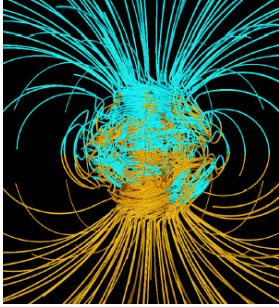


# Geomagnetic Archaeointensity as a Tool for Dating Ancient Slag Deposits: Examples from the Southern Levant

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## Abstract

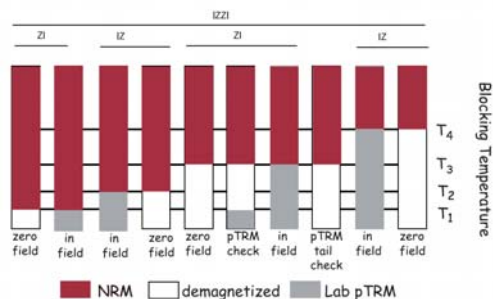
Extracting the intensity of the ancient geomagnetic field out of slag samples enables independent dating of slag deposits. This was demonstrated for various sites in Israel and Jordan. The resolution of the method depends on the quality of the pre-established variation curve for the region and its accuracy depends on application of rigorous experimental methods.

## Methodology

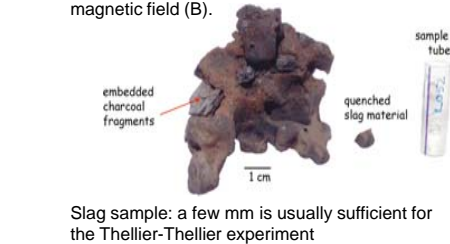
We have found slag samples (fine grained with glassy texture) to be an excellent recorder of the ancient magnetic field, yielding reliable intensity results when subjected to the *Thellier-Thellier* experiments.

$$\frac{TRM_{lab}}{B_{lab}} = \frac{TRM_{ancient}}{B_{ancient}} \Rightarrow B_{ancient} = \frac{TRM_{ancient} \cdot B_{lab}}{TRM_{lab}}$$

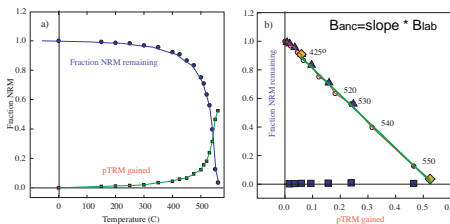
Principle of linearity in the acquisition of thermal remanent magnetisation (TRM) when sample is cooled under Curie Temperature in a magnetic field (B).



The experimental procedure: heating the sample in stages under controlled magnetic field (I = in field, Z = zero field) and tracking the partial thermal remanent acquired (pTRM) vs. natural remanent (NRM) left.



Slag sample: a few mm is usually sufficient for the Thellier-Thellier experiment



Interpreting the results: "Arai plot"

## Case studies: sites in the southern Levant



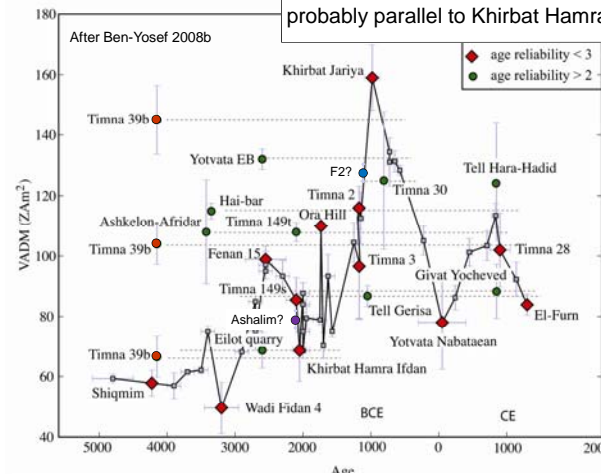
**Reference curve:** Levantine ever-growing database, Ben-Yosef et al. 2008a and others

*Along the Arava Valley, Israel:*

**Timna Site 39:** Considered by its excavator to represent the oldest smelting installation in the world, dated to the 5<sup>th</sup> millennium BCE. Our results show multi-period usage, including probably this early phase.

**Timna Site F2:** Considered by its excavator to represent Neolithic smelting. Our results show it belongs to the Late Bronze – Iron Age phase of metal production at Timna.

**Ashalim site:** Was never excavated and no good date can be obtained from surface artifacts. Our results indicate Early Bronze smelting, probably parallel to Khirbat Hamra Ifdan, Faynan, Jordan.



## Conclusions and caveats

- Dating using archaeointensity is still tentative and will improve according to the resolution of the variation curve
- It is easier to exclude dates (e.g. Site F2) than to assign a definite age to a site
- Dating resolution can be improved using oriented samples and geomagnetic direction measurements
- Well dated slag deposits are an excellent source for constructing variation curves all around the world (most pyrotechnological materials are suitable and are commonly associated with 14C samples)

## References:

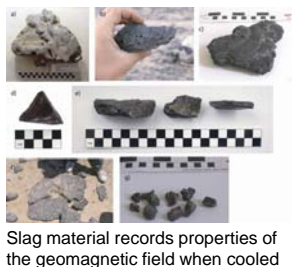
- Ben-Yosef, E., et al. 2008a. Application of copper slag in geomagnetic archaeointensity research, *Journal of Geophysical Research* 113.
- Ben-Yosef, E., et al. 2008b. A New Approach for Geomagnetic Archaeointensity Research: Insights on Ancient Metallurgy in the Southern Levant, *Journal of Archaeological Science* 35, 2863-2879.

## Acknowledgments

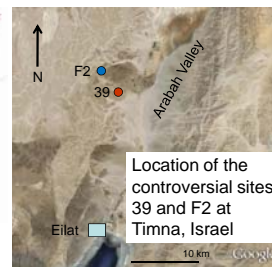
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Slag deposits are often hard to date (Be'er-Ora, Israel)



Slag material records properties of the geomagnetic field when cooled



Location of the controversial sites 39 and F2 at Timna, Israel



Site 39 at Timna – Is it the oldest smelting furnace in the world?



Standing stones and a scatter of slag pieces at Ashalim – enigmatic site near the Dead Sea, Israel



Sampling slag at Faynan, Jordan