Remote sensing and thematic mapping applied to mineral exploration in the Moura-Ficalho base metals mining region, Ossa-Morena Zone, Portugal

ZOM-3D Modelos Metalogénicos 3D da Zona de Ossa-Morena

EGU General Assembly 2019

Session ITS2.2/ERE4.4 – The New Roadmap for Mineral Exploration

Pedro Gonçalves (1), João Xavier Matos (1), Lídia Quental (2), Maria João Batista (2), Fábio Marques (1), Pedro Sousa (1), Igor Morais (1) and Luís Albardeiro (1)

(1) Laboratório Nacional de Energia e Geologia, Apartado 14, 7600-909 Aljustrel, Portugal, (2) Laboratório Nacional Energia e Geologia, Apartado 7586, 2721-866 Amadora, Portugal,
pedro.goncalves@lneg.pt

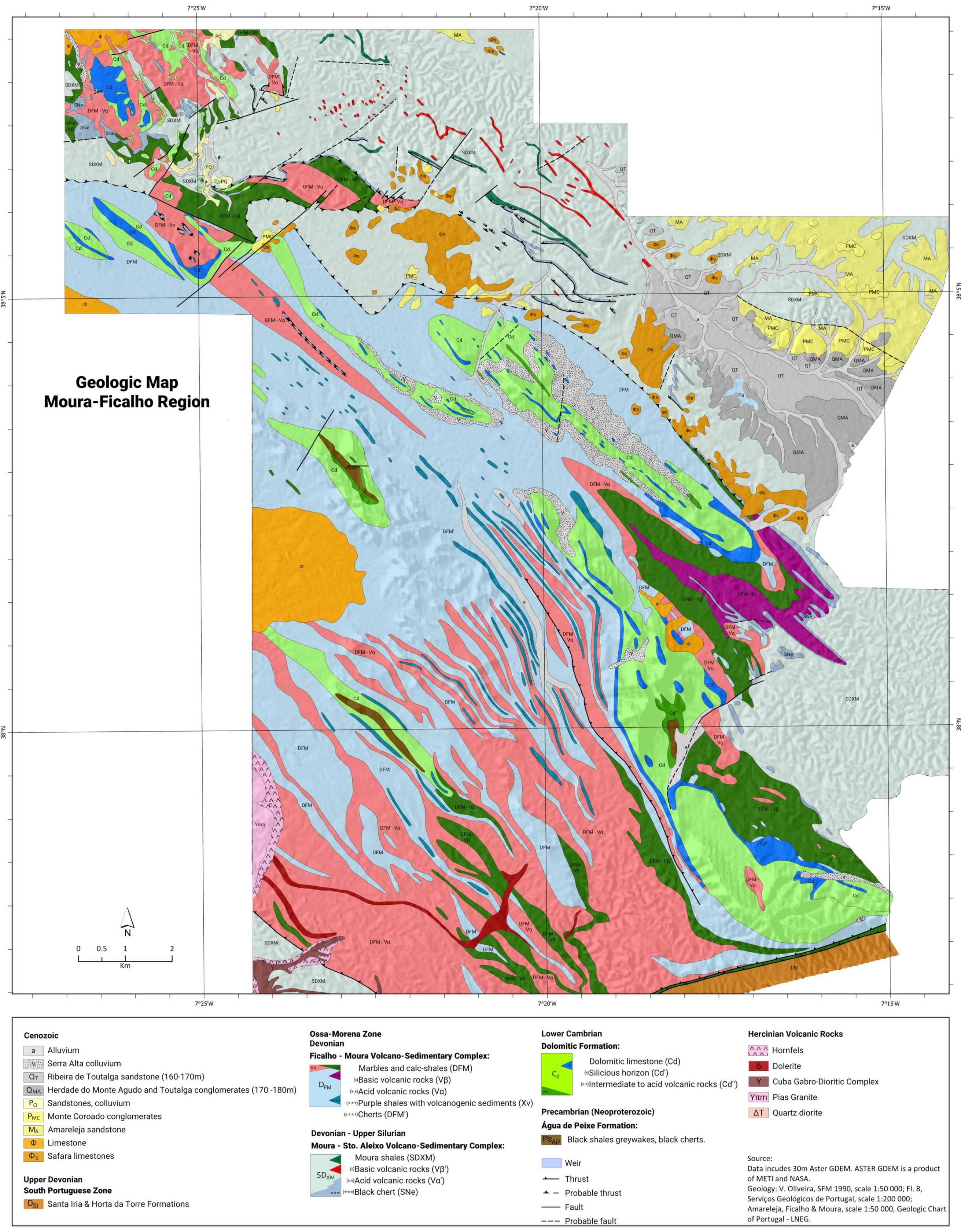
Photography encouraged

1 Introduction & Geologic Setting

Moura-Ficalho sector, is located in south of Portugal. It is part of Ossa-Morena Zone (OMZ) one of the principal paleo-stratigraphic and tectonic zones in Iberian Peninsula [12].

In this work, we attempt to define potential anomalous zones, that can be used for mineral exploration combining data and several techniques such as: geology, geochemistry, geophysics and remote sensing.

This sector is characterized by the presence of Zn and Pb massive and semi-massive sulphide deposits (<1 Mt), associated with acid volcanic rocks and dolomites belonging to the Dolomitic Fm. (probable Lower Cambrian age) [4,6,7,8,11,13]. The geological setting includes from base to top [11,12] a Pre-Cambrian basement; the Dolomitic Fm. and an upper silica horizon, probable related with a Cambrian-Ordovician discordance; the Moura Volcano-Sedimentary Complex (Upper Ordovician?-Devonian? age), represented by bimodal volcanism, marbles, shales and calcoshales and the Moura Phyllonitic Complex "Xistos de Moura" (Silurian) represented by chlorite-sericite phyllites and black cherts (lidites). The geology of the Ficalho sector is conditioned by the southern limit of the OMZ, defined by the Ferreira-Ficalho thrust. Geological structures are NW-SE oriented and large scale folds are present. The geomorphology is clearly conditioned by the differential positive erosion of the Dolomitic Fm. Considering the sulphide mineralization assemblages that occur with magnetite and the host rock geochemistry, several authors consider the Moura-Ficalho ore mineralizations as a SEDEX-Ireland type [4,7]. The primary sulphides shows significant metamorphic and post-metamorphic reworking and late disseminated and fracture-controlled assemblages are present. The outcropping ore lenses shows intense oxidation and supergene enrichment, exposed in gossans conditioned by the karstic erosion of the Dolomitic Fm. [4,6,7,11].



2 Geochemistry and Geophysics

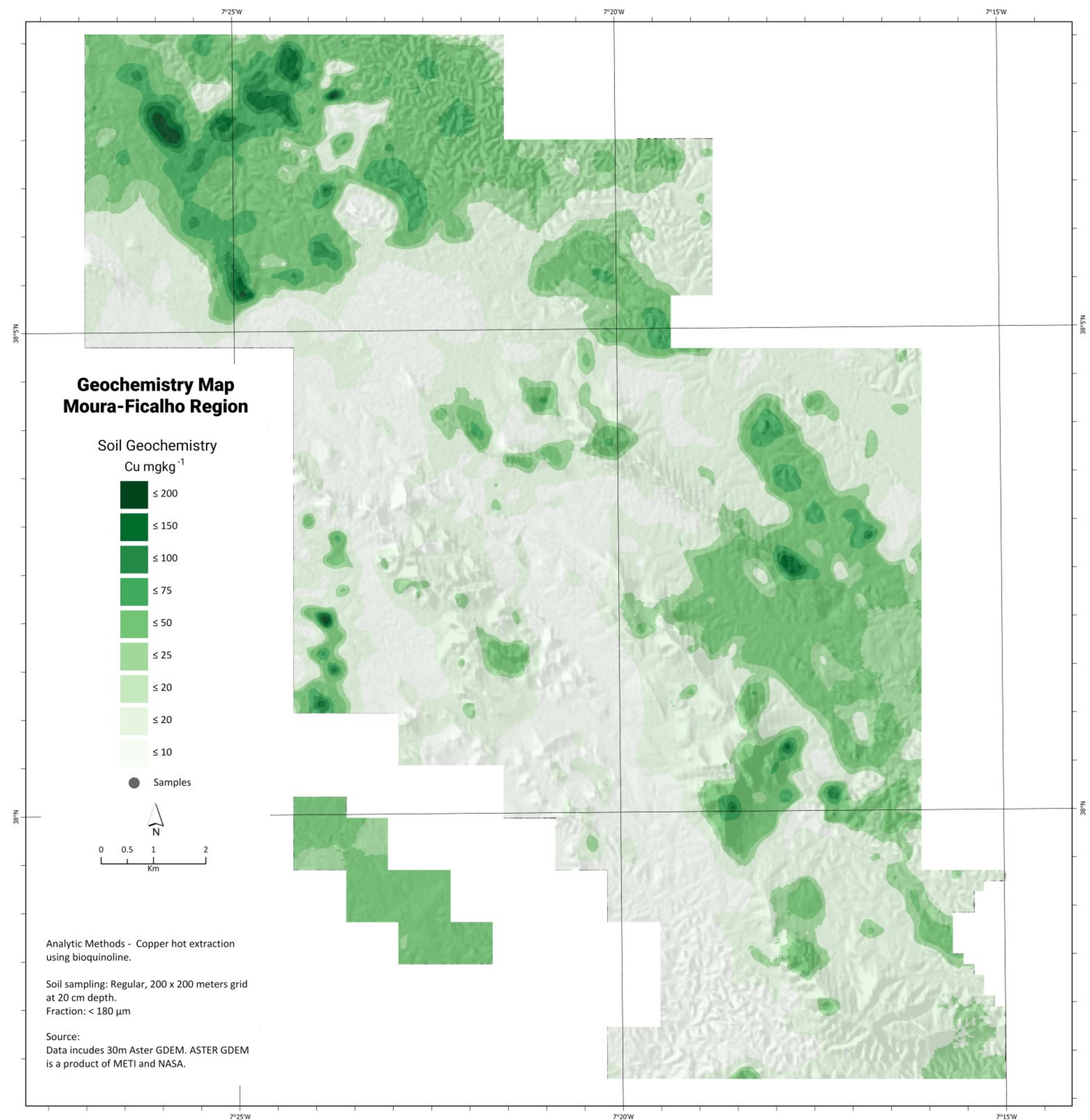
The mineral potential of this area lead to detailed exploration surveys executed by the former SFM Government Agency (currently LNEG) in the 1980s as well as several mining exploration companies. These surveys generated a large knowledge database containing geologic, soil geochemistry (copper, zinc and lead) and geophysics ground surveys (gravity and magnetics) [11].

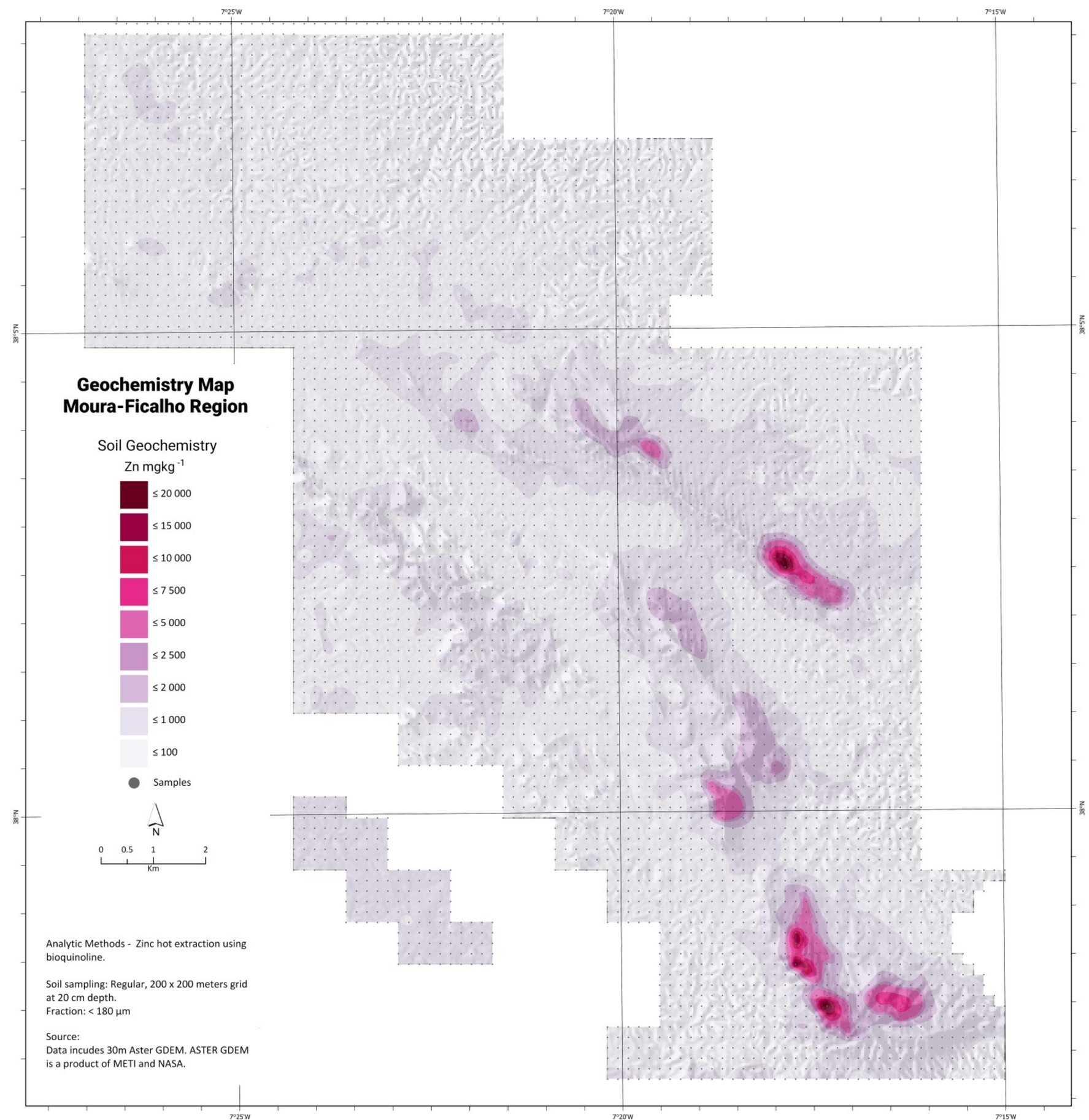
Geochemical data was acquired on a regular mesh grid (200 m x 200 m), at 20 cm depth. Copper and Zinc values were extracted using bioquinoline hot process.

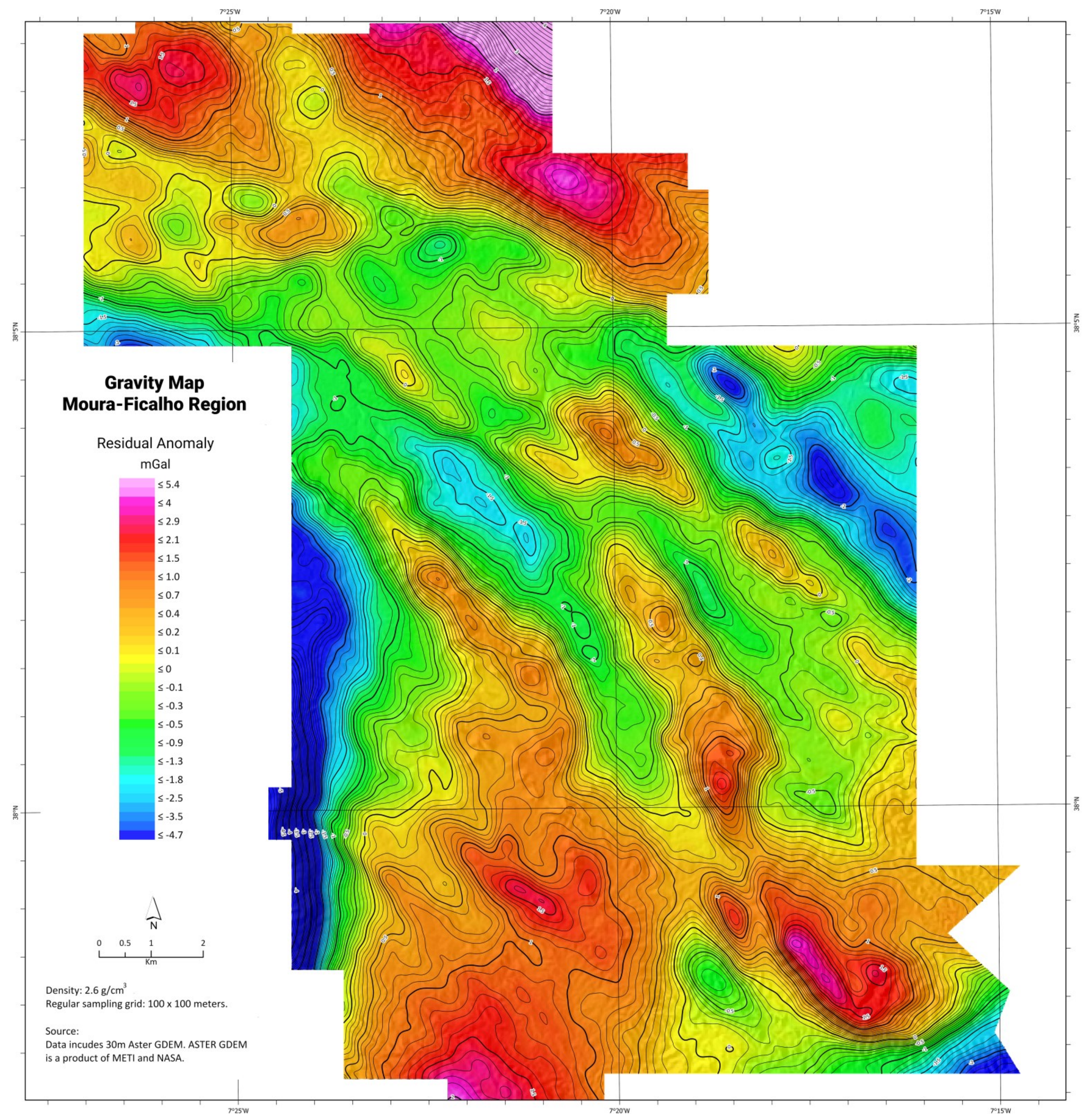
Geophysical data was collected on the field using a regular mesh grid (N-S; E-W) on 100 m x 100 m.

The SFM regional exploration thematic mapping program lead to the identification of NW-SE lineaments well correlated with the Paleozoic antiform structures. Several key areas were selected for further study (induced polarization - IP profiles and drilling). These surveys allowed and promoted new discoveries: Enfermarias (SFM, 1988) [11,12] and Machados (Northern Lion, 2010), both located in the NW Moura sector and still on evaluation stage. Other key target areas were identified near old mine sites (from NW to SE) [8,11]: Carrasca, Preguiça and Vila Ruiva, Merlinha and Palhais and Vale de Vargo.

Both zinc and copper soil geochemistry and ground magnetometry and gravimetry are well correlated with geological formations. The most positive correlation is observed in the Dolomitic Formation and associated volcanic rocks, especially when the outcrops are well exposed, like the Ficalho SE sector, characterized by a significant basement uplift.







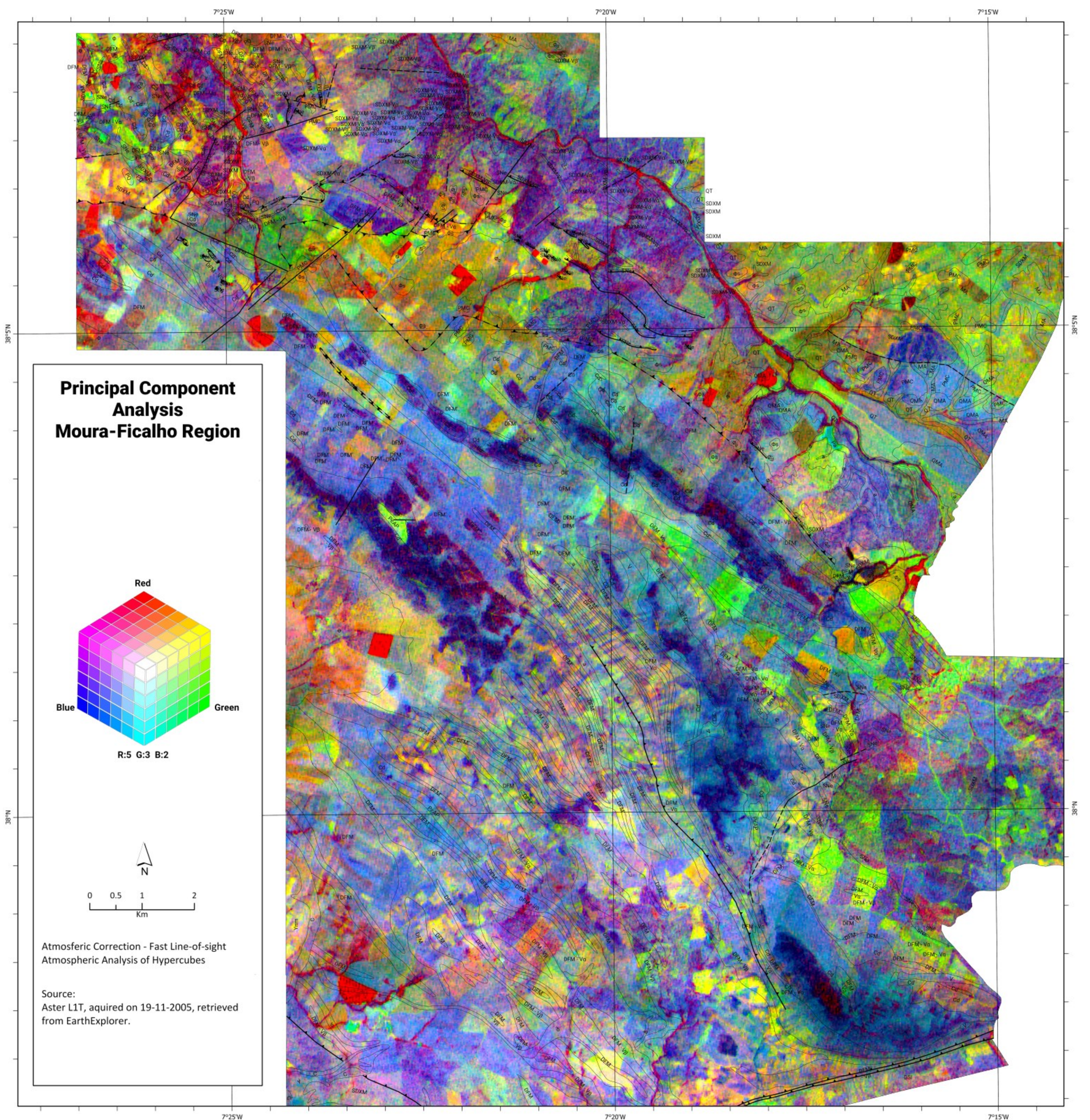
3 Remote Sensing

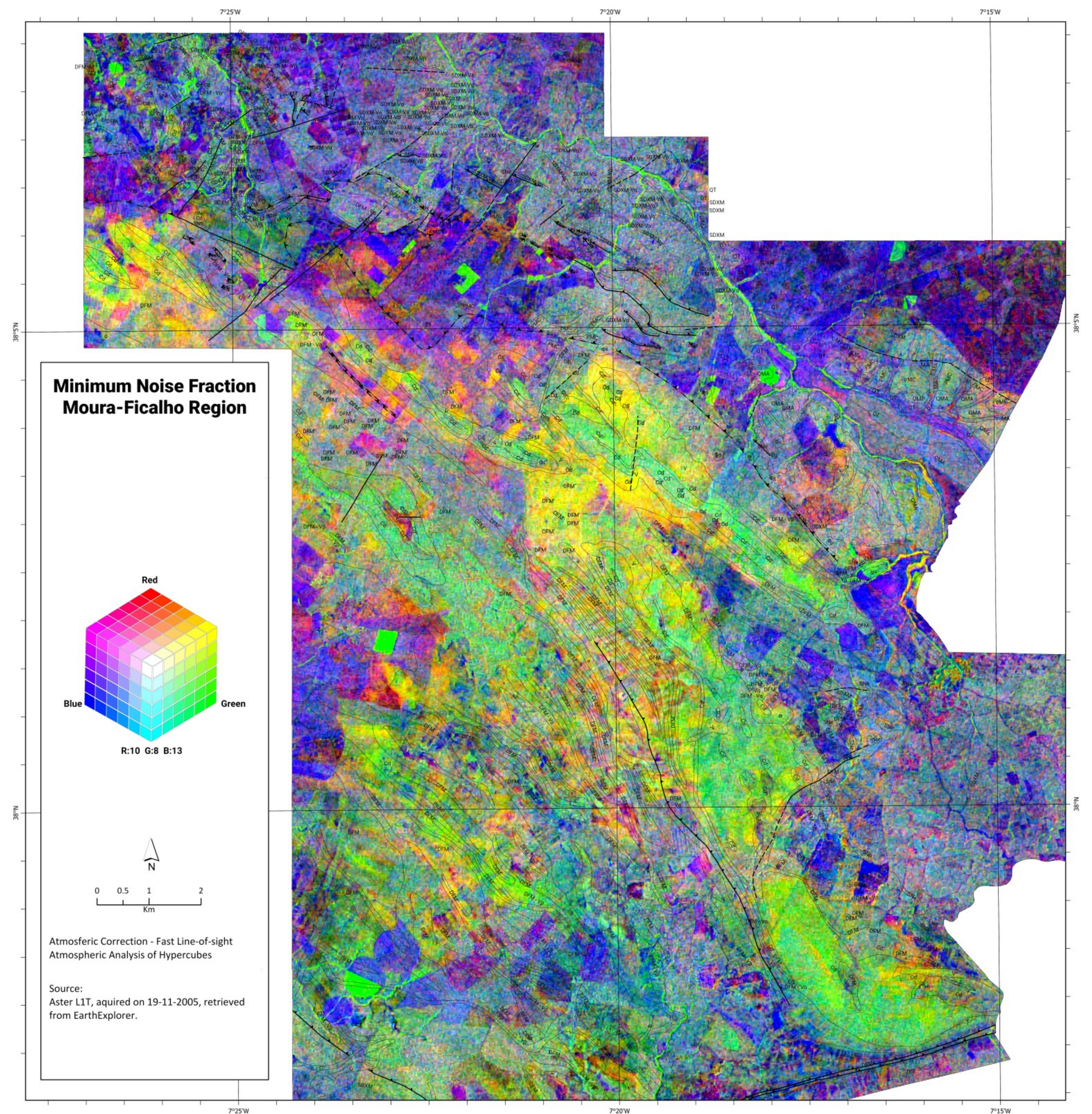
In order to improve mineral and geological understanding of the Moura-Ficalho sector of Ossa-Morena Zone, LNEG acquired an image from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) mission. ASTER is aboard of TERRA platform and provides 14 spectral bands in the wavelength range 0.52-0.82, 1.60-2.43 and 8.12-11.650 µm, with a variable spatial resolution between 15 to 90m [2,9,10,14]. These characteristics are particularly interesting in geological and exploration studies [2,9] given the added SWIR and TIR discrimination [2].

In this work, an ASTER L1T (Precision Terrain Corrected Registered At-Sensor Radiance) image, captured on 19-11-2005 was used.

Principal component analysis (PCA) and minimum noise fraction (MNF), available in Envi, were computed to enhance the spectral response on the different geologic features [10,14] and to be compared to geological 1:50 000 scale maps to assess the potential of Aster capability to differentiate different geologic formations in an heterogeneous and heavily vegetated area.

In both maps (PCA and MNF) it is shown a very high correlation between remote sensing data and Dolomitic Fm. which has associated high anomalies of zinc at Preguiça and Serra de Ficalho (Merlinha, Palhais).



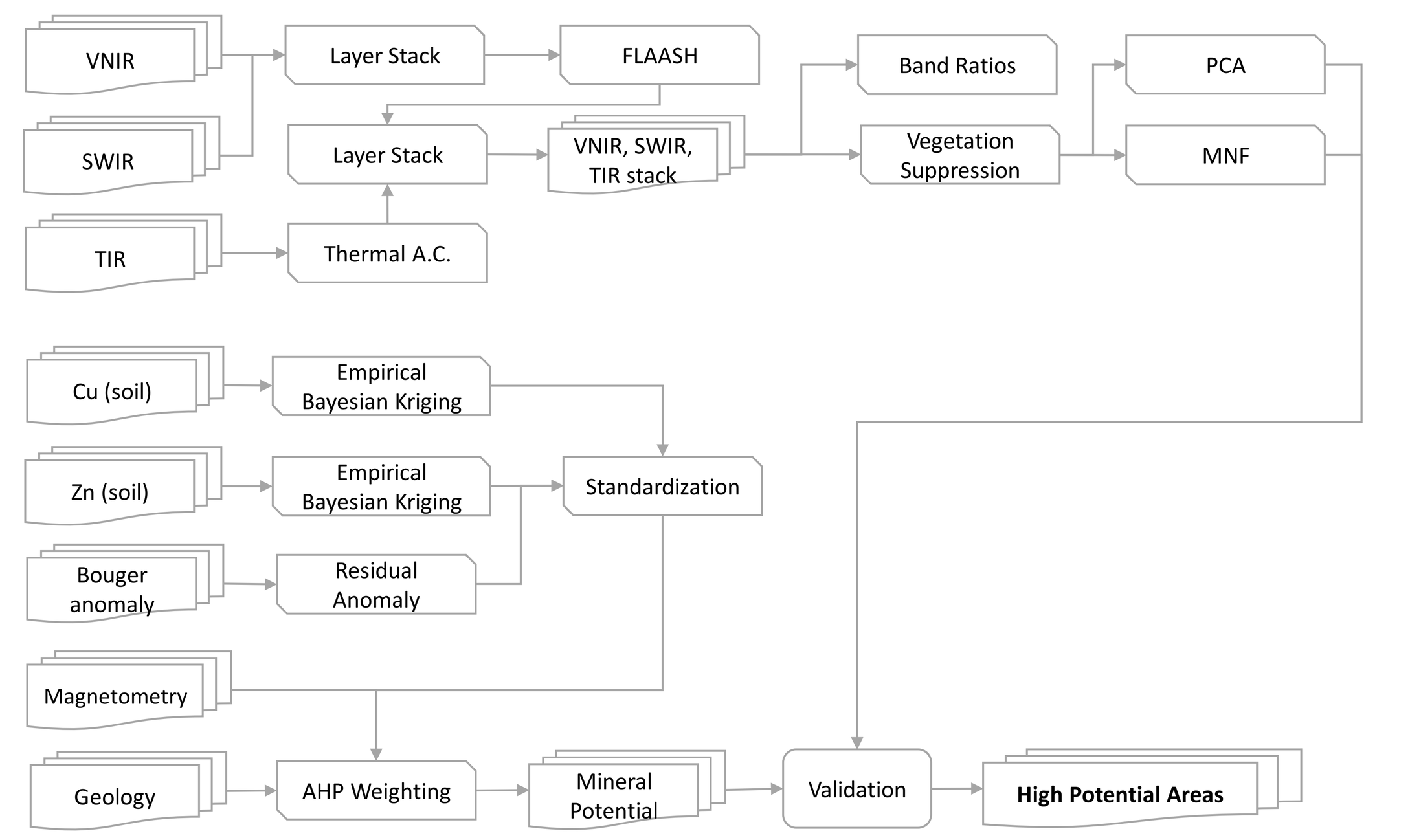


4 Workflow

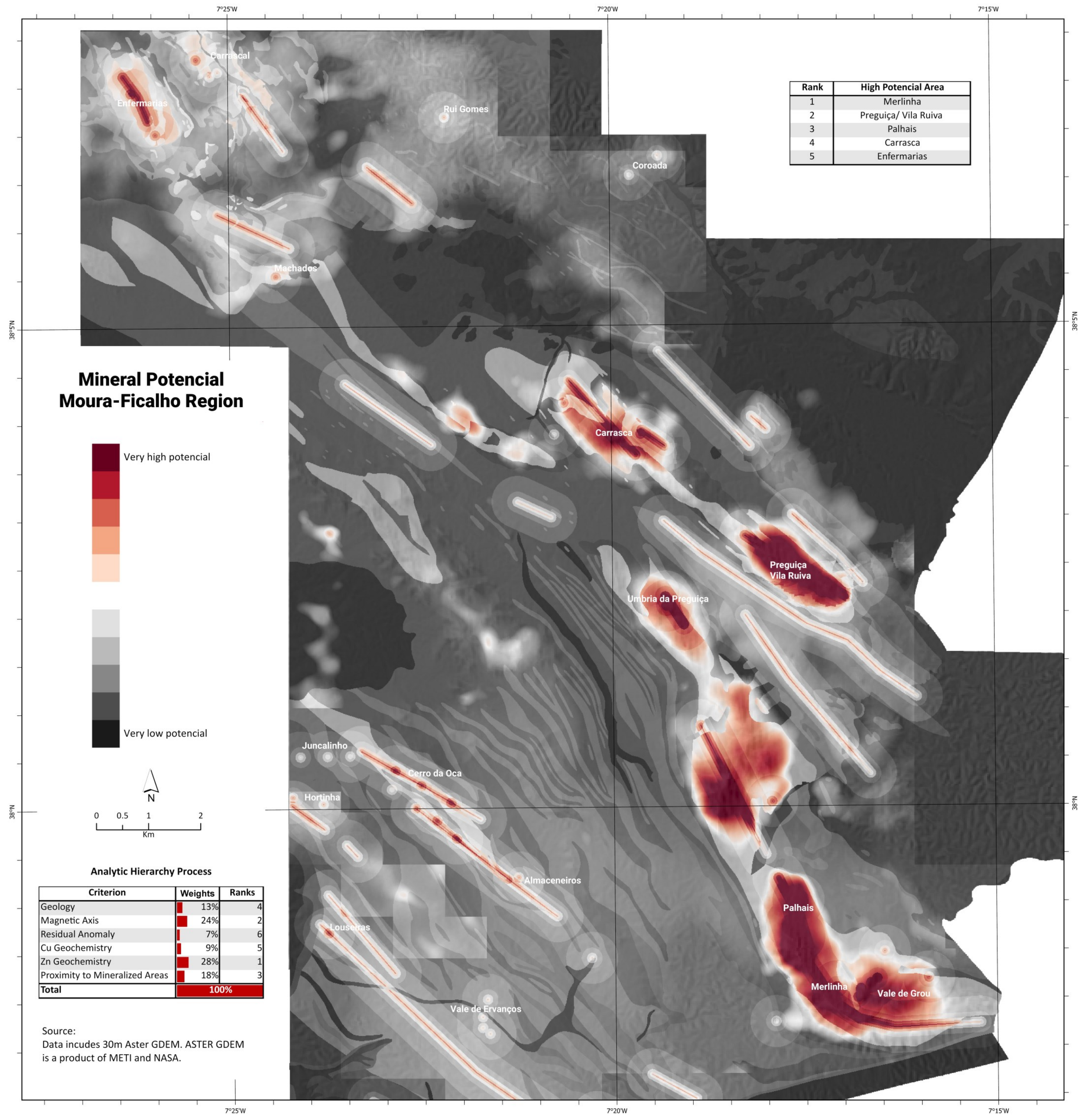
The workflow indicated below encompassed some of the procedures that were undertaken to create the Moura-Ficalho **mineral potential map**. On this work, geophysical, geological and geochemical information was reprocessed, using modern techniques, since most of the information was still on analogic support.

Cu and Zn geochemical data were reprocessed using empirical bayesian kriging. Bouger Anomaly (2.6p gcm^{-3}), from gravity data, was used to compute Residual Anomaly. This method is effective on defining the more superficial geological structures, because it removes the regional tendency of Bouger Anomaly [1].

In order to convert ASTER radiance at the sensor to apparent reflectance, atmospheric correction was applied to the VNIR and SWIR bands [2,14] of the image using Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH). Thermal atmospheric correction was applied to TIR Bands. VNIR, SWIR and TIR bands were stacked on 15 m spatial resolution multiband raster. Geological, geophysical and geochemical information was ranked and normalized to be used as input in Analytic Hierarchy Process (AHP) [3]. This knowledge-driven method is used to determine the weights and ranks of each factor on a given set of data [5].



5 Mineral Potential



Considering the potential of the OMZ Moura-Ficalho sector for exploration, a **mineral potential map** was produced, which combine key factors using a knowledge driven method. Each dataset was calibrated and ranked according to its specific weighting value regarding all datasets. This weighting was conditioned by the existing knowledge of the area, supported by regional and local surveys and exploration drill holes.

The applied methodology highlights the following sectors: Merlinha, Preguiça/Vila Ruiva and Palhais (Ficalho SE area), Carrasca and Enfermarias (Moura NW area). These locations are associated with the Dolimitic Formation, that can be considered the most important exploration target. Despite the complexity of the studied area remote sensing data showed a good correlation with this geological formation.

This holistic and interdisciplinary approach must be developed in future research work regarding a more robust model and considering surface and subsurface information in order to achieve more accurate results.

[1] Dobrin & Savit, 1988. Introduction to Geophysical Prospecting. 4th Ed., McGraw-Hill, New York, 867. **[2]** Gad & Kusky, 2007. ASTER spectral ratioing for lithological mapping in the Arabian–Nubian shield, the Neoproterozoic Wadi Kid area, Sinai, Egypt. Gondwana Research, 11(3), 326–335. **[3]** Goepel, K.D. (2018). Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS). International Journal of the Analytic Hierarchy Process, Vol. 10 Issue 3 2018, pp 469-487 **[4]** Goinhas, 1971. Minas de Vila Ruiva e Preguiça. I Cong. Hispano-Luso-Americano 1: 78-84. **[5]** Hosseinali & Alesheikh, 2008. Weighting Spatial Information in GIS for Copper Mining Exploration Farhad Hosseinali and Ali Asghar Alesheikh. Fac. Geomatics Engineering , Toosi Univ. Technology. American Journal Applied Sciences, 5(9), 1187–1198. **[6]** Mateus et al., 2003. Recrystallised (Fe-) Zn-Pb ores of the Portel-Ficalho region (Ossa Morena Zone, Portugal). Ciências da Terra V, F86-89. **[7]** Mateus et al., 2013. Cap.II.2.4-Mineralizações no sector português da Zona de Ossa-Morena. Geologia Pré-mesozóica de Portugal. Escolar Ed., 577-620. **[8]** Matos & Filipe Coord. 2013. Carta de Ocorrências Mineiras do Alentejo e Algarve 1:400 000. LNEG ISBN: 978-989-675-030-5. **[9]** Moulay & Boulevard, 2013. ASTER VNIR & SWIR Band Enhancement for Lithological Mapping - A case study of the Azegour Area (Morocco). Journ. Environmental Earth Sciences, 12(3), 33-45. **[10]** Noori et al., 2019. Comparison of Different Algorithms to Map Hydrothermal Alteration Zones Using ASTER Remote Sensing Data for Polymetallic Vein-Type Ore Exploration: Toroud–Chahshirin Magmatic Belt (TCMB), North Iran. Remote Sens, 11(5), 495.**[11]** Oliveira & Matos, 1992. Enquadramento Geológico-Mineiro da Jazida de Enfermarias (Faixa Magnetítico-Zincífera, Z. Ossa Morena). Abs. . Museo de Extremadura 1, 114-115, Mérida. **[12]** Oliveira et al., 1991. Traços gerais da evolução tectono estratigráfica da Zona de Ossa Morena, em Portugal: síntese crítica do estado actual dos conhecimentos. Com. Serv. Geológicos Port. 77, 3-26. **[13]** Represas, et al., 2005. A case study of two and three-dimensional inversion of dipole-dipole data: the Enfermarias Zn-Pb (Ag, Sb, Au) Prospect (Moura, Portugal). Near Surface Geophysics, 21-31. **[14]** Testa et al., 2018. Lithological and Hydrothermal Alteration Mapping of Epithermal, Porphyry and Tourmaline Breccia Districts in the Argentine Andes Using ASTER Imagery. Remote Sens., 10(2), 203.

LNEG · Universidade de Évora · República Portuguesa – Ambiente e Transição Energética · Alentejo 2020 · Portugal 2020 · União Europeia – Fundo Europeu de Desenvolvimento Regional

ZOM 3D/Alentejo2020-Op ALT20-03-0145-FEDER-000028 Project is funded by Alentejo2020/Portugal2020 & European Regional Development Fund/ERDF.