High-Resolution Marine Magnetic Mapping of the Portuguese Nearshore: Unraveling Geological Domains, Faults and Magmatic Structures

Marta Neres[1], Pedro Terrinha[1], Pedro Brito[1], Marcos Rosa[1], João Noiva[1], Vitor Magalhaes[2], Mariana Silva[1], Manuel Teixeira[1], Luis Filipe Rodrigues Batista[3], and Carlos Ribeiro[4]

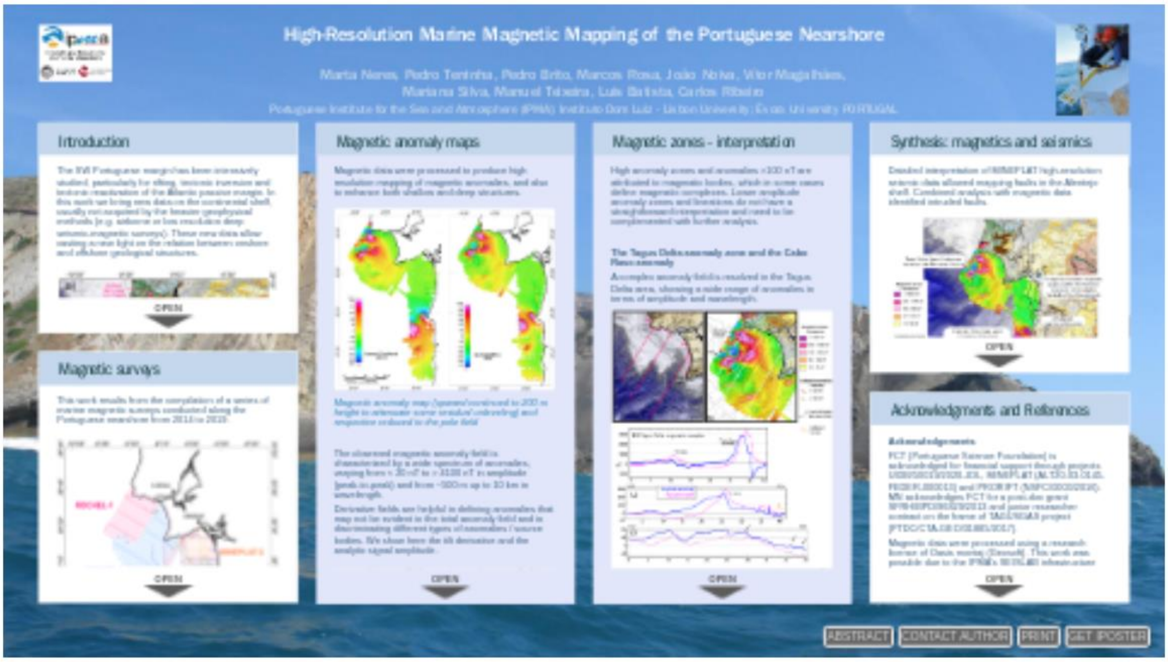
[1]Instituto Portugues do Mar e da Atmosfera
[2]Portuguese Institute for the Sea and Atmosphere (IPMA)
[3]Instituto Português do Mar e da Atmosfera
[4]Universidade de Evora,Universidade de Evora

November 22, 2022

Abstract

The SW Portuguese margin has been intensively studied, particularly for rifting, tectonic inversion and tectonic reactivation of the Atlantic passive margin. In this work we bring new data on the continental shelf, usually not acquired by the heavier geophysical methods (e.g. airborne or low resolution deep seismic-magnetic surveys). These new data allow casting a clear light bridging between the geological structures onshore and offshore. The geology of this margin went through the Variscan orogeny of Paleozoic age, the North Atlantic rifting, the Late Cretaceous alkaline magmatism (intrusive and extrusive), the Alpine tectonic inversion and the Quaternary reactivation of the passive margin. We present results from the compilation of a series of marine magnetic surveys conducted along the Portuguese nearshore from 2014 to 2019. Magnetic data were acquired with 1 nautic mile line separation, resulting in near full coverage of the nearshore along a 120 km long margin segment, from Sintra to Odeceixe. For a large part of the surveyed area, ultra-high resolution seismics and multibeam bathymetry were simultaneously acquired. Magnetic data were processed to produce high resolution mapping of magnetic anomalies, and also to enhance both shallow and deep structures, using several derivative and filtering techniques. We combine the interpretation of high-resolution magnetic mapping with the interpretation of ultra-high resolution and vintage deep penetration seismic data to infer the local and regional expression of tectonic structures and magmatic bodies. Our results allow: identifying the offshore extension of important faults, e.g. the Grândola, Pinhal Novo and Messejana faults; resolving previously blurry-imaged magmatic structures, e.g. Sines and Cabo Raso anomalies; identifying faults recycled from the Paleozoic through Present; constraining the relation between magmatic intrusions and faults; and bringing constraints to the discussion of magmatic emplacement.

High-Resolution Marine Magnetic Mapping of the Portuguese Nearshore



Marta Neres, Pedro Terrinha, Pedro Brito, Marcos Rosa, João Noiva, Vítor Magalhães, Mariana Silva, Manuel Teixeira, Luis Batista, Carlos Ribeiro

ipma instituto português do mar e da atmosfera

UNIVERSIDADE DE ÉVORA

INSTITUTO DOM LUIZ

Neres, M., P. Terrinha, P. Brito, M. Rosa, J. Noiva, V. Magalhães, M. Silva, M. Teixeira, L. Batista, C. Ribeiro (2020). ***High-Resolution Marine Magnetic Mapping of the Portuguese Nearshore: Unraveling Geological Domains, Faults and Magmatic Structures***, Abstract (GP012-0005) presented at 2020 AGU Fall Meeting, 1-17 Dec

AGU FALL MEETING
Online Everywhere | 1–17 December 2020

Session GP012 - Magnetics and Electromagnetics at Sea: From Seafloor Spreading to Mineral Exploration - Posters

ABSTRACT

The SW Portuguese margin has been intensively studied, particularly for rifting, tectonic inversion and tectonic reactivation of the Atlantic passive margin. In this work we bring new data on the continental shelf, usually not acquired by the heavier geophysical methods (e.g. airborne or low resolution deep seismic-magnetic surveys). These new data allow casting a clear light bridging between the geological structures onshore and offshore. The geology of this margin went through the Variscan orogeny of Paleozoic age, the North Atlantic rifting, the Late Cretaceous alkaline magmatism (intrusive and extrusive), the Alpine tectonic inversion and the Quaternary reactivation of the passive margin.

We present results from the compilation of a series of marine magnetic surveys conducted along the Portuguese nearshore from 2014 to 2019. Magnetic data were acquired with 1 nautic mile line separation, resulting in near full coverage of the nearshore along a 120 km long margin segment, from Sintra to Odeceixe. For a large part of the surveyed area, ultra-high resolution seismics and multibeam bathymetry were simultaneously acquired.

Magnetic data were processed to produce high resolution mapping of magnetic anomalies, and also to enhance both shallow and deep structures, using several derivative and filtering techniques.

We combine the interpretation of high-resolution magnetic mapping with the interpretation of ultra-high resolution and vintage deep penetration seismic data to infer the local and regional expression of tectonic structures and magmatic bodies. Our results allow: identifying the offshore extension of important faults, e.g. the Grândola, Pinhal Novo and Messejana faults; resolving previously blurry-imaged magmatic structures, e.g. Sines and Cabo Raso anomalies; identifying faults recycled from the Paleozoic through Present; constraining the relation between magmatic intrusions and faults; and bringing constraints to the discussion of magmatic emplacement.

INTRODUCTION

The SW Portuguese margin has been intensively studied, particularly for rifting, tectonic inversion and tectonic reactivation of the Atlantic passive margin. In this work we bring new data on the continental shelf, usually not acquired by the heavier geophysical methods (e.g. airborne or low resolution deep seismic-magnetic surveys). These new data allow casting a new light on the relation between onshore and offshore geological structures.

The geology of this margin went through the Variscan orogeny of Paleozoic age, the North Atlantic rifting, the Late Cretaceous alkaline magmatism (intrusive and extrusive), the Alpine tectonic inversion and the Quaternary reactivation of the passive margin.

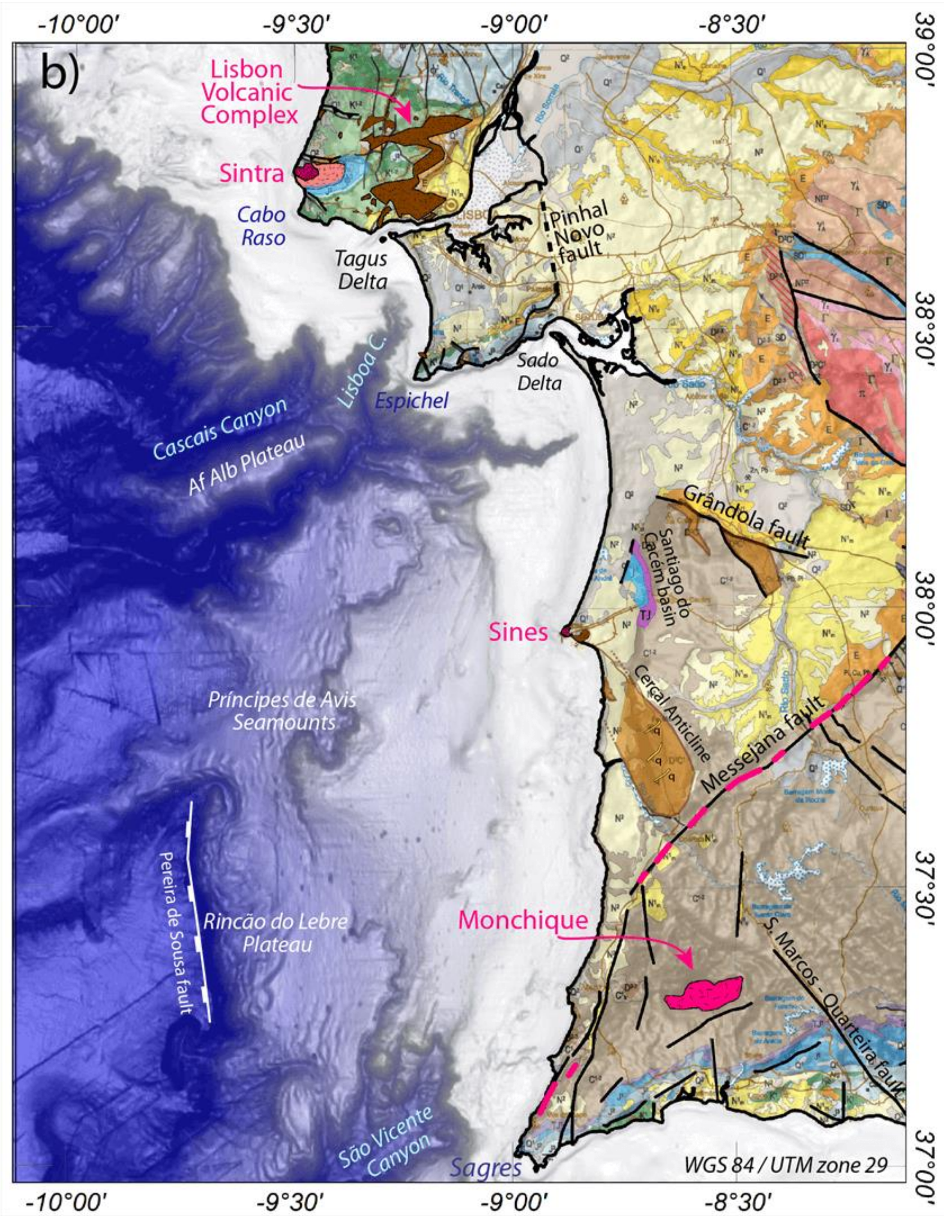


Figure 1: Onshore geological setting and bathymetric map of the study area, with main magmatic occurrences highlighted.

MAGNETIC SURVEYS

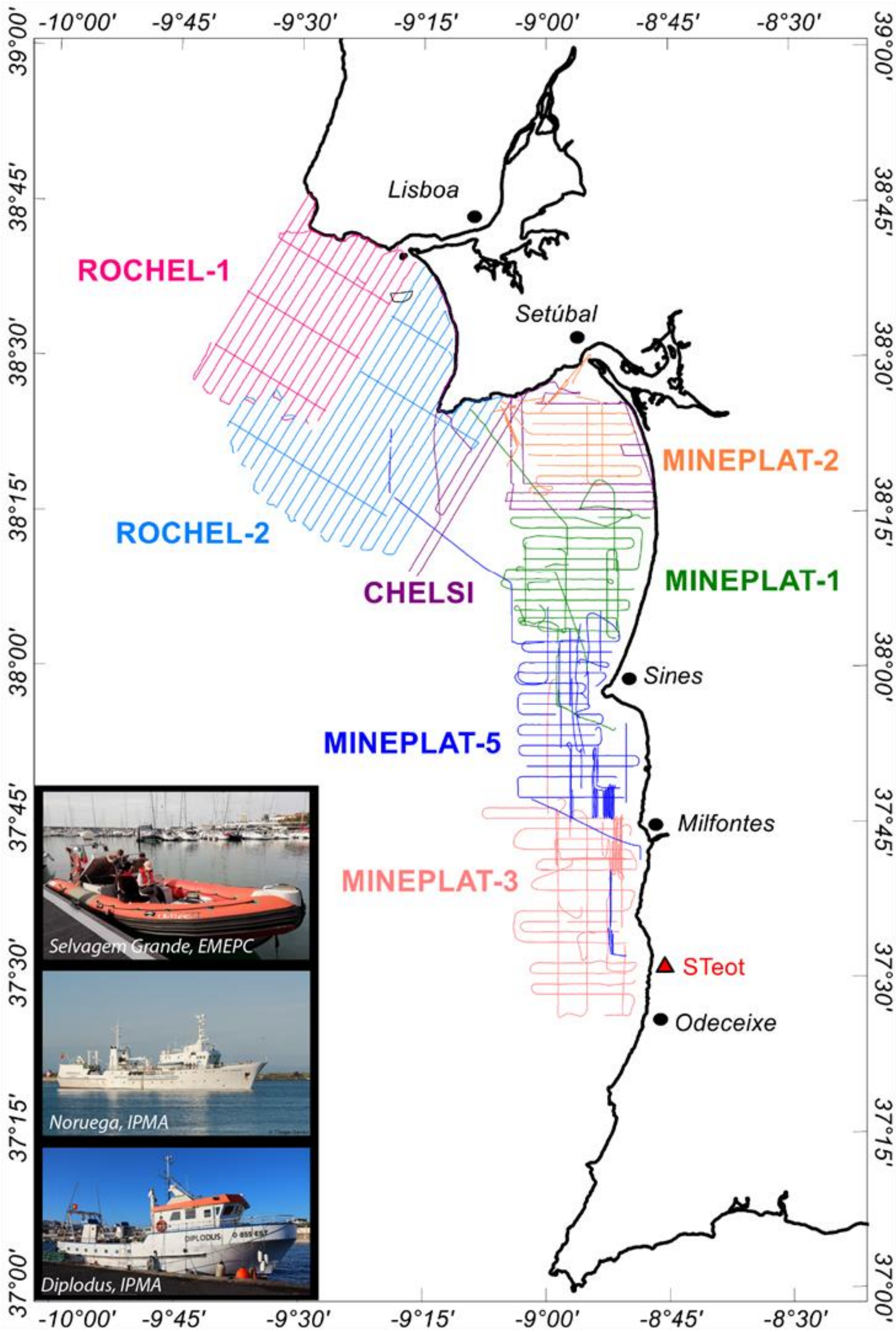


Figure 2: Survey tracks of the several magnetic surveys used in this work. Photos show the vessels used for magnetic data acquisition.

This work results from the compilation of a series of marine magnetic surveys conducted along the Portuguese nearshore from 2014 to 2019.

ROCHEL and CHELSI surveys were fully dedicated magnetic surveys. MINEPLAT surveys also acquired multichannel seismics, multibeam bathymetry and backscatter data.

Magnetic data were acquired with a total field G-882 (Geometrics) magnetometer with average 1 nautic mile line separation, resulting in about 4400 km2 surveyed area along a 120 km long nearshore segment, from Sintra to Odeceixe.

Data processing included noise removal, IGRF and diurnal corrections, iterative line leveling, gridding.

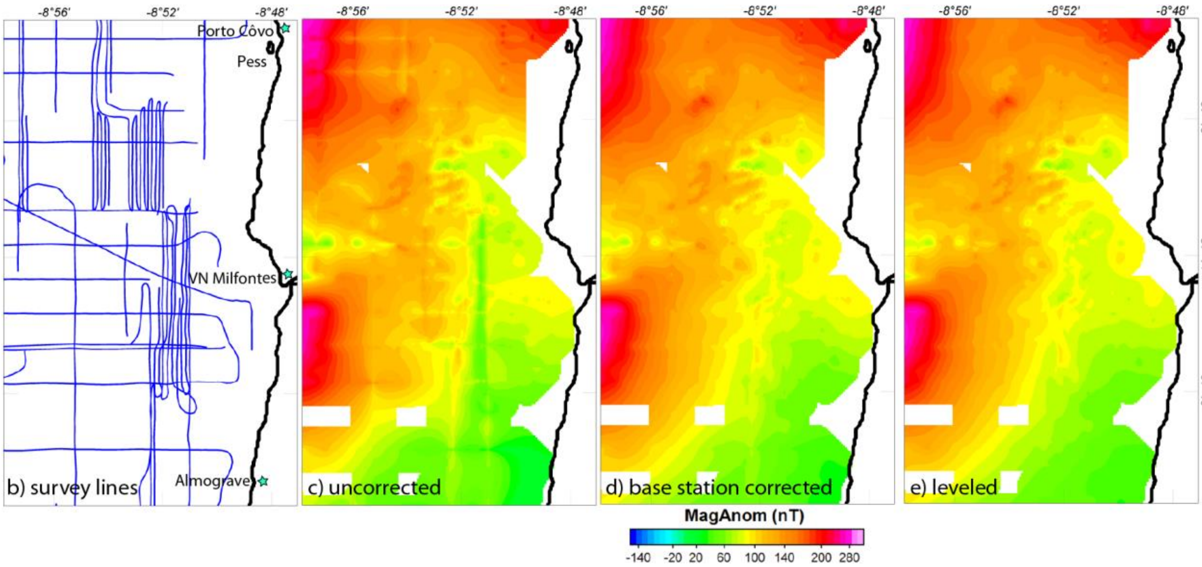


Figure 3: Detail of magnetic data processing, showing base station correction and line leveling

MAGNETIC ANOMALY MAPS

Magnetic data were processed to produce high resolution mapping of magnetic anomalies, and also to enhance both shallow and deep structures.

The observed magnetic anomaly field is characterized by a wide spectrum of anomalies, varying from < 20 nT to > 4100 nT in amplitude (peak-to-peak) and from ~500 m up to 10 km in wavelength.

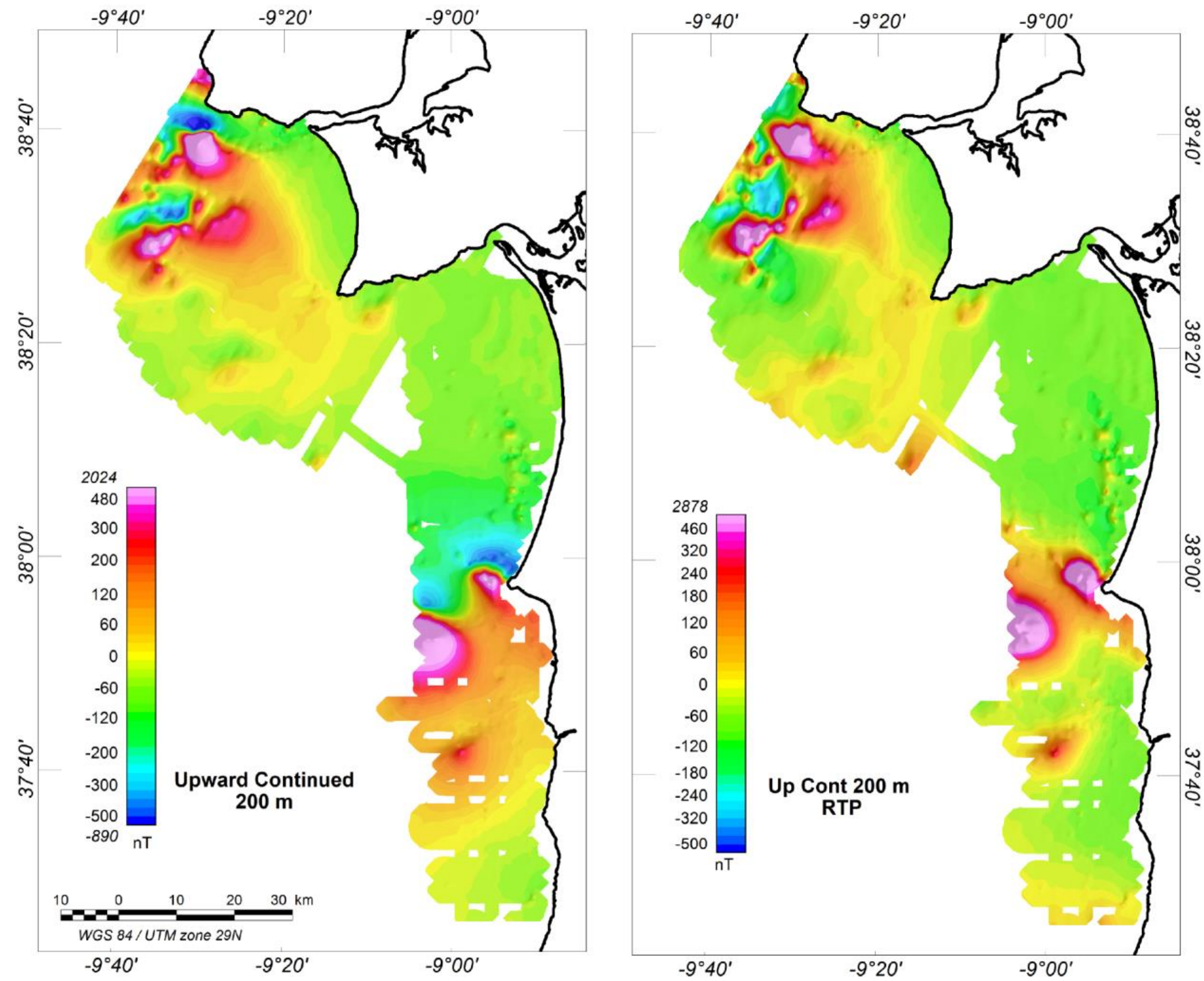


Figure 4: Magnetic anomaly map (upward continued to 200 m height to attenuate some residual unleveling) and respective reduced to the pole field

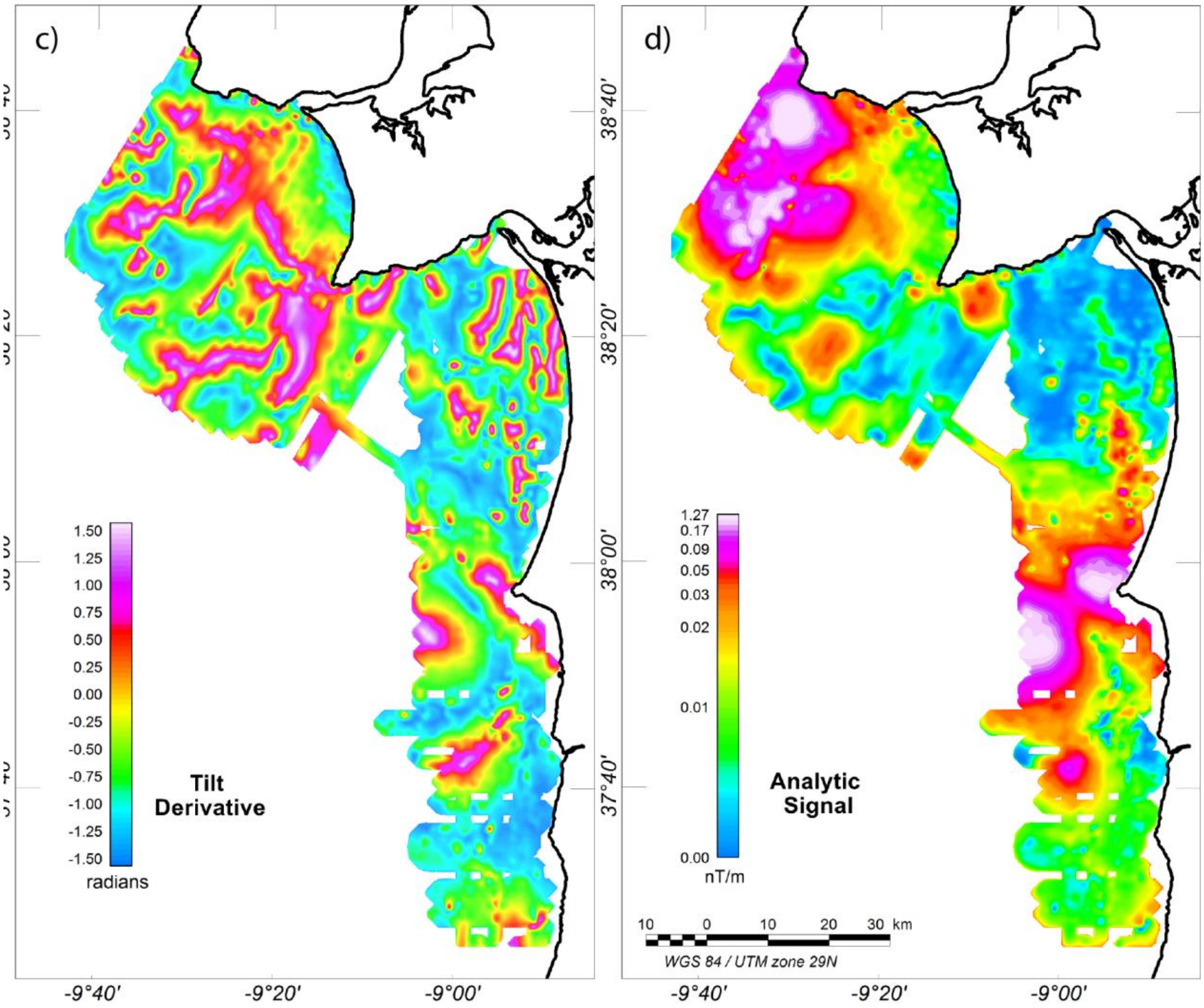


Figure 5: Tilt derivative and analytic signal of the magnetic field

Derivative fields are helpful in defining anomalies that may not be evident in the total anomaly field and in discriminating different types of anomalies / source bodies. We show here the tilt derivative and the analytic signal amplitude.

The tilt derivative enhances low amplitude anomalies, since it is independent from the anomaly amplitude. The analytic signal amplitude has maxima over the magnetic sources with the advantage of being independent from the magnetization (induced or remanent) of the source bodies.

Relation with onshore magnetic anomaly

Our data show a very good agreement with Iberia aeromagnetic data (3 km altitude, flight lines spaced of 10 km), showing the prolongation of onshore anomalies into the offshore.

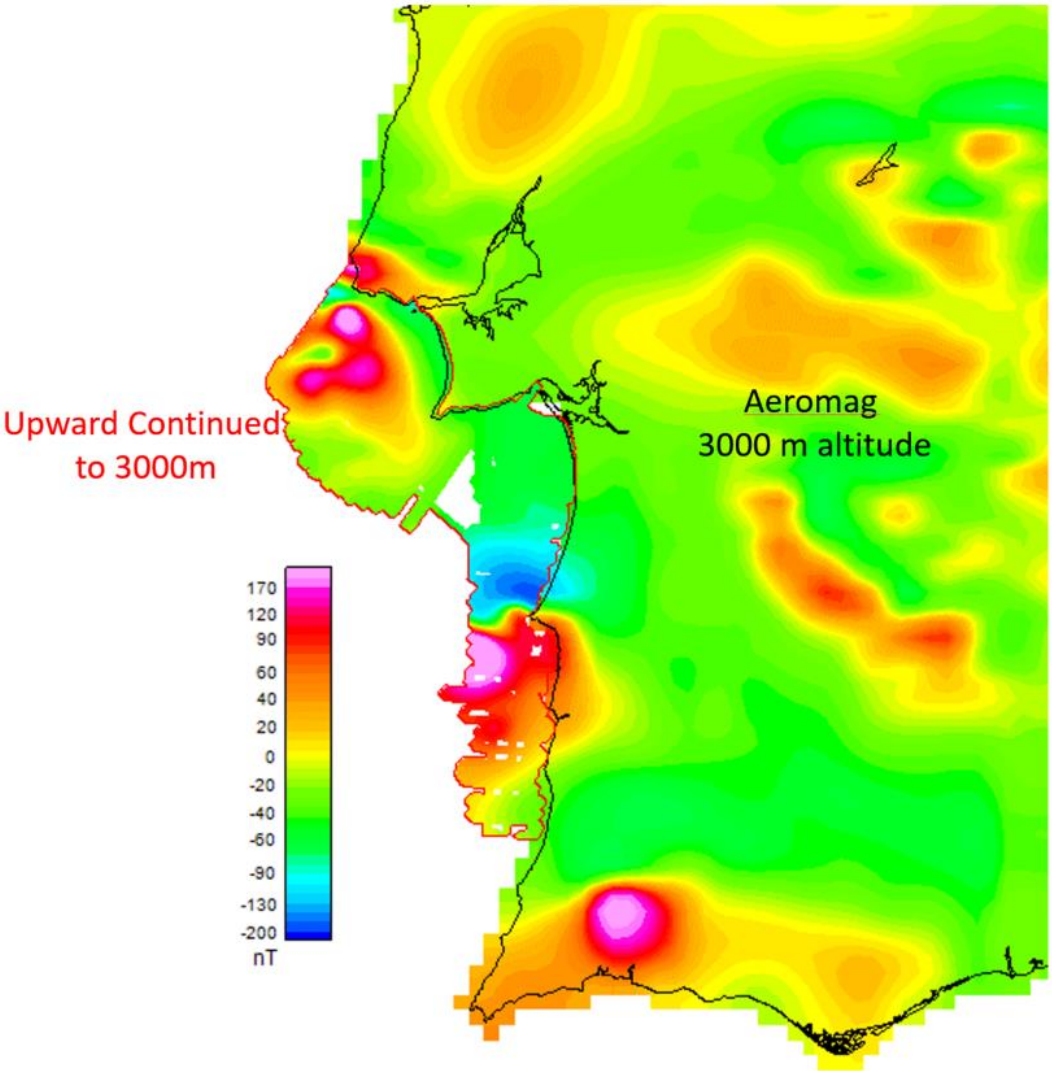


Figure 6: Offshore: magnetic anomaly upward continued to 3 km height (this work). Onshore: the aeromagnetic map of Iberia surveyed at 3 km altitude (Miranda et al 1989; Socias 1994). Scale is the same for both.

MAGNETIC ZONES - INTERPRETATION

High anomaly zones and anomalies >100 nT are attributed to magmatic bodies, which in some cases define magmatic complexes. Lower amplitude anomaly zones and lineations do not have a straightforward interpretation and need to be complemented with further analysis.

The Tagus Delta anomaly zone and the Cabo Raso anomaly

A complex anomaly field is resolved in the Tagus Delta area, showing a wide range of anomalies in terms of amplitude and wavelength.

It is crucial in this region to distinguish between geological and artifact magnetic sources. Several high-frequency anomalies close to the coast were verified to be due to man-made sources such as submarine cables and sewage outfalls (yellow marks over lines in Figure 7).

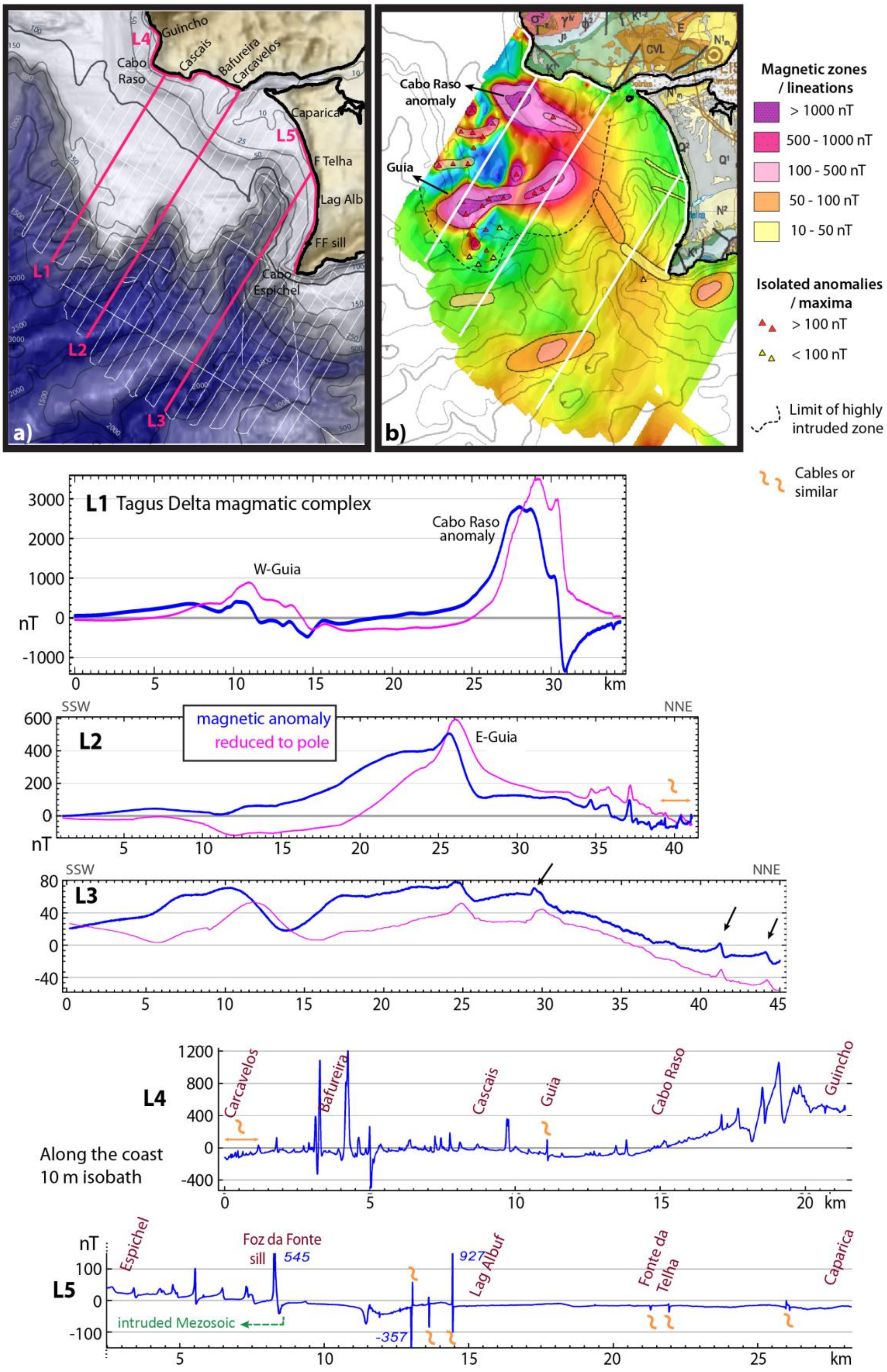


Figure 7: The Tagus Delta magnetic anomaly zone

The most outstanding Cabo Raso anomaly corresponds to a buried Upper Cretaceous volcanic body (Neres et al 2014).

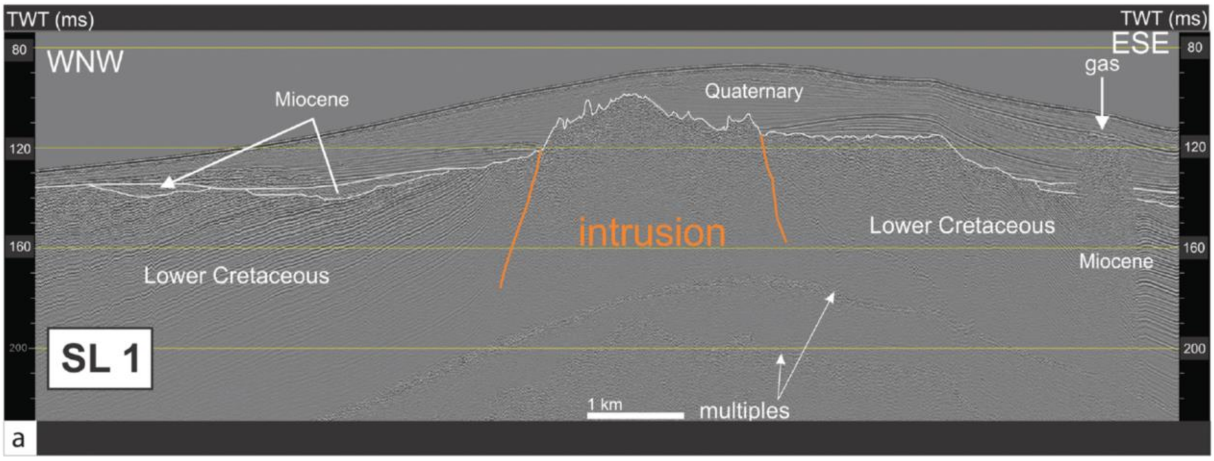


Figure 8: The Cabo Raso intrusion imaged in seismic data (in Neres et al 2014)

Comporta anomaly zone and the Grândola fault

A magnetic zone with ~N-S low amplitude lineations is mapped to the south of Setúbal. The anomalies sharply terminate against a limit that perfectly coincides with the offshore prolongation of the Grândola fault.

It is deduced that the lineations are sourced in the Paleozoic basement, and that the Grândola fault works as a northern barrier to the propagation of the magmatic intrusions observed to its south.

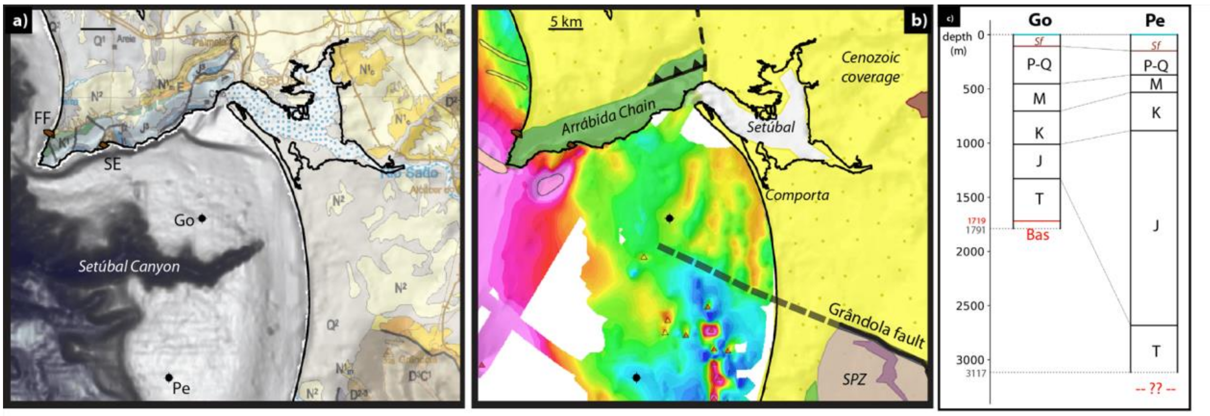


Figure 9: Comporta magnetic zone and the deduced offshore prolongation of the Grândola fault. c) Simplified logs for Golfinho and Pescada wells

The Sines anomaly zone in the Alentejo shelf

The Alentejo shelf shows several distinct types of anomalies.

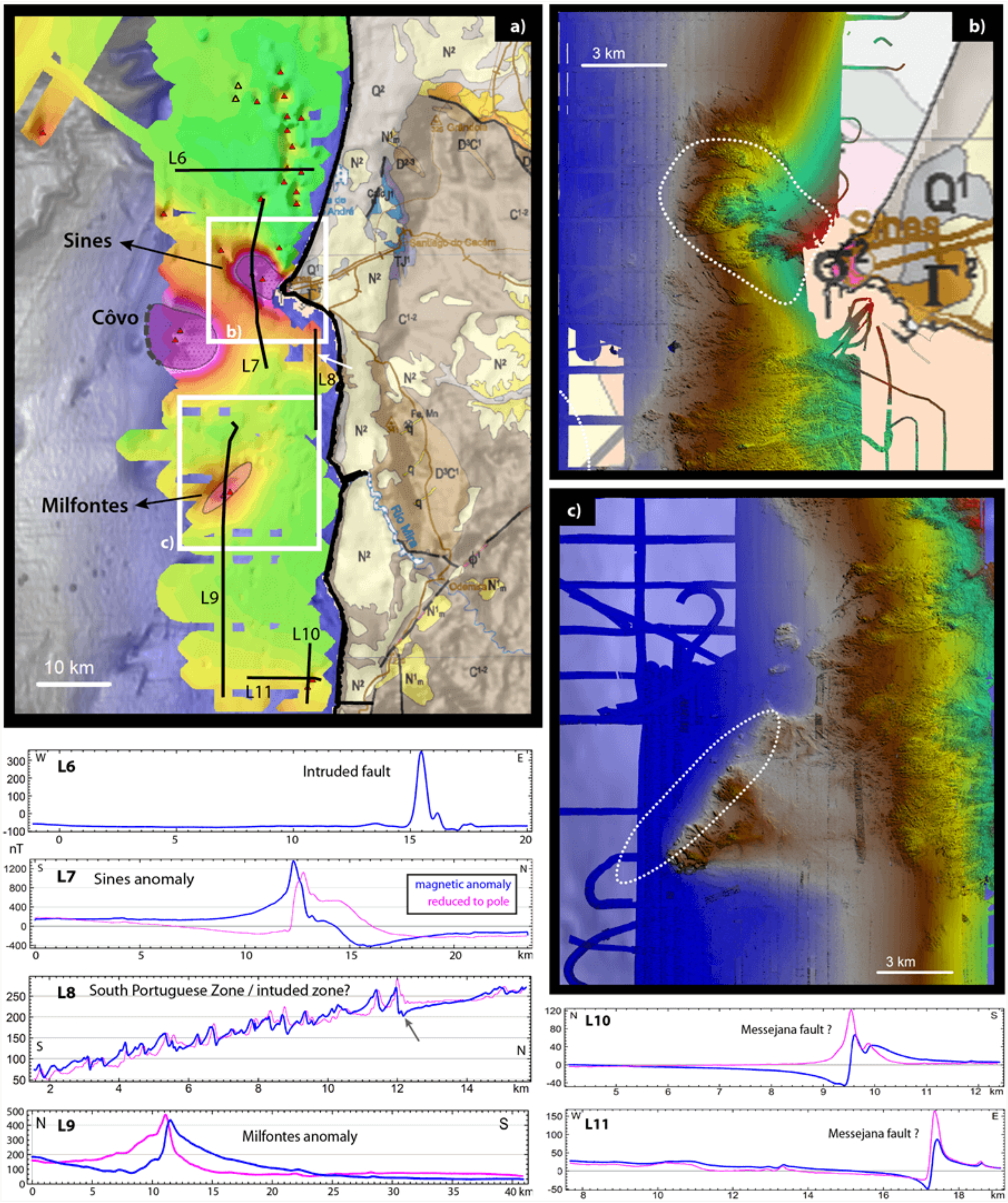


Figure 10: Magnetic anomaly map of the Alentejo shelf, including the Sines magnetic complex. b) and c) show MINEPLAT multibeam bathymetry data

To the north of Sines up to the Grândola fault, several individual anomalies align and likely correspond to magmatic intrusions intruding a ~N-S fault.

The Sines anomaly is the offshore extension of the outcropping Upper Cretaceous Sines magmatic complex. The Côvo anomaly is now resolved as a separated anomaly and implies a buried intrusion with high magnetization.

High-resolution seismics and bathymetry data collected by MINEPLAT surveys reveal that the Milfontes anomaly corresponds to a sharp fault scarp that hosts an outcropping magmatic intrusion.

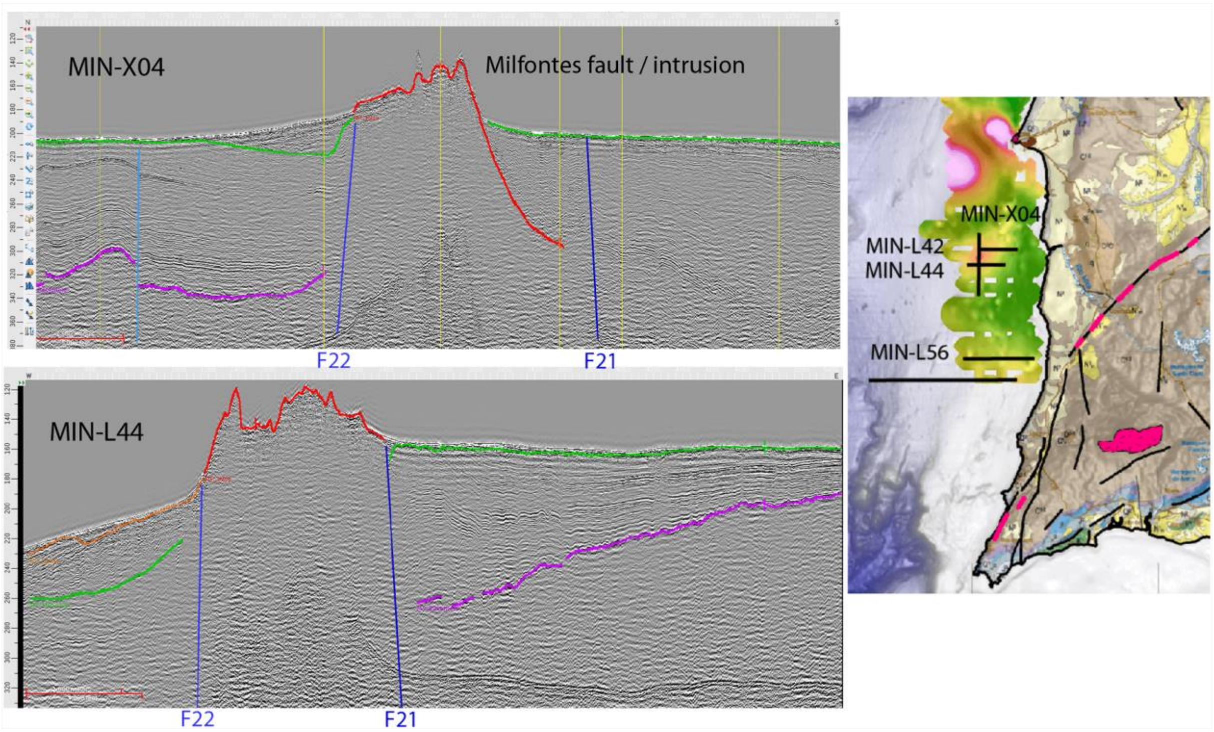


Figure 11: MINEPLAT multichannel seismics across the Milfontes anomaly show an intruded fault

SYNTHESIS: MAGNETICS AND SEISMICS

Detailed interpretation of MINEPLAT high-resolution seismic data allowed mapping faults in the Alentejo shelf. Combined analysis with magnetic data identified intruded faults.

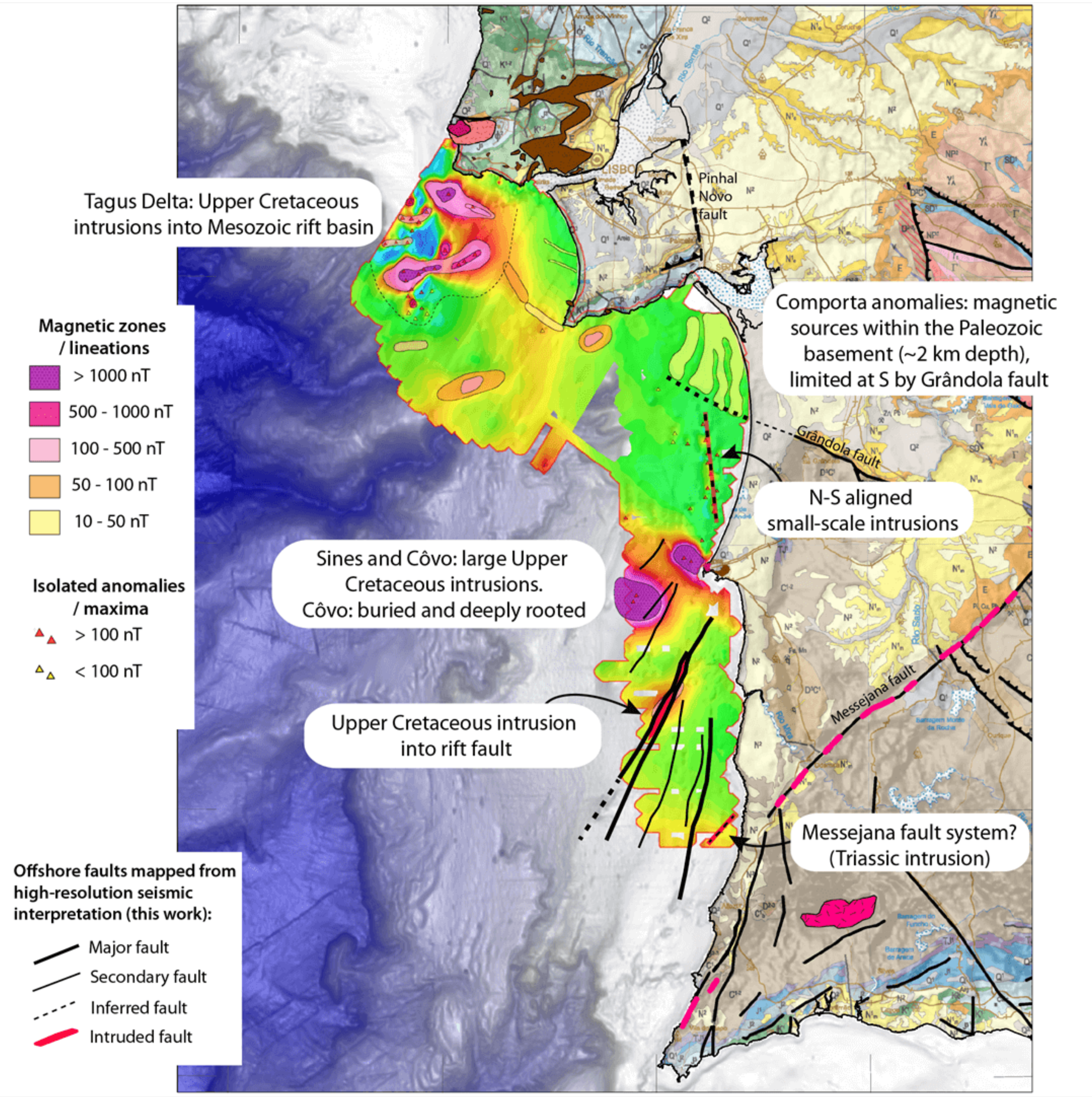


Figure 12: Synthesis of magnetic and seismic data interpretation: magnetic zones, magmatic intrusions, and mapped faults

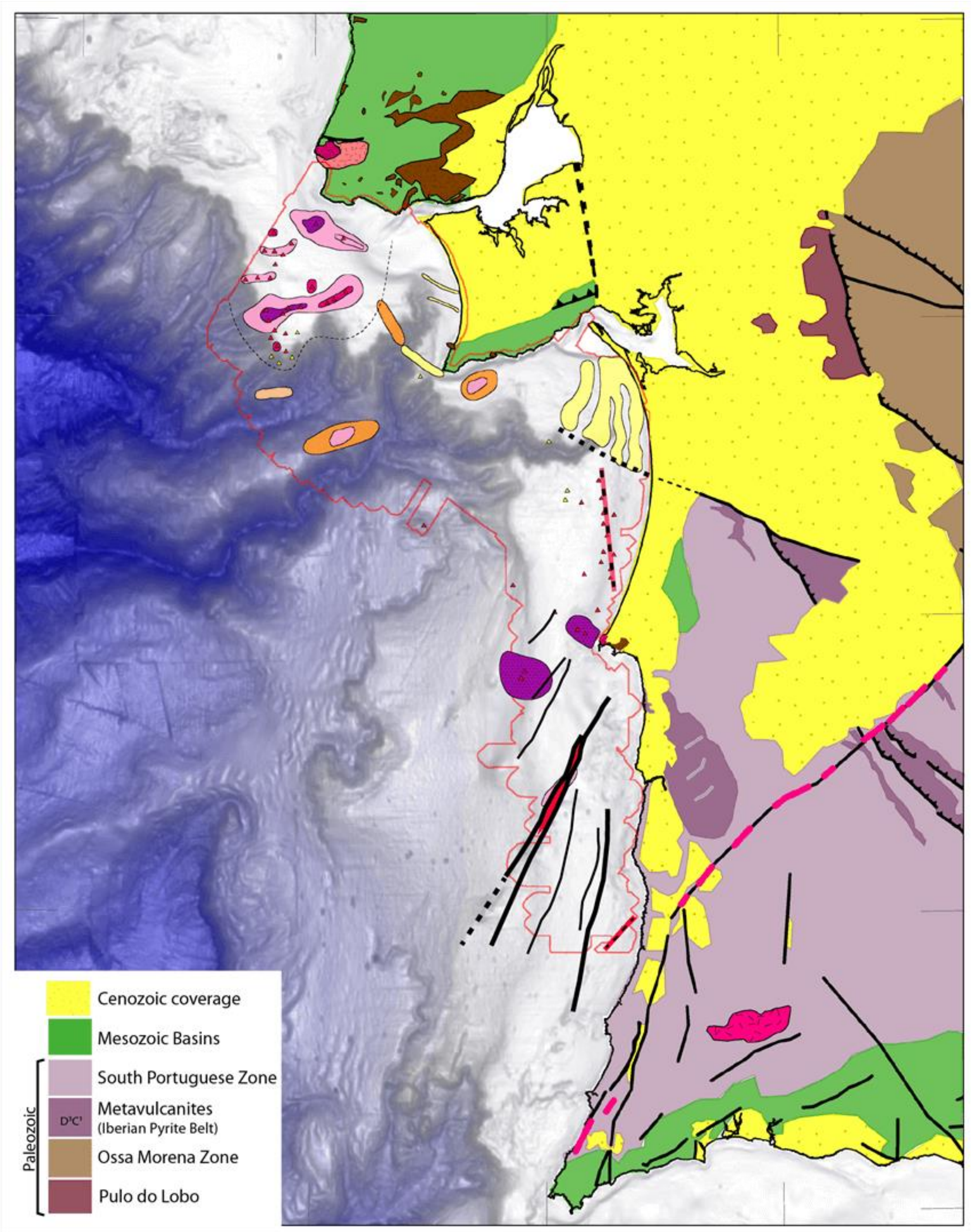


Figure 13: Synthesis of results and simplified map of onshore geological units

This work is ongoing towards a final joint interpretation of magnetic, seismic and bathymetric data, and relation with the known geology.

ACKNOWLEDGMENTS AND REFERENCES

Acknowledgements

FCT (Portuguese Science Foundation) is acknowledged for financial support through projects UIDB/50019/2020–IDL, MINEPLAT (ALT20-03-0145-FEDER-000013) and PRORIFT (NSFC/0003/2016). MN acknowledges FCT for a post-doc grant SFRH/BPD/96829/2013 and junior researcher contract on the frame of TAGUSGAS project (PTDC/CTA-GEO/31885/2017).

Magnetic data were processed using a research license of Oasis montaj (Geosoft). This work was possible due to the IPMA's SEISLAB infrastructure funded by C4G (Collaboratorium for Geosciences).

We are indebted to EMEPC (Portuguese Task Force for the Extension of the Continental Platform) for magnetometer lending whenever requested and for making possible and conducting the ROCHEL and CHELSI surveys onboard Selvagem. Special thanks to the pilots António Calado, Andreia Afonso and Bruno Ramos. We also thank the crews of IPMA's Noruega and Diplodus research vessels. Thanks to Ícaro Dias da Silva for fruitful discussion.

We thank Guilherme Madureira for the maintenance of IPMA's São Teotónio magnetic base station. We thank the Observatório Geomagnético de Coimbra (https://www.uc.pt/org/observatorio/observacoes), namely Paulo Ribeiro, for providing base station magnetic data whenever requested. We thank Instituto Geografico Nacional, Spain, for supporting the operation of the San Pablo - Toledo INTERMAGNET geomagnetic observatory (www.intermagnet.org). We thank José Manuel Tordesillas from the Observatório Geofísico de Toledo for making available the compilation of Iberian aeromagnetic data.

References

Neres M, Bouchez JL, Terrinha P, Font E, Moreira M, Miranda R, Launeau P, Carvallo C (2014). Magnetic fabric in a Cretaceous sill (Foz da Fonte, Portugal): magmatic flow model and implications for regional magmatism. Geophysical Journal International, 199 (1).

Alves T, Moita C, Cunha T, Ullnaess M, Myklebust R, Monteiro JH, Manuppella G (2009). Diachronous evolution of Late Jurassic - Cretaceous continental rifting in the northeast Atlantic (west Iberian margin). Tectonics 28, TC4003.

Socias I, Mezcua J (2002). Mapa de Anomalias Magneticas de la Peninsula Ibérica. Instituto Geográfico Nacional, Madrid.

Miranda JM, Galdeano A, Rossignol JC, Mendes Victor LA (1989). Aeromagnetic anomalies in mainland Portugal and their tectonic implications. Earth and Planetary Science Letters, Vol 95, 1–2.