Gravity and Magnetic Data in the Vicinity of Virgin Valley, Southern Nevada

By Robert L. Morin

Open-File Report 2006–1042

U.S. Department of the Interior
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Abstract

Gravity and magnetic data were collected in the vicinity of Virgin Valley to help better characterize the buried sedimentary Mesquite and Mormon basins. Detailed gravity measurements were made over the buried saddle between the Mesquite and Mormon basins, discovered by earlier gravity studies, in order to calculate the depth to pre-Cenozoic basement. The purpose of this study was to provide estimates of sedimentary fill in this area prior to drilling a water well on Mormon Mesa. The calculated depth-to-basement results in an estimate of about 1.5 km of alluvial fill in this area. Additional gravity data were collected to help better define the shape and magnitude of the anomaly associated with the Mesquite Basin. Testing of an experimental towed magnetometer was also carried out, which showed very good correlation with an existing aeromagnetic survey.

Introduction

Geophysical data were collected in Virgin Valley, southern Nevada. This data release completes the requirements of a Joint Funding Agreement between the U.S. Geological Survey and the Virgin Valley Water District. The study area (fig. 1) lies between 36° 30' and 37° 15' N latitude and between 113° 30' and 114° 30' W longitude. In the course of this study, 547 new gravity stations were made and about 22 km of ground magnetic measurements were collected with an experimental cart, mounted with a magnetometer and integral Global Positioning Systems (GPS). This carriage was towed behind a vehicle along roads at an average speed of 10 mph and collected data at one-second intervals.

Gravity data collection

Gravity data for this study were collected with a LaCoste and Romberg G-model gravity meter and measurements were recorded to 0.001 mGal. Most of the data collected were along roadways, where spacing was measured with vehicle odometers. The detailed surveys on Mormon Mesa typically have station spacing of 0.1 miles, whereas the more regional data is spaced at 0.2 to 0.4 miles. Precise locations and elevations were made with a Trimble GeoXT GPS, which are later processed through publicly accessible sites that produce elevations that claim to be sub-meter in accuracy. The gravity base station used in these surveys is located at the base of the flagpole at the city hall in Mesquite, Nevada. The base station is named MESCN and was established with multiple ties from several gravity base stations in Las Vegas, Nevada. The observed gravity at MESCN is 979624.14 mGal. This base station was read at the beginning and end of each survey session and checked at the close of each session for excess meter drift or tares using prepared tables of earth tide, which are applied to the base reading.

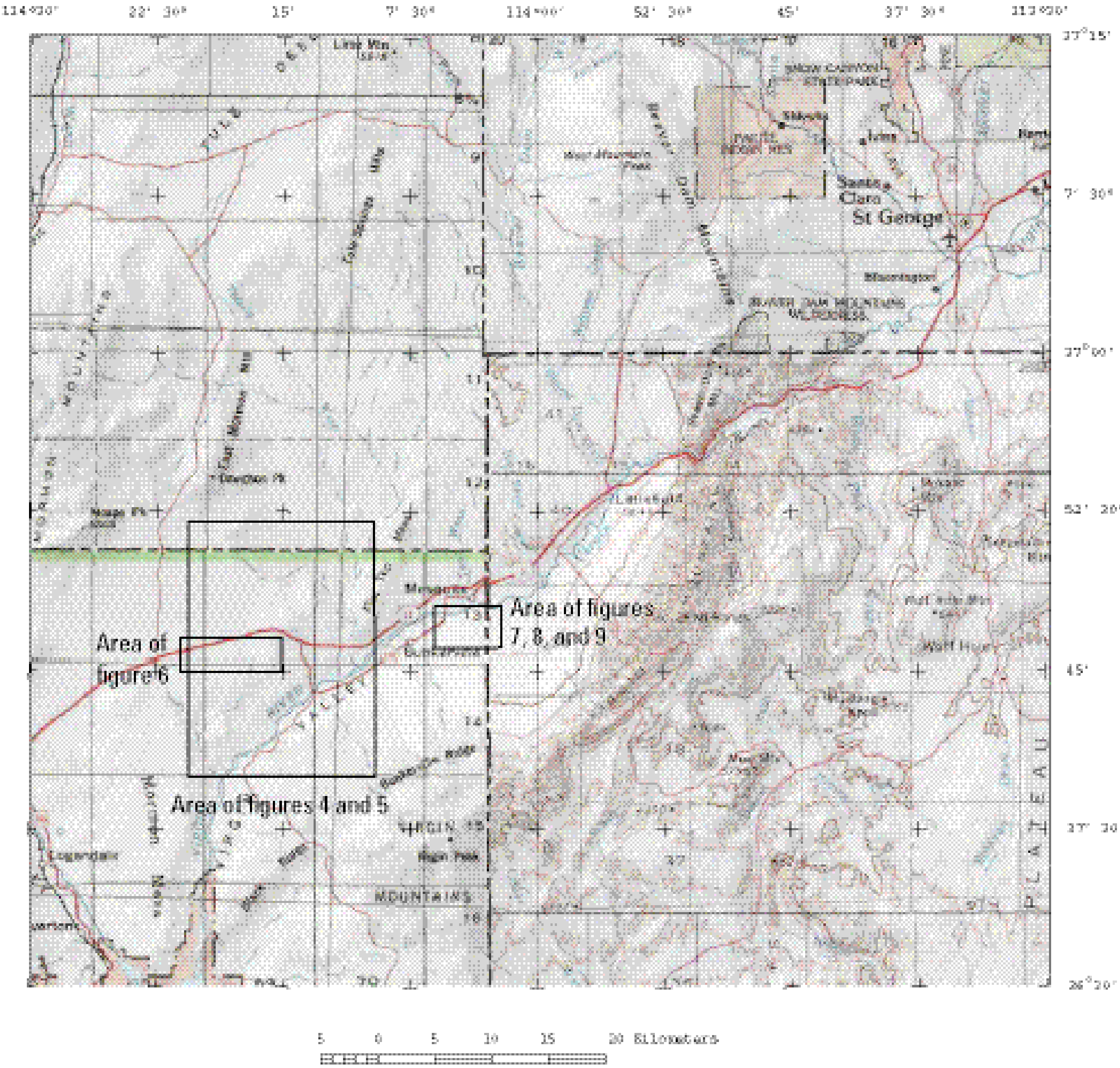

Figure 1. Location of study area. Boxes show outlines of figures 4, 5, 6, 7, 8, and 9.

Gravity data reduction

Conversion to milligals is made using factory calibration constants and a calibration factor, which varies with each gravity meter and has been determined by multiple gravity readings over the Mt. Hamilton calibration loop east of San Jose, CA (Barnes and others, 1969). Observed gravity values are based on an assumed linear drift between successive base readings. Vertical and horizontal control is mostly provided by small portable differential GPS.

Field terrain corrections are made in the field by calculating the effect of the local terrain from the station to a radial distance of 68 m. Inner terrain corrections from 68 m to 0.59 km are calculated using 30 m digital elevation models (DEM's). Terrain corrections are computed from a radial distance of 0.59 km from the station to a radial distance of 166.7 km with a FORTRAN program (Plouff, 1977) and a digital terrain model. These data are processed through an isostatic reduction program (Jachens and Roberts, 1981) in order to suppress the effects of deep density distributions that buoyantly support the topography. The isostatic reduction assumes an Airy-Heiskanen model with the following parameters from the station to 166.7 km: density of topography above sea level, 2.67 g/cm^3; crustal thickness at sea level, 25 km; and density contrast across the base of the model crust, 0.4 g/cm^3. From 166.7 km to a point on the opposite side of the Earth, isostatic and terrain corrections are taken off maps by Karki (1961). These corrections are added to the output of the isostatic program of Jachens and Roberts (1981) to produce the isostatic correction.

Theoretical gravity at sea level is based on the Geodetic Reference System 1967 (GRS 67) (International Association of Geodesy, 1971, p. 58) for the shape of the spheroid. The datum for the observed gravity is the International Gravity Standardization Net 1971 (IGSN 71) (Morelli, 1974. p. 18). Observed gravity values are calculated by adding meter drift and earth-tide corrections to the milligal equivalent meter readings. Free-air anomalies are calculated by subtracting the theoretical gravity from the observed gravity and adding the free-air correction as defined by Swick (1942, p. 65). Simple Bouguer anomalies are calculated by subtracting the Bouguer correction, which accounts for the attraction of rocks between the station and sea level using a rock density of 2.67 g/cm^3 from the free-air anomaly. Complete Bouguer anomalies are calculated by adding the terrain correction and the curvature correction to the simple Bouguer anomaly. Isostatic anomalies are calculated by adding the isostatic correction to the complete Bouguer anomaly.

Gravity map

The isostatic gravity map (fig.2) shows the locations, in red, of the data points collected for this study. These data were added to previously collected data in the area and gridded at a 0.1 km interval. This grid is displayed as a color image with a 3-mGal contour interval. There is about 82 mGal of range in the grid. The largest negative anomalies in the gravity are caused by low-density fill in sedimentary basins. The basin in the center of the figure is called the Mesquite basin and has an anomaly of about 50 mGal. New data collected in the Mesquite basin help constrain the lowest part of the anomaly. The data collected on the northwest portion of the anomaly only slightly improves the control on the gradient and more data are needed in the northern and western parts of the anomaly to better constrain the anomaly.

Additional gravity data were collected over the basin to the southwest of Mesquite basin, a basin referred to as Mormon basin. Mormon basin has a gravity anomaly of about 30 mGal. The majority of the gravity data collected for this study were made over the geophysical saddle between the Mesquite and Mormon basins. These data are located on Mormon Mesa, which is relatively flat, topographically.

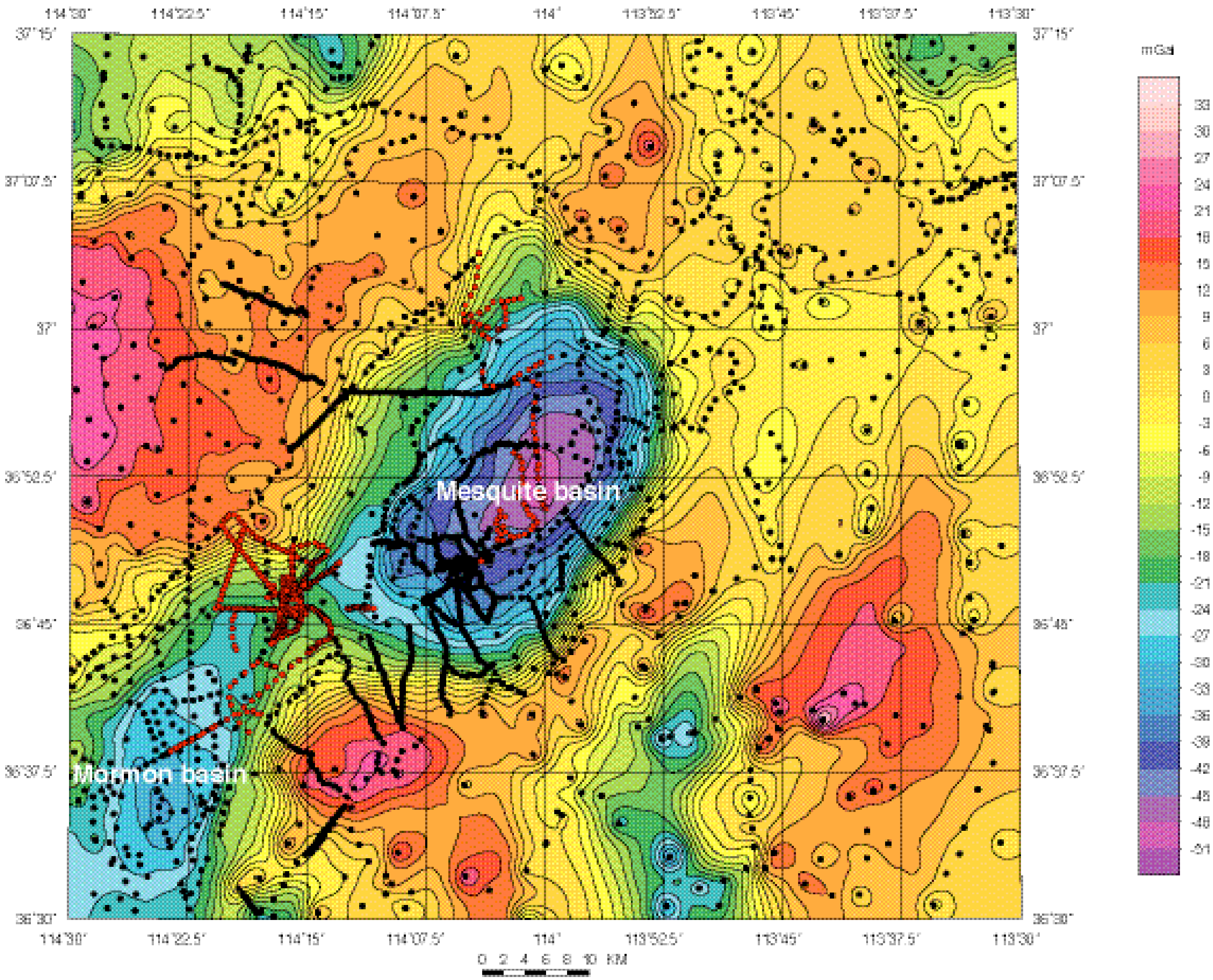

Figure 2. Isostatic gravity map of Virgin Valley. Contour interval 3 mGal. Red circles are locations of gravity stations made for this study.

The purpose of collecting data in this area was to investigate how deep the sedimentary fill is in the area prior to drilling a water production well.

Depth-to-basement maps

A depth-to-basement map was made using the technique of Jachens and Moring (1990) applied to an interactive FORTRAN program (Bruce Chuchel, U.S. Geological Survey, written commun., 1996). This technique analyzes gravity data and predicts the depth to pre-Cenozoic basement. A complete explanation of the technique is made in Langenheim and others (2000). The depth-to- basement grid used the same parameters as Langenheim and others (2000), but includes data collected for this study. The density-depth function for the basin fill as well as the volcanic rocks uses a density contrast of -0.56 g/cm^3 from the surface to 0.5 km; a density contrast of -0.52 g/cm^3 from 0.5 km to 1.2 km; a density contrast of -0.33 g/cm^3 from 1.2 km to 2.1 km; and a density contrast of -0.20 g/cm^3 below 2.1 km. A sub-grid of the larger area was made that focuses on the Mesquite and Mormon basins (fig 3). The new gravity data help control the predicted depth of the Mesquite basin. In the center of the gravity low in figure 2, the predicted depth to Cenozoic basement is about 9.5 km from the surface.

Figures 4 and 5 are depth-to-basement maps of the Mesquite saddle area, a predicted saddle between the Mesquite and Mormon basins based on gravity data. It is in this area that there is interest in drilling a water production well and the maximum predicted thickness of sediments could be useful in the budgeting of this project. Figure 3 uses a depth interval of 0.3 km to show depths of the entire area, whereas figure 4 uses a depth interval of 0.1 km to highlight the area of interest, which is about 2 km northwest of the center of the map. Using a 30 color contour limit and a 0.1 km interval, all predicted depths below 2.8 km are shown as the same color. If this estimate of basin fill is accurate, it is estimated that about 1.5 km of sediments are in the area of the proposed well site.

Magnetic data collection

Magnetic measurements were made with a Geometrics G-858 cesium vapor magnetometer with an integral Trimble AG-132 GPS. This unit is designed to be mounted on a pack frame and worn by an individual walking over the study area. An experimental cart was built to allow the magnetometer to be towed behind a vehicle, allowing for much faster coverage of the study area. Several vehicles in our fleet were tested for the generation of magnetic signals, which would mask the values measured from geologic rock units. It was discovered that not only the mass of iron in the vehicles produced a magnetic field, but the ignition system could also produce an additional strengthening of the field. The 1990, 1999, and 2001 vehicles produced a magnetic field that the magnetometer could detect from up to 100 feet away. The 1987 vehicle's magnetic signal dropped to almost zero at just over 30 feet.

A cart was then designed and built which could be towed behind the 1987 vehicle. The basic cart design is a vertical frame on two wheels with several horizontal segments to extend the cart to be just over 30 feet from the vehicle. The cart and its connecting segments are all made from welded aluminum box material. The wheels have large balloon tires with plastic hubs. There are some small parts in the hub made of stainless steel, which are nonmagnetic. The cart is connected to the vehicle by means of an articulating mount. The pack frame with all of the electronic gear is then mounted on the vertical part of the cart, farthest from the vehicle. The wheels of the cart are designed to run at a maximum speed of 10 mph, but tests have shown that speeds up to 40 mph are possible without failure. The runs made for this study were made at no more than 10 mph. The acronym for this towed magnetometer is TOM.

Two TOM surveys were run for this study. Both were repeated in opposite directions to check the consistency of the data. The results were comparable so only one run of each area was used for this

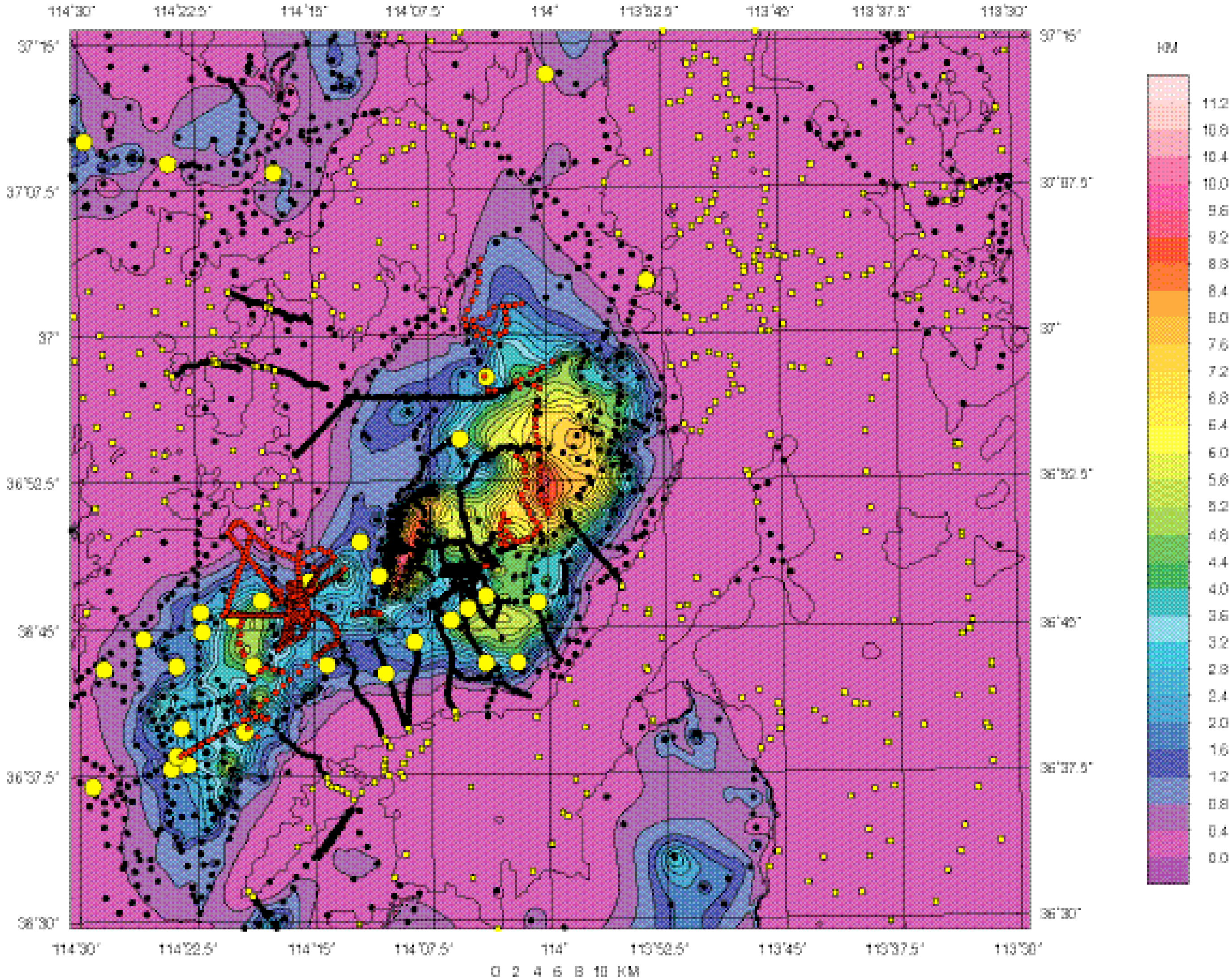

Figure 3. Depth-to-basement map of Virgin Valley. Contour interval 0.4 km. Red circles, new gravity stations; black circles, old gravity stations; yellow circles, seismic control; yellow squares, basement stations.

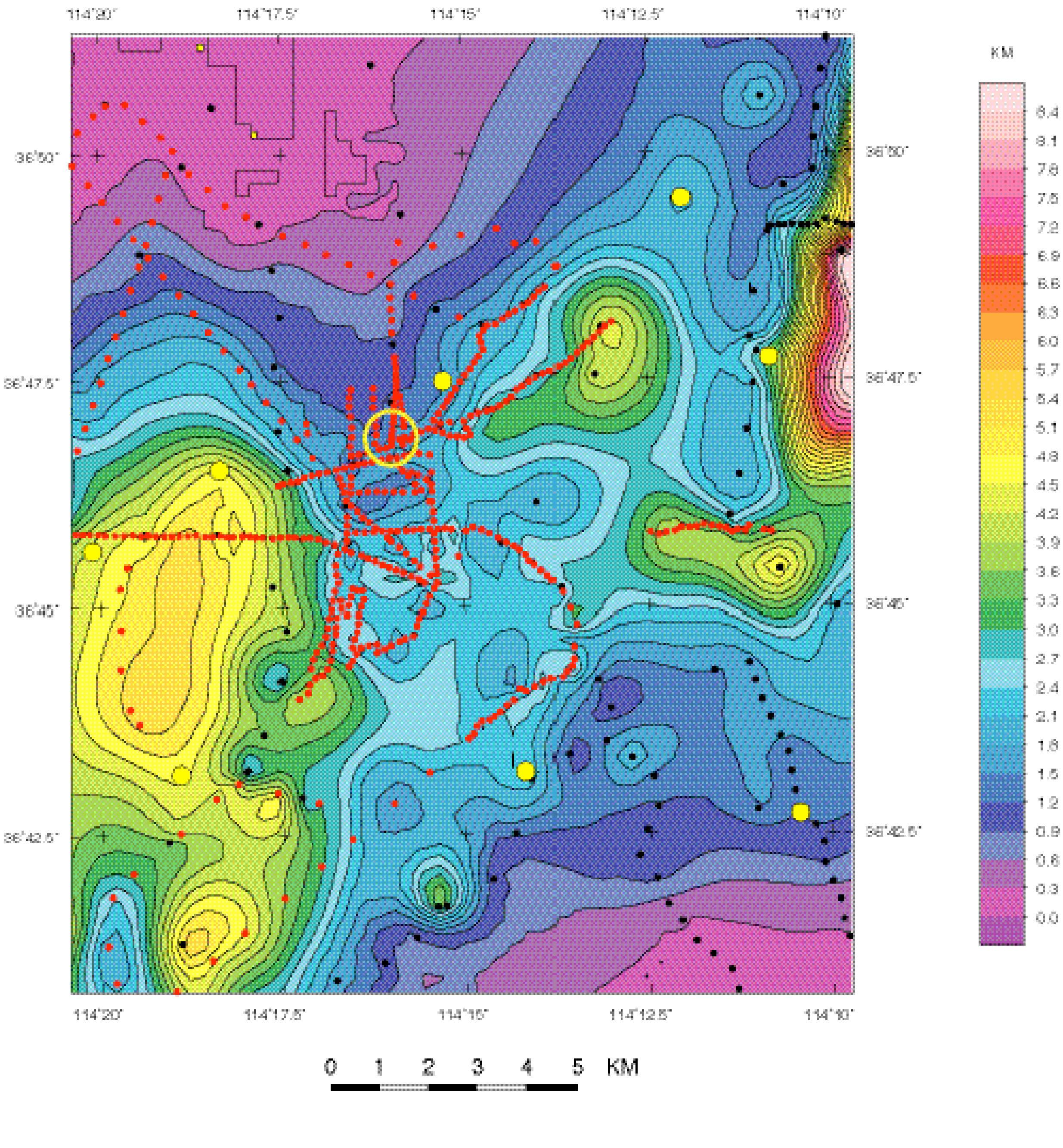

Figure 4. Depth-to-basement map of Mesquite saddle area. Contour interval 0.3 km. Red circles, new gravity stations; black circles, old gravity stations; yellow circles, seismic control; yellow squares, basement stations; large open yellow circle, location of proposed well.

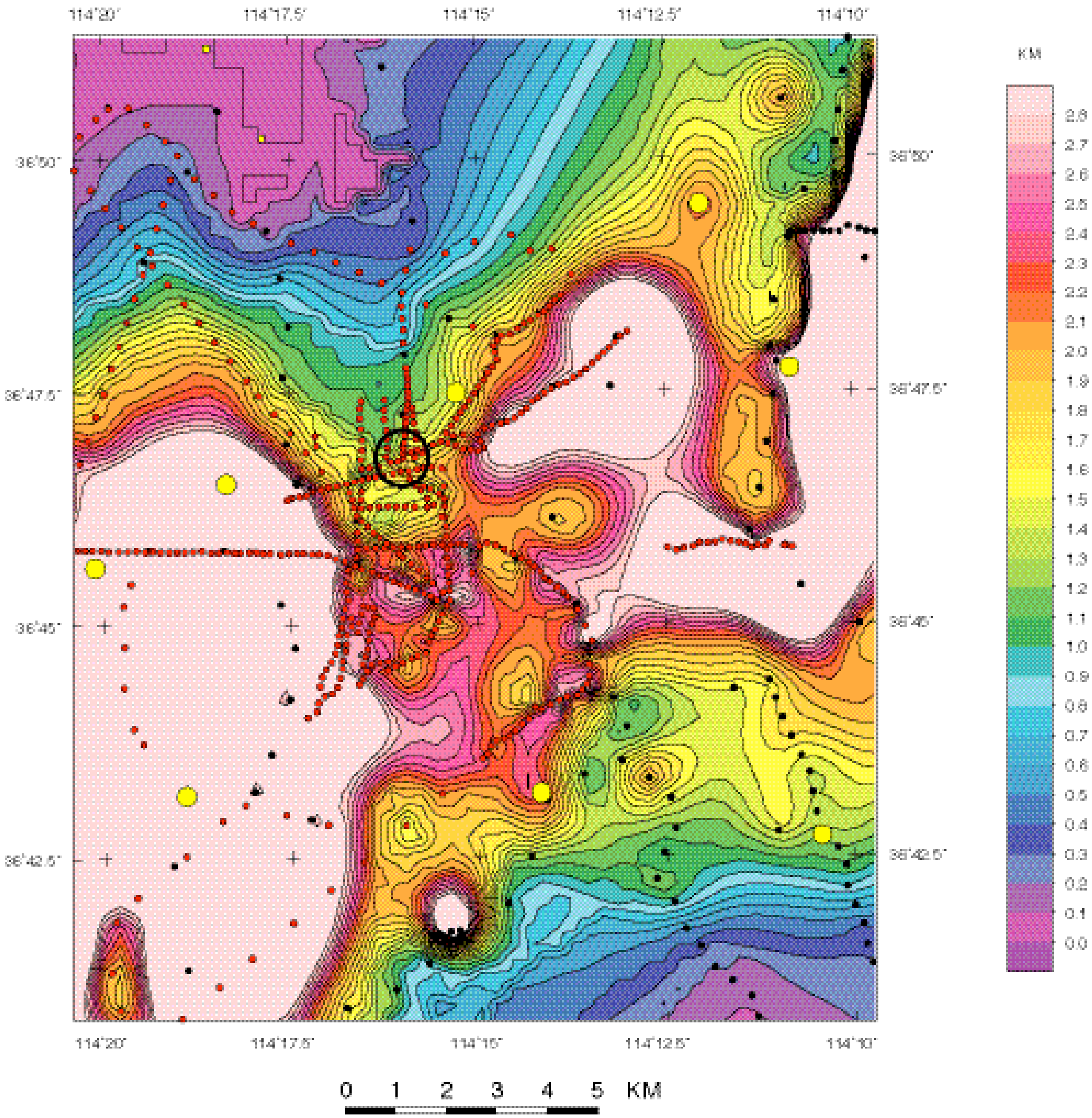

Figure 5. Depth-to-basement map of Mesquite saddle area. Contour interval 0.1 km. Red circles, new gravity stations; black circles, old gravity stations; yellow circles, seismic control; yellow squares, basement stations; large open black circle, location of proposed well.

report. The first TOM survey was conducted on Mormon Mesa (figs. 1 and 6) along roads that also have detailed gravity measurements. This traverse is about 15 km long and has over 4,900 magnetic measurements. The second TOM survey (figs. 1 and 7) was run just south of Mesquite along roads that cross a large magnetic anomaly detected from a high resolution aeromagnetic survey (Jachens and others, 1998). This TOM survey was done to check the repeatability of ground magnetic measurements with those from an aeromagnetic survey. This traverse is about 7 km long and has over 1,500 magnetic measurements.

Magnetic data reduction

Magnetic data were collected with a cesium vapor magnetometer with a collection rate of one reading per second. Typically, a base station proton precession magnetometer is set up at a fixed location and records the magnetic field at one-minute intervals to record the changing magnetic field. One-second interpolated base station values are then subtracted from the roving magnetometer values, resulting in the total field values. A base station was set up for the work on Mormon Mesa, but a malfunction of the magnetometer did not allow for the removal of regional drift. The survey south of Mesquite was of short duration, so a base station was not set up. Locations and elevations of magnetic measurements were recorded with a GPS unit, which receives a secondary differential signal, resulting in position accuracies of about one meter. The GPS unit makes a measurement at one-second intervals. The locations obtained by this GPS unit are in the 1983 horizontal datum. Locations were converted to the 1927 datum to correlate with published U.S. Geological Survey topographic maps.

Magnetic maps

The TOM survey on Mormon Mesa is displayed in figure 6. A constant of 50300 nT was removed from the total field values making the range of values easier to compare. The data show that there is a constant gradient along the traverse with the higher values at the west end of the line and decreasing by about 100 nT at the east end of the line. This could be caused by a thicker section of magnetic rocks under the west end or a tilted magnetic layer that is closer to the surface at the west end.

A second TOM survey (fig. 7) was made south of the town of Mesquite in order to see if the TOM data accurately located a magnetic anomaly detected in a high-resolution aeromagnetic survey. Figure 8 shows part of the aeromagnetic survey. The magnetic high in the eastern portion of the figure has been interpreted as buried volcanic rocks (Jachens and others, 1998). The TOM survey passed over the southern part of the magnetic high and continued partially into a magnetic low. Figure 7 shows the TOM data running along part of the road system in the area. Some data have been discarded that are probably measurements over culverts or miscellaneous metal debris that caused large high-frequency magnetic anomalies. These missing data can be seen as spaces in the otherwise continuous profile. Figure 9 superimposes the TOM data over the regional aeromagnetic data. The two data sets have been leveled for a better comparison. In general, there is a very good agreement with the measured magnetic fields from both surveys. With additional adjustment, these two surveys would compare even better. The regional aeromagnetic survey was flown at 150 m above the ground, whereas the TOM survey measured the magnetic field at 3 m above the ground. The closer the sensors are to the source, the larger the magnitude of magnetic anomalies. That explains the high frequency anomalies along the TOM line and the higher amplitude of the magnetic high. The high frequency data along the TOM line is probably caused by foreign iron located in, under, on, or beside the road fill. The higher amplitude of the magnetic high is probably also related to the distance to the source of the anomaly. Because the TOM

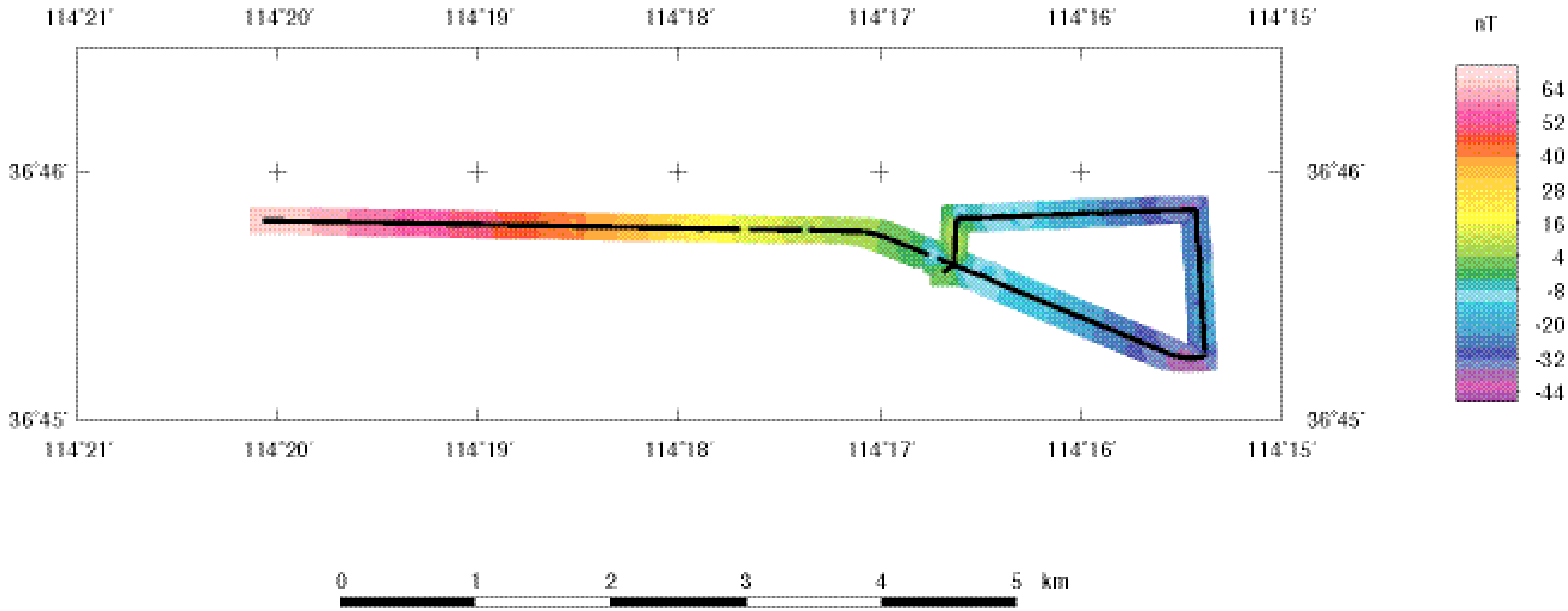

Figure 6. Magnetic data collected with towed magnetometer (TOM) on Mormon Mesa. Contour interval 4 nT. Black line, data points.

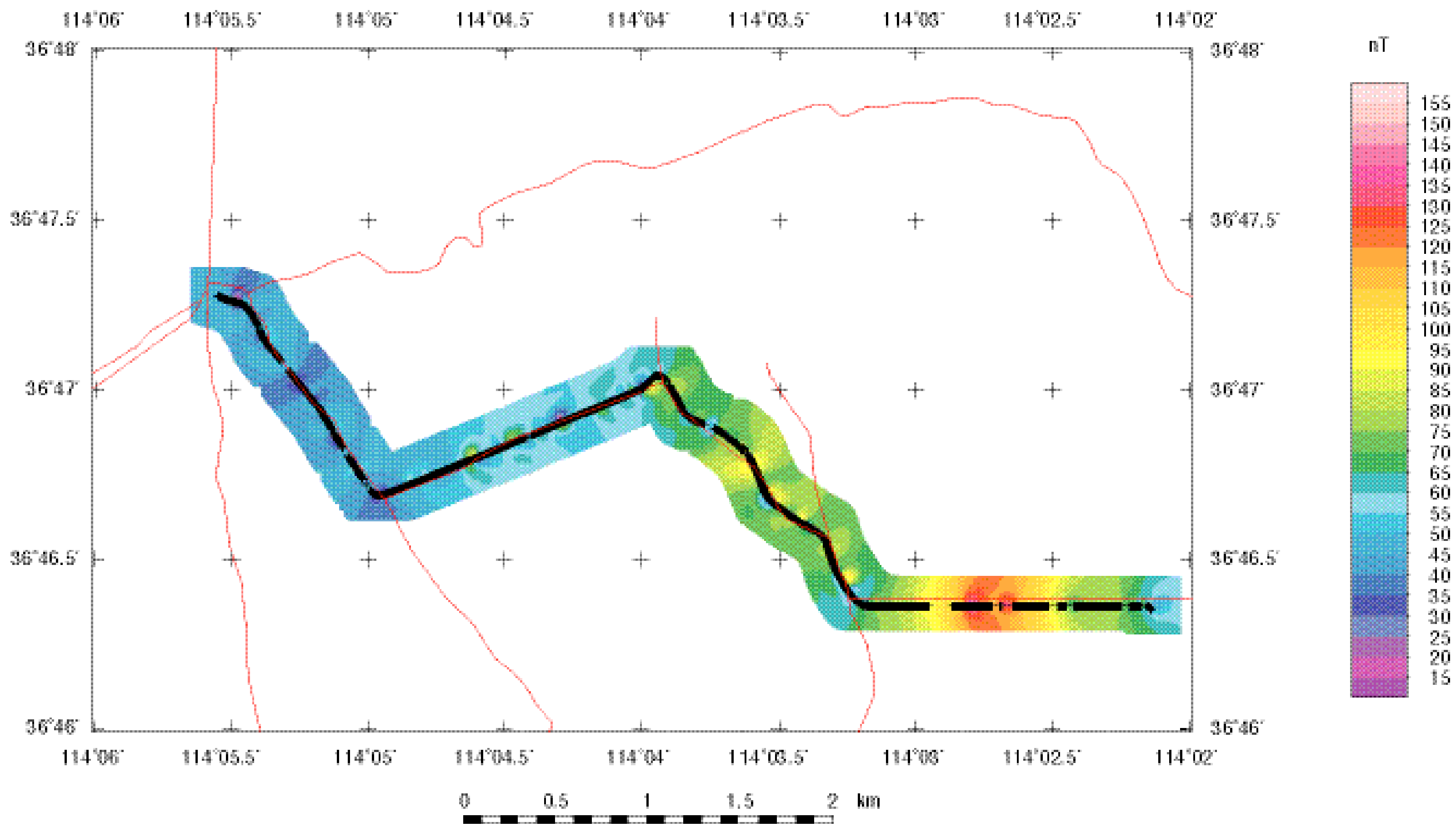

Figure 7. Magnetic data collected with TOM south of Mesquite. Contour interval 15 nT. Black line, data points; red lines, roads.

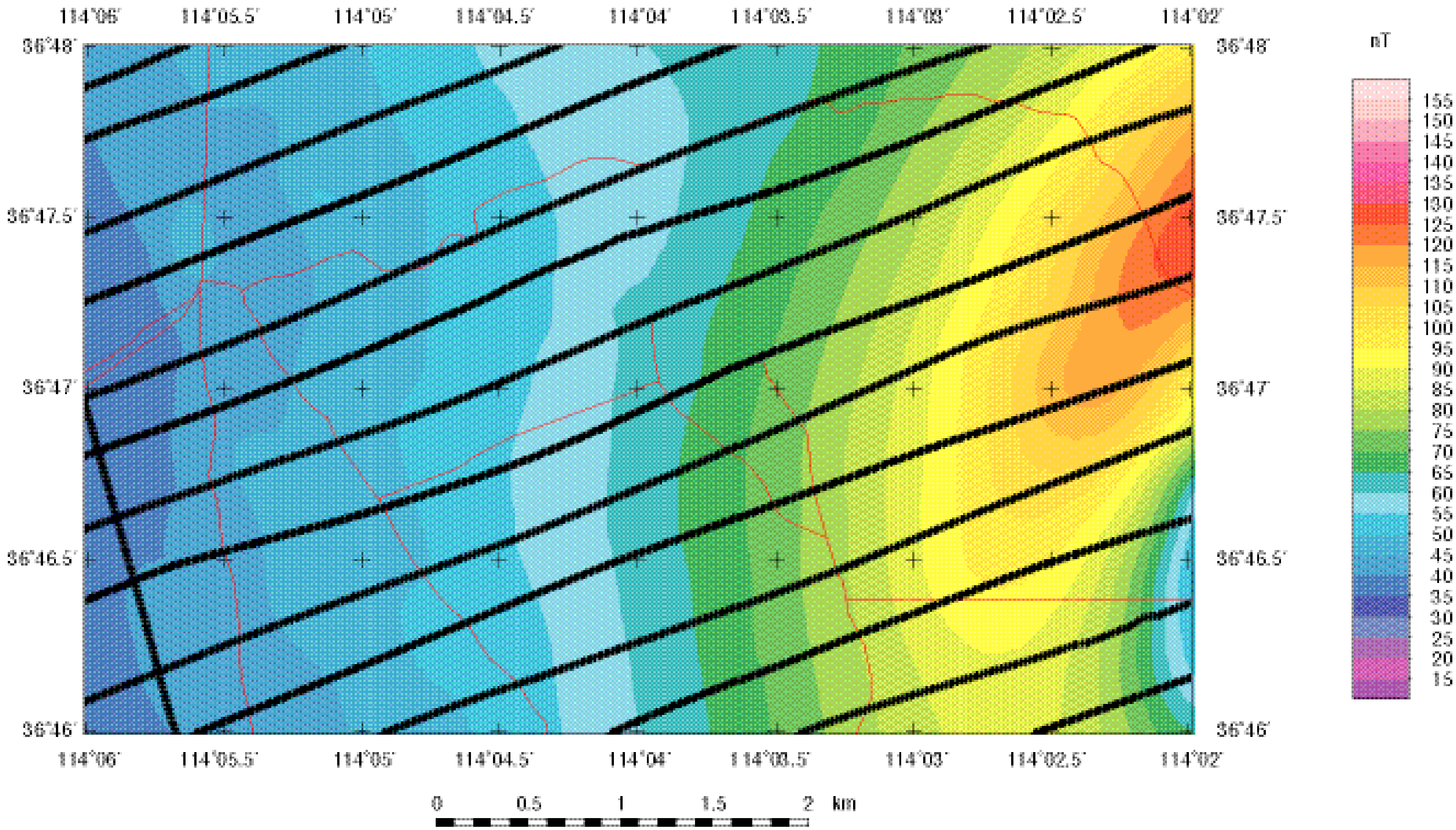

Figure 8. Portion of regional high-resolution aeromagnetic survey south of Mesquite. Contour interval, 15 nT. Black lines, data points; red lines, roads.

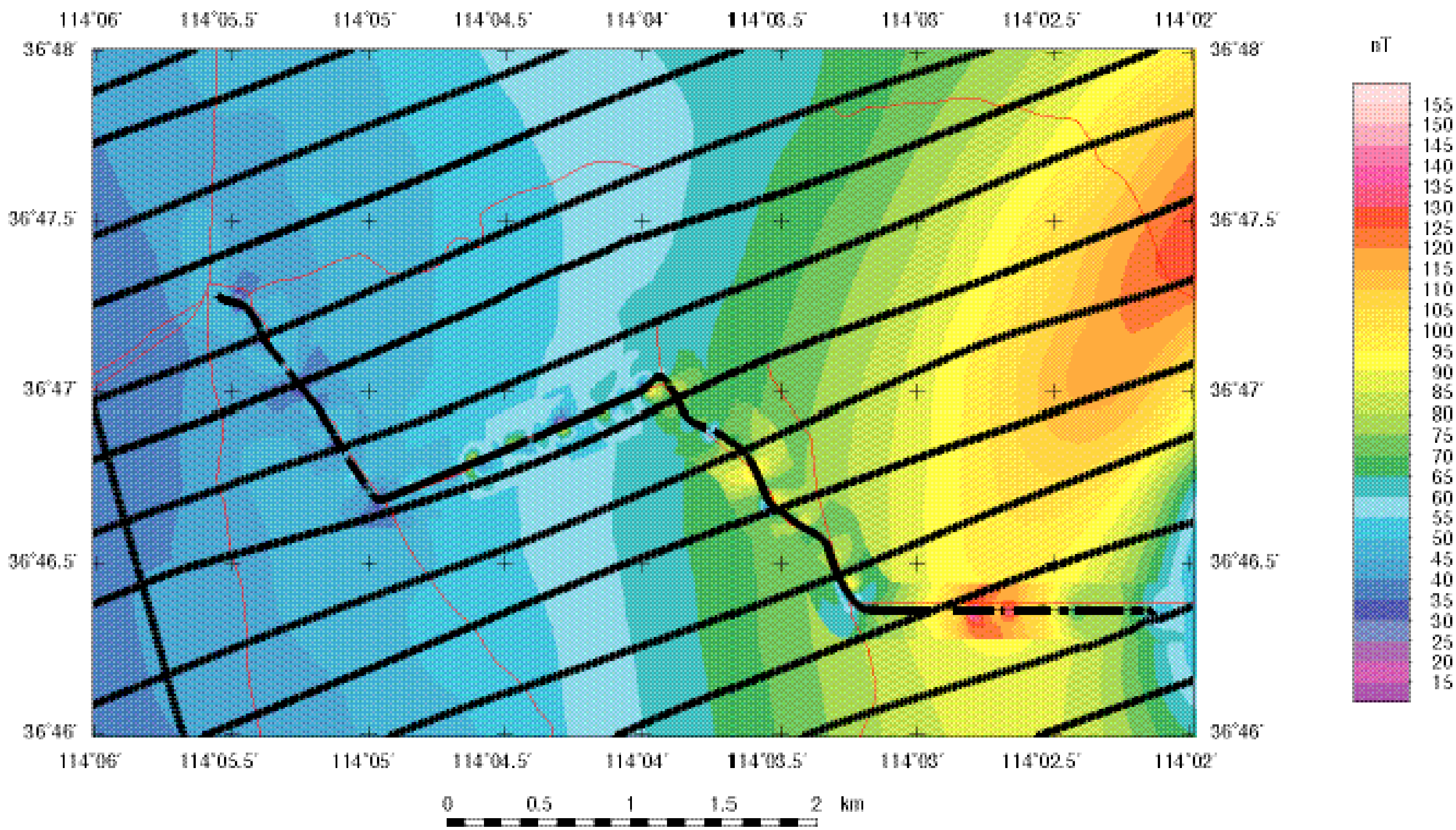

Figure 9. Portion of regional high-resolution aeromagnetic survey south of Mesquite with TOM survey superimposed. Contour interval, 15 nT. Black lines, data points; red lines, roads.

survey is about 150 m closer the to magnetic source causing the anomaly, it implies that the rocks causing this anomaly are probably fairly shallow. Additional filtering of either data set would likely result in both surveys having about the same amplitude. This filtering technique, either upward continuing the TOM survey or downward continuing the aeromagnetic survey, has not been performed at this time because the location and approximate amplitude of the anomaly and surrounding magnetic field correspond close enough to show that the TOM magnetometer and GPS data agree with the aeromagnetic survey.

Data files

Gravity and magnetic data collected for this study can be downloaded from this website: http://pubs.usgs.gov/of/2006/1042/. The files are ascii space delimited and are formatted for easy insertion into a data base. The gravity file is named *gravity-data.txt*. The first few lines of the gravity file are:

```
Station  Latitude    Longitude Elevation Observed     FAA      SBA    Terrain corr.   CBA       ISO
 ID      deg min     deg min      feet     Gravity      mGal     mGal   inner  total    mGal      mGal

MESCN    36 48.23   114  4.00    1590.0  979624.14  -114.06  -168.29   0.03    1.11  -167.80   -41.39
03V001   36 45.55   114 15.08    1938.3  979631.08   -70.49  -136.60   0.77    1.12  -136.21   -17.92
03V002   36 45.26   114 15.38    2079.0  979622.86   -65.06  -135.97   0.37    0.93  -135.82   -17.88
03V003   36 45.26   114 15.56    2081.0  979624.31   -63.42  -134.40   0.06    0.55  -134.63   -16.79
03V004   36 45.30   114 15.63    2066.2  979624.49   -64.69  -135.16   0.03    0.44  -135.50   -17.66
```

The magnetic data files are named *mornon-mesa-mag-dat.txt* and *mesquite-mag-data.txt*. The first few lines of one of the two magnetic data files are:

```
   ID       LONGITUDE      LATITUDE       BLANK    MAGNETIC     SENSOR   GROUND    TIME OF DAY   YEAR/DAY
            (DEGREES)      (DEGREES)               RESIDUAL     HEIGHT  ELEVATION   (SECONDS)    (JULIAN)
                                                     (nT)         (M)      (M

29233678 -114.3344562   36.7634369      0.000      71.399      3.000    640.630   92118.000    2003.292
29233679 -114.3344562   36.7634370      0.000      71.664      3.000    640.640   92119.000    2003.292
29233680 -114.3344562   36.7634370      0.000      71.680      3.000    640.640   92120.000    2003.292
29233681 -114.3344561   36.7634370      0.000      71.679      3.000    640.650   92121.000    2003.292
```

Also available on this website is a 1:100,000 scale map of figure 2 and a 1:24,000 scale map of figure 5. These require a large-format (36 inch) plotter to print.

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