A two-part seabed geomorphology classification scheme

PART 2: GEOMORPHOLOGY CLASSIFICATION FRAMEWORK AND GLOSSARY - Version 1.0

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Summary

Maps of seabed geomorphology provide foundational information for a broad range of marine applications. These maps rely on bathymetry data from which geomorphic units can be identified, supported by knowledge of the geological setting and/or processes. Bathymetry data are becoming more widely available thanks to several key global initiatives, notably the Seabed 2030 project, United Nations Sustainable Development Goals and UN Ocean Decade, together with global recognition of the value of the Blue Economy. To contribute most effectively to supporting these global efforts, geomorphic characterisation of the seabed requires standardised multi-scalar and interjurisdictional approaches that can be applied locally, regionally and internationally based on the best available data. An ongoing collaboration between geoscience agencies in the United Kingdom (British Geological Survey), Norway (Geological Survey of Norway), Ireland (Geological Survey Ireland and University College Cork) and Australia (Geoscience Australia) has focused on developing a new standardised approach to meet this need. Dove et al., (2016) initially described a two-part approach for mapping the geomorphology of the seabed. Part 1 is intended to guide the mapping of the seabed surface shape (Morphology), and Part 2 is intended to classify these shapes with their geomorphic interpretation.

- Part 1 (Morphology: Dove et al., 2020) is available as an open access glossary. It contains an illustrated list of terms and definitions that primarily draw on the well-established *International Hydrographic Organization* standard. Morphology maps can be created by applying Part 1 Morphological terms to bathymetry data.
- **Part 2 (Geomorphology) is described in this report.** Geomorphic *units* are structured within geomorphic Settings and Processes and (consistent with Part 1) these terms are primarily sourced from established literature. The application of this second mapping step requires further seabed data and/or contextual information and expert judgement, and is intended to constrain the uncertainty that is inherent to subsurface interpretation to this step.

This document describes and illustrates the structuring of established geomorphic terminology into eleven geomorphic *Settings* and related *Processes* that drive the formation, modification and preservation of geomorphic units along the coast and at the seabed. Unit terms and Settings/Processes have been selected and structured to balance established terminology with the need for consistency between the broad range of included geomorphologies. This document also presents a glossary defining 406 units that are structured within the Part 2 Geomorphology classification system, and lists the applied insights that can be gained by mapping each unit.

This two-part approach is not intended to replace discipline-specific classification systems (e.g. ecological, geological). Rather, it is intended to support consistent classification of seabed geomorphology for uptake and ingestion by multiple discipline-specific end-users and their classification systems. Translations between this Part 2 Geomorphology approach and several other key classifications are described herein.

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Report contacts

This report is the product of an international collaboration between contributors representative of geoscience agencies in the United Kingdom, Norway, Ireland and Australia who have developed consistent terminologies for mapping seafloor Morphology (Part 1: Dove et al., 2020) and Geomorphology (Part 2). This Part 2 report (Version 1.0) will continue to evolve via its application to marine datasets by the community. Please contact the chapter leads indicated below to provide feedback and to suggest amendments for consideration in future versioning.

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Version 0.9 of this document (Nanson et al., 2022) was distributed on 14th June 2022 to registered attendees for the *International Association of Geomorphologists* affiliated *Seafloor Geomorphology Mapping Workshop* at the *International Conference on Seafloor Forms, Processes and Evolution* (University of Malta: 4th to 6th July 2022). This updated report (Version 1.0) reflects feedback from that workshop. Registered workshop attendees, and other individuals who have provided feedback since, are listed in the table below.

Institution	Name	Country of employment	Setting / Process
Geoscience Australia	Kim Picard; Brendan Brooke; Dan Clarke; Zhi Huang; Michal Wenderlich; Andy Carroll; Tony Nicholas	Australia	Fluvial, Coastal, Solid Earth, Marine, Biogenic
University of Wollongong	Tim Cohen; Gerald Nanson; Colin Woodroffe	Australia	Fluvial, Coastal
British Geological Survey	Heather Stewart	United Kingdom	Solid Earth
University of Haifa, University of Münster	Or Bialik	Israel, Germany	Biogenic
Università di Milano-Bicocca	Daniela Basso	Italy	Biogenic
Australian Hydrographic Service	Jamie Murphy; Alper Celebi	Australia	Anthropogenic
University of Adelaide	Kathryn Amos	Australia	Current-induced
Newcastle University	Christine Batchelor	United Kingdom	Glacial
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Contents

1 Introduction

Seabed geomorphology exerts a first-order control on marine ecosystem services (Harris, 2012; Micallef et al., 2017; Spalding, 2016), and geomorphology maps can synthesise and communicate such foundational information for uptake by a broad range of related marine industries. Global realisation of the Blue Economy during this United Nations Decade of Ocean Science (2021–2030) is driving the proliferation of seabed bathymetric data acquisition, and the geomorphic characterisation of these data require a standardised, multi-scalar and inter-jurisdictional approach.

The world's first global seafloor geomorphology map (Harris et al., 2014) was mapped at a scale of 1:500,000 using a 30 arc sec (~1 km) grid (modified from: Becker et al., 2009). That dataset defines the extent of over 130,000 polygons that are classified into 29 (primarily International Hydrographic Office-derived) geomorphic categories. This global seafloor map has had significant uptake (e.g. Google Scholar citation count on 1st April 2023: 495) and provides important regional context for higher resolution studies. Other broad, overview-scale products (e.g. for the Australian margin - Heap and Harris, 2008a) have proved similarly useful for providing geomorphic context for more detailed studies, however, geomorphic mapping at finer scales has thus far remained relatively unsupported by universal geomorphic classification systems.

Figure 1-1 illustrates the temporal and spatial scales represented by various seabed geomorphic mapping approaches. The larger spatial scales over which the global (Harris et al., 2014) and

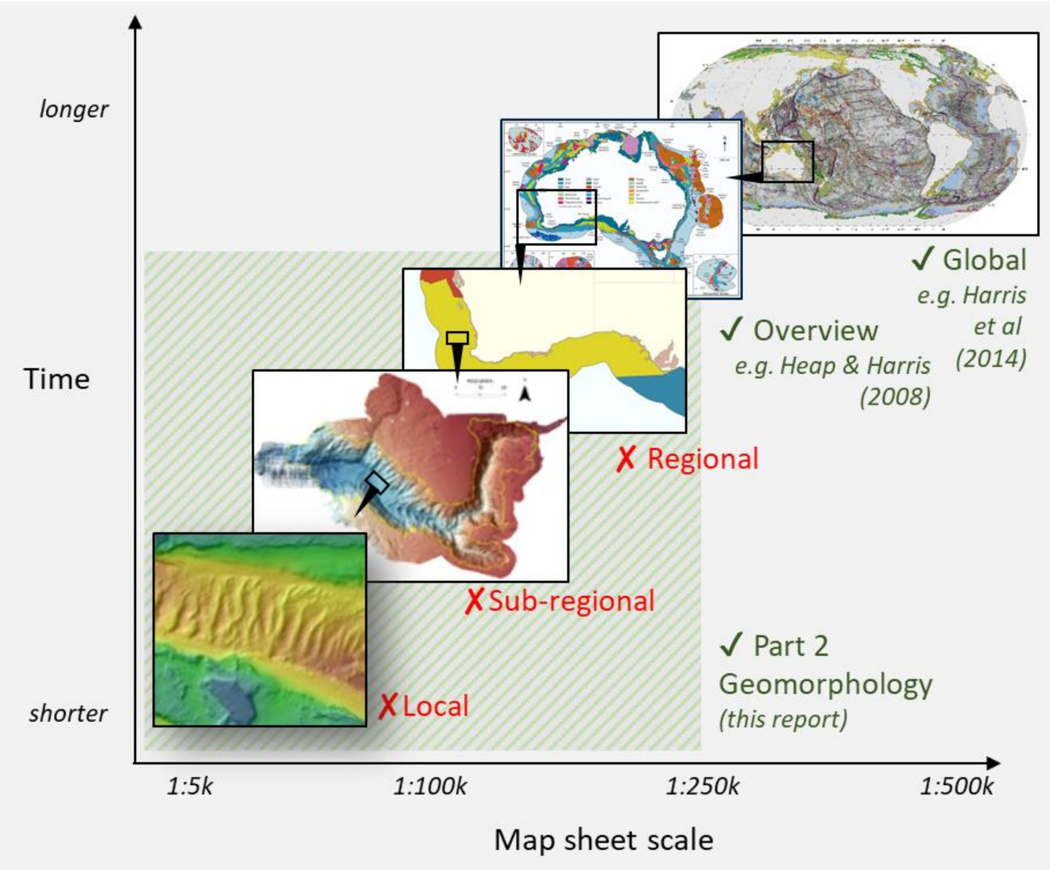

Figure 1-1 Previous standardisation of marine geomorphic mapping primarily classify coarser resolution datasets that represent overview to global scale morphologic and geomorphic forms. The approach described in this report has been designed to be applied at finer (regional to local) scales to match the acquisition of higher resolution datasets and the increasing need for similar standardisation at these scales.

continental (e.g. Heap and Harris, 2008a) geomorphic unit extents are matched by their generally longer temporal scales for their evolution and preservation. The approach presented herein has been designed for application to datasets representing smaller temporal and spatial scales that can nest within broader overview and global classification frameworks. The scheme is divided into two "parts" (Dove et al., 2016), which first describes seabed features by their shape (i.e. Part 1: Morphology as mapped from bathymetry) and then interprets (and classifies: Part 2) the geomorphology of those shapes. Part 1 of this scheme (Morphology: Dove et al., 2020) provides an illustrated glossary of minimally modified International Hydrographic Organization terms, and is suited to either manual or (semi-) automated geographic information system (GIS) based mapping of bathymetry datasets. Part 2 (Geomorphology – **this document**) structures established geomorphic terminology and classification schemes to classify Part 1 shapes by their origin, and requires additional seabed and subsurface data and / or interpretation for its implementation (Figure 1-2).

This report is intended to serve as a guide for seabed mappers seeking to consistently classify fluvial, coastal to marine geomorphic units and to thereby facilitate interoperability between map products produced by different practitioners. The structure of this scheme has thus been developed to support direct integration into agency-specific GIS databases, but this document is not intended as a database manual per se.

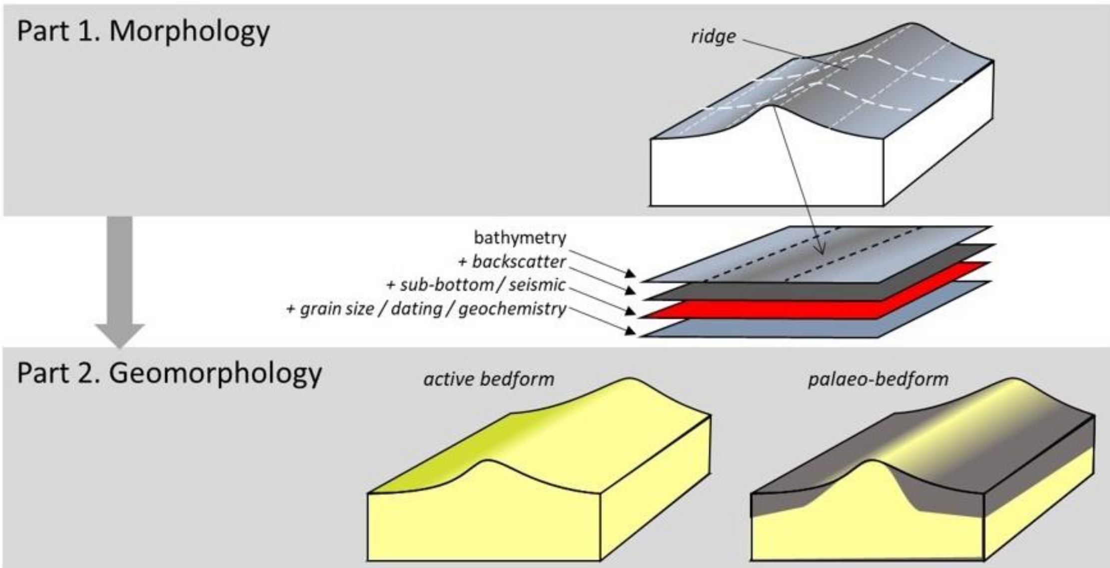

Figure 1-2 Two- part classification (Dove et al., 2020). Part 2 is the focus of this report.

2 Methods and approach

2.1 Part 2 Geomorphic mapping framework: *Settings* and *Processes*

The shape, orientation, distribution and depth of mapped seabed Morphology Features (Part 1: Dove et al., 2020) can be used alongside subsurface data (e.g. sub-bottom profiles, cores) to interpret seafloor geomorphology (Goudie, 2006; Lecours et al., 2016). Such detailed interpretations can be extrapolated to similar mapped units within a study area to produce geomorphology maps where the mapped units are intrinsically linked to their geological history.

For clastic systems (e.g. fluvial, coastal, glacial and marine) sequence stratigraphy is frequently used to frame such interpretations: a *stratigraphic sequence* defines a succession of strata deposited during a full cycle of change in the accommodation (i.e. relative sea level) to sediment supply ratio (Catuneanu et al., 2009). Stratigraphic sequences typically consist of multiple, genetically related *systems tracts* that link together contemporaneously developed *depositional systems* (e.g. a forced regressive Holocene highstand delta; Brown Jr and Fisher, 1977). Though depositional systems and their composite facies often overlap with one another and represent continuums in ratios between their formative processes (e.g. the combined influence of waves, tides, and fluvial processes on delta geomorphology: Ainsworth et al., 2011), they can be divided into relatively discrete combinations of landscape (or *seascape*) units (Galloway, 1998) that form several of the Settings described herein (Fluvial, Coastal, Marine and Glacial). However, not all seabed geomorphologies can be described using a sequence stratigraphic framework. For example, though some volcanic deposits do accrete (e.g. from pyroclastic flows and ash falls), volcanic processes are often massive and penetrative. Karstic geomorphic units are also not formed by exclusively accretionary stratigraphic processes, with chemical dissolution a fundamental process in shaping these systems. Similarly, though biogenic geomorphology can incorporate accretionary stratigraphy, shapes and patterns are largely modulated by chemical and physical controls on carbonate precipitation and biotic community evolution (Schlager, 2005).

To reflect the interdisciplinary terminology (clastic depositional systems; massive and penetrative volcanic deposits; chemical dissolution; biotic growth of carbonates) we use the term "*Setting*" to group geomorphic units that are generally formed in specific depositional environments, and the term "*Process"* to group geomorphic units formed by groups of similar processes. The "Solid Earth" system, although not a "*Setting*" *per se*, is defined this way as it includes several different processes and can often be considered the general background for other Settings and Processes.

Dove et al., (2016) presented classification structures for eight geomorphic Settings relevant to marine and coastal systems. The Part 2 Geomorphic Settings and Processes structured and described herein revises that work and extends the framework to include a total of five Setting and six Process classification trees (Figure 2-1). Consistent with Dove et al., (2020, 2016), this Part 2 Geomorphology framework explicitly seeks to structure existing classification systems and to thereby provide consistency between Settings/Processes and practitioners while avoiding "reinventing the wheel" of geomorphic classification. The discipline of geomorphology has also evolved comprehensive classification systems for application to primarily discrete depositional systems at the sub-facies to systems tract scale. This document collates and structures these existing classification systems to support the geomorphic classification of mapped (Part 1) Morphology Features. The range of the resulting Setting / Process categories are expected to overlap with one another, and their potential extents are illustrated in Figure 2-2.

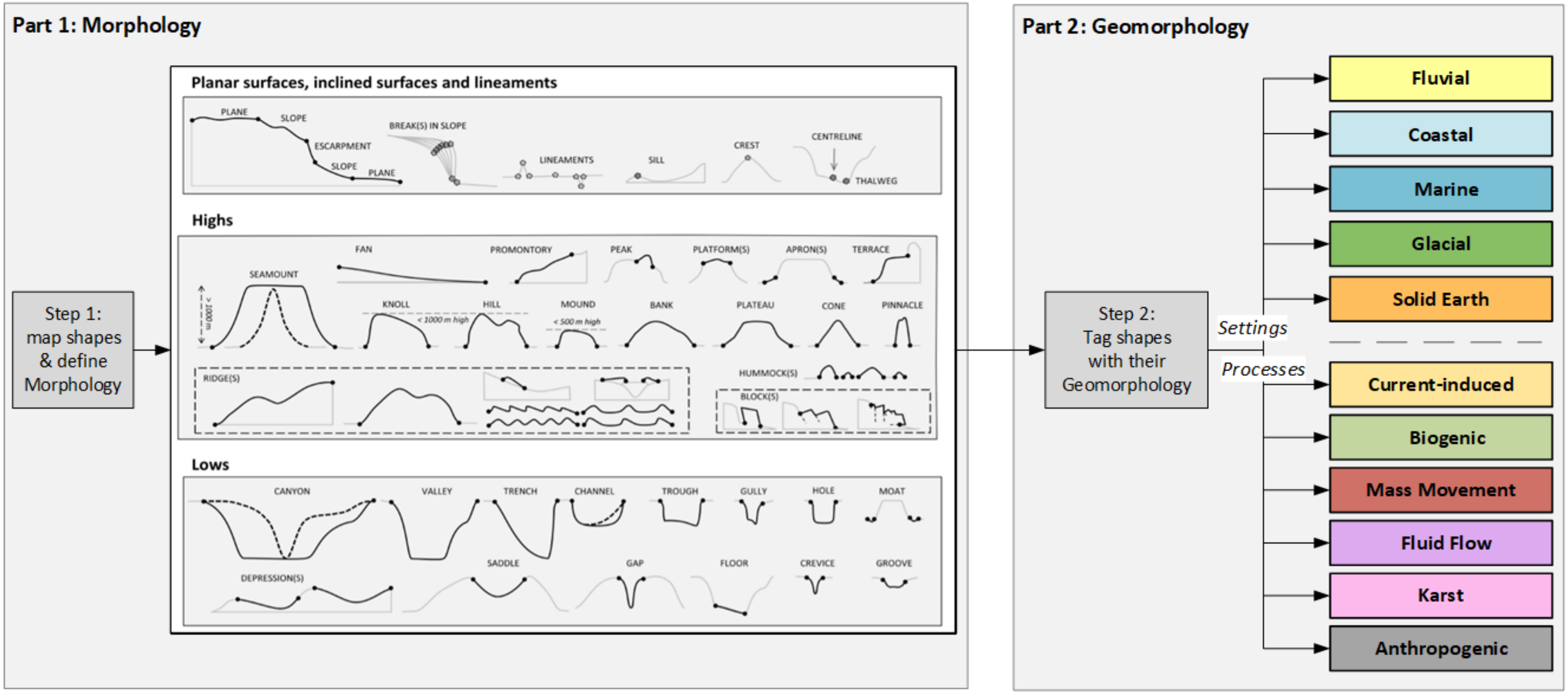

Figure 2-1 The Part 2 Geomorphology framework is structured into five Setting and six Process categories that provide structured terminology for classifying mapped (Part 1 Morphology: Dove et al., 2020) Features. Settings/Processes are colour coded to correspond to their classification trees presented in later chapters. All six Process categories define geomorphology units that can be mapped across multiple Settings (see also the following figure).

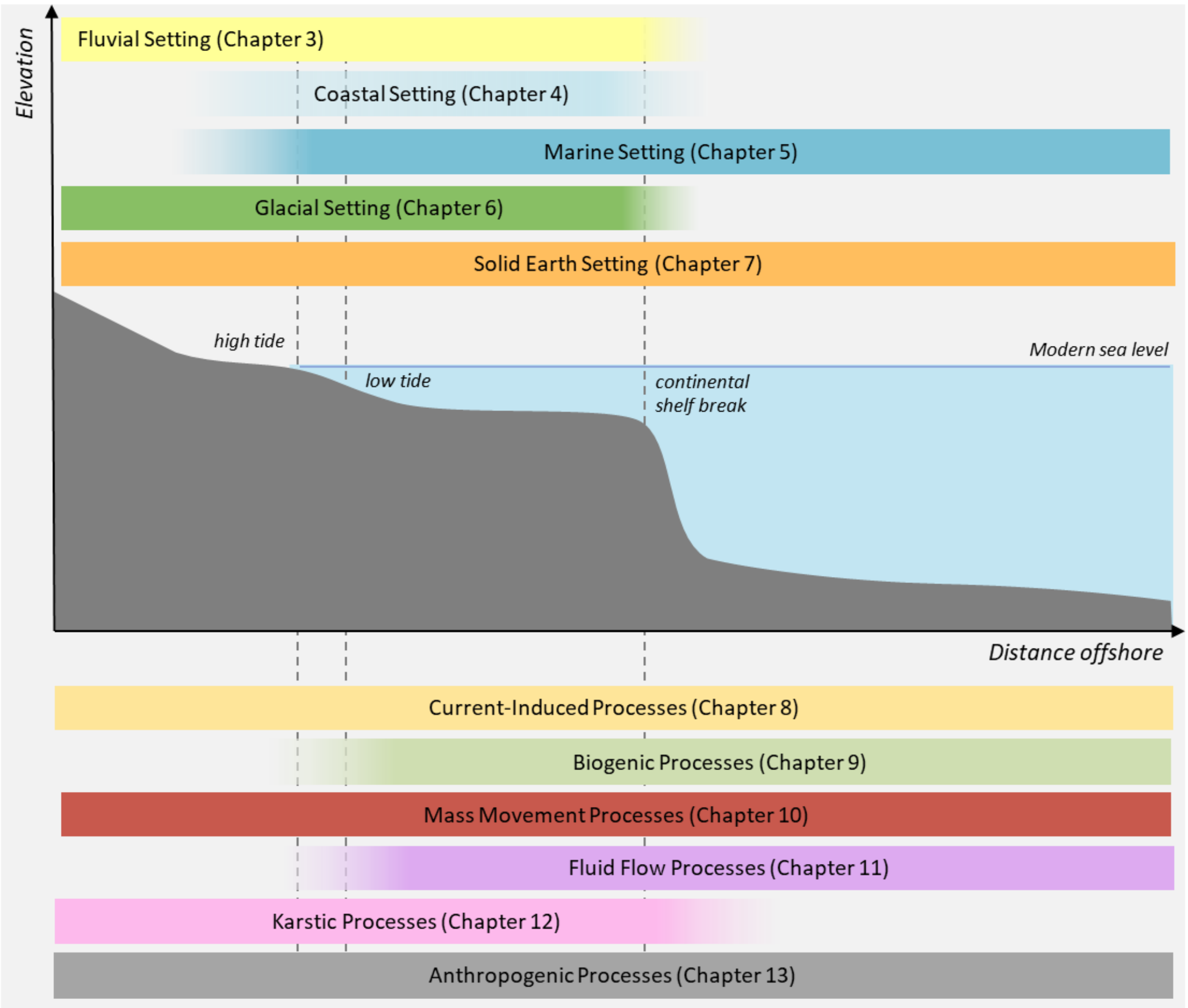

Figure 2-2 The approximate distribution of all Settings / Processes that are described in subsequent chapters. Note that many of these categories overlap with one another, and that the distribution of many geomorphic units extend beyond their modern day (high stand sea level) formative ranges.

2.2 Part 2 Terminology and classification

An illustrated glossary of terms used to classify shapes mapped in Part 1 (Morphology) is provided in Dove et al., (2020), which draws primarily on the terms and definitions provided in the IHO (International Hydrographic Organization, 2019) list of seabed terminology. Part 1 Morphology Feature terms (e.g. Ridge, Canyon) are capitalised as proper nouns to help distinguish them from more general morphological descriptors (e.g. upper canyon, canyon wall).

All terminologies specific to Part 2 Geomorphology and this report are defined in the Glossary of Terms (Chapter 17). At the highest level of the classification, *Settings* group geomorphic units that are formed in specific environments, and *Processes* group geomorphic units formed by similar processes. Settings and Processes are capitalised (e.g. Fluvial, Coastal, Mass Movement etc). All finer scale geomorphic terms are called *units*. To distinguish these units from those in the broader literature, Part 2 units are italicised in the body text of this report (e.g. *delta*, *floodplain*). Unit terms are generally not capitalised, except where there is duplication between geomorphic Settings/Processes. In such cases, duplicated terms are clarified by stating their (capitalised) Setting in their assigned unit name (e.g. *Fluvial barform* versus a *Coastal barform).*

Many Process units can develop or be situated within multiple Settings; similarly, many Setting units can be found amongst those formed in other Settings. For example, a Fluvial Setting *subaerial channel* unit might be mapped on the continental shelf in the vicinity of a *Marine canyon head* and may contain and be surrounded by *Marine submarine bedforms*. And the Setting in which *Current-induced Process* units formed may be known, in which case their classification can be reassigned to that Setting.

Figure 2-3 illustrates the universal framework used to structure Part 2 Geomorphology terminology for all 11 Setting / Process trees. Shaded boxes are colour-coded to each Setting / Process tree and indicate the most generic geomorphic unit label (the *basic geomorphic unit: BGU*) for a given Morphology shape. Increasingly granular levels of the geomorphic interpretation of units are defined within BGU “Type” (BGU-T) and BGU “sub-Type” (BGU-sT) levels. A Coastal Setting example is illustrated at the base of Figure 2-3 a (Part 1 Morphology) Valley can be classified most broadly as having formed in the Coastal Setting. More specifically, it may be classified as a *subaerial valley* (BGU), or more specifically as an *incised valley* (BGU-T), and most specifically as *cross-shelf* (BGU-sT) where the practitioner requires and can reasonably support these more specific levels of interpretation.

The following chapters describe and illustrate the structure of the terminology for classifying mapped Morphology (Part 1) shapes within each Part 2 Geomorphology Setting / Process classification tree. Note that where the Setting / Process classification is hierarchical it is not necessary to always map or tag the parent unit. For example, in a Coastal Setting a mapped Morphology shape (e.g. Ridge) can be tagged as a (BGU) *barrier* without the need to have mapped (or classified) its parent (BGU) *barrier complex*. The parent-child relationship is indicated in the classification trees where it is known that child units will always form part of a parent unit, though only one may have been mapped.

The list of geomorphic unit terms to apply within each Setting / Process is intentionally limited to scales and levels of classification precision that are useful to a broad range of marine applications (e.g. infrastructure planning, fisheries management, habitat mapping). A complete list of potential application categories for each BGU and BGU-T is provided in Chapter 16 and for each unit in the glossary (Chapter 17). In summary, these geomorphic unit terms have been selected to: (1) define those most frequently used; (2) provide consistent terminology between Settings / Processes; and (3) support more granular levels of classification of these same units by specialists using sub-discipline specific classification systems (see Chapter 15 for some examples).

The following section of this chapter describes a translation between this Part 2 Geomorphology scheme and the global physiographic geomorphic classification of Harris et al., (2014), within which this Part 2 approach can be nested. Subsequent chapters describe and illustrate each Setting / Process classification tree (Chapters 3 - 13), before the final chapters describe additional attributes that can be optionally applied to these units (Chapter 14), translations to other commonly-used marine classification systems (Chapter 15), and some considerations of specific applications for each geomorphic unit defined herein (Chapter 16).

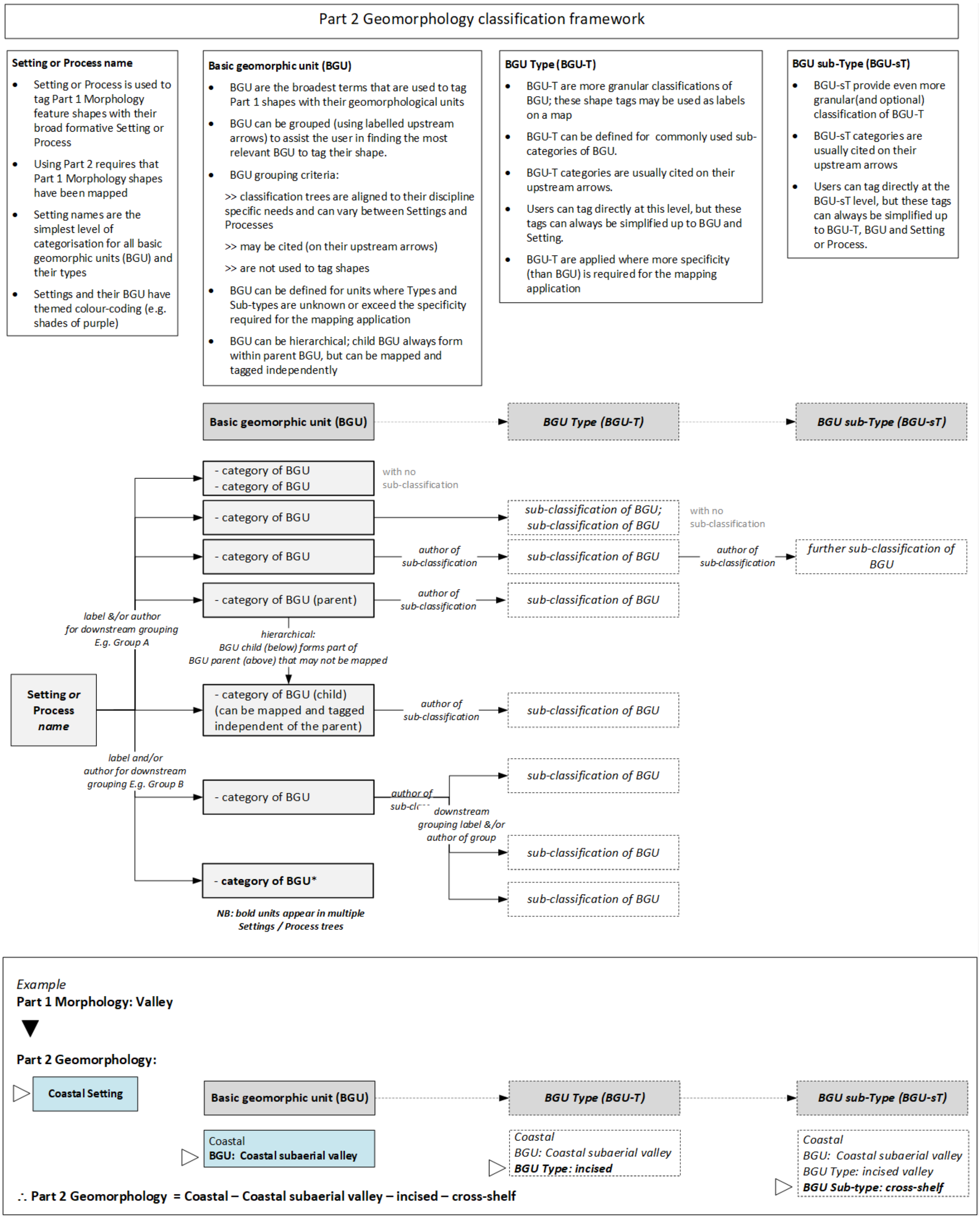

Figure 2-3 The framework used to structure all Part 2 Setting / Process classification trees.

2.3 Integration with the Global Seafloor Geomorphology map

Harris et al., (2014) presents a global digital seafloor geomorphology map that includes 131,192 separate polygons classified into 29 categories (Table 2-1). Their system defines four physiographic zones (1. shelf, 2. slope, 3. abyss and 4. hadal) that each contain lists of subordinate terms that are sometimes repeated between zones (e.g. their basins are found across all four settings). Two zones (shelf and abyssal) are also subdivided into terms based on their roughness attributes: low, medium and high relief shelves; and abyssal plains, abyssal hills and abyssal mountains.

Table 2-1 Global seafloor geomorphology map terms (Harris et al., 2014).

1. Shelf	2. Slope	3. Abyssal	4. Hadal
5. Low relief <10 m	10. Terraces	11. Abyssal plains (<300 m relief)	
6. Medium relief 10–50 m		12. Abyssal hills (300–1,000 m relief)	
7. High relief >50 m		13. Abyssal mountains (>1,000 m relief)	
8. Shelf valleys		14. Continental rise	
9. Glacial troughs		15. Mid–ocean ridge	
Coral reefs*		16. Rift valley	
17. Basins** (shelf perched)	17. Basins** (slope perched)	17. Basins**	17. Basins**
18. Sills	18. Sills	18. Sills	18. Sills
	19. Escarpments	19. Escarpments	19. Escarpments
	20. Seamounts	20. Seamounts	20. Seamounts
	21. Guyots	21. Guyots	
	22. Canyons (shelf incising)	22. Canyons (shelf incising)	
	23. Canyons (blind)	23. Canyons (blind)	
	24. Ridges	24. Ridges	24. Ridges
	25. Troughs	25. Troughs	25. Troughs
		26. Trenches	26. Trenches
		27. Bridges	27. Bridges
	28. Fans	28. Fans	
	29. Plateaus	29. Plateaus	

The global classification system and shapefile dataset thus provides a unique representation of macroscale submarine features, and offers useful context for framing higher resolution investigations. For example, *shelf physiographic zone* or *seamount* polygons can be used to plan more detailed mapping surveys. However, the list of terms described by Harris et al., (2014) and listed in Table 2-1 includes both macroscale morphological (e.g. ridges) and geomorphic (e.g. spreading ridge) terms, which span both Parts 1 (Morphology) and Part 2 (Geomorphology) terminology of the Dove et al., (2016) two-part approach. Table 2-2 presents a translation between these classification systems, and includes additional macroscale terms (e.g. *accretionary prism*) that complement Harris et al. scheme to provide a complete terminology that we recommend for macroscale mapping (i.e. at regional to national and global scales: Figure 1-1).

The complete list of terms in our adopted terminology in Table 2-2 are defined in the Glossary (Chapter 17) Table 17-1 under the heading of “Physiography”. Only the term “Hadal”, which relates to areas at a particular depth, has not been retained in this translation as depth ranges are outside the scope of the classification presented herein.

Table 2-2 Translation from Harris et al., (2014) to Part 1 (Morphology: Dove et al., 2020) and Part 2 (Geomorphology: this report) terminology. Some additional terms have been added for Part 2 (indicated as 'new').

Harris et al., (2014)	Part 2 Setting	Adopted Part 2 translation	Part 1 (Morphology) or Part 2 (Geomorphology)	Adopted definition
Shelf		[Plain]	Morphology	*see Part 1*
	Physiography	*continental shelf*	*(retained in Geomorphology only if continental)*	see glossary (Physiography Table 17-1: Chapter 17)
Slope		*continental slope*	Geomorphology	
Rise		*continental rise*		
Trench		*oceanic trench*		
Spreading ridge		*mid-ocean ridge*		
Rift valley		*axial valley*		
		axial high (new)		
Abyss - plains		*abyssal plain*		
		accretionary prism (new)		
		back-arc basin (new)		
		fore-arc basin (new)		
		island arc (new)		
Seamount		[Seamount]	Morphology	*see Part 1*
	Solid Earth Setting	*seamount*	Geomorphology	See Solid Earth (Chapter 7); glossary Table 17-2 (Chapter 17)
Guyot		*guyot*		
Abyss - hills		*abyssal hill*		
Canyon	Marine Setting	*submarine canyon*		See Marine Setting (Chapter 5); glossary Table 17-2 (Chapter 17)
Fan/apron		*submarine fan*		
		[Apron]	Morphology	*see Part 1*
Shelf valley	Fluvial Setting	*cross-shelf valley*	Geomorphology	see Fluvial Setting (Chapter 3); glossary (Chapter 17)
Glacial trough	Glacial Setting	*cross-shelf trough*		see Glacial Setting (Chapter 6); glossary (Chapter 17)
Bridge		[Ridge]	Morphology	*see Part 1*
Sill		[Sill]		
Escarpment		[Escarpment]		
Trough		[Trough]		
Ridge		[Ridge]		
Terrace		[Terrace]		
Plateau		[Plateau]		
Abyss - mountains		[Seamount] (chain of)		
Hadal	*not retained in MIM-GA classification*			

3 Fluvial Setting

Fluvial systems can connect terrestrial and marine realms and the distribution of their geomorphic processes are particularly sensitive to climate change and sea level fluctuations (Blum and Törnqvist, 2000). During sea level lowstands fluvial systems extend across continental shelves where they can develop *subaerial channels* which can *incise valleys* (Boyd et al., 1994) and deposit *floodplains*, *fans* and *deltas.* During sea level transgression marine processes migrate up-dip and can drown continental shelves, encroaching into these fluvial systems. Modern fluvial systems are similarly sensitive to variations in sea level and climate (e.g. estuarine squeeze: Little et al., 2022) which, although likely to be sub-geological in scale, are forecast to severely impact coastal and fluvial geomorphology and the communities that rely on them (Nicholls et al., 2007). As such, fluvial and coastal (marginal marine) systems tracts are inextricably linked, and their geomorphic classification requires consistency. This Fluvial Setting classification is included here to support seamless marginal marine terminology and mapping.

Fluvial Setting BGU have been sourced from general published texts (e.g. Brierley and Fryirs, 2013; Knighton, 1998). The order of BGU presented in the Fluvial Setting classification tree (Figure 3-1) reflects the transition from primarily fluvial BGU (*drainage basin*, *drainage network, alluvial fans* and their *lobes*) through to potentially coastally-influenced BGU (e.g. *floodplains*, *deltas* and *subaerial channels)* in the marginal marine environment. Two-tone BGU colour-shading in Figure 3-1 highlights the potential for many units to be formed by either purely Fluvial (yellow) or purely Coastal (blue) processes, or for them to be formed by combinations of both (cf. Additional Attributes Chapter; Ainsworth et al., 2011). These two-tone BGU are duplicated in Fluvial and Coastal Setting trees, and their text are presented in bold to highlight their occurrence in multiple Settings. Finer-scale Fluvial *bedforms* and *barforms* are presented in the Current-induced Setting chapter, and these can be reclassified from Current-induced to Fluvial where their origin is known (cf. *Current-induced Process* BGU in Figure 3-1).

More specific classification systems are used to sub-classify Fluvial BGU where doing so provides insights into their discrete formative processes and composition. For example, nine distinct patterns (BGU-T) of d*rainage network* can be used to interpret their controlling slope or bedrock structure (Twidale, 2004) and, where such systems extend across drowned continental shelves, this classification can provide insights into their origins, seafloor stability and potential habitat (e.g. Linklater et al., 2019). *Drainage networks* are comprised of *subaerial valleys* that usually contain *floodplains* and *floodplain terraces*; the hydraulic conductivity of these deposits, and their vulnerability to salt-water incursion, vary with their sedimentology (e.g. Klassen and Allen, 2017). Nanson and Croke (1992) described three broad categories of *floodplain*, and these are adopted herein as BGU-T. The geometry and sedimentology of *subaerial valley* BGU can similarly be linked to their formative processes (Pritchard, 1952). *River valleys* form by fluvial incision into bedrock upstream of continental shelves, whereas *incised valleys* form by fluvial incision into the continental shelf and *coastal plain* during lowstands (Boyd et al., 1994) and their facies vary between *coastal plain* and *cross shelf* sub-types (BGU-sT; Wang et al., 2020). The distinct behaviours and scale of *subaerial channel* sub-types similarly contain distinct facies. For example, the behaviour and sedimentology of erosional *subaerial gullies* and *rills* (BGU-T) contrast with *rivers, creeks* and *distributary channels (BGU-T),* and the latter can be further characterised by the relatively distinct facies that are associated with *straight, meandering, braided* and *anabranching (BGU-sT)* channel patterns (BGU-sT; Schumm, 1977).

Floodplains and *subaerial channels* and their *channel belts* are not confined to *subaerial valleys; alluvial fans* develop where such channels become unconfined, and *deltas* can form where they discharge into standing bodies of water (Nemec and Steel, 1988). The boundary between an *alluvial fan* and its *delta* is defined by the upstream limit of the hydraulic effect of base level (termed the backwater length: Lane, 1957); its position can migrate with time, and avulsions can result in the development of discrete *delta lobes*. The effects of coastal processes on the architecture of Coastal *deltas* are captured within the following Coastal Setting chapter.

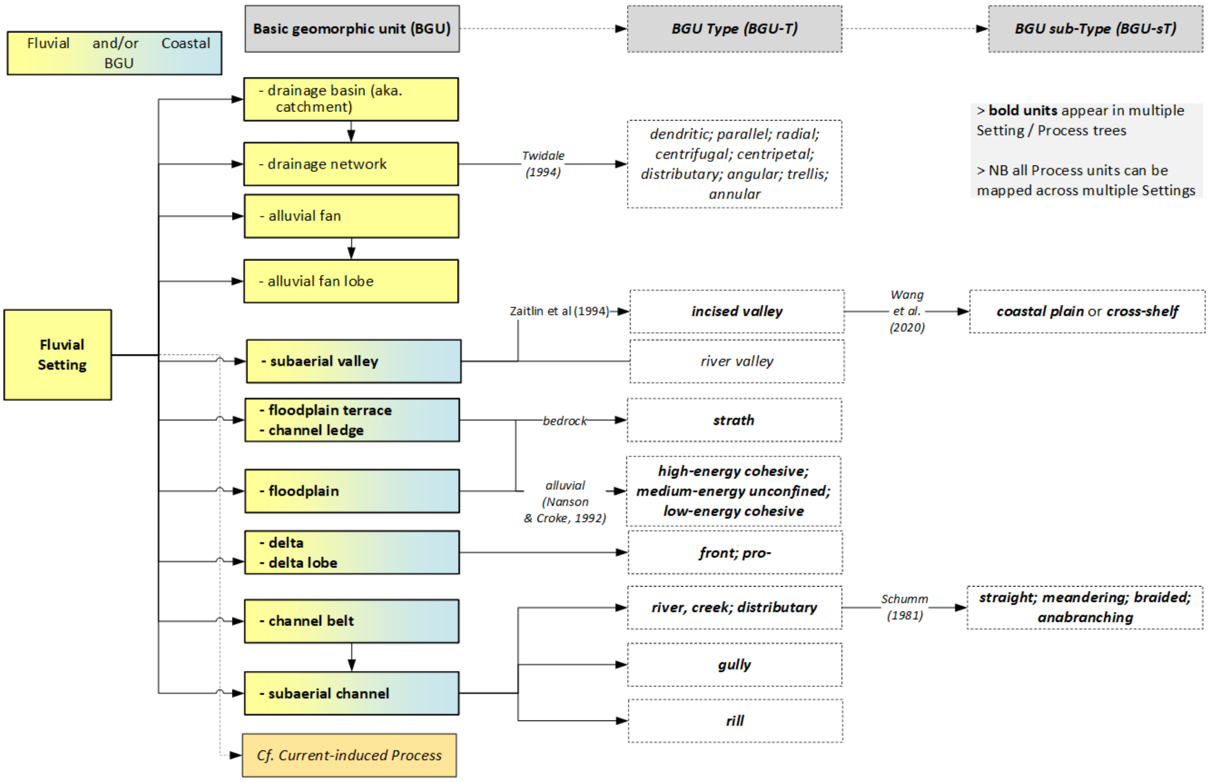

Figure 3-1 Fluvial Setting classification tree. Table 3-1 illustrates a simple tabulated application of this tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms. NB. Definitions are not provided in the Gl;ossary (Chapter 17) for the geometric drainage network (BGU) sub-types (BGU-sT)*

Table 3-1 Example GIS attribute table for mapped units in a Fluvial Setting.

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Valley	*Fluvial*	*subaerial valley*	*incised valley*	*coastal plain*
Channel	*Fluvial*	*subaerial channel*	*gully*	NA
Plane	*Fluvial*	*floodplain*	*confined / cut and fill*	NA

4 Coastal Setting

Coastal systems develop in response to often complex interactions between tide, wave, fluvial (Boyd et al., 1992) and aeolian processes, and their architecture and composite units vary between transgressed and prograded states (see Chapter 14.4 - relative sea-level; Boyd et al., 1994). Many coastal texts (e.g. Boyd et al., 1992; Woodroffe, 2002; Griffin et al., 2012; Wright et al., 1974) were used to develop the list of units structured into the Coastal Setting tree (Figure 4-1). For example, Griffin et al. (2012) developed a hierarchical coastal classification system that includes an extensive glossary of terms. These are integrated throughout Part 1 Morphology (Dove et al., 2020) and various Part 2 Geomorphology Settings presented herein: Current-induced *barforms* (e.g. *levee* and *scroll bar: see* Current-induced Process BGU in Figure 4-1); and primarily Coastal Setting (e.g. *lagoon closed BGU-T*). A direct translation between Griffin et al. (2012) and Part 2 Geomorphology is beyond the scope of this report. Consistent with the preceding Fluvial Setting chapter, two-tone BGU colour-shading in Figure 4-1 highlights the potential for these units to be formed by either purely Fluvial (yellow) or purely Coastal (blue) processes, or for them to be formed by combinations of both (cf. Additional Attributes Chapter; Ainsworth et al., 2011). These two-tone BGU are duplicated in Fluvial and Coastal Setting trees where their texts are presented in bold to highlight their multi-Setting potential.

Coastal processes can extend furthest inland via tidal and sea-level influences on *subaerial channels* and *subaerial valleys (*BGU-T*: incised valleys, river valleys* and *drowned valleys - fjords and rias)* (Boyd et al., 1994; Wang et al., 2020), and these processes are preserved in their *channel belt* and *floodplain* facies*.* Coastal fan-deltas are similarly impacted by base level fluctuations and can be divided into three zones that preserve characteristic facies assemblages: (1) the *alluvial fan* (upstream of the backwater limit: see Fluvial Setting chapter above); (2) the *delta - upper* (BGU-T; between the backwater limit and the tidal limit); and (3) the *delta – lower* (BGU-T), within the tidal zone. The division between the *upper* and *lower delta* is a key classifier as this zoning captures contrasting river avulsion frequency (Chatanantavet et al., 2012) and facies assemblages (e.g. Woodroffe et al., 1989; Lane et al., 2017). It is also a dynamic division that responds quickly to channel adjustments (e.g. avulsions and cut-offs) and base level changes (Bianchi and Allison, 2009). In addition to the full spectrum of delta types that are captured as Additional Attributes (Chapter 14.8) using the wave, tide and fluvial contributions described in Ainsworth et al., (2011), *bayhead*, *shelf edge* and *tidal deltas* are provided as explicit options for *delta* BGU-T. The subaqueous portion of all *lower deltas* can also be further subdivided into their stratigraphically distinct *front* and *pro-delta* portions (cf. these BGU-T in the Fluvial Setting for Fluvial Setting *deltas*).

Exclusively Coastal units are presented in blue shades in the lower half of Figure 4-1, though these can be affected by fluvial processes (e.g. sediment supplied to prograde *chenier plains*). Along wave-dominated clastic coasts, *beaches* (BGU-T: reflective, dissipative or intermediate: Short, 2003, 2006) and, where sediment supply is sufficient, *barriers* and *barrier complexes* (*chenier plain* and *strandplain* BGU-T) tend to net-prograde. These *barriers* are comprised of *beach* and *chenier ridges* and can be land attached at both ends (t*ombolos / salient* and *bay-mouth barriers*), or at one end (*barrier spits*) or have no land attachment (*barrier islands*) (Ollerhead and Davidson-Arnott, 1993). Along open coasts or in *backbarrier* zones (e.g. *lagoons*) where tides dominate over waves, *tidal flats* can form and, depending on their elevation and setting controls, these can be supratidal, intertidal or subtidal. *Reef* and *rock-affected* (BGU-T) *beaches* (BGU) have immobile intertidal zones, with limited clastic material, and the anatomy of fully rocky coasts (BGU) can be mapped using a range of BGU-T terms (e.g. outcrop, shore platform: Trenhaile, 1987; Sunamura, 1992; Masselink and Hughes, 2014). A comprehensive list of Coastal *barforms* (BGU) types (BGU-T) are provided in Figure 4-1, however, additional *bedforms* and *barforms* can be adopted from the Current-induced Process tree (Figure 8-1) and process-classified as Coastal where their formative setting is known to be so.

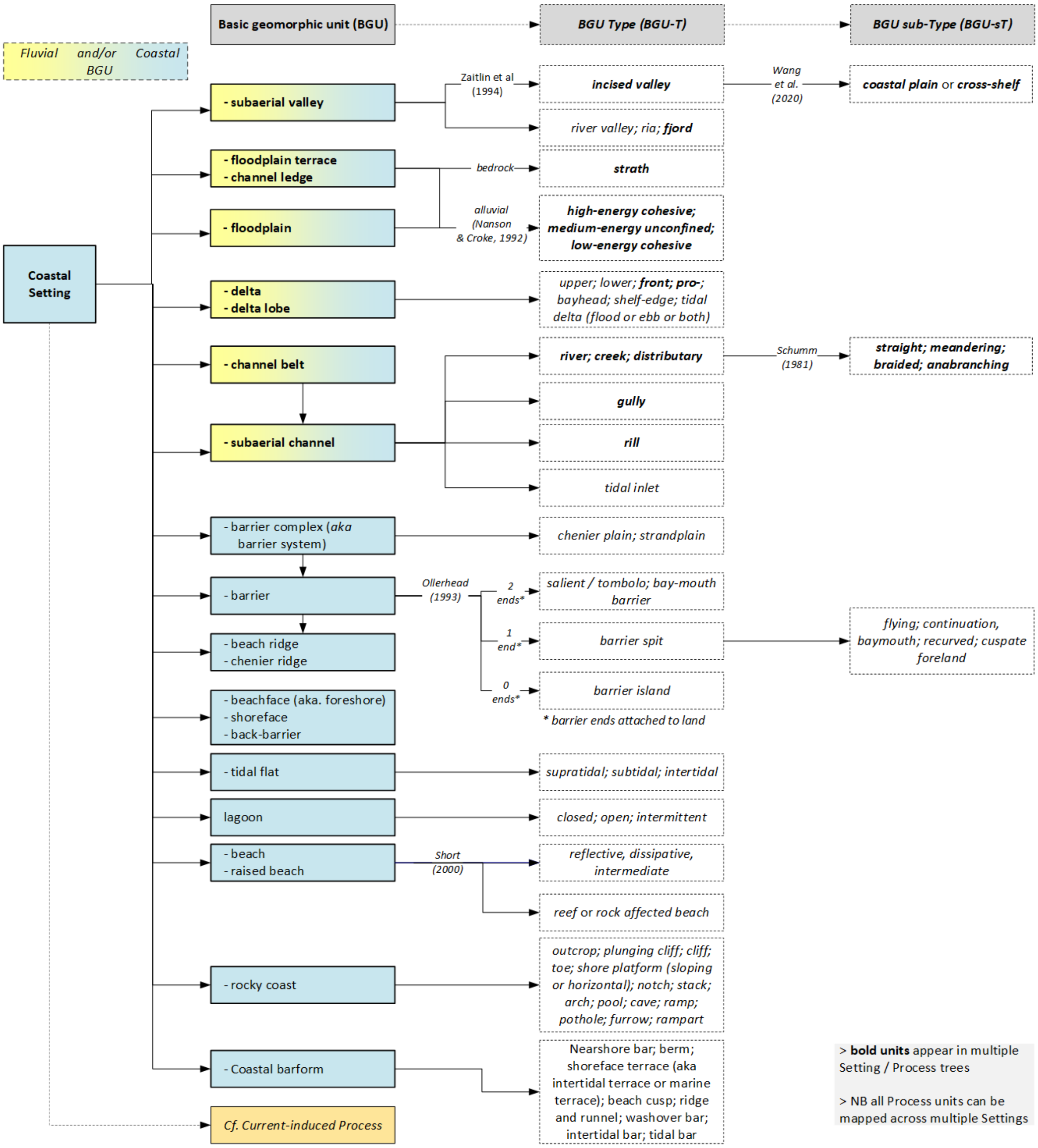

Figure 4-1 Coastal Setting classification tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 4-1 Example GIS attribute table for mapped units in a Coastal Setting. The blank field indicates that the BGU-T for the Coastal *floodplain is unknown, whereas the field marked NA has no BGU-sT as options.*

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Valley	*Coastal*	*subaerial valley*	*incised valley*	*coastal plain*
Channel	*Coastal*	*subaerial channel*	*distributary*	*straight*
Plane	*Coastal*	*Floodplain*		NA

5 Marine Setting

We describe units occurring below Lowest Astronomical Tide (LAT) within this Marine Setting. As such, there is some overlap with units presented in the Coastal Setting (Chapter 4) and, consistent with all other settings described herein, a suite of other Current-Induced Process units (Chapter 8; Figure 8-1) that can also form under marine conditions. For example, *cyclic steps* are supercritical net-accretionary units that can accumulate over multiple turbidity current events (Slootman and Cartigny, 2020), or can alternatively form in Fluvial Settings (Slootman and Cartigny, 2020). Similarly, *dunes* develop across Fluvial, Coastal (including aeolian) and Marine Settings. Any of the Current-Induced Process units from Chapter 8 have the potential to be reclassified as Marine Setting units if their origin can be distinguished as such. A full review of Marine Setting sedimentary units is beyond the scope of this report, but the topic has been a subject of extensive theoretical and applied research (Allen, 1982, 1980, 1968; Ashley, 1990; Belderson et al., 1982; Damen et al., 2018; Hulscher and Dohmen-Janssen, 2005; Lefebvre and Winter, 2021; Perillo et al., 2014) and we have attempted to incorporate their terminology and reasoning herein.

Seabed geomorphic units form within the marine environment through interactions between complex hydrodynamic processes and variable geological substrates, developed over variable spatial and temporal scales (Camerlenghi, 2018). Relatively shallow continental shelves are impacted by both wave and tidal-current forcings, where *bedforms* and *barforms* of unconsolidated sediments are common (e.g. Hashemi et al., 2015; King et al., 2021). Their character and distribution are functions of the balance between wave and tidal forcing (and their amplitudes/ variability), as well as the underlying geological substrate (e.g. sediment composition, consolidation, and thickness) and relative sediment supply (e.g. Durán and Guillén, 2018). These processes lead to a spectrum of both positive and negative-relief units that are commonly ephemeral and potentially mobile. As such, Marine Setting units are of significant interest for both anthropogenic developments and ecosystem characterisation. Figure 5-1 illustrates the spectrum of geomorphic units that form exclusively in the Marine Setting.

For *Marine barforms* on continental slopes, tide and wave processes give way to oceanic and density/gravity currents as the dominant forcing on unit genesis and character (e.g. *contourite drifts – BGU-T*) (e.g. Stow et al., 2009; Rebesco et al., 2014). Relatively large erosional units develop over longer time periods. *Submarine channels* can form on continental shelves and slopes, as well as at abyssal depths (e.g. Peakall et al., 2000). *Submarine gullies* and *submarine canyons* are the subject of significant research, due to their ecosystem significance and role in sediment delivery to the deep ocean basins. *Submarine canyons* form via a combination of turbidity currents and mass wasting, but may also have links to *submarine channels, submarine valleys* and terrestrial fluvial systems (Amaro et al., 2016; Amblas et al., 2018; Harris and Whiteway, 2011; Puig et al., 2014).

Some marine unit terminology varies slightly from Fluvial and Coastal Setting literature, partly resulting from distinct hydrodynamic processes and environments, but largely also due to variable usage between disciplines and researchers. In particular, the term *sediment wave (e.g. 'sand wave')* has persistently been the preferred term for many practitioners describing marine *dunes* (Hulscher and Dohmen-Janssen, 2005) and so requires some explanation herein. Consistent with *dunes* in other Settings, the relative scale of sediment waves can be defined using their height / length as small (0.075 – 0.4 / 0.6 – 5.0), medium (0.4 – 0.75 m / 5 - 10 m), large (0.75 – 5.0 / 10 – 100 m) and very large (>5 / >100 m: Ashley, 1990). The term *megaripple* has also been used to describe smaller dunes in fluvial and marine systems (e.g. McCave and Geiser, 1979; Miall, 1988). Though Ashley (1990) reported the findings of a SEPM symposium focused on standardising the use of these three terms (*megaripple*, *sediment wave* and *dune),* and recommended the universal use of the term "*dune*", many practitioners continue to use their preferred terminology. The glossary of terms (Chapter 17) and the Current-induced Processes tree (Figure 8-1) presented herein is intended to support these preferences and includes megaripple and sediment waves as alternatives ("aka") terms to describe *dunes*. For further discussion on *bedform* terminology see Hulscher and Dohmen-Janssen (2005), Madricardo and Rizetto (2018) and Lefebvre and Winter (2021).

In the Marine Setting *reef* includes any spatially heterogeneous, three-dimensional structures with morphological form that is different from the underlying substrata (Goudie, 2006). This broad definition encompasses any rocky outcrop substrate without inferring any particular process interpretation. (See also *reef* (BGU) in Biogenic Processes - Chapter 9 - for bioconstructed reefs).

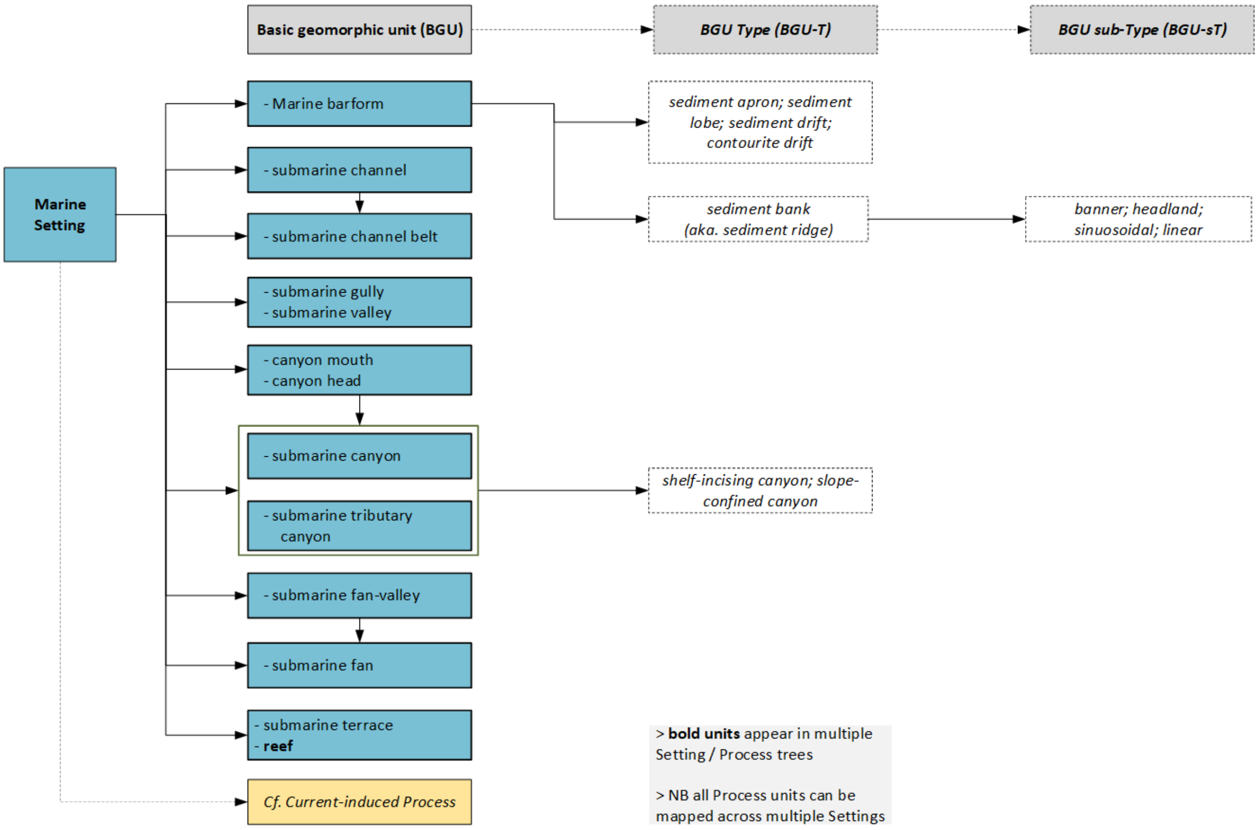

Figure 5-1 Marine Setting classification tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 5-1 Example GIS attribute table for mapped units in a Marine Setting.

Part 1 Morphology Feature	Part 2 Geomorphology Setting *or* Process	Basic geomorphic unit (BGU)	*Type (BGU – T)*	*Sub-type (BGU – sT)*
Valley	*Marine*	*submarine valley*	NA	NA
Plain	*Marine*	*submarine fan*	NA	NA
Ridge	*~~Current-induced~~ Reclassed as: Marine*	*Bedform*	*dune (aka sandwave)*	*large*

6 Glacial Setting

The Glacial Setting describes submarine landforms formed on currently or previously glaciated continental shelves. The majority of the described landforms are products of direct glacial action such as erosion, transport, deposition and deformation, but selected features of glacifluvial and periglacial origin are also included. The transient nature of glacial environments and processes means that many of the units are transitional and may be hard to differentiate, e.g. different types of streamlined landforms (e.g. Benn and Evans, 2010; Stokes and Clark, 2002, Stokes et al., 2011; Krabbendam et al., 2016).

Glacial landforms can be subdivided in different ways, such as based on their placement within a glacial sedimentary environment or land system, by their main formational processes and/or whether they are erosional or depositional (Benn and Evans, 2010). Here we subdivide the landforms by their glacial sedimentary environment setting (e.g. “subglacial”, “ice-marginal”, “proglacial”). The Glacial Setting tree (Table 6-1; Figure 6-1) includes branches for these three environments, as well as a fourth branch for describing geomorphic units that are formed on the surface of, within and beneath the glacier (“supraglacial/englacial/subglacial”).

The “subglacial” branch includes fourteen BGUs formed at the glacier bed. It is further subdivided into glacifluvial and glacitectonic units formed subglacially. This part of the Glacial Setting tree includes eleven BGU-Ts and five BGU-sTs. Eight of the BGU-Ts and all the BGU-sTs belong to the BGU *streamlined landform*. Such units are frequently used as indicators for both ice flow speed and directions and are often mapped at this generalised level.

The “supraglacial/englacial/subglacial” branch of the Glacial Setting tree includes four depositional units that can form in all three parts of a glacial system, where *erratic* is one example. The remaining three landforms are typically identified in the ice-marginal environment, where they have the highest preservation potential (although that varies somewhat between them). For instance, *medial moraines* are generally easy to spot on glacier surfaces but can be hard to distinguish post-deposition, while glacifluvial *eskers* usually stand out clearly in a glacier forefield. *Crevasse-squeeze ridge* units are primarily observed post-deposition close to the ice-margin. Therefore, this BGU is included in both the “supraglacial/englacial/subglacial” and the “ice-marginal” sub-settings.

The “ice-marginal” branch includes units formed in the zone immediately beneath and beyond the glacier margin. This branch contains nine BGUs and seven BGU-Ts. The latter all belong to the BGU *moraine*. As moraines mark the extent and pattern of retreat of a glacier/ice sheet they are often mapped at the BGU level. However, identification at the BGU-T level may further inform on both their palaeo-glacial environments and dynamics.

The “proglacial” branch of the Glacial Setting tree includes eight BGUs and two BGU-Ts. Four of the BGUs are related to calved icebergs and four are of glacifluvial origin. There is a degree of overlap or transition between the “ice-marginal” and “proglacial” branches. One of the BGUs described in the Glacial tree (*glacifluvial outwash plain (sandur)* on the “proglacial” branch) is formed in sub-aerial landscapes. Submarine examples have later been drowned during a marine transgression.

The basic geomorphic units (BGU´s) represent the coarsest level of meaningful mappable landform, which in some cases are collective terms for a generalised landform population. Examples in the glacial tree include *streamlined landform* and *moraine*. Streamlined landforms are indicators of ice flow direction and in some cases ice flow velocity. Similarly, moraines mark the lateral extent of glaciers, and their relative positions show the pattern of glacier/ice sheet retreat. These collective terms thus have value for geomorphic mapping and understanding of landscape evolution even without classifying the landforms to BGU type or subtype. Landforms that are typically found in close proximity to, or nested on top of, the glacial landforms described here are not included in the Glacial tree. Examples of these include *submarine gullies* and *submarine channels* (both in Marine Setting) on trough mouth fans. Landforms described from the terrestrial environment, but good examples of which have yet to be identified in marine records) have also been omitted here (e.g. 'ice shelf moraine': Smith et al., 2019).

For the majority of the BGU, BGU-T and BGU-sT included in the Glacial Setting tree in this report, we have adopted the terminology and glossary definitions (Bell et al. 2016, adapted from Bell et al. 1997) provided in the *Atlas of Submarine Glacial Landforms* (Dowdeswell et al., 2016*),* which is one of the most comprehensive collection of papers on submarine glacial landforms currently available. In addition to the geomorphic units described here, the Atlas also includes other common landforms from glacimarine settings around the world.

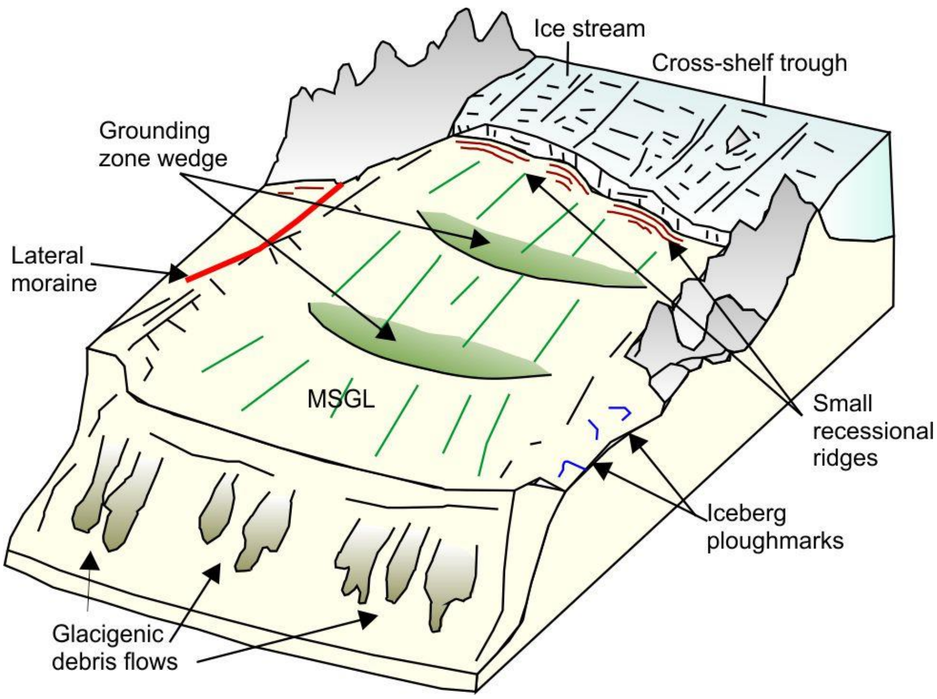

Figure 6-1 Conceptual model showing a typical ice stream landform assemblage, from fjord to continental shelf slope (adapted and modified after Ottesen and Dowdeswell, 2009)

Table 6-1 Example GIS attribute table for mapped units in a Glacial Setting.

Part 1 Morphology Feature	Part 2 Geomorphology Setting or Process	Basic geomorphic unit (BGU)	*Type (BGU – T)*	*Sub-type (BGU – sT)*
Mound	*Glacial*	*streamlined landform*	*drumlin*	*sediment drumlin*
Ridge	*Glacial*	*streamlined landform*	*flute*	*megaflute*
Ridge	*Glacial*	*esker*	NA	NA
Ridge	*Glacial*	*moraine*	*terminal moraine*	NA

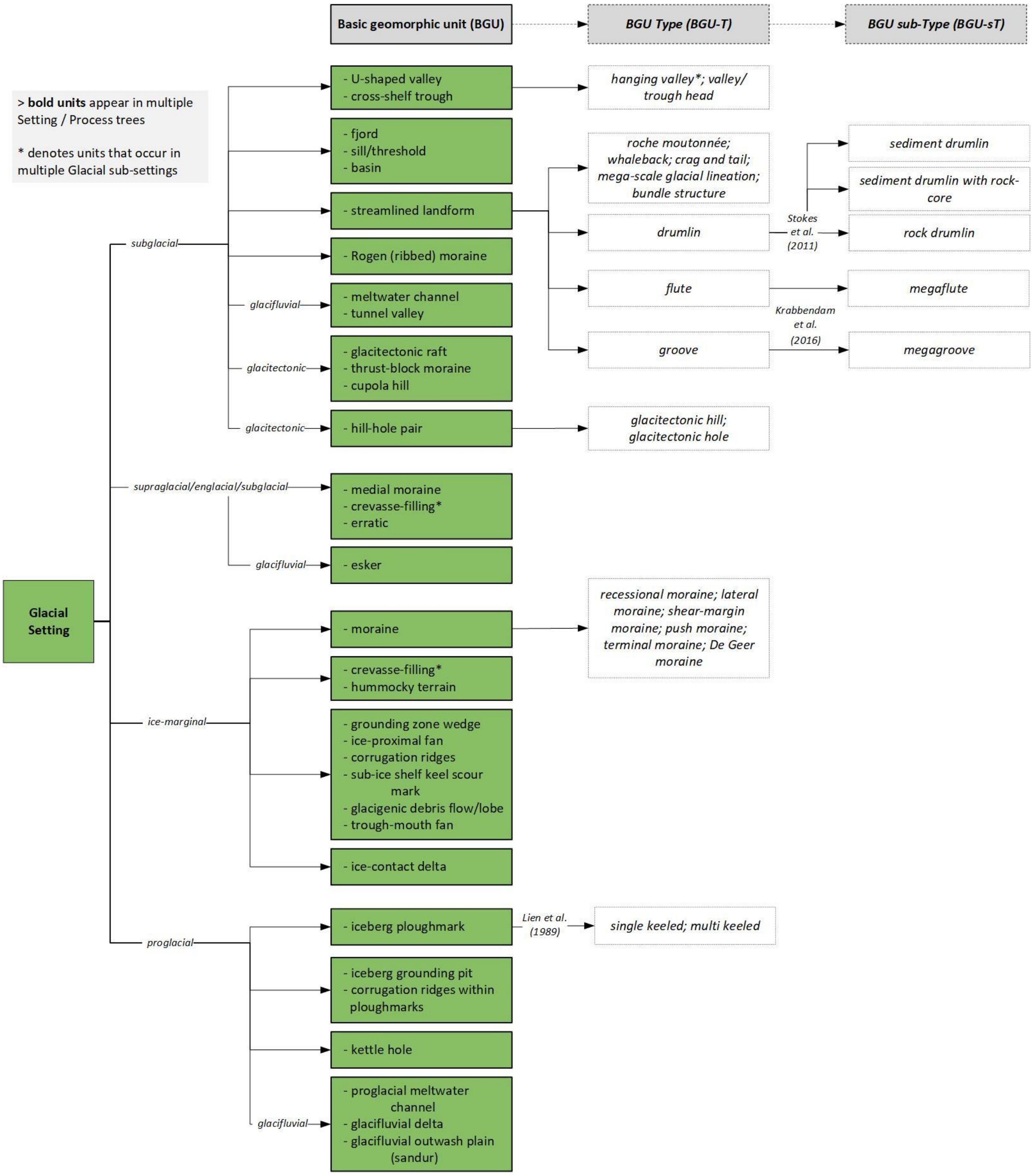

Figure 6-2 Glacial Setting classification tree. See glossary (Chapter 17) for definitions of BGU and BGU-T *terms.*

7 Solid Earth Setting

The Solid Earth Setting classifies geomorphic units that belong to the broad remit of what has been traditionally called "solid geology". Although it cannot be considered as a "Setting" *sensu stricto*, it includes units that may act as background to all other Settings and Processes listed in this glossary, as bedrock underlies any location. The units in this setting include any bedrock outcrop independent of scale and lithology and thinly buried basement and strata, including volcanic intrusions and extrusions. Only units related to the configuration of the bedrock geology itself (where no other processes are involved apart from those that formed or tectonically deformed the rock) are structured and classified herein. For example, wave-cut platforms or bedrock channels are not included as they are formed by wave and water erosion, respectively.

Though there is a rich established terminology for describing bedrock geology, there is no equivalent system for grouping and structuring these terms for the purpose of geomorphic seabed classification, which is often more generalised than onshore mapping. In the structuring of the Solid Earth Setting we have relied on standard handbook terminology of subaerial geology or geomorphology (e.g. basic fold types) that could be transposed to the marine setting (Davis et al., 2012; Huggett, 2017; e.g. Thouret, 1999). Specialised marine geomorphology terms were instead sourced from anthologies (Harff et al., 2016; Micallef et al., 2017) and internationally recognised classification systems, such as the EMODnet glossary (Asch et al., 2021). The classification tree operates a split between magmatic, tectonic and general outcrop units. It essentially distinguishes between forms produced by magmatic activity, crustal deforming forces (e.g. folding, faulting and diapirism) and forms created by the geometrical disposition of bedding planes. *Volcanoes*, *abyssal hills*, *axial volcanic ridges* and *oceanic core complexes* are kept separate from *magmatic outcrop* for their composite, specific nature and significance. *Seamounts* are classed as BGU-T for *volcanoes*, as volcanism is the main cause for their formation; however, it is important to note that there exist a few instances where faulting or plate tectonics are the dominant formational processes (Fryer and Fryer, 1987). *Abyssal hills* are also formed by competing crustal extension and volcanism.

The list of units adopted herein aims to ease of use and efficacy in the marine landscape where very high-resolution data or ground-truthing is often absent. Units are also sometimes grouped into a practical framework for geomorphic application. The *bedrock outcrop (undefined)* and *tectonic lineament* units cover the specific need for uncertainty when mapping bedrock, and can be replaced by any of the other more accurate BGUs (e.g. *magmatic outcrop* or *fault trench*) if a better knowledge of the nature of the outcrop is acquired. Reference for the magmatic classification system were mainly based on Casalbore (2018), Harff et al., (2016) and Thouret (1999), while structural terms were based on general textbooks (Huggett, 2017). Particular emphasis is given to morphological types of magmatic intrusions or extrusions and tectonic forms, rather than prioritising their structural or petrological implications. While the *mid-ocean ridge* unit is strongly linked to volcanic processes, we have opted to retain their physiographic nomenclature (Table 2-2; Glossary Table 17-1) for consistency with other macrozones (as trenches and continental shelves etc.). Other subordinate units related to mid-ocean-ridge volcanism, e.g. *oceanic core complexes* (Maffione et al., 2013; Tucholke et al., 1998) and *axial volcanic ridges* (Searle et al., 2010), have been retained in this Solid Earth Setting.

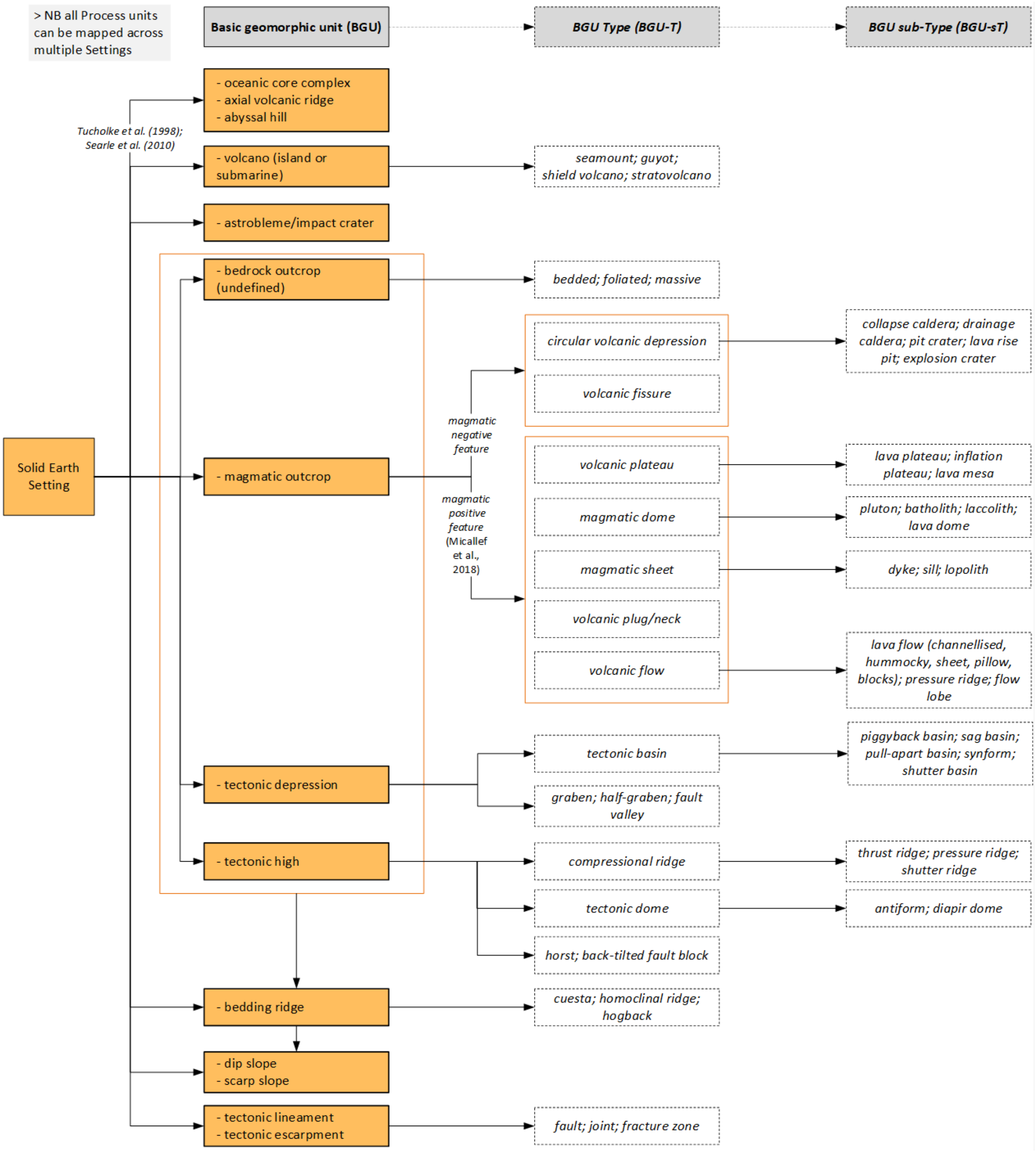

Figure 7-1 The Solid Earth classification tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 7-1 Example GIS attribute table for mapped units in a Solid Earth Setting.

Part 1 Morphology Feature	Part 2 Geomorphology Setting or Process	Basic geomorphic unit (BGU)	*Type* *(BGU – T)*	*Sub-type* *(BGU – sT)*
Seamount	*Solid Earth*	*volcano*	*guyot*	NA
Ridge	*Solid Earth*	*tectonic high*	*tectonic dome*	*antiform*
Pit	*Solid Earth*	*magmatic outcrop*	*circular volcanic depression*	*collapse caldera*

8 Current-induced Processes

The development of some *barforms* is unique to specific Settings (e.g. Coastal *barform* BGU*: shoreface terrace* BGU-T) and so are included in those Setting trees (Coastal and Marine Settings: Figure 3-1 and Figure 4-1). Other *barforms* and incisional units, and many *bedforms*, can form within multiple settings (e.g. *dunes* can form in Marine, Fluvial, Coastal and Solid Earth Settings), though their origins are not always known or even discernible; these units are captured here in the Current-induced Processes tree (Figure 8-1). Where the formative origin of these units is known their classification can be amended to the appropriate Setting, and their colour-code can be similarly modified (e.g. See Figure 3-1, Figure 4-1, Figure 5-1).

The BGU of the Current-induced Processes classification tree are broadly split into negative relief (erosional - e.g. *chute-channel, plunge pool*)), intermediary *knickpoints,* and (generally) positive-relief *bedforms* and *barforms*. The rational for this distinction is twofold: (1) bathymetric highs (accretionary) and lows (erosional) are fundamental divisions within the Part 1 Morphology mapping approach, and will usually match the relief of these geomorphic units; (2) erosion and deposition are a logical first step as they represent inverse ratios between sediment transport and flow energy.

Bedforms are also distinguished from *barforms* to reflect their fundamentally different relationships with their formative flows (Dalrymple and Rhodes, 1995). For example, *bedforms* tend to respond more rapidly to variations in flow energy / sediment supply to moderate their flow resistance and sediment transport (Best, 1996; Simons and Richardson, 1966), and the type and magnitude of *bedforms* are thus scaled to grain size, flow velocity, shear stress and flow depth (Allen, 1982; Best, 1996; Simons and Richardson, 1966). An exception is the term *dune* (BGU-T) which has multiple applications including *bedforms* that form in higher velocity and higher shear conditions than ripples, but which may alternatively be used to describe marine sediment waves and megaripples that are longer-lived and so more akin to *barforms*. *Barforms* generally develop more slowly during multiple flow events (e.g. *mouthbars*), and are often forced by the broader landscape (e.g. *pointbars* on channel bends). We adopt the terminology of Church and Jones (1982) to classify channelised *barforms*. Non-channelised *barform* units have been collated from a broader range of publications.

Hydrodynamic classifications of *bedforms* have relied on extensive flume and field data. Increased flow velocity (Ashley, 1990) or shear stress (Best, 1996) and Froude number relative to sediment grain size have been comprehensively demonstrated to drive the transition of mobile bed reorganisation from no movement through *ripples* to *dunes* and upper stage *plane beds*, and these relationships are captured in bedform phase diagrams. Stow et al., (2009) extended the phase diagrams of Ashley and Best to also include slope and deep marine *bedforms* and some *barforms*; we incorporate Stow et al.,'s list of terms (NB: without grain size descriptors - See section 14.6) into the Current-induced Processes classification tree. *Dunes* are also further subclassified into various BGU-sT on the basis of their scale (Ashley, 1990; Dalrymple and Rhodes, 1995) and using historically aeolian terminologies (McKee, 1979), that have since been applied to dunes formed in many Settings (e.g. Marine, Fluvial, Coastal). Combinations of many such *dunes* frequently comprise coastal dunefields (*foredune* BGU-sT) and these can be preserved on continental shelves and slopes (e.g. Bøe et al., 2015).

Additional geometric characteristics and flow attributes can be assigned to Current-induced units in multiple Settings (including but not limited to Marine, Fluvial and Coastal) to infer formative processes than are captured in their respective Setting classification trees. These additional classifiers are arranged into two categories: (1) Geometry - antidunes, barchan, trochoidal, crest geometry (2D, 2.5D or 3D: Perillo et al., 2014), primary, secondary or compound; and (2) Process -

Erosional, Accretionary/Aggradational, Unidirectional flow, Bidirectional flow, Constrained flow, Open flow, Tidal current, Turbidity current, Density current.

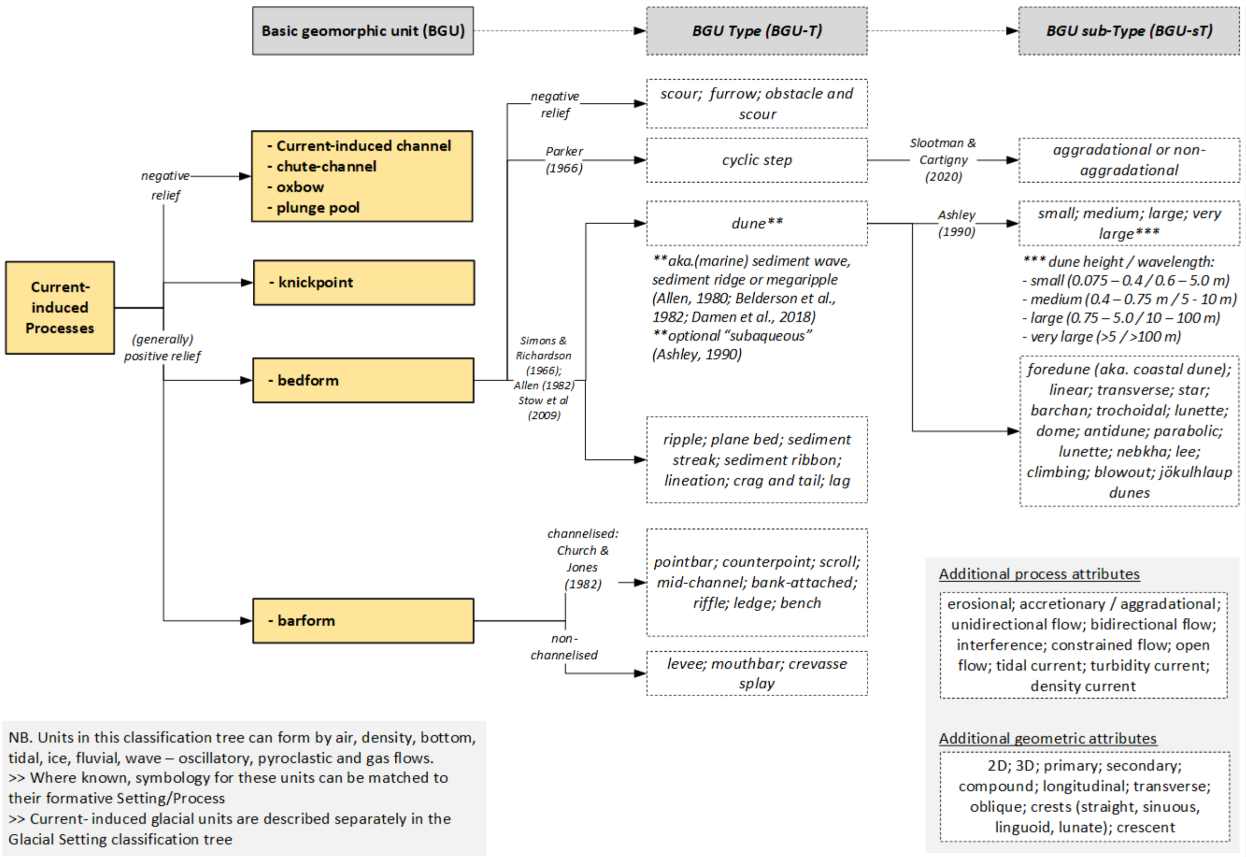

Figure 8-1 Current-induced Processes classification tree. Units can be reclassified to their formative Setting / Process as illustrated in Table 8-1 See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 8-1 Example GIS attribute table for units mapped using the Current-induced Process tree. Note that the Ridge (Morphology) example below is of unknown origin and so is maintained as a Current-induced Process classification, whereas the second Ridge (Morphology) example below has been Setting reclassified as Coastal in origin, and BGU-sT* foredune, with *additional tags* field *and* Aeolian *in additional fields that are out of view. Similarly, the Ridge** (Morphology) example has been determined to be of likely Marine origin and so reclassified by that Setting. On a map these three example units would be symbolised using yellow (Current-induced bedform dune – i.e. origin undetermined), light blue (Coastal bedform foredune) and blue (Marine bedform dune).*

Part 1 Morphology Feature	Part 2 Geomorphology Setting or Process	Basic geomorphic unit (BGU)	*Type (BGU – T)*	*Sub-type (BGU – sT)*
Ridge	*Current-induced*	*Bedform*	*dune*	*medium*
Ridge*	*~~Current-induced~~ reclassed as Coastal*	*Bedform*	*dune*	*foredune*
Ridge**	*~~Current-induced~~ reclassed as Marine*	*Bedform*	*dune*	*NA*

9 Biogenic Processes

Biogenic landforms (bioconstructions and build-ups) are three dimensional structures that can be attributed to the activity of organisms. Bioconstructions are formed in the submerged environment by a wide variety of organisms belonging to diverse taxa. Construction is typically modulated by biologically controlled or induced carbonate mineralization. The term 'bioconstruction' (Höfling, 1997) is a useful catch-all term in the context of biogenic geomorphology as it infers a process, as well as a landform component (Lo Iacono et al., 2018). The more general term 'build-up' can also be universally applied to morphological features of biogenic origin which develop from processes such as sediment trapping & baffling, or when no further information is available.

This Biogenic Processes classification scheme attempts to define BGU terms that describe bioconstructions and build-ups that can be universally applied across any biogeographic region. The selection of terms and their definitions are intended to translate equally between cold, temperate, and tropical settings to enable consistency between workers irrespective of oceanographic/climatic regime. The separation of BGU terms reflects discrete processes of formation resulting in geomorphic forms that can logically group together (form plus process). Further, these BGU terms and their definitions are intended specifically for application to geomorphic mapping, while acknowledging that other disciplines (e.g., ecology, geology) and applications (e.g., habitat mapping) may apply different interpretations of these terms (e.g. 'reef' as a common catch-all term for all biogenic build-ups, can also be applied as a habitat type or community description).

Unlike most Settings described in Part 2 (Fluvial, Coastal, Glacial etc.) which have a mature, widely accepted and applied nomenclature, biogenic processes and bioconstructions are comparatively poorly defined in the context of geomorphology. Over time and across disciplines, a wide range of disparate features have been classified as 'reef' (Goudie, 2006; Riding, 2002) producing much debate in the literature over what constitutes a reef, and what non-reef or 'reef-like' features should be called. Despite almost a century of scientific discussion, most attribute-based definitions have proven contentious and difficult to apply (Riding, 2002). The challenge is further exacerbated in the context of geomorphology, where there is currently no unified, widely accepted and applied classification scheme inclusive of both cold, temperate and tropical terminology.

In defining the term "bioconstruction", (Höfling, 1997) recognised four main categories: bioherm, biostrome, reef mound, and mud mound. In Höfling's scheme, skeletal 'true reefs' were a subdivision of bioherms (Riding, 2002). The *Encyclopedia of Geomorphology* (Goudie, 2006) defines 'Reef' as "spatially heterogeneous, three-dimensional structures which have morphological form that is different from the underlying substrata". This broad definition includes rocky outcrops not just bioconstructions, and does not infer any particular process interpretation (see entry in Marine Setting: *reef* BGU). Definitions for 'Coral reef' are often tropical-centric and not inclusive of cold-water coral reefs (e.g. Goudie, 2006). *Submarine Geomorphology* (Micallef et al., 2017) provides a comprehensive chapter on cold-water-coral reefs and mounds (Lo Iacono et al., 2018), but tropical reefs are only mentioned quite generally in a section on continental shelf landforms, with no descriptions of geomorphic units. Similarly, the geomorphology of tropical coral reefs is well-described (Hopley, 2011, 1982; Maxwell, 1968), but does not translate well to cold-water-coral or temperate algal reefs. Bioconstructions that are aggregations of individual small elements such as rhodoliths (maerl), and non-calcareous bioconstructions are also poorly captured.

Temperate coastal bioconstructions by serpulids, vermetids, oysters and agglutinating polychaetes such as *Sabellaria* must also be satisfactorily captured in a unified biogenic geomorphic classification scheme. In temperate regions 'reefs' are often more like bioherms or biostromes in structure and include constructors such as *Sabellaria*, oyster, calcareous red algae, vermetids and serpulids (Goudie, 2006). Bioherms are “reef-like, mound-like, or lens-like” features with positive relief and of purely organic origin, while biostromes are thinner, sometimes bedded, and less developed structures than bioherms (Cumings, 1932). These categories have some merit in the context of geomorphology (Goudie, 2006) since discrete geomorphic units should differentiate between process, as well as form. However, many authors persist with the universal term ‘reef’, and this remains problematic since it provides no distinction between formative processes (e.g., autochthonous skeletal framework precipitated by tropical or cold-water corals vs agglutinated sediment constructions by *Sabellaria* polychaetes).

The term ‘mound’ is similarly problematic. Several definitions for ‘mound’ and ‘carbonate mound’ are in common usage (see Riding, 2002 for discussion), that are equally as broad as ‘reef’. In carbonate sedimentology ‘mound’ commonly refers to ‘carbonate mud’ mounds. Mound is also commonly applied to deep/cold-water coral bioconstructions (Lo Iacono et al., 2018). In this context a cold-water-coral mound comprises a high skeletal component plus matrix, whereas a mud mound, by definition, contains few or no skeletons (Riding, 2002). These descriptions provide no unambiguous distinction to separate ‘mound’ from either reef or bioherm. Additional confusion is introduced since ‘Mound’ is an IHO Feature name and one of the adopted terms in Part 1 Morphology (Dove et al., 2020) describing any ‘mounded’ seafloor feature whether biogenic or not. Where ‘mound’ is used in literature in relation to biogenic build-ups, it is often not apparent whether the author is describing morphology or geomorphology, or using the term interchangeably.

We have attempted to address these challenges and resolve a unified Biogenic geomorphology classification scheme that incorporates form as well as process, that is largely modified from the organic ‘reef’ classification scheme of Riding (2002). Some aspects of Riding’s scheme readily translate to geomorphology (with modification) because the structure-based definitions (i.e., the physical, sedimentary support of the feature), rather than attribute-based (e.g. “wave-resistant”) can infer the biophysical processes that reflect fundamental controls on formation (Riding, 2002) (Fig 9-1).

The list of BGUs provided herein can be grouped firstly as autochthonous, parautochthonous or allochthonous skeletal components, and secondly (*sensu* Riding, 2002) as frame, segment/cluster, or agglutinated (Figs 9-1 and 9-2) to provide discrete BGUs based on form, structure, and process. The catch-all suffix ‘reef’ is removed except as applied to autochthonous framework *reefs*, and we include the terms *bioherm* (synonym *mound*) (adapted definition to exclude framework reefs) and *biostrome* (synonym *bed*). The bioherm/mound and biostrome/bed synonyms provide flexibility for workers to apply established terms in common use according to their discipline.

Reef may be further classified as *cold-water-coral reef*, *coralligène*, *patch*, *fringing*, *barrier*, *atoll* and *platform* Types (BGU-T). The tropical coral reefs may also be classified using the evolutionary stages *juvenile*, *mature*, *senile* described by Hopley, (1982) which relate to geomorphic forms resulting from biophysical processes and response to sea-level change. Biogenic build-ups are often described by naming the bioconstructor: e.g. *coral* reef, *Halimeda* bioherm, *algal* mat etc. These names are independent of geomorphology but for convention we have provided groupings of important bioconstructors as BGU sub-Type (BGU-sT) following the Carbonate Factory concept of Schlager (2003) where appropriate. The BGU *excavation* includes all features of positive or negative relief formed by the activity of living organisms (i.e. bioturbation). Some common excavations are listed as examples (BGU-T), but a full classification of ichnofacies/lebenspuren is beyond the scope of this scheme. Consideration should be given to the mapping scale whereby excavations may be mapped as a single *Field* rather than individual elements.

The supporting classifiers Frame, Segment and Cluster adapted from Riding (2002) (Fig 9-1, 9-2) are used as directional signposts to navigate the Biogenic classification tree (Fig 9-3).
Frame: Where structure is provided primarily by in-situ skeletons that are in mutual contact.
Segment: Primarily matrix supported; skeletons are adjacent and some may be in contact, but are mostly disarticulated.
Cluster: Primarily matrix supported including sediment trapping; skeletons are adjacent but not in contact.

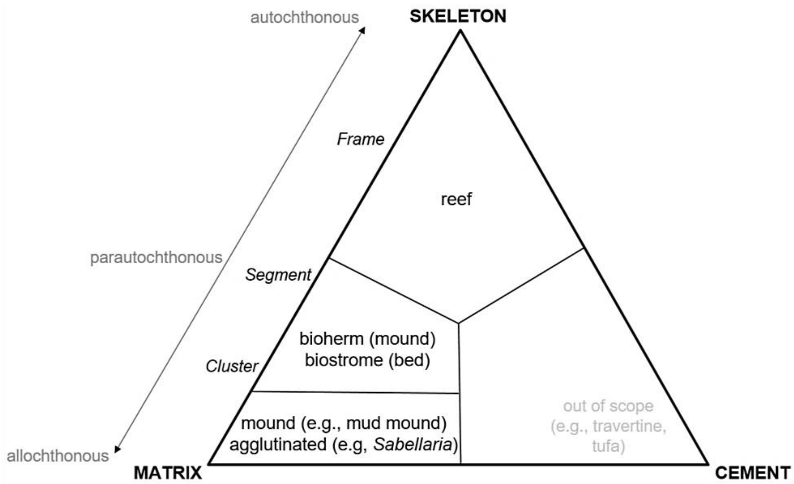

Figure 9-1 Skeleton, Matrix, Cement (SMC) structure ternary diagram illustrating idealised compositional fields for BGU terms *(adapted and modified after Riding,* 2002).

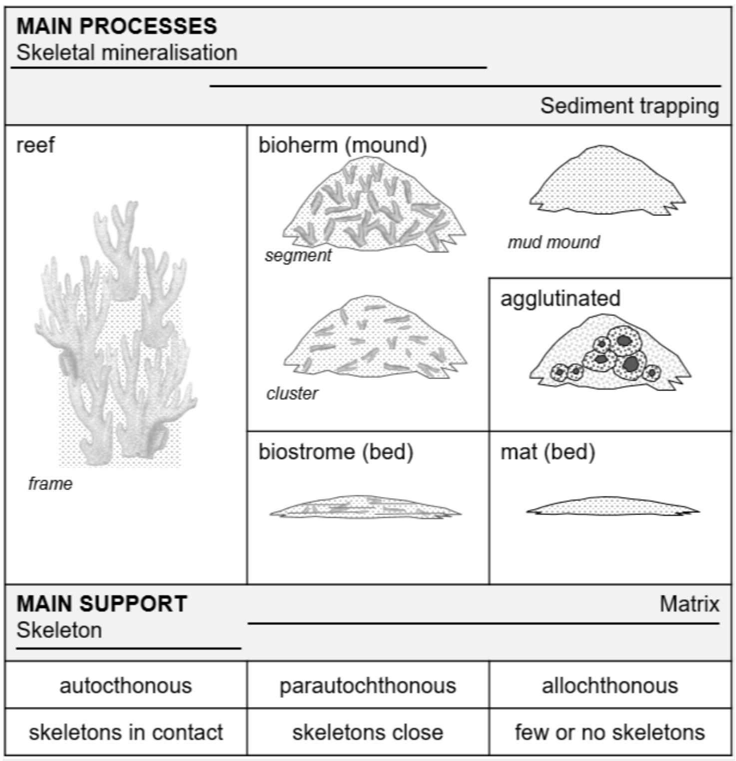

Figure 9-2 Concept diagram of BGU classification, encompassing form, process and structural support (adapted and modified after Riding, 2002).

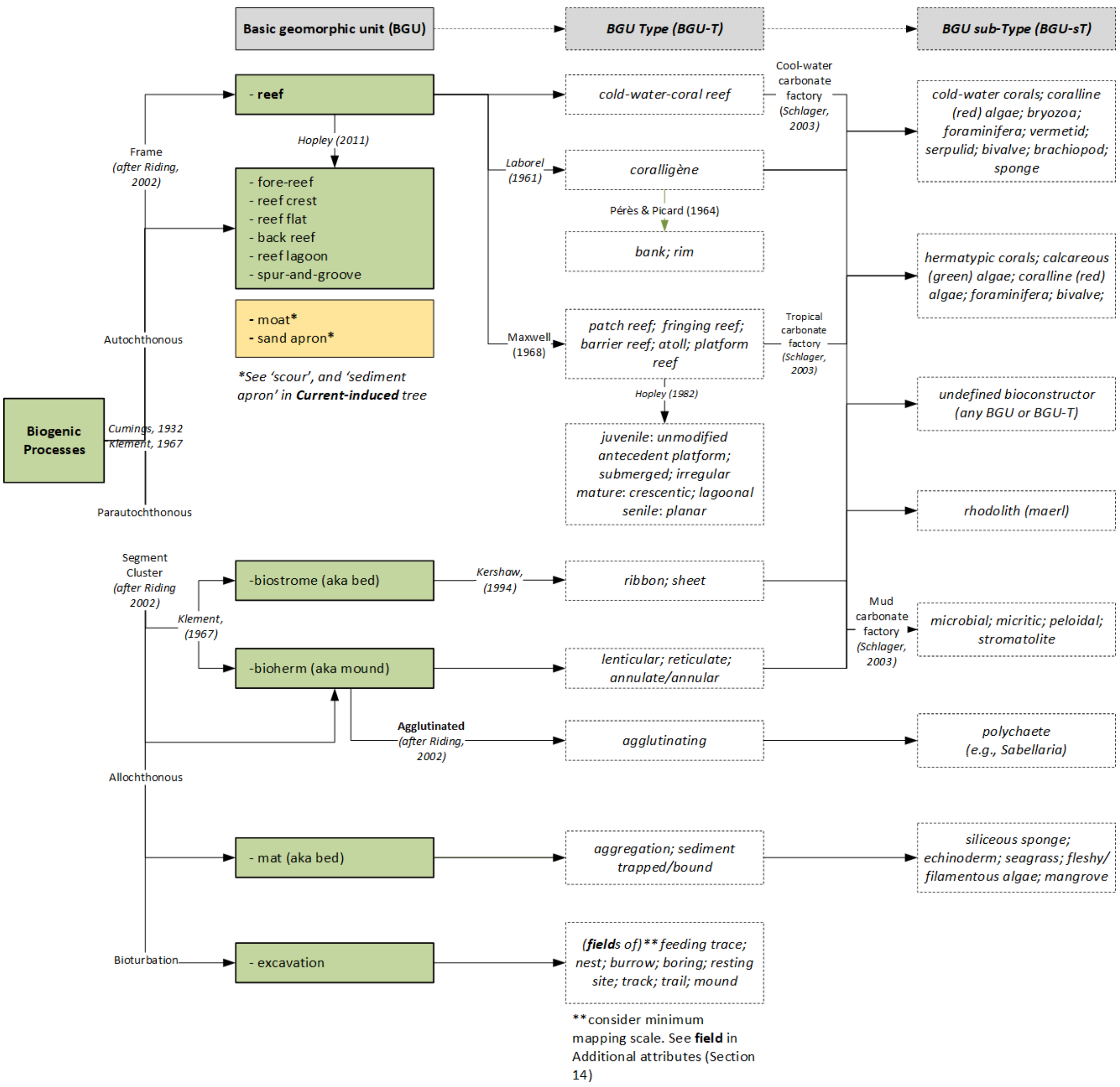

Figure 9-3 Biogenic Process class*ification tree. See Chapter 17 for definitions of BGU and BGU-T terms.*

Table 9-1 Example GIS attribute table for units mapped using the Biogenic Processes tree.

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Terrace	*Biogenic*	*reef*	*fringing reef*	*hermatypic corals*
Plateau	*Biogenic*	*reef*	*platform reef*	*hermatypic corals*
Ridge	*Biogenic*	*reef*	*cold-water coral reef*	*cold-water corals*
Mound	*Biogenic*	*bioherm (mound)*	*lenticular*	*microbial mud mound*
Mound	*Biogenic*	*bioherm (mound)*	*annulate*	*green algae*
Plane	*Biogenic*	*biostrome (bed)*	*sheet*	*rhodolith (maerl)*

10 Mass Movement Processes

Mass movement deposits include a vast spectrum of deposits which result from downslope *en masse* transport driven by gravity. The gravity-induced mass movement processes are also referred to in the literature as: gravitational collapse, mass-wasting, slope failure and, more often, mass-transport. Although more limited than its subaerial counterpart, literature dedicated to submarine mass movement has increased markedly in the last 20 years, reflecting improvements in marine geophysical techniques. The classification of submarine mass movements has been the subject of continuing debate since the earlier papers (e.g. Dott, 1963). This debate is partly due to the fact that these processes occur in distinct geological settings and at different scales, that the remoulded material can be transported by a wide variety of mechanisms (from rigid block motion to turbulent flow), and that a continuum of different types of transport processes may occur in a single event (Nardin et al., 1979). Moreover, over the years, many geological and geotechnical researchers and applied research engineers studying these processes have been using terminology influenced by their diverse backgrounds (Mulder and Alexander, 2001; Nardin et al., 1979; Shanmugam, 2000).

Mass movement classification schemes generally use factors like mechanical behaviour, particle-support mechanisms, sediment concentration by volume, and geometry of the remaining deposits to discriminate mass movement types (e.g. Moscardelli and Wood, 2008; Nardin et al., 1979; Normark and Piper, 1991). Nevertheless, static classifications often do not adequately account for the continuous changes in shape and dynamics that may occur in a mass movement between its initiation and the final deposition (Mulder and Cochonat, 1996).

The Mass Movement Processes tree is organised as follows (Figure 10-2): firstly, the terms are grouped in three branches, which indicate if the base geomorphic unit represents: a) the totality of the seabed disrupted by a particular mass movement type; b) a zone within the mass movement; or c) a particular element. Zones and elements can be associated with certain mass movements but are not necessarily found in all of them. The terminology for the units in the “mass movement” branch is mainly inherited from that applied to subaerial mass movements and it is based on the classification by Varnes (1978; Figure 10-1). The dynamic or mechanical behaviour of the process, whether elastic, plastic or fluid is behind the separation; *falls*, *topples* and *slides* represent elastic transport mechanisms while *flow* types are linked to a more plastic or fluid behaviour (Middleton and Hampton, 1973). These geomorphic units can be then subdivided into different types based on the nature of the displaced material (i.e., rock, debris or mud) or the geometry of the sliding surface (translational vs rotational slides). The “zone” branch is comprised of two BGUs, the *evacuation zone,* and *depositional zone*, corresponding to areas dominated by either the depletion or accumulation of the displaced material. The “element” BGUs are grouped by their prevalent morphology (Part 1 Morphology Glossary) and are sourced from commonly accepted and utilised terminology (e.g. Bull et al., 2009; Scarselli, 2020; Varnes, 1978).

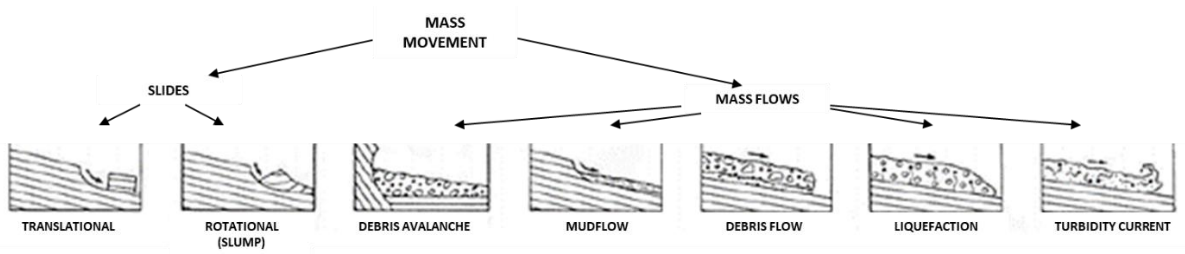

Figure 10-1 Classification of different types of submarine mass movement modified from Varnes’ classification by Coleman et al., (1993). Credit: U.S. Geological Survey.

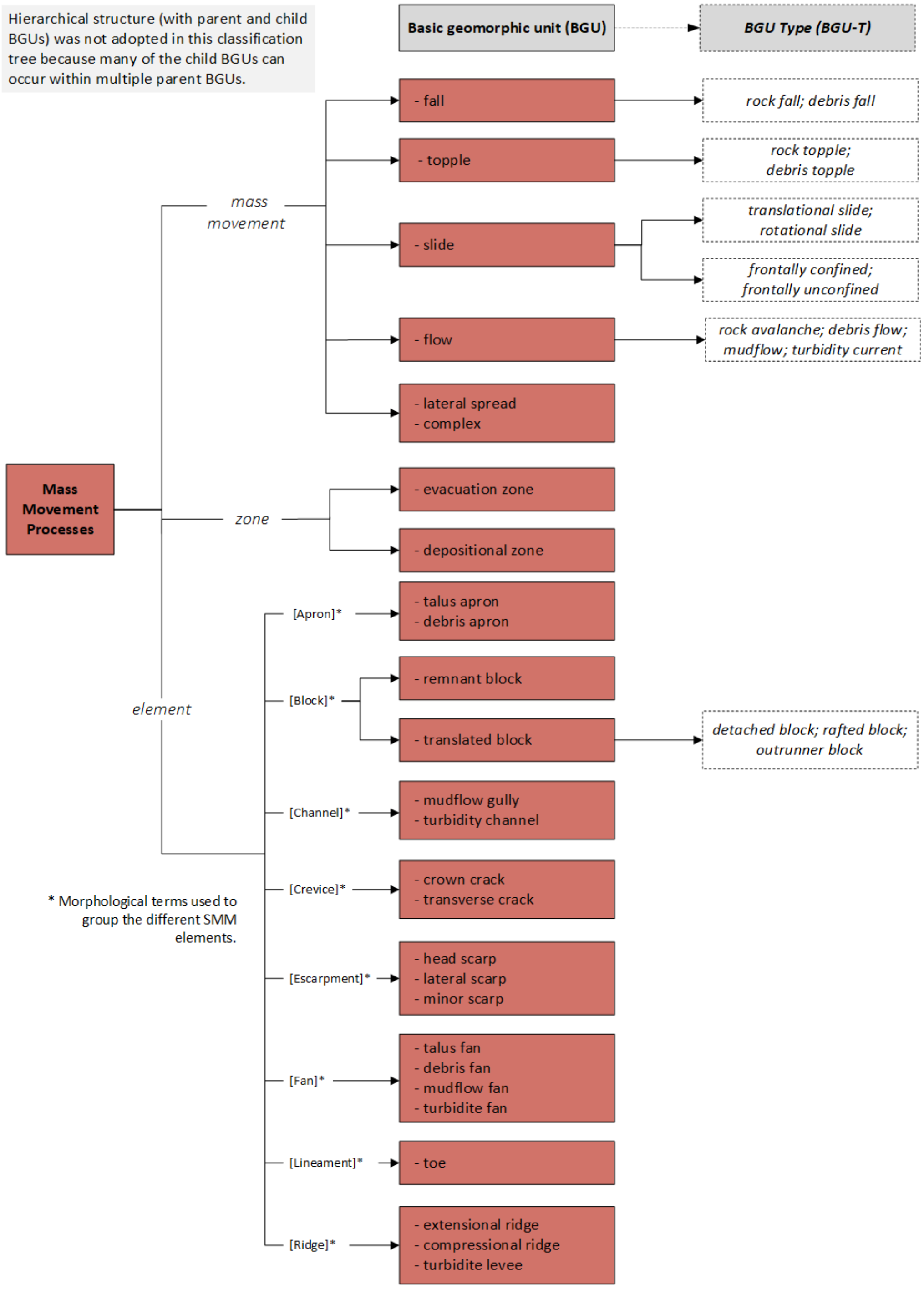

Figure 10-2 Mass Movement Processes classification tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 10-1 Example GIS attribute table for units mapped using the Mass Movement Processes tree.

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Ridge	*Mass movement*	*turbidite levee*	NA	NA
Block	*Mass movement*	*translated block*	*outrunner block*	NA
Channel	*Mass movement*	*mudflow gully*	*debris fall*	NA

11 Fluid Flow Processes

The Fluid Flow Processes tree classifies seabed geomorphic units that can be attributed to the migration of fluids (liquids or/and gasses) driven by a pressure gradient. Fluid flow processes can lead to the formation of structures of very different dimensions, from small methane-derived authigenic carbonate (MDAC) chimneys (typically 10-30 cm wide) to large mud volcanos (several kilometres wide) and found at very different water depths, from pockmarks in shallow coastal areas, as in the Ria the Vigo, Spain (Martínez-Carreño and García-Gil, 2013) to black smokers typically in depths from 2,500 to 3,000 m. The source of the migrating fluids can be equally diverse (Figure 11-1), including biogenic gas produced by microbial methanogenesis under anaerobic conditions (Judd and Hovland, 2007) within shallow-water sediments, thermogenic gases generated, several kilometres below, from thermocatalytic breakdown of complex organic molecules.

Within the marine environment, fluid flow processes have been the subject of a wide body of research due to being of major significance for several distinct scientific fields, such as biology (e.g. by creating unique ecosystems and habitats), petroleum geology (e.g. by revealing the origin of natural gas), geohazard (e.g. by inducing slope instability) or climate change (e.g. by contributing to the global methane emissions to the atmosphere).

Petroleum geology literature often uses the term “seepage” to describe the expulsion from the subsurface of hydrocarbon-rich fluid, composed mainly of methane (CH_4) that is formed in petroleum (oil and gas) prone sedimentary basins. As described by Etiope (2015) gas seepage has been classified into “macro-seeps” and “microseepage”. “Macro-seeps” are divided into “focused flow*”* and “diffuse flow*”* (or miniseepage), with the first, subdivide into “gas seeps”, “oil seeps”, “gas bearing springs” or “mud volcanoes”. However, this type of classification based on their dimension, visibility, and fluid typology, relies on the characterisation of the fluid, which is not often possible from seabed survey data, especially due to the sporadic nature of the seepage events. Therefore, there has also been the adoption of terms that do not require knowledge of the fluid typology. The term pockmark was first used in the field of marine geology by King and MacLean (1970) to describe depressions formed in soft sediments offshore Nova Scotia as the result of fluid escape at the seabed. Hovland and Judd (1988) classified different types of pockmarks based on their morphology and other characteristics (like, the presence of outcropping MDAC at their base) and reinforce the association of the term with a fluid flow structure. However, the term pockmark has also been used occasionally for depressions at the seabed with similar geometry but of different origins (e.g. depressions excavated by fish: Mueller, 2015). Nevertheless, herein this term is used exclusively to describe a seabed depression that is the direct result of fluid flow.

The Fluid Flow Processes tree is organised into two branches (Figure 11-2), broadly based on the temperature of the fluids migrating through the sediments: a) hydrothermal or b) cold seepage. Hydrothermal systems differ from cold seepage as the temperatures of the fluids expelled may reach 200–400 °C (though the fluids expelled by cold seepage are generally warmer than the surrounding seawater, are lower than 100 °C). *Hydrothermal vents* (BGU) are the result of seawater percolating down through fissures in the ocean crust in the vicinity of spreading centres or subduction zones. The cold seawater is heated by hot magma and remerges to form the vents. The particles are predominantly very fine-grained sulphide minerals formed when the hot hydrothermal fluids mix with near-freezing seawater. These minerals solidify as they cool, forming chimney-like structures. *black smokers* (BGU-T) are black chimneys formed from deposits of iron sulphide, whereas *white smokers* (BGU-T) are white chimneys formed from deposits of barium, calcium, and silicon. *Hydrothermal mounds* are structures formed by the precipitated minerals that accumulate at *hydrothermal vent* sites. *Hydrothermal mounds (BGU)* are not subdivided herein, however, these structures could be further divided on the basis of their dominant minerology (e.g. seabed massive sulphide; predominantly comprised of iron sulphides, accompanied by sphalerite, chalcopyrite, and/or galena as the principal economic minerals).

The cold seepage branch comprises the following BGUs: *mud volcano* and their linked child-BGUs, *outcropping MDAC, pingos, blowout craters, collapsed pingo* and *pockmarks. Mud volcanos* can be further classified into BGU-T using their morphologies, with the key distinction made on the grounds of angle of the flanks, defined by the conduit morphology and the lithology of the mobilized sediments. *Outcropping MDAC* BGU can also be further be subdivided into BGU-T's as their geometry reflects their development from the migration style and pathways of the methane-rich fluids. Accumulation of hydrate within the subsurface can result of the formation of *gas hydrates pingos* and *blow-out crater* result of the abrupt gas expulsion. *Permafrost pingos* and *pingo depressions* occur of submarine permafrost are closely linked to glaciations and the associated sea level changes (e.g. Paull et al., 2022). The last of the cold seepage BGUs is the most frequent of them, *pockmarks,* as they can be found in vast numbers and diverse marine settings. Pockmarks can be further classified into BGU-T using pockmark types defined by Hovland and Judd (1988). Additional morphological attributes (e.g. asymmetric, elliptical, W-shaped) are often use to describe the shape of a pockmark and can be indicative of a particular aspect of their development or seabed conditions.

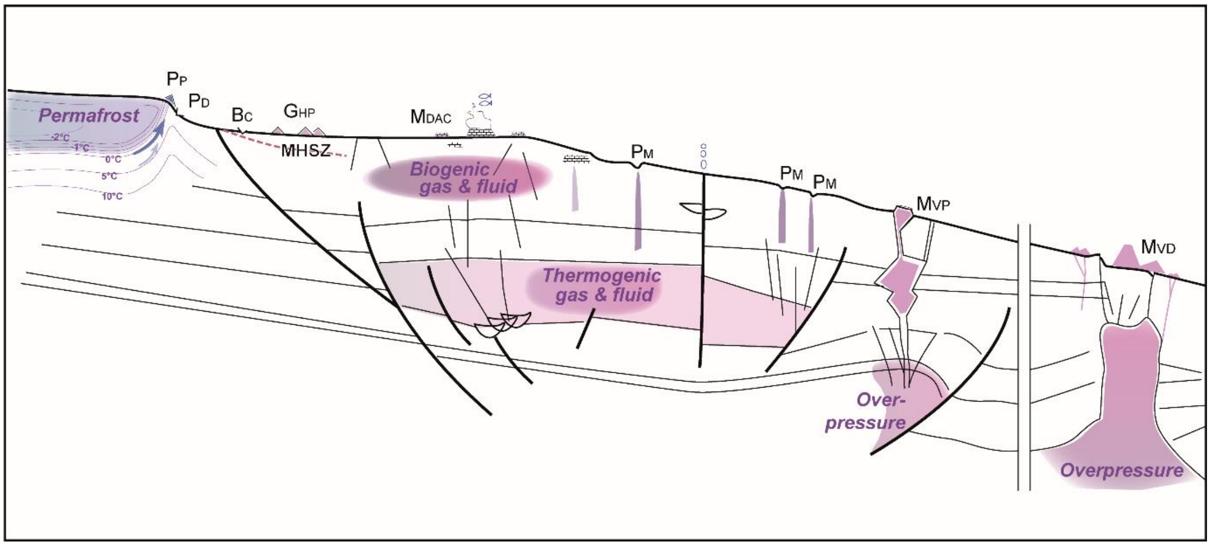

Figure 11-1. Schematic synthesis of origins and trigger mechanisms of the BGUs include in the of cold seepage branch of the Fluid Flow Processes classification tree. Modified from (Talukder, 2012) and combined with Paull et al (2022). PP, permafrost pingos; PD, pingo depressions; BC, blowout crater; GHP, gas hydrates pingos; MHSZ, methane hydrate stability zone; MDAC, methane-derived authigenic carbonate; PM, pockmarks; MVP, mud volcano pie; MVD, mud volcano dome. Scale is arbitrary.

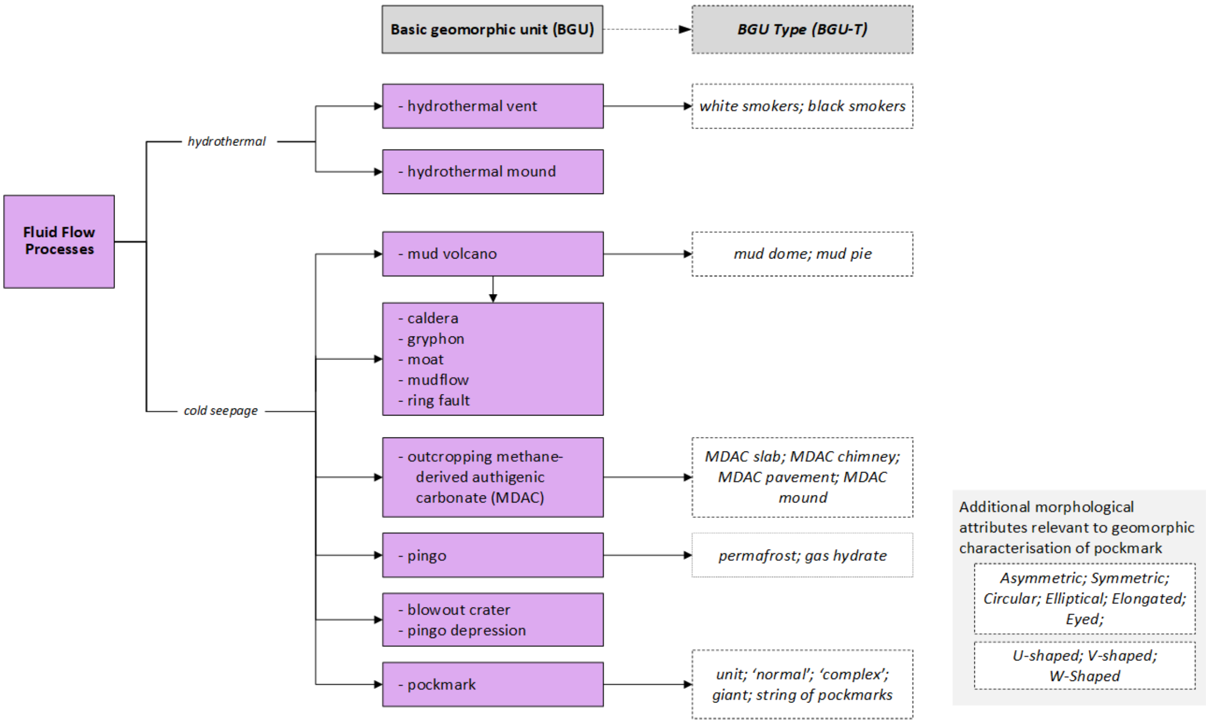

Figure 11-2 Fluid Flow Processes classification tree. See glossary (Chapter 17) *for definitions of BGU and BGU-T terms.*

Table 11-3 Example GIS attribute table for units mapped using the Fluid Flow Processes classification tree.

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Depression	*Fluid Flow*	*pockmark*	*unit pockmark*	NA
Mound	*Fluid Flow*	*mud volcano*	*mud pie*	NA
Moat	*Fluid Flow*	*moat (mud volcano)*	NA	NA

12 Karst Processes

The overriding geomorphic process forming karst landscapes is dissolution. Karst has been defined as a separate category (Process) in seabed geomorphology for those areas that have been dominantly shaped by chemical dissolution of soluble rocks, either carbonates (most commonly; *carbonate karst* BGU) or salt (halite; *salt karst* BGU), but also found in quartzite and sandstones (Wray and Sauro, 2017).

The key indicator of seabed karst geomorphology in carbonate rocks is generally the presence of closed depressions (dolines). Karstic landforms in the Marine Setting are primarily relict (i.e. palaeokarst), and did not form under current conditions; seawater is saturated with respect to carbonate rocks and cannot dissolve them on the sea floor. The frequent glacio-eustatic sea-level changes throughout the Quaternary have led to the submergence of karst landscapes that developed subaerially, and submerged Karst units, including *cone karst*, *dolines*, caves (with stalactites) and *springs*, have been identified in many coastal areas globally (e.g. Kan et al., 2015; Smart et al., 2006; Taviani et al., 2012). The *blue holes* found in reefs around the world, including the Bahamas and the Great Barrier Reef, are submerged karst features (Backshall et al., 1979; Mylroie et al., 1995). Some seabed karst landforms are still active; submarine Karst *springs*, which generally occur at shallow depths (<30 m below sea level), discharge a mixture of freshwater and seawater that favours continuing limestone dissolution, resulting in ongoing enlargement of the caves feeding the *springs* (Surić, 2002).

Around the Mediterranean, submarine palaeokarst features can occur much deeper than elsewhere in the world, because sea level in the Mediterranean at the end of the Miocene dropped over 1500 m (Fleury et al., 2007), much greater than the ~120 m decrease during the LGM. *Dolines* along the South Florida Margin, too deep to have ever been exposed subaerially, probably formed by enhanced dissolution due to freshwater/seawater mixing at the downgradient end of the groundwater flow system (Land and Paull, 2000). The seafloor *dolines* along the Bahama Escarpment, that lie at water depths of over 4 km, are interpreted to have formed by karstic processes at abyssal depths (Cavailhes et al., 2022).

Seawater is undersaturated with respect to salt (halite), and submarine karst topography appears to be actively developing on exposed areas of salt on the seafloor in the Gulf of Mexico and the Red Sea, forming rough terrain with networks of ridges and valleys (Augustin and Talbot 2016). On the floor of the Red Sea there are also collapse dolines due to dissolution by upwelling fluids.

Sandstone landforms controlled by solutional weathering have been observed and described onshore for the past forty years (Wray and Sauro, 2017). As for their counterparts in carbonate rocks, they range from small etchings to *dolines* and *ruiniforms* (Migoń et al., 2017). A combination of different processes increase from small to large features, usually involving other weathering factors and increasing the role of mechanical erosion with increasing size. These factors set sandstone landforms apart from dissolution-dominated carbonate karst, however, they are included in the Karst Processes tree for their similarities.

The Karst Processes geomorphic terminology is sourced from general published texts (e.g. Ford and Williams, 2007). This nomenclature has been applied to submarine karst, although there is often some uncertainty when applying onshore geomorphic terminology to seabed landforms.

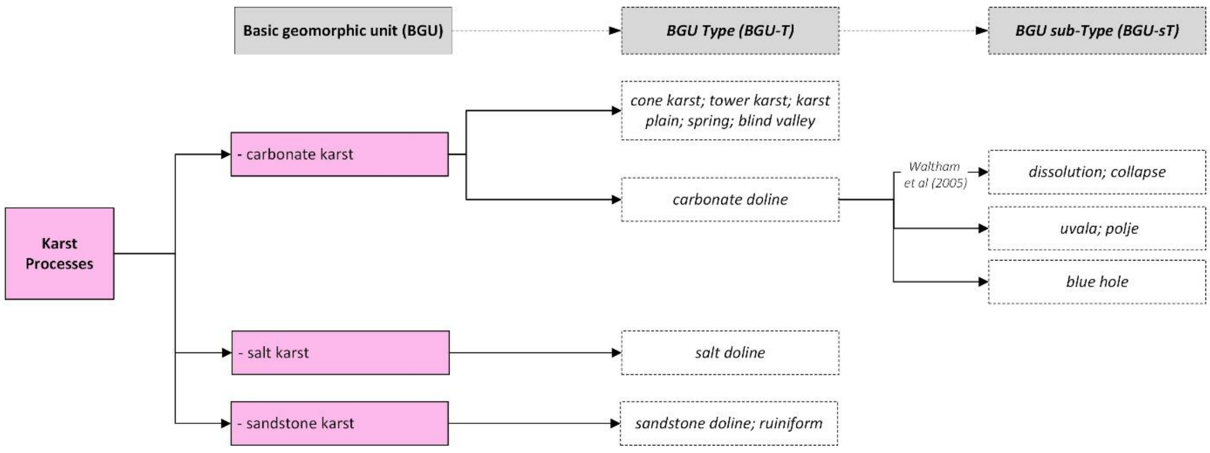

Figure 12-1 Karst Process classification tree. See glossary (Chapter 17) for definitions of BGU and BGU-T terms.

Table 12-1 Example GIS table for Karst Processes. See Chapter 17 for definitions of BGU and BGU-T terms.

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Mound	*Karst*	*carbonate karst*	*cone karst*	*NA*
Plane	*Karst*	*sandstone karst*	*ruiniform*	*NA*
Valley	*Karst*	*salt karst*	*NA*	*NA*

13 Anthropogenic Processes

From the nineteenth century onwards Earth surface processes and landscapes have been increasingly and profoundly influenced by human activity. In the marine realm these activities include (but are not limited to) fishing, aggregate mining, oil and gas exploration, infrastructure and development, coastal development, tourism, seafloor cables, shipping, and construction of wind farms. In addition to the threat that these activities can pose to the marine environment (Harris, 2020) they can also result in the placement of a broad range of ephemeral to long lasting structures and anthropogenic landforms that are mappable units on the seafloor. While this report primarily targets geomorphic mapping, the Anthropogenic Processes classification tree (Figure 13-1) structures the fundamental terminology for mapping human-made landforms.

The three BGUs in the Anthropogenic Processes tree represent the main groupings of anthropogenic units found at seabed. Following Watson et al. (2020), we separate *structure* and *disturbance* units, which represent mainly constructional (positive) and erosional human activities (negative), respectively. A third BGU, *archaeological,* adds further distinction to highlight units that might have particular heritage or cultural importance. As a complete list of Anthropogenic Process BGU-T would exceed the needs of this primarily geomorphic classification system, listed units are intentionally limited to those that are most frequently encountered. Additional BGU-T are captured as the generic *other* to support the user in inserting their own bespoke unit terms as required.

Where a BGU from any other Setting or Process is the result of anthropogenic modification, that BGU can be classified using the original Setting or Process tree but with an added tag, "Anthropogenic". For example, a scour caused by the presence of a wreck will be classified as *Current-induced* (Process) – *bedform* (BGU) - *scour* (BGU-T), anthropogenic (additional attribute).

Figure 13-1 The Anthropogenic Processes classification tree See glossary (Chapter 17) *for definitions of BGU and BGU-T terms. See glossary (Chapter 17) for definitions of BGU and BGU-T terms.*

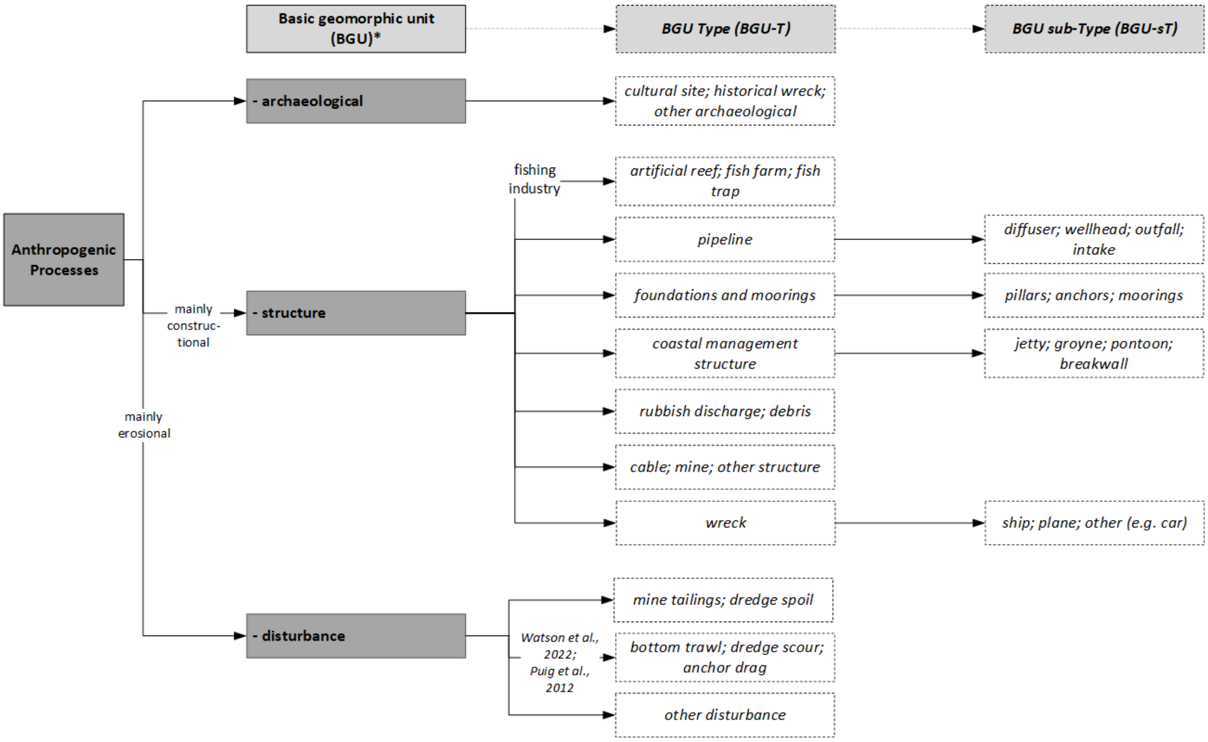

Table 13-1 Example GIS table for Anthropogenic Processes

Part 1 Morphology Feature	**Part 2 Geomorphology Setting or Process**	**Basic geomorphic unit (BGU)**	***Type (BGU – T)***	***Sub-type (BGU – sT)***
Mound	*Anthropogenic*	*archaeological*	*historical wreck*	NA
Ridge	*Anthropogenic*	*structure*	*pipeline*	*outfall*
Depression	*Anthropogenic*	*disturbance*	*bottom trawl / dredge scour*	NA

14 Additional attributes (for all Settings / Processes)

Eight additional attributes can be optionally applied to further describe geomorphic units within multiple Settings / Process trees (Table 14-1). In a GIS these attributes essentially form additional fields that can be added to a feature class with fields containing the Setting / Process and unit classifications (BGU, BGU-T and BGT-sT).

Table 14-1 Additional attributes that are typically used to further describe geomorphic units.

Additional attribute category		**List of possible attributes**
(I)	Group (of units)	Field, chain
(II)	Age (relative)	Relict, Palimpsest, modern
(III)	Stratigraphic position	Surface, buried or partially buried
(IV)	Sea level (relative)	Transgressive, regressive, stillstand
(V)	Lithology	Hard, soft sediment (siliciclastic or carbonate), consolidated sediment.
(VI)	Particle-size characterisation	Particle size (mm or phi), texture
(VII)	Terrain attributes	Quantitative indices and qualitative descriptions which further describe the geomorphic unit in terms of terrain attributes such as slope, orientation, curvature or variability.
(VIII)	Marginal marine process classification	Fluvial (F), Wave (W) or Tide (T) processes listed as primary, secondary or tertiary processes (e.g. Ft*w* = Fluvial-dominated, tide-influenced and wave-affected) or Aeolian for any unit.

14.1 Group of units

Groups of BGU, BGU-T or BGU-sT can be collectively mapped as fields (e.g. Marine Setting *dunes;* Biogenic Process *excavation*) chains (e.g. Solid Earth Setting *volcanoes*), or can be used to group individually and/or partially mapped units (e.g. a field of Marine Setting *submarine gullies*; a field of Coastal Setting *bedforms*).

14.2 Relative age

The absolute (e.g. radiocarbon) ages are unlikely to be available for most geomorphic units, however, their relative degrees of activity and antiquity may be interpreted and tagged to provide additional geomorphic insights. We adopt the terms *palimpsest* and *relict* from McManus (1975) description of shelf sediment antiquity. In this report palimpsest is used to define units that are relict in origin but that are also experiencing ongoing modification, while modern units are those which have formed under the process regime, climate and sea level of the late Holocene. We recommend that the relative ages and activity of geomorphic units be tagged using a continuum of these three terms: *relict* (entirely) >> *palimpsest* (relict units undergoing modern modification) >> *modern*.

14.3 Stratigraphic position

Although the Part 2 Geomorphology described herein has primarily been developed to classify Part 1 Morphology (Dove et al., 2020) shapes mapped in plan view, the method can also be applied to subsurface units. For example, lowstand (Fluvial Setting*) subaerial channels* on continental shelves may retain complete or partial surface expression on the seafloor (e.g. boundaries indicated by small escarpments, or by areas of contrasting backscatter: partially-buried). Lowstand *Fluvial subaerial channels* may also be buried by marine strata, and only indicated at the seafloor by fields of (Fluid Flow Processes*) pockmarks*. Alternatively, such a channel may not be visible at the seafloor and only visible in the vertical plane in sub-bottom profiles or in seismic profiles (buried). As such, the additional depth attributes of *surface*, *partially-buried* and *buried* can be applied to Part 2 Geomorphology interpretations beyond the seafloor and into subsurface datasets.

14.4 Relative sea-level

Seabed units can be related to periods of relative sea-level history in broad terms, on the basis of their morphology, water depth and location on the margin (e.g. coastline, shelf, shelf edge). Three categories of relative sea-level may be applied, as follows:

1) *Transgressive.* This category is applied to units that are interpreted to have formed under condition of relative sea-level rise and landward migration of a shoreline (transgression). Examples include remnant Coastal Setting *barriers*, *tidal inlets*, and *lagoons* that are partly preserved on the continental shelf.
2) *Regressive*. A regressive seabed or coastal unit is one that has formed during a period of relative sea-level fall that results in the seaward advance of a shoreline (regression), including forced regression. Examples include Coastal Setting *deltas*, *strandplains* and *chenier plains*.
3) *Stillstand*. Seabed and coastal units that have formed under conditions of relative sea-level stability can be classified as stillstand units. This typically includes most coastal units formed at present sea level (i.e have formed during the Holocene stillstand) but may also include units that formed during a previous stillstand at a level lower than present. Examples include Coastal Setting *barriers* and *dunes* that formed during a late Quaternary stillstand period and were drowned in situ and now form part of the continental shelf.

14.5 Lithology

The lithological characterisation of samples obtained by grab sampling, dredging, sediment coring and rock drilling is often of critical importance for the geomorphic interpretation of seafloor units. Though an exhaustive geological terminology to describe such samples is beyond the scope of this report, their bounding lithology and/or composition can be usefully classified into three broad categories:

1) *Hard*. This term can be applied to any lithified/indurated sediment or magmatic/metamorphic rock. For example a Fluvial Setting *subaerial channel* incised into bedrock; an ancient lithified Fluvial Setting *subaerial channel* (*relict; hard*); a Glacial Setting *drumlin* formed by ice incision into bedrock, a semi-lithified Coastal Setting *beach ridge;* or a Solid Earth Setting *magmatic outcrop*.
2) *Soft*. Can be applied to non-lithified, potentially active sediment and can additionally can be *siliciclastic* or *carbonate* in composition. For example, a Fluvial Setting *subaerial channel (soft - siliclastic)*, a Coastal Setting *dune (soft – siliclastic)*, a Coastal Setting *barrier (soft – carbonate)*, or a Marine Setting *contourite drift (soft – siliciclastic)*.
3) *Consolidated* sediment (compacted, dewatered sediment). For example, a sediment Glacial Setting *drumlin* or a relict Mass Movement Process *slide*.

14.6 Particle-size characterisation

The particle-size distribution of a sediment sample can be used to infer the energy conditions under which sediment has been transported, sorted and deposited. We adopt the Wentworth scheme (Wentworth, 1922) to describe particle size (Figure 14-1), which uses a geometric progression of sizes that are based on a logarithmic scale (phi – Φ). The particle size distribution of a sample can be subsequently used to describe its texture, for which we adopt Folk's (1954) approach (Figure 14-1). This method uses a ternary classification of the relative proportions of mud (0.063 mm), sand (0.063

– 2.0 mm) and gravel (>2.0 mm) to describe 15 classes of texture. Subsequent iterations of the approach have been customized to various depositional systems across multiple disciplines, and we suggest the selection of the most appropriate derivation to match the specific application.

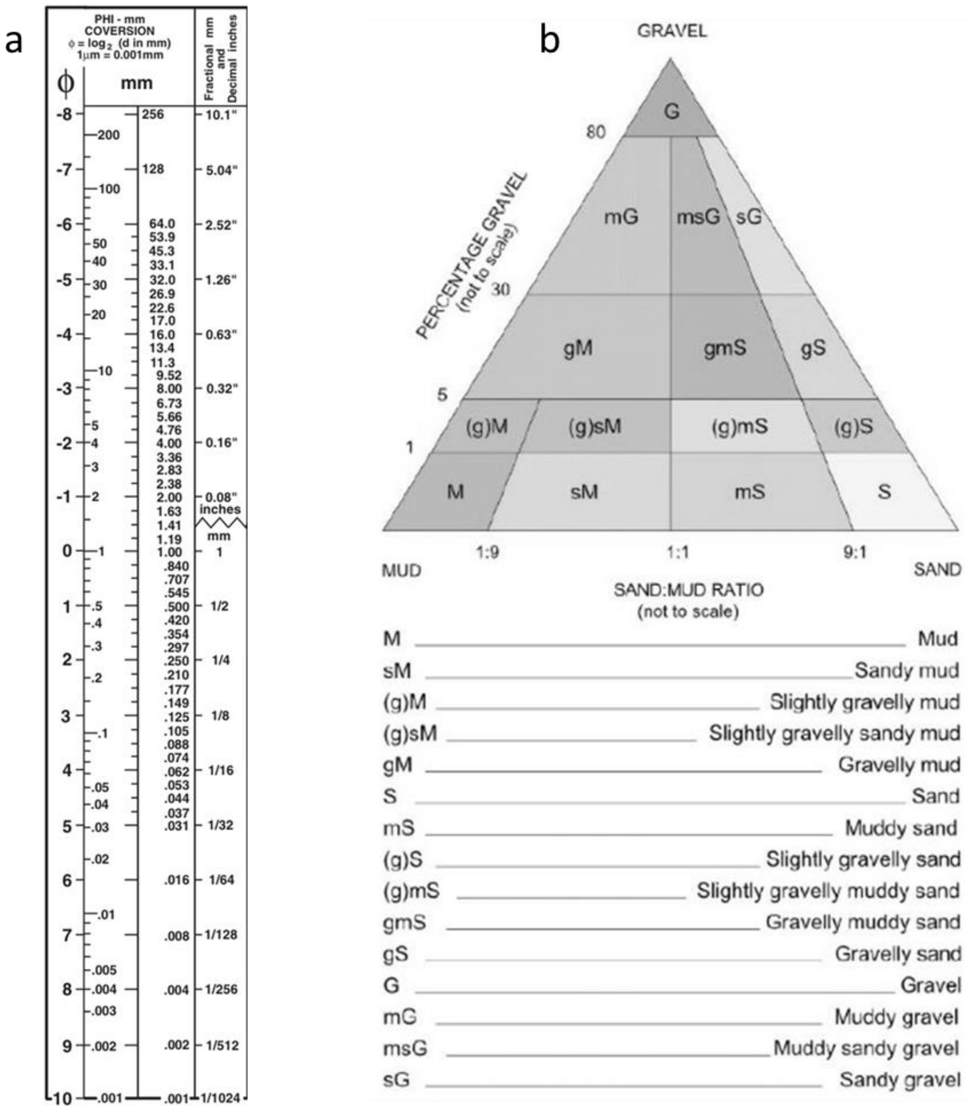

Figure 14-1(a) Wentworth grain size scale (modified from Wentworth, 1922); (b) Sediment textural classification (modified from Folk, 1954)

14.7 Morphometrics

The characterization of mapped shapes using quantitative terrain attributes derived from bathymetric data such as slope, orientation, curvature or rugosity are often used to classify seafloor morphology (e.g. using the Part 1 - Morphology Features). In some instances these characteristics, whether as quantitative attributes or as qualitative descriptions, may also aid their Part 2 - Geomorphology classification. Single or multiple attributes or descriptions may be added, and these may relate to single or multiple spatial scales. Many options for computation of quantitative terrain attributes are available in GIS and related software.

Many of the terrain attributes relevant to geomorphic characterisation are discussed in the Dove et al., (2019) report from the GeoHab Workshop on Seafloor Geomorphology. This includes an overview of many of the commonly used tools for computing such information in quantitative form. Lecours et al., (2016) recently reviewed terrain attributes, including special reference to geomorphology, in the wider context of marine geomorphometry. Issues such as the underlying bathymetric data resolution, quality, as well as the choice of algorithm and analysis distance will affect both the values obtained, their uncertainty and usefulness in comparative studies (Dolan and Lucieer, 2014; Lecours et al., 2017; Misiuk et al., 2021). It is therefore advisable that such information is documented with the attribute.

Where quantitative terrain attributes are difficult or impractical to calculate, qualitative descriptions of terrain attributes (e.g., rough, smooth, hummocky, etc.) are frequently used by geomorphologists during expert interpretation.

14.8 Marginal marine process classification

Where data supports the interpretation of the formative process ratios (wave, tide and fluvial) for geomorphic units (in *Fluvial* and *Marine Settings* and *Current-induced Processes*), we recommend using the primary, secondary and tertiary ternary classification levels of Ainsworth et al., (2011; e.g. Twf: tide-dominated, wave-affected, fluvial-influenced). This combination of ternary processes are typically associated with distinct facies for coasts and their deltas (Boyd et al., 1992), channels (e.g. Woodroffe et al., 1989; Lane et al., 2017) and beaches (Short, 2006). Where a unit has an element of aeolian origin or modification, we also recommend the use of an aeolian tag.

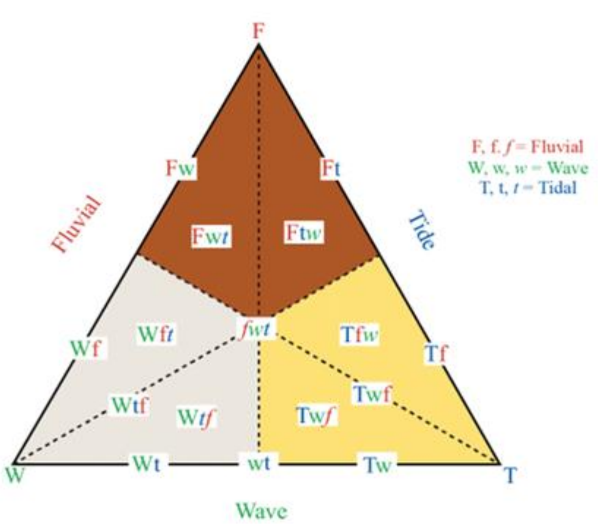

Figure 14-2 The ternary coastal classification system of Ainsworth et al., (2011) can be applied to marginal marine systems (Fluvial, Coastal and Marine Settings). F = *Fluvial dominated;* W = *Wave dominated;* T = *Tide dominated;* Fw = *Fluvial dominated, wave influenced;* Ft = *Fluvial dominated tide influenced;* Tf = *Tide dominated fluvial influenced;* Tw = *Tide dominated wave influenced;* Wt = *Wave dominated tide influenced;* Wf = *Wave dominated fluvial influenced;* Fwt = *Fluvial dominated, wave influenced, tide affected;* Ftw = *Fluvial dominated, tide influenced, wave affected;* Tfw = *Tide dominated, fluvial influenced, wave affected;* Twf = *Tide dominated, wave influenced, fluvial affected;* Wtf = *Wave dominated, tide influenced, fluvial affected;* Wft = *Wave dominated, fluvial influenced, tide affected;* fw = *fluvial and wave influenced;* tf = *tide and fluvial influenced;* wt = *wave and tide influenced;* Fwt = *fluvial, wave and tide influenced;* Fwt = *Fluvial dominated, wave and tide influenced;* Tw*f* = *Tide dominated, wave and fluvial influenced;* Wt*f* = *Wave dominated, tide and fluvial influenced.*

15 Relationship with other geomorphology-related mapping schemes

Practitioners tend to use classification systems that are particular to their own discipline and/or agency or region, and the two-part approach is not intended to replace these. Rather, the geomorphic mapping approach described herein is intended to help standardise geomorphic terminologies between analysts. The relationships between some related marine classification systems and this scheme (Part 2 - Geomorphology) are briefly summarised below by way of example. This highlights synergies between systems and also how Part 2 - Geomorphology may help to fill gaps in some existing schemes.

15.1 EMODnet

European Marine Observation and Data Network - Geology (based on GSI partnership)

The geomorphology for the European seas was a new theme introduced in Phase 3 of EMODnet-Geology; a harmonised geomorphic map did not exist prior to this. Within the framework of EMODnet-Geology the geomorphology layer describes the submarine 'landscape', including information on the genesis of the seabed (https://emodnet.ec.europa.eu/geoviewer/). The compilation of geomorphology data is based on the INSPIRE vocabulary (INSPIRE Thematic Working Group Geology, 2013) and is supplemented by definitions developed in conjunction with the Commission for the Geological Map of the World /International Union for Quaternary Science CGMW/INQUA project of the *International Quaternary Map of Europe and Adjacent Areas* (Vallius et al., 2020). Their geomorphic mapping aims to optimise the semantic description of the INSPIRE compliant terms by including hierarchies. Translation of national descriptions of geological and geomorphic units or semantic transformation is carried out by transforming the descriptions, with each description (legend item) translated according to the INSPIRE vocabulary (e.g. Table 15-1). Feature 'Synonym's' are provided where applicable to capture the variation in terminology used by different researchers and disciplines. While the INSPIRE vocabulary presents a list of useful terms for geomorphic mapping, it does not structure these into different environmental settings, which limits the utility of the terms.

Table 15-1 Example of landform categories – EMODnet-Geology – IQUAME (International Quaternary Map of Europe) Geomorphology Working group

Term (landform)	**Synonyms**	**Definition Landforms / physiographic features (polygons)**
continental shelf		The zone adjacent to a continent that is between the shoreline and a noticeable break in slope, to the steeper continental slope.
continental shelf plain		Plane on the continental shelf forming a relatively flat (relative relief <50 m) platform between the continental slope and the strandflat/coast.
continental slope		The zone of steeply sloping seafloor that lie between continental shelves and the continental rise.
continental slope plain	intraslope basin	Plateau on the continental slope where the seabed has minor relief variations (relative relief <50 m) and usually a thick sediment cover.
contourite deposit	contourite deposit	Any contour-current deposit, esp. a layer of coarse sediment in a marine mud sequence, usually consisting of fine sand or coarse silt, deposited on the continental rise by countour-following currents
contourite drift		Large-scale morphological expression of contourite deposition. Sediment accumulations deposited by contour currents with a mounded or sheeted in overall morphology and elongation more or less parallel to the continental margin
coralmound	Coral reef, reef	A coral-algal or coral-dominated organic reef; a mound or ridge of in-place coral colonies and accumulated skeletal fragmants, carbonate sand, and limestone resulting from organic secretion of calcuim carbonate that lithifies colonies and sands
current channel		Channel in the seabed formed by currents

15.2 CMECS (Coastal and Marine Ecological Classification Standard)

The Coastal and Marine Ecological Classification Standard (United States National Ocean Service; United States Federal Geographic Data Committee, 2012) characterises the marine and coastal environment within two settings: (i) Aquatic, and (ii) Biogeographic. Four components provide further levels of classification within these settings: (1) Water column component, (2) Geoform component, (3) substrate component, and (4) Biotic component. All components are applicable to both settings, and each component is a stand-alone construct that can be used on its own or in combination with other components. Of these, the Geoform Component (Figure 15-1) is used to represent the structural aspects of the physical environment that are relevant to biological community distribution.

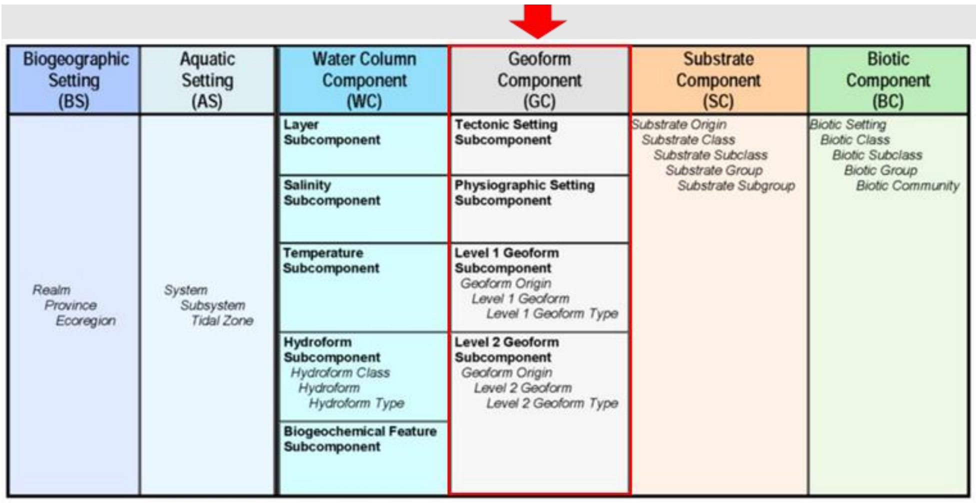

Figure 15-1 The CMECS (2012) classification hierarchy; the Geoform Component contains many of the Part 2 Geomorphology units structured herein.

The Geoform Component is divided into four Subcomponents that describe tectonic and physiographic settings and two levels of geoform elements that include geological, biogenic and anthropogenic geoforms. The geoform component was not intended as a geological classification *per se*, rather CMECS expanded the earlier ecological classification of Greene et al., (2007, 1999). Water Column Components and Geoform Components contain non-hierarchical subcomponents. The CMECS Framework also includes modifiers that are additional terms that can be used where CMECS does not provide the necessary level of description for the data, allowing users to define and add their own additional modifiers as needed. Table 15-2 provides a comparison between selected elements of the CMECS Geoform classification (bold type) with the Part 2 Geomorphology approach described herein.

Applications of CMECS (Kingon, 2018) have highlighted the difficulty in accounting for the complexity of geoforms at fine scales, particularly when multiple geoforms are present (Keefer et al., 2008) and recommended improvements to refining the classification thresholds and more explicitly linking physical and biological processes with habitat patterns. Kingon (2018) noted the challenges associated with divisions into geologic, biogenic and anthropogenic classes when overlap exists. Guarinello et al., (2010) proposed a multi-scale hierarchical framework with a focus on finer scale application as an alternative.

Table 15-2 A translation between aspects of the CMECS and the Part 2 Geomorphology approach described herein.

CMECS terminology	**Part 2 Geomorphology**
Tectonic Setting	Solid Earth Setting
Physiographic Setting	Biogenic Processes (e.g. CMECS Barrier Reef); Marine Setting (e.g. CMECS Abyssal fan or Marine Basin Floor); Glacial Setting (e.g. CMECS Fjord); Coastal Setting (e.g. CMECS Lagoonal Estuary or Major River Delta).
Geoform Levels 1 and 2 Subcomponents	Distributed throughout Part 2 Geomorphology Settings eg: [*CMECS*] [Geoform] Bar > [Geoform Type] Baymouth Bar = [*Part 2 Geomorphology*] Coastal Setting > [BGU] barrier > [BGU-T] *bay-mouth*

15.3 Seamap Australia

Seamap is a national benthic marine habitat classification scheme and spatial database that collates disparate seabed habitat datasets into a synthesised spatial product for the Australian coast and marine zone (Butler et al., 2017). *Seamap* is primarily a habitat classification system for the continental shelf for benthic ecologists with utility for management decision-support. Several internationally applied benthic classification schemes were considered in the development of *Seamap*, including the Coastal Marine Ecological Classification Scheme (CMECS: United States National Ocean Service; United States Federal Geographic Data Committee, 2012), the European Nature Information System (EUNIS: Davies et al., 2004) classification, the Coastal Marine Classification for New Zealand (MFDC, 2008) , and the British Columbia Marine Ecological Classification (MSRM: Ministry of Sustainable Resource Management, 2002). Whilst not explicitly stated, the *Seamap* classification scheme may be implemented by tagging a suite of benthic images.

The *Seamap* classification scheme incorporates geomorphic attributes by applying a 'Substratum Component' classifier, which comprises a hierarchy of levels (hard, soft, mixed, consolidated, unconsolidated, coarse, fine etc) and classifiers based on geologic origin (igneous, metamorphic, sedimentary), biogenic origin (algae, carbonate, terrigenous and worm) and anthropogenic origin (construction, garbage, metal, rock, wood). The webmap product includes existing geomorphic feature layers (e.g. Griffin et al., 2012), but the *Seamap* scheme does not classify and delineate individual geomorphic units in a GIS environment.

The *Seamap* 'Biotic Component' refers to the community of living biota colonising a substratum that comprises a habitat, and should not be confused with the Biogenic Processes presented herein which refers to biologically induced mineralisation (bioconstruction) or excavation/construction of the substratum. It is intended that the MIM-GA Part 2 Geomorphology classification scheme will be considered for adoption within the *Seamap* scheme as the Geoform component (Butler et al., 2017).

16 Insights from individual geomorphic units

Full coverage seafloor geology and geomorphology maps provide ideal context for a broad range of marine applications, and so form the ideal standard for multipurpose marine map products (e.g. Bristol Channel 1:10,000 scale geology and geomorphology map: British Geological Survey, 2022). For many applications, however, only discrete assemblages of geomorphic units are of interest to the user (e.g. Perth Canyon Mass Movement and Current-induced Process units: Nanson et al., 2022); indeed, the detail provided by full coverage maps may obscure priority units. In many cases full coverage maps can be simplified and their symbology modified to emphasise subsets of units for specific end-users. Alternatively, it may be economical to consider priority geomorphic unit targets much earlier in a project program, particularly in survey planning stages. Indeed, the identification of target geomorphic units early in a project is key to the appropriate prioritisation of typically finite survey resources; geophysical data should be collected at appropriate scales to support the development of bathymetry grids at optimal resolutions for their end-users, and planning should ensure that there is sufficient ancillary data collected (e.g. sub-bottom profiles, sediment samples) to minimise uncertainty in seafloor geomorphic interpretations.

Table 16-1 lists six broad indicative applications for mapping BGU and BGU-T. Though this list is not intended to be exhaustive, it forms a useful initial step towards indicating and supporting the communication of marine geomorphic map unit priorities for the decision maker, and to ensure their prioritisation for optimal end-user uptake, internal agency communication, and other budgeting considerations. Future work will refine this list of applications and will include additional metrics for the spatial and temporal scales over which BGU and BGU-T develop and are preserved, and the realistic scales of bathymetry grid that are sufficient for capturing the seafloor expression of each unit.

*Table 16-1 Potential applications for mapped BGU and BGU-T. These applications are indicated alongside each term in the Glossary. *Note this list is primarily intended to emphasise the primary insights to be gained by mapping geomorphic units at the seabed; nearly all buried palaeo-units could be used to reconstruct past environments (Application IV).*

Potential applications		Examples
(I)	to infer potential habitat	Ocean management, seafood industry, biodiversity, conservation (e.g. Harris and Baker, 2011).
(II)	seafloor stability assessment	To assess landslide and tsunami risk (e.g. Bardet et al., 2003); develop GIS ground models for offshore renewables (e.g. Barwise et al., 2014); for safe navigation, infrastructure for hydrocarbons.
(III)	sediment modelling	To infer near seafloor energy, sediment transport pathways, volumes / budgets (e.g. Stow et al., 2009).
(IV)	climate and past environment reconstruction	For studies of modern climate change, palaeoenvironmental reconstruction, archaeology (e.g. Brooke et al., 2017; O'Leary et al., 2020).
(V)	coastal and marine management	To investigate environmental, erosion, seafood industry, recreational fishing, administrative borders.
(VI)	mineral resources assessment	To locate fluvial and coastal placer deposits (Kudrass, 2017) and aggregates.

17 Glossary of terms

The full glossary of terms used in this report is divided into two parts. The next chapter (Chapter 18) provides an index of these terms to assist the user in determining which Setting / Process each BGU and BGU-T is described in. Table 17-1 defines general terms used to support the application of the approach. Table 17.2 presents definitions for over 400 individual BGU and BGU-T that are described and illustrated in each Setting / Process chapter. The next chapter (Chapter 18) provides an index of these terms to assist the user in determining where to find the Setting / Process for each BGU and BGU-T.

Table 17-1 Glossary of general terms used in this report.

	Term	Sub-term	Definition
General terms	geomorphology (adj.: geomorphic)		The study of the shape of the Earth's surface and the processes forming them (modified from Harris and Baker, 2011). This may include, but is distinct from, geomorphometry - the science of quantitative terrain characterization, which encompasses acquisition and processing of topographic data as well as analyses and applications related to geomorphology (see Lecours et al., 2016).
	landform		One of the central study objects in the field of geomorphology (the other objects being special linear or point features, like break lines, thalwegs or peaks), a feature of the land surface with conspicuous shape and distinct characteristics (Evans, 2012; MacMillan and Shary, 2009)
	Setting		Used herein, the term SETTING is used to group geomorphic units formed in specific environments and are the broadest (alongside PROCESS) Part 2 terms for classifying Part 1 Morphology FEATURES.
	Process		The term PROCESS is used herein to group geomorphic units formed by similar processes and are the broadest (alongside SETTING) Part 2 terms for classifying Part 1 Morphology FEATURES.
	Basic Geomorphic Unit (BGU)		BGU are the broadest geomorphic terms used to classify Part 1 (MORPHOLOGY) FEATURE shapes and can always be simplified up to their SETTING/PROCESS categories (this report).
	BGU – Type (BGU-T)		BGU-T are defined for commonly used sub-categories of BGU, and can always be simplified up to their BGU and SETTING/PROCESS categories (this report).
	BGU – sub-Type (BGU-sT)		BGU-sT provide more granular classification of BGU-T, but can always be simplified up to their BGU-T, BGU and SETTING/PROCESS categories (this report). BGU-sT definitions are not included in this glossary.
	Unit		Used herein, the term UNIT refers to a three-dimensional geomorphic interpretation of (Part1: MORPHOLOGY) FEATURES, and usually incorporate both sub-surface (stratigraphic) and formative process interpretations.
	Feature		A list of terms that are used to define seafloor MORPHOLOGY; these were primarily sourced from the list of terms and definitions provided in the IHO (International Hydrographic Organization, 2019) list of undersea Feature Names which were subsequently updated and illustrated in Dove et al., (2020: Part 1). MORPHOLOGY FEATURE terms (e.g. Ridge, Canyon) are capitalised as proper nouns to help distinguish them from more general morphological descriptors (e.g. upper canyon, canyon wall, crests; Dove et al., 2020)
	Morphology		The shape of the seafloor surface. Where capitalised, "Morphology" is used in specific reference to Part 1 MORPHOLOGY (Dove et al., 2020) and the FEATURES defined therein.
Additional attribute terms	field (of units)		Delineation of groups of smaller geomorphic units that may or may not be individually and / or partially mapped (e.g. a polygon defining a field of partially mapped DUNES; a polygon defining a field of submarine GULLIES)
	age, relative	relict	Units that formed prior to the Late Holocene under a different process regime to the present, and which are no longer active.
		palimpsest	Units that are relict in origin but which are still undergoing modification by modern processes.
		modern	Units formed by active processes, typically more recently than the Late Holocene
	depth, relative	surface	Units that have been mapped at the surface and have minimal discernible buried component.
		buried	Units that have been mapped either at the surface or in the sub-surface (e.g. using sub-bottom imagery) and have minimal surface expression (e.g. a buried FLUVIAL VALLEY visible in sub-bottom data).

	Term	Sub-term	Definition
		partially-buried	Geomorphic units that have clear, though partial, seafloor expression (e.g. coarser-grained BEDFORMS amongst muddier PLANE BED).
	sea level	transgressive	Units formed during a shoreline transgression (landward migration) associated with a relative sea-level rise (Muto and Steel, 1997)
		regressive	Units formed during a shoreline regression (seaward advance) associated with a relative sea-level fall (forced or normal; (Muto and Steel, 1997)
		stillstand	Units formed during a relative sea-level stillstand.(Muto and Steel, 1997)
Additional attribute terms	lithology		Categories for defining the composition of geomorphic units may include, but are not limited to: siliclastic, carbonate, beach rock or bedrock
	grain size	particle size	The size distribution of a unit sample, described using the Wentworth (1922) scheme.
		texture	The proportion of mud, sand and gravel that comprise a sample, described using the Folk (1954) classification scheme.
	morphometrics		Quantitative analysis of the external shape and size of morphological features. Terrain *derivatives* such as: bathymetric position index (BPI), terrain ruggedness index, slope, aspect, curvature and rugosity are widely used as morphometric parameters with the help of geographic information systems.
	marginal marine process		The relative contribution of wave, tide and fluvial processes that have formed a unit. E.g. A mapped MOUTHBAR may be fluvial-dominated, tide-influenced and wave-affected (Ftw Ainsworth et al., 2011).
Physiography	continental shelf		The seabed regionadjacent to a continent (or around an island), composed of continental crust, and extending from the low-water line to a depth at which there is usually a marked increase of slope towards oceanic depths (modified after Harris et al., 2014).
	continental slope		Geological boundary marking the transition between continental and oceanic crust. It is located seaward from the shelf edge to the upper edge of a CONTINENTAL RISE or the point where there is a general reduction in slope. There are two kinds of CONTINENTAL SLOPE, one associated with passive continental margins, the other with active margins (Harff et al., 2016).
	continental rise		A gentle slope rising from the oceanic depths towards the foot of a CONTINENTAL SLOPE, created by the accumulation of sediments at the foot of CONTINENTAL SLOPES (Harris et al., 2014).
	mid-ocean ridge		A linear, narrow volcanic and tectonic region which marks the constructive boundary between two tectonic plates. It is divided into segments by transform FAULTS and other offsets. Depending on the speed of the spreading centre, AXIAL HIGHS or AXIAL VALLEYS can form (Harff et al., 2016).
	axial high		Elongated ridge up to 15–20 km wide and 500 m high relative to nearby abyssal plain with the shallowest points around neovolcanic zone. The presence of axial highs is due to the upwelling of hot mantle beneath fast spreading centres (Harff et al., 2016).
	axial valley		The axial depression of a MID-OCEAN RIDGE, characteristic of slow spreading centers (Harff et al., 2016).
	abyssal plain		An extensive, flat or gently sloping region, usually found at depths greater than 4 km, covered by up to 1 km sediment thicknesses consisting of fine-grained erosional detritus and biogenic particles (Harff et al., 2016).
	oceanic trench		elongated, deep and narrow trench between the ABYSSAL PLAINS and the border of the upper plate where oceanic lithosphere is bent downward under the margin of the upper plate and dives into the asthenosphere. An oceanic trench is about 2 km deeper than the surrounding ocean floor (Harff et al., 2016).
	accretionary prism		Sedimentary wedge at a convergent plate margin above a subduction zone created by material of the subducting lower plate scraped off and transferred to the overriding upper plate (modified after Harff et al., 2016).
	back-arc basin		An oceanic basin behind a volcanic arc associated with an intraoceanic subduction zone (modified after Harff et al., 2016).
	fore-arc basin		An oceanic basin in forearc regions between the OCEANIC TRENCH and the volcanic front (modified after Harff et al., 2016).
	island arc		Marine subset of currently active or formerly active VOLCANOES located near the boundary between two converging tectonic plates. The VOLCANOES are located 150–350 km away from the OCEANIC TRENCH on the overlying plate and define an arc in plan view (modified after Harff et al., 2016).

*Table 17-2 The glossary of BGU and BGU-T terms: * **BGU** and **BGU-T** terms in bold can develop in multiple Settings / Processes; **where definitions include terms in* CAPS *these are BGU and BGU-T that are defined elsewhere in this glossary; *** Apps I – VI refer to indicative applications and / or implications for identifying and mapping each unit; these categories are described in Chapter 16 (Table 16-1).*

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Fluvial	drainage basin (*aka. catchment*)		Includes the DRAINAGE NETWORK and all surfaces draining to them (modified from Goudie, 2006).	III, IV
Fluvial	drainage network		A collection of SUBAERIAL CHANNELS joined together (modified from Goudie, 2006). Can be sub-classified by their planform pattern, which are frequently used to infer their processes and development (BGU-T: dendritic; parallel; radial; centrifugal; centripetal; distributary; angular; trellis; or annular: Twidale, 2004)	ALL
Fluvial	alluvial fan		Usually cone-shaped forms with surface slopes radiating away from an apex located at the point where the feeder SUBAERIAL CHANNEL splits to form DISTRIBUTARY CHANNELS. Their fan-like geometry can be modified by the confinement of neighbouring fans or valley walls (modified from Goudie, 2006).	III, IV, VI
Fluvial	alluvial fan lobe		ALLUVIAL FAN sedimentation is usually restricted to one part of the fan surface at a time, and the sedimentology of these FAN LOBES are typically internally consistent. ALLUVIAL FAN LOBES are abandoned, and new ones are initiated, by channel avulsion.	III, IV, VI
Coastal *or* Fluvial	**subaerial valley**		Form via combinations of fluvial and coastal processes (see *Additional Attributes: Marginal marine process classification*); they widen by lateral SUBAERIAL CHANNEL erosion and weathering, and lengthen by both headward erosion and progradation in their lower reaches. SUBAERIAL VALLEYS can form networks with a variety of drainage patterns (see DRAINAGE NETWORK; modified from Goudie, 2006). Cf. RIVER VALLEY; INCISED VALLEY; RIA; FJORD.	ALL
Fluvial		river valley	A type of SUBAERIAL VALLEY formed by fluvial processes upstream of any tidal limit (though can be affected by base-level changes; cf. INCISED VALLEY).	ALL
Coastal *or* Fluvial		**incised valley**	A type of SUBAERIAL VALLEY; fluvially-eroded, elongate paleotopographic lows that are generally larger than a single channel, and usually develop during a fall in relative sea level and so display abrupt basinward shift of facies at their base. INCISED VALLEY fills typically begin to accumulate during base-level rise (Zaitlin et al., 1994). Cross-shelf and coastal plain (BGU-sT) INCISED VALLEY fills have relatively distinct facies (Wang et al., 2020).	ALL
Coastal		ria	A type of SUBAERIAL VALLEY; a coastal inlet resulting from the drowning of a former SUBAERIAL VALLEY (modified from Goudie, 2006).	ALL
Coastal		**fjord**	A type of SUBAERIAL VALLEY; a glacial valley that is drowned by seawater. Cf. Glacial Setting: FJORD; U-SHAPED VALLEY.	ALL
Coastal *or* Fluvial	**floodplain terrace**		Planar-surfaced units that remain after the adjacent channel has incised and abandoned the surface (Brierley and Fryirs, 2013) and can be comprised of alluvial material (cf. FLOODPLAINS) or rock (cf. STRATH; modified from Goudie, 2006).	ALL
Coastal *or* Fluvial	**floodplain terrace**	**strath**	STRATH are FLOODPLAIN TERRACES that are comprised of bedrock; their elevation can be used as indicators of palaeo sea levels (modified from Goudie, 2006).	II, III, IV

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Coastal or Fluviall	**channel ledge**		Distinctly stepped, flat-topped, elongate, bank-attached units. Have straight to gently curved planforms and flank one or both banks. Composed of the same materials as the adjacent FLOODPLAIN (i.e. sediments are laterally continuous from the ledge into their adjacent FLOODPLAIN) and are formed by channel expansion processes where flows selectively erode the upper units of the adjacent surface as the channel incises and expands (Brierley and Fryirs, 2013).	II, III, IV, V
	floodplain		The relatively flat area of land between the banks of the parent stream and the confining valley walls, over which water from the parent stream flows at times of high discharge. The sediment that comprises a FLOODPLAIN is mainly alluvium derived from the parent stream (modified from Goudie, 2006) and can be comprised of CONFINED / CUT-AND-FILL, BRAIDED, LATERAL MIGRATION or ANABRANCHING FLOODPLAIN deposits (Nanson and Croke, 1992).	II, III, IV, V, VI
		high-energy confined floodplain	Develop in steep-walled, high energy (>300 W/m^2) VALLEYS, can be comprised of poorly sorted or vertically accreted alluvium, and typically erode and deposit during catastrophic flows (Nanson and Croke, 1992).	II, III, IV, V, VI
		medium-energy unconfined floodplain	Develop in medium energy (10 – 300 W/m^2) and generally unconfined settings by both lateral migration and overbank accretion during regular flow events, and usually have coarser-grained (high permeability) basal strata (Nanson and Croke, 1992).	II, III, IV, V, VI
		low-energy cohesive floodplain	Develop in low energy (<10 W/m^2), low gradient settings by overbank accretion of coarse to more typically fine sediment, deposited by anastomosing or laterally-stable meandering channels (Nanson and Croke, 1992).	II, III, IV, V, VI
	delta		A discrete shoreline sedimentary protuberance formed where a river enters a body of water and supplies sediment more rapidly than it can be redistributed by basinal processes (modified from: Elliott, 1986).	ALL
		front	The subaqueous portion of the delta between the subaerial delta and its associated MOUTHBARS and above wave base, where relatively coarse material is deposited (Postma, 1984; Suter, 1994)	I, II, III, IV, V, VI
		pro-	The relatively low gradient, subaqueous portion of a delta below wave base, where relatively fine material is deposited.	III
Coastal		upper	The portion of a DELTA that is situated between the backwater and tidal limits.	III, IV, V, VI
		lower	The portion of a DELTA directly affected by tides.	III, IV, V, VI
		bayhead	A type of DELTA located in the landward zone of an embayment, comprising terrigenous sediment sourced from the catchment (Dalrymple et al., 1992).	III, IV, V, VI
		shelf edge	A DELTA located at the continental shelf break and extending onto the slope that forms during a lowstand of sea level and subsequent sea level rise, resulting in (partial) preservation (Steel et al., 2013))	III, IV, V, VI
		tidal delta	Ebb- and flood-TIDAL DELTAS are comprised of intertidal and subtidal deposits that accumulate where tidal flows expand after passing through a tidal inlet. Ebb-tidal deltas form seaward and flood-tidal deltas form landward of an inlet (Hayes, 1980).	ALL
Coastal *or* Fluvial	**delta lobe**		Discrete accumulations of sediment that form at the distal end of relatively confined river channels and may represent distinct avulsion events (Chatanantavet et al., 2012). Multiple DELTA LOBES sum to comprise entire DELTAS.	ALL

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
	channel belt	A conglomeration of relatively coarser-grained sediment comprised of amalgamated SUBAERIAL CHANNEL, BEDFORM and BARFORM deposits (modified from Bridge and Tye, 2000; cf. Marine versus Fluvial CHANNEL BELT geometries: Jobe et al., 2016)		ALL
	subaerial channel	Formed of alluvium, usually have mobile boundaries and are self-adjusting in response to changing conditions. Commonly parabolic or trapezoid in cross section with adjacent, roughly horizontal FLOODPLAINS are inundated when the channel exceeds bankfull capacity (modified from Goudie, 2006).		ALL
		river	A relatively large SUBAERIAL CHANNEL.	ALL
		creek	A relatively minor SUBAERIAL CHANNEL, which may be a tributary to a RIVER or DISTRIBUTARY or may flow directly into a BACKBARRIER or the open coast.	I, II, III, V
		distributary	DISTRIBUTARY channels radiate from a parent SUBAERIAL CHANNEL, which they may re-join, and tend to decrease in capacity and sediment calibre, and increase in heterogeneity, downstream as they become increasingly influenced by coastal processes (e.g. tides, waves, backwater effects: Nichols and Fisher, 2007; cf. Lane et al., 2017)	III, IV, V, VI
		gully	Though diverse in form, GULLIES tend to be relatively small (though larger than RILLS), steep, narrow, deeply incised SUBAERIAL CHANNELS that are carved into unconsolidated regolith (modified from Goudie, 2006).	I, II, III, IV
		rill	Very small (< 30 cm depth and width) SUBAERIAL CHANNELS caused by runoff from rainsplash puddles. RILLS sometimes extend downslope where they can flow into GULLIES (modified from Goudie, 2006).	II, III, IV
		tidal inlet	An opening in the shoreline through which water penetrates the land, thereby providing a connection between the open ocean and the BACK-BARRIER that is maintained by tidal currents (modified from Davis Jr and FitzGerald, 2009).	II, III, IV, V
Coastal	Coastal barform	Any type of BARFORM formed in a Coastal Setting; the exact BGU-T or BGU-sT may be unknown or may exceed classification requirements.		ALL
		nearshore bar	A deposit of sand or gravel that forms in the nearshore (subtidal) zone of a BEACH. Variable in planform, ranging from straight to cresentic to transverse (oblique to shoreline). May be continuous alongshore or discontinuous with rip channels separating adjacent bars (Short, 1999).	II, III, IV, V
		berm	A bench of sand, gravel or cobble sediment formed directly landward of the high-tide level on a BEACH, incorporating a berm crest that defines a steepening of the beach seaward (Otvos, 2000).	II, III, IV, V
		shoreface terrace (*aka. intertidal terrace* or *marine terrace*)	SHOREFACE TERRACES are formed by subaerial weathering during lowstand exposure and wave erosion that drove the coastline landward during subsequent sea-level rise (Micallef et al., 2017) Cf. RAISED BEACH	IV
		beach cusp (*aka. crescentic bar*)	A rhythmic shoreline unit that forms by wave swash action on sand or gravel BEACHES. Crescentic shape in planform comprising a gently sloping embayment (erosional) flanked by steeper cusp horns (depositional). Typically present as sets of evenly spaced multiple cusps (Masselink and Hughes, 2014).	V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Coastal		ridge and runnel	A low gradient sand bar and trough that forms alongshore in the intertidal zone of a BEACH. On macrotidal beaches, multiple ridges (Cf. INTERTIDAL BARS) and runnels may form across the intertidal zone spanning tens to hundreds of metres (Masselink and Hughes, 2014).	V
		washover bar	A low gradient sandy to gravelly deposit located on the landward side of a BARRIER deposited over a BACK-BARRIER FLAT or LAGOON facies, formed by storm surge or tsunami run-up. Typically fan shaped in plan view (Reineck and Singh, 2012).	III, IV, V
		intertidal bar (*aka. ridgebar*)	A low gradient sand bar that forms in the intertidal zone of BEACHES. On macrotidal coasts, multiple bars typically form into a RIDGE AND RUNNEL system (Masselink and Hughes, 2014).	II, III, IV
		tidal bar	Discontinuous COASTAL BARS that typically form in tide-dominated SUBAERIAL CHANNELS, which are aligned to the dominant flow direction (Dalrymple et al., 1992).	II, III, IV
	barrier complex *(aka. barrier system)*	Amalgamated, shore-parallel sand bodies incorporating BEACH, coastal dunes (DUNE - foredune BGU-sT), WASHOVER and backbarrier FLAT deposits. May comprise multiple shorelines to form a PLAIN (STRAND- or CHENIER) (modified from Griffin et al., 2012).		ALL
		chenier plain	Assemblages of CHENIER RIDGES and the FLATS or marsh that separate them (modified from Griffin et al., 2012).	I, II, III, IV, V
		strandplain	Assemblages of multiple BEACH RIDGES and BARRIERS. Small CREEKS (Fluvial) draining the immediate hinterland may exist within a STRANDPLAIN, however, they are usually associated with negligible river input (Heap, 2001).	ALL
	barrier	Elongate accumulations of sand or coarser sediment primarily deposited by waves and longshore currents, rising above the present sea level, often impounding terrestrial drainage or blocking off a LAGOON in the BACKBARRIER (modified from Griffin et al., 2012; Woodroffe, 2002). Can be sub-classified using their number of attachment points to the mainland (cf. SALIENT/TOMBOLO; BAY-MOUTH; SPIT).		ALL
		salient / tombolo	A type of BARRIER that joins an island to the mainland or other islands, and are the result of longshore sediment drift or the migration of an offshore bar toward the coast. Salients are the subtidal version of tombolos (modified from Goudie, 2006)	II, III, IV, V
		bay-mouth barrier	A type of BARRIER that blocks a bays entrance; are commonly backed by shallow bays and LAGOONS. Often found along microtidal coasts where there is insufficient tidal energy to maintain an open TIDAL INLET (modified from Davis Jr and FitzGerald, 2009).	ALL
		barrier spit	Types of BARRIERS that tend to form on irregular coasts where relatively high rates of longshore sediment supply promote spit building across embayments and effectively straighten the coast, or in the case of flying spits where the shoreline is protected and BARRIER SPITS extend into deep water. Subtypes (BGU-sT) include *flying spits*, *continuation*, *constrained bay-mouth* and *cuspate foreland* spits (modified from Davis Jr and FitzGerald, 2009).	I, II, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Coastal		barrier island	A type of BARRIER that are generally narrow, parallel with, and detached from the main shoreline. Tend to occur in chains that may extend for hundreds of kilometres, (modified from Davis Jr and FitzGerald, 2009).	ALL
	back-barrier	A relatively protected area between the BARRIER and the mainland, which may be occupied by FLATS or a LAGOON. (modified from Davis Jr and FitzGerald, 2009)		I, III, IV, V
	beach ridge	Relict ridges of wave origin, sub- to parallel to the open coastline, possibly including wind deposits that collectively form STRANDPLAINS. Active BEACH and shore ridge forms (cf. Current-induced Processes: DUNES – foredune BGU-sT), regardless of their dimensions, shape or origin, are not considered to be BEACH RIDGES by most authors (e.g. Otvos, 2020, modified from 2000).		ALL
	chenier ridge	Sandy or shelly elongate Ridges (MORPHOLOGY), differentiated from other sand or shell BEACH RIDGES by the fact that they are perched over fine-grained, muddy (or sometimes marshy) sediments and are separated from one another by these finer-grained deposits (modified from Goudie, 2006).		I, II, III, IV, V
	beachface (*aka. foreshore*)	The coastal area between the low-tide shoreline (SHOREFACE) and the maximum height of wave effect.		II, III, V
	shoreface	The relatively steep surface between the low-tide shoreline and the inner shelf. The lower boundary of the SHOREFACE commences where ocean swell waves begin to shoal towards the shore (modified from Boak and Turner, 2005; Woodroffe, 2002).		II, III, V
	tidal flat	Low gradient intertidal to supratidal surfaces formed in fine-grained sediment (Woodroffe, 2002).		I, III, V
		supratidal flat	A near-horizontal depositional surface formed above mean high water spring tide level. Typically located on the landward margins of saltmarshes and along estuary and lagoon shorelines.	I, III, V
		subtidal flat	A low gradient surface formed below mean low tide level. Typically located at the seaward of saltmarsh and mangrove communities.	I, III, V
		intertidal flat	A low gradient surface that emerges at low tide and is inundated at high tide. Typically occupied by mangrove and saltmarsh communities.	I, III, V
	lagoon	A stretch of usually saline water separated from the sea by a low BARRIER or coral reef (Cf. REEF LAGOON - Biogenic; Goudie, 2006).		I, III, IV, V
		closed lagoon	A LAGOON that is isolated from the sea by a BARRIER.	I, III, IV, V
		open lagoon	A LAGOON that is open to tidal exchange via a narrow tidal inlet, or channel through a BARRIER - Coastal.	I, III, IV, V
		intermittently closed and open lagoon	A LAGOON that switches from being open and closed to tidal exchange, due to flucutations in freshwater input.	I, III, IV, V
	beach	A wave-deposited body of sand or gravel formed along open coast (marine), estuarine and lacustrine shorelines.		III, IV, V
		reflective	A relatively steep sand or gravel deposit comprising a wide and high berm, steep beachface, subtidal step and low gradient nearshore zone (Short, 1999).	III, IV, V
		intermediate	A low gradient sand or gravel deposit comprising a berm of variable width and height, BEACH CUSPS, and nearshore trough and bar of variable planform (straight, crescentic, transverse); may also feature a SHOREFACE TERRACE or RIDGE AND RUNNEL attached to the beachface (Short, 1999).	III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Coastal		dissipative	A gently sloping sand or gravel deposit, comprising a flat to concave beachface and shallow nearshore trough with no longshore variability (Short, 1999).	III, IV, V
		reef *or* rock affected beach	A steep (reflective) BEACH fronted by exposed rock that extends seaward as an intertidal rock platform or rock flat (Short, 2006).	III, V, VI
	raised beach	A relict landform comprising mostly wave-transported sedimentary material preserved above and landward of the active shoreline. RAISED BEACHES are distinguished here from raised SHOREFACE TERRACES on the basis that the former are solely the product of physical depositional mechanisms, whereas the latter have a broader genesis that may incorporate depositional, erosional and/or biogenic processes (modified from Goudie, 2006).		IV
	rocky coast	Any length of coast that is predominantly characterised by rock (rather than sediment or vegetation).		III, V
		outcrop	A general term to describe coast and seafloor that is composed of undifferentiated ROCKY OUTCROP.	I, II, III, IV
		plunging cliff	A near-vertical slope that continues below the water line, typically greater than 100 m high and formed in resistant lithology.	V
		cliff	A steep slope, or ESCARPMENT formed in rock, ranging in height from tens to hundreds of metres.	II, V
		toe	The base of a CLIFF defined by a marked change in gradient, typically associated with deposits of rock debris or talus.	II, V
		shore platform	An horizontal or gently sloping rock surface located in the intertidal zone and typically extending from the base of a cliff. Also termed wave-cut platforms, but this term is no longer used in recognition that platforms are the product of the combined effects of mechanical, chemical and biological processes (Trenhaile, 1987).	I, IV, V
		notch	A shallow erosional indentation in a CLIFF face that forms around mean high tide level. More common in rocks less resistant to weathering, notably limestone (Masselink and Hughes, 2014).	IV, V
		stack	A free-standing, isolated pillar of rock located seaward of low tide line, typically formed in more resistant lithology and defining the former position of a CLIFF line.	II, V
		arch	An erosional unit that forms a sea opening (or tunnel) through a rocky headland but with a land connection maintained, forming the roof (Woodroffe, 2002).	II, V
		pool	A shallow (< 3 m) depression formed in the intertidal zone of SHORE PLATFORM, typically resulting from solution of rock by standing water and are enclosed by small ridges (also known as Lapies or marine karren) (Guilcher, 1988).	I, V
		cave	A large erosional indentation in a CLIFF face that forms around mean high tide level. May extends tens of metres into the cliff face, particularly in less resistant lithologies such as limestone or sandstone. Typically the product of wave action.	V
		ramp	A seaward sloping steeper section of a sub-horizontal SHORE PLATFORM, typically abutting the TOE of a CLIFF (Sunamura, 1992)	II, V
		pothole	A deep POOL formed in the intertidal zone of a SHORE PLATFORM, typically formed by the gouging action of loose boulders (Woodroffe, 2002).	I, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
		furrow	A narrow incision across the surface of a sub-horizontal SHORE PLATFORM, in some cases extending the width of the platform to low tide line (Sunamura, 1992).	V
		rampart	A slightly raised edge that forms at the seaward margin of sub-horizontal SHORE PLATFORMS, possibly associated with a more resistant lithology.	V
Marine	marine barform	Tend to be larger than CURRENT-INDUCED BEDFORMS (e.g. Venditti, 2013), are often forced by macro-scale topography (e.g. channels – point bar; headlands - banner), and develop over longer periods of time (e.g. Dury, 1970).		ALL
		contourite drift	A type of SEDIMENT DRIFT associated with contourite deposition. CONTOURITE DRIFTS are commonly formed on continental rise to lower slope settings, and produced primarily by thermohaline-induced deepwater bottom currents though may be influenced by wind or tidal forces. The geomorphology of contourite deposits is mainly influenced by the bottom-current velocity, sediment supply, and seafloor topography, and the morphology of the drifts can be variable (Heezen and Hollister, 1964; Rebesco et al., 2014; Stow et al., 2002).	II, III, IV
		sediment apron	A typically smooth-surfaced, gently-dipping accumulation of sediment (of variable spatial-scale), connected to a separate bathymetric high, that is at least partially elevated relative to the adjacent seafloor (Gardner, 1970).	II, III, V
		sediment drift	Typically longitudinal unit (I.e., aligned with dominant current flow) of variable sediment thickness, sometimes observed in the lee of another large unit (Belderson et al., 1982).	I,II, III, V
		sediment bank (*aka. sediment ridge*)	Formed by interactions between current instabilities (commonly generating cyclonic flows) and unconsolidated sediment at the seabed. SEDIMENT BANKS are the largest Current-induced BEDFORMS within the Submarine Setting and require sufficiently rapid current flows and high rates of sediment supply. Their morphology, orientation, and potential mobility depends on local hydrodynamic and physiographic conditions (Belderson et al., 1982; Dyer and Huntley, 1999; Kenyon and Cooper, 2005).	I,II, III, IV, V, VI
		sediment lobe	SEDIMENT LOBES, together with channels, are a major component of turbiditic SUBMARINE FAN systems and deposits. Lobate in plan-view and mounded in cross-section, depositional lobes are expected to be connected to feeder channels. SEDIMENT LOBES are commonly sand-rich, exhibiting coarsening upwards grain size trends (David M. Hodgson et al., 2022; Shanmugam and Moiola, 1988).	II, III, IV
	submarine valley	Smaller than SUBMARINE CANYONS and generally located on more gentle slopes. SUBMARINE VALLEYS may be associated with internal and/or external LEVEES and SUBMARINE TERRACES and, in contrast to SUBMARINE CHANNELS, they are shaped by supplementary processes including channel entrenchment, lateral migration, and aggradation (Harris et al., 2014; Lemay et al., 2020).		ALL
	submarine channel	Formed by sediment-laden turbidity currents and other sediment-rich gravity currents (Klaucke and Hesse, 1996; Peakall et al., 2000; Peakall and Sumner, 2015).		ALL

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Marine	submarine channel belt		A a coherent package of channel-related depositsthat may incorporate both vertical and/or lateral accretion components Their planform morphology may include linear, sinuous, or meandering channels (Janocko et al., 2013; Jobe et al., 2016).	III, IV, VI
	submarine gully		Small-scale (<10 km) confined channels, generally on the order of tens of meters deep and often linear in planform. SUBMARINE GULLIES are commonly found within or alongside SUBMARINE CANYONS on the continental slope and may represent an incipient stage of canyon development (Amblas et al., 2018; Gales et al., 2013; Izumi, 2004; Micallef and Mountjoy, 2011; Pratson et al., 2007).	II, III, IV
	submarine canyon		Steep-sided, GENERALLY V-shaped valleys with heads at or near the CONTINENTAL SHELF edge. They extend across the CONTINENTALSLOPE and are commonly linked to numerous tributaries, similar to unglaciated river-cut canyons on land (Amblas et al., 2018; Covault, 2011; Harris and Baker, 2011; Huang et al., 2014; Pratson et al., 2007; Puig et al., 2014).	I, II, III, IV
		shelf-incising canyon	SUBMARINE CANYONS that extend up from the CONTINENTAL SLOPE and are incised into CONTINENTAL SHELF towards the coast, where potentially associated with a terrestrial fluvial system (Harris and Whiteway, 2011).	I, II, III, IV
		slope-confined canyon (*aka. blind canyons*)	SUBMARINE CANYONS that are restricted to the CONTINENTAL SLOPE, and are not geometrically connected to the CONTINENTAL SHELF (Harris and Whiteway, 2011).	I, II, III, IV
	submarine tributary canyon		Secondary or subordinate components of SUBMARINE CANYONS that are, directed towards a typically larger primary SUBMARINE CANYON. They have their own CANYON HEAD.	I, II, III, IV
	canyon head		The upslope start or boundary of a SUBMARINE CANYON (Amblas et al., 2018).	I, II, III, IV
	canyon mouth		The downslope terminus or boundary of a SUBMARINE CANYON.	I, II, III, IV
	submarine fan		Develop on the CONTINENTAL SLOPE, RISE and ABYSSAL PLAIN, normally at the mouths of SUBMARINE CANYONS. They are constructed principally from the deposits of sediment gravity flows (mainly turbidity currents and debris flows) as terrigenous and shallow marine sediment is redistributed into deeper water (Clark et al., 1992; Covault, 2011; Deptuck and Sylvester, 2018; Shanmugam, 2016).	II, III, IV, VI
	submarine terrace		Form within SUBMARINE VALLEYS and SUBMARINE CANYONS as a result of the incision of their adjacent SUBMARINE CHANNEL, which causes the decoupling of their surfaces from the active channel.	II, III, IV, VI
	reef		A general term for an occurrence of rock, biogenic, or other stable material that lies at or near the sea surface, and is elevated at least partially above the surrounding seabed. REEFS may be further classified using the chapters on Anthropogenic Processes or Biogenic Processes.	I, II, III, IV, V
	marine barform		Tend to be larger than CURRENT-INDUCED BEDFORMS (e.g. Venditti, 2013), are often forced by macro-scale topography (e.g. channels – point bar; headlands - banner), and develop over longer periods of time (e.g. Dury, 1970).	ALL
Glacial	U-shaped valley		*A valley having a pronounced parabolic cross-profile suggesting the form of a broad letter 'U' with steep parallel walls and a broad, nearly flat floor; specifically a valley carved by glacial erosion, such as a glacial trough or fjord* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		hanging valley	*A tributary glacial valley opening at a relatively high level on the steep side of a larger glacial-cut valley occupied, or formerly occupied, by a trunk glacier. The height drop between the floors of the two valleys is due to the greater erosive power of the trunk*	I, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Glacial			*glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	
	cross-shelf trough		*A wide (several to tens of kilometres) elongate depression of the seafloor, usually a few hundred metres deep, extending across the continental shelf between shallower banks; commonly eroded by grounded ice-sheets over successive full-glacial periods. See transverse channel/trough* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, II, III, IV, V
		valley/trough head	A valley/trough head is the upper end of a valley/trough, formed at the upper part of a valley glacier or ice stream (Benn and Evans, 2010).	I, III, IV, V
	fjord		*A U-shaped glacial trough whose floor is occupied by the sea. Typically, fjords are steep-sided, overdeepened rock basins with shallow thresholds at the coast. Their form is characteristic of erosion by ice streams, outlet glaciers or valley glaciers which exploited either pre-existing river valleys or underlying weaknesses in the bedrock* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, II, III, IV, V, VI
	sill/threshold		*A relatively shallow ridge or rise separating one basin from another. Sills are common in fjords where they consist of a sub-marine barrier of rock or moraine that occurs at the mouth of, or between, basins* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V
	basin		*In marine geology, a more or less equi-dimensional depression in the seafloor...* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016). Basins ranging from small depressions to trough-width basins may be formed in bedrock and/or soft sediments, by glacier erosion, glacitectonic thrusting and/or sediment deformation on soft beds (Benn and Evans, 2010).	I, III, IV, V
	streamlined landform		Streamlined landforms have been sculpted and moulded by glacier ice, moving in a coherent direction. These landforms can consist of bedrock, unconsolidated sediments or both. They are formed parallel to the ice flow direction and are considered good palaeo-flow indicators. Elongation is considered to be positively correlated with higher ice flow velocities (Stokes and Clark, 1999, 2002; Krabbendam et al., 2016)	I, IV
		roche moutonnée	*A bedrock landform is streamlined by subglacial that erosion in the direction of ice flow. The landform is often asymmetrical in long profile, with a smooth up-ice end produced by ice abrasion and a rougher down-ice termination produced by plucking associated with lee-side subglacial cavities. Whalebacks are also elongate streamlined bedrock landforms but are usually symmetrical in form* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V
		whaleback	See definition for ROCHE MOUTONNEE.	I, III, IV, V
		crag and tail	*An elongate hill or ridge in which a resistant mass of bedrock (the crag) has withstood the passage of an ice sheet or glacier, thereby either protecting, or causing the deposition in a lee-side cavity, of an elongate ridge (the tail) of more easily eroded sedimentary debris, often till, on its ice-distal side* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V
		drumlin	*A low, smoothly rounded and streamlined overall hill or mound, commonly elongated parallel to the former ice-flow direction with a blunter up-ice face, composed of till or stratified drift, and sometimes having a bedrock core; formed by either erosion or deposition beneath an actively flowing glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Glacial		flute	*Narrow, elongate, straight, parallel ridge generally consisting of till but sometimes composed of sand or silt/clay* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V
		groove	An elongate, ice flow-parallel furrow cut in bedrock (Benn and Evans, 2010; Krabbendam et al., 2016).	I, III, IV, V
		mega-scale glacial lineation	*Elongate landforms, produced typically in subglacial sediments, which reflect fast ice flow of an ice sheet and thought to be indicative of ice streaming. MSGLs characteristically have length:width ratios greater than 15:1 and have a convergent flow pattern. MSGLs typically have a large zone of convergence feeding into a main trunk, which may then diverge again near the ice margin* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV, V
		bundle structure	An elongated sediment body consisting of groups of mega-scale glacial lineations (MSGLs) (Canals and Amblas 2016 In: Dowdeswell et al., 2016).	I, II, III, IV, V
	rogen (ribbed) moraine		*A moraine transverse to the direction of ice flow, formed of large transverse ridges, giving the overall appearance of an animal's ribs. The ridges, consisting of till for the most part are generally steep-sided. In plan view, they appear slightly curved and wavy, and their ends merge to form poorly defined ridges which intersect at different angles* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	meltwater channel		*A channel produced by the flow of glacial meltwater. Where the channel is subglacial, pressurized water may flow upslope as well as downslope, producing an undulating channel long-profile* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	tunnel valley		*A large subglacial, steep-sided channel cut into unconsolidated sediment or bedrock by meltwater. The channel may have a reverse gradient in places* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, II, III, IV, V
	glacitectonic raft		*Dislocated slab of unconsolidated sediment or rock that has been entrained and transported from its original position by subglacial processes. Large rafts are sometimes referred to as megablocks* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016). See also HILL-HOLE PAIR.	I, III, IV, V
	thrust-block moraine		THRUST-BLOCK MORAINES (composite ridges) are heavily glacitectonised ridges formed by thrusting of blocks/slabs of sediments in front of a glacier (Benn and Evans, 2010).	I, III, IV, V
	cupola hill		CUPOLA HILLS are THRUST-BLOCK MORAINES or HILL HOLE PAIRS that have been overridden by glaciers (Benn and Evans, 2010).	I, III, IV, V
	hill-hole pair		*A discrete hill of ice-thrust material, often slightly deformed, situated downglacier from a depression of approximately the same size and shape. Either pre-existing drift or bedrock may be contained in the dislocated hill* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		glacitectonic hill	See definition of HILL-HOLE PAIR.	I, III, IV, V
		glacitectonic hole	See definition of HILL-HOLE PAIR.	I, III, IV, V
	medial moraine		*Moraine formed at the confluence of two glaciers, where debris can be entrained at the glacier bed and surface. Entrained debris can be a shallow unit or extend to the base of the glacier, depending on the detailed mechanisms of formation* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016)	I, III, IV
	crevasse-filling		*A relatively straight ridge of stratified sand and gravel, till or other sediments, formed by the filling of a (surface or basal) crevasse in a*	I, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Glacial	*(aka. crevasse-squeeze ridge)*	*stagnant glacier which later melted* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		
	hummocky terrain	A glacial landscape with a highly irregular surface, characterised by a series of small mounds, ridges and depressions. Associated with glacier/ice sheet grounding zones (Ottesen and Dowdeswell, 2009).		I, III, IV, V
	erratic	*Said of a large rock or boulder carried by a glacier or by floating ice and deposited when the ice melted, well away from its place of origin and therefore contrasting with the country rock* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		I, III, IV, V
	esker	*A long, narrow, sinuous ridge of stratified glacifluvial material (generally sand and gravel) deposited by a stream normally flowing beneath a stagnant or retreating glacier in an ice tunnel or subglacial stream bed, and left behind after the disappearance of the glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		I, III, IV, V
	moraine	*A mound, ridge or other distinct accumulation of generally unsorted, unstratified glacigenic sediment, predominantly till, deposited chiefly by direct contact with glacier ice, commonly subglacial. See De Geer moraine, end moraine, fluted moraine, interlobate moraine, kame moraine, lateral moraine* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		I, III, IV, V
		recessional moraine	*An end moraine built during a temporary but significant pause in the final retreat of a glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		lateral moraine	*A ridge of glacial debris flanking a glacier side or lying along the sides of a valley formerly occupied by a glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		shear-margin moraine	*Elongate ridges found on the edges of shallow bas at cross-shelf trough lateral margins, formed subglacially at ice-stream shear zones with surrounding slower-moving ice* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		push moraine	*An end moraine formed by the 'bulldozing' of sediment by an advancing ice front* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		terminal moraine	*An end moraine that marks the furthest advance of a glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
		De Geer moraine	*A moraine transverse to the direction of ice flow, formed of a succession of low, relatively narrow, regularly spaced ridges. It forms in shallow bodies of water at the glacier terminus* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	grounding zone wedge	*A sedimentary depocentre formed at the grounding zone of an ice-sheet/ice-shelf system, formed of dipping diamicton beds overlain by horizontal sheets of diamicton, mainly subglacial till. Till emerging from beneath the glacier along a line-source is redistributed by subaqueous debris flows, producing diamicton beds that dip away from the margin. GZWs are usually asymmetrical in long-profile, steeper in the ice-distal direction* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		I, III, IV, V
	ice-proximal fan *(aka. grounding-line fan, grounding*	*Fan-shaped sediments produced by deposition from sediment-laden meltwater as it exits from subglacial meltwater tunnels, usually at the base of tidewater glacier terminal ice cliffs* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).		I, II, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Glacial	*zone fan, ice-contact fan)*			
	ice-contact delta		ICE-CONTACT DELTAS form at glacier margins and develop from e.g. ice-proximal grounding line fans or other submerged depositional units (Benn and Evans, 2010).	I, II, III, IV, V
	corrugation ridges *(aka. ribs)*		Small, regularly spaced ridges formed by tidal-induced movement of icebergs or a glacier grounding line during retreat (Bell et al. 2016; Dowdeswell et al. 2020). Ridge spacing indicates the rate of iceberg drift and grounding line retreat (Batchelor et al. 2023).	I, III, IV, V
	sub-ice shelf keel scour mark		Sub-ice shelf keel scour marks consist of highly linear splayed lineations, occasionally cross-cutting, that display low parallel conformity. They record the transition from a grounded to a sub-ice shelf environment and form an intermediary landform between curvilinear iceberg ploughmarks and glacial lineations. They are hypothesised to where ice reaches flotation in newly opened ice shelf cavities (Smith et al., 2019).	I, III, IV, V
	glacigenic debris flow/lobe		GLACIGENIC DEBRIS FLOWS are consecutive mass-flows that deposit prograding lobes/wedges of sediment beyond a glacier grounding-line (King et al., 1998; Laberg and Vorren, 1996).	I, II, III, IV, V
	trough-mouth fan		*A large fan-shaped depositional body located at the seaward end, or mouth, of a cross-shelf trough that has been largely eroded by grounded ice-sheets. The fan is built mainly from sediments carried by the ice sheets, and especially by fast-flowing ice streams within it. Some authors restrict the term to fans built principally of glacigenic debris-flows* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, II, III, IV, V
	iceberg ploughmark		*Groove or furrow caused by the impact and movement of grounded icebergs along the sea or lake floor* (Excerpt from Bell et al. 2016 In: Dowdeswell et al., 2016).	I, III, IV, V
		single-keeled ploughmark	An ICEBERG PLOUGHMARK characterised by one groove ploughed by an iceberg with a singular keel (Lien et al., 1989).	I, III, IV, V
		multi-keeled plouhgmark	An ICEBERG PLOUGHMARK characterised by several parallel grooves ploughed simultaneously by multiple iceberg keels (Lien et al., 1989)	I, III, IV, V
	iceberg grounding pit		*A discrete, usually roughly circular depression in seafloor sediment caused by the impact of the keel of an iceberg* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	corrugation ridges within ploughmarks		*Small, parallel ridges formed within ice-berg ploughmarks by icebergs moving up and down in response to tides while ploughing the seafloor* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	kettle hole		*Steep-sided hollow produced by the melt-out of an original deposit which also contained finer materials that were removed by wind or water action* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
	proglacial meltwater channel		*Meltwater channel (see definition further up), occurring in area immediately beyond the limits of a glacier* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, II, III, IV, V
	glacifluvial delta *(aka. glacier-fed delta)*		*There are many different kinds of deltas; all have relatively flat delta plains, frequently triangular (fan) shaped in plan view, and steeper delta-front slopes. In cross-section, the archetypal delta consists of flat-lying topset beds over steeper foreset beds, which rest on bottomset beds that are usually thin and fine-grained. The typical GLACIFLUVIAL DELTA usually consists of coarser-grained sediments, and their front slopes are steep with foreset beds generally dipping 10-30°* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016). GLACIFLUVIAL DELTAS are also referred to as *glacier-fed* deltas as terrestrial proglacial meltwater streams/rivers carry sediments from a glacier to the marine/lacustrine environment (Benn and Evans, 2010).	I, II, III, IV, V

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
	glacifluvial outwash plain (Sandur)		*Laterally extensive flat plain of sand and gravel with braided streams of glacial meltwater flowing across them when active. It is an Icelandic term meaning 'sand'* (Excerpt from Bell et al. 2016, adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, III, IV, V
Solid Earth	oceanic core complex		The uplifted footwalls of oceanic detachment FAULTS. They are elevated, dome-shaped massifs, typically with prominent spreading-parallel corrugations on smoothly curved upper surfaces. These surfaces represent exposed now-inactive low-angle FAULT planes that have been directly responsible for the exhumation of mantle and plutonic lithologies onto the seafloor (Maffione et al., 2013; Tucholke et al., 1998).	II
	axial volcanic ridge		Composite volcanic edifices, comprising an elongate, typically spreading-normal orientated topographic high, produced within the inner valleys of mid-ocean ridges, usually those that are slow spreading (modified after Harff et al., 2016).	II
	abyssal hill		An isolated (or tract of) small elevation(s) on the deep seafloor parallel to a mid ocean ridge and formed by volcanism and block faulting.	II
	volcano (island or submarine)		A mountain or hill, typically conical, having a crater or vent through which lava, rock fragments, hot vapour, and gas are or have been erupted from the earth's crust (modified after Huggett, 2017).	I
		Seamount	Any geographically isolated topographic unit on the seafloor taller than 1000 m. Most seamounts are formed by igneous activity close to mid-ocean ridges, island arcs, or in mid-plate settings, although blocks of continental crust, stranded during the opening of ocean basins, can form nonvolcanic seamounts (Harff et al., 2016; Harris and Baker, 2020).	I, V
		Guyot	Flat-topped SEAMOUNTS, usually former VOLCANOES that are in many cases capped by drowned atoll REEFS and pelagic sediments (Harff et al., 2016).	I, V
		Stratovolcano	a conical VOLCANO built up by many layers of hardened lava and tephra (modified after Huggett, 2017).	II
		shield volcano	very large, broad, shield-like VOLCANOES that have a low aspect ratio caused by low viscosity lava eruptions that spreads far from the source (modified after Huggett, 2017).	II
	impact crater (*aka. astrobleme*)		Remains of an ancient meteorite-impact structure on the Earth's surface, generally in the form of a circular scar of crushed and deformed bedrock (modified after Huggett, 2017).	II
	magmatic outcrop		A magmatic bedrock outcrop of unspecified lithology (modified after Huggett, 2017).	II, VI
		circular volcanic depression	Roughly circular, cauldron-like depression generally characterized by steep sides and formed during or after a volcanic eruption by volcanic or structural processes (modified after Huggett, 2017).	II
		volcanic fissure	Elongate fracture or crack at the surface of a volcanic unit from which lava erupts (modified after Huggett, 2017).	II
		volcanic plateau	Large areas of elevated, over-thickened basaltic ocean floor, formed either as the result of seafloor spreading processes and melting of ambient upper mantle or by decompression melting of hot mantle plumes (Harff et al., 2016).	II
		magmatic dome	Dome-shaped magmatic structures formed by intrusive forces are found within the lithosphere (modified after Huggett, 2017).	II
		magmatic sheet	Tabular, sheet-like magmatic intrusions into crustal structural weaknesses (Harff et al., 2016).	II

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Solid Earth		volcanic flow	Lobated or fan-like low-relief and rugged unit representing a submarine lava flow (Casalbore, 2018).	II
		volcanic plug/neck	Pinnacle or knoll formed by magma solidified within a volcanic vent or magma chamber (modified after Huggett, 2017).	II
	tectonic depression		A depression generated by an unspecified tectonic/structural process	II
		tectonic basin	A depression or basin of variable size and shape formed by tectonic processes	II
		graben	A long and narrow valley formed by subsidence between two parallel FAULTS (modified after Huggett, 2017).	II
		half graben	A GRABEN-like structure bounded by a major FAULT only on one side (modified after Huggett, 2017).	II
		fault valley	A linear depression produced by faulting; e.g. a small, narrow valley created within a major FAULT zone by relative depression of narrow slices (modified after Huggett, 2017).	II
	tectonic lineament		A lineament that forms as a result of unspecified tectonic/structural activity (modified after Huggett, 2017).	II
		fault	A discrete surface, or zone of discrete surfaces, expressed as fractures at seabed, separating two rock masses across which one mass has slid past the other (Asch et al., 2021).	II
		joint	Small-scale fractures along which no movement has taken place, or at least no differential movement (Huggett, 2017).	II
		fracture zone	Linear units on the ocean floor—often hundreds, even thousands of kilometers long—resulting from the action of offset MID-OCEAN RIDGE axis segments (Harff et al., 2016).	II
	tectonic escarpment		An escarpment that forms as a result of unspecified faulting activity (Huggett, 2017).	II
	tectonic high		A positive relief generated by an unspecified tectonic/structural process.	II
		compressional ridge	A topographic ridge produced by compression caused by tectonic and/or volcanic processes.	II
		horst	Long and fairly narrow section of seabed raised by upthrust between two FAULTS (modified after Huggett, 2017).	II
		back-tilted fault block	Section of tilted seabed between two FAULTS. The tilting may produce high relief and intervening basins (modified after Huggett, 2017).	II
		tectonic dome	A dome-like unit of variable size formed by tectonic processes.	II
	bedding ridge		A positive relief generated by bedrock bedding (modified after Huggett, 2017).	I, II
		cuesta	Gently dipping BEDDED BEDROCK OUTCROP with an asymmetrical cross-section of escarpment and dip-slope(modified after Huggett, 2017).	I, II
		homoclinal ridge	Moderately dipping BEDDED BEDROCK OUTCROP with just ridge about asymmetrical cross-section (modified after Huggett, 2017).	I, II
		hogback	Steeply dipping BEDDED BEDROCK OUTCROP with symmetrical cross-section (modified after Huggett, 2017).	I, II

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
	dip slope (*aka. bench*)		A natural/gradual slope on the surface of the seabed which is parallel to the dip of the underlying strata (modified after Huggett, 2017).	I, II
	scarp slope (*aka. cliff*)		A relatively steep face of a scarp created by a resistant cap rock overlying a relatively weak and erodible stratum (modified after Huggett, 2017).	I, II
	bedrock outcrop (undefined)		A relief formed by bedrock of unspecified lithology and genesis cropping out of the surrounding seabed.	I, II
		bedded	a BEDROCK OUTCROP whose texture shows bedding or sedimentary stratification.	
		foliated	A BEDROCK OUTCROP showing a foliated texture, indicative of a metamorphosed nature.	
		massive	A BEDROCK OUTCROP showing a massive texture, often indicative of a magmatic nature.	
Current-induced	**Current-induced channel**		A channel of any scale that has been formed by any type of flow.	ALL
	chute channel		A channel with typically more rapid flow that cuts through constrictive material and so short-cuts the main flow (e.g. through a BARFORM in a SUBAERIAL CHANNEL; between BARRIER ISLANDS; Goudie, 2006).	II, III, IV, V
	oxbow		An abandoned channel reach, typically meandering in planview, formed as a result of channel cut-off and channel adjustment (Reineck and Singh, 2012).	III, IV, V, VI
	plunge pool		Depressions situated downstream of steep reaches of SUBAERIAL and SUBMARINE CHANNELS, VALLEYS and GULLIES, and CANYONS, and downstream of escarpments where flows either excavate basement material (e.g. downstream of indurated sediment in SUBAERIAL CHANNELS or CANYONS) or maintain depth and deposit material further downstream.	I, II, III
	bedform		Quasi-rhythmic, erosional or depositional units formed at the interface between sediment and a lower-density medium (e.g. water, air, ice or pyroclastic flows). BEDFORMS constitute the bulk of sediment transport (Robert, 2014) and scale to changing flow properties (e.g. Simons and Richardson, 1966). BEDFORMS often develop over BARFORMS in response to changing flow conditions (Simons and Richardson, 1966).	ALL
		Scour	An erosive BEDFORM depression, aligned with the flow direction; can form at a large range of scales, and may be associated with a forcing unit (e.g. OBSTACLE AND COMET SCOUR).	II, III
		Furrow	Elongate, primarily erosional BEDFORMS, with regular to irregular spacing and a parallel to slightly sinuous planform. They are characterized by incision into the seafloor and are relatively large in scale (width 5–150 m, length 1–10 km). Once established they may develop BEDFORMS within them, in contrast to finer-grained deposition between FURROWS (modified from: Stow et al., 2009).	II, III
		obstacle and comet scour	OBSTACLE (*aka. crag*) AND COMET SCOUR refers to the crescentic to elongate scour marks around and extending downstream from an obstacle in the path of flow. Although these may include depositional tails, they occur at relatively high flow velocities (0.4 to >1 m s−1) and are principally erosional in origin. Scour length varies from meters to hundreds of meters. Forms transitional to CRAG AND TAIL structures with small-sized obstacles and less well-developed SCOUR marks (decimeter scale) occur at the lower end of this velocity spectrum. Erosional SCOUR crescents, irregular pluck marks, and tool marks may all occur without an associated obstacle (Stow et al., 2009).	II, III

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Current-induced		**cyclic step**	Supercritical net-accretionary units which accumulate over multiple turbidity current events (Slootman and Cartigny, 2020).	II, III, IV
		dune (*aka*: *sediment wave*, *sediment ridge*, or *megaripple*)	Dunes have a broad range of morphologies and represent larger transverse bedforms (wavelength 0.6–10 m, height 0.1–1 m) than RIPPLES (modified from: Stow et al., 2009). Used herein, DUNES include typically large sand waves and megaripples, as well as coastal foredunes (BGU-sT).	ALL
		ripple	Ripples are the smallest-scale transverse bedforms (wavelength 0.1–0.6 m, height 0.02–0.1 m), representing lower flow velocity (0.1–0.6 m s−1) over a fine to medium sandy substrate. In planform, there are straight-crested, undulatory (sinuous crested), and linguoid (3-D) types. In profile, most are asymmetrical with sharp to rounded crestlines (Stow et al., 2009).	I, III
		plane bed	Can develop during opposing ends of flow energy spectrum, via limited to no sediment movement (sub-critical flow) or by excess flow velocity relative to sediment supply (supercritical flow) (Simons and Richardson, 1966). Alternatively, PLANE BEDS can accumulate via passive fallout of suspended sediment (e.g. biogenic accumulation).	II, III, V
		sediment streak	Linear BEDFORMS elongated sub- to parallel to the flow direction, which may merge laterally or longitudinally, and vary greatly in scale and grain size. Form in velocity ranges from 0.1 to 0.2 m s−1 on mud, up to 0.3 m s−1 on sand, and 0.5 m s−1 on sand and/or gravel (modified from: Stow et al., 2009).	I, II, III
		sediment ribbon	Ribbon marks are elongate mounded filaments of sand (and/or gravel), mostly regularly spaced, with parallel to slightly sinuous plan-form. They may show gentle curvature in parallel with the flow pattern, and merge into or diverge from broad sand sheets. Most of those reported are large-scale bedforms (width 10–100 m, length 5–50 km), although smaller-scale units (width of a few meters) have been referred to as narrow ribbons, sand streamers and sand streaks. They are high-velocity bedforms (generally 0.7–1.5 m s−1) that involve winnowing and erosion of a sand or sand and gravel substrate coupled with redeposition of the material into elongate ribbon mound (Stow et al., 2009).	I, II, III
		lineation	Thin and narrow linear accumulations of sediment that may develop downstream of OBSTACLE AND SCOUR or CRAG AND TAIL, or ielsewhere under relatively low flow velocities and independent of other BEDFORMS (cf. Stow et al., 2009).	I, II, III
		crag and tail	The elongate mound (tail or shadow) deposited immediately downstream of an obstacle (crag) in the path of flow (tail length centimeter to decimeter). They begin to appear on muddy and sandy substrates in association with surface lineation (0.1–0.3 m s−1). They become more prominent and widespread, and occur in association with comet scour and erosional pluck marks, at slightly higher velocities (<0.4 m s−1). Mound and tail is the term used for similar structures where the obstacle is a biogenic (or other) mud mound. There may also be a genetic link with	I, II, III

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Current-induced			rhomboid ripples or rill marks, which develop on generally planar beds at flow velocities slightly greater than those required for surface lineation (Stow et al., 2009).	
		lag	Relatively coarse sediment that remains after finer material has been winnowed away by flows. Often forms a protective layer over mixed / finer grained sediment below, but may also occur over unrelated hard substrate.	I, II, III, VI
	barform	Tend to be larger than BEDFORMS (e.g. Venditti, 2013), are often forced by macro-scale topography (e.g. channels – point bar; headlands - banner), and develop over longer periods of time (e.g. Dury, 1970).		ALL
		pointbar	Are situated along the convex banks of bends in SUBAERIAL and SUBMARINE CHANNELS. They typically have an arcuate shape that reflects the radius of curvature of the bend. The cross-sectional slope of the bar is inclined towards the centre of the channel, reflecting the asymmetrical channel geometry at the bend apex. Textural attributes of the bar reflect patterns of secondary helical flow over the bar surface, which vary between Settings (e.g. Marine, Fluvial, Coastal; Modified from: Goudie, 2006) and POINT BARS may develop into SCROLL BARS. In preserved deposits POINT BARS may appear to be superficially similar to COUNTERPOINT BARS.	III, IV, V, VI
		counterpoint	Occur downstream or distal to bends in SUBAERIAL and SUBMARINE CHANNELS and are preserved as concave-shaped SCROLL BAR patterns. In preserved deposits COUNTERPOINT BARS are superficially similar to POINT BARS (modified from: Smith et al., 2009).	III, IV, V, VI
		scroll	Quasi-regularly spaced ridges that form over POINT BARS, which continue subsurface as laterally accreted heterolithic strata that fine upwards. Their development may be related to episodes of channel widening and, in SUBAERIAL CHANNELS, may form in association with vegetation growth on the POINTBAR (modified from: Nanson, 1980; van de Lageweg et al., 2014).	III, IV, VI
		mid-channel	Most common in actively meandering channels and tend to develop in steeper channel sections downstream of rapidly eroding bends where the channel is overwidened, and though they have lower preservation potential (Goudie, 2006) they may evolve towards bank attachment (Hooke, 1986; Alabyan and Chalov, 1998). Cf BANK-ATTACHED BARS	III, V, VI
		bank-attached	Any kind of bank-attached BARFORM in SUBAERIAL or SUBMARINE CHANNELS. Tend to form in channels that are well adjusted to their supplied sediment load (Goudie, 2006).	III, V, VI
		riffle (and pool)	A type of channelised BARFORM that alternates with pools, and are characterised by higher velocity flow over their surfaces. Develop in alluvial and bedrock channels and are most common in meandering channels with moderate gradients (modified from: Goudie, 2006).	III, V, VI

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Current-induced		**ledge**	An erosional channelised BARFORM that develops through flow erosion into a channel bank. LEDGE stratigraphy is continuous with the adjacent channel margin (usually FLOODPLAIN or TERRACE) into which the channel flow has eroded. Unpaired LEDGES reflect lateral flow shift during incision, whereas paired ledges indicate incision only (modified from: Brierley and Fryirs, 2013). Cf FLOODPLAIN TERRACE.	III, IV, VI
		bench	A channelised, bank attached BARFORM. A distinctly stepped, elongate, straight to gently curved unit that is inset along one or both banks, usually over other BARFORMS and are formed by oblique- and vertical-accretion in overwidened channels (modified from: Brierley and Fryirs, 2013).	III, IV, VI
		levee	A typically wedge-shaped BARFORM formed of channel-derived, suspended sediment that fines upwards and also away from the channel source. LEVEES vary markedly in scale, though Marine LEVEES tend to be much larger than their terrestrial counterparts (modified from: Goudie, 2006).	II, III, IV, VI
		mouthbar	Form where coarse sediment is delivered to the mouth of SUBAERIAL (Wright et al., 1974) and SUBMARINE CHANNELS (David M Hodgson et al., 2022).	I, II, III, IV, VI
		crevasse splay	Generally fan-shaped deposits that accumulate downstream of breaches in subaerial and submarine LEVEES.	II, III, IV, V, VI
	knickpoint	A KNICKPOINT is a substantially steepened section of a long profile (modified from Goudie, 2006), usually measured along the thalweg or centreline of a CHANNEL, VALLEY or CANYON.		III, IV
Biogenic	**reef**	In-situ, positive relief, persistent build-ups of primarily skeleton-supported framework (+ internal binding), that influence the local sedimentary environment (Klement, 1967), and supports (or supported) living communities during active accretion. Definition modified from a range of sources: (Cumings, 1932; Goudie, 2006; Harris and Baker, 2020; Klement, 1967; Lo Iacono et al., 2018). Cf. REEF (Marine Setting)		I, II, III, IV, V
	fore-reef	The outside slope of a coral REEF seaward of the REEF CREST (or reef edge) facing open sea (Cabioch, 2011; Maxwell, 1968).		
	reef crest	Reef top behind the FORE-REEF, comprising an elevated rim and hard coralgal pavement which attenuates wave energy (Maxwell, 1968).		
	reef flat	The most recent expression of coral growth at sea level, extending back from the FORE-REEF. There are two forms of reef flats: (1) coral-dominated and (2) rubble-dominated, modulated by the ambient energy conditions as the growing reef approaches sea-level (Maxwell, 1968; Thornborough and Davies, 2011).		
	back reef	Wide (up to kms) zone extending back from the REEF FLAT, mainly found in linear-shaped reefs. Back reef zone supports scattered small submerged PATCH REEFS and extensive sand bank development (Maxwell, 1968).		
	reef lagoon	Fully or partly enclosed shallow depressions in coral REEFs (Hopley, 2011; Maxwell, 1968).		
	spur-and-groove	Best developed on the windward side of coral REEFS, the spur-and-grooves consists of parallel elongate Channels (MORPHOLOGY) or Grooves (MORPHOLOGY), a few metres wide and deep, separated by seaward-extending coral Ridges (MORPHOLOGY) or spurs (Harris and Baker, 2020; Maxwell, 1968; Shinn, 2011).		
		cold-water-coral reef	Framework REEF constructed by azooxanthellate coral, commonly *Lophelia pertusa* and *Madrepora oculata* (Lo Iacono et al., 2018), plus sediment	I, II, III, IV

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Biogenic			trapping/baffling interspersed with dead framework rubble. Other organisms from the cool-water carbonate factory (Schlager, 2003) contribute to build-ups (Lo Iacono et al., 2018).	
		Coralligène	Calcareous algal-invertebrate build-ups mainly produced by generations of calcareous red algae, common in the temperate Mediterranean region, with relatively low relief (cm to m) (Basso et al., 2022; Laborel, 1961; Lo Iacono et al., 2018). May be further classified as bank or rim (Pérès and Picard, 1964).	I, II, III, IV, V
		patch reef	Often found nearby or within other REEF types. Characterised by isolated patches of reef that are physically separated from other reef patches by the surrounding substrate (Brodie and Cohn, 2021; Maxwell, 1968).	I, II, III, IV, V
		fringing reef	REEFS that grow very close to the shore on mainland or high island (continental shelf or volcanic mid-ocean island) coasts. Generally shore-attached, although BACK-REEF areas can be shallowly submerged (Maxwell, 1968; Smithers, 2011).	I, II, III, IV, V
		barrier reef	A REEF that is separated from the main coast by a deep Channel (MORPHOLOGY) or LAGOON (Coastal Setting). Initial formation occurs on the offshore edge in open water, with subsequent growth parallel to or toward the coast (Brodie and Cohn, 2021; Maxwell, 1968).	I, II, III, IV, V
		Atoll	Annular mid-ocean REEFS; the REEF rim supports isolated, or near-continuous, reef islands composed of unlithified or poorly consolidated sand or gravel, and encloses a central lagoon (Harris and Baker, 2020; Woodroffe and Biribo, 2011).	I, II, III, IV, V
		platform reef	A flat or nearly flat area of live or dead coral REEF elevated above the surrounding seafloor and dropping off in depth abruptly on one or more sides (Harris and Baker, 2020). Platform reefs tend to grow in all directions, and can reach sea level (Maxwell, 1968), forming islands which then may form fringing reefs around them (Brodie and Cohn, 2021).	I, II, III, IV, V
	bioherm (*aka. mound*)	Build-ups with lens-like positive relief (Cumings, 1932), with variable skeletal and matrix components (± binding); skeletal components are adjacent and some may be in contact, but are mostly disarticulated (modified from Riding, 2002). (e.g., *Halimeda* bioherm). Synonym 'mound'; includes carbonate 'mud mound' (modified from Riding, 2002). Usually parautochthonous to allochthonous.		I, II, III, IV, V
		lenticular	Three-dimensional structure with convex lens-like shape.	
		reticulate	Three-dimensional structure with net-like or honeycomb-like shape/pattern.	
		annulate/annular	Three-dimensional structure with ring-like shape/pattern.	
		agglutinating	Organic binding of inorganic sediment providing structural support; no skeletal component and limited topographic relief (Riding, 2002) (e.g. *Sabellaria* polychaete bioherm/mound). Usually allochthonous.	I, III, V
	biostrome (*aka. bed*)	Build-ups lacking the lens-like positive relief that would otherwise classify the unit as a bioherm (Cumings, 1932); bedded or unbedded (Kershaw, 1994) with variable skeletal and matrix components. Synonym 'bed' (Kershaw, 1994). Usually parautochthonous to allochthonous.		I, II, III, IV

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Biogenic		ribbon	Biostrome geometry may be further classified as 'ribbon' or 'sheet' (Kershaw, 1994).	I, II, III, IV
		sheet	Biostrome geometry may be further classified as 'ribbon' or 'sheet' (Kershaw, 1994).	I, II, III, IV
	mat (*aka. bed*)	A sheet-like organic and detrital-rich accumulation generated from baffling and trapping (± binding) by macrophytes (e.g. seagrass), filamentous algae and cyanobacteria to form an organo-sedimentary build-up. Examples include 'algal mat' and 'seagrass bed'. Usually allochthonous.		I, II, III
	excavation	A mappable unit representing sediment transport or reworking by the activity of living benthic infauna and epifauna (bioturbation) (modified from Kristensen et al., 2012). Often mapped as a FIELD, rather than individual components, including (not limited to) feeding trace, nest, burrow, boring, resting site, track, trail, mound.		I, II, III
Mass Movement	fall	A relatively free-falling abrupt movement of newly detached material from steep slopes or cliffs. The source area of a fall is not usually directly identified in bathymetry data, being only indirectly mapped, by identifying the cliff face associated with debris or rock fragments accumulation at the base of the slope. Different types of FALLS can be described by the nature of the material remobilized.		II
		rock fall	A type of FALL where rocks break away from the cliff face and fall, bounce or roll downslope. The rock normally breaks along discontinuities such as fractures, joints, and bedding planes.	II
		debris fall	A type of FALL where debris break away from a steep slope and fall, bounce or roll downslope.	II
	topple	A mass movement produced by forward rotation around a pivot or hinge on a slope below the centre of gravity of the displaced mass. Different types of falls are described by the nature of the material remobilized.		II
		rock topple	Forward rotation and overturning of rock columns or plates (one or many) separated by closely-spaced, steeply-dipping joints.	II
		debris topple	A type of TOPPLE where a block of cohesive material, separated by vertical joints, rotates forward.	II
	slide	A slide consists of the movement of a coherent mass of material along a distinct shear surface. The shear surface type is used to divide different SLIDES into two groups (modified from Goudie, 2006).		II, III
		translational slide	A type of SLIDE characterised by a non-circular failure which involves translational motion on a near planar slip surface. The movement is largely controlled by surfaces of weakness within the structure of the slope-forming material.	II, III
		Rotational slide (*aka. slump*)	A type of SLIDE characterised by a rotational movement on a circular or spoon-shaped shear surface.	II, III
		frontally confined slide	A SLIDE where the compressional TOE region was buttressed by a ramp separating their fill from their foreland. This type of SLIDE does not show a prominent bathymetric expression compared to their total thickening and implies a relatively modest downslope transfer of sediment (Frey-Martínez et al., 2006).	II, III
		frontally emergent slide	A SLIDE where the compressional TOE region develops above the downslope undisturbed strata, having overridden their ramps. This type of SLIDE shows major bathymetric expressions and involves the downslope transport of significant volumes of material (Frey-Martínez et al., 2006).	II, III

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Mass Movement	flow		A mass movement where the individual particles travel separately within a moving mass. They involve highly fractured rock, clastic debris in a fine matrix or small grain sizes.	II, III
		rock avalanche	A FLOW where rock break away from the source area, disintegrates and propagates as a flow of cohesionless rock fragments, blocks and clasts with high mobility.	II, III
		debris flow	A FLOW where the mobilised material is a mixture of fine material (sand, silt and clay) and coarse material (gravel and boulders), with a variable quantity of water, forming a muddy slurry which moves downslope (see GLACIOGENIC DEBRIS FLOW within the Glacial Setting).	II, III
		mudflow	A FLOW where the mobilised material is of single and fine grain size and coarse clasts are rare.	II, III
		turbidity current	As fluid content increases due to continued downslope movement, a debris flow can evolve into a turbulent flow such as a turbidity current where the mobilised material is supported by a fluid. Turbidity currents can travel nearly hundreds to thousands of kilometres over very gentle slopes (Bagnold, 1962) before their dissipation and deposition.	II, III, IV
	lateral spread		A mass movement produced by the lateral extension of a cohesive rock or debris over a deforming mass of softer underlying material (modified from Goudie, 2006). They usually occur on very gentle slopes or flat terrain and the failure is caused by liquefaction, the process whereby saturated, loose, cohesionless sediments (usually sands and silts) are transformed from a solid into a liquefied state.	II, IV
	complex		A mass movement where one form of failure develops into a second form of movement *i.e.* a change of behaviour downslope by the same material.	II
	evacuation zone (aka. headwall domain; depletion zone; extensional domain)		The most upslope zone of a mass movement, within which the remobilized material lies below the original ground surface (modified from: Cruden, 1993). Its upper limit is set by the geometry of the HEAD SCARP and this zone is normally dominated by extension features such as Blocks or elongated Ridges (Nissen et al., 1999).	I, II
	depositional zone (aka. accumulation zone; compressional domain)		The most downslope zone of a mass movement, within which the displaced material lies above the original ground surface (modified from: Cruden, 1993). Its lower limit is set by the geometry of the TOE. The DEPOSITIONAL ZONE of SLIDES tends to be dominated by a compressional regime (e.g. thrust and fold systems), whereas for FLOWS the material tends to disperse forming fans or aprons at the base of the slope.	II
	head scarp *(aka. headwall)*		The upslope boundary of a mass movement, set between undisturbed and remobilised material. It is the visible part of the surface of rupture and can be defined as an extensional failure surface linked at depth to the basal shear surface. In plan-view, head scarps are typified by an arcuate geometry well-defined continuous scarp, particularly in mass movements associated with a higher degree of desegregation (e.g., SLIDES, FLOWS). However, a head scarp can also present a sinuous geometry due to localised retrogressive erosion of the scarp (Bull et al., 2009).	II
	lateral scarp *(aka. sidewall)*		A scarp, normally parallel to the main direction of transport, which represents the lateral confining boundary to a mass movement. Depending on the overall structure and type of collapse, a lateral scarp may only have a minor superficial expression or be associated with a steep relief.	II

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Mass Movement	minor scarp *(aka. secondary escarpment)*		A scarp that can appear morphologically similar to a HEAD SCARP but is fully located within the EVACUATION ZONE and downslope the HEAD SCARP.	II
	crown crack (aka. tension cracks)		A type of open fracture found within partically undisplaced material upslope the EVACUATION AREA and generally parallel to the HEADD SCARP.	II
	transverse crack		A type of open fracture, perpendicular to the main direction of transport, they tend to be found either at the EVACUATION ZONE or overlying the intersection between the lower part of the surface of rupture and the original ground surface (Cruden and Varnes, 1996).	II
	remnant block		A Block of undisturbed, coherent sediment, found within the remobilised material but which has not been displaced during the mass movement. This type of in situ block can be recognised in seismic profiles by the contrast between areas of lateral concordant and continuous seismic facies and the often chaotic facies of the remoulded material.	II
	translated block		A Block of undisturbed, coherent sediment, which has been displaced by a mass movement, preserving at least two relatively flat surfaces.	II
		detached block	A TRANSLATED BLOCK that shows minimal transport and, when elongated, aligned with their long axis parallel to the nearest upslope scarp.	II
		rafted block	A TRANSLATED BLOCK of undisturbed material which have been transported within the main body of a mass movement.	III
		outrunner block	A TRANSLATED BLOCK that glided beyond the main body of a mass movement, in some cases over sufficient distances to become aligned with their long axis parallel to the direction of flow (Nissen et al., 1999).	II
	extensional ridge		An elongated Ridge separated by normal faults, typically observed close to the head scarp.	II, V
	compressional ridge *(aka. transverse ridge)*		An elongated Ridge perpendicular to the main direction of transport, typically found in the distal parts of slides with the deformation front limiting the downslope extent of the slide.	II,
	turbidite levee		An elongated Ridge flanking the margins of a turbidity channel, formed by the embankment of sediments overflowed a TURBIDITY CHANNEL.	II, V
	toe		The lower boundary of a mass movement, set between the remobilised and undisturbed material. This, usually curved, margin will coincide with the intersection between the lower part of the surface of rupture of a landslide and the original ground surface, in the case of the FRONTALLY CONFINED SLIDES. Whereas if the remobilised material moved beyond the lower part of the surface of rupture, overlying the original ground surface, this boundary may be diffuse, showing limited bathymetric expression.	II
	mudflow gully		A narrow, incised SUBMARINE GULLY formed by a single or multiple mudflows events. Mudflow gullies of varying scales exert different influences on the distribution of the associated DEPOSITIONAL ZONE and influence the connectivity and continuity reservoirs.	II, III
	turbidity channel		A SUBMARINE CHANNEL formed by the interaction of TURBIDITY CURRENTS with an erodible seabed.	II, III
	talus apron		An Apron (MORPHOLOGY) formed by the accumulation of broken rock fragments at the base of a steep slope as the result of multiple mass movement events. These are not typically developed within the marine environment but can be found associated with nearshore slope instability.	II
	debris apron		An Apron formed by the accumulation of debris at the base of a steep slope. as the result of multiple mass movement events. These are not typically developed within the marine environment but can be found associated with nearshore slope instability.	II
	talus fan		A Fan formed by the accumulation of broken rock fragments at the base of a steep slope as the result of multiple mass movement events. These are	II

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
		not typically developed within the marine environment but can be found associated to nearshore slope instability.		
	debris fan	A Fan formed by the accumulation of debris at the base of a steep slope, as the result of multiple mass movement events, in particular, DEBRIS FLOWS.		II
	mudflow fan	A Fan formed by the accumulation of sediments as the result of multiple MUD FLOW events. These will be smaller and less complex than SUBMARINE FAN.		II, III
	turbidite fan	A Fan formed by the accumulation of sediments as the result of multiple TURBIDITY CURRENTS. These will be smaller and less complex than SUBMARINE FAN.		II, III
Fluid Flow	mud volcano	A positive topographic unit, usually conical, formed by the periodic upwelling of sediments (mud) fluidised by gas and water (Etiope, 2015). It can develop as a single isolated cone (that can be several hundreds of meters high) or, more frequently, as groups of cones. MUD VOLCANOES can be classified by their morphologies, with the key distinction made on the grounds of angle of the flanks.		I, II, III, V, VI
		mud dome (aka. cone)	A MUD VOLCANO (a mean surface slope of >10°) formed when the upwelling mud remains plastic (Lance et al., 1998).	I, II, III, V, VI
		mud pie	This type of MUD VOLCANOES is characterised by a mean surface slope of <5°. The feeder, or *conduit*, is the central feature through which mud extrusion is facilitated (Kopf, 2002) and usually wider.	I, II, III, V, VI
	caldera (mud volcano) (aka. crater)	A circular Depression at the summit of a MUD VOLCANO, where the central conduit crops out at the surface. These structures are related to fluid-rich seeps generally associated passive margins (Ceramicola et al., 2018).		I, II, III, V, VI
	gryphon (mud volcano)	A steep-sided Cone formed at gas-mud vents. This small-scale Cones (<3-4 m high) generally occurs at the flanks or on the summit of a MUD VOLCANO DOME and can be characterised by intense and continuous degassing or more periodic emissions (Etiope, 2015).		I, II, III, V, VI
	moat (mud volcano) (aka. subsidence rim)	An annular lowland around the base of a MUD VOLCANO. Kopf (2002) suggested these types of Depressions form after mud-volcano activity has ceased and dewatering occurs, resulting in subsidence around the structure.Alternatively, Somoza et al., (2002) proposed they could also be caused by erosional bottom currents that are deflected by the mud-volcano cone.		I, II, III, VI
	mudflow (mud volcano)	A type of FLOW where the sediments (mud) fluidised by gas and water form a muddy slurry which moves downslope from the flanks of a MUD VOLCANO. The composition of the mudflows can be highly variable and usually corresponds directly to the nature of the conduit and the lithology of the mobilized sediments, although it may also include loose conduit wall rock fragments removed by the ascending mud specially at the initial phase of an eruptive cycle.		I, II, III, VI
	ring fault	A semi-circular scarp interpreted as extensional fault, around the carter of a MUD VOLCANO.		I, II, III, VI
	outcropping methane-derived authigenic carbonate (MDAC)	Exposed authigenic carbonate structures, mostly in the form of hardground with positive relief, associated with the seepage of methane-rich fluids as a result of the anaerobic methane oxidation coupled with sulphate reduction by associations of archaea and bacteria (Hovland et al., 1987).		I, II
		MDAC slab	OUTCROPPING MDAC structures in the form of 'high relief' slabs (up to a few metres in thickness) (Judd and Hovland, 2007).	I, II
		MDAC chimney	OUTCROPPING MDAC pillars that can reach several metres in height and ~1.5 m width. They consist of poorly cemented vertical pipe structures (Judd and Hovland, 2007).	I, II

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
Fluid Flow		MDAC pavements	OUTCROPPING MDAC structures in the form of low-relief (tens of centimetres thick or less) pavements (Judd and Hovland, 2007).	I, II
		MDAC mounds	OUTCROPPING MDAC structures in the form of large mounds or hillocks (O'Reilly et al., 2014).	I, II
	pingo		A conical Mound up to a few tens of metres in height and a few hundred metres in diameter, which has been domed up from beneath. PINGOS can be either PERMAFROST PINGO or GAS HYDRATE PINGOS.	I, II, III, IV, V
		permafrost pingo	PINGO with an ice-core formed by either the intrusion of water under pressure which freezes or by the growth of segregated ice lenses (adapted from Bell et al. 1997. In: Dowdeswell et al., 2016).	I, II, III, IV, V
		gas hydrate pingo (*aka. gas hydrate mound*)	PINGO formed by volume expansion of existing bedrock or sediment caused by the accumulation and regrowth of gas hydrate within the subsurface (modified after Andreassen et al., 2017).	I, II, IV
	blow-out crater		Large circular or irregular Depression created by the release of gas from decomposed hydrate accumulations. Gas decomposition creates hydrofractures through the overburden rocks and sediment, triggering abrupt gas expulsions which blow out the overlying seafloor and collapse of GAS HYDRATE PINGOS (modified after Andreassen et al., 2017).	I, II, IV
	permafrost pingo depression		An irregularly shaped, steep-sided depression that is formed when the ice core of a submarine permafrost pingo thaws. An 'inverted landform' originating as a *pingo* (Paull et al., 2022).	I, II, III, IV, V
	pockmark		A concave crater-like Depression formed by gas and/or fluid expulsion, typically one to tens of meters in diameter but can be up to a few hundred meters wide (Hovland et al., 1987). Pockmarks tend to be characteristic V-shaped depressions, with circular, or elliptical geometry. However, they can also present a W-shaped profile or more complex geometries.	I, II, III, IV, V
		unit pockmark	A very small POCKMARK (typically 1–10 m across and up to 0.5 m deep). This type of pockmark can be found in isolation, in groups, or in association with larger pockmarks (Hovland and Judd, 1988). Hovland et al., (2010) suggested that unit pockmarks likely manifest cyclic pore-water seepage.	I, II, III, IV
		'normal' pockmark	A POCKMARK, typically measuring from 10 m up to a few hundred meter in diameter, and from 1 m to 25 m deep. Hovland et al. (2010), suggested that these could manifest periodic or intermittent gas bursts (eruptions), with extended intervening periods of slow, diffusive, and cyclic pore-water seepage.	I, II, III, IV, V
		strings of pockmarks	UNIT POCKMARKS or small NORMAL POCKMARKS arranged in curvilinear chains or strings, that may be kilometres in length. They are suspected to be a result of fluid focusing along near-vertical FAULTS, flexures, or weakness zones in the upper sedimentary layer (Hovland et al., 2002).	I, II, III, IV, V
		giant pockmark	A POCKMARK measuring more than 250 m in diameter. This large-scale seepage structures, that may reach diameters >500 m and up to 1–1.5 km across, have been described as the result of very long period of seepage (e.g. Wenau et al., 2017).	I, II, III, IV, V
		'complex' pockmark	A cluster of 'NORMAL' POCKMARKS or amalgamations of larger POCKMARKS.	
	hydrothermal vent		Fissures on the oceanic crust in volcanically active sites (e.g. mid-ocean ridges, back-arc spreading centers, and hot-spot or arc-related submarine volcanoes), from which geothermally heated water is released. Circulating seawater is heated by a heat source such as a magma chamber or associated hot rock and, during heating and chemical reaction with the	I, VI

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
		surrounding rock, undergoes a suite of chemical modifications (modified after Harff et al., 2016).		
		white smokers	Bulbous chimney or stack-like edifices composed of mixtures of copper-, iron-, and zinc-sulfide minerals and calcium- and barium-sulfate minerals. White smokers emit cooler (<330°C) fluids at slower flow rates compared to black smokers, with light colored precipitates suspended within exiting waters (modified after Harff et al., 2016).	I, VI
		black smokers	One to five metre tall chimney or stack-like edifices composed of mixtures of copper-, iron-, and zinc-sulfide minerals and calcium- and barium-sulfate minerals. They form as very hot (>350°C) fluid with dark-colored (black) precipitates suspended within exits on very young seafloor and mix with cold seawater (modified after Harff et al., 2016).	I, VI
	hydrothermal mound	Circular or irregular mounding structures formed by the precipitated minerals that accumulate at hydrothermal vent sites (modified after Harff et al., 2016).		I, VI
Karst	carbonate karst	Landscape where the dominant geomorphic process is dissolution of carbonate rocks; characterised by distinctive landforms, e.g. caves, CARBONATE DOLINES, underground drainage (modified after Field, 2002).		I, II, III
		cone karst	Karst landscape dominated by uniform conical hills separated by star-shaped dolines; narrow steeply-walled valleys may also be present (modified after Field, 2002).	I, II, III
		tower karst	Karst landscape dominated by steep or vertical-sided limestone towers, that may have flat tops; separated by areas of alluvium; may form as isolated hills or in groups (modified after Field, 2002).	I, II, III
		carbonate doline	Funnel-shaped (dissolution) or steep-sided (collapse) subcircular closed surface depression in a carbonate karst terrain; also called sinkhole.	I, II, III
		karst plain	Limestone plain with karst units, most commonly CARBONATE DOLINES and caves (modified after Field, 2002).	I, II, III
		blind valley	Karst valley that terminates abruptly where its stream sinks; the water disappears underground into a doline (modified after Field, 2002).	I, II, III
		spring	Coastal karst aquifer conduits with outlets in submarine settings (modified after Field, 2002).	I, II, III
	salt karst	Landscape where the dominant geomorphic process is dissolution of salt (halite); characterised by distinctive rough terrain and landforms, e.g. dolines (modified after Field, 2002).		I, II, III
		salt doline	Funnel-shaped subcircular closed surface depression in a salt karst terrain (modified after Field, 2002).	I, II, III
	sandstone karst	Landscape where the dominant geomorphic processes are a combination of chemical weathering and other erosional processes of sandstone (quartz); characterised by distinctive rough terrain and landforms, e.g. ruiniform.		I, II, III
		sandstone doline	Funnel-shaped subcircular closed surface depression in a sandstone terrain.	I, II, III
		ruiniform	Rock-cut landscapes consisting of closely spaced residual rock blocks separated by narrow criss-crossing crevices or passages (modified after Migoń et al., 2017).	I, II, III
	archaeological	Any anthropogenic unit of archaeological, historical, cultural or ceremonial significance.		IV

Setting / Process	BGU *	BGU-T *	Part 2 Geomorphology definition **	Apps *** I – VI
		historical wreck	As a WRECK but with archaeological or historical value.	IV
		cultural site	Any human-made site of archaeological, historical, cultural or ceremonial significance.	IV
		other archaeological	Any other marine unit of archaeological or cultural value.	IV
	structure	All anthropogenic structures or units placed into the nearshore or marine environment (Watson et al., 2020).		I, IV
		artificial reef	anthropogenic benthic structures built to defend, boost or restore components of the marine ecosystems (Seaman and Lindberg, 2009).	I, IV
		fish farm	Enclosures where fish are bred for commercial purposes.	IV
		fish trap	A device for catching fish that consists of a net or other structure which diverts the fish into an enclosure.	IV
		pipeline	A pipeline that is laid on the seabed or below it inside a trench (Randolph and Gourvenec, 2017).	IV
Anthropogenic		foundations and moorings	The lowest load-bearing part of, or any permanent structure to which marine infrastructure may be secured (Randolph and Gourvenec, 2017).	I, IV
		coastal management structure	A coastal structure (usually of rock, sediment, concrete or wood) projecting into the sea or aligned to the coast, that either protects a shore area by reducing the wave energy or reduces the longshore drift and trap sediments, or delimits and protects a navigation channel and enables the docking of ships (Bulleri and Chapman, 2010; Masselink et al., 2014).	IV, V
		cable	A submarine cable laid at the seabed.	IV
		mine	A self-contained explosive device placed in water to damage or destroy surface ships or submarines.	IV
		wreck	Derelict found in or on the shores of the sea or any tidal water (UK GOV, 1995).	IV
		rubbish discharge	Any type of mound, hillock or bank created by the discharge of anthropogenic material onto the seafloor.	IV, V
		other structure	Any other human marine-based structure.	IV
	disturbance	All anthropogenic seabed alteration or erosional units sited into the nearshore or marine environment (Watson et al., 2020).		IV
		mine tailings	Erosion or accumulation areas produced by the discharge of ground rock and process effluents that are generated in a mine processing plant.	IV, V
		dredge spoil	Any type of mound, hillock or bank created by the discharge of sediment or dredged material onto the seafloor.	IV, V
		bottom trawl	Penetrates the seabed and the resulting FURROWS temporarily remain in the sediment.	IV, V
		dredge scour	Any deep and wide mark, depression or scour, caused by the dredging or removal material from the seabed.	IV
		anchor drag	Narrow and often sinuous groove left by a dragging anchor on the seafloor (Watson et al., 2022).	IV
		other disturbance	Any other anthropogenic disturbance.	I, IV, V

18 Index of terms

The following list of terms is provided to assist the user in finding which Setting / Process chapter each term is classified. BGU-T marked with an asterix are not defined in the glossary.

A

B

C

Closed lagoon	*Coastal*	*BGU-T*
Coastal barform	*Coastal*	*BGU*
Coastal management structure	*Anthropogenic*	*BGU-T*
Cold-water-coral reef	*Biogenic*	*BGU-T*
Complex	*Mass Movement*	*BGU*
Complex pockmark	*Fluid Flow*	*BGU-T*
Compressional domain	*see "Deposition zone"*	
Compressional ridge	*Mass Movement*	*BGU*
Compressional ridge	*Solid Earth*	*BGU-T*
Cone	*see "Mud dome"*	
Cone karst	*Karst*	*BGU-T*
Contourite drift	*Marine*	*BGU-T*
Coralligène	*Biogenic*	*BGU-T*
Corrugation ridges	*Glacial*	*BGU*
Corrugation ridges within ploughmarks	*Glacial*	*BGU*
Counterpoint	*Current-induced*	*BGU-T*
Crag and tail	*Current-induced*	*BGU-T*
Crag and tail	*Glacial*	*BGU-T*
Crater (mud volcano)	*see "Caldera (mud volcano)"*	
Creek	*Coastal*	*BGU-T*
Crescentic bar	*Current-induced*	*BGU-T*
Crevasse splay	*Current-induced*	*BGU-T*
Crevasse-filling	*Glacial*	*BGU*
Cross-shelf trough	*Glacial*	*BGU*
Crown crack	*Mass Movement*	*BGU*
Cuesta	*Solid Earth*	*BGU-T*
Cultural site	*Anthropogenic*	*BGU-T*
Cupola hill	*Glacial*	*BGU*
Current-induced channel	*Current-induced*	*BGU*
Cyclic step	*Current-induced*	*BGU-T*

D

De geer moraine	*Glacial*	*BGU-T*
Debris	*Anthropogenic*	*BGU-T*
Debris apron	*Mass Movement*	*BGU*
Debris fall	*Mass Movement*	*BGU-T*
Debris fan	*Mass Movement*	*BGU*
Debris flow	*Mass Movement*	*BGU-T*
Debris topple	*Mass Movement*	*BGU-T*
Delta	*Coastal or Fluvial*	*BGU*
Delta lobe	*Coastal*	*BGU*
Dendritic drainage network*	*Fluvial*	*BGU-T*
Depletion zone	*see "Evacuation zone"*	
Depositional zone	*Mass Movement*	*BGU*
Detached block	*Mass Movement*	*BGU-T*
Dip slope	*Solid Earth*	*BGU*
Dissipative beach	*Coastal*	*BGU-T*
Distributary	*Coastal*	*BGU-T*
Distributary drainage network*	*Fluvial*	*BGU-T*
Disturbance	*Anthropogenic*	*BGU*
Drainage basin	*Fluvial*	*BGU*
Drainage network	*Fluvial*	*BGU*
Dredge scour	*Anthropogenic*	*BGU-T*
Dredge spoil	*Anthropogenic*	*BGU-T*
Drumlin	*Glacial*	*BGU-T*
Dune	*Current-induced*	*BGU-T*

E

Erratic	*Glacial*	*BGU*
Esker	*Glacial*	*BGU*
Evacuation zone	*Mass Movement*	*BGU*
Excavation	*Biogenic*	*BGU*
Extensional domain	*see "Evacuation zone"*	
Extensional ridge	*Mass Movement*	*BGU*

F

Fall	*Mass Movement*	*BGU*
Fault	*Solid Earth*	*BGU-T*
Fault valley	*Solid Earth*	*BGU-T*
Feeding trace*	*Biogenic*	*BGU-T*
Fish farm	*Anthropogenic*	*BGU-T*
Fish trap	*Anthropogenic*	*BGU-T*
Fjord	*Coastal or Fluvial*	*BGU-T*
Fjord	*Glacial*	*BGU*
Floodplain	*Coastal or Fluvial*	*BGU*
Floodplain terrace	*Coastal or Fluvial*	*BGU*
Flow	*Mass Movement*	*BGU*
Flute	*Glacial*	*BGU-T*
Foliated bedrock outcrop	*Solid Earth*	*BGU-T*
Fore-reef	*Biogenic*	*BGU*

Foundations and moorings	*Anthropogenic*	*BGU-T*
Fracture zone	*Solid Earth*	*BGU-T*
Fringing reef	*Biogenic*	*BGU-T*
Front delta	*Coastal or Fluvial*	*BGU-T*
Frontally confined slide	*Mass Movement*	*BGU-T*
Frontally emergent slide	*Mass Movement*	*BGU-T*
Furrow	*Coastal*	*BGU-T*
Furrow	*Current-induced*	*BGU-T*

G

Gas hydrate mound	*see "Gas hydrate pingo"*	
Gas hydrate pingo	*Fluid Flow*	*BGU-T*
Giant pockmark	*Fluid Flow*	*BGU-T*
Glacifluvial delta	*Glacial*	*BGU*
Glacifluvial outwash plain	*Glacial*	*BGU*
Glacigenic debris flow/lobe	*Glacial*	*BGU*
Glacitectonic hill	*Glacial*	*BGU-T*
Glacitectonic hole	*Glacial*	*BGU-T*
Glacitectonic raft	*Glacial*	*BGU*
Graben	*Solid Earth*	*BGU-T*
Groove	*Glacial*	*BGU-T*
Grounding zone wedge	*Glacial*	*BGU*
Grounding-line fan	*see "Ice-proximal fan"*	
Gryphon (mud volcano)	*Fluid Flow*	*BGU*
Gully	*Coastal*	*BGU-T*
Guyot	*Solid Earth*	*BGU-T*

H

Half graben	*Solid Earth*	*BGU-T*
Hanging valley	*Glacial*	*BGU-T*
Head scarp	*Mass Movement*	*BGU*
Headwall	*see "Head scarp"*	
Headwall domain	*see "Evacuation zone"*	
High-energy confined floodplain	*Coastal or Fluvial*	*BGU-T*
Hill-hole pair	*Glacial*	*BGU*
Historical wreck	*Anthropogenic*	*BGU-T*
Hogback	*Solid Earth*	*BGU-T*
Homoclinal ridge	*Solid Earth*	*BGU-T*
Horst	*Solid Earth*	*BGU-T*
Hummocky terrain	*Glacial*	*BGU*
Hydrothermal mound	*Fluid Flow*	*BGU*
Hydrothermal vent	*Fluid Flow*	*BGU*

I

Iceberg grounding pit	*Glacial*	*BGU*
Iceberg ploughmark	*Glacial*	*BGU*
Ice-contact delta	*Glacial*	*BGU*
Ice-proximal fan	*Glacial*	*BGU*
Impact crater	*Solid Earth*	*BGU*
Incised valley	*Coastal or Fluvial*	*BGU-T*
Irregular mature: crescentic	*Biogenic*	*BGU-T*
Intermediate beach	*Coastal*	*BGU-T*
Intermittent lagoon	*Coastal*	*BGU-T*
Intertidal bar	*Coastal*	*BGU-T*
Intertidal flat	*Coastal*	*BGU-T*
Intertidal terrace	*see "Shoreface terrace"*	

J

Joint	*Solid Earth*	*BGU-T*
Juvenile: unmodified antecedent platform	*Biogenic*	*BGU-T*

K

Karst plain	*Karst*	*BGU-T*
Kettle hole	*Glacial*	*BGU*
Knickpoint	*Current-induced*	*BGU*

L

Lag	*Current-induced*	*BGU-T*
Lagoon	*Coastal*	*BGU*
Lagoonal senile: planar	*Biogenic*	*BGU-T*
Lateral moraine	*Glacial*	*BGU-T*
Lateral scarp	*Mass Movement*	*BGU*
Lateral spread	*Mass Movement*	*BGU*
Ledge	*Current-induced*	*BGU-T*
Lenticular	*Biogenic*	*BGU-T*

Levee	*Current-induced*	*BGU-T*
Lineation	*Current-induced*	*BGU-T*
Low-energy cohesive floodplain	*Coastal or Fluvial*	*BGU-T*
Lower delta	*Coastal*	*BGU-T*

M

Magmatic dome	*Solid Earth*	*BGU-T*
Magmatic outcrop	*Solid Earth*	*BGU*
Magmatic sheet	*Solid Earth*	*BGU-T*
Marine barform	*Marine*	*BGU*
Marine terrace	*see "Shoreface terrace"*	
Massive bedrock outcrop	*Solid Earth*	*BGU-T*
Mat	*Biogenic*	*BGU*
MDAC chimney	*Fluid Flow*	*BGU-T*
MDAC mounds	*Fluid Flow*	*BGU-T*
MDAC pavements	*Fluid Flow*	*BGU-T*
MDAC slab	*Fluid Flow*	*BGU-T*
Medial moraine	*Glacial*	*BGU*
Medium-energy unconfined floodplain	*Coastal or Fluvial*	*BGU-T*
Megaripple	*see "Dune"*	
Mega-scale glacial lineation	*Glacial*	*BGU-T*
Meltwater channel	*Glacial*	*BGU*
Mid-channel	*Current-induced*	*BGU-T*
Mine	*Anthropogenic*	*BGU-T*
Mine tailings	*Anthropogenic*	*BGU-T*
Minor scarp	*Mass Movement*	*BGU*
Moat (mud volcano)	*Fluid Flow*	*BGU*
Moraine	*Glacial*	*BGU*
Mound (biogenic)	*see "Bioherm"*	
Mound*	*Biogenic*	*BGU-T*
Mouthbar	*Current-induced*	*BGU-T*
Mud dome	*Fluid Flow*	*BGU-T*
Mud pie	*Fluid Flow*	*BGU-T*
Mud volcano	*Fluid Flow*	*BGU*
Mudflow	*Mass Movement*	*BGU-T*
Mudflow fan	*Mass Movement*	*BGU*
Mudflow gully	*Mass Movement*	*BGU*
Multi-keeled ploughmark	*Glacial*	*BGU-T*

N

Nearshore barform	*Coastal*	*BGU-T*
Nest*	*Biogenic*	*BGU-T*
Normal pockmark	*Fluid Flow*	*BGU-T*
Notch	*Coastal*	*BGU-T*

O

Obstacle and comet scour	*Current-induced*	*BGU-T*
Oceanic core complex	*Solid Earth*	*BGU*
Open lagoon	*Coastal*	*BGU-T*
Other archaeological	*Anthropogenic*	*BGU-T*
Other disturbance	*Anthropogenic*	*BGU-T*
Other structure	*Anthropogenic*	*BGU-T*
Outcrop	*Coastal*	*BGU-T*
Outcropping methane-derived authigenic carbonate (MDAC)	*Fluid Flow*	*BGU*
Outrunner block	*Mass Movement*	*BGU-T*
Oxbow	*Current-induced*	*BGU*

P

Parallel drainage network*	*Fluvial*	*BGU-T*
Patch reef	*Biogenic*	*BGU-T*
Permafrost pingo	*Fluid Flow*	*BGU-T*
Pingo	*Fluid Flow*	*BGU*
Pingo depression	*Fluid Flow*	*BGU*
Pipeline	*Anthropogenic*	*BGU-T*
Plane bed	*Current-induced*	*BGU-T*
Platform reef	*Biogenic*	*BGU-T*
Plunge pool	*Current-induced*	*BGU*
Plunging cliff	*Coastal*	*BGU-T*
Pockmark	*Fluid Flow*	*BGU*
Pointbar	*Current-induced*	*BGU-T*
Pool	*Coastal*	*BGU-T*
Pothole	*Coastal*	*BGU-T*
Pro-delta	*Coastal or Fluvial*	*BGU-T*
Proglacial meltwater channel	*Glacial*	*BGU*
Push moraine	*Glacial*	*BGU-T*

R

Radial drainage network*	*Fluvial*	*BGU-T*
Rafted block	*Mass Movement*	*BGU-T*
Raised beach	*Coastal*	*BGU*
Ramp	*Coastal*	*BGU-T*
Rampart	*Coastal*	*BGU-T*
Recessional moraine	*Glacial*	*BGU-T*
Reef	*Biogenic*	*BGU*
Reef	*Marine*	*BGU*
Reef crest	*Biogenic*	*BGU*
Reef flat	*Biogenic*	*BGU*
Reef lagoon	*Biogenic*	*BGU*
Reef or rock affected beach	*Coastal*	*BGU-T*
Reflective beach	*Coastal*	*BGU-T*
Remnant block	*Mass Movement*	*BGU*
Resting site*	*Biogenic*	*BGU-T*
Reticulate	*Biogenic*	*BGU-T*
Ria	*Coastal or Fluvial*	*BGU-T*
Ribbed moraine	*see "Rogen moraine"*	
Ribbon	*Biogenic*	*BGU-T*
Ridge and runnel	*Coastal*	*BGU-T*
Ridgebar	*see "Intertidal bar"*	
Riffle (and pool)	*Current-induced*	*BGU-T*
Rill	*Coastal*	*BGU-T*
Rim	*Biogenic*	*BGU-T*
Ring faults	*Fluid Flow*	*BGU*
Ripple	*Current-induced*	*BGU-T*
River	*Coastal*	*BGU-T*
River valley	*Coastal or Fluvial*	*BGU-T*
Roche moutonnée	*Glacial*	*BGU-T*
Rock avalanche	*Mass Movement*	*BGU-T*
Rock fall	*Mass Movement*	*BGU-T*
Rock topple	*Mass Movement*	*BGU-T*
Rocky coast	*Coastal*	*BGU*
Rogen moraine	*Glacial*	*BGU*
Rotational slide	*Mass Movement*	*BGU-T*
Rubbish discharge	*Anthropogenic*	*BGU-T*
Ruiniform	*Karst*	*BGU-T*

S

Salient / tombolo	*Coastal*	*BGU-T*
Salt doline	*Karst*	*BGU-T*
Salt karst	*Karst*	*BGU*
Sandur	*see "Glacifluvial outwash plain"*	
Sandstone doline	*Karst*	*BGU-T*
Sandstone karst	*Karst*	*BGU*
Scarp slope	*Solid Earth*	*BGU*
Scour	*Current-induced*	*BGU-T*
Scroll	*Current-induced*	*BGU-T*
Seamount	*Solid Earth*	*BGU-T*
Secondary escarpment	*see "Minor scarp"*	
Sediment apron	*Marine*	*BGU-T*
Sediment bank	*Marine*	*BGU-T*
Sediment drift	*Marine*	*BGU-T*
Sediment lobe	*Marine*	*BGU-T*
Sediment ribbon	*Current-induced*	*BGU-T*
Sediment ridge	*see "Sediment bank"*	
Sediment streak	*Current-induced*	*BGU-T*
Sediment wave	*see "Dune"*	
Shear-margin moraine	*Glacial*	*BGU-T*
Sheet	*Biogenic*	*BGU-T*
Shelf edge delta	*Coastal*	*BGU-T*
Shelf-incising canyon	*Marine*	*BGU-T*
Shield volcano	*Solid Earth*	*BGU-T*
Shore platform	*Coastal*	*BGU-T*
Shoreface	*Coastal*	*BGU*
Shoreface terrace	*Coastal*	*BGU-T*
Sidewall	*see "Lateral scarp"*	
Sill/threshold	*Glacial*	*BGU*
Single-keeled ploughmark	*Glacial*	*BGU-T*
Slide	*Mass Movement*	*BGU*
Slope-confined canyon	*Marine*	*BGU-T*
Slump	*see "Rotational slide"*	
Spring	*Karst*	*BGU-T*
Spur-and-groove	*Biogenic*	*BGU*
Stack	*Coastal*	*BGU-T*
Strandplain	*Coastal*	*BGU-T*
Strath	*Coastal or Fluvial*	*BGU-T*

Stratovolcano	*Solid Earth*	*BGU-T*
Streamlined landform	*Glacial*	*BGU*
Strings of pockmarks	*Fluid Flow*	*BGU-T*
Structure	*Anthropogenic*	*BGU*
Subaerial channel	*Coastal*	*BGU*
Subaerial valley	*Coastal or Fluvial*	*BGU*
Sub-ice shelf keel scour mark	*Glacial*	*BGU*
Submarine canyon	*Marine*	*BGU*
Submarine channel	*Marine*	*BGU*
Submarine channel belt	*Marine*	*BGU*
Submarine fan	*Marine*	*BGU*
Submarine gully	*Marine*	*BGU*
Submarine terrace	*Marine*	*BGU*
Submarine tributary canyon	*Marine*	*BGU*
Submarine valley	*Marine*	*BGU*
Submerged	*Biogenic*	*BGU-T*
Subtidal flat	*Coastal*	*BGU-T*
Supratidal flat	*Coastal*	*BGU-T*

T

Talus apron	*Mass Movement*	*BGU*
Talus fan	*Mass Movement*	*BGU*
Tectonic basin	*Solid Earth*	*BGU-T*
Tectonic depression	*Solid Earth*	*BGU*
Tectonic dome	*Solid Earth*	*BGU-T*
Tectonic escarpment	*Solid Earth*	*BGU*
Tectonic high	*Solid Earth*	*BGU*
Tectonic lineament	*Solid Earth*	*BGU*
Tension crack	*see "Crown crack"*	
Terminal moraine	*Glacial*	*BGU-T*
Terrace (mud volcano)	*Fluid Flow*	*BGU*
Thrust-block moraine	*Glacial*	*BGU*
Tidal bar	*Coastal*	*BGU-T*
Tidal delta	*Coastal*	*BGU-T*
Tidal flat	*Coastal*	*BGU*
Tidal inlet	*Coastal*	*BGU-T*
Toe	*Coastal*	*BGU-T*
Toe	*Mass Movement*	*BGU*
Topple	*Mass Movement*	*BGU*
Tower karst	*Karst*	*BGU-T*
Track*	*Biogenic*	*BGU-T*
Trail*	*Biogenic*	*BGU-T*
Translated block	*Mass Movement*	*BGU*
Translational slide	*Mass Movement*	*BGU-T*
Transverse crack	*Mass Movement*	*BGU*
Transverse ridge	*see "Compressional ridge"*	
Trellis drainage network*	*Fluvial*	*BGU-T*
Trough-mouth fan	*Glacial*	*BGU*
Tunnel valley	*Glacial*	*BGU*
Turbidite fan	*Mass Movement*	*BGU*
Turbidite levee	*Mass Movement*	*BGU*
Turbidity channel	*Mass Movement*	*BGU*
Turbidity current	*Mass Movement*	*BGU-T*

U

Unit pockmark	*Fluid Flow*	*BGU-T*
Upper delta	*Coastal*	*BGU-T*
U-shaped valley	*Glacial*	*BGU*

V

Valley/trough head	*Glacial*	*BGU-T*
Volcanic fissure	*Solid Earth*	*BGU-T*
Volcanic flow	*Solid Earth*	*BGU-T*
Volcanic plateau	*Solid Earth*	*BGU-T*
Volcanic plug/neck	*Solid Earth*	*BGU-T*
Volcano (island or submarine)	*Solid Earth*	*BGU*

W

Washover bar	*Coastal*	*BGU-T*
Whaleback	*Glacial*	*BGU-T*
White smokers	*Fluid Flow*	*BGU-T*
Wreck	*Anthropogenic*	*BGU-T*

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