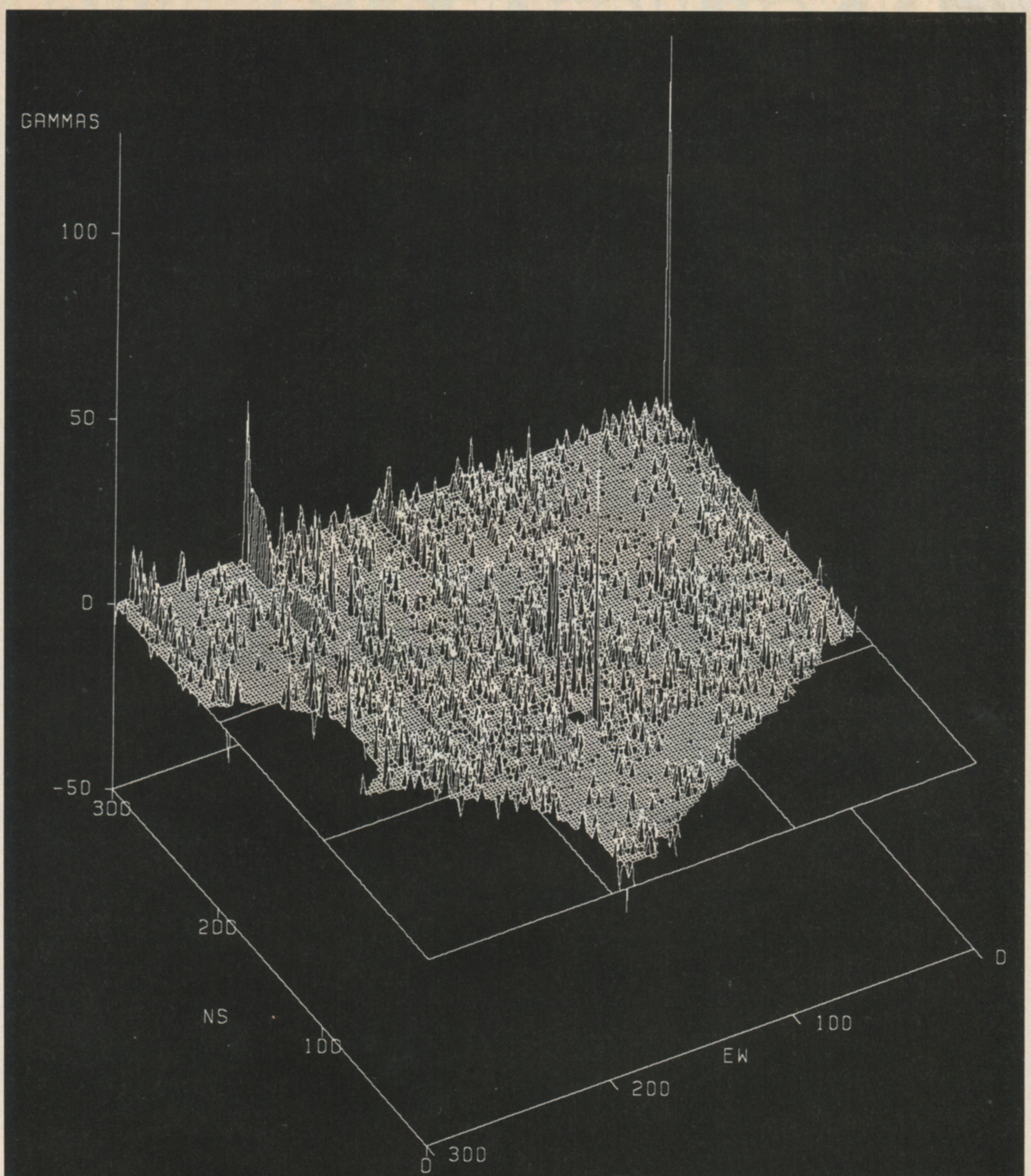



This image displays more than 26,000 readings taken by a magnetometer on St. Catherines Island. Magnetic intensity (measured in gammas) is plotted as peaks or valleys, depending on whether the readings are greater than or less than that of the background. Each spike will be investigated further; groups of spikes often indicate structures such as buildings.

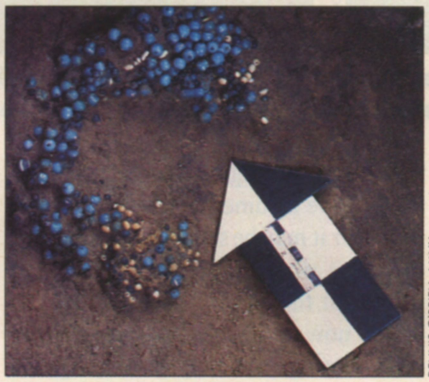
JAMES GRAHAM BAKER, TEXAS A&M UNIVERSITY

# Leave No Stone Unturned

*"Archaeology is about the only science that destroys its own data," says one expedition leader. Radar, sonar, and satellites help map the past without disturbing it. by John Sedgwick*

Somewhere off the coast of Georgia on St. Catherines Island, among the magnolias and oaks hung with Spanish moss, missionaries founded a settlement half a century before the pilgrims arrived. When archaeologists assembled there in 1980 to look for the site, no trace of the Spanish settlement remained. Historical records helped narrow the search, but the conventional methods for finding an ancient site—searching for potsherds or a telltale bulge of ground that might indicate a remnant of a wall—turned up no further clues. Because the island was so vast—about the size of Manhattan—sample trenches and test digs were considered hopeless. "It was just a swampy, godforsaken scrub forest," says one archaeologist. "It didn't look as though a human had ever been there."

Determined if not desperate, expedition leader David Hurst Thomas, of New York's Museum of Natural History, called in Ervan Garrison, a researcher and lecturer in civil engineering at Texas A&M and one of about a dozen United States experts in remote-sensing technology. These specialists probe the earth with rare and delicate equipment, searching for indications of ancient human activity. To prepare the site, Garrison mapped the terrain using a plastic tape measure stretched out between a grid coordinate system of stakes. He then crisscrossed the forest with a magnetometer, a cylindrical device about the size of



DENNIS O'BRIEN, AMNH

**A glass-bead necklace is unearthed next to a 5-cm scale.**

a coffee can that scans for magnetic anomalies in the subsurface terrain and graphs them with the aid of a microprocessor. In less than two weeks Garrison had located the settlement's barrel-like well, an outbuilding, and the ancient daub-walled church itself.

Just as X rays help doctors read beneath the body's surface, remote sensing assists archaeologists in determining what lies underneath a given terrain. Most archaeological sites are hidden six inches to five feet under the surface. The traditional method for turning them up—digging exploratory trenches—is a hit-or-miss process that can waste much time, labor, and money. With remote sensing, archaeologists can speed up the process and even find objects they never would have discovered otherwise.

The sensors range from magnetometers and electrical-resistivity probes to more complicated radar and sonar scanners. The essential function of all remote sensing is to detect incongruities. The devices work either by sending an electromagnetic or sound signal into the earth to map submerged features or by measuring a chemical or electrical feature that might be an indication of buried objects. Hidden objects show up in remote sensing only if they have properties that don't mesh with those of their environment. Such anomalies generally mean humans have been there.

Although remote sensing is still a novelty for some archaeologists, many of the instruments date back to World War II and earlier. A relatively impecunious science, archaeology has imported devices from more heavily endowed fields like defense, geophysics, and aerospace that share an interest in scouting concealed objects, be they enemy submarines, oil, or distant planets.

For all their potential, the devices are used in only about 10 percent of the digs in the United States and slightly more in Europe. It is typical that Thomas, for example, had never used remote sensing before the dig at St. Catherines and is uncertain when he will use it again. The instruments' popularity seems limited primarily because the majority of sites have ancient artifacts lying on the surface to guide diggers. In addition, the devices are expensive, ranging from $5,000 for the simplest magnetometer to 10 times that for ground-penetrating ra-

DENNIS O'BRIEN, AMERICAN MUSEUM OF NATURAL HISTORY

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**Following the plastic tape measure used to map the St. Catherines site, Deborah Mayer directs the sensor while Ervan Garrison records the magnetometer's readings (left). Their results helped locate the ancient site (right).**

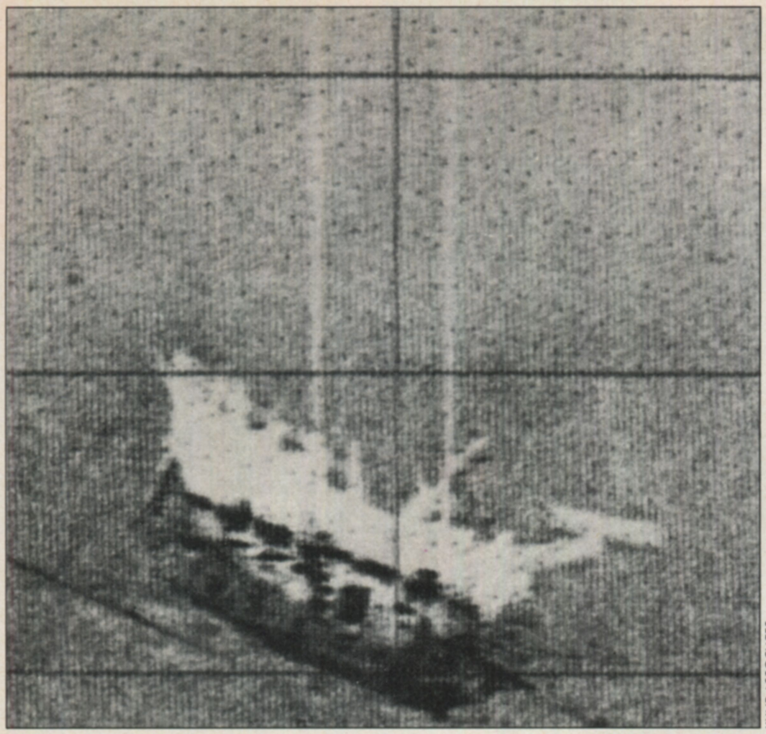
dar—a prohibitive sum in a field where the average budget for a project is $70,000. Finally, the equipment is still somewhat unsophisticated. The magnetometer, for example, can miss objects that are screened by metal trash or magnetic rock. Radar images tend to be jumbled by echoes from objects of greater density than the surrounding material, such as a cannonball lying behind an ancient wall. Electrical-resistivity probes can mistake man-made anomalies for geological ones. So although the field is "bombarded" by new equipment, says Thomas, the Americans' reaction is to stick with what they know—old-fashioned "dirt archaeology."

Thomas, among others, nevertheless recognizes that the technological advances in remote sensing are tempting. "Archaeology is about the only science that destroys its own data," he explains. "So the less archaeology we do, the better." During excavation, material that might prove useful in dating the artifacts is displaced when the historical remains are removed. Remote sensing, on the other hand, allows archaeologists to dig more selectively. "If you'd dug a site a few decades ago," Thomas continues, "you wouldn't have thought to save the charcoal, but that's what we need now for carbon dating. Recently plant remains have assumed a new importance; next year it may be something else. It's to the point where we're almost afraid to throw out the dirt."

For now, archaeologists employ remote sensing primarily to investigate a wide area more quickly than they could with spade and trowel. Typically, this broad search is used to look for historical holdings buried in government lands or to search for artifacts before a large tract is developed. The Mormon church, for example, recently turned to Garrison when it was planning to build a visitors' center in Nauvoo, Illinois, on the site of an early-19th-century center. Church authorities wanted to be sure that the building wasn't constructed over buried religious artifacts. Although the building site was the size of a city block, Garrison scanned it all with a magnetometer in a number of days. He turned up a kiln and a couple of small houses but no significant religious relics that would stop the project.

In the late 1970s Richard Adams, an archaeologist now at the University of Texas at San Antonio, inventoried 50,000 square miles of Mayan lowlands in Guatemala in five days (although the data analysis took considerably longer) by flying over the region in a plane bearing a sophisticated sensing device called synthetic aperture radar. Originally developed by NASA's Jet Propulsion Laboratory to pierce Venus's perpetual vapor shroud, the long-range radar cut through the jungle's persistent cloud cover as well as the heavy forest undergrowth. Adams had hoped to turn up more ancient cities. Instead, he found a stretch of raised fields lined with canals that had been totally invisible—and unexpected. While the gray honeycomb pattern that emerged on the radar image plainly outlined Mayan fields dating back to the sixth century, Adams is unsure exactly what the radar picked up. He suspects the image could be traced to something as subtle as the variations in the height of the tree canopy rising out of the network of old fields.

Adams has also taken radar pictures from a Seasat satellite—essentially the oceanographic version of Landsat but better equipped and capable of terrestrial work. Shooting images of Mexico from 500 miles up, he found indications of a Mayan roadway running several miles through the jungle. "You get a better perspective from that height," Adams says, "so you can pick up the large-scale patterns of land modification—roads,


KLINE ASSOCIATES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**In this side-scanning sonar image of the wrecked USS *Hamilton,* the ship appears dark below its paler shadow. The image, made with an underwater scanner, was recorded on a graphic recorder (right).**

canals, crop fields."

Still, radar pictures only show hazy outlines that can be difficult to interpret. Ervan Garrison believes that in the future images will be clearer, and he points to the results from underwater work as evidence of what someday may be obtained underground. The limited visibility under the water and the expense of sending divers to the ocean bottom have compelled marine archaeologists to rely on remote sensing more routinely than their counterparts have done on land. Marty Klein, founder of a firm specializing in undersea search, has hunted John Paul Jones's famous battleship the *Bon Homme Richard*, a pair of ships abandoned by Columbus in Jamaica, and even the Loch Ness monster. For that purpose he used an imaging device called side-scanning sonar that can give a clear picture even in dark waters of ships—or monsters—lying on the ocean floor several hundred yards away. The device covers a wide swath of the seafloor, using a transducer to send down sound signals and record them when they bounce back. From a research vessel 290 feet above, Klein's scanner produced monochromatic shots showing the distinct outline of the hull and masts of the schooner *Hamilton* that sunk in a storm on Lake Ontario in the War of 1812.

The Japanese have developed a sonar system that bridges the gap between sea and land exploration—by penetrating the sediments lying on the ocean floor. Called the subbottom profiler, the instrument was used recently to sweep across the floor of the Sea of Japan for evidence of the Kublai Khan's two attempted armada invasions that were smashed in storms in the 13th century. To penetrate the sea bottom, the profiler fires off sonar impulses at frequencies lower than those of the side-scanner. Because sonar can only discern features larger than the wavelength of the sound used, such a system can identify few surface details of foreign materials.

The Japanese, however, have refined an experimental sonar instrument to distinguish the hardness of buried materials. Developed from a color sonar system designed to identify schools of fish, the instrument analyzes sound wavelengths to determine the relative hardness of objects, in much the same way a prism separates light into different colors. The harder substances such as metal or porcelain show up as bright red. The Japanese have used the device to locate a variety of armaments and sailing equipment that date back to the Mongolian invasions, including iron spearheads, copper nails, and stone anchors.

Garrison believes that eventually the equivalent of Klein's sonar images will be obtained underground either by radar or by acoustical holography. The latter uses sound waves to generate apparent 3-D images akin to the ones now produced in the air by laser. But solid ground offers greater signal-jumbling interference than air or water. Garrison suspects that what may be required is more accurate signal enhancement at the receiving end—elaborate microprocessing to eliminate background noise and echoes. "We need a system that can take the signal and remove the trash," he says. Unfortunately, since archaeologists require more precise images than the geologists who are likely to pay for such research, a trash-free image probably won't be available soon.

But even if it were, archaeologists are convinced they will still need to dig—if only to get their hands on the artifacts themselves and see the handiwork of ancient peoples close up. "That's just something about human nature," concludes Garrison. "We feel the need to touch, to make physical contact with the past."

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