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Bouguer gravity map and related filtered anomaly maps of Morocco

by

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Résumé

La plupart des données gravimétriques couvrant les provinces Nord du Maroc ont été collectées à partir de levés réalisés dès 1949.

La carte gravimétrique du Maroc au 1/500.000 en sept feuilles (Provinces du Nord) a été publiée en 1969, et sa notice explicative en 1984 (Van Den Bosch: Notes et Mémoires du Service Géologique du Maroc, n° 234 et 234 bis).

D'autres levés systématiques complémentaires de semi-détail ont été réalisés par la Direction de la Géologie et on interessé essentiellement le Rif occidental et les régions de Zagora et de Foum Zguid (Anti-Atlas Oriental).

Dans le cadre du projet "Block structure of the lithosphère and its role in the distribution of metallic ore deposits" réalisé en collaboration entre le Service Géologique du Maroc et l'U.S.G.S l'ensemble des levés gravimétrique a été intégré dans la nouvelle version de la carte gravimétrique du Maroc au 1/1.000.000 (Provinces du Nord), et ont ainsi abouti à la réalisation des cartes suivantes:

- Carte gravimétrique de l'Anomalie de Bouguer,
- Carte regionale et résiduelle (R = 100 km),
- Carte regionale et résiduelle (R = 250 km),
- Carte du gradient vertical,
- Carte du gradient horizontal

Abstract

A set of gravity anomaly maps of Morocco are presented here to assist in identifying the boundaries and extent of major tectonic provinces. No attempt is made to interpret these maps. Rather, the maps are shown as a data source for regional geologic and geophysical framework studies of Morocco.

In addition to an index map (Map A) and the simple Bouguer gravity map (Map B), various filtered gravity anomaly maps (Maps C-H) are provided. Analysis of geophysical data by filtering involves conversion of the data into a form that enhances particular anomaly characteristics, such as wavelength and trend. Three 3 filtering operations were made: (1) regional-residual anomaly separation by wavelength filtering; (2) first vertical derivative, to sharpen or resolve anomalies of small areal extent; and (3) horizontal gradient magnitudes, to delimit lithologic or structural boundaries. Although a considerable amount of information can be obtained by studying these filtered anomaly maps, each has limitations and thus should be used with caution and only in a qualitative analysis.

Data Reduction

The primary source of data is from a gravity study by Van den Bosch (1971). The data shown here were in two forms -- digital form and analog form (shown by black dots and yellow dots, respectively on Map A). In the digital data file, 8501 stations are from Van den Bosch's work and 2392 stations were collected by the Moroccan Ministère de l'Energie et des Mines (Bellot, 1985; Bellot and Hamouda, 1988) in two small regions (near lat. 35°30'N and long. 5°30'W; and lat. 30°15'N and long. 6°30'W). Principal facts (observed gravity, elevation, latitude, and longitude) for the total 10,893 stations were provided by the Moroccan Ministère de l'Energie et des Mines. On compiled simple Bouguer gravity maps Van den Bosch displayed several areas where the coverage was very dense; the data in those areas were available only in analog contour form. In order to incorporate the information in these areas of dense coverage, the simple Bouguer gravity contours on Van den Bosch's maps were digitized and combined with the digital data base of 10,893 stations discussed above. To avoid problems in merging the two different data types, the regions of digitization of the analog data were trimmed back 5 km from any gravity station with known principal facts.

All gravity values are referenced to the International Gravity Standardization Net of 1971 (Morelli, 1974). Bouguer gravity anomaly values were computed using the 1967 gravity formula (International Association of Geodesy, 1967) with a reduction density of 2.67 g/cm^3. No terrain corrections were made. A grid with an interval of 2 km was derived from the irregularly spaced Bouguer anomaly values by means of a computer program (Webring, 1981) based on minimum curvature (Briggs, 1974). The data were plotted on a Lambert conformal projection with standard parallels of 33°N and 45°N and with a central meridian of 6°W. All data sets were plotted using Applicon Incorporated[1] color proprietary software.

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

Bouguer Gravity Map

The following short discussion is intended to give the reader a sense of significance of Bouguer gravity anomalies. It leaves out many technical details of the gravity reduction process. For a more complete discussion, the reader is referred to Dobrin (1976) and Nettleton (1976).

Measurements of gravity are normally compared with the values that would theoretically be obtained if the measurements were made on an idealized surface (the reference ellipsoid) approximated by sea level. If only the latitude and the vertical distance of the gravity observation above sea level are compared, the difference between observed and theoretical gravity is known as the "free-air" anomaly; if the mass between the point of observation and sea level is also taken into account, then the difference is known as the "simple Bouguer" anomaly. Simple Bouguer anomalies of Morocco are shown in Map B.

Filtered Gravity Anomaly Maps

Regional-residual gravity anomaly separation

A Bouguer gravity anomaly map exhibits the effects of source bodies of varying densities, 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 somewhat arbitrary, depending upon the map scale and source bodies of interest, but are commonly used to make a distinction between anomalies arising from local, thin masses and those arising from larger and usually thicker features, respectively. There are many methods for preparing regional and residual maps (Grant, 1972). For our study we have chosen a general wavelength (or frequency) filtering method to obtain a separation of long-wavelength anomalies (regional) that are associated with large-crustal or subcrustal features, from short-wavelength anomalies (residual) that are associated with shallow features. It should be noted that the separation is not complete and, in particular, long-wavelength anomalies can be caused by broad, shallow features. The short wavelength anomalies on the residual maps emphasize the contributions of shallow sources, 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 wave number domain using the fast Fourier transform and then were low-pass filtered (Hildenbrand, 1983). The low-pass filter was a simple rectangular window (passing long wavelengths), 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 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 field (Map D) was calculated by subtracting the computed regional field from the unfiltered gravity field.

The effectiveness of the wavelength filtering process in calculating regional-residual gravity fields is partly a function of the relation of the cut-off wavelength of the filter and the maximum depth of sources. The residual gravity map (Map D), composed of wavelengths of 100 km and less, exhibits anomalies which probably are associated primarily with sources within the crust; the effects of broad, shallow sources, however, are not present on this map. Conversely, the complementary low-pass map composed of wavelengths of 100 km and greater (Map C) generally represents the effects of deeper sources, such as the shape of the crust-mantle boundary and anomalous masses in the mantle and middle and lower crust, although the contributions of any broad, shallow masses are also included.

A similar set of regional-residual maps using a cutoff wavelength of 250 km is shown in Maps E and F.

First vertical derivative

In areas of steep, broad gravity gradients, low-amplitude and spatially restricted anomalies (related to near-surface features) and other subtle features or trends tend to escape notice on the Bouguer gravity map. This is especially the case for features having amplitudes less than 5 mGal, which is the color contour interval of Map B. To resolve short-wavelength anomalies, a first vertical derivative filter (Bhattacharyya, 1965) was applied to the gravity data. The vertical derivative anomaly map shown in Map G thus enhances local features and reduces the effects of broad regional gradients.

Horizontal gravity gradient

The magnitude of the horizontal gravity gradient g' is determined by a computer program (R. W. Simpson, U.S. Geological Survey, unpub. computer program) using the following equations:

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

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

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

where x is the longitudinal coordinate, y is the latitudinal coordinate, and $g_{i,j}$ is the pseudo-gravity field defined at grid point i,j. Grid intervals in the x-direction and y-direction are Δx and Δy, respectively.

Gravity gradient maxima occur immediately over steep or vertical boundaries separating rock masses of contrasting densities. On the gravity gradient map, lines drawn along ridges formed by enclosed high horizontal gradient magnitudes correspond to these boundaries. If the boundaries dip, or if contributions from adjacent sources are significant, the maximum gradient will be shifted a certain distance from the boundary (Grauch and Cordell, 1987).

Acknowledgment

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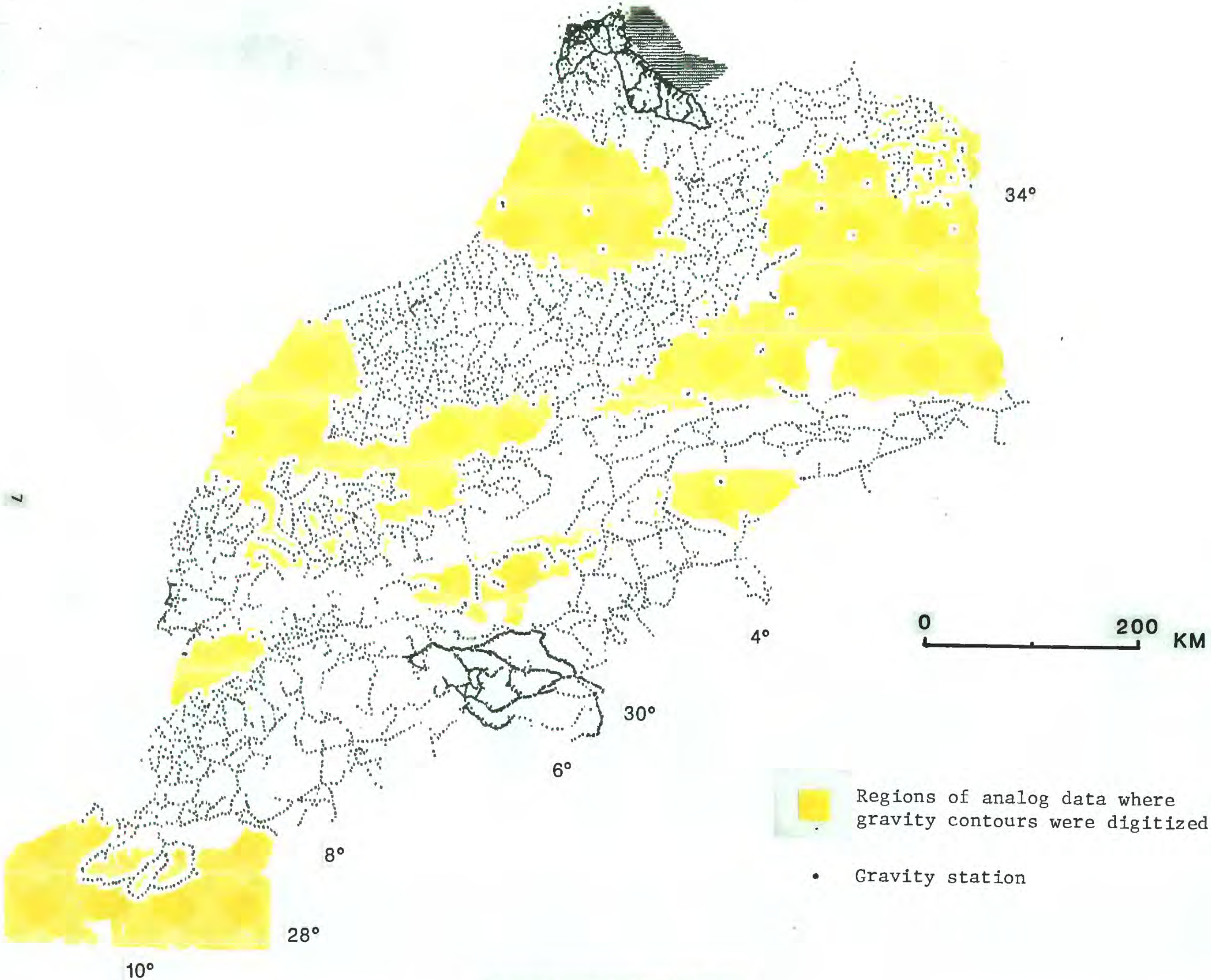
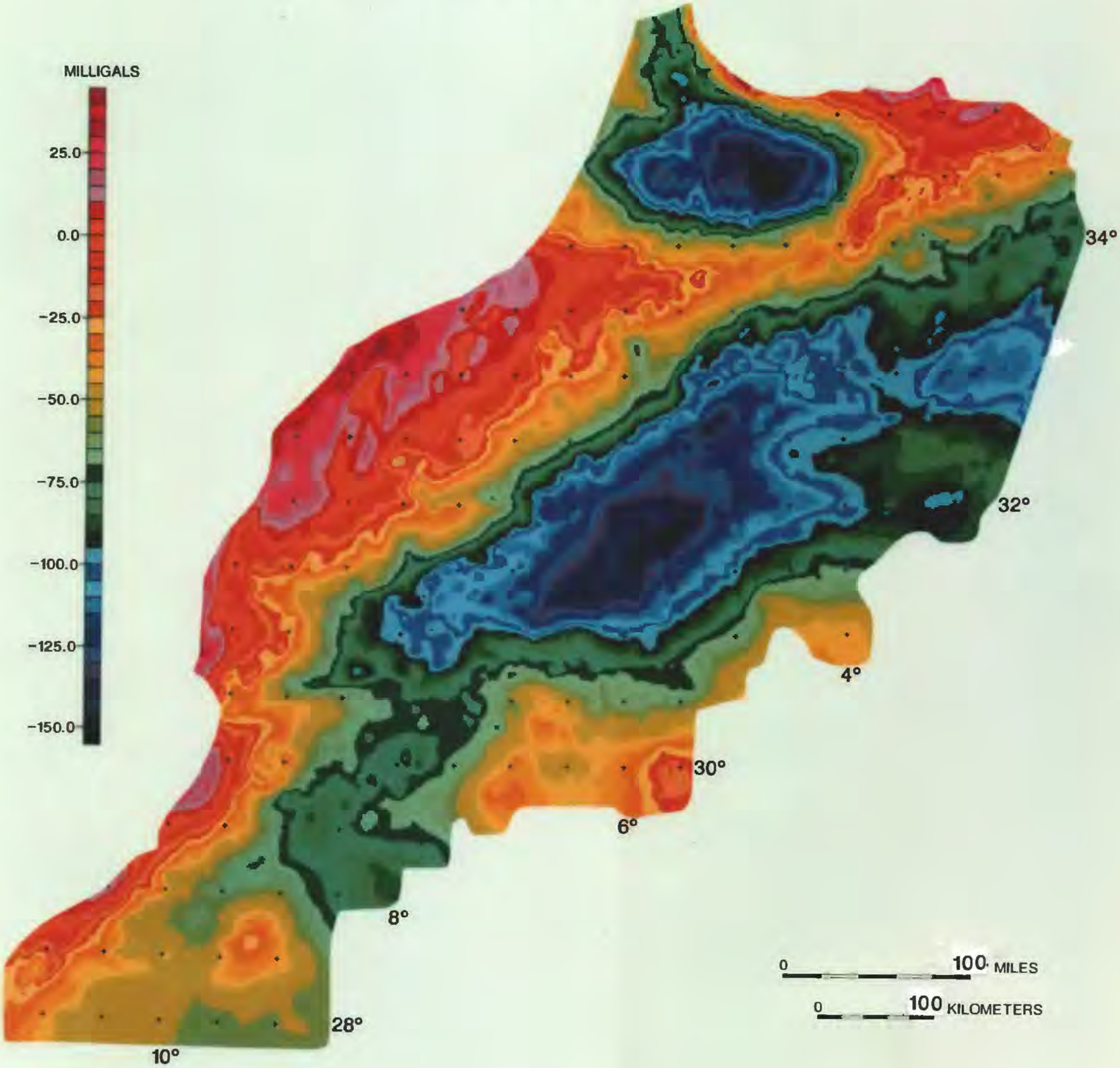
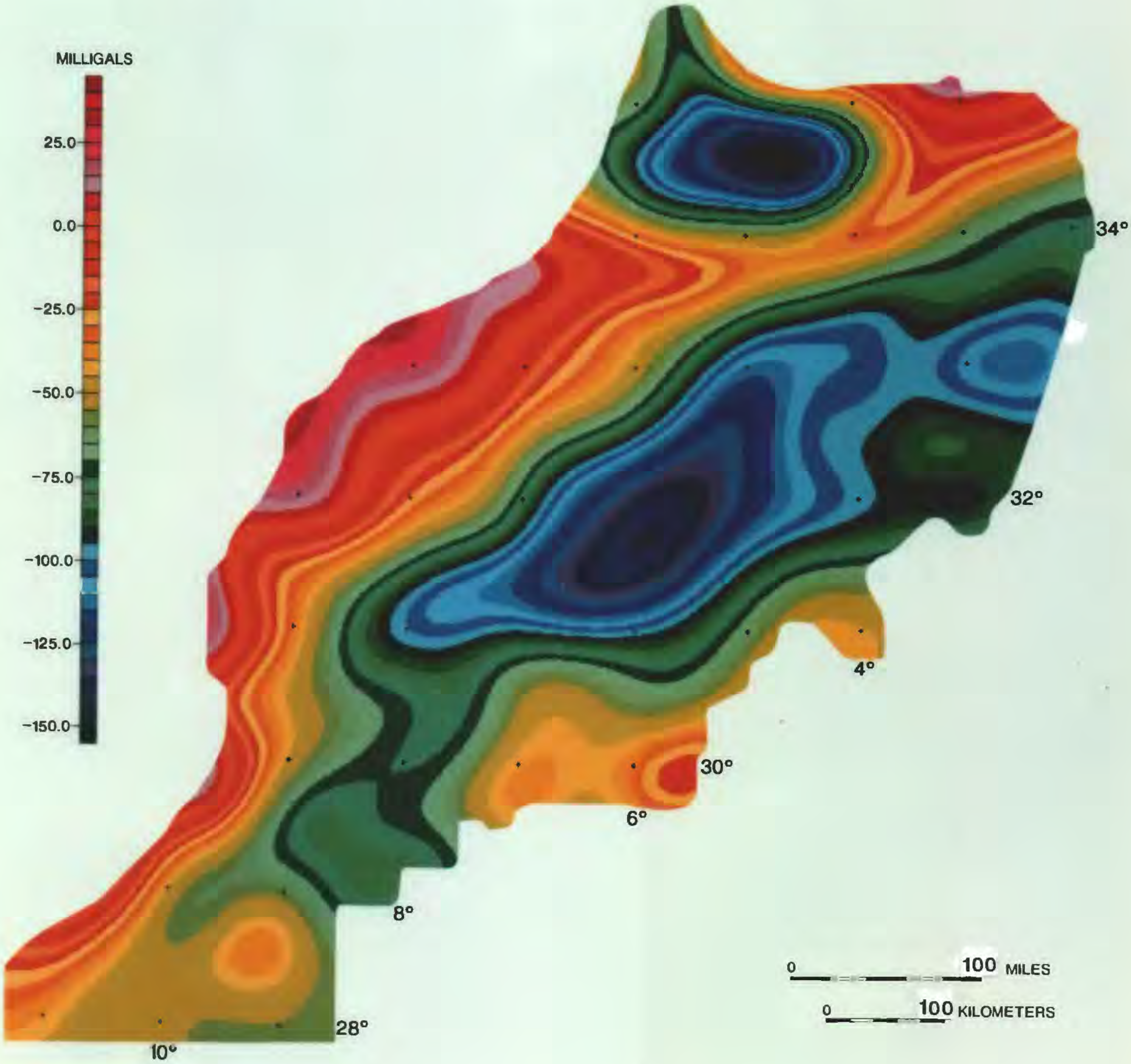


MAP A - INDEX MAP

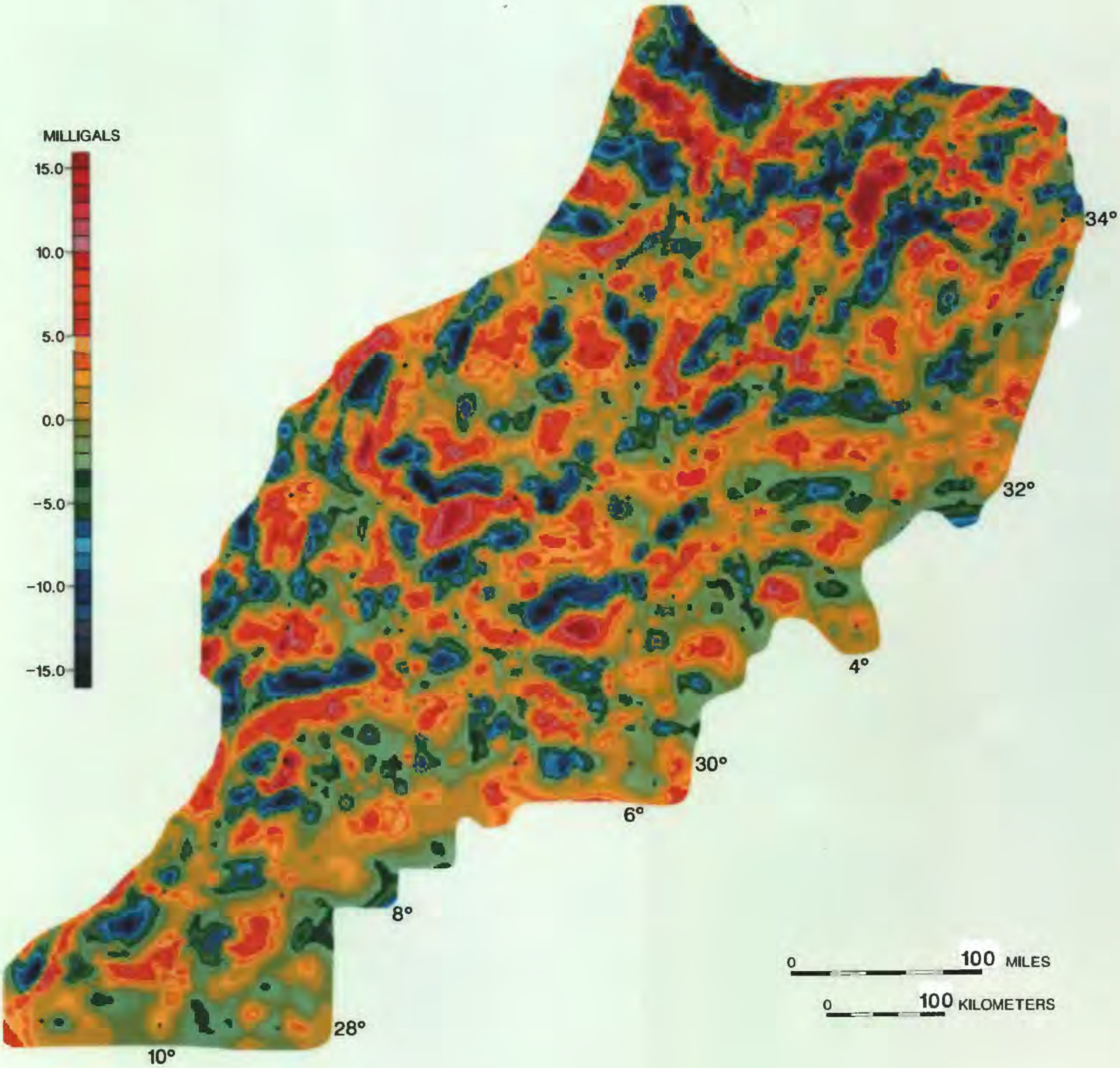
MAP B – BOUGUER GRAVITY



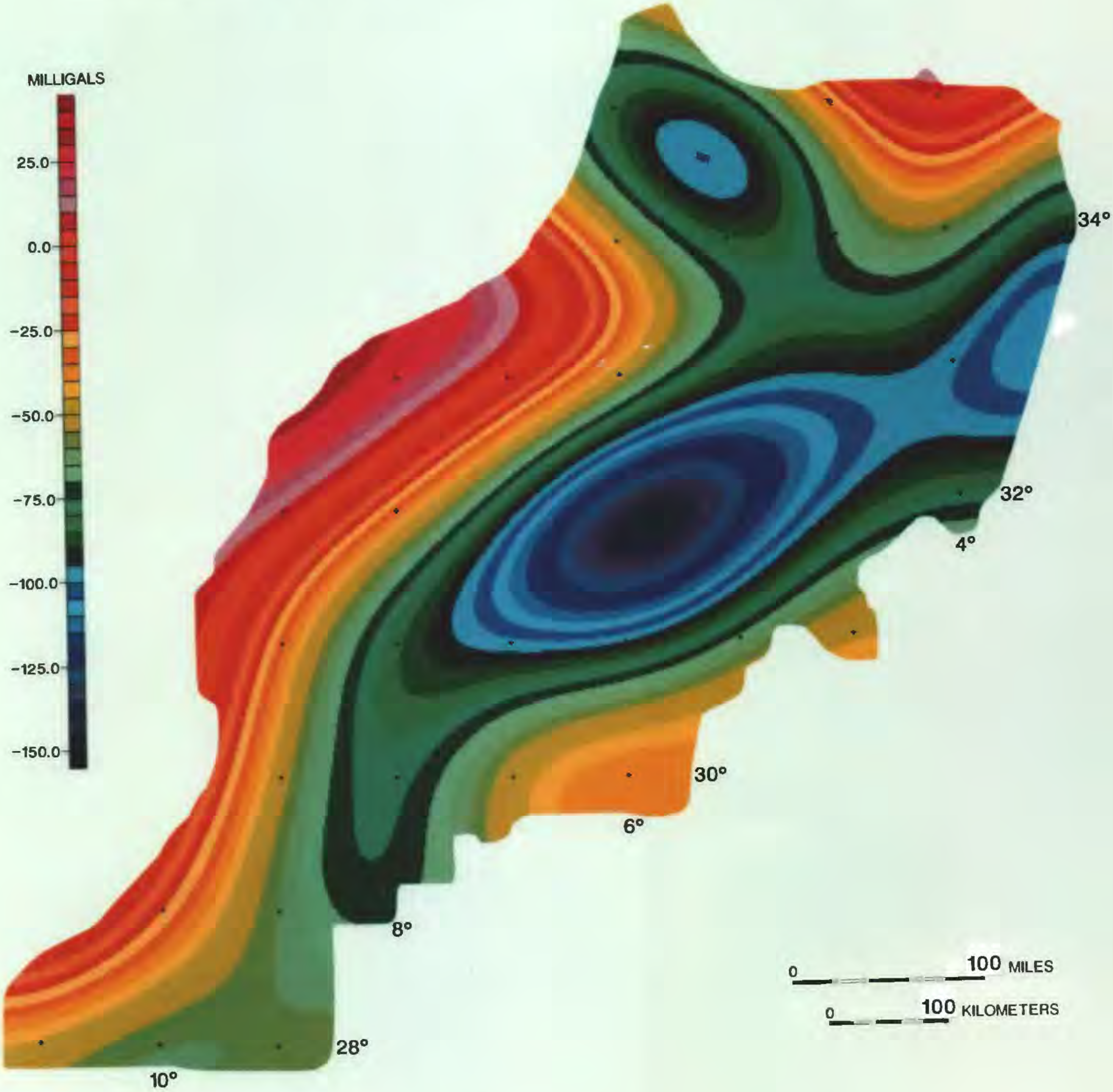
MAP C – REGIONAL GRAVITY: WAVELENGTHS >100 KM



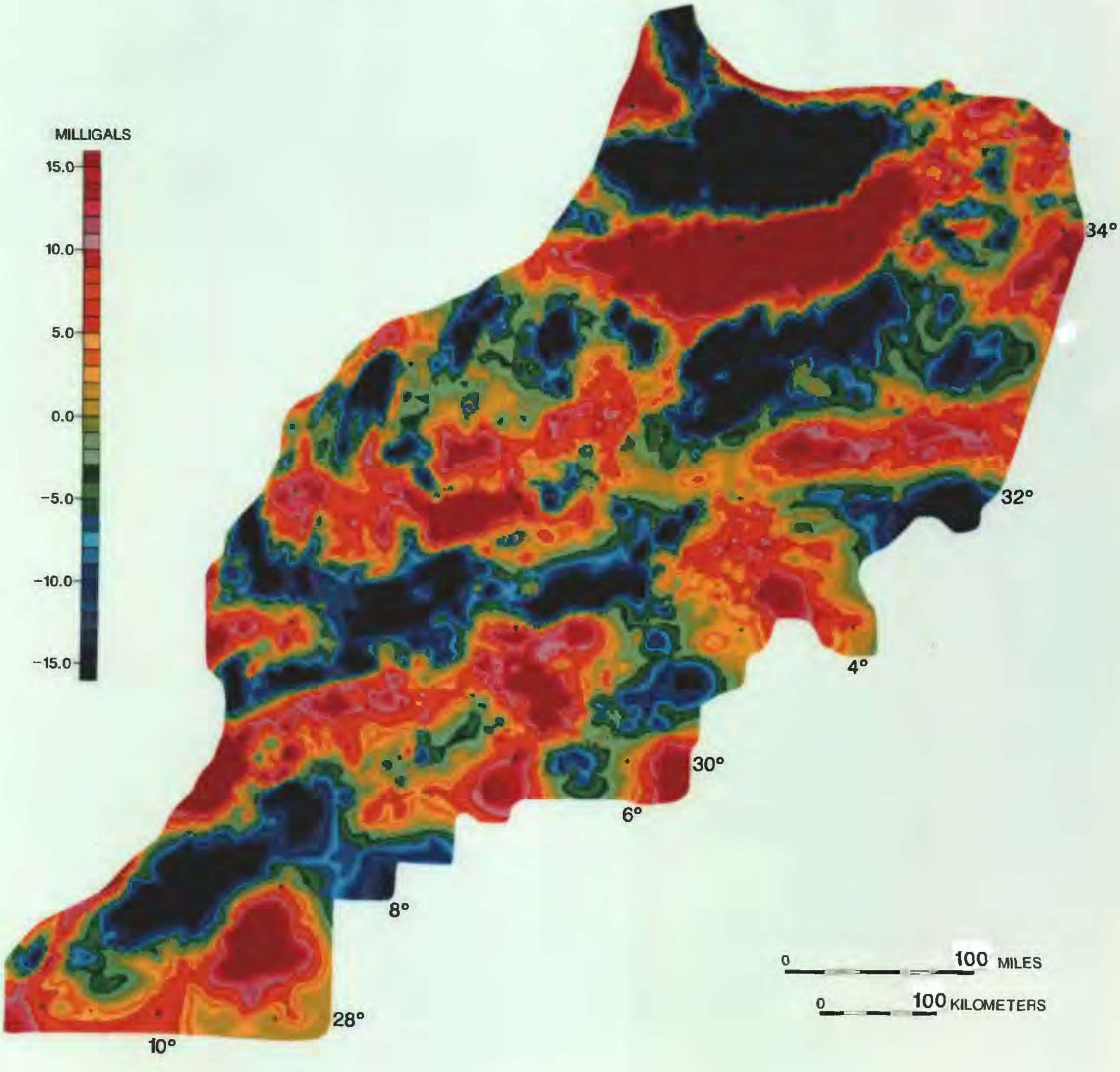
MAP D – RESIDUAL GRAVITY: WAVELENGTHS <100 KM



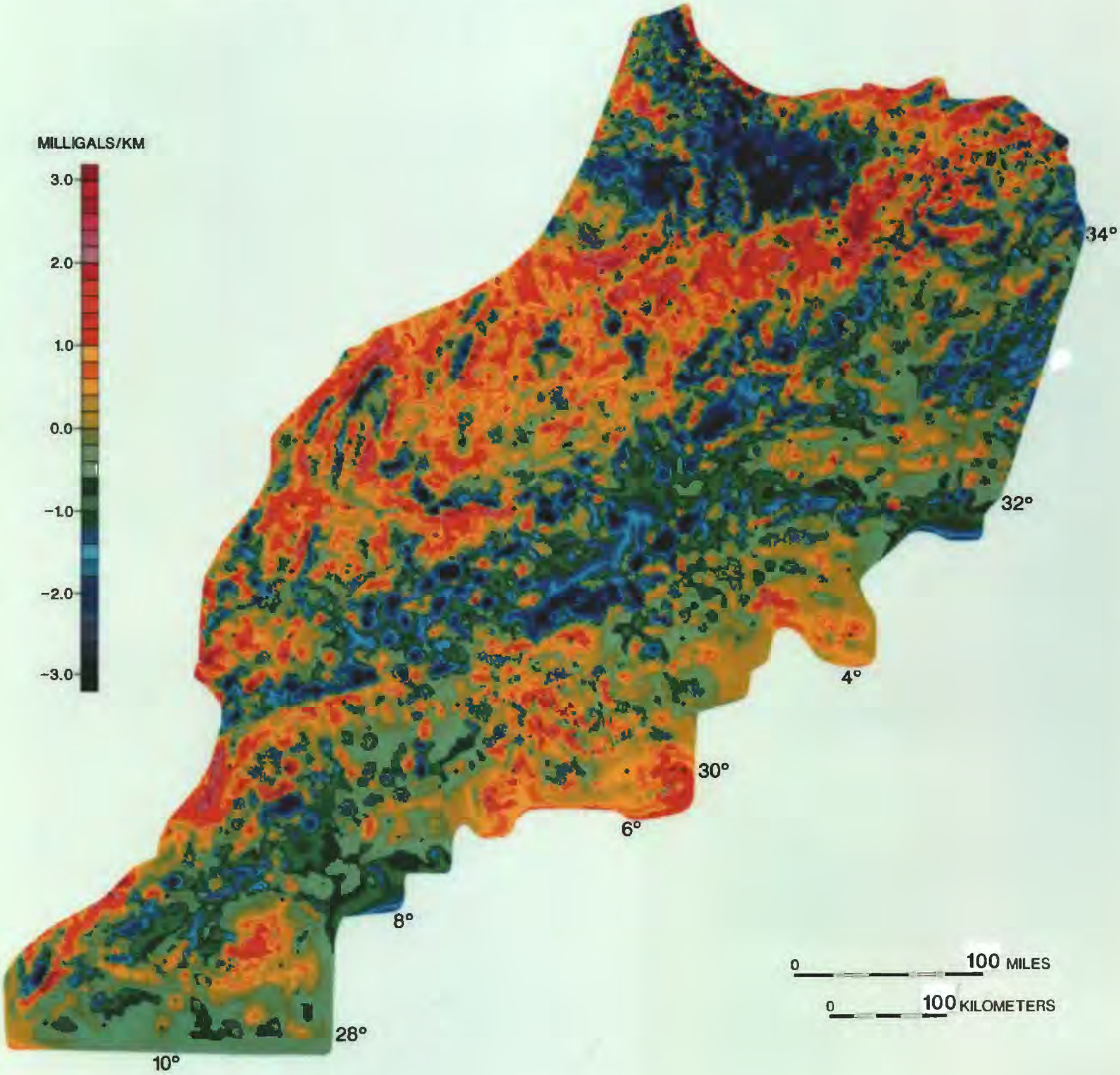
MAP E – REGIONAL GRAVITY: WAVELENGTHS >250 KM



MAP F – RESIDUAL GRAVITY: WAVELENGTHS <250 KM



MAP G – GRAVITY: 1ST VERTICAL DERIVATIVE



MAP H - GRAVITY: HORIZONTAL GRADIENT