



Volcaniclastic stratigraphy of Gede Volcano, West Java, Indonesia: How it erupted and when



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ABSTRACT

Gede Volcano, West Java (Indonesia), is located 60 km south of Jakarta within one of the regions with highest population density in the world. Therefore, knowledge of its eruption history is necessary for hazard evaluation, because even a small eruption would have major societal and economic consequences. Here we report the results of the investigation of the stratigraphy of Gede (with the focus on its volcaniclastic deposits of Holocene age) and include 23 new radiocarbon dates. We have found that a major part of the volcanic edifice was formed in the Pleistocene when effusions of lavas of high-silica basalt dominated. During this period the volcano experienced large-scale lateral gravitational failure followed by complete reconstruction of the edifice, formation of the summit subsidence caldera and its partial refilling. After a repose period of >30,000 years the volcanic activity resumed at the Pleistocene/Holocene boundary. In the Holocene the eruptions were dominantly explosive with magma compositions ranging from basaltic andesite to rhyodacite; many deposits show heterogeneity at the macroscopic hand specimen scale and also in the minerals, which indicates interactions between mafic (basaltic andesite) and silicic (rhyodacite) magmas. Significant eruptions of the volcano were relatively rare and of moderate violence (the highest VEI was 3–4; the largest volume of erupted pyroclasts 0.15 km³). There were 4 major Holocene eruptive episodes ca. 10,000, 4000, 1200, and 1000 yr BP. The volcanic plumes of these eruptions were not buoyant and most of the erupted products were transported in the form of highly concentrated valley-channelized pyroclastic flows. Voluminous lahars were common in the periods between the eruptions. The recent eruptive period of the volcano started approximately 800 years ago. It is characterized by frequent and weak VEI 1–2 explosive eruptions of Vulcanian type and rare small-volume extrusions of viscous lava. We estimate that during last 10,000 years, Gede erupted less than 0.3 km³ DRE (Dense Rock Equivalent) of magma. Such small productivity suggests that the likelihood of future large-volume (VEI ≥ 5) eruptions of the volcano is low, although moderately strong (VEI 3–4) explosive eruptions capable of depositing pyroclastic flows and lahars onto the NE foot of the volcano are more likely.

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1. Introduction

Gede Volcano (2958 masl – meters above sea level), sometimes also spelled as Gedeh, together with the adjacent Pangrango Volcano (3019 masl) form a large (base diameter 30 km) volcanic massif, just 60 km south of the Indonesian capital Jakarta, West Java (Figs. 1 and 2). The volcano belongs to the Sunda arc, the volcanism of which is associated with the subduction of the Indo–Australian plate beneath the Eurasian plate at rate of approximately 6 cm/y. While Pangrango has no historically recorded eruptions, Gede is one of the more active volcanoes in Indonesia: 26 eruptions were reported since 1747; the last of them occurred in 1947–1957 (Siebert et al., 2010; Smithsonian database at www.volcano.si.edu/volcano.cfm?vn=263060; Supplementary Fig. 1). The earliest reports of Gede eruptions are very brief and allow only inferring that those eruptions were mild and mostly explosive. The 1747–1748 and 1840 eruptions apparently were relatively

important and possibly included lava extrusions. Photos and descriptions of the 20th century eruptions suggest that they consisted of sporadic ash- and bomb-laden explosions akin to Vulcanian type in a broad sense (according to the definition given in Clarke et al., 2015). Modern activity of the volcano includes persistent solfataric activity in the summit crater (with temperatures 150–200 °C) and periodic seismic swarms possibly indicating shallow intrusions of magma in 1990, 1991, 1992, 1995, 1996, 1997, 2000, 2007, 2010, 2011, and 2012 (Suantika et al., 1999; Zaennudin, 2008; Hidayat et al., 2012).

Due to the fertile volcanic soil and warm, humid climate, land at the ring plain of Gede has one of the highest population densities in the world. Population data for 1990 indicate an average of 1085 persons per km² with total population of 29.4 million around the volcano (Small and Naumann, 2001). An almost uninterrupted belt of towns and villages occupies the elevations up to 1500 masl, while individual households and gardens climb up to 1800 masl. Higher up the volcano is covered by the

famous rain forest of Gede–Pangrango National Park, which is visited by numerous tourists, many of whom camp in the summit area. Considering all this, the reconstruction of eruptive history and accurate hazard assessment of the Gede–Pangrango volcanoes is an important objective. The Volcanological Survey of Indonesia mapped the distributions of volcanoclastic deposits (Situmorang and Hadisantono, 1992) and composed a volcanic hazard map of the area (Hadisantono et al., 2006). However, this work was lacked radiocarbon dating and thus only a general stratigraphic scheme for the volcano could be proposed.

In this paper we report the results of investigation of stratigraphy of Gede with the focus on its volcanoclastic deposits of the Holocene age. We also give the basic petrological and geochemical information that allows understanding the main magmatic processes involved in the evolution of Gede as well as potential eruption triggers. We visited multiple outcrops of the deposits and obtained 23 new radiocarbon dates for the area and as a result the timing and character of activity of Gede in Holocene time has been revealed.

2. General geology and geomorphology of Gede Volcano

The first descriptions of geology of Gede Volcano were made by Verbeek and Fennema (1896), Taverne (1926), Van Bemmelen (1949), Petroshevsky and Klompe (1951), and Neumann van Padang (1951). Data on modern petrography, mineralogy, and geochemistry were

published by Davidson et al. (2007), Handley et al. (2010, 2011) and Dempsey (2013).

The edifice of the volcano (Fig. 1) consists of 3 major parts having different ages (from old to young):

- (1) Main stratocone (called Gumuruh) with 1.8-km-wide summit caldera;
- (2) Intra-caldera cone (Gede proper) with 900-m-wide summit crater;
- (3) Intra-crater infill composed of lava dome with 3 small explosive craters on its top (below we informally call them “explosive funnels” to distinguish from much larger summit crater of the volcano).

The Gumuruh stratocone has relative elevation 2400 m above the volcanic base. Its strongly truncated edifice (with a volume of the order of 100 km³) comprises more than 95% of the total volume of the volcano (Fig. 1). The upper-middle slopes of Gumuruh are covered by thick lava flows and have only a few outcrops. The internal structure of the cone can be inferred mostly from the geology of the voluminous South-Eastern (SE) debris avalanche deposit formed by ancient gravitational collapse of the volcano (MacLeod, 1989; Situmorang and Hadisantono, 1992). The scar of the collapse is completely refilled with younger volcanic products and not visible now. The SE avalanche

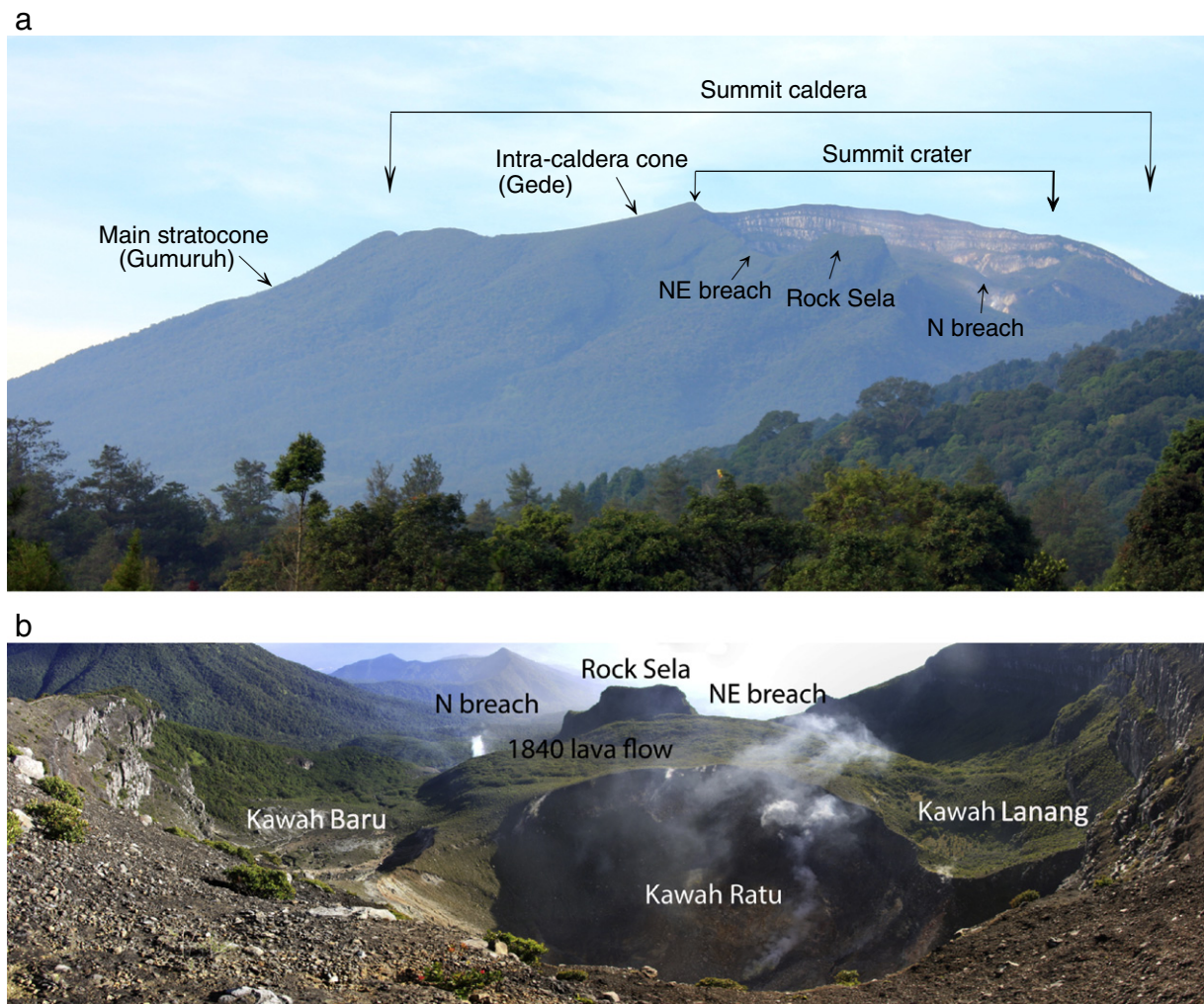


Fig. 1. Edifice of Gede Volcano with main topographic features indicated. a) General view from NE. b) Panorama of Gede crater from the volcano summit toward the NE. Slope of Pangrango Volcano is visible in the upper left corner. Photos by A. Belousov.

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