Wavelet analysis of 3D Analytic signal for contacts identification from aeromagnetic data

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Abstract

In this paper we have analyzed the aeromagnetic data using the 3D analytic signal technique combined with the 2D continuous wavelet transform (CWT). The objective is to delineate structural boundaries using the spatial distribution of maxima of modulus of the CWT of the analytic signal (AS). The proposed idea has been applied at geomagnetic data of In Ouzzal area, it is located in the western of Hoggar(Algeria).
Obtained results are compared with geological map and analytic signal solutions. It shows that with this approach we are able to resolve the problem of noise effect on the analytic signal solutions, and the reduction to the pole in the contacts identification by the CWT. Our method shows a good precision where geological contacts are known.
Keywords: *Aeromagnetic data, analytic signal, boundaries, CWT, maxima.*

Introduction

The continuous wavelet transform has becoming very useful tool for analysis of potential field data (Martlet et el, 2001, Cooper, 2006, Ouadfeul et al, 2010). Many model of potential field data interpretation are proposed, the horizontal gradient (Blakely and Simpson, 1986) and the analytic signal or full gradient (Nabighian, 1984, Roest et al, 1992) are the classical methods of the last decades. The big weakness of these techniques is sensitivity to noise (Cooper, 2006). Since the presence of noise in the potential field can give fictitious contacts. This is due to the de derivative operator that amplifies noise effect. Usually we use a threshold to eliminate these fictitious contacts. However by this way, many high frequency causative sources will be missed. For this reason we propose in this paper a technique of boundaries delimitation from geomagnetic data. This last is based on the analysis of the amplitude of 3D analytic signal defined by Roest et al (1992) by the 2D CWT. After that maxima of the modulus of the CWT for all range of scales are mapped. The set of maxima will give geological boundaries.

The processing algorithm

The proposed idea is based on the calculation of maxima of the modulus of the 2D continuous wavelet transform of the amplitude of the analytic signal. Figure 1 shows a detailed flow chart of this technique.

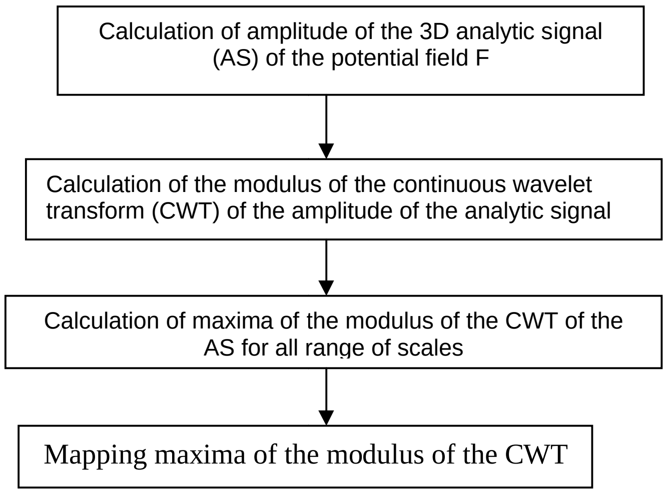


Figure1: Flow chart of the potential field analysis using the 3D AS and 2D CWT

Application on real data

Geological context of In Ouzzal

The In Ouzzal terrane (Western Hoggar) is an example of Archaean crust remobilized by a very-high-temperature metamorphism (Ouzeggane and Boumezza, 1996) during the Paleoproterozoic (2 Ga). Structural geometry of the In Ouzzal terrane is characterized by closed structures trending NE-SW to ENE-WSW(figure2) that correspond to domes of charnockitic orthogneiss. The supracrustal series are made up of metasediments and basic-ultrabasic rocks that occupy the basins located between these domes. In In Ouzzal area, the supracrustal synforms and orthogneiss domes exhibit linear corridors near their contacts corresponding to shear zones. The structural features in In Ouzzal area (Djemaï et al, 2009), observed at the level of the base of the crust,

argue in favour of a deformation taking place entirely under granulite-facies conditions during the Paleoproterozoic . These features are compatible with D_1 homogeneous horizontal shortening of overall NW-SE trend
that accentuates the vertical stretching and flattening of old structures in the form of basins and domes. This shortening was accommodated by horizontal displacements along transpressive shear corridors. During the Pan-African event, the brittle deformation affected the granulites which were retrogressed amphibolite and greenschists facies (with the development of tremolite and chlorite (Caby and Monie, 2003), in the presence of fluids along shear zones corridors. Brittle deformations were concentrated in the southern boundary of In Ouzzal. An important NW-SE-trending dextral strike-slip pattern has been mapped along which we can see the Eburnean foliation F1 overprinted. This period was also marked by ductile to brittle deformation along the eastern shear zone bordering the In Ouzzal terrane with steep fracture cleavage (NNW-SSE) and conjugate joint pattern. All these structural features are compatible with an ENE-WSW shortening in relation with the collision between the West African Craton and the Hoggar during the Pan-African orogeny.

Data processing

The proposed technique has been applied at the aeromagnetic data of In Ouzzal, the data has been processed with a regular grid of 750m. Figure 3 shows the total magnetic field; firstly the normal magnetic field has been removed using the IGRF75 model. Figure 4 represents the anomaly magnetic field. The next operation consists to calculate the amplitude of the analytic signal. This last is represented in figure5. The modulus of the continuous wavelet transform of the amplitude of the AS is represented in figure 6; the analyzing wavelet is the Poisson Kernel (Martlet et al, 2001). Maxima of the modulus of the CWT are mapped for all range of scales (scales varied from 2121m to 9094m). The set of maxima will give structural boundaries. . Figure 7 is a comparison of these contacts with the geological map.

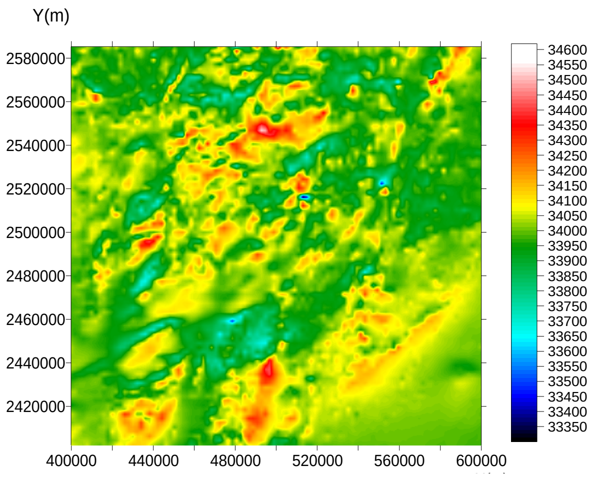


Figure3: Total magnetic field of In Ouzzal

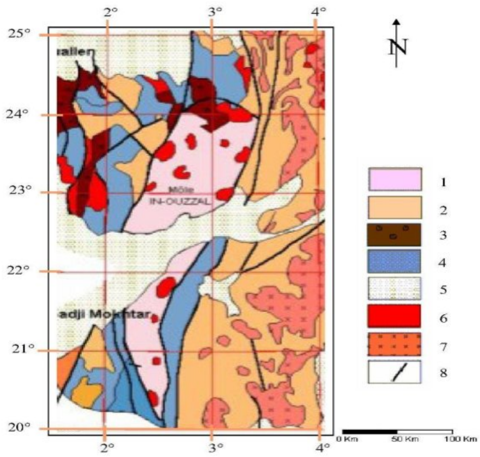


Figure2 Geological map of the Mole In Ouzzal extracted from the map of Hoggar(After Caby et al, 1981)
1-Archaean granulites ;
2- Gneiss and metasediments ;
3- Gneiss with facies amphibole;
4- Indif gneiss;
5- Paleozoic curvature;
6- Panafrican granite;
7-Volcano-sediments of Tafassasset .
8- Major faults

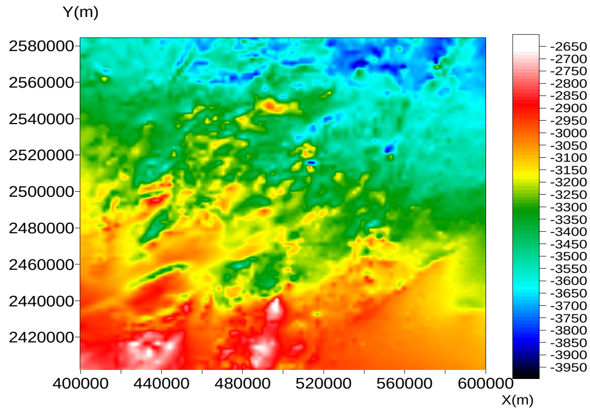


Figure 4 Anomaly magnetic field of In Ouzzal

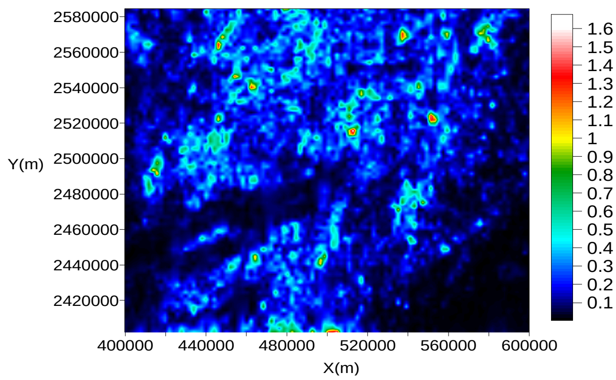


Figure5 Amplitude of the analytic signal

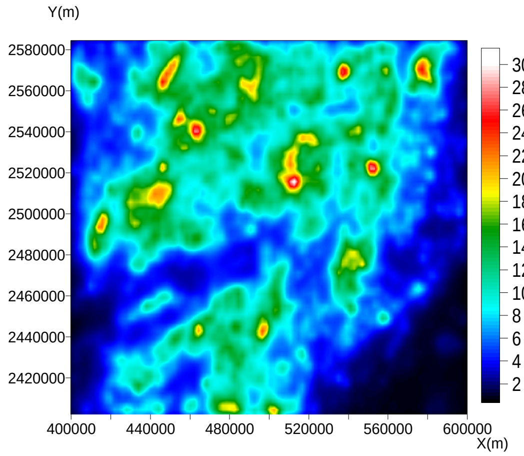


Figure 6 Modulus of the CWT of the AS plotted at the scale a=2121m

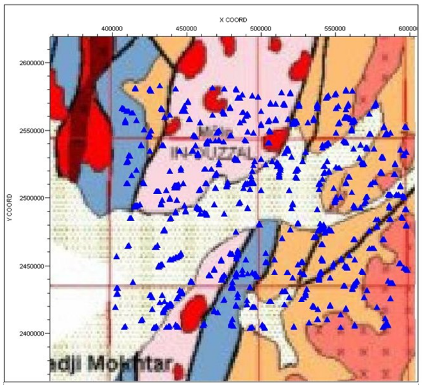
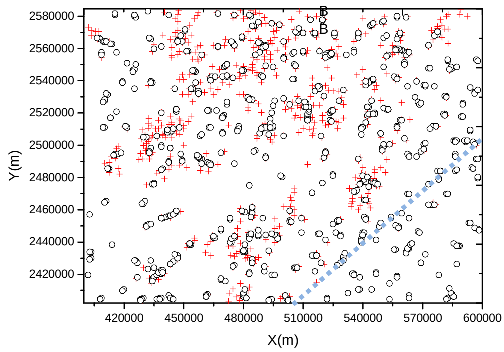


Figure 7 Obtained contacts by the CWT analysis combined of AS compared with geology

Results interpretation

One can remark that the proposed method is able to identify contacts defined by geology. Obtained boundaries by the proposed method are compared with contacts of analytic signal; for this last we eliminate fictitious contacts dues to noise using a threshold of 0.5nT/m. Figure 8 represents the two models of contacts. We observe that by using this threshold we have eliminated a lot of contacts, for example the contact defined by the dashed line in figure 8 is identified by the CWT combined with AS, however it is not detected by analytic signal, this is due to the threshold effect, this last has been applied to reduce the noise effect on the AS.



o Obtained contacts by the proposed method
+ Obtained contacts by analytic signal

Figure 8 Obtained contacts by the proposed method compared with contacts of AS

Conclusion

We have proposed a technique of contacts identification based on the maxima of the modulus of the 2D continuous wavelet transform of the amplitude of the 3D analytic signal, application at the real aeromagnetic data of In Ouzzal shows that the proposed idea is able to identify contacts that are not detected by the analytic signal solutions. By implanting our method we have resolved the ambiguity of application of a threshold at the maxima of analytic signal, which can eliminate a lot of high frequency causative sources. Secondly we have resolved the ambiguity of a reduction to the pole that exist in the classical methods of application of the CWT for contacts delimitation, since this last needs a data reduced to the pole, which is not very efficient in the case of high magnetic remanance.

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