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# Ripple Marks

## The Story Behind the Story

BY CHERYL LYN DYBAS

## Glass Palaces at the Bottom of the Sea

Mummies, they're called, these strange shapes that form one of the largest structures that ever existed on Earth.

Stretching some 2,900 kilometers from Spain to Romania, the long, sinuous curve of millions of mummies—once-living, vase-shaped animals—is a fossil reef. In its heyday in the Jurassic, the reef dwarfed today's Great Barrier Reef on Australia's northeast coast.

Now visible only in outcrops dotted across a vast area of central and southern Spain, southwest Germany, central Poland, southeastern France, Switzerland, and eastern Romania near the Black Sea, the ancient reef was made up not of corals, but of deep-sea sponges called hexactinellids.

Hexactinellid, or glass, sponges use silica dissolved in seawater to manufacture a skeleton of four- or six-pointed siliceous spicules. Individual glass sponges, such as the beautiful Venus' flower basket sponge (*Euplectella aspergillum*), are still found in the deep sea, but they are different species than the Jurassic reef-builders.

Reef-building glass sponges became extinct 100 million years ago, leaving evidence of their presence only in fossilized remains across Europe. The reef-builders were likely driven out by competition from newly arrived diatoms. Single-celled algae, diatoms also use the silica in seawater to build cell walls.

Diatoms, however, need the light of the sea's euphotic zone and so don't live in the deepest parts of the ocean. These nether regions were an open niche for reef-building glass sponges. But none was able to colonize the deep.

Or so it was thought.

"Nature had a few tricks up her sleeve," said Sally Leys, a glass sponge biologist at the University of Alberta, Canada, "tricks that none of us could have imagined."

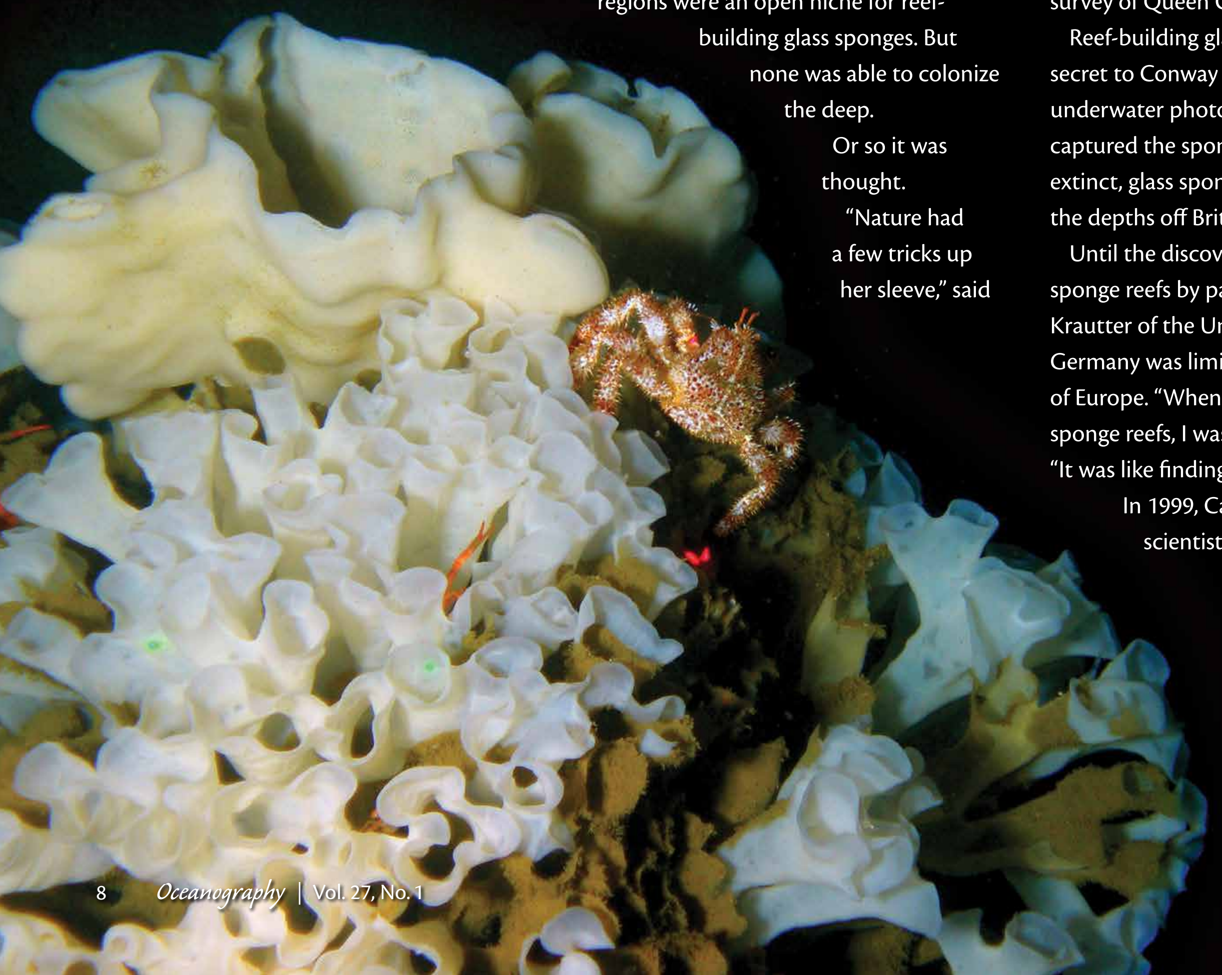
For millennia, the darkness beneath British Columbia's Hecate Strait and Queen Charlotte Sound concealed the next chapter in an eons-old tale.

The first hint that something odd might be at the bottom of Hecate Strait came during a 1984 seafloor mapping expedition. Using sonar imaging, scientists from the Geological Survey of Canada saw mounds over huge areas of the seafloor—places that should have been completely flat. Similar acoustic anomalies, as geological survey scientists Kim Conway and Vaughn Barrie referred to them, were observed again in 1986 during a survey of Queen Charlotte Sound.

Reef-building glass sponges gave up their secret to Conway and Vaughn in 1987: underwater photography in Hecate Strait captured the sponges on film. Far from extinct, glass sponge reefs were thriving in the depths off British Columbia.

Until the discovery, the study of glass sponge reefs by paleontologists like Manfred Krautter of the University of Stuttgart in Germany was limited to the fossilized reefs of Europe. "When I first heard about the sponge reefs, I was electrified," said Krautter. "It was like finding a living dinosaur."

In 1999, Canadian and German scientists, including Conway and



A hairy-spined crab (*Acantholithodes hispidus*) clambers over a lacy cloud sponge (*Farrea occa*). *Credit: Fisheries and Oceans Canada/Sally Leys*

Krautter, descended to the depths of Hecate Strait in a submersible for a firsthand look. Glass sponges, they found, not only were alive, but had formed reefs that extended as far as a submersible porthole view could see.

The sponge reefs—some of which are 8,000 or more years old, 18 meters high, and 700 square kilometers in surface area—are all below 150- to 250-meter water depths, according to biological oceanographer Verena Tunnicliffe of the University of Victoria. "That's why we didn't find them for so long," she said. "What we know of these animals had been constrained by limited access to their deepwater habitat."

The reefs occur as bioherms, or mounds, and as biostromes, or sheets. The sponge bioherms off British Columbia are steep-sided, six-story glass castles. The biostromes extend over distances many times the length of the island of Manhattan.

Two main types of glass sponges are known, said Leys, those whose spicules are loosely held together—non-reef-forming species—and those that mold silica into a rigid, three-dimensional scaffolding that resembles a delicate glass palace—the reef-forming variety.

The ocean environment off the Pacific Northwest offers an enticing locale for reef-forming sponges. More than 13,000 years ago, glaciers covered much of Hecate Strait and Queen Charlotte Sound. Icebergs scoured their way along the continental shelf, leaving behind berms of coarse gravel. It was on these berms that the sponges likely began their construction.

Glimpsed through a submersible or ROV lens, today's glass sponge reefs loom out of dark waters as forests of white, yellow and orange bushes. Some species have vast, gaping oscula, or openings, while others have undulating, billowy palm-like extensions. Still others are masses of snow white frills.

"The sponges turn silica from ocean water into long, sharp shards, which they mount together like a set of tent poles," Leys said. "Glass sponge reefs form just like coral reefs, with new generations growing on previous generations."

Three main species make up the glass sponge reefs off British Columbia: *Chonelasma calyx*, the goblet sponge; *Aphrocallistes vastus*, the cloud sponge; and *Farrea occa*, which has no common name.

Because the sponges are found in so few locations, there must be specific requirements for their growth, scientists believe. Cold water, low light, high dissolved silica concentrations and low sedimentation rates are the keys.

The first three are found throughout the coastal waters of the Pacific Northwest. Water temperatures at depths where reef-building glass sponges live are between 6°C and 12°C. Little light reaches the sponge reefs; all are in very deep waters.

Levels of dissolved silica are low in both the Atlantic and tropical Pacific Oceans, but high in the coastal waters of the Pacific Northwest.

A result of glass sponges' uptake of silica, they may form a major component of the global silica cycle, becoming a sink for dissolved silica that's comparable, if not larger than, that of diatoms.

The role of sediment in the lives of glass sponges is more uncertain. While some sediment is needed to cement the skeletons into a reef matrix, Tunnicliffe said, reef-forming glass sponges don't survive where particulates are high. Most animals that filter water to feed—such as glass sponges—have ways of foiling sediment clogs before they happen, however.

"Glass sponges are unusual animals because the majority of their soft tissue is made of one giant multinucleated cell," said Leys. "As a result, some species of glass sponges can send electrical signals through the whole animal, in much the same way signals travel through nerves."

(top) Canada's remotely operated vehicle ROPOS is lifted out of the Pacific Ocean after a dive to a glass sponge reef. *Credit: Sally Leys*
(middle) Shrimp peer out of a refuge: a giant cloud sponge (*Aphrocallistes vastus*). *Credit: Fisheries and Oceans Canada/Sally Leys*
(bottom) Newly formed spicules of *Aphrocallistes vastus* labelled with a fluorescent dye. *Credit: Amanda Kahn*

When sediment levels increase, these signals reach all parts of the sponge and cause it to stop filtering water for bacteria, its main food source. "After a few minutes," said Leys, "the sponge will start filtering again, but if the irritation is still there it will stop, 'testing the waters' until they're clear."

Research on glass sponge distribution in four British Columbia fjords—Saanich Inlet, Howe Sound, Jervis Inlet, and Knight Inlet—showed that the sponge reefs are least abundant in Knight Inlet. This inlet has the most sediment input of the four, a result of runoff from the Klinaklini River.

Juvenile reef-building glass sponges must settle on surfaces that aren't smothered by sediment: fjord walls, or the living surfaces of existing glass sponge reefs.

Reef-building glass sponges grow two to seven centimeters per year. The age of one glass sponge reef in Queen Charlotte Sound is estimated at 6,000 years.

Although the only living glass sponge reefs known had been those off British Columbia, "it's possible," said Tunnicliffe, "that other such sponge reefs might exist."

Scientists Bob Stone of NOAA and Kim Conway recently proved her right. They discovered glass sponge reefs in Portland Canal, an arm of Portland Inlet, part of the border between southeastern Alaska and British Columbia. Despite its naming as a canal, the inlet is a fjord. They also found the sponge reefs in Alaska's Lynn Canal, which runs 140 kilometers from the Chilkat River south to Chatham Strait and Stephens Passage. At more than 601 meters deep, Lynn Canal is the deepest fjord in North America, and one of the deepest and longest in the world.

"We documented the presence there of long-lived glass sponge reefs, similar in species composition and form to, but much smaller in size than, the massive reef complexes farther south on the British Columbia continental shelf," says Stone. "The Portland Canal and Lynn Canal glass sponge reefs are the northernmost such reefs discovered to date."

Glass sponge reefs have now been found along the Pacific Coast from the southernmost major fjord, Howe Sound, to the northernmost Alaskan fjord at Lynn Canal, a distance of 1,300 kilometers. The findings indicate that glass sponge reefs likely occur in other areas of Southeast Alaska where favorable areas for reef development exist.

Spectacular as these discoveries are, perhaps more so is another made in June 2007. Geologist Paul Johnson of the University of Washington located large colonies of glass sponges thriving on the seafloor 50 kilometers west of Grays Harbor, Washington. The find extended the range of reef-building glass sponges into the open ocean. Those off British Columbia and Alaska are all in nearshore areas.

The Washington glass sponges added a new chapter to the glass sponge reef story.

"They appeared to be thriving on specialized bacteria that consume methane gas, which we were surprised to discover flowing out of the seafloor in copious amounts," said Johnson. "The reefs could be an ecosystem that's fueled by methane gas derived from ancient carbon in the sediments."

While undersea methane seeps aren't unusual, the sponges off Grays Harbor, Washington, are sitting right on top of one.

The bacteria on which the glass sponges feed may be methanotrophic, or methane-eating. "Wherever you find methane seeps in the ocean," said Johnson, "there are usually huge populations of methanotrophic bacteria."

Methanotrophic bacterial mats in other parts of the deep sea support animal communities dominated by tubeworms and clams. Johnson believes that methane beneath the Washington glass sponge reefs could be fueling an analogous food web off the Washington coast.

"I've spent a lot of time looking at the exotic animals around hydrothermal vents," said Johnson, "but glass sponge reefs and the ecosystem they support are even more incredible."

All is not well in these deep-sea palaces of glass, however.

Many glass sponge reefs have been damaged by trawl fishing. The future of these globally unique and

The chalice cloud sponge (*Heterochone calyx*) rises above other glass sponges to reach faster-flowing waters. *Credit: Fisheries and Oceans Canada/Sally Leys* fragile reefs hangs in the balance.

"The reefs off Washington seem to be completely trawled," Leys said. "We might have discovered them 100 years too late."

Off British Columbia, paired tracks of otter trawl fishing nets are visible on side-scan sonar. "Given the fragile nature of the sponges," said Conway, "they likely wouldn't survive being dragged with this type of equipment."

A correlation may exist between steep terrain, Conway and colleagues found, and the health of sponge reefs. "Steep glacial and rough bedrock slopes are where the healthiest glass sponge reefs are largely found, due to more difficult access by trawl-equipped fishing vessels," they wrote in a paper in the Geological Survey of Canada's *Current Research* series. "It's probable that reefs in deeper, low-slope-angle [flatter] seabed areas have been trawled."

In one British Columbia reef Conway and others surveyed, "living but broken sponges, and dead sponge debris, were very common," they wrote in *Current Research*. "Trawling may accentuate the piling up of sponge debris." The near absence of rockfish at damaged sites, compared with undisturbed reefs where rockfish were abundant, indicated reefs that had been subjected to trawling.

A startling summary of observations from the British Columbia bottom trawl fishery shows that between 1996 and 2002, about 253 tons of corals and sponges were harvested as bycatch, states Leys in *The Biology of Glass Sponges*. Because these are non-commercial species, it's thought that many additional observations went unreported.

An analysis of the regions in which the most bycatch happened showed 12 locations where 97% of all coral and sponge bycatch occurred. Many were next to or directly on glass sponge reefs.

Voluntary avoidance of the reefs was agreed upon by trawl fishers in 1999. Although fishing was reduced, landings continued in areas near glass sponge reefs.

In 2002, the Canadian government stepped in and mandated trawl fishery closures directly over the reefs. Despite these closures, however, new damage to previously unaffected reefs has been found.

Researchers in submersibles observed reefs in Hecate Strait with broken skeletons, the remains piled in mounds on the seafloor. Stumps of sponges, and sponges with abraded edges, were also seen.

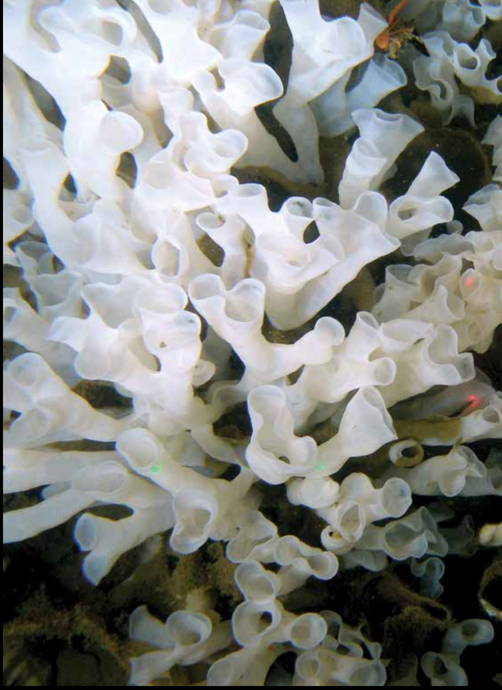
"It was a shock to find that the northernmost reef in Hecate Strait had been damaged," said Krautter. "What was once the most pristine part of these reefs will take thousands of years to recover—if it ever does."

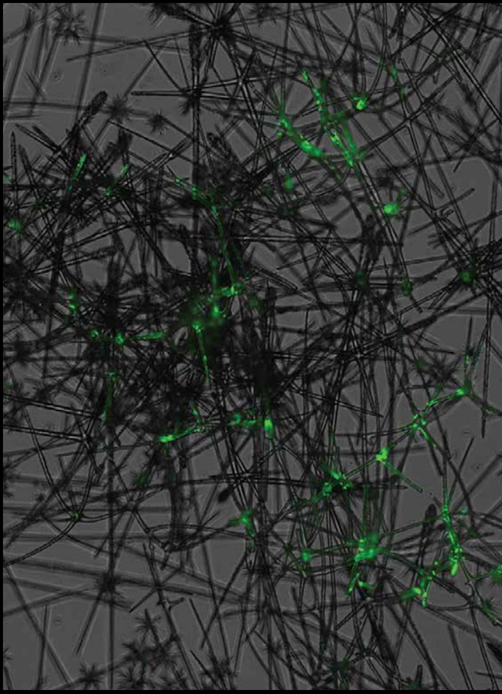
Brighter days may be ahead. Unlike many of the reefs, says Stone, "those in Portland Canal and Lynn Canal have not been affected by 'bottom-contacting' fishing activity."

In June 2010, Canada declared the glass sponge reefs in Hecate Strait an "Area of Interest" for a Marine Protected Area, the last stage before their conservation can be legally established. And the Canadian Parks and Wilderness Society is working to obtain international recognition for the reefs as a UNESCO World Heritage Site.

Otherwise, the glass sponges of the Pacific Northwest may join their European counterparts in history. In death, their lovely silica glass bodies hollowed out and fossilized, they, too, will have become mummies.

*A previous version of this article appeared in* Natural History *magazine*





(top) White branches of the lacy cloud sponge *Farrea occa* reach upward in the depths. *Credit: Fisheries and Oceans Canada/Sally Leys*
(middle) Newly formed spicules of *Aphrocallistes vastus* labelled with a fluorescent dye. *Credit: Amanda Kahn*
(bottom) The glass sponge *Farrea occa* offers protection for two squat lobsters (*Munida quadrispina*). *Credit: Fisheries and Oceans Canada/Sally Leys*

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