The purpose of this Atlas is to facilitate improved environmental management of the Outer Continental Shelf (OCS) by developing one depository of maps and information on major submarine canyons of the OCS. This Atlas provides the Bureau of Ocean Energy Management (BOEM) with geospatial and resource information to assist in the preparation of environmental documents. To accomplish this, submarine canyons were inventoried and delineated using a methodology consistent with terrestrial watershed mapping. A criteria-based algorithm-generated spatial polygons used to calculate canyon slope, length, and depth. A concurrent literature review was conducted, which provided the notable facts seen in the Atlas. In addition, the literature citations were cataloged in an EndNote library and a synopsis thereof was included as a geodatabase file.

Canyon polygons developed by Harris et al. (2014) (hereinafter, Harris) was the starting point for defining canyon boundaries and guiding the initial canyon inventory and selection process. Harris utilized both geographic information system (GIS) tools (Topographic Position Index, calculated by comparing each cell slope value to the mean slope of the cell’s neighbors) and the judgement of subject matter experts (SMEs). For this project, CSIA Ocean Sciences Inc. (CSIA) developed an objective, numerically repeatable delineation process using the Harris data as a starting point. As with Harris, canyon bathymetry, and subsequently, their boundaries were derived using Shuttle Radar Topography Mission (SRTM30) data because of its consistent geographic coverage.

The first step in this process was to extract the approximate Harris canyon thalweg, which represents the deepest continuous path down the canyon. The bathymetric data were clipped at the Harris polygon border for thalweg extraction using the Strahler method in the Esri Toolbox (Strahler 1957). The Strahler method assigns stream order values to tributaries as they intersect one another. Typically, the first three stream orders were adequate to create a continuous polyline along the Harris thalweg extent in less linear and more dense canyon systems, management of stream order was utilized to ensure an continuous polyline. To simplify the stream order network, \( \log_{10} \) was applied to the result of the flow accumulation calculation tool before calculating stream order.

The effect of boundary extent on the 2SD percentile was also examined for three visually distinct canyon geometry scenarios. The three geometry scenarios were: 1) isolated and narrow relative to length, 2) isolated and wide relative to length, and 3) canyon systems (many canyons occurring conterminously). For each of these canyon scenarios, the 2SD percentile was plotted as a function of the five boundary extents and visually examined for sensitivity of the 2SD percentile to these extent by canyon geometry scenario combinations. By evaluating how seafloor slope percentiles stabilized as a function of boundary extents, it was concluded that use of the 2SD percentile within a 10-km boundary would be used to eliminate surrounding seafloor from the definition of canyon boundaries.


Heezen Canyon walls are steep and mud covered, with complex terrain of mud ridges, steep gullies, and some exposed bedrock outcrops with occasional glacial erratics (NEFMC and NMFS 2017).

The NOAA Okeanos Explorer documented 18 species of corals inhabiting a depth range of 703 to 1,723 m in Heezen Canyon (Quattrini et al. 2015).

The walls in Nygren Canyon are suggested to be highly stable due to the presence of iron-manganese oxide coating and heavy colonization of attached fauna (Quattrini et al. 2015).

Nygren Canyon was shown to have the highest species richness compared to other canyons surveyed (Quattrini et al. 2015).

A possible shipwreck has been identified south of Nygren Canyon in water depths of approximately 3,500 m (CSA et al. 2017).
CHAPTER 1 - ATLANTIC SUBMARINE CANYONS

OCEANOGRAPHER CANYON SYSTEM

NOTABLE FACTS

Oceanographer Canyon is deeper than the Grand Canyon (more than 2,000 m deep). The maximum water depth within the entire Oceanographer Canyon system is more than 3,800 m.

Canyons within the Oceanographer System are known to have a high abundance of fauna, including numerous deep-water corals. A 2013 survey observed a high abundance of fauna living on the underside of ledges, including bivalves, cup corals, squat lobsters, and sponges (Quattrini et al. 2015). In Gilbert Canyon, black corals were discovered for the first time in this area (NEFMC and NMFS 2017).

Lydonia, Oceanographer, and Gilbert Canyons are included in the first and only National Marine Monument to be designated in the Atlantic Ocean (81 FR 65161).
CHAPTER 1 - ATLANTIC SUBMARINE CANYONS

HYDROGRAPHER CANYON

NOTABLE FACTS

Siliciclastic and carbonate-rich lithologic sequences are prevalent in this canyon (Quattrini et al. 2015).

Outcrops in this canyon are most likely of Late Cretaceous to Eocene age (Quattrini et al. 2015).

A variety of biota have been characterized within the canyon, including eels, cod, dogfish, flounder, crab, corals, sponges, mollusks, shrimps, and cephalopods (Quattrini et al. 2015).

This canyon is designated as a Habitat Area of Particular Concern (HAPC) based on its unique geomorphology and the presence of deep sea corals (NEFMC and NMFS 2017).
Veatch canyon’s formation has been linked to glacial outwash from the George’s Bank area (Forde 1981).

Cold seeps and associated biota such as deep sea mussels have been identified in this canyon. Corals and sponges have also been observed living on the canyon walls (NEFMC and NMFS 2017).

This canyon has been designated as a “Tilefish Gear Restricted Area” and is closed to vessels with bottom-tending mobile gear, such as trawls, seines, and dredges (50 CFR 648.297).
CHAPTER 1 - ATLANTIC SUBMARINE CANYONS

HUDSON AND ATLANTIC 2 CANYONS
Atlantic 2 Canyon runs almost parallel to the southern portion of Hudson Canyon and is approximately 15 km east.

Hudson Canyon is the largest canyon on the U.S. Atlantic shelf and slope (Covault et al. 2011) and is a deep trough that connects the canyon to the mouth of the Hudson River (Lentz et al. 2014).

Hardbottom areas have been identified along the floor of Hudson Canyon, as well as pock-mark fields associated with methane release from sediments (NEFMC and NMFS 2017).

Along the canyon walls near the head of Hudson Canyon, the strata are believed to be of Cretaceous, Paleogene, and Neogene age (Butman et al. 2006).

Sediment transport in Hudson Canyon is primarily driven by tidal currents, internal waves, and storms (Pierdomenico et al. 2017).

Hudson Canyon, especially its upper reaches, represents an area of enhanced primary productivity and organically rich sediments, which enhances fish and invertebrate communities around the canyon. It is also home to soft coral species in deeper portions of the canyon (Pierdomenico et al. 2017).

Hudson Canyon is recognized as a hotspot for commercial and recreational fishing (Pierdomenico et al. 2017).

The area adjacent to the head of Hudson Canyon includes a group of shipwrecks, both named and unnamed (NOAA 2019).

The morphology of the Hudson Canyon, particularly the north-south orientation of the canyon head and a braided channel near its southeastern outlet, supports archaeological site preservation (Garrison et al. 2012).

Hudson Canyon has been designated as an HAPC based on its unique geomorphology and the presence of deep sea corals (NEFMC and NMFS 2017).

Observations of large seasonal aggregations of krill within Hudson Canyon may also attract marine mammals (Pierdomenico et al. 2017).
Atlantic 3 Canyon is approximately 240 km long, is located about 333 km east of the Chesapeake Channel in Virginia, and is possibly an extension of the Baltimore Canyon system to the west-northwest.

There have been four shipwrecks identified adjacent to the Atlantic 3 Canyon edges (NOAA 2019).
CHAPTER 1 - ATLANTIC SUBMARINE CANYONS

WILMINGTON CANYON AND BALTIMORE CANYON SYSTEM

---

**NOTABLE FACTS**

- Canyon walls in the upper part of Baltimore Canyon support abundant sessile communities of sponges, anemones, octocorals, and hard corals (Brooke et al. 2017; CSA et al. 2017). Motile fauna, such as crabs, squat lobsters, shrimps, and fishes, are abundant and diverse (Ross et al. 2015; CSA et al. 2017). An active methane seep with associated communities occurs near the southern edge of the canyon (Prouty et al. 2016; CSA et al. 2017).

- It was suggested that Wilmington Canyon is older than both South Wilmington and North Heyes Canyons (Kuenzel 2011). A seismic reflection survey suggests that the ancestral Delaware River valley was the most recent of a series of valleys to enter the canyon from the west (McGregor 1981).
The Norfolk Canyon system comprises Norfolk Canyon, Washington Canyon, and the smaller Hull Canyon. The heads of Washington and Norfolk Canyons are approximately 45 km apart and are cut 11.7 km and 19.3 km onto the shelf, respectively (Ford 1981, Obelcz et al. 2014).

Offshore of Washington and Norfolk Canyons’ bends, the canyons contain higher densities of steep tributary canyons and gullies, especially along their north walls, which have a greater roughness and local steepness when compared to their southern walls (Obelcz et al. 2014). A series of terraces is characteristic of many places along the walls of Norfolk Canyon (Obelcz et al. 2014).

Canyons within the Norfolk Canyon system likely originated from non-riverine erosional processes (Tucholke 1987). Seismic profiles of Washington and Norfolk Canyons indicate an erosional origin of these canyons; however, profiles of the continental slopes reveal a history of alternating episodes of deposition and erosion (Ford 1981).

Currents within the area are largely driven by the shelf-slope front, with current speeds controlled by semidiurnal tides. Current velocities are highest in the heads of the canyon (CSA et al. 2017).

Norfolk Canyon contains known habitats for deep sea, habitat-forming coral species (Lophelia pertusa) as well as sessile fauna, such as octocorals, sponges, pink anemones, and soft tube worms (Brooke et al. 2017; CSA et al. 2017). Motile fauna are diverse and abundant and include crabs, squid, lobsters, shrimps, and fishes (Ross et al. 2015; CSA et al. 2017). Various investigations of seep sites within, and at the mouth of, Norfolk Canyon have showed active methane seepage.

Several shipwrecks have been identified along the shelf edges, near the canyon heads, and along the walls of canyons within the Norfolk Canyon system. Most famous of these are the recently explored “Billy Mitchell” fleet, most of which are located just north of Norfolk Canyon (CSA et al. 2017).

Washington and Norfolk Canyons have been designated as HAPCs based on their unique geomorphology and the presence of deep sea corals (NEFMC and NMFS 2017). Norfolk Canyon has been designated as a “Tilefish Gear Restricted Area” (50 CFR 648.297). It is part of the Frank R. Lautenberg Deep Sea Coral Protection Area.
CHAPTER 1 - ATLANTIC SUBMARINE CANYONS

THE POINT (HATTERAS MIDDLE SLOPE)

NOTABLE FACTS

The Point, also referred to as Hatteras Middle Slope (HMS), is a region of numerous, mostly parallel, small canyon or gully features on the continental slope just north of Cape Hatteras.

Investigations documented various unusual conditions on the HMS, including: 1) the highest densities of benthic infauna on the U.S. East Coast continental slope; 2) unusual concentrations of benthic fishes and megafaunal invertebrates; 3) reduced species richness, motility, and sizes in fish community, perhaps related to environmental conditions; and 4) an exceptionally high flux of organic carbon to the bottom (Schaff et al. 1992; Hecker 1993; Sulak and Ross 1996).

Atlantic Ocean waters along the North Carolina coast have been the scene of an unusually large number of shipwrecks, and this area often is referred to as the “Graveyard of the Atlantic.”
NOTABLE FACTS

The San Demenio, believed to have sunk in 1942, was identified near the head of Keller Canyon in a water depth of approximately 50 to 70 m (Hoyt et al. 2014).

Hatteras Canyon has deep valleys that cut across the upper continental rise, which terminates on the lower rise in fans characterized by transverse sediment waves (Gardner et al. 2005).

Many organisms have been observed in Hatteras Canyon, indicating a highly productive area. Bacterial mats were present, but higher order chemosynthetic organisms were not observed (Raineault et al. 2018).

The rock faces within Pamlico Canyon host a number of organisms, including sea spiders, cup coral, skates, cusk eels, octopus, red crabs, spider crabs, and brittle stars (Raineault et al. 2018).
CHAPTER 2 - GULF OF MEXICO SUBMARINE CANYONS

GULF OF MEXICO CANYONS OVERVIEW
CHAPTER 2 - GULF OF MEXICO SUBMARINE CANYONS

MISSISSIPPI AND DE SOTO CANYONS
The origin of Mississippi Canyon is generally thought to have been attributed to channel entrenchment of the Mississippi River during low stands of sea level and erosion (Coleman et al. 1982).

Currents in the upper Mississippi Canyon generally oscillate up/down canyon in twelve-hour time intervals and are bottom-intensified (Ross et al. 2009).

Mississippi Canyon is an important avenue for sediment transport and organic carbon input from the Mississippi River to the deep sea in the Gulf of Mexico (Wei et al. 2010).

Organic matter transport through Mississippi Canyon supports an abundant biological community that includes numerous polychaete and fish species (Wei et al. 2010, 2012).

The Mica Wreck, dated to the first half of the 19th century, is located in Mississippi Canyon in 808 m of water. The 20-m long vessel is well preserved with low sedimentation, allowing for identification of its wooden hull and metal sheathing, and recovery of a variety of artifacts (Krivor et al. 2011).

De Soto Canyon is thought to have formed in the Late Cretaceous period, and although its exact formation is uncertain, recent studies indicate the topographically induced eddies shed off of the Loop Current may have contributed to the modern-day shape (Dunn 2016).

Considerable nutrient enrichment and enhanced primary production occurs at the head of De Soto Canyon during periods of high regional river discharge (Jochens et al. 2002).

Approximately 52 species of fishes have been observed in De Soto Canyon, based on pooled trawl data from 1964 to 2002 (Wei et al. 2012). De Soto Canyon is near the Pinnacle Trend, a high-relief area of carbonate mounds with unique biological communities.

The head of De Soto Canyon is within the year-round Biologically Important Area for the endangered Gulf of Mexico Bryde’s whale (Balaenoptera edeni) (LaBrecque et al. 2015).
A deep cyclonic boundary current along the Sigsbee and Perdido escarpments has been observed, showing that the flows below the escarpments are more vigorous than above it (Donohue et al. 2008).

The area around Perdido and Alaminos Canyons has been recognized for decades as having a high potential for petroleum and is considered an important ultra deep water source for both U.S. and Mexico (Fiduk et al. 1999).

Chemosynthetic organisms, including species of gastropods, crustaceans, echinoderms, gorgonians, fishes, and their related carbonate deposits have been identified within the Alaminos Canyon area (Roberts et al. 2007).

The origin of Keathley Canyon began with underlying lateral salt movement beneath the upper canyon, uplifting the continental slope and raising and coalescing the sediments, resulting in a valley-like feature with walls of uplifted and deformed strata (Lee et al. 1992).
Chapter 3 - Pacific Submarine Canyons

Juan de Fuca Canyon System

Notable Facts

- Juan de Fuca Canyon has been identified as the most important source for the net upwelling of nitrate onto the Washington shelf (Hickey and Banas 2008). The canyon is also known to have high krill biomass concentration (Santora et al. 2018).
- Large deep-sea communities were discovered in Juan de Fuca Canyon in 2017, including long-lived species of coral and sponges (Raineault et al. 2018).
- The trawling fleet in Washington focuses their efforts around the Juan de Fuca Canyon to catch rockfish, Pacific hake, arrowtooth flounder, and Dover sole (Tagart 1997).
- The Coast Trader was sunk in 1942 by a Japanese submarine, and the shipwreck lies at the head of Juan de Fuca Canyon (NOAA 2019).
CHAPTER 3 - PACIFIC SUBMARINE CANYONS

GRAY'S CANYON SYSTEM
AND ASTORIA CANYON

NOTABLE FACTS

The Gray's Canyon system's influence over regional flow may facilitate transport of zooplankton species from the canyon onto the continental shelf, which benefits fish species by providing prey (Peterson et al. 2010).

Astoria Canyon, the largest canyon offshore Oregon, has been shaped by periodic major earthquakes and sea level changes (Embley 2010).

Benthic and pelagic communities of Astoria Canyon have been described in Bosley et al. (2004), with overall productivity linked with the canyon's physical circulation.

Astoria Canyon is a popular fishing spot because its unique underwater geography upwells nutrients near the mouth of the Columbia river, providing a food source for fish (Whittaker 2019).
**NOTABLE FACTS**

Eel Slump, a feature within the canyon, is a landslide scar located 2.5 km southwest of the sharp bend in the canyon between 1,230 and 1,800 m water depth (Gwiazda et al. 2016). Most of the sediment feeding into Eel Canyon originates from storm-induced resuspension events on the adjacent shelf (Puig et al. 2003).

The Eel River is thought to have run directly into Eel Canyon until the end of the Pleistocene, when sea levels were lower; the two features are now separated by about 20 km of shallow marine shelf (Paul et al. 2014).

Patches of chemosynthetic clams were observed in this canyon, suggesting the presence of hydrogen sulfide in the sediment (von Thun 2013).
**NOTABLE FACTS**

- Analysis of bathymetric surveys suggests that the Delgada Canyon mainstem is actively carved into bedrock by turbidity currents generated at the Delgada Canyon head wall (Smith et al. 2018).

- Delgada Canyon is one of the tributary canyons to the Delgada Fan complex (Atwater 1970). It is possible that the coalescing canyon systems on the continental slope have remained with the fan and adjacent sea floor during the Neogene transform offset. Another possibility is that the two main lobes of the fan, which include the bulk of the upper-fan deposits, are relatively recent features. (Normark and Gutmacher 1985).

- Sediment transport and accumulation at the Delgada Canyon head is controlled primarily by wave-induced shear stress influenced by the regional longshore current (Smith et al. 2018).
CHAPTER 3 - PACIFIC SUBMARINE CANYONS

PACIFIC 2 AND PIONEER CANYON

NOTABLE FACTS

The head regions of the Pacific 2 Canyon begin within three different National Marine Sanctuaries (NMSs): Greater Farallones NMS, Cordell Bank NMS, and Monterey Bay NMS.

Pioneer Canyon originally developed as the seaward channel of Monterey Canyon and was displaced northward to its present locations by right lateral faulting (Howell et al. 1980).

Black-footed albatross have been reported to concentrate in great numbers at the head of Pioneer Canyon (Santora et al. 2012). In 2016, an expedition of Pioneer Canyon discovered many bamboo coral forests and rocky features with multiple coral species, sponges, invertebrates, and fish (Risotto et al. 2016).
Partington Canyon is a major tributary branch of Sur Canyon (Harris et al. 2014). The Sur Canyon system is intersected on the upper slope by a segment of the San Gregorio Fault Zone (part of the San Andreas Fault System), which has rates of lateral motion of around 6 to 9 mm/yr (Harris et al. 2014).

In a 2003 survey, the Sanctuary Integrated Monitoring Network reported that 48 species of fish were observed in Partington Canyon, including 27 species of rockfish (SIMoN n.d.).

The head of the Lucia Canyon system acts as a funnel for the rapid transport of detritus eroded from the Santa Lucia Mountains to the deep abyssal plain (SIMoN n.d.).
Monterey Canyon is the largest submarine canyon on the U.S. Pacific continental shelf (Covault et al. 2011). Soquel and Carmel Canyons are two tributaries of Monterey Canyon. The system is composed of two parts, which contain a total of six canyons: 1) Ascension, Ano Nuevo, and Cabrillo Canyons to the north and 2) Monterey, Soquel, and Carmel Canyons to the south.

Monterey Canyon sits on an active tectonic margin, and its shape is greatly influenced by fault zones in the region (Covault et al. 2011).

Recent studies indicate that Monterey Canyon started forming between 10 and 6.8 million years ago and was likely carved by rivers carrying material from shore (Conrad et al. 2017). The last turbidity current to occur in waters > 2,000 m within Monterey Canyon occurred about 150 years ago (Symons 2017).

Monterey Canyon is within a major upwelling system that enhances productivity in the canyon, with the highest intensity between March and November (Ryan et al. 2010).

Monterey Canyon is a productive ecosystem hosting an abundant biological community, including various species of fish, squid, nematode, jellyfish, and plankton (Goffredi et al. 2012). It is also home to numerous chemosynthetic communities in deeper waters below 2.5 km depth (Paull et al. 2010). Soquel Canyon hosts numerous species, including polychaetes, crustaceans, mollusks, and rockfish (McClain and Barry 2010).

Marine debris and pollutants may pose a risk to communities in Ascension and Monterey Canyons. Debris transported from terrestrial sources is carried through the canyon to where it accumulates in the deep sea (Schninnig et al. 2013). Levels of pollutants like DDT in sediments and fish are significantly higher from deep in Monterey Canyon compared to nearby continental shelf sediments and fish (Hartwell 2008).

Within the Monterey Canyon System, two possible shipwrecks have been identified. One lies within Monterey Bay near the head of the canyon system. The other is believed to be the UMPQUA 11, a barge that sank in 1982 (NOAA 2019).

Monterey Canyon is a prominent feature of Monterey Bay National Marine Sanctuary.
NOTABLE FACTS

Seasonal north and south current movement deposits sediment that is then carried seaward via the Arguello Canyon to the Arguello fan (Wilde 1965).

On a Nautilus expedition in 2016, researchers found deep sea corals, octopus, and a potentially new species of sea slug in Arguello Canyon (NOAA 2016).

Pacific 1 Canyon is west of San Miguel and Santa Rosa Islands.

Pacific 1 Canyon reaches into Channel Islands National Marine Sanctuary.
CHAPTER 3 - PACIFIC SUBMARINE CANYONS

HUENEME CANYON

Bathymetric Contour (m)
National Marine Sanctuary or Monument
BOEM Planning Area Boundary
Canyon Boundary
CSA Ocean Sciences Inc. et al. 2019
Delineation Method
Coordinate System: USA Contiguous Lambert Conformal Conic
Submarine Canyon Bathymetry
Depth in meters
30 410 780

NOTABLE FACTS

This canyon was formed by turbidity currents beginning approximately 15,000 years ago (Romans 2011). In modern day, the canyon rim morphology coupled with storm-induced sediment resuspension on the shelf are the major controls of sediment fluxes into the canyon (Xu et al. 2010). The canyon is still active today, receiving huge volumes of sand from the northwest-to-southeast longshore transport of beach sand.

Because the head of this canyon is accessible from the shoreline, it is a popular spot for recreational diving.

In 2003, a 24-m wood hull fishing vessel sank in this canyon (NOAA 2019).
CHAPTER 3 - PACIFIC SUBMARINE CANYONS

NEWPORT CANYON

**NOTABLE FACTS**

Newport Canyon was formed at a point where the shelf is narrow, and the sand was moved by waves in longshore drift and concentrated at a convergence zone near the canyon head (Felix and Gorsline 1971).

The benthic biodiversity in this canyon has been reported to be higher than in other Southern California canyons. This has been attributed to calmer conditions in terms of bottom current dynamics (i.e., less physical disturbance affecting the surface sediments at the axis of the canyon [Maurer et al. 1995]).

Similar to Hueneme Canyon, the head of this canyon is accessible from the shoreline and is a popular spot for recreational diving.
NOTABLE FACTS

Data from the La Jolla Canyon walls indicate that it is less than 1.2 million years old. There is evidence that a lagoon once existed at the head of the canyon, based on photographs in the early 1900s and a 10-m thick deposit of estuarine material throughout the head (Paull et al. 2013).

The heads of the La Jolla Canyon system extend into shallow water, which modifies nearshore circulation, surface wave patterns, and sediment transport (Le Dantec et al. 2010).

Abundance and diversity of benthic macrofauna and megafauna are higher in the Scripps Canyon compared to the adjacent slope (Vetter and Dayton 1998, 1999).

Ecological reserves have been designated around the head of the canyon, as it is a known spawning ground for market squid, potential nursery habitat for juvenile giant sea bass, and prime location for aggregations of leopard sharks (Nosal et al. 2013).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

ALASKA CANYONS OVERVIEW

Map Scale: 1:6,000,000

Map Scale: 1:11,000,000

Map Scale: 1:5,000,000

Coordinate System: Alaska Albers Equal Area Conic

Depth in meters

Submarine Canyon Bathymetry

Bathymetric Contour (m)

BOEM Planning Area Boundary

Canyon Boundary

Harris et al. 2014 Delineation Method

CSA Ocean Sciences Inc. et al. 2019

Hernae (p.25)

Havre (p.25)

Shumagin 1 (pp.46-47)

Chukchi Sea 3 (p.35)

Navarin Basin 2

Kodiak 1 (p.47)

Bowers Basin 1 (p.38)

Havre (p.25)

Navarin Basin 3

Wildcat (p.47)

Bowers Basin 2 (p.24)

Summit System (pp.42-43)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)

Chukchi Sea 2 (p.35)

Chukchi Sea 1 (p.35)

Bowers Basin 3 (p.24)

Alaska Arc 2 (p.38)
NOTABLE FACTS

Hanna Canyon may be an abandoned late Pleistocene course of the Hope-Herald Sea Valley system (Grantz and Eittreim 1979).

Circulation through the Chukchi Sea canyons may include subsurface Atlantic water, which flows from the northeast as upwelling to the continental shelf, and possibly circulation from the Central Channel, which flows from the Bering Sea (Day et al. 2013).

Hanna Canyon is positioned on the shelf edge north of Hanna Shoal, which is a shallow feature on the continental shelf and recognized as one of the Chukchi Sea’s most productive areas (Day et al. 2013).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

BARROW AND BEAUFORT SEA CANYONS 1-6

NOTABLE FACTS

The flow of nutrient-rich waters along the west wall enhances the abundance of burrowing benthic organisms, which in turn promote high bioerosion of the canyon wall (Eittreim et al. 1982).

The confluence of different water masses near Barrow Canyon promote high biological productivity in the area (Shroyer 2012). At high latitudes, Barrow Canyon and all Beaufort and Chukchi Sea canyons are connected to shelf systems that are highly productive during seasonal ice melting and open-water periods (Grebmeier et al. 2006). Seasonal changes in water temperature and salinity enable Barrow Canyon to be a hotspot for biological communities (Shroyer 2012).
The Canadian Beaufort Sea continental shelf is characterized by three major bathymetric depressions, including the Mackenzie cross-shelf trough, which is the former location of ice streams that drained the northwest margin of the Laurentide Ice Sheet during Quaternary full-glacial periods (Geological Survey of Canada 1972). In the deeper waters of the Beaufort Sea (Canada Basin) and over the continental margin and slope, large-scale circulation features include the Beaufort Gyre, the Beaufort Undercurrent, and the intrusion of Atlantic waters. These features, combined with the effects of regional winds and the Mackenzie River plume, create a complex of regional surface currents (Fissel et al. 2013). Bowhead and beluga whale occur within waters near these canyons on a seasonal basis (Moors-Murphy 2014).
NOTABLE FACTS

Younger strata in the Aleutian Basin seem to be draped over basement relief and composed of oceanic crust, probably of Cretaceous age. Volcanism occurred on the basin margins throughout most of the Cretaceous Period and Cenozoic Era (Wiley 1986).

The deep waters of the southern Bering Sea contain biological communities distinct from the adjacent Aleutian Island shelf (Batten et al. 2006).

Prior to management actions in the area of these canyons, it was estimated that, from 1997 to 1999, Alaska groundfish fisheries (bottom trawling) removed an extrapolated average of approximately 40 metric tons of coral yearly in the Bering Sea and Aleutian Islands (Hourigan 2009).
NOTABLE FACTS

Navarin Canyon has two main branches and does not lead to any distinct submarine fan morphology, suggesting that it has not been effective as a major conduit for sediment transport from the continent (Normark and Carlson 2003).

Skates (Rajidae) have been reported to deposit their large leathery egg cases in specific canyon areas, with 10 of 14 identified nursery sites reported at the heads of 5 large canyons in the Bering Sea, including Navarin Canyon (VanPelt 2015).

Canyons (such as Navarin and Pervenets) that indent the shelf break can interrupt along-slope currents and may create unique physical environments compared to the adjacent slope (Sigler et al. 2015).
Canyons of the eastern Bering Sea slope support a rich fauna, comprising marine birds, mammals, fish, and benthic invertebrates on hard substrates (Miller et al. 2012; Sigler et al. 2015). Populations of the rare and endangered short-tailed albatross (Phoebastria albatrus) are known to concentrate at the head of St. Matthew Canyon due to availability of prey (Piatt et al. 2006). The area has been called the “Bering Sea Green Belt” to describe its productivity, due to the abundance of phytoplankton, zooplankton, squids, fishes, birds, and mammals along this shelf edge (Zimmermann and Prescott 2018).

Zhemchug Canyon was likely excavated in the Pleistocene by mass wasting, slumping, and creeping of sediment accumulated at the heads of the Yukon and Kuskokwim Rivers during periods of glacially lowered sea level (Miller et al. 2012).
NOTABLE FACTS

Corals in the Gulf of Alaska, including red tree coral, black coral, and hydrocorals, are known to occur along the continental shelf edge in hard bottom habitat. ROV cruises and habitat suitability studies indicate various coral and sponge species may be found at the head of this canyon (Rooper et al. 2017). In some places, such as the central and western Aleutian Islands, deep sea coral and sponge resources can be extremely diverse and may rank among the most abundant deep sea coral and sponge communities in the world (Rooper et al. 2017).

To protect the Steller sea lion, NMFS closed all Alaska Atka Mackerel fisheries in this region in 1990 (50 CFR 679).
NOTABLE FACTS

Pribilof, Bristol, Bering, Bogoslof, Inanudak, and Pribilof Canyons comprise a system of features that share a common mouth within the Aleutian Basin (Miller et al. 2012).

Pribilof Canyon was likely excavated in the Pleistocene by mass wasting, slumping, and creeping of sediment accumulated at the heads of the Yukon and Kuskokwim rivers during periods of glacially lowered sea level (Miller et al. 2012). Bering Canyon is characterized by a wide slope valley (Duffy-Anderson et al. 2013). A fan channel extending basinward from Bering Canyon extends several hundred kilometers into the Aleutian Basin as a low-relief (10 to 20 m), very broad (20 km), and flat-floored turbidite channel. The Bering Fan lacks the distinctive fan morphologic expression that is generally present on other fans; instead, it forms a relatively thin veneer of sediment in the Aleutian Basin.

The eastern Bering Sea slope and outer shelf is a region of enhanced primary and secondary productivity (the "Bering Sea Green Belt") and attracts large numbers of fish, seabirds, and marine mammals. Productivity is enhanced in this region because of physical processes at the shelf break, which include intensive tidal mixing, and transverse circulation and eddies in the Bering Slope Current; collectively, these bring nutrients into the local photic zone (Sigler et al. 2015).

Pribilof canyon and adjacent continental shelf slope form important spawning grounds for several fish species including skates, rockfishes, smooth tongues, and flatfishes. Other fish species that have been observed in the canyon include Greenland halibut, Pacific Ocean perch, cottids, zoarcids, agonids, and the giant grenadier (Miller et al. 2012).

Commercial fishing activities pose a risk to benthic communities in Bering Sea Canyons through seafloor disturbance from trawling and marine debris from loss of gear (Miller et al. 2012; MacLean et al. 2017).

The following shipwrecks are believed to be located within Bering Canyon, in addition to four unnamed wrecks: F/V America Star, F/V Desperado, Maren 1, T&T, KP21, Qanirtuuq Princess, F/V Gene Maru No.7, Cecilia barge, Atuan (NOAA 2019).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

UMNAK CANYON SYSTEM
The Umnak Canyon system includes Uliaga, Umnak, Carlisle, Herbert, Yunaska, Chagulak, and Amukta Canyons, which run roughly parallel to the Aleutian Islands.

The eastern Bering Sea shelf consists of inner, middle, and outer shelf ecological zones separated by oceanographic fronts associated with the 50-, 100-, and 200-m isobaths, respectively, each of which possesses fundamentally different physical processes and species compositions (Aydin et al. 2002).

The eastern Bering Sea slope and outer shelf is a region of enhanced primary and secondary productivity and attracts large numbers of fish, seabirds, and marine mammals.

Productivity is enhanced in this region because of physical processes at the shelf break, which include intensive tidal mixing, and transverse circulation and eddies in the Bering Slope Current; collectively, these bring nutrients into the local photic zone (Sigler et al. 2015).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

SHUMAGIN 1 CANYON

**NOTABLE FACTS**

- Dredge samples taken from the outer wall of this canyon indicate limestone and sedimentary rock with carbonate cement (Horowitz et al. 1989).
- Flow in this basin, primarily driven by the Alaska Coastal Current (ACC), is affected by the canyons in this region, which funnel energy from the ACC and contribute to strong tidal mixing (Bailey et al. 2008).
- The canyon’s influence over regional circulation patterns facilitates the distribution of fish eggs and larvae from deeper slope waters up onto the continental shelf (Bailey et al. 2008).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

KODIAK 1 AND WILDCAT CANYONS

Notable Facts

Submarine canyons play a key role in cross-shelf transport of heat, salt, and nutrients, and flow in this basin is primarily driven by the Alaska Coastal Current (Mordy et al. 2019).

Waters around Kodiak Island and the Kenai Peninsula are valuable nursery habitat for fish in the area due to submarine canyons facilitating the transport of fish larvae from deeper slope waters onto the continental shelf (Doyle et al. 2019; Mordy et al. 2019).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

GULF OF ALASKA 6 CANYON

NOTABLE FACTS

Flow in this basin is primarily driven by the Alaska Coastal Current, a prominent feature in this region, and is often affected by submarine canyons, which can disrupt coastal flow and may facilitate the flow of nutrient rich water onto the shelf (Mordy et al. 2019).

Corals in the Gulf of Alaska, including red tree coral, black coral, hydrocorals, and sponges, are known to occur along the continental shelf edge in hard bottom habitat. ROV cruises and habitat suitability studies indicate these species may be found in this canyon (Rooper et al. 2017).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

GULF OF ALASKA CANYONS 1 to 5

NOTABLE FACTS

- Gulf of Alaska 5 Canyon sits on the Queen Charlotte Fault line in southeastern Alaska (Brothers et al. 2018).
- Bottom trawling has been banned in this region since 1998 to protect deep sea coral species.
- The floors of these canyons contain well-defined bedforms or sediment waves located down-canyon of small scarps. This area is susceptible to frequent landslides, which transform into debris flows that are funneled through the canyons (Brothers et al. 2018).
CHAPTER 4 - ALASKA SUBMARINE CANYONS

NOYES CANYON

**NOTABLE FACTS**

- This canyon sits on the Queen Charlotte Fault Line, an active fault line that contributes to changes in geologic features in the region (Brothers et al. 2018).
- Dickins Seamount is located approximately 16 km southwest of the lower part of the canyon, around which numerous species of gorgonian corals and glass sponges have been observed during deep sea research cruises conducted by NOAA. Gorgonian coral within the canyon itself have been observed on the shelf slope closer to the head of the canyon.
- A possible shipwreck was identified approximately 3 km north of this canyon in water depths between 2,000 and 3,000 m (NOAA 2019).
Department of the Interior (DOI)
The Department of the Interior protects and manages the Nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)
The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program
The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).