New territory. The vessel *Goor* carries researchers to a site that was off-limits during the Cold War.

ARCHAEOLOGY

A Stone Age World Beneath the Baltic Sea

As they map Germany's changing coastline, members of a research team called SINCOS are learning about settlements that were covered by water 6000 to 8000 years ago

On a warm afternoon in September, archaeologist Harald Lübke looked out from the pilot house of the *Goor*, a bright red dive boat moored 200 meters off Germany's Baltic seacoast. Three meters below the water's glassy surface, divers in bulky drysuits were excavating a prehistoric hunting camp. A deafening motor mounted on the *Goor*'s deck powered a pressure pump, which they were using to suck sediment from the sea bottom into mesh bags.

Along with sand and shells, the divers brought to the surface bones and bits of wood—debris left by ancient hunters who caught eel, fish, wildfowl, and the occasional seal. A growing body of evidence gathered by these and other undersea researchers reveals that about 7000 years ago—more than 2000 years before Stonehenge—people built fish fences, dug food-storage pits, and established sizable Stone Age communities along the shores of what appears to have been a rapidly rising Baltic.

At some point, as glaciers receded northward, the land along this coast began to sink, and over the centuries the sea moved in, submerging the hunting camps. Lübke, an archaeologist with the Mecklenburg-Vorpommern Cultural Heritage Agency, is part of a multidisciplinary German project called The Sinking Coasts: Geosphere, Ecosphere, and Anthroposphere of the Holocene Southern Baltic Sea project (SINCOS). It is trying to learn exactly how and when this landscape changed and already has determined that the water rose very rapidly, drowning the low settlements, then gradually but inexorably covering the higher ground. There's no doubt in Lübke's mind that "they must have seen the sea level rise and must have thought it wouldn't end."

Into the deep. Archaeologist Harald Lübke (*right*) watches a diver descend to an ancient hunting camp 3 meters below sea level.

CREDITS: A. CURRY/SCIENCE

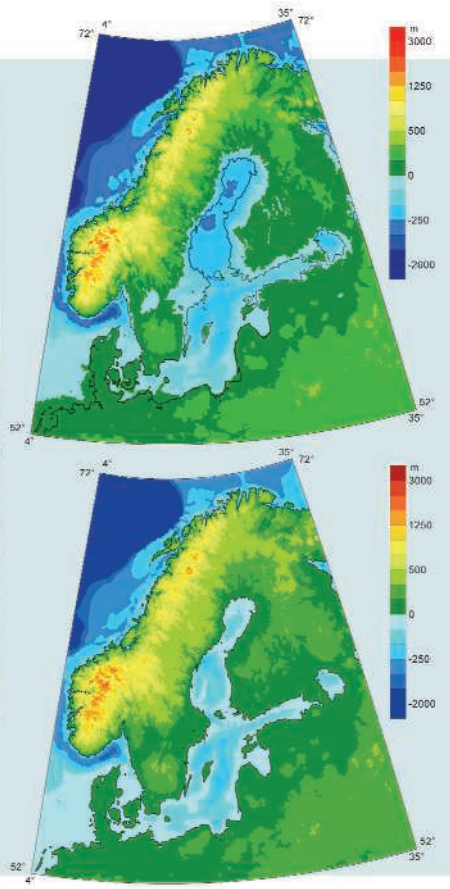
SINCOS is a "unique" collaboration linking geology, archaeology, geodesy, socioeconomics, and other fields, says Director Jan Harff. Its goal is to gather information about the Baltic coast over the past 10,000 years and, in cooperation with the Baltic Sea Research Institute in Warnemünde, also directed by Harff, to create a model that can predict future changes. Harff argues that the methods being developed here will have broad application. "Coastal retreat and erosion are so important," he says, that the approach taken in the Baltic could be useful "anywhere in the world."

Geological seesaw

Every summer, tourists come to the island of Poel, a short swim from Lübke's dive site, to sunbathe on its sandy beaches. Twenty thousand years ago, when the great ice sheets last reached their lowest latitudes, the island and nearby sea floor were frozen solid under ice at least 3 kilometers thick. The tremendous weight pressed down on the northern end of the Baltic Shield, a continental plate that includes Poel, Scandinavia, the Baltic Sea floor, and much of northern Europe. With ice sitting on the plate like a fat kid on a seesaw, the southern end, including Germany's coast, rose.

About 12,000 years ago, the world warmed up, the glaciers began to melt, and sea levels all around the world rose. As the ice sheets thinned and retreated, the pressure on the northern Baltic Shield dropped. The seesaw tipped back, lifting prehistoric beaches in northern Sweden and Finland to their present elevation 20 meters above sea level. At the same time, settlements from the same period in Germany sank deep underwater.

A channel of saltwater penetrated the land bridge between Germany and Denmark, forming the Baltic Sea out of what was once a freshwater lake, then a brackish one. But until the SINCOS project began, the timing was a mystery. Archaeological data gathered from a handful of underwater settlements are critical to determining a more precise picture of the Baltic's birth. "We wanted to find out if there was a big flood that changed everything dramatically, or if it changed step-by-step," says Friedrich Lüth, SINCOS's co-director and the head of the German Archaeological Institute's Roman-Germanic Commission. In addition to mapping the coast, the team



Corroboration. Jan Harff, with a sediment core that marks the sea's flooding into the ancient Baltic (*top right*), leading to today's coastline (*bottom right*).

wanted to learn how the people who lived here responded.

As they sort through bags of sediment for bones and wood fragments, some as small as a fingernail, Lübke's team keeps track of which sediment layers they came from (see sidebar, p. 1535). From a carbon-dating analysis of the organic fragments picked from pebbles and bits of shell, they concluded that the sea rose significantly 8000 years ago, plunging a site called Jäckelberg 3.5 meters underwater in the space of a century, and perhaps much faster. By 6000 years before the present (BP), the sea had risen another 3 meters to cover the site Lübke calls Timmendorf after the nearby village.

The project involves more than a dozen institutes in cities across Germany. Dendrochronologists from the Institute for Wood Biology in Hamburg are studying wooden artifacts and logs that are well preserved by the oxygen-poor seabed to create a continuous timeline for organic artifacts discovered in the future. They intend to tease out information about temperature and humidity to align wooden artifacts with climatic changes. And researchers at the Institute for Planetary Geodesy in Dresden and Harff's Baltic Sea Research Institute are creating computer sea-level models showing relations between temperature, melting glaciers, and sea-level rise.

Studying the ancient hunters' diet is helping to fill in the chronology. Tens of thousands of eel bones and fragments of dozens of specialized eel spears have been identified at underwater sites. Paleozoologists Ulrich Schmölke and Dirk Heinrich of Christian Albrechts University in Kiel have concluded that over the course of 2000 years, the region's inhabitants went from a diet of land mammals and freshwater fish to almost exclusively marine fish.

Evidence from drilling cores taken in deeper water tells a similar story. In a small building behind the Baltic Sea Research Institute, Harff keeps core samples covered in plastic-wrapped tubes about 10 centimeters thick. With a pen, he points out how sand and mud have been compacted in hundreds of dark, narrow bands, year after year going back millennia. Then, toward the bottom, there's a sudden change. Pulling back the plastic, Harff examines a thick, brownish layer in which he says freshwater organisms churned the sediment.

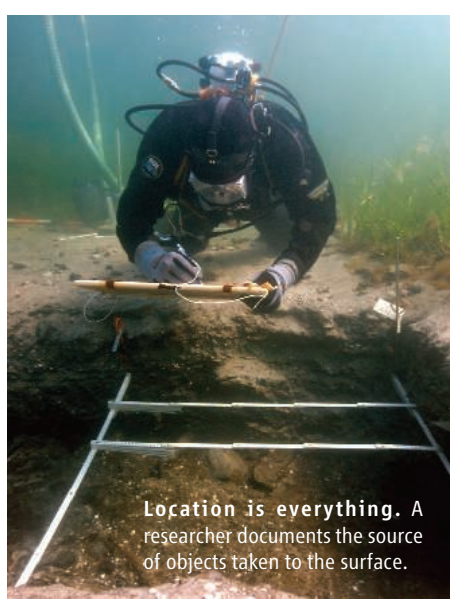
Using carbon and paleomagnetic dating, Harff's team put the freshwater layer at about 8000 years BP, or about the same time the Jäckelberg hunting camp began to be covered by rising water. Because rivers wash silt into the Baltic annually, core samples reveal regular layers during periods when the saltwater sea bottom was lifeless; these can be counted to see how many years passed. This geologic evidence agrees exactly with the date the archaeologists determined from analysis of the artifacts. "When I took this core, I was so excited," Harff says. "That we could trace back the history with such accuracy was totally unexpected."

Recently, the SINCOS project refined its estimates of timing, concluding that the Baltic rose almost 8 meters between 8100 and 5400 years BP. To some, the evidence suggests that the first 3.5 meters flooded in very rapidly, possibly within days. "It's clearer and clearer that it was a massive, sudden flood," says Lüth. "Log boats were lost, fish traps were lost—it can't have come in centimeter by centimeter." To Lübke, the evidence seems more ambiguous; he thinks the flood could have taken decades.

A Cold War ice box

The Baltic is a good place for undersea research, partly because of its history. Pinned to a whiteboard in Harff's office is a large brown index card labeled "Travel Request Form," a memento from the Cold War era. It was almost impossible to explore the Baltic before 1990, recalls Harff, who began working as a geologist in Potsdam, then part of East Germany, in 1977. Cold War politics put Baltic Sea research into a 50-year deep freeze: Until 1989, sonar scans, diving, underwater excavation, and aerial surveying were forbidden in East Germany for fear scientists would run (or swim) away.

Restrictions sometimes led to absurd scenes. In 1985, recalls Lüth, a local fisher found part of a Bronze Age spoked wheel in peat about 100 meters off the East German shore. Visiting West German archaeologists



Location is everything. A researcher documents the source of objects taken to the surface.

CREDITS: (TOP, LEFT TO RIGHT) A. CURRY/*SCIENCE*; M. MEYER, Ph.D. THESIS/GREIFSWALD UNIVERSITY (2002); (BOTTOM) HARALD LÜBKE/STATE AGENCY OF CULTURE AND CULTURAL HERITAGE MECKLENBURG-VORPOMMERN, GERMANY

were permitted to look for the rest of the wheel but forbidden to bring any equipment or look out to sea. Walking backward in swim trunks and goggles, they failed to find the site.

Yet the politics had positive consequences. Coastal development, which might have disturbed sites near shore, was nearly nonexistent. The ban on sport diving, which has resulted in the looting of underwater heritage elsewhere in the world, kept hundreds of shipwrecks safe. Ten thousand years of the region's history were almost perfectly preserved. "We knew from Danish and Polish and Swedish colleagues there were sunken ships and Mesolithic and Neolithic sites to be expected," Lüth says. "We knew something was out there, but we had no idea what it was."

"The real world—especially working at sea—began after 1990," following the reunification of Germany, Harff says. For the first time, scientists such as Harff were free to travel and meet scientists from other countries. Archaeologists and geologists dove into the virgin territory of the Baltic; they now rank it among the world's most exciting areas, says Nicholas Flemming, a British oceanographer who pioneered many underwater research techniques and is based at the Southampton Ocean Centre in the U.K. The Baltic is good for diving. And because it is isolated from the tides that churn the North Sea and Atlantic, sediments build up slowly and predictably, leaving an easy-to-read geologic record. Best of all, its cold, brackish water, low in oxygen, preserves organic materials.

Using the deep-water research vessel *Professor Albert Penck*, Harff began surveying the sea bottom in 1999 using video sleds, side-scan sonar, sediment echolocation, and core samples. His first look at the ocean floor was a revelation. Submerged forests of tree trunks and stumps lay where they fell 8000 years ago. Ancient topography—valleys, hills, river channels, inlets, and bays—could all be easily seen on sonar surveys. "It was a drowned coast," says Harff. "It was the same landscape, just underwater."

"Nirvana"

Studies of the Baltic are part of a recent wave of exploration targeting submerged prehistoric sites around the world. Ancient land bridges, huge fertile plains, and long coastlines have been submerged since the last glacial maximum, when sea levels were as much as 120 meters below where they are today.

Yet it is only recently that prehistoric underwater archaeology has begun to take off. One reason: Excavations are still expensive, slow, and risky; it may take a team of divers all day to excavate a 1-square-meter sediment layer. Another is that until recently, many archaeologists assumed that looking for underwater sites would be a waste of time because they believed that "waves would have pounded anything out of existence," says archaeologist Geoff Bailey of the University of York, U.K. But, he says, "when coastlines have convoluted features, archaeological materials may have survived." For example, it's long been assumed that the rough, storm-tossed North Sea is an archaeological wasteland. But in the past few years, archaeologists have found evidence of whole villages 11 meters beneath the water in sheltered channels near the Isle of Wight.

In the last few decades, archaeologists have found underwater prehistoric settlement sites and artifacts stretching back as much as 500,000 years near South Africa, Europe, Japan, the Middle East, the United States, and Canada. The discoveries are often made possible by interdisciplinary cooperation: archaeologists using maps of the sea bottom prepared by geologists for oil companies, for instance. Such data, added to what climate-change researchers know about sea levels, provide a new guide to how and where ancient hominids might have traveled across the now-submerged landscape. "As more academics start to get involved, the dots join together," says Southampton's Flemming. "The last 5 years, everything's been happening. If you ask me, we're heading toward nirvana."

But perhaps the greatest new resource promised by the SINCOS project, according to Lüth, is its 10,000-year data set. "Measurements of deloading from ice usually assume it's uniform, [but] there's evidence that there are local differences," says geologist William Hay of the University of Colorado, Boulder, who evaluated the SINCOS project for the German Research Foundation in 2003.

Researchers at Dresden Technical University's Geodesy Institute have constructed a computer model incorporating the data from the last 10,000 years. Lüth hopes the model will enable the team to make a reasonable attempt at predicting what's to come. There are a lot of factors involved. As sea levels rise and the Baltic's volume increases, for instance, the German coast will sink faster under the weight. "We can put it all together to give an outreach for the future," says Lüth. "The system [that] worked for the last 8000 years should work for the next 200 to 300. It could give the basis for planning and development decisions."

The SINCOS collaboration is a reminder: "We're not the only ones faced with a retreating coast," Harff says. "Our ancestors also had to leave their settlements to the ocean."

–ANDREW CURRY

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A Hunter's Paradise

In 1999, archaeologist Harald Lübke was diving to the wreck of a medieval cog boat just off the island of Poel on Germany's north coast when he noticed flint artifacts on the ocean floor. "I dove a little deeper, and I found seven or eight flint axes in 10 minutes," Lübke recalls. It is one of about two dozen Stone Age sites identified along Germany's Baltic Sea coast since 1993.

One of the most productive is Timmendorf-Nordmole. The outlines of this hunting camp 3 meters underwater are marked by postholes and smooth stones that may have once anchored fishing fences. Divers have also uncovered a collapsed structure that may have served as an eel smokehouse or storage area. Some of the artifacts are in stunning condition, as though "they were produced yesterday," says Lübke. In 2001, he uncovered a palm-sized stone scraping tool with intact threads lashing the wood handle to the stone scraper—the first such discovery in the world. "I wasn't sure it was real when I first saw it," says Lübke.

Intact. The lashings on a stone scraper were preserved in the Baltic's chilly waters.

In addition to helping create a data set for climate and sea-level changes in the area (see main text), the artifacts have added to what scientists know about how people lived along the Baltic coast thousands of years ago. The artifacts link them to the Ertebølle cultures, which flourished in and around Denmark between 5450 and 4100 B.C.E., and fill in what had been a blank spot in the archaeological record along the Baltic coast. Lübke says the coastal settlers here remained hunter-gatherers, relying on a diet of fish, eel, birds, and seal, for centuries after people farther inland turned to agriculture. "When the ocean flooded the landscape, it created a very rich biotope," Lübke says. "It would have been like a paradise." **–A.C.**

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