Magnetic anomalies associated to extensional detachments?

An example at Xistral Tectonic Window of the Lugo Dome (NW Spain)

José R. **Martínez Catalán**
Puy **Ayarza**
Fernando **Álvarez Lobato**
Juan José **Villalaín**
Manuela **Durán Oreja**
Manuel **Martín Paramio**
Silvia **Rodríguez Gómez**

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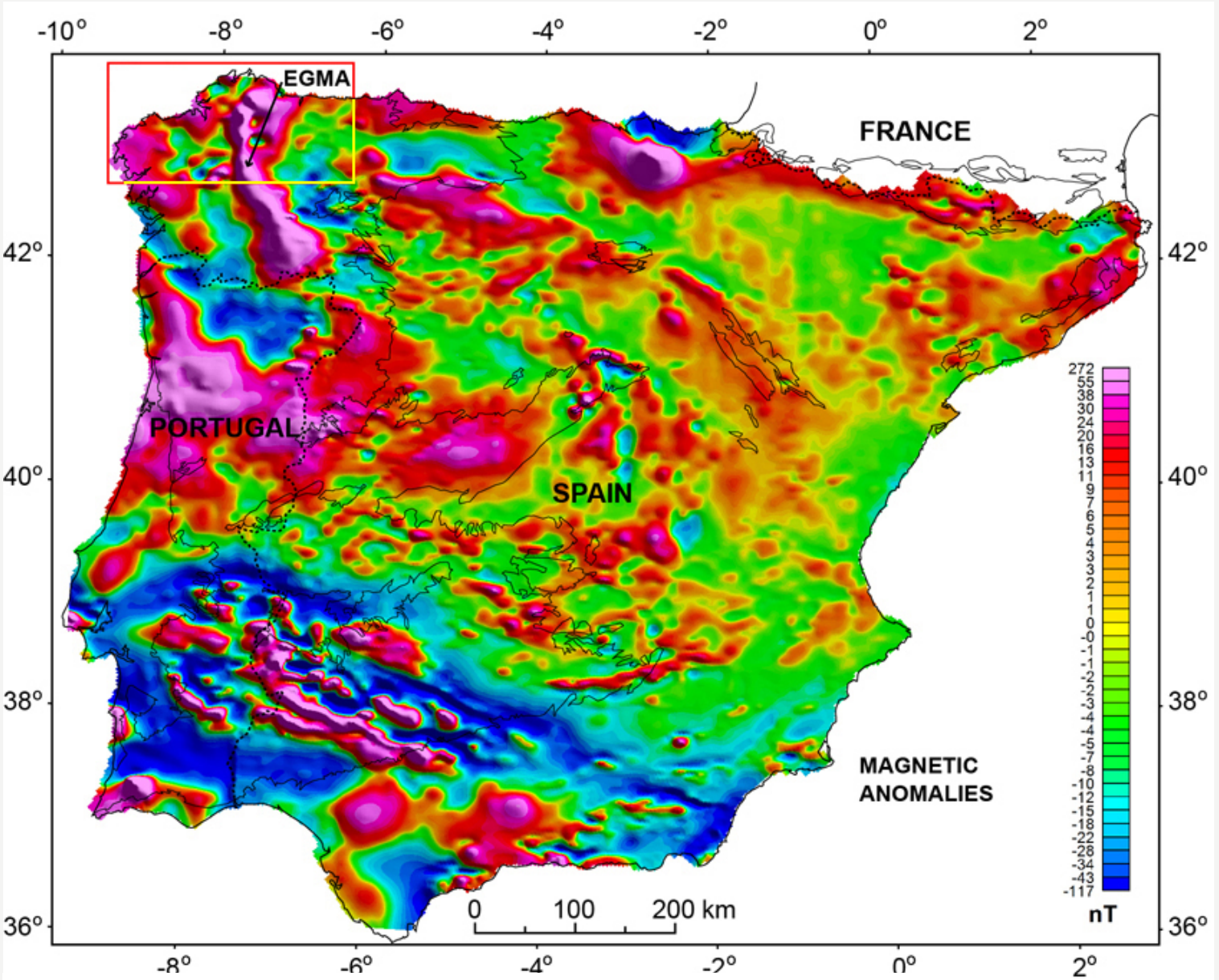
Aeromagnetic map of the Iberian Peninsula

Flown at 3000 m ASL

EGMA: Eastern Galicia Magnetic Anomaly

Maximum amplitude: 389 nT

The EGMA is the northern part of a broad, arcuate anomaly that continues SE to the Spanish Central System and then it turns W to Portugal and the Atlantic coast



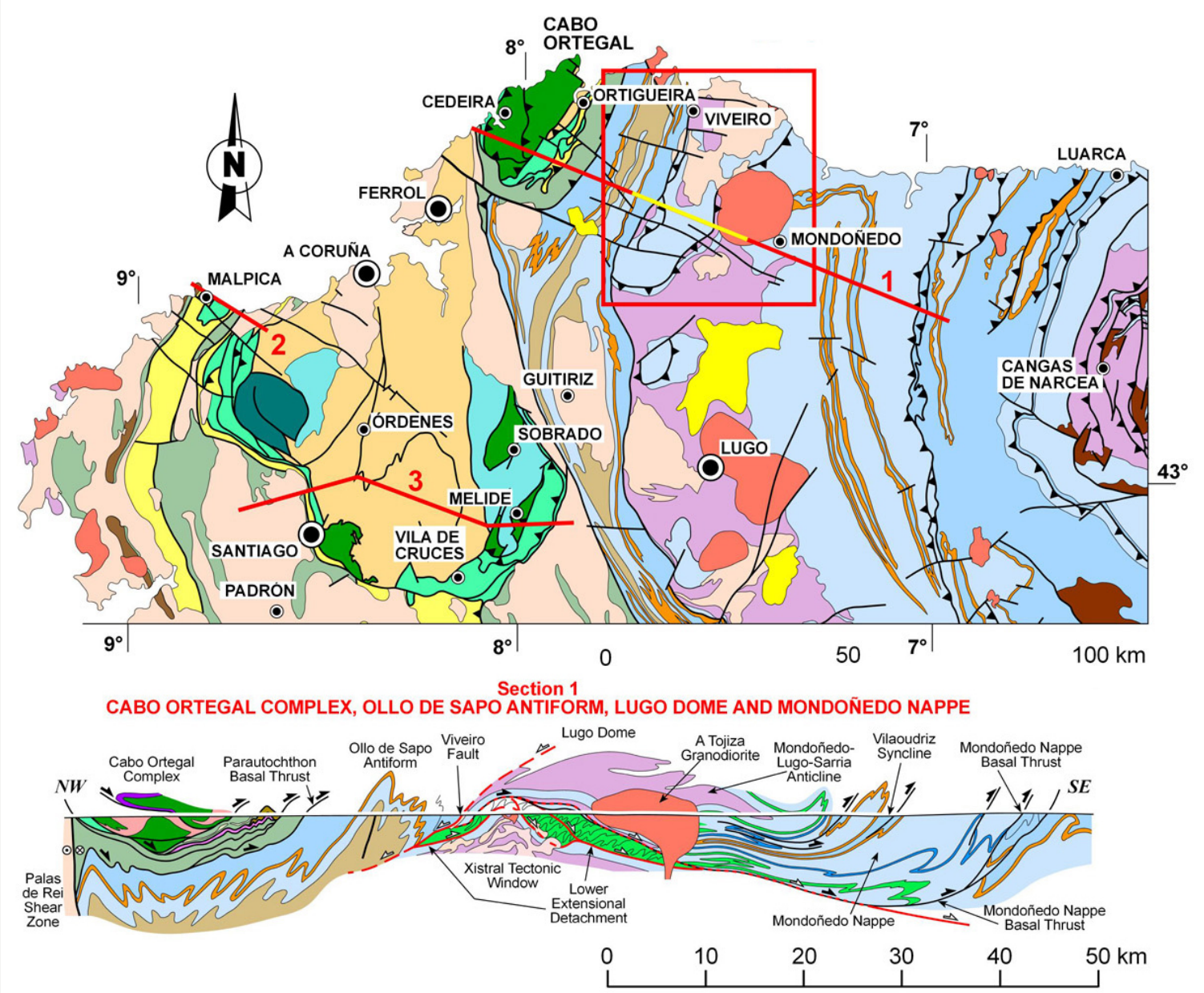
Ardizone et al. (1989), 1: 1000 000, Instituto Geográfico Nacional, Madrid

Miranda et al. (1989), Earth and Planetary Science Letters, 95, 161-172.

Geologic map of NW Spain and section across the Lugo Dome

The rectangle shows the area investigated: the **Xistral Tectonic Window**

High-T/low-P rocks crop out in a migmatitic dome beneath the **Mondoñedo Thrust Sheet**

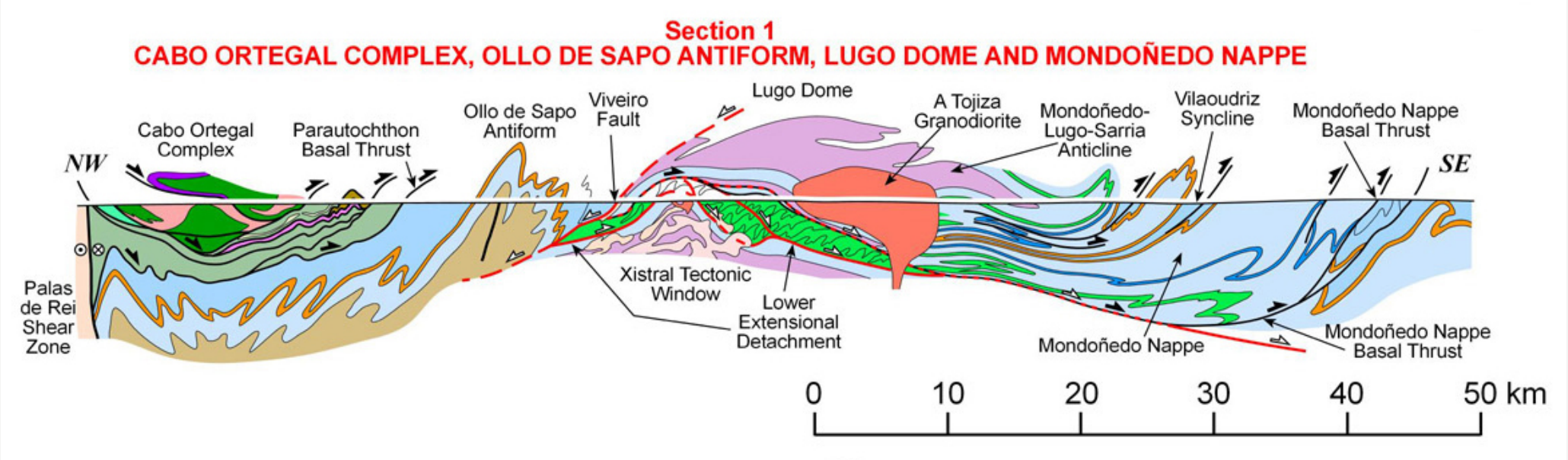


Martínez Catalán et al. (2007), Geological Society of America Memoir 200, 403-423

Geologic map of NW Spain and section across the Lugo Dome

The section shows the relationship with other major structures, which include thrust sheets (**Mondoñedo Thrust Sheet** and **Allochthonous Complexes**) and extensional detachments folded by the **Lugo Dome,** and overprinted by the **Viveiro Fault**

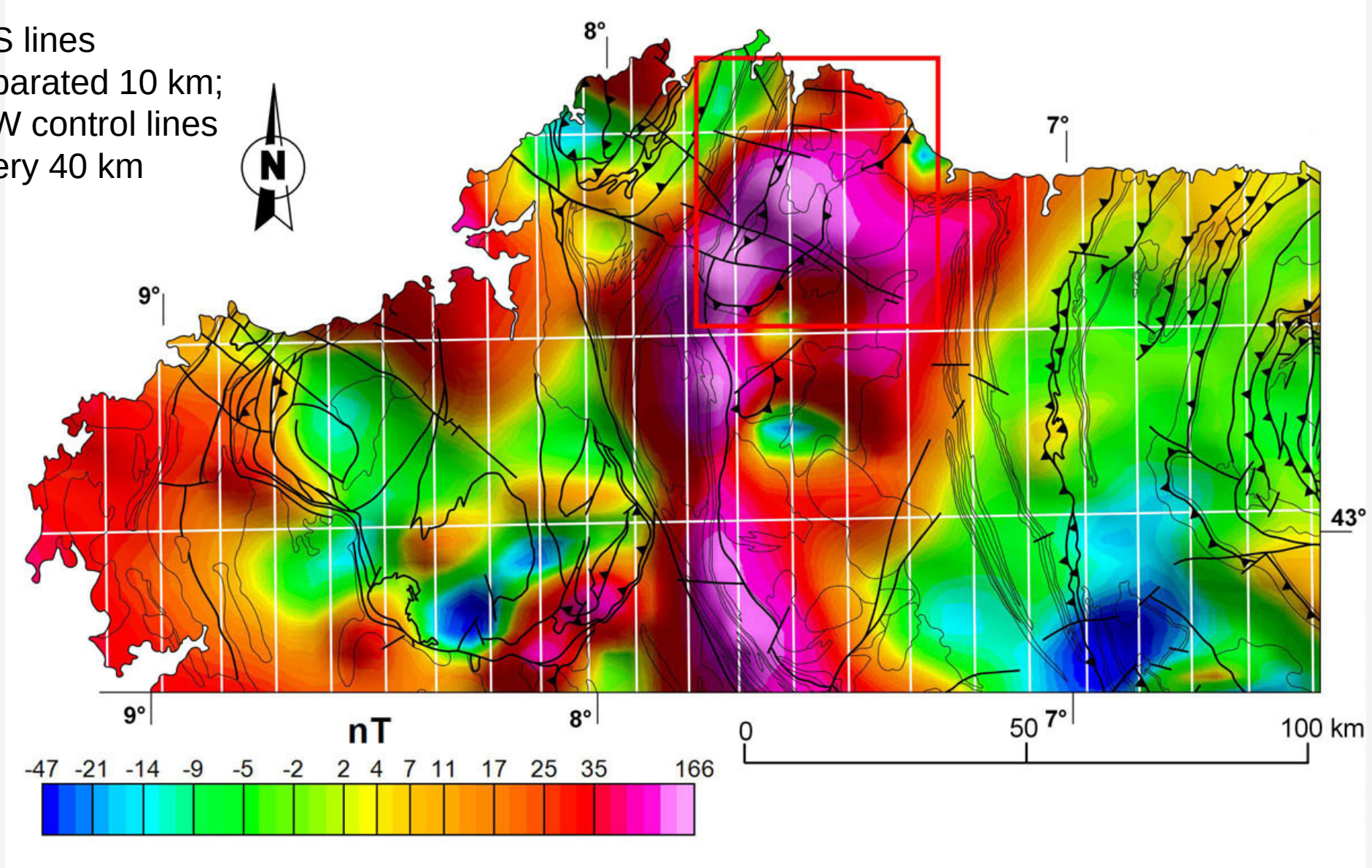
Extension reflects orogenic collapse following **thermal relaxation** after crustal severe crustal tickenning



Martínez Catalán et al. (2007), Geological Society of America Memoir 200, 403-423

Aeromagnetic map of NW Spain including the N part of the EGMA

The red rectangle shows the area investigated; flight lines are shown white



Ardizone et al. (1989), 1: 1000 000, Instituto Geográfico Nacional, Madrid

Carriers of magnetization

The **Xistral Tectonic Window** exposes a deep section of the Variscan continental crust

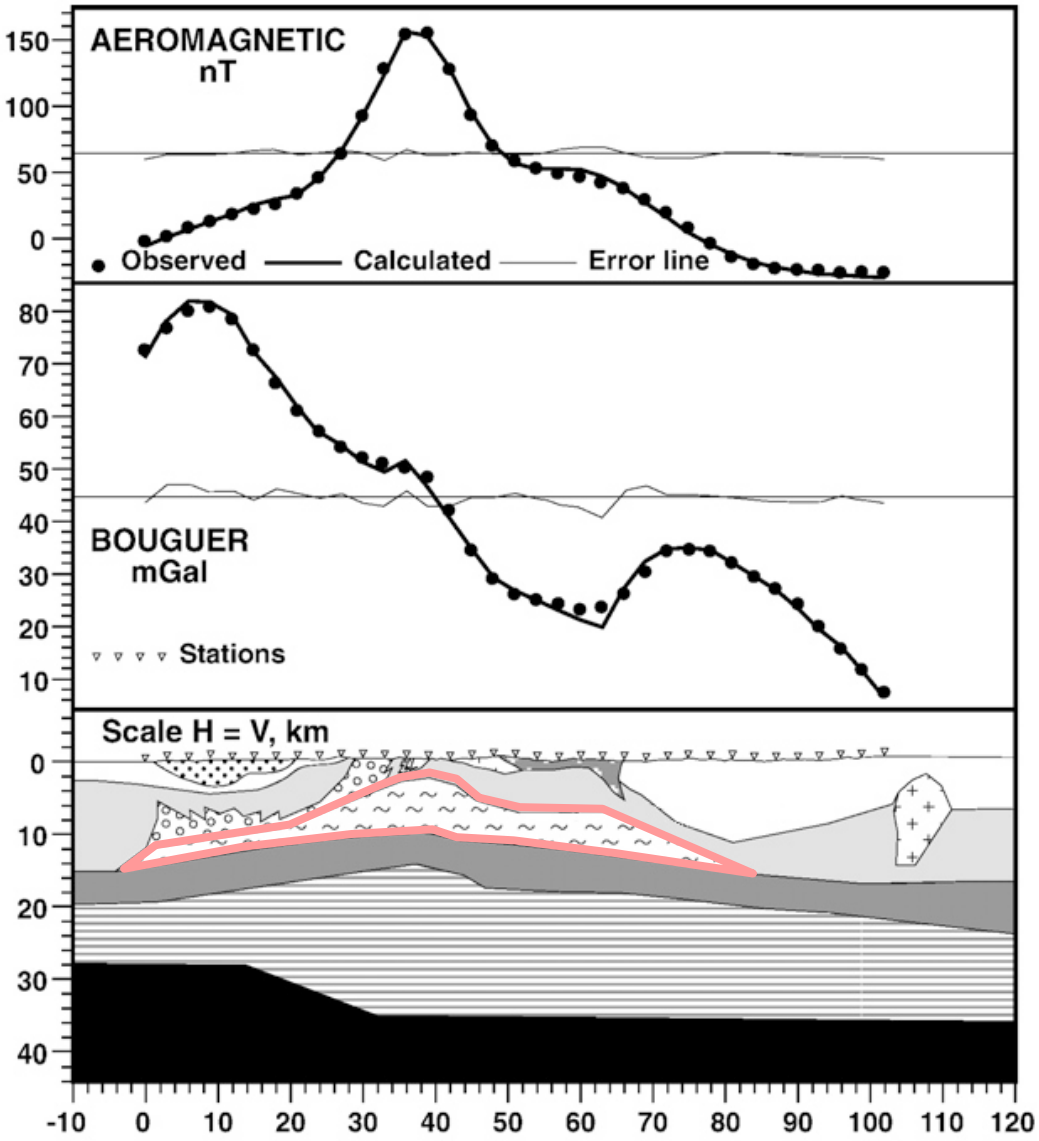
Lower Cambrian and Neoproterozoic quartzites, schists, paragneisses, migmatites and inhomogeneous granites crop out at the core of the window

Large metamorphic grains of magnetite are the primary carrier of induced magnetization (***Mi***)

Other iron oxides resulting from alteration, exsolution and replacement, are responsible for remanent magnetization (***Mr***)

Ayarza and Martínez Catalán (2007)

Main source of the EGMA: a low density, **lens-shaped magnetic body formed by migmatites and inhomogeneous granites**



DIABASES
$\rho = 2900$ kg m^{-3}, $\kappa = 55 \times 10^{-3}$ SI

ALLOCHTHONOUS COMPLEXES
$\rho = 2790$-2900 kg m^{-3}, $\kappa = 0$-30×10^{-3} SI

GRANITES
$\rho = 2600$ kg m^{-3}, $\kappa = 0$

GRANODIORITES
$\rho = 2630$-2640 kg m^{-3}, $\kappa = 0$

SLATES
$\rho = 2640$-2790 kg m^{-3}, $\kappa = 0$

LUARCA SLATES INCLUDING IRON ORE BODIES
$\rho = 2680$-2790 kg m^{-3}, $\kappa = 5$-20×10^{-3} SI

QUARTZITES
$\rho = 2630$ kg m^{-3}, $\kappa = 0$

SCHISTS
$\rho = 2640$-2680 kg m^{-3}, $\kappa = 0$

OLLO DE SAPO FM.
$\rho = 2660$-2680 kg m^{-3}, $\kappa = 0$

MIGMATITES AND INHOMOGENEOUS GRANITES
$\rho = 2700$ kg m^{-3}, $\kappa = 20 \times 10^{-3}$ SI

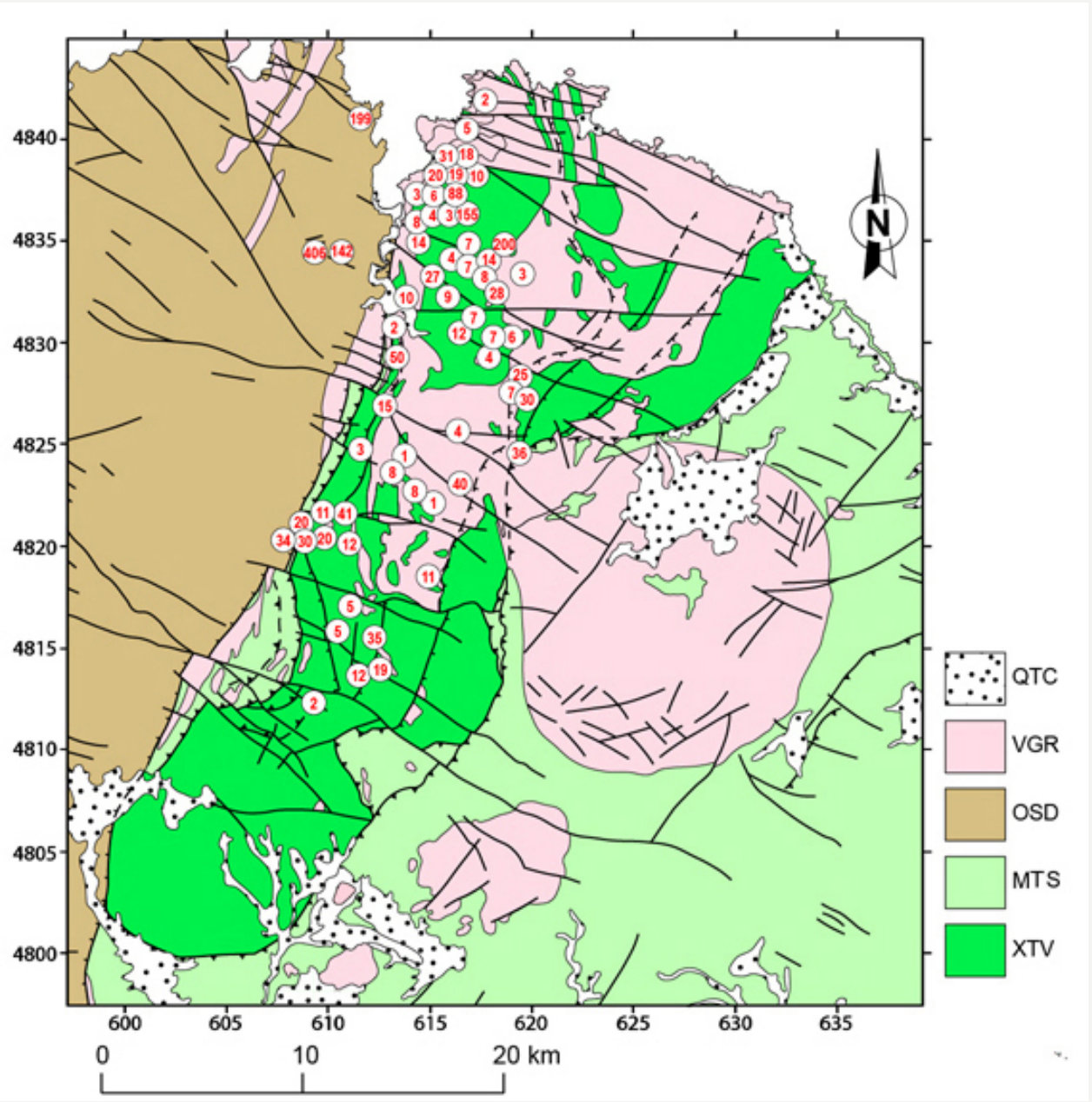
REWORKED SIALIC BASEMENT
$\rho = 2750$ kg m^{-3}, $\kappa = 0$

LOWER CRUST
$\rho = 2900$-2950 kg m^{-3}, $\kappa = 25 \times 10^{-3}$ SI

MANTLE
$\rho = 3260$ kg m^{-3}, $\kappa = 0$

Ayarza and Martínez Catalán (2007),
Tectonophysics, 439, 67-87, 403-423

Domains of the study area and κ values



The area investigated includes the **Xistral Tectonic Window** (XTV), part of the **Mondoñedo Thrust Sheet** (MTS), and the **Ollo de Sapo Domain** (OSD)

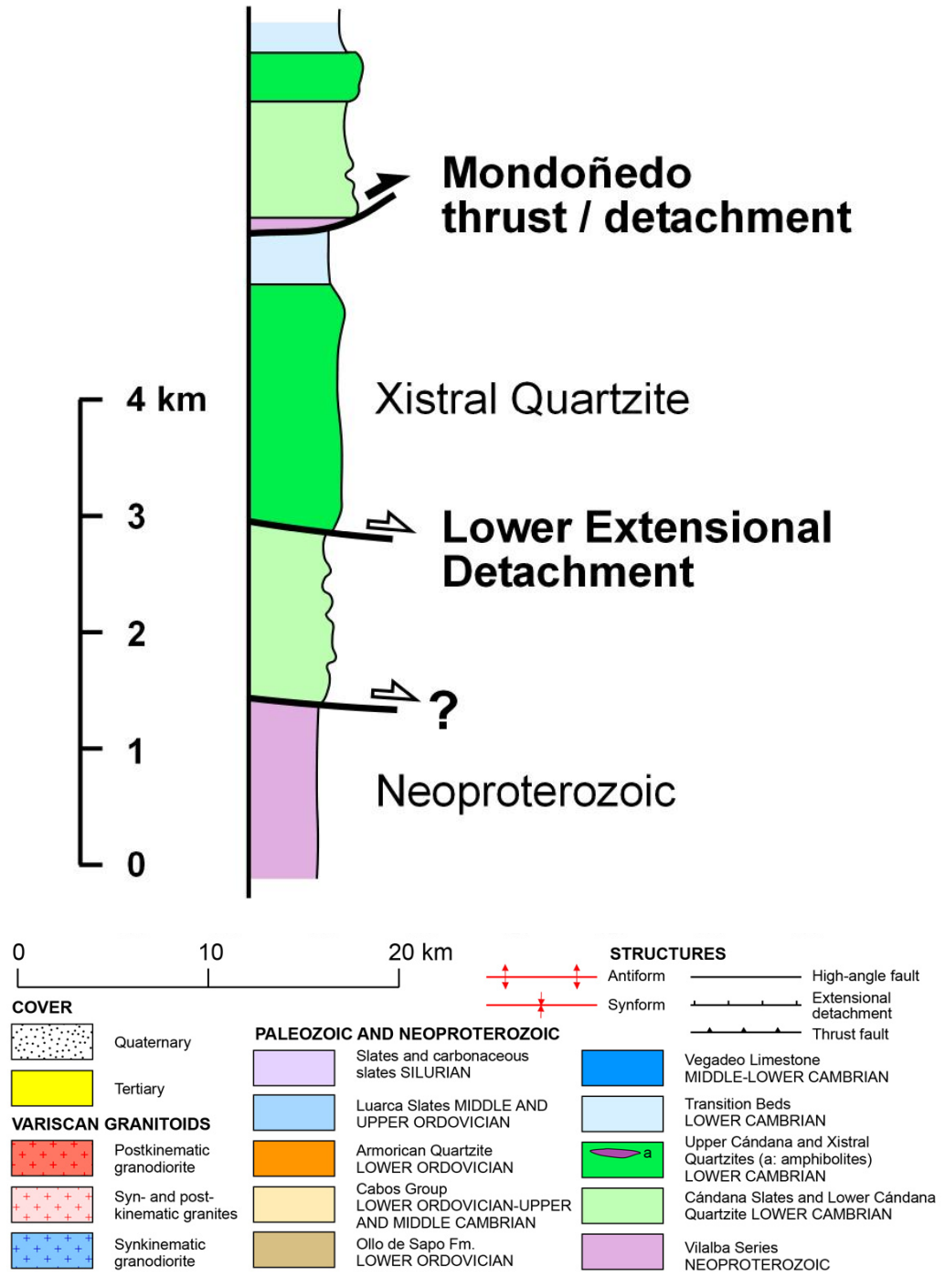
QTC: Quaternary & Tertiary cover
VGR: Variscan granitoids

kappa measured *in situ* (multiplied by 10^3). equal or higher than 1 (0.001 SI) are shown

Magnetic susceptibility (κ) is extremely variable

High susceptibilities characterize some migmatites and inhomogeneous granites, but paragneisses and quartzites may also show high values

Geologic map of the study area



The **Xistral Tectonic Window** includes a thick package of quartzites (green) underlain by an alternation of schists and quartzites (light green), both of early Cambrian age. Below, Neoproterozoic paragneisses with various stages of migmatization occur.

A large extensional detachment occurs at bottom of the quartzitic unit; the **Lower Extensional Shear Zone** developed at its footwall

The **Viveiro Fault**, normal and dipping W, bounds the window to the W, overprinting all previous structures

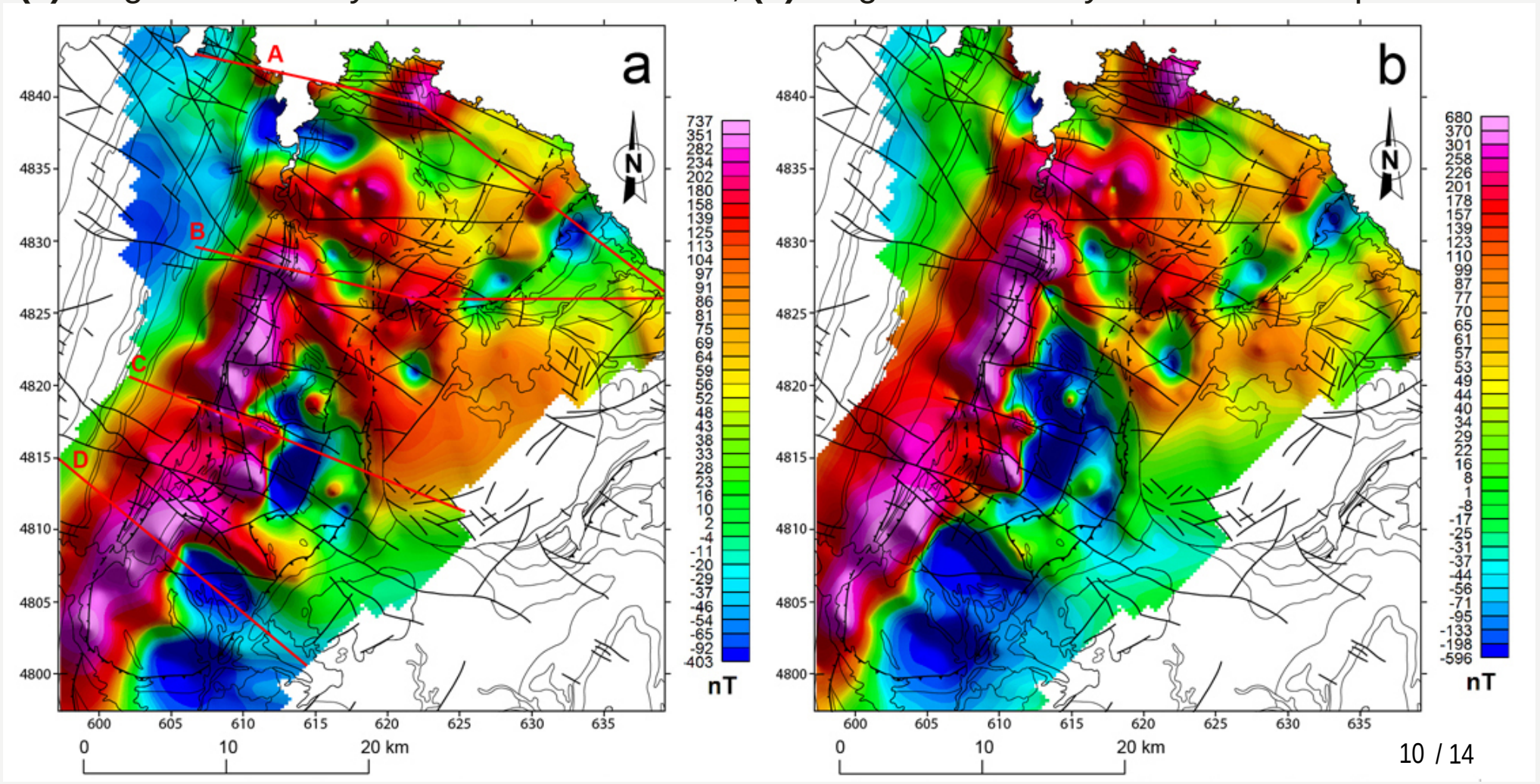
Thick ductile shear zones developed around the extensional structures, mostly at their footwall

Ground-based magnetic anomaly

315 measures of the Earth's magnetic field were acquired with two Geometrics G-856 proton magnetometers, using one as a base station. The survey covers 750 km^2

Maximum amplitude: 1214 nT; after gridding: 1140 nT

(a) Magnetic anomaly and modeled sections; **(b)** Magnetic anomaly reduced to the pole



Magnetic analyses

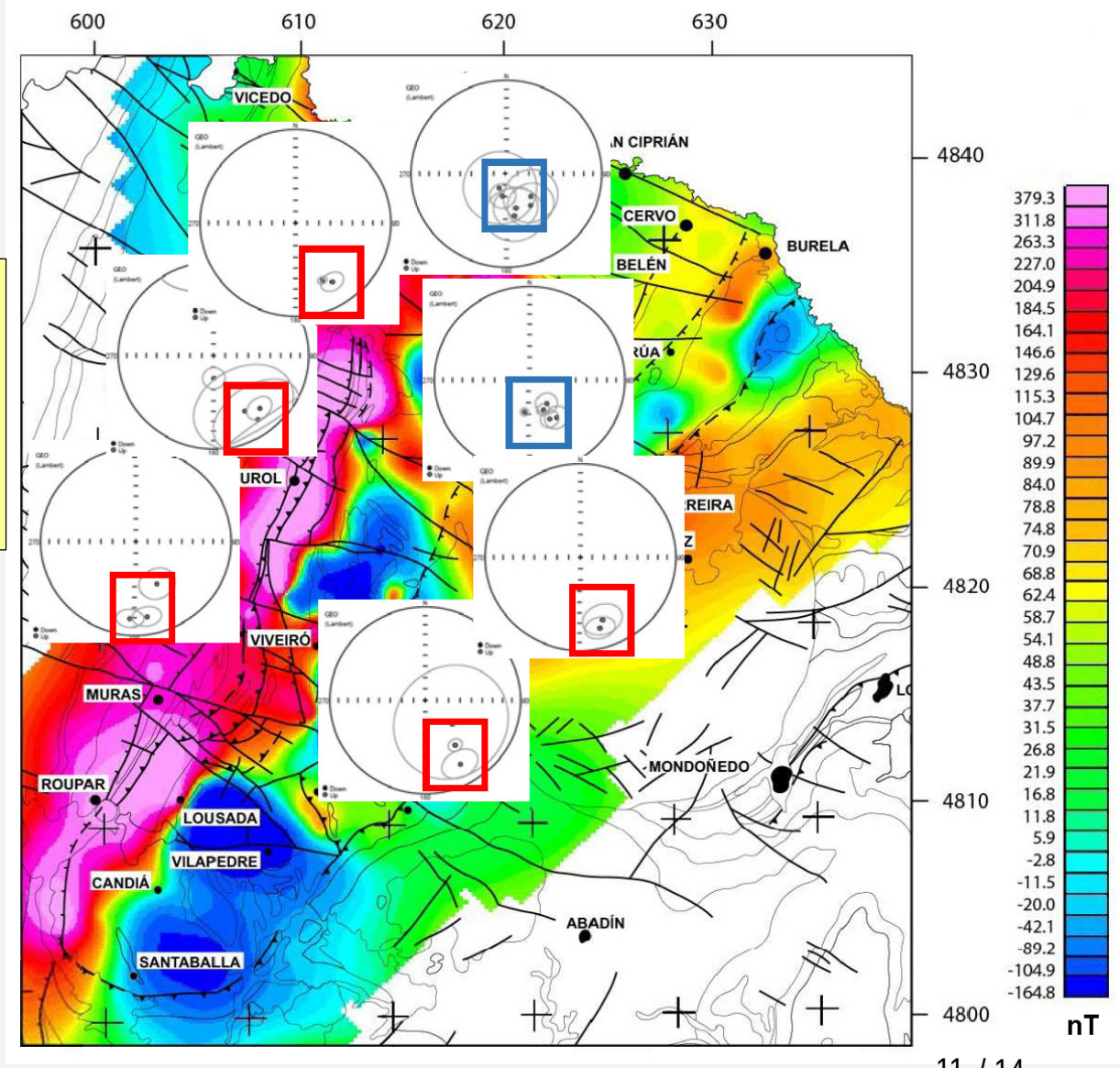
To establish the carriers of both magnetizations ***Mi*** and ***Mr***, and the age and value of the latter, oriented cores were analyzed. Analyses include **AMS**, **incremental demagnetization** (AF and thermal), and **thermomagnetic curves** using a Variable Field Translation Balance

The results are exposed in:

Poster **EGU2018-6216** (Hall X2.174)
Puy Ayarza et al.: *Characterization of the Eastern Galicia Magnetic Anomaly. A warning regarding the interpretation of aeromagnetic data*

Mean values obtained (39 samples):
Mr = 0.267 A m^{-1}; Q_n = 0.875
I = -28º, ***D*** = 156º; **Polarity**: reverse

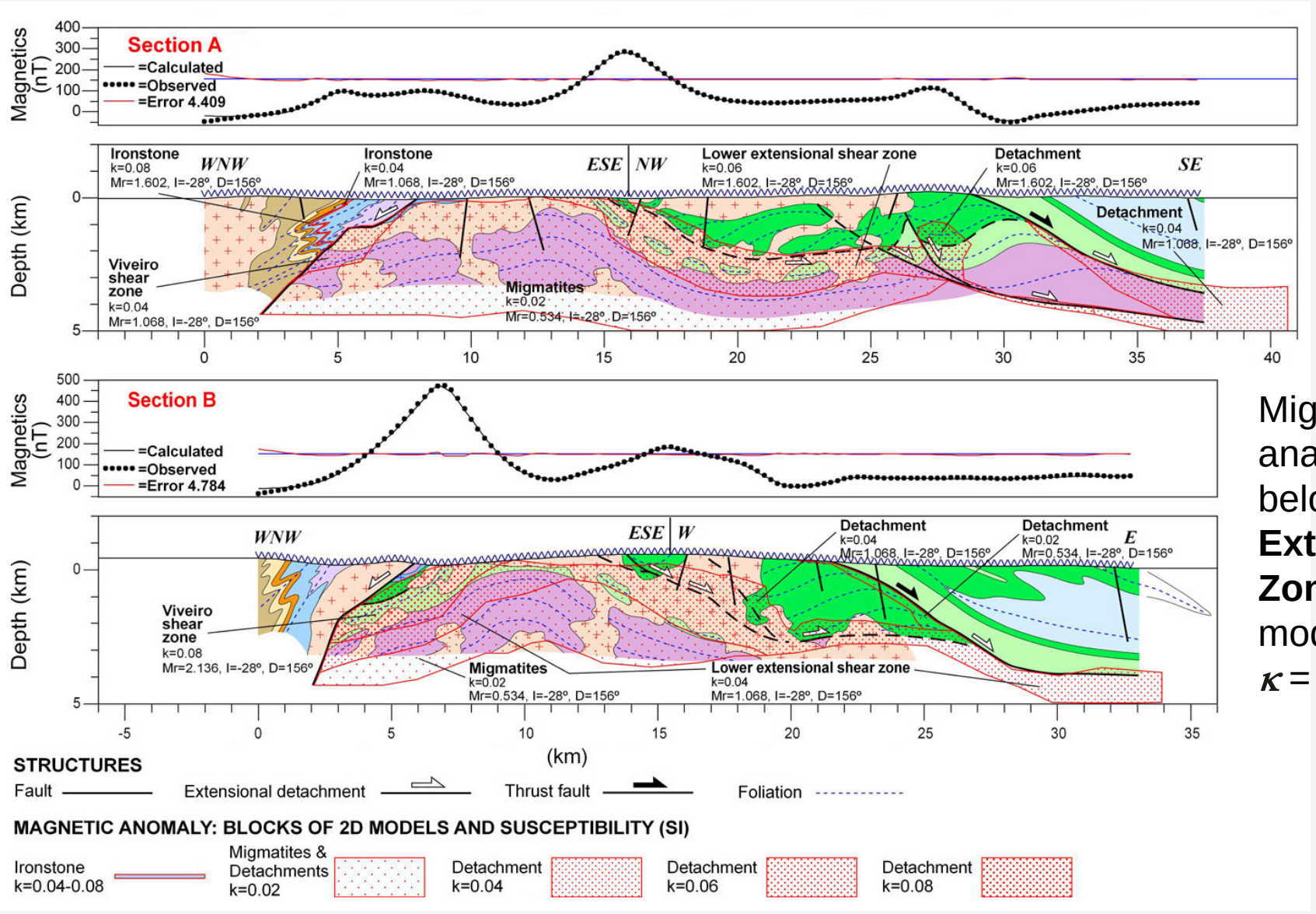
The low inclination and reverse polarity suggest remanence from the **Kiaman superchron** (312-262 Ma), which fits the age of cooling of the Lugo Dome



Models of sections A and B; *Mi* and *Mr* considered

The **Viveiro Fault** normally localizes the mean peak (except in Section A)

Other peaks coincide with outcropping of earlier extensional shear zones and detachments



κ values used for the extensional shear zones: 0.02, 0.04, 0.06 and 0.08

Migmatites and anatectic granitoids below the **Lower Extensional Shear Zone** have been modeled with κ = 0.02 SI

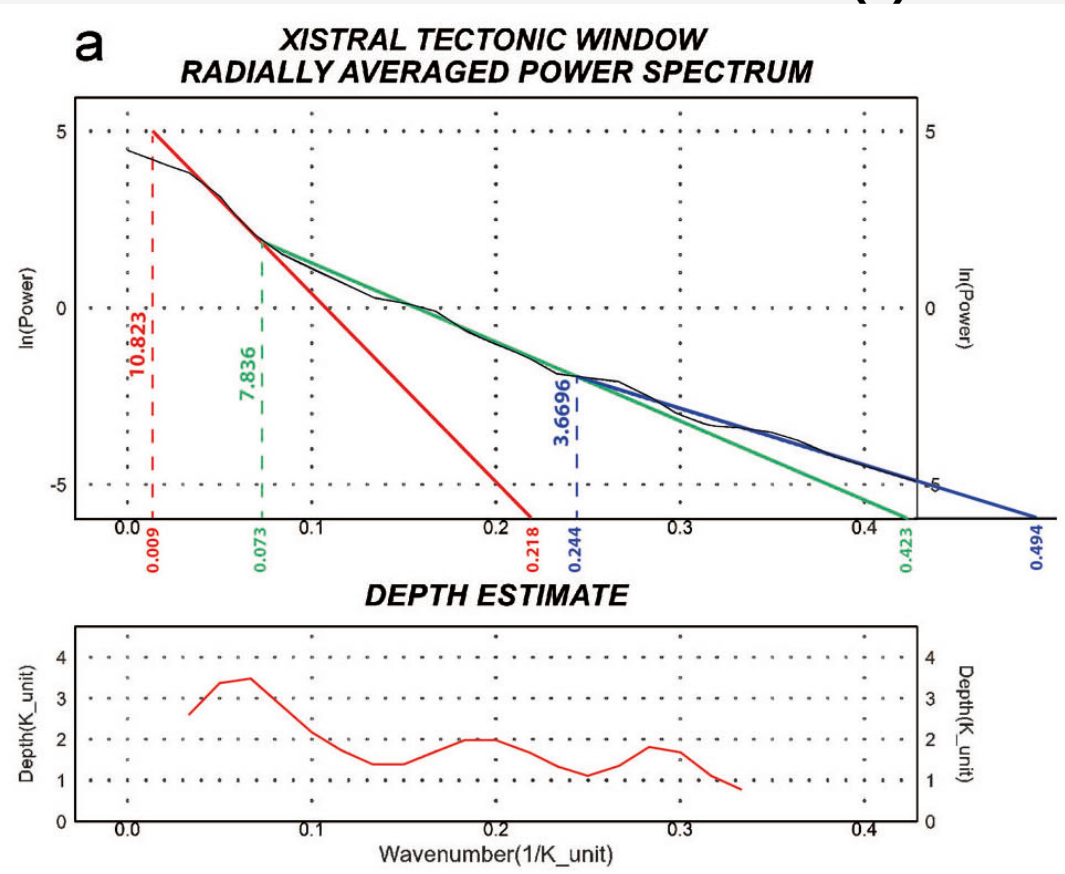
Radially averaged power spectra and depth estimates of the sources of magnetic anomalies

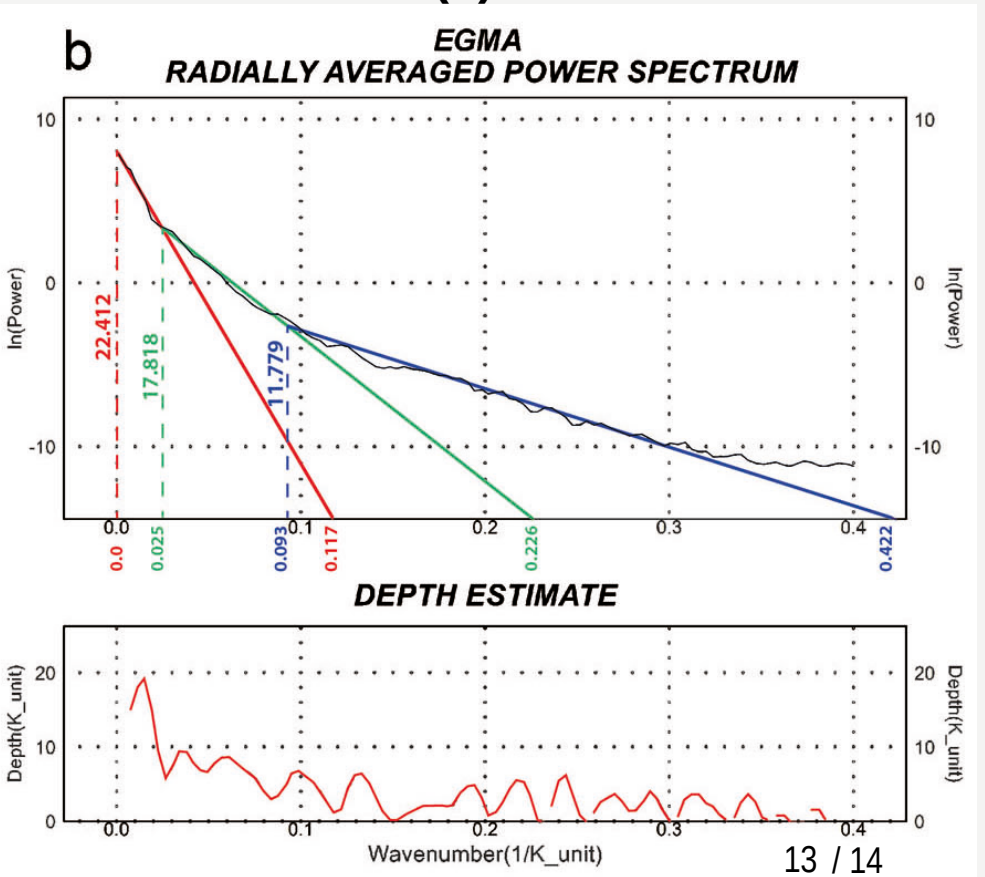
(a) Data from the ground-based magnetic anomaly; **(b)** Data from the whole **EGMA**

In both, three slopes are traced, corresponding to shallow, intermediate and deep sources

The values in axes horizontal (wave number) and vertical (ln Power) are used to calculate the slopes, which divided by 4π yield the corresponding depths in km

These are **1.18**, **1.78** and **4.12 km** in **(a)** and **0.25**, **4.45** and **12.63** in **(b)**





Conclusions

- The new magnetic map of the **Xistral Window** shows **high amplitude, short wavelength anomalies** that can be modeled only with shallow magnetic bodies
- The maxima coincide with outcrops of **late Variscan extensional shear zones** and **detachments**. These are considered responsible for the magnetization
- Although lithology was considered responsible for the anomalies (Aller et al., 1994; Ayarza and Martínez Catalán, 2007), **extensional structures play an essential role** in the growth of magnetite: special P-T and redox conditions and evolution (research is under way)
- Sources deeper than *c*. 5 km do not explain the waveforms, but they possibly exist, as shown by the power spectra of the whole **EGMA**
- The S and SE continuation of the **EGMA** to central Spain, and then W to Portugal has probably the same origin: buried extensional shear zones

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Thanks for your attention