Workshop to Identify National Ocean Exploration Priorities in the Pacific

White Paper Submissions

March 2020

Consortium for Ocean Leadership and NOAA's Office of Ocean Exploration and Research

Table of Contents

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Steven Auscavitch
Institution: Temple University
Email Address: steven.auscavitch@temple.edu
Office Phone Number: 215-204-4067

Collaborators/Co-Authors: Erik Cordes, Temple University (ecordes@temple.edu)

Title: The Northern Line Seamounts: Opportunities for new exploration of deep-water communities in the Pacific prime mineral crust zone.

Priority Geographic Area:
U.S. EEZ, Pacific Remote Islands Marine National Monument (PRIMNM), and International Waters

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)

The Line Seamounts lie at the northern end of the Line Islands, primarily within the boundaries of the US EEZ but external to the PRIMNM unit of Kingman and Palmyra Atoll. The region encompasses at least 20 high-profile seamounts and guyots with summit depths as shallow as 120m (Nicholas Seamount) (Fig. 1). In 2014, the expansion of PRIMNM by Presidential Proclamation 9173 did not include the remainder of the US EEZ surrounding Kingman Reef and Palmyra Atoll leaving a majority of the Line Seamounts external to the monument boundaries. During the 2015-2017 CAPSTONE (Campaign to address Pacific Science Technology and Ocean Needs) expeditions, the NOAA ship *Okeanos Explorer* mapped portions of the PRIMNM Boundary Guyot and EEZ Boundary Seamount Complex as a part of the end of the EX1705 transit to Honolulu (Bohnenstiehl et al 2018). More recently, expedition by the E/V *Nautilus* in June 2019 filled in some missing bathymetry from the region as a part of the NA110: Exploration of the US Line Islands cruise (Auscavitch et al *in press*). However, seamounts outside the boundaries of the Kingman and Palmyra unit of PRIMNM have never been surveyed with ROVs or submersibles.

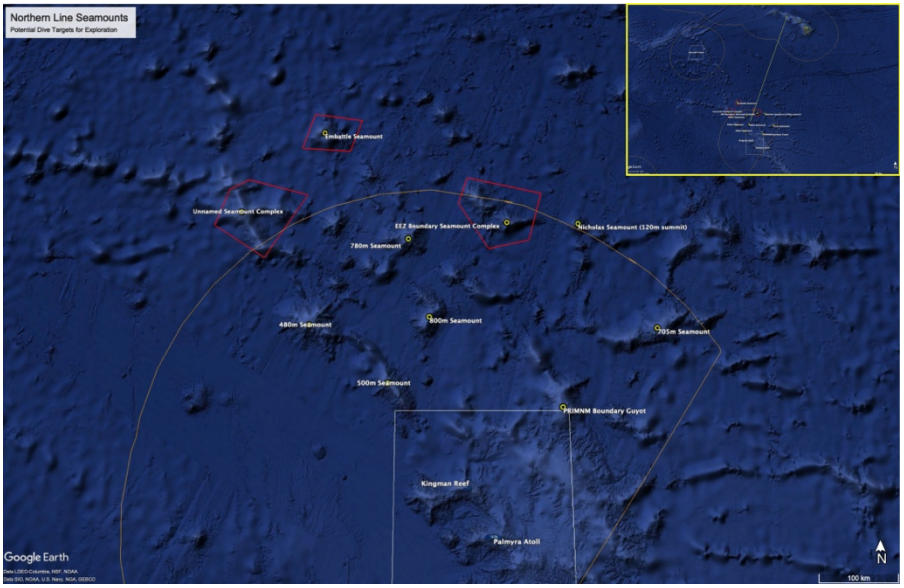


Figure 1: Overview map of the proposed target area of the Northern Line Islands Seamounts. An overview map in the upper right corner indicates location of this area relative to Hawaii. The US EEZ boundary is indicated by an orange solid line and the Kingman & Palmyra PRIMNM unit boundaries in white.

Nothing is known about deep-water biological communities on these seamounts, benthic or pelagic. Additionally, several seamount summits in this are occur within the mesophotic zone, likely resulting in a greater biological diversity of habitats and biological diversity

compared to deeper features. Suspected biological communities include precious coral beds (*Hemicorallium* sp.), like those that were encountered on Kingman Ridge in June 2019 (Fig. 2). In order to establish baseline metrics of deep-water communities, initial basic exploration should include ROV surveys and biological sampling. Baseline data also helps establish change in deep-water communities for this area should they be subjected to future disturbance.

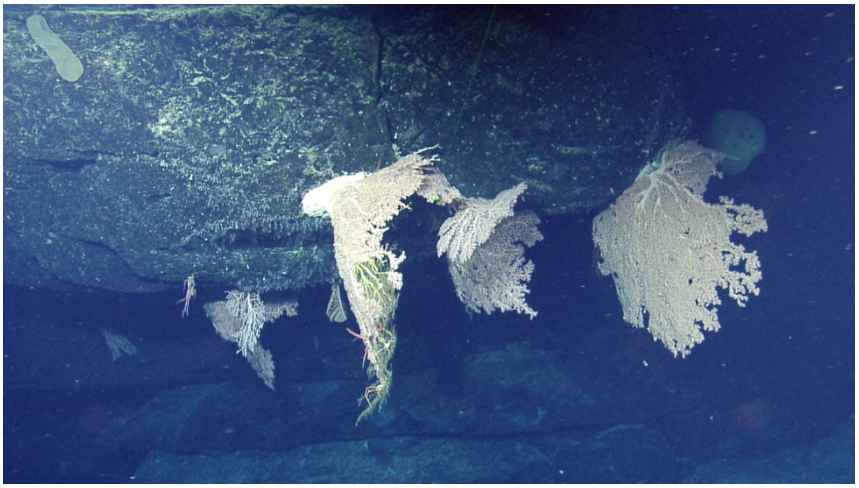


Figure 2: An overhang with dense precious coral colonies encountered at Kingman Ridges, a site explored during NA110 (E/V Nautilus*) in 2019.*

Geologically, the northern Line Islands is region of volcanic complexity that is not yet fully understood. Features in this area have not been found to be associated with any one or multiple hotspots suggesting that volcanism may have arisen from lithospheric extension at multiples times in history (Davis et al 2002). Geological specimens (e.g. rocks, cores) in this area would serve two purposes: 1) to better understand the origins of the Line Islands and 2) to better understand the extent of mineral crust (FeMn and Co-rich crusts) distribution in this area of the Pacific Prime Crust Zone (Fig. 3)

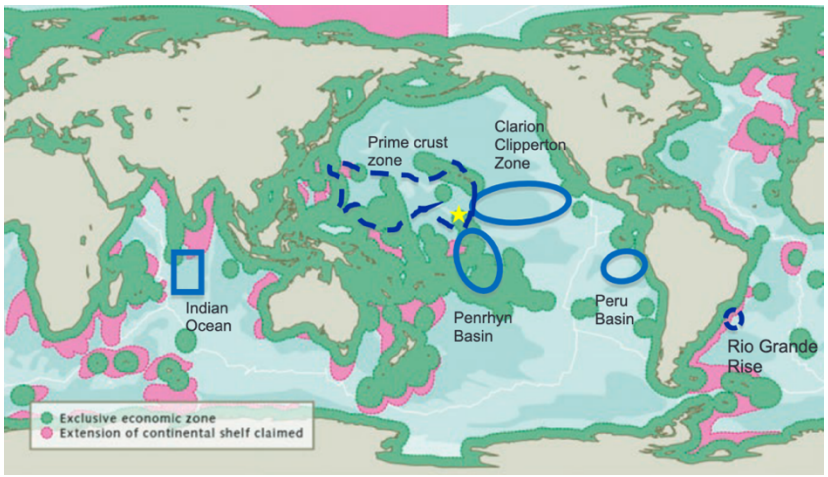


Figure 3: Pacific Prime Crust Zone. A yellow star denotes the subject location for exploration (From Weaver & Billett 2019).

What are the characterization and data needs in this area?
Check all that apply:
__x_ Biology
_x__ Geology
___ Marine Archaeology
___ Physical Oceanography
__x_ Chemistry (Geochemistry)
__x_ Other (Human activity indicators – e.g., plastic debris, fishing gear, trawl marks)

Provide a list or brief description of the data needed within this area, from your perspective:

Seafloor Mapping

1) Multibeam mapping is needed to gap-fill or improve existing bathymetry (Fig. 3)

Geological

1) What are the geologic origins of the Northern Line Seamounts?

2) Where do deep-water mineral crusts (FeMn and Co-rich crusts) occur relative to the depth range of these features? What is the thickness of these crusts and are they of commercial interest? Are there distinct, and potentially vulnerable, communities on these crusts?

Biological/Biochemical

1) How abundant and diverse are deep-water benthic species and communities on the Line Seamounts?
2) What is the connectivity of deep-water coral and sponge communities in the Line Seamounts with other regions (Hawaiian Islands, Line Islands, Johnston Atoll)? Answers may provide an understanding of community resilience in response to disturbance.
3) Collections of deep-water megafauna and associated organisms to facilitate identification in video analyses and promote vital taxonomic research.
4) Characterization of seafloor carbonate chemistry profiles in the region from seawater sampling.

Describe relevance to national security, conservation, and/or the economy:

All sites lie within the Pacific Prime Crust Zone (Fig. 3) and are likely to have Iron-Manganese (FeMn) and Cobalt-rich mineral crusts. At the same time, these features also likely have biological communities that lack resilience to mining activities (Weaver et al 2019). Shallow seamounts are aggregation points for commercially important deep-water fishes like tuna and swordfish (Morato et al 2008, 2011). However, those features straddling the US EEZ boundary and those immediately exterior to the EEZ in international waters are potential fishing targets that are managed very differently. The resulting impacts can include increased marine debris on the seafloor and direct habitat loss as a result of physical damage to long-lived ecosystem engineers like deep-water corals and sponges.

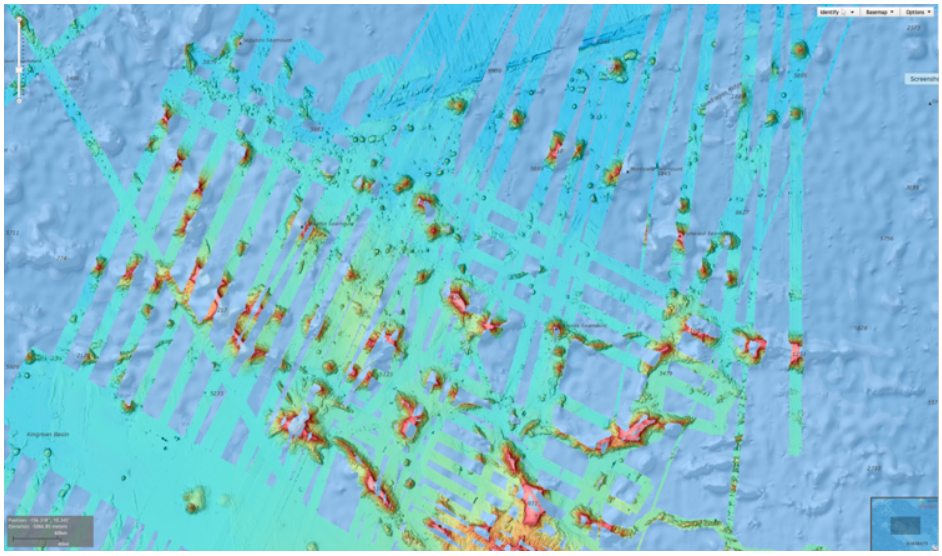


Figure 4: Mosaic of known bathymetry for this area from the NGDC as of 2/24/2020. This area represents a patchwork of previous surveys and would benefit immensely from gap-filling existing bathymetry.

From your perspective, what makes this area unique?

This area is still a black box for deep-water biodiversity in the central Pacific. Surveys have been extremely limited, even following the CAPSTONE expeditions and a recent cruise by the E/V Nautilus (Kennedy et al 2019). The Line Seamounts is one of the largest bodies of US EEZ external of the PRIMNM unit boundaries in the Pacific, yet it lacks the protections of monument status. Given that deep-sea mining interests (both nodules and mineral

crusts) are expected to increase in the central Pacific in the near future, it is important to establish baseline data in this locality.

Please list other partners or organizations that may also be interested in this area:
Kevin Konrad, Oregon State University (Geology)
Robert Pockalny, University of Rhode Island, Graduate School of Oceanography (Geology)

References

Auscavitch S, Pockalny R, Konrad K, Humphreys J, Clark TB, Heffron E, Fundis A. In Press. Deepwater Exploration of Kingman Reef, Palmyra Atoll, and Jarvis Island: Geological and biological discoveries from the US Line Islands. *Oceanography*.

Bohnenstiehl DR, France SC, Cantwell K, White M. 2018. Mountains in the Deep: Exploration of the Seamounts of the Central Pacific Basin. *OCEANOGRAPHY* 31:78–79.

Kennedy BRC, Cantwell K, Malik M, Kelley C, Potter J, Elliott K, Lobecker E, Gray LM, Sowers D, White MP, France SC, Auscavitch S, Mah C, Moriwake V, Bingo SRD, Putts M, Rotjan RD. 2019. The Unknown and the Unexplored: Insights Into the Pacific Deep-Sea Following NOAA CAPSTONE Expeditions. *Frontiers in Marine Science* 6:1–21. DOI: https://doi.org/10.3389/fmars.2019.00480.

Morato T, Varkey DA, Damaso C, Machete M, Santos M, Prieto R, Santos RS, Pitcher TJ. 2008. Evidence of a seamount effect on aggregating visitors. *Marine Ecology Progress Series* 357:23–32. DOI: 10.3354/meps07269.

Morato T, Hoyle SD, Allain V, Nicol SJ. 2011. Tuna Longline Fishing around West and Central Pacific Seamounts. *PLOS ONE* 5:e14453.

Weaver PPE, Billett D. 2019. *Environmental Impacts of Nodule, Crust and Sulphide Mining: An Overview*. DOI: 10.1007/978-3-030-12696-4.

NOAA Ocean Exploration Cooperative Institute: Exploration Vessel *Nautilus* Pacific Field Proposal 2021-2023

In May 2019, the National Oceanic and Atmospheric Administration Office of Exploration and Research (NOAA OER) announced it was awarding the University of Rhode Island (URI) as the leading institution for their Ocean Exploration Cooperative Institute (OECI). In partnership with the University of New Hampshire (UNH), the University of Southern Mississippi (USM), the Woods Hole Oceanographic Institution (WHOI), and the non-profit Ocean Exploration Trust (OET), the consortium will receive an initial 5-year award of up to $94 million.

The mission of this new OECI is three-fold: (1) to explore the 3 billion acres of submerged US ocean territory in order to strengthen our Nation's Blue Economy, aid responsible management, and promote greater scientific understanding of our Nation's vast underwater territory, known as the Exclusive Economic Zone (EEZ); (2) to develop the technology needed to carry out this effort including the greater use of autonomous vehicle systems operating from a broad range of sea-going platforms that explore the entire water column; and (3) to educate the next generation of scientists, engineers, and educators needed to maintain our Nation's leading role in STEM-related professions and our nation's growing workforce.

The field programs carried out by E/V *Nautilus*, beginning in 2021 will focus on three primary regions of the US EEZ: in the Central and Western Pacific including the Northern Hawaiian Islands, Guam and the Northern Marianas Islands, and American Samoa and the territorial Trust Islands of the Central Pacific.

During this period of time *Nautilus* will remain in these regions and not return to its home base in San Pedro, California until the end of 2023 to maximize time spent in remote and under-characterized or unexplored parts of the US EEZ.

Since this will involve *Nautilus* working near islands, atolls, and reefs where the ocean floor rises up abruptly from abyssal depths, we plan to utilize OECI partner technologies to optimize exploration potential. This includes UNH's aerial drones and autonomous surface vehicles (ASVs) with multibeam echosounders capable of mapping down to 500 meters and drop cameras provided by the National Geographic Society, both of which can be used while *Nautilus* conducts mapping surveys in adjacent deeper waters. In addition, the ASV will also be used to serve as a "command/control" link for the USM's *Eagle Ray* AUV, which can work to depths of 2,000 meters.

In the past, OET's *Argus*/*Hercules* ROVs have traditionally focused on exploring the benthic and epi-benthic zones of the deep sea. That effort will be expanded using WHOI's *Nereid* UI hybrid ROV/AUV to conduct simultaneous exploration in the nearby area capable of rendezvousing with *Hercules* and utilizing an optical modem to relay the data it has collected to the surface, and then via satellite, to scientists ashore to analyze and possibly redirect the assets in the field in near real-time. When operating in 24/7 ROV mode, the vehicles will commonly remain on the bottom for days.

The OECI program will use the ROV's vertical cable to investigate the entire water column when in this mode. Two systems are presently being brought online for this effort. The first is USM's plankton imaging system that will be able to rise up and down on the ROV cable imaging marine life living in the mid-water zone. A second mid-water vehicle will use the eDNA sampling system developed under WHOI's Ocean Twilight Zone project. This sampling system will also use the ROV's vertical cable to collect water samples to determine the marine organisms living in various depth zones based upon their DNA signature.

The long-term goal of this effort is to duplicate the Mesobot AUV that WHOI developed and is perfecting under separate funding. The Mesobot will follow mid-water organisms to observe their behavior for long periods of the time before reattaching to the ROV's vertical cable in order to return to the surface with samples and images and to be recharged so it can continue its work until the ROV is recovered.

To maximize the operational efficiency of E/V *Nautilus* when not conducting its traditional joint mapping and characterization program under NOAA's OECI, OET plans to use the ship for additional purposes. OET will take advantage of the ship being located in the most remote regions of America's EEZ in the central and western Pacific between 2021-2023, to convert *Nautilus* into a platform capable of supporting diving operations and scientists interested in island/reef/atoll studies while also mapping the seafloor.

Another major focus of the new OECI is to develop a series of mobile systems capable of operating on a broad range of research platforms including privately operated Global-Class ships as well as Intermediate-Class and the new Regional Class Research Vessels (RCRVs) operated by the UNOLS fleet using the new 6,000-meter mobile system that comes on line in 2020. Two of these RCRVs will be operated by two of the OECI partners, URI and USM.

When it comes to the OECI's third mission focused on STEM education, this expansion of seagoing capabilities will make it possible to broaden our present educational programs — including 24/7 live streams of our expeditions, at-sea and onshore opportunities for educators and students, live ship-to-shore broadcasts to classrooms and public venues, curricular and educational resources for educators, and online outreach — over the entire year. This allows us to scale our programs along with our OECI partners to other ships, and to amplify the significance of engaging the public and next generation in ocean exploration.

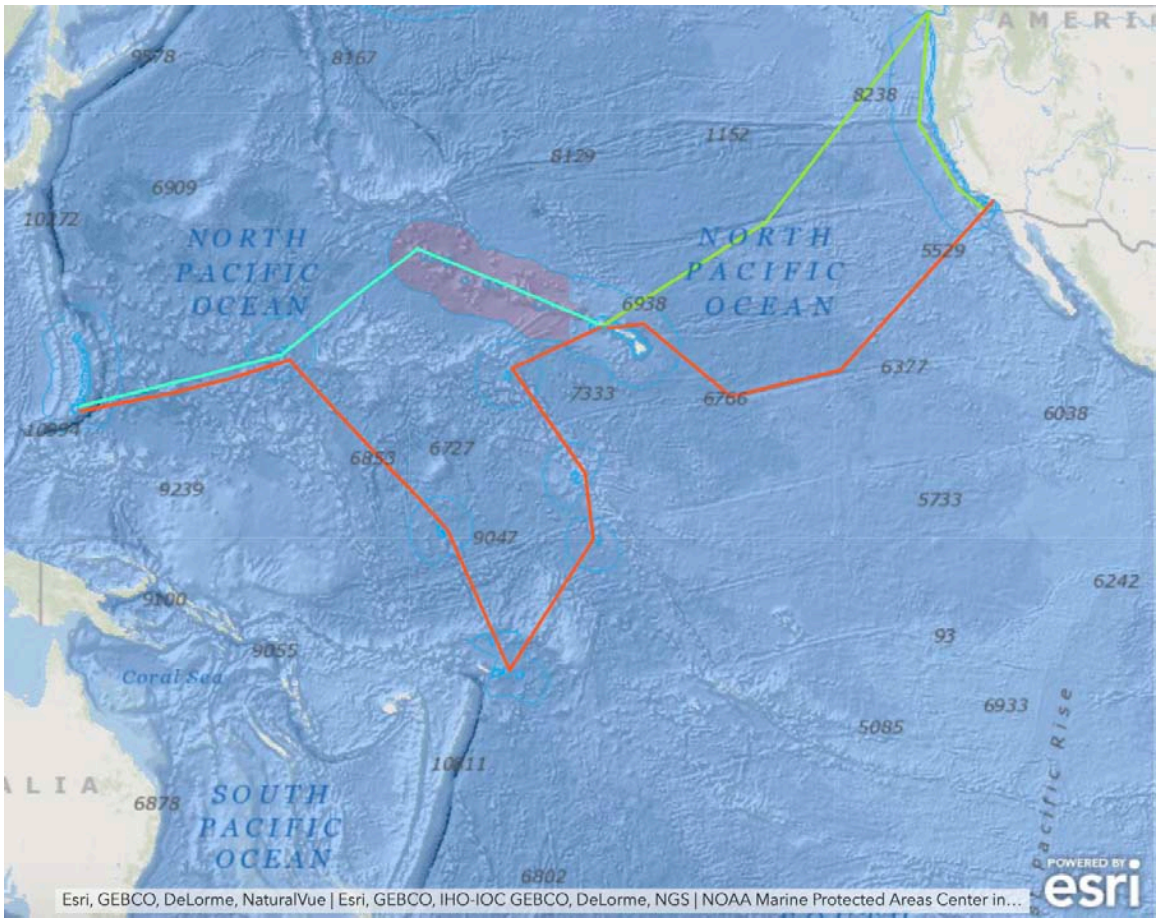


Figure 1 Overview of *Nautilus* proposed operating areas (2021-green, 2022-blue, 2023-orange)

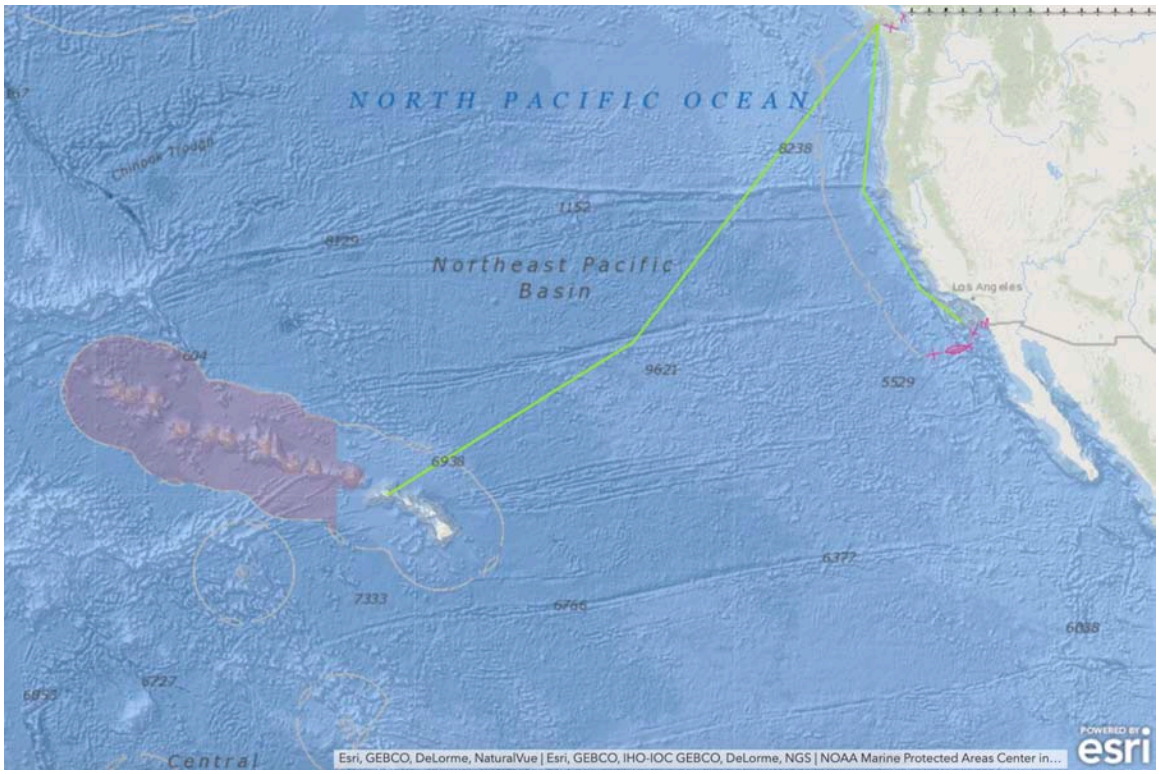


Figure 2 2021 *Nautilus* proposed operating areas between west coast of the US to Hawaii and the Papahānaumokuākea Marine National Monument

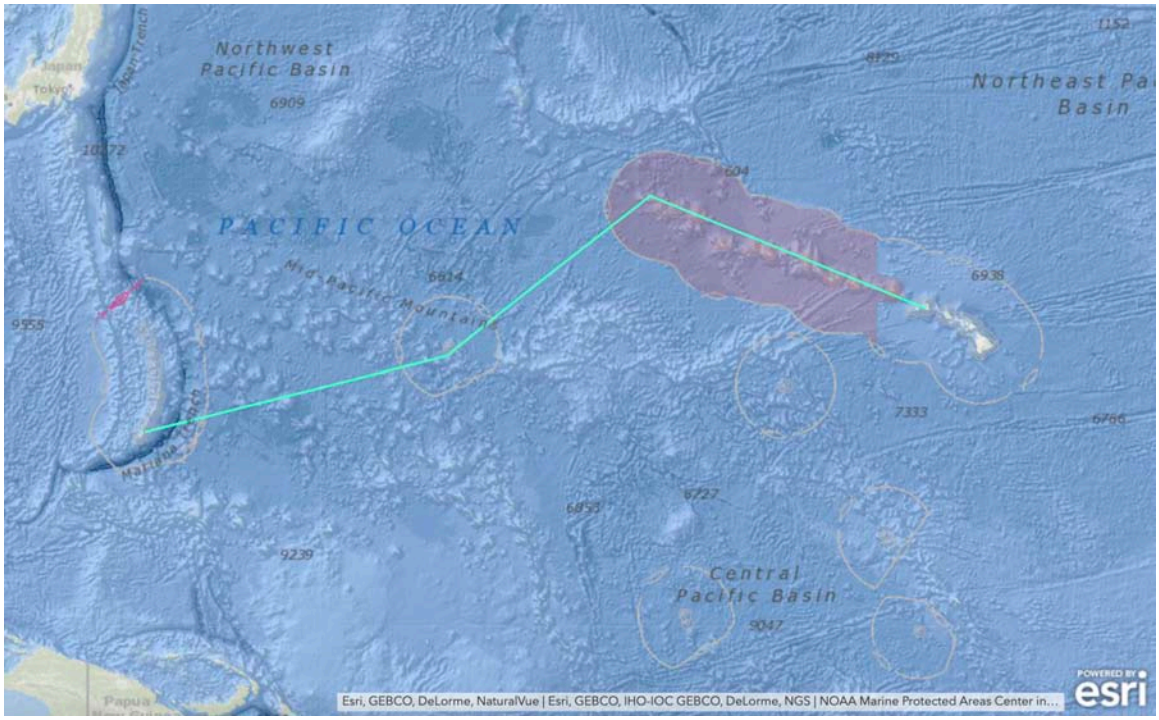


Figure 3 2022 *Nautilus* proposed operating areas between Hawaii and Guam

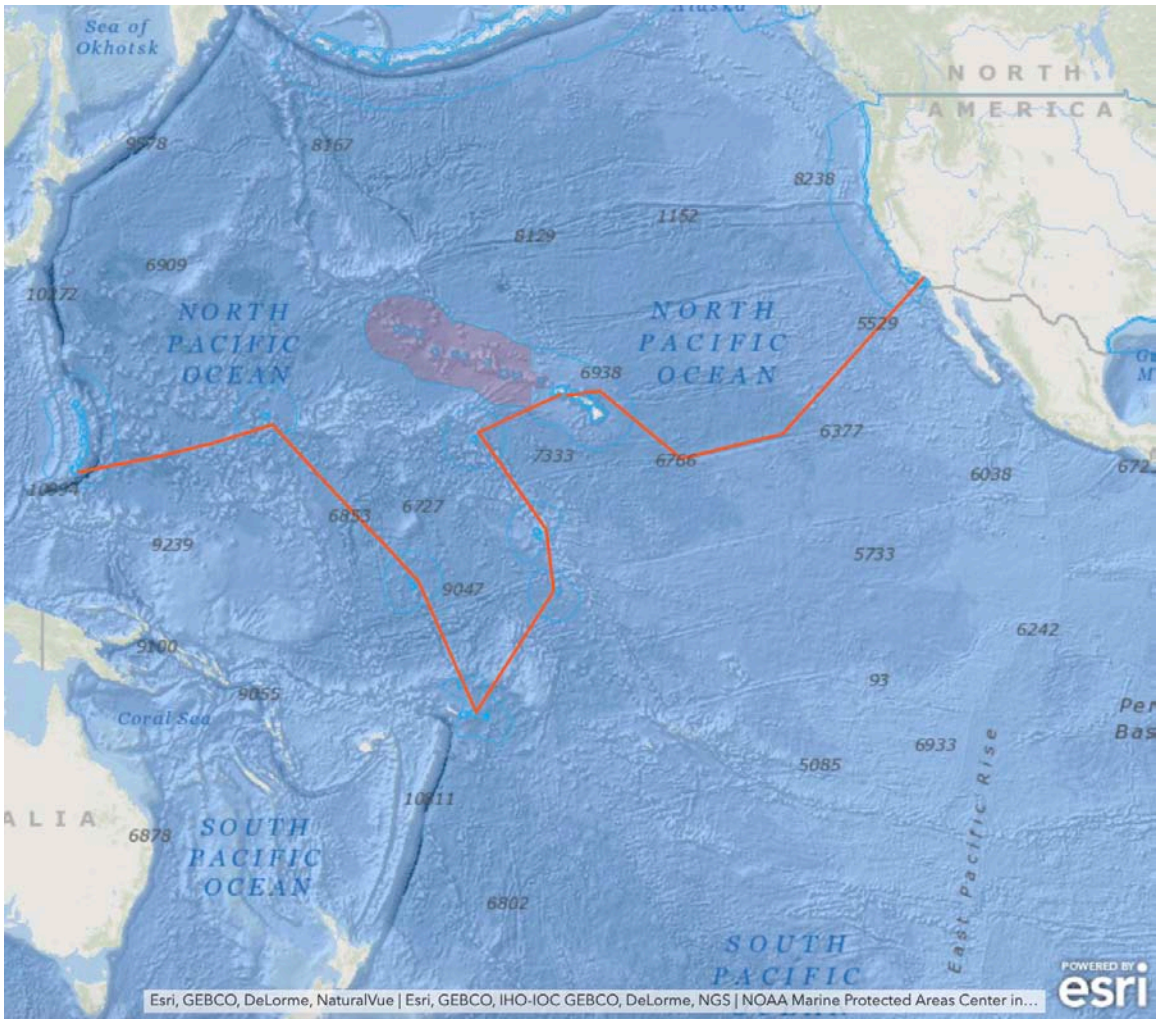


Figure 4 2023 *Nautilus* proposed operating areas between Guam, American Samoa, Honolulu, and US west coast

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Authors: Dr. Jeff Beeson[1], Dr. Tamara Baumberger[1], Dr. David Butterfield[2]
Institution: NOAA Pacific Marine Environmental Lab, Oregon St. University CIMRS, and U. Washington JISAO
Email Address: tamara.baumberger@noaa.gov, david.a.butterfield@noaa.gov, Joseph.Resing@noaa.gov, jeff.beeson@noaa.gov
Office Phone Number: 206-526-6722
Collaborators/Co-Authors: Dr. Joe Resing[1], Dr. Calvin Mordy[2]
[1]NOAA Pacific Marine Environmental Lab / Oregon State University CIMRS
[2]NOAA Pacific Marine Environmental Lab / U. Washington JISAO

Title: Seep and Hydrothermal Vent Exploration at the Alaska Margin through Multibeam Mapping, Targeted Sampling, Plume Mapping, and Geochemical Analysis.

Priority Geographic Area: Aleutian Arc offshore the Alaska Margin.

Description of Priority Area:
Two priority areas are proposed along the Alaska Margin (Figure 1). These locations represent both relatively unexplored regions and areas of relevance.

Eastern Margin - Methane Seep Exploration - Seafloor geological and biological characterization.

Western Margin - Hydrothermal Venting and Submarine Volcanism - In combination with methane seep exploration.

What are the characterization and data needs in this area?
Check all that apply:

- ✓ Biology
- ✓ Geology
- ✓ Physical Oceanography
- ✓ Chemistry

Provide a list or brief description of the data needed within this area, from your perspective:
High-resolution seafloor maps from ship- and AUV-mounted multibeam sonar, water column chemistry and plume mapping, seafloor ROV surveys and sampling for chemistry, mineralogy, geology, and biology.

Describe relevance to national security, conservation, and/or the economy:
Through Presidential Memorandum, the Administration has notified relevant agencies that the waters offshore Alaska are to be prioritized for mineral exploration, mapping and characterization, and assessment of resources to ensure national security and economic development. The Bering Sea and Gulf of Alaska are also home to the largest U.S. fishery (by a wide margin), so there is strong interest in fisheries management and ecosystem research in the region to support a sustainable "Blue economy". The seafloor is an important part of the ecosystem, but is inadequately mapped. Cold-water corals are an integral part of the Aleutian Islands food web and ecosystem, supporting the highest diversity and abundance of these species in the world's oceans (Heifetz et al., 2005). The Aleutian arc is therefore a high priority for ocean exploration.

Submarine volcanism on volcanic arcs generates a wide range of volcanic and hydrothermal features (Embley et al., 2007). The vast seafloor area and water column of the Aleutian arc are still relatively poorly mapped, with only one known hydrothermal site in the Inter-Ridge database (https://vents-data.interridge.org/). There are certainly many more undiscovered submarine arc hydrothermal sites that may form a semi-continuous chain of chemosynthetic habitats connecting the NE and NW Pacific, making the

Aleutian arc an important region to target for understanding the biogeography of endemic chemosynthetic fauna. Exploration and characterization of hydrothermal and submarine volcanic activity at the Aleutian Island Arc will generate a baseline and inform about the spatial distribution of natural resources and chemosynthetically fueled ecosystems. The distribution and quality of mineral resources in this region are largely unknown and the biological communities associated with hydrothermal activity along the Aleutian arc are uncharacterized. These factors make the Aleutian arc a prime target for exploration that includes locating hydrothermal systems and systematically sampling the fluids, minerals, and biota associated with them.

Recent exploration efforts offshore the Pacific Northwest (Cascadia margin) have imaged thousands of methane seeps fluxing carbon into the ocean and potentially the atmosphere (Riedel et al, 2018). Alaska likely also hosts extensive methane seepage throughout its margin, likely on its sediment-rich eastern margin (Figure 1), and is an unknown contributor of carbon to the ocean and atmosphere. Mapping the spatial distribution, characterizing the geochemical make-up, and understanding the flux of methane seepage is an important first step to quantifying the impact of this poorly known flux of carbon into the ocean and atmosphere.

Methane seepage is also a substantial contributor to authigenic carbonate formation and thus hard ground locations on the seafloor. These carbonate mounds, platforms, ridges, etc. make up key habitats for fisheries. Multibeam mapping is an efficient tool at identifying and mapping these essential fish habitats and would contribute to fisheries assessments and management.

An unknown amount of methane is fluxing through continental margins, and up to ~1800 gigatons of carbon are stored in icy methane hydrate deposits within their sediment (Ruppel and Kessler, 2017). Sources of this methane include biogenic production, disassociation of the methane hydrate layers, and deep thermogenic sources. Geologic methane storage in the Arctic is large when compared to the global methane pool. Methane is one of a group of carbon species that have been recognized as important greenhouse gases and thus the methane geochemical cycle is important to climate modeling.

The inert gas ^{3}He is a unique tracer for mantle gas. Recently, mantle gas input into Cascadia Margin seep gases has been observed (Baumberger et al., 2018). Collecting and analyzing seep gases at the Alaska margin for mantle helium input allows recognition of active pathways and potentially provides information about the presence of connecting fractures from the mantle to the seafloor. Helium isotope ratios can thus be used as a tracer for the dynamics of fracture systems and reactivated faults at subduction systems, which is extremely relevant in the tectonically active Aleutian arc region.

From your perspective, what makes this area unique?

- Lack of modern multibeam datasets (bathymetry, backscatter, water-column)
    - Foundational datasets that contribute to core understanding of the margin.
- High-latitude margins may be disproportionately impacted by a warming climate and ocean acidification (Mathis et al., 2015; Roots 1989)
    - This high-latitude margin may be an indicator of how other margins will respond to a changing ocean.
- ~4,500-kilometer-long U.S. margin that is relatively poorly understood compared to the other U.S. Margins
    - Unknown potential of resources, contributor to carbon cycle, natural hazards, possible biological bridge between hydrothermal systems of the NW and NE Pacific
- Importance of the regional fishery to food supply and the US economy.

Please list other partners or organizations that may also be interested in this area:

NOAA – hydrographic survey division, NOAA – National Marine Fisheries Service, NOAA – Ocean Exploration and Research, US Geological Survey, State of Alaska Division of Geological and Geophysical Surveys, Alaska Department of Fish and Game, U.S. Bureau of Ocean and Energy Management, many academic institutions.

References:

Baumberger, Tamara, et al. "Mantle-Derived Helium and Multiple Methane Sources in Gas Bubbles of Cold Seeps Along the Cascadia Continental Margin." *Geochemistry, Geophysics, Geosystems* 19.11 (2018): 4476-4486.

Embley, R. W., E. T. Baker, D. A. Butterfield, W. W. Chadwick, Jr., J. E. Lupton, J. A. Resing, C. E. J. De Ronde, K. Nakamura, V. Tunnicliffe, J. Dower, and S. G. Merle (2007), Exploring the Submarine Ring of Fire: Mariana Arc - Western Pacific, Oceanography, 20(4), 69-80

Mathis, J.T., S.R. Cooley, N. Lucey, S. Colt, J. Ekstrom, T. Hurst, C. Hauri, W. Evans, J.N. Cross, and R.A. Feely (2015): Ocean acidification risk assessment for Alaska's fishery sector. Prog. Oceanogr., 136, 71–91, doi: 10.1016/j.pocean.2014.07.001.

Riedel, Michael, et al. "Distributed natural gas venting offshore along the Cascadia margin." *Nature communications* 9.1 (2018): 1-14.

Roots, E. F. "Climate change: High-latitude regions." *Climatic Change* 15.1-2 (1989): 223-253.

Ruppel, Carolyn D., and John D. Kessler. "The interaction of climate change and methane hydrates." *Reviews of Geophysics* 55.1 (2017): 126-168.

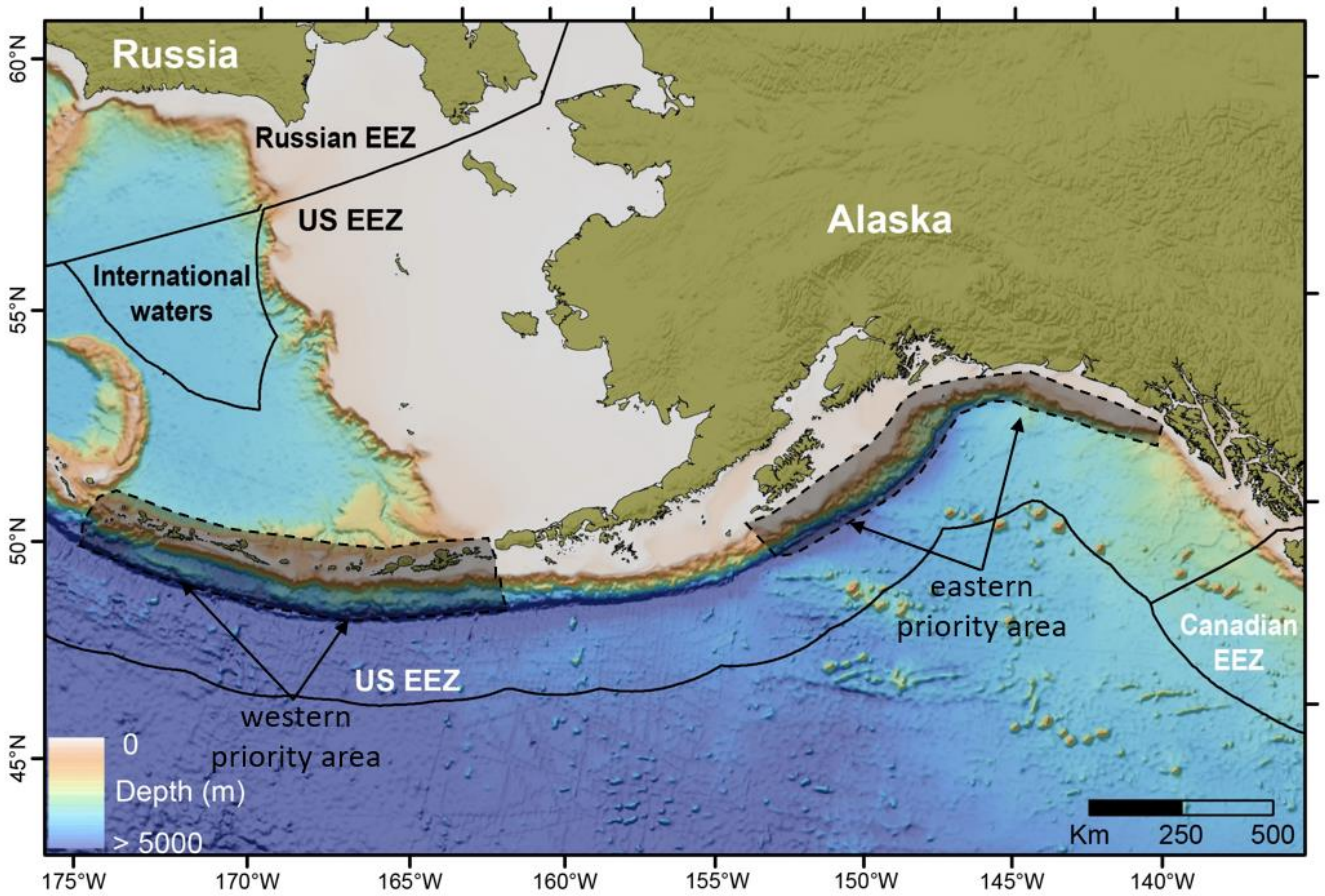


Figure 1: Eastern and western priority areas on the Alaska Margin.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Michael L. Brennan
Institution: SEARCH
Email Address: mike.brennan@searchinc.com
Office Phone Number: 904-379-8338
Collaborators/Co-Authors: James P. Delgado, Russell E. Matthews

Title: Pacific Wrecks of World War II: Submerged Landscape of an Aerial War

Priority Geographic Area:
Target shipwrecks and landscape both within EEZ and international waters (see attached description and map)

Description of Priority Area:
Wide-ranging areas of the deep Pacific were impacted by engagements of World War II with historically significant ships and aircraft sunk. See attached description.

What are the characterization and data needs in this area?
Check all that apply:
___ Biology
___ Geology
_x_ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
High resolution multibeam bathymetry and, where possible, ROV dives for target identification, inspection, and characterization.

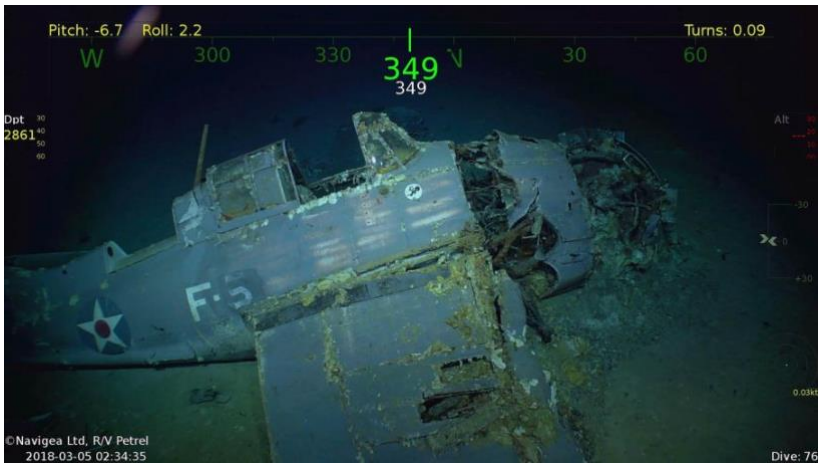
Describe relevance to national security, conservation, and/or the economy:
Historic resources from WW2 have been underwater for more than 75 years and many have not been found or documented. These sites can be preserved through high resolution sonar and imagery.

From your perspective, what makes this area unique?
Each shipwreck and submerged battlefield from World War II has its own story to tell that can be brought to light through telepresence-enabled exploration of the wrecks.

Please list other partners or organizations that may also be interested in this area:
Navy History and Heritage Command, BOEM, NOAA, DPAA

Pacific Wrecks of World War II: Submerged Landscape of an Aerial War
Michael L. Brennan, James P. Delgado, Russell E. Matthews

The Pacific theater of World War II sent US forces across the largest body of water on the planet, and thereby today represents the vastest maritime cultural landscape in history. Across the Pacific seabed lies the wrecks of warships and support vessels from Japanese and Allied forces, most of which now serve as war graves in the depths. Recent work by R/V *Petrel* and the team from Vulcan, Inc. has showcased the effectiveness of deep-water AUV technology combined with historical archive research for narrowing search areas. The team's discoveries in the deep Pacific include the heavy cruiser USS *Indianapolis* (CA-35), the American aircraft carriers USS *Wasp* (CV-7), USS *Hornet* (CV-8) and USS *Lexington* (CV-2), Japanese aircraft carriers IJN *Kaga* and *IJN Akagi*, light cruiser USS *Juneau* (CL-52), and Japanese cruiser IJN *Chokai,* among many others (Vulcan Inc. 2019). Shipwrecks such as these in deep water are part of the submarine landscape, and also serve as artificial reef substrate for biological colonization.



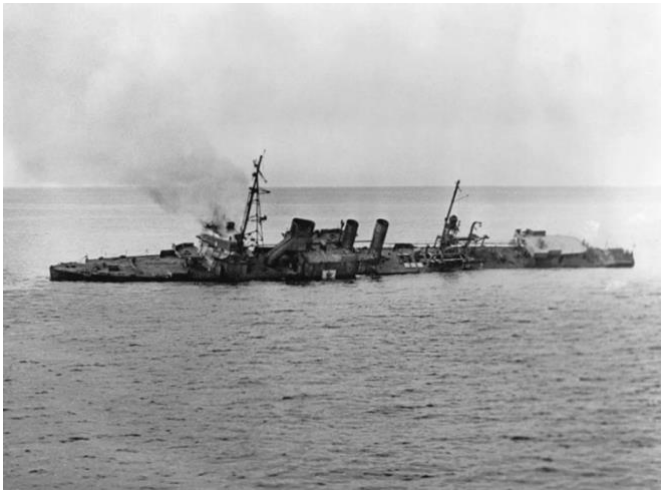
Aircraft from USS Lexington located in the Coral Sea by R/V Petrel.

Despite the recent successes at discovering these significant World War II losses in the deep Pacific, these missions lacked the telepresence-enabled participation of scholars to help guide the ROV documentation of the sites. Most of the shipwrecks located by *Petrel* are in need of return ROV missions with full telepresence capability to engage with the scientific community as well as public outreach for telling the stories of these warships. Additionally, full documentation of the wreck sites is needed for full archaeological and environmental characterization; comprehensive high definition video can be used to construct 3D orthomosaics for evaluation of the sites as well as data products for public outreach. This comprehensive documentation has not been achieved on these wrecks to date, but could be done upon return visits, potentially with the *Petrel* team. Some of the observations made, however, have shown the level of preservation at such sites in the deep Pacific to be very good, as evidenced by the paint still on aircraft located on the USS *Lexington* and USS *Hornet* wrecks. Aircraft losses in the Pacific war include those that were shot down during carrier battles as well as those than were sunk with their carriers.

Other aircraft carriers lost in the Pacific and that are yet to be found include USS *Gambier Bay* (CVE-73) and USS *Liscome Bay* (CVE-56). These were Casablanca-class escort carriers launched in late 1943 and who participated in the late war. *Liscome Bay* was launched in August and lost a few months later in November when it was torpedoed by Japanese submarine I-175. The submarine fired torpedoes at an entire task force the carrier was traveling with and one torpedo struck the bomb magazine, causing a massive explosion that sank the carrier in 23 minutes. The ship sank 20 miles southwest of Butaritari Island in Kiribati and 656 men went down with the ship (NNAM 2014). USS *Gambier Bay* participated in the Battle off Samar in the Philippines in October 1944. The escort carrier was part of the Taffy 3 task force which came under attack by Japanese battleships and cruisers, including IJN *Yamato*. Shells from

the ships struck the carrier in the engine room and began to flood the ship and *Yamato* closed to point blank range. *Gambier Bay* eventually capsized and sank along with three other ships, destroyers USS *Hoel* (DD-533) and USS *Johnston* (DD-557) and the destroyer escort USS *Samuel B. Roberts* (DE-413). The ships sank approximately 40 miles east of Samar (Evans 2019). These two escort carriers are significant wartime losses and war graves for the many sailors who died on board. In addition, as shown by the recent *Petrel* discoveries, the aircraft that went down with the ships may be well preserved in the deep sea.

In 2019, R/V *Petrel* followed Robert Ballard's discovery of USS *Yorktown* (CV-5) at Midway with the Japanese aircraft carriers IJN *Kaga* and IJN *Agaki*. Carriers IJN *Soryu* and IJN *Hiryu* remain undiscovered. However, in addition to these important shipwrecks, the main battle at Midway was in the skies. Dozens of aircraft were shot down over a vast stretch of ocean between the two aircraft carrier groups over the course of four days in 1942, spanning one of the largest battlefields in military history. None of these aircraft, aside from those that sank with their carriers, have been located on the deep abyssal plain below where these dogfights took place. With many of the aircraft rests the bodies of the pilots, and in addition to finding and documenting these sites, DPAA and the Navy may have an interest in locating and determining the conditions of the wreckage.

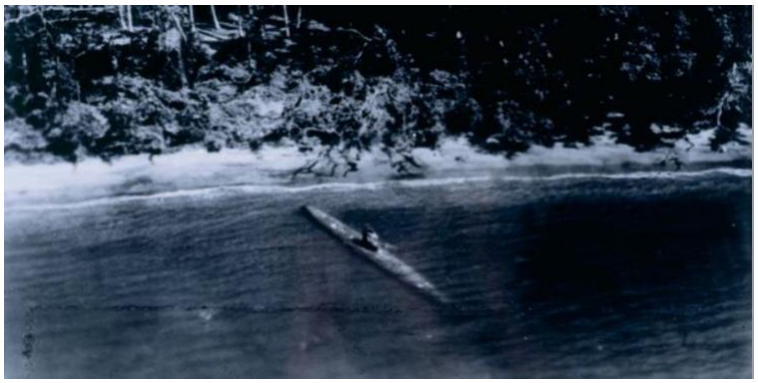


USS *Stewart* sinking off California, 1946.

In addition to aircraft carrier and aircraft wrecks in the Pacific, a number of other warships remain undiscovered. One such wreck is that of destroyer USS *Stewart* (DD-224). After being captured by the Japanese, the destroyer was returned at the end of the war. *Stewart* was sunk by aerial rocket 55 miles northwest of San Francisco in waters now part of Cordell Bank National Marine Sanctuary on May 24, 1946. *Stewart*'s location in an unexplored area of CBNMS positions it as an essential component of that region's ecological benthic landscape. It is also one of the most historically significant wrecks known to be within the NMS system. During the 2014 Workshop on Telepresence-Enabled Exploration of the Eastern Pacific Ocean, Central California was identified as a high priority area for exploration, including Bodega Canyon and specifically the discovery of USS *Stewart*. The upwelling system off California around Cordell Bank, the general unexplored nature of this region, especially Bodega Canyon, and the need for finding and documenting this World War 2 shipwreck dictate the interdisciplinary importance and significance, and an ideal target for a telepresence-enabled, multidisciplinary mission.

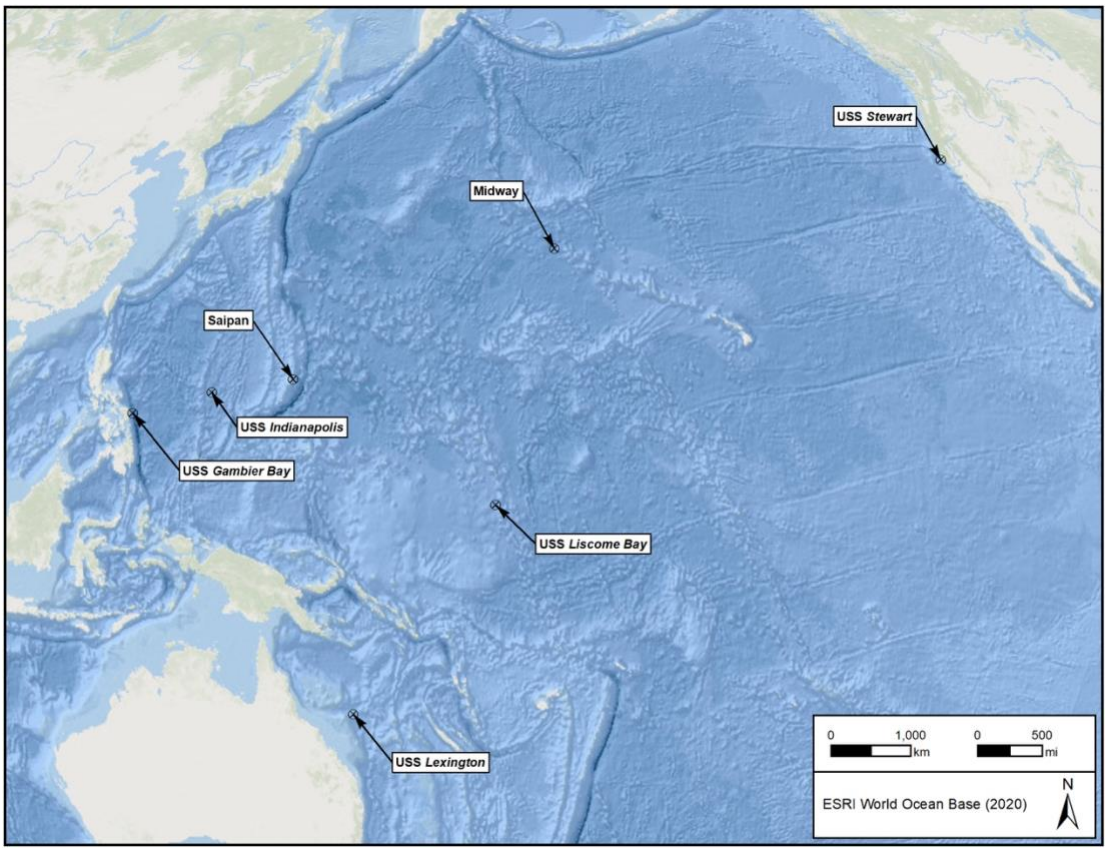
In 2016, *Okeanos Explorer* conducted a live ROV dive to the wreck of the Japanese mini submarine that was sunk just outside Pearl Harbor the morning of December 7, 1941 on the 75th anniversary of the attack. These midget submarines were used in a variety of campaigns after Pearl Harbor, including at Guadalcanal, many of which ended up being scuttled or abandoned (Delgado et al. 2016). One wreck of a midget sub has been found on land in Guam, but there are reports of two that were recovered after the war and then scuttled off of Saipan. Others were similarly examined quickly and sunk off Okinawa

(Delgado et al. 2016). Such wrecks are important aspects of World War Two and are examples of the type of exploration and discovery of naval action from the war remaining to be found.



Midget submarine abandoned in the Solomon Islands (Delgado et al. 2016)

In addition to the historical significance of each of these shipwrecks, and the importance of conducting detailed archaeological and environmental characterization of the wreck sites, is the opportunity such exploration provides for public engagement. Enabling these expeditions with telepresence vastly increases the value of the ship time by providing access to a limitless number of scholars and scientists to join the work in real time and offer their insights, ideas and interpretation. We have conducted live work on deep water shipwrecks from both *Nautilus* and *Okeanos Explorer* (Brennan et al., 2018), including the sites of the aircraft carrier from Operation Crossroads, USS *Independence* (Delgado et al., 2018a), the Cold War submarine, USS *Bugara* (Delgado et al., 2018b, and the World War II loss in Canadian waters, SS *Coast Trader* (Delgado et al., 2018c). Public engagement with such work has also shown to be impactful and exciting and these platforms offer immense opportunity for students, classrooms, and others to participate and join in the work remotely. We anticipate a web presence for any such mission undertaken in the Pacific to be able to engage with scholars and the public ahead of and during the exploration for finding and documenting these shipwrecks.



References

Brennan, Michael L., Frank Cantelas, Kelley Elliott, James P. Delgado, Katherine L.C. Bell, Dwight Coleman, Allison Fundis, Jack Irion, Hans K. Van Tilburg, Robert D. Ballard, 2018. Telepresence-enabled maritime archaeology in the deep. *Journal of Maritime Archaeology* 13: 97-121.

Delgado, James, Michael L. Brennan, Kelley Elliott, Russell E. Matthews, Megan Lickliter-Mundon, John G. Lambert, Frank Cantelas, Robert V. Schwemmer, 2018. Archaeological survey of the ex-USS *Independence* (CVL22). *Journal of Maritime Archaeology* 13: 123-144.

Delgado, James, Frank Cantelas, Robert V. Schwemmer, Robert S. Neyland, Agustin Ortiz, Jr., George Galasso, Michael L. Brennan, 2018. Archaeological survey of the ex-USS *Bugara*. *Journal of Maritime Archaeology* 13: 191-206.

Delgado, James P., Frank Cantelas, Lisa C. Symons, Michael L. Brennan, Richard Sanders, Evan Reger, Deanna Bergondo, Donald L. Johnson, Jacques Marc, Robert V. Schwemmer, Lea Edgar, Duncan MacLeod, 2018. Telepresence-enabled archaeological survey and identification of S/S *Coast Trader*, Straits of Juan de Fuca, British Columbia, Canada. *Deep-Sea Research Part II* 150: 22-29. doi:10.1016/j.dsr2.2017.05.013

Delgado, James P., Terry Kirby, Hans K. Van Tilburg, Steven Price, Ole Varmer, Maximilian D. Cremer, Russell Matthews, 2016. The Lost Submarines of Pearl Harbor. Texas A&M University Press, College Station.

Evans, Mark L., 2019. USS Gambier Bay (CVE-73). Accessible: <https://www.history.navy.mil/research/histories/ship-histories/danfs/g/gambier-bay.html>. Accessed 17 February 2020.

National Navy Aviation Museum, 2014. The sinking of USS Liscome Bay. Accessible: <https://www.navalaviationmuseum.org/history-up-close/sinking-uss-liscome-bay/>. Accessed 17 February 2020.

Vulcan Inc., 2019. R/V Petrel. Accessible: <https://www.rvpetrel.com/>. Accessed 17 February 2020.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Michael L. Brennan
Institution: SEARCH
Email Address: mike.brennan@searchinc.com
Office Phone Number: 904-379-8338
Collaborators/Co-Authors: James P. Delgado, Russell E. Matthews

Title: Shipwrecks of the Cold War: The Target Ships from Operation Crossroads

Priority Geographic Area:
Target shipwrecks and within EEZ (see attached description and map)

Description of Priority Area:
The target ships from Operation Crossroads at Bikini Atoll were scuttled or sunk as targets in areas of the Pacific ranging from the Marshall Islands to the west coast of the US. See attached description.

What are the characterization and data needs in this area?
Check all that apply:
___ Biology
___ Geology
_x_ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
High resolution multibeam bathymetry and, where possible, ROV dives for target identification, inspection, and characterization.

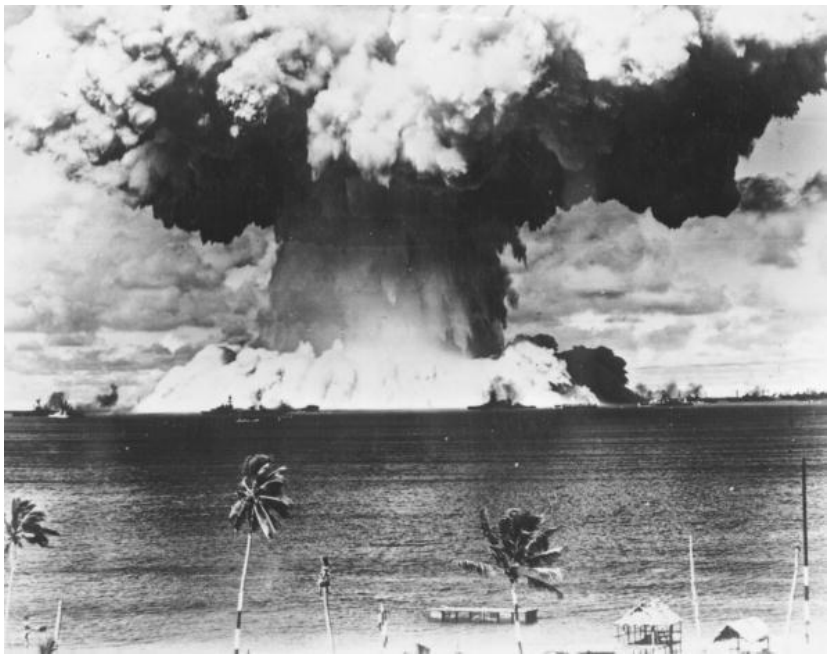
Describe relevance to national security, conservation, and/or the economy:
Historic resources from the late 1940's have been underwater for nearly 75 years and many have not been found or documented. These sites can be preserved through high resolution sonar and imagery.

From your perspective, what makes this area unique?
Each shipwreck from Crossroads has history from its service in World War II and its own story to tell that can be brought to light through telepresence-enabled exploration of the wrecks.

Please list other partners or organizations that may also be interested in this area:
Navy History and Heritage Command, BOEM, NOAA

Shipwrecks of the Cold War: The Target Ships from Operation Crossroads
Michael L. Brennan, James P. Delgado, Russell E. Matthews

In the aftermath of World War II, the US Navy jettisoned a variety of material into the deep sea for disposal, including munitions and chemical weapons as well as old ships from the war. Many of the ships sunk, either by scuttling or as targets, were those that survived the initial nuclear tests during Operation Crossroads. These tests were conducted in July 1946 at Bikini Atoll in the Marshall Islands. A test array of 97 warships, loaded at various levels with fuel, ammunition, military equipment, and, in some cases, aircraft, as well as instrumentation and test animals were subjected to two nominal yield (20 KT) detonations of a MKIII plutonium core implosion bomb. In the aftermath of the tests, which sank 21 of the ships, nearly all of the remaining vessels were found to be radioactively contaminated, as were a large percentage of ships being used for logistical support of the tests. Operation Crossroads ended with the abandonment of Bikini Atoll and the withdrawal of the fleet. During the next five years, nearly all of the former target vessels were sunk in various locations throughout the Pacific, ranging from Kwajalein Atoll to offshore San Diego. These ships played a unique role, first as ships of war during World War II and then as components of the simulated nuclear battlefield of Bikini Atoll and subsequent research into radioactive contamination of materials at the dawn of the nuclear age.



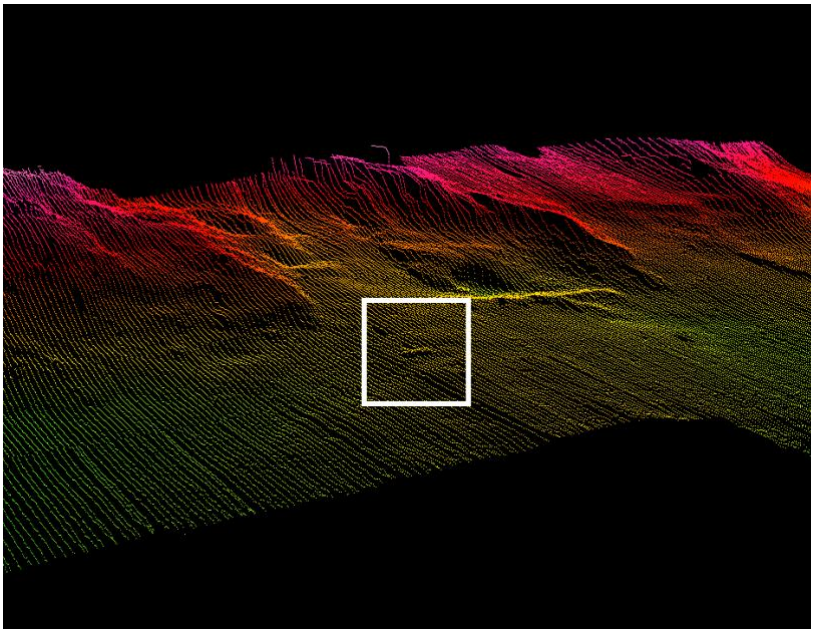
Test Baker at Bikini Atoll in July 1946, which irradiated the target ships moored in the lagoon.

Surveys to relocate and archaeologically study the sunken ships of Operation Crossroads commenced in 1989–1990 at Bikini Atoll. By the mid-1990s, 13 of the ships had been found and studied to varying levels within the 58-meter depths of Bikini Atoll lagoon. None of the 40 other Operation Crossroads wrecks that lie off Kwajalein, California, Washington State, or Hawaii have been found or studied, other than the light aircraft carrier USS *Independence* (CVL-22) (Delgado et al., 2018a). The Operation Crossroads fleet is more than a collection of historically important ships from World War II; it is a significant collection of sites that speaks to the archaeology of the recent past, the Cold War, the effects of nuclear weapons, and the behaviors inherent in discard and abandonment (Brennan et al., 2018). Additional exploration, discovery, and assessment can do much to examine this aspect of history and the various scientific, forensic, and archaeological results that can be learned from the scuttled ships of Operation Crossroads.

USS *New York* sinking off Pearl Harbor, 8 July 1948.

In 2016, we conducted environmental characterization dives on the wreck of USS *Independence* from E/V *Nautilus*. This wreck was evaluated for potential environmental hazards, including corrosion, potential for oil leaks, unexploded munitions, and, specifically for this wreck, remnant radiation from the Operation Crossroads bombs (Delgado et al., 2018a). This comprehensive remote assessment was able to characterize the environmental impact of the wreck and condition of the ship's hull to determine the stability of the site. In addition, analysis of sponges collected from the wreck and the remotely-operated vehicle (ROV) upon its return to the surface found no trace of remnant radiation above the ambient levels naturally occurring in seawater. The same approach of environmental and archaeological characterization conducted simultaneously can be done for locating and investigating these other wrecks.

Two veteran battleships, USS *Nevada* (BB-36) and USS *New York* (BB-34), were scuttled off Oahu in July 1948: USS *New York* on July 8 and USS *Nevada* on July 31. USS *Nevada* was painted bright orange prior to the Able test at Bikini Atoll as it was the intended target for the airdropped bomb; however, the bomb missed so *Nevada* did not sink (Delgado, 1996). USS *New York*, positioned just past Yard Oiler YO-160, which sank in the blast, was close to the Baker blast and was deemed too hot with radioactivity, so along with Nevada, was sunk by gunfire off Pearl Harbor (Delgado, 1996). We have conducted extensive research on these two battleships, and through analysis of naval records, we have tightly defined search boxes of 10 x 10 miles for each. Similarly, USS *Pennsylvania* (BB-38) survived both Able and Baker test blasts but was heavily irradiated by the water displaced by Baker. The damaged vessel was towed to Kwajalein and underwent decontamination tests before being scuttled in the deep water west of the atoll. A multibeam target located by *Okeanos Explorer* in 2016 may be the sunken battleship.

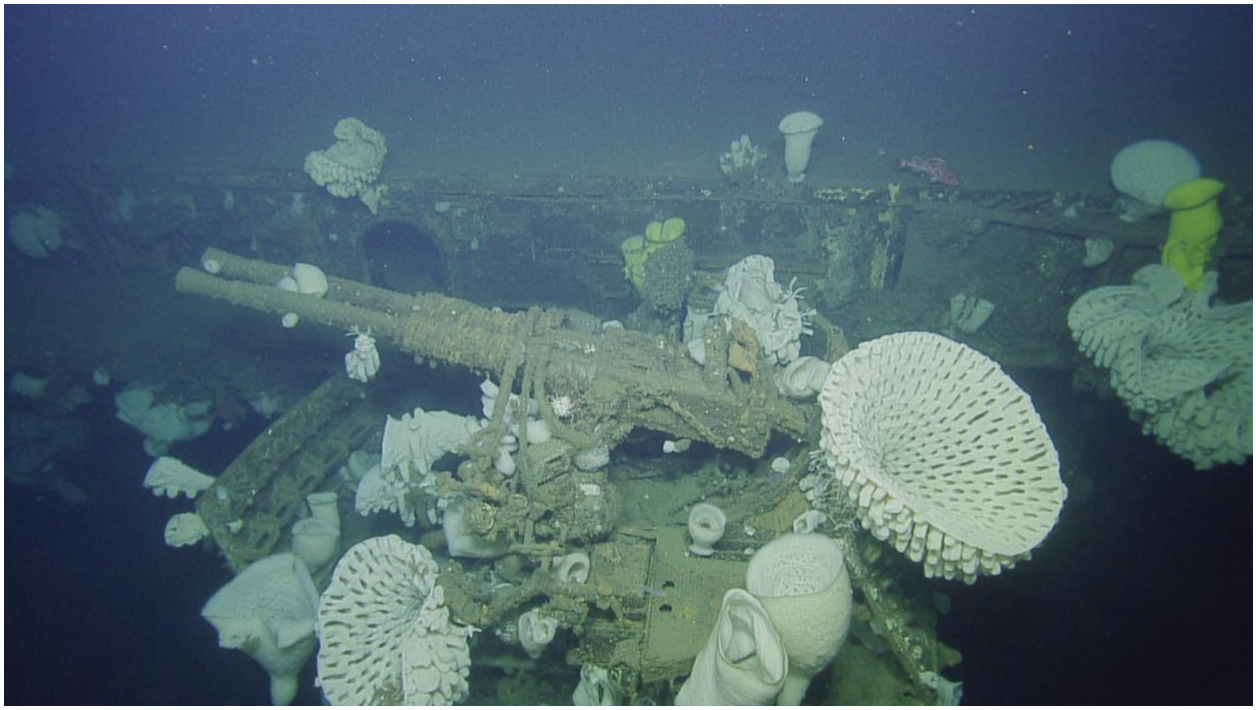


Multibeam data showing anomaly suspected to be the shipwreck of battleship USS *Pennsylvania*.

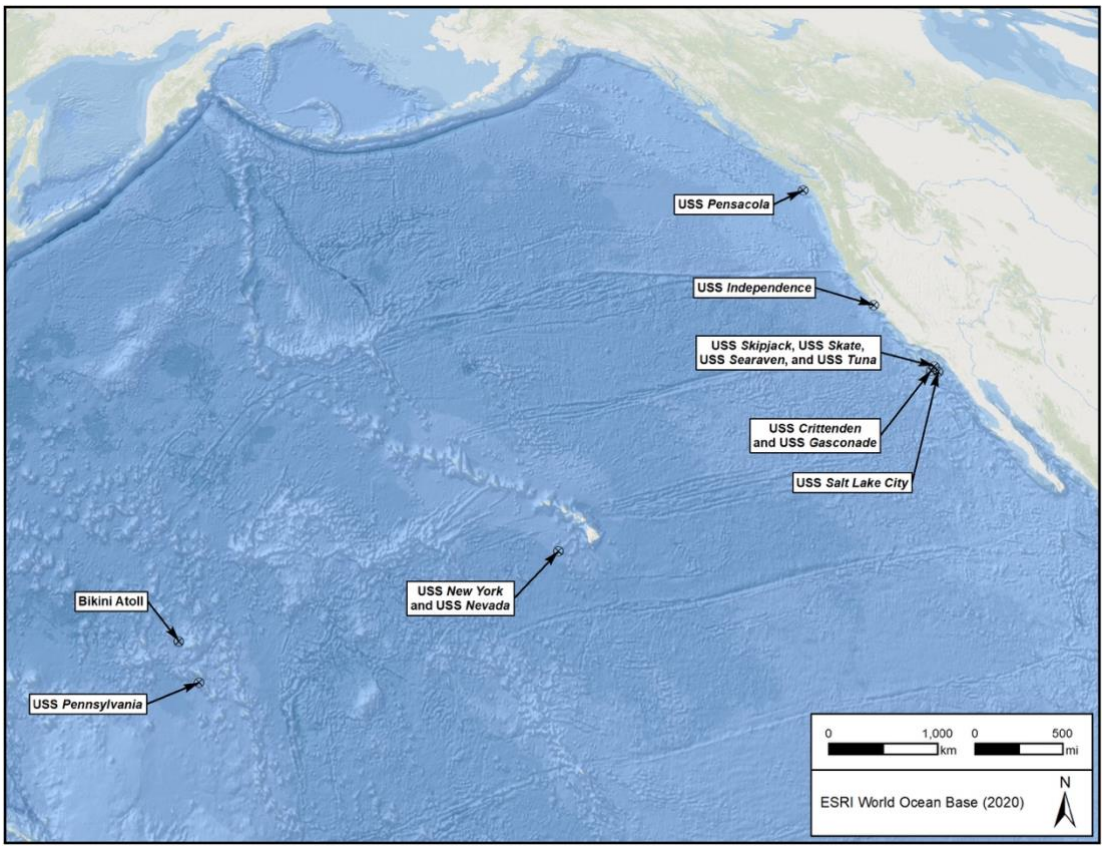
Many of the ships irradiated only lightly from Baker were safe enough to tow to Pearl Harbor and then on to Hunter's Point in San Francisco for further decontamination testing and training. Over the following few years, until the scuttling of USS

Independence off San Francisco in 1951, the Navy sank these ships as targets in various places along the US west coast. Heavy cruiser USS *Pensacola* (CA-24) was sunk off Washington state while her sister ship USS *Salt Lake City* (CA-25) was towed offshore San Diego for sinking. Two attack transports, USS *Gasconade* (APA-85) and USS *Crittenden* (APA -77) were both sunk off southern California. Four submarines, USS *Skate* (SS-305), USS *Skipjack* (SS-184), USS *Searaven* (SS-196), and USS *Tuna* (SS-203) were all sunk off the navy base at San Clemente Island off California (Delgado 1996). None of these have been found.

In addition to the historical significance of each of these shipwrecks, and the importance of conducting detailed archaeological and environmental characterization of the wreck sites, is the opportunity such exploration provides for public engagement. Enabling these expeditions with telepresence vastly increases the value of the ship time by providing access to a limitless number of scholars and scientists to join the work in real time and offer their insights, ideas and interpretation. We have conducted live work on deep water shipwrecks from both *Nautilus* and *Okeanos Explorer* (Brennan et al., 2018), including the sites of the aircraft carrier from Operation Crossroads, USS *Independence* (Delgado et al., 2018a), the Cold War submarine, USS *Bugara* (Delgado et al., 2018b, and the World War II loss in Canadian waters, SS *Coast Trader* (Delgado et al., 2018c). Public engagement with such work has also shown to be impactful and exciting and these platforms offer immense opportunity for students, classrooms, and others to participate and join in the work remotely. We anticipate a web presence for any such mission undertaken in the Pacific to be able to engage with scholars and the public ahead of and during the exploration for finding and documenting these shipwrecks.



ROV photo of an antiaircraft tub on the USS *Independence* shipwreck off San Francisco.



References

Brennan, Michael L., Frank Cantelas, Kelley Elliott, James P. Delgado, Katherine L.C. Bell, Dwight Coleman, Allison Fundis, Jack Irion, Hans K. Van Tilburg, Robert D. Ballard, 2018. Telepresence-enabled maritime archaeology in the deep. *Journal of Maritime Archaeology* 13: 97-121.

Delgado, James P., 1996. Ghost Fleet: The Sunken Ships of Bikini Atoll. University of Hawaii Press, Honolulu.

Delgado, James, Michael L. Brennan, Kelley Elliott, Russell E. Matthews, Megan Lickliter-Mundon, John G. Lambert, Frank Cantelas, Robert V. Schwemmer, 2018a. Archaeological survey of the ex-USS *Independence* (CVL22). *Journal of Maritime Archaeology* 13: 123-144.

Delgado, James, Frank Cantelas, Robert V. Schwemmer, Robert S. Neyland, Agustin Ortiz, Jr., George Galasso, Michael L. Brennan, 2018b. Archaeological survey of the ex-USS *Bugara*. *Journal of Maritime Archaeology* 13: 191-206.

Delgado, James P., Frank Cantelas, Lisa C. Symons, Michael L. Brennan, Richard Sanders, Evan Reger, Deanna Bergondo, Donald L. Johnson, Jacques Marc, Robert V. Schwemmer, Lea Edgar, Duncan MacLeod, 2018c. Telepresence-enabled archaeological survey and identification of S/S *Coast Trader*, Straits of Juan de Fuca, British Columbia, Canada. *Deep-Sea Research Part II* 150: 22-29. doi:10.1016/j.dsr2.2017.05.013

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Authors: Danny Brothers[1], Peter Haeussler[1] and Nancy Prouty[1]
Collaborators/Co-Authors: [2]Vaughn Barrie, [3]Gary Greene, [1]Rob Witter, [1]Amanda Demopoulos, [1]Nathan Miller, [1]Janet Watt, [1]Jenna Hill, [4]Emily Brodsky, [5]Jim Baichtal
Institutions: [1]U.S. Geological Survey, [2]Natural Resources Canada, [3]Moss Landing Marine Laboratory, [4]Univeristy of California Santa Cruz, [5]U.S. Forest Service, Ocean Networks Canada
Email Addresses: dbrothers@usgs.gov, pheuslr@usgs.gov, nprouty@usgs.gov
Office Phone Number: 831-460-7460

Title: Exploring Earthquake Hazards, Environmental History, and Seabed Ecosystems along the Aleutian Subduction Zone and Queen Charlotte Fault, southern and Southeastern Alaska

Priority Geographic Area:
(Indicate if within U.S. EEZ or international waters.)
Gulf of Alaska Region mostly within US EEZ (Figure 1; a portion of the Queen Charlotte Fault is in Canadian EEZ)

Description of Priority Area:
The priority areas are along the continental margins surrounding the Gulf of Alaska, including the Aleutian Subduction Zone and the Queen Charlotte fault zone (Figure 1). Both regions represent active tectonic plate boundaries where large earthquakes commonly occur. Despite the recognized hazards, including coseismically generated transoceanic tsunamis, both regions require systematic mapping data. A significant portion of the deep-water mapping has been conducted in the Gulf of Alaska as part of the Extended Continental Shelf program, but these surveys did not extend far enough to the west along the Aleutian margin, or east across the Queen Charlotte Fault (QCF). Some mapping has been conducted by the USGS, AK Department of Fish and Game, Natural Resources Canada and NOAA along the continental slope of southeastern Alaska and British Columbia, which led to numerous discoveries of active fault traces, submarine landslides, basalt volcanoes, mud volcanoes and seabed fluid seeps (e.g., Greene et al., 2007; Barrie et al., 2012; Brothers et al., 2018; Barrie et al., 2019; Brothers et al., 2019; Greene et al., 2019; Brothers et al., 2020). In areas where high-resolution bathymetry data already exist, we find complex topography, with gullies, rills, and channels that have been offset by tectonic movement, as well as active fluid seeps supporting chemosynthetic communities. Near the Aleutian trench, there is the expression of local folds and faults that extent to the surface. Sometimes there is the path of where a seamount has been subducted into the Aleutian trench. The spatial distribution of habitats, seeps, submarine canyons, active faults, submarine landslides and deep sea fans throughout these regions remain relatively unexplored due to an absence of systematic mapping data. Lastly, the marine geology and glacial history in the region has fundamental implications for human migration from Asia into North America (e.g., Barrie and Conway, 1999; Carrara et al., 2007; Kaufman et al., 2011; Shugar et al., 2014; Lesnek et al., 2018). Exploration of Late Pleistocene ice-carved troughs, outwash pathways and deep-sea sediments derived from glacial erosion would help reconstruct environmental conditions during this critical time in human history.

What are the characterization and data needs in this area?
Biology, Geology, Marine Archeology, Physical Oceanography and Chemistry

Provide a list or brief description of the data needed within this area, from your perspective:
The goal is to develop a multidisciplinary community effort focused on the Gulf of Alaska Region and to emulate the OER supported Atlantic Deep-water Canyons project as a successful template.

Aleutian subduction zone: needs systematic multibeam bathymetry and water column backscatter data starting at the shelf-edge and extending seaward across the trench for at least 200 km southeastward.
Queen Charlotte Fault: needs systematic multibeam bathymetry and water column backscatter data along much of the Canadian portion of the margin. The USGS and NOAA have recently mapped 80% of the U.S. portion of the margin, but water column data are only available for 50%. The region has several documented seep sites supporting chemosynthetic communities that would be targeted by ROV dives for geological, biological and chemical sampling.

Describe relevance to national security, conservation, and/or the economy:
The largest earthquakes and tsunamis on Earth are generated from megathrust earthquakes at subduction zones. The entire southern Alaska margin is a subduction zone that has almost completely ruptured in historical earthquakes of magnitude 8 or larger in the last hundred years. Ground shaking from these giant earthquakes can have a huge effect on the local economy, and the population of Alaska is focused along the southern Alaska margin. Even in remote parts of Alaska, the fishing industry depends on shoreside fish processing plants for getting product to market. Furthermore, the Queen Charlotte Fault is the most significant earthquake hazard to western Canada and southeastern Alaska, having 7 magnitude >7 earthquakes in the last 120 years. The shallowest part of the proposed acquisition area – from the shelf edge to 1500 m water depth- is one of the areas of greatest fisheries productivity in the north Pacific.

From your perspective, what makes this area unique?
The continental margins surrounding the Gulf of Alaska contain a relatively unexplored confluence of hazards, energy/mineral resources, underwater ecosystems, and archeological significance. Comprehensive bathymetric mapping from the shelf edge to beyond the Aleutian trench will provide the framework for a better understand of the earthquake and tsunami hazards of Alaska. Without this data, we are crippled in evaluating other types of studies aimed at addressing hazards. The southern Alaska margin is ideal for studying giant subduction zone earthquakes as there are numerous rupture patches with variable locking behavior on them. This physical environment will more likely improve our basic understanding of these hazards, because of the variability along the margin. Deep sea minerals, gas hydrates and other potential energy resources are largely unexplored in this region. Fluid seepage by cold seeps, where hydrogen sulfide, methane, and other hydrocarbon-rich fluids are released on the seafloor, play an important role in transferring long-buried carbon into the ocean. A primary goal is to discover and characterize the seafloor communities that live in association with active faults, seeps, and submarine canyons surrounding the Gulf of Alaska and provide essential information on the ecology and biodiversity of deep-sea communities. Of particular interest are linkages between geologic substrate, deepwater coral ecosystems, and/or other unusual habitats observed along active continental margins, such as methane seeps.

Please list other partners or organizations that may also be interested in this area:
NOAA – hydrographic survey division, NOAA – National Marine Fisheries, Alaska Seismic Hazards Safety Commission, State of Alaska Division of Geological and Geophysical Surveys, Alaska Department of Fish and Game, Natural Resources Canada, U.S. Bureau of Ocean and Energy Management, U.S. National Science Foundation, U.S. Forest Service, U.S. National Parks Service, Alaska Longline Fisherman's Association, and dozens of academic institutions.

References:
Barrie, J. V., and Conway, K. W., 1999, Late Quaternary glaciation and postglacial stratigraphy of the northern Pacific margin of Canada: Quaternary Research, v. 51, no. 2, p. 113-123.

Barrie, J. V., Conway, K. W., and Harris, P. T., 2013, The Queen Charlotte fault, British Columbia: Seafloor anatomy of a transform fault and its influence on sediment processes: Geo-Marine Letters, v. 33, no. 4, p. 311-318.

Barrie, J.V., Greene, H.G., Brothers, D., Conway, K.W., Enkin, R.J., Conrad, J.E., Lauer, R.M., McGann, M., Neelands, P.J., East, A., 2018. Open File 8398, Geological Survey of Canada, p. 161.

Brothers, D.S., N.C. Miller, et al., 2020, Plate boundary localization, slip-rates and rupture segmentation of the Queen Charlotte Fault based on submarine tectonic geomorphology, Earth and Planetary Science Letters, v. 530, https://doi.org/10.1016/j.epsl.2019.1158

Brothers, D.S., Haeussler, P.J., et al., 2018, A closer look at an undersea source of Alaskan earthquakes. Eos, 98, https://doi.org/10.1029/2017EO079019.

Brothers, D. S., Andrews, B. D., Walton, M. A., Greene, H. G., Barrie, J. V., Miller, N. C., ten Brink, U., East, A. E., Haeussler, P. J., and Kluesner, J. W., 2018a, Slope failure and mass transport processes along the Queen Charlotte Fault, southeastern Alaska: Geological Society, London, Special Publications, v. 477, p. SP477. 430.

Carrara, P., Ager, T., and Baichtal, J., 2007, Possible refugia in the Alexander Archipelago of southeastern Alaska during the late Wisconsin glaciation: Canadian Journal of Earth Sciences, v. 44, no. 2, p. 229-244.

Greene H.G., O'Connell, V.M., Wakefield, W.W., Brylinsky, C.K., 2007, The offshore Edgecumbe lava field, southeast Alaska: geologic and habitat characterization of a commercial fishing ground. In: Todd, B.J., Greene, H.G. (Eds.), Mapping the Seafloor for Habitat Characterization, Geological Assocication of Canada Special Paper 47, pp. 277–295.

Greene, H. G., Barrie, J. V., Brothers, D. S., Conrad, J. E., Conway, K., East, A. E., Enkin, R., Maier, K. L., Nishenko, S. P., and Walton, M. A., 2018, Slope failure and mass transport processes along the Queen Charlotte Fault Zone, western British Columbia: Geological Society, London, Special Publications, v. 477, p. SP477. 431.

Kaufman, D. S., Young, N. E., Briner, J. P., and Manley, W. F., 2011, Chapter 33 - Alaska Palaeo-Glacier Atlas (Version 2), in Ehlers, J., Gibbard, P. L., and Hughes, P. D., eds., Developments in Quaternary Sciences, Volume 15, Elsevier, p. 427-445.

Lesnek, A. J., Briner, J. P., Lindqvist, C., Baichtal, J. F., and Heaton, T. H., 2018, Deglaciation of the Pacific coastal corridor directly preceded the human colonization of the Americas: Science advances, v. 4, no. 5, p. eaar5040.

Shugar, D. H., Walker, I. J., Lian, O. B., Eamer, J. B., Neudorf, C., McLaren, D., and Fedje, D., 2014, Post-glacial sea-level change along the Pacific coast of North America: Quaternary Science Reviews, v. 97, p. 170-192.

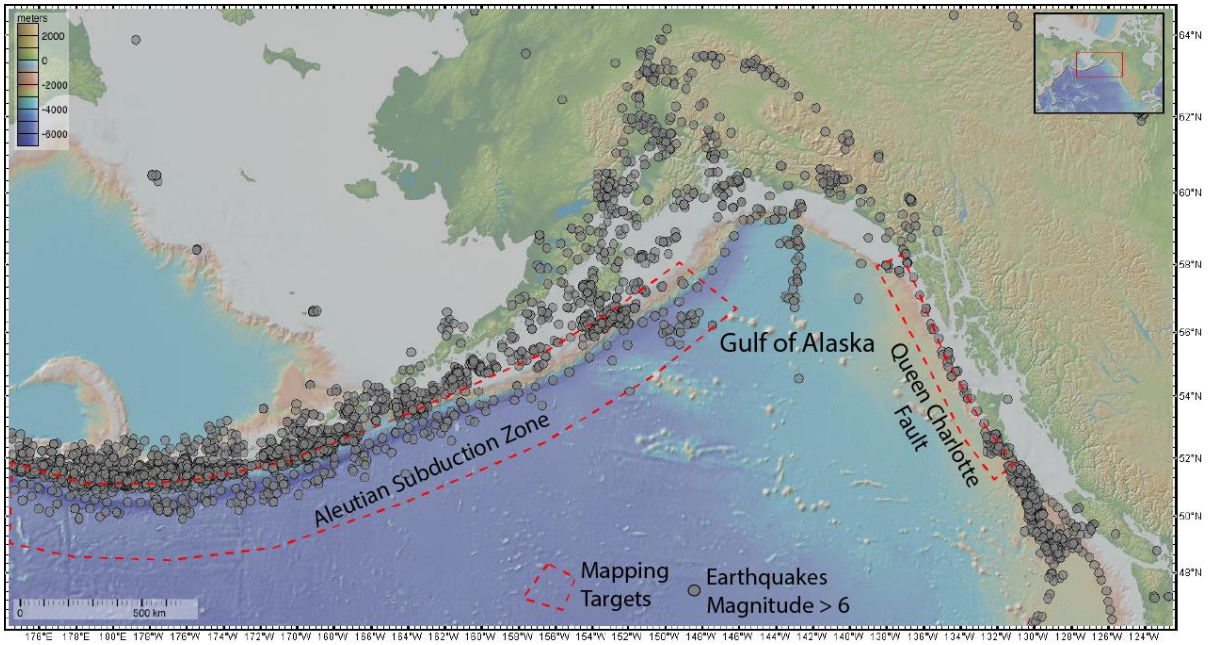


Figure 1. Priority exploration areas surrounding the Gulf of Alaska, including the Aleutian Subduction Zone and the Queen Charlotte Fault.

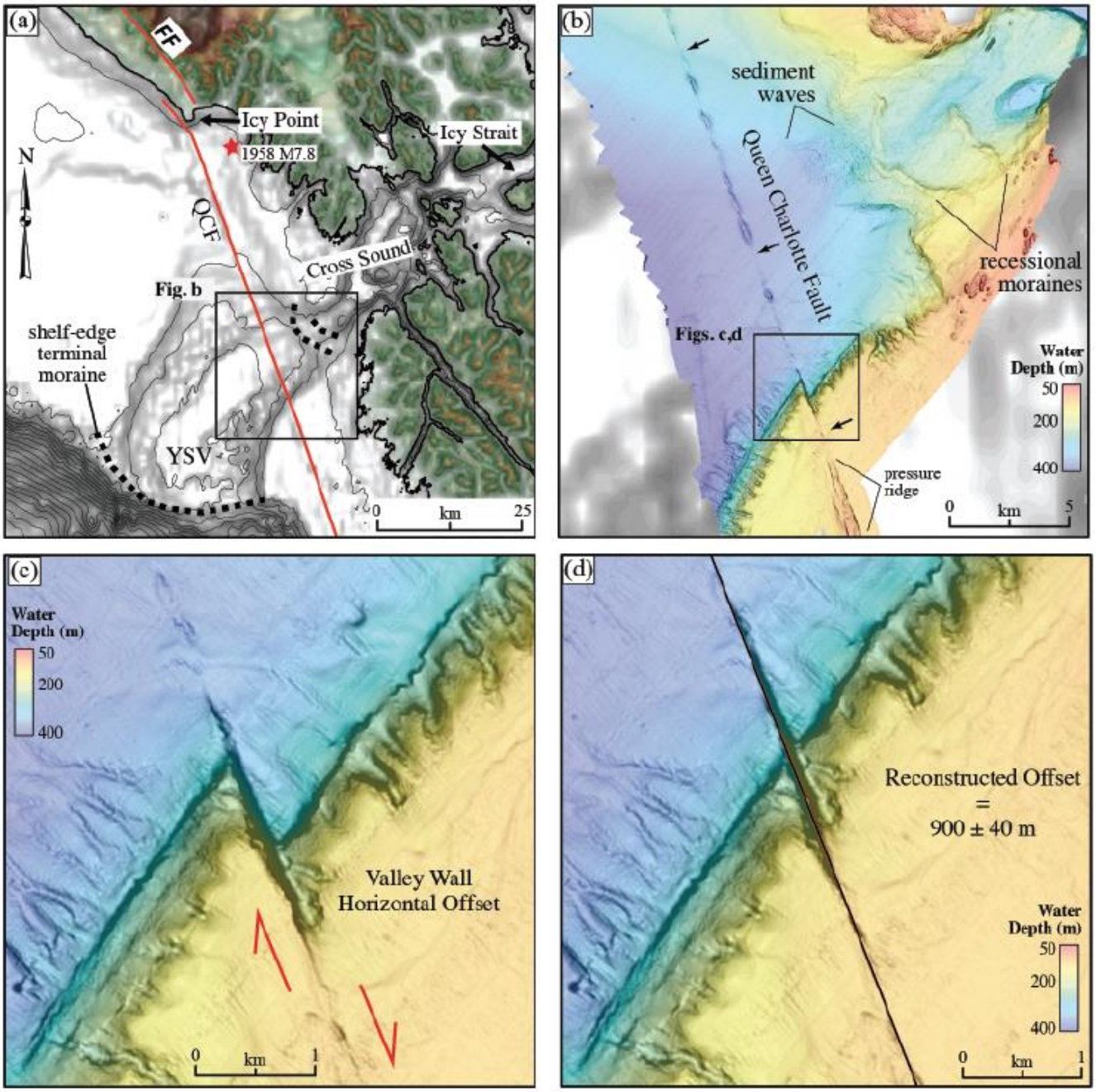


Figure 2. Shaded relief imagery of the Queen Charlotte Fault (QCF) as it steps onshore in Glacier Bay National Park, Alaska, to become the Fairweather Fault (FF)(Modified from Brothers et al., 2020). This portion of the fault system last rupture during a M7.8 earthquake in 1958 that killed three people and generated a landslide above Lituya Bay, which created the largest tsunami runup ever documented (1,740' high). The imagery highlights USGS seafloor mapping data in the Yakobi Sea Valley (YSV) that revealed a seabed feature that has been horizontally offset by the fault and was used to estimate the fault's long-term slip-rate (53 mm/yr). Robust slip-rate estimates for the entire Queen Charlotte Fault, like the San Andreas Fault in California, are a critical first step in developing probabilistic seismic hazard assessments for southeastern Alaska and western British Columbia.

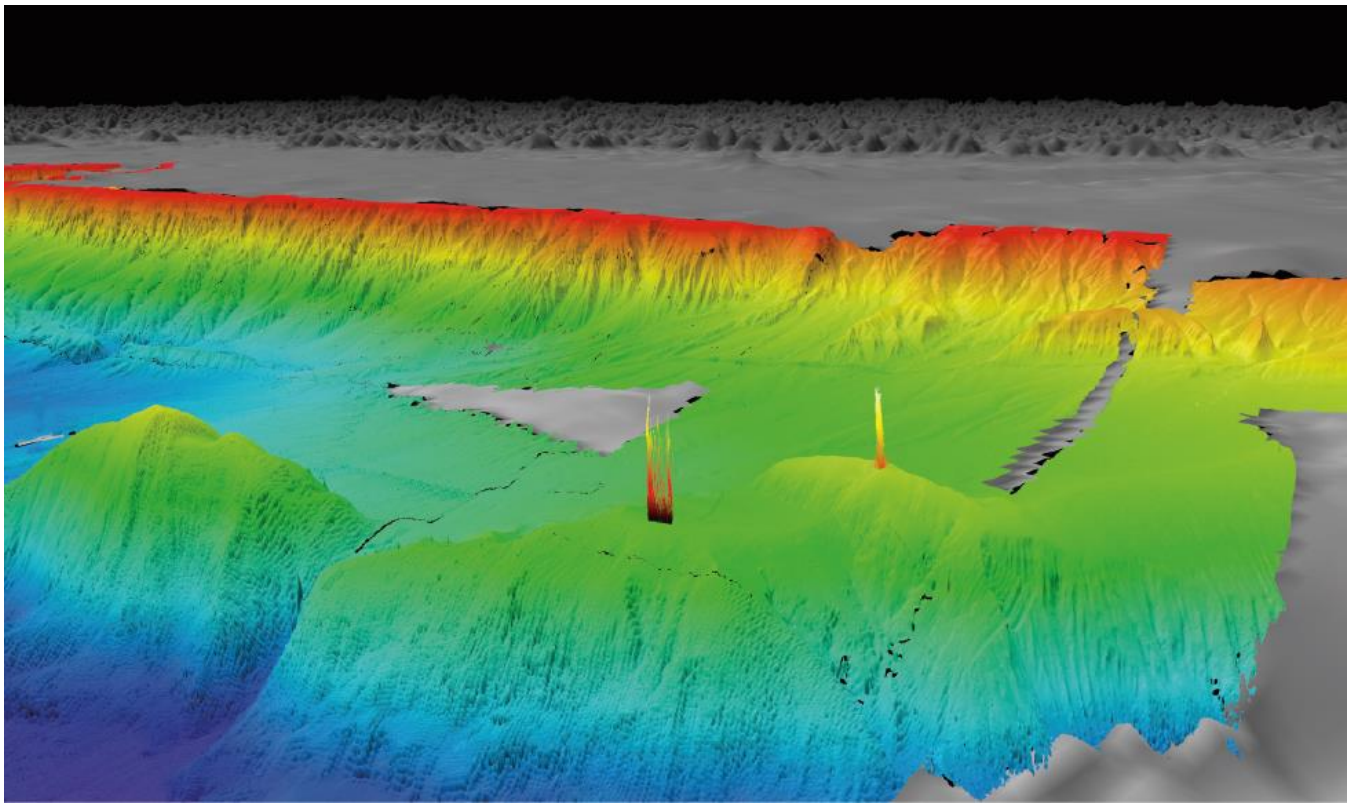


Figure 3. Two water column bubble plumes imaged near the Queen Charlotte Fault by NOAA Ship Fairweather in 2018. The seabed at these sites was photographed and sampled, but required state-of-the-art ROV tools for water geochemistry and surgical sampling of vented fluids. Image from Prouty et al. (in revision).

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Valerie Brown
Institution: Office of National Marine Sanctuaries, National Marine Sanctuary of American Samoa
Email Address: valerie.brown@noaa.gov
Office Phone Number: (684) 633-6500 ext. 1114
Collaborators/Co-Authors: Randall Kosaki and Steve Gittings

Title: Exploration Priorities in the National Marine Sanctuary of American Samoa

Priority Geographic Area:
National Marine Sanctuary of American Samoa, American Samoa, U.S. EEZ

Description of Priority Area:
All priority areas identified lie within or adjacent to the National Marine Sanctuary of American Samoa (NMSAS). The sanctuary covers 13,581 square miles of ocean (Figure 1.), much of which has never been explored. It is the only sanctuary south of the equator and includes diverse ecosystems from deep sea hydrothermal vents to highly diverse shallow coral reefs.

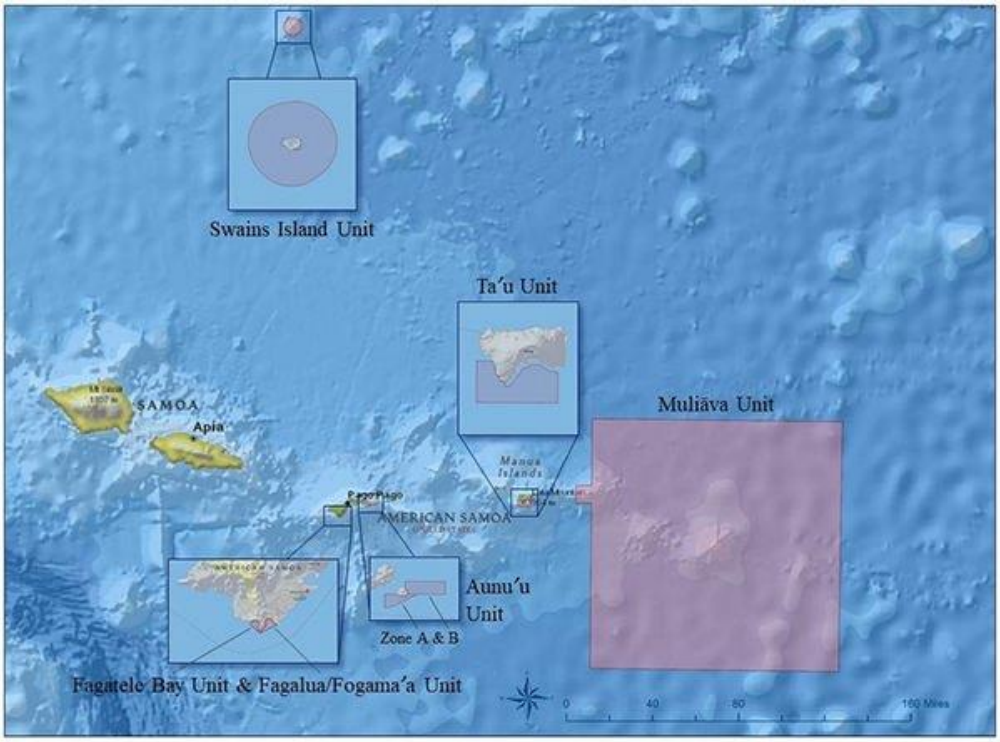


Figure 1 The National Marine Sanctuary of American Samoa covers 13,581 square miles.

NMSAS has three exploration priorities: 1.) Improve our understanding of ecosystem linkages and connectivity across depths; 2.) Further explore and assess the dynamic processes at the geologically active Vailulu'u Seamount; 3.) Explore previously undocumented seamounts and other unique habitats within NMSAS.

Previous exploration activities conducted by the National Oceanic and Atmospheric Administration aboard the NOAA ship *Okeanos Explorer*[i] and the Ocean Exploration Trust aboard the *R/V Nautilus*[ii] captured the progression of physical and biological zonation across depth gradients from the deep sea to shallow ecosystems along coastal shorelines. NMSAS's science team is conducting surveys of shallow water coral reef ecosystems, and collaborating with a team of researchers from the University of Hawai'i, NOAA Papahānaumokuākea Marine National Monument, and Bishop Museum who will monitor mesophotic reef systems down to 100m. Both teams are interested in understanding the potential overlap with these zones and the biological communities below 100m and how all of these ecosystems interact. More importantly, researchers are interested in how these interactions may be affected by changing ocean conditions such as ocean acidification and increased temperatures.

These explorations, and others, have also documented relatively rapid geological changes at the Vailulu'u Seamount. Vailulu'u was first discovered in 1975 and explored in 1999. Subsequent expeditions have observed significant changes in the topography of the seamount over time, particularly at the active Nafanua cone area, where hydrothermal vents have been located. There is limited information about the dynamic processes occurring at Vailulu'u, and past expeditions strongly encourage additional exploration and research to further understand the geological processes, explore the ever changing hydrothermal vent features, and further document and assess biota on the seamount, particularly the chemosynthetic communities associated with the vents. As significant geological shifts may affect nearby islands through earthquakes and tsunamis, the further study of Vailulu'u is also warranted to better predict and prepare for potential disasters.

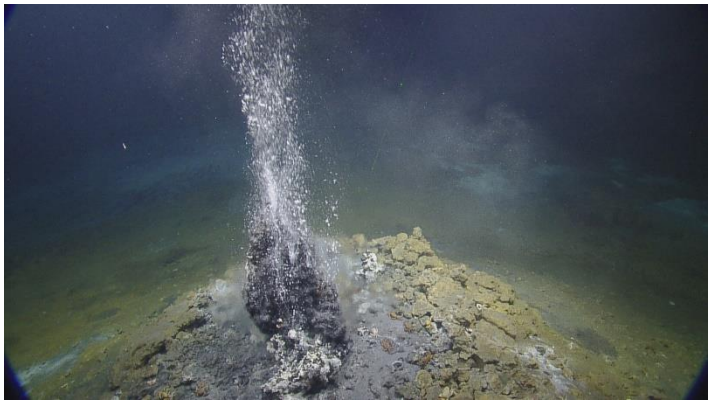


Figure 2 Newly discovered hydrothermal vent in the Nafanua cone on Vailulu'u Seamount. Photo: OET-RV Nautilus

Finally, past mapping of the seafloor within NMSAS and adjacent areas has shown that there are approximately 50 additional seamounts that have not been mapped in high resolution or visually explored[iii]. These seamounts may have unique biological communities and exploration of their geologic structure may further explain the geological processes in the region.

What are the characterization and data needs in this area?
Check all that apply:
_x__ Biology
_x__ Geology
____ Marine Archaeology
_x__ Physical Oceanography
_x__ Chemistry
____ Other

Provide a list or brief description of the data needed within this area, from your perspective:

1.) Nearshore ecosystem linkages and connectivity – A suite of data to understand ecosystem functions and connections. This should include 1.) Biological data - emphasis on macrofauna such as fish, corals, large invertebrates like crabs, shrimp, sea cucumbers, and crinoids; 2.)Physical Oceanography – topographic structure, currents, and geomorphological processes; 3.) Chemistry – carbonate chemistry, temperature, pH, dissolved oxygen, and nutrients.

2.) Vailulu'u Seamount – Data collection should focus on mapping and geological sampling of the seamount, with a focus on the Nafanua cone, to improve understanding of geological processes. Secondary focus on unique chemical and biological conditions around the hydrothermal vents including 1.) Biological data - particular emphasis on macrofauna such as fish, crabs, shrimp, snails, and polychaetes; 2.)Physical Oceanography – topographic structure, currents, and geomorphological processes; 3.) Chemistry – carbonate chemistry, temperature, pH, dissolved oxygen, and nutrients.

3.) Seamount Exploration – High resolution mapping of seamounts and visual documentation and sampling of geological structure and biota.

Describe relevance to national security, conservation, and/or the economy:

NMSAS's overarching goal is to protect resources within the sanctuary. The conservation and protection of these unique resources is the primary focus of all work done by NMSAS. In 2012, NMSAS expanded from the 0.25 square mile Fagatele Bay unit to the current 13,581 square mile extent. Much of this area has not been inventoried or characterized and there is much work to be done to complete this critical step to inform conservation actions. All of the priorities listed are listed in the NMSAS Conservation Science Needs assessment will promote this effort and enhance conservation.

Figure 3 "Big Momma" a large Porites *colony located in the Ta'u Unit of NMSAS. Photo: XL Catlin Seaview Survey / The Ocean Agency.*

Further, as stated in the sanctuary's Management Plan, NMSAS seeks to improve ecosystem based management and conservation by providing a strong foundation of science on sanctuary ecosystems and minimizing impacts from climate change events on these systems. As part of this effort, NMSAS hosts the only US MAPCO2[iv] buoy to

monitor ocean acidification in the southern hemisphere and is working to create a robust science program to understand how changes in ocean temperature and chemistry will affect tropical marine ecosystems from shallow reefs to deep reefs and beyond. Evidence that systems below the "mesophotic" share a strong evolutionary affinity with shallower ecosystems down to over 300m[v], highlights the importance of understanding connections between these systems. Deep reef research will complement shallow and mesophotic surveys to help us understand interactions between these systems, track changes over time to test whether deeper reefs will act as depth refugia for shallow species affected by changing ocean conditions, and help inform future management of these systems.

Further, while the risk is deemed low, Vailulu'u Seamount's continued volcanic activity could affect neighboring islands or aviation in the future should the cone continue to grow. Monitoring conditions and changes in the Nafanua cone, in particular, could provide a valuable warning of changes in condition that would increase this risk.

From your perspective, what makes this area unique?
NMSAS is the largest and most diverse sanctuary in the United States. It is also the only one south of the equator. The sanctuary was expanded to include significant unique features from highly diverse shallow reef ecosystems to deep sea hydrothermal vents. These shallow reefs have proven to be more resilient to disturbance events, and the Ta'u Unit of NMSAS is home to one of the largest and oldest corals ever documented. This coral known as "Big Momma", is over 500 years old and as big as a house and there are many other large colonies in the area. Further away, Rose Atoll has extremely high crustose coralline algae growth and some of the highest aragonite saturation measures documented in waters around US Pacific Islands. And in between those, is the Vailulu'u Seamount, and the ever changing Nafanua cone, supporting hydrothermal vent communities. All of these features are unique and deserving of future exploration and conservation.

Please list other partners or organizations that may also be interested in this area:
Hawai'i Undersea Research Lab (University of Hawai'i)
Ocean Exploration Trust
Government of American Samoa
National Marine Fisheries Service
United States Fish and Wildlife Service (Rose Atoll)
National Park Service of American Samoa

---

[i] Raineault, N.A, J. Flanders, and A. Bowman, eds. 2018. New frontiers in ocean exploration: The E/V Nautilus, NOAA Ship Okeanos Explorer, and R/V Falkor 2017 field season. Oceanography 31(1), supplement, 126 pp., https://doi.org/10.5670/oceanog.2018.supplement.01.

[ii] Sudek, M., H. Spathias, G. Coward, N. Que, R. Kane, V. Schmidt, R. Ballard, and C. Roman. In press. National Marine Sanctuary of American Samoa Expedition: Exploring the Deep Sea in the American Samoa Archipelago. Oceanography

[iii] Roberts, Jed T. 2008. The Marine Geomorphology of American Samoa : Shapes and Distributions of Deep Sea Volcanics. Thesis. Oregon State University. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/qv33s015r

[iv] https://www.pmel.noaa.gov/co2/story/Fagatele+Bay

[v] Baldwin, C. C., Tornabene, L., & Robertson, D. R. 2018. Below the Mesophotic. Scientific reports, 8(1), 4920. https://doi.org/10.1038/s41598-018-23067-1

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Kelley Brumley
Institution: Fugro
Email Address: kbrumley@fugro.com
Office Phone Number: 210-471-1630
Collaborators: Jennifer Reynolds (University of Alaska Fairbanks)

Title: Collaboration for exploring offshore Alaska: leveraging current projects for value added seafloor mapping and characterization

Priority Geographic Area:
Gulf of Alaska and Aleutian Islands in US EEZ

Description of Priority Area:
The Gulf of Alaska, east of the Aleutian Islands, is part of the North Pacific Ocean and supports one the country's largest fisheries. This region is also home to large populations of marine mammals. Here, nutrient-rich waters upwell and circulate along the steep continental shelf break, mixing with fresh water runoff from Alaska's rivers and glaciers (Figure 1). The narrow continental shelf runs along a tectonically complex plate boundary approximately 2,500 miles in length between the North American Plate and the Pacific Plate, extending to the Kamchatka Peninsula. In the eastern Gulf of Alaska is the Queen Charlotte-Fairweather transform fault system, along which the Pacific Plate moves northwest with respect to the North American Plate. Along the margin to the west is the Aleutian Trench, whereby the Pacific Plate converges against the North American Plate to produce the Alaska/Aleutian subduction zone.

Figure 1: Graphic from Gulf Watch Alaska showing upwelling of nutrient rich waters and circulation with fresh water from snow melt and glacial input, creating one of the richest fisheries in the world.

What are the characterization and data needs in this area?
Check all that apply:
_x_ Biology
_x_ Geology
_x_ Marine Archaeology
_x_ Physical Oceanography
_x_ Chemistry
_x_ Other; safety of navigation, seafloor characterization, seafloor mapping

Provide a list or brief description of the data needed within this area, from your perspective:
Because of its diverse ecosystems, unusual geomorphology, tectonic complexity, and sensitivity to climate change in the Arctic and sub-Arctic regions, ocean observations in the Gulf of Alaska and Eastern Aleutians are critical. ***The most fundamental ocean observation is seafloor mapping***. These data can help determine baseline information on both pelagic and benthic habitats, can provide information for ocean models (e.g. circulation, climate, tsunamis, submarine hazards), and can guide more detailed studies. A modern seafloor map is the first-order data need in Alaska waters.

With a “map once use many times” philosophy, a regional map (including quality multibeam bathymetry, backscatter, and water column data) is a useful first-order dataset to guide more detailed study in this area. For instance, one of the most direct interactions between the solid earth and the ocean is the venting of methane-rich fluids at seabed cold seep; locating and characterizing these occurrences is important for many reasons. The methane-rich fluids released at cold seeps may be related to subsurface petroleum deposits and/or microbial methane generation in the deep continental margin sediments. This methane expulsion has implications for methane and carbon budgets, climate models, resource assessment, and habitat characterization. There is substantial evidence that the continental shelf and slope in the Gulf of Alaska support active cold seeps at depths ranging from shallow subtidal to greater than 4,400 meters.

Mapping the seafloor with multibeam echosounders is an excellent tool for finding hydrocarbon seeps because the geomorphology and characteristics of the seafloor around seeps are typically distinctive. Upwelling fluids may create expulsion mounds or pockmarks that can be interpreted from bathymetric digital elevation models (Figure 2a). Multibeam backscatter data can also show differences in seafloor characteristics, such as soft and/or smooth versus hard and/or coarse seafloor. This part of a multibeam data set is helpful in locating cold seeps because the accumulation of authigenic carbonate, as well as the hard parts of chemosymbiotic communities supported at cold seep locations, create localized “hard grounds” visible with multibeam backscatter data (Figure 2b). Identifying hard seafloor or exposed rock is also useful in identifying habitats for other species such as deep-sea corals, sponges, and rockfish that prefer hard substrates.

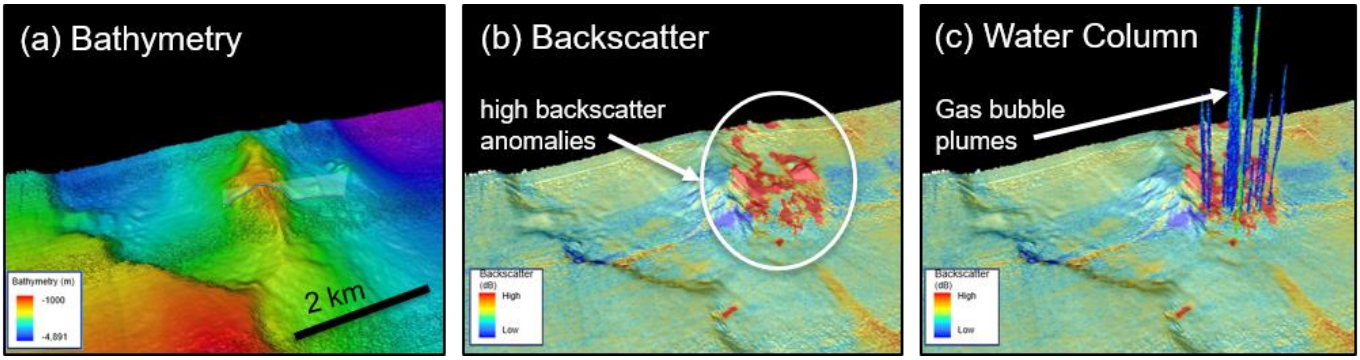


Figure 2: (a) Multibeam bathymetry can help determine geologic structures offshore. (b) Multibeam backscatter anomalies show where the seafloor is hard/rough (high backscatter, warm colors) or soft/smooth (low backscatter, cool colors). (c) Multibeam water column data show anomalies in the water column such as gas bubble plumes at cold seep sites, or deep scattering layers caused by plankton important to fisheries studies. (Images by Fugro.)

Good multibeam water column data can help to determine the location of actively venting gas-rich hydrocarbon fluids (Figure 2c). Furthermore, in the water column above seeps, the vent fluid supports methane-oxidizing microbial populations that under normal conditions play a role in marine food webs and seawater chemistry. Cold seep microbial populations are also a potential source of cold-water species that could assist with oil spill recovery in Alaska where oil production is ongoing, and where other countries are shipping oil from high arctic oil fields bordering Alaska waters. Finally, although somewhat outside the region covered by this discussion, fluid vents on the floor of the Bering Sea basin (known from USGS seismic surveys in the 1980s) might also be a significant source of recycled silica to the diatom-rich Bering Sea ecosystem, which may also be a factor in the Gulf of Alaska.

The pattern of seep occurrence can reveal the seafloor expression of subsurface fluid pathways and geologic structures that can guide assessment of subseafloor hydrocarbon resources. An inventory of seeps can also help quantify methane release into the ocean water and atmosphere, which is important to climate modeling. Also, rising ocean temperatures at the seafloor have the potential to destabilize existing methane hydrate deposits, potentially changing the behavior of existing sub-seafloor systems and expanding the geographic extent of active seafloor vents and geologic hazards. Characterizing the

seafloor with multibeam data can define some of these hazards and help mitigate and monitor potential problem areas.

The combination of detailed seafloor bathymetry, backscatter, and water column data is the base layer for constructing seabed habitat maps. These data can aid in management of marine species and ecosystems by identifying a distribution of seabed characteristics that potentially provide habitat for benthic and demersal species. These maps can also reveal oceanographic information such as current-driven bedforms on the seafloor.

Multibeam water column data, besides being useful for identifying gas bubble plumes related to active hydrocarbon seepage, also gives useful information about animals that are distributed throughout the water column in distinct layers,thought to comprise animals of the same species and similar size (Figure 3). The so-called "deep scattering layers" can be observed and studied using the same multibeam dataset collected for seep studies or bathymetric mapping.

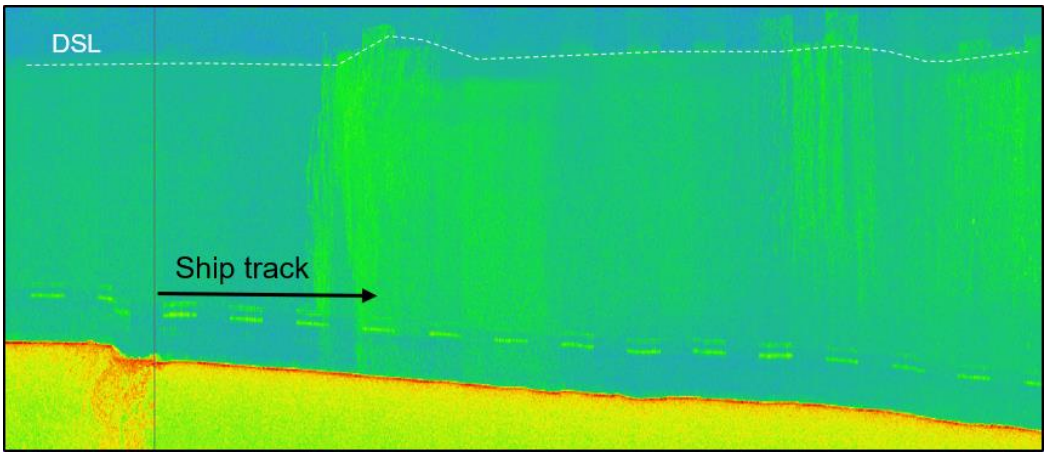


Figure 3: Screen grab of multibeam water column data showing the deep scattering layer (DSL), with time increasing to the right as the ship moves along its track. In this image, the diurnal migration of planktonic animals in the water column occurred at sunrise (sudden appearance of bright green anomalies; image courtesy of Fugro).

A host of other studies, such as geohazard assessment, tsunami modeling, and geologic monitoring of t;he earthquake prone subduction zone, are just some of the ways that scientists could utilize a regional multibeam dataset. Regional seafloor maps would also address basic safety of navigation needs in Alaska where charts are notoriously outdated or non-existent. Also, multibeam data have sufficient resolution to reveal shipwrecks and other features of potential archeological and/or military significance.

From your perspective, what makes this area unique?
In addition to the unique and diverse habitats that thrive within the rich waters of Alaska, as well as the active geology, a recent Presidential Memorandum (https://www.whitehouse.gov/presidential-actions/memorandum-ocean-mapping-united-states-exclusive-economic-zone-shoreline-nearshore-alaska/) identifies Alaska as a priority area of interest and encourages the nation to "act boldly to safeguard our future prosperity, health, and national security through ocean mapping, exploration, and characterization." The difficulties of mapping in Alaska waters are unique within the U.S. EEZ and territorial waters. There are few deep draft ports, and the field season for operating non-ice-strengthened research vessels is short. Nevertheless, a strong base of experience exists among NOAA, industry, and academia for multibeam mapping operations in Alaska waters. To meet the goals set out in the presidential memo, researchers and funding agencies will need to be creative and collaborative in their approach to mapping and characterizing the seafloor in this region. This effort would greatly benefit from leveraging existing funded projects, and collaborations between agencies, universities, and industry.

Please list other partners or organizations that may also be interested in this area: The presidential memo referenced above also directs stakeholders to look for opportunities to "reduce duplication and promote efficiency across agencies." Currently, the Bureau of Ocean Energy Management (BOEM) is funding a desktop study, in collaboration with University of Alaska Fairbanks (UAF) and Fugro, to inventory known cold seeps in the Gulf of Alaska and Beaufort/Chukchi Seas (Figures 4, 5, 6). The two

motivations of the study are to better assess potential oil and gas lease sale areas and to better understand the region's ocean ecosystem. This study is using published reports, informal reports, BOEM internal records, and examining water-column single beam sonar data acquired by NOAA Fisheries and R/V Sikuliaq. One result of this study, which ends in August 2020, will be recommended areas where multibeam mapping and geochemical coring would be useful for baseline studies and to guide more detailed investigations of benthic and marine habitats. These same recommendations are valid for ocean exploration priorities, as known seep areas provide good targets for remotely operated vehicle dives, important for education and telepresence needs, as well as ongoing seep studies.

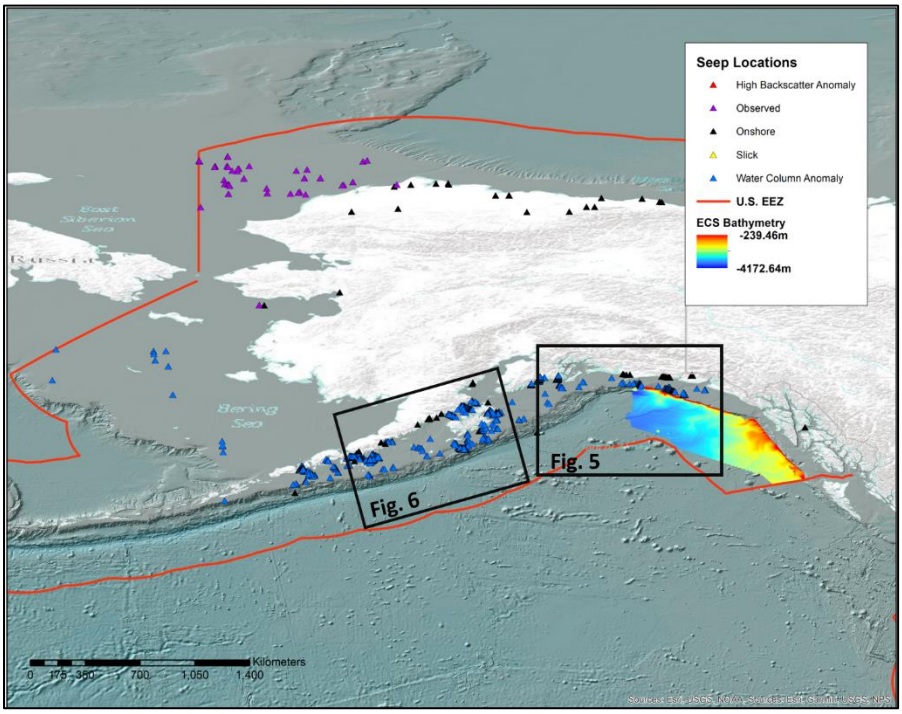


Figure 4 Project area of the study funded by BOEM in collaboration UAF and Fugro. Black boxes are suggested areas where mapping would be beneficial to help reach BOEM goals, NOAA exploration needs, and EEZ mapping requirements.

The rainbow bathymetry shown here is from extended continental shelf (Law of the Sea) mapping in 2005, but was for bathymetric purposes only. Though backscatter is available, it is of poor quality and water column data were not collected.

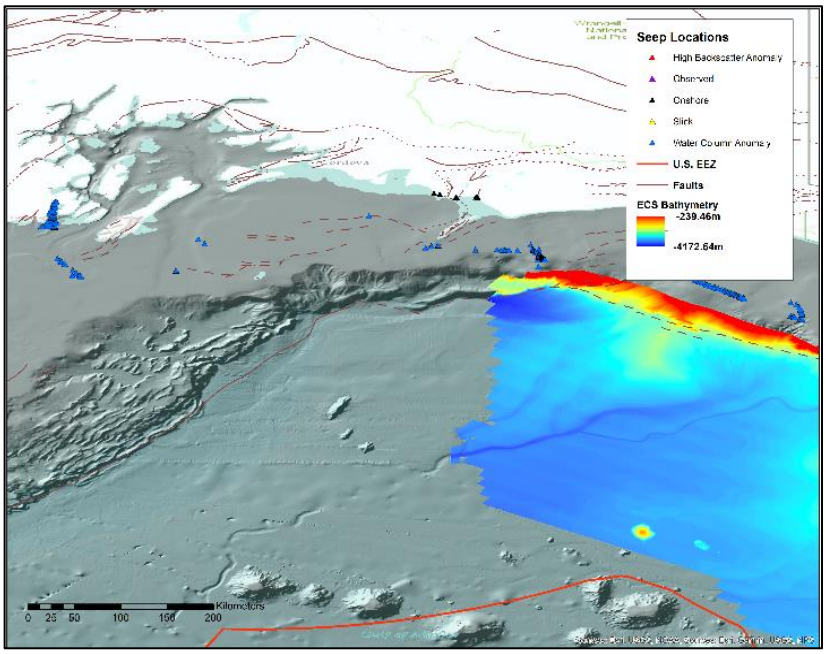


Figure 5 Most of the seeps that have been interpreted in this area (see Figure 4 for location) were observed along geologic structures where seeps were described on land during early oil exploration at the beginning of the 20th century. The geologic structures were followed offshore and fisheries single beam echosounder data in those regions were investigated to identify gas bubble plumes in the water column near these structures. These seeps could be related to deep hydrocarbons utilizing faults as conduits to the surface.

Note seamounts, channels, unstable slope features, and subduction related compression features, that provide unique habitats and interesting areas for exploration.

Several goals outlined in the presidential memo would be reached by leveraging the information and recommendations of this study to guide national ocean exploration priorities, and/or by partnering with

BOEM and expanding the scope of this program utilizing funding mechanisms already in place. These goals include mapping in Alaska waters, characterizing the seafloor, promoting efficiency across agencies, and reducing duplication of effort. These activities would also help meet National Oceanographic Partnership Program (NOPP) goals to facilitate partnerships between federal agencies, academia, and industry to advance ocean science research and education.

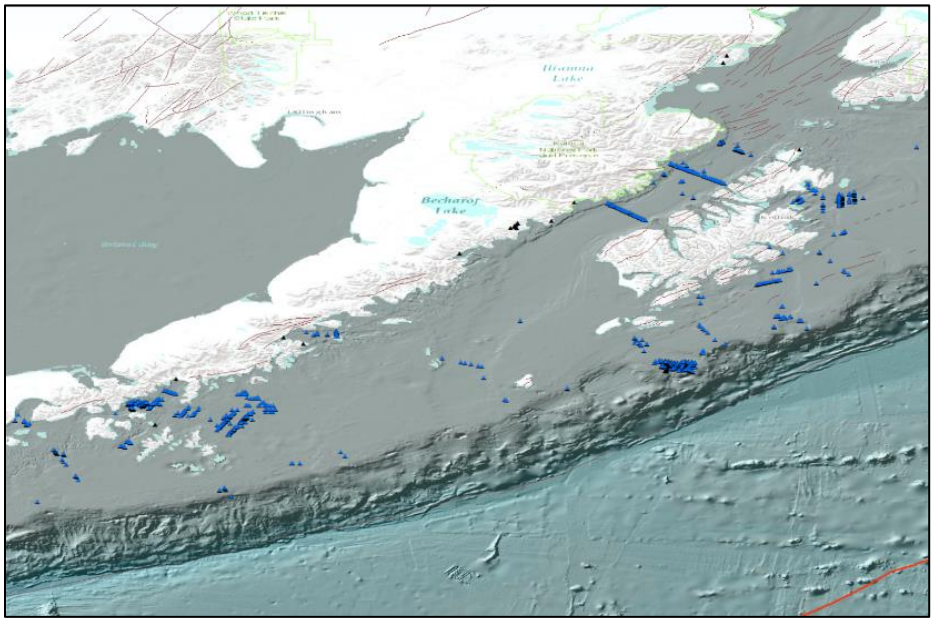


Figure 6 Seeps in this area were interpreted in the same manner as those in Figure 5, but most were observed in fisheries-related single beam data and noted by NOAA scientists as possible seep anomalies. Many of these are in shallow water areas and some are near oil seeps found on land. Other interpreted seeps were found in deeper water along the shelf break in the accretionary prism and along slope failures.

Describe relevance to national security, conservation, and/or the economy:
The so-called Blue Economy is advancing further into the oceans without a map of sufficient resolution or accuracy for most maritime activities, especially in Alaska. A regional seafloor map of Alaskan waters in the Pacific Ocean would help the US meet the goals laid out in the November 19, 2019, Presidential Memorandum on *Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska*. By partnering with other agencies, universities, and industry in ongoing studies, the goals set forth in the memorandum to reduce duplication of effort and promote efficiencies across agencies would also be addressed. A map of the seafloor helps the US define international borders, maritime boundaries and ensures safety of navigation within her waters, while also indicating areas of potential geohazards such and slope failure and tsunami generation. A regional seafloor map is a first-order ocean observation that guides all other ocean models and helps to define areas of interest for further study. Only with a good map can the extent and distribution of benthic habitats be defined, for sustainable use and conservation of these important ecosystems.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: David Butterfield
Institution: NOAA Pacific Marine Environmental Lab and U. Washington JISAO
Email Address: David.a.butterfield@noaa.gov
Office Phone Number: 206-526-6722
Collaborators/Co-Authors: Joe Resing (PMEL), Tamara Baumberger (PMEL), Carol Stepien (PMEL), Melissa Anderson (U. Toronto), Julie Huber (WHOI), Verena Tunnicliffe (U. Victoria, B.C.), Amanda Bates (Memorial Univ. Newfoundland)

Title: Systematic Exploration of the Mariana Region

Priority Geographic Area: (Indicate if within U.S. EEZ or international waters.)

The Mariana region (all but the far northern end where it meets the Izu-Bonin arc) is within the US EEZ. This makes it a priority area for exploration and research. As co-manager of the Mariana Trench Marine National Monument, NOAA has a stewardship interest in the region.

Description of Priority Area:

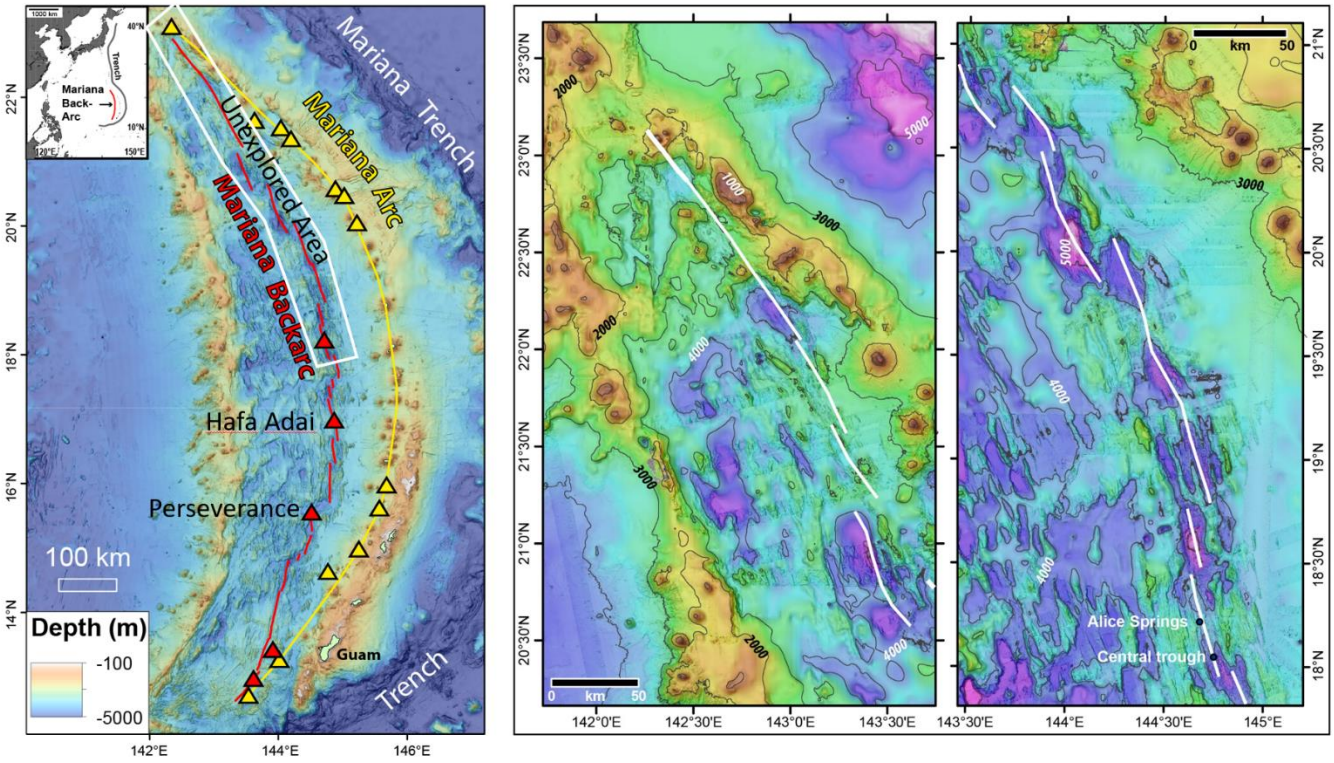


Figure 1. Map of the Mariana Trench, Arc, and Backarc region of the Western Pacific. Initial exploration and survey over several decades has mapped portions of the arc and backarc with multibeam sonar (EM302 or similar quality) and discovered and characterized volcanic and hydrothermal sites on the arc (yellow triangles) and backarc (red triangles). There are significant gaps in high-resolution bathymetry and the area outlined in white is largely unexplored. The two panels at right are a zoomed in view of the northern half of the backarc. White lines indicate location of the spreading axis and neo-volcanic zone.

What are the characterization and data needs in this area?

Check all that apply:
_**X**_ Biology _**X**_ Geology _**X**_ Marine Archaeology _**X**_ Physical Oceanography _**X**_ Chemistry

Provide a list or brief description of the data needed within this area, from your perspective:

High-resolution seafloor maps from ship- and AUV-mounted multibeam sonar, water column chemistry and plume mapping, seafloor ROV surveys and sampling for chemistry, mineralogy, geology, and biology.

Describe relevance to national security, conservation, and/or the economy:

The oceans are a critical, life-sustaining force on Earth, and humanity is still very much engaged in exploring and understanding the deep ocean, its resources, and our role in sustainably harvesting resources for the benefit of society. Intelligent management of ocean resources is not possible without systematic knowledge of resource distribution and ecosystem function. Actively forming sulfide mineral structures are the primary habitat for many endemic animals with chemosynthetic symbionts. There is a need to build a regional view of deep-sea chemosynthetic ecosystems, while producing data that can be used to characterize and model the distribution of critical minerals and the connectivity of biological communities within and beyond the Mariana region. Results of this exploration will open new avenues of research with benefits for ecosystem modeling and ocean resource management.

Planetary scale tectonic processes play a poorly understood role in creating biogeographical patterns. By characterizing multiple deep ocean chemosynthetic ecosystems within a geologically diverse region that is largely unaffected by human activity, we may make a leap forward in understanding how tectonics and geochemistry shape biodiversity. To that end, we must quantify which geological, physical and chemical drivers are most important in explaining microbial and macrofaunal biodiversity patterns in the Mariana arc/backarc region, and connect our findings to the surrounding hydrothermal systems of the broader western Pacific region. With deep-sea mining being planned, understanding regional ecosystem connectivity is needed now.

Recent expeditions supported by NOAA Ocean Exploration and the Schmidt Ocean Institute have explored the southern Mariana backarc (from 13-18.5°N) on R/V Falkor, and found 13 new hydrothermal vent ecosystems in and near the Mariana Trench Marine National Monument (Baker et al., 2017). Expeditions are being planned to continue that search in the northern backarc (from 18.5°-23.5°N) and the convergence zone of the arc and backarc to complete the systematic investigation of this poorly mapped and sparsely explored area. The results will help link the biogeography of the arc and backarc and understand the connection of the Mariana region to neighboring regions in the western Pacific (Izu-Bonin Arc, Okinawa Trough and Manus Basin).

The first systematic survey of the entire Mariana volcanic arc in 2003 revealed that 1/3 of the 60 arc seamounts were hydrothermally active and hosted remarkable vent environments with unique biological communities [Embley et al., 2004; Embley et al., 2007a; Baker et al., 2008; Resing et al., 2009]. Subsequent exploration of these sites with remotely operated vehicles (ROVs) discovered an actively erupting submarine volcano [Embley et al., 2006; Resing et al., 2007; Chadwick et al., 2008; Butterfield et al., 2011; Chadwick et al., 2012; Schnur et al., 2017], vents emitting liquid CO2 [Lupton et al., 2006; Tunnicliffe et al., 2009], and lakes of molten sulfur on the seafloor [Butterfield et al., 2007; de Ronde et al., 2015]. Each of these sites supports unique ecosystems [Embley et al., 2007a; Huber et al.,

2010; Tunnicliffe et al., 2010, 2013]. These discoveries directly inspired the establishment of the Marianas Trench Marine National Monument in 2009.

There is an opportunity now to: systematically explore the northern half of the Mariana backarc; produce expanded high-resolution seafloor maps; locate, survey and sample hydrothermal vents to understand mineralogy, chemistry, and biological communities. This multi-disciplinary survey approach can test the relative importance of spreading rate, magma supply, and distance from the arc in the distribution and frequency of backarc vent sites [Baker et al., 2017; Beaulieu et al., 2015; Anderson et al., 2017]. These factors vary with distance along the backarc [Fryer, 1996; Kato et al., 2003; Stern et al., 2013], and the northern arc/backarc convergence may host exceptional geochemical diversity and hydrothermal activity. Additional exploration of the forearc also has great potential for discovery.

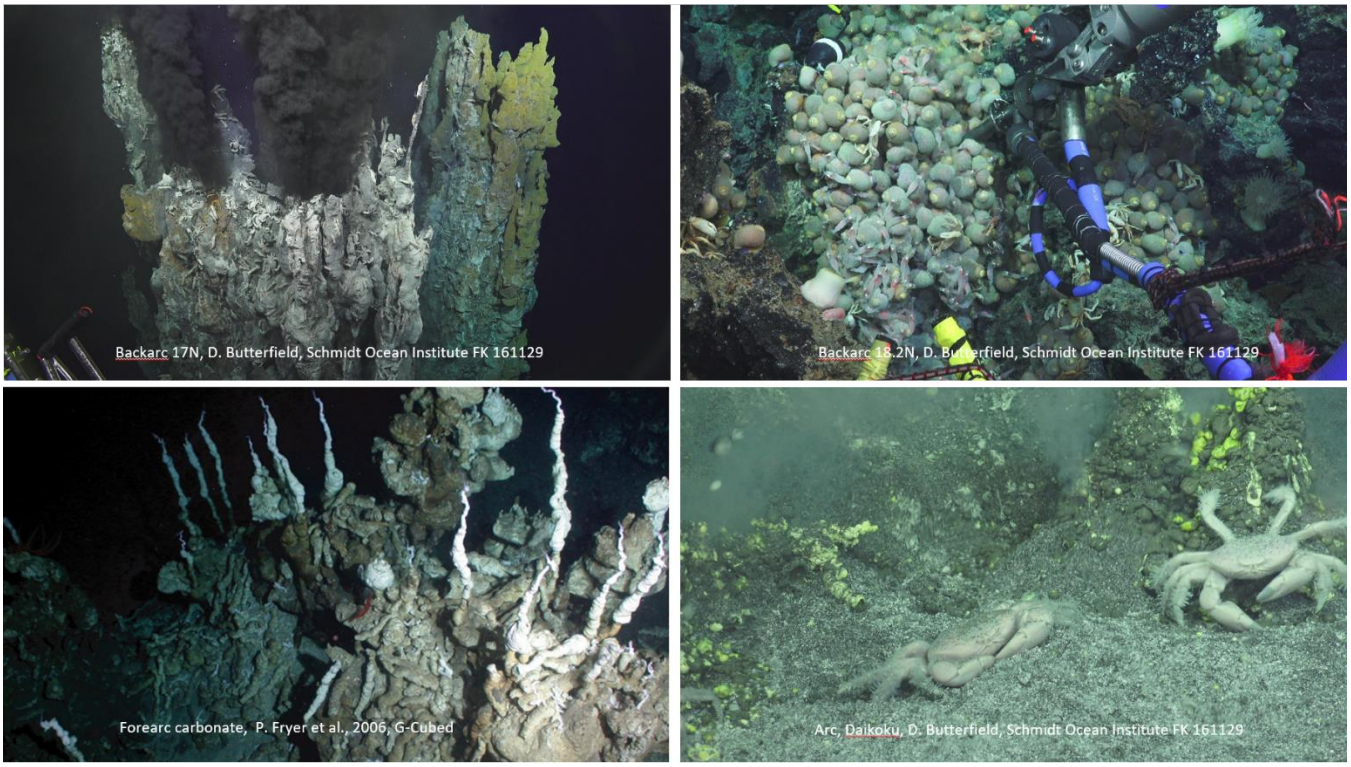


Figure 2. Images of vents and seeps from the Mariana region. Upper left, large metal sulfide chimney at the Hafa Adai vent field near 17°N on the backarc. Upper right, backarc fauna at Alice Springs area, 18.2°N. Lower right, Daikoku volcano on the arc, volcaniclastic sediment with sulfur and magmatic gas. First 3 images from 2016 cruise on R/V Falkor. Lower left, small carbonate growths on a forearc cold seep, Quaker Seamount near 18.7°N (from Fryer et al., 2006, G-Cubed). The range of fluid types and mineral substrates in the Mariana region is astounding.

From your perspective, what makes this area unique? (If applicable, why is this area relevant to your organization?)

Discovering new seafloor features and resources is a priority for NOAA. The Mariana region is unique in its diversity. The Mariana arc consists of over 60 shallow seamounts and 9 volcanic islands that have formed due to plate subduction along the Mariana trench. In contrast, the backarc is a line of deep basins to the west of the arc formed by tectonic spreading. The arc and backarc converge at both ends

and are separated by at most 120 km (Fig. 1). These two geologic settings produce starkly different hydrothermal systems and fluid chemistries. For example, arc sites commonly have abundant native sulfur and acidic fluids [Gamo et al., 2004, 2006; Butterfield et al., 2007, 2011; de Ronde et al., 2015] while backarc and MOR sites host metal sulfide chimneys and near-neutral pH fluids. The Mariana forearc leading down to the trench, has cold seeps where serpentinization of mantle rocks produces fluids with pH >12! (Mottl et al., 2003). Ocean processes strongly influence the dispersal of larvae and the connectivity and gene flow between sites, and inter-site distance and degree of connectivity is a key driver of biodiversity and biogeographic patterns along mid-ocean ridges. Examining patterns and differences in biodiversity between proximal sites having different geochemical properties allows us to test the importance of geochemistry in structuring biological communities. Regional surveys of the backarc reveal a complex geophysical history that varies along strike ranging from robust magmatic spreading in the south to deep rifting/sea-floor spreading in the central section, and asymmetric rifting/spreading in the north. These geophysical differences may influence ecosystem structure.

Please list other partners or organizations that may also be interested in this area:

NOAA National Marine Fisheries Service, Pacific Islands Fisheries Science Center, NOAA Ocean Exploration and Research, Schmidt Ocean Institute, U.S. Fish and Wildlife Service (Co-Mangers of Marianas Trench Marine National Monument), US Geological Survey.

References Cited

Anderson, M.O., W.W. Chadwick, Jr., M.D. Hannington, S.G. Merle, J.A. Resing, E.T. Baker, D.A. Butterfield, S.L. Walker, and N. Augustin (2017): Geological interpretation of volcanism and segmentation of the Mariana back-arc spreading center between 12.7°N and 18.3°N. Geochem. Geophys. Geosyst., 18(6), 2240–2274, doi: 10.1002/2017GC006813.

Baker, E. T., R. W. Embley, S. L. Walker, J. A. Resing, J. E. Lupton, K. Nakamura, C. E. J. de Ronde, and G. J. Massoth (2008), Hydrothermal activity and volcano distributions along the Mariana Arc, J. Geophys. Res., 113, B08S09, doi:10.1029/2007JB005423

Baker, E. T., S. L. Walker, J. A. Resing, W. W. Chadwick, S. G. Merle, M. O. Anderson, D. A. Butterfield, N. J. Buck, and S. Michael (2017), The Effect of Arc Proximity on Hydrothermal Activity Along Spreading Centers: New Evidence From the Mariana Back Arc (12.7 degrees N-18.3 degrees N), Geochemistry Geophysics Geosystems, 18(11), 4211-4228, doi:10.1002/2017gc007234.

Beaulieu, S. E., E. T. Baker, and C. R. German (2015), Where are the undiscovered hydrothermal vents on oceanic spreading ridges?, Deep-Sea Research Part Ii-Topical Studies in Oceanography, 121, 202-212, doi:10.1016/j.dsr2.2015.05.001.

Butterfield, D. A., J. Resing, W. W. Chadwick, Jr., R. W. Embley, J. E. Lupton, K. Nakamura, M. D. Lilley, and J. A. Huber (2007), Sulfur Lakes and Sulfur-rich Volcanic Hydrothermal Systems on the Mariana Arc, Eos Trans. AGU, 88(52, Fall Meet. Suppl.), Abstract V34B-03

Butterfield, D. A., K. Nakamura, B. Takano, M. D. Lilley, J. E. Lupton, J. A. Resing, and K. K. Roe (2011), High SO2 flux, sulfur accumulation and gas fractionation at an erupting submarine volcano, Geology, 39(9), 803-806, doi:10.1130/G31901.1.

Chadwick, W. W., Jr., K. V. Cashman, R. W. Embley, H. Matsumoto, R. P. Dziak, C. E. J. de Ronde, T.-K. Lau, N. Deardorff, and S. G. Merle (2008), Direct Video and Hydrophone Observations of Submarine Explosive Eruptions at NW Rota-1 Volcano, Mariana Arc, J. Geophys. Res., 113, B08S10, doi:10.1029/2007JB005215

Chadwick, W. W., Jr., R. P. Dziak, J. H. Haxel, R. W. Embley, and H. Matsumoto (2012), Submarine landslide triggered by volcanic eruption recorded by in-situ hydrophone, Geology, 40(1), 51-54, doi:10.1130/G32495.1.

de Ronde, C. E. J., W. W. Chadwick, Jr., R. G. Ditchburn, R. W. Embley, V. Tunnicliffe, E. T. Baker, S. L. Walker, V. L. Ferrini, and S. M. Merle (2015), Molten sulfur lakes of intraoceanic arc volcanoes, in Volcano Lakes, edited by D. Rouwet, B. Christenson, F. Tassi and J. Vandelbroulemuck, Springer-Verlag.

Embley, R. W., E. T. Baker, W. W. Chadwick, Jr., J. E. Lupton, J. A. Resing, G. J. Massoth, and K. Nakamura (2004), Explorations of Mariana arc volcanoes reveal new hydrothermal systems, Eos Trans. AGU, 85(4), 37, 40

Embley, R. W., W. W. Chadwick, Jr., E. T. Baker, D. A. Butterfield, J. A. Resing, C. E. J. De Ronde, V. Tunnicliffe, J. E. Lupton, S. K. Juniper, K. H. Rubin, R. J. Stern, G. T. Lebon, K. Nakamura, S. G. Merle, J. R. Hein, D. P. Wiens, and Y. Tamura (2006), Long-term eruptive activity at a submarine arc volcano, Nature, 441, 494-497, doi:10.1038/nature04762.

Embley, R. W., E. T. Baker, D. A. Butterfield, W. W. Chadwick, Jr., J. E. Lupton, J. A. Resing, C. E. J. De Ronde, K. Nakamura, V. Tunnicliffe, J. Dower, and S. G. Merle (2007), Exploring the Submarine Ring of Fire: Mariana Arc - Western Pacific, Oceanography, 20(4), 69-80

Fryer, P. (1996), Evolution of the Mariana convergent plate margin system, Rev. Geophys., 34(1), 89-125

Gamo, T., H. Masuda, T. Yamanaka, K. Okamura, J. Ishibashi, E. Nakayama, H. Obata, K. Shitashima, Y. Nishio, H. Hasumoto, M. Watanabe, K. Mitsuzawa, N. Seama, U. Tsunogai, F. Kouzuma, and Y. Sano (2004), Discovery of a new hydrothermal venting site in the southernmost Mariana Arc: Al-rich hydrothermal plumes and white smoker activity associated with biogenic methane, Geochemical Journal, 38, 527-534

Gamo, T., J. Ishibashi, U. Tsunogai, K. Okamura, and H. Chiba (2006), Unique geochemistry of submarine hydrothermal fluids from arc-backarc settings of the western Pacific, in backarc Spreading Systems: Geological, Biological, Chemical, and Physical Interactions, edited by D. M. Christie, C. R. Fisher, S.-M. Lee and S. Givens, Geophysical Monograph 166, pp. 147-162, American Geophysical Union, Washington DC.

Huber, J. A., H. V. Cantin, S. M. Huse, D. B. M. Welch, M. L. Sogin, and D. A. Butterfield (2010), Isolated communities of Epsilonproteobacteria in hydrothermal vent fluids of the Mariana Arc seamounts, FEMS Microb. Ecol., 73, 538-549, doi:10.1111/j.1574-6941.2010.00910.x.

Kato, T., J. Beavan, T. Matsushima, Y. Kotake, J. T. Camacho, and S. Nakao (2003), Geodetic evidence of backarc spreading in the Mariana Trough, Geophys. Res. Lett., 30, doi:10.1029/2002GL016757

Lupton, J. E., D. A. Butterfield, M. Lilley, L. Evans, K. Nakamura, W. W. Chadwick, Jr., J. Resing, R. W. Embley, E. Olson, G. Proskurowski, E. Baker, C. E. J. de Ronde, K. K. Roe, G. T. Lebon, and C. Young (2006), Submarine

venting of liquid carbon dioxide on a Mariana arc volcano, Geochem. Geophys. Geosyst., 7, Q08007, doi:08010.01029/02005GC001152

Mottl, M.J., S.C. Komor, P. Fryer, C.L. Moyer (2003) Deep-slab fluid fuel extremophilic Archaea on a Mariana forearc sepentinite mud volcano: Ocean Drilling Program Leg 195, Geochem. Geophys. Geosys. 4:11, doi:10.1029/2003GC000588

Resing, J.A., G. Lebon, E.T. Baker, J.E. Lupton, R.W. Embley, G.J. Massoth, W.W. Chadwick, Jr., and C.E.J. de Ronde (2007): Venting of acid-sulfate fluids in a high-sulfidation setting at NW Rota-1 submarine volcano on the Mariana Arc. Econ. Geol., 102(6), 1047–1061, doi: 10.2113/gsecongeo.102.6.1047.

Resing, J. A., E. T. Baker, J. E. Lupton, S. L. Walker, D. A. Butterfield, G. J. Massoth, and K. Nakamura (2009), Chemistry of hydrothermal plumes above submarine volcanoes of the Mariana Arc, Geochem. Geophys. Geosyst., 10(2), Q02009, doi:02010.01029/02008GC002141

Schnur, S.R., W.W. Chadwick, Jr., R.W. Embley, V.L. Ferrini, C.E.J. de Ronde, K.V. Cashman, N. Deardorff, S.G. Merle, R.P. Dziak, J. Haxel, and H. Matsumoto (2017): A decade of volcanic construction and destruction at the summit of NW-Rota-1 Seamount: 2004–2014. J. Geophys. Res., 122(3), 1558–1584, doi: 10.1002/2016JB013742.

Stern, R. J., Y. Tamura, H. Masuda, P. Fryer, F. Martinez, O. Ishizuku, and S. H. Bloomer (2013), How the Mariana Volcanic Arc ends in the south, Island Arc, 22, 133-148, doi:10.1111/iar.12008.

Tunnicliffe, V., K. T. A. Davies, D. A. Butterfield, R. W. Embley, J. M. Rose, and W. W. Chadwick, Jr. (2009), Survival of mussels in extremely acidic waters on a submarine volcano, Nature Geosci., 2, 344-348

Tunnicliffe, V., Koop, B.F., Tyler, J. & So, S. (2010) Flatfish at seamount hydrothermal vents show strong genetic divergence between volcanic arcs. Mar Ecol Prog Ser, 31 (sup 1), 1 - 9.

Tunnicliffe, V., J. Tyler, and J. F. Dower (2013), Population ecology of the tonguefish Symphurus thermophilus (Pisces; Pleuronectiformes; Cynoglossidae) at sulphur-rich hydrothermal vents on volcanoes of the northern Mariana Arc, Deep-Sea Res. II, doi:10.1016/j.dsr2.2013.01.026.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Dr. Megan Carr, Ms. Catherine Coon, and Dr. James Kendall
Institution: BOEM Alaska OCS Region
Email Address: James.Kendall@boem.gov, Megan.Carr@boem.gov, Catherine.Coon@boem.gov
Office Phone Number: 907-334-5200
Collaborators/Co-Authors: BOEM, NOAA, USGS, and State of Alaska

Title: Targeted Seafloor Mineral Science and Mapping in the Arctic and Aleutian Arc Large Marine Ecosystems

Priority Geographic Area: Within U.S. EEZ and Alaska OCS

Description of Priority Area:
There are two priority regional areas for ocean exploration in the Alaska Region of BOEM. The first, the Arctic Ocean (Figure 1), is likely to contain the three marine mineral deposit types generating the greatest global interest: manganese (Mn) nodules, ferromanganese (Fe-Mn) crusts, and seafloor massive sulfides. Extensive Fe-Mn crust and Mn nodule deposits are known to exist and are globally unique because of their high content of scandium, a very rare metal used to make fuel-efficient aircraft. However, the extent of these mineral deposits is poorly constrained. In addition, the Arctic Ocean is a unique biological and geochemical region that will become an increasingly competitive arena for resource exploration and development as shipping lanes open in tandem with reduced sea ice. Cognizant U.S. agencies need to plan and prepare now for near-future marine mineral mining prospects in the Arctic.

Second, the Aleutian Arc (Figure 2) constitutes a permissive region for seafloor sulfides that has never been explored. Seafloor sulfides in arcs may be particularly rich in antimony, important for corrosion resistance in alloys and batteries. Critical mineral priority areas and regions unmapped overlap along the Aleutian chain. Priority areas are in the Western Aleutians and include: inter alia, the Buldir Basin, Sunday Basin, Amlia Basin, and Ingenstrem Depression. These areas should be mapped using water-column acquisition to identify shallow active hydrothermal systems; all mapping should include the basins and adjacent ridge structures.

What are the characterization and data needs in this area?
Check all that apply:

- ✓ Biology
- ✓ Geology
- ___ Marine Archaeology
- ✓ Physical Oceanography
- ✓ Chemistry
- ___ Other

Note: While not a priority data need, formations from marine archaeological features will be identified as a residual effect of bathymetric surveys.

Provide a list or brief description of the data needed within this area, from your perspective:
One core set of research questions will focus on marine minerals: What are the regional mechanisms of seafloor mineral development? What are the location and types of significant mineral deposits? What is the viability of harvesting identified deposits? What are the environmental impacts of marine mineral mining? Baseline environmental measurements should be conducted simultaneously with deposit assessments to initiate critical research needed prior to leasing or future development. Methane and oil-seep communities could also be explored, mapped, and assessed from the same research platform, providing additional information relevant to ongoing oil and gas operations in the Beaufort and Chukchi Seas. Refined seafloor bathymetry data could also be strategically collected and put to productive scientific use.

BOEM has the authority through the OCSLA to establish the Submerged Lands Act Boundary (SLAB), it does so by using the National Baseline (NB) data where and when available. Baseline points and Bay/River closing lines are ambulatory and change with coastal erosion and accretion. These are the most seaward points along the Nation's shoreline, e.g. those that would contribute to the 3 nautical mile SLAB. However, due to the difference between NB requirements verses SLAB baseline points, BOEM has the requirement to evaluate relevant rock data proscribed by the SLAB. This Strategy should consider data collection for the base line as collateral data for priority areas to include SLAB coast line needs in order to support future management requirements. The Arctic Area of Beaufort and Chukchi Seas have since been fixed by Supreme Court Decree, but other areas in Alaska could still be updated with better baseline data found on updated NOAA Nautical Charts. Some areas have no SLAB yet.

Describe relevance to national security, conservation, and/or the economy:
The Administration has prioritized the need for critical mineral exploration and mapping, both onshore and offshore, wherever there is potential to expand the domestic supply that is vital to ensure national security and economic viability. While governments and private entities from other nations have moved aggressively to expand marine mineral mining, little activity exists in the U.S. despite growing interest among potential leaseholders.

The mission of BOEM is to serve as the lead Federal agency and liaison in support of assessing, leasing, and managing the Nation's current and long-term interests in OCS energy and marine minerals. This mission has been prioritized and focused by the current Administration's call to "ensure access to mineral resources, especially the critical and rare earth minerals needed for scientific, technological, or military applications". Executive Order 13817 outlines a new Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals by "increasing activity at all levels of the supply chain, including exploration, mining, concentration, separation, alloying, recycling, and reprocessing."

From your perspective, what makes this area unique?
The proposed study will provide invaluable baseline and exploratory seafloor observations in targeted areas of the Arctic EEZ that holds great potential for marine mineral discovery and extraction. Results specific to marine minerals would be immediately useful for consideration in BOEM's National Leasing Program, while results specific to seep communities, bathymetry, and benthic ecosystems would be timely for consideration in environmental reviews for any Leasing Program.

This study aims to provide vital baseline and exploratory seafloor observations in a geographic "hotspot" of the OCS and Extended Continental Shelf that holds great potential for marine mineral discovery and extraction (Figure 3). Research will also extend observations pertaining to seafloor bathymetry, seep communities, and benthic ecosystems. Additionally, this proposed work pertains to the Arctic Ocean and Aleutian Arc regions within the Alaska OCS, both of which contain permissive regions for marine minerals types that are of interest for base (Mn, Cu) and critical (Co, Sb, Sc, Te) elements.

Please list other partners or organizations that may also be interested in this area:
The study will bring together experts across multiple Federal and State agencies who will collaborate to improve our understanding of the distribution, ecology, and underlying geological foundation of valuable marine minerals and seafloor features of the Arctic EEZ. The primary agencies that play a role in assessing and managing marine mineral resources (BOEM, NOAA, USGS) must work together to collect essential baseline data that can be used to map, sample, and understand seafloor deposits and associated benthic ecosystems. In regard to baseline data, primary users of the data and information are the Department of State, Department of Commerce (NOAA, NOS), Department of Justice, Department of Interior (BOEM, FWS), Department of Homeland Security (USCG), Department of Navy, Department of Defense (NGA), Environmental Protection Agency (EPA), and the Federal Communications Commission (FCC).

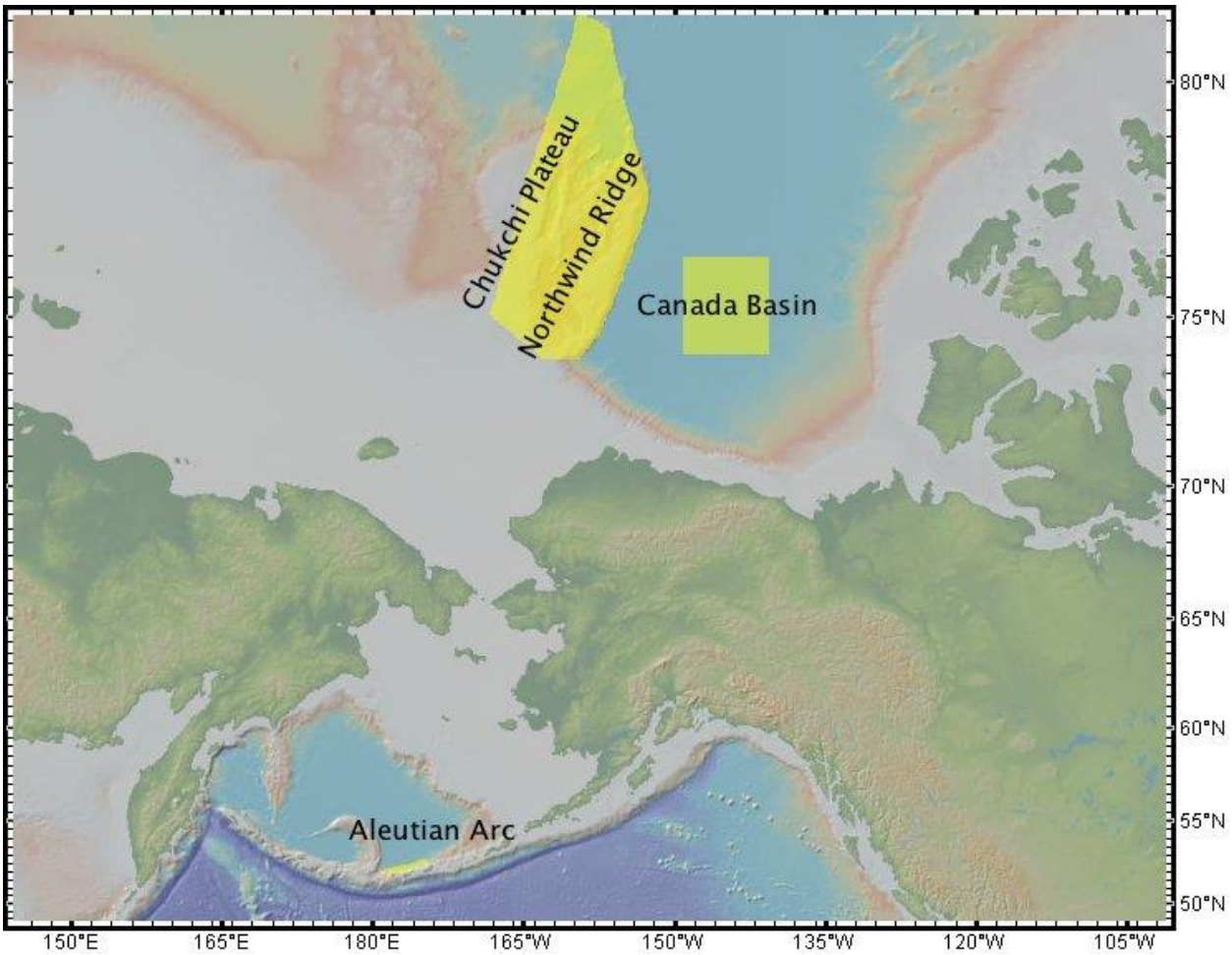


Figure 1. Broadly defined permissive regions in the Alaska OCS region. The Chukchi Plateau is permissive for ferromanganese crusts, the Canada basin is permissive for manganese nodules, and the Aleutian Arc is permissive for seafloor massive sulfides and hydrothermal oxides.

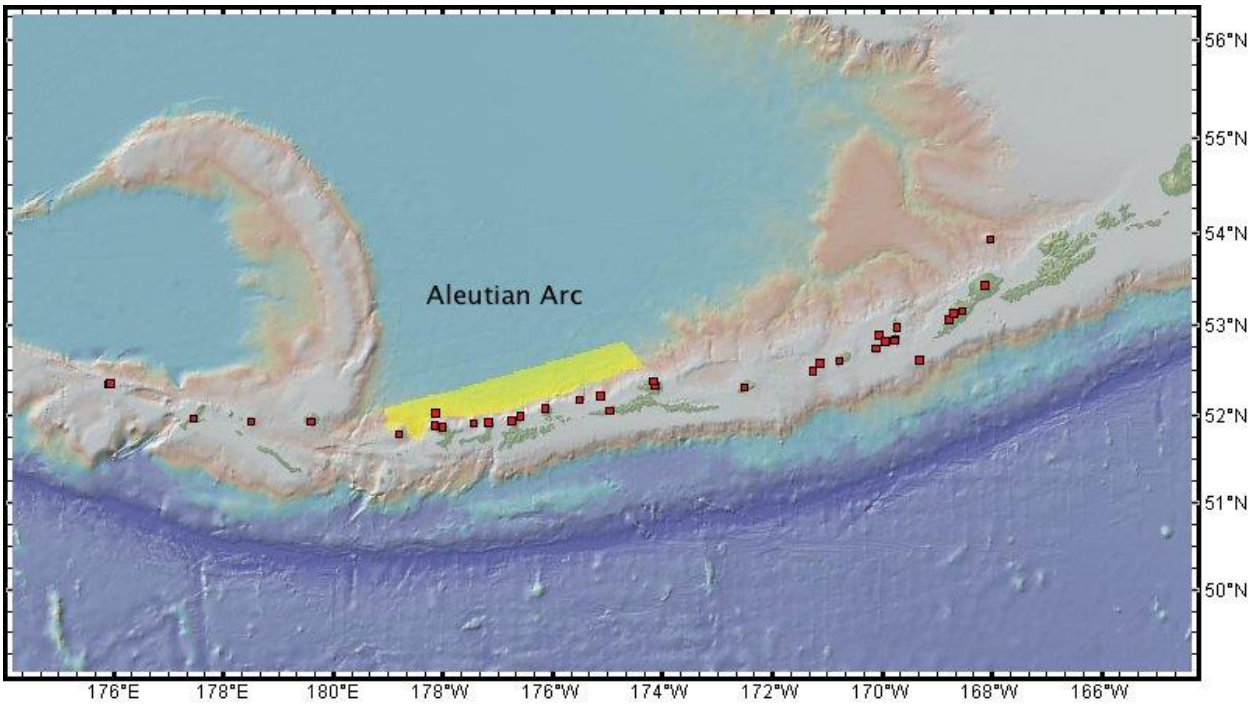


Figure 2. Active volcanoes (red squares) on the oceanic crust section of the Aleutian Arc. The highlight shows regions of interest on the Aleutian Arc where bathymetric mapping and seismic surveys have been performed at high enough resolution to support water column surveys for active hydrothermal venting.

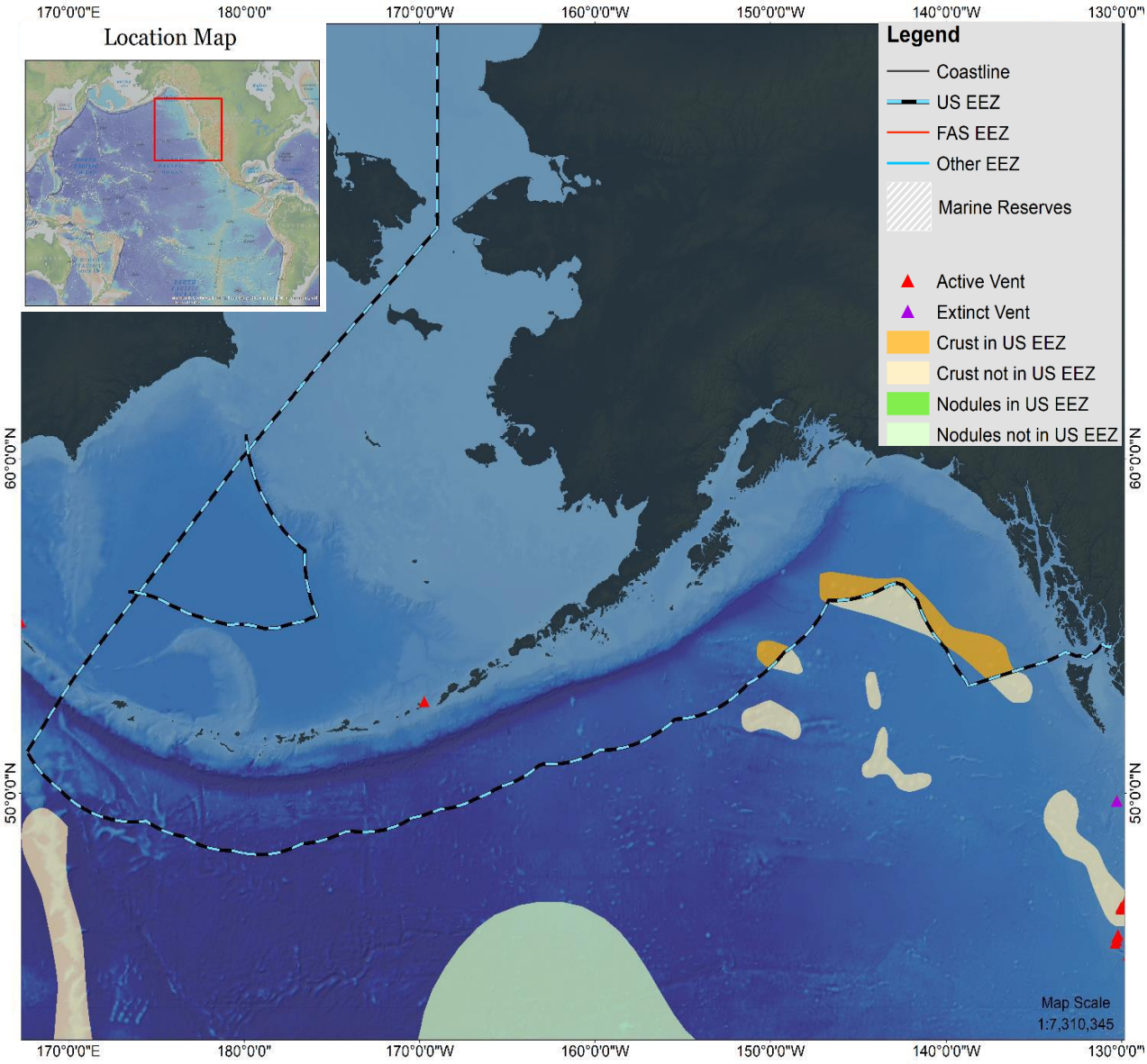


Figure 3. Crust and Nodule Occurrence off Aleutian Island Chain. This potential is largely unexplored and likely a host to multiple hydrothermal sulfide deposits.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Jorge Cortés
Institution: Universidad de Costa Rica
Email Address: Jorge.cortes@ucr.ac.cr
Office Phone Number: 858-534-3579
Collaborators/Co-Authors: Lisa Levin, Scripps Institution of Oceanography (llevin@ucsd.edu), Erik Cordes, Temple University (ecordes@temple.edu)

Title: Biodiversity and connectivity along a Costa Rican mountain range from offshore to the mainland

Priority Geographic Area:
(Indicate if within U.S. EEZ or international waters.)
Costa Rica EEZ

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)
The Coco Volcanic Range extends for 1,000 km from the Galápagos Islands hotspot to the southern Pacific mainland of Costa Rica, with Isla del Coco as the only above sea level point. The range has peaks with summits ranging from several hundreds to over a 1000 m depth. On both sides of the volcanic range there are extensive abyssal plains; to the east these occur in a relatively enclosed basin and to the west they are open to the rest of the Pacific Ocean. There has been practically no research along this volcanic range.

What are the characterization and data needs in this area?
Check all that apply:
__x_ Biology
_x__ Geology
___ Marine Archaeology
___ Physical Oceanography
__x_ Chemistry (Geochemistry)
__x_ Other (Human activity indicators – e.g., plastic debris, fishing gear, trawl marks)

Provide a list or brief description of the data needed within this area, from your perspective:

1) Species composition, diversity, and functional attributes as well as indicators of human activity at the seafloor along a gradient from the open ocean to the coast.
2) Species composition on both sides of the mountain range to determine whether the mountains act as a barrier to dispersal (as in high latitude mountains on land.)
3) Comparison of the biodiversity and dominant taxa:
    a. along a continuous range with seamounts close-by studied by our group in the last 3 years.
    b. on island slopes [Cocos, Galapagos] versus (fully submerged) seamount slopes.
    c. Under lower oxygenation (300-800 m) and higher oxygenation (below 1000 m)

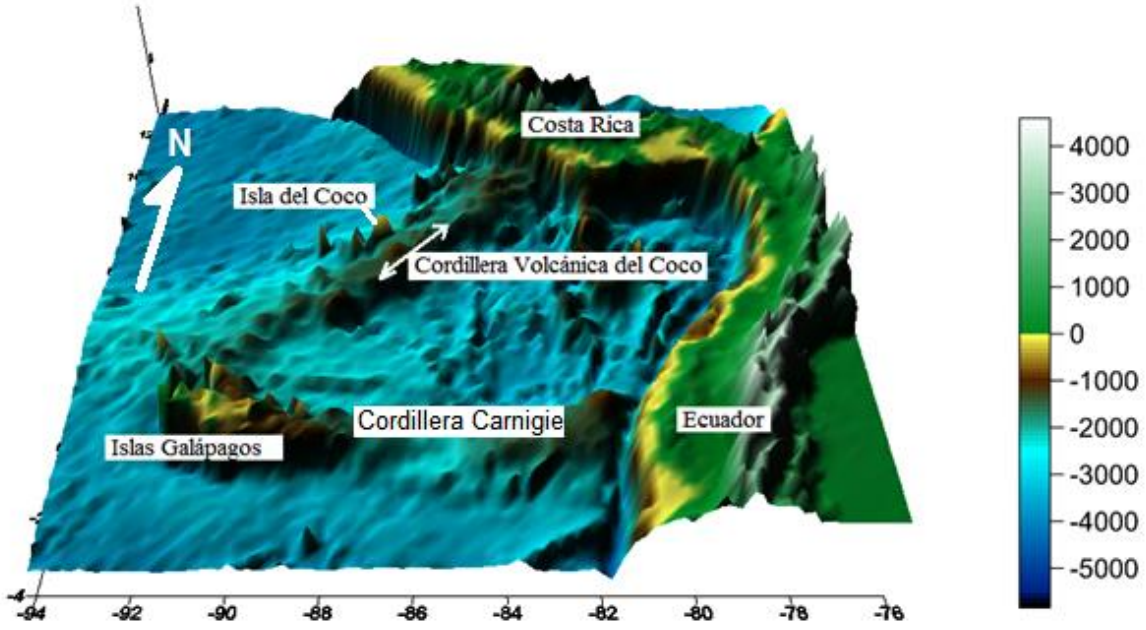
4) Bathymetric data for the region.

5) Chemical characterizations of the waters along the mountain range.

Describe relevance to national security, conservation, and/or the economy:
With growing interest in fishing and metals from the deep sea, the biological characterization of these areas has both conservation and economic relevance.

From your perspective, what makes this area unique?
(If applicable, why is this area relevant to your organization?)
The area presents a unique situation of a continuous mountain range from a hotspot to the mainland of the American continent, a relative enclosed deep embayment on the east and open basin on the west. The enclosed embayment may be a region of high endemism.

Please list other partners or organizations that may also be interested in this area:
Greg Rouse – University of California, San Diego
Victoria Orphan California Institute of Technology
Shanna Goffredi – Occidental College
US Geological Survey – Kira Mizell



Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: James P. Delgado
Institution: SEARCH
Email Address: james.delgado@searchinc.com
Office Phone Number: 904-379-8338
Collaborators/Co-Authors: Michael L. Brennan

Title: Maritime Heritage of Alaska

Priority Geographic Area:
Northern Pacific and Bering Strait within EEZ (see attached description and map)

Description of Priority Area:
This area covers the historical eras of Russian and American early trade and exploitation of Alaska's natural resources through World War II and more modern marine accidents.

What are the characterization and data needs in this area?
Check all that apply:
___ Biology
___ Geology
_x_ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
High resolution multibeam bathymetry and, where possible, ROV dives for target identification, inspection, and characterization.

Describe relevance to national security, conservation, and/or the economy:
Historic shipwreck sites can be preserved through high resolution sonar and imagery.

From your perspective, what makes this area unique?
The cold and treacherous waters of Alaska and the North Pacific have made for some tragic shipwrecks where no one has survived. These wrecks need to be located and documented, and the stories told through telepresence-enabled exploration.

Please list other partners or organizations that may also be interested in this area:
Navy History and Heritage Command, BOEM, NOAA

Maritime Heritage of Alaska
James P. Delgado, PhD and Michael L. Brennan, PhD

The intercoastal, coastal, and EEZ waters of Alaska in the North Pacific, Bering Sea, Beaufort Sea and the Arctic are a largely unsurveyed and uncharacterized region regarding a number of significant shipwrecks that are tied to the colonial and post-colonial history of the region and the state. Hundreds of shipwrecks have taken place in and off Alaska's coastal waters. Historian Michael Burwell, working with BOEM, estimates 3,681 wrecks in Alaskan waters since 1750; of these, the majority (3,149) were lost between 1900 and 2000. (BOEM 2011; https://alaskashipwreck.com/shipwrecks-a-z/). These wrecks collectively tell a story of the sagas of Russian exploration and colonization from 1750 through 1868. They include the activities of the seal fur trading Russian American Company, the Russian Imperial Navy, and early American colonial activities after the purchase of Alaska by the United States in 1868. Alaska's rich natural resources inspired a variety of maritime trades – whaling, offshore fishing, fish canning, fur sealing, and regular freight and passenger trade along the Inside Passage. The Klondike Gold Rush, starting in 1896 and continuing through the First World War, brought increased traffic and wrecks.

Other shipwrecks in the region correspond to Alaska's role as a strategic frontier in World War II, where it was the setting for military bases and a campaign against Imperial Japan following the invasion and occupation of the Aleutian Islands of Kiska and Attu in 1942. Examples of the warships sunk during this campaign include The Japanese destroyers *Nenohi* and *Arare*, sunk off Kiska by US submarines in early July 1942, and the Japanese submarine I-24, which was sunk off the Aleutian Islands in June 1943 after participating in the attack at Pearl Harbor and the Battle of Coral Sea.

Modern wrecks also lie in Alaska's waters. The cruise ship MV *Prinsendam*, which caught fire and sank in the Gulf of Alaska on October 5, 1980, reportedly lies at a depth of over 9,000 feet. Many of these wrecks are not charted, and those that are with few exceptions have not been characterized. Those that have been found or investigated show the potential for significant finds, well-preserved vessels, and powerful human stories that attract public attention and support.

Notable shipwrecks that are in need of further mapping and archaeological characterization include:

Kad'yak (1860)
A Russian American Company ship engaged in trade between Russian Alaska and to date the only Russian-era shipwreck discovered in Alaska. The ship was part of the Russian fleet that moved marine trade goods throughout the northern Pacific. In February 1860, the ship was carrying a cargo of ice from Kodiak to San Francisco when it struck a submerged rock and flooded, kept afloat for three days by the cargo of ice before sinking (NOAA 2004). The wreck now lies in 80 feet of water between two submarine ridges. Some wood remains due to burial in sand, but much of the ship has deteriorated.

Kad'yak's name on the bronze hub for the ship's now vanished wooden wheel (NOAA Photograph by Tane Casserley).

Clara Nevada, ex-*Hassler*
This vessel, formerly a US Coast Survey steamer used to chart the coast, is a significant vessel in the history of a NOAA predecessor agency. It was surveyed as part of a NOAA OER-sponsored survey of SE Alaska wrecks in 2006. In February 1898, the ship departed Skagway, AK with passengers. Strong winds and high waves pummeled the ship until it struck a submerged rock and broke apart; there were no survivors (NOAA 2007). The wreck now lies broken up with machinery and hull sections scattered on the seabed with the bow roughly pointing north.

Princess Sophia
Well known, this "*Titanic*" of Alaska saw the loss of all on board in exceptionally tragic circumstances. This Canadian Pacific Railway steamer departed Skagway, AK on October 24, 1918 when it struck Vanderbilt Reef. The rough seas made rescue impossible. The ship sank after 40 hours on the reef, but none of the 353 people on board could be rescued (Lattka 2016). The wreck today has been dived but full site mapping and archaeological characterization remains to be done.

1871 Lost Whaling Fleet
A fleet of whaling ships stayed in the Chukchi Sea late into the year to capture the last whales of the season when they became trapped by rapidly shifting ice floes. The crews abandoned all 32 vessels, which combined with other losses between 1850 and 1900 made for 42 ships lost along this stretch of the north Alaskan coastline (Barr et al. 2016). A remote sensing survey in 2015 located five sites believed to be remains of wooden vessels consistent with those lost in 1871, but could not positively identify which ships they were. Further mapping and detailed documentation of these wrecks as well as surveys for the remaining ones lost needs to be conducted.

SS *Aleutian*
This 1929 steamship wreck is a famous vessel involved in early coastal trade, the construction and maintenance of the Panama Canal, and finally as an Alaskan freight and passenger ship for its final three years. Discovered off Kodiak Island in 2004, the wreck is listed on the National Register of Historic Places and is largely intact. In addition, Aleutian is listed as a potentially polluting wreck in NOAA's 2012 PPW study and is likely to contain a large amount of fuel that could pose a threat if it were to spill (NOAA 2013).

USS *Grunion*
After sinking two Japanese sub chasers, CH-25 and CH-27, the submarine disappeared on July 30, 1942. The wreck was found in 2006 and the missing bow section in 2019. Further site inspection and mapping would assist in full characterization of the site and determining what sank the vessel.

In addition to the historical significance of each of these shipwrecks, and the importance of conducting detailed archaeological and environmental characterization of the wreck sites, is the opportunity such exploration provides for public engagement. Enabling these expeditions with telepresence vastly increases the value of the ship time by providing access to a limitless number of scholars and scientists to join the work in real time and offer their insights, ideas and interpretation. We have conducted live work on deep water shipwrecks from both *Nautilus* and *Okeanos Explorer* (Brennan et al., 2018), including the sites of the aircraft carrier from Operation Crossroads, USS *Independence* (Delgado et al., 2018a), the Cold War submarine, USS *Bugara* (Delgado et al., 2018b, and the World War II loss in Canadian waters, SS *Coast Trader* (Delgado et al., 2018c). Public engagement with such work has also shown to be impactful and exciting and these platforms offer immense opportunity for students, classrooms, and others to participate and join in the work remotely. We anticipate a web presence for any such mission undertaken in the Pacific to be able to engage with scholars and the public ahead of and during the exploration for finding and documenting these shipwrecks.

References

Barry, Bradley W., James P. Delgado, Matthew S. Lawrence, Hans K. Van Tilburg, 2016. The search for the 1871 whaling fleet of the Western Arctic: Writing the final chapter. *International Journal of Nautical Archaeology* 46: 149-163.

BOEM, 2011. Shipwrecks off Alaska's coast. Available: <https://www.boem.gov/about-boem/shipwrecks-alaskas-coast>. Accessed 18 February 2020.

Brennan, Michael L., Frank Cantelas, Kelley Elliott, James P. Delgado, Katherine L.C. Bell, Dwight Coleman, Allison Fundis, Jack Irion, Hans K. Van Tilburg, Robert D. Ballard, 2018. Telepresence-enabled maritime archaeology in the deep. *Journal of Maritime Archaeology* 13: 97-121.

Delgado, James, Michael L. Brennan, Kelley Elliott, Russell E. Matthews, Megan Lickliter-Mundon, John G. Lambert, Frank Cantelas, Robert V. Schwemmer, 2018. Archaeological survey of the ex-USS *Independence* (CVL22). *Journal of Maritime Archaeology* 13: 123-144.

Delgado, James, Frank Cantelas, Robert V. Schwemmer, Robert S. Neyland, Agustin Ortiz, Jr., George Galasso, Michael L. Brennan, 2018. Archaeological survey of the ex-USS *Bugara*. *Journal of Maritime Archaeology* 13: 191-206.

Delgado, James P., Frank Cantelas, Lisa C. Symons, Michael L. Brennan, Richard Sanders, Evan Reger, Deanna Bergondo, Donald L. Johnson, Jacques Marc, Robert V. Schwemmer, Lea Edgar, Duncan MacLeod, 2018. Telepresence-enabled archaeological survey and identification of S/S *Coast Trader*, Straits of Juan de Fuca, British Columbia, Canada. *Deep-Sea Research Part II* 150: 22-29. doi:10.1016/j.dsr2.2017.05.013

Lattka, Anne, 2016. The *Princess Sophia*. National Park Service. Available: <https://www.nps.gov/articles/khns-princess-sophia.htm>. Accessed 19 February 2020.

NOAA, 2004. The Russian-American Company Bark, *Kad'yak*. NOAA Office of National Marine Sanctuaries. Available: <https://sanctuaries.noaa.gov/maritime/expeditions/kadyak.html>. Accessed 19 February 2020.

NOAA, 2007. The 2007 *Hassler* Expedition. Available: <https://sanctuaries.noaa.gov/maritime/expeditions/hassler/last_days.html>. Accessed 19 February 2020.

NOAA, 2013. Screening Level Risk Assessment Package, *Aleutian*. Available: <https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/protect/ppw/pdfs/aleutian.pdf>. Accessed 19 February 2020.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: James P. Delgado
Institution: SEARCH
Email Address: james.delgado@searchinc.com
Office Phone Number: 904-379-8338
Collaborators/Co-Authors: Loren G. Davis, E. James Dixon, Michael L. Brennan, David Ball

Title: Submerged Landscapes, Human Coastal Migration, and Early Maritime Adaptations

Priority Geographic Area:
Northern Pacific Ocean and Bering Strait within EEZ (see attached description)

Description of Priority Area:
This stretch between Alaska and northeastern Russia was a land bridge during the last glacial maximum that allowed people to first populate North America. Habitation sites and evidence of their routes is now submerged and in need of further mapping and documentation.

What are the characterization and data needs in this area?
Check all that apply:
___ Biology
_x_ Geology
_x_ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
High resolution multibeam bathymetry and sub-bottom profiler and, where possible, ROV dives for ground truth and video.

Describe relevance to national security, conservation, and/or the economy:
With rising temperatures and sea levels, erosion of preserved paleoshorelines and habitation sites may be threatened, so documentation and characterization of these is important.

From your perspective, what makes this area unique?
This is likely the route that the earliest inhabitants of North America took from Asia and one of the only such submerged land bridges that ever connected two continental land masses.

Please list other partners or organizations that may also be interested in this area:
BOEM, NOAA

Submerged Landscapes, Human Coastal Migration, and Early Maritime Adaptations
James P. Delgado, PhD, Loren G. Davis, PhD, E. James Dixon, PhD, Michael L. Brennan, PhD, David Ball, MA

Mapping and characterization of the U.S. Pacific EEZ, and by extension, the Canadian Pacific EEZ offers new opportunities to gather important evidence from submerged landscapes that once existed on continental shelf zones. The question of human migration and settlement of the Americas increasingly has focused on those portions of the Americas that existed as a likely route for migration and subsequent New World adaptations during the last glacial maximum (LGM) and up to the last several thousand years.

The most recent lower sea level event, and the one most relevant to North America, occurred during the LGM about 23,000 years ago when the world's oceans stood at an elevation approximately 130 meters below modern sea level. At this time, near coastal landscapes expanded seaward, and coastal plains, embayments, and riverine systems developed across North America's continental shelves. These ancient coastal environments attracted early human settlers and the physical evidence of their occupation remains preserved and buried beneath the sea floor (Bailey and Flemming 2008).

The archaeological record of the Americas shows that humans were south of massive continental glacial ice sheets that covered much of Canada and Alaska before ~16,000 years ago (Dillehay et al. 2012, 2017; Waters et al. 2011, 2018; Williams et al. 2018; Davis et al. 2019)—more than 1,000 years before an ecologically viable travel route would appear as the ice sheets melted (Dixon 2013, Heintzman et al. 2016; Pedersen et al. 2016; Potter et al. 2018; Margold et al. 2019). Ancient human genetic studies show that the First Americans are descended from humans who migrated from northeast Asia during the last glacial period and made their way to North America during a period of lower sea levels and expanded coastal landscapes (Raghavan et al. 2015) (Figure 1). Given these current facts, archaeologists hypothesize that humans initially migrated around the western edge of the glacial ice sheets along a Pacific coastal route (Davis et al. 2017, 2019; Braje et al. 2020). The archaeological evidence that records this journey is expected to be found in sites held in ancient but now-submerged landscapes along the southern Alaskan and western Canadian coastlines (Dixon 1999, 2000, McLaren et al. 2020). Traditional knowledge from coastal tribes may also hold clues to better understanding paleo-landscapes. Oral histories from Willamette Valley Tribes of Oregon, for example, tell of mass flooding events, which are believed to correspond to the Bretz floods that occurred 15,000 to 13,000 years ago (Edwards and Thorsgard 2017).

Identifying submerged non-shipwreck archaeological sites is essential to understanding the nature of our species as colonizers and our ability to adapt to new and challenging environments. The study of submerged ancient landforms is critical to understanding the processes, timing, and related parameters involved in the global spread of modern humans (Gusick and Faught 2011). Learning about ancient coastal environments and submerged archaeological sites is not only central to the larger issue of understanding how humans spread around the world, but is critical to building a more realistic understanding of how humans began to establish permanent settlements, and past human responses to sea level rise. The study of submerged coastal landscapes and their associated archaeological record is essential to our understanding of how humans live in and respond to dynamic and changing coastal environments.

We cannot fully understand the archaeological record of human societies without knowledge about past coastal environments and how they changed through time. Today ~80% of the world's population lives in maritime settings. Therefore, it is likely that a large majority of the archaeological record may lie below modern sea level as yet undiscovered on national continental shelves. No large-scale interpretations of human evolution, migration, or cultural development are complete without science-based knowledge of the submerged archaeological record that is preserved on the continental shelves.

This realization has resulted in a series of studies, predictive models and assessment over the last two decades. An overarching study undertaken for the Bureau of Ocean Energy Management (BOEM) in 2013 focused on the Pacific Coast of the continental U.S. building models of probable paleo-shorelines from the terminal Pleistocene through the Holocene, assessing data from various sites, marine cores, and building predictive models of where submerged sites might be located (ICF et al. 2013). More focused work on region-specific studies have included work around Southern California's Channel Islands (Braje et al. 2019), off Oregon at Heceta Bank (Davis et al. 2017), off British Columbia in Canada (Josenhans et al. 1997, McLaren et al. 2020), the coast of Southeast Alaska (Dixon and Monteleone 2014) and off Chile (Carrabias et al. 2014). Still needed are specific and focused studies off the Alaska coasts, and in Bering and Chukchi Seas, where now submerged Beringia has long been both a land and water-crossing for plants, animals and people between Asia and the Americas (Figure 2). Recent studies based on geological, paleontological, and human genetic data suggest this route was open for human travel as early as 17,000 years ago (Lesnek et al. 2018; McLaren et al. 2020).

EEZ mapping and characterization of the Pacific Coast offers opportunities for partnerships and collaborative science with various scholars, universities, federal agencies, and tribal nations. The first step approaching this research frontier is to improve the extent of high-resolution bathymetric mapping of the Bering Sea and adjacent areas of the Pacific and Arctic Oceans. It would provide a foundation submerged landscape and geomorphic interpretation and modeling to guide sediment coring and ROV exploration of submerged features such as relict channels where habitation sites have been found in terrestrial contexts. This mode of research is currently underway in Oregon and California through partnership projects directed by university researchers in collaboration with NOAA and BOEM (Davis et al. 2017; Braje et al. 2019). While important in their own right, the results of these projects represent veritable drops in the ocean of knowledge about the past that is yet to be discovered.

At a recent workshop funded by NSF, an international gathering of researchers defined the research themes for advancing submerged paleolandscape research (Dixon and Davis 2020). Research aimed at collecting a broad range of multidisciplinary information, and where appropriate Native American tribal knowledge, about ancient submerged paleolandscapes and their archaeological records was identified as a priority for all missions working on the mapping and characterization of the US and Canadian Pacific EEZ, with a higher priority assigned to Alaska, specifically along the hypothesized Pacific coastal migration route. In addition, enabling these expeditions with telepresence vastly increases the value of the ship time by providing access to a limitless number of scholars and scientists to join the work in real time and offer their insights, ideas and interpretation (Brennan et al. 2018). Public engagement with such work has also been shown to be impactful and exciting. These platforms offer immense opportunity for students, classrooms, and others to participate and join in the work remotely. We anticipate a web presence for any such mission undertaken in the Pacific to engage scholars and the public ahead of, and during the exploration of submerged landscapes.

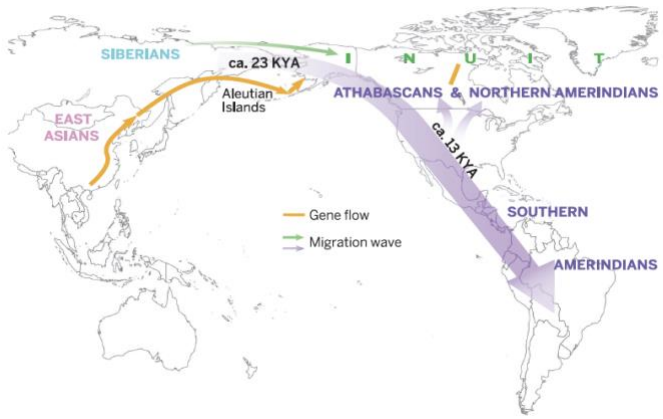


Figure 1. Map showing the route of initial human migration into the Americas as reconstructed from ancient skeletal genetic records

References

Bailey, G. N. and Flemming, N.C., 2008. Archaeology of the continental shelf: Marine resources, submerged landscapes and underwater archaeology. *Quaternary Science Reviews 27*: 2153–2165.

Braje, Todd, J., Jon M. Erlandson, Torben C. Rick, Loren G. Davis, Tom Dillehay, Daryl W. Fedje, Duane Froese, Amy Gusick, Quentin Mackie, Duncan McLaren, Bonnie L. Pitblado, Jennifer Raff, Leslie Reeder-Myers, and Michael R. Waters, 2020. Fladmark +40: What Have we Learned About a Potential Pacific Coast Peopling of the Americas? *American Antiquity* 85(1):1–21.

Figure 2. Map of greater Beringia and the Bering land bridge (light tan), exposed by lowered sea levels, that connected Asia with North America during the last glacial maximum. This region played a critical role in the initial peopling of the Americas (Illinois State Museum).

Braje, T.J., Maloney, J.M., Gusick, A.E., Erlandson, J.M., Nyers, A., Davis, L., Gill, K.M., Reeder-Myers, L. and Ball, D., 2019. Working from the Known to the Unknown: Linking the Subaerial Archaeology and the Submerged Landscapes of Santarosae Island, Alta California, USA. *Open Quaternary* 5(10):1–15. DOI: https://doi.org/10.5334/oq.66

Brennan, Michael L., Frank Cantelas, Kelley Elliott, James P. Delgado, Katherine L.C. Bell, Dwight Coleman, Allison Fundis, Jack Irion, Hans K. Van Tilburg, Robert D. Ballard, 2018. Telepresence-enabled maritime archaeology in the deep. *Journal of Maritime Archaeology* 13: 97-121.

Carrabias D, Cartajena I., Simonetti R., López P., Morales C., Ortega C., 2014. Submerged Paleolandscapes: Site GNL Quintero 1 (GNLQ1) and the First Evidences from the Pacific Coast of South America. In: Evans A., Flatman J., Flemming N. (eds) *Prehistoric Archaeology on the Continental Shelf*. Springer, New York, NY.

Davis, Loren, Frank Cantelas, and Nathalie Valette-Silver, 2017. Discovering Oregon's Lost Coast: Finding and Studying Submerged Archaeological Sites and Landscapes on the Pacific Continental Shelf. *Oceanography suppl.* 30-1: 38.

Davis, Loren G., David B. Madsen, Lorena Becerra-Valdivia, Thomas Higham, David A. Sisson, Sarah M. Skinner, Daniel Stueber, Alexander J. Nyers, Amanda Keen-Zebert, Christina Neudorf, Melissa Cheyney, Masami Izuho, Fumie Iizuka, Samuel R. Burns, Clinton W. Epps, Samuel C. Willis, and Ian Buvit, 2019. Late Upper Paleolithic Occupation at Cooper's Ferry, Idaho, USA, ~16,000 Years Ago. *Science* 365:891–897.

Dillehay, Tom D., Duccio Bonavia, Steve L. Goodbred, Mario Pino, Victor Vásquez, and Teresa Rosales Tham, 2012. A Late Pleistocene Human Presence at Huaca Prieta, Peru, and Early Pacific Coastal Adaptations. *Quaternary Research* 77(3):418-423.

Dillehay, Tom D., Steve Goodbred, Mario Pino, Víctor F. Vásquez Sánchez, Teresa Rosales Tham, James Adovasio, Michael B. Collins, Patricia J. Netherly, Christine A. Hastorf, Katherine L. Chiou, Dolores Piperno, Isabel Rey, Nancy Velchoff, 2017. Simple technologies and diverse food strategies of the Late Pleistocene and Early Holocene at Huaca Prieta, Coastal Peru. *Science Advances* 3:e1602778.

Dixon, E. James, 1999. *Bones, Boats, and Bison*. Albuquerque: University of New Mexico Press.

Dixon, E. James, 2000. Human Colonization of the Americas: Timing, Technology and Process. in *Beringian Paleoenvironments: Festschrift in Honor of David M. Hopkins*, S. E. Elias and J. Brigham-Grette guest eds. *Quaternary Science Reviews*, London 1-3:277-299.

Dixon, E. James, 2013. Late Pleistocene colonization of North America from Northeast Asia: New Insights from large-scale paleogeographic reconstructions. Quaternary International. 1-11. *Quaternary International*, Elsevier Press.

Dixon, E. James and Loren G. Davis, 2020. Submerged Paleolandscape Archeology of North America Workshop, June 11-12, 2019. National Museum of Natural History Smithsonian Institution, Washington D.C. Final Report.

Dixon, E. James and Kelly Monteleone, 2014. Submerged Beringia. Chapter 6 in *Submerged Prehistoric Archaeology: How Climate Change and Technology Are Rewriting History*, Amanda Evans, Joe Flatman, and Nic Flemming, eds. 95-114, Springer, New York.

Edwards, Briece R., and Eirik Thorsgard, 2017. Confederated Tribes of Grand Ronde Case Study, in Ball D., R. Clayburn, R. Cordero, B. Edwards, V. Grussing, J. Ledford, R. McConnell, R. Monette, R. Steelquist, E. Thorsgard, J. Townsend. 2017. Characterizing Tribal Cultural Landscapes. Volume II: Tribal Case Studies. US Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region, Camarillo, CA. OCS Study BOEM 2017-001. 232 p.

Gusick, Amy and Michael K. Faught, 2011. Prehistoric archaeology underwater: A nascent subdiscipline critical to understanding early coastal occupations and migration routes. In N. F. Bicho, Jonathan Haws, and Loren G. Davis (Eds.), *Trekking the shore: changing coastlines and the antiquity of coastal settlement* (pp. 27–50). New York: Springer.

Heintzman, Peter D., Duane Froese, John W. Ives, André E. R. Soares, Grant D. Zazula, Brandon Letts, Thomas D. Andrews, Jonathan C. Driver, Elizabeth Hall, P. Gregory Hare, Christopher N. Jassi, Glen MacKay, John R. Southon, Mathias Stiller, Robin Woywitka, Marc A. Suchard, and Beth Shapiro, 2016. Bison phylogeography constrains dispersal and viability of the Ice Free Corridor in western Canada. *Proceedings of the National Academy of Sciences of the United States of America* 113(29):8057-8063.

Josenhans, H, Fedje, D., Pienitz, R. and Southon, J., 1997. Early Humans and Rapidly Changing Holocene Sea-levels in the Queen Charlotte Islands – Hecate Strait, British Columbia, Canada, *Science* 277: 71-72.

Lesnek, Alia J., Jason P. Briner, Charlotte Lindqvist, James F. Baichtal, and Timothy H. Heaton, 2018. Deglaciation of the Pacific coastal corridor directly preceded the human colonization of the Americas**.** *Science Advances* 4(5), eaar5040.

Mandryk, C.A.S., Josenhans, H., Fedje, D. W., Mathewes, R.W., 2001. Late quaternary Paleoenvironments of northwestern North America: Implications for inland versus coastal migration routes. *Quaternary Science Reviews*, 20:301–314.

Margold, Martin, John C. Gosse, Alan J. Hidy, Robin J. Woywitka, Joseph M. Young, Duane Froese, 2019. Beryllium-10 dating of the Foothills Erratics Train in Alberta, Canada, indicates detachment of the Laurentide Ice Sheet from the Rocky Mountains at ~15 ka. *Quaternary Research* 92, 469-448.

McLaren, Duncan, Daryl Fedje, Quentin Mackie, Loren G. Davis, Jon Erlandson, Alisha Gauvreau, Colton Vogelaar, 2020. Late Pleistocene archaeological discovery models of the Pacific coast of North America. *PaleoAmerica* 6(1): 43-63.

Pedersen, Mikkel W., Anthony Ruter, Charles Schweger, Harvey Friebe, Richard A. Staff, Kristian K. Kjeldsen, Marie L. Z. Mendoza, Alwynne B. Beaudoin, Cynthia Zutter, Nicolaj K. Larsen, Ben A. Potter, Rasmus Nielsen, Rebecca A. Rainville, Ludovic Orlando, David J. Meltzer, Kurt H. Kjær and Eske Willerslev, 2016. Postglacial viability and colonization in North America's ice-free corridor. *Nature* 216:45-49.

Potter, B.A., James F. Baichtal, Alwynne B. Beaudoin, Lars Fehren-Schmitz, C. Vance Haynes, Vance T. Holliday, Charles E. Holmes, John W. Ives, Robert L. Kelly, Bastien Llamas, Ripan S. Malhi, D. Shane Miller, David Reich, Joshua D. Reuther, Stephan Schiffels, Todd A. Surovell, 2018. Current evidence allows multiple models for the peopling of the Americas. *Science Advances* 4:eaat5473.

Raghavan, Maanasa, et al., 2015. Genomic Evidence for the Pleistocene and Recent Population History of Native Americans. *Science* 349(6250): DOI:10.1126/science.aab3884.

Waters, Michael R., Joshua L. Keene, Steven L. Forman, Elton R. Prewitt, David L. Carlson, James E. Wiederhold, 2018. Pre-Clovis projectile points at the Debra L. Friedkin site, Texas—Implications for the Late Pleistocene peopling of the Americas. *Science Advances* 4 eaat4505.

Waters, Michael R., and Thomas W. Stafford, Jr., 2007. Redefining the Age of Clovis: Implications for the Peopling of the Americas. *Science* 315: 1122–1126.

Williams, Thomas, Michael B. Collins, Kathleen Rodrigues, William Jack Rink, Nancy Velchof, Amanda Keen-Zebert, Anastasia Gilmer, Charles D. Frederick, Sergio J. Ayala, Elton R. Prewitt, 2018. Evidence of an early projectile point technology in North America at the Gault Site, Texas, USA. *Science Advances* 4 eaar5954.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Demopoulos, Amanda
Institution: U.S. Geological Survey
Email Address: ademopoulos@usgs.gov
Office Phone Number: 352-264-3490
Collaborators/Co-Authors: USGS: Carolyn Ruppel, Nancy Prouty, Janet Watt; PMEL: Tamara Baumberger, David Butterfield

Title: Cascadia Margin Cold Seeps: Subduction Zone Fluids, Gas Hydrates, and Chemosynthetic Habitats

Priority Geographic Area: The outer continental shelf and upper continental slope from Canada/USA border offshore Washington State to the Mendocino Fracture Zone (Northern California), entirely within the US EEZ, from the outermost shelf to at least 2000 m water depth (Figure 1).

Description of Priority Area:

Since 2015, over a thousand water column gas plumes originating at seafloor gas seeps have been discovered landward of the Cascadia deformation front (e.g., Embley et al., 2016; Johnson et al., 2015, 2019; Merle and Embley, 2016; NA-95 Cruise Report, 2018; Riedel et al., 2018), adding to those that had long been known on Hydrate Ridge (e.g., Heeschen et al., 2003; Tréhu et al., 2004). The recently-discovered seeps stretch from offshore Vancouver Island to the Mendocino Fracture Zone and from the outer shelf to ~2000 m water depth, occurring both landward and seaward of the nominal limit for gas hydrate stability zone on the upper continental slope (Figure 1). Hundreds of seeps likely remain undiscovered. Water column imaging is incomplete both within the target geographic area and farther seaward, between the 2000 m isobath and the deformation front, which is the subject of an imaging study described in a white paper by J. Watt and others.

The recently-discovered Cascadia margin cold seeps partially overlap an important active margin gas hydrate province (Spence et al., 2001; Tréhu et al., 2003, 2004), as well as an area where sediments on the North American plate are folded and faulted and affected by fluids generated in the subduction complex beneath the Cascadia forearc (e.g., Saffer and Tobin, 2011). Several Ocean Drilling Program expeditions have focused on hydrate systems offshore Vancouver and Oregon (e.g., Riedel et al., 2009; Tréhu et al., 2004) and on the connection between the shallow and deep hydrogeologic systems. Cabled observatories now continuously monitor physical, chemical, and venting processes on south Hydrate Ridge (OOI; e.g., Philip et al., 2016a) and offshore Vancouver Island (NEPTUNE; e.g. Römer et al., 2016). Outside of these well-studied gas hydrate areas, a subset of recently-discovered Cascadia seeps, including some that we visited with *R/V Falkor* in 2019 (e.g., https://schmidtocean.org/cruise/methane-seeps-at-edge-of-hydrate-stability/), also likely emit methane associated with shallow subseafloor gas hydrate systems. Other seeps are delivering not only methane, but also deep-derived gases (Baumberger et al., 2018, 2020), to the seafloor. Many Cascadia margin seeps have also been recognized at water depths too shallow (e.g., 175 m) to be connected to gas hydrate dynamics. These seeps are postulated to be emitting gas and fluids that originated deep in accretionary wedge before migrating up normal faults generated during forearc extension associated with large earthquakes (Johnson et al., 2019).

Only a small fraction of the recently-discovered U.S. Cascadia margin water column gas plumes has so far been verified by ROVs (Hercules from *E/V Nautilus* in 2016 and 2018; SuBastian from *R/V Falkor* in 2018 and 2019) to correspond to seafloor seeps. Careful scientific mapping, investigation, and sampling at the seeps have also been limited (e.g., Baumberger et al., 2018, 2020; Merle and Embley, 2016; Seabrook et al., 2018; Greinert et al. 2019). This white paper focuses on expanding exploration of already-identified U.S. Cascadia margin cold seeps through a multipronged and multidisciplinary discovery program that could be accomplished with a variety of NOAA assets. The goals of the proposed exploration activities are to develop high-resolution maps of seep fields from deep ocean vehicles; to verify (and sample) seafloor gas emissions at the locations of water column plumes for compositional and isotopic studies; to map, sample, and conduct analyses on

chemosynthetic communities and deep-sea coral habitats near seep sites to document species distributions and habitats as a function of depth and latitude along the margin; to collect seep geologic samples that can constrain the timing of methane emissions through geochronology; and to record environmental data (e.g., CTD) near the seafloor and in the water column above the seeps. Seafloor mapping using shipboard systems (multibeam/backscatter) would be needed to characterize seafloor features near seep sites. Water column imaging (EK60/80 and/or multibeam WCD data) conducted before and after seafloor explorations would capture active methane plumes and constrain temporal variations in seep emissions (e.g., Kannberg et al., 2013; Philip et al., 2016a, 2016b), which are known to vary on time scales as rapid as tidal cycles on this margin (e.g., Römer et al., 2016).

What are the characterization and data needs in this area?
Check all that apply:
__x_ Biology, Geology, Physical Oceanography, Chemistry
___ Marine Archaeology
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

1. Water column backscatter to image active gas plumes
2. High resolution multibeam bathymetry, seafloor backscatter, and shallow sub-bottom imaging
3. Visual characterization and groundtruthing of potential seeps, including high-resolution mapping and photography from near-seafloor vehicles; collection of seep-associated species, corals, sediments, authigenic carbonates, gases, and seawater

Describe relevance to national security, conservation, and/or the economy: The Cascadia margin seeps provide significant ecosystem services, including habitat for commercially important fishes and support for diversity along the continental margin. Methane seeps are also biological hotspots for krill, plankton, and crustaceans, which in turn sustain higher trophic levels (e.g., whales). Methane-derived authigenic carbonates serve as a hard substrate for deep-sea corals and sponges on millennial time scales. The studies proposed here will elucidate the relationship among seep environments, deep-sea corals, sponges, fisheries, and other organisms and provide new insight into subduction zone and hydrate-associated fluids in this important seismogenic zone. The studies address fishery management concerns and inform future conservation of sensitive species (e.g., deep sea corals) and benthic habitats.

From your perspective, what makes this area unique? The Cascadia margin seeps are a critical component of the leaky margin that stretches from Baja California to the Aleutian Arc along the Pacific coastline of North America. Cold seeps have been intensely studied on the Gulf of Mexico and U.S. Atlantic passive margins with a focus on chemosynthetic communities, deep-sea corals, and leakage of microbially-generated and/or thermogenic hydrocarbons; however, the recently-discovered Cascadia margin seeps, as well as active margin seep systems in general, remain more poorly characterized. Such seeps not only contribute to the ocean carbon cycle (e.g., Pohlman et al., 2011), thereby fueling the base of the food chain in these settings, but also emit subduction zone fluids that provide clues about processes within the seismogenic zone and the accretionary complex. The Cascadia seeps area allows both biological (e.g., benthic habitats, coral distributions) and physical processes (e.g., generation of subduction zone fluids) to be studied along both depth (perpendicular to the deformation front) and latitudinal gradients.

Please list other partners or organizations that may also be interested in this area: NOAA PMEL, OER, NMFS, DSCRTP, National Marine Sanctuaries, BOEM, GEOMAR, British Geological Survey, Schmidt Ocean Institute, NSF (2020 seismic survey, prior surveys), OOI

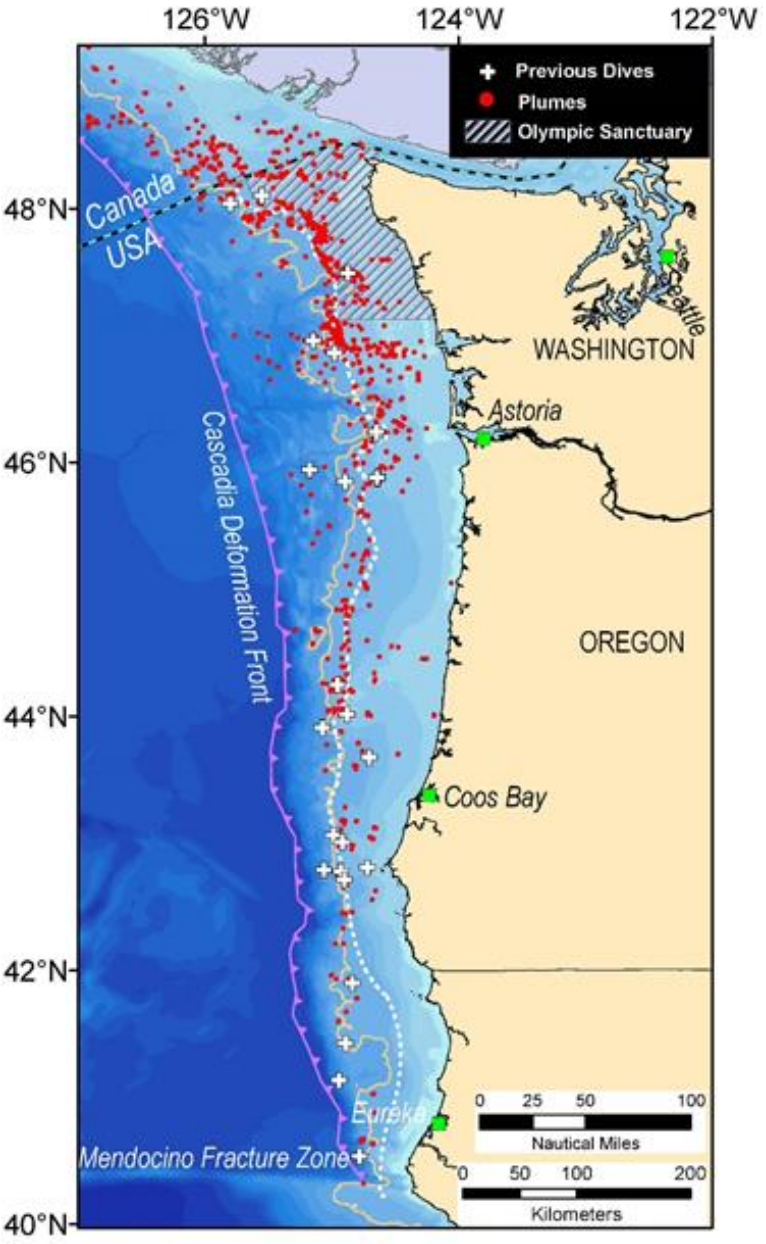


Figure 1. Map of the Cascadia seeps province from the Mendocino Fracture Zone on the south to Vancouver Island on the north. The boundary for the U.S. EEZ is shown as the green-black line on the upper left. Red circles indicate publicly available water column methane plume locations published by PMEL authors and Riedel et al. (2018) since 2015. White crosses are the locations of ROV dives conducted from E/V Nautilus (2016, 2018) and R/V Falkor (2018, 2019), including dives our group conducted with the ROV SuBastian in 2019. The pink curve denotes the plate boundary (deformation front), which is the focus of the USGS white paper submitted by J. Watt. The orange contour traces the 1000 m isobath, and the white dashed line is unpublished information from C. Ruppel showing the approximate landward limit of gas hydrate stability determined from empirical data (not a thermal model). This white paper focuses on already-discovered seeps, but large parts of this area have not yet been fully surveyed for water column methane plumes.

References:

Baumberger, T., Embley, R. W., Merle, S. G., Lilley, M. D., Raineault, N. A., & Lupton, J. E. (2018). Mantle derived helium and multiple methane sources in gas bubbles of cold seeps along the Cascadia continental margin. *Geochemistry, Geophysics, Geosystems*, 19, 4476– 4486. doi:10.1029/2018GC007859

Baumberger, T. et al. (2020), Chemical distribution and range of the Cascadia margin methane seep bubbles, Ocean Sciences Meeting, February 16-21, San Diego, CA, OB24G-0534.

Embley, R. *et al.*, (2016) Water Column and Cold Seep Exploration of the Cascadia Margin. *Oceanography (supplement)* **30**, 94 pp doi:10.5670/oceanog.2017.supplement.

Greinert, J., Weiss, T., Demopoulos, A.W., Danforth, W., Ruppel, C., 2019, Gas flow offshore Oregon and California, how much is coming out: Results from MBES, SBES, GasQuant, BubbleBox and ROV-based studies during FK190612 [abs.], 2019 AGU conference, December 9-13, 2019, San Francisco, 1 p., https://www2.agu.org/fall-meeting.

Grupe, B.M., Krach, M.L., Pasulka, A.L., Maloney, J.M., Levin, L.L., Frieder, C.A., 2015. Methane seep ecosystem functions and services from a recently discovered southern California seep. Mar. Ecol. 36, 91–108. http://dx.doi.org/10.1111/maec.12243.

Heeschen, K. U., Tréhu, A. M., Collier, R. W., Suess, E., and Rehder, G. (2003), Distribution and height of methane bubble plumes on the Cascadia Margin characterized by acoustic imaging, *Geophys. Res. Lett.*, 30, 1643, doi:10.1029/2003GL016974, 12.

Johnson, H. P., Merle, S., Salmi, M., Embley, R., Sampaga, E., & Lee, M. (2019). Anomalous concentration of methane emissions at the continental shelf edge of the northern Cascadia margin. *Journal of Geophysical Research: Solid Earth*, 124, 2829– 2843. doi:10.1029/2018JB016453

Johnson, H. P., Miller, U. K., Salmi, M. S., & Solomon, E. A., (2015). Analysis of bubble plume distributions to evaluate methane hydrate decomposition on the continental slope. *Geochemistry, Geophysics, Geosystems* **16**, 3825-3839.10.1002/2015GC005955

Kannberg, P. K., Trehu, A. M, Pierce, S. D., Paull, C. K., & Caress, D. W. (2013). Temporal variation of methane flares in the ocean above Hydrate Ridge, Oregon. Earth and Planetary Science Letters, 368, 33-42. doi:10.1016/j.epsl.2013.02.030

Liu, X., & Flemings, P. B. (2006). Passing gas through the hydrate stability zone at southern Hydrate Ridge, offshore Oregon. Earth and Planetary Science Letters, 241, 211-226.

Merle, S. and Embley, R., (2016) "NA72-Seeps and Ecosystems of the Cascadia Margin, June 1-20, 2016 Victoria BC, Canada to San Francisco CA, USA (cruise report of the E/V Nautilus)," (2016).

NA095-Cascadia Margin, July 18-29, 2018, San Francisco, CA to Astoria, OR (cruise report of the E/V Nautilus prepared by PMEL).

Philip, B. T., Denny, A. R., Solomon, E. A., and Kelley, D. S. (2016a), Time-series measurements of bubble plume variability and water column methane distribution above Southern Hydrate Ridge, Oregon, *Geochem. Geophys. Geosyst.*, 17, 1182– 1196, doi:10.1002/2016GC006250.

Philip, B.T., D. S. Kelley, E. A. Solomon and J. R. Delaney, (2016b). "Monitoring methane emissions at Southern Hydrate Ridge using an OOI Cabled Array Acoustic Doppler Current Profiler," *OCEANS 2016 MTS/IEEE Monterey*, Monterey, CA, pp. 1-5.

Pohlman, J. W., Bauer, J. E., Waite, W. F., Osburn, C. L., and Chapman, N. R. (2011). Methane hydrate-bearing seeps as a source of aged dissolved organic carbon to the oceans. *Nat. Geosci.* 4:37–41. doi: 10.1038/ngeo1016

Riedel, M., Collett, T., and Malone, M.J. (2009). Gas hydrate drilling transect across northern Cascadia margin – IODP Expedition 311, Geological Society of London—Special Publications 319, 11-19, doi:10.1144/SP319.2

Riedel, M., Scherwath, M., Römer, M. *et al.* (2018) Distributed natural gas venting offshore along the Cascadia margin. *Nat Commun* **9,** 326. doi:10.1038/s41467-018-05736-x

Römer, M., Riedel, M., Scherwath, M., Heesemann, M., and Spence, G. D. (2016), Tidally controlled gas bubble emissions: A comprehensive study using long-term monitoring data from the NEPTUNE cabled observatory offshore Vancouver Island, *Geochem. Geophys. Geosyst.*, 17, 3797– 3814, doi:10.1002/2016GC006528.

Saffer, D. M. & Tobin, H. J. Hydrogeology and Mechanics of Subduction Zone Forearcs: Fluid Flow and Pore Pressure. *Annu Rev Earth Planet Sci* **39**, 157–186 (2011).

Seabrook, S. C., De Leo, F., Baumberger, T., Raineault, N., and Thurber, A. R. (2018). Heterogeneity of methane seep biomes in the Northeast Pacific. *Deep. Res. Part II Top. Stud. Oceanogr.* 150, 195–209. doi: 10.1016/j.dsr2.2017.10.016.

Spence, G. D., N. R. Chapman, R. D. Hyndman, and C. Cleary (2001), Fishing trawler nets massive “Catch” of methane hydrates, *EOS*, **82**(50), 621– 627, doi:10.1029/01EO00358.

Tréhu, A. M., Flemings, P. B., Bangs, N. L., Chevallier, J., Gràcia, E., Johnson, J. E., Liu, C.-S., Liu, X., Riedel, M., and Torres, M. E. (2004), Feeding methane vents and gas hydrate deposits at south Hydrate Ridge, *Geophys. Res. Lett.*, 31, L23310, doi:10.1029/2004GL021286.

Tréhu, A. M., Stakes, D. S., Bartlett, C. D., Chevallier, J., Duncan, R. A., Goffredi, S. K., Potter, S. M., and Salamy, K. A. (2003), Seismic and seafloor evidence for free gas, gas hydrates, and fluid seeps on the transform margin offshore Cape Mendocino, *J. Geophys. Res.*, 108, 2263, doi:10.1029/2001JB001679, B5.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Demopoulos, Amanda
Institution: U.S. Geological Survey
Email Address: ademopoulos@usgs.gov
Office Phone Number: 352-264-3490
Collaborators/Co-Authors: USGS: Nancy Prouty, Daniel Brothers, Janet Watt, Jamie Conrad, Jason Chaytor; NOAA: Chris Caldow

Title: Mapping, exploration, and characterization of the California continental margin and associated features from the California-Oregon border to Ensenada, Mexico

Priority Geographic Area: Both within and outside US EEZ. California continental margin: this area includes and continues south of the geographic area captured in the *Watt et al.* white paper.

Description of Priority Area: The California continental margin, from the narrow shelf to abyssal depths, contains diverse seafloor features that influence benthic community types, biological connectivity, and is associated with significant seafloor geohazards. These complex features include marginal basins, depositional slopes, submarine canyons, ridges, and seamounts, with associated seep environments as a result of fluid seeps along active faults. Water column characteristics are variable, with steep gradients in current velocities, influencing sediment transport, from depositional fans (slow flow, muddy) to submarine canyons and seamounts (high currents, rocky, rugged terrain). These features and associated environments can influence the distribution of deep-sea habitats, including coral and sponge communities.

South of the region described in the *Watt et al*. and *Demopoulos et al.* white papers, plentiful seeps occur from Northern California down to the Southern California Borderland. However, the underlying foundational geology associated with these seeps varies along the margin, changing with contrasting tectonic settings, from convergent tectonics to regions dominated by strike-slip faulting (Barry et al. 1996; Paull et al. 2008; Bernardo and Smith 2010; Maloney et al. 2015). For seeps located off southern California, the relationship to strike-slip fault systems may influence the distribution of seep fluid expulsion sites and associated seep habitats (Maloney et al. 2015; Grupe et al. 2015; Conrad et al., 2017), where transpression plays a key role in formation and localization of fluid seeps. Further exploration is required in order to understand these connections.

Several submarine canyons intersect the shelf within this region, serving as important channels of energy and transport of sediment from shelf to slope depths. Canyons are typically associated with high currents, turbidity flows, steep and rugged terrain, and high food availability, all of which structures canyon communities and supports hotspots of biodiversity. Specific canyons along the California margin that have been well studied include Scripps and La Jolla Canyons off San Diego, and Monterey Canyon off Monterey, but many more remain relatively unexplored. Commercially important species of fish and invertebrates have been found associated with canyons, as well as deep-sea corals and sponges (e.g., Barry et al. 1996). However, in contrast to their Atlantic counterparts (e.g., through ACUMEN and ASPIRE campaigns) there has been a dearth of exploration and characterization of canyons along the California Margin. A number of questions remain regarding canyon and slope wall stability and associated geohazards, plus how the canyons connect and influence the broader regional biogeography of benthic communities is unknown.

Seamounts along the California margin are characterized by steep slopes, large areas of rocky substrate, and high currents, due to their topography. Hydrological complexity is associated with seamounts given they impinge different watermasses, depending on depth range. This heterogeneity yields complex and diverse benthic communities, including commercially important fishes (e.g., Tracey et al., 2012). The geology of Davidson, Pioneer, San Juan, and Rodriquez Seamounts has received considerable study (e.g., Davis et al., 2010) but other seamounts are less known, including how they are biologically and ecologically connected. For example, how the benthic communities associated with Rodriguez and San Juan Seamounts, located outside of

the Channel Islands National Marine Sanctuary and within the proposed Chumash Heritage National Marine Sanctuary compare to communities found within the sanctuary is critical for managing and protecting resources within the sanctuary and modifying sanctuary boundaries. Exploration would yield the data needed to delineate and characterize essential fish habitats, deep-sea coral and sponge communities, thus directly connecting the utility of exploration and discovery to decision making.

The southern California Borderland is a geomorphologically heterogeneous area, containing deep basins separated by shallow ridges and islands, created by a complex network of faults. Persistent fault-related deformation has created complex features, such as exposure of scarps and uplift rocks/ridges, seeps, erosional terraces, hydrate mounds, and mud volcanoes that provide support for thriving benthic communities. That said, significant oxygen minimum zones and low aragonite saturation states persist within several of the basin environments, influencing energy flow, community ecology, and calcification. For example, the combined effects of hypoxia and acidification pose serious threats to marine organisms and biological resources along the California Margin. Mapping and exploration of the extensive faults and fault scarps can help constrain past earthquake activity. But many questions remain regarding how the underlying geology and geological processes have shaped the biological communities.

What are the characterization and data needs in this area? Check all that apply:
__x_ Biology, Geology, Marine Archaeology, Physical Oceanography, Chemistry

Provide a list or brief description of the data needed within this area, from your perspective:
1. Water column characteristics for environmental context (data critical for habitat suitability models)
2. High resolution seafloor bathymetry/backscatter to inform geohazard assessments and benthic community surveys (for conservation and management)
3. Visual surveys of seafloor terrain and associated benthos
4. Physical samples of fauna, sediments, and hard substrate to ground-truth visual and geophysical surveys

Describe relevance to national security, conservation, and/or the economy:
1. Key connections among seep environments, deep-sea corals, sponges, and fisheries, including areas for fisheries management concerns and National Marine Sanctuaries.
2. Geohazards' influence on coastal infrastructure, human safety.
3. Seafloor characterization will be useful for future wind energy applications
4. Degree to which sensitive and/or commercially important species are using habitats as refuges across the suite of feature types encompassed within the margin.
5. Characterizing high profile, steep features, like seamounts is of strategic importance for military operations.

From your perspective, what makes this area unique? Combined with a narrow continental shelf, coastal upwelling, large latitudinal gradient, and an active tectonic setting, the California Margin both supports and shapes diverse biological communities, including deep-sea corals, sponges, and seep habitats, and essential habitat for key fishery species. Baseline biological information that reveal the biodiversity and benthic community distribution on the seafloor, and how these different environments shape and connect the biological communities is needed to manage both marine resources and hazards. This region covers several major biogeographic boundaries including: Mendocino Ridge, Monterey Bay, and Pt. Conception. These northern and southern species range termini contribute significantly to the biodiversity of the region. The role of seeps in shaping benthic communities, influencing fish productivity, and linking chemosynthetic habitats to continental shelf ecosystem services is understudied along the California Margin despite evidence of a growing sphere of seep influence (Levin et al., 2016). The distribution of National Marine Sanctuaries along the margin also offers an opportunity to explore connections among habitats within and outside of environmental protection.
Please list other partners or organizations that may also be interested in this area: NOAA: DCRTP, PMEL, OER, National Marine Sanctuaries (several), NMFS, BOEM, California State agencies (e.g., Cal. Geological Survey)

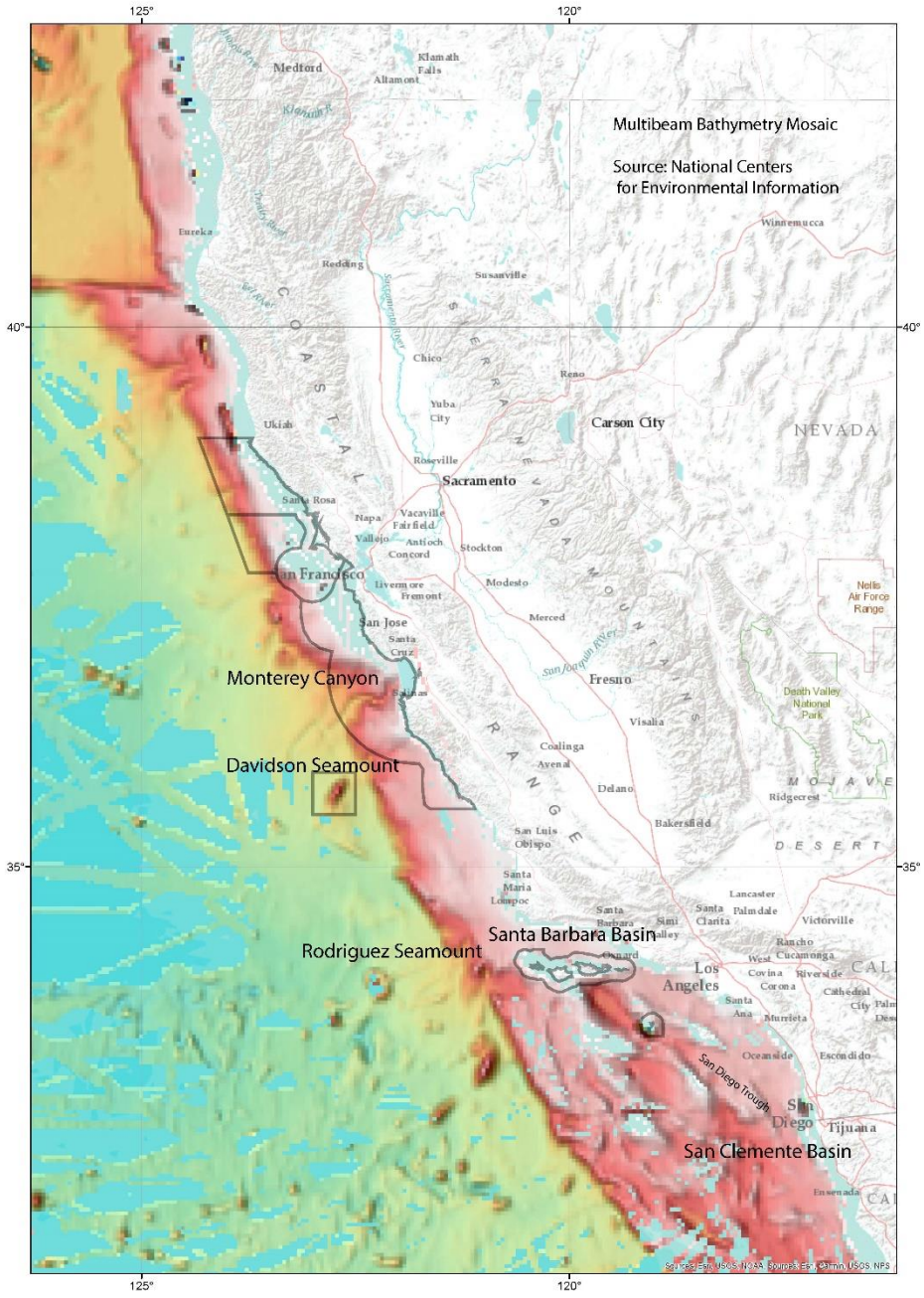


Figure 1. California continental margin. Several seamounts and basins have been labeled. The grey lines indicate boundaries of several National Marine Sanctuaries.

References:

Barry, J. P., Gary Greene, H., Orange, D. L., Baxter, C. H., Robison, B. H., Kochevar, R. E., Nybakken, J. W., R, D. L., and McHugh, C. M., 1996, Biologic and geologic characteristics of cold seeps in Monterey Bay, California: Deep Sea Research Part I: Oceanographic Research Papers, v. 43, no. 11, p. 1739-1762.

Bernardino AF, Smith CR. Community structure of infaunal macrobenthos around vestimentiferan thickets at the San Clemente cold seep, NE Pacific. Marine Ecology. 2010;31:608–621. [

Conrad, J. E., Prouty, N. G., Walton, M. A. L., Kluesner, J. W., Maier, K. L., McGann, M., Brothers, D. S., Roland, E. C., and Dartnell, P., 2018, Seafloor fluid seeps on Kimki Ridge, offshore southern California: Links to active strike-slip faulting: Deep Sea Research Part II: Topical Studies in Oceanography, v. 150, p. 82-91.

Davis, A. S., Clague, D. A., Paduan, J. B., Cousens, B. L., and Huard, J., 2010, Origin of volcanic seamounts at the continental margin of California related to changes in plate margins: Geochemistry, Geophysics, Geosystems, v. 11, no. 5.

Grupe, B.M., Krach, M.L., Pasulka, A.L., Maloney, J.M., Levin, L.L., Frieder, C.A., 2015. Methane seep ecosystem functions and services from a recently discovered southern California seep. Mar. Ecol. 36, 91–108. http://dx.doi.org/10.1111/maec.12243.

Levin, L. A., Baco, A., Bowden, D., Colaco, A., Cordes, E. E., Cunha, M., Demopoulos, A. W. J., Gobin, J., Grupe, B., Le, J., Metaxas, A., Netburn, A., Rouse, G., Thurber, A., Tunnicliffe, V., Van Dover, C. L., Vanreusel, A., and Watling, L., 2016, Hydrothermal vents and methane seeps: Rethinking the sphere of influence: Frontiers in Marine Science, v. 3.

Maloney, J. M., Grupe, B. M., Pasulka, A. L., Dawson, K. S., Case, D. H., Frieder, C. A., Levin, L. A., and Driscoll, N. W., 2015, Transpressional segment boundaries in strike-slip fault systems offshore southern California: Implications for fluid expulsion and cold seep habitats: Geophysical Research Letters, v. 42, no. 10, p. 4080-4088.

Paull, C. K., Normark, W. R., Ussler Iii, W., Caress, D. W., and Keaten, R., 2008, Association among active seafloor deformation, mound formation, and gas hydrate growth and accumulation within the seafloor of the Santa Monica Basin, offshore California: Marine Geology, v. 250, no. 3-4, p. 258-275.

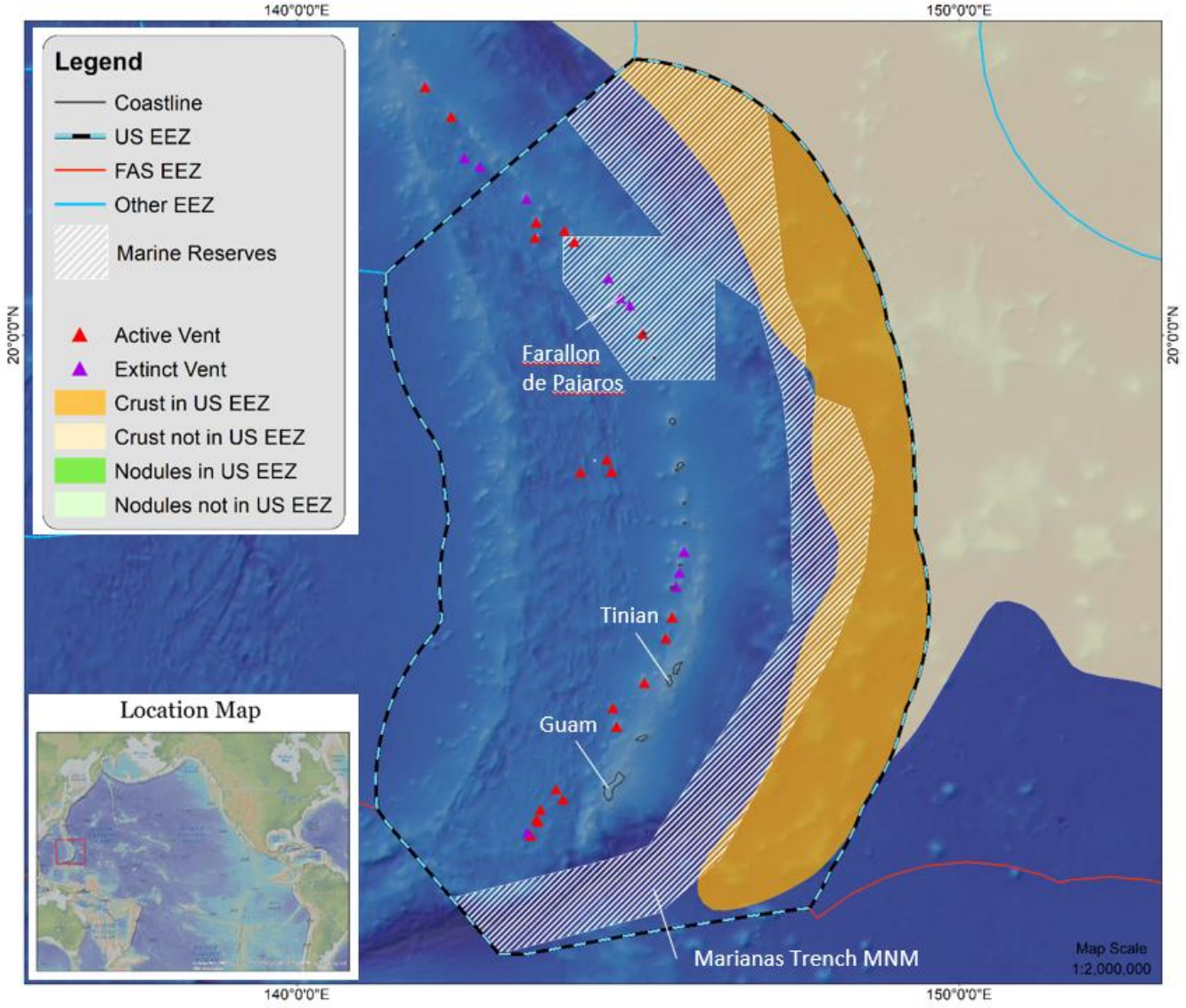
Tracey, D.M., Clark, M.R., Anderson, O.F., Kim, S.W. 2012, Deep-sea fish distribution varies between seamounts: results from a seamount complex off New Zealand. Plos One, 7:e36897.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Alden Denny
Institution: Bureau of Ocean Energy Management, Marine Minerals Division
Email Address: alden.denny@boem.gov
Office Phone Number: 703-787-1142
Collaborators/Co-Authors: Jeremy Potter – Bureau of Ocean Energy Management, Pacific Region

Title: Guam and Commonwealth of Northern Mariana Islands Critical Marine Minerals

Priority Geographic Area:
US EEZ IVO Guam and Commonwealth of Northern Mariana Islands (CNMI)



Description of Priority Area:

The US EEZ in the vicinity of CNMI and Guam contains regions permissive for multiple seafloor resources and associated endemic biota. To the west of CNMI there are multiple known active and extinct seafloor massive sulfide systems. To the east and outside of the Marianas Trench Marine National Monument is a region in excess

of 160,000 km^2 that is permissive of cobalt-rich crust and potential for manganese nodules and is to date almost wholly unexplored.

While this region is outside of the jurisdiction of BOEM, which draws its authority from the Outer Continental Shelf Lands Act, pending legislation in both the House and Senate may update this Act. BOEM is interested in identifying both the resource potential and environmental baseline of these mineralized areas to properly execute our role as stewards of the United States offshore resources.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
_X_ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Bathymetry, backscatter, seafloor imagery, water column acoustics, water column chemistry, detailed AUV-based acoustic and chemical survey of target areas, direct sampling from ROV or human-occupied submersible of geology, benthic biota, and fluid chemistry (if fluids present).

Describe relevance to national security, conservation, and/or the economy:
Securing a domestic supply of critical minerals is a key issue for the U.S government, as highlighted in E.O. 13817 and in federal strategies responding to this executive order. In addition, the recent Presidential "Memorandum on Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska" has raised the priority of mapping, exploring, and characterizing the US EEZ, with a focus on the potential of seafloor resources. Both the executive order and memorandum have elevated the importance of understanding the mineral and biological resources within the US EEZ, and the Guam and CNMI region are one of the most promising regions for initial exploration.

From your perspective, what makes this area unique?
Highly permissive for all modalities of seafloor mineralization, with a poorly understood benthic biota. There is also high potential for endemic benthic organisms either associated with, dependent on, or adjacent to regions of seafloor mineralization.

Please list other partners or organizations that may also be interested in this area:

USGS, NOAA, Department of the Navy, DOI office of Insular and International Affairs, US International Development Finance Corporation, DOE EERE

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Jeff Drazen
Institution: University of Hawaii at Manoa
Email Address: jdrazen@hawaii.edu
Office Phone Number: 808-956-6567
Collaborators/Co-Authors: Jamie Gove (NOAA-PIFSC), Gareth Williams (Bangor University, UK), Mike Vecchione (NOAA/NMFS Systematics Lab)
Consultant: Dick Young (University of Hawaii, Emeritus)

Title: Exploration of Mesopelagic Boundary Layer Communities and Near Island Aggregations of Micronekton

Priority Geographic Area: Main Hawaiian Islands within US EEZ

Description of Priority Area:
Leeward coasts of Oahu, Lanai and Hawaii Islands from depths of 50m to 1000 m. The 400- 800 m range is the daytime habitat of the mesopelagic boundary fauna in the Hawaiian Islands. The seafloor habitat varies between the islands but is generally steep and rocky, interspersed with more gradual sandy areas. Most data about this peculiar fauna comes from night trawls where the fauna moves into the upper 200m and some species also move towards shore (Benoit-Bird *et al.*, 2001; Reid *et al.*, 1991). Very little is known about the fauna during the daytime as trawling on the rugged ocean floor in this area is impractical. Another fauna of largely non-migratory micronekton is found off the leeward Kona coast of Hawaii Island in a concentration 4 fold higher than offshore (Abecassis et al 2015). This hotspot has been characterized by trawl only and its interaction with the seafloor is completely unknown.

What are the characterization and data needs in this area?
Check all that apply:
__x_ Biology
__x_ Geology
___ Marine Archaeology
__x_ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Data are needed on the relationship of the faunal components to the distance from the ocean floor, to the varying physical structure of the ocean floor and to the non-migratory resident fauna.

Describe relevance to national security, conservation, and/or the economy:
It is likely that the micronekton associated with islands play a critical role in moving energy and organic material between nearshore coral reefs and the open ocean and/or deep slope ecosystems. It is known that these fauna are found in locations where a host of deep diving marine mammals and large nekton are in abundance (particularly off the Kona coast (Abecassis *et al.*, 2015)). Island-associated micronekton likely form a forage base for these larger fauna. A better understanding of the habitat associations of these communities is critical to evaluating their importance and predicting their extent throughout the islands and in other areas of the Pacific. There is also renewed interest in harvesting mesopelagic fauna for fisheries (Economist, 2017), largely for fish

meal production, so processes that aggregate this fauna could become relevant to management of such fisheries should they develop.

From your perspective, what makes this area unique?
It is not clear that the mesopelagic island-associated fauna (Mesopelagic boundary layer plus apparent non migratory aggregations) is unique to the islands. However, it is possibly a very ecologically important community and is much easier to study in Hawaii than elsewhere due to past trawling efforts and logistical ease of access.

Please list other partners or organizations that may also be interested in this area:
NOAA-PIFSC
State of Hawai‘i
NOAA/NMFS National Systematics Lab, National Museum of Natural History

References.

Abecassis, M., Polovina, J., Baird, R.W., Copeland, A., Drazen, J.C., Domokos, R., Oleson, E., Jia, Y., Schorr, G.S., Webster, D.L., Andrews, R.D., 2015. Characterizing a foraging hotspot for short-finned pilot whales and Blainville's beaked whales off the west side of the Island of Hawai‘i with tagging and oceanographic data. PLoS ONE 10 (11), e0142628.

Benoit-Bird, K.J., Au, W.W.L., Brainard, R.E., Lammers, M.O., 2001. Diel horizontal migration of the Hawaiian mesopelagic boundary community observed acoustically. Marine Ecology Progress Series 217, 1-14.

Economist, T., 2017. The mesopelagic: Cinderella of the oceans. The Economist.

Reid, S.B., Hirota, J., Young, R.E., Hallacher, L.E., 1991. Mesopelagic-boundary community in Hawaii: Micronekton at the interface between neritic and oceanic ecosystems. Marine Biology 109 (3), 427-440.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Jeff Drazen
Institution: University of Hawaii at Manoa
Email Address: jdrazen@hawaii.edu
Office Phone Number: 808-956-6567
Collaborators/Co-Authors:

Title: Exploration of Seafloor and Midwater Communities in the Clarion Clipperton Zone

Priority Geographic Area: Clarion Clipperton Zone between Hawaii and central America, on the high seas

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)
The CCZ represents a vast area between Hawaii and Central America consisting largely of abyssal plains (depths 4000-5500m) punctuated by a diversity of seamounts and abyssal hills. Quite a lot of research has occurred on the eastern end to document habitats, megafaunal assemblage, macrofauna and meiofauna of the seafloor (e.g. (Amon *et al.*, 2016; Gooday *et al.*, 2017; Jones *et al.*, 2018; Leitner *et al.*, 2017; Vanreusel *et al.*, 2016). This region is largely unexplored at its western most end, near Hawaii. Recently the DeepCCZ program (funded by NOAA-OER and Moore Foundation) visited three no-mining zones in the western end forming a first data set to evaluate these communities in relation to those at the eastern end of the CCZ (Drazen *et al.*, 2019a). There are clear faunal differences evident from preliminary data. However, such a vast area requires greater exploration, particularly of its seamounts which remain unvisited aside from the 3 visited in the DeepCCZ expedition.

What are the characterization and data needs in this area?
Check all that apply:
__x_ Biology
__x_ Geology
___ Marine Archaeology
__x_ Physical Oceanography
___ Chemistry
___ Other

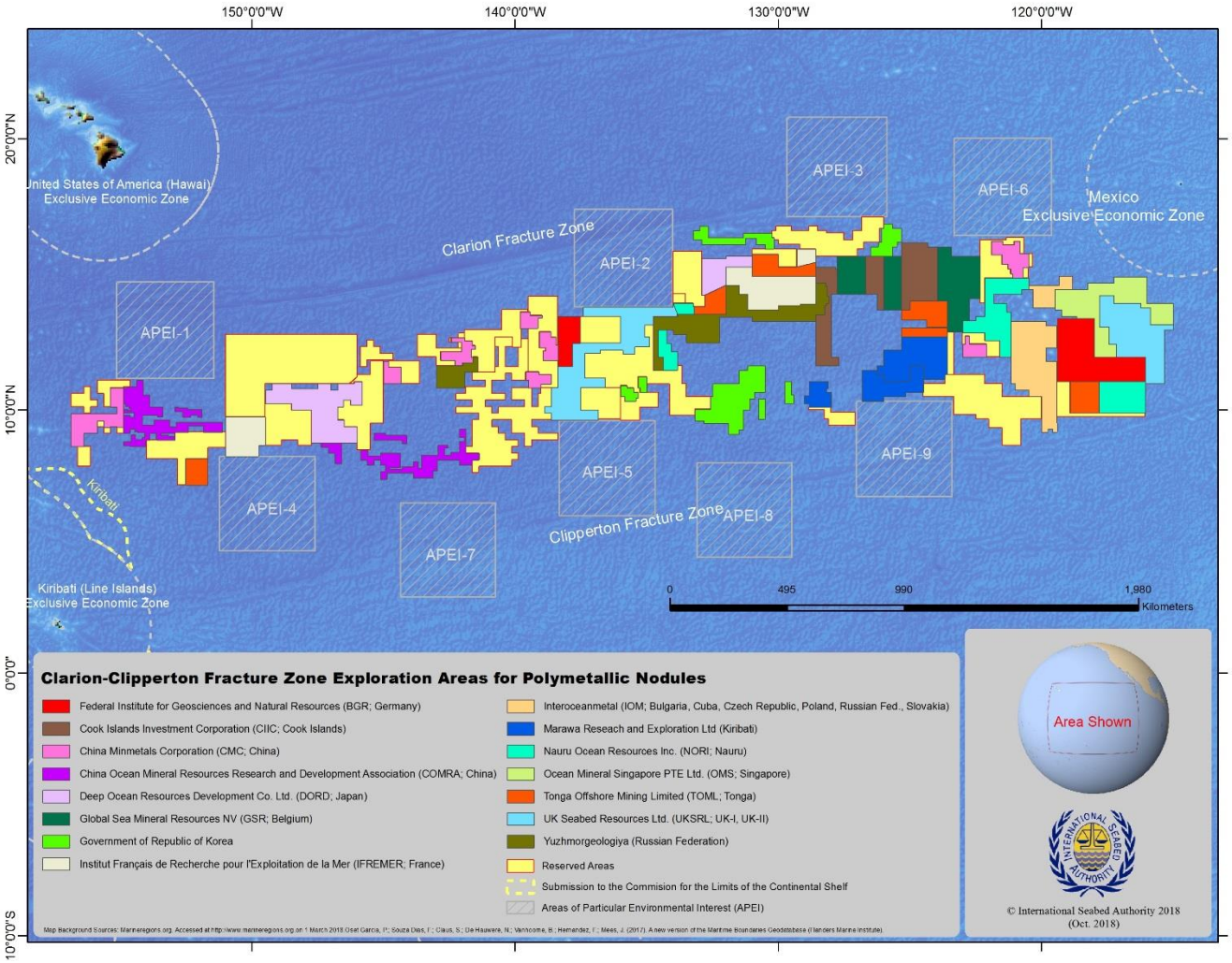
Provide a list or brief description of the data needed within this area, from your perspective:
Visual transects and megafaunal animal collections are required to create biological inventories and to characterize biodiversity and biogeography of the region. Thus far there are no data at all for meso and bathypelagic organisms in the western CCZ though affinities to both equatorial assemblages and Hawaiian assemblages are expected. Thus midwater transects and sampling would be a priority.

Describe relevance to national security, conservation, and/or the economy:
It is quite likely that high seas deep-sea mining will begin in the CCZ shortly after the ISA approves the mining code later this year. Nodule mining in this region is likely to have very large scale and lasting effects on seafloor

communities. Due to onship dewatering of ore and likely midwater discharge of separated sediments and seawater impacts on the water column are also expected (Drazen *et al.*, 2019b). It is imperative to characterize the communities before mining occurs. While we have some baseline characterization of seafloor communities in the eastern CCZ very little data exists in the western CCZ. Almost no data exists for the deep midwaters across the CCZ. Data is required as soon as possible so that biogeographies and biodiversity inventories can be created and used for management.

From your perspective, what makes this area unique?
This is the location where deep-sea mining at an industrial scale is likely to begin. Some companies such as Deep Green say they plan to be mining by 2023. This is ambitious but there is little doubt that activities could begin soon on the timescales of scientific progress. Though contractors are required to create environmental baselines in their claim areas. There is no venue to study the Areas of Particular Environmental Interest (see map below) or the no-mining zones. These areas within the CCZ could be a priority for exploration.

Please list other partners or organizations that may also be interested in this area:
International Seabed Authority
Scripps Institution of Oceanography
NOAA



Amon, D.J., Ziegler, A.F., Dahlgren, T.G., Glover, A.G., Goineau, A., Gooday, A.J., Wiklund, H., Smith, C.R., 2016. Insights into the abundance and diversity of abyssal megafauna in a polymetallic-nodule region in the eastern Clarion-Clipperton Zone. Scientific Reports 6, 30492.

Drazen, J.C., Church, M., Dhalgren, T., Durden, J.M., Glover, A.G., Goetze, E., Leitner, A., Smith, C.R., Sweetman, A.K., 2019a. Exploration of biodiversity and ecosystem structure on seamounts in the Western CCZ. Oceanography 32 (1 supplement), 120.

Drazen, J.C., Smith, C.R., Gjerde, K., Au, W., Black, J., Carter, G., Clark, M., Durden, J., Dutrieux, P., Goetze, E., Haddock, S., Hatta, M., Hauton, C., Hill, P., Koslow, T., Leitner, A., Measures, C., Pacini, A., Parrish, F., Taymans, C., Peacock, T., Perelman, J., Sutton, T., Tunnicliffe, V., Watling, L., Yamamoto, H., Young, E., Ziegler, A., 2019b. A report of the workshop: evaluating the nature of midwater mining plumes and their potential effects on midwater ecosystems. Research Ideas and Outcomes 5, e33527.

Gooday, A.J., Holzmann, M., Caulle, C., Goineau, A., Kamenskaya, O., Weber, A.A.T., Pawlowski, J., 2017. Giant protists (xenophyophores, Foraminifera) are exceptionally diverse in parts of the abyssal eastern Pacific licensed for polymetallic nodule exploration. Biological Conservation 207, 106-116.

Jones, D.O.B., Amon, D.J., Chapman, A.S.A., 2018. Mining deep-ocean mineral deposits: What are the ecological risks? Elements 14 (5), 325-330.

Leitner, A.B., Neuheimer, A.B., Donlon, E., Smith, C.R., Drazen, J.C., 2017. Environmental and bathymetric influences on abyssal bait-attending communities of the Clarion Clipperton Zone. Deep Sea Research I 125, 65-80.

Vanreusel, A., Hilario, A., Ribeiro, P.A., Menot, L., Arbizu, P.M., 2016. Threatened by mining, polymetallic nodules are required to preserve abyssal epifauna. Scientific Reports 6, 26808.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Vicki Ferrini
Institution: Lamont-Doherty Earth Observatory
Email Address: ferrini@ldeo.columbia.edu
Office Phone Number: (845) 365-8339
Collaborators/Co-Authors: Donna Shillington, Northern Arizona University

Title: Alaska/Aluetian Subduction Zone

Priority Geographic Area:

Plate boundaries along the Alaska/Aleutian subduction zone. This largely falls within the US EEZ but also encompasses International waters.

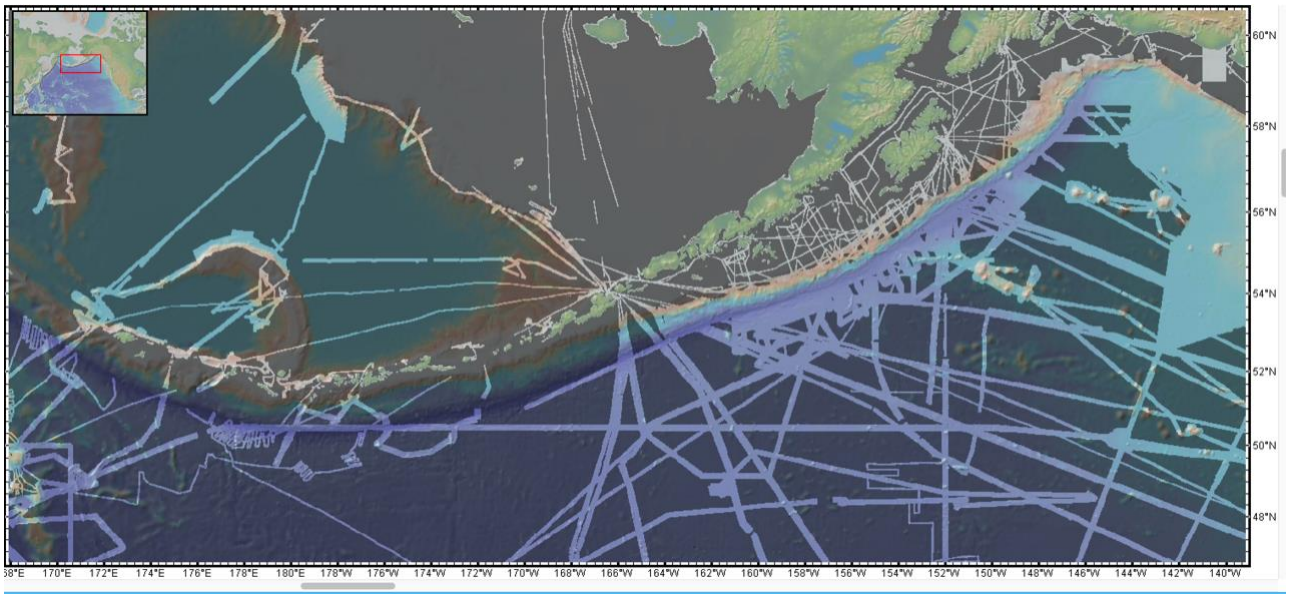


Figure 1: *Image showing current extent of cleaned, processed bathymetry data integrated at 100m resolution for the Alaska/Aleutian area from the GMRT Synthesis (www.gmrt.org)*

Description of Priority Area:

The Alaska/Aleutian region is a very volcanically and seismically active plate tectonic boundary. This region has hosted very large, tsunamigenic earthquakes over the last century. Such events not only impact local communities, but the large tsunamis from this area pose a threat to the western coast of the US and Hawaii. Volcanic eruptions in this corridor impact air travel and local communities. Because this region exhibits profound along-strike variations in island arc magmatism, plate boundary deformation style and sediment input, it also continues a rich target for basic science research into a host of geological processes. However, current bathymetric coverage of this region is quite limited, and geological samples are biased to volcanic islands.

What are the characterization and data needs in this area?
Check all that apply:
_X__ Biology

_X__ Geology
___ Marine Archaeology
_X__ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

Bathymetric data is crucially needed along the entirety of this margin. Such data can be used to identify active fault systems that can be used to understand plate boundary deformation and associated hazards. In particular, splay faults off of the megathrust can be particularly tsunamigenic. Additionally, this region will certainly host future great earthquakes, and having baseline mapping of the entire subduction zone will enable before and after comparisons to characterize the event. Offshore geological sampling can be used to reconstruct eruptive histories of Aleutian volcanoes.

Describe relevance to national security, conservation, and/or the economy:

Further focus on this region would benefit our understanding of geological hazards relevant to the US and other countries around the Pacific Ocean.

From your perspective, what makes this area unique?

Because of the high levels of volcanic and seismic activity and the large variations in volcanic and seismic behavior along the plate boundary, this is one of the best regions in the world for making scientific advances in our understanding of subduction zones. In part due to its remoteness, however, we lack essential data that could be used for both basic science and hazards assessments.

Please list other partners or organizations that may also be interested in this area:

NSF, USGS

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Vicki Ferrini
Institution: Lamont-Doherty Earth Observatory
Email Address: ferrini@ldeo.columbia.edu
Office Phone Number: (845) 365-8339
Collaborators/Co-Authors: Suzanne Carbotte & Andrew Goodwillie, Lamont-Doherty Earth Observatory

Title: Juan de Fuca Plate

Priority Geographic Area:

Comprehensive mapping of the Juan de Fuca plate with modern sonar to replace to multi-generation and incomplete mosaic of data that is currently available (~ 123-132W, 43 to 50N). This area is a focus of coordinated research but lacks modern systematic bathymetric mapping coverage.

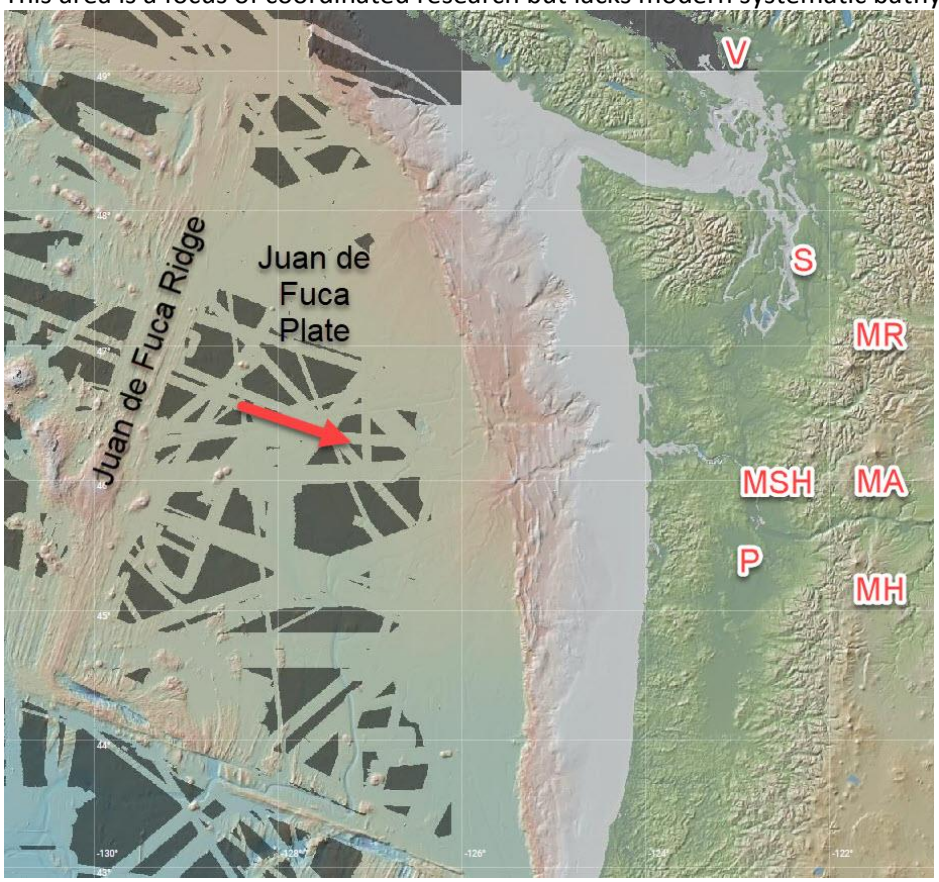


Figure 1: *Cascadia regional physiography. Base map image is GMRT version 3.7, accessed 2020-02-27, with mask function turned on (https://www.gmrt.org/GMRTMapTool/). Longitude and latitude lines are at 2 degrees and 1 degree intervals respectively.*

Description of Priority Area:

The Juan de Fuca plate is formed at the Juan de Fuca Ridge, moves southeasterly (red arrow) and slides beneath the North American plate at the Cascadia Subduction Zone (Figure 1). The descending plate partially melts, generating magma that erupts at Cascadia volcanoes including Mount St. Helens (MSH), Mount Ranier (MR), Mount Adams (MA) and Mount Hood (MH). Huge megathrust earthquakes are known to have occurred

throughout history at this subduction zone, an area now home to millions of people in major population centers including Vancouver (V), Seattle (S) and Portland (P). Grey tracts in the ocean indicate areas that lack publically-available modern-day multibeam swath sonar mapping.

What are the characterization and data needs in this area?

Check all that apply:

___ Biology
_X__ Geology
___ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

Systematic multibeam mapping and single channel airgun seismics to characterize the thick sediment blanket.

Describe relevance to national security, conservation, and/or the economy:

The Cascadia subduction boundary represents a dipping fault zone capable of generating huge "megathrust" earthquakes and explosive volcanic eruptions. From detailed examinations of sediment core turbidite deposits and high-resolution CHIRP sub-bottom profiling data, the palaeo-seismic record indicates that a series of megathrust earthquakes, with recurrence intervals of about 500 years, have ripped through this region. A similar megathrust earthquake today could devastate the Pacific Northwest, severely damaging the area's towns and cities, infrastructure and economic vitality. The Cascadia Subduction Zone is a region of coordinated national and international research because of its potential to improve our understanding of many subduction-related processes such as how the balance of sediment accretion and subduction subduction changes with time, the relationships between slow slip, non-volcanic tremor, great earthquakes, and the geological and geophysical conditions on the plate interface, the causes of the large compositional diversity of Cascadia lavas, and the role of volatiles in megathrust coupling/decoupling. Complete bathymetric mapping and sediment thickness imaging across the entire Juan de Fuca plate are foundational planks to help address these questions.

This would be relevant for various ongoing investigations of Cascadia Subduction Zone and past history of sediment transport from the North American margin through the glacial cycles of the Pleistocene. This would complete the systematic mapping of the Gorda plate done by NOAA in the 1990's.

From your perspective, what makes this area unique?

Please list other partners or organizations that may also be interested in this area:

Numerous groups including NSF-funded researchers from Lamont, WHOI, U of Washington, Oregon State University, and USGS.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Amy Gartman
Institution: U.S. Geological Survey
Email Address: agartman@usgs.gov
Office Phone Number: 831-460-7562
Collaborators/Co-Authors: Kira Mizell (USGS), Nancy Prouty (USGS), Amanda Demopoulos (USGS), Kiana Frank (University of Hawai'i at Mānoa), John Jamieson (Memorial University), Eoghan Reeves (University of Bergen)

Title: Baseline data collection- Gorda Ridge through Blanco Fracture Zone

Priority Geographic Area:
Gorda Ridge and Blanco Fracture Zone

Description of Priority Area: This area encompasses the entirety of Gorda Ridge, including the southern half of Gorda Ridge known as Escanaba Trough, as well as the Blanco Fracture Zone, occurring to the north of the ridge and separating it from the Juan de Fuca Ridge. Although detailed individual studies have been conducted in some regions, there is still a lack of baseline information across the region including habitat mapping, regions of active hydrothermal venting and inactive sulfide mineralization, and connectivity from the heavily sedimented south and the unsedimented north, and through the deep basins occurring in the fracture zone, which also include active hydrothermal venting.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Baseline environmental data is required over the inactive sulfide system including seafloor substrate (sampling and habitat mapping), water column data, and micro and macrofaunal characterization.

Describe relevance to national security, conservation, and/or the economy:
The permissive nature of this region for critical minerals makes it relevant for national security (critical minerals), conservation (necessary to consider in context with any extraction of critical minerals), and the economy (critical minerals).

From your perspective, what makes this area unique?
Gorda Ridge is the only mid-ocean spreading center in the US EEZ. Escanaba trough, the southern half of Gorda Ridge, is one of the few heavily sedimented spreading centers in the global ocean, and critical as well as potentially toxic elements (Sb, As, Ba, Co, Ga, Ge, Te) are contained in Escanaba sulfides in greater concentrations than in typical seafloor sulfide deposits (Morton et al., 1994). Regions of The Juan de Fuca Ridge are among the best studied in the global ocean and include the cabled array on Axial Seamount and the Endeavour Segment, which was an integrated study site during the NSF Ridge 2000 program. The detailed nature of study that has previously occurred at a handful of locations across this more than 1000 km series of

segments makes this an ideal location to begin connecting the dots and explore the nature of spreading center connectivity.

References

Morton JL, Zierenberg RA, Reiss CA (1994) Geologic, Hydrothermal, and Biologic Studies at Escanaba Trough, Gorda Ridge, Offshore Northern California. U S Geol Surv Bull 2022, 359 p

Ryan, W. B. F., S.M. Carbotte, J. Coplan, S. O'Hara, A. Melkonian, R. Arko, R.A. Weissel, V. Ferrini, A. Goodwillie, F. Nitsche, J. Bonczkowski, and R. Zemsky (2009), Global Multi-Resolution Topography (GMRT) synthesis data set, *Geochem. Geophys. Geosyst.*, 10, Q03014, doi:10.1029/2008GC002332.

Please list other partners or organizations that may also be interested in this area: BOEM, NOAA, University of Hawai'i at Mānoa, Memorial University of Newfoundland, University of Bergen

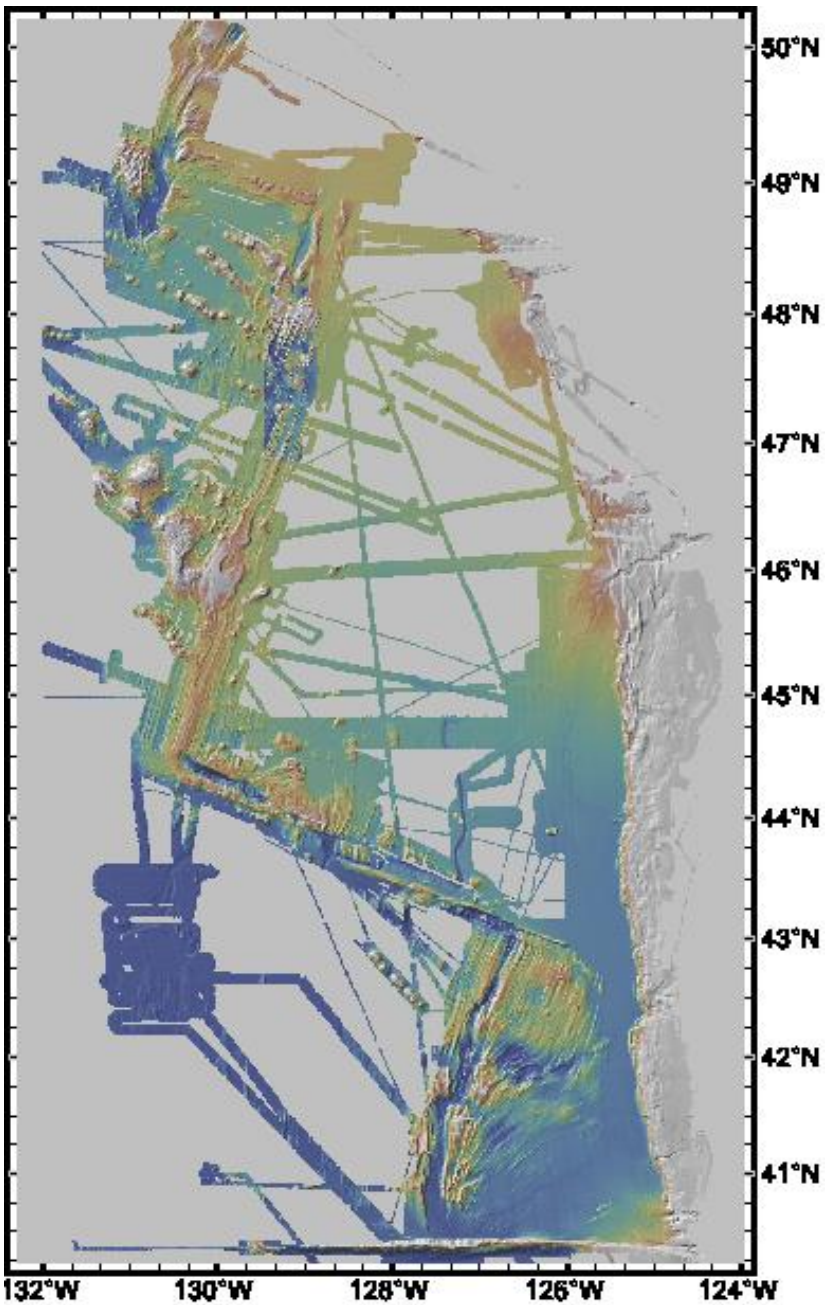


Figure 1. Mapped regions throughout the combined Northeast Pacific spreading centers and offsets. Gorda Ridge and Blanco Fracture Zone are the features occurring south of 44.5° N. Bathymetry compilation from GeoMapApp (Ryan et al., 2009).

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Amy Gartman
Institution: U.S. Geological Survey
Email Address: agartman@usgs.gov
Office Phone Number: 831-460-7562
Collaborators/Co-Authors: Kira Mizell (USGS), Nancy Prouty (USGS), and Amanda Demopoulos (USGS)

Title: Polymetallic-Nodule-bearing Abyssal Plains and Associated Ecosystems in the Western Pacific Ocean

Priority Geographic Area:
This oceanographic region of interest encompasses large abyssal plain regions both within the US EEZ and in areas beyond national jurisdiction in the Western Pacific.

Description of Priority Area:

Polymetallic nodules occur over vast regions of abyssal plain in the global ocean. They are most studied, and associated with, the Clarion Clipperton Fracture Zone (CCZ) region of the central Pacific; however they have long been predicted to occur more broadly. This fact is increasingly recognized, including with the 2019 granting of an exploration contract by the International Seabed Authority for polymetallic nodules northeast of the Mariana Arc. Due to the depth and remoteness of these enormous permissive regions (Figure 1), important baseline questions about composition, extent, and density of nodules, as well as associated ecosystems, are entirely unknown. It is likely that the majority of these permissive regions would not be of economic interest for polymetallic nodules, however without more data it is impossible to refine estimates of nodule abundance, to consider influences of varied oceanographic and sedimentary factors on nodule composition, and to evaluate biodiversity and biomass between regions.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

A detailed baseline characterization of these areas needs to occur. In many regions, ship-based mapping (bathymetry and backscatter at a minimum, sidescan and subbottom also useful) is still needed. In addition, exploratory baseline studies of mineralogical, geochemical and biological regimes in this region are needed to understand the extent and distribution of nodules and their environmental setting and interactions with life. In areas where ship-based bathymetry and backscatter has already been collected, such a characterization would include box and piston core sampling across the abyssal plain coupled to video collection. Water column characterization would also be an invaluable baseline and necessary to consider any potential disturbance.

Describe relevance to national security, conservation, and/or the economy:

The permissive nature of this region for critical minerals makes it relevant for national security (critical minerals), conservation (necessary to consider in context with any extraction of critical minerals), and the economy (critical minerals).

From your perspective, what makes this area unique?
The question of uniqueness is central to this recommendation. As can be seen in Figure 1, vast areas of the Pacific Ocean meet the minimum oceanographic criteria to be permissive for nodules. However, it is unclear what fraction of these regions actually contain nodules, what fraction contain nodules in relevant densities and with substantive mineral concentrations to be considered of interest economically, and how the background abyssal fauna varies across these enormous abyssal plain regions. The CCZ is often looked to as a uniquely abundant nodule-bearing province, however the amount of sampling ongoing there makes this a somewhat biased assessment. Evaluating whether or not these areas are unique is a first order priority.

References

Dutkiewicz, A., Judge, A., and Müller, R.D., 2020, Environmental predictors of deep-sea polymetallic nodule occurrence in the global ocean: Geology, v. 48, p. XXX–XXX, https://doi.org/10.1130/G46836.1

Hein, J.R., Mizell, K., Koschinsky, A., and Conrad, T.A., 2013, Deep-ocean mineral deposits as a source of critical metals for high- and green-technology applications: Comparison with land-based resources: Ore Geology Reviews, v. 51, p. 1–14, https://doi.org/10.1016/j.oregeorev.2012.12.001.

Please list other partners or organizations that may also be interested in this area: BOEM, NOAA

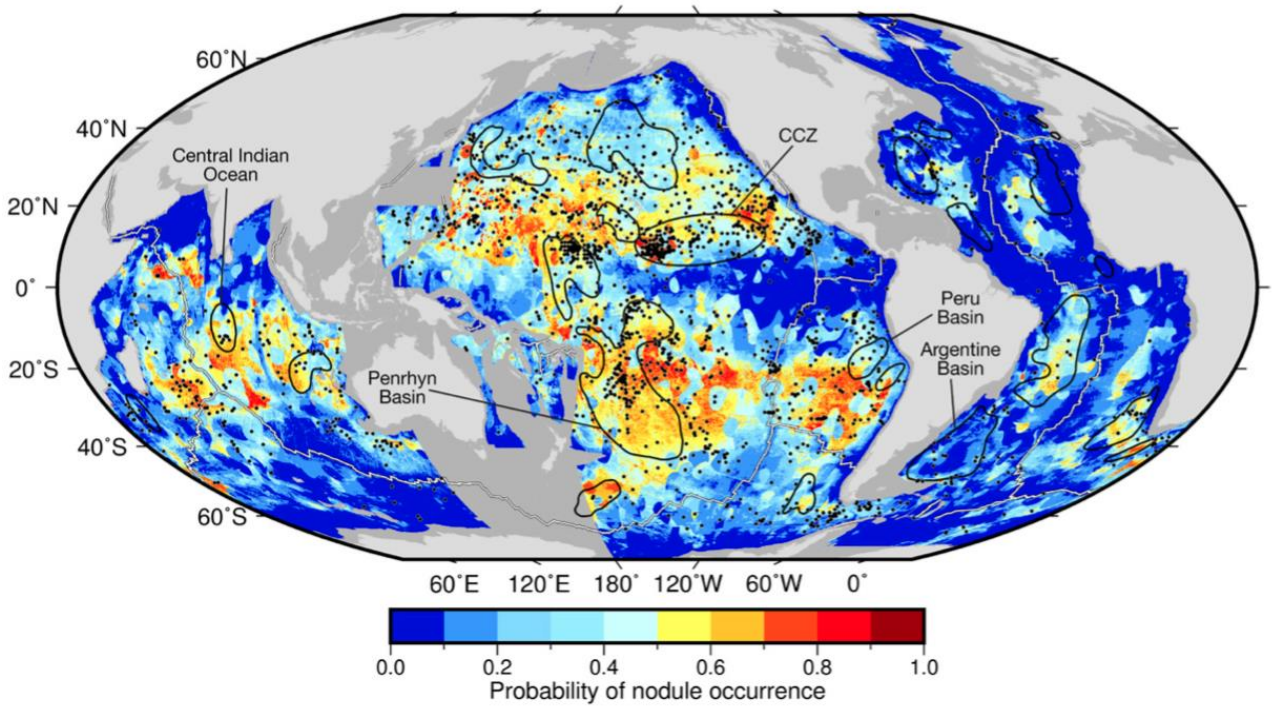


Figure 1. Map predicting the probability of polymetallic nodule occurrence, from Dutkiewicz et al., 2020. Dark outlines are USGS polymetallic nodule permissive regions, from Hein et al., 2013. Black dots are nodule samples. Reconciling huge permissive regions for nodules with a paucity of samples and environmental context reveals an enormous amount of work to do for baselines in nodule occurrence, frequency, metal content, water column and sediment chemistry, and faunal distributions and associations.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author:	**Christopher R German**
Institution:	**Woods Hole Oceanographic Institution**
Email Address:	**cgerman@whoi.edu**
Office Phone Number:	**508 289 2853**
Collaborators/Co-Authors:	**SCOR Working Group 159 (Co-Chairs: K.Howell, UK & A.Hilario, PT)** https://scor-int.org/group/159/

Title: **Unknown but not Unknowable: The South Pacific Basin**

Priority Geographic Area: **The South Pacific Basin (International Waters, Primarily)**

Description of Priority Area:

At the end of the Census of Marine Life decade in 2010, the separate field programs that had investigated different aspects of the deep realm of Earth's Oceans, from ocean margins (CoMargE) to abyssal plains (CEDAMAR), from seamounts (CenSeaM) to chemosynthetic ecosystems (ChEss) arrived at a common sense of knowledge. While our diverse groups had each progressed our own areas of knowledge enormously, one specific, yet massive, component of Earth's Oceans had remained almost untouched by any of our campaigns: the South Pacific Ocean (Fig.1).

This single ocean basin represents perhaps the largest contiguous space for life on Earth as well as being the repository for large mineral resources (not least, high concentrations of hydrothermally sourced metalliferous sediments that are hugely enriched in rare earth elements). Yet at the closing of the Census of Marine Life decade we still knew so little about this region that entire swathes across the South Pacific basin could not be assigned a classification in terms of their biodiversity because in the entire history of the exploration of Earth's Ocean Basins, spanning more than 150 years, not enough measurements had been made in each of multiple 500km x 500km grid cells, anywhere from the ocean surface to the deep ocean floor, to assign a statistically meaningful value for their species richness (Fig.2).

As of 2020, this absence of knowledge has not been improved and the basic characterization of the South Pacific Ocean has not improved despite the fact that this massively under-explored area links regions with some of the highest biological productivity and highest biodiversity anywhere in Earth's Oceans including, in the SW Pacific, regions where NOAA's Okeanos Explorer has previously played a signature exploratory role. While all aspects of the South Pacific Ocean remain relatively poorly explored, programs such as WOCE and, more recently, GEOTRACES have begun to investigate the water column down to full ocean depths. In terms of deep ocean life and the seafloor environments that sustain that, however, there remains much to be done.

In 2011, our teams generated a synthesis paper that laid out a "roadmap" for how a future program could explore systematically across the breadth of the Pacific Ocean (German et al., 2011). Such an approach would not seek to investigate everywhere but, rather, would select up to 10 key "type localities", informed by the Census of Marine Life decade, that would be sufficiently diverse and well separated to allow us to begin to "connect the dots" across this vast and unexplored ocean (Fig.3). Noting that most of our understanding of the shape of the seafloor in this region was inferred from satellite altimetry, this level of exploration would require detailed multibeam mapping in key "focus" areas to pave the way for geological reconnaissance by robotic systems (AUV, ROV) together with biological characterization.

In the decade that has since passed, the technologies to approach the problem as outlined above has increased tremendously. In parallel, the societal needs to understand our oceans so that they can be managed sustainably have expanded dramatically – both nationally within the US and on the international stage. Whether it be access to strategically important minerals not available within national boundaries, or basic food security (an

increasing proportion of the protein in human diet is anticipated to be sourced at sea) whether from the potential impacts of marine mining to the exposure to risk of insurance companies attending climate change to the loss of diversity which may otherwise have the potential to unlock as-yet-unanticipated medical advances.

It is in this spirit that the new SCOR Working Group 159 was initiated in January 2020, seeking to reinvigorate the ideas arising from the CoML a decade earlier, in a timely manner to help guide international thinking during the International Decade of Ocean Sustainability.

What are the characterization and data needs in this area?

Check all that apply:
_x__ Biology
_x__ Geology
___ Marine Archaeology
_x__ Physical Oceanography
_x__ Chemistry
_x__ Other

Provide a list or brief description of the data needed within this area, from your perspective:

We need to understand the diversity of life in the (South) Pacific Ocean as the largest refuge for marine life on our planet, which is already known to host some of the regions of highest biodiversity on Earth, and yet which has remained extensively under-explored and uncharacterized to date.

It is not just enough to learn what lives there to manage the ecosystem sustainably, however – we need to understand how that ecosystem functions to sustain life there which means we need to understand the ocean physics and chemistry of the region which, in turn, requires that we also understand the underlying seafloor process which can regulate both geochemical inputs (mineral deposits, life sustaining nutrients) and fluxes of heat and mass, not least because of the physical mixing of the ocean which can be dominated by interactions with the topography of the deep ocean floor.

Describe relevance to national security, conservation, and/or the economy:

Basic understanding of our deep oceans is essential if we are to understand how perturbations to that natural system can be managed, both nationally and internationally. We need to ensure that actions we take locally (e.g. within the US EEZ) don't have unforeseen consequences elsewhere within the contiguous ocean system, where multidisciplinary processes typically fail to recognize such abstract constructs as national jurisdiction.

Key areas of interest/stakeholders identified to date include marine mining, bio-/pharmaceutical prospecting, fisheries sustainability & food security.

From your perspective, what makes this area unique?

It represents the largest ocean basin on Earth and also the least explored. It should be an INTERNATIONAL priority for Ocean Exploration but the US should recognize its leadership role in that regard.

Please list other partners or organizations that may also be interested in this area:

- The UN's International Decade of Ocean Sustainability (DOS) to be launched in 2021
- SCOR Working Group 159 which has a specific interest in ensuring the deep ocean is featured in the DOS
- Pacific rim (SE Asia, S.America) and Pacific Island nations with opportunities for capacity building & strategic diplomacy through collaborative environmental research, protection and mitigation activities.

Reference cited German et al., (PLoS One, 2011) is freely available to all via open access, here: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0023259

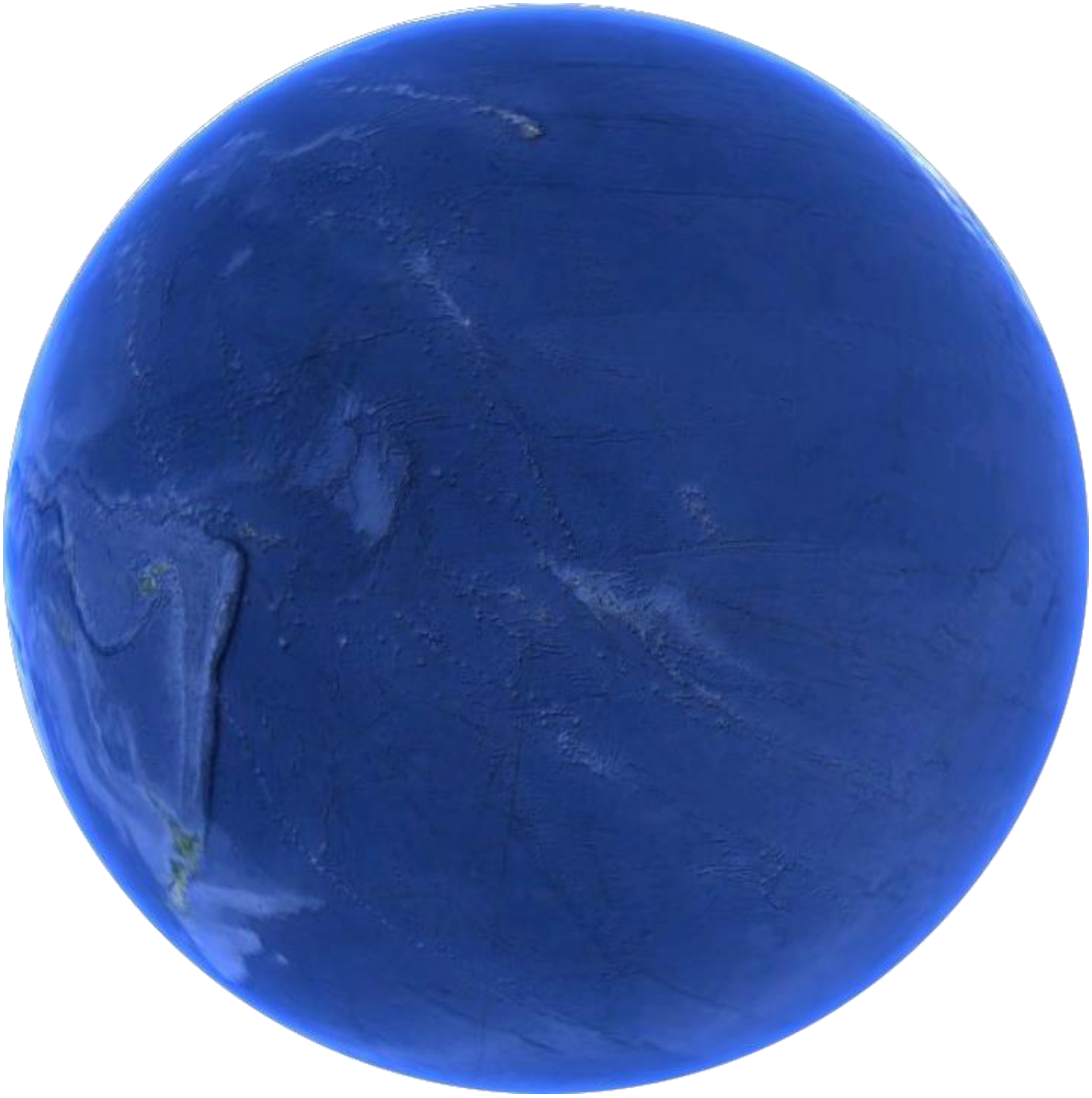


Fig.1. The Earth as viewed from space (courtesy of Google Earth) from directly above Tahiti in the South Pacific Ocean. This projection shows 50% of the surface of the planet and the only land masses visible are New Zealand, Tonga and Fiji at lower left, the Hawaiian archipelago (top, center) and (extreme top right) Baja California. The size and remoteness of the South Pacific basin have precluded even basic exploration of this system although in recent decades the WOCE and, to a lesser extent, GEOTRACES programs have conducted basin-spanning sections to provide first insights into the physics ± chemistry of its water column.

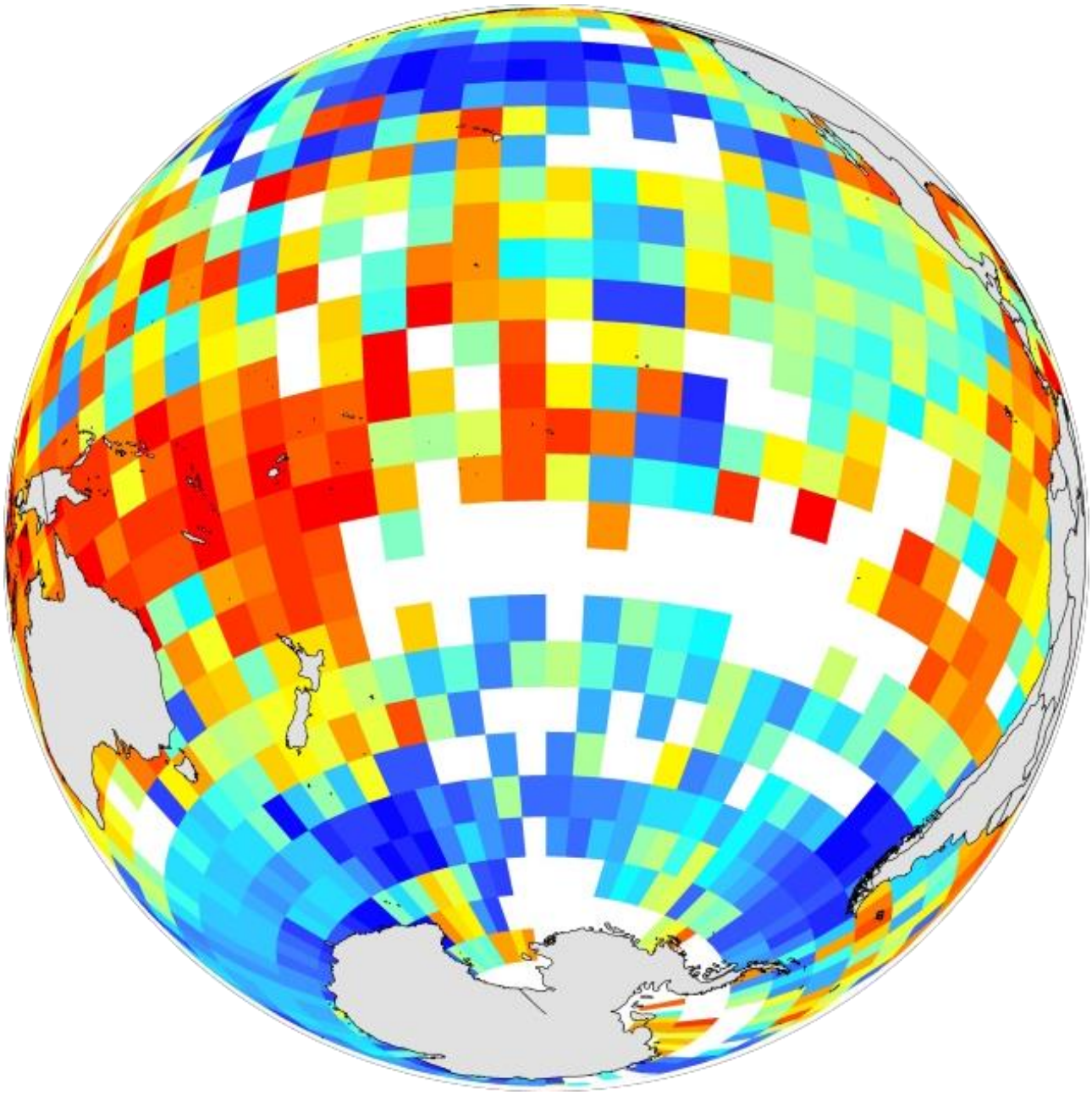


Fig.2 A synthesis of species richness compiled at the completion of the Census of Marine Life decade in 2010. Each grid square is ~500km on a side and the colors assigned (blue = low, red = high) reflect the diversity of species that have been reported from within each marine region, anywhere between the surface ocean and the seabed. White pixels represent 500km x 500km boxes where, **throughout the entirety of humanity's exploration of the oceans**, insufficient observations have been reported - anywhere in the water column from the surface on down – to assign a statistically meaningful value for species richness. Note that there are multiple empty (white) pixels in the northern hemisphere, including between Hawaii and the North American continent, but the absence of data is particularly marked In the South Pacific where a vast swathe of the tropical/subtropical ocean remains almost completely uncharacterized even though it connects regions north of New Zealand and along the Peru Margin that boast some of the highest marine biodiversity yet observed.

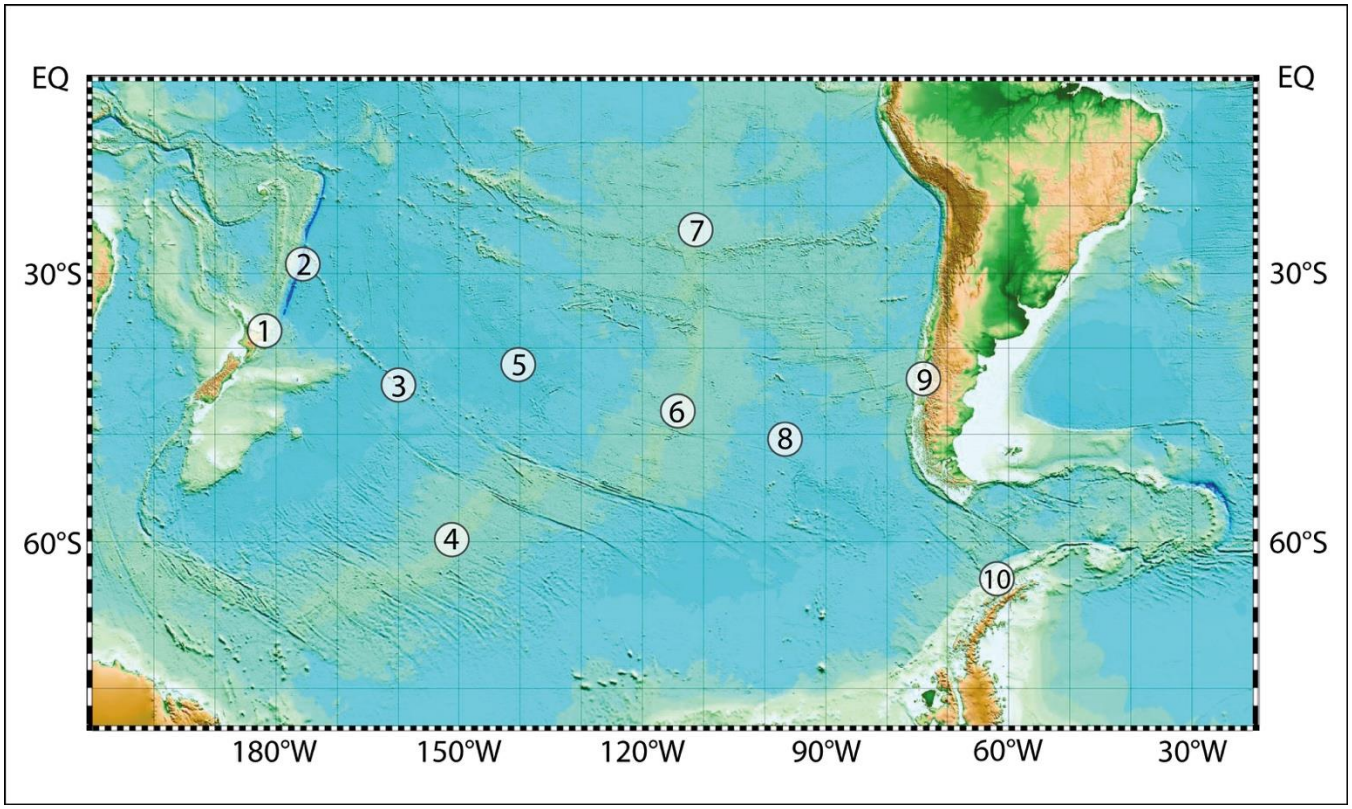


Fig.3 A proposed "RoadMap" for Ocean Exploration that could bring together US and international expertise to conduct basic characterization of life in the deep ocean realm, across the South Pacific Basin, and the processes that sustain it: 1, Tonga-Kermadec arc; 2, deep-ocean trenches; (3) mid-plate seamounts of the Louisville Ridge; 4 & 6, Pacific-Antarctic Ridge; 5 & 8, abyssal plains; 7, Southern EPR; 9, Chile margin; 10, Bransfield Strait back-arc basin.

Note: this image and the detailed rationale for the work was originally published in PLoS One (German et al., 2011) and remains freely available via Open Access:
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0023259

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Send completed form (Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org).

Author: Steve Gittings
Institution: NOAA Office of National Marine Sanctuaries

Email Address: steve.gittings@noaa.gov
Office Phone Number: 301-529-1854
Collaborators/Co-Authors: Andrew Devogelaere, Chris Caldow, Jan Roletto, Dani Lipski, Jenny Waddell (all in field units of the Office of National Marine Sanctuaries)

Title: Exploring the Deep Reaches of West Coast National Marine Sanctuaries

Priority Geographic Area:
Channel Islands, Monterey Bay, Greater Farallones, Cordell Bank and Olympic Coast National Marine Sanctuaries, U.S. EEZ

Description of Priority Area:

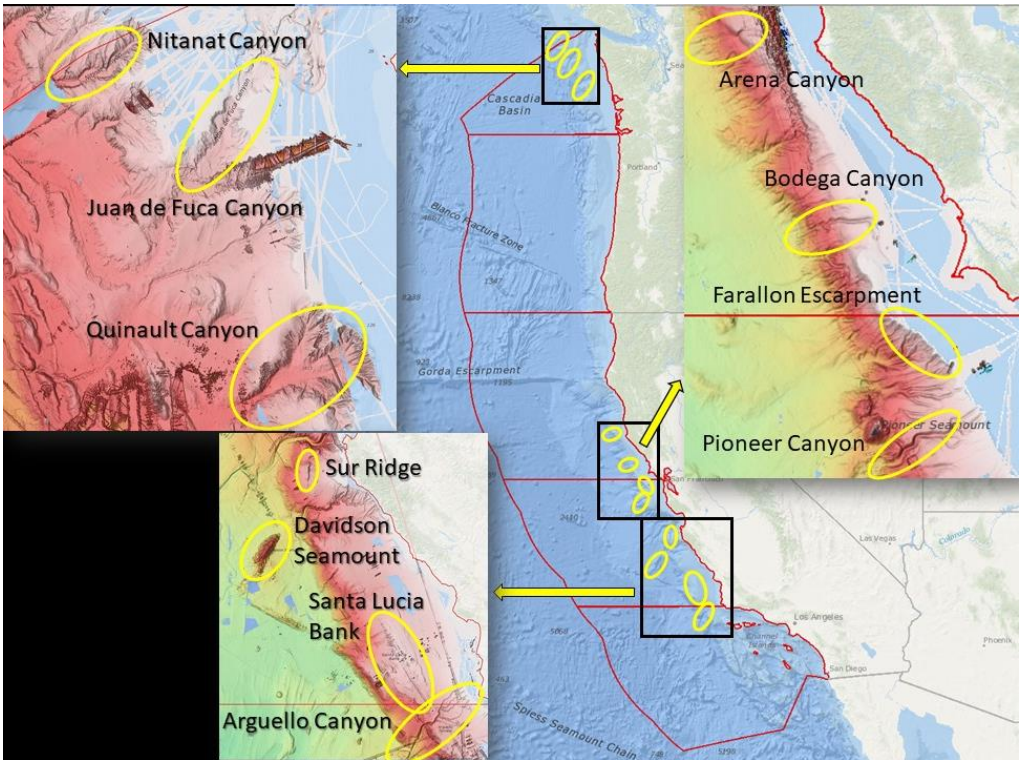
Five units of the U.S. National Marine Sanctuary system are located along the west coast of the United States. Three are directly adjacent to each other and the other two are separate. There is also a proposed national marine sanctuary north of the Channel Islands NMS. Each was designated primarily because of individually unique ecological attributes, such as serving as important feeding, nesting, or nursery areas, or collectively as sources of recruitment or pathways of migration for birds and marine mammals. Some also contain important shipwrecks and archaeological and cultural sites. Recent documentation of changing oceanographic conditions that have affected the entire west coast of the U.S., as well as new discoveries of critical habitat for cephalopods, rare corals, new sponge species, and fish/habitat associations, all indicate the need for exploration of particular habitat types in this region within the marine sanctuaries.

In 2018, more than 1,000 female brooding octopus and their eggs were discovered near Davidson Seamount at a depth of 3,200 meters. This "octopus garden" was associated with warm water seeps. Photo by Ocean Exploration Trust.

Priority targets for mapping, exploration, and characterization:

Olympic Coast: Juan de Fuca Canyon; Quinault Canyon; Nitinat Canyon
Cordell Bank: Bodega Canyon and slope
Greater Farallones: Farallon Escarpment, Pioneer and Arena Canyons and shipwrecks
Monterey Bay: Davidson Seamount (original octopus garden to collect instruments left in 2019, 2nd octopus garden, and warm vent areas); Sur Ridge
Channel Islands: Arguello Canyon; Santa Lucia Bank

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
_X_ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other



Priority sites for exploration, characterization and mapping along the U.S. west coast.

Provide a list or brief description of the data needed within this area, from your perspective:
Multibeam mapping is desired from any unmapped targets. Documentation of biodiversity will require ROV dives to obtain high resolution video images and the collection of voucher specimens. Measurements of oxygen, pH, and other environmental parameters (e.g., osmosamplers to collect fluids from seeps and assess chemical composition) will be required in some areas. Temperature probes that can be manipulated into crevices are needed to measure water temperature at vents associated with octopus nursery habitat or other unique assemblages. Live telepresence feeds are desired at all locations to ensure maximal participation by science partners ashore.

Describe relevance to national security, conservation, and/or the economy:
Documentation of biodiversity is a critical cornerstone of conservation biology and effective fisheries management. Within these marine sanctuaries are previously unknown hotspots of biodiversity. Due to their relative isolation and long-term protection, they may harbor numerous unique endemic species and species that are new to science. Damage to canyons and seamounts, and overexploitation can have widespread consequences for ocean health, food security, and potential discovery of valuable pharmaceutical compounds.

Understanding presence, distribution, condition, and connectivity of these ecosystems is a primary goal of conservation science programs within the sanctuaries. The canyons and seamounts identified here as priority research sites lie within the US EEZ, offering an unusual opportunity to establish baselines to evaluate these factors, and ultimately the effect of existing levels of sanctuary protection and fisheries management in unique and/or biodiverse communities.

Only a small portion of Arena Canyon has been explored. An ROV dive to -1590 meters in 2016 revealed several species of bubblegum and bamboo corals.

From your perspective, what makes this area unique?

We expect these proposed priority dive sites to harbor some of the most unusual and rare assemblages within the west coast national marine sanctuaries. Characterization of unique habitats and biodiversity within the sanctuaries supports assessments of ecosystem integrity that are documented in sanctuary condition reports, and informs management plans with actions need for long-term protection of these places. Other aspects of sanctuary management, ranging from education to boundary modification, also benefit from new discoveries and improved understanding. Together these actions build on a foundation of exploration and discovery, and demonstrate the use of the best available science to drive adaptive natural resource management.

Steep walls of the Farallon Escarpment have many species of corals, such as this black coral.

Other partners or organizations that may also be interested in this area:
NOAA: Deep Sea Coral Research and Technology Program (build on WCDSCI and EXPRESS); National Centers for Coastal Ocean Science; National Marine Fisheries Service Protected Species, Deep-sea Corals Research and Technology Program; Restoration Center; Pacific Marine Environmental Laboratory; Northwest Fisheries Science Center; Ocean Acidification Program
U.S. Geological Survey
Bureau of Ocean Energy Management
Ocean Exploration Trust
Global Foundation for Ocean Exploration
Universities: UC Santa Barbara; UC Davis Bodega Marine Lab; University of Victoria; Scripps Institute of Oceanography; Occidental College; Texas A&M University; University of Alaska Fairbanks, San Francisco State University
Coastal Treaty Tribes: Makah Tribe; Quileute Tribe; Quinault Indian Nation, Kashia Band of Pomo Indians of the Stewarts Point Rancheria
MBARI
California Academy of Sciences
Santa Barbara Museum of Natural History
Museum of British Columbia
Chicago Field Museum

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper

Author: Goordial., J.
Institution: Lamont-Doherty Earth Observatory
Email Address: goordial@ldeo.columbia.edu
Office Phone Number: 207-518-3144
Collaborators/Co-Authors: Keisling, B., Habicht, H., Meyer, N., Valencia Villa, A., Subbarao, G.

The Bering Strait:

A rapidly-changing subpolar environment with underexplored potential

Priority Geographic Area:
The Bering Strait spans ~8º of Latitude from the North Pacific Ocean to the Arctic Ocean (64º–72ºN) and stretches from western Alaska to far eastern Siberia (approximately 170ºE–160ºW) (Figure 1). The majority of the Bering Strait is part of the US Exclusive Economic Zone (EEZ).

Description of Priority Area: The Bering Strait is a broad, shallow (~60m water column depth) Strait connecting relatively fresh and restricted Arctic Ocean basin with the salty, expansive North Pacific. Due to historically extensive sea-ice coverage, multibeam, seismic, and other oceanographic data are limited in the Bering Strait region. Today, the rapidly retreating sea-ice edge is making the region increasingly viable for commercial ship traffic and resource exploration. High-resolution topography and seismic data are needed in this area to provide a baseline for understanding the extent and impacts of future expected change, such as degradation of submarine permafrost and coastal erosion.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
___ Physical Oceanography
_X_ Chemistry
_X_ Other: Multibeam Mapping
_X_ Other: Seismic mapping

Provide a list or brief description of the data needed within this area, from your perspective:

- Acquisition of high-resolution bathymetry from the Bering Sea through to the Chukchi. High priority areas include the southern and northern shelf of the Bering Strait, and near coast environments.
- Sub-bottom profiles including but not limited to Chirp, single-channel, and multi-channel seismic profiles to map, identify and characterize the extent of subseafloor permafrost as baseline data in this rapidly changing environment. These data will also map the potential

for free gas, gas hydrate, and fluid seeps that are important for supporting economic development and characterizing natural hazards in this region.

- ROV exploration and characterization of the density and diversity of benthic habitats and sampling of seafloor material for understanding microbial and biological ecosystem services, including the potential for bioprospecting in unique habitats, and identifying potential methane seeps.

Describe relevance to national security, conservation, and/or the economy:

The Bering Strait is one of the most rapidly changing regions on Earth. Sea-ice conditions in the summer of 2017-2018 reached a record low of less than 10% of the 1981–2010 average (Stabeno & Bell, 2019). It is not known how seasonal disappearance of sea ice will impact local/ regional ecosystems, many of which have been shielded from environmental impacts of human activities like oil and gas exploration and mineral extraction due to logistical difficulties of operating in harsh (sub)arctic conditions. Bering Strait sea ice loss may also be transformative for commercial shipping, coastal national security, and high-latitude hydrocarbon resource development. Taking advantage of the Bering Strait as a navigational channel for commercial and other purposes requires comprehensive bathymetric mapping with multibeam profiles and physical characterization of the seafloor. In addition, the extent and stability of free gas, gas hydrate, and fluid seep features in this region is largely unknown as the area has thus far been partially mapped, despite these features being widespread in similar geologic settings in other parts of the Arctic (e.g. Madrussani et al., 2019) and northern Alaska (Ruppel, 2018). Submarine permafrost and associated habitats may provide unique microbial genetic resources for bioprospecting due to the extremophilic life likely to be present. Expeditions to this region would support OER strategic goal to ‘conduct scientific baseline characterizations of poorly-known/unknown coastal marine areas, processes and resources’ including the extent and distribution of submarine permafrost undergoing rapid change, and the possible presence of gas hydrates. These data will support the goals of the Memorandum on Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska (Issued November 19, 2019). For example, topography as well as subsurface seismic data will identify and evaluate natural and cultural resources within these areas, which will inform conservation, management and balanced use of the U.S. EEZ near Alaska.

From your perspective, what makes this area unique?

The majority by area of the Bering Strait is within the US EEZ, and it represents a uniquely efficient and emerging pathway for transport of goods between mainland Asia and economies in the Atlantic basin. Due to the abutting nature of US EEZ with its Russian equivalent, there is also increased opportunity for territorial dispute. Despite its economic potential, harsh high-latitude conditions have prohibited most activities, including scientific mapping. The northern coastal area of Alaska is the only location of submarine permafrost in the US, and is expected to undergo rapid and irreversible change; knowledge of the physical and biological characteristics of this rapidly-changing marine environment is critical to establish a baseline against which we can study the impacts of human activity and environmental change on unique submarine ecosystems.

Please list other partners or organizations that may also be interested in this area:
The United States Geological Survey (including the Coastal and Marine Geology Program, Energy Resources Program), The Department of Energy (including National Energy Technology Laboratory), The Canadian Geological Survey, International Ocean Discovery Program.

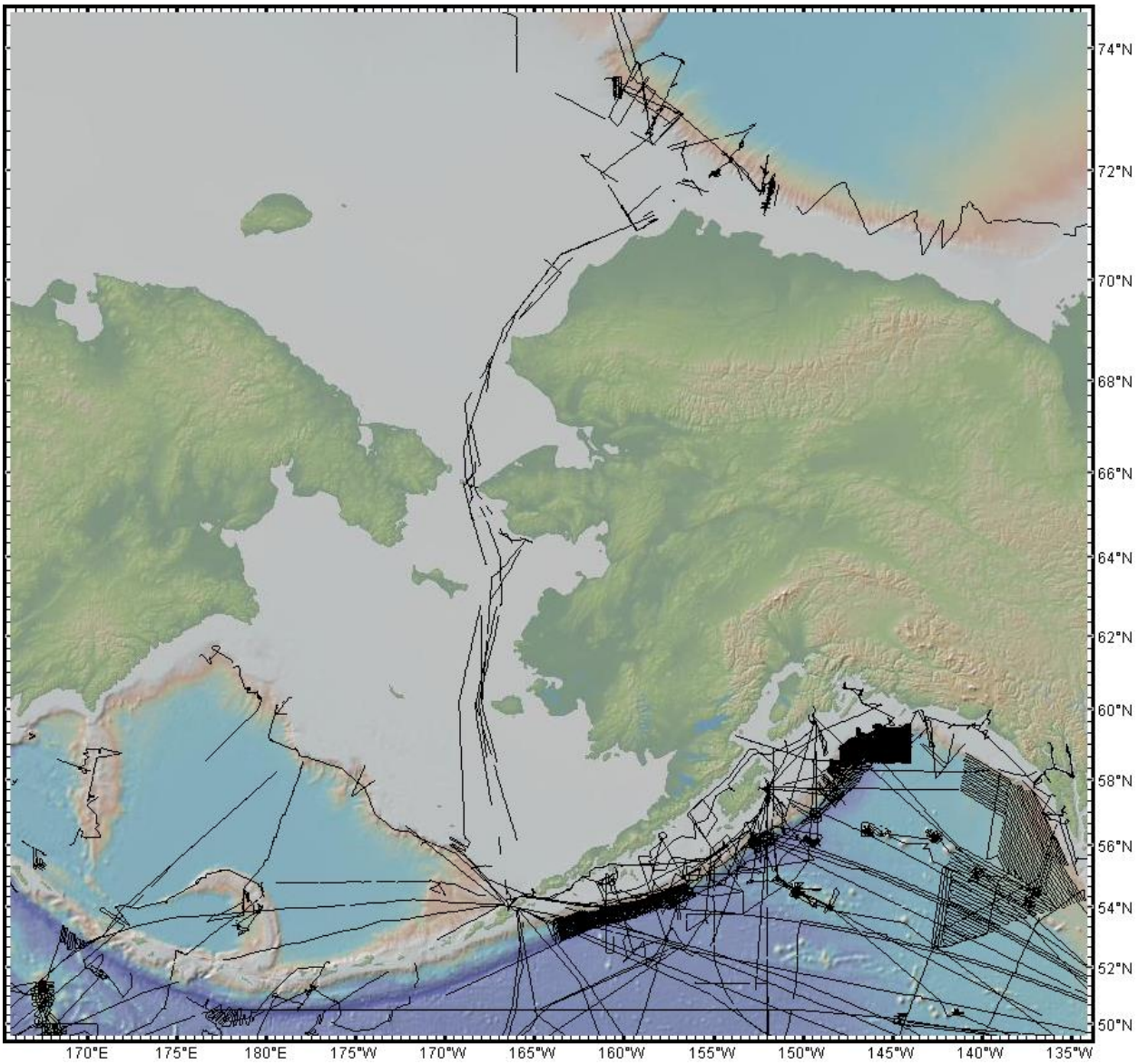


Figure 1. Map of the Bering Strait overlain with available multibeam bathymetry tracks emphasizing that the nearshore and shelves are currently poorly characterized. Figures created in GeoMapApp with data from the NOAA MBB database.

Figure 2. Using data from the National Snow and Ice Data Center, this time series shows the maximum ice extent in the Bering Sea during April for the years 2013 through 2018. The year 2018 set the record for the least amount of sea ice dating back to 1850. (NASA Earth Observatory, Joshua Stevens) (Figure and caption from NOAA: ttps://www.noaa.gov/stories/unprecedented-2018-bering-sea-ice-loss-repeated-in-2019)

References:

Madrussani, G., Rossi, G., Camerlenghi, A. Gas hydrates, free gas distribution and fault pattern on the west Svalbard continental margin, Geophysical Journal International, Volume 180, Issue 2, February 2010, Pages 666–684, https://doi.org/10.1111/j.1365-246X.2009.04425.x

Ruppel, C.D., 2018, The U.S. Geological Survey's Gas Hydrates Project: U.S. Geological Survey Fact Sheet 2017–3079, 4 p., https://doi.org/10.3133/fs20173079.

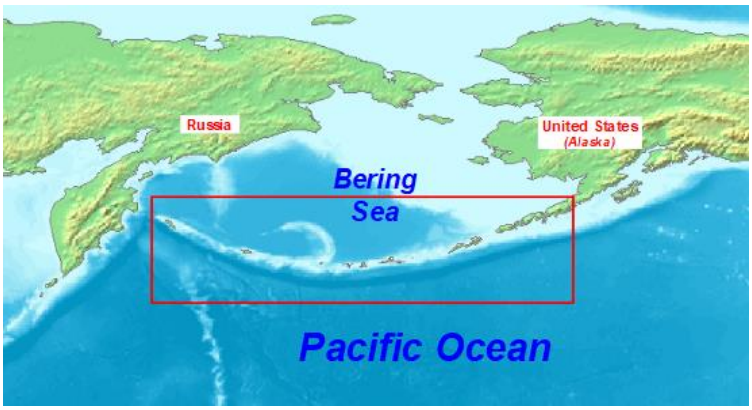
Stabeno, P. J., & Bell, S. W. (2019). Extreme conditions in the Bering Sea (2017–2018): Record-breaking low sea-ice extent. Geophysical Research Letters, 46, 8952– 8959. https://doi.org/10.1029/2019GL083816

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Prof. Russ Hopcroft
Institution: University of Alaska Fairbanks
Email Address: rrhopcroft@alaska.edu
Office Phone Number: 907-474-7842
Collaborators/Co-Authors: Dhugal Lindsay JAMSTEC, Katrin Iken UAF

Title: Exploration of deep waters of the Aleutian Islands: America's last Marine Frontier

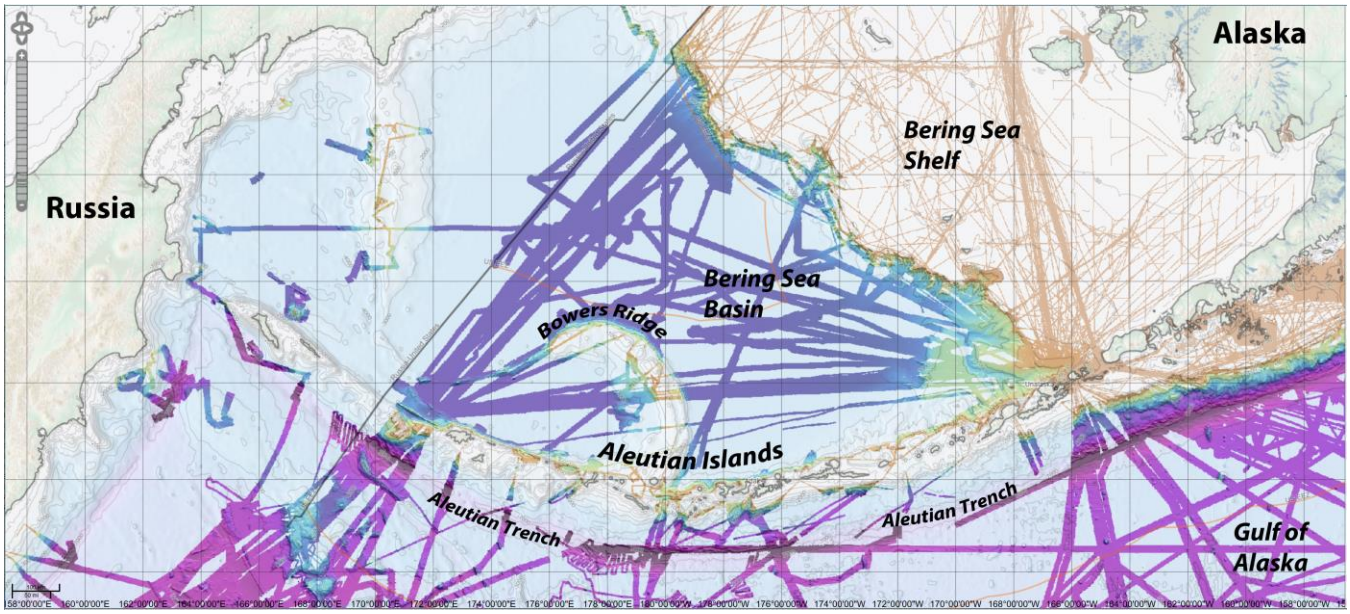
Priority Geographic Area: US EEZ



Description of Priority Area:
Stretching over 1200 miles from the Alaskan mainland to Russia's Kamchatka Peninsula, the 300^{+} islands that make up the Aleutian Archipelago remain some of the remotest locations within the US EEZ. Rising from the collision of abyssal plains to the north and south this island chain divides the Bering Sea from the North Pacific. Within the US it is considered the diving line between the Arctic and subarctic. The numerous and frequently shallow passages between islands create vigorous tidal mixing that stimulates high marine productivity and support rich colonies of many seabirds and marine mammals leading to its designation as a National Wildlife. Despite ongoing studies of their terrestrial flora and fauna, plus those of iconic seabirds and marine mammals, most other elements of the Aleutian's marine fauna remains poorly studied. In the past, UAF scientists have conducted extensive shallow-water surveys via SCUBA revealing the high diversity of the Aleutian's kelp and benthic communities. NOAA does maintains standard shallow-water fisheries surveys in the eastern-most end of the chain, but pelagic studies in the central and western part of the chain are sparse. Information on the deep-water communities, in this region is even rarer, despite expectations they should harbor unique and biologically rich communities, both within the water column and on the seafloor.

Not surprisingly the entire region remains poorly mapped by modern standards (see figure next page), with the exception of the major passages (Unimak and Buldir) leading to the Arctic. Even major geological features such as the deep Aleutian Trench to the south and the curiously-shallow Bowers Ridge arching northward mid-chain are poorly characterized. This lack of basic knowledge is surprising given its location along maritime shipping routes plus the long history of military activity through the archipelago, including the use of several islands for nuclear test during the cold-war. Lastly, given the high volcanic activity recorded across the entire chain, the lack of survey data for deep-sea volcanoes, vents, and seeps is also enigmatic.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other



The Aleutian Archipelago, showing major geological features and the current extent of multi-beam mapping available for the region.

Provide a list or brief description of the data needed within this area, from your perspective:
In addition to providing basic knowledge of deep-water ecosystems and biodiversity in this poorly-know region, it is likely that many novel life-forms will be discovered. Much as we have done in other Alaskan regions, using a combination of ROV activities combined with traditional oceanographic sampling tools could greatly expand our knowledge of this area across the entire spectrum of oceanography: geology, physics, chemistry and biology. The expected rocky nature of much of the archipelago may make traditional benthic sampling gears ineffective and favor primarily visual ROV surveys, whereas both traditional CTDs, nets and ROVs would be effective for water column studies. In both cases, we would foresee multiple transects each with a series of stations along a depth gradient moving from the Pacific side of the chain through some passes into the Bering Sea Basin, and/or similarly across Bowers Ridge. Station work could be supplemented with highly instrumented tow-yowed bodies that would resolve frontal features between water masses. Geological surveys would likely employ a combination of multi-beam surveys plus targeted ROV dives. These activities could be done either by mounting multidisciplinary cruises from a large platform deployed in the region such as R/V *Sikuliaq*, or more discipline-narrow cruises, potentially from *Sikuliaq* or the *Okeanos Explorer*, as distinct cruise legs. (Alaska Airlines still maintains service twice weekly to Adak during summer). This is such a large and unknown area that a multi-year series of campaigns might also be appropriate.

Describe relevance to national security, conservation, and/or the economy:
The Aleutian Islands have a long history of military activity throughout the archipelago. At the height of WWII, nearly 100,000 troups were deployed scattered throughout these islands, and major bases remained in operation until nearly the end of the last century. OER has undertaken some prior archeological studies in the Aleutians related to this rich history. Due to use of several islands as nuclear test sites during the cold-war, leakage from test sites remains a public concern, such that some periodic monitoring still occurs.

As indicated previously, much of the archipelago is part of Alaska's National Wildlife Refuge and there have been recent attempts to elevate this region to a National Marine Sanctuary to protect its rich flora and fauna. These attempts conflict and compete with interests of commercial fisheries in the region that seek greater and less restrictive access to the rich harvestable resources of the region. As more accessible fisheries in the Gulf of Alaska and Bering Sea begin to falter, increased fishing effort can be anticipated within the Aleutians.

Finally, the Aleutians fall on the great-circle shipping route between Seattle and Japan, meaning that some commercial shipping chooses to pass through the chain rather than to its south. Furthermore, storms have been known to force vessels to seek shelter near these islands. The lack of modern and detailed charts in this region places vessels and habitats at risk, with several grounding having occurs in recent decades, leading to loss of life, cargo and/or significant oil spills. These risks can be expected to increase in the future as trans-Pacific and trans-Arctic commercial shipping increases.

From your perspective, what makes this area unique?
Everything

Please list other partners or organizations that may also be interested in this area:
North Pacific Research Board
USFWS National Marine Sanctuaries
NOAA NMFS
Alaska Department of Environmental Conservation
The Aleut Corporation

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Prof. Katrin Iken
Institution: University of Alaska Fairbanks
Email Address: kbiken@alaska.edu
Office Phone Number: 907-474-5192
Collaborators/Co-Authors: Russ Hopcroft UAF, Dhugal Lindsay JAMSTEC

Title: Unexplored seamounts in the Gulf of Alaska

Priority Geographic Area: US EEZ and international waters

Description of Priority Area:
The Gulf of Alaska (GOA) shelf system is subject to intense fishing activities and trawl surveys with the processes governing community structure well understood and continuously observed through multiple long-term scientific efforts. It is, thus, almost paradoxical that the adjacent deep basin of the GOA is little known. The GOA deep-sea region is hydrographically and topographically complex with ~35 seamounts in several distinct chains (Figure 1). Most of the seamounts rise between 1000 to 3500 m above the basin seafloor, with their summits still relatively deep, but several reach within 650 m of the surface. They contribute dominantly to the seamounts being located within the Pacific Ocean and worldwide. Seamounts in general interact with the surrounding deep-sea system through alteration of the deep water column structure with effects on mixing and nutrient exchange as well as propagule exchange. Oceanographic processes (e.g., Taylor caps) on seamounts differ from surrounding deep-sea habitats, in part due to typically high carbon input and more topographically complex habitat structure. These conditions can contribute to high biodiversity regions within deep-sea ecosystems, both in the benthic as well as pelagic realm, often leading to seamount classification as biodiversity hotspots.

Figure 1: Gulf of Alaska region with seamounts dispersed in deep basin.

To date, only a handful of studies have investigated the fauna of the GOA seamounts, most recently our own investigations of Giacomini and Quinn seamounts (Figure 2). As with previous investigations, only a single incomplete transect on each seamount was visited during our own recent exploration. Thus, it is still impossible to draw any generalized conclusions about the biodiversity or uniqueness of these systems. For example, benthic communities of Giacomini and Quinn seamounts were distinctly different despite being only 70 km apart. It is unknown if that is related to the specific sites visited or if indeed seamounts build distinct assemblages rather than a biologically-connected chain. While one can think of seamount bathymetry to be very similar to that of the continental slope rising to the GOA shelf, it seems from our extremely limited comparison that oceanographic processes are shaping vastly different biological communities, both pelagic and benthic. In addition, most of the seamounts are still not fully mapped, impeding our understanding of small-scale structures that could influence oceanographic processes as well as habitat structure.

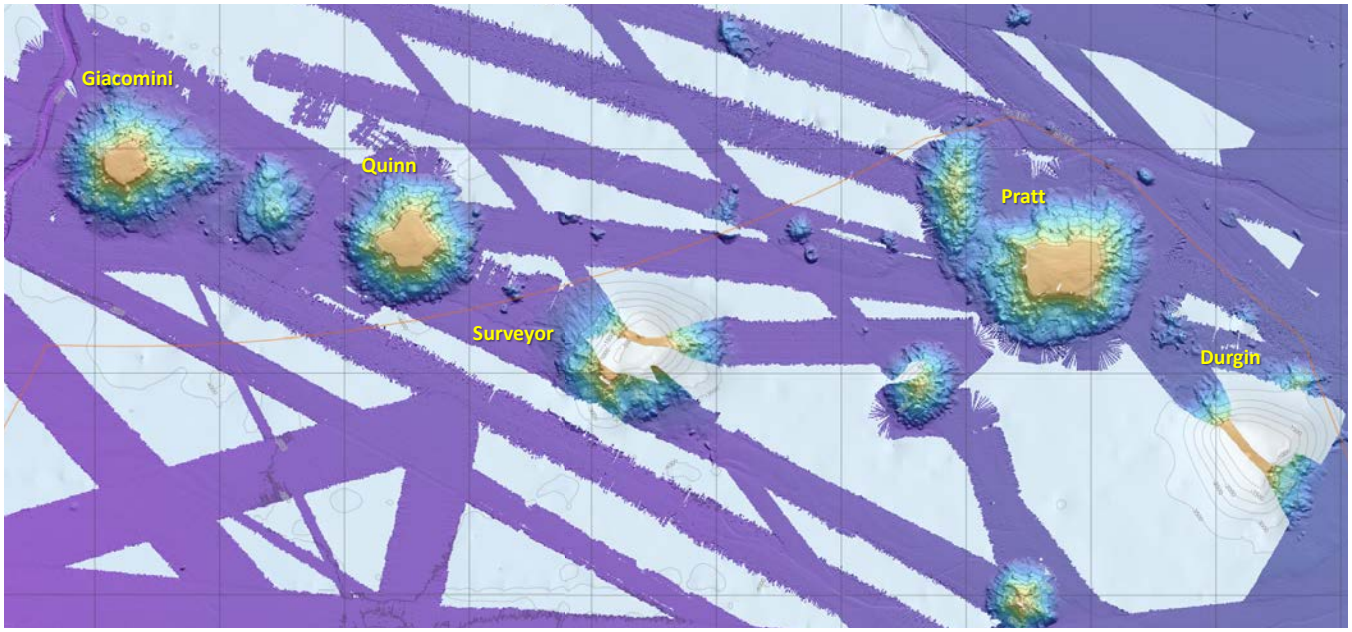


Figure 2: Seamount chain in the northern Gulf of Alaska. Mapping and biological studies are needed to understand the role and possible uniqueness of these seamounts within the GOA. Orange line is the US EEZ boundary.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
The information need for this region ranges from bathymetric mapping, to hydrographic measurements, to biological inventories of these seamounts and the surrounding basin in comparison with the GOA shelf and slope systems. Most modern research vessels have the capacity for multibeam mapping while transiting, which would assist in more fully capturing the details of seamount structure in the GOA. Oceanographic sampling using traditional tools such as CTD transects can provide essential information on changes in hydrography between the deep basin and the seamounts, as well as determine if the seamount slopes and the continental slope have similar effects on upwelling, frontal formations, and nutrient exchange, ultimately setting the environment for pelagic and benthic communities. Past NOAA Ocean Exploration work in Alaska has successfully used a combination of ROV activities with traditional oceanographic sampling tools to create new inventories of biodiversity in underexplored regions. Since seamounts are habitats sensitive to physical disturbances such as from trawling, using high-resolution imagery to survey seamount communities is a high priority. This high-quality imagery is also the only tool that can provide new information about many sensitive gelatinous zooplankton species that are major components of these habitats.

Multiple transects across each seamount reaching from the summit to the deeper slopes of the seamounts would assist with better understanding of topography (mapping/geology), hydrographic conditions (physical oceanography), and community structure plus biodiversity (biology) of these systems. Comparison to the

continental slope and shelf system with similar transects would add greatly to our understanding how seamount systems may be functioning very differently to the shelf/slope. Given the large region and great depth (the GOA abyssal plain is 4000-4500 m deep), such a comprehensive survey is likely a multi-cruise/multi-year endeavor.

Describe relevance to national security, conservation, and/or the economy:
The Gulf of Alaska is an important fisheries region, contributing fundamentally to the economic well-being of Alaska and the US. Seamounts in other regions of the world are known to be highly productive and habitat for many fisheries-related species. High abundance of corals and sponges on the tops of seamounts typically create complex three-dimensional habitat for associated species, adding to overall high biodiversity. It would be important to understand if commercial species such as sablefish occur on seamounts and may be using them as nursery grounds. Similarly, seamounts may serve as possible refuges or source populations for crabs, which were observed regularly during the recent but limited surveys on Giacomini and Quinn. These large crabs are a fisheries species of interest in the GOA, where some populations have been declining with slow signs of recovery. While all trawling activities on these seamounts are currently prohibited, better understanding of these systems is needed to justify such restrictions long-term so that their conservation can be assured.

From your perspective, what makes this area unique?

- The close vicinity of multiple seamounts suggests that biological exchange among them should be possible but there is indication that this may not be the case.
- The close vicinity of these seamounts to the continental shelf and slope, makes comparison of the processes governed through these bathymetric features logistical practical and would be highly informative.
- Recent large-scale and persistent climate anomalies in the GOA, such as the Pacific Marine Heatwave, create urgency to these investigations if we are to understand the structure and role of these seamounts before they may be persistently impacted by such disturbances in the future.

Please list other partners or organizations that may also be interested in this area:
North Pacific Research Board
USFWS National Marine Sanctuaries
NOAA NMFS
Alaska Department of Environmental Conservation

Workshop to Identify National Ocean Exploration Priorities in the Pacific

Author: David Itano
Institution: Western Pacific Regional Fisheries Management Council, Scientific and Statistical Committee
Email Address: daveitano@gmail.com
Office Phone Number: (808) 522-8220
Collaborators/Co-Authors: Western Pacific Regional Fisheries Management Council

Title: Deep bottomfish habitat characterization of American Samoa, Guam and the Commonwealth of the Northern Mariana Islands (CNMI)

Priority Geographic Area:

American Samoa, Guam and CNMI Exclusive Economic Zones (U.S. Territorial waters

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)

American Samoa is located in the South Pacific Ocean, between independent Samoa, Tokelau, the Cook Islands, Niue and Tonga, and centered on 14.3°S, 170.1°W (Figure 1) and is the southernmost U.S. possession. The U.S. Territory consists of two atolls (Swains, Rose), the main island of Tutuila and the Manu'a Islands (Ofu, Olosega and Tau Islands) that anchor the eastern limit of the Samoan archipelago (Figure 2).

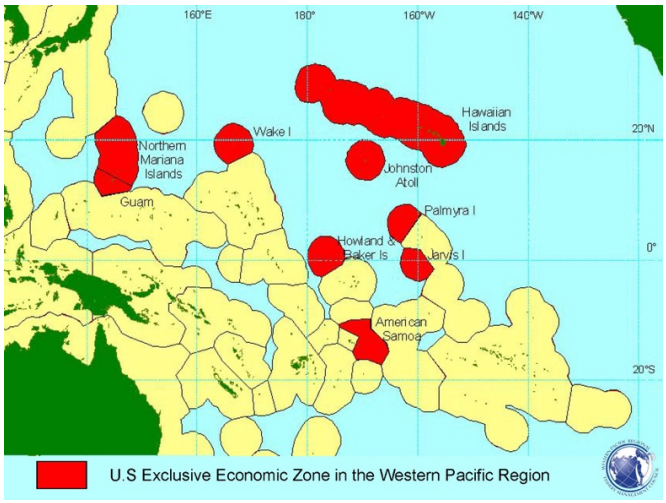


Figure 1. American Samoa is the southernmost US territory or insular area of the Pacific. Guam and CNMI the westernmost US possession

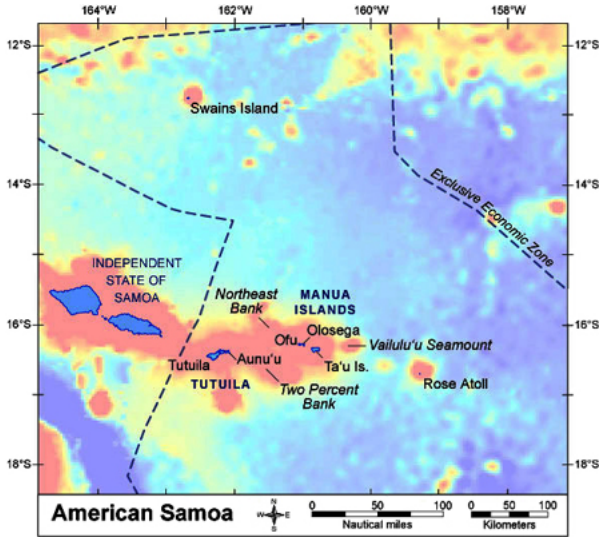


Figure 2. American Samoa EEZ

Two submarine guyots and a series of banks formed by a submarine ridge that runs between Tutuila and the Manu'a group are shallow enough to create access to harvestable stocks of snappers, groupers and jacks. These offshore bathymetric features are locally known to fishermen as Northeast Bank, South Bank, East Bank, Southeast Bank and 2% Bank.

Guam and the CNMI represent the most western US territories in the Pacific Ocean and are formed by the South/North arc of the Marianas archipelago (see Figure 1). The area is roughly bounded by 13° – 21° N latitude and 142° – 147° E longitude (Figure 3). The Marianas region is part of the Pacific rim of fire with numerous

seamounts and submarine volcanic features. Several of these rise to depths useful for bottomfish exploitation by simple hook and line gears.

The summits of these submarine features can include soft sediment, sand, rocky shale and debris to hard rock or rubble substrate. Desirable bottomfish species generally prefer hard bottom and are accessible by current fishing gears commonly used in both regions to a depth of 450 meters. In some cases, stocks of deepwater precious corals may be present at greater depths.

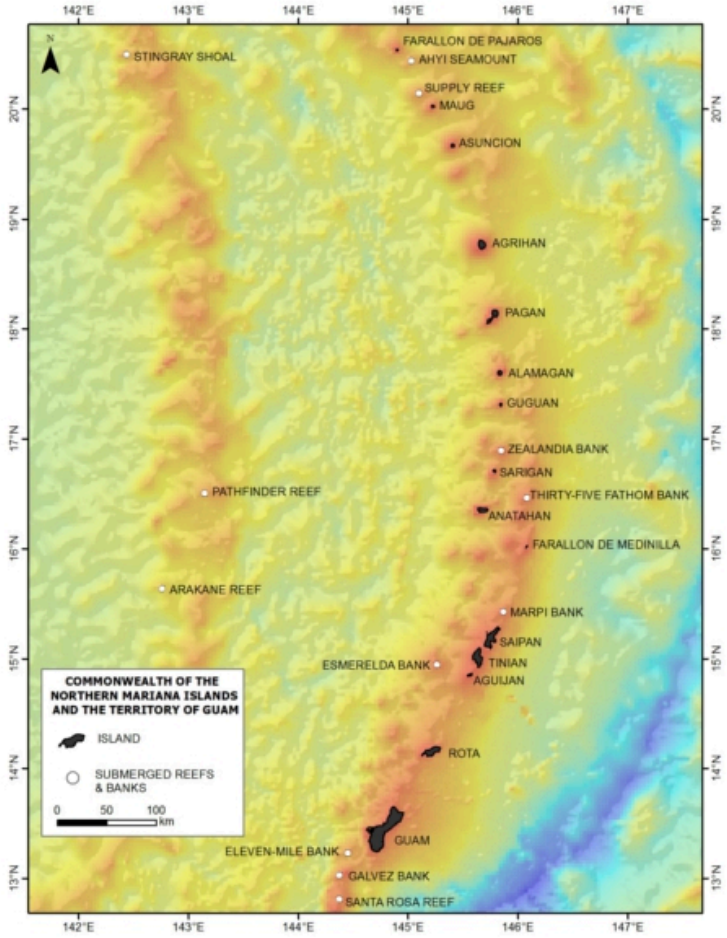


Figure 3. Islands (black) and submerged banks (white) of Guam and the CNMI

Data types and needs from this area?

Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

For the most part, the same bottomfish species exist in both regions and are important to support subsistence and artisanal small boat fisheries. The offshore bank areas are particularly productive for high value species such as the eteline snappers (*Etelis coruscans/*onaga, and *E. carbunculus* /ehu) and many species of high quality

snappers (*Pristipomoides* spp.) desirable for restaurant, hotel and export markets. Modern mechanical reels and new line materials allow fishers to exploit deeper waters for pomphrets (i.e. *Eumegistis illustris*) and alfonsins (*Beryx* spp.) Deepwater *Heterocarpus* spp. shrimp that are highly regarded in the sushi trade are also known to inhabit these submarine environments.

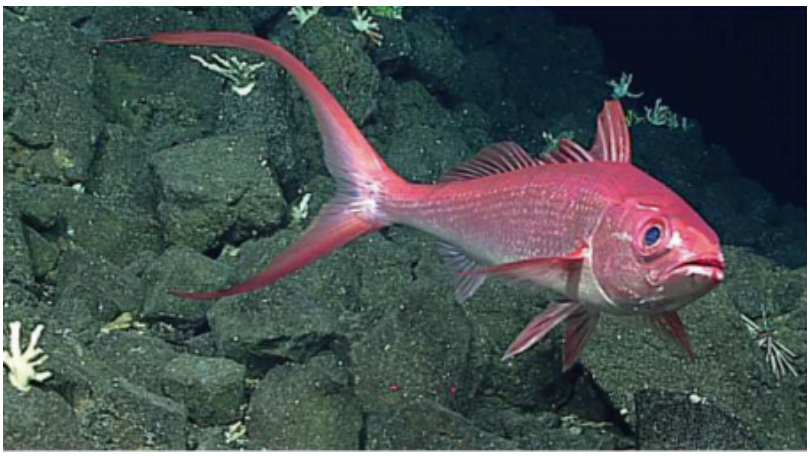


Figure 4. Onaga (Etelis coruscans) over hard bottom substrate (photo by HURL)

A considerable amount of bathymetric mapping has been done in these areas but fisheries management needs more than attractive pictures. In order to better manage these fisheries, the Western Pacific Fishery Management Council needs to know the amount of favorable benthic habitat that is available to these bottomfish species in federal waters under council management. These valuable species are found between 80 – 450 m and generally over hard bottom substrate (Figure 4). Bathymetric surveys and survey output should identify and display charts and provide output that highlights depth strata useful to examine discrete species assemblages such as the deep bottomfish complex.

In other words, bathymetric data should be collected on submarine features that can be directly useful to characterize and quantify bottomfish benthic habitat and productivity. This will allow more accurate estimates of resource biomass, improve stock assessment and promote the design of fishery independent surveys. More accurate characterization of benthic habitats as to substrate type and rugosity coupled with direct observations and sampling of different species will further refine their habitat preference in an iterative fashion. Information on the biology of the species, habitat preference and geology of the substrate will be required.

Relevance to national security, conservation, and/or the economy:

Surveys that support improved stock assessment and management can only be positive for the long term sustainability and conservation of bottomfish resources and the fisheries they support.

From your perspective, what makes this area unique?

Seamount environments are some of the most unique ecosystems on the planet and support fish communities not found elsewhere. These benthic communities are also sensitive to over exploitation, stressing the importance of sound management based on accurate stock assessment and estimates of sustainable yield.

Please list other partners or organizations that may also be interested in this area:
American Samoa Department of Marine and Wildlife Resources
Guam Division of Aquatic and Wildlife Resources
CNMI Division of Fish and Wildlife
NOAA Fisheries, Pacific Islands Fisheries Science Center

Workshop to Identify National Ocean Exploration Priorities in the Pacific

Author: David Itano
Institution: Western Pacific Regional Fisheries Management Council
Email Address: daveitano@gmail.com
Office Phone Number: (808) 522-8220
Collaborators/Co-Authors:

Title: Monitoring the condition and rate of recovery of fishery resources of the Emperor Seamounts useful for management

Priority Geographic Area:

Central North Pacific: Hancock Seamount (U.S. EEZ) and adjacent Emperor Seamounts (international waters)

Description of Priority Area:

The Hawaiian=Emperor seamount chain stretches from the Aleutian Trench some 6200 km south and southeast to the island of Hawaii and the Loihi submarine volcano that marks the mid-Pacific hotspot that created the entire chain of islands, atolls and seamounts. The populated main Hawaiian Islands extend northwest from Hawaii Island and connect to the Northwest Hawaiian Islands that terminate at Kure Atoll (28.4°N, 178.3°W) which represents the last emergent land in the chain. Further west, the Emperor Seamounts angle sharply north towards the Aleutian island chain (Figure 1).

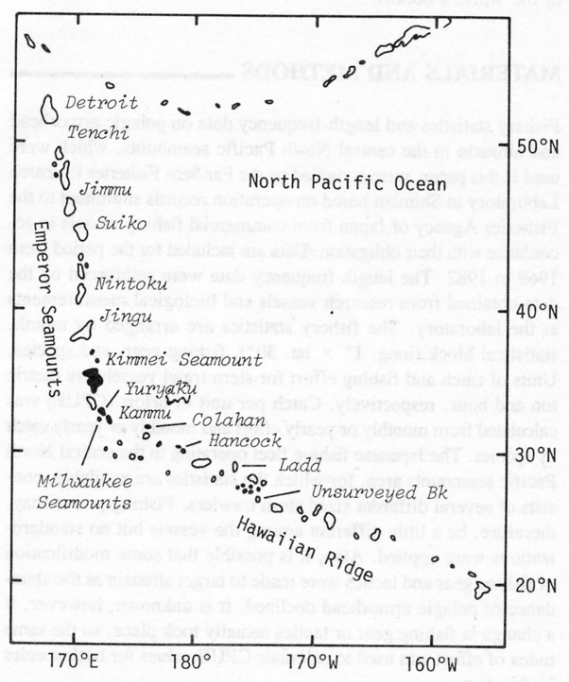


Figure 1. Hawaiian ridge and Emperor Seamounts (Sasaki 1986)

In 1967, Soviet stern trawlers began exploitation of seamount associated North Pacific armorhead (*Pseudopentaceros wheeleri*) with Japanese vessels joining the fishery two years later. Fishing concentrated initially on the Milwaukee and Kimmei Seamounts with effort including the Colahan Seamount. The Hancock Seamount lies within the U.S. 200 mile EEZ and consists of two discrete banks; Northwest Hancock and Southeast Hancock (Figure 2).

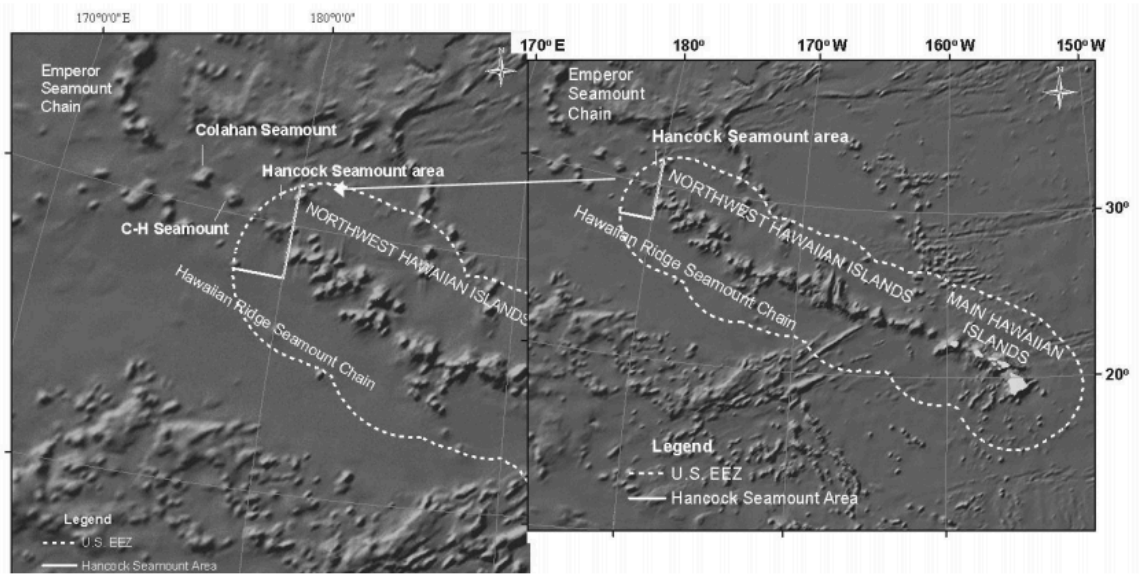


Figure 2. Right panel: the Main Hawaiian Islands and the Northwest Hawaiian Island chain. Left panel: close-up of the Hancock Seamount inside the U.S. EEZ. The Emperor Seamounts extend to the northwest (WCPFC 2010)

As stocks of armorhead declined, effort shifted to alfonsin (*Beryx splendens, B. decadactylus*) and other non-target species (Figure 3). The southern Emperor Seamounts were also heavily exploited for deepwater "Midway coral" (*Corallium secundum*) and other precious coral species, supplying more than half the world's pink and red coral during the late 1970s and early 1980s.

Figure 3. The north Pacific armorhead (left panel) and the splendid alfonsino (right panel)

Heavy fishing effort in the southern Emperor Seamount chain resulted in the largest documented biomass removals of fish and invertebrates from any seamount fishery in the world (Baco et al. 2019). The fisheries used deep trawl and coral tangle gear, both potentially damaging to seamount habitat and deep-water ecosystems. Poorly monitored and unregulated harvest lead to a stock collapse of North Pacific armorhead on all exploited seamounts. With passage of the Magnuson-Stevens Act in 1976 the U.S. gained management authority of the Hancock Seamount. Exploitation of both armorhead and precious corals has been placed in moratorium by the Western Pacific Regional Fishery Management Council since 1986 and the Hancock Seamount has since been included in the expansion of the Papahānaumokuākea Marine National Monument adding further protections to the seamount ecosystem (WPRFMC 2010).

The area is also an important fishing ground for albacore, fished by Japanese pole-and-line and longline vessels and is known to aggregate Pacific Bluefin tuna (*Thunnus orientalis*).

Data types and needs from this region

Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Benthic video surveys using autonomous underwater vehicles and deep diving manned submersibles were conducted in the 2014 – 2017 time period. A primary goal of these surveys was to document the condition of substrate, precious corals and coral beds on protected and still trawled sites of the Emperor Seamount chain, including Hancock seamounts. Surprisingly, protected areas showed some signs of coral regrowth from fragments at this 30-40 year time scale and a higher abundance of benthic megafauna (Baco et al. 2019).

Exploratory fishing and fish faunal surveys of the Hancock Seamount were conducted by NOAA/NMFS in the mid to late 1970s. Since active surveys by NOAA ceased, little or nothing is known of the seamount associated marine fauna of the Hancock and neighboring seamounts. Limited commercial fishing continues on adjacent seamounts in international waters under management by the North Pacific Fisheries Commission (NPFC).

If precious corals, known for their longevity and slow growth show some signs of recovery over a 30-40 year time scale, it would be useful and to survey the Hancock Seamount to document the status and recovery rate of the associated armorhead and alfonsin resources and general condition of the seamount ecosystem. Data needs include habitat mapping and characterization, the condition, distribution and abundance of habitat types with estimates of biomass present.

Information on the habitat condition, habitat recovery rates and species-specific biomass estimates from a fully protected seamount would be beneficial to science and the management of exploited seamounts managed by the NPFC and other agencies. Data on species-specific biomass estimates from acoustic surveys are required to provide information on recovery rates of these unique seamount environments.

Relevance to national security, conservation, and/or the economy:

The Hancock Seamount is protected from fishing activity being within the U.S. management system while sharing biotic characteristics of unprotected seamounts to the west. As such, it is a valuable study area to document the life history, biology and rates of recovery of seamount associated North Pacific armorhead resources useful for long term conservation of the species.

However, the location of the Hancock Seamount at the western extreme of the Hawaii EEZ, almost 2300 km northwest of Honolulu is difficult to monitor and protect from IUU fishing activity. Added interest and increased U.S. presence in this area would help to protect this area and enhance national security of US waters.

The seamount has been subject to a fishery moratorium since 1986 when the Fishery Management Plan for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region was implemented. The Hancock Seamount has now been included within the expansion area of the Papahānaumokuākea Marine National Monument and reopening of any commercial fishery is highly unlikely. However, this protected seamount can serve as a study site of seamount ecology and recovery from overfishing useful for the management and conservation of seamount ecosystems.

From your perspective, what makes this area unique?

The Emperor Seamounts are one of the most extensive and biologically unique seamount groups in the world. Seamounts are known to support highly productive and specialized ecosystems that include precious corals and unique deep water habitats. If seamount summits are within 200-500 m, they often form productive fishing grounds for tuna and other pelagic species. The Emperor Seamounts are unique in being the biological center and home to the North Pacific armorhead that is not known from other areas of the Pacific.

Please list other partners or organizations that may also be interested in this area:

North Pacific Fisheries Commission
NOAA Office of National Marine Sanctuaries (Papahānaumokuākea Marine National Monument)

References

Baco, A. R., E. B. Roark, N. B. Morgan. 2019. Amid fields of rubble, scars, and lost gear, signs of recovery observed on seamounts on 30- to 40-year time scales. Sci. Adv. 2019.

Sasaki, T. 1985. Development and present status of japanese trawl fisheries in the vicinity of seamounts. Bull. Jpn. Soc. Fish. Oceanogr. 47/48, 161-166, 1985.

WPRFMC. 2010. Management Measures for the Hancock Seamounts to Address the Overfished Condition of Armorhead (*Pseudopentaceros wheeleri).* Amendment 2 to the Fishery Ecosystem Plan for the Hawaii Archipelago. August 6, 2010. Western Pacific Regional Fishery Management Council. 41 pp.

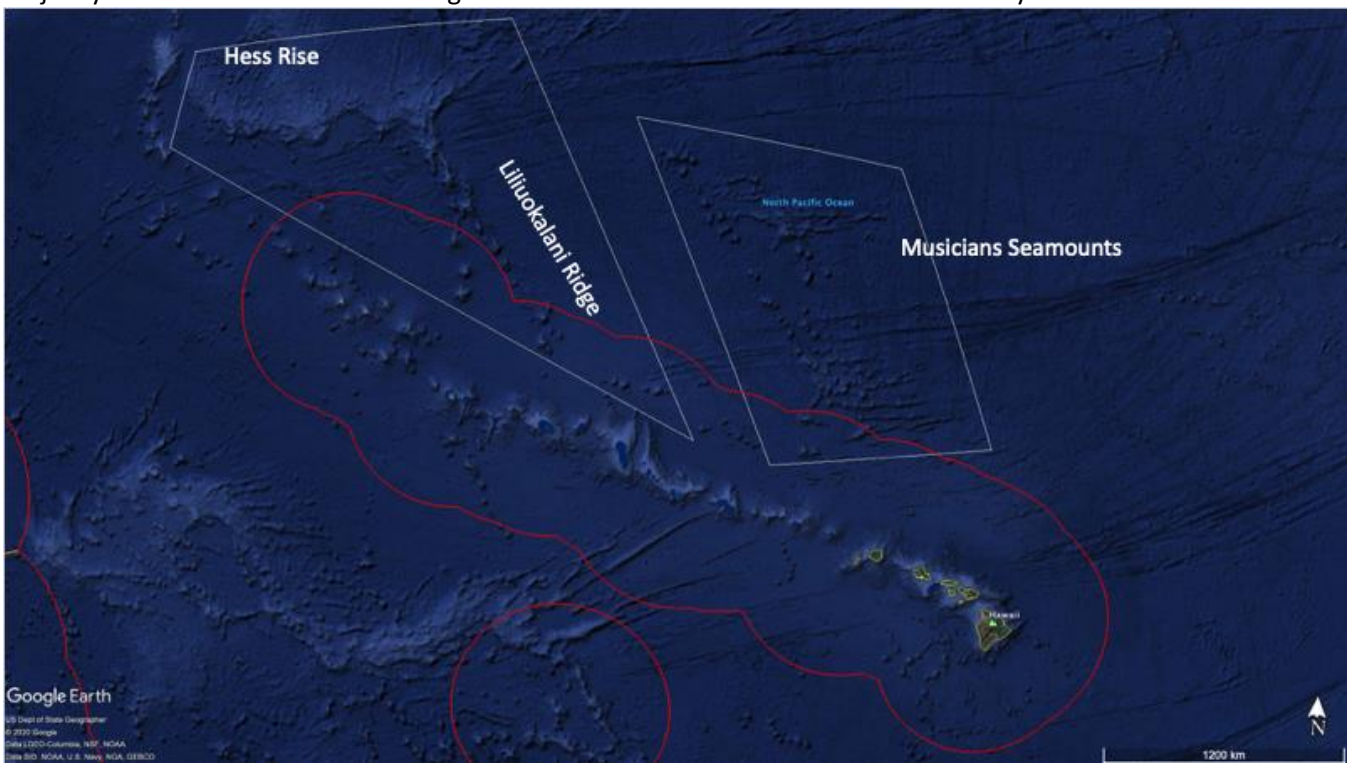
Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Brian Kennedy
Institution: Boston University
Email Address: KennedyB@bu.edu
Office Phone Number: 706-540-2664
Collaborators/Co-Authors: Randi Rotjan(rrotjan@bu.edu)

Title: Hess Rise, Liliuokalani Ridge, and Musicians' Seamounts

Priority Geographic Area:
The Liliuokalani Ridge, and Musicians' Seamounts both have seamounts that are inside the US EEZ but the majority of the features are on the High Seas north of Hawaii. The Hess Rise is entirely in international waters.



Description of Priority Area:
The Musicians Seamounts are a line of seamounts Northwest of the main Hawaiian Islands that continue to the Northwest for about 1,200 kilometers. There are numerous seamounts in this group, with most having never been visited using deep submergence technology. The Musicians Chain also intersects the western end of the Maury fracture zone.

Similar to the Musicians Seamounts, the Hess Rise and Liliuokalani Ridge are comprised of numerous seamounts, but also has a general rise of the seafloor. This feature lays at an interesting junction of the Emperor Seamounts,

Mendocino Fracture Zone, and the Northwest Hawaiian Islands making this area a possible mixing area for different endemic fauna. It should also be noted that the southernmost reaches of the Liliuokalani Ridge fall within the expanded boundaries of Papahanaumokuakea.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Both regions will benefit greatly from mapping and visual exploration. The only exploration of these areas we are aware of is from the Okeanos Explorer in 2017, which only explored the Musicians Seamounts (Kennedy et al., 2019; Smith et al., 2018). To the best of our knowledge, no deep submergence exploration has occurred at either Hess Rise or Liliuokalani Ridge.

The only mapping data available at NCEI other than transit lines is from the Okeanos' work in 2017 leaving the majority of these features completely unmapped.

Describe relevance to national security, conservation, and/or the economy:

The waters above the Musicians Seamounts is known to be an active fishing ground for Hawaiian based long liners. Given similar organographic and bathymetry it stands to reason that the Hess Rise and Liliuokalani Ridge may also be productive fishing grounds. As such, these areas may be of particular interest to the Pacific Islands Fisheries Management Councils.

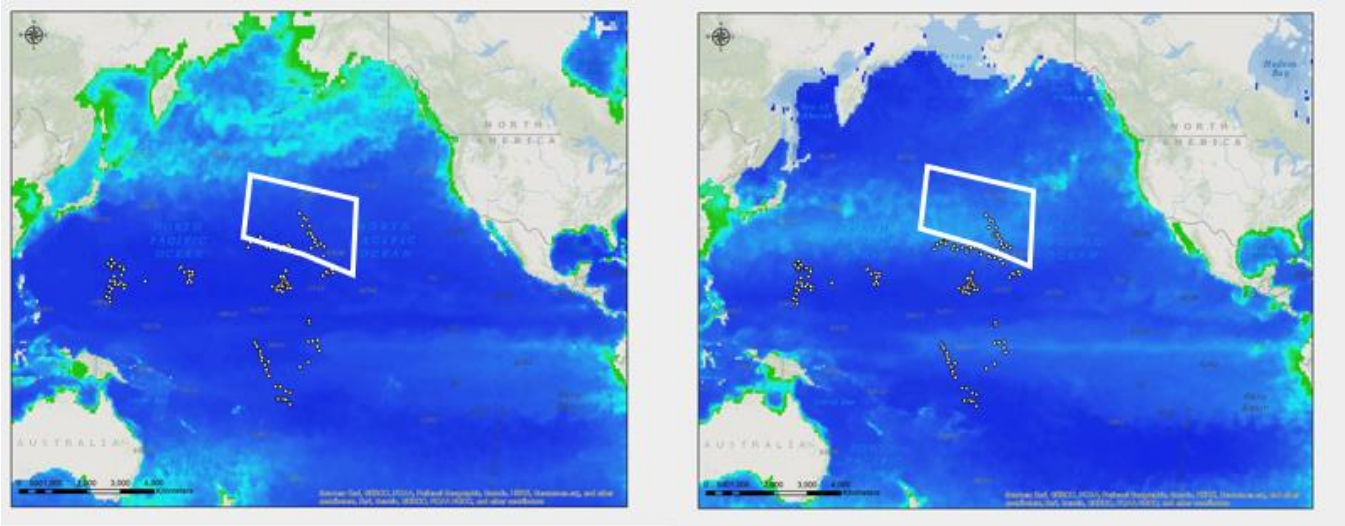
From your perspective, what makes this area unique?
(If applicable, why is this area relevant to your organization?)

Initial exploration of the Musicians Seamounts by the *Okeanos Explorer* in 2017 revealed an unexpected diversity and abundance of deep sea sessile fauna. Compared to other areas visited during CAPSTONE, the Musicians were notably different with the majority of the dive sites hosting high density coral and sponge communities. Dive sites revealed high density coral and sponge communities much more frequently than other areas. As such, the Musicians' are worthy of additional exploration effort.

Similarly, the Hess Rise and Liliuokalani Ridge are at approximately the same latitude and further west than the Musicians. As such, they likely have a similar diversity and abundance of deep-sea corals and sponges, but to our knowledge, these areas have never been explored. These areas are thus a prime target for the next round of Pacific exploration.

These three feature all lay at interesting intersection of oceanographic conditions between the oligotrophic waters of the subtropical gyre and the much more productive waters of the North Pacific. As shown in the images below, the area of the Hess Rise and Musicians Seamounts are seasonally below much more productive waters, which likely explains - at least in part - the increase in abundance discovered by the *Okeanos* in 2017. This convergence of water masses has also been hypothesized to be a break between biogeographic provinces

(Sutton et al., 2017; Watling et al., 2013). Therefore, these regions are likely to reveal interesting new life in great abundance, but will also help us better understand the biogeography of the deep sea.



Net Primary Productivity(NPP) with CAPSTONE dive sites. Summer 2015 is displayed in the left pane with winter shown on the right. The white polygon denotes the rough location of the Rise Rise, Liliuokalani Ridge, and Musicians Seamounts The annual changes in the location of high NPP make the Hess Rise and Musicians Seamounts particularly interesting areas to explorer.

Please list other partners or organizations that may also be interested in this area:

Pacific Island Science Center
Pacific Islands Regional Office
Pacific islands Fisheries Management Council
University of Hawaii

Work cited:

Kennedy, B. R. C., Cantwell, K., Malik, M., Kelley, C., Potter, J., Elliott, K., et al. (2019). The Unknown and the Unexplored: Insights Into the Pacific Deep-Sea Following NOAA CAPSTONE Expeditions. *Frontiers in Marine Science*, *6*(August), 1–21. https://doi.org/10.3389/fmars.2019.00480

Smith, J. R., Putts, M. R., Mittelstaedt, E., Cantwell, K., Lobecker, E., & White, M. (2018). Symphony of the Deep: Exploration of the Musicians Seamounts. *Oceanography*, *31*(1 Supplemental).

Sutton, T. T., Clark, M. R., Dunn, D. C., Halpin, P. N., Rogers, A. D., Guinotte, J., et al. (2017). A global biogeographic classification of the mesopelagic zone. *Deep-Sea Research Part I: Oceanographic Research Papers*, *126*(May), 85–102. https://doi.org/10.1016/j.dsr.2017.05.006

Watling, L., Guinotte, J., Clark, M. R., & Smith, C. R. (2013). A proposed biogeography of the deep ocean floor. *Progress in Oceanography*, *111*, 91–112. https://doi.org/10.1016/j.pocean.2012.11.003

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Randall Kosaki
Institution: NOAA Office of National Marine Sanctuaries (Papahānaumokuākea Marine National Monument)

Email Address: randall.kosaki@noaa.gov
Office Phone Number: 808-725-5816
Collaborators/Co-Authors: Christopher Kelley, Hawai'i Undersea Research Lab (University of Hawai'i)

Title: Biodiversity of Seamounts in the Papahānaumokuākea Marine National Monument

Priority Geographic Area:
(Indicate if within U.S. EEZ or international waters.)
Papahānaumokuākea Marine National Monument (PMNM), Northwestern Hawaiian islands, U.S. EEZ

Description of Priority Area:

All proposed seamount sites are unexplored. These seamounts represent unique deep-sea environments, providing hard bottom benthic substrate in an otherwise pelagic and/or soft-sediment environment. These seamounts are geographically isolated, and likely support high diversity, high endemism benthic communities.

Priority areas for exploration lie outside of PMNM's old 50 nautical mile boundaries, and within the so-called "expansion area" that was added to PMNM via a presidential proclamation 2016. The new boundaries extend to the 200 nautical mile limit of the US EEZ, and encompass over 1.5 million square kilometers.

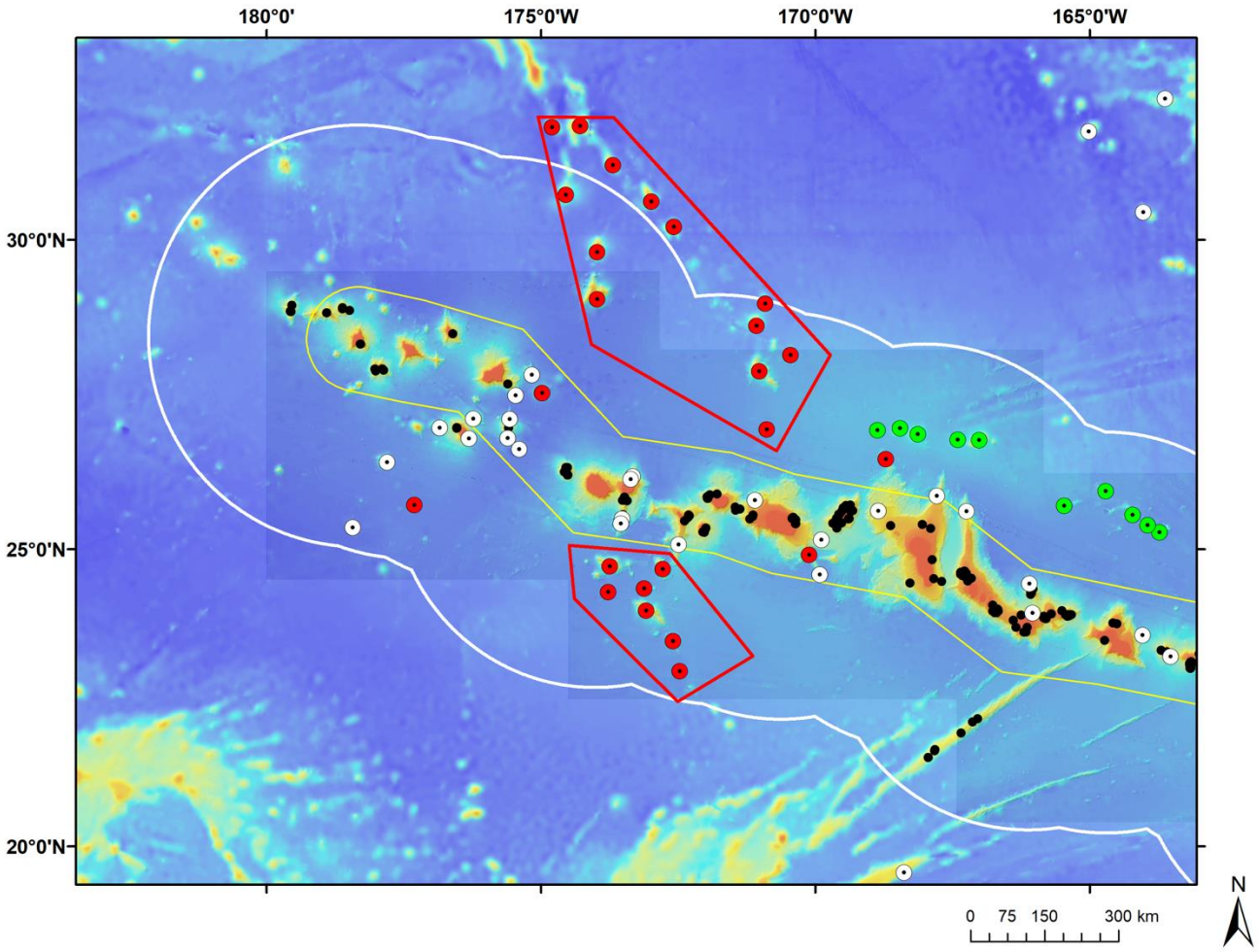
On the figure, the black dots are old Hawai'i Undersea Research Lab (HURL) dive sites, the white dots are *Okeanos Explorer* 2015-16 dive sites, and the green dots are the 2018 *Nautilus* sites. The red dots are proposed priority dive sites for this new initiative and are boxed into two groups, one above and the other below the Hawaiian Ridge.

The northern sites straddle the PMNM boundary and are seamounts of the Lili'uokalani Ridge. These seamounts most likely did not originate at or near the Hawaiian hotspot, and are likely of Cretaceous origin. The biological communities should be spectacular given how remote they are. Of geological interest is that this chain appears to split right at the upper part of the red box. Basalt samples will enable us to determine the volcanic process (es) that created this anomaly (hot spot volcanism, spreading center volcanism, or both) and whether both legs should be considered part of the Lili'uokalani Ridge, or whether some other process created at least one of the lower legs extending into the monument. Even if dives were restricted to sites within PMNM, the rock samples would enable us to better understand this peculiar seamount pattern. The seamounts in this chain that are located inside PMNM include Nootka, Boussole, King George, Loudoun, Mercury, and Solide.

The southern sites includes seamounts that appear to be a part of the Wentworth seamount chain that originated further north at the Hess Rise then continued down into PMNM, bisecting the Hawaiian Ridge and continuing down towards the Necker Ridge. Again, there is a very high probability of encountering high density sponge and coral communities, and rock samples would determine whether the Wentworth chain does indeed

run through the monument. These are also likely to be very old Cretaceous seamounts, and confirmation of their ages would support the hypothesis that the Hawaiian chain actually ran right through this chain which was already on the sea floor when the Hawaiian Ridge was formed. These seamounts include Don Quixote, Ha'aheo, and the Voyager seamounts.

Four other seamount sites are also shown on the map, all of which are lower priority and could be visited during transit between the 2 boxes. None of the seamounts in or outside of the boxes has ever been explored or dredged. Furthermore, most have never been mapped.



What are the characterization and data needs in this area?
Check all that apply:
__X_ Biology
__X_ Geology
___ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Multibeam mapping is desired from all unexplored seamounts. Documentation of biodiversity will require ROV dives to obtain high resolution video images and the collection of voucher specimens. Dating of seamounts to

confirm the hypothesis of their Cretaceous origin will require samples of basalt from each seamount for potassium-argon or other radiometric dating.

Describe relevance to national security, conservation, and/or the economy:
Documentation of biodiversity is a critical cornerstone of conservation biology. In particular, seamounts are considered hotspots of biodiversity, and due to their isolation, may harbor numerous unique endemic species and many species that are new to science. Damage to seamounts and overexploitation can have widespread consequences for ocean health, food security, and potential discovery of valuable pharmaceutical compounds. Seamount biodiversity is threatened by a number of human activities, including direct and indirect impacts from deep-sea mining of manganese nodules and crusts. A majority of seamounts are found in waters beyond national jurisdictions, which makes enacting protections problematic and challenging. A majority of the seamounts identified as priority research sites here lie within the US EEZ, offering an unusual opportunity to effect high levels of protection should unique and/or biodiverse communities be discovered.

From your perspective, what makes this area unique?
(If applicable, why is this area relevant to your organization?)
The proposed priority dive sites lie within the expansion area of PMNM. The presidential proclamation protecting this area directs NOAA to consider initiating the process to designate PMNM as a National Marine Sanctuary under the National Marine Sanctuaries Act (16 USC 1431 *et seq*.), as well as to undergo a management plan revision. With these actions, all aspects of Sanctuary management are on the table for consideration, including boundaries, levels of protection, and rules/regulations. This proposed exploration provides a unique opportunity for the best available science to drive natural resource management and the design and execution of the largest marine protected area under US flag (and one of the largest MPAs in the world).

Please list other partners or organizations that may also be interested in this area:

Hawai‘i Undersea Research Lab (University of Hawai‘i)

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Lisa Levin
Institution: Scripps Institution of Oceanography
Email Address: llevin@ucsd.edu,
Office Phone Number: 858-534-3579
Collaborators/Co-Authors: Paul Jensen, Scripps Institution of Oceanography

Title: Characterizing the ecosystems associated with mineral deposits (phosphorites and polymetallic crusts) in the North Pacific Ocean.

Priority Geographic Area:

Phosphorites: Southern California (US EEZ)
Fe-Mn Crusts: Southern California Borderland (US EEZ); seamounts of the Clarion Clipperton Zone (International waters); Magellan Seamounts (within the EEZ of the Commonwealth of the Northern Mariana Islands).

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)

California (Fig 1,2): Fe-Mn crusts are common on seamounts off California (**Fig. 1**) and are enriched in Te, Co, Mo, Bi, Pt, Nb, W, Zr, as well as rare earth elements (REEs) (Hein et al. 2016, Conrad et al. 2017). These mineral formations not only have commercial value but also provide substrate for foundation species like sponges and corals, and habitat for feeding, reproduction, and refuge (Tissot et al. 2006). Phosphorite is enriched in the Southern California Bight (SCB), having long ago been documented at depths from 80-1000 m where it occurs as slabs and fragments, with high concentrations of heavy REEs. The SCB phosphate deposits were considered for mining by dredging as early as the 1940s (Dietz et al. 1942). Phosphorites are present in this region as oolites (small spherical grains) to large 50 cm nodules with an average size of 5 cm, and can have attached to them corals, bryozoans, sponges, serpulids and brachiopods, as well as animals that bore into the rock.

Clarion Clipperton Seamounts (Fig. 3): The Clarion Clipperton zone abyssal plain is punctuated by more than 300 seamounts with diameters ranging from 3 to 30 km and heights between a few hundred meters up to 2700m (Rühlemann et al., 2011, Wedding et al. 2016). Some of these fall into the depth zone suitable for formation of Fe-Mn crusts (ie, with summits above 2500 m) (Hein et al. 2009); these would be targeted for observation. There are few biological observations on these seamounts as attention has been focused on the deeper abyssal plains hosting polymetallic nodules.

The Prime Crust Zone CNMI (Fig. 4): Ferromanganese crusts have been slowly precipitating (~1mm/Myr) onto the exposed rock surfaces of the Magellan seamounts, ridges, and guyots since 55 MYA and as a result of the long growth time are some of the thickest in the world (Glasby et al., 2007). The Dutton Ridge, Fryer Guyot, half of Vogt Guyot, and various smaller seamounts are either known or suspected to have ferromanganese crusts and nodules, and fall within the Exclusive Economic Zone (EEZ) of the Commonwealth of the Northern Mariana Islands (CNMI), a U.S. territory (Hein et al., 2005).

What are the characterization and data needs in this area?
Check all that apply:
__x Biology
__x Geology (geochemistry)
___ Marine Archaeology
___ Physical Oceanography
__x Chemistry
__x Other (microbiology)

Provide a list or brief description of the data needed within this area, from your perspective:
Data needed would include bathymetric data (multibeam mapping to guide ROV activities), mineralogical characterizations, hydrographic profiling and biological surveys for both faunal and microbial components including genomic/metabolomics. Video surveys, rock sampling, CTD casts (to the seafloor) for characterization of oxygen, T, S and suspended particles), and sediment coring would all be desired.

Describe relevance to national security, conservation, and/or the economy:
There is an ongoing search for new mineral resources to meet growing industrial demands for phosphorous, a key component of fertilizer, metals and rare earth elements, which drive myriad technologies including important new green technologies. In an effort to meet these needs, deep-water phosphorites and Fe-Mn crusts and nodules are being targeted by the mining sector as a source of phosphorus, cobalt, nickel, copper, and rare earth elements including yttrium. Phosphorites occur on continental margins, seamounts and in lagoons. Fe-Mn crusts and nodules are targeted in international waters (and within the Cook Island EEZ) as polymetallic nodules on abyssal plains, as well as on and cobalt-rich crusts on seamounts, banks and ridges. Exploitation often occurs prior to characterization of the ecosystems associated with the targeted resources, and rarely are other potential ecosystem services or genetic resources considered in these debates.

Acquiring baseline information describing biodiversity and community structure prior to commercial exploitation provides a basis for future decision making and impact assessments should these resources be considered for development. Here we describe a need for biodiversity exploration via biotic surveys of poorly known ecosystems that are rich in phosphorites and polymetallic crusts. These ecosystems often support fisheries activities, and the hardgrounds support corals, sponges, xenophyophores and other structure-forming taxa (often indicators of vulnerable marine ecosystems). Seamount substrates with and without ferromanganese crusts appear to differ from one another (e.g., Schlacher et al., 2014). Furthermore, baseline data describing the microbial diversity associated with these habitats will provide opportunities to assess biopharmaceutical potential in addition to community structure. This research has both conservation and economic relevance.

From your perspective, what makes this area unique?
These areas contain resources potentially targeted for minerals mining, but also are in settings typically of interest to fisheries. They span national and international waters and may provide clues about changes in resource-rich habitats from the East to West Pacific, and from nearshore to offshore regions with different oxygen minimum zone influence. Exploration could contribute to decision making by the US (BOEM and other agencies), the International Seabed Authority, and even BBNJ negotiations.

Please list other partners or organizations that may also be interested in this area:
US Geological Survey

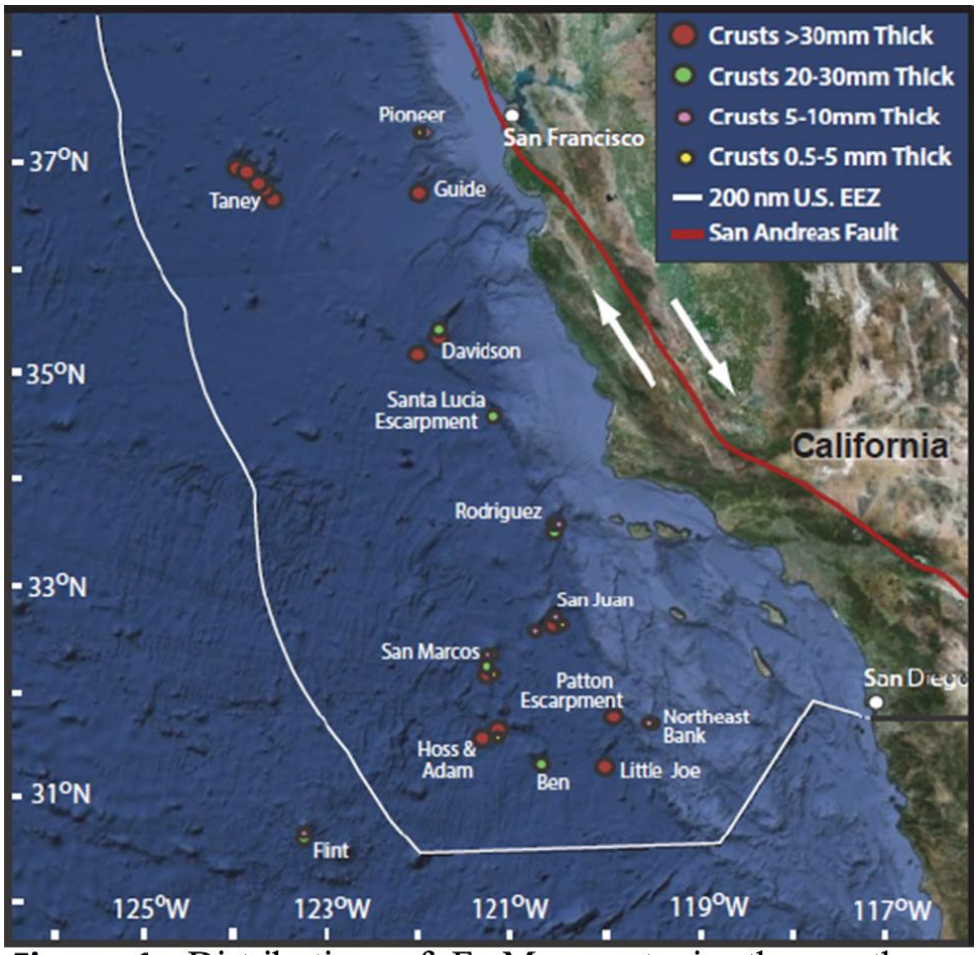
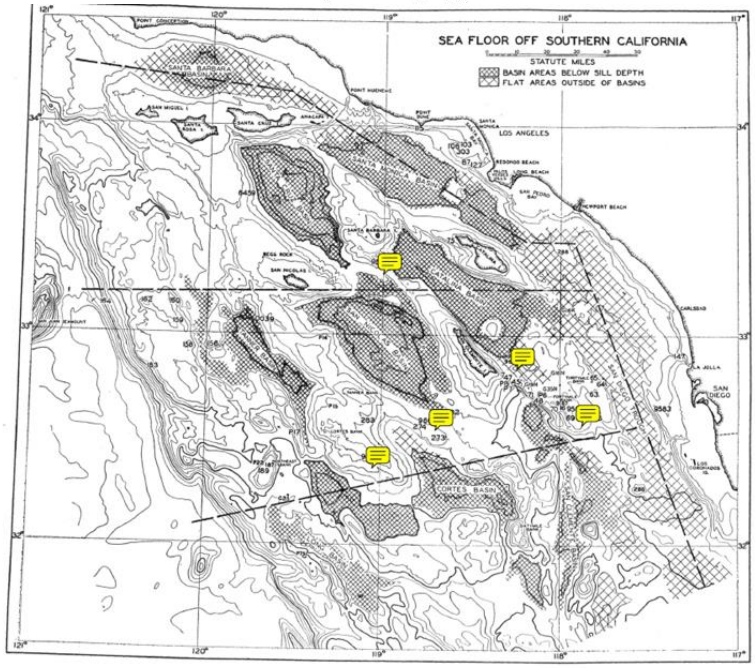


Figure 1. Distribution of Fe-Mn crusts in the southern California Borderland (from [5]).



PHOSPHORITE *LOCALITIES OFF SOUTHERN CALIFORNIA*

Showing the relation of phosphorite to the topographic highs. Contour interval 900 feet with the 300 foot contour added. Large numbers refer to samples containing large fragments of phosphorite and small numbers to samples containing only phosphatic oölites or phosphatic coverings on other rocks. Dashed lines indicate arbitrary divisions of continental borderland related to phosphorite abundance. (*See* text).

Fig. 2. Distribution of phosphorites in southern California from Dietz 1942.

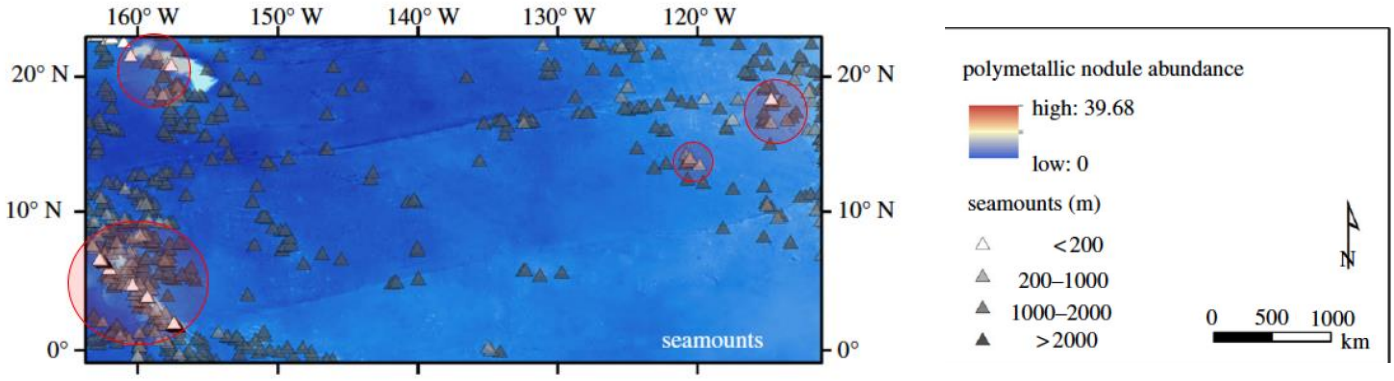


Figure 3. Location of seamounts with summits of varying depths, from Wedding et al. 2016. Areas circled in red contain multiple seamounts at depths suitable for precipitation of polymetallic crusts.

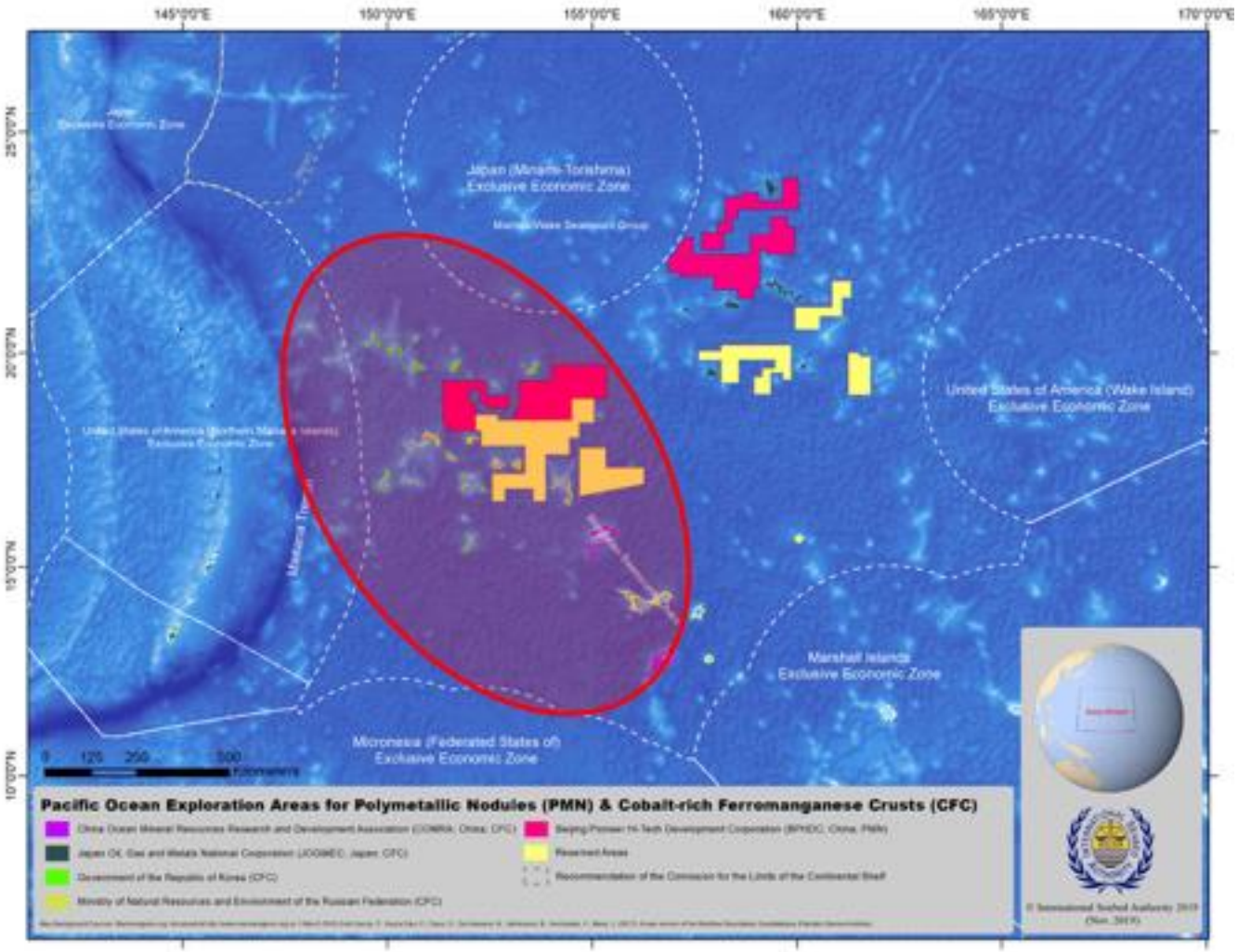


Figure 4. Pacific Ocean exploration areas for polymetallic nodules (PMN) and cobalt-rich ferromanganese crusts (CFC) with the Magellan chain circled in red. (modified from International Seabed Authority).

References

Conrad, T., et al., *Formation of Fe-Mn crusts within a continental margin environment.* Ore Geol Rev, 2017. **87**: p. 25-40.

Dietz, R.S., K. Emery, and F. Shepard, *Phosphorite deposits on the sea floor off southern California.* Bull Geolog Soc Amer, 1942. **53**(6): p. 815-848.

Glasby, G. P., Ren, X., Shi, X., and Pulyaeva, I. A., (2007). Co–rich Mn crusts from the Magellan Seamount cluster: the long journey through time. Geo-Mar Lett. 27: 315–323. doi: 10.1007/s00367-007-0055-5

Hein, J. R., McIntyre, B. R., and Piper, D. Z., (2005). Marine Mineral Resources of Pacific Islands – A Review of the Exclusive Economic Zones of Islands of U.S. Affiliation, Excluding the State of Hawaii. Circular 1286, U.S. Geological Survey, Reston, Virginia.

Hein, J.R.; Conrad, T.A.; Dunham, R.E. Seamount characteristics and mine-site model applied to explorationand mining-lease-block selection for cobalt-rich ferromanganese crusts. Mar. Georesour. Geotechnol. **2009**, 27, 160–176

Hein, J.R., et al., *Marine phosphorites as potential resources for heavy rare earth elements and yttrium.* Minerals, 2016. **6**(3): p. 88.

Rühlemann, C., Kuhn,et al. 2011. Current status of manganese nodule exploration in the German license area. In: Proceedings of the ninth(2011) ISOPE Ocean Mining Symposium .International Society of Offshore and Polar Engineers(ISOPE),Maui,pp.168–173.

Schlacher, T.A., Baco, A.R., Rowden, A.A., O'Hara, T.D., Clark, M.R., Kelley, C. and Dower, J.F. (2014), Seamount benthos in a cobalt-rich crust region of the central Pacific: conservation challenges for future seabed mining. Diversity Distrib., 20: 491-502. doi: 10.1111/ddi.12142

Tissot, B.N., et al., *Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral.* Fishery Bulletin, 2006. **104**(2): p. 167-181.

Wedding LM, Friedlander AM, Kittinger JN, Watling L, Gaines SD, Bennett M, Hardy SM, Smith CR. 2013 From principles to practice: a spatial approach to systematic conservation planning in the deep sea. Proc R Soc B 280: 20131684. http://dx.doi.org/10.1098/rspb.2013.1684.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Russell E. Matthews
Institution: SEARCH
Email Address: mike.brennan@searchinc.com
Office Phone Number: 904-379-8338
Collaborators/Co-Authors: Michael L. Brennan, James P. Delgado

Title: Aviation's Lost Pioneers: Pan American Airways *Samoan Clipper* (NC16734)

Priority Geographic Area:
Within EEZ off American Samoa (see attached description and map)

Description of Priority Area:
Survey area 8-12 miles north of American Samoa. See attached description.

What are the characterization and data needs in this area?
Check all that apply:
___ Biology
___ Geology
_x_ Marine Archaeology
___ Physical Oceanography
___ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
High resolution multibeam bathymetry and, where possible, ROV dives for target identification, inspection, and characterization. Potential for AUV survey.

Describe relevance to national security, conservation, and/or the economy:
This target is to locate and document the crashed Samoan Clipper aircraft that carried some of America's aviation pioneers, and can be preserved through high resolution sonar and imagery.

From your perspective, what makes this area unique?
The well-known story of Ed Musick and the crew of the Samoan Clipper can be brought to light through telepresence-enabled exploration.

Please list other partners or organizations that may also be interested in this area:
BOEM, NOAA, DPAA

Aviation's Lost Pioneers: Pan American Airways *Samoan Clipper* (NC16734)
Russell E. Matthews, Michael L. Brennan, James P. Delgado

Throughout the 1920s and 30s, Pan American Airways was at the forefront of an audacious effort to establish aerial links between the USA and the rest of the globe that would ultimately help to define the modern air transport industry. The most challenging and highly romanticized routes were those that stretched across the vast Pacific Ocean and the flying "Clippers" that plied them came to symbolize Aviation's Golden Age.

Captain Edwin C. Musick.

Today, virtually nothing of PAA's trailblazing fleet of seaplanes may be seen anywhere on Earth. The major traces that survive remain hidden beneath the sea and the most significant of these is *Samoan Clipper* (NC16734).

Built by Sikorsky Aircraft, *Samoan Clipper* was an S-42B type flying boat specially modified for long distance survey work. It went down in January 1938 on a pioneering flight attempt to inaugurate regular air mail service between the United States and New Zealand under the command of Pan Am's legendary Chief Pilot, Captain Edwin C. Musick. An accomplished veteran with an impressive 25 year career in the skies, Musick held more records and honors than any other active flier, including the Harmon Trophy which recognized him as "the world's outstanding aviator."

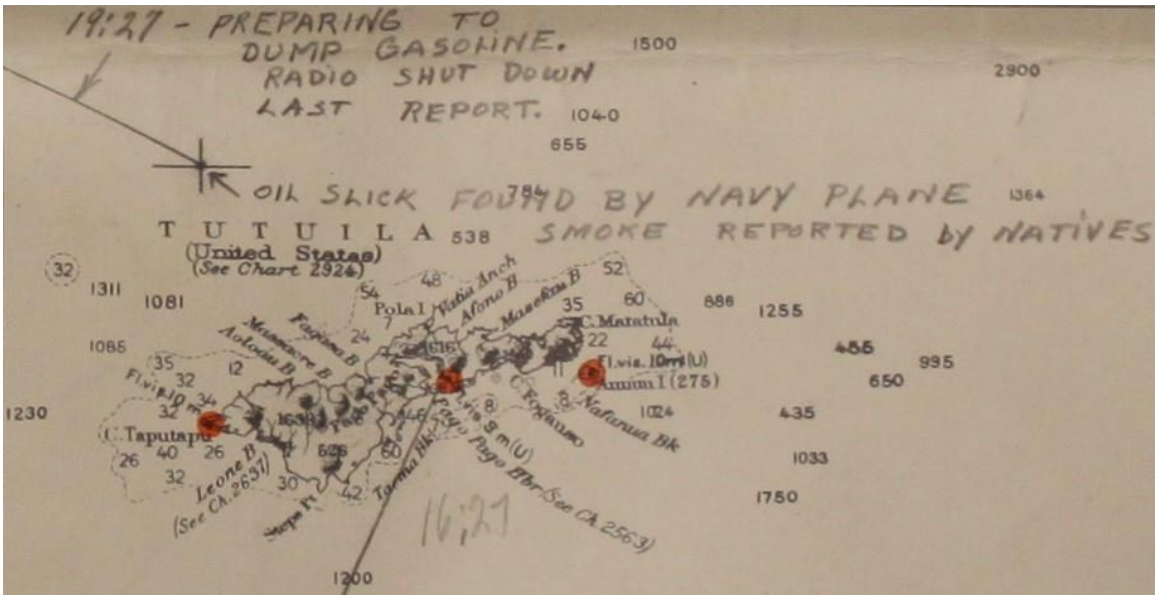
On the morning of 11 January 1938, shortly after takeoff from Pago Pago, American Samoa and bound for Auckland, an oil leak forced the shutdown of one of the plane's four engines and Musick elected to return to base. The stricken craft was mere minutes from safety when all radio communication ceased. Soon eyewitness reports of a crash and rising smoke filtered in from the island's northwest coast, leading to a US Navy air search that discovered an ominous oil slick on the ocean surface. At dawn the following day, USS *Avocet* (AVP-4) reached the scene and confirmed everyone's worst fears, recovering small charred items of floating debris definitively tied to *Samoan Clipper*. The tragic news filled banner headlines in America and around the world. Investigators from the Bureau of Air Commerce (BAC) later speculated that the plane caught fire and exploded while dumping fuel to shed weight prior to landing, instantly killing all seven crew members on board. However, a precise determination of cause was impossible without examining the wreck, believed to rest at least 1,000 fathoms beneath the waves, far beyond the reach of any technology available at that time.

76 years later, the search for *Samoan Clipper* was renewed with a white paper study (Matthews et al) presented at the 2014 workshop on Telepresence-enabled Exploration of the Eastern Pacific Ocean. Musick's lost plane emerged from that expert gathering as a "high priority" target and the investigation continued in earnest, collecting and analyzing a wealth of original plans, specifications, photographs, ship's logs, radiograms and reports from a wide variety of archival sources.

In July 2019 an expedition was launched by the nonprofit Air/Sea Heritage Foundation in collaboration with SEARCH and the Ocean Exploration Trust (OET) to hunt for the wreckage of *Samoan Clipper*. Sailing from Pago Pago aboard E/V *Nautilus*, it took only a brief transit to reach the estimated loss position as

recorded in the BAC accident report (12 miles north of Tapu Tapu Point, the western most tip of American Samoa's main island, Tutuila). There, for six straight days, a combined complement of 45 scientists and crew worked around the clock, methodically scanning the ocean floor below for signs of the sunken airliner and following a grid overlaid on recent bathymetry collected by the NOAA ship *Okeanos Explorer* at the request of the project team back in April 2017. The main investigative tool was *Argus*, a tethered Remote Operated Vehicle (ROV) specially equipped for this mission with side-scan sonar transducers in addition to its usual camera and lighting package. *Argus* crisscrossed the prime search area in disciplined rows, "mowing the lawn" for a record-setting 125 hours of continuous underwater operations at depths averaging more than 3,000 meters (and for a total dive time of 133 hours). A second ROV, *Hercules*, with additional cameras and lights as well as greater maneuverability, stood by to be reintegrated with *Argus* in the event of any promising discovery.

Sonar readouts and direct video feeds from the seabed, along with audio of the science team on watch, streamed uninterrupted over the internet via satellite in real time throughout the expedition. These powerful telepresence tools allowed for robust public engagement to a worldwide online audience in no fewer than 100 countries. They also permitted a handpicked cadre of additional specialists, scholars, and scientists ashore to contribute remotely as needed. And a select number of museums, educational institutions and STEM oriented youth camps were given the opportunity for live video interaction with search team members in the field.



Detail of original *Samoan Clipper* search map from the PAA Archives.

Ultimately the 2019 *Samoan Clipper* expedition mapped and eliminated more than 25 square kilometers of previously unexplored seabed, yet the team was frustrated in its principal objective to locate the lost plane. However, we remain undaunted. The evidence collected immediately after the crash is unequivocal and there can be no doubt that the wreck rests somewhere very close by. The clock simply ran out on this mission before we could pinpoint it.

The entire team is eager to return and finish the job we started. Ideally, the next search for *Samoan Clipper* will be equipped with a deep-diving Autonomous Underwater Vehicle (AUV), enabling us to cast a far wider net. The major limiting factor of our previous effort was the sheer weight and drag of the 3,000 meter steel tether which limited the ship's speed of advance to little more than 1 knot. An

unencumbered AUV could survey the same amount of territory at far higher resolution and with 200% coverage over the course of a single day, making it possible to blanket the sea floor off Tutuila's northwest coast in relatively short order.

Given more time and the proper tools, we are confident the remains of *Samoan Clipper* will be found (likely very near the previous search area and probably closer to shore, which would align with the eyewitness account and known wind and sea states from the hours following the crash). Such a discovery would be of major significance to aeronautical history. *Samoan Clipper* was the first serious loss suffered by seminal air carrier Pan American and its illustrious Pacific Division. At present, no example of the innovative Sikorsky S-42 type aircraft survives in any museum or private collection worldwide, nor are there any (currently) known wrecks. The sunken *Samoan Clipper* represents a unique opportunity to study the most consequential of these craft and to do so in context of its pioneering survey work and tragic loss. It would contribute immensely to our (so far limited) knowledge about the formation of deep-water aviation archaeological sites. Further heightened by association with the influential Edwin Musick, his remarkable career and untimely death, the importance of this site cannot be denied. Nor should it be forgotten that the remains of *Samoan Clipper* now serve as a grave marker for the captain and his crew. Discovery of the wreck could shed light on the root cause of the 1938 accident that claimed their lives while providing closure for seven families and the wider air transport community at large. It would also inform and enhance our collective understanding of the adjacent American Samoa National Marine Sanctuary, perhaps even prompting consideration of extending its protections to the area surrounding such a precious cultural heritage resource.

***Samoan Clipper* in Pago Pago**

References

Matthews, Russ, James Delgado, Lonnie Schorer. Samoan Clipper (NC16734). White paper submission for *Telepresence-enabled Exploration of the Eastern Pacific Ocean Workshop*. Ocean Exploration Trust and NOAA Office of Ocean Exploration Research. 2014.

REPORT OF THE INVESTIGATING BOARD (April 1, 1938)
Statement of probable cause concerning an accident which occurred to an aircraft of Pan American Airways Company near Pago Pago, Tutuila, American Samoa, on January 11, 1938
DEPARTMENT OF COMMERCE, BUREAU OF AIR COMMERCE
Prepared by E.L. Yuravich, Chief, Airline Inspection Section (Foreign)
and Richard C Gazley, Chief, Safety and Planning Division
https://upload.wikimedia.org/wikipedia/commons/3/37/Bureau_of_Air_Commerce_Aircraft_Accident_Report%2C_Pan_American_Airways_Sikorsky_S-42B_Samoan_Clipper.pdf

Pan American Airways Archive
University of Miami Libraries, Special Collections
www.library.miami.edu/specialcollections

Igor I. Sikorsky Historical Archives
https://www.sikorskyarchives.com/

S-42 Seaplane Specifications (1937)
Sikorsky Aircraft Corporation, Bridgeport, CT

USS *Avocet* (AVP-4) deck logs for 11-12 January 1938
Archives I, RG 24, Stack Area 18W4, Row 15, Compartment 16

Krupnick, Jon E. *Pan American's Pacific Pioneers: the Rest of the Story: a Pictorial History of Pan Am's Pacific First Flights, 1935-1946*. Pictorial Histories Pub. Co., 2000.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Kira Mizell
Institution: U.S. Geological Survey
Email Address: kmizell@usgs.gov
Office Phone Number: 831-460-7423
Collaborators/Co-Authors: Amy Gartman (USGS), Nancy Prouty (USGS), and Amanda Demopoulos (USGS)

Title: Marine Minerals and Associated Ecosystems in the Northwest Pacific Ocean

Priority Geographic Area:
This oceanographic region of interest encompasses deep waters (~1000 m to 6000 m) within the EEZ of the Commonwealth of the Northern Mariana Islands (CNMI), a U.S. territory, as well as areas beyond national jurisdiction.

Description of Priority Area:

The seamounts immediately east of the Mariana Trench are part of the Magellan Seamount group, some of the oldest seamounts in the world's oceans. Ferromanganese crusts have been slowly precipitating (~1mm/Myr) onto the exposed rock surfaces of the Magellan seamounts, ridges, and guyots since 55 Ma and as a result of the long growth time are some of the thickest in the world (Glasby et al., 2007). The Dutton Ridge, Fryer Guyot, half of Vogt Guyot, and various smaller seamounts are either known or suspected to have ferromanganese crusts and nodules, and fall within the Exclusive Economic Zone (EEZ) of the Commonwealth of the Northern Mariana Islands (CNMI), a U.S. territory (Hein et al., 2005). However, the Magellan Seamount group and associated ferromanganese crust permissive region extends out of the US EEZ, as does the deep abyssal plain, which is a permissive region for manganese nodules and has recently begun to generate exploration interest (Figure 1). This intersection of multiple mineral permissive regions, overlapping various oceanographic provinces and ecosystems requires urgent study.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

A detailed baseline characterization of this area needs to occur. Within the US EEZ, multibeam mapping of Dutton Ridge, Fryer Guyot, and Vogt Guyot was completed by the University of New Hampshire in 2010 as part of the US Law of the Sea mapping effort; however, exploratory baseline studies of mineralogical and biological regimes in this region are needed to understand the extent and distribution of crusts, nodules, and their environmental setting. In areas where ship-based bathymetry and backscatter has already been collected, such a characterization would include boxcore sampling across the abyssal plain combined with ROV based grab sampling for rocks and fauna, suction sampling for fauna, and video collection in the seamounts of this region. Water column characterization would also be valuable.

Describe relevance to national security, conservation, and/or the economy:

The permissive nature of this region for critical minerals makes it relevant for national security, conservation, and the economy. The International Seabed Authority has to date issued four exploration contracts for ferromanganese crusts, as well as one for manganese nodules, in the western Pacific, including in the Magellan Seamount Chain directly adjacent to the US EEZ. Ferromanganese crusts in this region are of interest for manganese, cobalt, nickel, copper, the rare earth elements, as well as potentially platinum.

In addition to minerals, the deep waters of the CNMI EEZ also host diverse seafloor ecosystems, resulting from the wealth of geological and geochemical niches available. Questions as to the environmental context of these mineral deposits are timely; in addition to increasing interest in marine minerals, the suggestion has recently been made that seamounts should be managed as vulnerable marine ecosystems (Watling and Auster, 2017). Initial studies suggest that the fauna inhabiting seamount regions with and without ferromanganese crusts differ from one another, and are also slow growing (e.g. Schlacher et al., 2014).

From your perspective, what makes this area unique?

This region has been defined as the "prime crust zone" (Hein et al., 2009) and contains an adjacent permissive region for manganese nodules. The close spatial association between multiple oceanographic provinces hosting critical marine minerals, the interest taken in marine minerals in that region, and the need for baseline characterization of the biological ecosystems makes this area unique and of high priority for oceanographic research.

References

Glasby, G. P., Ren, X., Shi, X., and Pulyaeva, I. A., (2007). Co–rich Mn crusts from the Magellan Seamount cluster: the long journey through time. Geo-Mar Lett. 27: 315–323. doi: 10.1007/s00367-007-0055-5

James R. Hein, Tracey A. Conrad & Rachel E. Dunham (2009) Seamount Characteristics and Mine-Site Model Applied to Exploration- and Mining-Lease-Block Selection for Cobalt-Rich Ferromanganese Crusts, Marine Georesources and Geotechnology, 27:2, 160-176. doi: 10.1080/10641190902852485

Hein, J. R., McIntyre, B. R., and Piper, D. Z., (2005). Marine Mineral Resources of Pacific Islands – A Review of the Exclusive Economic Zones of Islands of U.S. Affiliation, Excluding the State of Hawaii. Circular 1286, U.S. Geological Survey, Reston, Virginia.

Schlacher, T.A., Baco, A.R., Rowden, A.A., O'Hara, T.D., Clark, M.R., Kelley, C. and Dower, J.F. (2014), Seamount benthos in a cobalt-rich crust region of the central Pacific: conservation challenges for future seabed mining. Diversity Distrib., 20: 491-502. doi: 10.1111/ddi.12142

Watling, L., and Auster, P. J., (2017). Seamounts on the High Seas Should Be Managed as Vulnerable Marine Ecosystems. Front. Mar. Sci. 4:14: 1-4. doi: 10.3389/fmars.2017.00014

Please list other partners or organizations that may also be interested in this area: BOEM, NOAA

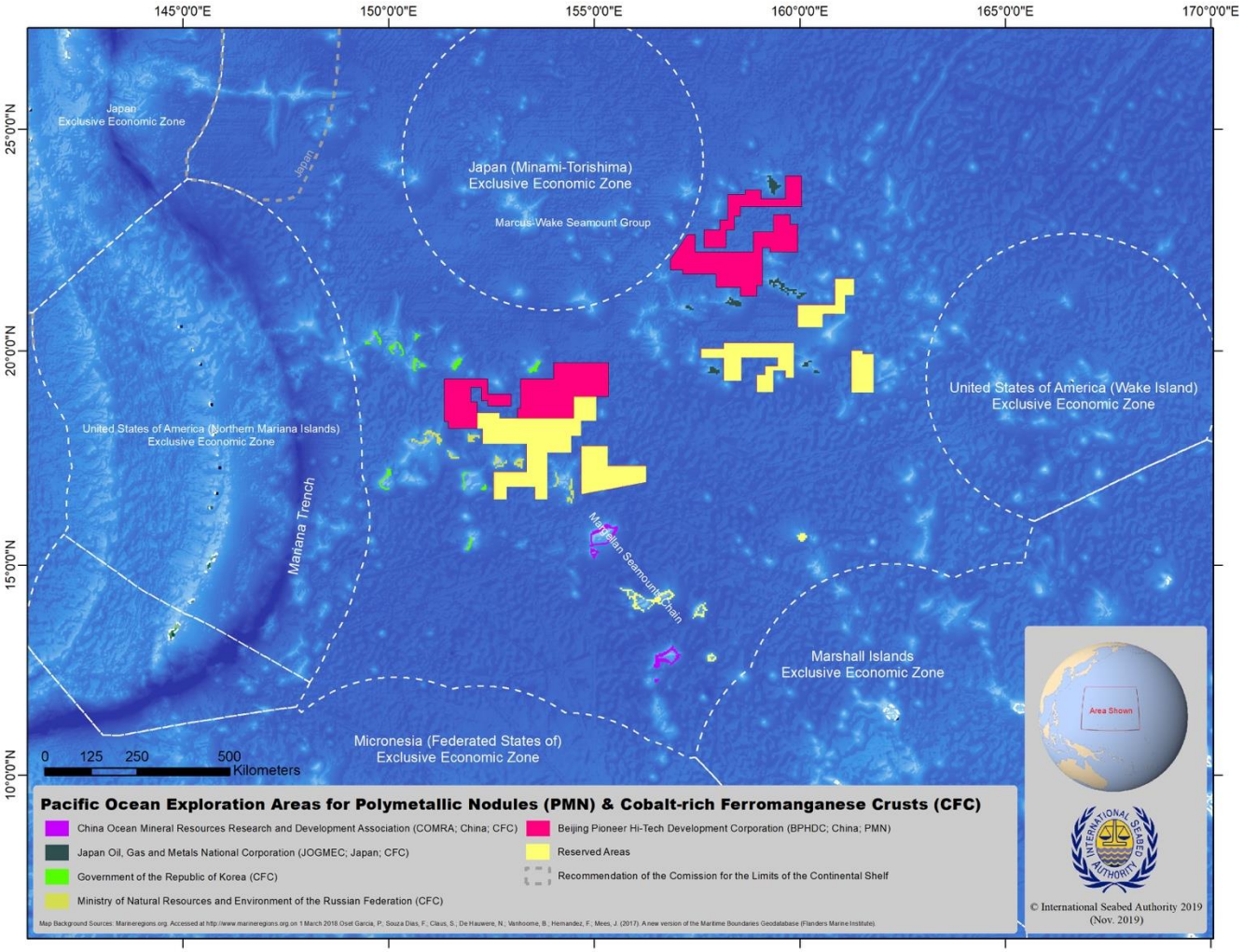


Figure 1. Pacific Ocean exploration areas for polymetallic nodules (PMN) and cobalt-rich ferromanganese crusts (CFC). This figure was generated by the International Seabed Authority and is included here for reference.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Dr. Beth N. Orcutt, Senior Research Scientist
Institution: Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA
Email Address: borcutt@bigelow.org
Office Phone Number: (207) 315-2567
Collaborators/Co-Authors: Dr. James Bradley, Queen Mary University London; Dr. Julie A. Huber, Woods Hole Oceanographic Institution; Dr. Rose Jones, University of Minnesota; Dr. Nagissa Mahmoudi, McGill University; Dr. Jeff Marlow, Boston University; Dr. Geoff Wheat, University of Alaska Fairbanks

Liliuokalani Ridge Seamounts:

Mineral Crusts, Benthic Habitat, and Ecosystem Services in an Un-mapped and Unexplored Region of the US EEZ and International Waters

Priority Geographic Area:
The Liliuokalani Ridge straddles the US EEZ on the western end of the Hawaiian Islands in the Northern Pacific Ocean, north of (and outside of) the Papahānaumokuākea Marine National Monument (Figure 1).

Description of Priority Area:

The Liliuokalani Ridge is a seamount chain that straddles the northwestern-most end of Hawaiian Island chain U.S. Exclusive Economic Zone (EEZ; Figure 1). To our knowledge, no prior expeditions have visited this region for mapping or characterization, thus a full description of the area is not possible. While there are a few seamount features along the Liliuokalani Ridge that have names (i.e., Mercury, Loudoun, Nootka, and King George's seamounts), there is no verified information about water depths of these features. Based on information in the Global Multi-Resolution Topography (GMRT) database, these seamounts' likely rise from ~5000 m water depth at the base to ~600 m water depth at the summits. For example, Mercury Seamount (174.0ºW/29.8ºN) is estimated to be approximately 25 km in diameter with a summit near 650 m water depth. Loudoun Seamount (174.0ºW/29.2ºN) has a rough diameter of 50 km and a summit near 940 m water depth. Based on surveys of similar seamounts, the seamount habitats may contain exposed rock outcrop features that support a diversity of deep-sea corals and/or sponges or attached fauna, mobile fauna such as octopus and fish, and mineral alteration rinds that may have high metal content.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
___ Physical Oceanography
_X_ Chemistry
_X_ Other: Multibeam Mapping

Provide a list or brief description of the data needed within this area, from your perspective:

- Acquisition of high-resolution bathymetry in areas on the southern end of the Liliuokalani Ridge with seamounts in the US EEZ and in international waters where no mapping data exists. Priority targets include seamounts.
- ROV exploration and characterization of the density and diversity of benthic habitats, including deep-water corals, sponges, and fish habitats on seafloor features potentially present on mineral crust zone seamounts in the north central Pacific U.S. EEZ.
- Exploration of geological structure of seamounts and sampling of basalt from seamounts at any sites of fluid flow for dating through geochemical analyses and for determination of microbial ecosystem services in ferromanganese crusts.
- Acquisition of other physical and chemical data in support of conservation and exploration goals for remote units of the Pacific Remote Islands Marine National Monument, including dissolved oxygen and eDNA samples.

Describe relevance to national security, conservation, and/or the economy:

The seamounts of this ridge are indicated as places that may have mineral crusts with high metal content that might be of interest for deep-sea mining (Figure 1A, modified from Orcutt et al. 2020, *Limnology & Oceanography*; DOI: 10.1101/463992). While seamounts and other deep-sea features south and east of this ridge have previously been explored with either mapping or ROV expeditions, including by NOAA's OER CAPSTONE program (Figure 1B), the Liliuokalani Ridge seamounts have not been mapped before at high resolution (based on lack of multibeam data in NGDC database; Figure 1C). Thus, to our knowledge, this seamount system has never been characterized before. Given that many seamounts with mineral crusts in the US EEZ are within national monument protected areas that are expected to prohibit extractive industrial use, characterization of the Liliuokalani Ridge seamounts within the US EEZ would enable evaluation of if these seamounts have commercial value and/or unique benthic ecosystems worthy of additional protection. OER expeditions to this region would collect deep-water baseline information to support science and management decisions in the US EEZ around a marine protected area. These data will also support the GEBCO Seabed 2030 initiative to map the world's seafloor by 2030.

From your perspective, what makes this area unique?

Seafloor seamount features in a mineral crust zone in the US EEZ that have not been mapped or characterized before.

Please list other partners or organizations that may also be interested in this area:

- Christopher Kelley, University of Hawaii – for comparison to characterization of Papahānaumokuākea Marine National Monument seafloor features
- Randi Rotjan, Boston University – for comparison to characterization of seafloor benthic ecology in the CAPSTONE region encompassing remote Pacific Islands
- Amy Baco-Taylor, Florida State University – for comparison to seamount benthic ecology and connectivity studies

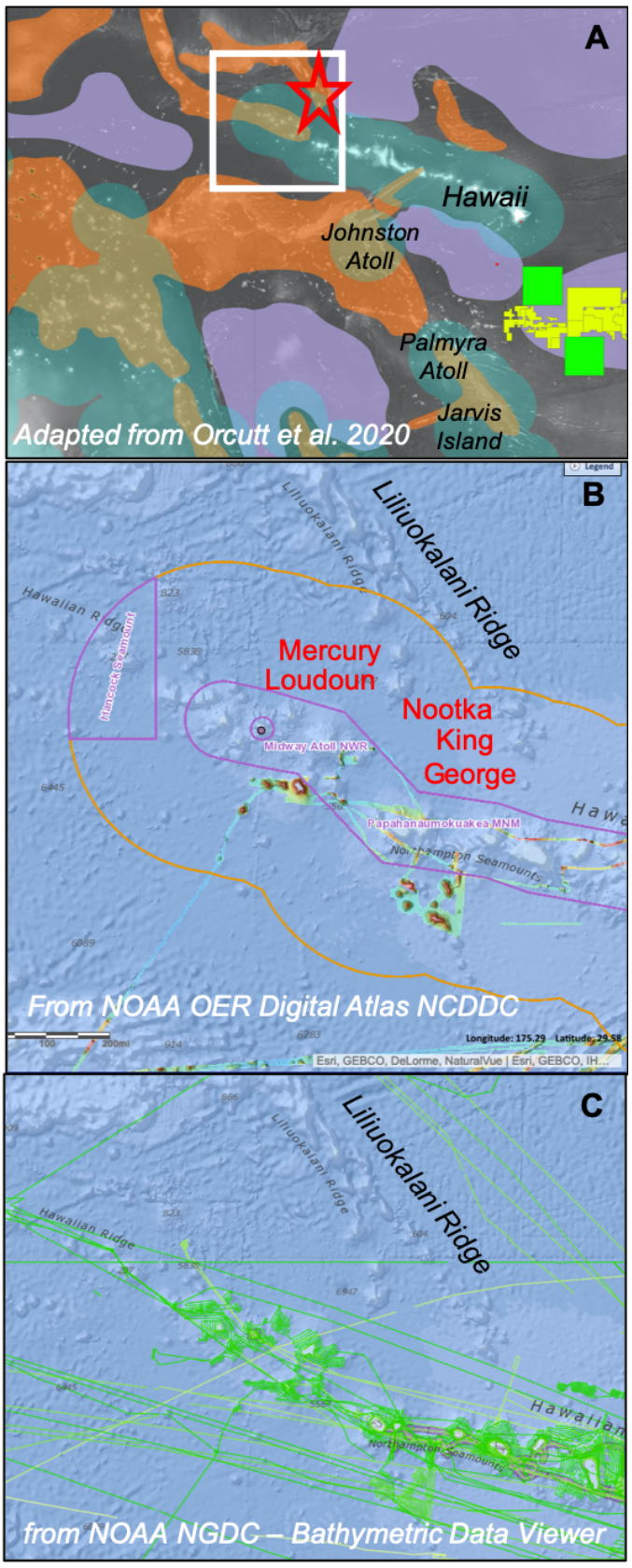


Figure 1. Map of seamount features on the Liliuokalani Ridge in the central North Pacific. (A) Map of predicted seafloor mineral resources in the central North Pacific – "cobalt" mineral crusts, shaded orange; ferromanganese nodules, shaded purple; hydrothermal sulfides, red dots; and areas contracted by the International Seabed Authority for nodule exploration (yellow) or protection (green) – in relation to EEZs of various countries (shaded light blue). The priority focus area indicated by the red star in the white bounding box (i.e., the area shown in panels B and C) lies within the US EEZ around the Hawaiian Islands in an area predicted to have high mineral crust content. Figure modified from Orcutt et al. 2020 Limnology & Oceanography. (B) Bathymetric map of the priority focus area showing the spatial relation of seamount features of the Liliuokalani Ridge within the US EEZ, outside of the Papahānaumokuākea Marine National Monument. Figure created with the NOAA OER Digital Atlas. (C) Bathymetric map overlain by multibeam mapping tracks available in the NOAA NGDC database, emphasizing that the seamounts of the Liliuokalani Ridge have not been previously mapped.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Dr. Beth N. Orcutt, Senior Research Scientist
Institution: Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA
Email Address: borcutt@bigelow.org
Office Phone Number: (207) 315-2567
Collaborators/Co-Authors: Dr. James Bradley, Queen Mary University London; Dr. Jacqueline Goordial, LDEO at Columbia University; Dr. Julie A. Huber, Woods Hole Oceanographic Institution; Dr. Rose Jones, University of Minnesota; Dr. Nagissa Mahmoudi, McGill University; Dr. Jeff Marlow, Boston University; Dr. Geoff Wheat, University of Alaska Fairbanks

The Pacific-Antarctic Rise:

An Uncharacterized Mid-Ocean Ridge

Priority Geographic Area:
The Pacific-Antarctic Rise stretches from the Southern Ocean in the southern Pacific Ocean to the East Pacific Rise and is the divergent boundary between the Pacific and Antarctic plates (Figure 1).

Description of Priority Area:

The Pacific-Antarctic Rise (PAR) is a Mid-Ocean Ridge (MOR) system under international waters where two ocean plates – the Pacific and Antarctic plates – pull apart as part of plate tectonics (Figure 1A). Mid-Ocean Ridges often host active and inactive hydrothermal vent systems along the ridge axis, supporting abundant and distinct benthic communities and mineral deposits. The PAR is extremely poorly characterized along its length, with only a handful of multibeam mapping efforts crossing the ridge axis in sparse locations (Figure 1B). The southern end of the East Pacific Rise from the Menard Fracture Zone south to the Eltanin Fracture Zone System (encompassing the Heezen and Tharp Fracture Zones) was mapped in 1991. An additional southern segment was mapped from the Eltanin Fracture Zone to an unnamed fracture zone around 142ºW 56ºS in 1994. To our knowledge, no seafloor characterization has ever taken place along these segments mapped in the 1990s, and there is also no multibeam mapping of seamount and other seafloor features off-axis in these segments. The remaining section of the PAR south to the Heirtzler Fracture Zone – *a 1200 km long MOR system* – has essentially never been mapped or characterized before. Thus, it is totally unknown what kind of seafloor features, such as hydrothermal vents, exist is this region of the Earth's ocean.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
___ Physical Oceanography
_X_ Chemistry
_X_ Other: Multibeam Mapping, Seismics

Provide a list or brief description of the data needed within this area, from your perspective:

- Acquisition of high-resolution multibeam bathymetry in areas along the 1200 km-long Pacific-Antarctic Rise in international waters where no mapping data exists. Priority targets include the ridge axis, fracture zones between segments, and seamounts near the ridge axis.
- Acquisition of high-resolution bathymetry of seamounts south of the Menard Fracture Zone (142ºW 56ºS)
- Potentially, ROV exploration and characterization of the density and diversity of these benthic habitats and sampling of basalt from ridge axis and seamounts for dating through geochemical analyses and for determination of microbial ecosystem services in ferromanganese crusts.
- Where possible, seismic lines crossing and parallel to the ridge axis and over seamount features

Describe relevance to national security, conservation, and/or the economy:

While this priority area is entirely within international waters outside of the US EEZ, it consists of the longest Mid-Ocean Ridge segment on Earth that has not yet been mapped or characterized. There is a high probability of discovering new hydrothermal vent ecosystems along the ridge axis as well as off-axis. As such, there is also a high probability of discovering new animal species and animal-microbe symbioses, which may lead to new biotechnology applications derived from novel genetic materials. There is also a high probability of identifying new species distribution patterns of relevance to conservation planning. There is also a high probability of identifying new seafloor mineral deposits that may have concentrations of metals that are economically attractive. Mapping this area would also contribute to goals of the international Seabed 2030 mapping campaign.

From your perspective, what makes this area unique?

The global Mid-Ocean Ridge system hosts diverse and charismatic animal ecosystems at hydrothermal vents, supported by unique animal-microbe symbiosis. Such sites are important for understanding the range of conditions under which life can exist on Earth, and they inform the search for life elsewhere in the Universe. Considering its vast length, the unexplored PAR likely hosts animals never seen before by humanity. Furthermore, characterizing the age and mineral structure of rocks along the PAR can lead to better understanding of formation and movement of the Pacific Plate.

Please list other partners or organizations that may also be interested in this area:

- British researchers with the National Oceanography Center, such as Dr. Jon Copley, are some of the few who have worked near this area to understand deep sea fauna distributions. There might be interest in collaboration.

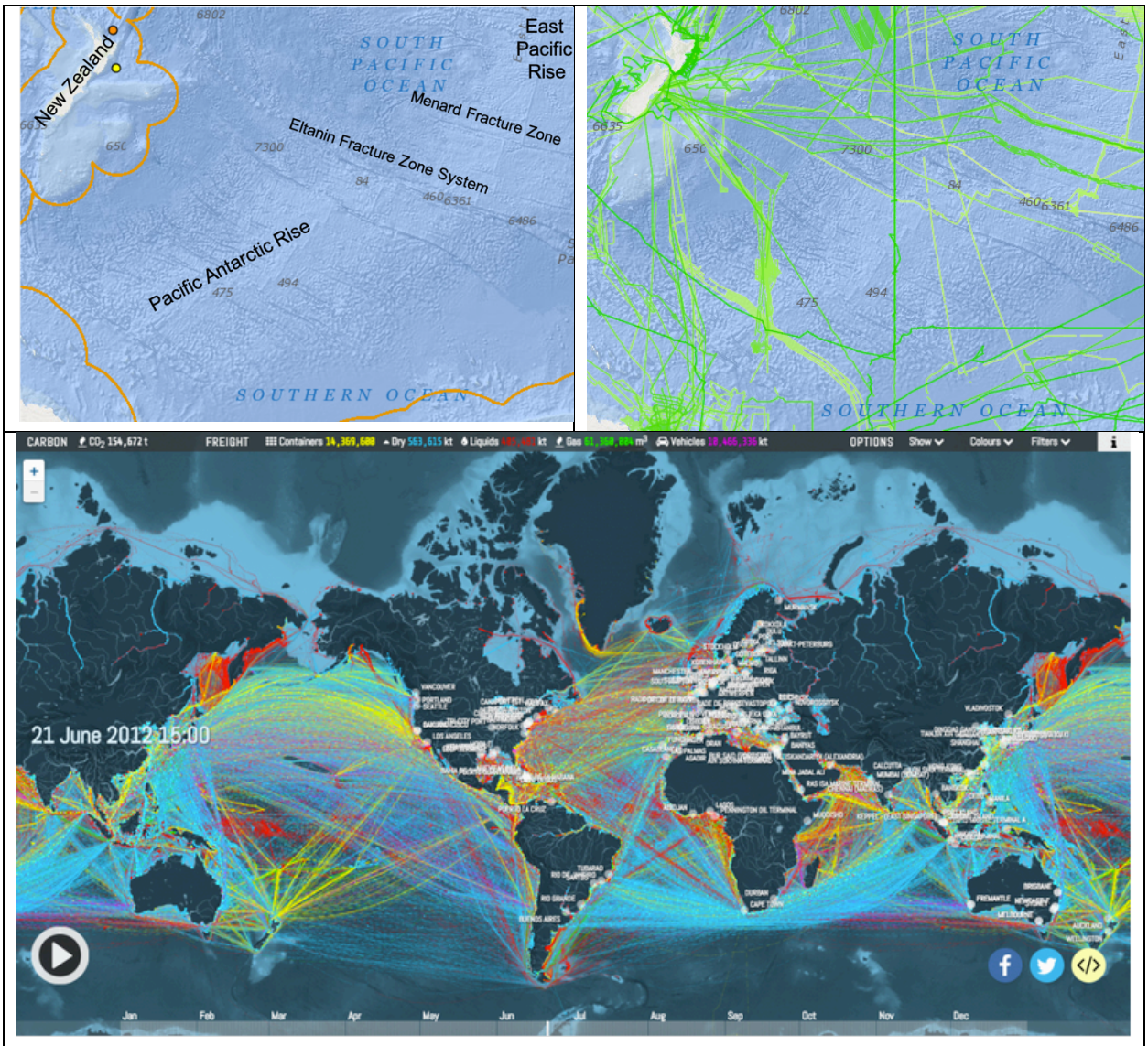


Figure 1. Overview of the Pacific-Antarctic Rise south of the East Pacific Rise and east of New Zealand. (top left) Bathymetric map of the Pacific-Antarctic Rise system area in the South Pacific Ocean in relation to the EEZ of New Zealand and Antarctica (orange outlines). Figure created with the NOAA OER Digital Atlas. (top right) Bathymetric map overlain by multibeam mapping tracks available in the NOAA NGDC database, emphasizing that this mid-ocean ridge system is very poorly mapped. (bottom) Visualization of global ship traffic, emphasizing that this region of the world's oceans cannot be mapped in partnership with industry, who rarely crosses this region. Image created by Kiln using data from the UCL Energy Institute and used courtesy of https://www.canadiangeographic.ca/article/map-lets-you-visualize-shipping-traffic-around-world.

Aleutian Trench/Arc System

Location

The portion of the seafloor along the Aleutian Trench/Arc system within the U.S. EEZ has a very limited amount of multibeam data, and much of these data are preferentially located inboard of the trench and toward the eastern end of the region.

Suggested Mapping Techniques

Multibeam bathymetry/backscatter and sub-bottom profiling would provide first-order information about this very complex tectonic and volcanic region. ROV surveys are possible for much of the overriding plate above 4500 m and even on some portions of the down-going plate eastward of 155˚W.

Relevance to National Security, Conservation, and/or the Economy

Important to identify potential natural hazards (e.g., frequency mass wasting events or potential volcanism), mapping for potential resources, and conservation of possible protected regions.

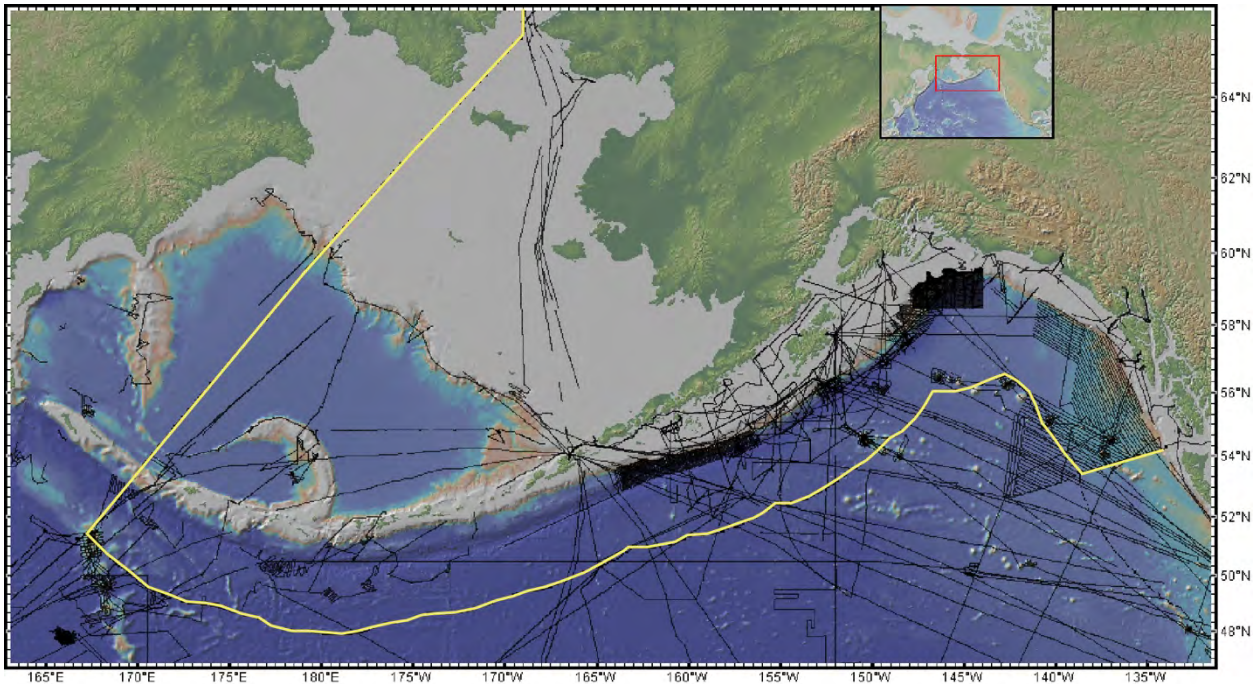


Figure 1. Image of the region along the Aleutian Trench/Arc system indicating the extent of the U.S. EEZ (yellow line) and the relative paucity of multibeam data in the region.

Central Pacific Abyssal Channel

Location

Due west of the Line Islands near Kingman Reef is a broad 100 km x 200 km anomalously shallow plateau that rises about 500 m above the regional seafloor depth of 4700 m (Fig. 1). Along the central portion of the plateau is an enigmatic 60-km-long north-south-trending channel that is about 2 km wide and 100 m deep. There are also several other anastomosing channel-like features along the northwest corner of the plateau that appear to coincide with individual seamounts.

The main plateau is centered at about 6˚N, 164˚W and extends another 500 km to the west and tapers to the northwest for a generally horn-shaped feature. Sediment thickness on the plateau ranges from 250 to 400 m, based on global maps of sediment thickness (Whitakker et al., 2013). The predicted age of the original basement ranges from 125 to 128 Ma (Müller et al., 2016) and indicates the plateau is located along the trace of the Pacific-Farallon and Pacific-Phoenix triple junction trace.

The origins of these enigmatic channel are uncertain, but a couple of potential explanations could be related to volcanism or sediment dissolution. The volcanism scenario might include an eruption event that created the plateau and the channels are feeder tubes to or from the seemingly connected adjacent seamounts. The channels with negative relief could be analogous to collapsed lave tubes. The sediment dissolution scenario could be similar to seawater transport in the basement aquifer and sediment dissolution models described by Fisher et al. (2008) and Moore et al. (2007), respectively. In the dissolution scenario, seawater enters the basement aquifer from an adjacent topographic high, warms the seawater, and deposits carbonate veins in the basement due to retrograde solubility of carbonates. As the seawater exits the basement along cracks and fissures, it cools, becomes undersaturated in carbonate and dissolves the overlying carbonate-rich sediments, which causes the depressions.

Suggested Mapping Techniques

Multibeam bathymetry/backscatter and sub-bottom profiling would provide key information about the origin of these channels. Since these channels are on seafloor shallower than 4500m, near-bottom mapping with ROV's is a possibility to identify possible evidence of volcanism-related or dissolution-related features.

Relevance to National Security, Conservation, and/or the Economy

Determining the origin of the plateau and channels may enable the U.S. to expand its EEZ farther to the west, especially if these features can be shown to be intimately related to existing U.S. territories (e.g., Kingman Reef).

References

Fisher, A.T., Davis, E.E. and Becker, K., 2008. Borehole-to-borehole hydrologic response across 2.4 km in the upper oceanic crust: Implications for crustal-scale properties. *Journal of Geophysical Research: Solid Earth*, *113*(B7).

Moore Jr, T.C., Mitchell, N.C., Lyle, M., Backman, J. and Pälike, H., 2007. Hydrothermal pits in the biogenic sediments of the equatorial Pacific Ocean. *Geochemistry, Geophysics, Geosystems*, *8*(3).

Müller, R.D., Seton, M., Zahirovic, S., Williams, S.E., Matthews, K.J., Wright, N.M., Shephard, G.E., Maloney, K.T., Barnett-Moore, N., Hosseinpour, M. and Bower, D.J., 2016. Ocean basin evolution and global-scale plate reorganization events since Pangea breakup. *Annual Review of Earth and Planetary Sciences*, *44*, pp.107-138.

Whittaker, J.M., Goncharov, A., Williams, S.E., Müller, R.D. and Leitchenkov, G., 2013. Global sediment thickness data set updated for the Australian-Antarctic Southern Ocean. *Geochemistry, Geophysics, Geosystems*, *14*(8), pp.3297-3305.

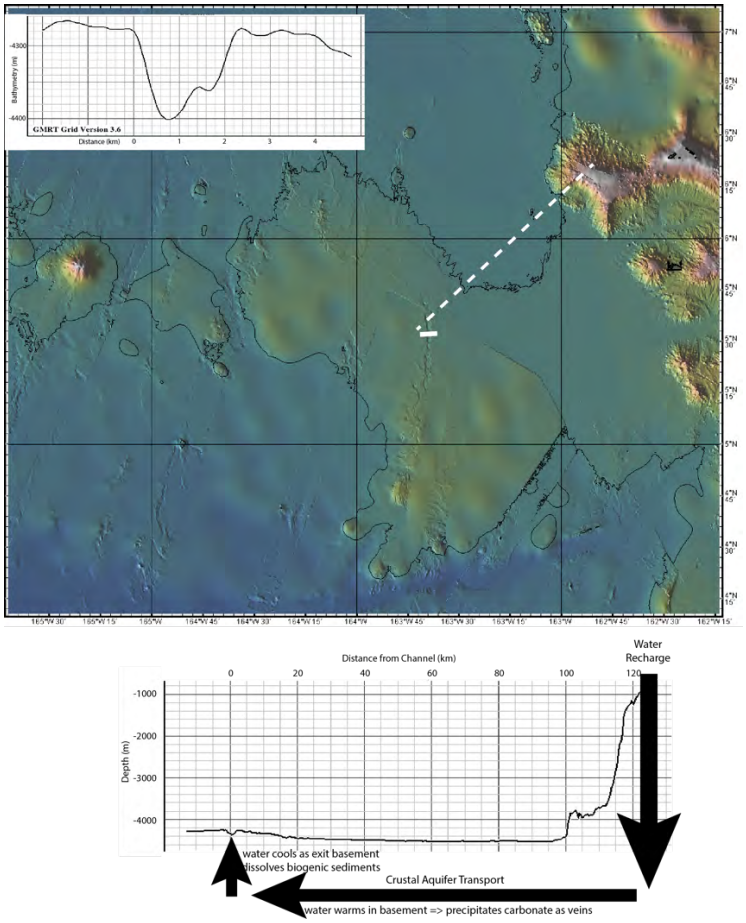


Figure 1. Bathymetry map of Pacific seafloor due west of the Line Islands with the 4500m contour identifying an anomalous channel on a regional bathymetric rise. Detailed bathymetric cross-section (upper left) indicates 2-km-wide and 100-m-deep channel. Bathymetric cross-section from Line Islands to channel (dashed line on map) illustrates one of possible mechanisms for the channel's origin.

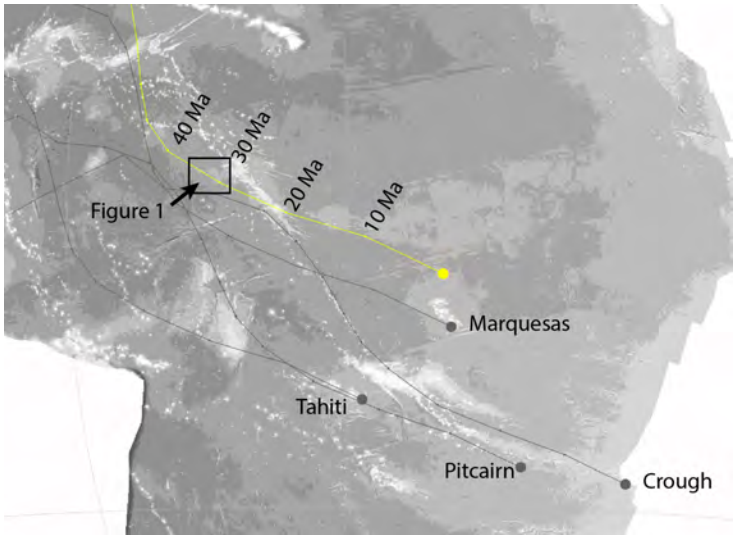


Figure 2. Portion of the Pacific Plate topography with the locations of proposed hotspots and hotspot tracks (grey dots and lines). In yellow is the possible location of a melt source and historic path if the region of interest (e.g., black box) were produced by off-axis volcanism about 30 Ma.

Niue Trough

Location

The Niue Trough is located at about 18˚S, 170˚ W on the portion of the Pacific plate being subducted at the northern end of Tonga Trench (Fig. 1). The trough is a 500-km-long scissor-shaped rift that is narrowest at Niue Island and opens up wider at the northern terminus of the Tonga Trench. The trough has local relief of 500 m to 1200 m and the shoulders are uplifted ~ 500 m from regional topography, suggesting a flexural response to rifting. The majority of the seafloor in the region is deeper than 4500 m, but there are seamounts and some portions of the uplifted rift flanks that are shallower than 4500 m. Existing multibeam and seismic data in the region are limited and only one multibeam line with backscatter data are available in the region of interest. The northern portion of the trough within the U.S. EEZ while the southern portion is in the Niue/New Zealand EEZ.

Features

There are at least two primary features or areas of interest in the region. First, the overall age and origin of the rifting is uncertain, but conventional models suggest it may be related "tearing" of the down-going Pacific lithosphere (Millen and Hamburger, 1998). Alternatively, the rifting may be due to bending and uplift of the peripheral bulge or even may have occurred earlier in the tectonic plate's evolution. If the origin is related to recent uplift, then some of the seamounts in the region may be related to incipient melting due to the uplift and decompression. Second, there are tens to hundreds of 3 to 5 km-wide, 200 to 500 m-high conical features distributed across the trough. The origin of these features is unknown, but similar features termed "petit spots" have been documented on subducting near the Japan and Kermadec trenches (e.g., Hirano et al., 2006). The geochemical character of the petit spots is unique, and some suggest they represent melts from the lithosphere-asthenosphere boundary.

Suggested Mapping Techniques

Multibeam bathymetry/backscatter and sub-bottom profiling would provide key information about the morphology and relative age of seafloor features, as well as the relative timing of the rifting event. Near-bottom mapping with ROV's and sampling of the small cones shallower than 4500 m would provide samples to determine the geochemistry and absolute age of these features.

Relevance to National Security, Conservation, and/or the Economy

Determining the origin of the trough has important implications for potential natural hazards in the region, since the trough may be intimately associated with the large earthquake that generated a tsunami in 2009 that did significant damage to Samoa and American Samoa. The petit spots may have unique and strategic geochemistry.

References

Hirano, N., Takahashi, E., Yamamoto, J., Abe, N., Ingle, S.P., Kaneoka, I., Hirata, T., Kimura, J.I., Ishii, T., Ogawa, Y. and Machida, S., 2006. Volcanism in response to plate flexure. *Science*, *313*(5792), pp.1426-1428.

Millen, D.W. and Hamburger, M.W., 1998. Seismological evidence for tearing of the Pacific plate at the northern termination of the Tonga subduction zone. *Geology*, *26*(7), pp.659-662.

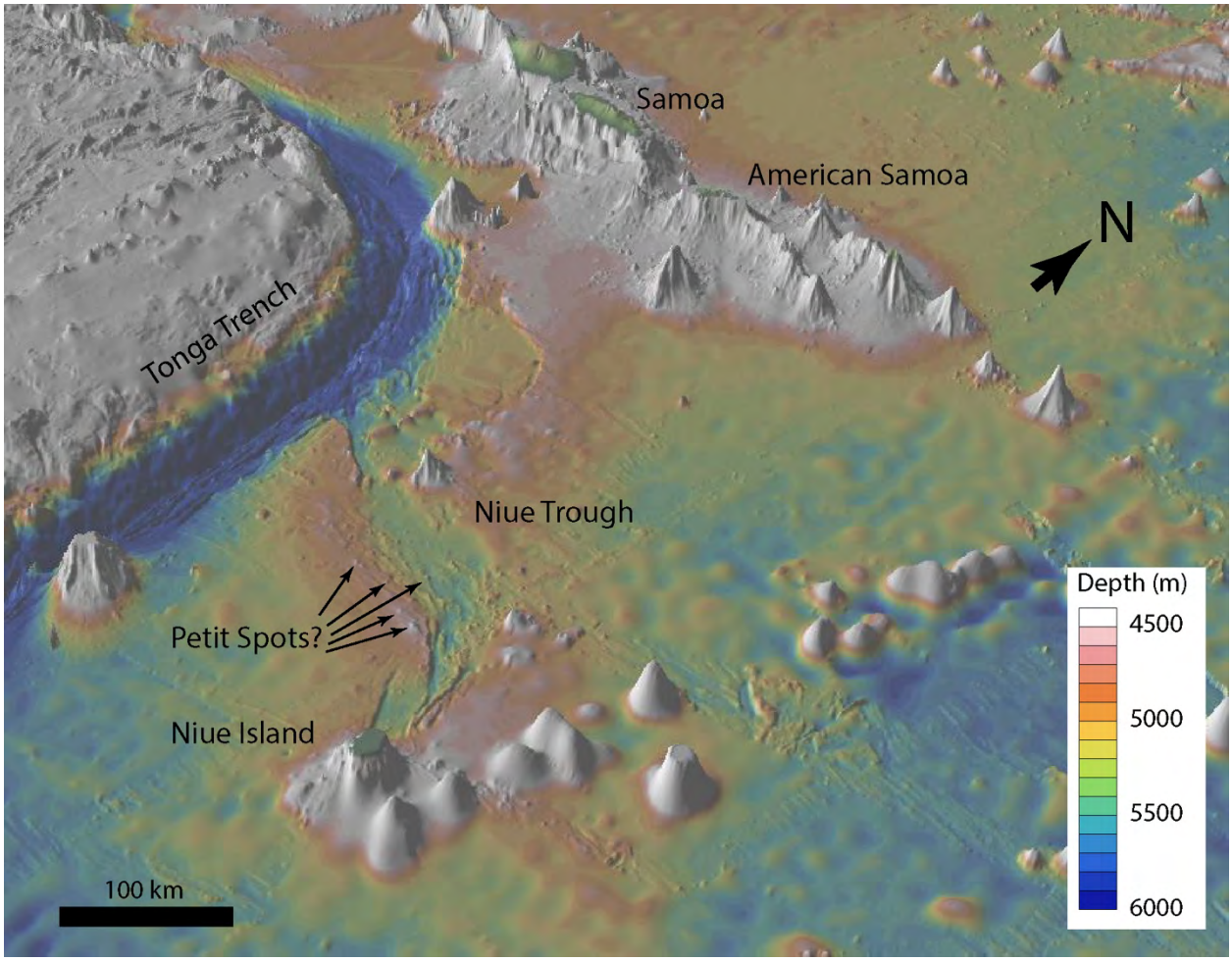


Figure 1. Perspective view of the Niue Trough as viewed from the southeast. Key features are identified (e.g., petit spots?) and depths shallower than 4500 m are shown as white.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Jeremy Potter
Institution: Department of Interior (DOI), Bureau of Ocean Energy Management (BOEM), Pacific Region
Email Address: Jeremy.Potter@boem.gov
Office Phone Number: 805-384-6343
Collaborators/Co-Authors:

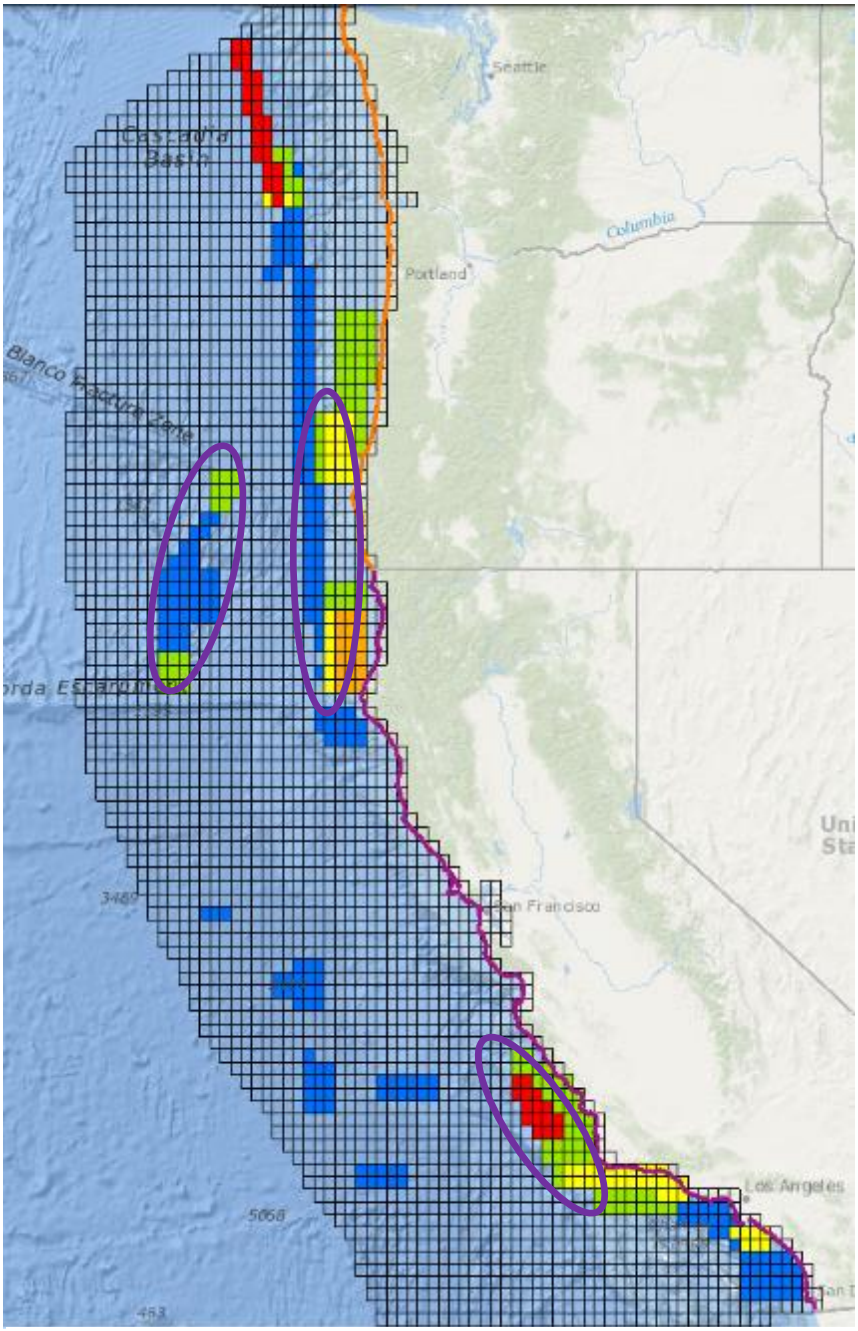


FIG1: BOEM input in Spring 2019 NOAA-led west coast seafloor mapping and visual survey prioritization exercise. Areas prioritized within – not across – 5 subregions offshore CA, OR, and CA. Highest to lowest priorities within subregions are red-orange-yellow-green-blue. Ovals show 3 distinct areas of exploratory interest. A fourth area – offshore the island of Oahu – is only described in the text. Priorities would change somewhat if exercise were redone today.

Title: BOEM West Coast and Hawaii Ocean Mapping, Exploration, and Characterization Priorities

Priority Geographic Area: US EEZ Offshore California, Oregon, Washington, and Hawaii

Description of Priority Areas:
Four priority areas are noted below. All are directly related to near, mid, and long-term BOEM Pacific Region management priorities. Federal, academic, and private partners have implemented some level of exploratory effort in recent years. The Nation would benefit from a greatly expanded effort in all areas. coordinated efforts:

-Cascadia Subduction Zone (Northern California to Southern Oregon) – Generally 200 – 3500m depth

-Central California (Point Conception to Southern Portion of Monterey Bay National Marine Sanctuary) - Generally 200 – 1500m depth

-Gorda Ridge (Particularly Escanaba Trough) – ~2000-3500m depth

-Oahu, Hawaii (Offshore areas NW and S of the island) – Generally 200-1500m. Map not included, but available upon request.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
_X_ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Bathymetry, backscatter, seafloor imagery (capable of resolving small, discrete targets 0.5 meters in length at maximum range), water column acoustics, water column chemistry, detailed AUV-based acoustic and chemical survey of target areas, direct sampling from ROV or human-occupied submersible of geology, benthic biota, and fluid chemistry (if fluids present).

Describe relevance to national security, conservation, and/or the economy:
Expanding offshore renewable energy and securing a domestic supply of critical minerals in environmentally and economically responsible ways are critical issues for our Nation. All four ocean exploration priority areas highlighted in this white paper were selected because they are already under discussion as potential sites for offshore wind development or the private sector previously expressed commercial interest related to critical marine minerals. Despite recent or planned exploration and characterization efforts in all of these priority areas, successfully balancing environmental and economic issues requires enhancing and expanding exploratory efforts beyond existing plans.

All priorities include overlapping issues of interest to multiple federal and non-federal organizations.

From your perspective, what makes this area unique?

Cascadia Subduction Zone – Subset of area under active discussion with State of California for offshore wind development. Discussions just restarted with Oregon about the potential for offshore wind development. Includes MPAs (i.e., Essential Fish Habitat) that have been proposed for modification. Recent/ongoing exploration and research efforts focused on deep corals, seeps, and submerged hazards by federal and non-federal organizations (e.g., Ocean Exploration Trust, NOAA, USGS, BOEM, MBARI). Planned investments by USGS and MBARI that can be greatly enhanced with modest investments. Primary BOEM interests are in areas <1500m however deeper work along the Cascadia Deformation Front would be valuable.

Central California - Subset of area under active discussion with State of California for offshore wind development; Includes MPAs (i.e., Essential Fish Habitat) that have been proposed for modification. Data and information would inform future management decisions for Monterey Bay National Marine Sanctuary and potentially Channel Islands National Marine Sanctuary. Recent/ongoing exploration and research efforts focused on deep corals, seeps, and submerged hazards by federal and non-federal organizations (e.g., Ocean Exploration Trust, NOAA, USGS, BOEM, MBARI). Recent/ongoing efforts have primarily focused in the shallower depths. Much remains to be explored, particularly in deeper areas.

Gorda Ridge – Anticipated to be the area of current greatest commercial interest for critical minerals development in the US EEZ where BOEM currently has jurisdiction. Note: Little is currently known about the true extent of critical mineral resources in US waters. There is likely greater commercial interest in the US Territories, however BOEM does not currently have jurisdiction there. Previous work has been conducted on the Gorda Ridge and a limited new tri-agency exploratory effort is planned in the Escanaba Trough in fall 2020. We

anticipate the fall effort will identify numerous targets for future exploratory geological and biological investigations.

Oahu, Hawaii – Areas to northwest and south of the island have been discussed off and on with the State of Hawaii about potential offshore wind development; coordinated efforts could potentially also inform MPA management (e.g., Humpback Whale National Marine Sanctuary, Bottomfish Restricted Fishing Areas). The areas have substantial potential for maritime heritage discoveries.

Please list other partners or organizations that may also be interested in this area:

Groups that BOEM has been in active conversation with about mutual interest in one or more of the areas:

- **National Oceanic & Atmospheric Administration**: NOS – Office of Coast Survey, National Centers for Coastal Ocean Science, Office of National Marine Sanctuaries; NMFS –Southwest Fisheries Science Center, Northwest Fisheries Science Center, Deep Sea Coral Research and Technology Program; OAR – Office of Ocean Exploration & Research, Pacific Marine Environmental Laboratory; NESDIS - National Centers for Environmental Information; and OMAO.
- **Bureau of Ocean Energy Management**: Pacific Region; Environmental Studies Program; Marine Minerals Division
- **U.S. Geological Survey:** Pacific Coastal and Marine Science Center; Wetland and Aquatic Research Center
- **Monterey Bay Aquarium Research Institute**
- **State of California –** California Energy Commission, Ocean Protection Council
- **State of Oregon**
- **State of Hawaii**
- **Department of Energy:** Office of Energy Efficiency and Renewable Energy
- **Various federally recognized tribes**

Additional prospective partners/organizations that BOEM has not directly engaged but would likely have interest in one or more of these areas:

- Naval Historical Center
- Naval History and Heritage Command Underwater Archaeology
- Ocean Exploration Trust
- Schmidt Ocean Institute
- National Sea Grant Program
- NMFS Pacific Islands Fisheries Science Center
- SEARCH, Inc
- Pew

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Jeremy Potter
Institution: Department of Interior (DOI), Bureau of Ocean Energy Management (BOEM), Pacific Region
Email Address: jeremy.potter@boem.gov
Office Phone Number: 626-808-6496
Collaborators/Co-Authors: Guy Gelfenbaum, DOI, U.S. Geological Survey (USGS), Pacific Coastal and Marine Science Center (PCMSC)

Title: 'EXPRESS': An ongoing U.S. west coast campaign and potential 'cell' in broader Pacific effort

Priority Geographic Area:
U.S. EEZ offshore California, Oregon, and Washington

Summary:
EXPRESS (Expanding Pacific Research and Exploration of Submerged Systems) is an ongoing multi-agency collaboration to facilitate and prioritize seafloor mapping in high-priority areas offshore the U.S. west coast. In just two years, EXPRESS helped coordinated 24 cruises covering > 22,000 km^2 of seafloor supporting multiple federal and private agency and stakeholder information needs. Its demonstrable achievements are due in part to a self-organized coordination body composed of scientists and marine resource managers spanning numerous disciplines, as well as a willingness of multiple agencies to cost share otherwise expensive deepwater expeditions.

Despite no explicit funding for EXPRESS coordination, the Team identifies common geographic priorities and data needs, aligns previously disparate field programs to address mutual priorities, and successfully markets prior accomplishments to obtain new resources to expand the collaborative effort.

Successfully implementing a National Strategy for Mapping, Exploring and Characterizing the U.S. EEZ requires both a coordinated and nimble effort that spans organizations and hierarchies. Specific to the Pacific, sub-regional networks – or 'cells' – of diverse federal, academic, and private individuals could be formed to serve as core team members empowered with the flexibility and resources to achieve the grand vision.

The EXPRESS Team provides a glimpse into what is possible. With appropriate leadership and a shared vision, this model can be expanded beyond the U.S. west coast and replicated in other sub-regions like Alaska, Hawaii, and the Pacific Territories.

What are the characterization and data needs in this area?
Check all that apply:
_x__ Biology
_x__ Geology
_x_ Marine Archaeology
_x_ Physical Oceanography
_x__ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

Describe relevance to national security, conservation, and/or the economy:
Objective scientific information is critical to ensure that ongoing and potential marine resource development proceeds in an environmentally and economically responsible way. EXPRESS is providing valuable data designed to inform management decisions related to:

- guiding wise use of living marine resources;
- informing potential offshore wind energy and mineral resource decisions; and
- improving offshore earthquake, landslide, tsunami, and nautical hazard assessment.

The effort includes activities to support MPA management through work in and around 5 National Marine Sanctuaries as well and baseline characterization of Essential Fish Habitat (EFH) sites. A critical marine minerals field component will begin in fall of 2020

From your perspective, what makes this area unique?
EXPRESS is a public-private partnership that brings shared resources to fund multi-organization and often multi-disciplinary seafloor mapping and characterization expeditions. The EXPRESS Team is self-organized and is self-managed. There has been no explicit tasking from federal agency leadership to form the group. While that creates challenges (e.g., limited resources, voluntary participation), it has spurred the group to forge new relationships, take risks, and seek creative solutions to address joint needs. Early successes created a shared sense of trust that facilitated greater opportunities and an increased willingness to take risks.

Please list other partners or organizations that may also be interested in this area:

Currently, the EXPRESS team is primarily composed of three federal agencies - Bureau of Ocean Energy Management (BOEM), National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS) - and Monterey Bay Aquarium Research Institute (MBARI), a private, non-profit oceanographic research center.

- **National Oceanic & Atmospheric Administration**: NOS – Office of Coast Survey, National Centers for Coastal Ocean Science, Office of National Marine Sanctuaries (Olympic Coast, Greater Farallones, Cordell Bank, Monterey Bay, and Channel Islands National Marine Sanctuaries); NMFS – Southwest Fisheries Science Center, Northwest Fisheries Science Center, Deep Sea Coral Research and Technology Program; OAR – Office of Ocean Exploration & Research, Pacific Marine Environmental Laboratory; NESDIS - National Centers for Environmental Information; and OMAO.
- **Bureau of Ocean Energy Management**: Pacific Region; Environmental Studies Program
- **U.S. Geological Survey:** Pacific Coastal and Marine Science Center; Wetland and Aquatic Research Center
- **Monterey Bay Aquarium Research Institute**

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

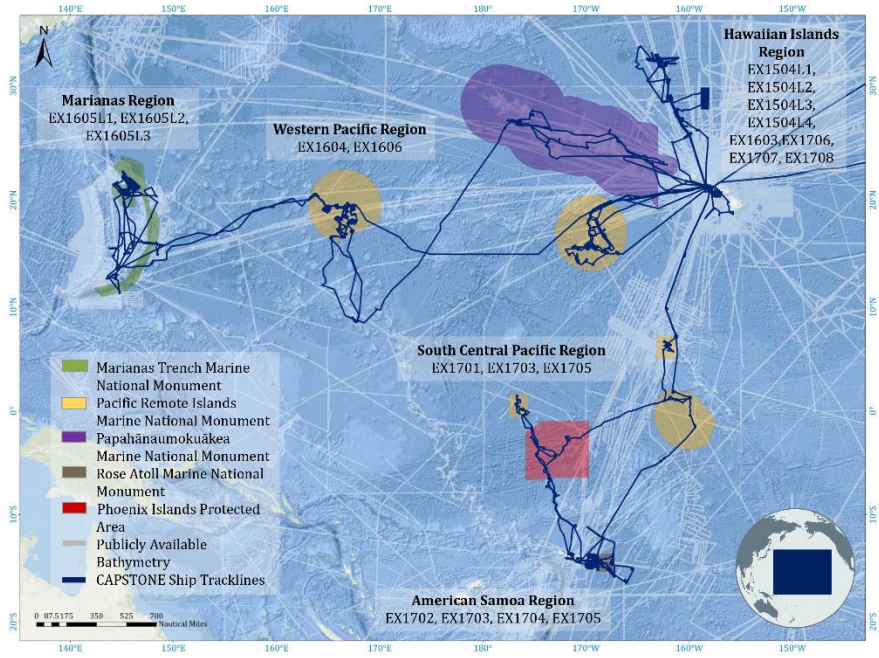
Author: Randi Rotjan and Brian Kennedy
Institution: Boston University
Email Address: rrotjan@bu.edu / bkennedy@bu.edu
Office Phone Number: 617-791-1985
Collaborators/Co-Authors:

Title: Augmenting sample size for depth, feature, and region from CAPSTONE 2015-2017 efforts

Priority Geographic Area:
The Pacific Ocean

Description of Priority Area:

From 2015-2017, the NOAA Ship Okeanos Explorer conducted one of the first large-scale, systematic ocean exploration efforts in the Pacific (see ship tracks below). As part of this effort, almost ~900 hours of seafloor video were captured and analyzed, but when you split the CAPSTONE dives out by different depths, regions and geological feature type there are significant difference in over effort with in the CAPSTONE data set. For an anyalsis we lead in 2019 of CAPSTONE data we compared 5 regions (Hawaii, Marianas, Western Pacific, American Samoa, and South Central Pacific), 9 geological feature types (island, atoll, bank, guyot, conical seamount, ridge seamount, inactive vents, vents, and abyssal plains), and a gradient of depths ranging from 200-6000m. Effort across each region / feature / depth was not even or controlled, and thus the resulting data set has many artifacts of effort and, in some cases, reduced statistical power for analysis. Thus, the priority areas are to fill in the depth / region / feature gaps to generate a more even data set across the original CAPSTONE regions.



What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

The below tables and figures are featured in the Supplementary Information from the recently published paper in Frontiers of Marine Science:

> Kennedy BRC, Cantwell K, Malik M, Kelley C, Potter J, Elliott K, Lobecker E, Gray LM, Sowers D, White MP, France SC, Auscavitch S, Mah C, Moriwake V, Bingo SRD, Putts M and **Rotjan RD.** 2019. The unknown and the unexplored: Quantifying what we now know, and still don't know, about the Pacific deep-sea following the 3-year NOAA CAPSTONE expeditions. *Frontiers in Marine Science* 6:480. doi: 10.3389/fmars.2019.00480

These tables and figures articulate the # dives and/or # hours and/or estimated km of seafloor imaged per region, feature, and depth. Creating more even effort across categories will increase statistical power for subsequent analyses. For ease of comparison, table numbers have retained their original published numbers, so they can be cross-referenced with the original publication as-needed.

Supplementary Table 2. CAPSTONE ROV dive effort shown by region, feature, and depth, showing effort by number of total annotations, number of dives, hours of bottom time, and seafloor imaged. Percent unidentifiable taxa by number of annotations at each taxonomic level depicted.

	# annotations	# of dives	bottom time (# hours)	Estimated Seafloor imaged (Km)	#unidentifiable at Species level	#unidentifiable at Genus level	#unidentifiable at Family level
Total	90,079	168	891.48	29.386225	71,182	34765	11531
Geographic Region:							
Hawaiian Islands	53,575	74	391.4	13.682625	41,385	19,409	4,953
Marianas	13,073	40	216.4	7.69395	10,776	5,611	2,467
Western Pacific Plate	5,785	12	62	2.04875	4,702	1,780	585
American Samoa	2,443	13	64.9	1.5015	1,948	840	434
Southern Central Pacific	15,200	29	156.7	4.01775	12,371	7,116	3,092
Geologic Feature:							
Island	7,606	16	92.9	3.21695	5,791	3,168	1,580
Atoll	5,045	13	69.4	2.011625	3,772	1,648	782
Bank	17,190	18	107.1	3.78565	13,556	6,415	1,853
Guyot	27,466	48	157.7	8.001675	22,129	10,273	2,890
Conical Seamount	17,001	31	163.2	5.0952	13,457	6,516	1,692
Ridge Seamount	12,981	21	108.1	3.511475	10,239	5,548	2,069
Inactive vent	582	4	21.8	0.86075	539	340	130
Vent	1,482	7	46.4	1.19075	1,053	524	341
Abyssal	705	10	39.8	1.2705	628	310	182
Depth:							
0-250	359	14	5.7	0.15675	311	181	153
250-500	12,371	32	149.5	4.62	9,300	4,884	2,218
500-750	4,447	27	57.3	1.5785	3,187	1,507	859
750-1000	3,762	18	38.1	1.08625	2,624	1,698	903
1000-1500	10,654	33	112.1	3.465	8,422	4,481	1541
1500-2000	26,482	53	179	5.918	20,990	9,476	2,470
2000-2500	6,451	56	213.1	6.400625	5,579	2,157	326
2500-3000	3,248	22	68.6	2.2165	2,799	1,444	539
3000-3500	940	11	33.5	1.14675	799	396	145
3500-4000	1,082	10	34.3	1.122	954	455	154
4000-4500	476	6	22.8	0.8525	429	197	119
4500-5000	332	5	18.8	0.39875	280	169	107
5000-5500	0	1	0.4	0.011	0	0	0
5500-6000	172	4	14.9	0.4345	154	95	52

Supplemental Table 3. CAPSTONE ROV dive effort shown by region and feature, categorized by each depth bin, showing effort by time (number of hours).

Time in Depth (hours)

REGION	0-250	250-500	500-750	750-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500-5000	5000-5500	5500-6000
HAWAII	0	31	7	8	50	108	136	41	13	10	8	3	0	0
MARIANAS	5	75	16	7	7	17	17	13	15	18	13	13	0	11
WESTERN PACIFIC	0	4	4	5	17	12	18	6	3	0	0	0	0	0
AMERICAN SAMOA	0	18	13	4	5	2	13	8	3	7	0	0	0	0
SOUTH CENTRAL PACIFIC FEATURE	0	21	17	14	34	40	30	0	0	0	2	3	0	4
ISLAND	0	59	17	3	1	6	10	0	0	0	2	0	0	0
ATOLL	0	22	11	8	17	2	8	7	0	0	0	0	0	0
BANK	0	27	11	1	11	34	21	5	2	0	0	3	0	0
GUYOT	0	0	0	5	41	88	91	20	7	0	0	0	0	0
CONICAL SEAMOUNT	0	16	3	3	28	39	34	12	7	26	0	0	0	0
RIDGE SEAMOUNT	0	8	8	10	7	10	44	13	10	0	2	3	0	0
INACTIVE VENT	0	0	0	0	0	0	6	12	0	6	0	0	0	0
VENT	5	18	8	9	7	0	0	0	7	2	4	0	0	0
ABYSSAL	0	0	0	0	0	0	0	0	0	0	14	13	0	15

Supplemental Table 4: CAPSTONE ROV dive effort shown by region and feature, categorized by each depth bin, showing effort by number of ROV dives.

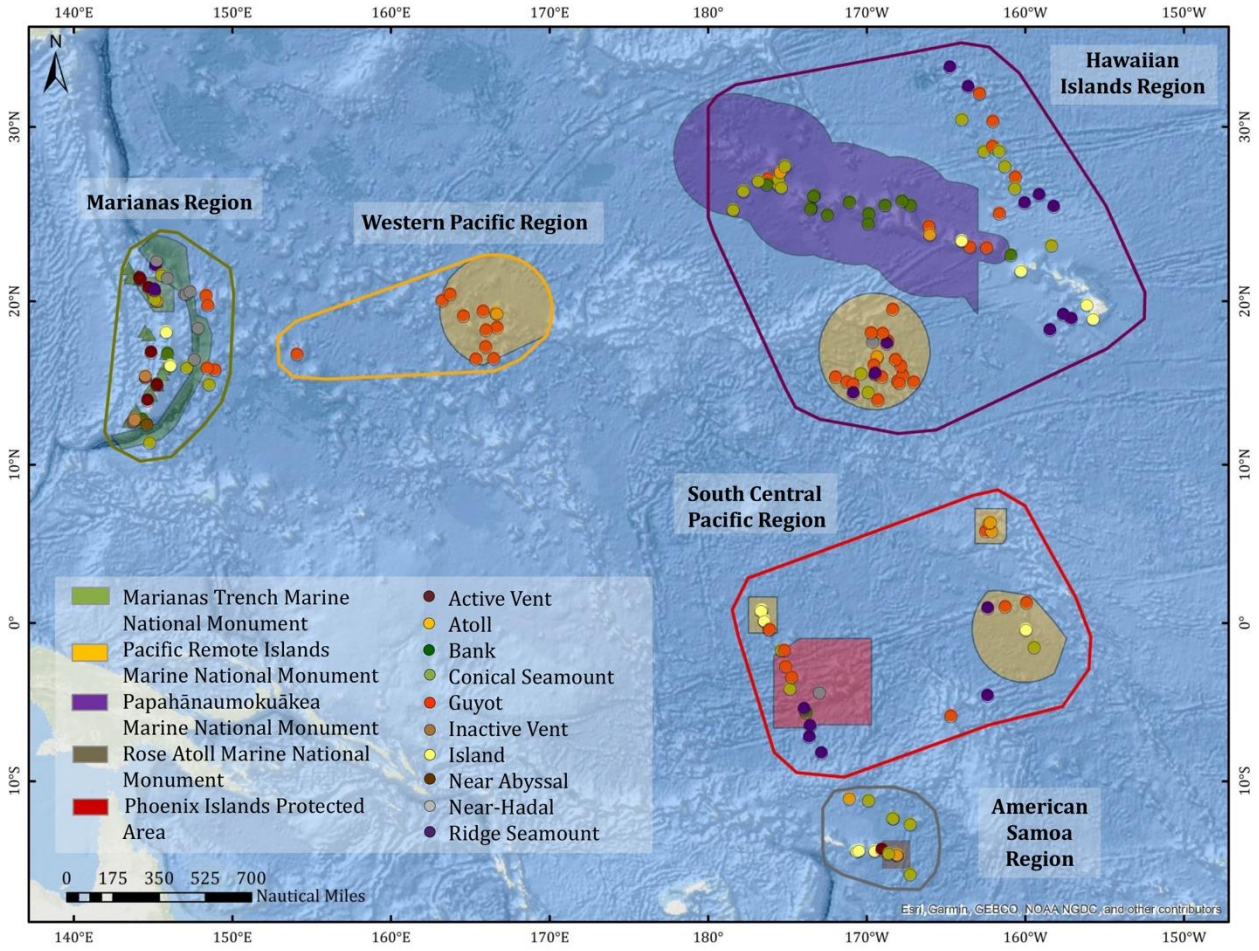
Number of Dives

REGION	0-250	250-500	500-750	750-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500-5000	5000-5500	5500-6000
HAWAII	0	6	6	5	18	30	34	12	4	2	2	1	0	0
MARIANAS	7	13	7	1	1	5	6	3	3	5	3	3	1	3
WESTERN PACIFIC	0	2	3	2	4	5	5	2	1	0	0	0	0	0
AMERICAN SAMOA	0	4	4	2	1	1	3	3	2	2	0	0	0	0
SOUTH CENTRAL PACIFIC FEATURE	0	6	6	6	9	10	8	0	0	0	1	1	0	1
ISLAND	1	12	8	1	1	1	2	0	0	0	1	0	0	0
ATOLL	0	5	4	3	5	1	2	2	0	0	0	0	0	0
BANK	1	5	5	1	3	9	5	1	1	0	0	1	0	0
GUYOT	0	0	0	2	12	26	25	7	2	0	0	0	0	0
CONICAL SEAMOUNT	0	2	1	2	6	9	9	3	2	6	0	0	0	0
RIDGE SEAMOUNT	0	2	3	2	3	3	10	4	3	0	1	1	0	0
INACTIVE VENT	0	0	0	0	0	0	1	2	0	1	0	0	0	0
VENT	1	3	1	2	1	0	0	0	1	1	1	0	0	0
ABYSSAL	0	0	0	0	0	0	0	0	0	1	3	3	1	4

Supplemental Table 5: CAPSTONE ROV dive effort shown by region and feature, categorized by each depth bin, showing effort by estimated area imaged (m^2).

REGION	Estimated Area Imaged (m^2)													
	0- 250	250-500	500-750	750-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500-5000	5000-5500	5500-6000
HAWAII	0	119,250	31,000	19,500	164,250	328,250	389,875	120,500	39,000	21,500	37,750	0	0	0
MARIANAS	12,750	197,500	42,000	27,750	20,250	86,250	48,000	50,250	53,000	66,750	34,000	30,750	1,000	31,000
WESTERN PACIFIC	0	13,750	11,250	11,250	50,500	28,750	56,000	18,250	4,250	0	0	0	0	0
AMERICAN SAMOA	0	34,750	30,500	6,500	8,250	8,500	18,500	12,500	8,000	13,750	0	0	0	0
SOUTH CENTRAL PACIFIC	250	55,250	29,250	33,750	71,750	86,250	69,500	0	0	0	5,750	5,500	0	8,500
FEATURE														
ISLAND	4,500	201,500	38,250	5,500	2,000	12,250	19,500	0	0	0	9,250	0	0	0
ATOLL	0	59,000	29,250	20,250	41,500	8,500	16,000	14,000	0	0	0	0	0	0
BANK	2,750	77,500	28,500	0	39,000	107,000	56,000	17,500	8,500	0	8,250	0	0	0
GUYOT	0	0	0	12,000	106,750	289,500	269,625	56,250	21,250	0	0	0	0	0
CONICAL SEAMOUNT	250	27,500	15,000	10,750	81,250	97,250	82,750	22,000	33,000	71,000	0	0	0	0
RIDGE SEAMOUNT	0	21,250	12,750	22,500	24,250	23,500	125,250	49,750	29,250	0	5,750	5,500	0	0
INACTIVE VENT	0	0	0	0	0	0	12,750	42,000	0	23,500	0	0	0	0
VENT	6,500	33,250	19,750	27,750	20,250	0	0	0	12,250	5,250	11,750	0	0	0
ABYSSAL	0	0	0	0	0	0	0	0	0	2,250	42,500	30,750	1,000	39,500

Supplementary Figure 1. CAPSTONE ROV dive sites organized by region (Marianas, Western Pacific, Hawaiian Islands, South-Central Pacific, American Samoa). Marine Protected Areas boundaries are indicated by polygons. Dive site markers are color coded by feature type.



Describe relevance to national security, conservation, and/or the economy:

A nation cannot effectively manage its resources if it does not know what it has. Basic exploration of US waters is imperative to support national security, conservation, and stimulate the blue economy

From your perspective, what makes this area unique?
(If applicable, why is this area relevant to your organization?)

The central and western Pacific MPAs encompass over 742,000 square miles. They contain some of the last relatively pristine marine ecosystems on the planet and harbor numerous protected species. CAPSTONE was conceived to help document these unknown reaches of the US and it was a great success but despite all of the effort gaps remain in the data.

Please list other partners or organizations that may also be interested in this area:

All of the original CAPSTONE partners will most likely be interested in rounding out the data set.

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Submissions should be no longer than **two pages** of text and **five pages** total, including any graphics, figures, captions, and references. Graphics and figures are highly encouraged. A minimum of 11-point font is required. Please send your completed form (either as a Word document or PDF) to Katie Fillingham (kfillingham@oceanleadership.org) and Dan Rogers (drogers@oceanleadership.org) by **COB February 20th.**

Author: Randi Rotjan
Institution: Boston University
Email Address: rrotjan@bu.edu
Office Phone Number: 617-3535087
Collaborators/Co-Authors: Brian Kennedy and Tim Shank

Title: Phoenix Islands Protected Area (PIPA) and Howland and Baker unit of PRIMNM

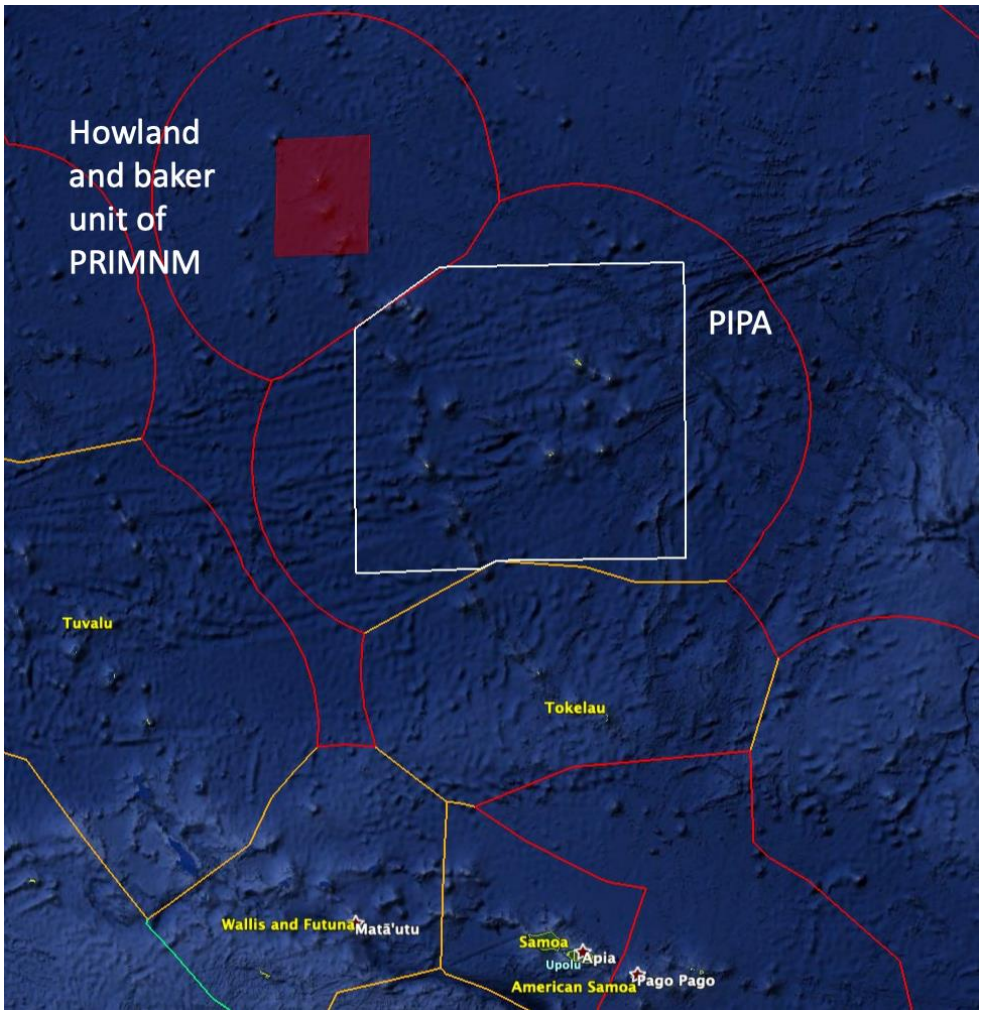
Priority Geographic Area:
The Central Pacific along the Tokelau Ridge including the Phoenix Islands Protected Area (PIPA), Howland and Baker unit of PRIMNM and US waters around Howland and Baker that are outside of the monument.

Description of Priority Area:
(Include a brief summary of the habitat, what is known about the area, and provide a rationale for exploration.)

PIPA is one of the oldest large scale marine protected areas (MPAs) in the world that contains large expanses of deep sea ecosystems, making it a natural laboratory for understanding how no-take MPAs impact the deep sea. However, before we can ask these questions, we must be able to set a baseline at or near closure. PIPA was closed to all extractive activity in 2015 (save for some subsistence shallow water fishing by the MPA caretakers) so the window to properly set the baseline at near closure is rapidly closing and previous exploration efforts have only documented an extremely small sample of the seafloor. Furthermore, nearly no mesophotic work has been completed.

Howland and Baker are two remote US Island Territories; 99% of this area covers ocean deeper than 1000 meters. A significant portion of the US EEZ around these two islands is protected by the Pacific Remote Islands Marine National Monument (PRIMNM). The waters around Howland and Baker are very interesting oceanographically with the equator passing just south of the islands; there are dynamic currents associated with the equatorial currents and the counter current.

Importantly, the 8 islands associated with PIPA and the 2 islands in the Howland/Baker portion of the PRIMNM make up a single archipelago (10 islands total) that traverses the equator, both with very large-scale marine protected areas AND with adjacent waters open to extractive activities. As such, this region is a) oceanographically interesting across the equator and b) geopolitically interesting with two countries (a most and least-developed country) managing their EEZ waters both within and outside of large scale marine protected areas.



What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
_X_ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:

Primarily, additional mapping and ROV exploration is required. BU, in partnership with SEA and many other organizations, has been running annual cruises onboard the SSV Robert C Seamans to study the physical, biological and chemical oceanography, coupled with detailed analyses of plankton assemblages, in the Kiribati surface waters. In addition, shallow coral reefs have been intermittently monitored (via SCUBA) since 2000 in PIPA, and NOAA has monitored the PRIMNM routinely as part of its coral monitoring program. What is needed now is a better understanding of the deep sea fauna in the area, building on the work started in 2017 by the *Okeanos Explorer*, *Nautilus* and the *Falkor*. Given the existing data sets in PIPA and the US Phoenix Islands, this region provides a unique opportunity to examine spatially-explicit ecology in a relatively pristine, but oceanographically dynamic, part of the Pacific Ocean.

Describe relevance to national security, conservation, and/or the economy:

PIPA is of global conservation relevance, as the largest and deepest UNESCO World Heritage Site. It is also a part of the Big Ocean Network, which coordinates strengths and challenges amongst large-scale MPAs. Though owned and operated by the Republic of Kiribati, PIPA has many ties with the US. The PIPA Conservation Trust is a US based 501C3 with partnered US institutions such as Conservation International and the Aquarium of the Pacific, including members of the Conservation Law Foundation. Formally, PIPA has a sister-site agreement with Papahanaumokuakea, p. Finally, PIPA and the PRIMNM have a signed cooperative agreement (as of October 2014) with stated mutual interests to collaborate as part of the Treaty of Friendship signed between the US and Kiribati governments in 1979.

As part of the US EEZ, it should be noted that the PRIMNM area around Howland and Baker is one of the least mapped areas of the United States. To meet the US Seabed 2030 goals, a significant mapping effort will need to be launched in this area. Additionally, the waters around Howland and Baker have the potential to contain commercially viable resources in both polymetallic nodules and crusts that have not been well-characterized yet.

From your perspective, what makes this area unique?
(If applicable, why is this area relevant to your organization?)

The oceanography of the central pacific is very dynamic and relatively productive compared to typical oligotrophic reef waters. The interesting oceanography in the region – a north south chain of seamounts running from 10S to 2N - presents an interesting natural experiment to understand how latitudinal gradients effect coral and sponge communities, and to what effect surface currents might act as biogeographic barriers for deep sea fauna.

Anecdotal observations from the Okeanos Explorer's 2017 expedition to this area showed an interesting species transition from North to South along this line of seamounts, which supports the idea that the complex currents in this area may lead to the discovery of previously unknown controls on deep sea biogeography. Additional exploration is needed in this area to lay the groundwork for future research into these questions.

Additionally, this area is interesting because it is one of the few places in the world where two large scale MPAs boundaries are close to each other. The Howland and Baker unit of PRIMNM is only ~120 km from the PIPA boundary. This provides an interesting opportunity to compare the impacts of the policy's set by both Kiribati and the US in how they manage their respective MPAs effect the deep sea. However, in order for this research to be conducted in the future, we much explore these waters now to set the baselines for future hypothesis-driven research.

Please list other partners or organizations that may also be interested in this area:

NOAA Fisheries Pacific Island Regional Office
Government of Kiribati
PIPA Conservation Trust

Exploration of high seas coral reefs in the North Central Pacific

Author: Daniel Wagner
Institution: Conservation International
Email Address: dwagner@conservation.org
Office Phone Number: 808-256-5014
Collaborators/Co-Authors:

- ʻAulani Wilhelm, Conservation International, awilhelm@conservation.org
- Ashleigh McGowern, Conservation International, amcgovern@conservation.org
- Tamara Thomas, Conservation International, tthomas@conservation.org
- Richard Pyle, Bishop Museum, deepreef@bishopmuseum.org
- Alan Friedlander, University of Hawaii & National Geographic Society, friedlan@hawaii.edu
- Jim Costopulos, Global Ocean, jcostopulos@global-oceans.org
- Cassandra Brooks, University of Colorado at Boulder, cassandra.brooks@colorado.edu
- Sylvia Earle, Mission Blue & National Geographic Society, saearle@aol.com
- Kristina Gjerde, International Union for Conservation of Nature, kristina.gjerde@eip.com.pl
- Mike Conathan, Aspen High Seas Initiative, michael.conathan@aspeninstitute.org
- Matt Gianni, Deep Sea Conservation Coalition, matthewgianni@gmail.com
- Elizabeth Karan, PEW Charitable Trusts, ekaran@pewtrusts.org
- Nichola Clark, PEW Charitable Trusts, nclark@pewtrusts.org

Priority Geographic Area: International waters in the North Central Pacific Ocean. Specifically, this proposal seeks to explore seamounts that are predicted to have depths of ~300 m or shallower (Figure 1) using multibeam mapping, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUV), or mixed-gas technical SCUBA.

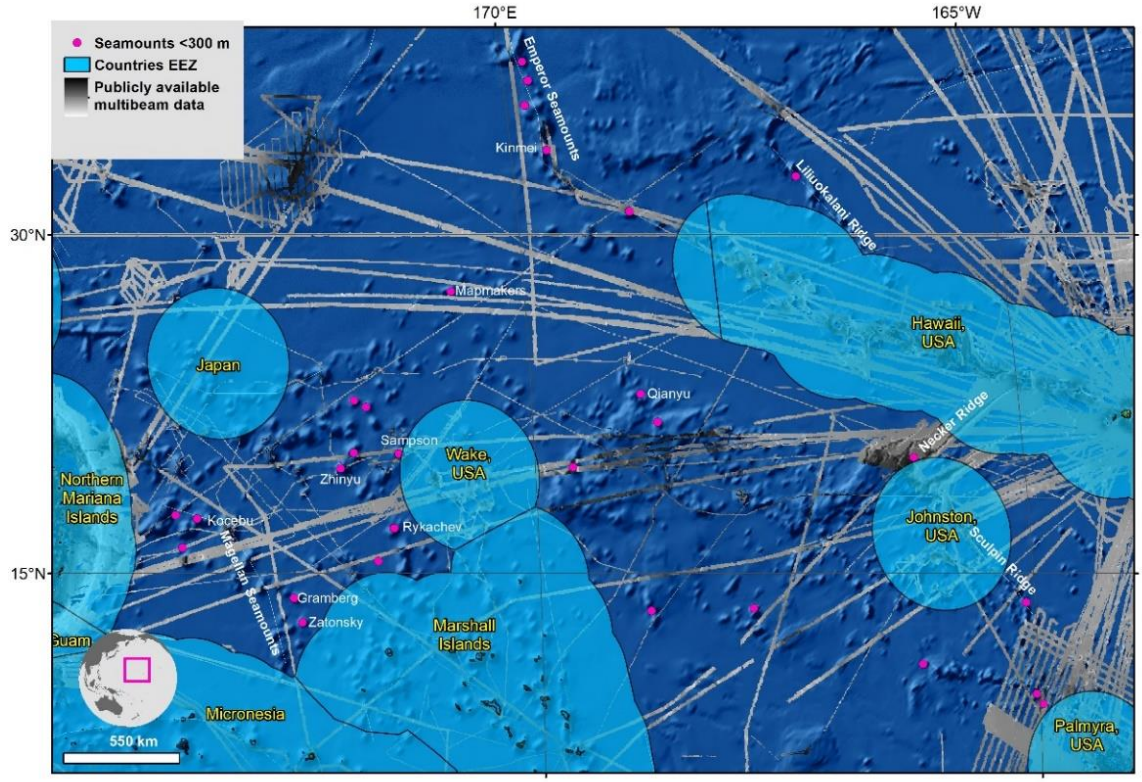


Figure 1. Map showing the exploration targets of this proposal (pink dots), which seeks to explore mesophotic coral reefs on the high seas in the North Central Pacific Ocean. Satellite-derived bathymetry data (ETOPO1) indicates that international waters of this region contain at least 29 seamounts with summits shallow enough (<300 m) to host mesophotic coral reefs. None of these locations have previously been mapped using high-resolution sonars (NOAA 2020) nor surveyed visually.

Description of Priority Area:
This proposal seeks to explore mesophotic coral reefs in international waters of the North Central Pacific Ocean. Satellite-derived bathymetry data (ETOPO1) and global seamount inventories (Yesson et al. 2011) indicate that there are at least 29 seamounts in international waters of this region with summit depths shallow enough (<300 m) to host mesophotic coral ecosystems. However, none of these seamounts have been mapped with high-resolution multibeam sonars (NOAA 2020), nor have they been surveyed visually. The proposed work is therefore highly exploratory; however, it is also very relevant and timely to the ongoing international dialogue on the conservation and sustainable use of biological diversity in marine areas beyond national jurisdiction, commonly known as the high seas. Specifically, two pivotal events for the management of high seas ecosystems will occur this year, including (1) the possible finalization of a United Nations agreement that would provide a legally-binding framework to create marine protected areas (MPAs) on the high seas, and (2) the possible release of International Seabed Authority regulations that would enable the exploitation of deep-sea minerals on the high seas.

The current draft text of the United Nations agreement specifically calls out the need for the best available science to identify high seas areas requiring protection (United Nations 2019). The work proposed here directly addresses this United Nations call by targeting coral reefs, ecosystems that are widely regarded as a conservation priority due to their remarkably high levels of biodiversity and the valuable ecosystem services they provide. Furthermore, the geographic area of this proposed work falls within the Prime Crust Zone, the region on Earth with the greatest accumulatio of commercially-valuable, mineral-rich seafloor crusts (Hein et al. 2013). The International Seabed Authority has already issued deep-sea mineral exploration leases for a total of 600 lease blocks in the North Central Pacific (ISA 2020), which cumulatively cover over 10,000 km^2 of seafloor (Figure 2). The work proposed here seeks to survey the marine fauna in or near these deep-sea mining exploration areas, and thereby provide important information to help support management decisions. Specifically, the proposed work seeks to identify and survey the most vulnerable ecosystems of the region, so they can be conserved using appropriate management measures.

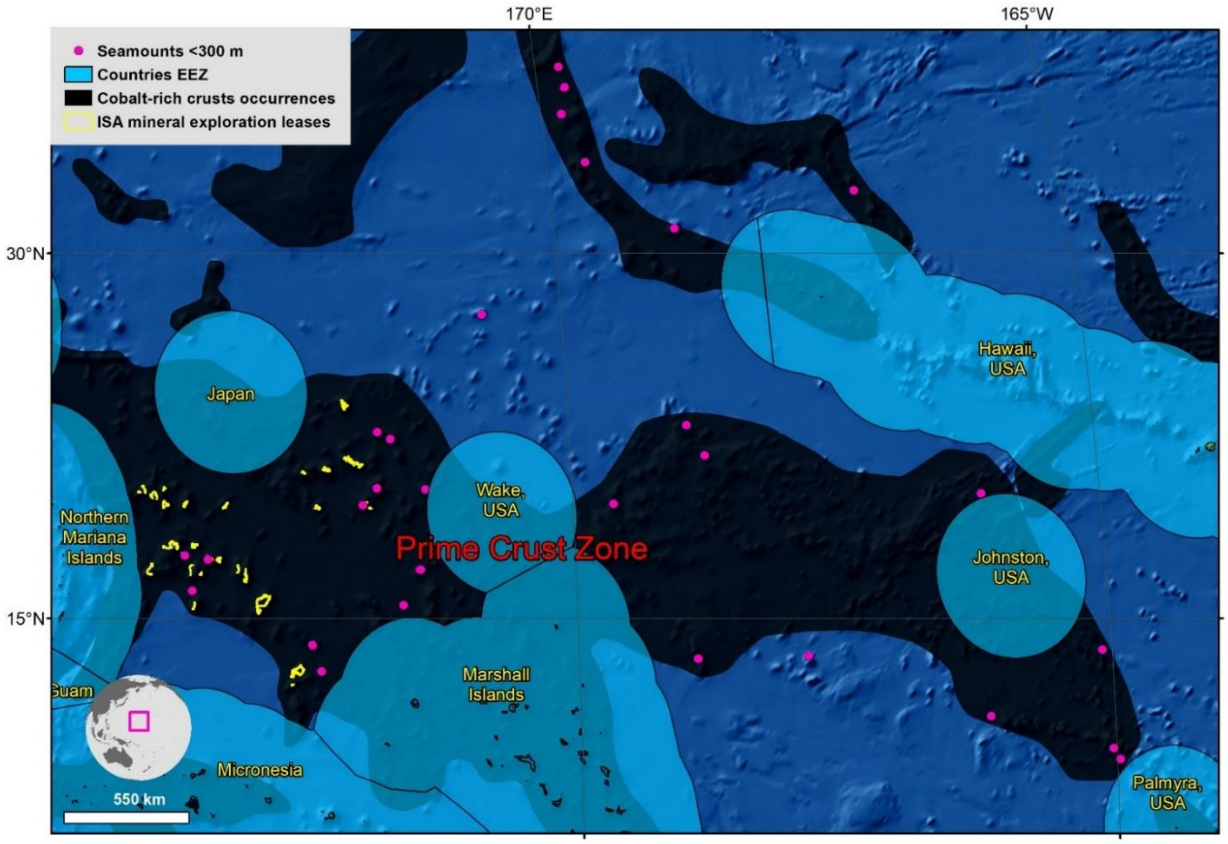


Figure 2. Map showing the exploration targets of the proposed work (pink dots), along with deep-sea mineral exploration contracts issued by the International Seabed Authority (yellow polygons; ISA 2020) in the Prime Crust Zone (black polygon), the region with the most commercially valuable cobalt-rich crusts on Earth (Hein et al. 2013; Miller et al. 2018).

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
___ Geology
___ Marine Archaeology
___ Physical Oceanography
___ Chemistry
_X_ Other: Seafloor mapping

Provide a list or brief description of the data needed within this area, from your perspective:
Collect high-resolution multibeam data on seamounts that are predicted to have summit depths of ~300 m or shallower based on satellite altimetry data (Figures 1-2), and therefore likely to host mesophotic coral ecosystems. Once the summit depths of these seamounts are confirmed using multibeam sonar data, deploy remotely operated vehicles ROVs, AUVs or technical SCUBA divers to conduct visual surveys of the benthic fauna of the region.

Describe relevance to national security, conservation, and/or the economy:
The proposed work targets international waters that are directly proximal to waters that fall within U.S. jurisdiction around Wake, Palmyra, Johnston, Hawaii and the Mariana Islands. This region is known to have an exceptionally rich and unique biodiversity. As a result, the U.S. has already protected most of the waters that fall within its jurisdiction through large-scale marine protected areas (MPAs), including the Papahānaumokuākea Marine National Monument, the Pacific Remote Islands Marine National Monument, and the Marianas Trench Marine National Monument. While these MPAs represent important advances in safeguarding the unique biodiversity of the region, they could be impacted by activities that occur outside these managed areas. In particular, mineral exploitation on seafloor crusts is expected to be the most destructive form of deep-sea mining that is currently being explored (Miller et al. 2018). Direct impacts will result from extraction activities directly disturbing the seafloor, as well as via sediment plumes that will impact habitats over large areas surrounding mining sites, and via increased noise, light, water temperature, electromagnetic disturbance as a result of mining operations. The International Seabed Authority has already issued deep-sea mineral exploration leases for a cumulative area covering over 10,000 km^2 of seafloor in the North Central Pacific (ISA 2020), and might release regulations later this year that could lead to the commercial exploitation of deep-sea minerals in this region. This project seeks to identify and survey the most vulnerable ecosystems of the region, so they can be protected using appropriate conservation measures.

In addition to its conservation merit, this project also has direct implications for safeguarding against countries trying to extend their jurisdictions into international waters. This has been an issue throughout the South China Sea. By focusing global attention on the management and conservation of ecosystems in marine areas beyond national jurisdiction, this project could help mitigate potential U.S. national security issues in the region.

Finally, since the exploration sites proposed here all lie between waters that are under U.S. jurisdiction (Figure 1-2), surveying them has practical advantages. Specifically, many of them could be explored opportunistically while ships transit between different U.S. national waters, and thereby collect valuable information without having to make major adjustments to transit routes.

From your perspective, what makes this area unique?
Marine areas beyond national jurisdiction cover over 61% of the global oceans by area and over 73% by volume. These remote areas are not only vast, but also provide many vital ecosystem services that are critical for sustaining life on our planet, such as producing nearly half the oxygen we breathe, absorbing a quarter of the carbon dioxide we emit into the atmosphere, and providing habitat for a myriad of ecologically and commercially important species. Yet, only 1% of the high seas currently lie within marine protected areas (MPAs), in large part due to the patchwork of a legal framework that is in place to protect the high seas, as well as the lack of awareness that important ecosystems exist within these remote ocean areas.

Tropical coral reefs are heralded as the rainforests of the sea due to their remarkably high levels of biodiversity. Despite only covering 1% of the oceans by area, coral reefs harbor 25% of the total marine biodiversity. Their high levels of biodiversity, coupled with a range of other ecosystem services and human benefits, have resulted in a long history of coral reef protection in the exclusive economic zones (EEZ) of many countries, particularly throughout the Indo-Pacific. While most people assume that coral reefs only exist in shallow and nearshore waters, deeper extensions of tropical coral reefs, known as mesophotic coral ecosystems (MCEs), have been documented down to depths of 300 m in many remote locations, including on the high seas.

Satellite-derived bathymetry data and global seamount inventories indicate that there are at least 29 seafloor areas in international waters of the North Central Pacific that are suitable for mesophotic coral reefs, with none of these having been explored. In fact, mesophotic coral reefs are some of the most undersurveyed of all ocean ecosystems, and therefore have been identified as a top research and conservation priority by the International Union for the Conservation of Nature (IUCN). Furthermore, because high seas coral reefs are currently not protected by the laws of any country, they are among the most vulnerable reefs on Earth to overexploitation.

Conservation International, along with its partners, seeks to galvanize the conservation and sustainable use of 18,000,000 km^2 (~5% of our oceans) of ocean by 2025, and thereby move us closer to achieving global targets of conserving 30% of our oceans by 2030 (IUCN 2016). With less than 8% of our oceans currently protected, and over 60% of the world's oceans lying on the high seas, protection of these remote areas offers our only real hope of achieving global conservation targets and arresting global declines in biodiversity.

Please list other partners or organizations that may also be interested in this area:
This proposal is submitted on behalf of the Coral Reefs on the High Seas Coalition, a multi-disciplinary alliance of partners coordinated by Conservation International that includes various organizations that seek to advance high seas science, policy and conservation. These include Aspen High Seas Initiative, The Pew Charitable Trusts, Bernice P. Bishop Museum, National Geographic Pristine Seas, University of Colorado at Boulder, Mission Blue, Global Oceans, Global Seamounts Project, Association for Marine Exploration, Oceana, Deep Sea Conservation Coalition and Big Ocean.

In addition to the above partners, this proposal is also highly relevant to several other organizations that are advancing high seas conservation efforts globally, including the High Seas Alliance, Strong High Seas Project, United Nations Common Oceans ABNJ Program, Greenpeace 30x30 Blueprint for Ocean Protection Initiative, among many others.

References:
ETOPO1. ETOPO 1 global relief model. Available at: https://ngdc.noaa.gov/mgg/global/global.html

Hein JR, Mizell K, Koschinsky A & Conrad TA (2013). Deep-ocean mineral deposits as a source of critical metals for high- and green-technology applications: Comparison with land-based resources. Ore Geology Reviews 51: 1-14. Available at: https://www.sciencedirect.com/science/article/pii/S016913681200234X

International Seabed Authority (2020). International Seabed Authority deep-sea mineral exploration maps. Available at: https://www.isa.org.jm/maps

International Union for the Conservation of Nature (2016). Increasing marine protected area coverage for effective marine biodiversity. 2016 World Conservation Congress Resolution 50. Available at: https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_050_EN.pdf

Miller KA, Thompson KF, Johnston P & Santillo D (2018). An overview of seabed mining including the current state of development, environmental impacts, and knowledge gaps. Frontiers in Marine Science 4(418): 1-24. Available at: https://www.frontiersin.org/articles/10.3389/fmars.2017.00418/full

National Oceanic and Atmospheric Administration (2020). NOAA National Centers for Environmental Information bathymetry data viewer. Available at: https://maps.ngdc.noaa.gov/viewers/bathymetry/

United Nations (2019). Revised draft text of an agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. Available at: https://www.un.org/bbnj/sites/www.un.org.bbnj/files/revised_draft_text_a.conf_.232.2020.11_advance_unedited_version.pdf

Yesson C, Clark MR, Taylor M & Rogers AD (2011). The global distribution of seamounts based on 30-second bathymetry data. Deep Sea Research Part I: Oceanographic Research Papers 58: 442-453. Available at: http://data.unep-wcmc.org/datasets/41

Workshop to Identify National Ocean Exploration Priorities in the Pacific
Pre-Workshop White Paper Submission Form

Author: Janet Watt
Institution: USGS Pacific Coastal & Marine Science Center, Santa Cruz, CA
Email Address: jwatt@usgs.gov
Office Phone Number: (831) 460-7565
Collaborators/Co-Authors: Jenna Hill, Nathan Miller, Brian Sherrod, Charlie Paull, Nancy Prouty

Title: Systematic deepwater mapping along the Cascadia Subduction Zone critical for exploration and hazard science

Priority Geographic Area: (see Figure 1)
Deepwater area (~1500 m to 4000 m) along the deformation front of the Cascadia Subduction Zone where the plate boundary thrust fault approaches the seafloor and associated deep sea fans. Entirely within U.S. EEZ

Description of Priority Area:

KEY TAKEAWAYS
• The lack of high-resolution seafloor mapping data along the deformation front of the Cascadia Subduction Zone limits our ability to characterize earthquake and tsunami hazards and explore deepsea habitats throughout the Pacific Northwest.
• Systematic imaging of the Cascadia margin deformation front requires significant ship-time resources on a specialized vessel with deep-water mapping capabilities (e.g., NOAA Ships Okeanos Explorer and Ron Brown, or Ocean Exploration Trust's E/V Nautilus with EM302 or equivalent).
• NOAA investment in mapping the deepest areas of the Cascadia subduction zone complements major ongoing USGS Cascadia hazards and deep-water ecosystems research initiatives and can be wrapped into existing DEM product development.
• 36 total DAS are required for complete systematic high-resolution multibeam coverage of the entire deformation front. 12 DAS are required to target the highest priority areas (see Figure 1).

Recent large subduction earthquakes, such as the Mw 9.0 2011 Tohoku-Oki earthquake in Japan, highlight the tsunami hazard associated with trench-breaching rupture, where fault slip extends to the deformation front and displaces the seafloor. Comparison of high-resolution multibeam bathymetry collected before and after the Tohoku-Oki earthquake showed that the fault ruptured to the seafloor at the deformation front, something previously thought impossible. The seafloor uplift was the primary cause of the devastating tsunami that claimed lives and the meltdown of the Fukushima Daiichi Nuclear Power Plant. An earthquake of similar magnitude struck the Pacific Northwest in January of 1700, causing a transpacific tsunami. The observations from the 2011 earthquake in Japan highlight the utility of seafloor mapping for understanding subduction zone hazards and the need for similar mapping efforts in Cascadia.

Mapping efforts here will compliment and expand major ongoing Cascadia hazards and ecosystems research initiatives into deeper waters. Unraveling the geologic record of past earthquakes along submarine faults is fundamental to earthquake and tsunami hazard assessment, just as it is for faults on land. For confident interpretations of these records it is critical to have seafloor maps of sufficient resolution to measure tectonic deformation (similar to lidar on land) and clearly outline the sediment dispersal systems that cross the margin and run out onto the abyssal plain. The geologic complexity and fluid expulsion often associated with active submarine faulting contributes to margin habitats along an active tectonic boundary. For example, Cascadia focused research on the E/V *Nautilus* over the last several years has documented the importance of carbonate structures to form habitat for corals, sponges, and fishes, with links to species richness and

diversity of microbial communities at seeps sites. In contrast, the habitats and sedimentary systems in >1500 water depths along the Cascadia Subduction Zone are poorly known, in part because of the lack of modern bathymetry. However, the bold topography here provides promising hard bottom environments for communities of special biologic significance. These include deep sea coral - sponge communities as well as cold seep chemosynthetic communities associated with the enhanced fluid expulsion in this tectonic setting.

What are the characterization and data needs in this area?
Check all that apply:
_X_ Biology
_X_ Geology
___ Marine Archaeology
_X_ Physical Oceanography
_X_ Chemistry
___ Other

Provide a list or brief description of the data needed within this area, from your perspective:
Systematic imaging with deep-water mapping capability (EM302 or equivalent), with 10% overlap on each side, in water depths >1500m (bathymetry, backscatter, and water column). The goal would be to collect bathymetry data that can be gridded to 20m resolution or better.

Describe relevance to national security, conservation, and/or the economy:
Nearly the entire U.S. Exclusive Economic Zone offshore the tectonically inactive U.S. East Coast has been mapped with modern multibeam echosounders. In contrast, less than fifty percent of the tectonically active U.S. West Coast has been mapped with the same resolution. This is remarkable given the much greater potential for submarine earthquakes, landslides and tsunamis to impact communities and marine resources (alternative energy, fisheries) along the Pacific coastline.

The deformation front along the 700 hundred-mile-long Cascadia subduction zone represents one of the greatest geologic hazards in the United States (Figure 1), yet there exists inadequate multibeam maps of this active plate boundary. Without accurate imagery along the deformation front we have a limited ability to forecast mitigate impacts from future subduction earthquakes and tsunamis, and we will not have a pre-event baseline to asses seafloor offset after the next great earthquake.

From your perspective, what makes this area unique?
The Cascadia Subduction Zone is currently the focus of extensive efforts by government agencies (NOAA, USGS, BOEM, EXPRESS), academia (NSF and multiple west coast universities), and private partners (MBARI) to better characterize geologic hazards (earthquake, tsunami, landslide), describe deep sea habitats, and assess offshore wind potential. Systematic imaging along the deformation front, as described above, provides a fundamental dataset for all these efforts and represents a major interagency deliverable associated with the recent Presidential Memo on Ocean Mapping. In addition, the mapping data and information would be broadly applicable to a wide range of NOAA Blue Economy interests and set the foundation for multiple lines of deep-water exploration in the region.

Please list other partners or organizations that may also be interested in this area:
NOAA (PMEL & OCS), BOEM, Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS), Monterey Bay Aquarium Research Institute (MBARI), NSF, University of Washington, University of Hawaii, Scripps Institution of Oceanography, Oregon State University, Humboldt State University

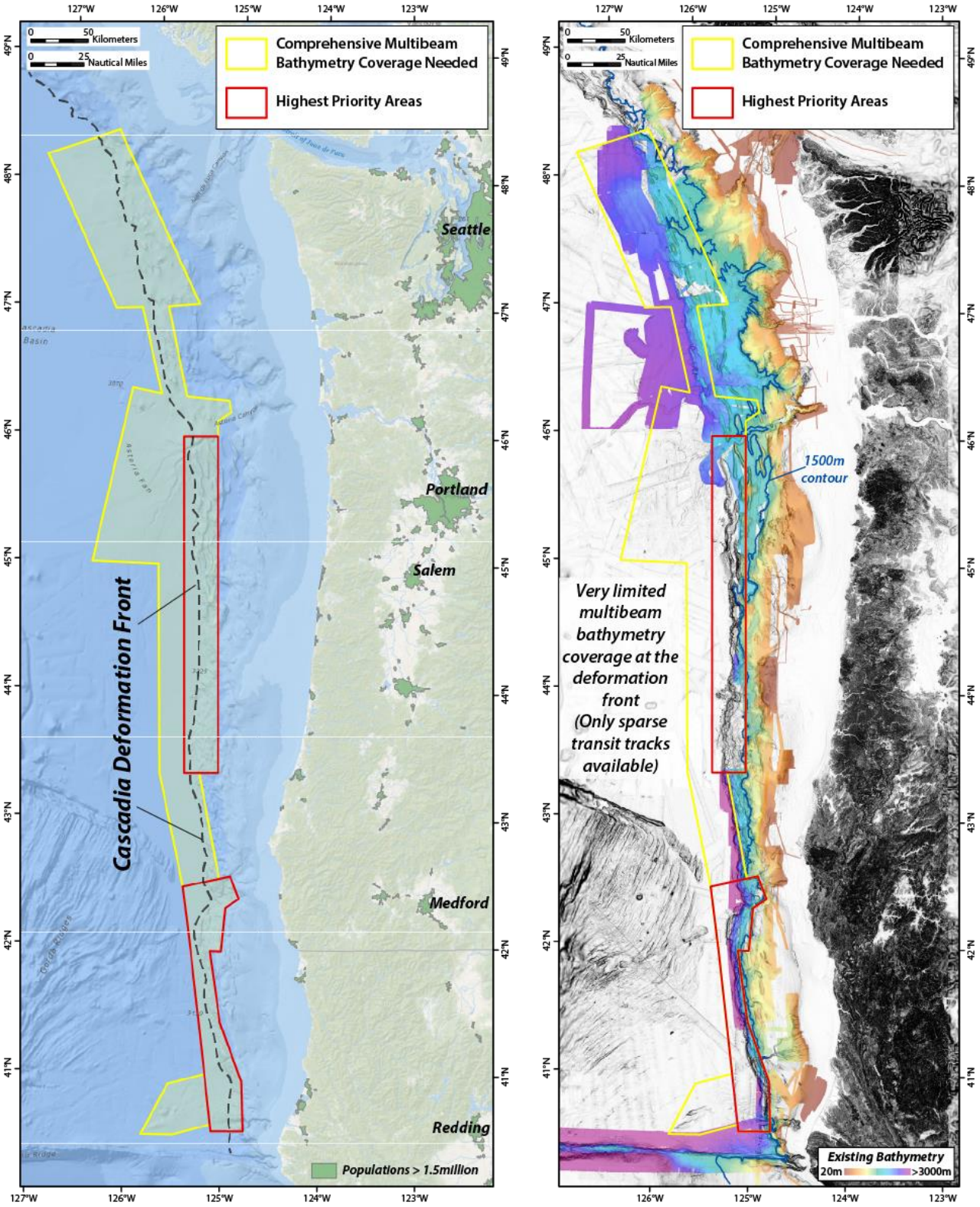


Figure 1. Maps of the Cascadia subduction zone: (left) consistent multibeam bathymetry coverage is needed along the length of the subduction zone, and particularly in areas outlined in red; (right) major gaps in seafloor imagery exist along the deformation front where only sparse transit data are available.