The formation, alteration and significance of pyrogenic magnetic fabric in mid-paleolithic burnt cave facies

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Site and sampling – Why ash?

In situ (anthropogenic) (gravitational-falling?) + ‘post-burning’

Provide pioneering information to archaeologists about the forming and alteration of pyrogenic anthropic cave sediments.

The aims

➤ to evaluate the potential of cave ashes to record the Earth’s magnetic field variations

➤ to reconstruct the burning conditions studying their magnetic properties

➤ identifying the syn/post-burning taphonomical processes

The rock shelter of Crvena Stijena (Montenegro) is one of the longest and best-preserved Middle Paleolithic sequences in southeastern Europe.
Crvena Stijena (meaning ‘Red Rock’) / Dinaric Karst

![Image of Crvena Stijena with a view of the landscape and a close-up of the rock formation.]

![Diagram illustrating geological features such as the wall of the cave, massive block from a rock fall, unconsolidated poorly sorted slope debris, and slope sediment.]

Legend: [Diagram icons and symbols explained in the legend section of the diagram.]
(Post)pyrogenic mineral forming – characteristics of magnetic contributors

- **a** → very uniform grain size in a MD+SD (~75%:25%) [Day-plot]
- **b** → dominantly magnetically soft/low coercivity contributors [acquisition of IRM]

- **c,d** → four characteristic population:
  - Bacterial magn.
  - SD magn.
  - MD magn.
  - Noise [decomp. of IRM]
(Post)pyrogenic mineral forming – characteristics of magnetic contributors

**a →** Type1; quasi reversible curve and inflection around 300-400 °C

**b →** Type2; quasi reversible curve with a hump between 105-112 °C and 218-245 °C and inflection around 300-400 °C

**c** → same as Type1 (a) and Type2 (b) irreversible curve with mineral neoforming

**d** → repeating measurements of Type2 (b) curve – no hump at the second time: mineral neoforming

**e, f** → experiments in reduced and zero background field – same inflections [M(T) curves]
Magnetic contributors of ash (?) – the preliminary candidates

**Magnetite** → indicated in all sample by its Tc: 585°C

~110 °C hump and the inflection between 300-400 °C (candidates):

Transition from **SD to SP behavior** → transition from SD to SP behavior in magnetic grains close to the SSD/SP (Day, 1975):

(+) supported by hysteresis and IRM; (++) result of mineral forming by burning;

(-) thermal experiments in various DC fields did not show significant change;

**Siderite** → decomp. ~250 °C (Pan et al. 2002). Additional Mn and Mg comp. decrease the decomp. T (Gallagher and Warne, 1981):

(+) authigenic minerals by precipitation from groundwater;

(-/+ ) inverse fabric

(-) no significant paramagnetic comp [hysteresis and M(T) curves]

**Goethite** → 'broad minor peak' just above 100 °C and defined as antiferromagnetic (AFM)/paramagnetic (PM) transition (Néel temperature - TN) (Özdemir and Dunlop 1996);

(+) imperfect burning;

(-) non-significant amount of high coercivity component

Pyrrhotite and magnetite forming from **greigite** → ~95 °C the creation of pyrrhotite from greigite → ~125-250 °C the neoformation of magnetite (Aubourg and Pozzi 2010).

*Theory*: loose ash + (saturated) pore water + intense decomposition of organic matter → dissolved iron and sulphide → greigite/greigite-producing magnetotactic bacteria

(+) decomp of IRM.
Basic low field anisotropy of magnetic susceptibility (AMS) parameters
Fabric forming processes

CS5 and CS7
• initial pyrogenic MF, formed on slope
• influenced by gravity and slow slope processes

Infiltrating water into the loose ash strengthen
→ the influence of slope processes, triggered by the change in the consistency of the ash
→ the realignment of the grains toward vertical

Gravity + slope processes + sheet wash (water-lain)

↓

Strengthening of the grains’ alignment:
• slopeward orientation of the grains
• discrepancy of $k_{\text{min}}$ from vertical (→ imbrication; Nawrocki et al. 2006)
Fabric forming processes II. – *Under pressure*

**a, b** → Flow-transverse fabric (e.g. Mammoth Cave, Kentucky, Ellwood 1984) flowing water along the passages (CS2, CS4).

**a** → may indicate stress field, triggered by rockfalls and the impact of a huge block.

Analogue:
- L-type tectonites (Borradaile, 2001)
- Rock deformed by e.g. meteorite impacts (Yokoyama et al., 2012) (~huge block impacts into the ash.

Common in all type: *mark of forming /accumulation/redeposition on slope.*
Inverse fabric can be formed by:

- water infiltration → vertical migration triggered re-orientation of grains (e.g. Bradák-Hayashi et al., 2016).

- freezing thawing (+gelifluction and frost-creep on slope) → tension, triggered by the expansion of frozen pore water → vertical reorientation the grains

- the segregation of ice lenses further lead to vertical translocation, rotation and deformation of the material (Van Vliet-Lanoë, 2010).

Exclusively SD magnetic grains (Hrouda, 1984) → inverse fabric ‘looking’ MF → BUT the kmax in fact indicates the shortest crystallographic axis → therefore the fabric is quasi-horizontally oriented

(-) Day-plot shows mixed SD and MD character
Forming and alteration of ‘pyrogenic MF’ – theoretical model

Scattering alignment of grains and discrepancy of the foliation plane from vertical (dip) → forming on slope

Mixed quasi-horizontal and vertical, and also poor orientation → lack of current or stress field → no strengthening force on the alignment of the grains

The referred MFs may influenced by:

- rheomorphic processes - deformation of the MF due to the change in the (Tarling and Hrouda, 1993)
- low velocity slope processes (creeping, solifluction)
- water-lain processes (sheet-wash, water infiltration)
- stress field related mechanism.
Thank you for your attention

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