Satellite Remote Sensing and Archaeology: a Comparative Study of Satellite Imagery of the Environs of Figsbury Ring, Wiltshire

MARTIN J. F. FOWLER*
60 Harrow Down, Badger Farm, Winchester, Hampshire SO22 4LZ, UK

ABSTRACT The abilities of three satellite remote sensed image products (low spatial resolution LANDSAT Thematic Mapper (TM); medium resolution SPOT Panchromatic; high resolution KVR-1000) to detect archaeological features in the environs of the Iron Age hillfort at Figsbury Ring, Wiltshire, have been evaluated. Given prior knowledge of their locations, relatively large features together and those possessing a strong linear nature could be detected on the LANDSAT TM multispectral and SPOT Panchromatic image products. Near-infrared TM imagery showed promise for the detection of smaller features as a result of differences in vegetation cover, but was constrained by its low spatial resolution. High resolution Russian KVR-1000 imagery was found to be capable of detecting both upstanding and ploughed-out archaeological features without the need for prior knowledge of ground truth.

It is concluded that satellite imagery, although not a substitute for conventional aerial photography, represents a complementary source of information when prospecting for archaeological features. In a regional context, low resolution multispectral imagery can be used for the prospection for areas of high archaeological potential through the use of image processing and modelling techniques and, together with medium resolution imagery can be used to prepare base maps of regions for which up to date mapping is not available. High-resolution imagery, together with conventional aerial photographs, can be used subsequently to detect and map archaeological features. Copyright © 2002 John Wiley & Sons, Ltd.

Key words: satellite imagery; remote sensing; LANDSAT Thematic Mapper; SPOT Panchromatic; KVR-1000

Introduction

The past 20 years have seen significant advances in both the availability and quality of publicly accessible satellite imagery of the Earth’s surface. Formerly exclusively in the domain of the military, high resolution satellite images of most parts of the globe can now be purchased at costs per square kilometre that are becoming comparable with conventional aerial photography. Furthermore, this period also has seen an enormous growth in desktop computing power. Whereas in the past, expensive, dedicated, image processing systems were required to analyse satellite imagery, this can now be conducted using relatively low cost packages running on readily affordable personal computers.

Concurrent with these advances has been an increasing interest in the exploitation of satellite remote sensed products for archaeological studies (El Baz, 1997; Fowler, 2000a) as well as an increased use of mapped information derived from the aerial perspective (Bewley, 2001; British Academy, 2001). Particular interest in the use of satellite imagery has been shown in the USA, where products from the LANDSAT series of...
Table 1. Satellite imagery used in the study

<table>
<thead>
<tr>
<th>Satellite Scene</th>
<th>Date</th>
<th>Spatial resolution</th>
<th>Band</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSAT Thematic Mapper</td>
<td>202/24 8 May 85</td>
<td>30 m</td>
<td>Band 1</td>
<td>0.45–0.52 µm (visible blue)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Band 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Band 3</td>
</tr>
<tr>
<td>SPOT 029/246</td>
<td>8 May 87</td>
<td>10 m</td>
<td>Panchromatic</td>
<td>0.51–0.73 µm (visible)</td>
</tr>
<tr>
<td>KVR-1000</td>
<td>Jun 93</td>
<td>1.5 m</td>
<td>Panchromatic</td>
<td>0.51–0.76 µm (visible)</td>
</tr>
</tbody>
</table>

satellites have been used extensively (e.g. Ebert and Lyons, 1980; Custer et al., 1986; Farley et al., 1990; Showalter, 1993), albeit with mixed results. In contrast, limited use has so far been made of satellite imagery in support of archaeological studies in Britain, with only a couple of investigators exploiting the products. Cox (1992) used LANDSAT Thematic Mapper (TM) imagery together with conventional aerial photographs to define and classify areas of peat in the wetlands of Cumbria in order to identify areas of archaeological potential. Likewise, Shennan and Donoghue (1992) used LANDSAT TM and SPOT Panchromatic imagery to detect and map archaeological features, such as a medieval field boundary and part of a probable Romano-British water feature, in the Fenlands of eastern England. However, in anticipation of a wider utility of these products, a ‘guide to good practice’ for the archiving of digital aerial photographs and remote sensing imagery has been formulated (Bewley et al., 1998).

In order to evaluate the usefulness of satellite remote sensed imagery to archaeological study in Britain, the abilities of a variety of commercially available products to detect archaeological features in southern England have been addressed by the present author. To date, the study has concentrated on the interpretation of satellite imagery of the chalklands of Wessex covering the environs of Danebury (Fowler, 1994), Stonehenge (Fowler, 1995; 1996; 2001) and Winchester (Fowler, 1999), as these areas are particularly well documented and include a variety of standing archaeological features as well as numerous ploughed-out features that are now visible only as cropmarks and soilmarks on aerial photographs.

This paper describes a comparative study of satellite imagery of the environs of the Iron Age hillfort at Figsbury Ring, Wiltshire. Three satellite image products (LANDSAT Thematic Mapper (TM); SPOT Panchromatic; KVR-1000) (Table 1) are assessed for their ability to detect a range of archaeological features present in this area.

Study area

The study area (Figure 1) covers an area of some 9 by 15 km and is approximately centred on Figsbury Ring (NGR SU 188338). The area is a mixture of chalk grassland, farmland and woodland and includes part of the city of Salisbury in the southwest corner and villages scattered across the region. The major archaeological features present in the study area comprise:

(i) the courses of four Roman roads that converge on the former Iron Age hillfort and later medieval site at Old Sarum;
(ii) the hillfort at Figsbury Ring and enclosure at Ogbury Ring;
(iii) the sites of neolithic long barrows and Bronze Age round barrows, enclosures, linear earthworks and ‘Celtic’ field systems, many of which have been ploughed away and which are now visible only as cropmark and soilmark features (Palmer, 1984).

Imagery and image processing

Digital LANDSAT TM imagery was purchased from the National Remote Sensing Centre (NRSC)
Satellite Remote Sensing and Archaeology

Figure 1. The Figsbury Ring study area. The locations of the three major features at Old Sarum, Figsbury Ring and Ogbury Ring are shown together with the courses of the former Roman Roads to Cirencester (RR44), Silchester (RR4b), Winchester (RR45) and Dorchester (RR4c). Negative areas, in the form of built-up areas, roads and woodland that preclude the detection of archaeological features from the overhead perspective, are shown in dark grey. The extent of the chalk downland on Porton Down and Idmiston Down is shown in light grey.

Ltd, Farnborough, and was provided as 8-bit, 256 grey scale, binary flat files covering an area of some 20 km by 20 km centred approximately on Amesbury. Six image files were provided, corresponding to TM spectral bands 1–5 and 7, and had been resampled to give a ground pixel size of 25 m. Imagery from Band 6, covering the thermal infrared region of the spectrum (10.5–12.5 µm), was not purchased owing to its inferior spatial resolution of 120 m.

The SPOT Panchromatic imagery was purchased from NRSC Ltd in the form of a film-written photographic print at a scale of approximately 1:130,000. The print was scanned at a resolution of 600 dots per inch (dpi) to give a digital product with an equivalent ground pixel sizes of 6 m compared with 10 m for the original digital product.

Nigel Press Associates Ltd, Edenbridge, kindly provided an extract from a Russian KVR-1000 image for the cost of writing the original digital image to film. The image, covering approximately 25% of the study area (Figure 1), was provided as a film-written print at a scale of 1:25,000. This was scanned at a resolution of 300 dpi to give a digital product with a ground pixel size of approximately 2 m compared with 1.4 m for the original digital product.

The LANDSAT TM images were displayed and manipulated using the TNTLite Version 5.7 (MicroImages Inc.) image-processing package (Ostir and Stancic, 1997). This freeware version of the full TNTMips package was found to be more than adequate for the analysis of the TM imagery covering the study area but was unable to accommodate the SPOT Panchromatic and KVR-1000 images because of limitations on the sizes of images that can be used with the freeware package. As no manipulations other than contrast stretching were to be undertaken, it was decided to use the Corel PhotoPaint graphics package (Corel Corporation) to display and enhance these images.

Copyright © 2002 John Wiley & Sons, Ltd.
Archaeol. Prospect. 9, 55–69 (2002)
Evaluation of imagery

The satellite imagery under consideration have been graded into three levels of spatial resolution:

(i) low-resolution product with a spatial resolution > 10 m (LANDSAT TM);
(ii) medium resolution product with a spatial resolution of 5–10 m (SPOT Panchromatic);
(iii) high-resolution product with a spatial resolution < 5 m (KVR-1000).

For each of the satellite products, manual comparisons were made with available large-scale maps of the archaeological features known to be present in the study area. These comprised Palmer’s 1984 transcript of features visible on aerial photographs and Ordnance Survey 1:25 000 scale Explorer maps (Sheets 130 and 131).

Low resolution imagery

LANDSAT TM—visible wavelengths

Bands 1–3 of the LANDSAT TM sensor cover the visible blue, green and red regions of the spectrum with a spatial resolution of 30 m. A natural colour composite of these three bands, created by displaying the three TM bands 1-2-3 as blue, red and green respectively is shown in monochrome in Figure 2. The low spatial resolution of the TM product is apparent from this image with little detail being discernable of the features at Old Sarum, Figsbury Ring and Ogbury Ring. However, relatively small features such as paths and tracks on the chalk downland of Porton Down and Idmiston Down to the northeast of Salisbury are apparent because of the strong contrast between the exposed chalk and the surrounding vegetation.

LANDSAT TM—infrared wavelengths

Bands 4, 5 and 7 of the LANDSAT TM sensor cover part of the reflected infrared region of the spectrum. Of these three bands, band 4 covering the near infrared (NIR) (0.76–0.90 µm) appears to be the most useful for the detection of archaeological features (Figure 3). This band is particularly sensitive to vegetation and water, with arable fields and grasslands showing as lighter tones and water, built-up areas, roads and trees showing as darker tones. Bands 5 and 7, covering the near mid-infrared and mid-infrared respectively, also reveal some of the archaeological features in the area, albeit not as clearly as the NIR band 4 image.

On the band 4 image, Old Sarum (Figure 3) can be seen as a prominent circular feature outlined with a dark-toned perimeter from the trees that surround the site. Within the ramparts, the presence of upstanding masonry can be made out as dark features but are not fully discernible. Leading away from Old Sarum to the east, the course of the former Roman road to Winchester is particularly prominent as a linear feature that has become fossilized in the landscape in the form of field boundaries and modern roads. Similarly, the courses of the Portway and the road to Cirencester can be traced leading away from Old Sarum to the north; the former being represented by the course of a modern road and the railway line from Salisbury, the latter by the course of a modern road. The course of the Ackling Dyke, leading away from Old Sarum to the south, cannot be traced easily as it is covered by the northwest suburbs of the modern city of Salisbury.

Some 500 m to the north of the Roman road from Old Sarum to Winchester, the outline of the circular rampart and inner ditch of the Iron Age hillfort at Figsbury Ring can be discerned on the image. Although the width of the inner ditch is below the spatial resolution of the TM sensor, it appears to be visible on the image as a result of the difference in the near-infrared reflectance of the vegetation in the ditch compared with the grass of the berm. Similar examples have been observed on band 4 imagery of the Stonehenge study area, where islands of older grass covering Bronze Age round barrows were discerned within arable fields and more recent grassland (Fowler, 1995).

Given the prior knowledge of its shape from a map, the outline of the polygonal Iron Age enclosure at Ogbury Ring can be discerned to
Figure 2. LANDSAT Thematic Mapper Bands 1-2-3 composite image acquired on 8 May 1985 of the study area. Imagery supplied by Infoterra © 1985. Reproduced with permission. Maps reproduced by kind permission of Ordnance Survey. © Crown copyright. All rights reserved. NC/01/390.
Figure 3. LANDSAT Thematic Mapper Band 4 (near infrared) image of the study area. Imagery supplied by Infoterra © 1985. Reproduced with permission. Maps reproduced by kind permission of Ordnance Survey. © Crown copyright. All rights reserved. NC/01/390.

Old Sarum  Figsbury Ring  Ogbury Ring

Figure 3. LANDSAT Thematic Mapper Band 4 (near infrared) image of the study area. Imagery supplied by Infoterra © 1985. Reproduced with permission. Maps reproduced by kind permission of Ordnance Survey. © Crown copyright. All rights reserved. NC/01/390.
the north of Old Sarum. The northern side of this feature is shrouded in trees and shows up as a dark-toned area on the image. No further detail of the site could be discerned on the image.

Within many of the fields covered by the image, linear markings are apparent but cannot be discerned fully because of the low spatial resolution of the TM sensor. Although many of these may be reflections of recent agricultural practices—such as former field boundaries—or aspects of the underlying geology of the area, others possibly may be the result of more ancient human activities.

False colour composite

A false colour composite of the Figsbury Ring study area, created by displaying the three TM bands 3 (visible red), 4 (near infrared) and 5 (mid-infrared) as blue, red and green respectively, is shown in monochrome in Figure 4. On the colour original of this image, different types of land cover are apparent. Fields under arable at the time of acquisition appear orange, red and pink, and woodland areas appear green and brown. In contrast, fields of low vegetation cover appear light blue and built-up areas, such as the city of Salisbury, appear blue.

Although the sites of Old Sarum, Figsbury Ring and Ogbury Ring are apparent on the composite image, they are less clear than on the single band 4 image. Similarly, the courses of the former Roman roads can still be traced in the landscape but no additional archaeological features can be directly discerned on this image. However, the areas of chalk downland at Idmiston Down and Porton Down can be readily discerned as tracts of green colour. Having been under military control for the past 75 years, they have avoided the ravages of modern agriculture and represent areas of considerable archaeological and natural history value and potential (Carter, 1992; 86–87). Although such areas of chalk downland are well mapped for southern England, false colour TM images could have some utility in monitoring their extent and ‘health’ in support of both natural history and archaeological conservation management.

Medium resolution imagery

SPOT Panchromatic

The improved spatial resolution of the SPOT Panchromatic product (10 m) compared with the LANDSAT TM products can be seen in Figure 5. More detail of the structure at Old Sarum is hinted at, but once again it cannot be readily discerned. The courses of the former Roman roads that could be traced on the LANDSAT images can again be discerned, but the hillfort at Figsbury Ring is less apparent than on the band 4 TM product, with only a faint trace being apparent of the inner ditch. Although some degradation of the quality of the SPOT Panchromatic product through the use of a printed intermediate inevitably will have occurred compared with the original digital imagery, the inability to detect evidence of this latter feature indicates that in addition to high spatial resolution, a multispectral capability extending from the visible to the near infrared is beneficial for the detection of archaeological features by satellite sensors.

High-resolution imagery

KVR-1000

The spatial resolution of Russian KVR-1000 panchromatic satellite imagery is comparable to orthodox medium-scale aerial photography and has been shown to be capable of detecting both standing archaeological features as well as cropmarks and soilmarks without the need for prior recourse to ground truth (Fowler, 1996; Fowler, 1999).

A comparison of the features visible on the 1.5 m resolution KVR-1000 image of part of the study area with those mapped by Palmer (1984) shows that only a subset of the features mapped from aerial photographs can be seen (Figure 6). This is not surprising given the transient nature of many of the archaeological features that can be detected by aerial photography (Wilson, 2000). A number of features that were not included on Palmer’s (1984) map were observed on the KVR-1000, demonstrating the ability of high-resolution satellite imagery to detect ‘new’ archaeological features.
Figure 4. Thematic Mapper false colour composite of the study area. Imagery supplied by Infoterra © 1985. Reproduced with permission. Maps reproduced by kind permission of Ordnance Survey. © Crown copyright. All rights reserved. NC/01/390.
Figure 5. SPOT Panchromatic image acquired on 8 May 1987 of the study area. Imagery supplied by Infoterra © CNES 1987. Reproduced with permission. Maps reproduced by kind permission of Ordnance Survey. © Crown copyright. All rights reserved. NC/01/390.

Old Sarum  Figsbury Ring  Ogbury Ring

Figure 6. Transcription of archaeological features visible on the KVR-1000 image (A) and aerial photographs (B) in the environs of Figsbury Ring. Aerial photographic transcription adapted from Palmer (1984).
Two extracts from the KVR-1000 image are shown in Figures 7 and 8. In Figure 7, the ramparts and ditch of the hillfort at Figsbury Ring can be seen vividly in relief. To the south of the hillfort, the raised agger of the Old Sarum to Winchester Roman road also can be seen as a slight highlight and shadow. Further south, the ditches of the destroyed long barrow at Fussell’s Lodge (Ashbee, 1984) can be seen as cropmarks. However, few of the additional banks, ditches and barrows mapped by Palmer (cf Figure 6B) can be detected on this single image. By way of contrast, in Figure 8 an area of banks and ditches that were not mapped by Palmer can be seen as soilmarks to the south of the course of the Roman road from Old Sarum to Winchester. To the north of the Roman road, the high spatial resolution of the KVR-1000 product is well illustrated by the runway designation numbers at either end of the grass runway of the airfield at Old Sarum being readily discernable.

Discussion

Despite the low spatial resolution of the LANDSAT TM product, relatively large archaeological features (such as the Figsbury Ring hillfort, the site at Old Sarum and the Ogbury Ring enclosure) as well as those possessing a strong linear component (such as the courses of former Roman roads) can be detected on these images given some prior knowledge of their location and form. Although NIR TM imagery shows promise for the detection of smaller features as a result of differences in vegetation cover, its

Figure 7. KVR-1000 image acquired in June 1993 of the hillfort at Figsbury Ring. Image supplied by Nigel Press Associates Ltd, © SOVINFORMSPUTNIK 1993. Reproduced with permission.
Figure 8. KVR-1000 image acquired in June 1993 of ancient banks and ditches to the south of Old Sarum airfield. Image supplied by Nigel Press Associates Ltd, © SOVINFORMSPUTNIK 1993. Reproduced with permission.

use is constrained by the low spatial resolution of the product. Rather than being used in the direct detection of archaeological features, low resolution multispectral imagery is considered to be better suited to the prospection for areas of high archaeological potential through the use of image processing and modelling techniques (e.g., Cox, 1992; Showalter, 1993; Clark et al., 1998; Church et al., 2000).

Medium resolution SPOT Panchromatic imagery represents an improvement in spatial resolution over LANDSAT TM, but lacks the multispectral characteristics of the latter. Recently declassified KH-4B CORONA photographic imagery has a slightly higher spatial resolution than SPOT Panchromatic imagery (McDonald, 1995). Dating from the 1960s to early 1970s, the best of the third-generation photographic negative products distributed by the United States Geological Survey have spatial resolutions of the order of 5–10 m, somewhat less than the 2–3 m best resolution of some of the original first generation negatives. Although the limited coverage that is available of southern England is severely constrained by the lack of cloud-free cover, a fortuitous break in the cloud cover on the KH-4B image near Andover, Hampshire, some 20 km to the northeast of Figsbury Ring, revealed the circular outline of the tree-shrouded ramparts of the Iron Age hillfort at Bury Hill (Fowler, 1997a). Although none of the ploughed-out prehistoric ditches and banks in the vicinity of the hillfort that were mapped by Palmer (1984) could be discerned on the image, the ability to readily recognise the hillfort hints at the archaeological potential of this product for those areas of Britain for which cloud-free coverage is available. Such declassified intelligence satellite photographs represent
an important, cost effective, resource for use in other countries where either conventional aerial photography is prohibited or impractical (Fowler, 1997b; Kennedy, 1998). Indeed, with more and more archaeological surveys being undertaken in the Near East (e.g. Kennedy and Bewley, 1998), where cloud-free conditions pertain and where there are a higher percentage of stone built and still upstanding sites (Kennedy and Riley, 1990), the archaeological utility of this resource is potentially immense.

High resolution Russian KVR-1000 imagery is comparable to conventional medium-scale vertical aerial photography and is capable of detecting relatively small standing and ploughed-out archaeological features that are now visible only as cropmarks and soilmarks. Although inferior to the spatial resolution of conventional aerial photography acquired for archaeological purposes, the ability to collect imagery over a large area makes this a cost effective tool for the prospection for medium-scale archaeological features from the aerial perspective.

The latest high-resolution satellite products that are available commercially are the panchromatic and multispectral products from the IKONOS satellite operated by Space Imaging. Although the lack of available coverage of the study area precluded a formal evaluation of these products in this study, the 1-m-resolution IKONOS panchromatic product appears capable of detecting both upstanding and plough-levelled archaeological features (Fowler, 2000a,b). Furthermore, imagery from the 4-m-resolution IKONOS multispectral sensor represents a sevenfold increase in spatial resolution compared with the LANDSAT TM product and equates to an approximately fiftyfold increase in information content of the area covered by a single TM pixel. As the IKONOS multispectral product includes coverage of the NIR equivalent to band 4 LANDSAT TM, this product has the potential of improved detection of archaeological features through differences in the NIR reflectance of vegetation.

Notwithstanding the demonstrable ability of high-resolution satellite products to detect archaeological features, some of the characteristics of the low Earth orbit perspective can restrict their utility for archaeological purposes. Orbital constraints currently limit satellites to the collection of single pass images acquired at a specific time of day and generally from a vertical perspective. This is in contrast to conventional aerial photographs that are taken for archaeological use, which tend to be oblique and are taken from a range of directions in order to maximize the appearance of features that can be critically dependent on ambient lighting and viewing angle (Wilson, 2000). Furthermore, the constant potential for cloud cover to obscure the area of interest during the limited time available for imagery collection on each orbital pass, can further limit the utility of satellite imagery for archaeological purposes. However the ‘open skies’ nature of the overhead perspective does allow images to be collected over areas that are otherwise prohibited or impractical to conventional aerial photography (e.g. airspace restrictions, political restrictions, inhospitable areas) and also permits the regular monitoring of areas without the need for human involvement.

Conclusions

Satellite imagery should not be seen as a substitute for orthodox oblique and vertical aerial photographs; rather, it is a complementary source of information when prospecting for archaeological features (Table 2). In a regional context, low resolution multispectral imagery can be used in prospecting for areas of high archaeological potential and, together with medium resolution imagery, can be used to prepare base maps of regions for which up to date mapping is not available. High-resolution imagery, together with conventional aerial photographs, can be used subsequently to detect and map archaeological features.

With improved half-metre resolution panchromatic and 2-m resolution multispectral imagery on the horizon (Anon., 2001), and the cost of imagery reducing, over the next few years the archaeological utility of satellite imagery can be expected to continue to develop to the point whereby satellite remote sensed products take their place as a just another routine source of imagery for use by the aerial archaeologist.
Table 2. Archaeological utility of satellite imagery

<table>
<thead>
<tr>
<th>Product</th>
<th>Spatial resolution (m)</th>
<th>Prospection/modelling</th>
<th>Small-scale feature mapping</th>
<th>Medium-scale feature mapping</th>
<th>Large-scale feature mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSAT Thematic Mapper</td>
<td>30</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>SPOT Multispectral</td>
<td>20</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPOT Panchromatic</td>
<td>10</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KH-4B CORONA</td>
<td>5–10</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>IKONOS Multispectral</td>
<td>4</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KVR-1000</td>
<td>1.5</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>IKONOS Panchromatic</td>
<td>1</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Aerial photographs</td>
<td>&lt;0.2</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Acknowledgements

This paper is dedicated to the memory of the late Ernest Fowler (1920–1998). I would like to thank the National Remote Sensing Centre Ltd and Nigel Press Associates Ltd for permission to reproduce the images included in this paper. Thanks also are due to my wife, Yvonne, for allowing me to complete this paper over Easter 2001 when I should really have been preparing for our wedding!

References

Fowler MJF. 1997b. It may not be done well... but it could be the best that is available. AARGnews 15: 33–35.


