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Earth Sciences

Submarine volcanic edifices in the Bransfield Strait (Antarctica): towards a unified toponymy

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Abstract

The Bransfield Strait stands out as one of the most accessible places to study Antarctic submarine volcanism, hosting seven active principal submarine volcanic edifices (Edifices A, B and C, Three Sisters, Orca, Hook Ridge, G Ridge) and ~100 smaller seamounts. Only two of them have names (Eastern and Western Seamounts), and ~80 are grouped into two named areas: Spanish Rise and Gibbs Rise. During recent decades, numerous studies have assigned different names to the same volcanic edifices, leading to confusion. Only one of them, Orca, is formally registered in the Scientific Committee of Antarctic Research Composite Gazetteer of Antarctica, which is the catalogue collecting all of the official location names in Antarctica. A unified toponymy is essential, particularly to effectively manage regional logistic operations in case of eruption. Therefore, this study compiles the distinct names assigned to these edifices as a toponymy reference for future research. We recommend using the names most commonly cited in previous studies and, when new names are necessary, submitting them to the Scientific Committee of Antarctic Research Composite Gazetteer of Antarctica to avoid further confusion.

Keywords: Bransfield Strait; SCAR Composite Gazetteer of Antarctica; submarine volcanic edifices; toponymy

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Introduction

Active volcanic processes are abundant in Antarctica and can be grouped into 1) hotspot-related oceanic islands (e.g. Balleny Islands), 2) intraplate rift-related alkaline volcanism across the West Antarctic Rift System in Marie Byrd Land, Ellsworth Land and Victoria Land (e.g. Mount Berlin, Mount Takahe, the Hudson Mountains, Mount Melbourne, Mount Rittmann and Mount Erebus), 3) volcanic activity associated with the closing stages of very slow subduction close to the north-eastern tip of the Antarctic Peninsula in the James Ross Island Group (e.g. James Ross Island) and post-subduction volcanism further south on the Antarctic Peninsula and 4) back-arc rifting volcanism related to the opening of the Bransfield Strait (e.g. Deception Island; Geyer 2021 and references therein). Of all of these sites, the Bransfield Strait stands out as one of the few places with relatively easy access for studying active Antarctic submarine volcanic activity, and hence it has been the focus of attention of multiple volcanological, petrological, geochemical and geophysical studies over the past decades (e.g. Gràcia *et al.* 1996, Keller *et al.* 2002, Fretzdorff *et al.* 2004, Almendros *et al.* 2020, Haase & Beier 2021, Li *et al.* 2021, Smellie 2021, Cesca *et al.* 2022, Anderson *et al.* 2023, 2024).

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The Bransfield Strait is a 400 km-long and 80 km-wide basin located between the Antarctic Peninsula and the South Shetland Islands (West Antarctica; Fig. 1; Fretzdorff & Smellie 2002). The basin formation is related to a back-arc spreading process due to the subduction of the Phoenix plate under the Antarctic plate during the Mesozoic-Cenozoic (Burton-Johnson *et al.* 2023). The opening of the Bransfield Strait was accompanied by volcanic activity, leading to the formation of several submarine volcanic edifices along its main spreading axis (Gràcia *et al.* 1996) and three prominent volcanic systems: Bridgeman, Penguin and Deception islands (Fig. 1; Smellie 1990). Bridgeman and Penguin islands, located on the eastern side, are considered dormant, with their last eruptions occurring in 1821 and 1905, respectively (Geyer *et al.* 2023, Smellie *et al.* 2023). However, Deception Island, situated on the western end of the basin, is considered one of the most active volcanoes in Antarctica, which last erupted in 1970, with a high probability of a further eruption in the near future (e.g. Smellie 2001, Bartolini *et al.* 2014, Geyer *et al.* 2019, 2021, Álvarez-Valero *et al.* 2020, 2022).

To date, a total of seven main submarine volcanic edifices and up to 112 little seamounts (including two named seamounts (Eastern and Western Seamounts) and two named areas (Spanish Rise and Gibbs Rise), which group 80 seamounts) have been identified along the main axis of the Bransfield Strait (Fig. 1 & Table I). All of them are located at depths between 700 and 1600 m below sea level (Fig. 1). The seamounts have basal areas of up to 1 km^2 and heights reaching 400 m (Smellie 2021).

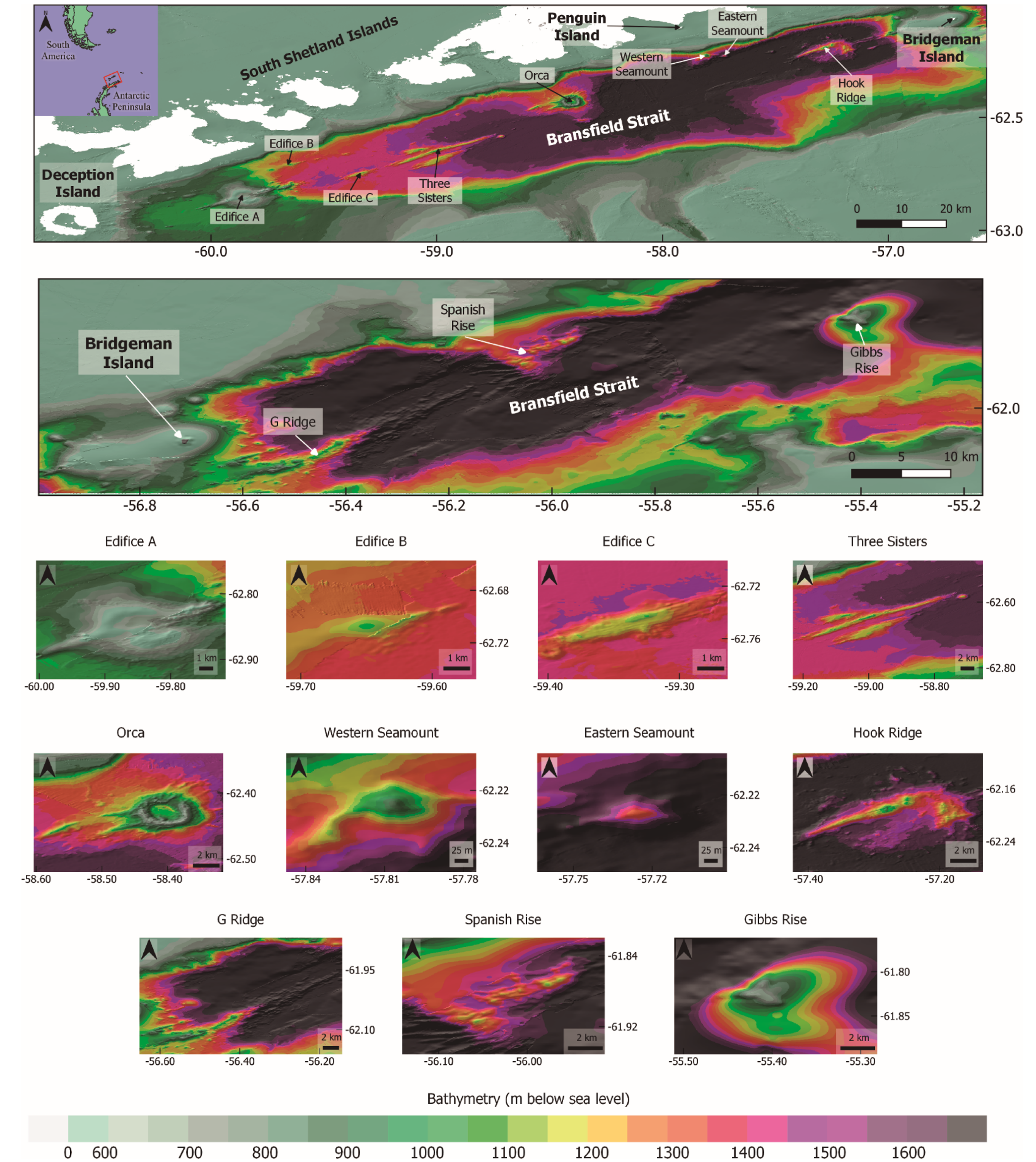

Figure 1. Spatial location of the submarine volcanic edifices compiled in Table I. Edifices identified by the frequent names (see 'Frequently named' column in Table I). Bathymetry from the GMRT database (https://www.gmrt.org/; Ryan *et al.* 2009). Coordinates expressed in decimal degrees (WGS-84 Projection).

In contrast, the seven main volcanic edifices have basal areas ranging from 12.05 to 177.9 km^2 and rise between 250 and 500 m from the sea bottom (Gràcia *et al.* 1996). These main edifices show different morphologies, from conical (Orca; Fig. 1) to elongate (Three Sisters, Hook Ridge, G Ridge; Fig. 1). Among them, five (Edifices A, B and C, Three Sisters and Hook Ridge; Fig. 1) show grabens associated with rectilinear faulting, whereas only two (Orca and Edifice A) show circular depressions (Fig. 1) interpreted as small calderas (Smellie 2021) of a few hundred metres depth (Gràcia *et al.* 1996). Finally, Three Sisters is composed of three rectilinear elongated volcanic edifices (Fig. 1 & Table I).

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Table I. Compilation of the different names assigned for the same volcanic edifice. The numbers below the name of the edifice refer to the references consulted during the compilation of these various names. Three Sisters edifice (i.e. Edifice D) is presented divided into the three individual sectors (D1, D2 and D3) of the volcano, following the classification of Gràcia *et al.* (1996).

Volcanic edifice (Gràcia *et al.* 1996)	Frequently named	Alternative names	Observations
A	Edifice A[2, 4, 10, 12, 14, 15, 16, 23, 26, 32]	The Axe[8, 13, 17, 27] Humpback[22, 24, 29] Ex Seamount[19, 28]	Almendros *et al.* (2020) introduced the name Humpback for the first time, highlighting that the volcano was previously named The Axe and Edifice A
B	No name assigned	No name assigned	-
C	No name assigned	Little Volcano[13]	Little Volcano is not considered to be a frequent name, as it is only used by Petersen *et al.* (2004)
D1	Three Sisters[2, 4, 5, 8, 10, 12, 13, 14, 15, 16, 18, 19, 22, 23, 24, 26, 27, 28, 29, 32, 33, 34]	No name assigned	-
D2	Three Sisters[2, 4, 5, 8, 10, 12, 13, 14, 15, 16, 18, 19, 22, 23, 24, 26, 27, 28, 29, 32, 33, 34]	Middle Sister[7, 17]	Klinkhammer *et al.* (2001) cites the whole volcano as Three Sisters, but they only study the biggest one, referring to it as the Middle Sister
D3	Three Sisters[2, 4, 5, 8, 10, 12, 13, 14, 15, 16, 18, 19, 22, 23, 24, 26, 27, 28, 29, 32, 33, 34]	No name assigned	-
E	Orca[2, 3, 4, 10, 11, 12, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 35]	Viehoff Seamount[8, 13]	Orca was first identified by González-Ferrán (1991). The CGA also attributes the first name to this author; nevertheless, the CGA reports Viehoff Seamount as the first name officially approved in 1995, while Orca was officially approved in the CGA in 2000
F	Hook Ridge[2, 5, 6 ,7, 8, 10, 12, 13, 17, 19, 23, 26, 27, 32, 34]	Edifice F[4, 14, 16, 29] Jiawang Seamount[31]	Cui *et al.* (2023) introduced the name Jiawang Seamount for the first time, highlighting that the volcano was previously named Hook Ridge and Edifice F
G	G Ridge[12, 23, 26, 34]	No name assigned	-
Identified seamount with no name assigned	Western Seamount[1, 9]	No name assigned	-
Identified seamount with no name assigned	Eastern Seamount[1, 9]	No name assigned	-
Identified seamount with no name assigned	Spanish Rise[12, 23, 26, 34]	No name assigned	-
Identified seamount with no name assigned	Gibbs Rise[12, 23, 26, 34]	Wordie Caldera[15, 20, 21]	-

References are listed chronologically and, when from the same year, alphabetically. 1: Fisk (1990). 2: González-Ferrán (1991). 3: Jin *et al.* (1996). 4: Lawver *et al.* (1996). 5: Bohrmann *et al.* (1998). 6: Dählmann *et al.* (2001). 7: Klinkhammer *et al.* (2001). 8: Fretzdorff & Smellie (2002). 9: Keller *et al.* (2002). 10: Christeson *et al.* (2003). 11: Roberston-Maurice et al. (2003). 12: Fretzdorff *et al.* (2004). 13: Petersen *et al.* (2004). 14: García *et al.* (2008). 15: Dziak *et al.* (2010). 16: García *et al.* (2011). 17: Aquilina *et al.* (2013). 18: Catalán *et al.* (2013). 19: Schreider *et al.* (2014). 20: Bohoyo *et al.* (2016). 21: Bohoyo *et al.* (2019). 22: Almendros *et al.* (2020). 23: Haase & Beier (2021). 24: Li *et al.* (2021). 25: Loureiro Olivet *et al.* (2021). 26: Smellie (2021). 27: Soloviev *et al.* (2021). 28: Cesca *et al.* (2022). 29: Liu *et al.* (2022). 30: Poli *et al.* (2021). 31: Cui *et al.* (2023). 32: Espinoza Celi *et al.* (2023). 33: Parera-Portell *et al.* (2023). 34: Smellie *et al.* (2023). 35: Scientific Committee on Antarctic Research (SCAR) Composite Gazetteer of Antarctica (CGA; https://data.aad.gov.au/aadc/gaz/scar/).
Note: In Keller *et al.* (2002), all of the main edifices classified by Gràcia *et al.* (1996) are described with coordinates, yet without names.

The geochronological database of the main edifices is very limited. Gràcia *et al.* (1996) estimated an age of 100 ka for Three Sisters and Hook Ridge, although the dating method used was not specified. The only precise age data, obtained through K-Ar geochronology, comes from the Western and Eastern Seamounts (Fig. 1), located 20 km north-east of Orca. These seamounts have reported ages of 103 ± 35 ka and 53 ± 36 ka, respectively (Fisk 1990). Most recent manifestations of volcanic activity along Bransfield Strait include the seismic unrest at Orca (August 2020–February 2021) associated with a magma intrusion episode beneath the volcano. With 85 000 earthquakes recorded within half a year, this seismic event is the largest ever monitored in Antarctica (Cesca *et al.* 2022). Additionally, there is an active hydrothermal system along the volcanic edifices showing shimmering water, altered sediments and mineralization deposits (Klinkhammer *et al.* 2001, Petersen *et al.* 2004, Aquilina *et al.* 2013), as well as high thermal flux (49–626 mW/m^2; Smellie 2021) and excess ^{3}He in water (Schlosser *et al.* 1988, Dorschel *et al.* 2016, Rodrigo *et al.* 2018).

These manifestations of submarine volcanic activity highlight the importance of understanding their magmatic systems, as they pose a direct hazard to the stations of the South Shetland Islands and the Antarctic Peninsula due to their shallow depths (e.g. Nomikou *et al.* 2022). Over the years, the main submarine volcanic edifices have been assigned numerous names by different authors

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(Table I), leading to confusion among the scientific community. Except Orca, these names do not appear in the Scientific Committee on Antarctic Research (SCAR) Composite Gazetteer of Antarctica (CGA; https://data.aad.gov.au/aadc/gaz/scar/), which serves as the official catalogue for placenames in Antarctica. Furthermore, the official name Three Sisters in the CGA is assigned not only to mountain peaks on Alexander Island, located ~1100 km south of the Bransfield Strait, but also to volcanic cones situated on the south-west slope of Mount Erebus, located 4,150 km farther south.

Standardizing this nomenclature would also be of importance to relate the different research works among the scientific community as well as to enhance the preparedness for logistical management operations at research stations and vessel traffic in the event of an eruption. This is particularly important in the Bransfield Strait, which hosts the highest density of stations and vessel traffic in Antarctica due to its proximity to inhabited countries such as Argentina and Chile (e.g. Geyer *et al.* 2023). For these reasons, this study aims to compile all of these different names to establish a comprehensive toponymic reference for further research in the Bransfield Strait region. Additionally, we provide a brief description of the guidelines to be followed when proposing new toponymic names.

Methodology

From the extensive literature dataset (Connected Papers: https://www.connectedpapers.com; ResearchRabbit: https://researchrabbitapp.com), numerous articles describe the Bransfield Strait with no mention of the individual volcanic edifices (e.g. Anderson *et al.* 2023, 2024). In this review, we found up to 34 articles, covering different geological topics such as volcanology, oceanography, geochemistry or geophysics, to have distinguished each volcanic edifice individually. These articles have been compiled along with the names officially registered in the SCAR CGA. To organize the names in a concise way, the nomenclature of Gràcia *et al.* (1996) was applied as a starting reference (Table I), as this study was the first to provide a morphological description and a comprehensive grouping of all of the main edifices. The named seamounts are also included in the compilation (Table I). All volcanic edifices are listed geographically from south-west to north-east (Fig. 1 & Table I). The distinction between frequent and alternative names is based on citation frequency, with the most cited one considered as the frequent name. In case of two names having the same number of references, the earliest reference is designated as the frequent name.

Results

In recent decades, Edifice A has received up to four different names, but it is most commonly referred to as Edifice A. Conversely, Hook Ridge shows three different names (Table I); Three Sisters and Orca only show two different names each, whereas Edifice C and G Ridge have only one name each (Table I). The name Little Volcano, associated with Edifice C, is considered an alternative designation, as it has been used exclusively by Petersen *et al.* (2004). Meanwhile, Edifice B is the only edifice with no designated name beyond its classification by Gràcia *et al.* (1996). Only a minority of studies used the alternative names for the same edifice. For instance, Edifice E is mostly named as Orca; only Fretzdorff & Smellie (2002) and Petersen *et al.* (2004) refer to it as Viehoff Seamount (Table I). Among the seamounts, all have a single frequent name except Gibbs Rise (Table I).

Discussion

Although some volcanoes, such as Edifice A and Hook Ridge, have been referred to by multiple names, most have a commonly used name (Table I). Therefore, for further studies, it is recommended to avoid assigning new names to these edifices and instead to use the most frequently cited name, as listed in Table I. For Edifices B and C, the classification of Gràcia *et al.* (1996) is encouraged, as these edifices are rarely identified by other names. If a new name must be assigned to one of the main edifices or the seamounts in future studies, the appropriate procedure is to initiate the process by submitting a name proposal to SCAR for inclusion in the CGA. Once accepted, subsequent studies should consistently refer to the name as listed in the CGA and refrain from assigning new names to prevent further confusion.

However, it is important to note that the name proposal process may take longer than the publication process for the research requiring the new name. A potential solution to mitigate this issue could be the adoption of a temporal, first-come, first-named approach system for newly identified sites, similar to the procedure used for naming astronomical objects (e.g. Bishop 2004), followed by a formal request, with its respective justification, for inclusion in the SCAR CGA.

Conclusions

The Bransfield Strait is one of the few easily accessible regions for researching Antarctic submarine volcanic activity. Over recent decades, multiple studies have assigned different names to the same volcanic edifices. Reviewing the toponymy from diverse articles covering different geological topics in the Bransfield Strait, it is observed that some edifices, such as Edifice A and Hook Ridge, have been identified using up to four different names. However, most of them are referred to by a frequently cited name. Due to the importance of using a unified toponymic nomenclature, particularly for organizing logistical operations in case of an eruption, it is highly recommended to keep referring to the most frequently cited name. To maintain such consistency, any new name assignments should be formally proposed to the SCAR CGA. Ideally, this process should be completed before publishing any new names. Taking into account that making a formal proposal may take a long time, a possible way to circumvent this issue could be to assign new names by following a temporal, first-come, first-named approach, followed then by a justified formal request for inclusion in the SCAR CGA.

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