

Aerial Photographs and archaeology

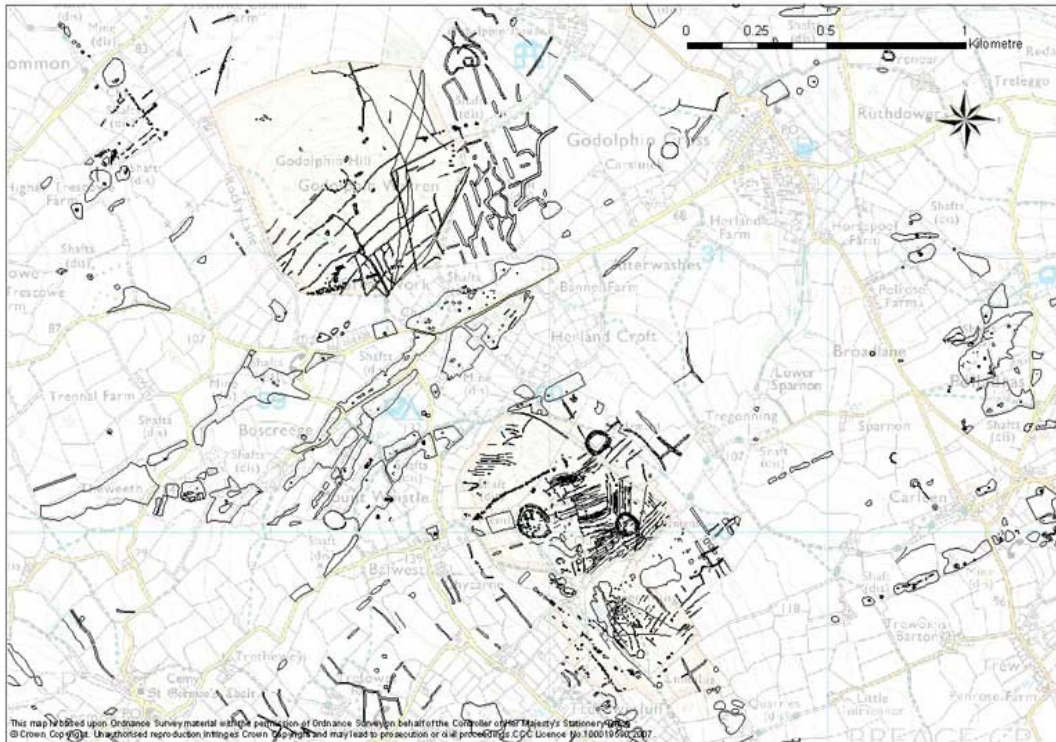
Introduction

The term aerial archaeology is used to describe the various processes relating to the discovery and recording of archaeological sites from the air. These activities include both the actual taking of photographs and the mapping and interpretation of archaeological sites visible on aerial photos. Aerial survey is one of the most important tools for the discovery of archaeological sites in this country. Each year hundreds of previously unknown sites are discovered and photographed through aerial reconnaissance.



Higher Treworder, Egloshayle. A prehistoric enclosure appears on an aerial photo as two concentric cropmarks. The entrance is on the left hand side, where there is a gap in the circuit of the enclosure. Photo © Cornwall County Council Historic Environment Service

In 1965, the Royal Commission on the Historic Monuments of England (RCHME) established a national archive for aerial photographs which was taken over by English Heritage in 1999. This archive contains three million photos, making it the largest collection of aerial photographs in the country. Recognising the need to interpret and map the mass of archaeological information contained in this vast collection of photos, RCHME and English Heritage initiated an ambitious programme of archaeological mapping from aerial photographs - the National Mapping Programme. The overarching aim of the Programme is to map, interpret and record all archaeological features visible on aerial photographs to a consistent standard.



An example of mapping from Cornwall's National Mapping Programme. This example shows prehistoric, medieval and industrial features in the Godolphin area.

History of Aerial Archaeology

Aerial survey is one of the most important tools for discovering archaeological sites; half of all known archaeological sites in the UK have been recorded from aerial photographs. Aerial archaeology involves both the photographic recording of archaeological sites from the air and the interpretation of sites visible on aerial photographs. Thousands of previously unknown sites have been discovered by archaeologists carrying out reconnaissance flights, and by the study of aerial photographs taken for various purposes by organisations such as the Ordnance Survey.

Aerial archaeology has a hundred year history. It was not long after the camera was invented that people first started taking to the skies, capturing unique birds-eye views of familiar places. From this new perspective archaeological features that had not been recognised before on the ground were first identified and aerial archaeology was born. The first archaeological site to be photographed from the air was Stonehenge. The photographs were taken from a balloon in 1906 by Lieutenant Philip Henry Sharpe of the Royal Engineers' Balloon Section. Based at Aldershot, the Royal Engineers' balloonists were the forerunners of the Royal Flying Corps which later became the Royal Air Force (RAF). Aerial reconnaissance developed during the Great War of 1914-1918 to meet the needs of military intelligence, and aerial photography remained a significant part of RAF training in the post war years.

The development of aviation accelerated rapidly during the Great War and this resulted in a dramatic increase in the number of fliers. One of these was O G S Crawford, an observer in the Royal Flying Corps, who first recognised the real potential of aerial reconnaissance for archaeological purposes and who was to become the pioneer of aerial archaeology. Crawford used aerial photographs from

RAF training flights of the 1920s for his pioneering work. Then in 1924, in collaboration with Alexander Keiller another war-time flier, he undertook a number of his own flights over Dorset, Hampshire and Wiltshire. The results of these flights were published in 1928. The book, *'Wessex from the Air'* is a seminal work, demonstrating to the world for the first time the true potential of aerial archaeology.



*An aerial photo of Samson in the Isles of Scilly, taken by OGS Crawford in July 1926.
© Crown copyright. NMR. Crawford Collection. 8758/9*

Aerial archaeology continued to develop during the 1930s. Crawford founded the archaeological journal *'Antiquity'* in which he published the remarkable discoveries of other RAF fliers as well as private pilot Major G W G Allen. Crawford also began mapping and interpreting the archaeological sites visible on aerial photographs; for the first time using the terms cropmark and soilmark which are so familiar to today's archaeologists.

Crawford did not see aerial photography simply as a means of recording individual archaeological sites but as a way of providing archaeological information to put on a map and therefore as a tool for mapping the prehistoric and historic landscape. This concept – of understanding how each site fits into its wider landscape context – is central to the way today's aerial archaeologists work. Crawford also recognised that today's landscape is multi-layered; each successive generation have left their imprint upon it. As he wrote in 1953: 'The surface of England is a document that has been written on and erased over and over again; and it is the business of the archaeologist to decipher it'

In the summer of 1939, Crawford and J K St Joseph arranged a programme of reconnaissance flights in Scotland. Interrupted by the outbreak of the Second World War, it was not until 1945, six years later, that St Joseph began his systematic reconnaissance work on which the Cambridge University Committee for Aerial Photography was founded.

In 1965, the Royal Commission on the Historic Monuments of England (RCHME) established an Air Photographs Unit (APU) as part of its National Monuments Record. The unit, under the direction of John Hampton, provided a national archive for aerial photographs and, since 1967, has carried out its own flights throughout England. The archive was taken over by English Heritage in 1999 and is currently

home to two million vertical photographs, mainly taken by the RAF and Ordnance Survey, and to over half a million specialist oblique photographs. This makes it the largest collection of aerial photographs in the country.

Various individual archaeologists and archaeological organisations across the country have carried out mapping from aerial photographs in a number of different ways, using a range of methods, and at varying levels of detail. Some of these surveys used large numbers of photos; others only a small selection. Recognising the inconsistent levels of mapping, and aware that many of the aerial photographs in the national archive had never been studied by archaeologists, RCHME and English Heritage initiated an ambitious programme of archaeological mapping from aerial photographs in 1988.

Initially four pilot projects were set-up and the results of these pilots led to the creation of the National Mapping Programme. The overarching aim of the Programme is to map, interpret and record all archaeological features visible on aerial photographs to a consistent standard. When this programme is completed all the aerial photographs in the national archive will have been used by aerial archaeologists to produce a map of England's prehistoric and historic landscape.



Archaeological features plotted from aerial photographs on Tregonning Hill, Godolphin as part of Cornwall's National Mapping Programme.

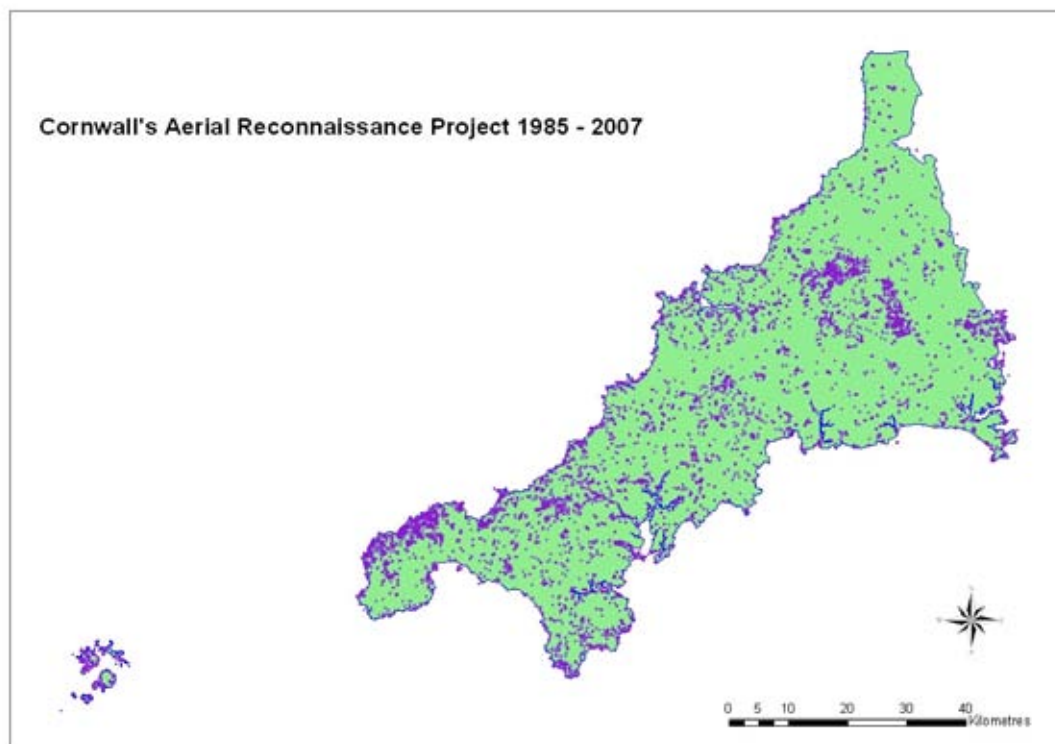
Aerial Reconnaissance in Cornwall

Archaeologists have been regularly flying over Cornwall photographing archaeological sites since the late 1940s. This work was begun by Professor J K St Joseph of Cambridge University who made his first flight in Cornwall in 1948. Professor St Joseph continued to undertake regular archaeological aerial reconnaissance until the late 1970s and his successors at Cambridge still make occasional flights today. In total Cambridge University has a collection of 4,000 aerial photographs of the Cornish landscape.

During the 1970s the Air Photographs Unit of the Royal Commission on the Historic Monuments of England began a programme of aerial survey in the county. These flights span more than a decade after which the role was taken over by English Heritage, who continue to fly in Cornwall today. In total the Royal Commission and English heritage have taken roughly 5,000 aerial photographs of Cornwall in this time.

Aerial archaeologists with English Heritage are based at airfields in Oxfordshire and Yorkshire from which they cover the south and north of England. To spread the work load and to meet the logistical challenges such as regional differences in weather conditions, English Heritage also provides funding to local flyers to carry out aerial survey in their own areas.

Since 1985 archaeologists at the Historic Environment Service of Cornwall County Council have used these funds to undertake the bulk of the archaeological aerial reconnaissance in Cornwall. Over the last twenty years more than 70 flights have been made as part of Cornwall's Aerial Reconnaissance Project. Each year we have taken photographs of previously known archaeological sites and have discovered new ones. In total we have now taken more than 6,000 aerial photographs.



Distribution of oblique aerial photos taken by Cornwall County Council's Historic Environment Service.

Aerial Photographs

There are two main kinds of aerial photograph; oblique images which are taken specifically to record archaeological sites and vertical photographs which are usually taken for other purposes.

Vertical photography

Vertical photographs are taken with the camera pointing straight down to the ground and provide a plan view. The camera is usually fixed to a mount inside the aircraft over an opening in the fuselage. Vertical photographs are taken at a specific nominal scale, for example 1:5,000 (which means that an object in the photographs is 5,000 times smaller than it is on the ground). In order to achieve the nominal scale, vertical sorties are flown at a specific height above ground level.

The photographs are taken at set intervals so that each frame overlaps the next by 60%. This ensures that all parts of the ground are covered by at least two photographs taken from slightly different positions. When viewed through a specially designed optical instrument called a stereoscope, these two photographs are combined to form a single three-dimensional image. Using computers accurate plans and measurements can be made from these stereoscopic models; this technique is known as photogrammetry.



A vertical photo taken for military reconnaissance purposes by the United States Air Force in 1944. Many American troops were housed in temporary camps in this area – the countryside around Chacewater – during the build up to the D Day invasion. This photo provides a unique and historic record of the landscape at that time. © English Heritage. NMR. US 7PH/GP/LOC213/3053

Vertical photographs are not usually taken for archaeological purposes, but for reasons such as military and cartographic reconnaissance and civil engineering projects. Numerous vertical sorties were (and still are) undertaken by the Ordnance Survey who use them to update their mapping. Some sets of vertical photos cover the whole county; these include photos taken by the RAF during training flights after the Second World War in the 1940s and 1950s. Cornwall County Council also commissioned county-wide flights for Census purposes in 1988, 1995-6 and 2005/6.

Vertical surveys usually provide complete cover of a wide area of landscape. This, and the regularity with they have been carried out over the last 60 years, means that

they often capture and record changes in the landscape over time, changes which may not be recorded on modern maps.



The river Fal between Falmouth and Penryn in 1946 and 1996. Although little has changed on the north bank, on the south bank the post-war expansion of Falmouth, including housing, industrial units and the marina, is very striking. © Cornwall County Council

Oblique photography

Oblique photographs are usually taken specifically for archaeological purposes and are very simply those taken at an oblique angle, usually from the open aircraft window. For this reason archaeological aerial reconnaissance flights are always undertaken in high-winged aircraft so that the wing does not obstruct the view of the ground.



Steve Hartgroves, an aerial archaeologist with Cornwall County Council's Historic Environment Service, photographs the Hayle Estuary through the open window of a Cessna light aircraft. Photo © Cornwall County Council Historic Environment Service

The oblique view is more familiar than the vertical plan view. However, the effects of perspective mean that the scale of the image varies across the photograph; the background being of smaller scale than the foreground which is closer to the camera.



Vertical shot of Caer Bran hillfort and associated features. © Crown copyright. NMR.



A similar area of Caer Bran taken as an oblique image. Photo © Cornwall County Council Historic Environment Service

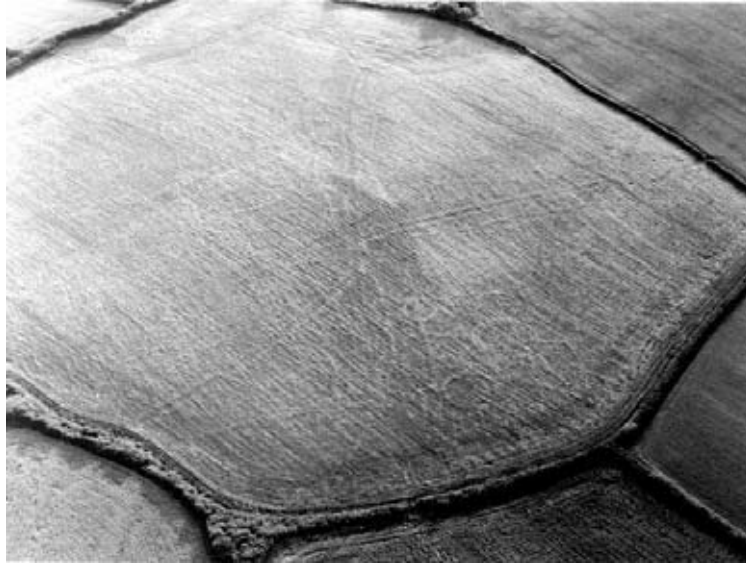
Because they are taken specifically to record archaeological sites and are therefore taken from the most rewarding angles, oblique photographs usually offer much clearer images than verticals. Oblique reconnaissance flights are undertaken from lower altitudes than vertical sorties; consequently the sites are much bigger on the resulting photographs and more detail can be seen. Unlike vertical sorties which are unselective and therefore offer complete cover of a wide area, during oblique sorties the archaeological air photographer only photographs those sites which he or she decides is worthy of a photograph. This is a very selective process and if a site goes unnoticed at the time of flying it will not be photographed. Photo interpreters sometimes identify archaeological sites on the periphery of oblique photographs; sites that were not seen at the time the image was taken.



The low earthworks of medieval strip fields associated with the deserted settlement of Carwether, St Breward are clearly visible as shadow marks in low sunlight. Photo © Cornwall County Council Historic Environment Service

Media used in archaeological aerial photography

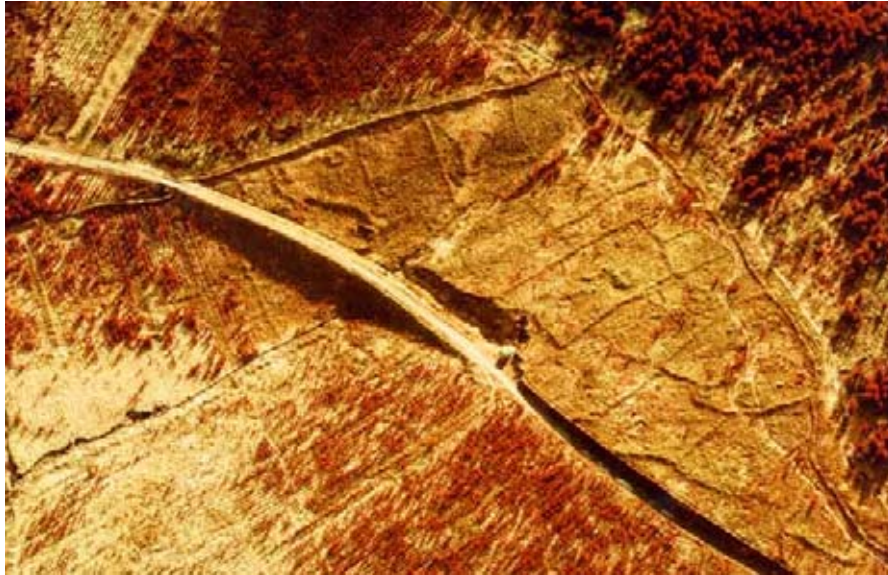
Colour photographs are far better than black and white images for photographic interpretation as they allow the recognition of subtle colour changes in cropmark sites. For a long time, however, black and white was the preferred film in the profession with colour used only sparingly. This was in part due to cost, but also to the unpredictable nature of colour film; incorrect exposures affecting colour balance and saturation, and producing disappointing images. Recent improvements in film and cameras have meant that colour film has increasingly been more widely used. Today with the advent of the digital camera, digital images and computer facility to alter colour balance after the image is taken, colour images are predominant.



Cropmark ring ditches and field boundaries at Moyles, St Minver. A comparison of black and white and colour imagery. Photo © Cornwall County Council Historic Environment Service



Some aerial archaeologists use false colour infra red film. Its emulsion is sensitive to the near-infra red portion of the light spectrum. It is often used in the study of vegetation as it can pick up changes in vegetation including that which is dead or diseased. It has been used for archaeological purposes although its advantages over normal colour photography are debatable.



This image of a prehistoric settlement at Smallacombe, St Cleer has been taken using false colour infrared film. © Crown copyright. NMR

An exciting recent development in aerial archaeology is LIDAR (Light Detection and Ranging). This uses an airborne laser to measure the distance of the aircraft from the ground and produces an extremely accurate digital model of the landscape over which the plane has flown. In the computer the landscape model can be viewed from any position and lit to produce 'shadows'.

Its very high resolution means that the smallest variations in surface height can be recognised, even those of only a few centimetres. It has great potential uses for aerial archaeology as the most subtle of archaeological earthworks can be identified. Whilst in its infancy and still a relatively expensive method of aerial survey, LIDAR is likely to become an invaluable tool to the aerial archaeologist in the future.

Photographic Collections

The two principle national archives which specialise in archaeological aerial photographs are those held at English Heritage's National Monuments Record in Swindon and at Cambridge University's Unit for Landscape Modelling. In addition to these there are two archives held locally in Cornwall at the County Council offices in Truro.

The Cambridge University Committee for Aerial Photography (CUCAP) was first set up by Professor J K St Joseph who started taking aerial photographs after the war. The collection of photographs is the result of annual survey conducted since 1947 and is now in the care of the university's Unit for Landscape Modelling; the collection currently holds half a million images.

The aerial photograph collection of the National Monuments Record (NMR) is located at the National Monuments Record Centre in Swindon. This public archive was taken over by English Heritage in 1999 and is currently home to two million vertical

prints, mainly taken by the RAF, and to more than half a million specialist oblique photographs, making it the largest collection of aerial photographs in the country.



A recent digital photo of St Ives held at the National Monuments Record Centre in Swindon. © English Heritage. NMR. 23892.20

The Historic Environment Service of Cornwall County Council holds an archive of oblique aerial photographs as part of the Historic Environment Record. This is housed in the Old County Hall campus in Truro. The Historic Environment Record is a public archive and consultation is encouraged.



A photo from our collection of the Lizard Life Boat Station. Photo © Cornwall County Council Historic Environment Service

The Support Services of the Planning, Transportation and Estates department of Cornwall County Council holds complete vertical coverage of the county. It holds copies of RAF sorties undertaken in 1946 as well as colour images from Census flights undertaken in 1988, 1995-6 and 2005/6. This collection can be viewed by the public by prior arrangement.



A colour vertical photo from 1996 of Lands End © Cornwall County Council

How we find the sites

Many of the archaeological sites mapped by aerial archaeologists have been levelled by ploughing and are identified from the photos as cropmarks or soilmarks.

Archaeological sites which have not been ploughed down generally survive as low earthworks or slight stony banks. From the air these are best viewed in low light conditions, especially in the early morning or evening.

Cropmarks

Cropmarks are simply patterns in vegetation reflecting differences in the rate of germination, growth and ripening of a crop. These differences are caused by variations in the moisture and nutrient content of the soil. These variations in turn are caused by differences in the structure and profile of the subsoil and can be due to the presence of buried features.

For example natural fissures or man-made ditches in the underlying bedrock or subsoil are usually filled with deeper, richer soils and will retain more moisture than the surrounding undisturbed ground. Crops planted over a buried ditch will germinate quicker and grow more rapidly than the surrounding crop. In dry weather conditions they will grow taller and ripen later due to the extra reserves of moisture held in the buried ditch.

The opposite is true for buried walls or compacted surfaces which retain less moisture than the surrounding field. Here crops will germinate later, grow more slowly and may be stunted due to the lack of moisture and nutrients. In drought conditions, crops planted over walled features will ripen more quickly than the surrounding crop.



Iron Age or Romano-British enclosures at Tregear showing as germination marks. The circular enclosure is surrounded by a bank and an outer ditch. The line of the ditch is marked by a green line where the crop has germinated and is growing strongly. The line of the bank is marked by a pale band of bare soil where the crop has not yet germinated. Photo © Cornwall County Council Historic Environment Service

In this way under the right conditions, buried archaeological features can be traced on the surface by their affect on the growing crop. Most archaeological sites have been levelled flat by years of ploughing and are no longer visible on the surface; these sites may only be visible as cropmarks. Since much of England has been cultivated, cropmarks are the most important source of information that can be recorded by the aerial archaeologist. The vast majority of the specialist oblique photographs held by the National Monuments Record are of cropmark sites.

Many types of crop develop cropmarks, although the best are found in cereals, especially wheat and barley. Cropmarks can be formed in all stages of a crop's growth cycle but the optimum time is from May to July when the crops are starting to ripen. Cropmarks are usually visible as differences in colour although sometimes as differences in height, in a similar way that earthworks are seen from the air.



Roscarrock, St Endellion. Natural irregularities in the subsoil are causing the pattern of cropmarks visible as colour differences in this ripening cereal crop. In the top corner of the field a rectilinear ditched enclosure is clearly visible. Photo © Cornwall County Council Historic Environment Service



A prehistoric enclosure at Carnevas, St Merryn. Here the crop is beginning to ripen around the edges of the field. The line of the enclosure ditch is clearly marked by the crop over it growing taller than elsewhere. Photo © Cornwall County Council Historic Environment Service

Soilmarks

During ploughing time, in the months between autumn and spring, differences may be seen in the colour of freshly ploughed bare soils as lighter sub-soils are brought to the surface.

When buried archaeological features are ploughed they cause differences in the colour of the soil across the field. Ditches will have filled with organic matter giving them a darker hue, whereas material forming banks or mounds will have been quarried from sub-soil deposits and are paler than the surrounding topsoil. With soilmarks therefore, the aerial archaeologist is looking directly at the archaeological deposits brought to the surface by the plough where they show as colour differences against the non-archaeological plough soil.



An Iron Age enclosure visible as a soilmark at Helland. Material forming the enclosure bank has been brought to the surface where it shows as a pale band against the darker topsoil. © English Heritage. NMR. 18527/10

Earthworks and stoneworks

Earthwork sites are those where standing archaeological remains in the form of ditches, earth banks or low walls survive. Even the most substantial of earthworks can appear almost invisible in flat light so they are best photographed when the sun is low in the sky. The optimum times to photograph earthworks are in the early morning, the late evening or in winter, when the low angle of sun-light picks out the slightest of archaeological earthworks as highlights and shadow-marks.



Sharp Tor, Linkinhorne. Earthworks of prehistoric field boundaries are clearly visible as shadow marks underlying the modern field system which was laid out in the eighteenth or nineteenth century. Photo © Cornwall County Council Historic Environment Service

The direction of the sun is as important as its elevation in the sky. Different parts of site may be more or less easy to see due to their orientation in relation to the sun. A deep linear ditch would cast a good shadow along its length if it was orientated at right-angles to the sun, however the same feature would be almost invisible if the sun was shining directly along it.



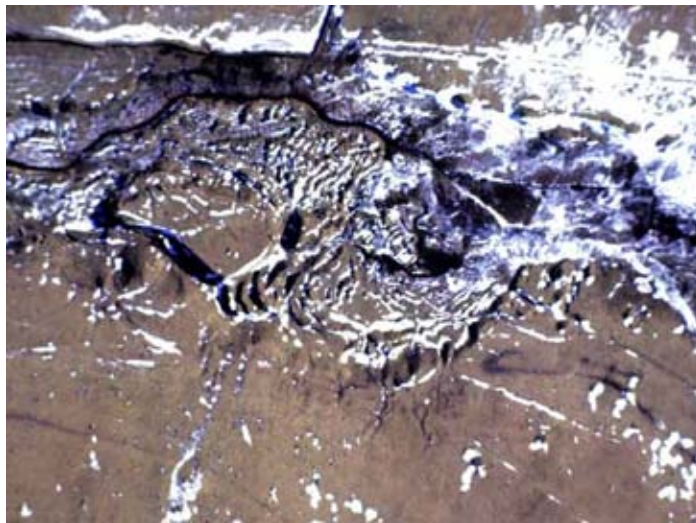
Medieval tin streamworks and later mining remains on Craddock Moor, showing very clearly in low light. Photo © Cornwall County Council Historic Environment Service

The vegetation covering an earthwork site will also affect how distinct the site is when viewed from the air. Shadow sites are most easily seen on heavily grassed pasture where the grass is kept short. Shadows are less distinct on areas of rough ground where heather and bracken create an uneven vegetation cover camouflaging the earthworks. Only the most substantial of earthworks can be identified under trees or shrub.



Largin Castle, an Iron Age hillfort visible in dense woodland at Broadoak, Caradon. The interior of the hillfort is covered by ancient oak woodland, but all the surrounding ancient woodland has been replaced by conifers. Photo © Cornwall County Council Historic Environment Service

Earthworks may also be accentuated by floodwater or by differential melting after a light fall of snow. The snow on the raised banks or low stone walls of a field system are likely to melt quicker than the surrounding area and these earthworks can be picked out as dark lines on the light snow. Alternatively snow lying in shallow ditches will melt slower than the surrounding areas.



Tin streamworks at Altarnun, Bodmin Moor; the parallel patterns of spoil banks resulting from medieval streamworking are picked out by a light dusting of snow. Photo © Cornwall County Council Historic Environment Service

Mapping the historic landscape

The aim of the modern aerial archaeologist is to create a map of the prehistoric and historic landscape by mapping all archaeological features visible on aerial photographs. So how do we do it?

All available photographs, both oblique and vertical, are examined and any archaeological features are identified. We would normally use a stereoscope to do

this. Pairs of photographs are taken with an overlap in which a point on the ground is visible on both images, each taken a small distance apart. This is true of all vertical photographs and on some oblique images as well. When the pair of photographs is looked at stereoscopically, a three-dimensional image can be seen. In a stereoscopic view the landscape appears in exaggerated relief which makes it easier to see slight earthwork features.

Once an archaeological site has been identified, the photograph is scanned and then digitally manipulated in order to remove all the distortions due to height and camera angle. This process is known as rectification or transformation and requires a number of control points to be chosen from the aerial photograph (for example corners of fields or buildings) each of which need to be marked on the corresponding map of the area. These control points are then used to transform the image into a corrected plan view using specialist computer software.

The archaeological features can then be digitally plotted from the rectified images in the computer using a drawing package (we use AutoCAD). As each successive photograph is scanned, rectified and plotted, so a map of the historic and prehistoric landscape gradually emerges.



Using a stereoscope to view a pair of vertical photographs