From the Mariana Anticline to the Santo Antônio do Pirapetinga Complex: a gravimetric investigation of the southeastern Quadrilátero Ferrífero

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Abstract

The Quadrilátero Ferrífero is one the most studied and important mineral provinces in Brazil, hosting world-class iron and gold deposits, and yet, several questions concerning its basement and structural framework remain unanswered so far. Using terrestrial gravimetric data and 2D gravimetric models, the present study sheds light on the subsurface framework of the main megastructures in the southeastern portion of this province. According to the Bouguer anomaly data, a gravimetric low extends from the Bação Complex towards the Mariana Anticline. The 2D gravimetric model of this anticline suggests that, at this specific location, the metasedimentary rocks of the upper Nova Lima Group directly overlie granitic basement rocks instead of a greenstone belt association. This observation also strengthens the hypothesis of a link between the genesis of the Mariana Anticline and a pre-existing basement high related to the Bação Complex. Additionally, a gravimetric high associated with the Santo Antônio do Pirapetinga Complex, to the south of the Quadrilátero Ferrífero, points to a significant amount of metamafic and metaultramafic rocks in this unit and shows continuity across the Engenho Fault towards the Dom Bosco Sincline. Such continuity suggests that this complex is part of the basement below the metasedimentary rocks of the Minas and Estrada Real supergroups in the southeastern Quadrilátero Ferrífero.

Introduction

The Quadrilátero Ferrífero province, in the Southern São Francisco Craton, is a polydeformed area composed of an Archean greenstone belt association (Rio das Velhas Supergroup) and Archean TTG nuclei, along with Paleoproterozoic rift to passive margin metasedimentary rocks of the Minas basin and syn- to post-orogenic metasedimentary rocks of the Estrada Real Supergroup (Endo et al., 2020). This province is known worldwide for hosting several gold deposits in the Rio das Velhas greenstone belt including world-class mines such as Cuiabá and Morro Velho, alongside huge iron deposits associated with chemical sedimentation in the Minas basin. Due to its economic importance, the Quadrilátero Ferrífero has been target of several studies dating from the XVIII century to the present days. However, there is still a long way to go understanding the complex tectonic framework of this province.

The main deformational events recognized in the supracrustal rocks of the Quadrilátero Ferrífero are related to the Neoarchean, Rhyacian and Brasiliano orogenies. The last two events involved the metasedimentary rocks of the Minas basin and originated and/or reworked the megastructures that frame the province.

In this study, we focused on the southeastern sector of the Quadrilátero Ferrífero (Figure 1), near the cities of Ouro Preto, Mariana and Catas Altas da Noruega (Minas Gerais), where we have performed a terrestrial gravimetric survey transecting major structures such as the Mariana anticline, the Dom Bosco syncline and the Engenho Fault.

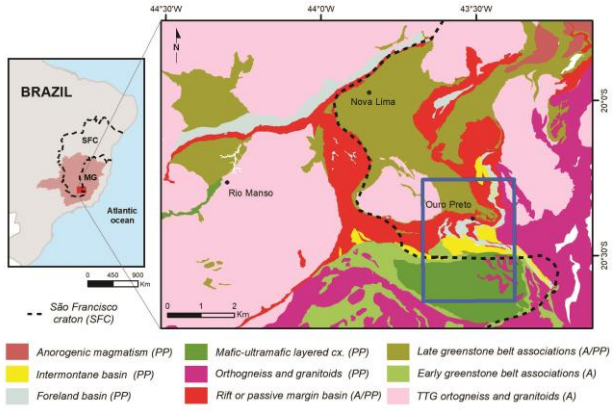

Figure 1 – Simplified tectonic map of the Quadrilátero Ferrífero and its surroundings showing the location of the study area location (outlined in blue).

The Mariana anticline and the Dom Bosco syncline are interconnected megafolds which axes strike WNW-ESE, slightly plunging towards east. The Mariana anticline is remarkable for hosting a great amount of ancient gold mines and excavations along its southern limb. Several theories have been proposed so far for the genesis of this megafold, such as: (i) multiple phases of deformation (Lacourt, 1935); (ii) doming driven by an underlying granitic batholith (Oliveira, 1933); and (iii) influence of an underlying basement high related to the Bação Complex (Dorr, 1969; Marshak & Alkmim, 1989).

The Engenho Fault is a notable E-W strike-slip structure that defines the southern limit of the Quadrilátero Ferrífero. In the study area, it mainly juxtaposes the supracrustal rocks of the Minas Supergroup (to the north) to the plutonic-volcanic Santo Antônio do Pirapetinga Complex (to the south; Figure 2).

The geophysical data acquired and processed in this study help enlightening the framework of the basement underlying some of the main megastructures in the southeastern Quadrilátero Ferrífero. Besides, it provides clues concerning both the genesis of the Mariana Anticline and the transition from the Quadrilátero Ferrífero and its supracrustal association (to the north of the Engenho Fault) to the Barbacena Block and its plutonic-volcanic complex (to the south of the Engenho Fault).

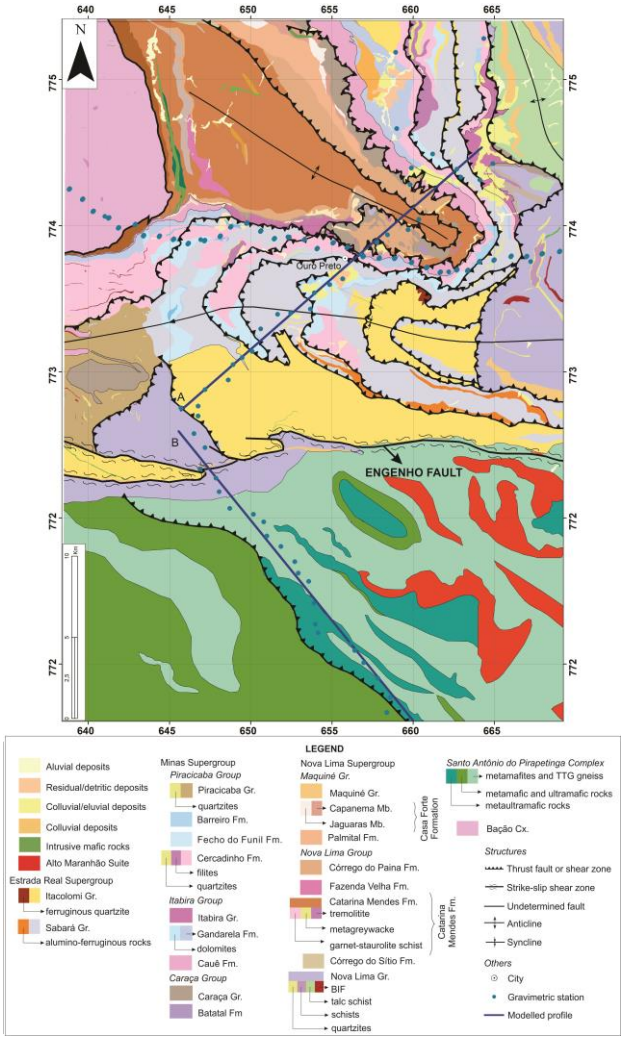

Figure 2 – Geological map of the study area (modified from Baltazar et al., 2005a and b; Santos & Baltazar, 2013 and Pinto & Silva, 2014). A) Itatiaia-Ouro Preto profile/model; B) Itatiaia-Catas Altas da Noruega profile/model.

Method

The terrestrial gravimetric survey was performed by the Geological Survey of Brasil (CPRM – Companhia de Pesquisa de Recursos Minerais) between 2015 and 2017. The gravimetric stations acquired in this survey along with those made available by the Banco Nacional de Dados Gravimétricos have been used to create two 2D gravimetric models. These models have been built through direct 2D modeling associated with inversion of residual Bouguer anomaly data, acquired after subtraction of the 2nd order regional field. Density contrasts have been estimated based on a pre-existing database of absolute densities including various rocks of the Quadrilátero Ferrífero.

The first model is called Itatiaia-Ouro Preto and represents a SW-NE profile transecting the Dom Bosco syncline and the Mariana anticline, with initial and end points at 645762mE / 7735704mN and 664112 mE/ 7751732 mN, respectively (SIRGAS 2000/UTM zone 23S). In this case, data acquisition during the gravimetric survey took place mainly along the MG-129 road, and gravimetric stations are spaced at intervals ranging from 300 m to 2.5 Km, due to the winding nature of the road and to the lack of shoulders.

The second model is called Itatiaia-Catas Altas da Noruega and symbolizes a NW-SE profile crossing the Engenho Fault and the Santo Antônio do Pirapetinga Complex, with initial and end points at 659534mE / 7717080mN and 644903mE / 7735137mN, respectively (SIRGAS 2000/UTM zone 23S). In this model, the gravimetric stations are spaced at intervals between 500 m and 1.5 Km.

Results

The geological map in Figure 2 has set the ground for the definition of geological-geophysical units and gravimetric modelling. Overall, the main geological-geophysical units proposed in this study belong to four different groups, from base to top (Figure 3): granitic basement rocks, plutonic-volcanic association, metavolcanosedimentary association and metasedimentary rocks. The granitic basement rocks present an estimated density of 2730 Kg/m³. The plutonic-volcanic association belongs to the Santo Antônio do Pirapetinga Complex and, in this model, comprises metamafic rocks (2900 Kg/m³), metaultramafic rocks (3000 kg/m³) and a metamafic-ultramafic association (2950 Kg/m³). An Archean metavolcanosedimentary association of unknown stratigraphic position is also present and shows an estimated density of 2870 Kg/m³. At last, the metasedimentary rocks include, from base to top: 1) greywackes, schists and quartzites of the Batatal (Caraça Group), Moeda (Caraça Group), Pau d'Óleo and Catarina Mendes formations (Nova Lima Group), with estimated density of 2737 Kg/m³; 2) banded iron formations of the Cauê Formation (estimated density 3267Kg/m³); 3) varied metasedimentary rocks of the Gandarela Formation, Piracicaba, Sabará and Itacolomi groups (estimated density of 2817 Kg/m³); 4) quartzites and schists of the Itacolomi Group (estimated density 2787 Kg/m³).

The Bouguer anomaly map of the study area (Figure 4) shows a gravimetric low of approximately -100 mGal at the Mariana Anticline. In the 2D Itatiaia-Ouro Preto model (Figure 5A), this anomaly has been represented by a granitic rock underneath the metasedimentary rocks, with estimated density close to that of the Bação Complex.

Structural and lithological features in this model follow the geological maps of Baltazar et al., (2005a, b).

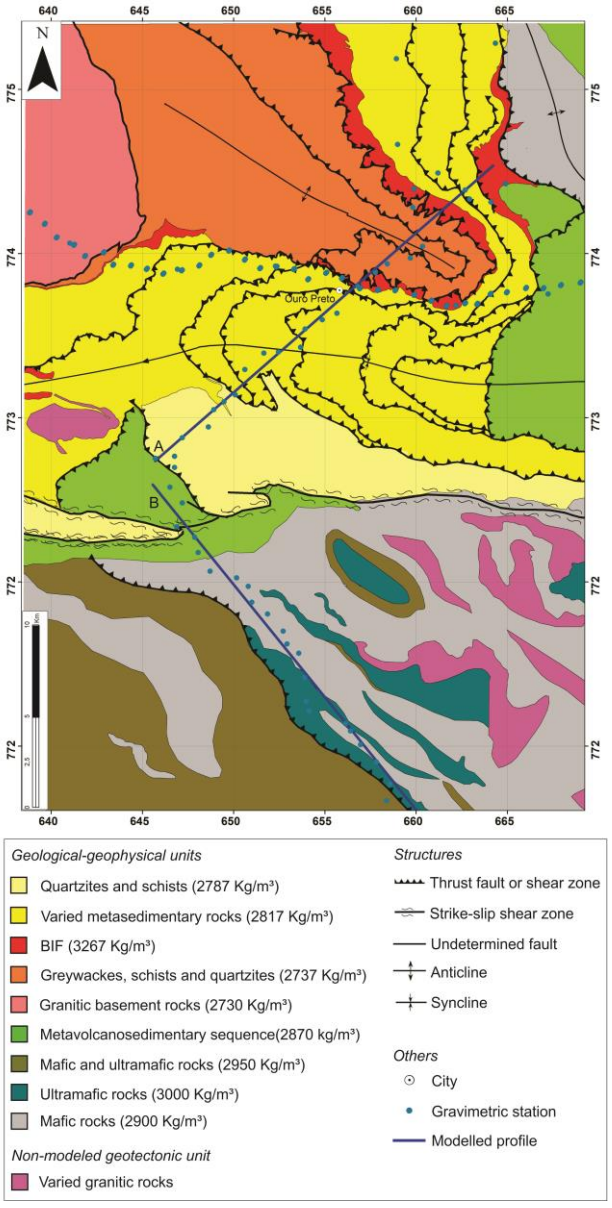

Figure 3 – Geological-geophysical map of the study area; A) Itatiaia-Ouro Preto profile/model; B) Itatiaia-Catas Altas da Noruega profile/model.

The Santo Antônio do Pirapetinga Complex (Figure 2), outcropping to the south of the Engenho Fault, is commonly interpreted as an association of TTG gneisses, mafic-ultramafic rocks and subordinate metasedimentary rocks, but different authors diverge with respect to the proportion of TTG gneisses *versus* mafic-ultramafic rocks in this complex (Heineck et al., 2003; Raposo, 1991; Santos & Baltazar, 2013; Endo et al., 2020).

According to the Bougher anomaly map of the study area, there is a gravimetric high of ca. -73 mGal related to the Santo Antônio do Pirapetinga Complex (Figure 4). This anomaly shows continuity towards north across the Engenho Fault and has been signified in the present models (Figure 5B) by an association of metamafic-ultramafic rocks and TTG gneiss, following the geological map of Santos & Baltazar (2013). However, with the purpose of highlighting the overall relative proportion between metamafic-ultramafic and felsic rocks, the total volume of TTG gneiss in the Itatiaia-Catas Altas da Noruega model (including the continental crust underlying the Santo Antônio do Pirapetinga Complex) has been represented altogether at the base of the model. In this context, TTG rocks interleaving or intruding the mafic-ultramafic association are not considered in the outlines and estimated densities of the upper part of the model (Figure 5B). Therefore, the results show that TTG gneisses prevail in the upper 6 Km of crust and thus are probably relevant in the Santo Antônio do Pirapetinga Complex. However, the amount of metamafic-ultramafic rocks associated with this complex is also substantial and might have been underestimated by some previous works.

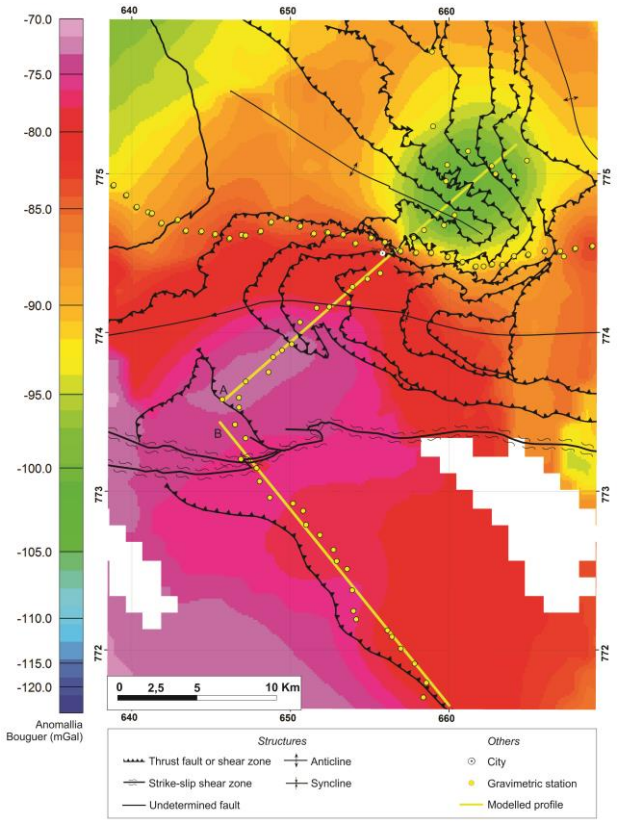

Figure 4 – Bouguer anomaly map of the study area, showing A) Itatiaia-Ouro Preto profile/model; B) Itatiaia-Catas Altas da Noruega profile/model.

Conclusions

The Itatiaia-Ouro Preto 2D gravimetric model built in this study indicates that the granitic rocks associated with the Bação Complex indeed lie beneath the metasedimentary rocks of the Mariana anticline and thus favors a link between the genesis of the anticline and a basement high, as proposed by previous authors. Additionally, the model suggests that the metasedimentary rocks of the upper Nova Lima Group outcropping in this anticline lie

directly over the basement gneiss dome, lacking the lower greenstone belt sequence of the Nova Lima Group.

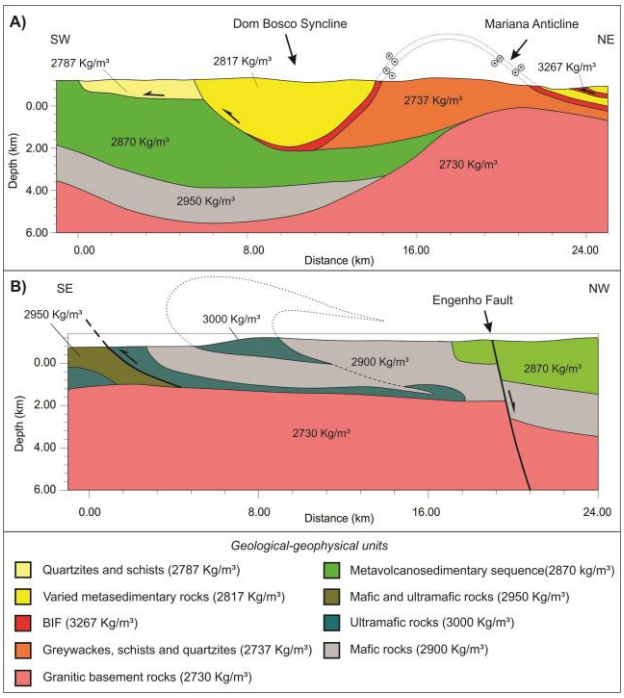

Figure 5 – Gravimetric 2D models: A) Itatiaia-Ouro Preto; B) Itatiaia-Catas Altas da Noruega. Scale = 1:150.000; vertical exaggeration = 1x.

The Itatiaia-Catas Altas da Noruega 2D model shows that the amount of mafic-ultramafic rocks in the Santo Antônio do Pirapetinga Complex is substantial and might have been underestimated by some authors. Besides, the gravimetric high associated with this complex extends across the Engenho Fault towards the Dom Bosco syncline, suggesting that the Santo Antônio do Pirapetinga Complex is present underneath the metasedimentary rocks of the Minas Supergroup in the southeastern Quadrilátero Ferrífero, similarly to what has been proposed by Endo et al. (2020). In this context, the limit between the Quadrilátero Ferrífero and the Barbacena Block continues under cover to the North towards the Mariana Anticline and the Bação dome (Figure 6).

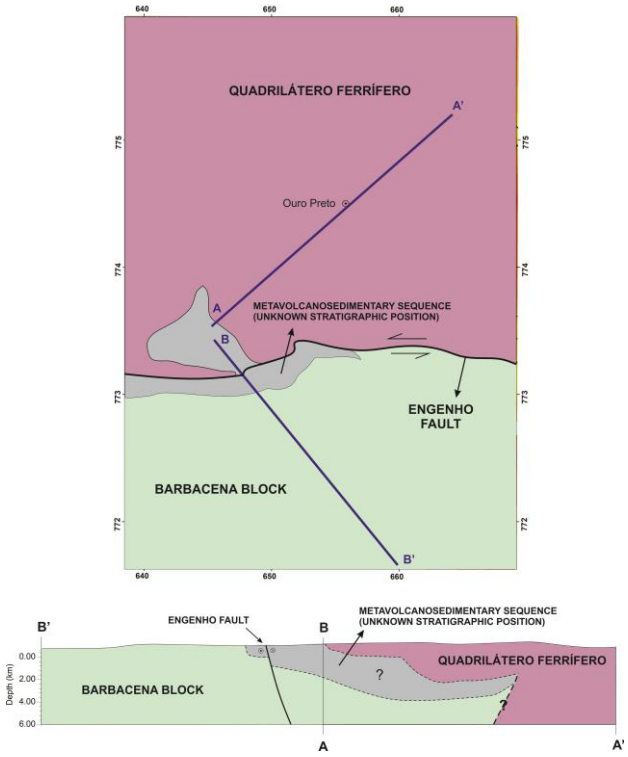

Figure 6: Graphic representation of the Quadrilátero Ferrífero and the Barbacena Block in the studied area and modelled profiles. Between these domains lies a metavolcanosedimentary sequence of unknown stratigraphic position.

Acknowledgments

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