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Gravimetric and magnetic characterization of structural controls on sn-wore deposits. A case study in the san finx deposit (A Coruña)

Caracterización gravimétrica y magnética de controles estructurales en depósitos de Sn-W. Ejemplo del yacimiento de San Finx (A Coruña)

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ABSTRACT

Critical raw materials are essential for the development of our society. However, most shallow ores have already been exploited and only deep targets remain unexplored. This work aims to apply indirect geophysical techniques to the San Finx Sn-W deposit (A Coruña) in order to get further constrains of its deep structure and geometry. Accordingly, a magnetic and a gravity survey have been carried out in the area (SE of Noia, A Coruña), at the southern part of the Malpica-Tui Complex. The resulting absolute magnetic anomaly and the relative gravity anomaly have been studied analytically and through 2-2.75D forward modeling. Results indicate that, the sampling interval (~1 km) is too high to characterize the anomalies related to the Sn-W mineralization. Contrarily, they show the potential field imprint of the regional Variscan tectonics. To better assess the relationship between the regional Variscan tectonics and the mineralization, a higher resolution survey should be acquired to detect this deposit.

Key-words: *Potential field anomalies, compressional tectonics, extensional tectonics, granites, Sn-W deposits*

RESUMEN

Las materias primas críticas son fundamentales para el desarrollo de nuestra sociedad. Sin embargo, la mayoría de los yacimientos poco profundos ya han sido explotados, quedando únicamente sin explorar los objetivos profundos. En este trabajo se presentan los resultados de la aplicación de técnicas geofísicas indirectas al estudio del yacimiento de Sn-W de San Finx (A Coruña). Su objetivo es constreñir la geometría y estructura del yacimiento en profundidad. En este sentido, se ha realizado una campaña de adquisición de datos magnéticos y gravimétricos en dicha zona (SE de Noia, A Coruña) en la parte sur del Complejo Malpica-Tui. La anomalía magnética absoluta y la anomalía gravimétrica relativa resultante se han estudiado analíticamente y mediante modelización directa 2-2,75D. Los resultados indican que el intervalo de muestreo usado (~1 km) es muy alto para individualizar la respuesta magnética y gravimétrica del yacimiento. Sin embargo, los mapas obtenidos muestran que la signatura de campos potenciales está ligada a la tectónica Varisca a gran escala. Encontrar la relación entre esta última y la mineralización y hacer un muestreo geofísico de alta resolución en la zona son la clave para entender este depósito.

Palabras clave: *Anomalías de campos potenciales, tectónica compresiva, tectónica extensional, granitos, yacimientos de Sn-W.*

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Introduction

Currently, the European Union is extremely dependent on imports of raw materials in order to assure a sustainable supply (Schoer *et* al., 2012). As result of centuries of exploitation, most of the shallow ores are already exhausted (Humphreys, 2018). Thus, the mining industry needs to look for deeper targets, which means to find indirect methodologies to characterize the location and the geometry of ore bodies. In this sense, geophysical methods are the best solution. Accordingly, overlapping gravity and magnetic surveys have been carried out at the San Finx deposit zone (Sn-W bearing), in the southern part of the Malpica-Tui Complex (A Coruña, Spain) in order to help to constrain the deep geometry and structure of the ore. A 12x12 km^2 area has been sampled at regular intervals of ~1km.

The relative gravity anomaly and absolute magnetic anomaly have been calculated for the prospected area. Analytical studies of the anomalies and 2-2.75D forward modeling of three cross-sections provide depth models of the geological setting hosting the mineralization and give insights of the context in which the ore was formed.

We conclude that high resolution surveying is needed in order to place constraints on the extent of the mineralization.

Geological Setting

The Malpica-Tui Complex is located in the Galicia-Tras-os-Montes Zone (GTMZ) and outcrops to the W of the Órdenes Complex and its relative autochthonous (Fig 1). The unit has a length of 150 km and a width of ~ 10 km, with a N165E orientation in the southern part of the unit that changes in the northern part to N15E or N30E. This complex is tectonically limited by a basal shear zone that puts it in contact with the parautochton of the GTMZ, outcropping in its eastern part. The lithological limits of the Malpica-Tui Complex are related to the intrusion of Variscan igneous bodies, which are divided into syn-kinematic and post-kinematic granitoids (Díez Fernández, 2011).

Stratigraphically, the Malpica-Tui complex is formed by the allochthonous and its relative autochthonous. The allochthonous is divided into two main domains: the lower and the upper sequences, each represented by different sets of metasedimentary levels with granite intrusions.

The working area, located to the SE of Noia, shows two main groups of sedimentary rocks accompanied by a great variety of plutonic rocks. The Noia Complex is formed by schists and albite paragneisses of the lower sequence. In this unit, a series of plutonic rocks (biotic orthogneisses and amphibolites) can be found (Fig 1) (Díez Fernández, 2011). On the other hand, the Lage Group is formed by schists and derived migmatites of the relative autochthonous. The plutonic rocks in this unit are divided in syn-kinematic granites that outcrop in the western and eastern part of the area and the post-kinematic granites (Confurco granite) outcropping in the southern part (Fig 1) (Díez Fernández, 2011).

The main Malpica-Tui unit deformation is caused by the Variscan Orogeny in the GTMZ. In this complex, different tectonic events can be distinguished, being the sequence of deformation phases: C1 → C2 → E1 → C3 where C stands for compressional and E for extensional tectonics (Allock *et al*., 2009).

The mineralization of the area appears associated to the emplacement of quartz veins after C2 thrusting and prior to the intrusion of the Confurco Granite (Fig 1). We expected that potential field data can help us to trace these veins.

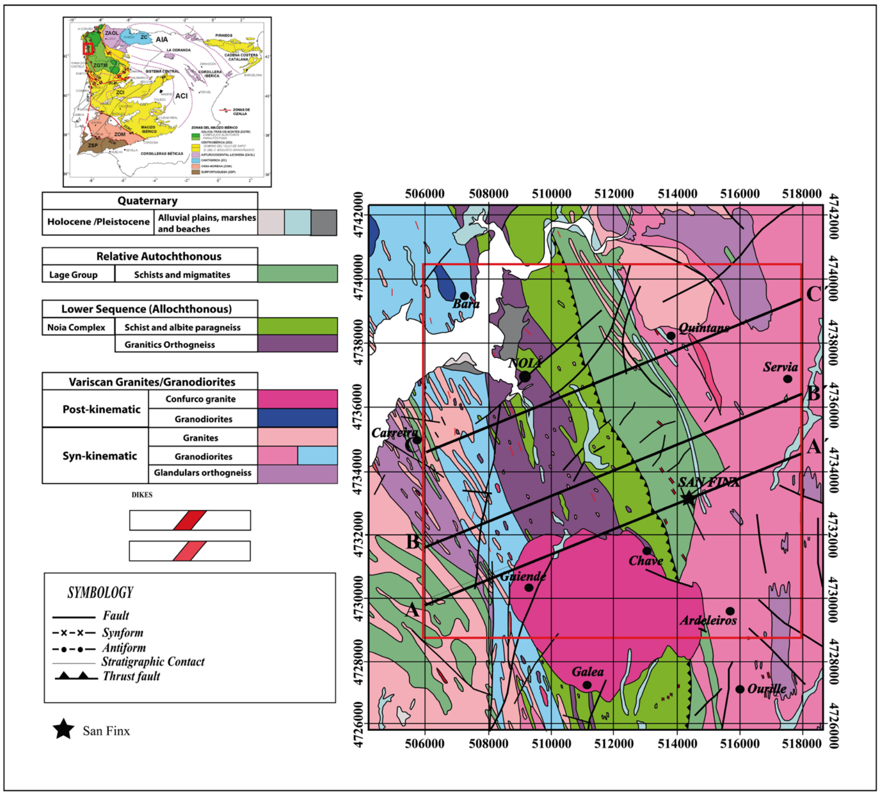


Fig. 1. Geological map of the study area. The red rectangle represents the acquisition area. Sections A-A', B-B' and C-C' represent the modeled profiles. UTM WGS84 H29N coordinate system

Fig.1. Mapa geológico de la zona de estudio. El rectángulo rojo representa el área de adquisición de datos. Los cortes A-A´, B-B´ y C-C´ representan las secciones modelizadas. Sistema de coordenadas UTM WGS84 H29N.

Methodology

Data Acquisition

A total of 75 points of gravity and magnetic data have been measured in around the San Finx ore at an average spacing of 1 km, resulting in ~12x12 km^2 area. Magnetic susceptibility, κ, has been assessed with a portable Kappabridge KM-7 susceptilometer. B_t has been obtained with a GEOMETRICS G-856 portable proton magnetometer with a 1 nT resolution. Relative gravity data were acquired with a SCINTREX-CG6 gravimeter with a resolution of 0.1 µGal.

Data Processing and Results

Different standard corrections have been applied to both datasets with the to obtain gravimetric and magnetic anomaly maps

-Magnetic corrections:

A) Diurnal and Secular

The high-energy radiation emitted by the sun causes ionization in in the ionosphere which generates an external magnetic field that changes depending on several factors.

The superposition between the latter field and the internal Earth´s magnetic field is the value (Bt) measured by the magnetometer. To calculate just the correct value for the Earth´s internal field is necessary to remove the ionosphere magnetic field.

There are several ways to perform the diurnal correction. One of them implies removing the Bt diurnal variations as observed from continuous measurements from an observatory. In this case we used the data from the Geophysical Observatory of San Pablo, in Toledo.

This process also allows to correct the secular variation if a constant Bt value is given to the base station used during fieldwork.

B) Calculation of the absolute magnetic anomaly

Once the diurnal and secular corrections have been applied, the corrected internal Bt has been compared with the IGRF 2020 (International Geomagnetic Reference Field 2020) in order to obtain the absolute magnetic anomaly (Fig 2A).

The magnetic anomaly features a ENE-WSW minimum in the San Finx area coinciding with the direction of mineralized quartz veins. Maxima to the SE and W of the prospecting grid, coincide with the syn-kinematic granites that outcrop in this area. In fact, the rim of the Confurco granite features some relative maxima to the SW of the mine. Moreover, the reduction to the pole has been calculated but the results are not conclusive as there is not an estimation of the magnetic remanence.

-Gravity corrections

To obtain the relative gravity anomaly map, the instrumental drift, latitude, free air, Bouguer plate and terrain corrections have been carried out. A 5x5 m grid of DEM LIDAR data from Downloads Center of the Spanish National Geographical Institute,

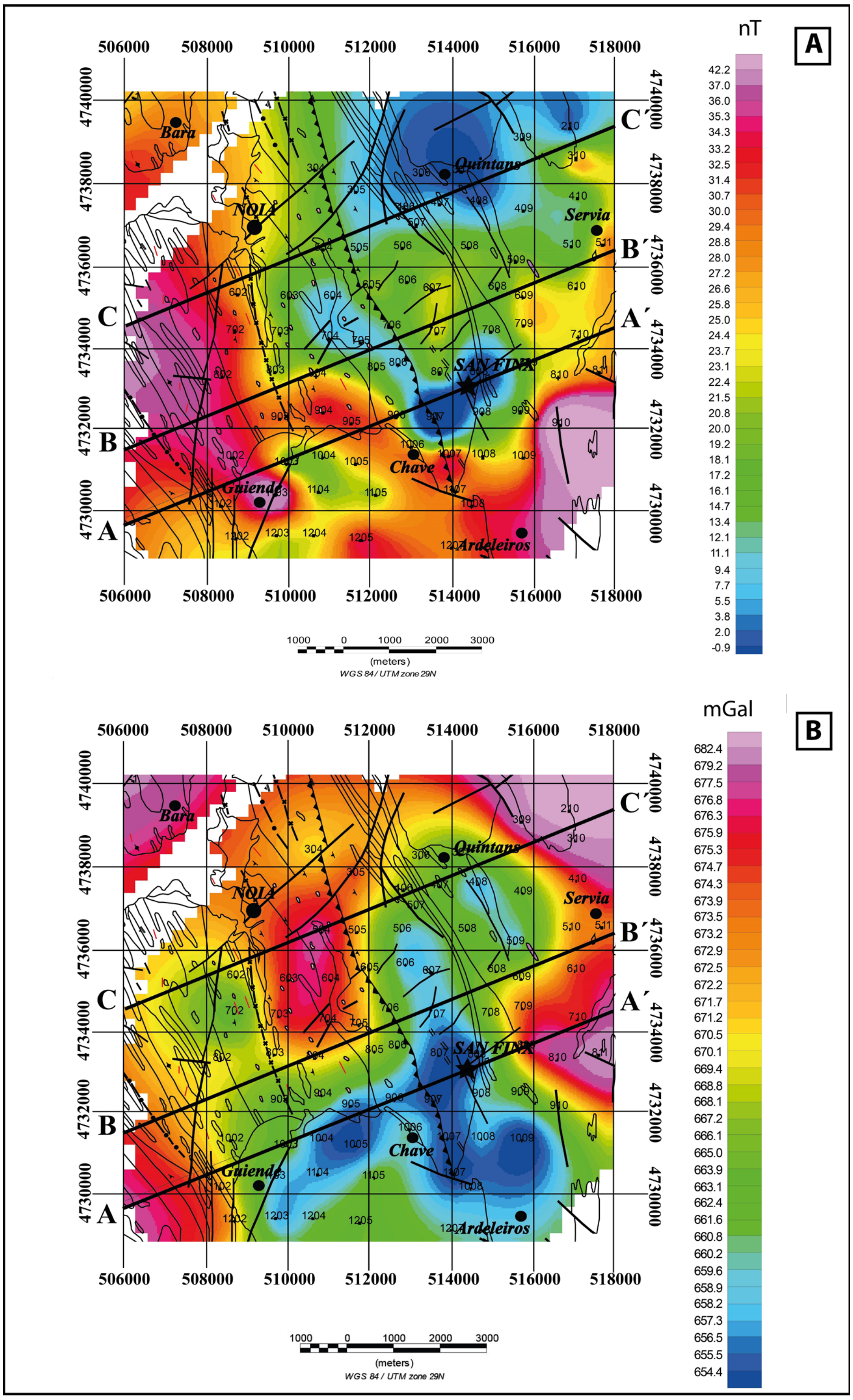


Fig. 2. A) Absolute magnetic anomaly map. B) Relative gravity anomaly map. Sections A-A', B-B' and C-C´ represent the modeled cross-sections. Points represent the potential field stations.

Fig. 2. A) Mapa de la anomalía magnética absoluta. B) Mapa de la anomalía gravimétrica relativa. Las secciones A-A´, B-B´ y C-C´ representan los cortes modelizados. Cada punto representa una estación de medida.

with an approximate radius of 20 km has been used for the correction has been used for the terrain correction (https//ign.es).

C) Calculation of the relative gravity anomaly

After applying these corrections, a map of the relative gravity anomaly has been obtained (Fig 2B). It shows ENE-WSW minimum relative gravity values in the San Finx area coinciding with the quartz veins directions. Other minima striking NNW-SSE overlapping the trace of regional veins. Maxima appear to the SW and NE of the prospected area showing no apparent relation with the area of interest.

Interpretation by analytical methods

Radial Average Power Spectrum

The calculation of this spectrum, carried out in the Fourier space, allows us to estimate the depth to the potential field (gravity) source in relation to the anomaly wavenumber. Results, shown in Fig. 3, indicate that, for the prospected area, the source of the anomalies should be located at shallow depths, always <1 km.

2-2.75D Modelling

Forward modeling of the magnetic and gravimetric anomalies presented in Fig. 2 has been carried out. Three sections (A-A´, B-B´ and C-C, Fig. 1.) cross the structures in three different zones. In this work we only present the section A-A´. Density values derive from direct laboratory measurements while magnetic susceptibilities were measured in the field.

Profile A-A´ (Fig 4) crosses the San Finx deposit. The model cuts the allochthonous, relative autochthonous and Variscan granites. The gravity minimum in San Finx and to the N of the Confurco granite is modeled as the response of Confurco granite and that of veins, some related to the mineralization. Surprisingly, the NNE-SSW gravity minimum to the S of San Finx does not correspond to magnetic minimum (Fig. 2), indicating that even though the ENE-WSW and the NNW-SSE veins feature little density, the former ones are less magnetic. In fact, only these are mineralized, further pointing out to important differences.

Discussion and Conclusions

The potential field data acquired at the Malpica-Tui complex (Fig. 2) show a significant relation with tectonic/lithological boundaries, which strike NNW-SSE. This implies that the Variscan compressional tectonics is responsible for the gravity and magnetic signature in this area, as evidenced at the resolution used in this work.

The Confurco granite, preliminarily related to the mineralization, shows a weak magnetic signature and an irregular gravity signature. However, gravity and magnetic minima around San Finx may help to differentiate between two families of veins, where only one of them is mineralized.

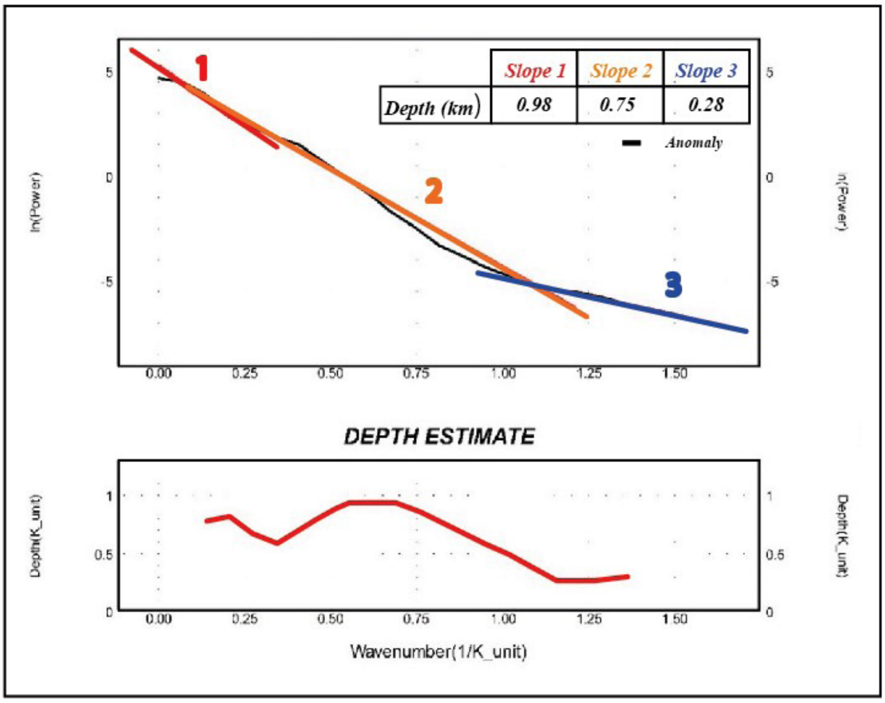
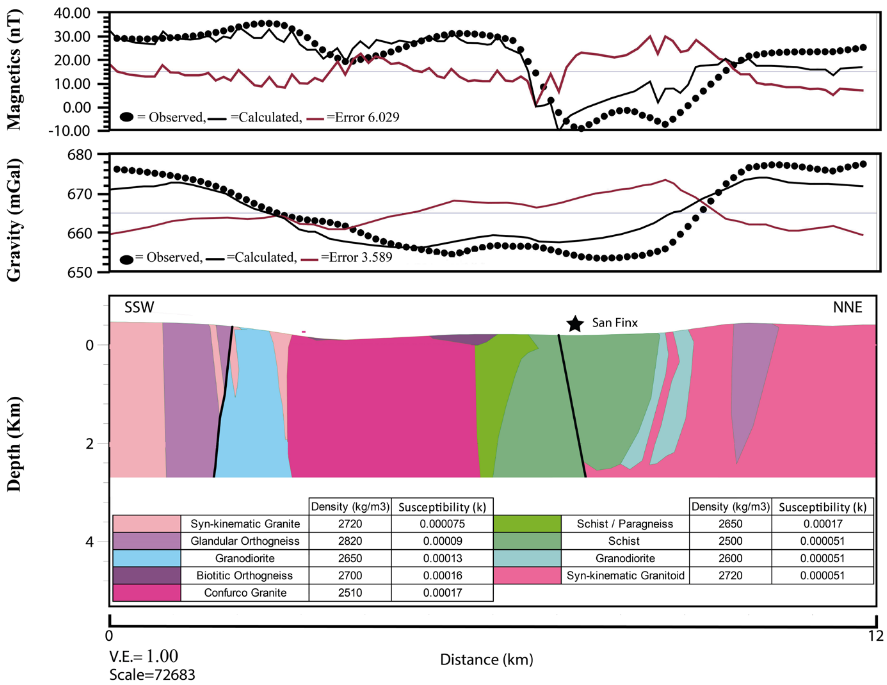


Fig. 3. Radial average power spectrum of the relative gravity anomaly with the slopes and their calculated depth values.

Fig. 3. Espectro de potencia media de la anomalía de gravedad relativa con las pendientes y sus valores de profundidad calculados .



	Density (kg/m3)	Susceptibility (k)		Density (kg/m3)	Susceptibility (k)
Syn-kinematic Granite	2720	0.000075	Schist / Parageniss	2650	0.00017
Glandular Orthogneiss	2820	0.00009	Schist	2500	0.000051
Granodiorite	2650	0.00013	Granodiorite	2600	0.000051
Biotitic Orthogneiss	2700	0.00016	Syn-kinematic Granitoid	2720	0.000051
Confurco Granite	2510	0.00017			

Fig. 4. 2D Magnetic and gravimetric model of section A-A´. Petrophysical properties are shown in the table.

Fig. 4. Modelo 2D magnético y gravimétrico de la sección A-A´. Las propiedades petrofísicas se muestran en la tabla.

Further potential field studies geared to study this mineralization must be carried out at a smaller sampling rate. The mineralization is probable overlooked when data are as sparse as 1 km. This also implies that the extension of the mineralization is laterally limited.

Author contributions

Alberto Santamaría Barragán processing and interpretation of the datasets, Puy Ayarza Arribas acquisition, processing and interpretation, Juan Alcalde acquisition, Eduard Saura acquisition, David Martí Linares acquisition, Imma Palomeras acquisition, Javier Elez provided DEM data.

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