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THICKNESS AND STORAGE CAPACITY OF BASIN FILL OF THE NORTHERN PART OF THE ELDORADO VALLEY, NEVADA, AND THE EXTENT OF THE BOULDER CITY PLUTON

By

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Abstract

The U.S. Geological Survey collected detailed gravity data west of the town of Boulder City to characterize the thickness and storage capacity of part of the Eldorado Valley groundwater basin and to determine the subsurface extent of the Boulder City pluton. Two models of the basin configuration of the study area were created using a modified version of the method of Jachens and Moring (1990). Both models indicate that the thickness of basin fill in the area of interest is on average less than 1000 ft (300 m). The deepest part of the basin coincides with the northern tip of the playa in Eldorado Valley. Storage capacities of the study area estimated by using the basin gravity range from 4 to 8 x 10^6 acre-ft. Basement gravity lows coincide with exposures of the Boulder City pluton and other similar Tertiary intrusive rocks, suggesting that the basement gravity field can map the regional extent of the Boulder City pluton and other similar Tertiary plutons.

Introduction

The U.S. Geological Survey conducted a detailed gravity study west of the town of Boulder City, Nevada to characterize part of the Eldorado Valley groundwater basin and to determine the subsurface extent of the Boulder City pluton for the Las Vegas Valley Water District (fig. 1). This work will help site a new water well within a one-mile square southwest of the city of Boulder City. Most of the new gravity stations were collected in the one-mile square, hereafter called the area of interest. However, in order to do the iterative depth-to-basement calculation, additional stations were collected over a larger area (hereafter referred to as the study area, fig. 1) to provide regional coverage. The gravity data were inverted for thickness of alluvial deposits using a modified version of the method developed by Jachens and Moring (1990). Existing aeromagnetic data were also examined for correlation with exposures of the Boulder City pluton to determine the lithology of basement rocks beneath the area of interest.

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Geologic Setting

The study area lies within the northern part of Eldorado Valley, about 20 mi (32 km) southeast of Las Vegas (fig. 1). It lies within a highly-extended region called the northern Colorado River extensional corridor (Howard and John, 1987). Eldorado Valley is an alluvial basin (surface area about 530 square miles; Rush and Huxel, 1966) that is ringed by mountains consisting primarily of Tertiary volcanic and plutonic rocks and, to a lesser extent, Precambrian crystalline rocks (Longwell and others, 1965). The northern part of the valley is bounded by the Hamblin Bay fault, a left-lateral fault that is part of the Lake Mead shear zone. Weber and Smith (1987) estimate an offset of 12 mi (20 km) on the Hamblin Bay fault by restoring on the basis of geochemistry the volcanic rocks of the Eldorado and McCullough Mountains above and adjacent to the Boulder City pluton. They suggest that the Hamblin Bay fault does not extend southwest across the McCullough Mountains, but bends to form the Eldorado Valley fault, an inferred high-angle, west-dipping normal fault (fig. 1). They argue that the Hamblin Bay and Eldorado Valley faults accomodate differential amounts of extension between the Eldorado Mountains and the River and McCullough Mountains.

For this study, basement rocks are defined as all pre-Cenozoic rocks and as Tertiary intrusive rocks. Basin deposits are defined to be Cenozoic and may consist of both volcanic and sedimentary rocks. Unlike the thick Paleozoic and Mesozoic sedimentary sequences exposed on Frenchman Mountain to the north, Tertiary volcanic rocks rest directly on Precambrian crystalline rocks (or a thin conglomerate composed of Precambrian debris) in the study area (Longwell and others, 1965; Anderson, 1971). The closest basement exposures to the area of interest are low-lying hills just south of the town of Boulder City (fig. 1). The hills consist of granodiorite and quartz monzonite of the Boulder City pluton and schist and gneiss of the Precambrian country rock. The Boulder City pluton is Miocene in age and characterized by fine to coarse grain sizes (Longwell and others, 1965).

In Eldorado Valley, basin fill consists of Tertiary and Quaternary sedimentary and volcanic rocks. Volcanic rocks exposed in the River, McCullough, and Eldorado Mountains were erupted between 21 and 12 Ma (Anderson, 1971; Weber and Smith, 1987). Compositions range from basalt to rhyolite, but most rocks are andesites or dacites (Weber and Smith, 1987). The thickness of the volcanic pile is as great as 17,000 ft (5.2 km) in the Eldorado Mountains (Anderson, 1971).

Rush and Huxel (1966) discuss the water bearing properties of the various rock units exposed in the area. In general, the Precambrian crystalline rocks and the Tertiary volcanic and intrusive rocks are relatively impermeable and therefore should not be considered potential reservoir rocks. However, there is potential for fracture permeability and spring discharge in these rocks. Tertiary sedimentary rocks of the Muddy Creek formation are potentially a significant groundwater reservoir in the region, but are too thin or nonexistent in the area of interest (Gary L. Dixon, U.S. Geological Survey, written commun., 1996). The principal groundwater reservoir consists of Tertiary and Quaternary alluvial deposits (Rush and Huxel, 1966). In Eldorado Valley, the alluvial deposits consist of lenticular beds of gravel, sand, silt and clay. Lacustrine clay and silt interleaved with coarser debris underlies the playa.

Gravity Data

Gravity data were collected with LaCoste & Romberg gravity meter G-614 during May 1996 to supplement regional gravity coverage (fig. 2; Kane and others, 1979; Bracken and Kane, 1982) and provide detailed data over the area of interest. Over 30 stations were collected in the area of interest, outlined by the dense concentration of stations west of the basement exposures south of Boulder City (fig. 3 and 4). Additional gravity stations were collected over basement and basin-fill areas to augment the regional coverage (fig. 4). The data were tied to a base station, LVGS, established in front of the U.S. Geological Survey office in Las Vegas. LVGS has a value of 979593.62 mGal based on ties to CPA, a gravity base station that is part of the Mt. Charleston calibration loop (Ponce and Oliver, 1981; observed gravity value of 979522.22 mGal).

Gravity data were reduced using the Geodetic Reference System of 1967 (International Union of Geodesy and Geophysics, 1971) and referenced to the International Gravity Standardization Net 1971 gravity datum (Morelli, 1974, p. 18). Gravity data were reduced to isostatic residual anomalies using a reduction density of 2.67 g/cm^3 and include earth-tide, instrument drift, free-air, Bouguer, latitude, curvature, and terrain corrections. An isostatic correction using a sea-level crustal thickness of 16 miles (25 km), a crustal density of 2.67 g/cm^3, and a mantle-crust density contrast of 0.40 g/cm^3 was applied to the gravity data to remove long-wavelength gravitational effect of isostatic compensation of the crust due to topographic loading.

Horizontal control on the gravity station locations was provided by both surveying and by U.S. Geological Survey 7-1/2 minute series maps. Most station elevations were surveyed using an electronic-distance-measurement instrument. Other elevations were taken from spot elevations on the U.S. Geological Survey 7-1/2 minute series maps or estimated using altimetry. The uncertainty in the elevations of the surveyed stations is about 0.1 foot. Uncertainties in the elevations derived from altimetry are about 10 feet, with a corresponding error in the reduced gravity values of less than 0.6 mGal.

Terrain corrections were computed to a radial distance of 104 miles (167 km) and involved a 3-part process: (1) Hayford-Bowie zones A and B with an outer radius of 223 feet (68 m) were estimated in the field with the aid of tables and charts, (2) Hayford-Bowie zones C and D with an outer radius of 1936 feet (590 m) were computed manually, and (3) terrain corrections from a distance of 1936 feet (0.59 km) to 104 miles (167 km) were calculated using a digital elevation model and a procedure by Plouff (1977). Total terrain corrections for the stations collected for this study ranged from 0.16 to 10.9 mGal, averaging 1.05 mGal. If the error resulting from the terrain correction is considered to be 5 to 10% of the total terrain correction, the largest error expected for the data is 1.1 mGal. However, the average error resulting from the terrain correction for the area of interest is small (< 0.1 mGal).

Drill Hole Data and Physical Properties

Few wells have been drilled in the study area; none have penetrated pre-Tertiary rocks (Rush and Huxel, 1966). One well in Eldorado Valley (24/63-29b1) did penetrate the entire thickness of alluvium, encountering rhyolite at a depth of 1040 ft (317 m) and bottoming at 1570 ft (479 m) (Rush and Huxel, 1966, fig. 3). Water was encountered at 475 ft (145 m), but rose to a static water level of 275 ft (84 m) below the ground surface.

Table 2 shows density measurements of hand samples of basement and volcanic rocks from the study area. Densities of volcanic rocks range from 2.27 to 2.58 g/cm^3. Basement densities vary from 2.59 to 2.78 g/cm^3; the average density of the Boulder City pluton is 2.67 g/cm^3. Table 2 indicates that the density of the Precambrian basement rocks exposed in the hills south of Boulder City is indistinguishable from the density of the Boulder City pluton.

Information on the density of the alluvial deposits of Eldorado Valley is not available. However, one drill hole in Las Vegas Valley does provide information on porosity of the alluvial deposits there (Las Vegas Valley Water District, written commun., 1996; Langenheim and Jachens, 1996). Well logs indicate that the upper 570 ft (174 m) of alluvium (primarily gravel and sand) has an average porosity of 23%. Below 570 ft, the alluvium has an average porosity of 15%. Using the equations in Langenheim and Jachens (1996), the density of the alluvial deposits (as derived from the porosity data) is 2.08 and 2.30 g/cm^3, assuming that all the clasts have a density of 2.7 g/cm^3 and that the deposits are not saturated. If all the pores are filled with water, the bulk densities would be 2.31 and 2.45 g/cm^3, respectively.

Magnetic susceptibility data were also collected on hand samples. The Boulder City pluton is moderately magnetic, with susceptibilities ranging from 0.43 to 1.12 x 10^{-3} cgs units. Precambrian rocks are slightly less magnetic, with susceptibilities ranging from 0.20 to 0.85 x 10^{-3} cgs units. Volcanic rocks are characterized by variable susceptibilites, ranging from 0.00 to 0.92 x 10^{-3} cgs units. Although no measurements were made on sedimentary rocks from the study area, these rocks are generally weakly to nonmagnetic (Dobrin and Savit, 1988).

Gravity Anomalies

The regional gravity data show that the study area lies in the transition zone between anomalies with predominant trends of N60°E and N45°W over the area north of the Hamblin Bay fault and anomalies with more northerly trends south of the fault (fig. 2). In general, areas of exposed or shallowly buried basement rocks produce gravity highs; see, for example, the positive gravity anomalies of over +20 mGal over Frenchman Mountain and Saddle Island (fig. 2). Gravity lows generally occur over thick accumulations of low-density rocks; for example, the Cenozoic deposits of Las Vegas Valley produce isostatic gravity values as low as -30 mGal.

In contrast to the large positive isostatic gravity values over Frenchman Mountain, Precambrian crystalline rocks in the southern McCullough Mountains produce isostatic gravity values as low as -20 mGal (fig. 2), suggesting that significant variations in the density of basement rocks exist or that the surface rocks are structurally decoupled from less dense rocks below. Figure 4 also indicates variations in basement density within the study area. Precambrian crystalline rocks exposed in the eastern part of the study area and at Saddle Island produce isostatic gravity values as high as +15 to +20 mGal. Values as low as -5 mGal are present over exposures of Boulder City pluton. The average density of the Boulder City pluton and the Precambrian rocks it intrudes is 2.67 g/cm^3 whereas density measurements on basement rocks exposed in the Black Mountains (isostatic gravity values as high as 15 mGal) just east of the study area (fig. 2) range from 2.61 to 3.02, averaging 2.75 g/cm^3. Part of the range in gravity values over basement rocks exposed near Boulder City and the Black Mountains can thus be explained by density variations in exposed basement rocks.

The area of interest lies on the northern edge of a significant gravity low of -20 to -25 mGal over Eldorado Valley (fig. 2 and 4). The low is segmented, suggesting that the valley is underlain by two sub-basins. The geometry of these basins appears to be structurally controlled by the Hamblin Bay fault and the proposed buried Eldorado Valley fault. The gravity data not only support Weber and Smith's (1987) geometry of the Eldorado Valley fault, with down-to-the-west displacement, but also suggest that a major change in basement density occurs in the vicinity of the Eldorado Valley fault. Isostatic gravity values measured on basement rocks vary from -15 mGal on the southern McCullough Mountains to +15 mGal over Eldorado Mountains (fig. 2; fig. 4). A rough estimate of the thickness of the valley fill is about 6000 feet (1800 m), assuming an average density contrast of -0.40 g/cm^3 between the sedimentary fill and the basement rocks.

Depth to Basement

Method

The method used in this study to estimate the thickness of Cenozoic rocks is an updated version of the iterative method developed by Jachens and Moring (1990) that incorporates drill hole data (Bruce Chuchel, U.S. Geological Survey, written commun., 1996). Necessary inputs to the method consist of knowledge of the residual gravity field, of the exposed geology, and of the variation of density with increasing depth within the basin deposits. Drill holes that penetrate basement rock can also be input into the model and provide useful constraints to the method as well as a test of the results. The method attempts to separate the gravity field into two components, that which is caused by variations of density within the pre-Cenozoic basement and that which is caused by variations of thickness of the Cenozoic basin fill (fig. 6). To accomplish this, the gravity data are separated into observations made on basement outcrops and observations made on Cenozoic deposits. The second set of observations is inverted to yield the thickness of Cenozoic deposits, based on an estimate of the density-depth function that characterizes the Cenozoic deposits. The inversion is complicated by two factors: (1) basement gravity stations are influenced by the gravity anomaly caused by low-density deposits in nearby basins, and (2) the basement gravity field varies because of density variations in the basement. The inversion presented here does not take into account lateral variations in the density distribution of the Cenozoic deposits.

To overcome these difficulties, a first approximation of the basement gravity field is determined by interpolating a smooth surface through all gravity values measured on basement outcrops (curve labeled "iteration 1" in lower panel of figure 5). Basement gravity values are also calculated at locations where drill holes penetrated basement, using the density-depth function. The basin gravity is then the difference between the observed gravity field on the original map and the first approximation of the basement gravity field and is used to calculate the first approximation of the thickness of Cenozoic deposits. The thickness is forced to zero where basement rock is exposed. This first approximation of the basement gravity is too low near basins because of the effects of the nearby low-density deposits on the basement stations. The basement gravity station values are "corrected" for the effects of the low-density deposits (the effects are calculated directly from the first approximation of the thickness of the Cenozoic deposits) and a second approximation of the basement gravity field is made by interpolating a smooth surface through the corrected basement gravity observations. This leads to an improved estimate of the basin gravity field, an improved depth to basement and a new correction to the basement gravity values. This procedure is repeated until successive iterations produce no significant changes in the basement gravity field.

Results

Two models are presented here in order to provide a range of basin configurations and to determine how sensitive the results are to modifications in density-depth functions. Both models use only basement gravity stations to calculate the basement gravity field; no drill-hole data were utilized as no wells penetrate pre-Cenozoic rocks in the study area. The first model assumed a density-depth function based on density information compiled for the state of Nevada (Jachens and Moring, 1990; table 2). The second model uses a modified density-depth function derived from the porosities measured at well 78E in Las Vegas Valley and an assumed water table depth of 328 ft (100 m) (table 2).

The basement gravity field produced by the first model (fig. 6a) indicates high basement gravity values in the northern and eastern parts of the study area where Precambrian rocks are exposed. Low basement gravity values coincide with exposures of Tertiary intrusive rocks. In general, the basement gravity values decrease from east to west.

The resulting distribution of basin sediments (fig. 6b) generally mimics the isostatic gravity field. One exception is the local basin 10 km east of the playa. This basin is an artifact caused by the change in density-depth functions used for sedimentary versus volcanic rocks. According to our model, the average thickness of Cenozoic deposits for the Eldorado Valley in the study area is about 2000 ft (600 m). The calculated basin thickness is consistent with the minimum basin thickness penetrated in drill hole 24/63-29b1 (total depth 1570 ft or 479 m).

The second model uses a density-depth curve based on the calculated densities of the alluvial units encountered in well 78E and assuming that the water table is 330 ft (100 m) deep. In reality, the water table elevation varies throughout the area, but for the sake of simplicity, we assumed that an average depth of 330 ft (100 m) would be adequate for the area of interest. Rush and Huxel (1966) report that the minimum depth to the water table in Eldorado Valley is at least 270 ft (82 m) below the ground surface, supporting our assumption. The resulting basement gravity field (fig. 7a.) is similar to that produced by model 1 (fig. 6a); the difference between the two models is 2 mGal or less within Eldorado Valley. The basin configuration for model 2 is also quite similar to that of model 1, but the thicknesses are greater because the density contrast is lower for depths greater than 330 ft (100 m) and less than 3940 ft (1.2 km) (table 2). Because of the lower density contrast, a greater thickness of basin fill is required to produce the negative gravity anomaly. Model 2 is thus more sensitive to small gravity anomalies; compare, for example, the calculated thicknesses for the two models for the area 4 km west of Boulder City (figs. 6b and 7b). The average thickness of Cenozoic deposits is 4030 ft (1230 m).

Within the area of interest, both models indicate that thickness of basin fill does not exceed 2000 ft (600 m) and is on average less than 1000 ft (305 m) (Fig. 6c and 7c), although Model 2 predicts a greater average thickness of basin fill than does Model 1. Thicknesses could be greater if a dense body within the basement underlies this area because the basement gravity field is constrained only on the east side of the area. The pediment edge is directly south of or coincides with the southern edge of the area of interest. The thickest part of the basin fill is under the northern tip of the playa.

Aeromagnetic data for the study area (Mariano and Grauch, 1988; Saltus and Ponce, 1988; fig. 8) suggest that magnetic rocks are shallowly buried (< 3300 ft or 1 km) in the area of drill hole 24/63-29b1 whereas the inversion of the gravity data indicate Cenozoic fill reaches thicknesses of 1 km or greater. In this area, the aeromagnetic data are sensitive to the distribution of volcanic rocks; drill hole 24/63-29b1 penetrated rhyolite at 1040 ft (317 m). The gravity data, however, are sensitive to the density contrast between the crystalline basement rocks and the lower-density volcanic and sedimentary fill. Thus, the two data sets are consistent with the drill hole data. Both data sets indicate a north-south-trending change in density and magnetization in the area of the well, probably reflecting the presence of the Eldorado Valley fault.

Neither inversion indicates that the aggregate thickness of volcanic rocks in the Eldorado Mountains reaches 17000 ft (5.2 km)(Anderson, 1971). However, the discrepancy can be explained if one considers the greatly extended and disrupted nature of volcanic rocks exposed in the Eldorado Mountains. Anderson (1971) documented that over 100% extension occurred in the Eldorado Mountains on numerous, west-dipping, listric normal faults. This deformation proudces a dramatic structural thinning of the volcanic sequence. Although the aggregate thickness of the volcanic sequence is 17000 ft in nearby areas, the gravity data are consistent with the deformation style and suggest that nowhere in the study area does the volcanic sequence approach that vertical thickness. Another possible reason for the discrepancy is that the density contrast between the volcanic rocks and the basement is actually smaller than that used in themodels. In this case, a greater thickness of denser volcanic rocks would be needed to produce the gravity anomaly.

Discussion

The principal reason for calculating the thickness of the basin fill is to determine the storage capacity of the groundwater basin. Rush and Huxel (1965) estimated a storage capacity of 1 x 10^6 acre-ft for the Eldorado Valley assuming that half of the area covered by alluvium had 100 ft of saturated alluvium with a specific yield of 10%. We used a method to estimate the storage volume of the area of interest that does not involve calculating the basin thickness, but only utilizes the basin gravity field (Langenheim and Jachens, 1996). Assuming that the observed gravity has been correctly separated into its basement and basin components and that the density of the clasts is 2.7 g/cm^3, one can use the following formulas to calculate the storage per unit area in feet:

$$pz = 29.0g_b \text{ if total thickness of basin fill is unsaturated} \quad (1)$$

$$pz = 46.1g_b \text{ if total thickness of basin fill is saturated} \quad (2)$$

where g_b is the basin gravity field and pz is the storage per unit area. Figures 9a-b show the storage capacity per unit area for the two models of the area of interest, assuming that the basin fill is unsaturated (Equation 1). Summing the storage capacity per unit area over the area of the groundwater basin, the estimated storage capacities for the Eldorado Valley within the study area are 4.46 x 10^6 acre-feet (5.5 km^3; Model 1) and 4.72 x 10^6 acre-feet (5.79 km^3; Model 2). If one assumes that the basin fill is completely saturated (equation 2b), estimated storage capacities are greater, ranging from 7.08 x 10^6 acre-feet (8.69 km^3, Model 1) to 7.74 x 10^6 acre-feet (9.50 km^3; Model 2). Storage capacities assuming the basin fill is saturated are larger because for a given porosity, the density contrast between saturated sediments and basement is smaller than that between unsaturated sediments and basement. Thus, a greater thickness or porosity of saturated fill is needed to produce the basin gravity anomaly.

The method using basin gravity tends to overestimate the storage capacity at the edges of the basin where the gravitational effects of the basin sediments spill over into the basement outcrops. The method will even predict that the storage capacity per unit area will be greater than the total thickness of the basin sediments at the extreme edges of the basin fill. Because we use an infinite slab approximation to estimate the storage capacity and we assume that the basin fill is completely saturated, equation (2) provides a maximum bound to the storage capacity for the Eldorado Valley, assuming that the basin gravity has been accurately extracted from the observed gravity field.

Subsurface Extent of Boulder City Pluton

Gravity data cannot address the subsurface extent of the Boulder City pluton in detail because the density contrast is insignificant between the Boulder City pluton and the Precambrian rocks it intrudes (south of Boulder City). The basement gravity maps (fig. 6a and 7a), however, show a gravity low that coincides with regions that have been intruded by Tertiary intrusive rocks. Thus, the gravity data could be used to map the regional extent of Precambrian basement rocks that have been intruded by Boulder City-type plutons.

Aeromagnetic data compiled for the area (Mariano and Grauch, 1988; Saltus and Ponce, 1988) show that the hills south of Boulder City lie on the edge of a magnetic high of 100 nT (fig. 8). Analytically determined magnetization boundaries (+'s on fig. 8; Blakely and Simpson, 1986) indicate that the magnetic high continues to the southwest over the basin fill of Eldorado Valley. Both the Boulder City pluton and the Precambrian rocks it intrudes are possible candidates for the source of the magnetic high. Exposures of the Boulder City pluton north of Boulder City, however, do not produce magnetic highs, but are on the south edge of a prominent magnetic low centered over the River Mountains. The resolution of the aeromagnetic data (flightline spacing 1 mile) is not sufficient to determine precisely the northern edge of the Boulder City magnetic high and its relation to the northern exposures of the Boulder City pluton. However, the southwest-trending edge of the Boulder City magnetic high is on trend with a similar southwest-trending gradient in the gravity data on the eastern edge of the Eldorado Valley playa (fig. 4). This suggests that the magnetization boundary, most likely within the basement rocks, could also delineate a fault in the basin fill.

Recommendations

Additional gravity data on basement exposures north of Boulder City and east of Eldorado Valley would better constrain the basement gravity field. More density data would help determine the sources of basement gravity anomalies. Drill hole data and a better density-depth function also would refine the resulting basin configuration. Because our models are constrained only by basement gravity stations, the basement gravity field over Eldorado Valley cannot resolve basement gravity anomalies that have wavelengths less than the spacing between basement outcrops with gravity observations (>26,000 ft or 8 km). Drill hole data, particularly those wells that provide depths to basement rocks, could greatly improve the resolution of the basement gravity field. Other geophysical data, such as seismic reflection or refraction or electrical data, could also provide basin thickness constraints. The density-depth function could be improved by borehole gravity surveys. Susceptibility measurements on the Boulder City pluton north of Boulder City and ground magnetic profiles could help address whether magnetic data are useful in determining the extent of the Boulder City pluton.

Conclusion

Two iterative models of the basin configuration of the study area were created using the method of Jachens and Moring (1990). The second model uses more information to constrain the solution than the first. Both models indicate that the thickness of basin fill in the area of interest is on average less than 1000 ft (305 m). The edge of the deep basin crosses the southwest corner of the area of interest. Storage capacities of the study area were estimated by (1) summing the basin fill over the area and assuming an average porosity and (2) using the basin gravity. The accuracy of these storage estimates depends on the validity of the depth-density curve and the accuracy of the basin-basement gravity separation. With additional data to constrain the basement gravity field and the density-depth function, better models of the basin thickness and the storage capacity of the basin can be constructed.

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Table 1. Densities, in g/cm^3 and susceptibilites (10^{-3} cgs units)

Tertiary intrusive rocks			
BC-01	2.67	1.11	Boulder City pluton
BC-02	2.65	0.92	Boulder City pluton
BC-03	2.66	1.09	Boulder City pluton
96111	2.67	0.43	Boulder City pluton
96112	2.78	0.90	Boulder City pluton
96180	2.61	1.12	Boulder City pluton
96166a	2.61	0.99	Tertiary intrusive rock
96166b	2.59	0.84	altered Tertiary intrusive rock
Precambrian crystalline rocks			
BC-04	2.64	0.28	Precambrian gneiss
BC-05	2.72	0.85	Precambrian schist
96109	2.76	0.70	Precambrian
96110	2.64	0.20	Precambrian
96179	2.61	0.27	Precambrian
Tertiary volcanic rocks			
96114a	2.39	0.01	volcanic
96114b	2.47	0.01	volcanic
96115	2.34	0.02	altered volcanic
96165	2.45	0.02	volcanic
96167	2.27	0.00	volcanic
96168	2.43	0.92	volcanic
96170	2.56	0.02	volcanic
96184	2.58	0.32	volcanic

Table 2. Density-depth functions*

Depth Range	Model 1 ("Average" for state of Nevada)		Model 2 (Based on well 78E)	
	sediments	volcanics	sediments	volcanics
0-100 m	-0.65	-0.45	-0.60	-0.45
100-200 m	-0.65	-0.45	-0.40	-0.40
200-600 m	-0.55	-0.40	-0.25	-0.25
600-1200 m	-0.35	-0.35	-0.25	-0.25
>1200 m	-0.25	-0.25	-0.25	-0.25

*density contrast in g/cm^3.

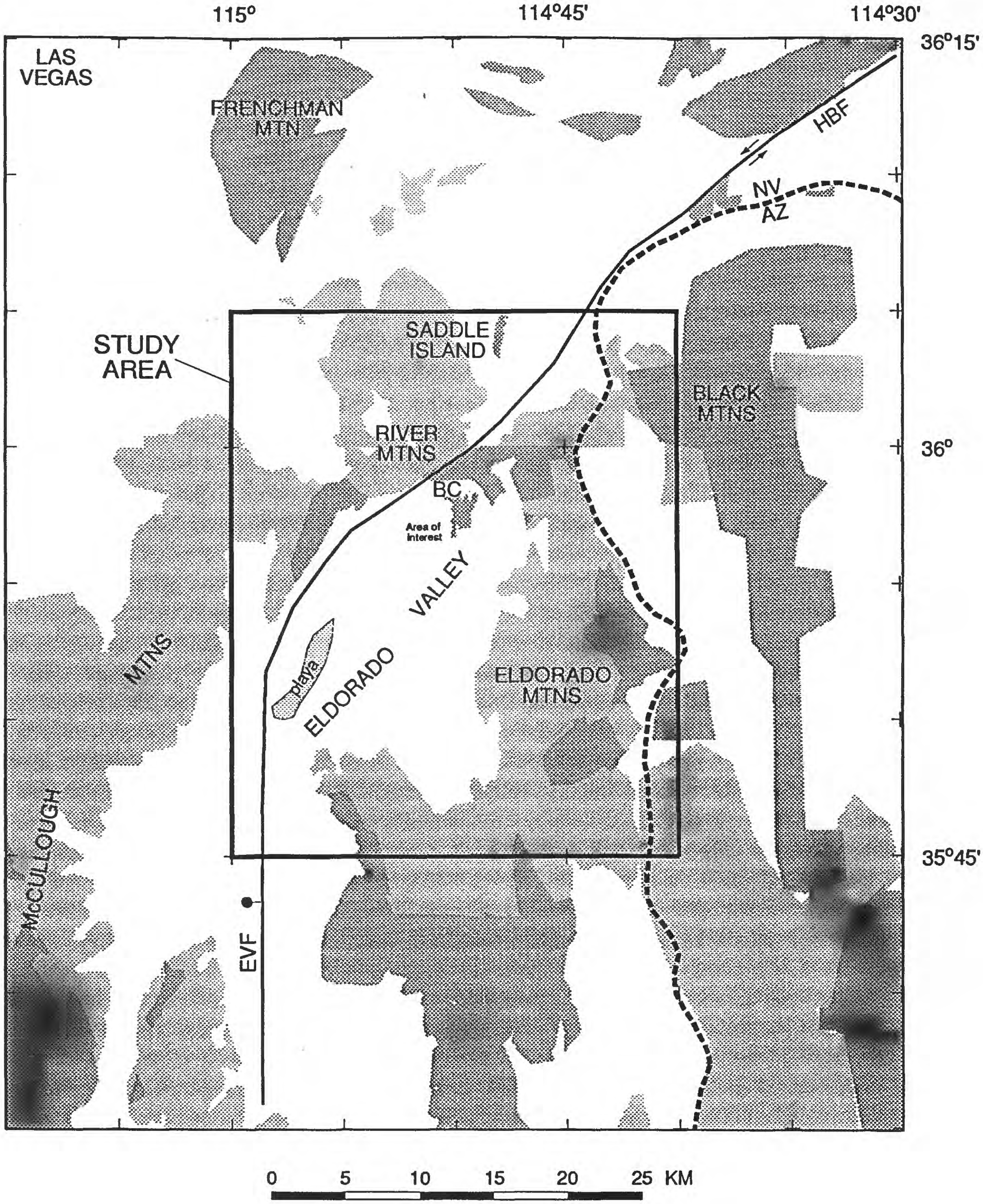

Figure 1. Index map. Dark areas denote exposures of basement rocks; lightly shaded areas, Cenozoic volcanic rocks; white areas, Cenozoic sedimentary deposits. Area of interest is 1 mile square west of basement exposures south of Boulder City (BC). HBF, Hamblin Bay fault; EVF, Eldorado Valley fault.

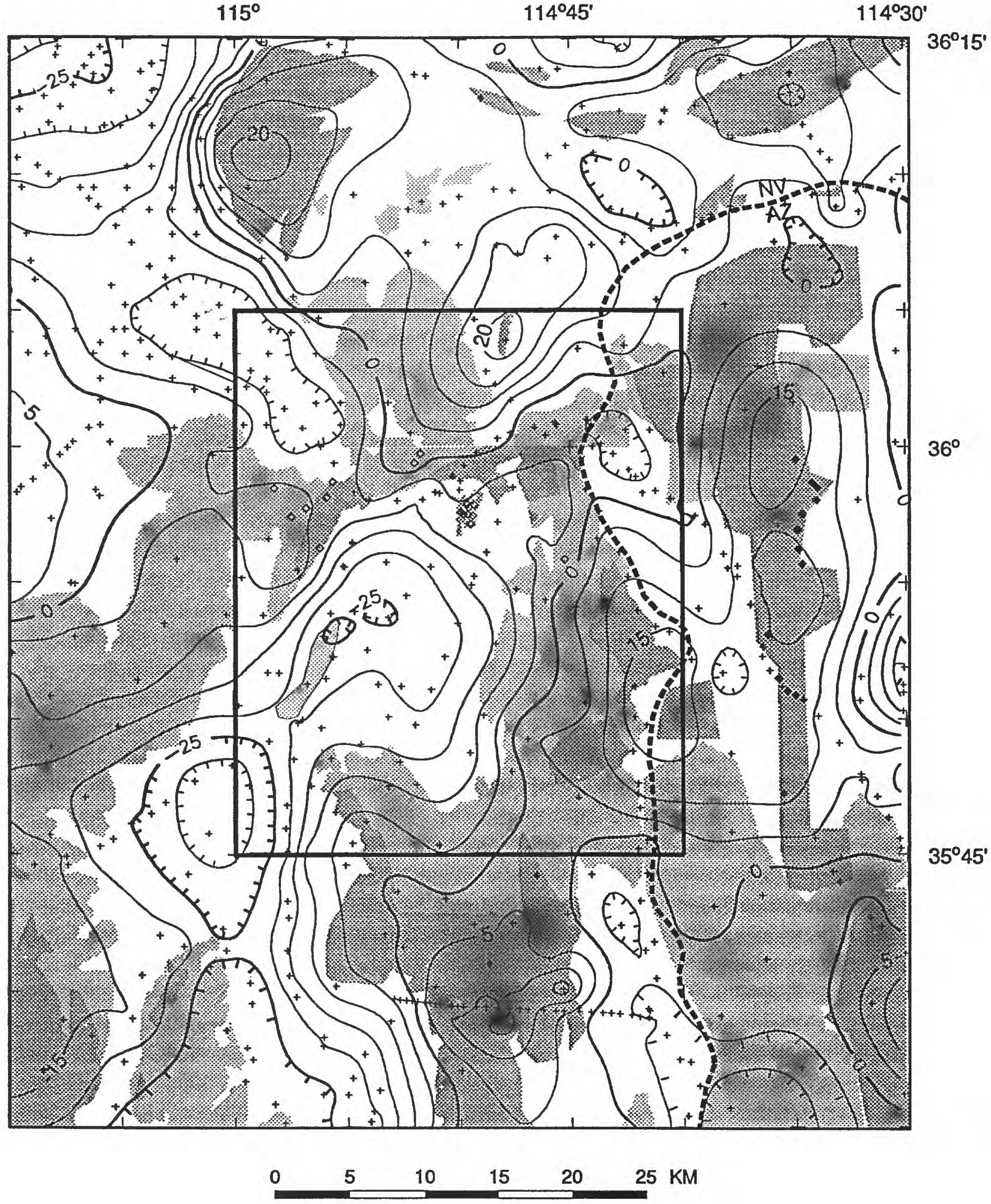

Figure 2. Regional isostatic gravity map. Contour interval 5 mGal. Crosses mark station locations (Kane and others, 1979; Bracken and Kane, 1982). Solid diamonds mark locations of physical property measurements for the Black Mountains; open diamonds, physical property measurements in this report (Table 1). Thick line outlines study area. See Figure 1 for explanation.

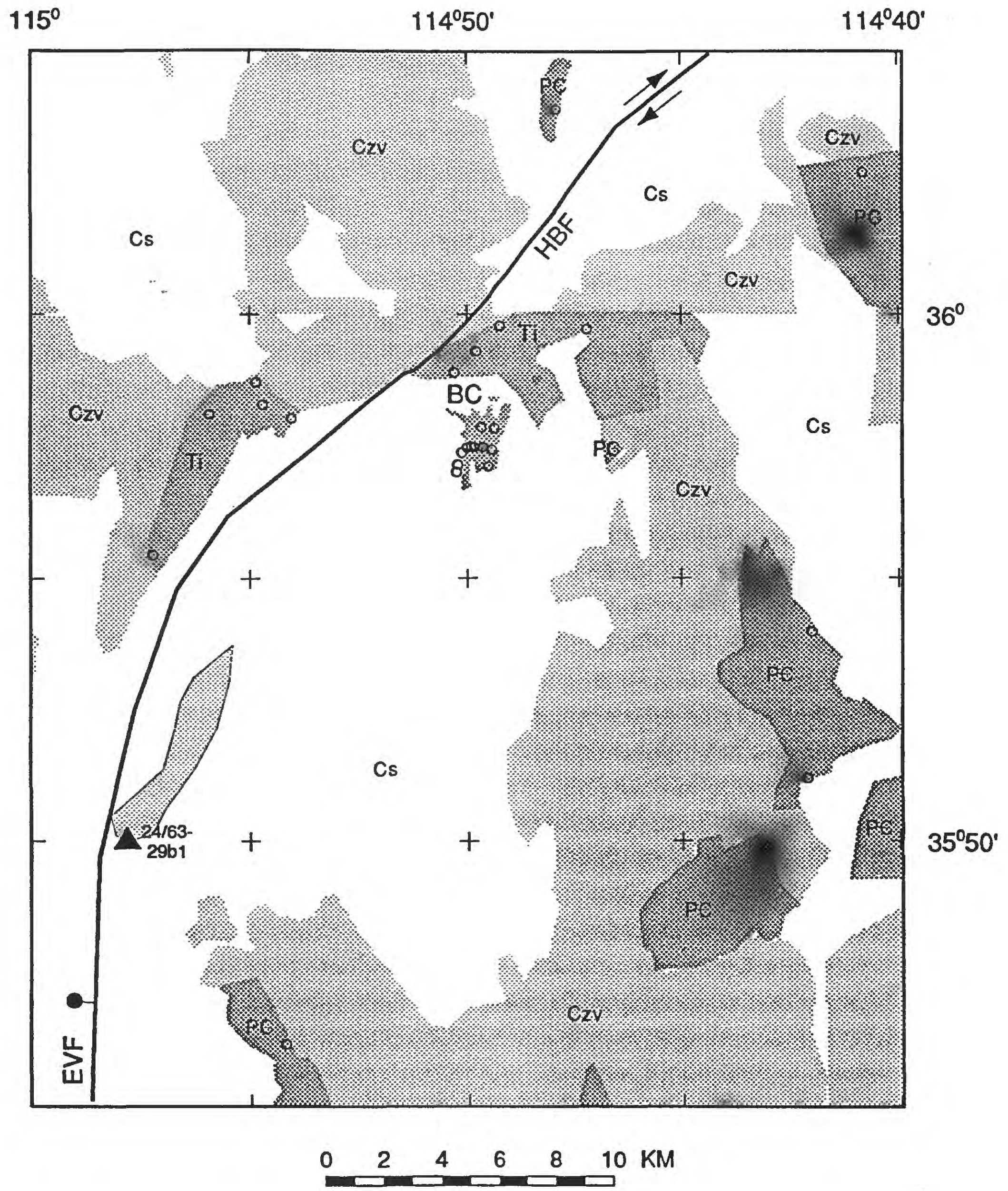

Figure 3. Geologic map of study area. Circles, basement gravity stations. Czv, Cenozoic volcanic rocks; PC, Precambrian rocks; Ti, Tertiary intrusive rocks; Cs, Cenozoic sedimentary deposits. Geology from Ekren (1995) and Longwell and others (1965). Solid triangle, well location.

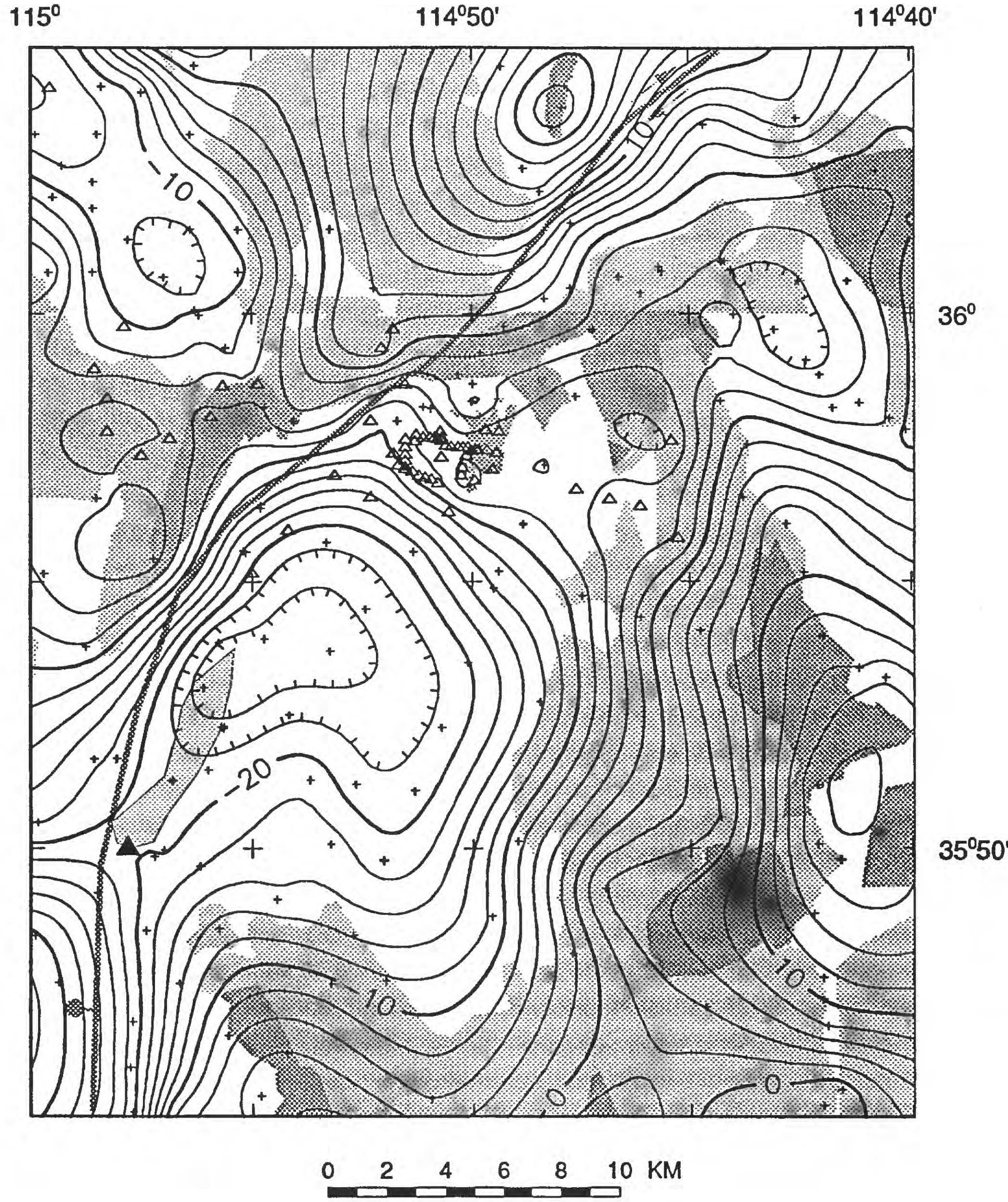

Figure 4. Isostatic gravity map of study area. Contour interval, 2 mGal. +, previously collected station; triangle, new stations. Area of interest delineated by close concentration of stations west of basement exposures south of Boulder City. See Figure 3 for explanation.

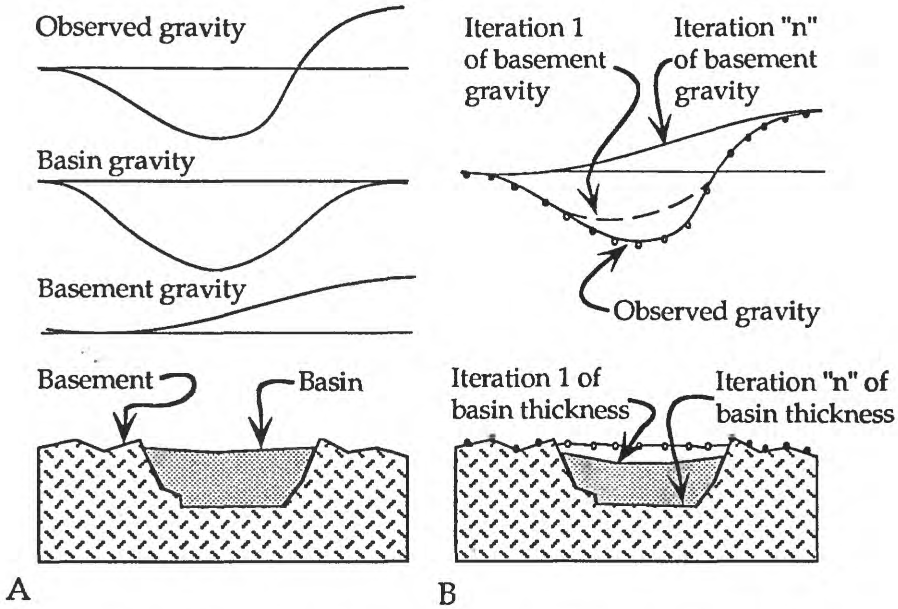

Figure 5. Schematic representation of the gravity separation procedure. "n" represents final iteration of basin-fitting procedure. From Jachens and Moring (1990).

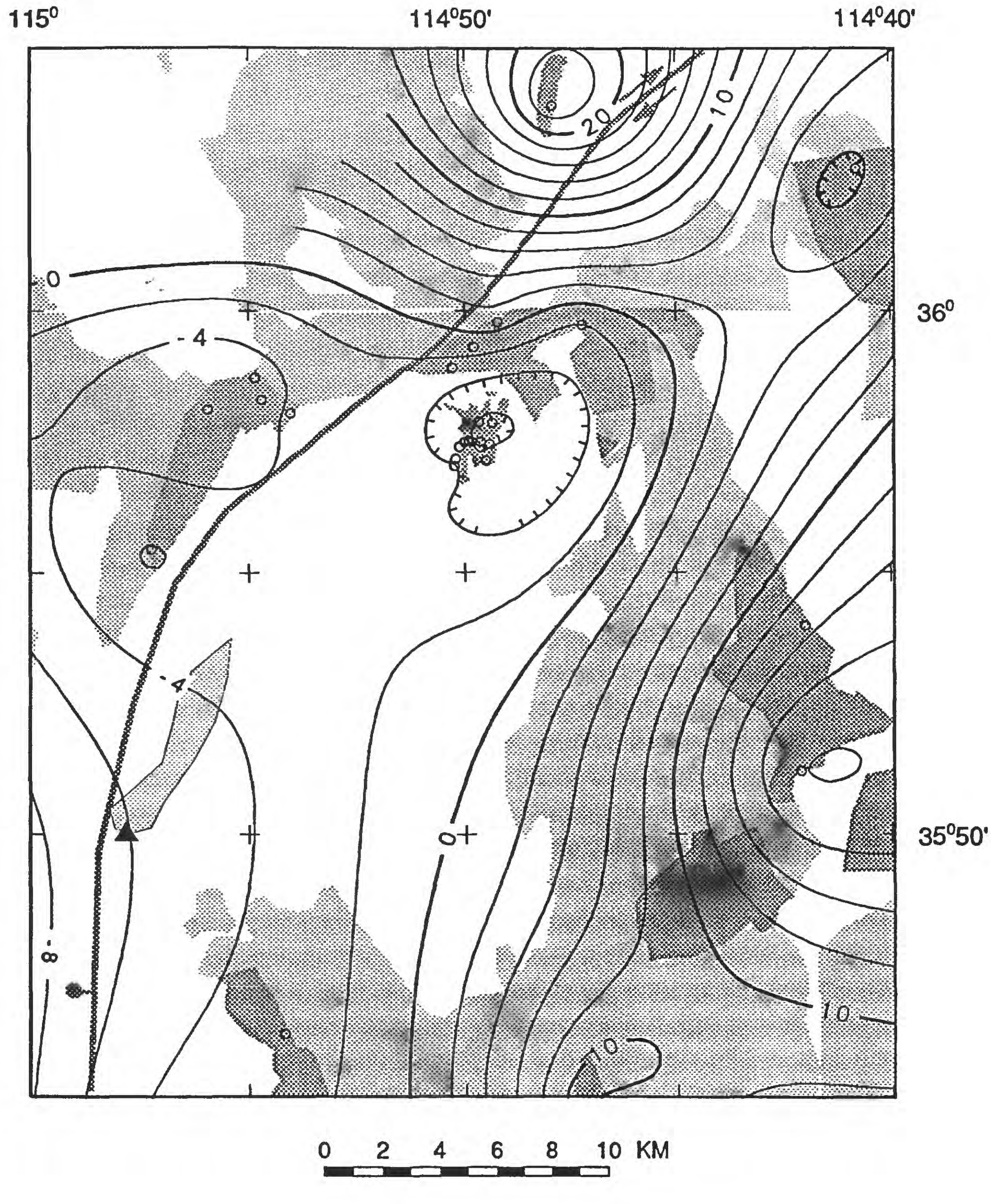

Figure 6a. Basement gravity field (Model 1). Contour interval 2 mGal. See Figure 3 for explanation.

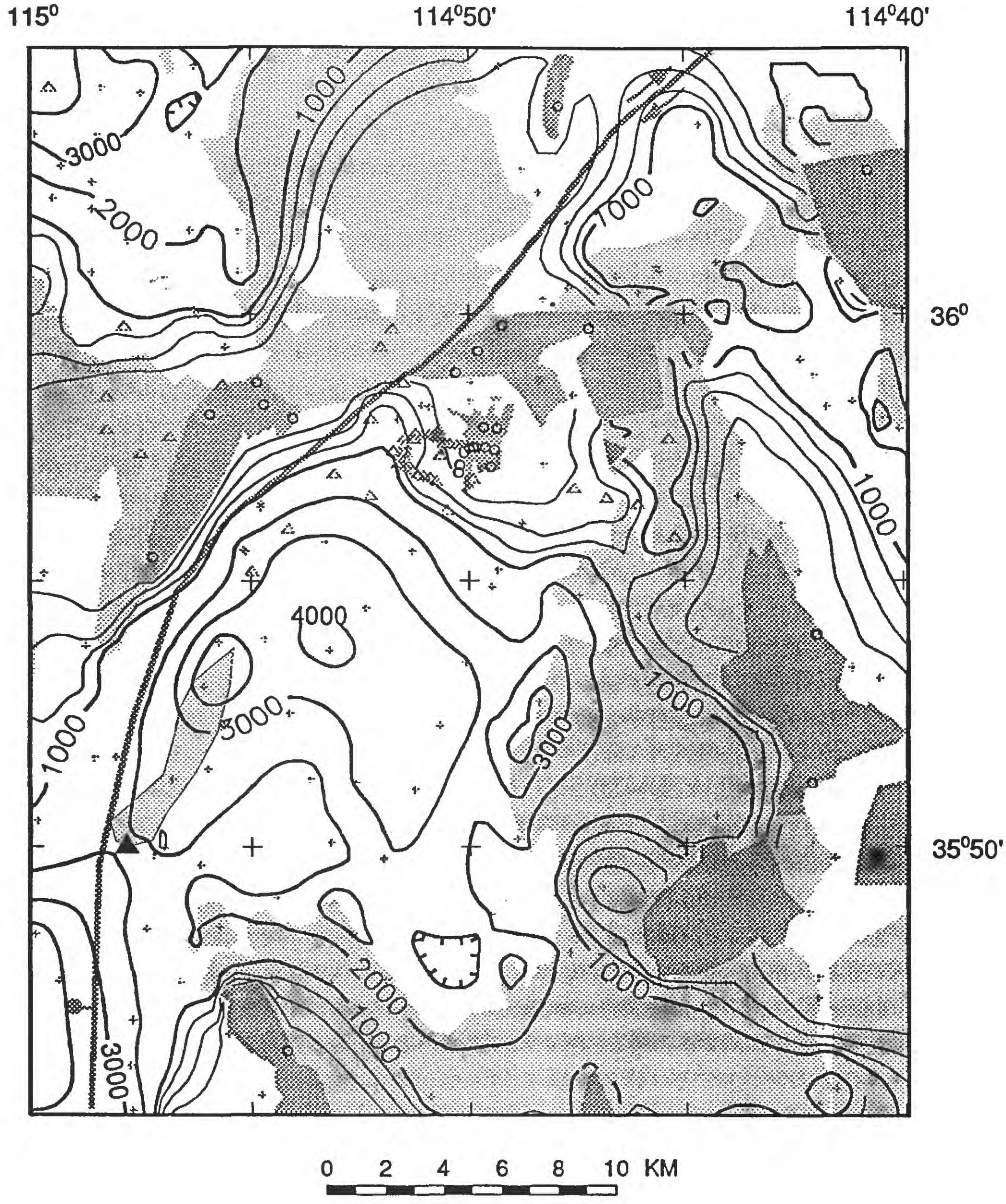

Figure 6b. Calculated thickness of Cenozoic basin fill (Model 1). Contour intervals, 250, 1000 ft. See Figures 3 and 4 for explanation. Total depth of well, 1570 ft (479 m).

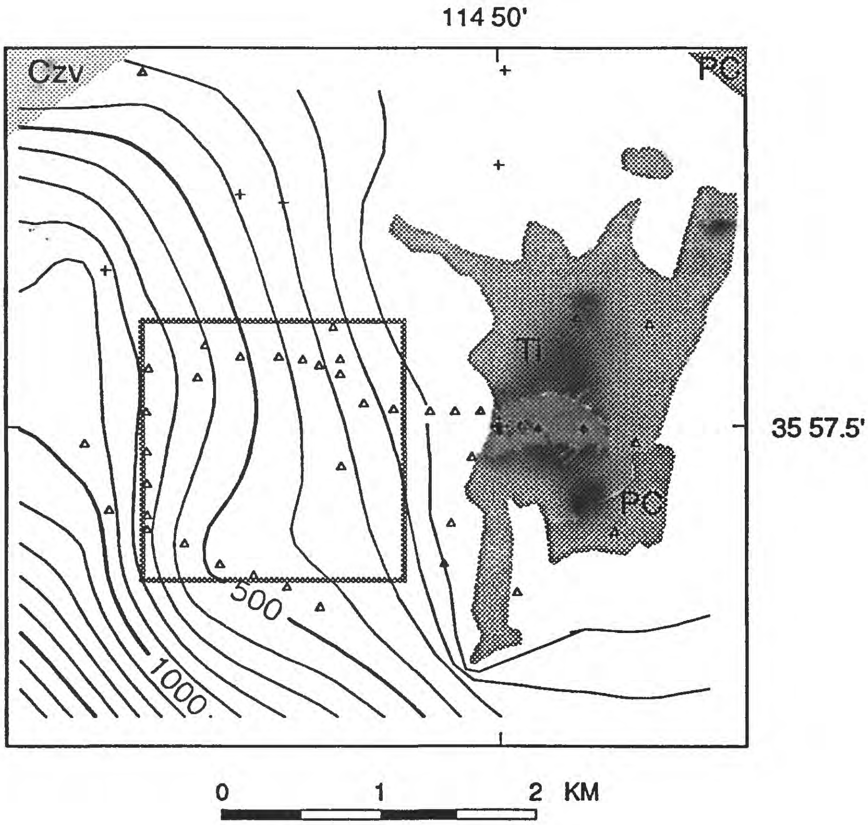

Figure 6c. Calculated thickness of Cenozoic fill in area of interest (Model 1). Contour interval, 100 ft. Triangles are new stations; crosses, previously collected stations. Area of interest outlined by thick gray line.

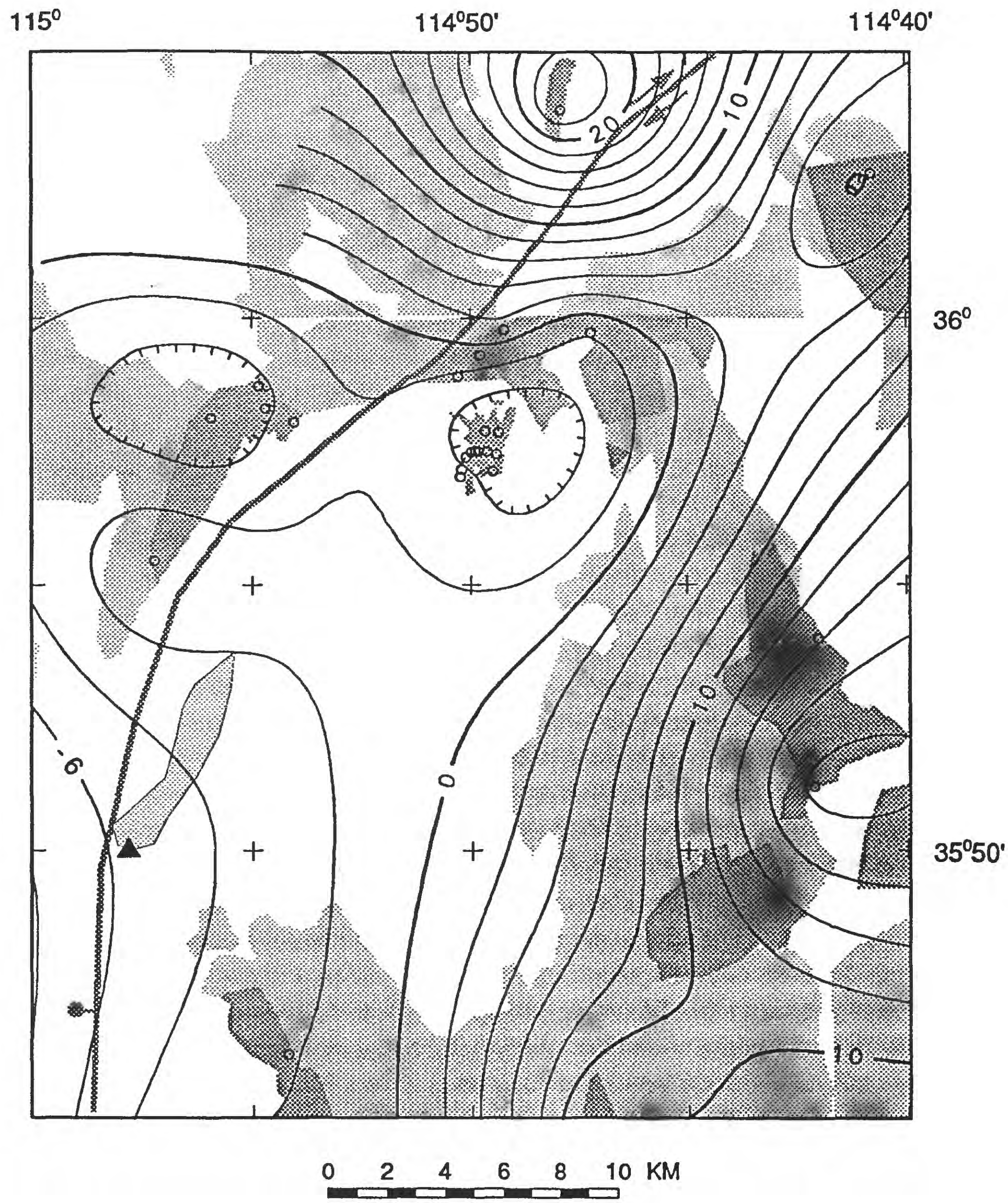

Figure 7a. Basement gravity field (Model 2). Contour interval, 2 mGal. See Figure 3 for explanation.

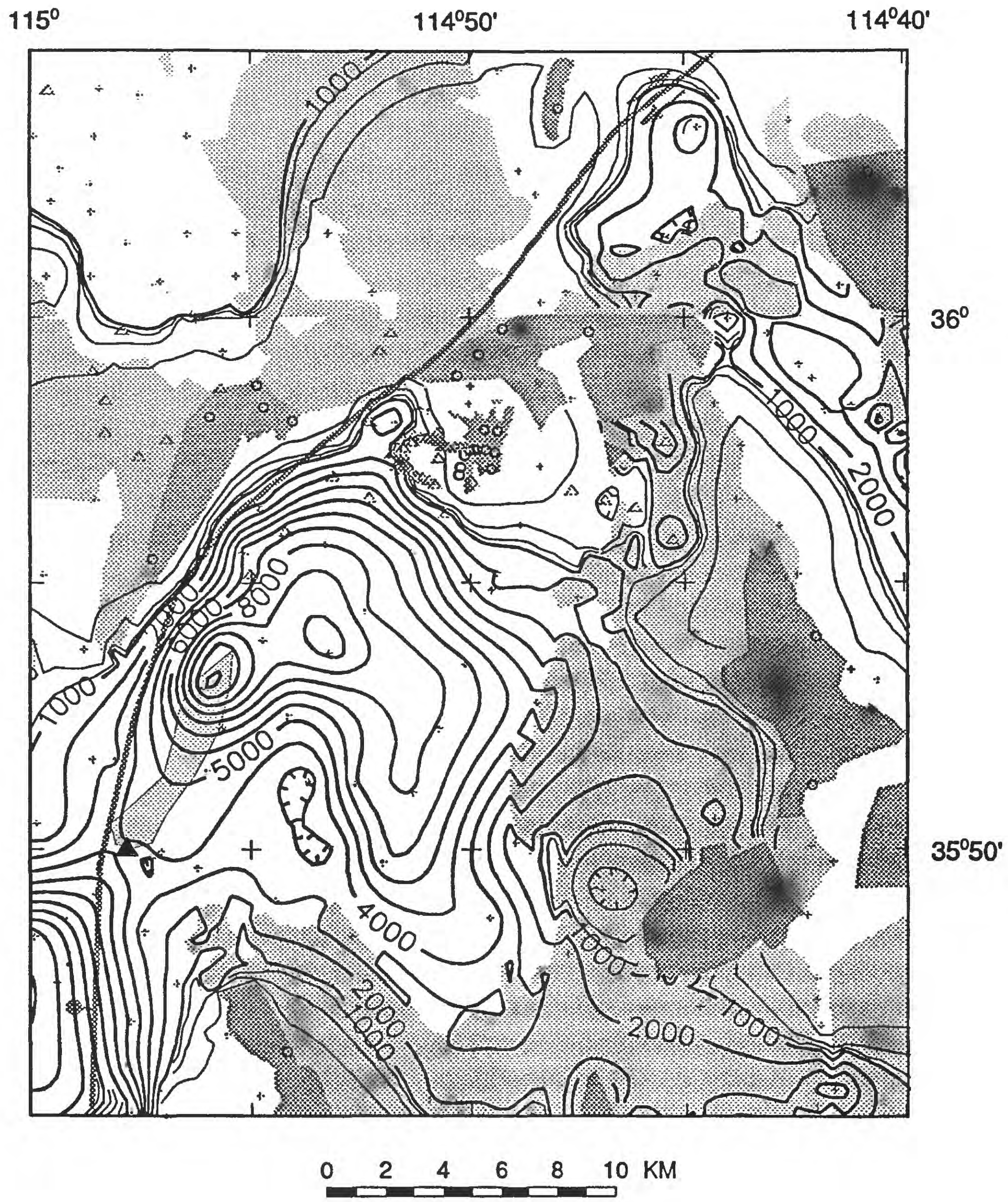

Figure 7b. Calculated thickness of Cenozoic basin fill (Model 2). Contour intervals, 250 and 1000 ft. See Figures 3 and 4 for explanation.

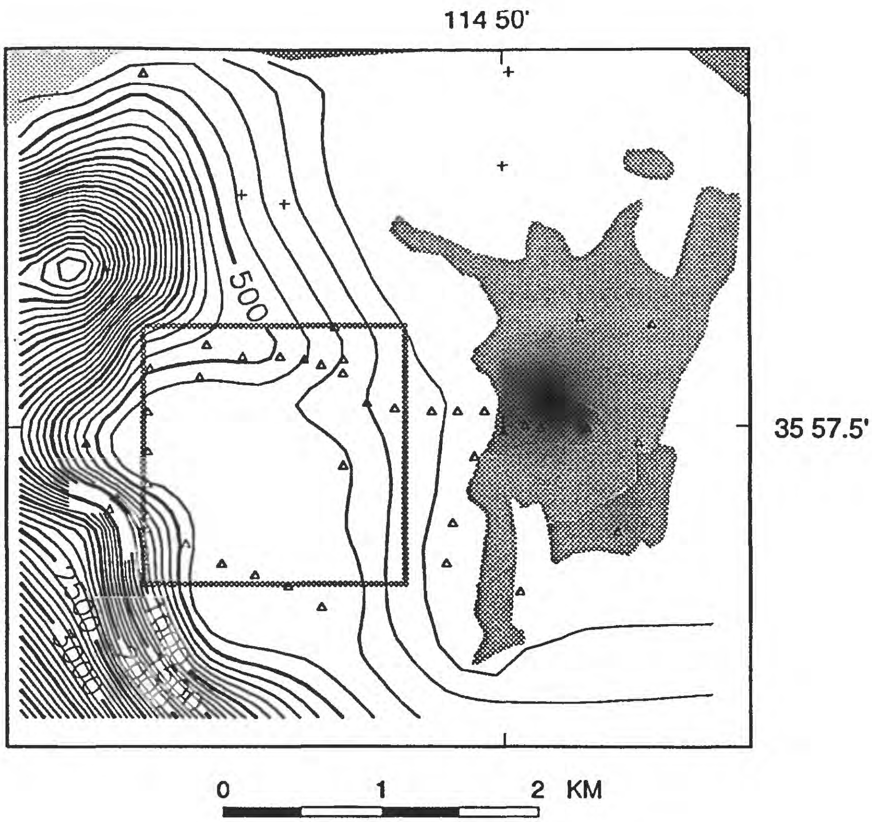

Figure 7c. Calculated thickness of Cenozoic fill in the area of interest (Model 2). Contour interval, 100 ft. See Figure 6c for explanation.

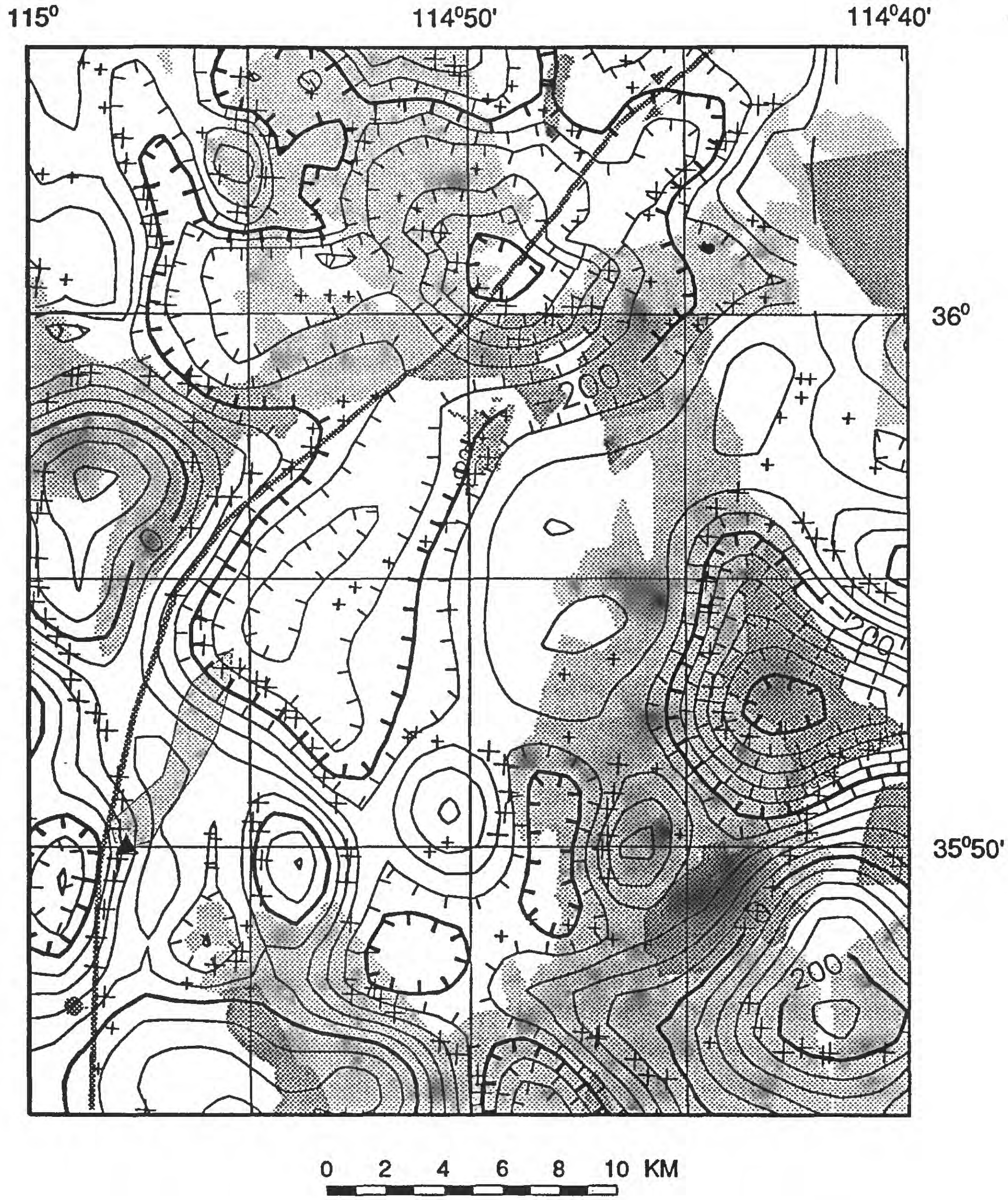

Figure 8. Aeromagnetic map of study area. Contour interval 40 nT. Crosses show locations of magnetization boundaries. Size of cross determined by magnitude of horizontal gradient. See Figure 3 for explanation of patterns. Triangle, welll location.

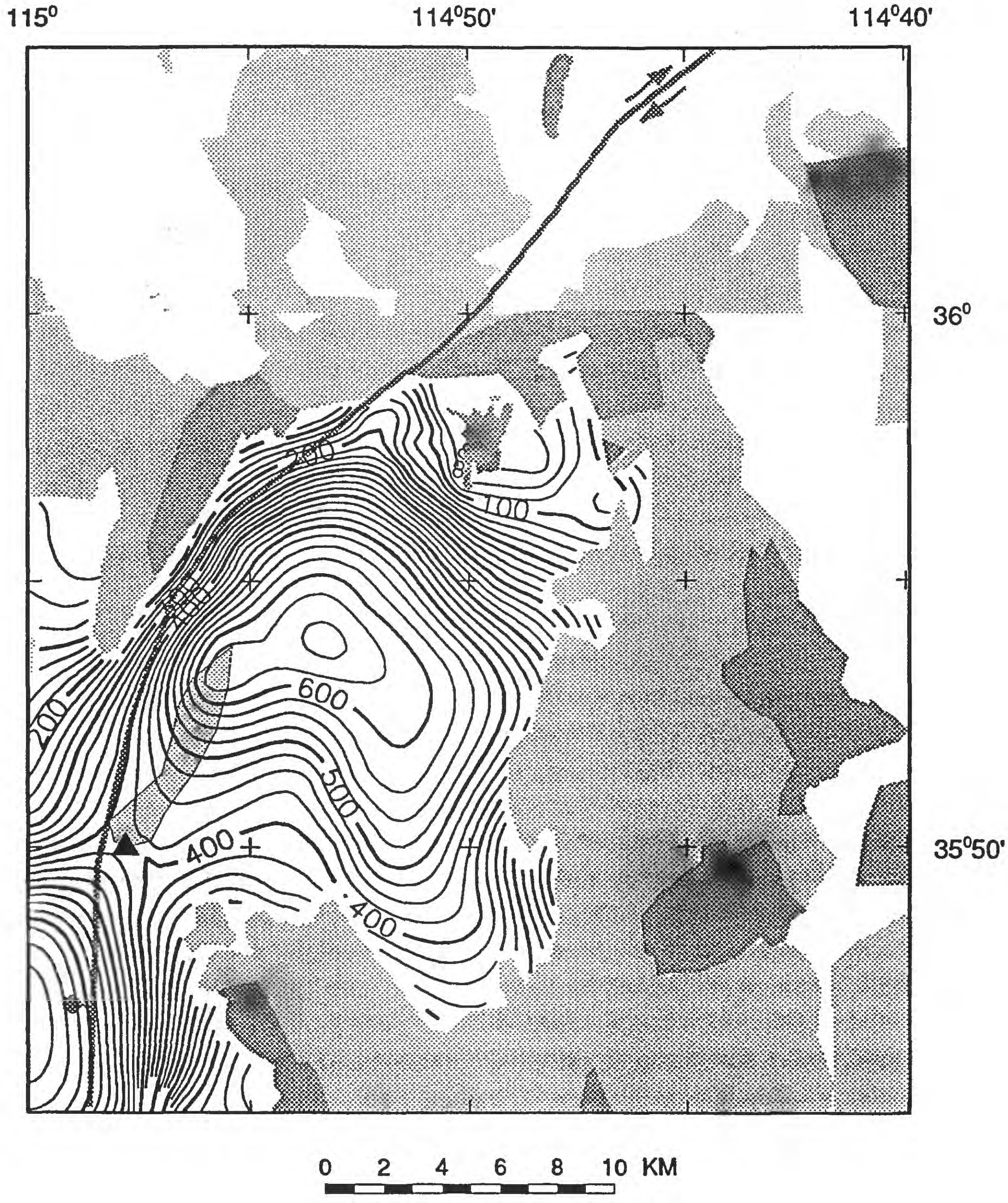

Figure 9a. Storage capacity of alluviated areas in Eldorado Valley (Model 1) assuming basin fill is unsaturated. Contour interval, 25 ft. See Figure 3 for explanation.

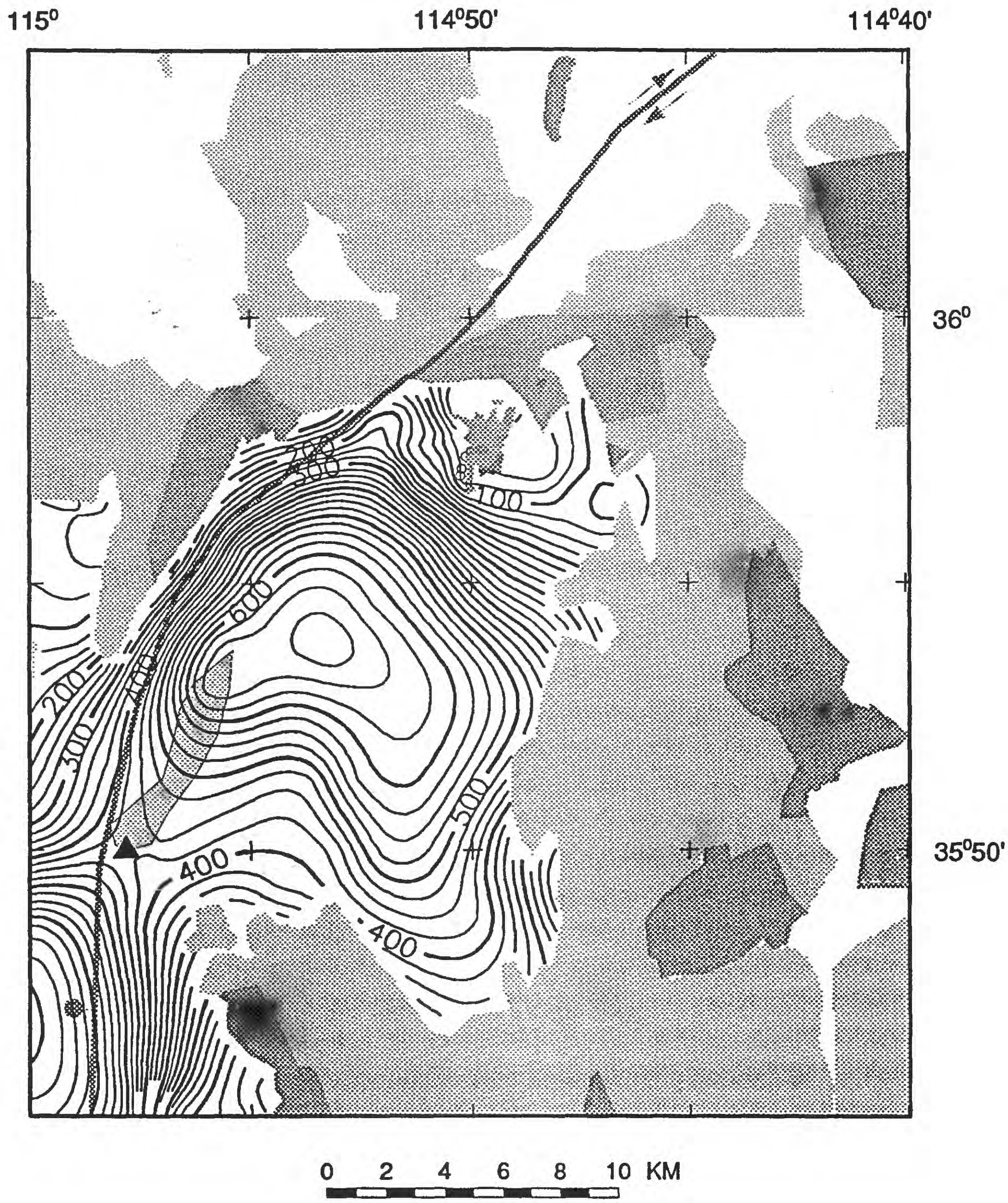

Figure 9b. Storage capacity of the alluviated areas of Eldorado Valley (Model 2) assuming basin fill is unsaturated. Contour interval 25 ft. See Figure 3 for explanation.