GEOLOGIC UTILITY OF IMPROVED ORBITAL MEASUREMENT CAPABILITIES IN REFERENCE TO NON-RENEWABLE RESOURCES

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The following is an abbreviated attempt at defining spectral and spatial characteristics for future orbital remote sensing systems. These conclusions are based on the past decade of experience in exploring for non-renewable resources with reference to data from ground, aircraft, and orbital systems. This turns out to be a difficult task in that the final decisions concerning discriminability of features and basic interpretability are really subjective decisions. In terms of spectral band selection, we have extensive laboratory spectroscopy data to point our decisions.

Spatial Resolution Requirements

Based on the experience of the Geosat test case program as well as the Aircraft Thematic Mapper Group Shoot, we have gained a good deal of experience in non-renewable resource areas using various scanner systems at various ground resolutions. Using the approximate thematic mapper bands as they will be seen on Landsat D as a spectral case, we can make comparisons from original 10 meter resolution data using the 24 channel scanner or thematic mapper simulator (NS001) up to any resolution simply by a pixel averaging method. For our discussion, we will use two principle areas of investigation. A structural interpretation in a basin area for hydrocarbon exploration, and a discrimination of altered areas in the Cuprite district in Nevada.

Hydrocarbon Basins

The first case is really a subjective decision based on examination of several basins using remote sensing data with ground resolutions of from 8 meters to 80 meters. There are obviously many variables involved in mapping structural elements which may or may not contribute to their identification. Lineaments in particular may be detected by any or all of several attributes including changes in slope, physical offset, changes in soil or rock material, changes in soil moisture, or changes in vegetation cover. Then correspondingly different scanners or radar systems more or less sensitive to these attributes will do a highly variable job in discriminating them. Fortunately, there seems to be a basic ability of the eye-mind system to integrate pixel displays into a smooth image, which based on the general scale of intra basin lineaments, seems to be optimal at about 20 meter resolution. Based on experiences from 1:50,000 scale images and looking at examples at 10, 20, 30, and 80 meter resolutions; 30 meter resolution is quite nearly as interpretable as 10 meter resolution while a reduction of resolution to 80 meters loses considerable information This conclusion should be quantified if possible.

Goldfield (Cuprite Area)

An example of the spatial resolution requirements for the accurate delineation of alteration zones can be presented from a study of the Cuprite mining district in western Nevada. Figure 1 (from Abrams and others, 1977) demonstrates the successful discrimination of silicified, opalized, and argillized rocks employing 10 meter resolution 24-channel scanner data. Figure 2 is a nearly equivalent color ratio composite (1.6/0.48, 1.6/2.2, 0.6/1.0 = g,r,b) employing 30 meter resolution airborne thematic mapper (ATM) data. Though the color rendition with the ATM data at 30 meters is not identical, under close study the discrimination and mapping of the three alteration zones is nearly equal. Figure 3 is the same ATM data after having averaged the pixels to 90 meter resolution. At this resolution accurately distinguishing the opalized and silicified zones is far more difficult, and our ability to recognize the argillized zone is severely reduced, as the geologic environment is less clear.

Nevertheless, recognition of the separate alteration phenomena at Cuprite is still possible, if not as accurate at 90 meter resolution. This obviously re-inforces the importance of the 1.6 and 2.2 bands to improved mapping of surface mineralogy even at poor spatial resolutions.

Spectral Resolution Requirements

The value of improved spectral resolution to non-renewable resource exploration can be enormous. Our objectives are improved discrimination of vegetation stress, lithology, and soil type and identification of specific surface mineralogy. Exploration for base metals and hydrocarbons can be facilitated by the recognition of: 1) vegetation stress caused by abnormal soil mineralogy or gas content as opposed to normal environmental water stress; 2) recognition of surface carbonates or gypsum; and 3) identification of specific alteration iron-oxides or hydroxides (goethite, limonite, jarosite, hematite) and clays (alunite, sericite, kaolinite, montmorillonite, pyrophyllite, chlorite). However, to accomplish these goals future scanners must be at the forefront of technology in filter and detector development.

Based upon our objectives and current technology an ideal scanner system is proposed with approximately 50 nanometer resolution in the visible, 100 nanometer resolution in the near-ir, and 2000 nanometer resolution in the thermal infrared. Table 1 lists the bands of this ideal system. These proposed bands are based upon our previous experience with high spectral resolution field and airborne systems. However, detailed simulation studies employing these or other bands must be performed and studied if our next generation system is to be designed intelligently.

For geologic purposes, we tend to lean toward a C band (10 cm) radar to provide optimal information on texture variability which could be related to rock type discrimination. Based on experience with X band systems, L band systems and the radar equation, maximum variability in back scatter energy return vs wavelength radar vis-a-vis erosional geometry of sedimentary surfaces points toward the need for maximum sensitivity to particle size variations around 2-3 cm. which would correspond to a C band radar. Naturally to define geologic surfaces for topographic information using radar systems we need variable look angle. The Seasat experience illustrated the utility of a small angle off Nadir ($\sim 23°$) as being very effective in topographically flat areas. For mountain areas, we need larger angles ($\sim 70°$). Unfortunately the middle range at 45° while providing faithful information on geometry is almost useless for texture information, or small scale slope variability.

Table 1

Channel	Bandwidth (nm)	Objective
1	400-450	Iron-oxide minerals
2	450-520	Iron-oxide minerals
3	520-600	Spectral response
4	630-690	Spectral response
5	680-730	Vegetation stress
6	760-900	Vegetation vigor
7	850-950	Iron-oxide minerals
8	1000-1300	Igneous rock types
9	1550-1750	Spectral ratioing
10	2050-2150	Clay minerals
11	2100-2200	Clay minerals
12	2200-2300	Clay minerals
13	2300-2400	Clay minerals
14	8000-10,000	Thermal/Silicates
15	10,000-12,000	Thermal/Silicates
16	C Band Radar tunable at ~25°/70°	Texture/Geometry