Variability of the 0–3 Ma palaeomagnetic field observed from the Boring Volcanic Field (USA)

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Motivations

from a geodynamical viewpoint
⇒ dynamo process in the outer core

from an observational viewpoint
⇒ fluctuations in the reversal frequency

How to link dynamo process and observations?

investigation of **palaeosecular variation** (PSV)
⇒ variability in time of direction and intensity

⇒ sampling of time-independent epochs
(typically piles of lava flows)

Lowrie & Kent (2004)
Which quantity to investigate PSV?

- site latitude
  - $\lambda_S = 0^\circ$
  - $\lambda_S = 45^\circ$
  - $\lambda_S = 85^\circ$

\[
\begin{align*}
\alpha_{95} &= 1.7 \\
E_D &= 2.3 \\
k_D &= 7.4 \\
S_D &= 31.0
\end{align*}
\]

\[
\begin{align*}
\alpha_{95} &= 1.2 \\
E_D &= 1.2 \\
k_D &= 13.8 \\
S_D &= 22.6
\end{align*}
\]

\[
\begin{align*}
\alpha_{95} &= 1.1 \\
E_D &= 1.1 \\
k_D &= 15.4 \\
S_D &= 21.6
\end{align*}
\]

Lhuillier & Gilder (2013)
**Latitudinal dependency**

1) Intensity and direction contents can be used in combination to better discriminate the models.
2) The relative variability in palaeointensity ($\varepsilon_F$) is almost independent of site latitude.
Geological setting & Sampling

• volcanism associated with the subduction of the Juan de Fuca plate beneath WN America

• ~ 80 monogenetic volcanic centres (subalkaline basalts to basaltic andesites)

• sampling at ~130 localities

• 40Ar/39Ar geochronology for each site ages ranging from 0.06 to 3.2 Ma

Fleck et al. (2014); Hagstrum et al. (2017)

For this study:

5 samples per site → 660 samples divided into various specimens to conduct

rock-magnetic experiments
thermal / AF demagnetisations
absolute palaeointensity experiments
relative palaeointensity experiments
**Rock-magnetism**

- **Graph a.**
  - Sample: 058-1A
  - Temperature: $T_c = 489^\circ$C

- **Graph b.**
  - Sample: 015-1A
  - Temperature: $T_c = 132^\circ$C

- **Graph c.**
  - Sample: 036-1A
  - Temperature: $T_c^{(1)} = 231^\circ$C, $T_c^{(2)} = 524^\circ$C

**Group 1**
- High temperature exsolution lamellae
- Slightly oxidised low-titanium magnetite (+ cation substituted haematite)
- Suitable for palaeointensities
**Directional analysis**

site-mean directions/VGPs grouped by eruptive units of same age

between-site dispersion corrected for within-site dispersion

**Normal polarities**

\[ S_B = 22.8^\circ \left( 27.2^\circ \right) \quad N = 38 \]

**Reverse polarities**

\[ S_B = 15.4^\circ \left( 18.3^\circ \right) \quad N = 38 \]

**All polarities**

\[ S_B = 19.3^\circ \left( 21.8^\circ \right) \quad N = 76 \]
**Wilson experiments (N=40)**

- **Borok observatory**

- **3D-VSM**

![Graph showing magnetisation vs temperature](image)

**NRM** vs **TRM** demagnetisation

![Graph showing magnetisation vs temperature](image)

**002-1C**

- $B_{anc} = 27.60 \pm 0.08 \mu T$
- RSE = 0.003
- **ACCEPTED**

**006-1C**

- $B_{anc} = 13.52 \pm 0.80 \mu T$
- RSE = 0.059
- **REJECTED**

**Selection criterion:** RSE < 0.02 (Muxworthy, 2010)

40 experiments ⇒ 17 values (40% success rate)
Thellier-Coe experiments ($N=200$)

in Borok (3D-VSM) and in Munich (ASC furnace)

Selection criteria:

- $n \geq 4$
- $\beta \leq 0.1$
- $q \geq 5$
- $f \geq 0.4$
- $|\text{DRAT}| \leq 15\%$
- $|\text{CDRAT}| \leq 15\%$
- $\text{MAD} \leq 10^\circ$
- $\alpha \leq 10^\circ$

200 experiments $\Rightarrow$ 54 values / 12 sites (27% success rate)
Pseudo-Thellier method

1) step-wise AF demagnetisation of NRM

2) step-wise acquisition of ARMs with the same steps as previously

3) step-wise AF demagnetisation of the ARM still with the same steps as previously

The same grains must carry NRM and ARM!
**Pseudo-Thellier method (N=620)**

Selection criteria:
$R^2>0.95$, $f>0.30$, $f_{res}<0.20$, $20<B_{1/2}(ARM)<60$ mT
averages computed when: $N \geq 3$ and RSE<50%

⇒ robust estimate for 47 sites

Empirical calibration: (just for VADM computation)

$$b_{cal} = [\lfloor b \rfloor - \text{med}(\lfloor b \rfloor)] \times \frac{\sigma(B_{\text{anc}})}{\sigma(b)} + \text{med}(B_{\text{anc}})$$
Time evolution of palaeointensities

Comparison with the World Palaeointensity Database (WPD)
http://wwwbrk.adm.yar.ru/palmag/database_e.html
E.g. Shcherbakov & Sycheva (2013)
Relative variability in palaeointensity

\[ \varepsilon_F = \text{pseudo-Thellier slope} \]

\[ \varepsilon_F = 0.44 \pm 0.05 \ (1\sigma) \]

d. bootstrap estimate

\[ \varepsilon_F = 40 - 45\% \]

For the past 3 Myr

**this study**

all polarities \( \varepsilon_F = 44 \pm 5\% \) \( (N = 34) \)

Brunhes (0-0.78 Ma) \( \varepsilon_F = 35 \pm 8\% \) \( (N = 12) \)

Matuyama (0-0.78 Ma) \( \varepsilon_F = 41 \pm 7\% \) \( (N = 16) \)

**database**

\( \varepsilon_F = 42 \pm 1\% \) \( (N = 570) \)
Conclusions & Perspectives

- asymmetry between reverse and normal polarities
  - normal directions more scattered than reverse directions
  - reverse intensities more scattered than normal intensities
  ⇒ contradiction!

- comparison with the cretaceous normal superchron

  this study  
  \[ S_B \approx 19.3^\circ \]
  \[ \varepsilon_F \approx 40 - 45\% \]

  \[ Lhuillier \ et\ al. \ (2016) \]
  \[ S_B \approx 18.1^\circ \]
  \[ \varepsilon_F \approx 32\% \]

Pavlov and Gallet (2005)

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investigated period

06.10.2017
Merci pour votre attention!

Спасибо за внимание!

Full details:
