Tectonophysics 478 (2009) 19–33

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Aeromagnetic constraints on the subsurface structure of Stromboli Volcano, Aeolian Islands, Italy

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ARTICLE INFO

Article history:
Received 30 November 2007
Received in revised form 29 December 2008
Accepted 22 February 2009
Available online 10 March 2009

Keywords:
Aeromagnetic
Magnetic anomaly
Magnetization
Imaging
Stromboli Volcano

ABSTRACT

Two helicopter-borne magnetic surveys were conducted over Stromboli Volcano and its surrounding areas on the Aeolian Islands, southern Italy in 2002 and 2004 to better understand the subsurface structure of the area. Observed data from those surveys were merged and aeromagnetic anomalies for Stromboli Island and its vicinity were reduced onto a smoothed surface, assuming equivalent anomalies below the observed surface. The magnetic terrain effects were calculated for the magnetic anomalies of the study area, assuming the magnetic structure comprised of an ensemble of prisms extending from the ground surface to a depth of 3000 m below sea level: the average magnetization intensity was calculated to be 2.2 A/m for the edifice of Stromboli shallower than 1200 m below sea level by comparing the observed and synthetic data. Next, apparent magnetization intensity mapping was applied to the observed anomalies using a uniform magnetization of 2.2 A/m as the initial value. The apparent magnetization intensity map indicates magnetic heterogeneities among volcanic rocks which constitute the edifice of the volcano. The most remarkable feature of the magnetization intensity map is a magnetization low which occupies the center of the island where the summit craters reside, suggesting demagnetization caused by the heat of conduits and/or hydrothermal activity in addition to the thick accumulation of less magnetic pyroclastic rocks. By comparing topographic and geologic maps, it can be seen that magnetization highs are distributed on the exposures of basaltic-andesite to andesite lavas (Paleostromboli I), shoshonitic lavas with an eccentric vent and a shield volcano (Neostromboli), on the south, north and west coasts of the volcano, respectively. These magnetization highs further extend offshore, implying the seaward continuation of these volcanic rocks. 3-D magnetic imaging was preliminarily applied to the same magnetic anomalies as well as for the magnetization intensity mapping. The result implies that the bottom depths of these magnetic structures are relatively shallow (<1500 m below sea level at the maximum). A distinctive regional magnetization high is distributed on a saddle area between Stromboli and Basiluzzo islands and extends to the two submarine eruptive centers on the southwestern submarine edifice of Stromboli. A careful examination on the results of the 2-D and 3-D magnetic imaging implies that the saddle area is occupied by volcanic rocks from these eruptive centers and is also underlain by partially and/or completely concealed volcanic structures formed along a NW–SE direction conjugate to the main axis of regional tectonic trend in this area.

1. Introduction

The Aeolian Island Arc is located in the Tyrrhenian Sea, southern Italy and composed of seven volcanic islands: Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea, and Stromboli from west to east and several seamounts (Fig. 1). The volcanic activity of the islands is thought to originate from the subduction of the African Plate beneath the European Plate at the southern edge of the Tyrrhenian Sea (Gasparini et al., 1982). Since ancient Greek times, Stromboli in particular has been noted for its mild explosive eruptions which emit ash, lava fragments and volcanic bombs.

Due to its persistent and very regular activity and its relatively small size, Stromboli Volcano is an ideal study object or natural laboratory for volcanologists. Thus the volcano has been continuously observed and studied since the beginning of 19th century (e.g. Mercalli, 1891). Stromboli Island has been also investigated by a number of geophysical studies (Falsaperla and Schick, 1993). Geophysical investigations for volcanoes can be divided generally into two categories. Studies of the first category aim at investigating the internal structure of the volcanic edifice related to its activity. Studies in the second category strive to build physical models for Strombolian eruptions. Studies of the first category cannot be easily conducted on volcanic islands especially with steep flanks. In the first category, gravimetric studies were conducted on Stromboli by Bonasia and Yokoyama (1972) and Bonasia et al. (1973). The

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0040-1951/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2009.02.035

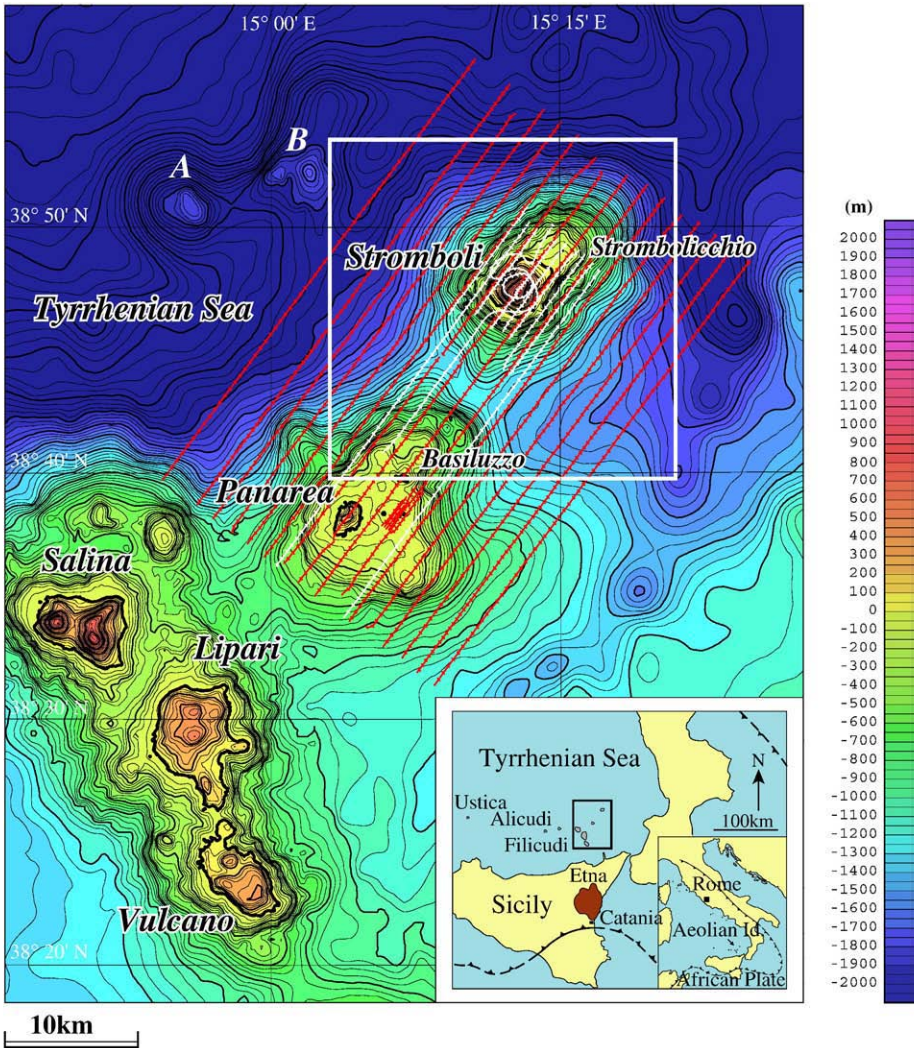

Fig. 1. Location map of study area. Red and white tick-marked lines indicate the 2002 and 2004 flight line paths, respectively. A rectangle shows the detailed study area of Stromboli Volcano and its vicinity, corresponding to the area in Fig. 5. A and B stand for the North A and North B seamounts by Gabbianelli et al. (1993), respectively. Topographic contour interval is 50 m. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

investigations revealed a Bouguer anomaly low in the very center of the island corresponding to low-density material filling the buried caldera.

The first geomagnetic survey was conducted as early as 1940 by Bossolasco (1943) with 218 measuring points distributed over Stromboli Island. Magnetic anomalies concentrate along a NE–SW line associated with recent activity. Further magnetic studies were conducted by Yokoyama (1959) and Casertano and Pinna (1971). In the 1970s, an aeromagnetic and gravity survey was conducted in the southern part of the Aeolian Islands by Iacobucci et al. (1977). In the 1980s, a regional airborne magnetic survey was conducted by Azienda Generale Italiana Petroli (AGIP) (1982). The magnetic anomalies were interpreted as an indication of the structural continuity between Stromboli and Panarea (Gabbianelli et al., 1993).

Since the 1990s, high-resolution aeromagnetic survey (HRAM) has made great progress with the development of GPS. HRAM is a practical tool for understanding shallow subsurface structures. Since the second half of the 1990s, HRAM has been applied for geologic hazard mitigation purposes such as earthquake and volcanic hazard mitigation (e.g. Okuma et al., 2001).

The Geological Survey of Austria (GBA) and Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST) started airborne geophysical surveys on the Aeolian Islands in 1999 to better understand the subsurface structure of active volcanoes in the area. In addition to intensive studies in the Vulcano–Lipari volcanic complex (e.g. Supper et al., 2001, 2004; Stotter, 2005; Okuma et al., 2006a,b), aeromagnetic surveys were conducted over the area from Panarea to Stromboli in 2002 and over Stromboli Island and its vicinity in 2004 (Fig. 1) with a flight altitude of 100 m above terrain.

In this paper, we deal with these aeromagnetic surveys and the derived aeromagnetic anomalies of Stromboli Volcano. The results of apparent magnetization intensity mapping and preliminary 3-D magnetic imaging are also discussed with a special reference to the geologic structure compared with other geophysical data.

2. Geologic settings

The geology of Stromboli Island has been discussed by several authors including Rosi (1980), Hornig-Kjarsgaard et al. (1993), Keller et al. (1993), Guest et al. (2003). Here, we follow a detailed chemical description from Hornig-Kjarsgaard et al. (1993). Deep focus seismicity shows hypocenters in the area of Stromboli at depths between 250 km and 300 km in the area of Stromboli. The continental crust, on which the Aeolian Islands reside, thins out towards the center of the Tyrrhenian Basin and has a crustal thickness of about 18 km underneath Stromboli (Morelli, 1975). The age of the oldest products has been determined to 100 ka for Stromboli Island and 250 ka for the Strombolicchio volcanic neck (Gillot and Keller, 1993). The latter is likely to be the remnant of an older eroded volcanic edifice.