RECENT ADVANCES IN GEOLOGICAL REMOTE SENSING OF THE EARTH. Mark Settle and James V. Taranik, Office of Space Science and Applications, NASA Headquarters, Washington, DC 20546

Geological remote sensing research is primarily concerned with determining what types of useful geological information can be extracted from remotely sensed data. Measurement techniques currently under development include electromagnetic remote sensing methods that obtain measurements of reflected solar radiation in the visible, near infrared, and shortwave infrared (0.4-2.5 um wavelength region); emitted thermal radiation in the thermal infrared (8-14 um region); and reflected microwave radiation at radar wavelengths (1-30 cm region). Potential field mapping methods are being developed to determine global variations in the earth's gravity and magnetic fields. Analysis of data obtained by these measurement techniques provides information concerning: (1) rock type which generally refers to the lithology and chemical composition of geological materials, (2) geobotanical correlations which involve relationships between the distribution, density, and/or vigor of vegetative species and the geological characteristics of substrate materials, (3) surface topography which provides insight into the lithology and structure of geological formations at or near the earth's surface, and (4) subsurface structure related to major discontinuities (e.g. fault planes, intrusive contracts, unconformities) in the distribution of geological materials at depth.

Visible-Near Infrared-Shortwave Infrared. Laboratory measurements of the reflectance properties of geological materials indicate that many minerals and rocks posses diagnostic spectral obsorption characteristics. Orbital measurements of reflected solar radiation can, in principle, be used to detect these spectral features and thus identify specific mineral assemblages exposed on the ground. In practice, our ability to identify particular rock types on the basis of orbital multispectral measurements is hampered by atmospheric effects (scattering and absorption) and sensor system characteristics (gain and bias in each spectral channel, stability of internal calibration mechanisms, digitization errors, etc.). Abrams(1), Lang(2), and Conel(3) have recently employed in situ field measurements of surface reflectance to empirically calibrate aircraft scanner data. Ground based reflectance measurements obtained over large, homogeneous surface units have been used to develop a series of linear equations which relate airborne measurements of spectral radiance to the absolute reflectance of surficial materials. Qualitative evaluation of multispectral imagery produced by this method indicates some improvement in rock type discrimination capabilities. Parallel research on the use of multiple, narrowband spectral measurements in the shortwave infrared is being pursued by Collins(4). Collins has developed an airborne radiometer with a spectral resolution of 8.6 nm at wavelengths of 2.0-2.5 um and a ground resolution of 20m square. Analysis of data acquired over a series of test sites situated in western Nevada has indicated that narrowband measurements in this spectral region are sensitive to subtle differences in clay mineral assemblages (e.g. alunite - kaolinite - montmorillonite) and also can be used to discriminate between siliceous and calcareous rock types.

Thermal Infrared. Recent research in the thermal infrared has concentrated upon analysis and interpretation of data acquired by the Heat Capacity Mapping Mission (HCMM). The HCMM sensor obtained diurnal measurements of thermal radiance over a spectral band of 10.5-12.5 m with a spatial resolution (pixel size) of 600 m square. HCMM ground tracks crossed at mid-latitudes in the northern hemisphere at roughly 1:30 PM and 2:30 AM local time. Temporal differences in apparent surface temperature can be used to estimate areal variations in apparent thermal inertia. Watson and co-workers(5) have iden-

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tified a series of photogeologic lineaments on enhance HCMM imagery that had not been previously recognized. The discovery of one such lineament in the Powder River Basin of Wyoming was subsequently shown to coincide with areas of helium leakage believed to be associated with hydrocarbon reservoirs at depth. Hayden and coworkers(6) developed a stereographic projection of daytime and nighttime HCMM infrared imagery in which areas of large temperature difference appear as artifical topographic highs and areas of minimal thermal variation appear as lows. Co-registration of HCMM and Landsat imagery in the Harrisburg, PA area employing this method revealed the presence of thermal variations in Appalachian forests which may be correlated with the boundaries of known geologic units.

Microwave. Seasat synthetic aperture radar (SAR) imagery exists for most of the conterminus U.S. and Alaska. The Seasat SAR was an L-Band (23 cm wavelength) radar which illuminated the earth's surface at an angle roughly 20^{o} from vertical. Optically correlated Seasat imagery has a pixel resolution of 25 x 40 m, whereas digitally correlated imagery has a resolution of 25 x 25 m. Radar backscattering from natural surfaces is governed by the viewing geometry (relationship of surface azimuth and slope to sensor viewing azimuth and antenna depression angle), surface roughness, and the electrical properties of surficial materials. Brightness variations in SAR imagery are commonly dominated by slope effects which tend to obscure subtle variations in backscattering associated with the roughness and intrinsic electrical properties of surficial materials. Naraghi and co-workers(7) have developed a method of rectifying slope distortion effects in radar imagery by co-registering backscattering measurements to a digital topographic data base. This technique holds promise for eliminating brightness variations caused by local topographic relief and extracting information on roughness characteristics and electrical properties from SAR imagery. Daily(8) has developed a method of displaying Seasat imagery which makes use of spatial filtering techniques to differentiate between high and low frequency variations in image brightness. This method has been applied to imagery acquired over an area in West Texas of relatively low regional relief. A color display which merges the high and low frequency components of the original image has produced substantial improvement in delineating rock units and regional geological structures.

Magnetic Field Mapping. MAGSAT recently performed the first global survey of the earth's vector magnetic field. This satellite measured total (scalar) field strength to an accuracy of $\pm$ 3 gammas and three orthogonal field components to an accuracy of $\pm$ 6 gammas. Crustal magnetic anomalies in total field strength can be largely accounted for by variations in the radial field component (i.e. the strength of N-S an E-W crustal anomaly components is comparatively small). This observation and the geometric arrangement of anomaly components oriented in N-S, E-W, and radial directions have led investigators to tentatively conclude that large scale variations in crustal magnetism detected at orbital altitudes are caused by magnetic induction and not remanant magnetism.

REFERENCES

(1,2,3) Geosat Remote Sensing Workshop, Flagstaff, AZ, Nov. 1981; (4,5) IEEE, 1981 Intn'l Geoscience & Remote Sensing Symposium, Abs. Digest; (6) HCMM PI Final Rpt, GSFC 1982; (7) Photogram. Eng. & Remote Sensing, 1982; (8) IEEE Trans. Geosci. & Remote Sensing, 1982.

DATA AVAILABILITY

Landsat - EROS Data Center, User Services, Sioux Falls, SD 57198

HCMM and Magsat - National Space Science Data Center, Code 601, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

Seasat - Environmental Data and Information Service, World Weather Bldg. (Room 100), Washington, DC 20233

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