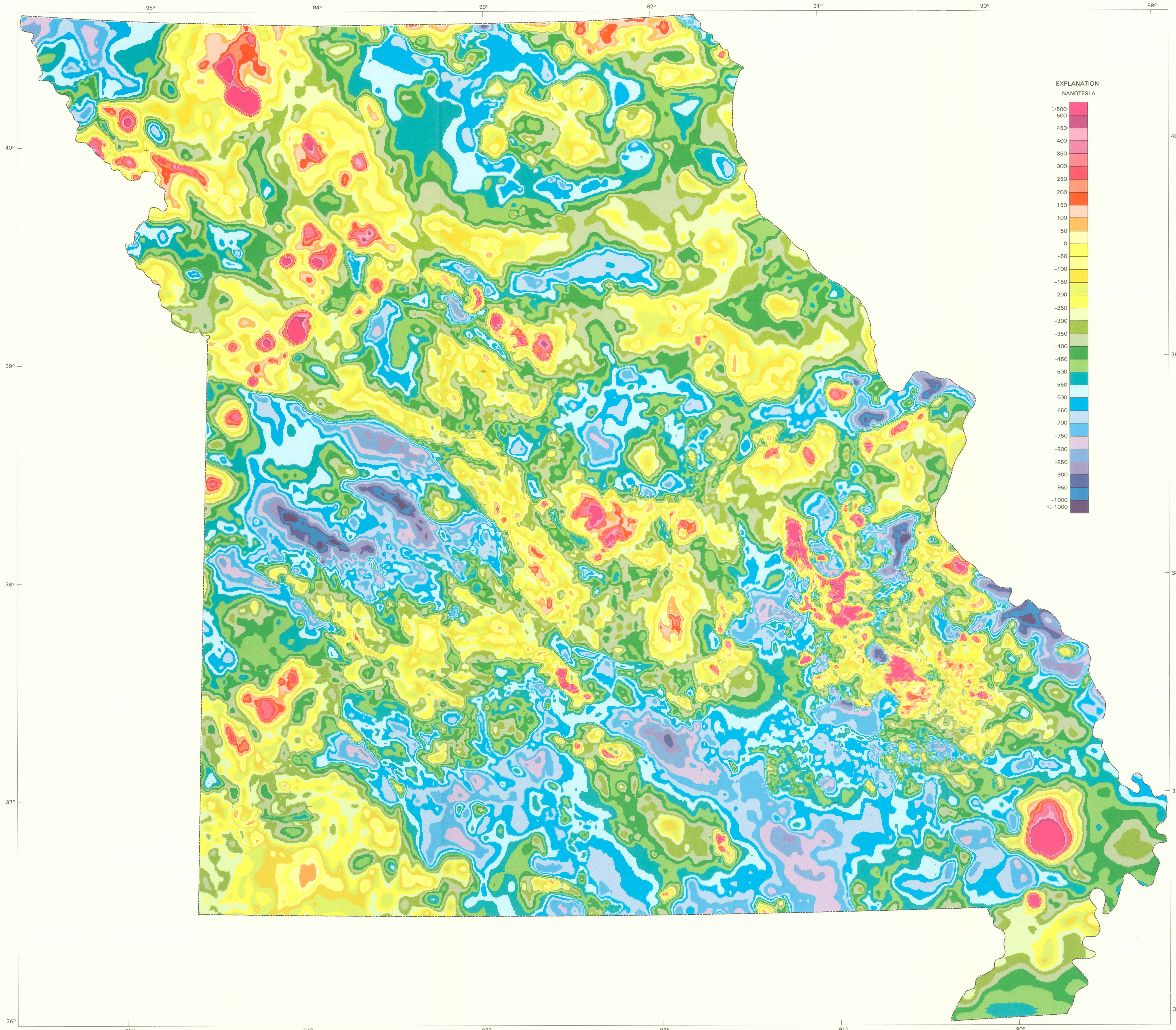
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOPHYSICAL INVESTIGATIONS
MAP GP–1000 (SHEET 1 OF 2)



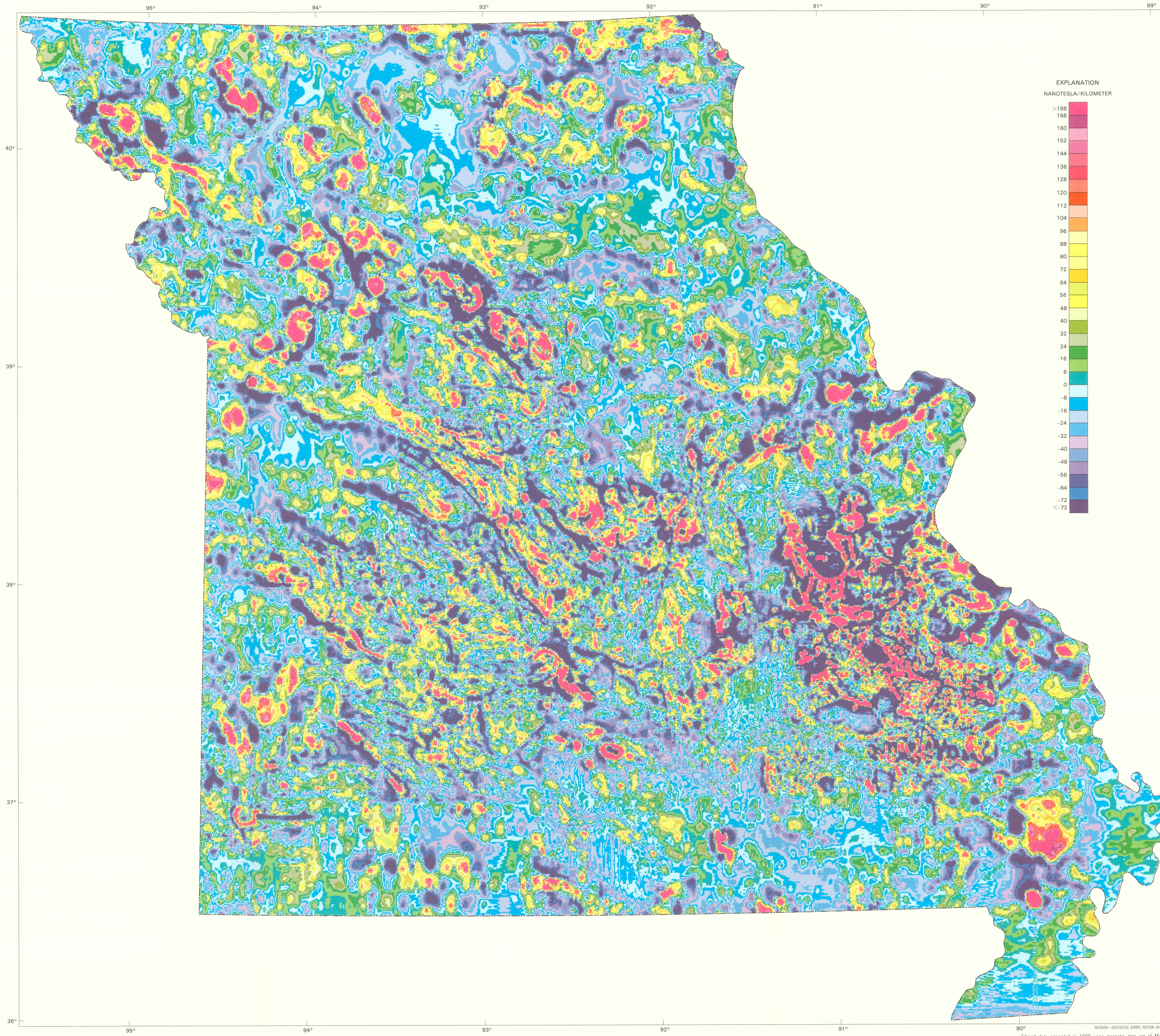
State boundary provided by Missouri Department of Natural Resources, Division of Geology and Land Survey
Grid spacing 1 km
Lambert Conformal conic projection, central meridian 93° W.

MAP A—RESIDUAL TOTAL MAGNETIC FIELD REDUCED TO THE NORTH MAGNETIC POLE

SCALE 1:1 000 000

25 0 25 50 75 100 MILES

25 0 25 50 75 100 KILOMETERS



MAP B—FIRST VERTICAL DERIVATIVE OF THE MAGNETIC FIELD

Filtered data generated in 1990 using magnetic data set of Missouri assembled by Hildenbrand and Kucks (in press)
Manuscript approved for publication, January 17, 1991

INTRODUCTION

These filtered magnetic anomaly maps were generated from a digital data set of Missouri, compiled by Hildenbrand and Kucks (in press). In this earlier compilation, reference geomagnetic fields that approximate the Earth's main (core) field were subtracted. Although these data were obtained from aeromagnetic surveys made at different times, spacings, and flight elevations, a consistent data set was constructed by analytical continuation to a common surface of 305 m (1000 ft) above the terrain. The availability of this compatible digital data set allows herein application of a variety of analytical techniques to enhance different aspects of the anomalies and provide new interpretive information. The application of these techniques would have been impractical had the data been in other than digital form.

In geophysical applications, analysis by filtering involves conversion of the data into a form that enhances particular anomaly characteristics, such as wavelength and trend. Four filtering operations are used here: (1) reduction to pole, an attempt to shift anomaly patterns to positions directly above the associated magnetic sources; (2) first vertical derivative, to sharpen or resolve anomalies of small areal extent; (3) pseudogravity transformation, to determine common sources of anomalous magnetization and density; and (4) magnitude of the horizontal gradient of pseudogravity, to delimit lithologic or structural boundaries. New interpretive information may be obtained by studying these filtered anomaly maps (maps A–D), as discussed below, but they have important limitations and should be used with caution and only in a qualitative analysis.

The magnetic data set used in the filtering process was gridded at a spacing of 1 km (0.62 mi) (Hildenbrand and Kucks, in press). A computer program using the principles of Fourier analysis (Hildenbrand, 1983) was utilized to prepare reduced-to-pole, pseudo-gravity, and first-vertical-derivative data sets. A Lambert Conformal conic projection (standard parallels of 33° N. and 45° N.) with a central meridian of 93° W. was used to prepare all maps.

REDUCTION TO POLE

Rocks that contain magnetic minerals, such as magnetite, have a type of magnetization proportional to and in the direction of the Earth's present-day magnetic field; such magnetization is called "induced." Induced magnetization can also be accompanied by permanent or remanent magnetization, with highly variable orientations, acquired during the rock's history. The polarization vector of a magnetic body is the sum of the remanent and induced magnetization vectors.

The shape of a magnetic anomaly depends on many factors, including the direction of magnetization of the causative body and the direction of the Earth's ambient magnetic field (Nettleton, 1971). For example, at moderate to high latitudes in the northern hemisphere, an intrusion with induced magnetization will be expressed as a magnetic high, with the peak located as far as several kilometers south of the intrusion's central location and with a less intense magnetic low flanking it on the north. To remove these types of polarization effects from a map, the data are analytically reduced to the north magnetic pole (Bhattacharyya, 1965). The advantages of the reduction are that the anomalies (caused by symmetrical bodies) become centered above and symmetrical around the source.

Both the directions of polarization and of the Earth's magnetic field are needed in making the reduction to the north magnetic pole. Although the orientation of the Earth's field vector is known in Missouri (approximately an inclination of 69° N. and a declination of 4° E.), it is necessary to assume a direction of the polarization vector. A problem therefore arises in assigning one particular direction of magnetization to all the magnetic sources in Missouri, especially because Missouri spans a large region. It is assumed that all the rocks' magnetizations are nearly coincident with the Earth's present-day inducing field. The dominance of induced magnetization over remanent magnetization is normally assumed to be the rule, rather than the exception. We do not believe, moreover, that the errors in assuming only induced magnetization in Missouri are important in studying anomalies (map A) at the scale of 1:1,000,000.

FIRST VERTICAL DERIVATIVE

In areas of steep, broad magnetic gradients, low-amplitude and spatially restricted anomalies (related to near-surface features) and other subtle features or trends tend to escape notice on the reduced-to-pole map. This is especially the case for features having amplitudes less than 50 nT, the contour interval of map A. To resolve these short-wavelength anomalies, a first-vertical-derivative filter (Bhattacharyya, 1966) is applied to the reduced-to-pole data. The first-vertical-derivative map (map B) thus enhances subtle local and shallow features and reduces the effects of broad regional gradients. It also emphasizes short-wavelength noise, and care should be used in interpreting features of this map.

PSEUDOGRAVITY

Gravity and magnetic anomalies that reflect a common source of magnetization and density contrast are related to each other by Poisson's equation. Baranov (1957) suggested using Poisson's relation to calculate a pseudogravity anomaly map from magnetic data. The transformation of the magnetic field to the pseudogravity field (map C) requires no assumption regarding a common source of magnetization and density. The magnetization contrast related to a source is simply converted to a hypothetical density contrast to take advantage of analyses in terms of gravity. The pseudogravity field can be compared, however, with the actual gravity field of Missouri (R.P. Kucks, U.S. Geological Survey, written commun., 1991) to delineate common sources of magnetization and density. In the calculations, the ratio of the rocks' magnetization contrasts to density contrasts is set to a constant value (2.5×10^{-2} A/m/g/cm^3), and induced magnetization in a uniform direction (inclination of 69° N., declination of 4° E.) is assumed.

PSEUDOGRAVITY GRADIENT

Cordell (1979) made use of horizontal gravity-gradient maxima to map graben-bounding faults. This technique, designed to delineate lithologic or structural boundaries, was later extended to the analysis of magnetic data through the use of the pseudogravity transformation (Cordell and Grauch, 1982).

Having made the pseudogravity transformation, the magnitude of the horizontal pseudogravity gradient (g′) is determined by a computer program (R.W. Simpson, U.S. Geological Survey, unpub. computer program) using the following equations:

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

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

and

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

where x is the longitudinal coordinate, y is the latitudinal coordinate, and $g_{i,j}$ is the pseudogravity field defined at grid point i,j.

Pseudogravity gradient maxima occur immediately over steep or vertical boundaries separating contrasting magnetizations. On the pseudogravity gradient map (map D), lines drawn along ridges (in other words, continuous maxima) of high horizontal gradient magnitudes correspond to these boundaries. The lines are drawn either manually by hand or automatically with the aide of a computer (Blakely and Simpson, 1986). If the boundaries have shallow dips, if remanent magnetization is strong, or if contributions from adjacent sources are significant, the maximum gradient will be shifted a certain distance from the uppermost part of the boundary (Grauch and Cordell, 1987).

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FILTERED MAGNETIC ANOMALY MAPS OF MISSOURI

By
T.G. Hildenbrand and R.P. Kucks

1992

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225