Transforming understanding of paleomagnetic recording: Insights from experimental observations of laboratory aged thermal remanences

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Néel theory (doi: 10.1080/00018735500010120) predicts that natural remanent magnetizations (NRMs) of thermal origin will be nearly linearly related to the magnetic field in which they are acquired for field strenghts as low as the Earth's. This makes it in principle possible to estimate the strength of ancient magnetic fields. In practice, however, recovering the ancient field strength is complicated. The simple theory only pertains to uniformly magnetized (single domain, SD particles). While SD theory predicts that a magnetization acquired at a temperature T should be demagnetized by zero-field reheating to T, yet failure of this "reciprocity" requirement has long been observed and the causes and consequences for grains with no domain walls are unknown. Recent experiments (Shaar and Tauxe, doi: 10.1073/pnas.1507986112 and Santos and Tauxe, doi:10.1029/2018GC007946) have demonstrated that, in contrast to the stability of SD remanences over time, the remanence in many paleomagnetic samples typically used in paleointensity experiments are unstable, exhibiting an "aging" effect in which the unblocking temperature spectrum changes over only a few years. This behavior is completely unexpected from theory. Solving these mysteries is key to cracking the problem of paleointensity estimation. In this presentation we will demonstrate that it is a shift in unblocking temperatures observed over even relatively short time intervals (two years) in certain samples that leads to the failure of reciprocity which in turn limits the ability to acquire accurate and precise estimates of the ancient magnetic field. From rock magnetic experiments (xFORCs) it seems likely that magnetic grains larger than the highly stable single vortex state are the source of the non-ideal behavior. This non-ideal behavior which leads to differences between known and estimated fields that can be rather large (up to 10 μT) for individual specimens, does appear to lead to a bias in field estimates. It is unclear how this behavior can be compensated for using the most common paleointensity estimation methods.

Alternate title:
Paleointensity: What could Go Wrong?

When considering paleointensity data, some questions spring to mind

- What causes curvature in Arai plots? [domain walls and something else]
- Why are many curves not reproducible (“fragile”) when the experiment is repeated with a fresh TRM? [no idea]
- Does this fragile curvature increase with time? [yes!]
- Are the data from curved Arai plots generally biased? [yes!]

Two different causes of curvature - same consequence

- Domain walls (e.g., Dunlop and Ozdemir, 2001). These are reproducible - fresh laboratory TRMs will produce curved Arai plots. And these are biased low relative to the cooling field. (Krasa et al., 2003).

- But something else too! “Fragile” curvature is not reprodicible (cause is a mystery! … the hard aligned single vortex of Nagy et al., 2017?).

- Separation of Tub and Tb spectra (curvature) tends to yield estimates that are biased low relative to the cooling field (Krasa et al., 2003; Sbarbori et al., 2009; Cromwell et al., 2015).

Outstanding questions

- What causes “fragile” curvature?
    - Nagy et al.’s (2017) “hard-aligned single vortex??
- What causes high Tub VRM?
    - Fabian & Shcherbakov (2018)
- What causes low Tub self-reversal???
    - make something up…