Theoria, Vol. 15 (1): 25-31, 2006 ISSN 0717-196X

Artículo

HORIZONTAL GRADIENT SIGNATURE OF MOROCCO BOUGUER ANOMALY

ESTIMACIÓN DEL GRADO DE INCLINACIÓN DE LAS ANOMALÍAS DE BOUGUER, EN MARRUECOS

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ABSTRACT

The grid of the anomalies of the horizontal gradient of the field of gravity of Morocco represents the variations of the field of gravity ascribable to the side variations of density in the earth's crust and the higher coat, which reflect variations of composition and thickness. The systematic gravimetric cartography in Morocco is very recent and always continues. All the data are attached to the international Network of gravimetric standardization of 1971. On a local scale, the gravimetric anomalies are due to the juxtaposition of rocks of relatively low density and rocks of relatively high density. The map of the horizontal gradient is a fundamental utility in prospection for minerals. The horizontal gradient reaches its maximum with the balance of the contact between lithological units of contrasting densities, or with little distance of this contact.

Keywords: Morocco, gravity, gradient, filtering.

RESUMEN

La rejilla de las anomalías del gradiente horizontal de la gravedad de Marruecos representa las variaciones de la gravedad adscribibles a las variaciones laterales de la densidad en la capa más alta de la Tierra y que reflejan variaciones de la composición y la cartografía gravimétrica sistemática en Marruecos es muy reciente y continúa siempre. Todos los datos se unen a la red internacional de la estandardización gravimétrica de 1971. En una escala local, las anomalías gravimétricas son debido a la yuxtaposición de las rocas de la densidad relativamente baja y de las rocas de relativamente de alta densidad. El mapa del gradiente horizontal es de una utilidad fundamental en la prospección para los minerales. El gradiente horizontal alcanza su máximo con el equilibrio del contacto entre las unidades lithological de densidades que ponen en contraste, o con poca distancia de este contacto.

Palabras claves: Marruecos, gravedad, gradiente, filtrado.

Recepción: 26/08/05. Revisión: 15/12/05. Aprobación: 24/05/06.

GEOGRAPHY AND GEOLOGY

Morocco (Fig. 1) is located at the north-western point of the African continent. Of

km of coasts) and is not separated from Spain that by the 14 km of the Straits of Gibraltar. It has terrestrial borders common with Algeria (1350 km) to the east, Mauri-

FIGURE 1. map of the situation of Morocco.

ous corridor separates it from another chain, the Means-Atlas, which stretches the North-East in south-west. More to the south, the chain of the High-Atlas. The plates of Meseta constitute Atlantic Morocco and arid plates are present in the East.

Morocco profits from a moderate and hot climate of Mediterranean type, with oceanic in the west, continental in the center and the east, and arid or desert nuances in the south. The Moroccan climate comprises two seasons; one dries and hot (May at September), the other colder and wet (October at April). The vast mountainous complex formed by Rif and the Atlas also influences the climate and the hydrographic mode. The plates and the Western and septentrional slopes of the mountains receive rains sufficient for the cultures of the Mediterranean type. These mountainous areas are covered with forests (12% of the territory) of holm oaks, holm oaks and coniferous. The zones located beyond the Atlas are on the other hand dry. It is Morocco of the palm plantations and the oases which touch the desert the other colder and wet (October at April).

The country's geological framework evolved during four cycles of continental accretion, which were associated with four successive orogenies. The orogenic belts are clearly defined and thus have served as the basis for the subdivision of the country's geology into the main geological domains that include: the Anti-Atlas domain, the Atlas and Meseta domain, and the Rif domain.

The Rif domain is notable in that it belongs to the European Alps and forms the bow of Gibraltar. It is composed of different units, concentrated around this bow, and these units are subdivided into three areas: internal area, external area, and the area of flyschs. The internal area (Fig. 2) comprises: a massive peridotite containing indices of nickel, chromium, and copper, a Palaeozoic schisto-sandatone complex and Triassic formations containing copper and antimony. The external area comprises three zones: intra-Rif zone, meso-Rif zone, and pre-Rif zone. The area of flyschs is constituted by macro-schist components. The Atlas and Meseta domain extends to the north, up to the contact with the Rif tertiary formations. This domain comprises a Palaeozoic basement of schist-sandstone formations with volcanic rocks and is intruded by a number of granite massifs (Arboyela & al., 2004). The volcano-sedimentary rocks of the Occidental High Atlas are favourable to polymetallic sulphide deposits. The main topographical feature of the Anti-Atlas domain is the Anti-Atlas Mountains. Its Precambrian or Achaean basement and its cover of sub-Precambrian and Palaeozoic rocks bound this domain to the West African Shield.

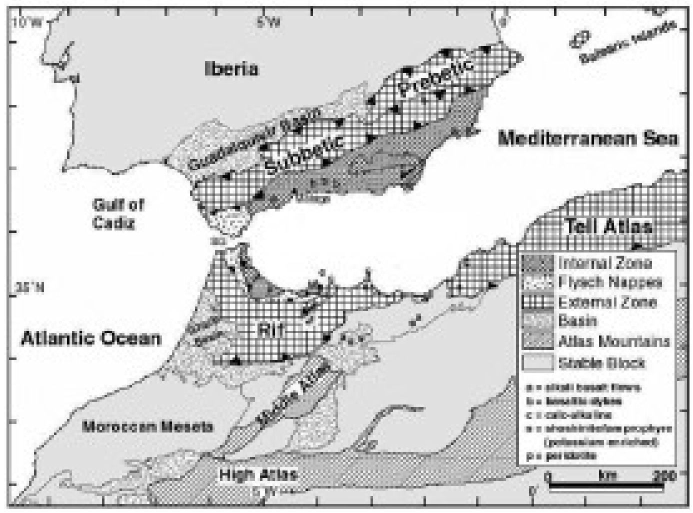


Figure 2. map of the principle features of Morocco.

GRAVITY DATA

The attraction of gravity is not constant on the surface of the Earth: it varies from a point to another. To know the field of gravity it is to be able to determine the intensity and the direction of gravitational acceleration in any point of space. The paramount interest of the study of this size is the variations of the field of gravity are directly related to the in-depth distribution of the masses. The Earth being in rotation on itself, the bodies of surface are also subjected to accelerations known as of inertia. The resultant of all these effects is called gravity.

The gravitation is the force of attraction which a body exerts on another. When it is exerted by the Earth, this force is called "gravity". According to the law of the gravitation of Newton, the force of attraction increases when the mass increases. It also increases when one approaches the centre another, its mass per unit of volume will be larger and the gravitational attraction which will be exerted on him will be stronger. Measurements of gravity do not provide much direct geological information, put aside the representation of the flattened spheroid shape of the Earth, unless corrections are not applied to them to compensate for the effects of the form of the Earth and its relief

As the diameter of the Earth is of approximately 20 km shorter from one pole to another than in the equatorial plan, the force of gravity increases when one approaches the poles. Moreover, the rotation of the Earth makes so that the measured value of gravity is slightly lower at the equator than with the poles. In order to isolate the effects ascribable to side variations of density inside the Earth, it is necessary to remove the sum of the gravitational effects ascribable to the latitude.

BOUGUER GRAVITY ANOMALY

The studied zone is limited between longitudes West 2° to 10°, and latitudes North 30° to 36°. The gravity data references used were obtained from the "Bureau Géodésique International" (Fig. 3). All measurements were brought back to the level of reference of the international Network of gravimetric standardization of 1971. The theoretical values of gravity were calculated using the gravimetric formula of the geodetic System of reference (I.A.G., 1971). The Bouguer anomaly was calculated by employing a vertical gradient of the gravity of 0,3086 mGal·m-1 and a density of 2.67 $g.cm^{-3}$ for crustal lithologies. If φ represents the geographical latitude of the station in degrees of a point given to the surface of the Earth, the theoretical value of gravity g_T in this point is provided by the following international gravimetric formula:

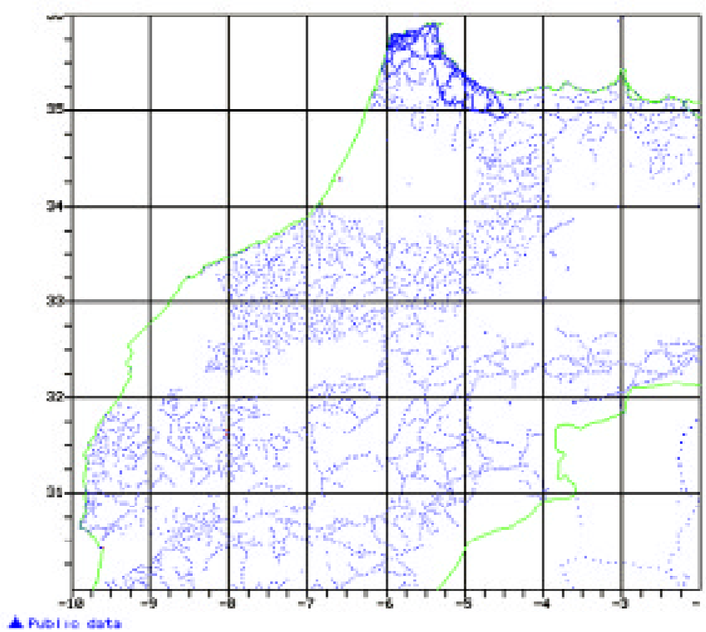


FIGURE 3. map of Morocco data references.

$$g_T = 978031,85(1+0,005278895 \sin^2(\varphi) + 0,000023462 \sin^4(2\varphi))$$

Bouguer anomalies () for each station were calculated using the following expression:

$$\Delta g_B = g_{obs}+(0.3086 - 2\pi G\rho)H - G_T$$

where g_{obs} is the observed gravity, H is the orthometric altitude in meters, is the average density of the crust (2.67 kg/m^3) and G the universal gravitational constant which value is 6.673×10^{-11} N.m^2.Kg^{-2}. We applied this method to the gravimetric map of the area of Morocco. This map (Fig. 4) was traced starting from 5075 data station references and 4661 data measurements which made it possible to calculate a regular square grid of step 450m with about 1 mGal of precision. The Bouguer anomaly reflects the lateral variations of the density of the rocks.

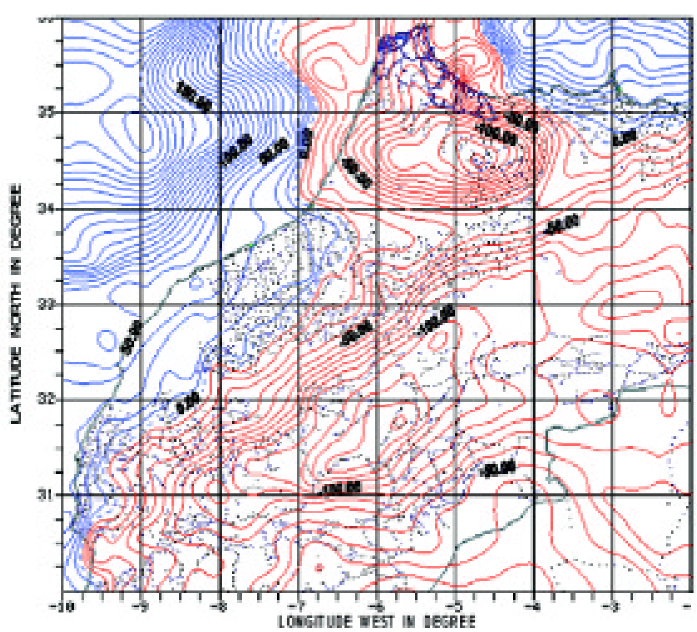


Figure 4. map of Morocco Bouguer anomaly (interval contour: 20 mgal) (Blue contours correspond to positive anomalies)

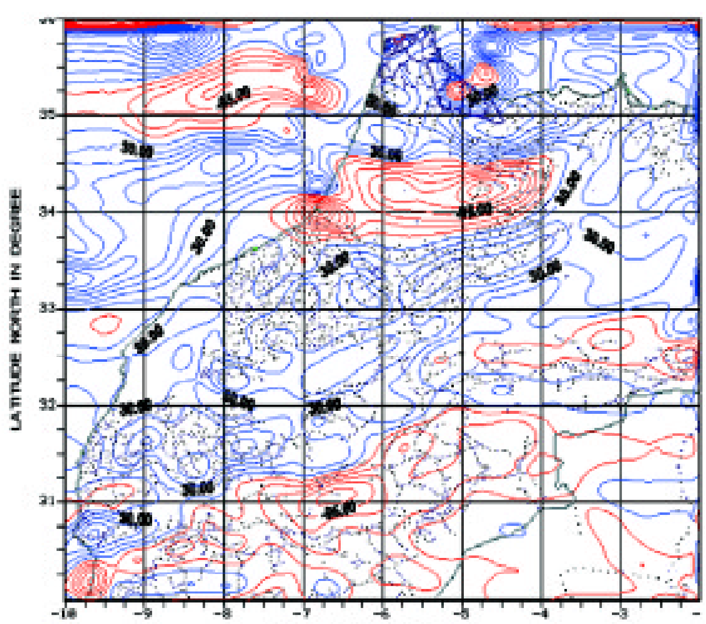
PROCESS

We have applied to the data numerical operator in the space domain. Horizontal gradient is applied to the Bouguer gravity anomaly data. Indeed, the only knowledge it possible to delimit contours in a precise way. The interest of the spatial transformation appears thus fundamental in order to circumscribe the gravity signature of the studied zone. Aliasing and Gibbs phenomena are perfectly circumscribe by the sym-

(regular grid) (Lutz, 1999). The magnitude (Fig. 5) of the horizontal gradient gravity $|g'(x,y)|$ is usually estimated by finite difference methods from values measured at gridded points on the Bouguer gravity anomaly map. The magnitude is determined by a computer program using the following equations:

$$|g'(x,y)| = \sqrt{\frac{\partial^2 g(x,y)}{\partial x^2} + \frac{\partial^2 g(x,y)}{\partial y^2}} \quad \text{with} \quad \frac{\partial g(x,y)}{\partial x} = \frac{g_{i+1,j} - g_{i-1,j}}{2\delta x} \quad \text{and} \quad \frac{\partial g(x,y)}{\partial y} = \frac{g_{i,j+1} - g_{i,j-1}}{2\delta y}$$

where x is the longitudinal coordinate and y the latitude coordinate. $g_{i,j}$ is the pseudo-gravity defined at grid point (i,j). Grid intervals in the x-direction and y-direction are δx and δy respectively. Maxima gravity gradient 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 boundaries (Rakotoniaina, 1999). The absolute value of the intensity of the horizontal gradient was calculated starting from a plan obtained by an adjustment by the method of least squares of a grid of 5 cells out of 5 cells centered on the



point to determine. The filtered data raise the anomalies short wavelength which are the reflection of the existence of contrasts of density close to surface.

DISCUSSION & CONCLUSION

The Bouguer gravity anomaly signatures of the aera of study were circumscribed easily. The horizontal gradient operator applied to Morocco Bouguer gravity anomaly map attest overall homogeneïty and continuity of the zone of study. Contours of the various Bouguer anomalies are well specified and delimited. The analysis of the horizontal gradient map shows that the area enough disturbed along longitude West 5°. This effect is the resultant combined effects of topography and the local tectonic undulations. On the horizontal gradient Bouguer gravity anomaly map, the aera is dominated by an anomalic zone which represents a particular gravity signal of the Riffian zone: this result is probably explained by strong gradients which materialize the brutal changes of density in the basement. That could be possibly used to locate the points of inflection of the vertical contacts (Cordell & Grauch, 1982) between the internal (basalts) and external zones in the Spanish northern side of the Gibraltar Strait zone. The influence of the peridotites present on southern side is also and probably to be consider. Within sight of these results we propose for a future study to consider the study of these strong gradients by analysis multi-scale by wavelet. Indeed, the superposition of the maximas determined buildings on various scales will make it possible to highlight the various contacts present on the horizontal gradient map (Hornby & al., 1999). The linear contacts generally correspond to faults, whereas the contacts of circular form are the limits of the diapirs or intrusive bodies.

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