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SEAFLOOR GEOMORPHOLOGY AS BENTHIC HABITAT

GEOHAB ATLAS OF SEAFLOOR GEOMORPHIC FEATURES AND BENTHIC HABITATS

EDITED BY
PETER T. HARRIS • ELAINE K. BAKER

Seafloor Geomorphology as Benthic Habitat

p0010 ***Peter T. Harris***
p9000 *Senior Marine Science Advisor*
p0015 *Geoscience Australia,*
Canberra, Australia

p0020 ***Elaine K. Baker***
p9010 *Marine Scientist, UNEP/GRID Arendal*
p0025 *School of Geoscience,*
University of Sydney,
NSW Australia

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c0058 # 58 Seamounts, Ridges, and Reef Habitats of American Samoa

Dawn J. Wright[1], Jed T. Roberts[2], Douglas Fenner[3], John R. Smith[4], Anthony A.P. Koppers[5], David F. Naar[6], Emily R. Hirsch[7], Leslie Whaylen Clift[8], Kyle R. Hogrefe[9]

[1]Department of Geosciences, Oregon State University, Corvallis, OR, USA, [2]Oregon Department of Geology and Mineral Industries, Portland, OR, USA, [3]Department of Marine and Wildlife Resources, American Samoa Government, Pago Pago, AS, USA, [4]Hawaii Undersea Research Laboratory, University of Hawaii, Honolulu, HI, USA, [5]College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA, [6]College of Marine Science, University of South Florida, St. Petersburg, FL, USA, [7]Geospatial Consulting Group International, Alexandria, VA, USA, [8]Coastal Marine Resource Associates, Honolulu, HI, USA, [9]US Geological Survey, Alaska Science Center, Anchorage, AK, USA

p1490 ## Abstract

p1495 We present the geomorphology of the Eastern Samoa Volcanic Province, covering 28,446 km^2, and depths ranging from ~50 to 4,000 m. A new compilation of available multibeam data reveals 51 previously undocumented seamounts, and delineates major submarine rift zones, eruptive centers, and volcanic plateaus. Moving from a regional to local scale, and with regard to specific coral reef habitats, we report the results of three *Pisces V* submersible dives to the submerged flanks of Tutuila, with overall objectives of species identification of deep water fish and invertebrates (32 species of invertebrates and 91 species of fish identified, 9 new records), determining the base of extensive live bottom (i.e., coral cover of 20% and greater) as well as relations to any prior benthic terrain classifications at 100 m and deeper.

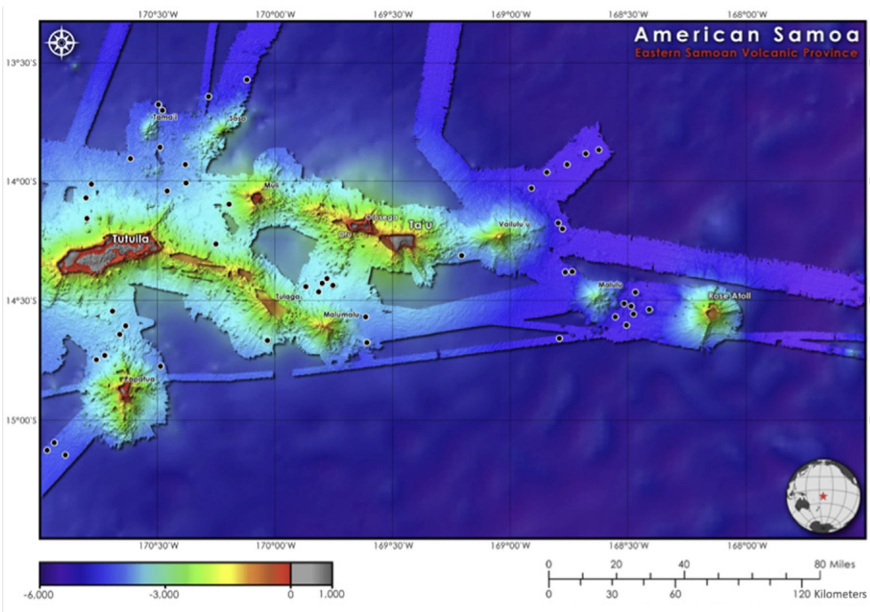
p1500 ***Key Words:*** bathymetry; geomorphology; submarine volcanism; seamounts; American Samoa; South Pacific; coral reefs; coral reef habitat

Seafloor Geomorphology as Benthic Habitat. DOI: 10.1016/B978-0-12-385140-6.00058-X

s0010 Introduction

p0030 The Samoan volcanic lineament in the southwest Pacific Ocean extends from the large subaerial islands of Savai'i and Upolu (independent nation of Samoa) in the west to the small island of Ta'u (American Samoa) in the east. Hart et al. [1] in addressing the longstanding debate as to whether or not the Samoan volcanic lineament is plume driven, along with the direction of the lineament's age progression, established a Western Samoa Volcanic Province (WSVP) and an Eastern Samoan Volcanic Province (ESVP).

p0035 With regard to geomorphology, we focus at the broad regional scale on the ESVP, which is comprised of the American Samoa islands of Tutuila, Aunu'u, Ofu, Olosega, and Ta'u, the large submarine volcanoes known as Vailulu'u, South Bank (renamed "Papatua" by Hart et al. [1]), 2% Bank (renamed "Tulaga" by Hart et al. [1]), Southeast Bank (renamed "Malumalu" by Hart et al. [1]), Malulu, Soso, and Tama'i; as well as Rose Atoll (aka Motu O Manu Atoll) and numerous smaller guyots and submarine seamounts (aka volcanic knolls; Figure 58.1). It should also be



f0010 **Figure 58.1** Bathymetry of American Samoa and the broader ESVP [2]. The resolution of the multibeam bathymetry is 200 m, but for visual continuity, a 1 km grid of bathymetry derived from the satellite altimetry of Sandwell and Smith [3] is used as a backdrop (this backdrop is present in Figures 58.2–58.4 as well). Filled circles indicate the distribution of 51 previously unidentified seamounts, several to be contributed to the Seamount Catalog [4]. Map projection for this and all other figures is Mercator, and map geodetic datum is WGS-84.

noted that Rose Atoll is a highly eroded edifice with stellate morphology, suggesting that it is substantially older than the other volcanoes of the American Samoa province [5]. It is therefore not considered a part of the ESVP and is perhaps the product of either volcanism in the Cook-Austral region or ancient ridge origin and plate transport. However, it is included in the discussion and map compilation described below by virtue of its location. In addition, Swains Atoll, within the unincorporated US territory of American Samoa, is located approximately 320 km to the north, far beyond the extent of the ESVP.

p0040 Seamounts, guyots, and knolls, with the fluid flow, nutrient supply, and modification to local circulation patterns they provide, are all extremely important habitats (e.g., corals, invertebrates, benthic fish, sea turtles, and sharks) and may include some of the richest biological "hotspots" in the oceans [6–8]. In the American Samoa region, the most well known and spectacular example thus far is Vailulu'u seamount at the eastern end of the Samoan archipelago, particularly with the hydrothermal vents discovered at its summit and rapidly growing Nafanua volcanic cone within the summit crater/caldera [9–11]. Indeed, seamounts have become priority habitats under the Convention on Biological Diversity [12], and in 2004 the Oslo–Paris Convention for the Protection of the Marine Environment of the Northeast Atlantic included seamounts on a list of priority habitats in need of protection, along with other deep-sea reefs, sponge aggregations, and hydrothermal vent sites on the Mid-Atlantic Ridge [13].

p0045 At a more local scale, and with regard to specific coral reef habitats, this project focuses on areas just offshore of the island of Tutuila, which is home to the Fagatele Bay National Marine Sanctuary (FBNMS). Geologically, the shallow flanks of Tutuila, and of the Samoan islands in general, are characterized by outcrops of basalt and limestone, biogenic and volcanic silt, sand and gravel, calcareous pavements, and calcareous ooze [14]. Many of the "cookie cutter" bays that are found along the southern coast of Tutuila, such as Fagatele Bay, Larsen's Bay, Pago Pago Harbor, and Faga'itua, are thought to be the result of volcanic collapse and erosion [15]. Then, as the island subsided due to crustal loading, large portions of these eroded valleys were flooded by the sea.

p0050 A particular emphasis is on understanding the mesophotic reefs in these areas, mesophotic meaning lower light levels at 30–150 m in the transition from euphotic to dysphotic. Knowledge of American Samoan mesophotic reefs is very limited, yet they include the deepest reefs—and those most untouched by humans in the archipelago—thus helping to delineate what unimpacted coral reefs are like in the territory [16–18]. Knowledge of what natural unimpacted reefs are like in the territory is very important for gauging the impacts humans have had on reefs at this location. Unfortunately, there are no good examples of shallow unimpacted reefs around Tutuila, where human impacts are greatest. Mesophotic reefs around Tutuila have the potential to be some of the least impacted reefs around Tutuila, and thus information on them is extremely valuable for determining the baseline, and the goal for reef management and conservation.

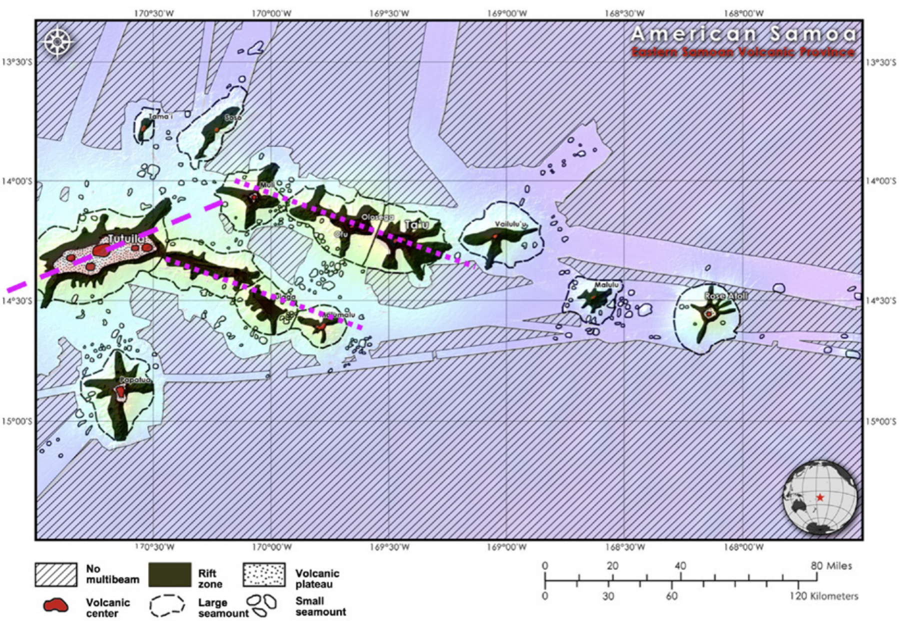
s0015 Regional Scale Geomorphic Features

p0055 *Seamounts*: Previous studies of the Samoan islands have reported regional bathymetry as predicted from satellite altimetry [1]. Multibeam bathymetry surveys have been restricted to local areas covered by one or two cruises [19,20] that primarily supported studies of the geochemical signature and age progression of western portion of the Samoan volcanic province 1,20–22. This case study introduces the first regional scale, multicruise, multibeam bathymetry of the eastern portion of the Samoan lineament, providing an overview of the bathymetric setting west of Savai'i and Upolu, and clearer implications of the seamount trails and other volcanic knolls revealed therein. Although we are using the IHO [23] definition of seamount in this book, it is useful to note that definitions of what constitute a "seamount" do vary, especially in light of a growing multidisciplinary seamount biogeosciences community where knolls are included in the definition (as discussed in more detail in Ref. [24]).

p0060 Figure 58.1 shows a new bathymetric compilation of American Samoa based on multibeam sonar data available from 14 cruises from 1984 through 2006, covering an area of 28,446 km^2. The map also shows the locations of 51 previously undocumented seamounts and volcanic knolls. Figure 58.2 summarizes the geomorphic interpretation for the region by delineating major rift zones, subaerial and submarine eruptive centers, volcanic plateaus, and the outlines of the most prominent seamounts and volcanic knolls. Particularly of note are the many small seamounts prevalent throughout ESVP from Ofu-Olosega westward, especially on the northern flank of South Bank and stretching from Ofu-Olosega across the inter-rift valley to the 2% Bank-Southeast Bank (aka Tulaga-Malumalu) saddle.

p0065 In the current global census of seamounts, only 200 have been sampled, and in no systematic fashion [7], but future studies based on this current study hold promise for exploring a possible relationship between seamount shape and habitat. Topographic/bathymetric position index (TPI/BPI) is important in a vertical sense (e.g., species richness along a vertical biodiversity gradient, as discussed in Refs. [25–27]). Further studies (beyond the scope of this case study) will test the hypothesis if seamount size and shape (in a more horizontal cross-sectional sense) bear any relationship to species diversity and richness, especially with geomorphic and hydrodynamic processes influencing marine ecological communities on a range of scales [28,29]. Below we focus on some of the largest seamounts, but the reader is referred to Roberts [30] for more extensive description and geomorphic analysis of undersea volcanic features throughout the entirety of the ESVP, as well as shape and distribution analyses of seamounts and a discussion of the age progressions of volcanic lineaments.

p0070 *Tutuila*: The large seamounts, guyots, knolls, and breaching islands of the ESVP demonstrate complex eruptive patterns. Perhaps the most intricate is the Tutuila complex, composed of five separate volcanic centers ([15]; Figure 58.2) and representing the largest structure in the ESVP, with a volume of 4,957 km^3 (as calculated using sources from Ref. [4]. Tutuila is unique with its highly elongate primary rift zone that trends 70° [15], as opposed to the rest of the Samoan chain trending at 110°. Indeed, en echelon lineaments both to its east and west delineate that primary rift zone trend (110°), with the island itself marking an interruption in that dominant rift

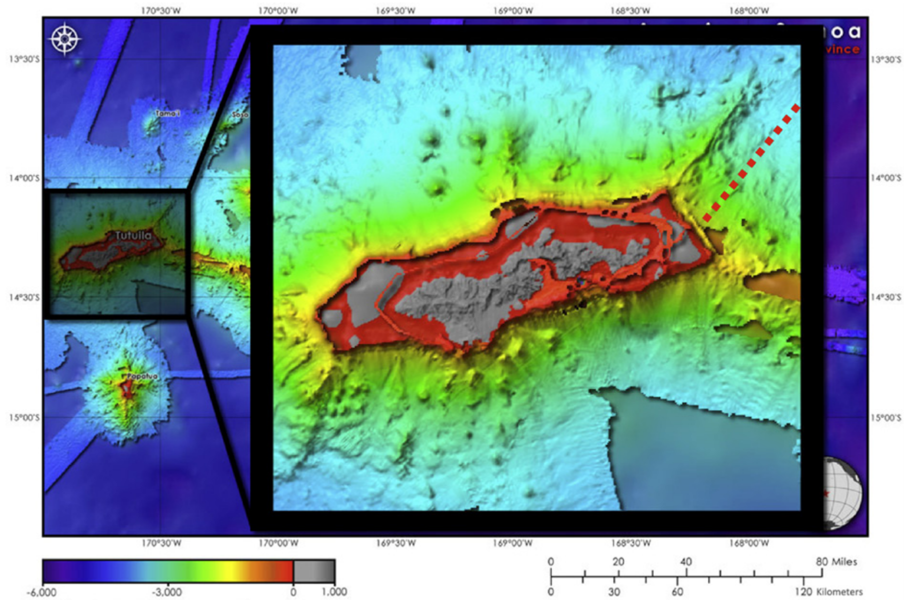


f0015 **Figure 58.2** Geomorphic interpretation of major volcanic features of the islands of American Samoa and the broader ESVP, based on the multibeam bathymetry of Figure 58.1. Major rift zones are shown in black, subaerial and submarine eruptive centers in red, volcanic plateaus in stipple, outlines of the most prominent large seamounts in dashed circles, and small seamounts in small open circles. Cross-hatching indicates no multibeam bathymetry coverage. Large dashed line shows the northeasterly volcanic rift trend of Tutuila, which differs markedly from the southeasterly trends of the two major seamount chains directly to the east (shorter dashed lines). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this book.)

direction. Tutuila may in fact be an extension of the North Fiji Fracture Zone far to the east, which also trends 70° [31].

p0075 The morphology of Tutuila exhibits several highly incised secondary rift zones radiating away from the primary trend (Figure 58.3). Protruding slightly from the southwestern corner of the island is a rift oriented 20°. Reinstating the primary en echelon trend, a massive rift protrudes at 110° and connects to 2% Bank (aka Tulaga). A third rifting system extends from the northeastern corner of the island in a 30° trend. The linear nature of these features implies structural guidance of volcanism by fault or fracture zone. The island flanks are in a stage of advanced erosion, exhibiting numerous slope failures and incised rifts (Figure 58.3). Sparse populations of small seamounts occupy the western flank, as well as the northern and southern flanks, which are in line with the primary rift of South Bank.

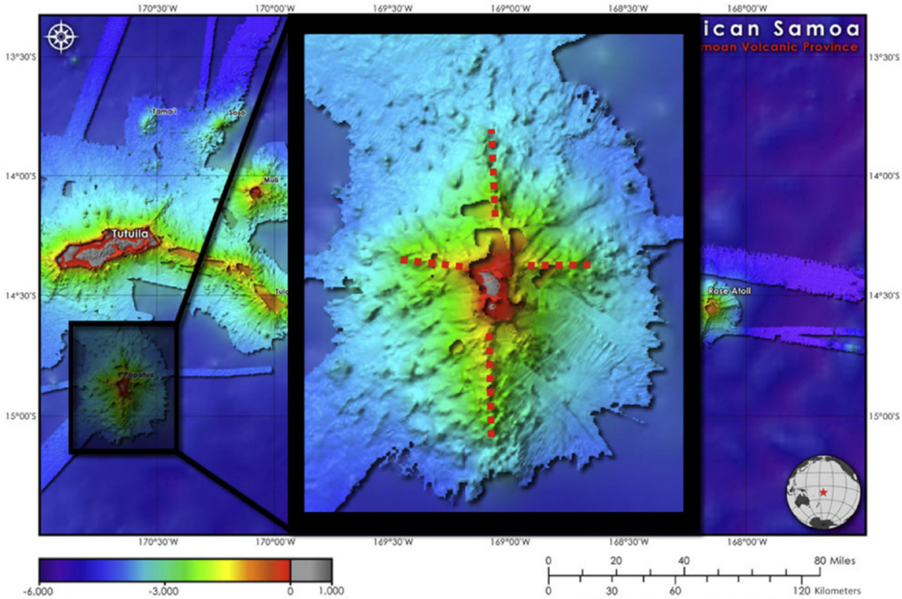
p0080 *South Bank*: South Bank (aka Papatua Guyot) is the largest isolated edifice in the ESVP. Though it has not been radiometrically dated, it is probably at least as old as Tutuila, based on its location in the ESVP. The summit of South Bank sits very near



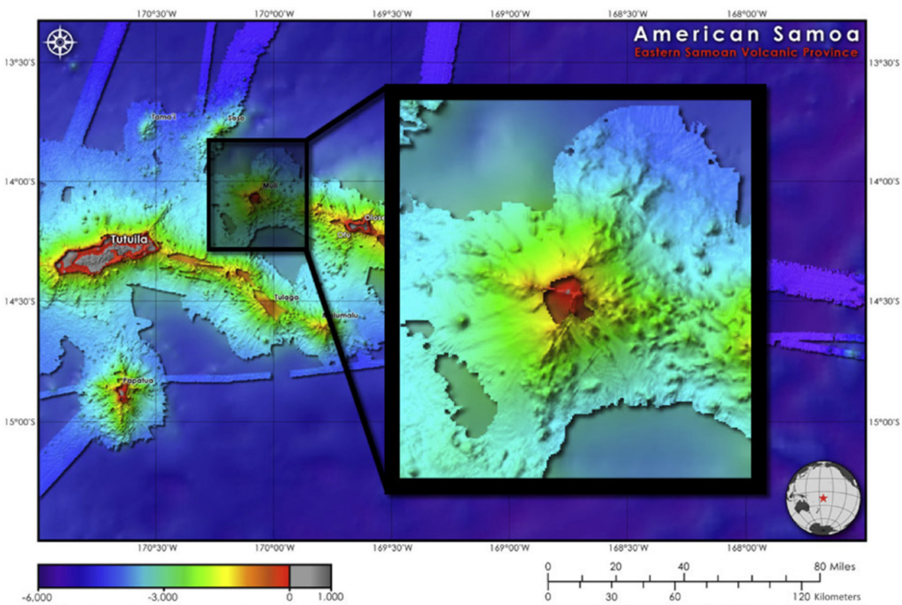
f0020 **Figure 58.3** Detailed bathymetry of Tutuila Island, based on the 200 m multibeam bathymetry of Figure 58.1, as well as available nearshore multibeam bathymetry at 2–5 m resolution. The morphology of Tutuila exhibits several highly incised secondary rift zones radiating away from the primary trend, a primary one of which extends from the northeastern corner of the island in a 30° trend (dashed line). The linear nature of these features implies structural guidance of volcanism by fault or fracture zone.

to sea level. It likely breached in the past and has since been eroded by wave action to produce a flat summit surface. South Bank has two perpendicular rifting zones trending nearly in line with the four cardinal directions (Figure 58.4). Though it is probably at least 1 million years old [1], its northern and southwestern flanks show relatively little evidence of slope failure and are superimposed with small seamounts. It possesses an emerging stellate morphology, though it is not nearly as developed as on Tutuila or Northeast Bank. The shield-building stage for South Bank is not easily attributable to a plume source, based on its divergent location and anomalous primary rift trending at N0°E, though Hart et al. [1] suggest that decompressional melting due to slab–plume interactions could account for the location of South Bank.

p0085 *Northeast Bank*: Northeast Bank (renamed "Muli" by Hart et al. [1]) is the second largest isolated edifice in the ESVP. It is partially connected to the Ofu-Olosega complex by a deep saddle and exhibits a near-stellate morphology, a testament to its highly eroded state and once circular shape (Figure 58.5). Its flat summit lies within 100 m of sea level and therefore we speculate that, like South Bank, it may have breached sea level at some point in the past. Northeast Bank has two primary rift zones trending at 30° and 120°. Its flanks are smooth and largely vacant of small



f0025 **Figure 58.4** Detailed bathymetry of South Bank (aka Papatua Guyot), the largest isolated edifice in the ESVP. South Bank has two perpendicular rifting trends nearly in line with the four cardinal directions (dashed lines).



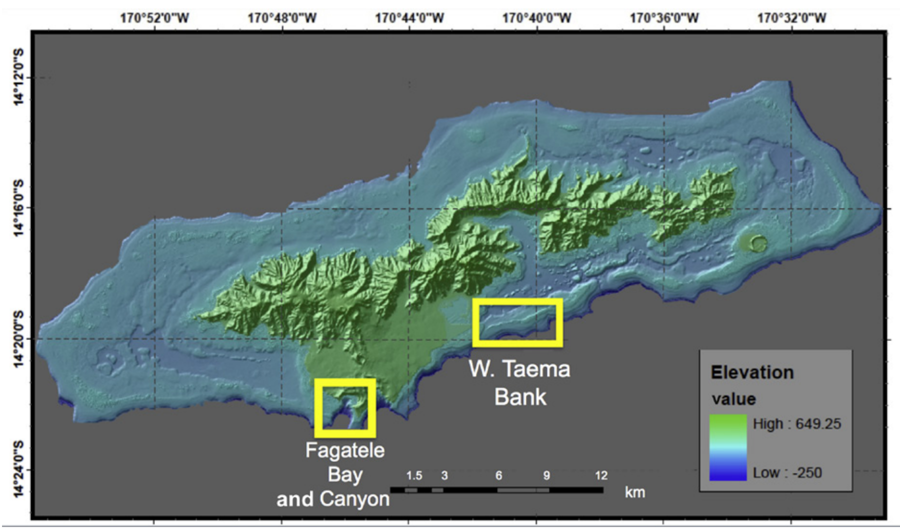
f0030 **Figure 58.5** Detailed bathymetry of the Northeast Bank, the second largest isolated edifice in the ESVP. Northeast Bank has two primary rift zones trending at 30° and 120°.

seamounts. The exception is its eastern rift forming the saddle with the Ofu-Olosega complex, which is interspersed with small seamounts.

s0020 Local Scale Geomorphic Features and Habitats

p0090 *Reefs*: In terms of biological surveys in the study area, the NOAA Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center (PIFSC) surveyed the flanks of Tutuila and the Manu'a Islands in 2004 for management of benthic habitats associated with coral reefs [32]. The following year, the Hawaii Undersea Research Laboratory (HURL) initiated another survey of the Tutuila nearshore, this time accompanied by submersible dives again aimed at documenting the characteristics of the benthic habitat [33]. HURL extended its benthic habitat surveying to Rose (Motu O Manu) Atoll as well [34].

p0095 Towed camera and scuba surveys in the area are ongoing, but deeper submersible surveys into the mesophotic, dysphotic, and aphotic zones are rarer. As such, we provide examples here from HURL cruise KOK0510 (Figure 58.6; [36]). The cruise consisted of three *Pisces V* submersible dives to the submerged flanks of Tutuila, American Samoa, specifically the coral reef platform of Taema Bank, and the submerged caldera forming Fagatele Bay and Canyon, with overall objectives



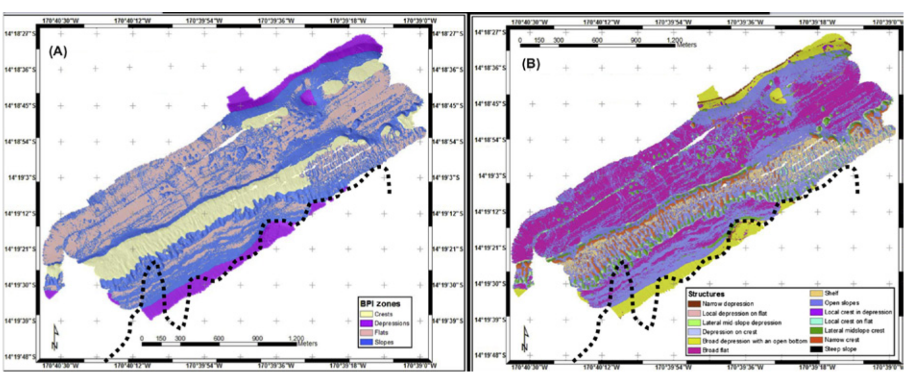
f0035 **Figure 58.6** Coastal terrain model of Tutuila, American Samoa with surrounding bathymetry, after Hogrefe et al. [35]. Rectangles show the locations of the two dive sites of Cruise KOK0510: West Taema Bank offshore of south-central Tutuila (Dives P5–648 and P5–640) and Fagatele Bay and Canyon to the southwest (Dive P5–649). The coastal resolution coastal terrain model was developed at 5 m resolution from a USGS digital elevation model, the multibeam bathymetry of NOAA PIFMC, and nearshore bathymetry derived from IKONOS 4 m satellite imagery [35].

of species identification of fish and invertebrates (32 species of invertebrates and 91 species of fish identified, 9 new records) and determining the base of extensive live bottom (i.e., coral cover of 20% and greater). In addition and where possible, we sought to ground-truth previous benthic terrain classifications at 100 m and deeper that had been derived from bathymetric position index and rugosity analyses in GIS. Lundblad et al. [37] describe these methods in complete detail and the resulting classifications specifically for American Samoa.

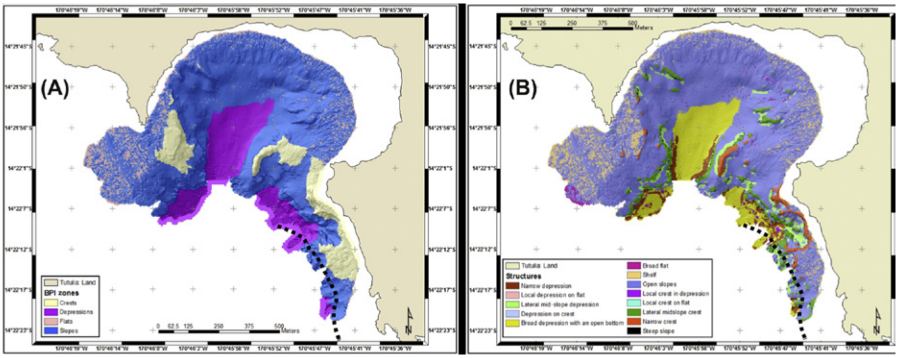
p0100 Taema Bank and Fagatele Bay and Canyon (Figure 58.6) were chosen as primary dive sites due to the occurrence of previous shallow (≤150 m) multibeam surveys in the area (especially by Oregon State University, OSU, and University of South Florida, USF, as described in Refs. [38–40]), their importance for coral monitoring and protection, and for safety. Indeed, at both sites the water is suitably deep for the safe navigation of a 68 m long research vessel needing to track a submersible almost directly below it for shallow dives of 500 m or less.

p0105 *Taema Bank*: Taema Bank (Figures 58.6 and 58.7) is a long, narrow, submarine platform located ~3 km off the south central coast of Tutuila. It is ~3 km long by 30 m wide, rising ~30 m above a surrounding seafloor, averaging 50–100 m in depth [38]. Because the platform is largely flat and fairly smooth, it is interpreted as an ancient reef terrace that may have once experienced wave erosion at sea level.

p0110 Figure 58.7 shows BPI "zone" and "structure" maps for West Taema Bank, created from 1 m resolution multibeam bathymetry data of Lundblad et al. [37]. BPI is a scale-dependent index representing a grid cell's location within a seascape relative to its local surroundings. Lundblad et al. [37] defines a "zone" as a coarse-scale surficial characteristic of the seafloor that combines slope with a coarse-scale BPI, to delineate large crests or ridges, valleys, basins, plains, and slopes. "Structures" are finer scale classifications resulting from the combination of bathymetry and slope, with both coarse- and fine scales of BPI. Therefore, structures include categories



f0040 **Figure 58.7** (A) BPI "zone" map of West Taema Bank, created from 1 m resolution multibeam bathymetry data, with classifications based on the scheme of Lundblad et al. [37]. Dashed line shows the smoothed trackline of *Pisces V* Dive P5–648. (B) Classification of same West Taema Bank bathymetry into "structures," with same submersible track overlain.



f0045 **Figure 58.8** (A) BPI "zone" map of FBNMS, created from 1 m resolution multibeam bathymetry data, with classifications based on the scheme of Lundblad et al. [37]. Dashed line shows smoothed track of *Pisces V* Dive P5–649. (B) Classification of same FBNMS bathymetry into "structures," with same submersible track overlain.

such as narrow depressions or grooves, narrows crests or ridges, local depressions/crests on plains, lateral mid-slope depressions or grooves, lateral mid-slope crests or ridges, open slopes, shelves, and broad flats [37]. Zone and structure classifications of Taema Bank (Figure 58.7) are based on the scheme of Lundblad et al. [37] for American Samoa.

p0115 Taema Bank is made up of mostly flats and slopes in terms of zones, but there are very distinct crests and depressions throughout (Figure 58.7A). Open slopes surround the crests of the bank along with the broad flats. As the shelf reaches an escarpment near a series of broad flats, there is also a series of spurs and grooves. These pervasive features are given structure classifications of narrow crests, lateral mid-slope depressions, and lateral mid-slope crests (Figure 58.7B). The open slopes lead down to broad depressions with open bottoms on both sides of Taema Bank. Submersible observations on Dives P5–648 and P5–650 visually confirmed these classifications and noted that the shelf contains stretches of colonized pavement covered with a veneer of sand [41]. Within the fringing lateral mid-slope depressions and crests on the open slopes are colonized pavement and hummocky bottom with low relief and ~5% sand cover.

p0120 *Fagatele Bay and Canyon*: Fagatele Bay (Figures 58.6 and 58.8), and its continuation deeper offshore as a canyon, is the result of an ancient caldera that collapsed and subsided, causing the seaward rim to be breached by the ocean and flooded [38]. The fringing coral reef is indeed of continuing interest and concern in this US federal marine sanctuary that has essentially recovered from a near-devastating infestation of crown-of-thorns starfish in the late 1970s [42]. The bay was also affected by hurricanes in 1990, 1991, 2004, and 2005; and a coral bleaching event occurred in 1994, possibly due to high sea-surface temperatures from an El Niño [43]. The live coral cover has recovered well from near-total destruction, and populations of small benthic fish still thrive, particularly surgeonfish, damselfish, and angelfish [44,45].

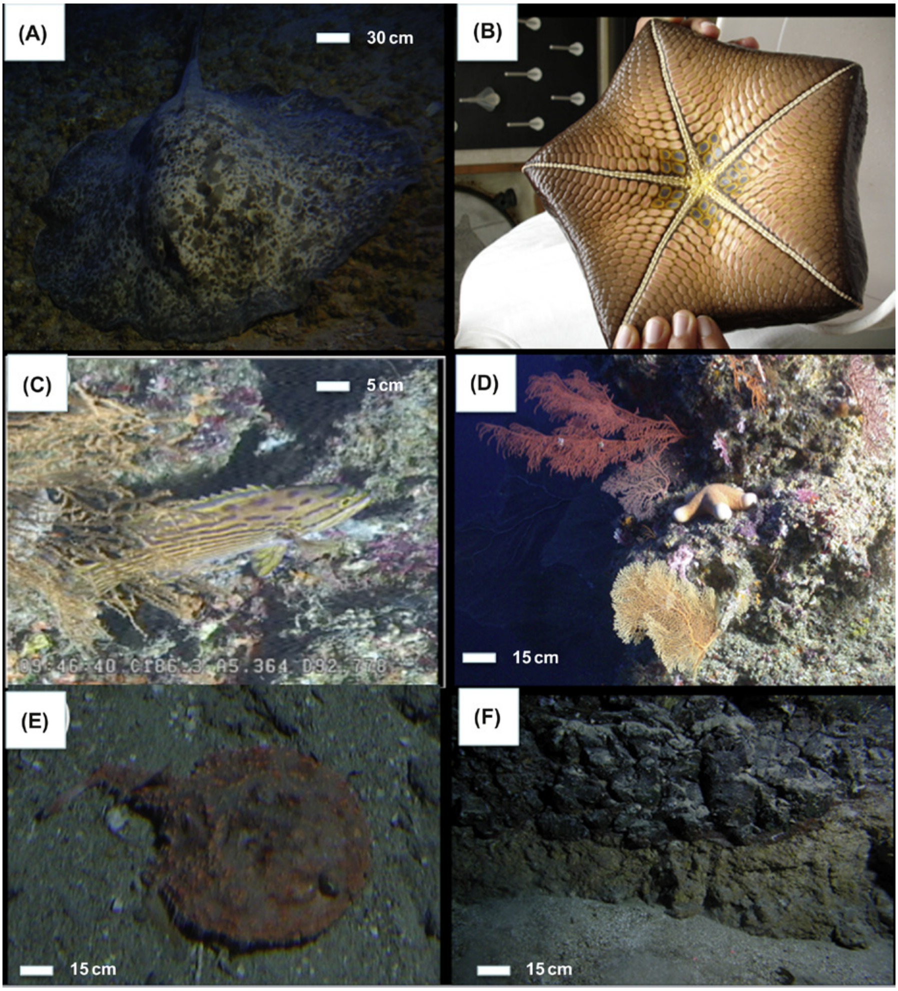
p0125 The submerged caldera that is Fagatele Bay dramatically slopes downward into a canyon (canyon has not yet been classified with regard to habitat). At around 20 m open slopes dominate, which further descend toward the broad depressions with open bottoms (Figure 58.8A). Open slopes above and on the edge of the narrow depressions in the center of the bay suggest prior seafloor subsidence, resulting also in a noteworthy ridge at the east center of the bay (~14°22″1′S, 170°45″52′W; Figure 58.8B). It is classified as a narrow crest with fringing lateral mid-slope crests and depressions. The edge of the narrow crest deepens so dramatically in some places that there is a narrow strand of steep slopes around it. Steep slopes are also seen at the edge of other narrow crests and lateral mid-slope features throughout the bay. The area that appears most complex, containing a diverse combination of BPI zones, as well as high to medium-high rugosity, is in the southeast portion of the bay, which extends to depths safe enough for submersible observations. Submersible observations on Dive P5–649 visually confirmed the presence of narrow mid-slope depressions and lateral mid-slope crests, while noting also the presence of several small box canyons cut into the southeast wall that were not detected in the original terrain classification. Of note also is a transition at ~185–209 m depth from old carbonate reef to a basalt layer, and another carbonate layer before transitioning to sediment at ~235 m.

s0025 Biological Communities

p0130 *Pisces V* submersible Dive P5–648 consisted of a video and photographic survey up the southwest wall of Taema Bank, noting 36 m as the depth at which the main corals extend to (base of main reef on bank) on a fairly consistent basis. It then proceeded to a deeper, safer contour of interest for sub/ships operations (down to 110 m, below significant surface wave surge), following it to the east along the south side of the bank, making observations of biota and physical structure.

p0135 The dive followed the 110 m depth contour for ~7 km in the broad depression/open bottom habitat class, and noted a significant assemblages of gorgonian corals (*Iciligorgia*), sea fans (e.g., *Annella reticulata*, *Melithaea*), whip corals (*Cirrhipathes*), and sea cucumbers (*Holothuria edulus*, *Thelonota anax*). A transition was noted from west to east of sea fans in the east having crinoids attached to their tops, and with three-armed, feathery brittlestars. There were also alternating “provinces” of barren, sloping calcareous (*Halimeda*) algae, sand plains, to slopes cut by deep crevices in calcareous conglomerate blocks to sea fans assemblages. In this same habitat class, various species of groundfish (e.g., greeneye or *Chlorophthalmus priridens*, orange sea toad or *Chaunax fimbriatus*, and the black-botched stingray or *Taeniura meyeni*; Figure 58.9) congregated in high rugosity, carbonate rubble piles, which may have been created by the fish as habitat.

p0140 Dive P5–649 consisted of a video and photographic survey around the edge of Fagatele Bay and Canyon, starting from the southwest corner and reaching the far southeast portion of the national marine sanctuary. Most of the dive scaled both southwest and southeast walls of the bay and canyon; hence, the predominant habitat classes were narrow (vertical) depression and lateral mid-slope crest. Main species observed included the harlequin grouper (*Cephalopholis*; Figure 58.9), the bigeye (*Heteropriacanthus cruentatus*), sea fans (*Annella reticulata*), gorgonian corals (*Iciligorgia*), and “doughboy”



f0050 **Figure 58.9** Photographs of new records for American Samoa as observed on Dives P5–648 and P5–649 from the *Pisces V* submersible, to Taema Bank, and Fagatele Bay and Canyon: (A) black-blotched stingray (*Taeniura meyeni*), ~2 m wide, 110 m depth on calcareous (*Halimeda algae*) sand and high-rugosity carbonate rubble, broad depression/open bottom habitat class, Taema Bank; (B) underside of "lounge cushion" sea star, recovered from 57 m depth, broad flat habitat class, Taema Bank—returned to ocean; (C) harlequin grouper (*Cephalopholis polleni*), 93 m depth, west wall of Fagatele Canyon, lateral mid-slope crest habitat class; (D) doughboy sea star (*Choriaster granulatus*) with orange and purple sea fans (*Annella reticulata*, *Melithaea*), 90 m depth, west wall of Fagatele Canyon, lateral mid-slope crest habitat class; (E) batfish (*Ogcocephalidae*), 247 m depth on calcareous sand, east Fagatele Canyon floor, broad depression/open bottom habitat class; (E) base of west wall of Fagatele Canyon, 230 m, showing clear contact between basalt flow overlying carbonate province. http://dusk.geo.orst.edu/djl/samoa/hurl/

sea stars (*Choriaster granulatus*). At the floor of the canyon, in the broad depression/open bottom habitat class, a notable discovery was the batfish (*Ogcocephalidae*) and the black-blotched stingray (Figure 58.9), as well as sightings of the deep water grouper (*Epinephelus timorensis*) among many other fish species.

p0145 Dive P5–650 returned to Taema Bank to investigate the full extent of the sheer carbonate wall encountered on P5–648, and hence was below the depth of prior benthic terrain classifications. Upon finding the base of the wall at 440 m, a video and photographic survey proceeded north from that point along that contour, where a preponderance of galatheid and hermit crabs, urchins, shrimp, a soft corals, sea cucumbers, and small stars were noted. Farther up the bank at ~115 m (broad flat habitat class), a large province of foraminifers in calcareous sands was noted: genus *Cycloclypea*, the largest in the world.

p0150 All three dives were extremely successful, with a cumulative bottom time of 18 h and identification at both sites of 32 species of invertebrates and 91 species of fish, at least nine of which are "new records" for American Samoa (Figure 58.9). The base of extensive live bottom for Taema Bank (coral cover of 20% and greater) was identified at a depth of 36 m. Alternating sections of carbonate reef and basalt were observed at ~185–220 m depth along both the east and west walls of Fagatele Canyon, and large, grooved, mass-wasting scarps were noted at ~300–400 m depth near the base of the south central wall of Taema Bank. No evidence of eutrophication or slurry from Pago Pago harbor was seen on the south side of Taema Bank. Complete species lists, dive track maps, and cruise report are available in Wright [41].

s0030 Surrogacy

p0155 At this time, no statistical analyses have been carried out on these data sets to examine relationships between physical surrogates and benthos. We await additional video and photographic surveys.

s0035 Acknowledgments

p0160 We thank captains, crew, and scientific personnel aboard the several ships who have been responsible for obtaining bathymetric data throughout the Eastern Samoa region.

p0165 Special thanks to Nancy Daschbach, former manager of the Fagatele Bay National Marine Sanctuary, for providing travel funding over the years via the NOAA National Marine Sanctuary Program. Thanks also to Joyce Miller, Emily Lundblad Hirsch, and Scott Ferguson, NOAA Coral Reef Ecosystem Division/Pacific Islands Benthic Habitat Mapping Center/Pacific Fisheries Science Center, as well as to Peter Craig of the National Park of American Samoa for helpful discussions. The manuscript benefited greatly from the comments of an anonymous reviewer and Robin Beaman of James Cook University. This work was supported in part by the US NOAA-National Undersea Research Program Hawai'i Undersea Research Laboratory and the US National Science Foundation.

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