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EL USO DEL PROCESAMIENTO DE IMÁGENES LOGARÍTMICAS APLICADO AL ANÁLISIS DEL MAPA DE ANOMALÍA GRAVITATORIA DE BOUGUER (ÁREA DE TANGER–TETUAN, MARRUECOS)

THE USE OF THE LOGARITHMIC IMAGE PROCESSING APPLIED TO ANALYSING BOUGUER GRAVITY ANOMALY MAP (TANGIER-TETUAN'S AREA -MOROCCO)

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RESUMEN

El procesamiento de imágenes es una herramienta poderosa para mejorar los bordes en imágenes utilizadas en la interpretación del potencial geológico de campos. Mediciones gravimétricas aéreas y terrestres se realizaron en la región de Tánger-Tetuán. A partir de los datos observados y medidos de la anomalía gravitatoria de Bouguer, un mapa fue creado. Este trabajo reporta los resultados y las interpretaciones de los mapas transformados de anomalía gravitatoria de Bouguer en la zona de Tánger-Tetuán utilizando el procesamiento de imágenes logarítmica. Se aplicó el análisis de filtrado basado en procesamiento de la imagen clásica. Así mismo, se utilizan operadores del procesamiento de imágenes como el operador logarítmico y la herramienta de corrección de gamma. Este artículo también presenta los resultados obtenidos del análisis del procesamiento de imágenes para mejor la detección de bordes en el mapa de anomalía gravitatoria de Bouguer de la zona de Tánger - Tetuán.

Palabras claves: Bouguer, Tangier, filtrado, corrección gamma, mejora de bordes logarítmica.

ABSTRACT

Image processing is a powerful tool for the enhancement of edges in images used in the interpretation of geophysical potential field data. Arial and terrestrial gravimetric surveys were carried out in the region of Tangier-Tetuan. From the observed and measured data of gravity Bouguer gravity anomalies map was prepared. This paper reports the results and interpretations of the transformed maps of Bouguer gravity anomaly of the Tangier-Tetuan area using the logarithmic image processing. Filtering analysis based on classical image process was applied. Operator image process like the logarithmic operator and the associated gamma correction tool are used. This paper also present the results obtained from this image processing analysis of the enhancement edges of the Bouguer gravity anomaly map of the Tangier-Tetuan zone.

Keywords: Bouguer, Tangier, filtering, gamma correction, logarithmic enhancement edges.

INTRODUCTION

In applied geophysics, we are often required to represent a set of measured data in the form of a curve from which desirable parameters or attributes are to be extracted. So sharpening and edge-enhancement filters are often applied to geophysical data that were collected with sample spacing. Consequently, the first step in any processing of such geophysical data is the "cleaning up" of the noise in a way that preserves the signal sharp variations. In the literature, we find several methods that try to analyse and filter the data. The natural question is how we should choose the adequate "interpolating" method from the data so as to analyze the measured physical phenomena. So an alternative methodology to the usual gridding/digital processing pathway is the use of the analytical operators as the logaritmic operator which is an effective edges detection operator.

In edge detection methods based upon logarithmic image processing as the logarithmic operator is proposed in analizing geophysical data as gravity. The contrast operator is introduced for edge detection gravity variation with impressive results. It is usually proven that this method is not dependent on the intensity level of the illumination and that it is robust in small scale changing illumination, specifically at the locally pixel-by-pixel scale represented by the variation of the Bouguer gravity anomaly. The logarithmic image processing method that optimally selects points to represent the data is proposed and applied to analyse the Moroccan Bouguer gravity data map in the erea of Tangier-Tetuan. The The logarithmic image processing is constructed to optimize some property of the Bouguer gravity anomaly data map such as smoothness. In this paper we propose to optimize the responses of the filtered Bouguer gravity anomaly data map using the logarithmic operator that become a powerful signal and image processing tool used to filtering geophysical data.

Geography

The area of Tangier-Tetuan (figure 1) is located at the extreme North-West of Morocco. It is limited to north by the Strait of Gibraltar; in the West by the Atlantic Ocean, in the East and the South by the provinces of Tetuan and Asilah. The area of Tangier is characterized by a Mediterranean climate, with an annual average pluviometry of about 800 mm and an average temperature of 17°C approximately. Precipitations start as from September, reach their maximum in December and then decrease gradually to reach the minimum in August and July. The broad marine opening of Tangier's external unity softens the temperatures, whose values lower than 0°C and higher than 40°C are exceptional. The average diurnal variation is of 8°C.

It is a plain open on the strait, strewn by hillocks and hills and limited by two solid masses with unequal importance: solid mass of Anjera and solid mass of Jbel El Kebir.

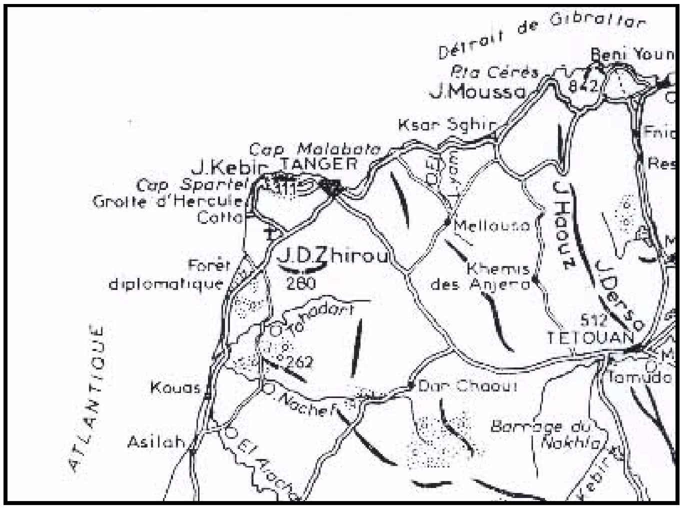

Fig. 1. Situation of the study area

Geology

The area of Tangier-Tetuan belongs to the Riffian field (figure 2). It can be divided into three great morphological units (Biju-Duval and Montadert, 1977):

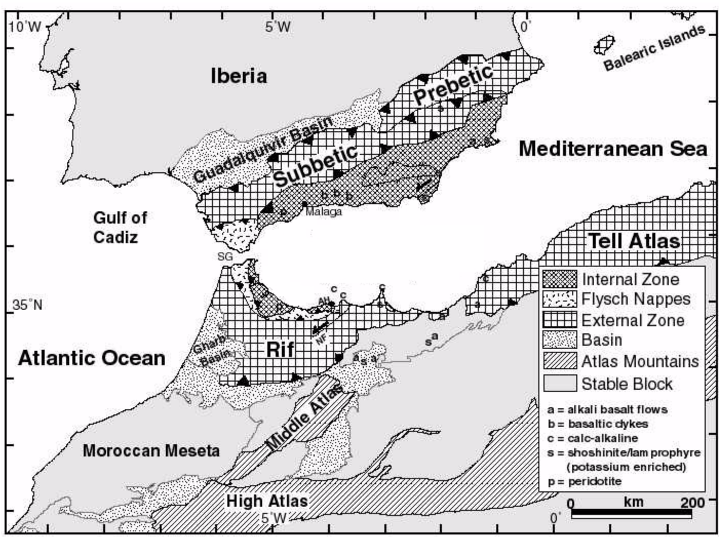

Fig. 2. Principal geological features of the Riffian field

- In the western side a mountainous and coastal solid mass sandy (Jbel El Kebir), parallel with the Straits of Gibraltar and morphology of plate. Average altitude is 150 with 200m there. It is an independent coastal solid mass, parallel at the coast which finishes in a very abrupt way on the strait. It forms the "Numidienne" tablecloth made up of siliceous sandstone, in massive and thick benches pertaining to the Oligocene.

- In the center, the undulating plain of Fahs emerging in the Straits of Gibraltar by bay of Tangier. The hills which strew it have an average altitude of 100 m and dominate a whole of broad valleys succeed either to the ocean or in the Straits of Gibraltar by the means of various wadis.
- In the eastern zone, the solid mass of Anjera, Western northern spur of the chain of Rif, finishing on the littoral in the Cap Malabata. The reliefs marked and are separated by there deep valleys. The tops have altitudes varying from 194 m to 376 m . The solid mass of Anjera is a formed compact solid mass of marno-sandy grounds constituting the unit of Beni Ider. The reliefs are very broken and are separated by deep valleys.

The back coast constitutes a low sablo-muddy plain strewn by marly and argillaceous outcrops towards the east and the south. It is lower and seldom exceeds the 50 m. The littoral has a layout close to an arc of circle having a radius of curvature from approximately 1 500m. Its orientation is between the North-West and the North-East.

Bouguer gravity anomaly

A gravity anomaly is the difference between the measured gravity at a particular location and the theoretical gravity given by a reference Earth model (e.g. The International Gravity Formula/Geodetic Reference System 1980) for the same location. It is widely used in the study of density inhomogeneities inside the Earth. Measured gravity data contain the effects of latitude, Earth tides, instrumental drift, distance from the reference ellipsoid, and masses between the actual topography and the reference ellipsoid (Telford and al., 1991).

In order to obtain anomalies that are comparable over large areas, a number of corrections must be applied. These are commonly referred to as Earth tides, instrumental drift, latitude, free-air and topography corrections. When the first four corrections are applied to measured gravity data we obtain the free-air gravity anomaly, which at short wavelengths correlates strongly with topography. The end-product of all gravity correction is the Bouguer anomaly ΔgB , which should correlate mainly with lateral density variations within the crust and Moho topography. The Bouguer anomaly is readily obtained by applying the correction for the gravitational attraction of topography to the free-air anomaly. The main purpose of the complete Bouguer correction is to remove all non-geological components of the gravity anomalies enhancing subsurface mass variations (Blakely, 1995) (Griffin, 1989). Gravity measurements are used in studying the figure, composition, and structure of the Earth. Density variations of bedrock and soil in the immediate vicinity of measuring points influence the force of gravity in a discernible way. Quantities describing position, shape, and structure of geological formations can be interpreted from this local variation of gravity. Measuring gravity has thus become an important method in geological mapping and exploration for mineral resources.

The field area lies between latitudes 35.035°N and 36.057°N. The studied zone is also limited between longitudes 5°W and 6°W. The gravity data used were obtained from the “Bureau Géodésique International” (I.A.G, 1971) (figure 3) and were supplemented by aerial gravity data.

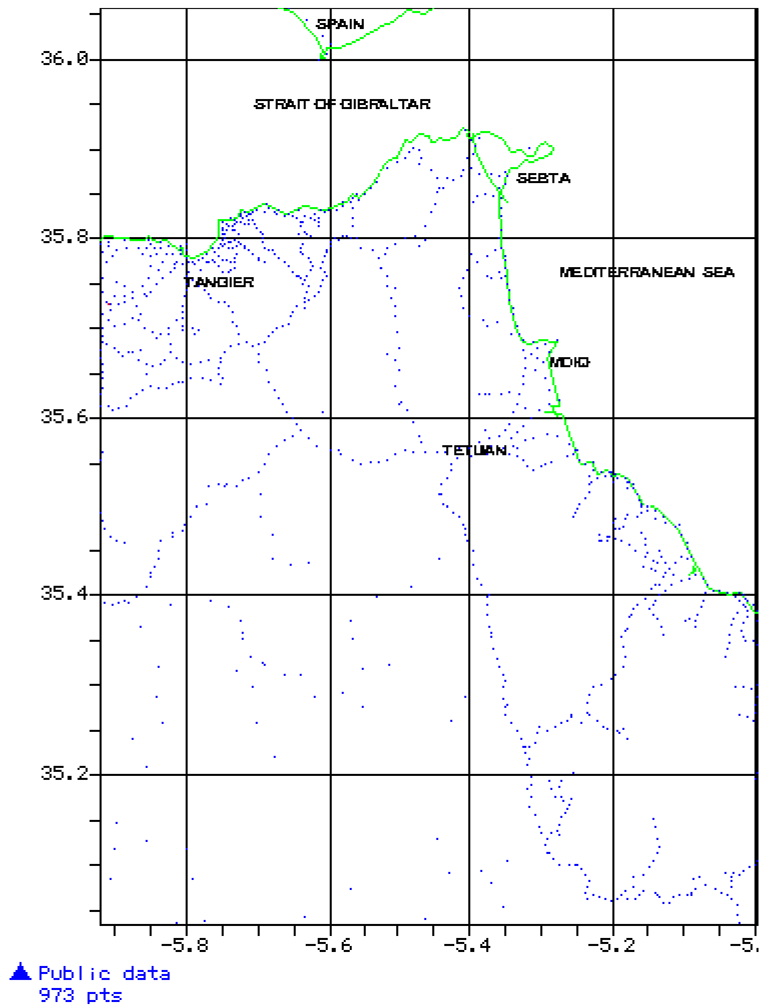

Fig. 3. Data gravity reference map (BGI,2005)

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. The Bouguer anomaly was calculated by employing a vertical gradient of the gravity of 0,3086 mGal·m-1 (Swick, 1942) and a density of 2.67 g.cm-3 for crustal lithologies.

If represents the geographical latitude of the station in degrees of a point given to the surface of the Earth, the theoretical value of gravity in this point is provided by the following international gravimetric formula:

$$g_T = = 978031,85(1+0,005278895 \sin^2( ) + 0,000023462 \sin 4(2))\text{mGal}$$

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

$$\Delta g_B = g_{obs} + (0.386 - 2\pi G\rho)H - g_T$$

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 6.673x10-11 N.m2.Kg-2. We applied this method to the gravimetric map of the area. The corresponding map (figure 4) is been generated using about 1050 free public data and 1200 measured data which made it possible to calculate a regular grid with a step of 450 m and also with about 1 mGal of precision. The Bouguer gravity anomalous zones (figure 5) is obtained using Golden Surfer software (Surface Mapping System, 1997) (Cooper, 2000). The Bouguer anomaly reflects the lateral variations of the density of the rocks (Lutz, 1999).

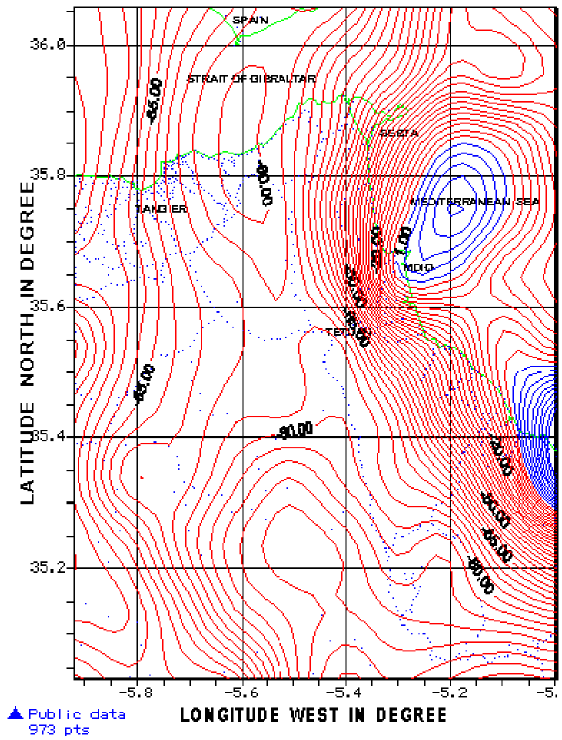

Fig. 4. Bouguer anomalies map of the area of Tangier-Tetuan
(interval contour 3 mGal, blue contours correspond to positive Bouguer anomalies)

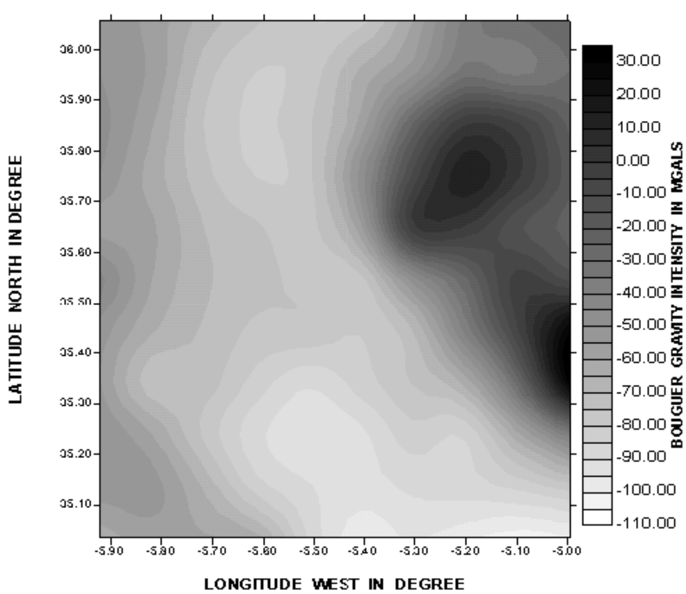

Fig. 5. Bouguer gravity anomalous zones of the area of Tangier-Tetuan

We notice that the positive anomaly centered on the zone of M'diq and radiant on the zone of Tetuan correspond probably to the basaltic base and also to the presence of peridotites. This map also indicates the limit of the lateral variations of the densities of the base. Positive and negative anomalies also result from the contrasted variations of topographic altitudes (Lutz, 1999).

Map of the Bouguer gravity anomaly is assimilated to image where anomalous areas have different levels of reflectance in gray scale. Levels of reflectance were in first approach considered directly linked to the intensities of the Bouguer gravity anomaly. In this particular context anomalous zones will appear disturbed on a scale going from slightly to very strongly in accordance with a scale of levels of gray. As the data of the Bouguer gravity anomaly will induce noise implicitly, contours of anomalous zones, corresponding to positive Bouguer anomaly on the zones of M'diq and Tetuan, present distortions. The image processing operated in these work aims to effectively circumscribe its singular zones of the Bouguer anomaly.

METHODOLOGY

The Logarithmic Image Processing, the LIP operator

An edge detector is defined as a mathematical operator of small spatial extent that responds in some consistent manner to the discontinuities, usually classifying every image pixel as either constituting an edge or not. Much research has been spent developing effective edge detection algorithms. Traditionally, edge identification is performed by derivative measures (gradient or Laplacian) and thus implemented by linear filtering structures. The derivative is computed along a set of fixed orientation or along the orientation of the strongest intensity variation. Basically, all edge detection operators rely on the computation of an edge intensity map (that provides important values for the pixels that are on the boundaries of uniform regions) which is further thresholded in order to obtain a binary edge map.

The logarithmic image processing (LIP) operator is a mathematical framework based on abstract linear mathematics which provides a set of specific algebraic and functional operations that can be applied to the processing of intensity images valued in a bounded range. The LIP has been proved to be physically justified in the setting of transmitted light and to be consistent with several laws and characteristics of analizing geophysical data. Successful application examples have also been reported in several image processing areas, e.g., image enhancement, image restoration, three-dimensional image reconstruction, edge detection and image segmentation of geophysical data mapping.

The key to the logarithmic image processing approaches is a homomorphism which transforms the product into a sum (by logarithm), allowing the use of the classical linear filtering in the presence of additive components. So, in the edge detection method based upon Logarithmic Image Processing (LIP), a contrast operator is introduced for edge detection with impressive results. The dynamic range of an image can be compressed by replacing each pixel value with its logarithm. This has the effect that low intensity pixel values are enhanced. Applying pixel logarithm to an image can be useful in applications where the dynamic range may too large to be displayed on a screen. The logarithmic image operator is a simple point processor where the mapping function is a logarithmic curve. In other words, each pixel value is replaced with its logarithm. Most implementations take either the natural logarithm or the base 10 logarithm. However, the basis does not influence the shape of the logarithmic curve, only the scale of the output values which are scaled for display on a 8-bit system. Hence, the basis does not influence the degree of compression of the dynamic range.

The logarithmic image processing mapping function is given by equation (1)

$$Q(i,j)=c\log\left(1+\left|P(i,j)\right|\right) \quad (1)$$

where Q(i,j) and P(i,j) are respectively the output and input images (Gonzalez and Woods, 1992) assimilated in our case as the anomalous zones of the Bouguer gravity anomaly map.

The scaling constant c is chosen so that the maximum output value is 255 (providing an 8-bit display).

That means if R is the value with the maximum magnitude in the input image, c is given by the following equation (2)

$$c=\frac{255}{\log\left(1+\left|R\right|\right)} \quad (2)$$

The degree of the compression (which is equivalent to the curvature of the mapping function) can be controlled by adjusting the range of the input values. Since the logarithmic function becomes more linear close to the origin, the compression is smaller for an image containing small input values. These operator increase the contrast of low pixel values at the cost of the contrast of high pixel values. Hence, the logarithm operator is suitable to enhance details contained in the high values corresponding to high values of the Bouguer gravity anomaly. However, it produces slightly different enhancements, since the shape of their curves are not identical (Jain, 1989)

So the enhancement edges in geophysical potential data is useful as it allows lineaments to be made more apparent, thus helping the geological interpretation process. Another method currently used to the enhancement edges is termed gamma correction method. The transformation macro implements a gamma correction function. The brightness of an image can be adjusted with a gamma correction transformation. This is a nonlinear transformation that maps closely to the brightness control. Gamma correction functions are often used in image processing to compensate for non-linear responses.

Different reflectance models are available for gamma intensity factor. The gamma contrasting mapping function is given by the above equation (3)

$$Q(i,j)=255\left(\frac{P(i,j)}{255}\right)^{gamma} \quad (3)$$

where Q(i,j) and P(i,j) are respectively the output and input images where (Cooper, 2003) .

RESULTS

The data process was executed using the Golden Surfer software (Cooper, 1999, 2004). The gamma correction and the logarithmic tools are basically spatial filters to the enhancement edges of anomalous zones. This process allows to better constrain the anomalous contours zones.The various Bouguer gravity maps obtained from the survey had been considered as maps of discrete potentials on the free surface, and any major singularity in the Bouguer gravity due to the presence of a perturbation would be due to the crossing from a “normal” into a “perturbed” area or vice versa (Cooper and Cowan, 2003). The transformed Bouguer gravity maps obtained and based under those hypothesis, had allowed us direct images for an interpretation of the gravity survey. The various sunshaded Bouguer gravity maps (figure 6) obtained starting from this process allowed us to optimize the edges of the anomalous zones (Horn, 1982).

We were, in first approach, able to identify the anomalous zones which turned out to be strongly correlated with the microtectonics. The degree of correlation is directly connected to the level of reflectance.

These zones correspond to the disturbances of peridotic origin of the areas of Tetuan and M'diq. Theses results were corroborated by the filtered sunshaded Bouguer gravity maps using the optimization contrast tool of Image Enhancement software (Backström, 2004).

The transformed maps represent an effective indicator of the level of disturbance measured on the topographic surface corresponding to the study area. The maxima reflectance would be occur immediately over rock masses of contrasting densities. The reflectance will represent in this case an indicator of variation level of contrasting densities. A high reflectance ratio will represent a strong level of contrasting densities. In our case, the anomalous areas edges were better enhanced. According to the appreciation of the geologists anomalous zones will be described as little, slightly, fairly, enough or highly disturbed. These properties will be correlated to the enhancement edges of the anomalous zones resulting from the image processing.

CONCLUSIONS

We found that the image processing approach using logarithmic and gamma correction spatial operators help to better constrain the location of anomalous areas on the surface. We have described an analytical procedure, which is a spatial filter, to enhance edges of anomalous zones of a specific problem in the geosciences image processing. The results proved satisfying. Data processing procedures as image processing were found to be consistently useful and may be used as auxiliary tool for decision making under field conditions.While assimilating the reflectance level to disturbances of densities, spatial operators appear to be an interesting technique of optimization of enhancement edges on the Bouguer gravity anomaly map. While assimilating the grey scale level to level of anomalous zones of Bouguer gravity, this singular study appears to be an interesting technique of geological interpretation. A comparison with the responses of different spatial filters such as Gradient and Laplacian would be beneficial and effective. Nevertheless it would seem that these results are similar by analogy, in terms of interpretation of anomalous zones, to results obtained in the filtering of a resistivity data map by Sunshading technique (Bakkali, 2007).

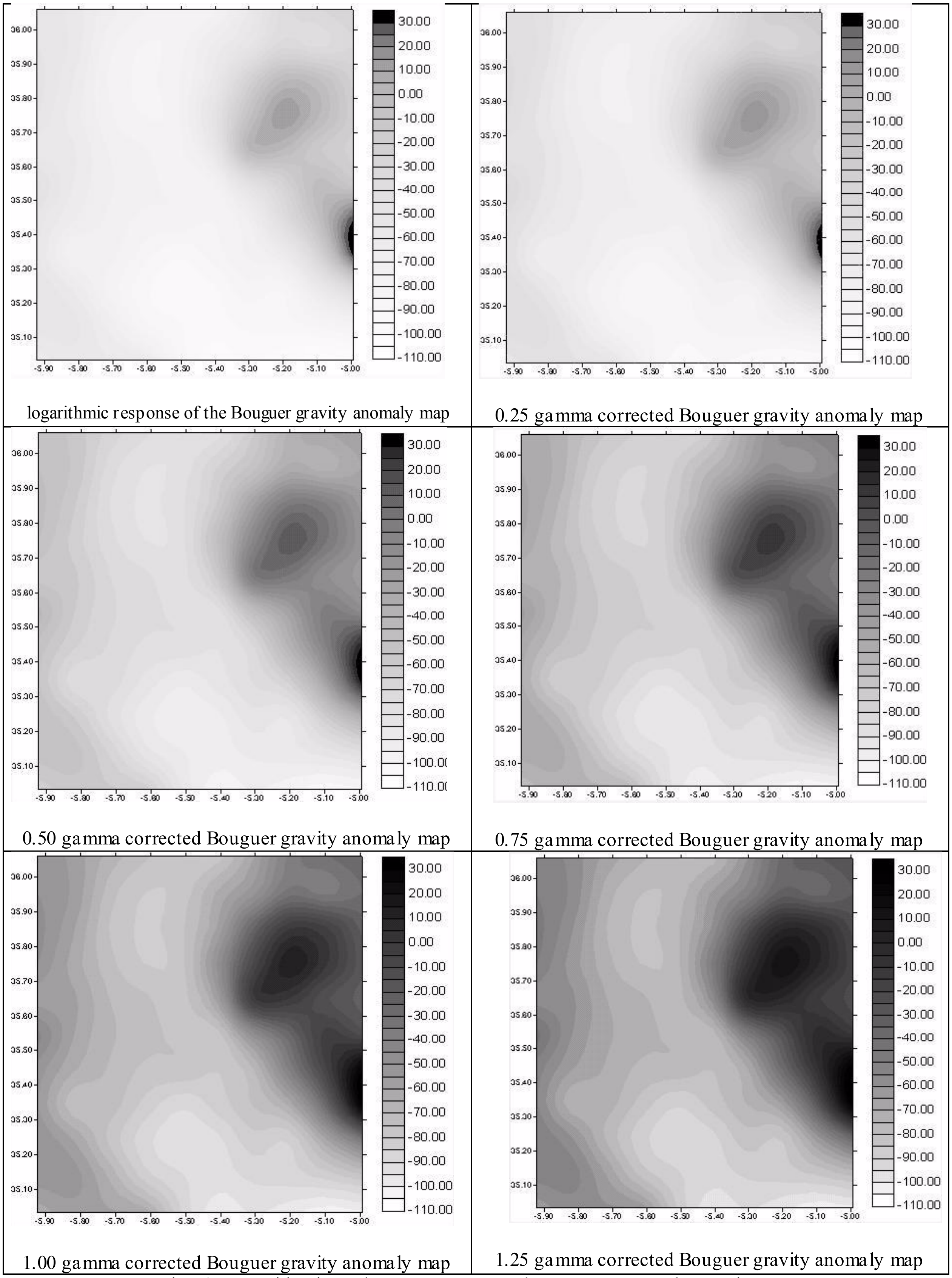

Fig. 6. Logarithmic and gamma corrected Bouguer anomaly gravity maps

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