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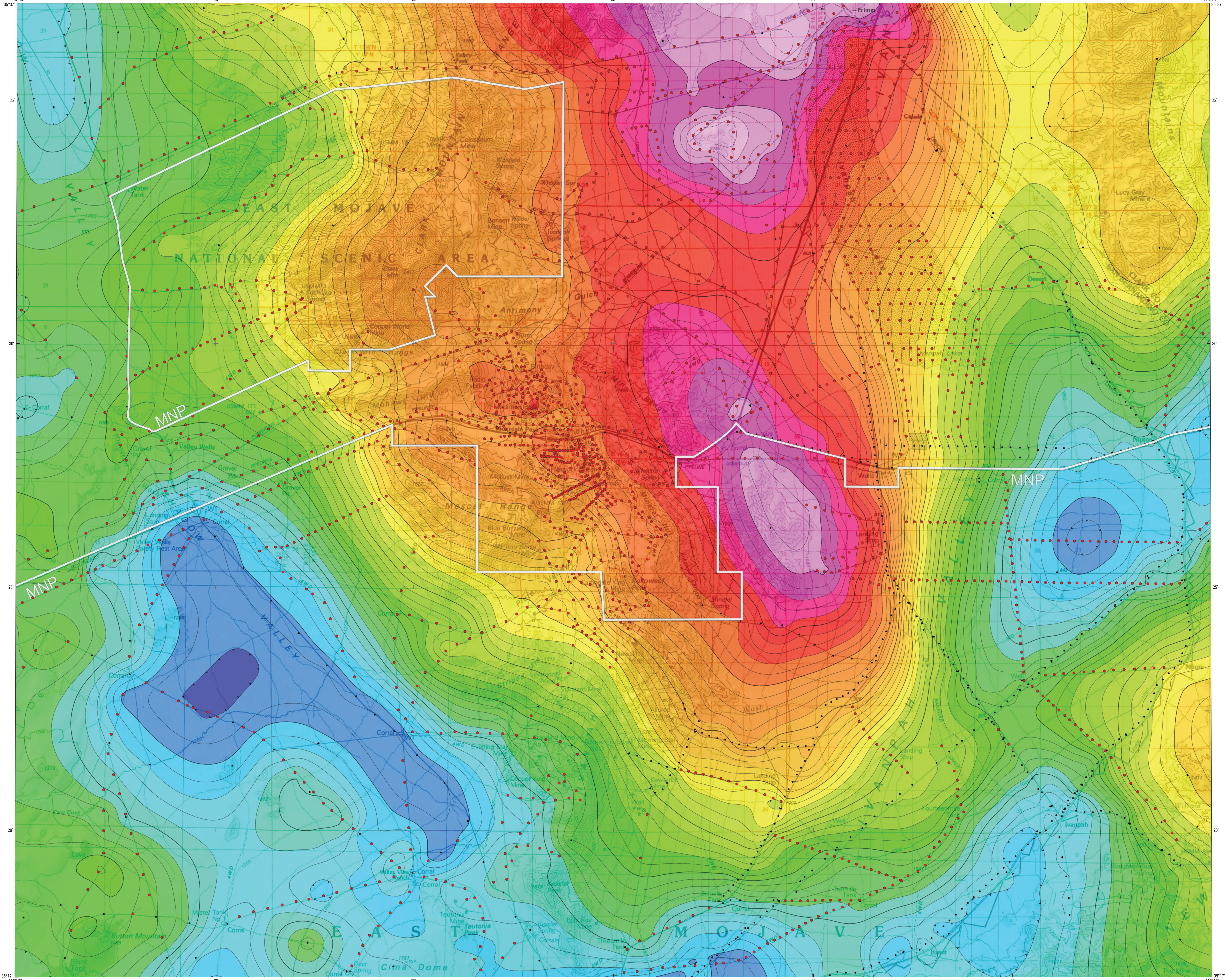
U.S. Geological Survey

Scientific Investigations Map 3412–A



Base map from U.S. Geological Survey 1:100,000-scale quadrangles: Ivanpah, 1985; Mesquite Lake, 1985

Universal Transverse Mercator projection, Zone 11N, North American Datum of 1983 (NAD 83)

11½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2018

SCALE 1:62 500

5 MILES

7 KILOMETERS

CONTOUR INTERVAL 50 METERS

Data compiled in 2018

GIS database and digital cartography by D.A. Ponce and K.M. Denton

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EXPLANATION

Isostatic gravity, in milligals (mGal)

>2, 2, 0, −2, −4, −6, −8, −10, −12, −14, −16, −18, −20

−20, −22, −24, −26, −28, −30, −32, −34, −36, −38, −40, −42, <−42

Gravity station (from Denton and Ponce, 2016)

Other gravity station

Boundary of Mojave National Preserve (MNP)

Gravity contours—Hachures indicate gravity low

Index (5 mGal intervals)

Intermediate (1 mGal intervals)

INTRODUCTION

Gravity investigations of Mountain Pass and vicinity were begun as part of an effort to study regional crustal structures as an aid to understanding the geologic framework and mineral resources of the eastern Mojave Desert. The study area, which straddles the state boundary between southeastern California and southern Nevada (fig. 1), encompasses Mountain Pass, which is host to one of the world's largest rare earth element carbonatite deposits. The deposit is found along a north-northwest-trending, fault-bounded block that extends along the eastern parts of the Clark Mountain Range, Mescal Range, and Ivanpah Mountains (fig. 1). This Paleoproterozoic block is composed of a 1.7-Ga metamorphic complex of gneiss and schist that underwent widespread metamorphism and associated plutonism during the Ivanpah orogeny (Wooden and Miller, 1990). The Paleoproterozoic rocks were intruded by a Mesoproterozoic (1.4 Ga) ultrapotassic alkaline intrusive suite and carbonatite body (Olson and others, 1954; DeWitt and others, 1987; Premo and others, 2016). The intrusive rocks include, from oldest to youngest, shonkinite, mesosyenite, syenite, quartz syenite, potassic granite, carbonatite, carbonatite dikes, and late shonkinite dikes (Olson and others, 1954).

GRAVITY METHODS

Gravity data were collected and processed to identify lateral changes in subsurface density. Generally speaking, gravity anomalies can be used to infer subsurface geologic structure, provided that a physical-property contrast is present across the geologic boundaries. Gravity anomalies can, for example, reveal variations in lithology and delineate geologic features such as faults, plutons, volcanic centers, calderas, and deep sedimentary basins, all of which may play an important role in defining the geologic framework of a region.

The gravity stations, over 2,400 of which were collected as part of this study, were concentrated in areas of poor control and along traverses of interest. Gravity stations were distributed across parts of Shadow Valley, Clark Mountain Range, Mescal Range, Ivanpah Mountains, and Ivanpah Valley. All gravity data were tied to primary base stations in Primm, Nevada, as well as a secondary base station established near Mountain Pass, California. These stations ultimately were tied to high-precision gravity base station PB1021 near Baker, California, as part of a southern California high-precision gravity base-station network (Roberts and Jachens, 1986), as well as to a World Relative Gravity Reference Network of North America gravity base station at Nipton, California (Jablonski, 1974; see also, Denton and Ponce, 2016).

Gravity data, which were processed using standard geophysical methods (see, for example, Blakely, 1995), include the following corrections: (1) earth-tide correction, which accounts for tidal effects of the Moon and Sun; (2) instrument-drift correction, which compensates for an assumed linear drift in the gravity meter's spring each day; (3) latitude correction, which accounts for variation in the Earth's gravity with latitude; (4) free-air correction, which accounts for the variation in gravity owing to elevation relative to sea level; (5) Bouguer correction, which corrects for the attraction of material between the station and sea level; (6) curvature correction, which adjusts the Bouguer correction for the effect of the Earth's curvature; (7) terrain correction, which removes the effect of topography to a radial distance of 167 km from the station; and (8) isostatic correction, which removes long-wavelength variations in the gravity field related to the compensation of topographic loads.

Observed gravity values were 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) and Swick's (1942) formula for the free-air correction. Bouguer, curvature, and terrain corrections (Godson and Plouff, 1988) were added to the free-air correction to determine the complete Bouguer anomaly at a standard reduction density of 2,670 kilograms per cubic meter (kg/m^3). Finally, a correction from the Airy-Heiskanen model for isostatic compensation of topographic loads (Jachens and Roberts, 1981), using an assumed crustal thickness of 25 km, a crustal density of 2,670 kg/m^3, and a density contrast across the base of the model of 400 kg/m^3, was made to remove a regional isostatic gravity field from the Bouguer gravity field.

New gravity data (Denton and Ponce, 2016) were combined with preexisting gravity data (Ponce, 1997; Langenheim and others, 2009) from the surrounding areas in California and Nevada. All gravity data, which were gridded using a minimum curvature algorithm at an interval of 200 m, are displayed as a color-contour isostatic gravity map. Observed gravity values are accurate to about 0.05 milligals (mGal), and gravity anomalies are accurate to about 0.1 mGal, where 1 mGal is equal to 10^{-5} centimeters per second squared (cm/s^2).

DISCUSSION

Generally speaking, carbonatites have distinctive gravity signatures because these deposits are relatively denser than the surrounding host rocks. Previous gravity studies in the eastern Mojave Desert carbonatite terrane are limited in areal extent (Carlisle and others, 1980; Swanson and others, 1980; Hendricks, 2007; Langenheim and others, 2009). From west to east across the study area, Shadow Valley is characterized by a 20-mGal gravity low that is associated with relatively low density basin-fill material and also, in part, a buried pluton that is relatively lower in density as compared to carbonate and dolomitic rocks. Gravity data indicate that the maximum depth to basement is probably about 1.5 km, on the basis of a semi-infinite sheet (Nettleton, 1976, p. 193) and assuming a 20-mGal gravity anomaly and an average density contrast between basin fill and basement rocks of 400 kg/m^3. This density contrast is based on rock-sample measurements made throughout the study area (Denton and Ponce, 2016). An iterative depth-to-basement study that incorporated geology, gravity, and drill-hole data applied to the Mojave National Preserve (green outline on map and on fig. 1) indicated that Shadow Valley reaches a maximum depth of about 1.5 km (Langenheim and others, 2009).

The Clark Mountain Range, the Mescal Range, and the northeastern part of the Ivanpah Mountains are characterized by gravity highs that are associated with relatively dense bodies of Proterozoic gneiss and Cambrian dolomite. The southwestern part of the Ivanpah Mountains is characterized by a gravity low that reflects relatively lower density granitoid rocks. The central and western parts of Ivanpah Valley are characterized by a prominent gravity high that decreases from west to east, which suggests that dense rocks are present at relatively shallow depths. In the northwestern part of Ivanpah Valley, bodies of Proterozoic gneiss and the Cambrian to Devonian Goodsprings Dolomite are exposed in small outcrops (see, for example, Hewett, 1956). On the basis of geophysical data, Carlisle and others (1980) suggested that Ivanpah Valley is an asymmetric graben, deeper along its southeastern margin, and that the depth to basement or thickness of sediment is as much as about 2.4 km. This compares well to drill-hole data that show depths to basement of 1.9 km in the southeastern part of the valley, as well as depths of 0.7 and 1.1 km in the central part of the valley (Hodgson, 1980; Carlisle and others, 1980); basin depths inferred from the inversion of gravity data (Langenheim and others, 2009) agree with these values and show that most of Ivanpah Valley is quite shallow, less than about 500 m near the Clark Mountain Range, but it may reach depths of about 3 km south of Nipton.

In the vicinity of Mountain Pass, a local gravity high of several milligals reflects relatively more dense carbonatite and shonkinite rocks; the high is within a broader terrace (that is, an area of flattening) in the regional gravity field. The terrace in the gravity field probably reflects a decrease in subsurface rock densities owing to the termination of thrusted sheets of relatively dense Paleozoic carbonate rocks to the west along the Clark Mountain Range and also to relatively more dense Proterozoic rocks to the east. In addition, this area likely is underlain by relatively less dense granitoid rocks of unknown age.

The diverse physical properties (Denton and Ponce, 2016) of rocks that underlie the study area are well suited to geophysical investigations. The contrasts in density between Proterozoic crystalline basement, Mesozoic granitoids, Cenozoic volcanic rocks, and Cenozoic unconsolidated alluvium, for example, produce a distinctive pattern of gravity anomalies that can be used to infer subsurface geologic structure, which in turn aids in the understanding of the geologic framework and mineral resource potential of the eastern Mojave Desert.

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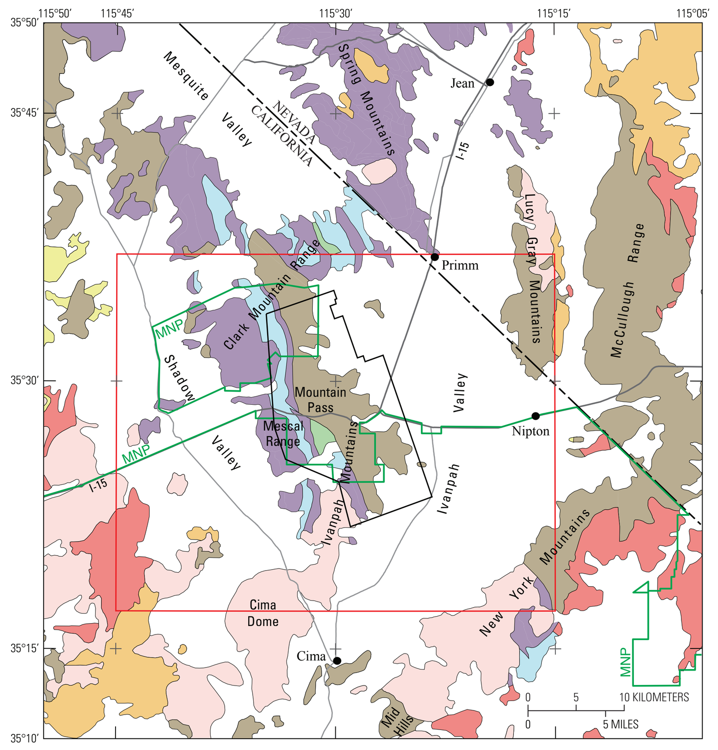

Figure 1. Index map showing simplified geology of eastern Mojave Desert (modified from Jennings and others, 1977; Stewart and Carlson, 1978). Red outline, study area; green line, boundary of Mojave National Preserve (MNP); gray lines, roads.

Isostatic Gravity Map of Mountain Pass and Vicinity, California and Nevada

By

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