ERTS (II): A New Way of Viewing the Earth

Less than three-quarters of the earth's habitable land has been mapped in detail, and at least a third of the maps that have been prepared are already out of date. Accurate crop censuses are available only in limited areas, and most of these are weeks or months out of date; censuses of other vegetation are practically nonexistent. Mineral deposits, geothermal power sources, and underground reserves of fresh water have only begun to be identified. Man's knowledge of his planet, in short, is fragmentary and superficial.

That situation is changing rapidly, however. On Sunday morning, 23 July 1972, the National Aeronautics and Space Administration launched the first Earth Resources Technology Satellite (ERTS), whose mission is to demonstrate that these resources can be surveyed inexpensively from space. Preliminary results indicate that it is performing that mission far more successfully than had been anticipated. ERTS has shown its capability not only for cataloging natural resources, but also for such disparate activities as monitoring air and water pollution, charting land use, and monitoring crop damage caused by pests and disease.

Most of ERTS' capabilities arise from its pair of imaging systems, the Return Beam Vidicon (RBV) and the Multispectral Scanner (MSS). Orbiting the earth in a circular path 914 kilometers above sea level, these systems photograph 185-km-wide strips of the earth's surface in three bands of the visible spectrum and one in the near-infrared (*Science*, 6 April, page 49). The satellite's orbit offers the opportunity of imaging virtually the entire earth's surface once every 18 days, thereby providing systematic, repetitive global land coverage under conditions of maximum consistency.

Transmitted imagery from the satellite is processed into photographs at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and distributed to the 206 U.S. and 106 foreign principal investigators who are working with NASA to assess the utility of remote sensing in specific applications. Last month, most of these investigators gathered near Goddard to discuss ERTS' first half year of operation and to report their initial findings. Those findings encompassed a multitude of subject areas and individual topics, but perhaps some of the most interesting and significant results were in the areas of geology, environmental monitoring, and agriculture and land use.

A wide variety of information is available from any one ERTS image or series of images. Marion F. Baumgardner of Purdue University, West Lafayette, Indiana, for example, studied a 31,000-km^2 test site near Lubbock, Texas. Using computer scanning of ERTS images, he found that his group could map and measure crops, other vegetation, damaged crops, and gross soil patterns with an accuracy of at least 90 percent. Surface features he found easily identifiable in the ERTS images included row crops, unimproved and improved rangelands, bare soil, playas, rivers and streams, ground water recharge, and such crops as winter wheat, corn, and soybeans.

Toward a World Food Inventory

Other investigators have identified a wide variety of crops from ERTS images. Charles E. Poulton of the Earth Satellite Corporation, Berkeley, California, and Arthur J. McNair of Cornell University, Ithaca, New York, have separately obtained spectral signatures for the world's most important food crop, rice, under many different conditions in both the wet and dry growing seasons. Working with reconstituted false-color photographs, Poulton has also found within-field color variations that he hopes to link to crop yield and production. The availability of this information is a major step in preparing the first worldwide inventory of food resources.

ERTS images have also shown great potential for monitoring plant health and identifying potentially hazardous situations. Cotton fields in some areas of California, for example, have been heavily infested with a pink cotton bollworm that can be controlled in part by plowing cotton plants under the ground after harvesting so that emerging larvae will have no food. Virginia B. Coleman of the University of California, Riverside, has found that repetitive ERTS imagery can be used to distinguish between healthy and infested cotton fields and to ensure that infested fields have been plowed under. Forests and vegetation infested with other pests or infected with plant diseases have also been identified in other areas.

The ability to distinguish between healthy and dead or dying vegetation in ERTS images provides a new way to assess hazards from fires, says Robert N. Colwell of the University of California, Berkeley. Photographs of the Oakland-Berkeley area, he notes, show clearly the more than 1200 hectares of eucalyptus trees that were destroyed by a 9-day period of freezing weather in December 1972. They also reveal that the current rainy season is producing a record growth of grass vegetation on the range and park lands intermingled with the eucalyptus forests. This grass will dry out next summer and, in combination with the dead trees, present a tremendous fire hazard to homes in the area. Armed with data from ERTS and ground surveys, area officials are seeking more than $4 million in federal and state disaster aid loans to reduce the fire hazard.

The line that separates agricultural and environmental monitoring is a fine one, and many applications could be placed in either category. Brian Gilbertson of Spectral Africa (Pty.) Limited, at Randfontein in the Republic of South Africa, for example, is using satellite images to monitor the health and growth of vegetation planted to curtail environmental pollution from mine tailings dumps. J. M. Wightman of the Canadian Forestry Service, Ottawa, Ontario, has found that the images can be used for detection and mapping of areas destroyed by forest and grass fires; in some cases, the rate of spread of the fire can also be determined.

ERTS imagery should also prove valuable for monitoring such environmentally disruptive activities as strip mining. Charles E. Wier of the Indiana Geological Survey, Bloomington, has made a preliminary study of Warrick and Pike counties in that state and has found that an area of 26 km^2 has been mined since the last ground survey in 1968—bringing the total mined area in the two counties to 216 km^2. Disturbed areas smaller than 2 hectares could not be mapped, but Wier suggests that increments to the larger areas could be mapped at regular intervals in less than

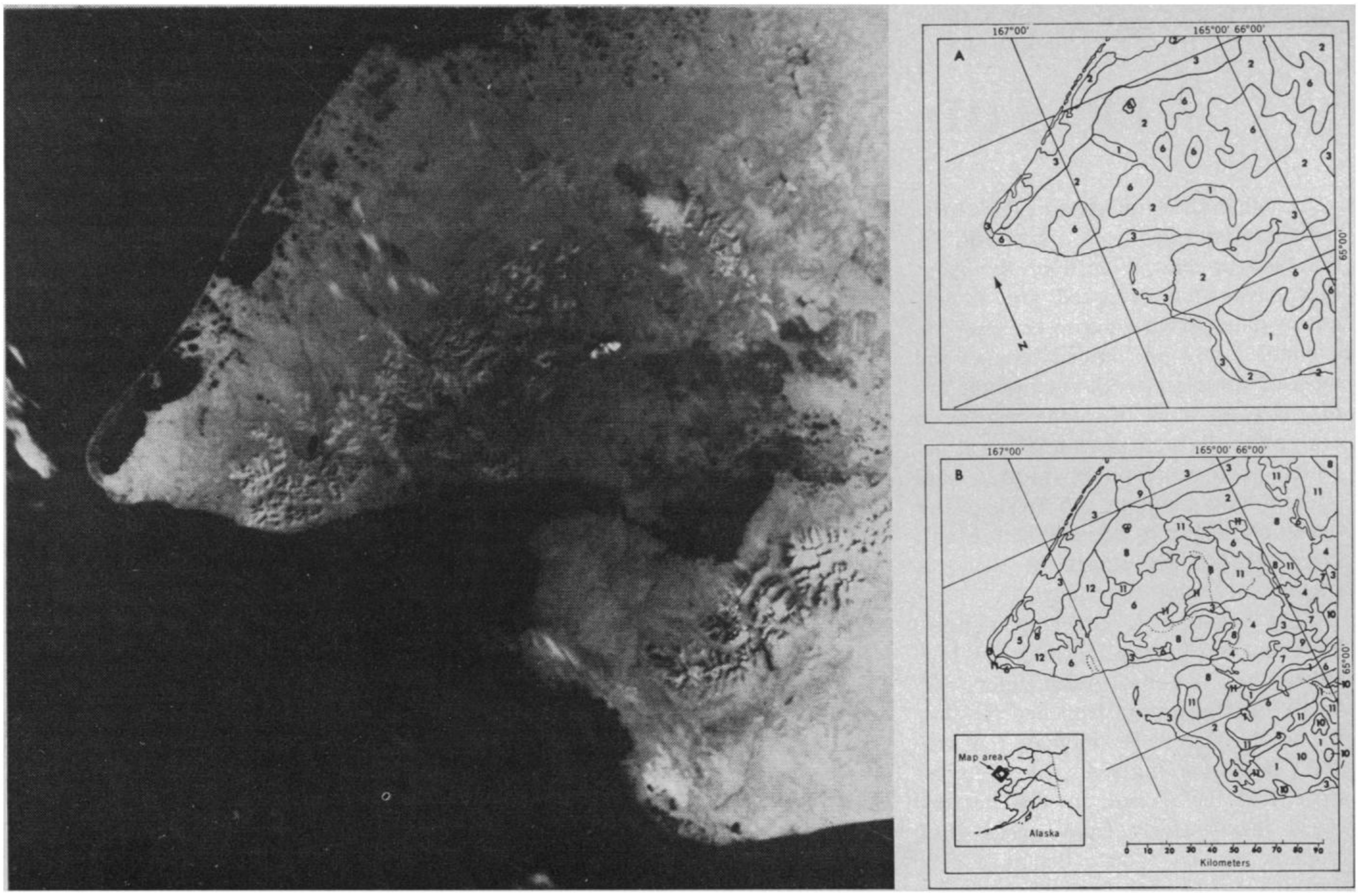

Fig. 1. An MSS image of Alaska's Seward Peninsula and two vegetation maps of the same area. The top map was prepared over a period of many weeks from ground surveys and aircraft photographs, and shows four distinct types of vegetation. The lower map was prepared in 3 days from the ERTS image and shows seven distinct vegetation types and several combinations of types. The numbered areas represent; (1) shrub thicket; (2) upland tundra; (3) wet tundra; (4) fire scar; (5) senescent vegetation; (6) alpine barrens; (7) grassland tundra; (8) shrub thicket and upland tundra; (9) shrub thicket and wet tundra; (10) shrub thicket and alpine barrens; (11) shrub thicket, upland tundra, and alpine barrens; and (12) upland tundra with some senescent vegetation. [Courtesy of James H. Anderson, University of Alaska, Fairbanks, and National Aeronautics and Space Administration]

an hour by ERTS, whereas each ground survey requires many man-weeks.

Wayne Pettyjohn of Ohio State University, Columbus, and D. P. Gold of Pennsylvania State University, University Park, have mapped strip-mined areas in their own states with ERTS images. Their results indicate that the satellite can also be used to monitor pollution abatement procedures at the mines and reclamation of the disturbed areas. This type of monitoring could prove very valuable if strong federal legislation regulating strip mining is enacted.

Enforcement of other environmental laws is also made easier with ERTS. G. E. Copeland and his associates at Old Dominion University, Norfolk, Virginia, have found that they can observe particulate emissions from some 10,000 smoke stacks in that state. By mapping the locations of these sites, some of which were not known to pollution control authorities, they are then able to observe new stationary emission sources, as well as such unauthorized sources as fires at construction sites. By incorporating meteorological, air quality, and emission concentration data obtained on the ground into their study, they also hope to develop techniques for monitoring stack emission rates using only ERTS imagery.

Water pollution can also be monitored effectively. Algal blooms in eutrophied lakes, for example, show up quite clearly in false-color photographs. Suspended sediment and turbulence in rivers and lakes are also readily observed and, in many cases, effluent from large plants is visible. In one image examined by Aulis O. Lind of the University of Vermont, Burlington, effluent from an International Paper Corporation mill north of Fort Ticonderoga, New York, can be seen entering Lake Champlain and crossing to the Vermont shore. This photograph may be used as evidence in a court suit that Vermont has filed against New York in an effort to halt the discharge. The photograph is not crucial to the case, which is supported by much other evidence, but its introduction could establish a precedent for use of such images in other cases.

Potentially the most financially rewarding—and the most controversial—use of ERTS data, however, is in geological mapping. Major geological features such as linear fracture traces, faults, and boundaries (classified in general terms as lineaments) are readily discernible in ERTS images, even though many are so masked by other surface features or are so large in scale that they are not recognized from the ground or from low-altitude aircraft. Identification of these features is especially valuable because major deposits of minerals and fossil fuels are generally found along such lineaments, and especially at their intersections. Areas of seismic activity are also associated with the lineaments.

Yngvar W. Isachsen and his associates at the New York State Museum and Science Service, Albany, have used ERTS imagery to map more than 500 km of previously unknown lineaments

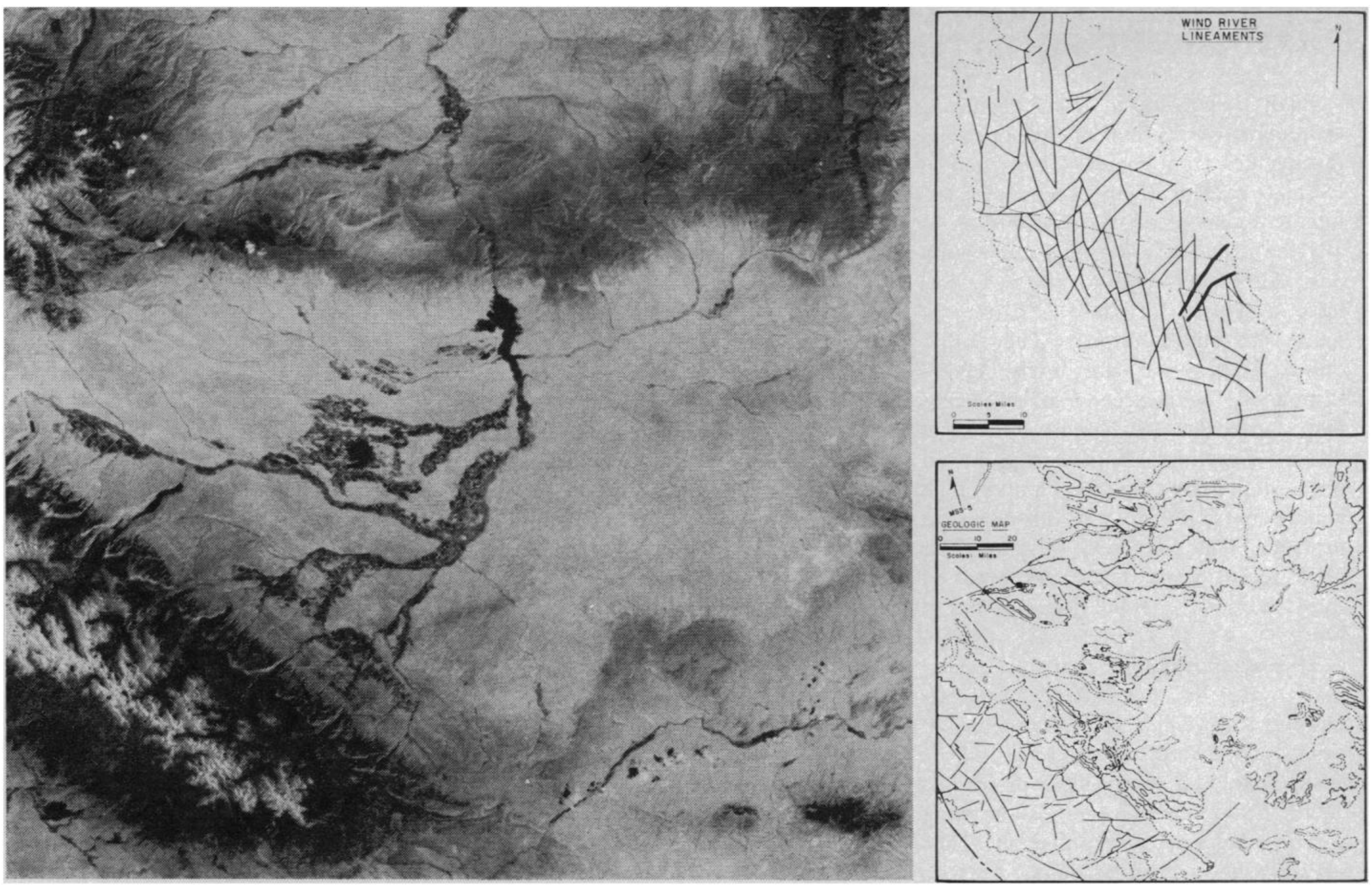

Fig. 2. An MSS-5 image of the Wind River Basin of central Wyoming and two geological maps prepared from the image. The top map shows the major fractures of the Wind River Mountains (lower left corner of image); the lower one is a geological map of the entire area in the image, showing contacts, faults, and unconformities. These maps were prepared in hours, compared to the months or years that would have been necessary if ground surveys had been used. The Bighorn Mountains are visible at the upper right; the Absaroka Mountains, at the upper left. The Bighorn River flows south through the Owl Creek Mountains in the upper center into the Boysen Reservoir. The patchy areas at the center and left center are irrigated farmland along the Wind River and its tributaries. [Courtesy of National Aeronautics and Space Administration]

in New York. Ernest H. Lathram of the U.S. Geological Survey, Washington, D.C., has identified several areas of extensive fracturing in Alaska that may be correlated with mineral deposits. A previously unobserved, large east-trending lineament in Alaska's Arctic Coastal Plain, for example, has great potential for petroleum exploration, as does a strongly lineated area north of a shallow oilfield at Umiat. Close examination of the ERTS imagery, he adds, reveals no traces of environmental damage caused by the extensive petroleum exploration of the last 20 years. James H. Anderson of the University of Alaska, Fairbanks, has also identified an unmapped radial drainage pattern, about 7 km in diameter, in Alaska's Seward Peninsula. This pattern suggests the presence of tin deposits.

ERTS images are also providing much new data about seismic activity. Monem Abdel-Gawad of the North American Rockwell Science Center, Thousand Oaks, California, plotted the epicenters of historic earthquakes in California, Nevada, and Mexico, and found that many of the epicenters are located on previously unrecognized major faults. He has also identified several fault zones transverse to California's San Andreas fault that may mark the presence of mercury deposits. Larry Gedney of the University of Alaska, Fairbanks, has identified one newly discovered fault that appears to intersect the proposed site where a bridge and the trans-Alaska oil pipeline will cross the Yukon River.

The identification of potential mineral deposits by satellite has raised the specter of economic imperialism and exploitation of undeveloped countries. Environmentalists and representatives from some of these countries have voiced fears that the wide availability of the ERTS data will allow multinational corporations to acquire mineral deposits before the countries are aware of their existence. But Leonard Jaffe of NASA argues that the ERTS images only indicate the more favorable sites for ground exploration, and access to these sites is more easily controlled by the countries' governments. In any case, NASA claims it has scrupulously informed such countries of any promising areas as soon as they are discovered, so the point may be moot.

The results cited here are but a small sampling of the great amount of new information derived from ERTS and of the uses made of it. Cartographers, for example, have used ERTS images to update old maps and to prepare new ones for areas to which there is limited access. Environmentalists have prepared land-use maps of several U.S. cities and at least four states, preparing in hours maps that formerly took months or years of work. Hydrologists have used ERTS imagery to locate new sources of fresh ground water. Oceanographers are using ERTS to locate underwater features that might be hazardous to navigation and to develop new techniques for assessing fishery resources. But even with all of these applications, the potential of ERTS has just barely begun to be tapped, and the benefits derived from its use may soon themselves become unmeasurable.

—THOMAS H. MAUGH II