Potential of high-temperature magnetization measurements for archeo- and paleointensity studies

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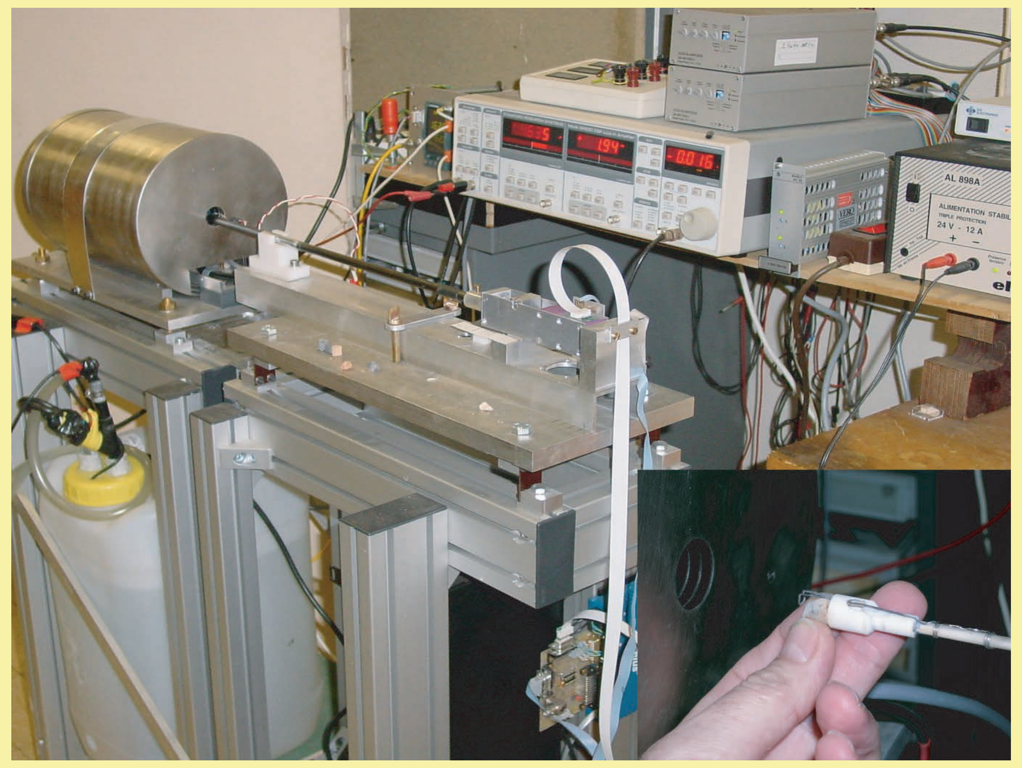


Figure 1 : Triaxe magnetometer (Le Goff and Gallet, 2004)

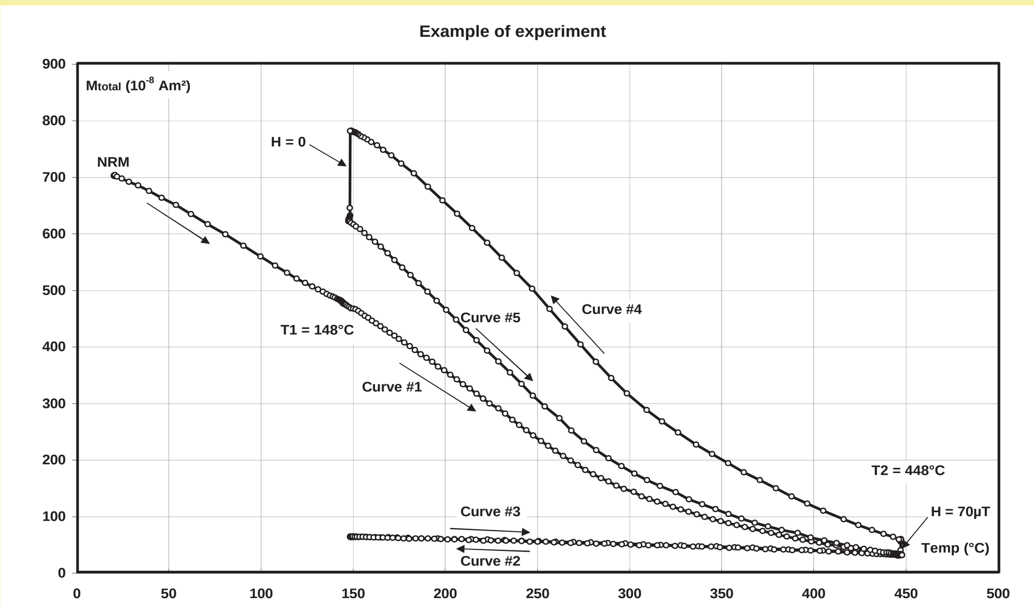
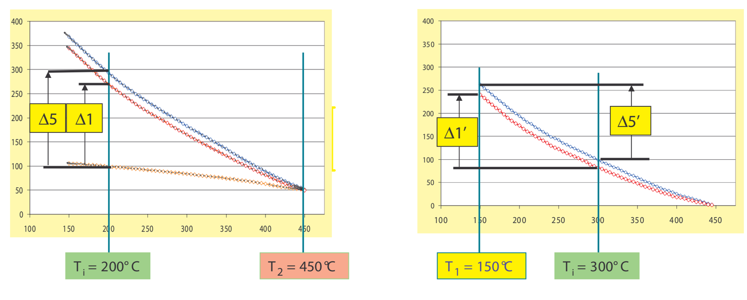


Figure 2: Magnetization data acquired during a complete cycle of measurements for intensity determination. Curve 1 shows the thermal demagnetization between 150°C and 450°C of the natural remanent magnetization (NRM) together with the thermal variation of the remaining (blocked) NRM. Curves 2 and 3 display the temperature dependence of the NRM fraction with unblocking temperature >450°C. Curve 4 shows the acquisition of a new TRM in a known laboratory field, while Curve 5 shows its demagnetization.

1. The Triaxe magnetometer and a new intensity method

We have developed a new three-axis vibrating sample magnetometer, which allows continuous high-temperature magnetization measurements of small individual cylindrical samples up to 650°C and the acquisition of thermoremanent magnetization (TRM) in any direction and field intensity up to 200µT (Fig. 1). We then have proposed a fast (less than 2.5 h) automated experimental procedure (Fig. 2, 3) which provides continuous intensity determinations over a large (typically 300°C) temperature interval for each sample. This procedure allows one to take into account both the cooling rate dependence of TRM acquisition and anisotropy of TRM.

Figure 3: Two possibilities to derive intensity data



Remaining NRM (Δ1) and TRM (Δ5) between Ti and T2 : R ratio

Lost NRM (Δ1')and TRM (Δ5') between T1 and Ti : R' ratio

$$R(T_i) = H_{lab} * \Delta 1(T_i) / \Delta 5(T_i)$$

$$R'(T_i) = H_{lab} * \Delta 1'(T_i) / \Delta 5'(T_i)$$

City 3 of Mari (Syria), 21th century BC

Figure 4: Tomb in the Oriental Palace (site MR15)

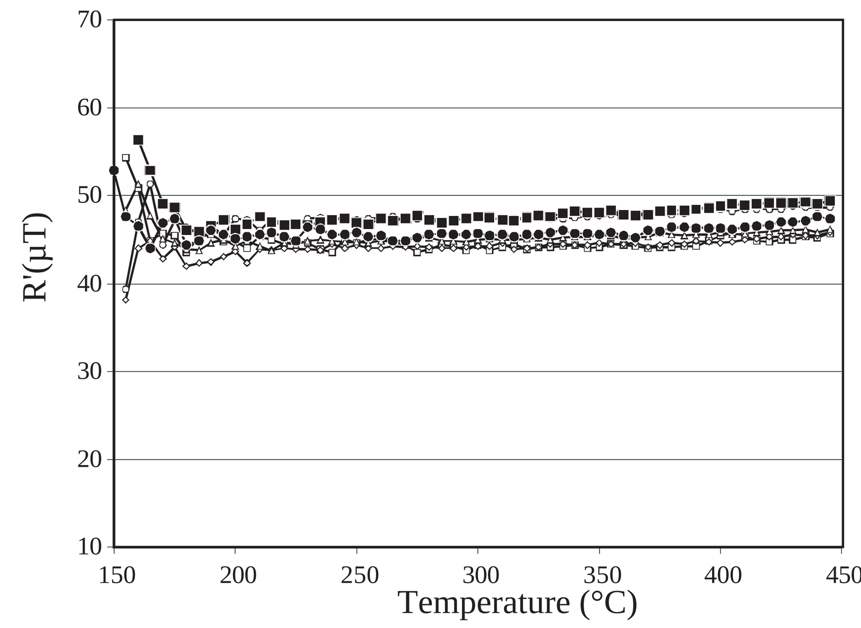


Figure 5: Archeointensity results from site MR15

2. Acquisition of new archeointensity data in the Middle East

Several hundred samples, principally from French and Mesopotamian archeological artifacts were analyzed using the new Triaxe procedure (Fig. 4,5). Some of these samples were previously analyzed using the classical Thellier and Thellier (1959) method revised by Coe (1967) with stringent selection criteria and corrected for the anisotropy of the TRM and for the cooling rate dependence of TRM (Genevey et al., 2003). A detailed comparison between the results derived from the two methods was thus possible (Fig. 6; Gallet and Le Goff, 2006). The differences both at the fragment and site levels are mostly within +/-5%, which strengthens the validity of the methodology developed for the Triaxe.

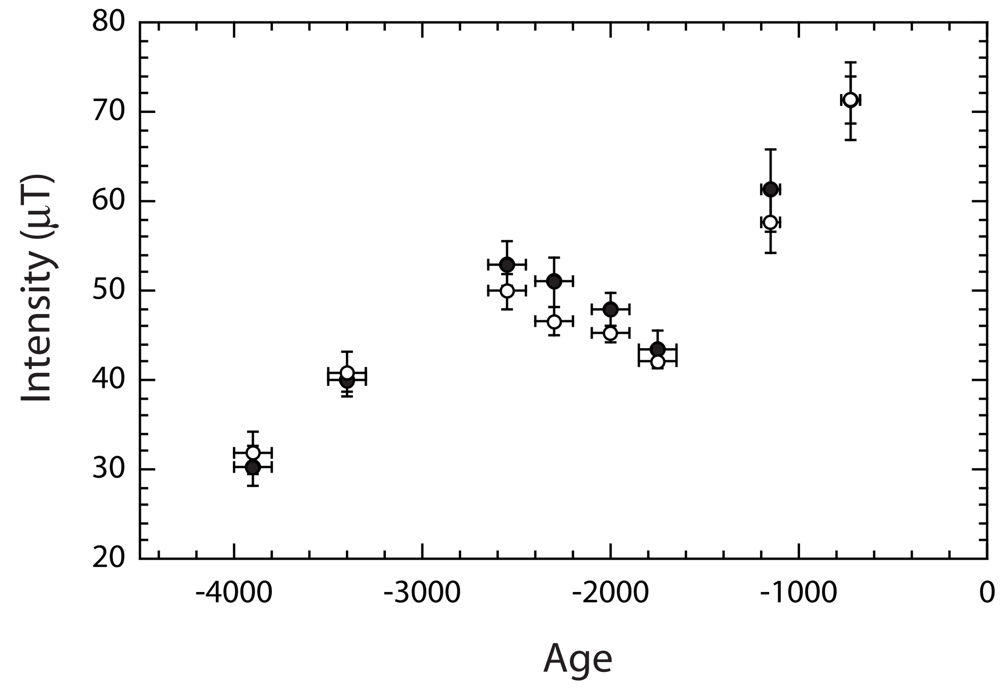


Figure 6 : Comparison between Mesopotamian mean intensity values obtained at the site level from the Triaxe (open symbols) and Thellier-Thellier (solid symbols) methods.

3. Rock magnetism experiments using the Triaxe

In addition to intensity determinations, the Triaxe can be used to design new rock magnetism experiments. As examples, we report in Fig. 7 viscosity experiments made on a brick sample at different temperatures and the Fig. 8 shows two tests on the TRM additivity property for an archeological and a volcanic samples.

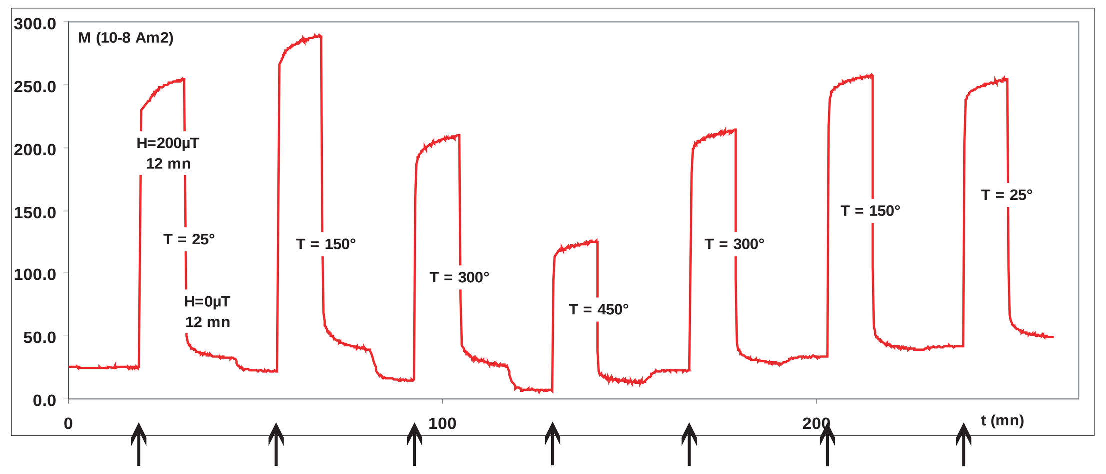
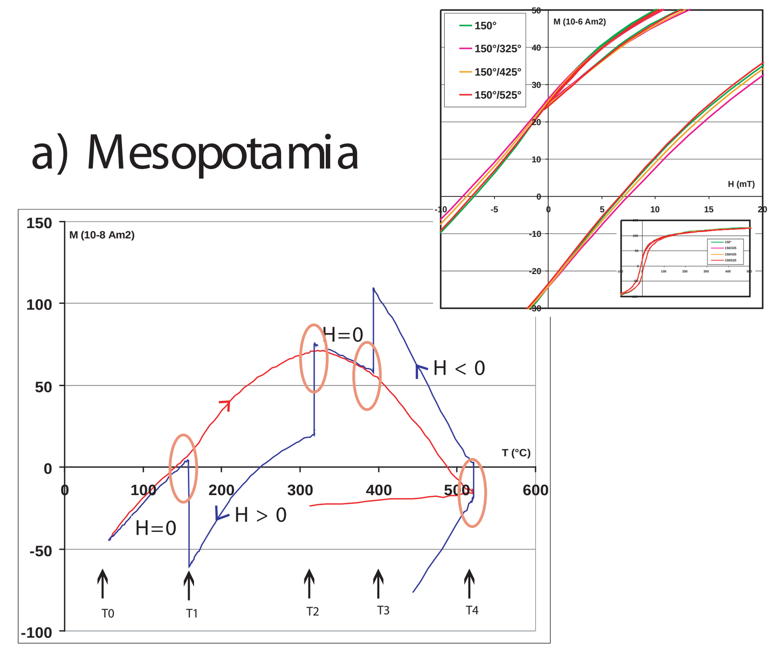


Figure 7: Example of viscosity experiments on a Mesopotamian brick sample. The vertical arrows indicate the time a field of 200 µT is applied during 12 mn and then turned off during the same duration. This sequence is repeated at different temperatures, from 25°C to 450°C and then back to 25°C.

a) Mesopotamia



b) Etna

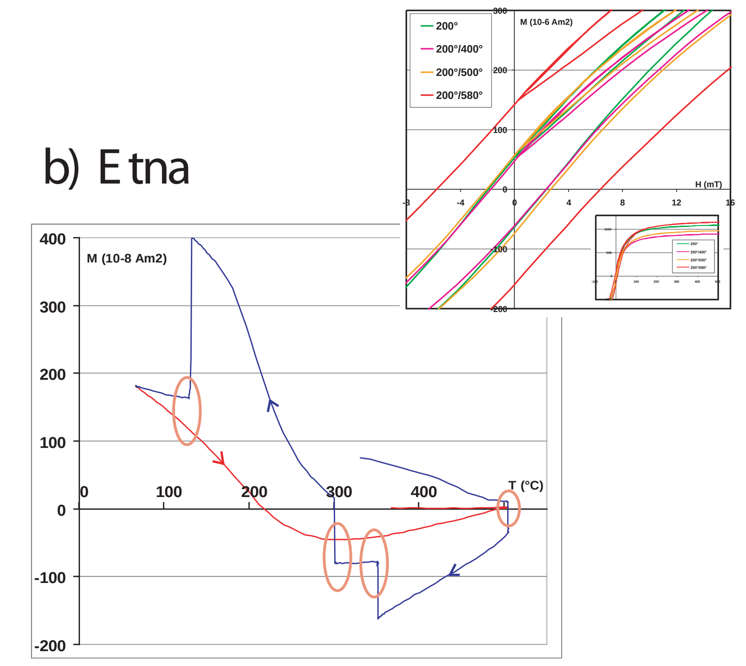


Figure 8: TRM additivity test carried out for two samples (a: a Mesopotamian brick sample, b: a volcanic sample from Etna). In the first case, the additivity property is valid and hysteresis loops performed at different temperatures on the same fragment do not show significant variations in Jrs. An opposite situation is observed in the second case (see ovals).

References :

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