GEOPHYSICS, VOL. 46, NO. 1 (JANUARY 1981); P. 30–39, 9 FIGS.

Analysis of multisource gravity and magnetic anomaly data sets by moving-window application of Poisson's theorem

V. W. Chandler,* J. S. Koski,‡ W. J. Hinze§ and L. W. Braile§

Use of Poisson's theorem to calculate single-source magnetization-to-density ratios may be extended to multisource data by repeatedly applying the theorem within a small, moving data window. In this approach, the moving window traverses the data set in increments of the data interval, and a linear regression is conducted between the first vertical derivative of gravity and the magnetic values reduced to the pole within each window position. Three parameters—correlation coefficient, slope, and intercept—are thereby generated at each data interval that describe the internal correlation existing between gravity and magnetic anomalies and may yield information regarding anomaly source properties. The slope parameter provides an estimate of source magnetization-to-density ratio for the anomaly segments within each window position.

Studies of models and observed data indicate that the moving-window application of Poisson's theorem allows rapid estimation of source magnetization-to-density ratios from multisource data sets. Although anomaly interference may cause spurious magnetization-to-density estimates, accurate values can occur over the high-gradient flanks of anomalies and are associated with correlation coefficient values approaching ± 1.0 and locally level intercept values. Wavelength filtering to enhance specific anomalies may be helpful in situations where long- and short-wavelength anomalies are interfering. Analysis of a gravity and magnetic anomaly in Michigan yielded many magnetization-to-density ratio estimates close in value to a ratio derived from a more conventional application of Poisson's theorem. Analysis of profile data across the United States along the 37th parallel yielded several consistent suites of magnetization-to-density estimates that correspond to known crustal features. Consistently high intercept parameters over the western United States indicate the presence of an extremely long-wavelength magnetic anomaly component and may reflect improper removal of the regional geomagnetic field.

INTRODUCTION

The relationship between gravitational and magnetic potentials arising from a common, isolated source was shown by Poisson (1826) to be

$$V = 1/G\,(\Delta J/\Delta\sigma)(\delta U/\delta i), \tag{1}$$

where V = anomalous magnetic potential, U = anomalous gravitational potential, ΔJ = anomalous source magnetization, $\Delta\sigma$ = anomalous source density, i = direction of source magnetization, and G = universal gravitational constant. For this simple linear relationship to be valid, the isolated source must have a uniform density and magnetization contrast. The relationship, however, is independent of the shape and position of the source.

Several methods of application of Poisson's theorem have proven to be useful in the combined analysis of gravity and magnetic anomaly data. For example, the theorem has been used to determine anomaly source magnetization-to-density ratios (e.g., Garland, 1951; Kanasewich and Agarwal, 1970) and direction of source magnetization (e.g., Ross and Lavin, 1966; Cordell and Taylor, 1971). Wilson (1970) demonstrated that this theorem can be used to separate interfering anomalies if the physical properties of the sources are known. Wilson also demonstrated that Poisson's theorem is useful in investigating source heterogeneity and deformation. Theoretical considerations, however, have generally limited the application of Poisson's theorem to the analysis of single anomalies that are isolated from interference by neighboring or broader scale anomalies. Thus, correlation of regional-scale potential field data sets, including anomalies from a variety of sources, is usually limited to qualitative observations involving visual correlations.

Poisson's theorem can be modified to express the relationship between the total field magnetic intensity anomaly reduced to the pole (T_z) and the gravity anomaly (g),

$$T_z = 1/G(\Delta J/\Delta\sigma)(\delta g/\delta z), \tag{2}$$

where $\delta g/\delta z$ is the first vertical (z) derivative of the gravity anomaly. Thus, the value of the magnetization-to-density ratio ($\Delta J/\Delta\sigma$) for a single anomalous source can be determined at any common point from equation (2) by isolating its gravity and total field magnetic anomalies, calculating the first vertical derivative of gravity, and reducing the magnetic data to the pole, taking into account the direction of magnetization (induced plus remanent).

If regional-scale anomalies with wavelengths much greater than those of the isolated source are present in the data, Poisson's relationship can be approximated by

$$T_z = A + 1/G(\Delta J/\Delta\sigma)(\delta g/\delta z), \tag{3}$$

Presented in part at the 46th Annual International SEG Meeting October 28, 1976 in Houston. Manuscript received by the Editor October 12, 1978; revised manuscript received June 16, 1980.
*Formerly Department of Geosciences, Purdue University, West Lafayette, IN 47907; presently Minnesota Geological Survey, St. Paul, MN 55108.
‡Formerly Department of Geosciences, Purdue University, West Lafayette, IN 47907; presently Mapco Production Company, Billings, MT 59102.
§Department of Geosciences, Purdue University, West Lafayette, IN 47907.

where A is approximately constant and accounts for anomaly base-level changes caused by long-wavelength anomaly components. In a complex data set containing interfering anomalies, spatial segments may exist where the anomalous expression of a particular source is dominant. Within such a segment, the anomaly relationship can be approximated by equation (3). A linear regression of common point values within the segment would then yield an estimate of the $\Delta J/\Delta\sigma$ of the dominant source. The advantages of restricting Poisson's analysis to limited segments of interfering anomalies were briefly discussed by Wilson (1970).

Selection of a segment of the data set where a particular source is dominant is a subjective decision, and the results must be used with appropriate caution. In addition, the assumptions of coincident sources and proper reduction to the magnetic pole will not always be suitably upheld in an actual geologic situation. With these limitations in mind, the remainder of this discussion will illustrate the utility of analyzing multisource data sets, a limited spatial segment at a time, using a moving-window Poisson's analysis.

IMPLEMENTING MOVING-WINDOW POISSON'S ANALYSIS

Basic procedure

The methodology of moving-window Poisson's analysis is summarized in the flow chart in Figure 1. The gravity and magnetic anomaly data sets, either in map or profile form, are digitized at a constant interval and registered. All data must be observed at or continued to a common level. The first vertical derivative of the gravity data and the magnetic data reduced to the pole are calculated, and it is on these data that analysis is performed according to equation (3). It is assumed that the direction of total magnetization is known or can be suitably approximated by the direction of the earth's magnetic field. In the examples to follow, the reduction to the pole, as well as differentiation, continuation, and all other filtering operations, is accomplished in the frequency domain by standard procedures (Baranov, 1957; Bhattacharyya, 1965, 1972).

The operational window (whose size is selected by the user) is initially positioned along a margin of the data set. For profile data the window is a linear segment, whereas for gridded map data it is a square subarea. A least-squares linear regression is performed between the geographically coincident data points within the window. The first vertical derivative of gravity has been arbitrarily assigned as the independent variable for the regression. The regression yields three parameters: correlation coefficient, slope, and intercept. The regression parameters are assigned to a location at the center of the window position. The window is then shifted one grid position and the process is repeated. This operation is repeated until the entire data space has been covered by the moving window and three regression coefficient arrays have been generated.

The correlation coefficient expresses the quality of the linear fit to the observed data for a given window position, and the sign indicates whether the relationship is direct (+) or inverse (−). The most significant linear regression has coefficients approaching ± 1.0. The slope parameter, after correction for G and conversion to cgs units, provides an estimate of the $\Delta J/\Delta\sigma$ for anomaly values within a window position. This ratio is not uniquely definitive of the anomaly source physical properties because it is a function of the physical properties of both the source and the country rock. In addition, varying combinations of ΔJ and $\Delta\sigma$ will yield the same ratio values. However, an accurate $\Delta J/\Delta\sigma$ estimate provides an initial constraint useful to further interpretation such as modeling. Furthermore, if the general distributions of

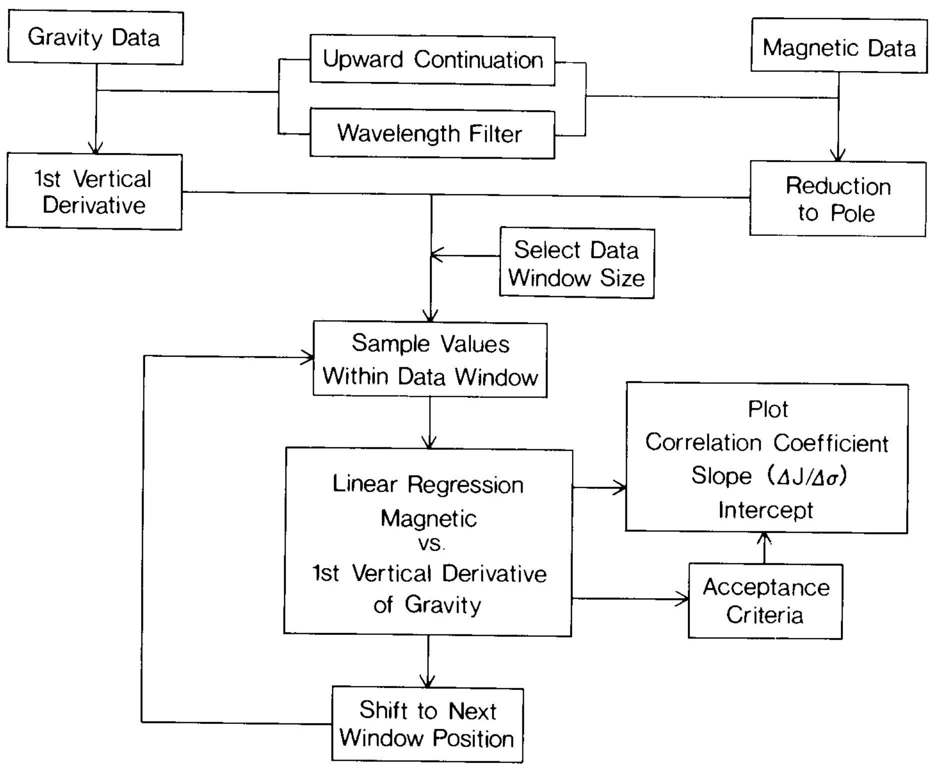

FIG. 1. Moving-window Poisson's analysis procedural flow chart.

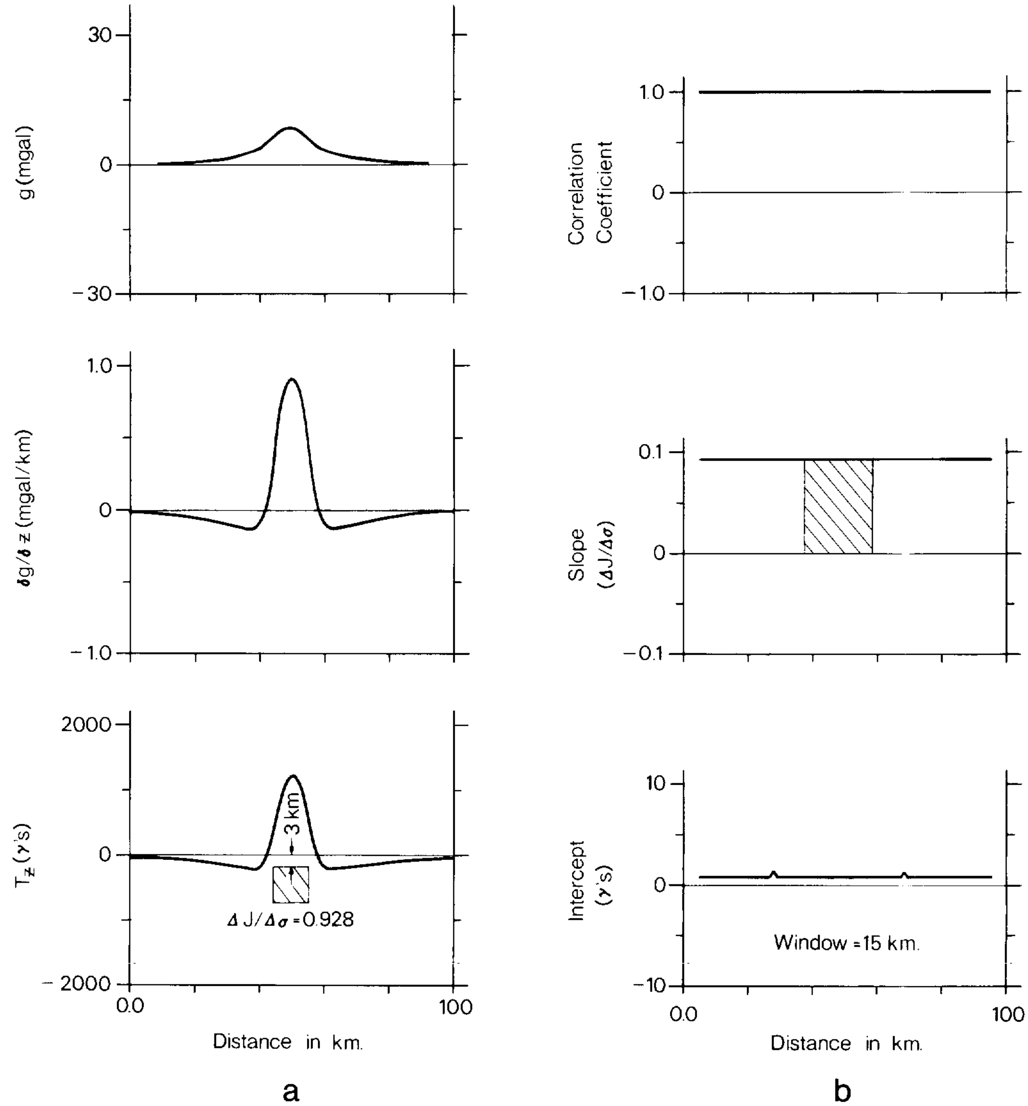

FIG. 2. Analysis of isolated source. (a) Source configuration with anomaly profiles and (b) profiles of regression coefficients from moving window Poisson's analysis. Patterned bars on the slope profile represent position and actual $\Delta J/\Delta\sigma$ value.

density and magnetization are known for the rocks of an area, an accurate $\Delta J/\Delta\sigma$ estimate can be used to assign possible lithologies to a locally concealed gravity and magnetic anomaly source. The spatial behavior of the intercept parameter is sensitive to anomaly interference and can reflect anomaly base-level changes caused by regional anomalies.

Selection of window size

The choice of optimum window size involves an interplay between the number of data points necessary to achieve a credible linear regression, which constitutes a lower limit in window size, and the interference from neighboring anomalies, which constitutes an upper limit. Ideally, the window size should be sufficiently small to allow several window positions within the high-gradient limbs of the anomalies to be analyzed, thereby allowing a consistency check among adjacent $\Delta J/\Delta\sigma$ estimates. Thus, before selecting the window size, the interpreter must consider the data interval and the average wavelength of the anomalies of primary interest. In the examples to follow, suitable results have been obtained with windows that include at least five data points and that are between 0.5 and 1.0 times the half-width of the anomalies of primary interest.

Recognition of significant $\Delta J/\Delta\sigma$ estimates

Due to the interfering anomalies of multisource data sets, the results of moving-window Poisson's analysis will consist of both geologically significant and spurious $\Delta J/\Delta\sigma$ estimates. There are no quantitative criteria for discriminating correct values of $\Delta J/\Delta\sigma$ ratios, but emphasis should be focused on results from the high-gradient limbs of spatially matched gravity and magnetic anomalies. In these areas an anomaly source is at maximum signal above anomaly interference, and the resulting $\Delta J/\Delta\sigma$ estimates are most likely to be significant. Furthermore, these regions should be checked for high correlation coefficient magnitudes and spatially stable $\Delta J/\Delta\sigma$ and intercept values. Stability in the slope and intercept parameters over several window positions implies the dominance of a particular anomaly. In transition zones between the dominance of adjacent anomalies, the regression parameters, especially the intercept, become spatially unstable,

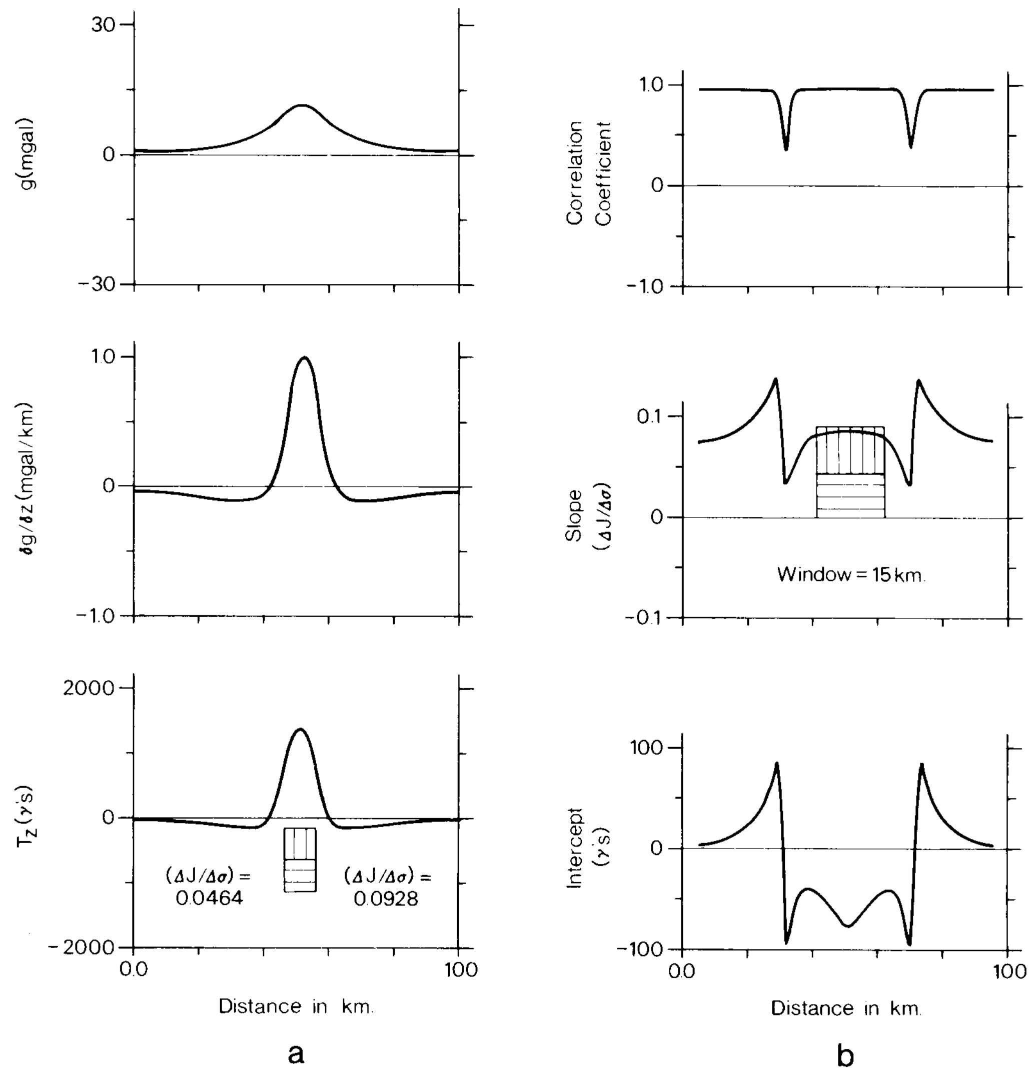

FIG. 3. Analysis of two vertically superimposed sources. (a) Source configuration with anomaly profiles and (b) profiles of regression coefficients from moving-window Poisson's analysis. Levels of patterned bars on slope profiles represent actual $\Delta J/\Delta\sigma$ values of sources.

exhibiting marked local fluctuations. This characteristic is illustrated in the following model studies.

MODEL STUDIES

Model studies assuming two-dimensional (2-D) (strike infinite) sources were used to investigate the utility of moving-window Poisson's analysis. All sources are uniform in character and are polarized by a vertical magnetic field of 58,000 gamma.

Isolated anomaly source

The gravity and magnetic anomalies and the moving-window regression parameter profiles of an isolated source are shown in Figure 2. The source is 10×10 km in cross-section and the top is 3 km below the observation surface. The density and magnetization contrasts of the source are 0.05 and 0.0046 cgs, respectively. The sampling interval was 1 km, and the window size selected was 15 km. The moving-window Poisson's analysis results in this model have a correlation coefficient of essentially 1.0 or nearly perfect direct correlation and yield correct estimates of $\Delta J/\Delta\sigma$ over the source. The intercept is essentially nil.

Vertical superposition of anomaly sources

In the case of anomaly interference, a $\Delta J/\Delta\sigma$ estimate is a weighted average of the involved sources and will be most heavily weighted toward the source, causing the largest anomaly component. The anomalies and moving-window regression parameters for two vertically superimposed sources are shown in Figure 3. Each source is 10×10 km in cross-section and has a magnetization contrast of 0.0046 cgs. The density contrasts for the upper and lower sources are 0.05 and 0.10 cgs, respectively. The top of the upper source is at a depth of 3 km, whereas the top of the lower source is at a depth of 13 km. The resulting combined anomalies are simple in form and could be misinterpreted as arising from a single, uniform source. Sampling interval for the profile is 1 km.

Analysis of the combined anomalies using a window of 15 km reveals the actual complexity of what appeared to be a simple anomaly (Figure 3). The resulting regression parameter profiles show variable patterns, in contrast to the results of the analysis of the isolated source in Figure 2. The $\Delta J/\Delta\sigma$ estimates are not exactly correct for either source, but near the center of the profile the estimates approximate the $\Delta J/\Delta\sigma$ value of the shallower, more dominant source. The intercept profile shows a pronounced minimum at the center of the profile, reflecting in part the apparent change in anomaly base level for the upper source caused by the deeper source.

Horizontal superposition of anomalies

The anomalies and analysis results for a model consisting of four horizontally distributed pairs of sources are shown in Figure 4. All sources are 5 $\times$ 5 km in cross-section and have magnetization contrasts of 0.0046 cgs. The depth of all source tops is 3 km. Each source pair includes bodies with density contrasts of 0.05 and 0.10 cgs. Sampling interval was 1 km. From left to right, the anomaly sources become closer until, at the extreme right, the sources are actually in contact. The combined anomalies at the extreme right might be mistaken from strictly visual evaluation as arising from a single, essentially uniform source.

Using a window of 5 km, a moving-window Poisson's analysis

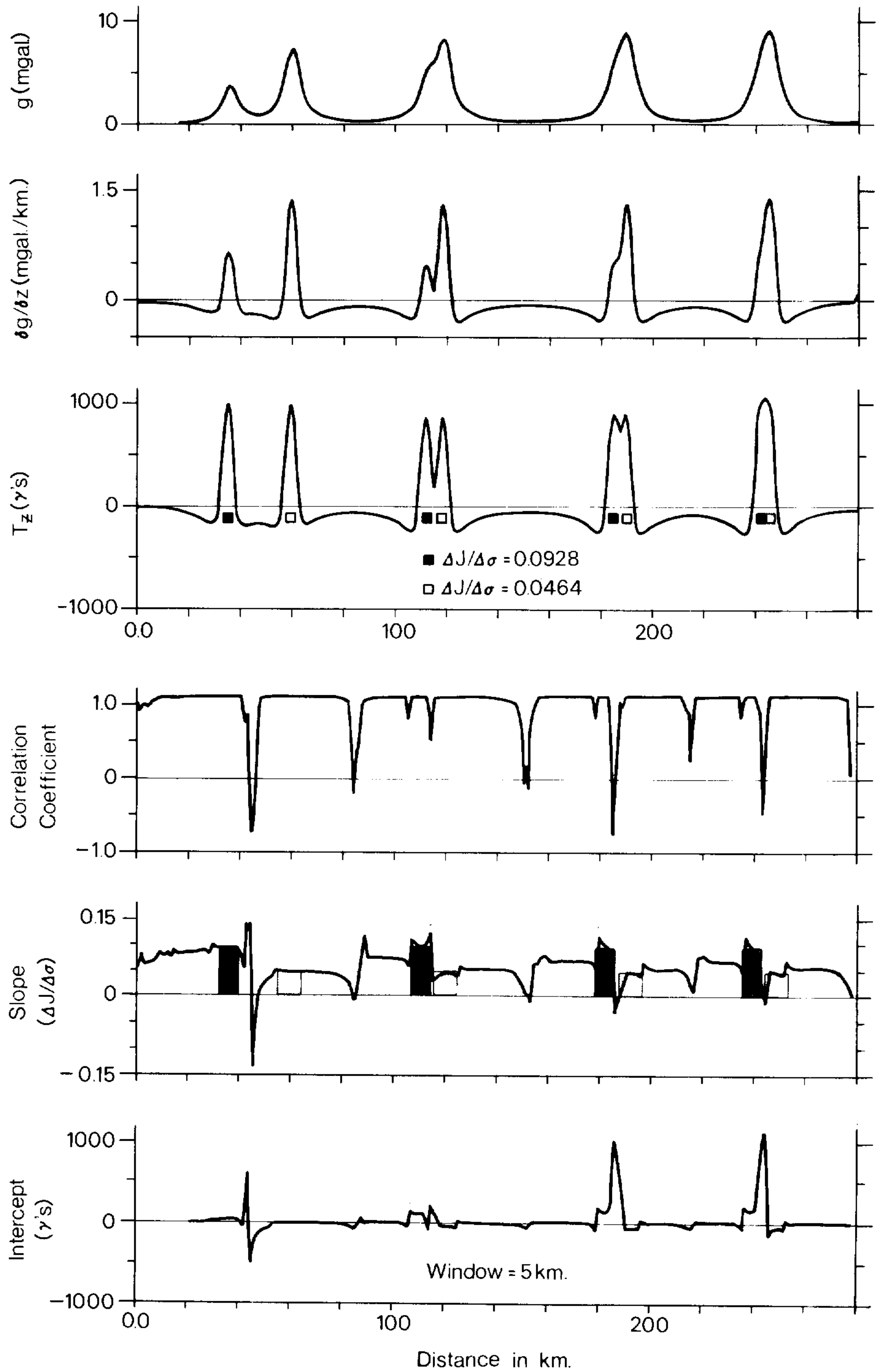

FIG. 4. Anomaly and regression coefficient profiles of two vertically polarized, 2-D sources separated by varying distances. Levels of patterned bars on slope profile represent actual $\Delta J/\Delta\sigma$ values of sources.

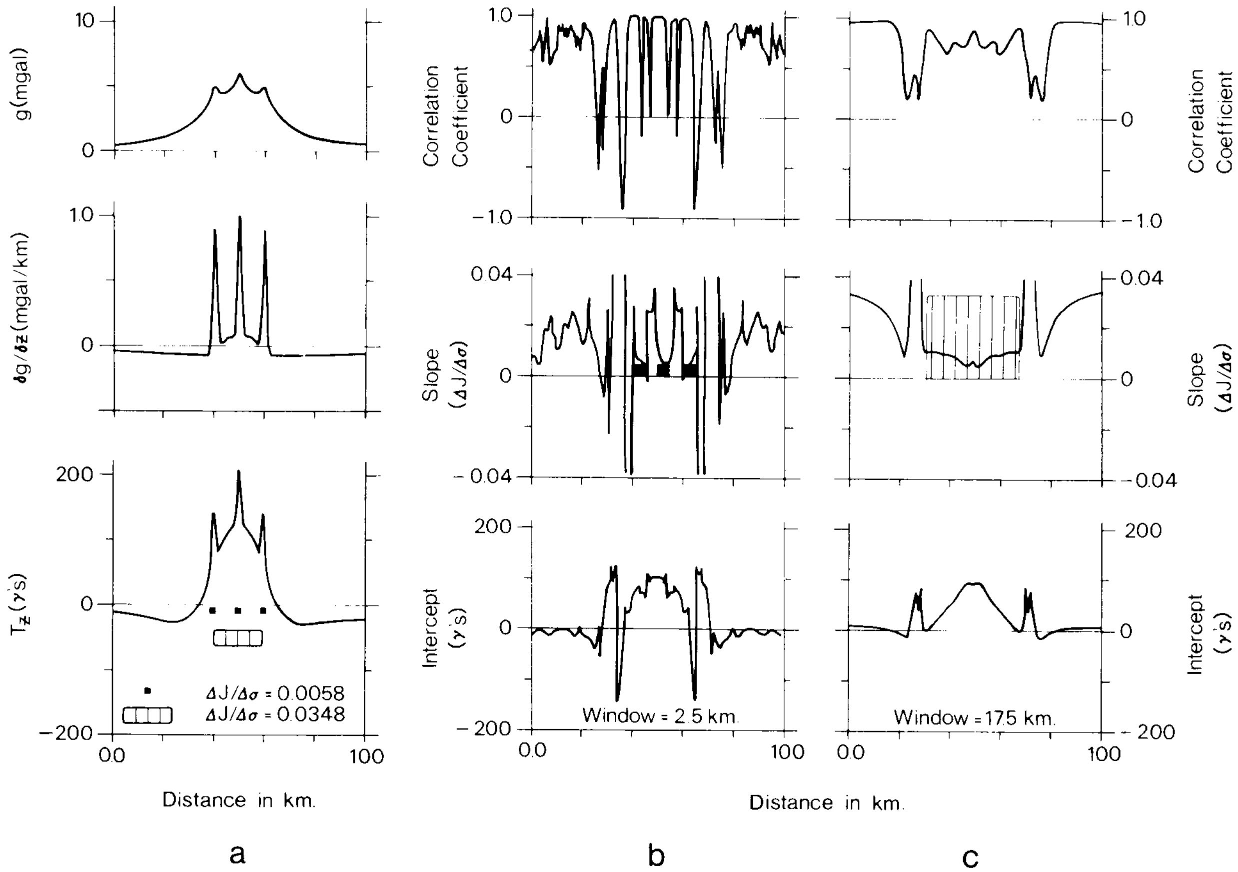

FIG. 5. Analysis of anomalies with differing wavelength characteristics. (a) Source configuration with anomaly profiles and profiles of regression coefficients from moving-window Poisson's analysis using (b) a 2.5-km window and (c) a 17.5-km window. Levels of patterned bars on slope profiles represent actual $\Delta J/\Delta\sigma$ values of sources.

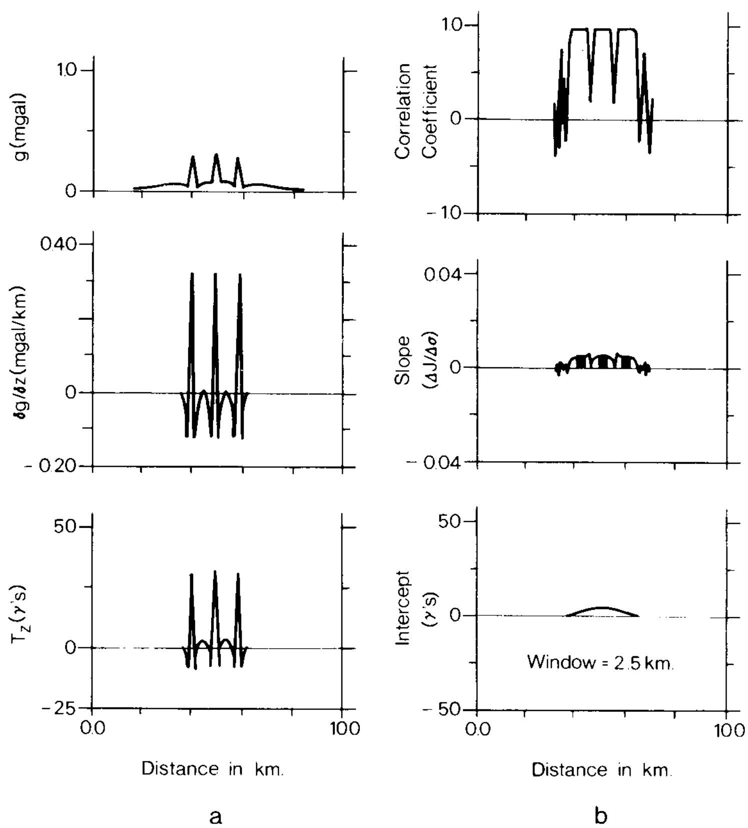

FIG. 6. Analysis of high-pass filtered data. (a) Anomaly profiles filtered to pass wavelengths of less than 4 km and (b) profiles of regression coefficients from moving-window Poisson's analysis. Levels of patterned bars on slope profiles represent actual $\Delta J/\Delta\sigma$ values of shallow sources.

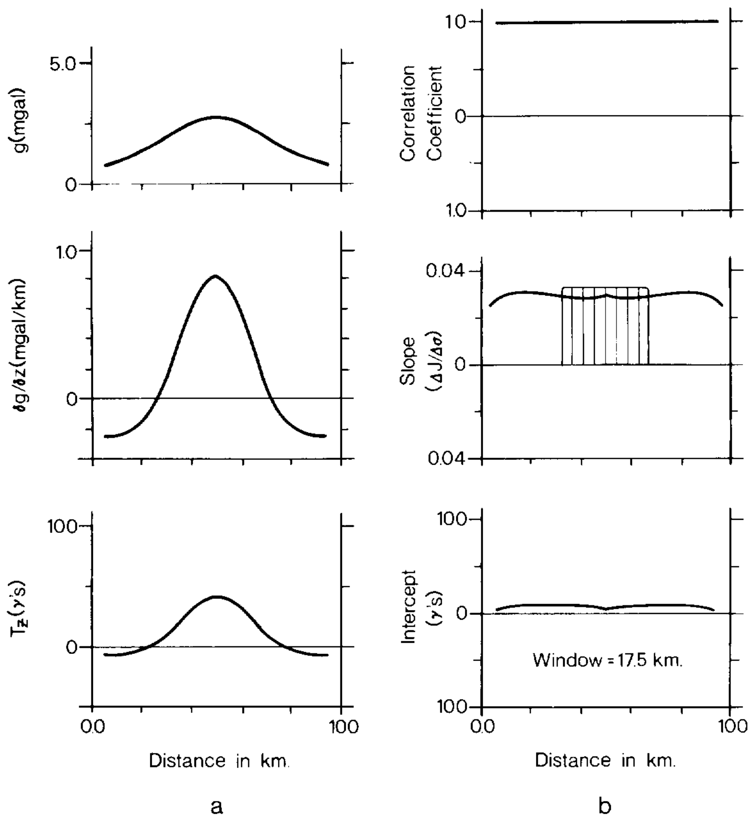

FIG. 7. Analysis of upward continued data. (a) Anomaly profiles upward continued to 15 km and (b) profiles of regression coefficients from moving-window Poisson's analysis. Level of patterned bar on slope profile represents the actual $\Delta J/\Delta\sigma$ of the deep source.

of this profile yields numerous $\Delta J/\Delta\sigma$ estimates that are not representative of any specific source. However, by restricting attention to the areas directly above the sources, approximately correct values are obtained from each source pair. These approximately correct values are associated with the high-gradient limbs of the anomalies, large-magnitude correlation coefficients, and nonzero but locally level intercept values. The results for the source pair at the extreme right imply that the moving-window Poisson's analysis procedure is useful in recognizing anomaly source heterogeneity and may, in some cases, allow approximately correct $\Delta J/\Delta\sigma$ estimates of the source components.

Enhancement by filtering

Interference caused by anomalies of widely different wavelengths can lead to confusing or erroneous Poisson's analysis results. Wavelength filters used as preprocessing steps to enhance data components of interest can improve results. The anomalies and regression parameter profiles of a model employing various source sizes and depths are shown in Figure 5. The longer wavelength components of the data are caused by a 2-D source, 5 × 20 km in cross-section at a depth to top of 20 km, which has a $\Delta J/\Delta\sigma$ ratio of 0.0348. Above the deep source, at a depth to top of 1.0 km, are three sources, all having a 1 × 1 km cross-section and $\Delta J/\Delta\sigma$ ratios of 0.0058. Sampling interval is 0.5 km.

Assuming that the shallower sources are of interest, an analysis was performed using a narrow window of 2.5 km. Over the shallow sources in Figure 5b, the moving-window analysis yields approximately correct $\Delta J/\Delta\sigma$ estimates. The interference from the deeper source, however, tends to obscure the results. Assuming that the deeper source is of interest, an analysis was conducted using a broader window of 17.5 km (Figure 5c). The results of the analysis indicate that interference from the shallow sources prevents accurate $\Delta J/\Delta\sigma$ estimates of the deeper source.

Poisson's theorem is, in theory, independent of anomaly wavelength considerations and thereby allows separation of anomalies by filtering. To enhance the analysis of the shallower sources, the gravity and magnetic data were high-pass filtered to emphasize wavelengths of 4 km or less. The filtered data and the resulting analysis at a window size of 2.5 km are shown in Figure 6. The attenuation of the long-wavelength interference has considerably improved the Poisson's analysis results for the shallower sources. The gravity and magnetic data were also upward continued 15 km to minimize the anomaly components from the shallower sources. The upward continued data and the results of the analysis using a window size of 17.5 km are shown in Figure 7. Values for $\Delta J/\Delta\sigma$ over the body are 10 to 12 percent lower than the correct value, but they are a much improved estimate considering that no values were acceptable from analysis of the raw data.

APPLICATION TO OBSERVED DATA

Anomaly in Lake County, Michigan

The Bouguer gravity, total field magnetic anomaly, and calculated first vertical derivative of gravity data from a 900 km^2 area in Lake County, Michigan are shown in Figures 8a, 8b, and 8c, respectively. The dominant feature in the data is a gravity and magnetic anomaly which arises from an unknown source in the basement complex. In this area the basement complex lies concealed beneath approximately 1.5 km of low-dip Paleozoic sedimentary rocks. The data were digitized at a grid interval of 1.61 km. The data were upward continued to 1 km prior to analysis, and reduction to the pole was accomplished assuming magnetization along the earth's magnetic field with an inclination of +75 degrees and a declination of 1°W.

The data were digitized from maps compiled by Meyer (1963) who conducted a ground-based gravity and magnetic survey at an approximate interval of 1.61 km. Using Garland's (1951) traditional approach, Meyer employed Poisson's theorem to calculate a $\Delta J/\Delta\sigma$ estimate of 0.013 cgs for the anomalous source after isolating residual anomalies. Using the calculated ratio as a constraint, Meyer postulated that the anomalous source was probably a stock of mafic intrusive, possibly related to Keweenawan (Late Precambrian) igneous activity.

Moving-window Poisson's analysis was also conducted on the upward continued (to 1 km) data using a window of 4.8 × 4.8 km. The resulting slope, correlation coefficient, and intercept

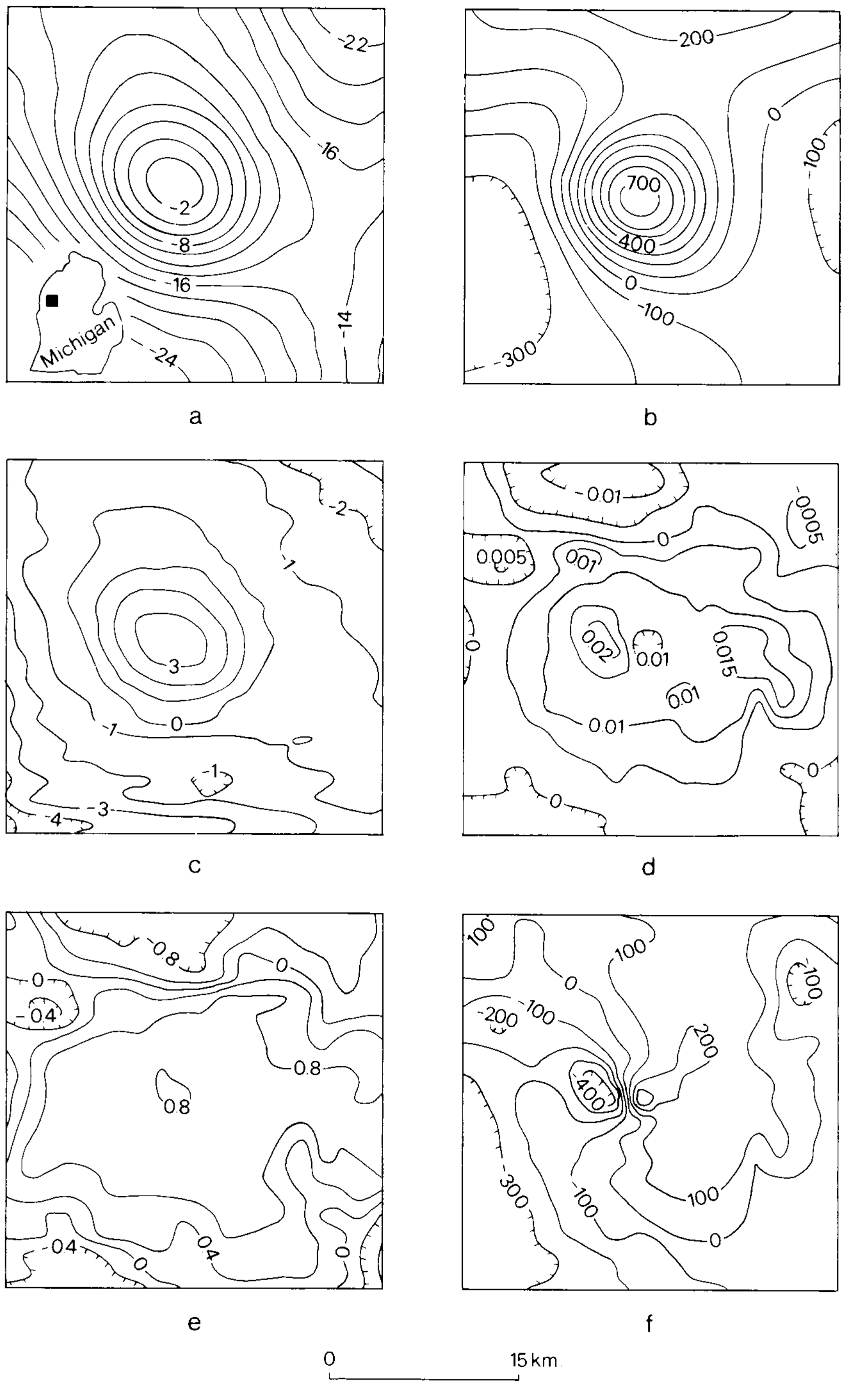

FIG. 8. Anomaly and regression coefficient maps of the Lake County, Michigan anomaly. Map (a) is the Bouguer gravity anomaly, contour interval 2 mgal; map (b) is total magnetic intensity anomaly reduced to the pole, contour interval 100 gamma; map (c) is first vertical derivative of gravity, contour interval 1 mgal/km. All anomaly data have been upward continued to 1 km. Map (d) is the $\Delta J/\Delta\sigma$ map, contour interval 0.005; map (e) is the correlation coefficient map, contour interval 0.4; map (f) is the intercept map, contour interval 100 gamma.

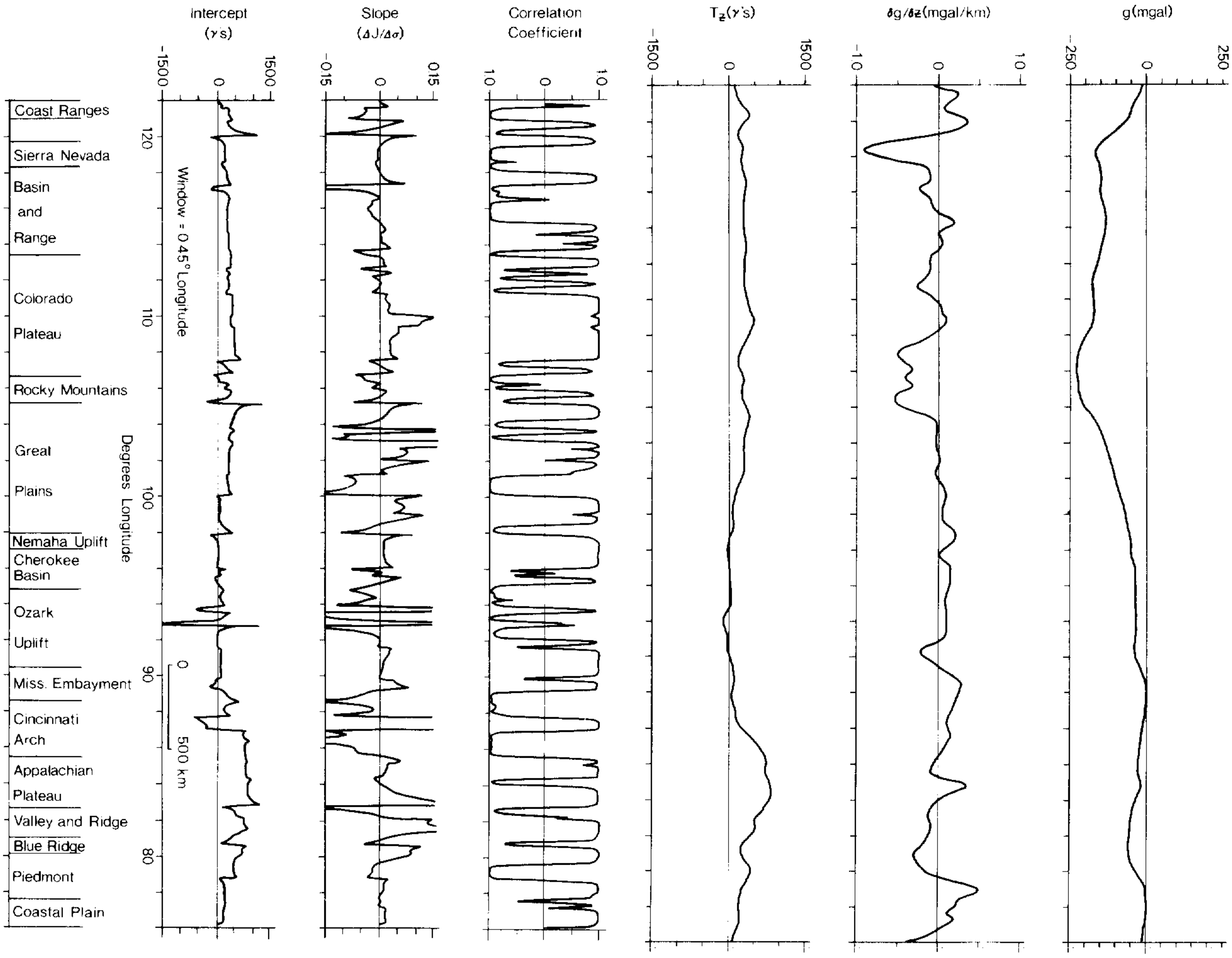

FIG. 9. Anomaly and regression coefficient profiles across the United States along the 37th parallel of north latitude. Generalized geologic provinces are indicated at the bottom.

maps are shown, respectively, in Figures 8d, 8e, and 8f. Over most of the anomalous area, correlation coefficient values approach ± 1.0 and intercept values are locally constant. Over the areas corresponding to the high-gradient flanks of the gravity and magnetic anomaly, the $\Delta J/\Delta\sigma$ estimates average near 0.011. Thus, the $\Delta J/\Delta\sigma$ estimates over much of the anomalous area closely approximate the value obtained by Meyer in his Poisson's analysis. However, the moving-window approach did not necessitate the time-consuming regional-residual anomaly separation prior to analysis. The western margin of the anomalous area displays an increase in $\Delta J/\Delta\sigma$ values and a sharp break in intercept values. This variation in the regression parameters suggests a complication in source characteristics, perhaps a magnetization-density heterogeneity localized along the western margin of the anomalous source.

Transcontinental gravity and magnetic anomaly profile

Bouguer gravity and magnetic anomaly data across the United States along the 37th parallel of north latitude (Zietz and Kirby, 1965) were upward continued to a level of 40 km and subjected to moving-window Poisson's analysis to investigate regional crustal structure. The original anomaly profiles were sampled at an interval of 0.05 degrees longitude (4.48 km). The total magnetic anomaly data were obtained by subtracting the 1955 epoch geomagnetic reference field of the U.S. Coast and Geodetic Survey from the observed data. The data were reduced to the pole using mean declination and inclination values over 12 degrees of longitude overlapping segments of data. The overlap was 4 degrees on either end of the segments, and values in these regions were averaged to provide the smoothest join.

The anomaly data were upward continued to a level of 40 km to emphasize the contribution of regional crustal features. The anomaly data and results of moving-window Poisson's analysis at a window size of 0.45 degrees longitude (40.3 km) are presented in Figure 9. Generalized geologic provinces are not necessarily directly related to basement and upper crustal geology as delineated by gravity and magnetic data, but several segments of relatively consistent $\Delta J/\Delta\sigma$ values in Figure 9 do correlate with geologic provinces. Examples are the Sierra Nevada batholith, the Colorado Plateau, the Nemaha uplift, and the Atlantic coastal plain. These areas are associated with regions of correlation coefficient values approaching ± 1.0. The local consistency of $\Delta J/\Delta\sigma$ and intercept values implies that the long-wavelength anomalies are caused by sources of province dimensions within the crust that are approximately homogeneous at this level of observation.

The central portion of the Sierra Nevada batholith province is one of the regions on the profile which possesses a strong negative correlation. This is caused by a spatially matched positive magnetic anomaly and a negative gravity anomaly related to the granitic rocks. This segment has approximately constant apparent $\Delta J/\Delta\sigma$ values between -0.007 and -0.009. Both the eastern and western borders of this region are marked by strong interference patterns in the slope and intercept parameters. It is noteworthy that the results indicate a possible boundary between the Sierra Nevada batholith province and the Basin and Range province about one degree east of the boundary on Figure 9. The eastern extension of the Sierra Nevada province in the subsurface is evidenced by partially buried satellite intrusive bodies related to the Sierra Nevada batholith (Zietz et al, 1969). The Colorado Plateau region between longitude 107.5 and 111°W is characterized by gravity and magnetic maxima and the widest zone of strong positive correlation along the profile. Three major suites of apparent $\Delta J/\Delta\sigma$ values are implied on the slope plot with the central zone reaching values in excess of $+0.1$. The marginal areas of the Colorado Plateau are marked by weak and rapidly varying correlations and irregular slope and intercept patterns. The Nemaha uplift-western Cherokee basin area of the Great Plains exhibits strong positive correlation and constant apparent $\Delta J/\Delta\sigma$ values of approximately $+0.011$. This positive correlation originates from gravity and magnetic minima. Over the Piedmont and Atlantic coastal plain, the correlation coefficients are positive due to gravity and magnetic maxima, and the intercept and slope parameters are locally constant. Here the apparent $\Delta J/\Delta\sigma$ values are consistently near $+0.016$.

Analysis of the 37th parallel profile has yielded results that are significantly related to known crustal features and the associated $\Delta J/\Delta\sigma$ estimates could provide a starting point for further interpretation such as modeling. However, even the recognition of spurious results due to the lack of correlation of gravity and magnetic anomalies may be useful to the interpreter for identifying possible anomaly sources and physical properties. Examples include sources in which strong remanent magnetization does not coincide with the earth's magnetic field; temperatures which exceed the Curie point of the ferromagnetic minerals, thus largely eliminating the rock magnetization; and sources of gravity anomalies which occur within nonmagnetic sedimentary rocks. Moreover, the intercept parameters may provide additional information regarding anomaly base levels. For example, on the 37th parallel anomaly profile, the consistently high intercept value west of longitude 100°W indicates changes in effective anomaly base levels caused by extremely long-wavelength anomaly components which may be a result of removal of an incorrect geomagnetic reference field.

CONCLUSIONS

The moving-window Poisson's analysis technique based on linear regression of the total magnetic anomaly reduced to the pole and the first vertical derivative of gravity can be used to calculate accurate $\Delta J/\Delta\sigma$ estimates from multisource gravity and magnetic anomaly data sets. Time-consuming anomaly isolation procedures can thereby be avoided. Analysis of data sets having anomalies of widely different wavelength characteristics may be enhanced by appropriate wavelength filtering. An accurate estimate of $\Delta J/\Delta\sigma$ provides an initial constraint for further interpretation such as modeling. When combined with existing geologic and rock-property data, it could serve as a useful supplement to geologic interpretation. Gravity and magnetic data are now commonly digitized and gridded as standard procedure, and moving-window analysis could readily be included.

ACKNOWLEDGMENTS

The authors acknowledge valuable discussion and manuscript review by several colleagues that has led to improvement of this paper. This study was supported in part by the Goddard Space Flight Center (NASA). Special thanks are given to I. Zietz and J. R. Kirby of the U. S. Geological Survey for providing magnetic data.

REFERENCES

Baranov, V., 1957, A new method for interpretation of aeromagnetic maps; Pseudogravimetric anomalies: Geophysics, v. 22, p. 359–382.
Bhattacharyya, B. K., 1965, Two-dimensional harmonic analyses as a tool for magnetic interpretation: Geophysics, v. 30, p. 829–857.
——— 1972, Design of spatial filters and their application to high-resolution aeromagnetic data: Geophysics, v. 37, p. 68–91.
Cordell, L., and Taylor, P. T., 1971, Investigation of magnetization and density of a North American seamount using Poisson's theorem: Geophysics, v. 36, p. 919–937.
Garland, G. D., 1951, Combined analysis of gravity and magnetic anomalies: Geophysics, v. 16, p. 51–62.
Kanasewich, E. R., and Agarwal, R. G., 1970, Analysis of combined gravity and magnetic fields in the wave number domain: J. Geophys. Res., v. 75, p. 5702–5712.
Meyer, H. J., 1963, A combined magnetic and gravity analysis of the sauble anomaly, Lake County, Michigan: M.S. thesis, Michigan State Univ., 55 p.
Poisson, S. D., 1826, Mémoire sur la théorie du magnétisme: Mémoires de l'Académie Royale des Sciences de l'Institut de France, p. 247–348.
Ross, H. P., and Lavin, P. M., 1966, In-situ determination of the remanent magnetic vector of two-dimensional tabular bodies: Geophysics, v. 31, p. 949–962.
Wilson, G. D. V., 1970, The use of the Poisson relationship for separating the anomalies due to neighboring bodies, and for recognizing inhomogeneities and structural deformation: Bull. de Geofig. Teor. ed Apl., v. 12, p. 158–182.
Zietz, I., and Kirby, J. R., 1965, Aeromagnetic and gravity profiles of the United States along the 37th parallel: A contribution to the Upper Mantle Project: U.S.G.S. geophys. inv. map GP-597.
Zietz, I., Case, J. E., Crittenden, M. D., Jr., Griscom, A., King, E. R., Roberts, R. J., and Lorentzen, G. R., 1969, Aeromagnetic investigation of crustal structure for a strip across the western United States: GSA Bull., v. 80, p. 1703–1714.