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Gravity and magnetic investigations in the Haouz basin, Morocco. Interpretation and mining implications

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ABSTRACT

The Marrakech region is known for its significant mining potential concealed by the Hercynian basement. In order to extend the exploration of this basement beyond its outcrops in the Jebilets and Guemassa massifs, we used magnetic and gravity data from a sub-area in the Haouz basin. Our methodology in this study consists of processing the data, so as to highlight the buried geological contacts and to reveal their dips. The study of the geological contacts is ensured by the upward continuation processing of the residual gravity map at various altitudes, followed by the determination of the horizontal gradient maxima for each level. The progressive migration of these maxima while increasing the upward continuation altitude indicates the dip direction. The structures deduced from gravity are superimposed on the magnetic map in order to emphasize their possible association with magnetic sources.

Comparison between gravity anomalies and local geology shows that these anomalies are mainly caused by basement topography undulations. Moreover, lows coincide with granite and thick sedimentary depressions while highs coincide with basement outcrops. The local maxima of the horizontal gradient of the residual gravity data and its upward continuation at various altitudes define a field of features, organized into groups oriented both NE–SW and NW–SE, which correspond to the regional Hercynian structures. Moreover, the main highlighted lineaments coincide perfectly with known fractures such as the North-Atlas and the Guemassa faults whose dip and direction are well documented. These detected features allow us to complete and enrich the structural map of the Haouz basin. A joint detailed analysis of the mapped gravity contacts and the magnetic data was carried out, through the use of Magnetic and Gravity Euler Trends in terms of depth and rooting, taking into account the local geology, to identify potential structures for mining exploration.

1. Introduction

The Marrakech area belongs to the Southwestern Moroccan Meseta, which constitutes a portion of the Variscan belt. Its basement is mainly made of intensively deformed Hercynian rocks which outcrop in the Paleozoic massifs of Jebilets and Guemassa (Fig. 1). The mining potential of this area has aroused the interest of many geologists and explorers, so numerous mining prospecting and academic works have been carried out there since the thirties. This led to the discovery of several deposits, some of which were economically important (Hajar, Draa Sfar, Kettara, etc.) (Fig. 1). Since the beginning of the 1980s, mining exploration has particularly intensified, especially in the outcrops of the Hercynian basement at the Jebilets and Guemassa massifs (Bouloton and Le Corre, 1985; Felenc et al., 1985; Mellal and Maier, 1988; Bellott et al., 1991; Soulaïmani, 1991; Leblanc, 1993). However, research activity was very limited in the Haouz basin where the Paleozoic basement is masked by a thick sedimentary cover. Nowadays, exploration has completely exhausted the surface data, so mining research must be re-oriented towards the prospecting of increasingly deep deposits. The recognition of ore deposits requires the implementation of research programs mainly based on geophysical techniques of investigation.

The purpose of the present study is to provide a better understanding of the deep structures of the Haouz basin where gravity and magnetic data are available. An interpretation of these data is proposed to help mining exploration develop.

2. Geological and mining setting

The Haouz basin consists of a large depression filled with recent sediments resulting from the dismantling of the Atlas chain. Most

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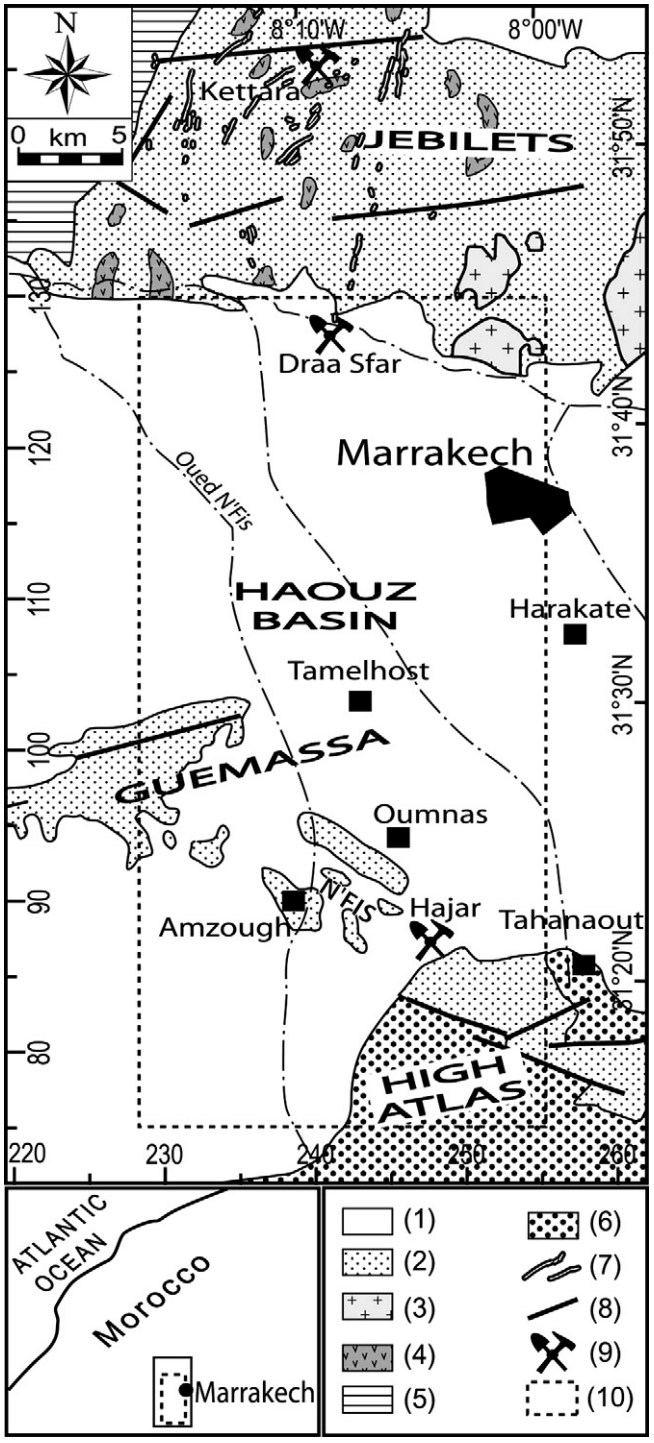

Fig. 1. General location of the study area. (1) Mio–Plio–Quaternary cover, (2) Metapelites Hercynian basement, (3) Hercynian granite, (4) Visean Gabbro, (5) Cambro-Ordovician formations of the Western Jebilets, (6) Mesozoic series of the High Atlas, (7) Gossan, (8) Fault, (9) Mining site, (10) Study area boundary.

of the sediments are made up of Neogene and Quaternary alluvia which may have filled up a Paleozoic or a Mesozoic paleotopography. The stratigraphic sequence is relatively complete. The Hercynian basement which constitutes the substratum of this series outcrops in the Jebilets and the Guemassa massifs, located respectively towards the north and the centre of the study area. In the Jebilets, the basement is mainly built of metapelites corresponding to an argillaceous series intercalated with sandstone and limestone layers and assigned to Middle and Upper Visean (Essaïfi et al., 2003). At the end of the Carboniferous, several magmatic intrusions (gabbros and granites) were emplaced through this metamorphic series affected by a sub-vertical schistosity (Essaïfi, 1995; Essaïfi et al., 2003; Lagarde et al., 1990). Southwards, this basement disappears under the Haouz plain and reappears in the Guemassa massif where it is mainly composed of flyshoid sequences (sandstone and pelite alternation) intercalated with limestone (Fig. 1).

From a structural point of view, the study area is characterized by a succession of several tectonic episodes (Soulaïmani, 1991). The Hercynian deformation which constitutes the major structural phase is marked in Namurian and Wesphalian time by a significant compression responsible for the ENE–WSW to NE–SW orientation of regional schistosity. During this episode, two distinct domains were separated in the Haouz of Marrakech: The Guemassa massif in the West where the structures are oriented NE–SW to NS and the N'fis domain in the East, with a NNW–SSE single structural direction. After the Hercynian orogeny, the area was subjected to the Oligocene Atlasic tightening which generated in particular the uplift of the Paleozoic massifs of the Haouz of Marrakech. This tightening is mainly expressed by faulting tectonics of roughly ENE–WSW direction.

As far as mining is concerned, the Hercynian basement of the Marrakech region hosts a large number of sulphide massifs. They are found as stratabound polymetallic mineralized bodies and often associated with volcanic rocks which crop up as submarine effusions of rhyolite and rhyo-dacite. These are volcano-clastic type mineralizations presenting a relatively distal character regarding the emplacement of the contemporaneous volcanic expressions (Bernard et al., 1988). Such mineralizations are often associated with underlying stockworks zones. Their mineralogical and chemical characteristics indicate a strongly reducing environment leading to the paragenesis formation of syngenetic pyrrhotite of highly dominant primary origin of Variscan age. In the Guemassa–Jebilets metallogenic province, pyrrhotite ore deposits outcrop as limonitic products forming gossans. They are roughly organized along sub-meridian lineaments (Fig. 1). They are formed of mineral occurrences or ore bodies within the Visean volcano-clastic deposit of Sarhlef (Bernard et al., 1988). Felenc et al. (1986) proposed a genetic model in which such massive sulphide deposits are supposed to be emplaced during an extensional phase, during which sandy clay deposits infill in a sedimentary basin. The development of this basin is favoured by the action of normal faults leading to horst and graben structures. Such an extensional regime, dated to ca. 330.5 Ma (U–Pb on zircons) by Essaïfi et al. (2003), is followed by important magmatic activity characterized mainly by a bimodal plutonism emplacement. This led to high thermal perturbations generating a hydrothermalism which could appear as convection cells affecting magmatic bodies as well as their host rocks (Essaïfi and Hibti, 2008). However, the proximity of sulphide ore enriched in base metals and the acid plutonism (depleted in base metals) may indicate that this kind of plutonism is the main source zone for this hydrothermal system (Essaïfi and Hibti, 2008). The sulphide ore deposits of the Visean metallogenic province of Guemassa–Jebilets may have been emplaced in an epicontinental rift environment of the external zone of the Hercynian chain (Lescuyer et al., 1998).

Exploration of these sulphide ore deposits is widely based on magnetic prospecting because of their content of pyrrhotite. However, even if magnetic measurements seem necessary to mining exploration of the Hercynian basement of the Marrakech region, they remain ineffective since this basement is known for its rich magmatic mafic bodies (gabbros) which also present magnetic sources. That is why we need to use other geophysical methods to help discriminate between the two magnetic signatures. Gravity