ROCHELmag: Marine magnetic survey between Cabo da Roca and Cabo Espichel (near Lisbon, Portugal)

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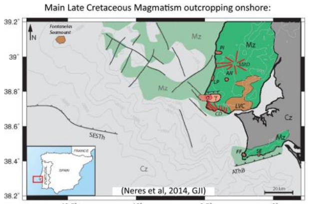
MOTIVATION

It has been recognized that the magnetic anomalies around Lisbon and off the West Portuguese Margin are associated with high-susceptibility sources, likely related to the West Iberia Late Cretaceous Alkaline magmatic complex.

This complex occurs onshore - as a variety of magmatic bodies, such as elliptical laccoliths with 15 km of diameter, volcanic flows extending for ~30 km and numerous plugs, sills and dykes; as well as offshore - as dykes extending fom the coast to the OCT (i.e. with ~300km length) and numerous plugs and volcanic chimneys.

This magnetic survey aims at understanding the relationship between the on-shore and offshore magmatic bodies, their size, depth of emplacement, and relation with rift and tectonic inversion structures.

Main Late Cretaceous Magmatism outcropping onshore:



LVC: Lisbon Volcanic Complex
σ, γ: Sintra syenite and granite
FF, AN, PI, LP, AN, SE: basic sills
CD, MRD: basic dykes
AThB: Arrábida thrust belt
SESTh: South Estremadura Spur thrust

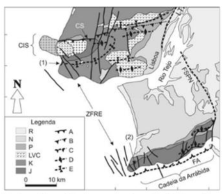


Fig. 1a – Mapa estrutural esquemático da região Arrábida – Sintra. Abreviaturas da legenda: J- Jurássico, K- Cretácico, CVL- Complexo Vulcânico de Lisboa, P- Paleogénico, N- Neogénico, R- Recente, A- Cavalgamento, B- cavalgamento cego, C- Cavalgamento inferido, D- anticlinal, E- sinclinal. Abreviaturas do mapa: FA- Falha da Arrábida, FBT- Falha do Baixo Tejo, ZFRE- Zona de Falha Cabo da Roca-Cabo Espichel, CIS- Complexo Ígneo de Sintra, FSPN- Falha de Setúbal-Pinhal Novo, CS- Cavalgamento de Sintra, (1) e (2)- falhas normais sin-sedimentares (Kimeridgiano e Bajociano, respectivamente).
(Kullberg et al, 2006)

Previous knowledge and data

In 1958 the R.R.S. Discovery II was engaged in a wide variety of research work in the Eastern Atlantic. A proton magnetometer was towed whenever the ship was on passage, and it was while on passage to Lisbon that a very large magnetic anomaly was recorded at the mouth of the River Tagus. Although a magnetic survey of this area was not part of the research programme, in was decided, in view of the magnitude of the anomaly, to carry out further investigations.

[T.D. Allan (1965), A magnetic survey off the coast of Portugal, GEOPHYSICS vol. 30:3, 411-417]

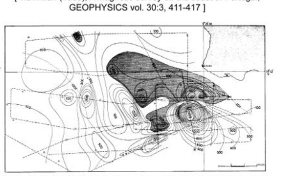
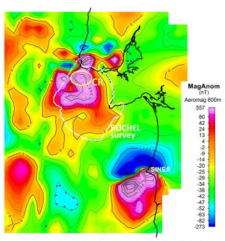


Fig. 1. Anomaly in the total-magnetic intensity at the mouth of the Tagus. The shaded area represents negative values. Contour interval 100 gammas. AB is the profile shown in Figure 3. The 20-, 50-, and 100-fathom depth contours are shown dotted.

Allan (1965) modeled the anomaly as a magnetic dipole generated by a magnetized sphere. He estimated for the magnetic source a minimum volume of 10 km³ of basic igneous intrusive rock, and linked its occurrence to the neighboring intrusive and volcanic rocks (Sintra pluton and Lisbon Volcanic Complex).
During this survey, deflections of the magnetic compass in the order of 10° were detected in the vicinity of the main anomaly.



Aeromagnetic data at 600 m (industry data)

Here the maximum value of Cabo Raso (CR) anomaly is ~270 nT, much lower than the maximum surveyed in 1958 and by ROCHEL. This indicates a very shallow location of that particular source.

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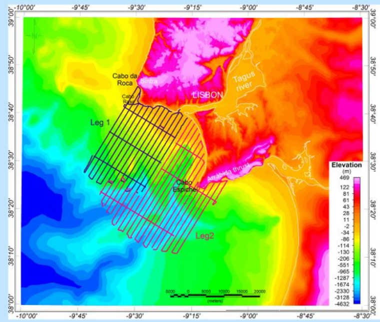
The ROCHEL magnetic survey



Data acquisition:

- Ship: *Selvagem Grande*, 7.5 m semid-rigid
- 2 legs (October 2014 and June 2015)
- 27 lines - spacing: 1 mile
- 6 tielines - spacing: 5-6 miles
- magnetometer: G-882, Geometrics (total field)
- frequency of data logging: 10 Hz
- navigation speed: ~10 knots
- average resolution along profile: 0.5 m
- tow cable length: 35 m

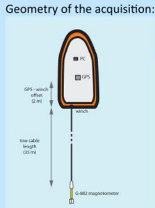
Data processing:

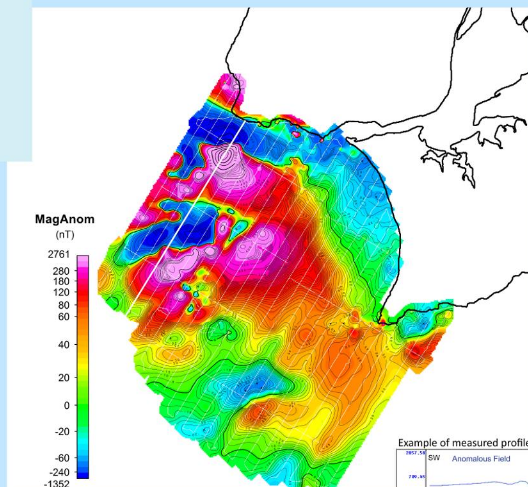
- noise removal (despike)
- DGRF subtraction
- Levelling using tielines
- Gridding (minimum curvature)

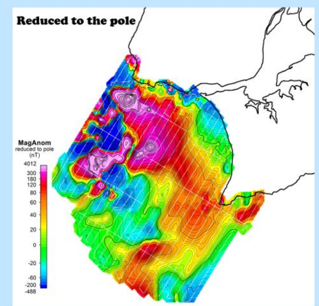
Photos of the operation

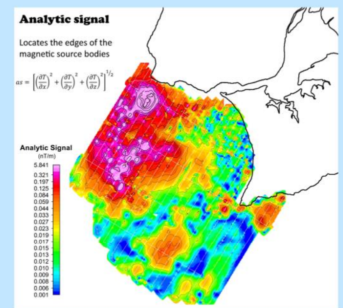
(A) Traction cable (white) winched at the boat stern, and both cables being towed.
(B) Recovery of the fish to the boat, by pulling the traction cable.
(C) Traction cable knotted to the magnetometer's hold.
(D) The boat prow and the logging computer.

Geometry of the acquisition:

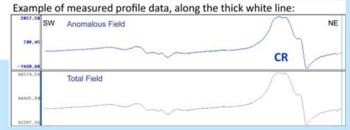




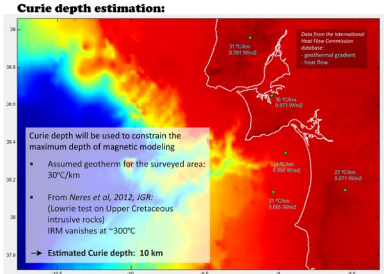




Example of measured profile data, along the thick white line:



Curie depth estimation:



Curie depth will be used to constrain the maximum depth of magnetic modeling

- Assumed geotherm for the surveyed area: 30°C/km
- From *Neres et al, 2012, JGR:* (Lowrie test on Upper Cretaceous intrusive rocks) IRM vanishes at ~300°C

→ **Estimated Curie depth: 10 km**

This survey reveals the existence of a large and complex buried sub-volcanic system. The wide range of amplitude and wave-number of the measured anomalies imply the existence of sources with varyious lateral and vertical extents: volcanoes, dykes, sills, plugs,...

Ongoing and future work:

- Inverse and direct magnetic modeling, constrained by seismics
- Interpretation of seismic reflection profiles
- Inferrence of source depth and geometry
- Link to onshore and offshore Late Cretaceous magmatism
- Role of inherited tectonic fabrics in the sub-volcanic emplacement
- Estimation of the magma volume intruded during this magmatic event

Example of the imaging, in a seismic reflection profile, of the Cabo Raso magnetic source: