Analysis of Airphoto Linear Pattern in Eastern Massachusetts

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INTRODUCTION

AN AIRPHOTO linear as herein described is any narrow, fairly continuous lineation of natural origin which is discernible under stereoscopic analysis of aerial photography. In this area, which includes portions of Clinton, Boylston, Berlin, Northboro, and Marlborough Townships, Massachusetts, the majority of these features was expressed primarily as tonal lineations in the soil or vegetative cover, and less often as aligned topographic features such as straight stream segments or lake banks. Occasionally combinations of the above were noted, e.g., a straight stream segment perfectly aligned with a lineation in the adjacent vegetation. The average length of the linears in this area is approximately $\frac{1}{8}$ of a mile, and all are shorter than $\frac{3}{4}$ of a mile.

The object of this study is to determine 1) if a relationship exists between the airphoto linear pattern and the surficial or bedrock geological conditions of the area, and 2) if the recording of total *number* of linears in relation to orientation will yield similar results when compared with total *length* of linears in relation to orientation. To accomplish this the length, orientation and location of 1,234 linears were measured.

GEOLOGICAL SETTING

The area lies in the east-central portion of Massachusetts, approximately 30 mi west of Boston and 10 mi northeast of Worcester Figure (1). As mapped by Emerson (1917) it is underlain generally by a northeast trending complex of gneisses and schists of moderately high metamorphic grade. These rocks have been tightly folded and intruded by granite and pegmatite (Skehan, personal communication).

The terrain has been greatly modified by the Pleistocene ice advance. The region is almost entirely veneered by glacial drift, the drainage pattern has been deranged and where exposed even the most competent bedrock is in many places deeply gouged and fluted.

PREPARATION OF AIRPHOTO LINEAR MAP

To prepare the Airphoto Linear Map (Figure 2) the entire area was analyzed stereoscopically, and linears were delineated on transparent overlays attached to every second print. Using these delineated photographs[1] a staple photomosaic was assembled (Figure 3). Because each overlay is attached at only one end of a print it is possible to join them so that none of the interpreted information is hidden by side or forward lap. Due to the inherent distortions in a single exposure the photographs do not match perfectly along common edges. To correct partially for the larger discrepancies found at the overlap zones, an editing stage was included prior to final drafting. Whenever two or more seemingly individual linears (mapped along overlap zones) were actually a single feature duplicated by photo mismatch, a final linear was annotated which represented the mean location and orientation of the originals. Because none were displaced over a few hundred feet, or rotated more than a couple of degrees, these minor inaccuracies should not affect the results of the study.[2]

The final map (Figure 2) is a tracing of the annotated mosaic and covers approximately 40 sq mi.

ANALYSIS OF AIRPHOTO LINEAR PATTERN

The histogram of airphoto linear orientation in relation to per cent of total *number* (Figure 4) is distinctly peaked and reflects a

[1] Aerial photography was obtained from the U.S.D.A. at contact scale of 1:20,000. The prints were supplied through the courtesy of Boston College, Dept. of Geology.

[2] Linears were grouped in 10° orientation segments.

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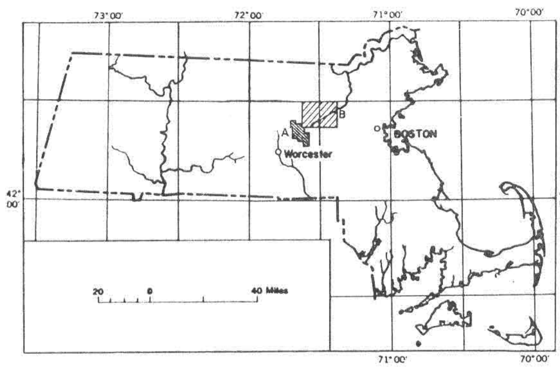

FIG. 1. Index map showing location of study area (A), and Hudson and Maynard Quadrangles (B), Massachusetts.

non-random distribution of orientation. Maximum occurrence is in the N 11°–20° W segment (19%) with lows in the northeast and northwest directions (Table 1).

The histogram of per cent of total *length* of airphoto linears in relation to orientation (Figure 5) is in very close agreement with (Figure 4) (number vs. orientation) showing that there is no preferred orientation with length of linear.

a) RELATIONSHIP TO BEDROCK GEOLOGY

Various workers in this interest area have noted the presence of similar linear features seen under stereoscopic examination of airphotos. Occassionally attempts have been made to relate their pattern to the geologic setting in order to determine their origin. Lattman refers to similar features as fracture traces (1958, p. 569) and a parallelism of "fracture trace," and joint orientations in the Allegheny Plateau, Pennsylvania has been shown successfully (Lattman and Nickelsen, 1958).

Blanchet terms these features fractures and has reported (1957) on the detection of a buried reef in Alberta by the presence of a surface "fracture" anomaly discernable on

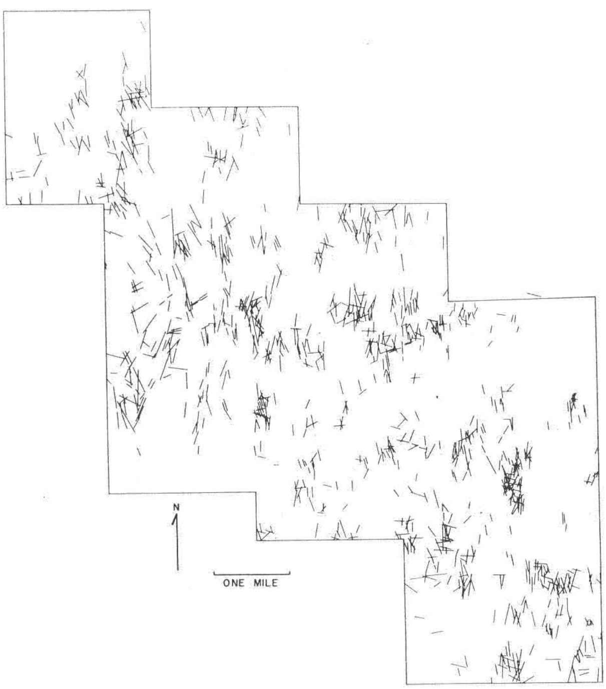

FIG. 2. Airphoto linear map of study area, Massachusetts.

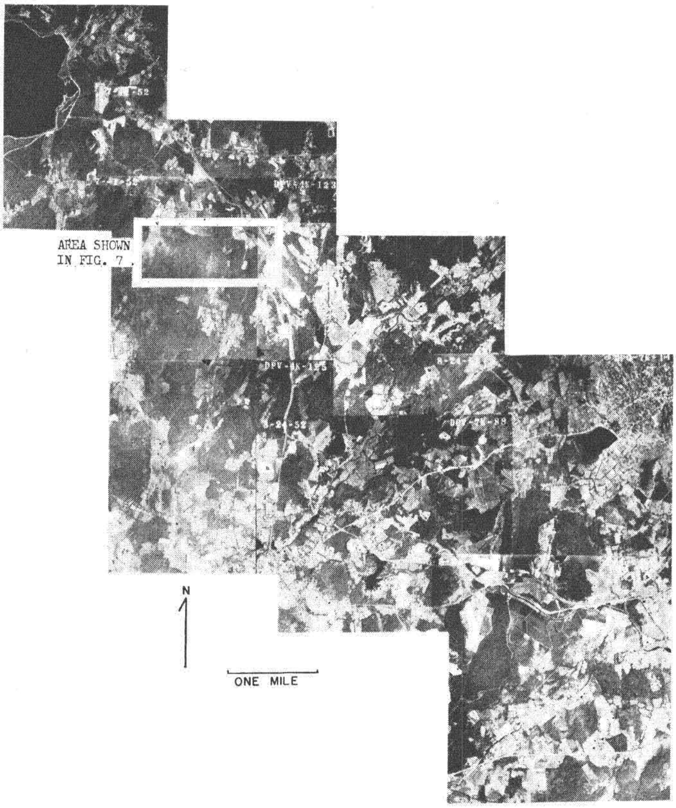

FIG. 3. Staple photomosaic of study area, Massachusetts.

aerial photographs. It was assumed that upward propagation of fractures to the surface through bedrock, unconsolidated soils, and glacial overburden does occur.

In the study area underlain by crystalline rocks there is no related parallelism between subsurface fracturing (joints and/or faults) and bearing of airphoto linears. A preliminary study of data from a detailed subsurface mapping program along an 8 mile tunnel trending northwestward through the center of the area reveals that primary fracturing orientation is N 60° W, and secondary direction is

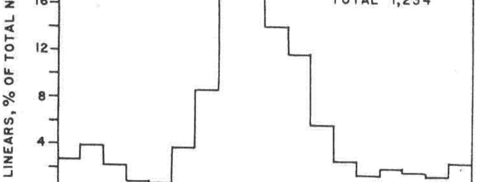

FIG. 4. Per cent of total *number* of airphoto linears in relation to orientation.

approximately N 45° W (Skehan, personal communication). The bedrock strike is generally N 20°–50° E which also indicates no correspondence with the airphoto linear pattern.

b) RELATIONSHIP TO SURFICIAL GEOLOGY

Figure 6 compares per cent of total number of glacial striations with orientation. These features which were mapped in the adjacent Hudson and Maynard quadrangles by Hansen (1956) (see Figure 1) represent the direction of the latest advance of continental glaciation. Of 112 striations found on bedrock outcrops, a peak of 44 per cent trend N 1°–10° W, 92 per cent trend N 20° W to N 9° E, and all are distributed between N 30° W and N 20° E.

The close agreement between the direction of the glacial striae and the orientation of the airphoto linears proves almost conclusively that the linears discerned on these aerial photographs are indeed indications of the latest ice flow direction (compare Figures 4 and 5 with Figure 6).

Because the length of the linears average

TABLE 1

ORIENTATION OF AIRPHOTO LINEARS AND GLACIAL STRIATIONS, EAST-CENTRAL MASSACHUSETTS

	Airphoto Linears				*Glacial Striae*	
Orientation	*Total No.*	*% Total No.*	*Total Length (mi)*	*% Total Length*	*Total No.*	*% Total No.*
N 90°–81° W	32	2.59	3.64	2.30		
N 80°–71° W	47	3.80	5.48	3.46		
N 70°–61° W	27	2.18	2.68	1.70		
N 60°–51° W	9	.73	.99	.62		
N 50°–41° W	7	.57	1.00	.63		
N 40°–31° W	45	3.65	5.96	3.77		
N 30°–21° W	105	8.51	13.33	8.43	4	3.57
N 20°–11° W	235	19.03	29.19	18.43	21	18.75
N 10°– 1° W	209	16.94	28.40	17.96	49	43.75
N 0°– 9° E	173	14.02	22.20	14.04	33	29.46
N 10°–19° E	143	11.59	19.32	12.21	5	4.46
N 20°–29° E	69	5.60	9.77	6.17		
N 30°–39° E	32	2.60	3.31	2.10		
N 40°–49° E	17	1.38	2.11	1.33		
N 50°–59° E	22	1.79	2.53	1.60		
N 60°–69° E	20	1.62	2.35	1.49		
N 70°–79° E	15	1.21	1.88	1.19		
N 80°–89° E	27	2.19	4.05	2.56		
Total	1,234	100	157	100	112	100

675 ft they obviously are not photographic images of striations. However, they probably do reflect geomorphic features which are genetically similar. These features are quite subtle on the photographs and may be difficult to observe in the field Figure (7).

The Airphoto Linear Density Map (Figure 8a) consists of contours drawn around zones of high linear density. Its comparison with Figure 8b shows a definite relationship with the land use pattern. The wooded zones, usually on topographic highs, are almost always represented by high linear densities while along cleared areas (mostly farms) airphoto linears are scarce. At present either or both of the following reasons are believed responsible for this relationship.

1. Many airphoto linears in this area were mapped on the basis of lineations in the natural vegetative pattern. Therefore, where the land has been cleared a major clue is missing.

2. An examination of the surficial geology map of nearby similar areas (Hudson, Maynard Quads., Hansen, 1956) (see Figure 1) shows a relationship between type of exposed unconsolidated deposits and topography. The areas of low relief are identified almost always by stratified drift deposited by glacial meltwater, while the topographic highs are covered by ground moraine composed of heterogeneous deposits of rock fragments. The reworking of the valley materials by meltwater may have disrupted the linear pattern still evident along the higher elevations.

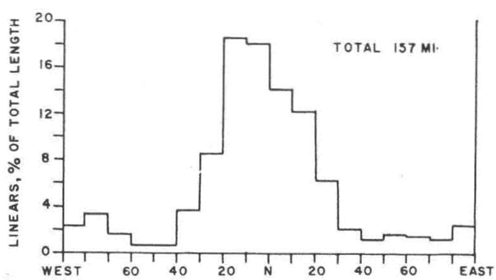

FIG. 5. Per cent of total *length* of airphoto linears in relation to orientation.

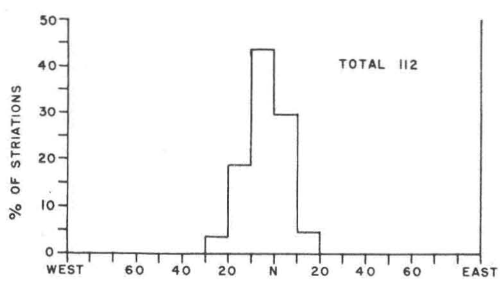

FIG. 6. Per cent of total number of glacial striations in relation to orientation.

FIG. 7. Various lineations seen on aerial photography, (A) airphoto linear, (B) lineation in vegetation reflecting bedrock strike, (C) lineation due to cultural activity. In this study only features of type A were mapped. Location shown on Figure 3.

CONCLUSIONS

1. A definite parallel relationship in orientation exists between the airphoto linears in the study area and the glacial striae on bedrock outcrops in an adjoining but partially overlapping area. No such similar relationship exists between the linears and bedrock strike or subsurface fractures (joints and/or faults). This indicates that the linears are related genetically to the glacial striae and reflect the latest movement of the glacier.

2. The plotting of total *number* of linears in relation to orientation and total *length* of linears in relation to orientation shows that in the study area there is no preferred orientation of length of linears.

3. The topographic highs usually covered by heterogeneous ground moraine and usually wooded are characterized by high densities of airphoto linears. Linears rarely occur in the lower areas which are mostly veneered by stratified glacial meltwater deposits and cleared by cultural activity.

RECOMMENDATIONS

Future research in the interpretation of airphoto linear patterns may require that only one of the parameters be determined, i.e., total length or total number of linears in relation to orientation. This would save considerable effort. In studies such as this one where all measurements were made manually total number would require less time. However, semi-automatic equipment has been built which is capable of determining only total length of lines in relation to orientation.

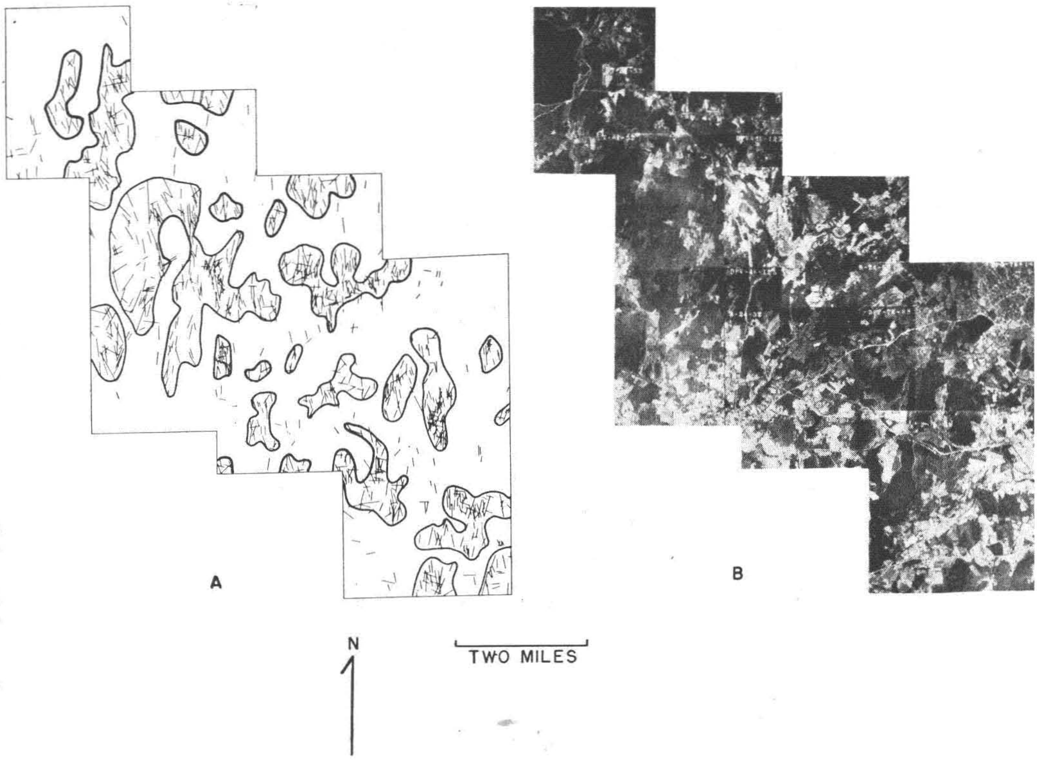

FIG. 8. (A) Airphoto linear density map; Contours enclose areas of linear concentration. (B) Photomosaic of area.

If available, this equipment would reduce the time required for surveys of this type by more than 50 per cent.

Field investigations should be undertaken to locate and determine the nature of features reflected as airphoto linears. These features may be quite subtle, presumably due to 1) aligned minor contrasts in soil composition and 2) narrow, fairly straight changes in vegetation height, density or type.

Systematic soil sampling and testing to determine grain size, gradation, moisture content, mineralogic content and color, as well as vegetation studies including tree counts, trunk diameter measurements, stand heights, and variations in vegetal types may be necessary to establish definitely the surface location of these airphoto linears.

Locating airphoto linears in the field will be greatly facilitated if undertaken at the same time of year at which the photography was exposed. During July–August the surface conditions will most closely resemble these aerial photographs of the study area.

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