EFFECTS OF SPATIAL RESOLUTION

Michael Abrams, JPL

I. Introduction

Studies of the effects of spatial resolution on extraction of geologic information are woefully lacking. This writer was unable to find even a single systematic, quantitative study bearing on this problem, though there has been a never-ending hue and cry for better spatial resolution. Figures of 10-30 m are often mentioned, with little substantive evidence to support these demands. However, pieces of various reports do have bearing on this subject, and they will be discussed as appropriate.

Spatial resolution effects can be examined as they influence two general categories: detection of spatial features _per se_; and the effects of IFOV on the definition of spectral signatures and on general mapping abilities.

II. Detection of Spatial Features

Mapping of lineaments and curvilinear features from remote sensing images has been one of the most widely pursued uses of these data. Lineaments can be manifestations of faults, fractures, and joints which may be of geologic significance. Or they may be caused by fortuitous topographic alignments or by a wide range of culturally-related phenomena, such as roads, fence lines, etc.

Lambert and others (1975) examined detectability of lineaments on Landsat images (80 m resolution), Skylab S190A photography (40 m resolution) and Skylab S190B photography (~20 m resolution) for the area of Alice Springs, Australia, and compared these to faults shown on a 1:250,000 scale geological map (Table 1).

Table 1. Number of faults identified

Source	>10km	<10km	Total
Map	26	39	65
Landsat	48	26	74
S190A	48	4	52
S190B	72	71	143

Two to three times as many faults were identified from the 20 m data compared to the 40 or 80 m data. Similar results have been reported by other investigators.

The two features which are improved by better spatial resolution are: 1) detection of short lineaments, which may represent joint systems. Landsat data at 80 m do not have the necessary resolution to detect any but the grossest joint patterns; 2) fine structure of large lineaments which have complex surface expression. Again, Landsat is inadequate for detecting these features. The Landsat Follow-on Working Group (Billingsley and others, 1976) concluded that the 30 m resolution of Landsat-D would provide a large improvement in the ability to map lineaments.

Mapping of geomorphic features is another area where spatial resolution is a critical factor. Billingsley and others (1976, p. III-17) reported that the threefold increase in resolution of Landsat-D compared to Landsats 1, 2 and 3 would "significantly improve the capability to map glacial (individual drumlins, isette lakes, eskers), fluvial (drainage boundaries, meanders, terraces, fans), desert (dune types) and permafrost (pingoes, polygonal ground) features, which are marginally observable or below the limits of detection on earlier Landsat imagery."

III. Definition of Spectral Signatures and Mapping Abilities

Measurement of spectral reflectance characteristics is accomplished at widely varying scales, ranging from laboratory analyses of 1 cm^2 powders or chips, to km size areas from orbital scanners. Conel (1982) examined the effects of spatial resolution at three different IFOV's: 1 cm^2, 200 cm^2, and 225 m^2. Spectral reflectance curves for a variety of rock types in the 0.45 to 2.45 μm region are shown in Figures 1 and 2. Figure 1 depicts hemispherical reflectance curves obtained in the laboratory for 1 cm^2 samples using a Beckman UV 5240 Spectrophotometer. Figure 2 depicts: a) the upper and lower range of Portable Field Reflectance Spectrometer (PFRS) in situ measurements. These spectra are normalized bi-directional reflectance measurements of a 200 cm^2 area on the ground; and b) image spectra from the NS-001 Thematic Mapper Simulator. These data were calibrated to reflectance using ground control measurements; the IFOV of the instrument is about 15 m (225 m^2 area). The laboratory measurements display sharp, well-defined absorption features characteristic of the samples' mineralogical composition. Cutler unbleached (#1), for example, has bands at 0.9, 1.4, 1.9, 2.2 and 2.35 μm due to the presence of ferric iron, water, water, kaolinite, and carbonate respectively (confirmed by X-ray analyses). Besides the absorption features, the general shapes of the curves and overall brightnesses provide diagnostic information relating to composition.

Field acquired reflectance data for these same materials reveal several effects of increasing the IFOV of the measurement. The most obvious effect is the inclusion in the 200 cm^2 IFOV of a wider variety of materials than is represented by a tiny laboratory sample. In addition to rock materials, such materials as soil and vegetation contribute their spectral properties to the measured spectrum. Only rarely do the two measuring systems observe the same materials. A major effect is to reduce the intensity of absorption bands in many cases. There is a fair similarity between the Beckman and PFRS spectra for Wingate, bleached; Kayenta; and Upper Chinle Sandstone. Cutler Formation PFRS represents samples of both bleached and unbleached Beckman samples; Moss Back MBR, Chinle PFRS curves include the three types of Beckman Moss Back samples. PFRS curves show absorption bands at 2.35, 2.2, 0.9, and 0.65 μm. All of these features are seen in the Beckman curves, though not all are present in any individual curve. The effect of increasing the IFOV is to average and include a greater diversity of materials. In the PFRS curve for Navajo Sandstone, the 2.2 μm band is not visible; the area sampled in the field included some dry vegetation and soil which tend to mask this feature.

Increasing the resolution one step further is crudely shown by the aircraft scanner image spectra on Figure 2. For most of the rock types, the image spectra fall within the range of PFRS values. The Cutler formation shows the effects of the inclusion of a significant vegetation component in the spectral signature - albedo is depressed and falls below the range of PFRS measurements, which excluded piñon-juniper prevalent on this rock type. Again the same types of effects are seen going from the ground (20 cm^2) to aircraft (225 m^2) as from laboratory (1 cm^2) to the ground. More heterogeneous materials are included in the field of view, contributing a mixture of spectral signatures to the reflectance measurements.

Mapping capability is probably the bottom line for remote sensing. Landsat data with 80 m IFOV are usable to produce maps equivalent to 1:250,000 geological maps. Landsat-D resolution (30 m) is expected to allow mapping at 1:100,000 scale (Billingsley and others, 1976). Systematic studies of resolution for mapping are scarce. Vincent of GeoSpectra Corp. used 7.5 m IFOV aircraft scanner data to produce spatial resolution simulations of different IFOV's. An area near Knoxville, Tennessee was overflown, and false color infrared composites were produced. Figure 3 shows: (1) quick-look 7.5 m data, (2)10 m, (3) 20 m, (4) 30 m, (5) 40m, and (6) 80 m simulations. It is instructive to examine the appearance of small roads, houses, fields, and treed areas as a function of spatial resolution. At 10 m they are all visible. At 20 m, there is little loss of detail. At 30 m, small streets are less clear, individual houses can no longer be resolved; fields and treed areas are still distinct and boundaries between them are still detectable. At 40 m only the larger streets are detectable; houses are unrecogizable; field boundaries are starting to break down, though some are visible. At 80 m, individual fields are no longer detectable; only the largest roads and building complexes are discernible.

Abrams and Brown (1982) compared Landsat data to high resolution aircraft scanner data over the Silver Bell copper deposit in Arizona; the scanner data were acquired at 12 m resolution, and were then degraded via computer processing to 30 m and 80 m resolution. Figure 4 shows the same strip of area for: (1) 12 m scanner ratio composite data, (b) 30 m degradation, (c) 80 m degradation, (d) Landsat 80 m false color infrared composite, and (e) Landsat ratio composite. At 12 m resolution, small drainages, cross-cutting dikes and roads on the dump are visible. At 30 m these features are barely visible; and by 80 m, they are indistinguishable. The detail visible on the degraded 80 m resolution aircraft scanner image is the same as on the Landsat image.

At about 1:125,000 scale, the 80 m data appears grainy, as the individual pixels are about 0.5 mm in size. At 1:50,000 scale, the pixels are about 1.5 mm each, and the images start to become unusable due to the appearance of grain due to the large pixel size.

The 30 m data at 1:50,000 scale is similar in appearance to the 80 m data at 1:125,000 scale: the pixels are starting to be discernible. At higher enlargements, no additional information is visible; the pixels merely get larger.

This little exercise, perhaps provides some quantitative feel for the useful scale of various resolutions; i.e., digital data can be displayed at a sacle of 1500 X the IFOV in meters. With sophisticated image processing, this can probably be increased by a factor of 2.

IV. Recommendations for Future Work

It is obvious that there is a crying need for detailed, systematic studies of effects of spatial resolution on information extraction. These studies should be conducted over a wide variety of geological terrains, and examine a range of problems. The field of geology encompasses many subdisciplines, each of which has its own requirements for the scale of information necessary to address key problems. Global or continental tectonics needs data at scales on the order of $1:10x10^6$. Geological mapping is done at various scales, from 1:250,000 to 1:2,000. Resolution requirements are grossly different: 50-100 m may be adequate for small scale mapping; ~1 m resolution for detailed mapping. Therefore, the requirements are to a large extent problem or site specific. Nevertheless, detailed studies of the effect of decreasing resolution on information content should be done.

Similarly, the effects of resolution on spectral signatures should be systematically studied. One experiment would be to examine a heterogeneous area, measuring spectral reflectance at increasingly larger FOV's (Perhaps using the PFRS in a helicopter). Characterizing the resulting mixed signatures and developing satisfactory methods for estimating components would be fruitful.

REFERENCES

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