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Journal of volcanology and geothermal research

Journal of Volcanology and Geothermal Research 153 (2006) 301 – 312

www.elsevier.com/locate/jvolgeores

In situ observation of dome instabilities at Merapi volcano, Indonesia: A new tool for volcanic hazard mitigation

Matthias Hort [a,*], Malte Vöge [a], Ralf Seyfried [b], Antonius Ratdomopurbo [c]

[a] *Institut für Geophysik, Universität Hamburg, Bundesstr. 55, D-20146 Hamburg, Germany*
[b] *IAV GmbH, Nordho str. 5, 38518 Gifhorn, Germany*
[c] *Volcanological Technology Research Center (VTRC/BPPTK-Yogyakarta), Jalen, Cendana 15, Yogyakarta-55166, Indonesia*

Received 7 March 2005; received in revised form 27 October 2005; accepted 15 December 2005
Available online 24 February 2006

Abstract

Understanding the mechanism and repetition frequency of dome instability events at high risk, dome building volcanoes located near densely populated areas is one crucial piece of information when dealing with volcanic hazard mitigation. Although some visual in situ observations of such processes have been made at Unzen volcano and on Montserrat, continuous monitoring of dome activity has been severely hampered by weather conditions such as cloud coverage. Using a newly designed microwave Doppler system, we are able to continuously monitor in situ processes at active dome systems. With our instrument we can determine the velocity of material breaking off an active dome as well as the approximate amount of material passing through the radar beam allowing us to continuously identify different types of dome instabilities. A data set collected during a highly active period at the end of Oct. early Nov. 2001 at Merapi volcano indicates two different instability types: a) purely gravitational instabilities and b) gravitational instabilities that are followed immediately by an explosion. Such information, continuously collected, allows tight constrains on the activity status of dome building volcanoes and is an important information for hazard mitigation. The number of instabilities detected by the radar during the observational period is larger than the number of rockfall events detected by the seismic network operated at Merapi during that time.

Keywords: dome instability; Merapi; Doppler radar; in situ measurement

1. Introduction

Among the 25 volcanoes on Earth exhibiting Merapi type activity, Merapi volcano on Central Java (Indonesia) had the most frequent eruptions in historic times (about 70 since 1548 Simkin and Siebert, 1994). It is considered one of the most dangerous volcanoes in Indonesia mainly because of its proximity to the city of Yogyakarta. Today's activity of Merapi volcano (Newhall et al., 2000; Camus et al., 2000) is mostly restricted to the west and southwest sector (see Fig. 1) along the highly populated valleys. Different hazard studies mark this region as very dangerous, but in case of a very large eruption, even parts to the east of Merapi volcano may be endangered (Thouret et al., 2000). Merapi volcano has been continuously active from at least 1972 up to now, with four periods of significantly increased activity (1984, 1994, 1998, 2001). The average magma production rate of Merapi volcano is about 10^5 m^3/

* Corresponding author.
E-mail address: hort@dkrz.de (M. Hort).

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doi:10.1016/j.jvolgeores.2005.12.007

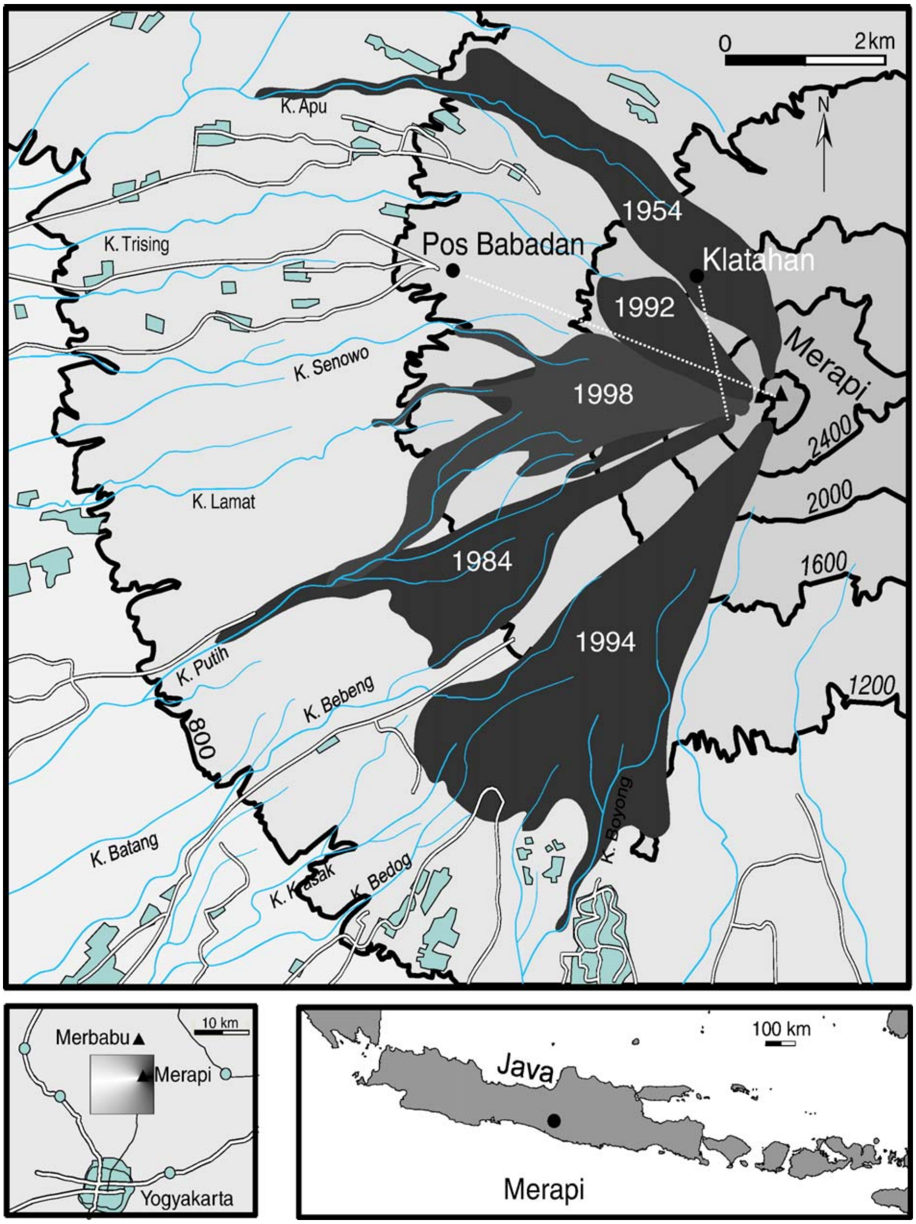

Fig. 1. Recent block- and ashflow deposits at Merapi volcano, Indonesia (Schwarzkopf, 2001). Setup locations for the two experiments as well as the direction of the two radar beams are shown on the map.

month (Siswowidjoyo et al., 1995), but periods of low extrusion rates interchange with short periods of high extrusion rates and very short explosive events. The intervals of those different periods are highly variable with different authors (Boudon et al., 1993; Thouret et al., 2000), indicating that a regular pattern does not continue for long periods.

For monitoring purposes as well as for scientific research the Volcanological Survey of Indonesia (VSI) and different foreign research teams operate complex monitoring systems at Merapi volcano. Main components of the network (Voight et al., 2000a) are: (a) a seismic network with short period as well as broad band stations and acoustic arrays (Ratdomopurbo and Poupinet, 2000; Wassermann and Ohrnberger, 2001); (b) deformation measurements (Rebscher et al., 2000; Voight et al., 2000b); (c) magnetic observatories (Zlotnicki et al., 2000); (d) gas composition and temperature monitoring (Zimmer and Erzinger, 2003); (e) self-potential measurements