Arizona Geological Society Digest, Volume IX, December 1971

AEROMAGNETIC MAP OF THE NORTHERN PART OF THE TUCSON BASIN, PIMA COUNTY, ARIZONA1/

By

W. A. Sauck, J. S. Sumner, and J. P. Christensen

Department of Geosciences, University of Arizona, Tucson, Arizona

INTRODUCTION

An aeromagnetic survey covering the northern part of the Tucson basin was flown August 21 and 22, 1968. The aircraft, a Cessna 180, and magnetometer system, a University of Wisconsin-Elsec digital recording proton precession magnetometer (Wold, 1964) were the same as those used for the 1968 aeromagnetic survey of Arizona (Sauck and Sumner, 1971). A survey altitude of 6,000 feet (1830 m) above sea level was maintained on east-west flight lines that were spaced one-half and one mile (0.8 and 1.6 km) apart. A north-south tie line was also flown. The surveyed area is approximately 18 by 20 miles (29 by 32 km), and data were collected along more than 450 miles (724 km) of flight lines. The magnetometer cycled every four seconds and vertical flight recovery photographs were taken every twenty seconds.

Diurnal variations were removed using the records of the Tucson Magnetic Observatory (formerly ESSA, now NOAA), and the main geomagnetic field, described by the spherical harmonic coefficients of Cain, et al., (1967) was removed, resulting in a map of the residual magnetic intensity (Figure 1).

PREVIOUS WORK

Aeromagnetic surveys in this area which are available to the public are the open file U. S. Geological Survey aeromagnetic map of part of the Cortaro quadrangle (1952), located northwest of the Tucson basin, and the aeromagnetic map of the Twin Buttes area (Andreason and Pitkin, 1963). The aeromagnetic map of Arizona (Sauck and Sumner, 1971) includes the Tucson basin, but the survey was flown at 9,000 feet (2740 m) barometric altitude, and three-mile spacing (5 km) of north-south flight lines, hence only eight flight lines cross the area described in this report. Figure 2 shows the area of the Tucson basin survey on the Residual Aeromagnetic Map of Arizona. Ground-based geophysical surveys in the Tucson basin are summarized by Davis (1967).

1/ Contribution No. 21, Department of Geosciences, University of Arizona, Tucson, Arizona.

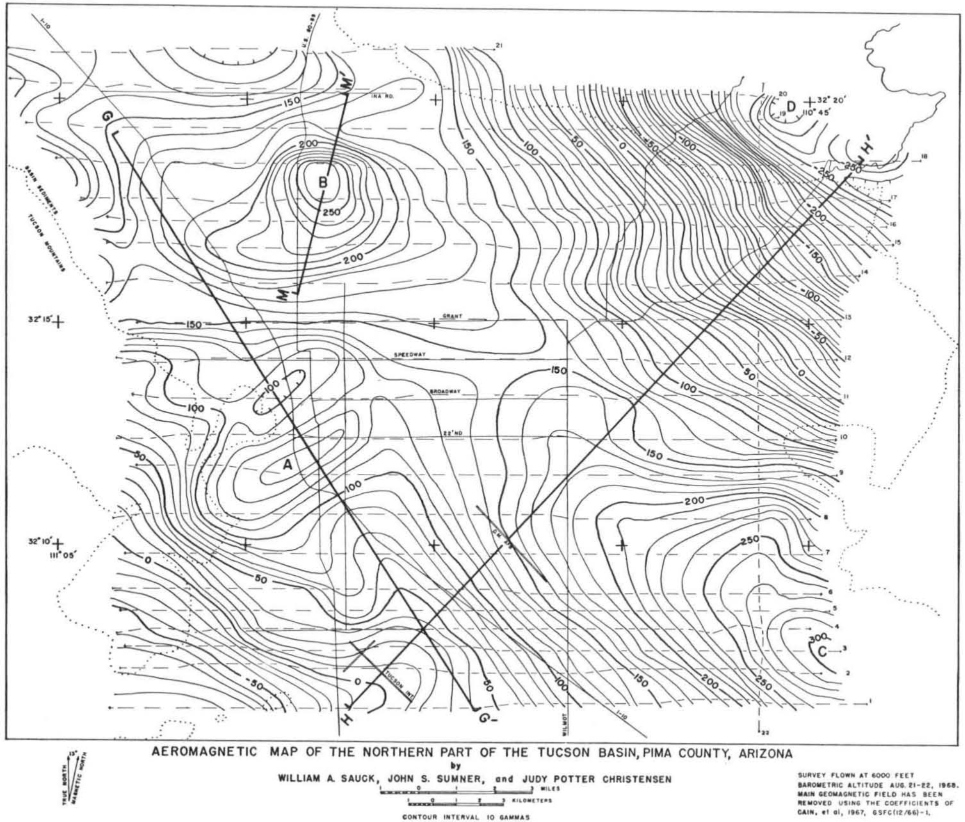

Figure 1.--Aeromagnetic Map of the Northern Part of the Tucson Basin, Pima County, Arizona.

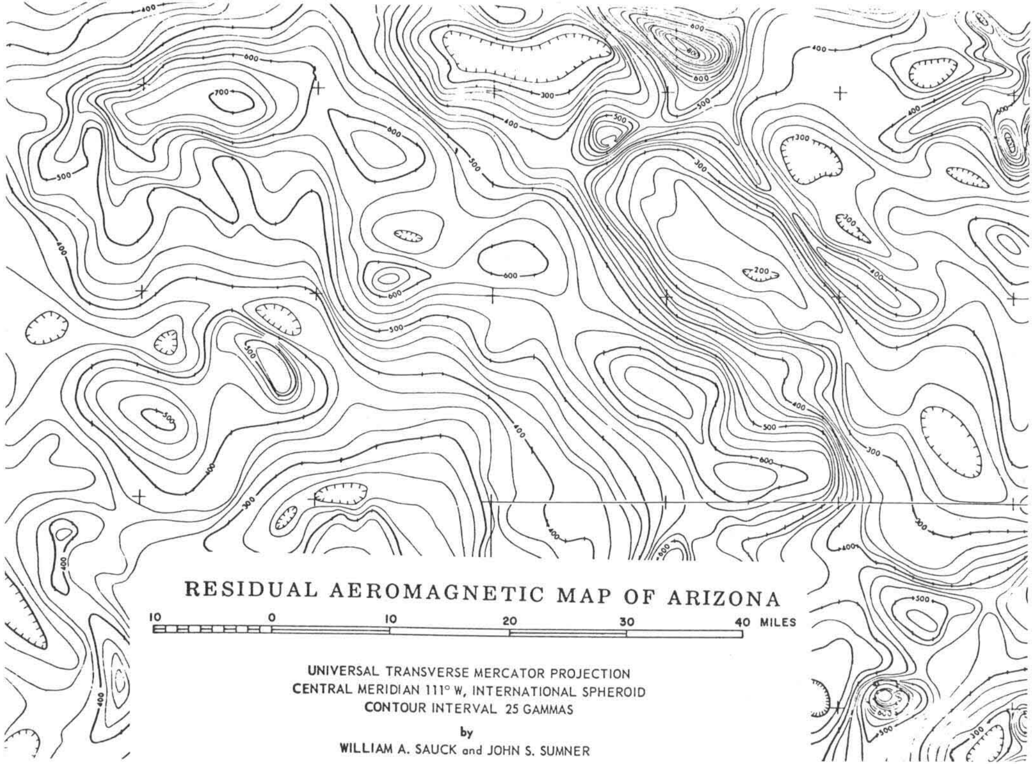

Figure 2.--Portion of the Residual Aeromagnetic Map of Arizona Flown at 9,000 Feet Above Sea Level and Showing Location of Tucson Basin Aeromagnetic Survey.

GEOLOGY

Tucson lies in the Basin and Range Province of generally north to northwest trending mountains and valleys. The Tucson basin is generally described as a down-dropped fault block.

Figure 3 shows the survey area on a portion of the Geologic Map of Arizona (Wilson, et al., 1969). The Geologic Map of Pima and Santa Cruz Counties (Wilson, et al., 1960) also shows the regional geology.

The rock outcrops adjacent to the north and east of Tucson in the Catalina and Rincon Mountains are almost entirely gneiss of mid-Tertiary age (Damon, et al., 1963), while the exposed rocks to the west are almost all volcanic, ranging from Late Tertiary basaltic andesites to Cretaceous and Tertiary rhyolites and andesites. Cretaceous sediments and Laramide intrusives also outcrop on the western flank of the Tucson Mountains.

Gravity data (Davis, 1967) imply a minimum thickness of low-density alluvium of 5,000 feet (1524 m) in the central basin. This thickness is obtained by assuming a constant 0.4 gm/cm^3 density contrast between basin fill and pre-Tertiary basement rocks. If the density contrast decreases with depth, as would be expected from compaction and lithification, then the calculated thickness of alluvium could be appreciably greater than the above figure.

Various geologic structures affected the Tucson basin and they are observed around the edges of the basin and vicinity. Black Mountain, or the Del Bac Hills, define a N60°E trend at least seven miles (11 km) long and with unknown extent to the northeast. Percious (1968) reports that this trend is in part a high angle normal fault, down to the south, with associated andesitic dikes. Ganus (1965) suggests that this feature extends through Twin Hills on the east side of the basin and continues northeast to the Redington Pass area between the Catalinas and Rincon Mountains.

Sherman and Hathaway (1964) reported "linears" in the alluvium of the central part of the Tucson basin trending N50°W and N10°W, although no measurable relative displacements have been found. These are possibly the result of differential compaction over buried structures due to withdrawal of groundwater.

Pashley (1966) mapped many exposures of the Catalina fault, which bounds the Tucson basin on the north and east. He concludes that the Catalina fault is a surprisingly shallow angle fault, dipping, basinward 8 to 53 degrees, and in general, is concordant with the gently southwest plunging folds of the Catalina gneiss.

ANALYSIS OF MAGNETIC MAP

The magnetic anomalies can only have a crustal source since the internal main geomagnetic field and the time-varying field have been removed. Also, the source must be shallower than the Curie geotherm (about 580°C, attained between 10 and 20 km, depending upon the geothermal gradient) because below that depth no materials can remain magnetic. The magnetization may be caused by induction which is proportional to the magnetite content of the rock, and/or by remanence (permanent magnetization) locked into the rock at the time of cooling below the Curie temperature. Anomalies can also be caused by changes in topography of the

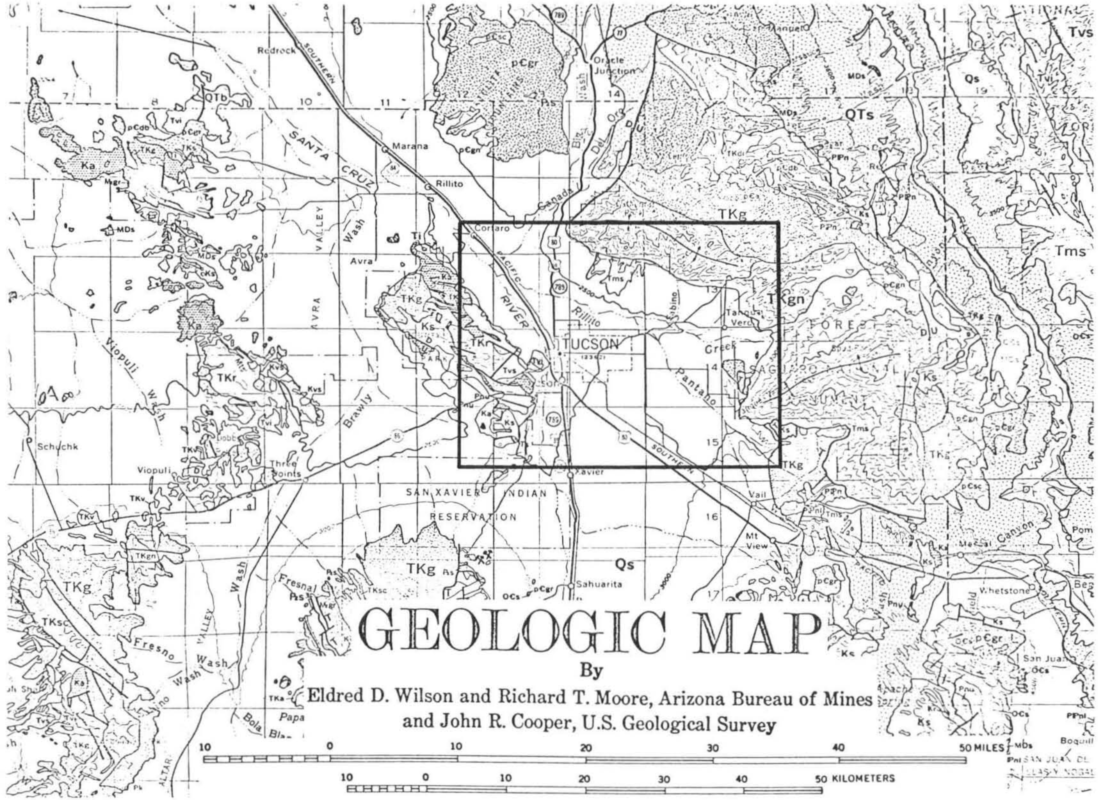

Figure 3.--Location of the Tucson Basin Aeromagnetic Survey on a Part of the Geologic Map of Arizona.

surface of a homogeneous body of rock or by the contact between two bodies of rock having different magnetite contents.

By far the most dominant feature of the magnetic map (Figure 1) is the positive anomaly having amplitudes up to 300 gammas and trending N45°W directly through the Tucson basin. This remarkable anomaly is only a part of a much longer high (Figure 2) extending from the Silverbell Mountains to the area south of the Rincon Mountains, a distance of about 75 miles (120 km). Most of the Tortolita, Catalina, and Rincon ranges lie within a magnetic low of similar large extent.

Profile H-H' (Figure 4) is a general cross-section perpendicular to the long magnetic high. Anomaly A, shown on the map (Figure 1), and profile G-G' does not appear to be a part of the main Tucson basin anomaly, but rather a smaller, shallower anomaly superposed on the southwest flank of the main anomaly, and showing an induced magnetic low to the north. Anomaly A can be modeled approximately by a thin vertical dike striking N65°E. The dike is about four miles (6.5 km) long, with its northeast end near South Park Avenue and 17th Street. Removing the main Tucson basin anomaly and then applying Smellie's (1967) line of dipoles approximation results in the placement of the center of the model at about 2400 feet (730 m) below sea level. Better depth estimates are difficult because no flight line crosses both the maximum and the minimum in a north-south direction. This anomaly cannot be modeled exactly with a thin dike of great vertical extent and may be caused by a pair of dikes, the northward one having reversed remanent polarity (as in Grant and West, 1965, Figures 11-18) because the residual anomaly profile approaches zero too rapidly on its flanks and the low is more pronounced than it should be for a simple inducing field of 60° inclination. Percious (1968) reports that one of the andesitic dikes in the Del Bac Hills is reversely magnetized. Two aeromagnetic profiles (Figure 5) made at low altitude on July 9, 1971, over Black Mountain, located just off the southwest corner of the Tucson basin aeromagnetic map, indicate that the dominant magnetization is reversed in direction. This is supported by the field measurements of Percious (1968), and is probably the cause of the ENE trending magnetic low which "noses out" northeast of Tucson International Airport.

Hence, one could interpret anomaly A as an en-echelon continuation of the Del Bac Hills trend. The Del Bac Hills trend loses its magnetic expression 2.5 miles (4 km) ENE of Tucson International Airport, and does not appear to extend to the east side of the Tucson basin.

Anomaly B, located between North Oracle Road and North First Avenue and just north of Rillito Creek, does not have ideal flight coverage for detailed analysis, as the maximum was obviously missed. This anomaly, shown in section (Figure 6, Line 18), suggests a vertical prism source, standing above the deeper source of the main Tucson basin anomaly. Anomaly B should be amenable to model studies using the methods of Vacquier, et al., (1951), if better coverage were available. Their "G" index on the steep north slope gives a very approximate position for the upper surface of the source as about 1500 feet (460 meters) above sea level. In July, 1971, a low altitude aeromagnetic profile was made over anomaly B in a magnetic N-S direction, and is shown on Figure 7. The "G" index of Vacquier and others (1951) for this profile leads to a depth estimate of 1680 feet (500 m) below the flight level of 3,000 feet (900 m) above sea level. Use of their vertical prism model A-59 and a positive anomaly amplitude of 250 gammas results in a computed susceptibility

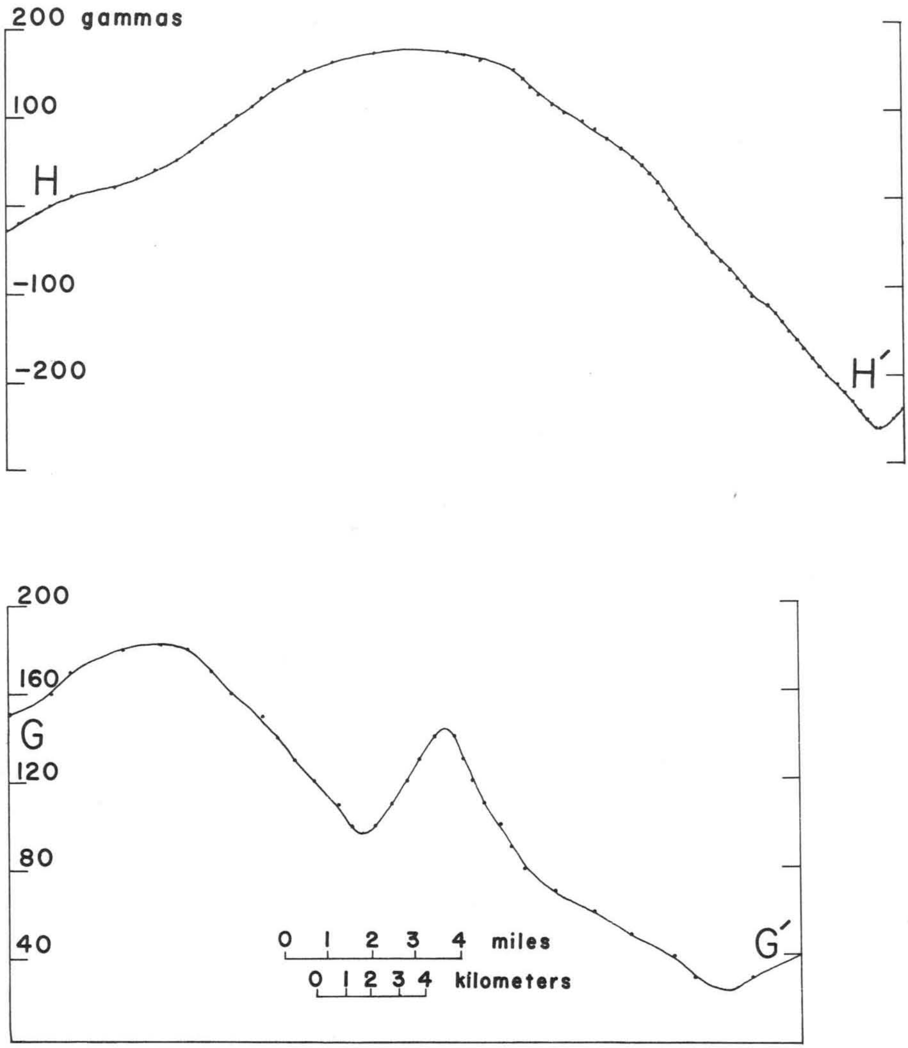

Figure 4.--Two Profiles Constructed From the Contoured Aeromagnetic Map. Profile G-G' Crosses Anomaly A.

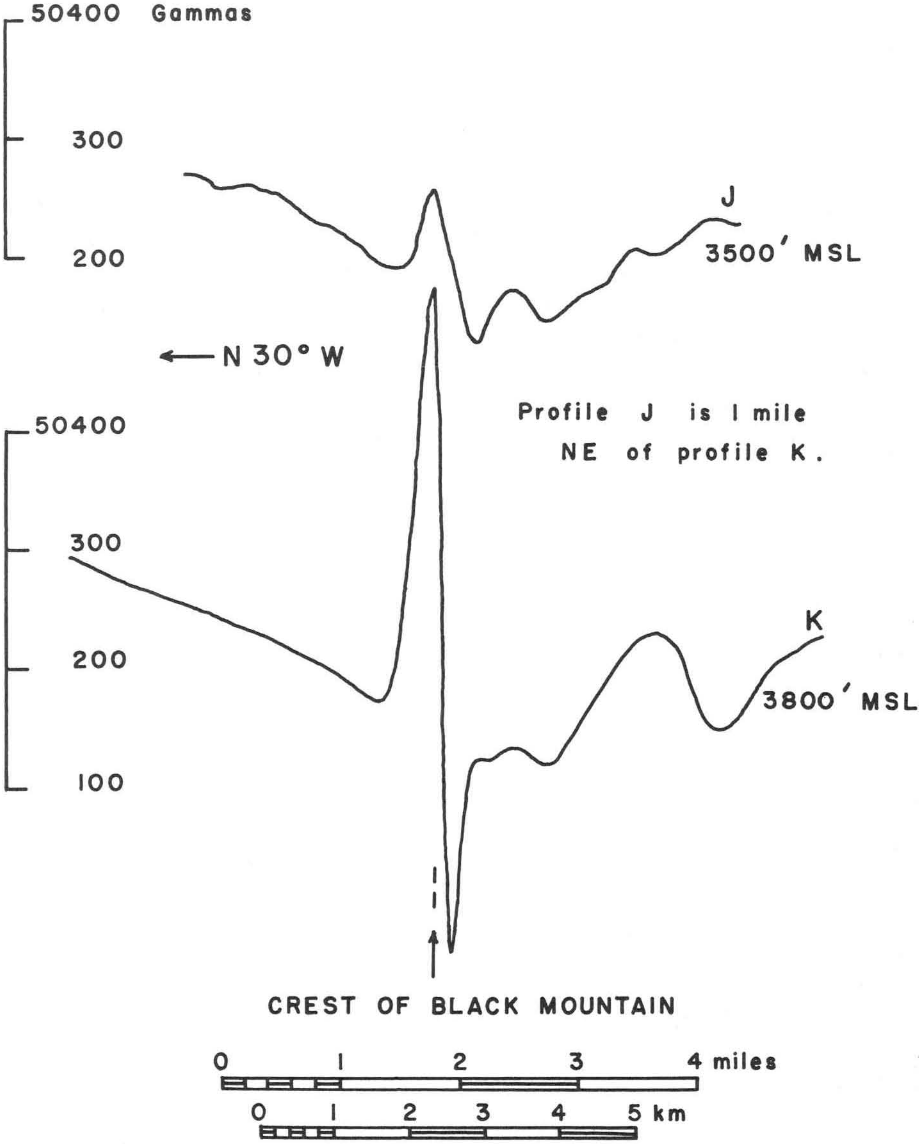

Figure 5.--Two N30W Aeromagnetic Profiles Over Black Mountain.

of 0.001560 cgs for the square vertical prism whose top is one depth unit below the flight level and is four depth units on a side. Also shown on the figure is a calculated profile assuming only two-dimensional features and susceptibility of 0.001560 cgs.

Other approximations of the depth to sources result in a figure of 860 feet (260 meters) below sea level for anomaly C, measured on a steep north sloping segment along Line 22, flown along Houghton Road, and a figure of 2,000 feet (610 meters) above sea level for the steep southwest flank of anomaly D, near the mouth of Bear Canyon. This steepening of the gradient can be seen at the north end of Line 22 and the east end of Line 18 (Figure 5).

The N50°W "linears" of Sherman and Hathaway (1964) coincide very well with the trend of the main Tucson basin positive magnetic anomaly. Both the main magnetic high and the "linears" could be in part due to a basement scarp, down-dropped to the southwest, with high susceptibility material to the northeast.

The other prominent structural direction visible on the aeromagnetic map is northeast. A probable northeast magnetic trend associated with the Del Bac Hills "noses out" near Tucson International Airport. The trend is repeated at anomaly A, and appears again as an elongate contour closure north of anomaly B, at Ina Road. The northeast structural trend is shown well by Pashley's (1966, Figures 21, 22, and 30) maps of the Rillito beds along the north margin of the Tucson basin. This direction is, of course, also coincident with the plunge of the major folds in the gneiss of the Catalina and Rincon Mountains. An interesting observation in this regard is that in comparing Figures 2 and 3, four of the five closed magnetic highs occurring along the axis of the main Tucson basin magnetic high appear to lie southwest of structural highs in the mountains to the north. Magnetic highs lie southwest of the Tortolita Mountains, Pima Canyon anticline, Tanque Verde ridge, and the south Rincon Mountains. Thus, the structural highs could have controlled the emplacement of a younger, high-susceptibility rock, they are the result of emplacement of intrusive rocks, or they have merely elevated existing high-susceptibility material closer to the plane of observation, causing the magnetic peaks.

The average magnetic susceptibility of eight samples of Catalina gneiss is $65(10^{-6})$cgs and the average of nine samples of the finer fraction (coarse sandstone to mudstone) of the Rillito beds is $300(10^{-6})$ cgs. The median of the nine samples if $200(10^{-6})$ cgs. The Rillito beds contain a wide assortment of intrusive and extrusive rock fragments, as well as some fragments of massive magnetite and a gray schist (Pinal Schist?). The susceptibilities of many of these fragments are much higher than the above figures; two samples of the schist measure 850 and $1760(10^{-6})$ cgs. If the Rillito beds thicken appreciably toward the basin, they could contribute appreciably to the magnetic high which traverses the Tucson basin, but are not likely to be the main contributor.

The dimensions of the main positive anomaly passing through the Tucson basin imply a very large and fairly homogeneous body as the source, perhaps a batholith. Gilluly (1963) mentions the very large volume of Late Cretaceous (but not Laramide) plutons in the western United States, and also the possibility of some batholiths of Laramide and mid-Tertiary ages in southern Arizona. The age of such a postulated batholith is indeterminate from the magnetic data, but the proximity of the Catalina gneiss of mid-Tertiary age makes that age a good possibility. The south margin of the batholith would be approximately 1 km southwest of the crest of the

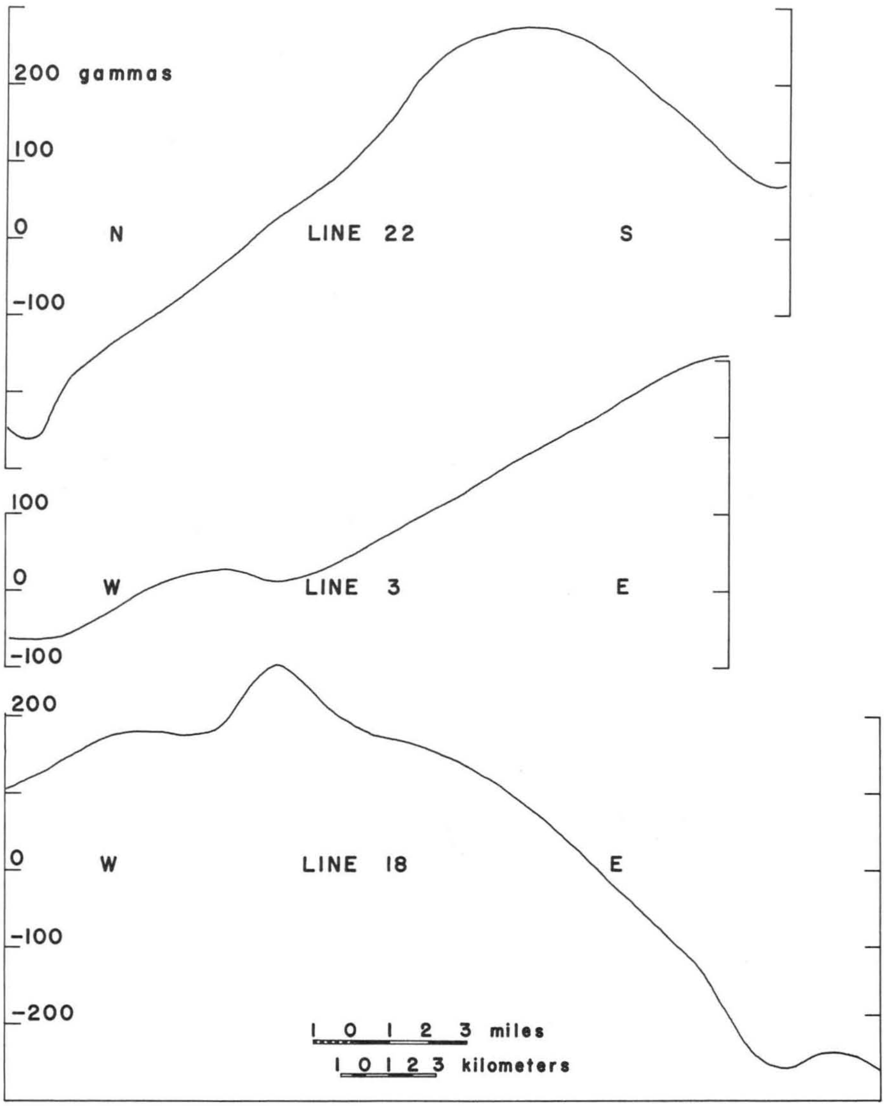

Figure 6.--Profiles of Two East-West and One North-South Flight Line. Line 18 Crosses Anomaly B.

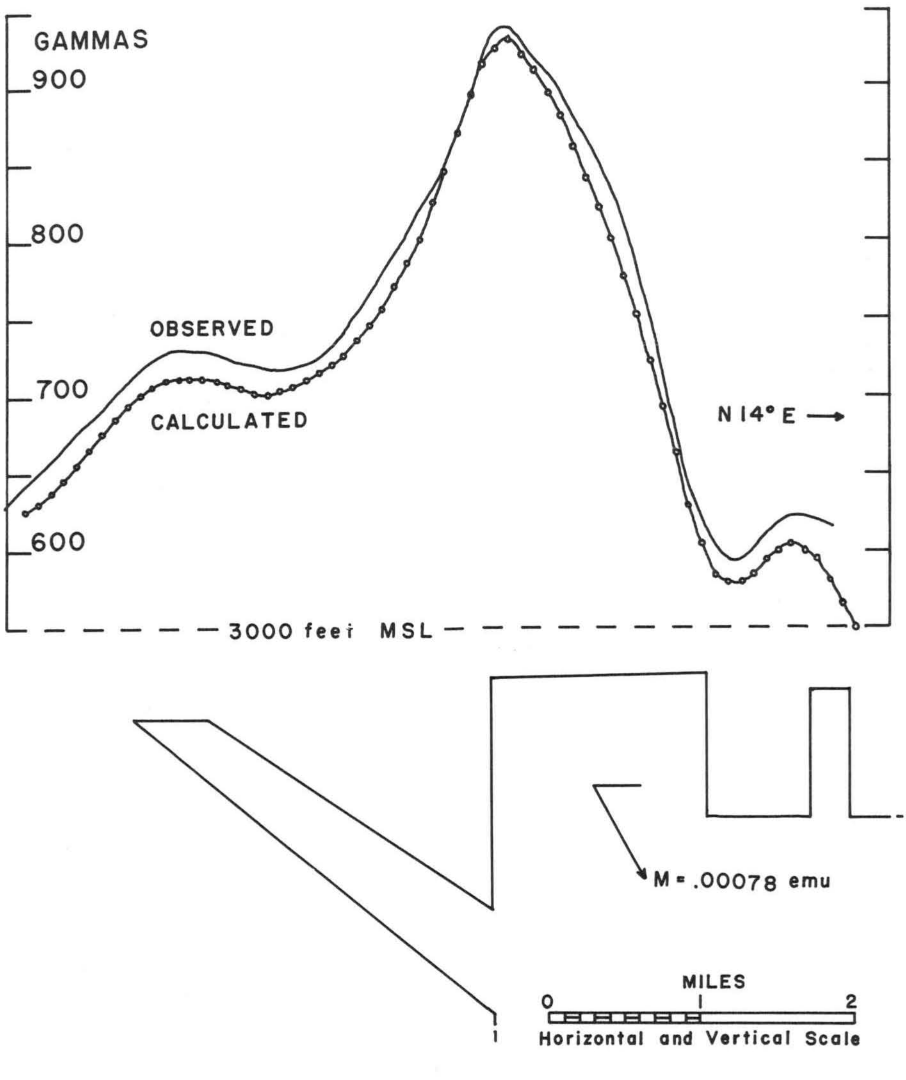

Figure 7.--Observed Profile Over Anomaly B, Flown at 3,000 Feet MSL (900 m), and Computed Profile From a Two-Dimensional Model.

Tucson basin positive anomaly, and the north margin a similar distance southwest of the trough of the elongate magnetic low passing through the Rincon, Catalina, and Tortolita Mountains. This places the north margin near a line passing through Mica Mountain in the Rincons and Romero Pass in the Catalina Mountains.

SUMMARY

The Tucson basin positive magnetic anomaly represents a major crustal feature within or at the surface of the basement rock underlying the Tucson basin. The positive magnetic anomaly is 75 miles (120 km) long in a northwest-southeast direction and it is about 15 miles (24 km) wide. Depth estimates to shallow parts of the anomaly at B and C yield depths of 1,080 and 3,700 feet (330 and 1130 m) below the surface, while most of the source must be considerably deeper. The source of the Tucson basin positive anomaly is probably a major intrusive igneous body having a susceptibility of at least 0.0016 cgs units, which is equivalent to approximately 0.7 volume percent of magnetite. Transverse to the dominant northwest magnetic trend are several northeast trending features. The anomaly at A is probably not related to the main positive anomaly and can be approximated by a thin northeast trending dike whose top is about 4,800 feet (1460 m) below the surface. Gneiss from the mountains to the north of the basin has a very low magnetic susceptibility (65×10^{-6} cgs) and the mid-Tertiary clastic sediments exposed at the north end of the basin have a susceptibility of 200×10^{-6} cgs.

The data used to compile the aeromagnetic map, with the main geomagnetic field removed, are available from the authors (W. A. Sauck and J. S. Sumner) at cost in the form of standard punched cards.

REFERENCES

Andreason, G. C. and J. A. Pitkin, 1963, Aeromagnetic Map of the Twin Buttes area, Pima and Santa Cruz Counties, Arizona: U. S. Geological Survey, Map GP-426.

Anonymous, 1952, Preliminary Total Intensity Map of Part of the Cortaro Quadrangle, Arizona: U. S. Geological Survey Open File Map.

Cain, J. C., S. J. Hendricks, R. A. Langel, and W. F. Hudson, 1967, A Proposed Model for the International Geomagnetic Reference Field - 1965: Journal of Geomagnetism and Geoelectricity, v. 19, no. 4, p. 335-355.

Damon, P. E., R. C. Erickson, and D. E. Livingston, 1963, K-Ar Dating of Basin and Range Uplift, Catalina Mountains, Arizona: Nuclear Geophysics, 1975, p. 113-121.

Davis, R. W., 1967, A Geophysical Investigation of Hydrologic Boundaries in the Tucson Basin, Pima County, Arizona: University of Arizona, Ph.D. Dissertation, unpublished.

Ganus, W. J., 1965, Lithologic and Structural Influences on the Hydrodynamics of the Tucson Basin, Arizona: University of Arizona, M.S. Thesis, unpublished.

Gilluly, J., 1963, The Tectonic Evolution of the Western United States: Quarterly Journal of the Geological Society of London, v. 119, p. 133-174.

Grant, F. S. and G. F. West, 1965, Interpretation Theory in Applied Geophysics: McGraw-Hill Book Co., New York.

Pashley, E. F., Jr., 1966, Geology and Geochronology of the Del Bac Hills, Pima County, Arizona: Southern Arizona Guidebook III, Arizona Geological Society, p. 199-207.

Sauck, W. A. and J. S. Sumner, 1971, Residual Aeromagnetic Map of Arizona: University of Arizona Press.

Sherman, J. E. and A. W. Hathaway, 1964, Occurrence of Linears in the Tucson South Quadrangle, Pima County, Arizona: Arizona Geological Society Digest, v. 7, p. 79-86.

Smellie, D. S., 1967, Elementary Approximations in Aeromagnetic Interpretation: Mining Geophysics, v. 2, Society of Exploration Geophysicists, Tulsa, p. 474-489.

Vacquier, V., N. C. Steenland, R. G. Henderson, and I. Zietz, 1951, Interpretation of Aeromagnetic Maps: Geological Society of America, Memoir 47.

Wilson, E. D., R. T. Moore, and J. R. Cooper, 1969, Geologic Map of Arizona: Arizona Bureau of Mines and U. S. Geological Survey.

Wilson, E. D., R. T. Moore, and R. T. O'Haire, 1960, Geologic Map of Pima and Santa Cruz Counties, Arizona: Tucson, Arizona Bureau of Mines.

Wold, R. J., 1964, The Elsec-Wisconsin Digital Recording Proton Precession Magnetometer System: University of Wisconsin Geophysical and Polar Research Center, Report 64-4.