Coastal Impressions

A Photographic Journey along Alaska's Gulf Coast

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We gratefully acknowledge the support of organizations working in partnership for the Alaska ShoreZone effort, including over 40 local, state, and federal agencies and organizations. A full list of partners can be seen at www.shorezone.org. Several organizations stand out as being the earliest or staunchest supporters of a comprehensive Alaskan ShoreZone program. The Board of Directors of Cook Inlet RCAC supported the earliest Alaska surveys and continues to develop applications for ShoreZone imagery and data. The staff at NOAA's Alaska Fisheries Science Center Auke Bay Laboratories and the Alaska Regional Office has taken on a leadership role and are fully responsible for efforts to complete a state-wide ShoreZone program and to integrate and deliver imagery and data to any user. The Nature Conservancy has provided outreach and organization to Alaska ShoreZone partners and ensures the continued coordination of survey and mapping efforts.

Preface

Alaska's coasts are remote and logistically inaccessible to most residents and visitors, but are a national treasure in terms of the diverse natural history and spectacular scenery. The Alaska ShoreZone program is developing an inventory of biological and geological habitats of Alaska's coast, and in the process has developed an archive of high resolution digital imagery. *Coastal Impressions: A Photographic Journey along Alaska's Gulf Coast* is intended to share some of the collected imagery so that all can marvel and learn about the natural wonders in our stunningly beautiful coastal backyard.

This selection of images represents a range of ecology, geology, geomorphology, and natural forces that create the mosaic of habitats along Alaska's gulf coast. The images capture the shore during some of the lowest tides of the year, providing a visual portal to the benthos and the unique zonation and assortment of intertidal and shallow subtidal biota.

Each image also tells a different story of the natural history and dynamic forces captured by the camera at the instant of the overflight. Every sand grain, pebble, boulder, and bedrock cliff provides clues for understanding local coastal processes and yet even experts are sometimes surprised by some of the unique features of Alaska's coast. Subtle shifts in waves, currents, ice scouring, salinity, or other influencing factors can alter beach configurations and biological communities at various spatial scales. In this booklet, photos are annotated with descriptions of the natural history, ecology, and/or coastal processes shaping the coastline based on an analysis of each image.

Enjoy the photographs for their beauty alone. Or, spend time reading this exhibit catalogue to gain insights into the mysteries of Alaska's dynamic and ever-changing land-sea margin. Either way, our goal is to leave you with unforgettable impressions about our complex and wild coast.

Exhibit Photos and Photographers

Photo Access and Referencing

All photographs presented in this exhibit are from the Alaska ShoreZone program, except for the lower photograph on page 69 which was provided by www.seaweedsofalaska.com.

All imagery from Alaska ShoreZone are available for non-commercial use and accessible at www.shorezone.org or http://www.alaskafisheries.noaa.gov/shorezone. Use of this imagery should reference Alaska ShoreZone.

This exhibit does not include imagery from the earliest Alaska ShoreZone surveys prior to the shift to digital imaging technology. Thus, some areas of the Gulf of Alaska are not included in the exhibit at this time (e.g. Katmai Coast, outer Kenai Peninsula).

Photographers

ShoreZone imagery acquisition relies on multiple field crews to facilitate the gathering of both video and digital still photographs and specific aerial surveys are for particular sponsoring or funding organizations. Thus, imagery collected during ShoreZone surveys is a product of Alaska ShoreZone rather than individual photographers.

However, two of the most experienced Alaska ShoreZone survey team members have flown as the biologist/photographers for most of the Alaska ShoreZone surveys since 2004. All of the aerial photographs presented in this exhibit were taken by Mandy Lindeberg and Mary Morris, with the exception of photos from the Copper River Delta taken by Heather Anderson.

During a typical 5-day survey flown only during minus tide windows, Mandy and Mary take full advantage of digital camera technology and capture upwards of 10-12,000 photos that facilitate the interpretation of coastal features for habitat mapping. Among this massive collection of images are photographs possessing great beauty or showing excellent examples of coastal features.

In addition to aerial surveys, Alaska ShoreZone includes intertidal surveys to conduct species-level assessments on various beaches. Exhibit photos from these surveys were taken by Mandy Lindeberg, Robyn Fyles, Allan Fukuyama, or Susan Saupe.

There are tens of thousands of additional aerial and on-the-beach photographs that have been archived by Alaska Shorezone. It is our hope that future exhibitions will tap into these archives and feature even more of Alaska's amazing coastline.

Alaska ShoreZone

The images in this exhibit were selected from tens of thousands of digital photographs obtained during ShoreZone aerial surveys in the Gulf of Alaska. ShoreZone is a coastal classification and mapping system based on the collection and interpretation of aerial imagery of the coastal environment. The imagery is taken at 100-300 meter altitude at an oblique angle while flying just offshore and is geo-referenced to the helicopter track-line. Video and still photographs are captured by a geomorphologist and biologist as they synchronously record audio commentary about specific shoreline features. The video, digital stills, and audio data are later used to map coastal features such as wave exposure, substrate type, sediment texture, intertidal and very shallow nearshore biota. In order to map the most comprehensive shoreline data possible, surveys are flown during the lowest tides in late spring and summer to ensure that the surveys capture the entire intertidal zone.

Biological habitat is mapped as biobands, spatially distinct alongshore and across-shore patterns of color and texture that can be observed during the surveys and in the aerial imagery. They are described from the supratidal to the shallow subtidal and are named for the dominant species or group that typifies the bioband. These biobands can be seen in many of the exhibit photographs. For example, some biobands are named for a single indicator species such as blue mussels or canopy kelps. Others are named for assemblages of species that are identifiable by band color, for example assemblages of red algae or green algae are clearly identifiable in many of the exhibit photos.

ShoreZone methods were initially developed in the 1980s to map coastal features in British Columbia for the Provincial Government and through the 1990s in Washington for their state government. The objectives were to use imagery to produce a searchable inventory of geomorphic and biological features that could provide habitat maps for coastline resource management and oil spill planning and response. Over the years ShoreZone imagery and habitat maps have been used by coastal resource managers, researchers, and educators.

In 2001, Cook Inlet RCAC initiated ShoreZone aerial surveys for Cook Inlet and the Kenai Peninsula and sponsored a pilot program to deliver ShoreZone imagery and data on-line for the first time. While the imagery has always been key for interpreting and mapping shoreline features, the development of the Alaskan ShoreZone program coincided with advances in technology that allowed the imagery to take an even more important role. Now, sharing web-accessible ShoreZone imagery and data has become a reality and a priority.

Easy access to ShoreZone data and imagery led to the rapid expansion of ShoreZone survey and mapping efforts, supported by multiple agencies and organizations. It soon became clear that a partnership was necessary to ensure the integration and coordination of these efforts and in 2004 The Nature Conservancy agreed to develop and administer such a partnership. NOAA's Alaska Fisheries Science Center Auke Bay Laboratories and the Alaska Regional Office took the lead in compiling and serving up all data and imagery online. NOAA has also funded or sought partners to complete ShoreZone surveys and mapping in the Gulf of Alaska.

Full protocols for ShoreZone coastal habitat mapping in the Gulf of Alaska are available at www.shorezone.org and imagery and data can be viewed, queried, and downloaded at the NOAA ShoreZone website (www.alaskafisheries.noaa.gov/maps). Also available are summary reports for various survey regions around the Gulf of Alaska.

Eagle Harbor, Nagai Island, Shumagin Islands

Enclosed Lagoon on Recurved Spit *N 55 05.887, W 160 04.837*
May 18, 2011

A spit is a narrow accumulation of sand or gravel with one end attached to the mainland. Some spits can develop complex shapes as a result of wave refraction in a narrow embayment or the interplay of waves having different angles of approach. If the curved distal end is very pronounced then the spit is recurved. Many spits have formed over long periods (hundreds of years) and are characterized by complex morphologies reflecting different stages of development. One example is the compound recurved spit which has a narrow proximal end and a wide recurved distal end that often encloses a small lagoon. The distal end may consist of several beach ridges associated with older shorelines. Spits grow in the direction of the predominant littoral drift and are an example of a drift aligned feature that can only exist through the continued supply of sediment. If the longshore sediment supply ceases, the spit will eventually subsume itself and disappear.

Christianson Lagoon, Unimak Island, Urilia Bay

Wave Barrier *N 54 54.539, Long W 164 16.49*
May 17, 2011

Coastal lagoons are shallow water bodies parallel to the coastline and separated from the open ocean by prograding, elongate, and shore-parallel accumulations of unconsolidated sediments forming barrier islands or beaches. Barrier islands and beaches are bordered at one or both ends by transverse tidal inlets, allowing free exchange with the ocean. The tidal inlets may be migratory and subject to periodic closure, especially during the winter. Barrier islands are formed on wave-dominated coasts with relatively small tide ranges (<4 m) and typically have well developed and relatively stable backshore dunes. Onshore winds drive fine sediments upslope from the beach face forming dunes that are colonized by stabilizing beach grasses. Strong winter storms may cause waves to overtop the barriers islands or beaches creating outwash fans or washovers. Lagoons are very productive and important to salmon, migratory birds, marine mammals, coastal brown bears, and other predators.

East Bight, Nagai Island, Shumagin Islands

Beach Cusps, Beach Cusps, and Beach Cusps *N 55 07.697, W 159 56.178*
May 16, 2011

Cusps are morphological features found on the beach face, consisting of steep-gradient, seaward-pointing cusp horns and gentle-gradient cusp embayments. Beach cusps are formed by swash action when wave crests are parallel to shore and in the presence of sub-harmonic standing edge waves. They usually develop under accretionary wave conditions and often display a marked alongshore rhythmicity in cusp spacing. The alongshore spacing of cusps is related to wave height and can range from less than a meter to tens of meters. The relief of cusps can also range from centimeters to tens of centimeters. Coarser sediments are deposited on the cusp horns and finer sediments are deposited in the cusp embayments. Tides modulate the height and cross-shore position of beach cusps. During rising tide, beach cusp height decreases as embayments accrete more than horns and the cross-shore extent of beach cusps decreases. During falling tide, beach cusp height increases as embayments erode more than horns and cross-shore extent increases. Once formed, beach cusps can be self-sustaining if the prevailing wave pattern remains regular and from the same direction.

Ocean Bay, Sitkalidak Island, Kodiak Archipelago

A Perfect Beach *N 57 04.710, W 153 12.220*
June 23, 2005

Beach slope, grain size, and wave climate (e.g., wave height, period, direction, storm frequency, etc.) combine to shape beach geomorphology. The orbital motions of incoming deep-ocean waves are affected by decreasing water depths. Waves shoaling over a gradually sloping bottom will steepen and wave troughs will broaden until the wave crests break. Energy is dissipated through turbulence and transferred to forward momentum forces in the surf zone. On steep beaches, surf zones are relatively narrow and waves break directly on the beach face causing high rates of sand transport and partial wave reflection. Low slope beaches are generally more uniform and tend to dissipate wave energy across broad surf zones. On very low slope beaches a wave bore will progress up the beach face dissipating energy through turbulence, bottom friction, and percolation into the sand prism. The constant migration of sand in this dynamic environment will often form sand bars and troughs visible on the beach face at low tide. Most marine macroalgae are unable to tolerate this habitat due to the scouring effect of the moving sand.

Naugolka Point, Viekoda Bay, Kodiak Island

Stunned by Zonation *N 57 53.472, W 153 12.550*
May 25, 2005

Rocky shores typically support a highly diverse community of intertidal plants and animals. This is partly because bedrock is a stable substrate that allows for attachment of sessile organisms, and also because of the many microhabitats formed by an irregular surface. Crevices and holes are important to mobile organisms seeking refuge from predators especially during low tide. Many organisms of the intertidal have adapted to specific environmental niches and heterogeneous rocky shores provide more of these niches than more homogenous rock or dynamic beach habitats. Subtle changes in wave energy exposure or slope angle can dramatically affect species diversity on rocky shores. The width of shore, and subsequently the width of zonation bands, is a function of slope angle, tidal range, and wave energy. Steeper shores are narrower and subjected to higher wave energy than lower angle shores that are wider and tend to dissipate wave energy. The upper intertidal zone is the most stressful for marine plants and animals, which experiences the longest emersion periods, and therefore has generally lower species diversity and biomass than lower zones.

Middle Cape, Shelikof Strait, Kodiak Island

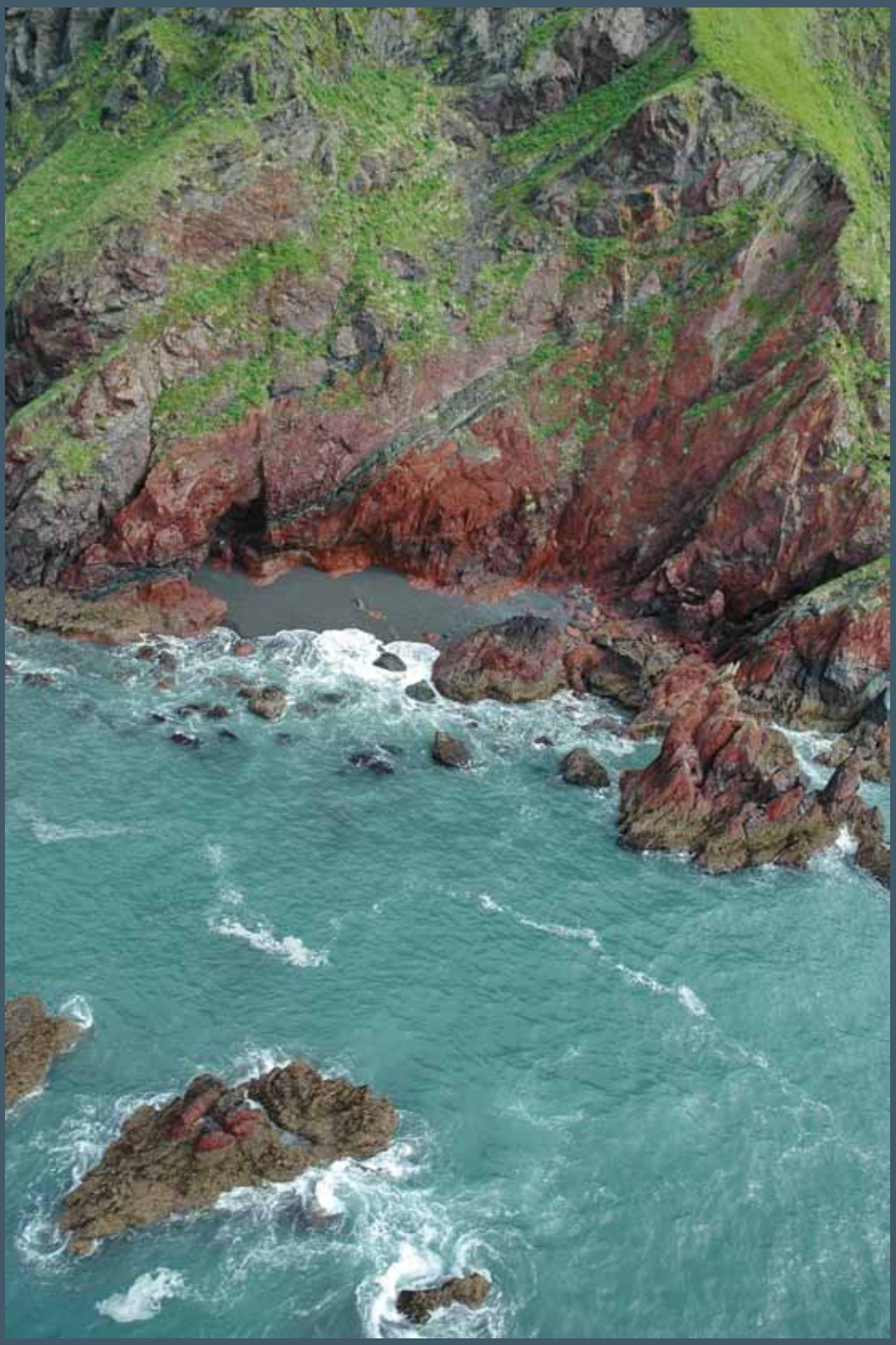
Wild and Remote Headlands *N 57 22.147, W 154 46.243*
May 28, 2005

Rock strata folded vertically and oriented perpendicular to shore, are eroded by waves so that more resistant rock will form headlands. Waves approaching shore are refracted so that wave energy is concentrated on headlands and dissipated in embayments. This focused energy can transform headlands into a variety of erosion features largely based on the strength of the rock type. Headland cliffs may be undercut, forming sea caves, and if the rock integrity is sufficient, sea arches may form. Continued erosion will eventually cause the arch to collapse forming small islands or sea stacks. The sea stacks may continue eroding into thinner pinnacles, eventually collapsing into rubble mounds that are in turn washed away so that only a shallow wave-washed reef remains. Wave attack on rubble mounds causes boulders to be reduced to smaller cobbles and pebbles and eventually sand. Small sediments may remain suspended in the wave induced turbulence and transported by alongshore currents into the energy dissipative environment of adjacent embayments to accumulate as pocket beaches.

Bumble Bay, Shelikof Strait, Kodiak Island

Red Cretaceous Chert *N 57 16.126, W 154 37.865*
May 28, 2005

This red chert is an erosion-resistant rock forming part of the Uyak Formation that extends for approximately 600 km along the coast from the Shumagin Islands, through the Kodiak Archipelago, and into the Chugach Mountains near Anchorage. Chert is a hard silica-based rock formed from lithified radiolarian ooze. Radiolarian zooplankton are found throughout the ocean and the intricate silica skeletons they produce cover larger portions of the ocean bottom. In areas of high biological productivity, such as nutrient-rich upwelling zones, radiolarian ooze accumulates on the ocean floor and is rapidly buried. After burial, some radiolarian oozes are lithified into chert and incorporated into orogens, or bands of highly deformed rock. Orogenic belts, such as the Uyak Formation, generally consist of long parallel strips of rock exhibiting similar characteristics along the length of the formation and are associated with subduction zones. The Uyak Formation was accreted to the Alaska margin in the late Cretaceous period or about 100 million years ago.



Chief Point, Spiridon Bay, Kodiak Island

Barnacle Domination *N 57 42.067, W 153 55.550*
May 26, 2005

Headlands and points of land jutting out into wave exposed seas often have the lowest species diversity since most plants and many animals cannot survive the high energy environment. A NOAA buoy in Shelikof Strait adjacent to this headland has measured wave heights in excess of 5 meters (16 feet) during winter storms. The impact of waves of this magnitude can cause high mortality of intertidal organisms, particularly in the winter when plants and animals are already stressed by freezing temperatures. Usually, the intertidal zone has little available space for the recruitment of new individuals, but winter events that cause high mortality often result in bare rock. Plants and animals must compete for the available new space and the most successful organisms are often the ones that recruit early in the year such as barnacles. Here they have covered the intertidal rock leaving little bare space for other organisms and forming a relatively uniform monoculture above the sharply delineated lower zone red algae zone.

Cape Elizabeth, Kennedy Entrance, Cook Inlet

A Verdant and Rocky Cape *N 59 08.673, W 151 52.786*
June 26, 2009

In 1867, George Davidson, a geodesist with the U.S. Coast and Geodetic Survey, supervised what many consider the first American coastal assessment of Alaska. Davidson compiled a descriptive account of coastal positions and natural resources from Sitka to the Pribilof Islands which he submitted to Congress in the 1869. In it, Davidson offered the following introductory description of the vicinity: "From Cape Puget to Cape Elizabeth the shores have been very well explored by the Russian navigators, searching for good harbors and shelter for the Russian whalers. Their reports show that the line of coast is broken by bays and coves, but none offering good anchorage; there being very close to shore not more than thirty to fifty fathoms of water. The coast is very rocky, steep and mountainous, yet covered with wood, while the ravines and gorges between the mountains contain in many places, glaciers which stretch back from the heads of the bays even to the gorges descending towards Cooks inlet."

Grewingk Glacier River, Kachemak Bay, Cook Inlet

Delta Braids *N 59 39.627, W 151 11.003*
June 24, 2009

Large volumes of accretional sediments can be delivered to the coast by rivers. Glaciers in retreat produce high river discharges, large volumes of sediment, and steep channel slopes. Rivers emanating from glaciers respond to these processes by developing a braided river pattern with multiple channels separated by bars or islands. Braided channels are variable and dynamic systems, with high rates of channel adjustment. Although the threshold between meandering (sinuous, single channel river pattern) and braiding is not clearly understood, three factors are probably necessary for braiding to occur: 1) an abundant bedload supply (portion of a river's sediment load supported by the channel bed), 2) erodible banks, and 3) high stream power (the potential energy for a given river channel length). The beach sediments can be highly dynamic with erosion events caused by storm driven waves and deposition events caused by glacier surges and retreats. During periods of relative sediment stability, opportunistic animals such as the blue mussel (*Mytilus trossulus*) and marine algae such as the rockweed (*Fucus distichus*) may colonize the beach face, creating the beautiful colored patterns seen here.

Homer Spit, Kachemak Bay, Cook Inlet

Spit Perspective *N 59 35.852, W 151 24.315*
June 24, 2009

Sand and gravel that erode from sea cliffs are often worked by waves and currents into a variety of accretional shoreline forms. Southeastward movement of nearshore sediment is responsible for constructing the most striking geomorphic feature in the Kachemak Bay area: the 6-km (4 miles) long Homer Spit. The Homer Spit may have initially formed as a submarine end-moraine complex by the partial grounding of one or more ancient tidewater glaciers. The spit is located at the eastern (downdrift) end of the Homer littoral cell adjacent to a deep (200 m) submarine trough. This trough may be a local sink for sediment moving along shore, limiting further spit extension. The sediments that make up spits come from a variety of sources, including rivers and eroding bluffs, and changes in sediment supply can have a large impact on spits and other coastal landforms. Activities such as road building and seawalls or bulkheads built along bluffs can drastically reduce the volume of sediment eroded and can reduce sediment transport to levels unable to naturally maintain the spit. Much of the Homer Spit and the adjacent mainland have been altered with bulkheads, boulder riprap, or some other shore protection structure.

Tignagvik Point, Kamishak Bay, Cook Inlet

Plants on Platforms *N 59 26.940, W 153 42.320*
June 25, 2009

Waves erode coastal rocks and often create shore platforms. The level or depth of the platforms typically conforms to the range of tide and depth of wave energy. Surface waves are generated by wind, and stronger winds create larger and more energetic waves. While large waves can occur any time of year they are more frequent in the winter. Wave energy decreases with depth, and at a depth of about 10 m (33 feet), most wave energy is completely attenuated. While shore platforms represent an erosional coastal feature and are geomorphologically dynamic, at time scales of most benthic marine plants and animals (months to years) they represent a stable habitat that supports prolific algal growth. Algal biomass reaches a peak in the late summer, and then decreases as waves generated by winter storms damage macroalgal blades. Winter ice floes carried by Cook Inlet currents scour away all but the most persistent plants and animals from the rock often leaving a bare surface for new recruitment of plant spores and animal larvae in the spring.

Rocky Cove, Kamishak Bay, Cook Inlet

Platform Erosion *N 59 27.524, W 153 42.293*
June 25, 2009

Marine erosion produces a general retreat of the coast and this shore platform on the west coast of Cook Inlet is an erosional feature indicating an actively retreating coast. The surging motion of waves eroding folded and vertically tilted sedimentary rocks forms the platform. A platform is generally broadened as waves erode a notch at the base of a sea cliff, which causes overhanging rock to fall. Coastal recession is generally not uniform because of variations in rock resistance. The ripples in the rock are caused by different rates of erosion of alternating layers of hard and soft sediments. Headland and embayments are also caused by differential rates of erosion. Active sediment transport dynamics on the beach face, at the base of the sea cliff, and in shallow subtidal areas prevent the recruitment and colonization of benthic marine plants and animals. But, as wave energy decreases with depth some marine algae adapted to this environment may colonize the rock platform in lower intertidal zones that are only exposed during the lowest tides.

Burr Point, Augustine Island, Kamishak Bay, Cook Inlet

Gravel Hummocks of the Intertidal *N 59 25.107, W 153 23.850*
June 25, 2009

The nearly circular uninhabited Augustine Island, formed by the active Augustine Volcano, is 12 km (7.5 mi) wide from east-west and 10 km (6 mi) from north-south, and has a nearly symmetrical central summit with an elevation of 1,260 m (4,134 ft). Ash from its last major eruption in 1986 reached Anchorage, about 290 km (180 mi) to the northeast. A major eruption in 1883 caused a 9 m (30 ft) tsunami. Debris avalanches and landslides are the likely origin of Augustine's hummocky coastal topography around Burr Point. The 1883 debris avalanche buried the former shoreline of Augustine Island, and displaced the new shoreline 2 km seaward at Burr Point. Bathymetry indicates the 1883 debris avalanche traveled an additional 3 kilometers northward beneath the sea. Most of the material is comprised of angular fragments of cobbles to boulders but clasts as large as 4 to 8 meters (10 to 25 feet) also occur. These fragments in the mid intertidal zone provide an excellent substrate for marine macroalgae (e.g., *Palmaria* spp.) that would otherwise not be able to attach and grow.

Cape Douglas Reefs, Kamishak Bay, Cook Inlet

Resilient Reefs *N 59 06.643, W 153 51.759*
June 25, 2009

Elevated marine beach deposits and wave cut platforms along the west coast of Cook Inlet indicate that this coast is rising. Material dated from Kamishak Bay suggests that the rate of uplift is about a half meter (1.5 feet) per century. This uplift is partly in response to tectonic activity, and possibly in part to isostatic adjustments following deglaciation. In Kamishak Bay there are remnants of two older generations of wave cut bedrock platforms at levels approximately 15 and 30 m above high tide line. The present-day wave cut platforms on the south shore of Kamishak Bay, that are shown here completely exposed at low tide, are gently dipping sandstone strata of the Naknek Formation. A composite section from a sea cliff suggests a thickness of about 600 m. This fine-grained sandstone forms the highest exposed beds of the formation on Augustine Island and this island near the mouth of the Douglas River. Kamishak Bay also contains extensive deposits of estuarine silts that are exposed at low tide. The heads of most embayments are completely dry on minus tides and the silt deposit in Kamishak Bay can be exposed for 5-10 km offshore. The estuarine silts are mostly an accumulation of rock flour carried into the bays by rivers and streams from melting glaciers and forming a veneer on the sandstone platforms. An unidentified red alga with a morphology that appears unique to this area grows abundantly and can be seen in the image as a reddish tint at the perimeter of the sandstone platforms.

Ursus Cove, Kamishak Bay, Cook Inlet

Closed Estuary, Coastal Lake *N 59 30.920, W 153 45.201*
June 25, 2009

Coastal lakes can be formed when rapidly prograding beach sediments dam small watersheds and estuaries. The development of coastal lakes is dependent on the amount of sediments transported by waves and currents along the coast and the amount of freshwater discharge from the watershed. A large volume of river discharge can easily flush a small volume of sediment. In the winter, when watersheds are typically frozen and river discharge is minimal, waves and currents generated by energetic storms will transport large volumes of beach sediment. Under certain conditions, sediments can prograde faster than the minimal amount of freshwater can flush, effectively damming the drainage and creating coastal lakes. In the spring and summer, when freshwater discharge is high and sediment transport is low, the beach dams may be partially or completely destroyed.

Dam Creek, Chinitna Bay, Cook Inlet

Salt Marsh Mosaic *N 59 51.795, W 153 11.772*
June 22, 2009

Salt marshes typically occur on low wave energy, tidally dominated coasts such as heads of bays, behind spits, and in fringing coastal lagoons. Tidal inundation is important for delivering sediments, nutrients and plant water supply to the marsh. A salt marsh is dominated by dense stands of halophytic (salt-tolerant) terrestrial plants such as herbs, grasses, and low shrubs, but plant species diversity is relatively low. Salt marshes typically show distinct patterns of vertical zonation caused by differences in the frequency of tidal inundation with elevation and the plants must respond to these differences according to individual species tolerance of salinity and water table levels. Groups of species similarly adapted to a specific suite of physical conditions form distinct communities that can be mapped. At higher elevations in the upper marsh zone, tidal flooding is infrequent and freshwater more influence than lower in the marsh, but plants can still experience dry, low-nutrient conditions. Species adapted to the lower marsh zone must survive high salt concentrations, complete or partial submersion, anoxic mud substrate, and a certain amount of water movement. Salt marshes are photosynthetically active and extremely productive habitats, feeding a broad food chain of organisms from bacteria to mammals, and playing an important role in aquatic and marine food webs by exporting nutrients to coastal waters. Various concentrations of suspended sediments, dissolved minerals, and organic pigments may cause ponded water in the marsh to turn different colors.

Falls Creek, Kachemak Bay, Cook Inlet

Coal Seams and Talus Cones *N 59 45.972, W 151 07.852*
June 24, 2009

The Kenai Group is a sequence of middle to late Cenozoic (about 50 million year ago) fine-grained sedimentary rocks comprising the only bedrock along the coast between Kenai and the Fox River at the head of Kachemak Bay. The unit is exposed almost continuously in the precipitous wave cut cliffs and steep walls of stream canyons. The sequence consists of at least 1,500 m (5,000 ft) of moderately to weakly hardened, locally conglomeratic sandstone with interbedded siltstone, claystone, and coal (seen here as the darkest horizontal lines). The proportion of sandstone increases northward and the number and thickness of coal beds and the quality of the coal decreases. The coal is relatively low grade lignitic to sub-bituminous. Coal beds are generally lenticular, ranging from one to two meters thick. Many former coal beds have been burned, thus baking the adjacent rocks a distinctive brick-orange color. The rock is highly friable and actively mass-wasting to form deep gullies. Talus cones develop at the base of the sea cliff from accumulating rock fragments. These deposits typically have a concave upward shape, and the maximum inclination of such deposits corresponds to the angle of repose for the mean particle size.

Stockdale Harbor, Montague Island, Prince William Sound

Stockdale Sine Waves *N 60 17.815, W 147 12.431*
May 17, 2007

Repeating patterns of marine biota are often the result of repeating patterns of the substrate or habitat. Benthic intertidal plants and animals have developed adaptations to tolerate a range of atmospheric and oceanic conditions. These adaptations have evolved over time to allow for a competitive advantage for food, space, or sunlight. Many sessile organisms only occur on certain substrate types and within either the high, mid, or low intertidal zone and rarely across all elevations. Motile organisms, such as sea stars, crabs, and fishes, will take advantage of the high tides to forage in the intertidal and then seek shelter in pools, crevices, or deeper water at low tide. Studies have shown that groups of organisms, or communities, coexist in repeatable patterns when physical conditions are the same.

Point Nowell, Knight Island Passage, Prince William Sound

Ancient Rock *N 60 27.471, W 147 57.077*
July 3, 2004

The rock forming these mainland sea cliffs are of the Valdez Group and composed of tightly folded and metamorphosed marine greywacke, and dark gray to black slate, intruded in some areas by granite. The Valdez Group is probably tens of thousands of feet thick and underlies much of the adjacent Chugach and Kenai Mountains. This formation includes the oldest bedded rocks exposed in the Prince William Sound region and is resistant to weathering, thus forming most of the steep cliffs and pinnacles in this region. The relatively uniform slope of this sea cliff allows for well-defined vertical zonation of intertidal organisms with the black lichen (*Verrucaria maura*) in the supratidal, the brown rockweed (*Fucus distichus*) in the high zone, and a new set of barnacle recruits in the mid zone. A small section of the low zone is visible near the waterline where larger adult barnacles (*Semibalanus cariosus*) dominate the rock surface.

Unnamed Islet, Chenega Island, Prince William Sound

An Island in the Sound *N 60 16.683, W 148 07.753*
July 3, 2004

The rock ramp surrounding this islet is formed by rock strata dipping or angled seaward. Rock ramps are common shoreline features with low to moderate angle strata and the bedding-plane determines the shore slope. The blue water color is caused by fine sediments suspended in the freshwater discharge of nearby tidewater glaciers flowing from the Sargent Icefield. The finely ground rock flour was eroded from the surrounding Kenai Mountain Range. Clay (2-4 microns in diameter) and silt (4-65 microns in diameter) that compose rock flour have a high absorption coefficient for short wavelength light and absorbs only part of the blue light. The water absorbs the red, orange, and yellow light, so only green and some blue light are reflected. The glacial water is less dense than ocean water and, in the absence of strong winds, waves, or currents, the freshwater layer does not readily mix and literally floats on the ocean surface through the semi-diurnal tide cycle. This has a profound effect on intertidal organisms and only the most tolerant marine plants and animals can survive these conditions, such as the rockweed (*Fucus distichus*) and black lichen (*Verrucaria maura*) on this rock ramp.

Prince of Wales Passage, Prince William Sound

Bas Relief of Columnar Basalt *N 60 05.630, W 148 04.529*
July 1, 2004

Sea cliffs are a common feature of an eroding coastline. There are many factors involved in sea cliff erosion, one of which is the rock itself, principally its material composition and structure. Igneous rocks, such as columnar basalts, are particularly strong and resistant to erosion. In the relatively wave protected environment of Prince William Sound, the cliffs erode primarily by thermal expansion of freezing groundwater seepage and rain water. The broken rock particles tumble into the sea and accumulate as talus at the base of the sea cliff. Ocean waves and currents act only to remove the finer particles from the debris pile. The vertical structure of the columnar basalt is emphasized in this image by intertidal plants. The upper extent of marine zonation on rocky shores in Prince William Sound is typically indicated by a horizontal band of black lichen (*Verrucaria maura*) occupying the portion of shore above the highest tide level and wetted only by sea spray. Here on a wave protected near vertical sea cliff, the height of zonation below the spray zone is approximately equal to the tidal range.

Granite Bay, Knight Island Passage, Prince William Sound

A Natural Granite Quarry *N 60 25.795, W 148 01.090*
July 3, 2004

Exfoliation joints or sheet joints are surface-parallel fractures in rock caused by temperature differences between the surface and subsurface. These fractures in granite, an igneous rock formed from magma, often lead to the sloughing of concentric slabs by a process called exfoliation. Granitic magma has many potential origins but by definition it must intrude other rocks. Most granite intrusions occur in the Earth's crust at depths between 1.5 and 50 km, and typically under great pressure. The fracturing of this rock is also called axial cleavage, longitudinal splitting, or extensional fractures. Exfoliation slabs, like those seen here, are commonly observed on granitic outcrops and are the primary erosion mechanism of this rock type.

Entrance Island, Prince William Sound

Pillow Basalt *N 60 31.150, W 147 34.883*
May 19, 2007

Basalt is an extrusive volcanic rock most commonly found on the sea floor. When basalt erupts underwater or flows into the sea, contact with the water rapidly cools the surface forming an elastic skin. The molten rock under the skin continues extruding to form a lobe. The lobe expands until the pressure ruptures the skin and another lobe forms creating the distinctive pillow shapes. The lobes are very plastic and conform to the underlying surface. Cross sections of pillows typically show a fine-grained core with a glassy crust and radial jointing. The size of individual pillows varies from 10 cm up to several meters. These pillow basalts are inter-bedded with sedimentary rocks and commonly found in the Orca rock formation of Prince William Sound, uplifted sometime during the Cretaceous Period (about 100 million years ago).

Whale Bay, Prince William Sound

Roundabout a Plunge Plume *N 60 11.447, W 148 11.668*
July 2, 2004

The snowfall in Prince William Sound is often over 700 cm (300 inches) per year. Combined with the steep terrain and rapidly changing maritime air temperatures, powerful avalanches occur that have the capability of entraining massive volumes of ice, rocks, and vegetation. Avalanche paths are often indicated in the summer by deeply incised ravines filled with scree (gravel) and cascading streams. Avalanches and avalanche paths share common elements: a start zone where the avalanche originates at high elevation, a track along which the avalanche flows, and a runout zone where the avalanche comes to rest. The debris deposit is the accumulated mass of material that remains in the avalanche runout zone when the snow melts. Rapid deceleration of the debris at the shoreline will often form an alluvial fan of poorly sorted gravel that gradually becomes vegetated with avalanche-tolerant grasses and alders.

Strawberry Channel, Hinchenbrook Island, Prince William Sound

Recurve at Point Bentinck *N 60 22.401, W 146 04.712*
May 20, 2007

A common feature on an irregular coast is a spit or a beach with associated backshore and dunes connected to the coast at one end. Most spits grow in the direction of predominant alongshore currents and sediment transport. The free end of the spit may terminate in a hook or recurve formed by wave refraction or by the interplay of waves coming from several directions. Spits will continue prograding into the sea until water velocity (such as from a channel or river) or bathymetry prevents further sand deposition. As a spit grows, the water behind it is sheltered from wind and waves, and a salt marsh is likely to develop. On prograding beaches and spits, storms can pile up sand into beach ridges, well above normal high tide level, that may eventually become stabilized by vegetation. A parallel series of beach ridges may develop from successive storms providing a time series of shoreline accretion events.

Cottonwood Point, Copper River Delta

Hauled Out, Mid-channel *N 6 0 18.564, W 145 03.276*
June 5, 2007

Harbor seals (*Phoca vitulina*) are one of the most common and widely distributed pinnipeds in coastal waters of southern Alaska. They occur in a variety of habitats, from rocky intertidal areas to river estuaries and glacial fiords. In the Copper River Delta, seals haul out on many of the barrier islands and pup on the sand bars. Harbor seals generally haul out in greatest numbers during mid-day, though this may vary by region or even by haul-out site. There are two seasonal peaks in the numbers of harbor seals hauled out in Alaska: one during May-June with pupping, and the other during August-September with molting. The Copper River Delta is one of the most productive and critical habitats for harbor seals in Alaska. The harbor seal population is at least 1,700 animals and they feed primarily on herring, salmon, and eulachon. An estimated 16 million shorebirds and one million waterfowl stop at the delta during the spring bird migration. The Copper River is also one of the state's major salmon producing streams and supports an important commercial and subsistence salmon fishery.

Martin River, Copper River Delta

A River Runs Through It *N 60 16.248, W 144 46.500*
June 5, 2007

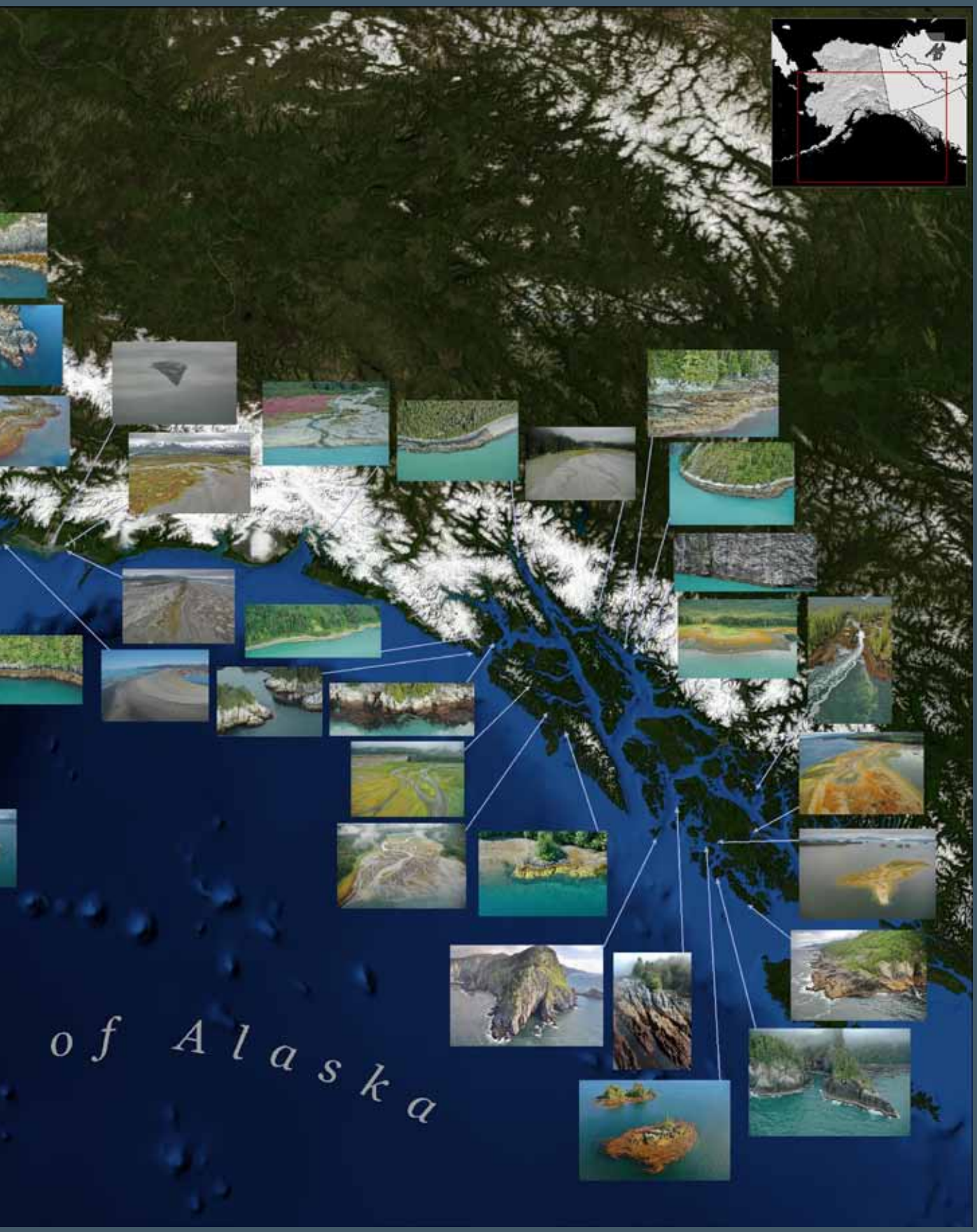
The delta formed by the Copper River extends for more than 75 km along the coastline of southcentral Alaska and supports the most extensive coastal wetland on the Pacific Coast of North America. All major rivers that flow into the delta arise either directly from glaciers or from large moraine lakes. These rivers carry extremely high loads of very finely textured suspended sediments and the Copper River alone is estimated to deposit an average of 97 million metric tons of sediment a year into the Gulf of Alaska. The Copper River Delta has approximately 1000 km^2 of intertidal and supratidal wetlands and associated creeks, rivers, ponds and lakes. In 1964, an earthquake of Richter magnitude 9.2 raised the entire delta 1.8-3.4 m (5.9-11.2 ft) above the previous mean sea level. The resulting abrupt change in slope significantly altered the tidal regime and wetland vegetation patterns and normal plant succession gradients were replaced by more sharply defined edges.

Softuck Bar, Point Martin, Copper River Delta

Sand Moves on Softuck Bar *N 60 13.000, W 144 44.137*
June 5, 2007

Beaches and dunes are integral parts of a dynamic environment in which sand is constantly exchanged. During the summer, calmer waves transport sand from offshore bars and the surf zone to the beach, causing the beach to gradually build up, or accrete. In time, wind blows the finer sand onto the foredune, where it is trapped by vegetation and stored until displaced by storms. During a storm, waves washing against the base of a foredune erode sand, undermining and collapsing the seaward dune face. In severe storms the dune may be completely destroyed. The eroded sand is transported offshore and deposited just seaward of the surf zone in large bars. This process of dune erosion and sand movement dissipates much of the energy of storm waves. Sandbars also dissipate storm wave energy by causing waves to break further offshore. If the supply of sand remains constant, the natural exchange between the beach, dunes, and offshore areas will eventually rebuild dunes. However, the loss of vegetation that traps and holds sand makes the beach and dunes more susceptible to wind and water erosion, thus inhibiting their recovery from storms.

Map Compiled by Geographic Resource Solutions, Anchorage AK
Image Source: http://goto.arcgisonline.com/maps/World_Imagery


of Alaska

Strawberry Reef, Copper River Delta

Ice rafted sediments *N 60 15.082, W 144 46.556*
June 5, 2007

The spring breakup of ice on the Copper River, and other watersheds such as the Martin River that drain into the Copper River Delta, flushes a large volume of ice debris downstream that often accumulates in the delta where current velocities and channel depths diminish. The inland side of sand bars and barrier islands may collect a substantial volume of stranded ice floes that subsequently melt in place. Ice floes calved from glaciers upstream on the Copper River and broken shorefast river ice can entrain or otherwise transport sediments many miles and deposit them where the floes become stranded and melt. This is called ice rafting and relatively heterogenous patches of mounded coarse-grained sediments on otherwise relatively fine-grained bars and islands can identify the residual gravel.

Cottonwood Point, Copper River Delta

Copper River *N 60 17.307, W 144 57.781*
June 5, 2007

The Copper River (or Ahtna River in Athabascan) is a 480 km (300 mile) long river flowing into the Gulf of Alaska about 50 km east of Prince William Sound. It drains a large glaciated region of the Wrangell and Chugach Mountains. The name of the river comes for the historically abundant copper deposits used by Alaska Natives and later by Russian and American settlers. Large scale commercial extraction of the copper ore was made possible by the construction of the Copper River and Northwestern Railway from Cordova to the Kennecott Mine. The mine was abandoned in 1938 and much of the railroad grade is now a discontinuous road. The Copper River is known for its extensive delta ecosystem, as well as for its wild salmon, which are among the most highly prized stocks in the world. It is the tenth largest river in the United States by volume (20th in North America). The Copper River Delta (2,800 km^2) is considered the largest contiguous wetlands along the Pacific coast of North America. It is used by 16 million shorebirds annually, including the world's entire population of western sandpipers. It is also home to the world's largest population of nesting trumpeter swans and is the only known nesting site for the dusky Canada goose.

Ruins Point, Kosciusko Island, Sumner Strait, Southeast Alaska

Karstscape *N 56 03.965, W 133 42.165*
July 17, 2007

Karst landscape is shaped by the dissolution of a layer or layers of soluble bedrock, usually carbonate rock like these limestone shores in Southeast Alaska. Karst develops over many thousands of years and results in unusual terrestrial and marine features. Mildly acidic water begins to dissolve the surface along fractures or bedding planes in the limestone bedrock. Over time, these fractures enlarge as the bedrock continues to dissolve. Openings in the rock increase in size, allowing more water to pass through the area, and accelerating the formation of surface and underground karst features. The karstification of a landscape may result in a variety of large or small scale features. On exposed surfaces, small features may include flutes and runnels. Medium and large-sized surface features may include sinkholes, vertical shafts, and disappearing and reappearing springs. International experts have recognized the karst of the Tongass National Forest as a paleontological and geological resource of global significance.

Tracy Arm, Southeast Alaska Mainland

Struggling in a Glacier Fjord *N 57 54.994, W 133 31.025*
August 4, 2008

In areas of recent glacial retreat, newly exposed wave protected habitats can be harsh environments for marine plants and animals because of ice scour and a silt laden low salinity ocean. The marine species diversity here will likely be exceptionally low and limited to tolerant opportunistic animals such as barnacles and colonizing annuals such as the green ulvoid group of macroalgae. Species that do survive the ocean conditions must also tolerate ice scour. For example, the black lichen (*Verrucaria maura*) is found between the high intertidal and supratidal zones but may still be subjected to severe damage from ice scour as evident by the discontinuous or patchy pattern in this image. The white lichen (*Coccotrema maritimum*) grows on shoreline rock ramps above the tidal zone. The lack of soil makes for a marginal terrestrial habitat. Nitrogen-fixing terrestrial plants first colonize cracks, depressions, and horizontal glacial striations where freshwater runoff may first deposit soil.

Tracy Arm, Southeast Alaska

Coast Range Batholith *N 57 53.203, W 133 19.380*
August 4, 2008

The glacially striated cliffs on the north shore of upper Tracy Arm show the granite and partially metamorphosed rock associated with the Coast Range Batholith. The Coast Range Episode of mountain building began 115 million years ago when a chain of volcanic islands riding on an oceanic plate collided with the western shoreline of the continental plate in the northeast Pacific. These islands were welded to the edge of the continent by molten rock that cooled deep beneath the Earth's surface to form the Coast Range Batholith – an enormous body of granitic rocks. This batholith is the largest such body of granitic rocks in North America. The granites intruded highly deformed ocean-floor rocks and assorted island fragments. Vast quantities of molten granite were injected over this period. In some places, mixtures of older plutonic rocks and the original oceanic rocks were deformed under great heat and pressure to form exotic swirled patterns called migmatites that can be found scattered throughout Tracy Arm.

Steven's Passage, Southeast Alaska

Disturbance and Intertidal Mosaics *N 57 51.583, W 133 46.350*
August 21, 2005

The intertidal zone is dominated here by a high zone of barnacles (*Balanus* spp.), a mid-zone of mussels (*Mytilus trossulus*), a low zone of another barnacle (*Semibalanus cariosus*), and coralline crusts and kelp in the shallow subtidal zone. Some intertidal algae occur (*Endocladia muricata*, *Mastocarpus* spp., *Fucus distichus*, etc.), but the isolated patches of these immature populations and the populations of relatively robust invertebrates indicates a periodically disturbed environment. The mechanism of disturbance is evident by the clusters of rounded cobbles filling shallow depressions of the nearly horizontal bedrock ledge. The proximity of several large glaciers also suggests that low water salinity and ice scour could be another disturbance mechanism. Although not exposed to the open sea, there is apparently enough energy in winter to mobilize the cobbles that subsequently batter the ledge organisms, creating bare patches where recruitment occurs in spring and summer to repopulate the ledge.

Cape Magdalena, Dall Island, Southeast Alaska

Marble for Mary *N 54 50.299, W 133 00.810*
July 28, 2007

Dall Island contains deposits of marble on both the west and east coasts, with excellent examples in Waterfall Bay, Cape Muzon, and View Cove. Marble is metamorphosed sedimentary carbonate rocks, most commonly limestone or dolomite, but here in Alaska most likely the former. Commercial extraction of marble has occurred on Dall Island since the very early 20th century. Much of the remaining marble is tightly interbedded with other metamorphic rocks and extraction is not commercially viable. The marble stratum on the west coast of Dall Island is vertically dipping, or lying straight up and down. This exposes the relatively soft marble to weathering and it erodes faster than the harder surrounding rock. The interbedded rocks are shales and slates derived from clays and muds which have also passed through a series of metamorphic processes. The layered metamorphic rocks of different origins results in the alternating light and dark color of the vertically folded bedrock.

Shinaku Inlet, Prince of Wales Island, Southeast Alaska

A Spit Forms *N 55 34.683 W 133 10.583*
July 10, 2006

Beaches and spits can form in the absence of clastic sands by the slow accumulation of shell fragments. Barnacle and clam mortality from predation by sea stars and carnivorous molluscs, or perhaps from freezing winter temperatures, will cause the calcium carbonate tests and shells to break apart and gradually disintegrate into sand sized fragments. Even in the recesses of deep embayments, tidal currents and waves can accelerate the fragmentation process. The shell fragments are then transported and redistributed in the same way as clastic sands to form depositional features such as beaches and spits. The refraction and convergence of waves on the leeward side of the island have focused barnacle shell fragments, which probably originated from the surrounding cobble and boulder shoals, into a low aggradational spit.

Mills Bay, Kasaan Bay, Prince of Wales Island, Southeast Alaska

Tombolo Dynamics *N 55 33.837, W 132 28.807*
July 13, 2007

When a large rock or island is a short distance from shore, with shallow water in between, sediments may accumulate in a zone protected from wave attack. Eventually, when a spit forms linking the mainland to the offshore island, it becomes a tombolo. A tombolo is formed by wave refraction. As waves approach the island, they are slowed by the shallow water surrounding it and refract or bend to the opposite side. The wave pattern created by this water movement causes a convergence of longshore drift on the opposite side of the island. Beach sediments are moving by lateral transport from the wave exposed shore to the more protected lee shore and accumulate there. In other words, the waves sweep sediment together from both sides and the resulting beach conforms to the shape of the refracted wave pattern. The perennial rockweed (*Fucus distichus*) gives us a clue to where more stable sediments occur and the ephemeral green ulvoid seaweeds indicate the less stable sediments.

Libby Island, Graves Harbor, Cape Spencer, Southeast Alaska

Bull Kelp Channel *N 58 16.341, W 136 46.088*
July 21, 2005

Wave dominated rocky shores of the exposed outer coast typically indicate the effects of wind and sea spray by a wide uninhabited supratidal zone between the terrestrial vegetation and the upper edge of marine biota. Few organisms can withstand this violent environment and diversity is relatively low. Bladed algae are mostly absent and the intertidal community is composed mainly of encrusting algae and sessile or highly mobile animals. Bull kelp (*Nereocystis luetkeana*) has adapted to this type of environment, with strong holdfasts to anchor them to subtidal rocks and a streamlined blade shape to reduce drag in high velocity currents. However, even these plants do not persist in the turbulent surf of breaking waves adjacent to the most exposed vertical rock walls. They are often found in more protected channels and embayments where waves do not break directly and currents are less turbulent.

Arena Cove, Suemez Island, Southeast Alaska

Towering Columnar Basalt *N 55 12.392, W 133 24.792*
July 12, 2006

Basalt is an extrusive volcanic rock and one of the most common rock types in the world. During the cooling of a thick lava flow, contraction joints or fractures form. If a flow cools relatively rapidly, significant contraction forces build up. While a flow can shrink in the vertical dimension without fracturing, it cannot easily accommodate shrinking in the horizontal direction unless cracks form and the extensive fracture network that develops results in the formation of columns. These structures are sometimes described as being predominantly hexagonal but, in reality, polygons with three to twelve or more sides occur. The diameter of the columns depends loosely on the rate of cooling; very rapid cooling may result in very small (<1 cm) columns, while slow cooling will likely produce larger columns. The intertidal zonation on this high energy coastline is indicated by a very high black supratidal spray zone (the black lichen *Verrucaria* spp.), a narrow zone of barnacles, and awash in the low zone are red coralline algae and some kelps.

Deep Bay, Peril Strait, Chichagof Island, Southeast Alaska

Estuary in the Mist *N 57 26.683, W 135 38.048*
August 1, 2008

Many of the coastal streams in southeast Alaska are relatively short, steep, and drain watersheds with very high precipitation. This causes large volumes of water and entrained material (sediment and organics) to be discharged into the estuary. When the slope of the drainage basin suddenly decreases at the ocean, and the water velocity and turbulence can no longer suspend the sediment load, the material is deposited as an alluvial fan (gravel) and plain (sand and silt). Distributaries and estuarine meanders develop from tidal current reversals and differential rates of sediment deposition. Finer sediments are deposited at the edges of the plain where perennial sedges colonize and stabilize the substrate. Semi-diurnal tidal flooding perfuses the marsh with organics and nutrients. Sediment trapping by marsh vegetation may gradually elevate the marsh, allowing for succession of plants less tolerant of tidal immersion.

Scow Cove, Taku Inlet, Southeast Alaska

Mud Mask *N 58 21.176, W 134 03.302*
August 21, 2005

Mudflats or tidal flats, are coastal wetlands that form when fine sediments are deposited by tides or rivers. Glaciers are an important source of fine sediment and in Alaska most of the tidal mudflats are a result of glacial runoff. Mudflats are typically found in areas sheltered from currents and water turbulence where fine sediments can settle from the water column such as in bays, lagoons, and estuaries. Most of the sediments in mudflats are within the intertidal zone and in most areas of Alaska are submerged and exposed twice daily. Tidal creeks form to drain a mudflat and although they may be full as the tide begins to ebb, they may dry to muddy channels with little or no flow at low tide. Due to the temporal variability of water volume and quality within the tidally influenced zone, there are unique biota associated with tidal creeks and mudflats. Mudflats near retreating glaciers are also undergoing glacial isostatic adjustment and are likely to become elevated over time. This gradual rise promotes the development of salt marshes along the high elevation margins as successional vegetation not tolerant to repeated tidal submersion becomes established.

Nunatak Fjord, Russel Fjord, Yakutat Bay

Fireweed on A Flood Plain *N 59 51.417, W 139 13.217*
July 23, 2005

From Disenchantment Bay, at the upper end of Yakutat Bay, Russell Fjord penetrates about 56 km (35 miles) inland. The slow advance of the Hubbard Glacier periodically isolates Russell Fjord from Yakutat Bay and the ocean. Nunatak Fjord branches from the Russell Fjord and extends another 24 km (15 miles) to the east in a dramatic, narrow, ice carved embayment with numerous glacial and snow fed rivers cascading from the surrounding mountains. The spring snowmelt causes these rivers to swell and periodically flood a broad swath of flood plain flanking the river channel. The brilliant display of fireweed has colonized a portion of the flood plain that is frequently, but not annually, inundated.

North Arm Dundas Bay, Glacier Bay National Park

A Stable Line *N 58 25.650, W 136 30.400*
July 21, 2005

The restricted circulation of semi-enclosed estuaries and very protected embayments, particularly in Southeast Alaska, allows for a low salinity water layer to develop at the surface. This results in low species diversity since few marine organisms can tolerate the fresh water summer conditions and the cold air temperatures of winter. Rockweed (*Fucus distichus*) and a few isolated patches of the blue mussel (*Mytilus trossulus*) are primarily the species forming the narrow homogeneous band shown here. The variable width of the rockweed band is attributed to slight changes in beach slope (the beach is narrower where the slope is steeper) while the rockweed occupies a very specific elevation range on the beach. The steeper sections of beach have coarser gravel, mostly cobbles and boulders, and the lower slope and wider beach has finer pebbles and sand. The steeper and coarser sections of beach are evidently the remains of avalanche debris indicated by the vegetation lines on the surrounding slopes of the fjord.

Brownson Island, Ernest Sound, Southeast Alaska

Skookumchuck *N 55 59.45, W 132 9.817*
May 6, 2008

A tidal race is a naturally occurring rapid formed by fast moving tidal currents passing through a constriction, often resulting in large waves, eddies, and hazardous currents. These features are common in Norway, Maine, and the Pacific Northwest. In the pidgin of the Chinook a "chuck" is a water body, and "skookum" means strong or able. Thus, a rapid is a "skookumchuck", literally meaning strong water. In coastal usage, skookumchuck refers to the powerful tidal rapids at the mouths of most of the major coastal inlets in the Pacific Northwest. Ernest Sound in Southeast Alaska has a tidal range of up to 7 m (23 feet) forcing large amounts of seawater through the many surrounding inlets and embayments. On a typical tide, hundreds of cubic meters (billions of US gallons) of water can surge through these narrows, with current speeds that exceed 16 knots creating turbulent rapids and whirl pools. These areas of high current may have dense concentrations of filter feeding invertebrates such as mussels and anemones.

Tracy Arm, Snettisham Peninsula, Southeast Alaska

Omega Bands *N 57 47.225, W 133 37.744*
August 4, 2008

During the most recent glaciated period, this fjord was filled with the Sawyer Glacier which has now receded about 48 km (30 miles). During the summer, the fjord still has considerable floating ice ranging from small chunks of 1-10 cm to pieces as large as a three-story building. The larger pieces strand on an underwater moraine perpendicular and adjacent to this shore and gradually disintegrate into smaller pieces that drift and strand on the mainland. Poorly sorted glacial till forms much of the shoreline substrate and the larger particles on the upper beach form stable anchors for the attachment of rockweed (*Fucus distichus*) that can tolerate low salinities of the glacial fjord and cold air temperatures. A fringing salt marsh of sedges (*Carex* spp.) lines the shore and a successional community of terrestrial grasses, alder, and spruce has colonized the uplands.

North Arm Hoonah Sound, Southeast Alaska

Estuarine Splendor *N 57 46.217, W 135 49.612*
August 1, 2008

There is a spatial distribution of depositional sediments in an estuarine delta, with coarser sediments deposited closer to the distributary channels and fines deposited at the margins of the alluvial plain. The alluvial margins are lower energy and the substrate is relatively more stable than at the channel edges. However, in the summer when wave energy is lower than in winter, and river discharge of non-glacial streams is low, the gravel substrate may be sufficiently stable to support macroalgal growth. This establishes a temporal distribution of plants with perennial sedge communities developing on the stable perimeter substrates and ephemeral macroalgae, such as ulvoid species, temporarily colonizing the gravel bars. The principal genera belong to the green algae phylum (Chlorophyta) include *Blidingia, Cladophora, Ulva, Ulvaria,* and *Monostroma*. In some locations, the growth can be very prolific and blooms have been blamed for eradicating seagrass meadows, altering faunal community structure, and creating unsightly, malodorous piles on beaches.

Helm Point, Coronation Island, Southeast Alaska

Sea Cave Mysteries *N 55 49.283, W 134 17.133*
June 15, 2010

Coronation Island is primarily limestone and has many karst features including Colander Cave and numerous sea caves on the more exposed west and south shores. The driving force in littoral or sea cave development is wave action, but with limestone there are also solutional processes. Erosion is ongoing anywhere that waves batter rocky coasts but, where sea cliffs contain zones of weakness such as bedding planes and fissures, rock is removed at a greater rate. Wave action will widen and deepen the fissure due to the tremendous force exerted within a confined space, not only by direct action of the surf and any rock particles that are suspended, but also by compression of air. Some caves have rounded and smoothed walls as a result of the swirling motion of sediment in the surf zone.

Nakwasina Sound, Sitka Sound, Southeast Alaska

Ephemeral and Perennial Simplicity *N 57 11.684, W 135 23.288*
June 7, 2004

A near monoculture can occur on intertidal shores seasonally or perennially disturbed by mechanisms such as low salinity, ice scour, or air temperatures cold enough to cause mortality of less tolerant species. The homogeneous bands of macroalgae, within well-defined elevation zones on this rock deep within the recesses of a Southeast Alaska fjord, suggests a combination of conditions suitable for only a limited number of species. Spruce trees (*Picea sitchensis*) grow to near the height of the highest tides, suggesting a shore very protected from even the most severe winter storm waves. A narrow band of gravel separates the terrestrial from the upper edge of the supratidal zone where the ubiquitous black lichen (*Verrucaria maura*) occurs. A band of dark brown rockweed (*Fucus distichus*) occupies the high zone and the light green alga (*Cladophora sericea*) has colonized the mid to low zone. This alga is an annual and typically an early colonizer of bare substrates in clear water and low carbon dioxide levels. The water clarity in the image also shows a light colored sandy bottom and a fringe of eelgrass (*Zostera marina*) surrounding the rock ramp.

Kiliuda Bay, Kodiak Island

June 24, 2005 *N 57 17.95, W 152 53.55*

Chilkoot Inlet, Lynn Canal

July 20, 2005 *N 59 8.017, W 135 19.500*

Sharply contrasting intertidal habitats are often caused by rapidly changing wave energy gradients and sediment dynamics. Waves travel faster in deep water so that waves approaching shore over a shoaling bottom are steered or refracted towards headlands and away from embayments. This results in waves breaking with higher velocities at headlands, creating an erosional environment where fine sediments are rapidly exported leaving only bedrock and boulders. Embayments are more energy dissipative, resulting in a depositional environment where fine sediments accumulate. Headlands are also steeper than embayments so that changes in slope will affect the rate of sediment accumulation. Large changes in slope over short distances will cause sharply delineated habitat changes. Sediment shores of exposed coasts and embayments will also experience seasonal changes. Lower energy waves of summer will cause fine sediments to be transported from the subtidal to the intertidal and higher energy waves of winter will generally transport fine sediments from the intertidal to the subtidal.

Changing Conditions Influence Coastal Environments

River dominated coastal deltas, such as the glacier-derived sediments forming braided channels in Cochran Bay, Prince William Sound (a), and the non-glaciated watershed delta of Gambier Bay, Admiralty Island (b), develop when sediment brought down to the coast by rivers accumulates more rapidly than can be removed by waves, tides, and currents. Along a natural delta coast, most of the shoreline is either prograding or in equilibrium between accumulating sediments deposited by rivers, and erosion. Seismic events, such as the 1964 Richter 9.2 Alaska Earthquake, also cause significant subsidence by sediment compaction.

Tide dominated coasts in Alaska include salt marshes, and tidal flats such as in Shipyard Bay, Hawkins Island, Prince William Sound (c). The response of these environments to changing ocean conditions primarily depends on the volume of organic and inorganic sediment supply from the watershed, the rate of vertical accretion, seismic or isostatic uplift (or subsidence), and the rate of ocean change (e.g., storm intensity and frequency, sea level rise, etc.).

Wave and current dominated shores, such as this ridge and runnel beach in Pavlof Bay, on the Alaska Peninsula (d), with an adequate and constant sediment supply and strong alongshore transport, may be prograding or in equilibrium with local wave conditions. Sea level rise will generally cause eroding shores to erode faster, stable shorelines to begin eroding, and accreting shoreline to stabilize or begin to episodically erode.

The effect of sea level rise on rocky coasts, such as this sea cliff in Lynn Canal, Southeast Alaska (e), will include submerging the existing intertidal zone and thereby increasing wave attack at the base of the cliff and cliff erosion. This will be particularly evident on exposed coasts where sea level rise is likely to be accompanied by an increase in precipitation and storminess, both promoting erosion and sea cliff failure. However, on resistant or wave protected vertical cliffs, the sea level may just rise vertically without any effect on cliff erosion. In areas of active alongshore sediment transport, increased sea cliff erosion will introduce more sediment into the nearshore, possibly causing beach accretion or widening and shoaling of the nearshore.

(a)

(b)

(c)

(d)

(e)

Eelgrass, Seaweeds, and Crusts

Eelgrass is the common name for the perennial, rooted vascular plant *Zostera marina* that grows in shallow sandy substrates as seen here in Prince William Sound (a). Zostera flowers, fertilizes and sets seeds underwater and can also spread through vegetative growth. Rhizomes (underground stems) branch and produce a tangled mat that stabilizes the substrate. A wide variety of mobile organisms use eelgrass beds including salmonids, shrimp, flatfishes, and early life stages of other important fishery species.

In some areas where the shore is rocky, protected from high wave energy, and the water is well flushed by tidal currents, lush growths of bladed kelps are found in the lower intertidal zone such as the Split kelp (*Saccharina groenlandica*) in Sulua Bay near the southern tip of Kodiak Island (b).

Some brown algae, and all the canopy kelps, have gas-filled chambers to float the blades and stems and enhance photosynthesis and nutrient perfusion at high tide, such as the intertidal rockweed (*Fucus distichus*) in Foul Pass, Ingot Island, Prince William Sound (c).

Red algae (Rhodophytes), such as the red ribbon (*Palmaria mollis*) on Perevalnie Island at the very north end of the Kodiak Island Archipelago (d), have developed pigments to better absorb blue and green light for photosynthesis. Since light with shorter wave lengths (e.g., blue and green), are able to penetrate water better than the longer wave lengths (e.g., red and yellow), the red algae have adapted to live at water depths where other algae cannot survive.

Some types of red algae cannot be considered seaweeds since they form hard calcareous crusts on rocks such as at Posliedni Point, Afognak Island, north of Kodiak Island (e). Over hundreds of years, successive layers of coralline algae can develop into thick crusts of up to 0.5 m (20 inches) with complex structures that provide habitat for diverse invertebrate communities. Larger invertebrates, such as the blood star (*Henrica leviuscula*), may be found searching for prey within the coralline structure.

In the absence of other pigments, chlorophyll provides the distinctive color to green algae (Chlorophytes). These include species of various spongy, fuzzy, and stringy forms. In the intertidal there are several larger species such as the bladed sea lettuce (*Ulva lactuca*) being grazed by a limpet (*Lottia scutum*) on Kitoi Bay, Afognak Island, north of Kodiak Island (f).

(a)

(b)

(c)

(d)

(e)

(f)

Mobile and Sessile Invertebrates

Along the Pacific coast, the sunflower star (*Pycnopodia helianthoides*), is a large (up to 1 m) invertebrate commonly found on sandy substrates in search of bivalve molluscs, such as seen here in Japanese Bay, Kodiak Island (a). When submerged, the sunflower star can move rapidly across the bottom. This locomotion, as well as the ability to cling to vertical rocks and open clams, is facilitated by tube feet arranged in rows along the underside of each arm. On the aboral, or upper surface of sea stars, the small bumps are called dermal branchiae and are used to absorb oxygen from the water for respiration (b). Also seen in the upper left of (b) is the madreporite, the larger white spot which is a calcareous component of the vascular system and acts as a filter for seawater.

The lined chiton (*Tonicella lineata*) is often found on coralline algae encrusting bedrock or boulders in the low intertidal zone, such as on Perevalnie Island at the north end of the Kodiak Archipelago (c). This chiton grazes on the superficial layer of the plant as well as opportunistically on other surface organisms. It can grow to about 5 cm and is brightly colored, yet well camouflaged on coralline crusts.

The green anemone (*Anthopleura xanthogrammica*) is a carnivorous sessile invertebrate of the lower intertidal zone, such as this one in Kiliuda Bay, Kodiak Island (d). Also seen are a variety of coralline crusts, barnacles, and limpets. The distinctive green color is derived from two microscopic algae. The algae are concentrated in the tissues that line the anenome's digestive tract where organic compounds synthesized by the algae are absorbed.

The majority of sea anemones feed on fishes, shrimp, crabs, and other prey sometimes of considerable size. The mouth and body cavity is surrounded by tentacles (e) armed with many specialized cells called Cnidocytes and each one contains a nematocyst. Each nematocyst contains a small vesicle filled with toxins, an inner filament, and an external sensory hair. When the hair is touched it mechanically triggers the Cnidocytes to fire the harpoon-like structure which attaches and injects a dose of poison in the flesh of the aggressor or prey. Most sea anemones are harmless to humans, but the fired nematocysts gives the anemone its characteristic sticky feeling when touched by hand.

(a)

(b)

(c)

(d)

(e)

Canopy Forming Kelps

Three canopy forming kelps occur in Alaska and their geographic ranges overlap in the Gulf of Alaska. In a few places they co-exist in the same kelp forest, but they are often seen as separate beds based on their specific preferred habitats. Images of these kelp beds are shown on the following three pages and include aerial images of the dragon kelp *Eualaria fistulosa* (1a), the giant kelp *Macrocystis pyrifera* (2a), and the bull kelp N*ereocystis luetkeana* (3a).

The dense vertical infrastructure of a kelp forest forms a system of microenvironments similar to those observed in a terrestrial forest, with a sunny canopy region, a partially shaded middle layer of understory kelps, and a darkened seafloor community of encrusting coralline algae and invertebrates. The thin stipe (stalks) of canopy kelps rises from a holdfast (anchor) and can reach tens of meters to the surface where blades spread broadly to maximize the photosynthetic surface area. The kelps are kept afloat by gas bladders (pneumatocysts) filled with carbon monoxide, but the flotation system differs slightly by species. The floats are integrated in the stipe and blades of *Eularia* (1b), *Macrocystis* floats occur at the base of each blade at irregular intervals along the entire stipe (2b), and *Nereocystis* has one large pneumatocyst providing flotation for the entire stipe and all the blades (3b). A kelp forests may become home to many marine species that depend upon the kelp directly for food and shelter, or indirectly as a hunting ground for prey. Both the large size of the kelp and the large number of individuals can significantly alter the availability of light, the flow of ocean currents, and the chemistry of the ocean water in the area where they grow.

(1a)

(1b)

(2a)

(2b)

(3b)

(3b)

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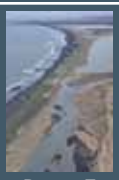
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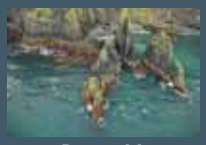
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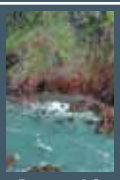
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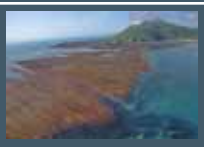
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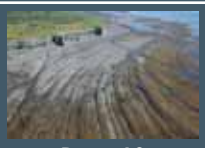
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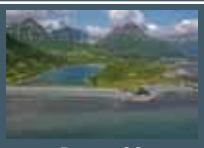
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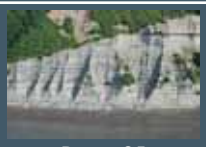
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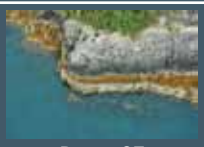
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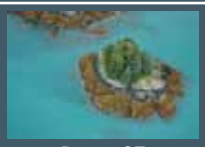
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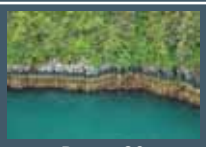
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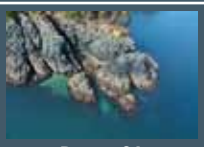
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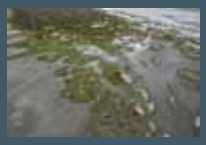
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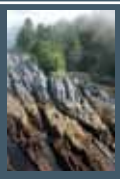
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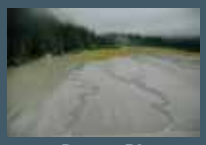
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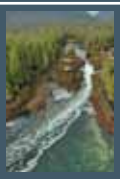
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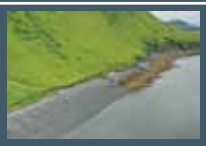
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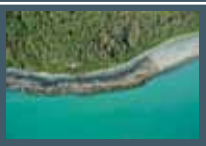
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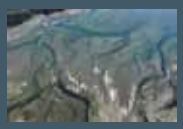
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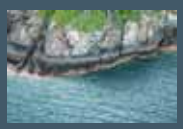
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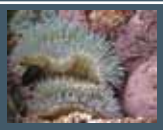
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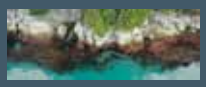
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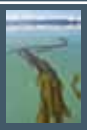
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