## Supplementary material for

# Reconstruction of the Virtual Geomagnetic Pole (VGP) path at high latitude for the last 22kyr: the role of radial field flux patches as VGP attractor. 

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## APPENDIX A

## NORMALIZATION METHOD FOR RELATIVE PALEOINTENSITY CURVES AND MODELS

Each record has been scaled so that the location parameter (median) is equal to one, then interquartile range have been used to scale the variations about the median value.

1) As first step all records have been scale to median value as follow:

$$
\begin{equation*}
\mathrm{RPI}_{\mathrm{N}}=\mathrm{RPI} / \operatorname{Median}(\mathrm{RPI}) \tag{1}
\end{equation*}
$$

2) After $\mathrm{RPI}_{\mathrm{N}}$ values have been translated so that the variations are about a median of zero

$$
\begin{equation*}
\mathrm{RPI}_{1}=\mathrm{RPI}_{\mathrm{N}}-1 \tag{2}
\end{equation*}
$$

3) Then $\mathrm{RPI}_{1}$ values have been scaled by interquartile range of $R P I_{1}$ to allow smooth records to have their variations amplified to simulate larger dynamic range.

$$
\begin{equation*}
\mathrm{RPI}_{2}=\mathrm{RPI}_{1} / \mathrm{IQR} \tag{3}
\end{equation*}
$$

4) In the and $\mathrm{RPI}_{2}$ values have been relocate to a median value of 1

$$
\begin{equation*}
\mathrm{RPI}_{3}=\mathrm{RPI}_{2}+1 \tag{4}
\end{equation*}
$$



Figure S1 Comparison between RPI curves according to former (Caricchi et al., 2019) and new age models (this work) for cores GS191-02PC and GS191-01PC. RPI curves and models have been normalized following the method outlined in appendix A. RPI curves for the GS191-02PC and GS191-01PC cores are plotted together with the RPI curves from the GGF100k model and GICC05-GLOPIS75 stack. These curves have been normalized only for the time interval spanned by the analyzed cores.


Figure S2 Comparison between RPI curves according to former (Caricchi et al., 2020) and new age models (this work) for cores EG-03 and EG-02. RPI curves and models have been normalized following the method outlined in appendix A. RPI curves for the EG-03 and EG-02 cores are plotted together with the RPI curves from to SHA.DIF.14k and CALS10k. 2 models.


Figure S3 Comparison between RPI curves according to former (Caricchi et al., 2020) and new age models (this work) for SV-04. RPI curves and models have been normalized following the method outlined in appendix A. The RPI curves of the SV-04 core are plotted together with the RPI curves from the CALS10k. 2 and GGF100k models and the GICC05GLOPIS75 stack. The latter curves have been normalized only for the time interval spanned by the SV-04 core.

## CALS10k. 2



Figure S4. Maps of the radial field component of the geomagnetic field at CMB calculated using CALS10k. 2 and SHAWQ-Iron Age models from 3.2 cal kyr $\mathrm{BP}_{2000}$ to $2.1 \mathrm{cal} \mathrm{kyr} \mathrm{BP}_{2000}$.


Figure 55 Rate of change of the NBS22.2 k VGP (blue) compared to the VGP calculated from models using maximum harmonic degree $\mathrm{N}=1$ (dipole) (solid lines) or $\mathrm{N}=10$ (dashed lines). In order to properly compare the various data sets, the rate of change of the VGP from the models has been calculated considering sliding windows of 200 yrs. See text and legend for more details about the models used. It is clear that there are times where the field behavior differs substantially from a pure dipole $(\mathrm{N}=1)$. The effect of a significant non-dipole contribution is visible when calculating the mean and standard deviation for each curve, resulting in higher values (from $16 \%$ to $58 \%$ higher) for $\mathrm{N}=10$ than for $\mathrm{N}=1$.


Figure S6 Maps of the radial component of the geomagnetic field (in $\mu \mathrm{T}$ ) at the Core-Mantle Boundary from SHAWQIron Age model in 2200 yr $\mathrm{BP}_{2000}$ calculated considering different maximum harmonic degree N : from $\mathrm{N}=1$ (dipole), N $=2$ (dipole + quadrupole) up to $\mathrm{N}=6$ (the value chosen to carry out our study). Present refers to 2000 CE .

GGF100k


Figure S7 VGP path reconstruction from the NBS22.2k PSV stack (in red), Levant (in blue) and Mexico (in green), overlaid on maps of the radial component of the geomagnetic field (in $\mu \mathrm{T}$ ) at the Core-Mantle Boundary from GGF100k model in (a) 14 cal kyr $\mathrm{BP}_{2000 \text {, (b) }} 13.4$ cal kyr $\mathrm{BP}_{2000}$, (c) $12.4 \mathrm{cal} \mathrm{kyr}_{\mathrm{BP}}^{2000}$, (d) $12 \mathrm{cal} \mathrm{kyr} \mathrm{BP}_{2000}$, (e) $11 \mathrm{cal} \mathrm{kyr}_{2000}$ and (f) 10 cal kyr $\mathrm{BP}_{2000}$. Present refers to 2000 CE .

## CALS10k. 2



Figure S8 VGP path reconstruction from the NBS22.2k PSV stack (in red), Levant (in blue) and Mexico (in green), overlaid on maps of the radial component of the geomagnetic field (in $\mu \mathrm{T}$ ) at the Core-Mantle Boundary from CALS10k. 2 model in (a) 8 cal kyr BP 2000 , (b) $6.8 \mathrm{cal} \mathrm{kyr} \mathrm{BP}_{2000}$, (c) $5.6 \mathrm{cal} \mathrm{kyr} \mathrm{BP}_{2000}$; (d) $5 \mathrm{cal} \mathrm{kyr} \mathrm{BP}_{2000}$; (e) $4.4 \mathrm{cal} \mathrm{kyr}^{\mathrm{BP}} 2000$ and (f) 3.2 cal kyr BP 2000 . Present refers to 2000 CE.

