Karst and Caves of Southeast Alaska

A Teachers' Resource

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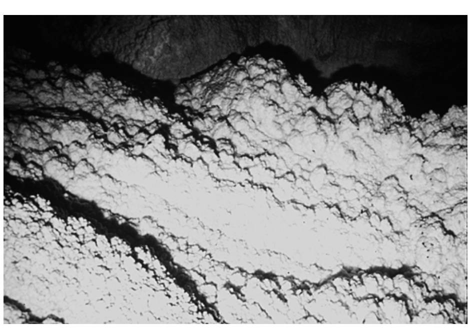

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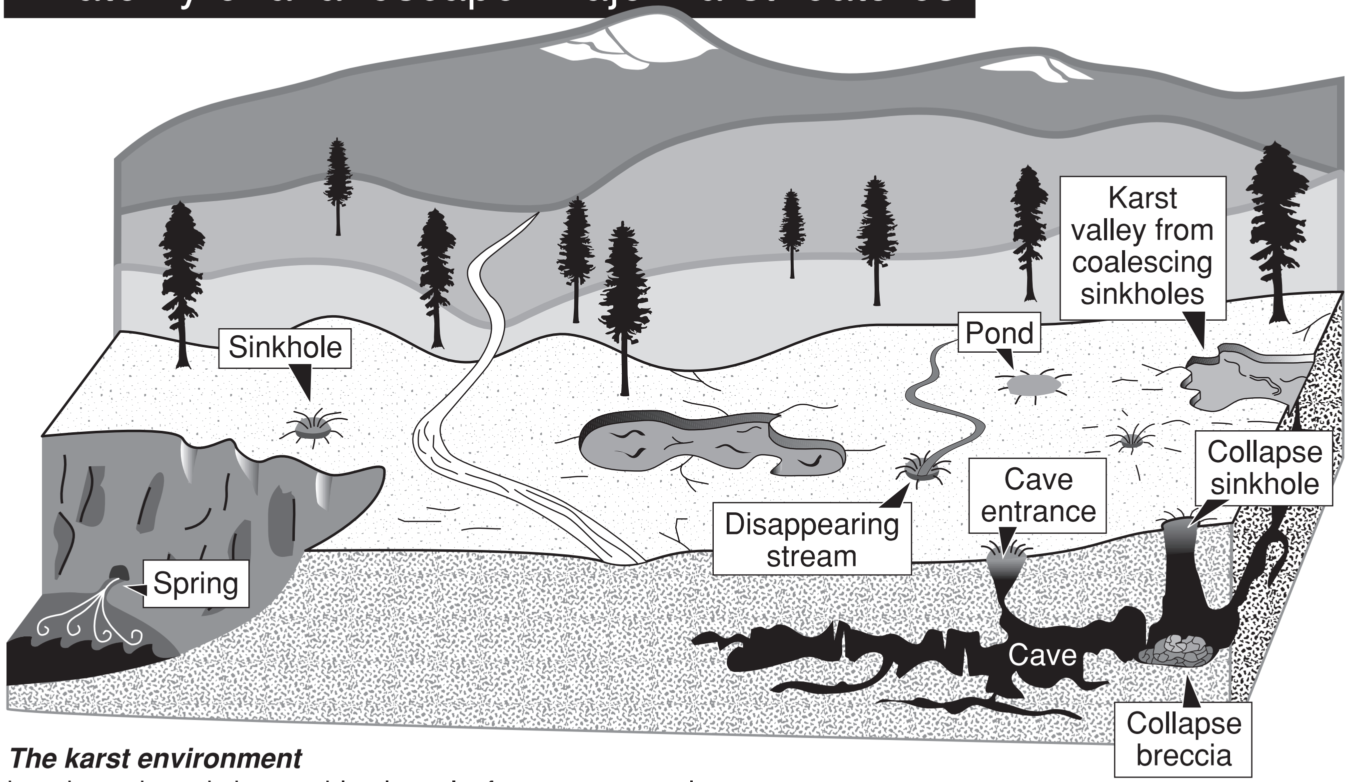
Anatomy of a landscape: major karst features



The karst environment
is a dynamic and changeable place. Its features are rarely as obvious as our diagram suggests, and you don't find all of them together this neatly. However, the diagram offers a guide to the most typical physical traits of the landscape we'll discover in this book on the karst and caves of southeast Alaska.

Introduction

This resource guide was prepared for middle-school and secondary-school teachers to use as a source of information and ideas about the caves and karst of southeast Alaska. In this digital version of the Guide we include descriptive background information with glossary and student activities, and a slide show in PowerPoint (.ppt) format and digital images in .bmp format. In addition, we have included the 14-minute video of the "*Caves of Southeast Alaska*" in RealPlayer and QuickTime formats. Installers for these plug-ins are also included.

Another good overview of caves and karst has been prepared by the American Cave Conservation Association. *Learning to Live With Caves and Karst* includes some excellent teaching activities and resources. Send your request to:

American Cave Conservation Association
P.O. Box 409
Horse Cave, KY 42749
Or call them at 502-786-1466

This guide and the ACCA publication together provide a comprehensive discussion of the general topic as well as information specific to our own Alaska caves.

The Karst and Caves of Southeast Alaska

Some of Alaska's most impressive natural and scientific wonders are out of sight.

And that's where the fascinating underground world of southeast Alaska caves remained for thousands of years — in the dark and known only to a uniquely adapted assortment of cave creatures, along with the rare visiting bear, otter or human.

It's only in the past several years that scientists and other explorers have pushed into the region's intricate systems of subterranean karst forms, mapping the geological and biological features of the caves.

An overview of the underground

This resource guide provides you with a broad perspective on karst and caves. We look at the origins of southeast Alaska's karstlands. We see the geological and chemical processes that sculpt them. These pages survey the working of water on the land forms and review the creatures that have inhabited and visited the caves — and how their remains tell scientists more about the ancient past in this area.

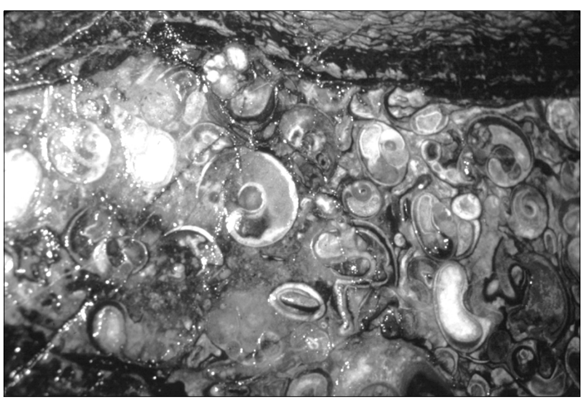
This book also offers a guide to conserving this precious natural world while safely visiting it.

First, the fundamentals: what is karst?

Karst is a landscape that forms on and in bedrock that can be dissolved by surface water and groundwater. About 20 percent of the earth’s surface is karst. It’s especially common in the continental United States: 40 percent of the lands east of Tulsa, Okla., are karst.

Why we have karst in southeast Alaska: it's just a lucky combination of things

- Pure carbonate bedrock
- Bedrock contortions: faulting , fracturing, folding
- Intrusions of igneous rock
- Local tectonic events
- Glacial history
- Proximity of carbonates to peatlands and forest vegetation
- Abundant precipitation
- Moderate temperatures



Well-traveled fossils: *Marine invertebrates embedded in limestone on Heceta Island died near the equator in the Silurian period more than 400 million years ago.*

“Karst” — a name that came from the Balkans

The name used for this geological feature derives from Kras, an area of Croatia near the coast of the Adriatic Sea. Some of the earliest research on karst was conducted in that Balkan region.

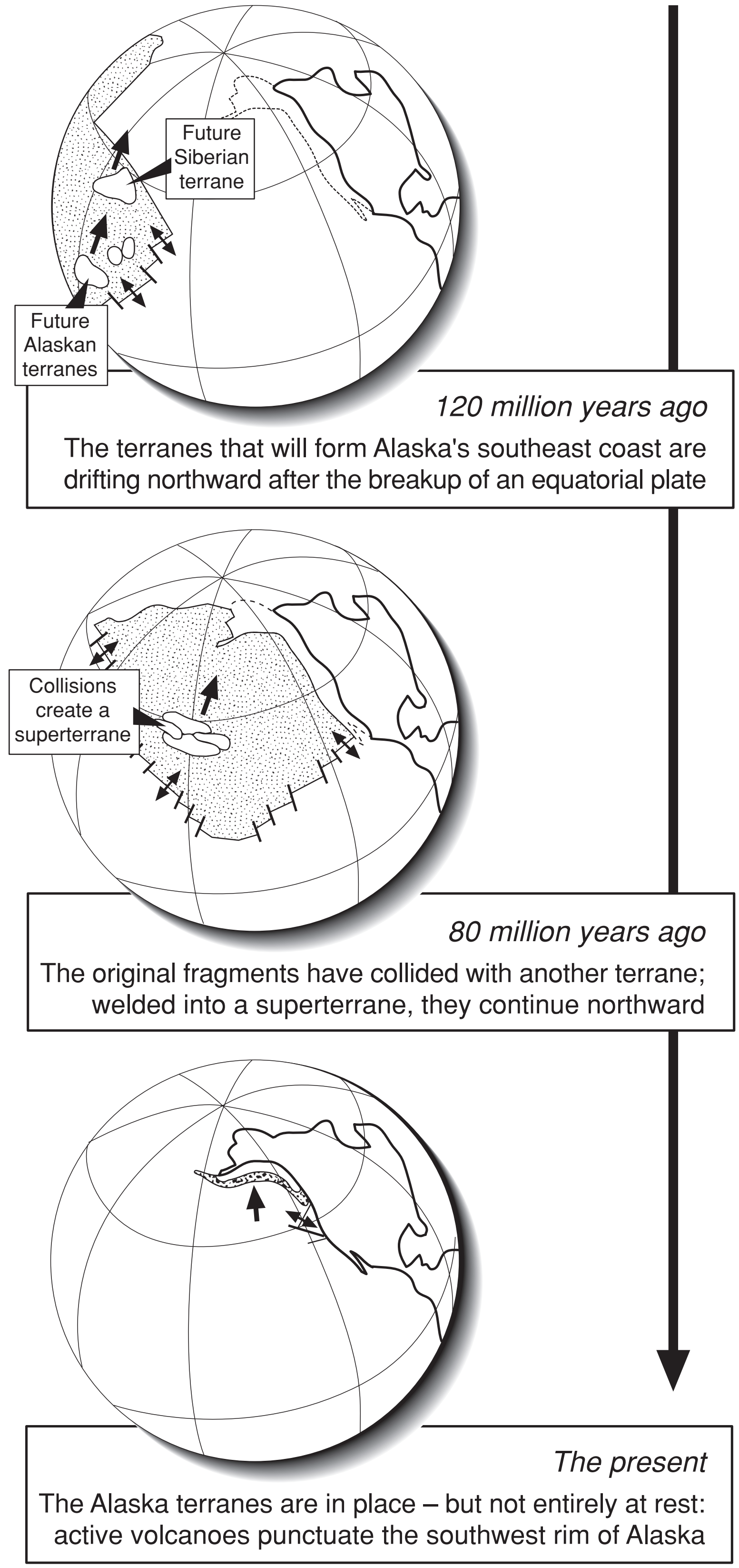
GEOLOGY

Karstlands in southeast Alaska, like other karst areas around the world, are characterized by surface features we can easily see, such as ***sinkholes*** and disappearing streams. They are also places of subsurface wonders, such as underground streams and cave systems. Interaction of soluble bedrock — usually limestone — and acidic surface water produces these unusual features.

Alaska landscape made in the South Pacific

The story of the karstlands of southeast Alaska begins with the formation of its carbonates in the South Pacific during the Silurian Period, 438 million to 408 million years ago. Warm, shallow equatorial waters teemed with ***cyanobacteria***, plankton, algae and numerous kinds of invertebrates. Many of these organisms took dissolved ***calcite*** from the water to build shells, external skeletons, and other hard body parts. When they died, soft body parts deteriorated and hard parts drifted to the ocean floor. Mats of photosynthetic bacteria and sediments trapped in them accumulated as ***stromatolites***. These reef formations also shed fragments. Over time, huge calcite deposits were transformed into limestone by compaction and cementation.

Alaska's coast: how it got here



Adapted from Stone, Panuska and Packer 1982

***The karst of southeast Alaska** tells stories tens of millions of years old — tales of plate tectonics and chemical processes*

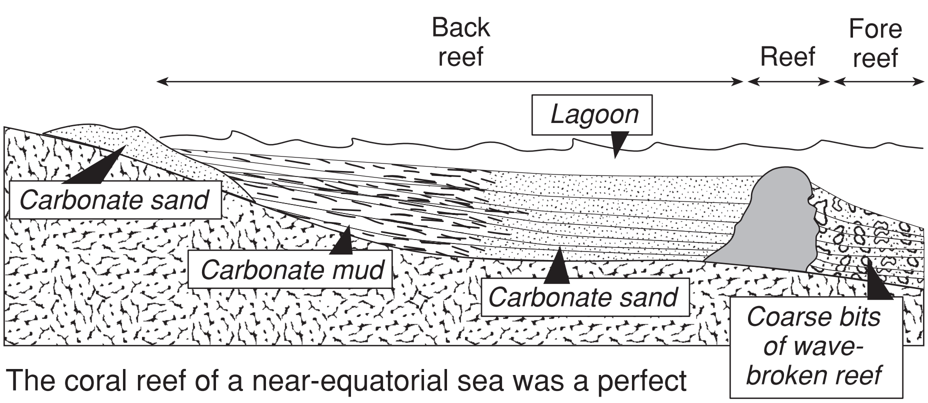
North to Alaska: migration of South Pacific land

About 400 million years ago, our continental fragment and others began riding northeast on the slow-moving Pacific *TECTONIC PLATE*. Some fragments collided with other continental pieces and joined in a large microplate as they drifted thousands of miles northward. This microplate and other fragments "docked" with the northern coast of North America between 150 million and 100 million years ago. The oblique collisions smeared the fragments along the coast, like multiple icings applied haphazardly to the side of a cake. After the collision with the North American continental mass, the fragments continued their northern migration, leaving bits and pieces behind. The forces that keep these fragments in motion have folded, fractured, and sheared the bedrock. Because these fragments traveled great distances to their new geologic home, they are called ***EXOTIC TERRANES.*** Southeast Alaska is a mosaic of at least 11 different terranes. Each has a distinct geologic character, range of ages, sites and characteristics of origin.

The wandering Alexander terrane comes to rest

The Alexander terrane is the principal terrane of southeast Alaska. Carbonates in the land form record its wanderings from an oceanic origin in the Silurian Period. These carbonates are massive limestones of three distinct types: fore reef deposits; reef deposits; and back reef deposits of thin, wavy-bedded, fossil-rich limestone. The heat and pressure of extreme collisions and forces of plate tectonics caused a metamorphosis of some of the limestone into marble during certain "docking" events. When the Alexander terrane

Ancient seas: a site for calcite



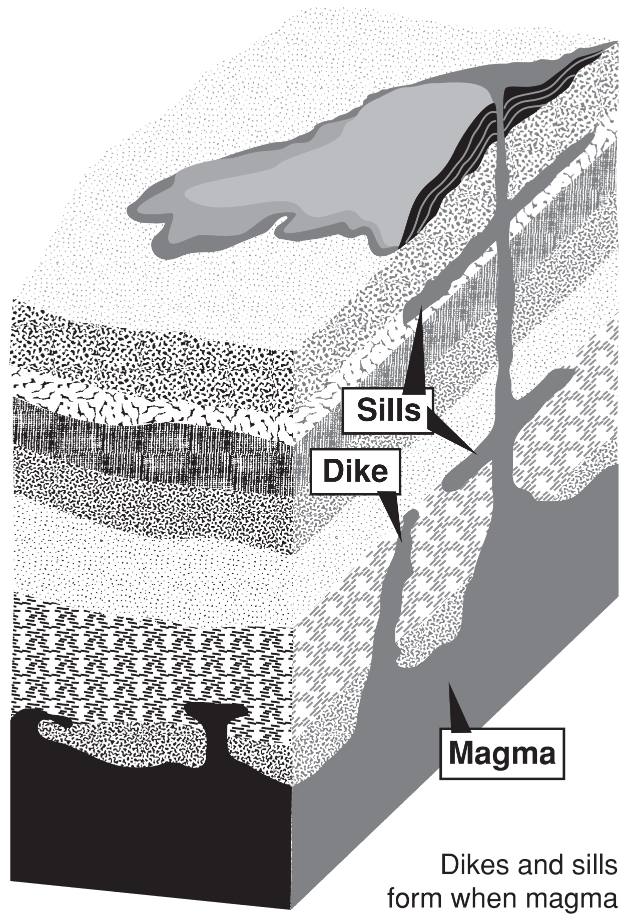
The coral reef of a near-equatorial sea was a perfect calcium carbonate collection scene in the Silurian Period. Such sites and the sea-bottom in deeper areas gathered the organically produced minerals that moved thousands of miles to Alaska and became part of our karst landscape.

collided with the ancient shore of southeast Alaska, it was spectacularly fractured and then fragmented. The force of the collision made large strike-slip faults, oriented north-west-southeast. Smaller strike-slip faults oriented north-south intersected these and broke the terrane into huge blocks. Thus, terrane blocks bounded by the large faults are in turn broken into smaller blocks by small faults; these small faults mimic the pattern of their larger counterparts. The same fault pattern can be seen at all scales of magnitude, from terrane boundaries to outcrops and specimens you can hold in your hand. The large-scale faults — as big as islands or mountains — help to define karst system boundaries in southeast Alaska.

About 560,000 acres (875 square miles) of carbonate rock have been mapped throughout southeast Alaska. Southern southeast Alaska carbonates are especially pure, averaging more than 96 percent calcite. These carbonate formations provide soluble bedrock that is fundamental in the karst landscape. Limestone and marble in karst areas have been dissolved or chemically weathered by abundant acidic surface waters.

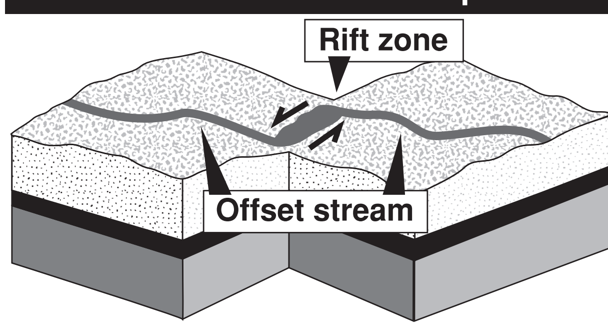
Surface waters focus on fractures, faults and folds in the carbonates, sculpting both the surface of the karst and dissolving out cave systems below. Igneous intrusions such as dikes and sills also provide sites of structural weakness in the bedrock where solution features can develop. Surface waters in southeast Alaska are acidic due to carbonic acid in rainwater and organic acids in runoff through forest soils and peatlands. Recharge areas, which supply water to karst systems, may lie on carbonate rock or on non-carbonate *SUBSTRATES*, such as conglomerates, sandstones, or volcanic rocks.

Formations from fiery rock

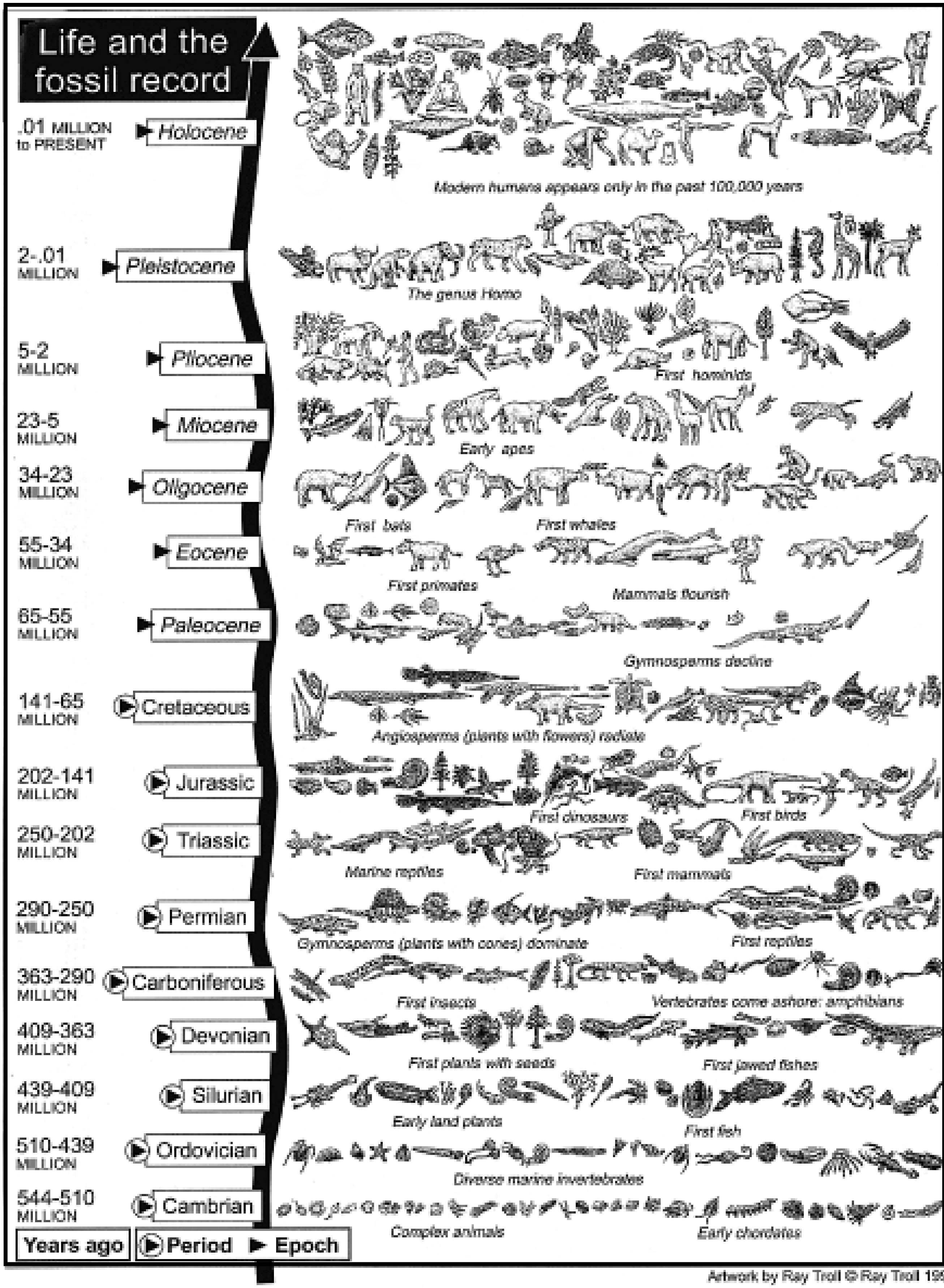


Dikes and sills form when magma invades subsurface rock. Vertical igneous intrusions are dikes; horizontal igneous intrusions are sills.

Faults with shear power



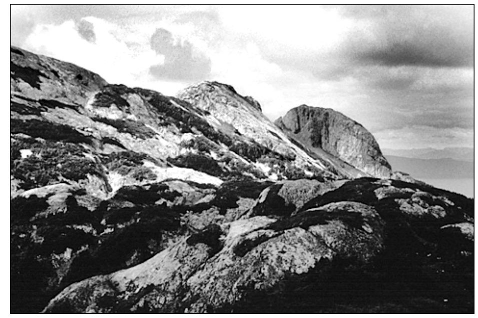
Strike-slip faults occur with horizontal movement of blocks on opposite sides of a fault plane. These shearing forces were commonplace as the Alexander terrane took its present place along the coast.



Artwork by Ray Troll © Ray Troll 1994

Karst has existed in southeast Alaska for a long span of geologic time and has been impacted by *GLACIERS*. For example, passages in two different caves on Prince of Wales Island are found through what may be Tertiary (65 million to 2.5 million years ago) ***PALEOKARST BRECCIAS.*** These findings suggest that caves have been forming in the carbonate for a long period. Most caves predate the latest glacial advance, which reached its maximum extent between 22,000 and 17,000 years ago. At that time the vast Cordilleran ice sheet covered most of the landscape, although it is likely that some ice-free *REFUGIA* remained at high elevations and along the coast. The inferred ages of the caves are based on the presence of glacial clays, glacial sediments, wood, *VERTEBRATE* remains from the late Pleistocene (2.5 million to 10,000 years ago), and possibly even ancient ice. One small cave has yielded a *MARMOT* tooth which has been dated to more than 44,500 years ago. The remains of a black bear more than 41,000 years old and a brown bear 35,300 years old have been found in another cave. Similar features have been found in field reconnaissance on Kuiu and Chichagof islands and on islands seaward of Prince of Wales Island. Such evidence clearly suggests that glaciation modified a pre-existing karst landscape. Glacial activity collapsed certain cave passages and systems, gouged into others, and filled some with sediments. Features of the *EPIKARST* were also influenced by glaciers.

Epikarst is the highly dissolved karst connection zone that links the surface to the subsurface. Vertical fractures in the epikarst are conduits between upper areas and cave systems below. The extent of epikarst development in southeast Alaska is linked to the glacial history of the land, the elevation, and other factors. Epikarst is well-developed throughout the karstlands of southeast Alaska, but is exceptionally pronounced at higher elevations (above 1,800 feet), where the most recent glaciation has not removed deep and elaborate epikarst features. Epikarst in alpine areas is less vegetated and is characterized by deep shafts, crevasse-like fissures, eroded rills of all sizes and spires and spikes of carbonate rock. Below treeline, epikarst is more vegetated and shallower.



***Epikarst** on display on an alpine mountaintop in southeast Alaska.*

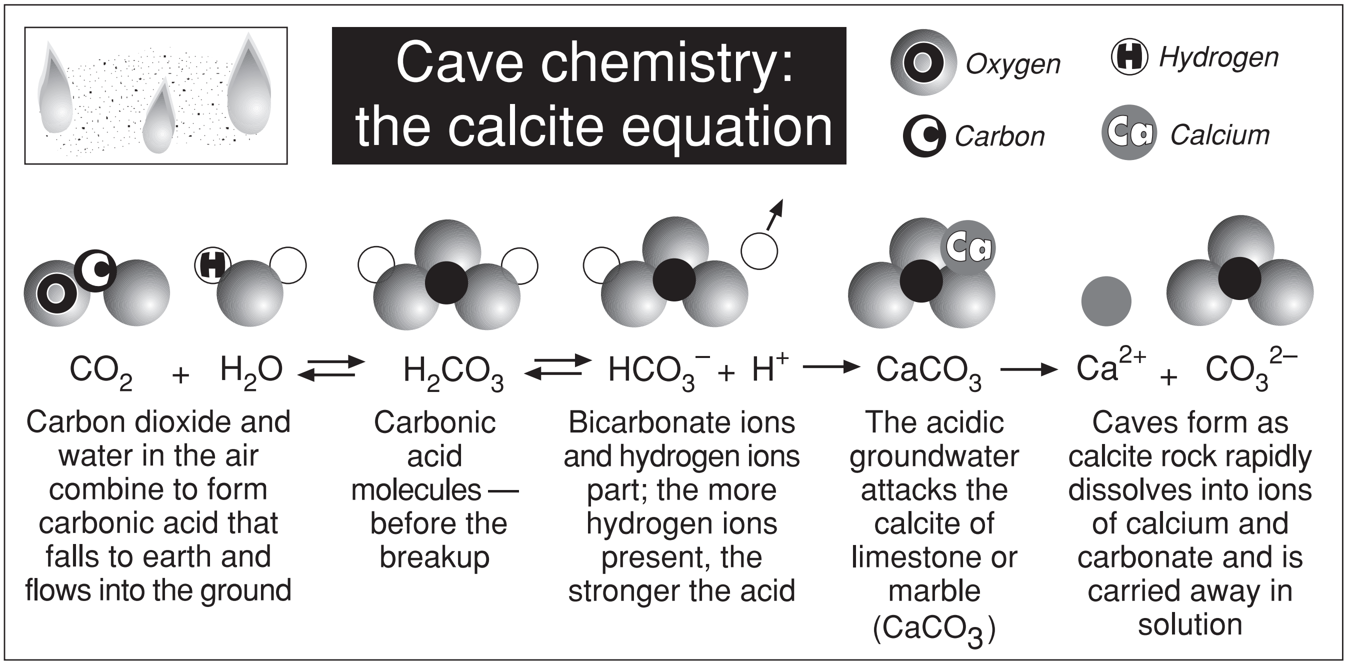
***Thin soil** lies atop low-lying epikarst.*

Explorations continue

Hundreds or even thousands of yet-unexplored caves exist in Southeast karst. El Capitan Cave is the longest cave discovered so far, with 10,190 feet of surveyed passages and a depth of 256 feet.

Caves can keep secrets of glacial times

Most caves predate the latest glacial advance, which reached its maximum extent between 22,000 and 17,000 years ago. Because of this, we can use the caves to look at ancient life.



Epikarst in the alpine zone may be more than 100 feet deep, compared to less than 5 feet along the coast and at lower elevations. Epikarst at all elevations is very important in moving water, inorganic nutrients, organic matter and soil from the land surface and rooting zone into subsurface regions. From subsurface areas, these materials move laterally to seeps and springs, or to vertical collecting structures which channel materials down to caves.

Hundreds or even thousands of caves in Southeast karst are still unexplored. They typically have vertical entrances and shafts that open to networks of cave passages. Huge volumes of groundwater surge periodically or continually through the passages. Scalloped walls and ceilings, spiral passages, deep plunge pools, flooded passages and *sumps* are common features. Boulders more than 2 feet in diameter seasonally batter the walls of some cave passages.

The 96 percent solution

Southern southeast Alaska carbonates are especially pure and provide soluble bedrock for the karst landscape. Acidic surface waters focus on fractures, folds, or other weaknesses in the carbonates, sculpting both the surface of the karst and dissolving out cave systems below.

Hydrology

Hydrology is the study of underground water and its relationship to surface aquatic systems. Karst topography and caves are dramatic examples of the action of acidic groundwater on soluble bedrock. Karst is formed primarily by chemical weathering of rock, rather than by mechanical weathering.

Carbonic acid occurs naturally in the ample rainfall of southeast Alaska due to the combination of atmospheric carbon dioxide and water. Organic matter in the soil also produces carbon dioxide, which reacts with water percolating through the soil to form more carbonic acid. Another source of acidity in the ***groundwater*** is organic acids, common components in the soils of coniferous forests and peatlands. The resulting acidic groundwater dissolves calcite in limestone and marble into its constituent ions, such as calcium and carbonate ions. The dissolved ions remain in solution and are then carried away in surface water and groundwater. A complex network of vertical shafts and lateral cave systems develops over time as the carbonate rock dissolves along joints and bedding planes.

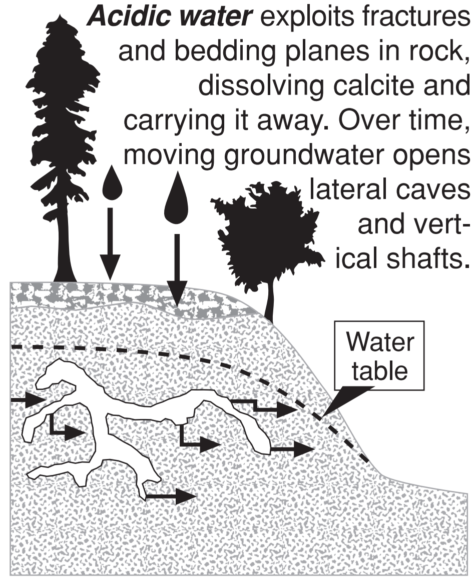
Speleothems: cave features we like to see

Deposits of calcite form in caves when the mineral precipitates from the groundwater onto the cave's ceiling, walls, or floor. Because hydrologic activity is intense in the caves of southeast Alaska and they are relatively young in geologic terms, dripstone deposits, or ***speleothems***, are not as plentiful as in older, drier cave systems. But some striking formations of flowstone and delicate structures of helictites and soda straws can be observed. Another speleothem, called ***moon milk***, forms in deposits several feet thick — unusual for this type of formation. Interiors of the marble caves of the region are highly sculpted by the action of the groundwater.

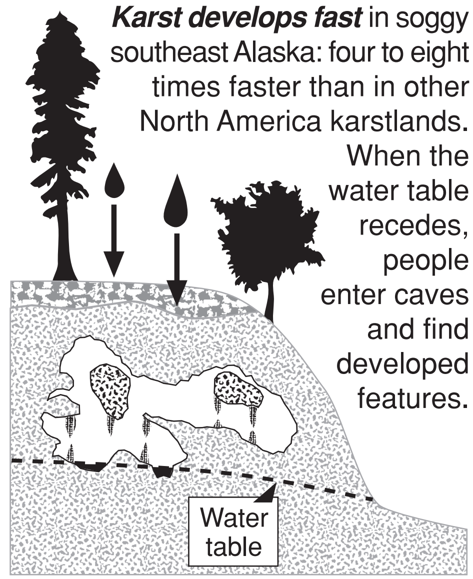
Peatland waters are particularly important contributors to karst topography and caves in southeast Alaska. Peatlands occur around the world and have a variety of

Water works: how karst creates caves

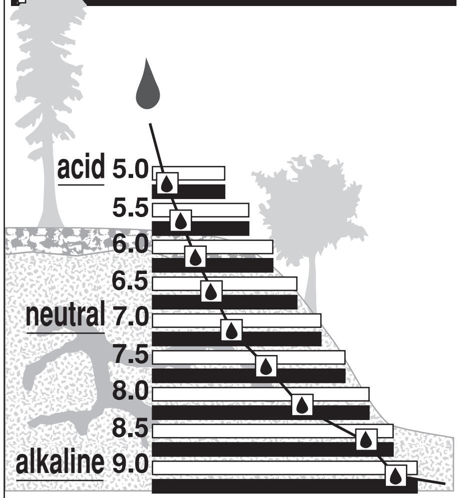
Acidic water exploits fractures and bedding planes in rock, dissolving calcite and carrying it away. Over time, moving groundwater opens lateral caves and vertical shafts.



Karst develops fast in soggy southeast Alaska: four to eight times faster than in other North America karstlands. When the water table recedes, people enter caves and find developed features.



pH: Karst numbers



The flow from muskegs is acidic — in some areas, with a pH value as low as 2.4. Rainwater is also acidic. But the karst process chemically changes the water as it flows through calcite rock. Outflows from karst commonly have pH values of 7.5-9.0.

common names, such as fens or bogs. Here in Southeast Alaska they are called muskegs. They are always characterized by waterlogged, acidic soils. In this region, peatlands develop on two types of sites: atop poorly drained, non-carbonate rocks, or on top of impermeable, compact glacial tills and marine silts that lie above non-carbonate or carbonate rocks. Plants characteristic of the peatlands, such as sphagnum moss and sedge species, tolerate acidic water. The decay of dead plant material further increases the acidity of the water. Water flowing from these peatlands is quite acidic, with pH values as low as 2.4. Water movement is slow in these poorly drained areas, but when the water reaches true carbonate substrate, it seldom flows more than a few yards before diving below ground, down vertical shafts, or into cave entrances. Here, the highly acidic water from the peatlands accelerates development of karst and caves. The buffering capacity of the pure carbonates is evident, for water flowing from cave systems charged by acidic water commonly shows a pH of 7.5-9.0.

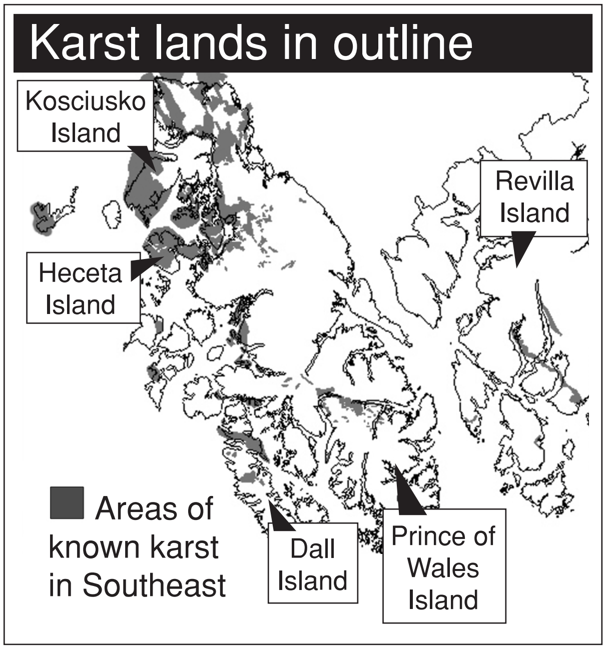
Ample precipitation drives karst process faster

Rainfall in areas dominated by karst terrain is heavy, with average annual precipitation ranging from 80 to 250 inches. Flooding events occur as well, particularly when rainstorms fall on wet snowpack. Most of the caves studied so far in southeast Alaska are hydrologically active and very dynamic. Limited dye tracing work on Prince of Wales Island has demonstrated that karst groundwater systems routinely transport water thousands of feet to receiving caves, springs and surface streams. The limited specific conductance information gathered to date from the same area suggests that values from karst systems in southeast Alaska are about half the mean values typically encountered in most other North American karst areas. However, karst areas in southeast Alaska yield an annual runoff which is typically eight to16 times greater than that in other North American karsts. The net effect is that solution of soluble bedrock occurs at least four to eight times faster in southeast Alaskan karst compared to other North American karst.

It is important to understand the differences in material transport mechanisms between karst and non-karst landforms. For example, a particle of soil in a deposit atop non-carbonate substrate must be transported by gravity, landslides and/or surface water flows, sometimes over great distances, into a surface watercourse to become sediment. Atop a karst landform, depending on the openness of the karst system, a soil particle is transported laterally only a few inches or feet before it washes vertically through a solution-widened fissure of the epikarst into the deep conduits of the system. Fissures in the epikarst become injection points for water and sediments to move rapidly downward into the complex subsurface drainage system. Even the presence of a single sinkhole, which intermittently retains water, indicates the presence of a direct surface/subsurface connection.

Subsurface drainage networks generally operate independently of the surface drainage systems above them, and with more complexity. The watershed characteristics of the surface topography may have little or no relationship to the subsurface karst drainage system. Sediment transported from roads and disturbed lands may emerge unexpectedly at distant springs, or even across the boundaries of surface watersheds or topographies.

Physical Geography



Southeast Alaska is a narrow strip of mainland coast and hundreds of islands in the Alexander Archipelago. The islands of the archipelago vary greatly in size, from small, unnamed outcrops to Prince of Wales Island, the third-largest island in America. The mainland strip averages only 25 miles wide from the tidewater to the mountain crests which mark the United States-Canada border. Large peaks dominate this boundary. For example, Mt. St. Elias, in northern southeast Alaska, is more than 18,000 feet tall. The peaks on the islands are less formidable, but still range in height from 2,000 to 4,000 feet. Only a little karst has been identified on the mainland portion of the region.The majority of the karst is in the archipelago, primarily on Prince of Wales Island and on nearby Dall and Heceta islands.

Southeast Alaska is a temperate rain forest – a rich biological setting. As the name implies, this rain forest is the product of mild temperatures and abundant rain. The warm Alaska current, an offshoot of the northern Pacific Ocean's Kuroshio Drift, moderates temperatures: freezing winter weather and hot summer weather are infrequent and brief. Average Fahrenheit temperatures range from the high teens to the low 40s in the winter, and from the 40s to the mid-60s in the summer. The moderating influence of the ocean is even more pronounced along the outer coasts than farther inland. The maritime air masses carry great amounts of precipitation. As incoming clouds from the Pacific are intercepted by mountains of the islands and the mainland, the terrain is bathed with frequent showers and storms. Average rainfall ranges from 80 to 160 inches, although local topography and climatic conditions cause much variation. One area may receive only 27 inches a year, while another area is drenched with 400 inches.

This magnitude of moisture is pivotal in the biotic environment, just as it shapes the physical features of the karstlands. The landscape of southeast Alaska forms an intricate pattern of mountain, alpine, forest, and wetland terrain, all interconnected by a network of streams, ponds, and lakes. The variability of bedrock, soil and microclimatic conditions provides the foundation for a rich mosaic of ecosystems across the landscape of southeast Alaska. The ecosystems of most relevance to the karst are those of the alpine, forest and peatland.

Alpine areas do not support tree growth above about 2,500 feet, due to their elevation, cooler temperatures and greater snow accumulation. At these higher elevations, alpine meadows and alpine tundras persist.

At lower elevations, where sites are not too wet, coniferous forests become established; they are dominated by western hemlock and Sitka spruce. Where wind-throw topples small areas of trees, sunlight reaches the forest floor and fosters growth of shrubs and herbs. Because of the great amount of precipitation, disturbance by fire is not an ecological factor.

The landscape of lower-elevation karst in southeast Alaska contains nutrient-rich, well-drained soils that promote vigorous plant growth. Although the soil is shallow, well-developed subsurface drainage encourages growth of large trees because the numerous bedrock fractures provide root-holds. The trees are anchored to better withstand strong winds. In turn, the mature hemlock and spruce forest of the karst landscape supports highly productive terrestrial and aquatic animal communities.

In areas with poor drainage, wetlands or peatlands occur. Peatlands are in fact ancient wetlands. They are dominated by mosses in the genus *Sphagnum* and various sedge species, which thrive in the acidic waters.

The watery web

Southeast Alaska is an intricate network of water, terrain and life. Alpine, forest and wetland areas are interconnected by a web of streams, ponds and lakes, all of them influenced by the rainforest's moisture.

Portal to a unique *environment and community of creatures — where the forest gives way to the darkness of the cave, scientists and cavers find fascinating adaptations.*

Cave Biology

The terrestrial and aquatic environments of southeast Alaska provide a variety of habitats, and the array of organisms living here is just as diverse. Caves of the region provide unique habitats and niches for many life forms. These animals, plants, and other organisms range from opportunistic users of caves to species which are totally dependent on the caves' specialized environment. ***Disjunct*** and ***relictual*** populations of cave organisms also can provide valuable clues about ecosystems in the geologic past. Relictual populations can no longer live in the surface world due to long-term climatic changes, but can persist in the more stable conditions of caves. These populations are often found as disjunctive groups, living in caves separated by hundreds or thousands of miles.

Go into a cave and you progress through a series of environments, from a realm of light at the entrance, to the twilight zone of more limited light, and then to the region of complete darkness in the interior spaces of the cave. These environmental gradations are home for different communities of organisms. Because many of the life forms that inhabit caves are small or microscopic, we can also visualize the cave community as an interconnected assemblage of ***habitats*** and organisms, varying in size from the ***microscopic*** to the ***macroscopic***. All the habitats of Southeast caves also contain some degree of moisture, from slick rock to pools of water and rushing streams.

Biologists who study cave life — their work is called ***biospeleology*** — classify cave-associated organisms according to their degree of dependence on and adaptation to cave conditions. Three categories are used: ***trogloxenes***, ***troglophiles***, and ***troglobites***.

Caves in southeast Alaska do not host the variety and abundance of organisms found in their southern counterparts. This is probably due to a combination of factors: the young geologic age of these caves, their northern

Creatures of the caves fit three main categories

Trogloxenes — *cave visitors:* they use cave habitat for specific purposes, on a sporadic basis, and exhibit no cave-related adaptations.
Troglophiles — *cave lovers:* they have a strong affinity for the dark, moist and cool conditions of cave interiors, and sometimes show changes in their anatomy, physiology or behavior.
Troglobites — *Cave dwellers:* they spend their entire life cycles in the dark zones of caves and exhibit a variety of adaptations to interior cave conditions.

location and the high incidence of water movement in the passages. Nonetheless, each of the five kingdoms of life has many representatives in southeast Alaska caves, including some rare and unusual creatures.

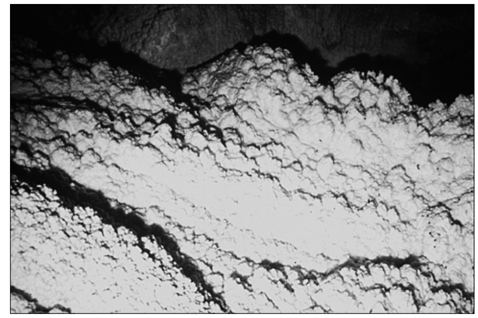
Bacteria, members of the kingdom *Monera*, are common inhabitants in a range of cave environments and play an important role as decomposers of organic matter. These organisms are ***prokaryotic*** (without a nucleus in the cell). ***Cyanobacteria***, the photosynthetic ***monerans***, live in moist or watered sites exposed to light.

Phytoplankton, the unicellular algae of the kingdom Protista, are also found in the waters at or near cave entrances. Protozoans, the animal-like ***protists***, inhabit the aquatic communities of all the cave zones. The bacteria and plankton are microscopic, but their sheer numbers have ramifications on the life cycles of larger organisms and on the cave environment.

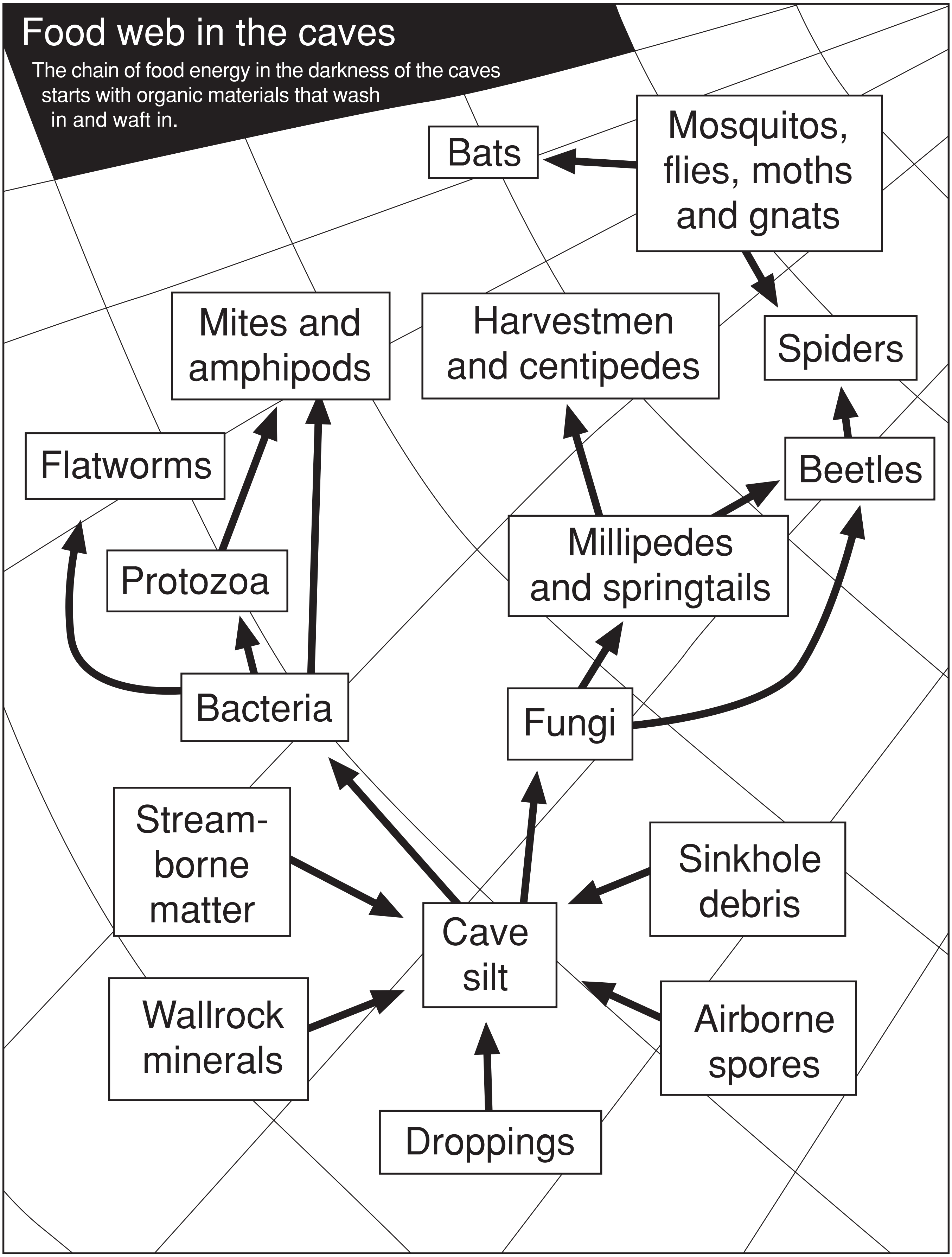
Members of the kingdom ***Fungi***, which are eukaryotic and multicellular, exist in both the light and dark regions of caves. Because fungi usually obtain nutrients through extracellular digestion of dead organic matter, they act as decomposers in the food webs, like the bacteria.

Plants, of the kingdom ***Plantae***, are photosynthetic, multicellular eukaryotes. They, of course, need light to carry out their autotrophic processes. Thus, they are restricted to cave entrances and to the twilight zone.

Members of the kingdom ***Animalia***, multicellular eukaryotes which ingest their nutrients, belong to either of two broad categories: invertebrates or vertebrates. Most cave invertebrates are ***arthropods***, with jointed legs and exoskeletons — external coverings composed of hard ***chitin***. The other invertebrates are species of ***gastropods*** (snails and slugs) and various kinds of worms (flat, round, or segmented). Cave-associated vertebrates (animals with internal skeletons of bone) include most of the living classes of vertebrates — bony fish, amphibians, birds, and mammals. Southeast Alaska karstlands lie too far north to support warmth-loving reptiles.



Moon milk *in a Southeast cave — a peculiar deposit of calcium carbonate that looks a little like cottage cheese. Does moon milk have a bacterial component? Some scientists believe bacteria are involved in the unusually thick growth of this cave feature.*


Food web in the caves
The chain of food energy in the darkness of the caves starts with organic materials that wash in and waft in.
Bats
Mosquitos, flies, moths and gnats
Mites and amphipods
Harvestmen and centipedes
Spiders
Flatworms
Beetles
Millipedes and springtails
Protozoa
Bacteria
Fungi
Stream-borne matter
Sinkhole debris
Cave silt
Wallrock minerals
Airborne spores
Droppings

Into the cave: a spectrum of critters

Now let's explore the organisms of southeast Alaska caves as one moves from the cave entrance to the interior. The environment at the entrance to a cave and in the twilight zone is exposed to sunlight and is readily accessible to cave visitors — the trogloxenes. Plants, especially those adapted to low levels of light intensity such as bryophytes (mosses, liverworts, and hornworts) and ferns, thrive at these sites. Various fungi also prosper here. Little is known about the ***BOTANY*** and ***MYCOLOGY*** of cave entrance flora, but it is probable that ***RELICTUAL POPULATIONS*** persist here.

***This spider** tracing its way across moon milk is a troglophile: it often visits the cave for shelter or food, but it's just as much at home in moist, dark places outside the cave.*

Sitka black-tailed deer are known to rest around cave entrances both in summer, when the air coming from the caves is cooler, and in winter, when the cave entrance environment is warmer than elsewhere. Certain passerine birds — such as the dipper, at least two swallow species and three species of thrush — use entrances for nesting and foraging. Some ***LITTORAL*** cave entrances support rookeries of cormorants, pigeon guillemots, murres, and puffins. Streams associated with cave systems support vigorous and plentiful species of fish because of their diverse and abundant aquatic invertebrate populations. For example, measurements indicate that fish from these streams grow six to eight times faster than fish from other streams. Although not yet observed, it is likely that other vertebrates such as rodent species and the region's two amphibian species, the rough-skinned newt and the western toad, utilize the resources of the entry areas.

In addition to the aquatic invertebrates found in cave entry waters, ***TERRESTRIAL*** invertebrate populations are present on the ground and in the soil. The moist litter of decaying organic matter and shelters such the undersides of rocks provide habitats for a diverse microcommunity of worms, snails, slugs, spiders, harvestmen ("daddy longlegs"), milllipedes, centipedes, mites and beetles. Like their aquatic relatives, these trogloxenic invertebrate populations of the terrestrial world are important components of the food webs of the entry areas.

Bats are probably the best-known of the trogloxenes. Preliminary surveys in southeast Alaska show that bats are using some of the inventoried caves. Bats pick caves that fulfill some very particular requirements: the right cave structure, good air circulation, appropriate temperatures and humidity, and proximity to feeding areas. Bats in Southeast eat a variety of insects and arachnids. The interaction of bats and their prey species is a vital part of the forest ecosystem. Two species of bats have been observed in Southeast caves: the little brown bat (*Myotis lucifugus*) and the California bat (*Myotis californicus*). Another member of the genus *Myotis* has been collected in karst areas: the Keen's long-eared bat (*Myotis keenii*). The silver-haired bat (*Lasionycteris noctivagans*) may also use karst regions in Southeast.

***A trogloxene sleeps:** this creature represents one of four species of bats found in Southeast.*

Bats take shelter in the zone of darkness

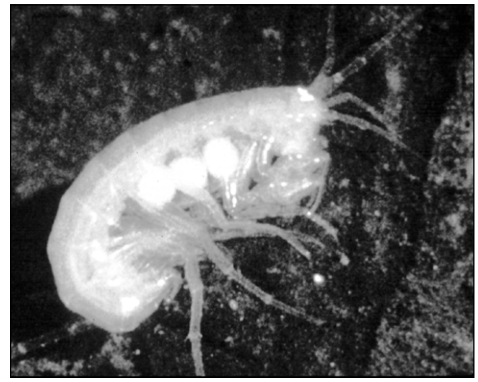
As the twilight zone merges into the zone of darkness, some trogloxenic species also use these dark regions for more extended periods of time. Southeast Alaska caves are especially important hibernacula for bats because freezing temperatures sometimes occur outside the caves during the winter. Colonies of hibernating bats are found in the protected interior areas, where temperatures remain above freezing. It's likely that female bats also aggregate in Southeast caves to rear their young during summer months. Such maternity colonies are common in caves of locales farther south. It has been noted that other mammals, such as bears, wolves, and river otters, use interior areas for hibernating and for giving birth to their young.

The zone of darkness in Southeast caves is home to both troglophilic and troglobitic species. One study at two karst areas found more than 17 troglophilic species of terrestrial and aquatic invertebrates. On the floors of the caves, springtails — wingless insects with specialized springing organs — hop about while spiders, harvestmen and stoneflies cling to the walls. The calm surface of streams and pools provides habitat for white mites that skim the surface, searching for prey. Beneath the surface, flatworms, segmented worms and insect larvae move slowly on the bottom and amphipods swim through the water, filtering it for minute particles of food.

Amphipods are the best invertebrate representatives for troglophilic and troglobitic types in Southeast caves. These animals are members of the crustacean subphylum, which also includes shrimp, lobsters and crabs. Their laterally compressed bodies give amphipods a shrimplike appearance. The occurrence of the troglophilic amphipod *Cratigonyx olliquus richmondensis* is the first observation of this species in any cave in northwestern North America. Troglobitic species of amphipods, such as the blind *Stygobromus quatsinensis*, have been collected from cave groundwater on Dall and Heceta islands of outer Southeast, but not from cave systems on Prince of Wales Island. This may indicate that glaciation caused the extinction of cave-adapted species on Prince of Wales Island, but that the outer islands were ice-free and thus retained the troglobites.

Troglobites are distinguished from troglophiles by their total dependence on the cave environment, and by a range of adaptations to this environment. These adaptations include small bodies and long limbs, highly sensitive receptors to chemical and tactile stimulation, reduced or lost vision, lowered metabolic rate, and greater efficiency in movement and feeding behaviors. The last two types of adaptations especially reflect the limited amount of nutrients available in the dark cave interiors. Without the rich source of food from photosynthetic organisms, food chains and webs in the dark zone involve more limited nutrient sources, with bacteria, fungi, and invertebrates playing the important roles. All these organisms are ultimately dependent on the flow of water from the surface world, which carries inorganic and organic nutrients to the obligate cave dwellers.

An intriguing potential bacterial association may occur in moonmilk, a deposit of calcium carbonate which reaches a thickness of several feet in some southeast Alaska caves. Bacterial species may be involved in the unusually thick growth of these formations. Clearly, caves of southeast Alaska hold mysteries of life yet to be discovered.



FOR BEST ADAPTATION BY A SPECIES FROM ANOTHER ENVIRONMENT, THE NOMINEES ARE … *This amphipod typifies the cave-adapted features of the troglobite: a small body, long appendages and sightlessness. This* Stygobromus *was discovered on Heceta Island. It's virtually identical to its counterparts in caves on Vancouver Island. Our area of southeast Alaska is the farthest-north extent of* Stygobromus*.*

Troglobites: they caved in to their new environment

Troglobites are totally dependent on the cave environment. Their adaptations are well-developed: small bodies and long limbs; receptors that are highly sensitive to chemical and tactile stimulation; reduced or lost vision; lowered metabolic rate; and greater efficiency in movement and feeding behaviors.

Illuminating the darkness: diverse explorers go into the caves of Southeast

A member of a scientific exploration team drops carefully into a southeast Alaska cave. Sophisticated equipment, good preparation and teamwork are prerequisites for this work. The results are significant for biologists, paleontologists, archaeologists, geologists and others with an interest in the region's underground world.

Paleontology and Archaeology

Over the last decade, a small group of people has emerged with a determination to bring light to the mysteries of the limestone caves of the Alexander Archipelago. They come from diverse ethnic and professional backgrounds and include archaeologists, paleontologists, biologists, geologists, hydrologists, divers, pilots, fishermen and loggers. By pooling their information, they are piecing together the cultural and ecological past of Tongass National Forest.

The caves are on beautiful rain-drenched islands separated from the mainland of Alaska and British Columbia by wide straits. Strong currents, extreme tides and unpredictable weather dominate. The islands' rugged mountains rise sharply from the shore. The land is densely covered with trees, shrubs, bushes, ferns and mosses. The caves on these islands have preserved animal bones, tools, wood, and artwork. Cool air and constant temperatures and pH levels protect artifacts and fossils from decay. These keys to the past are sheltered from weather, wind and animals that might move them.

Exploration and excavation is a wet business

Outside the caves, weather and the rainforest environment of southeast Alaska make it difficult to find archaeological sites. Heavy rains wash away and destroy artifacts. Plants, bushes and huge trees grow quickly, covering sites and artifacts. Large trees of southeast Alaska develop massive root systems; when one of these giant trees dies and falls, soil above and below the roots is scattered. This can bury artifacts. It also mixes the layers of the soil, making scientific investigation difficult. These circumstances make the search for scientific evidence of natural and cultural change in southeast Alaska a challenging proposition.

Discoveries of many caves accompanied the intensification of logging and other development on the Tongass

National Forest. Scientists working for the USDA Forest Service studied the caves and found entire karst systems.Their job was to help decide where logging companies should be allowed to cut trees. The Forest Service was concerned about preserving water systems, animal habitat, and archaeological sites while permitting responsible development and timber harvest. As scientists and loggers found more and more caves, they recognized that important new information was being discovered.

Forest Service scientists shared their discoveries with other scientists around the world. Now, many cave experts travel to the islands of southeast Alaska each summer to search for evidence about how the island environment has changed since the last ice age. They also look for clues about how ancient peoples traveled throughout the islands and how the caves served for shelter and ceremonies.

***This fossil bear skull** and the remains of other animals taken from the caves tell scientists a lot about ancient climates and seacoasts. They can also provide clues to the human history of this region.*

Although the Pleistocene and Holocene vertebrate record has captured the attention of researchers studying the evolution of the modern environment, the Devonian and Silurian limestones that form the medium for cave formation contain a fascinating invertebrate fossil record of a period 450-350 million years ago. Nautilus Cave on Heceta Island was carved from Silurian gray and black marbilized limestone. Spaces between the stromatolites hold gastropod and brachiopod fossils that are replaced by white calcite or stained red by iron oxides.

Paleontology

The caves of Southeast Alaska are a paleontologist's dream. Bones of animals trapped over thousands of years rest in countless sinkholes across the landscape. There is an undisturbed record of the animals that inhabited the area. Scientists are doing paleontological work where the caves' stable environment has preserved shells, bone, teeth, fibers, wood and charcoal. Radiocarbon dating has provided an age framework for the fossils collected in the caves of Southeast Alaska. Fossils from most sites studied date to the early postglacial interval (13,000-8,000 years Before Present (BP)). Two other caves have yielded the remains of animals dating from the intervals of the Last Glacial Maximum (LGM) (24,000-13,000 years BP) and the pre-glacial interval (24,000-40,000+ years BP). Many fossils which date to beyond 40,000 years BP have been recovered. Radiocarbon dates on bones beyond 40,000-45,000 years BP are considered limitless dates (no measurable Carbon-14), so it is difficult to work out a chronology beyond 40,000 years ago.

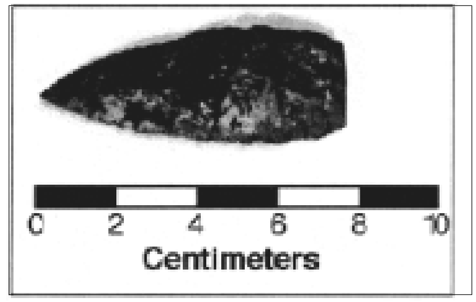
Fossilized Remains, *such as this shed caribou antler, indicate to scientists that the environment of ancient southeastern Alaska was much different than that of today.*

The fossil record before the LGM, 24,000 years BP and older, suggests that much more alpine or tundra conditions existed prior to development of the dense rain forest that now dominates the archipelago. Brown bear, black bear, arctic and red fox, hoary marmot, heather vole, brown lemming, long-tailed vole, caribou, wolverine, river otter, and possibly Siaga antelope, roamed the planes and hills of southernmost Alaska. The distribution and abundance of small mammals such as the voles and lemmings and the marmot in the older sediments of one cave show that as the last Ice Age progressed, the climate changed from a warmer to a much colder climate than would be expected.

Much of southeastern Alaska was covered by the advancing ice from between 24,000-13,000 years BP as the ice reached its maximum extent. Refugia existed on the western side of the archipelago as the sea level had fallen some 120 meters (nearly 400 feet) exposing vast areas of the continental shelf. The remains of mammals from this period have been found in only one cave. These fossils include the bones of numerous ringed seals, Steller's sea lions, and arctic foxes. In the modern circum-arctic region, ringed seals feed on fish that live under the ice, and they are preyed upon by polar bears and arctic foxes. Polar bears quietly sneak up on their snow-covered dens then try to crush them before the seals can escape into the water through their access hole. The foxes scavenge bear kills and catch seal pups.

How did these marine mammal bones get into this cave which is over a kilometer from the ocean? Either foxes or bears must have dragged them to their den. Some of the adult bones appear to have been chewed by bears (based on large puncture marks). Many juvenile seal teeth (with the enamel barely developed) have also been found. Since foxes are much more likely to cache food in their dens than bears, they are probably responsible. Whether bears chewed on the remains before or after they were brought to the cave is unknown. No polar bear bones have been identified from any of the caves, but the presence of ringed seal and arctic fox suggests that it too was in the area during the LGM.

From 13,000 years BP until some time between 9,000-8,000 years BP, a warmer climate and tundra vegetation returned to Southeast. Brown and black bear, red fox, caribou and river otter were still present. The youngest caribou remains date to 10,515 years BP, while the youngest brown bear remains date to 7,205 years BP. Some time soon after 9,000 years BP the forests and muskegs familiar to Southeast Alaska replaced the tundra vegetation in the valleys and lower slopes. The oldest Sitka black-tail deer remains date to 8,100 years BP.

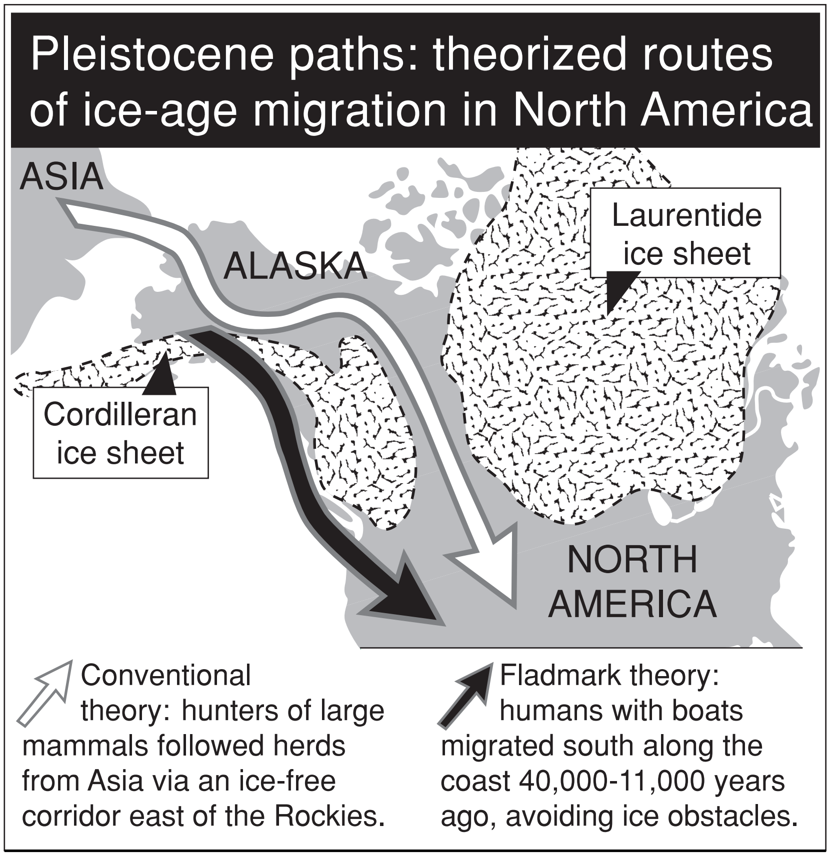


Cultural artifacts *such as this projectile point fashioned from dark grey chert, dated about 9,800 years ago, may be clues to human migration and habitation along this part of the coast. Scientists are watchful for circumstantial evidence for a theory that people with boats and navigation skills migrated southeastward along the Gulf of Alaska coast tens of thousands of years ago.*

Besides the large and small mammal remains, thousands of bird bones and fish bones have been collected. The bones recovered, taken together with related research into the pollen record found in lakes sediments and the peat of the muskegs and bogs, paints a fascinating story of the prehistory of Southeastern Alaska. Until 1990 it had been thought that ice covered the land to the continent's margin with only the peaks higher than 3,000 feet exposed. Exploration and research in the caves is, for the first time, writing the prehistory and paleoecology of southeastern Alaska.

Archeology

For many years, most archaeologists believed that human migration to North America from Asia was blocked by massive glaciers in Alaska and Canada during the Pleistocene ice age. But recent evidence from the karst regions of southeast Alaska indicates that the southwesternmost islands of the Alexander Archipelago may not have been glaciated during the late Pleistocene. This region may have served as a corridor for human populations much



earlier than scientists thought possible. We see two indicators of an early coastal refugium: remnants of Pleistocene plant communities in alpine areas and greater genetic variation in chum salmon populations. Surveys conducted by the Tongass Cave Project reveal caves and passages that predate the end of the Pleistocene. They would have been crushed by the weight of the ice had they been glaciated at the end of the Pleistocene. Not only do the caves exist, but the paleontological and archaeological components in them indicate they were ice-free.

Who was here first, and how?

Speculations about the first inhabitants of the Northwest Coast and the first human entry into North America are among the most intriguing topics of current archaeological research. In the "traditional view" popular for most of the 20th century, early Asian migrants traversed the Bering Land Bridge and followed herds of megafauna, or large prey animals, such as caribou and bison south through an ice-free corridor between the Cordilleran and Laurentide Ice Sheets, eventually entering into the northern plains and dispersing across North and South America. Another theory, introduced by Knut Fladmark in 1975, is gaining acceptance among archaeologists studying the Northwest Coast. According to this theory, as recently as 11,000 years ago or as early as 40,000 years ago, people with boats and ocean-going navigation skills migrated south along the coast. These people followed the exposed southern shore of the Bering Land Bridge, along the Alaska Peninsula and Gulf of Alaska, eventually traversing the exposed continental shelf of the Alexander Archipelago on their way south.

Evidence for this theory is sparse and circumstantial at present. Study of the glacial history and paleontology of the coastal route suggests that no insurmountable obstacles to the journey existed and that ice-free refugia existed between 10,000 and 12,000 years ago and possibly even as much as 38,000 years ago on Prince of Wales Island. An obsidian source on Suemez Island was utilized for tool manufacture as early as 9,500 years ago. This distinctive volcanic glass has been found at archaeological sites of that age in northern southeast Alaska and in British Columbia. This provides evidence that a boating people with an intimate knowledge of the resources was present in southeast Alaska at that time. Such familiarity suggests some length of occupation.

A link to the past: *this drawing reminds us that caves have provided shelter and a cultural canvas for Native inhabitants for millennia.*

In 1996 a remarkable find was made by Dr. Timothy Heaton, a paleontologist working in a cave on north Prince of Wales Island. Portions of a human skeleton and three tools were recovered from the same cave that had previously yielded bear bones dating to 41,600 and 35,363 years ago. The human bones proved to be about 9,300 years old, the oldest from Alaska and the Northwest coast, and offered a tremendous opportunity to learn about the early peoples in this area.

Archeological research near the entrance of this cave has brought to light a 9,200-year-old camp with spearpoints and tiny stone tools (microblades) characteristic of hte earliest occupations of the North Pacific Rim. Future studies of this and other early sites may provide clues to the puzzle of the first Americans.

***Some caves** in southeast Alaska result from physical weathering. Littoral or sea caves found along the coast demonstrate this process, as at this Baker Island site.*

Human presence in Southeast Alaska

All of this supports the theory that there was a human presence in southeast Alaska significantly earlier than 10,000 years ago. We still have not found that elusive site of 15,000 or more years ago where the first migrating groups of humans sat out bad weather and wondered what was ahead to the south. The search for such sites intrigues archaeologists and geologists of the Outer Island Cave Inventory Project, as well as many of the speleo-specialists of the Prince of Wales Island Expedition. The search brings together diverse scientific disciplines to answer questions such as: Where was the shoreline 15,000, 13,000 or 11,000 years ago? What species of marine and terrestrial animals were present? When were anadromous fish runs established and where? What plant resources were available and how were they distributed? In short, what ***PALEOECOLOGICAL*** clues are present to help us narrow down the search for the first human inhabitants of southeast Alaska?

Understanding the changes in sea level with the melting of the Pleistocene glaciers is a major factor in finding the older sites. The sea level 17,000 years ago was 120 meters lower than it is today. The ice melted and by 10,000 years ago sea level was a few meters to as much as 100 meters higher than today — depending on the local magnitude of isostatic rebound, in which the earth rises as its burden of glacial ice is removed. For most of the time prior to 10,000 years ago, the shoreline was much lower than it is today. The archaeological remains of coastal camps from those times are now under water and difficult to find. Therefore, the search has focused on inland or elevated locales, where hunters and foragers would have sought temporary refuge. Caves offer the best opportunity for finding such sites.

Cave archaeology also sheds light on the more recent past

The bulk of archaeological evidence from caves in southern southeast Alaska is less than 4,000 years old. Most significant deposits are from rock shelters and shoreside caves rather than from deep solution passages. Only at El Capitan Cave do we find artifacts 600 feet back in a solution cave. Researchers are trying to determine the role of caves in the settlement pattern and seasonal round of inhabitants of Prince of Wales over the past several thousand years. Shells, animal bones, charcoal and a few broken tools provide the best evidence of what people were doing in caves. There are also a few caves with beautiful rock art panels. Archaeologists made exciting discoveries in one cave: two decorated wooden planks and an L-shaped wooden club. The planks have unique carved and painted designs and seem to have been made for connecting with lashing: in fact, cedar cordage was found in holes in the planks. Broken fish spines are embedded in the club and archaeologists think it may have been used as a fishing tool.

This wooden artifact *is believed to be a simple fish club — used and left behind 4,500 years ago by people who took shelter in a cave.*

Memories and oral histories of the Tlingit, Haida, and Tsimshian peoples are important sources of information on these caves and their uses. Alaska Native peoples of southeast Alaska have a rich heritage and deep knowledge and understanding of the area and its resources. Their histories recount the spiritual as well as the everyday significance of localities in southeast Alaska.

***A caver prepares** his equipment. Most Southeast caves are at least partly vertical; proper gear is essential for safe exploration. Technical training is also a good bet for safety.*

Good gear makes for safer cave exploration

- Use headlamps or highly portable flashlights—or both
- Carry at least three reliable sources of light per person
- It is especially important to protect the head: wear a hard hat
- Wear some kind of tough, water-resistant cloth as outer protection

Safety in the Caves

Caves throughout the world are fragile places of mystery, wonder and beauty. But they are also places of danger. Caves in Southeast can pose greater danger than others when cavers enter them without proper preparation. The National Speleological Society's observation is especially valid for southeast Alaska caves: "Reasonable safety in caving can be achieved only through a combination of a proper attitude, good equipment and training from those already well-versed in the specialized techniques of cave exploration."

Caves are dark, so take several sources of light. The type and quantity of lights used in southeast Alaska caves are important considerations. Unlike caves in some other areas, southeast Alaska caves typically contain rugged passages. Even in caves that have large passages, cavers must clamber over boulders and duck under low ceilings. Although a Coleman-type lantern provides bright light, there are several problems. It is difficult to maneuver in the passages while positioning the lantern and protecting the delicate mantle. And some caves "breathe": air movement from a gentle breeze to a strong wind can extinguish lanterns. Climbing through windy passages while carrying a Coleman lantern is a challenge most people avoid. An easier solution is to use headlamps or highly portable flashlights, or both. It is also important to carry at least three reliable sources of light per person. Extra lights are vital if first sources fail, if a partner's source goes out, or if lights are lost or broken — all common occurrences. Be sure to start with new batteries and test every light before entering the cave.

A hard hat is the second most important item of equipment. No matter what care the caver takes when negotiating difficult moves, encounters with the hard rock interior can happen. It is especially important to protect the head. Limestone can also be very sharp and the hard hat protects the head from cuts as well as impact injuries. It's useful for the hard hat to be secured by a quickrelease device; even if the hard hat is jammed in a crevice, the caver's head can be freed. A light mounted to the hard hat frees the hands for maneuvering, but it adds weight.

To explore southeast Alaska caves, dress as if preparing to hike in the forest during the winter. Caves drip water throughout the year, so it is a good idea to wear some kind of tough, water-resistant cloth as outer protection. Underneath exterior clothing, wear several layers of warm clothes so that some can be removed during strenuous activity, or replaced during less-active periods. Wear or bring plenty of clothes. Caves are about 40 degrees Fahrenheit year-round, so hypothermia is a threat. Sturdy boots with slip-resistant soles are important. A small pack is useful for carrying extra clothing and equipment.

File a trip plan before going into the caves

Before departing for the cave, notify friends or family about the itinerary: destination, expected time of return, etc. Even cavers on professional expeditions file daily trip plans. In the harsh underworld environment, little incidents can lead to major difficulties. Someone will be alerted to take action if accidents or complications knock you off schedule.

Before deciding which caves to explore, find out which caves are subject to flooding. Some caves in southeast Alaska can flood two days after rain stops. Consider the length of time to be spent in the cave and recent and current weather conditions outside the cave. If there is any concern about flooding, do not enter that cave. It can wait for a future trip.

While hiking to the cave, remember that although more than 350 caves have been identified, hundreds more wait to be discovered. Watch for cave entrances that might be covered with vegetation. Since many cave entries in southeast Alaska are vertical shafts and pits, careful observation of the terrain is also a safety precaution.

Consult an expert for information on caves

Information and training for exploration of southeast Alaska caves is available through The Glacier Grotto in Ketchikan. For information on caves and caving nationwide, get in touch with the National Speleological Society at Cave Avenue, Huntsville, AL 35810; telephone 205-852-1300.

Cave explorers *find a raw but delicate beauty in formations such as this stalactite and stalagmite. And though such features develop over decades or centuries, they can be ruined in a moment.*

Get info on karstlands

For more information on Tongass National Forest caves, contact USDA Forest Service staff …

- Forest Supervisor in Ketchikan at 907-225-3101
- Craig Ranger District Office at 907-826-3271
- Thorne Bay Ranger District Office at 907-828-3304.

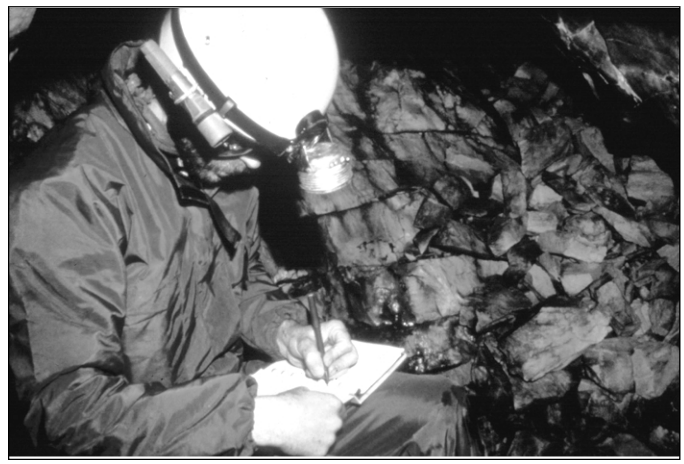
After entering the cave, move slowly and take note of all the surroundings. Careful exploration prevents the accidental breaking of delicate formations. Watch for side passages and have some way of marking the main passage. Use some method that will not disturb the cave. If survey tape is used, be sure to pick it up on the way out. Arrow symbols should point the way *out* of the cave and not the way *in*. Know your limits and never exceed them. Unlike a mountain hike, the trip out of the cave can be just as strenuous as the trip in, so save enough energy for the return trip. Remember that it can be easy to climb up something that is very difficult to climb down. Turn around often and look back. Many people get lost on the way out because the cave looks very different from that perspective. Look up at the ceiling for rocks that might fall.

Careful observation increases the safety and enjoyment of the trip. Cave decorations can be quite dainty but very beautiful. Bats can be small enough to fit into a 35mm film canister. Other organisms are even smaller. Fossils and bones can blend into surrounding rocks. It takes a keen eye to see these things.

The buddy system makes for smart caving

It's always a good idea to team up in a cave. As in scuba diving, a buddy provides help or points out interesting formations. One member of the party should bring first aid supplies and a small quantity of survival gear; a space blanket is a good item to have. If the trip is to be very long, carry food and water. Caving requires much energy simply to stay warm and it is important to maintain a high energy level. Water in the cave is subject to the same problems as on the surface, so don't drink the water in the cave without first purifying it. Partners can also watch for signs of stress in each other. Stress can include chills, discomfort in small areas, fatigue, hunger, and fear of the unknown. A team that enters a cave should depart as a team, with one exception: when there is an adequate number of team members to leave some individuals behind, at least one of whom has experience in that cave, or is an experienced caver. A person who wishes to leave should not be made to feel badly. It's not a good trip unless everyone is having a good time.

Sometimes, despite all precautions, cavers can get disoriented and lost. What to do? The worst thing is to rush up and down passages. That will probably lead to more disorientation. Don't panic. Stop, think, and assess the situation. Remember that it's impossible to panic if your breathing is normal. If there is any immediate danger, move to a safe area and stay there. Move in place to stay warm. This common kind of emergency emphasizes the importance of leaving a trip plan with family or friends. A detailed itinerary facilitates an informed rescue effort



Help science, but don't hinder nature. *If you find an apparently valuable object in a cave, don't take it out or get a sample. Just note its position. Sketch it. And then report it to cave experts.*

Technical gear may be needed

It is important to remember that most of the caves in southeast Alaska are vertical. Technical training and proper gear are essential if rope is needed for exploration. Mud, unstable rock, humidity and total darkness underground can't be surmounted with the usual above-ground climbing techniques.

USDA Forest Service has information on the caves of Tongass National Forest. Two cave sites have been developed by the agency for easier public access. Cavern Lake Cave has a trail and viewpoints at the entry area. Swimming through the cave should not be attempted due to the dangers of hypothermia and drowning. An excellent trail leads to El Capitan Cave and guided tours of the front passages are available during the summer. This cave is subject to rapid flooding and a gate was installed at the entrance to eliminate entrapment. El Capitan also has other hazards, such as deep vertical pits. Exploration of even developed caves in southeast Alaska requires care and caution.

Conservation in the Caves

Every time people enter a cave, some kind of impact results. For example, in Carlsbad Caverns, New Mexico, species of microscopic organisms now line the visitor paths, waiting for hair, dead skin and other particles people shed as they pass through. These species were not there before humans entered. In another instance, ancient paintings in the caves of southern France are decomposing due to changes in the caves' climatic conditions caused by visitors. Visitors to developed caves and cavers in "wild" caves should minimize their impacts on cave environments.

Karst varsity *— the scientists, cavers, biologists and others whose teamwork opened southeast Alaska caves to the light.*

Responsible cavers leave no signs of their presence and pack out any signs other parties may have left behind. They move slowly through caves and carefully consider their next sequence of movements. They watch the placement of muddy hands. Conservation-minded cavegoers try not to lose their balance and accidentally grab some decoration; contact with even skin oil can stop formation of stalactites or stalagmites. These formations grow continually, over hundreds of years, and should not be disturbed. A removed formation may be decorative in a home, but it is even more beautiful in its natural setting, where many more visitors can enjoy it. Careful cavers leave alone any broken formations they find: removing broken formations simply encourages further collection. Visitors should bear in mind that many cave passages remain unsurveyed, because entry into the passages would have damaged the formations. No-impact cavers know to avoid handling or moving something of scientific interest, because its scientific value can be diminished. They note its position in the cave and notify a professional later.

Although it is a thrill to see a large wall of flow stone, moon milk, or a stalactite, cavers should take time to watch for cave popcorn and small fossils. Cave popcorn, a formation of delicate crystals, is very common in southeast Alaska caves. Fossils embedded in cave walls have drawn micro-paleontologists to southeast Alaska from other areas of the country for several years. Sometimes bats may be seen in the caves. It's important not to disturb them. A hibernating bat can use up most of its stored energy if it is disturbed and will be unable to live through the winter.

The value and the vulnerability of southeast Alaska caves were recognized in the 1980s, with El Capitan (or El Cap) Cave first in focus. In 1984, USDA Forest Service staff saw the recreational potential at El Cap about the same time as they noted vandalism to formations inside. By 1992, they were developing a management plan and solutions to vandalism. Forest Service staff decided that a gate would most effectively prevent vandalism to fragile speleothems and disturbances to little brown bats — *Myotis lucifugus*. The management plan further identified the need to control access beyond a gate and looked at protecting recreational cavers from several deep pits along the main passage at El Cap Cave.

The Forest Service installed a so-called air flow bat gate about 150 feet inside El Cap Cave during the summer of 1993. A lot of research and experience went into the gate. Air flow, temperature, humidity and deterring human intrusion are essential factors in a successful design. A heavy steel gate with few opening will keep people out, but won't allow proper air exchange and regulation of temperature and humidity — requirements to maintain an undisturbed population of bats and to preserve growth of cave formations. A properly used gate is one of the most powerful tools for implementing and enforcing a cave closure. Gates are, on the other hand, expensive to install and to maintain. They can also be ineffective if they're designed poorly or installed incorrectly — or if they're not part of a comprehensive management plan.

El Cap Cave gate: a ton of prevention

Weight of steel: 2,100 pounds
Cost of steel: $2,000
Labor cost: $9,000
Logistical support cost: $4,000
Configuration: horizontal steel members 5.75 inches apart keep out people and let in air

Not much is known about the effects of gates on caves. Some caves have flora and fauna that are susceptible to the minutest of changes. At a minimum, efforts should be made to study a cave before and after installation of a gate in order to record these effects. Future designs should take such effects into consideration and be modified to accommodate them.

The bats *Myotis lucifugus* and *Myotis californicus* have been seen behind the gate at El Cap and don't seem to mind flying past the gate.The eastern species *Myotis grisecens*, or gray bat, isn't so easygoing—the bats will not tolerate any kind of full gate on their maternity caves, but will tolerate some gating on hibernation caves. This goes to prove that cave gating is an inexact science.

The best way to protect the cave is for cavers to be on the alert for all the wonders of the cave, large and small. They can then avoid moves or actions that could damage the caves. By following these guidelines, the caves can be protected and we can continue to enjoy the mystery and beauty that lie underground.