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Paleosecular variation of the earth magnetic field at the Canary Islands over the last 15 ka

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ABSTRACT

We report on new paleomagnetic directions obtained from 38 lava flows located at Tenerife and Gran Canaria (Canary Islands, Spain). One flow is a historical one (1706 AD) and 28 other flows are dated by radiocarbon between 1550 AD and about 13 200 BC. Nine other flows are not dated but they have stratigraphic links with the other flows. Thermomagnetic curves, unblocking temperatures and coercivities suggest that the main carrier of the remanent magnetization is titanomagnetite with various titanium contents in the pseudo-single domain range. Paleodirections were obtained by thermal and alternating field demagnetization on more than 400 specimens. The two youngest flows yield directions well consistent with the data previously published from the Canary Islands but only covering the last 500 yr. Comparison with model predictions indicates that the models account on the long-term for most of the data. However, on short-term scale, a better agreement is observed with the archeomagnetic-based model predictions (ARCH3K and SHA.DIF.14k). Two time intervals (between 25 BC and 85 AD and around 600–700 BC), however, are characterized by more variable paleomagnetic directions, suggesting that the variability of the earth magnetic field was faster than predicted by the models. On a wider geographical scale, a rather good consistency is observed between the Canarian dataset and those from Northern Africa, Spain and Azores. Field information is well consistent with paleomagnetic information for the undated sites and they both confirm that the eruption rate of the Gran Canaria volcanic system was high around 600 BC, 1000 BC and 4650 BC. Refined ages could be obtained for two of the undated sites using archeomagnetic dating. Combined with the data previously published for the last 500 yr, this new dataset is the first long PSV record available for the Canary Islands, significantly contributing to the archeomagnetic/paleomagnetic database at latitudes lower than 30°N. Improvement in the time resolution of model predictions is now needed to allow more detailed data-model comparisons on short time scale.

1. Introduction

Studies dedicated to paleosecular variations (PSV) of the earth's magnetic field during the Holocene have been considerably developed in the last 10–15 yr. Both acquisition of new data from different archives (lake and deep-sea sediments, lavas, archeomagnetic artifacts) and numerical modeling have been addressed. Significant efforts have been made to construct paleomagnetic databases in order to compile all the available information about the space/time variability of the earth magnetic field. A list of sedimentary sequences has been compiled by Nilsson et al. (2014) and results from volcanic products (lavas, pyroclasts) and archeological artifacts (kilns, brick wall, ceramics) are reported in the GEOMAGIA50 database (Donadini et al., 2006; Korhonen et al., 2008 and references therein), up-dated by Pavón-Carrasco et al. (2014 and references therein).

Although it is still difficult to retrieve precisely dated Holocene sedimentary sequences with the pristine, uniform and stable magnetic properties, lake and marine sediments can yield continuous records of the Holocene vector changes of the earth magnetic field with no limitation *a priori* in their geographical distribution. However, we observe that only 6 Holocene sedimentary records

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are reported from low latitudes i.e. between the equator and about 30°N: two from China, one from Mexico, one from Hawaii, one from Cameroon and one from Cape Ghir (e.g. Nilsson et al., 2014). In the same way, the archeomagnetic database (Donadini et al., 2006; Korhonen et al., 2008; Pavón-Carrasco et al., 2014) is strongly biased in the same low latitudinal band toward Hawaii and to a smaller extent toward Central America.

Data obtained from low latitudes at longitudes other than Hawaii are therefore strongly needed to complete the databases and to constrain numerical models of the global earth magnetic field variations. These numerical models have progressively been developed, extending the investigated time period beyond the historical period described by GUFM model (Jackson et al., 2000). Two different models cover only the last 3000 yr. One of these models is only based on archeomagnetic data (series of models ARCH3K.4; Donadini et al., 2009; Korte et al., 2009) and the other one also includes lake sediments (series CALS3K.4; see Korte et al., 2009). For longer time periods, a continuous time-varying global field model spanning the last 10 ka (CALS10K.1b) has been proposed by Korte et al. (2011). CALS10K.1b introduces a higher degree of smoothing than the other models because it is largely based on sedimentary data, some of which characterized by low accumulation rates and not always well defined age models. Therefore, Nilsson et al. (2014) have recently proceeded to a selection and to a refining of the sedimentary database used for the CALS10K.1b model and proposed new spherical harmonic model calculations for the last 9 ka (model pfm9k). Very recently, Pavón-Carrasco et al. (2014) developed a new simulation for the earth magnetic field over the last 14 ka, based only on archeomagnetic and volcanic data (model SHA.DIF.14k). All these models allow to calculate the vector changes of the earth's magnetic field at the surface of the earth and therefore to compare them with data at any location.

However, as mentioned above, low latitudes at longitudes away from Hawaii are poorly documented for a wider spread of longitudes and improvements of the models would therefore benefit from a wider distribution of available data.

We report here on new paleomagnetic directions obtained from 38 Canarian lava flows, from a latitude of ∼28°N and distributed in time between about 300 and 15 000 yr BP. In this study we have taken advantage of the intensive studies of Holocene lavas in Tenerife and Gran Canaria that have been conducted in order to evaluate potential hazards related to possible renewed activity in these highly populated and volcanically active ocean islands (Carracedo et al., 2007; Rodriguez-Gonzalez et al., 2009). Precise ages of the lavas were established by radiocarbon dating of charcoal found at the bottom contact of the flows or within the flows by the mean of tree molds or within or beneath tephra deposits (Carracedo et al., 2007; Rodriguez-Gonzalez et al., 2009).

The obtained paleomagnetic results are complementary to previous data obtained from the Canary Islands but only covering the last 500 yr (Soler et al., 1984; Tulloch, 1992). When combined together, the three datasets bring the first constraints on the paleosecular variation in this region over the entire Holocene. The results are compared with other time series and with model results.

2. Geological setting and sampling

In Tenerife, as reported by Carracedo et al. (2007), Holocene lava flows are distributed along the northern flank of El Teide volcano, either originating from fissure eruptions along the NW and NE rift zones or erupted from domes at the periphery of the main El-Teide/Pico-Viejo complex. The flows emplaced from the rift zones are basic to intermediate in composition, while phonolitic lava is more frequently associated with isolated domes. Because Tenerife represents the peak of the evolutionary development in the Canarian archipelago (maximum growth) and Gran Canaria represents the late rejuvenation stage (decreasing phase), the Holocene eruptive activity is more discontinuous in Gran Canaria than in Tenerife (Rodriguez-Gonzalez et al., 2009). In Gran Canaria, it occurred during three main periods: around 10 000 BC (the single eruption of El Draguillo), around 4700–4600 BC and between 1500 BC and 38 AD. Geochemical analyses document that these lavas, geographically restricted to the northern flank of Gran Canaria, are of basanite–tephrite composition (Rodriguez-Gonzalez et al., 2009). Based on geographical considerations, they have been separated by Rodriguez-Gonzalez et al. (2009) in an eastern and a western areas. Not all the flows are dated but in each of the two areas, stratigraphic relationships could be established in the field between dated and undated eruptive events.

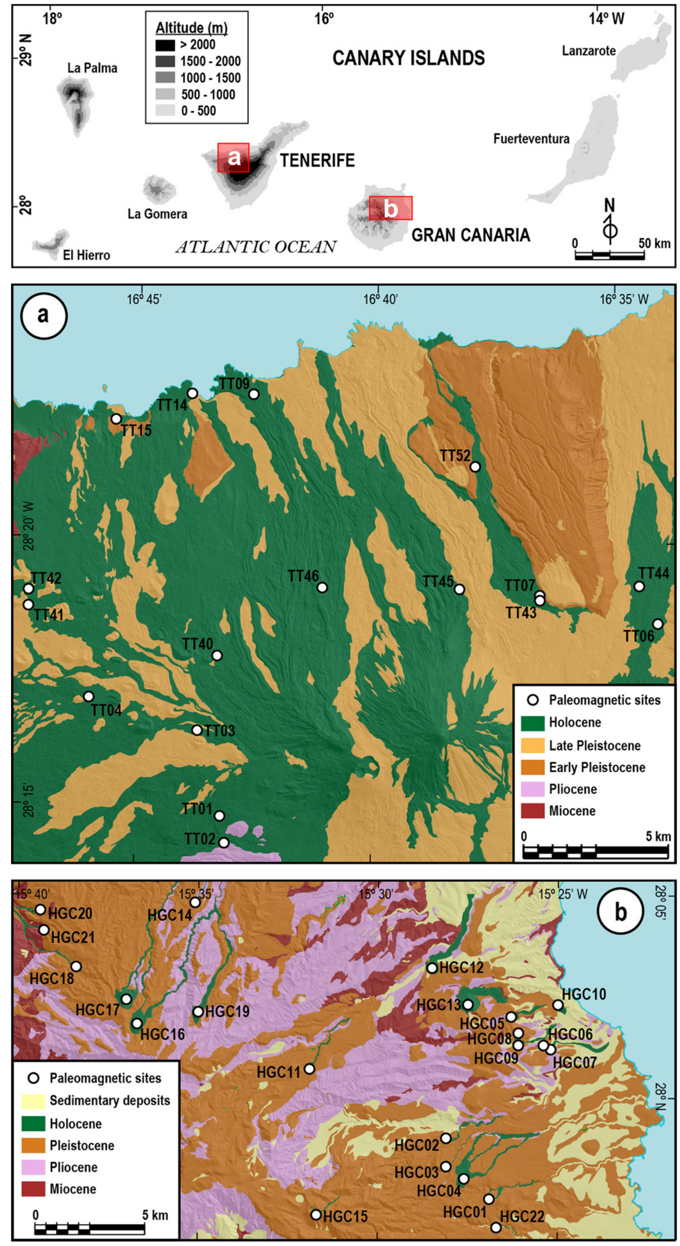

Fig. 1. Schematic geological map showing the location of the paleomagnetic sites.

The distribution of the sampled sites in Tenerife is shown in Fig. 1a and they are listed in Table 1. We sampled one historical flow (Garachico, erupted in 1706 AD) and 16 other sites from 15 lava flows (all labeled TT#) (the flow from the lower unit of El