Alteration processes in Deception Island volcano (Antarctica), a first step in the study of the current hydrothermal system

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INTRODUCTION AND GEOLGICAL OVERVIEW

Hydrothermal systems play an important role on the type and location of post-collapse volcanic activity in volcanic caldera systems (Martí et al., 2016; Acocella, 2021; Einarsson et al., 2022). Progressive hydrothermal alteration and mineral precipitation can modify the physical properties and mechanical behaviour of the affected rocks (Bons et al., 2022); among other effects, this can result in increased probabilities of phreatic or hydrothermal explosive eruptions due to changes in rock porosity and permeability.

In this work we focus on the study of rock alteration within the hydrothermal system of Deception Island, which is one of the most active volcanoes in Antarctica with more than 20 eruptions and three documented unrest periods over the past two centuries (Pedrazzi et al., 2018). The history of the island is divided into the pre-caldera, the syn-caldera and the post-caldera stages by a caldera-forming event dated at 3,980 ± 125 cal yr BP (calibrated years before the present; based on tephrochronology, sedimentological studies and ^{14}C dating (Antoniades et al., 2018) which had a strong effect on the magmatic and volcanic evolution of the island (Geyer et al., 2019).

After the caldera-forming event, the activity on the island has been characterized by monogenetic magmatic and phreatomagmatic eruptions (Pedrazzi et al., 2018), and the development of a hydrothermal system in the Port Foster area (the caldera depression). Although the past and current volcanic activity has been largely studied, no detailed research of the hydrothermal fluid circulation has been done so far. For this reason, the aim of this work is to shed further light in the dynamics of the Deception Island hydrothermal system. This is done by studying representative samples of magmatic rocks from both the pre-caldera (Fumarole Bay Formation and Basaltic Shield Formation) and the syn-caldera stages (Outer Coast Tuff Formation), which currently form the upper crust of the island and where the hydrothermal system is suspected to be hosted (Ben-Zvi et al., 2009; Geyer et al., 2019; Martí et al., 2013).

METHODOLOGY

We have conducted a mineralogical and petrological study of pre- and syn-caldera rocks by using optical (Zeiss - Axiophot) and back-scattered electron (Hitachi - TM4000) microscopes. We have also used X-Ray Diffraction (XRD) and microRaman spectroscopy to complete the mineralogical study.

RESULTS

In the Fumarole Bay Formation (pre-caldera) the deposits of pyroclastic density currents and hyaloclastites are pervasively altered; the palagonitisation of the glasses is extensive and the precipitation of secondary phases is widespread. The mineral phases related to alteration which have been identified are predominantly smectite and zeolites (such as analcime, chabazite and phillipsite); other less common phases such as offretite, clinoptile and tobellite are also present. In addition, secondary phases have been found such as intergranular and intragranular calcite and apatite. On the other hand, in rocks of the lava flows and scoria deposits from the pre-caldera stage the alteration is also extensive but not as much as in the pyroclastic and hyaloclastic deposits; in these we have found smectite, magnesite and, occasionally, phenocrysts altered to smectite. Regarding syn-caldera deposits, in rocks of the Outer Coast Tuff Formation the alteration is not very pervasive and is equally distributed throughout all the localities, except for the deposits sampled at the SE Point, which have a more extensive and pervasive alteration. These deposits display palagonitisation, and alteration mineral phases such as smectite, zeolites and, occasionally, calcite.

DISCUSSION AND CONCLUSIONS

The alteration processes that have affected pre-caldera deposits are related to low temperature (< 200°C, constrained by the alteration mineral association) fluids, which have produced pervasive palagonitisation and precipitation of smectite and zeolite; in some samples, carbonate is also present. This alteration is interpreted as having affected rocks located within the first 500-600 meters depth of the pre-caldera shield volcano, where the upper part of the sequence would have been affected by low-temperature acidic hydrothermal fluids that would have caused the dissolution of some phenocrysts and the consequent precipitation of magnesite. Syn-caldera deposits are characterised by an extensive palagonitisation, with smectite and minor zeolite also precipitating. This is interpreted as resulting from syn-depositional and meteoric alteration. Therefore, we suggest that in the studied syn-caldera samples there is no evidence of persistent hydrothermal alteration that could be related to the current hydrothermal system. It would be necessary to do a further exhaustive sampling in the areas with fumaroles and heated ground to better discuss the extension of the hydrothermal system.

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