Available online at www.sciencedirect.com
SCIENCE DIRECT®

Earth and Planetary Science Letters 240 (2005) 445–453

EPSL

www.elsevier.com/locate/epsl

Alteration induced changes of magnetic fabric as exemplified by dykes of the Koolau volcanic range

David Krása [a,*], Emilio Herrero-Bervera [b]

[a] *Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität, Theresienstr. 41, D-80333 Munich, Germany*
[b] *Paleomagnetics and Petrofabrics Laboratory, SOEST-Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 1680 East West Road, Honolulu, HI 96822, USA*

Received 24 May 2005; received in revised form 19 September 2005; accepted 20 September 2005
Available online 27 October 2005
Editor: R.D. van der Hilst

Abstract

We studied 93 samples from 8 basaltic dykes of the Koolau volcanic range on the island of Oahu,Hawaii,USA,to determine the influence of hydrothermal alteration on the magnetic fabric as determined by anisotropy of magnetic susceptibility (AMS) measurements. Rock magnetic as well as microscopic investigations show that only ≈25% of the samples have retained their original magnetomineralogical composition of unaltered Ti-poor titanomagnetite. The remaining samples have undergone hydrothermal alteration which transformed the primary magnetic phase into a granular intergrowth of titanomagnetite, titanomaghemite and hematite. In both sample groups,this magnetic phase occurs in coarse (tens of microns),irregularly shaped particles as well as interstitial clusters of smaller (<5 μm) grains. Our investigations show that hydrothermal alteration does change the bulk susceptibility and the degree of anisotropy but not the directions of principal axes of the AMS ellipsoid which are predominantly corresponding to normal magnetic fabric. The stability of AMS directions, regardless of the degree of alteration, points towards the model of distribution anisotropy as the controlling factor for the observed magnetic fabric.

Keywords: petrofabrics; magnetic fabrics; rock magnetism; magnetic mineralogy; hydrothermal alteration; dykes

1. Introduction

Measurements of the anisotropy of magnetic susceptibility (AMS) have been used successfully in the past to infer the petrological fabric in order to determine flow orientations or even flow directions in volcanic dykes (e.g.,[1–4]). AMS is a quickly measurable proxy for the petrofabric, however, there is not necessarily a one-to-one correspondence between magnetic fabric and petrofabric. Much effort has been put into determining how magnetic fabric is generated in flowing magma and how it relates to compositional and rock magnetic parameters. Khan [1] proposed that magnetic fabric reflects the alignment of early crystallising elongated ferrimagnetic particles by hydrodynamic forces in the flowing magma. The bulk AMS would then be caused by the shape anisotropy of these preferentially oriented individual particles. Later, Hargraves et al. [5] pointed out that titanomagnetite, as the dominating ferrimagnetic mineral in basic igneous rocks, often is a product of late-stage interstitial crystallisation

* Corresponding author. Now at: University of Edinburgh, School of Geosciences, West Mains Rd, Edinburgh EH9 JW, UK.
E-mail address: david.krasa@ed.ac.uk (D. Krása).

0012-821X/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsl.2005.09.028

(i.e.,when magma flow has already ceased) and additionally, often displays irregularly equant or skeletal grain shapes. Instead of Khan's model, Hargraves et al. proposed that magnetic fabric is governed by the crystallisation of ferrimagnetic grain clusters in preferentially oriented matrix interstices and coined the term "distribution anisotropy". In that case, magnetostatic interaction between the individual particles of these clusters plays an important role, as was shown by Stephenson [6] and Cañón-Tapia [7].

An important rock magnetic parameter having influence on the relation between flow fabric and magnetic fabric is the domain state of ferrimagnetic minerals. It was shown that in the case of elongated uniaxial MD magnetite, the major principal AMS axis (K1) is oriented along the long axis of the particle (normal fabric), whereas in the case of SD magnetite the same holds true for the minor axis (K3, inverse fabric)(e.g.,[8,9]).

Little is known, however, about the influence of magnetomineralogical alteration in igneous rocks on the magnetic fabric. Such processes do change rock magnetic parameters like domain state and the anisotropies governing magnetic stability which in turn may have an influence on the degree and orientation of the AMS. The aim of this paper is to exemplify such possible changes and their effect on magnetic fabric properties.

2. Samples and techniques

We studied 93 samples from 8 basaltic dykes exposed at Kapaa quarry, south eastern part of the island of Oahu, Hawaii, USA. These dykes are part of the Koolau dyke complex (Fig. 1) which was previously studied regarding the plumbing of the Koolau shield volcano [10,11,2]. The dykes are predominantly oriented along the main rift axis of the Koolau volcanic range (NW–SE). The Koolau volcanics erupted between 3.19 – 1.78 Ma ago [12,13]. Magnetostratigraphic evidence indicates that the dyke complex was exposed due to a giant landslide between 2.1 and 1.78 M.y. ago [14]. Estimates suggest that this landslide removed approximately the upper 3000 m of the volcanic edifice which means that the studied dykes are part of the volcanic plumbing deep inside Koolau volcano.

Between 7 and 14 oriented standard inch-sized cores were taken from each dyke and, where possible, samples were preferentially taken from both dyke margins to study potential imbrication of magnetic fabric data. Measurements of the low-field anisotropy of magnetic susceptibility (AMS) were carried out on an AGICO KLY-2 Kappabridge which was als used to measure mean susceptibility versus temperature curves. The

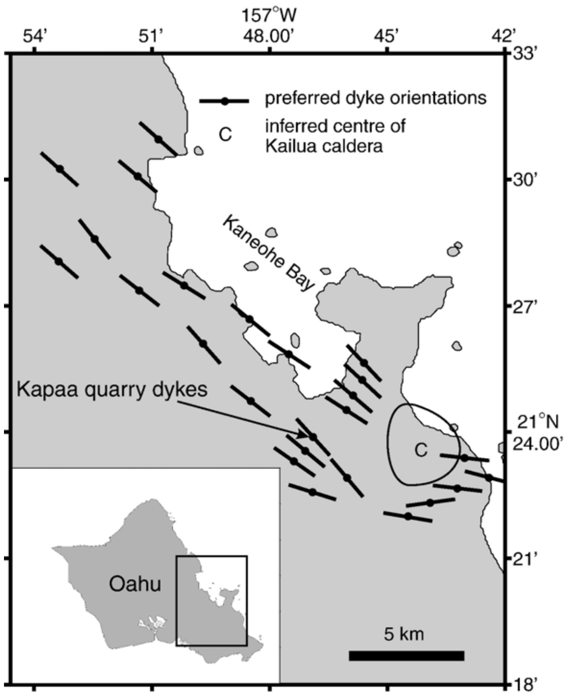

Fig. 1. Map of the south eastern part of the island of Oahu showing the preferred orientation of dykes from the dyke complex of Koolau volcano. The location of the studied Kapaa quarry dykes is marked. The inset shows the island of Oahu. Redrawn after [11].

AMS data was processed with the software package pmag1.8.5 [15]. Rock magnetic characteristics were determined by measuring IRM acquisition curves, hysteresis loops, back field curves and saturation magnetisation (M_S) versus temperature curves using a Variable Field Translation Balance (VFTB). Additionally, the samples were AF demagnetised and measured on a 2G cryogenic SQUID magnetometer to gain additional data on their coercivity. All magnetic measurements were carried out at the Paleomagnetics and Petrofabrics Laboratory of the University of Hawaii. A subset of samples was studied by means of reflected light microscopy and analysed microchemically with an Cameca SX50 electron microprobe at the Electron Microprobe Laboratory of the University of Hawaii.

3. Results

3.1. Rock magnetism

Rock magnetic measurements were carried out on a subset of 41 samples (with at least 4 samples from each dyke) to determine the magnetic mineralogy and magnetic grain size. The investigations show that the dyke samples can be subdivided into two groups with distinctive rock magnetic characteristics. The first