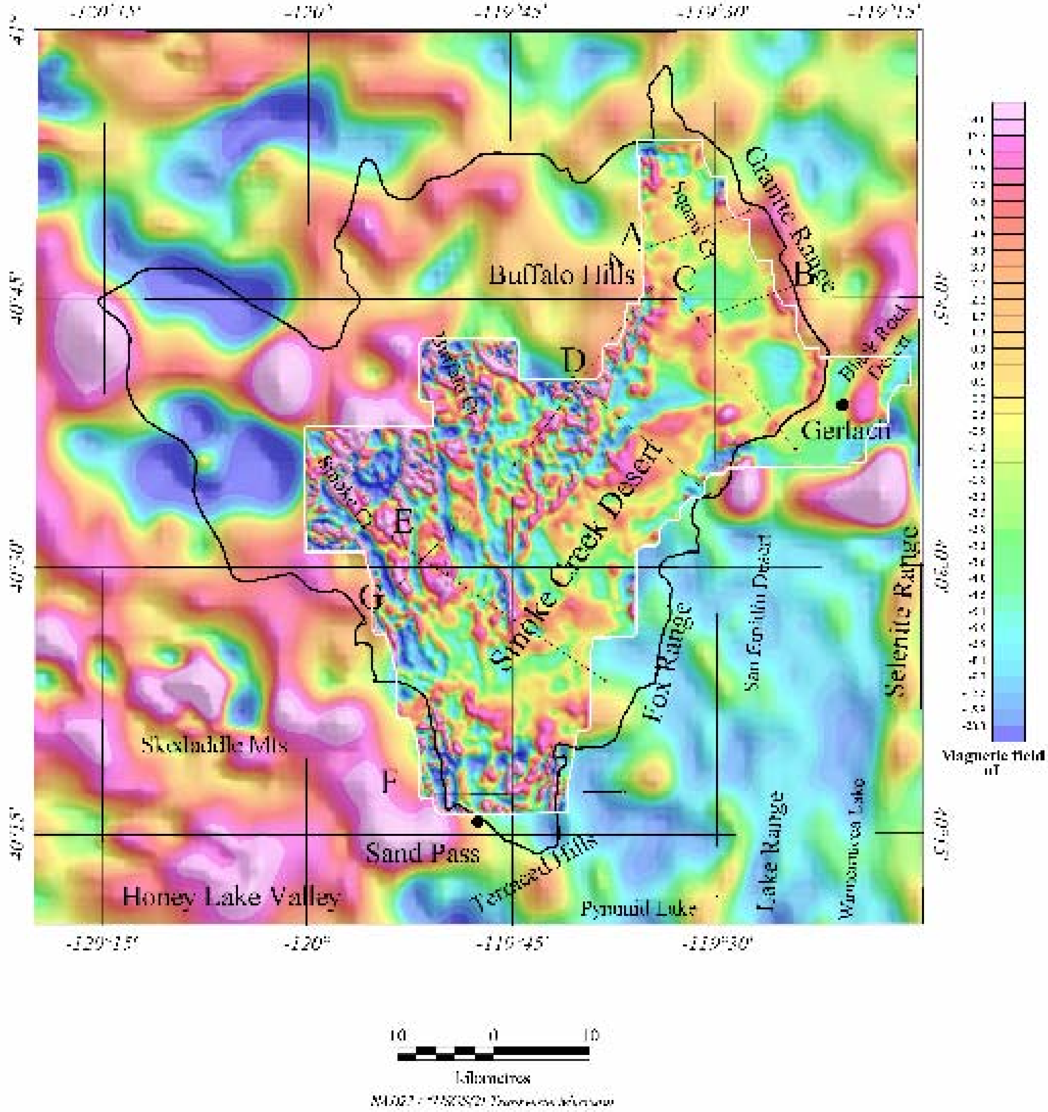

Figure 6. Shallow-source magnetic map of the Smoke Creek Desert (inset) and vicinity superimposed on a regional aeromagnetic map of the state of Nevada (Hildenbrand and Kucks, 1988) and California (Roberts and Jachens, 1999).

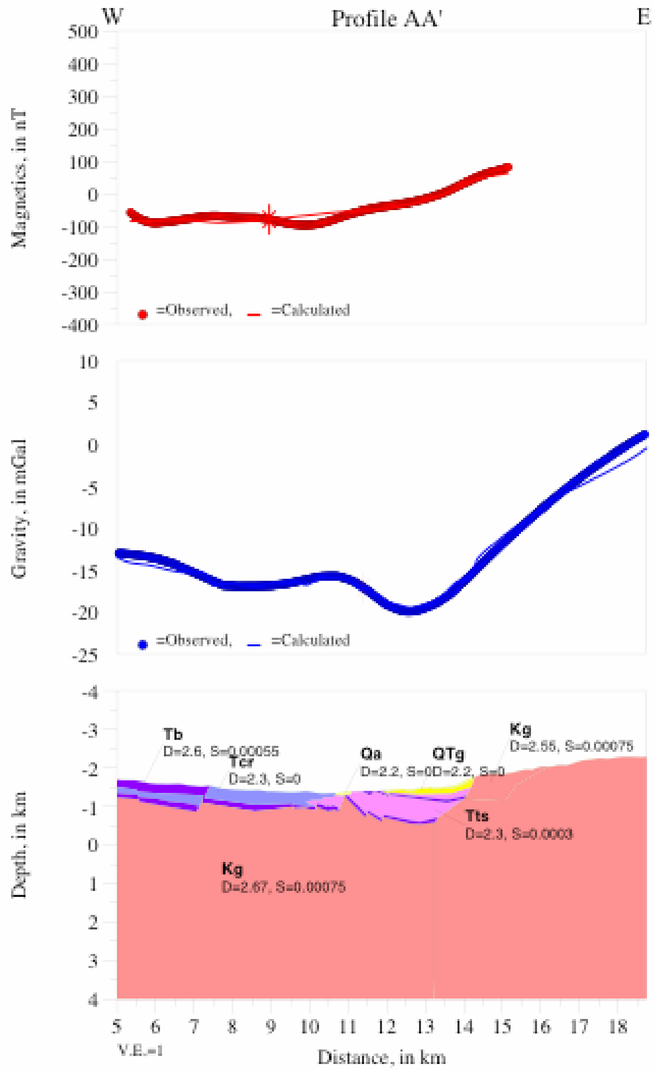

Figure 7. Two-dimensional geophysical models along selected profiles across the Smoke Creek Desert and vicinity. Because of limited drill hole data, physical property data, especially remanent magnetic properties, and the nonuniqueness theorem of potential fields, models should be used with caution and are somewhat schematic in nature. For example, modeling indicates that it is permissible (but not conclusive) for Mesozoic metavolcanic and metasedimentary rocks to be continuous across the floor of the basin. Starting models are based on geologic cross sections by G.L. Dixon and others (written commun., 2005). Geologic symbols: Qa, Quaternary alluvium; QTg, Quaternary and Tertiary basin-fill deposits; Tba, Tertiary basalt; Tr, Tertiary volcanic rocks reversely magnetized; Kg, Cretaceous grantic rocks; MPm, Mesozoic and Paleozoic metavolcanic and metasedimentary rocks. Other symbols: D, density in g/cm3; M, remanent magnetization in cgs units; MD, remanent magnetic declination in degrees; MI, remanent magnetic inclination in degrees; S, susceptibility in cgs units; V.E., vertical exaggeration.

Figure 7A. Geophysical model along profile AA' across northern Squaw Creek Valley.

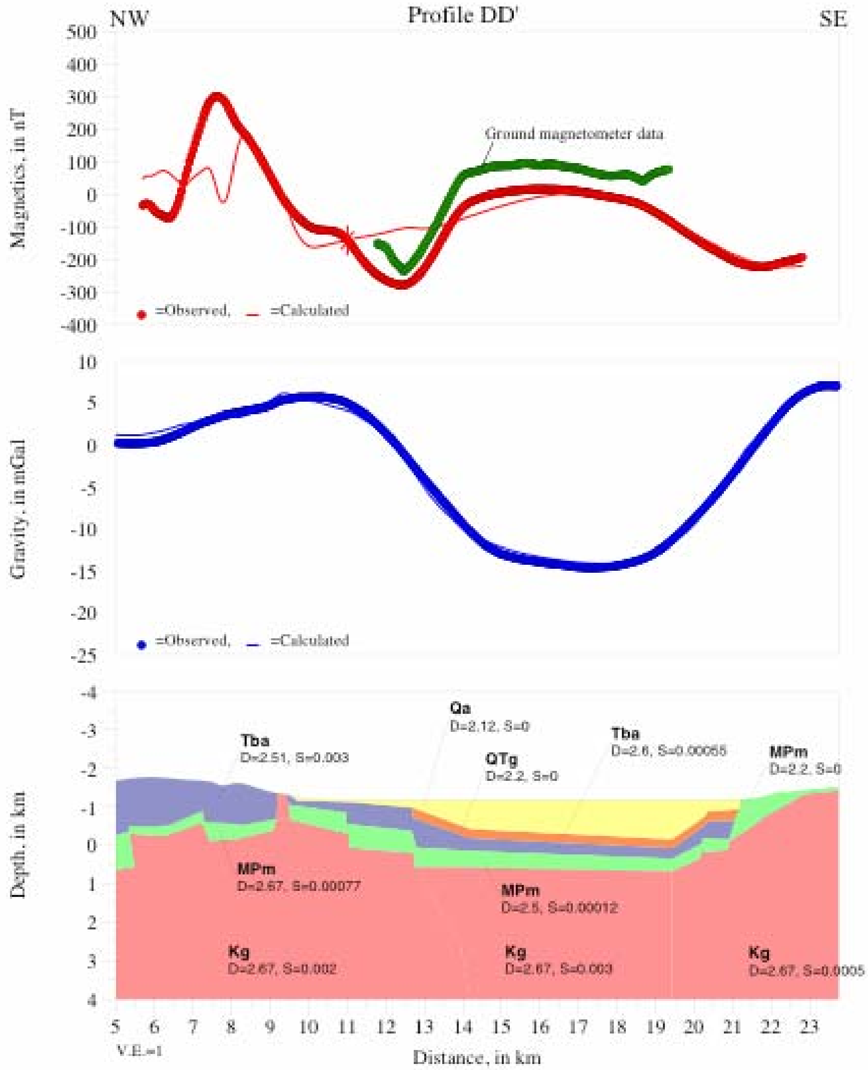

Figure 7B. Geophysical model along profile DD' across the central Smoke Creek Desert. See figure 7A for explanation. Green line, profile along part of DD' coincident with a ground magnetic traverse.

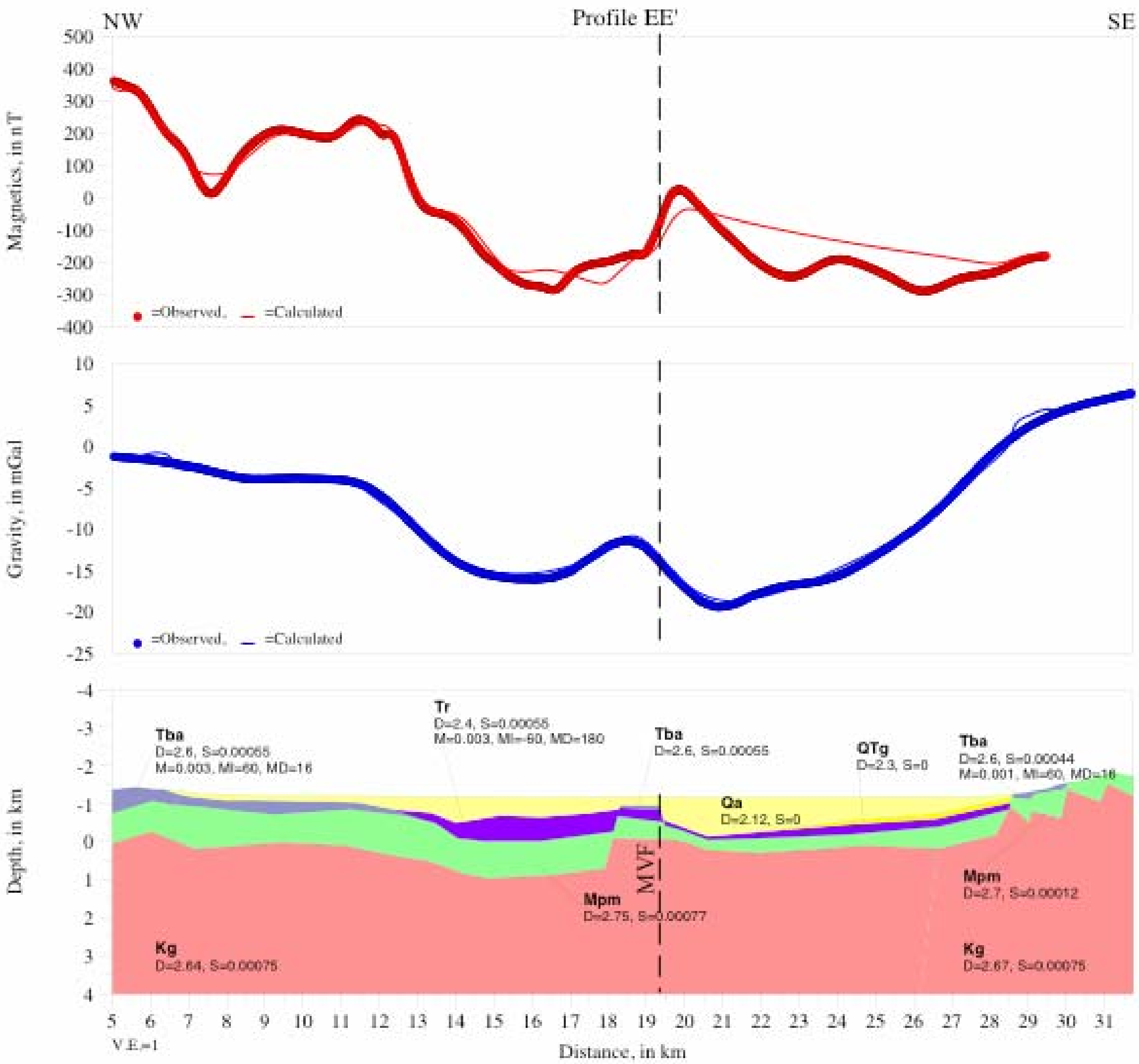

Figure 7C. Geophysical model along profile EE' across the southern Smoke Creek Desert. See figure 7A for explanation. MVF, Mid-valley fault.