

## THE TECHNIQUE OF AIR-ARCHAEOLOGY

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### INTRODUCTION

This paper records experience gained during wartime flying, which made the writer very familiar with the appearance of the English countryside from the air and with the numerous ancient remains which can be seen when flying. Most archaeological work has had to cease during the war, and it is therefore pleasant to be able to bring forward results made possible by the opportunities of war service. In the future, systematic archaeological research from the air may be practicable, and it is hoped that these notes will be of use.

An airman views the earth at a much greater range than a pedestrian and from a very different angle, and is able to see much that would almost certainly escape observation on the ground, or that if seen, would probably not be understood. The first point, the effect of the greater range, is best explained by the analogy of a newspaper half-tone illustration, printed by a large number of small dots, which, seen at the distance of a foot or two, coalesce to form varying shades of grey. Similarly, large numbers of different-coloured plants in a cornfield reveal little or nothing to a person walking over the site, while they may present a clear pattern to an aviator viewing the ground from a distance. The second advantage of the aerial viewpoint is that the surface of the earth is seen from a more or less vertical direction and perspective distortion is thus reduced to a minimum. On the ground, the nearly horizontal view makes it impossible to see large sites as a whole, except in a distorted way, and, for example, low earthworks, which may be meaningless when examined on foot, are explained at once by an air-photograph taken under the right conditions. In addition, the comprehensive view from an aircraft enables a large tract of land to be examined in a relatively short time, and a great deal may be discovered even in a single flight.

Unfortunately, however, certain factors, geological and agricultural, limit the terrain favourable for aerial study, and much is entirely unsuitable. These factors, which are discussed in the following pages, as far as they are understood at present, must be considered when undertaking the exploration of any part of the country. It is therefore misleading to expect too much of air-archaeology, but nevertheless, within its limits, and providing that it is used intelligently,<sup>1</sup> it is of the greatest value, as demonstrated by the many important, sometimes spectacular, discoveries made by O. G. S. Crawford and the late Major G. W. G. Allen.

The results of aerial exploration, of course, do not in any way lessen the importance of work on the ground. Field-work and excavation are greatly helped by this new archaeological technique, but they are in no way superseded; indeed, unless based on knowledge of similar sites on the ground, the interpretation of air-photographs of crop-marks, etc., is very uncertain.

The general principles of archaeological work from the air were laid down by Crawford in his successive works, *Air Survey and Archaeology* (1924), *Wessex from*

<sup>1</sup> See also I. A. Richmond's remarks in *J.R.S.*, xxxiii (1943), 45.

*the Air* (1928), *Air Photography for Archaeologists* (1929) and *Luftbild und Vorgeschichte* (1938). The comprehensive sets of photographs in these volumes admirably illustrate the technique of archaeological air-photography, particularly those in *Luftbild und Vorgeschichte*. Crawford classified the types of sites, according to the means by which they were revealed, into shadow sites, soil-mark sites and crop-mark sites, and gave much detailed information, which the present paper is intended to supplement.

The writer would like to acknowledge the help given in the preparation of this paper by J. K. St. Joseph, W. J. Arkell, A. F. Hall and R. J. C. Atkinson.

#### SHADOW SITES

Old earthworks survive on land which has never been ploughed (unless in ancient times), usually on hill-tops or in low-lying and badly-drained country.

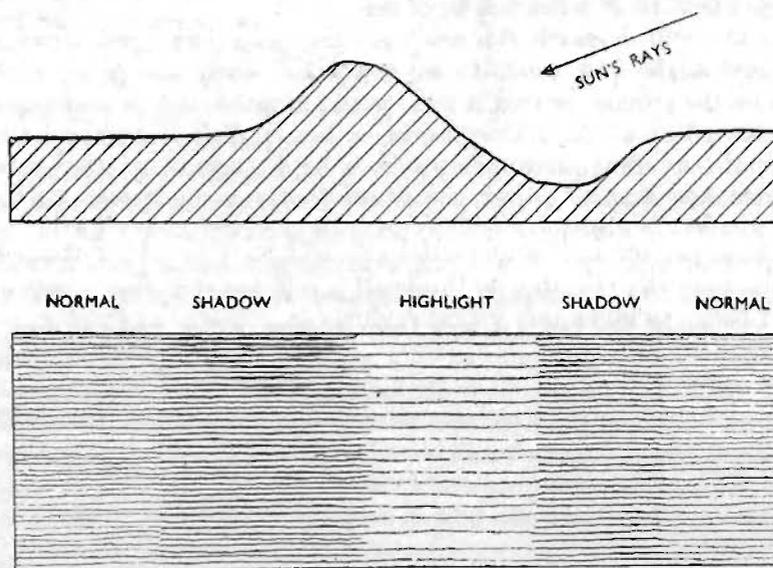


FIG. 1. SHADOW-SITE

When the sun is low, any unevenness of the ground is shown in relief, and previously unnoticed banks and ditches, such as those left by old field-systems, or fresh details of earthworks already known, are revealed with the greatest clarity, so that a single air-photograph may record more than the most painstaking ground survey. The study of such sites in Wessex by Crawford has made the technique quite well known, and little can be added to his conclusions.

The earthworks are shown by the contrast of shadows, normal lighting and highlights, the dark lines of shadow being the most important factors (fig. 1). The direction as well as the altitude of the sun must be considered. If its rays are parallel to a bank or ditch, the lighting will be perfectly even. To cast shadows it is obviously necessary for the direction of the sun to be different from the line of a bank or ditch, and the nearer the angle between the two approaches  $90^\circ$ , the more marked will be the shadow.

The lynchets left by the ploughing of 'Celtic' fields on the slopes of the Downs of Southern England may be shown by normal lighting and shadows with no highlights (fig. 2, *a*) or with the slope in a different direction, by normal lighting and highlights<sup>1</sup> without shadows (pl. I, A and fig. 2, *b*).

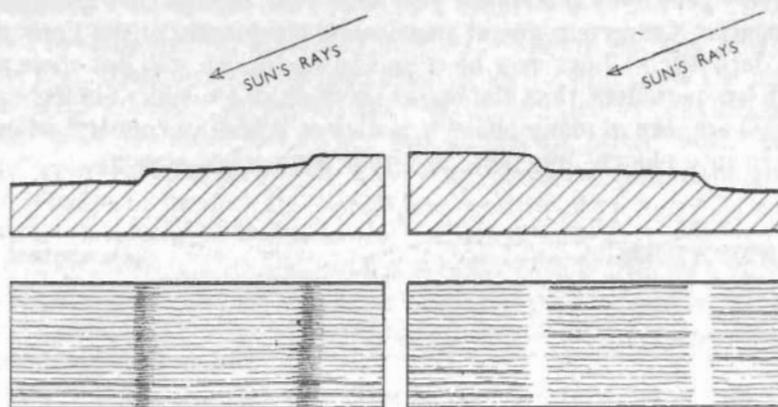


FIG. 2, *a*. LYNCHETS SHOWN BY SHADOWS AND NORMAL LIGHTING

FIG. 2, *b*. LYNCHETS SHOWN BY HIGHLIGHTS AND NORMAL LIGHTING

It has been pointed out<sup>2</sup> that earthworks seldom throw sharp shadows unless they are grass-grown. In the north, heather often camouflages the details of mounds and banks so much that air survey may be greatly hampered.

#### SOIL-MARKS

Earthworks are soon reduced when the land is taken under plough, but their positions are still shown by marks in the soil caused by the different colours of dark humus from old ditches, mixed soil and excavated subsoil from banks and mounds, and pure subsoil exposed on the edges of ditches, all of which are contrasted with normal-coloured soil on the surrounding land. A conventional diagram (fig. 3) is given to illustrate the formation of a soil-mark. The exact way in which the marks are formed naturally differs from one case to another.

Soil-marks show very distinctly after the first ploughing of old earthworks and reappear annually on ploughing, but gradually become weaker, and eventually, when the surface soil has been made nearly uniform by repeated cultivation, they disappear. One cannot help feeling regret while watching this gradual process of destruction. The marks are probably at their best when a field has been standing ploughed for some time and has been weathered. They are blurred by harrowing, drilling or ridging for potatoes. The weather seems to have little effect, except in the case of very weak marks, which are seen best when it is dry (see below under Damp-Marks).

<sup>1</sup> 'Highlight' is the best word to use when referring to the brightest parts of a photographic print; see Wall's *Dictionary of Photography* (15th edn.)—'Highlights, the brightest parts of a picture'. In describing lynchets shown by highlights (as pl. I, A) Crawford used the term

'reflected light' (*Air Photography for Archaeologists*, pl. V), but this is open to the objection that all parts of the earth shown on air photographs are seen by reflected light.

<sup>2</sup> By I. A. Richmond, op. cit.

The best subsoil for soil-marks is chalk, which contrasts strongly with the brown surface soil above it. The silt areas of the Fens (southern Lincolnshire and northern Cambridgeshire) are almost equally good, the colours there being the yellowish-brown of the silt and the black or dark brown of ditch-fillings. In both cases the marks are very persistent and appear year after year, though they gradually become more indistinct. On certain gravel areas round the margin of the Fens' soil-marks caused by dark ditch-fillings may be traced on the brown soil, but these are apparently much less persistent than the marks on chalk or fen silt. Similar dark marks on brown soil are seen in many places (e.g. clay or limestone country) when the land is first taken into plough, but they disappear after a few seasons.

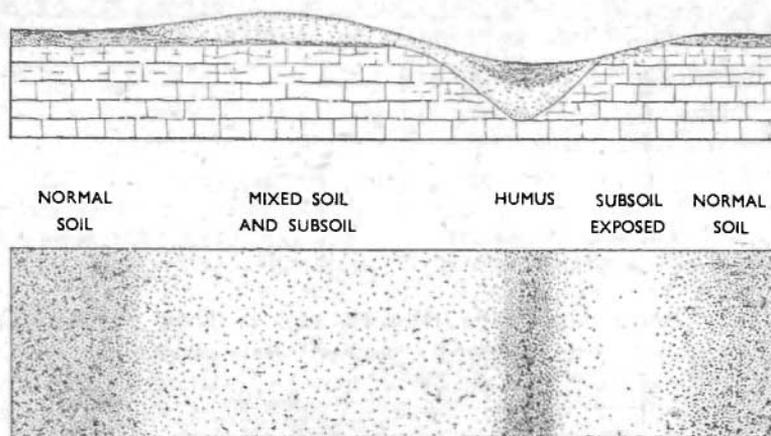


FIG. 3. FORMATION OF SOIL-MARK

Remarkable soil-marks are occasionally seen in gravel pits where the surface soil has been removed from large patches of ground before the excavation of the gravel. In such cases any ditches or pits in the gravel are shown prominently by their dark filling.

#### DAMP-MARKS

This term has been proposed to describe a variety of soil-marks recorded by Crawford. In fields with chalky subsoil where normal soil-marks have nearly disappeared, filled-in ditches are sometimes revealed by dark marks during a long dry spell, usually in the spring.<sup>2</sup>

#### FROST- AND SNOW-MARKS

Buried remains are reported<sup>3</sup> to be shown by marks in hoar frost or thin snow. The only instance which has come to the notice of the writer was at Radley, Berks., where Major Allen photographed white marks above filled-in ditches of destroyed Bronze Age barrows after a light fall of snow. The subsoil here is gravel. Marks

<sup>1</sup> Between Eye and Thorney, Cambs., north-east of Somersham, Hunts., and in Smithy Fen, Cottenham, Cambs.

<sup>2</sup> A good example, photographed near Old

Sarum, Wilts., is illustrated in *W.A.M.*, xlvii, 406 and pl. II, also in *Luftbild und Vorgeschichte*, 44.

<sup>3</sup> *Luftbild und Vorgeschichte*, 23.

of this type seem to be too rare to have much practical value, and the features which produce frost-, snow-, or damp-marks almost certainly would be revealed much more clearly, and for a much longer time, by crop-marks.

#### CROP-MARKS

Ancient remains such as ditches, pits or wall-foundations, now buried beneath the surface, may affect crops or herbage growing above, and cause the variations in colour and density known as crop-marks. Many of these old disturbances of the ground may have produced soil-marks, but unlike the latter, which do not last indefinitely, crop-marks appear year after year, whenever conditions are suitable. The buried remains lie beneath the plough level and are not affected by cultivation.<sup>1</sup> Crop-marks are thus a very valuable source of information in an intensively cultivated country like England. Their existence has actually been known for a long time—for example Stone in 1857<sup>2</sup> and Haverfield in 1899<sup>3</sup> recorded a number of crop-sites in the Upper Thames valley—but not until the advent of the aeroplane was it possible to find and record them easily.

The early remains are not seen directly, but are revealed by the medium of plant growth, and thus some understanding of the way in which the marks are

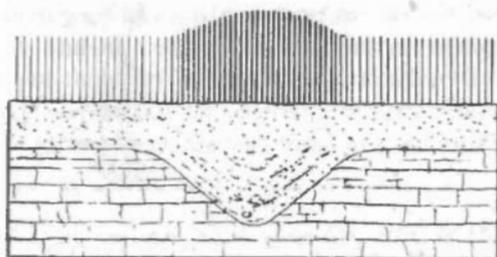


FIG. 4, *a*. POSITIVE CROP-MARK

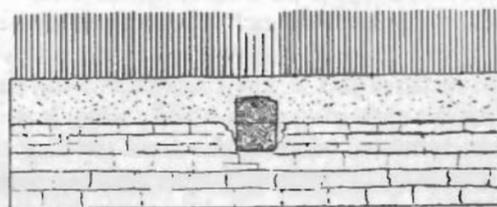


FIG. 4, *b*. NEGATIVE CROP-MARK

produced is essential for their interpretation. The buried ditches, foundations, etc., may cause (*a*) variations in the depth and/or richness of the soil, (*b*) lines favourable (ditches) or resistant (foundations) to root penetration, and (*c*) lines holding more water than the undisturbed subsoil. The surface geology would be expected to be a

<sup>1</sup> In many places in the upper Thames valley, crop-marks due to strip-cultivation intersect marks caused by prehistoric and Romano-British remains. By examination of old estate maps, Crawford showed that one of these sites,

the well-known crop-site near Foxley Farm, Eynsham, Oxon, had been under cultivation since at least 1615; *Antiquity*, vii, 293.

<sup>2</sup> *Proc. Soc. Antiq.*, iv, 99.

<sup>3</sup> *Ibid.*, 2nd ser., xviii, 10 ff.

controlling factor, and experience indicates that it is actually of great importance. Certain types of rock or subsoil seem to favour the development of crop-marks, while others are evidently uncongenial and result in their absence in many apparently suitable tracts of country. The right crops and dry weather are necessary, so that there are several variables to be considered when studying the causes of crop-marks. The precise manner in which these factors affect the crops is not yet fully understood; this lies in the field of the botanist, and archaeologists would be most interested in the results of any further research into it. But meanwhile, quite enough is known already, both of the cause (buried ditches, etc.) and the effect (crop-marks), to afford much practical assistance to archaeological work.

Two new terms are suggested to help to describe crop-marks: *Positive Marks*, lines and patches in the crops where growth is *increased* by filled-in ditches and pits, which augment the depth of soil (fig. 4, *a* and pl. III, *B*), and *Negative Marks*, the reverse of positive, growth being *reduced* by buried wall-foundations, etc. (fig. 4, *b* and pl. III, *A*).

It is worth noting that the crop-mark is seldom as wide as the ditch or other feature beneath it. Growth is hardly affected over the edges of a V-sectioned ditch, for instance, and a definite mark only appears above the central portion.

Crop-marks are quite often seen in combination with soil-marks (pl. II). They may also be valuable in helping to trace earthworks (negative mark in the grass on mounds or banks, positive in ditches) when the sun has risen too high to throw shadows. Similarly soil-marks and shadows, in combination, may reveal a ploughed earthwork.

## SURFACE GEOLOGY

### (a) *Positive Crop-marks*

Positive marks, by far the more common type, generally result from sharp local variations in the depth of soil, caused by old ditches and pits, which were dug deep enough to penetrate the subsoil and subsequently allowed to silt up. The marks are affected by the width and depth of such excavations in the subsoil and are most pronounced when they are large and deep. The minimum width to produce a crop-mark is about two or three feet. The thickness of the natural layer of surface soil also has an effect, marks appearing more readily when it is thin. Crop-marks are seldom produced by the lynchets which make such striking patterns of soil-marks on the chalk country of Wessex. The disturbances of the ground caused by lynchets are too shallow to affect crops much.

The subsoil must be of the right type: well drained, so that dry weather quickly has an effect and the plants standing on deeper soil are the only ones to flourish; soft enough to offer no obstacle to early man when digging ditches and pits; and compact, so that these excavations retained their shape when silting up and filling with soil. The question of the resistance of the different subsoils to root penetration may also prove important. It is possible that crop-marks may not readily appear on loose subsoils, open to root penetration, where the roots of crops may reach as far down in the undisturbed subsoil as in the silting of old excavations.

Compact gravel, such as that found in many river valleys, is undoubtedly the best subsoil, and chalk is also very good. Limestone may give good results when the

top layers are rubbly, but, for reasons not fully explained, crop-sites on limestone are rare. Possibly the hard rock generally comes too near the surface.

The silt areas of the Fens show crop-marks on a very large scale on the positions of the innumerable ditches of Romano-British date, now partly refilled with rich, peaty soil. The increased fertility of the soil is here certainly a major factor in the formation of the crop-marks. Elsewhere, on gravel, chalk, etc., differential growth appears to be due mainly to the greater amount of moisture available in deeper soil in dry weather.

Sand is generally unfavourable, because it is seldom compact enough to prevent the early collapse of the sides of holes, which are thus liable quickly to be refilled with material nearly identical with their surroundings. Coarse and loose gravels are unsuitable for the same reason, though a large enough excavation would produce a crop-mark. Dr. J. K. St. Joseph comments that hard glacial sands may be very good, for example those encountered in Nithsdale<sup>1</sup> and other Scottish sites.

Clay and similar formations, such as marl or shale, very seldom develop positive crop-marks. The reasons are probably that these formations are very badly drained and that holes dug in them refill with clayey soil difficult to tell from the undisturbed ground. Marshland, except for the silt areas of the Fens, mentioned above, is also unsuitable.

To summarize, the surface geology determines whether positive crop-marks will appear in a given area. They are found on most gravels, on chalk, rubbly limestone and in the silt fens. On the other hand, sand and loose gravels are generally unfavourable, while clay and similar formations, country where hard rock is near the surface, and marshland (apart from the silt fens) are not suitable for positive crop-marks.

#### (b) *Negative Crop-marks*

Negative marks are largely independent of the subsoil, as buried foundations, stony mounds of barrows or ramparts, and remains of metalled roads almost invariably have an adverse effect on the crops growing above, whatever the type of soil or subsoil may be.

Mounds and ramparts may actually produce positive marks if made of earth, negative if composed largely of stones or rock.

#### CROPS

Corn is the medium by which buried remains are revealed most clearly, but clover, sugar beet and grass also give good results, and in very dry weather almost any crop may show something. In general, deep-rooted plants seem the best. Positive marks are shown by lines of deeper green and/or denser and taller growth than on the surrounding land (pl. III, A). Negative marks are the reverse, the plants being pale and stunted. The marks appear gradually, the contrast and the amount of detail steadily increasing as long as the weather remains dry. The process is very reminiscent of the gradual emergence of the image during the development of a photograph.<sup>2</sup>

The following information on crops was collected, unless otherwise stated, by

<sup>1</sup> See *J.R.S.*, xxxiii, 51.

<sup>2</sup> The simile seems to be an apt one, as it

occurred to the writer before noticing Crawford's use of it in *Air Photography for Archaeologists*, 5.

the writer's visits to sites on the Thames valley gravels in the Oxford region. It has not yet been possible to confirm it by much work on the ground elsewhere, but as far as can be seen by aerial inspection, crops behave similarly everywhere in southern England. In the north, where crops are rather later, some differences may be expected. The account refers mainly to positive crop-marks; negative marks are rare and the writer has not yet been able to inspect one on the ground.

(a) *Cereals*

Barley, wheat and oats<sup>1</sup> are indistinguishable when young, and later, when the plants approach maturity, still look very similar from the air. They all produce similar kinds of crop-marks, though the best results for archaeological purposes are probably given by barley. The marks may be sought after the corn has reached a height of about one foot and, provided that the weather is dry, the first examples emerge in early April in winter-sown wheat or oats. In May or June, when the spring-sown corn has grown to a fair height, a few weeks of dry weather produce marks in many places, and by early July they are generally widespread wherever the right conditions of soil and subsoil exist.

There is often a strong contrast between the dark green of the crop-mark and the light green of the rest of the field, and inspection on the ground may also reveal surprising differences of growth, a few examples of which are given in the following table. Occasionally the field may be a uniform green and the crop-marks may appear only as lines of taller corn, which show as a "shadow-site" when the sun is low (pl. IV).

| Date           | Place               | Type of Site   | Crop   | Height of Crop |           | Subsoil        | Remarks     |
|----------------|---------------------|----------------|--------|----------------|-----------|----------------|-------------|
|                |                     |                |        | Crop-mark      | Elsewhere |                |             |
| April 27, 1945 | Northmoor, Oxon     | R.B. village   | Oats   | 21"            | 10"       | Gravel         | Dry weather |
| June 14, 1945  | Scaftworth, Notts.  | Roman fort ?   | Barley | 28"            | 20"       | Sandy gravel ? | Wet weather |
| June 20, 1944  | Fen Drayton, Cambs. | R.B. village ? | Barley | 33"            | 19"       | Gravel         | Dry weather |

During a spell of wet weather, colour differences on the majority of sites quickly vanish, but variations of height and density of growth to some extent remain. A second drought seldom brings out the marks again so well and their appearance may be rather patchy. On other sites, the crop-marks, presumably owing mainly to increased fertility of the soil, may persist in wet weather, though with reduced colour contrast; the site at Scaftworth, Notts., is a case in point.

When the corn grows high, it is liable to be beaten down by heavy rain or strong winds, and sometimes, when the plants above a buried ditch are particularly high, they may be 'laid' by a storm, while the rest of the field is unaffected (pl. V, A).<sup>2</sup> Crop-marks of this type are not very reliable, for the effect of wind and rain is erratic.

As cornfields ripen, they often change from green to yellow unevenly, and positive crop-marks, if present, may remain for a few days as vivid green lines in a

<sup>1</sup> Since writing the above I have seen good crop-marks in *rye*, which behaves like the other cereal crops.

<sup>2</sup> For another example, see *Wessex from the Air*, pl. XV (b).

yellow field. In ripe corn, differences in the density of growth are very noticeable, and positive crop-marks show quite distinctly as lines of brighter yellow, where the plants are crowded closer together (pl. V, B). Elsewhere in the field the crop is thinner and more of the dark-coloured ground is seen between the plants. Thus in ripe corn, crop-marks show mainly as lighter-coloured lines due to the denser growth, while in unripe corn they show as darker lines caused by the deeper colour of the plants. Sometimes the lines of denser growth can still be followed in the stubble after harvest, and examination of the stubble-rows after the reaping of a barley field at Standlake, Oxon, revealed that there had been about fifty stalks per foot above the ditch of a Bronze Age circle, against about thirty per foot elsewhere.

(b) *Clover (in Ley)*

The seeds of ley (often mixed rye grass and red clover) may be sown with corn crops, and the grass and clover will continue to grow after harvest. The next spring the ley is cut for hay and is followed by a second growth with clover predominating, in which excellent crop-marks may be formed (pl. VI, B). Positive marks are dark lines caused by higher and denser growth; negative marks are the reverse. They appear about a month after the hay-making in a dry summer and last until the field is mown again. Crop-marks in clover can sometimes be picked out very clearly by an observer on the ground and should be easier to find than marks in corn when air-survey is not possible.

(c) *Sugar Beet and other Root Crops*

During July and August, when the cornfields are everywhere being harvested and the marks on many crop-sites are thus disappearing, a drought causes other sites to appear in fields of roots, particularly sugar beet. This crop develops excellent marks (pl. VI, A), though with less sharpness and detail than corn or clover. As usual, positive marks are lines of darker green, caused by the leaves of plants growing on deeper soil. The contrast of colour is enhanced by flagging and fading of the leaves of plants on the thinner surrounding soil.

Mangolds produce marks similar to sugar beet, but rather weaker. Other root crops—swedes, turnips, potatoes—may show crop-marks, but they are seldom clear enough to be worth recording except as an indication that good results are likely when the land is next sown with corn.

(d) *Miscellaneous Crops*

Like clover, to which it is related, *lucerne*<sup>1</sup> develops good crop-marks.

*Beans*<sup>2</sup> and *peas* are sometimes useful, but peas straggle so much that the outlines of the marks are ill-defined.

(e) *Grass*

Grass is much less responsive than corn, the crop-marks being fainter and needing a longer period of drought to develop much contrast. Despite this, it is well worth watching. Long grass in hay-fields in early summer seldom shows much, probably because the ground is not dry enough, but quite good marks may be seen later in the season in pastures. During dry weather deeper soil retains its verdure, while the rest of the ground becomes parched, and brown rather than green in colour.

<sup>1</sup> *Oxoniensia*, i, 18.

<sup>2</sup> *Antiquity*, i, 470.

After a prolonged drought the whole pasture may be so scorched by the sun that the marks may disappear, though this does not happen in low-lying meadows, where the bottoms of filled-in ditches are near the water level.

Grass-grown earthworks are outlined in the summer by the deeper green in the ditches. If the ground is badly drained and often waterlogged, a different variety of grass may grow in the ditches from that on the banks, and the marks may then show permanently (pl. VII).

(f) *Wild Flowers*

Marks produced by wild flowers are interesting and sometimes very beautiful, but are not too common. Yellow charlock or red poppies<sup>1</sup> in cornfields are sometimes concentrated on deeper soil, the flowers making lines of vivid colour. Daisies and buttercups often reveal slight earthworks in meadows in the spring, the flowers being thick on mounds and banks, and scarce in ditches, which are presumably too wet; in early summer the effect is occasionally reversed when the ground dries.

#### WEATHER AND SEASON

The weather is a very important factor, as crop-marks are greatly emphasized by drought. Marks above major buried remains may appear in the normal showery weather of any English summer, but three or four weeks of dry conditions are needed for the best results. During a drought the contrast and amount of detail steadily increase, and marks on smaller ditches and pits appear. In wet weather the smaller marks soon disappear and even the large and prominent marks may fade out.

The following table shows the months when dry weather may produce marks in the more important crops grown in southern England. June and July are the best months.

|                 | April | May  | June | July | August | September |
|-----------------|-------|------|------|------|--------|-----------|
| Barley .. ..    |       | ///  | //// | //// | ////   |           |
| Wheat .. ..     | ///   | //// | //// | //// | ////   |           |
| Oats .. ..      | ///   | //// | //// | //// | ////   |           |
| Red Clover ..   |       |      |      | ///  | ////   | ////      |
| Sugar Beet ..   |       |      |      | ///  | ////   | ////      |
| Grass .. ..     |       |      | ///  | //// | ////   | ////      |
| Wild Flowers .. |       | ///  | //// | //// | ////   |           |

In some fields the crop-marks may show well for weeks on end, but elsewhere the best conditions for photography may last for only about a week, and to make a thorough survey of a district, a flight should be made over it at least about once a fortnight between May and August. A large site may be under several fields sown with different crops, in which marks probably will not show at the same time, so that a series of photographs may be needed.

#### CROP-MARKS OR SOIL-MARKS DUE TO NATURAL CAUSES OR TO MODERN AGRICULTURE

Crop-marks due to natural agencies<sup>2</sup> (generally irregular areas of any size caused by patches of deeper soil, etc.) and to modern farm-work (normally lines running

<sup>1</sup> See *Wessex from the Air*, pl. 13b, for mark formed by poppies at Meon Hill, Hants. I have seen poppy-marks at Abingdon, Berks.

<sup>2</sup> E.g. Matthew xiii, 4-8.

parallel to the boundaries of fields) or drainage operations are seen almost everywhere, but experience soon teaches one to distinguish most of such marks from those caused by the work of early man. In certain cases, however, natural markings may cause confusion. A few examples are given below.

(a) On gravel subsoil there are considerable areas (e.g. in the Upper Thames valley and the country immediately south-west of Peterborough) covered by irregular polygonal patterns of crop-marks probably caused by large cracks in the gravel (pl. VI, B). They may look at first sight to be of human origin and the writer once thought them to be old field boundary ditches, but actually the cracks were probably produced by freezing of the subsoil in the Glacial Period.

(b) Limestone near the surface may be intersected by countless small fissures, which sometimes result in cornfields being crossed by patterns of fine lines rather like the 'bricks' with which limestone is usually denoted on the geological map.

(c) Fungus rings (or 'fairy' or 'pixie' rings) in meadows can be recognized easily by their characteristic irregular outline.

(d) 'Pits' may prove to be old tree root-holes, in which case only excavation could decide their origin, or they may be just clumps of tall corn caused by uneven manuring.

Soil-marks are less equivocal, though humps of the chalk subsoil protruding to the surface in Norfolk in land newly taken into cultivation were found by the writer to be easily confused with barrows. The meandering beds of old streams and rivers may be followed everywhere in the Fens, but their origins are always obvious.

#### YEARLY PROGRAMME OF WORK

Crop-marks are confined to the period between April and August, the best months being June and July. Shadow-sites are available all the year round, but the weather in winter is frequently too cloudy or hazy for the sun to throw sharp shadows and photography must be carried out mainly in the summer months. Soil-marks can be studied only in winter and spring, when the soil is bare, although bad flying weather may hamper the work, particularly between December and February.

The programme of work for anyone able to devote the necessary time therefore would be :

May to August (the busiest time) : crop-marks and shadow-sites ;  
September to November, March and April : soil-marks, and when weather permits, shadow-sites.

#### PHOTOGRAPHY

While notes and sketches are valuable, photography is the only way of recording information accurately from the fast-moving aeroplane. The camera records permanently (though in monochrome) all that the eye sees only in fleeting glimpses, and makes it available for study at leisure on the ground.

To get the best results, the development of a suitable photographic technique is important.

#### *Viewpoint*

(a) *Vertical.* Shadow-sites, soil-marks and normal crop-marks (shown by strong colour differences) can be photographed without difficulty from any view

point; but, except in special cases, vertical pictures are preferable, as they are without perspective distortion and are thus more convenient than obliques for subsequent interpretation. A set taken at the same height can be mounted together as a mosaic, though it is probably seldom worth while undertaking the task of making a large mosaic because of the difficulty caused by the need to photograph adjacent areas at different times or dates.

(b) *Oblique.* For general views it is perhaps better to take oblique pictures, which give more indication of the relief of the countryside and look more 'normal' than verticals to people unaccustomed to air-photographs. By circling the area to be photographed, and adjusting the angle of view and the distance of the aircraft, it is usually easy to get a good picture, which excludes non-essentials but does not cut off any part of the site. When only simple equipment is available, such as the late Major Allen's hand camera and light aircraft flown solo, it is much easier to take obliques than verticals.

A point to be watched, when using this angle of view, is the direction of the sun in relation to the camera. When the sun is low, soil-marks in ploughed fields and colour differences in green corn are seen more distinctly looking with the sun than against it. In the former case, the sunlit sides of the stalks and leaves, or of the furrows and lumps of earth, are seen, and colour shows well, while looking from the opposite direction, a multitude of small shadows appears (the same effect can be seen by an observer on the ground). This obviously does not apply when the sun has risen too high to throw many shadows. The direction of the sun has to be considered similarly when taking oblique shots of earthworks; if the site is revealed mainly by shadows, the photograph must be taken looking against the sun, or, in the less usual case when the highlights are more important, the best view is with the sun.

(c) *Special Cases.* Faint crop-marks in green corn and marks in ripe corn need special treatment. For faintly-coloured marks, particularly in wheat, an oblique picture is much better than a vertical (pl. VIII), the reason being that from directly above an insufficient area is seen of the plants, which stand upright, whereas from the side enough is visible to reveal differences of colour more definitely.

Conversely, ripe corn, except sometimes barley, is best photographed from the vertical. The marks are areas of denser growth, which are appreciated best from directly above, when more of the dark-coloured ground shows in the thinner than in the thicker patches of corn (pl. V, B).

Ripe barley sometimes presents interesting problems. Areas of denser growth may show well only by light reflected from the heads of the plants and their shiny beards. It is necessary to circle round to find the angle from which the marks can be seen best. According to the viewpoint and the relative amount of light reflected by the crop-marks and the rest of the field, the marks first show as lighter lines in the field of yellow corn, then disappear, and then show again as darker lines. The photograph should be an oblique taken when the marks are showing as light lines.

#### *Time of Day and Height of Sun*

##### (a) *Shadow-sites*

Shadow-sites are visible only when the sun is low, that is, in the early mornings and the evenings. At midday, few slopes are steep enough to throw shadows and

practically nothing can be seen of some earthworks, which may have been conspicuous soon after sunrise. The lower a bank and shallower a ditch, the lower must be the sun to throw a shadow. The times when the sun is at a suitable altitude of course vary considerably between winter and summer. In winter it is always rather low in the sky, thus greatly prolonging the period after sunrise and before sunset when shadow-sites show well. Unfortunately the weather is seldom favourable then, the clear, bright sunlight required to throw sharp shadows being rare except in summer.

A second point to allow for is the direction (i.e. azimuth) of the sun. As far as possible this should be at an angle of between  $45^{\circ}$  and  $90^{\circ}$  to the line of the earthwork being photographed. In summer the sun is low only for a short time in morning and evening and little choice in the direction of the sun is available, but in winter it hangs low in the sky for a long time. Actually the direction of the sun is often of little importance, as many sites comprise earthworks running in all directions. The vital factor is the sun's elevation.

Suitable conditions of lighting are most fleeting on slopes of hills facing south, as the sun soon rises too high, its rays striking the ground at too steep an angle to throw many shadows. On northward slopes the converse applies, and it may be necessary to wait for a time until the sunlight reaches them. Matters also may be complicated by long shadows cast by belts of trees or other high objects, and it is always best to watch the site from the air to find the time when it shows best.

#### (b) *Crop-marks and Soil-marks*

Normal crop-marks, shown by differences of colour, can be photographed easily at any time of day, providing that the visibility is good. Sunshine is not essential, but is an advantage.<sup>1</sup> In hot summer weather, flying conditions are better in mornings and evenings when the air is cooler; a further slight advantage is that the low sun shows in relief lines of taller corn (pl. IV) and helps to emphasize crop-marks, which are usually different in height as well as colour. Windy weather should be avoided when possible, as corn is blown about so much that the marks become indistinct.

Soil-marks are very simple to photograph, but are available only in the winter and spring months, when air-photography is often hampered by bad weather, and it may be necessary to wait some weeks for suitable conditions. When they arrive, the time of day is of little importance.

#### AIRCRAFT AND CAMERA

The most useful type of aircraft for air-archaeology would be a small high-winged monoplane, which should be obtainable at a relatively low price. The high wing of this type would allow an unobstructed view downwards from the cabin, and its low speed would be an advantage.

Two cameras are necessary, a hand camera for taking obliques through the side windows, and an automatically operated camera for verticals, mounted in a frame

<sup>1</sup> Compare two of Major Allen's photographs of the Roman villa at Ditchley, reproduced in *Oxoniensia*, i, pls. III and IV. The former,

taken by diffused sunlight, is inferior to the latter, taken with bright sunlight.

and pointing out of an opening in the floor. Provision is needed for verticals to be taken either singly by a manual release, or as 'line overlaps' by an automatic control, making a series of exposures at predetermined intervals, each picture overlapping the last. The standard R.A.F. camera would be very suitable.

#### SUMMARY

1. Shadow-sites are important in country which has escaped modern ploughing. The technique of recording them has been developed fully by Crawford.

2. Soil-marks show well on bare earth where there is a contrast of colour between soil and subsoil, e.g. chalk, or between dark ditch-fillings and the normal soil, e.g. the yellowish silt fens. The marks may be very persistent, but eventually they are bound to fade out.

3. Damp-marks, frost-marks and snow-marks are rare and usually unimportant; as a rule, the features they reveal would probably be shown better by crop-marks.

4. (a) Crop-marks are very important in this intensively cultivated country. They may be described as 'positive' marks, where growth of crops is increased by the presence of filled-in ditches beneath the surface, and 'negative', where growth is reduced by buried foundations, etc. Negative marks are rare.

(b) The type of subsoil determines whether positive crop-marks will appear in a given area. Compact gravels, chalk and the silt fens are very suitable. Sand and loose gravel are generally, and clay almost always, unsuitable. Many other types of country are unfavourable and areas with many crop-sites are restricted. Negative marks, however, may appear on any subsoil.

(c) The second important factor is the kind of crop. Cereals are best, but clover, sugar beet and grass may also give good results. Other crops are less satisfactory. Positive marks are generally deeper green, taller and denser than the rest of the field. Negative marks are pale and stunted.

(d) Crop-marks are greatly intensified by drought and normally almost disappear in wet weather. In some cases the marks persist during a wet period, but with reduced contrast.

(e) Where the marks appear only in dry weather it is probable that they are due to the greater amount of moisture available in deeper soil; where they remain in long spells of wet weather, they are presumably caused by richer soil.

5. Photography is the only satisfactory way of recording sites seen from the air. Vertical views are preferable for subsequent plotting and interpretation, though obliques may be taken for general views and in certain special cases. The photography of shadow-sites is complicated by the need to have the sun in the correct position, but soil-marks and crop-marks are generally straightforward subjects. Weak crop-marks may be difficult and show best from an oblique view, looking with the sun.

## DESCRIPTION OF PLATES

## PLATE I

## A. Shadow-site on Green Down, Childrey, Berks.

Lynchets, a boundary ditch and a possible settlement site (top right) on this southward sloping hillside are shown mainly by highlights. The large pits are natural swallow-holes in the chalk.

By : D. N. Riley.

Date : November 25th, 1943. Time : 8.30 a.m. G.M.T.

Height : 3,000 ft.

Subsoil : Chalk.

## B. Soil-marks at Throckenholt, near Parson Drove, Cambs.

This is a site in the silt Fens, where the yellowish soil is seamed with dark marks caused by the peaty filling of old ditches, probably Romano-British in date. It will be noticed that where the ditches run at right angles to the direction of ploughing the soil-mark, instead of being straight, is a zigzag line, the result of displacement of soil by the plough. This eventually results in the obliteration of soil-marks.

By : Major Allen.<sup>1</sup>

Date : April 4th, 1938.

Subsoil : Silt.

## PLATE II

Site near Providence House, Moulton Fen, near Postland, Lincs., shown by shadows, soil-marks and crop-marks.

At this silt Fen site, ditches (probably R.-B. date), shown by shadows in a meadow (right), run in to arable land, where they form soil-marks (right centre, top left and bottom left) and crop-marks (left centre). The soil-marks are not as clear as the crop-marks, which are fed by the deeper layers of soil, below the plough level.

By : Major Allen.

Date : May 8th, 1938.

Subsoil : Silt.

## PLATE III

## A. Positive and Negative Crop-marks at Ditchley, Oxon.

The foundations of a Roman villa, its premises and boundary wall here show as negative marks. A positive mark indicates the surrounding enclosure ditch. The thickness of the walls was found to be from 2 ft. to 2 ft. 6 in., when the site was excavated, the width of the ditch about 10 ft.

By : Major Allen.

Date : June 16th, 1934.

Subsoil : Thin layer of limestone with clay beneath (Great Oolite series). The ditch penetrates to the clay.

## B. Section of Crop-mark in a Gravel-pit north of Dorchester, Oxon.

The gravel-pit has cut into a field of growing corn and sectioned the filling of an Early Iron Age ditch, above which is growing a positive crop-mark. The corn in the crop-mark is taller and darker.

By : Major Allen.

Date : July 9th, 1933.

## PLATE IV

Crop-marks (Differences of Height and of Colour) west of Stanton Harcourt, Oxon.

In the foreground Early Iron Age pits and enclosures are marked by taller corn, revealed by shadows (compare shadow-sites). The colour of the corn is uniform. In the background a different corn crop shows the positions of Bronze Age circles by darker coloured marks. These variations in the marks in adjacent crops may perhaps be explained by different times of sowing.

By : Major Allen.

Date : July 4th, 1933.

Subsoil : Gravel.

<sup>1</sup> There is no record of the time or height at which any of Major Allen's photographs were taken.

## PLATE V

- A. Crop-marks (Corn 'laid' by Bad Weather) north of Dorchester, Oxon.

The positions of the ditches of the great double circle (? Bronze Age date) are shown by lines of corn 'laid' by storms. No doubt there was previously a crop-mark where the corn had grown excessively tall. The field is being harvested and it will be seen that the reaper is greatly hampered by this crop-mark.

By: Major Allen.

Date: July 16th, 1933.

Subsoil: Gravel.

- B. Crop-mark in Ripe Corn, west of Dudgrove Farm, Kempford, Glos.

Enclosures, possibly of Early Iron Age date, are here revealed by lighter coloured lines (denser growth) in ripe corn.

By: D. N. Riley.

Date: August 6th, 1943.

Time and height not recorded.

## PLATE VI

- A. Crop-mark in Sugar Beet, east of Hampton Poyle, Oxon.

A series of enclosures, possibly of Roman date, are shown quite well by this crop.

By: D. N. Riley.

Date: August 4th, 1943. Time: 3.15 p.m. G.M.T.

Height: 2,000 ft.

Subsoil: Gravel.

- B. Probable Frost-cracks revealed by Crop-marks, north of Stanton Harcourt, Oxon.

The crop-marks which wander across this area are probably caused by frost-cracks formed in the Ice Age. The marks show in green wheat (top left) as dark lines, ripe barley (top right) as faint light lines, and in clover (bottom) as dark lines. The clover was a second growth which had sprung up after the hay had been cut.

By: D. N. Riley.

Date: July 16th, 1943. Time: 3.15 p.m. G.M.T.

Height: 1,800 ft.

Subsoil: Gravel.

## PLATE VII

Permanent Crop-mark in Meadow north of Thornhaugh, Northants.

This earthwork, of unknown date, lies in marshy ground at the bottom of a small valley. Grass, different from that on the surrounding land, grows in the ditches, which are thereby shown all the year round as a permanent mark in the herbage.

By: Major Allen.

Date: July 16th, 1939.

Subsoil: Clay.

## PLATE VIII

- A and B. Vertical and Oblique Views of a rather faint Crop-mark near Foxley Farm, Eynsham, Oxon.

The oval seen here (adjoined by a narrow zigzag line or mark), in a field of barley, probably marks the ditch of a destroyed double barrow. The whole crop-mark is indistinct in the vertical picture, but shows well in the oblique.

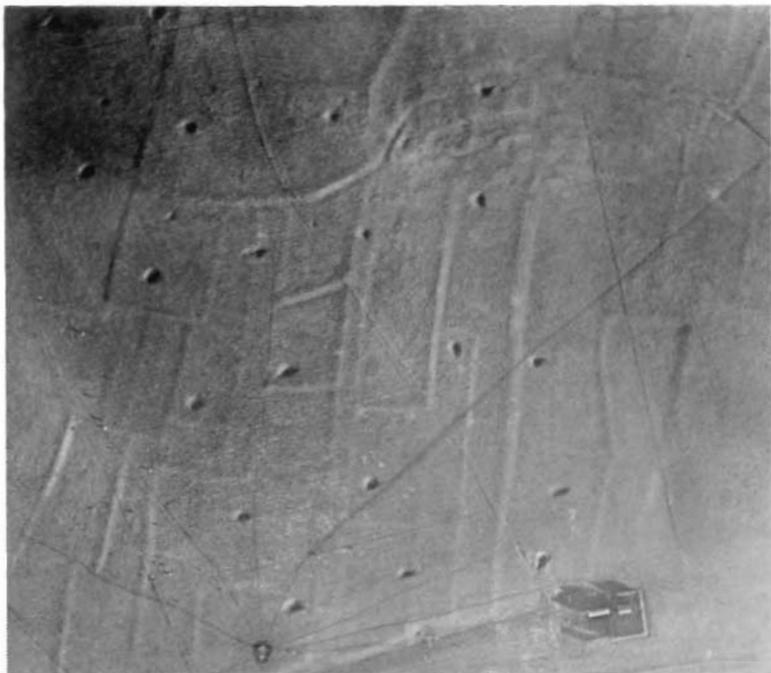
By: D. N. Riley.

Date: July 1st, 1943. Time: 8.0 a.m. G.M.T.

Height: 1,000 ft.

Subsoil: Gravel.

Plates IB, II, IIIA, IIIB, IV, VA, and VII, from photographs by the late Major G. W. G. Allen, are reproduced by permission of the Ashmolean Museum, Oxford.



A



B

PLATE II





A



B

PLATE IV





A

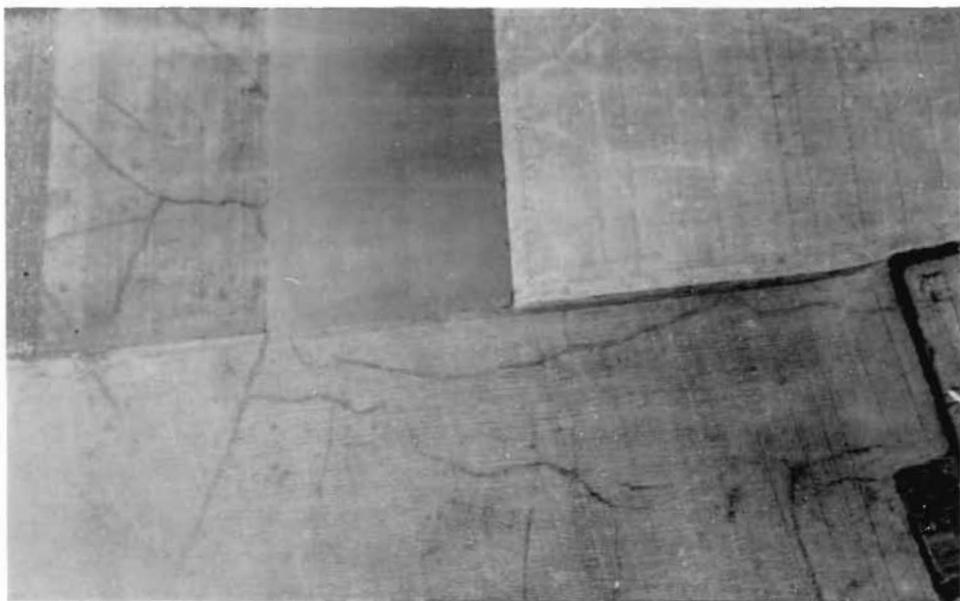


B

PLATE VI

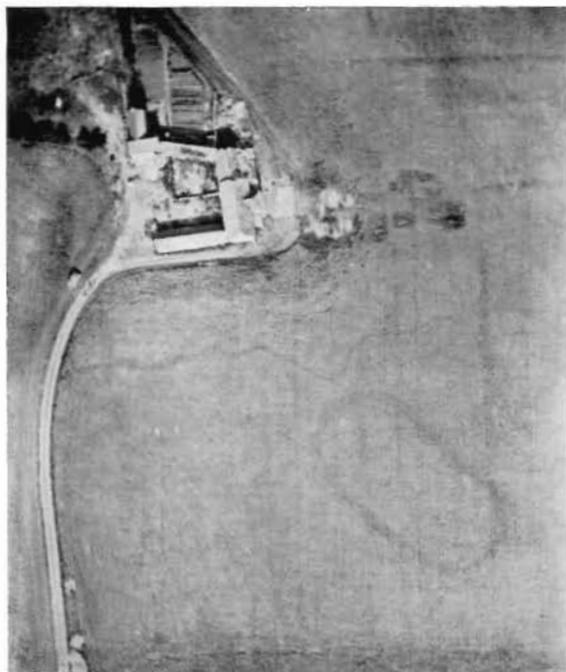


A



B





A



B