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Floating Marks for the Evaluation of Altitude Differences and Slopes from Air-Photographs

by

C. Maffi

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Sets of floating marks in back pocket

SUMMARY

Stereoscopic marks with fixed parallax were prepared as a substitute for the parallax bar to evaluate, almost without calculations, altitude differences and inclinations from air-photographs.

This paper describes their construction and use.

INTRODUCTION

The photo-interpreter is often faced with the necessity of measuring altitude differences and inclinations from air-photographs. These measurements are generally made with a parallax bar, an accurate but rather expensive instrument, whose use involves calculations that may be a nuisance in particular circumstances.

On the other hand, the evaluation of such data without a proper device may be affected by errors deriving from the vertical stereoscopic exaggeration.

When an approximate but quick measure is required, floating marks can be used. They are transparent marks with fixed parallax, designed to be used in pairs under the stereoscope. A pair is chosen to obtain a stereo-model that tallies with the topographic or structural feature to be measured. The measure is obtained by entering into a conversion table the value printed on the marks.

CONSTRUCTION AND USE

Two sets of marks were prepared:

a) Marks for altitude measurements;

b) Marks for slope measurements.

The parallax displacement, which characterizes each mark, depends upon:

1) The quantity to be measured;

2) The airphoto data, namely flight height, focal length of camera and overlap; they are a function of the fundamental ratio f/b between focal length and photo-base.

The obtainable measure and the value of f/b are printed on each mark.

Normally the actual photo-coverage data are slightly different from the theoretical ones supplied by the photographer; therefore the measures are approximate.

The letters 'L" and "R" printed on the marks refer to the left and right eyes.

The arrows on the marks refer to the direction of the parallax displacement. Therefore, if two marks are used in normal position, with their arrows in opposite directions, the values of the marks are to be added up to obtain the measure. If one of the two marks is overturned (arrows in the same direction) the value of the overturned mark is to be subtracted from the value of the other mark; negative differences correspond with inverted stereo-models.

The best results are obtained when marks of similar value are used: e.g. two 5° marks instead of a 0° and a 10° mark.

It was impossible to prepare sets of marks for every possible value of the fundemental ratio; therefore the value f/b = 1 was chosen and for different values a correction has to be applied.

The photo-scale is a factor for the calculation of the altitude marks. The 1:100,000 scale was chosen and for different values a scale correction has to be applied in addition to the f/b correction.

Both corrections can be made by means of the tables enclosed at the end of this paper.

The first step for the use of the marks is the calculation of the ratio f/b and, for the altitude marks, also the calculation of the photo-scale.

The value of f is printed on the air-photographs. To obtain the value of b, the following process is suggested:

1) Plot on each photo the principal point PP (geometrical centre) and the transferred principal point TPP (principal point of the other photo);

2) Measure the distance between PP's and TPP's on each photo; they will be slightly different: chose the shorter one.

An accurate value for the photo-scale is obtainable by measuring the distance between two easily identifiable points, both on the photo and on a map. But often this is impossible and the only solution is the use of the nominal scale,

$$\frac{1}{S} = a \frac{H}{f}$$

where: S = denominator of scale

H = flight height (printed on the photo)

f = focal length of camera (printed on the photo)

a is a constant depending on the system of measure:

a = 1 if H and f are given in the same system;

a = 305 if H is given in feet and f in mm.

NOTE 1 - The air photographs should be always set so that the flight line is parallel to the stereoscope axis.

NOTE 2 - The floating marks are to be used always with the axes of the arrows parallel to the flight line.

NOTE 3 - The decimal system was used; a conversion table to the english system is enclosed at the end of this paper.

ALTITUDE FLOATING MARKS

The stereo-model is a small circle that floats above a base-surface. The base is formed by crosses, squares and circles, arranged in rows having different directions, in order to allow altitude measurements to be made on randomly oriented slopes.

The parallax differences for the floating circles were calculated from the equation:

$$\Delta p = \Delta h \cdot \frac{b}{f} \cdot \frac{1}{S} \cdot \frac{H}{H - \Delta h}$$

where: Δp = parallax difference between floating circle and base

Δh = corresponding altitude difference

b = photo-base

f = focal length of camera

S = denominator of photo-scale

H = flight altitude

As Δh is very small in comparison with H, the factor $\frac{H}{H - \Delta h}$ was assumed = 1.

Altitude floating marks were prepared for the following values of h: 10 m , 20 m , 50 m , 100 m , 200 m. By combining different marks, a large range of values up to 400 m in obtainable.

Measuring process of elevation difference between two points

Calculate the values of f/b and S. If they are respectively 1 and 100,000, then:

1) Put one of the "L" marks on the left image and one of the "R" marks on the right image.

2) Adjust marks and image under the stereoscope until the floating circle coincides with the upper point to be measured.

3) If the base-surface of the mark is higher or lower than the lower point to be measured, switch to another pair of marks until the nearest pair is found.

4) If the arrows on the marks are in opposite directions add up the values of the marks; if they are in the same direction subtract the value of the overturned mark from the value of the other. The result is the elevation difference between the two points.

When $f/b \neq 1$ the measure obtained through points 1) to 4) has to be corrected by means of Table 1.

When the photo-scale is different from 1:100,000, also Table 2 has to be used.

A rapid evaluation of the average inclination of slope between two points is possible as well. Crosses, squares and circles that form the base-surface are set at constant intervals from the centre of the mark. The length in millimeters of the constant interval, "d" is shown on the marks and may be used to measure the horizontal distance between the images of the two points. As the photo-scale is known, from this distance the average inclination of slope is easily calculated. However, for more accurate measures, the slope floating marks should be used.

SLOPE FLOATING MARKS

The stereo-model is an inverted cone. The angle between base and generatrix was calculated from the equation

$$\tan\alpha = \Delta p \cdot \frac{f}{b} \cdot \frac{1}{r}$$

where: α = angle of slope with horizontal plane
Δp = parallax difference between vertex and centre of cone
f = focal length of camera
b = photo-base
r = radius of base of cone.

Slope floating marks were prepared for the following values of α: 1°, 3°, 5°, 9°, 10°, 12°, 15°, 20°, 25°, 30° and 40°. By combining different marks, a large number of values up to 40° is obtainable; values higher than 40° are difficult to evaluate because of the excessive parallax difference.

Measuring process of inclinations

Calculate the value of f/b. If f/b = 1, then:

1) Put one of the "L" marks on the left image of the exposed bed or slope and one of the "R" marks on the right image.

2) Adjust marks and image under the stereoscope until the vertex of the mark coincide with the base of the bed or slope.

3) If the generatrix of the inverted cone is higher or lower than the surface of the bed or slope, switch to another pair of marks until the nearest pair of marks is found.

4) if the arrows on the marks are in opposite directions, add up the values of the marks; if they are in the same dirrection, subtract the value of the overturned mark from the value of the other. The result is the dip of bed or slope.

When $f/b \neq 1$, the measure obtained through points 1) to 4) has to be corrected by means of Table 3.

The perspective effect (relief displacement) can remarkably alter the slope estimation. This effect was not accounted for in the preparation of the marks; their use is thus correct only for a belt of 10° on both sides of the line of flight. On usual air photographs, this limit is about 3 cm off the line of flight; however a limit of 6 cm is considered good enough for approximate measurements. Outside this belt the use of the marks should be restricted to the measure of features dipping less than 5° (perspective effect is directly proportional to the inclination) or to the measure of dips or slopes having strike perpendicular to the line of flight (no perspective effect).

CONCLUSIONS

The use of floating marks rather than a parallax bar for the evaluation of altitude differences and inclinations allows the photo-interpreter a remarkable saving of time, particularly when experience has been gained through exercise. The measures are not accurate, but good enough for normal work.

Because of these characteristics the floating marks are considered particularly useful during field mapping supported by photo-interpretation.

TABLE 1 - ALTITUDE FLOATING MARKS, f/b CORRECTION

If f/b is →	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
and Δh (m) is ↓	the correct value of Δh (m) is ↓										
10	10	11	12	13	14	15	16	17	18	19	20
20	20	22	24	26	28	30	32	34	36	38	40
30	30	33	36	39	42	45	48	51	54	56	60
40	40	44	48	52	56	60	64	68	72	76	80
50	50	55	60	65	70	75	80	85	90	95	100
60	60	66	72	78	84	90	96	1022	108	112	120
70	70	77	84	91	98	105	112	119	126	~~133~~	140
80	80	88	96	104	112	120	128	136	144	152	160
90	90	99	108	117	126	135	144	153	162	171	180
100	100	110	120	130	140	150	160	170	180	190	200

For greater values of Δh: e.g. Δh = 140, f/b = 1.3

100	correct value: 130
40	correct value: 52
140	correct value: 182

TABLE 2 - ALTITUDE FLOATING MARKS, SCALE CORRECTION

If S is →	100,000	90,000	80,000	70,000	60,000
multiply the correct Δh by →	1.0	0.9	0.8	0.7	0.6

IfsS is →	50,000	40,000	30,000	20,000	10,000
multiply the correct Δh by →	0.5	0.4	0.3	0.2	0.1

Example: Let assume that an altitude difference of 60 m has been measured on photos having f/b = 1.6 and S = 50,000. From Table 1 we obtain a correct Δh = 96 m; on Table 2 we find the correction factor 0.5. Thus the final correct value is 48 m.

NOTE: Intermediate values can be easily interpolated.

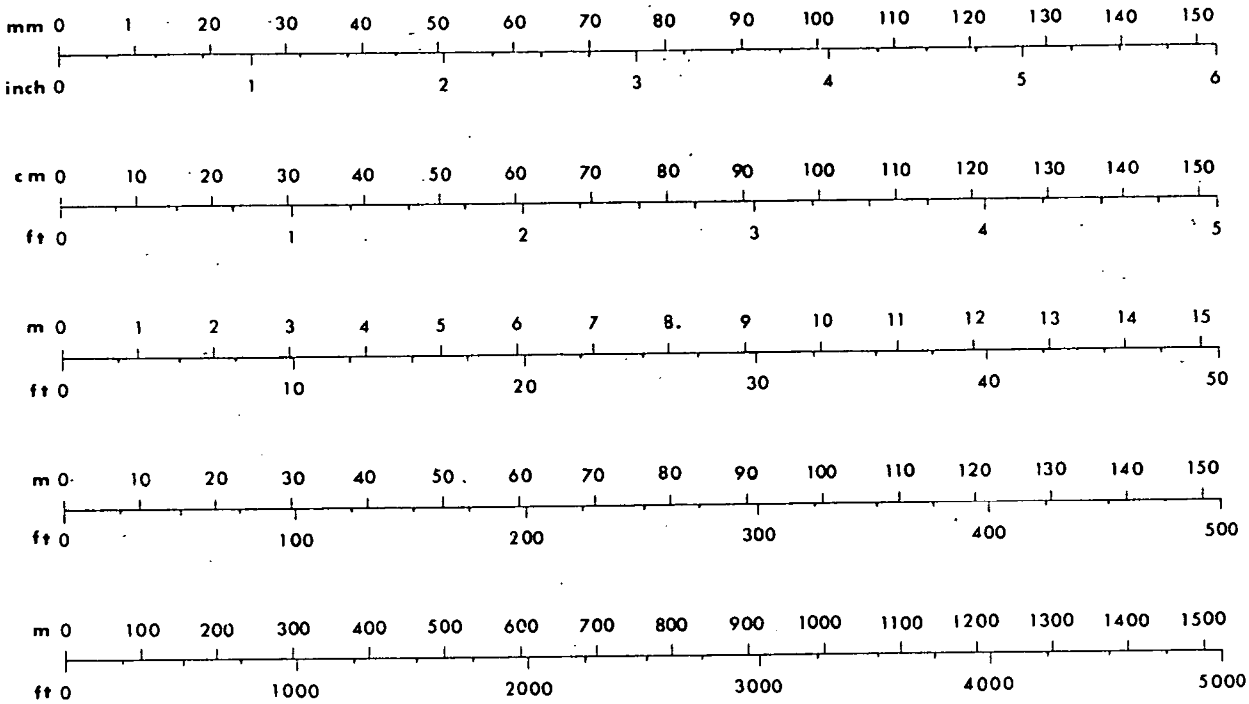
TABLE 3 - SLOPE FLOATING MARKS, f/b CORRECTION

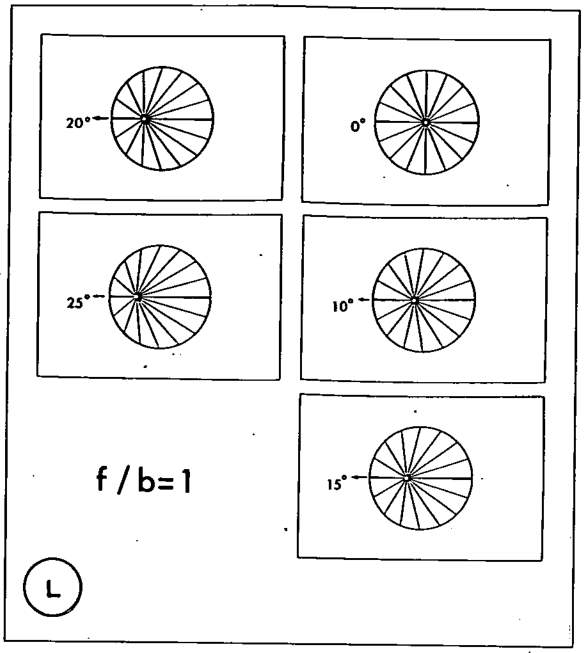
NOTE: For $\alpha < 5^\circ$ the correct value is approximated to the nearest 30'.
For greater α the correct value is approximated to the nearest 1°.

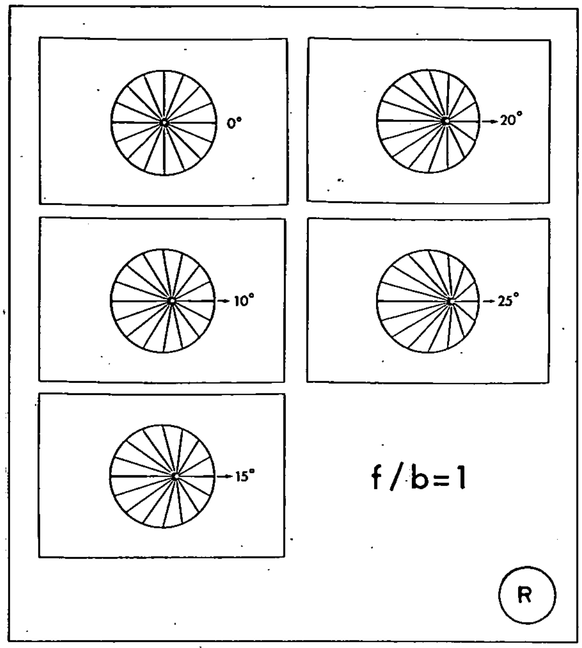
If f/b is →	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
and α is ↓	the correct value of α is ↓										
1°	1°00'	1°00'	1°00'	1°30'	1°30'	1°30'	1°30'	1°30'	2°00'	2°00'	2°00'
2°	2°00'	2°30'	2°30'	2°30'	3°00'	3°00'	3°00'	3°30'	3°30'	4°00'	4°00'
3°	3°00'	3°30'	3°30'	4°00'	4°00'	4°30'	5°00'	5°00'	5°30'	5°30'	6°00'
4°	4°00'	4°30'	5°00'	5°00'	5°30'	6°00'	6°30'	7°00'	7°00'	7°30'	8°00'
5°	5°	5°	6°	6°	7°	7°	8°	8°	9°	9°	10°
6°	6°	7°	7°	8°	8°	9°	10°	10°	11°	11°	12°
7°	7°	8°	8°	9°	10°	10°	11°	12°	12°	13°	14°
8°	8°	9°	10°	10°	11°	12°	13°	13°	14°	15°	16°
9°	9°	10°	11°	12°	12°	13°	14°	15°	16°	17°	18°
10°	10°	11°	12°	13°	14°	15°	16°	17°	18°	18°	19°
11°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°
12°	12°	13°	14°	15°	16°	18°	19°	20°	21°	22°	23°
13°	13°	14°	15°	17°	18°	19°	20°	21°	22°	24°	25°
14°	14°	15°	17°	18°	19°	20°	22°	23°	24°	25°	26°
15°	15°	16°	18°	19°	20°	22°	23°	24°	26°	27°	28°
16°	16°	17°	19°	20°	22°	23°	25°	26°	27°	28°	30°
17°	17°	18°	20°	22°	23°	25°	26°	28°	29°	30°	31°
18°	18°	20°	21°	23°	24°	26°	27°	29°	30°	31°	32°
19°	19°	21°	22°	24°	26°	27°	29°	30°	32°	33°	34°
20°	20°	22°	23°	25°	27°	29°	30°	32°	33°	35°	36°
30°	30°	32°	35°	37°	39°	41°	43°	44°	46°	48°	49°
40°	40°	43°	45°	47°	49°	51°	53°	55°	56°	58°	59°
50°	50°	53°	55°	57°	59°	61°	63°	64°	65°	66°	67°
60°	60°	62°	64°	66°	68°	69°	70°	71°	72°	73°	74°
70°	70°	72°	73°	74°	75°	76°	77°	78°	79°	79°	80°
80°	80°	81°	82°	83°	83°	84°	84°	84°	85°	85°	85°
90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°

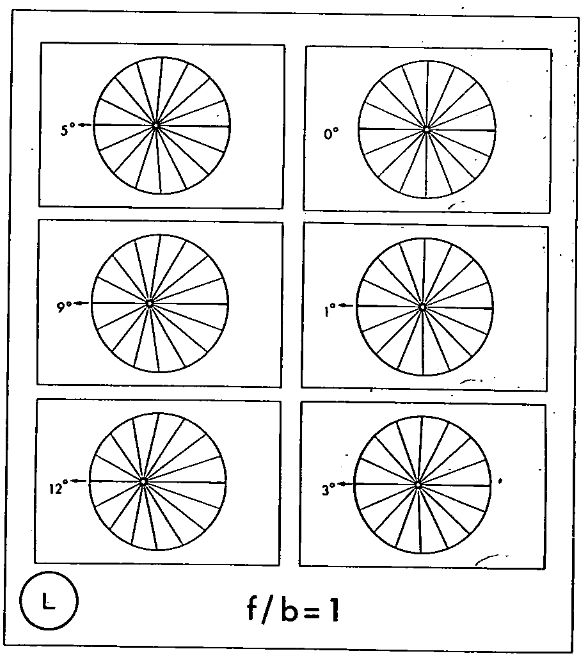
Example: Let assume that a dip of 12° has been measured on photos having f/b = 1.6. The correct value is 19°.

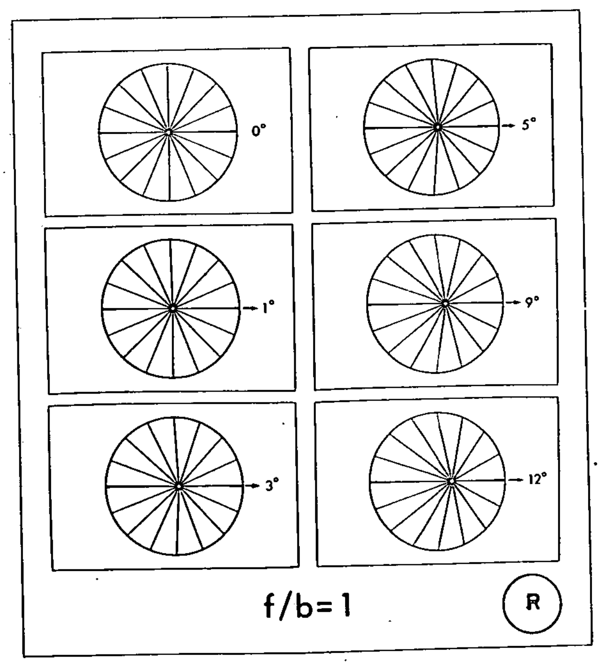
TABLE 4 — CONVERSION TABLE BETWEEN DECIMAL AND ENGLISH SYSTEMS

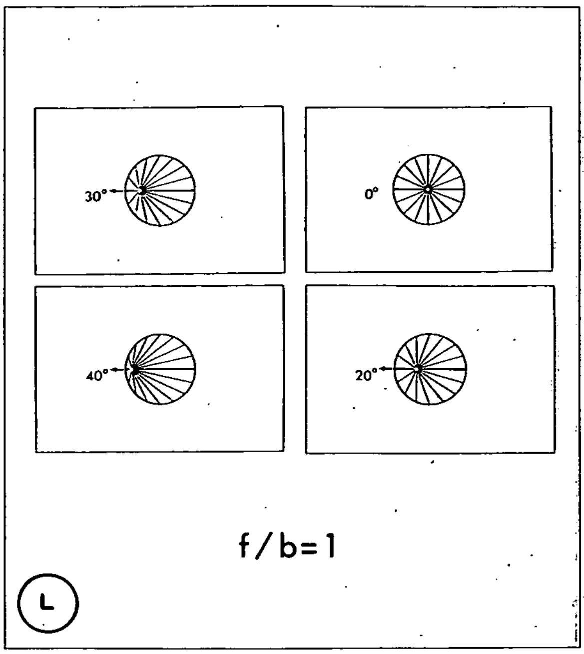


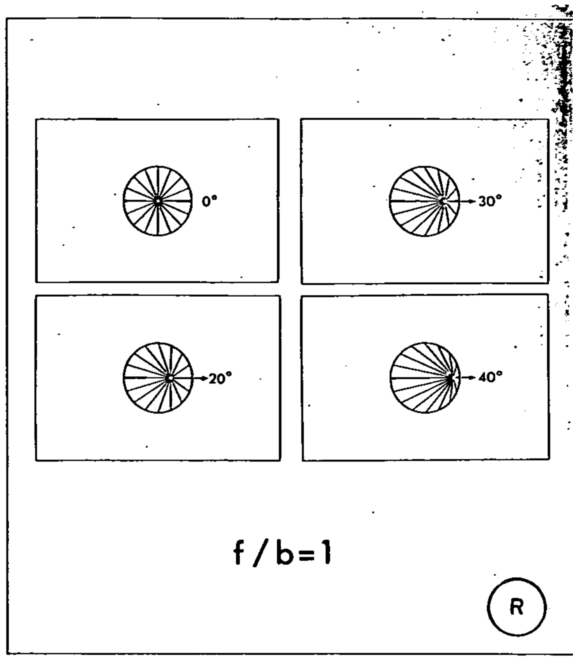

20°
0°
25°
10°
15°
f / b=1
L

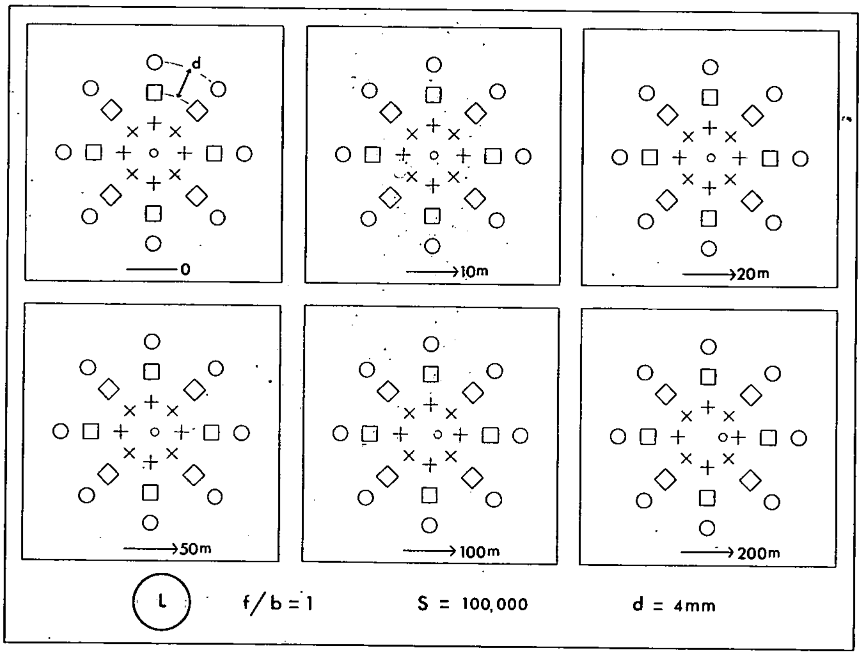

0°
20°
10°
25°
15°
f / b=1
R

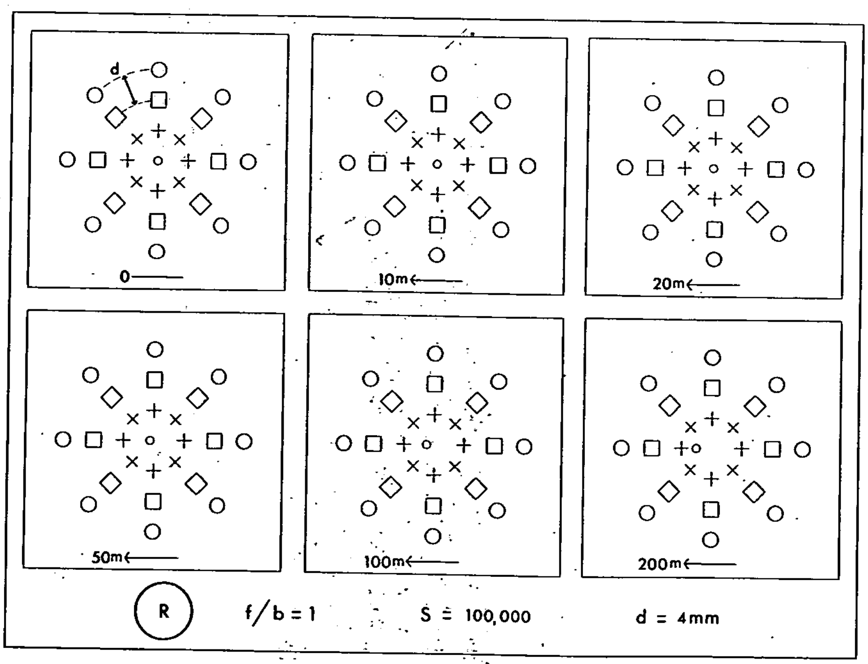

5°
0°
9°
1°
12°
3°
L
f / b=1


0°
5°
1°
9°
3°
12°
f/b=1
R


30°
0°
40°
20°
f/b=1
L


0°
30°
20°
40°
f/b=1
R


d
0
10m
20m
50m
100m
200m
L
f/b=1
S = 100,000
d = 4mm


d
0
10m
20m
50m
100m
200m
R
f/b=1
S = 100,000
d = 4mm