INTRODUCTION

These maps are part of a folio of maps of the Ajo and Lukeville 1° × 2° quadrangles, Arizona, prepared under the U.S. Geological Survey's Conterminous United States Mineral Assessment Program (CUSMAP). The folio collectively displays geophysical, geochemical, and geologic data in order to assess the mineral resources of the Ajo and Lukeville quadrangles from an interdisciplinary perspective.

Map A is a complete Bouguer gravity anomaly map that includes gravity station locations. Map B is a residual Bouguer gravity anomaly map derived by removing anomalies having wavelengths greater than 67 km. The regional (long-wavelength) Bouguer gravity anomalies are also shown on map B. Figure 1 shows the regional gravity field. Map C is an aeromagnetic map compiled by merging four surveys (areal extent shown in fig. 3) flown over the Ajo and Lukeville 1° × 2° quadrangles.

PREVIOUS GRAVITY AND AEROMAGNETIC WORK

Lysonski and others (1981a,b) published alternative residual Bouguer gravity maps for the Ajo and Lukeville 1° × 2° quadrangles as part of a complete set of 1° × 2° quadrangle gravity maps for the State of Arizona. The regional correction for their maps is a Bouguer correction based on a second-harmonic representation of elevations over the State of Arizona (Aiken, 1975, 1976). Oppenheimer and Sumner (1980) provided an interpretation of Arizona gravity data as a set of depth-to-basement maps for the southern part of the state.

The regional gravity setting of the Ajo-Lukeville area is shown on the Arizona State Map (Lysonski, 1980; Lysonski and others, 1980), and on the maps of the Basin and Range province and the continental-scale maps of Hildenbrand and others (1982a,b) and Hildenbrand and Kucks (1982a,b). The regional aeromagnetic setting is shown on an aeromagnetic map of Arizona (Sauck and Sumner, 1970; Sauck, 1972) as well as on a regional map of the Basin and Range province (Hildenbrand and others, 1983). Sauck included some anomalies in the Ajo-Lukeville area in his interpretative discussion of the aeromagnetic map of Arizona. The gravity and aeromagnetic maps of Arizona provided the base for an interpretative discussion of a large anomalous region of southern Arizona, part of which is the Ajo area (Klein, 1982b).

A gravity investigation by Greenes (1975) exists for the Papago Farms area in the southeast corner of the Ajo-Lukeville area (long 112° 15′ to 112° 25′ W., and from the Mexican border to lat 31° 50′ N.). There is also an interpretation of gravity and aeromagnetic data for the northern part of the Gulf of California (Sumner, 1972), the study area extending into the southwestern part of the Ajo quadrangle, and an interpretation of gravity data for the Papago Indian Reservation (Hargon, 1978).

Greenes (1975), Hargon (1978), and Klein and Johnson (1983) provided data on the density of rocks in the Ajo-Lukeville area. Hargon's data, which are limited to the area of the Papago Indian Reservation, were incorporated into the report by Klein and Johnson. The latter report also includes data on density and magnetic properties of 202 rock samples collected during the course of the U.S. Geological Survey Ajo-Lukeville gravity surveys. Additional data on the magnetic properties of surface rocks in the area of this map are available in May's work (1968) for the vicinity of the Ajo deposit and in Sumner's work (1972) for the southwest corner of the Ajo quadrangle.

GRAVITY SURVEYS

Maps A and B incorporate data from 4,157 gravity stations. These data comprise (1) data from the U.S. Defense Mapping Agency Aerospace Center (1974, 1975), including data from the U.S. Geological Survey (Peterson, 1965; Peterson and others, 1967; Hassemer and Dansereau, 1980) and from other Federal agencies (Boler and Baer, 1981); (2) data acquired by the University of Arizona from 1976 to 1978 under contract with the U.S. Geological Survey (Boler and Baer, 1981); (3) data acquired by the U.S. Geological Survey from 1978 to 1980 (Boler and Baer, 1981); (4) five stations acquired by the U.S. Geological Survey in 1982 in the area of the Aztec Hills (lat 32° 46′ N., long 113° 27′ W., data not previously published); and (5) 39 stations acquired by the U.S. Geological Survey in 1982 in the area of the Sauceda and Quitotosa washes (lat 32° 45′ N., long 112° 39′ W., data not previously published). Gravity base stations are listed in table 1.

Gravity data from the U.S. Defense Mapping Agency Aerospace Center (1974, 1975) and from Kleinkopf and others (1980) are incorporated into a map of the larger region bordered by lat 31° 00′ to 33° 20′ N. and long 110° 45′ to 114° 15′ W. These data (5,758 stations excluding repeat observations) form the basis for determining the regional gravity map (fig. 1). The Ajo-Lukeville area is not centered in this expanded region because it was convenient to use the same regional correction as was used for a residual gravity map of the Papago Indian Reservation (U.S. Geological Survey contract with the Bureau of Indian Affairs, unpub. report, 1982).

Observed gravity, corrected for instrument drift and Earth tides, is the primary data base. U.S. Geological Survey observations were acquired by closing gravity loops daily and tying into the base station net (table 1) at least weekly. Roughly 50 percent of the U.S. Geological Survey data were acquired with helicopter support, inasmuch as a large part of the study area was accessible for only a short time due to military activity.

GRAVITY DATA REDUCTION AND COMPILATION

COMPLETE BOUGUER GRAVITY ANOMALY MAP

Terrain corrections were calculated from 0.053 to 166.7 km around each station (Hammer, 1939; Plouff, 1977). Earth curvature, free-air and Bouguer corrections are based on the 1967 International Gravity Formula (International Association of Geodesy, 1971). The reduction density used was 2.67 g/cm^3. Gravity values are based on the 1971 gravity standardization net (Morelli and others, 1974; Woollard, 1979). Data were reduced by computer (U.S. Geological Survey, unpub. programs) using formulae defined in the references above.

The complete Bouguer gravity anomaly map (map A) was made by interpolating the irregularly spaced data on a 1.0-km square grid (Briggs, 1974; Webring, 1981). The gridded data provided the basis for the computer-generated contours shown (Cline, 1974; Evenden, 1975; Godson and Webring, 1982).

Sources of error in the observed data were evaluated by Boler and Baer (1981). Based on the differences between repeat observations and the likely errors associated with uncertainties in elevation and horizontal location, they concluded that an uncertainty of 1.6 mGal is probably representative of each station. The map may reflect additional unknown error (probably less than 1 mGal) caused by interpolation to create values on a grid and to create and place the contours. Contour placement is considered accurate within one-half the contour interval.

RESIDUAL BOUGUER GRAVITY ANOMALY MAP

The residual Bouguer gravity anomaly map (map B) was made by eliminating long-wavelength (greater than 67 km) gravity anomalies from the complete Bouguer anomaly data. Anomaly wavelengths were defined by two-dimensional Fourier analysis (Dean, 1958; Fuller, 1967; Naidu, 1969) using the computer program of Hildenbrand (1983).

Data in the region (fig. 1) were digitized on a 1-km-square grid. The gridded data were processed to minimize the introduction of spurious gravity anomalies during the Fourier analysis. Processing consisted of establishing a zero-level datum, removing wavelengths longer than the maximum dimension of the gridded area, and smoothing values near the edges of the area to zero. The last of these steps attenuates false, short-wavelength anomalies caused by Fourier transformation on data that do not extend to infinity.

The zero-level datum was established by removing the mean of the complete Bouguer anomaly data (−73 mGal). Correction for wavelengths longer than the gridded area consisted of removing a best fitting plane surface (calculated by least squares) from the data. This plane surface is defined by a 0.328-mGal/km slope, decreasing N. 86° W. Data values on the edge of the grid were smoothed to zero by applying a half-cosine taper to the border areas. The half length of the cosine smoothing function is ten percent of the dimensions of the gridded area, thus being about 36 km east-west and 22 km north-south.

These data were then converted into the frequency domain, filtered by using a linear, frequency-domain, high-pass filter, and converted back into the space domain. The complementary regional map (shown on map B) was similarly constructed by using low-pass linear filtering.

Figure 2 shows the resulting radial amplitude spectra and the frequency-domain filter responses. The high-pass filter fully retains harmonics having wavelengths less than 40 km (spatial frequencies greater than 0.025 km^{-1}). Harmonics having wavelengths from 40 to 67 km (spatial frequency of 0.015 km^{-1}) are attenuated according to the slope of the filter, and harmonics having wavelengths greater than 67 km are removed.

The gravity anomalies after low-pass filtering are shown in figure 1 for the region analyzed. The low-pass filter (fig. 2) fully retains wavelengths greater than 40 km, linearly attenuates the harmonics having wavelengths between 40 and 28 km, and removes wavelengths less than 28 km. Although the map showing data modified by the low-pass filter is distorted near the borders due to the effects of the half-cosine function, this distortion is not considered serious in the area of map B.

The filtered data were finally contoured by computer to make map B.

AEROMAGNETIC SURVEYS

Four aeromagnetic surveys over the Ajo-Lukeville quadrangles were digitized and merged to form a compatible data set that was then adjusted to a uniform geomagnetic datum. These data are presented here as the aeromagnetic anomaly map C. The original data for survey areas A, B, C, and D (fig. 3) were acquired through contract surveys during the period 1975–80.

Specifications for the aeromagnetic surveys are listed in table 2. The nominal flight-line elevation was 1,220 m above sea level. Although most topographic elevations in the survey area are below 450 m, mountains in the eastern one-third of the area exceed 1,000 m, some peaks being higher than 1,220 m. Areas where topographic elevations are more than 1,000 m are shown on map C. Aeromagnetic anomalies in these areas may be influenced by either draping of flight lines or nearby high-elevation magnetic rock and should not be quantitatively analyzed without referring to the original flight-line maps and flight-elevation records (U.S. Geological Survey, unpub. data, 1975, Project 3090, area B; 1976, Project 3095, area A; 1979, Project 3166, area C; 1980, Project 792, area D). Anomalies at Cimarron Peak (lat 32° 27′ N., long 112° 23′ W.) and at Table Top (lat 32° 45′ N., long 112° 7′ W.), are examples of sharp, high-relief aeromagnetic anomalies associated with prominant mountainous topography.

North-south tie lines were flown at intervals of about 40 km for areas A, B, C, and 24 km for area D. Data were corrected for transient geomagnetic variations, known from simultaneous ground-magnetometer observations, and further corrected for the Earth's main geomagnetic field as indicated on table 2.

Aeromagnetic maps for the individual areas were previously published separately (U.S. Geological Survey 1979, 1980a,b,c) and as one map for the Ajo-Lukeville area (Klein, 1982a). There was no attempt to find a common datum for the mosaicked map, nor to smoothly merge the data across borders between different surveys; thus, the mosiac provides an indication of discrepancies among the different data sets. Additionally, parts of the data just referenced for the region of Hat Mountain (area C1) and Crater Range (area C2) (fig. 3) are available (Klein, 1983; Gray and others, 1985, 1987) combined with geologic studies dealing with the volcanic rocks in those areas.

AEROMAGNETIC DATA COMPILATION

Digital flight-line data from the original surveys are available for areas C and D (fig. 3); however, to maintain consistency, all data for the present map were digitized from contour maps acquired from the survey contractors. The maps were contoured at a scale of 1:62,500 and contour intervals of 10 or 20 nT. Values at the intersections of flight lines and contour lines were digitized. Digital data for the four areas were interpolated separately onto equispaced grids (Briggs, 1974; Webring, 1981) having 1.0-km intervals and common origins.

The grids were merged by establishing a uniform geomagnetic datum for the different areas and by smoothing across the common borders (R.E. Sweeney, unpub. computer programs). The grids overlap by at least one row (column) at their common borders. To establish a uniform geomagnetic datum, constant datum corrections were added to the grid values of areas C and D (see table 2) so that the resulting mean of overlapping grid values was equal to that of areas A and B. To smooth remaining discrepancies, grid values along common borders were replaced with values derived from a linear spline (Bartacharyya, 1969). The spline was formed on the basis of the five grid values on either side of the replaced value. The final map was contoured by computer (Evenden, 1975; Godson and Webring, 1982) at a final grid interval of 0.75 km.

Although map C does not obviously show the effects of merging the different data sets, there are greater uncertainties in the aeromagnetic anomalies near the merged borders than elsewhere. All data were acquired following similar specifications, but at different times. There are uncertainties in the corrections for the transient magnetic variations and in the corrections for the Earth's magnetic field and its secular variation between the times of the different surveys. Additional discrepancies can be related to flight-line mislocations and to contouring errors at the edges of the data sets.

There are differences between the current map C and the initial mosaic (Klein, 1982a) along the west border of area A (north of Organ Pipe Cactus National Monument and south of Interstate Highway 8). In the area of the Sand Tank Mountains southwestward to the area of the Little Ajo Mountains (the area shown by a diagonal line pattern enclosure on map C), it was found that anomalies could be altered by the parameters chosen for merging and contouring due to the differences between overlapping data sets that are apparent on the mosaic (Klein,1982a), or by comparing the original maps referenced in table 2. These differences are primarily in the shape of anomalies having wavelengths less than about 10 km. The appearance of this area on map C is the result of subjective decisions based on an attempt to maintain the consistency of anomalies that continue across adjoining survey areas. Critical decisions included the selection of a common border and the selection of the radius of averaging to establish grid values. In addition to possible distortions mentioned above, the uncertainty in contour placement is at least 0.5 km (half of the grid interval), and the uncertainty in horizontal resolution of anomalies is at least 2.0 km (twice the grid interval). Considering other sources of error, such as associated with the 1.6-km flight-line interval and possible mislocations of flight-line position, it is likely that the uncertainty associated with horizontal locations of anomalies is about 2.0 km.

EFFECTS ON THE AEROMAGNETIC MAP OF VARIATIONS IN ELEVATION OF THE SENSOR ABOVE THE MAGNETIC SOURCE

Most of the short-wavelength anomalies, 2–5 km in horizontal dimension, are east of long 113° W. The area to the west of long 113° W. shows anomalies of longer wavelength and more subdued amplitude. This characteristic is partly a function of the distance between the magnetic rocks and the sensor. Whereas the elevation of the sensor was nominally constant at about 1,220 m, the elevation of the ground varies from about 90 m to more than 910 m in many places. Inasmuch as magnetic fields decrease inversely with distance from the magnetic source in the least attenuated case (a magnetic step discontinuity), the effect of height of the sensor above bedrock can have a significant influence on the amplitude of visible anomalies.

The distribution of short-wavelength anomalies is apparently correlated with the higher topography found east of long 113° W., particularly along a corridor extending north-northeast from the Mexican border between long 112° 30′ and 113° 16′ W. Topographic elevations in this corridor are greater than 910 m in many places. West of this corridor, topographic elevations are considerably less, decreasing to minimum elevations of about 90 m along the Gila River. In addition, many of the larger and presumeably deeper alluvial basins are west of long 113° W. The increased separation between the magnetic source and the sensor caused by magnetic bedrock at depth beneath virtually nonmagnetic basin fill will smooth out short-wavelength anomalies. The effect is analogous to decreased topographic elevations.

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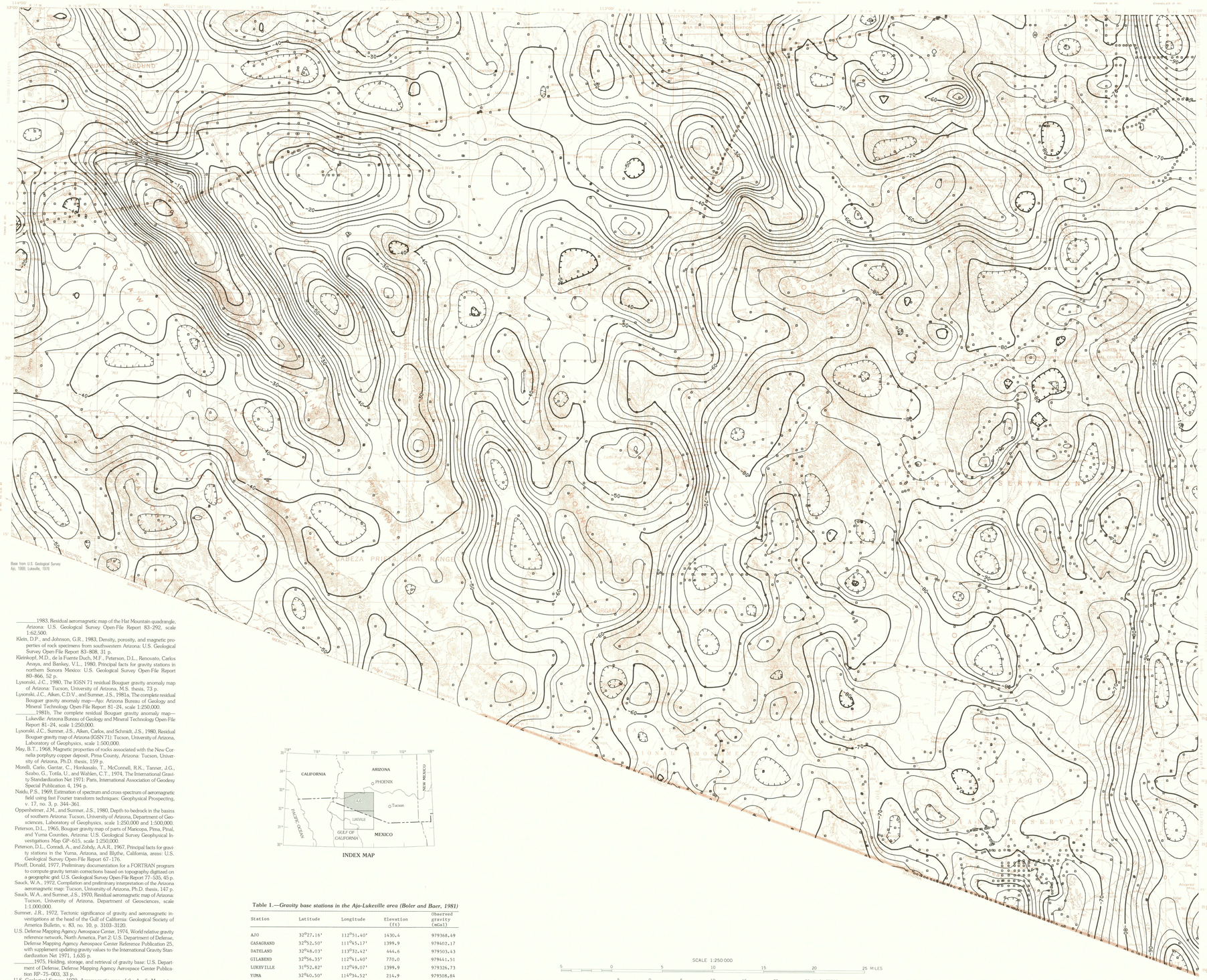

MAP A.—COMPLETE BOUGUER GRAVITY ANOMALY MAP

INDEX MAP

Table 1.—*Gravity base stations in the Ajo-Lukeville area (Boler and Baer, 1981)*

Station	Latitude	Longitude	Elevation (ft)	Observed gravity (mGal)
AJO	32°27.16′	112°51.40′	1430.4	979368.49
CASAGRAND	32°52.50′	111°45.17′	1399.9	979402.17
DATELAND	32°48.03′	113°32.42′	444.6	979303.43
GILABEND	32°56.35′	112°51.40′	770.0	979441.51
LUKEVILLE	31°52.82′	112°49.07′	1399.9	979326.73
YUMA	32°40.50′	114°34.52′	214.9	979508.84
AF81	32°53.19′	112°43.66′	852.0	979452.87
AF82	32°53.05′	112°43.41′	845.0	979452.08
AJO-1711	32°21.34′	112°49.53′	1714.0	979339.83
GILA	32°57.56′	112°40.68′	770.0	979446.53
SCM-438	32°16.10′	112°44.29′	1784.0	979326.59
SEN-644	32°51.90′	113°12.72′	676.0	979476.21
TACNA	32°41.52′	113°57.14′	349.0	979482.13
YUMAAP	32°39.57′	114°36.12′	593.2	979513.66
PAPBS01	32°23.06′	111°32.70′	2437.0	979277.11
PAPBS02	32°08.90′	112°06.15′	2398.0	979273.26
PAPBS03	32°48.45′	111°40.14′	1475.0	979391.09
PAPBS04	32°26.54′	112°01.14′	1661.0	979316.19
PAPBS05	32°52.45′	111°50.77′	1345.0	979399.07
PAPBS06	32°53.89′	111°45.21′	1387.0	979403.55

EXPLANATION

−70 Complete Bouguer gravity contour—Contour interval 2.5 mGal. Inscribed hachures indicate closed gravity low

Gravity station location

CONVERSION FACTORS

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

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GRAVITY AND AEROMAGNETIC ANOMALY MAPS OF THE AJO AND LUKEVILLE 1° × 2° QUADRANGLES, SOUTHWESTERN ARIZONA

By
Douglas P. Klein and Robert P. Kucks
1991