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GEOPHYSICAL INVESTIGATIONS MAP
GP-963

## INTRODUCTION

A complete Bouguer gravity-anomaly map of Ohio at a scale of 1:500,000 (Hildenbrand and Kucks, 1984) was recently prepared from a data set containing 6,591 gravity stations. Map A is a colored version of this map at a reduced scale of 1:1,000,000. All gravity values are adjusted to conform to the International Gravity Standardization Net of 1971 (Morelli and others, 1974). Bouguer gravity anomaly values were computed using the 1967 gravity formula (International Association of Geodesy, 1967) and a Bouguer reduction density of 2.67 g/cm$^3$.

Accompanying the Bouguer anomaly map is a set of four filtered gravity anomaly maps. Filtering analysis in geophysical applications involves conversion of the data into a form that enhances particular anomaly characteristics, such as wavelength or trend. I have considered here three filtering operations: (1) regional-residual anomaly separation by wavelength analysis, an attempt to separate near-surface sources from deep sources; (2) a first-vertical- derivative operation to sharpen anomalies of small areal extent; and (3) horizontal gravity gradient determination to delimit lithologic or structural boundaries. New interpretative information may be obtained by studying the filtered anomaly maps, but they have their limitations and thus should be used with caution and only in a qualitative analysis. More detailed discussions on the usefulness of the compiled maps (Maps B–E) are given below.

The unfiltered data set used in the filtering process was gridded at a spacing of 2 km (1.24 mi) (Hildenbrand and Kucks, 1984). A computer program using the principal of Fourier analysis (Hildenbrand, 1983) was utilized to compile the wavelength-filtered and first-vertical-derivative data sets. After filtering, the gridded data were plotted using Applicon Incorporated[1] proprietary color software. A Lambert conformal conic projection (standard parallels of 33° N. and 45° N.) with a central meridian of 83° W, was used to prepare all maps.

## FILTERED ANOMALY MAPS

### Regional-residual gravity anomaly separation

A gravity-anomaly map exhibits the effects of bodies of distinctive density, which may have varying shapes, dimensions, and burial depths. In any region the gravity field is usually caused by the superposition of the overlapping gravitational effects of many bodies whose individual gravity anomalies may be difficult to separate. The terms "residual" and "regional" are arbitrary with respect to scale but are used to make a distinction between anomalies arising from local, near-surface masses and those arising from larger and usually deeper features, respectively. There are many methods for preparing regional and residual maps (Grant, 1972). For this study I chose a general wavelength (or frequency) filtering method to obtain a separation of long-wavelength anomalies (regional) that are typically associated with deep-crustal or subcrustal features, from short-wavelength anomalies (residual) that are associated with shallow features. I am aware, however, that the separation is not complete and that in particular some long-wavelength anomalies can be caused by broad shallow features. The short wavelengths on the residual maps bring out and emphasize small features, but in many cases the anomaly amplitudes are distorted by the removal of the long wavelengths (Kane and Godson, 1985).

The gridded data were transformed to the frequency domain by fast Fourier transform and then were low-pass filtered (Hildenbrand, 1983). The low-pass filter used a simple rectangular window, modified so that the gain of the filter drops from one to zero along a ramp centered at the cut-off wavelength. The ramp was located between 75 and 125 km; the cutoff wavelength was 100 km. The regional (low-pass) field (Map B) was calculated by taking the inverse Fourier transform of the product of the low-pass filter and the Fourier-transformed Bouguer gravity field. The residual field (Map C) was calculated by subtracting the computed regional field from the unfiltered gravity field.

### First-vertical-derivative operation

In areas of steep, broad gravity gradients, small anomalies (related to near-surface features) and other subtle features or trends tend to escape notice on the gravity-anomaly map. This is especially the case for features having amplitudes less than 5 mgals, which is the color-contour interval of Map A. To resolve small-wavelength anomalies, a first-vertical- derivative filter (Bhattacharyya, 1966) was applied to the gravity data. Unlike the filter used in the preparation of the residual gravity-anomaly map (Map C), the first-vertical-derivative filter magnified the amplitude of small-wavelength anomalies. The anomaly map of the first vertical derivative shown in Map D thus enhances local features and reduces the effects of regional gradients.

[1] Use of a specific brand name does not necessarily constitute endorsement of the product by the U.S. Geological Survey.

### Horizontal gravity gradient determination

Lithologic and structural boundaries are often difficult to accurately locate on gravity-anomaly maps, especially contacts expressed as broad gradients. Cordell (1979) made use of horizontal gravity gradient maxima to resolve this problem of ambiguity in mapping graben-bounding faults. The magnitude of the horizontal gradient g' is determined by a computer program (R.W. Simpson, U.S. Geological Survey, unpub. data) using the following equations:

$$|g'(x,y)| = \sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2},$$

$$\frac{\partial g}{\partial x} \simeq \frac{g_{i+1,j} - g_{i-1,j}}{2\Delta x},$$

and

$$\frac{\partial g}{\partial y} \simeq \frac{g_{i,j+1} - g_{i,j-1}}{2\Delta y},$$

where x is the longitudinal coordinate, y is the latitudinal coordinate, and g is the gravity field defined at grid point i,j as $g_{i,j}$. The basic principle of Cordell's method is that the inflection point of a gradient, and thus the maximum gradient, occurs immediately over a vertical density inho-mogeneity or contact. (If the contact dips or if contribution from adjacent sources is significant, the maximum gradient will be shifted a certain distance from the contact). On the gravity-gradient map (Map E), lines drawn along ridges formed by enclosed high-gradient magnitudes thus generally correspond to properly located contacts.

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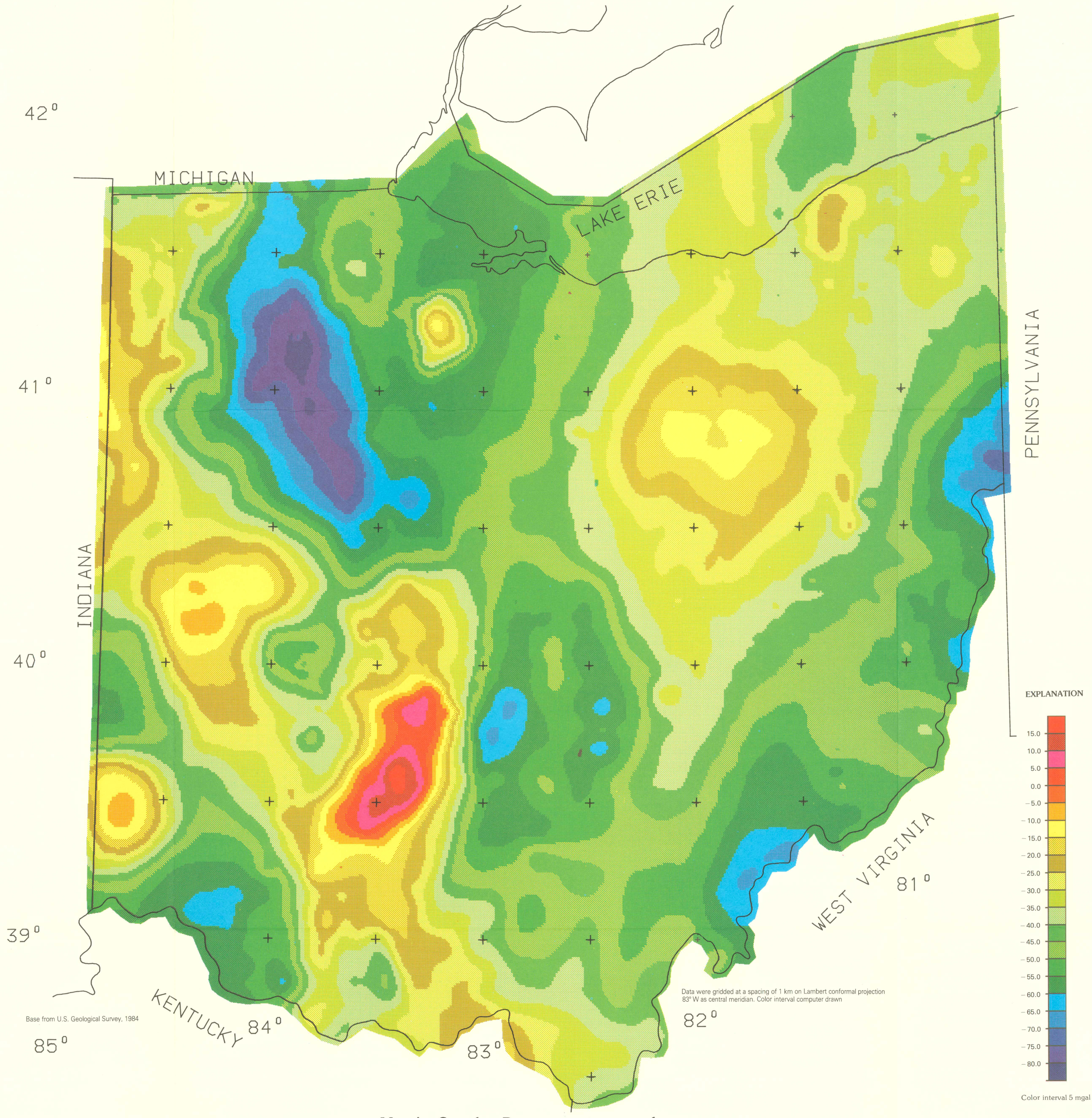
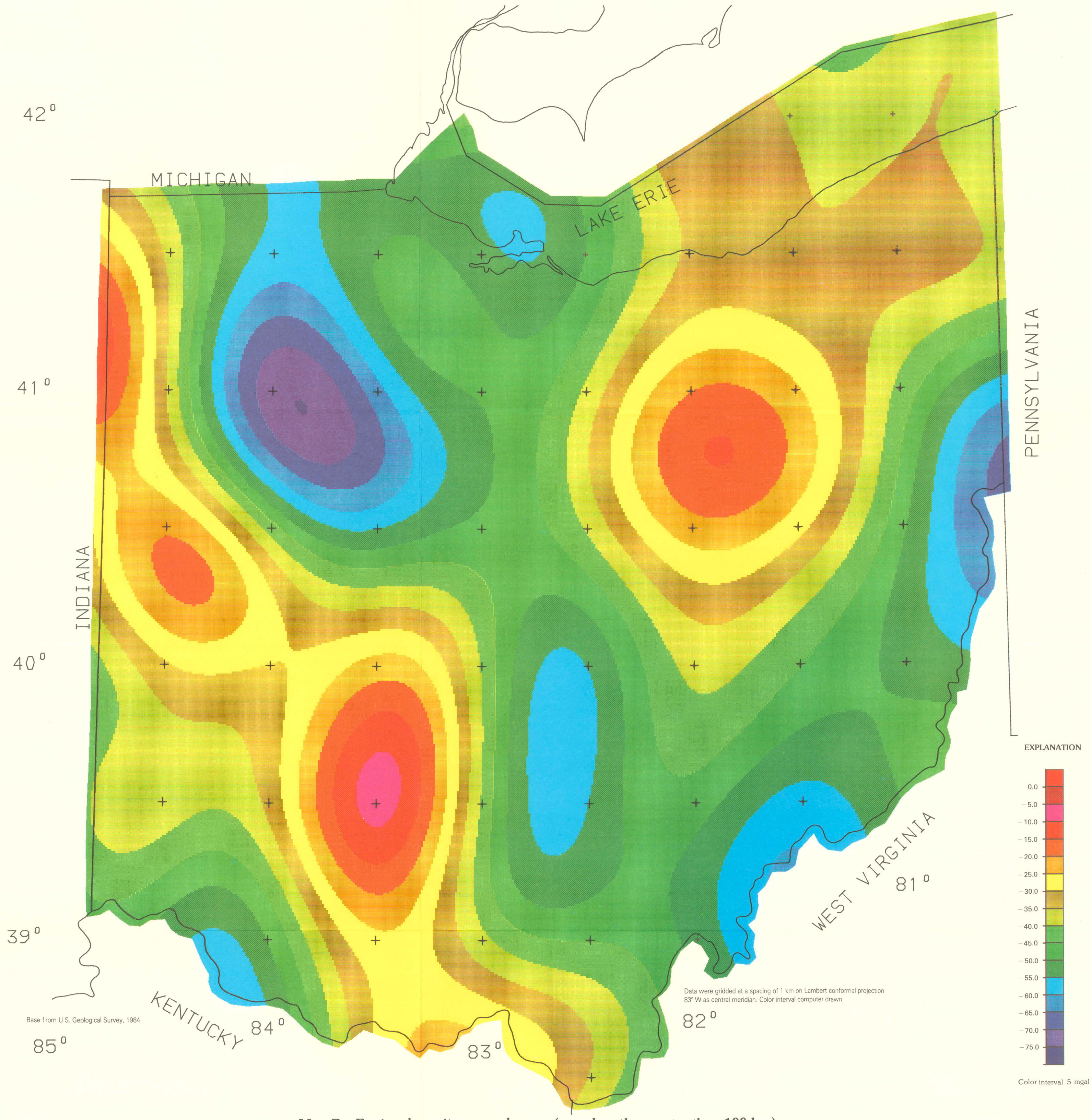
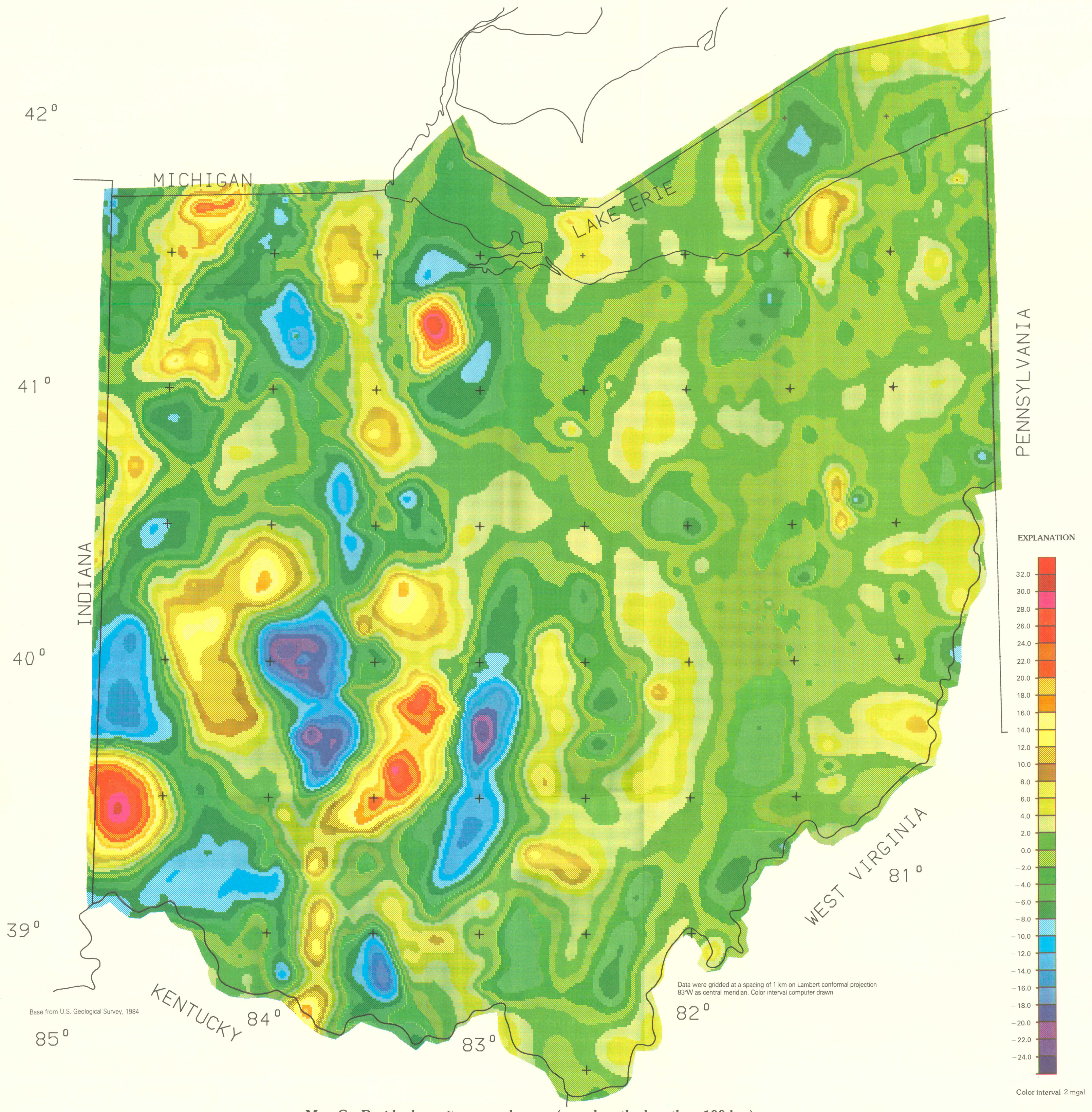


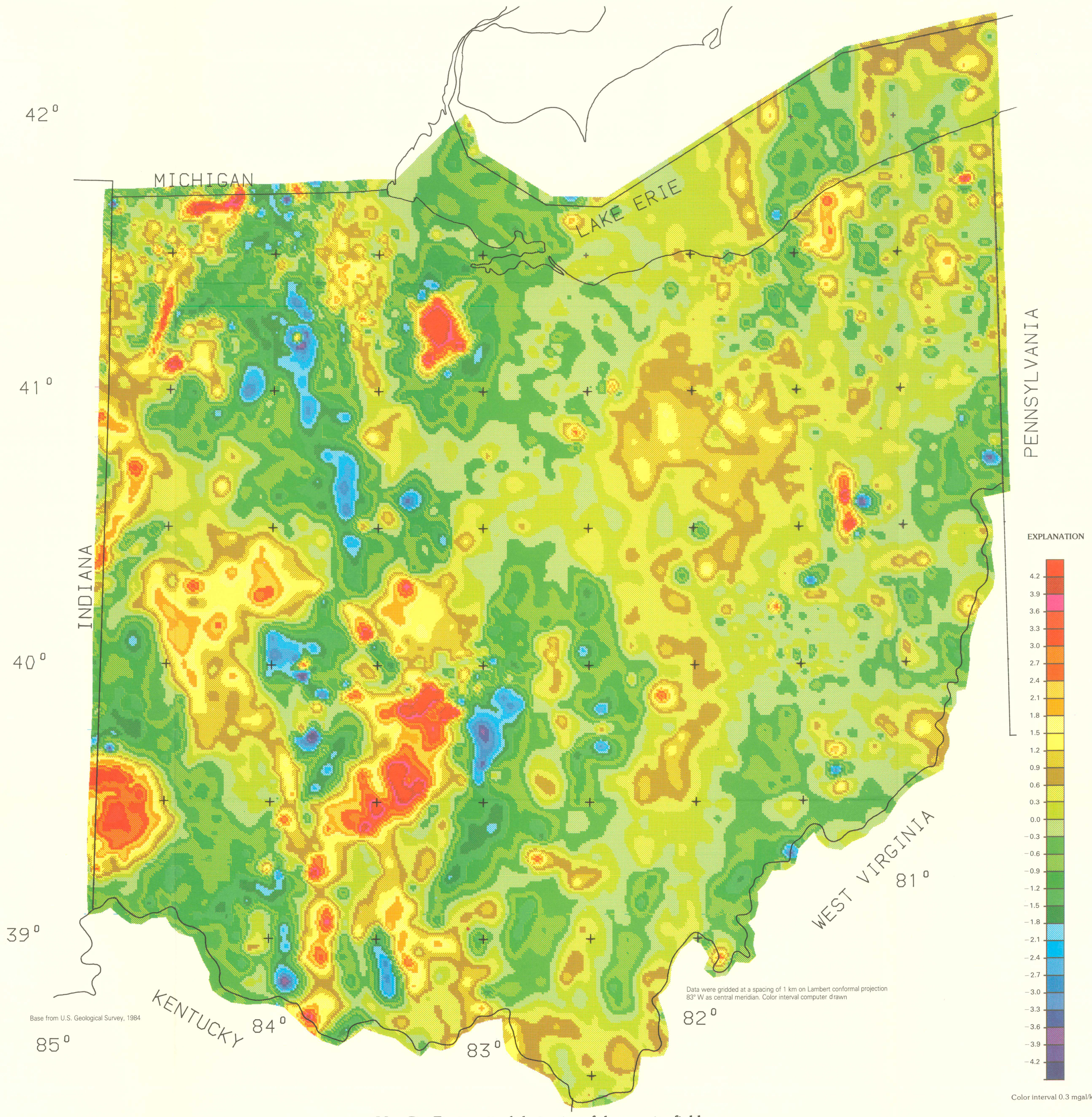

Map A—Complete Bouguer gravity-anomaly map



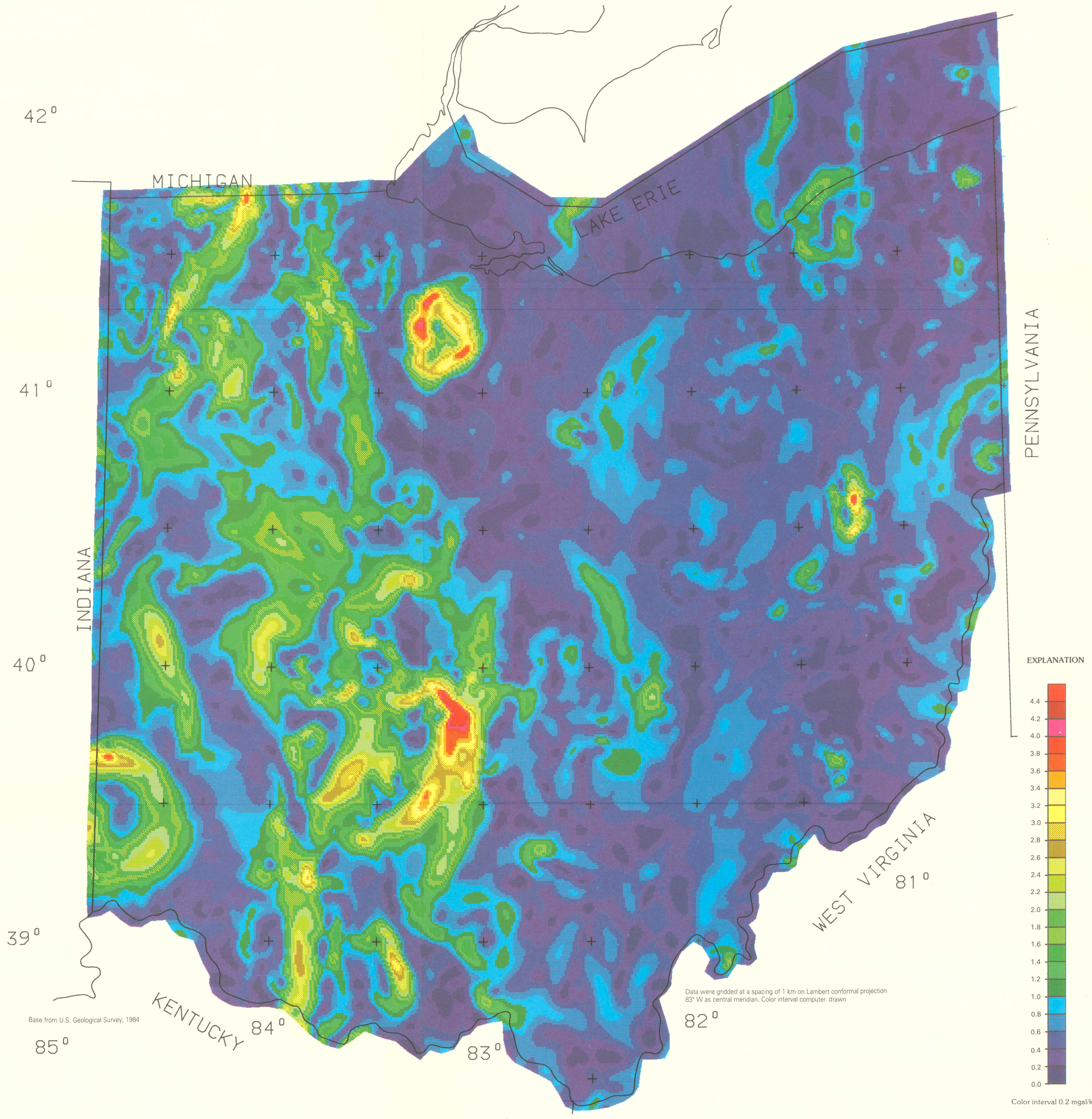

Map B—Regional gravity-anomaly map (wavelengths greater than 100 km)




Map C—Residual gravity-anomaly map (wavelengths less than 100 km)




Map D—First-vertical-derivative of the gravity field




Map E—Magnitude of the horizontal gravity gradient

SCALE 1:1 000 000

# GRAVITY ANOMALY MAPS OF OHIO

By

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1988