A Merging of Aeromagnetic Data Sets in Southwest Arizona and Northwest Mexico and Analysis of the Results

by

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Abstract

Aeromagnetic data for Yuma, Arizona, and vicinity from four surveys have been merged to provide three composite maps. These maps were produced by reprocessing the original data where possible. Map A is a simple juxtaposition of data sets representing flight elevations of 0.3, 0.61, and 1.2 km. Flight lines not included in the original published versions of the maps were added. Map B resulted from normalization by upward continuation of all data of Map A to a 1.2-km elevation. Map C resulted from the merger of data in Map B, upward continued to 2.7 km, with the data of the State of Arizona aeromagnetic map, also at 2.7 km.

The area of interest includes portions of the Basin and Range province and the Salton trough. Previous analyses have suggested that the San Andreas fault may traverse the area. Other analyses have indicated that the area includes a magnetic "quiet" zone of very low amplitude anomalies, suggesting a possible past or present thermal condition in the crust. Such conclusions were evaluated by examining the magnetic data that extends across the area.

Five profiles across Map A have been processed by upward continuation, second vertical derivative, and reduction to the pole to define detailed structures traversing the area. Southeast trends in Map A correspond to the Banning-Mission branch of the San Andreas fault south of Yuma. The results of previous studies and recent analysis of LANDSAT lineations indicate a close correlation, implying recent movement along the structures defined by the magnetic anomalies. However, the structures appear to be dominantly normal faults with no large-scale strike-slip component.

Upward-continued Maps B and C allow interpretation on an absolute basis of the magnetic signature of a north-south region from the Gulf of California to west-central Arizona. The maximum absolute amplitudes of the anomalies appear to be subtly less in the region north and east of Yuma, perhaps reflecting combined lithologic changes and thermal conditions.

Introduction

The Salt River Project considered the Yuma, Arizona, area for the location of the Yuma Dual Purpose Nuclear Power Plant (YDPNP) (Fig. 1). Woodward-Clyde Consultants carried out a site analysis of the area, and in conjunction with that study a composite aeromagnetic map of the area was produced in 1974 using the available magnetic data of the area, including that of Mattick, Olmsted, and Zohdy (1973), de la Fuente (1973), and Sumner (1971).

Except for that of Mattick and others (1973) all the data sets had the unique characteristic of having been collected by the same equipment and have been or can be processed by the same set of software and methodology as used by Sauck (1972). This optimized the possibility of an eventual good merger of the data sets.

The object of the Woodward-Clyde Consultants study was to detect trends in the magnetic data that may be related to active faulting or potential hazards to a nuclear power plant. Because of the location of the site with

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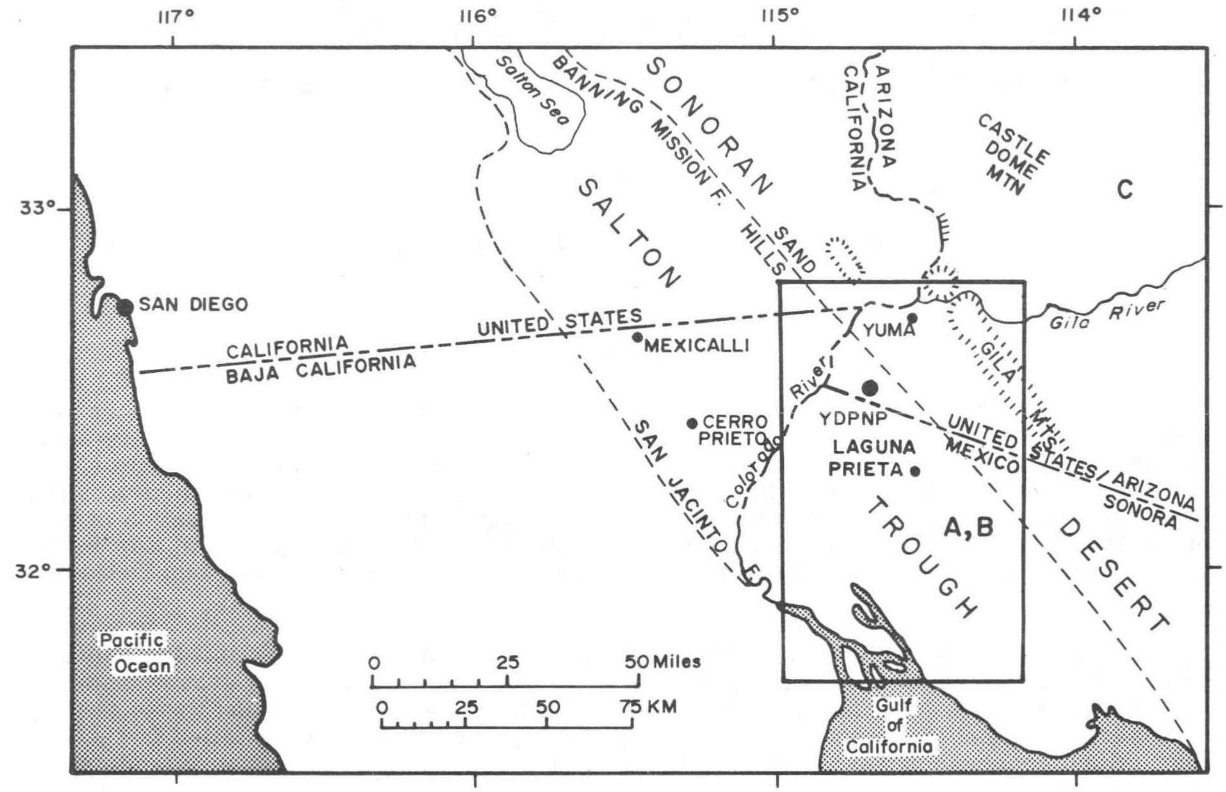

Fig. 1. Area of interest and outlines of Maps A, B, and C discussed in text. Map C includes data from Arizona and the area of Maps A and B. YDPNP = Yuma Dual Purpose Nuclear Power Plant.

relation to the San Andreas fault, the determination of whether that structure or an associated fault (such as the Banning-Mission fault) trends through southwestern Arizona is of interest.

Once the data have been reprocessed there is the problem of normalizing the data to the same flight elevation. Upward continuation of the different data sets onto a common observation plane allows all the data to fit together and provides a continuous magnetic map along a corridor that extends from an apparent spreading area, the Gulf of California (de la Fuente, 1973), through the general vicinity of the San Andreas fault and Salton trough structural systems, into the Basin and Range province. It has been suggested that the area between the Gulf of California and central Arizona is distinctive, being a magnetic "quiet" zone perhaps directly related to a spreading rise in the Salton trough and Gulf of California.

The objects of this paper are (1) the creation of composite maps, (2) the further intergration of the data sets by upward continuation, and (3) a general discussion of the significance of anomalies.

Geotectonic Setting

The general area of Yuma, Arizona, lies in the Basin and Range province and in what has been called the Salton trough (Mattick and others, 1973; Elders and others, 1972; Sharp, 1972) (Fig. 2). The Basin and Range structure is as young as middle Tertiary in the area and is characterized by elongate low mountain ranges trending northwest. The mountain ranges appear submerged under alluvium to the south in the Salton trough, with as much as 7.0 km or more of Cenozoic valley fill. The San Andreas system appears to traverse the Salton trough on its northern end at acute angles. Geophysical studies of its southern portion (de la Fuente, 1973; Sumner, 1971; Lomnitz and Allen, 1970; Biehler, Kovach, and Allen, 1964; Kovan, Allen, and Press, 1962) indicate the Salton trough may be related to oblique rifting, "a leaky transform." Along this general transform, spreading centers are thought to exist southeast of the Salton Sea near the Cerro Prieto in Mexico (southwest of Yuma) and the Walker Basin in the northern Gulf of California.

The Algodones fault zone trends northwest through the Yuma area (Mattick and others, 1973). It can be projected toward the postulated southern extension of the San Andreas fault along the eastern edge of the Sand Hills west of Yuma (Figs. 1 and 2).

Directly south of the Yuma area and north of the Gulf of California is the Gran Desierto, a huge region with little topography and considerable wind-blown sand. The only geophysical data available for this region is aeromagnetic data. Geophysical and geological data for the area west of the Gran Desierto indicate that the more narrow basins east and north of Yuma, characteristic of the Basin and Range province in the area, change to broader and deeper (up to 7.0 km) basins under the Gran Desierto. This is also supported by the analyses of magnetic data of de la Fuente (1973) and Sumner (1971) to the southwest and southeast, respectively, of the Gran Desierto. Their models assume that anomalies in the magnetic data reflect basement topography. This is true in other areas of Arizona (Aiken, 1978), but Biehler (1964) warns that in the Imperial Valley in California thermal effects in the basin and magnetic sediments can create significant anomalies not related to basement rocks. Depths calculated from anomalies related to such features could produce erroneous depths to basement.

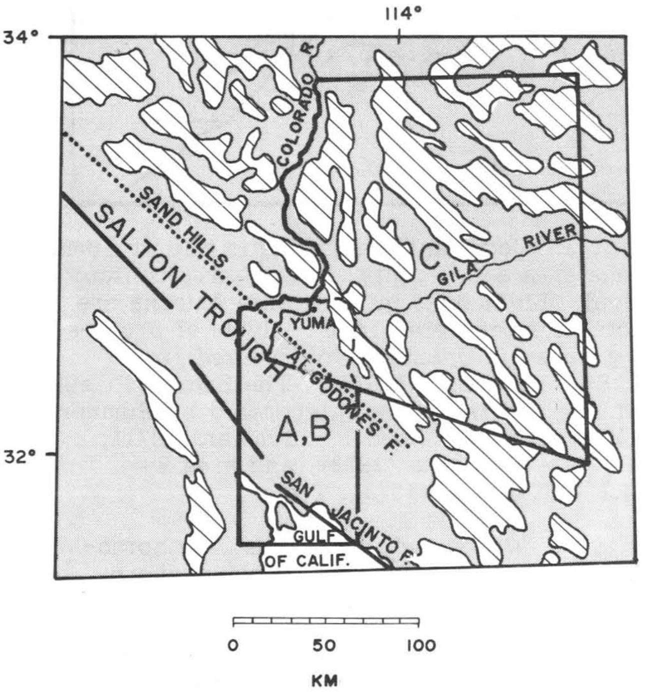

Fig. 2. Tectonic and general geologic map of area and outlines of maps A, B, and C. Stripes indicate non-alluvium rock outcrop.

Aeromagnetic Data

There are four sources of magnetic data in the area, which includes parts of Arizona, California, and Mexico: Mattick and others (1973), Sauck and J. S. Sumner (1970), de la Fuente (1973), and J. R. Sumner (1971).

Sauck and Sumner (1970) flew the area at 3.3-km constant barometric elevation with a 5-km spacing as part of a state survey of Arizona. Sauck (1972) noted that southwest Arizona has very low amplitude anomalies, a "subdued zone" perhaps related to a shallow depth to Curie temperature.

Mattick and others (1973) published a map with 0.8-km line spacing flown 0.3 km above the ground surface. Because the area from Yuma to the south is essentially at 0.07-km average ground elevation or less, the lines are basically equivalent to a 0.4-km constant barometric elevation. The detailed magnetic anomalies of the Yuma area correlate closely with gravity anomalies in reflecting the structural configuration of the mountains and basins. This correlation of magnetic with gravity anomalies and basin structure is typical of Arizona in general (Aiken, 1976, 1978). The Algodones fault and a series of parallel faults were interpreted in the area from several geophysical surveys and geologic studies. The inference is that, although there are normal faults in the area, they are part of the San Andreas system because of their location on line with the San Andreas fault zone to the northwest.

Sumner (1971) flew the area between 31° N. to 32°30' N., 113° W. to 114°30' W., including southwestern Arizona and northwestern Sonora, overlapping de la Fuente's (1973) map area with one common flight line. The lines were north-south, 5 km apart at 1.3-km constant barometric elevation. J. R. Sumner's (1971) original published data were not processed with the same methodology and software as described by Sauck (1972) and used by Sauck and J. S. Sumner (1970) and by de la Fuente (1973).

De la Fuente (1973) flew north-south lines in the area of the Colorado River delta at a constant 0.61-km elevation with a 5-km line spacing from 114°30' W. to 115° W., from the U.S.-Mexican border to the Gulf of California. De la Fuente's interest was in detecting in areas some distance south of Yuma possible spreading centers such as that speculated to be the cause of the Cerro Prieto volcano. The data were processed using the same methods and computer software as described by Sauck (1972).

Sumner (1971) discussed tectonism and its relation to the Gulf of California. A computer model along a northeast profile that crosses the southern portion of his composite map area indicates generally broad, deep basins in the area of the Gran Desierto. He discussed the significance of the so-called subdued anomalies, ascribing them to either deeply buried continental crust or to crust transitional between continental and oceanic with a shallow Curie depth.

Comínquez and del Castillo (1973) evaluated Sumner's (1971) data by filtering and continuation analyses. They also fit a three-dimensional model where Sumner (1971) has a two-dimensional model and derived similar maximum depths to basement of 5 km. A dominant west-northwest trend was observed.

Composite Aeromagnetic Maps

The aeromagnetic data from the surveys of Sumner (1971), de la Fuente (1973), and Mattick and others (1973) were merged into one continuous map, Map A (Fig. 3), by computer processing of the original data, including plotting and smoothing flight-line data. The International Geomagnetic Reference Field (IGRF) has been removed from de la Fuente's (1973) and Sumner's (1971) maps. Previously, Sumner's (1971) map had been processed by hand and not normalized with the map of de la Fuente, but in this study the same IGRF value is removed. Although some regional anomaly has been removed from the aeromagnetic survey of Mattick and others (1973), the exact details are not known. This lack of certainty must be considered in merging the maps.

Sumner's (1971) data do not always have many recoverable location points (fiducials) along the lines. Commonly with Sumner's (1971) data no fiducial points were picked in the desert between the U.S.-Mexican border and the east-west railroad line along the northern coast of the Gulf of California because the desert has few points that can be recognized in strip photographs during flights. Straightness of flight lines over long distances is questionable if few or no fiducials exist. However, features such as "herring-bone" anomalies that indicate obvious errors between flight lines are not apparent in the data.

The Sumner (1971) and de la Fuente (1973) data have been recontoured (Fig. 3). The data of Sumner (1971) and Mattick and others (1973) show trends that indicate possible northwest structures. East-west tie lines along the California-Mexico border, Line MA (Sumner, 1971), and the Arizona-Mexico border, Line MC (de la Fuente, 1973) that were not previously used in the published maps, have been included in Figure 3 (Map A) to aid in contouring. Although the surveys of de la Fuente (1973) and Mattick and others (1973) were flown at 0.61-km and 0.30-km elevations, respectively, and Sumner's (1972) survey at 1.2 km, the northwest trends on the anomalies coincide where the data are spliced together.

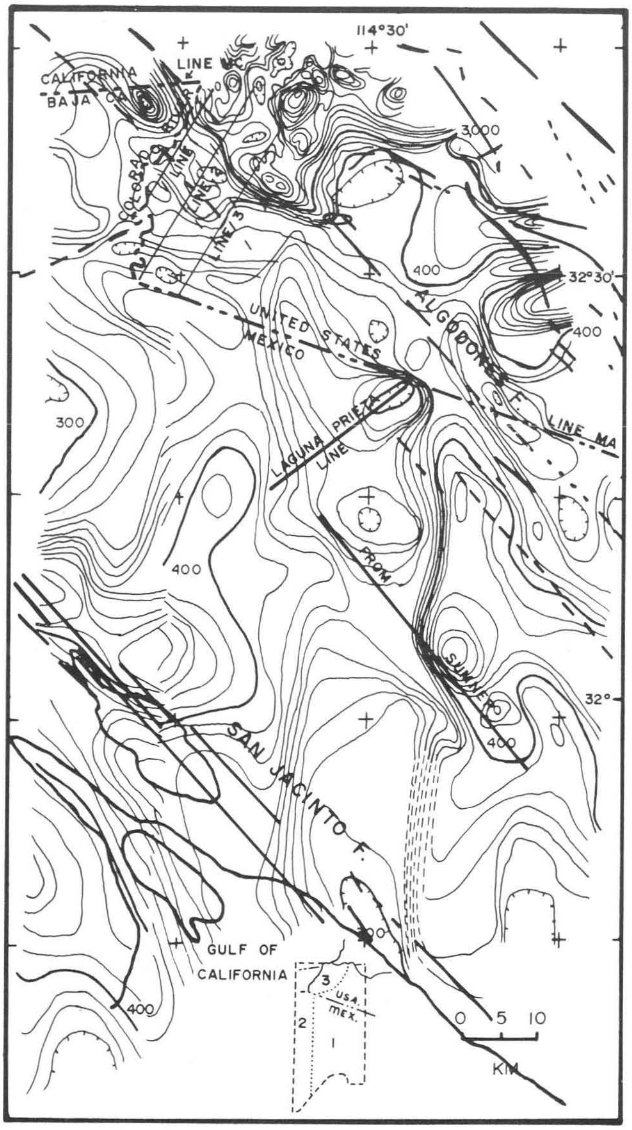

Fig. 3. Composite aeromagnetic map of Yuma, Arizona area and vicinity. Ten-gamma contour interval. Light lines in southwest Arizona are structures interpreted from analysis of profiles. Heavy lines are lineations interpreted from LANDSAT by Lepley (1977). The Laguna Prieta flight line and the linear interpreted by Sumner (1971) are shown. Area 1 = Sumner (1971), area 2 = de la Fuente (1973), and area 3 = Mattick and others (1973).

Northwest-trending anomalies could be related to the Salton trough—San Andreas tectonic system. However, Tertiary tectonism has produced high basement relief in the Basin and Range province in southern Arizona. This may obscure magnetic anomalies reflecting structural features, which could

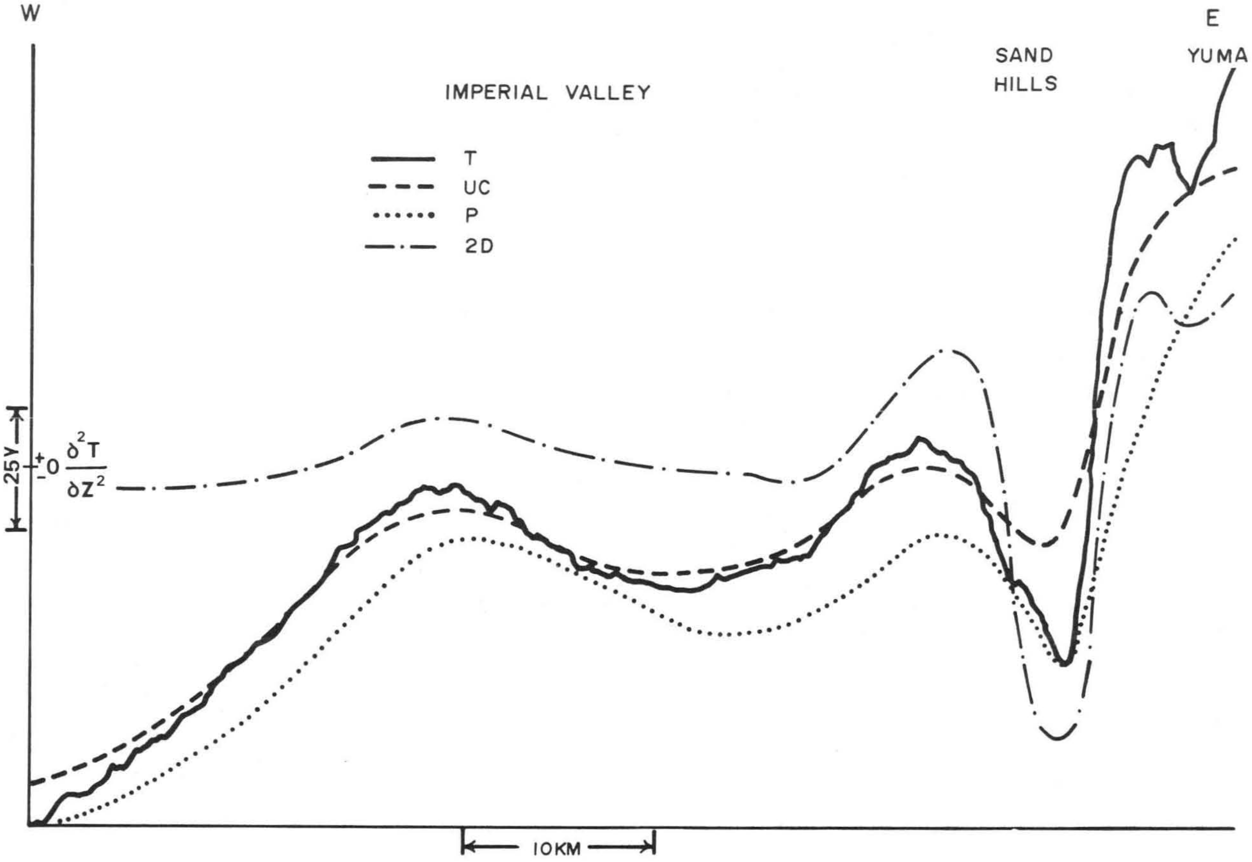

Fig. 4. Profile along California-Mexico border from de la Fuente (1973). T = total magnetic field (IGRF removed); UC = upward continued (to 1.7 km); P = reduction to pole of UC; 2D = second vertical derivative of UC.

determine whether the Salton trough structures trend through the Yuma area.

Because of these complicating factors, tracing magnetic trends through the Yuma area is a difficult process. Sumner (1971) interpreted a general northwest trend of magnetic anomalies and structures in northwest Sonora. Extrapolating a particularly strong magnetic trend of Sumner northwest toward the Yuma area indicates that it would not traverse the Yuma area itself but pass to the south near Laguna Prieta (Fig. 3).

Laguna Prieta is an anomalous isolated lake in the Gran Desierto south of Yuma in Sonora. One edge of the lake has a very straight bank that can be interpreted as a fault line. Separate lines such as Line LP (Fig. 3) were flown by Sumner (1971) across this lake, perpendicular to the possible fault.

Although magnetic anomalies in the Colorado delta area shown in the composite map (Fig. 3) may be related to magnetic effects of sediment rather than basement lithology or topography, certain features support a basement source. The anomalies do seem to trend parallel to the structural trend in the area, and analysis of the anomalies indicates very deep sources.

Profile Analysis

Profile analyses included upward continuation, second vertical derivative, and reduction to the pole. The methods applied are based on the approach discussed by Nabighian (1972) and are completely described in his paper. The details of the general use of these techniques were discussed by Nettleton (1976) and Dobrin (1976) and in other general texts.

Upward continuation computes the magnetic field at observation planes above the level at which the data were originally observed. In this way surveys originally flown at different elevations can be merged together. Another benefit of upward continuation is the filtering of short-wavelength components, or "noise," from the original flight data. This is especially important if further processing is to be carried out because such noise will produce aliasing and other errors in the results.

The second vertical derivative is a classic enhancement method in which the curvatures of the anomalies are emphasized. The inflection points of anomaly gradients are indicative of the lateral extent of the sources. Such inflection points are indicated by zero values of the second vertical derivative. Shorter wavelength anomalies are enhanced and longer wavelength regional anomalies are removed in the process.

Only anomalies in magnetic fields of the earth's poles are caused by a 90° inducing field and as such are symmetric with respect to their causes. They therefore resemble gravity anomalies, and for that reason they are also termed "pseudo-gravity" anomalies. The process of reduction to the pole accounts for this. Anomalies at the pole are easier to interpret and their sources can be more directly determined. Because the survey area is in a region in which the inducing field is inclined at approximately 60 degrees, reduction to the pole can significantly enhance interpretation of the magnetic data.

Profile MC (Fig. 4) traverses normal to the supposed trend of the San Andreas fault system along the Sand Hills. Because of the easterly orientation of the profile the reduction to the pole does not significantly alter the shape of the anomaly. Profile MC shows a narrow anomaly low west of the Yuma basement high over the Sand Hills, approximately in line with the trend of the gravity low thought to be related to the Banning-Mission trend (Biehler, 1964). The anomalies indicate depths to the sources of the anomalies west of Yuma similar to basement depths of 3 to 6 km calculated from seismic and gravity studies carried out nearby and parallel to Line MC (Biehler, 1964). This indicates that the magnetic anomalies are related to basement effects.

The possible extension of the Banning-Mission fault—Sand Hills trend southeastward would traverse the flank of the Yuma basement high, a basin-and-range-related structure. The magnetic anomalies in that area are dominated by the effect of the Yuma basement high. Three northeast profiles (Figs. 5, 6, and 7) along northeast flight lines (1, 2, and 3, Fig. 3) were analyzed to determine more detail structures.

Subtle breaks in the general magnetic gradient can be seen in profiles 1-3. The reduction to the pole and second vertical derivative profiles bring out a set of parallel lows and highs extending southeasterly through the area. The interpretation of the apparent "edges" of sources of the anomalies is plotted on the composite magnetic map (Fig. 3).

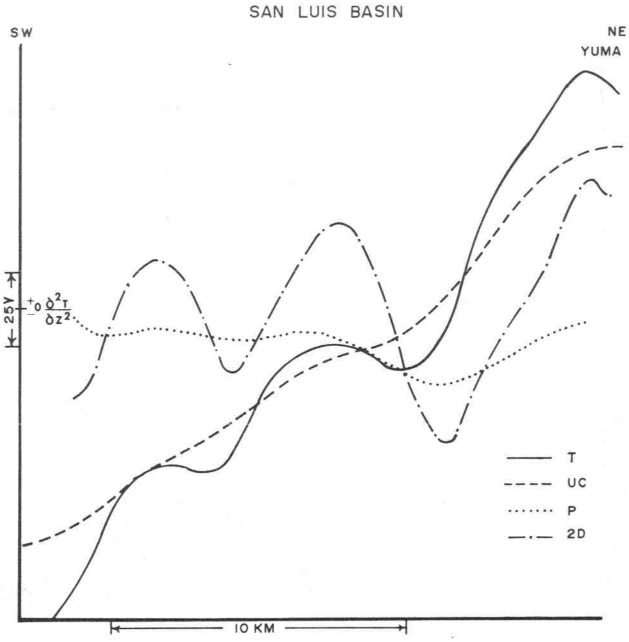

Fig. 5. Profile 1 in the Yuma area, from Mattick and others (1973). T = total magnetic field; UC = upward continued (1.2 km); P = reduction to pole of UC; 2D = second vertical derivative of UC. (See Fig. 3 for location of profile.)

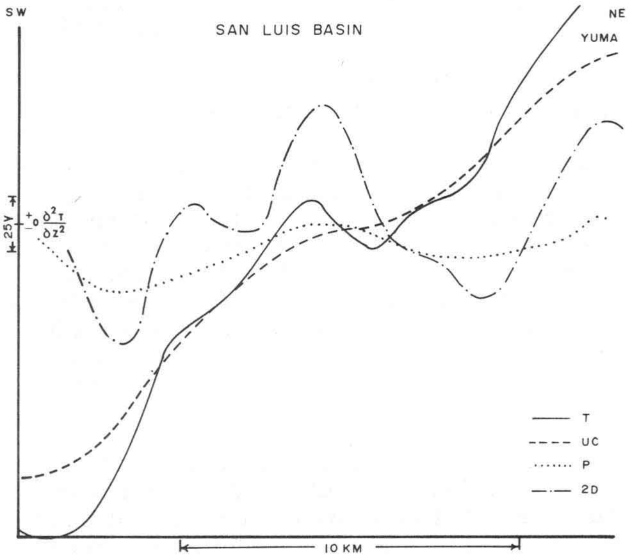

Fig. 6. Profile 2 in the Yuma area, from Mattick and others (1973). T = total magnetic field; UC = upward continued (1.2 km); P = reduction to pole of UC; 2D = second vertical derivative of UC. (See Fig. 3 for location of profile.)

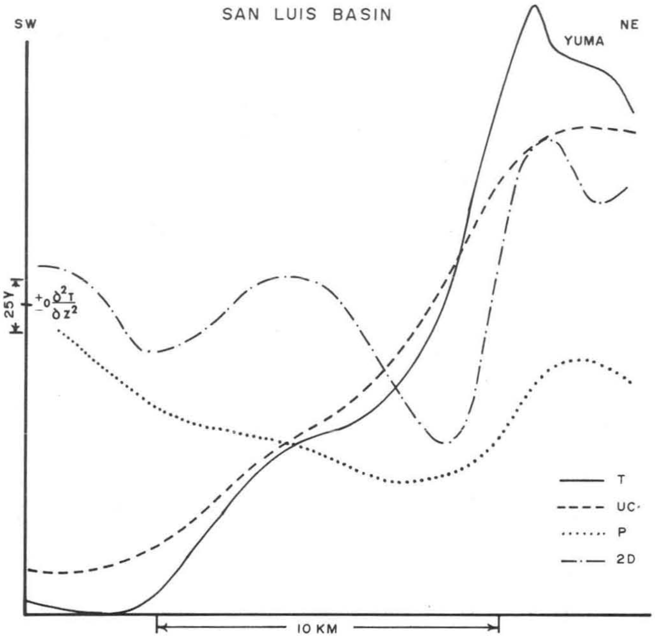

Fig. 7. Profile 3 in the Yuma area, from Mattick and others (1973). T = total magnetic field; UC = upward continued (1.2 km); P = reduction to pole of UC; 2D = second vertical derivative of UC. (See Fig. 3 for location of profile.)

Breaks in the basement slope are interpreted to occur from other geophysical studies south of the Yuma high (Mattick and others, 1973). These changes in the slope of the basement sometimes correspond to the basement features indicated by our analysis of the magnetic anomalies, but the magnetic anomaly pattern indicates even more complexity.

Profile MA (Fig. 8) extends along the Arizona-Mexico border. This profile traverses anomalies at an acute angle so that results of profile analyses assuming that the profile is perpendicular to the anomalies and their sources may be somewhat in error. The central high is related to an exposed basement ridge west of the Fortuna Basin. The east flank of this high has been considered to be the location of the Algodones fault zone.

There is a distinct correlation between satellite-interpreted lineations and the magnetic anomalies (Fig. 3). The San Jacinto fault, considered to be the west edge of the Salton trough, is indicated by a strong series of parallel lineations and a narrow magnetic anomaly low. The magnetic anomaly trends indicated to cross lines MC, 1, 2, 3, and MA correlate with satellite-interpreted lineations. The concentrations of satellite lineations appear to fit the boundaries of the apparent Salton trough. There is no apparent correlation between Sumner's (1971) fault zone and Lepley's (1977) lineations.

Merging of Aeromagnetic Data Sets

There were two major purposes in merging the three data sets of Figure 3 (Map A). The first was to obtain a map with all three data sets at 1.2 km by upward continuation of the data in area 2 (de la Fuente, 1973) and area 3 (Mattick and others, 1973) and by merging the resultant continued field with the field of area 1 (Sumner, 1971) already at 1.2 km. The second was to continue the data of areas 1 and 2 (Fig. 3) upward to 2.7 km to permit a merger with the aeromagnetic map of Arizona (Sauck and Sumner, 1970). Bhattacharyya, Sweeney, and Godson (1979) discussed the problems involved in merging different aeromagnetic data sets; however, many of the potential problems were alleviated by processing the data sets in the same way.

The merger of the data of areas 2 and 3 with those of area 1 involved several steps. The data in areas 1, 2, and 3 were digitized on a grid and the gridded data of areas 2 and 3 fit to a double Fourier series. Upward-continued values were calculated at each grid point for areas 2 and 3, and finally the gridded values of areas 2 and 3 were merged with the data of area 1, resulting in Map B (Fig. 9).

The grid size required to accurately sample the smallest anomaly varied from area to area because of differences in flight elevation and variable depths to basement in the three areas. The data in area 1 were digitized at 1.6-km spacings on a grid of 51(x) and 34(y) (x-axis, NS; y-axis, EW). Map scale for areas 1, 2, and 3 was 1:125,000. The data in area 2 were digitized at 0.95-km spacings on a grid of 102(x) by 20(y) (x-axis, NS; y-axis, EW). The data in area 3 were digitized at 0.63-km spacings on a grid of 38(x) by 51(y) (x-axis, S.22° W.; y-axis, S. 68° E.). The grid coordinate axes of area 3 were skewed with respect to the coordinate axes of areas 1 and 2 to allow maximum coverage of the area and still establish a rectangular grid necessary in the double Fourier series fitting procedure.

For upward continuation, a functional representation of the data is required. Toward this end a double Fourier series, equation (1), was used to represent the data of areas 2 and 3.

A program by James (1966), which uses a least-squares regression to fit a double Fourier series to gridded data, was used to generate 12 x 12 coefficient matrices from the data in areas 2 and 3. The noncontinued data in areas 2 and 3 are thus represented by equation (1) with $z = 0$, $P = Q = 12$, and $X = Y =$ map dimen-

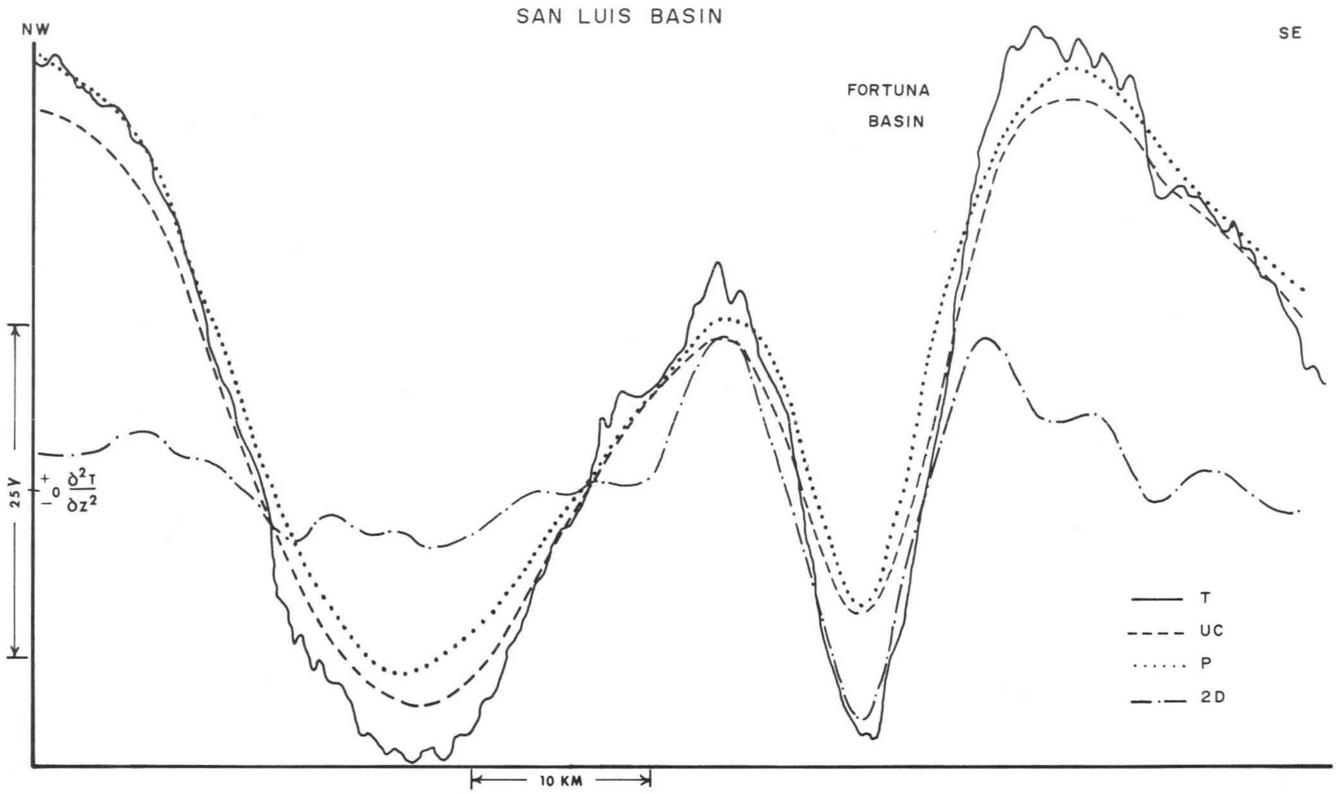

Fig. 8. Profile MA along Arizona-Mexico border, from Sumner (1971). T = total magnetic field; UC = upward continued (2.7 km); P = reduction to pole of UC; 2D = second vertical derivative of UC. (See Fig. 3 for location of profile.).

$$\begin{aligned}\Delta T(x,y,z) = \sum_{m=0}^{P}\sum_{n=0}^{Q} &\{\exp(-2\pi(\frac{m^2}{x^2}+\frac{n^2}{y^2})^{\frac{1}{2}} Z)\}\\ &\{\gamma_1{}^{mn}\cos\frac{2\pi mx}{X}\cos\frac{2\pi my}{Y}\\ &+\gamma_2{}^{mn}\cos\frac{2\pi mx}{X}\sin\frac{2\pi my}{Y}\\ &+\gamma_3{}^{mn}\sin\frac{2\pi mx}{X}\cos\frac{2\pi my}{Y}\\ &+\gamma_4{}^{mn}\sin\frac{2\pi mx}{X}\sin\frac{2\pi my}{Y}\}\end{aligned} \quad (1)$$

x,y = horizontal coordinates
z = continuation distance
$\Delta T(x,y,z)$ = total magnetic field as a function of position
X,Y = fundamental wavelengths in x,y directions
m,n = wave numbers in x,y directions
P,Q = maximum wave numbers in x,y directions
$\gamma_i{}^{mn}$ = amplitudes of coefficients; $i = 1,2,3,4$.

sions of areas 2 or 3 in grid point units. The goodness of fit of the double Fourier series to the gridded data in both areas is better than 97 percent. Continued gridded data for areas 2 and 3 were obtained by evaluating equation (1) at each (x,y) grid point using the appropriate 12 x 12 coefficient matrix and a continuation distance of z = 0.6 km for area 2 and z = 0.9 km for area 3.

The merger of data in area 2 with that of area 1 involved the following. First, the 102(x) by 20(y) array of continued data in area 2 is functionally represented, using the routine of James, by equation (1) with z = 0, P = Q = 12, and X = 102 and Y = 20. The resultant 12 x 12 coefficient matrix is inserted back into equation (1) with the same parameter values, and equation (1) is evaluated on a 1.59-km grid compatible with that of area 1. This yields an array of continued data at 1.2 km for area 2 of size 79(x) by 12(y) (x-axis, NS; y-axis, EW). The last two columns of the array of area 2, or 1.59 km, overlapped with area 1 and were truncated to eliminate the Gibbs edge effect. A constant bias of 20 γ was added to the data of area 2. Finally, a computer routine that contours equally spaced gridded data in a rectangular array was used to generate a map of the merged data in areas

1 and 2. Area 1 has array size 51(x) by 34(y). Area 2 with array size 79(x) by 10(y) exceeds the area 1 array by 16(x) rows on the north and by 12(x) rows on the south. These extra rows of area 2 were truncated and merged separately onto the main area. The data of area 1 and the remaining data of area 2 combined to form an array of 51(x) by 44(y) used to generate a computer contour map.

The continued gridded data of area 3 was contoured, using the same computer routine. Because the coordinate system of area 1 is skewed with respect to areas 1 and 2, it was not possible to recalculate continued values on a 1.59-km-spaced grid that would be compatible with areas 1 and 2. Thus the continued data of area 3 were merged with those of areas 1 and 2 by hand-fitting the contours. To accomplish this, a bias of 2,540 gammas was subtracted from the data of area 3. The rationale for choosing the bias is to allow a minimum of discontinuity everywhere along the join between the data sets. Figure 9 is the final aeromagnetic map (Map B) of all three areas at 1.2-km flight elevation.

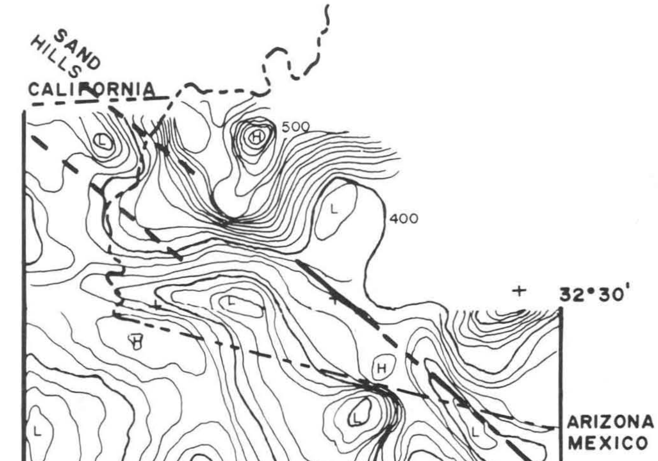

Fig. 9. Upward-continued (1.2 km) composite aeromagnetic map. Data include those of Mattick and others (1973), de la Fuente (1973), and Sumner (1971). Ten-gamma contour interval. L = low, H = high. Lineations from Lepley (1977) included.

The merger into Map C (Fig. 10) of the data in Figure 9 with the Arizona state aeromagnetic map required an upward continuation to 2.7 km. Only data in areas 1 and 2 were treated because the data of area 3 are covered by the data of the Arizona state aeromagnetic map (Sauck and Sumner, 1970).

The data of areas 1 and 2 were upward continued in two separate sets: the combined rectangular array, 51(x) by 44(y), of data from areas 1 and 2 discussed earlier forms set A and the data at the northern end of area 2 of size 16(x) by 10(y) form set B.

For both sets A and B a functional representation of the data was obtained by using the routine of James (1966) to fit equation (1) to the data, with z = 0, P = Q = 12 for set A, P = Q = 5 for set B, and X = Y = map dimensions for set A or set B in grid point units. Continued magnetic values were calculated by substituting the appropriate Fourier coefficients as determined above into equation (1) with z = 5,000 ft (1,525 m) and other parameters as above. The continued values of both Sets A and B were then contoured by a computer routine. Sets A and B were re-merged by a minimal amount of hand-smoothing of contours.

Before merging these data with the Arizona aeromagnetic data, consideration of the bias in each data set was made. The Arizona aeromagnetic map has a bias of +400 gammas and the data of Figure 9 (Map B) have a bias of −500 gammas. Thus the data of Figure 9 have a net bias of −100 gammas. For the best fit of contours across the join between the Arizona aeromagnetic data and the data of Figure 9, the net bias of 100 gammas and an additional bias of 25 gammas were subtracted from the data of Figure 9. The resultant aeromagnetic map at 2.7 km is shown in Figure 10 (Map C).

The upward-continued data sets used to produce Maps B and C fit together very well, within a few gammas. The differences can be explained by slight differences in the calibrations of the magnetometers, 5-20 gammas. That data of Mattick and others (1973) did not fit as well

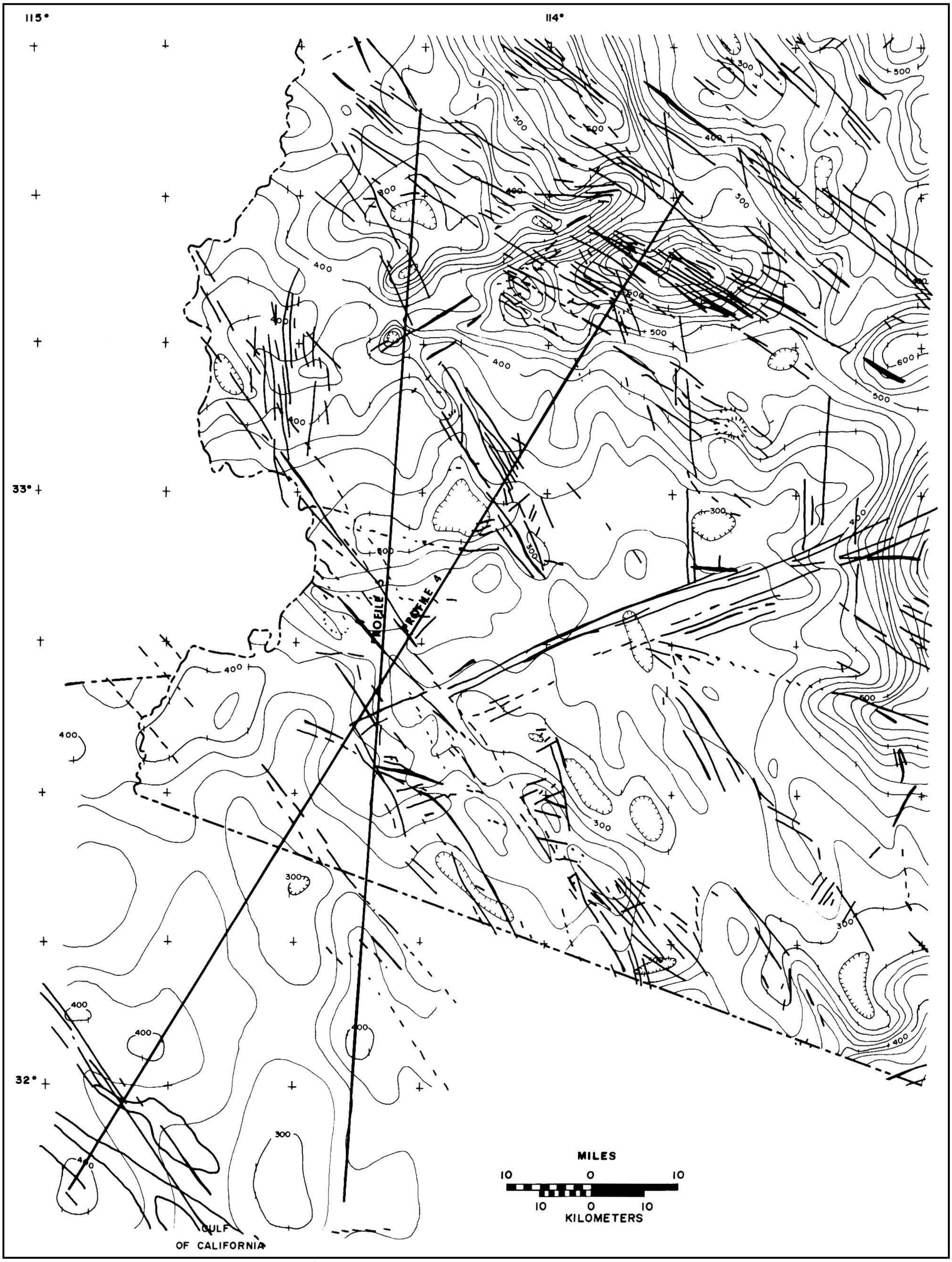

Fig. 10. Upward-continued (2.7 km) composite aeromagnetic map. Data include those of de la Fuente (1973), Sumner (1971), Sauck and Sumner (1970). Twenty-five-gamma interval. Lineations from Lepley (1977) included. Profiles 4 and 5 shown.

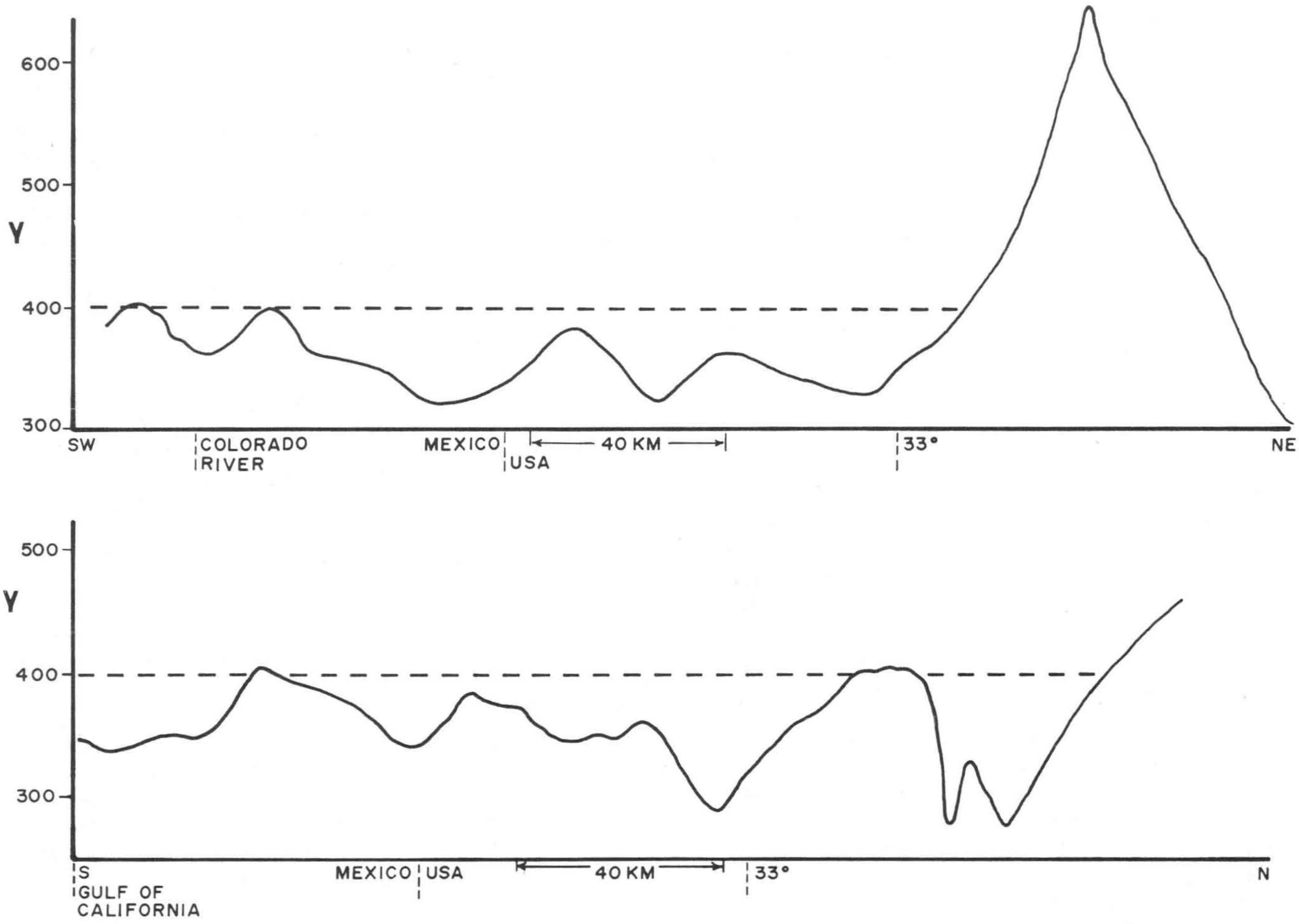

Fig. 11. Profiles 4 and 5 from upward-continued (2.7 km) map of Fig. 10.

with the other data, but that is to be expected due to the lack of information on that survey's parameters.

Profiles 4 and 5 (Fig. 11) show the general small-amplitude anomaly characteristic of the apparent "subdued" zone as discussed by Sumner (1971) and Sauck (1972). This characteristic appears to change at the northwest-trending magnetic high (Tucson-Ajo high) that extends across Arizona (Sauck, 1972; Aiken, 1978). By normalizing the magnetic data (Fig. 10) it can be seen that the area of "subdued" amplitudes of the anomalies as defined by Sauck actually includes an area of values less than 400 gammas and that area may not extend from the Gulf of California to the Tucson-Ajo high (see profiles 4 and 5, Fig. 11) as suggested by Sumner. Otherwise the area of smaller amplitude anomalies can be seen to exist north of the Tucson-Ajo trend (Aiken, 1976). The subtle apparent area of decreasing residual values (all less than 400 gammas) actually starts north and east of Yuma as seen in profiles 4 and 5 (Fig. 11).

It is apparent that the distinct change in the characteristics of the anomalies in Sumner's (1971) map from higher amplitudes and shorter wavelengths in northeast Sonora and southern Arizona to lower amplitudes and longer wavelengths to the west can be explained by the tectonic framework and the topography of the area. The basement topography is buried to the west and the basins are wider and deeper, hence the corresponding wide, low-amplitude anomalies. Comparisons of the magnetic with the geologic and topographic maps clearly indicate that such a geologic and topographic change in character probably occurs.

The apparent zone of subdued anomalies has been explained by one cause or a combination of causes. Sumner (1971) suggested a change from granitic to basaltic crust in a high-thermal regimen. Sauck (1972) suggested a shallow depth to Curie temperature due to elevated crustal temperatures.

Contributions to creating a "subdued" zone could be the constant change in average elevation of topography and therefore decrease in ground clearance, south to north, in the survey or a change in the magnetic character of the shallow lithologies to lower susceptibilities in the subdued area. However, there is a significant area of high average elevation in the center of the "subdued" zone northeast of Yuma in which the magnetic anomalies are generally low in amplitude and, in fact, are lower than to the south or north. A more complex cause involving several conditions probably contributes to the "subdued" anomalies and not just a single cause such as Curie depth.

Conclusions

The merging of aeromagnetic data into Maps A, B, and C (Figs. 3, 9, and 10) aid in interpreting and comparing the magnetic signatures across the ara. Because the data from three of the four sources in the area have been observed with similar or the same equipment and have subsequently been processed in a similar manner, many of the problems described by Bhattacharyya and others (1979) in merging magnetic data sets are minimized. A Fourier series technique of upward continuation was used to normalize the data, and the fit of their absolute values is very good. Two different maps were produced: Map B (Fig. 9) at 1.2 km elevation and Map C (Fig. 10) at 2.7-km elevation. In this way the general amplitudes and values of magnetic anomalies from the Gulf of California through the Basin and Range province can be compared. Comparisons with satellite lineations indicate a strong apparent correlation. If the Banning-Mission fault extends through the Sand Hills, vestiges of it should also be traceable across Arizona south of Yuma. The Algondones fault zone is seen as one of those trends.

It has been pointed out that because the San Andreas fault system is a strike-slip feature, the lack of significant offset of the middle Cenozoic Bouse Formation by a fault such as the Algodones indicates that such structures are dip-slip and perhaps not related to the San Andreas. The magnetic anomalies and satellite-derived lineations indicate the outline of the Salton trough, with the Algodones fault being its northeastern boundary and the San Jacinto fault its southern boundary. It would seem that movements along these apparent normal normal faults may be caused by interaction between some Basin-and-Range normal faults, the Salton trough extension of the Banning-Mission fault, and the strike-slip of the San Andreas fault zone. Such faults could possibly be hazardous to structures in the area, although perhaps not with any general large-scale offset as in the San Andreas zone.

There is a subtle regional magnetic low north of the U.S.-Mexico border and south of the Tucson-Ajo magnetic anomaly high. The Tucson-Ajo anomaly is related to a lithologic change in the crust. Anomalies north of this trend have lower amplitudes, but these are slightly higher than those in the area toward Yuma. The subtle low is not obviously related to shallow lithologic or structural effects because it is similar in those aspects to other areas without such anomaly amplitudes. The variation must be due to a deep or pervasive source that could include a decrease in the total magnetic intensity due to elevated temperatures at depth.

Sumner's (1971) area of subdued anomalies is more likely related to deep basement in the Salton trough in the northwest portion of his area and is south of the regional magnetic low seen in profiles 4 and 5 (Figs. 10 and 11).

Acknowledgments

We wish to thank J. R. Sumner presently of Exxon, USA, Houston for his full cooperation and use of his aeromagnetic data without which this paper could not have been done.

Edward Heath and George Brogan of Woodward-Clyde Consultants, Orange, California, gave permission for the use of some of the magnetic data analysis done in behalf of the Salt River Project. They also provided additional information requested as well as advice.

Portions of this study were supported by Woodward-Clyde Consultants and the Salt River Project; by A. W. Laughlin of the Geological Applications group (G-9) of the Los Alamos [New Mexico] Scientific Laboratory of the University of California (Contract N28-4950H-1); and by the Texas Christian University Research Foundation, Fort Worth.

Computer work was done on the IBM 360/70 computer at the University of Texas Regional Computer Center, Dallas, the Xerox Sigma 9 computer of Texas Christian University, Fort Worth, and the PDP-11/40 at Digitgraph Computer Systems Co, Tucson, Arizona.

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