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Volcano–ice–sea interaction in the Cerro Santa Marta area, northwest James Ross Island, Antarctic Peninsula

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ABSTRACT

We present here the results of detailed mapping, lithofacies analysis and stratigraphy of the Neogene James Ross Island Volcanic Group (Antarctic Peninsula) in the Cerro Santa Marta area (northwest of James Ross Island), in order to give constraints on the evolution of a glaciated volcanic island. Our field results included recognition and interpretation of seventeen volcanic and glacial lithofacies, together with their vertical and lateral arrangements, supported by four new unspiked K–Ar ages. This allowed us to conclude that the construction of the volcanic pile in this area took place during two main eruptive stages (Eruptive Stages 1 and 2), separated from the Cretaceous bedrock and from each other by two major glacial unconformities (U1 and U2). The U1 unconformity is related to Antarctic Peninsula Ice sheet expansion during the late Miocene (before 6.2 Ma) and deposition of glacial lithofacies in a glaciomarine setting. Following this glacial advance, Eruptive Stage 1 (6.2–4.6 Ma) volcanism started with subaerial extrusion of lava flows from an unrecognized vent north of the study area, with eruptions later fed from vent/s centered at Cerro Santa Marta volcano, where cinder cone deposits and a volcanic conduit/lava lake are preserved. These lava flows fed an extensive (>7 km long) hyaloclastite delta system that was probably emplaced in a shallow marine environment. A second unconformity (U2) was related to expansion of a local ice cap, centered on James Ross Island, which truncated all the eruptive units of Eruptive Stage 1. Concomitant with glacier advance, renewed volcanic activity (Eruptive Stage 2) started after 4.6 Ma and volcanic products were fed again by Cerro Santa Marta vents. We infer that glaciovolcanic eruptions occurred under a moderately thin (~300 m) glacier, in good agreement with previous estimates of paleo-ice thickness for the James Ross Island area during the Pliocene.

1. Introduction

The reconstruction of eruptive environments within insular and glaciated volcanic terrains can be a difficult task, especially in old (pre-Quaternary) sequences. The James Ross Island Volcanic Group (JRIVG) is one of the largest Cenozoic mafic volcanic fields of Antarctica (Smellie, 1990) and represents an excellent example of such terrains, given that it records a long history (~6 Myr) of volcano–ice and volcano–sea interactions. JRIVG was formed by late Miocene-Recent alkali basaltic lavas which interacted in different degrees with external water (i.e., seawater and glacial ice) (Smellie, 1999; Smellie et al., 2006a, 2008). The presence of fossil-bearing marine and glacial strata, intimately associated with eruptive units, are important proxies to help unravel this region's paleoclimatic and volcanic history for the last ~6 Myr (Smellie et al., 2006a, 2008, 2009; Hambrey et al., 2008; Williams et al., 2010; Nývlt et al., 2011). Several publications, concerned with the eruptive history of JRIVG (see Smellie, 2006; Smellie et al., 2008), chose a rather regional approach, covering the bulk of the JRIVG. However, detailed studies over small areas are fundamental to construct a clearer picture of its volcanic evolution. This includes full understanding of their relationships with epiclastic strata, recognition of unconformities between different units and the discovery of undocumented eruptive centers.

James Ross Island is considered a large polygenetic shield volcano and Mt. Haddington (Fig. 1, 64.21°S–57.63°W) seems to be the main vent area (Smellie, 1990). However, in some areas of the James Ross Island (Ulu Peninsula, Fig. 1) volcanic strata dip towards the ice-capped Mt. Haddington volcano, implying that some of the eruptive units were emitted from satellite vents (see Smellie et al., 2008; Nehyba and Nývlt, 2014). One of these locations is the Cerro Santa Marta area,

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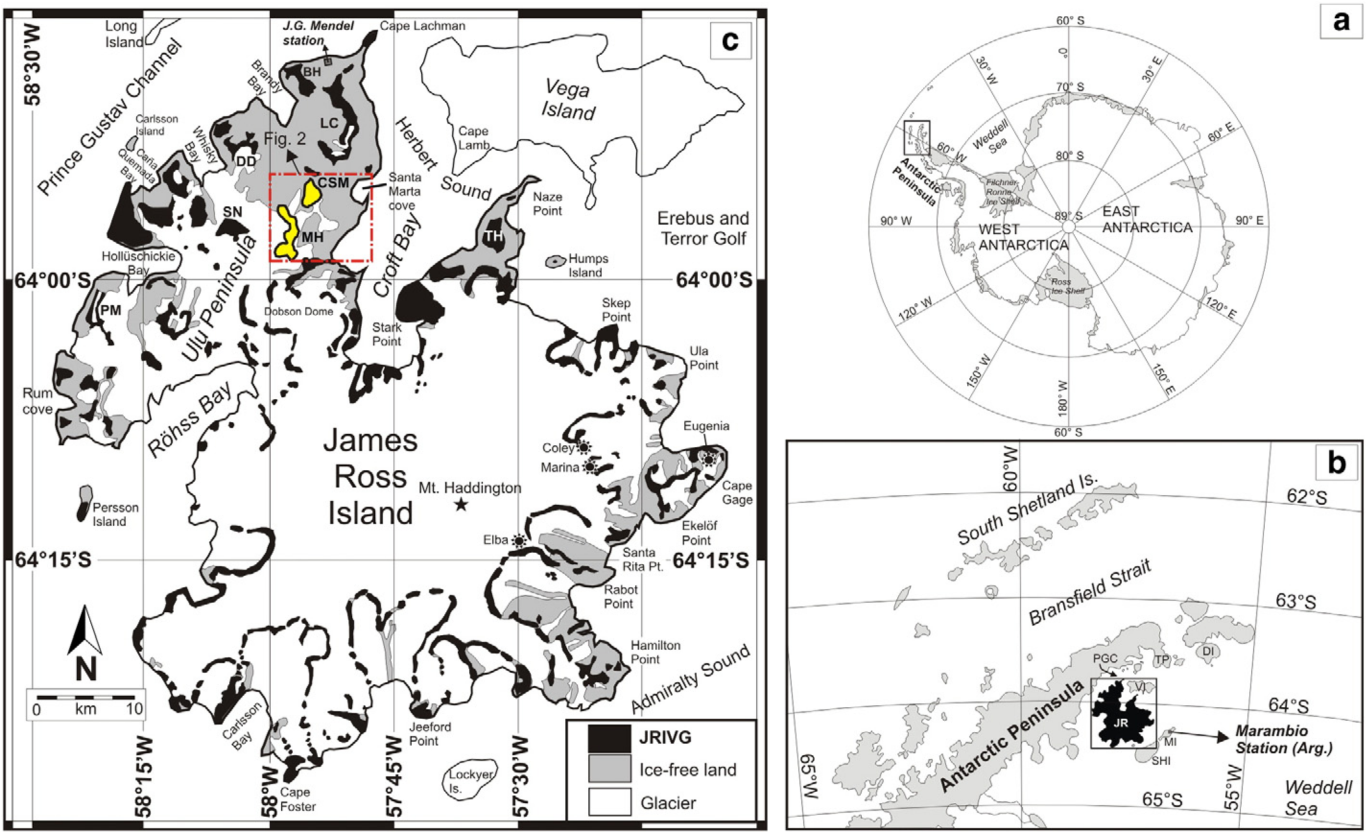

Fig. 1. Location map showing: a. the Antarctic continent with a box marking the northern tip of the Antarctic Peninsula, b. Antarctic Peninsula's northern tip, showing the location of James Ross Island (inset box) and the Argentine Marambio station, and c. James Ross Island map, showing the outcrops of the James Ross Island Volcanic Group (JRIVG), the ice-free and ice-covered terrain. The dashed red square marks the study area in Fig. 2. Cerro Santa Marta/Smellie Peak (CSM) and Massey Heights (MH) are highlighted in yellow. Eugenia, Coley, Marina and Elba refer to four Holocene monogenetic volcanoes. The J.G. Mendel station (Czech Republic) is also shown. Other localities discussed in the text are also shown. Key for abbreviations: JR James Ross Island, VI Vega Island, SHI Snow Hill Island, MI Marambio/Seymour Island, TP Tabarin Peninsula, DI Dundee Island, PGC Prince Gustav Channel, PM Patalamon Mesa, TH Terrapin Hill, LC Lachman Crags, DD Davies Dome, SN Seacatch Nunataks, BH Bibby Hill.
Adapted from Strelin and Malagnino (1992).

in the northwest region of James Ross Island (Fig. 1). It includes two volcanic hills, Cerro Santa Marta and Massey Heights, where foreset beds dip towards Mt. Haddington. Therefore, an eruptive vent located northwest of Mt. Haddington is more probable, as originally noted by Strelin et al. (1987). We present here our stratigraphic interpretation of the volcano-epiclastic succession within the Cerro Santa Marta area, based on detailed field mapping, lithofacies description, and unspiked K–Ar dating, which allowed us to postulate that at least two main eruptive centers within this region acted as peripheral vents of the Mt. Haddington shield volcano, during late Miocene/early Pliocene times. These vents were most likely responsible for the deposition of the volcanic pile now exposed at Massey Heights. Our results provide new insights into James Ross Island's volcanic eruptive environments and their chronological evolution together with paleoclimatic implications for the area during late Miocene/early Pliocene times.

2. Geological background

2.1. Geographic location and geochronology of the JRIVG

The JRIVG comprises a suite of back-arc alkaline basalts (Hole et al., 1995; Košler et al., 2009) widely distributed over more than 5000 km^2 between 63.5° and 64.5°S on the eastern side of the Antarctic Peninsula (Fig. 1), and whose eruptions took place over a long period of time (>6 Myr). The most voluminous and best exposed outcrops are found on James Ross and Vega Islands (Fig. 1). James Ross Island, with an area exceeding 2500 km^2 and a N–S length of ~65 km, is the largest island on the east side of the Antarctic Peninsula, from which it is separated by a narrow (10–20 km) and deep (~1280 m) sea strait known as Prince Gustav Channel (Fig. 1). The northwestern region of the island, referred to as Ulu Peninsula (Fig. 1), is a less glaciated area characterized by tidewater outlet glaciers, different types of valley glaciers and minor ice caps on top of volcanic mesas (Strelin and Malagnino, 1992; Engel et al., 2012), which provides accessible and well-exposed eruptive units. Less voluminous basaltic outcrops are found on several smaller volcanic islands along Prince Gustav Channel, reaching as far north as Cape Purvis on Dundee Island (Fig. 1, Smellie et al., 2006b). Within the Antarctic Peninsula overall, JRIVG localities are restricted to Tabarin Peninsula (Skilling, 1994; Smellie et al., 2006b). To the east of James Ross Island, on Marambio/Seymour and Snow Hill Islands (Fig. 1), JRIVG is represented by basaltic dikes and plugs intruding Cretaceous–Paleogene sedimentary rocks (Massabie and Morelli, 1977). Overall, the maximum thickness of the JRIVG probably reaches more than 1400 m at Mt. Haddington (Smellie, 1990).

Earlier geochronological studies using the conventional K–Ar method (Rex, 1976; Massabie and Morelli, 1977; Sykes, 1988; Lawver et al., 1995), together with more recent $^{40}Ar/^{39}Ar$ dating (Kristjánsson et al., 2005; Smellie et al., 2006a, 2006b, 2008; Nývlt et al., 2011) showed that *in-situ* outcrops afford ages between ~6.2 Ma (late Miocene) and ~0.13 Ma (late Pleistocene), but eruptions probably started as far back as ~12 Ma (Marenssi et al., 2010). With the available geochronological and field data, Smellie et al. (2008) concluded that at least fifty eruptions built the volcanic pile in ~6 Myr. The presence of four pristine monogenetic cones (Eugenia, Coley, Marina and Elba in Fig. 1), erupted