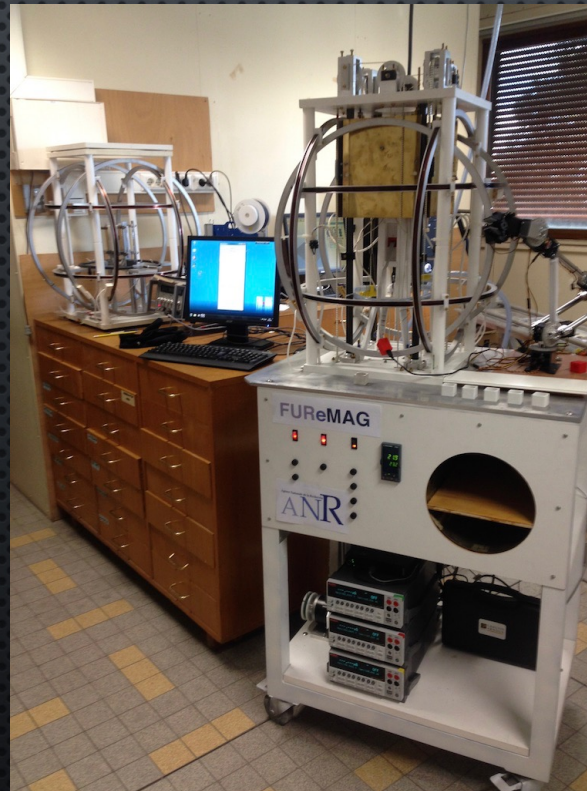


Theillier-Multispecimen-Triaxe:

Which method for which kind of samples ?

Paul Antonio & Pierre Camps (Géosciences Montpellier)



Theillier-Multispecimen-Triaxe:

Theillier protocol

References :

- Folgheraiter, JPTA, 1899
- Koenigsberger, TMAE, 1938.
- Roquet & Theillier, 1946
- Theillier & Theillier, Ann. Geophys., 1959.

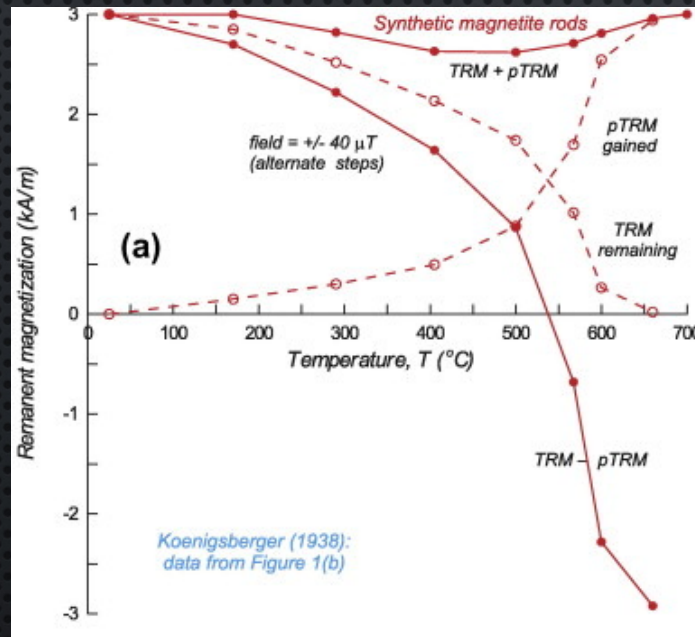
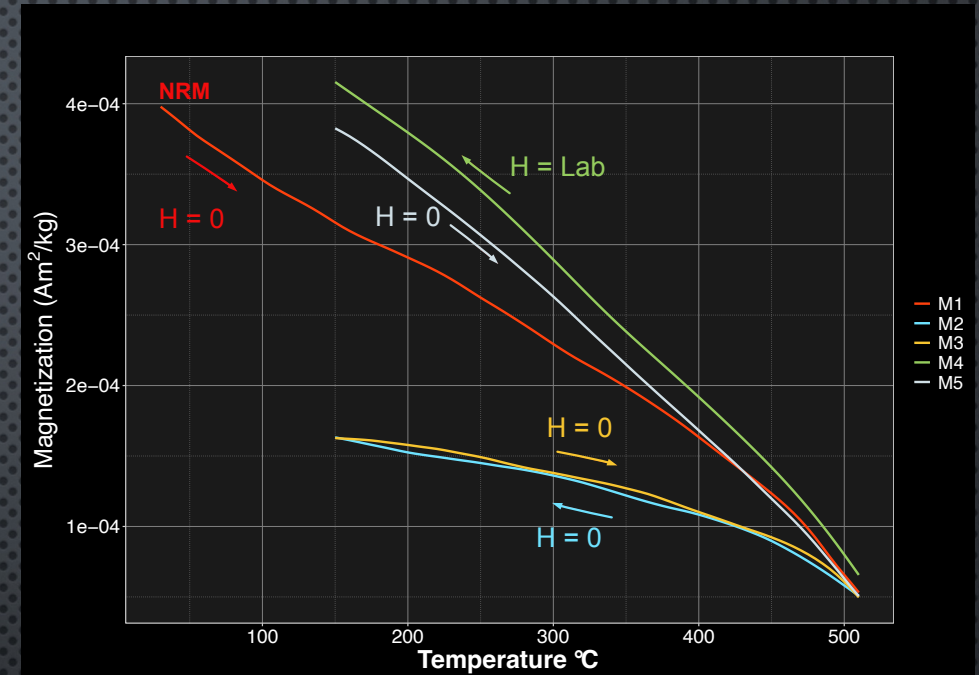


Fig. from Dunlop, PEPI, 2011

Tri-Axis protocol

References :

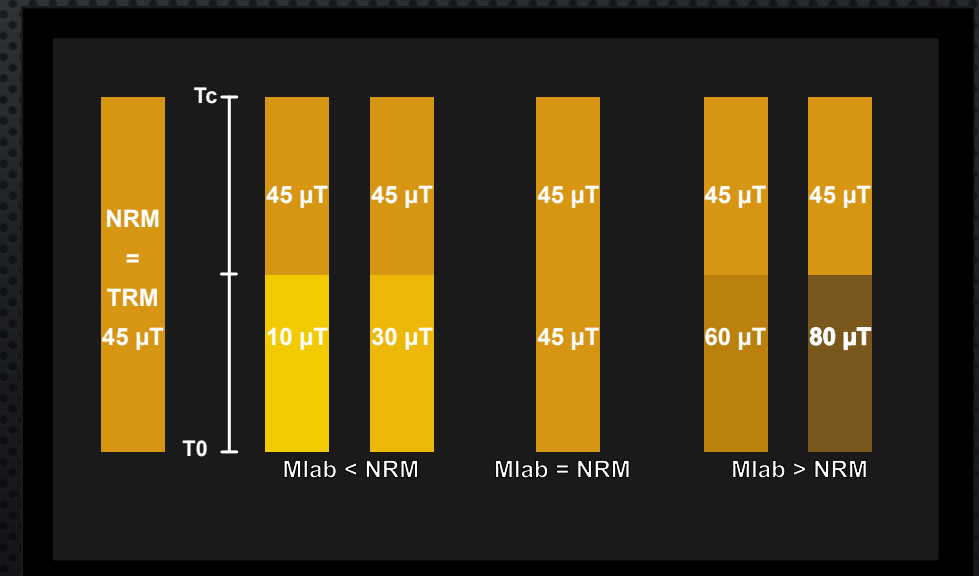
- Le Goff & Gallet, EPSL, 2004.
- Gallet et al., PEPI, 2022.



MSP-DSC protocol

References :

- Biggin & Poidras, EPSL, 2006.
- Dekker & Bohnel, EPSL, 2006.
- Fabian & Leonhardt, EPSL, 2010.

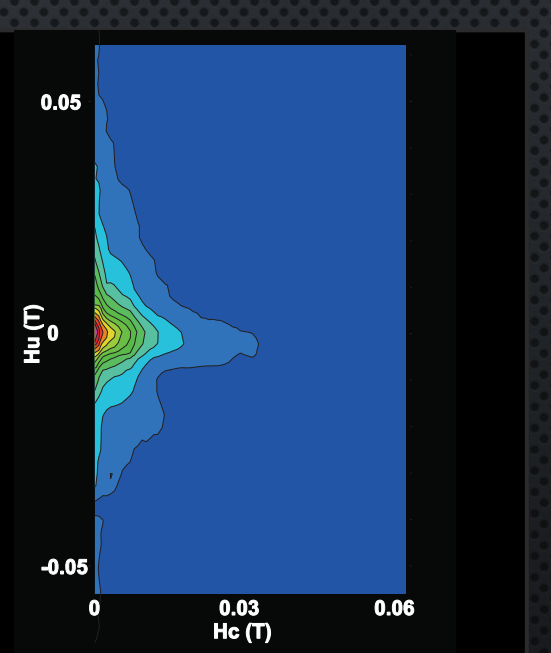
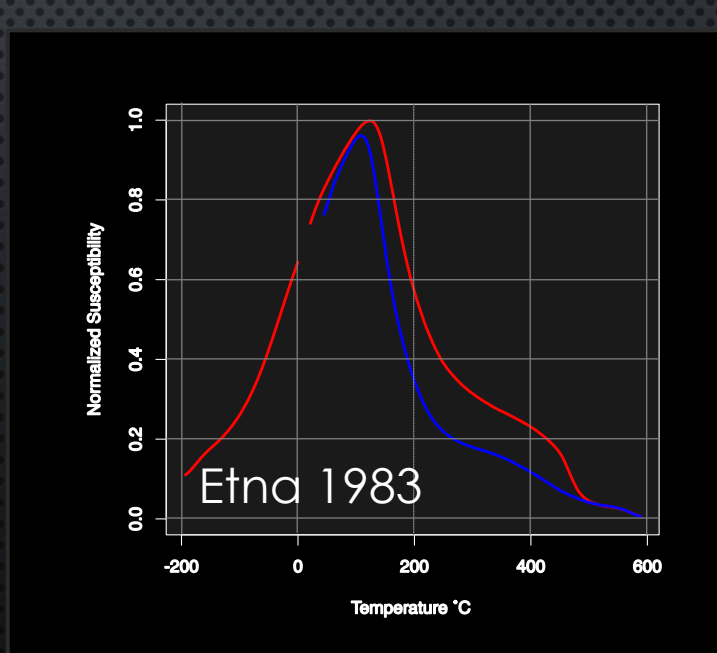
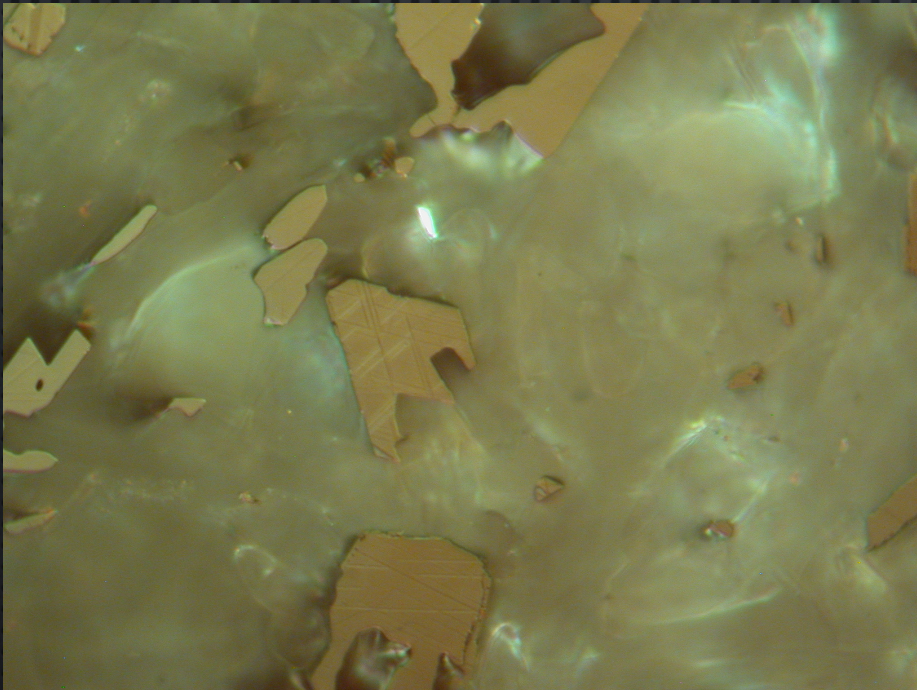
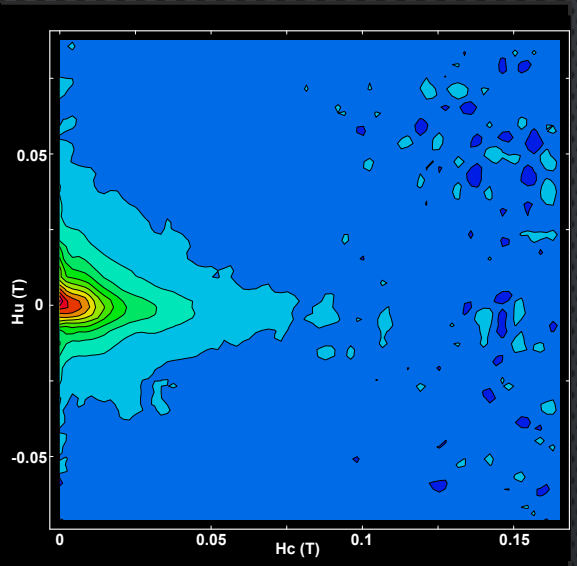
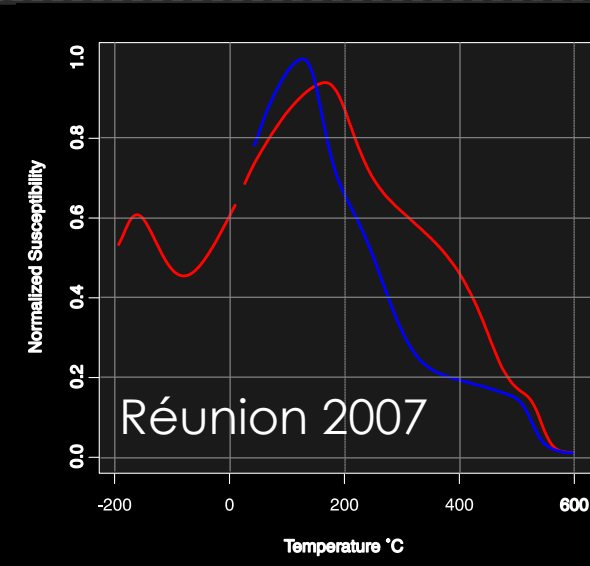
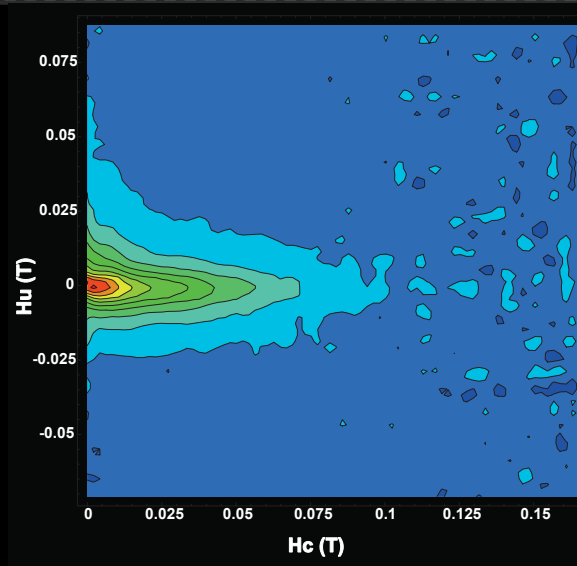
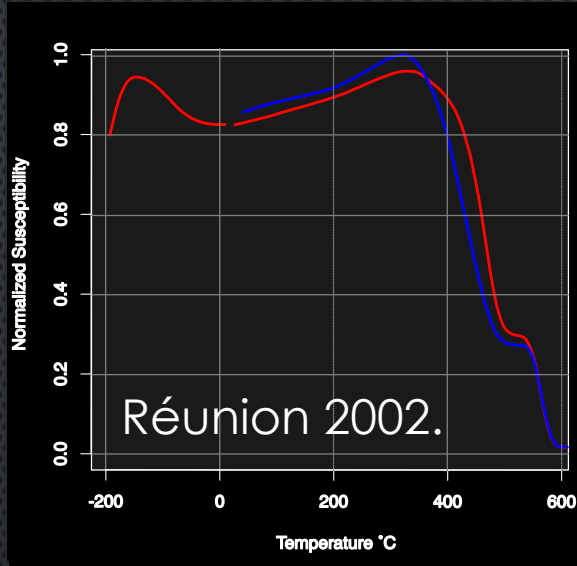


Thellier-Multispecimen-Triaxe:

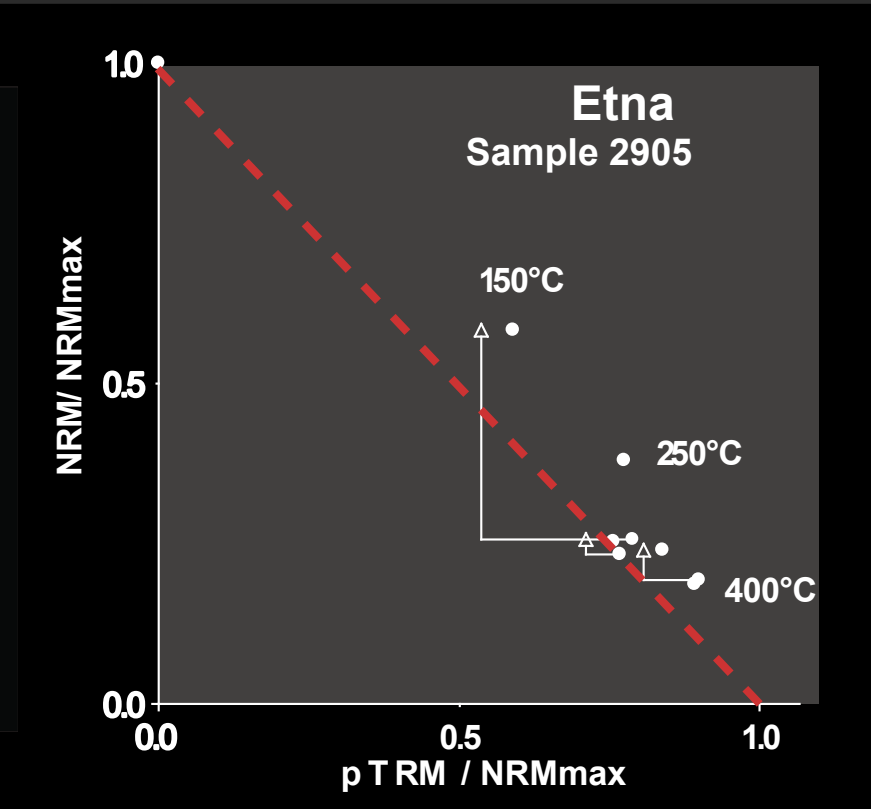
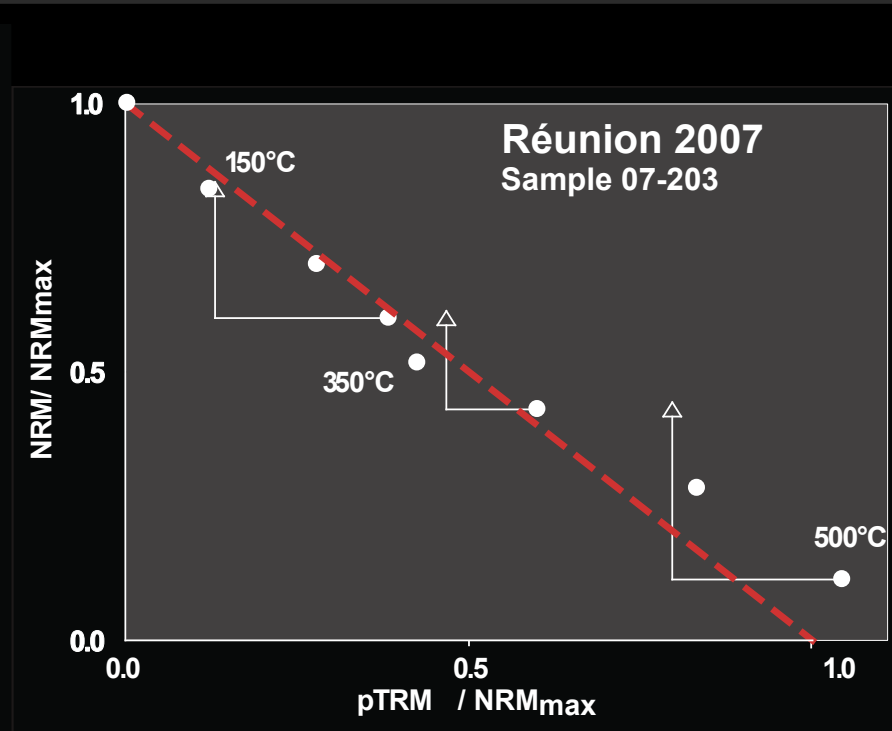
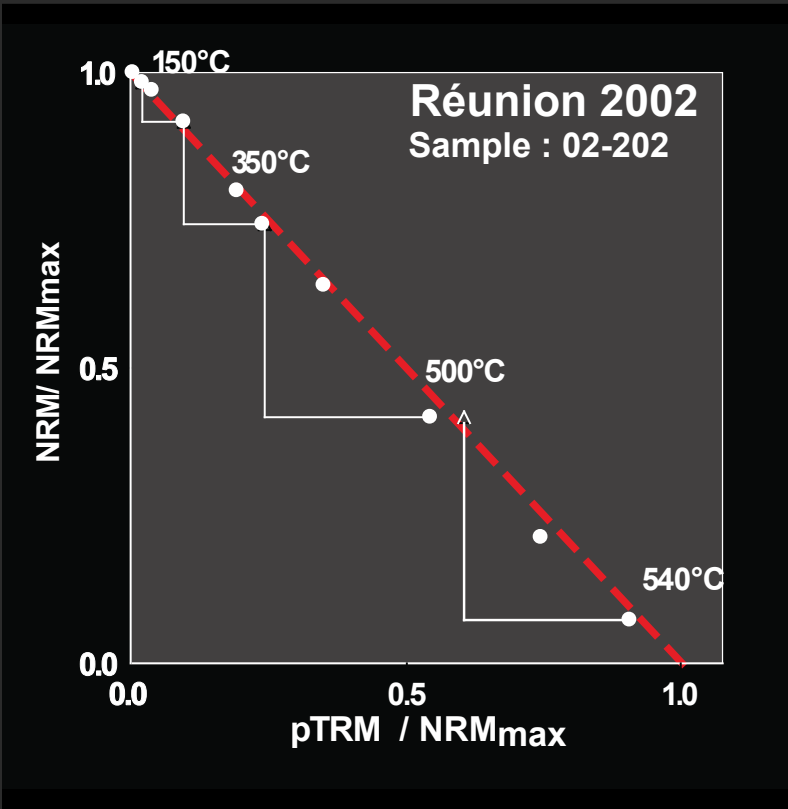
		Thellier	MSP-DSC	Wilson Muxw.	Triaxe
	Conditions:	Room Temperature		@ high temp.	
Folgheraiter, 1899	$H_{anc} / H_{lab} = TRM_{anc} / TRM_{lab}$				
	NRM is a TRM	R	R	R	R
	TRM = $\alpha \cdot H$	R	R	R	R
	No alteration of mag. minerals	(R)	(R)	R	(R)
Koenigsberger, 1938	$T_{bloking} = T_{unbloking}$ (reciprocity)	R	N.R	N.R	?
Roquet & Thellier, 1946	Independence of pTRMs	R	N.R	N.R	?
Thellier & Thellier, 1959	Additivity of pTRMs	R	N.R	N.R	?

R : required
NR : not required

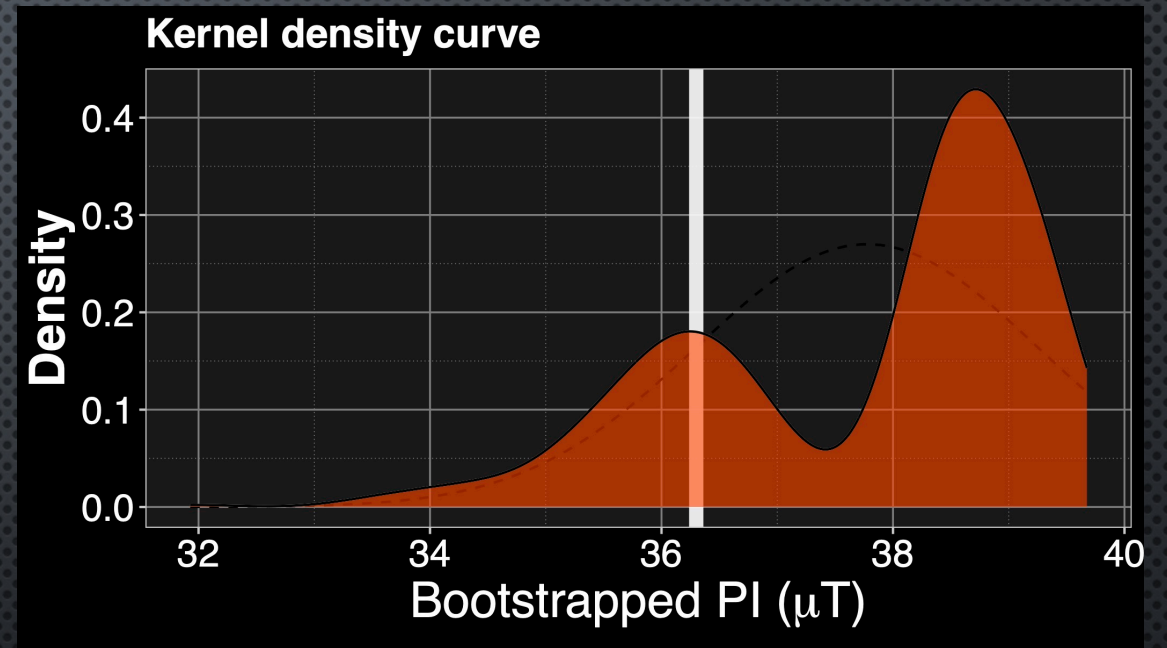
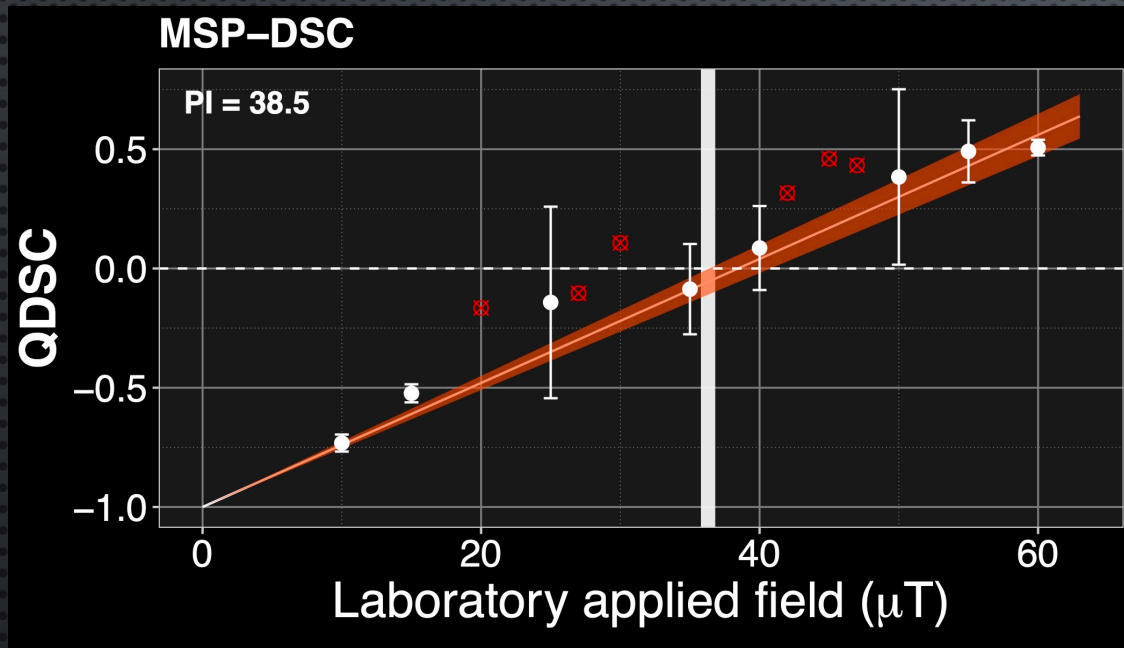
Three test lava flows : Rock magnetic properties.



Thellier protocol



MSP-DSC protocol



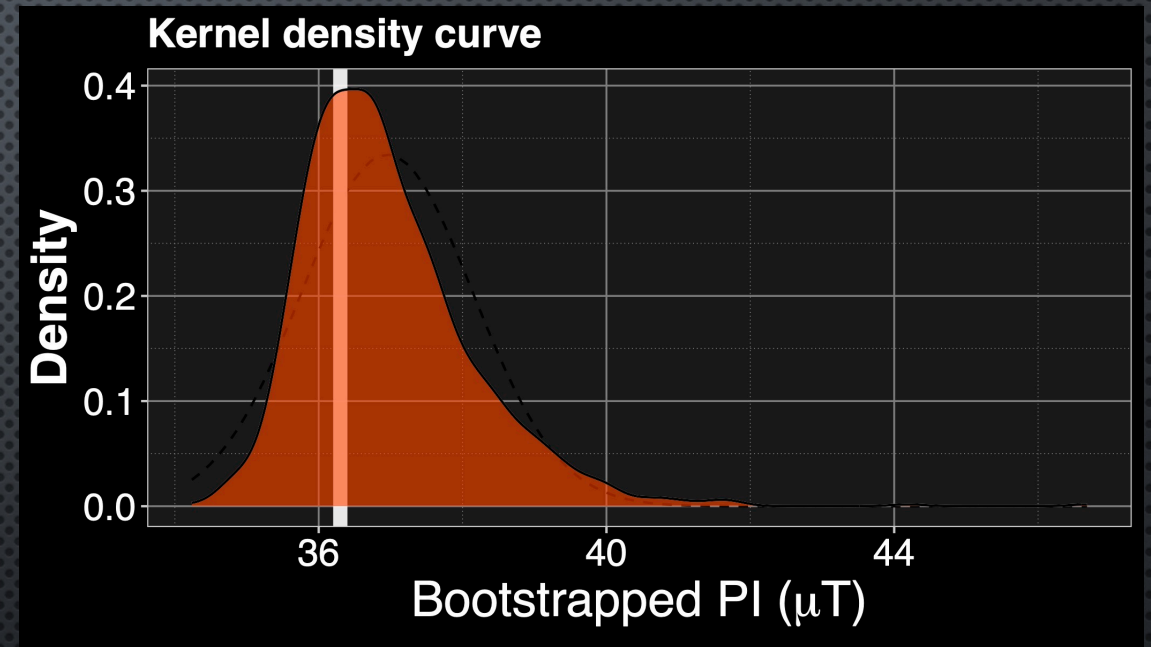
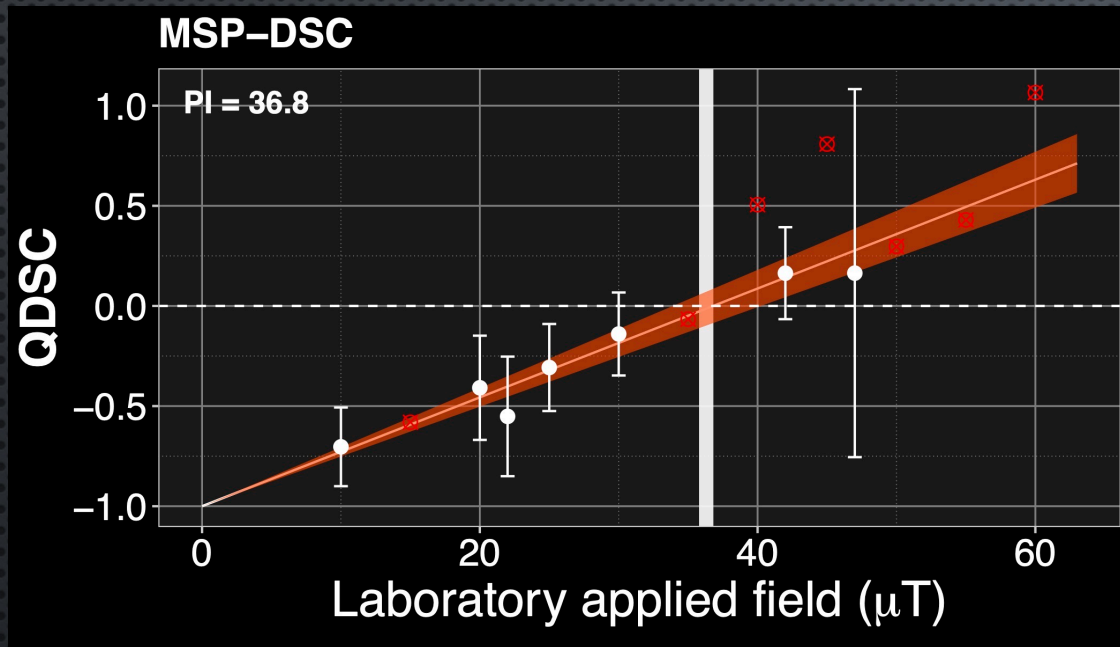
Réunion 2002 : IGRF 36.3 μT

PI = 35.8 [34.5 – 39.0] confidence interval @ 68%

R-squared = 0.9842



MSP-DSC protocol



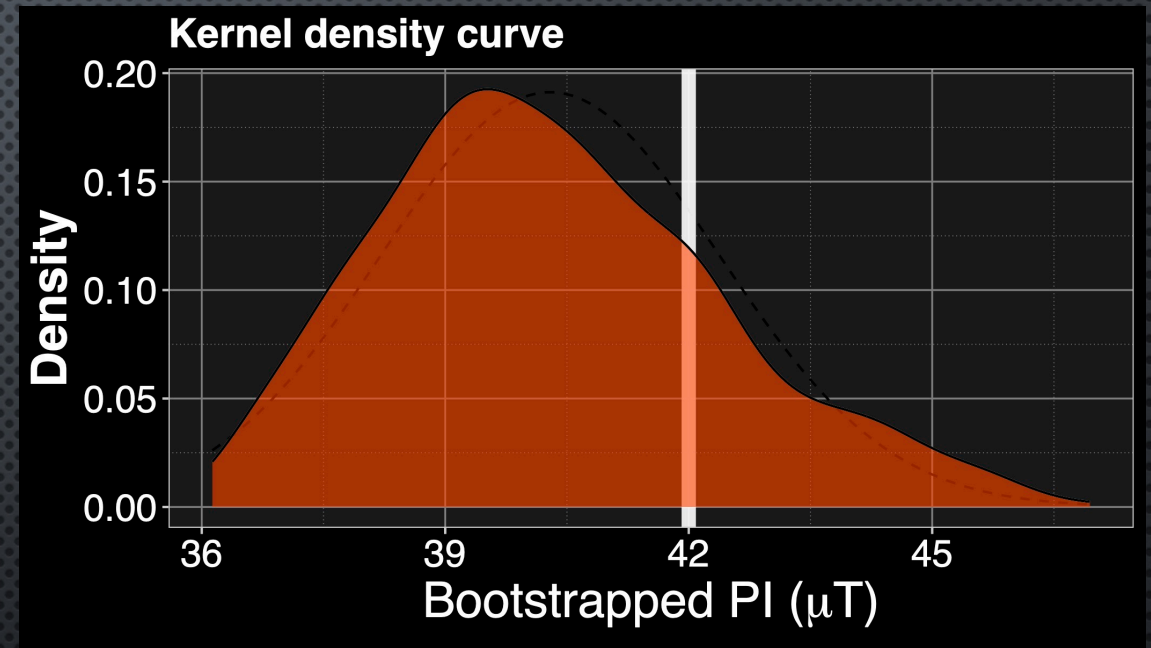
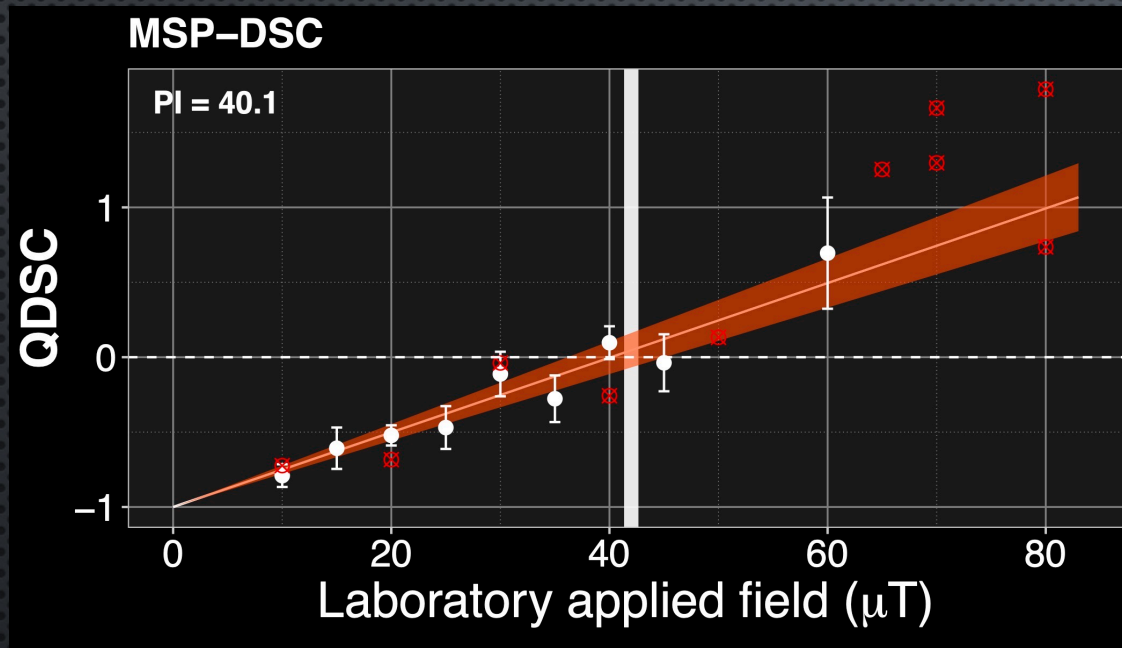
Réunion 2007 : IGRF 36.6 μT

PI = 36.8 [34.4 – 38.9] confidence interval @ 68%

R-squared = 0.9960



MSP-DSC protocol



Etna 1983: IGRF 44.0 μT ; Measured 42 μT

PI = 40 [35.9 – 44.0] confidence interval @ 68%

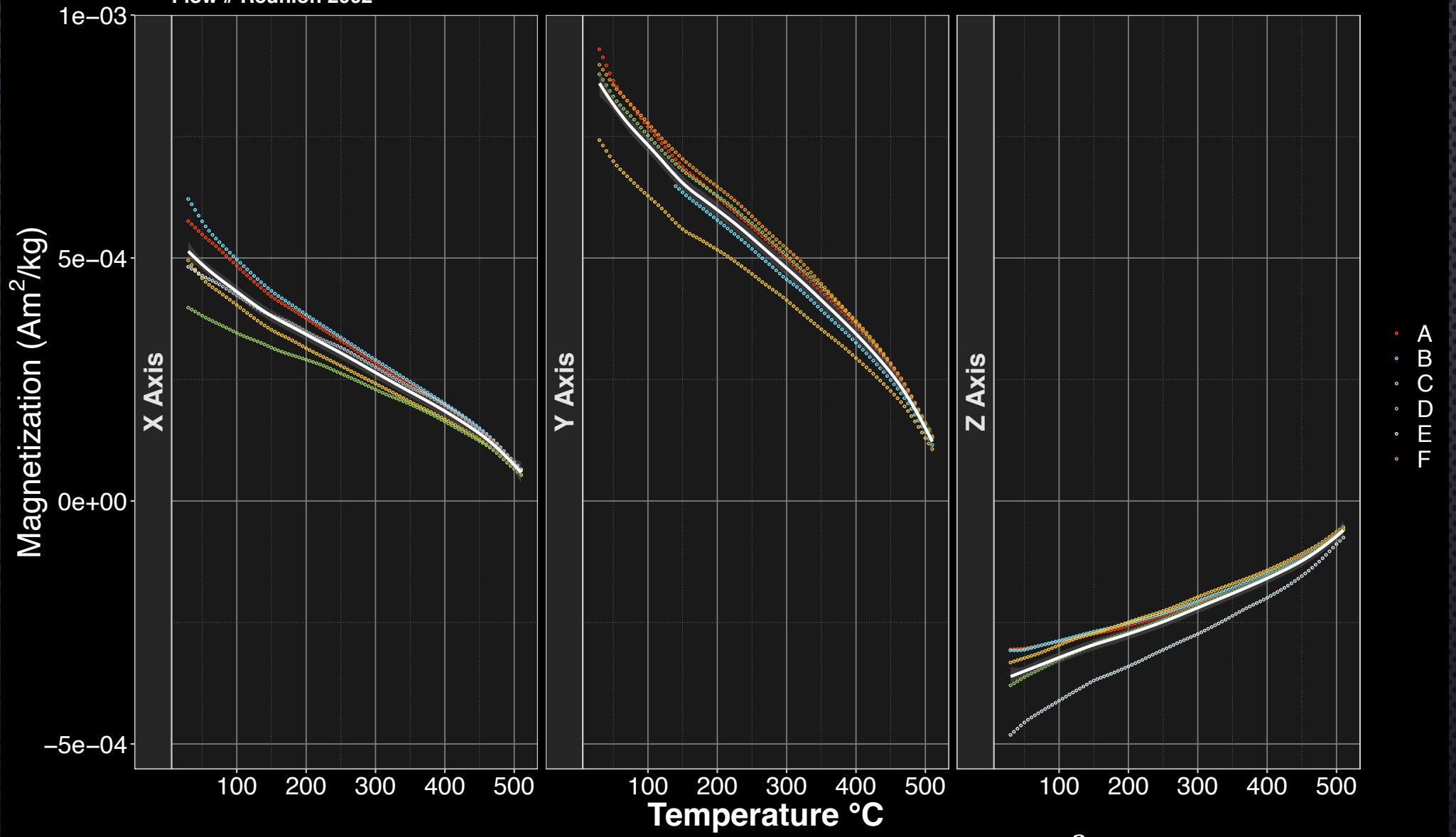
R-squared = 0.9828



Triaxe protocol

NRM demagnetization (M1), raw data

Flow # Réunion 2002



Experimental setting:

Applied field

$0 \mu\text{T}$

Temperature

$150 - 510^\circ\text{C}$

Heating @ $10^\circ\text{C}/\text{mn}$

Cooling @ $10^\circ\text{C}/\text{mn}$

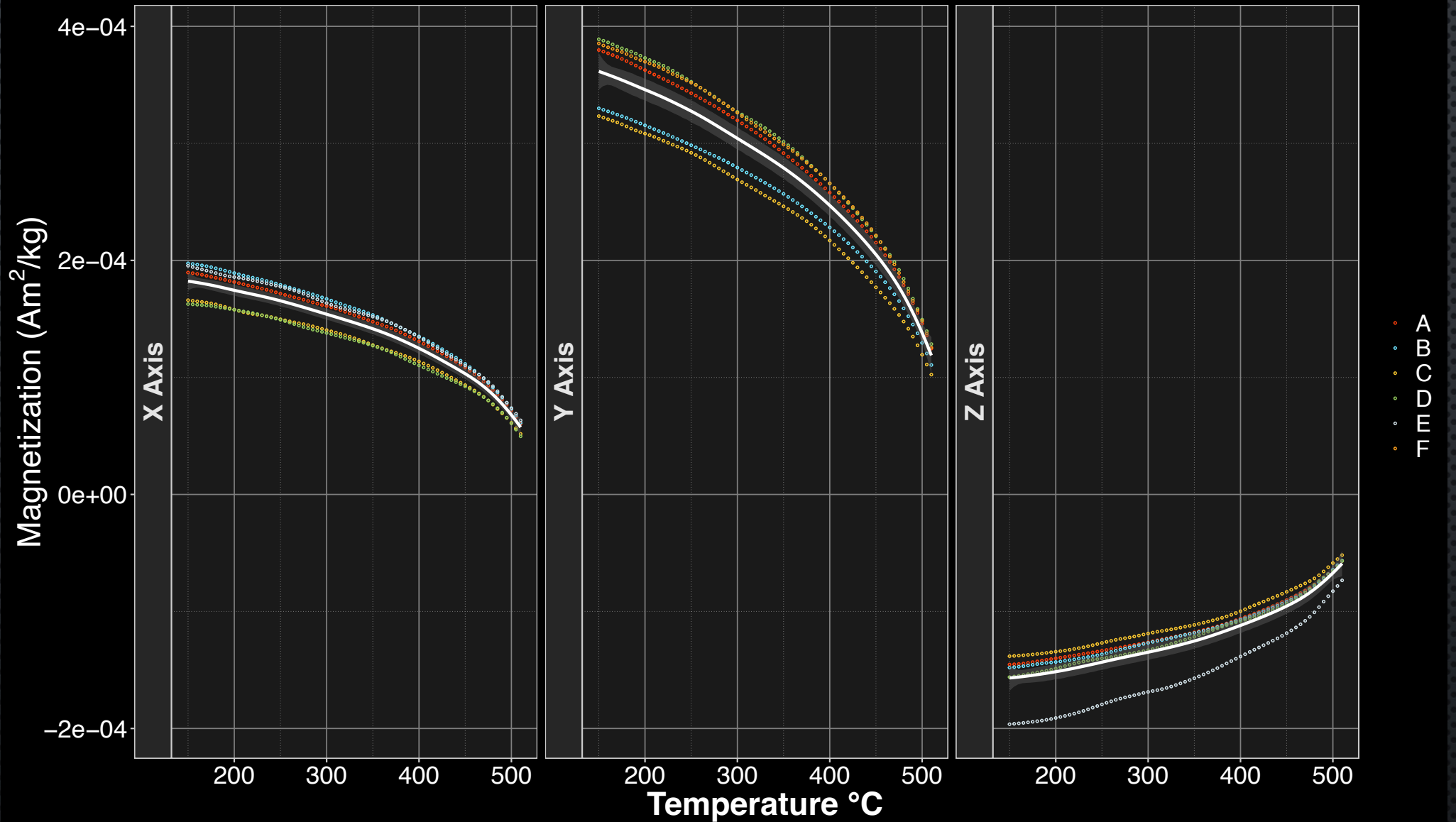
Dwell during 5 mn

$$\text{Confidence interval for M1: } \varepsilon_{x,y,z} \simeq \frac{\vec{M} \cdot \vec{\varepsilon}}{\|\vec{M}\|} + \frac{\|\vec{\varepsilon}\|^2}{2\|\vec{M}\|} + \frac{(\vec{M} \cdot \vec{\varepsilon})^2}{\|\vec{M}\|^3} + \dots$$

Triaxe protocol

Variation of Spontaneous Magnetization (M3)

Flow # Réunion 2002



Experimental setting:

Applied field

0 μ T

Temperature

150 – 510°C

Heating @10°C/mn

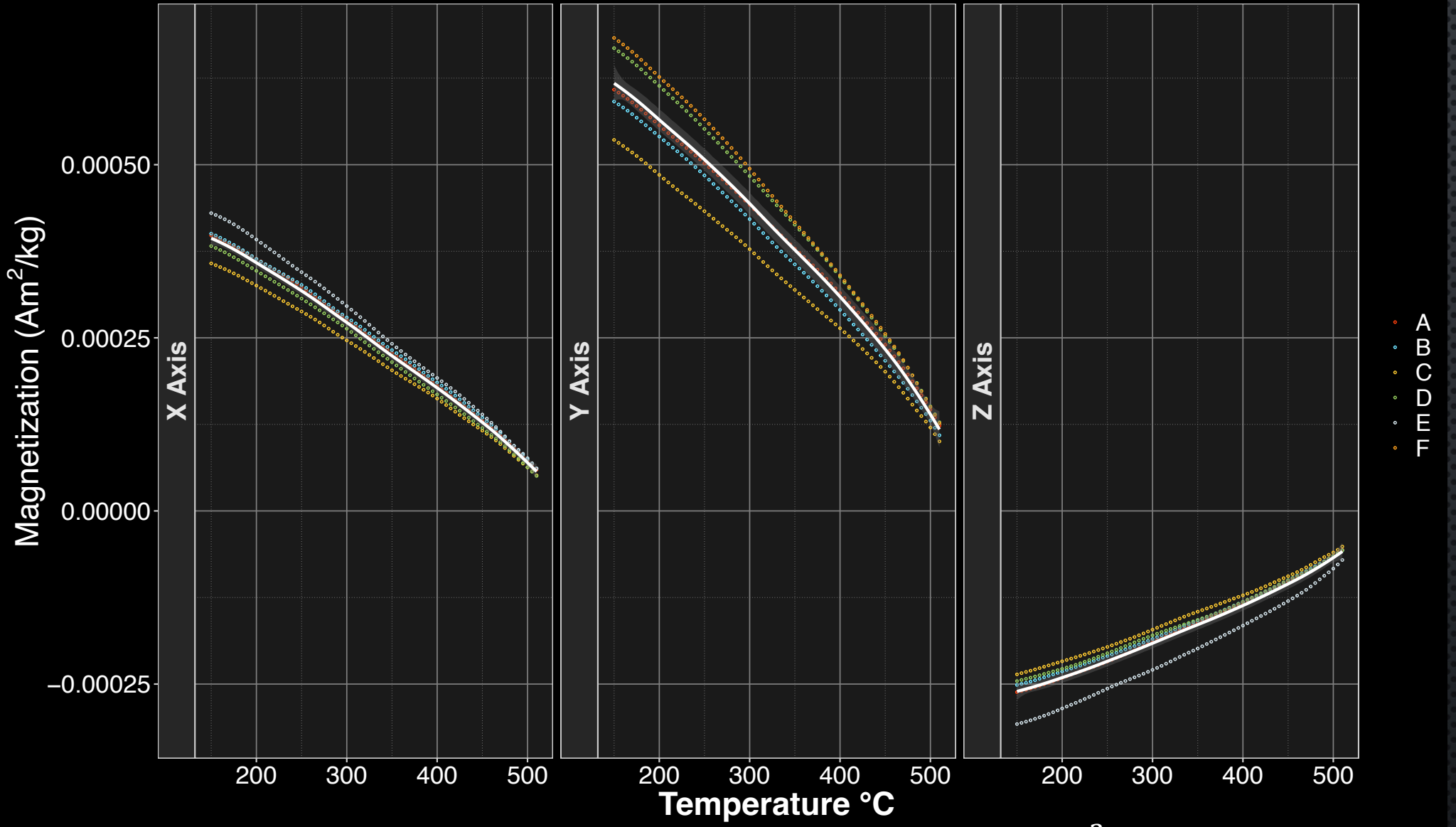
Cooling @10°C/mn

Dwell during 5 mn

$$\text{Confidence interval for } M3: \varepsilon_{x,y,z} \simeq \frac{\vec{M} \cdot \vec{\varepsilon}}{\|\vec{M}\|} + \frac{\|\vec{\varepsilon}\|^2}{2\|\vec{M}\|} + \frac{(\vec{M} \cdot \vec{\varepsilon})^2}{\|\vec{M}\|^3} + \dots$$

Triaxe protocol

pTRM demagnetization (M5), raw data
Flow # Réunion 2002



Experimental setting:

Applied field: M4
40.1 μT
Temperature
150 – 510°C

Heating @10°C/mn
Cooling @10°C/mn
Dwell during 5 mn

Confidence interval for M5 : $\varepsilon_{x,y,z} \simeq \frac{\vec{M} \cdot \vec{\varepsilon}}{\|\vec{M}\|} + \frac{\|\vec{\varepsilon}\|^2}{2 \|\vec{M}\|} + \frac{(\vec{M} \cdot \vec{\varepsilon})^2}{\|\vec{M}\|^3} + \dots$

Triaxe protocol

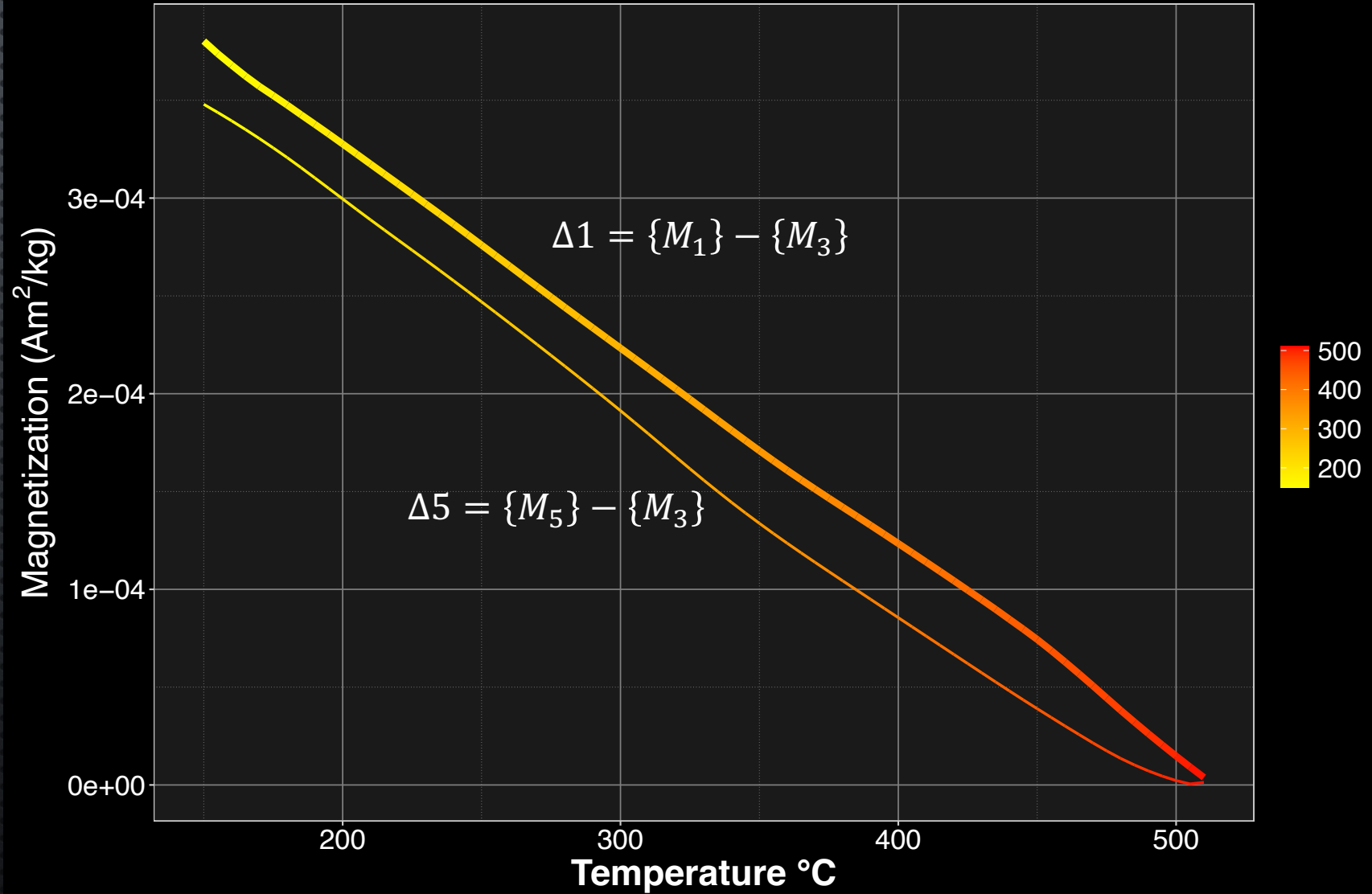
Zijderveld Plot

Flow # Réunion 2002



Demagnetization Plot

Flow # Réunion 2002



Triaxe paleointensity results

$$R'T_i = H_{lab} \cdot \frac{\Delta 1'T_i}{\Delta 5'T_i}$$

where :

$$\Delta 1'T_i = \{M_1[T_1] - M_1[T_i]\} - \{M_3[T_1] - M_3[T_i]\}$$

$$\Delta 5'T_i = \{M_5[T_1] - M_5[T_i]\} - \{M_3[T_1] - M_3[T_i]\}$$

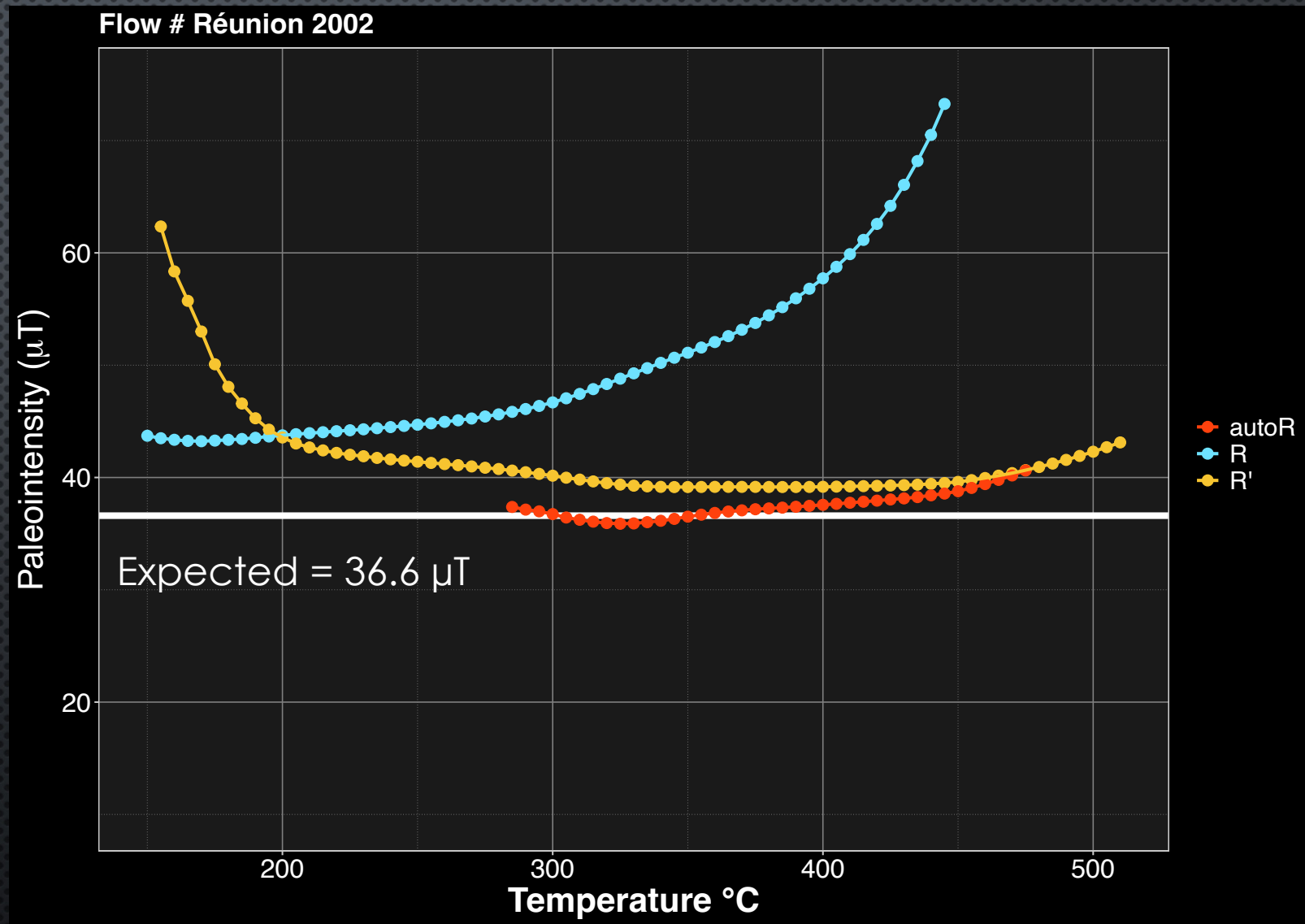
Ref.:

Le Goff & Gallet, EPSL, 2004.

Gallet et al., PEPI, 2022.

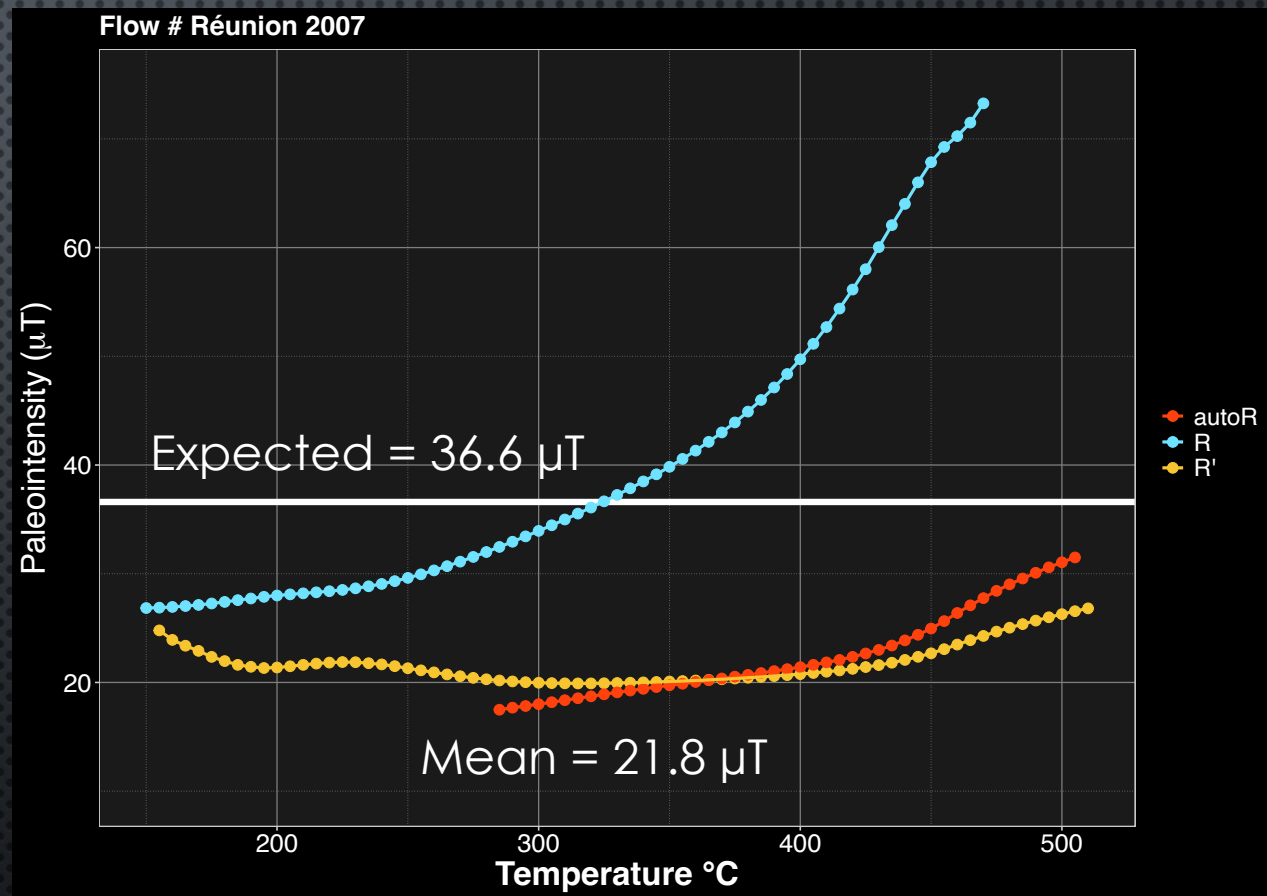
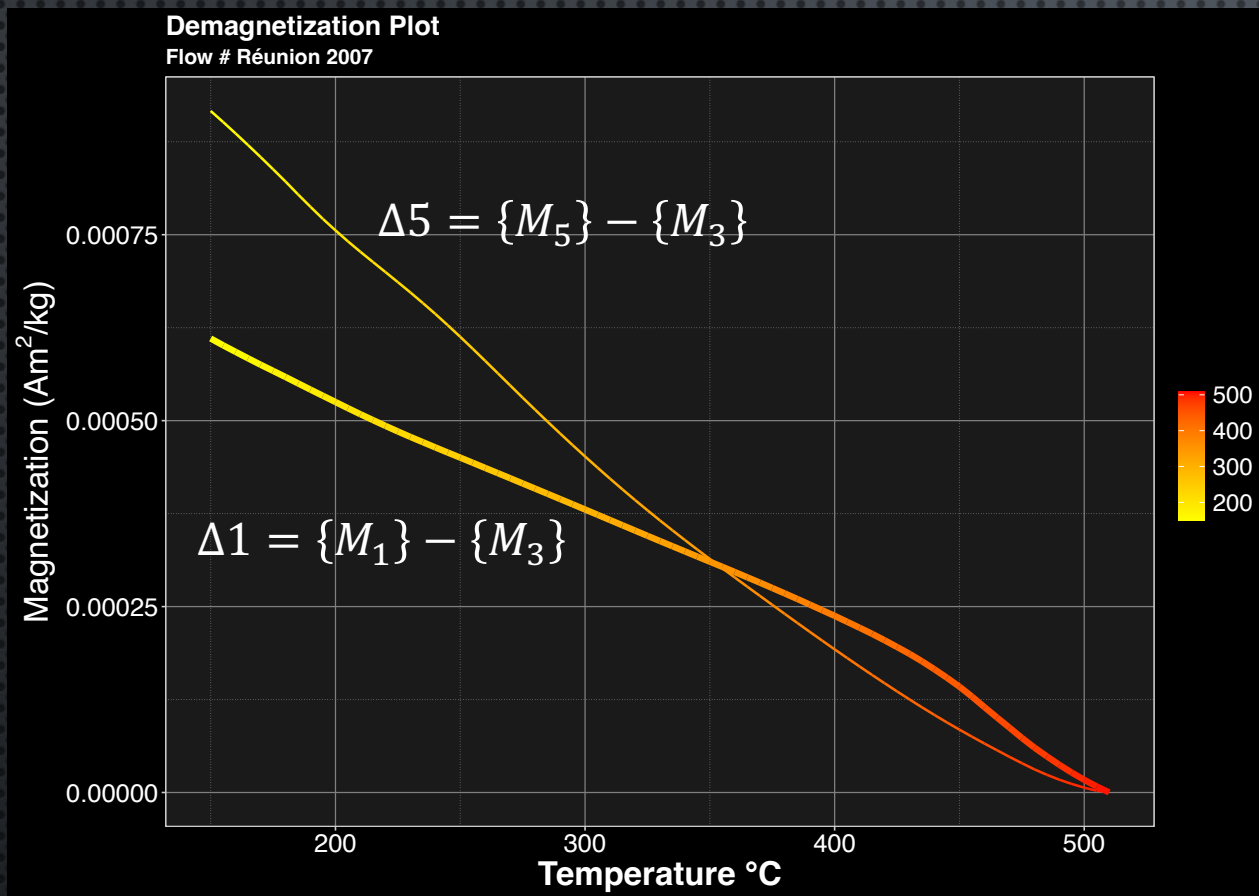
$$\varepsilon_{R'} = \frac{1}{\Delta 5'} \left(\varepsilon_{\Delta 1'} + \frac{\Delta 1'}{\Delta 5'} \varepsilon_{\Delta 5'} \right)$$

$$\varepsilon_{\Delta 1'T_i} = \varepsilon_{M_1(T_1)} + \varepsilon_{M_1(T_i)} + \varepsilon_{M_3(T_1)} + \varepsilon_{M_3(T_i)}$$



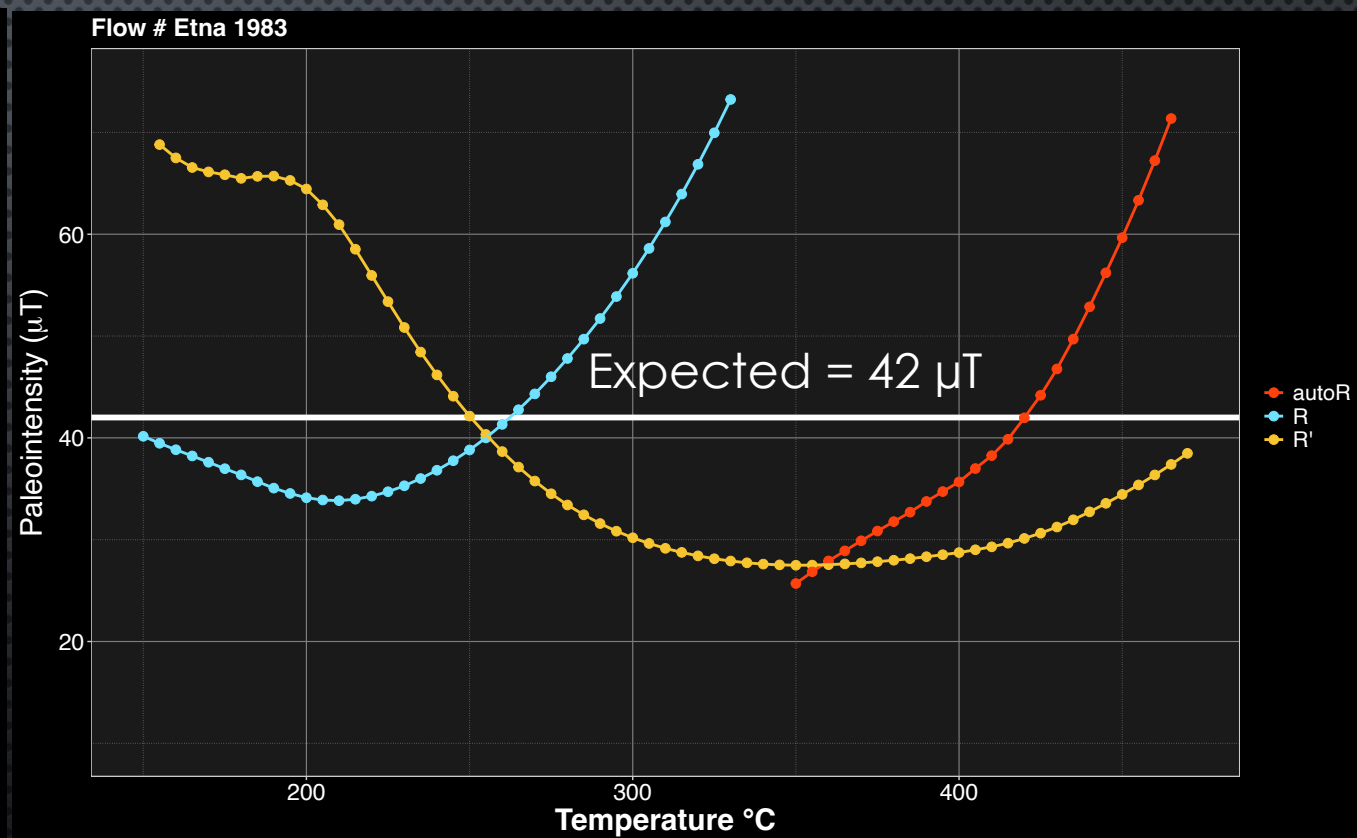
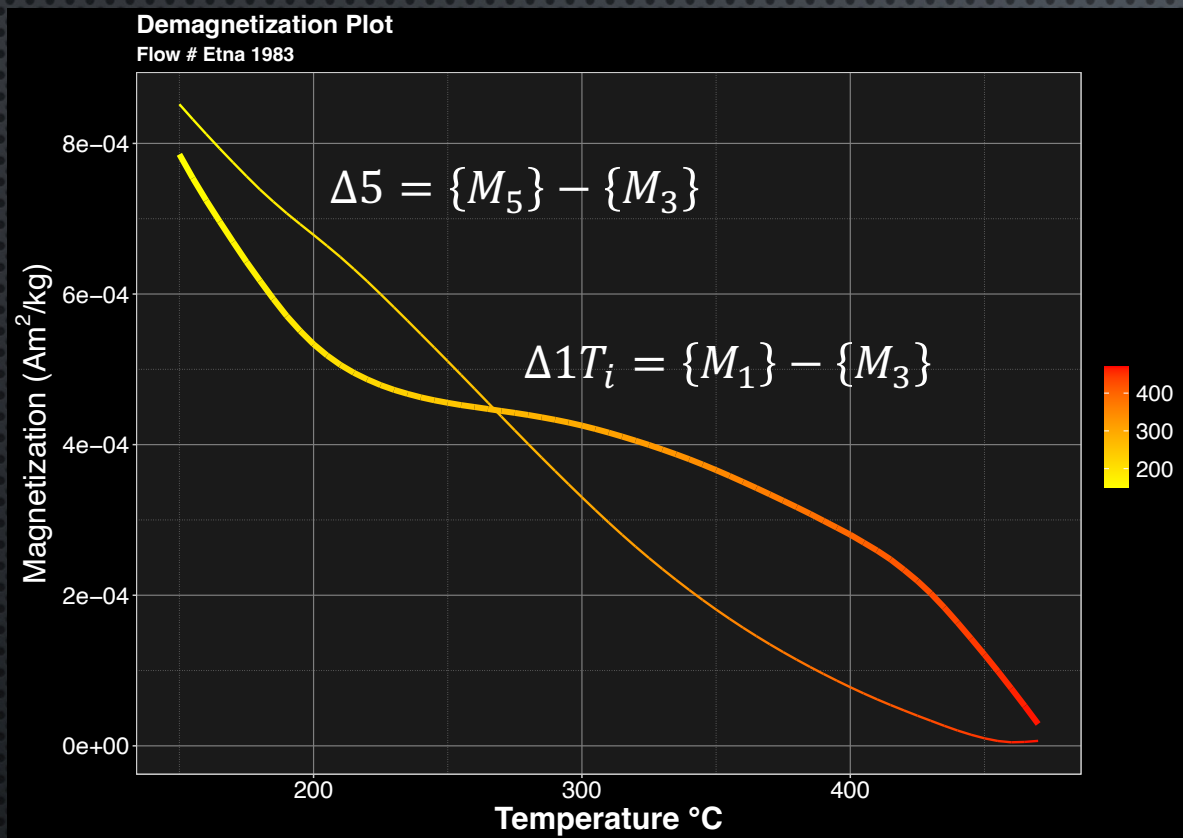
Triaxe paleointensity results

Réunion 2007
Applied field during M4 : 40.3 μT



Triaxe paleointensity results

Etna 1983
Applied field during M4 : 42.8 μT



Key points

To

Remember :

- i. Determining paleointensity from volcanic records remains challenging.
- ii. Devices and protocols that process a single sample at a time enable experimental conditions to be fine-tuned as quickly as possible.
- iii. The MSP-DSC protocol appears to be the most suitable for lava flows.
- iv. Further work is planned on the development of a hybrid Triaxe - MSP protocol.