MAGNETIC ANALYSIS OF THE PALEOCENE/EOCENE TRANSITION IN A TERRESTRIAL SEDIMENTARY SEQUENCE (ESPLUGAFREDA AND CLARET FORMATIONS, TREMP-GRAUS BASIN, PYRENEES

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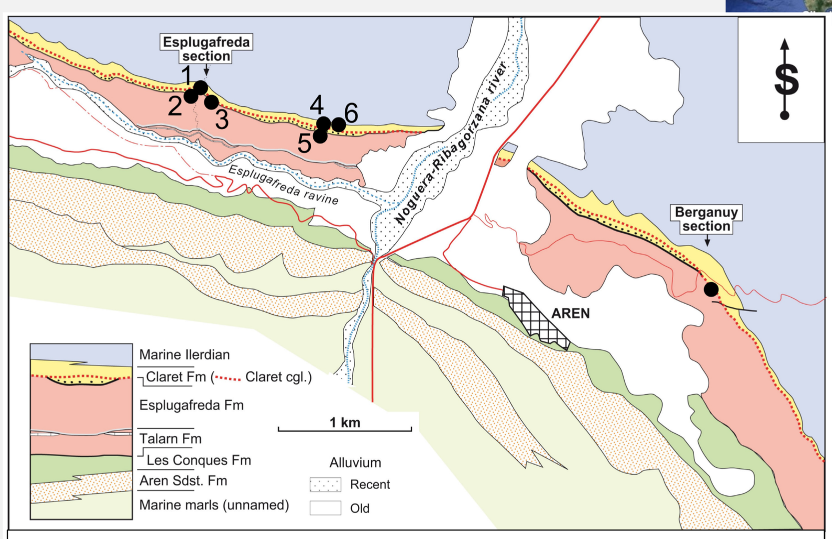
INTRODUCTION

The Paleocene-Eocene thermal maximum (PETM) occurred about 56 Ma ago and corresponds to a rapid (~ 170 ky) global warming of 5–8 °C, profound floral/faunal turnovers and alteration of the global hydrological cycle.

Climate and environmental changes are well-preserved in the alluvial deposits of the Tremp-Graus Basin in the Pyrenees, which was located in the subtropical climatic belt (paleolatitude ~35 °N).

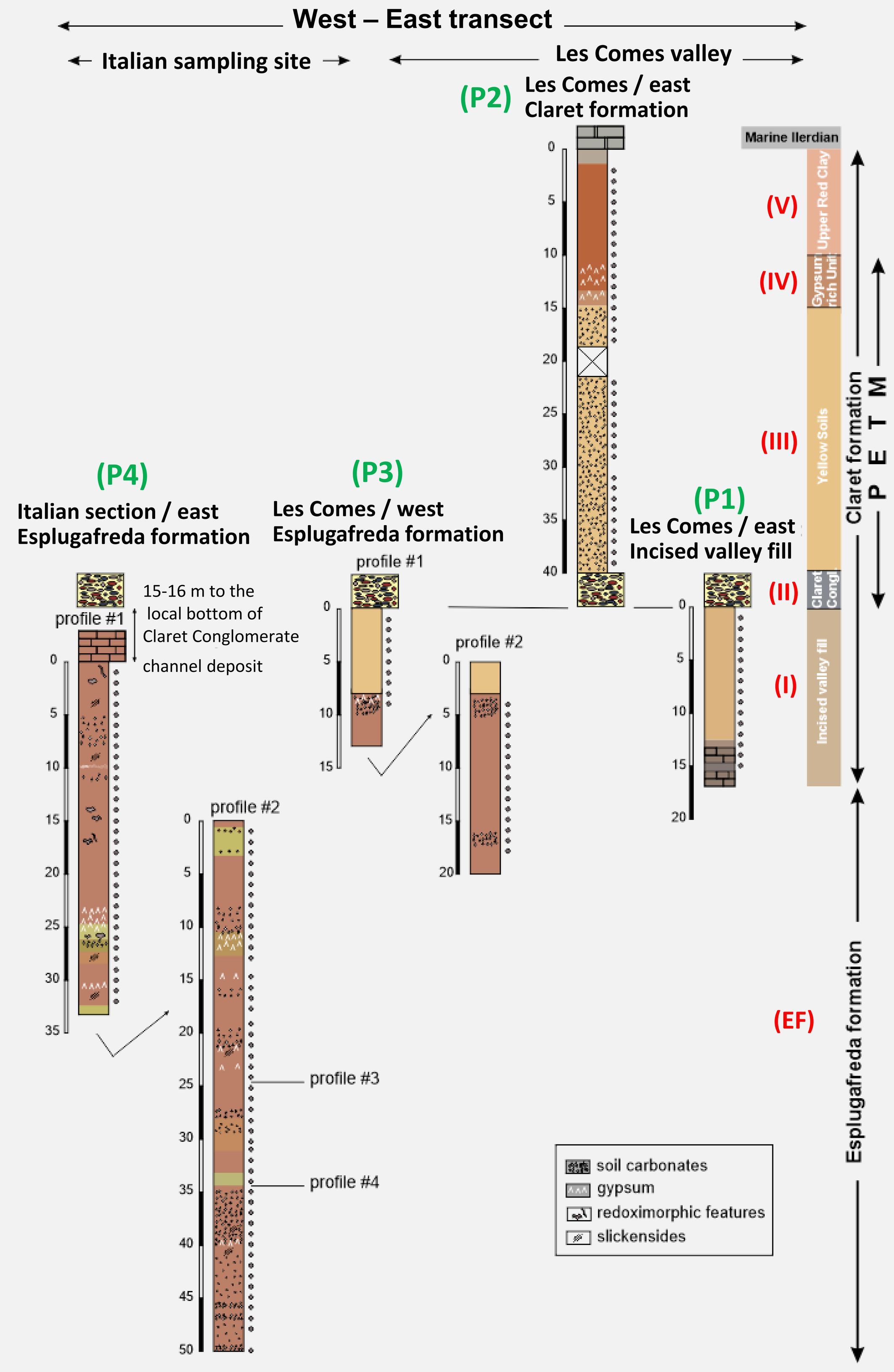


1. Les Commes east / yellow soils, 2. Les Commes east / incised valley, 3. Les Commes west / Esplugafreda formation, 4. Italian section east / yellow soils, 5. Italian section east / Esplugafreda formation, 6. Italian section west / yellow soils

Four profiles covering the Esplugrafeda and Claret formations were sampled. The lower ~250 m of the succession studied in Esplugafreda (province of Lleida) correspond to reddish mudstones with abundant paleosols and numerous multi-episodic channel-like bodies (mostly Esplugafreda Formation **(EF)**). This unit is overlain by the Claret Formation, which includes four distinctive subtropical members: **(I)** the incised valley fill; **(II)** the Claret conglomerate, **(III)** the yellowish soils, **(IV)** the gypsum-rich unit, and **(V)** the upper reddish mudstones.

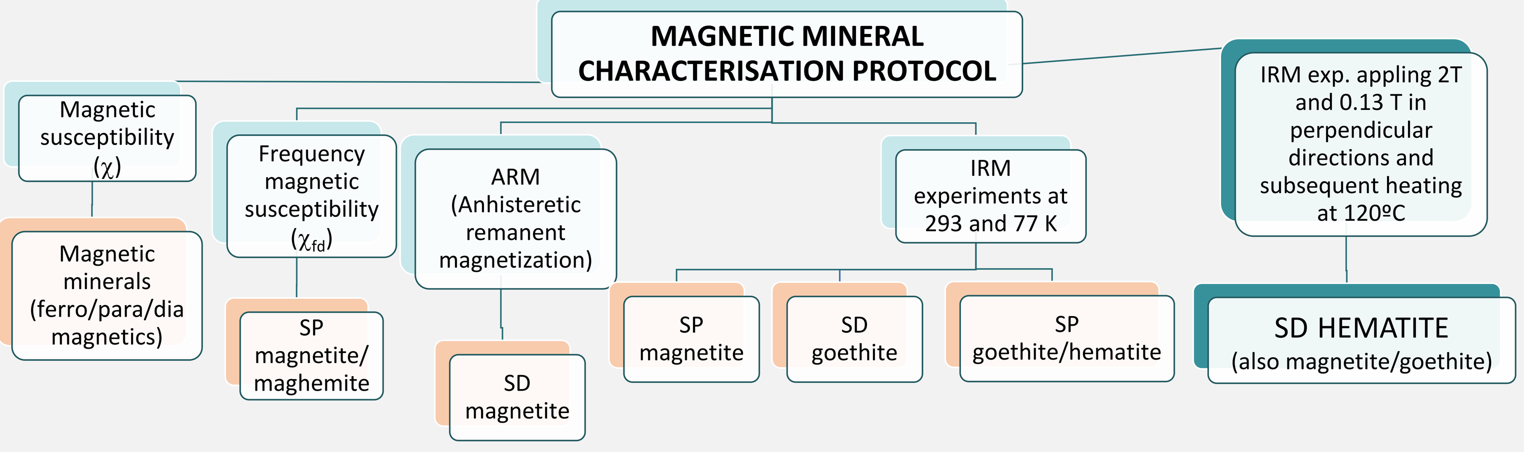
According to stable isotope data, the first three intervals of the Claret Formation correspond to the PETM and record changing hydroclimatic conditions throughout the hyperthermal event.

A detailed study of rock magnetism has been carried out to analyse the variation of the magnetic mineralogy along the sequence. Non-oriented and unconsolidated samples were taken at 1 m intervals across the 180 m composite profile. In the laboratory, grain-sizes smaller than 1mm were separated by sieving. The samples were packed into 3.6 cm³ cylindrical plastic boxes and were weighed for rock magnetic analysis. Magnetic measurements were carried out at the Paleomagnetic Laboratories of Burgos University and CNIEH (Burgos).

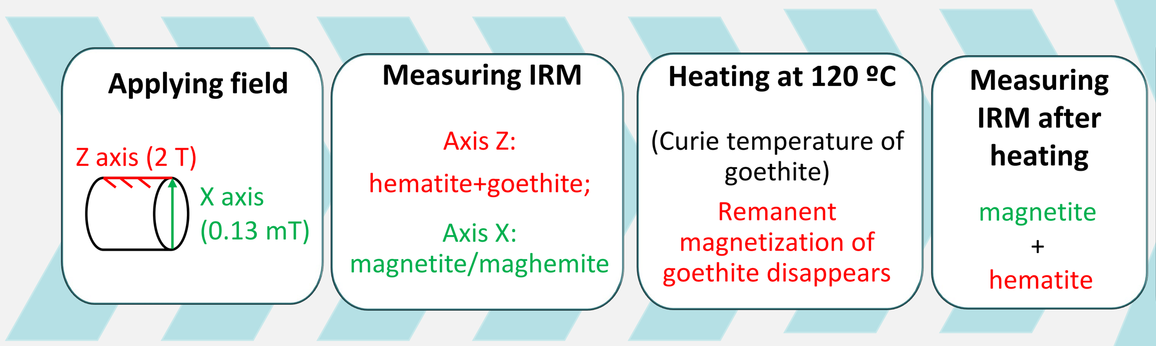


Magnetic property studies of sedimentary sequences allow a simple and rapid evaluation of the presence of ferrimagnetic minerals and the ferri/antiferromagnetic ratio for paleoenvironmental purposes. The presence and co-occurrence of goethite and hematite can play an important role in the identification of climatic fluctuations in Mediterranean climate regions, however, it is not so common to find works in which their concentration is evaluated in different magnetic states. In this work, the concentration of goethite is evaluated following the protocol proposed by Bógalo et al. (2001), and for the estimation of hematite, a new protocol has been designed, which can be quickly applied to a large volume of samples.

ROCK MAGNETIC EXPERIMENTS



CHARACTERIZATION OF HEMATITE (AND ALSO SP AND SD MAGNETITE, SD GOETHITE)



MINERAL IDENTIFICATION

Magnetite/Maghemite: $IRM_{Mg} = IRM(X)_{0.13T}$

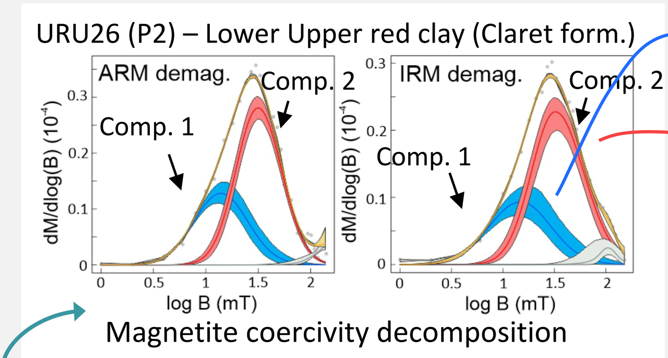
Goethite+Hematite: $IRM_{Hm/Gt} = IRM(Z)_{2T}$:

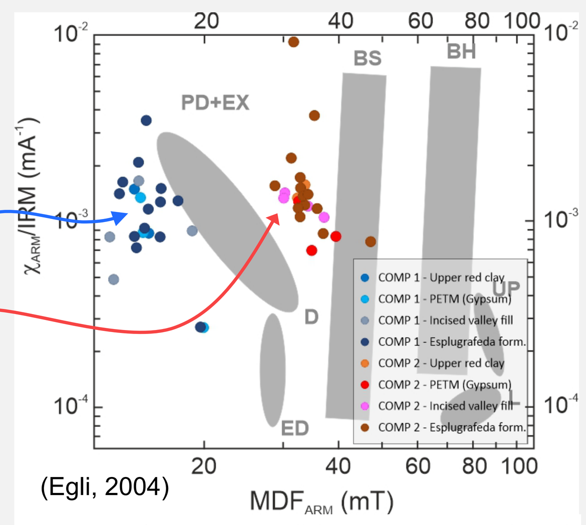
Hematite: $IRM_{Hm} = \mathbf{IRM(Z_{2T})_{120°}}$

Goethite: $IRM_{Gt} = IRM(Z)_{2T} - IRM(Z)_{2T)120°}$

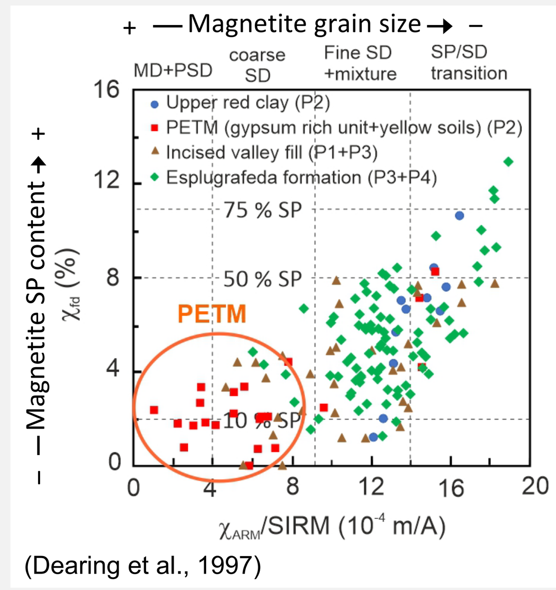
SP Magn./maghem.:

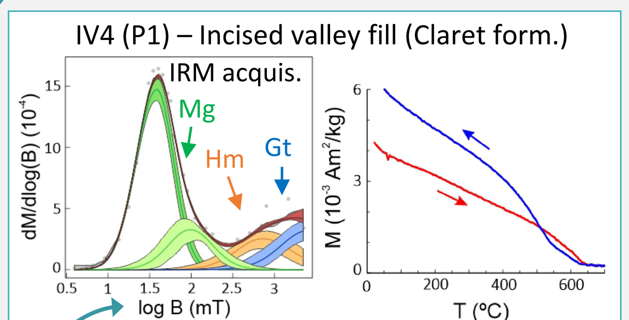
$IRM_{SP(Mg)} = IRM(X)_{0.13T} - IRM(X)_{0.13T)120°}$





PD+EX = pedogenic + etracellular magnetite, D = detrital particles, BS = biogenic soft, BH = biogenic hard, ED = eolian dust, L = loess and UP = atmospheric PM

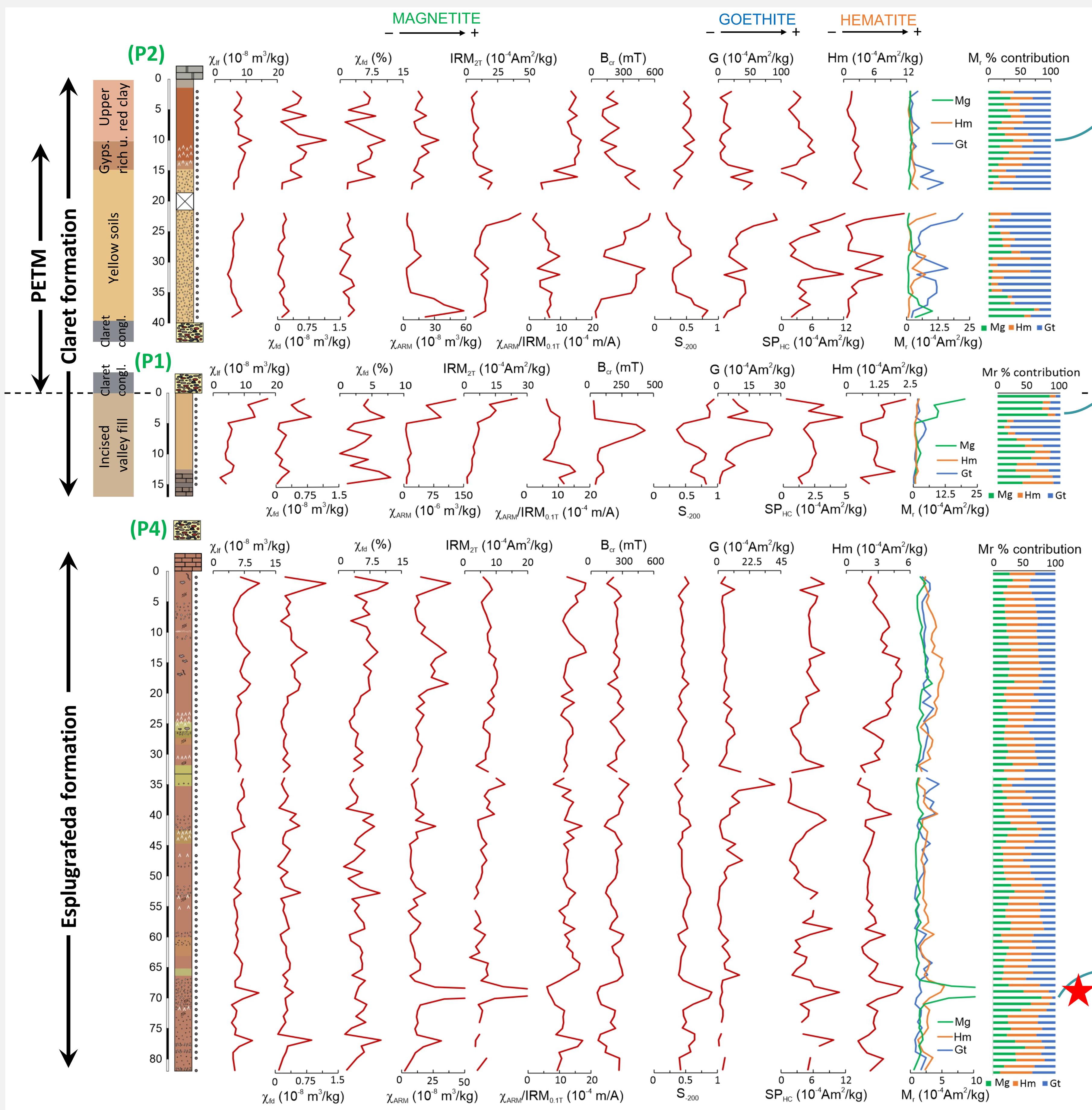


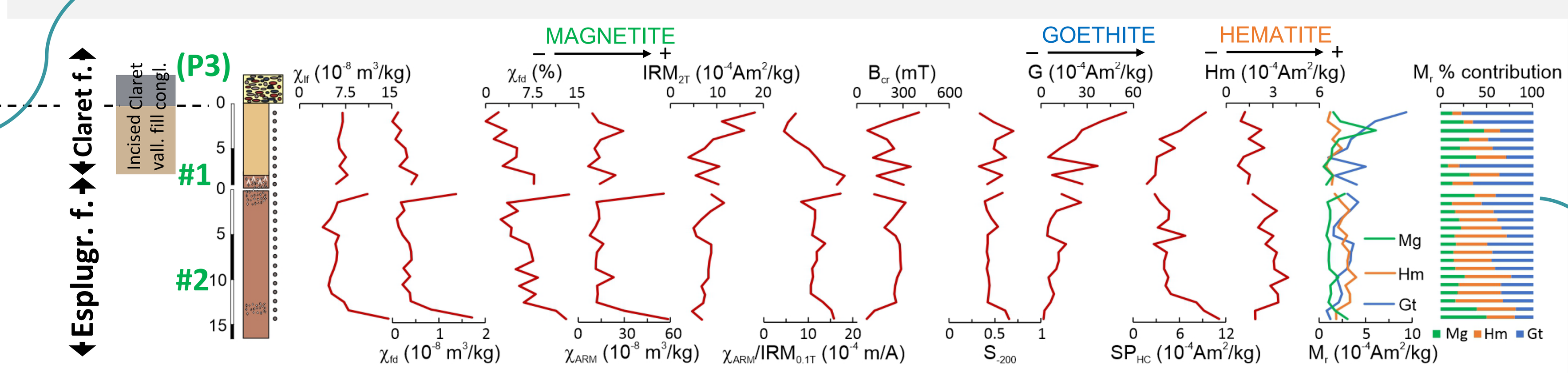


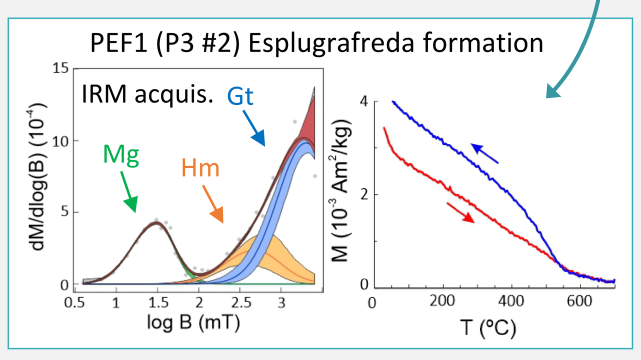
The first derivative of the ARM and IRM demagnetization curves have been fitted by two low coercivity components of average MDF_{ARM} values 15.2 and 33.9 mT, which could be associated with pedogenic and detrital magnetite, respectively.

Samples from yellow soils / Gypsum rich unit (Claret formation) (PETM) exhibit the lowest relative contribution of SP grains and higher concentration of coarse SD to MD grains.

ROCK MAGNETIC PROFILES

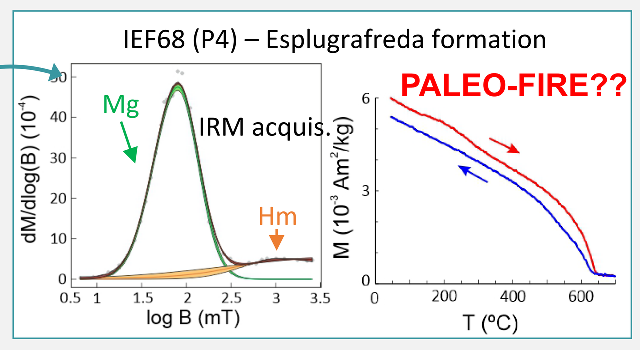






Low susceptibility values are indicative of a low concentration of magnetite compared to the concentration of antiferromagnetic (hematite and goethite) and para/diamagnetic grains. In most of the units χ_{ARM} and IRM_{2T} do not correlate (see e.g. yellow soils (P2, Les Comes valley, Claret form., corresponding to PETM). This is due to a high concentration of hematite and goethite, as indicate the B_{cr} curves. Low temperature IRM experiments (Bógalo et al., 2001) has allowed to identify the concentration of goethite (parameter G) and fine grained high coercivity minerals (SP_{HC}).

The proposed methodology has made it possible to asses the hematite content and, in addition, to estimate the goethite content (already calculated with low-T IRM experiments) and SD and fine-grained SP/SD magnetite. Good correlation in the calculation of goethite by both methods, corroborates the validity of this new method.



The bar chart shows the percentage contribution to the remanent magnetization (Mr) of **magnetite (Mg)**, **hematite (Hm)** and **goethite (Gt)**. The relative contribution of hematite in the **Esplugafreda formation** (Les Comes valley and Italian section, Profiles 3 and 4, respectively) is very uniform throughout the profiles, except at 68 m depth (P4) where practically only magnetite is observed. The values of the different magnetic parameters, as well as the reversibility of the thermomagnetic curve, suggest that this level may have been affected by a paleo-fire. The high hematite relative concentration may indicate that the paleosols of Esplugafreda formation were developed in a semi-arid to arid paleoenvironment, as was suggested by, for instance, Pujalte et al. (2014). Fluctuations in goethite content could be related to strong seasonal moisture variations (Basilici et al., 2022).

CONCLUSIONS

- A new protocol for estimating the hematite content in soils and sedimentary sequences has been proposed.
- The magnetic signal of the whole sequence is controlled by magnetite/maghemite, haematite and goethite.
- The Esplugafreda Formation shows high hematite content related to an arid/semi-arid palaeoenvironment.
- In the yellow soils, lower part of the PETM, the increase and variability of the goethite content would indicate at least a seasonally more humid environment.

The upper part of the **incised valley** (Profile 1, Les Comes valley) shows higher magnetite content than Esplugafreda formation, mostly of pedogenic origin. In addition, in the central part of the profile, the high goethite occurrence could be associated with a higher soil moisture content which favored the formation of this mineral.

In Profile 2, **yellow soils** (Les Comes valley, Claret formation, corresponding to **PETM**), a decrease in hematite content is observed in favor of an increase in goethite content, mainly in the lower part (yellow soils). Significant fluctuations in the goethite and in the magnetite content may be due to changes in palaeoenvironmental conditions (higher humidity favouring the formation of goethite) or to a change in the source of the materials (maybe due to changes in the hydrological cycle) (e.g. Schmitz and Pujalte, 2007; Payros et al., 2022).

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