LOCALIZATION OF THE SOURCE OF LARGE SILICIC IGNIMBRITES THROUGH MAGNETIC TECHNIQUES: APPLICATIONS IN TURKEY

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INTRODUCTION AND BACKGROUND

Pyroclastic density currents (PDCs) are inhomogeneous mixtures of volcanic particles and gas that flow over the topography according to their density. PDCs pomiceous and ash-rich deposits, commonly known as ignimbrites, represent good marker beds for stratigraphic correlations (Hildreth & Mahood, 1985; Self *et al*., 1991; Le Pennec *et al*., 2005) and have been object of many paleomagnetic studies (Black *et al*., 1996; Urrutia-Fucugauchi & Ferrusquìa-Villafranca, 2001). Moreover, research of the source area represents not only a merely volcanologic goal, but has also relevant economic implications, since PDCs eruption forming calderas are often associated to ore deposits, mineralization and geothermal activity (Lipman, 1992; Bibby *et al*., 1995).

Extrapolation and interpretation of accurate and reliable data from ignimbrites to resolve the aforementioned goals may often represent difficult issues. Stratigraphic correlations are the complex result of the combination of field observations with other investigation techniques such as magnetic, geochemical, radiometric and biostratigraphic. The exploitation of such techniques requires the preservation of essential conditions in ignimbrite deposits. Field observations are based on the outcrop-scale evidence of textural and mineralogic features of the deposits, and the analysis of three-dimensional sedimentary structures to infer flow directions. Magnetic investigation requires deposits *in situ* which have not suffered enhanced alteration processes affecting the primary magnetic mineralogy. Geochemical and radiometric analyses require the absence of strong alteration processes which can modify the bulk geochemical composition of the rock. However, such optimal conditions are not always achieved. In fact, ignimbrite deposits are not homogeneous bodies, they predominantly comprise a poorly sorted mixture of pumice and lithic lapilli supported in a matrix of vitric shards and crystal fragments, and significant alteration processes, such as divitrification and hydrothermal alteration, may occur during the ignimbrite history. The ignimbrite architecture is considered to be the result of the conditions and processes affecting the flow-boundary zone of a PDC through the time (Branney & Kokelaar, 2002). Clasts and magnetic fabrics, from which flow direction is inferred, are therefore not only the result of emplacement processes related to PDC rheology and paleo-topography, but they may also reflect spatial inhomogeneities within the PDC conferred by anomalous clasts concentration which may influence the flow at small-scale. Moreover, alteration processes may lead to the origin of secondary magnetic minerals and the growth of uneven magnetic mineralogy throughout the deposit that can bias the primary magnetic signal, by affecting both paleomagnetic and magnetic fabric data. Alteration processes can bias radiometric data as well, if the geochemical system relative to the analyzed mineralogic phase is not strictly closed. Because of these issues, ignimbrite investigation techniques should be devised in order to take into account all the possible variations occurring in the deposit and to obtain reliable data.

The present research proposes a combination of field, paleomagnetic and rock-magnetic techniques for the investigation of ignimbrite deposits, taking into account eventual magnetic variations occurring throughout the deposits. The first goal consists in understanding how and why variations of the magnetic properties occur throughout a same ignimbrite unit. To achieve this point, a detailed stratigraphic magnetic study was carried out on a single ignimbrite flow unit by sampling the deposit at different stratigraphic levels. Various magnetic analyses were performed in order to investigate the variation of paleomagnetic directions, magnetic fabric and magnetic mineralogy; finally, such variations were related to physical, chemical or emplacement processes which have been acting in specific levels of the ignimbrite. The second goal aims to the improvement of magnetic fabric data, whose quality is essential to infer reliable flow directions and constrain the source area.

This was realized by conceiving and testing a method based on the selection of magnetic fabric data on the ground of the specimens density, considered to be a proxy of lithic and pumice clasts concentration within the ignimbrite matrix, which might contribute to the origin of micro-flows non representative of the main flow related to the source. The third goal consists in the localization of the source of large silicic ignimbrites by combining volcanologic and magnetic techniques, by exporting the magnetic investigation techniques discussed above. Moreover, U-Pb radiometric dating were performed on zircon crystals. Such technique represents a robust method for ignimbrite dating and correlation, since zircon crystals are resistant to geochemical alteration and represent a closed system in the environment.

In the specific, the research carried out in this project has been addressed to investigate the pyroclastic deposits exposed within two large ignimbrite complexes in Anatolia (Turkey) with a dual objective:

1) perform a stratigraphic study of the variation of the magnetic properties throughout a single ignimbrite unit in the Cappadocia region, whose volcanic stratigraphy is well constrained, in order to identify the factors at the origin of vertical magnetic variation;

2) reconstruct the volcanic stratigraphy and research of the source area of the pyroclastic deposits exposed in a region located in western Anatolia, where no similar studies have been performed, yet.

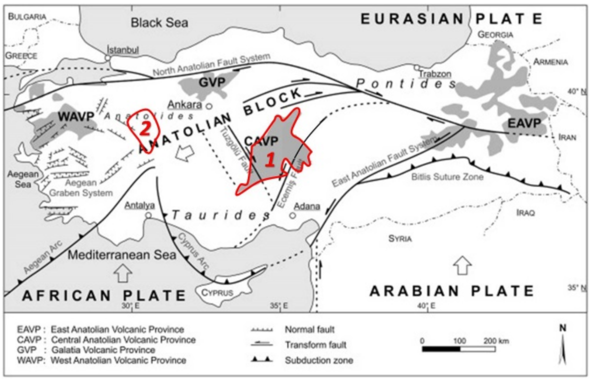

Fig. 1 - Simplified tectonic map of Turkey showing the distribution of major neotectonic structures and Anatolian volcanic provinces and the study areas of Cappadocia region (1) and Afyon-Eskişehir region (2) (modified after Lepetit *et al.*, 2009).

The two study areas are located in the Cappadocia region (central Anatolia) and in the region comprised among the cities of Afyon, Küthaya and Eskişehir (western Anatolia), respectively (Fig. 1). The two large ignimbrite successions cropping out in these areas have been object of different attentions and of a number of studies through the time. The Cappadocian ignimbrite succession has been deeply investigated under many aspects as concern stratigraphy, age, source locations and paleomagnetism (*e.g.*, Pasquarè, 1968; Le Pennec *et al.*, 1994; Schumacher & Mues-Schumacher, 1996; Le Pennec *et al.*, 1998; Le Pennec, 2000; Piper *et al.*, 2002; Paquette & Le Pennec, 2012). On the contrary, few studies were performed on the Afyon-Eskişehir ignimbrite succession, which consisted mainly in geochemical and to a lesser extent in volcanologic and paleomagnetic investigations, concentrated over limited study areas (Keller & Villari, 1972; Yalçın, 1990; Aydar *et al.*, 1998; Gürsoy *et al.*, 2003). No stratigraphic works, including distinction and dating of the pyroclastic units, neither information about source area location exist on these pyroclastic deposits, which are exposed over an area larger than 14,000 km^2 and reach considerable thickness.

The Kızılkaya ignimbrite unit, belonging to the Cappadocia region, was chosen as case study to perform a stratigraphic investigation of the variation of the magnetic properties through the deposit. The purpose in developing this objective arises because ignimbrites have been widely used in previous paleomagnetic works, but little attention has been spent in evaluating the consistency and reliability of the paleomagnetic data when results are obtained on a single volcanic unit, especially if characterized by uneven magnetic mineralogy. The present work investigates these issues on the Kızılkaya ignimbrite through the combination of many techniques of rock-magnetism, bringing evidence of significant magnetic heterogeneities in magnetic mineralogy, susceptibility, natural remanent magnetization and coercivity, and recommending revised sampling strategies for these types of volcanic rocks.

The purpose of the work performed on the Afyon-Eskişehir ignimbrite succession has been mainly directed to the reconstruction of the stratigraphy and the research of the source, by volcanologic and magnetic techniques. Moreover, the ignimbrite succession has been dated using latest geochronologic techniques, including the exploitation of the U-Pb technique on zircon crystals and Ar/Ar technique on plagioclase crystals. Finally, ignimbrite area extension and volume were estimated to achieve the VEI index, thus calculating the magnitude of the eruption. The new insights on these topics reveal the occurrence of large ignimbrite eruptions from the lower Miocene to the upper Miocene, bringing out relevant information on a still unstudied large silicic complex of Anatolia, and conferring new data on the present-day knowledge about the volcanism of the Mediterranean region.

FIELD AND LABORATORY METHODS

Field investigation

The work performed on the Afyon-Eskişehir ignimbrites firstly consisted in a volcanologic investigation which comprises: *i*) facies analysis; *ii*) description and comparison of cross-sections through the performance of stratigraphic measurements; *iii*) detection of field directional structures and production of isopach and isopleth maps of the pyroclastic deposits for the volume and magnitude eruption calculations. Stratigraphic measurements were performed on 76 sections and consisted in thickness and clasts grain size measurements (both maximum pumice, MP, and maximum lithic, ML) of the fall and ignimbrite deposits. Field directional structures, detected both in ignimbrite and surge deposits, were oriented with a geologic compass and used to produce imbrication maps in order to infer flow directions and localize the source area. For each pyroclastic unit, isopach and isopleth maps of the fall and flow deposits were performed reporting on a DEM map (Digital Elevation Model) thickness, MP, and ML values. Then, volume estimations were calculated using the program Global Mapper (version 15.0.5) on the basis of the isopach maps, and the magnitude of the eruption was defined both conferring a VEI index (Newhall & Self, 1982) on the basis of the bulk volume of the deposits and calculating the magnitude *M* (Pyle, 2000).

Paleomagnetic sampling and laboratory methods

A stratigraphic paleomagnetic sampling was performed by sub-dividing each section into several sites at different stratigraphic heights along sub-vertical profiles using an electric-powered drill. At each site, 5 to 17 cores were collected, which were oriented using both magnetic and, when possible, solar compasses. A total of 7 localities, 35 sites and 444 specimens were sampled from the Kızılkaya ignimbrite; the Afyon-Eskişehir ignimbrites were sampled at 22 localities, 36 sites for a total of 600 specimens.

Rock-magnetic analyses consisted in paleomagnetic (NRM), magnetic fabric (AMS, AIRM and AARM) and magnetic mineralogy investigations (IRM, thermal demagnetization of the IRM and S-ratio).

Isothermal remanent magnetization (IRM) acquisition was performed applying a stepwise increasing external magnetic field through an AGICO PUM-1 pulse magnetizer and measuring the remanent magnetization at the end of each step with an AGICO JR-6 spinner magnetometer. Then, identification of ferromagnetic phase assemblage was made on the basis of the evaluation of saturation isothermal magnetization and B_{cr} values, following the method proposed by Kruiver *et al.* (2001).

Thermal demagnetization of the IRM components, was performed according the 3D IRM unblocking technique of Lowrie (1990), by imparting an IRM along three orthogonal directions in three different fields (0.1 T, 0.5 T and 1.5 T) through an AGICO PUM-1 pulse magnetizer. Then, specimens were stepwise heated and cooled in zero field to successively larger temperatures with a Schonstedt thermal demagnetizer, and their remaining magnetization was measured with a AGICO JR-6 spinner magnetometer.

The S-ratio was calculated in order to better discriminate the magnetic mineralogy. This parameter is the ratio of the IRM acquired in a back-field of a certain magnitude, for this work at 0.1 T and 0.3 T, to the saturation IRM ($S_{-0.1\,T} = -IRM_{-0.1T}/SIRM_{1T}$; $S_{-0.3\,T} = -IRM_{-0.3T}/SIRM_{1T}$).

The NRM was obtained by: (1) thermal demagnetization, selecting at least 12 specimens for each site which were stepwise thermally demagnetized up to a temperature of 580-600 °C; (2) AF demagnetization, selecting at least 12 specimens for each site which were stepwise AF demagnetized up to a peak-field of 80 mT, by a 2G AF demagnetizer.

AMS was measured using an AGICO KLY-3 kappabridge, selecting at least 12 specimens for each site which were oriented in 15 different positions in order to reconstruct the susceptibility tensor and get the principal susceptibility directions. In order to investigate the orientation of the ferromagnetic minerals only, measurements of anisotropy of remanence magnetization (both AIRM, and AARM) were performed. For the AIRM measurement, each specimen was tumbling demagnetized using a Molspin AF demagnetizer at 60 or 80 mT peak-field, and then given an isothermal remanent magnetization (IRM) with a steady field of 20 mT, by an AGICO PUM-1 pulse magnet. After measurement with a JR-6 spinner magnetometer, the sequence was repeated for a total of twelve different positions in order to calculate the anisotropy tensor. AARM was measured according to the following procedure: specimens were first tumbling demagnetized in a peak AF of 100 mT, which was enough to erase the initial NRM carried by Ti-magnetite. Then the ARM was given by a bias direct field of 0.1 mT applied during static AF demagnetization. As before, the procedure was repeated in twelve different positions. Three runs were done in order to study the ARM of low-coercivity and high-coercivity fractions, and the whole of the grains.

U-Pb and ^{40}Ar-^{39}Ar dating were performed at Laboratoire Magmas et Volcans (LMV, Clermont-Ferrand, France) and at Laboratoire des Sciences du Climat by Hervé Guillou (LSCE, CEA, Gif-Sur-Yvette, France), respectively on the zircon crystals contained in the ignimbrite deposits and on plagioclase crystals contained in lava.

KIZILKAYA IGNIMBRITE

Data analysis

Thermal demagnetization of the IRM components shows dominant low and medium coercivity components. The maximum blocking temperature is mainly around 560-580 °C, up to 650 °C. These results, confirmed also by the IRM acquisition data and S-ratio values, point to low-Ti titanomagnetite as the main ferromagnetic mineral in the Kızılkaya ignimbrite, locally associated to a high coercivity phase (probably altered magnetite and/or hematite). Crossover diagrams (Cisowski, 1981), performed for selected sites of the Kızılkaya ignimbrite, confirm the absence of SD and/or MD grains interacting grains.

The value of the degree of anisotropy in the Kızılkaya ignimbrite is low, $P < 1.035$, as is typical for ignimbrites. It shows no systematic variations between sites, nor is any relation to the apparent bulk susceptibility. The fabric is mainly oblate and typically well developed: the dispersion of the principal axes is small and the site mean directions are well defined. Assuming that AMS is due to the preferential alignment of inequant Ti-magnetite crystals, which are characterized by shape anisotropy, and that the alignment is due to the flow of the volcanic material moving over the palaeotopographic surface, three types of fabric can be defined in the Kızılkaya ignimbrite on the ground of the angle θ between the direction of the magnetic lineation (K_1) and that of the foliation plunge (K_3): 1) parallel ($\theta < 35°$), in 18 out 35 sites; 2) transverse ($\theta > 55°$), in 10 sites; 3) oblique ($35° < \theta < 55°$), in 7 sites. Finally, the foliation plane is nearly horizontal and no plunge can be confidently defined at 8 sites. Based upon the above assumptions, the magnetic fabric results from the preferential alignment of the free Ti-magnetite grains by the clastic flow. However, in the Kızılkaya ignimbrite, Ti-magnetite occurs as well as inclusions in other minerals, within glass shards and as crystals within lithic and pumice clasts (Le Pennec *et al*., 1994). The flow orients these particles but not the included Ti-magnetite, whose orientation can be assumed as random. Their contribution to the measured susceptibility can therefore be regarded as noise that increases the dispersion of the fabric elements. The same occurs for lithic clasts, which, in addition, act as micro-topography, causing local deviation in the flow path of fine particles (LaBerge *et al*., 2009). A high content of clasts produces a large variation in density (lithic clasts increase the density whereas pumice clasts decrease it). The density values that differ more than $+/-1\sigma$ from the site mean value were regarded as strongly inhomogeneous and discarded and the statistics recalculated. The main result is that, in the sites in which Ti-magnetite is the only ferromagnetic mineral, the oblique fabric changes to normal or transverse. This fabric can therefore be interpreted as the result of compositional inhomogeneities and not of poor alignment by the flow. On the whole, these data filters produce a small improvement in the confidence values and, in a few cases, a change of the mean lineation direction and foliation pole. The number of sites with a horizontal magnetic fabric is reduced from 8 to 4. The AIRM magnetic fabric is well-defined and mostly oblate. The degree of anisotropy, $1.067 < P < 1.384$, is higher than for susceptibility. The lowest values occur in the sites with abundant oxidized phases. The AMS and AIRM fabrics are fully consistent at 9 out of 16 sites, aside from the mineral assemblage. On the whole, these results show that AIRM is mainly controlled by the low-coercivity ferrimagnetic fraction, as also attested by the AARM results; therefore it is possible conclude that the magnetic fabric is controlled by multi-domain Ti-magnetite grains.

Magnetic remanences are not vertically homogenous through the deposits. Two main cases are distinguished: 1) a stable and well-defined TRM, whose direction is consistent with previous literature data (Piper *et al.*, 2002), that is detected at sites where Ti-magnetite (or weakly altered Ti-magnetite) is the only magnetic career; 2) two magnetization components, with overlapping T_b and coercivity spectra. This case is typically found where magnetic mineralogy is given by Ti-magnetite, altered Ti-magnetite and hematite. This secondary component has been regarded as a CRM. The mean paleomagnetic direction obtained for the Kızılkaya ignimbrite is: D = 179.5°, I = -42.9°, k = 93, α_{95} = 2.6°, which is in agreement with the results obtained by Piper *et al*. (2002).

Data interpretation

The results obtained from the study of magnetic fabric show that AMS data may not be enough to define the primary fabric of an ignimbrite with a composite magnetic mineralogy. On the other hand, measurements of the anisotropy of remanent magnetization (AIRM in the present study) help to separate the effect of the various minerals and thus the possible overprints that mask the fabric derived from the emplacement dynamics. Correspondence between AMS and AIRM fabrics attested the primary origin of the magnetic fabric and the allowance to use the AMS indicators as proxies for flow direction. The tested AMS enhancing method on the basis of density discrimination, resulted in a net improvement on the quality of magnetic fabrics in terms of confidence values and reduction of horizontal magnetic fabrics, thus obtaining more accurate flow directions to constrain the source area.

Paleomagnetic directions recorded in the Kızılkaya ignimbrite at some localities are well defined and consistent with those of Piper *et al*. (2002). In these cases, the Kızılkaya ignimbrite possesses a single and stable direction of thermal remanence, which from all evidence appears to be a reliable representation of the ambient field at the time of cooling. A different behavior characterizes the remaining localities, where the remanent directions change systematically with stratigraphic height. In 14 out of 33 cases, the ignimbrite is characterized by two remanence components, as a result of the complex magnetic mineralogy (occurrence of Ti-magnetite, oxidized Ti-magnetite and hematite) and variations in the thermal cooling and alteration histories. Paleomagnetic data suggest the occurrence of a primary TRM and a secondary CRM acquired a short time later, and their angular difference is consistent with the paleosecular variation. The Kızılkaya mean paleomagnetic direction shows a significant difference in the inclination value with that expected for GAD in the region, which is sensibly reduced when inclination value is re-calculated using the P_{AIRM} value. Therefore, part of this difference can be attributed to compaction processes which have been acted during ignimbrite cooling. The consideration of this factor would reduce the considerable northwards movement of the region as proposed by Piper *et al*. (2002).

AFYON-ESKIŞEHIR IGNIMBRITES

Data analysis

The pyroclastic succession exposed in region located among the cities of Afyon, to the south, Eskişehir, to the north, and Kütahya to the west, has been investigated over a ≈ 14,300 km^2 area. The calc-alkaline, rhyolitic

Afyon-Eskişehir ignimbrite succession consists of at least three distinct eruptions that originated the Incik (18.866 ± 0.071 Ma), Sabuncu (9.43 ± 0.09 Ma) and Seydiler (older than 14.8 Ma) ignimbrites, different for areal distribution, structure and textural features of the deposits (Fig. 2).

Pyroclastic deposits constitute a thick succession (up to 170 m for Incik, 52 m for Sabuncu and 250 m for Seydiler ignimbrite) composed by a series of ignimbrite units and relative fall layers interbedded with surge and volcaniclastic deposits and overlain by limestone deposits and lava. Ignimbrites are constituted by several flow units, some of them characterized by multiple eruption stages. The Incik ignimbrite is formed by a lower unit (Incik 1) composed by 3 sub-units separated by fall and/or surge layers (Incik 1a, Incik 1b and Incik 1c) and an upper unit (Incik 2). Incik ignimbrite is widespread distributed over the northern part of the study region, where it constitutes the thickest ignimbrite. The Incik ignimbrite is well preserved and laterally sub-continuous in the area north-east from Kütahya, where it is capped by lava sheets and limestone. Further to the east, the deposits are more eroded, discontinuous, and generally overlain by reworked detrital deposits. The Sabuncu ignimbrite comprises two main flow units, Sabuncu 1 and Sabuncu 2, exposed in the western part of the northern area toward the city of Kütahya. This ignimbrite is exposed over a restricted area, it is generally well preserved and laterally continuous because of the presence of lava sheets capping the ignimbrite deposits. Seydiler ignimbrite is made up of two main units, Seydiler 1 and Seydiler 2, comprising multiple minor and local sub-units. A sequence of surge and pumice fall layers is interbedded between Seydiler 1 and Seydiler 2 units. The Seydiler ignimbrite is well preserved and laterally sub-continuous. In the south-eastern area, lava sheets cap the ignimbrite deposits and evidence of a widespread effusive activity consisting of lava flows, lava breccias and peperite deposits occur.

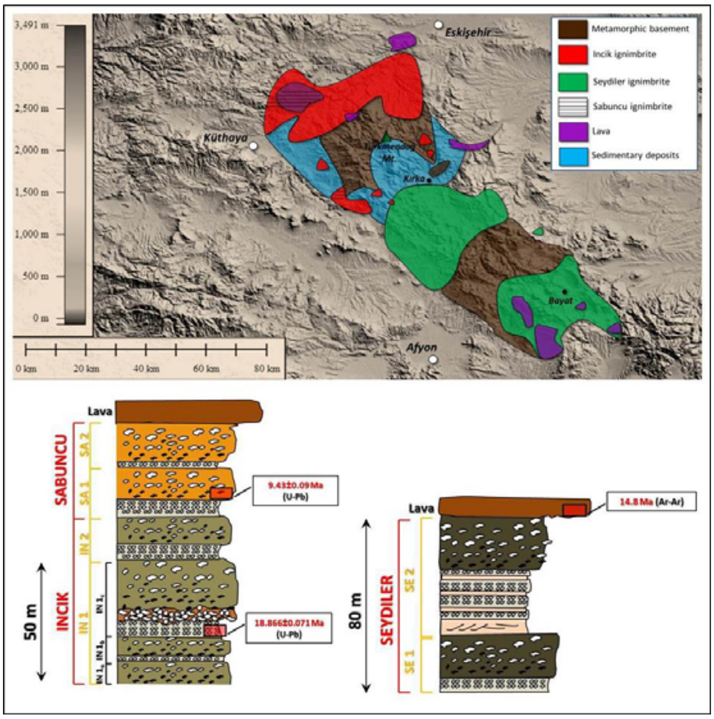

Fig. 2 - Schematic areal distribution map of the pyroclastic deposits cropping out in the area between Afyon and Eskişehir, and generalized stratigraphic sections of the Incik, Sabuncu and Seydiler ignimbrites. Stratigraphic sections representation is not in scale; thicknesses are indicative.

IRM acquisition data and thermal demagnetization of the IRM components show the presence of two main mineral assemblages in the Afyon-Eskişehir ignimbrites: some sites are characterized by the exclusive presence of Ti-magnetite, whereas the others contain both Ti-magnetite associated to altered Ti-magnetite or hematite. Crossover diagrams exclude SD and/or MD grains interacting grains.

The AMS fabric is usually well developed. The Incik ignimbrite is characterized by low values of the degree of anisotropy P, comprised between 1.007 and 1.024. The AMS fabric is usually oblate, well developed and characterized by small dispersion of the principal axes, with the exception of few sites where low values of magnetic susceptibility causes a more dispersion of the data. Taking into account the θ angle comprised between the mean K_1 and K_3 site directions, three types of fabric can be identified: 1) parallel, in 14 out of 35 sites; 2) transverse, in 13 out of 35 sites; 3) oblique, in the remaining sites. As for the Kızılkaya ignimbrite, specimens whose density values differ more than +/-1σ from the site mean value were regarded as strongly inhomogeneous and discarded, and the statistics recalculated. The main results are that the oblique fabric changes to parallel or transverse at 4 out of 8 sites, the horizontal magnetic fabric is reduced from 10 to 8 sites and, on the whole, a general reduction of the dispersion angles occurs.

The AIRM magnetic fabric is well defined and oblate at 3 out 4 sites. Degree of anisotropy P is higher than for susceptibility, and comprised between 1.177 and 1.355. The highest value occurs in the site containing the greater amount of altered Ti-magnetite. Comparison of AMS and AIRM fabrics points out a general consistency between the two types of fabric, excluding inversions between the main axes. These results point out that AIRM is controlled by the low-coercivity ferromagnetic fraction (*i.e*., MD Ti-magnetite).

Data interpretation

The field evidence and AMS results highlight a strong topographic control on the emplacement of the Afyon-Eskişehir ignimbrites, pointing out an irregular paleo-topography characterized by the presence of several paleo-valleys and a westward paleo-drainage in the southern area of Eskişehir. The evidence of surficial interaction between ignimbrite flow and water is supported by the occurrence of lacustrine deposits preceding the Incik 1c ignimbrite. From the West to the East it is detected a lateral passage from limestone to silt, therefore the evidence of the presence of a lacustrine basin with a depocenter localized in proximity of the present-day Porsuk river. In this area, lacustrine deposits are followed by fluvial ones which underlain the Incik 1c ignimbrite, supporting the hypothesis of the presence of a paleo-valley (Porsuk paleo-valley). The interaction between paleo-topography and pyroclastic flow is evidenced by the channelization of the pyroclastic flow into minor east-to-west trending paleo-valleys and its confluence toward the Porsuk one. The topographic control on the ignimbrite emplacement was also detected for the Seydiler ignimbrite. Here, the presence of two main paleo-valleys is recognized along the present-day Midas and Derbent valleys. The presence of topographic barriers is also detected at some localities west from Bayat. Considering the pre-erosional volumes of the Incik (185 km^3), Sabuncu (94 km^3) and Seydiler ignimbrite (201 km^3), the resulting VEI index is 7, 6, and 7, respectively, evidencing Plinian eruptions; the calculated magnitude *M* (Pyle, 2000) is 7 for each ignimbrite. Areal and volumetric data, together with minimum traveled distance of the Seydiler ignimbrite, result to be greater if compared with the previous estimations of Aydar *et al*. (1998), pointing out a larger-scale eruption.

Source location of the Afyon-Eskişehir ignimbrites was inferred by the exploitation and combination of several volcanologic and magnetic techniques: 1) isopach and isopleth maps of the fall and ignimbrite deposits, 2) maps of the imbrication structures, welded and silicified facies of the ignimbrite deposits, and 3) AMS and AIRM magnetic fabrics. Both field data and magnetic fabric results concur for two source areas. The source area of the Incik and Sabuncu ignimbrites is identified in the area of Kırka. The source area of the Seydiler ignimbrite is identified in the proximity of the village of Bayat, which is consistent with the Koroğlu caldera described by Aydar *et al*. (1998). In order to test the efficacy of the AMS enhancing method, formerly developed for the Kızılkaya ignimbrite, a comparison between not selected AMS data and selected AMS data maps was done. On the whole, a sensible improvement of the quality of the results is evidenced from the maximum overlapping area extension, attesting the efficacy of the density discrimination technique in constraining more accurately the source areas with respect to the non selected AMS data.

In the area of Kırka, considered to be de source area of Incik and Sabuncu ignimbrites, the presence of a caldera system with a dimension of ≈ 20×20 km is supported by structural and volcanologic evidence, such as: 1) preserved northern rims along which proximal facies of the ignimbrite is exposed, 2) widespread presence of lacustrine and fluvial moat deposits, 3) presence of ring faults dislocating the ignimbrite deposits, of rhyolitic dome extrusions and of the Türkmendağ basaltic complex at the apex of the caldera system, 4) occurrence of borate deposits related to volcanic activity, 5) presence of ignimbrite deposits at 1000 m beneath the surface within the Kırka basin, and 6) evidence of a resurgent dome approximately located in the centre of the caldera system.

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