

Seismic characterisation and geomorphological interpretation of the summit area palaeoenvironment of Tropic Seamount, offshore Western Sahara: A sediment starved, ferromanganese crust and nodule rich guyot

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ARTICLE INFO

Keywords:

Tropic Seamount
Seismic units
Seismic facies
Depositional history

ABSTRACT

To understand and reconstruct the palaeoenvironmental development of Tropic Seamount, a guyot offshore Western Sahara, an assessment of landforms morphology and seismic facies interpretation was conducted. High resolution multibeam echosounder bathymetry and backscatter, two hours of ROV footage and 23 TOPAS-acquired seismic lines were analysed to derive a morphological model and define seismic facies and units. The seabed morphology was classified into seven morphological classes. Eight seismic (sub)facies were identified on the basis of their internal configuration, forming five seismic units separated by reflectors with distinct morphological geometries. The link between geomorphologies and seismic units allows for the reconstruction of the morphogenetic processes which have likely originated the landforms. According to the reconstructed geological history, Tropic Seamount, a former volcanic island, began to sink after the end of its eruptive activity. Wave action and erosion washed away the islands' terrigenous sediment. Tropic Seamount may then have experienced reefal deposition, with the formation of *syn*-depositionally cemented hardgrounds. The continuous sinking may have brought its summit in correspondence of the oxygen minimum zone where reduced Fe and Mn ions have undergone oxidation and precipitation on the seamount's summit, leading to the formation of Fe—Mn crusts and nodules. The onset of the glacial/interglacial climate pattern and the consequent aridification of the Sahara may have led to ocean fertilization due to iron-rich continental dust input, which enhanced pelagic sedimentation. Finally, submarine resedimentation processes have reshaped the seamount's summit. The reconstruction of Tropic Seamount's depositional history may help shed light on the geological evolution of deep-sea environments and on the processes shaping them.

1. Introduction

Tropic Seamount is a well-studied seamount (e.g. Palomino et al., 2016; van den Bogaard, 2013; Marino et al., 2017; Ramiro-Sánchez et al., 2019; Yeo et al., 2019; Josso et al., 2019) that has attracted significant attention due to the presence of ferromanganese (Fe—Mn) crusts and nodules (Marino et al., 2017; Yeo et al., 2019; Josso et al., 2020). The seamount also supports a diverse benthic megafaunal community (Ramiro-Sánchez et al., 2019; Somoza et al., 2021) including Vulnerable Marine Ecosystems (VMEs) (Somoza et al., 2021). Ferromanganese precipitates (whether as crusts or nodules) occur on the

seamount due to prolonged direct seafloor contact with seawater following a lack of sediment accumulation over millions of years (Hein et al., 2012; Hein and Koschinsky, 2014). However, sediment accumulations exist as drifts, while other areas remain sediment-free due to current scouring. Josso et al. (2020) proposed high energy currents maintaining a sediment-free accretionary surface, allowing the growth of Fe—Mn crusts with a laminar texture. In contrast, where sediments are not removed due to a lower energy regime, a botryoidal texture is formed on the crusts' surface (Josso et al., 2020).

Tropic Seamount was emplaced through old (155 Ma) oceanic crust (Blum et al., 1996; Josso et al., 2019) and is mainly composed of

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<https://doi.org/10.1016/j.geomorph.2026.110466>

Received 19 November 2025; Received in revised form 20 July 2026; Accepted 20 July 2026

Available online 24 July 2026

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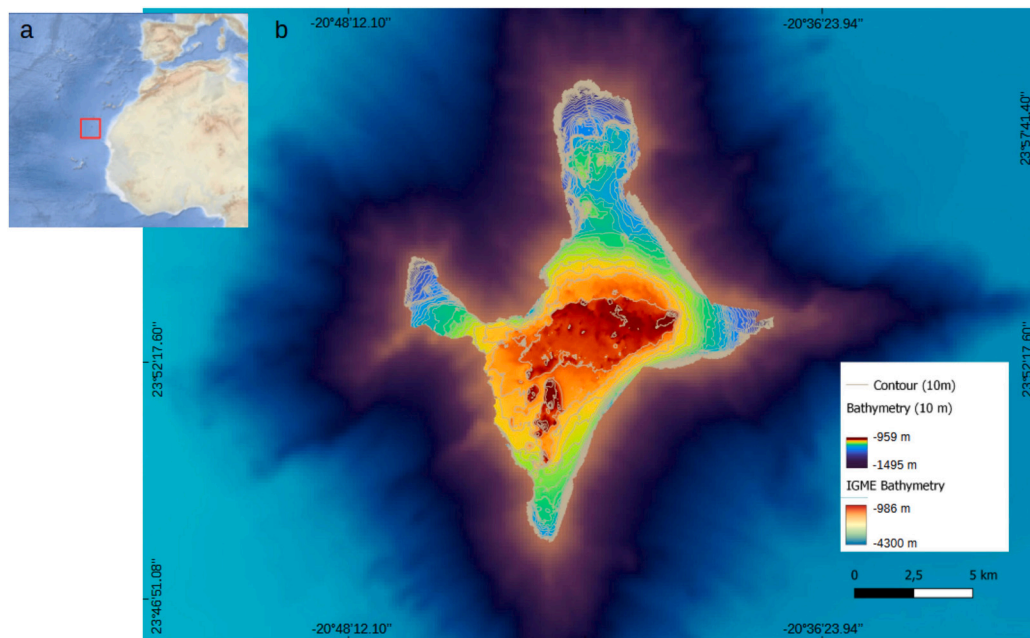


Fig. 1. a) Location of Tropic Seamount offshore Western Sahara. Basemap from <https://emodnet.ec.europa.eu/geoviewer/>. b) Tropic Seamount summit bathymetry.

volcanic alkaline rocks with a wide compositional range: from basalts to trachybasalts to trachytes (Blum et al., 1996). It lies beneath the northern end of an oxygen minimum zone (OMZ), which extends from 100 to 700 m water depths, from near the equator to 25° N (Marino et al., 2017). Dissolved oxygen levels here drop to 2.5–3.5 µg/ml in the core of the OMZ around 750 m depth, rising again to a concentration of 5 µg/ml around 3000 m (Koschinsky et al., 1996). On this seamount, Fe–Mn crusts, marine mineral deposits, precipitate on rock, phosphatic and carbonaceous hardground substrates directly from metals dissolved in seawater and by accretion of metal colloids (Hein and Koschinsky, 2014). The thickest Fe–Mn crusts (<20 cm) are located at the greatest depths of the seamount at 3000–4000 m on the eastern and western spurs, while the summit generally hosts the thinnest crusts (Murton et al., 2017). Nodules are also observed with these Fe–Mn deposits showing a bulk composition consistent with hydrogenetic precipitates (Koschinsky et al., 1995; Marino et al., 2017) and show evidence of phosphatisation indicative of nutrient redistribution from the deep-ocean to surface waters due to upwelling around the seamount (e.g. Halbach et al., 1989a, 1989b; Hein et al., 1993). Correspondingly, Tropic Seamount is also a hotspot of biodiversity hosting a diverse and near pristine benthic communities that include several Vulnerable Marine Ecosystems such as reef-building coral species *Solenosmilia variabilis*, and several species of octocorals and black corals that formed diverse coral gardens, as well as crinoid fields and sponge grounds (Ramiro-Sánchez et al., 2019; Dias et al., 2025).

Geomorphologically, Tropic Seamount is a guyot located in the northeastern sub-tropical Atlantic (23° 55' N, 20° 15' W) (Marino et al., 2017) offshore Western Sahara that is shaped like a four-pointed star, with four spurs running roughly N-S and W-E (Fig. 1). Tropic Seamount stands 3200 m above the abyssal plain, with a flat summit at c.1000 m below sea level (van den Bogaard, 2013; Palomino et al., 2016; Spearman et al., 2020). It has a surface area of 1537 km²; the regional slope at the summit is very low (0.5°–4°) and is characterized by small volcanic cones rising 15–20 m from the summit in the southern and eastern sectors (Palomino et al., 2016). Its flat-top summit was probably formed by wave erosion during subsidence and presents products of reef growth and sedimentation (Yeo et al., 2019). Tropic Seamount's summit ranges from –1020 m b.s.l. to –959 m b.s.l. (defined by the break of slope). The widest portion of the seamount's summit lies between –1010 m b.s.l. and –990 m b.s.l., with the shallowest portion forming a

multi-summitted topographic high.

The reconstruction of the geological history of the Tropic Seamount is limited by the fact that only few cores have been recovered from its summit, and the ones collected do not span a long geological record. The use of shallow seismic and geomorphological analysis in this paper provides critical information pertinent to the processes involved in shaping the seamount's summit palaeoenvironment. High-resolution seabed mapping is essential for improving the current knowledge and understanding of deep-seafloor (Somoza et al., 2021). The morphological features characterising the seabed form as a consequence of a variety of drivers. Studying the genesis of seafloor features and their respective sediments is critical to understand the palaeoenvironmental development of the seamount over the last 60 Ma when crusts have been forming and during its history of submergence below sea-level. While previous studies characterised Fe–Mn surface geochemistry and modern oceanography, the subsurface structure remains unknown. Our seismic data reveal for the first time the subsurface architecture and allow reconstruction of the complete depositional sequence. Complementing seabed morphological studies, seismic facies analysis (Berg, 1982) enables the interpretation of the palaeoenvironment of formation of morphological features by examining reflection geometries and stratal architecture, grouping them as depositional sequences (Mitchum et al., 1977a, 1977b; Roksandic, 1978).

This paper aims to take a wider look at the seabed facies and their development through geological time on Tropic Seamount's summit in order to contextualise the development of the sedimentological features within a relative temporal framework. The spatial and temporal characterisation of the various sedimentary features defines the development of the summit environment in the context of broader palaeoclimatic changes. Seismic facies interpretation and morphological analysis provide pertinent information on the palaeoenvironmental development of the entire summit area over the period of Fe–Mn crust and nodule formation which is ongoing today.

2. Materials and methods

Seabed mapping was conducted from October 29th to December 8th 2016 during the cruise JC142 on the research vessel *RSS James Cook* (Ramiro-Sánchez et al., 2019) collecting high resolution bathymetry using Autosub 6000 autonomous underwater vehicle (AUV) equipped

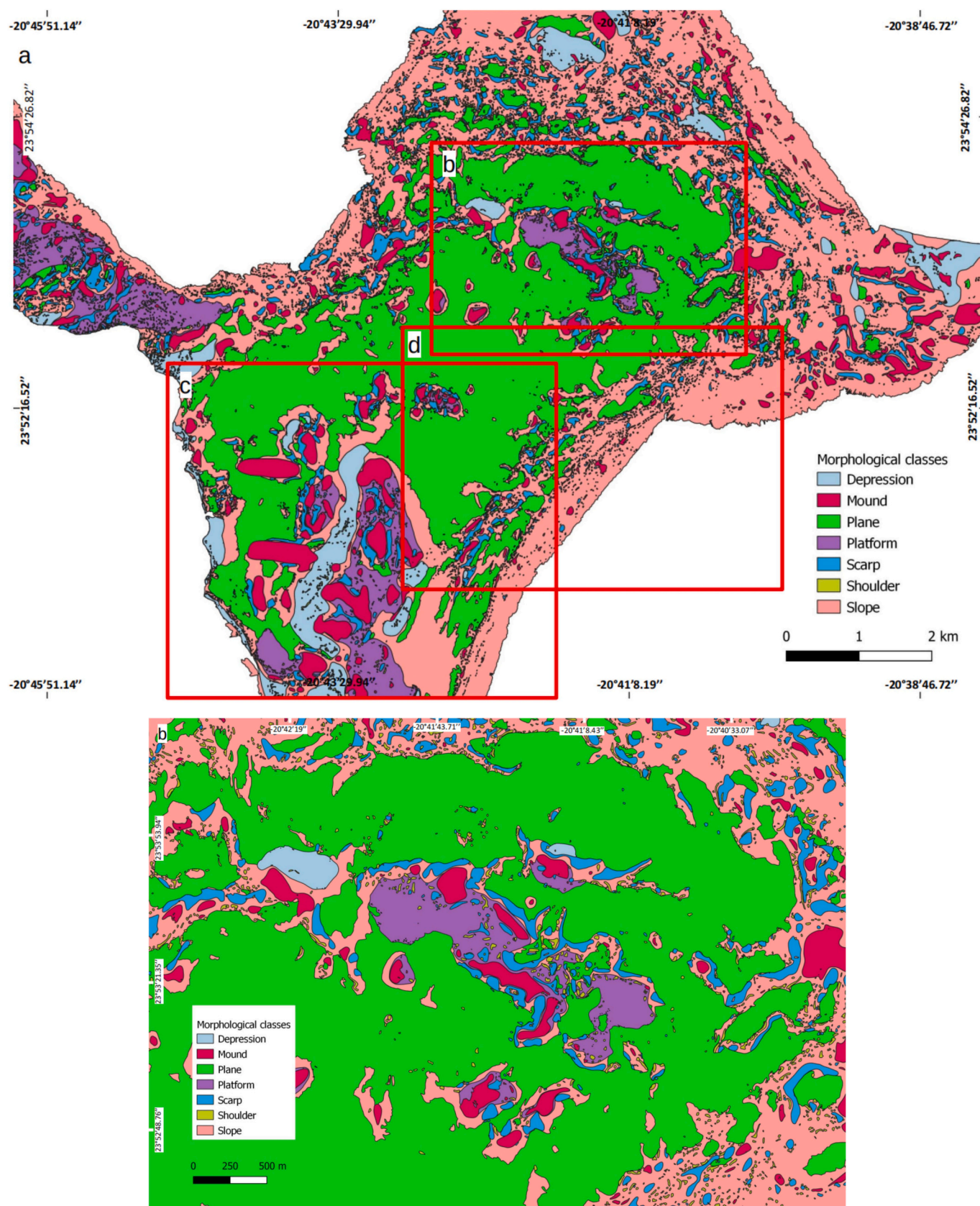


Fig. 2. Morphological elements observable on Tropic Seamount's summit. A) The entire summit; b) Northern highs cluster; c) Southern highs cluster; d) SE flank.

with a Kongsberg SIMRAD EM2040 multibeam echosounder with motion reference system, operating at 200 kHz, and an Edgetech 4200

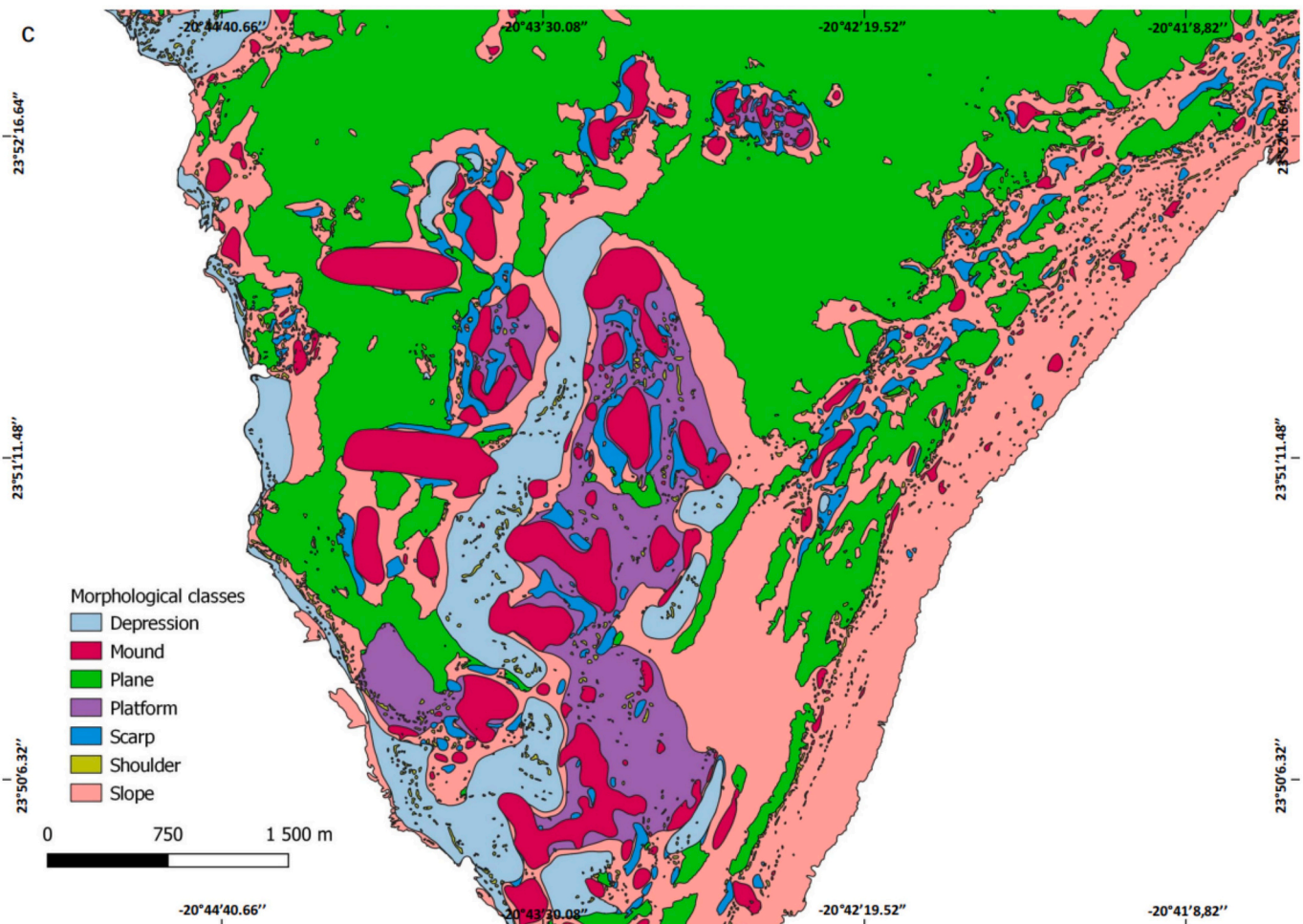


Fig. 2. (continued).

sidescan sonar operating at 100 kHz and 400 kHz (Yeo et al., 2019). Underwater navigation was performed using ultra-short-baseline (USBL) through the ship Sonardyne USBL system (Yeo et al., 2019). Two deployments of the AUV were undertaken with slightly different backscatter responses: the south-western half has a lower backscatter response than the north-western half where the data is also noisier (Yeo et al., 2019). Bathymetric data were processed with an MB-System (Caress, 1999; Yeo et al., 2019) and navigation was adjusted with the feature mapping module “mbnavdjust” within MB-System then matched to USBL position measured from the ship to the AUV using the ship Sonardyne USBL (Yeo et al., 2019). Sidescan sonar mosaics were produced with the QPS FM Geocoder Toolbox v7.6.3 (Yeo et al., 2019). Bathymetric grids were produced at 2 m grid spacing and sidescan sonar mosaics at 0.5 m for both frequencies (Yeo et al., 2019). The visualization of cleaned multibeam bathymetry and backscatter data was carried out in QGIS v. 3.34. Morphological characterisation was performed implementing algorithms contained in the CoMMA toolbox using the residual-relief separation method and the footprint casting method as described in Arosio et al. (2024).

Seismic data were acquired using a TOPAS PS18 Parametric sub-bottom profiler (Kongsberg Geoacoustic Ltd) during the TR1 cruise on board of the research vessel *Mario Ruivo* from June 15th to July 3rd 2024 (Terrinha et al., 2025). The +80% relative bandwidth, low frequency signal is generated in the water column by a non-linear interaction between two high-frequency signals, centred symmetrically around 18 kHz. The linear chirp, an FM pulse in which the frequency is swept linearly with time, was used to acquire data. The outer limit of the start and stop frequencies of the chirp are 0.5 and 6 kHz, providing a

maximum vertical resolution of approximately 0.2 milliseconds (Terrinha et al., 2025). Data were acquired in the TOPAS RAW format and converted in SEG—Y, then visualised in IHS Markit Kingdom Software 21.00. Data were imported as 2D SEG-Y files with coordinates; import parameters included a time data domain and a IEEE float shot-point and coordinates format. The start time byte location in the trace header considered 109 s as time zero. Variable start times and trace lengths were supported. The output data format was selected at 16 bit. Seismic (sub)facies were defined on the base of internal acoustic reflector's amplitude, structure and configuration following Xu and Haq (2022).

Video of the seafloor were retrieved during ROV dive 298 during the JC142 cruise, using the ROV *Isis* (Murton et al., 2017) equipped with a mini Zeus HD video and SCORPIO digital still camera, with scaling laser 10 cm apart (Murton, 2016). The ROV maintained a mean altitude of 2.24 m from the seabed to ensure constant field of view (Ramiro-Sánchez et al., 2019).

3. Results

3.1. Seabed morphology

Morphological assessment of the bathymetric data revealed seven classes of morphological elements: plane, depression, mound, platform, scarp, shoulder and slope (Fig. 2; Table 1). Plane is the dominant morphological class forming Tropic Seamount's summit since the vast majority of the summit area is relatively flat (Fig. 2). This planar aspect is interrupted by several topographic highs, belonging to the Mound and

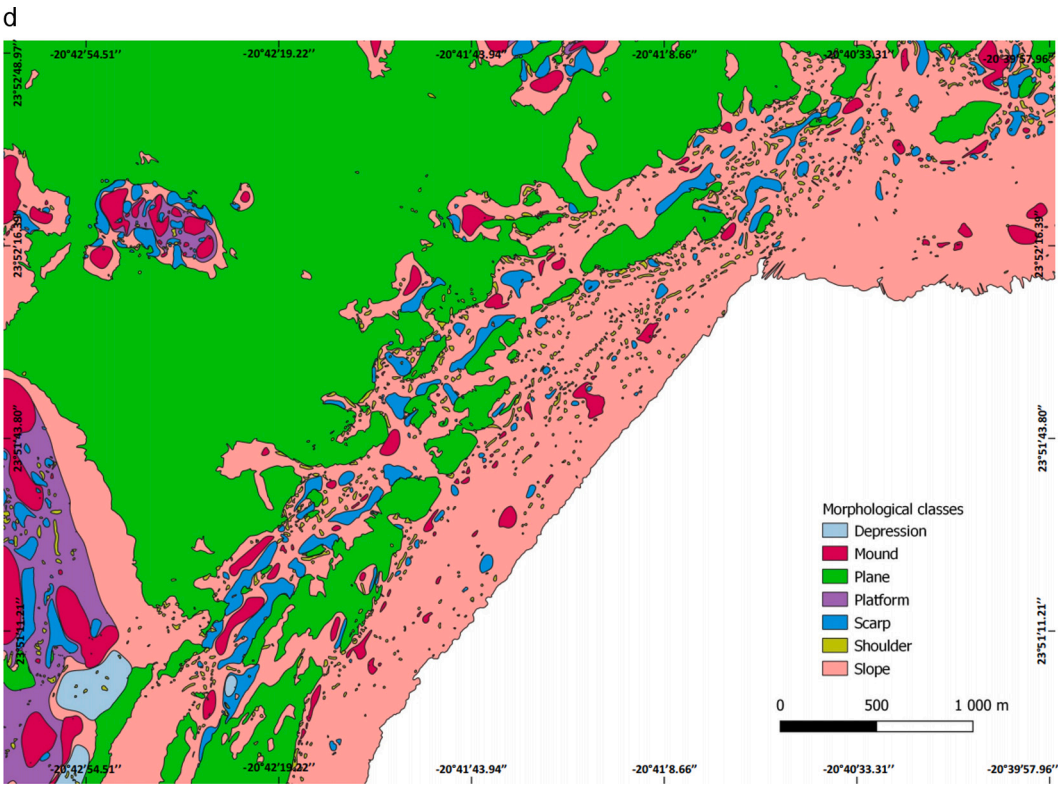


Fig. 2. (continued).

Table 1
Morphological classes.

Morphological class	Description
Depression	Close-contour bathymetric low (Dove et al., 2020)
Mound	Distinct elevation with a variable, sometimes rounded profile which is less than 500 m above the surrounding seafloor (IHO, 209; Dove et al., 2020)
Plane	Flat, sub-horizontal surface (Dove et al., 2020)
Platform	Broiad, planar surface at least partially elevated, and lower gradient, than the surrounding areas (modified from IHO, 2019; Dove et al., 2020)
Scarp	Steep slope, separating areas of relatively lower slope (modified from IHO, 2019; Dove et al., 2020)
Shoulder	Juncton between an upper planar surface and a relatively steeper descending slope
Slope	Inclined surface (Dove et al., 2020)

Platform classes (Fig. 2a) preferentially located in two clusters of topographic highs: one occupying the northern-northeastern part of Tropic Seamount's summit area and exhibiting a ENE-WSW axis (Fig. 2b), and the other located in the southern part of the summit showing a N-S axis (Fig. 2c). Other mounds can be observed across the summit area, especially in the area between the two major clusters and east of the southern high cluster (Fig. 2a). In the two identified topographic highs clusters both the Mound and the Platform classes represent an important feature, with the Platform class covering the majority of the area (Fig. 2a, b). Across the minor highs the Mound is the dominant morphological class, while the Platform is almost not represented (Fig. 2a, b).

The depression morphological class can be observed extensively bordering the eastern flank of the southern highs cluster (Fig. 2a, b). Less extensive depressions can also to be found along the central and southernmost part of the western flank of the same highs cluster, as well as east of the northern highs cluster. The main axes of the depressions

follow the orientation of the highs cluster that they are close to. For example, the southern depression exhibits a N-S axis while the northern an ENE-WSW to E-W axis.

Slope and Scarp classes cover only restricted areas on Tropic Seamount's summit, largely around the mound features and along the summit's edges, where the seamount's flanks start to plunge into deeper waters (Fig. 2a, b, c). Scarps follow the topography defined by the highs in the northern highs cluster (Fig. 2a), with slopes being a more prominent feature around the minor mounds on the summit between the two highs clusters (Fig. 2). In the southern cluster, the Slope class covers an extensive area, confined largely around the mounds and less around the platforms (Fig. 2b). Shoulder classes are scattered across the summit with a prevalence in correspondence to topographic highs like mounds and platforms and toward the summit's edges, when the flanks start to become steeper (Fig. 2a, b, c).

3.2. Backscatter response

Multibeam echosounder backscatter values differ across different area of Tropic Seamount's summit. There are two different kinds of backscatter responses visible in Fig. 3a, with the SW sector showing darker shades with respect to the NE sector. This difference in the average backscatter response is due to the combination of two distinct bathymetric datasets collected from two separate Autosub deployments. The Autosub dive in the NE sector presented roll errors resulting in a noisier backscatter signal with a relative response stronger than the one registered across the SW sector (Murton, 2019; Yeo et al., 2019). The flat areas lying at the centre and along the southeastern flank of the seamount, between the eastern and the southern spurs, present low backscatter signal values (Fig. 3a). Across the northern part of the summit, medium-to-high backscatter values are found. The highest backscatter response is registered in correspondence to the topographic highs, especially in the southern highs cluster. In the northern part of the summit, between 1000 m b.s.l. and 1020 m b.s.l., a vast area presents a medium backscatter signal, with patches of medium-to-high values,

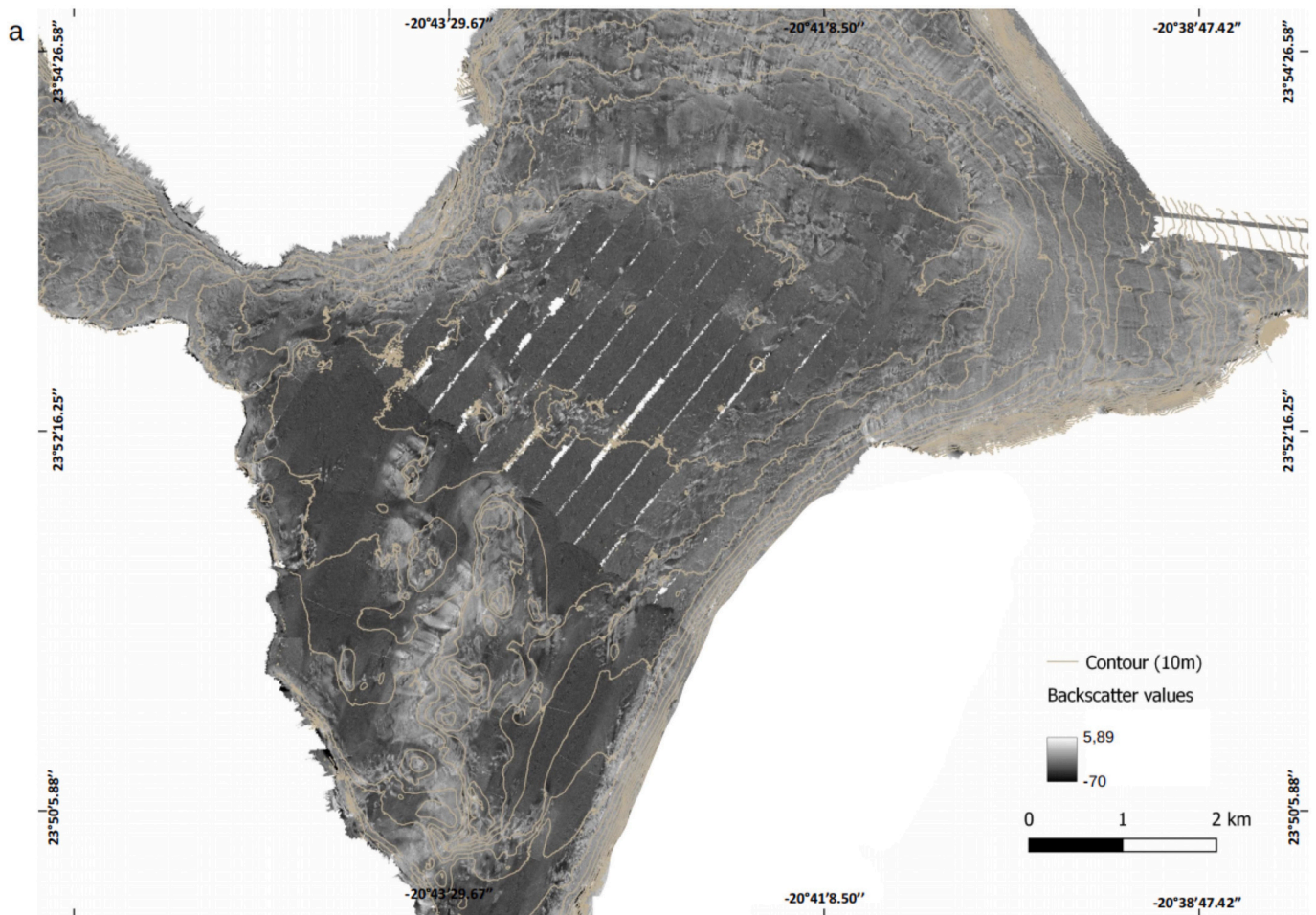


Fig. 3. a) Multibeam echosounder backscatter data across Tropic Seamount's summit b) Comparison between backscatter values and seamount summit's morphological classes, overlain with transparency.

especially where the topography gets steeper (Fig. 3a). Backscatter value variations follow the topography, showing higher signal contrast in correspondence to scarps and slopes. The northern highs cluster shows medium-to-high backscatter values alternating with lower values (from medium-to-low to low backscatter values). The same type of backscatter response is observable in correspondence to the highs scattered across the flat seamount's summit, between the northern and the southern highs clusters (Fig. 3a). The southern highs cluster registers medium-to-high and high backscatter values, especially in the cluster's portion lying to the east of the topographic highs' axis. The highest backscatter values are observable in correspondence to depression, mound and part of platform morphological elements (Fig. 3b). Part of the platform feature located in the south-central part of the highs cluster present a lower backscatter signal that the surrounding area (Fig. 3b).

3.3. Seismic facies

Four major seismic facies (Table 2) were identified from the seismic profiles based on the internal reflector configuration following Xu and Haq (2022). These comprise i) Stratiform, ii) Chaotic, iii) Granular and iv) Blind. Further subfacies were also observed. In particular, the Stratiform facies shows three subfacies: ia) Stratiform *Sensu Stricto*, ib) Stratiform-to-Subparallel and ic) Stratiform-to-Chaotic. The Chaotic facies does not present any subfacies, while the Granular facies shows two subfacies: iia) Granular *Sensu Stricto* and iib) Granular-to-Stratiform. Lastly, the Blind facies comprises two subfacies: iva) Blind

Sensu Stricto and ivb) Hummocky. Internal configuration refers to the permutation and combination mode of reflection events within a seismic facies unit, which mainly reflect the stratigraphic structure (Xu and Haq, 2022).

3.3.1. Stratiform facies

The Stratiform facies, comprised by its three subfacies, covers the most part of Tropic Seamount's summit, in particular the wide area exhibiting a planar morphology (Fig. 4). Stratiform-to-Chaotic subfacies is located also in correspondence of minor topographic highs and of slope morphological feature, as along the southeastern seamount's flank (Fig. 4, 5a, d). Stratiform *Sensu Stricto* and Stratiform-to-Subparallel subfacies are located preferentially across flatter areas (Fig. 4, 5b, c), but are also registered across some slope areas of the seamount's summit, albeit restricted to the less steep areas, like the south-southeastern portion of the SE flank (Fig. 4). In addition, depression features are frequently associated with those subfacies (Fig. 5c).

3.3.2. Chaotic facies

A purely chaotic acoustic signal is identifiable across a limited portion of Tropic Seamount's summit, toward the SW flank south to the western spur (Fig. 4). Here, slope morphological features are present and the transition between the planar and the slope elements coincide with the presence of the Chaotic seismic facies (Fig. 5c).

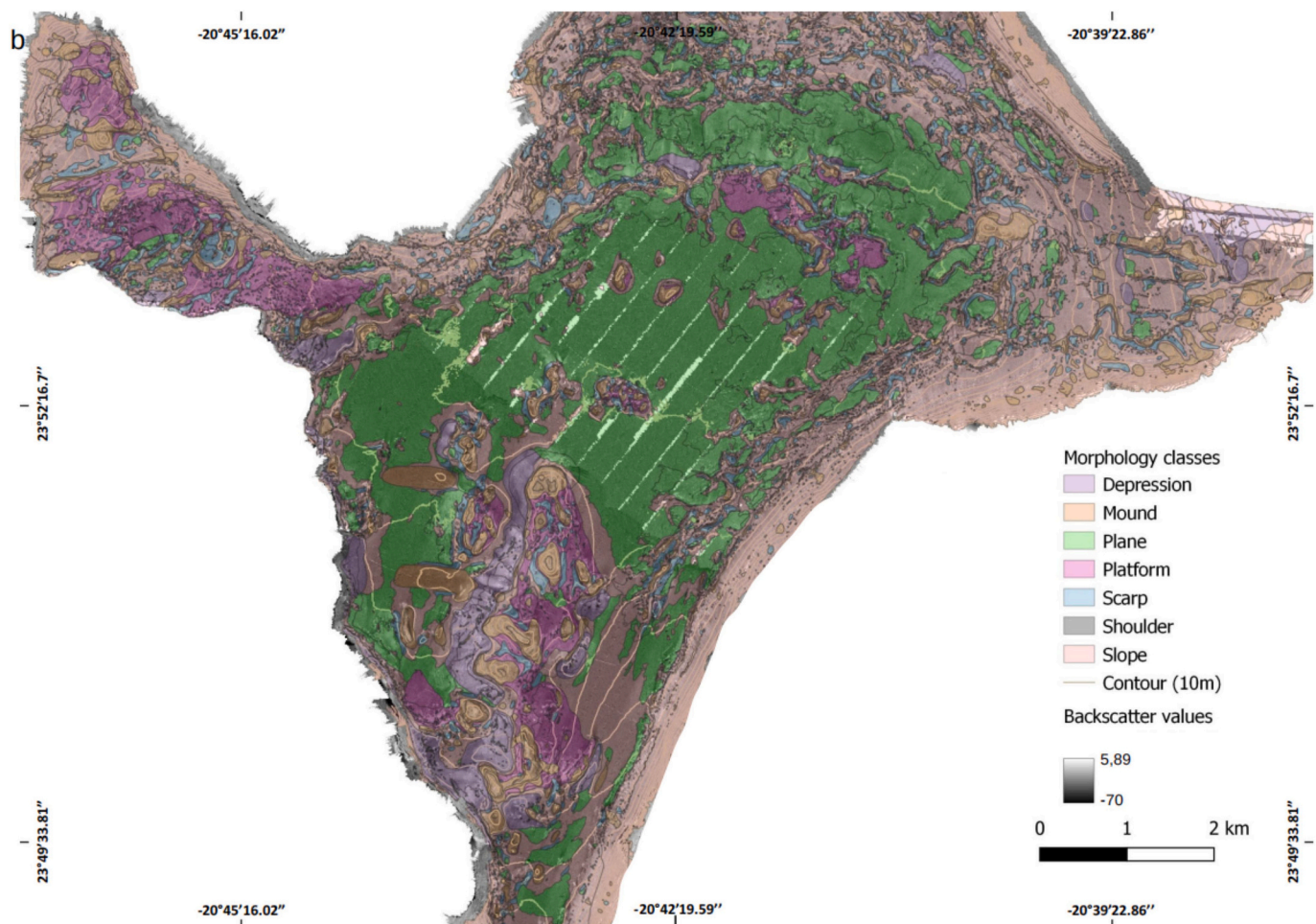


Fig. 3. (continued).

3.3.3. Granular facies

Granular facies and its subfacies are recognised mainly in correspondence of topographic highs across Tropic Seamount's summit (Fig. 4, 5a). The Granular *Sensu Stricto* subfacies occurs mainly in the highs located between the two major highs clusters (Fig. 4, 5a). Portions of this subfacies occur also in correspondence of a depression-plane transition region at the southeastern part of the seamount's summit, east to the southern highs cluster, and across a minor mound feature along the SE flank of the seamount (Fig. 4, 5b, c). The Granular-to-Stratiform subfacies occurs widely across the southern highs cluster, as well as in correspondence of a mound in between the two major clusters and along the SE flank of the seamount (Fig. 4, 5a, c).

3.3.4. Blind facies

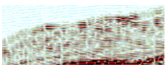
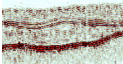
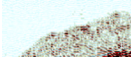
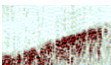
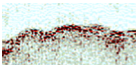
The presence of the Blind *Sensu Stricto* subfacies at the seafloor is restricted to the northern and central part of Tropic Seamount's summit, preferentially toward the west (Fig. 4, 5b). However, the Blind *Sensu Stricto* subfacies actually lies beneath the majority of the other seismic facies, constituting the deepest observable reflector R1 (Fig. 6). Its continuity is occasionally breached by bodies exhibiting a granular configuration (Fig. 5b). The Hummocky subfacies is found preferentially close to the edges of Tropic Seamount's summit where the planar morphological class starts to transition to slopes and scarps, in correspondence with topographic highs belonging to the northern highs cluster and along the southwestern end of the depression bordering the southern highs cluster (Fig. 4, 5c).

3.4. Seismic units

Based on differing seismic facies, stratigraphic profiles can be divided into five stratigraphic seismic units bounded by clear reflectors. The top reflector of the Blind facies (R1), including both its subfacies, is pervasive across the Tropic Seamount summit area (Fig. 5b) and is overlain in places by various units with different acoustic facies (e.g. Fig. 6). Most of the overlying (sub)units do not overlie each other and as such limited successional stratigraphic relationships between the (sub) units can be determined. Accordingly, R1 is defined as the top of Unit 3 (Table 3) whose internal character is defined by the Blind facies. The strength of the R1 reflector masks any details of older units below the summit area. All overlying units (Table 3) sit on the R1 reflector. Many of the units are bounded at the base by the R1 reflector and at the top by the seabed, however other subordinate reflectors showing less acoustic amplitude can be detected within the units constituted by Granular-to-Stratiform and Stratiform-to-Subparallel acoustic subfacies.

Overall, five seismic units were identified along the seismic profiles (Table 3). Unit 1 (Figs. 5, 6) is characterised by the presence of the Granular facies, in particular the Granular *Sensu Stricto* subfacies. It presents mound geometries often lacking a topographical expression and usually buried beneath a sedimentary cover belonging to upper units. Unit 1 outcrops almost always in correspondence of topographic highs such as mounds and platforms across the central region of the seamount's summit (Fig. 5c). In just one case, this unit is found outcropping in correspondence of a flat area, belonging to the Plane morphological class (Fig. 5c). Unit 2 (Fig. 6a-b, 6g-h) is characterized by the presence of the Granular-to-Stratiform subfacies. It expresses mound

Table 2
Seismic facies and subfacies.

Facies	Subfacies	Example	Description
Stratiform	Stratiform <i>Sensu Stricto</i>		Discontinuous to sub-continuous medium to medium-high amplitude reflectors
	Stratiform to Subparallel		Well-distinguishable, medium to high amplitude, sub-continuous to continuous reflectors
	Stratiform to chaotic		Discontinuous medium to low amplitude reflectors, gradient between stratiform and chaotic configurations
Chaotic			No clearly identifiable reflectors, extremely discontinuous events
Granular	Granular <i>Sensu Stricto</i>		No distinguishable reflectors, obliterated seismic structure
	Granular to Stratiform		Presence of feeble reflector (s) dividing portions with obliterated internal seismic structure
Blind	Blind <i>Sensu Stricto</i>		High-amplitude, continuous reflector hiding the underlying structure
	Hummocky		High-amplitude, continuous reflector, sometimes showing hyperbolae

geometries with a clear topographic expression with topographically elevated structures rising from a few decimetres to some metres from the seamount's summit. It outcrops mainly in the southern-central region of the summit, in correspondence of the Mounds, Platforms, Scarps, Slopes and Depressions of the southern highs cluster (Fig. 5c). Two minor topographic highs scattered across the summit's central region also show this outcropping unit (Fig. 4).

Unit 3 (Figs. 5, 6) underlies the R1 reflector and its upper part is defined by the Blind facies with its two subfacies: Blind *Sensu Stricto* and Hummocky. No information is known about its deeper characteristics and it comprises the basal unit on which all younger stratigraphically higher units rest. Unit 3 outcrops extensively along the Scarps and the Slopes morphological classes close to the SE-facing and NW-facing flanks and along a portion of the Platforms, Mounds and Scarps morphological classes of the northern highs cluster (Fig. 5c). It also covers a minor topographic high in the summit's central region, a portion of the central Plane morphological class and part of the Depression and Slope morphological classes along the SW side of the southern highs cluster (Fig. 5).

Unit 4 (Fig. 6) comprises a variety of geometries such as sheets, drift, filled concave and lens-like geometries. Lenses are forms which present a depocentre that tapers progressively toward their lateral boundaries; they are grouped together with the filled concave forms, in which a depression or concavity of the basal seismic reflector is filled with soft sediments. The term 'filled concave form' was also chosen due to two characteristics: the presence of a concavity in the basal reflector as well as the presence of a sedimentary infilling. The filling emphasizes sedimentary features, while the concave surface emphasizes the external geometry (Xu and Haq, 2022). Under the term 'sheet', the external form spreads more or less evenly with the same horizontal altitude. This encompasses flat forms, gently downward-dipping forms, and non-flat forms which nevertheless follows the underlying basal reflector and mantle the topography, like a sheet covering both the pillow and the mattress. Unit 4 is characterized chiefly by the Stratiform facies and all

its subfacies (Stratiform *Sensu Stricto*, Stratiform-to-Subparallel and subordinate Stratiform-to-Chaotic). Unit 4 outcrops across the vast majority of the flat central Plane morphological class, being present also in correspondence of minor highs (chiefly Mounds), Depressions, Slopes (mainly in the southern region of the seamount's summit), and of the central portion of the northern highs cluster (Fig. 5).

Unit 5 (Fig. 6d) shows filled concave, sheet- to drift-like and small mound geometries; it is characterized by the presence of the Chaotic seismic facies, with the subordinate presence of the Stratiform-to-Chaotic subfacies, belonging to the Stratiform facies. This unit outcrops along a minor portion of the SW-facing Slope and Scarp morphological classes, close to the seamount's SW flank (Fig. 5).

3.5. ROV video

ROV video data from the central region of the Tropic Seamount's summit area (Fig. 7a) reveals detail of the contemporary environment with direct observation of the seabed. The video line traverses a flat area predominantly characterised by low backscatter values at -1000 m b.s.l. with a minor, small topographic high reaching -990 m b.s.l. at the transects southern end (Fig. 7a, b). The predominantly low backscatter background signal is interrupted by ribbon-like patches of medium to high backscatter evident near the traversed high (Fig. 7b). This mound present two ribbon-like medium to high backscatter regions, roughly following the topography; between these two medium to high backscatter features, a zone characterized by lower backscatter values (slightly higher than the ones observed in the flatter region) can be seen (Fig. 7b). The ROV track traverses two seismic units; the flat area belong to Unit 4 while in correspondence of the topographic high, Unit 2 is recognised.

Several features are apparent in the ROV video dive including the presence of alternating areas of finer sediment (Fig. 8b), probably composed of medium to fine sand to silty sand, and coarser sediment (Fig. 8a) over the flat lying areas. Different sediment bedforms, such as small-scale ripples and lunate sediment waves, were observed in this region. Straight, undulatory and anastomosing-to-linguoidal ripples showing sometimes different direction of the axis orthogonal to their sediment wave crests (Fig. 8b), and SSE-oriented lunate sediment waves characterise a good fraction of the seafloor covered by unconsolidated substrate (Fig. 8a). The lunate sediment waves are composed of coarser sediment with respect to the background, finer sediment which forms the rest of the seafloor and which is often traversed by ripples. It's common to observe the lunate sediment waves overlaying the ripples which they have migrated across. Evidence of infaunal activity, such as burrows and long, wavy, closed-shape, ribbon-like finer sediment structures are observable in this region.

Moving toward the southern small topographic high, the seafloor changes from an unconsolidated substrate to a hard substrate. In this area, indurated, rocky outcrops of ferromanganese crusts and lobate pavements are exposed (Fig. 8d). Moving from the flank of the small high toward its top, the ferromanganese crusts and lobate crust pavements passes back into a small area of sediment with ripples and sporadically lunate sediment waves then, at the top of the mound downside its SE flank, back to ferromanganese nodules and scattered rocks (Fig. 8c).

4. Discussion

4.1. Acoustic signals and morphological expression

There is a strong correlation between sub-seabed seismic unit architecture and surface seabed classes. Fig. 3b shows that variations in backscatter values are linked with topography and morphological classes, showing higher value in correspondence of Mound morphological class rather than Platform, Scarp or Plane ones (Table 4). The backscatter strength depends on a number of factors including the angle of

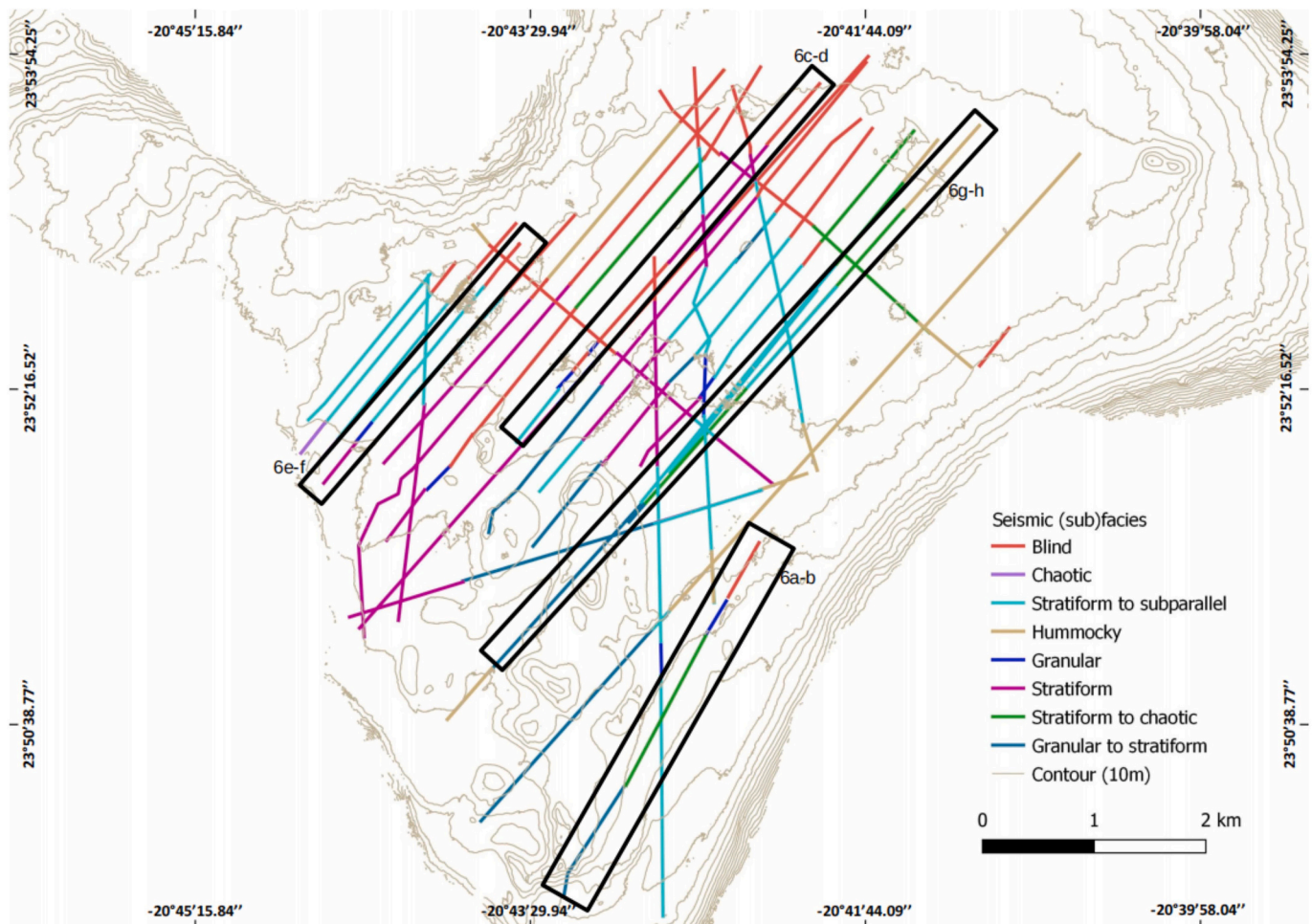


Fig. 4. Seismic facies and subfacies with their location along Tropic Seamount's seismic lines. Highlighted in the black boxes, the seismic profiles showed in Fig. 6 (a-h).

incidence, the geometry of sensor-target system, local slope, physical characteristics of the seafloor such as the roughness, and the intrinsic nature of the seafloor, including composition, density, ratio between volume and surface diffusion for the selected frequency, determining the scattering behaviour of the material at the seafloor (Klaucke, 2017). Unconsolidated substrate generally provides a different backscatter signal that indurated substrate although in reality there is a spectrum of backscatter return intensity depending on variation on hardness and roughness; even among the unconsolidated or indurated substrate, different sediments can return different signals (*i.e.* sand and gravel are both unconsolidated substrates but their backscatter values are quite different). In broad terms, low backscatter values are typical of unconsolidated substrate while hard substrates like rocks and crusts generally return higher values; the roughness of the substrate being another important parameter which affect the signal. In addition to the nature of the substrate, backscatter gives information about topography, although it doesn't provide the true measures. Seismic units also show strong correlation with morphological classes (Table 4); many of the units outcropping at the seabed have distinct morphologies arising from their processes of formation.

4.2. Seismic interpretation and geomorphological correlation

The correlation between the different seismic units and their associated seismic facies with morphological classes (their external geometries) allows for a reconstruction of the geoprocesses which have influenced Tropic Seamount's summit environment during its geological

history. Aspects of the summit environment can also be inferred from multibeam backscatter responses revealing information on seabed hardness and roughness, which when groundtruthed with ROV video, allows inferences to be made about the nature of the substrate and, together with outcropping seismic data, sub-seabed sediment. The seamount's summit area can be divided into three seabed megafacies: mounds, crusts and hardgrounds, and sediment drifts. Each one will be discussed below.

4.2.1. Mounds

Tropic Seamount is a basaltic to trachytic guyot: a former volcanic oceanic island rising from the Atlantic abyssal plain (Schmincke and Graf, 2000; Mazarovich et al., 2023). Numerous minor topographic highs scattered on its summit (*e.g.* the highs belonging to the northern highs cluster and the minor mounds located between this cluster and the southern one (Fig. 2a) are suggestive of a volcanic edifice hosting different secondary vents forming minor cones. Thereby, these relatively small mounds rising from a flat surface may indicate late stage low-intensity volcanic activity or may simply be partially eroded remnants of the island highs following atmospheric and marine transgressive erosion events. The two clusters of topographic highs present numerous mound-shaped external forms, while their internal acoustic signatures show mainly a Granular *Sensu Stricto* (northern highs cluster and most of minor highs) and Granular-to-Stratiform (southern highs cluster) seismic facies (Figs. 5, 6a-b, 6g-h). The Granular seismic facies is typical for bedrock from a variety of potential different rock types including shallow-water limestones, massive conglomerates, volcanic

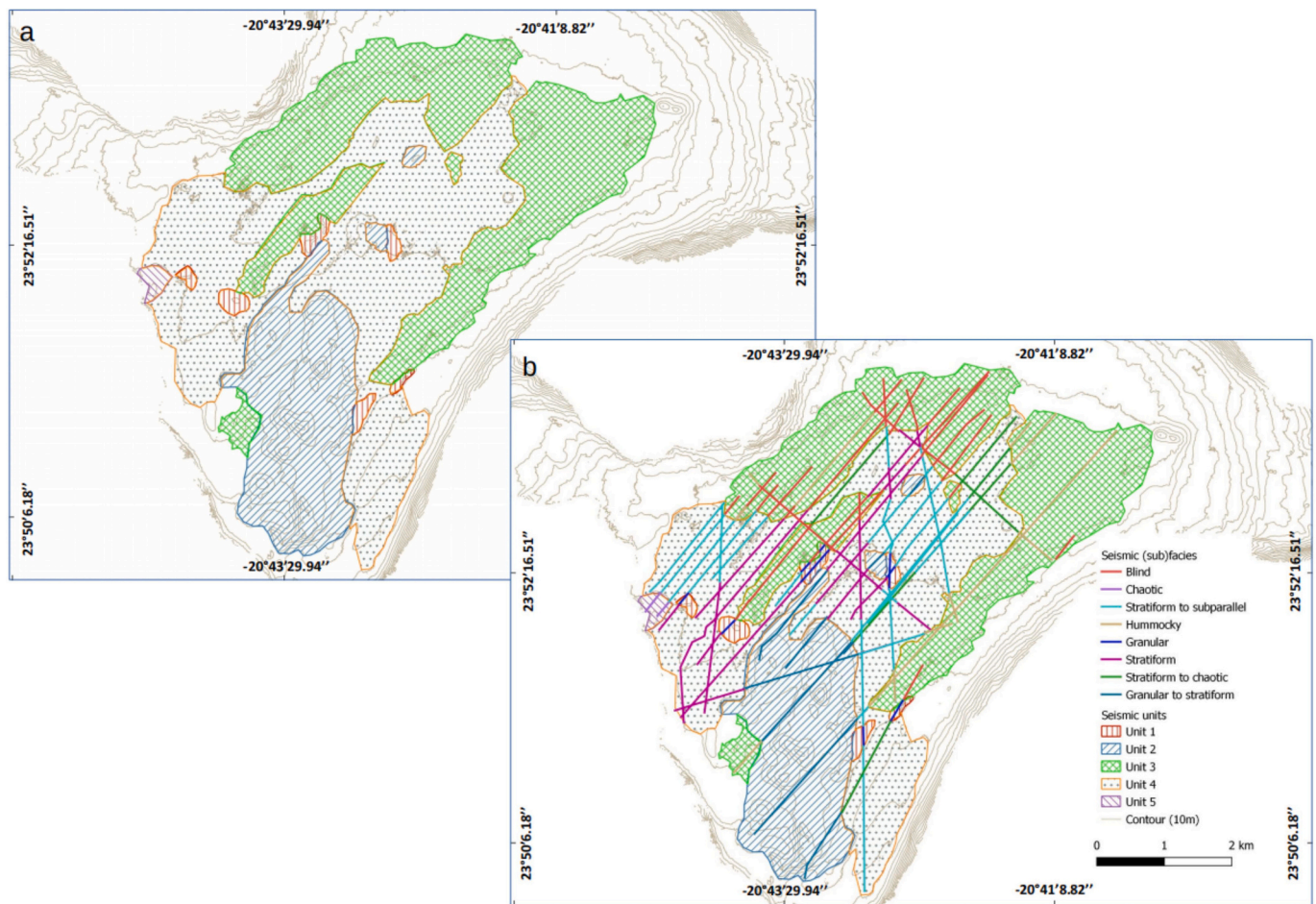


Fig. 5. a) Outcropping seismic units across Tropic Seamount's summit b) Seismic units with overlying seismic lines c) Comparison between seismic units and morphological classes.

agglomerates and volcanic intrusive rock masses and also fluid exhalation zones (Xu and Haq, 2022), whether cold seeps or hot vents. Given the basaltic to trachytic nature of Tropic Seamount's main edifice it is assumed that most of Granular *Sensu Stricto* acoustic response reflect volcanogenic rocks (Figs. 6a-b, 6c-d, 6e-f) although the Granular-to-Stratiform acoustic facies prevalent in the southern highs cluster may also indicate the presence of additional sedimentary strata derived from erosion, especially when deposited above the main reflector (R1) which in these areas might represent a lithified or syn-depositionally cemented carbonate layer (hardgrounds) as exposed on the seabed (Figs. 6-ba, 6 g-h). The overlying higher amplitude reflectors may also have formed this way. Both in correspondence to part of the northern highs cluster as well as to some minor topographic highs, a blind-hummocky acoustic signal is observable (Fig. 5). This type of signal could be related to the hard and consolidated nature of the substrate cover, constituted either of hardgrounds or Fe—Mn polymetallic crusts.

4.2.2. Crusts and hardgrounds

High backscatter signal areas over flat terrains may be related to the presence of Fe—Mn crusts in the form of lobate pavements, and hardgrounds. These substrates also cover portions of highs located in the northern cluster as well as of minor highs, and sloping, downward-leaning areas toward the seamount's flanks (Fig. 3). The acoustic signal response related to this substrate type is that of the Blind facies, incorporating both of its two subfacies Blind *Sensu Stricto* and Hummocky (Figs. 4, 5). Lobate pavements are outcrops of ferromanganese crusts with an irregular surface and gaps in exposure, usually filled by

sediments (Yeo et al., 2019). The availability of a hard, rocky and partially sediment free substrate (Yeo et al., 2019) may be linked to the combined action of currents and topography. Current speed on Tropic Seamount's summit ranges from 0.03 m/s up to 0.3 m/s, with an average of 0.1 m/s (Spearman et al., 2020). Maximum velocities are often registered along the seamount's flanks, with the highest values registered along the western and eastern spurs (Spearman et al., 2020). Moderate to high current speed acting along scarp and slope areas could contribute to the clearing of sediment from those zones, allowing for the presence of a clear and hard surface over which Fe—Mn oxides can precipitate. Fe—Mn crusts typically form when reduced Mn tends to form MnO_2 and $MnOOH$ when highly oxygenated deep waters enter in contact with oxygen minimum zone (OMZ) waters, and this mass of mixed waters encounter a hard, sediment-free surface over which precipitate. Fe—Mn crusts observed on Tropic Seamount's summit present various degrees of surface erosion, from pristine surfaces over which the botryoidal growth texture is easily recognised, to completely eroded ones in which the surface is a smooth planar surface (Yeo et al., 2019).

4.2.3. Sediment drifts

Backscatter values responses ranging from low to medium-low intensity, observed across the majority of the vast flat area on Tropic Seamount's summit (Fig. 3), are coherent with this kind of substrate; a softer, less dense substrate in comparison to the ones described before. The main seismic facies observed in this flat region is the Stratiform facies with its subfacies Stratiform *Sensu Stricto*, Stratiform-to-Subparallel and Stratiform-to-Chaotic (Figs. 4, 5). Additionally, the

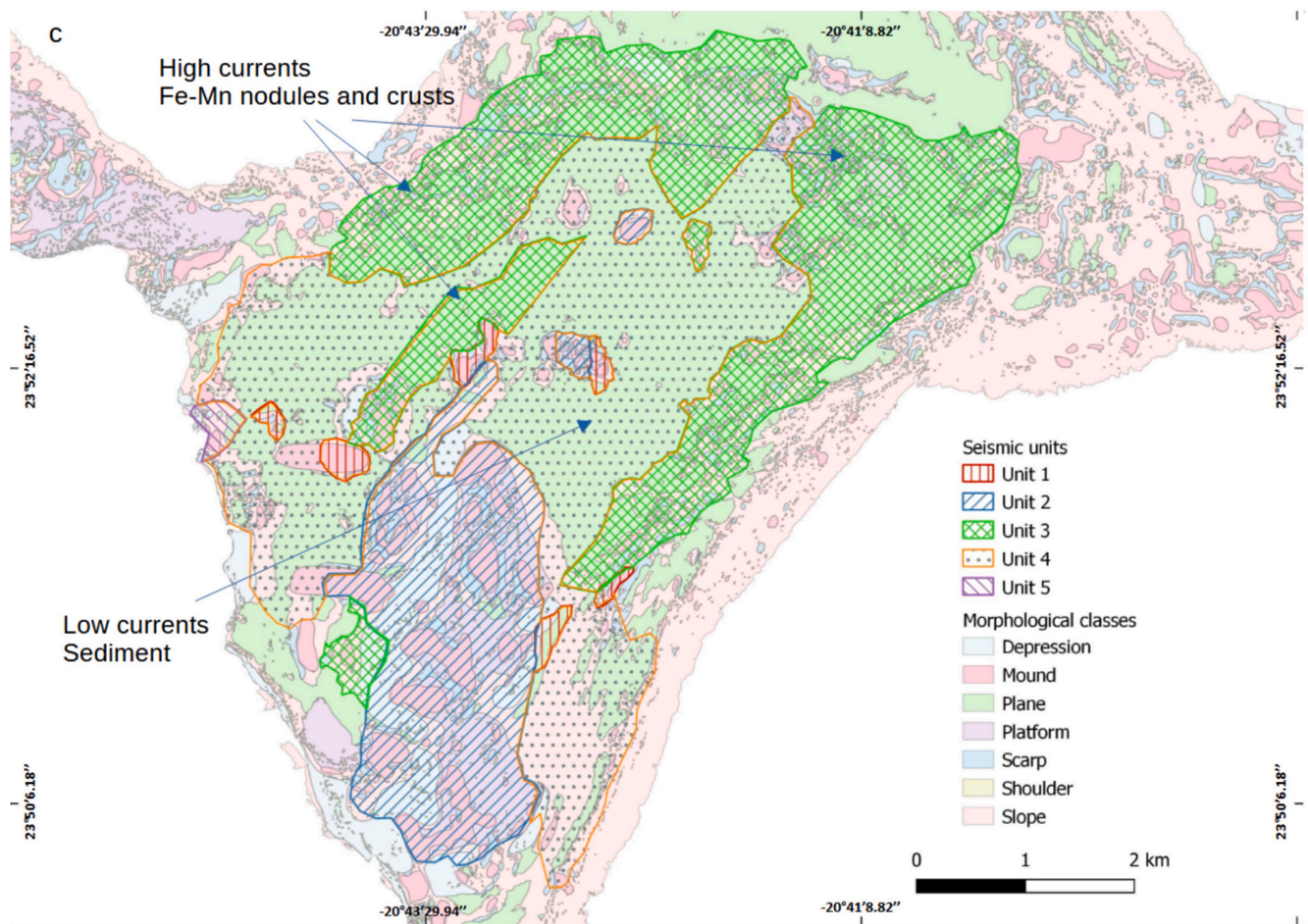


Fig. 5. (continued).

subordinate presence of the Chaotic seismic facies is also recorded in the western-southwestern region in which the planar morphology connects with the slope morphological class (Fig. 4). This region is very probably covered by unconsolidated, coarse- to fine-sandy sediment. The major observed external geometry is constituted by the sheet and sheet-like drifts, with the secondary presence of lenses/filled concave geometries (Fig. 6). Away from topographic highs or steep flanks, in these areas the deposition of continuous to sub-continuous reflectors due to the sedimentary supply of biogenic, pelagic carbonates was allowed and gave rise to these internal configurations. The retrieval of sediment cores from these areas during subsequent cruise surveys (Expedition TR1 on board of the R/V Mario Ruivo: Terrinha et al., 2025) confirmed the composition and nature of the substrate as fine to very fine sand to silty sand. Further analysis on the collected material will reveal more about the age and, maybe, the transport and depositional conditions under which this sediment accumulated.

4.2.3.1. Sedimentary bedforms. Based on the interpretation of video evidence, Tropic Seamount's summit wide central, flat region that is covered by low backscatter values is correlated with a soft substrate sedimentary cover constituting both finer, medium to fine sand to silty sand, and coarser sediment, characterized by the presence of bedforms such as ripples and lunate dunes with evidence of infaunal activity (Fig. 8a, 8b). The sedimentary bedforms are possibly an effect of the bottom currents generated by the tidal regime. Movement of water around the summit are dominated by internal tidal-generated currents which rotate in an anticyclonic direction around the seamount's centre (Spearman et al., 2020). The direction of the ripple's axis change across

the flat top according to the peak current curved-pattern direction. The numerous burrows scattered across the areas covered by finer sediment soft substrate provide a clear evidence of infaunal activity and according to Ortiz-Kfourri et al. (2021) they might indirectly have promoted impregnation of the substrate by Fe–Mn oxides through the reworking and mixing of the substrate. The wavy ribbon-like sedimentary bedforms observed in this area are probably feeding traces left by benthic organisms. Transverse bedforms are irregular to regular undulations oriented transverse to flow direction, among the most commonly occurring depositional bedforms beneath bottom currents (Stow et al., 2009). Observed ripples, the smallest-scale transverse bedforms, entails low flow velocity over a fine to medium sandy substrate (Stow et al., 2009). The presence of straight, undulatory and anastomosing-to-linguoid ripples can testify differences in flow velocity and direction. Ripples' planform evolves from straight to undulatory to linguoid with increasing current velocity (Harms, 1969; Allen, 1982; Stow et al., 2009). It is important, however, to notice that Baas (1999) propose the evolution of ripple planform being controlled by duration of flow rather than flow velocity. Patches of coarser sediment present lunate dunes, another type of transverse bedforms which represent a scale upward from the ripples.

4.2.3.2. Bedform development. The principal physical parameters controlling the development of bedforms include flow velocity and depth, fluid density and viscosity, particle density and size, sediment supply and bed roughness (Allen, 1982; Gardner et al., 1989). Tropic Seamount's summit lies almost exactly at the bottom of the thermocline. This interface in the water column between water masses with different

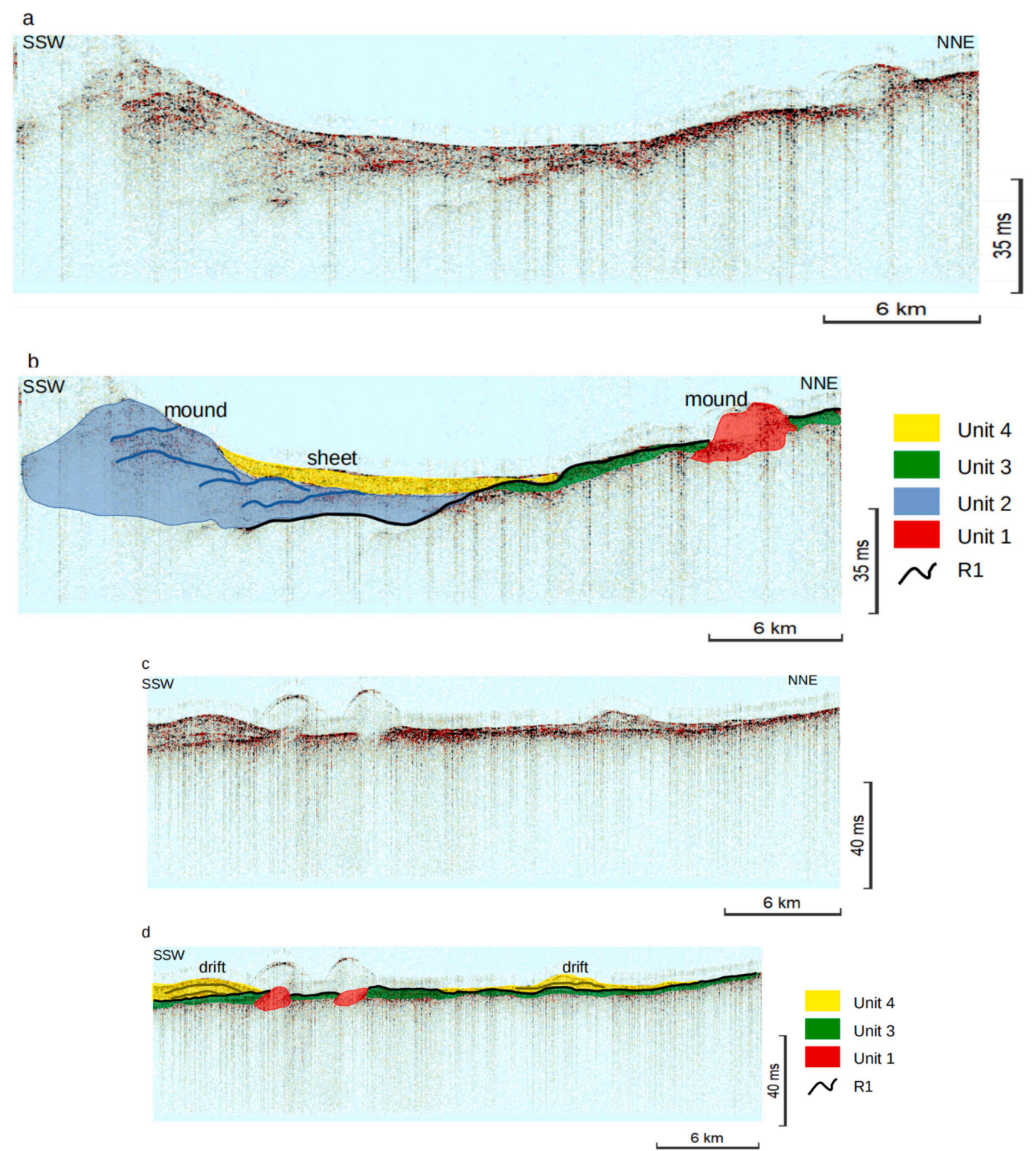


Fig. 6. Key seismic profiles and interpretation, showing seismic units.

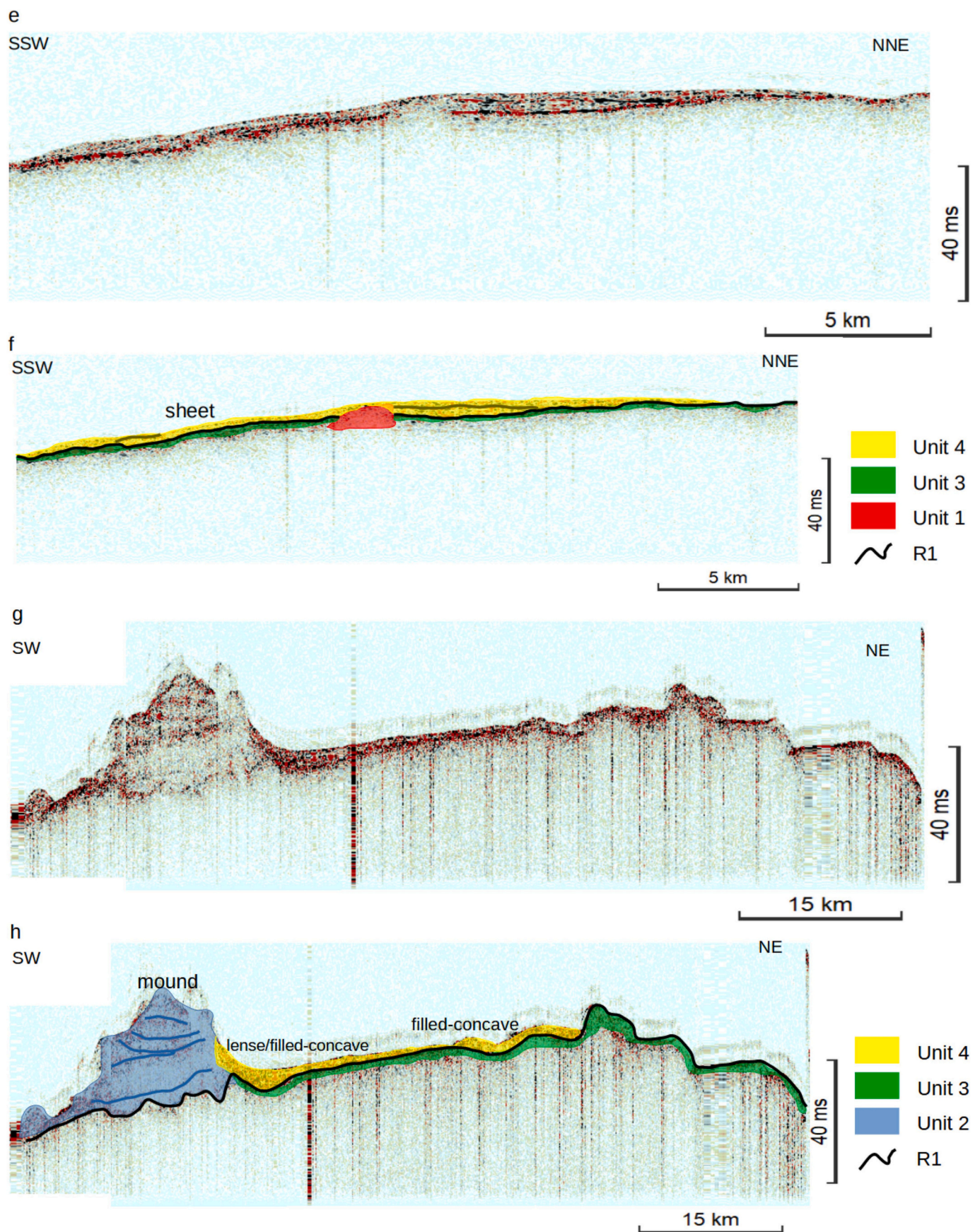


Fig. 6. (continued).

Table 3
Seismic units.

Seismic unit	Seismic pattern	Reflection continuity	Amplitude	Reflection configuration	Interpretation
5		Discontinuous	Moderate	Chaotic, Stratiform to Chaotic	Submarine resedimentation processes
4		Mostly continuous	Moderate to high	Stratiform and Stratiform to subparallel, with subordinate Stratiform to Chaotic and Granular to Stratiform	Pelagic sedimentation
3		Continuous	High to very high	Blind, Hummocky	Hardgrounds, lobate pavements and Fe—Mn crusts
2		Mostly discontinuous, locally continuous	Moderate	Granular to Stratiform	Reefal deposition
1		Discontinuous	Moderate	Chaotic, Stratiform to	Volcanic bedrock

physical properties can help generate internal waves which, in the case of an elevated flat top like the one showed at the Tropic Seamount, can in turn lead to the formation of bottom currents. The coarser sediments which form the lunate dunes appear to be partially constituted by lighter weight material than the finer one, such as coral rubble, pteropods shells or xenophyophore rubble, which are easier to move even for a weaker current than the one needed to move heavier sediments (Fig. 8a). The lunate dunes axis' direction in the ROV-surveyed area suggests a prevalent SSE-directed bottom current; ripple structures, however, shows different directions of the axis orthogonal to their crests (Fig. 8b). The analysis of further quantitative current measurements, in program during subsequent cruise surveys, will allow the testing of this current-control hypothesis. This different orientation could be ascribed to the circular bottom current pattern generated by the instauration of a Taylor column. A Taylor column is a flow pattern generated when a flow in geostrophic balance encounters an isolated topographic obstacle such as a seamount; in this case, an anticyclonic circulation following the isobaths is generated (Taylor, 1916; Proudman, 1920; White et al., 2004). It is to be noted, however, that a Taylor column above Tropic Seamount has been found to be weak (Lusty et al., 2018) although present. A strong amplification of tidal currents (Meinke, 1971; Huthnance, 1974; Loder, 1980; Hunkins, 1986; Genin et al., 1989) generated by the interaction of the seamount topography with impinging oceanic currents under the influence of stratification and rotation (Roden, 1987; White et al., 2004) could also have played a role in the formation of this polydirectional sedimentary bedforms.

4.3. Reconstructed depositional history

4.3.1. Subaerial stage

Tropic Seamount was an active volcano during the Late Aptian, from 119 to 114 Ma (Schminke and Graf, 2000; van den Bogaard, 2013) with possible resurgent eruptions until 60 Ma [Selandian, Paleocene] (van den Bogaard, 2013). The interplay between the erosion (sub-aerial, by palaeo-coastal waves and subsequently marine currents), the thermal contraction and magma depletion of the volcanic edifice led to the submersion of the former oceanic island to its current depth of 1000 m. Most sediments accumulated on the island by weathering and erosion were washed away by the wave action during the early stages of submersion, when the summit was just below the ocean's surface. The persistent wave action may be responsible for the mainly flat topography of the seamount's summit, shaping it into a guyot (Fig. 9b). It is

possible that part of these sediments, however, resisted erosion; portions of massive conglomerate deposits may have remained in place, forming the observed granular to stratiform mound-like features of the seamount's summit. Alternatively, the internal acoustic configuration of these topographic highs could be, in part or wholly, to carbonate palaeoreefs formed during the seamount's initial submersion stages (Fig. 9c). It is important to note that the composition and nature of this substrate are entirely inferred from acoustic signature and context with no ground-truthing.

4.3.2. Hardgrounds and Fe—Mn deposit formation

During the early submersion phase, Tropic Seamount may have experienced the deposition of typical warm shallow water carbonates, probably syn-depositionally cemented; this may have led to the extensive hardground coverage on its summit (Fig. 9c). Due to the inferred oligotrophic conditions for this area during the majority of its geological history, extensive areas barren of sediments for the majority of the Cenozoic could have led to the development of hardgrounds. Biogenic carbonate constituting these hardgrounds on Tropic Seamount are often phosphatized (Marino et al., 2018; Yeo et al., 2018; Marino et al., 2019; Josso et al., 2019). It is important to note that the composition and nature of this substrate are entirely inferred from acoustic signature and environmental/palaeoenvironmental conditions. No ground-truthing has taken place regarding this areas. Further hypothesis on the substrate nature involve the presence of conglomerates, volcanic product, and a diagenetic surface. During this time, the majority of hydrogenetic Fe—Mn crusts and nodules may also have formed. The age of collected Fe—Mn crusts spans from 12 Ma for crusts exhibiting a growth rate between 3.3 and 3.8 mm/Ma (Koschinsky et al., 1995) to 30–40 Ma for phosphatized crusts with slower growth rates in the range of 1.9 to 2.7 mm/Ma (Koschinsky et al., 1996; Marino et al., 2017) up to 75 Ma for the oldest collected samples (Josso et al., 2019). The presence of hardgrounds devoid of sedimentary material could have enhanced the available surface needed for the precipitation of Fe—Mn oxyhydroxides. The upwelling conditions favoured by the seamount may have provided well-oxygenated waters which, combining with the oxygen-depleted waters of the OMZ in which Fe and Mn ions in reduced form are present, have favoured their oxidation and subsequent precipitation (Fig. 9d). The same upwelling conditions combined with a preferential orientation of the palaeocurrents may have favoured the contact of large volumes of water with the seamount's bedrock, enhancing the rate of hydrogenetic Fe—Mn crusts deposition. The deposition of Fe—Mn

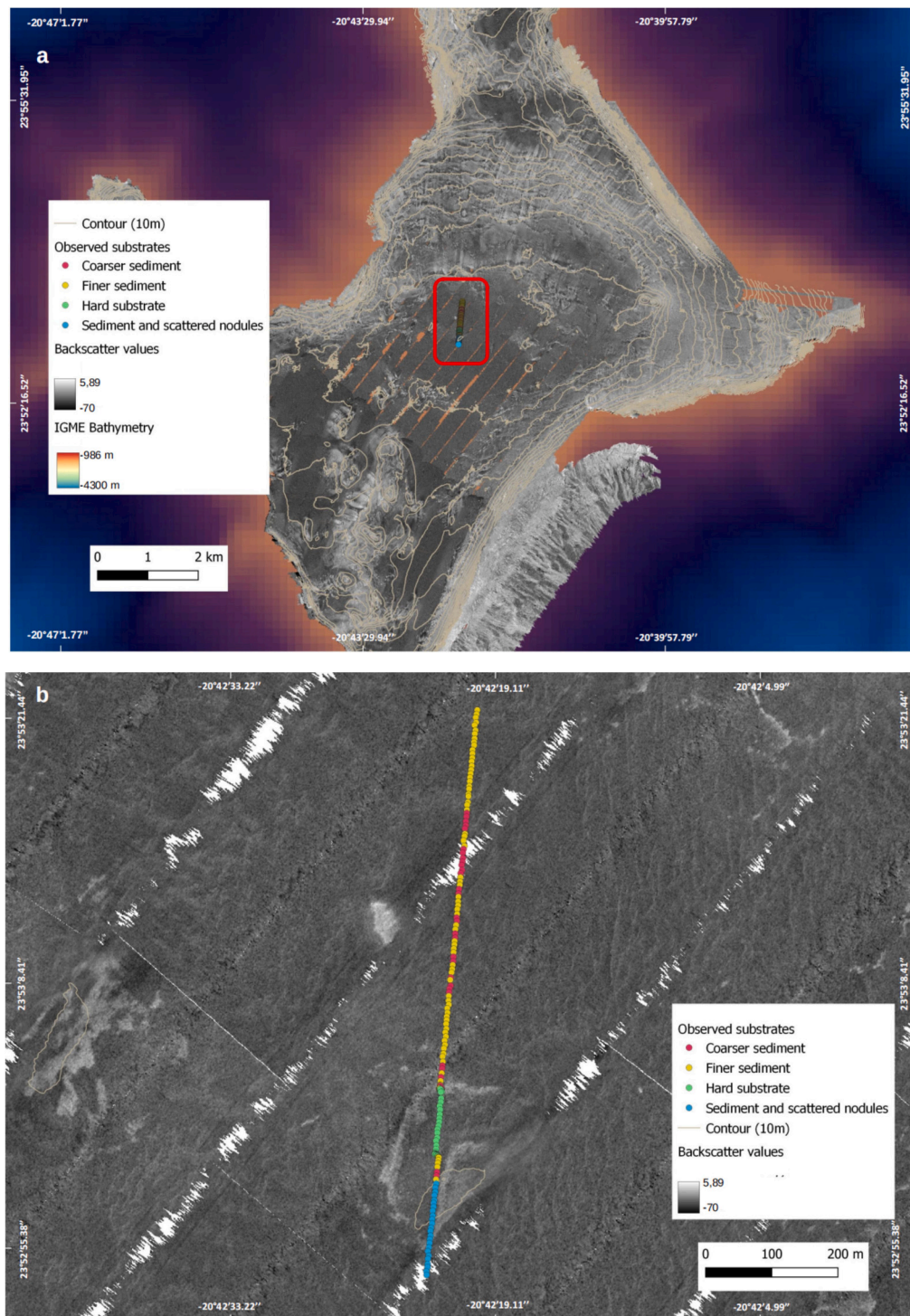


Fig. 7. a) ROV survey location; b) Zoom of the ROV survey location and backscatter response; c) morphology of the area traversed by the ROV survey.

oxides over carbonate hardground (or other hard substrates such as conglomerates or diagenetic surfaces as discussed above) is coherent with the acoustic signal observed in the seismic profiles. Reflector R1 can be traced below most of the mounds showing a Granular to Stratiform internal configuration (Figs. 6a-b, 6g-h); the acoustic impedance however is significantly higher for the portion of the reflector not underlying these mounds. The precipitation of Fe–Mn oxides over the carbonate/phosphatised hardgrounds constituting the original reflector may have enhanced its acoustic impedance, resulting in the type of

signal observed along the seismic profiles. The relatively low sediment supply may have been linked to a warm to hot climate for the great part of the Cenozoic; during the times prior the establishment of a proper ice cap in the boreal hemisphere, the tropical latitudes may have experienced a prolonged period of climate similar to the one characterising interglacial and interstadial times of the Pleistocene age. A wetter and more vegetated northern Africa (Hooghiemstra, 2004 and references therein) didn't allow for a huge supply of iron-rich continental dust (Moreno et al., 2001), leading in turn to a lower iron supply to the

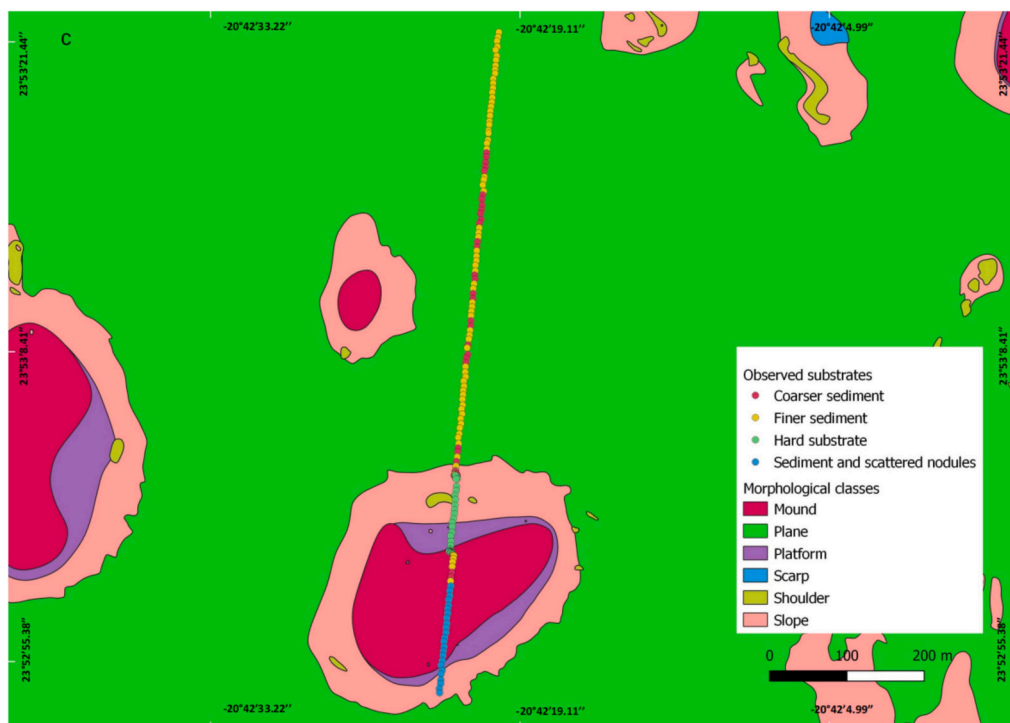


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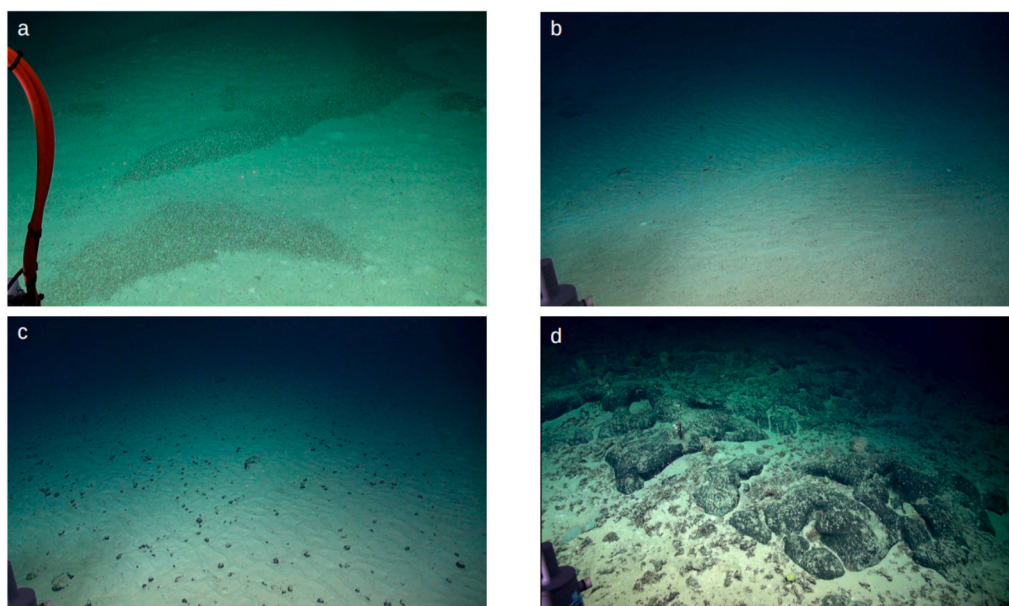


Fig. 8. a) coarser sediment with lunate sediment waves b) finer sediment with ripples showing different directions of the axis orthogonal to their crests due to the circular current pattern generated by the instauration of a Taylor column are visible c) sediment and scattered crusts and nodules with ripples d) lobate pavement.

Atlantic open waters overlying Tropic Seamount. Iron is a biolimiting nutrient (Greene et al., 1991; Schoffman et al., 2016 and references therein), scarce in the oceans and provided by continental input. A lower Fe concentration may have led to a reduced primary production impacting all levels of the trophic chain and significantly reducing the amount of available pelagic sediment, either organic and siliciclastic. The probable presence of (mainly) tidal currents (Spearman et al., 2020) strong enough to remove sediment from the summit may have helped

maintain a clean, exposed rocky surface over which Fe—Mn crusts could deposit. Various degrees of crusts surface erosion indicate a more complex interaction with currents' speed; the hydrodynamic energy has to be strong enough to remove sediments from the precipitation area but not exceedingly strong such to erode the botryoidal texture of the Fe—Mn crusts' surface (Yeo et al., 2019).

Table 4

Correlation between seismic units, morphological classes and backscatter values.

Seismic unit	Morphological classes	Backscatter
5	Slopes, with secondary Depressions, Mounds and Shoulders	Medium to low
4	Planes, with secondary Depressions, Slopes, Platforms and Mounds	Low
3	Extensive slopes, Scarps and Shoulders, with the presence of Planes	Medium
2	Mounds, Scarps, Slopes, Platforms and secondary Shoulders and Depressions	High
1	Minor Mounds, Scarps, and Slopes with secondary Depressions and Planes	High to medium

4.3.3. Sedimentary cover

The onset of enhanced glacial/interglacial climate cyclicity in the Plio-Pleistocene may have altered the conditions on the Tropic Seamount. The cyclical aridification of the Northern Africa, with the expansion and contraction of the Sahara, may have enhanced the supply of iron-rich continental dust, influenced also by the stronger winds characteristic of the glacial periods (Moreno et al., 2001). This fertilization of the ocean portion closer to the African coast may have led to an enhanced primary production (Reichert et al., 1997 and references therein) and in turn to a richer consumer fauna, leading to higher availability of pelagic sediments (Fig. 9e). Moreover, the seamount's progressive submersion may have seen a waning of the previously stronger currents due to increased depth and suppression of tidal signal. The interplay between waning currents and aridification cycles could have promoted the increase of sediment deposition on Tropic Seamount's summit (Fig. 9e, f). Sedimentary deposition over the guyot's summit might have rapidly formed into sediment drifts and sheets once slower currents enabled sedimentation in some areas (Fig. 9f).

4.4. Geological history of the Tropic Seamount's summit sedimentary environment

Observed stratigraphic relationships among the seismic subunits, and their different inferred nature and internal organization of the materials constituting them help to determine their relative deposition timings. Unit 2, which comprise the Granular to Stratiform subfacies related to palaeoreefal deposits, may have been the first to form, directly over the crystalline basement (likely reflected by the Granular *Sensu Stricto* acoustic signal, and comprising Unit 1) after the erosion of sub-aerial weathering products by wave action. Contemporaneously with carbonate reef formation, extensive, *syn*-depositionally cemented hardground without an appreciable topographic expression formed. These hardgrounds form the deposition site for Unit 3, which comprise Fe—Mn crusts and lobate pavements showing a blind/hummocky acoustic signal response. Unit 4 followed, comprising the Stratiform and Stratiform-to-Subparallel facies, reflecting pelagic undisturbed sedimentation presumably at the onset of more arid north African conditions, with the interplay of waning currents due to the progressive sinking of the seamount. This unit is characterized by sheet-like geometries, coherent with undisrupted and continuous pelagic sedimentation conditions; the presence of sporadic filled concave geometries may highlight the previous presence of channels and canyons, formed during the sinking phase in Tropic Seamount's geological history. Patches of Unit 4 are dominated by the Stratiform-to-Chaotic seismic subfacies with numerous lenses and filled concave geometries. These areas may be penecontemporaneous to the zones characterized by Stratiform/Stratiform-to-Subparallel facies with the only difference being the type of topography over which they have deposited. The Chaotic internal

configuration may be due to a disruption of pelagic sedimentation given by the rougher seafloor morphology, which may have also favoured the lenses and filled concave types of external geometries. Unit 5, showing Chaotic seismic facies and Stratiform-to-Chaotic subfacies, may have deposited slightly after the previously described subunits, although no clear stratigraphic sequence is identifiable in the seismic profiles. The nature of its internal configuration united with a drift-like external geometry, with lenses and filled concave forms, and to the presence in the bathymetry of steep slopes with breaks, likely corresponding to scarps and slopes failures, leads toward a gravitational origin. Mass resedimentation processes such as slides, slumps, debris flows and avalanches have reshaped Tropic Seamount's summit geomorphology after having accumulated enough sediment for overcoming the threshold needed to trigger a gravitational phenomenon. Submarine mass movements are caused by an increase in instability due to high sedimentation rates, cyclic repetition of phenomena increasing local stress like earthquakes or water mass movements due to currents, and high biological productivity (Mulder and Cochonat, 1996). This point to a relatively younger Unit 5 compared to the previous sedimentary units, given the time needed to accumulate enough sediment to trigger submarine mass resedimentation processes.

5. Conclusions

Tropic Seamount's depositional history, started when the volcanic activity ceased and after the erosion of the first generation of subaerial sediment by the action of the waves, have probably seen as first event the deposition of reef carbonates partly *syn*-depositionally cemented. The precipitation of Fe—Mn crust on these hardgrounds thanks to the scarce supply of pelagic sediments and to the interplay between OMZ waters rich in reduced Fe and Mn ions, upwelled deep and oxygenated waters, and current action enhancing the amount of iron-bearing water encountering the bare rock, may have followed. Lobate pavement characterized by a hummocky acoustic signal are linked to these crusts deposits. The enhanced continental dust supply following the onset of extended boreal hemisphere glaciation and the subsequent north Africa aridification allowed for oceanic iron fertilization and enhanced primary production, which in turn increased the supply of pelagic sedimentary material. The deposition of pelagic sediments on Tropic Seamount's summit is registered by the presence of seismic units showing extended sheet and drift-like geometries and a Stratiform and Stratiform to Subparallel acoustic reflectors internal configuration. Continuous pelagic sedimentation united to episodic phenomena reducing the shear strength of the accumulated sediments, like current action, earthquakes or tidal changes, gave rise to gravity-driven mass resedimentation events, registered in the depositional record by subunits presenting a filled concave, lenses or drift-like geometries with a Stratiform to Chaotic and Chaotic internal configuration. Bottom currents generated by the tidal regime have shaped various bedforms over the portion of Tropic Seamount's summit covered in soft sediments, like ripples, lunate dunes, crag and tails, and comet scours; the presence of these bedforms could help inferring bottom currents path and velocity.

CRediT authorship contribution statement

Lucrezi Commissario: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Audrey Recouvreur:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Riccardo Arosio:** Software, Methodology. **Pedro Antonio Terrinha:** Methodology, Investigation. **Luis Batista:** Methodology, Investigation. **Isobel Yeo:** Methodology, Investigation. **Andrew James Wheeler:** Writing – review & editing, Supervision, Methodology, Investigation, Funding

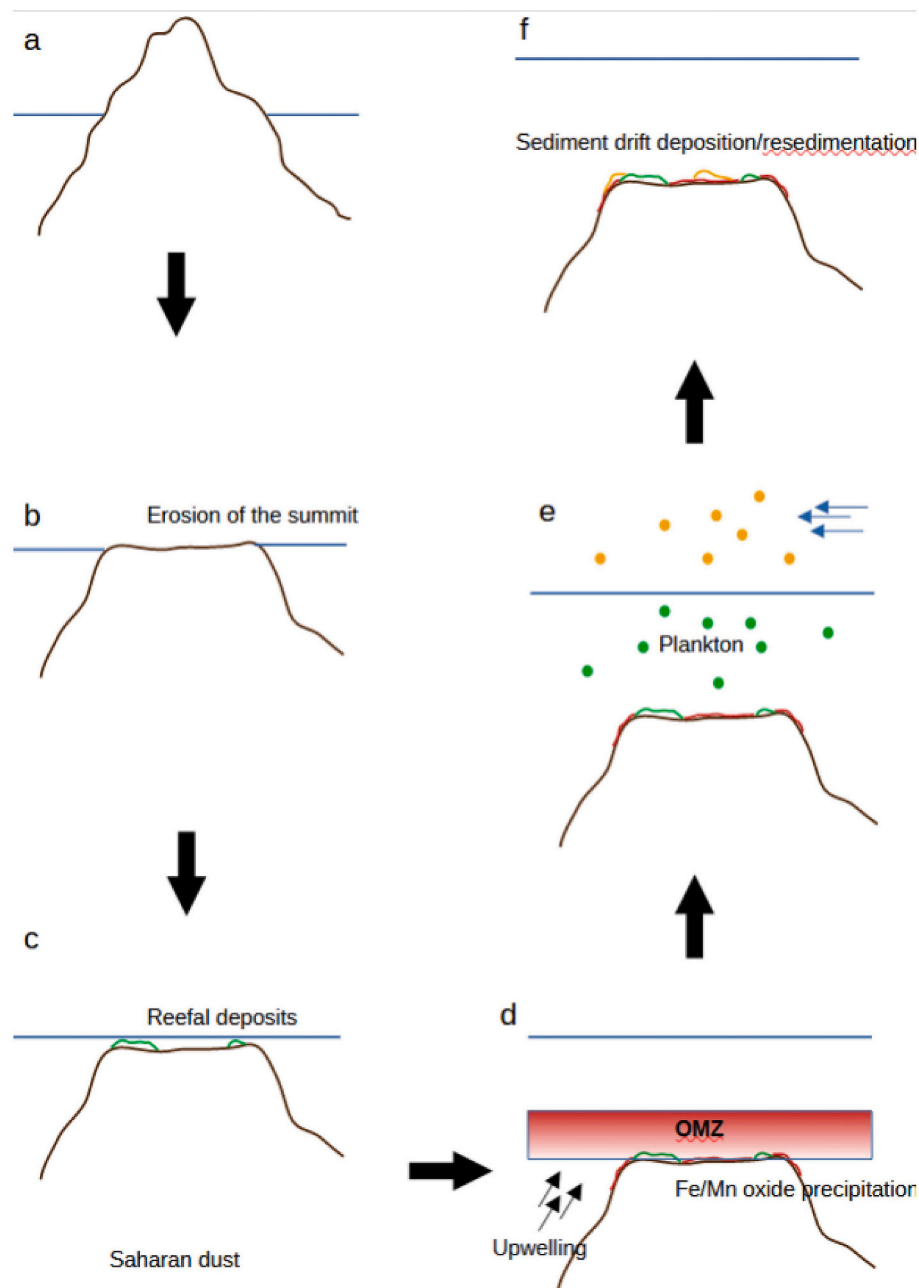


Fig. 9. Depositional history of Tropic Seamount. a) A former volcanic island, Tropic Seamount should have been the place of volcanoclastic-siliciclastic deposition, due to magmatic activity and erosion. b) After the end of eruptive activity, Tropic Seamount started sinking and the erosion due to wave action washed away the previous terrigenous sediments. c) Given the tropical latitude of its location, while at sea level or shallowly below Tropic Seamount, now a guyot, may have experienced reefal deposition. Part of these carbonatic bioherm, *syn*-depositionally cemented, may have given rise to hardgrounds. d) Upwelling conditions due to the seamount presence may have provided well-oxygenated waters which, combining with oxygen-depleted waters of the OMZ, may have favoured the oxidation of Fe and Mg ions and their subsequent precipitation, leading to the formation of hydrogenetic ferromanganese crusts. e) The onset of cyclical aridification of Northern Africa may have enhanced the supply of Fe-rich continental dust, which could have favoured pelagic primary production in the water above Tropic Seamount. This in turn may have led to an increase in pelagic carbonatic sedimentation. f) The sediment drifts and sheets constituted by pelagic particles have covered a large portion of Tropic Seamount's summit; where the shear stresses due to consistent sedimentary load overcame the resisting strength, mass resedimentation processes such as slides, slumps, debris flows and avalanches have reshaped part of the summit geomorphology.

acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge Dr. Bramley Murton, PI of the Marine E-Tech project, the NOC Autosub6000 team, and Dr. Marcos Rosa who run the TOPAS survey. Funding: The author(s) declare financial support was received for the research, authorship, and/or publication of this article. LC is funded by the EU HORIZON Trident project (HORIZON-CL4-2022-RESILIENCE-01) via a PhD scholarship.

Data availability

Data will be made available on request.

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