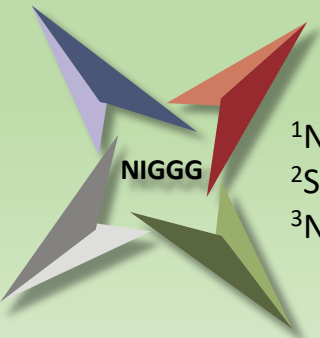


Geomagnetic field variations and low success rate of archaeointensity determination experiments for Iron Age sites in Bulgaria

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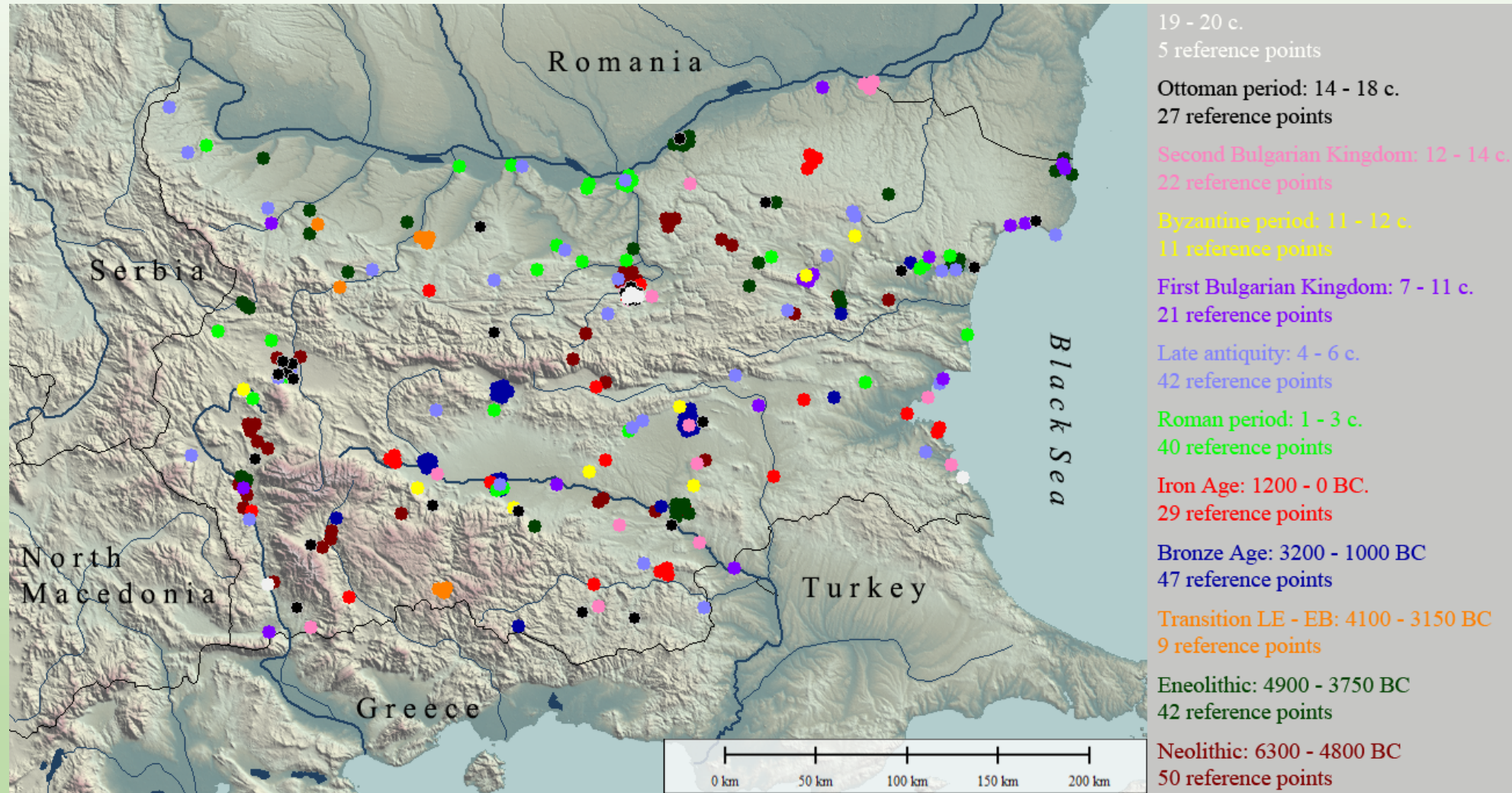


St. Petersburg
University



1892 - 1921 - 1948

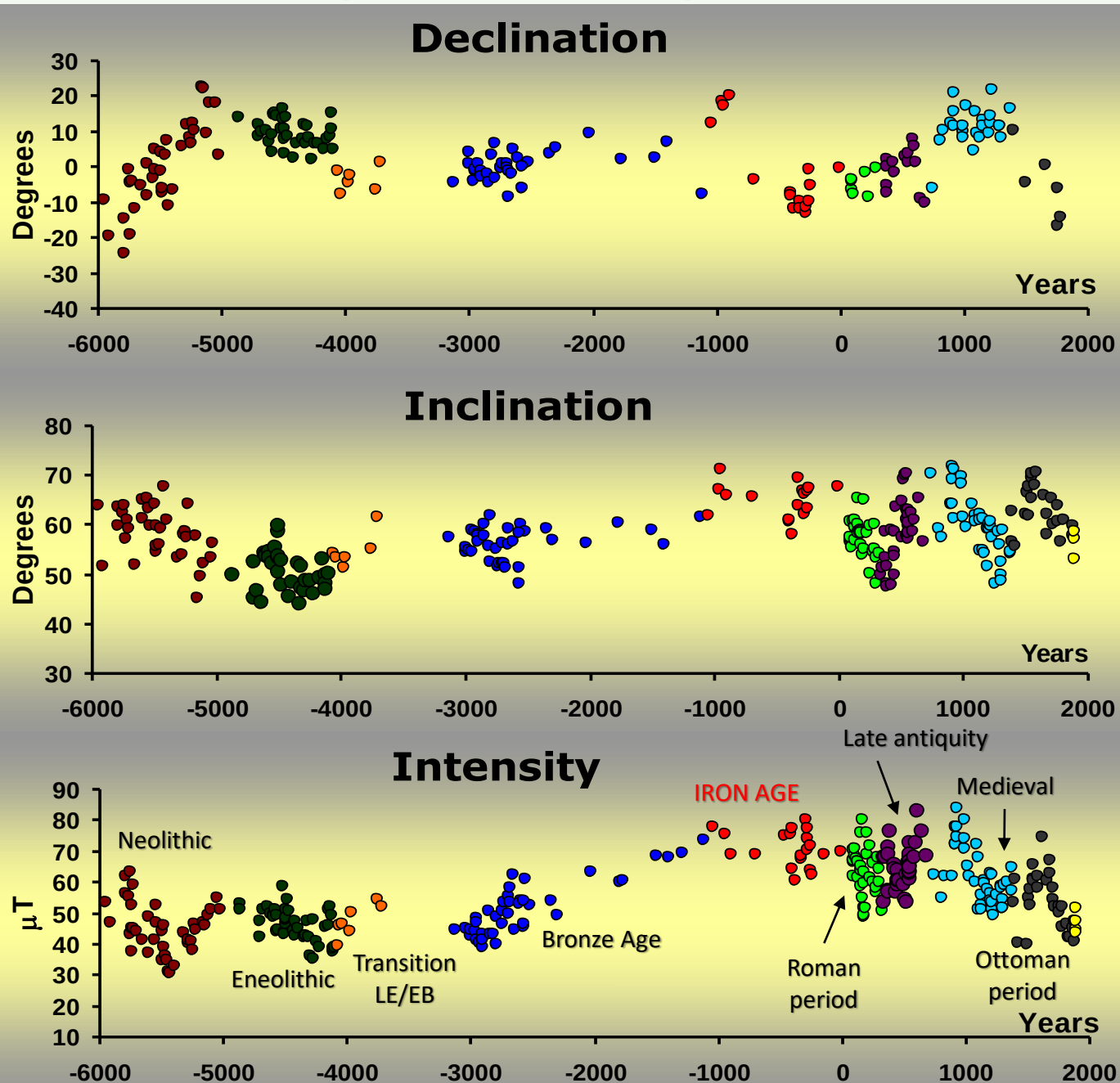
Bulgarian archaeomagnetic database – the longest local geomagnetic field record covering almost completely the last 8000 years



Archaeomagnetic database for Bulgaria is crucial for constructing the geomagnetic reference curves for the Balkan Peninsula

Large number of the reference archaeological sites together with experimental precision in archaeomagnetic determinations are the key issues influencing the representativeness of the reference curves

Poorly constrained periods in need of elucidation still exist

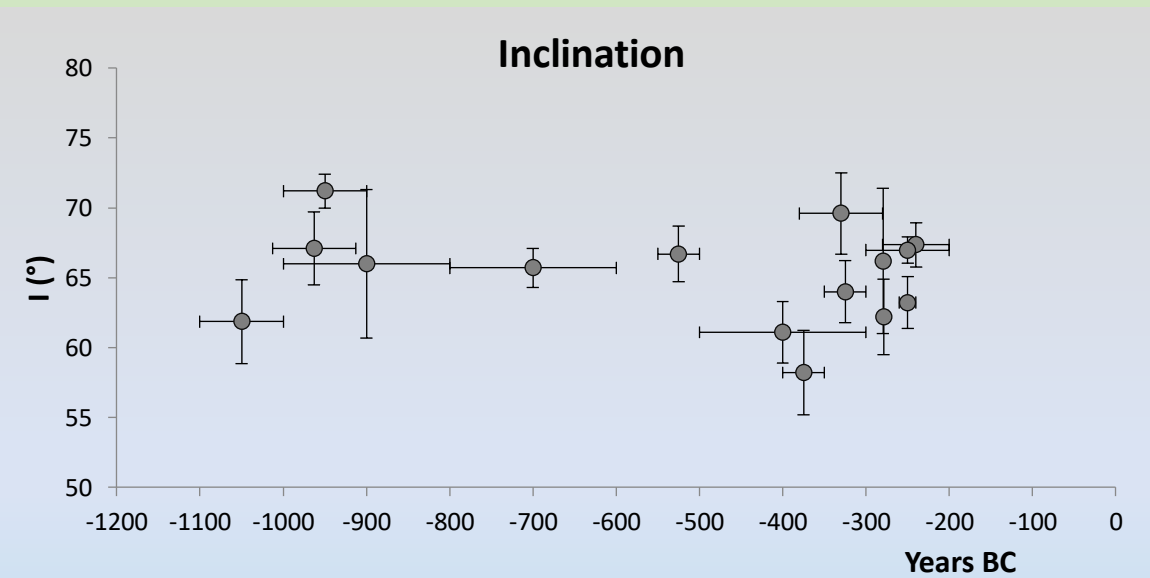
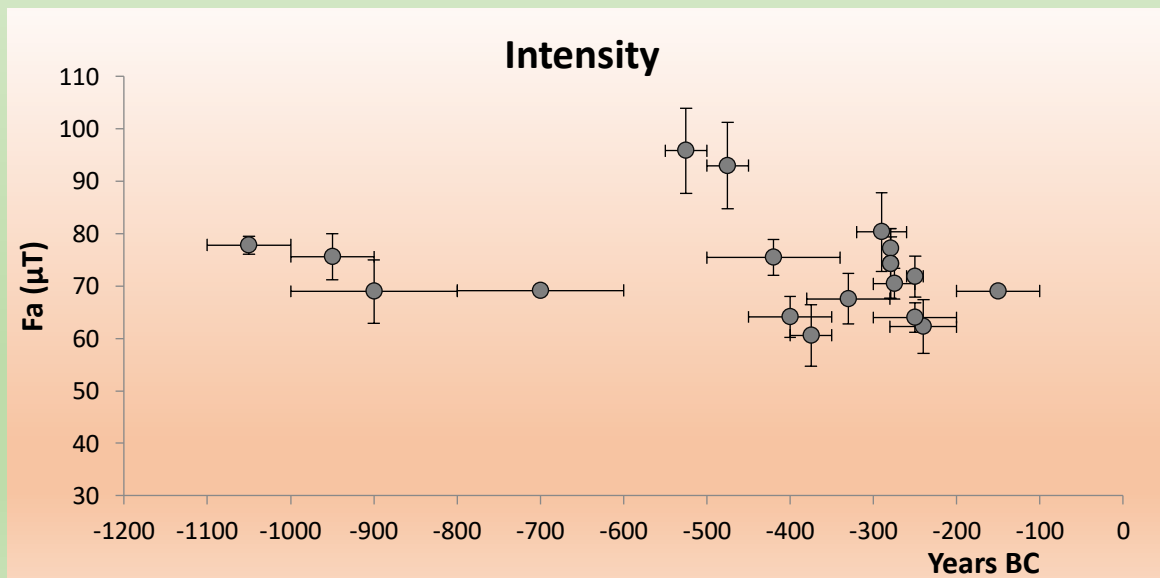
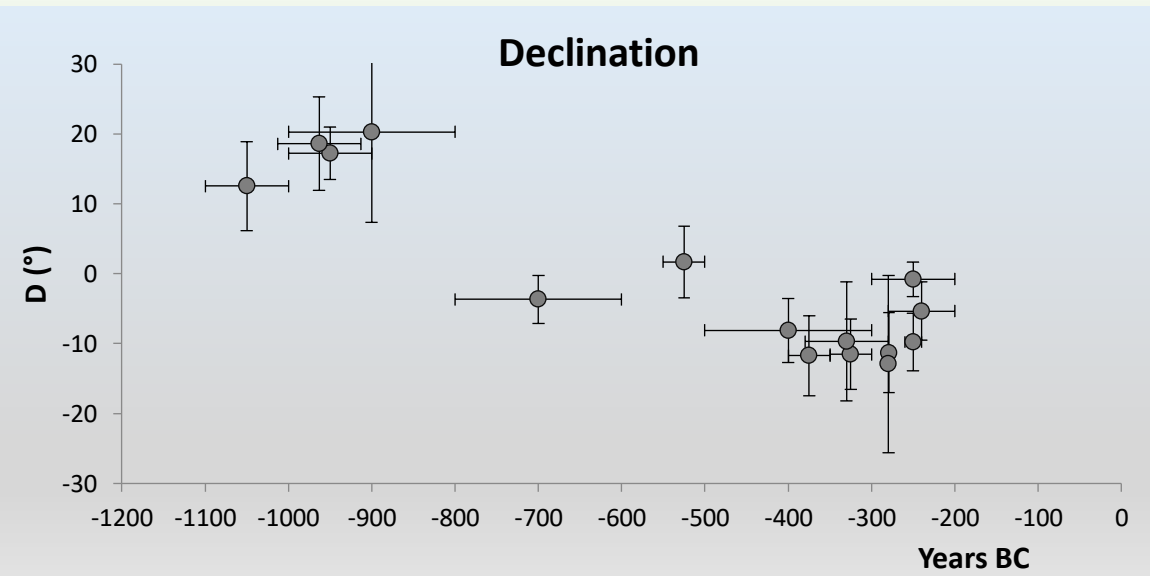


Raw archaeomagnetic data demonstrate that in several periods the number of reference sites is still insufficient to constrain reliably the geomagnetic elements variations

The last 1200 years BC corresponding to the Iron Age in Bulgarian lands are among the most problematic

In contrast to the relatively well studied Neolithic, Eneolithic and Bronze Age settlements, the Bulgarian Iron Age sites (especially in the Early Iron Age phase) do not possess precise stratigraphic frames. This hampers significantly the specification of their chronology.

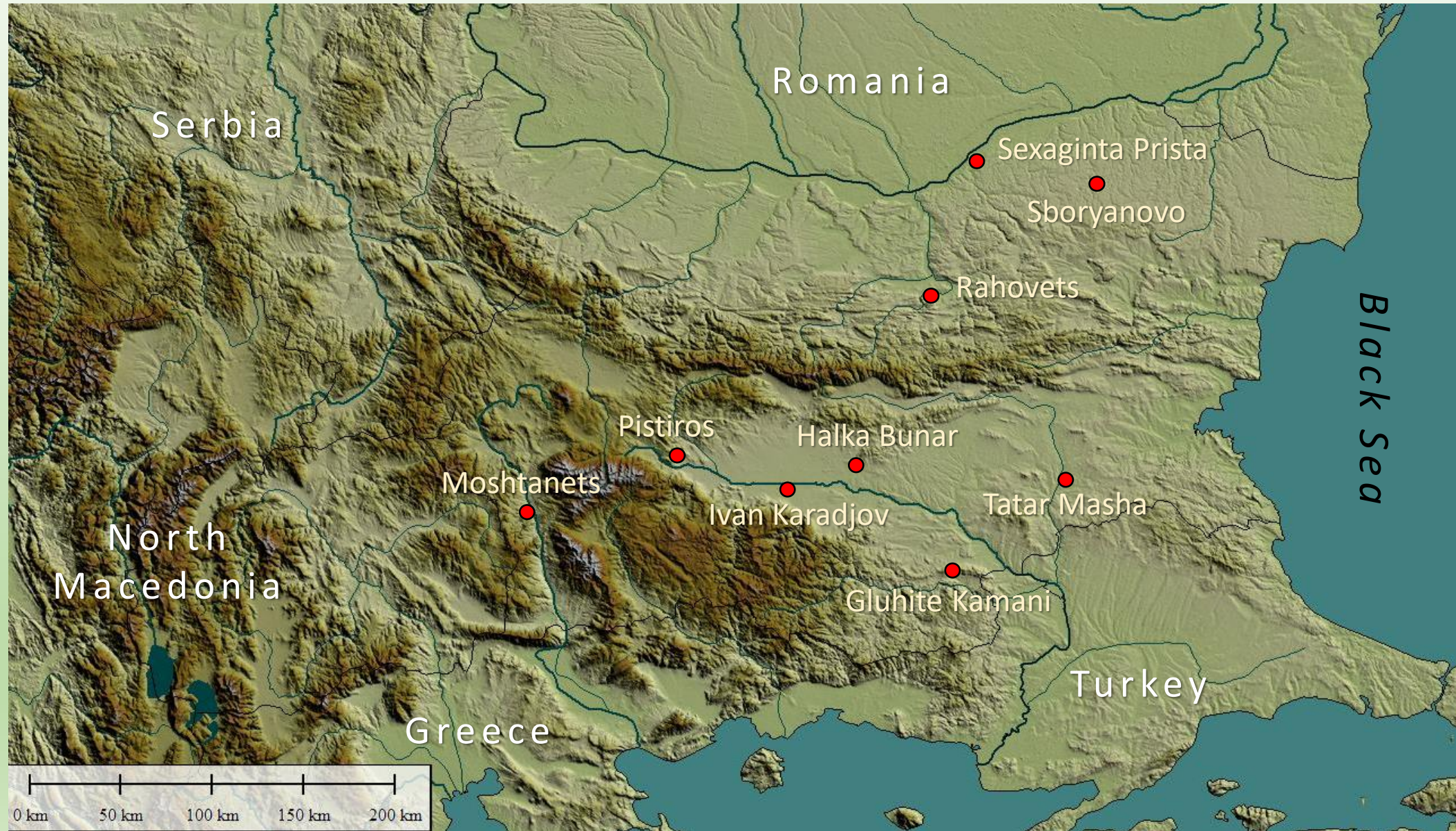
Thus, the discovered archaeological sites rather rarely can be used as reliable input data for the reference geomagnetic curves



Kovacheva et al. 2014 – 18 intensity and 16 directional data

Number of independently oriented samples per feature > 2; Number of accepted results ≥ 2

To fill the gap in the database 26 baked clay structures from 9 archaeological sites were sampled and studied archaeomagnetically



The new sites

Rahovets Fortress
(1 structure)



1300 – 1100 BC*

Gluhite Kamani
(3 structures)



1300 – 1100 BC

Moshtanets
(1 structure)



1100 – 800 BC

Pistiros
(9 structures)



400 – 300 BC

Ivan Karadjov
(1 structure)



400 – 250 BC

Sboryanovo
(2 structures)



400 – 200 BC

Tatar Masha
(5 structures)



290 – 285 BC

Sexaginta Prista
(2 structures)

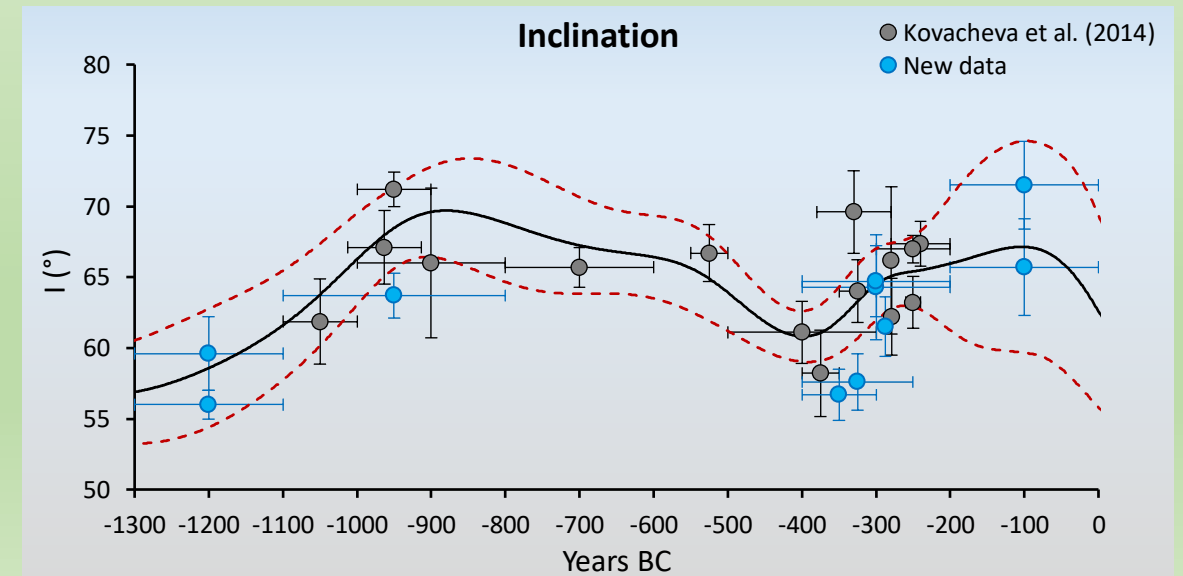
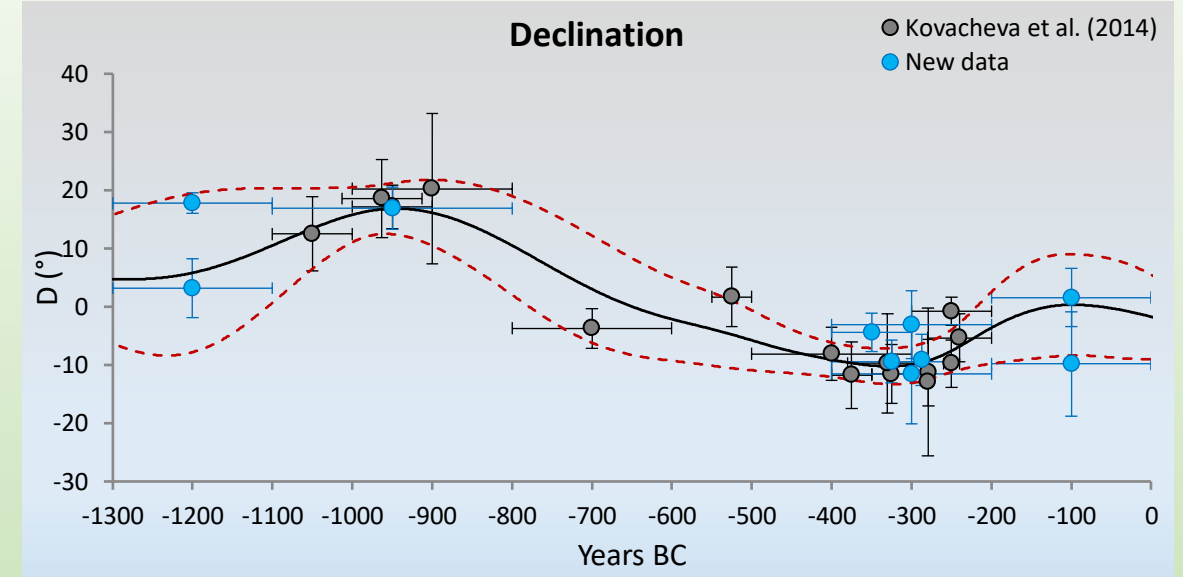
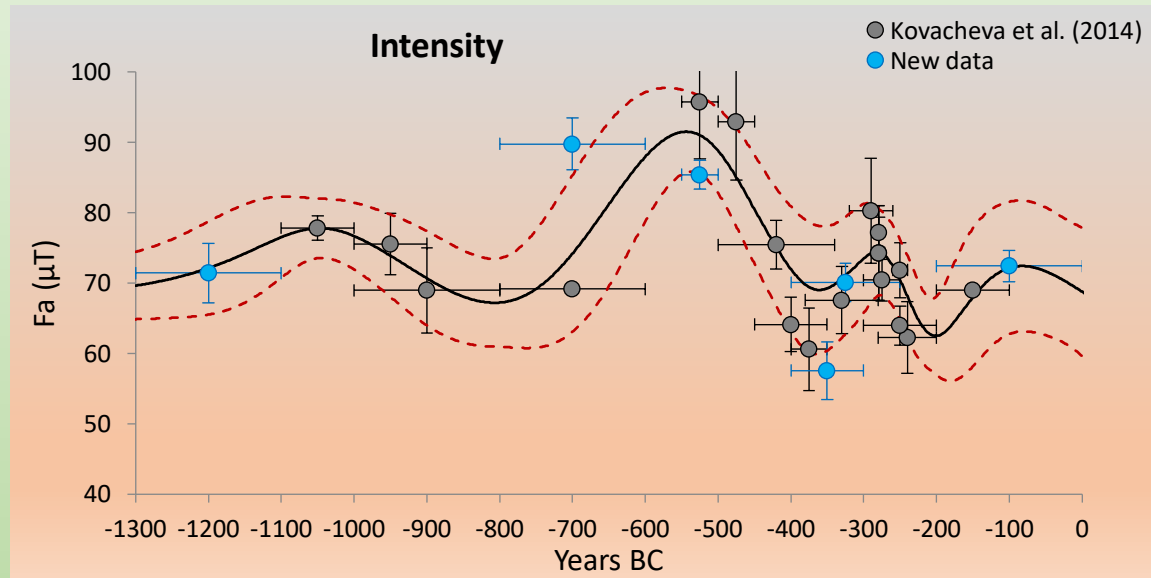


200 – 0 BC

* The dates given are archeological

Ten new directional but only six intensity data were obtained

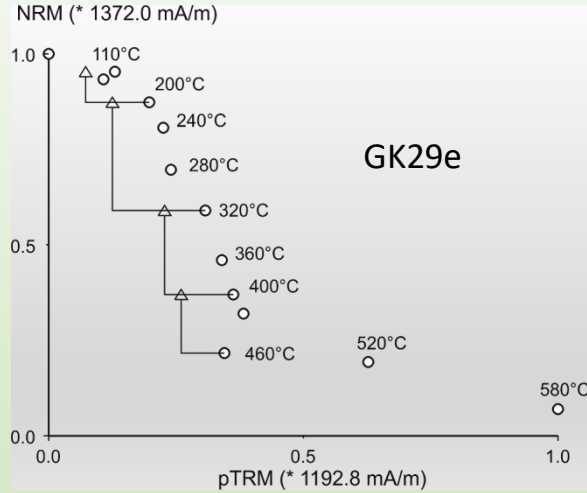
The new data agree well with the Bulgarian dataset
(Kovacheva et al. 2014)



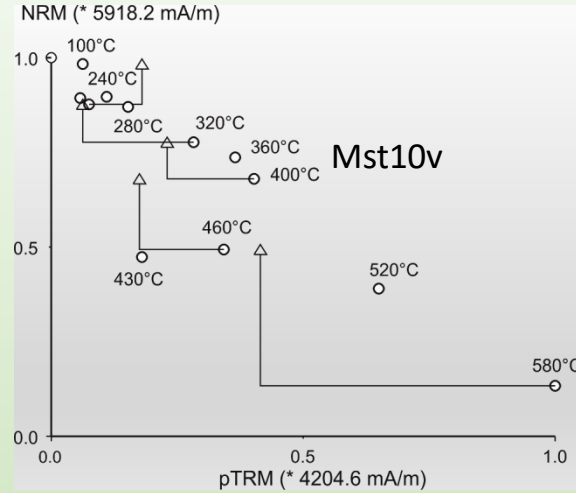
The abrupt AI change between 500 and 300
BC is confirmed

Numerous rejected archaeointensity determination for the new sites

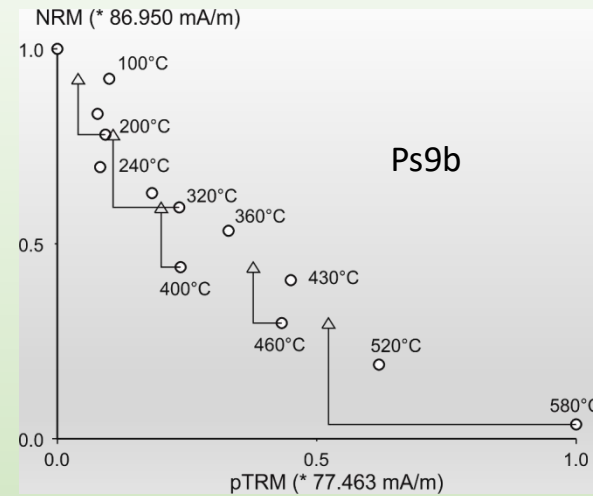
Gluhite Kamani



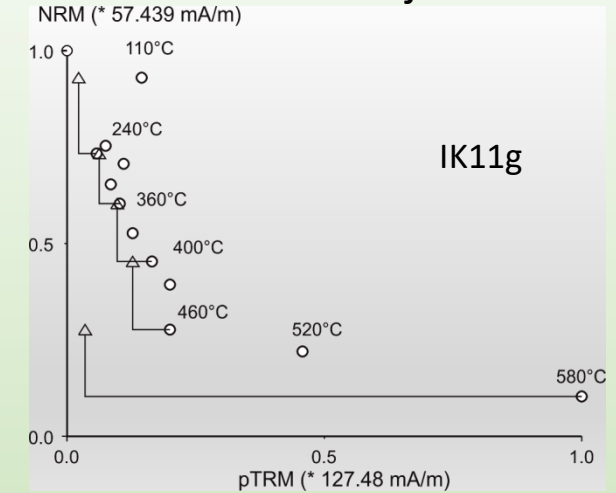
Moshtanets



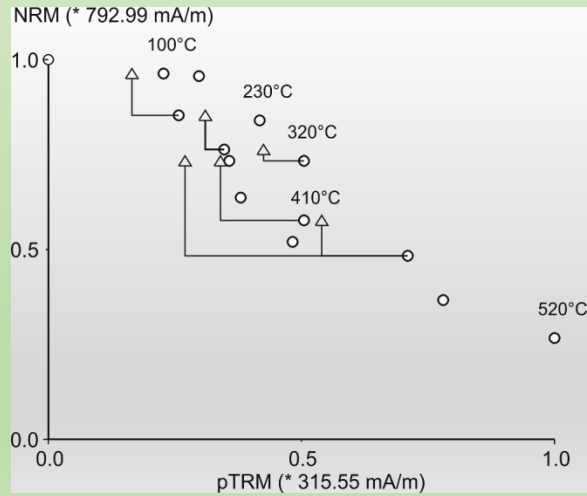
Pistiros



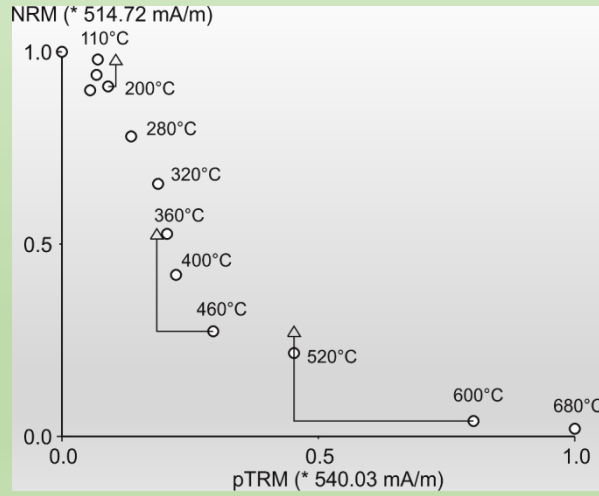
Ivan Karadjov



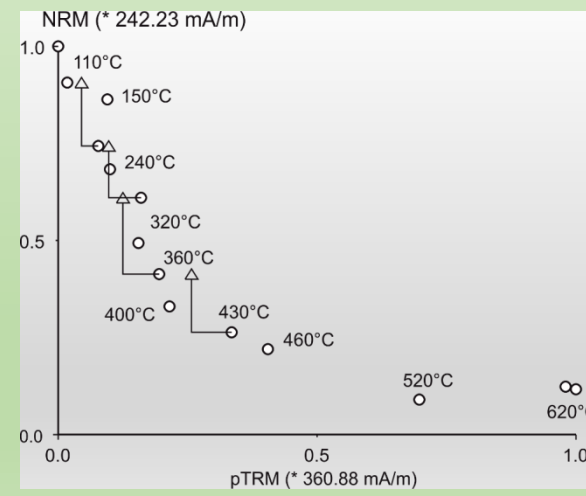
Sboryanovo



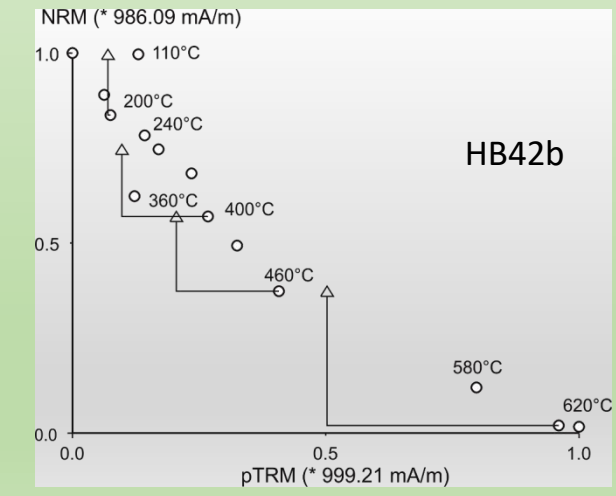
Tatar Masha



Sexaginta Prista

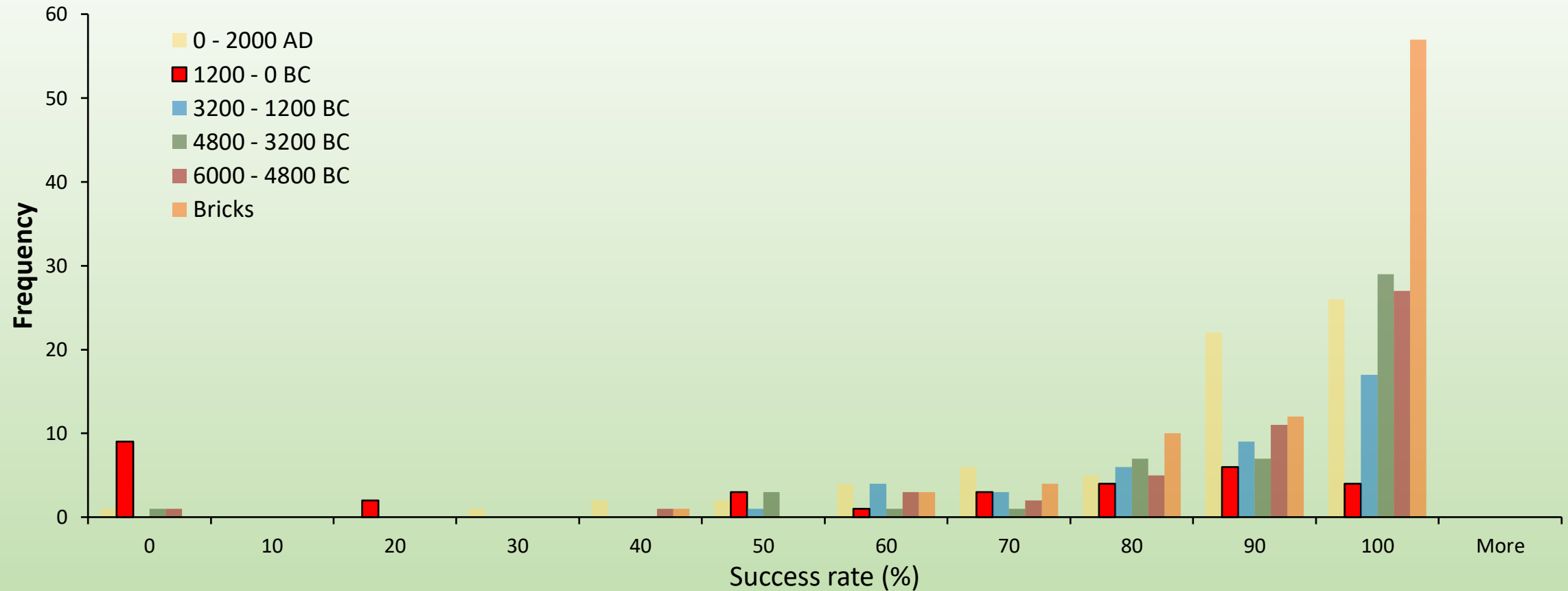


Halka Bunar



Iron Age materials often show magnetic properties unfavorable for archaeomagnetism, generally reflected in non-linear and concave Arai plots

Comparison of AI determination success rate for the different periods studied archaeomagnetically

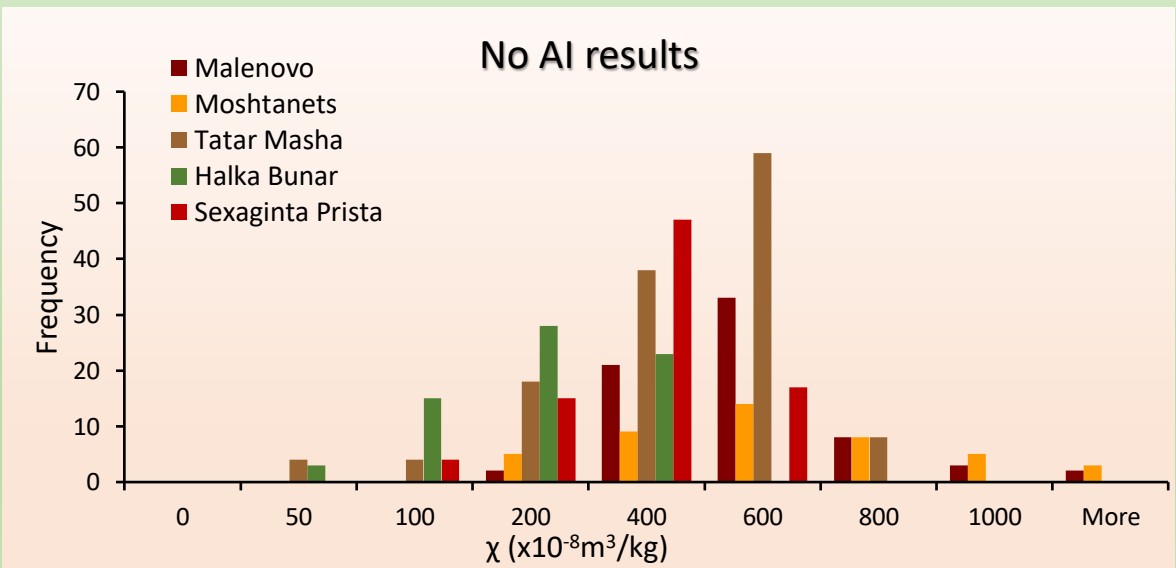
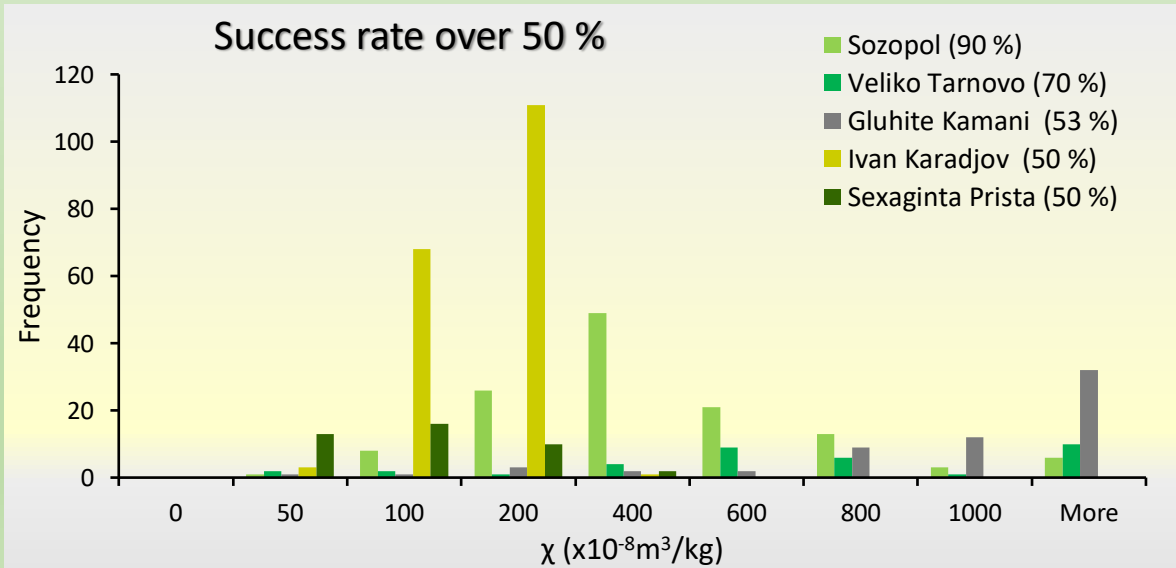
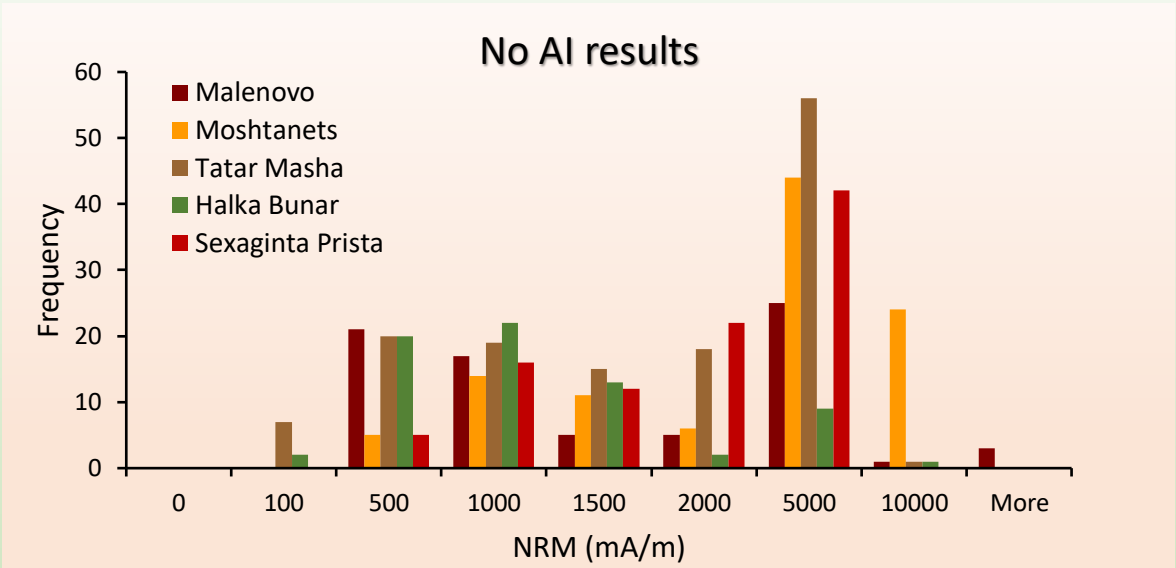
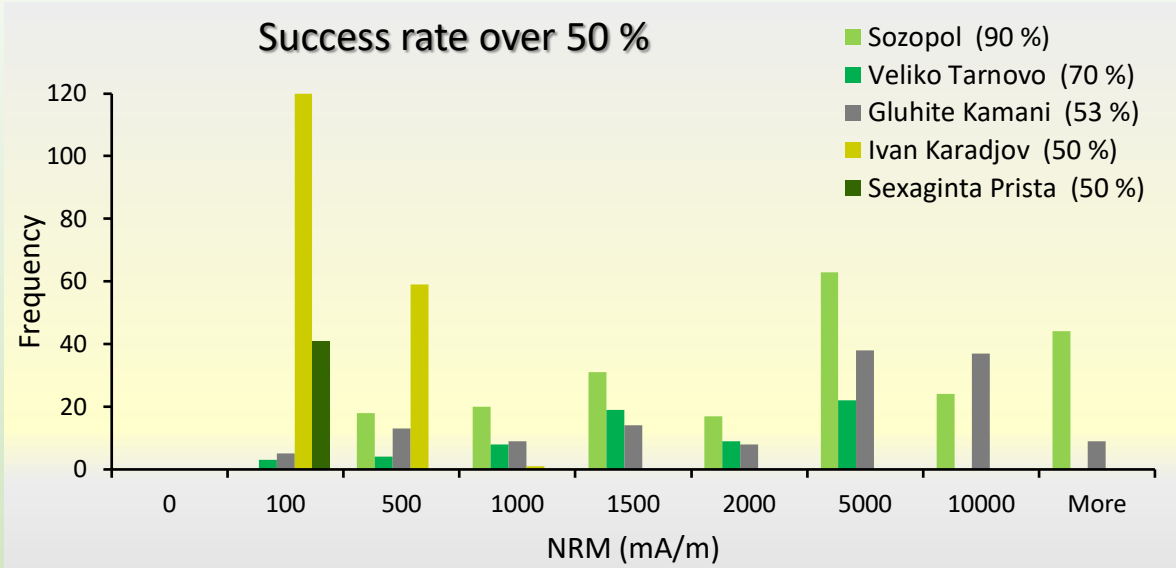


Iron Age – the epoch with the lowest number of reference points
where successful features comprise only 56 % of the total number studied (28 % failure)

More than 90 % of the investigated features belonging to other epochs normally display success rates over 50 %
(only for 1 – 2 % the archaeointensity determination experiments fail completely)

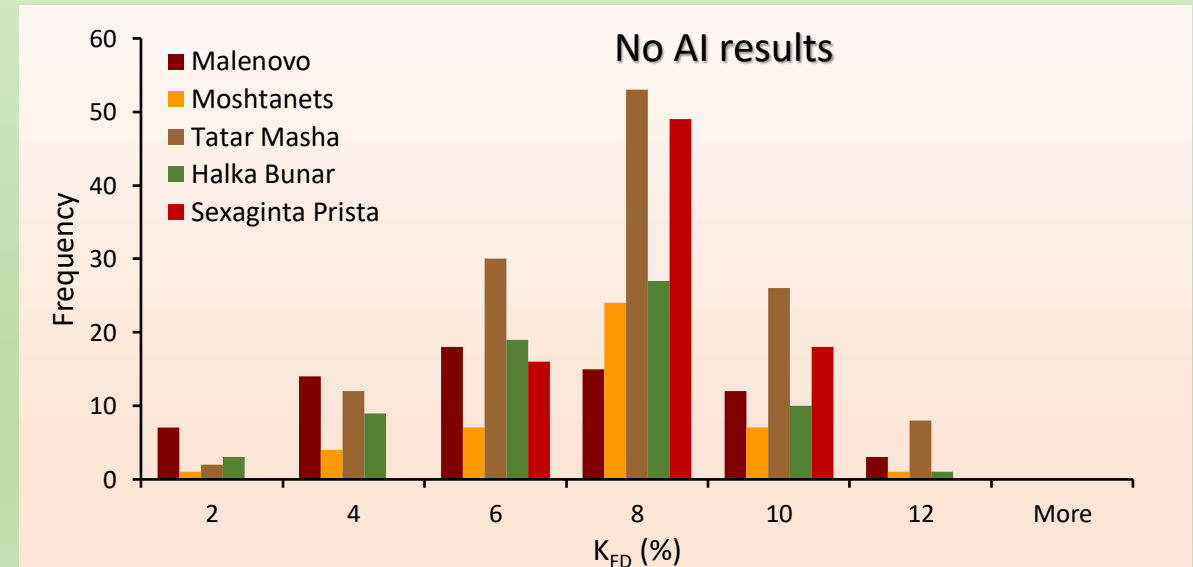
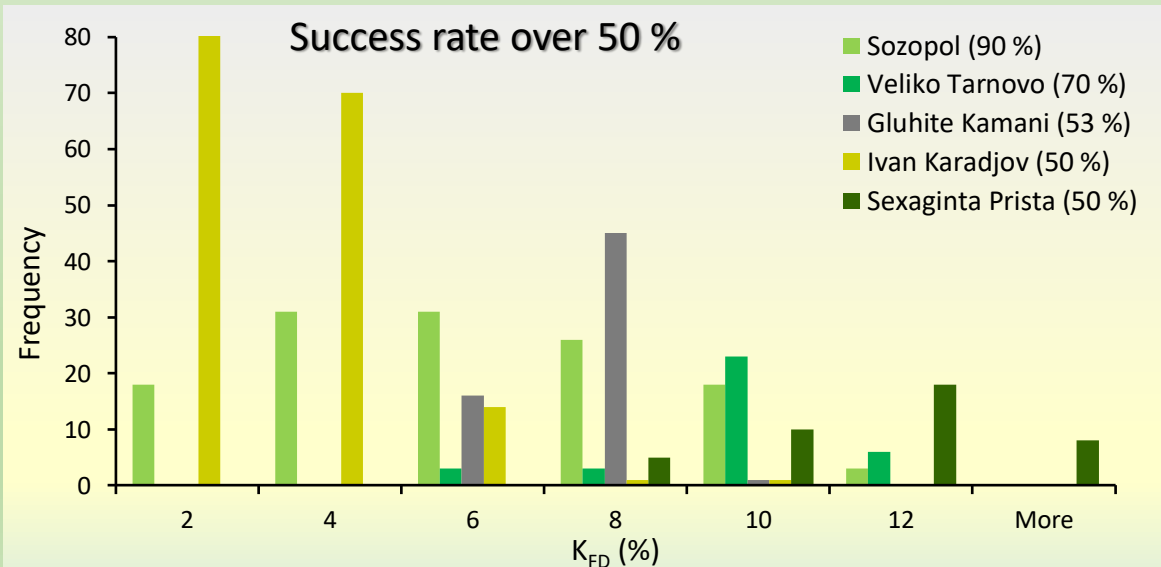
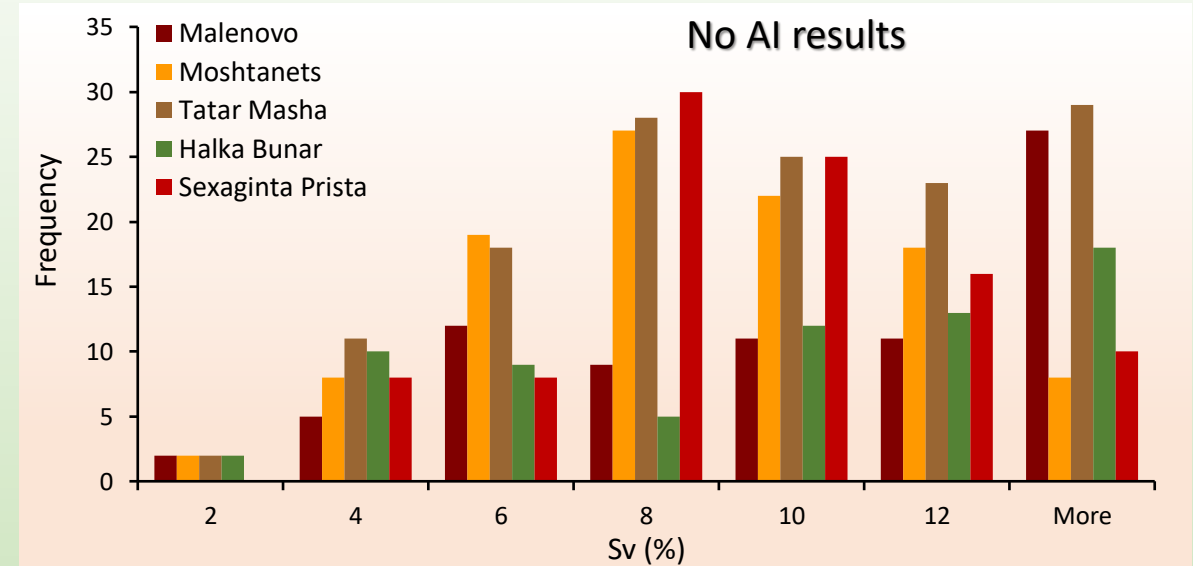
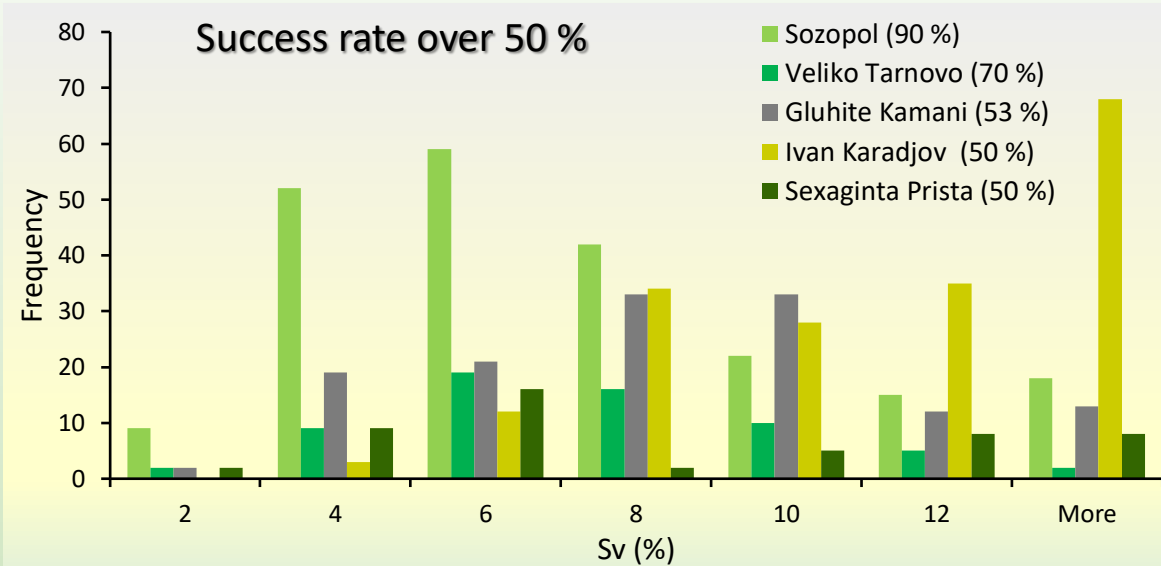
Kostadinova-Avramova and Kovacheva (2015) explain the failure of AI determination experiment of one Iron Age site – Malenovo with unfavorable grain-sizes of the prevailing magnetic carriers, paying attention to the importance of multiple heating for the stabilization of magnetic properties. The fact that the application of strict pre-selection criteria does not always ensure the success of AI determination experiment was also noted in this study.

It turns out that routinely applied pre-selection criteria do not help much to discriminate between appropriate and inappropriate (for AI determination) Iron Age samples



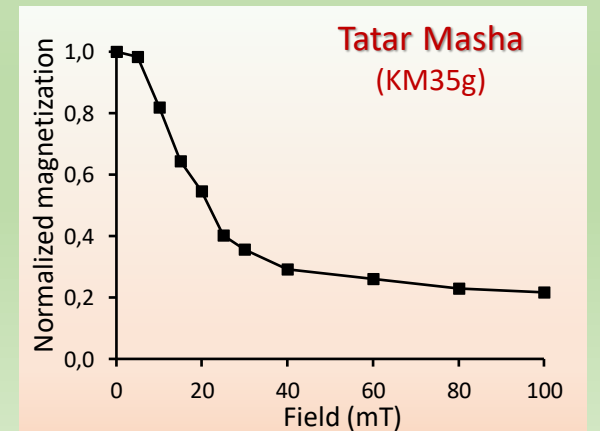
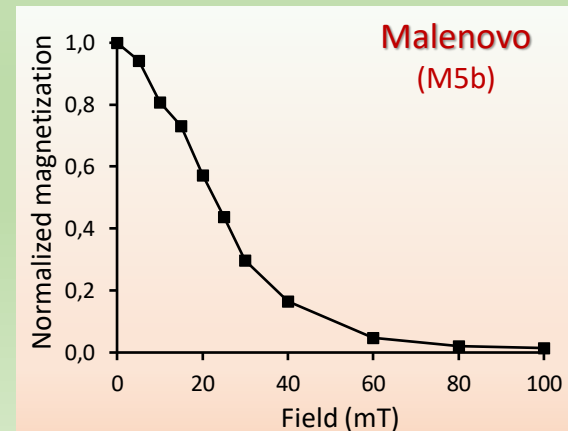
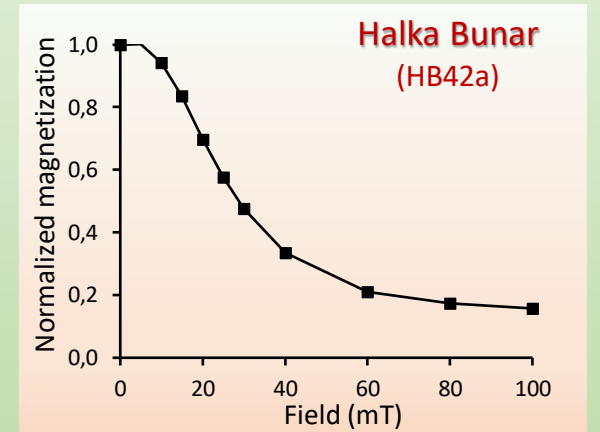
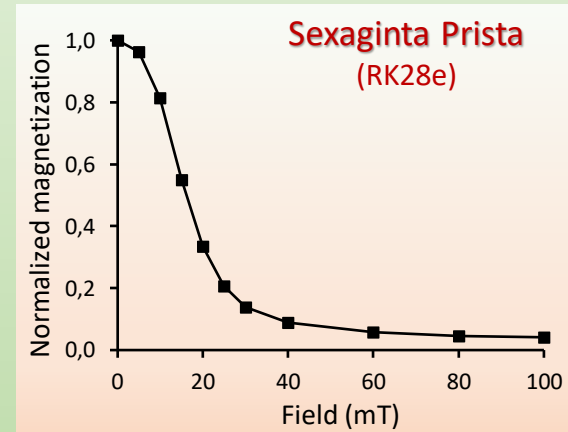
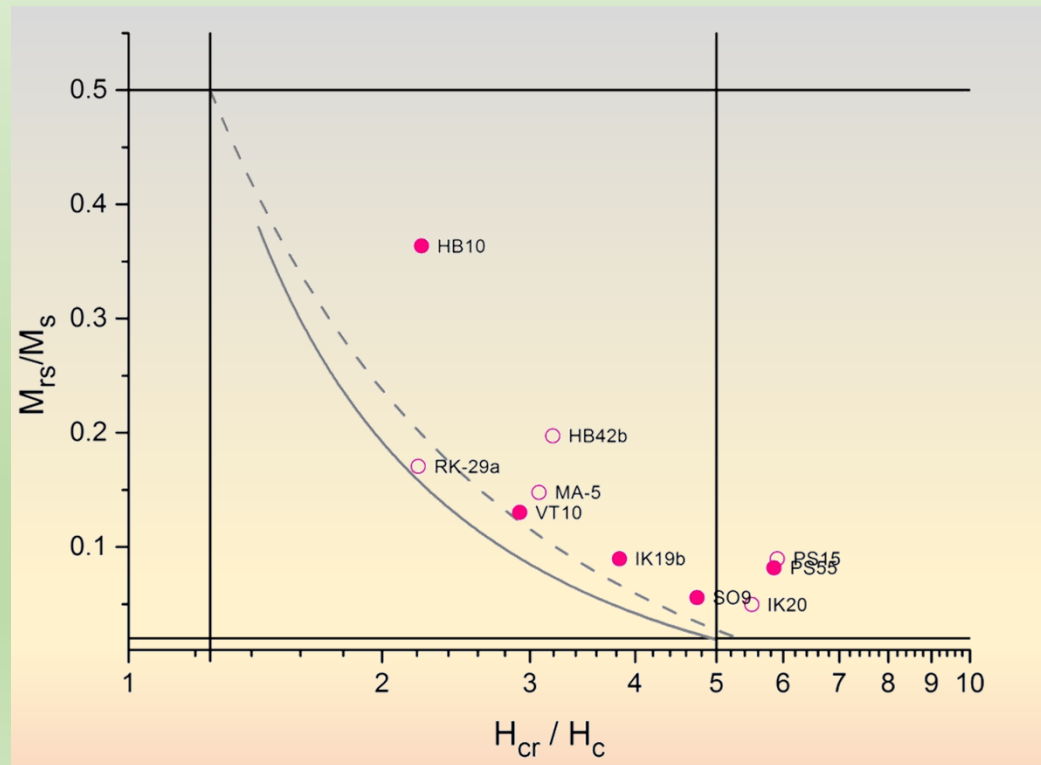
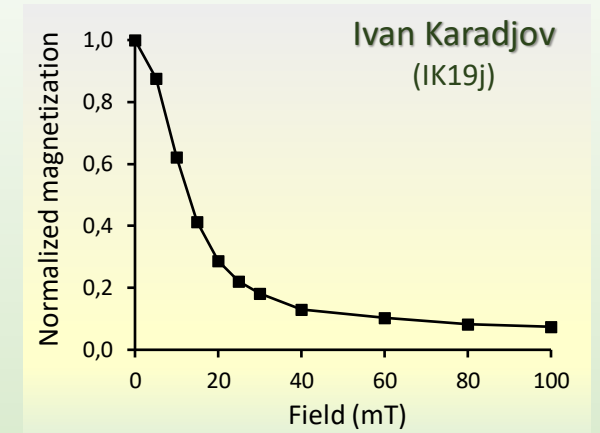
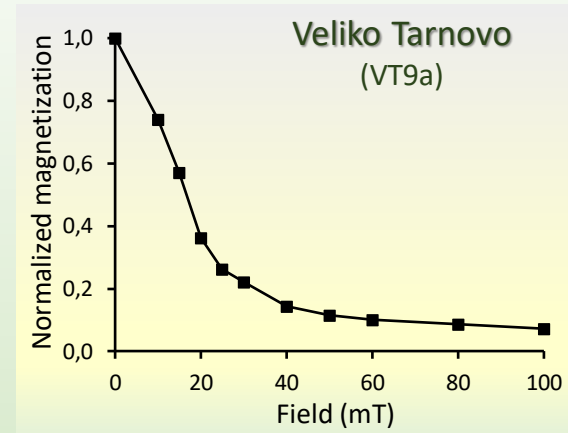
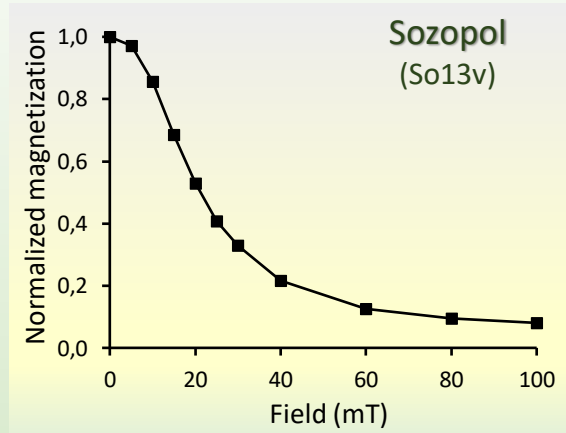
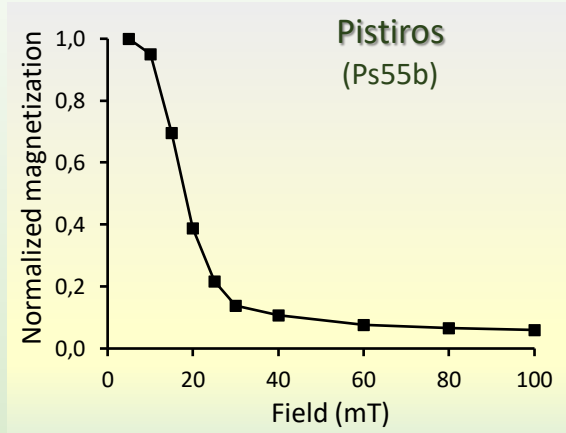
Measured magnetization (NRM) and mass-specific magnetic susceptibility (χ) often vary widely, suggesting variability in the concentration of ferromagnetic minerals typical for baked clay materials (*e.g. Kostadinova-Avramova et al. 2019*)

Wide distributions of Sv and K_{FD} values were observed within both groups of sites



It appears that “bad” collections contain more samples with viscosity over 10 % than the “good” ones.
AI determination experiment was applied only to the specimens having Sv below 6 – 8 %.

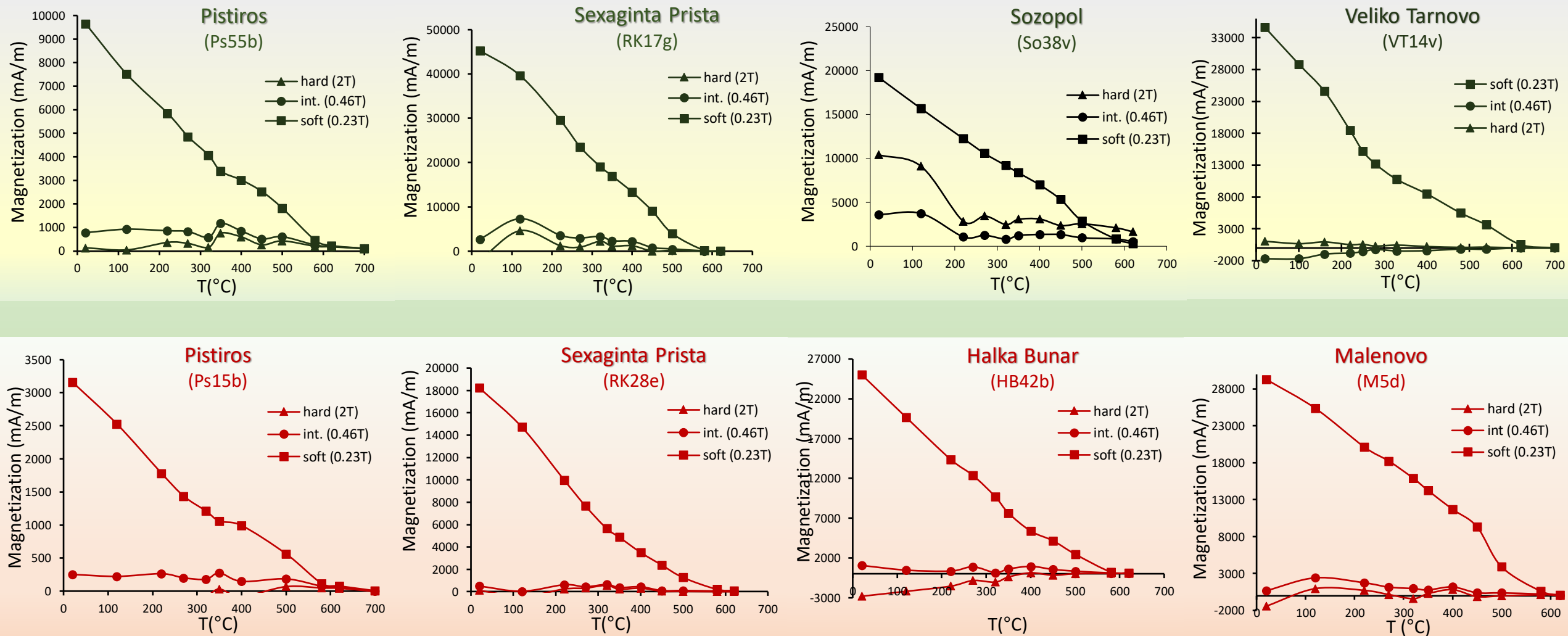
Magnetically soft minerals dominate in all collections but the presence of high coercivity phase can not be excluded



“good” sample – solid circle

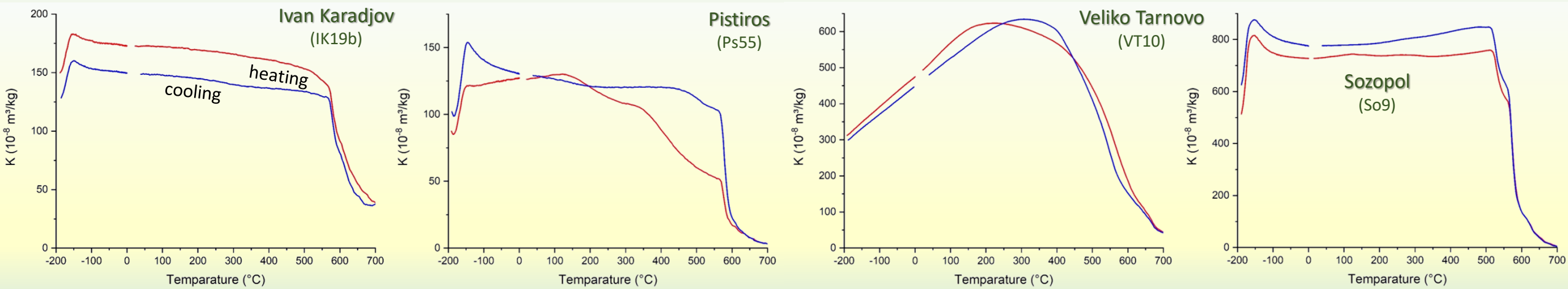
“bad” sample – empty circle

The dominant presence of soft phases – titanomagnetite, magnetite and maghemite is confirmed by *Lowrie (1990)* test

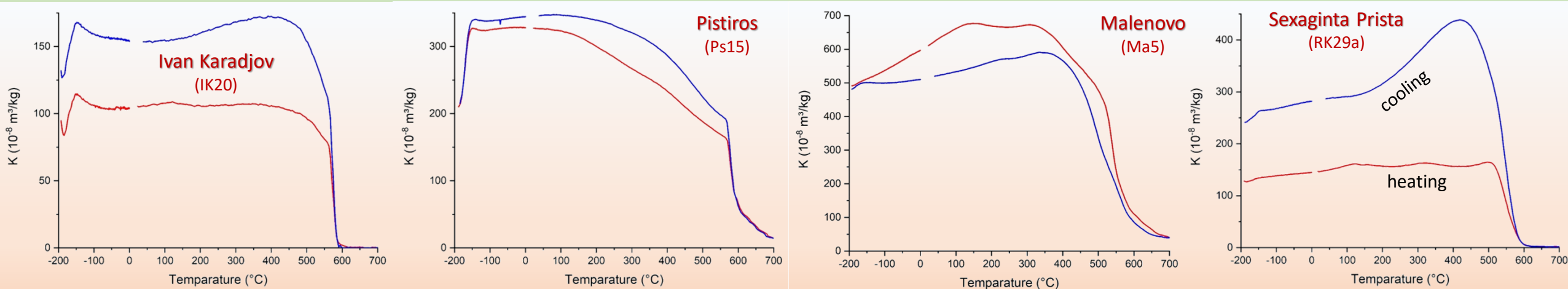


High coercivity minerals as hematite were less commonly suspected. Epsilon iron oxide (*McIntosh et al. 2007; Lopez-Sanchez et al. 2017*) was detected only in one collection – Sozopol (*Kostadinova-Avramova et al. 2020*)

As expected “bad” samples show greater irreversibility of heating-cooling curves than the “good” ones

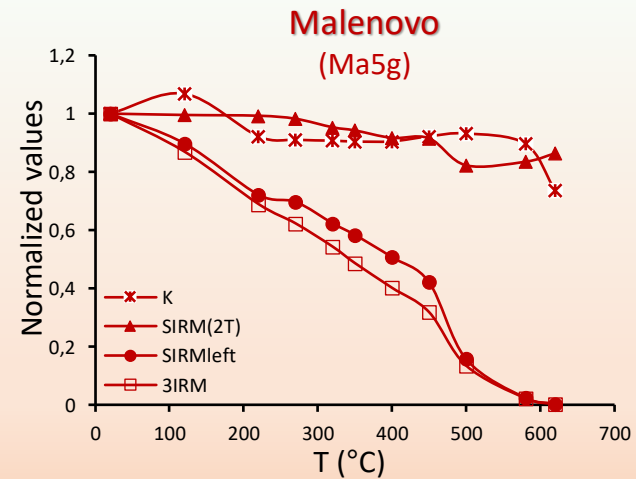
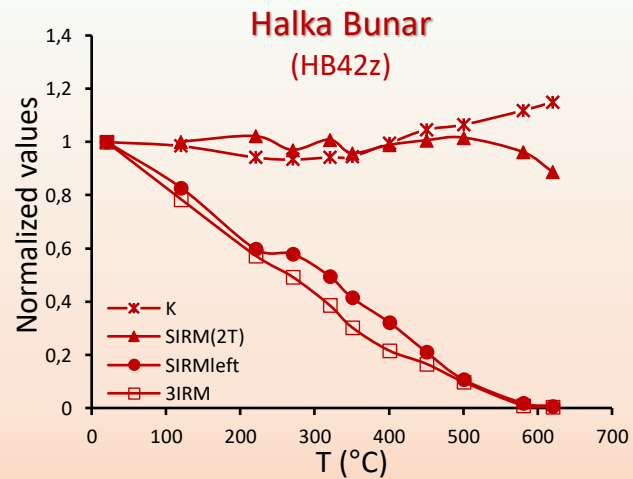
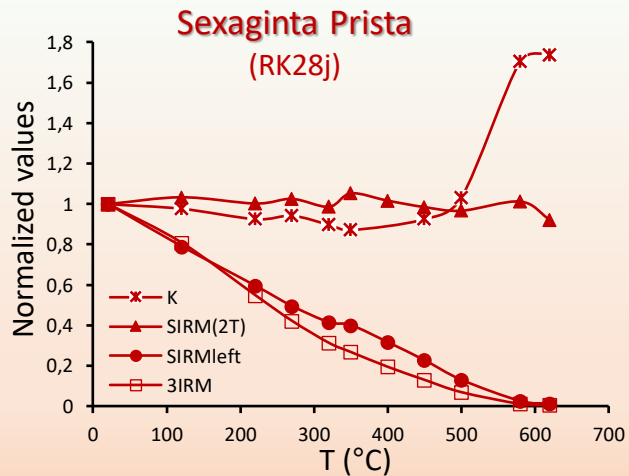
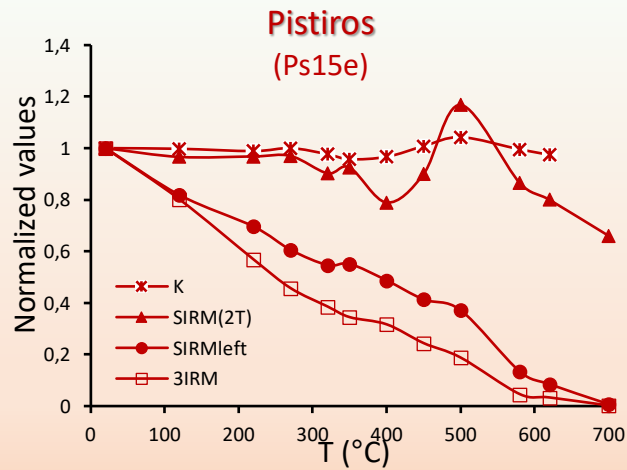
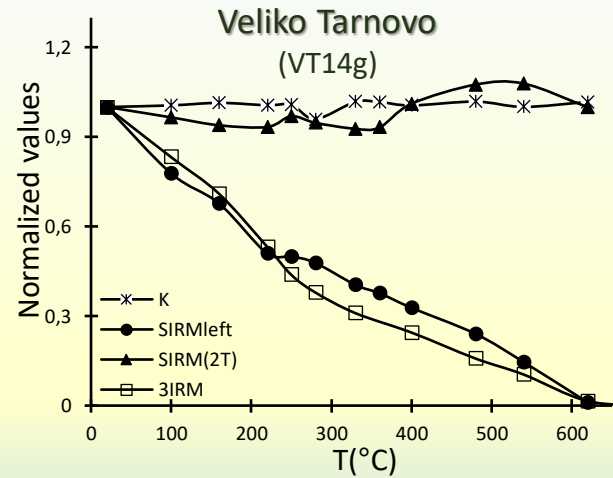
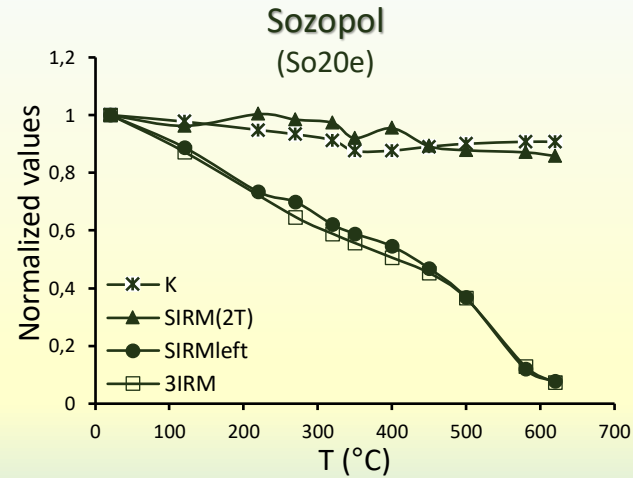
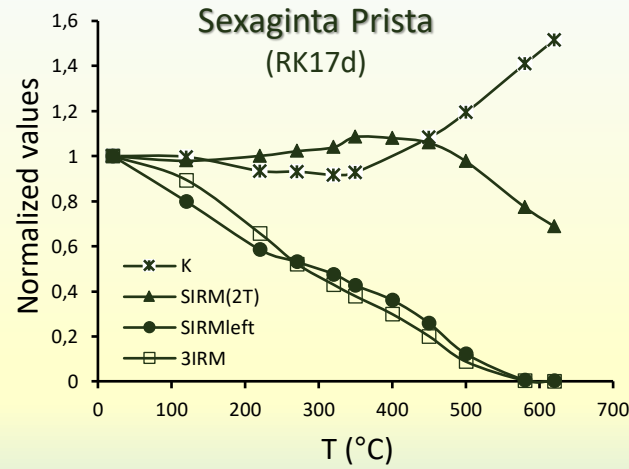
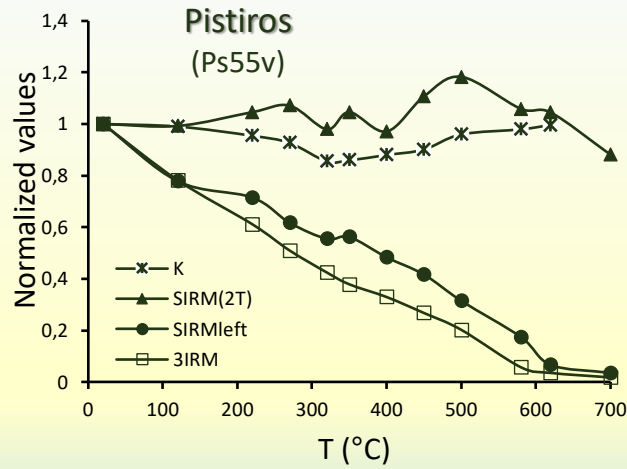


However, the observed differences are not so significant



Fairly complex magnetic mineralogy of the samples can be suggested

The observed mineralogical transformations are not substantially different between both groups of samples



$SIRM_{left}$ – residual part of laboratory induced isothermal magnetization; SIRM (2T) – isothermal magnetization induced (at 2T) after each heating step
 K – magnetic susceptibility; 3IRM – module of isothermal magnetization taken from Lowrie test induced once on a sister specimens.
 All values (measured at room temperature after each heating step) were normalized to the corresponding initial value.

Although, slight differences were observed for the “good” and “bad materials”, the performed experiments can not explain why exactly within the Iron Age archaeointensity determination is the most problematic.

Therefore, the question arises: What is specific to Iron Age baked clay material with regard to firing/burial conditions?

- ❖ Many studies document that Late Bronze Age (LBA) sites from the Balkan Peninsula through Mesopotamia to Egypt declined or collapsed during the first quarter of the twelfth century BC, termed LBA collapse. It is followed by the Dark Age (1200 – 825 BC) during which regional cultures are poorly documented. Hypotheses to explain the drastic changes in settlement patterns at the end of the LBA are divided into three broad classes: economic, military, and climatic (*Drake et al. 2012*). It is also widely accepted that an environmental change occurred in the first millennium BC, resulting in cooler, wetter climate and rising water-tables in the plain areas of Thrace which may be the cause of abandonment of flooded areas (*Chapmann et al. 2009*).
- ❖ Some authors (*e.g. Nikov 2000; Nehrizov 2005*) support a hypothesis of technological regress on the entire material culture through the Early Iron Age, which should also affect the combustion structures being constructed. In addition, there are some indications for single burning of a significant part of the sampled fireplaces (e.g. Pistiros, Gluhite Kamani) that could be a reason for insufficient stabilization of the magnetic properties.
- ❖ All the above facts taken separately may not be a sufficient explanation for the peculiar magnetic properties of the Iron Age materials. However, together they may be a reason for this unique discrepancy distinguishing the materials from the Iron Age from those of other periods. Further in-depth studies are needed to confirm this hypothesis.

Conclusions:

- Ten new directional and six new intensity data were obtained from nine Iron Age sites from Bulgaria (26 combustion structures studied).
- The new data agree well with the Bulgarian dataset confirming the possibility of abrupt change in archaeointensity between 500 – 300 BC.
- Fairly complex magnetic mineralogy can be suggested for the studied collections with dominant presence of soft phases (titanomagnetite, magnetite and maghemite). Hematite was less commonly suspected and an epsilon iron oxide-like phase was detected only in one site (Sozopol).
- Overall, the lowest success rate of archaeointensity determination experiments was observed for the Iron Age materials compared to the other epochs.
- The routinely applied pre-selection criteria were not very useful to discriminate between appropriate and inappropriate (for AI determination) Iron Age samples although slightly higher mineralogical changes imposed by heating correspond to the “bad” materials.
- A complex impact of several factors due to drastic environmental change followed by technological regress on the entire material culture through the Iron Age may be the reason for the so often observed failure of AI determination experiment. However, further in-depth studies are needed to confirm this assumption.

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Thank You
For Your Attention