depending on many factors including flow volumes, distance from source, type of source, and flow composition. The largest silicic volcanic events are comparable in size to the largest recorded mafic events; however, they are potentially more catastrophic if erupted as ignimbrite flows. Facies and facies associations identified in CFBs include simple-classic flows, compound flows, ponded flows, truncation-onlap volcanic disconformities, burial-onlap volcanic disconformities, prograding hyaloclastite facies, preserved shield volcanic features, and sill facies. Many of these features occur on an intermediate to large basin wide scale and may only be revealed by detailed fieldwork, photogrammetry, and 3D geological models (e.g., Jerram and Robbe 2001; Single and Jerram 2004).

Using examples of well constrained 3D geological earth models from the Skye Main Lave Series it is possible to work out lava stacking patterns and flow directions (Fig. 1), volumes of different lava packages and how they have been influenced by faults (Fig. 2). The 3D models can also be of use in terms of rock property information such as density and velocity of key horizons in lavas/intrusions, known as intra-facies (Single and Jerram 2004). Such intra-facies maps allow geophysical interpretation of the behavior of the igneous rocks which is of importance when exploring areas in offshore settings with significant flood basalt cover such as offshore North Atlantic Margin.

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Influence of titanomagnetite composition on the magnetic anisotropy in a dyke-sill complex of the Ság-hegy volcano, Little Hungarian Plain

D. Renk[1], H. de Wall[1], U. Martin[1], K. Németh[2]

[1]Institut für Geologie, Julius-Maximilians-Universität Würzburg, Pleicherwall 1, 97070 Germany

[2]Geological Institute of Hungary, 14 Stefania street, Budapest 1143, Hungary

Introduction

In the last decades low-field magnetic susceptibility measurements have become an increasingly attractive method for geological studies which use the scalar values (bulk susceptibility) as well as the directional information and the anisotropy of magnetic susceptibility (AMS). Because of the potential for detecting weak fabric anisotropies, AMS has become a routine method for assessing flow directions in magmatic bodies. Sources of AMS in ferrimagnetic basaltic rocks are mainly titanomagnetites. After Jackson et al. (1998) and de Wall (2000), the magnetic susceptibility (MS) of titanomagnetite varies strongly with mineral composition and is in the low-field range strongly dependent on the field amplitude of the inducing magnetic field.

In this contribution we present a systematic study to record the effects of field dependence on AMS of dykes, sills, and lava flows. Variation in MS characteristics have been found indicative for lava emplacement and flow dynamics (Cañón-Tapia et al. 1997, Cañón-Tapia and Pinkerton 2000). The contribution of the effect of field dependence on MS and AMS in titanomagnetite-bearing volcanic rocks needs to be assessed for a reliable interpretation of AMS variations.

The key study has been carried out at the Ság-hegy volcanic complex in the Little Hungarian Plain Volcanic Field. It is composed of a phreatomagmatic tuff ring, formed during the Pliocene–Miocene period. After the meteoric water supply ended, the phreatomagmatic eruptive style changed into an effusive behavior and the tephra ring has been filled with a lava lake and a dyke-sill complex transecting the pyroclastic successions.

We report AMS characteristics of sills, dykes, and lavas from the lake interior of individual subaeric flows on top of the tephra

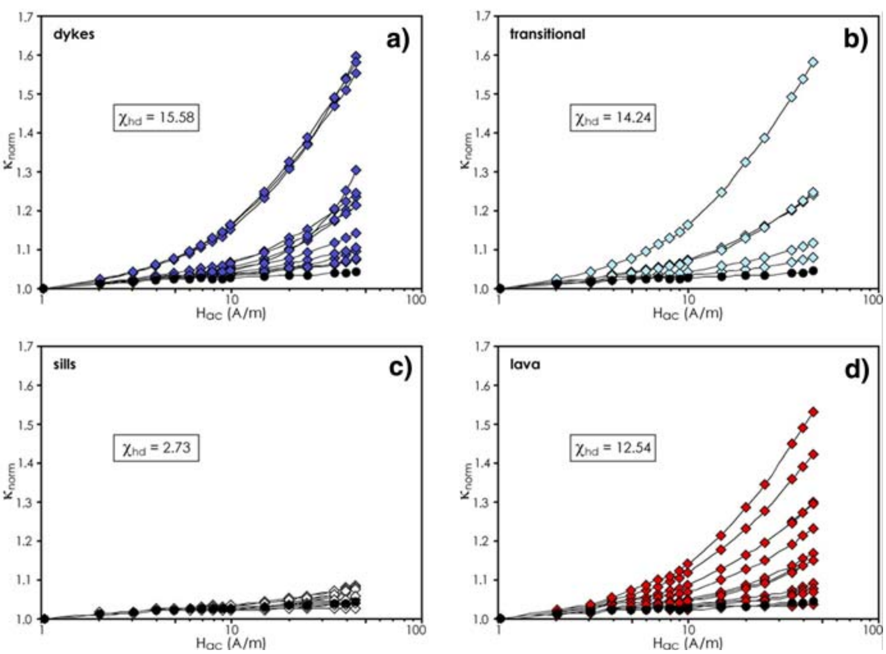

Fig. 1 Magnetic susceptibility of titanomagnetite as function of the ac field amplitude H_{ac} (normalized to k at $H_{ac} = 10$ A/m) for samples from **a** dykes, **b** dyke to sill and lava flow transition, **c** sills, **d** lava flows. For comparison, data for multi-domain pure magnetite is plotted. The average *Xhd* value (percentage of field dependence of magnetic susceptibility calculated from measurements in 30 and 350 A/m field amplitude) for the different sample sets is also given

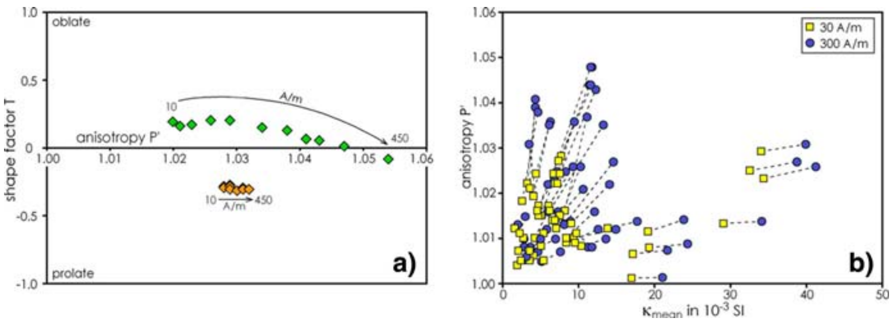

Fig. 2 **a** The variation of shape and anisotropy of AMS with increasing field amplitude in the range of 10–450 A/m for a sample with low Ti (*red symbols*) and high Ti (*blue symbols*) component, respectively. **b** The anisotropy versus bulk susceptibility for measurements in 30 and 300 A/m for the dyke sample set

deposits. Furthermore, we discriminated samples that represent the transition from dykes to sills and from intrusive (dyke) to effusive (lava flow) emplacement, respectively. The MS has been measured by a KLY-4S kappabridge (AGICO, Brno) which allows a record of the AMS at a high sensitivity and in various field amplitudes (2–450 A/m), commonly used for AMS in the range of 80–300 A/m (Hrouda 2002).

Results

Measurements of MS in the range of 10–450 A/m show that a linear relationship between magnetization and magnetizing field, as the basic assumption for the theory of low-field AMS measurements, is only realized in fields well below 100 A/m and behave non-linear with increasing field amplitude (Fig. 1). For comparison of magnetic characteristics we chose a data evaluation for measurements in 30 A/m assuming a linear behavior, whereas for 300 A/m it behaves definitely non-linear. Table 1 compiles the two data sets showing the mean susceptibility, the shape factor (T), and degree of anisotropy (P'), the parameters commonly used to describe magnetic fabrics (Jelinek 1981).

MS is highest for effusive lava rocks, whereby the highest values are related to samples from the lava lake. Susceptibility is successively decreasing from effusive rocks to dykes and shows lowest values for the sills. There is a distinct difference in MS for measurements in the two field amplitudes which is more pronounced in the lava and dykes compared to the sills. This is in agreement with the inferred compositional differences in titanomagnetite (Fig. 1) pointing to low Ti substitution in the sills compared to dykes and lava. Considering the whole sample set, a trend toward lower susceptibility and more isotropic fabrics for decreasing field amplitudes is evident (Fig. 2).

Obviously, measurements in fields of non-linear behavior have a strong effect on the degree of magnetic anisotropy which is varying with the composition of titanomagnetite. It is generally low in magmatic flow fabrics ($P' < 1.1$). Effects of field dependence can exceed the contribution for ''true'' magnetic anisotropy. The comparison of AMS-ellipsoids for measurements in the linear and non-linear field range shows this dramatic effect. However, it is still a difference in MS and P' between sills, dykes, and lavas which is also documented in the mean values in Table 1. This suggests an indication of variation in flow dynamics and cooling rate of the different volcanic bodies.

Table 1 Magnetic susceptibility characteristics (κ in 10^{-3} SI) of dykes, transitional, sills, and lavas for measurements in 30 and 300 A/m field amplitude

Number	Dyke 40	Transitional 20	Sill 20	Lava 16
κ_{30}	8.7	8.9	6.4	14.4
SD	8.4	7.0	2.7	16.5
κ_{300}	11.4	12.3	7.9	17.3
SD	9.6	6.9	3.3	18.6
P'_{30}	1.016	1.010	1.008	1.016
SD	0.007	0.005	0.005	0.007
P'_{300}	1.023	1.015	1.009	1.023
SD	0.013	0.006	0.004	0.010
T_{30}	0.114	0.286	0.011	0.234
SD	0.375	0.302	0.413	0.343
T_{300}	0.095	0.350	−0.052	0.154
SD	0.351	0.285	0.401	0.375

Concluding remarks

This study clearly documents the effects of field dependence of MS on the bulk susceptibility and on AMS in titanomagnetite-bearing rocks. Compositional effects have to be considered when comparing magnetic anisotropies in different types of volcanic rocks and when using the degree of magnetic anisotropy to obtain information on lava flow dynamics. It is therefore proposed to measure the AMS in the range of linear relationship between magnetization and applied field in ferromagnetic basaltic rocks.

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