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Seabed geomorphology, substrate and benthic habitats informing long-term conservation of the Ascension Island Marine Protected Area

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ABSTRACT

The Ascension Island Marine Protected Area (AI-MPA) is one of the largest areas of protected ocean, safeguarding a unique ecosystem in the South Atlantic Ocean. This study presents the first seabed geomorphology, substrate and benthic habitat maps of the AI-MPA, produced using high-resolution bathymetry data acquired by the British Geological Survey, the Royal Navy and the United Kingdom Hydrographic Office. Mapping combined a semi-automated approach with expert manual interpretation. The resulting datasets reveal a diverse range of previously unmapped volcanic, erosional, depositional and coastal features including submerged lava flows, rocky outcrops, ridges, submarine landslides, and sandy plains that support a rich variety of marine life seldom documented in such detail for remote mid-oceanic islands. These maps provide essential baseline data for monitoring of the marine environment and improve our understanding of geological features and processes around Ascension Island, supporting present and future marine conservation and management.

Key policy highlights
- We present the first detailed seabed geomorphology, substrate and benthic habitat maps of the Ascension Island Marine Protected Area.
- Mapping was undertaken using a combined semi-automated approach and expert manual interpretation.
- Internationally standardised mapping schemes were utilised for each of the produced maps.
- These maps provide a robust baseline to support improved management, monitoring and long-term conservation of the marine environment around Ascension Island.

1. Introduction

Ascension Island is a remote volcanic island in the South Atlantic Ocean, known for its rich biodiversity and rugged volcanic landscape, located approximately 90 km west of the Mid-Atlantic Ridge (MAR; Figure 1). The island has a subaerial surface area of around 88 km², rising to 859 m at Green Mountain, its highest point. The submerged portion is much larger, encompassing approximately 2000 km² of ocean floor, descending to depths of about 3000 m below sea level (Brozena, 1986).

The proximity of Ascension Island to the MAR suggests a hotspot volcanic origin (Brozena, 1986), reflected in the geological features and morphology of its insular shelf (Romagnoli et al., 2018). Volcanic activity likely initiated ~6–7 million years ago (Ma) with the emplacement of submarine lavas when the island was positioned closer to the MAR (Bruguier et al., 2003; Klingelhöfer et al., 2001). Research has

historically focused on the onshore geology due to the remote location of Ascension Island (Vye-Brown & Crummy, 2014) . Volcanism occurred in multiple phases, with the most recent lava flows proposed to be of late Holocene age (Jicha et al., 2013). The island has experienced both effusive and explosive eruptions, with numerous volcanic vents scattered across the island (Crummy et al., 2023).

In contrast, relatively little is known about the submarine volcanic activity, primarily due to limited data availability. Previous multibeam echosounder (MBES) bathymetry surveys focused on biodiversity assessments rather than geological mapping (e.g., Barnes et al., 2015). However, these datasets confirmed that the island sits on a 1000 km long segment of the MAR that includes the actively growing Proto-Ascension Seamount (Klingelhöfer et al., 2001) and several nearby seamounts likely associated with the Ascension hotspot. A 2002 geophysical survey for the installation

Figure 1. The main map (top) displays multibeam echosounder bathymetry and hillshade data, collected by the HMS *Protector*/ SMB *James Cairn*, and the British Geological Survey as well as the Satellite-Derived Bathymetry dataset (© British Crown Copyright 2022; BGS © UKRI 2025) which have been re-gridded at 10 m resolution for display purposes only. Coastline for Ascension Island © AIG Conservation and Fisheries Directorate, 2025. The inset map (bottom left) shows the location of Ascension Island relative to the Mid-Atlantic Ridge (MAR), Ascension Fracture Zone (AFZ), and other Atlantic volcanic islands such as the Azores, Madeira, Canary Islands and Cabo Verde (© 1995–2025 Esri). The location of Figures 4–6 is indicated on the main map. Coastline for Ascension Island © AIG Conservation and Fisheries Directorate. BGS © UKRI 2025.

of a subsea cable (Faneros & Arnold, 2003; Thomson et al., 2002) identified two seamounts to the northwest and south of the island. The 2015 Darwin Initiative Marine Sustainability Project (Barnes et al., 2015) acquired MBES bathymetry data (100–1000 m depth, 50 m resolution) to study the marine biodiversity,

revealing major topographic features and a broad shelf extending southwest of the island. Additional insights into seafloor morphology and crustal structure have come from studies such as Klingelhöfer et al. (2001), Evangelidis et al. (2004), and Cunningham and Mitchell (2001).

Earlier mapping efforts provided valuable insights into the evolution and marine biodiversity of Ascension Island (Barnes et al., 2015; Brickle et al., 2017; Bridges et al., 2021) but relied on lower-resolution bathymetry data and limited ground-truthing. This limited understanding of the geological features on the seabed and their relationship with marine ecosystems, particularly in waters shallower than 100 m. To address these knowledge gaps, the British Geological Survey (BGS) was awarded a Darwin Plus Grant (DPLUS142) to undertake new high-resolution MBES bathymetry surveys and targeted ground-truthing within the nearshore area of the Ascension Island Marine Protected Area (AI-MPA). Fieldwork was completed in two campaigns: the first collected high-resolution bathymetry data in November 2023, and the second conducted 50 drop-camera transects in January 2024.

This study presents the first detailed seabed geomorphology, substrate and benthic habitat maps of the submarine environment around Ascension Island. These new interpretations, covering ∼470 km^2 of the total AI-MPA area (>445,000 km^2), provide a critical baseline for future scientific research and for the long-term conservation and management of the unique marine environment.

2. Datasets and methods

2.1. Multibeam data acquisition and processing

Multibeam echosounder bathymetry (MBES) data were acquired during two survey campaigns: the first by the Royal Navy in 2021, and the second by the BGS in 2023. The spatial extent of each survey is shown in Figure 2, and an overview of data type, coverage area and resolution is summarised in Table 1. Further details on acquisition methodologies are provided in the respective Reports of Survey (Cooper & Macdonald, 2024; Royal Navy, 2021), available via the United Kingdom Hydrographic Office (UKHO) and BGS respectively.

The Royal Navy survey campaign (UKHO Hydrographic Instruction [HI] 1751) utilised two vessels:
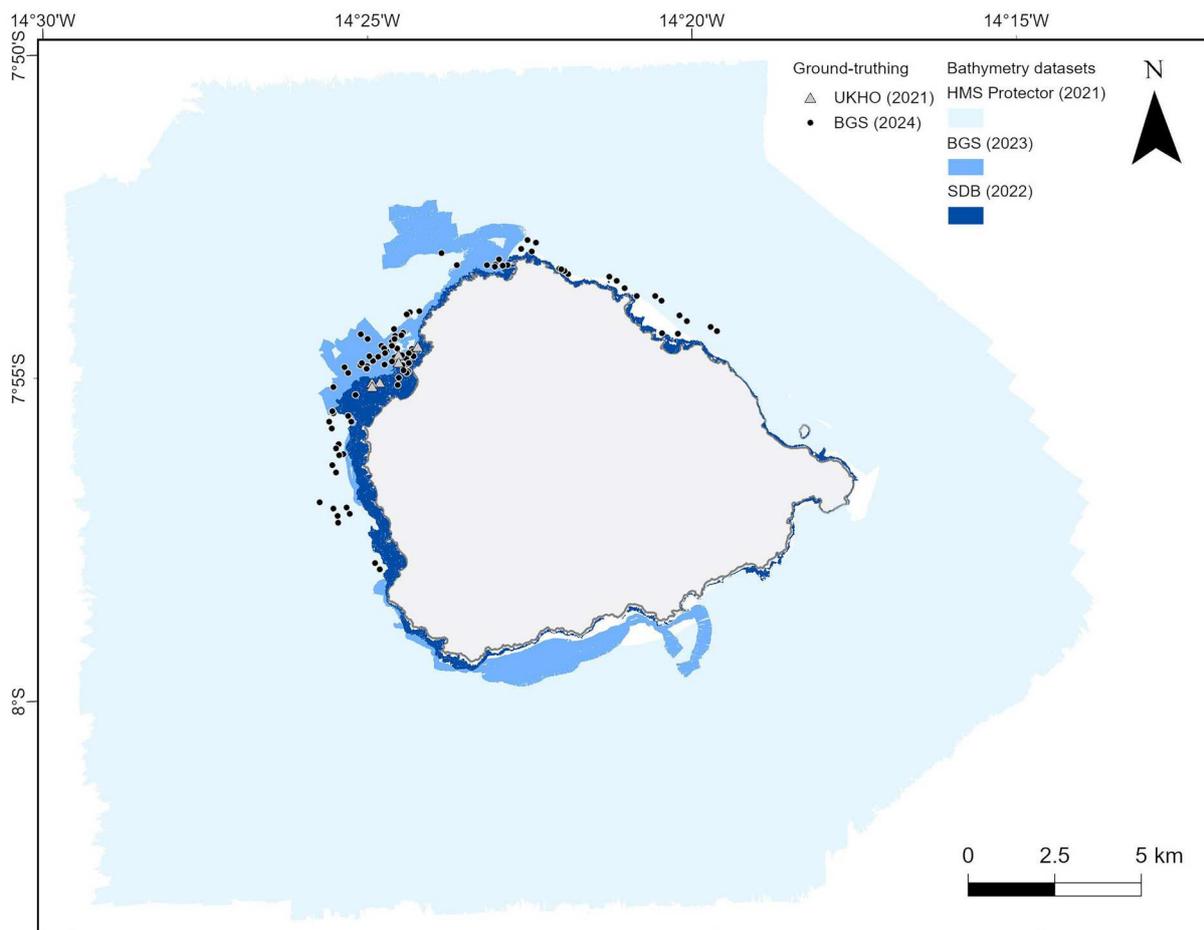
Figure 2. Overview of the datasets (© British Crown Copyright 2022; BGS © UKRI 2025) used in this study. Multibeam echosounder (MBES) bathymetry data collected by the HMS *Protector* in 2021, satellite-derived bathymetry (SDB) data acquired by the United Kingdom Hydrographic Office (UKHO) in 2022 and MBES data collected by the British Geological Survey (BGS) in 2023. Ground-truthing data comprises 9 grab samples collected by the UKHO in 2021 and 50 drop camera transects collected by the BGS in 2024. Coastline for Ascension Island © AIG Conservation and Fisheries Directorate, 2025.

Table 1. Overview of the multibeam bathymetry, backscatter intensity and seabed sampling datasets used within this study (© British Crown Copyright 2022; BGS © UKRI 2025).

Dataset	Type	Task	Area	Resolution (m)	Exports
HI 1751 HMS *Protector*/ SMB *James Cairn* (Royal Navy, 2021)	Multibeam Echo Sounder Bathymetry (MBES) • HMS *Protector* MBES – Kongsberg EM710 300kHz • SMB *James Cairn* – Kongsberg EM3002 300kHz	Bathymetry data reprocessing, generate associated raster layers, geomorphology/ seabed substrate interpretation	0 m–100 m contour 100–400 m contour 400–1000 m contour >1000 m contour	1 m 3 m 6 m 10 m	CSAR, ESRI Ascii Grids
	Backscatter Intensity	Original grids, seabed substrate interpretation	0–<120 m >60 ->1000 m	1 m 6 m	GeoTIFF, ESRI Ascii Grids
	Grab Samples	Original data from UKHO, filtered for area of interest, seabed substrate interpretation	Nine (9) samples within Clarence Bay	N/A	CSV, SHP
BGS NEE7366R (Cooper & Macdonald, 2024)	Multibeam Echo Sounder (MBES) Bathymetry • Kongsberg EM2040P 300kHz mounted using USM RIB mounting kit on an 8 m RIB.	Bathymetry data processing, generate associated raster layers, geomorphology/seabed substrate interpretation	All data All data <30 m All data >30 m Coastal Strip <15 m Long Beach <15 m South Coast	3 m 1 m 3 m 0.5 m 0.5 m 3 m	ESRI Ascii Grids, XYZ, BAG, GeoTIFF
	Backscatter Intensity	Backscatter processing, generate associated raster layers, seabed substrate interpretation	All data	1 m	GeoTIFF
	Drop Camera (GoPro11)	Visual Inspection, seabed substrate/ habitat interpretation	15 samples (west to north)	N/A	MP4, SHP, CSV
	Drop Camera (STR)	Visual Inspection, seabed substrate/ habitat interpretation	35 samples (west to north)	N/A	AVI, SHP, CSV
HI 1773 UKHO / EoMap	Satellite-derived bathymetry	Original data from UKHO, generate associated raster layers, geomorphology/ seabed substrate interpretation	Shallow water zone (HI 1773) <20 m	2 m	ESRI Ascii Grids, CSAR, GeoTIFF, XYZ

HMS Protector surveyed depths greater than 200 m to a maximum of ~1800 m using a Kongsberg EM710 system (300kHz), while SMB James Cairn operated in shallower waters (< 200 m) using a Kongsberg EM3002 system (300 kHz). Raw data were supplied to BGS via the UKHO and subsequently reprocessed using Teledyne CARIS HIPS and SIPS v11.4.22 to generate four higher-resolution bathymetric grids (1–10 m resolution). The 2023 BGS survey acquired additional high-resolution MBES data (0.5–3 m resolution) in strategic nearshore areas (<100 m depth) to the north and west of Ascension Island, prioritised by data availability, resolution and stakeholder interests. Data were acquired using a Kongsberg EM2040P system (300 kHz) mounted on an 8 m rigid-hulled inflatable boat (RHIB) via a Universal Sonar Mount (USM) mount kit and processed using Quality Positioning Services (QPS) Qimera v6.2.1. Backscatter intensity surfaces were generated for both the Royal Navy and BGS datasets using QPS Fledermaus Geomatics (FMGT) v7.10.3. Additionally, a satellite-derived bathymetry (SDB) dataset (UKHO HI 1773; 2 m resolution) covering shallow waters (~0–20 m depth) around Ascension Island was supplied by the UKHO to support mapping efforts.

2.2. Ground-truth data

During the 2021 Royal Navy survey, HMS *Protector* collected nine grab samples in Clarence Bay (Figure 2). Due to limited ground-truth data, BGS undertook a dedicated ground-truthing campaign in 2024, acquiring 50 drop-camera transects in water depths <100 m. The decision to use drop-camera systems rather than physical sampling was driven by vessel availability and launch conditions (i.e. crane-launched 8 m RHIB), local sea conditions and manual handling constraints.

Two systems were deployed: a custom Drifto 2000/ GoPro11 kit (15 transects) and the STR SeaSpyder Nano (35 transects). Surveys were concentrated to the west and northwest of the island (Figure 2) to take advantage of shelter from prevailing sea and wind conditions. Post-survey visual analysis of footage was used to determine dominant substrate types at the seabed allowing general qualitative observations of sediment composition.

2.3. Mapping techniques

Following acquisition and processing, the bathymetry, backscatter intensity and ground-truth transect data

(Table 1) were imported into ESRI ArcGIS Pro v3.1.2 for analysis and interpretation. For mapping and presentation, the individual bathymetry datasets were resampled and merged into a single continuous bathymetry surface gridded at 10 m resolution (i.e. the coarsest resolution). Higher-resolution grids were used for finer-scale feature analysis where appropriate.

All map products were presented in the projected coordinate system WGS84 / UTM Zone 28S (EPSG:32728) at a scale of 1:10,000. This scale provided the best balance between resolution and feature visibility; larger scales introduced excessive complexity, whereas smaller scales obscured key geomorphic features. This choice optimises the relationship between map scale, data resolution, and feature detectability (Tobler, 1988), enabling identification of features as small as 5 × 5 m in some areas.

Linework was generated using a combination of semi-automated processes (e.g. Lecours, 2015), manual interpretation and expert validation applied to the bathymetric and backscatter intensity surfaces. Derived layers, including hillshade, slope and rugosity, were created using the 3D analyst extension in ESRI ArcGIS Pro v3.1.2, and the Benthic Terrain Modeler (Walbridge et al., 2018). The semi-automated approach used an automated, clustering-based analysis of bathymetric derivatives (e.g. relative highs and lows at multiple scales) to identify and delineate seabed features, followed by manual attribution and editing of predicted linework.

Although the datasets provide broad coverage and high-resolution information in key areas, limitations such as variable survey resolutions, gaps in spatial coverage, differing acquisition methods and limited ground-truthing affect feature detectability and classification. Alternative approaches, such as the Confined Morphologies Mapping (CoMMa) Toolbox (Arosio & Gafeira, 2023) and geomorphometric clustering (e.g. Sowers et al., 2024) offer comparable functionality and may be useful for future refinement of feature mapping. However, these workflows are often comparable to expert interpretation (Arosio & Gafeira, 2023) and given the heterogeneous resolution and geological complexity of the Ascension Island datasets, the hybrid semi-automated, expert-validated workflow implemented here provides the most appropriate balance between reproducibility, flexibility and geomorphological accuracy.

Quality control procedures included visual inspection of seams, slope continuity checks, and removal of artefacts using standard BGS mapping protocols. Spatial checks were performed in ArcGIS Pro following Open Geospatial Consortium (OGC) standards to address issues such as data gaps and duplication (OGC, 2010). Confidence in mapped features was influenced by the spatial distribution and quality of input datasets, particularly ground-truth data and backscatter coverage. Areas lacking ground-truthing were flagged as lower confidence and identified as priorities for future data collection. Further information on the mapping techniques used in this study is available in Macdonald et al. (2025) and other BGS map publications (e.g. British Geological Survey, 2023).

2.4. Geomorphology

Geomorphological features were interpreted from the bathymetry datasets (utilising the combined and finer resolution grids). The resultant map extends from the shoreline to a maximum depth of ∼1800 m, reflecting the high quality of the bathymetry data. Mapping followed the 'two-part' approach for seabed geomorphology, developed by the International Seabed Geomorphology Mapping (ISGM) Working Group (Dove et al., 2016; Dove et al., 2020; Nanson et al., 2023), which is increasingly adopted in international seabed mapping initiatives. This scheme independently classifies 'Morphology' and 'Geomorphology'.

Morphology describes the physical form of seabed features (e.g. Bathymetric High > Ridge > Volcanic Ridge), based on measurable attributes such as size, shape and texture (Figure 3). In contrast, geomorphology incorporates both form and the interpreted geological or environmental processes responsible for the formation of the feature (e.g. Solid Earth > Volcano > Seamount). Morphological classes were applied only to features with a clear physical expression, while geomorphological interpretation was assigned where mapper confidence was high. An advantage of this approach is that features can be symbolised according to the level or type of information required by the user. In the accompanying map, features are symbolised according to their highest level of classification. The attribute fields included with the digital map are summarised in Table 2.

2.5. Seabed substrate and benthic habitats

Seafloor substrate mapping was undertaken to a depth of 300 m, constrained by the quality of the backscatter intensity data and the limited depth range of ground-truth samples. Predictive linework derived from the backscatter intensity data, identifying changes in seabed texture, was refined using drop-camera video analysis together with the geomorphology and rugosity layers. A simplified six-class sediment classification system (after Folk, 1954) was applied: (a) Sand; (b) Gravelly Sand; (c) Sandy Gravel; (d) Rhodolith Beds and Mixed Sediment; (e) Bedrock with discontinuous superficial sediment cover; and (f) Bedrock Outcrop. Class distinctions were based on visual grain-size estimates.

The seabed substrate map was subsequently converted into European Nature Information System
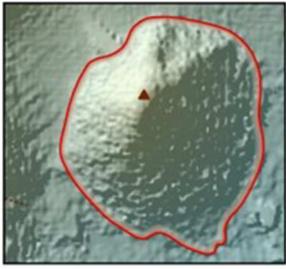
Feature	Attribute Category	Attribute
	Feature Description	Volcanic Mound
	Geomorphology Feature	Volcanic Mound
	Morphology Feature	Mound
	Morphology Attribute	High-relief
	Comment	~240m high

Notes: A full list of attributes is presented in Table 2. A complete description and explanation of the two-part classification scheme is given in Dove et al., 2016; Dove et al., 2020; Nanson et al., 2023.

Figure 3. Example of attributes that are used to describe the geomorphology units in the seabed geomorphology map using the 'two-part' classification scheme. This is example is attributed as a '*Volcanic Mound*'. The red triangle indicates the highest point of the feature. BGS © UKRI 2025.

(EUNIS) habitat types (EUNIS, 2019; Vasquez et al., 2023) by assigning biological zones based on water depth and broad regional context (e.g. circalittoral zone). As with the substrate classification, manual adjustments were informed by the ground-truth data.

3. Results

These new datasets collected by the BGS and Royal Navy have enabled the first detailed mapping of seabed geomorphology, substrate and benthic habitats around Ascension Island. The surrounding seafloor exhibits a diverse assemblage of volcanic, erosional, and depositional features, reflecting the influence of plate tectonics, volcanic activity and marine processes. Interpretation revealed a complex seascape comprising 24 geomorphological feature types and six substrate classes (Table 2), shaped by different geological processes over differing geological timescales. The following sections describe these features in more detail, highlighting their form, distribution, and interpreted origin.

3.1. Seabed geomorphology

Mapping revealed a narrow insular shelf, widest to the northwest, west and southwest (extending up to 9 km offshore, ~600 m maximum depth) and narrower to the south and east (typically 1–2 km offshore, ~300 m maximum depth). Beyond the shelf break, the seafloor descends steeply to the abyssal plain, reaching depths of ~3700 m. Shelf geometry provides insight into the evolution of the volcanic edifice, with broader shelves indicative of older volcanic deposits, and narrower areas reflect younger volcanic products exposed to fewer cycles of marine erosion (Romagnoli et al., 2018).

The shelf edge is defined by linear '*break in slope*' features (shown on the seabed geomorphology map), marking the transition to steeper volcanic flanks. While these features represent the modern shelf break, some may also correspond to palaeoshorelines or submarine depositional terraces formed by seaward sediment transport during storms and subsequent wave erosion (Romagnoli et al., 2018). In shallower areas, they coincide with the limit of eruptive lava flows. Localised features align with previously mapped marine terraces at ~200 m depth west of the island, and at ~700 m depth on the northeast slope (Klingelhöfer et al., 2001; Minshull et al., 2010). Their formation may reflect uplift (Nielson & Sibbett, 1996), subsidence (Minshull et al., 2010) or changes in sea level, shelf gradient and morphology, or hydrodynamics (e.g. Azores Islands, Quartau et al., 2014; Ricchi et al., 2018).

3.1.1 Volcanic features

The coastline is dominated by rocky cliffs composed of stacked lava flows (Vye-Brown & Crummy, 2014), typical of young oceanic islands lacking fringing reefs (Rodriguez-Gonzalez et al., 2022). These flows extend offshore as areas mapped as '*Bedrock at seabed*' (Figure 4). Similar to other volcanic islands, such as the Canary Islands (Rodriguez-Gonzalez et al., 2022), the bedrock reflects multiple eruptive phases, from ~6–7 Ma to the Holocene period (Bruguier et al., 2003; Jicha et al., 2013; Klingelhöfer et al., 2001). Figure 4 illustrates a submarine bedrock section extending northwest from Georgetown, displaying highly rugose surfaces (Figure 4(b)), steep slopes and fractured lobate flows, possibly representing a lava delta emplaced over a palaeo-cliff edge and across the shore platform (Rodriguez-Gonzalez et al., 2022).

Numerous additional volcanic landforms were identified. Previous studies documented five

Table 2. List of geomorphological and substrate types mapped in this study (BGS © UKRI 2025).

Feature Description	Mapping Style	Morphology Classification	Morphological Attribute	Geomorphology Classification	Definition
Geomorphology					
Possible wreck	Point	Platform Ridge Pinnacle	High		Remains of a vessel and/or debris which remains visible or partially visible on the seabed.
Wreck		Ridge			
Peak		Peak			A prominent, commonly pointed elevation rising from a larger feature (modified from IHO, 2019).
Bedrock at seabed	Line	Break in Slope	High Curved	Bedrock at seabed	Bedrock mapped where the geologist can observe characteristic morphologies and features within the bathymetry data, particularly along the coastline. Assumed to be igneous/volcanic in origin (Vye-Brown & Crummy, 2014).
Break in Slope (Convex)			Convex		A marked and/or abrupt change in slope curving outwards.
Break in Slope (Concave)			Concave		A marked and/or abrupt change in slope curving inwards.
Palaeoshoreline			Convex Concave	Palaeoshoreline	
Caldera		Crest	Crescentic Circular	Caldera	Circular depressions typically with a flat floor, with diameters ranging from few up to tens of kms (Micallef et al., 2018).
Crater			Continuous Circular	Crater	A line of highest elevation along a bathymetric high, the lateral position of which can vary longitudinally. CRESTS contrast with CENTRELINES which define mid-line axes along elongated features.
Ridge			Curvilinear Linear Sinuous Curved	Ridge	An elongated elevation of varying complexity, size and gradient (length > width) (modified from IHO, 2019).
Volcanic Ridge			High Curvilinear Curved Sinuous Linear	Volcanic Ridge	
Submarine Gully		Ridge Gully (Thalweg)	Curvilinear Linear Curved Discontinuous Branching	Submarine Gully	A steep-sided, low sinuosity, relatively high-gradient feature. GULLIES are typically smaller than CANYONS.
Caldera	Polygon	Depression	Deep	Caldera	Circular depressions typically with a flat floor, with diameters ranging from few up to tens of kms (Submarine Geomorphology, 2018).
Depression			Circular Low-relief Low		A general term for a closed-contour bathymetric low of variable scale. DEPRESSIONS vary in scale from small local features to larger basins. They generally have lower gradient sides than HOLES.
Peak		Peak	Ovular		A prominent, commonly pointed elevation rising from a larger feature (modified from IHO, 2019).
Ridge		Ridge	High High-relief Branching		An elongated elevation of varying complexity, size and gradient (length > width).
Saddle		Saddle	Low-relief		A broad pass in an elevated feature (modified from IHO, 2019). SADDLES are generally broader (relative to their height) than GAPS.
Submarine Channel		Channel	Elongated Irregular Meandering	Submarine Channel	A general term for an elongated bathymetric low (adapted from IHO, 2019). CHANNELS tend to have flatter and lower gradient FLOORS than GULLIES and CANYONS and have more variable cross-sections than TROUGHS.
Submarine Fan		Fan	Lobate	Submarine Fan	An elevated feature which expands (and typically descends) from a

Table 2. Continued.

Feature Description	Mapping Style	Morphology Classification	Morphological Attribute	Geomorphology Classification	Definition
					locus to a commonly curved outer margin.
Submarine Landslide Scar	Escarpment	Concave		Submarine Landslide Scar	Crescent-shaped scar on the side of a steep-slope where soil and/or rock has detached from the surface (Submarine Geomorphology, 2018).
Volcanic Hill	Hill	High-relief		Volcanic Hill	A distinct elevation generally of irregular shape, less than 1000 m above the surrounding relief as measured from the deepest isobath that surrounds most of the feature (IHO, 2019). HILLS have more irregular profiles than KNOLLS, and their length generally exceeds their height (contrast with PEAKS). They are also smaller than SEAMOUNTS, and larger than individual HUMMOCKS.
Volcanic Knoll	Knoll	High-relief		Volcanic Knoll	A distinct elevation generally of a smooth, commonly rounded profile, less than 1000 m above the surrounding relief. Knolls have more regular profiles than hills, and their width generally exceeds their height (contrast with PEAKS). They are also smaller than SEAMOUNTS, and larger than individual HUMMOCKS.
Volcanic Mound	Mound	High-relief Circular Ovular High		Volcanic Mound	A distinct elevation with a variable sometimes rounded profile which is generally <500 m above the surrounding seafloor (modified from IHO, 2019).
Volcanic Plateau	Plateau	High-relief		Volcanic Plateau	A generally closed-contoured, relatively flat-topped bathymetric high with one or more relatively steep sides (modified from IHO, 2019).
Volcanic Ridge	Ridge	High High-relief		Volcanic Ridge	An elongated elevation of varying complexity, size and gradient (length > width) (modified from IHO, 2019).

Substrate

Feature Description	Definition
Bedrock Outcrop	Assumed to be mainly volcanic/ igneous in origin (Vye-Brown & Crummy, 2014).
Bedrock with discontinuous sediment cover	Bedrock covered by a thin veneer of sand or mixed sediment.
Rhodolith Beds	Rhodolith Beds and Mixed Sediment (Gravel to Cobbles – minor sand). Typically described as 'colourful unattached calcareous nodules composed of marine red algae'.
Sandy Gravel	Mixed sediment – Gravel dominant with 30-80% gravel
Gravelly Sand	Mixed sediment – Sand dominant with 5-30% gravel
Sand	Sand with minor gravel i.e. c. 5%. Typically, coarse-grained with shell fragments. Occurrence of mobile bedforms and visible mobility of the sediment.

Notes: *Definitions are from Dove et al. (2020) and Nanson et al. (2023) unless otherwise stated. A complete description and explanation of the two-part classification scheme is given in Dove et al. (2016); Dove et al. (2020); Nanson et al. (2023). **Features may be represented as either lines or polygons depending on their morphology and scale. Narrow, elongated forms (e.g. ridges) are mapped as line features, while broader or more complex forms (e.g. ridge bases or volcanic edifices) are mapped as polygons, following the two-part classification scheme.

seamounts including Proto-Ascension, the only known actively growing seamount in the area (Klingelhöfer et al., 2001; La Bianca et al., 2018). The new datasets reveal a wide range of volcanic features, including lava flows, calderas, ridges, mounds, and plateaus (Figure 5). Figure 5a shows a volcanic complex on the eastern flank of the island, where a smooth mound with a central depression lies adjacent to an
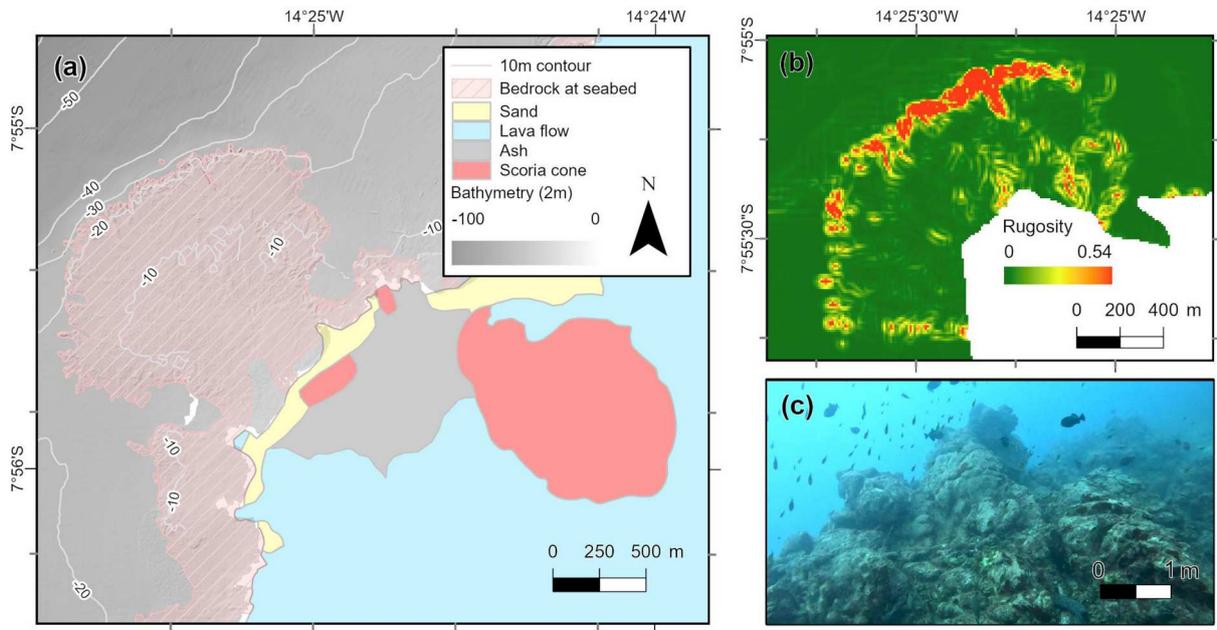
Figure 4. (a) Merged multibeam echosounder bathymetry and satellite-derived bathymetry data resampled at 2 m (lowest spatial resolution), showing lava flows (interpreted as '*bedrock at seabed*') extending offshore from Georgetown located in the northwest of Ascension Island (© British Crown Copyright 2022; BGS © UKRI 2025). The onshore geology map, adapted from Chamberlain et al. (2016), highlights a volcanic cone and intermediate mafic lava flow located onshore which may represent the source of these identified offshore flows. Onshore basemap is from OpenStreetMap via Esri (© 1995–2025 Esri). (b) Rugosity layer derived from the bathymetry grid shown in (a) (BGS © UKRI 2025). (c) Example of '*bedrock at seabed*' observed in drop-camera ground-truthing footage (BGS © UKRI 2025). For location see Figure 1. BGS © UKRI 2025.
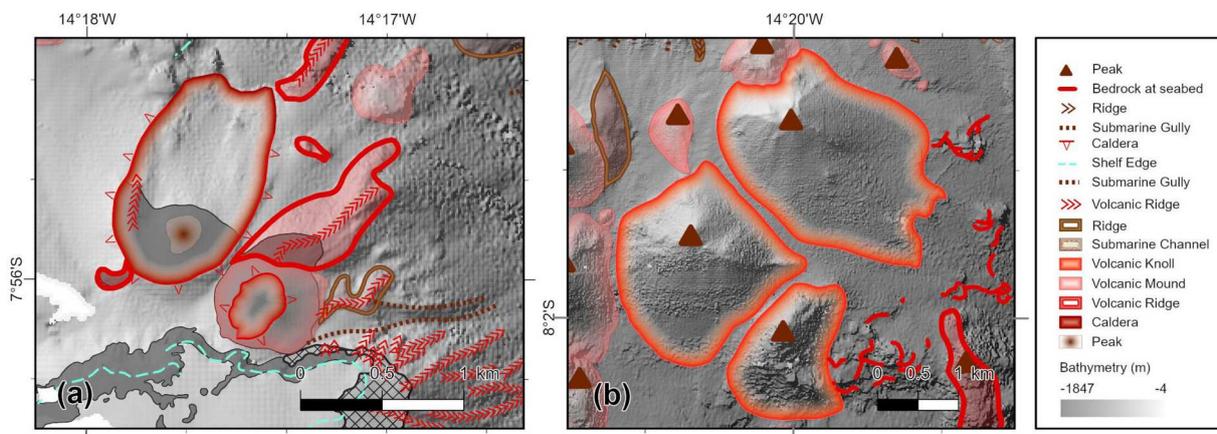

Figure 5. Extract from the seabed geomorphology map of Ascension Island (see Figure 1 for location) (BGS © UKRI 2025). (a) Shows bedrock outcropping at seabed, ridges, a palaeoshoreline, interpreted either as the boundary of a bedrock outcrop or as evidence of a former coastline, a caldera and a volcanic mound topped with a caldera depression located to the east of Ascension Island. (b) Displays three volcanic knolls with surrounding ridges and mounds located to the south of the island.

Note: Volcanic ridges and ridges are shown using two symbols to reflect the two-part classification scheme; line features represent narrow fissural ridges, while polygon features represent broader ridge bases or volcanic edifices. Bathymetry data from UKHO and BGS (© British Crown Copyright 2022; BGS © UKRI 2025). Panel (a) shows volcanic features on the seabed to the east of Ascension Island, including bedrock outcrops, a caldera, volcanic mounds and ridges. Panel (b) shows three volcanic knolls with surrounding ridges and mounds to the south of the island (© British Crown Copyright 2022; BGS © UKRI 2025).

elongated depression interpreted as a '*caldera*'. South of the island, volcanic cones of varying shapes and sizes dominate the seabed. Figure 5b shows three '*volcanic knolls*' with steep flanks; two are smooth and pointed, while the southernmost is more rugose with terraced flanks, suggesting multiple lobate flow phases.

Other mounds occur in isolation or in clusters, often associated with lava and debris flows on their flanks (Sanchez-Guillamón et al., 2018). For this project, interpretation was limited to morphological classification (e.g. volcanic mound). Further specialist analysis could refine the classification and mapping of the

volcanic features, offering deeper insights into their origin and evolution.

3.1.2 Erosional and depositional features

The coastline of Ascension Island is shaped by high-energy hydrodynamic processes including wave erosion, sea-level fluctuations, slope instability and density-driven flows (Micallef et al., 2018), resulting in a variety of erosional and depositional features. Narrow, irregular and infrequent coarse-grained sandy beaches are confined along the north and west coasts with no enclosed bays or sheltered lagoons. The beaches typically exhibit erosional profiles continuously reworked by strong wave action and storms. Submarine cables installed around the island have frequently failed at or near the shoreline (e.g. Thomson et al., 2002). Notably, large-scale bedforms are absent, likely due to the prevailing hydrodynamic regime and limited sediment availability. Sediment supply is influenced by volcanic activity, climate and sea-level change, and the island's age, area and location (Krastel et al., 2001).

Submarine gullies, channels and fan-shaped systems are common, particularly near the shelf edge. To the west of the island, a 'fan-shaped system', ~1000 m wide and 1800 m long, exhibits a ridge-and-trough morphology, indicative of stacked gravity flows (Micallef et al., 2018). The shelf edge is incised by narrow 'V-shaped gullies', with one major 'channel' system extending to the shelf edge (Figure 6). Submarine landslide scars are visible in the bathymetric data. Two 'small-scale scars' (<1 km wide headwall) are observed along the western shelf edge as shown in Figure 6. These may represent a small landslide failure or scour features (e.g. Quartau et al., 2018). No associated debris was identified, possibly due to the disintegration of the landslide mass during failure (Micallef et al., 2018) or insufficient data resolution (i.e. 10 m) resulting in uncertainty in classification. Previous studies inferred the presence of an embayment on the northeast and northwest slopes (Mitchell, 2003) where the shelf is very narrow. Little is known about the failure of these events (Mitchell, 2003), and smaller sized landslides such as these are a yet unquantified tsunami-risk of mid-oceanic islands (Tinti et al., 2005). These features may differ from larger island collapses seen in the Hawaiian and Canary Islands due to varying underlying sediment structures (Krastel et al., 2001; Le Friant et al., 2019). Further analysis is limited without the subsurface seismic data and high-resolution bathymetry data at these depths, which we highlight as priorities for future work.

3.2. Seabed substrate and benthic habitats

Six superficial sediment classes were identified: (a) Sand (minor gravel content <~5%); (b) Gravelly Sand (5–30% gravel); (c) Sandy Gravel (30-80% gravel); (d) Rhodolith Beds and Mixed Sediment (gravel to cobbles, minor sand); (e) Bedrock with
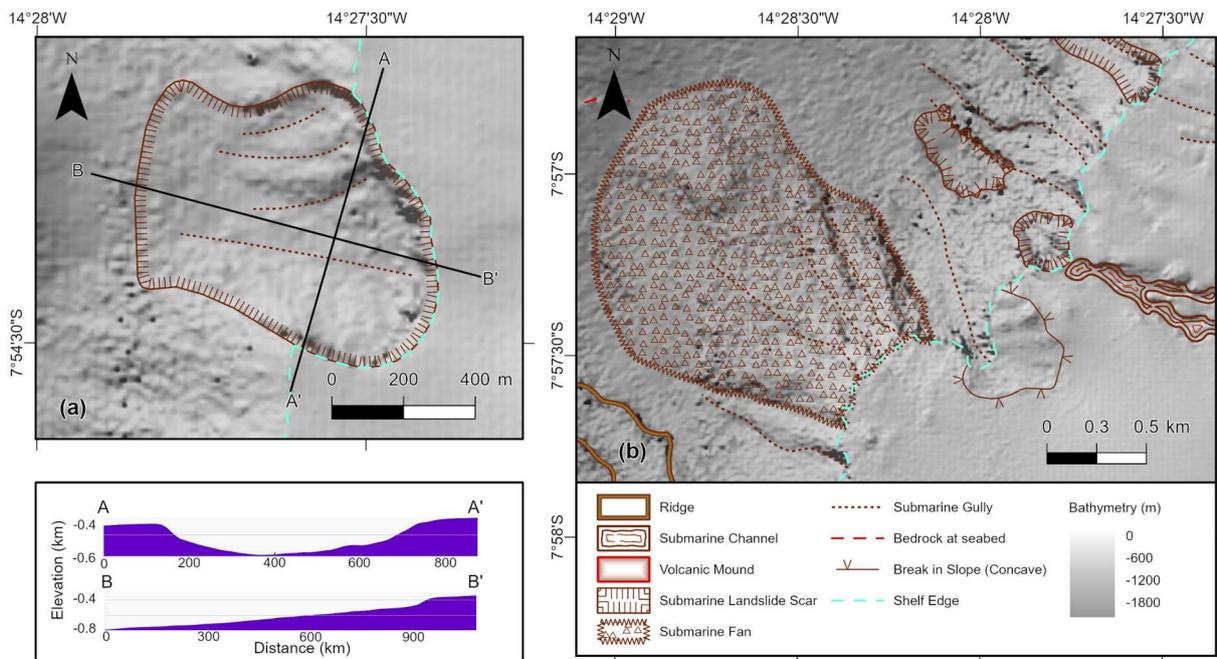

Figure 6. Example erosional-depositional features from the seabed geomorphology map around Ascension Island (for location see Figure 1) BGS © UKRI 2025. (a) Displays a submarine landslide headwall scar incised into the insular shelf edge northwest of the island with slope profiles from northeast to southwest and east to west. (b) Shows an example of a depositional submarine fan, and a submarine channel located west of the island. Two scars mapped beneath the shelf edge may represent a possible submarine landslide scour (e.g. Quartau et al., 2018). Bathymetry data from UKHO and BGS (© British Crown Copyright 2022; BGS © UKRI 2025).

superficial sediment cover; (f) Bedrock Outcrop. Mixed sediment, including 'Sandy Gravel' and 'Gravelly Sand', is the dominant sediment class interpreted within the study area. 'Sand-only' areas were primarily confined to the nearshore areas, featuring mobile bedforms and coarse-grained sediments with shell fragments. 'Rhodolith', defined as unattached calcareous nodules composed of marine red algae, was mapped only where clearly visible in the video transects and may be more widespread than recorded due to limited ground-truth coverage. Bedrock was classified either as 'Bedrock Outcrop', primarily volcanic, and concentrated along the coastline, or 'Bedrock with Discontinuous Sediment Cover', identified using backscatter and rugosity data.

The seabed substrate classes were translated into EUNIS habitat types. Five biological zones (i.e. Infralittoral, Circalittoral, Deep Circalittoral, Bathyal, and Abyssal) were defined based on depth and regional setting (Vasquez et al., 2023). Substrate classes such as 'gravelly sand' and 'sandy gravel' were renamed as 'mixed sediment' and 'coarse sediment', respectively, while 'Rhodolith' was mapped as 'biogenic habitat'. A unique classification, 'rock and other hard substrata', was applied to areas of bedrock with patchy sediment cover. The resulting benthic habitat map captures this refined classification across the different marine zones.

4. Discussion

The integration of high-resolution MBES bathymetry, backscatter intensity, and ground-truth data has enabled the first comprehensive mapping of seabed geomorphology, seabed substrate and benthic habitats within the AI-MPA, representing a significant advancement in baseline marine data. These datasets reveal a complex and dynamic seafloor shaped by volcanic, tectonic, and marine processes, reflecting the island's geological evolution and oceanographic setting. The identification of 24 distinct geomorphological features and 6 sediment classes highlight the spatial heterogeneity and ecological diversity of the marine environment, rarely documented in such detail for remote mid-oceanic islands.

4.1. Geological evolution

The seabed around Ascension Island has been shaped by volcanic, tectonic, and sea-level processes over multiple geological timescales (Bruguier et al., 2003; Jicha et al., 2013; Klingelhöfer et al., 2001). These processes have produced a rugged submarine landscape featuring widespread lava flows, volcanic knolls and other constructional landforms, providing insight into the eruptive history, lava emplacement mechanisms and volcanic evolution. Whilst the geomorphology resembles those of other volcanic islands (e.g. Azores, Madeira and Canary Islands; Quartau et al., 2015, 2018; Sanchez-Guillamón et al., 2018), the scale, isolation and unique volcanic setting underscores the need for site-specific mapping to better understand mid-Atlantic volcanic island morphology.

Erosional and depositional landforms, including submarine gullies, fan-shaped systems, and landslide scars, reveal the influence of hydrodynamic forces, sediment transport, and slope instability. Although large debris deposits were not observed at the available resolution, small-scale scars or possible scour features mapped near the shelf break may represent under-recognised geohazards. Differentiating between types of submarine landslides has implications for understanding triggering mechanisms and associated geohazards (Le Friant et al., 2019; Watt et al., 2012). These include the potential for flank collapse and tsunami generation, a significant concern for other volcanic ocean islands such as the Azores (Chang et al., 2021) but not yet fully assessed at Ascension Island (Crummy et al., 2023).

The absence of high-resolution subsurface seismic data limits the ability to assess the internal structure of submarine landslides and resolve the tectonic architecture of Ascension Island, such as zones of active faulting and magma emplacement. Acquisition of such data should therefore be a priority for future geohazard and structural assessments. Furthermore, repeated failure of submarine cables near the shoreline (Thomson et al., 2002) underscores the need for improved understanding of local hydrodynamics particularly for any future offshore infrastructure developments. Given the uncertain eruption history of Ascension Island, this dataset provides an essential baseline for monitoring potential submarine volcanic activity and slope failure risks.

4.2. Seabed substrate composition and benthic habitat mapping

Seabed substrate mapping complements the geomorphological data by characterising the distribution of surficial sediment types. The seafloor is dominated by mixed sediments, primarily 'Sandy Gravel' and 'Gravelly Sand', reflecting limited terrestrial sediment supply, high-energy oceanographic conditions, and steep slopes. The presence of 'Rhodolith' beds is ecologically significant due to their role as biodiversity hotspots and are likely to be much more extensive than the areas currently mapped due to limited ground-truth coverage. Additional features such as coarse mobile sands and patchy bedrock exposures provide further insight into nearshore sedimentary processes and benthic habitat distribution.

Substrate type and depth were found to be major controls on benthic assemblage structure, consistent with findings from other oceanic environments (Stephens & Diesing, 2015). Rugose volcanic slopes typically support hard-substrate reef communities, whereas low-relief sediment-filled depressions and flat areas host softer-sediment faunal assemblages. The observed substrate heterogeneity aligns with broader patterns of coastal evolution on volcanic oceanic islands, where volcanism, erosion, sedimentation, and biogenic production interact to shape seabed composition over time (Ramalho et al., 2013). In particular, the transition from constructional volcanic features to sediment-dominated substrates reflects the progressive aging of island systems and the increasing role of biogenic and hydrodynamic processes. However, Ramalho et al. (2013) highlight that post-erosional volcanic activity can locally reset this balance, renew coastline expansion and alter substrate composition in ways that may not be captured by surface mapping alone. This has implications for understanding unquantified volcanic risks, especially where renewed activity could impact benthic habitats through lava emplacement, reef growth or slope destabilisation. Additionally, submarine hazards such as explosive volcanic eruptions, landslides and lava flows may also impact benthic marine habitats and marine life within the AI-MPA.

4.3. Ecological significance and conservation implications

The geomorphological and sedimentary diversity of Ascension Island underpins a wide variety of ecologically important habitats, particularly across the nearshore and shelf environments. Like other isolated islands and seamounts, the region benefits from enhanced surface productivity due to localised oceanographic processes, including upwelling, tidal rectification, and vertical mixing (White et al., 2008). These processes boost primary productivity and biomass, attracting large pelagic species such as tuna, billfish, sharks, and marine mammals (Bridges et al., 2021; Campanella et al., 2021).

The structural complexity of volcanic features, including steep slopes, sediment-filled basins, and flat summits, creates heterogeneous habitats that support diverse benthic communities. The rocky subtidal zone, in particular, hosts some of the island's richest biodiversity, including at least 30 endemic marine species (Ascension Island Government, 2025). These habitats are critical to the ecological integrity of the AI-MPA but remain vulnerable to anthropogenic threats and climate change. The absence of typical tropical coastal ecosystems (e.g. mangroves, seagrass beds, and coral reefs), increases the importance of volcanic and rhodolith-dominated habitats (Barnes et al., 2015). These findings emphasise the need to prioritise monitoring of vulnerable habitats and assessing risks from geohazards and climate change.

4.4. Broader applications and future work

This study provides the first integrated geospatial and geological baseline of the AI-MPA, supporting scientific research, conservation and marine management. The combined geomorphological and substrate classification offers essential baseline data to inform conservation strategies, spatial planning, biodiversity assessments, and geohazard evaluation. The mapping framework and methodology presented here are applicable to other remote island and seamounts, contributing to global seabed mapping and marine conservation efforts.

Despite the comprehensive coverage of these maps, some areas remain less well constrained due to variable survey coverage and limited ground-truth validation. While a formal confidence assessment was beyond the scope of this study, the distribution of available data naturally highlights regions of higher and lower confidence. Future data collection, such as additional ground-truth surveys (drop-camera sampling, grab samples, cores, etc.) and targeted high-resolution bathymetry data, would improve classification accuracy and support development of predictive habitat models. Mapping broad confidence categories in future efforts would help guide prioritised data acquisition in future.

As human pressures and climate impacts on remote oceanic island environments continue to increase, foundational datasets such as these are essential for adaptive management, long-term monitoring, and evidence-based policy development. Future research should integrate biological surveys, sub-bottom seismic data and refined geomorphological classification (e.g. semi-automated or machine learning based methods) to improve reproducibility and enhance ecosystem understanding. Expanding quantitative habitat metrics, and assessing sediment transport, slope failure, and volcanic activity will further enhance the value of this dataset for scientific and conservation applications.

5. Conclusion

This study presents the first high-resolution, integrated mapping of seabed geomorphology, substrate and benthic habitats within the AI-MPA, establishing a foundational dataset for marine science, conservation and management. MBES bathymetry data, extending to depths of ∼1800 m, revealed previously unmapped volcanic, erosional, and depositional features, including volcanic knolls, ridges, gullies,

channels, and landslide scars. These features reflect the complex interplay of volcanic, tectonic, and oceanographic processes that have shaped Ascension's seafloor over the past million years.

Seabed substrate mapping identified six dominant sediment types, offering new insights into sediment distribution and seafloor processes. Coarse mixed sediments such as 'Sandy Gravel' and 'Gravelly Sand' were prevalent in high-energy, steep-sloped environments, while sand-dominated sediments accumulated in sheltered depressions. Exposed bedrock, mobile sands, and rhodolith beds further contributed to substrate heterogeneity, which strongly influences benthic habitat structure. These findings emphasise the ecological significance of substrate type and distribution in shaping species assemblages and highlight the importance of continued monitoring of habitat condition and change.

While the maps provide a robust baseline for conservation, spatial planning, and long-term monitoring, confidence in feature interpretation varies due to uneven survey coverage and limited ground-truth validation. Future targeted data collection, including additional drop-camera surveys, physical sampling, and high-resolution geophysical datasets (e.g. bathymetry and sub-bottom profiler data) would enhance confidence assessments, improve the predictability of habitat models and strengthen the reliability of seabed classifications.

Beyond their immediate mapping value, these datasets also offer new perspectives on volcanic island evolution, benthic habitat distribution, and submarine geohazards in isolated oceanic settings. The approach developed here provides a framework applicable both to local AI-MPA management and broader regional comparisons across mid-Atlantic islands. Further research should explore linkages between Ascension's subaerial and submarine morphology, examining how volcanic construction, mass wasting processes, and sedimentary dynamics interact across land-sea boundaries. Comparative studies with other Atlantic islands, such as the Azores, Canary Islands, St. Helena, and Tristan da Cunha, will enhance understanding of regional geological evolution and support coordinated conservation strategies and hazard mitigation across mid-Atlantic Island systems.

Software

All MBES bathymetry and backscatter intensity surfaces were reprocessed to the highest possible resolution using Teledyne CARIS HIPS and SIPS v11.4.22, QPS Qimera v6.2.1 and QPS FMGT v7.10.3. All geographic maps were produced in ESRI ArcGIS Pro v3.1.2 using the projected coordinate system WGS84 / UTM Zone 28S (EPSG:32728). Additional layers of slope, hillshade and aspect were derived from the processed bathymetry data using the 3D Analyst extension. Hillshade was generated using an azimuth of 45° and an altitude of 25°. Layers depicting terrain roughness or rugosity, were derived from the bathymetry data using the Benthic Terrain Modeler extension (Walbridge et al., 2018).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The multibeam echosounder (MBES) and ground-truthing data presented in this study were collected by the British Geological Survey (BGS) under the Darwin Plus Project DPLUS142. Additional MBES data and grab samples were provided by the Royal Navy (HMS *Protector*/SMB *James Cairn*) via the UK Hydrographic Office (UKHO) and satellite-derived bathymetry (SDB) was also provided by the UKHO. The coastline shapefile used in mapping was provided by the Ascension Island Government Conservation Department. Licensing restrictions apply to these datasets; requests for access should be directed to the relevant data owners. The final processed bathymetry grids, seabed geomorphology, substrate and benthic habitat maps, as well as supporting sample metadata, are available via the NERC Open Research Archive at: https://nora.nerc.ac.uk/id/eprint/539110/.

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References

Arosio, R., & Gafeira, J. (2023). CoMMa Toolbox v1.0.. https://doi.org/10.5281/ZENODO.8434457

Ascension Island Government. (2025). *Ascension Island marine protected area*. https://www.ascensionmpa.ac/. Accessed: 29/05/2025

Barnes, D., Brown, J., Brickle, P., Downes, K., Enderlein, P., Gowland, E., Hogg, O., Laptikhovsky, V., Morley, S., Nolan, E., Richardson, A., Sands, C., Weber, N., & Weber, S. (2015). *Marine biodiversity of Ascension Island's shelf; scientific support for a marine protected area*. JR15003 cruise report (*Unpublished*). British Antarctic Survey, Cambridge. Available at: https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/jr864.pdf

Brickle, P., Brown, J., Küpper, F. C., & Brewin, P. E. (2017). Biodiversity of the marine environment around Ascension Island, South Atlantic. *Journal of the Marine Biological Association of the United Kingdom*, 97(4), 643–646. https://doi.org/10.1017/S0025315417001175

Bridges, A. E. H., Barnes, D. K. A., Bell, J. B., Ross, R. E., & Howell, K. L. (2021). Benthic assemblage composition of south Atlantic seamounts. *Frontiers in Marine Science*, 8, 660648. https://doi.org/10.3389/fmars.2021.660648

British Geological Survey. (2023). User guide: BGS Seabed Geology 10k – Offshore Yorkshire. British Geological Survey Open Report, OR/22/063. 54pp.

Brozena, J. M. (1986). Temporal and spatial variability of seafloor spreading processes in the Northern South Atlantic. *Journal of Geophysical Research: Solid Earth*, 91(B1), 497–510. https://doi.org/10.1029/JB091iB01p00497

Bruguier, N., Minshull, T., & Brozena, J. (2003). 'Morphology and tectonics of the Mid-Atlantic Ridge, 7°–12° S'. *Journal of Geophysical Research: Solid Earth*, 108(B2), 2093. https://doi.org/10.1029/2001JB001172

Campanella, F., Collins, M. A., Young, E. F., Laptikhovsky, V., Whomersley, P., & Van der Kooij, J. (2021). First insight of Meso- and Bentho-Pelagic fish dynamics around remote seamounts in the South Atlantic Ocean. *Frontiers in Marine Science*, 8, 663278. https://doi.org/10.3389/fmars.2021.663278

Chamberlain, K. J., Barclay, J., Preece, K., Brown, R. J., & Davidson, J. P. (2016). Origin and evolution of silicic magmas at ocean islands: Perspectives from a zoned fall deposit on Ascension Island, South Atlantic. *Journal of Volcanology and Geothermal Research*, 327, 349–360. https://doi.org/10.1016/j.jvolgeores.2016.08.014

Chang, Y-C., Mitchell, N. C., & Quartau, R. (2021). 'Landslides in the upper submarine slopes of volcanic islands: The central Azores'. *Geochemistry, Geophysics, Geosystems*, 22(10), e2021GC009833. https://doi.org/10.1029/2021GC009833

Cooper, R., & Macdonald, C. (2024). *Report of survey - Ascension Island multibeam and video transects*. British Geological Survey Open Report, OR/24/014. 63pp. Available at: https://nora.nerc.ac.uk/id/eprint/538774/

Crummy, J. M., Vye-Brown, C., & Loughlin, S. C. (2023). St Helena, Ascension and Tristan da Cunha British Overseas Territory: Review of Volcanic Hazards and Submarine Volcanism. British Geological Survey Internal Report (Unpublished).

Cunningham, A. P., & Mitchell, N. C. (2001). *RRS James Clark Ross Cruise Report JR53*. September to October 2000. Atlantic Ocean Marine Geophysics. British Antarctic Survey, Cambridge. Available at: https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/jr53.pdf

Dove, D., Bradwell, T., Carter, G., Cotterill, C., Gafeira Goncalves, J., Green, S., Krabbendam, M., Mellett, C., Stevenson, A., Stewart, H., & Westhead, K. (2016). *Seabed Geomorphology: A two-part classification system. British Geological Survey, Open Report OR/16/001*. British Geological Survey. Available at: https://nora.nerc.ac.uk/id/eprint/514946/

Dove, D., Nanson, R., Bjarnadóttir, L., Guinan, J., Gafeira, J., Post, A., Dolan, M. F. J., Stewart, H., Arosio, R., & Scott, G. (2020). *A two-part seabed geomorphology classification scheme (v.2); Part 1: Morphology features glossary*. https://doi.org/10.5281/ZENODO.4075248

EUNIS Home. (2019). *Welcome to EUNIS, the European Nature Information System*. Available at: https://eunis.eea.europa.eu/index.jsp (Accessed: 27 August 2024)

Evangelidis, C. P., Minshull, T. A., & Henstock, T. J. (2004). *Three-dimensional crustal structure of Ascension Island from active source seismic tomography*. Geophysical Journal International, 159(1), 311–325. https://doi.org/10.1111/j.1365-246X.2004.02396.x

Faneros, G., & Arnold, F. (2003). 'Geomorphology of two seamounts offshore Ascension Island, South Atlantic Ocean'. *Proceedings of the OCEANS 2003 MTS/IEEE Conference, San Diego, CA, USA*, 1, 39–49. https://doi.org/10.1109/OCEANS.2003.178518

Folk, R. L. (1954). *The distinction between grain size and mineral composition in sedimentary rock nomenclature. The Journal of Geology*, 62(4), 344–359. https://doi.org/10.1086/626171

International Hydrographic Organization (IHO). (2019). *Standardisation of undersea feature names – Guidelines, proposal form, terminology*. Edition 4.2.0 – Oct. 2019, Monaco, International Hydrographic Bureau, IHO Publication B-6.

Jicha, B. R., Singer, B. S., & Valentine, M. J. (2013). 40Ar/39Ar Geochronology of subaerial Ascension Island and a re-evaluation of the temporal progression of Basaltic to Rhyolitic Volcanism. *Journal of Petrology*, 54(12), 2581–2596. https://doi.org/10.1093/petrology/egt058

Klingelhöfer, F., Minshull, T. A., Blackman, D. K., Harben, P., & Childers, V. (2001). Crustal structure of Ascension Island from wide-angle seismic data: Implications for the formation of near-ridge volcanic islands. *Earth and Planetary Science Letters*, 190(1-2), 41–56. ISSN 0012-821X https://doi.org/10.1016/S0012-821X(01)00362-4

Krastel, S., Schmincke, H.-U., Jacobs, C. L., Rihm, R., Le Bas, T. P., & Alibes, B. (2001). *Submarine landslides around the Canary Islands. Journal of Geophysical Research: Solid Earth*, 106(B3), 3977–3997. https://doi.org/10.1029/2000JB900413

La Bianca, G., Tillin, H., Hodgson, B., Erni-Cassola, G., Howell, K., & Rees, S. (2018). *Ascension Island Natural Capital Assessment: Marine ecosystem services report*. Available at: https://www.mba.ac.uk/wp-content/uploads/2022/05/La_Bianca_et_al_2018.pdf

Lecours, V. (2015). *Terrain attribute selection for Spatial Ecology (TASSE)*, v. 1.0. https://doi.org/10.13140/RG.2.2.15014.52800

Le Friant, A., Lebas, E., Brunet, M., Lafuerza, S., Hornbach, M., Coussens, M., Watt, S., Cassidy, M., & Talling, P. J. (2019). 'Submarine landslides around volcanic islands'.

In *Submarine Landslides: Subaqueous mass transport deposits from outcrops to seismic profiles* (pp. 277–297). American Geophysical Union & Wiley. https://doi.org/10.1002/9781119500513.ch17

Macdonald, C., Cooper, R., Bonde, C. E., Stewart, H. A., Baum, D., Simpson, D., Simpson, T., & Tieppo, M. (2025). *Mapping of geomorphology, seabed substrate and nearshore habitats within the Ascension Island Marine Protected Area*. Edinburgh, UK, British Geological Survey. OR/24/015, pp.52. Available at: https://nora.nerc.ac.uk/id/eprint/539110/

Micallef, A., Krastel, S., & Savini, A. (2018). *Submarine geomorphology*. Springer Geology.. ISBN 978-3-319-57851-4. https://doi.org/10.1007/978-3-319-57852-1

Micallef, A., Krastel, S., & Savini, A. (2018). Submarine Geomorphology. *Geological Society, London, Memoirs*, *58*(1), 379–394. https://doi.org/10.1144/M58-2021-2

Minshull, T. A., Ishizuka, O., & Garcia-Castellanos, D. (2010). Long-term growth and subsidence of Ascension Island. *Geophysical Research Letters*, *37*(23), L23306. https://doi.org/10.1029/2010GL045112

Mitchell (2003). Susceptibility of mid-ocean ridge volcanic islands. *Journal of Geophysical Research: Solid Earth*, *108*(B8), 2397. https://doi.org/10.1029/2002JB001997

Nanson, R., Arosio, R., Gafeira, J., McNeil, M., Dove, D., Bjarnadóttir, L., Dolan, M., Guinan, J., Post, A., Webb, J., & Nichol, S. (2023). *A two-part seabed geomorphology classification scheme; Part 2: Geomorphology classification framework and glossary (Version 1.0)*. https://doi.org/10.5281/zenodo.7804019

Nielson, D. L., & Sibbett, B. S. (1996). *Geology of Ascension Island, South Atlantic Ocean. Geothermics*, *25*(4-5), 427–448. https://doi.org/10.1016/0375-6505(96)00018-1

Open Geospatial Consortium. (2010). OpenGIS implementation standard for geographic information – simple feature access – Part 1: Common architecture. Document No., OGC 06-103r4, Version 1.2.1.

Quartau, R., Hipólito, A., Mitchell, N. C., Gaspar, J. L., & Brandão, F. (2015). 'Comment on "Construction and destruction of a volcanic island developed inside an oceanic rift: Graciosa Island, Terceira Rift, Azores" by Sibrant et al. (2014) and proposal of a new model for Graciosa's geological evolution'. *Journal of Volcanology and Geothermal Research*, *303*, 146–156. ISSN 0377-0273, https://doi.org/10.1016/j.jvolgeores.2015.07.007

Quartau, R., Hipólito, A., Romagnoli, C., Casalbore, D., Madeira, J., Tempera, F., Roque, C., & Chiocci, F. L. (2014). The morphology of insular shelves as a key for understanding the geological evolution of volcanic islands: insights from Terceira Island (Azores). *Geochemistry, Geophysics, Geosystems*, *15*(5), 1801–1826. https://doi.org/10.1002/2014GC005248

Quartau, R., Ramalho, R. S., Madeira, J., Santos, R., Rodrigues, A., Roque, C., Carrara, G., & Brum da Silveira, A. (2018). Gravitational, erosional and depositional processes on volcanic ocean islands: Insights from the submarine morphology of Madeira Archipelago. *Earth and Planetary Science Letters*, *482*, 288–299. ISSN 0012-821X. https://doi.org/10.1016/j.epsl.2017.11.003

Ramalho, R. S., Quartau, R., Trenhaile, A. S., Mitchell, N. C., Woodroffe, C. D., & Ávila, S. P. (2013). Coastal evolution on volcanic oceanic islands: A complex interplay between volcanism, erosion, sedimentation, sea-level change and biogenic production. *Earth-Science Reviews*, *127*, 140–170. ISSN 0012-8252. https://doi.org/10.1016/j.earscirev.2013.10.007

Ricchi, A., Quartau, R., Ramalho, R., Romagnoli, C., Casalbore, D., Cruz, J. V., Fradique, C., & Vinhas, A. (2018). Marine terrace development on reefless volcanic islands: New insights from high-resolution marine geophysical data offshore Santa Maria Island (Azores Archipelago). *Marine Geology*, *406*, 42–56. ISSN 0025-3227. https://doi.org/10.1016/j.margeo.2018.09.002

Rodriguez-Gonzalez, A., Fernandez-Turiel, J. L., Aulinas, M., Cabrera, M. C., Prieto-Torrell, C., Rodriguez, G. A., Guillou, H., & Perez-Torrado, F. J. (2022). *Lava deltas, a key landform in oceanic volcanic islands: El Hierro, Canary Islands. Geomorphology*, *416*, 108427. ISSN 0169-555X. https://doi.org/10.1016/j.geomorph.2022.108427

Romagnoli, C., Casalbore, D., Ricchi, A., Lucchi, F., Quartau, R., Bosman, A., Tranne, C. A., & Chiocci, F. L. (2018). Morpho-bathymetric and seismo-stratigraphic analysis of the insular shelf of Salina (Aeolian archipelago) to unveil its Late-Quaternary geological evolution. *Marine Geology*, *395*, 133–151., ISSN 0025-3227. https://doi.org/10.1016/j.margeo.2017.10.003

Royal Navy. (2021). Report of Survey – HI 1751 Ascension and St. Helena.

Sanchez-Guillamón, O., Vázquez, J. T., Palomino, D., Medialdea, T., Fernández-Salas, L. M., León, R., & Somoza, L. (2018). Morphology and shallow structure of seafloor mounds in the Canary Basin (Eastern Central Atlantic Ocean). *Geomorphology*, *313*, 27–47. ISSN 0169-555X. https://doi.org/10.1016/j.geomorph.2018.04.007

Sowers, D. C., Mayer, L. A., Masetti, G., Cordes, E., Gasbarro, R., Lobecker, E., Cantwell, K., Candio, S., Hoy, S., Malik, M., White, M., & Dornback, M. (2024). Mapping and geomorphic characterization of the vast cold-water coral mounds of the Blake Plateau. *Geomatics*, *4*(1), 17–47. https://doi.org/10.3390/geomatics4010002

Stephens, D., & Diesing, M. (2015). Towards quantitative spatial models of seabed sediment composition. *PLoS One*, *10*(11), e0142502. https://doi.org/10.1371/journal.pone.0142502

Thomson, H., Meggitt, D., & Saade, E. (2002). *Ascension Island hydroacoustic data system*. Paper No. 539. California. pp 27.

Tinti, S., Manucci, A., Pagnoni, G., Armigliato, A., & Zaniboni, F. (2005). *The 30 December 2002 landslide-induced tsunamis in Stromboli: Sequence of the events reconstructed from the eyewitness accounts. Natural Hazards and Earth System Sciences*, *5*(6), 763–775. https://doi.org/10.5194/nhess-5-763-2005

Tobler, W. (1988). Resolution, resampling, and all that. In H. Mounsey & R. Tomlinson (Eds.), *Building data bases for global science* (pp. 129–137). Taylor and Francis. See also: www.esri.com/arcgisblog/products/product/imagery/on-map-scale-and-raster-resolution

Vasquez, M., Ségeat, B., Cordingley, A., Tilby, E., Wikström, S., Ehrnsten, E., Al Hamdani, Z., Agnesi, S., Andersen, M.S., Annunziatellis, A., Askew, N., Bekkby, T., Bentes, L., Daniels, E., Doncheva, V., Drakopoulo, V., Ernstsen, V.B., Gonçalves, J., Karvinen, V., … Woods, H. (2023) *EUSeaMap 2023: A European broad-scale seabed habitat map* (Techni cal Report). EMODnet Seabed Habitats. https://doi.org/10.13155/97116

Vye-Brown, C., & Crummy, J. M. (2014). *Volcanic hazards on Ascension Island: Fieldwork report*. British Geological Survey Internal Report, IR/14/062.

Walbridge, S., Slocum, N., Pobuda, M., & Wright, D. J. (2018). Unified geomorphological analysis workflows with Benthic Terrain Modeler. *Geosciences*, *8*(3), 94. https://doi.org/10.3390/geosciences8030094

Watt, S. F. L., Talling, P. J., Vardy, M. E., Heller, V., Hühnerbach, V., Urlaub, M., Sarkar, S., Masson, D. G., Henstock, T. J., Minshull, T. A., Paulatto, M., Le Friant, A., Lebas, E., Berndt, C., Crutchley, G. J., Karstens, J., Stinton, A. J., & Maeno, F. (2012). Combinations of volcanic-flank and seafloor-sediment failure offshore Montserrat, and their implications for tsunami generation. *Earth and Planetary Science Letters*, *319-320*, 228–240. https://doi.org/10.1016/j.epsl.2011.11.032

White, M., Bashmachnikov, I., Aristegui, J., & Martins, A. M. (2008). Physical processes and seamount productivity. In *Seamounts: Ecology, fisheries and conservation* (pp. 62–84). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470691953.ch4