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Paper L 24

IDENTIFICATION AND MAPPING OF COAL REFUSE BANKS AND OTHER TARGETS IN THE ANTHRACITE REGION

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ERTS-1 MSS data covering parts of Pennsylvania's Southern and Eastern Middle Anthracite Coal Fields were studied to determine how well accumulations of coal refuse could be identified and mapped by computer analysis and processing. Spectral signatures of coal refuse targets were similar to water, but had higher reflectances in all channels. Relative reflectances were in the order 4>>5>6>>7. Although no underflight photography was at hand to judge mapping success, correlation was made with 1:24,000 scale USGS maps dated 1947 and 1948. Coal refuse targets correlated well with existing maps.

A widespread and ongoing problem affecting the utilization of earth resources is the devastation of land that often accompanies the extraction and processing of mineral resources. Few areas of the world are as drastically affected by this problem as the Anthracite coal region of eastern Pennsylvania. In addition to extensive strip-mined areas, at least 16,000 acres in the region are covered by waste from coal-processing plants. Although most prominent for their barren ugliness, these immense black piles of silt, shale, and rock also pollute streams with acid and sediment and preclude more beneficial uses of the land as well.

Knowledge of the location and extent of such problem areas will be required for effective planning of corrective measures. Most assessments to date have been compilations of information from a variety of sources (Peters, Spicer, and Lovell, 1968) and, while certainly useful, have been incomplete. Furthermore, reworking of refuse and silt, extinguishing burning refuse, strip-mining, and other such activities have resulted in elimination of some banks, moving of others, and creation of new ones, in addition to the normal increase in size of banks with continued coal production.

Thus, the capability of satellite-mounted sensors for repetitive observation of extensive areas seems to make ERTS-1 the ideal tool for routine mapping of the areas in need of reclamation. To test this supposition, an area encompassing the eastern ends of both the Southern and Middle Anthracite Fields was studied.

Bulk MSS digital data were used. The scene date was October 11, 1972, with the identification of 1080-15185. The computer processing was done within the system described by Borden (1972) for processing and analysis of MSS remote sensor data. Digital or character maps from printer output were used as working copy and for this report final maps, made from character maps, were output on a plotter.

An approximately nine-mile-square section of the study area, including the coal towns of Tamaqua, Coaldale, Lansford, Summit Hill, and Nesquehoning, was studied intensively to develop a set of spectral signatures for various targets of interest. Orientation with respect to ground locations was aided by a digital intensity map showing areas of low and high total reflectance. All of the signatures used in subsequent mapping of the entire area were obtained from this subarea.

A second digital map was produced using a program that identifies areas of relatively uniform local spectral response. Both maps were then studied to select training areas for the initial spectral signature calculations. As classification maps were produced, unclassified or confusing areas were delineated and cluster analyses were performed, establishing additional signatures in a kind of iterative process. The resulting profusion of signatures was reduced to manageable proportions by using distances of separation, such as those shown in Table 1(b), to identify groups similar enough to be represented by one mean signature. A total of 42 different signatures was used in the total mapping; the important ones relative to this report are listed in Table 1(a).

In the classification procedure used, each of the spectral signatures representing a particular target category is considered as a four-element vector. The point in four-dimensional space defined by this vector is considered the class centroid, which, together with a specified classification limit, defines the class. Each data point can also be considered a point in four-space and is assigned to that class for which its euclidean distance from the class centroid is minimum, provided it falls within the specified limit. If it does not, then it is checked to see whether it falls within the limit for the next closest category and so on. If a point is not within the limit for any category, it is classified as other. Although 42 different categories were used, related categories were mapped using the same symbol; all four coal refuse categories, for instance, were mapped as X's. In specifying the classification limit for each category, its distances of separation from unrelated categories (i.e., those with different map symbols) were studied and the limit set at two-thirds of the smallest such distance, except for coal refuse and water, which were set equal to that minimum distance. All categories were included in the final classification, but only those listed in Table 1(a) were assigned nonblank map symbols.

No NASA underflight or other photographic coverage of the area was available. The only supporting materials used were USGS topographic maps dated 1947 and 1948, and a report by Peters, Spicer, and Lovell (1968) showing the location of most of the larger refuse banks and silt deposits in the Anthracite Region. Time limitations have thus far prevented field checking of ground truth.

With respect to the primary objective, mapping coal waste materials, the maps shown in Figures 1 and 2 speak very well for themselves. Figure 1 shows the area in the Southern Anthracite Field from which the spectral signatures were obtained. Figure 2 shows an adjacent area in the Eastern Middle Field that was mapped using the same set of signatures. In both cases, every refuse pile or silt basin that shows on either the topographic maps or the Peters, et al. (1968) map also can be identified on the ERTS map. Some of the accumulations shown on the ERTS map, however, are not on either of the others. With few exceptions, these are close to mining operations where refuse piles might logically be expected. The total area classified as refuse or silt was 6,532 acres or 6.2 percent of the overall area shown.

As anticipated from its dark gray to dull black color, the coal wastes have quite low overall reflectance. The signatures, shown in Table 1(a), are somewhat similar to those for water--relatively high in channel 4, dropping off sharply from 4 to 5, dropping only slightly or not at all from 5 to 6, and with another sharp drop between 6 and 7. The refuse reflectances are significantly higher than three of the water signatures in every channel and consequently the distances of separation, shown in Table 1(b), are adequate for successful classification. Only muddy water has total reflectance as high as refuse and the pattern of its signature is sufficiently different to eliminate confusion.

Among the categories that were blanked out of the maps were six signatures thought to represent strip-mine spoils. Although there was virtually no problem with refuse being misclassified as strip-mine spoils, certain strip-mine spoils appear to be misclassified as refuse. One such area is a long, narrow band near the southwest corner of Figure 1 that is mapped as refuse, but shows on the topographic map as unreclaimed strip-mines. This, of course, is not surprising since some strip-mine spoils, being derived from the same geologic strata as the refuse, are closely similar to it in color. Such misclassification is, in one sense at least, not really a problem since the same environmental problems and reclamation difficulties are involved with both materials. Mapping of strip-mines will be more difficult than the coal refuse because of confusion with other targets such as roads, towns, and bare fields. The difficulties do not, however, appear insurmountable.

Other targets presented minimal problems. All water bodies that show on the topographic maps were plotted accurately. Several additional water bodies that show on the ERTS but not on the topographic maps appear to be unreclaimed stripping pits that have filled with water.

The small area near the east edge of Figure 1 that is mapped as "muddy water" is not definitely known to be that, and, as previously noted, its spectral signature is not greatly different from those of coal refuse. Although not on the topographic map, it is on the opposite side of the ridge from the coal deposits and the other mining activity. Its shape and its position astraddle Mauch Chunk Creek suggest that it is a pond, but the final determination will be made on the ground.

The signature for swamp vegetation was obtained from an upland swamp that shows on the topographic map and in the northeast corner of Figure 1. The same vegetation type also maps along the northwest side (the shaded side at 9:30 a.m.) of the ridges. This may be a direct consequence of the shading or it may indicate that the plant community is different, the shaded lower slope supporting a hemlock-rhododendron type that is similar to that of the swamp.

Again, the final interpretation must await the ground-truth determination.

Other features that were mapped more or less successfully included the four-lane highway between Hazleton and Tamaqua and a pipeline right-of-way that is apparently covered with low brush and weeds because it maps in small patches elsewhere.

What we have called on the maps an anomaly arose when one of the refuse banks, which appears on the topographic maps as almost perfectly circular, did not come out that way on the digital map. A cluster analysis gave the signature shown in Table 1(a). A glance at Table 1(b) shows that it is totally different from any other category shown and, in fact, its minimum distance of separation from any other category was 15.1 from one of the strip-mine signatures. The category has also mapped in small patches elsewhere, but we do not, at this time, know what it is. It is conjectured to be burned-out or burning refuse, known to be present in these coal fields.

In summary, use of the ERTS-1 data to map the location and areal extent of coal waste materials has been found to be feasible. It also appears that much additional useful information can be elicited from the data, particularly with regard to cultural changes over time.

LITERATURE CITED

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Peters, J. W., T. S. Spicer, and H. L. Lovell. 1968. A Survey of the Location, Magnitude, Characteristics, and Potential Uses of Pennsylvania Refuse. Coal Research Admin., The Pennsylvania State University, Special Research Report No. SR-67.

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Table 1. Specifications of map categories: (a) spectral signatures and category limits; (b) distances of separation between centroids of the categories.

(a)

Category Name	Channels 1	2	3	4	Limit
1 Refuse 1	20.88	14.43	12.34	4.42	3.6
2 Refuse 2	20.23	13.39	13.32	5.26	6.5
3 Refuse 3	21.77	15.59	14.73	5.84	4.7
4 Refuse 4	19.73	12.99	11.04	3.66	3.3
5 Wet Silt	18.49	10.79	9.79	3.26	2.1
6 Clear Water	16.79	7.57	4.79	0.69	6.7
7 Turbid Water	16.40	8.16	5.87	1.42	5.5
8 River Water	16.36	8.63	8.96	3.43	2.8
9 Muddy Water	20.12	15.67	10.10	1.98	3.3
10 Swamp Vegetation	18.39	12.72	20.56	11.94	5.5
11 Anomaly	36.00	41.33	42.50	17.00	10.0

(b)

	Category 1	2	3	4	5	6	7	8	9	10	11
1	0.0	1.8	3.1	2.4	5.2	11.6	10.5	8.2	3.6	11.5	44.9
2	1.8	0.0	3.1	2.9	5.1	11.8	10.6	7.7	5.1	10.0	44.9
3	3.1	3.1	0.0	5.4	8.1	14.6	13.5	10.8	6.3	9.5	42.0
4	2.4	2.9	5.4	0.0	2.8	9.3	8.1	5.9	3.3	12.7	47.3
5	5.2	5.1	8.1	2.8	0.0	6.7	5.5	3.1	5.3	14.0	50.0
6	11.6	11.8	14.6	9.3	6.7	0.0	1.5	5.1	10.3	20.1	56.5
7	10.5	10.6	13.5	8.1	5.5	1.5	0.0	3.7	9.4	18.7	55.4
8	8.2	7.7	10.8	5.9	3.1	5.1	3.7	0.0	8.2	15.1	52.6
9	3.6	5.1	6.3	3.3	5.3	10.3	9.4	8.2	0.0	14.8	46.8
10	11.5	10.0	9.5	12.7	14.0	20.1	18.7	15.1	14.8	0.0	40.4
11	44.9	44.9	42.0	47.3	50.0	56.5	55.4	52.6	46.8	40.4	0.0

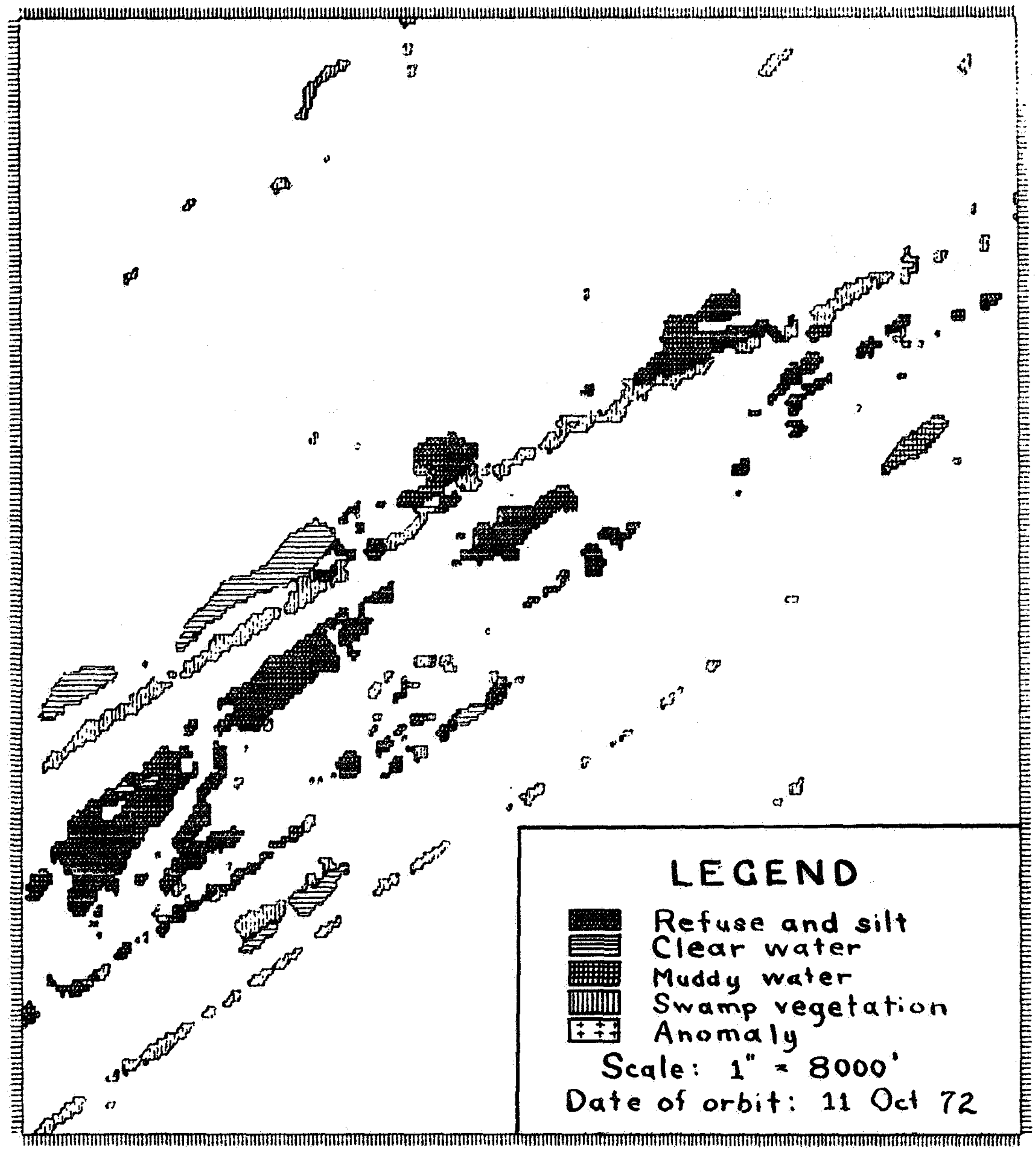

Figure 1. Computer-generated map showing coal waste accumulations in east end of Southern Anthracite Field.

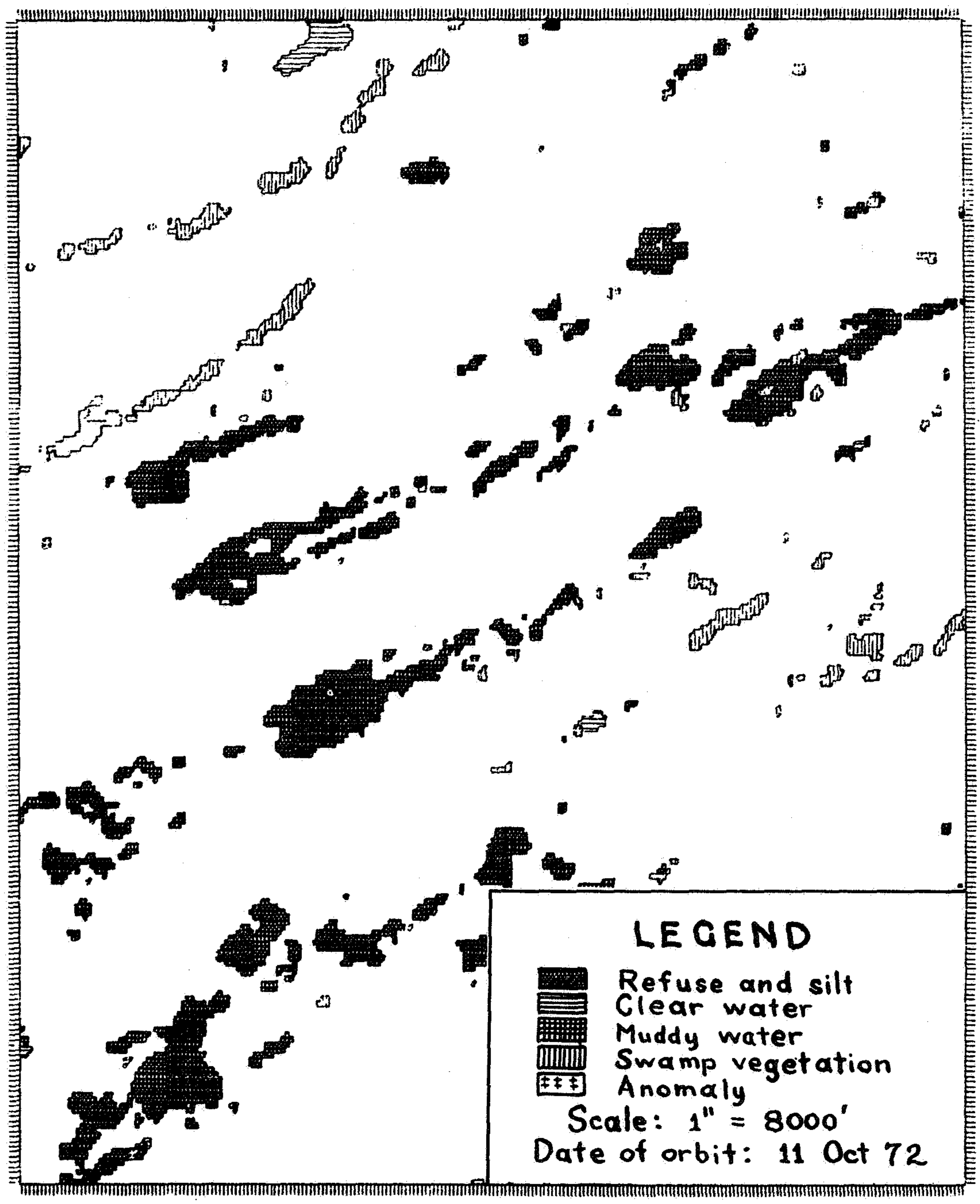

Figure 2. Computer-generated map showing coal waste accumulations in east end of Eastern Middle Anthracite Field.