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Holocene geomagnetic field intensity variations: Contribution from the low latitude Canary Islands site

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ABSTRACT

New absolute paleomagnetic intensity (PI) are investigated from 37 lava flows located at Tenerife and Gran Canaria (Canary Islands). They complete previously published directional results from the same flows and therefore allow to examine the time variations of the full geomagnetic vector. Twenty-eight flows are radiocarbon dated between 1706 AD and about 13 200 BC and one is historical. Eight other flows are not dated but they have stratigraphic links with the dated flows and archeomagnetic ages had been attributed to them based on their paleomagnetic directions. Various mineralogical analyses were conducted, giving access to the nature of the magnetic minerals and to their grain size. We performed the original Thellier and Thellier paleointensity (PI) experiments with a success rate of about 65% coupling this experiment with the strict set of selection criteria PICRIT-03. The mean PIs at the flow level are based on 3 to 12 independent PI determinations except for one site in which only one reliable determination could be obtained. The data indicate some variability in the local field intensity with a prominent PI peak centered around 600 BC and reaching 80 μT (VADM 16×10^{22} A m^2), documented for the first time in this region. Combined with the published data obtained from western Africa, Spain, Portugal, Morocco and the Azores within a 2000 km-radius around the Canary Islands, our data allow to construct a curve illustrating the Earth magnetic field intensity fluctuations for Southwestern Europe/Western Africa. This curve, compared to the one produced for the Middle East and one calculated for Central Asia shows that maximum intensity patches have a very large geographical extent. They do not yet appear clearly in the models of variations of the dipolar field intensity.

1. Introduction

Paleosecular variations (PSV) of the geomagnetic field have been increasingly studied over the last 15 yr and robust and precisely dated volcanic and archeomagnetic data have been produced for the Holocene period, leading to progressive improvements of the models.

Successive generations of models were produced based on different datasets: ARCH3K (Donadini et al., 2009; Korte et al., 2009), SHA.DIF.14k (Pavón-Carrasco et al., 2014) and A_FM (Licht et al., 2013) are based on volcanic and archeomagnetic data only while CALS10K (Korte et al., 2011), pfm9k (Nilsson et al., 2014), ASD_FM and ASDI_FM (Licht et al., 2013) also include sedimentary data. Because the sedimentary records are not always obtained at high resolution and the accuracy of their age model is variable, they introduce some variable degree of smoothing in the predictions given by CALS10K, pfm9k, ASD_FM and ASDI_FM models. The Holocene volcanic and archeomagnetic databases on which the models are based (Geomagia.v3 Donadini et al., 2006; Korhonen et al., 2008; Brown et al., 2015, ArcheoInt-2009 Genevey et al., 2008) show that the available data were collected mainly from latitudes higher than 30° N, with data from Middle East and Europe largely dominating and with a smaller contribution of data from North America, Iceland and Asia. Synthetic paleointensity curves have been proposed for Western Europe (Hervé et al., 2013), Middle East (Gallet et al., 2015) and China/Japan (Cai et al., 2014). By contrast, the low latitudes between the equator and 30° N are poorly documented.

Improvements of the models in predicting paleointensity behavior and therefore in a better understanding of the PSV mechanisms, require additional paleointensity data, precisely dated and

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Table 1
Paleomagnetic results from the Holocene lava flows from Tenerife and Gran Canaria (Spain).

Locality	Flow number	lat (°N)	Long (°E)	ages ± 2σ (yrs AD–BC)	n/N	decl. (°)	incl. (°)	k	α_{95} (°)	n/N	F (μT)	std dev (μT)	VADM ± 1σ (10^{22} A m^2)
Garachico	TT15	28.360	343.237	1706	6/9	0.4	57.2	846	2.3	4/9	49.9	3.9	10.0 ± 0.8
Mña Boca Cangrejo	TT04	28.283	343.233	1550 ± 110	8/11	−4.0	48.7	284	3.3	*8/9*	*71.5*	*16.5*	–
Mña Reventada	TT03	28.273	343.272	1055 ± 155	12/13	6.7	40.5	233	2.8	7/11	57.9	6.4	11.6 ± 1.3
Los Hornitos	TT02	28.238	343.282	85 ± 124	4/4	6.2	32.5	94	9.5	3/4	56.1	6.1	11.2 ± 1.2
Early Roques Blancos	TT09	28.378	343.290	−25 ± 148	5/8	−3.2	43.5	360	4.0	4/8	44.5	6.2	8.9 ± 1.2
El Boquéron	TT46	28.318	343.315	−579 ± 185	9/9	−8.2	34.9	118	4.7	8/9	44.9	5.7	9.0 ± 1.1
Volcan El Ciego	TT41	28.312	343.212	−667 ± 250	5/8	4.2	37.3	131	6.7	7/8	53.2	6.8	10.7 ± 1.3
Mña De Chio	TT01	28.247	343.280	−1985 ± 212	9/9	−11.2	37.3	329	2.8	8/9	42.2	5.1	8.5 ± 0.9
La Abajera Baja	TT45	28.318	343.363	−3536 ± 162	7/9	2.6	44.7	286	3.6	7/9	55.8	6.8	11.2 ± 1.2
La Abajera Alta	TT44	28.320	343.427	−3961 ± 264	8/12	−11.9	37.4	884	1.8	10/12	50.1	4.3	10.1 ± 0.8
Mña Curva del Ràton	TT40	28.297	343.278	−4195 ± 145	7/7	−5.2	41.4	109	5.8	5/7	49.0	5.9	9.8 ± 1.0
Mña Liferfe	TT14	28.378	343.268	−6300 ± 80	10/11	−5.4	36.7	111	4.6	9/10	36.9	4.8	7.4 ± 0.8
Mna Negra	TT52	28.357	343.368	−7260 ± 190	11/11	−4.9	37.5	272	3.1	8/9	38.9	2.9	7.8 ± 0.5
El Portillo. Up. Unit	TT06	28.308	343.433	−11 055 ± 132	6/6	−4.9	57.3	67	8.2	6/9	44.0	6.0	8.8 ± 1.0
El Portillo. Low. Unit	*TT07*			*−11 938 ± 163*	*10/12*	*−0.9*	*48.0*	*231*	*3.2*	*5/12*	*35.2*	*4.7*	*7.1 ± 0.8*
El Portillo. Low. Unit	*TT43*			*−11 938* ± 163	*8/8*	*3.7*	*45.0*	*92*	*5.8*	*3/9*	*36.0*	*1.8*	*7.2 ± 0.3*
El Portillo. Low. Unit	TT07-43	28.317	343.392	−11 938 ± *163*	18/20	1.6	46.0	139	2.9	8/21	35.6	3.7	7.2 ± 0.6
Mña Del Blanco	TT42	28.317	343.212	−13 190 ± 230	9/9	0.5	32.8	102	5.1	0/9	–	–	–
Bandama	HGC13	28.038	344.542	38 ± 85	10/11	−5.8	22.0	204	3.4	3/11	21.4	3.3	4.3 ± 0.7
El Garañon	HGC15	27.952	344.472	10 ± 70	11/11	−14.9	36.8	141	3.9	3/7	26.3	4.3	5.3 ± 0.9
Doramas	HGC14	28.080	344.415	−575 ± 175	11/12	17.8	47.4	172	3.5	8/12	47.8	5.8	9.6 ± 1.2
El Lentiscal	HGC12	28.053	344.525	−580 ± 168	11/11	20.4	50.7	137	3.9	7/9	70.9	5.9	14.2 ± 1.2
Sima de Jinàmar	HGC09	28.022	344.565	−590 ± 190	9/11	13.2	48.8	193	3.7	9/9	61.7	4.5	12.4 ± 0.9
Mña Rajada	HGC08	28.020	344.580	−590 ± 190[a]	12/12	11.0	50.7	293	2.5	10/12	79.9	7.8	16.0 ± 1.6
Volcan Gallego	HGC07	28.022	344.577	−590 ± 190[a]	12/12	15.9	48.4	129	3.8	9/12	63.5	5.8	12.7 ± 1.2
Cuesta Las Gallinas	HGC06	28.027	344.565	−590 ± 190[a]	11/12	12.5	53.8	205	3.2	9/11	70.6	5.0	14.2 ± 1.0
Mña Negra de Jinamar	HGC10	28.038	344.583	−615 ± 195	10/11	−12.6	26.0	87	5.2	8/11	33.8	2.3	6.9 ± 0.5
Jabalobos	HGC20	28.077	344.343	−920 ± 120	9/9	9.4	44.8	225	3.4	4/9	59.2	3.9	11.9 ± 0.8
Berrazales	HGC21	28.068	344.345	−960 ± 160[a]	12/16	9.7	45.2	196	3.1	7/16	51.3	5.5	10.3 ± 1.1
Pinos de Gaidar	HGC17	28.040	344.383	−1008 ± 102	7/9	7.0	46.0	72	7.0	7/9	47.6	4.7	9.5 ± 0.9
Mña Negro	HGC16	28.030	344.388	−1183 ± 126	13/13	11.8	42.0	76	4.8	9/13	50.8	8.1	10.3 ± 1.6
Fagajesto	HGC18	28.053	344.360	−1250 ± 240	11/12	3.0	48.0	375	2.4	7/12	36.3	5.8	7.4 ± 1.2
Valleseco	HGC19	28.035	344.417	−1857 ± 67[a]	11/12	11.6	24.4	77	5.2	4/9	30.9	3.0	6.2 ± 0.6
Mña Santidad	HGC04	27.967	344.540	−4120 ± 80[a]	9/9	−9.0	47.4	82	5.7	1/8	18.3	–	3.7 ± –
El Melosal	HGC01	27.958	344.552	−4120 ± 80[a]	12/12	−7.8	38.6	320	2.4	9/12	49.3	5.4	9.9 ± 1.1
Mña San Mateo	HGC11	28.012	344.468	−4632 ± 81	11/11	−1.3	30.3	65	5.7	5/14	61.7	6.9	12.4 ± 1.4
El Hoyo	HGC02	27.983	344.532	−4671 ± 119	13/13	3.5	28.2	105	3.5	12/13	31.8	3.4	6.4 ± 0.7
Barros II	HGC03	27.972	344.532	−6750 ± 250[a]	10/11	−3.0	36.7	197	3.5	4/11	48.1	2.7	9.7 ± 0.5
El Draguillo	HGC22	27.947	344.555	−10565 ± 615	12/12	−6.6	48.0	156	3.5	11/12	29.3	1.8	5.9 ± 0.4

[a] Ages based on field information and/or paleomagnetic characteristics (see text), all the other ages are deduced from radiocarbon dating (see Carracedo et al., 2007 and Rodriguez-Gonzalez et al., 2009). In italic are the data obtained from the two sites TT07 and TT43, sampled a few kilometers apart in the same flow. The compilation is reported for this flow under the flow number TT07-43. n/N is for the number of reliable data/number of studied sample; k and α_{95} are the dispersion and precision parameters of the Fisher's statistic. F is the field intensity and VADM is for Virtual Axial Dipole Moment.

with a larger geographical distribution. To contribute to this effort, we report here on a Thellier and Thellier paleointensity study conducted on 37 flows from Tenerife and Gran Canaria (Canary Islands) among which one is historical, 28 are radiocarbon dated (Carracedo et al., 2007; Rodriguez-Gonzalez et al., 2009), and 8 have stratigraphic constraints. The directional study of the same flows, discussed in the companion paper (Kissel et al., 2015), has shown both common features and differences with the declination and inclination curves predicted by the models at this location. The new paleointensities obtained in this study allow to describe the variations of the full vector of the Earth magnetic field at the location of the Canary Islands during the Holocene and to compare them with other data collected from the same region and predicted with various models.

2. Geological setting and sampling

In the Canary Islands, the Holocene volcanic activity is variable depending on the island. Lanzarote and Fuerteventura Islands have undergone only very few post-20–21 ka BP eruptions while La Palma, Tenerife, Gran Canaria and El Hierro are characterized by significant eruptive activity during the Holocene (Carracedo and Perez-Torrado, 2013) including the very recent (October 2011 to March 2012) eruption along the southern submarine rift of El Hierro (Carracedo et al., 2015).

For pre-historical period (last 13 ka), the volcanic activity in Tenerife and Gran Canaria is documented by extensive field observations combined with radiocarbon dating of lava flows reported in Table 1 (Carracedo et al., 2007; Rodriguez-Gonzalez et al., 2009). Datings were performed on charcoals found underneath the bottom contact of the flows or within the flows by the mean of tree molds or within or beneath tephra deposits. Calendar ages (cal yr B.P.) were calculated using the INTCAL04 terrestrial radiocarbon age calibration (Reimer et al., 2004).

The detailed field studies conducted by Carracedo et al. (2007) and Rodriguez-Gonzalez et al. (2009) guided our sampling as shown in Fig. 1 (coordinates and ages are reported in Table 1). The sampling sites are described in detail in the companion paper by Kissel et al. (2015) so we only give a summary here.

In Tenerife, we sampled 17 sites in 16 different flows. One historical flow was emplaced in 1706 AD in the northwest part of the island, and it buried the port town of Garachico, reconstructed since then on the flow itself (TT15; Table 1). Fifteen other flows are dated between 13 190 BC and 1550 AD (Carracedo et al., 2007) with a rather good distribution in age (Fig. 1; Table 1). One of the flows (El Portillo lower unit) was sampled at two different localities (TT07 and TT43).

The 21 studied flows from Gran Canaria (labeled HGC#) are less regularly distributed in time than in Tenerife. Thirteen of them are radiocarbon dated between 38 AD and 10 565 BC