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Volcanic hazard on Deception Island (South Shetland Islands, Antarctica)

S. Bartolini [a,*], A. Geyer [a], J. Martí [a], D. Pedrazzi [a], G. Aguirre-Díaz [b]

[a] Institute of Earth Sciences Jaume Almera, ICTJA-CSIC, Group of Volcanology, SIMGEO (UB-CSIC), Lluís Solé i Sabarís s/n, 08028 Barcelona, Spain
[b] Centro de Geociencias, Universidad Nacional Autónoma de México, Campus Juriquilla, Querétaro, Qro. 76230, Mexico

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ABSTRACT

Deception Island is the most active volcano in the South Shetland Islands and has been the scene of more than twenty identified eruptions over the past two centuries. In this contribution we present the first comprehensive long-term volcanic hazard assessment for this volcanic island. The research is based on the use of probabilistic methods and statistical techniques to estimate volcanic susceptibility, eruption recurrence and the most likely future eruptive scenarios. We perform a statistical analysis of the time series of past eruptions and the spatial extent of their products, including lava flows, fallout, pyroclastic density currents and lahars. The Bayesian event tree statistical method HASSET is applied to calculate eruption recurrence, while the QVAST tool is used in an analysis of past activity to calculate the possibility that new vents will open (volcanic susceptibility). On the basis of these calculations, we identify a number of significant scenarios using the GIS-based VORIS 2.0.1 and LAHARZ software and evaluate the potential extent of the main volcanic hazards to be expected on the island. This study represents a step forward in the evaluation of volcanic hazard on Deception Island and the results obtained are potentially useful for long-term emergency planning.

1. Introduction

Deception Island is the most active volcano in the South Shetland Islands group (Antarctica) and more than 20 eruptions have taken place there over the past two centuries (Orheim, 1972; Pallàs et al., 2001; Smellie, 2002a). Located at the spreading centre of the Bransfield Strait marginal basin (Fig. 1), this island consists of a horse-shoe-shaped composite volcanic system truncated by the formation of the collapse caldera that occupies the central part of the island (Valencio et al., 1979; Smellie, 1988; Martí et al., 2013) (Fig. 2a). The most recent eruptions took place in the late 1960s and 1970s and destroyed or severely damaged the scientific bases operating on the island (Baker et al., 1975; Roobol, 1982) (Figs. 3a, b). Interestingly, during the final eruption strong winds and the unusually low tropopause in the area (Smellie, 1999) led to an important spread of volcanic ejecta that reached distances of over 150 km (Pallàs et al., 2001; Fretzdorff and Smellie, 2002; Pedrazzi et al., in press).

Since its discovery in 1820, the island's natural harbours in Port Foster Bay (e.g. Pendulum Cove and Whalers Bay) (Fig. 2b) have been actively used during different peaks in the commercial exploitation of the Southern Ocean (Roobol, 1982; Smellie and López-Martínez, 2002). Between 1905 and 1930, the island served as the shore base for the Antarctic's most important whaling industry (Fig. 3c) and also played a military role during World War I due to its strategic location between the Atlantic and Pacific Oceans. This resulted in the construction of a British scientific station, which was occupied from 1944 until it was destroyed in 1969 (Roobol, 1982; Smellie and López-Martínez, 2002) (Fig. 3a). Following the British initiative, Argentina and Chile also established scientific bases on the island that, likewise, were either destroyed or abandoned after the eruptions occurring between 1967 and 1970 (Fig. 3b). After occasional expeditions to Deception Island, Britain, Spain and Argentina recommenced scientific activity in 1986. Argentina re-occupied and reconstructed its station (Fig. 3f), while Spain constructed a new station in 1989 (Fig. 3e); these two scientific bases operate every year during the Antarctic summer.

The number of tourists that visit Antarctica has increased since the first commercial cruise in 1966 and today over 30,000 visitors arrive during the austral summer (2012–2013) (IAATO, *International Association of Antarctica Tour Operators*) (Fig. 4a). Deception Island and Half Moon Island (Fig. 4) are two of the most popular destinations; specifically, the Antarctic Specially Protected Area (ASPA) sub-site of Whalers Bay (Fig. 2) receives over 15,000 visitors every year (Fig. 4b), while other sectors such as Telefon Bay or Pendulum Cove (Fig. 2) are visited by up to 5000 tourists annually (Fig. 4b).

The recent eruptions (1967, 1969 and 1970) have demonstrated that volcanic activity on Deception Island may become a cause for concern for tourists, scientists and the military personnel working on or near the island. Livingston and Deception Islands host a total of five research stations and three field camps, while Greenwich and King George Islands are home to 10 all-year and two temporary research stations (Fig. 2). For example, during the 1970 eruption, a considerable amount of ash – including a fine ash fall deposit of 4 mm on Arturo Prat station

* Corresponding author. Tel.: +34 934095410.
E-mail address: sbartolini@ictja.csic.es (S. Bartolini).

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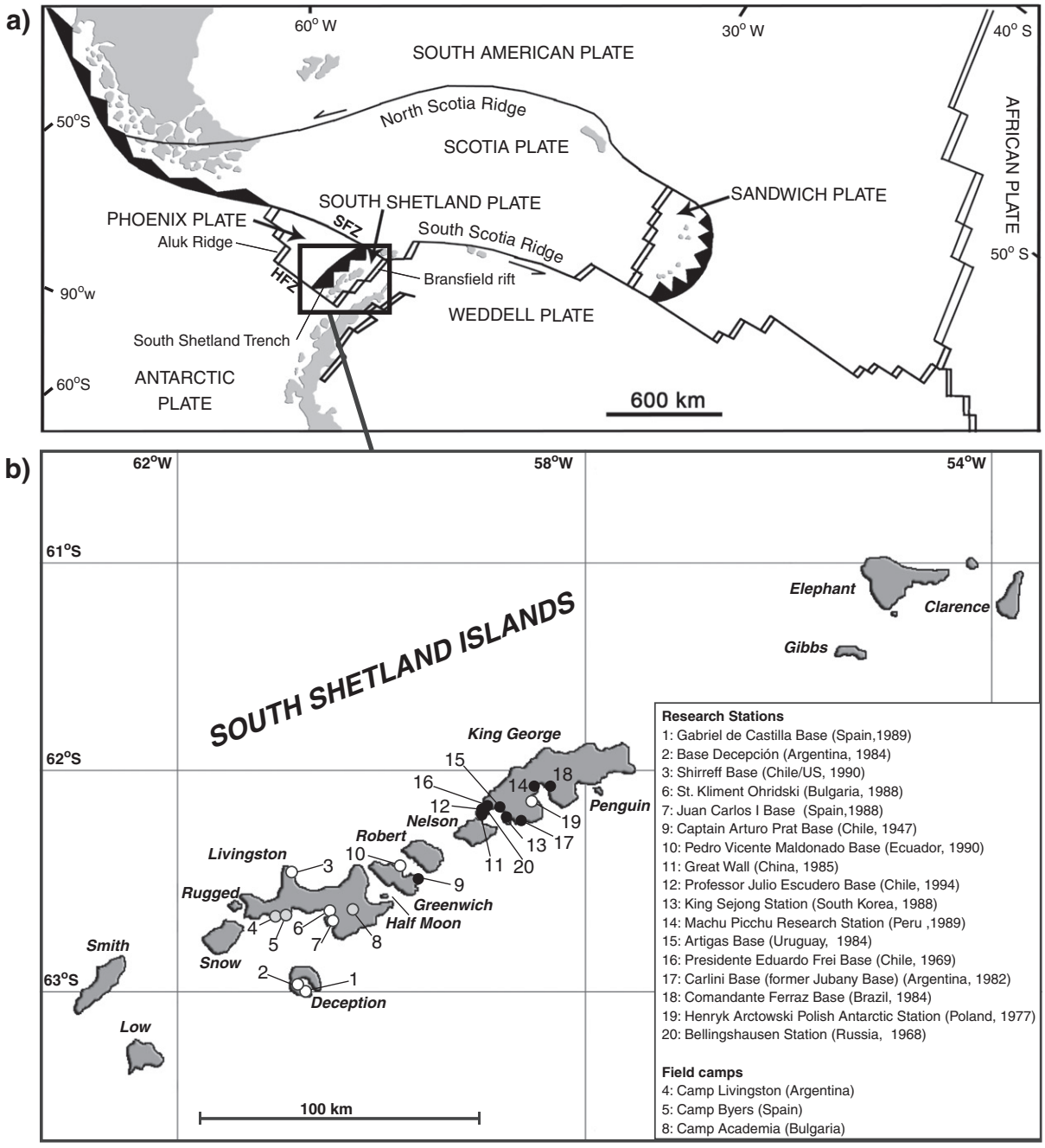

Fig. 1. a) Simplified regional tectonic map and location of the South Shetland Islands. HFZ: Hero Fracture Zone, SFZ: Shetland Fracture Zone. b) Location of Deception Island. Black and white dots indicate nearby year-round and temporary (only austral summer) research stations, respectively. Grey dots correspond to temporary field camps.
Panel a: modified from Ibañez et al. (2003); panel b: modified from Grad et al. (1992).

on Greenwich Island and about 1 mm on Bellingshausen station on King George Island (Baker et al., 1975; Pedrazzi et al., in press) – fell far from the island.

Aside from a paper by Roobol (1982) and the relatively recent work of Smellie (2002a), to the authors' knowledge no accurate volcanic hazard assessment has ever been conducted for Deception Island. Furthermore, previously hazard maps were either restricted to a single hazard (Roobol, 1982) (Fig. 5a) or were non-systematic (Smellie et al., 2002) (Fig. 5b). As pointed out by Smellie (2002a), as a popular destination for tourists and an area of constant scientific research, properly elaborated hazard maps and related assessments are now more necessary than ever. The latter are indispensable for the elaboration of emergency plans aimed at mitigating the potential human and economic losses of any future volcanic eruptions on Deception Island.

In order to improve the hazard assessment on Deception Island, it is important to estimate the temporal and spatial probabilities of future eruptions. In this paper, we carry out a threat analysis for Deception Island using the National Volcano Early Warning System (NVEWS) template (Ewert et al., 2005) and compare it with other volcanoes of similar characteristics. Then, we present a systematic analysis of the temporal and spatial long-term hazard assessment of the island using available geological data, including the past eruption record, stratigraphic information and volcano-structural data. We used HASSET (Sobradelo et al., 2014) to estimate the probability that a volcanic episode will occur within the forecast interval and to evaluate the long-term probability of different types of hazards on the island. For the spatial analysis we applied QVAST (Bartolini et al., 2013) to obtain the susceptibility map, and LAHARZ and VORIS 2.0.1 (Hoblitt et al., 1995; Schilling,