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Digital approaches and access for Aerial Survey - help or hindrance?

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Abstract: During the past decade there has been a major expansion in the use of digital methods for mapping from aerial photographs and record creation as well as in airborne recording systems (especially GPS). These have led to considerable changes in working practices, some beneficial, some not so. We must not forget that the process of human interpretation is essential in an increasingly digital world and also that the computer is merely a tool to help us do what is fundamentally the same task it was 50 years ago. Specifically the paper explores the basic philosophy and practical implementation of national programmes of mapping (especially English Heritage's National Mapping Programme) and reconnaissance and the current contribution of computerised mapping and record creation. Achieving consistency and compatibility at a national scale are two major objectives but they remain as much aspirations as reality.

1 Introduction

This paper examines the development of aerial survey from its earliest days and assesses how changes in methodology, especially working in a digital environment, have brought not just benefits, but some potential problems.

2 History and Methodology

Aerial survey, including aerial reconnaissance and mapping, is not new. As long as there have been cameras and a means of getting into the air people have been taking aerial photographs. The French author and artist Gaspard-Felix Tournachon (who used the *nom de plume* Nadar) is recorded to have taken the first aerial photo from a balloon tethered over the Bievre Valley in 1858, and the oldest surviving aerial photograph is a view of Boston (USA) by James Wallace Black taken in1860. It was less than six years after the first flight in an aeroplane that Wilbur Wright took the first aerial photograph from an aeroplane of Centrocelli, Italy. What is more, for almost as long as people have been taking aerial photographs they have been taking them of archaeological features. The earliest aerial photograph held by the National Monuments Record (NMR), the archive of English Heritage in Swindon, was taken from a balloon by one Lieutenant Sharpe in 1904 and shows Stonehenge with a number of fallen trilithons.

Aerial photography really came into its own during WWI when it was used to identify targets and then assess the effectiveness of bombardments. At the height of the conflict French aerial units were developing and printing up to 10,000 photographs a night. It was also during the war that the possibilities of using aerial photographs for mapping landscapes were first realised by one of the pioneers of aerial survey OGS Crawford. He was posted to the 3rd Army GHQ at St Omer to deal with map compilation, as the only maps the army had were 1:80,000 scale dating from the Napoleonic campaigns. Then in 1917 he transferred to the Royal Flying Corps (RFC) as an observer with the 23rd squadron. After the war he became the first archaeological officer for the Ordnance Survey (OS) and began to collect aerial photographs taken by various RAF stations around the country (and the world). These had been taken for non-archaeological reasons, but he foresaw their potential and built them into a collection, which could be used as a resource at a later date. On 12th March 1922 he gave a talk to the Royal Geographic Society on the use of aerial photographs in archaeology. It was a great success and apart from newspaper interest it also led to contact with Alexander Keiller who suggested a special expedition to take archaeological air photographs. This was carried out around Andover in May 1924 and led to the publication of "*Wessex from the Air*" in 1928 (Crawford and Keiller 1928). Using both specialist and non-archaeological photographs he went on to produce some of the first maps of archaeological landscapes (as opposed to individual sites). In the period between 1932-38 he worked on plans to publish a series of maps to be entitled "*The Celtic fields of Salisbury Plain*", but the outbreak of war in 1939 put a stop to his work and most never progressed beyond his original annotated OS maps (Fig 1).

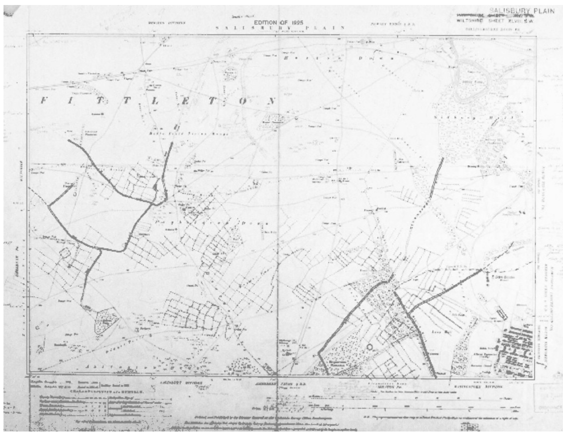


Fig. 1. *Ordnance Survey base map with prehistoric land boundaries and field systems drawn directly onto it by Crawford.*

After this initial foray it was then over 30 years until the next example of area landscape mapping. In 1974 Benson and Miles published "The Upper Thames Valley" (Benson and Miles 1974) the first published landscape survey based primarily on the evidence from aerial photographs. There then followed a number of volumes such as Danebury (Palmer 1984) and Stonehenge and its environs (RCHME 1979) and several county councils began to incorporate plots from aerial survey into their SMRs. Finally in the late 1980s the Royal Commission on the Historical Monuments of England (RCHME), now part of English Heritage (EH), commenced its National Mapping Programme (NMP). This is a programme to "map, document and classify, at a common scale and to a common standard, all archaeological sites and landscapes recorded in England on aerial photographs". As such it fits into the broader strategy of the Aerial Survey section of

English Heritage, which aims to increase our understanding of past human settlement and land-use. From pilot projects in Kent and the Thames Valley this progressed through England and to date has mapped c30% of the country. The basic mapping philosophy behind NMP was the same as that employed by Crawford 50 years earlier. Some features are much more easily visible from the air in certain conditions than when seen on the ground. Indeed there are a large number of features (visible as cropmarks or soilmarks) that are only visible from the air. Furthermore it is often only from the air that you can get the overall perspective of landscape change, and this only possible using a series of photographs taken over a period of time, so that a picture of changing land use regimes can be obtained.

However, although little has changed in the basic mapping philosophy there has been a major change in terms of the interpretation, or more specifically classification of sites. In Crawford's day and for many years thereafter, the map was the key element. A large number of site types such as cursus, henges or Roman camps could be interpreted with confidence as their forms were already known from the evidence of earthwork survey or excavation. These were but a tiny fraction of all the sites visible on aerial photographs, the vast majority of which did not fit into existing categories. As a result SMRs and other records began to be filled with such records as "AP site" or "Cropmark", where an area, or sometimes just a circle, was outlined on the map base and the record consisted of no more than "Cropmarks of features visible in fields centred at…." To address this patent inadequacy, in the 1980s, a number of researchers in Britain began to examine the possibility of a more rigid system of classification. (Bewley 1984; Palmer 1983; Riley 1980; Whimster 1989). This resulted in the morphological classification system used by English Heritage, which I will discuss in greater detail below. For the moment it is sufficient to note that there was an acceptance of the basic assumption that in some circumstances the shape and size of a feature were related to its date and function.

Despite this major change in thinking, even as late as 1997 not only was Crawford's original philosophy still being used but the actual mapping was also being done in much the same way as he had done 60 years earlier. The end product was a film overlay to the OS 1:10,000 scale base map rather than annotations on the actual map, but this was no great advance. The exception to this pattern was Northamptonshire where NMP data was input to the County Council GIS from 1994.

3 Old Problems

The use of overlays based on the OS 1:10,000 scale base map meant that where sites lay on the edge of two or more sheets it was impossible to get a simple plot of the whole site. This was even true for such world famous sites as the Neolithic henge at Avebury or the Iron Age enclosure at Cassington in Oxfordshire used on the front cover of Benson and Miles volume (Benson and Miles 1974) (Fig. 2).

This meant that in order to get a picture of the entire site you either had to create a composite (Fig. 3a) or copy data over sheet edges (Fig. 3b).

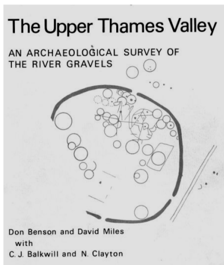
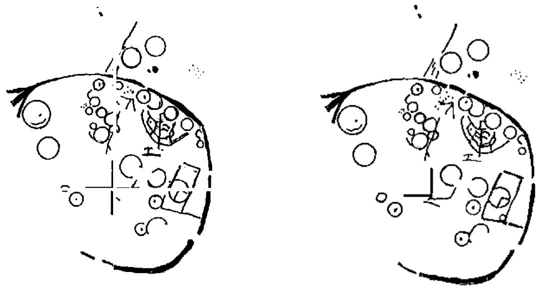


Fig. 2. The cover of Benson and Miles "The Upper Thames Valley", showing the enclosure at Cassington.



(a) (b)

Fig. 3. Two NMP illustrations of the Cassington enclosure showing a composite of four map sheets (a) – note the gaps running along the line of the cross; and a single sheet with data copied over the sheet edges (b).

In October 1997 RCHME made its first tentative steps into the digital era with the first project producing digital vector data. Of the nine sheets comprising the Avebury World Heritage Site Mapping Project (AWHSMP) eight were mapped in the conventional way and were then digitised using AutoCAD map, but one was mapped entirely in a digital environment. That is to say that overlays were produced from aerial photographs and rectified using the AERIAL 4.2 photo rectification program developed by John Haigh at Bradford University and this data was then imported into AutoCAD where it was compiled into a finished drawing (Haigh 1993).

Fig. 4. The area of the Avebury World Heritage site mapped by NMP. The small square represents the corner of four map sheets just like the Cassington enclosure.

4 Changes and Benefits

The removal of the restrictions of sheet edges led to a much more user-friendly product, which could be produced at any scale and centred on any feature (as seen below Fig. 4).

Shortly afterwards the next technological advance came with the introduction of AERIAL 5. Whereas previously it had been necessary to place an overlay over a given photograph, trace off the archaeological detail of interest (and control information) and then digitise this information on a tablet, the new version allowed the actual rectification of the scanned photographic image. This could then be imported into AutoCAD, where the archaeological information could be marked over the top. Figures 5 – 7 (below) show the key stages in this process.

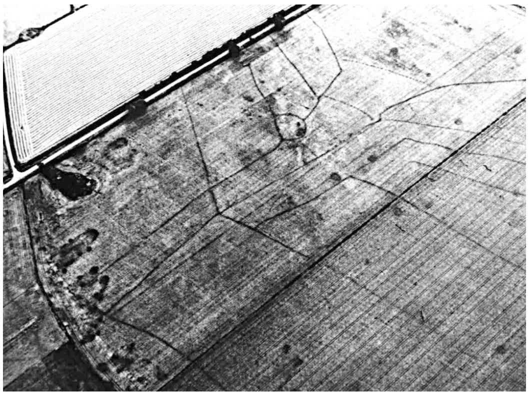


Fig. 5. *A photograph of a cropmark site on the Yorkshire Wolds showing evidence of a small sub-circular ditch defined enclosure with a number of attached linear ditches. This is a standard scan and shows the photograph with no georeferencing.*

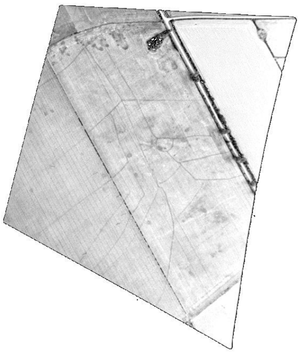


Fig.6. *The same photograph after rectification. This is now correctly referenced with north to the top.*

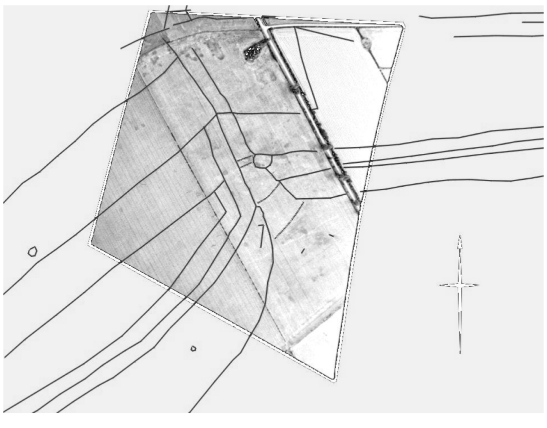
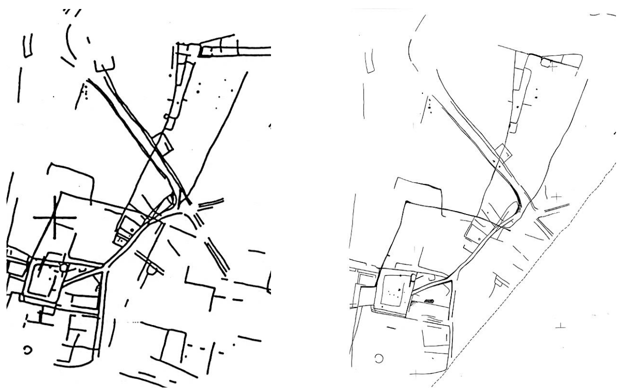


Fig.7. *The same photograph, this time with the archaeological detail traced off and combined with information from other photographs.*

5 New Problems

Indeed the use of the computer has not been entirely beneficial. A lot of people seem to associate automation with accuracy. People who would never dream of taking a hand drawn plot at 1:10,000 scale and enlarging it ten times so as to calculate where to position an excavation seem to think they can zoom in on a digital file and expect the accuracy to be maintained. It is important to remember the two key points of mapping philosophy and that the computer is merely a means to an end. Those points are:

- Mapping at whatever scale is done for a purpose and it is fit for that purpose. If you want to position trenches for an excavation of one small site then you want a very different product than if you are assessing the distribution of settlement over a parish.
- Mapping can only ever be as accurate as the control information on which it is based (e.g. if you use the O.S. 10:000 raster base maps for control you **cannot** expect an accuracy of greater than 5 – 10m as this is the level of accuracy the O.S. themselves specify).



1:10,000 (a)

1:2500 (b)

Fig. 8. *Examples of different mapping scales used for different purposes.*
(a) 1:10,000 mapping primary level survey used to plot the location of features and their general relation to one another.
(b) 1:2,500 mapping used for more detailed survey depicting nuances of features often in advance of other survey methods such as geophysical prospection or excavation.

Most of the surveys carried out by the Aerial Survey section of EH relate to NMP and as such are designed as primary level survey; an attempt to define the relationship of sites within a landscape. They are rapid surveys completing all data for a 25 sq km map in 15 - 20 days. This means that control information is taken from the O.S. 1:10,000 base map and that certain nuances of a site are not depicted (e.g. any feature such as a ditch less than 2m wide is depicted with a single line thickness) (Fig. 8a). In the event that a site needs to be examined in greater detail it is necessary to return to the original photographs and re-examine them with a higher degree of control information (Fig 8b).

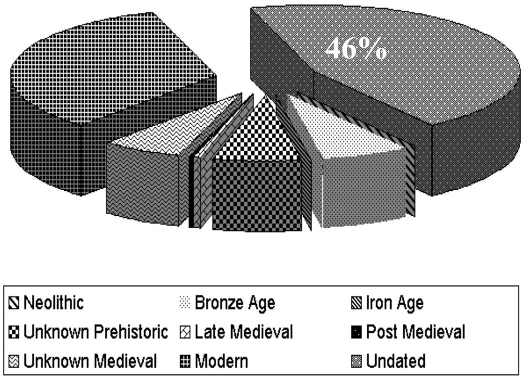


Fig. 9. Breakdown by period of new sites discovered during the Salisbury Plain NMP project.

The maps, however, are only half of the picture. They are impressive and useful in terms of the data they contain, but they have limitations. To the untrained eye they are merely a series of squiggles or spots that do not help in trying to explain the development of a landscape. For this you need records and information. This is not to say that people have not been recording the information about the sites they map. Indeed one of the key aims of NMP was to "classify…. all archaeological sites and landscapes recorded in England on aerial photographs" and since 1989 each feature was recorded as part of a database. Initially this was MORPH, a relational database recording both the core information such as *period*, *interpretation* and *form* and the more specific morphological characteristics of the individual elements of the site (hence its name)(Edis et al 1989). Latterly the primary data has been entered directly into NewHIS, the English Heritage national database of monuments, and morphological recording has been carried out only on those sites for which it has been assessed as useful, especially enclosures. The morphological assessment still follows the same pattern as was initially envisaged in the original discussions of the 1980s. The nature of aerial survey alone, without the opportunity to examine features for dating evidence on the ground, means that assigning a date is difficult. Some features such as round barrows are reasonably simple to recognise, but a lot of sites are much more difficult. As a result c 50% of all sites recorded from aerial photographs are unable to have any date assigned, and a further 20% - 30% can only be dated to a general era such as Prehistoric, which includes anything Roman or earlier (Fig. 9).

Furthermore, of those undated sites c 50% receive such unspecific interpretations as "enclosure" "settlement" or "field system" (Fig. 10). Equally high proportions of dated sites are given these same indefinite interpretations (Crutchley 2000). With such vague definitions it was recognised that a system had to be devised to help make meaningful comparisons between sites.

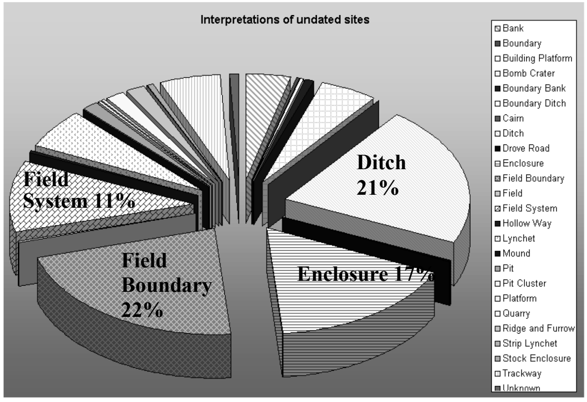


Fig. 10. Breakdown by interpretation of new undated sites discovered during the Salisbury Plain NMP project.

It was realised that the only information that could be gathered about most of these sites, besides their physical location in the landscape (i.e. on a slope, a hill top etc), was related to their size and shape. This had been recognised to a certain extent previously, but subjective names like "goal post enclosure" or "staple enclosure" merely hid the similarities that might help to identify site types.

The MORPH program attempted to introduce consistency in description (i.e. if it is square then describe it as such) and via a series of related databases record the basic morphological characteristics of a given site in terms of shape and pattern (Edis et al 1989). Without going into detail the program gave the user a series of options, each of which led them down a path (E.g. CURVILINEAR – SYMMETRICAL – CIRCULAR/OVAL; RECTILINEAR - SYMMETRICAL – SQUARE/RECTANGULAR) recording shape and dimensions. The idea was that comparisons could then be made between sites, which had been excavated or for which other information was known, and those known only from the air.

The program and the process of recording produced significant results allowing the recognition of sites that might otherwise have been missed amongst the masses of data generated by the projects. One particular example occurred on Salisbury Plain, where analysis of a number of previously undated enclosures and comparison with excavated examples suggested their interpretation as Iron Age defended settlements (Crutchley 2001). Further analysis of their distribution showed that they tended to be situated either on the edge of the scarps of the Plain or on high ground overlooking the central valleys traversing the plain. It was later discovered that several of these proposed sites had been subject to excavation as part of a research project run by Reading University, which confirmed an Iron Age date for all of them.

However, there was also a down side again brought about by the use of computers. There was a slight tendency to record the morphological characteristics of a site because it was possible, without regard to whether or not this information might actually be useful. Of the 4261 sites recorded for SPTA 45% were LINEAR FEATURES mainly field boundaries, lynchets etc, for which morphological recording is inappropriate. The same was true for other NMP projects to a greater or lesser extent: in the Thames Valley 41% were linears; Essex (58%); Yorkshire Dales (41%); National forest (56%). When NMP went over to recording the interpretative data for a site directly into NewHIS (the English Heritage monument database) the morphological recording module was changed so that it only recorded those sites for which it had proven useful to be able to interrogate their morphological details.

At present this system is still based on the visual assessment of a site and the input of relevant data into a database which can then be interrogated. It may be that in the future there may be a technological breakthrough in shape recognition, which will actually allow the scanning of the graphical elements of a map and searching for similar features, but I believe there are currently too many variables. There may even come a time in the future when a scan of the photograph can be analysed automatically to extract archaeological features but we are even further away from that.

For the moment we must rely on the human eye to pick out the features of relevance and record information about them. The big difference that digital mapping has made is that it is now much easier to link the two. When the map was a film overlay the only link that could be made with the data was a manual one, using reference numbers recorded on copies of the map, but once the data became digital it was possible to directly link data to the graphic objects. Initially this has only been at the level of recording the unique identifier for each feature, which allows an indirect connection to be made between the database and the map (Fig. 11). As the mapping is integrated into HSIS, the English Heritage GIS, there will be a direct link from every graphic object to the full data relating to period, interpretation etc.

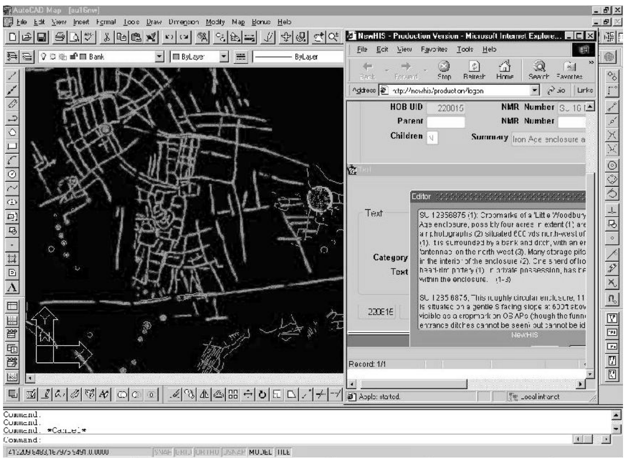


Fig. 11. Screen dump of the recording process showing the AutoCAD map and the NewHIS record alongside.

It will then be possible to compare sites all over England (e.g. all the sites that are between 100 – 200m in diameter on a hill top) or to examine all those sites of Prehistoric or Roman date and visually assess any points of similarity.

This, however, also leads to another potential hindrance, one that is not limited to aerial survey, nor even to archaeology in general, but is inherent in all aspects of computer technology – upgrades and compatibility across systems. While this is a general problem there are some specific elements encountered within archaeological circles especially relating to the proliferation of different versions, packages and even operating systems used by different sectors of the discipline. The Aerial Survey section at English Heritage aims to provide data to a variety of bodies including SMR's and archaeological units interested individuals. Although it was not as versatile when the product was "hard copy", it was at least simple to provide a product. Anybody can take a sheet of film and put it over a map whereas not everyone can deal with digital data. It is analogous to the situation of holding up a CD with lots of digital images on it and trying to read it as opposed to holding a print in your hand. Of course it is still possible to produce "hard copy" for those who want it, and what is more to produce it centred on any area at any scale thereby removing the "sheet edge" problem. It is really the digital data, which is more of a problem, and one that has to be addressed in terms of dissemination of the information and its long-term archiving. Indeed as each new version of the software comes out there are more implications not only to ensure backward compatibility, but also with regard to training.

However, the negative aspects are counterbalanced by the key benefit of having the data digitally, which is to allow the integration of different data sets. With a hard copy overlay it was possible (once it had been reduced to the appropriate scale) to overlay the data on geological or other maps, one at a time. It is now possible to assess the location of sites against all aspects of data held by different bodies, which may be relevant to the location of archaeological features (geological, pedological, contour, land-use, and rainfall) or as in the example below to their management (Fig. 12).

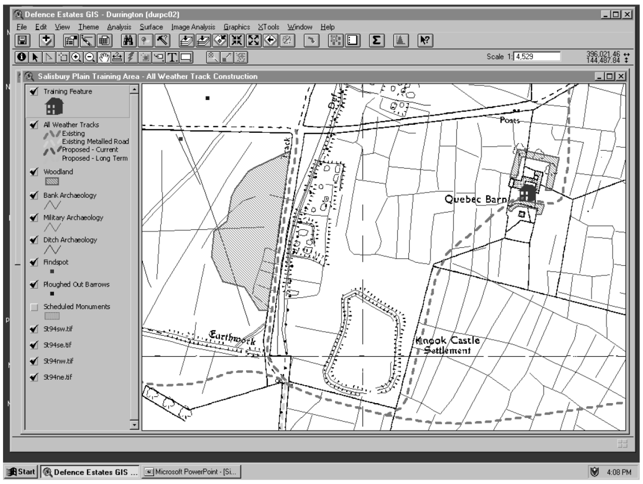


Fig. 12. Screen dump of the Defence Estates GIS system showing plans for all-weather tracks near the Iron Age fort at Knook on Salisbury Plain.

Figure 12 (above) shows the GIS system used by Defence Estates who are developing an integrated management plan for the Salisbury Plain Training Area (SPTA) that will take account of the archaeology, the flora and fauna as well as the farming regimes and obviously the planned military zones. The image shows how the integration of the NMP data has helped to determine the placing of a planned all-weather track so that it has minimum impact on the archaeological remains. The reason that the track follows a circuitous route through the edge of a field system, rather than going across the apparently blank area to the north and west of the fort is due to the fact that that area is under pasture and earthworks survive to a considerable height, whereas the fields to the south and east are under an arable regime and all traces of the field banks have consequently been ploughed away, leaving only faint soilmarks.

Amongst other things, being able to assess archaeological features against a geological background may help to show why some areas of the country are more responsive than others. This in turn allows for feedback, as Aerial Survey is a cyclical process whereby the data from NMP can be incorporated on the flight maps used by staff carrying out reconnaissance thereby alerting them to the presence or absence of features in a given area over which they are flying. There has been little mention so far of reconnaissance, but the final digital link in the chain of greater efficiency and understanding does relate to reconnaissance. The introduction of GPS in-flight recording in the early 1990s allows the making of a record of where the plane has flown irrespective of what has been photographed. This helps to show that there are some areas where a lot of reconnaissance survey has been carried out, but where there are no sites visible to be photographed. This then gives a greater validity to the national distribution of aerial photographs by showing that there are areas where aerial reconnaissance will produce fewer results (e.g. the Weald of Kent) and that other archaeological techniques should be used.

6 Summary and Conclusions

There are three main advantages to digital mapping and recording in aerial survey.

- Landscape analysis: the removal of false distinctions and arbitrary boundaries caused by the use of quarter sheets enables much easier analysis of the broader landscape.
- Morphological analysis: the use of tables of data allows a swifter and more efficient analysis of the numerous sites recorded from aerial photographs.
- GIS and the integration of data sets: the possibilities of linking archaeological data derived from aerial photographs with that from other sources and other data sets allows a massive increase in the usefulness of the data for analysis and research.

There are also three caveats in the new approach, which need to be recognised.

- Misuse of data: the assumption that digital data are more accurate than paper maps needs to be carefully monitored to ensure data are not stretched beyond the levels of accuracy imposed by the control from which they are derived.
- Compatibility: it is vital that the numerous and varied products (software, hardware, databases) produced by different areas with different requirements are able transfer data easily for the information to be useful.
- Technical complications: as with all systems based around computer technology the issue of up-grades and training must be built in to any programme to ensure that the data we produce today can still be read tomorrow, and ten years hence.

One of the big questions at the heart of aerial survey is to what extent the distribution of sites discovered by aerial survey (reconnaissance and NMP projects) is representative of past human settlement and land-use in England. By adopting a systematic and consistent approach to producing information, the expectation is that the results will be representative, even if a totally comprehensive picture cannot be achieved.

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