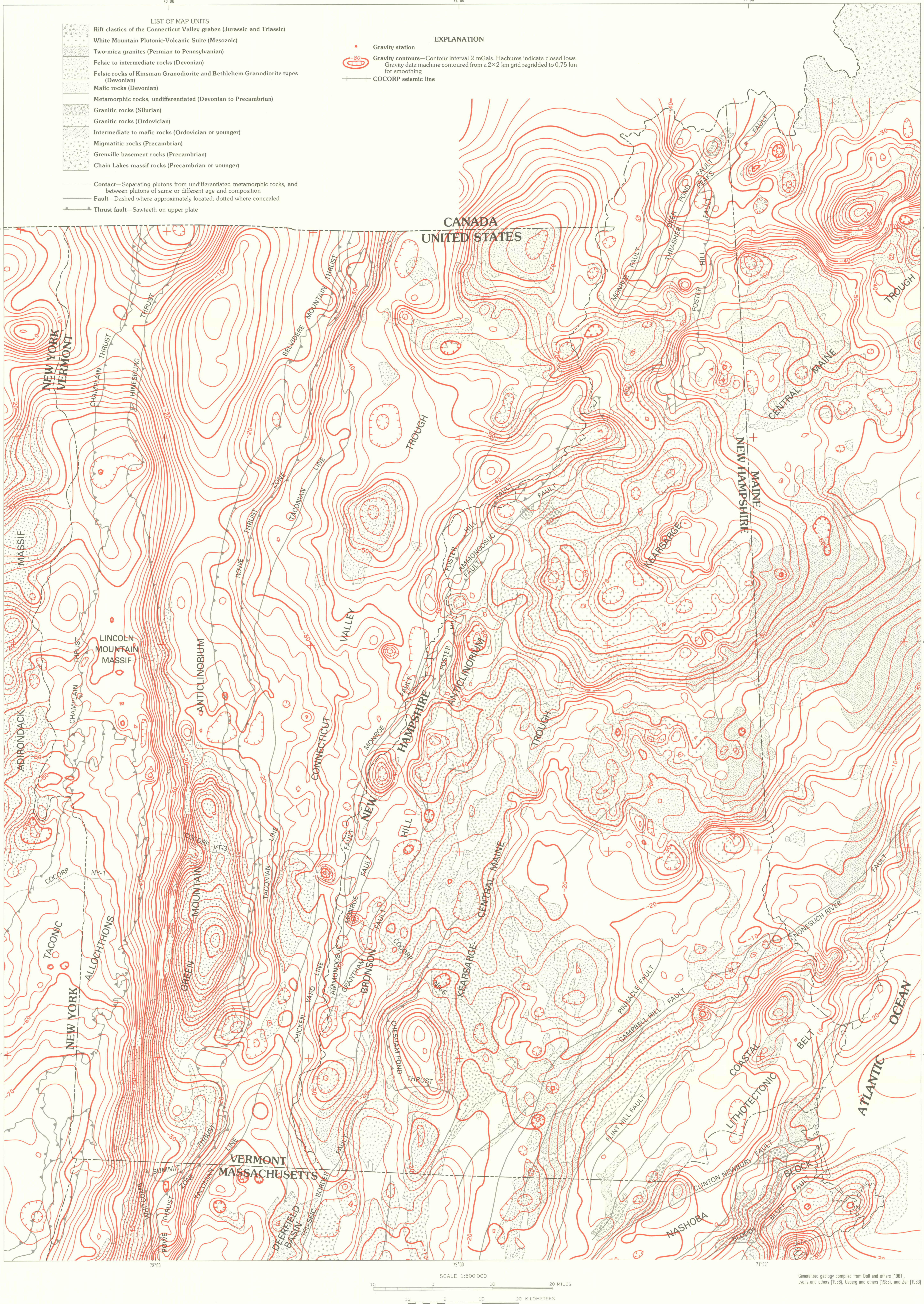


MAP B. BOUGUER GRAVITY ANOMALY MAP, SHOWING GENERALIZED BEDROCK GEOLOGY

## INTRODUCTION

A Bouguer gravity anomaly map (maps A and B) of New Hampshire, Vermont, and vicinity has been prepared by the USGS (U.S. Geological Survey). Three derivative maps have also been prepared, using discrete Fourier[1] transform methods, to enhance subtle gravity features, to separate gravity anomalies, and to help identify lithologic and structural boundaries. These maps include a regional gravity anomaly map (map C), a residual gravity anomaly map (map D), and a first vertical derivative map (map E). In addition, we have included a derivative map of the magnitude of horizontal gravity gradient (map F). Maps B–F are printed on a base that shows the generalized geology of the region [compiled from Doll and others (1961), Lyons and others (1986), Osberg and others (1985), and Zen (1983)]. Compilation of these maps was supported by the National Geologic Mapping Program/COGEOMAP.

Approximately 11,200 gravity stations out of a regional data base of 15,953 were used to generate the Bouguer gravity anomaly map of New Hampshire, Vermont, and vicinity. The gravity stations were established by, or the gravity data were obtained from, the USGS, the Defense Mapping Agency Aerospace Center, and the University of New Hampshire (Bothner, 1985; Bothner and others, 1980, 1985; Daniels, 1988; Defense Mapping Agency Aerospace Center, 1974; Snyder and others, 1988). Gravity station locations (shown on map A) are spaced at irregular intervals. Because of this irregular station spacing, a few anomalies on maps A and B may be poorly defined, and may consequently be exaggerated on the four derivative maps. Therefore, any interpretation of the derivative maps should include comparison with the locations and values of the original data.

The derivative maps enhance subtle features in the Bouguer gravity anomaly data, but carefully constrained geologic data and accurately measured density contrasts are required as aids in geologic interpretation. The regional gravity map (map C) enhances deep or broad regional geologic features, such as batholiths. The residual gravity map (map D) enhances shallow, more local features, such as faults, plutons, and grabens. The first vertical derivative map (map E) magnifies the amplitudes of anomalies and enhances subtle gravity expressions related to local geologic features. The magnitude of horizontal gravity gradient map (map F) enhances physical property contrasts, such as lithologic units separated by a fault, or mafic dikes injected into more felsic crystalline basement.

In the sections that follow we explain the procedures used to reduce the Bouguer gravity data and to generate the four derivative maps.

[1] We do not discuss Fourier analysis in detail in this report; those readers desiring further information on Fourier analysis should refer to Nettleton (1976, p. 157–170).

## PROCEDURES USED IN MAP PREPARATION

### DATA REDUCTION AND GRID GENERATION

Observed gravity data relative to the IGSN–71 datum (Morelli, 1974) were reduced to the Bouguer anomaly using the 1967 gravity formula (International Association of Geodesy, 1967) and a reduction density of 2.67 $g/cm^3$. Standard USGS gravity reduction equations and related formulae are discussed in Cordell and others (1982). Terrain corrections were made for the area extending radially from each gravity station at a distance of 0.895–167 km using the computer method of Plouff (1977).

The latitudes and longitudes of the gravity stations were transformed into map coordinates using a Lambert conformal conic projection with a central meridian of 72° W. and a base latitude of 42°30′ N. The data were gridded at a 2.0-km spacing using a computer program by Webring (1981) that is based on minimum curvature (Briggs, 1974). The gridding process replaces the gravity values measured in the field at random spacing with interpolated gravity values calculated every 2.0 km. Areas with many stations lose some detail; areas with few stations show less exact anomalies. The value of 2.0 km was chosen as a compromise between areas with few stations and areas with many stations. Because derivative maps are calculated from grid values rather than original values, grid spacing can affect the appearance of the maps. The Bouguer anomaly map was plotted at 1:250,000 using a program by Godson and Webring (1982) and was generated from a 0.75 km regridded data set for smoothing purposes.

Data from gravity stations extending beyond the map boundaries were included to create the original grid as well as the derivative grids. These data eliminated distorted anomalies near the map boundaries caused by abrupt termination of data. The final maps were trimmed to the existing border after filtering and were regridded to 0.254 km for plotting using Calcomp color software and equipment.

### 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 we chose a general wavelength (or frequency) filtering method to separate long-wavelength anomalies (regional) typically associated with deep-crustal or subcrustal features from short-wavelength anomalies (residual) associated with shallow features. We are 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 and high-pass filtered (Hildenbrand, 1983). The filter used is a simple rectangular window, modified so that the gain of the filter drops from 1 to 0 along a ramp centered at the cut-off wavelength. The ramp was located between 75 and 125 km; the cutoff wavelength was 100 km (chosen as a standard for USGS-State cooperative maps). The regional (low-pass) field (map C) 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 (high-pass) field (map D) was calculated by the same procedure using only the high-pass filter.

### 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 2 mGals, which is the contour interval of maps A and B. To resolve small-wavelength anomalies, a first vertical derivative filter (Bhattacharyya, 1966) was applied to the gravity data using a program by Hildenbrand (1983). Unlike the filter used in the preparation of the residual gravity anomaly map (map D), the first vertical derivative filter magnified the amplitude of small-wavelength anomalies. Thus, the first vertical derivative map (map E) enhances local features and reduces the effects of regional gradients.

### 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, USGS, unpub. data) using the following three equations:

$$|g'(x,y)| = \sqrt{\left(\frac{\delta g}{\delta x}\right)^2 + \left(\frac{\delta g}{\delta y}\right)^2}, \quad \frac{\delta g}{\delta x} = \frac{g_{i+1,j} - g_{i-1,j}}{2\Delta x}, \quad \frac{\delta g}{\delta y} = \frac{g_{i,j+1} - g_{i,j-1}}{2\Delta y}$$

where x is the longitudinal coordinate, y is the latitudinal coordinate, and g 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 inhomogeneity 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). Thus, on the horizontal gravity gradient map (map F), lines drawn along ridges formed by enclosed high-gradient magnitudes generally correspond to vertical or steeply dipping contacts.

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# BOUGUER GRAVITY ANOMALY MAPS AND FOUR DERIVATIVE MAPS OF NEW HAMPSHIRE, VERMONT, AND VICINITY

By
Wallace A. Bothner and Robert P. Kucks
1993