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A description of colored gravity maps of the Basin and Range province, southwestern United States

by

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INTRODUCTION

As part of the Geologic and Hydrologic characterization and evaluation of the Basin and Range province for high level radioactive waste disposal (Task 1), we have compiled available gravity data on a regional scale and many daughter products such as wavelength filtered and gradient data sets. Photographic prints of colored maps displaying these data are included in this report, although necessarily at a greatly reduced scale. (Reproductions of these maps may also be obtained as standard 2" x 2" color slides from the U.S. Geological Survey Photo Library Mail Stop 914, Box 25046, Denver Federal Center, Denver, CO 80225; telephone 303/234-4004.) These maps reveal (1) many interesting anomalies that may aid in gaining a better understanding of the tectonic development of the Basin and Range province, and (2) regional patterns which aid in providing a perspective for more detailed local studies.

DATA PROCESSING

Reduction of gravity data

Principal facts (observed gravity, elevation, latitude, and longitude) from more than 200,000 stations were assembled for processing. These data were obtained from data files maintained by the Defense Mapping Agency of the Department of Defense and from many workers who kindly furnished us with additional gravity stations within California and Nevada (H. W. Oliver, C. Roberts, R. W. Saltus, and D. B. Snyder, U.S. Geological Survey, Menlo Park), Utah and Arizona (G. R. Keller and Carlos Aiken, University of Texas), New Mexico (Lindrith Cordell, U.S. Geological Survey, Denver), Oregon (D. L. Williams and C. A. Finn, U.S. Geological Survey, Denver), and Nevada (D. H. Schaefer, D. K. Maurer, and R. W. Plume, U.S. Geological Survey, Carson City). In spite of considerable editing, erroneous gravity values are still apparent; for example, very intense highs and lows of small wavelength should be viewed with caution.

All observed gravity values have been adjusted to conform to the International Gravity Standardization Net of 1971 (Morelli, 1974). The resulting data set was screened to select one station within a 4 x 4 km area, reducing the number of stations to approximately 50,000. Bouguer gravity anomaly values were computed using the 1967 gravity formula (International Association of Geodesy, 1971) and a reduction density of 2.67 g/cm^3; the equations and related expansions are given by Cordell and others (1982). Terrain corrections were made by computer (Plouff, 1977) for the region extending radially from 0.895 to 167 km from the station. The terrain corrections omitted from the inner zone (0.0 to 0.895 km) are estimated to be small, generally less than 2 mgal, but may be larger for stations located in deep canyons or on steeply sloping terrain.

A data set on a 4 km grid was derived from the irregularly spaced Bouguer anomaly values by means of a minimum curvature interpolation formula (Webring, 1981). The data were plotted on the Albers Conic Equal-area projection with standard parallels for the U.S. (29.5° N, 45.5° N) and with a central meridian of 96° W. The maps were made using an Applicon color plotter.

Wavelength filtering

A gravity-anomaly map exhibits the effects of geological 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 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 our study we 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. 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 validity of the wavelength-filtering process in calculating regional-residual gravity fields is dependent on the assumption that the cut-off wavelength of the filter and maximum depth of source are related. Preliminary analyses suggest that the maximum source depth is roughly equal to the cut-off wavelength divided by a factor ranging from 6 to 12, depending on the geometry of the source. Thus, the residual gravity map composed of wavelengths of 250 km and less, exhibits anomalies which most probably are associated with sources that lie above a depth of 21 and 42 km; the effects of broad shallow sources such as low-density sedimentary strata, however, are not present on this map. For example, we conclude that the 250 km wavelength cut-off residual map discussed below contains anomalies associated with anomalous mass distributions residing primarily in the crystalline portion of the Earth's crust. Conversely the complementary 250 km wavelength low-pass regional map represents the effects of deeper sources, such as the shape of the crust-mantle boundary and anomalous masses in the mantle, and presumably those of any broad shallow masses that may be present.

To obtain residual-regional maps the gridded gravity data were transformed to the frequency domain by fast Fourier transform and then were low-pass filtered. The low-pass filter (Hildenbrand, T. G., unpub. data, 1979) is a simple rectangular window, modified so that the gain drops from one to zero along a ramp centered at the cut-off wavelength. The ramp was located between 300 km and 200 km for the 250 km wavelength cut-off filter. The regional (low-pass) field was calculated by taking the inverse Fourier transform of the product of the low-pass filter and the Fourier transformed Bouguer gravity field. Residual fields were calculated by subtracting the computed regional fields from the unfiltered gravity field.

It should be mentioned that wavelength filtering may produce spurious anomalies flanking real anomalies (Ulrych, 1968). For example, a broad linear high will be separated into several highs and lows having a wavelength roughly equal to the cut-off of the filter. Thus, anomalies must be interpreted with care, especially those having a wavelength near the cut-off wavelength.

DESCRIPTION OF MAPS

1. Locations of Gravity Stations: Data Screened to 4 km Spacing

   This map displays the nearly 50,000 stations in the screened data used to produce the colored maps.

2. Free Air Gravity (color interval = 5 mgals)

   This map displays the free air anomaly field calculated using the 1967 Geodetic Reference System formula for theoretical gravity (International Association of Geodesy, 1971).

3. Complete Bouguer Gravity (color interval = 10 mgals)

   Bouguer gravity anomalies were calculated using the new geodetic reference system and a reduction density of 2.67 g/cm^3.

4. Regional Bouguer Gravity: Wavelengths Greater Than 250 km (color interval = 10 mgals)

   Wavelengths less than 250 km in the Bouguer anomaly field were suppressed using a ramped low-pass filter with the ramp between 200 km and 300 km.

5. Residual Bouguer Gravity: Wavelengths Less Than 250 km (color interval = 5 mgals)

   By subtracting the long-wavelength regional from the original Bouguer gravity field, we produced the complementary short-wavelength residual map in which wavelengths greater than 250 km have been removed.

6. Regional Bouguer Gravity: Wavelengths Greater Than 100 km (color interval = 10 mgals)

   Wavelengths less than 100 km in the Bouguer anomaly field were suppressed using a ramped low-pass filter with the ramp between 75 km and 125 km.

7. <u>Residual Bouguer Gravity: Wavelengths Less Than 100 km</u> (color interval = 2 mgals)

Similar to #5 (above) except that wavelengths greater than 100 km have been removed.

8. <u>Band-Pass Gravity: Wavelengths Between 50 and 250 km</u> (color interval = 5 mgals)

Wavelengths less than 50 km and greater than 250 km were removed with two ramps from 25 km and 75 km and from 200 km and 300 km, respectively.

9. <u>Derivative Bouguer Gravity: Horizontal Gradient Magnitude</u> (color interval = 0.2 mgal/km)

The magnitude of the horizontal gradient of the Bouguer anomaly field was calculated using the basic equation:

$$\left|\text{gradient}\right| = \sqrt{\left(\frac{\partial \beta}{\partial x}\right)^2 + \left(\frac{\partial \beta}{\partial y}\right)^2}$$

and the approximation that

$$\left(\frac{\partial \beta}{\partial x}\right)_{i,j} = \frac{\beta_{i+1,j} - \beta_{i-1,j}}{2(\Delta x)}, \text{ and } \left(\frac{\partial \beta}{\partial y}\right)_{i,j} = \frac{\beta_{i,j+1} - \beta_{i,j-1}}{2\ (\Delta y)}$$

where B is Bouguer gravity value,

i and j are, respectively, column and row indices defining grid point,

x and y are Cartesian coordinates in an eastward and northward direction, respectively,

and Δx and Δy are grid spacing in x- and y-direction, respectively.

This approximation can be shown to be equivalent to fitting a parabola at grid point i using β_i and its 2 neighboring values β_{i+}, β_{i-1} and then calculating the slope of the parabola at i. The magnitude of the gradient of an anomaly depends on both the size of the density contrast and the nearness of the source to the surface. The largest gradients will often occur nearly over the mass contrast at the edges of geologic bodies. Cordell (1979) has used the horizontal gradient to locate faults.

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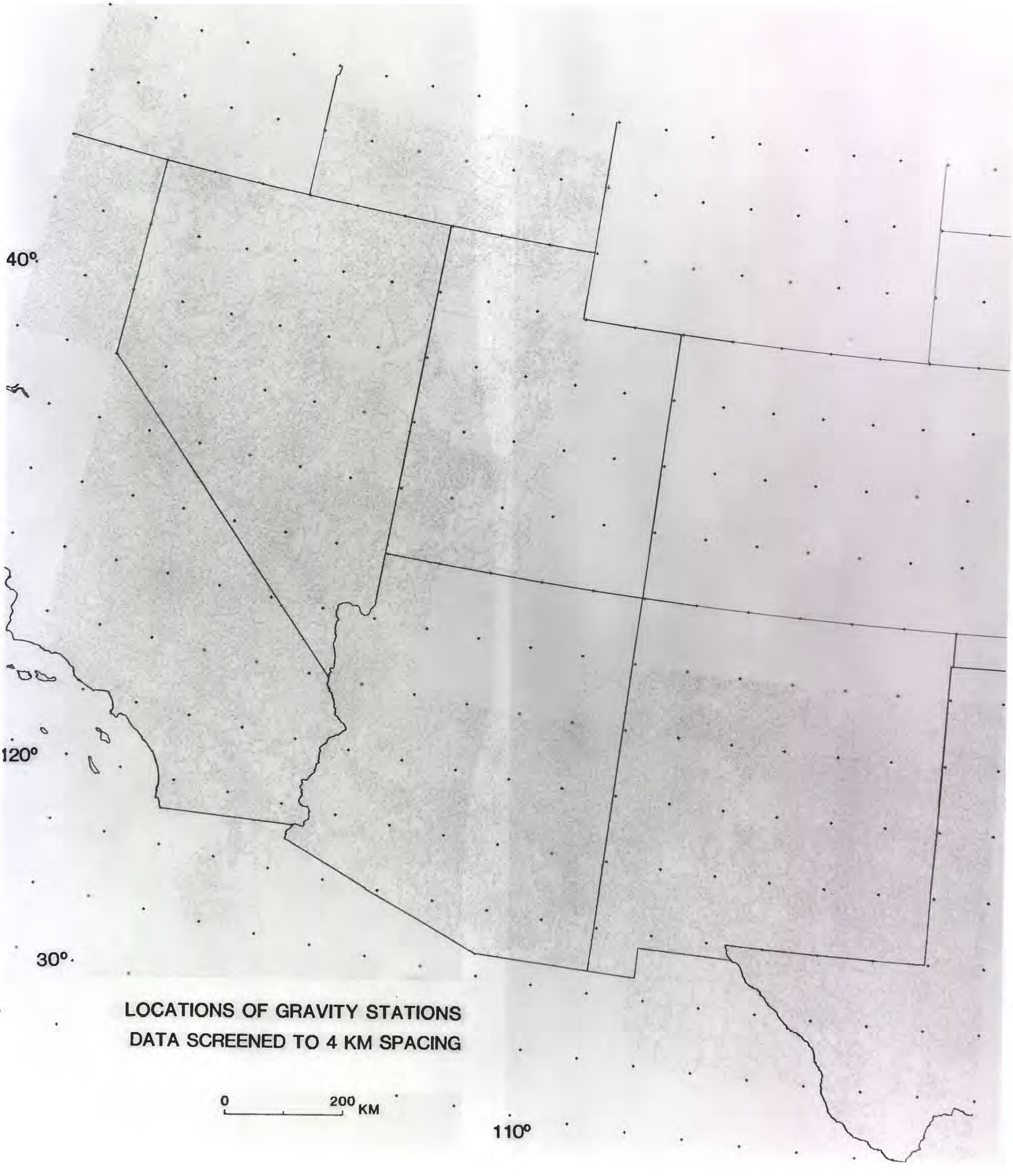
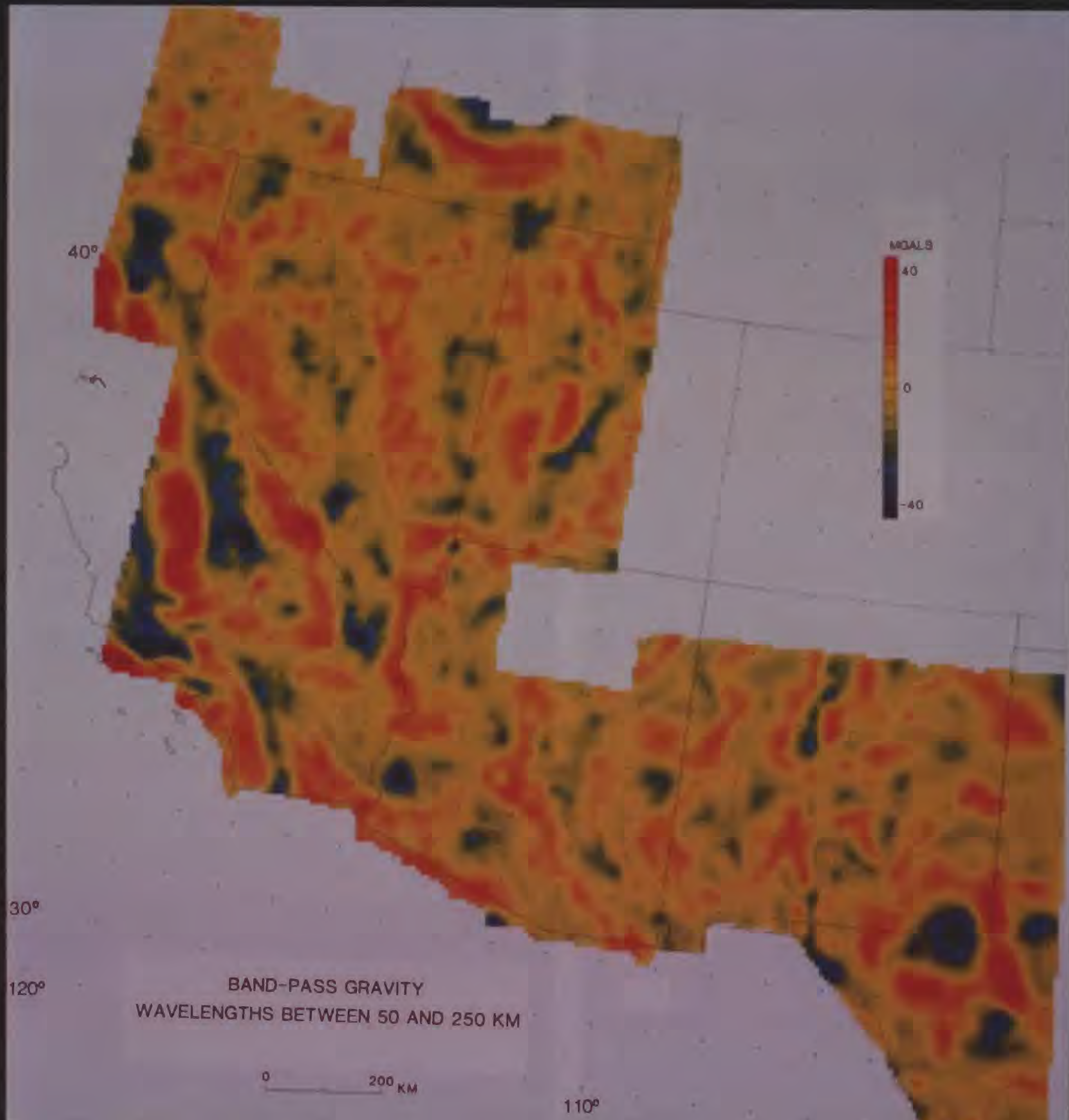
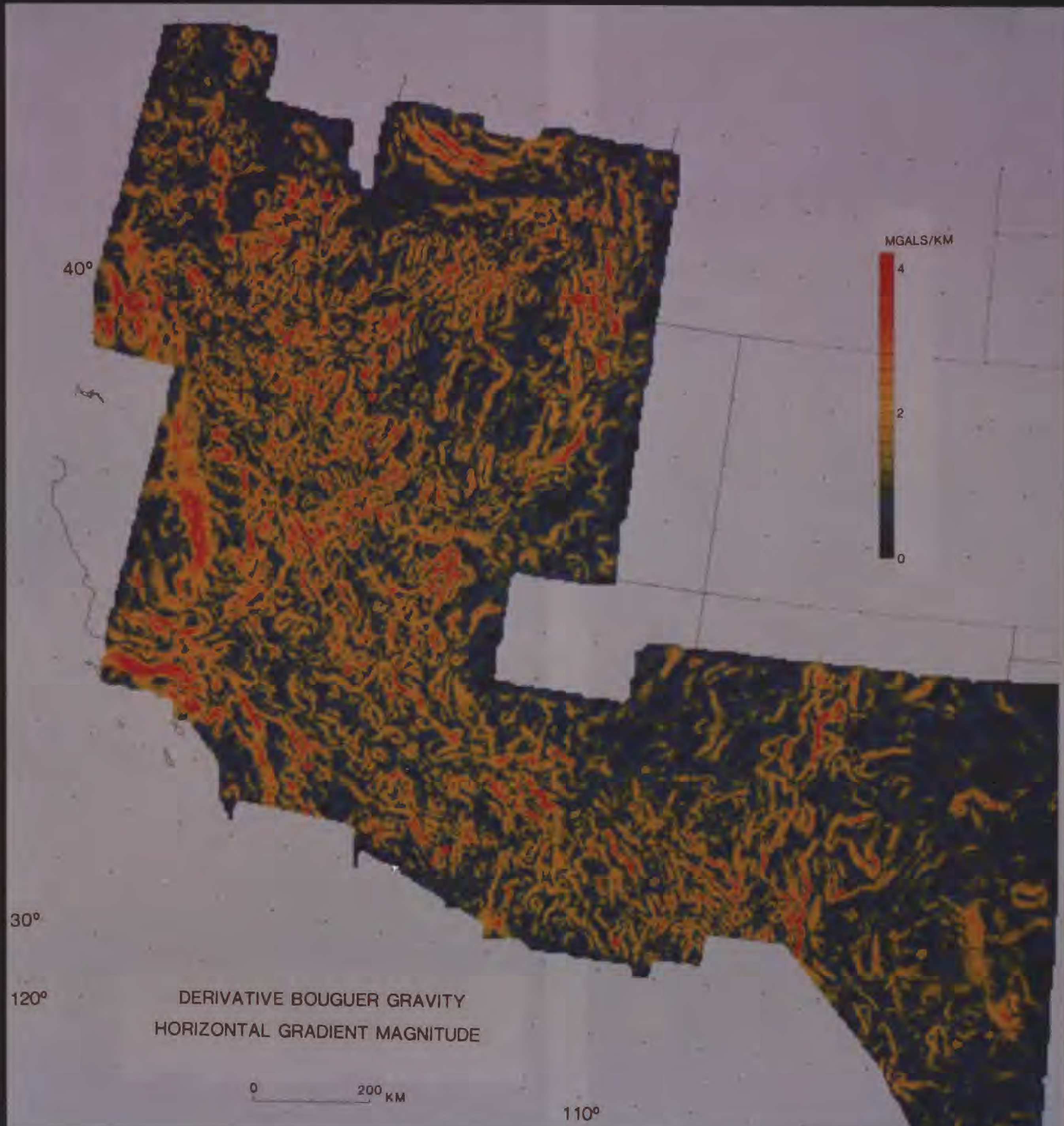


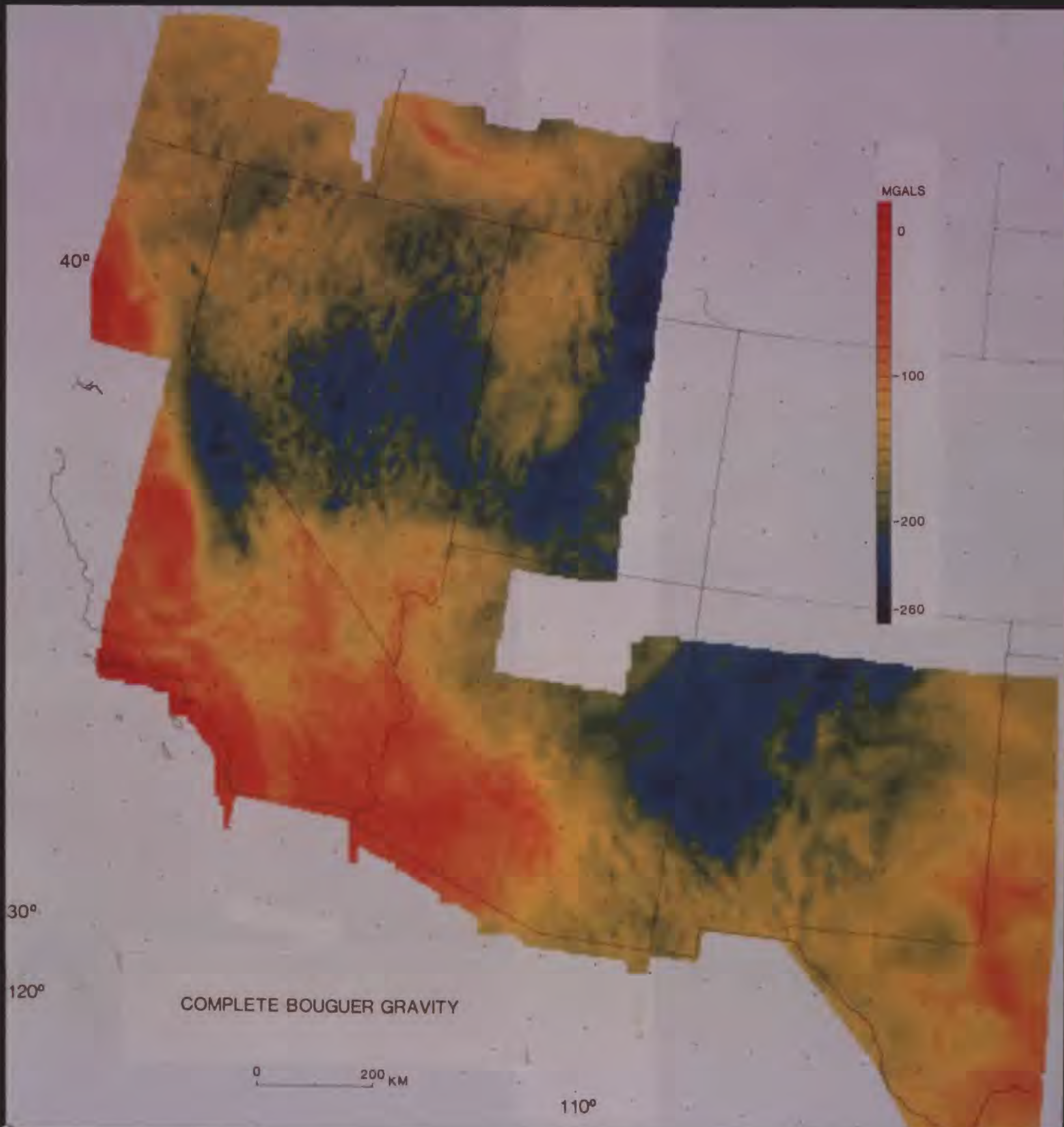
LOCATIONS OF GRAVITY STATIONS
DATA SCREENED TO 4 KM SPACING

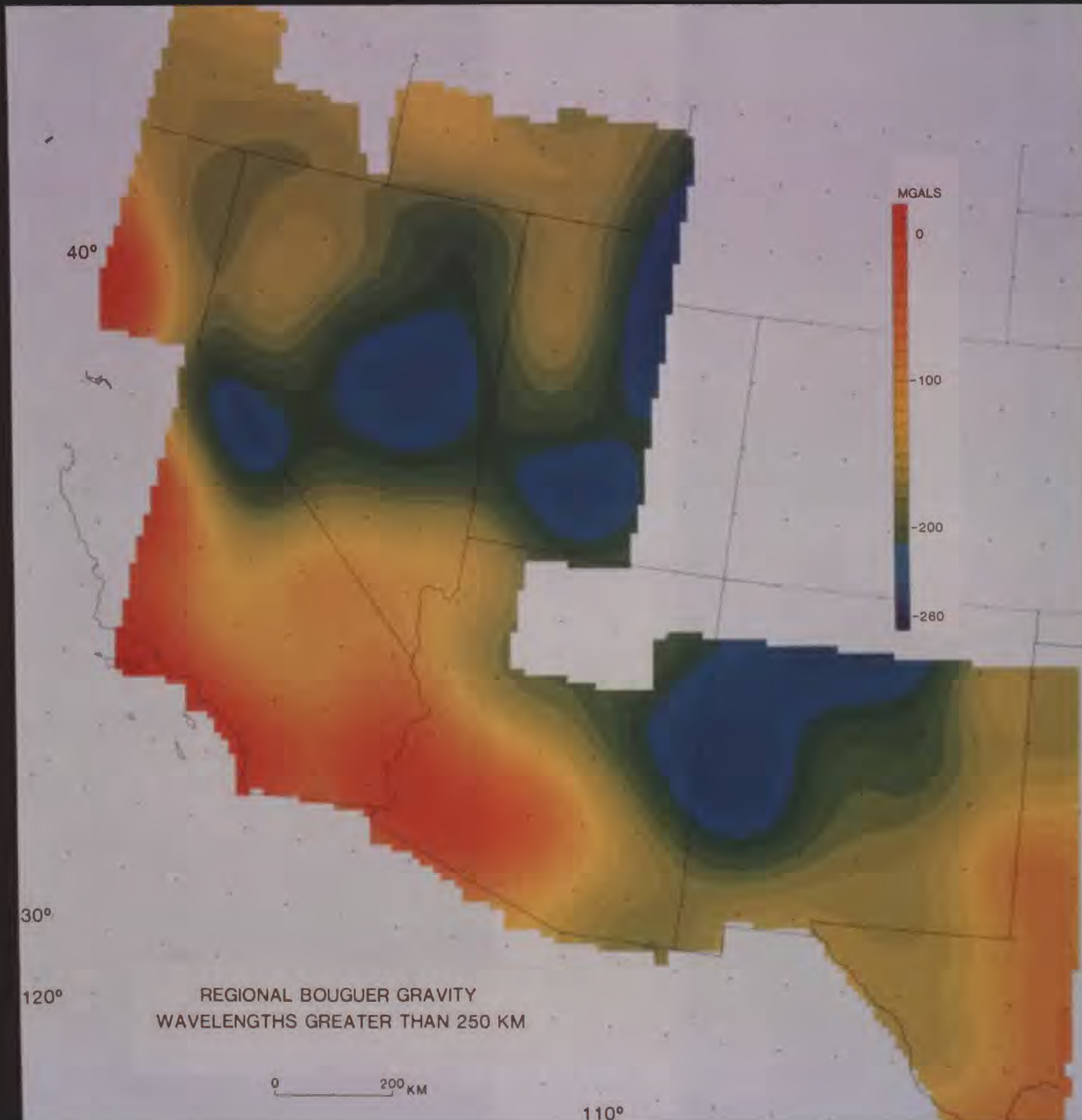
RESIDUAL BOUGUER GRAVITY
WAVELENGTHS LESS THAN 100 KM

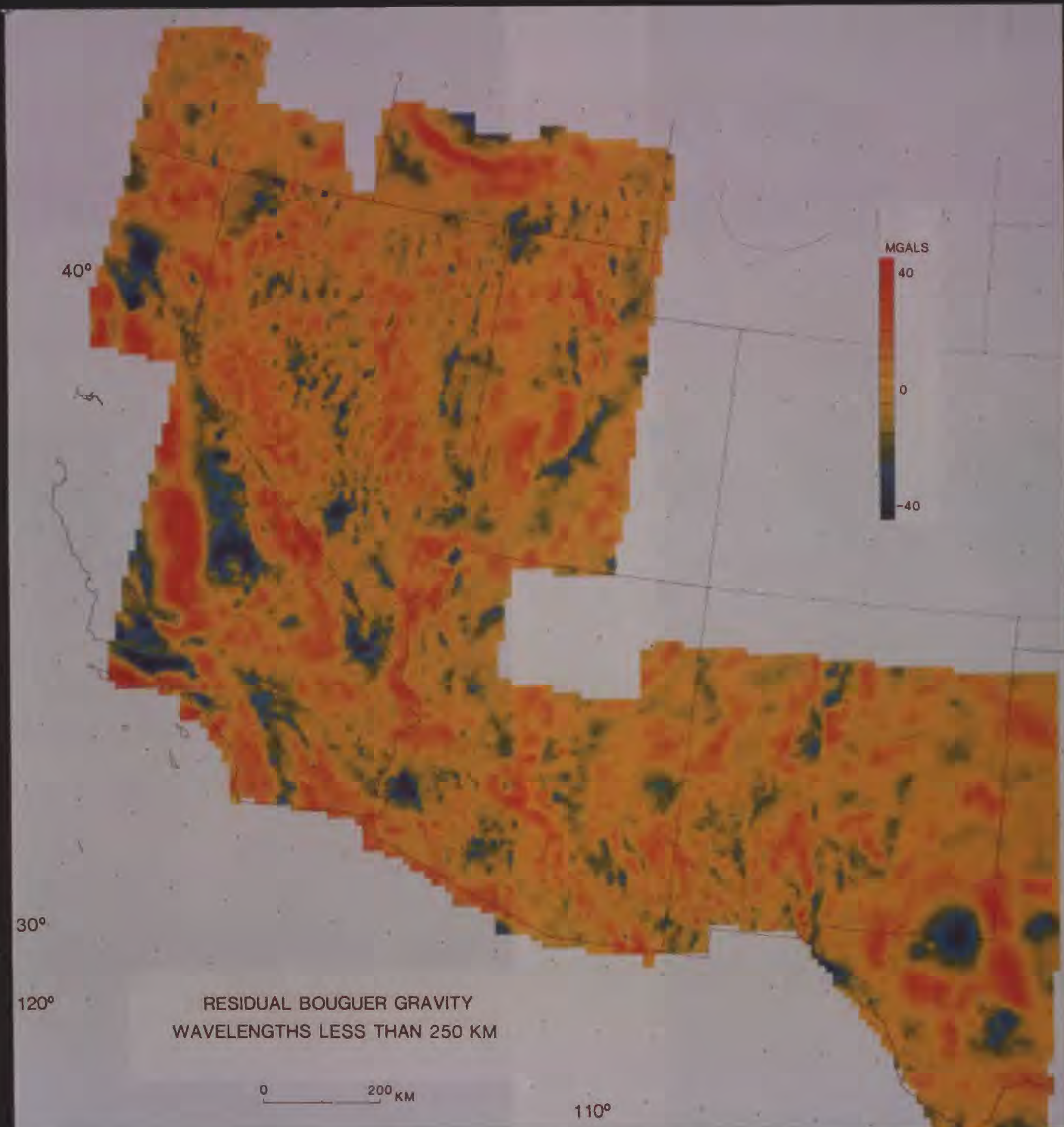

MGALS
40
0
-40
40°
30°
120°
110°
BAND-PASS GRAVITY
WAVELENGTHS BETWEEN 50 AND 250 KM
0
200 KM

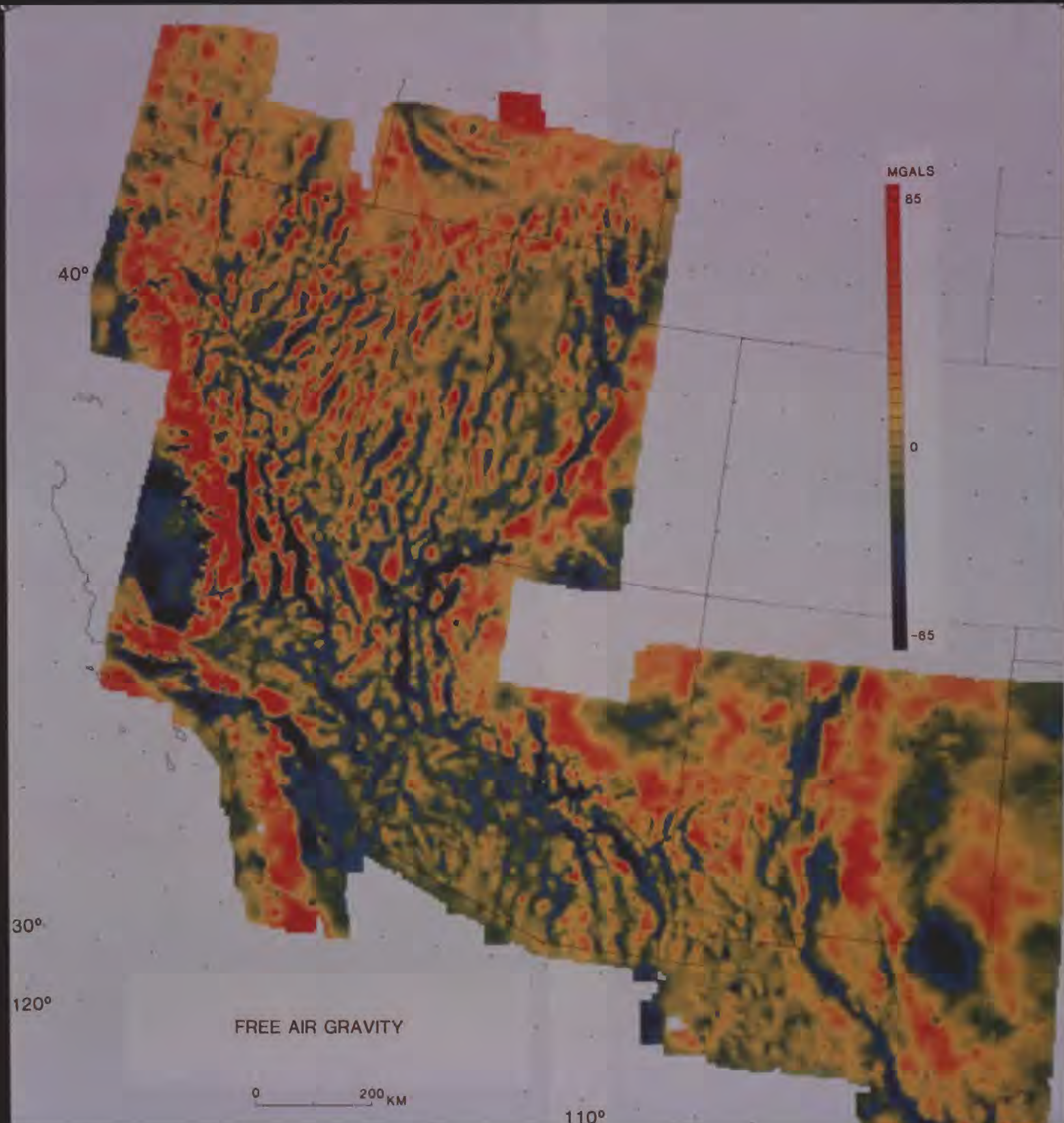


DERIVATIVE BOUGUER GRAVITY
HORIZONTAL GRADIENT MAGNITUDE


MGALS
0
-100
-200
-280
40°
30°
120°
110°
COMPLETE BOUGUER GRAVITY
0
200 KM


MGALS
0
-100
-200
-260
40°
30°
120°
110°
0
200 KM
REGIONAL BOUGUER GRAVITY
WAVELENGTHS GREATER THAN 250 KM


40°
30°
120°
110°
MGALS
40
0
-40
RESIDUAL BOUGUER GRAVITY
WAVELENGTHS LESS THAN 250 KM
0
200 KM


MGALS
85
0
-65
40°
30°
120°
110°
FREE AIR GRAVITY
0
200 KM