

Recovering LOST LANDSCAPES

Edited by

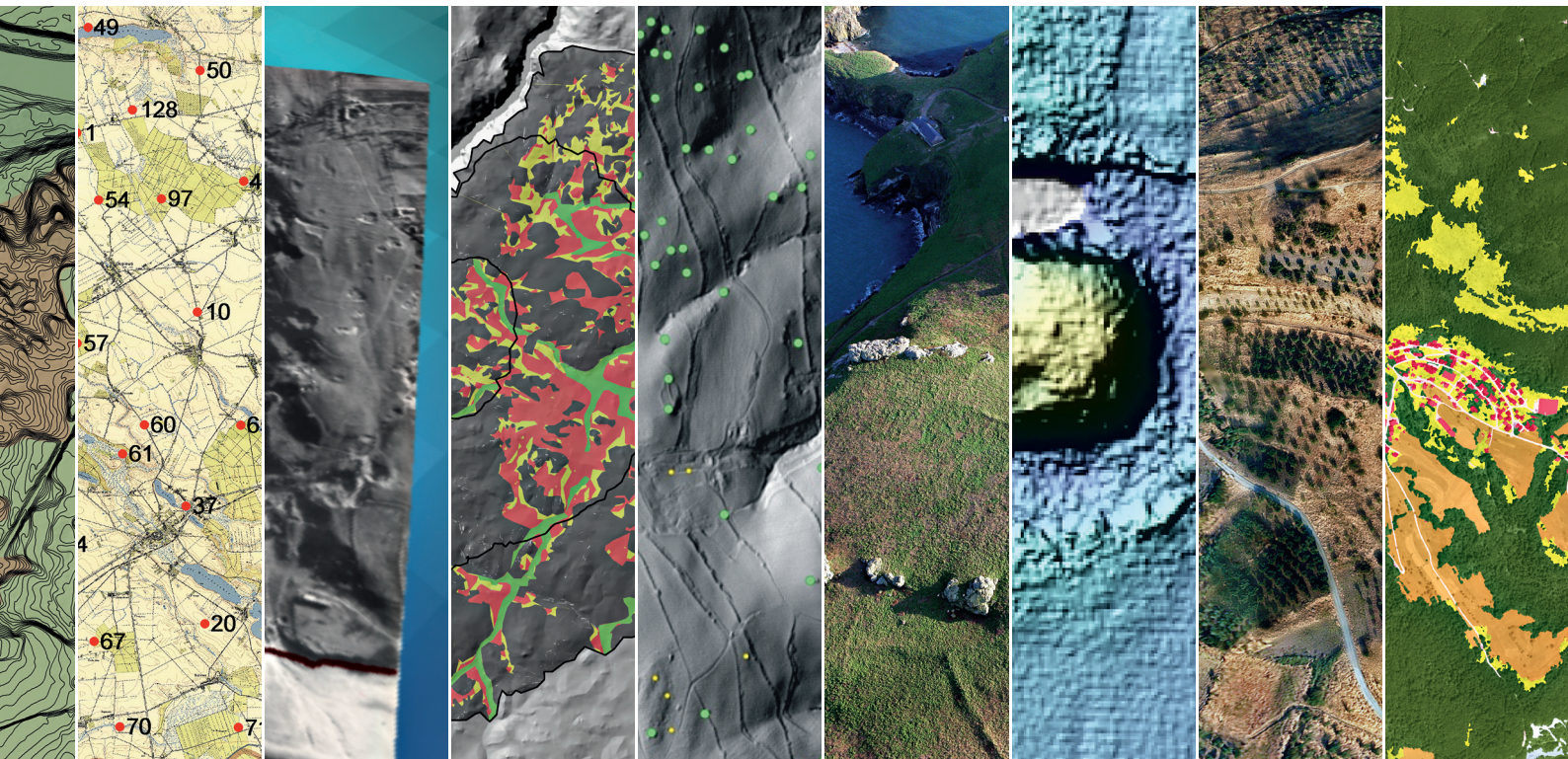
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Belgrade 2015

— LIST OF CONTENTS

page 7

Vujadin Ivanišević, Tatjana Veljanovski, David Cowley, Grzegorz Kiarszys & Ivan Bugarski
Recovering Lost Landscapes – introduction to an aerial perspective

page 11

Rog Palmer
Why are historical aerial photographs categorised as something special?

page 21

Grzegorz Kiarszys
*Why are maps often misleading about archaeological sites?
Ideology, maps, ALS and historical aerial photographs of district Góra, Lower Silesia Region, western Poland*

page 35

Dawid Soszyński, Cyprian Jaruga, Barbara Sowińska-Świerkosz
A river in a rural public space in the early 1940s: a case study of the Bug river valley (East Poland)

page 45

Agnieszka Latocha
Recovering the lost landscapes of abandoned villages in the Sudetes Mountains, southwest Poland

page 57

Vujadin Ivanišević, Ivan Bugarski
Landscape reconstruction in the Middle Danube Roman Limes: case studies from Lederata and Smorna

page 67

Brais X. Currás, María Ruiz del Árbol, F. Javier Sánchez-Palencia, Almudena Orejas, Damián Romero
*Ancient landscapes of north-western Iberia:
historical aerial photographs and the interpretation of Iron Age and Roman territories*

page 79

Chris Musson, Toby Driver

Recovering lost landscapes in Wales

page 89

Miloš B. Petričević

Aerial photography and remote sensing on the Karst: a case study of Boka Kotorska Bay, Montenegro

page 97

Helen Winton

Recovering lost or hidden landscapes – Aerial photographs and the English National Heritage Protection Plan

page 107

Rafał Zapłata, Sebastian Różycki

Historic aerial photographs in the analysis of cultural landscape – case studies from Poland

page 117

Gianluca Cantoro

Aerial photogrammetry: when archaeology meets SIFT

page 129

Cristina Charro Lobato

Historical aerial photographs to recover a lost landscape using digital photogrammetry: a case study of the Iron Age site of Cerro de la Mesa (Alcolea de Tajo, Toledo, central Spain)

page 141

Tatjana Veljanovski, Žiga Kokalj

3D model generation and landscape change: contributions to image-based digital retrospection of the village of Breginj

page 155

Sławomir Królewicz, Lidia Żuk

To trust or not to trust: maps vs. aerial photographs within political discourse

Vujadin Ivanišević
Tatjana Veljanovski
David Cowley
Grzegorz Kiarszys
✉ Ivan Bugarski

Recovering Lost Landscapes – introduction to an aerial perspective

The scale of landscape transformation over the last century, within Europe and globally, has been great. War, urban expansion, land use and land cover change and construction projects, amongst other activities and processes, have heavily altered our landscapes, destroying or covering up ancient monuments and the historic environment. The resulting loss of evidence from which to understand the past has been great, and sources that give us an insight into earlier conditions can be invaluable. So-called ‘historic’ aerial imagery is a privileged source for documenting and understanding these lost landscapes since it provides information that cannot be found anywhere else. To the historic aerial perspective can be added complementary sources such as historic cartography, modern aerial photographs and new technology such as Airborne Laser Scanning, recognizing that integrated approaches are key to more comprehensive interpretations of landscape processes.

The uses of historic aerial photographs, amongst a range of available sources, to better understand and manage dynamic landscapes are at the heart of this volume, with a particular focus on areas that have undergone dramatic change over the last century. Case studies from across Europe present varying approaches to interpretation drawing on current practice from a range of different landscapes. Technical challenges are also discussed, for example in extracting 3D topographical data from historic aerial imagery or integrating multiple sources of information, and pointers to future directions. Here, the synergies of ‘old’ data and new technology with the rapid developments in soft-bench photogrammetry open up new avenues for integrated cross-disciplinary landscape investigation. Such interdisciplinarity is also reflected in the archaeological, geographical and historical perspectives that authors draw into discussions that extend to social context, ideology, political frameworks and perception. This recognises the contingent nature of landscape understanding, and the interwoven dynamics of landscape form, past and present perception and our own engagement.

While multiple sources of information and perspectives are represented in this volume, the unique insights that historic aerial photographs and the aerial perspective can give is a consistent theme throughout. Thus, it will be no surprise that varying accessibility and availability of imagery is touched on by many authors. The application of an aerial perspective can vary between countries depending on intellectual or academic traditions, but the availability of imagery and ease of access to archives to a large degree define whether or not these underused sources of knowledge can be utilised effectively.

THE ORIGINS OF THIS VOLUME

This volume has emerged from discussions between those using historic aerial photographs and other means of archaeological prospection in landscape studies, drawing on pan-European perspectives presented at two meetings held within the framework of the ‘ArchaeoLandscapes Europe’ project. The first event was a seminar and workshop on *Recovering Lost Landscapes* that dealt with the applications of historic aerial images. This was organised by the Institute of Archaeology in Belgrade and the Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU) in Ljubljana, and held in Belgrade on 19th/20th November 2013. The second meeting was a conference on *Patterns, Processes & Understanding: historic aerial photographs for landscape studies* organised by the Institute of Prehistory of the Adam Mickiewicz University in Poznań,

the Department of Archaeology of the University of Szczecin and RCAHMS, with the support of the Remote Sensing & Photogrammetry Society (RSP-Soc) and the Aerial Archaeology Research Group (AARG). This was held in Będlewo near Poznań between the 24th and 26th of April 2014.

The origins of this volume in trans-national collaboration will be evident from the listing of the organisers of the events above, working together in the framework of the European Union Culture 2007–2013 funded ArchaeoLandscapes Europe (ArcLand) project (<http://www.arcland.eu/>). A central objective of ArcLand is the exchange of knowledge and skills across Europe, and it is this funding and other support that has made it possible for the editors to develop this volume. Reflecting its genuinely international origins, editorial meetings have been held in Dublin and Frankfurt, with the editing done in Belgrade, Ljubljana, Edinburgh and Szczecin. The support of ArcLand has been vital to the success of this volume, and the editors are especially grateful to its project manager, Axel Posluschny of the Roman-Germanic Commission, Frankfurt am Main, for his support.



Figure 1. *Belgrade Conference: Gianluca Cantoro's presentation.*

THE STRUCTURE OF THIS VOLUME

The contributions to this volume present various archaeological and methodological perspectives from across Europe that deal with a broad chronological span from prehistory to the very recent past. Inevitably, many of the papers are cross-cutting in nature, and we encourage the reader to keep in mind the framework of integrated landscape investigation that we aspire to. The contents and structure of the volume are described below, not to précis the papers, but to try to sketch out some central themes, already mentioned in passing above, that recur across different landscapes. Five of these themes reflect the structure and running order of the chapters, but we begin with the recurrent theme of availability of aerial imagery.

Using archives

Throughout this volume, and earlier publications on applications of historic aerial imagery (e.g. Cowley et al. 2010; Comer and Harrower 2013; Hanson and Oltean 2013), access to archives and the selection of appropriate imagery for a variety of purposes are common concerns. In Chapter 2 Rog Palmer presents his experience working at different archives in England, reflecting on the tensions between his interest in the aerial photographs as sources of information and knowledge and that of the archive that may prioritise preservation or commercial gain over ease of access. Similar themes, and the problems of finding imagery that is fit for particular purposes, are discussed in case studies from Spain (Chapters 6 and 11), Poland (Chapter 12), Montenegro (Chapter 14) and again England (Chapter 15). The problems are not just with access (e.g. to military archives), but also concern uneven metadata that might help in locating the most suitable images for the purpose at hand, though other problems, such as the technical challenges of working with older imagery that lacks calibration data are being overcome by technical developments (e.g. Chapters 6, 7 and 9).

Landscape change

The often wholesale transformations of landscape that are a hallmark of the 20th century in many parts of Europe have resulted in massive losses to parts of the historic environment, even over the last few decades as even a cursory examination of the Corine land cover inventory (<http://www.eea.europa.eu/data-and-maps/data/corine-land-cover>) shows. Consistently through this volume, authors refer to historic aerial photographs to see what may have been lost, and in Chapter 2 (*Why are historical aerial photographs categorised as something special?*) Rog Palmer examines how aerial photographs allow us to see patterns and processes and to understand these, and how we reach a level of understanding of past landscapes. This paper highlights how

important is knowledge of contemporary and recent land use and a fuller understanding of the landscape context of the past we seek, issues that are also discussed in case studies from Poland (Chapters 3, 4 and 5), Serbia (Chapter 6), Spain (Chapters 7 and 12) and Slovenia (Chapter 14).

Perceptions of landscape and interdisciplinarity

Landscapes are the product of many processes, not least amongst which are the perceptions and perspectives of inhabitants and observers, past and present. The common desire to objectify elements of our surroundings, through description, classification or devices such as mapping is at the core of Chapter 3 (*Why are maps often misleading about archaeological sites?*) in which Grzegorz Kiarszys examines the ideological context for the recording of earthworks on large-scale topographical maps in the Lower Silesia Region, western Poland. This illustrates the degree to which the cartographic depiction of monuments in this area is influenced by political and social transformations, and by pre-understanding and varying perceptions of cultural heritage sites.

The changing perceptions of inhabitants in a rural landscape are explored by Dawid Soszyński, Cyprian Jaruga and Barbara Sowińska-Świerkosz in Chapter 4 (*A river in a rural public space in the early 1940s: a case study of the Bug river valley (East Poland)*). The role of the Bug river and the definition and functioning of public spaces is set in a historical context from the late 1930s, and, in a contribution that emphasises the social dimension of landscape, aerial photographic and cartographic analyses are compared with information from interviews with residents, especially the oldest people who have lived in the area since the 1940s.

Staying in Poland, in Chapter 5 (*Recovering the lost landscapes of abandoned villages in the Sudetes Mountains, southwest Poland*) Agnieszka Latocha examines an area characterised by widespread depopulation and the extensive survival of ruinous settlement and land use remains. The exploration of the methodological issues of investigating such relict places provides a foundation for discussion of the human impact on the landscape and the persistence of the traces of the past.

Exploring landscapes – case studies

The papers collected as case studies of landscape exploration begin with Chapter 6 (*Landscape Reconstruction in the Middle Danube Roman Limes*) in which Vujadin Ivanišević and Ivan Bugarski use a variety of sources to study an area on the Danube inundated by the construction of a dam. Eighteenth century and later maps, topographic data and aerial photographs are used to understand the flooded area and to provide landscape context for excavated sites otherwise isolated from their environment. In Chapter 7 (*Ancient Landscapes of north-western Iberia: historical aerial photographs and the interpretation of Iron Age and Roman territories*) Brais Currás, María Ruiz del Árbol, Francisco Javier Sánchez-Palencia, Almudena Orejas, and Damián Romero present the use of archive aerial imagery in a diachronic study of social and territorial changes during late pre-history and the Roman period in part of present-day Spain. Turning to Wales, in Chapter 8 (*Recovering Lost Landscapes in Wales*) Chris Musson and Toby Driver discuss the results of three decades of aerial reconnaissance for primary discovery of archaeological sites and for documenting changing landscapes throughout the country. Working in a country with a rather different archaeological tradition, where no attention has been paid in the past to the interpretation of historical or archaeological landscapes, in Chapter 9 (*Aerial Photography and Remote Sensing on the Karst: a case study of Boka Kotorska Bay, Montenegro*) Miloš Petričević presents preliminary results of a pioneering use of aerial photographic and remote sensing data in Montenegro.

Heritage Management

The creation of reliable knowledge about the past to support effective heritage management is a central objective of much archaeological work, and the two papers grouped together here are not the only ones to address heritage management. In Chapter 10 (*Recovering Lost or Hidden Landscapes – Aerial Photographs and the English National Heritage Protection Plan*) Helen Winton reports on the extensive and systematic work in England to compile landscape-scaled information to support the discovery, analysis and protection of landscapes. Developing similar themes, in Chapter 11 (*Historic aerial photographs in the analysis of cultural landscape – case studies from Poland*) Rafał Zapłata and Sebastian Różycki discuss the acquisition of archival resources, the quality of historical aerial photographs, including their spatial resolution, and their cultural heritage potential in site identification, inventorisation and monitoring change and damage.

Technical challenges and developments

The four papers in this section include case studies from Spain, Poland and Slovenia, but are grouped here for their contribution to developing technical solutions to problems of working with historic and contemporary imagery. This is a rapidly changing field, which is benefiting from developments in software and processing power, and in Chapter 12 (*Aerial Photogrammetry: when Archaeology meets SIFT*) Gianluca Cantoro provides general information about digital photogrammetry and shares his experiences with free and affordable software. In Chapter 12 (*Historical aerial photographs to recover a lost landscape using digital photogrammetry: a case study of the Iron Age site of Cerro de la Mesa (Alcolea de Tajo, Toledo, central Spain)*) Cristina Charro Lobato describes an application of digital photogrammetry to reconstruct the original extent of a prehistoric settlement damaged by the construction of a reservoir in the 1960s, also discussing the problems of identifying suitable sources. In a more recent context, Chapter 14 (*3D model generation and landscape change: contributions to image-based digital retrospection of the village of Breginj*) by Tatjana Veljanovski and Žiga Kokalj presents a study of a village in Slovenia which was severely damaged by earthquakes in 1976. This paper presents the generation of a 3D model of the original village using Structure-from-Motion software and an analysis of its changing landscape and the conservation of architectural and cultural heritage.

The final paper of the volume, Chapter 15 (*To trust or not to trust: maps vs. aerial photographs within political discourse*) by Sławomir Królewicz and Lidia Żuk presents an analysis of the reliability of maps created during the Soviet era and widely believed to be falsified deliberately to compromise their value. This is an important archaeological issue because these maps were used as the base for the Polish Archaeological Programme, and map distortions would carry serious implications for the spatial accuracy of sites plotted on them. The paper describes the use of vertical photographs to assess the map accuracy, concluding that there is no evidence for distortions in the cartography, in an object lesson in not accepting orthodoxies or ‘truth’ without question.

RECOVERING LOST LANDSCAPES

To conclude this introduction we return to the title of this book, which was chosen for its many potential meanings. Here its scope extends to destroyed features only recorded in archives and buried or unnoticed archaeological sites and landscapes that can be considered hidden until interpreted, and their meaning and significance explored in the search for knowledge and understanding.

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Why are historical aerial photographs categorised as something special?

Abstract: *This contribution first examines how aerial photographs allow us to see patterns and processes and to understand these. Each individual aerial photograph will show patterns at the instant of the exposure but to see processes we need to see those patterns change as, naturally and culturally, the land and the landscape has been continually altering, and is being altered, through time. It is through our investigations of patterns and processes on aerial photographs that we reach a level of understanding of past uses of the land and its landscape.*

There are few, if any, places in the world that have been photographed only once, be this from an aircraft or a satellite and, to differing degrees, all the resulting images are 'historical'. Routine photo interpretation usually begins by selecting the most informative photographs from those that are appropriate for the work in progress, so why are these mid-20th century 'historical aerial photographs' singled out as something special rather than part of a series of snapshots that enable us to identify and examine processes and change? One reason may be because we have many separate archives of photographs and promotion of any 'special' characteristics may be used to encourage their use.

Personal experience at various archives has identified characteristics that seem good or bad from a user's point of view. In large collections, usually hosted by a state organisation, there may be divisions of interest between archivists, who are responsible for the physical contents (prints and negatives) and may see their possession as a source of power, and internal and external users who see those items as sources of information. This dichotomy of interests needs to be resolved so that archives may best serve the user rather than the archivist. In the digital age, this does not seem to be too much to ask – albeit with a loss of power to the archivists.

PREAMBLE

An earlier version of this paper was given at the Patterns, Processes & Understanding: historic aerial photographs for landscape studies conference at Będlewo, Poland. My starting point was to look at the relevance, meanings and implications of the meeting title in relation to our uses of aerial photographs as sources of information about the past. How do aerial images let us realise those themes of Patterns, Processes and Understanding either separately or together?

Patterns is the easy one and 'pattern' is often described in books on photo interpretation as one of the important properties of a photograph along with tone (or colour), texture, shadow, size, shape and relief (e.g. Avery and Berlin 1992). Patterns themselves come in a range of levels that help us identify natural or cultural features and so help guide our perception towards the subject(s) we are trying to isolate through our examination of any photograph. At a landscape level, patterns are more likely to be of larger scale and may

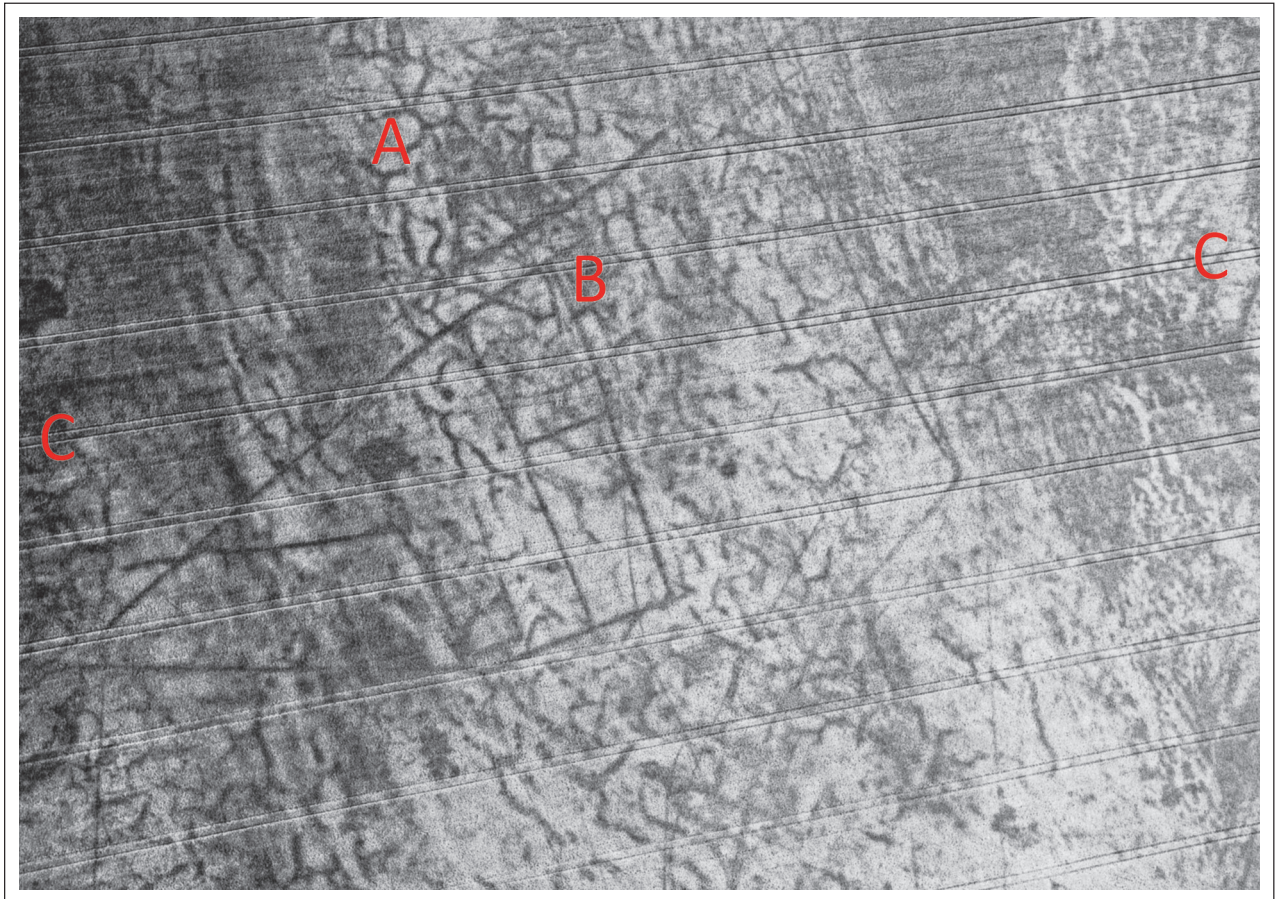


Figure 1. *On a single aerial photograph, patterns help us to identify processes. In this picture, darker growth of the cereal crop occurs over deeper soil so the pattern of irregular wiggly lines and blobs (A) indicates fissures in the ground caused by intense cold in periglacial conditions. Straighter lines show the ditches that defined enclosures and tracks (B) that were dug in, perhaps, Iron Age or Roman times with the enclosure located on the slightly higher ground that is suggested by the area of lighter crop central to the photograph. Now, the field has a managed plane surface as is indicated by the straight ‘tram lines’ (C–C) of the modern cultivation process. Photograph © Rog Palmer, 20100709-161.*

indicate the geological background in an area or show division of the countryside through the use of artificial boundaries and also to help indicate types of land use within those bounded areas. These cultural features are not always static and each aerial photograph will fix those changing patterns at a single moment in time but will almost certainly retain a time depth that lets us identify patterns of the past.

However, to reach that moment in time recorded by a photograph, the land will have passed through a series of processes, some of which are noted above, that have led to its state at the time of exposure. Figure 1, for example, lets us identify a number of processes and their results. In chronological order we can see that before the Holocene, when ice sheets and glaciers covered parts of the northern hemisphere, low temperatures caused fissures and pits in the land surface. By a later date these had become backfilled and, we can suggest, barely noticeable to the communities who cut the ditched boundaries that define a track and enclosures and show us manifestations of land use in (probably) Iron Age or Roman times. That system of land use was abandoned at some time and we can imagine that hedges died and banks slumped to partly backfill the ditches we see crop-marked on the photograph. These remains may have survived as humps and bumps before being subsumed by later land use (perhaps medieval cultivation although no traces of that are visible on the photograph). More recent agriculture has completed the levelling process and given us the present-day field surface which the tractor tramlines through the crop show to be a virtually level surface.

When we seek to identify more recent processes, a single photograph may let us identify one that has occurred (such as the removal and levelling of field boundaries) or it may record a process that is happening

at the time of exposure (ploughing, for example, or a road being constructed). However, photographs taken on different dates will record patterns of land use that were extant at the time of exposure and so enable us to identify precisely those changes and perhaps also to indicate the processes that caused them.

Our understanding of the meaning of patterns or processes is subject to a host of variables and will change as theory and practice change. Understanding can be helped by examining as many suitable aerial photographs as are available. After this, our understanding will most effectively and critically be reached by interpreting the photographs and making a map of what we decide to be the most important or relevant features.

So why do we isolate aerial photographs of one narrow date range and call them ‘historical’? Unless photos are being examined to answer a specific and time-related question, such as ‘what was the extent of Poznań in 1943?’ it is usual practice to examine all suitable photographs, regardless of their date. Just what makes photographs ‘suitable’ or ‘unsuitable’ for purpose was discussed by Winton and Horne (2010) in regard to those used for England’s National Mapping Programme. For other projects, the range of suitable photographs may differ, but for most there will be a cut-off scale below which specific objects will not be identified. There also may be seasons that are more, or less, suited to the information being sought and so some photographs may be ignored on the basis of their date. However, when working in a small area – a few square kilometres – it may be easier to ask to look at all in a collection. Beginners are advised to do this as a way of learning the range of photographs that may be ignored without detriment to future projects.

The time-slice that these mid-20th century ‘historical’ photographs give us is a useful one because they show the pattern of land use at that time and depict one stage in the processes of landscape development. But we will not fully be aware of those processes, we may not understand how they fit into a sequence of change, unless we relate the mid-20th century information to earlier and/or later data and compare the information they contain as one time-slice among many others.

WHAT ARE ‘HISTORICAL’ AERIAL PHOTOGRAPHS?

The Będlewo conference website identified these as ‘for example, mid-20th century’ but why do we separate these from other aerial photographs? Why do we further isolate them by writing books about them (e.g. Cowley et al. 2010; Hanson and Oltean 2013)? One explanation may be because the archives of those photographs, many of which were taken during World War II, tend to be kept separately from other archives of aerial photographs and therefore may first be examined as a discrete collection. But in absolute terms all aerial photographs

Table 1. *An outline of three phases in the growth and range of historical aerial photography. In most cases dates have been rounded off to decades and use of ... shows present-day continuation of these methods.*

1860 ...	Photographs taken from balloons and kites.
1914–1918	Development of military vertical photography for intelligence and mapping. Use of oblique photographs for specific targets or views.
1920s ...	Beginning of commercial (civilian) vertical photography. Oblique photographs of archaeological targets.
mid-1930s ...	‘Spy’ vertical photographs for intelligence.
1940–1945	Boom in aerial reconnaissance for intelligence.
1945 ...	Beginning of recurrent archaeological observer-directed oblique photography.
1946–1960	Use of the military to undertake aerial survey of many countries.
1959 ...	Satellite reconnaissance for intelligence.
1960 ...	Commercial aerial survey operations.
2000 ...	Commercial high-resolution image satellites. Applications of airborne laser scanning.
2010 ...	Use of UAVs and Structure from Motion.

are ‘historical’ to some degree – some perhaps more so (or older) than others. It is usual for me to use more than one archive of photographs to examine a specific part of England and I would rarely select any of those on the basis of their date or historicalness.

For archaeological investigations, any or all of these sources may be of equal importance unless the answer to our question lies within a specific time frame that is covered by photographs of the relevant date. However, in Britain and elsewhere, photographs taken in the mid-20th century may serve two useful purposes. Firstly, they are likely to provide the earliest view we have of the ground in general – by which I mean the whole landscape rather than the site-centred field or two that may have been targeted by archaeological photographers. Secondly, these photographs predate the extensive and destructive changes to the rural landscape as farming practices became more mechanised after World War II. Photographs from Cold War satellite reconnaissance provide similar pre-development views of parts of the world in the 1970s.

USING AERIAL PHOTOGRAPHS

A description of the processes of photo interpretation was written by the author about ten years ago. This was on the brink of the digital age and, even if outdated in places, it gives an idea of the work entailed in progressing from photographs to a map that shows interpreted information (Musson et al. 2013: Chapter 8). To summarise here, in an ideal situation all potentially-informative photographs would be gathered together and then sorted to find those that best showed archaeological and non-archaeological information together with a sufficient number of control points to enable the photographs to be matched accurately to a map. At present, if an interpreter is working on material from two or more collections of paper prints these probably will have to be examined at each library and choices made on the basis of partial evidence seen at each. This can lead to duplication of effort and is not the most efficient way to work. Regardless of that, it is expected that prints will be examined as stereo pairs when possible and this requires prints to be handled on a flat surface under good lighting with no reflections. If a pocket stereoscope is used as a preferred viewing instrument, this means that one print may be curled to show parts of a lower print that is covered by its overlapping pair.

ARCHIVES I HAVE KNOWN (OR TRIED TO KNOW)

There are more archives of aerial photographs than we know about and one of the initiatives of the Archaeo-Landscapes Europe project has been an attempt to identify and secure access to those in Europe (ArcLand 2014). The supposed need for secrecy meant that, in some countries, access to aerial photographs and maps was the privilege of the military and a small number of civilian officials. Archaeologists and other potential users stood no chance of access to aerial photographs in those places. However, the situation is now improving thanks, perhaps, to the ubiquity of Google Earth and similar internet sources – although even Google have been persuaded to pixelate some parts considered sensitive to that cover-all phrase ‘national security’ (Wikipedia 2014). Google Earth and the declassification of satellite photographs from the US Corona programme and the Soviet equivalent have meant that high resolution images are available for almost anywhere we want to examine. In addition, the EU’s INSPIRE directive requires member states to provide access to their infrastructures through a geoportal as well as any other access points (Inspire 2014). These can be useful sources of information as most include maps and aerial photographs. However, there is no standard among the participating countries and the content of geoportals ranges from very informative (e.g. Estonia) to nothing (e.g. UK).

Access to archives in some countries depends on who you know and, in places, your nationality. When trying to obtain aerial photographs and maps of Armenia in the early years of this century, the excuse of security was used to deny me access. (I say ‘me’ because it seems that other archaeologists had managed to obtain some photographs. Perhaps they knew the right people.) A few years later the situation had improved slightly but it seemed that one either had to have been a citizen of the former Soviet Union – and then travel to Moscow to see the photographs – or to be prepared to pay for photographs of their choice without first having seen them. This was a case when I bought Corona photographs to provide a good first look at the country (Palmer 2002). Access to vertical photographs of Romania, a country I worked in between 2005 and 2010, was initially difficult but they are now in the public domain (ANCPI 2014). More recently in Croatia, we were limited to using Google Earth and Arkod (their geoportal site that has photographs of different date

to Google) because access to other verticals of the country was made difficult. These problems were unusual to someone used to working with archives in the UK where access is easy for members of the public, even if other problems then become dominant factors in their use.

Most of my archaeological life has been spent working with photographs in two English archives: Cambridge University Collection of Aerial Photographs (CUCAP) and the National Monuments Record Centre (NMRC) in Swindon. Those, along with other photographs from County Record Offices, my own flights and internet sources such as Google Earth, provide the bulk of the material that I work with.

In terms of dates of photographs at those archives, CUCAP has primarily targeted oblique photographs taken by St Joseph and Wilson between 1945 and 1980 (with some later vertical photographs) while, in England, the NMRC has photographs from the 1920s (with a handful of earlier pictures) to the present. At both collections, different types of photographs (vertical and ‘specialist’ – which usually means those taken for archaeological purposes) are filed and indexed separately but can be listed through a single search request. Searches from either collection do not sort photographs by date, which reinforces my opinion that all are ‘historical’ to some degree.

My access to CUCAP can be through a free self-made search on their web site, or I can go to their library (which is a half hour journey from me) and use the old card and map index on which the web site is based. The card index is almost 100% accurate because it was checked thoroughly as it was compiled. The website, though, has a lot of misplaced sites because data was input by uninterested short-term employees and it was never checked, either by a human or – as would have been so easy to design – automatically within the digital dataset. The website lets me draw a polygon of my search area and I am able to click on individual icons and see details of each photograph. Some of these also show thumbnail images. A click of a button gives me a list of photographs within my search area and I can save this as an Excel file. I can then phone and go in to look at the photographs, often on the same day, and order 1200 dpi scans at £30 each, which I can collect in two or three days [prices at 1 October 2014]. At present, CUCAP is run and managed by one person.

To access photographs at NMRC, I request a priority cover search using coordinates or by sending a polygon. This costs £66 and returns me an Excel list of vertical and ‘specialist’ photographs within two working days. NMRC then require one week to retrieve the photographs from their archive after which I can travel to Swindon to examine them. In their Public Search Room, I am expected to wear plastic gloves (which make hands and fingers go soggy) to handle prints of their photographs and I am allowed to make Xerox copies (20p each) or can photograph them using available light and a hand-held camera for a one-day licence costing £10. I am able to order prints (10x10 inch [25x25 cm] at £19.20) or high resolution scans (of unspecified resolution but which they describe as, “up to 50mb rgb/17mb Greyscale”) for £25.20 but these take some three weeks to be delivered and most of my work has a three to four week turnaround. ‘Express service’, for a maximum of five images, costs twice that of their normal service.

The difference in the locations of these two archives and the time it takes to get access to their photographs means that usually I will work first on CUCAP material and am often able to take a map made from that information to NMRC a week or so later. This lets me choose those photographs for copying that add new information to that obtained from the CUCAP photographs.

Usually at NMRC, I will photograph the photographs (Figure 2). This is far from ideal but the quality is better than a Xerox copy and it gives me the facility to zoom in to specific modern fields when this is necessary on a vertical print. Experimenting with cameras showed that hovering over a table holding a DSLR as a ‘vertical’ camera was less stable (the shallow depth of field in the available light required precision of focusing that was difficult to attain while still breathing) and much more uncomfortable than sitting with a hand-held compact camera that has a movable screen. With the compact camera, I can keep my elbows on the table to create a relatively-stable platform and not get back ache. The NMRC archive and public access is run by a staff of at least eight people plus those in the background responsible for cataloguing and curation of the material (Graham Deacon (NMRC), pers. com., mid-2014). Contact with any of the staff does not go much beyond the official (being given and returning boxes of photographs and permission to copy) and little or no interest is shown in the work visitors are doing. These are people doing their job.

The first opportunity I have to look at all of the photographs together is when I get back to my computer. There I am able to compare photos from the two archives plus any of my own and saved images from Google Earth and Bing. As an example of the numbers of photographs involved, in a recent assessment to examine

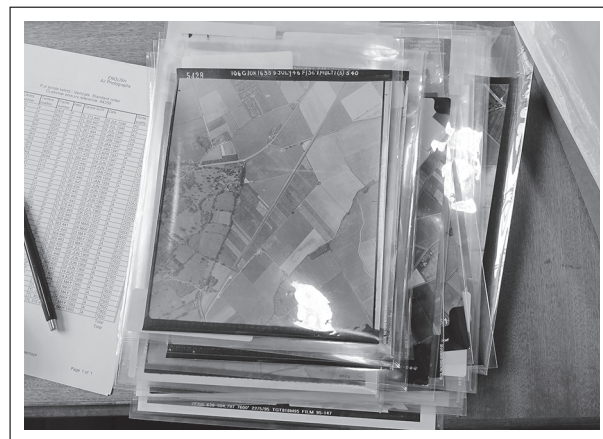


Figure 2. Four weights were used to try and hold a print flat so that this hand-held photograph could be taken. Note the reflection (ringed) which could not be avoided but, by moving the print in relation to the overhead light, has been placed in an unimportant part of the original photograph. Photograph © Rog Palmer, c20140122-041.

Figure 3. Prints placed in reflective transparent sleeves make them impossible to use effectively for interpretation. Photograph © Rog Palmer, c20140122-074.

200 hectares, the total from all searched sources was 159 photographs from which I used 19 as the principal data to prepare my map.

In that example, as well as internet sources and my own aerial photographs, the work was based on photos from two physical archives – one run by a national organisation with a large staff and an internal division between ‘archive’ and ‘public search room’, the other in a small room in a university department run by an enthusiastic person who is eager to learn what visitors are seeing on ‘his’ photographs. Does this make a difference to the ease of using them? And, more importantly, which one lets us do our job more effectively?

HAVE ARCHIVES BECOME MORE PRECIOUS THAN THE INFORMATION THEY CONTAIN?

What follows is about collections of photographs I have used in England but it applies equally to those collections of rarer material such as NCAP/TARA in Edinburgh. I get the impression that some collections of aerial photographs have slipped from being primarily a data bank of information for users to becoming important possessions that give power to their keepers, the archivists, and are seen as a potential source of income by organisations’ accountants. Collections may be acclaimed and promoted because of their size and the rarity of their content rather than by their usability and ease of access although, surely, these publically-accessible archives of photographs (or any other data) are there to serve users. In which case, it must be assumed that one of the prime aims of those archives would be to ensure the ease and effectiveness of their use and we may expect some advances in accessibility over time. For example, during the years I have been using photographs from major collections, both CUCAP and NMRC have enabled access to their former card indexes via computers. CUCAP’s is on-line and can be accessed freely by users, while NMRC’s is searched by internal staff at a cost to users. Physical access to their photographs seems to be unchanged at both but the ways in which some photographs are protected at NMRC makes it difficult to use them effectively. For that reason I would like to pose the question: have some of our archives become more precious as archives than for the information they contain? Or, twisting those words slightly: in this digital age, how may our archives best serve the user rather than be locked within the organisations that hold them? As usual, I will be a little extreme and possibly a little idealistic – but access to these sources of information is vital and our discussion needs to start somewhere.

Are we seeing a power game in action at users’ expense (perhaps a direct example of the Power of Image discussed by Rączkowski in 1999) or is this just an over-reaction to preservation at any cost – in this case, the cost of not being able to use the preserved material effectively? While we should expect there to be some protection of unique resources, I suggest that in this digital age, there is little reason to make access problematical

to images that can be reproduced for a small cost. For example, I am sometimes provided with prints, or sets of prints that have been put into glossy protective sleeves (Figure 3). This means that to look at the photographs as stereo pairs and with a minimum of reflections, I have to remove each from its 'protective' cover and replace it afterwards – actions that have the potential to cause more damage to old paper prints (and, for some unknown reason, new copies of colour prints are often similarly encased) than if they had been put in a box without that 'protection'. If, as seems likely, a user is expected to keep the print in its glossy sleeve I submit that this has the effect of degrading the quality of information that can be extracted from that print. The end result is that, far from easing access to archive material, such 'protection' of paper prints is not allowing users to do their job properly.

We could ask if any of this protection is really necessary anyway as it is unlikely that the vast majority of photographic prints will be examined more than a dozen times during the 100 year period after they were printed. Who, I wonder, is likely to look at old photographs?

- Archaeologist making a record of their local area (e.g. a county survey);
- Archaeologist making part of a national record (this has occurred twice in the UK – first by the Ordnance Survey, with more recent use by a national heritage organisation);
- Archaeologist working in advance of development;
- Soil scientist making soil map, studying drainage or land use;
- Historical geographer examining change to, for example, a cultural landscape;
- Geologist/geographer examining topography, natural resources or change;
- Photo interpreter seeking unexploded ordnance;
- Photo interpreter working on a legal dispute;
- People from a local group using aerial photos as one strand of evidence in a village or parish survey;
- Someone looking for 'my house' (which could result in several different viewings of any one photograph).

Perhaps there will be a few more uses but these still add up to a fairly low handling rate that is likely to give only minimal wear to the photographs especially if first-time users are shown how to handle them carefully. It may also be suggested that in the digital age, this wear could be minimised by making scans (but see below) of any photographs called for examination and letting the user work from those. So we could ask if archivists are over-reacting or keeping themselves in a job by unnecessarily fussing about something that seems to matter little. In large organisations, it is possible that archivists have little idea of how their archives may be used and that their protection of the source material seriously reduces the value of the information it can provide. If this is correct, I suggest that it is a somewhat inward-looking approach.

We can compare these problems of access with what seems to be an ideal situation at NARA (Maryland, USA) which holds a huge collection of World War II photographs. There, I am told (Chris Going, pers. com., November 2014), users can take in their own notebook and scanner or use one of the bank of copy stands that have lights and a mount for a camera. Such considerations for customers' needs make a user of UK archives very envious.

In the UK, particularly in some of the larger organisations, scanning is seen as a problem (apparently because the archivists see the possible damage and deterioration to the original) rather than being seen as a means that may help the user and, at the same time, will create a new primary use copy of original material. Their first question seems to ask whether it is 'safer' to scan existing prints or risk opening cans of negatives that may crumble to dust on exposure to the air or when they are unrolled on a scanner bed. Note that the keyword is 'safer' rather than 'how can we obtain the best image?' which again relates to the supposed preciousness of the archive as an item. Let us take the question of possible destruction of the films and ask if they are worth keeping if no one knows their condition. Film cans need to be opened and the condition of their contents assessed. If they can be used, use them. If they crumble to dust then throw them in the bin as they will not magically improve by keeping them. My own past experience has shown that new prints from negatives of 1940s and 1950s vertical photographs provide much more informative pictures for interpretation than the contemporary mass-produced prints that are currently in the archives. This point can be extended to scanning material and provides an argument in preference for scanning from negatives rather than prints. I would go further and suggest that if such scanning causes a film to self-destruct after it has been scanned then it is no great loss as we have secured from it the best possible duplicate that can be made using current technology. Plus, we have a digital file that can be freely-distributed to users. However, that proposition

suggests that the information on aerial photographs is more important than the archives themselves, which is a reversal of what I see as the archivist's viewpoint. Of course, the 'possession is power' syndrome is weakened once scans have been duplicated to become the main source of information for those who examine photographs. If we ever achieve a complete digital record of all available aerial photographs, and if copies of these are duplicated in other relevant collections or put in an easily-accessible digital archive, we can ask if we still will need archivists. USGS (2014) are doing this with material from aerial and satellite missions and this has led to considerably more use of the information. Is it so unreasonable to expect other government-funded material in other countries to be made similarly available? This process will, of course, lead to a total loss of power for those who manage collections of images – but is that an unreasonable state to desire if the present situation holds back our understanding of the past, present or future?

Mention of the USGS activity raises another aspect of access of collections: money. The US attitude seems to be that images originally taken using taxpayers money belong to them so, for the price of a single scan, they are accessible to the world's users who can do as they like with those images. In Britain, for example, images taken at taxpayers' expense belong to the Crown which sees these as a source of income (UK Government 1998, Annex B). As an illustration, this means that images can be bought from NCAP/TARA (2015) but prospective buyers also have to complete a licence application which is likely to result in an additional fee if the image is not for private use, for example, if it is to be included in a book. The website fails to mention whether previously-scanned images will be available free for subsequent users, but this is unlikely.

SUMMARY AND CONCLUSIONS

I see no reason why 'historical photographs' should be given special place among our broader archives of aerial photographs as this conflicts with usual practice for interpretation which is to examine all suitable photographs. All photographs become 'historical' once they leave the camera although those of different dates will always have specific value as records of those times and are useful to assess the survival and condition of features on the ground.

Aerial photographs of any date are valuable as sources of information that let users recreate elements of past settlement and land use as a way towards understanding past behaviour. However, access to these sources may be becoming increasingly difficult, especially in large organisations where archivists and users may never meet and discuss the balance between preservation and usefulness. To archivists, protection of photographs may be their overriding concern and, perhaps in their ideal situation, collections will be perfectly preserved and safely locked away from the rampages of any users who may dare to want to examine them. If uses of aerial photographs are seen as secondary to protection we could ask why we bother to make these collections? Is a pile of unused aerial photographs a worthwhile possession? No, their true value lies in their capacity to record information, not in their pristine condition.

So if we reverse that (hypothetical?) situation and put users' needs first – if collections of photographs are valued as sources of information and not as possessions – then ease of accessibility becomes the paramount issue. If it is essential to keep existing prints and film rolls (and has the need for this ever been discussed?) then we may eliminate or reduce deterioration to them by scanning from the most-informative originals and using digital copies for examination? Digital copies then become the prime sources of information while film and paper prints can either be locked safely away or discarded. Yes, this may be extreme, but if we have a good digital record do we any longer need the source material and its costly maintenance programme and storage space?

When making digital copies, and where there is a choice, it is essential to decide whether we will we get more information by scanning negatives or prints? Note that 'more information' is the key phrase, not fussing about damaging originals. So in this future ideal world, can we envisage the possibility of a freely-available digital archive that can be searched via the internet with high-resolution copies downloadable on demand? Elements of this already exist in US government collections so is it too much to expect the same freedom of information in other countries?

Collections of photographs ought not to be seen as an end in themselves as these are little more than meaningless heaps of material that we store at great expense. But cheap and effective access to those collections and the ability to use an image, be it taken yesterday or a hundred years ago, to gain glimmerings of understanding about events that occurred perhaps two or five thousand years in the past – that is power beyond anything that comes from possessing, unused, those photographs.

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Why are maps often misleading about archaeological sites?

Ideology, maps, ALS and historical aerial photographs of district Góra, Lower Silesia Region, western Poland

Abstract: *This paper discusses the relationships between pre-understanding and perception of cultural heritage sites with reference to the examples of archaeological earthworks recorded on large scale topographical maps from different periods. Maps can be understood as generalized projections of landscape perception, the ordered image of cultural space. Interpretation of historical maps can help to give an insight to the way the landscape was understood and valued in the past. The manner archaeological monuments were presented, symbolized and communicated on various editions of topographical maps will be presented. Cartographical images will be compared with other sources of knowledge about topography, such as contemporary and archival aerial photographs and airborne laser scanning.*

INTRODUCTION

From a ‘common sense’ perspective cultural landscape is a set of elements of the natural environment and manmade objects. But in what way can cultural landscape be connected with the past and serve as a subject of archaeological studies? According to American geographer Yi-Fu Tuan (1987, 239–240), such a relationship is easiest to realize for someone living in around historical architecture, archaeological sites and works of art. From this point of view the materiality of passing time would allegedly become more evident.

However, the presence of such features in itself does not necessarily have to encourage anyone to direct their thoughts towards the past. It may not be as evident as we presume either. The value of historical monuments and artefacts emerges from our knowledge and attitude towards them. The cultural landscape is never just the neutral surrounding or the container filled with things, places and people we share space with. Instead, most of all, it is the way we think and act in the world (Tilley 1994; Johnston 1998, 314; Casey 2008, 44; Wylie 2009, 1–2). It is not a scene that can be apprehended from a distance without an engagement.

Archaeological sites can be valued due to their physical form, their state of preservation, as well as chronology or relationship to historical events that are considered to be important. The meaning of archaeological sites can be created in relation to different phenomena like science, education, social identity, or become an active part of political discourse. However, if a site does not fit the prevailing ideology it may be erased from memory, physically transformed or gradually lose its meaning.

The idea of cultural landscape and its order is created in relation to the socio-political circumstances. Its values and meanings are continuously negotiated and often driven by ideological conflict. Cartographical sources considered to be the result of such interpretation indirectly communicate historical ideas of landscape at a certain period of time. Therefore, topographical maps can be understood as the generalized projection of landscape perception, the ordered image of cultural space. Interpretation of historical maps can help in giving an insight to the way landscape was understood and valued in the past.

In this paper I will focus on one of the many aspects of cartography, discussing the manner in which archaeological monuments were presented, symbolized and communicated on various editions of topographical

maps. I will attempt to define the general relationship between the historical contexts in which these maps were made and used and the image of archaeological heritage deriving from their symbolism.

To illustrate my narration I will use the example of archaeological earthworks from western Poland (Lower Silesia Region, district of Góra). The analyzed sources will be limited to selected examples of topographical maps (scales 1:25.000 and larger) created from the 19th century until the last decades of the 20th century. It is significant that this period covers several different political systems and territorial changes that took place within the area of contemporary western Poland. All of these produced a variety of cartographical images. I will refer to them in detail while discussing particular examples. Those ideological shifts also had an impact on the historical and archaeological scientific discourses.

The maps and the information they hold will be confronted with other sources of knowledge about the topography of the sites in question, such as contemporary and archival aerial photographs and airborne laser scanning data. All of these sources are culturally embedded attempts to present certain aspects of topography. Thus, comparing them may help in revealing their hidden agenda through the observed discrepancies and information that was not meant to be expressed explicitly or was not fully realized. Finding the enigmas that do not fit the overall picture can be more inspiring than confirmation of previously known facts.

Another type of analyzed source will be large scale maps drawn by archaeologists to document field-work. In this case I will investigate the influence of mental patterns and preliminary knowledge on the cartographical representations of archaeological sites. The main point of the presented study is not the maps themselves, but the historical changes in the ideas of cultural landscape and archaeological heritage reflected in the texts of the maps.

MAPS AS NARRATION

Maps are often misleading regarding archaeological sites. Archaeological earthworks marked on different editions of maps frequently change their shape and size. Sometimes they ‚travel’ from one location to another, ‚move’ from one side of the river bank to the other or simply disappear to emerge again later in a completely different form and place (Figure 1). Descriptions left by the cartographer in order to communicate their function and chronology can also vary depending on the period the map was created in.

It is also quite common that archaeological earthworks, despite imposing dimensions, are not included on topographical maps at all. Such situations do not always result, as one might imagine, from the physical transformation or destruction of the sites. Rather, it is often a consequence of more general cultural changes that influence human perception and rules of map making.

Critical interpretation of maps requires understanding of the context in which they were created and used (Harley 1988, 281). In contemporary geography, maps have ceased to function as objective representations of the surface of the earth or as a true reflection of geographical features. Instead, they are understood now as a kind of social discourse mediated by historical circumstances, ideology and social rules (Harley 1988, 278; 1989, 1–3; Monmonier 1996; Crampton 2001; Crampton, Krygier 2005). Thus, in my paper I am not going to discuss the credibility or accuracy of the maps. Instead, I will try to analyze the information they contain.

The cartographer never registers landscape in a neutral way, just as it is (Harley 1988, 279). It is always a landscape seen through a particular socio-political system. Maps are generalized, selective and scaled images, subjective to the conventions that define their content, applied symbols and styles of (re)presentation (Monmonier 1996, 25–42). They are also a way of influencing and convincing others of a certain vision of the world (Harley 1988, 278).

The text of the map is influenced by many different factors such as the physical and social settings for the production and consumption of the maps, the main aim of the map, the knowledge possessed by the map maker, the expectations of the ‚patron’ or institution that commissioned the map, and the ideological and political needs, knowledge, skills and resources the disposal of the cartographer disposed (Harley 1989, 5).

There is nothing passive or neutral about maps, as in the case of any other culturally embedded image that aims to represent certain features or abstract ideas. Not only are the symbols applied for the representation of geographical objects metaphorical (Harley 1988, 277; 1989, 7, 15), but so too is the choice of the specific colour (Monmonier 1996, 173), map projection or coordinate reference system (Monmonier

1996, 8–24; Wood 2002, 152). Even such basic activity as locating or naming the geographical features on the map often has political and ideological significance (Harley 1988, 278).

The text of maps is frequently the subject of deliberate manipulation (e. g. Monmonier 1996, 49–51, 87–112). Over-enlarging signs, shifting scales, and using certain emotive colours or descriptions can be a means of manipulation with defined propaganda purposes (Harley 1988, 287). On the other hand maps express as much through the features they represent and emphasize as through the objects they omit (Harley 1989, 14). In the eyes of military men (but also politicians) maps have often been regarded as ‘a sensitive type of knowledge’ (Harley 1988, 284, 290–291). As with any other document, cartographical sources can be subject to censorship. Some features can intentionally be misrepresented by the cartographer to mislead the potential user (Harley 1988, 288).

Following the ideas of J. B. Harley (1988, 277) we usually understand the process of map interpretation as a ‘search for’ geographical objects. A map is rarely thought of as a kind of manipulated knowledge, which does not simply describe but also creates the geographical features and fashions their understanding (Harley 1989, 14–15). The power of maps derives from their persuasiveness. They generally give the impression that their perspective is inevitable, the one and only (Sletto 2009, 147).

LANDSCAPES WITHOUT PAST

The starting point for my case study is the first credible cartographical images of western Poland – topographical maps called *Urmessischblatts*, created at a scale of 1:25,000. This series of maps were made from 1821 to 1876, during the period when the area of contemporary western Poland belonged to the Kingdom of Prussia. All the maps were drawn from very accurate (at that time) plane table measurements based on triangulation network. The technology of production, despite their high level of accuracy, may appear to us as somehow closer to the fine arts than to the methods of scientific cartography itself. The map sheets were produced with the use of watercolour technique (aquarelle) (Lorek 2011, 7; Konias 2010, 173). The topography was symbolized by formalized line drawing (but not contours yet). Additionally, specific colours were used to facilitate the interpretation of the map and to communicate the characteristics of features (Lorek 2011, 8; Konias 2010, 174).

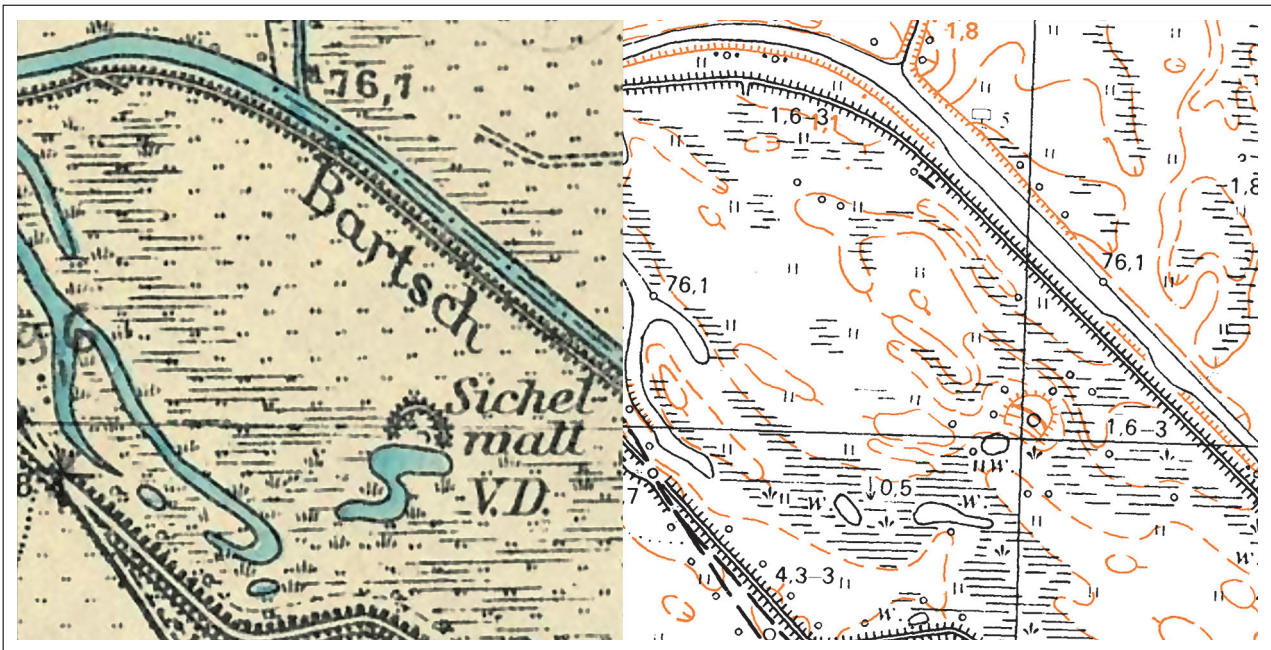


Figure 1. Two topographical maps of the same area. The early medieval earthwork is clearly marked on the Messtischblatt map from 1936 (original scale 1:25,000) while on Polish topographical map from 1970s (original scale 1:10,000) there is no description indicating that this is a cultural heritage site.

The production of *Urmesstischblatts*, starting from the technique of collecting field measurements, and finishing with the rules for depicting the topography of the terrain, specific geographical features and applied symbols, was based on specially prepared instructions (Lorek 2011, 16–23). This was done to ensure the same standards between different sheets of the map (Konias 2010, 174, 190).

Despite a high level of accuracy, these maps rarely include archaeological sites. Their main aims were military and administrative (Konias 2010, 173), and so cultural heritage did not have much importance. It is significant that *Urmesstischblatts* were created by the Prussian Army General Staff commanded by General Müffling (Lorek 2011, 13–14). In contemporary terms they would be referred to as top secret.

Often, when some archaeological earthworks were eventually marked on those maps, they were misinterpreted and described as *Schweden Schanze*, which can be translated as a ‘Swedish Earthworks’, referring to the early modern strongholds related to the implementation of gunpowder weapons. It does not matter if we are dealing with a prehistoric ringfort, a medieval enclosure or in fact an early modern stronghold, all of them could be described by just this one term. This shows that common knowledge about the archaeological earthworks and their purpose was very limited, as most of them were regarded as *Schweden Schanze*. In fact, originally *Schweden Schanze* was a toponym commonly used by the modern population that was later adopted by cartographers for description of the ‘defensive’ earthworks. In some cases, such features were marked on the maps without any additional explanation of whether it was a formation of either geomorphologic or anthropogenic origin.

It is important to mention that features such as *Schweden Schanze* were never officially defined in the instruction of the map, nor in the map legend (Lorek 2011, 28). These circumstances highlight the certain autonomy of representation that could be used by the cartographer. Due to the convention of the map, it was one of the few accepted ways of representation of such features.

Most likely, the reason why some archaeological earthworks were labelled on the maps is because they could serve as a landmark that might be helpful in reading the map and aiding in spatial orientation. It is also probable that some such features could have been regarded as militarily useful in the 19th century. Thus, the (only) reason for marking archaeological earthworks was pragmatic, and predominantly had nothing to do with acknowledging their cultural value. The image of the cultural landscape emerging from *Urmesstischblatts* is in fact ahistorical and the remains of the past have very limited meaning in it.

ARCHAEOLOGY, MAPS AND NATIONAL IDENTITY

The methods of presenting cultural heritage on maps within the study area changed significantly in the second half of the 19th century with a new series of topographical maps – the *Messtischblatt* (scale 1:25.000) produced from 1875 to 1945. *Messtischblatt* were based on more accurate measurements due to the introduction of a new triangulation network, and new rules of cartographical representation and symbology (Konias 2010, 190–197; Lorek 2011, 28–29).

The development of cartography is often linked with the rise of the nation state. Power and ideology have an impact on how landscape is perceived and consequently presented on maps (Harley 1988, 283–284; 1989, 10–11; Crampton 2001, 695). At the turn of the 19th and 20th century, together with the growing popularity of the idea of Pan-Germanism, archaeological monuments became an important part of the emerging national identity. Archaeological sites became meaningful places because they were seen as important to national ideology.

As a result, a new series of topographical maps were enriched with various types of features. Special categories and symbols describing archaeological and historical monuments were introduced by new map instruction. Following the ideological re-evaluation, the cartographic images underwent meaningful change. The map was no longer an ahistorical image of the social space. The existence of cultural heritage was acknowledged through the indication of some examples on the maps. The cultural landscape became a subject of the contemporary discourse of power.

Archaeological heritage sites marked on the *Messtischblatt* maps were still very often misinterpreted. It seems that academic archaeological and historical knowledge was never applied in the process of map creation, despite the fact that scientists were already capable of interpreting most of the archaeological features and their functional and often chronological classification. Some of the remains of prehistoric and medieval settlements with preserved defensive systems were, as before, described on the maps as ‘Swedish Earthworks’,

megalithic tombs and barrows were referred to as ‘the graves of the Huns or the stones of the Huns’ (Hünenstein, Hünengrab) etc. Furthermore, there were many ruins, castles, historical battlefield sites and other places relating to past events marked on the maps. As in the earlier maps, the referred names of archaeological features originated in a larger part from the toponyms that were commonly used by local societies.

The interpretation of numerous examples of methods of presenting archaeological earthworks shows that the cartographers exercised some autonomy in the process of map creation. Thus, the discussed sites were often marked and communicated by different symbols and descriptions, most of which are not found in the official instruction. The need to acknowledge the presence of the monuments in a certain area was sometimes so strong that some natural forms were misidentified as anthropogenic earthworks and functioned in the social awareness as such.

PAST LANDSCAPES WITHOUT MEANING

After the end of World War II, due to decisions made at the conferences in Yalta and Potsdam, the western and eastern borders of Poland changed. Poland lost large territories in the east, and gained as an amends some territories to the west and north that previously belonged to Germany. The territories of western Poland (together with the Lower Silesia Region), referred to by communistic propaganda as ‘regained territories’ (Rączkowski 1996, 208), had to be recorded on the new series of topographical maps. All German names of towns, villages, rivers, hills and other geographical features had to be changed to Polish versions. Some other features were purposely omitted, or misrepresented. The image of the cultural landscape presented on this new series of topographical maps had changed again. It became a subject of a propaganda struggle driven by the need to justify border changes.

The first series of topographical maps produced after the war were not distributed for civilian use as their purpose was military, and soon they received top secret status. Therefore, I am not going to discuss the examples of the earliest Polish maps produced in the coordinate reference system PUWG-1942 (Sobczyński 2000, 214).

Another series of large scale (1:10.000) topographical maps of Poland, in this case available (with some restrictions) for civil and administrative institutions, were produced from the end of the 1960s to the beginning of the 1990s. (Sobczyński 2000, 226–228, 247–256). The cultural landscape of western Poland presented on those maps significantly differs from the latest examples of German maps of this region. The passing of time (over two decades, and in some cases three) is not the only reason. Rather, the perception of the cultural landscape of ‘regained territories’ was a product of discourse based on opposition and denial in relation to the culture of previous inhabitants of those lands (e. g. Rączkowski 1996, 208–213).

As a consequence of such an approach most archaeological sites that had been marked on the German maps were not mentioned again on Polish maps after World War II (e.g. Figure 1), even though their physical form was not altered and they survived in very good condition, and despite technological innovations in cartography (e.g. use of photogrammetry), higher accuracy of measurements and larger scale of maps. The topographical instruction of the map does not give any leads to the standards of registration of archaeological earthworks, symbols that could be used for that purpose, or descriptions.

To find the explanation for this paradox we need to refer to the very specific circumstances of the role of cultural heritage in the first years after World War II. This time the reason was not the lack of historical awareness, but the urge to create new ideologically correct social memory. The meaning of archaeological and historical monuments in the post-war reality was devalued. Polish citizens resettled to the western territories perceived this landscape as ‘alien’ or ‘German’. They were often unable to recognize heritage sites or imagine their abstractive value and identify with it. Historical and archaeological monuments were not seen as their property. On the other hand, the communistic ideology was about creating new social order, therefore it exploited the past for political reasons (e.g. Kijowska, Kijowski, Rączkowski 2010, 161), developing interest only in the specific archaeological sites related, for example, to the early Polish Piast monarchy. Such archaeological sites could later be used in the propaganda discourse to justify border changes after World War II.

Along with the disappearance of the archaeological earthworks from the maps, they also vanished from the awareness of the local population, losing their cultural value. The consequence of that process had a great impact on the contemporary perception of cultural heritage in western Poland. This situation did not significantly change in the case of a new series of topographical maps in scale 1:10.000 (CRS PUWG-1992)

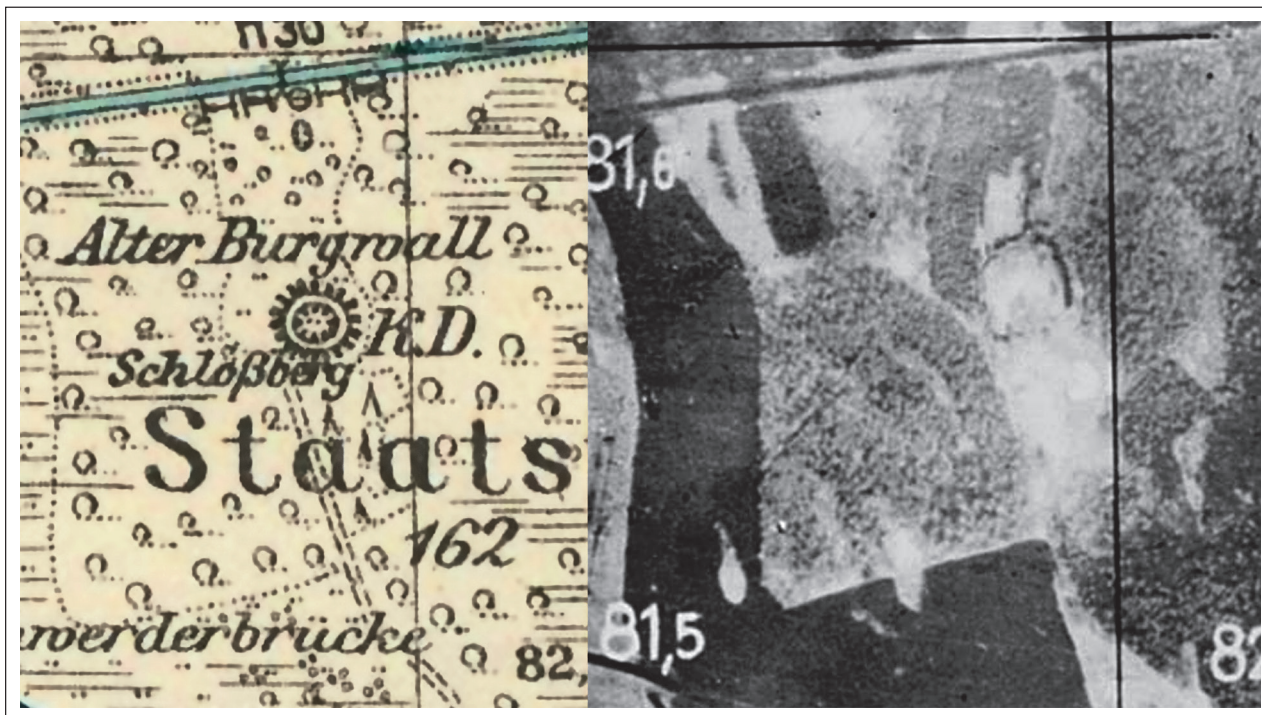


Figure 2. Early medieval stronghold from Chróścina (district Góra, Lower Silesia Region). Comparison of a fragment of the Messtischblatt map and Photomap. © Szczecin University; NCAP/ncap.org.uk.

produced from 1996 until the present day. As their coverage of territories of western Poland is very limited I am not going to discuss their example in detail.

To illustrate the points outlined, I will refer now to some selected examples of cartographical representation of archaeological earthworks and confront them with other sources of knowledge about the topography of archaeological features.

PRELIMINARY KNOWLEDGE AND TOPOGRAPHICAL (RE)PRESENTATION

The first example of an archaeological site recorded on topographical maps I am going to discuss is the relics of early medieval stronghold from Chróścina (district Góra, Lower Silesia Region). This was marked on the *Messtischblatt* map (sheet no. 4265) (Figure 2), using a topographical symbol that appears to represent a circular earthwork. In the map legend there is no explanation of this symbol, thus it is difficult to understand what circumstances influenced the decision of the cartographer and defined the rules of representation of this archaeological earthwork. Additionally, the archaeological site was described on the map as a heritage site (K.D. – kulturdenkmal), old castle walls (Alter Burgwall) and castle hill (Schlossberg). From a contemporary point of view those descriptions leave some doubts about their semantics, as in the early medieval period there were no castles in that region, only earth and wooden strongholds. However, the map clearly identified that as a place of interest, even though it was located in a remote and marshy area, overgrown by forest, and had no pragmatic contemporary function.

More details about the topography of the earthwork can be obtained from a German photomap made in the 1940s (Figure 2). The dark phototones clearly mark the rectangular shape of the moat filled by water, although the low resolution and contrast makes it difficult to interpret other related features.

The earthwork does not appear on the Polish topographical map from the 1970s (Figure 3). There is only a small irregularly-shape hill marked by a contour line and neither is there any description explaining that it is of anthropogenic origin.

In the 1960s, due to a survey undertaken, followed by test excavations, a large scale archaeological field map of this earthwork was drawn. This depicts a circular bank (remains of the rampart) surrounded by the moat

that is also of regular, circular shape. Additionally, a secondary outer earth bank was registered on the map several meters to the south of the moat (e. g. Kaletyn, Kaletyn, Lodowski 1968, 46–48; Lodowski 1966; 1980, 98).

As it appears, the archaeological field map does not confirm the information about the rectangular shape of the moat from the German photomap. However, the Digital Terrain Model (DTM) processed from Airborne Laser Scanning (ALS) data, and various visualizations based on it, presents a different situation (Figure 4). The remains of an inner earthen bank appear to be circular, but the moat is rectangular in shape. Also a much smaller, outer bank surrounding the whole earthwork appears to be rectangular on plan.

In what way can an archaeologist make sense of these completely differed attempts to represent the topography of an early medieval stronghold from Chróścina? The evidence seems to be misleading and contradictory. But this inconsistency exists only as long as we treat those images as neutral representations of the surface of the earth. When one thinks about these representations as text the cultural dimension of those images can be revealed.

The German cartographer that produced map sheet no. 4265 used a topographical symbol to mark the archaeological earthwork in Chróścina, probably to emphasize its meaning and because it was too small to be clearly represented through contour lines. The symbol itself is circular as are most of the medieval defensive structures from the region, thus it is clear communication to anybody interested in such features. The additional description reflects both the accepted convention and historical awareness of the cartographer. The *Messtischblatt* is much easier to read in comparison to the 1940s photomap. Most possibly the earthwork from Chróścina was recorded on it by accident (favourable conditions, moat filled by water etc.). There is no accompanying description on the photomap. The archaeological feature would probably be very difficult to identify, even by an experienced aerial interpreter, without any additional source of knowledge or tips pointing to the feature. Dark phototones, even though rectangular in shape, look very random.

As in the case of reading maps, the interpretation of aerial photographs and photomaps is also cultural activity (e. g. Rączkowski 2001, 2002; Musson, Palmer, Campana 2013). It refers to preliminary knowledge about the forms of archaeological earthworks and various means of their representations on aerial photographs. The functional classification of features seen on aerial photographs (e.g. moat, rampart) is always hypothetical and originates from the preliminary knowledge possessed by the interpreter, not the picture itself. Interpreted photomaps were produced from a mosaic of about 20 vertical aerial photographs taken during late autumn or early spring.

Due to the specific season of photography (when local flooding takes place), the ditch of the earthwork in Chróścina was filled by water. Probably the moat would not be as clear if the aerial photographs had been taken during the dry period. This shows that the defined procedures of collecting aerial photographs

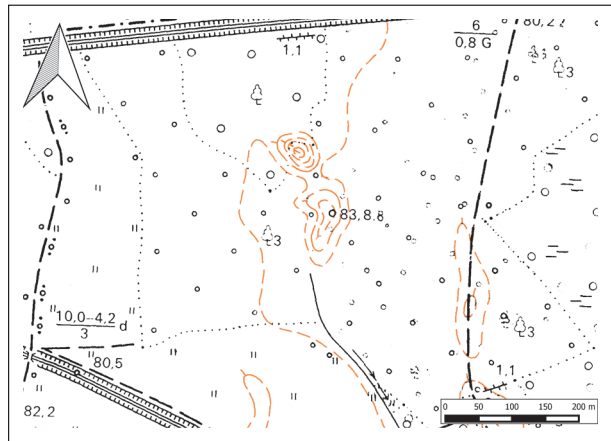


Figure 3. An extract of a Polish topographical map from the 1970s (PUWG 1965, original scale 1:10,000). The map does not indicate directly the presence of the early medieval stronghold. © CODGIK.

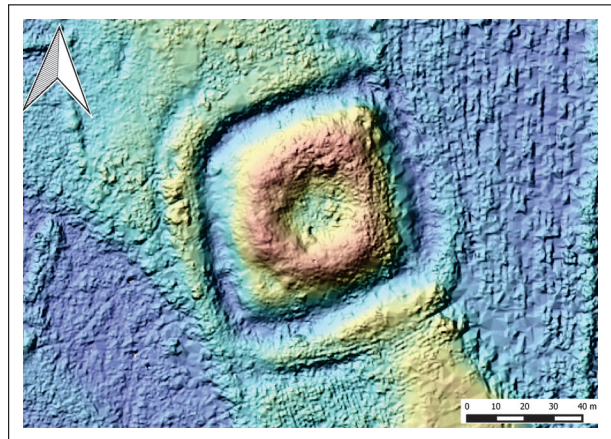


Figure 4. The early medieval earthwork from Chróścina, seen through Digital Terrain Model and Hill Shaded Relief processed from Airborne Laser Scanning data. © Grzegorz Kiarszys.

for photomap productions were critical for the recording of this specific feature. On the other hand, due to generally low resolution, it is impossible to interpret more details of topography of the site.

The absence of the earthwork on the 1970s Polish topographical map can be explained by political circumstances, and the applied convention (discussed in detail earlier). We can assume that the irregularly-shape hill presented in the place of the earthwork is the product of an insufficient number of measurements for the feature. If such a feature was to be represented through contour lines, the number of measurements would have to be much higher and the spacing between contour lines smaller than in the standards defined by the instructions for the map making. However, in such circumstances it would have to be considered to be meaningful enough to justify additional effort of the data collection or use of a topographical symbol on the map to acknowledge its presence. Instead, it was represented as any other natural topographical object and through that transformation it gained on the map the shape of irregular small hill.

The presented visualizations based on ALS, as with the maps, are symbolic images that exploit colour and shade to express topography (e. g. Opitz, Cowley 2013). Their interpretation also requires understanding of certain formal rules (e.g. if DTM height attribute is colour coded, the interpretation of such an image requires knowledge about specific colours assigned to certain height value, understanding of the principles of operation of used visualization algorithm etc.). In fact, very similar rules apply to the process of interpretation of ALS visualizations as in the case of aerial photographs and maps. In the case of ALS the meaningful cultural factors that influence the final conclusions depends on, for example, the type of scanner used, density of scanning, conditions of scanning, data processing and visualizing as well as our ability to recognize anthropogenic features and interpret their function. The manner in which these conclusions are later incorporated into the archaeological narration is not neutral either. Despite the fact that ALS is currently considered to be the most accurate means of recording topography, it cannot be regarded as a culturally neutral representation (Kiarszys, Szalast 2014).

Of all the presented sources, maps made by archaeologists during test excavations appear to be the most different from the rest. According to J. B. Harley (1988, 289) some distortions of maps are not deliberate acts, but arise from the application of common knowledge without realizing that it leads to distortion. That may explain why the analyzed earthwork was recorded by archaeologists as a circular structure. The identification of archaeological micro-topography always refers to the mental patterns that precede perception. It is based on earlier experiences and can be altered in time. Similar ideas can be found in the works of Immanuel Kant, who concluded that there is a noticeable difference between 'seeing things' and, 'understanding what we saw' (Skarga 1982, 46). In certain circumstances preliminary knowledge can appear as more credible and persuasive to archaeologists than field measurements and rules of topographical representation. In the discussed examples, field measurements were not used as verification but as an inductive confirmation of what was already known. Perhaps the rectangular shape of the moat (which is a very unusual feature, without any known comparison in the region) appeared to archaeologists to be so unlikely, that it was measured and drawn as circular. Both making and reading the map can be influenced by preliminary knowledge gained from sources such as books, photographs and paintings that structures the ideas of a landscape (Rewers 1996, 35–37).

Cartographical images influence to a certain extent human interaction with the cultural landscape. As mentioned earlier, it seems that in the 1940s when the earthwork was recorded on the photomap, the rectangular moat was well preserved as its extent can be clearly seen. In the 1980s, new forest was planted to the east of the stronghold in Chróścina, and this was preceded by deep ploughing. This destroyed the western part of the moat, almost completely levelling it. In this case, erasing the archaeological site from topographical maps negatively influenced its protection, as the people from the local office of Polish State Forestry Administration were not aware of its cultural value.

MAP AS A SUBJECT OF IDEOLOGICAL SELECTION

About 2,5 km to the southwest of the referred to early medieval earthwork, on the eastern edge of Chróścina village, is another archaeological site. It is a quite well preserved late medieval motte (Nowakowski 2008, 448–450), and is shown on the *Messtischblatt* map (sheet no. 4265) as a circular feature surrounded by water (Figure 5). However, there is no additional description explaining its origin, nor any information that it is a cultural heritage site. According to the 1940s German photomap its shape appears to be much closer to rectangular (Figure 5) and the same conclusion can be drawn from the interpretation of the DTM based on

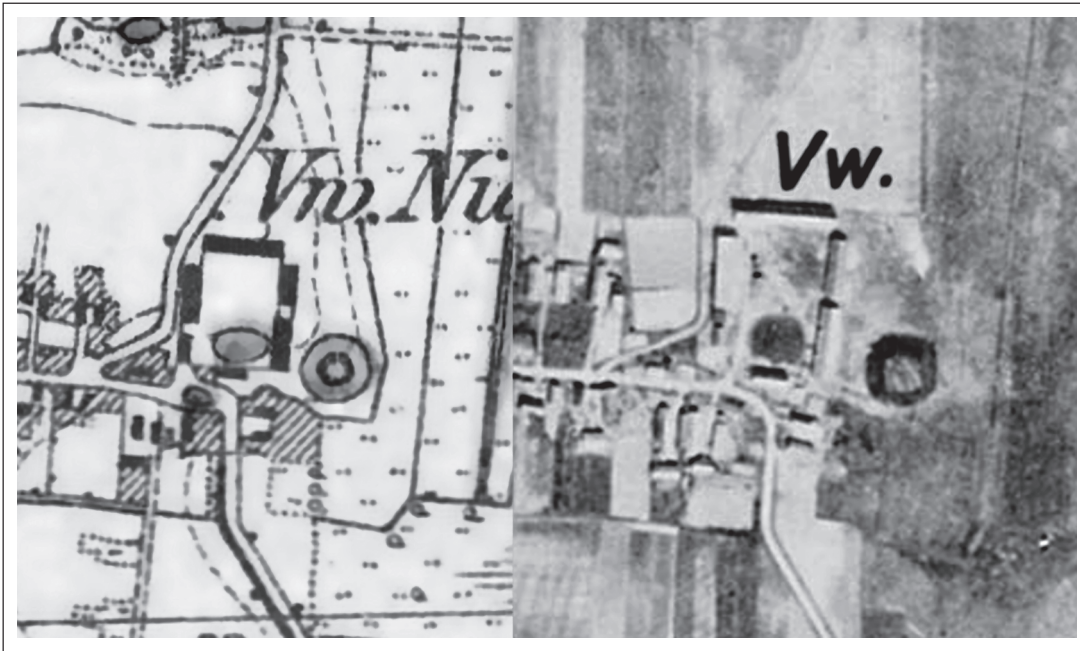


Figure 5. The remains of a late medieval motte from Chróścina. Comparison of Messtischblatt map and photomap.
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ALS (Figure 6). The 1970s Polish topographical map gives no description or local name of this place and presents the feature as an oval mound, with no mention of water in its vicinity.

Perhaps the remains of a late medieval motte were regarded by the German cartographer as less meaningful because of its late date and frequent occurrence in the region, or perhaps it simply was not recognized as an archaeological earthwork. Thus, due to the certain autonomy of the cartographical presentation, this example can be regarded as the result of selection. It is difficult to determine if it was a deliberate action of the cartographer or not. A similar explanation applies to the 1970s Polish topographical map. Unlike the previous example, the large scale map made by archaeologists during fieldwork is consistent with the information obtained from the photomap and ALS (Nowakowski 2008, 448).

A different means of selection applies in the case of the late medieval earthwork in Belcz Mały (Lower Silesia, District Wąsosz) (Lodowski 1965; Kaletyn 1968; Nowakowski 2011). The archaeological site was marked on the *Urmesstischblatt* map (sheet no. 2560) as a rectangular feature and identified as ‘Swedish Earthworks’. It was surrounded by several smaller tributaries of the Barycz River. On the next edition of the *Messtischblatt* map (sheet no. 4465) the landscape has changed, mainly due to the canalisation of Barycz River. On the *Messtischblatt* map the river has only one channel and flood protection earth banks on both sides. The late medieval earthwork was marked with some changes in comparison to the *Urmesstischblatt* map. A smaller mound was added to the west of the larger one, with a flood protection earthen bank cutting through it (Figure 7). Similar conclusions can be drawn from an interpretation of the German photomap from 1937. However, due to insufficient resolution and the presence of trees, the *Messtischblatt* map in this case appears to be a more detailed source than the photomap.

The image registered on the photomap indicates that before the 1930s the earthwork was converted to a park. After some years, trees have covered the whole feature, and its shape could no longer be determined from aerial photographs. This is probably the main reason why this stronghold was marked as circular on plan after World War II on the Polish topographical map (Figure 7). Due to vegetation, the cartographer was unable to determine the extent of the feature based on aerial photographs, and so referred to the common idea that medieval earthworks are usually circular in the shape.

But why exactly did the Polish cartographer register the location of this particular earthwork, as the general tendency was not to mark archaeological features on the maps at all? Perhaps the description on the map may be helpful in finding the answer to this question. From this we can learn that the cartographer

believed that they were registering the early medieval castellany stronghold, which was an important administration centre of the early Piast Monarchy. Such a feature could be exploited by communistic propaganda and presented as material proof of Polish presence in the ‘regained territories’.

In fact the earthwork in Belcz Mały, since the first survey, was considered by archaeologists as an example of the remains of a late medieval motte castle and has no relation to the early medieval Polish Monarchy. The cartographer confused it with the stronghold located about 2,3 km to the northwest, outside Sądowel village (e. g. Kaletyn, Kaletyn, *Lodowski 1968*, 129–132; *Lodowski 1972*). As a consequence, while the feature in Belcz Mały was clearly marked on the topographical map, the remains of the real early medieval defensive settlement in Sądowel were indicated very modestly, only as a topographical feature, with no proper description (Figure 8).

Many more details about the topography of the earthwork in Belcz Mały can be interpreted from the field map produced during the archaeological excavations in the 1980s. The feature was recorded as a rectangular mound surrounded by a wide moat, which is also rectangular in shape. The DTM based on ALS confirms this general outline (Figure 9). However, even here a small part is missing. On the DTM, just beside the bigger mound there is another, smaller rectangular earthwork. It was also marked on the *Messtischblatt* map, unfortunately due to insufficient resolution and the presence of vegetation, the photomap cannot be used as a source in this case. It is difficult to interpret the function of this feature, although it does resemble a smaller version of the adjacent bigger mound. We can also guess that in the past it was surrounded by similar moat, which could have been later destroyed by the river being regulated. Its remains are still preserved in the north and northeast part.

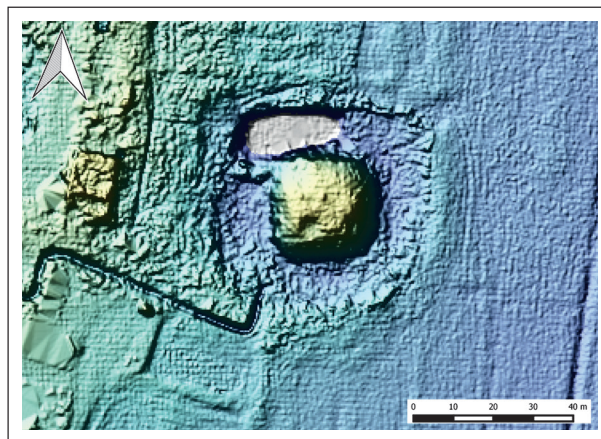


Figure 6. The remains of the late medieval motte from Chróścina, seen through Digital Terrain Model and Hill Shaded Relief processed from Airborne Laser Scanning data. © Grzegorz Kiarszys.

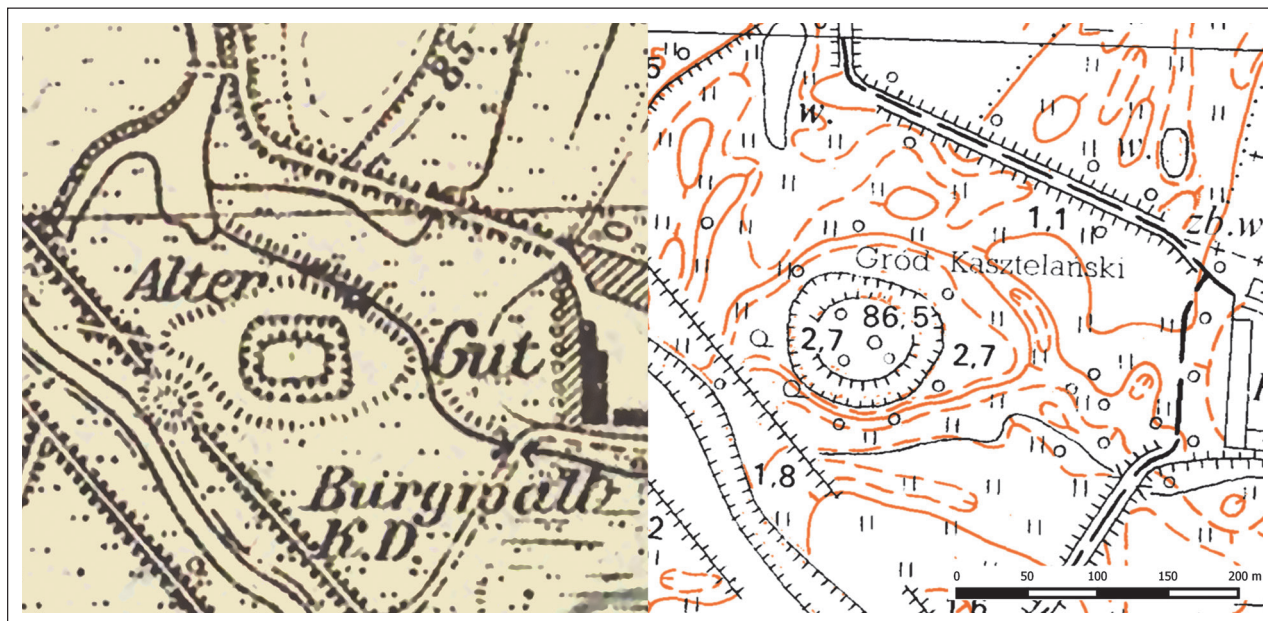


Figure 7. The late medieval earthwork in Belcz Mały (Lower Silesia, District Wąsosz). Comparison of the images of *Messtischblatt* map and a 1970s Polish topographical map. © Szczecin University; © CODGIK.

This smaller feature was not included on the archaeological maps reproduced in scientific publications. From an archaeological point of view it is very unusual to come across two late medieval fortifications – two towerhouses – located in such close proximity, and this is probably the reason why the smaller mound was never mentioned in any archaeological publication. What is even more significant, it appears on the original map drawn during the referred to excavations. Thus we can believe, it was certainly noted, measured and drawn by archaeologists. However, for some reason it was decided to omit its existence and erase it from the published version of the map. This was done perhaps either because it was regarded as a non-archaeological feature, or to avoid difficult questions.

CONCLUSIONS

Human perception is historically dependent and dynamic. It is involved in social and symbolic relations. Knowledge produced through this perception takes its starting point in the idea of the ordering of the world. Every historical epoch can be distinguished by different intellectual trends, ideology, economic bases and socio-political system. This variation results not only in different ways of thinking, but also different strategies of agency and their material products.

In my opinion attempts to represent cultural landscape through maps, images or narration, sometimes tells us more about the way we think about the world and how we rationalize it than about the places and features we deal with. In this article I have discussed the relationship between ideology, preliminary knowledge and perception of archaeological heritage sites. I purposely referred to examples from historical cartography, because in the specific conditions they can be regarded as a record of general changes in the ideas of cultural landscape. However, this image is both fragmentary and generalized and certainly does not cover the whole problem.

A map is a sort of formalized text. The reading of a map, as with the interpretation of a painting, does not have a definite beginning or ending, because it is usually problem oriented (Mayenowa 1973, 51) and subjective to the mechanisms of a hermeneutic circle. The code of a map consists only of vocabulary and does not have strict syntax rules (Rewers 1996, 34–35). Thus, the message of the map can be understood in different ways. The map is not a representation, nor a mirror (Wood 2002, 141).

An awareness of the cultural contingency of maps, aerial photographs and ALS-derived images is in my opinion a necessary part of their critical interpretation. Such sources can always be narrated in many different ways and often contain a hidden agenda – a perspective dictated by their creators. Understanding of the historical context of the spatial data in general helps to reveal their limitations. As any other archaeological sources they are selective and reductive in character. The image of the world created through them is simplified. The way archaeologists experience the cultural landscape through those sources is completely different from the experience of past societies. As soon as those factors are taken into consideration, they can be identified and controlled within archaeological narrations.

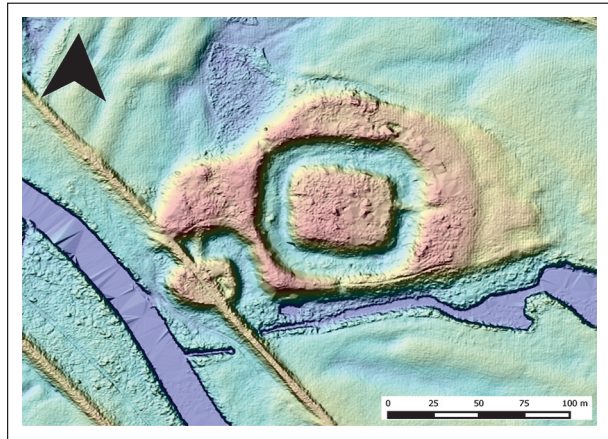


Figure 8. *The late medieval earthwork in Belcz Maty, seen through Digital Terrain Model and Hill Shaded Relief processed from Airborne Laser Scanning data.* © Grzegorz Kiarszys.

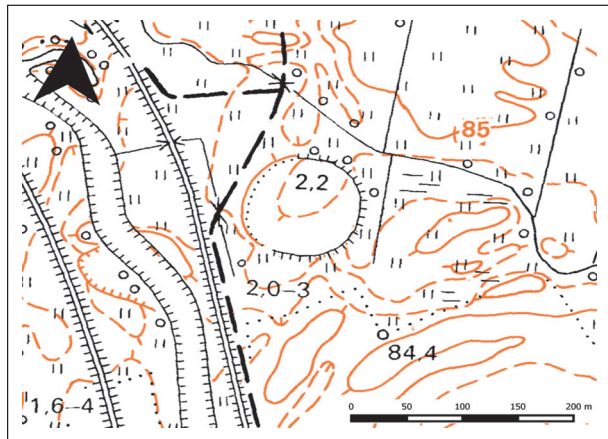


Figure 9. *The remains of early medieval stronghold from Sądowel as seen on a 1970s Polish topographical map.* © CODGIK.

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A river in a rural public space in the early 1940s: a case study of the Bug river valley (East Poland)

Abstract: *The paper presents selected aspects of the role of a river in rural public space, drawing on research for six villages in the West Polesie region, close to the Bug River in eastern Poland. Retrospective analyses were based mainly on archival aerial photographs from the 1940s and to a lesser extent on topographic maps from the late 1930s, overlain on contemporary orthophotomaps (using ArcGIS software). Results are compared with information obtained from interviews with residents, especially the oldest people who have lived in the area since the 1940s.*

The aim of the research was to discuss three basic issues. Firstly, to determine the former system of public spaces, how they functioned and their relation to the river. Secondly, to determine the landmarks of the traditional rural landscape of in these villages, in particular elements such as roads, squares, the main buildings, common spaces on river bank and other places of meeting. Particular attention was paid to the presence of the river in the landscape and its importance to landscape character. Finally, the question of the extent to which it is possible to determine the location of public spaces and the role of the river in the village social life on the basis of archival aerial photographs. All issues were considered for both the 1940s and for the present day. On this basis the changes in the rural landscape and functioning of public spaces that have occurred in this area over the last 60 years are discussed.

INTRODUCTION

Public spaces are very important parts of every town or village, both in social and visual respects. The main role of such space is to support or facilitate public life and social interaction (Carmona 2010, 137; Habermas 1991, 2; Cybriwsky 1999, 231; Mitrašinović 2006, 22), and the symbolic and aesthetic aspects of the public places are also very important (Chmielewski, 2004, 15), which makes it an integral part of rural community identity. Discussion of public spaces almost exclusively refers to urban contexts. This is because many authors regard rural areas as homogenous communities where most neighbours are known to each other and where meetings with strangers with new cultures and social ideas do not occur (Nowakowski 1960, 9; Gleeson 2006, 3, 84). On the other hand, a number of publications about rural sociology emphasize the heterogeneity and diversity of rural areas (Rigg 1994, 124; Bukraba-Rylska 2008, 415; Potter 2010, 17) confirming the validity of using the term “public places” in rural areas. Thus, for the purpose of this article we understand this term to include all important meeting places which also pertain to social space (Chmielewski, 2004, 14) or collective space (de Solà-Morales 1992, 8).

A typical feature of rural space is organicity and adaptation to natural conditions, characteristics that can be seen both in the settlement network and the single village pattern (Dobrowolska 1976, 137; Soszyński 2011, 191). This is why the village cannot be meaningfully studied from an exclusively naturalist or culturalist perspective (O’Rourke 2005, 69). Describing cultural landscape and social functioning of the site, we

have to take into account the characteristics of the environment. In the case study presented below a key element is a river valley. The role of flowing water in shaping settlement pattern is well known, and recently many authors have also highlighted the important role of the river in shaping social patterns and creating attractive public spaces (Williams 2001, 426; Tunstail et al. 2007, 369; Åberga and Tapsellb 2013, 102). In most cases this role means the location of public places along the riverside, and for many places the river becomes an important landmark – a key component of the genius loci (Kelman 2003, 8).

In this paper we discuss the role of the river in social functioning and landscape identity of selected villages in the 1940s. As the main object of analysis we chose the public spaces that existed at that time, including both those within the built-up area and in the surrounding rural countryside. For this purpose, in addition to standard sociological methods we used archival aerial photographs. These are commonly used in spatial analysis to reconstruct landscape character, but very rarely as a tool of social analysis. However, with sufficient image quality aerial photographs can provide valuable material for the identification of the key places in the social life of the village – defined as public places. In most papers aerial photographs are used to examine the social aspect indirectly, based on the interpretation of the visible traces of material culture, and are very rarely directly analysed from the perspective of social relationships (Gold 1995, 104; Harper 1997, 57). This paper shows the importance of 1940s aerial photographs for reconstructing selected aspects of rural social life. As Faccioli and Pitasi (1995, 52) state, to build an image of social life, visual sociology should be used in combination with other data, and so in addition to the aerial imagery, we use data from archival maps and interviews with the oldest inhabitants of the village who remember the period of World War II. This gave the most accurate depiction of the river valley as rural public space, and also showed the importance of archival aerial imagery in the recovering social aspects of rural public space. We also address two other specific objectives: firstly to define traditional landscape features of the study area; and secondly to characterize changes in the landscape and the function of public spaces from the 1940s to the present.

METHODS

The study examined five villages (Orchówek, Sobibór-Dubnik, Zbereże, Bytyń and Wola Uhruska) in the Bug river valley in eastern Poland (Figure 1). These villages are of varying size and function, and lie in a variety of locations in relation to the river. All are located on the edge of the valley, but in some cases a broad valley floor up to 1 kilometer across, or oxbow lakes, separates the built-up area from the river. These villages were chosen because they show a great diversity in form within a relatively short stretch of the valley and are representative of the Polesie region. An important factor was also the availability of archival photographs.

Between 1939 and 1941 the Bug valley was the border between Germany and the Soviet Union and in 1944 it was an important strategic military barrier. For this reason the area has a rich coverage of aerial photographs taken by the Luftwaffe, which are now in the collection of NCAP/TARA in Edinburgh. The aerial photographs used in the study are at 1:10.000 scale taken in 1941, and at 1:6000 scale taken in 1944. We used also the Polish WIG topographic maps at 1:100.000 scale produced in 1933. These materials are complemented by contemporary orthophotomaps at 1:6000 scale produced in 2009 and 2012. Recent

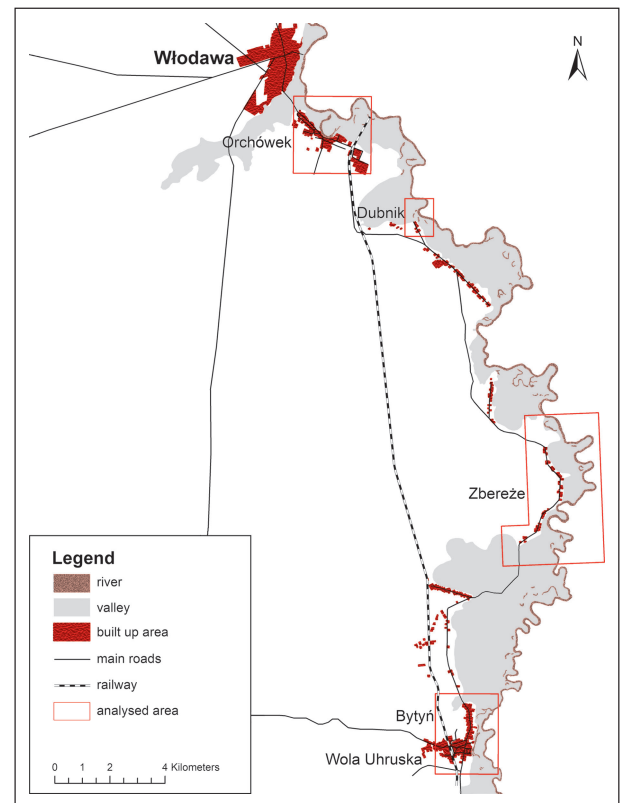


Figure 1. Location of the villages along the Bug River.
© Dawid Soszyński.

aerial images were made available by the Centralny Ośrodek Dokumentacji Geodezyjnej i Kartograficznej (CODGiK) in Warsaw.

The first stage of the study was the retrospective analysis of the older aerial photographs and the contemporary orthophotomaps in a GIS environment. This was the basis for the determination and initial characterization of public spaces and the reconstruction of the landscape. Designation of public places was based on the spatial arrangement of buildings, the location of major facilities, the layout of roads and paths, the positions of the river and lakes, and the visible signs of land use (sandy paths, sites, roadside). The second phase was based on loosely-structured interviews with eleven of the oldest indigenous undertaken in 2014. These interviews embraced a number of questions concerning the character and social functioning of the village with particular emphasis on the locations for outdoor activities and meeting places. Questions were open and the interviewer could explore particular themes or characteristics of the village. It is worth noting that in three cases we managed to interview people who were professional or amateur fishermen in 1940s (or their families were). In the third stage of our analysis, the results of the retrospective study of the aerial photographs were confronted with the results of the interviews.

RESULTS

Places of rural social life – village and the river in the 1940s

The most important and commonest type of public place is the main village roads (Figure 2). This space is evident in every village in the case study and its significance was defined as important or very important (Figure 3). Obviously, the role of rural roads as a place of social interactions is related to the location of a given road section to the centre of the village and to service facilities. Almost always the most important section was located in the centre of a village. The presence of services most often creates a large number of social activities. However, the importance of the areas around the major facilities is dependent on individual circumstances such as the type of service, opening hours and the personality of the owner or salesperson. In Orchówek, for example, according to the interviewees the small grocery was just a place of sale, while the barber shop, thanks to the personality of the owner, was very important place of every day meetings, and not only for customers.

The liveliest and bustling public places were identified in the two largest villages. In the Orchówek this was a main square at the centre of the village, near the church, on the edge of the riverside escarpment, with a view to the entire Bug river valley. It was a place of various daily activities, but in the memories of residents it was particularly a place of Saturday and Sunday meetings. These were spontaneous events with the “whole village” present, and music, dancing, fun and games. In the second village, Wola Uhruska, the most important public place was the railway station, which lay outside the main part of the built-up area and far from the river valley. This was the centre of social life, not only for the village inhabitants but also for neighbouring areas. The arrival of a train several trains per day was always an event, and people came to the station in that times “to see who arrived and who left, to talk with people, to watch the people, to have something to eat ...”.

In all the villages, an important space for social activities was riverside areas. Bathing places are clearly visible on aerial photographs, and are also the most commonly reported by interviewees. Almost always they were located on the riverbank, even if the river was separated from the village by oxbow lakes (Figure 2). According to the resident’s accounts, despite of the lack of footbridges these oxbow lakes did not constitute a barrier. Moderately important were places for washing clothes on the Bug River, streams or spring. These places are rather difficult to identify on aerial photographs. Other activities related to the river were scattered. Some sandy sites with many paths (suspected to be public space based on aerial photographs) proved to be cattle grazing land, but in the summer the same sandy areas served also as a rest place for holidaymakers. Some other sandy areas, initially identified as public spaces later proved to have a natural origin or were proved to be only communication areas.

Almost all the interviewees claimed that the former valley was very busy and teeming with life. It was a space of frequent meetings. The main types of activity were field works, bathing and swimming, fisheries, livestock watering and walking or leisure for holidaymakers. Many of these activities stimulate social interaction, and the areas in which these interactions concentrated became important public places. This happened especially in densely settled villages located close to the river (Figure 3). In villages slightly further away from the river (over a kilometer) and more dispersed in character, there were riverside public spaces of minor significance and all types of activity were rather scattered.

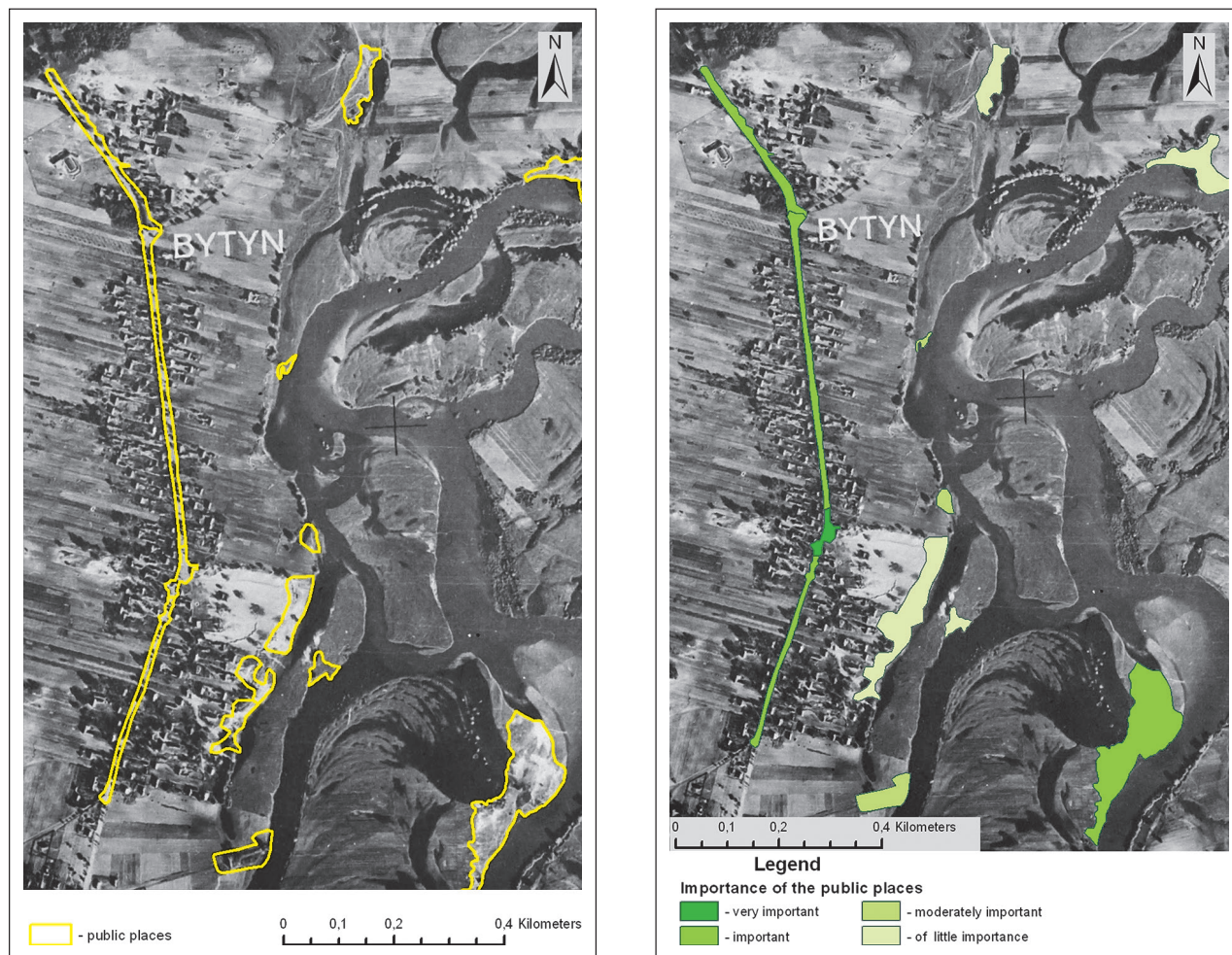


Figure 2. Location of public places in Bytyn during 1941–44 based on aerial photographs and interviews.
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Figure 3. The importance of public places in Bytyn during 1941–44 based on aerial photographs and interviews.
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Changes in rural public space between 1941 and 2014

Comparison of the character and distribution of public space in the past and present shows the scale of the changes that have taken place in social life and the development of villages in last 70 years (Figures 4 and 5). Within the built-up areas (on the plateau), the biggest changes are associated with building development, which have resulted in the appearance of entirely new places. In most cases older areas of public space have remained the same or changed slightly, adapting to the existing distribution of service facilities. However, despite of the development of services, the number of significant (important and very important) public spaces decreased (Table 1). This image is confirmed by the opinions of residents who insist that the current intensity in neighbourly relations is incomparably less than in the past.

	Number of public places in 1941–44	Number of important and very important public places in 1941–44	Number of public places in 2014	Number of important and very important public places in 2014
plateau	21	17	21	9
valley	24	3	8	3

Table 1. Changes in the amount of public places in all villages between 1941 and 2014.

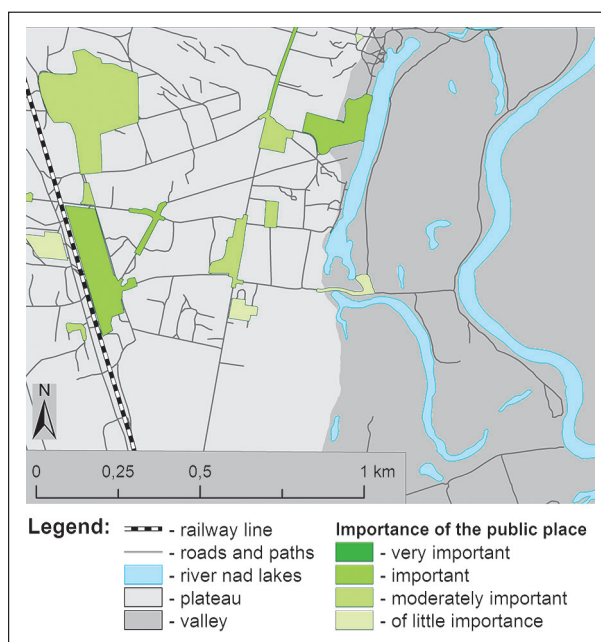
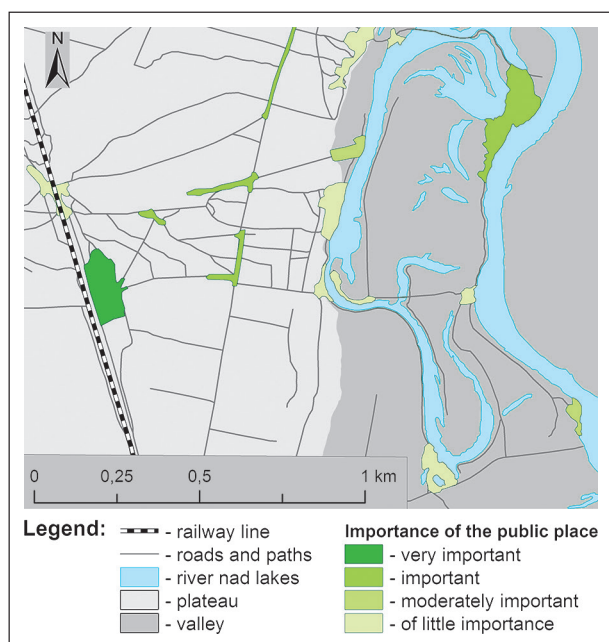


Figure 4. Location and importance of public places in Wola Uhruska during 1941–44 based on aerial photographs and interviews. © Dawid Soszyński.

Figure 5. Location and importance of public places in Wola Uhruska in 2014 basing on aerial photographs and interviews. © Dawid Soszyński.

	1941–44	2014
plateau	7,6 km/km ²	8,3 km/km ²
valley	6,6 km/km ²	5,1 km/km ²

Table 2. Changes in the length of roads and paths in all villages between 1941 and 2014.

Even greater changes occurred within the valley where the number of public spaces decreased significantly. Firstly, many less important daily life places disappeared. The number of important places remained at the same level, but they moved away from the river to the shores of oxbow lakes closer to villages. One of the reasons for this may be a ban on swimming in the river, which after war formed the national border. The change also applies to the development of the most important spaces. In recent years, some of them have acquired a complex infrastructure for recreation (catwalks, shelters, benches, equipment rentals and restaurants). Their popularity is still growing, but today the Bug valley is dominated by recreation and so it does not play such a big role in the village social life as before.

This situation is well illustrated by the density of roads and paths in the valley and on the plateau. As shown in Table 2 for the past 70 years the length of the trails on the plateau increased, which is mainly related to the development of the built-up areas. In contrast paths in the valley significantly decreased, which is connected with decreasing activity by residents in that area and the loss of daily occupations directly related to the river.

Characteristic landscape features

The perception of the landscape varies between different persons, depending on the individual characteristics of the evaluator. That is why, based on the interviewees opinions, it is difficult to determine the objective characteristics and qualities of the landscape (Amir and Gidalizon 1990, 252). In the interviews very general information was obtained and many of the interviewees were inconsistent with each other or with the

evidence from aerial images. It seems that the landscape issues were not and are still not significant enough for the inhabitants to describe it specifically and reliably. This applies in particular to the retrospective analysis aimed at reconstruction of the past landscape. Therefore, to describe the landscape features of the study area we primarily used aerial photographs supplemented by data from interviews, and a few available ground-based photographs. The characteristics of the landscape and the changes in it are presented in Table 3, based on four main features that can be evaluated using the available aerial photographs.

Years	Landscape characteristics
RURAL SPATIAL ARRANGEMENT (SHAPE AND VARIETY OF SPATIAL FORMS)	
1941–44	<ul style="list-style-type: none"> - regular arrangement of buildings (houses oriented), generally single frontage - irregular arrangement of routes and borders (especially in the valley) - little variety of land use: buildings–field–routs
2014	<ul style="list-style-type: none"> - irregular arrangement of buildings, single and double frontage, different types of farms (agricultural, residential, recreational) - irregular arrangement of routes but regular borders (even riverside public places) - higher diversity of land use
FORMS AND TYPES OF BUILDINGS	
1941–44	<ul style="list-style-type: none"> - generally uniform function, form, size and arrangement of buildings - few buildings with a distinctive form of (church, school, windmill) - no building in the valley
2014	<ul style="list-style-type: none"> - different form, size and arrangement of buildings, different types of farms (agricultural, residential, recreational) - numerous buildings with distinctive form (service facilities and industrial buildings) - accompanying buildings in all important public spaces in the valley
FEATURES OF RURAL GREENERY (AMONG BUILDINGS AND AS A BACKGROUND)	
1941–44	<ul style="list-style-type: none"> - in most of the area only low greenery; in some parts of the villages trees accompanying buildings or roads lined by trees; very few shrubbery - in Wola Uhruska characteristic numerous pine trees giving the village park character - in the Bug valley mainly meadows and fields, and single old trees; few shrubbery - around the villages fields with single trees on the balks
2014	<ul style="list-style-type: none"> - very few roadside trees; few trees between the buildings; many shrubs and even fragments of forest in the vicinity of the building - in Wola Uhruska still the most characteristic are pine trees - many villages completely or partially surrounded by forests and brushwood
SCENIC RELATIONSHIP (INCLUDING THE RIVER)	
1941–44	<ul style="list-style-type: none"> - most of public spaces had views on the open space of fields and meadows - most of public spaces in the valley had view of the river or lake but on main rural roads there are only 6 view points on the river
2014	<ul style="list-style-type: none"> - a few public spaces have views on the open space of fields and meadows (rarely on the river) - on main rural roads there are only 4 view points on the river

Table 3. *Characteristics of four analyzed landscape features in all the villages.*

As we can see, the main change in the landscape structure is the increased diversity and fragmentation of land use. In contrary to the trends reported for other parts of Europe, in the study area the intensification of agriculture has not occurred and the mosaic of land use has not been replaced by large homogenous areas like in Sweden, Germany or some other parts of Poland (Ihse 1995, 36; Nohl 2001, 224; Krysiak 2008, 101). Otherwise, especially in the river valley, large and homogenous open spaces were replaced by a mosaic of meadows, forests and wastelands (Figures 6 and 7). In contrast to better developed regions (Nohl 2001, 224), also

loss of naturalness has occurred here only with small areas of building and industry development. But at the same time, new geometric divisions (borders, lines of trees, sports facilities) have been introduced, especially in the river valley, where formerly the landscape was less natural but more adjusted to the natural, curvilinear landscape pattern. Also the increase of diversity in building is very distinct, both in terms of their function and form (Figures 6 and 7). However, this diversity resulted from a lack of regulation in land development which has produced spatial chaos and loss of regional identity, especially in heavily developed areas. Very significant changes have occurred in the rural greenery. Formerly villages were surrounded by open space and the main types of greenery in the villages were old trees. Today there is a considerable increase in the number of shrubs in the villages and forests, trees and bushes around the villages. This is mainly due to the collapse of agriculture and the presence of many abandoned plots and farms. Again, in the vicinity of inhabited buildings many of old trees have been cut down because the residents consider them a danger, underestimating (as formerly) the benefits arising from their presence. As a result of these changes, the scenic value of all the villages has been significantly reduced. First of all, most of the public places lost their view of the open spaces around the built-up areas. Also, places in the river valley that formerly had a good view with the river, in most cases currently do not have such a connection. This also applies to few public places in the central part of the village, which in the 1940s had a direct view of the river. Currently, in all the villages we identified only four view points of the river. It is worth noting that in two cases these views were restored in the last 2–3 years. This shows the growing importance of aesthetic aspects of space among the local community but also the role of the river as a key element of the landscape and village identity.

The value of aerial photographs to characterize the social use of rural space

The case study methodology built on the analysis of the cartographic sources and photo-interpretation as a basis for comparison with the results of interviews with the inhabitants, building the most complete possible understanding and allowing comparison of the different data sources. In general the aerial photographs of appropriate scales (1:10,000 and 1:6000) proved very useful for determining the location of public space. The location of public spaces in all villages was correctly determined in 81% of cases. The accuracy of identifying these sites within the built-up area of the village was higher at 96% and within the river valley was markedly lower at 67%. The errors arose from the misinterpretation of aerial photographs or the fact that some places were impossible to determine in the aerial image of that scale. But it should be stressed that these errors were mainly related to the places of less importance, and for the most important sites correct identifications are 90%.

Aerial photos were less useful to determine the function and importance of public spaces in the social life of the villages. Comparison of the data obtained from the photo-interpretation with data from interviews showed that attempts to determine the significance of public spaces were accurate only in 52% of cases. Also here, the results were much better for the built-up area of the village than for the river valley. In this case, also, most of the errors were related to spaces of little importance.

Finally we can confirm that historical aerial photographs are crucial for determining many of the traditional landscape features, most of which could not be determined only from interviews with former residents. At the same time, based only on aerial photographs we were not able to fully determine the actual function of public spaces. Tilley (1994, 15) claims that places are always far more than points or locations, because they have distinctive meanings and values for each person. Therefore it is difficult to analyze them solely as a physical space and on the basis of universal schemes. Also Uziel (2010, 278) points out that the history of a place can be analyzed from aerial photographs but to obtain a complete image personal testimonies are necessary. As we can see both methods used in this study are complementary and it is their combination that reveals the probable image of former public spaces and the role of the river in social life and landscape identity in the former and modern Polish countryside.

CONCLUSION

It is clear from our research that public spaces in rural areas can be identified, and that these places existed and were very important for the functioning of the villages. In the last 70 years the intensity of their use has strongly declined, but they still function, in most cases in approximate locations. Many places that were important for social relations were formerly associated with the river. This relates particularly to the summer

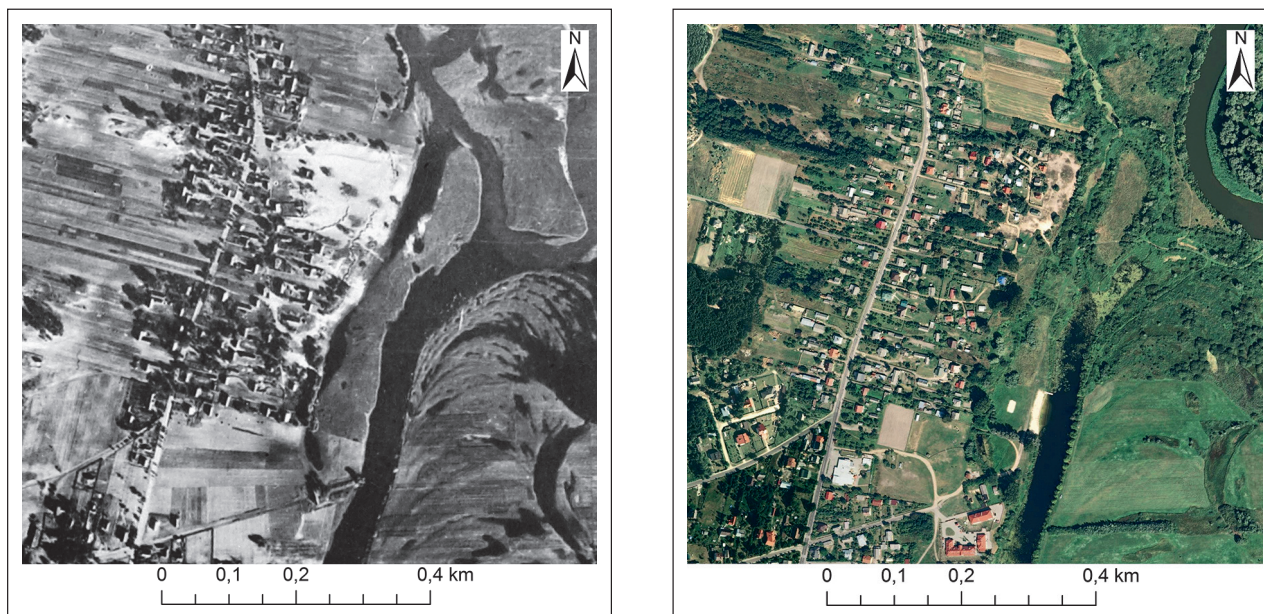


Figure 6. Character of the landscape features of Bytyń and Wola Uhruska visible on an aerial image taken in 1941. © TARA NCAP/ncap.org.uk.

Figure 7. Character of the landscape features of Bytyń and Wola Uhruska visible on an aerial image taken in 2014. © CODGIK/codgik.gov.pl.

time when the valley was the scene for all types of activities, which according to Gehl (1998, 193) are necessary, optional and social – the latter which is key to the right functioning of the public places. The importance of the river in rural life depended largely on the distance between the built-up area and the valley, river or oxbow lakes. Where the river lay close to a village it represents an important arena of social life (places of washing, bathing, meetings). Where the distance was greater (more than 0,5 kilometers) the number of these activities was lower and they were more scattered across the valley. As a result, in these villages important riverside public places did not develop.

Today the Bug River plays a minor role in the village social life as it was before. The valley is to a lesser degree used economically, while the naturalness of the landscape has increased. In the valley there are mainly recreational activities, which significantly limits its role as a space for everyday social interaction.

In the past, and even more so today, only in a few public spaces is the river a visible part of the landscape. In the 1940s this was mainly due to the spatial structure of the villages and the land forms. Today an additional cause is the loss of open spaces of meadows and fields and landscape fragmentation. However, the river is still present in the minds of inhabitants and, to a large extent, determines the identity of the villages. Evidence of this is the attempts to restore the view between public spaces and the river, not only because of tourism development, but also for the residents use.

As demonstrated in the case study above, archival aerial photographs can be a very important source of information about the social life of a village, especially in its spatial aspect that is often lacking in classical sociological research. But certainly, for a complete image of the function of public space the inhabitant's accounts analysis are also essential.

Acknowledgement

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Recovering the lost landscapes of abandoned villages in the Sudetes Mountains, southwest Poland

Abstract: *This article presents a study of abandoned villages in the peripheral mountain region in southwest Poland, where the remains of former settlements and past human activity are still preserved in the landscape. These are briefly described in the paper, but the main focus is on the methodological issues of reconstruction and investigation of such places. A variety of different methods from various fields of research were combined in order to assess the overall human impact on the landscape and the persistence of the traces of the past activities in the contemporary environment. The advantages and constraints of each method are also discussed.*

INTRODUCTION

The Sudetes Mountains have witnessed a large-scale depopulation and land abandonment starting at the end of the 19th century and occurring in three phases from the 1880s, during 1945–1947, and at a greater rate in the period 1950–1970. The depopulation was due to both environmental conditions (high elevation, steep slopes, poor and shallow soils, harsh climate) and socio-economic and political factors, such as the flow of people from rural areas to the cities with developing industry, difficult access to more remote villages, the distance to town and cities, and, in addition, after World War II, restrictions on settlement in border areas, the collapse of local industry and handicrafts, and the dilapidation of buildings (Ciok 1991, 1994, 1995). Moreover, in the period 1945–1947 there was a total exchange of population due to the shifts of the state border between Germany and Poland. The traditional knowledge of how to deal with the mountain environment was completely disrupted as the autochthonous inhabitants of the region were forced to leave the area, replaced by settlers mainly from lowland areas, usually with fertile soils. All these processes resulted in large-scale depopulation and substantial shrinkage of the settlement network, with many settlements completely abandoned. The depopulation was followed by major changes in land use and land cover. Natural, spontaneous secondary succession of vegetation developed on the former arable ground, which became overgrown with grass, shrubs and trees and eventually turned into permanent grassland or forests (Salwicka 1978, 1983). This pattern of land abandonment and outflow of people from mountain regions can be observed in many other European areas (e.g. Baldock et al. 1996; MacDonald et al. 2000), however, it is usually slow and occurred over a long period. By contrast, in the Sudetes the depopulation was rapid, especially in the immediate post-war period. The above mentioned processes affected the entire region of the Sudetes Mountains, though the most intense changes and greatest depopulation occurred in the Kłodzko region (Miszewska 1989). Thus, this paper will focus on the Kłodzko study area (Figure 1), although the methods used in the study can be applied in any type of similar research.

The research questions were as follows: (1) what was the scale of depopulation and land use/cover change?; (2) what are the remains of former human activity within the abandoned areas and what is their state of preservation in the landscape?; and (3) how did the environmental system function before the depopulation and how does it work now? In order to answer these questions, various cross-disciplinary research methods were

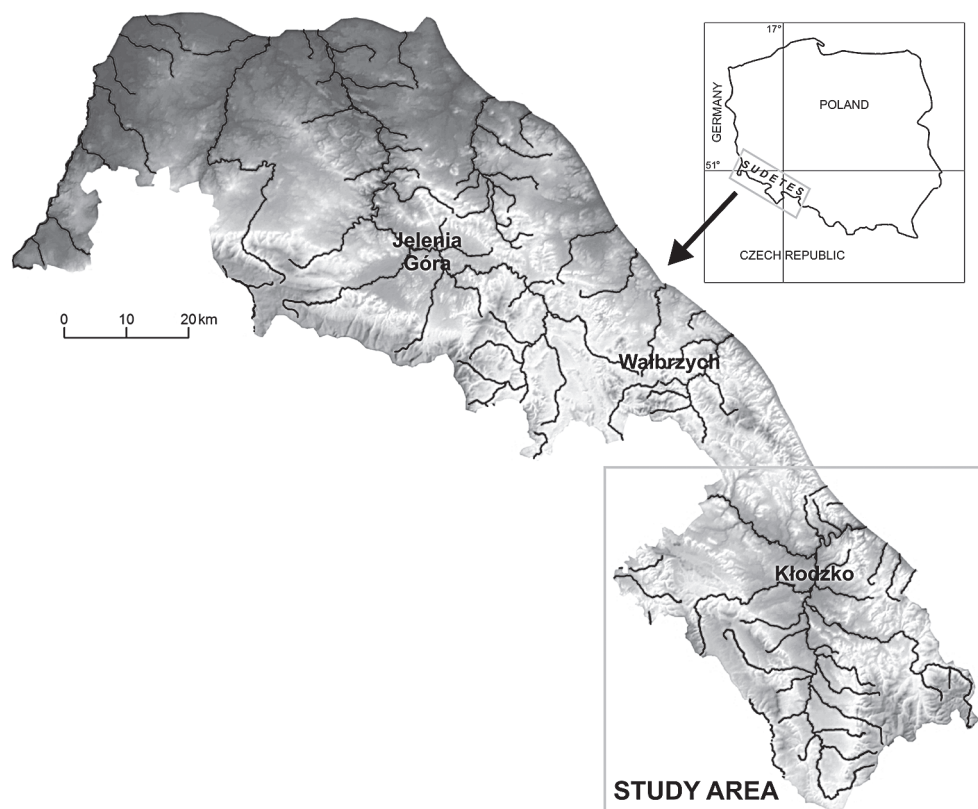


Figure 1. *Study area.*

applied, such as: historical geography, history, geomorphology, sedimentology, landscape ecology and botany, cartography, remote sensing (aerial photographs) and eventually GIS analysis of all the data. The main aim of this paper is to present a critical assessment of the methodological approach, discussing both the results which can be achieved by each method and their limitations, as well as the potential problems which one can encounter when using these methods. In the second part of the paper the final results of the research are briefly discussed.

STUDY AREA

The Kłodzko region covers an area of 1643 sq km and is a historical region with very well defined natural boundaries. Its large central basins (Kłodzko Basin and Upper Nysa Graben) are surrounded by medium-high mountain ranges of the Eastern and Central Sudetes rising up to 1425 m a.s.l. (Figure 1). The bedrock comprises metamorphic rocks (gneiss, schists), granite and sedimentary rocks (sandstone, marls). The region has a temperate climate with prevailing westerly winds and an average annual precipitation of 800–1000 mm. For centuries it was a sovereign administrative unit at the border between Silesia and Bohemia, first under the rule of the Kingdom of Bohemia, later the Prussian (German) Empire and since 1945 within the borders of Poland. The territory of the historical County of Kłodzko (Grafschaft Glatz) corresponds roughly with the present-day Kłodzko County within the Silesian Voivodeship in southwest Poland. The integrity of the region and the stability of its borders over many centuries make this an ideal study area to analyze long-term landscape changes.

MATERIALS AND METHODS – A CRITICAL APPROACH

Statistical population and settlement data – archives, historical sources and current data

The comparative analysis of the long-term statistical data on population and settlements were the fundamental base for research on the scale, rate and spatial extent of depopulation. The statistical analysis considered two main factors, firstly the number of inhabitants in every village and secondly the number of houses. The basic documents for these analyses were the national censuses from both pre- and post-war periods. The available sources covered the following years: 1867, 1871, 1885, 1895, 1905, 1925, 1933, 1939, 1950, 1960,

1970, 1988 and 2002. The comparison of the maximum and minimum number of inhabitants of each village allowed the rate and scale of population changes to be calculated, and also to define the areas for detailed on-site analysis and field mapping, where the depopulation was more than 90%. The statistics on population numbers were crucial to the study, but they were also the most difficult to establish because of various methodological challenges. First of all, the number of villages listed in the censuses changed over time – most often, as smaller settlements were amalgamated into larger villages or towns. These processes of amalgamation and aggregation of the settlement network intensified after the World War II. In the pre-war period the total number of the main settlement units, for which the statistical data was provided in the censuses (excluding colonies, hamlets and parts of villages), varied from 223 in the 1880s to 194 in 1939. In contrast, the present-day list of town and villages for which the statistical data on population number is provided, counts only 185 settlement units. In order to calculate the depopulation rate for the entire period, the aggregation of the pre-war settlements was necessary, along with the grouping in which the smaller settlements were included. Another difficulty was connected with changes in the names of the settlements, not only from German to Polish after World War II, but also in the 1930s some of the villages were re-named for political reasons. Therefore, various historical sources were crucial for matching individual settlement units with its sets of names. In contrast to the pre-war German documents, which are well preserved and easy to obtain in the libraries, the censuses from the post-war period are much more difficult to obtain and to analyze, as they are preserved only partially (i.e. not all the administrative units are covered with the 1950 census) and they are available only as the rough data from the original census forms (no official tabulation for each village), which makes the analysis extremely difficult. Moreover, the last census with available data for each village was performed in 2002, while the last census in Poland from 2011 provided data only for larger administrative units, such as gminas (communes) and regions (counties). To make the things even more complicated, it is not possible to compare the data from censuses with the current information collected by local authorities (Gmina's Office) because of different methods of calculating the number of inhabitants. In censuses the number of permanent inhabitants in-situ is provided, while in the present-day population record the number of inhabitants is based on the inhabitancy register. According to the oral information of the employees in the Gmina's Office, the latter can locally differ substantially from the actual number of inhabitants, due to high level of emigration from the rural, mountain areas. To summarise, the rate of depopulation and the scale of changes of the inhabitant numbers can be treated only as an estimation rather than the exact data. Nevertheless, the general trends of spatial variances of the depopulation process can be traced and they are the crucial base for designating the areas with the highest level of abandonment, where detailed analysis and field mapping could be undertaken in the lost landscapes.

Comparative analysis of the cartographic materials from various periods

Two data sets of cartographic sources were used to assess the qualitative and quantitative changes in land use/cover and in the settlement network in the study area. The historical topographic maps (23 sheets of *Messtischblatts*, 1:25.000) are based on survey during 1882–1884 with minor corrections in 1919–1920. It can be assumed that they represent the state of land use and settlement distribution before the major changes of depopulation and land abandonment occurred in the study area. The present-day data on settlement network and land use was obtained from the Database of Topographic Objects (BDOT), which is the newest and the largest digital database managed by the National Agency for Geodesy and Cartography. BDOT includes both geometric data obtained from the orthophotomaps (2010) and attribute data from the national registers revised by field observations. However, the BDOT topographic maps are in a different projection from the *Messtischblatts*. The content and classification of the types of land cover are also different. In order to compare these two different cartographic sources the historical maps were first scanned and then calibrated to the same coordinate system as BDOT, by transforming the kilometric grid to the Polish national coordinate system (ETRS1989 Poland CS92), followed by the calibration of rasters according to the grid. Afterwards the *Messtischblatts* were digitized and the land cover was divided into four classes comprising settlements, ploughing lands, forests and grasslands. In BDOT there are many more divisions and subdivisions of the land cover categories, therefore the original database was simplified and aggregated in order to obtain the same number and type of land use/cover classes as in *Messtischblatts*. The most problematic classes in BDOT were “areas under water bodies” and “areas under transportation lines”, as they were constructed as polygons,

even though they represent linear features. These two categories were eventually removed from both historical and present-day maps, as the location of main roads and river channels has not changed during the analyzed period. Otherwise, the comparative analysis of the land use/cover change would not be possible.

Time-series analysis of historical aerial photographs

For selected areas, which witnessed the highest level of depopulation and land use change, aerial photographs dating from the mid-1970s and mid-1990s (1:18.000 and 1:30.000 in scale) were analyzed. They were also compared with the orthophotomaps from 2002 and 2010. The aerial images were used to examine the type and extent of large-scale changes, and turned out to be very useful for comparing the land use and land cover from different time periods. The increase of forested areas is especially clearly visible. However, the aerial images also proved that the general landscape structure was very stable, in spite of the land use/cover changes. In many cases, while there were changes in land ownership and the former land boundaries fell out of practical use, they still are well pronounced in the landscape. Linear landscape features, such as field divisions, agricultural terraces, tree-lines along the field roads, and road terraces are clearly recognizable in the aerial photographs from all periods, even though they present often relic, 'fossil' features formed during more intense human activity in the past (Figure 2). In contrast, the aerial photographs are less usable for analysis of minor features because the large increase of forest have obscured them (Figure 3). Other methods have to be used to analyze the spatial distribution of features, such as stone piles and embankments within the former arable grounds or minor water management constructions. For these, field mapping or analysis of Airborne Laser Scanning (ALS) or LiDAR data are the best methods.

Geomorphic mapping and field survey

Detailed field work and geomorphic mapping were necessary to compile an inventory and to assess the state of preservation of the old anthropogenic landforms and features within the abandoned areas. This allowed evaluation of their persistence in the landscape and also to indicate the main factors influencing preservation or destruction of these features. The geomorphic mapping was conducted on the basis of the current 1:10.000 scale topographic maps and the 19th and 20th century German 1:25.000 scale topographic maps. The latter maps were indispensable for defining the extent and exact location of areas of former settlements and other human activities. Detailed mapping was undertaken for nearly 40 localities within the abandoned or highly depopulated villages and hamlets, and their surroundings. The mapping took five years (spring 2010 – autumn 2014), as the period suitable for field work is strictly limited to early spring (March–April) or late autumn (October–November), not to mention that it is also weather-dependant. In the full vegetation season most of the abandoned villages are practically inaccessible due to dense undergrowth that makes identifying features difficult, and in winter there is usually snow cover. Mapping was by GPS, with tape measure and laser rangefinder used for detailed survey. The field mapping allowed us to understand the form of preserved relict features, and to recognize the processes responsible for altering them. The final results of the field work are presented as sets of maps of the types and spatial distribution of various features, and tables with detailed morphological characteristics for each study area (e.g. Latocha 2014). While the field mapping is a vital part of the research, it presents some difficulties, including that the field work is very arduous and laborious, time-consuming and expensive. In addition, some of the places, for example ruins located within a dense coppice or brushwood, are difficult to access, even during the favourable seasons. The features within the forested areas are also difficult to locate precisely with the GPS, and the large number of minor features in some areas, for example stone piles within forests, make it extremely difficult to make sure that mapping is comprehensive. In these cases, additional methods of verification should be applied and ALS (or LiDAR) data are of special importance to solve these problems.

Airborne Laser Scanning data

The detailed Digital Terrain Model (DTM) was created for the entire Kłodzko region on the basis of the ALS data with resolution of 1 m, and used for further analysis such as the relationships between the scale and rate of depopulation and location of the villages (slope, topography, elevation a.s.l., aspect), the impact of land use/cover change on the rate of soil erosion from slopes, and modelling of the local topoclimate and assessing its correlation with depopulation and land use changes. The ALS-derived DTM was also very useful for

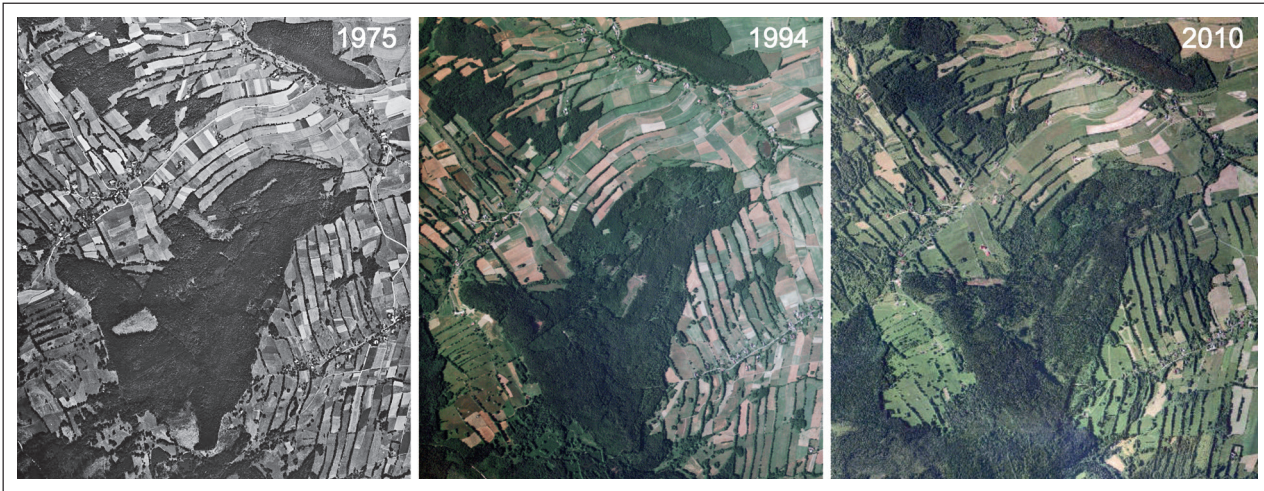


Figure 2. *The stability of major landscape structures and patterns over time. Source: Author’s elaboration on the basis of materials from the National Agency for Geodesy and Cartography (project no. NN 306 384 539).*

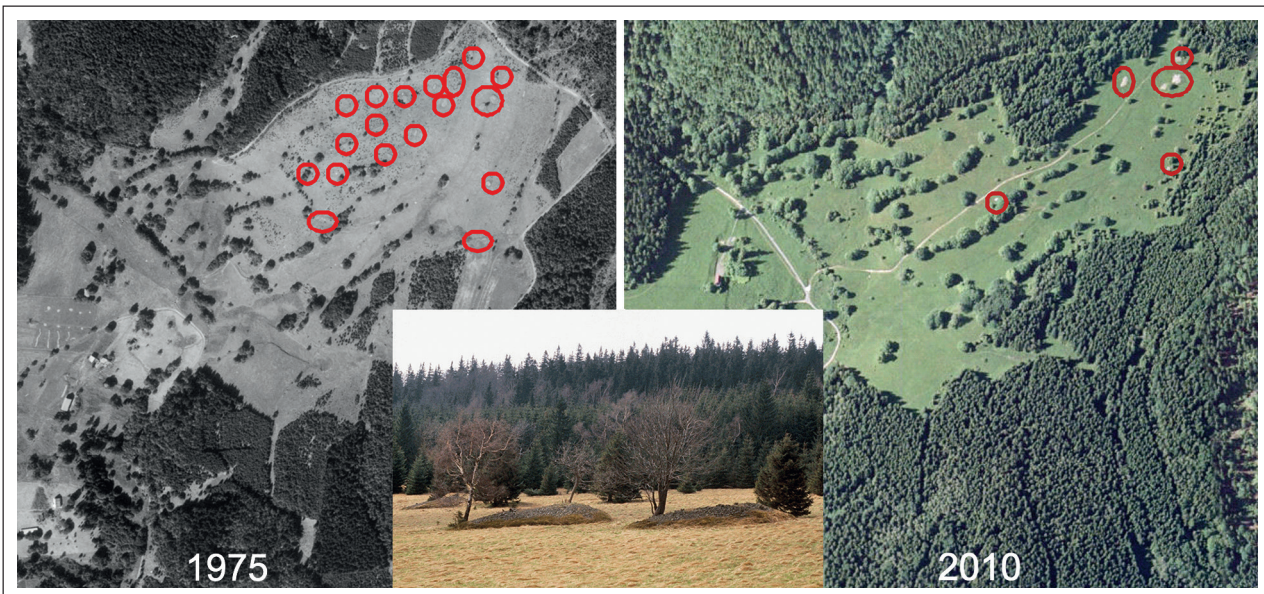


Figure 3. *Aerial photographs are less useful for areas with intense secondary vegetation succession – an example of stone piles overgrown by trees and shrubs. Source: Author’s elaboration on the basis of materials from the National Agency for Geodesy and Cartography (project no. NN 306 384 539).*

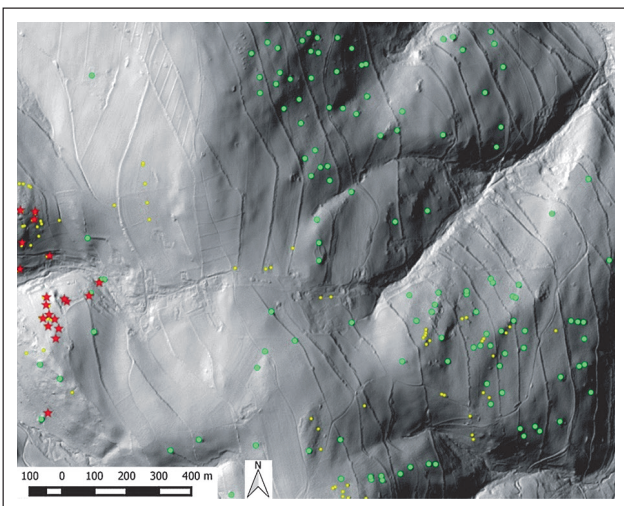


Figure 4. *Road escarpments and agricultural terraces are clearly visible on an ALS-derived DTM; the figure shows also the spatial distribution of stone piles (large – green dots and small – yellow dots) and old mining shafts and drifts (red stars). Source: Author’s elaboration on the basis of materials from the National Agency for Geodesy and Cartography (project no. NN 306 384 539).*

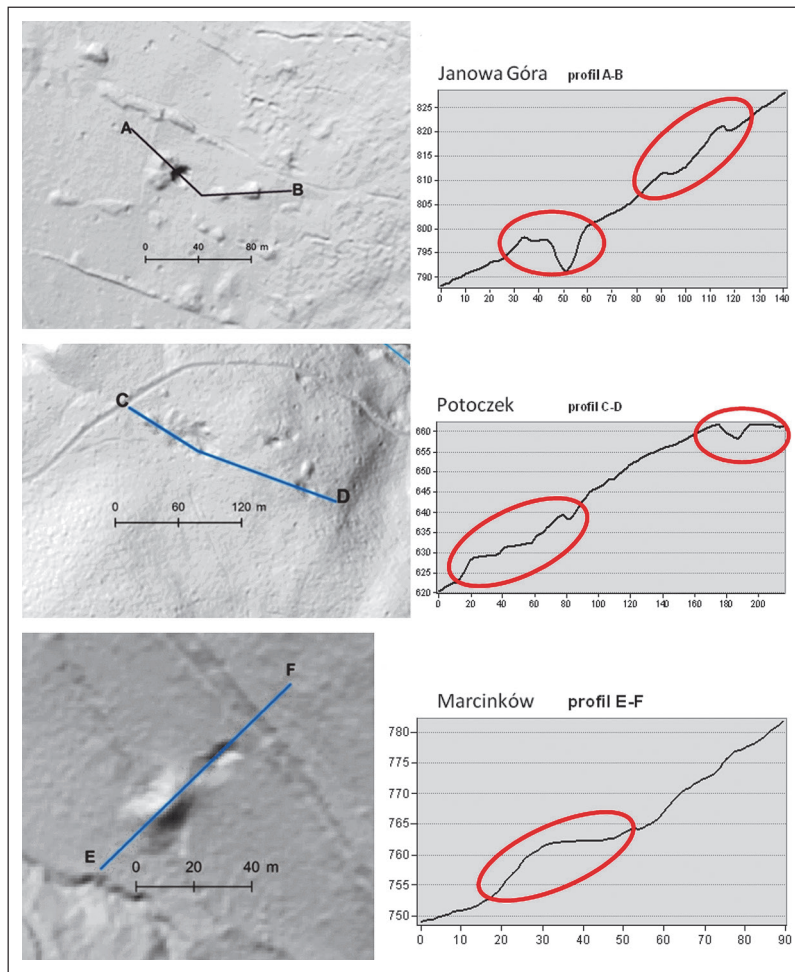


Figure 5. Examples of slope profiles changed by the old mining activity. Source: Author's elaboration on the basis of materials from the National Agency for Geodesy and Cartography (project no. NN 306 384 539).

detailed analysis of selected areas with limited accessibility due to dense vegetation. The ALS allowed us to assess the number and spatial distribution of features such as field road terraces, agricultural terraces, and piles and walls of stones collected from arable ground (Figure 4), complementing and extending the field mapping records. In addition, the combined field and ALS mapping methodology was applied to several areas with intense past mining activity, where the ALS proved especially valuable, especially in the densely vegetated areas where GPS mapping was not possible. The high resolution DTM supported calculation of the scale of human impact on slopes due to excavation and deposition within the mining sites (Figure 5).

Sedimentological analysis and radiocarbon dating

In order to assess the scale and rate of soil erosion from the former arable ground, slope and alluvial sediments were analyzed in several catchments where a large-scale withdrawal of agriculture had occurred (Latocha 2012). There were 150 exposures and coring sites, and more than 300 samples were collected for standard sedimentological analysis in the laboratory (grain-size, organic matter content). The sediments were collected both from slopes with and without agricultural terraces in order to evaluate the capability of these structures to store sediments on the slopes and limit the supply of sediments transported to valley floors and stream channels. The analysis of the alluvial sediments aimed to assess the amount of sediments stored within the catchment and which contributed to building-up the floodplains with fine-grained sediments. In one of the catchments, a thick layer of charcoal was identified at the boundary between the coarse-grained, periglacial sediments below and fine-grained sediments above. The charcoal was AMS-dated revealing a strong correlation with the dates of the foundation of a nearby village according to the historical sources. Three samples from adjacent locations in Jodłów village gave radiocarbon age dates of 365 ± 30 BP, 330 ± 30 BP and 310 ± 30 BP, calibrated to 1440–1530, 1480–1650 and 1480–1650 respectively. The fourth sample elsewhere in Jodłów dated to 600 ± 25 BP (1300–1410 calibrated) and might be linked with a glasswork that predated

the settlement in that area (Latocha 2009a). Thus, the sedimentological ‘archive’ helped to establish the date of the removal of primeval forests and the development of agriculture within this catchment, as well as to correlate the overlying sediments with human activity (agriculture) in the historical period.

Ecological analysis (vegetation indicators)

The basic ecological analysis proved to be very useful for identification of areas with different past land use. The tree lines within the former arable lands help to distinguish the location of former field boundaries and the lines of old roads, even if they are not in use any longer and they are barely visible in the contemporary landscape. The tree lines are persistent and stable in the landscape and easily recognizable both in the field and on the aerial images (Figure 6A). For abandoned field roads it is possible to recognize if they were reinforced by stone walls, even if the road terraces are densely overgrown with vegetation and no inner construction can be seen. However, along the terrace a different type of grass species is noticeable, and usually there is also a linear occurrence of various types of berries, which is an evidence for drier and thinner soil conditions in places where stone walls were built to strengthen the road terraces (Figure 6B). A distinct species of trees and shrubs grow at ruins of former farmsteads, while within the forested areas stone walls and piles can be easily detected, as they are usually overgrown with deciduous species in contrast to surrounding coniferous forest (Figure 6C). In addition, hygrophilous species can be very useful indicators of the location of former water reservoirs, fish and mill ponds, ditches, leats (mill-channels) or even old drainage systems. Surprisingly, in the central areas of many abandoned villages, wetlands and swamps have developed in recent decades, with specific vegetation species. The lack of clearance and maintenance of the old underground drainage system

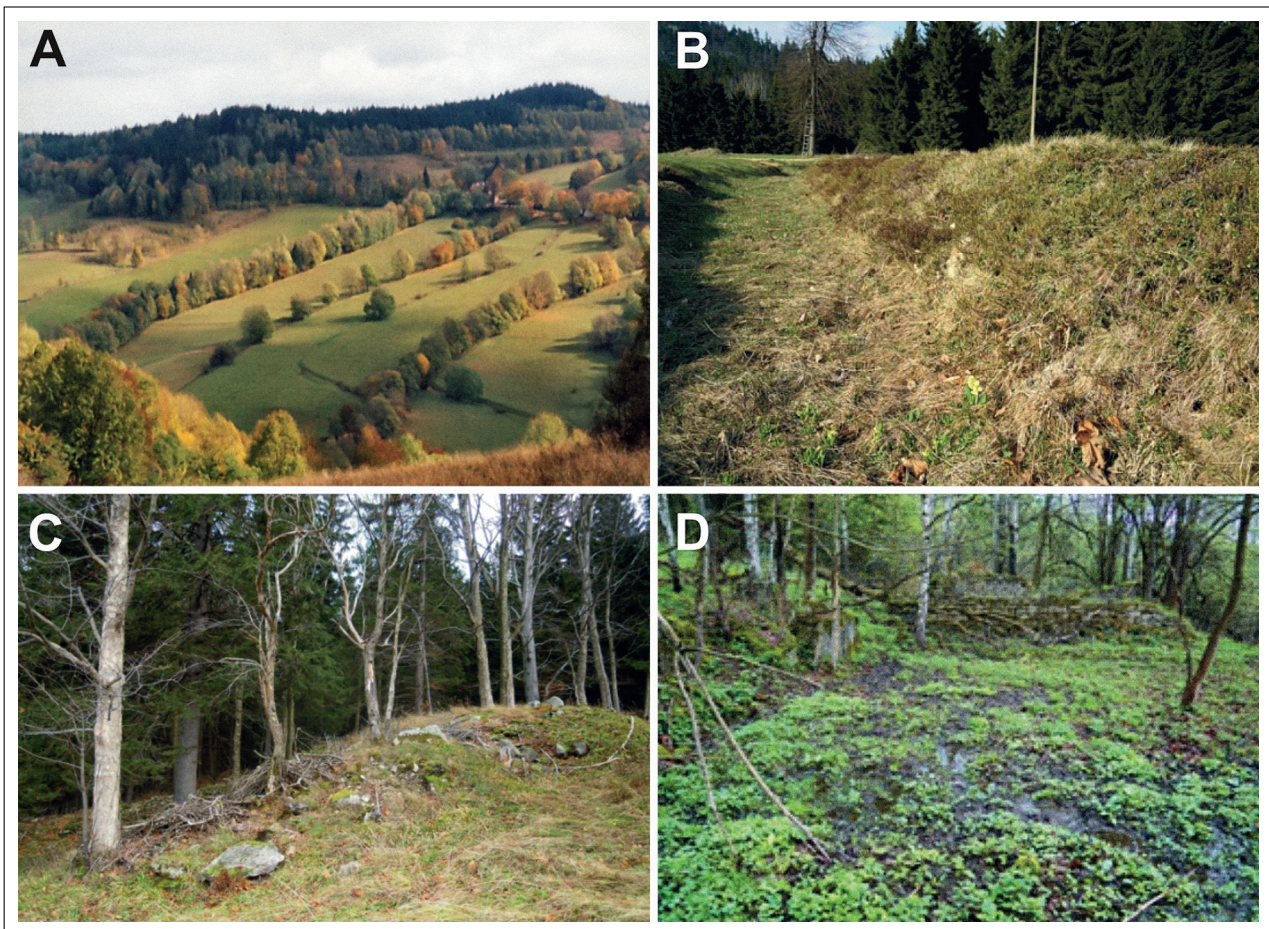


Figure 6. *Vegetation as an indicator of man-made landforms and features: A – tree lines along old field boundaries and field roads; B – stone embankment hidden under shrubs; C – stone piles and embankments are usually overgrown with deciduous trees; D – wetlands developed in the vicinity of former farmsteads as a result of neglect of the old drainage system. Photographs by Agnieszka Latocha.*

is responsible for its collapse and clogging, resulting in rising ground water level and encroachment of the hygrophilous species (Figure 6D). Last but not least, fruit trees are also valuable indicators of the location of former farmsteads, even if the ruins are not preserved. Some of the trees are still fruiting, while others have withered, but both categories are easily discernible from the surrounding forests.

RESULTS AND DISCUSSION

Methodological considerations

In the first stage of the research a database on population and settlement change for every village in the region was prepared from analysis of historical archival data. Comparative analysis of historical and contemporary statistical population data identified the villages and regions with the highest depopulation, as well as areas with total abandonment. All these places (c. 40 sites) were further investigated through detailed on-site research, with field mapping to assess the quantitative and qualitative characteristics of the preserved remains of the abandoned landscapes. This was supplemented by geomorphic mapping with additional use of vegetation indicators. The ecological analysis, along with the analysis of old cartographic sources, were very useful for identifying areas with different past land use, which, in turn, helped in searching for the remains of past cultural landscapes. The pre-war topographic maps were used both on-site during field mapping in order to identify places of former settlements and also during the desk-work, while conducting the comparative analysis of land use/cover and settlement changes in the entire region. The cartographic studies were supplemented by the analysis of the sets of historical aerial photographs, which allowed for a more nuanced visualisation of the changes. However, the aerial photographs are most suitable for showing changes of smaller areas, with a focus on selected landscape features, structures and patterns, while the cartographic analysis were better for larger areas in presenting the general trends of land use/cover changes over the entire region. One of the main aims of the field work was to assess the state of preservation of landforms and features. ALS data helped to provide a wider context for the spatial distribution of all the landforms, features and processes, which were measured in detail on site. In contrast, the sedimentological analysis allowed a deeper insight into the environmental effects of land use/cover changes (e.g. surface wash) and on the role of anthropogenic landforms in

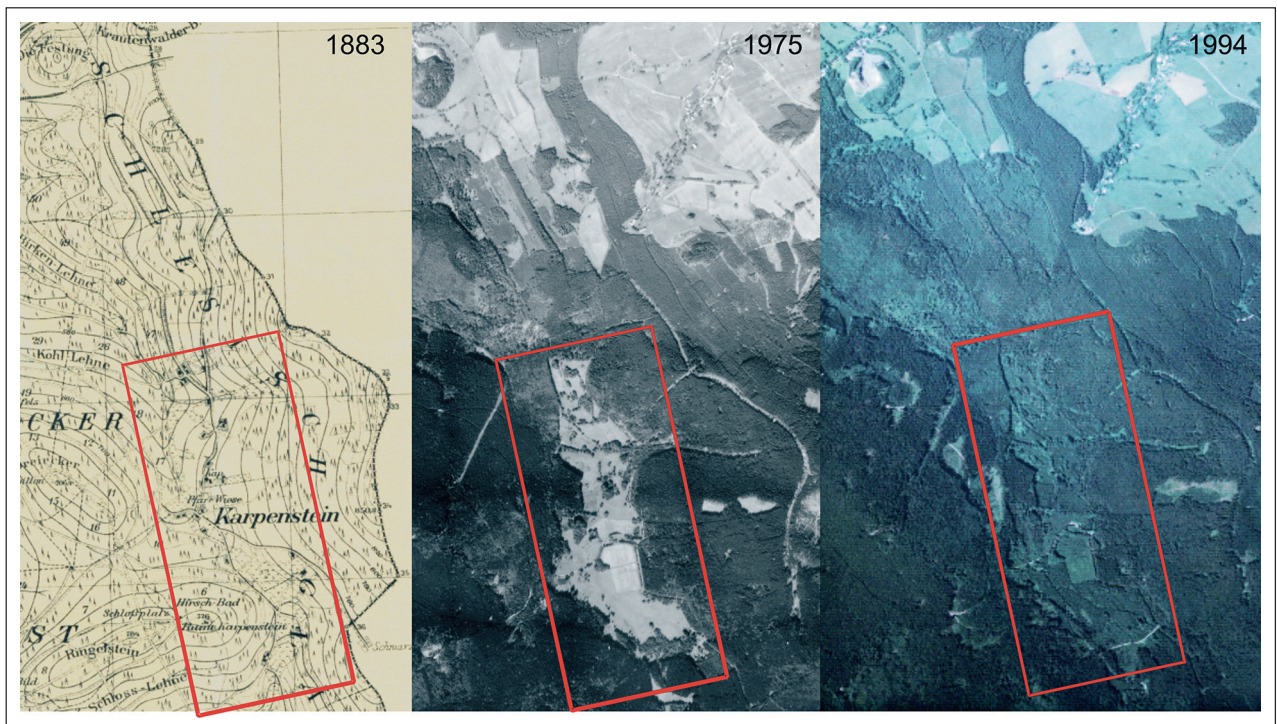


Figure 7. The process of depopulation (Karpno/Karpenstein village) and the encroachment of forests within the abandoned areas. Source: Author's elaboration on the basis of materials from the National Agency for Geodesy and Cartography (project no. NN 306 384 539).

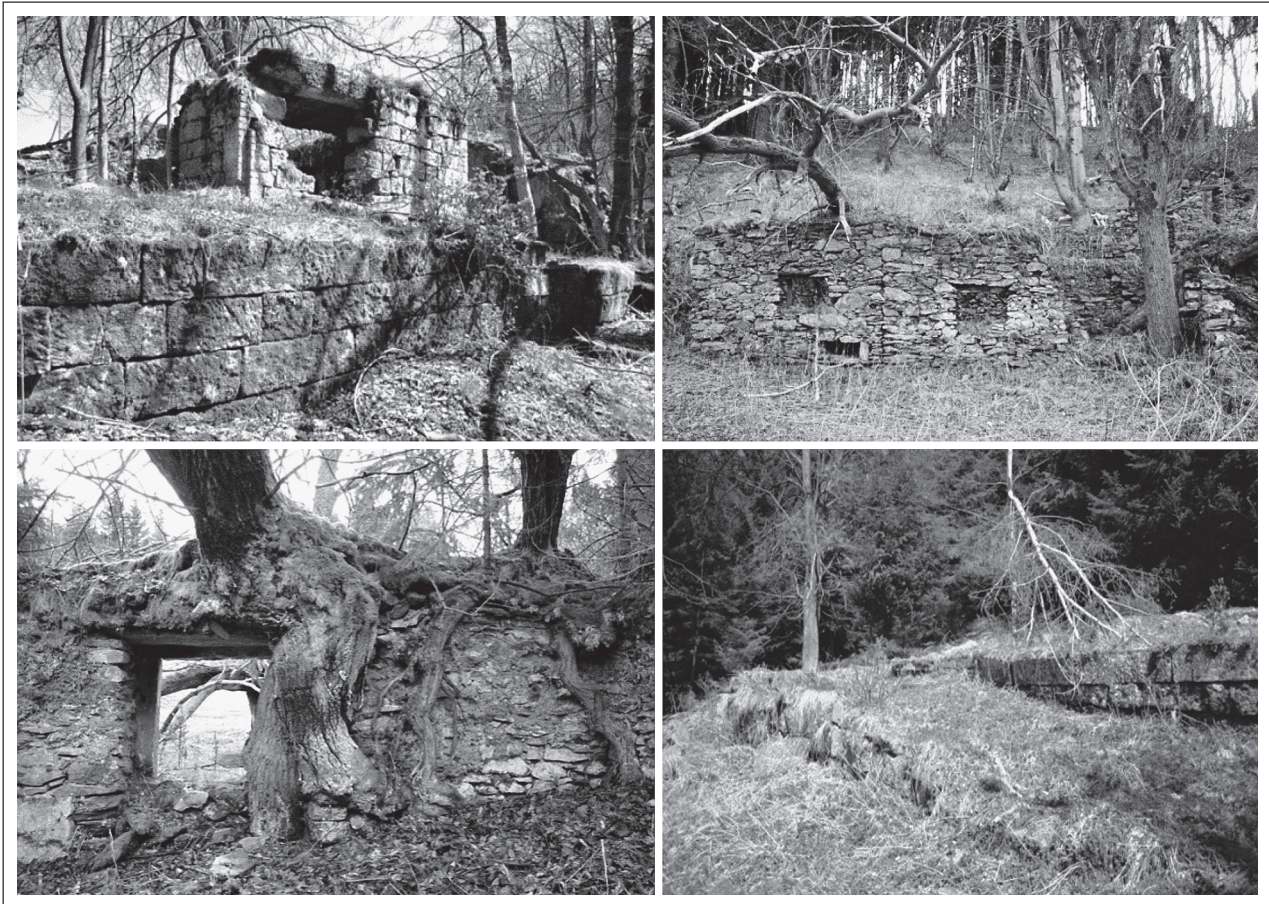


Figure 8. Ruins of former farmsteads are preserved in various states. Photographs by Agnieszka Latocha.

modifying natural processes (e.g. the impact of agricultural terraces on soil erosion). The ALS data was used not only for small-scale analysis of specific sites as an extension of field investigations, but also as source data for DTM construction and spatial analysis for the entire region.

Each method used has strengths and weaknesses, but the various methodologies and sources have contributed to creating a broad, multi-dimensional, cross-disciplinary and multi-scaled context for the study. Such complementary use of various methods and scales of the research allows for a more holistic approach to landscape studies.

This combined use of various research methods in a holistic framework has supported various outcomes: (1) the assessment of the scale and spatial diversity of the rates of depopulation and landscape change in the study area over last c. 150 years; (2) indicating completely abandoned areas where remains of former human activities are preserved; (3) presenting the spatial distribution of the man-made landforms and features; (4) indicating the main factors responsible for preservation or destruction of features; and (5) assessment of the changes in the morphological processes of the past and present.

LANDSCAPE CHANGE – SURVIVAL AND DESTRUCTION

The final part of this paper briefly presents the main aspects of landscape change with a focus on the impact on the differential preservation of remains and on the processes responsible.

Only a few of the settlements in the Kłodzko region has not witnessed depopulation. For most of the villages the rate of depopulation was over 50% between the pre-war period and the post-war period. The depopulation of more than one third of the villages exceeded 80% and 10 villages were totally abandoned. There are also a large number of former colonies and hamlets located either along the state boundary or at high altitudes with difficult access which are today completely deserted (Figure 7). However, even in the villages abandoned in the pre-war period, the traces of anthropogenic landscape alternations are still



Figure 9. *Stone piles and embankments within the former arable lands are numerous in the study area. Photographs by Agnieszka Latocha.*

recognizable, including the remains of buildings – walls, cellars, foundations, ruin mounds or settlement terraces (plantation terraces); the latter ones are usually the longest lasting in the landscape (Figure 8). The remains of former agricultural activity include stone piles and stone walls or embankments, which occur in large numbers due to the dominance of stony and shallow soils; field roads, road terraces and gullies. Water management features are also numerous and include channels, bridges and culverts, wells, dams, dykes, ponds, drains and leats. There are also many traces of former industrial activities, such as ruins of water mills, glass and textile factories, iron-ore plants, and limekilns. Old mining is represented by numerous quarries, drifts, pits, mineshafts, as well as slag heaps, excavation and trial trenches or various hollows and depressions formed by the collapse of drifts or shafts. The remains of sacral architecture, both ruined churches and chapels, and numerous wayside shrines, figures and crosses, are often found in isolated and remote places and are usually dilapidated. Fortunately, some of them have been renovated recently, and are ‘witnesses’ of cultural landscapes that do not exist anymore.

The most dynamic changes affected the field road network. While some are very stable, especially if their terraces are reinforced by stone or if they were paved, many have been disappearing because of overgrowing by vegetation and deformation of road surface and terraces by tree roots, dissection by linear erosion during episodic flows (rain or thawing), and accumulation of organic and mineral matter within the road gullies. Water management features are being destroyed mainly by lateral and deep erosion, while without maintenance the ponds, water reservoirs and leats fill up with mineral and organic matter. As far as buildings are concerned, today they are slowly disappearing from the landscape due to the destructive impact of vegetation, especially tree roots. However, in the first years after World War II many buildings were dismantled by the new settlers and their stones or bricks were re-used. Therefore the best preserved ruins are usually found far distant from contemporary villages, where access was too difficult.

In spite of the progressive disappearance of some old anthropogenic landforms from the landscape, the amount of anthropogenic features from past landscapes and different land use is still compelling. This is not only for the number and variety of the preserved features, but also to their dimensions. The size of stone piles and stone embankments is especially worth mentioning. Stone piles in the study area can reach up to 4 m in height, while their length and width can exceed 20–25 m, while stone embankments are usually up to 1,5–2 m high and can be several hundred meters long (Figure 9).

CONCLUSIONS

The Kłodzko region has witnessed large-scale population and land use changes over the last 150 years, though the traces of past human activities are still recognizable in the landscape, and despite progressive damage to past landforms and features, in many areas they are surprisingly well preserved. This is especially the case for large-scale structures and the patterns of old field boundaries and road networks, which are still easily visible both in the field and on aerial photographs. Minor features are also preserved, but are less easily seen, and therefore the use of various research methods is necessary in order to assess their extent, size and state of preservation. Modern research on landscape changes are usually based on various models and GIS analysis (i.e. Haase et al. 2007; Mottet et al. 2006; Pueyo, Beguería 2007; Reger et al. 2007; Swetnam 2007; Zomeni et al. 2008). However, small landscape features, which nevertheless have great importance for analysis of lost landscapes are often omitted in the modelling processes (Gellrich et al. 2007). The detailed field analysis, such as geomorphic mapping, should be an equally important tool for detecting traces of relict anthropogenic landforms and features, especially in abandoned areas (Lóczy, Pirkhoffer 2009; Latocha 2009b, 2015).

Long-term analysis of landscape change, and especially the reconstruction of landscapes which have vanished due to various reasons, need to involve various research methods and concepts. As illustrated in this paper all methods have advantages and limits, and it is the combination of techniques that gives a complementary, overall view on the patterns in the landscape and the processes that have produced them.

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Landscape reconstruction in the Middle Danube Roman Limes: case studies from Lederata and Smorna

Abstract: *The construction of the Djerdap I dam on the Danube resulted in a number of archaeological sites dating from the Mesolithic to the Late Middle Ages being submerged. A part of the Roman limes was lost, including some important military architecture. While rescue excavations were carried out from 1964 to 1970, the results were published mostly in the form of reports, so even the better publication gives little information on the landscape context of the forts. To address the lack of landscape information, this paper analyses cartographic sources from the eighteenth and nineteenth centuries and modern maps. For the reconstruction of the original position of the fortifications and the past landscape, to support a better understanding of this part of the Roman limes, especially important are the series of aerial photographs made by the Military Geographical Institute, housed in several institutions in Belgrade. These photographs are overlaid onto different surface models, providing much more information about their original spatial settings. Case studies of the Lederata fortification system and Boljetin (Smorna) are presented.*

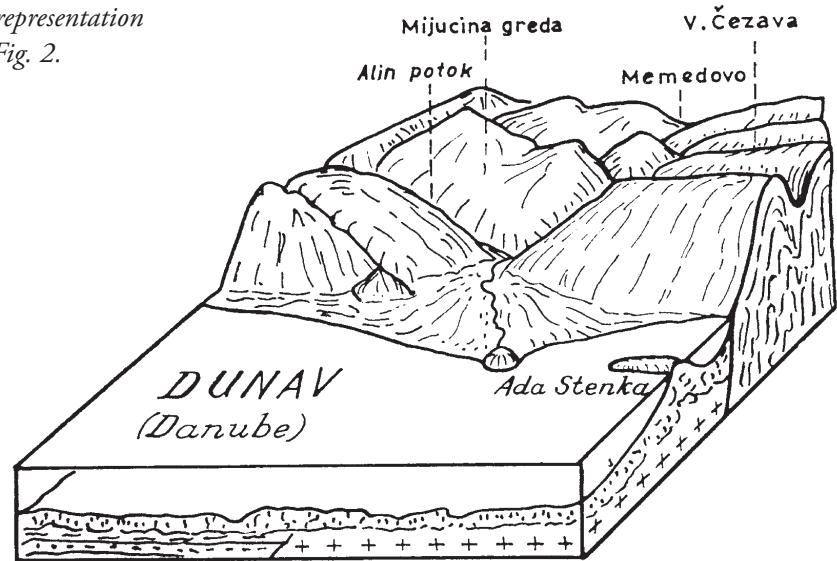
INTRODUCTION

Following the official announcements of the huge undertaking of erecting the hydroelectric power plant Djerdap I, after which large parts of the Danube shores were to be changed forever, archaeological surveys were undertaken. In 1958, the first systematic excavations started at the Veliki Gradac (Taliata) site, while from 1964 explorations were carried out across in wider area of the Serbian Danube region. Simultaneous research on some twenty sites from different periods, but mostly belonging to the Roman and Early Byzantine limes, lasted until 1970. These seven years saw explorations along the 130 km long stretch of the Danube riparian area, in a campaign often referred to as the largest European archaeological research project of the time. All the sites below 75 m above sea level were systematically researched before they were flooded by the rise in the water level of the Danube. This saw the loss of a part of the Roman limes, including some important monuments of their military architecture.

Apart from large area excavations, some work uncommon in Serbian archaeology of that time was undertaken, such as pollen and C14 analyses. For our purposes, geomagnetic surveys and analyses of aerial photographs are much more important (Trifunović 1984; Bošković 1984). Regrettably, most of these results are still unpublished, and the published ones are mostly in the form of reports. The most informative of these is the Starinar 33–34 volume from 1984, but even from this publication one could learn little of the position of the forts against their natural background, river terraces and the opposite bank, or communication routes. The work along the Danube is also reported in some overviews in world languages (Bošković 1978; Petrović, Vasić 1996).

In this paper, we will analyse the layout of the Lederata fortification system, near the very beginning of the Djerdap part of the limes, and the position of Smorna, a site lying at the start of a roughly 15 km long section

Figure 1. Schematic geomorphological representation of the Ljubkovska valley. Dukić 1969, Fig. 2.



of the limes which suffered the greatest changes after the increase in the Danube water level. In that area the course of the Danube was significantly widened, and the partly explored fortresses at Boljetin (Smorna), Greben, Ravna (Camps), Veliki Gradac (Taliata), and Ušće Porečke Reke (the Porečka Rivulet confluence) were inundated for good.

METHODS AND LIMITATIONS

Geographers participated in the multidisciplinary research of the Serbian Danube area, but only particular localities were thoroughly studied, like the sensational Mesolithic site of Lepenski Vir, located some 1,5 km upstream of Boljetin (Milić 1972). Yet, because the Danube water level was constant for a long time – at least judging by the measurements from 1838 to 1963 (Dukić 1964, 100) – geographic descriptions of that area before flooding are a considerable help to understand the Roman border.

At that time, the geographers used aerial photographs to make more precise geomorphological maps, including those of the Djerdap region (Dukić 1969). For example, stereoscopic pairs of aerial photographs from the Military Geographical Institute in Belgrade of the Ljubkovska Basin have been analyzed, situated between Lederata and the other part of the Danube limes we examine in this paper. As with the archaeology (Bugarski, Ivanišević 2014, 256, n. 19–22), in the geographic publications too one finds a schematic illustration and the textual explication of the data (Figure 1), but not the original photographs (Dukić 1969, n. 1), due to the strict military regulations of the time. The geologists faced the same restrictions (cf. Babović 1992, 184).

As stated above, the literature lacks reliable descriptions of site locations in the Djerdap region. The old cartographic sources – generally scarce in Serbia – showing the former Danube bank and the exact positions of the sites have been largely neglected (Marsigli 1726, Sectio XIII–XIV, T. XV–XVI; GoGG 1894). In the Marsigli maps, a number of Roman monuments are illustrated. The Widdin – Stanna section shows numerous Roman fortifications, a route of the Roman road cut into rock, and defensive walls and ditches (Marsigli 1726, Sectio XIV, T. XVI). This map was obviously not analyzed during the excavations of the Djerdap limes, as next to Taliata (Gradanitza on the map) it mentions another fortification, named Starevare. On the other hand, there are also some blanks in the map, as the Smorna fortification near present-day Boljetin was not illustrated.

Modern maps or Google Earth do not help, showing only the Djerdap Lake which has in the recent past flooded considerable parts of the shore, especially river terraces, isles, reefs, and the confluences of small rivers. A separate problem is the recent relocation of some settlements, even the small town of Donji Milanovac.

Thus, some forts of the Roman limes in this area are incorrectly located in the archaeological literature, and there are mistakes in reconstruction of the position of river isles as well. This is the case with the map published in Starinar 33–34, in which Taliata, present-day Veliki Gradac between Donji Milanovac and Ušće Porečke Reke, was pinpointed to the place of Donji Milanovac. Then, the river isle near the Campsa fortress was shown as if it was a large one, although in earlier maps we can observe a small isle. These sources, the 1726

Marsigli map and the late nineteenth century Serbian Headquarters map (GoGG 1894), are not precise enough – especially the first one (Figure 2) – but they are certainly very informative.

On the basis of cartographic sources and aerial photographs we will try to reconstruct the original position of these fortifications, their landscape context and their strategic importance. For the reconstruction of the landscape, that is for a better understanding of this part of the Roman *limes*, especially important are the series of aerial photographs taken by the Military Geographical Institute and housed in several institutions in Belgrade. Today it is possible to overlay historical aerial photographs onto different images, including the widely used Google Earth-derived Digital Elevation Models (DEMs), or the 90 m resolution Shuttle Radar Topography Mission (SRTM) derived Digital Terrain Model (DTM). By so doing, an aerial photograph becomes georeferenced and three-dimensional. Our case studies will present precisely this kind of analysis.

GEOGRAPHICAL FEATURES OF THE MIDDLE DANUBE ROMAN LIMES AND THE CASE STUDIES

The Djerdap section of Serbian Danube course is not precisely defined. According to hydro energy assessment, it starts near Ram, at the confluence of the Nera with the Danube. Hydrological and morphological parameters suggest a different conclusion, namely that Djerdap starts downstream of Ram, near Golubac (Dukić 1964, 99–100). Steep mountains lie beyond both riverbanks, and the river terraces were the main settlement areas along this section of the Danube. There were no towns in this narrow riparian area. The river isles and reefs were significant parts of the ecosystem, but also the most convenient places to cross the river. The valleys of the rivers leading from the Danube into the central parts of the Balkans were important communication routes. These geographical conditions played a key role in choosing the places for settlements and fortresses in the Djerdap region.

We will focus on the fortifications of Roman and Early Byzantine *limes* from the areas which gained special importance after the abandonment of the Dacia Province in AD 272, when the border on the Danube River was re-established. The *limes* also included repaired or newly built fortifications on the left bank of the Danube, namely the bridgeheads (e.g. Jovanović 2005; Bugarski, Ivanišević 2012). The main line of

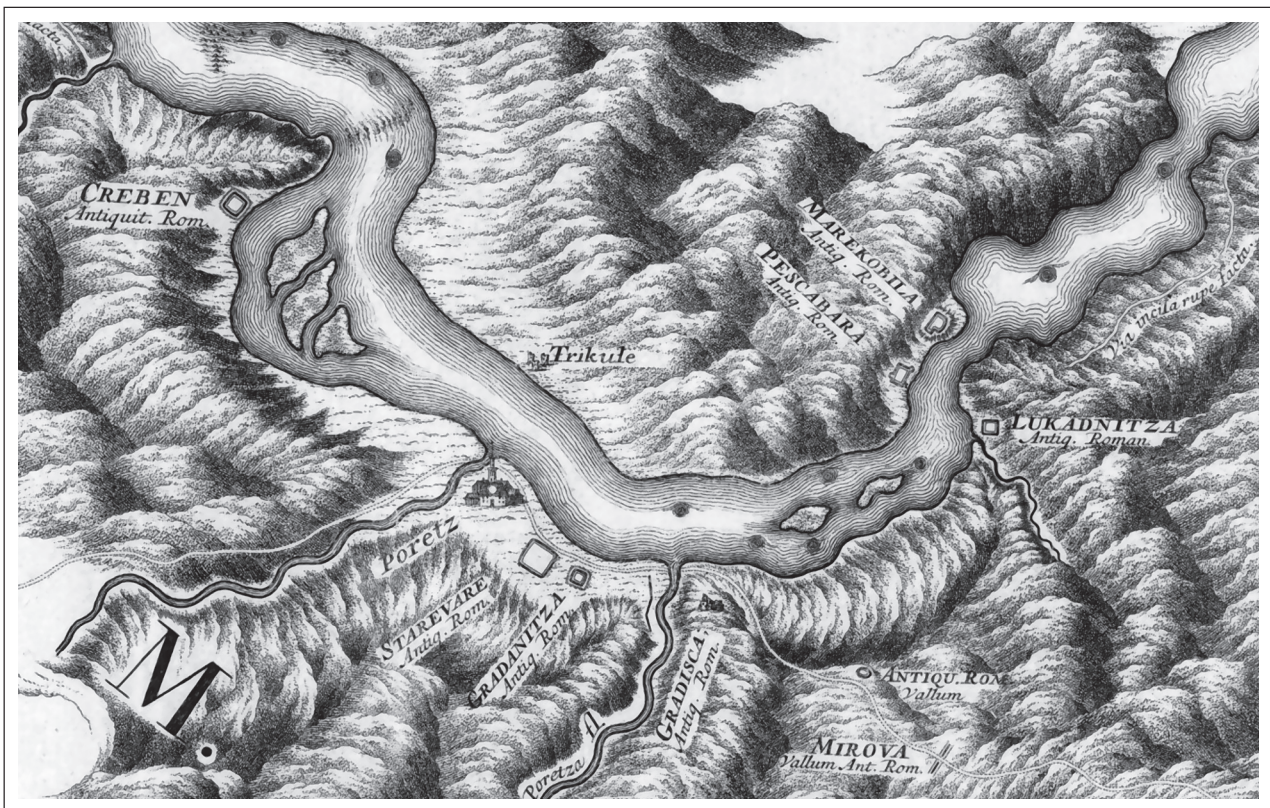


Figure 2. Map of the Danube from Boljetin to Pecka Bara. Marsigli 1726, Sectio XIII–XIV, T. XV–XVI.

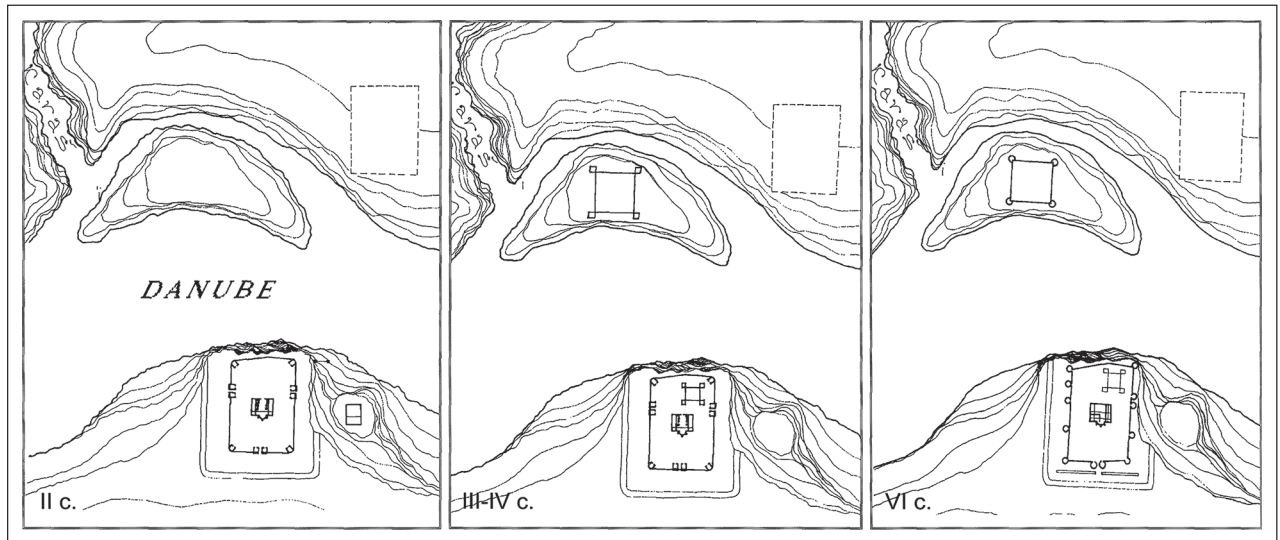


Figure 3. Location of Lederata and Nova Lederata. Jovanović 1996, Figs. 1–3.

the border was on the right bank, consisting of larger and smaller forts, watchtowers, systems of ramparts, ditches, and roads. To judge their real function, one should first reconstruct the original position of the sites, especially given the shortcomings in existing locational information outlined above.

Lederata and Nova Lederata

In terms of the spatial study of the limes, especially interesting is the relation between Lederata and Nova Lederata, situated near the beginning of the Djerdap Danube section. This fortification system is located at a very important strategic point used for millennia to cross the Danube. In the Roman period a bridgehead was established, illustrated in a late eighteenth century map of this area (Bugarski, Ivanišević 2012, Fig. 4). Still today there is a ferry there, transporting people and goods across the river.

Due to the insufficient level of archaeological research in the area of Ram and Stara Palanka, on both banks of the Danube, and on the nowadays inundated Sapaja river isle along the Banat shore, and scarce information from the written sources, the fortification system which lasted for six centuries is not satisfactorily understood. The architectural phases of Lederata and the Roman and Early Byzantine forts across the river were discussed by Aleksandar Jovanović (1996). This was one of the key bridgeheads over the Danube, which prevented movements into the Empire from Barbaricum in the last possible place before the riparian area contracted to a significantly smaller width. Its strategic position was appreciated also by modern military planners (Bugarski, Ivanišević 2012, 485, Figs. 3, 4).

At present it is hard to understand with certainty the Lederata system, first of all because Sapaja, the river isle on which the Late Roman quadriburgium 'Nova Lederata' was located, measuring some 90 m by 90 m, lay partly below the water level right after the 1970 rescue excavations. The isle was incorporated into the embankment system in the area of the confluence of the Karaš and the Danube. Following the available evidence, albeit schematic, idealized and not very precise, 'Nova Lederata' occupied the largest, central part of the Sapaja isle (Dimitrijević 1984; Jovanović 1996).

On the other hand, the main fortification of the system, situated on the right bank of the Danube, has not been sufficiently explored, so Jovanović could show its phases from the second to the sixth century only schematically (Figure 3). As an illustration, the author also used an oblique aerial photograph (Jovanović 1996, Figs. 1–4). Judging by the 1971 photograph presented here, and by the Google Earth Pro-derived DEM of this well-preserved fort, one can claim that neither the architectural phases, nor the fortification as a whole, have been explained satisfactorily. For example, in a recent book on Lederata the fortification, presumably built as a palisade, was dated to the pre-Trajanic period and even connected with the Celts, though with reservations (Cunjak, Jovanović 2014, 27, 179). This could in fact be the Doppelspitzgraben of the fortress from the time of Trajan's reign.

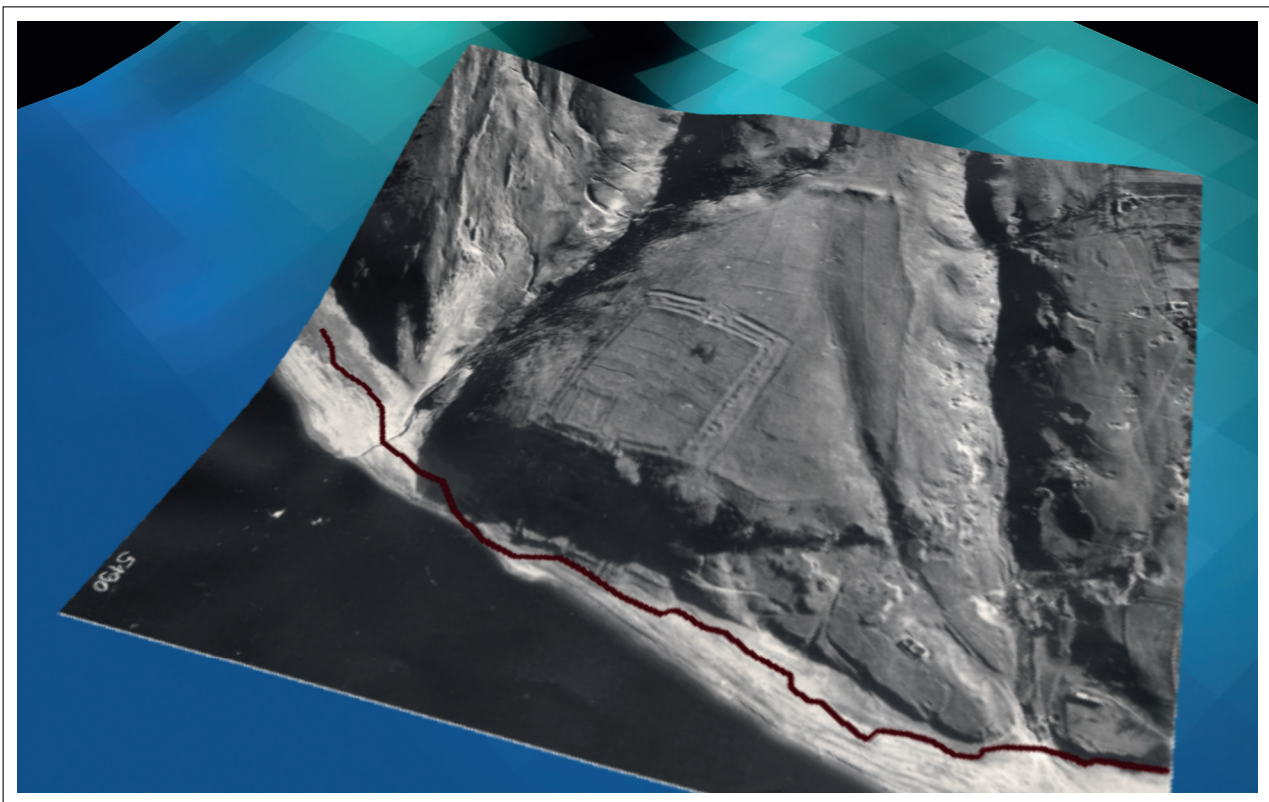
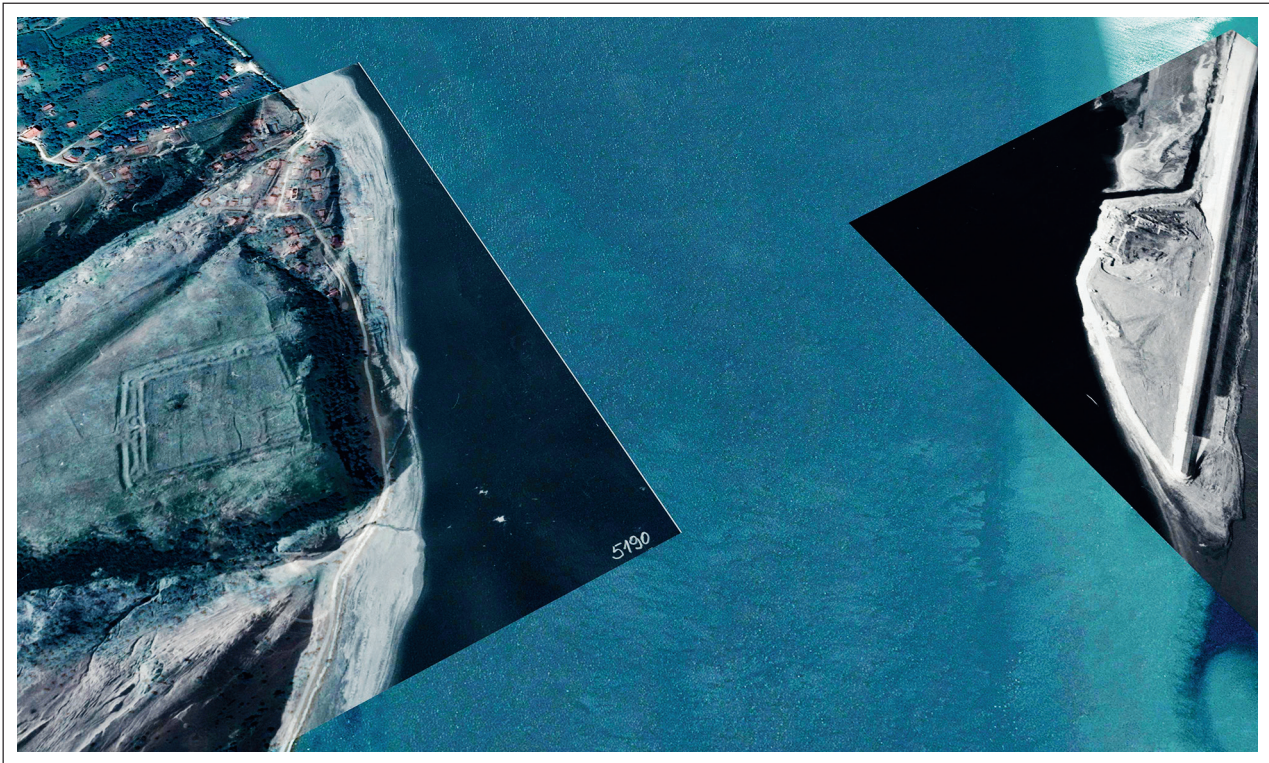


Figure 4. Reconstructed banks of the Danube near Lederata and Nova Lederata, archive aerial photographs overlaid onto the Google Earth Pro relief data. Vertical photograph at a scale of 1:2000, taken by the Military Geographical Institute, Belgrade, 1971. Documentation of the Institute of Archaeology, Belgrade, Inv. No. 3384.

Figure 5. Fortifications of Lederata, archive aerial photograph overlaid onto the SRTM-derived DTM. Vertical photograph at a scale of 1:2000, taken by the Military Geographical Institute, Belgrade, 1971. Documentation of the Institute of Archaeology, Belgrade, Inv. No. 3384.

Analyses of aerial photographs and overlaying them on different maps and models of the terrain give some information on the original forms of the river banks (Figure 4). They also enable us to study the topography of the terrain, the spatial spread of the fortresses, and their interrelationships. Here we are not going to engage in discussion of the chronological phases of the fortifications, as the results of the excavations are not fully published (cf. Cunjak, Jovanović 2014). On the other hand, we would like to point to the important issue of other possible fortifications in the area of Lederata.

According to Aleksandar Jovanović (1996), east of Lederata there was a small fortification (Figure 3, left), which cannot be seen in the aerial photograph or in the topography of the terrain. On the other hand, what we can see is another large fortification in the complex of Lederata. The aerial photograph and the Google Earth Pro image reveal the range of ramparts encircling a rectangular fortification measuring about 200 m by 145 m in size, or 2.9 hectares. These ramparts follow the configuration of the terrain. This fortification, irregular in plan, is about 400 m by 250 m across, extending across some 10 hectares (Figure 5). It has not been excavated, and it was not even mentioned in the literature. At this stage it is not possible to date it more accurately.

Boljetin (Smorna)

A similar method of reconstruction of the original shore can also be applied to the other parts of the Danube limes, and we have opted to present a case study of Smorna. The first information about this fort came from Felix Kanitz, a well-known traveler in the second half of the nineteenth century, who illustrated its position in a sketch. However, this was wrongly oriented (Kanitz 1892, 32–33; cf. Kostić 2011, 150–151), and the precise position of the fortification was recorded in the course of archaeological excavations (Figure 6). The Roman and Early Byzantine fortification at Boljetin is located some 100 m downstream from the confluence of the Boljetinka Rivulet with the Danube. Boljetinka is a mountainous watercourse with a steep descent, which has frequently changed its riverbed. At the confluence, at an original height of 65 m above sea level, the Boljetinka created a semi-circular alluvial fan – now flooded – which had extended into the course of the Danube (Mihajlović-Matić 1949, 111, 114).

Even without a mention in the archaeological publication (Zotović 1984, Fig. 1), the position of the fortification on the old Danube shore, with its architectural phases spanning the first to the sixth centuries, can easily be reconstructed with the help of aerial photographs from 1968 and 1971, quoted geographic observations, and the archaeological ground plan. By overlaying these onto the Google Earth Pro-derived DEM, certain features of the lost landscape can be reconstructed as well. With one part of the photograph overlaying the DEM of the preserved terrain, the rest of it completes the image with the representation of now sunk geographic and fortification features.

In the old cartographic sources (Marsigli 1726, Sectio XIV, T. XVI; GoGG 1894) it can be seen that Smorna was built at another Danube crossing, and our illustrations reveal that the fortress defended the corridor via the Boljetinka Valley to the Danube hinterlands and the southern part of the Central Balkans (Figures 7 and 8).

CONCLUSION

From a methodological point of view, in the case of the Lederata fortification system the aerial imagery helps us to reconstruct the original landscape, and it has also revealed a large new unit of the fortification system, which is an entirely new aspect of the interpretation of this strategically important area. The Nova Lederata quadriburgium is partly preserved on the former river isle of Sapaja. By overlaying the old vertical photograph on the satellite image we have obtained not only the partial reconstruction of

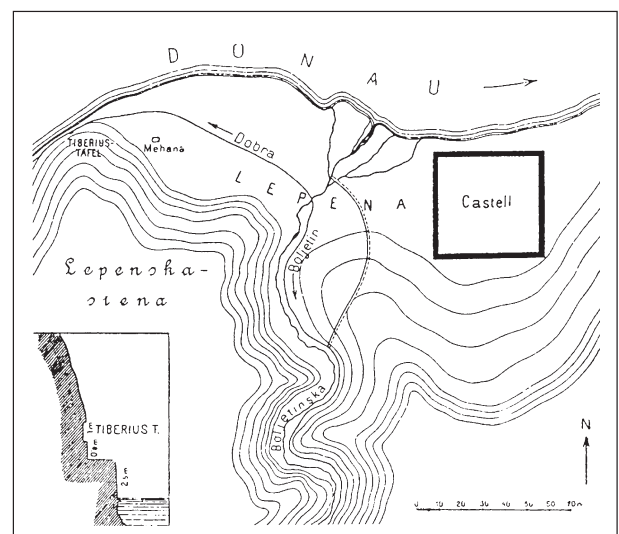
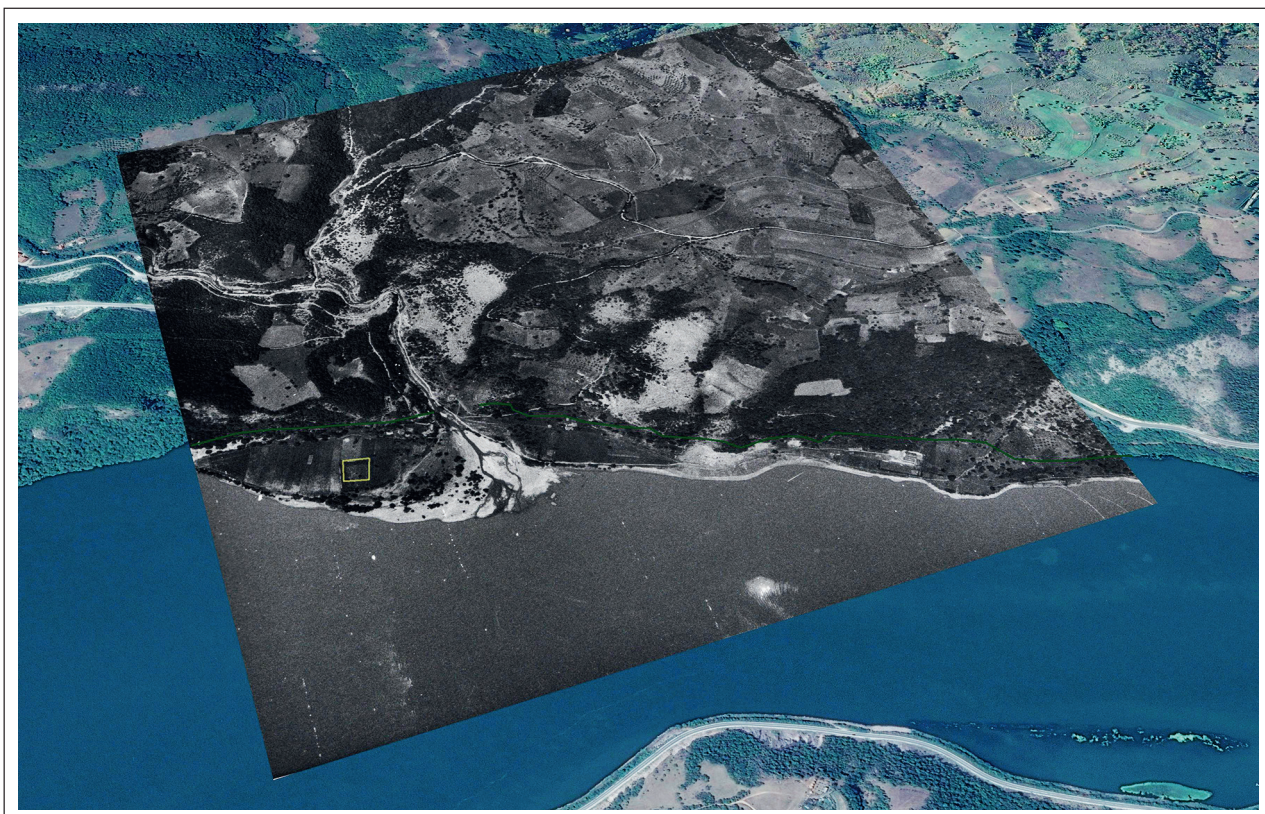
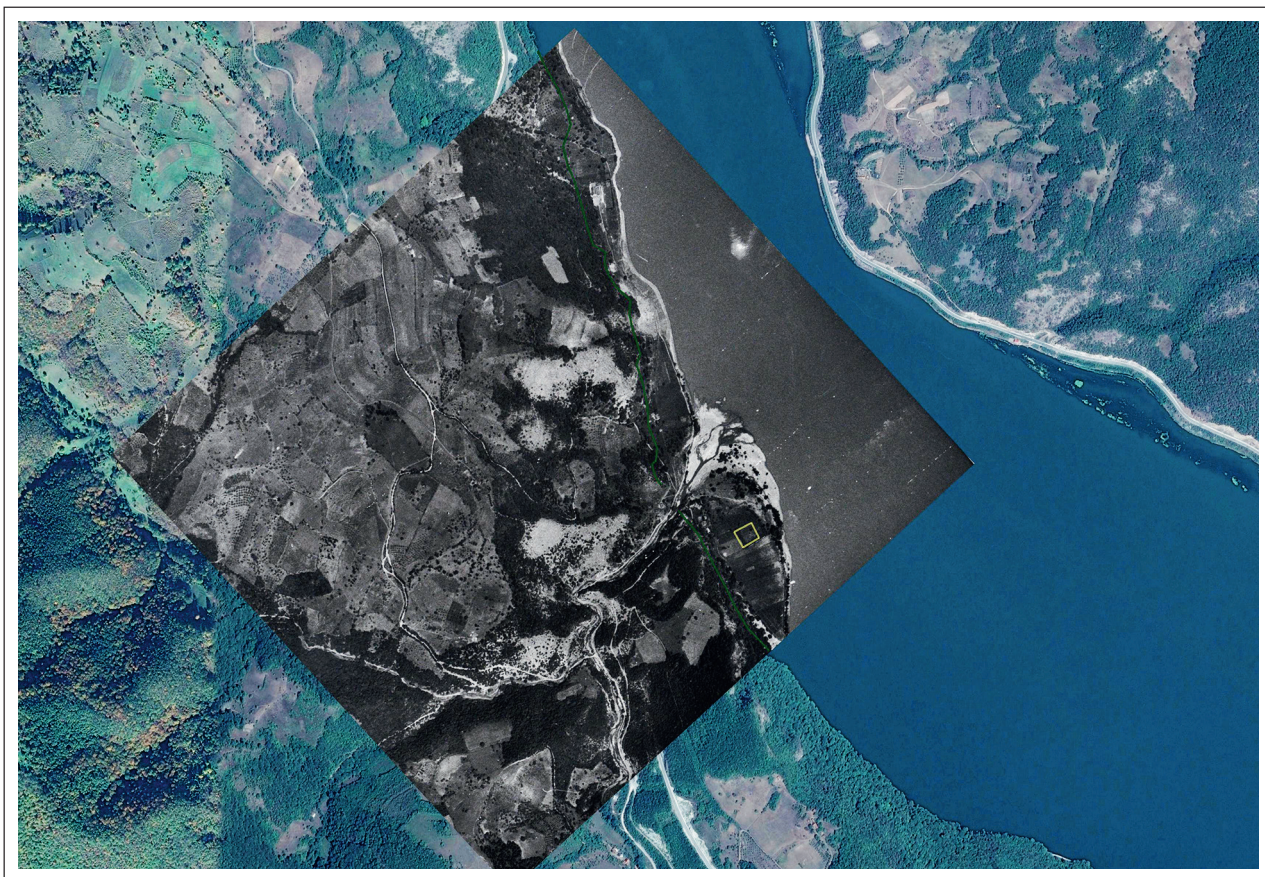


Figure 6. Plan of the Boljetin (Smorna) fortification. Kanitz 1892, 33, Fig. 15.



Figures 7 and 8. *Recovered landscape of Boljetin (Smorna), archive aerial photographs overlaid onto the Google Earth Pro relief data. Vertical photographs at a scale of 1:5000, taken by the Military Geographical Institute, Belgrade, 1968, 1971. Documentation of the Institute of Archaeology, Belgrade, Inv. No. 3384.*

that fort, but also the georeferenced layout of the whole fortification system of Lederata. From this it can be easily calculated that the distance between two shores before recent hydroregulatory works measured 680 m, or 3.68 stadia, a distance that a boat could cross in a short time, certainly a consideration in the study of the Roman limes.

On the other hand, the example of Smorna clearly points to the importance of recovering the damaged landscape for a better understanding of the settlement history, the defensive role of the fortress and the communication with the left bank of the Danube. Overlaying the archive vertical photograph on the three-dimensional terrain models significantly underlines its spatial information and makes it easier to discuss the original conception of fortifying the alluvial fan against the rocky background.

Since the construction of the hydropower plant Djerdap I, such issues can be very seldom studied by conventional archaeological methods. Only during periods of extremely low water levels in the Danube, as in the late summer of 2003, are some parts of its former bank accessible for surveys (Tomović, Antonović 2004), while underwater archaeological research would require considerable finances and great quantity of equipment, to leave aside all the organizational and technical issues (Karović 1996). The approach presented here is also highly cost-effective as it does not require any great financial commitment, expensive hardware or software, nor specialized computer knowledge. This is in contrast to the initial expense of obtaining Airborne Laser Scanning (ALS – or LiDAR), though this has shown its value at the town of Margum, the only site from Serbian part of the Danube limes recorded using this technology (Ivanišević, Bugarski 2012), and the expense and potential difficulties of obtaining Airborne Laser Bathymetry to record the underwater topography (cf. Doneus et al. 2015).

For all these reasons, we believe that our approach to exploring these inundated landscapes should be usefully applied in the other parts of the limes, and that it can be of some use in the study of areas damaged in different ways.

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Ancient landscapes of north-western Iberia: historical aerial photographs and the interpretation of Iron Age and Roman territories

Abstract: *This paper presents the use of historical aerial photographs in research of past landscapes in the north-western Iberian Peninsula, through several examples taken from a larger regional study, all connected with the diachronic study of social and territorial changes during the Iron Age and Roman period (5th century BC to 3rd century AD). Technical procedures are explained, but also the different solutions adopted and the consequences of the use of the historical aerial photographs. An important point of this paper is to demonstrate the great value of such imagery in an age when the use of other sources, such as Airborne Laser Scanning (ALS or LiDAR) data or modern aerial orthoimages, might be seen as all that is needed.*

LANDSCAPE ARCHAEOLOGY AND THE USE OF HISTORICAL AERIAL PHOTOGRAPHS

This paper presents the use of historical aerial photographs in our research of past landscapes of north-western Iberia. We will focus on the different uses of historical aerial photographs for documentation of ancient landscapes, for analysis and for interpretation, recognising also that their use for the management of cultural landscapes and dissemination of research results has an important place in our work (Ruiz del Árbol et al. 2005). As we will show, historical aerial photographs are essential to our study, even if other contemporary images and resources (such as ALS/LiDAR or aerial orthoimages) are also used in our work.

Archaeological research has relied on aerial photographs as a fundamental tool for the study of historical processes through the analysis and interpretation of landscape landmarks. Such studies have a long tradition and several approaches and theoretical perspectives can be distinguished (some useful works of synthesis are: Orejas 1991; Clavel-Leveque et al. 1994; Gillings et al. 1999; Bewley, Rączkowski 2002; Bourgeois, Meganck 2005; Barber 2011). Our work has developed within this context, and we have already published several papers showing our procedures and results (such as Sánchez-Palencia, Orejas 1991; Sánchez-Palencia 2000, 2014). Our point of departure is the idea that archaeological documentation must be understood in a broad sense. The archaeological record is not reduced to the material vestiges of culture but it involves all the products of human action in space and time: that is to say the whole landscape. From this perspective, the landscape, conceptualized as a cultural creation, is a key element in our research, because through it the processes of social change are visible in their complexity and integration (Orejas et al. 2002).

Landscape archaeology is conceived in our work as meaning the investigation of social formations and the processes of change within space and over time from an inter-disciplinary perspective. This requires the use of different methods and techniques within a multi-scaled approach to move beyond the environment as a vague framework for archaeological sites, and leading to an archaeological reading of landscape in all its complexity. And historical aerial photographs are one of the essential tools to record the dynamism of historical processes, a dynamism that is embedded in the landscape.

Historical aerial photographs have been a key instrument in all the stages of our research and also, an important tool to develop our proposals on the valorization and management of the archaeological heritage.

In this paper we present the use of these photographs in our research work, thorough selected examples of the main projects of our group “Social Structure and Territory – Landscape Archaeology” (GI EST-AP), developed for the last 30 years. In these projects we have used photo-documentation, photo-interpretation and photogrammetry for the study, understanding and interpretation of cultural landscapes.

However, and as a consequence of the long duration of our project, the use of historical aerial photographs has changed in our research over time. Historical photographs were, firstly, the main instrument employed in the remote sensing analysis, primarily through stereoscopy. As time went on, digital stereoscopy has been incorporated. Today, the use of historical aerial photograph can only be understood if integrated with other geospatial analysis instruments and digital technologies, such as the topographical analysis with ALS and the use of GIS.

In any case, as we intend to show the use of historical aerial photos is integrated in a very well programmed research with precise archaeological and historical objectives. The geospatial documentation or GIS systems constitute a useful tool, but these are technical tools that must be subordinate to the goal of Archaeology, that is understanding the historical processes and the recording of change. In fact, in the study of ancient Iron Age and Roman landscapes we are interested not only in specific activities developed over the territory (such as mining or agriculture), or sites or settlement patterns, but also in considering them in the framework of profound changes in our study areas during the past. Our interests are the transformations of the north-western territories between the Iron Age and the Roman conquest: new power relations, new economic interests and new organizational and territorial frameworks for the local societies (Orejas, Sánchez-Palencia 2002; Sastre, Sánchez-Palencia 2013; Ruiz del Árbol et al. 2014).

There is today, from our point of view, a proliferation of studies in which aerial photographs are used in a simplistic way, under the pretext of recording the landscape (not to mention the overuse of the term “archaeology of landscape”). Aerial photographs are in a vast majority of cases used as a mere illustration without any analytical capacity (the extreme example of this “abuse” is the un-critical use of Google Earth™ as illustration). The causes for this are to be found partly in the easiness of access to geospatial digital data and user friendliness of visualization services and map downloads, that has produced a notable increase in the use of aerial photographs in archaeological analysis during the last few years; also, on the empiricist approach that dominates the landscape in GIS-based Archaeology (Criado 2015). The consequence is that many studies developed from a pretended “landscape archaeology” and do not go beyond site analysis. Thus, the historical aerial photographs are used only to formally analyse a site, without paying attention to the multidimensionality of the landscape as a whole, understood as a complex reality. Often, these works are presented as innovative studies and even published in high standard (peer-reviewed) archaeological journals. This is the case (to cite but one example) of several papers related to the use of ALS to study gold mining in north-western Iberia (such as Fernández et al. 2015; Fonte et al. 2014) that even neglect the value of historical photographs in the research process. These papers in fact do not approach conceptual or historical problems. Although they do provide a technical and innovative methodology (ALS), this is not a contribution to the formal study of mining structures: the study is not included within a broader comprehensive analysis, oriented with historical criteria and with recourse to different sources. In fact the two papers cited present as “novel” mining workings previously detected and studied in depth through the photogrammetric analysis of several historical flights (Fernández-Posse, Sánchez-Palencia 1988; Sánchez-Palencia, Orejas 1993; Sánchez-Palencia et al. 2009).

To sum up, the use of historical photographs in archaeological analysis goes far beyond accompanying the study of a site with a picture for illustrative purposes, reducing it to a decorative role. Stereoscopic vision is a key component in working with aerial photographs that was recognised at the very origins of this discipline, but which nevertheless seems to have been neglected in many recent archaeological studies. The work of J. C. Sánchez and I. Fumadó (2006) is a good example of how the real capabilities of aerial photographs are underexploited. Their point of departure is a simplistic vision in which soil-marks and crop-marks seem to be the sole observable elements through aerial photograph. The authors create an index to evaluate the potential use of aerial photographs in which only the cultivated and less mountainous areas appear as suitable for their archaeological use. However, the real potential of photogrammetric analysis goes far beyond, and it is not limited to what can be seen with the naked eye on the photograph; it is only revealed by the stereoscopic vision of the formal elements that appear in the landscape. Therefore, only through the photogrammetric analysis of multi-temporal historical photographs can we access the great historical potential of these archives, and thus

contribute to the construction of interpretations to understand past landscapes.

THE HISTORICAL AND SPATIAL CONTEXT OF OUR RESEARCH

The several case studies we present below have been chosen from the different regional studies undertaken by our Research group in relation to the study of ancient landscapes of the western Iberian Peninsula (Figure 1). Chronologically, our work focuses mainly on the Iron Age and Roman periods (5th century BC – 3rd century AD).

During the 1980s the team started working in the Spanish provinces of Leon, Ourense and Asturias, especially in the La Cabrera Mountains (the River Cabrera and River Eria area); Las Médulas and its region; the north-western Duero valley; and in the upper and middle basin of the River Sil. There is very complete information for this area already published (Orejas 1996; Sánchez-Palencia 2000). From 1997 we have worked in Las Cavenes de El Cabaco (Salamanca) and other gold deposits in the Roman province of Lusitania. This area has provided very interesting details on the development of gold mining and Roman provincial organization (Ruiz del Arbol 2005; Ruiz del Arbol et al. 2014, Sánchez-Palencia 2014). Also, from 2005 we have worked in the area of Pino del Oro, in Zamora, and in the Lower Miño and Lower Tajo valleys (Sanchez-Palencia 2014, Sánchez-Palencia et al. 2013, Currás 2014). More recently other projects, such as the Via Nova Project, or the study and valorization of Sanabria (Zamora) (Currás et al. 2014) and Os Biocos (Ourense), have also made intensive use of historical aerial photographs.

All our study areas have in common that they are important regions for the study of ancient gold mining. It is out of the scope of this paper to stress the importance that the gold-bearing areas of the north-western Iberian Peninsula had to the Roman Empire, beyond stating that throughout the 1st and 2nd centuries AD secondary or alluvium gold deposits and primary or rock deposits were discovered and extracted here (Domergue 1990 and 2008; Orejas and Sánchez-Palencia 2002). The areas studied by our team are representative of this process.

SPATIAL ANALYSIS: OBTAINING, ORGANIZATION, ANALYSIS AND PRESENTATION OF DATA

Here the uses of historical aerial photographs in our regional studies and in the whole north-western Iberia are presented, outlining the technical procedures, the different solutions and consequences of the use of these historical documents. Our aim is to illustrate the analytical process undertaken for the archaeological characterization of the territory and is potential for the interpretation of the landscape.

There are several systematic historical flights available for north-western Iberia. For the Spanish territories, the main flights are the so-called “vuelo americano” (“American flight”), A series of USAF, from 1945–1946 (1:45.000); the “vuelo americano”, B series, taken during 1956 (1:33.000); and the “vuelo interministerial” (literally: “inter-ministerial flight”) from 1977–1983 (1:18.000).

Finally there is also the “vuelo nacional” (“national flight”) from 1980–1985 (1:30.000). These flights are partially accessible online (<http://mapas.xunta.es/> & <http://fototeca.cnig.es/>), although it is not possible to download a stereo-pair that makes photogrammetric use possible (the purchasing of stereo-pairs must be done by contacting the relevant agency).

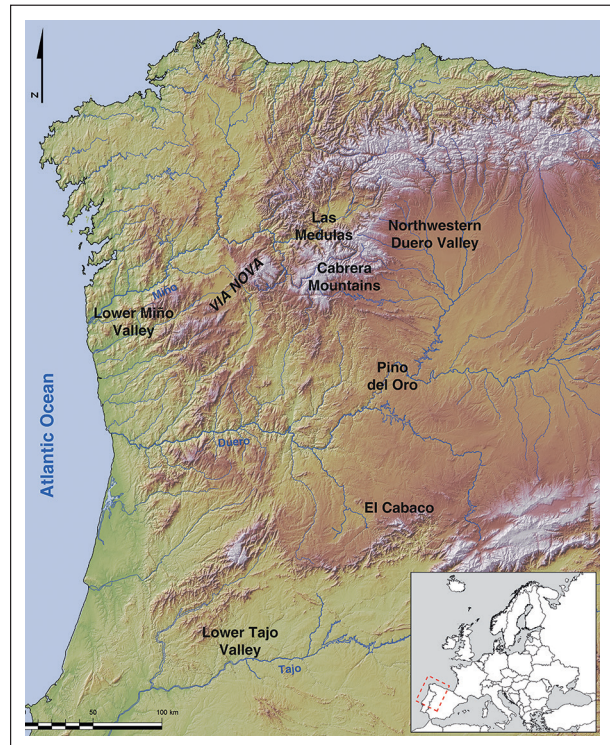


Figure 1. *The northwestern Iberian Peninsula showing the main areas of our research. Elaborated by EST-AP, CSIC.*

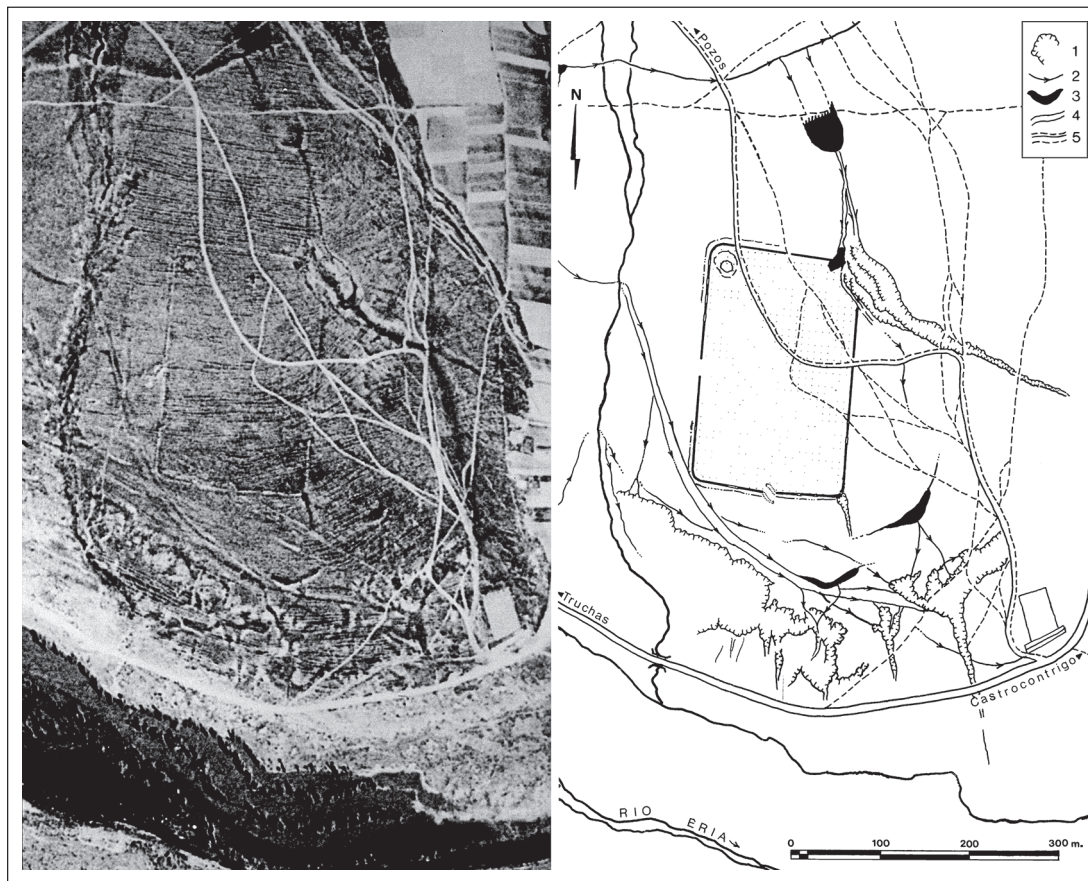


Figure 2. Photo-interpretation of the mining exploitations and Roman fort of Valdemedina (Truchas, León).

Legend: 1: mining exploitations; 2: network of Roman water canals for the supply of water to the mining exploitations; 3: water reservoirs; 4: modern main road; 5: modern secondary road (cfr. Fernández et al. 2015, figure 10, where the isolated use of ALS makes it impossible to detect many of these structures). Elaborated by EST-AP, CSIC.

For Portugal, and with a systematic character, there is, firstly, a RAF flight from 1947 (1:30.000) and secondly, the “American flight” taken in 1958 (1:33.000). There is also an interesting flight from the “Sociedade Portuguesa de Levantamentos Aéreos” (Portuguese Society for Aerial Surveys) taken from 1937, which is unfortunately not systematic in area coverage and nor does it have a constant scale.

As we are going to show in each study-case historical aerial photographs are an essential tool in several and complementary ways. The first works of our team in the 1980s illustrate very well the use of the historical aerial photographs in our fieldwork and analysis. The work at the Cabrera Mountains exemplifies how we have used photo-interpretation for the documentation and analysis of settlement morphology and the identification and recording of several structures (Figure 2). However, the “American flight” has also been used in the newer projects, such as the study of the Lower Miño Valley. Its main advantage is that the 1950s marks the greatest extension of cultivated and forested land: the landscape of these years – not abandoned, but fully under traditional agricultural use, not yet transformed – is ideal to the detection of ancient structures, such as mining exploitation.

Field survey (aerial survey)

The stereoscopic analysis of historical and modern aerial photographs offers the possibility of a general recognition of the territory, and thus providing a global perspective while allowing the identification of sites. The aerial photograph analysis is done with the use of a mirror stereoscope (a portable one is used in the field). A digital stereoscope has also been used for the photogrammetric survey of some specific sites.

The “American flight” of the 1950s has been generally used to make a systematic and intensive survey. Its scale (about 1:30.000) provides a general overview of the geomorphology of the studied region and allows (by

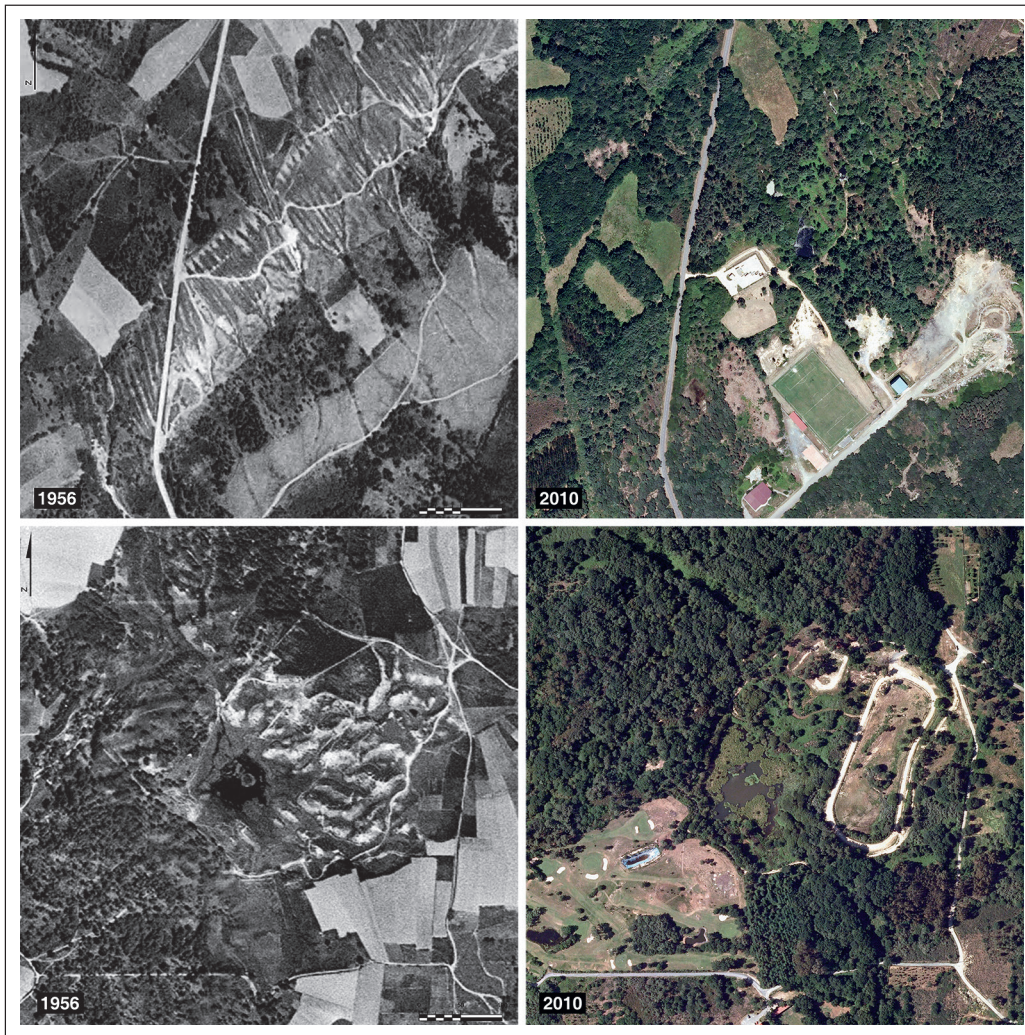


Figure 3. Transformation of the Roman mining exploitation of Os Medos (Pobra do Brollón, Lugo) and Puzo do Lago (Maside, Ourense) between the 1950s and the 2010. © Elaborated by EST-AP, CSIC from the USAF “American flight” (series B, 1956) and the IGN PNOA flight (2010).

using selected enlargements) identification of the different human actions on the landscape. Depending on the regions, along with the “American flight” we have used other available imagery, mainly from the 1980s. Also, in the last few years the possibility of using ALS-derived digital terrain models has offered the possibility to analyse the morphology of the territory as complementary resource to the historical aerial photographs.

The planning of fieldwork normally involves the selection of places to visit. The surface recognition of the archaeological sites is preceded by detailed photo-interpretation that facilitates the identification and characterization of each of the formal elements on the ground.

Field walking is extremely difficult in most of the studied areas of north-western Iberia. Most of the rural areas are in a situation of total abandonment, and in many cases archaeological sites are impossible to access because of thick vegetation. The morphological traits of ancient features and landmarks are often poorly defined due to the extension of the forest and the vegetation. Other alteration, even more serious, is the result of modern developments. In these cases the “American flight” is an essential element to record the surviving morphological elements of the ancient landscape and even to detect traces that have disappeared today. This potential is clearly exemplified by Figure 3 in which the transformation of the Roman mining exploitations of Os Medos (Lugo) and Puzo do Lago (Ourense) between the 1950s and the present is shown. Another example is the case of the study of the Via Nova (via XVIII of the Antonine Itinerary) in A Limia (Figure 4), only recognizable on the historical photographs due the significant changes in this region.

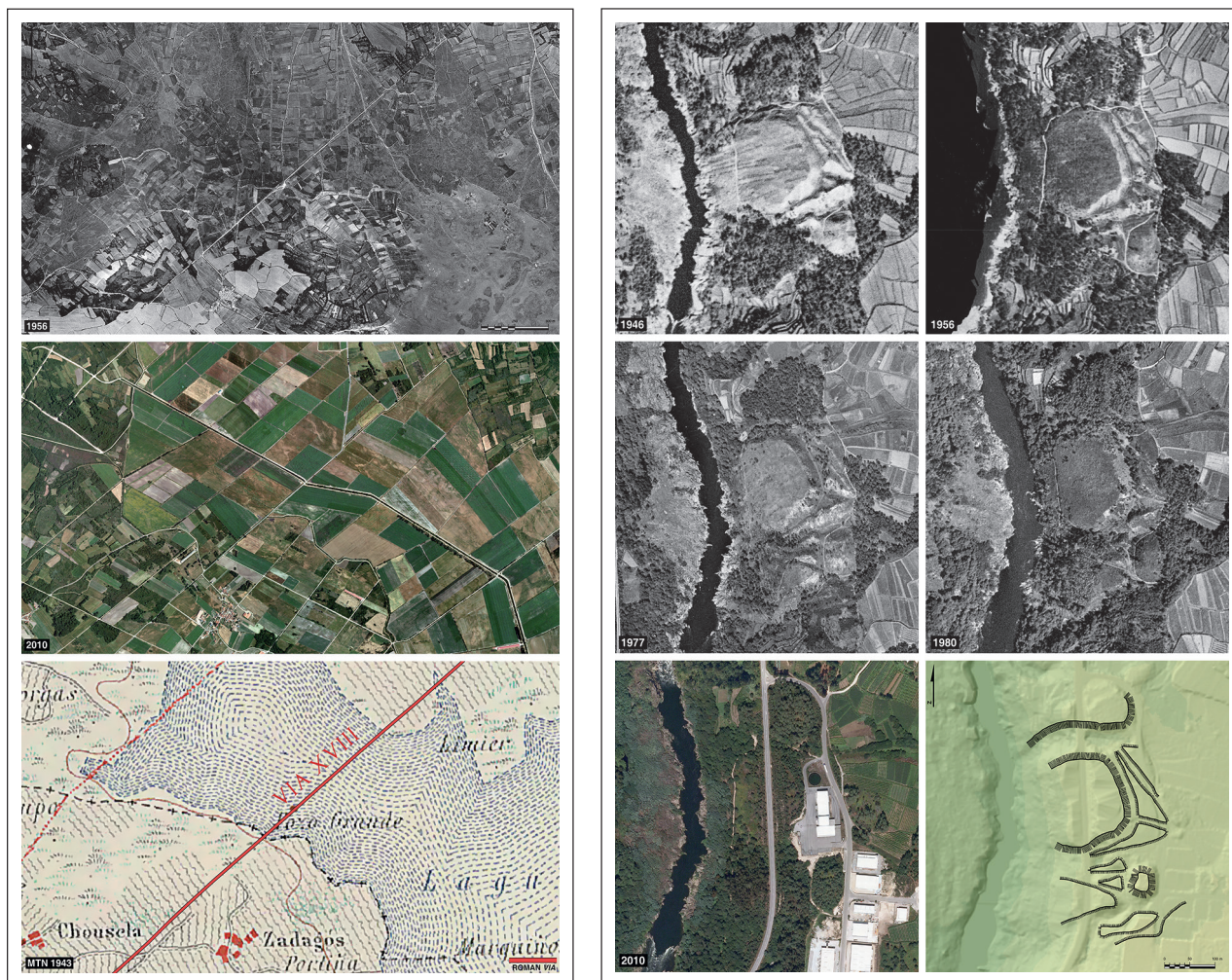


Figure 4. Photo-interpretation of the layout of the Via Nova or Via XVIII of the Antonine Itinerary on the 1943 National Topographic Map (1: 50.000) (A Limia, Ourense). The important changes caused by the drying of the Lagoa (lagoon) of Antela and the subsequent restructuration of the agrarian plots can be observed. © Elaborated by EST-AP, CSIC from the USAF “American flight” (series B, 1956), the IGN PNOA flight (2010) and the National Topographic Map (1943).

Figure 5. The Roman mining hillfort of Os Castelos (Melgaço, Portugal). Morphological analysis, made from the combined use of historical aerial photographs, shows a settlement bounded by the mining works undertaken with hydraulic power. The sequence shows the impossibility of analysing the settlement in the IGN PNOA flight (2010) due to the recent destruction of the site. © Elaborated by EST-AP, CSIC from the USAF “American flight” (series A and B, 1945–1947 and 1956), the “inter-ministerial flight” (1977–1983) and the “national flight” (1980–1985).

Sequential analysis of multi-temporal imagery supports understanding of abandonment processes and their consequences for landscape features. Recent evolution of elements such as road networks or land divisions show how some processes are deeply changing the traditional rural landscape, so such sequential analyses are very significant. However, the destruction and alteration of the archaeological record is not only a product of recent processes related uniquely to the abandonment of traditional rural land-uses and the disappearance of a traditional peasant society. Rather, while this is a process which has undoubtedly accelerated since the 1960s and 1970s, it is also easy to identify in the 1950s when the traditional peasant society still maintained its elemental structure, before rural depopulation gathered place (Currás 2014, 31). In this context the “American flight” is extraordinarily valuable as it allows us to establish an assessment of conservation over a period of more than 50 years. It can be considered as a true historical document.

Formal analysis of ancient settlement and mining structures

One of the crucial aspects of our work is the formal analysis of ancient settlement. Different data are considered in the diverse study areas, depending on the historical questions and the aspects of interest for a quantitative study that will allow identification of historically significant patterns and locational strategies. For every historical analysis the main aims and specific methodology must be adapted to the specific spatial and temporal reality and, even more important, to the specific problems that the work aims to solve (Currás 2014, 39).

Complementary to the survey, the historical aerial photographs and the cartography (mainly at 1:25.000 scale) have been essential in the formal study of archaeological sites, the determination of their situation and the characterization of their location. Here again the “American flight” of the 1950s is a basic source. As stated above its main advantage is that it offers a vision of the landscape at a very particular moment before the urban developments of the 1960s, where the spatial extents of agriculture were at their greatest. Figure 5 illustrates how it is much easier to work on the characterization of sites (settlements) from the “American flight” rather than on later images; some of the archaeological structures no longer exist (as is the case here) or are covered by the forest or vegetation that has grown after the abandonment of agriculture activities. As Figure 5 shows, the combined analysis of different flights, along with current ortophotographs, allows us to perform sequential diachronic studies and evaluate the transformation experienced by particular sites.

Morphological analysis concerns settlements as well as other structures and factors related to the ancient exploitation of resources. In our work historical photographs have been a key document for the evaluation and global restitution of large exploitation systems. In fact our research focuses on the Roman mining structures with large hydraulic networks. Its morphological study requires suitable documents to this scale (Figure 6; see also Figure 2).

Historical aerial photographs have allowed us to detect and to study a series of mining structures that do not stand out either through size or productivity. The surface prospecting mining works of Rosinos de la Requejada, Zamora (Figure 7) are a very good example. The Roman works at Rosinos are an example of an extensive prospecting over secondary deposits through the use of the aurum tallutum method (Currás et al. 2014; Plácido, Sánchez-Palencia 2014). When identified, several prospecting trenches were excavated with



Figure 6. Morphological analysis of the Roman gold mining exploitations of Cortes (Monção, Portugal). The combined analysis of aerial photographs of the “American flight” and the ALS-derived topography shows mining workings carried out by the so-called method of “series of convergent furrows”. © Elaborated by EST-AP, CSIC, from the USAF “American flight” (series B, 1956), the IGN PNOA flight (2010) and an ALS-derived terrain model (contour line interval = 0,5 m).

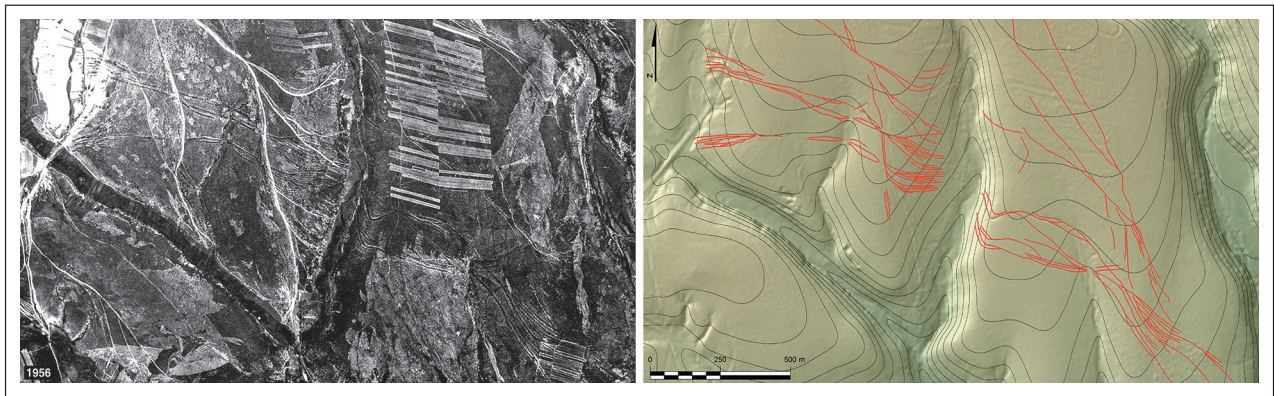


Figure 7. Photo-interpretation of the Roman surface prospecting mining works (*Rosinos de la Requejada, Zamora*).
 © Elaborated by EST-AP, CSIC, from the USAF “American flight” (series B, 1956) (contour line interval= 5 m).

the aim of evaluating the gold content of the area. These works (3 m wide, no more than 0,5 m deep, 900 m long) are almost imperceptible on the ground. Here, the aerial photo-interpretation on the 1950s images has been a key element for the identification, analysis and historical evaluation of the mining activity in the area.

Qualitative analysis

Historical aerial photographs also have a great analytical potential that goes beyond the formal understanding of the sites. The study of the relationships between resources and forms of land occupation is one essential aspect that allows us to interpret the locational logic of the settlement strategy. Many of the studies in the north-western Iberian Peninsula have analysed it from a descriptive point of view. Such work is often based on an overview of contemporary attributes of the region, the climate, the geological characteristics and land uses. The result is a picture which actually bears no relation to the nature of the ancient settlement.

In contrast, a number of authors have emphasized the relationship of each settlement to the potential resources of their environment. The Peña Redonda hillfort (Zamora) provides a good example of how aerial photographs can be very useful when analysing potential land uses (Figure 8). In this case the study combined several factors: pedological (soil depth, stoniness or rockiness), geomorphological (slopes), water (access to water resources) and historical (land use in the 1950s, from the “American flight”, which shows the period of wider agrarian exploitation in Spain, before the mechanization of the agriculture). From these factors four categories were established, based on the types marked on the maps of potential land uses from Galicia and north-western Portugal (MCPSG and CSATEDM) and the FAO project Agro-Ecological Zones: <http://webarchive.iiasa.ac.at/Research/LUC/GAEZ/index.htm>. A fourfold classification of potential land uses was obtained (irrigation/pastures, intensive, extensive, none/forestry) that applied to the catchment areas of each site and allowed the analysis of the exploitation model developed for every site. To this end, analyses of both physical factors (such as slope, calculated by GIS) and of historical land uses were combined as reference to evaluate the potential of the land. The advantage of using the “American flight” of the 1950s is that this is the period when rural areas of the Iberian Peninsula had almost all productive lands under intensive agricultural use. Also this period predates the mechanization of agriculture.

An integrated view

Often historical aerial photographs have been used in the analysis of single sites out of the context of their environment. The great potential of aerial photographs applied to the research of the past, from a landscape archaeology perspective, is precisely that it allows us transcend this type of restricted analysis of single sites and to achieve a comprehensive view of the territory, understood as an historical construct. In the different projects developed by our research team we have combined the formal study to a reduced scale of every site with a broader analysis of the forms of exploitation of the territory as whole. By incorporating different working scales, aerial photographs allow us to integrate the formal analysis of a settlement, the small agrarian structures such as terracing, the large mining infrastructures, and potential forms of land use.

A good example is the recent study of one of the routes of the Antonine Itinerary, the Via XVIII, where we have addressed the joint understanding of road structures with the system of settlement and gold mining resources. The holistic view that provides the combined use of different scales allows us to obtain a broad historical perspective of the landscape. At a first level, we can identify the layout of the road, very much altered today and often only recognizable on the historical photographs. In order to reconstruct the route of the road the first step was a broad reading of the record, including the location of milestones and the identification of surviving road elements, such as sections of road or bridges. “American flight” was used to integrate all these elements and to identify stretches of road now disappeared, and to obtain a complete picture of the layout.

On a smaller scale, the photo-interpretation shows the direct relationships between the Roman road and the settlement system. Through the “American flight” we identified and morphologically analyzed those settlements in the immediate vicinity of the road. We paid special attention to the mining exploitations, which were photo-interpreted individually. The results of the photo-interpretation of historical aerial photographs were combined with the analysis of ALS-derived topography, allowing us to obtain a more precise image of the formal elements of the settlements and mines. As a result, we obtained a map that reflects the landscape of the Via Nova (Figure 9).

This way of approaching the study of a Roman road, through the systematic use of aerial photographs, reveals that the Roman road is much more than one communication system, but a means of territorial articulation. The Roman road system played a key role in the *cursus publicus* and in the communication of the different provinces of the Empire. But, at the same time, the route also played a leading role in shaping the territory at a local scale.

FINAL CONSIDERATIONS

Historical aerial photographs have a long history of use as a powerful means of documentation and highly effective tool for Archaeology. And, contrary to some voices, despite the advent of new data sources, they are

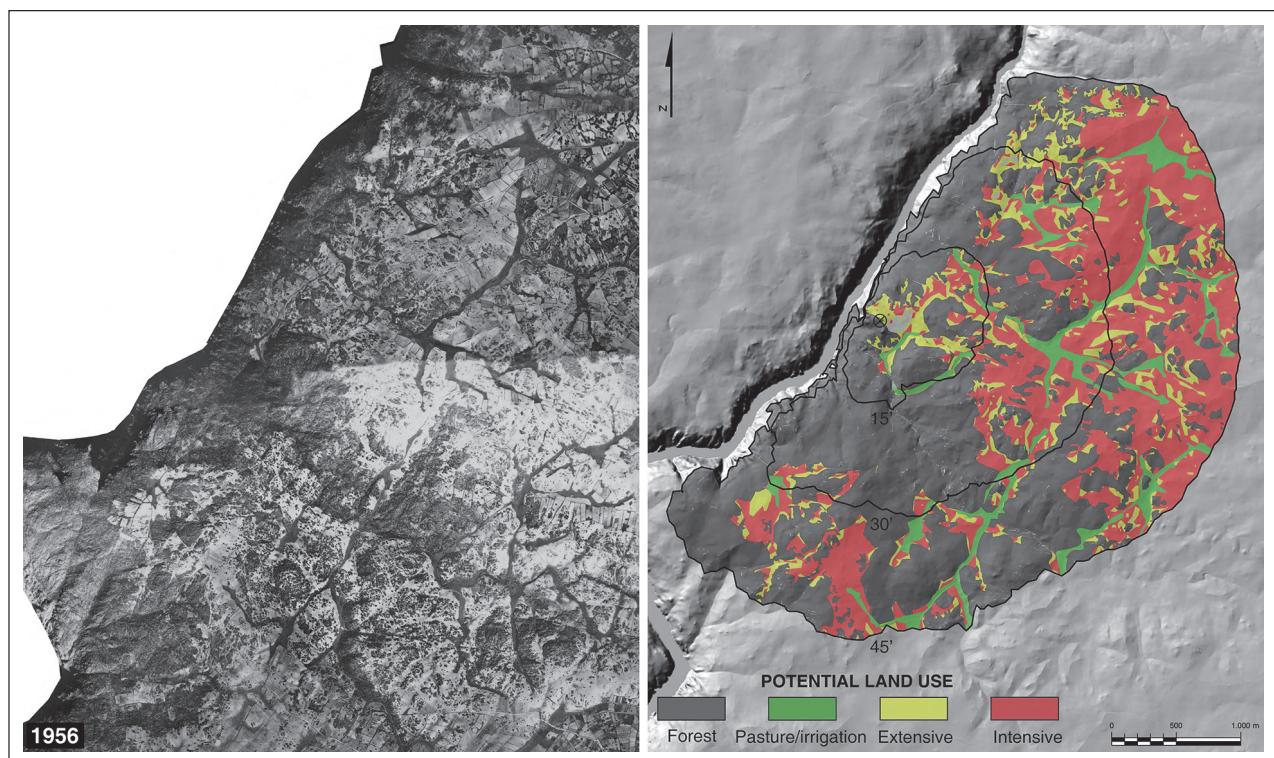


Figure 8. *Clasificación de the potential land use of the Peña Redonda hillfort (Villardiegua de la Ribera, Zamora) based on historical aerial photographs of the “American flight”. This is the period of maximum agrarian exploitation, before the mechanization of agriculture. The analysis is based on the combination of several parameters (pedological, geomorphological, hydrological and historical). © Elaborated by EST-AP, CSIC, from the USAF “American flight” (series B, 1956).*

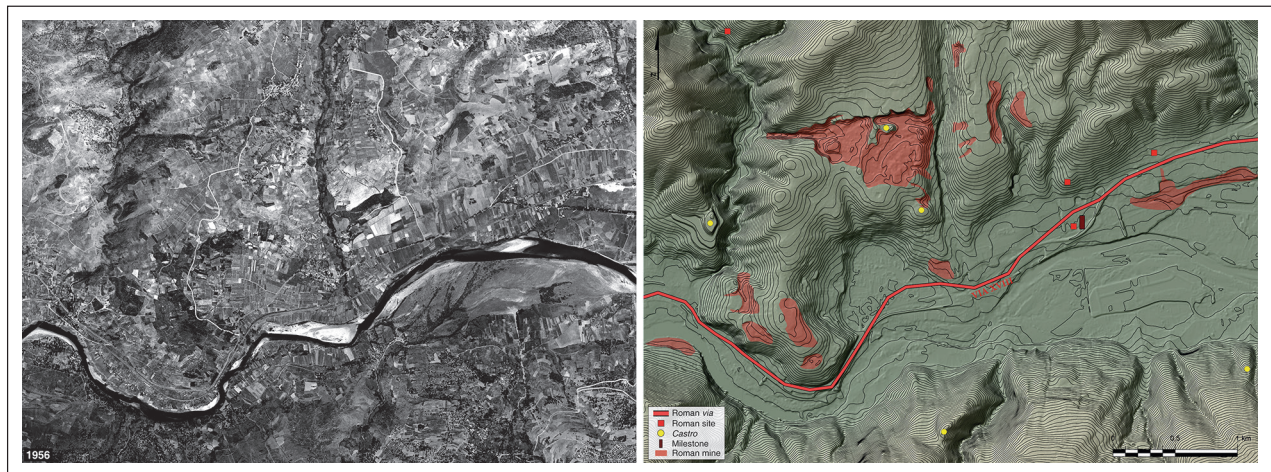


Figure 9. *Via XVIII of the Antonine Itinerary in Valdeorras (Ourense).*

The photo-interpretation has been elaborated by EST-AP, CSIC, from the USAF “American flight” (series B, 1956) and it allows detection of the gold mining exploitation, the hillforts and the layout of the Roman road.

The results are presented on an ALS-derived topographic model (contour line interval = 5 m). © EST-AP, CSIC.

not obsolete as they offer a large amount of data in a flexible (different film types, scales and formats) and accessible way (its acquisition is cheap). Historical aerial photographs are indispensable to interdisciplinary research, especially to the morphological study of landscape landmarks in which a large scale interpretation is necessary, such as opencast mining. Also, they are a fundamental basis for sequential multi-temporal study, important when a pre-industrial or a pre-mechanized situation is recorded in the photographs, and essential to the evaluation of the degree of landscape transformation and conservation.

Accumulating data adds nothing to an investigation, if these data do not support the analysis of hypotheses and if not organized in such a way that they can offer some analytical results in an integrated historical interpretation. Landscape is not a formal or monolithic reality that we can touch. Landscape is the relation between several aspects and thus analysis necessarily has a global character, which demands the articulation of several and distinct aspects and records (such as productive spaces, delimited spaces, and perceived spaces). These records form part of an epistemological strategy of research of the landscape as an object of historical investigation. They cannot be isolated. The research process needs an analytical approach, a dissection, but only the synthesis allows the study of the landscape. Historical aerial photographs, in conjunction with other geospatial methods, have the potential to support the comprehension of the significance of the different individual aspects that conform and structure the territory as a whole.

In the several regions investigated our work has come a long way: the analysis has been designed from the perspective of the historical questions and, at the same time, the analysis allows us to check these hypotheses. The incorporation of Geospatial digital technologies and GIS analysis to spatial studies raises the risk of driving us into a purely technical dimension of the landscape. In recent years the democratization of powerful spatial computing tools and papers addressing complex analyses in understanding ancient landscapes are becoming more frequent. This technological innovation, together with the advance of geo-archaeological and palaeo-environmental investigations, allows us to obtain a greater amount of information with increased accuracy, and these improve the study of the history of the landscape. However, at the same time, all this technological development does not lead us to hegemony of the techniques and methods of history, and we run the risk of the nonsense that the spatial analysis becomes an end in itself devoid of any historical significance. In this context, historical aerial photographs constitute a useful tool and, integrating them with the more technical components, to maintain a focus on what should be the goal of Archaeology: the posing and solving of a historical problem.

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Recovering lost landscapes in Wales

Abstract: *Over the past thirty years the authors have carried out regular exploratory and recording flights over Wales in their roles as past and present aerial survey officers of the Royal Commission on the Ancient and Historical Monuments of Wales. Here they describe some of the ways in which their own and earlier aerial photographs have been used to recover information about lost or vanishing landscapes throughout the country.*

RECOVERING LOST LANDSCAPES

‘Recovering lost landscapes’ can have a multitude of meanings. Even the present-day landscapes, townscapes and industrial complexes only become ‘real’ to the outside observer when they are described in detail, analysed as to their functional, social and economic backgrounds – and in one way or another ‘mapped’ to give them topographical depth. This applies even more so to the landscapes of the past, largely robbed of the intangible influences which gave rise to the physical remains that form our primary evidence as archaeologists and landscape historians.

‘Landscapes’, too, can be defined in various ways, broadly characterised over large areas or intensively mapped and interpreted in a more local context. In some cases the landscape may be represented by dispersed elements, such as individual settlements, which may or may not be accompanied by features such as field systems or communication routes. In all of these situations, and no doubt others, aerial photographs from the last hundred years or so can play a significant role in the analytical process. This applies whether the elements that they show are ancient or modern, well preserved or hardly visible at all. In that sense the vast archives of essentially ‘non-archaeological’ aerial photographs that survive across Europe from the 1920s or so onwards constitute an invaluable resource in our attempts to describe and understand both ancient and recent landscapes. This applies whether we are looking at slow transformation over time or at the vast changes brought about by events during the currency of aerial photography itself. Aerial photographs of the pre-1960s landscapes of Italy (e.g. Bradford 1946, 1949; Jones 1987), for instance, or of pre-communist Eastern Europe (e.g. Hanson and Oltean 2013), are an invaluable supplement to the often inadequate maps and landscape descriptions of today and yesterday. So too, for industrial complexes and for built-up areas which grow, change and sometimes decay over decades or years rather than centuries or millennia.

When we seek to understand the fragmentary physical traces of the more distant past the evidence that we can derive from aerial photographs is equally important. This is especially true when the aerial evidence can be combined in a mutually supportive relationship with other sources of information – past and present explanatory schemes, documentary research, detailed description and analysis in the field, geophysical prospection, excavation and core sampling, and new or developing sources such as Airborne Laser Scanning (ALS) and techniques such as 3D digital modelling. The particular contribution of aerial photographs, and perhaps even more so of ALS data, lies in their capacity to show the entirety of a landscape, in stasis or developing over time. They

reveal the interconnections of the various elements, the continuities, superimpositions and adaptive restructuring that help us to understand a landscape as a whole rather than as a collection of individual elements.

AERIAL PHOTOGRAPHS AND LANDSCAPE RECORDING IN WALES

This contribution describes how aerial photographs have contributed to the recovery of lost or rapidly vanishing landscapes in Wales, the relatively mountainous landmass on the western fringe of the United Kingdom. After a general introduction to the aerial-photo resources available in Wales the story will be told through illustrations and extended captions showing the ways in which aerial imagery has been used over the past thirty years or so by the Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW). In 1986, when the Royal Commission, the national body for archaeological and architectural recording in Wales, appointed its first ‘investigator in aerial photography’ (Chris Musson) there was still a heavy concentration on detecting previously unknown ‘sites’ – and hence in a sense landscapes – through reconnaissance during summer months looking for plough-levelled sites revealed through cropmarking, undertaken in hired light aircraft as and when conditions allowed.

By contrast, two of the Commission’s early projects in aerial survey focussed on the country’s rapidly disappearing industrial landscapes of coal mining and slate-quarrying. Another entailed (and still entails) the monitoring of legally-protected sites and monuments deemed to be of national importance. These programmes, and the desire to test the potential of aerial photography in all parts of Wales, soon confirmed that upland areas, particularly in the north and west of the country, still displayed extensively preserved prehistoric to post-medieval landscapes. Many of these landscapes remained virtually untouched by the agricultural activity or other destructive forces that had eroded (but occasionally revealed) so much archaeological evidence in the more low-lying parts of the country.

Only later, when a long-delayed second member of staff joined the Commission in 1997 (Toby Driver), was it possible to start the systematic but inevitably limited analysis of vertical photographs taken during and after World War II by the Royal Air Force (RAF, from 1940 to 1965) and later by the Ordnance Survey for national mapping purposes (OS, from 1962 to 2009). Available as over a million small-scale prints and selectively as enlargements of the OS photographs, these historic images, along with their related flight-traces, provide repeated stereoscopic coverage at various dates and seasons of the year for the virtually the whole of Wales from the 1960s to early in the present century. There is more sporadic coverage from the 1940s and 1950s. All of these photographs are open for public or specialist consultation, along with a few hundred prints of known and previously unrecorded (mainly cropmark) sites taken during sorties over Wales by Cambridge University in the 1950s to 1970s.

More recently the Commission has acquired several thousand oblique and vertical photographs from the archives of the former Aerofilms company, which undertook a wide range of commercial aerial photographic work across Britain and beyond between 1919 and 2006 (Crawford et al. 2014). While most exist as a printed reference collection, around 95,000 of the photographs from 1919 to 1953, including many from Wales, have been digitised and made available on the internet (www.britainfromabove.org.uk).

These historical collections represent an invaluable source of information and discovery about past sites and landscapes across Wales, especially when used in combination with the many thousands of colour, monochrome and now digital images taken during RCAHMW’s own exploratory flights from 1986 onwards. There are also many thousands of photographs collected from the late 1970s onwards during aerial exploration and monument monitoring by the four independent archaeological Trusts that deal with rescue work, development control and regional archaeology across Wales. To these must now be added access (albeit slightly restricted) to an accumulating amount of ALS data collected by or for the Environment Agency and local planning authorities over the last decade or so. For the most part these are freely available to download for educational and academic purposes in the United Kingdom. In total, the potential for documenting and interpreting lost or vanishing landscapes across Wales is immense, if only the necessary money and manpower could be mustered from limited and currently shrinking resources.

PRESERVED ANCIENT LANDSCAPES IN NORTH WALES

The mountainous areas of north-west Wales, especially the once-cultivated but now largely pastoral foothills of the coastal areas, preserve some strikingly extensive prehistoric and later landscapes, readily visible on the

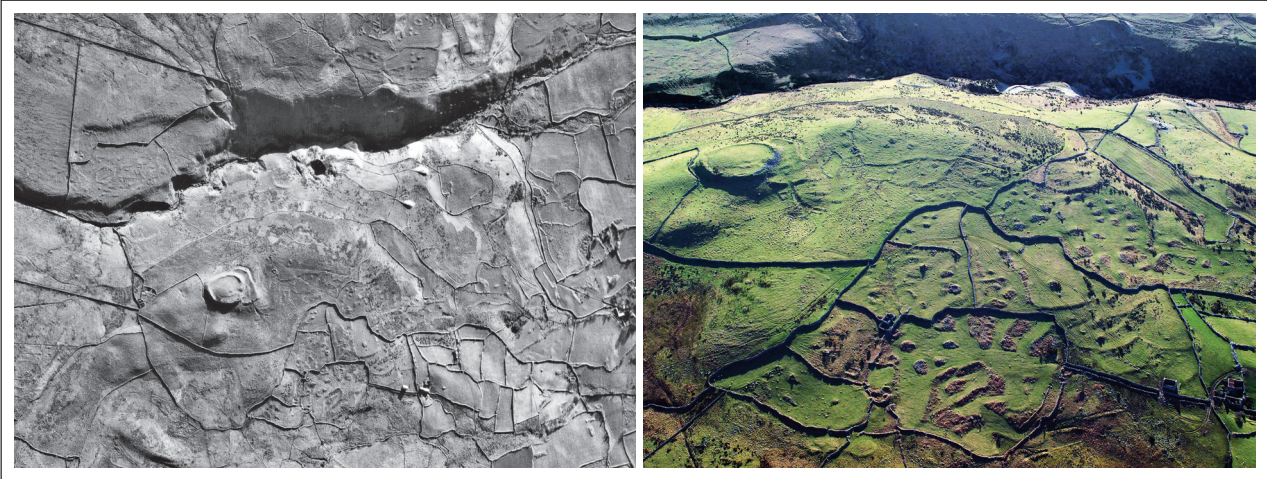


Figure 1. *Upland landscape in north-west Wales*

Above left the trackways, field banks, clearance cairns and enclosed settlements of a well-preserved prehistoric landscape are seen (1) in a vertical photograph taken by the Ordnance Survey for national mapping in 1958. Photographs for such purposes are for the most part acquired in relatively 'flat' lighting during the middle part of the year that produces imagery more suited to photogrammetric processing. They often need very careful stereoscopic examination to reveal the minor topographical irregularities that are essential features of any preserved archaeological landscape. The photograph on the right (2), an oblique colour image taken during a Royal Commission sortie almost half a century later in January 2005, shows how the archaeological aerial photographer, by contrast, will prefer the spring or winter months, when low vegetation cover and 'raking' lighting allow shadows and highlights to reveal the ancient features in their full topographical setting. Oblique photographs can also be viewed in virtual three dimensions if the original images are acquired in stereo pairs. Both vertical and oblique views (if the latter are taken in stereo pairs) can of course be examined in apparent three dimensions through the use of a portable or mirror stereoscope.

(1. DI2007_1990 © Crown Copyright MoD 1958; 2. AP_2005_0098 © Crown Copyright RCAHMW).

ground but even more clearly from the air. Their well-preserved trackways, field boundaries, stone-built hut groups and enclosed or fortified settlements belong for the most part to the first millennium BC and the first half of the following millennium. Some were mapped and described by the Royal Commission's field surveyors in the post-war years but even if this had not been done they would still have been recoverable from the vertical photographs taken by the RAF and the Ordnance Survey during those and later years. The complementarities of these historic and contemporary sources can be seen in the comparison of a typical 'archive' photograph from 1958 and a more recent oblique image from one of the Royal Commission's own aerial sorties in 2005 (Figure 1).

CROPMARKED SITES AND LANDSCAPES

It is debatable what one considers to be 'archive' or 'historic' aerial photographs (see Palmer this volume). Without doubt cropmarked sites, as elements in now-vanished landscapes, can be recovered from vertical photographs of the 1940s to 1980s already in the Commission's archives. However, the appearance of cropmarks depends on the timing of the flights, the local geology, the agricultural regime and weather patterns in the run-up to the time of recording (e.g. Cowley and Stichelbaut 2012). This limits the potential for recovering sites that now exist only as fleeting cropmark patterns. For the most part they become visible in Wales for only a few days or weeks in relatively dry years, mainly in the low-lying parts of the country where there is a reasonable amount of arable cultivation. But the results of exploratory aerial reconnaissance over the last 60 years or so can also be added to the equation, as has been demonstrated in Wales for lowland and hillslope contexts along the borderland with England and in the south and south-west of the country.

The search for cropmark evidence is a long task, however, which realises its potential only if pursued with resolution and flexibility year after year. Nevertheless the cumulative results can be startling in their transformation of the apparent patterns of later prehistoric settlement in these areas. In these areas the small

banked-and-ditched settlement enclosures of the later first millennium BC, many of them continuing in use during the subsequent Roman period, can be seen after 60 years of occasional and then more persistent cropmark survey to be far more densely distributed across the landscape than previously suggested by the much smaller number of surviving earthworks. As a result, the character of the later Iron Age and Romano-British landscape has been totally changed for those few parts of Wales that produce reasonably frequent cropmark evidence. Along the central borderland with England what once seemed to be a pattern of strongly defended 'hillforts' and occasional enclosed settlements on lower ground, now shows a spread of enclosed farmsteads in lowland and hillslope positions very similar in density to the distribution of local farms of the present day (Figure 2).

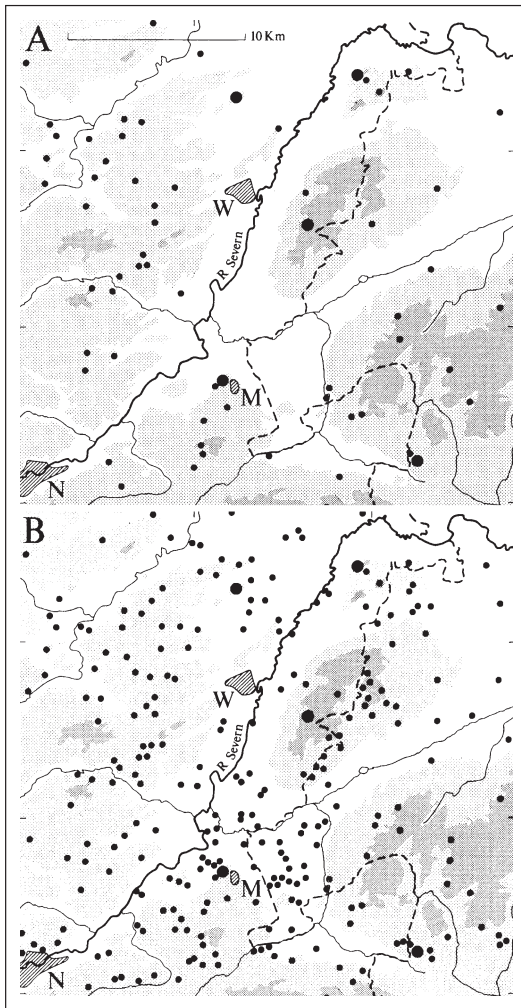


Figure 2. 'Dispersed' cropmark landscapes
 Later prehistoric settlements on the eastern borderland of Wales. The upper map showing hillforts and smaller settlements preserved as upstanding earthworks on high land and hillslopes. The lower map shows the impact of twenty years and more of 'cropmark' discoveries on the density of settlement, especially on the un-shaded lower land of the river valleys.
 (Musson, Palmer, Campana 2013, Figure 2.19).



Figure 3. Cropmark discoveries from 'archive' aerial photographs

Sometimes 'historic' vertical photographs can contain worthwhile cropmark evidence. Here, an Ordnance Survey photograph from the exceptionally dry summer of 1975 reveals three previously unknown ditched settlements (A, B, C) in lowland of south Wales.

This was a particularly valuable discovery since the area is very difficult to access for exploratory flights because it lies very close to a busy civilian airport. Exploratory aerial survey from light aircraft can to one extent or another target the responsive parts of the landscape in the critical weeks of the year. By contrast it is a matter of pure chance whether 'non-archaeological' vertical surveys are carried out during these potentially productive weeks – until, of course, archaeologists can secure the financial and technical resources to carry out their own vertical surveys at short notice during the critical stages of crop development.

(DI2011_0867 OS AP 75.308.012 © Crown Copyright).

The re-examination of historical aerial photographs, taken in the first instance for non-archaeological purposes, can sometimes reveal cropmark evidence for areas that have been lost to development in later years, or which lie in areas that are difficult to access, as is the case for the three settlement enclosures illustrated in Figure 3.

The evidence of attached field systems and communication routes is still lacking for most of these settlements in Wales but it seems inherently likely that topographically similar parts of the country with even a thin scatter of cropmark evidence may once have supported a comparable pattern of settlement, despite the scarcity of earthwork evidence to show that this was indeed the case. More pessimistically, it is clear that attempts at landscape reconstruction in such areas will remain fraught with uncertainty. Indeed, in some areas the task might be practically impossible because so much of the potential earthwork evidence has been lost beyond effective recovery, though the advent of large-scale geophysical survey may address this 'black hole' in the aerial and earthwork evidence. Until that time, it is worth noting that any area that produces even occasional cropmark evidence may in reality be hiding past landscapes that were once more complete and complex than they now appear to be.

AERIAL-PHOTO MAPPING AND GROUND-BASED SURVEY

For the last 30 years the Commission and its grant-aided agents have been carrying out a long-running programme of ground-based archaeological survey of selected parts of the Welsh uplands, defined for this purpose as land at elevations of 800ft/244m or more above sea level. This started as purely ground-based 'rapid survey', aimed at mapping and documenting the presence and essential characteristics of archaeological features of all periods from the earliest to relatively recent times. In recent years, however, the programme has been assisted by the preliminary mapping of all archaeological, industrial, agricultural or building remains that can be seen on the readily available vertical or oblique aerial photographs.

This kind of mapping, mostly from vertical photographs of varying quality taken for entirely non-archaeological purposes, can of course be hampered by a range of uncertainties, particularly in discerning low-lying or 'point-based' earthworks such as clearance cairns, burial mounds or pits half-hidden within the often-dense upland vegetation. Nevertheless the work done in Wales and elsewhere has shown that this kind of initial mapping can make an invaluable contribution to the speed and completeness of the subsequent ground-based survey, especially in revealing enclosures, boundaries and field systems detectable as 'linear' rather than point-based features). Taken into the field in hard copy, the mapped information can be elaborated during subsequent 'walk-over' survey by adding handwritten annotations, including notes on features not seen during the aerial-photo mapping. The outcome is a rapidly updated record for the surveyed area, the number of identified archaeological features often increasing by several hundred percent compared with the record before this kind of aerially-assisted work was carried out.

THE SKOMER ISLAND PROJECT

A more specific example, of a naturally-defined island landscape off the south-west coast of Wales, is Skomer Island (Figures 4 and 5). Survey and recording work by W. F. Grimes in the 1940s used sketch-mapping from vertical photographs to support his field explorations. A lack of modern cultivation, save for a central section of the island, together with an absence of permanent medieval and post-medieval settlement until at least the 17th century AD, suggested that the island's complex field systems and settlements were almost wholly pre-historic in date (Grimes 1950). Further fieldwork by J. G. Evans in the 1980s led to the conclusion that 'the occupation was short. There is little complexity in the field systems. It is likely that the entire occupation took place over a few generations, perhaps a period of no more than a century.' (Evans 1990). A map of the island's archaeology, based on ground observation as well as aerial-photo mapping by Terry James, is included here (Figure 4).

The special character of the island's landscape was stressed by its subsequent legal protection both as an ancient monument and as a place of special scientific interest. The Royal Commission's own aerial recording from the 1980s onwards added further support, especially through photographs from 2008 which demonstrated stratigraphical and chronological depth in the field systems. This evidence, and the highly valued and fragile nature of the island's landscape, made it an ideal candidate for a Royal Commission project incorporating aerial photography, remote-sensing and mapping (Barker et al. 2012). The objective has been the more complete and accurate mapping of the archaeological features from both vertical and oblique aerial

Figure 4. The Skomer Island Project

The relict archaeological landscape of Skomer Island is remarkably well-preserved. The first study of the island's landscape used a United States Air Force vertical photograph (1) to assist survey on the ground. The map of the island's ancient fields and settlement features (2) was made principally from aerial photographs in the late 1980s.

(1. © Crown Copyright MoD 1944 Courtesy of the Welsh Government; 2. Reproduced with kind permission from the Proceedings of the Prehistoric Society, 56, 1990, Figure 121.)

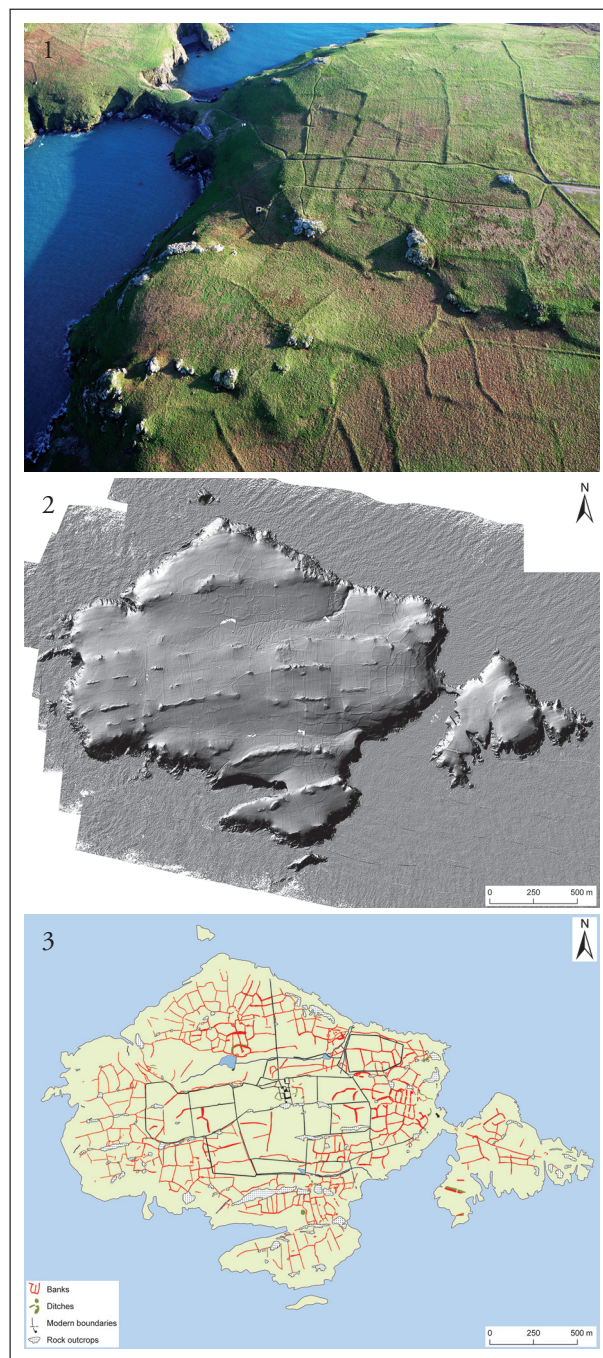
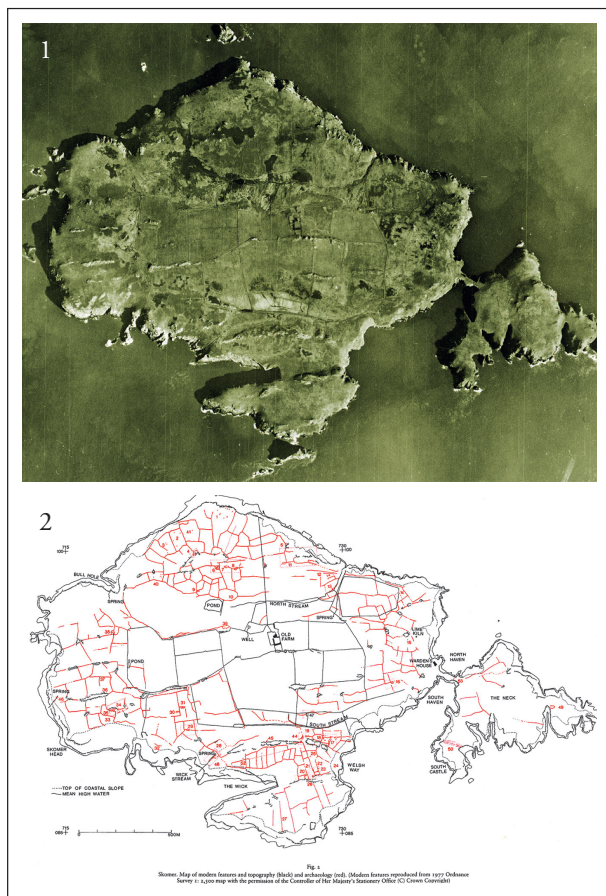


Figure 5. The Skomer Island Project

The Royal Commission's aerial sorties from the 1980s onwards progressively improved the island's aerial photographic record, a flight in March 2008 (1) showing important new elements in the field systems, with areas of relative stratigraphy providing firm evidence for a long and complex chronology. This provided a key impetus for initiation of the Skomer Island Project shortly afterwards. In February 2011 specially-flown 0.5 m ALS coverage was collected by the Geomatics Group of the Environment Agency after an exceptionally hard winter had flattened the island's scrub vegetation. The very clear dataset obtained on that occasion, shown here in a hill-shaded version (2), brought new clarity to the mapping of the prehistoric settlements and field systems, as shown in the updated map of the island's ancient landscape (3). It is instructive to compare this latest map with the earlier version made from aerial photographs and field observation alone in 1990 (Figure 4).

(1. AP_2008_0324 © RCAHMW; 2–3. © Crown Copyright All Rights Reserved Environment Agency 2011 – Geomatics Group – View generated by RCAHMW.)

photographs, and more recently through specially-flown ALS coverage at 0.5 m resolution. The enhanced mapping made possible by the acquisition of this data (Figure 5) has been accompanied by ongoing ground-based survey, geophysical prospection and sample excavation of the remains to re-assess their character and dating and to help in their long-term care and conservation. The first archaeological geophysics, in 2012, showed that unrecorded prehistoric fields and settlements survive beneath the modern fields in the centre of the island. Walkover surveys have also identified previously unknown Neolithic and Early Bronze Age ritual stone settings and standing stones. The work has shown that the field systems probably date back to the later Bronze Age (1200–700 BC), if not earlier. In 2014 the first sample excavation produced calibrated radiocarbon dates showing that the stone-walled roundhouses on the island were lived in around 150 years before the Roman conquest of west Wales in the first century AD.

The completeness and sophistication of the results demonstrates very clearly the benefit of combining aerial photographs and remote sensing of various kinds with detailed ground-based study. Such a combination, sadly, is likely to remain achievable only for limited areas of Wales within the restricted manpower, money and specialist skills that are available to undertake such work. (For online information on the project search for ‘Skomer archaeology’.)

VANISHING INDUSTRIAL LANDSCAPES

Sites and landscapes of relatively recent date can be damaged or erased by modern developments or by the demise of the industries that created them in the first place. South Wales, with its extensive coalfields, ore

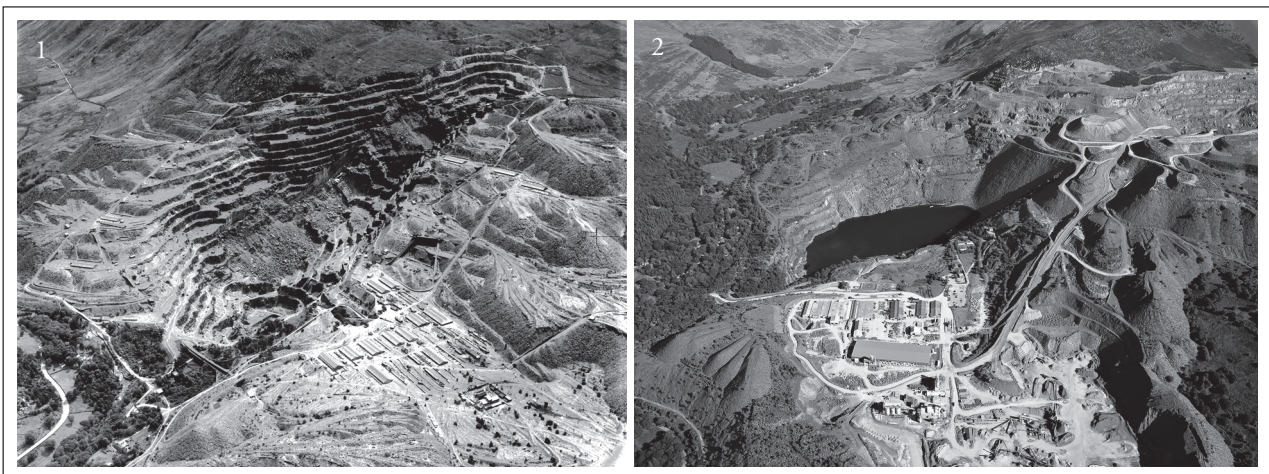


Figure 6. Six decades of the Penrhyn slate quarry, North Wales

Like towns and cities, industrial sites are for the most part in a state of continuous change, sometime slow but at other times very rapid – or even terminal, as with the closure of the deep-mined collieries of south Wales in the early 1990s. In these two photographs the focus is on developments over the past 60 years and more within the vast Penrhyn slate quarry in north Wales, the largest in the world from the mid 19th century onwards. From small scale beginnings towards the end of the 18th century the quarry’s expansion was rapid – and dramatic in its impact on the local landscape. The top-quality slate found here was ideal for roofing, in intense demand in the UK and abroad during the 19th and early 20th centuries. This is now the only large-scale slate quarry still operating in Wales, having been taken over and further modernised in the 1960s. The 1948 Cambridge University photograph on the left shows the serried ranks of 18m-high galleries (terraces) climbing up the hillside, with a deep extraction pit lower down the slope. Still in operation are ranks of processing sheds and stores in the foreground, along with parts of two inclined planes bringing quarried slate down from the upper levels. In the Royal Commission photograph from 2010 (above right) the upper galleries have bitten farther into the hillside and the deep pit in the centre of the photograph has been flooded and partly filled by quarry waste. The inclined planes have been replaced by roads for lorry transport and both sides of the workings, along with earlier processing floors, have been buried in later roads and accumulating quarry waste. (1. CUCAP BQ-3 Copyright Reserved Cambridge University Collection of Aerial Photographs; 2. AP_2010_2577 © RCAHMW.)



Figure 7. *A former industrial landscape*

The illustrations on this and the facing page show the way in which key features of an industrial landscape have been swept away by redevelopment and land reclamation after the effective death of the industries concerned. The vertical photograph, above left, taken over Tredegar by the RAF in May 1947, dramatically illustrates the complexity of the waste tips and tramways associated with coal mines and quarry workings cut into the steep eastern side of the valley, here cast into partial shadow by low sunlight from the east. At top right is a small cluster of individual vertical shafts from one of the earliest attempts to access an underlying coal seams. On the valley floor, amid towering waste tips, open areas mark the former positions of two pioneering iron works. At top left, just below five aligned buildings, lies the site of the Sirhowy Iron Works, which operated from the mid 18th to the late 19th century. At lower left, alongside the dark water of a tear-shaped reservoir, there once stood the Tredegar Iron Works which produced pig iron and then coke throughout the 19th century. In the photograph its former position is occupied by a brickworks, with two tall chimneys casting long shadows to their left in the morning sun. The Ordnance Survey map on the right, from around 1900, shows much the same pattern but cannot match the photograph's clarity in depicting the complex of waste tips, reservoirs, water-channels and tramways that supplied raw material, fuel and water power to the industrial workings in the valley below. (left: DI2011_0869 © Crown Copyright MoD 1947 Courtesy of the Welsh Government; right: 2013 historic mapping OS 4th edition © Crown Copyright RCAHMW.)

deposits, woodlands and limestone, became one of the key drivers of the Industrial Revolution in the late 18th and 19th centuries, renowned for its iron, steel and copper working as well as for its deep-mined collieries). The other end of the country, in north-west Wales, especially during the days of rapid urban growth in the 19th century, saw the widespread exploitation of slate deposits, especially for high-quality and long-lasting roofing slates (Gwyn 2015).

These once-dominating extractive and productive industries are now effectively dead, apart from a single large slate quarry (and a couple of smaller enterprises) in the north and some extensive open-cast coal extraction in the south. This revised method of extraction, along with widespread programmes of 'land reclamation', rapidly destroys all evidence of earlier workings in the affected areas. In their time, however, both industries created their own distinctive (if 'dispersed') landscapes, readable and recordable from the air in ways that escaped full expression in the national and local mapping programmes of the Ordnance Survey. Now, aerial photographs from up to 60 and more years ago can restore to the archaeological record essential elements



Figure 8. *A former industrial landscape today*
 This vertical photograph from the present day shows how vast areas of the waste tips and other ancillary features have been erased by land reclamation and planting on the valley floor and the eastern hillslopes. Similar situations can be multiplied many times over in the former coal-producing and iron-working valleys that made south Wales so important to the Industrial Revolution throughout the 19th century.
 (© Airbus Defence & Space.)

of these very specialised landscapes, relevant to our understanding of the social and economic development of relatively recent times (Figures 6, 7 and 8).

There is a lesson here for present-day aerial photographers, and for the ever increasing use of ALS for mapping and environmental purposes: whenever possible we should record our present-day rural, urban and industrial landscapes from the air, for the benefit of our successors in future decades. In 50 years' time, and often sooner than that, what we see and think we understand today will have become, in parts at least, 'things of the past', just as much as the earlier landscapes illustrated in this and other contributions throughout this volume.

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Aerial photography and remote sensing on the Karst: a case study of Boka Kotorska Bay, Montenegro

Abstract: *So far the archaeological interpretation of historical or archaeological landscapes in Montenegro has not received any attention. Indeed, landscape changes are not generally considered important to the creation of an overall picture of an archaeological site and its surroundings. This paper makes a contribution to the limited number of archaeological studies in Montenegro based on modern non-invasive methods for studying archaeological landscape. It reports on the preliminary stages of a PhD project that aims for a comprehensive survey and spatial analysis of archaeological sites in the Boka Kotorska Bay region, and presents the results of interpretation of aerial photographs and satellite images of the Luštica peninsula in Boka Kotorska. It aims to improve archaeological knowledge in this part of Montenegro, since other approaches have not yielded desired results (e.g. Archaeological Map of Montenegro).*

INTRODUCTION

Although aerial photography is a well-established form of archaeological remote sensing in Europe Montenegro is an exception, and to date not a single area has been photographed for archaeological purposes. The reasons for this lie in the profiles of archaeological professionals as well as in the scarcity of material resources. Archaeology in Montenegro has come to a troubled standstill at the crossroads of traditional understandings of science on one hand, and the possibility of applying other theoretical and methodological techniques on the other. However, the adoption of novel approaches remains only a possibility as the consensus in Montenegrin scientific circles hinders the application of “new” methodological techniques as well as theoretical approaches to tackling certain scientific issues. This paper discusses the opportunities presented by an aerial remote sensing approach.

A BRIEF HISTORY OF AERIAL PROSPECTION IN MONTENEGRO

The beginnings of aerial reconnaissance in what is today Montenegro lie at the start of the twentieth century during the Austro-Hungarian monarchy, when aerial images were taken during the World War I for military intelligence. Aerial reconnaissance was initially conducted from balloons (Figure 1) which were soon replaced by airplanes and hydroplanes that were more efficient in surveying, supported by infrastructure for processing and interpretation of the aerial photographs (Smokvina 2007, 132).

The first steps in aerial reconnaissance were undertaken for military intelligence from the Austro-Hungarian sea-plane base in Kumbor (*Seeflugstation der Kumbor*). One of the first vertical photographs of Montenegro was taken of the Lovćen mountain range. The photograph is annotated in black ink that mark the infantry lines of the Lovćen squad of Montenegro’s royal army (Figure 2) and scribbled over with interpretation. It was probably taken in late autumn 1915 as the orders to attack Lovćen were issued on 3rd January 1916 (Rakčević 1969, 156). Many more aerial photographs were taken during World War I, and there is a

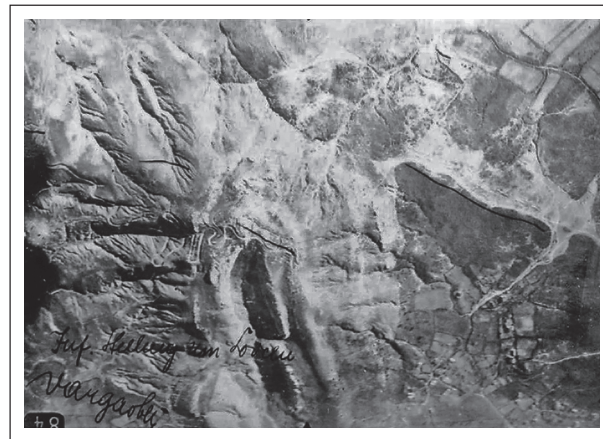
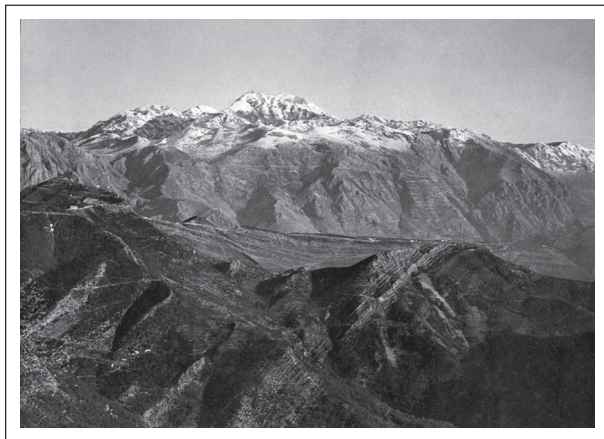


Figure 1. Aerial view of Lovćen from a balloon. Austrian States Archive/War Archive Vienna. Picture Collection WWI, sub-stock Montenegro picture number 1361. Original title: “Lovcen, Ballonaufnahme”.

Figure 2. Lovćen from the Air. Infantry lines of the Lovćen squad of Montenegro's royal army. Unknown source, private collection courtesy of Miljenko Smokvina.

large collection of many thousands of images in the Military Archive in Vienna taken by Austro-Hungarian pilots (Smokvina 2007, 132). Aside from images in Austria, Smokvina suggests that there is also imagery in Rome at the Archives of the Ministry of Defence and/or the Central State Archive (*Archivio centrale dello Stato*). Little is known of aerial photography between the two world wars, though there is information on aerial reconnaissance of the Adriatic coast and islands between 1934 and 1937 by the Hydroplane Command of the Kingdom of Yugoslavia.

The availability of aerial photographs and cartography increases dramatically in World War II. This was collected by the Axis powers and the Allies, and housed in the National Archives and Records Administration (NARA) in the USA and by the National Collection of Aerial Photography (NCAP) in Scotland (see Cowley and Stichelbaut 2012 for a general description of these archives). The NARA collection holds aerial photographs taken by the Luftwaffe and seized by the Allies at the end of World War II. This captured German aerial imagery was labelled “GX”. NCAP also holds a collection of Allied and Axis aerial photographs, some of it overlapping with NARA and some unique.

Montenegro is at least partially covered in these collections, with place name searches indicating that there is imagery for the so-called Dalmatian harbours including mentions of the towns of Herceg Novi, Risan, Tivat, Kotor, Budva and Bar. In both NARA and TARA the available aerial photographs are at a useful scale and some of the images for the Balkans area have been digitized. Furthermore, it appears that the quality of reproduction of originals is in most cases superior to the oldest series of aerial photographs at the Military Geographical Institute (MGI) in Belgrade.

After World War II, aerial reconnaissance of the former Socialist Federative Republic of Yugoslavia (SFRY) was taken over by the federal military institutions headed by the MGI in Belgrade. Upon gaining independence, survey of Montenegro's territory, including aerial prospecting and photogrammetry, was taken over by the Real Estate Administration (REA), a governmental institution located in Podgorica. This review of known and potential aerial photographic coverage of Montenegro demonstrates that there is imagery from World War I to the present, which as stated above remains little used. The following section discusses the challenges of aerial photographic interpretation on the karst in the case study area of Boka Kotorska Bay and its nearby hinterland.

AERIAL INTERPRETATION ON THE KARST

Reliable aerial photographic interpretation demands familiarity with the archaeological landscape being dealt with and how archaeological structures may be manifest, and also including knowledge of the geomorphology, topography and geology (Wilson 2000, 213). The karst geomorphology of most of Montenegro, beyond the limited areas of plains, is a challenge to aerial reconnaissance and photo-interpretation.

An interpreter must draw on knowledge about techniques of construction and distribution of archaeological sites over time. In rural parts of Montenegro traditional construction techniques are used over long periods of time, making it difficult to establish the date of many structures. Such structures are a challenge to interpretation in the field, and such problems are magnified many times when interpreting aerial photographs or viewing them from the air.

Past social and economic changes in the populations of the Montenegrin karst add to the interpretative challenges. In the former Socialist Federal Republic of Yugoslavia, Montenegro used to have the largest percentage head of population engaged in agrarian activities (Glušćević 2004, 355). Planned industrialization led to major landscape change, especially in a rapid reduction of the land set to farming. The emphasis on developing industry relegated agriculture and animal husbandry to a role of secondary importance and caused migrations of the rural population into urban centres. The new economic and social organization transformed the concept of living space. The Adriatic coast has had a long tradition of breeding small cattle, and due to the peculiarity of the karst with its very scarce vegetation, sheep and goats are the dominant breeding species in coastal regions. Sheep and goats graze on wild plants and, properly managed, ensure optimal exploitation of pasture and equilibrium of the ecosystem by preventing the proliferation of weeds (Garibović 2006, 513). The new state economic strategy resulted in a neglect of agricultural land and pastures and subsequent expansion of vegetation.

These circumstances complicate the analysis and interpretation of aerial photographs, as the vegetation cover makes it difficult to identify archaeological structures. However, the specificity of the Mediterranean landscape, where rock is the main building material, enables the application of Airborne Laser Scanning (ALS) technology for the detection of structures whose visual identification is not possible from recent aerial photographs.

SOME RESULTS OF AERIAL PHOTOGRAPH AND SATELLITE IMAGE INTERPRETATION

With its numerous archaeological sites the Boka Bay is a good case study for the application of spatial analysis and this is a focus for my PhD research. The study area is roughly limited to the maritime area of the Boka

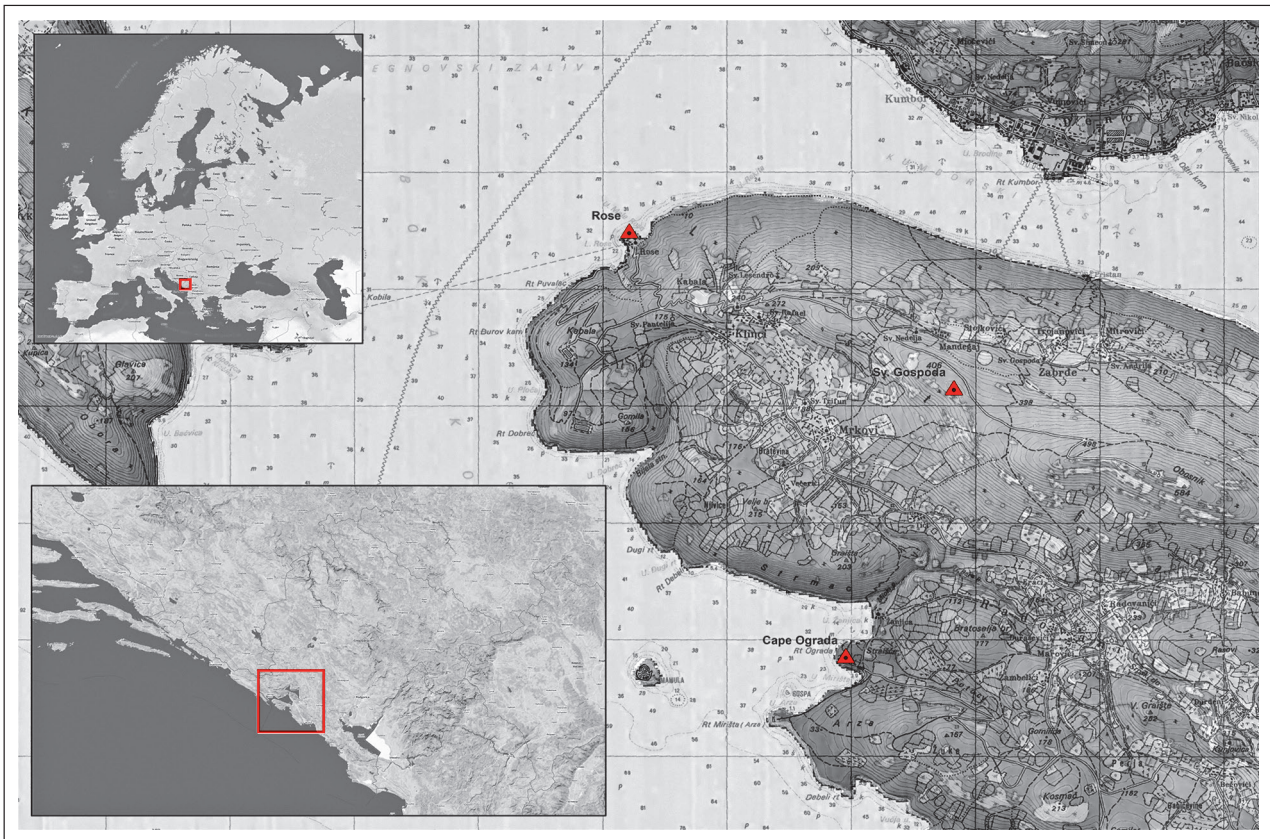


Figure 3. *Topographic Map (Scale 1:25,000) Military Geographical Institute in Belgrade.*

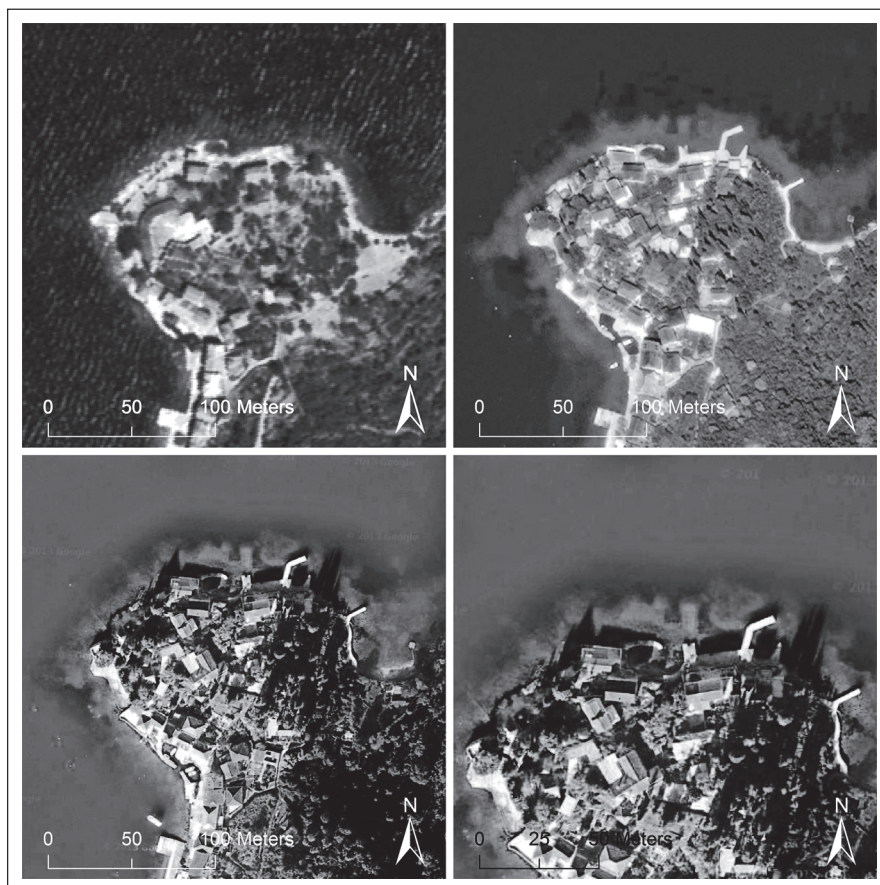


Figure 4. Visible rectangular structures below the sea at Rose. NCAP-006-024-002-426-R, Rose, Montenegro ©RCAHMS. Licensor RCAHMS/ncap.org.uk, ©2014 Microsoft Corporation, ©2012 Digital Globe and Real Estate Administration of Montenegro.

Kotorska Bay and its nearby hinterland extending to the Luštica peninsula and Grbalj plain. The case study presented here is based on the analysis of vertical aerial photographs taken in World War II from the Allied Central Interpretation Unit (ACIU) collection, satellite images and new digital orthophoto from the REA, supplemented by ALS data in some cases. This provides at least two time series of aerial photographs that allow better understanding of landscape change and the identification of archaeological structures (Grosman 2001, 146).

To these data sources will be added the analysis of digital surface models derived from Structure from Motion (SfM) processing of images from Unmanned Aerial Vehicle and low-altitude platforms (e.g. kite). While the analysis of the landscape for my PhD is ongoing, three examples of newly discovered sites on the Luštica peninsula (Figure 3) are presented below by way of illustrating the potential.

Rose

Rose is the first harbour at the mouth of Boka Kotorska bay and it is likely that the location had special significance over a long time period. Analysing the satellite images, aerial photographs and bathymetric data along this coast revealed regular geometric features that could be the remnants of a dock. Unfortunately the oldest available aerial photographs from 1944 (ACIU) were taken during rough seas, and the disturbed water surface did not allow observation of these features. Preliminary interpretation suggests that a visible rectangular structure resembling a mol could have served as a safe lateral dock relatively well protected from most winds typical for Boka. There is, therefore, a possibility that there is a submerged harbour or docks at Rose (Figure 4) though there is also a possibility that these features represent dumping of material to expand the shore line. Since the 1944 aerial photographs did not help in this respect, greater certainty in the interpretation of these features will required underwater survey.

Sv. Gospođa hill fort

Known hill forts in almost all parts of Boka Kotorska Bay and its hinterland generally occupy dominant peaks, while their morphology reflects diversity in their form and purpose, and geographical locations. The hill fort

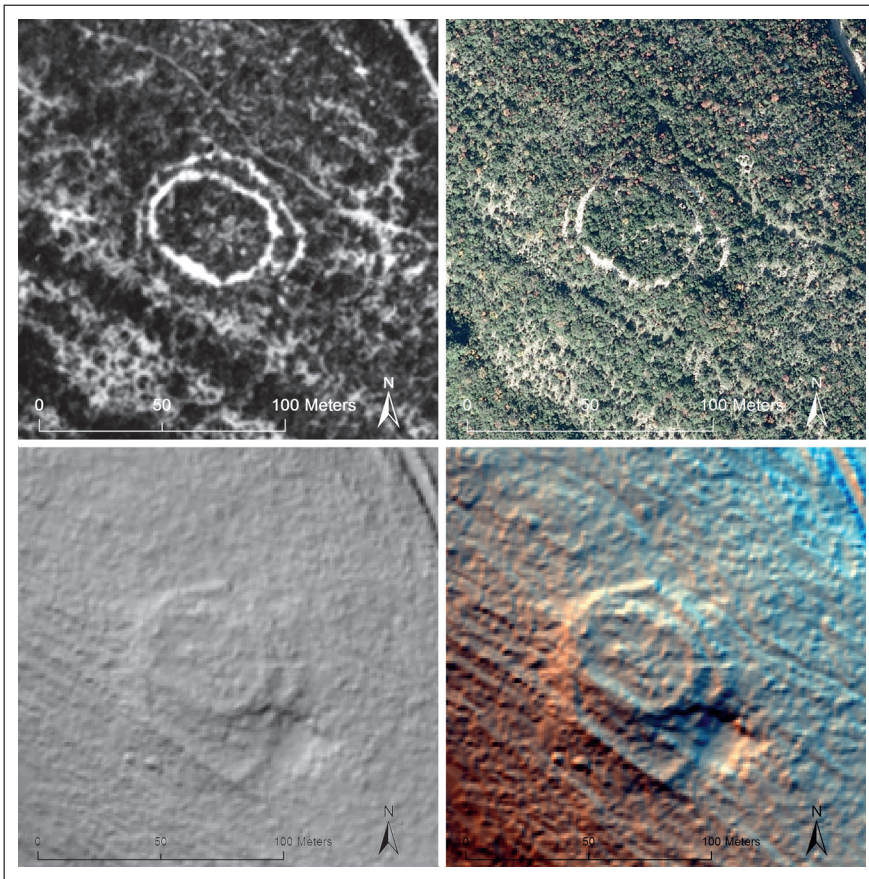


Figure 5. Ringfort with the outer semi circular rampart on the summit of Sv. Gospoda. NCAP-006-024-002-403-R, Sveta Gospoda, Montenegro ©RCAHMS. Licensor RCAHMS ncap.org.uk and Real Estate Administration of Montenegro.

Figure 6. Part of the rampart remains of Sv. Gospoda hill fort. Private collection Miloš B. Petričević.



near the village Mandegaj on the Luštica peninsula was discovered on 1944 aerial photographs (ACIU), and is likely to be the largest known prehistoric fortification in the area. The defences comprise two circuits, the inner a dry stone wall which delineates the plateau of the interior, with the outer rampart forming a semi circular partial circuit connected to the inner wall in three places (Figures 5 and 6).

These transverse connecting walls are visible only on the 1944 aerial photographs, and they are obscured by the spread of vegetation by the dates of the satellite images, and more recent aerial photographs unfortunately do not provide additional information about the nature of spatial relations due to the evident progression of vegetation as mentioned earlier. For this reason it was decided to examine the utility of ALS data for the interpretation of this site, which is available from the REA for the whole of Montenegro at a resolution one point per square meter, and opens up new possibilities for the visualisation, analysis and interpretation of the karst.

The effective filtering of the ALS data in order to examine the micro-topography of the terrain is crucial to the discovery of archaeological remains (Doneus and Briese 2011, 65). In particular filtering using the LASTools software package aimed to remove the thick maquis vegetation so as to highlight underlying archaeological features. Further examination of the digital terrain model produced made use of the relief visualization toolbox (Kokalj *et al.* 2011). However, despite the filtering and visualisation of the ALS data, the nature of the semi-circular rampart cannot be determined more closely because of the dense maquis vegetation and the resolution (PPSM) of the ALS data.

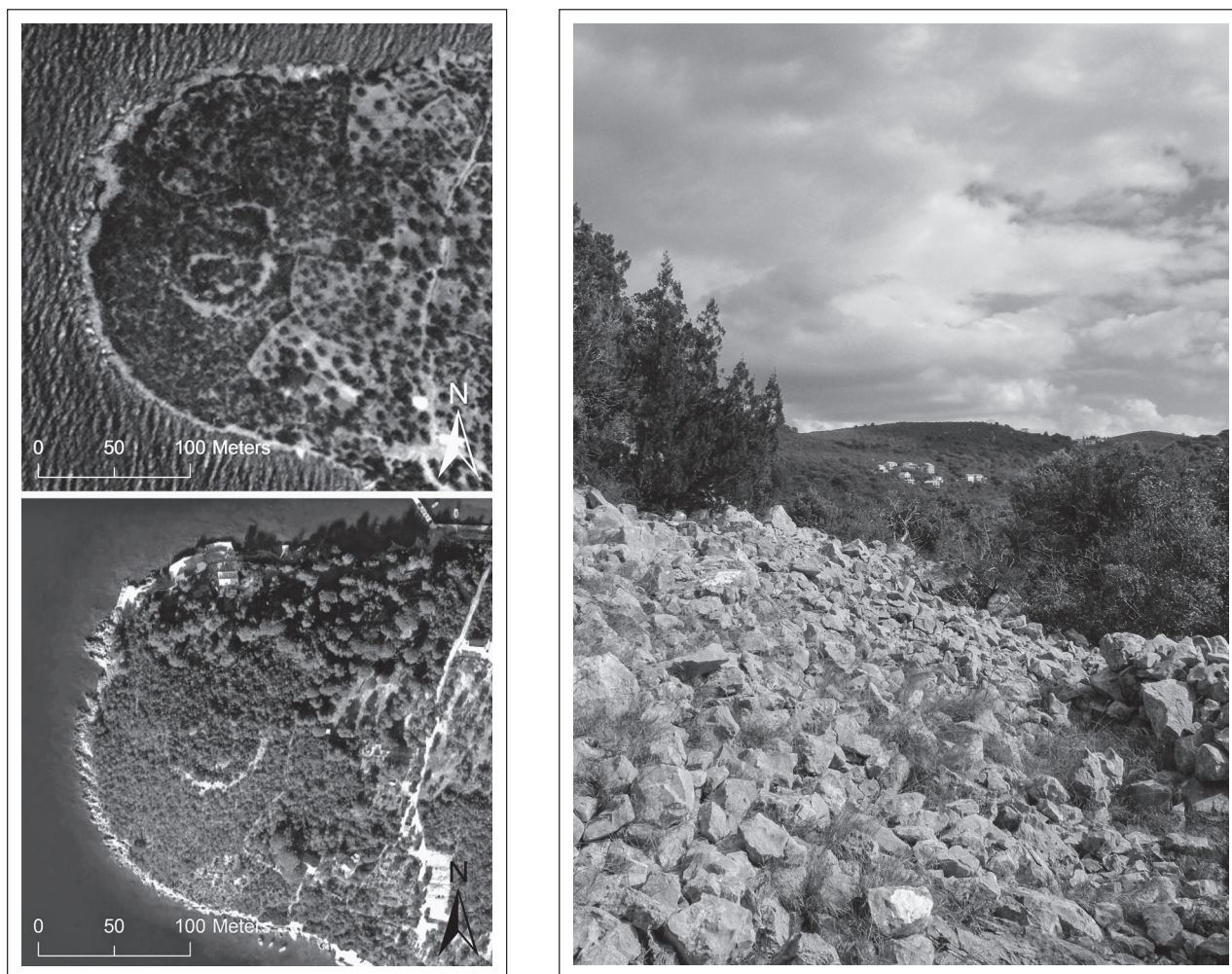


Figure 7. The possible hill fort at Cape Ograda, NCAP-006-024-002-625-R, Zanjica, Montenegro ©RCAHMS. Licensor RCAHMS/ncap.org.uk and Real Estate Administration of Montenegro.

Figure 8. Part of the rampart remains at Cape Ograda hill fort. Private collection Miloš B. Petričević.

Cape Ograda hill fort

The possible hill fort at Cape Ograda was also discovered from 1944 aerial photographs (ACIU), and comprises a dry stone wall (Figure 7) forming a circular rampart built of undressed stone (Figure 8). It lies in what appears at first sight as a very unusual position at an altitude of only 29 meters. The interior of the fort is divided by a transverse dry stone wall, which is feature that has not previously been observed in Boka Kotorska and therefore attracts special attention. However, the Cape Ograda fortification is also covered in thick maquis vegetation which makes spatial interpretation and the creation of a site plan difficult. The interpretation of the inner dry stone wall is difficult, but there is a possibility that the morphology of the hill on top of which the fortification is located determined the layout of the interior.

There are difficulties also in defining the line of the main rampart. From the June 1944 aerial photograph it is very difficult to fully trace the rampart, though one should take into account the limitations in the quality of reproduction of the original aerial photographs. However, a full circuit of the rampart cannot be seen around the south-western part of the hill and this raises suspicions about whether or not this is a fortification with a circular rampart.

Along the southern face of the interior dry stone wall there are the ruins of a small building with an entrance to the east. The floor of this building is made of tightly packed small undressed stone, and fragments of ceramic roof tiles were found during a field visit. Thus this site may have multiple phases of occupation, though the identification of part of this sequence as a fort remains provisional.

CONCLUSION

The application of aerial photographs extends beyond mere detection and recording of archaeological sites, to promoting a landscape and spatial perspective that opens up new possibilities for future archaeological studies if they include detailed analysis and interpretation of historical aerial photographic material. For such studies, archives, such as NARA and TARA, offer an invaluable source of information especially for the discovery and then protection of otherwise unknown archaeological sites, which are undeniably threatened by unplanned urbanization of the Montenegrin coast. The PhD project of which this paper is a part aims to improve the existing monument records to support significant improvements in the future protection of sites. It is also hoped that the demonstration of the value of “new” methodological techniques in archaeological reconnaissance will promote new approaches in archaeological prospecting and detection, which is important for further progress in the development of archaeology in this region. The advantages of remote sensing methods, especially when combined with analysis of historical aerial photographic sources, are a huge, largely unrecognised, potential development for archaeology in Montenegro, and one that I hope will see the start of a process of introducing “new” methodological techniques to Montenegrin archaeology.

Acknowledgments

My thanks to Snježana Šoškić, the Head of the Department of Cartography and Photogrammetry of the REA, who has recognized the importance of remote sensing in archaeology and supported my work by sharing photogrammetric material, ALS data and providing valuable advice.

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Recovering lost or hidden landscapes – Aerial photographs and the English National Heritage Protection Plan

Abstract: *This paper explores the role of aerial photographs in the discovery, analysis and protection of landscapes in England. The topic of 'lost' landscapes and aerial photographs will be discussed in the context of heritage protection. This includes destroyed features only recorded in the archives, but also buried or unnoticed archaeological sites and landscapes that could be considered hidden until recorded from aerial photographs. These landscapes could be considered 'lost' in the sense that their meaning and significance is unrecognised or not well understood.*

The main context for this discussion is the work of the government agency English Heritage. English Heritage split into two organisations on 31st March 2015. The new English Heritage is a charity which cares for and presents a portfolio of historic properties and archaeological sites open to the public. The other organisation, Historic England, is the public body which looks after England's historic environment. This includes the statutory protection of historic buildings and archaeological sites. Linked to this is the development and promotion of national frameworks, policies and best practice in heritage protection.

HERITAGE PROTECTION CONTEXT

Heritage protection is carried out in several contexts in the UK. Historic England, and sister organisations in Scotland, Wales and Northern Ireland, manage the assessment and protection of historic buildings and archaeological features thought to be of national importance. Nationally or internationally designated areas, such as Areas of Outstanding Natural Beauty, National Parks or World Heritage Sites, have management plans that include strategies for managing the historic environment.

Most archaeological sites and landscapes are managed at a local level, by a county council or other Local Authority, usually through the planning process. Planning authorities are required to consider archaeological remains and potential applications for developments such as housing and roads. The information required to support these decisions is contained in a local historic environment record (or site and monuments record) which contains records of archaeological sites and historic buildings. Publications such as the National Planning Policy Framework (DCLG 2012) and the Planning Statements and Guidance England (English Heritage 2010) inform decisions at a local level and are intended to protect the environment and promote sustainable growth.

Environmental Stewardship schemes form part of another national scheme managed locally. It is funded by the UK government and European Union and implemented in England by Natural England. These and previous initiatives provided financial support to farmers and land managers to enable them to manage the natural and historic environment in positive ways.

The promotion of understanding and appreciation of the historic environment also needs to be a key part of the process of heritage protection but can be challenging. Engaging with individuals and communities is

essential and a lot of excellent work is carried out by organisation such as the Council for British Archaeology or local groups and societies (<http://new.archaeologyuk.org/>).

THE NATIONAL HERITAGE PROTECTION PLAN

The National Heritage Protection Plan (NHPP) promotes strategic organisation of research and other activities that lead directly to heritage protection outcomes. It comprises a series of ‘Measures’ which form a flow line through an assessment of threats; identification and recognition; assessment of character and significance; protection of significance; appropriate management of change; advice and help for owners and land managers (English Heritage 2013). This framework is used by Historic England to target resources and plan activities to effectively build the evidence base, assess the significance of this information in order to inform responses, and therefore help people to achieve appropriate protection measures for the historic environment.

Aerial photographs have a role in several areas of the English Heritage NHPP Activity Plan. They are used to illustrate strategic threats to the historic environment such as flooding, coastal erosion, or major development (Figure 1). They can highlight and communicate certain issues such as the potential impact of change on the setting of a historic buildings or archaeological features. Aerial photographs also aid monitoring the condition of archaeological monuments and can chart major agricultural change, such as large scale conversion of traditional pasture to arable, which may affect archaeological sites and landscapes.

The main role of aerial photographs in heritage protection is in the discovery and record of archaeological sites. In the NHPP, this falls under the measures grouped as ‘building the evidence base’, in particular the measure characterised as ‘identification and recognition’. Aerial photographs are arguably one of the greatest sources of information on the location and general character of archaeological sites and landscapes.



Figure 1. *Floods in Somerset, England.*

The Iron Age settlement mounds of Meare Lake Village are highlighted above the flood water (bottom left). 27894_033 9th January 2014 © Historic England. Photograph by Damian Grady, English Heritage.

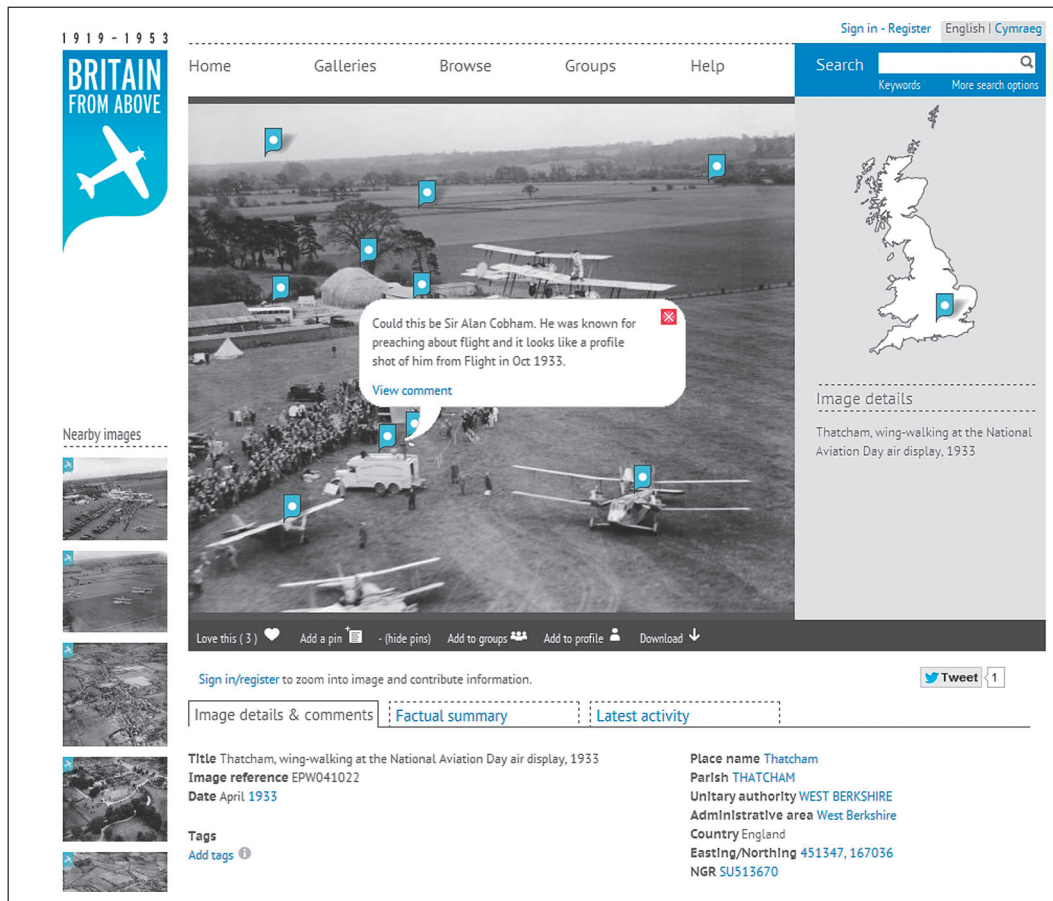


Figure 2. *Wing walking at the National Aviation Day air display 1933 with tags added by members of the public. EPW041022. © Crown Copyright.*

The NHPP therefore has an activity devoted to aerial reconnaissance and landscape projects led by analysis and mapping from aerial photographs. The extensive and important information from aerial photographs provides a framework for better understanding and assessment of significance. This is used to implement heritage protection measures and to target appropriate research and complementary survey techniques.

MINING THE ARCHIVES

The potential of aerial photographs in archives for the study of archaeological landscapes is explored in detail elsewhere (Cowley *et al.* 2010; Hanson and Oltean 2013). In the context of heritage protection, it can be argued that the archaeological information contained on aerial photographs in archives is not lost exactly but perhaps 'missing' if it has not been analysed and results communicated. Identification and recognition of archaeological sites and landscapes is the essential first stage in providing information for land managers and planners. In basic terms, to be able to protect a site we need an account, in a local or national historic environment record, of where and what it is.

The aerial photographs in the national, and some local, archives in England comprise those taken for non-archaeological purposes, usually vertical photographs, and those taken specifically to record archaeological sites, historic buildings and landscapes, usually oblique images (Winton and Horne 2010). Other sources include online image sets, such as the Britain from Above (Aerofilms) collection or the various layers on Google Earth. Finally, the increasing use of Airborne Laser Scanning (ALS) in archaeological and non-archaeological contexts means that, as with other aerial sources, there is body of information in various formats available to archaeological researchers. This includes what could now be considered 'historic' ALS data and visualisations that can be used for prospection but also form a benchmark of the condition of archaeological monuments or landscapes.

These sources span a date range from the 1920s to the present. The large volume of sources in England and the long time range in particular are important aids to understanding how, and why, we see archaeological evidence but also provides information on the survival and likely preservation of remains.

The Historic England Archive has approaching four million aerial photographs and the catalogue records the location of the centre point of each photograph. The catalogue does not usually record information on the contents of the photograph for a variety of reasons, but mainly due the way the collection was acquired and its large size. Some online sources are tagged with historical information but in most cases, this is not the focus of the service. For example, the Aerofilms collection is being made available online on the Britain from Above website (<http://www.britainfromabove.org.uk/>) where people are encouraged to add tags with information about details on the photograph and what is at the site or area today. This captures the perceptions and values the general public place on information from historic photographs (Figure 2).

Most programmes of archaeological aerial reconnaissance have a flow line whereby descriptions of significant sites are directly incorporated into the historic environment record. Different approaches are required to deal with the bulk of the available sources, usually those taken for non-archaeological purposes, or those acquired when there was no reconnaissance recording programme. In many cases aerial photographs, taken in different years, are required to build up a picture of an archaeological site or landscape. The best way to collate and understand the archaeological information on aerial photographs is to map the information accurately and to provide interpretations of the sites and landscapes.

Therefore, to recover the ‘lost or missing’ archaeological information on aerial photographs, or ALS, it needs to be interpreted and collated into geographical information systems or databases. Given the large volume of aerial sources available, we need strategies and methods to record the information effectively and efficiently. It is especially important that data from aerial photographs can be analysed or combined with information from other sources or survey techniques. In England the local and national historic environment records, and linked GIS, provide a platform for this.

MAPPING PAST LANDSCAPES

The English Heritage National Archaeological Identification Surveys (NAIS) aim to develop methods and produce guidance on best practice for recognising and identifying archaeological assets on a landscape scale, leading directly to heritage protection. Earlier English Heritage projects such as the ‘Mendip Hills’, ‘Miner-Farmers of the North Pennines’ and ‘Hoo Peninsula’ provided examples for the further development of integrated survey approaches to landscapes. The Hoo Peninsula project in particular applied the concepts described in the European Landscape Convention that encourages a broad definition of landscape as our living natural and cultural heritage, as perceived by locals and visitors, whether it is ordinary or outstanding, urban, rural on land or in water (Council of Europe 2000, English Heritage 2009). The landscape investigation of the Hoo Peninsula involved various non-intrusive survey techniques and included assessments of how nature and humans shaped the land, and the changing perceptions of the area over time (Carpenter *et al.* 2013).

The NAIS pilots aimed to carry out this kind of work in the context of the National Heritage Protection Plan and to develop a toolkit to help maximise resources in the application of integrated techniques. The two areas chosen have contrasting landscapes, the Lakes and Dales project area mainly comprises upland and pasture, and the West Wiltshire project area has a river valley lowland setting with a mix of arable and pasture.

The starting point for the NAIS projects was analysis and mapping from aerial photographs and other ‘desk-based’ sources. These large area assessments were used to identify research questions, gaps in knowledge, and archaeological sites and landscapes that require further work. This follow on work is ongoing and includes targeted ground techniques such as geophysical survey, analytical earthwork survey, architectural survey, field-walking, cartographic and documentary research, excavation, scientific dating, and environmental sampling (Figure 3).

The heritage protection results from these projects will be measured in terms of the knowledge fed into historic environment records, archives, and publications suited to those engaged in future planning and management initiatives, but may also include recommendations for statutory designation. The guidance developed as part of the two pilots will inform those working on landscapes, or large areas, and complement the site and period based approaches to assessment of significance.



Figure 3. *A field investigator explores a robbed-out prehistoric cairn during the English Heritage NAIS upland pilot. © Historic England. Photograph by Rebecca Pullen.*

The approach used for the first phase of the NAIS projects was developed from methods used as part of National Mapping Programme (NMP) projects (Horne 2011). This advocates using all available sources of aerial photographs and recording all information, from the Neolithic up to the Cold War, including earthworks and structures, or buried remains revealed as cropmarks. The standard products of NMP projects have developed over time but now comprise a digital archaeological map with linked archaeological descriptions, and a synthesis of the results. The archaeological site descriptions include a basic assessment of survival and include references to the source aerial photographs to inform further evaluation of the site or landscape.

This interpretation and mapping collates the information from numerous aerial sources and depicts the form and extent of archaeological information from different periods and with differing levels of visibility on the ground. The composite map encourages a layered view of the landscape, where the aerial evidence, and information from other sources and survey techniques, provides glimpses of the changing use of an area over thousands of years. This is an important viewpoint for heritage protection which considers all known aspects of the past land use in the context of managing future change. To take one example, Figure 4 illustrates an area around the Roman frontier Hadrian's Wall. This includes prehistoric or Roman settlement (far right and mid-left), Roman military camps (e.g. bottom left), and the turf wall, vallum and the military way extend right across the landscape. There are further layers of medieval cultivation seen as ridge and furrow and overlying all this is the Second World War military landscape associated with the airfield and ancillary buildings of what later became Carlisle Airport.

An additional value of this approach is that the mapping and records from projects like these feed, via the local historic environment records, into the Selected Heritage Inventory for Natural England (SHINE), which is an essential evidence base for conservation schemes such as farm environment plans.

MAPPING CHANGE

Potential threats to the historic environment, such as changing agricultural land use, development and coastal erosion, are recorded on aerial photographs taken at irregular intervals over the last 50 or more years and these provide an invaluable record of just how much has changed, or not, in England.

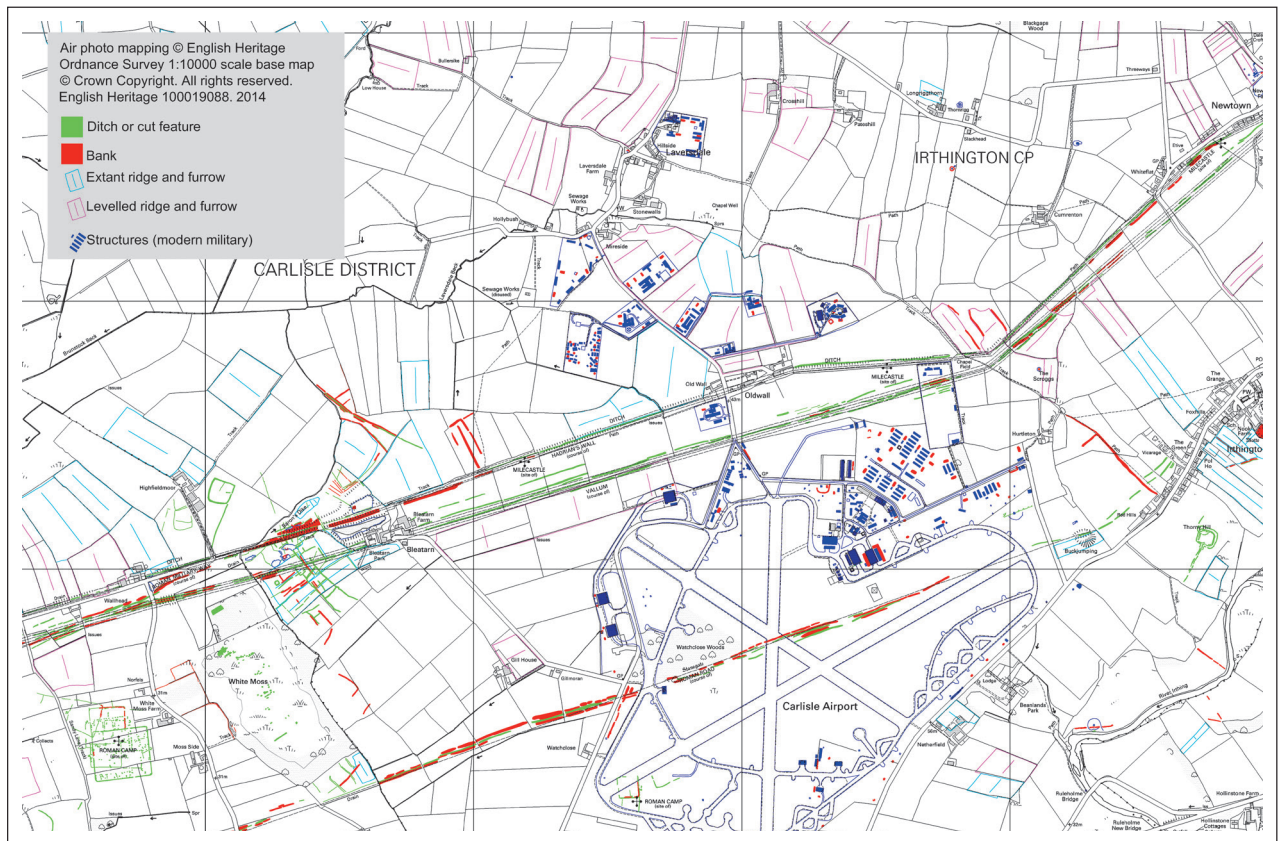
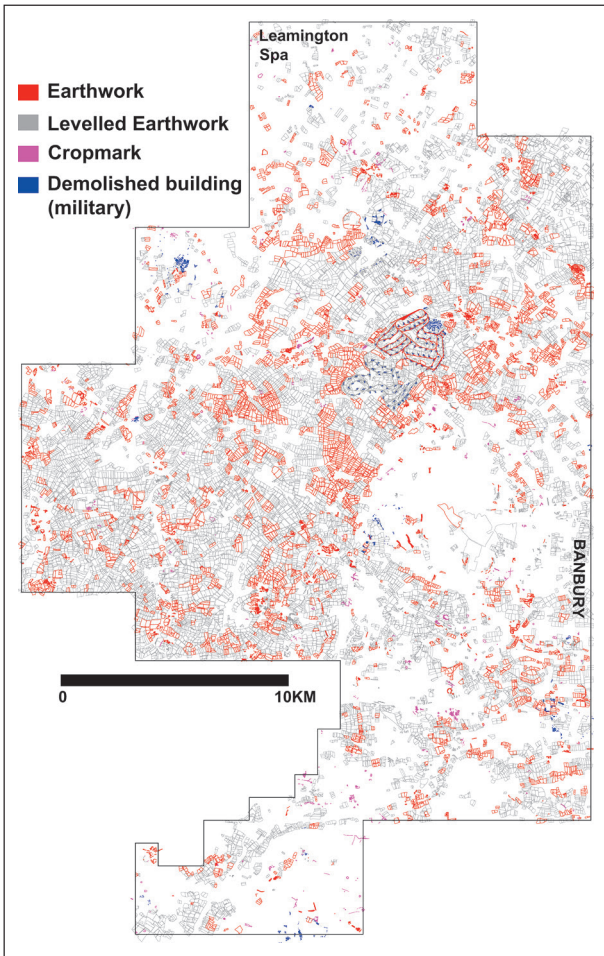


Figure 4. NMP interpretation and mapping of part of Hadrian's Wall and environs near Carlisle Airport. The mapping depicts the form of remains and a GIS record details the interpretation such as period and type. NMP mapping © Historic England. Background map © Crown copyright and database right 2014, all rights reserved. Ordnance Survey Licence number 100024900.

An extensive and largely lost landscape was created during the Second World War when around a fifth of the land area in Britain was used for military purposes. The use of aerial photographs in the study of military landscapes is explored in detail elsewhere (Stichelbaut *et al.* 2009, Cowley *et al.* 2010, Stichelbaut and Cowley 2015). Many of the remains were removed after the war, or were destroyed later, through re-use and adaptation of sites or by natural events, such as coastal erosion. In heritage protection terms, the aerial photographs, and the mapping derived from them, provide an important record of the original context and help to assess the significance of the surviving remains.

The mapping carried out as part of NMP or NAIS projects records the basic condition of the archaeological features, for example earthwork, levelled earthwork, cropmark or destroyed monument/demolished building. This enables analysis of the effects of 20th and 21st century farming and development on the archaeological features. An example of this is repeated in many areas in England where the process of plough levelling of major elements of the medieval landscape, such as settlements and fields, is recorded on aerial photographs taken at intervals since the 1940s.

NMP projects in North Yorkshire (Chalk Lowlands and Hull Valley) and Warwickshire recorded substantial plough levelling of archaeological earthworks (Evans *et al.* 2012; Priest and Dickson 2014). Many have been severely degraded or destroyed but parts of some of the sites still survive as sub-surface deposits. Figure 5 illustrates all the archaeological features mapped in the South East Warwickshire and Cotswolds Higher Level Stewardship Target Areas in an area measuring 670 square kilometres mainly in Warwickshire along with parts of Gloucestershire and Oxfordshire in the west midlands of England. The mapping is colour coded by the evidence for condition as seen on latest available aerial photographs. This kind of mapping, and record of basic condition, measures and highlights the impact of arable farming on archaeological earthworks in the post war period in England (Figure 5).



A consequence of the conversion of large areas of pasture to arable cultivation, especially in the midlands of England, is that it has increased the potential for discovery of buried archaeological remains. A different ‘lost’ or ‘missing’ landscape is revealed as cropmarks of the mainly prehistoric or Roman remains underlying the medieval landscape (Figure 6). For example, this was seen especially during mapping projects on the edges of the Gloucestershire Cotswolds and across Warwickshire and in reconnaissance projects in Bedfordshire and Cambridgeshire (Stoertz 2012; Priest and Dickson 2013; D. Grady, Personal comment).

Figure 5. *NMP mapping of SE Warwickshire and parts of Oxfordshire and Gloucestershire. Extensive medieval open fields interspersed with settlement once covered most of this area but much has been ploughed level. Based on mapping by Gloucestershire County Council, © Historic England.*

Figure 6. *A prehistoric or Roman settlement, overlain with the furrows from medieval ploughing, visible as cropmarks near Bolnhurst and Keysoe, Bedford 27060_09 29th June 2011. © Historic England. Photograph by Damian Grady, English Heritage.*



The examples above form part of multi-period, multi-source mapping projects aimed at building the evidence base to inform heritage protection. Mapping from aerial photographs has been used in other contexts as well. For example, in the 1990s the English Heritage Monuments Protection Programme instigated projects to assess the survival and significance of large areas of medieval cultivation, comprising well preserved earthwork ridge and furrow, in the midlands of England. The objective was not merely to identify individual well preserved fragments of field systems but to identify examples where the remains still presented an explanation for the economic model of a medieval settlement. Out of the 1,600 townships originally identified, a filtering exercise identified 43 townships that represented the very best in the region in terms of survival, historical interest and association with contemporary monument types. The combined results of these projects were published as ‘Turning the Plough’ (Hall 2001). This included an assessment and mapping of the survival of ridge and furrow in 40 parishes (relating to 43 ‘townships’) based on aerial photographs taken in 1999.

A follow up survey in 2012 used new aerial photographs to assess and map the current extent and condition of ridge and furrow in the 40 parishes to inform future management of these nationally significant heritage assets (Catchpole and Priest 2013). The original survey only recorded very well preserved ridge and furrow but the update recorded all earthwork ridge and furrow irrespective of condition. Therefore, the update mapped considerably more ridge and furrow but around 75% of this still appeared to be in good condition. This demonstrated that land management in the 40 parishes was largely beneficial to archaeological earthworks in the last 10 years. The projects also demonstrated how aerial photographs and mapping could be used to assess basic monument condition of certain extensive archaeological features through time and over very large areas.

AERIAL PHOTOGRAPHS AND HERITAGE MANAGEMENT

Aerial photographs are routinely used to monitor archaeological monuments legally designated to be of national importance. In England, this now takes place under the Heritage at Risk programme (English Heritage 2013). Recent aerial photographs are used to assess basic condition and to prioritise site visits and further work. Historic photographs have not played a major role in this process so far but have been used as part of an initiative called the Conservation of Scheduled Monuments in Cultivation (COSMIC).

The COSMIC project originated from work commissioned by the government Department of Environment Food and Rural Affairs (DEFRA) and was managed by English Heritage. It was designed to assess the risk levels from ploughing on nationally designated (scheduled) archaeological sites. The first phases of the project concentrated on scientifically testing the effects of different cultivation practices, on dummy earthworks and buried archaeological sites, and were carried out by Oxford Archaeology and the National Soil Resources Institute at Cranfield. The project assessed the effect of mouldboard ploughing, shallow ploughing, minimum tillage, and direct drilling and produced soil management recommendations and techniques for monitoring soil disturbance. Implementation phases by Oxford Archaeology (COSMIC 1 and 2) refined the methods for assessment of risk from cultivation and included use of historic aerial photographs and ALS-derived images to assess the impact of past farming regimes on scheduled monuments.

The heritage management projects, especially COSMIC, and Turning the Plough 2 to a certain extent, required a different set of interpretation skills to those usually applied in mapping projects. The COSMIC method in particular required the interpreters to have a level of understanding of how different agricultural regimes appeared on aerial photographs and the implications of these regimes for the condition of the archaeological monument. The methods trialled in these projects will be used to inform the assessment of sites and landscapes of potentially national significance. For example, aerial photographs were used to chart the past and modern agricultural regimes at the site of a rare example of a Roman Camp revealed as cropmarks in north Dorset (Winton and Grady 2013). This information can be used for any future work to assess the potential and survival of the buried remains.

ASSESSMENT OF SIGNIFICANCE

The various types of project using aerial photographs assess the significance of a site in archaeological terms at a local, regional and national scale. An archaeological landscape, and its components, are analysed in the context of what the evidence tells us about how people used a particular area over time. This understanding underpins judgements on the potential value of the physical remains and on future management. Historic

England sets out a method for thinking systematically and consistently about the heritage values that can be ascribed to a place in its guidance on ‘Conservation Principles’ (English Heritage 2008). This uses four broad groups of ‘value’ categorised as evidential, historical, aesthetic and communal.

In heritage protection terms, the criteria applied to assess the significance of archaeological sites inevitably places value on legibility which usually means a site that is deemed to be well preserved and can be ‘read’. Preservation and legibility can be difficult to assess when dealing with buried features visible as cropmarks but the developing COSMIC methods will improve approaches. Assessments are often carried out based on well understood site types because these can be relatively easily identified and compared regionally or nationally. For example, Historic England provides guidance on archaeological site types or themes, such as post-medieval water meadows or prehistoric funerary monuments, in their ‘Information on Heritage Assets’ series (Smith 2013, English Heritage 2011). Landscapes are recognised usually because of significant and highly visible components, such as the Neolithic and Bronze Age phases at the Stonehenge and Avebury World Heritage Site.

Interpretation and mapping from aerial photographs encompasses a wide range of archaeological features, with potential dates ranging from the Neolithic through to the Cold War. This inclusive approach recovers layers of ‘lost’ information including discrete and distinctive site types and components of largely lost landscapes. The sites can be assessed in themselves and in their archaeological landscape context and judged to be of local, regional or national significance. When collated and presented in suitable formats, the information from historic and recent aerial photographs can be used to apply appropriate heritage protection measures.

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Historic aerial photographs in the analysis of cultural landscape – case studies from Poland

Abstract: *This paper discusses issues related to (1) the acquisition of archival resources, (2) the quality of historical aerial photographs, including their spatial resolution, and (3) their potential for the study of cultural heritage.*

The scope and applicability of archive material to the study of cultural landscape is also discussed focussing on (1) archival aerial photographs as a source to identify heritage objects and make inventories, and for (2) monitoring change and damage to historic objects in the past.

INTRODUCTION

Aerial photographs are widely recognised as a highly valuable source of information for cultural heritage and environment studies (for example: Herbrich 2012; Bedkowski, Górski 2007; Mularz, Drzewiecki 2008; Cowley, Ferguson 2010; Cowley *et al.* 2010). For the authors, aerial photographs are the subject of integrated studies within a multi-disciplinary scientific project analysing the use of remote sensing in the protection, analysis and research of cultural heritage, primarily archaeology and architecture (Zapłata, in print). The project has already seen the growth of the database of sources, the development of new digital databases of cultural heritage and the development of non-invasive methods for the protection and research of archaeological and architectural heritage.

The central aim of this article is to present examples of the use of historic aerial photographs for cultural heritage, in the context of resources from Polish and foreign collections, mainly from World War II, and with a special focus on vertical photographs. Following an overview of the availability of imagery and of archives holding material for Poland, some case studies are presented in which aerial photographs provided one of the few, or even the only, available sources for the study of anthropogenic objects that have been altered or destroyed. The case study deals with the vicinity of Iłża, Mazowieckie Province, using aerial photographs from 1944, amongst other sources (Różycki 2014, 4).

WORLDWIDE ARCHIVES OF HISTORIC AERIAL PHOTOGRAPHS FOR POLAND

Aerial photographs of Poland are scattered across various archives in Europe and North America. Often, the lack of information about these collections is a major obstacle to their use, and so this section presents the Polish and international archives holding collections of aerial photographs dating from 1938 to 1960.

National Archives and Record Administration (NARA)

The National Archives and Records Administration (NARA) is an agency of the USA Government responsible for the protection and preservation of governmental and historic records as well as for providing access to the collections. These include aerial and satellite imagery, and of particular importance for this paper, aerial photographs captured during World War II. The main parts of this collection are summarised below.

Record Group 373

Record Group 373 includes aerial and satellite photographs and cartography, within which sub-group 373.3 is the Allied and German-flown aerial photographs covering the period 1935–1960, including 2.863.800 Allied photographs and 1.209.520 German images (Cowley *et al.* 2010, 2). Photographs in record group 373.3 are difficult to access because the catalogues have not been updated since the 1960s. The first attempts to catalogue this collection have already been undertaken (Crawshaw 2001, 46; Rączkowski 2004, 9; Going 2006, 30).

Luftwaffe-flown records held in this archive include original paper prints kept in cardboard boxes, approximately 32 x 32 cm in size. Some photographs are stuck together and some show mechanical damage while a significant number have scratches caused by repeated scanning (Figure 1). The majority of Luftwaffe photographs of Poland date from 1944–45, and relate to the intensity of German aerial reconnaissance on the Eastern Front. A smaller collection covers the period 1939–43, and may have been used to produce 1:25000 photomaps (Ger. Bildplan/Bildskizze). There are also German photographs antedating World War II, made most probably by special aerial reconnaissance units. The smallest set of photographs (in comparison to other parts of the country) covers the coast of the Baltic Sea. No German photographs focus on this area. Easily available are photographs of large cities, and middle- and small-sized towns. Photographs made in various years and to various scales are accessible.

The largest accessible collection in NARA is the Allied aerial photographs, which are kept as original negative films in metal cans held in off-site cold storage that require one or two days to retrieve.

Individual users are not permitted to scan photographs, though the viewing room is equipped with light tables (for example Richards). The Archive allows chosen private firms to scan photographs; such services are subject to a fee. To this fee, additional charges by the Archives are added that cover loan charges of “cans”.

Allied and German aerial photos from this collection are not often used by researchers in Poland, although recent aerial photos from NARA are used by private persons in Poland to prove property boundaries.

Record group 242

Record group 242 consists of the so called Alexandrian microfilms, which are copies of German records captured towards the end of World War II by the American army. The collection consists of approximately 75.000 rolls. Polish archives hold approximately 24.000 rolls, of which 7500 are kept in the Central Archives of Modern Records in Warsaw. This extensive NARA collection includes microfilmed aerial photographs as well as instructions and guidebooks for the interpretation of aerial imagery. The quality of the microfilm is not very high and its conversion to a digital format makes the interpretation of the aerial photographs more difficult. Often, aerial photographs are attached to microfilmed German documents and are not annotated. One way to find aerial photographs in this collection is to search the available catalogues (Guides to German Records Microfilmed AT Alexandria, Va, NARA/T-733) using names of Polish towns and cities and the key word ‘aerial photo’. For example, the Guides for Division (NARA/T-314) records that Roll 367 contains photographs of important tactical and strategic targets from the Polish campaign during September 6–11 1939.

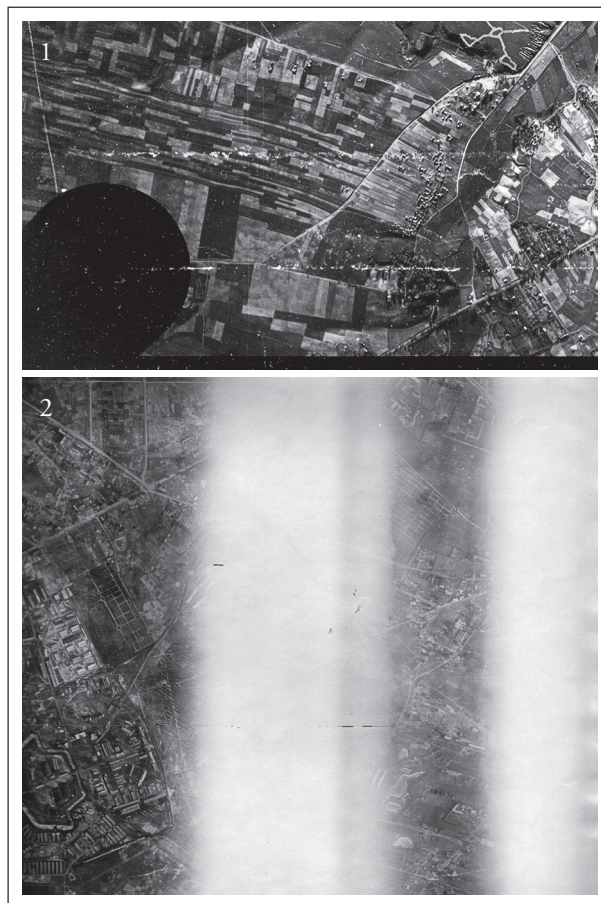


Figure 1. *Examples of poor quality of negatives and prints. 1: worn and defaced part of a photograph of Lublin city; 2: problem during photo chemical processing of exposed film from Warsaw area.*

National Collection of Aerial Photography

The National Collection of Aerial Photographs (NCAP), formerly known as The Aerial Reconnaissance Archives (TARA), is based in Edinburgh and holds an extensive collection of aerial photographs from WWII described by Cowley et al. (2013).

Access to records is through the search room in Edinburgh or through the website of the institution (aerial.rcahms.gov.uk). It is possible to order a paid image search. Where images have been digitised low-resolution ‘thumbnail’ photos can be viewed free of charge, while for a modest subscription enhanced quality images and extra features, such as photomosaics data, are available (Cowley 2013, 23). Currently (December 2014), 2952 Allied aerial reconnaissance aerial photographs of Poland area accessible online. Those photos are well catalogued and annotated, and can be exported to a kml file and viewed with the help of GIS software or in Google Earth.

Public Records Office (PRO)

The National Archives of the United Kingdom holds a small collection of photographs and interpretative records for Poland. Records for this area can be found in two groups:

- Allied interpretative records based on aerial reconnaissance, describing strategically important areas, such as industrial sites, airports, oil refineries (those records belong to group AIR 34/40),
- bulletins and magazines published during World War II, presenting spectacular successes of Allied forces in sea and land operations, based, among other, on information gathered through aerial reconnaissance. An example of such a magazine is IMPACT. Those records belong to group AIR 23.

Interpretive reports for Poland concern, for example, the military training ground in Blizna (AIR 40/2517, AIR 34/718), an aircraft replacement parts factory (AIR 34/694), an oil refinery in Trzebinia (AIR 34/696, AIR 34/697), and the port area and submarine building-yards in Gdańsk (AIR 34/642, AIR 34/643). The majority of these photos and documents have not as yet been published.

Herder Institute, Marburg, Germany

The Herder Institute holds a well annotated and catalogued collection of approximately 6300 vertical aerial photographs of east-central Europe taken by the Luftwaffe during 1942–1945 (Kreft, 2000; <http://www.herder-institut.de/bildkatalog/>). Of these, 5395 cover areas within the modern borders of Poland (Western Pomerania, Pomerania and Warmia-Masuria Provinces). The online catalogue can be searched by key words, such as historic or modern place-names, and provides previews of photographs spatially referenced through a Google Maps pin.

Central Military Archive, Czech Republic

A small collection of historic aerial photographs is available in the Central Military Archive of the Czech Republic (Praha). Photographs from this archive, featuring for example the Modlin stronghold and Gdańsk, have been published by Dubánek (2014).

State Archive of the Russian Federation, Russia

The least recognized archive in terms of the accessibility of aerial photographs is the State Archive of the Russian Federation (GARF) in Moscow (Russia). Despite numerous accounts of a mass use of aerial photographs by the Russians during World War II, the number of photographs is relatively low, but probably include images of Poland (Crawshaw 2001, 47).

POLISH ARCHIVES OF HISTORIC AERIAL PHOTOGRAPHS

The Central Military Archive holds, among other sources, a cartographic collection that includes maps, plans and sketches. These holdings are complemented by a collection of aerial photographs taken by the Polish Army every two years since 1945. The photos are at different scales and do not cover the whole territory of the country, and there is no catalogue.

At the time of writing (early 2015), the Archive is closed for modernization and the collection is not accessible, and the plans for providing access to this collection after the archive reopens are not known. However, as this is a military facility providing open access to its collection is not one of its priorities.

A small set of photographs taken by Russian military aerial reconnaissance is held, for example, by the Museum of the Polish Army in Warsaw. The most interesting collection is photographs of Warsaw taken in summer 1945, which includes 650 photographs taken with four AFA-3CN cameras with a focal length of 500 mm and a focal plane shutter, in a 18 x 24 cm format. These photographs were used to create an ortophotomap which can be seen today on the official website of Warsaw City Council (<http://www.mapa.um.warszawa.pl/>).

There are other, small collections of aerial photographs from World War II and from the post-war period, for example in the State Archives in Warsaw (small collection of German aerial photos of Warsaw from 1939) or at higher education institutions, such as the Institute of Prehistory at the Adam Mickiewicz University (Rączkowski 2004, 9).

Name of Archive	Localization (town/country)	Fee	State of cataloguing	No. of photos for Poland	Other
National Archives and Record Administration	College Park/ USA	Free (Public Domain)	None/poor	Unknown	-
National Collection of Aerial Photography	Edinburgh/ Scotland	Fee scan / paid search	GIS database for searching (OziExplorer) / all sortie on micro-film accessible in search room	2952 aerial photographs are accessible online, total number is unknown	-
Public Records Office	London/UK	Fee scan	Catalogue accessible online	Unknown	-
Herder Institute	Marburg/ Germany	Fee scan	Catalogue accessible online	5395	All photographs have low-resolution thumbnail accessible online
State Archive of the Russian Federation	Moscow/Russia	?	?	Unknown	Very little information about this archive
Central Military Archive in the Czech Republic	Czech Republic/ Praha	-	-	Unknown	Very small collection of aerial photographs
Central Military Archive in the Poland	Warsaw/Poland	Fee scan	Not available to the public	Unknown	Limited access / modernization of archive

Table 1. Comparison of the most important archives of historic aerial photographs for Poland.

Today, in addition to these resources, it is possible to access private collections, including those accessible online (<http://zdjecia.geoportal.edu.pl/>) or in collections correlated with such tools as Google Earth. An important example of this is the collection of aerial photographs of Warsaw from 1935 to 1945, available in Google Earth.

THE USE OF ARCHIVAL AERIAL PHOTOGRAPHS IN THE STUDY OF CULTURAL HERITAGE IN THE VICINITY OF IŁŻA

The use and potential of archival aerial photographs in research and documentation of heritage monuments will be explored through the example of the cultural heritage of Iłża, Pakosław and Seredzice in Mazovia (Figure 2) and its surroundings. This project drew on archival aerial photographs from NARA, among other sources. Seven photographs allowed, for example, to verify research results gathered through other non-invasive

research methods (Airborne Laser Scanning, satellite imagery), to integrate data with other information, as well as to pinpoint potential historic features and to study both those features and their surroundings with the use of non-invasive methods.

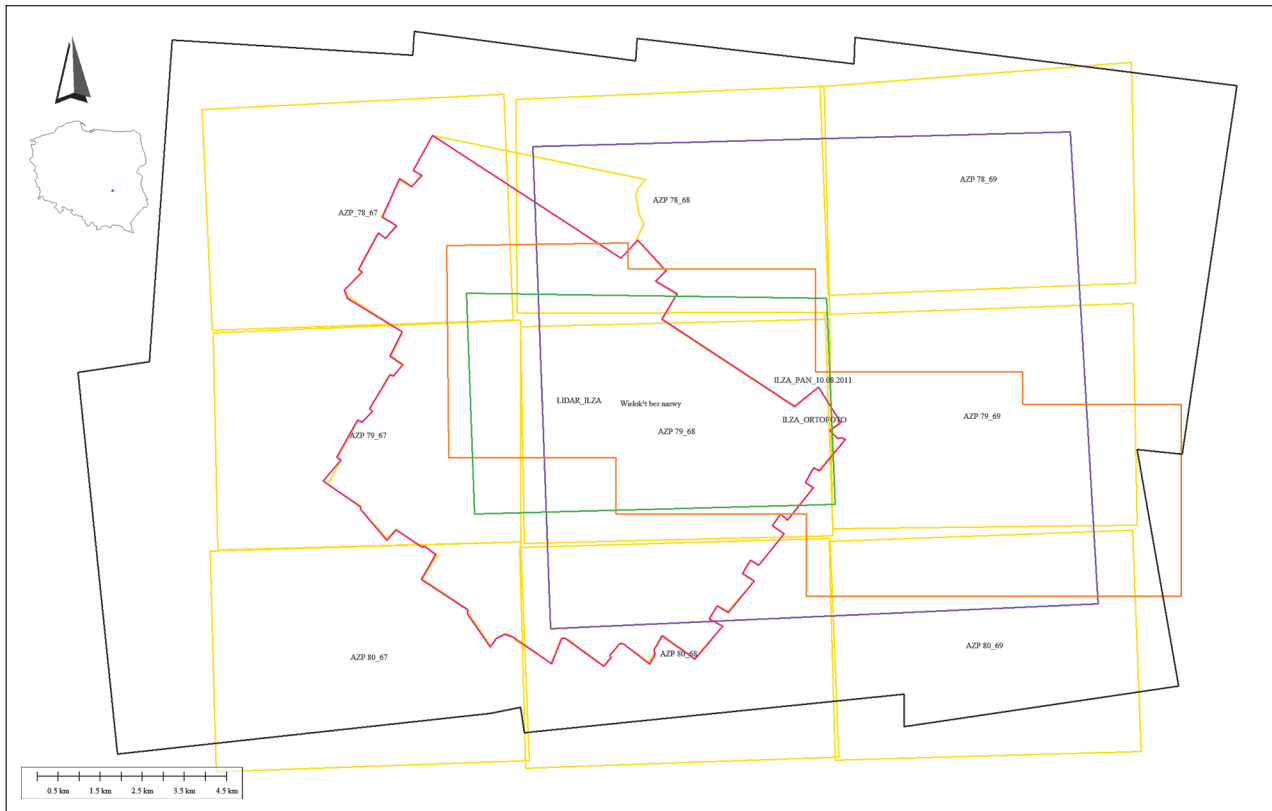


Figure 2. Research area and the coverage of remote sensing data, including archival aerial photographs, compared with data gathered through the Polish Archaeological Record project (AZP; traditional field surface survey). Copyright Cardinal Stefan Wyszyński University in Warsaw.



Figure 3. The division of land in the Starosiedlice area in Mazovia. Detail of a panchromatic, high resolution satellite image (1) – over 20 separate fields with different cultivation methods – satellite image WV2, 10 August 2011 (source: SmallGIS/UKSW) and detail of a 1944 aerial photograph (2) – six separate fields (source: NARA/UKSW). The visibility of geological structures is altered by the differentiation of crops. © DigitalGlobe/European Space Imaging. Distributor SmallGIS (1).

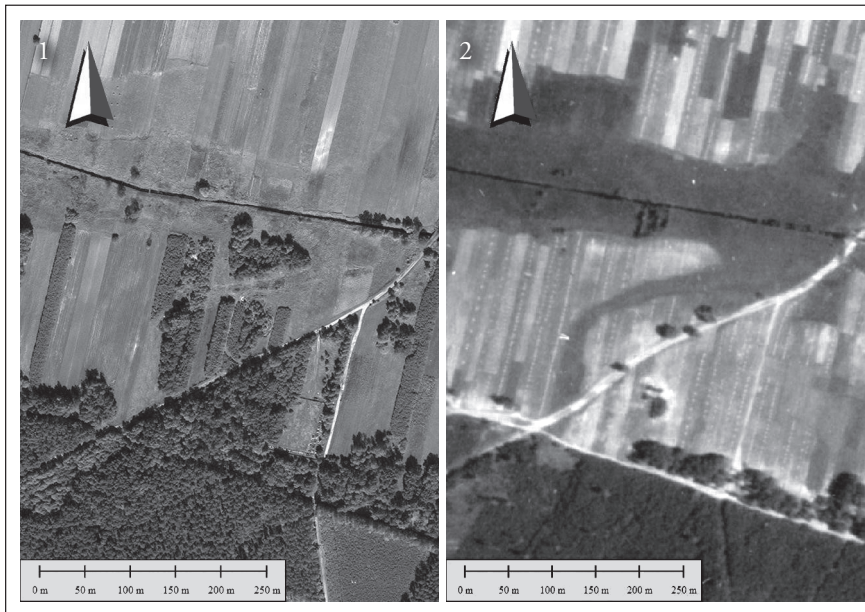


Figure 4. The Itzanka riverbed with tributaries in 1944. Today the riverbed is transformed by regulation works and the tributaries are overgrown. Detail of a panchromatic, high resolution satellite image WV2 from 2011 (1. source: SmallGIS/UKSW) and detail of a 1944 aerial photograph (2. source: NARA/UKSW). © DigitalGlobe/European Space Imaging. Distributor SmallGIS (1).

Archival aerial photographs can document cultural and natural features that have been destroyed or changed since photographs have been taken. Thus, archival aerial photographs play a dual role in the study of the past, supporting the analysis of the natural environment of the past and the study of anthropogenic features. An example of such an analysis is the study of transformed riverbeds (Figure 4), land cover and forestation. Where multi-temporal photographs are available they allow monitoring of changes and processes, including, for example, the overgrowth of formerly arable lands or former industrial areas. Such changes can be especially dramatic in urban areas, where historic aerial photographs may allow reconstruction and modelling of the development of pre-war towns (Mikrut, Dużyńska 2009; Chodorowski M. 2012), to document and verify cartographic sources and to study damages and losses (Raport o stratach wojennych, 2004). This is also the case in rural areas, where wholesale changes in the landscape make historic aerial imagery especially valuable (Figure 3).

Within the study area changes in the natural environment have been recorded, for example, in the riverbed of the Itzanka River and in the presently forested and previously arable lands in the vicinity of Serecz and Pakosław (Figures 4, 6). Secondary succession has been also recorded at the historic castle hill in Itza (ruins of a castle belonging to Cracow Bishops) (Figure 5).



Figure 5. Itza, Mazovia. Castle hill – castle of Cracow Bishops in Itza. Example of secondary succession post-dating the building of this monument and its dereliction in the 19th century. Detail of a panchromatic, high resolution satellite image WV2 from 2011 (2. source: SmallGIS/UKSW) and detail of a 1944 aerial photograph (1. source: NARA/UKSW). © DigitalGlobe/European Space Imaging. Distributor SmallGIS (2).

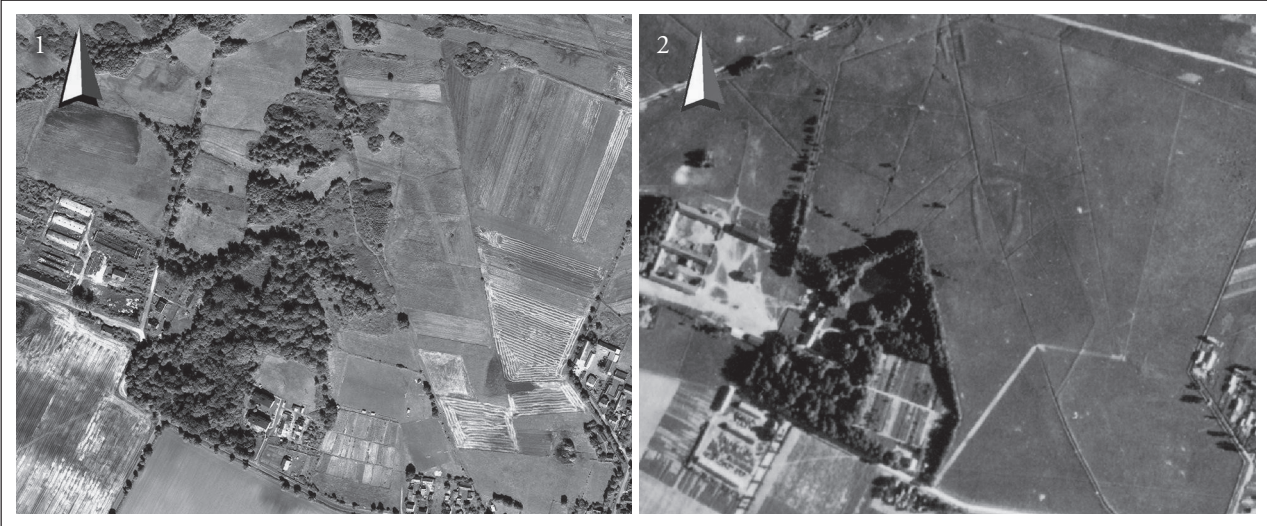


Figure 6. Pakosław, Mazovia. The present and former condition of: (1) park, (2) remains of buildings and (3) overgrowth of features (in the centre of the photograph). Detail of a panchromatic, high resolution 2011 satellite image WV2 (1. source: SmallGIS/UKSW) and detail of a 1944 aerial photograph (2. source: NARA/UKSW). © DigitalGlobe/European Space Imaging. Distributor SmallGIS (1).

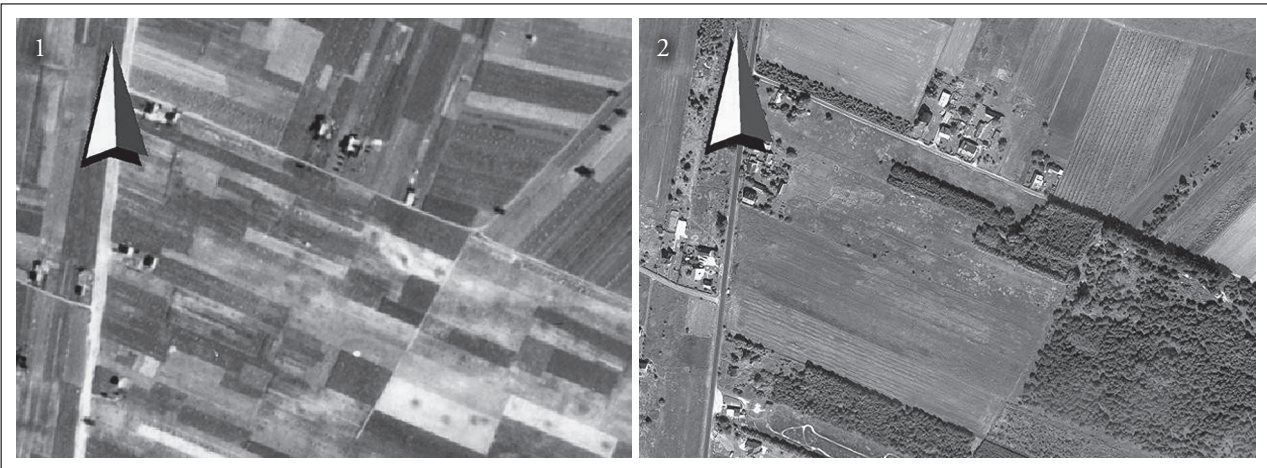


Figure 7. Seredzice, Mazovia (Forest Inspectorate Marcule). Possible remains of charcoal kilns. The area is presently built-up and partly forested (2). In 1944 it was arable land; dark spots are recognisable (1). Detail of a panchromatic, high resolution 2011 satellite image WV2 (2. source SmallGIS/UKSW) and detail of a 1944 aerial photograph (1. source: NARA/UKSW). © DigitalGlobe/European Space Imaging. Distributor SmallGIS (2).

The historic imagery also supports analysis of transformations and analyses of satellite imagery (Osińska-Skotak 2014) of destroyed buildings and communication routes in the area of Pakosław, Iłża and Seredzice. In Pakosław, it was also possible to analyse the state of a historic green area, a park, during World War II (Figure 6).

The aerial photographs also lead to detection of a cluster of industrial features, comprising the remains of charcoal kilns around Seredzice, which are presently covered by forest, built-up land and an open-area (Figure 7).

SUMMARY

While archival aerial photographs have applications across many disciplines there are some disadvantages and characteristics which limit usage. These include: (1) poor spatial resolution of photographs; (2) lack of coordinates of fiducial marks, distortion parameters of lenses generate problems for geo-referencing and production

of orthoimages; (3) seasonal diversity; the fact that photos were taken at various times of the year poses, especially for archaeology, creates some difficulties for the analysis and interpretation of images, particularly in overgrown areas; (4) poor quality of negatives and prints, which causes difficulties especially for digitisation and further processing; and (5) difficult accessibility of photographs and deficiencies in cataloguing (lack of catalogues of existing resources). However, recognising these challenges, aerial photographs for heritage support documentation of the earlier condition of monuments, providing spatial resolution that enables the detection of features smaller than 1 m, and supporting the interpretation of modern aerial photographs, satellite images or Airborne Laser Scanning data. In many cases archival aerial photographs are the only source of data about cultural and natural phenomena.

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Aerial photogrammetry: when archaeology meets SIFT

Abstract: *Accurate 3D documentation of artefacts and landscapes is one of the challenges in modern archaeological research. The possibility of achieving this goal in an affordable and straightforward way makes it even more attractive, allowing applications in an ever wider range of scenarios where such an approach may be of high value.*

Digital photogrammetry is a rapidly developing field of research and it allows the 'translation' of historical or modern 2D photography in three dimensional point clouds. This is not just about recording historical artefacts, since 3D information can now be processed and produce new data and also 3D displays of objects that may have been lost. This makes affordable 3D data an important tool in archaeological research, providing the possibility to look at details beneath design or texture, or to create replicas (or replace damaged parts by printing artefacts). This paper provides an overview of the current state of the art in digital photogrammetry for archaeology, with particular reference to the potentials and limitations of affordable and free software solutions.

WHAT IS PHOTOGRAMMETRY AND WHAT IS SIFT

Photography is definitely one of the most basic and important means of recording and documentation in archaeology and cultural heritage, whether at the moment of discovery during an excavation or in later phases for conservation or reconstruction. Most archaeological photographs include a North arrow, sometimes a blackboard with general indication about the subject (usually site name, project, date, trench or similar) and often a ruler, a metric pole or at least an object of known dimensions for comparison. These latter features are normally considered highly important for the general idea they provide about the form and size of objects. While photographs are considered to hold a large amount of information (i.e. construction material, relationships between objects, state of conservation, presence of patina to name a few) the complete and systematic documentation of artefacts is still provided via 2D drawings on paper or recently in computer aided environment in a situation that has not really developed since the start of the 20th century (i.e. Petrie 1904). According to the document on recording ratified by ICOMOS in 1996, "Recording is the capture of information which describes the physical configuration, condition and use of monuments, groups of buildings and sites, at points in time, and it is an essential part of the conservation process" (ICOMOS, 1996).

In this scenario, photogrammetry can play a major role, allowing extraction of metric information from a single or (better) a set of photographs of objects, given certain requirements are satisfied. Although mainly used for map making mostly for military intelligence (Chasseaud 1999; Heffernan 1996), photogrammetry, especially in its digital manifestation, has become a flexible and scalable tool that can help in documentation, from small objects, to buildings, and to entire landscapes.

Single images from metric cameras (with little to no lens distortion) can normally be processed to get two dimensional metrics, such as the width of a road, the height of a building or the dimensions of bricks in a wall. More accuracy is generally achievable when multiple images by the same camera from different angles can be photogrammetrically processed. In both cases, the availability of measured ground control points (GCP) or known metrics is often essential (Matthews et al. 2007) These measurements can be in a local coordinate system (with arbitrarily oriented Cartesian axes and measuring units) or absolute values (i.e. geographical projected coordinates).

Absolute coordinates are especially used for topographic or landscape scale works in geographical digital environments, usually as part of GIS projects. Indeed, landscape studies using aerial remote sensing datasets are probably one of the main points of contact between archaeology and photogrammetry, and, whether dealing with vertical or oblique images or with (historical and modern) terrain models, most GIS-based cultural heritage approaches (Gomez-Heras et al. 2014) involve some degree of photogrammetric operation. When large numbers of images are available for the same area, a relatively easy step towards landscape understanding is the creation of a mosaic of all photographs. This is usually done by assigning precise coordinates to pixels in each image. Sometimes, ground coordinates can be measured in the field or they can be extracted from already georeferenced orthophotos or maps. When at least three points have been assigned to a single frame (more points ensures greater accuracy, and are required unless the landscape is flat) an algorithm is applied to the image to match it with its spatial location. This operation also has the implicit goal of eliminating, minimizing or diminishing the lens distortions “hidden” in any image. But if this is a relatively easy operation when dealing with almost flat terrain, the registration of vertical or oblique images to reflect a perfectly orthographic view of a hilly or mountainous landscape is a challenging task. No algorithm can accomplish a satisfactory registration in such circumstances while preserving the uniform quality of the input image.

This is where photogrammetry can really make a difference. Non-metric, off-the-shelf digital cameras (D’Ayala and Smars 2003) can often be used to extract accurate and detailed 3D digital models of objects at almost any height or platform, from orbiting satellite (aerial) to tripod (close-range photogrammetry). Aerial photogrammetry in particular takes advantage of the overlap (usually around 60% forward and 30% side-wise) of large-format imagery to numerically recreate a portion of the earth in a virtual environment. Here, horizontal (X and Y or Longitude and Latitude) measurements can be made and recorded directly into a geo-spatial data file. Elevations can also be recorded, given that a few basic conditions are met:

- images have a certain degree of overlap;
- the precise coordinates of at least three points (Almagro 2001) are known;
- and these points can be identified in at least two adjacent images.

Whilst the identification of the same feature (a road junction, the corner of a building, the edge of a field-plot, etc.) in neighbouring overlapping images is quite an easy task for human-eye/brain, the same operation requires a complex set of procedures for the computer. It has to a) view, b) describe, c) match and d) convert two (or more) raster files (whether a still picture from digital camera or a scanned version of an old print) to obtain a three-dimensional reproduction of the depicted environment. This 2D-to-3D conversion involves a branch of IT called Computer Vision.

In 1999 David Lowe, a Canadian Professor of Computer Science, discovered a way to ‘give eyes to a computer’ and to allow it to ‘sense and describe real world object from images’ (Lowe 1999). His approach, known under the acronym of SIFT (Scale Invariant Feature Transform), was written into software and freely distributed online and has become the basis for many variants and improved algorithms for image matching (Cantoro 2012a, pp. 759–760). These image descriptors have been applied differently (Khvedchenia 2011) in several structure-from-motion applications: given the human ability to perceive the third dimension and the reciprocal size and position of objects (structure) from different images converging to the brain during movements (motion), computer vision tries to simulate this ability by uniquely identifying an object in a scene and recognizing the same object (through Euclidean distances computation) in the next one, allowing its position to be tracked and its size and location in a 3D digital world to be reconstructed.

The growing availability of commercial and cost-effective or free photogrammetric software (in clouds online or for offline user processing), the higher resolution and quality of cheap digital cameras, and ready availability of high performance computers, are between the main causes for the sudden spread of 3D reconstructions of archaeological heritage from photographs. The following section will present a discussion of some

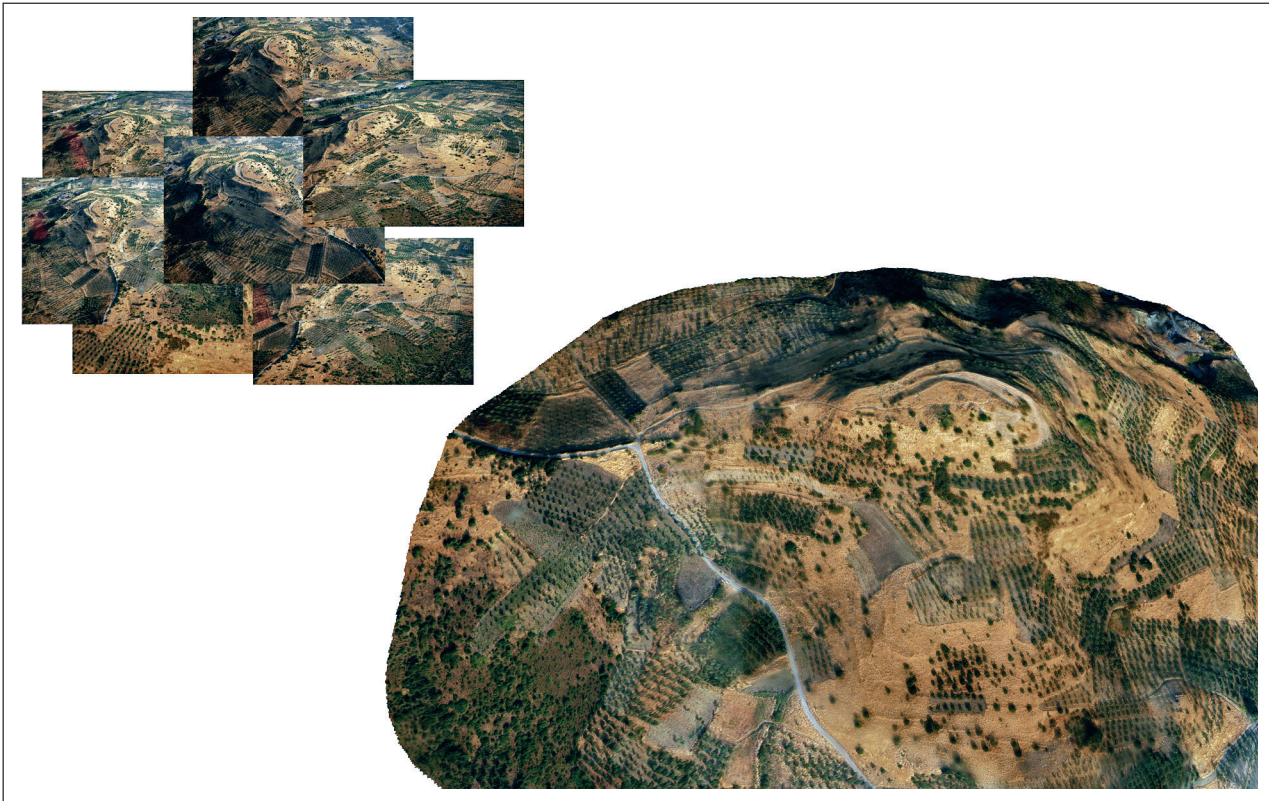


Figure 1. *Photogrammetric reconstruction of the archaeological site at Koroneia (Greece). This 3D model was generated from general purpose photographs not collected for photogrammetry. Aerial photographs by Darja Grosman.*

applications, and is followed by an overview of available hardware and software solutions with particular attention to free or low-budget options.

POSSIBLE APPLICATIONS: THE ADDED VALUE/S

In recent years the technical applications of photogrammetry in archaeology has grown rapidly (see, for example: Ioannidis et al. 2000; Guidi et al. 2009; Matsumoto and Ono 2009; Remondino 2011; Verhoeven 2011; Opitz and Nowlin 2012; Corsi et al. 2013). Cultural heritage applications are not only limited to documentation of new discoveries but also include the accurate reconstructions of heavily altered artefacts (Gruen et al. 2003) or landscapes where this technology provide unique information. The same is true of allied disciplines such as ecological studies and forest health monitoring, where the level of detail and accuracy that can be achieved with this approach cannot be matched by other technologies (Birch 2006).

For landscape studies, acquisition of aerial imagery is normally designed and planned according to the intended deliverable, with special attention to scale. For example, the final resolution required dictates the flying height (i.e. image scale is the result of the focal length divided by the flying height above terrain (Hussain and Bethel 2004). Thus, an airborne camera with a 6-inch focal length lens at 300 meters above the ground produces photographs at 1:2000 scale, allowing the detection of objects as small as 5 cm. The easy accessibility and usability of remotely piloted devices makes the production of high-resolution output more and more affordable and immediate. So, for instance, not only can a specific photogrammetric model of an area be created during a specific season or time of the day, but also several models of the same area can be overlaid for change detection and conservation purposes.

Even more interesting and promising for the purposes of archaeological research is the application of photogrammetric processing to photographs that were taken for different purposes. This can be illustrated through the case of the ancient city of Koroneia, Greece (Bintliff et al. 2008). In the summer of 2009 an aerial survey was conducted by Darja Grosman for the University of Ljubljana with the goal of documenting

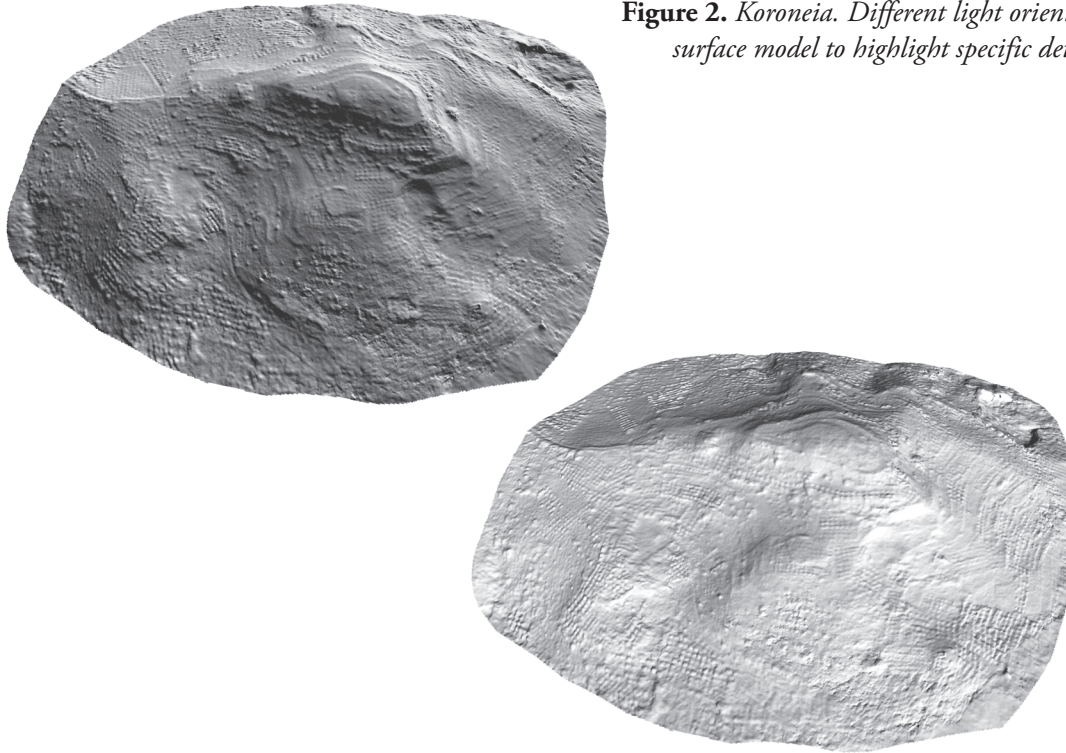


Figure 2. *Koroneia. Different light orientation on the same surface model to highlight specific details of the terrain.*

this site and to survey the entire region. About 30 images were taken of the remains of the city to document all sides of it (with the obviously different sunlight reflections) and its surroundings. While the objective was not a photogrammetric reconstruction, still, just by processing the dataset with photogrammetric software one could obtain an accurate 3D model of the site for further studies.

The Koroneia model is a good example of the many possibilities embedded in photogrammetric approaches, including:

1. The possibility to obtain 3D measurements all over the site;
With a few ground control points from precision instruments the entire digital model can be georeferenced, and each pixel allocated X, Y and Z values, that allow the topography to be studied.
2. Availability of digital elevation models with uniform high ground resolution, even on the side of a small hill;
The ground resolution of modern laser scanning is normally calculated on an ideal flat surface, which means that on steeper slopes or surfaces (in the case of an artefact) less points will be available to document shape.
3. Creation of a single mosaic orthophoto;
Georeferencing single frames can be a time consuming operation and results in hilly terrain may be unsatisfactory. Also, many aerial photographs are taken to document specific details of an area of interest and they do not always take into account the visibility of possible ground references for geo-registering. Thus, often only few frames can be properly georeferenced onto available maps (for a possible solution to this problem, see the free software AutoGR-Toolkit (Cantoro 2012b)).
4. The possibility to visualize a 3D model without texture and apply specific algorithms to enhance minor details;
There are times when texture and shadow may trick our eyes and compromise our ability to comprehend the real shape of objects. The availability of untextured models may help us read real form of the landscape. Minor variations in the surface may be highlighted through multiple visualisation techniques (Kokalj et al. 2013; see some examples in the Figure 2).
5. The possibility to generate virtual views of the object;
Reconstructed 3D objects can be rotated on computer screen and countless views can be generated, also with lens field-of-view or perspective distortion simulations.

6. The possibility to monitor site erosion with repeated flights;
The use of photogrammetric outputs to detect (and graphically visualize by means of surface subtraction operations) small changes in soil movement can provide valuable insight in assessing effects of surface activities on sites (Matthews et al. 2007).

WORKING SOLUTIONS: A REVIEW

This section reviews some practical solution for photogrammetric processing. Most software solutions now available are flexible in their requirements for input images. Nevertheless, there are some minor differences in approaches and it is worthwhile understanding certain aspects of software specifications before starting. In the examples below, tips on image acquisition for different applications are presented, with further details about the software in the following paragraphs.

There are also other potential issues hidden in every photogrammetric approach and it is wise to be aware of them during photographic capture. These include photo numbering issues and hidden parts of objects (Figure 5).

Many photogrammetric applications give the user the option to speed up processing by reducing the matching computations, rather than the default whereby each photograph is described and compared one to each other. According to the specific project, one may want to limit the comparisons just to a number of subsequent images (and not to all the others). This is normally done by the software on the basis of the file names (or input order), so in the case presented in Figure 5, “photograph 06” will not be compared with 02 and 03 but with 05 and so it will be excluded from the reconstruction because it is not matching.

The second example is probably more common and relates to potentially missing information during photo-capture. As with a laser scanner, areas that are not visible to the sensor (and in at least three photographs) cannot be measured and so some concavities of an object/landscape cannot be detected. At the same time, some obstacles hiding part of the subject may be masked out in post-processing with some software.

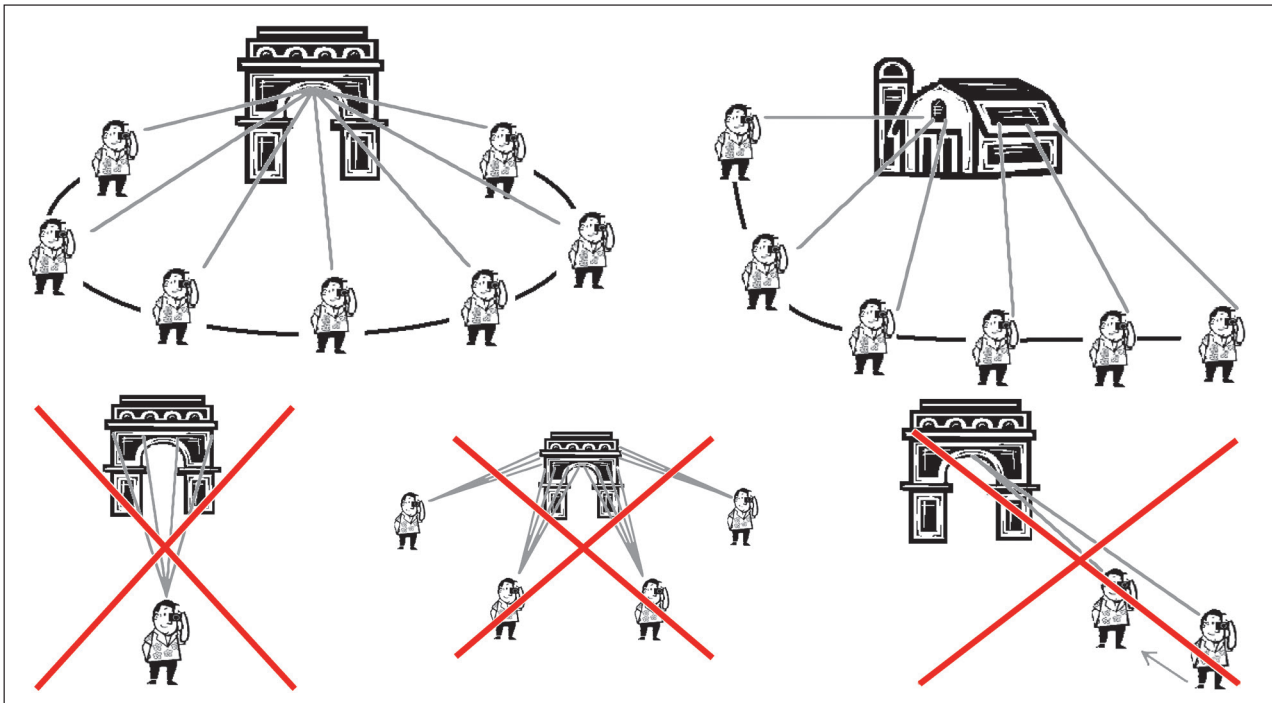


Figure 3. Suggested approach for image capture for Arc3D, Insight3D, Autodesk Recap, Photomodeler and Bundler/OSM-Bundler (images adapted from software’s tutorials published and freely accessible online). The first four require consistent zoom, lens and light conditions. The latter may work also with images taken with different cameras/lenses in different moments. As one can see from the above figures, what is considered bad image capture for one software may be accepted by another.

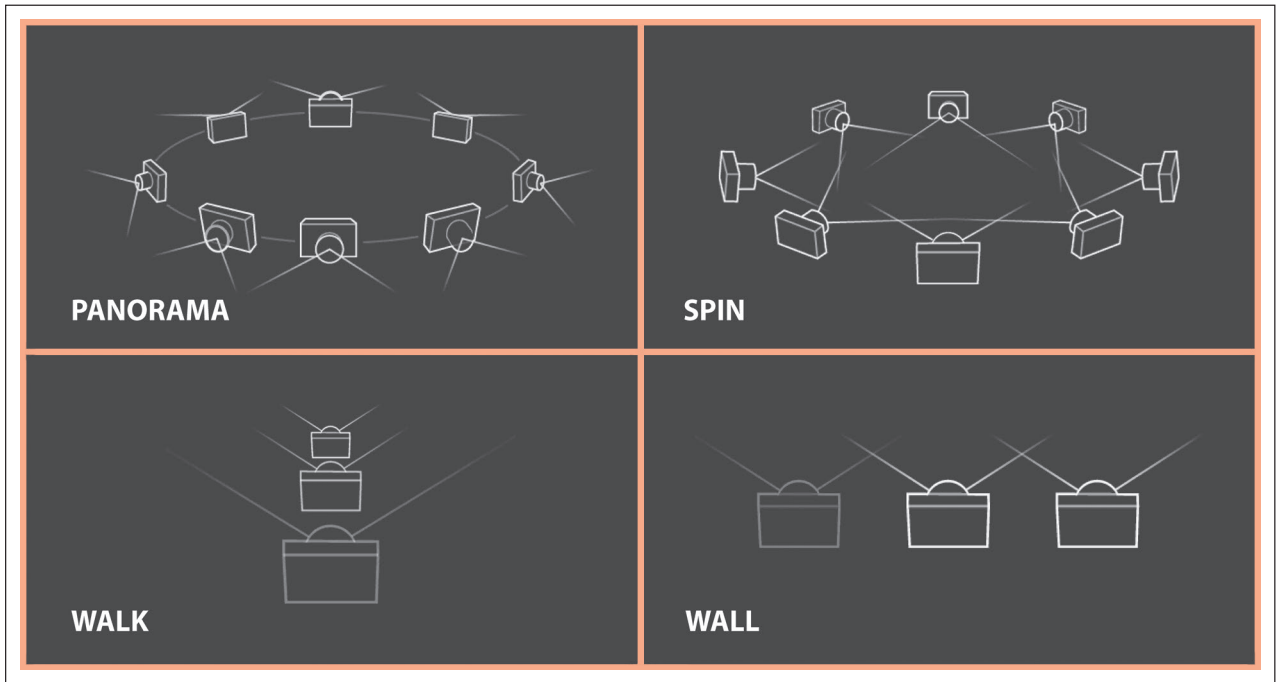


Figure 4. Microsoft Photosynth photo-shooting strategy. (Image adapted from “Photosynth technical preview [website],” 2014).

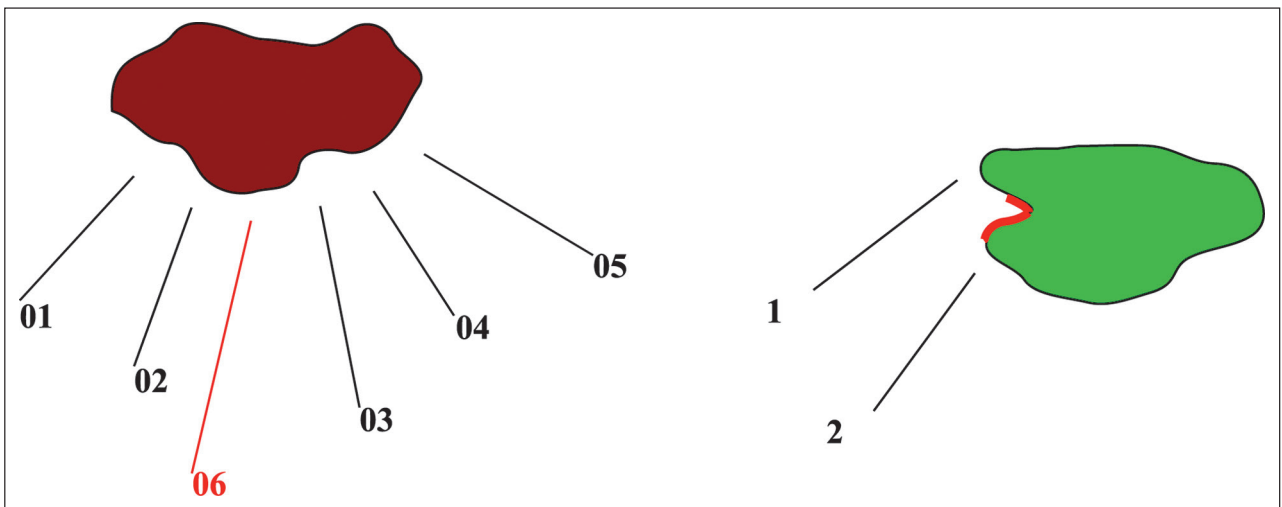


Figure 5. Photo-capture strategy is the most common source of problems. On the left, image file numbering and sequence match computing issues. On the right, potentially missed information (in red) during photo-capture.

Hardware components

There are three basic prerequisites for proper photogrammetric reconstruction, namely overlapping images, computer and photogrammetry software, the combination of which, and the desired output, define the required acquiring, processing and refining time for the entire workflow.

There are few restrictions on the type of camera used for the image acquisitions. In 2001 “cameras with [...] a resolution of one or two Mega pixels [...] represent the minimum requirement to deliver sufficiently good metric content” (Almagro, 2001), and today the minimum mega pixel resolution of the most basic camera is many times higher. For scanned images there are similar exponential developments, with some early studies (e.g. Pomaska 2001; D’Ayala and Smars 2003 amongst others) suggesting that better results might be obtained from the use of scanned images instead of born-digital images. However, today even

randomly collected web images with no information about camera, lens or file compression settings can be processed successfully (Snavely et al. 2008). Some modern cameras are equipped with internal GPS and despite the low or medium accuracy of such systems, the approximate coordinates for the camera at the time of photography can still be used for first archiving purpose of acquired images or for general georeferencing of the photogrammetric model (where allowed by the software).

Most photogrammetric software is normally very demanding of hardware, despite the fact that basically any computer above a minimum standard can be employed, though the processing time may vary considerably with specific solutions. In particular, most software (whether free or commercial) makes use of the powerful processing performance of the dedicated memory of some graphic cards (GPU, delivered with most Nvidia graphic cards). Because of the hard processing use of graphic cards, most laptops are not properly equipped. Nevertheless, a first processing in the field on a portable computer is highly recommended when possible to check for blurry or badly exposed images, or areas that have not been covered sufficiently with overlapping photographs.

With large datasets, it is also recommended to have dedicated computer for photogrammetry, since any other PC employed for this task would not allow parallel operations during processing time. A possible workaround to the computer requirements are internet/cloud solutions. As outlined in the following sections, different solutions have advantages and disadvantages and what is appropriate should be decided in accordance to the required output and available resources/processing time.

Software: Internet/cloud based VS offline/user-PC: some free and commercial solutions

A first basic distinction between photogrammetric software can be made on the basis of the processing being done online on a cloud of computers, or on a user PC, without connection required during processing. This schematic and over simplified division does not always demark a specific differentiation in the technology or actual algorithm used for processing. Indeed, most of the solutions presented here are all based (with minor or major improvements) on or compatible with Bundler. This is of course valid for open source software (where the code is visible), but it should work also for most of the commercial solutions now on the market (even though the code on which they are based is not visible). The following examples do not cover the entire range of available software. And of course in such a quickly evolving field most of the characteristics mentioned here may change, improve or disappear. Many more software (perhaps even better than the mentioned ones) are available in both commercial and free sectors, i.e. the very powerful Photomodeler, Micmac, OpenMVG and OpenMVS or SURE to mention a few.

–Arc3D (online)

ARC 3D Web-service is a family of web tools for remote 3D reconstruction. This solution does not require any user input (besides uploading the images to the server): all the process, once the photos are uploaded, is made remotely by a special server. The upload is done through a user-friendly interface that allows one to change some parameters and check for blurry images. Before the upload, the user is asked if the photographs should be down-sampled in order to reduce internet traffic band and speed up the processing. When the process is completed, an automatic email is sent to the specified address with links to the final products. Results can be then visualized with the free software Meshlab or WebGL compatible web browsers. More information and registration at <http://www.arc3d.be/>.

–MS Photosynth (online)

This is a kind of hybrid solution since part of the process is done on the user's computer before upload to the server. The progresses in processing and uploading can be followed by the user through the user interface. A percent of matching is also provided, but nothing can be done to improve it. Photographs do not have to be ordered or with consistent zoom or lens and this allows a denser cloud where the zoom is higher (for instance we can have a general cloud for a monument and details of the decorations). The main output is not a point-cloud but the web visualization of the results. Free tools available online (and a plugin inside Meshlab) are able to capture the result and save it for further processing on local machines. The output can be shared through the Photosynth website according to the Creative Commons rules. A (free) registration is required to access this service.<http://photosynth.net/>

– More online solutions

A large number of online services are available with different specifications. They all require a free registration and they are quite fast in producing the final output. The most important and easily used of them are: My3DScanner (<http://www.my3dscanner.com/>); Hypr3D (<http://www.hypr3d.com/>); AeroScan (<http://areo.co.nz/areoscan/>); Drone Mapper (<http://dronemapper.com/> not free); Autodesk 123D Catch (<http://www.123dapp.com/catch>). Of particular note is SFMservice (<http://ptak.felk.cvut.cz/sfm-service/websfm.pl>). Although its support is discontinued, this is definitely the best current online solution for photogrammetric processing. It provides a good variety of outputs and all the processing parameters are clearly visible in the online log. An offline version of the software is also available and produces remarkable results (especially in orthophoto production), including animation videos and DEMs.

– Insight3D

Insight3D works better with buildings but it is still in experimental phases, and while it may be worth testing expectations should not be too high. The user loads photographs through a graphical interface and Insight3D automatically matches them and calculates the photo positions (plus camera's optical parameters) and generates a 3D point-cloud. The point cloud can be improved with manual input of points recognized in at least three frames. Modelling tools can be used to create a textured polygonal model or to export the point-cloud to few output format (the best seems to be wrl, which is also compatible with Meshlab). With flat surfaces and good photo coverage, the software successfully creates a textured solid model. The Insight3d manual is essential. <http://insight3d.sourceforge.net/>

– Bundler/OSM-Bundler/SFM-Toolkit

Bundler and OSM-Bundler are quite similar software, with the latter being an evolution of the former oriented to city map making (OSM = Open Street Map, see <http://wiki.openstreetmap.org/wiki/Photogrammetry> for more information). With OSM-Bundler are also included PMVS and CMVS which are very powerful algorithms for dense cloud generation. It works better with 64bit architecture (as does most photogrammetric software) and it is cross-platform. The main outputs is a point-cloud with colours and this detail can be used for texturing the reconstructed surface (the detail of the textures depends on the point cloud density). OSM-Bundler is written in Python coding and it is used to work in Linux; binaries for Windows are also provided together with source-codes for experts. <http://www.cs.cornell.edu/~snaveily/bundler/> and <http://code.google.com/p/osm-bundler/>

Also AirPhoto by Irwin Scholar (<http://www.uni-koeln.de/~al001/airdown.html>) has a free bundler photogrammetric module for orthophoto production (via CloudCompare and built-in script or with Microsoft ICE).

– Agisoft Photoscan

This (commercial) professional solution has gained popularity because of the ease of use, the quality of the results in relatively short processing time and the large number of features, including use of automatically recognized coded targets or manual input for georeferencing models, the alignment and merging of different models and the creation of seamless orthophotos and DEMs. It has good assistance and an active user forum. It is a closed-source software but with a very powerful feature allowing the user to program specific activities in the embedded Python console (Verhoeven 2011).

– VisualSFM

The best free software at the time of writing in early 2015 is probably VisualSFM. Installation is not straight forward and requires some level of expertise but the author of the software and the user forum provide considerable assistance. It has a number of interesting features and processing results are visible in real-time through the interface. It is not open source, but most of its components are and anyway all the input parameters are openly visible and configurable. It requires some entry skills but it gives the best results in difficult contexts (where other commercial software normally fails) and it is not a black-box solution. It normally needs to be combined with other pieces of software to produce final results since its main output is a point-cloud. Meshes may be easily generated or cleaned with Meshlab (<http://meshlab.sourceforge.net/>) or CloudCompare (<http://www.danielgm.net/cc/>) together with some sort of orthophotos. Proper DEM and

orthophotos can be produced with CloudCompare, Meshlab or CMPMVS (see above the offline version of SFMservice).

Comparison of selected software solutions

Simplified comparisons of the some software are presented here to assist the user in choosing the best solution for the required output.

		SOFTWARE SOLUTION			
		Photoscan	VisualSFM	Bundler family	Online solutions
FEATURE	1. Manual image masking	+	-(+)	-	-
	2. Multiple models at once	-	+	+	-
	3. Pausing & Resuming	+	+	-	- (not needed)
	4. Blurriness check	+	-	-	- (only Arc3D has a tool for this)
	5. Manual matching	+	-	-	- (123D Catch)
	6. Command-line usability	+/-	+	+	+/-
	7. Georeferencing	+	+ (not too accurate)	-	- (only geotagging in some cases)

Table 1. Comparisons of some of the most required features in different software solutions.

The parameters considered in Table 1 are representative of the typical uses of photogrammetric software.

1. The ability to manually mask images before processing is valuable, especially with obstacles (such as fences, pillars or moving cars or animals) partially obscuring certain details. This function is not available in any of the free software mentioned here, but VisualSFM especially seems to have a better filter, able to deal with such issues without user interventions.

2. In dealing with large datasets depicting different contexts, automatic grouping is sometimes very important. Some commercial software, although allowing the processing of large numbers of images, may end up with a single model using only a few of the images and leaving the others as not aligned. VSFM seems to be the only with the function to generate different models at once.

3. Large datasets normally require long processing time. It may sometimes be necessary to pause the processing and while Photoscan has this function, the software needs to be open also during the pause. On the other hand VSFM allows a complete stop of the processing and resuming it even after a computer restart. For the online software, the pause function is not needed, since the process is normally handled by clouds of computers in shorter time.

4. Blurriness checking is also a very important feature, since an unintentionally captured blurry image may waste the entire processing or slow it down.

5. All the commercial and free software can be almost entirely controlled via a command line (especially useful in repetitive processing or remote applications). A few of the online solution have the same feature but generally not much developed.

6. Finally the possibility to georeference the model and the orthophoto from inside the software. This is the function where Photoscan excels but good results may be obtained also with VSFM or with the use of other free software such as *sfm_georef* (http://www.lancaster.ac.uk/staff/jamesm/software/sfm_georef.htm).

Making the results available

A further aspect of output from photogrammetric processing is a consideration of how to share results with the scientific community or the wider public.

The first and perhaps easiest solution for 3D model sharing is 3D-PDF, which is like a normal PDF but has an embedded 3D model and the ability to rotate, zoom-in and out and some other basic operations. While this is automatically supported by some commercial software (such as Photoscan), to obtain a 3D PDF from free software is slightly harder. Indeed, it requires the conversion of the first 3D surface to an intermediate format. For instance, VisualSFM can produce a dense point-cloud, but it needs to be converted to a mesh (or surface) in Meshlab and then saved in a U3D format. This file format can then be loaded into the free U3D-2-PDF application (<http://nj.riotdowntown.com/2011/04/u3d-2-pdf/>) and from there exported as 3D PDF.

Another solution may be to distribute the output file as is, but this will require users of the file to install a viewer. Many free software are available for point-cloud and mesh visualization, but the most useful ones are Meshlab and CloudCompare. Slightly more options are available for sharing a 3D model directly online through a web browser. This requires some basic programming skills but available solutions are normally free and highly customizable. Of these the most effective seems to be Jsc3d (<https://code.google.com/p/jsc3d/>), ThreeJS (<http://threejs.org/>; available also as QGIS plugin under the name Qgis2threejs to export DTM), SpiderGL (<http://spidergl.org/>) PoTree, especially suited for large point-clouds streaming (<http://potree.org/>) and XB Point Stream (http://zenit.senecac.on.ca/wiki/index.php/XB_PointStream). Alternatively, also Sketchfab allows its viewer to be embedded in any webpage, though a free registration is required.

CONCLUSIONS

Developments in software and hardware are generating a rapid uptake of photogrammetry in multiple fields of research. Until a few years ago only expensive professional commercial software was available that required specific expensive calibrated cameras. Alternatives for producing a point-cloud were a scan station (typically the Leica C-10 for 100.000 € plus annual calibration) which carried limitations in terms of coverage and resolution.

Today, consumer grade computers are more and more capable of rapid complex graphic computations and accurate processing at limited cost. This feature has been exploited in computer vision software to allow the application of photogrammetric processing to unsorted and uncalibrated cameras, to generate dense point cloud in a much simpler way than with past professional toolkits. At the same time, the development of low cost flying devices now allows inexpensive (but high-resolution) digital cameras to be taken aloft and their photographs used for excavation- or landscape-scale 3D digital reconstructions.

These factors (together with others) are driving the quick development of digital photogrammetry in previously unexplored directions and applications. This aspect of remote sensing is more accessible than ever to the general public, making aerial imagery a common tool for understanding surroundings or more global phenomena. And the ability to measure the landscape depicted in these remotely sensed images continues to boost the development of new systems and applications. Newly created companies claim to be able to shortly provide 3D sensors for cars at a cost of \$100–250 (Ramsey 2015), while affordable sensors (such as MS Kinect or Asus Xtion) for close range indoor applications are already available and continue to develop (Microsoft, 2013). Mobile devices (such as phones and tablets) also, always at hand and with improving computational performances, will soon be capable of acquiring 3D information as easy as capturing photographs (see for example the open source Google Tango Project – <https://www.google.com/atap/project-tango> or the Kickstarter Project Eora3D – <http://www.eora3d.com>).

All these applications have direct synergies with 3D printers and the possibility to create (or recreate) scaled objects or speculative reconstructions and accurately integrate missing parts of damaged or incomplete artefacts. Currently, the intensive (and informed) use of photogrammetry in archaeology promises to improve understanding of landscapes and artefacts. While there are countries where aerial photogrammetry has been successfully applied in a number of archaeological projects, there are still places where even simple maps

(if any) are hard to acquire and so no proper archaeological survey or landscape study can be progressed. In such a case, an affordable flying system with inexpensive image capture devices and free or low-cost software, are a powerful combination. This situation implies also the existence of laws to allow for correct and safe development of low altitude photogrammetric approaches and this seems to be the real challenge at the moment. And as the legal side of operations is defined there remains the hope that archaeologists (amongst others) will still keep on benefiting from this technological (and partly methodological) improvement.

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Historical aerial photographs to recover a lost landscape using digital photogrammetry: a case study of the Iron Age site of Cerro de la Mesa (Alcolea de Tajo, Toledo, central Spain)

Abstract: *Massive change has impacted the extent and landscape context of the settlement of Cerro de la Mesa on the Tagus River after a dam was built in the 1960s. As a result there are interpretative and archaeological problems, such as the original size of the settlement, the line of its perimeter, and the locations of entrances and the necropolis. By using digital photogrammetry with historical vertical aerial photographs from the 1950s a Digital Elevation Model (DEM) of the original surface of the area before the construction of the dam has been obtained. This paper examines the technical issues in generating the model, the reasons for using the images instead of other possible choices, as well as technical challenges commonly shared when working with historical images that lack calibration data. The photogrammetric process followed may be applicable in other geographic areas with similar characteristics and problems.*

INTRODUCTION

Cerro de la Mesa is an Iron Age settlement located on the right bank of the Tagus River, in the province of Toledo in the interior of the Iberian Peninsula. It was discovered in 1991 during irrigation works in the area and, since then, it has been protected by a perimeter fence and research started (Figure 1). During excavations, two phases of occupation were documented, firstly in the 7th–5th centuries BC, and a secondly between the 4th and 2nd centuries BC (Chapa and Pereira 2006). Radiocarbon dating of cereal seeds (Beta Analytic Inc., BETA-252781) places its abandonment in the late 1st century BC.

One of the main obstacles to understanding the site are the major transformations to the landscape following the construction of a dam in the 1960s, and the reorganization of the land and the introduction of intensive agriculture in the area.

During the second half of the twentieth century energy policies in Spain focused on hydroelectric exploitation, along with the development of flow regulation and increased irrigation, which saw construction of dams and associated infrastructure. Azután was one of the smallest dam projects along the Tagus River. The construction of a dam was usually planned for an area that could easily be flooded, and in this case at the transition between the granitic Hercynian massifs forming the Tagus corridor and the Tertiary and Quaternary (Olivé et al. 1989). This geological transition zone had also been chosen to place the protohistoric settlement of Cerro de la Mesa, on a flat-topped hill left by an ancient fluvial terrace. It is located adjacent to a ford of the Tagus, historically known as Puente Pino or Puente de Los Pinos, a name derived from its last known medieval bridge that has since disappeared. It is therefore in a strategic position occupying an isolated platform in a transition landscape, bounded by two streams and the Tagus River (Figure 2).

This formerly prominent location is now heavily altered (Figure 3). The construction of the dam required extraction of 125100 m³ of land (56600 m³ from the right bank of the river, affecting the Cerro) (Gómez 1965), as well as construction of access tracks, a hydroelectric station, roads and other infrastructures. In

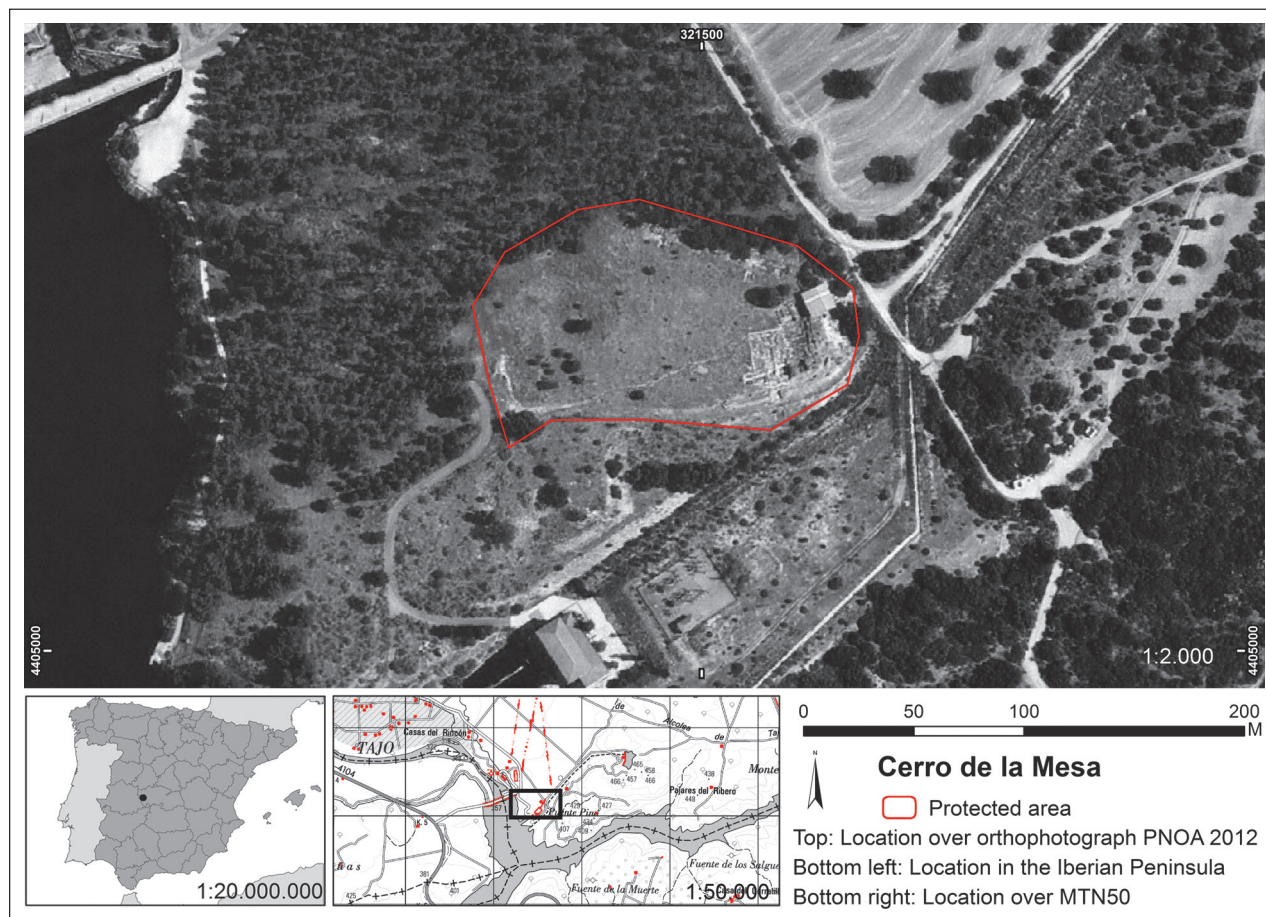


Figure 1. Location of the archaeological site of Cerro de la Mesa, based on Instituto Geográfico Nacional (IGN) mapping.

addition, the beds of the streams that flowed around the Cerro were filled. Two decades later, this location served as a platform for the construction of a pumping station, pipelines and associated buildings to provide irrigation to the area. At the same time, reforestation took place and pine trees were planted on one of the fillings. The result is a huge environmental impact which changed the landscape, in which Cerro de la Mesa is hardly recognizable.

SCOPE OF RESEARCH

Given this difference between the current and the earlier form of the site, there are certain interpretive difficulties, both from an intra-site and from an off-site perspective. The highest part of the platform, where archaeological excavations have been conducted, is fenced and protected (Figure 4), but without knowing the original landform a number of issues were not clear, including for example, whether a rampart surrounded the whole hill or just the highest area, or how entrances were organized (since only one possible entrance has been found in the excavated area). Neither is it known whether the whole of the platform was populated or just certain areas. The location of the necropolis is also unknown, as a result of which valuable information about the social group that inhabited this place is missing.

At the same time, territorial research is one of the objectives of the larger project *Identity and territory in the middle Tagus basin during Late Bronze and Iron Age*, of which the work reported on in this paper is one component. The larger project aims to study the characteristics of occupation in these periods to identify and define the social groups in this geographical area through a combination of palaeogeographic and archaeological studies to recognize key factors of the settlement network and its transformations over time. It seeks to apply methodologies and tools for modelling the study area as a means to understand the evolution of its landscape and land use. Among the techniques used non-invasive approaches are prioritized, using GIS tools to analyze information from digital elevation models (DEM), historical aerial photographs, high-resolution

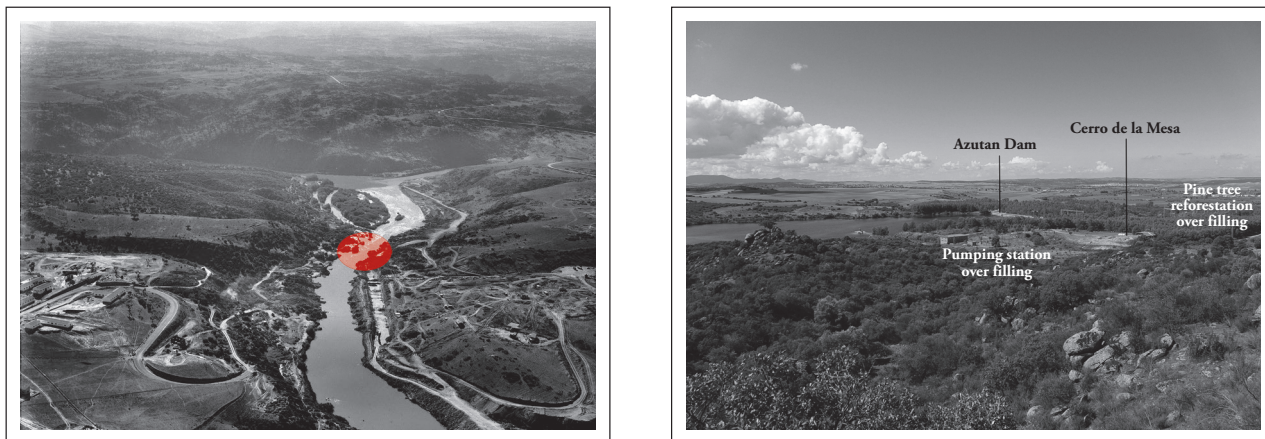


Figure 2. *View of the area of the construction of the Azután dam on 31/10/1965, during the first months of work. Cerro de la Mesa is the platform on the left. Highlighted in red are the remains of the bridge that crossed the ford. Photograph by Paisajes Españoles.*

Figure 3. *General view of the area around the settlement. Photograph by the author.*

satellite imagery, historical maps, and data from archaeological survey, amongst others. These sources allow comprehensive understanding of all the factors that interact in the decisions that led to human groups to exploit a territory in a certain way.

The Tagus River is a natural border and control of the fording points progressively became a key factor for the definition of territory and social groups during the Late Bronze and Iron Age, influencing not only the location of settlements, but also certain elements of symbolic representation, such as stelas, tombs and sanctuaries, while interfluvial areas defined agricultural and economic spaces. After construction of the dam, the catchment area of Cerro de la Mesa was completely transformed and the original natural ford disappeared. Thus, the intended analysis of mobility, whose analytical basis are digital terrain models (DTM), could not be achieved. Similarly, any visibility analysis for the ford and the site could not be made. Due to these limitations it was essential to reconstruct the topography of the area prior to the construction of the reservoir – to recover the landscape lost to the water.

RECOVERING A LOST LANDSCAPE

The central problem was to obtain a DEM that reflected the topography of the area prior to the 1960s, a solution to which was offered by recent work in a nearby area (Cerrillo 2011, 151). There were two options for obtaining a DEM that predated the dam construction, the first and possibly easier, was to get height data from a topographic map predating the construction of the reservoir, and the second option was to create it by applying digital photogrammetry to aerial photographs from a photogrammetric flight undertaken before construction of the dam.

Pre-1960s topographic maps

The search for pre-1960s topographic map sources for our area of interest lead us to consult documentation related to the construction project of Azután reservoir in a number of institutions that are listed briefly below.

The Confederación Hidrográfica del Tago (Hydrographic Confederation of the Tagus River) is one of the agencies in Spain responsible for water administration in the river basin, the development of Hydrological Plans, and the design, construction and operation of works carried out either by the institution or by the State. This agency presumably holds documents about every reservoir and its construction, but a request for information for our project has remained unanswered for years. The Archivo del Ministerio de Fomento (Ministry of Development Archive) holds some of the documentation of the various incarnations of the Ministries of Public Works, Transport, Communications, etc. until the early 1990s, and contained some data files and partial plans of the area of interest. The same is true of the Archivo General de la Administración

(General Archive of Administration), a centralized archive where most of the historical documentation for the Spanish public sector is kept. This contained some data and pictures of the dam and partial maps of the area. Iberdrola is one of the largest Spanish companies in the hydroelectric energy production sector, and managed the hydroelectric exploitation of the Azután reservoir. Its historical archives were created “to safeguard the rich documentary heritage accumulated during more than a hundred years” (translated from García and Diego 2005, 2) and so preserve historical documents related to the company and its projects. This contained some geological and geotechnical studies, but the most valuable information was from its photographic archive. Less useful for our purposes was the documentation on the construction of the dam of Azután that had been compiled by a mining engineering student in the Escuela Técnica Superior de Ingenieros en Minas y Energía de la Universidad Politécnica de Madrid (High Technical School of Mines and Energy Engineering of the Polytechnic University of Madrid) though this included much data and some plans and sections.

Alongside the search for a detailed topographic map of the construction of the dam, we looked for historical maps that could provide additional information about the area. Such geographical information supports understanding of landscape evolution with a focus on geographical and thematic characteristics such as hydrology and land use, among others. We located three useful sources for this purpose including a mapping project by Tomás López, various navigation projects along the Tagus River from the time of Felipe II in the second half of the sixteenth century until the early nineteenth century (Cáceres Provincial Archive), and the historical series of the National Topographic Map (MTN), accessible from the Centro Nacional de Información Geográfica (CNIG) (National Centre of Geographic Information) (<http://centrodedescargas.cnig.es/CentroDescargas/inicio.do>). However, while these provided landscape information, they were not useful for the creation of a DEM as they had inadequate scales, or were unscaled, or showed the post dam construction period. For these reasons we also discarded the cartography from other national institutions such as the Servicio Geográfico del Ejército (Army Geographical Service), or regional ones, such as the Diputación de Toledo.

Historical aerial photographic sources

Since the documentary research did not provide the necessary data, the search turned to finding appropriate historical aerial photographs from which to obtain a DEM. Ideally, for these purposes the aerial photographs should be vertical and taken with the correct specification to allow processing using photogrammetric techniques. Several early flights were undertaken in different areas, such as that in 1929 covering a small portion of Navarra, or the 1929–1930 coverage of the Segura Basin (Fernández 1998), but these provide only partial cover of our area. There is a brief reference to the main Spanish collections of aerial photographs in Fernández (2000, 17–51), which also refers to the companies that conducted them. The two institutions that currently archive photographs from flights with national coverage are the Instituto Geográfico Nacional (IGN) (National Geographic Institute) and the Centro Cartográfico y Fotográfico del Ejército del Aire (CECAF) (Cartographic and Photographic Centre of the Air Force).

The Fototeca del CNIG (Photographic Library of the National Centre of Geographic Information) preserves IGN photogrammetric flights undertaken since 1930, and part of this information is available through an online viewer (<http://fototeca.cnig.es/>). Among flights available, only the Interministerial Flight (1977–1983, scale 1:18.000) and the National Flight (1980–1985, scale 1:30.000) had photographs of our research area, but these post-date the dam construction and so could not serve our purposes.

The Archivo Fotográfico del CECAF (Photographic Archive of the Cartographic and Photographic Centre of the Air Force) where photographic work carried out by the institution, and others of historical value (1938, 1945–1946 and 1956–1957), are preserved proved to be more useful. The 1938 photographs covered the Tagus in several strips during different months at a scale of approximately 1:19.000 (since the terrain varies between 2000 and 4000 m the scale is also variable). During the Spanish Civil War (1936–1939) the Tagus corridor became a natural border, called Frente del Tajo, between the two sides (Barroso et al. 2011). Our study area was particularly unstable during the summer months of 1938 as the ground was changing sides, and this is why coverage dates to July and August. These strategic areas in the conflict were also mapped at 1:25.000 (Burgueño 2010, 287). Despite having several images with suitable characteristics, Cerro de la Mesa appears on only one, so stereoscopy was not possible and the image could not be used for photogrammetric processing, reflecting their acquisition in support of military activities such as bombing, rather than photogrammetry.

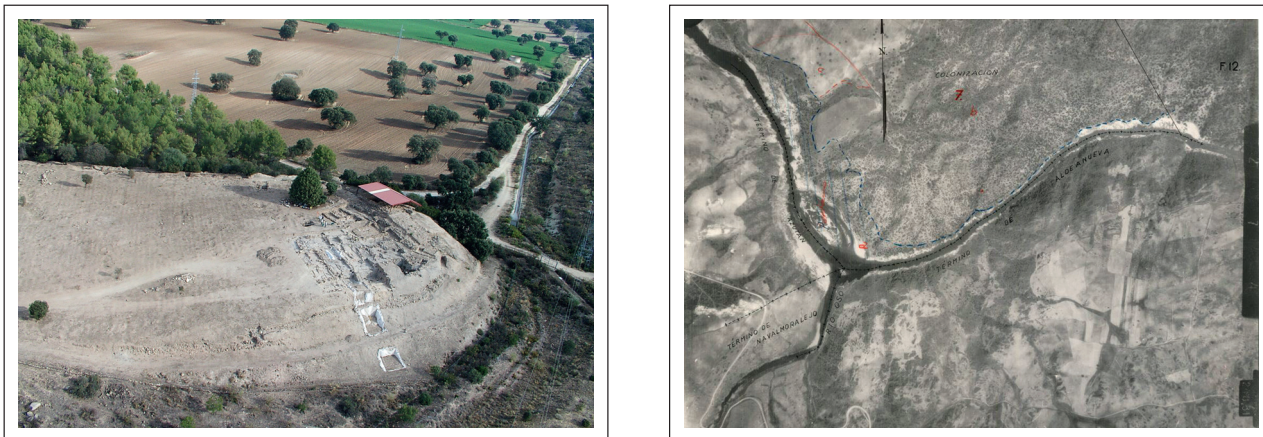


Figure 4. *Aerial photograph of the excavated area in 2009.*

Photograph by Iberdrola.

Figure 5. *Photograph of the area later covered by the reservoir of Azután (dashed blue line) by CETFA in 1952.*

The River Uso (also named “Huso” in different sources) is named “Oso” (“Bear”), an error that illustrates how sometimes toponyms may change due to cartographic mistakes.

Flights undertaken in 1945–1946 and 1956–1957 are known as “Series A” and “B Series” respectively of the “American flight” in Spain, and comprise two photogrammetric flights of the whole of the country. These have been discussed in a number of publications (Vera et al. 2011; Urteaga and Nadal 2001; Urteaga, Nadal and Muro 2000; Fernández and Quirós 1997), including their use for archaeological photo-interpretation (Fumadó and Sanchez 2013) and from a photogrammetric methodological perspective with applications in any field (Pérez, Bascón and Charro 2014, Perez et al. 2013a).

The “Series A” coverage of 1945–1946 (part of “Project Casey Jones”) was the first photogrammetric flight with national coverage, although some areas have since been lost. It was undertaken by the United States Army Air Forces (USAAF) and the Royal Air Force (RAF) at the end of World War II. Unfortunately, these photographs are too small scale (around 1:40.000) for our project. Fortunately, the “Series B” coverage of 1956–1957 has a scale around 1:30.000 providing photographs at an adequate scale to compile mapping at 1:10.000 scale which is suitable for our project. This flight was conducted by the United States Air Force (USAF) to obtain mapping of Europe in the face of the possibility of a new war with the Soviet Union.

Beyond these sources, we also looked for aerial images elsewhere, such as in the municipal archives of the area where the Azután reservoir is located. The most useful photographs came from the Iberdrola and Paisajes Españoles companies (Figure 2), which have oblique aerial photographs that documented, periodically, several sections of the river Tagus before, during and after the construction of the dam. Potentially useful images were also found in the Archivo Histórico Provincial de Toledo (Provincial Historic Archive of Toledo) (Figure 5). These were taken by Compañía Española de Trabajos Fotogramétricos Aéreos (CETFA) in 1952, a company that has since closed down. These images were planned for photogrammetric use at a suitable scale of detail, and could have been used for our purposes despite the lack of camera calibration data, flight details and scale. However, we could not use them because the images in the archive are poor quality copies and we were unable to locate the original negatives due to the sale of the company collections following its closure (Fernández 2000, 20).

DEM GENERATION METHODOLOGY

Thus, despite an extensive search, it proved that only the photographs from the USAF 1956–1957 flights were suitable for our purposes. The methodology of the photogrammetric process from camera calibration, interior and exterior orientation, generation and editing of the DEM, and creation of the orthophoto mosaic, is detailed in an earlier paper (Perez et al. 2014, 11–15), where solutions to specific problems are given, drawing on examples from other areas. This paper will cover these issues superficially, discussing the process followed, and solutions for the problems raised.

Problems in using the USAF photographs

Earlier publications have outlined some general problems when working with the Series A and B photographs (Cerrillo 2011, 152; Pérez et al. 2013b, 352, 353, 356, Pérez et al. 2014, Pérez et al. 2013a). These can be summarized as follows: 1) several series of cameras were used (the Fairchild K-17 and K-18 for Series A, and the Fairchild T-11 for Series B), complicating the identification of the fiducial marks, which vary between different cameras; 2) there are no calibration certificates, although distortions are available; 3) non-uniform heights of flight, ranging between 4570 and 5550 m in Series B and around 6100 m in Series A, which produces variations in the scale of the images; 4) the poor quality of the contact prints (some of the negatives are not preserved); 5) low radiometric quality, with darkening of marginal areas (vignetting effect); 6) temporal differences between adjoining strips flown in different seasons, show variations in vegetation cover and water flow, among others; 7) unsuitable weather conditions at the time of flights, sometimes with presence of clouds; 8) non-optimal times of day for photography, sometimes with long shadows. For our study area, the specific problems were the lack of calibration certificates, the non-uniform scale of the images, vignetting and both the temporal and radiometric quality differences between adjoining strips. Solutions adopted are detailed below.

Characteristics of the USAF aerial photographs

The chosen photographs of our 14.000 Ha area were taken on panchromatic film in two strips flown on 5th March and 7th April 1956, from which six photographs were used (strip 101: frame numbers 1114, 1115 and 1116; and strip 102: frame numbers 1747, 1748 and 1749). The focal length of the lens is given as 153.78 mm in the photograph margins, and the images were taken with a 60% forward overlap and a 35% lateral overlap. They were taken at an average height of 5489 m in strip 101 and 5029 m strip 102, giving scales of 1:33.000 and 1:32.200 respectively. The differences in scale did not prove to be a problem and neither was the one month difference in the dates of photography.

Work scale, digitizing and processing of the photographs

These characteristics of the photographs determined the scale of work and the approach to digitization of the images. The selection of the map scale is determined by the scale of the images, and for photographs of about 1:30.000 scale this may be between 1:5000 and 1:10.000 (Figure 6). The latter proved to be more appropriate given the characteristics of images. Having chosen the cartographic scale the maximum tolerances in the representation are calculated. For planimetry this is achieved by multiplying the limit of visual perception (0.2 mm) by the denominator of the map scale, in this case 2 m. In altimetry, the tolerance equals $\frac{1}{4}$ of the scale denominator or equidistance between the contour lines (Ojeda 1984), resulting in 2.5 m.

The characteristics of the film and lens distortion (which decreases the resolution capability of the film, in addition to its own resolution) have an impact on digitizing because they determine the definition of features that can be distinguished in the photograph, and are values used to generate the table of relations between the photographic and cartographic scale (Figure 6). There is an additional problem with the 1956–1957 photographs caused by the deformation of the film during storage. Thus the resolution of the film (measured in lp/mm – i.e. line pairs/mm) specified by the manufacturer is reduced as a consequence of the deformations of the mounting on the camera, in addition to over fifty years of storage, with the result that the film has lost its original geometric characteristics.

To avoid loss of geometric information when scanning, pixel resolution should match the photo-

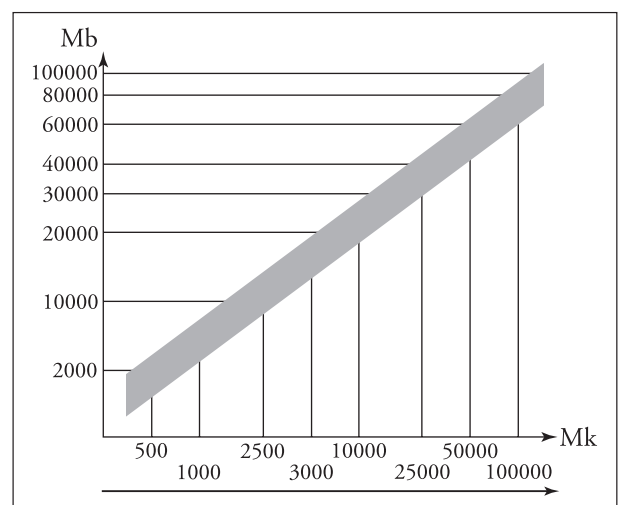


Figure 6. The relationship between flight scale (Mb) and cartographic scale (Mk). Chueca Pazos 1982, 711, Figure 4.

graph resolution, meaning that $lp/mm = 1000/3.Px (\mu m)$ (Warner, Graham and Read 1996, 127). The resolution of the film used in the laboratory was about 20 lp/mm (Spriggs 1966), but in working conditions that would be reduced to about half (Macdonald 1951), so that the pixel size of the scanned image should be about 34 μm . Images were digitised by CECAF and stored in TIFF format at a resolution of 21 μm and 8 bits, using a Zeiss PhotoScan TD scanner. This means that the scan resolution was higher than needed.

All the digital images were further processed to address low radiometric quality in some areas of the photographs. This was aggravated by homogeneous digital values in some areas (e.g. flat areas with cereal crops), which made it impossible to correctly identify pairs of homologous points. On some photographs, the film has stripes of varying brightness and darkening of marginal areas. These problems were resolved by analysing and modifying the radiometry (Redweik et al. 2010).

With the pixel size of the scanned image, we can calculate its size in the field or the ground sample distance (GSD). This is calculated by multiplying the denominator of the scale of the photograph (30.000 and 32.200) by the resolution of the scanned image (21 μm). Our GSD is about 0.6 m, while the most suitable should be derived from a resolution of 34 μm (about 1 m) more suitable to the actual size of the field corresponding to a pixel of the digital image.

Data were processed with the photogrammetric software PhotoMod 5.1, Photopol 6.8, Atlas 6.8 and Aerosys 7.4.

Camera calibration and interior orientation parameters

There is no calibration certificate despite calibrated cameras having been used. However, the internal parameters of focal length, radial and tangential distortion, coordinates of the fiducial marks and location of the principal point are known. Therefore, interior orientations have been calculated by measuring eight fiducials marks, adjusting the fiducial system through the pixels of marks called shrinkage fiducial marks, to control the dimensional stability of the format. Factors causing deformation (above) of the material were also considered. Parameters listed by Spriggs (1966) were used to calculate the radial distortions of cameras. The displacement of the principal point with respect to the fiducial marks is within the geometric range defined by one pixel, so both virtually match. Using these parameters, the following results have been obtained in the process of interior orientation as shown in Table 1.

Exterior orientation

Calculating exterior orientation requires ground coordinates of points identified in the photographs to adjust the scale of the stereoscopic model. The difficulty lies in locating identifiable objects that have not changed since 1956. This was accomplished using ground control points (Figure 7) taken directly in the field with differential GPS for features that could be identified. Other ground control points were taken from older maps with scales of either 1:5000 or 1:10.000.

In order to model possible defects in the interior orientation parameters, as well as potential systematic errors introduced during the adjustment of the block, adjustment of the models was initially done using the autocalibration method including the additional parameters proposed by Ebner (Aguilar, Aguilar and Negreiros 2010), using a minimum of six ground control points distributed over the block. As the photogrammetric blocks were small, orientations were performed independently (Cardenal et al. 2006), using a minimum of six ground control points distributed over each model and at least three

Photograph	Sx (mm)	Sy (mm)
1114	0.012	0.010
1115	0.009	0.011
1116	0.012	0.012
1747	0.009	0.008
1748	0.007	0.012
1749	0.014	0.011

Table 1. Results of interior orientation indicating the mean square error obtained in each photograph.

Models	SX (m)	SY (m)	SZ (m)
1116-1115	0.225	0.157	0.856
1115-1114	0.228	0.114	0.445
1749-1748	0.219	0.179	0.441
1748-1747	0.317	0.118	0.665

Table 2. Deviations in the oriented models.

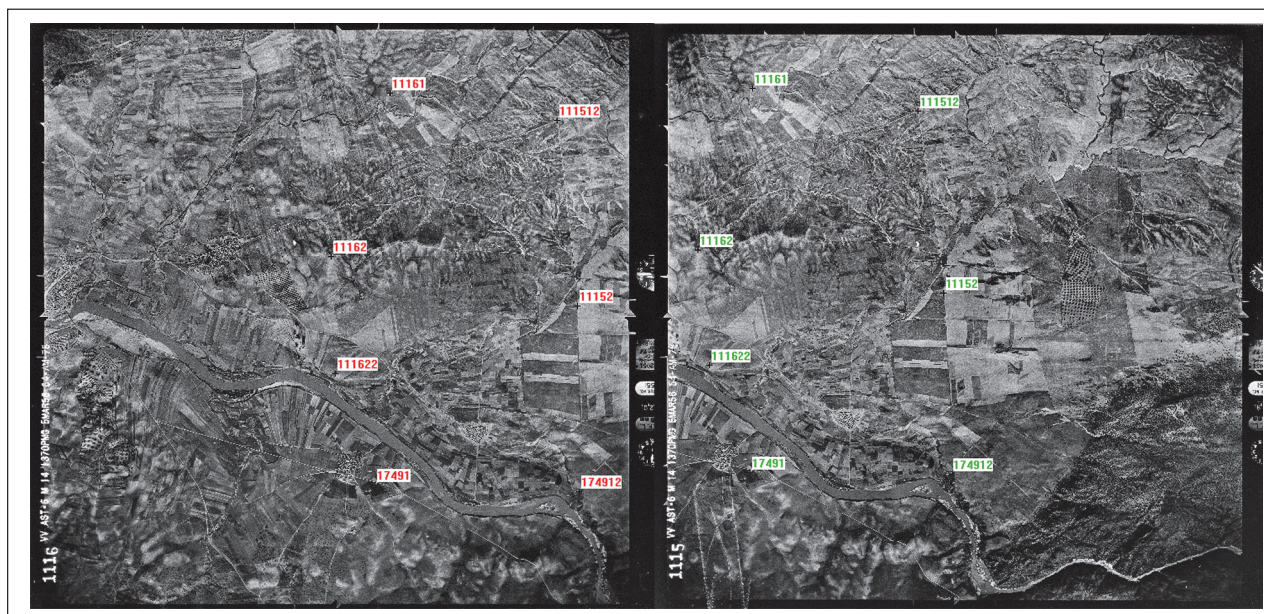


Figure 7. *Distribution of ground control points in model 1116-1115.*

of which were common to adjacent models. The adjustment results obtained (Table 2) were homogeneous, with mean values for deviations which were under 1 m in both planimetry and altimetry, which is a very good result considering the circumstances.

Generating the DEM

Other applications of this photographic series have usually used digital elevation models with a point density of 10 m, although this is largely an arbitrary decision (due to factors like the point density of other geospatial data) than empirically based. As there is no formula to establish this density, the choice of density is based on terrain characteristics, the scale of cartography and objective pursued together with technical experience. On terrain characteristics, stereoscopic restitution of breaklines (watersheds and height dividing lines) is of particular importance to determining terrain morphology and slope changes. The chosen map scale involves working with tolerable errors in planimetry and altimetry that cannot be greater than the distance between the points of the model, so the density must be greater than 2.5 m. Finally, the objective of the work and experience help in choosing the density of points. For 1:10.000 scale in cartography, distances between points of 25 m and 40 m usually depend on the terrain (e.g. in flat areas lower densities, while higher densities will be necessary on steep slopes) and the intended purposes.

Given these constraints, the DTM was generated by correlation from the epipolar pairs of models, with a density of 50 m, which can be interpolated to other distances depending on the analysis and data that will be used.

Generating the orthophotograph

An orthophoto was generated with both the DTM and digital images oriented internally and externally, through a process of differential correction. The pixel size is at least the same as the GSD. The texture of the orthoimage was extracted from the radiometric information of the original photographs. However, there is a problem in the orthoimage which is divided by a horizontal line that marks the boundary between the two strips, and is due to poor radiometric quality, despite the processing undertaken.

RESULTS

From the geographic products obtained it is possible to perform different analyses within a GIS environment. For this paper we present a map that reflects the extreme topographic changes in the environment of the Cerro de la Mesa between 1956 and 2009 (Figure 8.3). The area is shown at two stages (Figure 8.1 and 8.2): 1) before the construction of the Azután dam, in the orthophoto generated from 1956 aerial photographs;

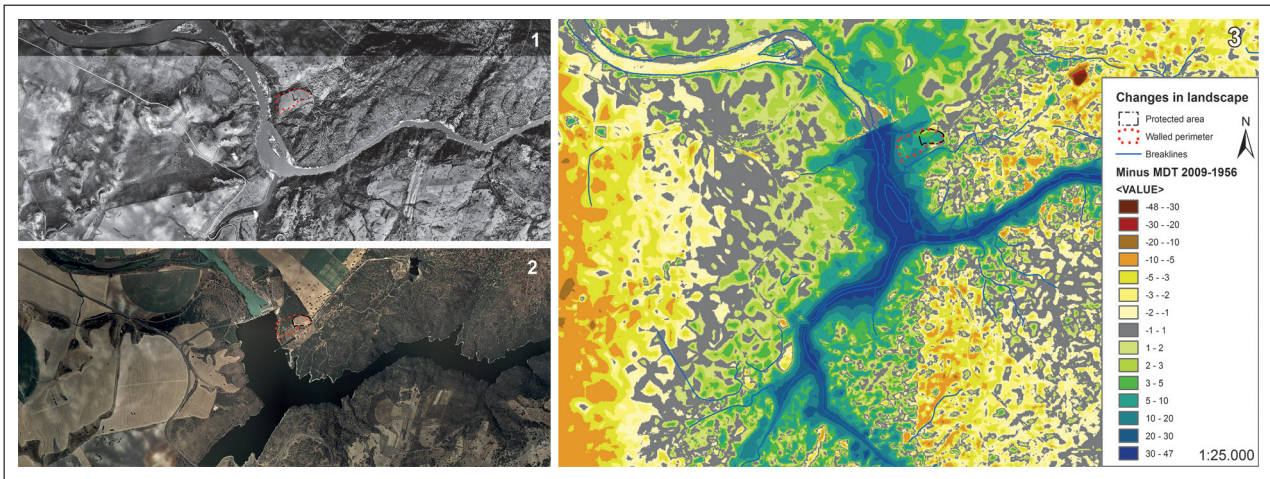


Figure 8. *Topographic changes in the area of the Cerro de la Mesa settlement between 1956 and 2009.*

and 2) in 2006 on the PNOA orthophoto (Plan Nacional de Ortofotografía Aérea). The analysis was undertaken using map algebra (Minus tool of Spatial Analyst module of ArcGIS 10 software) comparing the 1956 DTM and the PNOA 2009 Airborne Laser Scanning data-derived DTM. It is necessary to note that comparing geographic products obtained using different methodologies introduces error. A second source of error is the altimetric precision of both models, especially the 1956 model, in which the Z values can vary by up to 1 m (Table 3).

The differences in meters and the area affected can be seen in Table 4 and Figure 9. Negative differences correspond to areas that have lost volume (currently below the 1956 level), while positive ones to those that have increased volume (currently above the 1956 level). Due to the error in altimetry mentioned above, we considered any surface whose variation was been between -1 and 1 m as unchanged, which corresponds to 30 % of the total area. Surfaces with the most extreme variation values are a small irrigation dam on a nearby hill, whose construction required granite extraction, and the area of the reservoir, which changed the surface level in this area of the Tagus from 320 m to 354 m. Most of the surface has undergone minor changes, with gains and losses due to sedimentation and erosion, some natural, and others caused by human activities. Among the latter are not only farming, but also removal of aeolian sand deposits for building.

We were also able to quantify the changes in the original surface of the platform of the Cerro, and compare it with the current surface of the protected area. The platform area was 3.8 Ha, and the walled perimeter 873 m in length, of which only 175 m is presently known. The protected area of the archaeological site was only 1.4 Ha, but since December 2014 the original area of the archaeological site of Cerro de la Mesa has been designated as Bien de Interés Cultural (BIC), the highest level of legal protection for archaeological heritage in Spain.

CONCLUSIONS

The case study of Cerro de la Mesa illustrates the importance of archival sources for the documentation of a heavily altered landscape. These have given us knowledge of natural events such as Tagus floods which do not occur today due to the regulation of its flow, though they can be identified from stratigraphic profiles (Benito et al. 2003). Photogrammetric processing of 1956 aerial photographs has provided a model of the area as it was before 1965, allowing us to undertake quantitative analysis with an acceptable

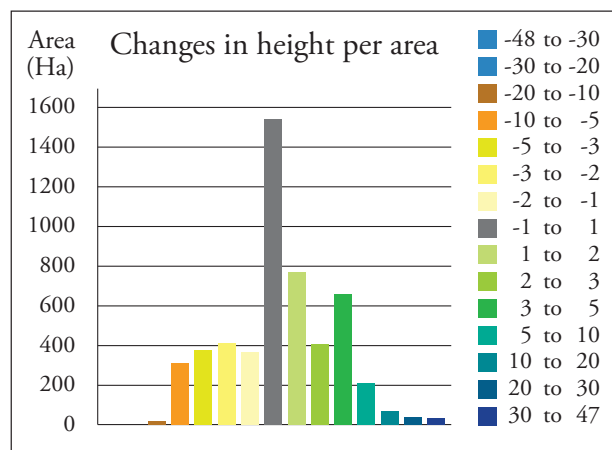


Figure 9. *Graphic showing changes in height (m) per area.*

Statistics	MDT 2009	MDT 1956
Total area (Ha)	5233,695	5233,7625
Maximum (m)	597,99	596,76
Minimum (m)	315,99	315,84
Mean (m)	390,8	389,84
Standard deviation	44,9	47,2

Table 3. *Statistics of each MDT.*

Table 4. *Table with changes in height per area, show as percentages of the whole area covered.*

Classes (m)	Count	Area (m ²)	%
-48 a -30	176	4400	0
-30 a -20	119	2975	0
-20 a -10	7449	186225	0
-10 a -5	124036	3100900	6
-5 a -3	151463	3786575	7
-3 a -2	164969	4124225	8
-2 a -1	147109	3677725	7
-1 a 1	618110	15452750	30
1 a 2	306890	7672250	15
2 a 3	163362	4084050	8
3 a 5	265507	6637675	13
5 a 10	86867	2171675	4
10 a 20	26548	663700	1
20 a 30	16350	408750	1
30 a 47	14514	362850	1
Total	2093469	52336725	100

margin of error. Combining oblique aerial photographs, and the 1956 orthophoto and DTM, we have identified the outline of the rampart as well as a possible entrance, yet to be further explored by geophysical survey.

In addition, we have developed a methodology for sources of information and image processing in the reconstruction of landscapes that is of wider relevance and may have applications in a number of disciplines (problems identified in Vales et al. 2010, 37–38 tables 3 and 4) that need to take account of chronological and geographical changes. Indeed, the photogrammetric process may be applicable in other countries where flights by the USAF were undertaken, including Italy, Portugal, Brazil, Colombia and Nicaragua (Pérez et al. 2014, 2, Table 1).

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3D model generation and landscape change: contributions to image-based digital reconstruction of the village of Breginj

Abstract: *The village of Breginj in Slovenia was an important national monument, which was severely damaged by earthquakes in 1976 and subsequently demolished. This paper presents the generation of a 3D model of the village from historic aerial photographs and an object-based landscape change analysis. The model is based on Structure-from-Motion (SfM) processing of six aerial photographs taken shortly after the first earthquake in May 1976. SfM requires a relatively large overlap between adjacent images, which was a problem because the images were acquired consecutively along a single flight line. However, despite the challenging data, the modelling the destroyed settlement is promising, and we managed to obtain a digital approximation of the village and its surroundings with an overall positional accuracy of better than 2 meters. However, this is merely the first step toward creating a 3D settlement and reconstructing its landscape.*

Post-earthquake actions and events thoroughly changed life in the village and the direct effects of this can be observed through a landscape change analysis. We used object-based classification of aerial imagery from several periods in order to obtain sequences of land cover during the last four decades. This added a quantitative dimension to the visually observable complete landscape change, as cultivated and pasture ground has been colonised by forest, covering 66 % of formerly pasture and 21 % of arable land over four decades.

The methodology used is outlined, followed by an examination of the potential of reconstructions of old settlements and the former form of landscapes to contribute to the conservation of architectural and cultural heritage, and the insight they provide to historic landscape transformations. This case study illustrates the capacity and potential for the use of historic aerial photographs for digital image-based reconstruction of settlements that may no longer exist, but have never-the-less left important traces in human and landscape history.

INTRODUCTION

The mountain village of Breginj, Slovenia, was an important municipality in the Soča region for many centuries, and its extraordinary folk architecture was protected as a cultural monument of national importance. This dynamic area on the border with Italy was subjected to politically driven decisions after it was severely damaged by two successive earthquakes, changing life there dramatically and leaving striking evidence in the landscape evolution of the past decades.

With the aim of retrospectively examining this lost village and to examine it through time we used historic aerial photographs and two different approaches, to obtain a detailed 3D village reconstruction (with Structure-from-Motion modelling), and a landscape change study (with object-based image analysis).

Technological solutions support archaeological and landscape interpretation, providing 3D reconstructions that allow visualization of lost buildings and settlements for a variety of uses. Landscape change studies allow measurements and interpretation of landscape transition related to specific societal or natural events supporting a variety of disciplines.

The village of Breginj

Breginj, a remote mountain village near the border with Italy, to the west of Kobarid, was once an independent municipality with a high degree of autonomy. For centuries it was a self-sufficient and highly organized local community exploiting the natural resources for agriculture and farming, as well as making use of its border location. Smuggling and temporary works across the border were amongst the most profitable and attractive activities for the village residents. Between the two World Wars, when the area was occupied by Italy, Breginj was affected by depopulation that had a major influence on the population structure. Additional depopulation followed earthquakes in the 1970s, with the result that current population numbers are less than a third of its peak a hundred years ago (Pipan 2011).

Breginj was one of a few major settlements with well-preserved 18th and 19th century buildings of a Venetian-Slovene architectural type (Lipušek 1995; Celarc and Erjavec 2012). Such houses were built on an elongated plan, with a wooden balcony, a gently sloping roof, and characteristic small windows protected by iron bars. The outer walls of some houses were adorned by simple paintings, reliefs, and coats of arms carved on stone panels (Figure 1). The two World Wars had a limited impact on the village, although the crude modernization popular in the post war period did not damage the buildings in Breginj. And, due to its extraordinary folk architectural heritage, the old village centre was protected as a cultural monument of national importance immediately after World War II.

Nevertheless, Breginj needed assistance if the quality of life in the village was to match the infrastructure standards of the time (Pipan 2011). Thus in 1975, on the initiative of local authorities, an extremely modern monument protection plan was prepared incorporating a comprehensive concept of modernization. In 1975 and 1976 the village was thoroughly documented and complex negotiations with the rather conservative local population began. As this was ongoing, on May 6th 1976 an earthquake struck the Friuli region in Italy and the Upper Posočje region in Slovenia. There were no deaths in the Upper Posočje area, but 12.000 buildings were damaged and 13.000 people were left homeless (Orožen Adamič 1980, 89).

Buildings in Breginj were damaged but not completely destroyed (61 % of the buildings were considered for demolition (Figure 2). Individual repair works soon began, but in the midst of the crisis these were not consistent with the guidelines outlined by the cultural heritage restoration and revitalisation plan. The municipality decided to gradually restore old Breginj while a new settlement of permanent prefabricated houses was to be built on the other side of the River Bela (Pipan 2011, 75). However, the course of the works and renovation plans was interrupted in mid-September when another earthquake struck the area. Many of the damaged buildings were now completely destroyed or re-assessed due to additional damage as a result of which 88 % homes and 94 % outbuildings were now marked for demolition. Despite these high numbers it



Figure 1. *A typical house of Venetian-Slovene architectural type in old Breginj*
(©Archivio Dal Molin).



Figure 2. Immediately after the earthquake in May 1976, people were settled in improvised emergency accommodation - tents, car trailers, and temporary wooden barracks (Orožen Adamič 1980). Residents, civil defence, fire brigades, and labour organizations from all over Slovenia carried out the repair work of damaged buildings in the old village centre during the summer, and the municipality started to prepare the plan for post-earthquake village reconstruction (Pipan 2011, 75) (© Source: The Surveying and Mapping Authority of the Republic of Slovenia).

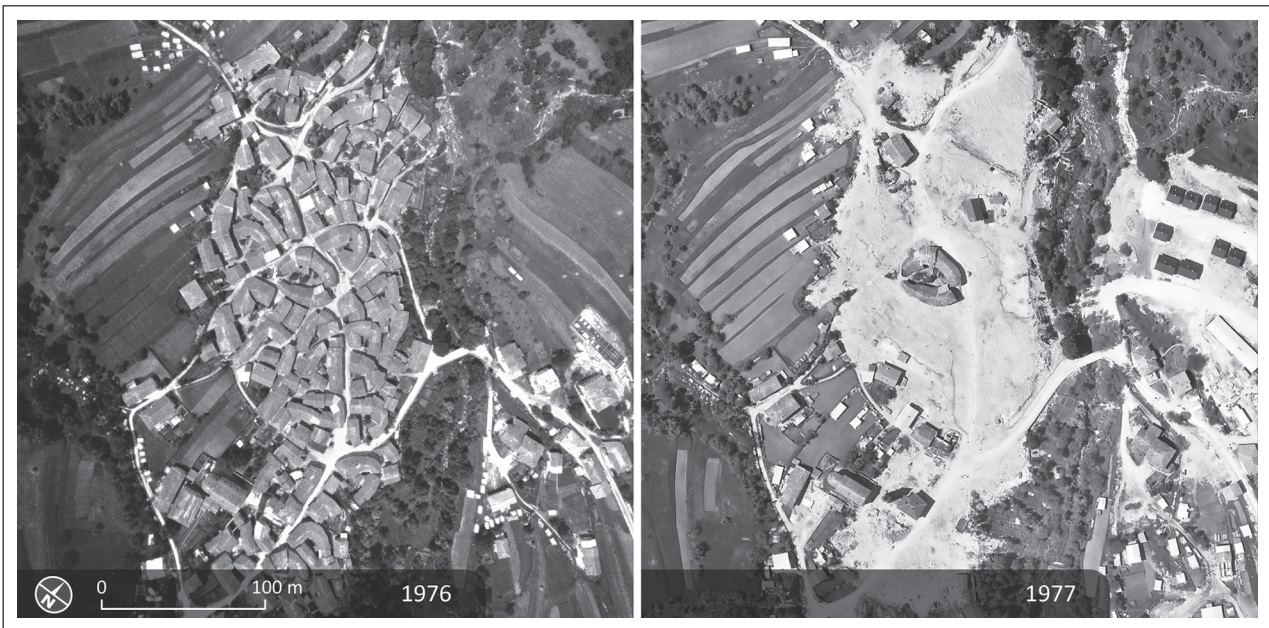


Figure 3. An aerial photograph of old Breginj immediately after the earthquake (left) and a few months later after post-earthquake measures (right) (© Source: The Surveying and Mapping Authority of the Republic of Slovenia).

is worth noting that the village was severely damaged but not completely destroyed. At that time a senior political delegation came to visit Breginj, and a revised plan was established, which proposed the construction of a new Breginj before the winter and the demolition of the old part of the village. The reasons for such a change in thinking and the rush to implement it are not clear, but old Breginj was demolished before the end of the year.

Old Breginj was not destroyed by earthquakes but by bulldozers (Figure 3), which effected the total removal of a rare and remarkable national cultural heritage monument. Before the end of 1976 the majority of the population from most affected settlements of the upper Posočje area were housed in new permanent dwellings (Pipan 2011).

Aerial photographs of the Breginj area

After the first earthquake a specifically targeted aerial-based recording of settlements in the affected region was undertaken. Since most of the villages were small, one pass was sufficient to cover an entire village, and so the aerial images only overlap in one direction. On the positive side they were acquired at low altitudes, and thus offer a great level of surface detail. These aerial photographs are the main source of data for the 3D model generation of old Breginj, for which scanned contact prints of six images were used.

A second set of aerial images was obtained from the spatial data archive of the Surveying and Mapping Authority of the Republic of Slovenia. A systematic aerial survey of Slovenia (CAS) has been undertaken approximately every three years since 1975, and this provides the means to inspect the state of the landscape over the last four decades. For this study images from 1975, 1998 and 2011 have been selected to examine major trends in the landscape (those from 1975 and 1998 are grayscale, while the latest one is RGB colour composite). The images are all vertical but vary in height of flight, camera used, scanning quality, spatial resolution, and time of day; thus they differ in the quality and clarity of details represented, length and direction of shadows, etc.

Such variability in the dataset does not allow the application of consistent automatic classification procedures. Since the interest of the study lay in the identification and tracking of particular geographical entities, like forests, settlements, pastures and fields, an object-based approach was the most appropriate choice to overcome these data issues (Hay and Castilla 2006; Veljanovski et al. 2011). Objects generated from the object based image analysis (OBIA) approach represent 'meaningful' entities or scene components that are distinguishable and reflect the geographical space recorded in an image. Objects derived in such a way support the creation of context-based landscape land cover/use inventory.

The following sections of this paper firstly describe the 3D settlement modelling through Structure-from-Motion (SfM) processing and then illustrate the object-based landscape change analysis. This is followed by analysis of the potential contribution of reconstructions of old settlements and past landscapes to the conservation of architectural and cultural heritage, and the insight they provide to historic landscape transformations. A final section deals with the image-based reconstruction and its potential for the retrospection of Breginj as a contribution to the presentation and preservation of a lasting remembrance of the settlement, which was the only complete example of remarkable Venetian-Slovene architectural heritage in the country.

SFM 3D MODELLING OF BREGINJ VILLAGE

The use of Structure-from-Motion (SfM) processing to model a settlement from six aerial photographs with an overlap of a 60 % in a single direction, in a rather complex environment (hilly region with diverse land use) is challenging. The strengths and limitations of this approach are discussed, including the method's inherent non-transparency and thus limited influence on the modelling, and the characteristics of the data.

Despite the fact that the aerial and terrestrial photographs were not necessarily systematically collected, the efforts to produce geometric three-dimensional models have proved successful using software that reconstructs geometry of objects from overlapping photographs. Automatic photogrammetry based on aerial or ground photographs has in the last decade become a powerful and widely used tool to produce three dimensional topographical models (Remondino and El-Hakim 2006; Matthews 2008), and has, together with computer-aided triangulation and algorithms of relief reconstruction from photographs, radically improved the quality of elevation models generated from overlapping stereo-pairs (Chandler 1999; Lane et al. 2000). Similarly, improvements and availability of non-metric digital cameras, with refined methods for calibration (Clarke and Fryer 1998; Chandler et al. 2005; Remondino and El-Hakim 2006) have increased availability of photogrammetric modelling and encouraged a wide range of applications.

In recent years, a true breakthrough was achieved with a Structure-from-Motion method (SfM). This is based on the same basic principles as stereoscopic photogrammetry, but is fundamentally different in that the

locations and orientations of camera positions and scene geometry are resolved automatically and simultaneously, without the need to first specify a network of targets with known three-dimensional coordinates. Instead, these are resolved simultaneously using a highly redundant, iterative bundle adjustment procedure, based on a database of features automatically extracted from a set of multiple overlapping images. Camera locations calculated by SfM do not have a real world scale and orientation. Therefore, the model produced has to be transformed into an absolute coordinate system with a small number of ground control points (GCPs) with known coordinates. GCPs can be obtained from highly visible locations in the point cloud and on the ground, for example with GPS measurements, or with positioning of high contrast targets in the scene before acquisition of photographs, which is more frequent in practice. This simplifies the registration of the images and provides a basis for an effective assessment of nonlinear structural errors in the reconstruction. The approach is best suited for sequences of photographs with a high proportion of overlap and a complete coverage of the three-dimensional structure of the scene from different angles and locations, or, as the name suggests, photographs taken by a moving sensor. A big advantage of the method is that it does not require any a priori information about the time and location of camera locations, nor about the detector or the instrument. Photographs can therefore be taken by an ordinary digital camera or older photographs without known information about the camera or acquisition parameters can be used. The method is particularly well suited as a low-cost alternative for high-resolution three-dimensional reconstruction of objects and terrain, especially in spatially remote and difficult to reach areas (Verhoeven 2011; Westoby et al. 2012).

Results of 3D settlement modelling

The 3D models of Breginj (Figure 4) were produced with Agisoft Photoscan (version 0.9.1). All the non-scene parts of the photographs were masked (i.e. edges, instruments, frame numbers) because they have a negative influence on the photo alignment process. The contact copies were scanned with a conventional A3 flatbed scanner at 1200 dpi.

Two models were produced: one from full resolution images and one with images with lowered resolution (resampled to 800 dpi). Processing settings were adapted to the type of the studied object (a village and its surroundings) and hardware capacity (a desktop computer with two Xeon E5620 processors, 32 GB of RAM, and GTX570 graphics card). Image alignment was computed with high accuracy at 50.000 potential tie points per image. Image geometry was selected as arbitrary and computed at high quality (the computer did not have enough RAM to compute with ultra-high quality). The final number of faces in the model was set to 10 million, filling the eventual holes. Ground control points were selected from orthophotos and a photogrammetric elevation model with a 5 m resolution.

The three-dimensional models produced differ in some respects, as illustrated by the height difference between the calculated elevation models in Figure 5B. This can partly be a result of poorly defined GCPs, especially in the reconstruction of terrain. We observe that the method does not provide stable and repeatable results, because it depends largely on the tie points identified in the first step, and a solution of their relationships which can be different in each iteration. Surprisingly, the buildings are better defined in the model calculated from the lower resolution images, for reasons that we currently have no answer for. There is no perceptible difference in the quality of the models where two or three photographs overlap.

Discussion on 3D settlement modelling

Based on the experience gained we can identify the following key advantages of the SfM technique:

- _ It is a simple and user-friendly method:
 - _ there is no need to calibrate the camera,
 - _ it does not require information about camera locations, and
 - _ unordered collections of photographs can be used.
- _ It is a semi-automatic method, which brings significant savings of time.
- _ Images without any known control points can be used. Thus historical photographs can be exploited.
- _ Software is free or relatively inexpensive (e.g., Bundler, VisualSFM, Photosynth, PhotoScan, MicMac).
- _ The method is very accurate because it is based on proven state-of-the-art photogrammetric principles and computer vision methods.
- _ True orthophotos can be produced from good quality aerial photographs captured for the task.

On the other hand, its main disadvantages are:

- _ The method requires extremely powerful hardware.
- _ Aligning the images can fail due to:
 - _ excessive level of noise on the images,
 - _ images that are too blurry,
 - _ images that are too oblique, or
 - _ images that are too different (e.g. very different focal length, different conditions or time of acquisition).
- _ Ground control points are required after modelling is complete (manual selection of control points). They are often difficult to obtain from historical photographs.
- _ Visual artefacts can occur because of over-triangulation.
- _ A lot of implemented methods are not sufficiently documented (a black box solution).
- _ The required overlap often demands a dedicated acquisition of photographs.

These weaknesses notwithstanding, the method is fast and gives excellent results (reconstruction of a 3D model) when conditions are optimal (e.g. adequate quantity and quality of the imagery acquired with a modern camera), and with minimal interaction from the analyst in the processing procedure. It is worth emphasizing that in case of Breginj a good 3D approximation of the village structure and its surroundings was obtained despite a very modest and therefore difficult data.

Generally speaking, 3D models are widely used for documentation, detailed analysis, reconstruction and virtual presentation of fragile and/or endangered objects. Existing objects can be laser scanned or precisely photographed and their (digital and virtual) models can be produced. This is already routine practice in museums and other cultural resource management institutions. However, there is a significantly greater limit in the reconstruction of large-scale objects, like settlements, which no longer survive. Namely, for digital retrospective of the state of the vanished place in the landscape (which can potentially lead to true 3D virtual reconstructions and augmented reality applications), we may only work with historic aerial photographs and old photos from the ground dating from approximately the same period.

OBJECT-BASED LANDSCAPE CHANGE ANALYSIS OF THE BREGINJ AREA

Remote sensing has developed various methods and technologies for cost-effective mapping of land cover/land use over large areas. The key factor for the availability and reliability of these maps for use in Earth sciences is development of effective procedures for satellite and aerial data analysis and classification. The main goal of the classification is to detect and classify the elements (geographical objects and phenomena) on the Earth's surface. A well-established approach for classifying low and medium resolution satellite images (pixel size is coarser than, or at best similar to, the size of geographical objects) is pixel-based classification in which an individual pixel is classified into the closest class based on its spectral similarity. With increasing spatial resolution the relationship between the pixel size and the dimension of the observed objects has changed significantly (Hay and Castilla 2006). Object-based image analysis (OBIA) was developed to address the classification of very high resolution satellite imagery (Blaschke and Strobl 2001). It aims to semantically analyse (i.e. imitate human perception) Earth observation imagery and facilitate high resolution digital image processing (Lang et al. 2006; Blaschke et al. 2008; Addink and Van Coillie 2010).

An OBIA approach consists (Figure 6) of various procedures for obtaining segments (i.e. delineation of homogeneous zones) and their characteristics or attributes (segmentation) for analysing these segments, sorting the segments into classes or objects based on their spectral, geometric, textural, temporal, and other attributes (classification), quality analysis techniques, and procedures for error removal (post-classification). The result is a geographical space classified according to its natural elements, land cover or land use. OBIA of imagery from different periods enables quantitative and contextual tracing of changes in the landscape, providing answers to what, where, and what extent changes occurred, detecting transformations or tracing the less abrupt transitions.

Object-based classification, a well-known procedure in high resolution satellite multi-spectral remote sensing, is under-exploited in aerial remote sensing, especially mono spectral (panchromatic – black and white) imagery. The procedure uses complex algorithms to derive a classification map, which makes it only possible for use within professional remote sensing toolkits. However, the result is easy to interpret and affords quantitative measurements (e.g. how much?) and semantic understanding (e.g. what has changed and

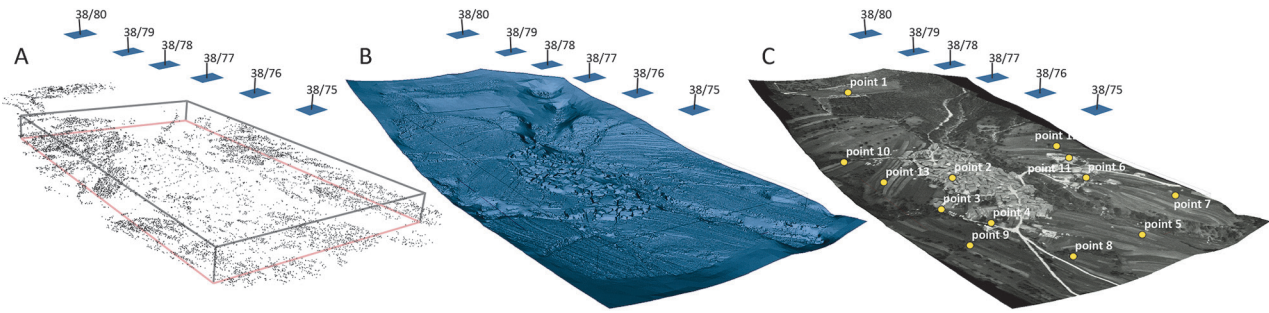


Figure 4. Reconstructed models from a series of vertical aerial photographs with Structure-from-Motion technique (SfM). Calculated acquisition point locations of six photographs are shown in blue. From left to right are a computed point cloud (A), a digital surface model (B), and a digital surface model draped with a texture and ground control points for geo-location (C).

where?). For landscape change study this approach was selected because it answers challenges of dealing with imagery of different spatial and spectral resolution. In addition we aimed to examine how it overcomes other differences in image properties (i.e. sharpness/blurriness, sun illumination – shadow directions etc., corresponding to aerial photographs taken at different dates, seasons, altitudes, and acquired with different cameras). One of the objectives was also to estimate the potential of OBIA to facilitate historic aerial photographs processing that can cover a temporal range of a hundred years, and thus introduce great variability in characteristics of aerial photography.

Results of landscape change analysis

The Breginj landscape study made use of Exelis ENVI Feature Extraction (version 5.2) and land cover maps were produced based on SVM classifier (SVM – Support Vector Machine) and semi-manual post

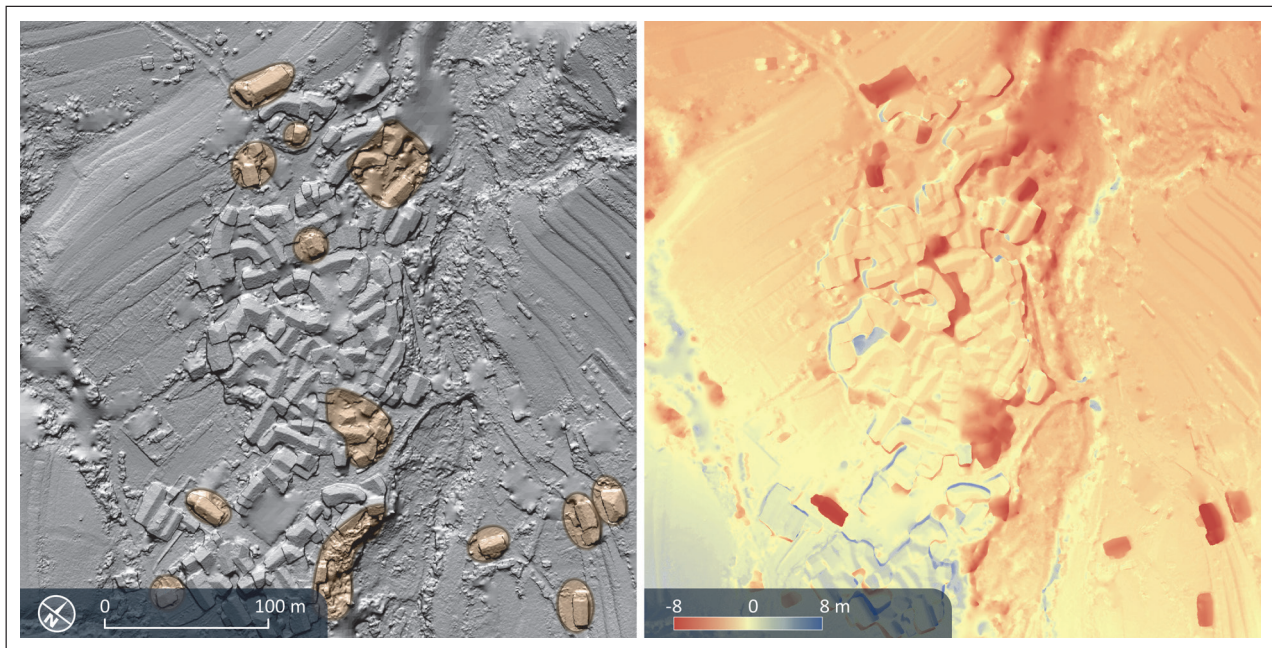


Figure 5. Shaded elevation model of Breginj calculated from images of reduced resolution (by 55%) (A), and an image of height differences between the full resolution and reduced resolution elevation models (B). The model from reduced resolution imagery better defines the buildings, therefore those missing in the second model are shown in red. There are also relatively large differences in the calculated shape of the terrain.

% coverage	1975	1998	2011
forest	73,1	79,2	87,8
roads	0,3	0,7	0,5
pastures	16,4	13,1	6,6
open soil	0,4	0,4	0,3
fields	7,1	5,9	4,1
buildings	0,5	0,6	0,5
masked	2,2	0,1	0,1

Table 1. Land cover (in percent coverage of area observed around Breginj village) over three consecutive periods derived from object-based classification maps.

in 2011. The area of agricultural fields and pastures approximately halved. The other main changes detected are associated with relocation and development of settlements and roads.

Aerial photographs allow highly detailed observation of even small scale objects in the landscape. On the other hand landscape classification aims to summarize the presence of objects of different types and sizes. As a result of “multi-class” land cover maps we can estimate areas or coverage and spatial distribution of selected land classes, while for counting individual objects (like houses), especially in densely clustered settlements, additional “mono-object” classification is needed. For example, to properly count the houses, we can only count identified roofs without distinguishing between residential households and supplemental buildings. Nevertheless, derived from both visual inspection and classification maps, we estimate that there were around 125 houses in old Breginj in 1976, after post-earthquake measures only 21 were left while around 80 new houses were built on a new location in 1977.

The changes identified in the landscape obviously reflect decisions taken and the scale of associated processes in Breginj after it was devastated by earthquakes. Notwithstanding the fact that the residents got new homes they could not adapt their traditional way of life, thus depopulation has been continuing and affected the population structure as well as their interaction with the nearby landscape in general and over decades.

Discussion on object-based approach applied to historic aerial photographs for landscape studies

A challenge in object-based analysis is to perform satisfactory segmentation – to achieve just the right number of spatial entities (objects) that differ in size and other characteristics – with a single procedure (Blaschke et al. 2008). In the segmentation process we use several homogeneity measures to divide an image into homogeneous segments. Generally speaking, segments prepared in this way do not represent real objects on the image, but are rather their parts. If optimal segmentation parameters are selected, it is expected that the image will be divided into semantically important segments, which can be recognized and classified in the steps to come. Yet segmentation processes face two common problems: one is over-segmentation, in which the tonality contrast between the neighbouring segments is too heavy, and the other is under-segmentation, in which the tonality contrast is insufficient and thus the segments are not dissimilar and not properly distinguished. We can to some extent control this process by adapting segmentation parameters, although if we want to keep delineation of small objects such as roads and houses, the segmentation of forest is simultaneously enhanced as well. The forest is thus typically over-segmented and has to be additionally treated in a post classification phase.

A particular problem in processing aerial photographs are the shadows of objects (from houses, trees) that can range significantly in length and direction from scene to scene. While shadows are well segmented out and separately classified, additional care must be taken in post-classification to contextually solve their membership.

We expected problems with segmentation due to different sharpness of photographs (related to acquisition and/or scanning quality). However, we did not observe many difficulties; despite the blurriness of 1975

classification. While the 1998 and 2011 aerial photographs were available orthorectified and georeferenced to the national coordinate system, the older 1975 had to be orthorectified (performed in ERDAS Imagine 2014) to assure positional consistency within the selected dataset.

Temporal evolution of five land cover classes that are typically represented in Breginj landscape was anticipated from the object-based classification. We have mapped states from the three periods where distribution of forests, fields, pastures, settlements and roads was analysed and compared (Figure 7). General trends of landscape evolution are confirmed (Table 1): forests have progressively expanded from 73 % observed land coverage in 1975, to 79 % in 1998 and reached 88 % coverage

and sharpness of the 2011 images, the method delineated the targeting objects (constituting land cover classes) well. Because OBIA was developed for multi-spectral imagery, we also expected worse results with greyscale photographs (1975, 1998) than with multispectral (2011). However the OBIA classification results for all three periods were similar in achieving delineation and recognition of anticipated land cover objects. This opens a way to encourage the application of an OBIA approach to historic aerial photographs with diverse image properties.

Dealing with evident errors (wrong classifications) and generalization of results is done in post-classification processing. Most errors can be identified and possibly eliminated by visual control, field inspection, and/or comparison with the reference source (if available). All of these procedures are predominantly manual and thus time consuming. In order to improve their visual quality and the content of the final result (the thematic map) the obtained object classes need to be generalised. If, for example, we do not wish to keep the small objects, we can eliminate them by merging them with the dominant neighbouring classes, based on their shape or size. In this regard there were noticeable differences among the three datasets. The 2011 colour image had the most errors in class assignments, which suggest that too many observable details are difficult to solve for automatic and complex classification procedures. Forest was difficult to post-classify because of over-segmentation on 1975 and 2011 imagery due to tree shadows, great diversity in forest texture (1975) and higher level of detail due to large scale and good quality (2011).

Despite the listed weaknesses, the OBIA approach is effective and gives excellent results even with less than optimal datasets (e.g. blurriness in aerial photographs). In the case of Breginj, we gained a comparable dataset of landscape changes over time, despite highly different characteristics of photographs, while using the same classification framework.

IMAGE BASED DIGITAL RECOVERY OF BREGINJ FOR THE PRESENTATION OF LOST CULTURAL HERITAGE

This section considers conditions that allow 3D settlement and/or landscape reconstruction and shows their potential role in heritage preservation.

Terrestrial photogrammetric measurements have been standard practice for precise documentation of architectural buildings and heritage sites for decades and offer great data for digital presentations. Because cultural heritage is frequently photographed it is thus well documented. Objects may have been destroyed or altered, and photographs often become the only evidence of its existence and modification. New photographs of Breginj, acquired for the purpose of digital reconstructions, can no longer be longer produced (Figure 3), but digital reconstructions based on historical imagery might still add to heritage preservation and enrich the cataloguing and museum collections programs.

Breginj completely changed its location, structure, and thus its settlement appearance. This, together with general depopulation of rural areas, gradually resulted in a change of daily life and use of the surrounding land. We are left with some historic aerial photographs and a remarkable documentation archive from old village revitalisation plans in the mid-1970s. Today, it is becoming possible to produce digital and virtual approximations of the former (old) settlement on the basis of these sources and modern technologies for spatial data treatment. The digital reconstruction of demolished Breginj that we have demonstrated in our case study is important in two respects:

- it helps involve historic retrospection and preservation of the memory of the village, which was an important monument of architectural heritage and
- it provides measurable evidence of the processes such as post-earthquake reconstruction and political decisions influencing the structure and function of the landscape and human life.

In the first case, efforts related to digital reconstructions can be a complement to the role of cultural heritage documentation and enrich tourist and museum offerings in Breginj today. Here a 3D to 4D digital representation with interactive (or augmented reality) component would be reasonable and welcomed. In the second case, the complex process of historical events can be observed and analysed through their footprints in the landscape (i.e. land use change) and so can better support the future plans for the development of the village and its hinterland. For the latter a 2D representation of several historical sequences may be sufficient.

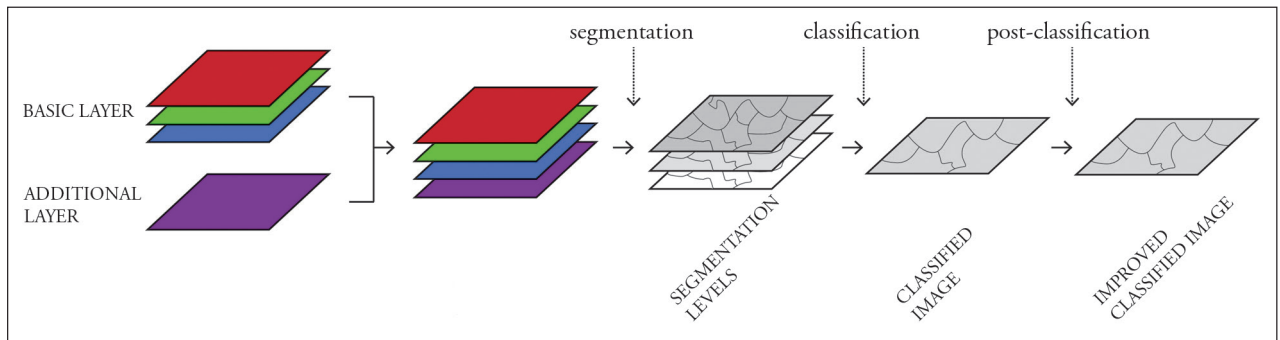


Figure 6. Processing steps in the object-based analysis of remote sensing data. Within the object-based image analysis we deal with two understandings of objects: a) objects on the image (i.e. segments that are already classified into objects, classes) and b) geographical objects (geographical entities, topographic objects). Geographical objects are real objects and phenomena on the Earth's surface; they are entities that belong to the geographical reality. Objects on the image are limited regions on the image that were created with the segmentation and classification processes; they have given spatial, spectral and textural characteristics. They are unified in the selected characteristics, and distinct from their neighbourhood. Objects on the image (alone or in groups) are – in various stages – simplified representations of geographical (topographical) objects and natural phenomena.

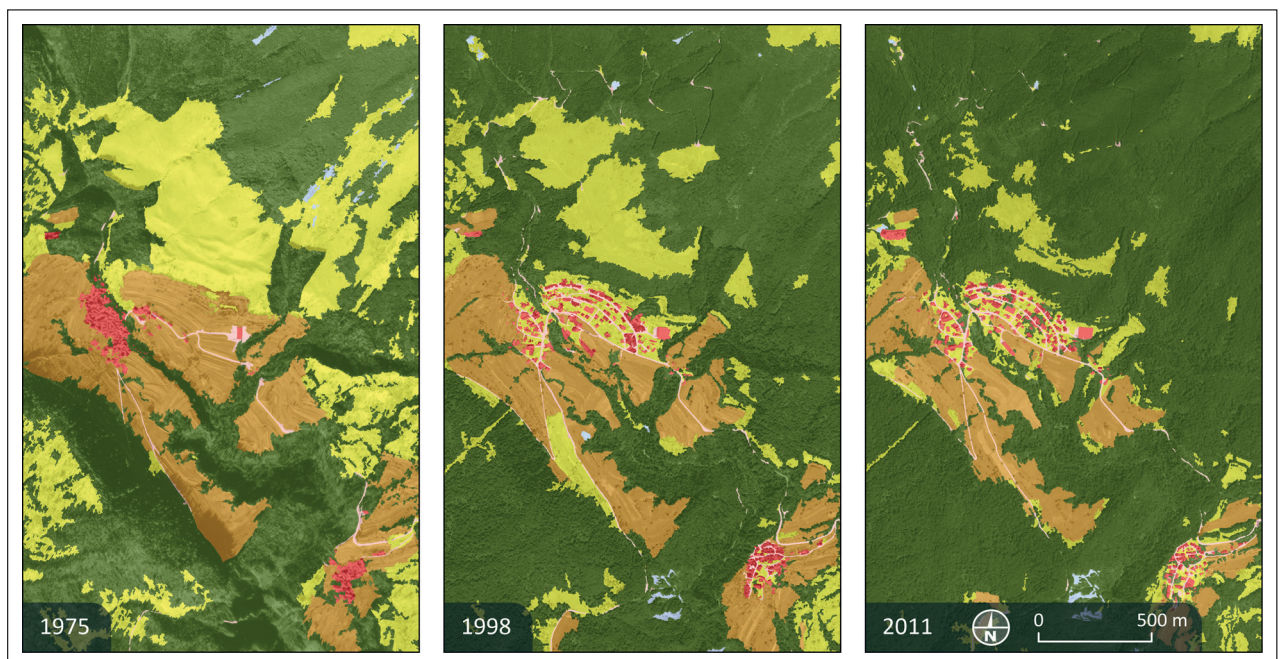


Figure 7. Landscape changes around Breginj from 1975 to 2011. The village itself was relocated and the buildings (in red) are now much more dispersed. Pastures, meadows (both yellow), and fields (ochre) are shrinking and giving way to forests (green).

From a 3D model to a true virtual model?

For making the digital reconstruction of the village, which no longer exists, we can proceed mainly from the archival image data. A three-dimensional model of old Breginj described in this study is a first approximation of a digital reconstruction of the village, which was generated from the available six aerial photographs. There are several issues to consider in working towards a true photo-realistic reconstruction and virtual (interactive) application. Improvements and upgrades are currently considered mainly in the following directions.

Firstly, obtaining a complete geometric 3D model that would be positionally accurate and semantically complete. To improve the completeness, positional and vertical accuracy of the buildings we need to apply

more aerial photographs from the period before the earthquake. These may be found in international archives of aerial photographs, as the Breginj area was a military frontier region from the First World War onwards. With the inclusion of high resolution aerial photographs from different flights we are likely to obtain enhanced conditions for 3D modelling. Integrating more cross-sections from different viewpoints thus provides improved semantic information, a better basis for reconstruction of geometry and an enhanced height component. This then also enhances positioning of boundaries of individual buildings (floor location, accuracy of surface and facade height) and differentiation of buildings from streets in a dense agglomeration.

Secondly, a step towards 3D photo-realistic representation of the village is the introduction of textures in the model building. This means collecting data for a side view of buildings from aerial (oblique and vertical) and terrestrial imagery, measurements, and plans. Terrestrial information can be obtained from the photo archives of the former monument documentation services, ethnographic museums, dedicated archives from the earthquake reconstruction activities, personal photo archives, random family photography, and the like. The prerequisite for this is a full and accurate geometric 3D model of the village. Currently an open question remains whether these data could be incorporated into the same model along with aerial photographs or separate models should be created and connected in post-processing.

The availability of virtual models in the cultural heritage field opens a wide spectrum of uses that can significantly improve and change our capacities to perceive, study, analyse and monitor heritage items, as well as possibly offering the basis for management of items, their conservation and restoration, decision making, and monitoring. 3D models are the starting point for the design of a highly complex and diverse possibilities of applications based on visual encoding and communication. Applications range from the passive, such as offering a pre-defined environment for still images, video and computer animations, to the more interactive and immersive ones, enabled by the environment of multimedia books, interactive navigation, virtual reality and augmented reality systems, and so on. At the moment there is limited availability of such 3D resources observed in practice and in the public (cultural heritage) domain (Cignoni and Scopigno 2008). The main reason limiting the development of advanced demonstrations is due to complex technological solutions and discrepancy with user-related applications and needs. In the case of Breginj this step would be highly appreciated but is only feasible with computer vision professionals joining the current team.

The three-dimensional model of the old Breginj described in this paper is only the beginning of the intended digital reconstruction of the village. Recovering a complete, detailed, accurate, and realistic 3D model from images is a demanding task, in particular for large and complex sites and with a less than ideal selection of images. Several encouraging examples to demonstrate the potential of such efforts are shown for the virtual reconstruction of submerged cities and other prominent archaeological sites. These examples are generated by modern data recording and processing technology. What they have in common is that remains or ruins of the site are present, which allows direct design of the structure of the former site, upon which arbitrary virtual space can be built on. Breginj is a different story. Not much remains and we know precisely what the appearance of the village was, which remains our binding guide in the 3D model creation. We are assembling new, additional imaging sources and will try to upgrade the existing 3D model of old Breginj where possible. The aim is to recall this once important place and folk architectural heritage monument at least in digital (and hopefully once also virtual) life and remembrance. However, realizing this vision requires addressing a number of related data-technology-research-use challenges.

THE POTENTIAL OF DIGITAL IMAGE-BASED RETROSPECTION OF SITES, SETTLEMENTS, AND LANDSCAPES

Many attempts at visualisation of 3D models of cultural heritage items and architectural objects have been made since the 1990s. Mostly items/objects were acquired with close range photogrammetry and displayed as wire-frame or static orthophotos. The use of computational methods for observation of historical phenomena relied heavily on the growing availability of digitised historical spatial data, as well as on advancement in computer processing and graphic capabilities, and development of smart data ingestion and processing software. Therefore complete geometric 3D models with textures are today a routine for photo-realistic representation of individual artefacts, architectural objects as well as cultural heritage sites (Remondino and El-Hakim 2006).

New information sources for digital reconstructions are provided nowadays through the facilities that multimedia can demonstrate. Multimedia support should assist in obtaining new knowledge and understanding the spatio-temporal development of places, objects, or items and can enhance education through its strongest component – visualisation and spatial interrelation of historic data. Digital historic reconstructions of sites or landscapes in 2D or 3D representation are just one of the possibilities to feed this domain and related historic retrospections. However an open issue remains if, and how, digital historical reconstructions can directly address expectations from archaeological, historical, geographical, tourist or urban/landscape planning disciplinary expectations.

Digital reconstructions of historic locations or places should be about active collaborative engagement in multidisciplinary environments (Remondino and El-Hakim 2006). With variability of providers and users of “digital historic environments” much can be gained from image-based reconstruction of sites, settlements, and landscapes and the efforts in creating them can be highly justified.

CONCLUSIONS

Breginj, a remote frontier mountain village, which was damaged by earthquakes and subsequently rebuilt on a different location in 1976, is an example of irreversible human destruction of a hundred houses belonging to an important cultural heritage monument. Modern image processing techniques open up new possibilities for the recovery of the memory of this remarkable place as it once was. With this contribution we aim to raise awareness and show the potential of historical photographs and digital image-based retrospection of places that may no longer exist, but have left important traces in human and landscape history.

The Structure-from-Motion method, where six aerial photographs with an overlap in one direction have been used, proved successful to produce a three-dimensional model of the settlement – a first approximation of a digital image-based reconstruction of old Breginj. Landscape change analysis covering almost four decades was possible with object based image analysis. We gained results of good quality and consistency, providing comparable results despite using imagery of very different characteristics.

In future work we would like to integrate aerial imagery with historical photographs taken from the ground to enhance the existing 3D settlement model. Improvements are expected in the semantic and geometric sophistication, and positional accuracy of the 3D model. In case of a successful upgrade of the model with texture, we expect to provide a photo-realistic 3D reconstruction of the old Breginj, which could enrich the content of museums and cultural monument preservation centres, their exhibitions and presentation activities.

An object-based image analysis approach applied on historic aerial photographs proved successful for land cover characterisation and change observation over decades. Despite exhibiting many differences in properties and quality of aerial photographs, the object-based approach is effective in overcoming these variations and should encourage even century long retrospective landscape studies based on remote sensing imagery.

Photographic collections together with modern imagery processing techniques support production of a variety of digital approximations of historical objects. Applying different approaches and strategies of digital reconstruction on available historical imagery sources supports the observation and retrospection at a variable temporal coverage (short to long-term) and spatial scale (objects, sites to landscapes).

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To trust or not to trust: maps vs. aerial photographs within political discourse

Abstract: *This paper presents an analysis of the first edition of Polish topographic maps for civilian use against contemporary vertical aerial photographs. These so-called mapy powiatowe or obrębówki were released in the 1950s and 1960s in the midst of the Cold War as a response to the growing economic needs of the country. However, their content was heavily influenced by military fear of letting slip any sensitive data to the enemy. Moreover, it is commonly believed that civilian maps were falsified on purpose in a random and unpredictable manner. Still, for a number of reasons they were used as a cartographic background for the Polish Archaeological Programme – a national project of recording archaeological features which was initiated in 1979. This raises the vital question of how accurate and reliable is the location of archaeological sites registered during fieldwalking survey and how to digitise those records for use in GIS. The answer may be provided by vertical photographs which, in contrast to maps, are regarded as an objective record that depicts landscape in an exact manner. Of crucial importance is the fact that the first regular vertical coverage of Poland for cartographic purposes was carried out in the 1960s. Thus it offers a landscape record contemporary to the publication of mapy powiatowe but without being burdened with human interference. It is hoped that this particular characteristic of vertical photographs will help answer the above questions of how trustworthy are mapy powiatowe and – consequently – the archaeological record based on it.*

INTRODUCTION: A HISTORICAL HICCUP

This paper deals with the intertwined relationships between historical maps and aerial photographs and their effect upon current archaeological practice. At the turn of the 1980s and 1990s a group of influential American geographers forming Critical Cartography, such as J. B. Harley, D. Wood and D. Cosgrove, were deconstructing maps as a power tool by linking geographical knowledge with power (Crampton, Krygier 2005). Within this school maps were regarded as a representation of space and as such related to power strategies and control. It is now commonly accepted that maps are subject to manipulation, distortion and concealing of information. They offer a selective, incomplete view of reality. It depends entirely upon map makers what information will be made available to users. Moreover, they may be subject to intentional deformation. M. Monmonier described a “deliberate, widespread cartographic “disinformation” (...) a distortion of the position and form of villages, coastlines, rivers, highways, railroads, buildings, boundaries, and other features shown on maps and atlases sold for public use” as a Cold War tactic of the USSR (Monmonier 1996, 115).

For nations ruled by totalitarian systems, links between (cartographical) knowledge and power/ politics may seem obvious or even trivial. For decades access to cartographic data under the communist regime in Poland was limited by various clauses of confidentiality and secrecy. The first edition of topographic maps at

1:25.000 for civilian use was published in the 1950s and 1960s. The content of these so-called *mapy powiatowe* or *obrębówki* was heavily influenced by ‘directives from Moscow’ and military attempts to guard sensitive information, such as projection parameters and grid system, from the enemy. Moreover, as a product of censorship, these maps were regarded with deep mistrust by professionals and society. There is a widespread opinion that distances, angles and heights were deliberately falsified in a random and unpredictable manner and as such those maps do not meet cartometric standards. Thus *mapy powiatowe* may be perceived as a result of the Cold War tactic as described by Monmonier.

Yet the question may be asked to what extent a totalitarian control makes those maps untrustworthy, unreliable and useless? This is of particular importance since Polish archaeology is still affected by decisions taken over sixty years ago. For a number of reasons those maps were used as a cartographic background for the Polish Archaeological Record Programme (Archeologiczne Zdjęcie Polski – AZP) which was initiated in the late 1970s. In the light of the above description one may instantly challenge the reliability of site locations recorded on falsified maps. In this paper we will analyse the contents of topographic maps used for the AZP to estimate the extent of potential distortion. Two random samples will be compared and examined in detail with contemporary aerial photographs and original military maps which were used as a background for the civilian edition. A methodology for effective geoprocessing of this data will be also offered. This will hopefully help estimate potential damage to the archaeological record and help us understand if problems experienced by archaeologists who were carrying out surveys were caused by distortions of the original map or whether other factors should be taken into consideration.

MAPS VS. VERTICAL PHOTOGRAPHS UNDER RIGOURS OF CENSORSHIP

After World War II one of the main drawbacks of Polish cartography was a lack of a uniform, large-scale topographic map. Thus in 1953 the Cabinet of the Polish Communist Government issued Resolution no. 16/S/53 „on developing a uniform national geodetic system and a basic map of the State”. Furthermore, § 2. declared the intention „to draw and publish a modern map at 1:25.000 scale by the end of 1957 for the economic and defensive needs of the State. At the same time it will serve as a basis to compile maps at smaller scales (1:50000, 1:100000, 1:200000 and 1:500000)”. However, under the communist regime maps were regarded sensitive and a decision to publish them was highly political, controlled by Moscow. In fact, the above-mentioned resolution resulted from a Soviet diktat which obliged Poland and other countries of the Eastern Bloc to publish basic topographic maps at 1:25.000 which would comply with the military doctrine of the USSR. This and other decisions were undertaken at the first conference of national geodetic services of the USSR and satellite states which was organised between 22nd June and 1st July 1952 in Sofia (Bulgaria). However, of crucial importance was the acceptance of a uniform grid system. As the solution “of the utmost scientific importance” for geodetic and cartographic work, the military grid system Pulkovo 1942 was approved (Sobczyński 2000, 229–230).

However, this decision strongly affected civilian cartographic services, public access to maps and subsequent editions of topographic maps. In order to protect the parameters of the grid system, a resolution of the Council of Ministers, issued on 9th July 1952 “on classifying topographic maps” stated that all topographic and other maps (including historical, pre-war publications) up to 1:500.000 were classified. Consequently, from 1957 the Topographic Unit of the Polish Army started to publish a “modified” version of the topographic map at 1:25.000 in “local systems” to meet economic needs of the country (Sobczyński 2000, 237). These maps were stripped of any sensitive information such as projection, grid system and grid lines. The only information provided at a map frame referred to a location of a given map sheet within an administrative unit (powiat) of the second level of local government administration in Poland (Figure 1).

Moreover, there is a widespread opinion among cartographers and other users that these maps were falsified on purpose. A particularly strong criticism was expressed by one of the key figures in Polish cartography, Prof. W. Grygorenko who for several years worked in the Military Cartographic Works and later was the head of the Department of Cartography at the University of Warsaw (Paślawski 2008, 321). According to Grygorenko, map making was accomplished by the most primitive deformation of the drawing of the basic map at 1:25.000. Namely:

- a) individual map sheets were cut into irregular pieces of between 10 and 30 cm²;
- b) at the next stage, cut pieces were assembled into map sheets which covered the area of powiat;

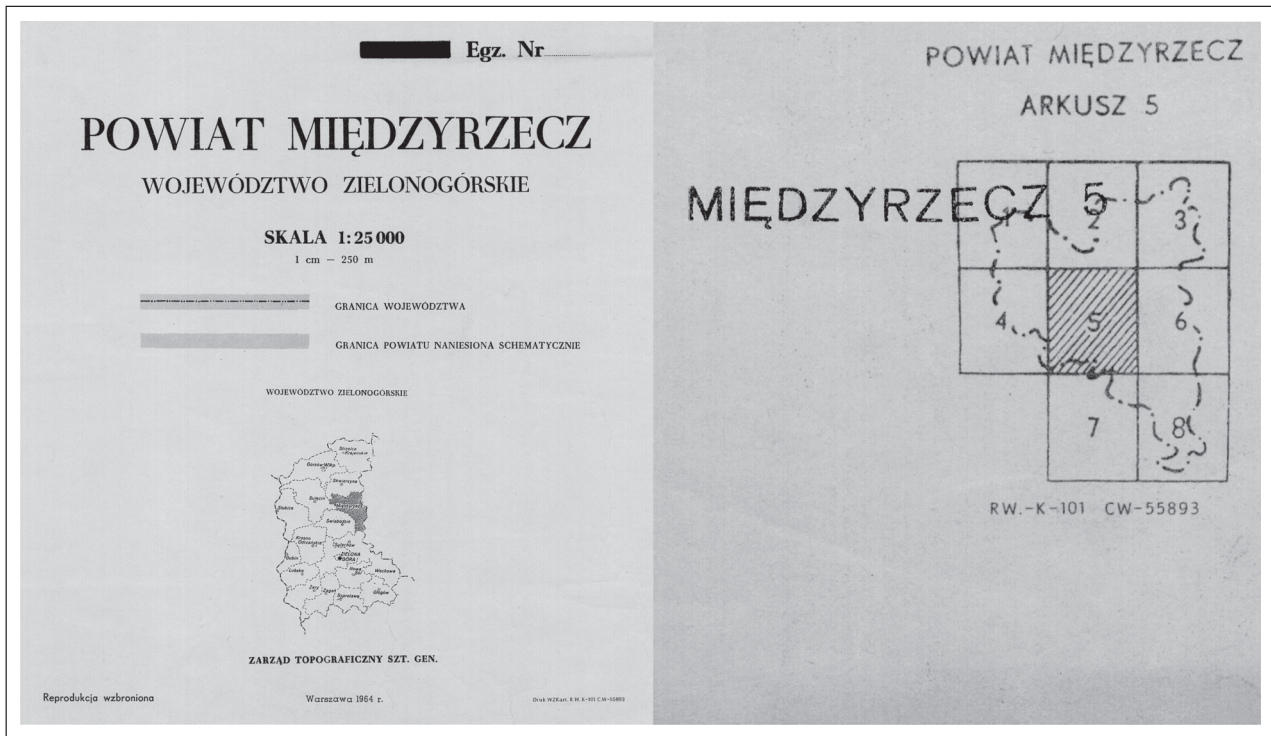


Figure 1. Extract of a *mapa powiatowa* frame showing an administrative location of a *powiat* (left) and a location of an individual map sheet within it (right). This was the only reference information provided for those maps.

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- c) at the assembly stage, pieces of maps were supposed to be drawn aside and twisted towards each other;
- d) also, tucks could have been made which were cut out and removed;
- e) gaps were completed by fictitious drawings, thus a continuous, seemingly real content of a topographic map was created;
- f) in fact, distances and angles between all elements of these maps were falsified;
- g) moreover, it is impossible to determine principles of falsification.

“In this way *mapa obrębowa powiatów* was made. However, it does not make any sense to call it a map and the information about its scale as 1:25.000 was an evident sham. Thus, it is not surprising that this map did not win recognition among users, as being of no practical use” (Grygorenko 1991, 3, S. K. and L. Ž. emphasis).

For aerial photographs, it is much easier to estimate the extent of interference by censors. Unlike maps, vertical photographs are regarded neutral at a stage of image acquisition/ production (Rączkowski 2001, 141–142). They are usually taken in order to photo-document a certain area. Aircraft taking them fly at a specified height to an agreed flight-plan with cameras automatically taking photographs every few seconds. There is no interference by a ‘human factor’ and the final record is subject only to optical distortions due to camera properties or caused by other mechanical factors. If standard photogrammetric processing is applied then users obtain a representation of the landscape as it was at the moment of image capture. Since the 1950s we can observe a growing interest in application of vertical coverage for photogrammetry (e.g. Piasecki 1958). The same resolution 16/S/53 stated that vertical coverage of 108.000 km² (approximately 1/3 of the country) would be taken by the Ministry of Defence and the Head Office of Geodesy and Cartography to support map production at 1:25.000 (Sobczyński 2014). From the 1960s a regular vertical coverage for Poland was carried out every decade, providing a rich record of landscape changes. However, access to aerial photographs was strictly controlled. As early as 1948 when vertical survey was still carried out at a limited scale, a resolution of the Council of Ministers on rights to take aerial photographs for photogrammetric purposes assigned those rights exclusively to the Ministry of Defence. According to Sobczyński, for the next



Figure 2. *Censorship interference on aerial photographs was accomplished by an unsophisticated masking of 'sensitive' areas.*

© CODGiK.

Figure 3. *Location of study areas. Illustration by L. Żuk.*

few decades this regulation posed severe limitations on uses of aerial photographs by civilian geodetic services and also scientific community.

Interestingly enough, a restricted access policy towards aerial photographs made other censorship precautions unnecessary. In an anecdotal account of falsification of aerial photographs for public viewing in the United Kingdom, Monmonier claimed that "Britain's national civilian mapping agency, the Ordnance Survey, apparently maintains lists of sensitive sites that must be (...) somehow camouflaged on aerial photographs" (Monmonier 1996, 120). This in practice may imply a very precise disguise of 'sensitive' objects by mosaicing selected areas with seemingly authentic fragments of photographs and taking into account scale, potential optical distortions, differences in tone, structure and texture. Apparently this method was too tiresome for Polish censors. If sensitive areas were to be provided to other users, information was concealed by most primitive masking and printing photographs with 'large, telltale blank areas' (Figure 2). Thus, contrary to maps, where it may be impossible to estimate the extent of censor interference without an external reference point, in the case of aerial photographs it can be safely assumed that they depict the landscape in an exact manner.

CASE STUDY: MIĘDZYRZECZ FORTIFIED FRONT AND MOSINA REGION

Two case studies located in western Poland, were selected to check the reliability of *mapy powiatowe* (Figure 3).

The Międzyrzecz Fortified Front (Międzyrzecki Region Umocniony – MRU) is a unique monument to the 20th-century art of fortification. This extensive complex of military structures comprises vast installations such as anti-tank barriers, bunkers and defensive elements over an area of nearly 80 km (50 miles). Built in the 1930s and during World War II to protect the eastern frontier of the Third Reich, it in fact never played an essential role in the war. It was captured by the Soviet Army in February 1945 after a brief battle. For the next five years underground installations were maintained by Russians who left the area towards the end of the 1940s stripping it of technical equipment. In 1953, after the Korean War, the underground system was taken into control by the Polish army and the entire system was prepared as a storage and an antinuclear bunker. In 1956 preparations were initiated to displace inhabitants of Wysoka and surrounding villages but these plans were scrapped a year later and the army abandoned the underground system. The final military

note occurred nearly 30 years later. In 1984 the underground chambers were considered as a potential storage place for radioactive waste. However, three years later these plans were also abandoned following strong protests of local inhabitants, enthusiasts of military constructions, experts in military history and ecologists (Miniewicz, Perzyk 1993, 78–82). For a test case, it was assumed that since there has been a strong military presence in the area, it was highly sensitive and, as such, paid special attention by the army. Thus it would provide a good insight into the extent of manipulation which was supposedly made to civilian editions of topographic maps.

The second case study is located 20 km south of Poznań. It was a typical rural landscape which from a military perspective did not have any particular significance. Some remains of World War II military trenches were still visible as earthworks on aerial photographs dated to 1961 but, being of no importance, they were ploughed out and today are recorded only as cropmarks. However, due to its close proximity to Poznań, this area is currently undergoing a rapid socioeconomic development, characterised by numerous industrial, commercial, infrastructural and housing investments. This poses a serious threat to the archaeological heritage and for that reason it has become a subject of intensive surveys carried out by the Institute of Prehistory since 2009. In 2012, a two-year project ‘Non-invasive support of AZP in the vicinity of Poznań’ was launched. Among its major tasks is digitisation of archaeological data which were recorded during the AZP project in the 1980s and also interpretation of archival aerial photographs to estimate landscape changes in the study area. The rich archival record and an opportunity to ‘verify’ existing archaeological records provided a unique opportunity to test a methodology for geoprocessing historical cartographical data.

To obtain reliable results it was crucial to have a set of independent data. Thus maps and vertical photographs were processed separately.

Vertical photographs

These were purchased from the Central Office of Geodesy and Cartographic Documentation (CODGiK) which stores vertical coverage taken by civilian cartographic services. Both sets were taken following cartographic standards (60% overlap making stereo pairs) in the early 1960s. The date of image acquisition was of crucial importance because only photographs contemporary to *mapy powiatowe* could provide a reliable reference point to characterize landscape features and estimate deformations of *mapy powiatowe*. Photographs had a contact scale of 1:10.000 and their generally high quality in terms of contrast, resolution and sharpness provided a more-than-adequate comparison with maps at 1:25.000 scale.

However, vertical coverage was purchased for two different projects and thus does not make a uniform collection. This considerably affected the choice of processing method. For the Międzyrzecz Fortified Front only every second image in a run was available. A lack of stereoscopic coverage resulted in basic geoprocessing. Each individual photograph was georeferenced in QuantumGIS against a background of a modern orthophotomap at 1:10.000, which was obtained from Geoportal (<http://geoportal.gov.pl/>) via WMS (Web Map Service). The Polish grid system PUWG-1992 was used. Up to 17 control points were identified but attempts to distribute them evenly were sometimes hampered by dense woodland coverage and also dramatic changes in landscape which have occurred in the last four decades. Nevertheless, the study area was rather flat and the mean mismatch of control points was no more than 6 m. Root mean square error (RMSE) for the affine model of geometrical transformation between image and projection planes was approximately 3,5 m. Given that spatial resolution for digital scans of maps at 1:25.000 was approximately 1,5 m per pixel, the mean accuracy of the air photo georeferencing was slightly more than two map pixels. Such accuracy is comparable with the theoretical graphical accuracy of 0,4 mm at a map scale (i.e. the narrowest feature that can be drawn on a map). This corresponds to 6.2 pixel for 400 dpi scanning resolution and 10 m in reality.

For the Mosina region stereoscopic coverage with approximately 66% overlap permitted photogrammetric processing of images in AgiSoft PhotoScan Pro software (Verhoeven 2011). This allowed us to obtain more accurate results in comparison with standard models of geometric transformation (e.g. affine, polynomial). To identify an external image orientation, information on the focal length was obtained from an image frame and also input ground control points (3–4 for each image) were identified. Since PhotoScan does not offer an automatic procedure of fiducial mark localization, images were cropped, rotated and resampled before photogrammetric processing so that the fiducial marks corresponded with image corners. XYZ coordinates for input set of points were obtained from a Geoportal orthophotomap with accuracy up to 1 m.

Photogrammetric processing resulted in the production of an accurate digital surface model (DSM), orthorectification of aerial photographs and subsequent mosaicing into an orthophotomap which also supported data interpretation. Accuracy of orthorectification was established on the basis of a control set of points which was independent from the input set of points. Coordinates of every control point were compared with those obtained from the geoportol orthophotomap. RMSE for affine model of geometrical transformation between images planes was approximately 2,5 m (0,4 mm for images at 1:10.000 which corresponds to 12 pixels for scans at 1200dpi).

Despite using two different methods to geoprocess vertical photographs and taking into consideration qualities of input data and a map scale, achieved accuracy seemed more than required for the aims of this work at between 1 and 6 m for images at 1:10.000.

Military maps

A thorough archival research of mapping resources of the Faculty of Geography permitted us to locate nearly 300 military map sheets at 1:25.000 from different parts of Poland and covering nearly 15% of its surface. As mentioned above, these maps were used as a basis for the civilian edition and proved to be an invaluable reference point. We assumed that falsification of military maps which were produced for the needs of the Polish Army would be pointless. Thus those maps would be indicative of the quality of cartographic works of that period. Currently this collection is being methodically scanned and indexed but since it is a work in progress it proved difficult to identify all required map sheets and only those for the Międzyrzecz Fortified Front were used. Four military map sheets were selected and georeferenced in the TNTmips software using the original military grid system Pulkovo 1942, 6-degree zone, Gauss-Kruger projection, and Krassovsky ellipsoid.

Data / Area	Międzyrzecz Fortified Front	Mosina region
1. vertical coverage:	single coverage	stereoscopic coverage
a) year	1963	1961
b) area	37,5 km ²	39,5 km ²
c) scale	1:10000	1:10000
d) software	QuantumGIS	AgiSoft Photoscan
e) RMSE	6 m	1 m
2. military maps:	4 map sheets	-
a) area	314 km ²	-
b) software	TNTmips	-
c) georeferencing	military grid Pulkovo 1942, zone 3	-
3. mapy powiatowe:	1 sheet of <i>powiat Międzyrzecz</i>	4 sheets of <i>powiat Poznań</i>
a) area	339 km ²	1275 km ²
b) background	military maps	2nd edition of civilian topographic maps at 1:10000.
c) georeferencing	military grid Pulkovo 1942, zone 3	Polish grid PUWG-1992
d) RMSE	12,5 m (0,5 mm at a map scale)	25 m (1 mm at a map scale)

Table 1. A summary of cartographic resources and processing methods for the Międzyrzecz Fortified Front and the Mosina region.

Mapy powiatowe

The *Mapa powiatowa* which covered the Międzyrzecz Fortified Front was georeferenced against a background of military maps. An affine transformation was used to calculate geometric deformations between two sets of maps. To compare maps and vertical photographs which were georeferenced in two different grid systems, a transformation library Proj4.dll was used (this code is implemented in most GIS software packages including QGIS, TNTmips, and Photoscan which were used within this work).

For the Mosina region *mapa powiatowa* was regarded as a surface of an unknown projection and georeferenced against a background of a topographic map at 1:10.000 which was obtained from Geoportal via WMS service. The Polish grid system PUWG-1992 was used. For the area of 1275 km², 129 control points were identified. Affine transformation was also used. The RMSE oscillated around 25 m (1 mm at 1:25.000) with 65 m of a maximum mismatch (approx. 2,5 mm at 1:25.000) (Figure 4).

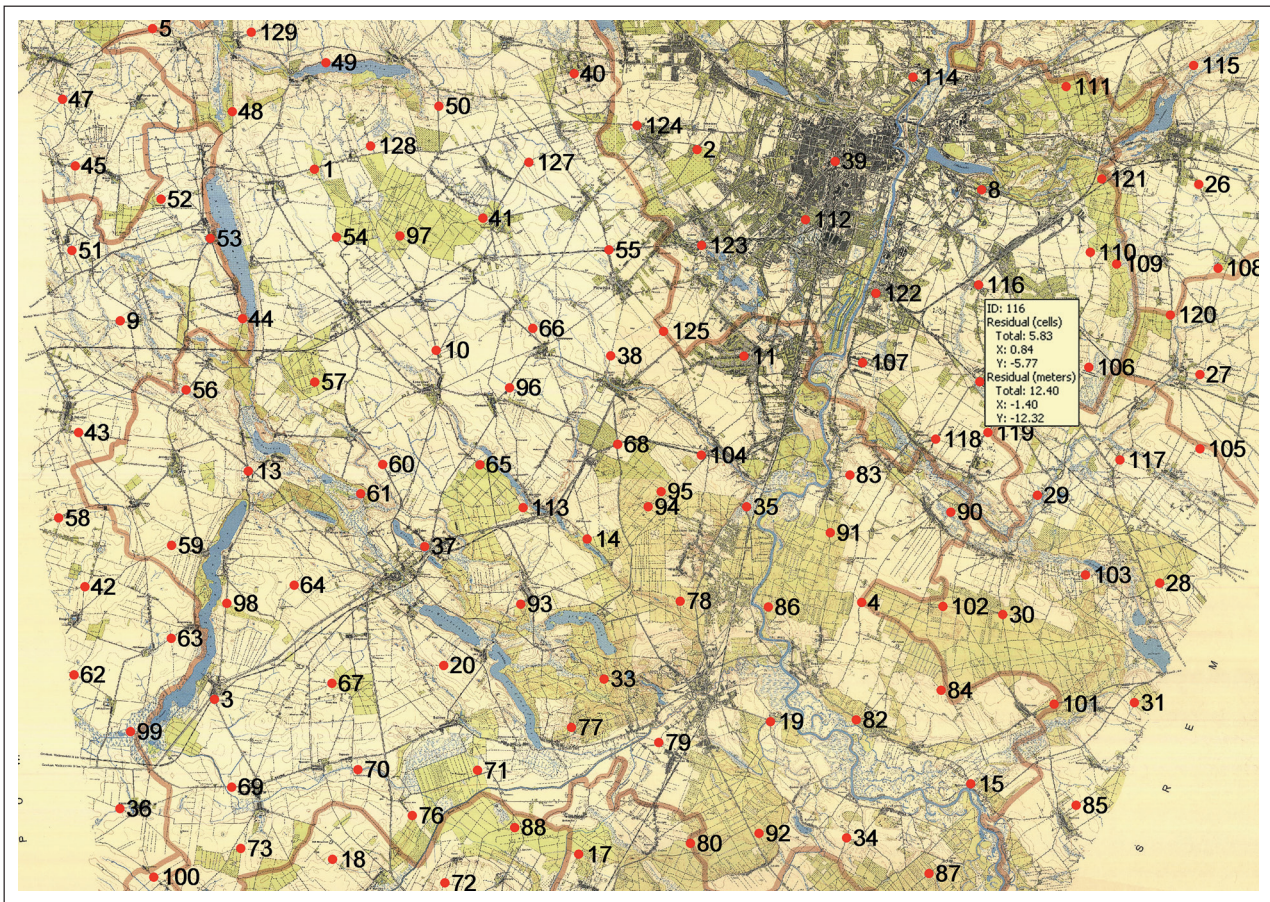


Figure 4. Part of *mapa powiatowa* georeferenced against a topographic map at 1:10.000. It shows the density of control points and RMSE of a random point. Illustration by S. Królewicz.

RESULTS

A systematic analysis was carried out for three basic map layers.

Man-made features (black layer)

Three different categories of roads were depicted on both sets of maps near the village of Wojciechówek in the Międzyrzecz Fortified Front. While main roads and lanes show accurate matching, some discrepancies (slightly different angles) may be noted for a gravel road. However, this error is noticeable on both sets of maps and may be caused either by map generalisation, mapping inaccuracies or somehow unstable characteristic of minor tracks running across fields (Figure 5). A modern railroad also showed an excellent matching on military and civilian maps.

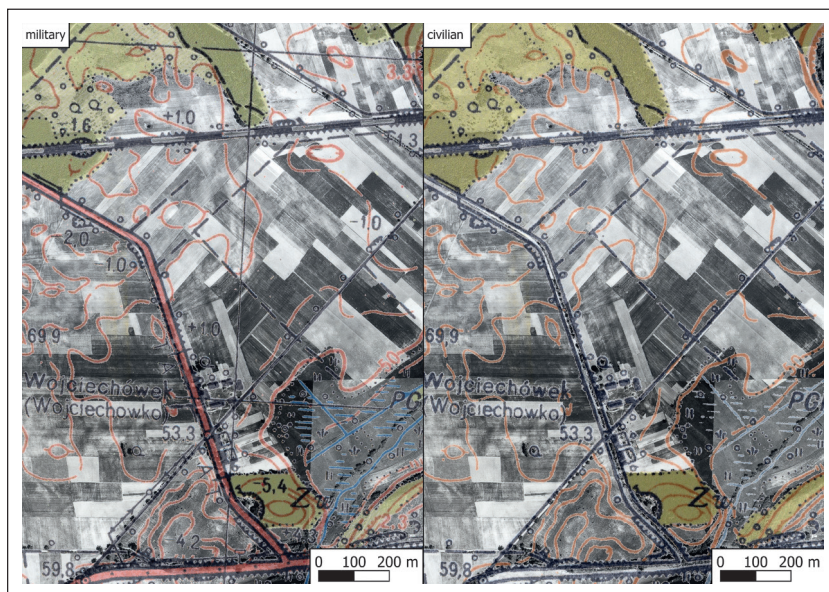


Figure 5. A comparison of roads on military and civilian editions. © CODGiK, Topographic Unit, General Staff of the Polish Army.

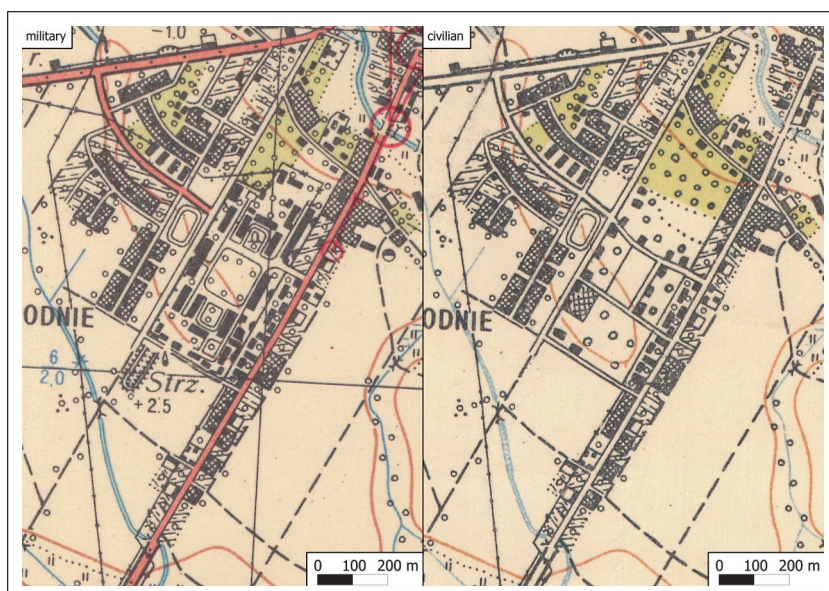


Figure 6. A garrison in Międzyrzecz with a shooting range (Strz.) to the south was masked as low-density housing and an arable field for public display. © Topographic Unit, General Staff of the Polish Army.

A separate category of features on the black layer were those related to a military activity in the Międzyrzecz Fortified Front. Two major categories of features were identified: remains of the World War II constructions and those connected with the Polish Army. Of particular interest is a depiction of a garrison in Międzyrzecz (Figure 6). On the military map it is presented in detail, accompanied by a shooting range in an adjacent field. As one would expect, this information was removed from the civilian edition and the internal zone of the garrison was completed with a fictitious drawing. However, no further distortions of angles and distances was noted for surrounding areas. An internal zone of the garrison is shown as a row of buildings while the shooting range was masked as an arable land but shapes, location and proportions are depicted accurately.

This observation was confirmed elsewhere. An extensive network of railroads leading to various structures of the German military system were identified 7,5 km southwest of Międzyrzecz (Figure 7). While the military map depicts those railroads accurately, the civilian edition does not show them at all. However, other elements such as lanes do fit accurately. There may be also noted some inconsistency in classifying of military features. Some elements such as trenches were apparently regarded of minor importance and were depicted on both sets of maps although the civilian edition shows only fragmentary evidence (see Figure 9). On the other hand, the same class of features was not mapped in the Mosina region despite the fact that those trenches still existed as earthworks in 1961.

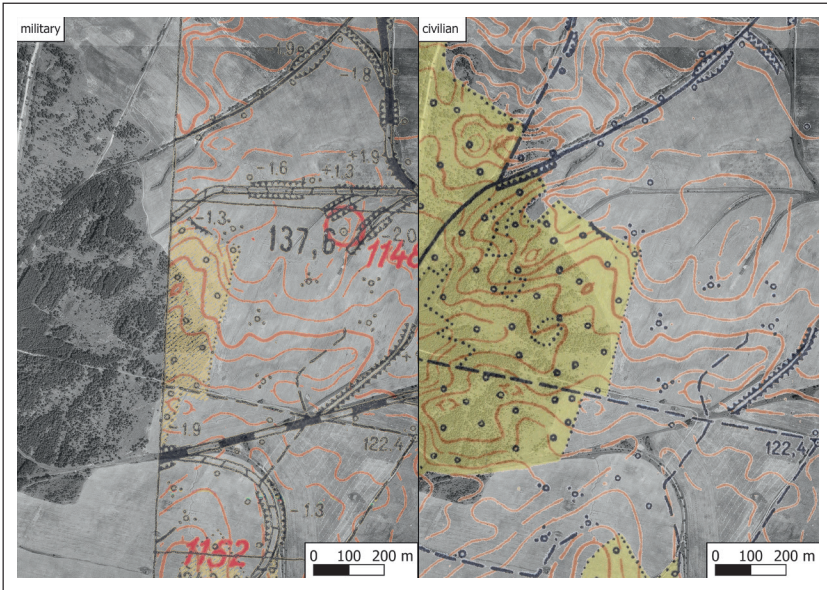


Figure 7. A network of railroads leading to various elements of the Międzyrzecz Fortified Front were removed from the civilian edition. ©CODGiK, Topographic Unit, General Staff of the Polish Army.

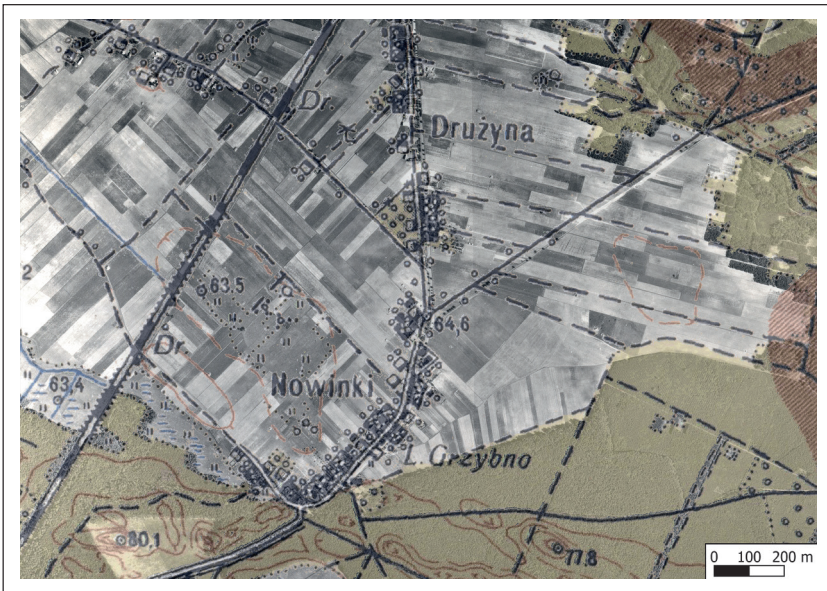


Figure 8. Villages of Drużyna and Nowinki in the Mosina region shown against a background of the orthophotomap. Houses, roads and the railroad match accurately while gravel roads again show some discrepancies. © CODGiK, Topographic Unit, General Staff of the Polish Army.

No interference in map quality was noted for settlements and civilian maps show accurate matching between various elements of villages (Figure 8).

It is also interesting to note that the same map convention was used on both sets of maps. The village of Kęszycza has a typical medieval oval layout depicted with its surrounding fields. While the location of a village green is rather accurate, field plots were depicted following a stylised map drawing convention rather than exact field measurements (Figure 9).

Water (blue layer)

Map accuracy in depiction of water can differ quite noticeably but errors do not show any regularity. For example, one of the largest lakes in this area, Kursko, makes a very good match with the military map but the civilian version showed a shift of around 30 m. Another lake shows an obvious discrepancy in location on both military and mapa powiatowa (Figure 10). This shift is around 60 m to the southeast and also a small ditch running to the lake is shifted around 35 m. Also minor ditches were not depicted on either map.

Also, the course of the Obra River was depicted with some inaccuracies on both editions of maps although the military map seems to be more precise. Nevertheless, it is still within the acceptable error limit of a map at 1:25.000 (Figure 11).

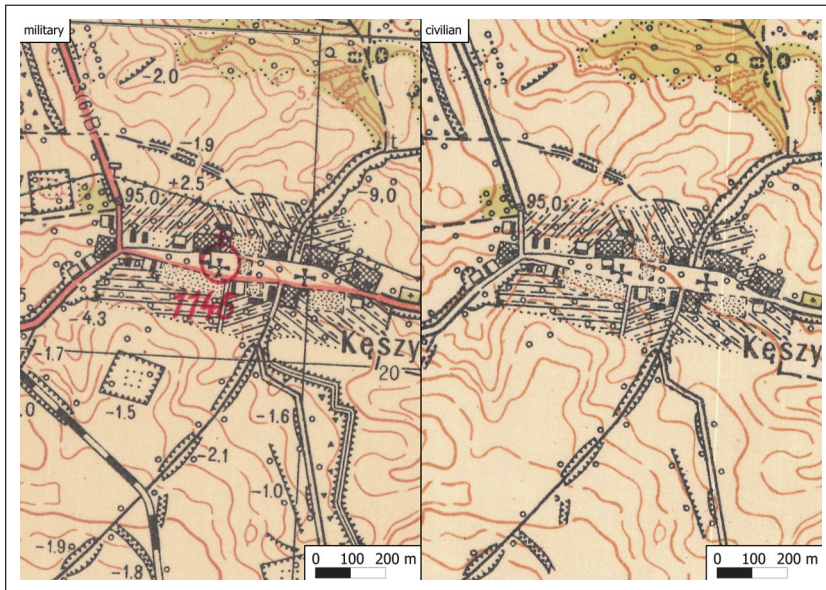


Figure 9. The medieval layout of the Kęszyca village. Adjacent field plots are depicted in the same stylised manner on both sets of maps. Military trenches were shown in the northwest corner of the civilian edition but removed along the road south of the village. © Topographic Unit, General Staff of the Polish Army.

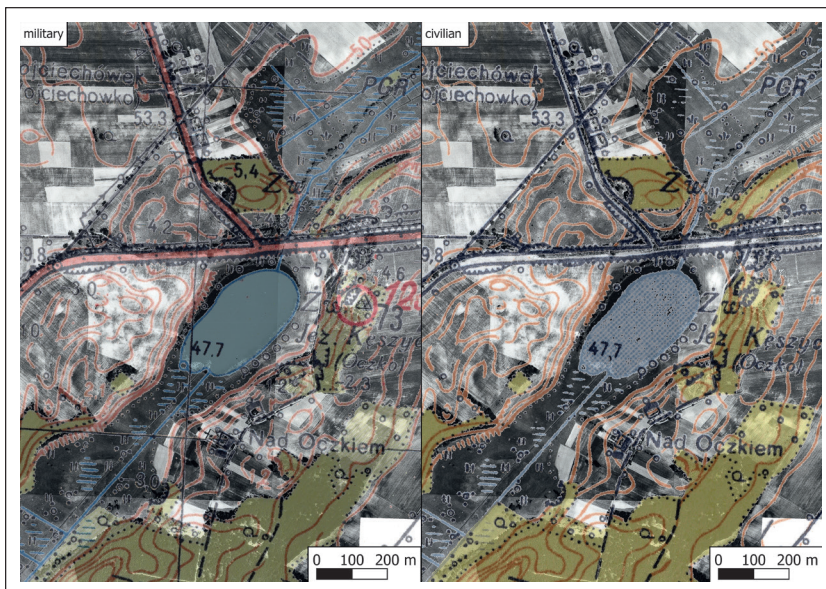


Figure 10. A discrepancy in the Kęszyckie lake location between a map and vertical photo was noted for both military and civilian maps. © CODGiK, Topographic Unit, General Staff of the Polish Army.

Contours (brown layer)

Similar observations were made for contours. Merging two sets of maps showed that contours on the civilian edition follow the pattern of the military maps. But there are also shifts in location which do not show any regularity. Within the same areas matches could be partially precise and partially showing some noticeable shifts. What is more confusing is that those shifts could occur in any direction (Figure 12).

DISCUSSION

Within scientific discourse *mapy powiatowe* have been marginalised. Publications are scarce and rather uncritically repeat the dominant opinion about their low quality (e.g. Jaskanis 1996, 15; Nieścioruk 2013, 40). Any attempts to defend them were focused on the fact that this was a leap towards declassifying of cartographic resources rather than their practical mapping utility. Very telling in this regard is an opinion expressed by Sobczyński „Although these maps were deformed, stripped of some features, projection, cartographic and geographic grid lines, they still had a clause “confidential”. Nevertheless, the publication of *obrębówki* was a serious step towards declassifying topographic maps because they could be passed to civilian services with no further restrictions” (Sobczyński 2014). One may consider then which elements of this critique were confirmed in the above analysis.

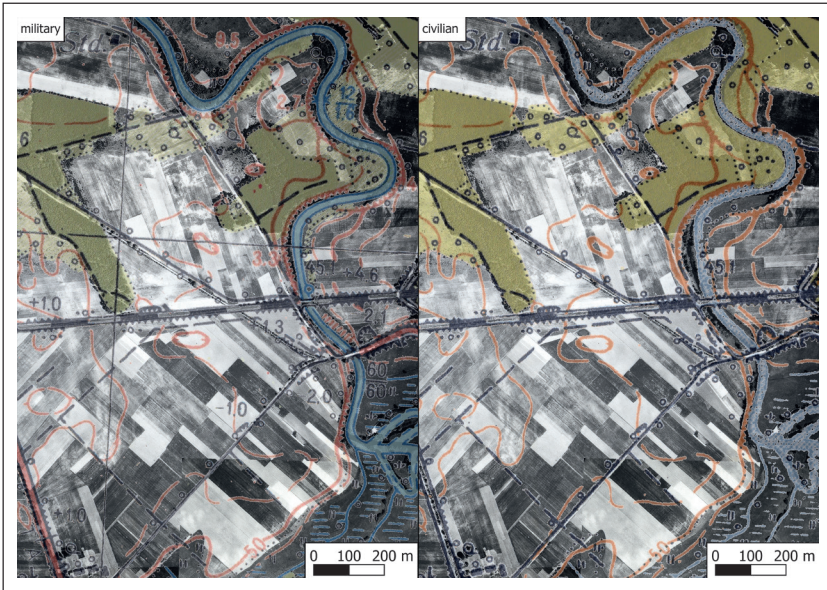


Figure 11. *The Obra River was depicted more accurately on a military map but it follows the same course and meanders show the same pattern on the civilian edition.*
 ©CODGiK, Topographic Unit, General Staff of the Polish Army.

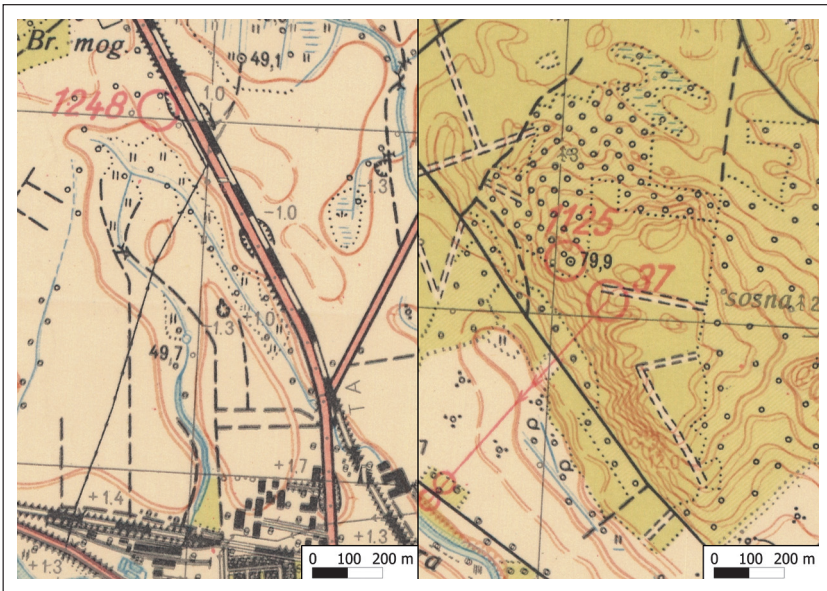


Figure 12. *Merging two sets of maps showed that contours follow the same pattern but there are some noticeable and unpredictable shifts in location.*
 ©Topographic Unit, General Staff of the Polish Army.

Map deformation

The main objections raised against *mapy powiatowe* focussed on their falsified depiction of distances, angles and heights. This was supposed to make them useless for any purpose and put them aside with a ‘historical curiosity’ label. The above analysis shows that there were indeed some differences in the precision of feature locations but there is no obvious pattern behind it. However, no discrepancies of the types suggested by Grygorenko were apparent in the test sample. Geometric dislocation of elements in the black layer (roads, railroads, villages etc.) are rare or even incidental. More evident inaccuracies were noted for contours (brown layer) and hydrographic elements such as lakes, canals and rivers (blue layer). To add to the confusion, a phenomena of matching roads and dislocated rivers/ contours may be observed for features located in close proximity (see Figure 11). If pieces of maps were drawn aside and twisted towards each other, errors would be constant for all three layers and this has not been observed. Moreover, from a military point of view it would seem pointless to shift a tiny rise in ground 50 m away or dislocate a lake by 60 m. It may be also worth noting that current technologies, which allow precise measurements and editing of spatial information, may make those errors look large (approximately 50–60 m) but in fact it is no more that 2–3 mm at a map scale.

Noted discrepancies provoked a number of questions regarding the map making process (drawing, printing) of that period. The nature of those errors may indicate printing failures when each layer was prepared

separately and at a later stage combined into a single map sheet. Errors of co-registration could produce artefacts which were noted for blue and brown layers. Some evidence to support this hypothesis was found by careful examination of military maps which showed elements of a blue layer outside a map frame. Moreover, individual sheets of *mapa powiatowa* were large and another deformation could be introduced by paper stretch and printing method. In any case, this should be regarded as a printing fault rather than a deliberate attempt to deform map content in order to confuse the enemy.

Removal of certain class of features

Differences between military maps and *mapy powiatowe* were noted in regard to the removal of information „of strategic importance from a defensive point of view”. For example, the following information was removed from the civilian edition: road category, embankment size, selected power lines, military structures, signatures of anti-tank trenches, location of a shooting range, selected railroads, tree heights, spacing and diameter at breast height (DBH) for woodlands, etc. The addition of fictitious drawing was also noted for civilian maps but it referred strictly to military features and it did not affect distances and angles of adjacent features. However, it may be worth remembering that similar masking of military features is also observed in democratic countries. Thus it may be regarded as *signum temporis* although the scale of those practices and general attitudes to sensitive information on both sides of the Iron Curtain cannot be treated in the same manner.

Removal of projection parameters

There is no doubt that censorship guidelines were carefully followed in this case. As mentioned above, *mapy powiatowe* were stripped of any information regarding grid system, grid lines or any other means which would permit georeferencing. For decades it made them useless since it was impossible to geolocate features depicted on those maps or relate them to other grid systems. In archaeology it resulted in the introduction of a separate system to ‘geolocate’ sites recorded during fieldwalking survey which for decades hampered the development of cartographic standards and made it impossible to combine archaeological data with other spatial information. However, a rapid development of technologies for processing spatial data in the last two decades (GIS and related software) solved that problem. Currently there are no obstacles to georeference those maps by using a set of control points which refer *mapy powiatowe* either to the original grid system of the military maps or to modern topographic maps/ orthophotomaps.

CONCLUSIONS: TO TRUST OR NOT TO TRUST?

During the Cold War, cartography of the Eastern Bloc “became a tool which was subordinated to rivalry between the two blocs. It was supposed to serve military aims and as such was an important element of a warfare strategy. Thus, cartographic resources received high clauses of confidentiality. Economic or social needs were of far less importance. Cartography of that period was trapped between limitations imposed by security requirements and reliability and professionalism” (Unverhau 2009, after Sobczyński 2014). This tension and balancing between cartographic standards and military demands can be also observed in Polish cartography. Undoubtedly, the decision to publish the first edition of topographic maps was political, enforced by Soviets and subordinated to the USSR’s military strategy. State power was exercised by controlling access to cartographic resources, classifying map parameters and selective dissemination of information. But it is equally true that due to historical turbulence Poland was lacking a uniform set of medium and large-scale maps and, on those that were available, several grid systems had been used. The first edition of topographic maps aimed to the development of a consistent system, completion of cartographic blank areas and production of a uniform set of maps. Between 1953 and 1959, 4140 military map sheets at 1:25.000 were prepared. It took two years longer than initially planned to edit these and few years more to publish a civilian edition. This was an enormous task and it was approached pragmatically by applying a compilation method. For western and northern parts of Poland where German *Mestischblätter* were available, maps were simply redrawn, converted to grid system Pulkovo 1942 and updated where necessary (Figure 13). Field measurements were taken for areas where no coverage at 1:25.000 existed. According to Sobczyński, the schedule between 1955 and 1958 was so tight that the Polish Army was unable to complete it with its own resources and printing of some areas was supported by Soviets. It seems that in the given circumstances, any ‘games’ with scissors and glue to deform civilian edition were simply out of question.



Figure 13. Fragment of *mapa powiatowa* against a background of a German *Mestischblatt*. This example shows a compilation method in practice and (in) accuracy in depicting contours which was probably caused by poor copying.
©Topographic Unit,
General Staff of the Polish Army.

Certainly *mapa powiatowa* tells white lies in a sense that some categories of information were removed or reclassified. However, the above analysis does not confirm in any way the somehow farcical falsification procedure described by Grygorenko. The quality of those maps does not differ substantially when accuracy of feature depiction, location and convention is considered. Admittedly, this is just a small a sample and further studies are required. Nevertheless, we would argue that the content of civilian maps was simply redrawn from military maps. Sensitive information was removed and sometimes replaced with fictitious drawing but no further distortions of distances, angles and heights were introduced. Thus, their usefulness should be considered from a perspective of individual users. From an archaeological point of view, the removal of military objects was of minor importance because those areas would be inaccessible for archaeological survey. The removal of other features in 'open' areas (e.g. power lines) could cause some confusion during survey and affect the accuracy in pinpointing site location. However, the major difficulty was probably caused by using maps which were outdated by at least three decades. This could also strengthen the opinion among archaeologists about their falsification. But generally speaking, site location is as accurate as outdated maps at 1:25.000 and archaeologists' skills to use them permitted. There are no reasons why digital copies of these maps cannot be used in GIS.

Still the question remains, how to understand the criticism which was addressed towards *mapy powiatowe*? While we do not question the interference of politics and censorship into cartography, it seems that after the fall of communism those maps were still entangled in a political discourse. It may be worth noting that the description of the falsification procedure was published in 1991, just two years after the fall of the system, when rigours of censorship ceased to exist. On one hand it permitted more open comments about numerous absurdities of that period, on the other hand a justified aversion towards the system could lead to a criticism which undermined entirely decisions and actions that had been undertaken. Thus this criticism could be more of a political than a scientific statement. So what is the final answer to the dilemma – to trust or not trust? Well, one can say: do not trust professors' claims about maps before checking them against verticals.

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