USGS-OFR-91-46

U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Revision of an aeromagnetic survey of the Lathrop Wells area, Nevada[1]

By

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1991

Open-File Report 91-46

Prepared in cooperation with the
Nevada Operations Office
U.S. Department of Energy
(Interagency Agreement DE-AI08-78ET44802)

Menlo Park, California
1991

[1]A magnetic tape of the revised aeromagnetic data of the Lathrop Wells area is available from the National Geophysical Data Center, National Oceanic and Atmospheric Administration, Mail Code E/Gcx2, 325 Broadway, Boulder, CO 80303.

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ABSTRACT

Review of an aeromagnetic survey of the Lathrop Wells area revealed two independent problems: (1) regularly spaced intervals of data amounting to one-quarter of the original flightline data are missing and (2) horizontal positioning errors are common. The horizontal positioning errors are as large as 900 m (2,950 ft), far greater than the 50-m (150-ft) positioning uncertainties for similar, nearby surveys. Missing records were restored by using interpolated values from the original contract grids. The positions of the flightlines were corrected by photographic methods of flight path recovery. The uncertainty of the corrected positions of the flightline data is about 150 m (500 ft). A new version of the aeromagnetic map of the Lathrop Wells survey has been prepared using the restored and repositioned data points.

INTRODUCTION

In 1977, an aeromagnetic survey of the Lathrop Wells area (fig. 1) was flown and compiled by Aero Service, Houston, Texas, under contract with the U.S. Geological Survey (U.S. Geological Survey, 1978). Part of the flightline data was used to make an aeromagnetic map of Yucca Mountain and surrounding regions, southwestern Nevada (Kane and Bracken, 1983). Subsequent review of the flightline data used to create the Yucca Mountain map revealed that regularly spaced intervals of missing records occurred and that horizontal positioning errors existed. The missing records caused gridded anomalies to appear distorted, and positioning errors caused displacements of gridded anomalies. The horizontal positioning of the Lathrop Wells aeromagnetic survey is important for locating magnetic anomalies associated with volcanic rocks buried by or intruded into alluvial deposits in the Lathrop Wells area.

The characterization of these magnetic anomalies is of interest for determining the rate of volcanism in the Yucca Mountain area, which includes a potential site for a nuclear waste repository.

ACKNOWLEDGMENTS

B.A. Chuchel, J.M. Glen, H.W. Oliver, and K.S. Kirchoff-Stein of the U.S. Geological Survey assisted in planning, analysis, and manuscript review.

The following number is for U.S. Department of Energy OCRWM records management purposes only and should not be used when ordering this publication. Accession number: NNA.910411.0079.

FLIGHTLINE DATA GAPS

The aeromagnetic survey of the Lathrop Wells area, hereafter referred to as the Lathrop Wells survey (LWS), was flown at a 400- and 800-m ($\frac{1}{4}$- and $\frac{1}{2}$-mi) flightline spacing (fig. 2). The northwest "panhandle" of the LWS was flown along north-south flightlines flown at 300 m (1,000 ft) above ground level with 150-m (500-ft) spacing between measurements. The remainder of the LWS, hereafter referred to as the southern portion of the LWS, was covered by east-west flightlines flown at about 120 m (400 ft) above ground level with about 45-m (150-ft) spacing between measurements.

The published aeromagnetic map of the LWS (U.S. Geological Survey, 1978) was made from the original contract flightline data. Hereafter, *original data* refers to the Lathrop Wells aeromagnetic data that contain no gaps and that were used to generate the 1978 aeromagnetic map (U.S. Geological Survey, 1978). Later, an aeromagnetic compilation of Yucca Mountain and surrounding regions (Kane and Bracken, 1983) used data from both the northern and southern portions of the LWS (fig. 1) provided by Aero Service. A comparison of a part of the Yucca Mountain and surrounding regions map (fig. 2a) with the Lathrop Wells contract map (fig. 2b) shows that anomalies are dropped out or smoothed on the Yucca Mountain map where gaps in data occur. Apparently, data containing gaps, not the original data, were used by Kane and Bracken (1983) for the area covered by the LWS. Hereafter, *data with gaps* refers to the Lathrop Wells aeromagnetic data set provided by Aero Service to the USGS. These gaps were created sometime between 1978 and 1983, perhaps in copying the data from magnetic tapes given by the contractor. The *data with gaps* contain a regular pattern of gaps about 1.2-km ($\frac{3}{4}$-mi) long and spaced 3.6-km ($2\frac{1}{4}$-mi) apart (fig. 3). Review of the *data with gaps* reveals that the gaps are a result of a consistent pattern of 25 missing records followed by 75 intact records for the southern portion of the LWS; the northern panhandle of the LWS consists of a pattern of 25 intact records and eight missing records.

RESTORING THE GAPS

It was determined (D.A. Ponce, B.A. Chuchel, and J.M. Glen, oral commun., 1987) that the original flightline data might be recoverable, but that it would be more cost-effective and less time-consuming to restore the gaps using the contract gridded data generated by Aero Service from the original flightline data. The gaps were restored in two steps. Within each gap, the positions of the missing records were located by linear interpolation between the flightline records that preceded and followed the gap. The linearly interpolated position is equivalent to assuming that within the gap the airplane flew along a straight line with constant velocity. This is a good approximation considering that the length of the gaps is equal to or less than 1.3-km ($\frac{3}{4}$-mi) and that standard photographic methods of flight path recovery often utilize intervals between tie points of greater than 1.3 km. The number of missing records within each gap for the southern part of the LWS was usually 26, implying 25 missing data points. Gaps that terminate at the end of a flightline have less than 25 missing records. For the northern panhandle of the LWS, the number of missing points within a gap was eight. Gaps that terminated at the end of a flightline in the north-south portion of the LWS have less than eight missing records.

The second step estimated values of the residual magnetic field for each missing record. At each position an anomaly value was interpolated from the contract grid data. However, the contract grid data also contain missing records and erroneous zero values. These missing records and erroneous zero values were replaced with values determined by interpolation from the surrounding grid values. Then, for each missing point along the flightline, an anomaly value was interpolated from the corrected contract grid data. The grid data tend to alias the original flightline data because the spacing between measurements for the LWS is the same or less than the grid cell dimensions; a comparison of the restored map (fig. 4a) with the contract map (U.S. Geological Survey, 1978; fig. 4b) shows that the interpolated anomaly values successfully reproduce the contract map. This is not surprising because the contract map was made from the contract grids.

HORIZONTAL POSITIONING ERRORS

Three independent lines of evidence indicate that the positions of original data points in the southern portion of the LWS, as received from Aero Service, are shifted to the west of their true positions. First, Lathrop Wells survey data are shifted to the west with respect to ground magnetic profiles collected in the vicinity of Lathrop Wells (D.A. Ponce and others, unpub. data, 1986). This was discovered by reduction of ground magnetic data and upward continuation to the same level of the Lathrop Wells survey by K.S. Kirchoff-Stein (written commun., 1986). Here, anomalies in the Lathrop Wells aeromagnetic survey are shifted 250±60 m (820±200 ft) to the west of the corresponding anomalies in the ground magnetic profiles.

Secondly, K.S. Kirchoff-Stein (written commun., 1986) and author J. Phillips independently discovered that the southern portion of the LWS is shifted with respect to an aeromagnetic survey of the Timber Mountain area (hereafter referred to as the Timber Mountain survey; U.S. Geological Survey, 1979) where they overlap (fig. 1). Grids of the Lathrop Wells data and the Timber Mountain data were compared. Anomalies were uniformly offset by about 300 m (980 ft) in an east-west direction. Anomalies in the Lathrop Wells data were located further to the west than the corresponding anomalies in the Timber Mountain data. The Timber Mountain data include radar and barometric altimetry. These components were gridded and compared to digital terrain data in order to establish that the horizontal positions within the Timber Mountain data set are accurate to within 50 m (160 ft). Consequently, the apparent 300-m (980-ft) westward shift of the Lathrop Wells data with respect to the Timber Mountain data is entirely due to positioning errors of the Lathrop Wells survey. A nearly perfect match of the positions of the anomalies was achieved in the area of overlap by shifting the Lathrop Wells data 300 m (980 ft) to the east.

Thirdly, a comparison with an aeromagnetic survey of the Yucca Mountain area, hereafter referred to as the Yucca Mountain survey (U.S. Geological Survey, 1984; fig. 1), also shows that the LWS is shifted to the west. The Yucca Mountain survey was flown along north-south flightlines, with a 400-m ($\frac{1}{4}$-mi) spacing, and at a constant terrain clearance of 120-m (400-ft).

The area of comparison of the Lathrop Wells survey with the ground magnetic data only amounts to a few square kilometers, overlap with the Timber Mountain survey constitutes only a narrow strip of about 140 km^2, and overlap with the Yucca Mountain survey amounts to about 30 km^2. Therefore, questions remained as to whether or not the positioning errors occur throughout the LWS, have a north-south dependency, a systematic dependency on location, or are related to each flightline independently.

To examine the character of the positioning errors throughout the area of the southern portion of the LWS, barometric altimetry minus radar altimetry of all flightlines and tie-lines were compared with 1:24,000-scale U.S. Geological Survey topographic maps. If the location and altimetry measurements along the flightline are correct, topographic elevations should be equal to the barometrically-determined elevation of the airplane minus the radar-obtained altitude above terrain. Barometric and radar altimetry were not available for the northern panhandle of the LWS. In localities characterized by distinctive topography, such as north-south trending ridges, the positions of the flightlines were clearly and consistently shifted to the west (fig. 5). However, the magnitude of these recognized shifts (364 in all) varied from 0 to 650 m (2,130 ft), implying that the positioning errors were variable. In addition, some north-south shifts were recognized, implying a north-south variation. Therefore, comparison of the barometric minus radar altimetry with topography revealed that the shift was variable in both east-west and north-south directions, and that a better method was needed to reposition the flightlines in the southern portion of the LWS.

Photographic filmstrip negatives of the ground surface directly beneath the plane were available from Aero Service for every 3 to 10 fiducial numbers along the flightlines and tie-lines of the northern portion of the LWS, but not for the panhandle. Film records of this sort are normally used to locate positions of selected points along each flightline on topographic quadrangles or to airphotos registered to geographic coordinates (Dobrin, 1976). We chose to verify the positioning by using orthophoto quadrangles because they have been registered to geographic coordinates, whereas the airphotos have not. The resolution of the orthophoto quadrangles, however, is inferior to that of many other unpositioned airphotos.

First, filmstrip negatives were matched with their correct position on the orthophoto quadrangles. Most often, this was possible where features such as roads, stream channels, vegetation, or buildings were readily identifiable on both the filmstrip negatives and the orthophoto quadrangles. This initial examination demonstrated that the positioning errors of the flightlines in the southern portion of the LWS were variable in both an east-west direction and a north-south direction by similar amounts. Generally, shifts are oriented southwest to northeast, from uncorrected to corrected horizontal position, by 0 to 900 m (2,950 ft). Regional trends are apparent in the positioning errors, but some flightlines transgress these regional trends.

As a result of this initial comparison, it was determined that each flightline in the LWS should be adjusted individually rather than shifting the entire survey by a constant amount. To accomplish this, additional comparisons of the filmstrip negatives with the orthophoto quadrangles were made so that at least one, but preferably more than one control point was identified for each flightline. A total of 823 control points were identified for the 88 east-west flightlines (fig. 6). The control points were used for repositioning each flightline. The repositioning was accomplished by a linear correction. Given a flightline with a number of identified positioning errors, $i = 1, n$, where (x_i, y_i) and (x'_i, y'_i) are the original and corrected positions of the control points, then the original position, (x, y), of each data point was adjusted to a new position, (x', y') by:

$$x' = x'_i + \left(\frac{(x - x_i)(x'_{i+1} - x'_i)}{(x_{i+1} - x_i)} \right)$$

$$y' = y + y'_i - y_i + \left(\frac{(x - x_i)(y'_{i+1} - y_{i+1} - y'_1 + y_1)}{x_{i+1} - x_i} \right)$$

where x lies between x_i and x_{i+1}. Where the fiducial number of (x, y) is less than the fiducial number of (x_1, y_1), the shift is a constant based on the first measured shift for that flightline

$$x' = x + x'_1 - x_1$$

$$y' = y + y'_1 - y_1$$

and where the fiducial number of (x, y) is greater than the fiducial number of (x_n, y_n), the shift is again a constant based on the last measured shift for the flightline

$$x' = x + x'_n - x_n$$

$$y' = y + y'_n - y_n$$

The average magnitude of the identified positioning errors is 396 ± 215 m (1300 ± 710 ft). The average magnitude of east-west shifts is nearly the same as that of the north-south shifts (278 ± 184 m (910 ± 605 ft) and 220 ± 209 m (720 ± 690 ft), respectively. The uncertainty in the repositioning of the flightlines is related to the number of identified positioning errors.

Obviously, the more identified control points per flightline, the more accurate the linear interpolation. Another source of uncertainty results from non-linearities in the x-velocity of the airplane. These errors become more pronounced as the flightline direction deviates from the direction of the x-axis. In order to assess the accuracy of the new positions of the flightline data, profiles of barometric altimetry minus radar altimetry were compared with 1:24,000 topographic maps. This comparison showed that the uncertainty in position of the corrected flightline data is about 150 m (500 ft).

CONCLUSIONS

Regularly spaced gaps in the LWS flightline data were restored with values interpolated from the contract gridded data. Maps made from the restored flightline data closely duplicate the original contract map (U.S. Geological Survey, 1978).

The positions of the flightline data of the southern portion of the LWS as received from Aero Service appear to be shifted by variable amounts. Along each flightline, positions were corrected by interpolating the amount of shift determined by comparing the photographic filmstrips of the ground directly beneath the plane with orthophoto quadrangles. Although photographic filmstrips of the northern portion of the LWS were not available, a comparison of the anomalies of the northern portion of the LWS with those of the Timber Mountain survey does not indicate that the LWS flightlines are significantly shifted.

DESCRIPTION OF MAGNETIC TAPE

A nine-track, 1600 bits per inch, 80 character record size, 4,000 character block size, Ascii unlabeled magnetic tape contains the original, restored, and repositioned files (table 1). The magnetic tape is available from the National Geophysical Data Center, National Oceanic and Atmospheric Administration, Mail Code E/Gcx2, 325 Broadway, Boulder, CO 80303. The format of the data files is described in table 2. The tape also contains a file that describes the contents of the other files (readme.txt).

TABLE 1.–*Description of data files on tape*
[LWS, Lathrop Wells survey]

File number	Name	Description
1	README.TXT	Description of tape contents.
		ORIGINAL CONTRACT DATA
2	LWEW.ORIG	Flightline data (with gaps) including tie-line data of the northern portion of the LWS.
3	LWNS.ORIG	Flightline data (with gaps) of the southern portion of the LWS; tie-line data not available.
4	LWNS1.GRD	Contract grid data for sheet 1 of U.S. Geological Survey (1978).
5	LWEW2.GRD	Contract grid data for sheet 2 of U.S. Geological Survey (1978).
6	LWEW3.GRD	Contract grid data for sheet 3 of U.S. Geological Survey (1978).
		RESTORED DATA FILES
7	LWEW.RES	Flightline data of the east-west portion of the LWS, with zero values deleted, and gaps filled by contract grid data.
8	LWNS.RES	Flightline data of the north-south portion of the LWS, with zero values deleted and gaps filled by contract grid data.
9	LWEWTIE.RES	Tieline data of the east-west portion of the LWS, with gaps filled by contract grid data.
		RESTORED AND REPOSITIONED DATA FILE
10	LWEW.REP	Flightline data of restored east-west portion of LWS, repositioned by comparison of orthophoto quadrangles and filmstrip negatives.

Table 2.–*Format of data files on tape*
[IGRF, International Geomagnetic Reference Field]

Format	Description
FIRST TEN RECORDS OF EACH FILE	
Record:	
1	File type (1=gridded, 7=ASCII) and creation date.
2	File name.
3	Description of file contents.
4	FORTRAN format of each record.
5	Information on file format.
6	Information on grid data, if applicable.
7	More information on grid data, if applicable.
8	Descriptive text.
9	Descriptive text.
10	Descriptive text.
FLIGHTLINE DATA FILE	
Beginning at record 11. ten items per record, Item:	
1	Flightline identification.
2	Flightline identification.
3	Longitude, in decimal degrees.
4	Latitude, in decimal degrees.
5	Total field minus IGRF, in nanoteslas.
6	Total field, in nanoteslas.
7	Height above terrain, in meters.
8	Barometric altitude, in meters.
9	Fiducial number.
10	Year and day, yr.day
GRID DATA FILE	
Beginning at record 11 four items per record, Item:	
1	Latitude of center of grid cell, in decimal degrees.
2	Longitude of center of grid cell, in decimal degrees.
3	Total field minus IGRF, in nanoteslas.
4	Total field, in nanoteslas.

REFERENCES

Dobrin, M.B., 1976, Introduction to Geophysical Prospecting: New York, McGraw-Hill Book Co., 630 p. NNA.890713.0200.

Kane, M. F. and Bracken, R. E., 1983, Aeromagnetic map of Yucca Mountain and surrounding regions, southwest Nevada: U.S. Geological Survey Open-File Report 83-616, 19 p, scale 1:48,000. HQS.880517.1290.

U.S. Geological Survey, 1978, Aeromagnetic map of the Lathrop Wells area, Nevada: U.S. Geological Survey Open-File Report 78-1103, scale 1:62,500, 3 sheets. NNA. 901005.0050.

U.S. Geological Survey, 1979, Aeromagnetic map of the Timber Mountain area, Nevada: U.S. Geological Survey Open-File Report 79-587, scale 1:62,500, 3 sheets. NNA.910220. 0059.

U.S. Geological Survey, 1984, Aeromagnetic map of the Yucca Mountain area, Nevada: U.S. Geological Survey Open-File Report 84-206, scale 1:62,500. NNA.910306.0173.

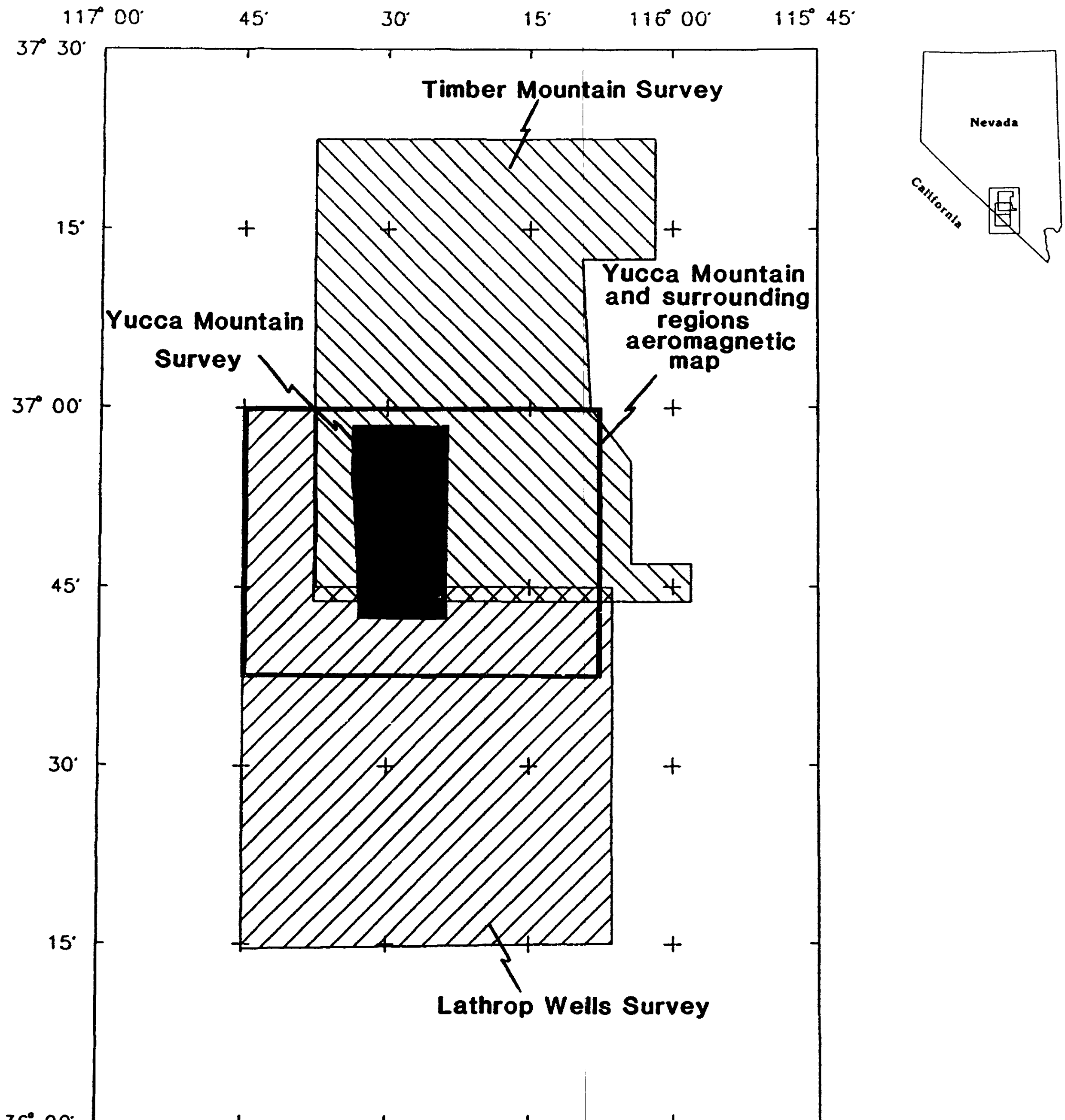

FIGURE 1.–Index map showing the locations of the Lathrop Wells, Timber Mountain, and Yucca Mountain aeromagnetic surveys. Bold outline indicates boundary of the Yucca Mountain and surrounding region aeromagnetic map (Kane and Bracken, 1983), a compilation of the Lathrop Wells and Timber Mountain surveys..

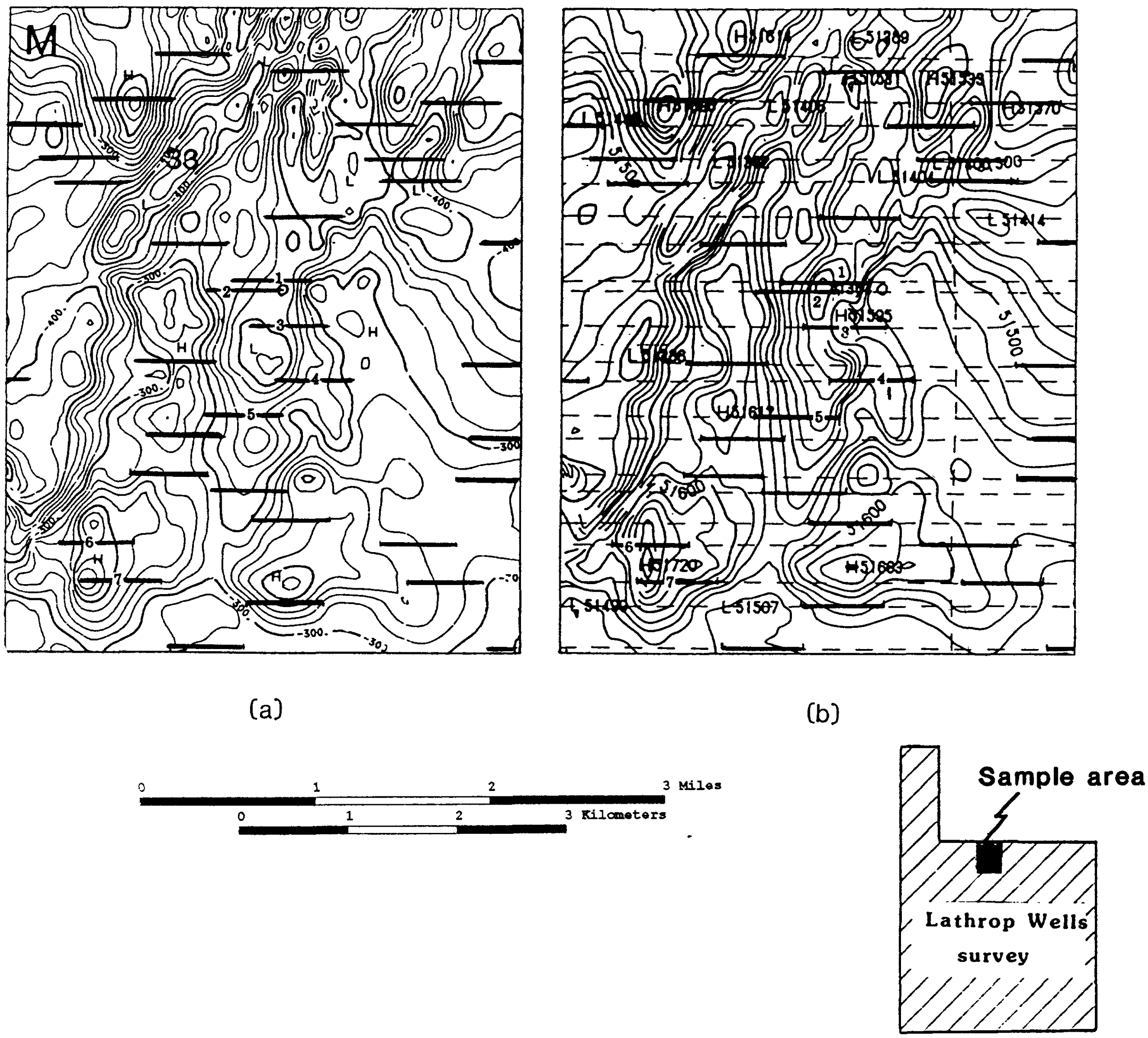

FIGURE 2.–Comparison of (a) Kane and Bracken (1983) map and (b) U.S. Geological Survey (1978) map in sample area. Noticeable discrepancies between these two maps occur in the flightline data gaps, as exemplified by gaps labeled 1-7. Bold lines, flightline data gaps.

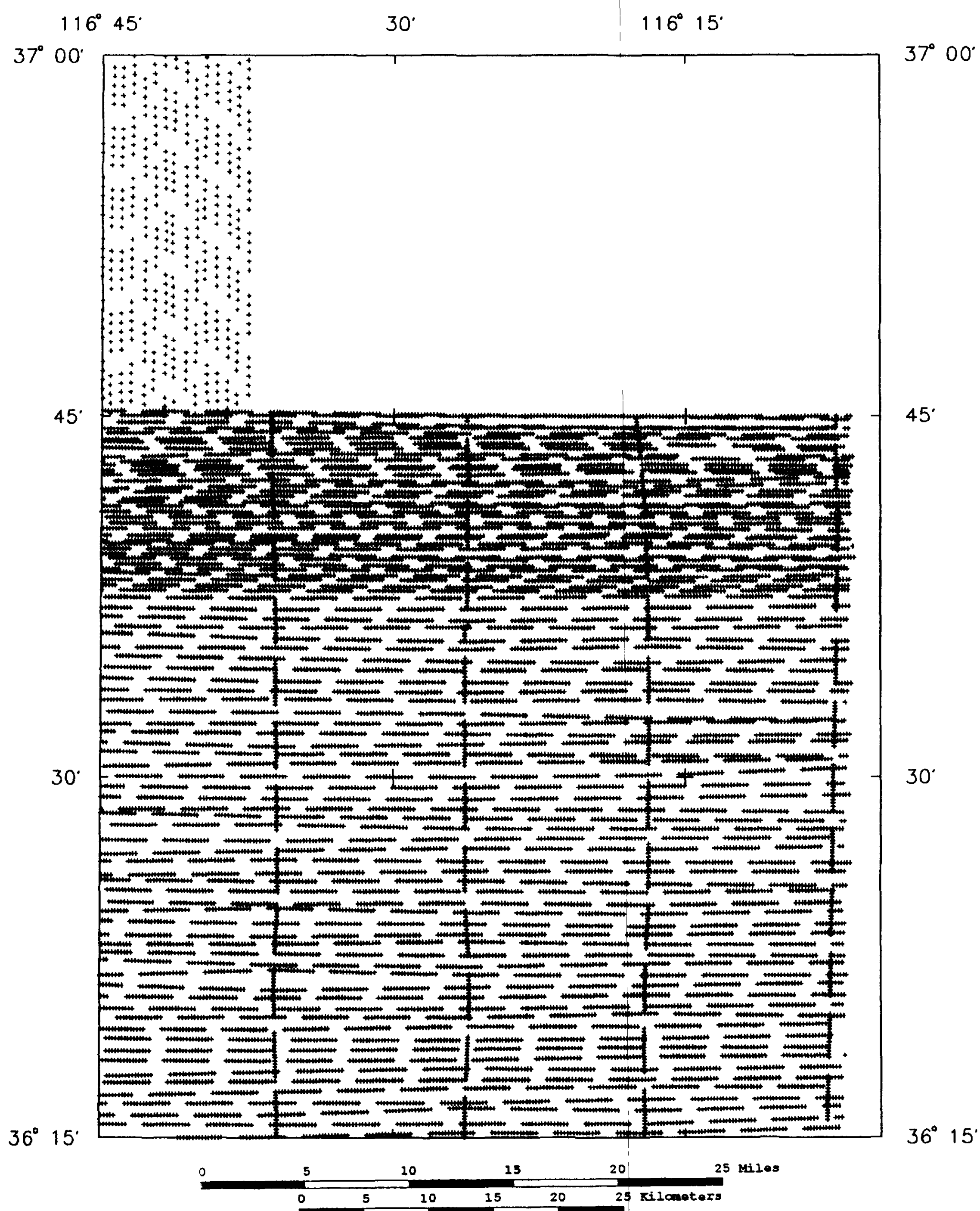

FIGURE 3.–Flightline locations of the Lathrop Wells survey as supplied by Aero Service showing the location of every fifth data point and gaps caused by missing data records.

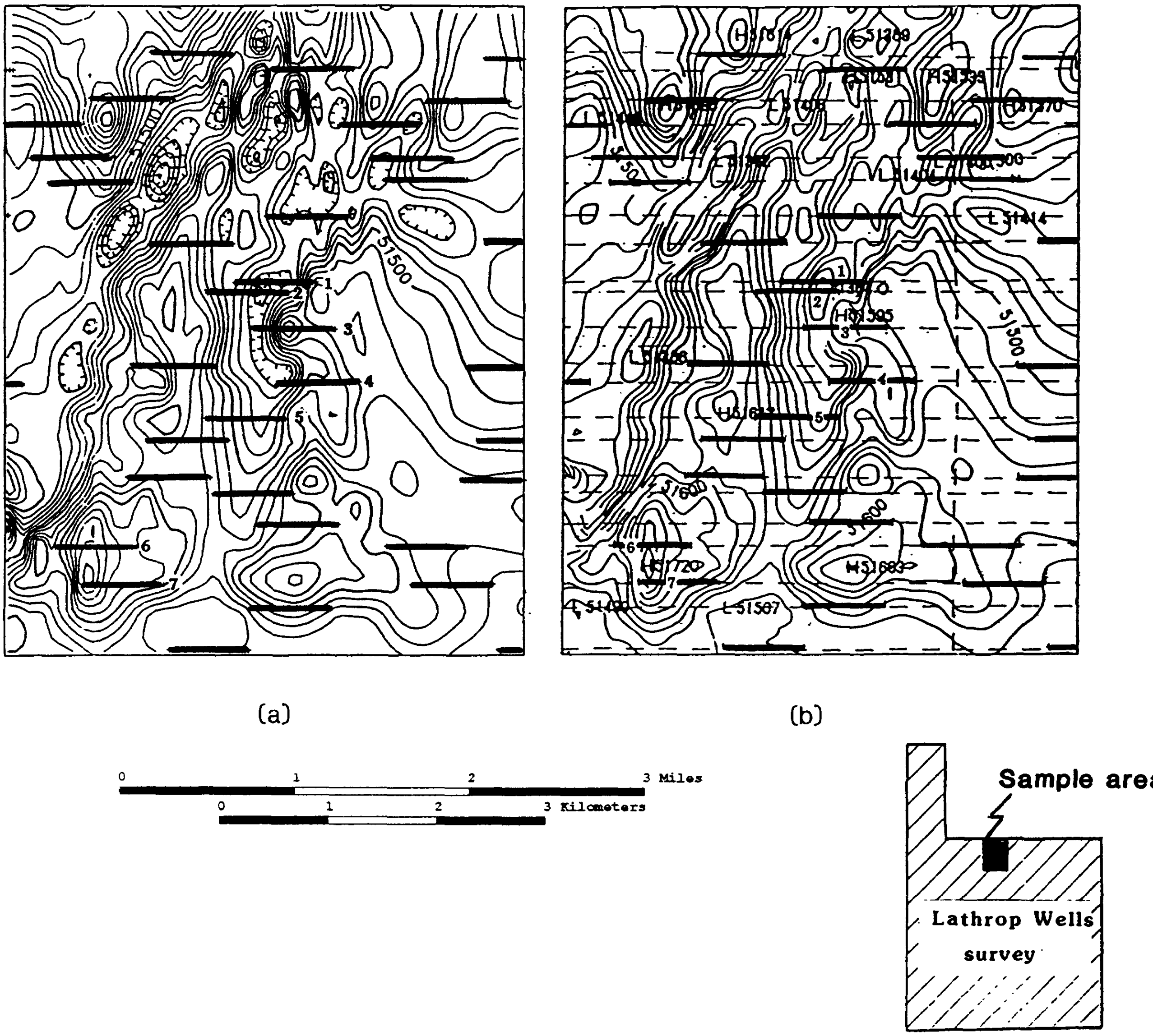

FIGURE 4.–Comparison of the (a) restored map with the (b) U.S. Geological Survey (1978) map. Note that the portions of the restored map controlled by the gridded data (bold lines) closely match the portions of the U.S. Geological Survey (1978) map controlled by original flightline data.

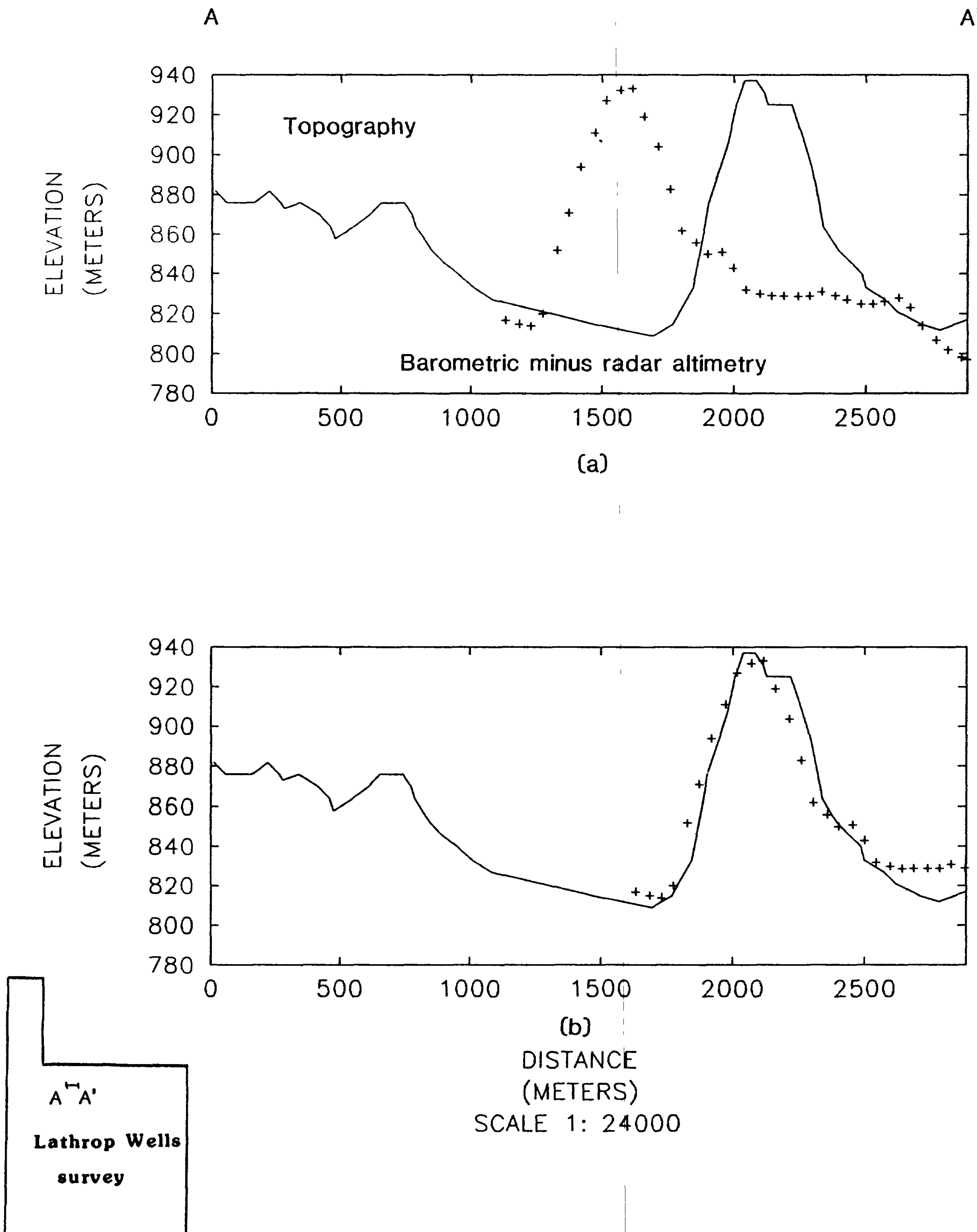

FIGURE 5.–Comparison of corrected positions (a) and uncorrected positions (b) determined by analysis of barometric minus radar altimetry and topography digitized from a 1:24,000-scale topographic map. The position of the LWS flightline was shifted about 500 m (1,640 ft) to the east in order to correct the error in location.

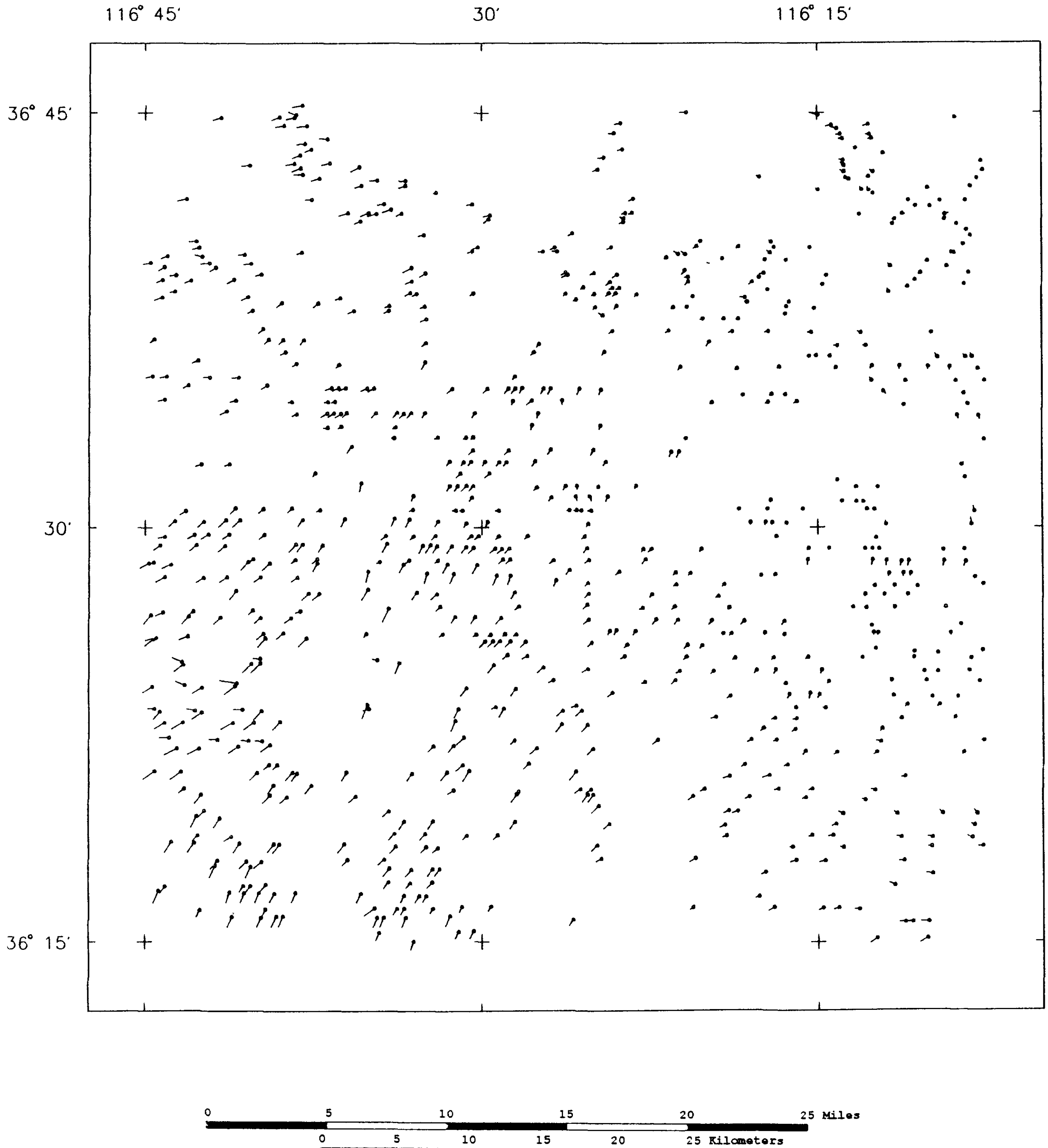

FIGURE 6.–Directions and magnitudes of corrections to the positioning of the east-west portion of the Lathrop Wells survey. Corrections were determined by comparison of the filmstrip negatives and orthophoto quadrangles and vary from 0 - 900 m (0 - 2,950 ft). Dashes denote direction and magnitude of corrections; length of dash is proportional to magnitude of correction. Circles indicate corrected locations. Diameter of circles is 200 m (660 ft) at scale of figure.

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