2-D and 3-D imaging of aeromagnetic and gravimetric anomalies causative bodies, in the Cheliff region (NW of Algeria), using the continuous wavelet transform.

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Summary

A method based on the wavelet transform is used to localize the causative bodies of potential field anomalies. The particular class of analyzing wavelets belonging to the Poisson semigroup such the analyzed anomaly has a conical signature in the wavelet domain with its apex pointing at the location of the causative homogeneous source. In previous studies we introduced by applying this formalism to the special case of anomalies produced by elongated sources like faults, dikes or prismatic bodies. We showed that, for this particular type of anomalies, the two-dimensional (2-D) wavelet transform corresponds to the ridgelet analysis and reduces to the 1-D wavelet transform applied in the Radon domain. In this work, we make a brief recall of the method and show the preliminary results obtained by applying this method on aeromagnetic and gravimetric data acquired in the Cheliff region, in the NW of Algeria.

Introduction

The characterization and the localization of the sources of geophysical potential fields (electrical, magnetic, gravitational, thermal, etc.) measured at the surface of the Earth continue to motivate numerous methodological studies resulting in a number of inversion and analysis techniques (e.g., Blakely, 1996). In more recent times, classes of methods intermediate, between the visual inspection and inversion have gained in popularity (Hornby et al., 1999). The wavelet approach independently proposed by Moreau et al. (1997) and Hornby et al. (1999) exploits the homogeneity properties of the potential field to detect, localize and characterize the sources. Further developments revealed that the wavelet approach is particularly efficient to deal with noise as shown through applications to aeromagnetic data (Sailhac et al., 2000; Boschetti et al., 2004), spontaneous electrical potential (Gibert and Pessel, 2001), gravity data (Martelet et al., 2001; Fedi et al., 2004), and electromagnetic data (Boukerbout et al., 2003). The 2-D wavelet method was developed (Boukerbout and Gibert, 2006) in order to account for the variety of shapes of the potential field anomalies which may be encountered in practice. In this work, we present a method based on the wavelet transform, which is used to localize the causative bodies or sources of potential field anomalies. In previous studies we introduced a particular class of wavelets belonging to the Poisson semi-group such that the analyzed anomaly has a conical signature in the wavelet domain with its apex pointing at the location of the causative homogeneous source, in particular, adapting the 1D wavelet method to the 2D case and to enable to process potential field maps. We attack this matter by proposing a wavelet method based on the use of the so-called ridgelet functions (Candès, 1998). We show how the method developed may be used to analyze anomalies caused by elongated source distributions. Latest developments show then when combined with a Radon transform, the continuous wavelet transform can help in the automatic detection of elongated structures in 3D, simultaneously to the estimation of their strike direction, shape and depth (Boukerbout and Gibert, 2006; Sailhac and al., 2009). We also present and discuss some preliminary and new results obtained by an application of this method to aeromagnetic and gravimetric data.
data acquired in the Cheliff region, in western Algeria, where we depict the geological structures on shore and off shore. This region is bounded by an Alpine-type orogen resulting from the subduction and closure of the Thetyan Ocean and from the interaction between the European and African plates. The region displays a complex geological setting. We aim at bringing, in this work, a little contribution to try to understand and replace the region in a regional geodynamical context.

Methodology

Wavelet Analysis and the 2-D Continuous Ridgelet Transform of Potential Field Anomalies
In this section we make a brief recall of the mathematical background of the method. A general presentation of the wavelet theory may be found in the book by Holschneider (1995) and a detailed discussion of the wavelet transform applied to potential field theory is given by Moreau et al., (1997, 1999). The two-dimensional (2-D) wavelet transform of potential fields, corresponds to the ridgelet analysis and reduces to the 1-D wavelet transform applied in the Radon domain, for more details on method, see (Boukerbout and Gibert, 2006).

The 1-D Continuous Wavelet Transform
We define the 1-D continuous wavelet transform, $W[a,b,\phi]$, of a function $\phi(x) \in \mathbb{R}$ as the convolution product,

$$W[a,b,\phi](x) = \int_{\mathbb{R}} g(\frac{b-x}{a}) \phi(x) dx = (D_a g \ast \phi)(b)$$

(1)

Where the function $g(x)$ is called the analyzing wavelet, $a \in \mathbb{R}^+$ is the dilation parameter, $b$ is the translation parameter, and the dilation operator $D_a$ is defined by the following action (Goupillaud and al., 1984),

$$D_a g(x) = \frac{1}{a} g\left(\frac{x}{a}\right)$$

(2)

The 2-D Continuous Ridgelet Transform
In the case of a 2-D potential field anomaly data measured in the horizontal plane, the 1-D wavelet transform given by equation (1) may be generalized to give ridgelet transform (Candès, 1998; Candès and Donoho, 1999),

$$R[r,\phi](b,a,s) = \int_{\mathbb{R}^2} \frac{1}{a^2} r\left(\frac{b-x}{a}, y, s\right) \phi_0(x,y) dxdy = \int_{\mathbb{R}^2} \frac{dx}{a^2} g\left(\frac{b-x}{a}\right) \int_{\mathbb{R}^2} \phi_0(x,y) dxdy$$

(3)

where $s$ is a unit vector perpendicular to the anomaly strike, $s$ is a unit vector in the direction of the elongated anomaly, the analyzing ridgelet is obtained by steering a 1-D Poisson wavelet $g(x)$ in the perpendicular direction $y$, $RT$ is the Radon transform of the potential field anomaly. Equation (3) shows that the ridgelet transform of 2-D anomalies is given by the 1-D wavelet transform applied in the Radon domain. In practice, this is done by computing a 1-D wavelet transform for each direction in the Radon domain. The ridgelet transforms display a conspicuous conelike pattern typical of homogeneous sources. The apex of the cone is located below the $a = 0$ horizontal axis of the ridgelet transforms, i.e., at a negative dilation corresponding to the depth of the homogeneous causative source. The determination of the position of the apex may be done either with the modulus or the phase of the ridgelet transform; however, the phase furnishes a more accurate localization because of both its more abrupt variations and also because the conical signature of the sources may directly be processed without performing the rescaling formulas (Boukerbout et al., 2003; Boukerbout and Gibert, 2006).
Application to gravimetric and aeromagnetic fields data in the Cheliff region
We apply the ridgelet analysis to gravimetric and aeromagnetic fields data (Figure 1) acquired in the Cheliff region, in the NW of Algeria (Figure 2). The Cheliff region is located in the NW of Algeria at the coordinates of $0^\circ33'E-2^\circ00'E$ and $35^\circ48'N-36^\circ55'N$ (Figure 1). It is bounded in the North by the Mediterranean Sea and in the South by the mounts of Ouarsenis which are part of Tellian chain. The studied zone is a part of Northern Africa which is affected by an Alpine-type orogen resulting from the subduction and closure of the Tethyan Ocean and from the interaction between the European and African plates (Auzende et al., 1973).

**Figure 1.** Map location and topographic relief of the studied area located at coordinates: $35^\circ48'N – 36^\circ56'N & 00^\circ33'E – 02^\circ00'E$

**Figure 2.** The Bouguer anomaly map (left) and the aeromagnetic anomaly map (right) of the studied region.

The Bouguer gravity map shows some positive anomalies oriented ENE-WSW, mainly due to the effect of the oceanic nature of the Mediterranean crust. While in the south, we note the negative effect of the roots of the Ouarsenis Mountains. The magnetic anomaly map shows in the South, an important anomaly elongated in approximate E-W direction, characterized by much longer wavelength, most likely reflecting variations in basement magnetization, and/or topography. Northward, there is another elongation axe, in the approximate NE-SW direction, which appears both on the magnetic anomaly map and topographic relief map. In the Mediterranean Sea, appear another important anomalies in the E-W direction caused probably by the Miocene volcanic structures.
Figure 3. Localization in 3-D of the gravity (a) and magnetic (b) anomalies causative bodies. The y axis indicates the North direction.

The results obtained from the wavelet and ridgelet analysis applied on the total magnetic and gravimetric fields anomaly data (Figure 3), show the deepest origin of the structures responsible of the anomalies in the North (offshore). The sources are identified at about 29 km of depth and are elongated in the E-W direction, while the thickness of the basin is at about 8 km; it is the depth of the basement. The identified structures are in a direction with general tendency NE-SW, intersected by structures in directions NW-SE, N-S and E-W. In the South of the region, the depths of structures are about 20 km. For gravimetric anomalies sources, the deepest ones are located in the East and West regions off the studied area at about 20 km and are oriented respectively in the NE-SW and N-S directions.

Conclusions

The depth or the thickness of the Cheliff basin is about 8 km. The most identified structures correspond to contact and faults across the basement or to volcanic structures in the North part of the region, in Mediterranean Sea. The structures identified are confirmed by the Neotectonic framework of the Tell Atlas (Meghraoui, 1982; 1988 and 1996) where it is suggested that NE-SW striking fault-related folds in Neogen and Quaternary basins show a parallel distribution. In the Cheliff basin, Quaternary folds have a dextral setting which suggests the occurrence of an E-W strike slip fault at depth. The E-W faults bordering the basin and cutting across the basement, limit Neogen basin, show a reverse component and likely control the NE-SW faults system.

References


