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Discussion

Comment on “Historical measurements of the Earth’s magnetic field compared with remanence directions from lava flows in Italy over the last four centuries” by R. Lanza, A. Meloni, and E. Tema

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By gathering archeomagnetic and paleomagnetic data from the South Italian volcanoes Etna and Vesuvius, Lanza et al. (2005) provide a useful basis of discussion about a controversy remained until now at a latent state. However, these authors mix indistinctly results obtained by means of entirely different methods, with entirely different degrees of confidence and trustworthiness. We have shown that volcanic materials are quite able to furnish a good record of the direction of the geomagnetic field, provided they are studied through suitable methodology (Tanguy, 1980; Tanguy et al., 1985, 1999, 2003; Principe et al., 2004; Arrighi et al., 2004). Here, we would like to clarify the situation and “separate the wheat from the chaff”.

For archeomagnetism at St. Maur Laboratory, we use a very particular methodology developed since the 1930s and constantly improved afterwards. This involves collection of large samples weighing 0.5–1 kg each and their measurements using an adapted rotating inductometer and an alternating field demagnetization device. Such a procedure allows reaching a precision of a few tenths of a degree for each derived paleomagnetic direction. Of course, a larger dispersion is observed among samples from the same site, mainly because possible small displacements of the samples during cooling and local distortion of the ambient field induced by the magnetization of neighbouring lava. However, the half-angles of the 95% confidence cones obtained ($\alpha95$) are always less than 2° and often close to 1° (see references above). We insist on this remarkable level of accuracy which is almost never reached (nor actually needed) in traditional paleomagnetism. The “large sample” method gave excellent results in strictly speaking “archeomagnetism”, i.e. dating of human archeological artifacts (Thellier, 1981; Bucur, 1994; Gallet et al., 2002; Le Goff et al., 2002). Its application to volcanic materials has extensively been described in our publications listed above, but this fundamental difference has unfortunately been overlooked by Lanza et al.

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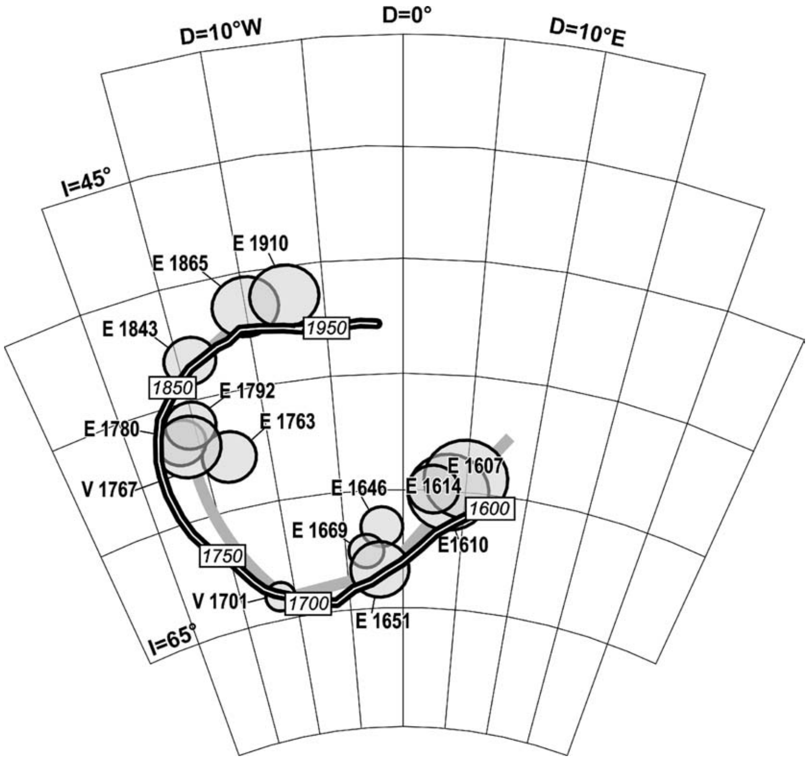

Fig. 1. Comparison between archeomagnetic paleodirections from lava flows (E: Etna, V: Vesuvius) and the curve traced from direct instrumental measurements, after Tanguy et al. (2003). Instrumental data come from Thellier (1981) and Alexandrescu et al. (1996), all reduced to Etna coordinates (37°45′N, 15°E).

We report on Fig. 1 the post-1600 part of the curve from Tanguy et al. (2003). All our lava paleodirections but one (Etna 1763) agree with the historical measurement curve extracted from Thellier (1981) and Alexandrescu et al. (1996), when taking into account their α95 confidence circles. Their frequently 1–2° lower inclinations, largely emphasized by Lanza et al., probably result from a magnetic refraction effect due to the demagnetizing field of thick lava flows (e.g. Coe, 1979). This effect was already envisaged by Chevallier (1925) and later mentioned in our publications. Evidence for this was found elsewhere, for example in the Lesser Antilles (Genevey et al., 2002). It has little bearing on our age results, however, because our reference curve of the directional secular variation is traced by using volcanic rocks. For the Etna 1763 flow, our samples were collected within an area where the geomagnetic field was later shown subject to unusual distortion of declination (Tanguy and Le Goff, 2004). The discrepancy disappears when making the small correction of 2.6° resulting from our instrumental measurements.

Fig. 2 shows the other results obtained by the core-drilling “paleomagnetic” method. The α95 are often so large (as much as more than 5°) that these results can hardly be used for archeomagnetic dating. When α95 is smaller, furthermore, this does not necessarily mean that the paleodirection is accurate. Let us consider, for instance, the 1983, 1981 and 1979 Etna flows, or the 1944, 1906 and 1855 Vesuvius flows, whose paleodirections deviate by 5–10° from instrumental measurements at the respective dates. These errors greatly exceed those expected in sampling and measurements, so that other causes must be involved. We suggested (Tanguy et al., 2003, p.113) the coring and sawing processes that are known to produce parasitic “DIRM”, or drilling induced remanent magnetizations (Burmester, 1977; Lauer, 1978; Audunsson and Levi, 1989; Genevey et al., 2002), which are not mentioned by Lanza et al. Although the largest part of these parasitic magneti-

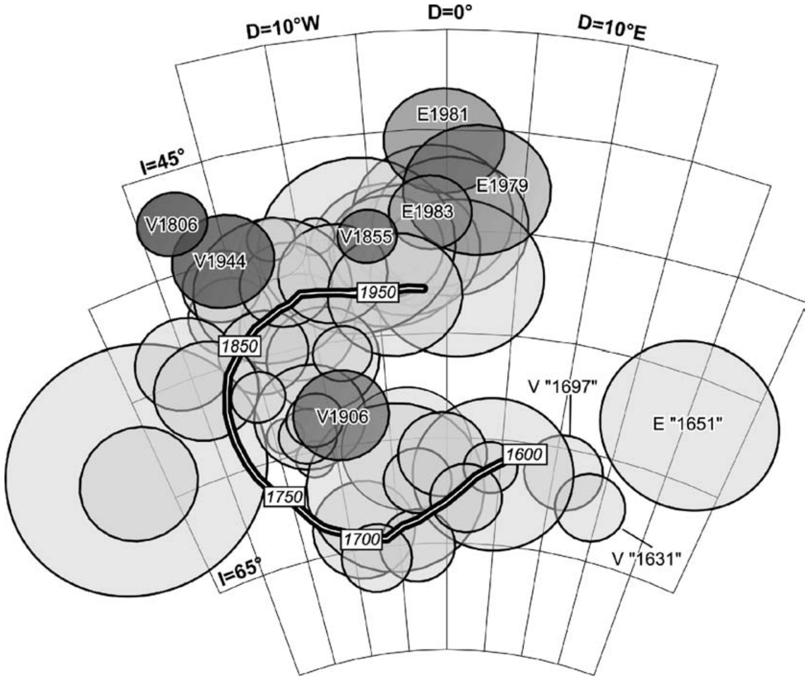

Fig. 2. Paleodirections of lavas from Etna and Vesuvius obtained through the core drilling method (results compiled by Lanza et al., 2005, reduced to Etna) and shown with their 95% confidence circles. Shadowed circles refer to major discrepancies with respect to instrumental measurements, years between quotation marks indicate spurious dates of eruption (see text).

zations can be removed through alternating field (AF) cleaning, problems still remain because of the weak AF resistance of the primary magnetization in most volcanic samples, more than half of it being sometimes lost by only 15–20 mT rms, whereas the DIRM extends to at least four times this value (Burmester, 1977).

Another possible cause of error in the coring method lies in the fact that all the samples were often collected within a very restricted area, less than a meter (Fig. 3). The results, though apparently consistent (low α95), can suffer from systematic bias if the block was slightly displaced during cooling of the lava, or more generally because of local disturbances of the geomagnetic field (Tanguy and Le Goff, 2004). In our sampling, we collected the various blocks over several tens of meters and, contrary to what is said by Lanza et al., our sampling of products from a given eruption was usually carried out at different sites.

In summary, we feel that unsatisfactory results obtained by means of the core drilling method are mainly due to these two causes, i.e. (1) sampling of a restricted area, which does not allow local disturbances to cancel each other and (2) use of an inadequate drilling tool which has been proven to produce parasitic magnetization. Because of these limitations, it is unsafe to mix the "core drilled" data with those from large plaster samples.

The Lanza et al. compilation is unsatisfactory in a number of other ways. Thus, their Table 1 is entitled "Historical direct measurements of the Earth's magnetic field in Italy", although all the values prior to A.D. 1800 but one (1640 Kircher's measure in Rome) come from Jackson's global modelling which is far from being accurate, especially for inclination (see Jackson et al., 2000, p. 986, for the 18th century). As a result, the "instrumental" reference curve shown in Fig. 1 of Lanza et al. disagrees with the single directional measurement of 1640. In trying to solve this discrepancy, Lanza et al. use a result from a mural painting whose α95 (2.4°) is large enough to encompass both figures of the curve. Curiously, they do not refer to the numerous available archeomagnetic data, possibly because they think that reduction of the *D, I* values through virtual geomagnetic pole calculation is subject to cau-

Fig. 3. Example of core-drilling "paleomagnetic" sampling of the 1646 flow from Mt. Etna. One of our plastered large samples can be seen aside the hammer at the upper left, the 18 others being distributed over the whole lava front (about 200 m).

tion. However, the resulting error on this procedure is small for Western Europe, on the order of 2° (dispersions of declination and inclination are not comparable and depend upon local inclination as cos(*I*), and this is taken into account when calculating the uncertainty, see Bucur, 1994). Whatever the size of this approximation, we point out that: (1) Vesuvius and Etna may be considered as two sites only 350 km distant and (2) it is an evidence that our individual "volcanic" results draw the geomagnetic variation path practically on that of the French archeological curve when reduced to Southern Italy (except for the short period 1150–1300 where imprecise archeological data led to a Western deviation that is being corrected, see Tanguy et al., 2003, end of section 4-1 p. 120).

For reconstructing the directional variation in the 1600 s the problem is complicated by the fact that the A.D. 800–1100 segment of the curve lies parallel and very close to the 1500–1650 one (e.g. Bucur, 1994). The two segments are nevertheless distinct, as is shown by both our Italian lavas results and the French archeological curve reduced to Southern Italy (Fig. 1 in Tanguy et al., 2003). These data are consistent with instrumental measurements in Western Europe (Thellier, 1981; Alexandrescu et al., 1996), and with the single directional measurement made in Italy at this epoch ($D = 2°$, $I = 66°$ in Rome in 1640): the latter value is in close agreement with our paleodirections from Etna flows between 1610 and 1669 ($D = 3.5$ to $-3.3°$, $I = 60–63.3°$, Tanguy et al., 2003), by taking into account the difference of about 4° in latitude. On the contrary, the curve derived from Jackson's model is inconsistent with all these data, so that its validity for the 1600 s may be questioned.

On the other hand, the directional reference curve of Incoronato et al. (2002), which resembles Jackson's model for the 1600s, is based on the misconception that some lavas from Vesuvius (with D from 11.5° to 17°) could belong to the "1631" and "1697" eruptions. These lavas were actually erupted in the Middle Ages (Principe et al., 2004). A similar misconception regards the presumed "1651" eastern flow of Etna, which was demonstrated to date from A.D. 1030 circa (Tanguy et al., 1985, 1999, 2003). Although Lanza et al. allude to the "age attribution problem" for this 1651 eastern flow of Etna, they fail to mention that the question is fully discussed, and solved, in our previous publications (Tanguy et al., 2003, pp. 118–120). We briefly recall the poor reliability of ages attributed (mostly in the 1800 s and without any dating method available) to the products of eruptions older than a few centuries, which are poorly located in ancient written accounts (Tanguy, 1980; Principe et al., 1987, 2004; Rosi et al., 1993). We believe that significant progress on the history of Vesuvius and Etna, and hence on the location of volcanic products that truly belong to one or another eruption, has resulted from comprehensive, pluridisciplinary studies performed by collaboration of volcanologists, paleomagnetists and archeologists working in close connexion. This allowed to solve many problems that otherwise would have remained obscure. For instance, a Vesuvius lava flow presumed to belong to the 1631 eruption was demonstrated to be medieval, simply because it is overlain by a tower built in the 1500 s (Principe et al., 2004, p. 709).

In conclusion, precise and reliable directional geomagnetic curves can be obtained from volcanic materials, as long as an adequate method is used. Conversely, these curves provide a powerful tool for archeomagnetic dating of lava flows and hot-emplaced pyroclastic materials, provided each site is studied by means of the same methodology. The classical core-drilling technique does not in general allow to reach the high degree of accuracy needed for such a purpose. In contrast, it has long been proven that the large sample method developed at St. Maur laboratory can be successfully applied to either archeological or volcanic materials.

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