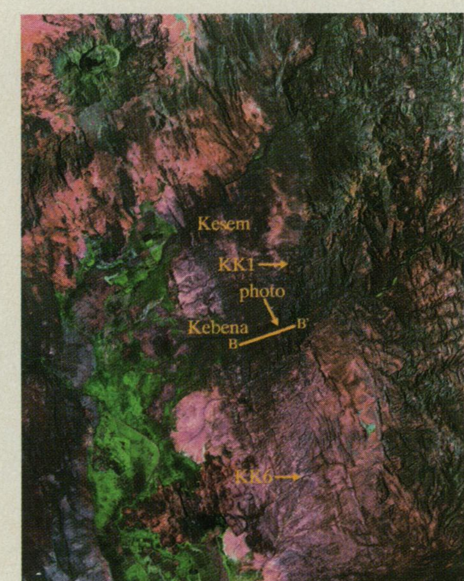
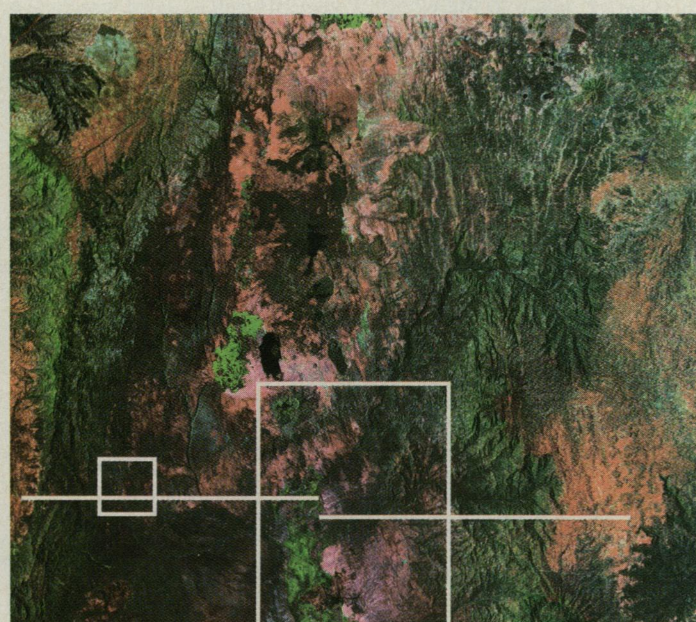
A "New Look" for Archeology

New high-tech methods for finding fossils from the air are becoming a standard part of the archeologist's tool kit—sometimes with dramatic results

John Fleagle of the State University of New York at Stony Brook just may be the first paleoanthropologist to find the remains of early human ancestors with the help of a spacecraft. Working in the Great Rift Valley of Ethiopia last fall, Fleagle's crew climbed atop an eroded bluff in the Fejej region and discovered fossil hominid teeth that are at least 3.7 million years old. The teeth, which are among the oldest remains of the species *Australopithecus afarensis*, are helping anthropologists pinpoint the age and distribution of that species, which was probably ancestral to humans and to several other hominids.



David Harding, NASA



Fossil reconnaissance: *Landsat image of northern main Ethiopian rift* (right) *shows two promising areas for hominid remains. The large rectangle corresponds to the image* (left) *of the Kesem-Kebena basin.*

Fleagle was guided to the spot by the Landsat satellite combined with good old-fashioned foot-slogging by a team that included Ethiopian paleoanthropologist Berhane Asfaw and UC Berkeley paleoanthropologist Tim White. Asfaw's team analyzed Landsat data to show that the little-explored Fejej was a likely place to look for fossils because the ancient sediments reflected light in a characteristic signature that set them apart from more modern terrain. "There's no question their survey work led us to our discoveries," says Fleagle, who discovered the teeth with a team of American and Ethiopian scientists who were urged to work in the area by Asfaw, of the Ethiopian Ministry of Culture and Sports Affairs. Asfaw and White had found so many fossil-rich areas in their spacecraft-aided survey that they were encouraging other scientists to begin exploring them last fall.

White adds that satellite data aren't a substitute for traditional archeological surveys but a sophisticated complement. "You're talking about a huge territory encompassing the fossil-rich regions of Ethiopia," he says. "So the satellite data are more a navigational tool that can help you turn enormous areas into manageable areas."

Navigational tools are not new in anthropology and archeology. Archeologists obviously can't dig everywhere, and so over the years they have used surveys to guide them, minimizing the amount of time, energy, and money spent in digging. Aerial photographs—taken from balloons and airplanes—have been used for such surveying for decades. But in the past 5 years a whole array of high-tech methods of surveying the landscape from satellites, the space shuttle, and airplanes has given archeology and paleoanthropology a boost. In some cases the results have been quite dramatic, including reinterpretations of the lifeways of entire cultures. In other cases—such as Fleagle's work—the payoff has been choice artifacts that wouldn't have been found otherwise.

"Advances over the past 6 years in the application of remote-sensing technology to archeological and anthropological research are in some ways astonishing," says James Wiseman, chairman of the department of anthropology at Boston University, who is now in Greece searching for remains of the 31 B.C. city of Nikopolis. "We seem to have come very far in a short period of time."

Current images from Landsat, the French SPOT satellite, and the space shuttle are much sharper than their predecessors, and new airborne instruments cover a far greater range of the electromagnetic spectrum. That's extremely useful in anthropology, because manmade features, such as ancient ruins, often emit infrared radiation (heat) at a different wavelength from the surrounding vegetation—and so airborne images can even be used to pick out traces of ancient cultures.

Technology isn't the only thing that's changing; attitudes are also in flux. Archeologists who were once skeptical of satellite observation because of its cost and complexity are now beginning to accept it as a standard method. That's a big change since the first attempts to use satellite data, in the early 1970s. Those efforts failed miserably, partly because the resolution was just too coarse. The original Landsat, launched in 1972, couldn't "see" objects less than 80 meters wide; today's commercially available satellite images distinguish objects 20 to 30 meters wide and aircraft images show objects smaller than 1 meter.

What's more, the original images were monochromatic, making them much less useful than today's four-color images because they contained far less information about energy emitted in different wavelengths. It wasn't until the early 1980s that the sensor technology improved sufficiently to start being useful—in part due to the work of NASA archeologist Tom Sever. Sever became frustrated with conventional ground survey methods as he trekked through the highlands of Peru trying to trace an ancient astronomical system. "It was just too slow," recalls Sever. "We walked for weeks looking for these astronomical calendric lines across the Andes Mountains. At the end of that time, all we had to show for our work were emaciated physiques."

So Sever joined a group of remote-sensing specialists at the NASA Stennis Space Center in Mississippi who were leaders in the development and testing of a variety of cameras and other sensors flown on low- and high-flying airplanes, blimps, balloons, and orbiting satellites. Those instruments can see beyond the optical part of the spectrum to scan energy waves emitted in the infrared and radio bands. One of the most sensitive of the new devices is the Thermal Infrared Multispectral Scanner (TIMS), which can measure thermal radiation given off by the ground. TIMS can distinguish forested areas that reflect heat differently from less densely vegetated regions, and may even be able to distinguish the wavelength emitted from one species of tree (the Ramon) that is often associated with Mayan ruins. Another instrument that's becoming a favorite of archeologists is the Calibrated Airborne Multispectral Scanner (CAMS), a 9-channel instrument that scans the visible and near infrared.

These tools allowed Sever and University of Colorado anthropologist Payson Sheets to overcome daunting obstacles such as rain and dense cloud cover to peer beneath a 150-foot rain forest canopy in Costa Rica. They found ancient footpaths created by prehistoric people near Lake Arenal more than 1000 years ago (with some dating back as far as 3000 years). These forest paths, which are only about a half-meter wide, linked villages, cemeteries, and springs. "The features we're detecting are not much larger than a foot, and invisible to the human eye," says Sever. (Although the sensors cannot actually detect objects 1 meter wide, they detected damage zones about 3 meters wide that are associated with the narrower paths.) Those findings are now changing theories about the lives of the Arenal, who previously were thought to have lived outside the forest.

Other remote-sensing studies of the range and subsistence strategies of ancient and modern people in the Amazon, Africa, and North America are also improving anthropologists' understanding of how these cultures used the environment and interacted with their neighbors. Indiana University anthropologist Emilio Moran has just won two National Science Foundation grants to use satellite data to study how current Amazonian tribes' agricultural practices affect regrowth of the tropical forest.

Tom Sever, NASA

Prehistoric sites. *Digitized topographic map shows where Arenal people lived in Costa Rica 1000 years ago.*

Across the Atlantic, Wiseman is hoping for similar insights as his team surveys the site of Nikopolis in Greece, the city built to commemorate Octavian Caesar's victory over Anthony and Cleopatra at the Battle of Actium. "We know where the ancient city is, but it would take centuries to excavate it," says Wiseman. As a result, his team has consulted French SPOT satellite data, as well as multispectral aerial photos taken from a tethered blimp, to help them rank priorities for buildings and areas that need further study and excavation—data will save time and give them a broader view of the buildings, roadways, and other structures in the walled city and its suburbs, which are now threatened by development.

While much of the work in the past 6 years has been to study the scars left on the landscape by ancient civilizations—particularly those in the Americas—Asfaw and White are applying remote-sensing methods to much older periods. They have been surveying the entire territory of Ethiopia in search of remnants of ancient landscapes—rocks and sediments from 1 million to 4 million years ago, when several species of hominids roamed the region. The task is daunting: Although Ethiopia is recognized as one of the richest areas for the study of early human origins and evolution, far less is known about its vast, arid landscape than is known about Kenya and Tanzania.

To get a handle on the problem, White began a collaboration with geophysicists at NASA's Goddard Space Flight Center who were studying Landsat images of the Great Rift Valley to understand how the rifts formed. They agreed to share several of these images with White and Asfaw in exchange for on-the-ground help in surveying geologic features in Ethiopia. Working with NASA scientists Cynthia Ebinger and David Harding, Asfaw's team looked for the signature of eroded sediments—which were recognizable in Landsat scenes as highly reflective gray patches.

Then, using both the Landsat images and photos taken by aircraft and the space shuttle's Large Format Camera, they studied the faults and drainage patterns to predict which regions had the right kind of geologic structure to contain fossil beds. By the process of elimination, they were able to zoom in on several regions that warranted further exploration on foot. On the basis of previous knowledge, the results were surprising.

Although one region—Fejej—was an obvious choice because it was a northern extension of rich fossil beds in Kenya, another region in a remote part of mid-eastern Ethiopia was a surprise. This area, known as the Kesem-Kebena basin, was "completely unknown paleoanthropologically," says White. Yet because the satellite data were so promising the team explored the site on foot and found a remarkably rich sequence of ancient sediments. White rattles off potassium-argon dates for rocks in one 45 kilometer by 5 kilometer area— 3.76 million years and 2.23 million years, with fossils associated with them, and a segment interlaced with volcanic layers dated to 1.04 million years and 1 million years—with handaxes and fossils sandwiched between them. These are all times when hominids were evolving, including the *Homo* line that led to humans.

In spite of these successes, there's still some skepticism about these high-tech techniques. "There has been a slowness by a majority of our colleagues to recognize the value of the methodology, or that it can affect theoretical concepts," Wiseman said at the NASA meeting last November. Complaints include cost, which went up with the privatization of Landsat (images cost $3,000 to $4,000), and the difficulty of analyzing the digitized data, which originally required state-of-the-art computers. Others worry that remote sensing will take them out of the field and into the lab, where they will be increasingly remote from their subjects.

But the situation is improving. The price of equipment is going down as the Japanese and Europeans leap into the market to develop sensors and cameras, says Sever, who shares NASA's technology with 15 to 20 researchers. And archeologists are collaborating to share costs—centers specializing in remote sensing have opened at the University of Colorado at Boulder and Boston University; the Boston center has a special emphasis on archeology. Personal computers and new software have made it relatively easy to process the data.

Prospects also are good for even better space-based systems. NASA is including anthropologists in its plans for future space platforms, including the proposed Earth Observing System (EOS). Improved remote sensors raise all sorts of intriguing possibilities, including the ability to track demographic, environmental, and agricultural changes. "I think it's going to become, not obligatory, but the most promising technique to come along in a while," says Moran. "It will connect our very precise micro-level work and let us extrapolate it to larger, regional scales. That will make anthropology more accessible to global issues."

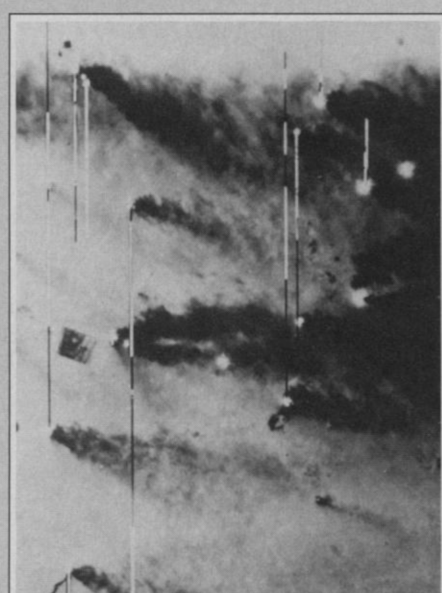
Finally, those who use remote sensing say that the specter of remote-control archeological digs is still, well, remote. Says White: "You're never going to be able to sit in the lab and say, 'There's a skeleton.' "

■ **ANN GIBBONS**

Remote Sensing in War's Aftermath

High-tech images made from satellites and airplanes are playing a bigger and bigger part in examining ancient cultures and environments. But that's obviously only part of what remote sensing can do. The same techniques—and in some cases the same researchers—are also are playing a key role in analyzing the environmental changes that are making today's headlines.

Take the aftermath of the Gulf war. Farouk El-Baz, director of the Center for Remote Sensing at Boston University, where most of the research is in archeology, has been using an array of satellite instruments to monitor the staggering environmental problems caused by the war. Last week he returned from a month-long trip to six Gulf states where he found that even the high-tech images from Landsat, NOAA 10 and 11, and the European Metosat—precise as they are—hadn't conveyed the true horror of the situation: "I was prepared for the worst, but the damage far exceeds anything I could imagine," says the Egyptian-born geologist, who was invited to survey the region by the Third World Academy of Sciences.



Farouk El-Baz, Boston University

Aerosol spray. *Dark clouds from fires in Kuwait, shown in a Landsat satellite image, may contain large amounts of oil mist in addition to soot and gas.*

In Kuwait, El-Baz says he was appalled to find that the huge cloud spreading from hundreds of oil fires contains far more crude oil than he had expected. "The one thing that stands out like crazy is the fact that the oil is jetted out of the wellheads in an aerosol form and streams of droplets are carried on the wind," says El-Baz. "It's really an oil fog. You'll be standing there for 15 minutes and you'll find crude oil on your shirt." When he saw it dripping from date palm leaves, he predicted that the oily cloud will have a destructive impact on agricultural plants—perhaps as far away as India, where the particulates and "oil rain" have already been detected in the Himalayas.

What worries El-Baz most, however, is where that black cloud is moving. The seasonal "shemal" winds that blow from the north starting at the end of May will blast that cloud southwest toward the relatively populous areas of Bahrain, Qatar, Saudi Arabia, and the United Arab Emirates. El-Baz has entered into a research agreement with the University of the United Arab Emirates to monitor the impact of the cloud; he plans to use satellite images to compare the environmental changes in the area before and after the war.

El-Baz isn't alone in his work. A team of 30 atmospheric scientists coordinated by the NSF left for the Gulf last week. That group is also studying the cloud, using remote-sensing instruments and direct sampling methods aboard two aircraft. They are concerned that the cloud will disturb weather patterns in the region, interfering with the summer monsoon and normal seasonal rainfall, says Richard Greenfield, a meteorologist who is coordinator of the mission for the National Science Foundation.

The satellite images are also offering El-Baz a way to observe and analyze the oil slicks in the Gulf that have been moving relentlessly toward the Saudi coast—and that's where concerns about the past and present come together. Although the oil slick hasn't clogged the desalinization plants at Jubail, Saudi Arabia, the Saudis may now have a new environmental problem. They stored the thick oily water in huge pools dug into the sand, where they could become a threat to groundwater supplies.

And the same oil slick—in the form of oil lapping onto beaches in the region—is threatening the last traces of the pre-Islamic Dilman civilization that flourished in the northern Gulf region. Although little is known about them, their burial mounds, with potsherds and other artifacts, have been found throughout the Gulf coast. But now they will be difficult to excavate because their stratigraphy has been damaged by oil and by trenches dug by soldiers.

The combined damage to land and sea, past and present, leads El-Baz to one depressing conclusion: "All in all, this is the mother of all environmental disasters." ■ **A.G.**