AIR-PHOTOGRAPH INTERPRETATION
FOR ROAD ENGINEERS IN BRITAIN

by

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AIR-PHOTOGRAPH INTERPRETATION FOR ROAD ENGINEERS IN BRITAIN

ABSTRACT

The Report gives a practical account of how vertical air photographs can be used in the study of ground conditions in Britain in connection with highway engineering. Sources of air photographs are given and the techniques for examining the photographs are described. Applications of air-photograph interpretation are reviewed; they relate mainly to the route location and site investigation phases of road construction, but include uses during construction and after the road has been completed. Examples are given in the form of stereopairs with an explanatory text, and full interpretation with mapping is also illustrated.

The Report should help road engineers in the United Kingdom to make full use themselves of air photographs as a supplement to other sources of site information, and to appreciate the potentiality and limitations of air-photograph interpretation when commissioning work from specialist firms.

1. INTRODUCTION

The purpose of this Report is to give a practical account of how vertical air photographs can be used in the study of ground conditions in Britain in connection with the planning and construction of roads. The Report aims to acquaint civil engineers with the scope of the method, to help and encourage them to make full use of it themselves, and to help them to judge when the services of a specialist interpreter would be valuable. The strength and limitations of the method also need to be appreciated if sound use is to be made of air-photograph interpretation studies carried out by others.

Vertical air photographs are used for two main purposes, photogrammetry and photograph interpretation.

Photogrammetry is the technique of making accurate measurements from photographs. It is used for the preparation or revision of maps and plans for all kinds of civil engineering works, and for drawing contours. In this country photogrammetry is in wide use in connection with major road schemes. The method can be carried out quickly, and the photographs once obtained are available for reference, interpretation or more detailed mapping at a future date. Although this report is not concerned with photogrammetry, air photographs taken for photogrammetric use are a valuable source of high-quality material for interpretation.
Air-photograph interpretation is the study from air photographs of the character of the ground or of vegetation or structures on it. It has been applied in many fields, including geology, land-form studies, vegetation studies, forestry, agriculture, land use, pedology, hydrology, archaeology and military reconnaissance. It can also be applied to problems of civil engineering. In contrast to photogrammetric applications, until recently little use has been made in Britain of air photographs for studying ground conditions in connection with roads, although it has been quite widely employed for this purpose abroad, e.g. in Africa and America. However, this use of air photographs in the course of site investigations for roads is now becoming more usual in this country. Advantages of the method are that it is cheap and rapid, the photography required is usually already available and provides a complete stereoscopic record of the site, a preliminary study of the site can be made in the office, and important features can often be seen in the air photographs which cannot be seen at ground level. The method is particularly suited to extended sites such as roads, and to reconnaissance over a considerable area before the route has been fixed.

The use of air photographs does not replace existing methods of site investigation but assists and supplements them, and at a small cost may provide information which might otherwise be overlooked with resulting heavy costs in construction delays, redesign work, or even re-alignment.

2. APPLICATIONS OF AIR-PHOTOGRAPH INTERPRETATION IN ROAD ENGINEERING

2.1 The users of air photographs

All engineers or engineering geologists engaged in ground engineering can profit from a familiarity with air-photograph interpretation, and without special experience can make good use of air photographs to provide additional information on ground conditions for use both in the site investigation phase of the work and during construction. Their aim will be to supplement existing maps and to pick out features of the site, such as unstable ground, poor drainage, swallow-holes or changes in soil type, which call for more detailed investigation on the ground. It is to these users that this Report is primarily directed.

A specialist interpreter of air photographs will be able to make a detailed analysis of an area from various points of view. For instance, he may divide the whole area into areas distinguished from each other on the basis of geological material, land form or soil type. To do this he will need to be an engineer or engineering geologist who possesses a knowledge of the characteristics being mapped (e.g. geological materials, land forms, soil types), and of the particular conditions in the area under study. Large organisations engaged in work for which air photograph interpretation is useful for engineering purposes would be advised to arrange for at least one member of their staff, who shows aptitude and has suitable experience in site investigation, to specialize in this work, so that he can advise his colleagues when appropriate, and undertake the more detailed applications. Alternatively, some firms can offer this service, and examples have been reported by Burton.
2.2 Application in Britain and overseas

In some countries no adequate topographical maps exist, let alone geological ones. In addition large areas may be involved, with problems of access due to mountains, forests, swamps, inadequate roads and low density of inhabitation. The landscape may have been very little affected by the activities of man, and the choice of a route may be unrestricted by existing land use. In these areas a full air photograph interpretation may be very valuable for the choice of the route of a road, and for information on site conditions and materials.

In contrast, Britain is well supplied with large-scale and very detailed topographical maps, and detailed geological maps are available; in addition nearly all areas, with the exception of some mountain and moorland areas, are readily accessible and very well known, as well as being greatly altered from their natural appearance by agriculture, forestry, and industrial and urban development. The number of possible lines for a new road will usually be limited by existing development and land use, and the general conditions along the line of the road will probably be well known.

It is clear, therefore, that the ways in which air photograph interpretation may be useful under British conditions are likely to be different from those in less well developed areas. A more localized examination of the possible lines will be more appropriate. The engineer or engineering geologist responsible for the investigation will be considering all the existing sources of information for the selected or possible lines. Photographic cover will generally be available, and can play a valuable part. Some of its uses will be described in the following sections, and illustrated later in the stereopairs (see Table 1) which accompany Section 4.

2.3 Use of air photographs

2.3.1 Air photographs as a supplement to maps. Air photographs provide a source of more detailed information on the area than can be given by a map. A map can represent only a small amount of the information in a photograph, and that only in symbolic form. Reference to the photograph will give information on the character of the features represented symbolically on the map, as well as additional information not represented on the map, e.g. character of boundaries (hedges, ditches, fences etc), character of buildings, width of streams, roads and verges, position and height of trees, density of woods, location of poles and pylons supporting wires, and agricultural use of fields.

In the field, in areas where the map shows little detail, the photographs may be a valuable aid in locating one's position on the ground by reference to small unmapped features such as trees, bushes, gullies or rocky outcrops. The photographs can save much time by indicating routes of access, such as the position of gates and gaps in hedges. They may also be used in the field as a base-map on which to mark the position of observed features or sampling points.
2.3.2 Air photographs as a record of conditions. A map takes a long while to make by conventional methods of surveying, and can only represent the state of affairs when seen by the surveyor. It is often not clear if any particular feature on a map represents the state of affairs at the time of the last revision or at an earlier time, although maps prepared or revised with the aid of air photographs are more likely to represent the true state of affairs at the time of revision.

In contrast, air photographs always represent the state of affairs at a particular instant of time. A series of photographs can form a useful record for reference purposes, and can be cheaper, more reliable, and more informative than a series of maps. They can show, for instance:

(a) Changes since the last full map revision, e.g. new roads and buildings, demolition of buildings, extension of gravel workings, removal of field boundaries.

(b) Conditions before the commencement of roadworks.

(c) Progress made in roadworks at a particular date.

(d) A record of the roadworks on completion.

Old air photographs, which can be obtained for some areas dating back to as long ago as the nineteen-twenties, form a record of past conditions. A good example of their use for the study of changing site conditions is the Report on the Aberfan area by Fairey Surveys Limited. By the interpretation of nine air photographs taken at intervals from 1945 to 1965, the history of tipping and collapse of the colliery spoil heaps could be followed over the 20 year period.

2.3.3 Interpretation of ground conditions from air photographs. In addition to their use for giving information on general conditions and surface features, air photographs may also be used to draw conclusions on ground conditions of engineering significance, such as soil type, drainage conditions, and the presence of marshy areas, unstable ground, and features such as mining subsidence, swallow-holes, spring lines and rock outcrops. More experience is required to carry out a comprehensive interpretation, but engineers and engineering geologists without special experience can make good use of air photographs to supplement other sources of information on ground conditions. This topic will be discussed in further detail in Section 4.

2.4 Air photographs and the phases of road planning and construction

The use of air photographs in each phase of the planning and construction of roads should go along with consultation of other sources of information, and with direct examination of the ground on site, except where access to the ground is not possible, when air photographs will be particularly useful as the only direct source of site information.
2.4.1. Route location. It is of the greatest importance that areas of potential engineering difficulty should be identified at the earliest possible stage in the route planning process. Although at an early stage special air photographs may not have been taken, cover will probably be available from earlier surveys carried out by the R.A.F. or by air survey firms for the Ordnance Survey, the Ministry of Housing and Local Government or the County or other Local Authorities (see Section 3.2 and Appendix 1). These photographs will be useful to supplement existing maps and to help to visualize the terrain along different possible routes, supplying information on land use and on the development which may have taken place during the period between the preparation of the maps and the taking of the photographs. They may also permit a tentative preliminary estimate of land values to be made.

2.4.2 Detailed site investigation and design. When the detailed site investigation is being planned, air photographs will continue to be useful as in the previous phase. A careful study of the air photographs should form part of an appraisal of other existing information relating to the site, such as geological maps and memoirs and site investigation reports for other jobs in the area, which can with advantage be accompanied by a thorough ground inspection with preliminary sampling. A study of the photographs will help to indicate areas of uniform site conditions, which will allow more economic placing of boreholes. It will allow exposures to be located where a preliminary examination of ground materials can be made without the use of boreholes. It will also assist in the location of areas offering difficult engineering conditions, where special attention will be required in the site investigation. For some recent site investigations the survey team has been supplied with a set of the air photographs and this procedure is to be encouraged.

2.4.3 Tendering. At the tendering stage an examination of the air photographs will give the contractor a good overall view of the character of the site and help him to predict places where costly construction problems may be encountered. It may also help in the search for routes of access to the site, and in the location of borrow areas and sources of base materials, or areas such as abandoned pits or quarries, for the disposal of surplus or unsuitable material.

2.4.4 Construction. During the construction stage the air photographs may continue to be used in much the same way as in the tendering stage. The resident engineer may find them useful as a record of the condition of the site before work commenced, as a supplement to the soil survey report and site plans, and in the investigation of unexpected ground conditions. Photographs taken during construction provide a valuable record of the progress of the contract at that particular time.

2.4.5 During service. Photographs may be taken to provide a record of the completed works. The examination of these and of photographs taken earlier can provide useful information on problems which may develop during service, such as settlement, movement of slopes in embankments or cuttings, or slips on hillsides which may threaten the road.
3. THE TECHNIQUE OF EXAMINING AIR PHOTOGRAPHS

The full benefit of using air photographs can be obtained only if they are examined stereoscopically. An introduction to the more practical aspects of air photographs and their stereoscopic examination is given in this Report, and further information is given by Allum\(^5\) and the War Office\(^6\).

3.1 The air photograph

Photographs taken from the air with a camera pointing vertically downwards are called vertical air photographs, while those taken with the camera at an oblique angle are called oblique air photographs. Oblique air photographs are sometimes used to illustrate reports, and to show the route of proposed roads in relation to the landscape, but it is the vertical air photograph that is used for air photograph interpretation. Panchromatic black-and-white film is used, except for special applications for which colour, infra-red black-and-white, or infra-red colour (also known as false colour) may be useful\(^7\),\(^8\).

The format of a vertical air photograph is shown in Fig. 1.
If the data panel is preserved it will show photographs of a spirit level, a clock, an altimeter and an exposure counter. The focal length of the camera lens, the date of the photography, the sortie, run and film reference numbers, and the serial number of the photograph may also be shown. A 230 mm (9 in) square photograph format is standard, and most modern air survey cameras have a 152 mm (6 in) focal length lens. The scale of a photograph, $s$, can be obtained from the formula $s = \frac{f}{(H-h)}$ where $f$ is the focal length of the camera lens, $H$ is the height of the camera above sea level, and $h$ is the height of the ground above sea level (see Fig. 2). The scale can also be obtained by comparing the distance between two features on a photograph with the distance between the same pair of features on a map of a known scale. The points should be of similar height above sea level. Photographs are often supplied with the data panel trimmed off but with the scale included in a title written along the border. Scales are nominal, because the scales to which features are rendered in the photograph vary with the relief, i.e. with the distance from the camera. Some R.A.F. photographs taken with multiple camera installations are not truly vertical, so that the scale is not constant across the photograph.

![Fig. 2 Scale of an air photograph](image)

In an air survey a strip of ground is photographed by an aeroplane flying at constant height on a straight course. The speed of the aeroplane and the interval between successive photographic exposures are so arranged that the field of each photograph overlaps that of the previous photograph by about 60 per cent, and this ensures that each point on the
ground appears on at least two photographs (Fig. 3). For road works
a single strip of photographs usually covers the width of ground required,
although successive runs will be required to accommodate the larger bends
in the road. To cover a broader area of land a number of parallel strips
are flown with a lateral overlap of about 25 per cent.

![Fig.3 Overlap of air photographs](image)

3.2 Sources of air photographs

It will not generally be necessary to take air photographs specially
for interpretation purposes, unless colour or infra-red photography is
required. A set of air photographs will usually be taken for the topo-
ographical survey and these can be used for interpretation purposes.
There may be two sets available from this source, one taken at a medium
scale (say 1:10 000) for the preliminary survey, and another at a larger
scale (say 1:3000) for the detailed preparation of site plans. The
1:10 000 scale photographs will be useful for making a reconnaissance
of a proposed road line (although 1:25 000 is a good scale for giving a
general view of the setting of a route and photographs at this scale may
be available from other sources). The 1:3000 scale photographs will be
useful for looking at the smaller details of a site and for work in the
field.

For smaller contracts and at the early stages of large projects
before the topographical survey has been carried out, existing air

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Fig. 4  Area covered by 230 mm (9 in) square air photographs at various scales in relation to the 1 km national grid lines
photograph cover will have to be used. Air photograph cover is available for most of the United Kingdom, but the usefulness of an air photograph may depend on its scale and on the date, season and time of day at which it was taken, and a search may have to be made to obtain the most suitable photographs.

The main sources of air photographs for the United Kingdom are given in Appendix 1. The collection of the Ministry of Housing and Local Government includes R.A.F. photography covering the whole of Britain; the quality is variable and, for a particular site, cover at a more suitable scale or taken more recently may be obtainable from other sources. The Aerofilms Book of Aerial Photographs is concerned mainly with oblique photographs, but contains a list of selected vertical stereopairs which can be supplied, and which may be useful as examples for study purposes.

Enquiries for air photographs should be accompanied by a tracing taken from the appropriate Ordnance Survey sheet (at present the 7th Series map at a scale of 1:63 360 or 1 in/mile), quoting the sheet number, outlining the area of interest, and with the National Grid lines drawn in and labelled. The request for photographs should specify that stereo-cover is required, and state the scale of photography preferred, as cover at several different scales may be available. The area covered by a 230 mm square air photograph in relation to the 1 km National Grid lines is shown in Fig.4 for various scales of photography.

3.3 Stereoscopic examination of air photographs

Any impression of relief experienced when looking down at the ground from an aeroplane is due to factors other than stereoscopic vision, because the distance between the eyes is very small in relation to the height of the aeroplane. However, the very much greater distance between the stations from which successive air photographs are taken allows the ground to be seen in greatly exaggerated relief when the area common to two consecutive air photographs is examined with a stereoscope. A great advantage is thereby gained compared with looking at single photographs. For the stereoscopic examination of stereopairs of air photographs a pocket or a mirror stereoscope is used (Plates 1 and 2). Suppliers are listed in Appendix 2.

3.3.1 The pocket stereoscope. The pocket stereoscope (Plate 1) consists of two lenses mounted in a frame which has folding legs. The distance between the lenses can be varied to suit the eye-base of the user. To use the pocket stereoscope two consecutive air photographs are placed one on the other so that the areas which they have in common are in register. An item of detail is selected in the area of overlap and the photographs are drawn apart until the separation of this item on the two photographs is the same as the distance between the observer’s eyes, about 60 mm. A strip of about 60 mm width is now available for stereoscopic examination. The stereoscope is placed with each lens over the same item of detail on the two photographs. A single stereoscopic image should now be seen through the stereoscope.
PLATE 1
Pocket stereoscope

PLATE 2
Mirror stereoscope
PLATE 3
Viewing board with the viewing aid in position

PLATE 4
Examining a stereopair in the field
EXAMPLES OF AIR PHOTOGRAPHS WITH INTERPRETATION

PLATES 5-16

TABLE 1-INDEX
TABLE 1

Index of examples and features illustrated by them
(The numbers refer to Plates 5-16)

Examples

Plate

5 Theale, Berkshire
6 Stokenchurch, Buckinghamshire
7 Tideswell Dale, Derbyshire
8 Black Down Common, Devonshire
9 Holyhead, Anglesey
10 Cadbury Camp, Somerset
11 High Halstow, Kent
12 Walton's Wood, Staffordshire
13 Swainswick, Somerset
14 Little Wymondley, Hertfordshire
15 Toddington, Bedfordshire
16 Whitestone, Devonshire.

Interpretation

Shadow - indication of relief, small surface features and texture 7; for identification and form of objects 14; length an indication of height 14; concealing hollows and north-facing slopes 7.

Tones - dark on waterlogged and marshy ground 5, on alluvium 11; light on exposed chalk 6, on new earthworks 14, on material freshly run to spoil 13.

Break in slope - change of materials 8, 10; edge of flood plain 5, 11.

Ground conditions

Unstable ground 8, 11, 12, 13, 16.
Swallow-holes 5, 6, 7.
Faults 10.
Mineshafts and workings 7.
Drainage conditions 5, 7, 8, 10, 11; streams 5, 8, 9, 11, 14; spring lines 8.
Erosion 8, 13.
Ground materials
Soil type 5, 8, 9, 10.
Peat 5, 10.
Exposure and rocky outcrops 7, 8, 9.
Igneous dyke 9.

Borrow and spoil areas
Waste heaps 12.
Borrow areas and sources of base materials 7, 12.
Spoil areas 7, 13.

Man-made features
Character of boundaries - hedges and gates 6; walls 7, 9.
Roads and verges 6, 13, 15.
Pipelines 5; pylons and wires 5, 14, 15.

Land use and agriculture 5, 8, 9, 10, 11
Trees and woods 10, 11, 12; orchards 11; position and height of
trees 10.
Ploughing 9; harvesting 10, 11, 15.

Supplement to maps
New roads 13, 14, 15; new building 6; extension of gravel pits 5.
Routes of access 7, 9, 16.
To locate position by reference to unmapped features 8, 9.
Use for record purposes - progress of works 14, completed
job 13, 15.
PLATE 5
Theale, Berkshire

Location: 7 km west of Reading. Nat. Grid Ref. SU 6471. Scale: 1:12 000 Date: 1 January 1965

This area shows a valley with river features and river deposits, bordered by an area of higher ground consisting of the Chalk with overlying sand and clay of the Reading Beds. Man-made features include roads, railway, canal, pipeline, drainage measures and domestic and industrial buildings.

The River Kennet K has associated with it a number of ox-bow lakes and abandoned channels. Above the river in the photograph are the Kennet and Avon Canal C and an area of Valley Gravel from which gravel has been extracted to leave a flooded gravel pit G. Below the river in the photograph the flood plain is occupied by Alluvium, and is crossed by the railway R and by numerous streams and abandoned stream channels. Most of the fields are under pasture, and the water table must be high. One of the streams passes through a small area of peat, where drainage measures can be seen at P. A soil survey showed that here the peat is between 1m and 3m thick. Theale T is situated on Valley Gravel clear of the Alluvium of the flood plain of the River Kennet, and the A.4 Trunk Road A-A', which passes through Theale, also avoids the flood plain as far as possible.

In the lower part of the photograph the Chalk rises from the edge of the flood plain, which is bounded by the unsurfaced road U and the stream S. The Chalk forms a well-drained area of rolling topography, free from surface drainage, and covered by a thin layer of Reading Beds except where it is exposed along its margins bordering the road and the stream. The fields are larger, and are under arable cultivation indicating a drier or lighter soil. At D and D' there are depressions due to swallow-holes caused by solution of the chalk.

The area illustrates how topography, drainage and land-use can be recognized on air-photographs, and can be used as pointers to the geology and soil conditions. It also shows how air photographs may assist in the detection of unfavourable natural features such as areas of peat, old river channels which may contain soft silty materials, and swallow-holes which may lead to subsidence. Mapped man-made features such as roads, canals and buildings can be examined as they are on the ground, and recent unmapped developments such as building construction and extensions to gravel pits can be located. Less obvious man-made obstructions can also be seen, such as the buried pipe-line L-L', and the site of a projected power-line Q, where a swath has been cut through a wood.

Holyport-Ashampstead (M.4) Sortie No. 6501. Film No. 1 Photographs Nos. 1018,7,6.

Maps: Ordnance Survey 1:63 360 Sheet 169 Aldershot, 7th Series.
Ordnance Survey 1:25 000 Sheet SU 67, Provisional Series.
Geological Survey 1:63 360 Sheet 268 (Drift) Reading.
The area shown is on the Upper Chalk, most of it covered with a level area of Clay-with-flints. Half-way across the rectangular field at the top of the photographs the edge of the Clay-with-flints is reached, and the land surface begins to drop away. Here the light tones of the chalk are visible though the crop, and two large depressions A and B can be seen. These have arisen from subsidence into swallow-holes caused by underground solution of the chalk. In the area covered with Clay-with-flints, smaller depressions C and D can be seen, caused by settlement of the overlying material into solution cavities in the chalk below. This can occur suddenly, often after heavy rain, and can result in the formation of vertical shafts which can initially be of diameter 1m and depth 2m, but which may eventually weather to form dished depressions liable to periodic re-activation. The detection of these features on the proposed line of a road is particularly important where they are at bridge sites.

Features of this type also occur widely on harder limestone deposits, and infra-red false colour film was used to study them in a moorland area on the Carboniferous Limestone on the line of the M.6 Motorway (R.J.S. Edwards, Scott, Wilson, Kirkpatrick and Partners, Unpublished). Using this film, incipient swallow-holes showed up in contrasting colour, because of differences in vegetation and moisture conditions.

The photographs also show the character of hedges and the position of gaps and gates, details of the B.482 road R including footway, verge and drain inlets, houses, gardens, and a building under construction.

Photographs: B.K.S. Surveys Ltd. for Buckinghamshire County Council, agent for Ministry of Transport.
High Wycombe By-pass (M.40) Job No. BKS 3023/24
Run No. 2(N) Photographs Nos. 514378,9.

Maps: Ordnance Survey 1:63 360 Sheet 159 The Chilterns, 7th Series.
Ordnance Survey 1:25 000 Sheet SU 79, Provisional Series.
Geological Survey 1:63 360 Sheet 254 (Drift) Henley on Thames.
Plate 6. Stokenchurch, Buckinghamshire
PLATE 7
Tideswell Dale, Derbyshire

Location: South of Tideswell. Nat.Grid Ref. SK 1574 Scale: 1:6000 Date: 15 November 1962

This is an upland area, cut by the main valley of Tideswell Dale running N-S and carrying the B.6049 road R-R'. The area consists of Carboniferous Limestone, together with associated lavas and dolerite intrusions ('toadstone' of the Old Series Geological Survey map) which on the air photographs differ little in appearance from the limestone. Numerous rock outcrops can be seen on the photographs (e.g. at A), which will provide sites for examining and sampling the rocks of the area. The large disused quarry at Q might be re-opened as a source of road-making materials, or could be used for running unwanted material to spoil.

There is no surface drainage, the water finding its way underground through the pervious limestone. Because of this, circular stock-ponds have been provided and are a conspicuous feature in the fields, which are under pasture. Dry-stone walls form the field boundaries, and access routes for boring rigs can be planned by observing the position of the gates, which can be clearly seen in the photographs.

At M, the spoil heaps of old mining activities mark the line of a mineral vein, and old shafts and galleries may be encountered here. Depressions in the fields, such as those at D, may be caused by swallow-holes which could lead to subsidence, or may be the sites of shallow quarrying. The relief of the old spoil heaps and of the depressions can be seen under stereoscopic examination, and illustrates how minor surface relief can be revealed and interpreted by an examination of the associated shadows. The side valleys at B and C show how north-facing slopes may be obscured by shadow, especially when the sun is low.

Photographs: Hunting Surveys Ltd. (Supplied by Aerofilms Ltd.)

Job No. HSL UK 62 285 Run No. 3 Photographs Nos. 2911, 10, 09.

Maps: Ordnance Survey 1:63 360 Sheet 111 Buxton & Matlock, 7th Series.
Ordnance Survey 1:25 000 Sheet SK 17, Provisional Series.
Geological Survey 1:63 360 Sheet 99 (Drift) Chapel en le Frith.
Geological Survey 1:63 360 Sheet 81 SE (Old Series).
PLATE 8
Black Down Common, Devonshire

Location: On the western margin of the Black Down Hills, 3.5 km east of Burlescombe. Nat. Grid Ref. ST 1116
Scale: 1:10 000 Date: 15 March 1967

The dotted line separates two areas which show contrasting land-use and appearance on the air-photographs, corresponding to differences in topography and ground material. To the right and bottom of the photographs is lower ground consisting of Keuper Marl, which is overlain on the footslopes of the higher ground by rainwash, and which is nearly all enclosed in fields under pasture or arable cultivation. To the left and top of the photographs is the higher unenclosed ground of Black Down Common. It consists of Upper Greensand, capped with Clay-with-flints except on the lower slopes, and is nearly all moorland with only a thin vegetation cover. The effect of erosion on the Upper Greensand can be seen by the fretted appearance of the hillside at C, where a marked step must indicate the presence of more resistant material. Water emerges from the rainwash and the Upper Greensand in springs and streams (as at D), and in this area there is the possibility of instability which is also suggested by slip-like features such as that at S.

In the planning of a site investigation before the first site visit, the air photographs will show the main areas having different materials and different problems of access. They will also show the location of existing exposures, such as those at A and C, which can give a guide to the nature of the materials and allow sampling to be carried out before any borings have been made.

Photographs: B.K.S. Surveys Ltd. for Freeman Fox and Partners, Consulting Engineers to the Ministry of Transport. M.5 Motorway Job No. BKS 2822 Run No. 11 Photographs Nos. 623179,8,7.

Maps: Ordnance Survey 1:63 360 Sheet 164 Minehead, 7th Series.
Ordnance Survey 1:25 000 Sheet ST 11, Provisional Series.
PLATE 9
Holyhead, Anglesey

Location: West of Holyhead, Holy Island. Nat. Grid Ref. SH 2382 Scale: 1:2800 Date: 11 May 1961

The photographs show two contrasting areas corresponding to different geological materials. In the upper part of the photograph, above the dotted line, the ground consists of a succession of grits, sandstones and shales of the South Stack Series of Pre-Cambrian rocks. In the fields in this area numerous outcrops of the harder beds can be seen trending NE-SW. Some of the areas of soil between these outcrops have been ploughed. A small valley V-V' crosses and interrupts the rock outcrops in a NW-SE direction. It corresponds in position to an igneous intrusion shown on the geological map, which appears to have weathered more rapidly than the surrounding rocks. In the lower part of the photographs, below the dotted line, the ground consists of Boulder Clay and the fields are smooth and free from rocky outcrops. The course of a small stream S-S' can be followed.

The photographs would be useful in planning access for boring rigs in a site investigation, and the numerous natural rock exposures would allow preliminary inspection and sampling to be done. In route planning, preference over the rocky areas might be given to the valley V-V' or to the smoother Boulder Clay area.

Photographs: Hunting Surveys Ltd. (Supplied by Aerofilms Ltd)
Job No. HSL UK 61 44 Run No. 1 Photographs Nos. 0421, 20, 19.

Maps: Ordnance Survey 1:63 360 Sheet 106 Anglesey, 7th Series.
Ordnance Survey 1:25 000 Sheet SH 28, Provisional Series.
Geological Survey 1:63 360 Anglesey Special Sheet (Drift).
PLATE 10
Cadbury Camp, Somerset

Location: 5 km east of Clevedon. Nat. Grid Ref. ST 4572  Scale: 1:10 000  Date: 20 June 1961

The central part of the area shown, bounded by steep wooded slopes, is a ridge of limestones, sandstone and mudstone of Carboniferous age. This area is occupied by open, well-drained parkland or heath. The ridge is flanked both to the north and to the south by lower ground, where the Carboniferous rocks are overlain by Keuper Marl. The surface of the Keuper Marl is gently sloping and relatively well-drained, and is enclosed in fields, many of them under arable cultivation, where crop and harvesting patterns can be seen. At the bottom of the photographs, below the dotted line, the Keuper Marl is overlain by the Peat of Weston Moor W; its flat surface is crossed by numerous drainage ditches and much of it is under rough pasture.

Sloping land that is unstable, or too steep for other uses, is often occupied by woodland. The distribution and density of the woods on the steep slopes of the ridge of Carboniferous rocks can be studied in the air photographs; they obscure areas in which landslips and unstable ground may be suspected, and a careful ground inspection should be made.

Major faults in the Carboniferous rocks are marked at F and F' on the geological map, and the small valleys A and B which cut into the ridge have formed along the line of another fault F". It may be that the valley D has formed along a similar but unmapped fault. In the neighbourhood of faults the rock may be shattered, which may make the excavation of the rock easier, but may affect the stability of the slopes of cuttings.

A prehistoric earthwork, Cadbury Camp, is situated at C. The sites of ancient monuments may not be apparent from a ground inspection, and are frequently first detected from the examination of air photographs. Many ancient monuments are protected under various Acts of Parliament, and if any ancient monument is liable to be affected by engineering works the case should first be referred to the Chief Inspector of Ancient Monuments, Ministry of Public Buildings and Works.

Photographs: Hunting Surveys Ltd. for Freeman Fox and Partners, Consulting Engineers to the Ministry of Transport. Birmingham-Exeter Motorway (M5)  Job No. HSL UK 61 75A  Run No. 2  Photographs Nos. 111,2,3.

Maps: Ordnance Survey 1:63 360 Sheet 165 Weston-Super-Mare, 7th Series.
Ordnance Survey 1:25 000 Sheet ST 47, Provisional Series.
Geological Survey 1:63 360 Sheet 264 (Solid and Drift) Bristol.
Geological Survey 1:25 000 Sheet ST 47 (Solid and Drift) Clevedon and Portishead.
PLATE 11
High Halstow, Kent

Location: North Kent. Nat. Grid Ref. TQ 7875  Scale: 1:10 500  Date: 28 August 1961

Most of the left-hand side of the area is London Clay with Woolwich Beds (sand and clay) and then Thanet Beds (sand) emerging on moving towards the right-hand side of the photographs. At the bottom of the photographs these deposits are overlain by the Alluvium A of the flood plain of the Thames, which forms a flat area of pasture land with high water table and numerous meandering streams. This area is enclosed by the dotted line, which also includes a forked tongue of Alluvium A' following two small streams. The marks in the fields H and H' are caused by harvesting.

The orchards O are situated mainly on the soils of the Woolwich Beds. On the London Clay slope at E, rising from the head of the stream towards High Halstow in the top left-hand corner, the irregular surface of a landslide area is clearly seen. The wooded area around Northward Hill N also occupies slopes on London Clay, and instability may be expected here as well, but the area is difficult to examine on the air photographs because of the tree cover, and a careful field inspection is indicated. In fact the geological map shows areas of instability both on the north side of the hill around F and on the south-west side around G.


Maps: Ordnance Survey 1:63 360 Sheet 172 Chatham & Maidstone, 7th Series.
Ordnance Survey 1:25 000 Sheet TQ 77, Provisional Series.
Geological Survey 1:63 360 Sheet 272 (Drift) Chatham.
PLATE 12
Walton's Wood, Staffordshire

Location: 6.5 km west of Newcastle under Lyme. Nat. Grid Ref. SJ 7846. Scale: 1:8300 Date: 28 September 1959

The area shown is on rocks of the Coal Measures. Checkley Brook, the stream in the tree lined valley towards the bottom of the photographs, follows the line of a fault. The underlying rock is predominantly mudstone, which is weathered to clay to a depth of up to 10m. A narrow strip of Alluvium lies in the bottom of the valley. The side of the valley A B is planted with young trees. Features at A have the appearance of landslip scars with slipped blocks and debris on the slope below, and similar signs of instability are seen in the hummocky ground at B. Similar conditions can be expected in the area C, partially obscured by more mature woodland. Further signs of instability can be seen on the other side of the valley at D and in Walton's Wood, a planted area of fairly young trees, where features including those at E, F and G have the appearance of landslips scars. The instability of the valley side became evident during construction of the M.6 motorway. Woodland22 comments that, although the geological maps do not indicate instability here, a geologist making a field inspection for the road would have detected it. In fact it had received a very brief mention in the report of a geological study of the area made for another purpose23. These photographs show that the landslips could have been detected by air-photograph interpretation.

Other features to note in this area are the heaps of mining waste at W, which might be suitable as a source of construction material.

Photographs: Ordnance Survey.
Sortie No. 05/59/110 Photographs Nos. 163, 4, 5.

Maps: Ordnance Survey 1:63 360 Sheet 110 Stoke on Trent, 7th Series.
Ordnance Survey 1:25 000 Sheet SJ 74, Provisional Series.
Geological Survey 1:63 360 Sheet 123 (Drift) Stoke upon Trent.
PLATE 13
Swainswick, Somerset

Location: 4 km north of Bath. Nat. Grid Ref. ST 7568 Scale: 1:3750 (enlarged from 1:7500) Date: 10 June 1968

The high ground around D is part of Charmy Down and consists of Great Oolite Limestone; over most of the rest of the area the ground consists of "foundered strata", a term used by the Geological Survey to denote strata which are disturbed, displaced and covered with material not in situ. The ground slopes down from Charmy Down D to the bottom of the photograph.

The A.46 Trunk Road R has been reconstructed with one descending and two ascending lanes, and to give a straighter alignment it has been built partly in cutting. Diagonal drains in the faces of the cutting are marked by lines of vegetation and scars due to slips in the topsoil can be seen. An abandoned section of the old road, which follows a more sinuous route round the contours of the ground, can still be seen. E and F are small side-valleys. Erosion debris forms a small fan at the lower end of valley F, and terracettes have formed around the steep valley sides. Both valleys contain material showing light photo-tones due to absence of vegetation, and in valley E numerous vehicle track marks can be seen on the surface due to the spreading of spoil, probably from the road cutting.


PLATE 14
Little Wymondley, Hertfordshire
Location: North-west of Stevenage. Nat. Grid Ref. TL 2226 Scale: 1:6000 Date: 14 June 1961

The geology of the area consists of Chalk overlain by Glacial Gravel and Sand and Boulder Clay. A narrow tract of Alluvium fringes the small stream S. The photographs show an interchange under construction on the A1(M) Motorway, and illustrate the value of air photographs as a record of the progress of a civil engineering job and the condition of the site at a particular time. Details which can be seen include the state of the earthworks and bridge abutments at the interchange I, the railway cutting B, and the state of construction of the bridge over it. An electricity transmission line L L' crosses the area, and three pylons can be seen; they illustrate how an object can often be identified, and more information can be obtained about it, by examining its shadow. In the small wood at the bottom of the photographs the swathe cut parallel to the railway marks the position of more wires, carried on poles; the wires themselves can be seen on the original photographs with the aid of a hand lens.

Photographs: Hunting Surveys Ltd. (Supplied by Aerofilms Ltd.)
Job No. HSL UK 61 67A Run No. 2 Photographs Nos. 073, 2, 1.
Maps: Ordnance Survey 1:63 360 Sheet 147 Bedford & Luton, 7th Series.
Ordnance Survey 1:25 000 Sheet TL 22, Provisional Series.
Geological Survey 1:63 360 Sheet 46 SE, Old Series.
PLATE 15
Toddington, Bedfordshire


These photographs show the M.1 Motorway with an overbridge and access roads. They show how air photographs faithfully record the details of a completed road. Features which are recorded and can be seen in these photographs include carriageways and hard shoulders, central reservation, guard-rails to central bridge-pier, cutting slopes with half-channel drains, drain inlets, road markings, cats' eyes and traffic signs. Also recorded are the types and numbers of vehicles using the motorway and adjacent roads. The effect of the movement of vehicles between successive photographic exposures will be noted. Note the patterns produced by haymaking H and by cutting the grass on the slopes of the cutting. The track-marks in the fields were made by agricultural vehicles. The pylon P is difficult to fuse stereoscopically because it is tall in relation to the flying height.

Photographs: Fairey Surveys Ltd. Sortie No. 69104 Photographs Nos. 0965, 6, 7.

Map: Ordnance Survey 1:25 000 Sheet TL 02 (Provisional Series).
PLATE 16
Whitestone, Devonshire

Location: 4.5 km west of Exeter. Nat. Grid Ref. SX 8792 Scale: 1:10 000 Date: 15 March 1967

These photographs are for an area which has been the subject of a larger study, and should be examined along with the maps and description given in Section 4.4 of this Report. The area is on the Carboniferous Culm Measures which here are weak laminated shales with thin hard sandstone layers present locally. Along the Alphin Brook A they are overlain by a narrow tract of Alluvium. The area is dissected by many small valleys, and these and other slopes are subject to instability in the weathered surface layers of the shales.

Two of the areas where the effects of instability can be seen are enclosed by dotted lines. In the map (Fig.7) these and other areas are divided into the categories: unstable slopes, incipient landslides and landslide debris. By examining the air photographs when planning the route for a new road it would be possible to avoid the areas of instability, or if they had to be crossed by the road line it would be realized at an early stage that special measures might be required to deal with them. It can be seen from the photographs that a first inspection of the large area of instability C and be made from the road B without entering private property.

Photographs: B.K.S. Surveys Ltd. for Freeman Fox and Partners, Consulting Engineers to the Ministry of Transport.
M5 Motorway. Job No. BKS 2822 Run No. 25 Photographs Nos. 623075, 6, 7.

Maps: Ordnance Survey 1:63 360 Sheet 176 Exeter, 7th Series.
Ordnance Survey 1:25 000 Sheet SX 89, Provisional Series.
Geological Survey 1:63 360 Sheet 325 (Drift) Exeter.
(It may be necessary to make small adjustments in the separation of the photographs and in the position of the stereoscope.) It will help if the photographs can be positioned so that any shadows in them appear to fall towards the observer, and if the direction of the light during examination is arranged to correspond with the direction of light in the photographs. It will also help to look first at a stereopair of a bold landscape, e.g. Plate 7, in which features expected to show relief can be anticipated. Features showing high relief may be difficult or impossible to view stereoscopically, e.g. the pylon P in Plate 15.

A strip of only about 60 mm width can be viewed stereoscopically at one time with a pocket stereoscope. If the overlapping of the photographs is interchanged, the lower being placed on top, another strip of the same width can be viewed stereoscopically, leaving in a standard 230 mm square photograph a strip about 22 mm wide still hidden. To examine this strip it is necessary to bend up the inner edge of the upper photograph. This can be done by hand, or a viewing aid made of sheet metal may be used (Fig. 5 and Plate 3).

Advantages of the pocket stereoscope are that it is cheap, light and easily carried in the pocket, and can be very quickly adjusted on a stereopair, so that it can be ready for use in the office or the field in a few moments. Its main disadvantage is that only a part of the area can be seen without readjusting the photographs.
3.3.2 The mirror stereoscope. The mirror stereoscope (Plate 2) overcomes the disadvantage of the pocket stereoscope by using a system of mirrors to displace the optical paths from the photographs to the eyes. This allows the photographs to be separated so that once they are set up the whole area common to both photographs is available for examination. Most mirror stereoscopes also have a base board on which the photographs may be held flat and in position after they have been accurately set, a scanning device for viewing the whole area common to both photographs, and provision for obtaining greater magnification if required. Two 'Old Delft' stereoscopes permit two people to examine a stereopair together, which can be of great value when discussing a site. Instructions for using particular instruments are supplied by the manufacturers. Mirror stereoscopes are more expensive, much larger and much heavier than pocket stereoscopes, and are therefore more appropriate for use in the office or site office.

A stereometer is an accessory which can be used with the mirror stereoscope to measure the difference in height between points in the stereoscopic image. Allum gives details on how the instrument is used, and suppliers are listed in Appendix 2.

3.4 Methods of working with air photographs

It is very useful to have an index plot showing the outline of alternate photographs on a map, so that the pair of photographs covering any particular area can be quickly found. A template in the form of a square frame of the appropriate size is useful for drawing the outlines, each of which is identified by marking it with the serial number of the photograph. A quicker procedure is to plot the flight strips, identifying only the first and last photographs of each flight. An index plot is often supplied with a set of photographs.

For working with air photographs the colour-printed 1:25 000 (about 2½ in/mile) Ordnance Survey maps are very useful; although at a smaller scale than the 1:10 560 (6 in/mile) maps, they have the advantages that watercourses are clearly distinguished by being printed in blue, and that relief is shown by additional contours interpolated at intervals of 25 ft between the 100 ft contours of the 1:10 560 map.

The proposed line of the road may be transferred from the map to the air photographs using a 'Chinagraph' pencil, and alternative routes may be drawn in different colours. Chinagraph pencil marks can be readily removed by rubbing with cotton wool. Only alternate photographs need be marked in this way, because a line drawn on one photograph of the stereopair will be seen clearly in the stereoscopic image. Thus details which have been obscured by the pencil lines on one set of alternate photographs are preserved on the other. An overall stereoscopic impression of the ground along the road alignment should first be obtained, followed by a more detailed examination. Whenever a noteworthy feature is seen, one photograph should be annotated with a Chinagraph pencil and the position of the feature should be marked on the map. A list should also be made in which a brief description of each feature is given against its National Grid Reference. In this way the engineer has a record of
his observations on photographs and map, and a list of features and their locations which can be used when making an inspection in the field.

An air photograph contains considerably more information than can be resolved with the naked eye, or with the magnification of a stereoscope (x2 to x4), and a hand lens giving a magnification of about x 10 is often useful for the examination of fine detail, but at the loss of stereoscopic vision.

3.4.1 Working in the field. Air photographs should be used in the field when making an inspection of the site, and when checking on features previously observed on the photographs; other field applications were reviewed in Section 2.3.1. Stereopairs may be readily examined in the field, using a pocket stereoscope. For this purpose the photographs should be clipped to a lightweight viewing-board (dimensions 255 mm x 460 mm are appropriate for standard 230 mm square photographs). Battens fitted under the board give clearance for the clips. Once the photographs have been adjusted correctly for stereoscopic viewing, the clips keep them in position for further examination later. The viewing aid can also be set in place and held with the clips. Plate 3 shows a pocket stereoscope and viewing board with viewing aid in position. For use in the field (Plate 4) the stereoscope and viewing board can be carried on cords round the neck.

4. THE INTERPRETATION OF AIR PHOTOGRAPHS

4.1 Applications

Some applications of air-photograph interpretation to site investigation have been discussed in the previous sections. Mollard reviews the techniques and applications of air-photograph interpretation in engineering geology, citing more than 80 references mostly of American origin. Dowling and Williams have considered the use of air photographs in materials surveys and in the classification of landforms as a basis for the analysis of terrain data for civil engineering purposes. They give examples from Northern Nigeria of an engineering soils and materials survey, and of the selection of the route for a road. Burton gives examples of the use of air photograph interpretation in site investigation for roads in Britain, and Norman discusses the photogeological detection of unstable ground.

The interpretation of air photographs has been used for many other purposes, such as military reconnaissance, geology, geography, hydrology, forestry, agriculture, soils, archaeology and land use, and some familiarity with these diverse applications can be of value to the road engineer when interpreting air photographs. Lueder, Colwell and Avery consider many of these applications in turn. A War Office Manual deals with air photographs in military reconnaissance, as well as giving practical background information on air photographs. Allum deals with photogeology and regional mapping, taking examples from overseas. Walker deals with the use of air photographs in the study of the
geography of Britain; topics covered include river erosion, glacial action, relief and soils and these are illustrated with numerous air photographs, but few of them are stereopairs. Stereopairs of rural and urban areas of Britain are given in Air-Photo Packs Nos. 116 and 217 produced by the Geographical Association in conjunction with C.F. Casella and Co. Ltd. Norman discusses the photogeology of areas covered with Boulder Clay. The interpretation of air photographs for areas in southern England in terms of physiography and soils has been studied by Webster, who gives examples illustrated by stereopairs.

4.2 Interpretation

Some general remarks will be made on the interpretation of air photographs, before discussing the examples given in the next section. The ability to interpret air photographs depends on acquiring experience in seeing the ground from above and in learning to recognize the significance of the differences in photographic tone, texture and relief. It requires an understanding of the structure of the landscape and its relation to the underlying geology, and of the special features of engineering significance which may occur in it. (This type of knowledge is, however, also desirable for site investigation without the aid of air photographs.) The type of features likely to occur in the particular terrain should be determined from a study of the geology of the area made from maps and memoirs, and the air photographs should be examined with these features in mind. When viewing a stereopair of photographs there is exaggerated relief. Relief is an extremely valuable factor in the interpretation of air photographs. The steepness of a slope tends to be characteristic of the material on which it has formed, so that a change in material is often marked by a change in slope which can be detected in the exaggerated relief obtained when using a stereoscope. With black-and-white photographs all detail and form, including differences in colour, are represented by patterns and textures in tones of grey, and tone may offer some guide to materials when they are exposed at the surface. Dark tones are often shown by moist soils such as clays, or where the drainage is impeded as in waterlogged and marshy ground and in unstable areas. Light tones are often shown by well-drained soils such as sands. Standing water usually appears dark where direct reflections are absent, and so do water-seeps and spring lines.

When they are present, shadows can be a considerable help when interpreting an air photograph. In the examples the prints have generally been mounted with the shadows falling towards the viewer, and it will be best to examine them with the light falling in the same direction. The heights of trees, buildings and pylons can be compared by comparing the relative lengths of their shadows. The shape of its shadow can help to identify or can give more information about an object seen only in plan on the air photograph. Shadows also help to indicate relief, surfaces inclined towards the sun appearing brighter. When the sun is low, shadow may conceal details in deep hollows and on hillsides with a northerly aspect, but surface texture and small features of surface relief may be shown up more clearly. Coarse-grained and rocky materials usually give rise to a rough surface texture, and fine-grained materials
to a smooth one, except where the surface has been disturbed by slope instability when a roughened or hummocky texture may be seen. It is useful to note the season, as indicated by the date on which the photograph was taken, or from evidence in the photograph. In the examples, the date of the photography is given. A light dusting of snow may mislead if its presence is not realized. Different agricultural practices give rise to different photographic patterns and tones on the same geological formation and may show seasonal variations. For instance, fields have a characteristic appearance after ploughing and after the harvesting of corn. Aspects of land use such as forestry may mask surface features and variations in the geology, although deciduous trees hide less of the ground surface in winter.

4.3 Examples

Examples of stereopairs of photographs from various parts of Britain are given in Plates 5-16, each of which is described by an accompanying text. Table 1 is an index to the plates and to the features illustrated by them. The examples should be examined using a pocket stereoscope (see Appendix 2 for suppliers), when most features will be found to be enhanced. A lens separation of 65 mm is suggested for a first trial. Most of the plates show a central photograph with a stereopair on either side. This enables a fairly wide area to be shown on a single photograph, while also allowing stereoscopic viewing by the examination of each half of the large photograph with its stereopair in turn. For correct viewing it will sometimes be necessary to orientate the stereoscope slightly obliquely to the frame of the stereopairs, and if necessary the stereoscope should be slowly turned until the correct position is found. In the plates, the line in the margin above the junction of each stereopair shows the approximate orientation for the stereoscope. Most of the photographs have been mounted so that the shadows fall towards the viewer.

A better interpretation of the air photographs is possible from the original prints than from the reproductions in this report, and full details of the source and identification number of each photograph are given, so that the reader may obtain prints if he wishes to.

The text accompanying each plate also gives details of the site location of each example, and the sheet numbers of the relevant topographical and geological maps. The geological sheets are of the New Series, unless otherwise stated. The scales quoted for the photographs are nominal. In practice, stereopairs should be studied along with the topographical and geological maps of the area, and all other relevant sources of site information. Interpretations should be regarded as tentative until a field check has been made, at which time the nature of any puzzling features can also be determined.
Fig. 7. AIRPHOTO INTERPRETATION: GEOLOGICAL OVERLAY

after Hunting Geology and Geophysics Ltd.
4.4 Full interpretation with mapping

An example will be given of a full interpretation of geological deposits and features, made from air photographs supported by site visits, by a firm offering this service\(^3\). Figs. 6 and 7 are maps of the soils and geological features of a short strip, about 1.5 km wide, of the proposed route of the Devon Motorway (M.5) west of Exeter. They are small parts, reduced for reproduction, of a set of transparent overlays to a 1:10 560 geological map prepared from the 1:63 360 Geological Survey map. These overlays were prepared by Hunting Geology and Geophysics Ltd. for Freeman Fox and Partners, Consulting Engineers to the Ministry of Transport. Air photographs at a scale of 1:10 000 were used, and the area marked on Figs. 6 and 7 is shown in Plate 16.

The soils overlay, Fig. 6, shows the nature of the surface materials. In some parts of the area shown the rock or 'solid' formation is at the surface, with little or no soil cover (RB). In the area shown on the map it consists of the Culm Measures, which here is weak laminated shale with thin hard sandstone layers present locally. Much of the outcrop of the Culm Measures is covered with residual soil derived from it (R), probably formed by frost action during the Glacial Period. It may extend to a depth of 3 m, and consists of grey plastic clay at the surface, associated with clay containing shale fragments and broken shale with clay seams passing down into the bedrock. Alluvial soil (A) occurs along the streams, and it was considered that it could be more accurately delimited using air photographs than by ground survey methods. Colluvial soils are found in topographical depressions, and form by creep or downwash from higher surrounding ground. Their composition reflects that of the adjacent solid formations, and on the Culm Measures (C) is a grey sandy clay with shale fragments.

The geological overlay, Fig. 7, indicates a range of features which are not shown on the Geological Survey map of this area, including faults, water-seeps, unstable ground, old landslide scars and landslide debris. The unstable ground occurs in the weathered surface layers of the shales of the Culm Measures. It is divided into unstable slopes and incipient landslides, and consists essentially of shallow rotational slides, which may develop into mudflows. The results suggest that, in further investigations, detailed investigation by boring should be concentrated on the Culm Measures outcrop, to determine the depth and effect of frost action, and that a further detailed study of the unstable areas using air photographs at a scale of about 1:2500 would probably be useful.
5. ACKNOWLEDGEMENTS

Acknowledgements are due to those who supplied the photographs and maps, who are named in the text. The Report was prepared in the Earthworks and Foundations Section of the Construction Division, under the general direction of Mr. W. A. Lewis.

6. REFERENCES


15. WALKER, F. Geography from the air. London, 1953. (Methuen and Co. Ltd.).


7. APPENDIX 1

SOURCES OF AIR PHOTOGRAPHS

The County authorities may be able to advise on air photograph cover for their areas.

OFFICIAL:

England and Wales

The Air Photographs Officer,
Ministry of Housing and Local Government,

Scotland

The Air Photographs Officer,
Scottish Development Department,
York Buildings,
Queen Street, Edinburgh, 2.

Northern Ireland

The Deputy Keeper of Public Records,
Public Records Office of Northern Ireland,
Law Courts Building,
May Street, Belfast, 1.

Ordnance Survey

The Air Photographs Officer,
Air Survey Branch,
Ordnance Survey,
Romsey Road,
Maybush,
Southampton, S09 4DH.

COMMERCIAL

Aerofilms Ltd.,
4 Albemarle Street,
London, WIX 4HR

Hunting Surveys Ltd.,
6 Elstree Way,
Boreham Wood, Herts.

B.K.S. Surveys Ltd.,
Cleeve Road,
Leatherhead, Surrey.

Meridian Airmaps Ltd.,
Commerce Way,
Lancing, Sussex.

Fairey Surveys Ltd.,
Reform Road,
Maidenhead, Berks.

Other addresses may be obtained from the Aerial Photography and Survey section of the London Classified Telephone Directory.
8. APPENDIX 2
SUPPLIERS OF EQUIPMENT
(Pocket stereoscopes, mirror stereoscopes, stereometers)

C.F. Casella and Co. Ltd.,
Regent House,
Britannia Walk,
London, N.I.

Degenhardt and Co. Ltd.,
Carl Zeiss House,
20-22 Mortimer Street,

Fairey Surveys Ltd.,
Reform Road,
Maidenhead,
Berks.
(Mirror stereoscope)

Hilger and Watts Ltd.,
98 St Pancras Way,
Camden Road,
(Suppliers of both Hilger and Watts
and Old Delft instruments)

Wild Heerbrugg (UK) Ltd.,
49-51 Church Street,
Maidstone,
Kent.
ABSTRACT

Air-photograph interpretation for road engineers in Britain: M. J. DUMBLETON, B.Sc., Ph.D., A.Inst.P., F.G.S. and G. WEST, L.Inst.P., F.G.S.: Ministry of Transport, RRL Report LR 369: Crowthorne, 1970 (Road Research Laboratory). The Report gives a practical account of how vertical air photographs can be used in the study of ground conditions in Britain in connection with highway engineering. Sources of air photographs are given and the techniques for examining the photographs are described. Applications of air-photograph interpretation are reviewed; they relate mainly to the route location and site investigation phases of road construction, but include uses during construction and after the road has been completed. Examples are given in the form of stereopairs with an explanatory text, and full interpretation with mapping is also illustrated.

The Report should help road engineers in the United Kingdom to make full use themselves of air photographs as a supplement to other sources of site information, and to appreciate the potentiality and limitations of air-photograph interpretation when commissioning work from specialist firms.