SOUTH CAROLINA WATER RESOURCES COMMISSION
GEOLOGY - HYDROLOGY DIVISION

COMPARISON OF LINEAMENT MAPPING ON VARIOUS REMOTELY SENSED IMAGERY OVER NEWBERRY COUNTY, SOUTH CAROLINA.

BY

Joseph A. Harrigan

Piedmont Regional Office
Green Gate Office Park, Suite 702
25 Woods Lake Road
Greenville, SC 29607-2723

March 1990

Open-File Report No. 33

ABSTRACT

Three types of remotely sensed imagery: false-color infared NHAP; black and white panchromatic photography; and SPOT images, both panchromatic and color multi-spectral, were used for lineament mapping over Newberry County, SC. Lineaments were mapped on the aerial photography with a mirror stereoscope. The SPOT imagery were also interpreted by using the mirror stereoscope, but for pseudo-stereo vision, owing to contrast of image features. One SPOT image was mapped singly. The mapped lineaments were not field checked for correlation with bedrock fracture traces.

Comparison of resulting lineament maps for each imagery type showed NHAP imagery to have the greatest number of lineaments, the greatest number of lineaments per area mapped, and the shortest average lineament length. Aerial photography displayed a strong westerly trend of lineament orientation whereas the SPOT imagery has a general easterly trend.

Lineament overlap by the various imagery types indicates a fair to poor correlation. Roughly 40 percent of the lineaments within the common comparison area, the NHAP imagery area, do not overlap with other imagery lineaments. The black and white aerial photography lineaments had the highest number of lineaments overlapping with NHAP lineaments.

SPOT imagery lineaments, though fewer in number, had a similar overlap correlation rate with NHAP imagery as the black and white photography. SPOT imagery allowed lineament mapping over a large area but identified much fewer lineaments than the aerial photography.

INTRODUCTION

As part of a cooperative project of the South Carolina Water Resources Commission (SCWRC) and the U.S. Geological Survey in Newberry County, lineament mapping with various remotely sensed imagery was undertaken in 1989. This report summarizes the results of lineament mapping on standard black and white aerial photographs, color IR NHAP aerial photographs, multi-spectral, false-color SPOT imagery, and panchromatic SPOT imagery. Field "truthing" of the lineaments was not performed. These data will be retained for reference if a well-siting project occurs in the mapped vicinity.

METHODOLOGY

AERIAL PHOTOGRAPHY

The air photos (aerial photography) used in this project were 1:58,000-scale color IR (infrared) NHAP (National High Altitude Photography) images flown February 14, 1984, and 1:40,000-scale B and W (black and white) photography, flown December 18, 1980 (see Figure 1). A mirror stereoscope was used and the lineaments were plotted with colored china markers on clear-transparency sheets taped to one of the stereo pairs.

The 1.8x magnification was the most useful in this project. This allows the identification of most lineaments sufficiently to permit

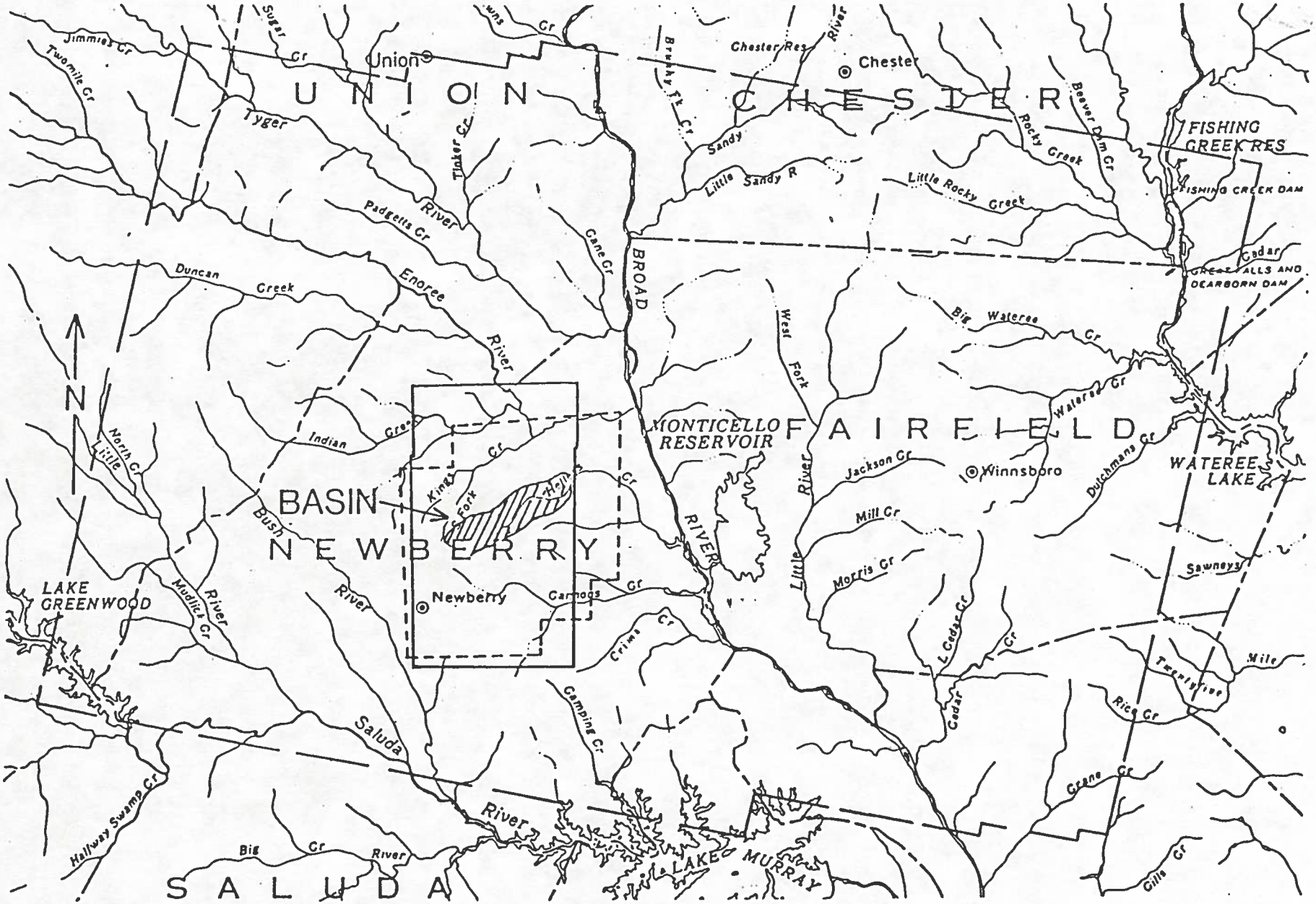


Figure 1. Aerial photography and SPOT coverage over Hellers Creek area of Newberry County.

- - - - - - - - ASCS 1:20,000-scale black & white photos

———————— NHAP 1:58,000-scale false-color photos

———— —— SPOT 1:54,000-scale black & white and false-color images

accurate delineation. The basic lens view is at too small a scale for comfortable viewing. The 3x magnification is useful for close inspection of subtle lineaments and when attempting to plot lineaments in urban areas. Close inspection is necessary to overcome cultural interference in urbanized areas.

To provide another "look" perspective for identifying lineaments, it was useful to rotate the photo positions 180 degrees, i.e., instead of north being to left it would be to right as one looks at the photos. A few additional lineaments became discernible.

The color IR NHAP photography has proven to be the easiest to use to identify lineaments. The color enhances topography more than black and white with gray shading. Less relief was detected in the B and W photography than in the NHAP photography.

SPOT IMAGERY

SPOT imagery was lineament mapped in three pseudo-stereo pairs. Two high-resolution panchromatic (black and white) images, May 10, 1987, and December 30, 1987, two multi-spectral false color images, May 10, 1987, and November 13, 1987, as well as one of each multi-spectral on May 10, 1987, and panchromatic on December 30, 1987, were viewed and interpreted under a mirror stereoscope. Also, the November 13, 1987, multi-spectral image was interpreted singly. The images all had different focal points and thus provided pseudo-stereo viewing. Two sources of contrast, vegetation leaf cover and sun angle, were utilized by the spring and late fall-winter image pairs.

The air photos were interpreted with typical end-lap (east up), whereas SPOT were interpreted with side-lap (north up). When the NHAP imagery was turned from end-lap to side-lap, stereo vision ceased and a flat image was viewed. When the SPOT images were rearranged to end-lap, no difference was noted between end-lap and side-lap. No true stereo vision was noted in either orientation, only pseudo-stereo vision owing to contrast of image features.

The late-fall/winter SPOT images appeared to display greater topographic texture. The spring imagery displayed stronger vegetative contrast, particularly between flood plains and hillslopes.

The six lineament maps, five stereo and one singular-image, show the various lineaments plotted at a single scale, 1:100,000. This happens to be the scale of the SPOT imagery, which also correlates directly with the new USGS 1:100,000-scale sheets. The SPOT images were interpreted only over the page-sized area of the map, centering over Hellers Creek, which is about one-seventh of the SPOT image area. The SPOT-image mapped area covered about 216 mi^2 (square miles) on the ground. The three NHAP and eight B and W air photos covering the immediate area around Hellers Creek covered one-third of the area of the SPOT images, 75 and 70 mi^2 respectively.

About 42 NHAP air photos would be needed to cover the area of the SPOT image, at a cost of 1,001 dollars for film-positive or 667 dollars for paper prints. The two panchromatic SPOT images, to provide for pseudo-stereo viewing, cost approximately 500 dollars each.

LINEAMENT MAPPING EVALUATION.

In order to quantify and compare the lineament mapping, several methods were used to summarize the results:

Qualitative and quantitative visual comparison of lineament maps;

The number and length of mapped lineaments were summarized in Table 1;

Radial, or rose, diagrams were used to show the number and length of lineaments by 10-degree increments from east to west.

VISUAL EVALUATION.

When all six lineament maps (Figs 2-7) are viewed at once the most obvious feature is the greater number and density of lineaments on the NHAP and B and W air photo lineament maps than on the SPOT lineament maps. Another feature is the uneven distribution of lineament orientations on the maps. Lineament orientations appear to cluster, pointing up the importance of not assuming a preferred fracture direction anywhere in the Piedmont.

When the lineament maps are compared to one another, some noteworthy features appear. Some lineaments are identified on all sets, only a portion of the lineaments overlap on some sets, and many lineaments show no overlaps. Only one of these lineaments has been field verified so no indication is available on the correlation of lineaments to fractures.

The air-photo lineaments, when plotted on a topographic map, show a fairly good correlation with linear topographic features. Some linear topographic features are not overlain by photo lineaments and some lineaments do not line up with linear topographic features. A stereo plotter scope, though costly ($10,000 to $20,000 range), might aid in air-photo lineament mapping, by superimposing the stereo image on the topographic map. This could, however, bias the stereo interpretation.

SPOT lineaments plotted on a topographic map show a fair alignment with some of the topographic linear features. Because of problems involved in transferring, by enlargement, lineaments from SPOT images to topographic maps, it is difficult, in some instances, to determine if the detected lineament lines up with topographic features or other imagery lineaments. It may be worthwhile to investigate the possibility of constructing mylar overlays of topographic lines at the scale of the SPOT imagery. This may enhance the lineament identification, using SPOT imagery.

COMBINED LINEAMENT CORRELATION.

Overlap by the various imagery lineaments is summarized by the number of overlap occurrences:

Figure 2. NHAP lineaments over Hellers Creek area.

Figure 3. B and W air photo lineaments over Hellers Creek area.

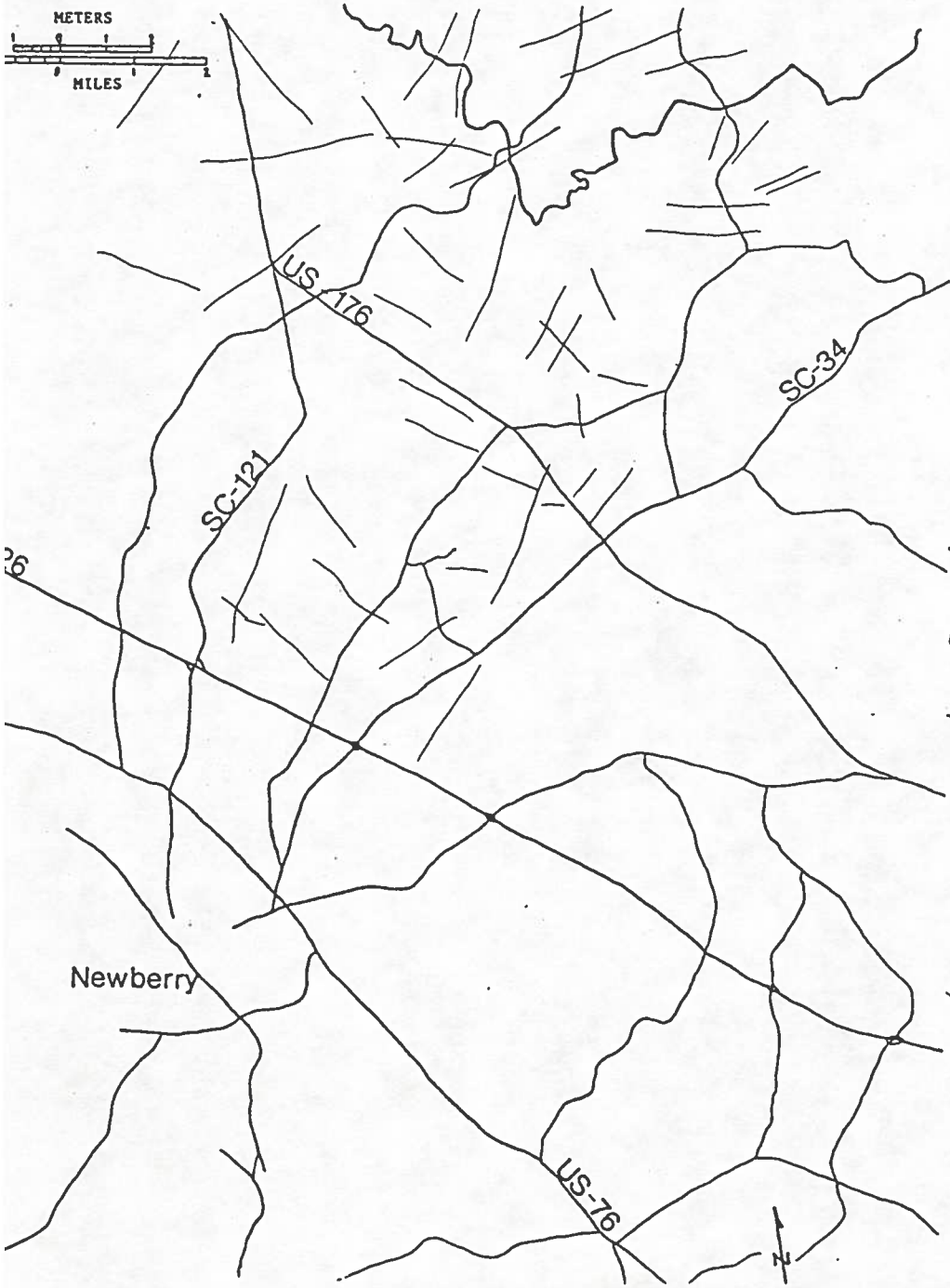


Figure 4. Panchromatic SPOT "pseudo-stereo" lineaments over Hellers Creek area.

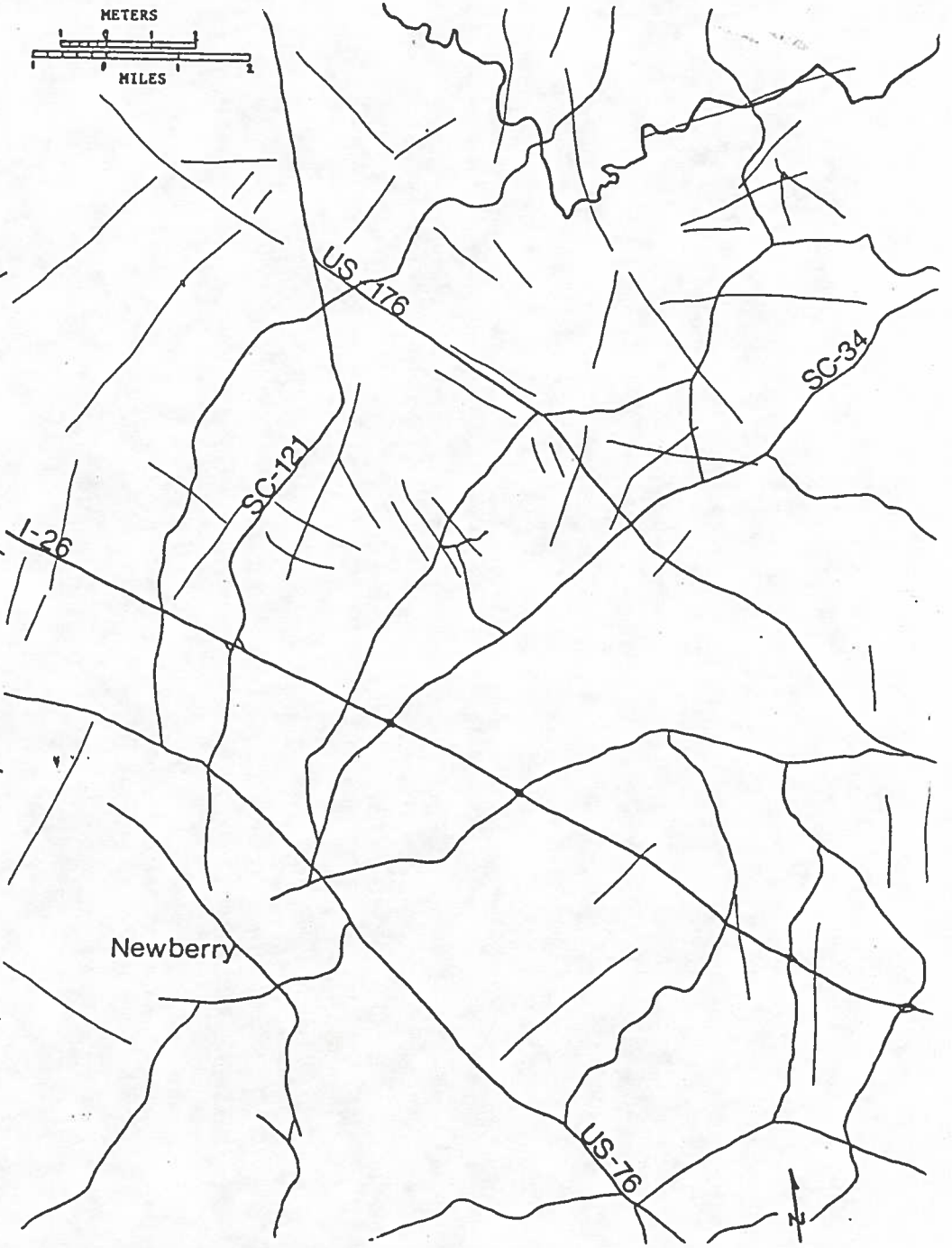


Figure 5. Multi-spectral SPOT "pseudo-stereo" lineaments over Hellers Creek area.

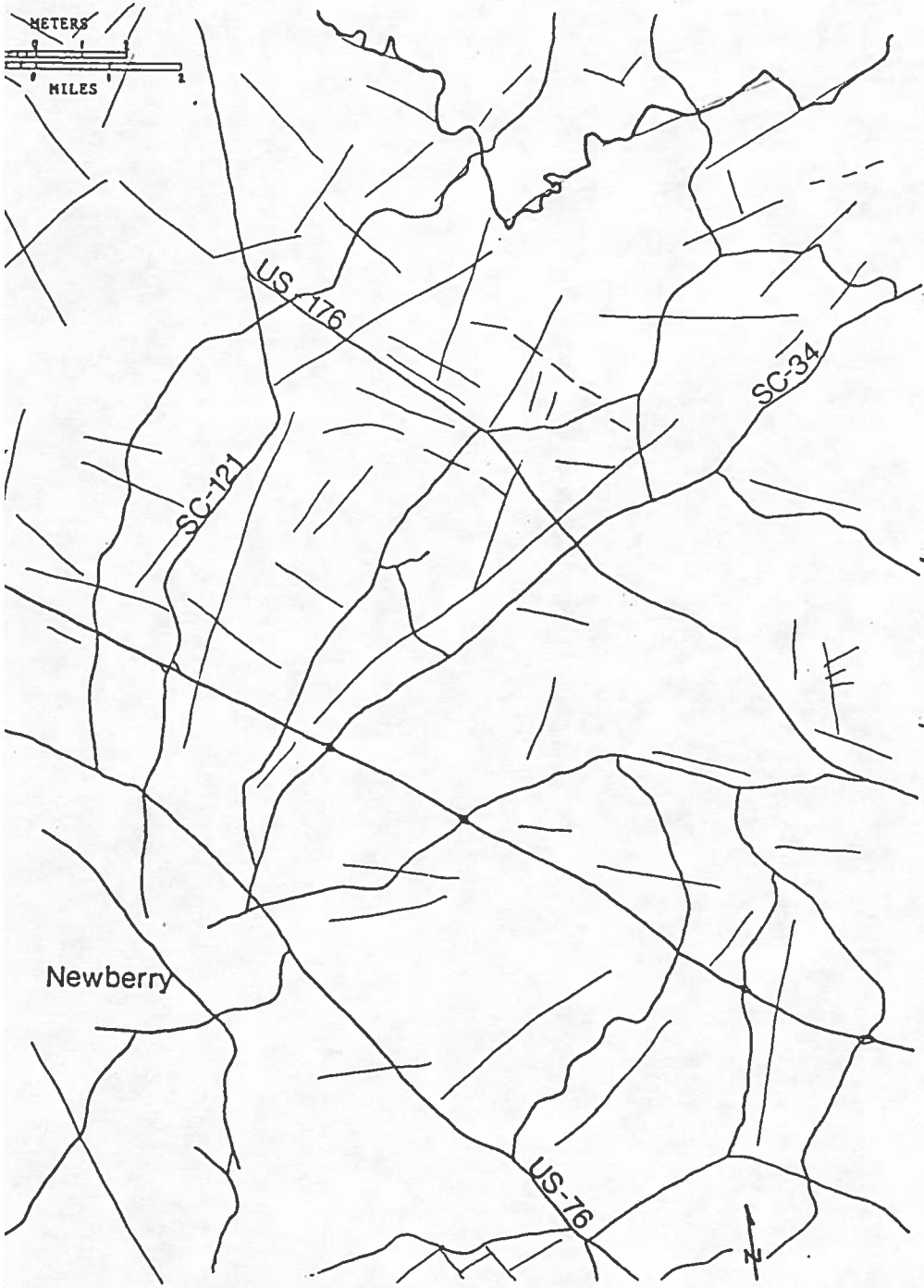


Figure 6. Single multi-spectral SOPT lineaments over Hellers Creek area.

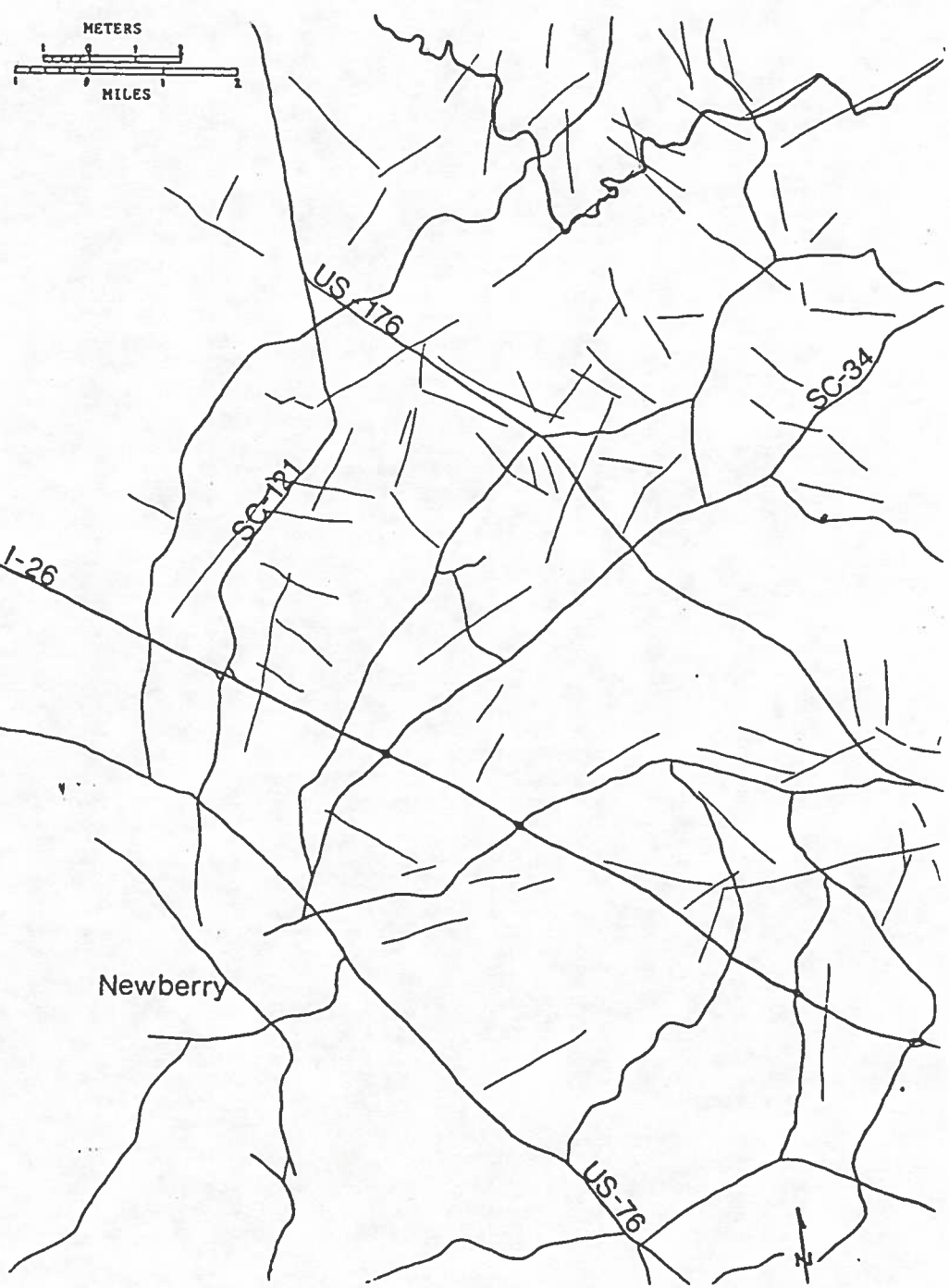


Figure 7. Panchromatic and multi-spectral SPOT pseudo-stereo lineaments over Hellers Creek area.

Table 1. Lineament overlap among images

NUMBER OF IMAGES OVERLAPPED	NUMBER OF OCCURRENCES
1	(53) 162 .....no overlaps at all;
2	59
3	16
4	7
5	2
6	3.

As expected, the number of match occurrences decreases as the number of overlaps increases. It is noteworthy that 162, or roughly 40 percent, of the plotted lineaments had no overlap. The number in parentheses, 53, represents the number of unmatched SPOT lineaments in the map area. Further analysis would be needed to explain the lack of correspondence of lineaments identification between imagery types. Part of the problem can be solved by looking only at the area common to all six images.

A total of 384 lineaments are accounted for in the above tally of the 551 total on all six images. The reasons for the discrepancy are (1) the map used was not large enough to contain all lineaments, particularly those of the SPOT imagery, and (2) in several cases, where longer lineaments were paired with shorter lineaments, they may have also matched at a different location with additional lineaments. These additional lineaments were not counted. If they were counted they should probably go in the single category, even though they had a match.

LINEAMENT CORRELATION WITH NHAP LINEAMENTS.

Because the NHAP imagery yielded the most lineaments it was used as the comparative template for the other five lineament maps. The following table summarizes the comparison results within the NHAP imagery coverage area.

Table 2. NHAP lineament overlap with other imagery lineaments

	OTHER IMAGERY LINEAMENTS NHAP IMAGERY AREA:					UNMATCHED NHAP LINEAMENTS	
		INSIDE		OUTSIDE			
IMAGERY	TOTAL	MATCHED	Percent		Percent		Percent
B and W	78	48	62	34	30	41	34
SPOT-Color, Stereo	22	17	77	27	55	137	89
SPOT-B and W, Stereo	25	16	64	32	56	138	90
SPOT-Color, Single	37	21	57	57	61	133	86
SPOT-B and W/Color, Stereo	42	20	48	43	51	134	87

The table above shows the comparison of the NHAP lineament map with the lineament maps of the other imagery. Since the NHAP imagery yielded the greatest number of lineaments it was used as a reference map for comparison. Its map area was used as the comparison area. The tabular results indicate that half or more of the various other imagery's lineaments, within the NHAP coverage area, match with NHAP-identified lineaments. The B and W imagery had the greatest number of overlapping lineaments. The SPOT imagery lineaments, though fewer in number, had a similar overlap correlation rate as the B and W imagery.

.e 3. Lineament mapping summaries

IMAGERY	NUMBER OF LINEAMENTS					AREA MAPPED (Mi2)	NUMBER OF LINEAMENTS PER SQ. MI (No./Mi2)	LINEAMENT LENGTH (MILES)			AVERAGE LENGTH (Miles)			LENGTH /AREA (Mi/Mi2)
	WEST		EAST		TOTAL									
	Number	Percent	Number	Percent				Total	West	East	Total	West	East	
AERIAL PHOTOGRAPY:														
NHAP	101	.656	53	.344	154	75.4	2.04	151.252	96.795	54.797	.982	.958	1.033	2.006
B & W	66	.589	46	.411	112	70.4	1.59	118.903	70.838	48.065	1.062	1.073	1.045	1.689
SUBTOTAL	167	.63	99	.37	266									
SPOT IMAGERY:														
STEREO B & W	22	.449	27	.551	49	216	.23	55.94	24.159	31.781	1.142	1.098	1.177	.259
STEREO COLOR	26	.456	31	.544	57	216	.26	85.985	37.794	48.191	1.509	1.454	1.555	.398
SINGLE COLOR 13NOV87	42	.447	52	.533	94	216	.44	127.835	56.071	71.765	1.361	1.335	1.38	.592
STEREO COLOR/B&W	44	.518	41	.482	85	216	.39	87.138	38.614	48.524	1.025	.878	1.184	.403
SUBTOTAL	134	.47	151	.53	285									

It also shows, particularly with the SPOT imagery, that a large number of the NHAP lineaments, more than 85 percent, are unmatched. This seems to indicate that where a single SPOT image could cover a large area relatively inexpensively, only 10 to 15 percent of the potential lineaments may be identified. This may be appropriate for regional analysis but not so for site evaluations on properties 50 acres (0.177" x 0.177" on SPOT image) or less.

TABULAR STATISTICS.

The lineament mapping results are summarized in Table 3 by imagery type, and numbered 1 to 6, in order of lineament mapping. The air photos generally yielded the most lineaments, the shortest average lineament length, and the greatest number of lineaments per mapped area, on the order of 4 to 8 times that for SPOT imagery. The air photos yielded a strong westerly trend of lineaments, 63 vs 37 percent, whereas the SPOT imagery only slightly favored an easterly trend, 47 vs 53 percent. The "look" direction and sun angles are approximately the same. Possibly the coarser lineaments identified on the SPOT imagery are northeasterly, whereas the finer or subtler lineaments are northwesterly in trend.

The NHAP photography, interpreted first, yielded the most lineaments, and greatest total length of lineaments, but the shortest average lineament length. This could be due to the larger scale of the NHAP imagery, limiting the length of lineaments compared with the tendency to draw longer segments on the smaller scale SPOT imagery. The fewer lineaments yielded from the SPOT imagery is probably due to the lack of true stereo viewing and the smaller scale, limiting the identification of smaller or subtle lineaments.

Of the SPOT images, the single-SPOT image interpretation yielded the greatest number of lineaments, greatest total lineament length, greatest average length, and the highest number of lineaments per mapped area. This is the late fall, false color, multi-spectral image, which shows the greatest topographic texture. The results indicate that single-SPOT image lineament mapping may be the best for SPOT images.

RADIAL DIAGRAMS.

Two radial diagrams were made for each lineament map: total number and total length of lineaments per 10-degree increment from east to west, Figures 8 - 13. The easterly verses westerly lineament orientations are consistent between total number and total length for five of the six comparisons. The stereo SPOT pair of panchromatic and multi-spectral yielded shorter westerly lineaments, so that, even though less numerous, the easterly lineaments had greater aggregate length. Some variations occur among the increment elements also. The data for these diagrams are listed in tables 4-9.

SUMMARY AND CONCLUSIONS.

The color IR NHAP photography has proved to be the easiest to use to identify lineaments. The color enhances topography more than black and white with gray shades. The scale is adequate for "seeing" coarse to subtle lineaments. The swing-in 3x magnifier lens provided higher magnification for close-up work with this imagery.

Table 4. NHAP Lineaments

ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	4	.026	2.604	.651
75E	2	5	.032	4.45	.89
65E	3	5	.032	3.961	.792
55E	4	5	.032	3.582	.716
45E	5	4	.026	4.308	1.077
35E	6	4	.026	3.251	.813
25E	7	11	.071	16.489	1.499
15E	8	6	.039	6.06	1.01
5E	9	9	.058	10.052	1.117
5W	10	10	.065	9.405	.941
15W	11	15	.097	13.539	.903
25W	12	10	.065	9.216	.922
35W	13	12	.078	11.772	.981
45W	14	17	.11	17.484	1.028
55W	15	7	.045	7.306	1.044
65W	16	13	.084	9.058	.697
75W	17	9	.058	9.405	1.045
85W	18	8	.052	9.61	1.201
TOTAL		154		151.552	.984
	EAST	53	.344	54.757	1.033
	WEST	101	.656	96.795	.958

Table 5. B and W Air Photo Lineaments

ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	3	.027	2.083	.694
75E	2	3	.027	1.562	.521
65E	3	3	.027	2.621	.874
55E	4	3	.027	2.335	.778
45E	5	3	.027	3.741	1.247
35E	6	7	.062	7.369	1.053
25E	7	11	.098	12.829	1.166
15E	8	8	.071	9.436	1.18
5E	9	5	.045	6.091	1.218
5W	10	7	.062	6.486	.927
15W	11	7	.062	8.837	1.262
25W	12	10	.089	10.999	1.1
35W	13	9	.08	10.999	1.222
45W	14	15	.134	15.433	1.029
55W	15	4	.036	5.002	1.251
65W	16	2	.018	1.247	.624
75W	17	8	.071	8.458	1.057
85W	18	4	.036	3.377	.844
TOTAL		112		118.905	1.062
	EAST	46	.411	48.067	1.045
	WEST	66	.589	70.838	1.073

Table 6. Panchromatic SPOT Lineaments; Stereo

ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	1	.02	1.452	1.452
75E	2	6	.122	7.256	1.209
65E	3	4	.082	5.334	1.334
55E	4	1	.02	.742	.742
45E	5	5	.102	5.728	1.146
35E	6	6	.122	7.401	1.234
25E	7	2	.041	2.841	1.421
15E	8	1	.02	.473	.473
5E	9	1	.02	.552	.552
5W	10	0	0	0	
15W	11	2	.041	1.262	.631
25W	12	2	.041	2.098	1.049
35W	13	4	.082	4.513	1.128
45W	14	2	.041	2.525	1.263
55W	15	2	.041	2.004	1.002
65W	16	5	.102	5.413	1.083
75W	17	3	.061	3.628	1.209
85W	18	2	.041	2.714	1.357
	TOTAL	49		55.936	1.142
	EAST	27	.551	31.779	1.177
	WEST	22	.449	24.157	1.098

Table 7. Multispectral SPOT; Stereo

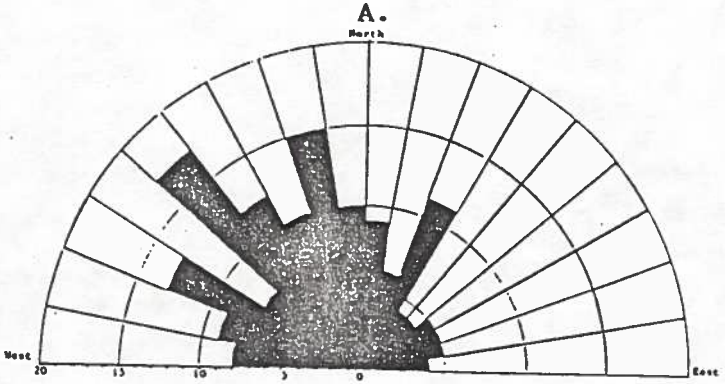
ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	1	.018	.868	.868
75E	2	2	.035	5.081	2.541
65E	3	2	.035	1.941	.971
55E	4	3	.053	6.596	2.199
45E	5	7	.123	9.656	1.379
35E	6	2	.035	3.266	1.633
25E	7	7	.123	9.342	1.335
15E	8	4	.07	7.653	1.913
5E	9	3	.053	3.787	1.262
5W	10	2	.035	2.367	1.184
15W	11	3	.053	2.209	.736
25W	12	3	.053	3.771	1.257
35W	13	4	.07	6.628	1.657
45W	14	5	.088	8.711	1.742
55W	15	4	.07	6.471	1.618
65W	16	1	.018	1.105	1.105
75W	17	2	.035	4.276	2.138
85W	18	2	.035	2.257	1.129
	TOTAL	57		85.985	1.509
	EAST	31	.544	48.19	1.555
	WEST	26	.456	37.795	1.454

Table 8. SPOT Pseudo-stereo, Panchromatic and Multispectral

ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	3	.035	2.446	.815
75E	2	6	.071	11.283	1.881
65E	3	6	.071	6.643	1.107
55E	4	2	.024	1.278	.639
45E	5	7	.082	6.975	.996
35E	6	5	.059	6.785	1.357
25E	7	4	.047	5.097	1.274
15E	8	3	.035	4.119	1.373
5E	9	5	.059	3.898	.78
5W	10	7	.082	4.987	.712
15W	11	4	.047	2.809	.702
25W	12	4	.047	2.525	.631
35W	13	3	.035	3.298	1.099
45W	14	9	.106	10.241	1.138
55W	15	6	.071	5.491	.915
65W	16	5	.059	4.434	.887
75W	17	5	.059	4.182	.836
85W	18	1	.012	.647	.647
	TOTAL	85		87.138	1.025
	EAST	41	.482	48.524	1.184
	WEST	44	.518	38.614	.878

Table 9. Single Multispectral SPOT Lineaments "13 NOV 87"

ORIENTATION	SECTOR	COUNT	PERCENT of TOTAL	LENGTH (Miles)	AVERAGE LENGTH
85E	1	4	.043	3.866	.967
75E	2	3	.032	4.577	1.526
65E	3	10	.106	12.009	1.201
55E	4	11	.117	19.901	1.809
45E	5	11	.117	9.784	.889
35E	6	4	.043	4.797	1.199
25E	7	7	.074	12.829	1.833
15E	8	1	.011	3.214	3.214
5E	9	1	.011	.789	.789
5W	10	2	.021	2.841	1.421
15W	11	1	.011	.663	.663
25W	12	3	.032	7.811	2.604
35W	13	3	.032	3.838	1.279
45W	14	8	.085	9.673	1.209
55W	15	8	.085	8.695	1.087
65W	16	6	.064	8.632	1.439
75W	17	8	.085	8.269	1.034
85W	18	3	.032	5.649	1.883
	TOTAL	94		127.837	1.36
	EAST	52	.553	71.766	1.38
	WEST	42	.447	56.071	1.335



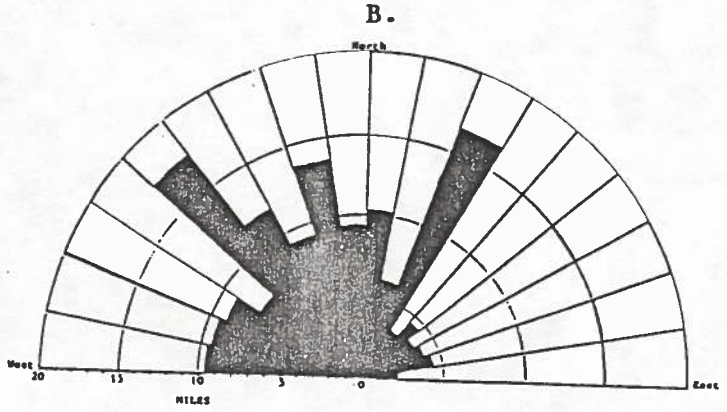
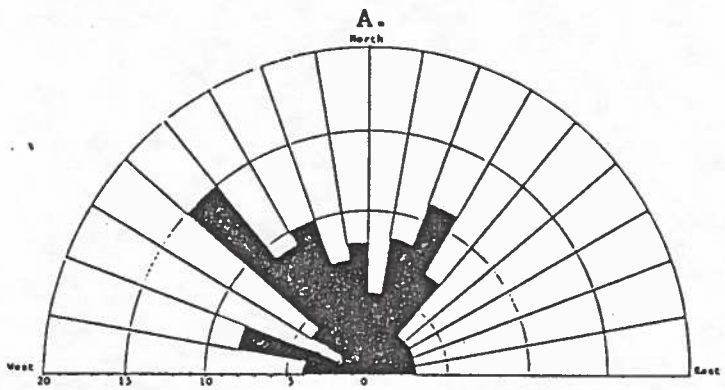


Figure 8. NHAP photo-lineament radial diagrams.
A. Number of lineaments per orientation.
B. Length of lineaments per orientation.



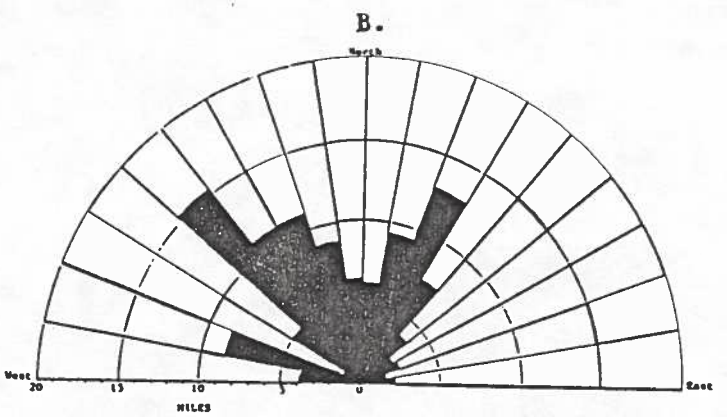
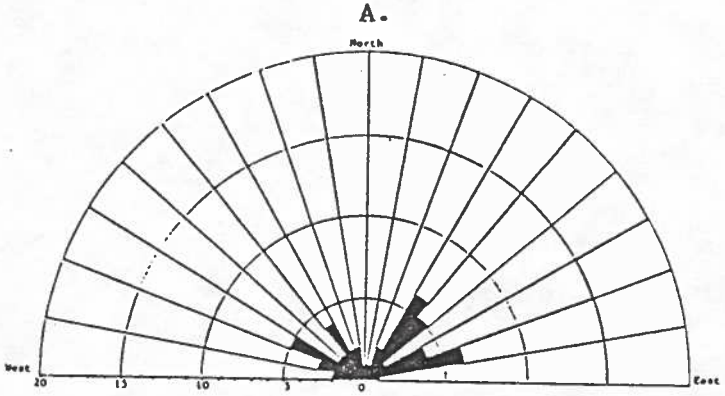


Figure 9. B and W air photo-lineament radial diagrams.
A. Number of lineaments per orientation.
B. Length of lineaments per orientation.



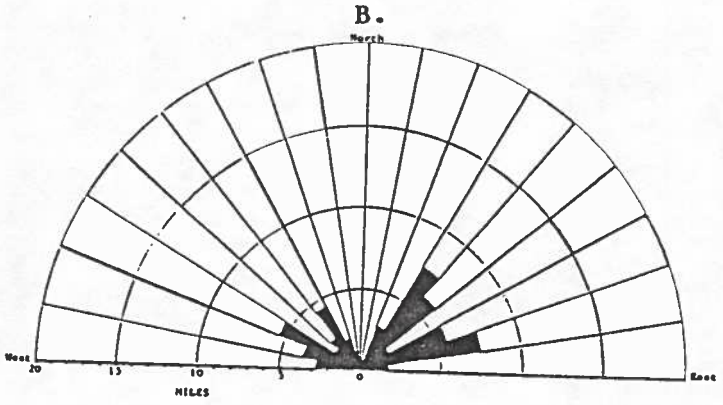
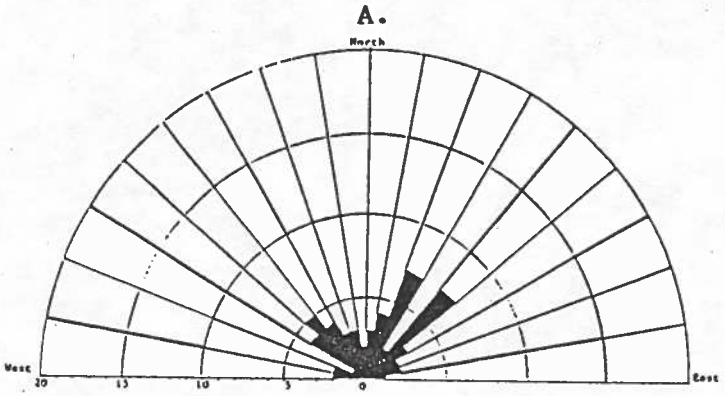


Figure 10. Panchromatic SPOT lineament radial diagrams.
A. Number of lineaments per orientation.
B. Length of lineaments per orientation.



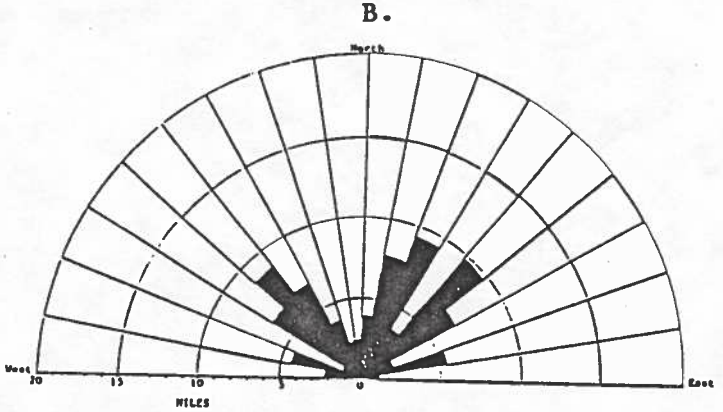
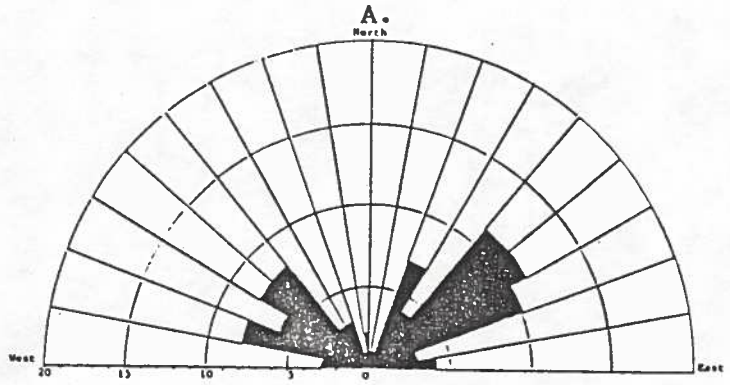


Figure 11. Multi-spectral SPOT lineament radial diagrams. A. Number of lineaments per orientation. B. Length of lineaments per orientation.



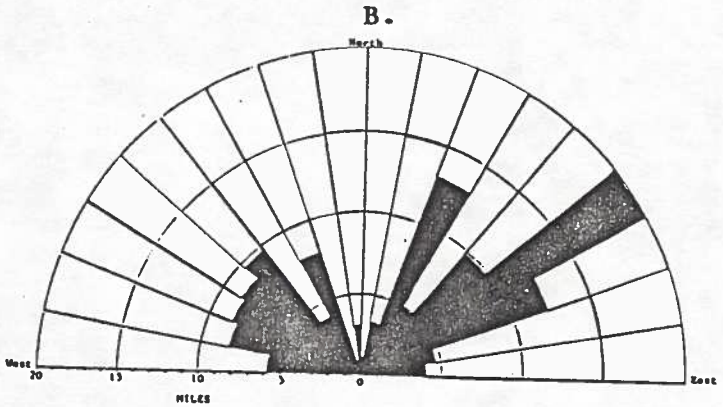
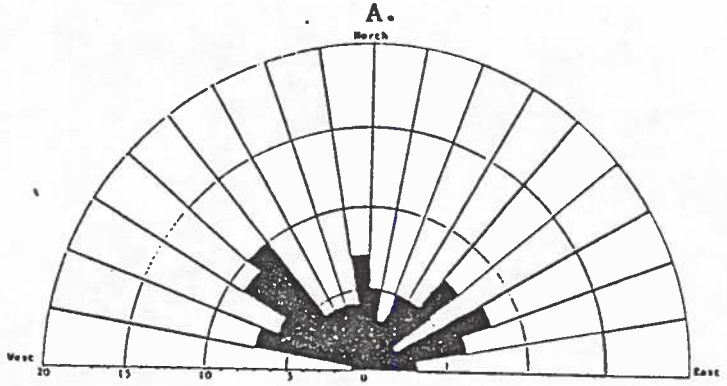


Figure 12. Single multi-spectral SPOT (13NOV87) lineament radial diagrams. A. Number of lineaments per orientation. B. Length of lineaments per orientation.



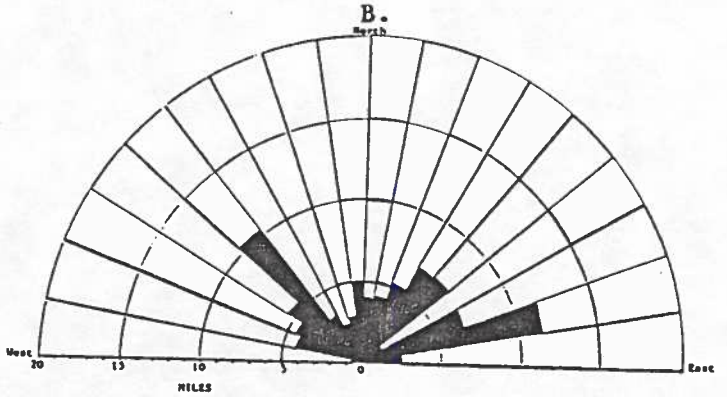


Figure 13. Panchromatic and multi-spectral SPOT lineament radial diagrams. A. Number of lineaments per orientation. B. Length of lineaments per orientation.

The aerial photography generally yielded the most lineaments, the shortest average lineament length, and the greatest number of lineaments per mapped area, on the order of 4 to 8 times that for SPOT imagery. The NHAP imagery yielded the most lineaments. The air photography yielded a strong westerly trend of lineaments whereas the SPOT imagery only slightly favored an easterly trend. Also, the lineament orientations are not evenly distributed over the maps, and the lineament orientations appear to cluster. Overlaying the lineament maps on a geologic map may partially explain the lineament orientations and clustering.

No true stereo vision was noted in any SPOT pair, only pseudo-stereo vision owing to contrast of image features. Of the SPOT images, the single-SPOT image interpretation yielded the greatest number of lineaments, greatest total lineament length, greatest average length, and the highest number of lineaments per mapped area. This is the late fall, false color, multi-spectral image which shows the greatest topographic texture. The results indicate that single SPOT image lineament mapping may be the best for SPOT images.

When compared to the NHAP lineaments, half or more of the other imagery's lineaments, within the NHAP coverage area, match with NHAP identified lineaments. Also, particularly with the SPOT imagery, a large number, more than 85 percent, of the NHAP lineaments are unmatched. This would seem to indicate that where a single SPOT image could cover a large area relatively inexpensively, only 10 to 15 percent of the potential lineaments may be identified.

If cost is the only effectiveness factor, a winter panchromatic SPOT image, the least expensive per area covered, is the most effective imagery. If cost and lineament mapping ability are considered together, the NHAP imagery is the most effective lineament mapping tool.

More work is necessary to explain the apparent lack of lineament correspondence between imagery types. Questions to be answered are:

Do different imagery types favor certain landscape features and thus yield different lineaments?

Will common-area comparison reduce the discrepancy?

Should lineament mapping be a two- or three- step process involving lineament mapping, comparison to topographic sheet, and reassessment of lineaments with topographic map plots on hand?

Another possible application of the lineament maps would be to compare yields of existing wells with their proximity to the various lineaments. This will not only require office map-overlay work but field work also. Field verification of lineaments, as well as investigation of fracture dip, will be needed to substantiate the overlay work.