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APPLICATIONS OF AIRCRAFT AND SPACECRAFT SURVEYS TO GROUND WATER INVESTIGATIONS

By
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The U.S. Geological Survey is mounting an active program to assess, on a regional basis, the total potential contribution of ground water to the water budget.

Concurrently, the Geological Survey is pushing forward with its EROS (Earth Resources Observation Satellite) Program; a program for utilizing remote sensor data, from both aircraft and spacecraft, for resources purposes. It is believed that the EROS Program will help significantly in achieving the ground-water assessment.

This paper is intended to:

1) Describe the remote sensor system that the Department of the Interior has asked NASA to place in orbit for earth resources observation purposes and to evaluate the potential contributions of data from this system to ground-water studies; and

2) Describe some of the newer aircraft and/or spacecraft remote sensor systems and speculate on their potential value in achieving understanding of regional ground-water regimes.

The Interior Department has asked NASA to place a television system in orbit to provide repetitive images of the United States in the visible and solar infrared parts of the spectrum. (Fig. 1)

Three cameras are to be employed: Camera #1 imaging in the blue/green part of the visible spectrum to provide information on the size and shape of features (landform), including subaqueous features; Camera #2 imaging in the solar infrared to provide information on the distribution of water and vegetation and the vigor of vegetation; Camera #3 images in the red and was added at the request of the Department of Agriculture, to aid in crop identification. The satellite may also carry a communications package to interrogate ground-based sensors, such as stream gages. It is believed that this system will provide several types of information of significance in ground-water studies; these will include:

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1) Improved knowledge of geologic structure. Every Gemini photograph that has been studied in depth has revealed previously unknown structures. Some of these structures, such as a major linear feature (presumably a fault) in Peru, have obvious bearing upon ground-water distribution.

2) Up-to-date inventories of surface water to aid in assessing the ground-water contribution from and to surface-water bodies.

Mr. R. F. Brown of the Geological Survey (written communication, 1968) comments that there are believed to be approximately 30,000 playa lakes in the southern High Plains areas of Texas, many of which may contribute to the ground-water supply. Of these lakes perhaps one-fourth are shown on current topographic maps; all would be visible on ultra-high-altitude photography.

Stage of the playa lakes represents available water stored in them at any one time. Estimates for the region for an average year range from 1.8 to 5.5 million acre-feet. This wide range bespeaks the inadequacy of present survey methods.

3) Near-surface ground-water distribution as expressed by vegetation vigor.

Moist areas or areas of spring discharge are readily, but not unambiguously, recognizable on images of the type we propose to acquire from space. Spillover from stock ponds, for example, has an effect on the vegetation that is similar to that created by a spring. Nonetheless, on a regional basis, it is believed to be possible to map the distribution of areas wherein the water table is close to the surface, and that this information will help in understanding regional ground-water dynamics.

4) Long-range changes in the ecology of areas. Ecological changes may occur as a result of changes in level of water table; with time and repetitive coverage, interpretable and predictable relationships between changes in water table and ecology may perhaps be established.

5) Up-to-date maps of scales of 1/250,000 and smaller that will be valuable for planning total regional water systems and analyzing the relationships of these systems to those of other regions.

6) Relative "drying rates" of rocks and soils in an areal context. The distribution of surface moisture may be observed with a number of remote sensing systems. By observing relative "dryness" through time, we may be able to improve our understanding of recharge characteristics in an areal context.

These and other types of remote sensor information may be obtained from either aircraft or spacecraft. It appears, however, that they can be most advantageously and economically acquired from orbit. Images acquired from space can cover 1000 times the area of conventional aerial photographs, thus greatly reducing the bulk of data. 'Space images' are near-orthographic and, therefore, are easily converted to map form, and they are more uniform than 'aircraft images', and hence easier to interpret. It is these unique qualities of 'space data' coupled with the great need for up-to-date surveys that led Secretary Udall in September 1967 to declare the potential of 'space data' for improving our resources posture.

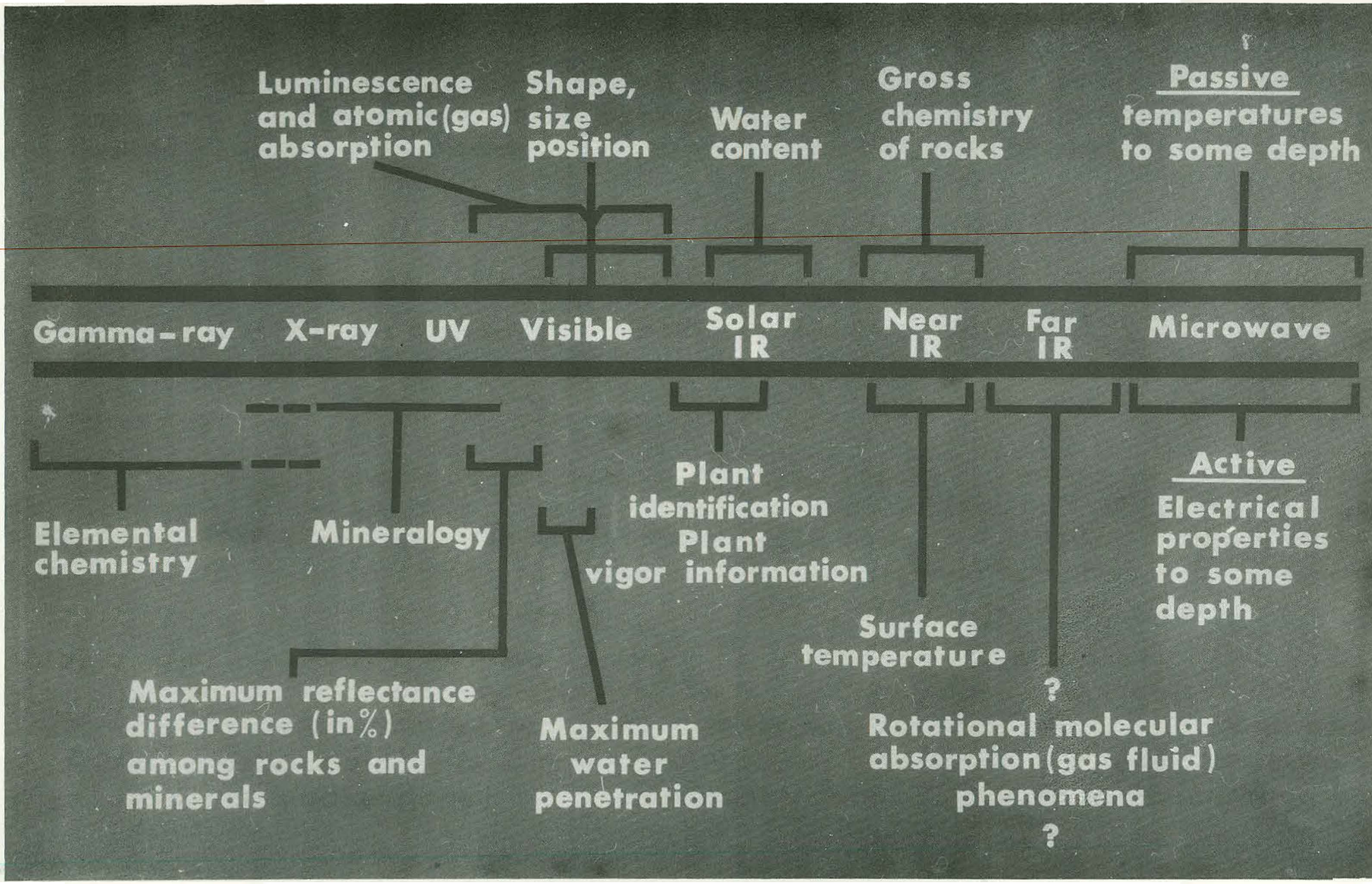
We do not claim, however, that an initial, relatively simple space system such as we have proposed will meet all resources needs or exhaust the economic and scientific potential of space as an "observation platform" for earth study. Accordingly, continuing research into the applications of newer, more sophisticated "remote sensors" is proceeding cooperatively by the Departments of Interior and Agriculture, NASA, and other organizations. At the present time emphasis is being placed on the applications of near-infrared sensors, ultraviolet-stimulated luminescence detectors, and active radar imaging devices (Fig. 1).

Infrared imaging devices have been successfully used to (1) image the influx of ground water into streams; (2) depict distributions of both cool and warm water issuing from the ground in Yellowstone Park; (3) image the movement of the fresh/salt water interface through time, and (4) map more than 200 fresh-water springs issuing into the ocean from the shores of the island of Hawaii. Of perhaps most significance, however, is the demonstrated use of infrared systems to detect faults or fractures that affect the movement of ground water.

Ultraviolet-stimulated luminescence "mappers" have succeeded in detecting rhodamine B dye in quantities of as little as 3 parts per billion. This system, soon to be tested in aircraft, will first be applied to problems of dynamics of lakes and estuaries. It is not impossible that a system of this type, in aircraft, could be used to "trace" ground water into open water areas, through the use of appropriate fluorescent markers.

Radar has been of most help, to date, by aiding in delineation of faults and fractures, mapping of geomorphic units, and classifying surfaces in terms of relative roughness. All these factors, of course, aid in understanding the recharge characteristics of given areas. As longer wavelength radars come into use, it is possible that they may provide a means of imaging near-surface electrical discontinuties, including moist rock or soil.

Other sensors, such as passive microwave spectrometers and imagers, are currently being evaluated. These sensors all have theoretical application to ground-water studies, but in most cases these applications remain to be demonstrated.



Luminescence and atomic (gas) absorption
Shape, size position
Water content
Gross chemistry of rocks
Passive
temperatures to some depth
Gamma-ray
X-ray
UV
Visible
Solar IR
Near IR
Far IR
Microwave
Elemental chemistry
Mineralogy
Plant identification
Plant vigor information
Active
Electrical properties to some depth
Surface temperature
Maximum reflectance difference (in %) among rocks and minerals
Maximum water penetration
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Rotational molecular absorption (gas fluid) phenomena
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