

Past, present and future of Remote Sensing in Archaeology: an explicitly European perspective

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Abstract

All non-invasive approaches to viewing the buried and nominally ‘invisible’ evidence of the past should be included within the definition of Remote Sensing for archaeology. These approaches include space- and airborne sensor platforms, including traditional air photographic sensors as well as technology-based multi-spectral or hyperspectral scanners, as well as ground based geophysics, under-water remote sensing and other non-invasive techniques such as surface collection. In essence any method that facilitates observation of the buried evidence without impacting the surviving stratigraphy is encompassed within the remit of remote sensing. The last ten years have seen many innovations in remote sensing, the most significant advances having been achieved in the field of satellite imagery, LiDAR, UAV and geophysical prospection. Remote sensing has grown progressively from an ‘aseptic tool’ aimed at documentation into an original methodology, highly effective for the identification of archaeological sites and landscapes. It is currently – in its most advanced applications – the key to overcoming an out-dated approach to archaeological research and conservation focused on individual sites and then on finds.

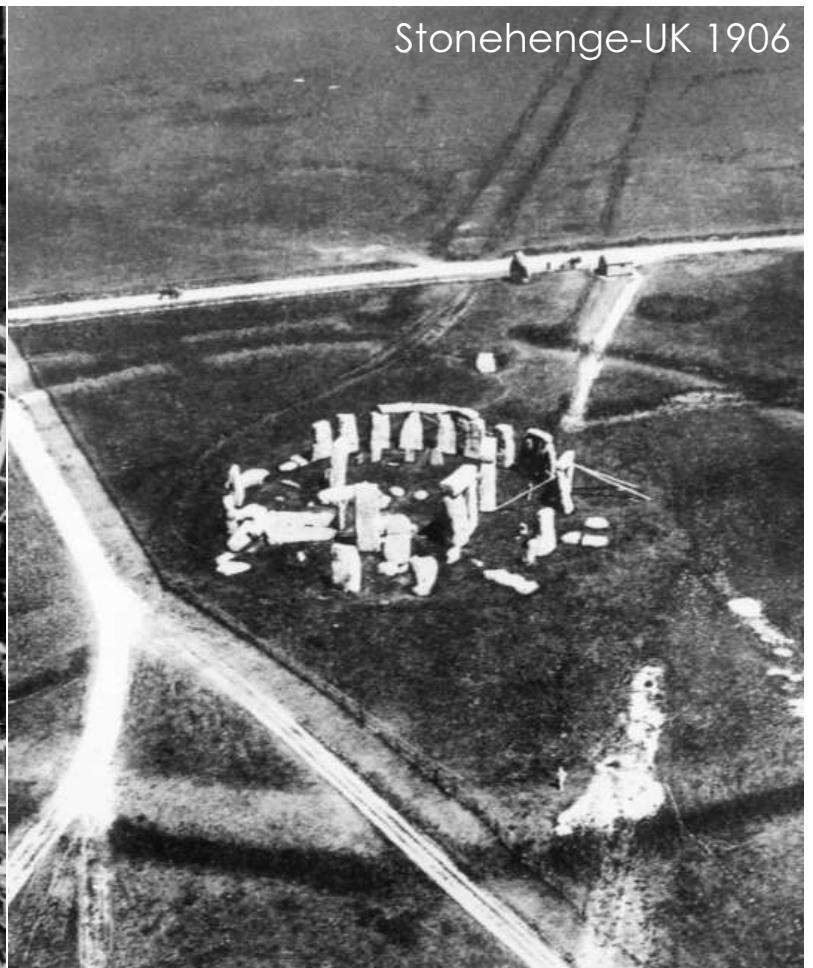


PAST, PRESENT AND FUTURE OF REMOTE SENSING

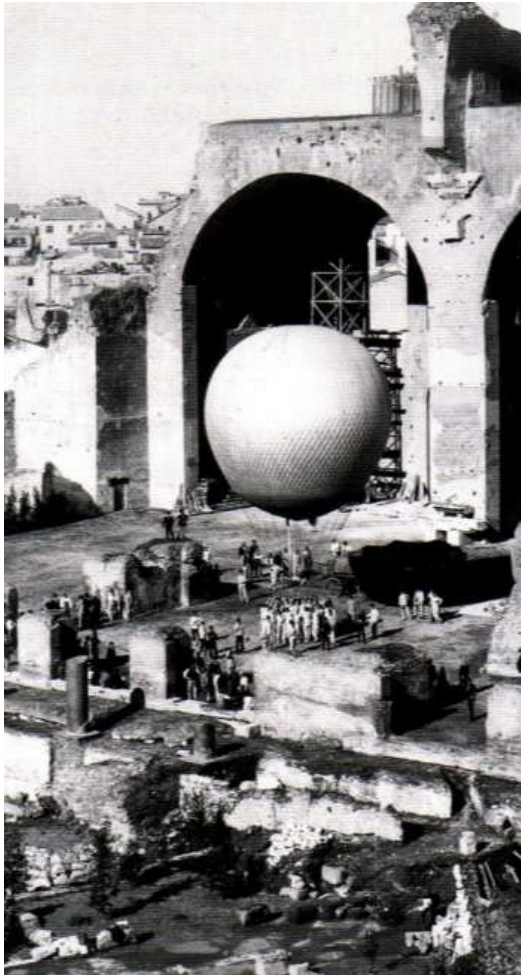
An explicitly Archaeological and European Perspective



Foro Romano-Italy 1899

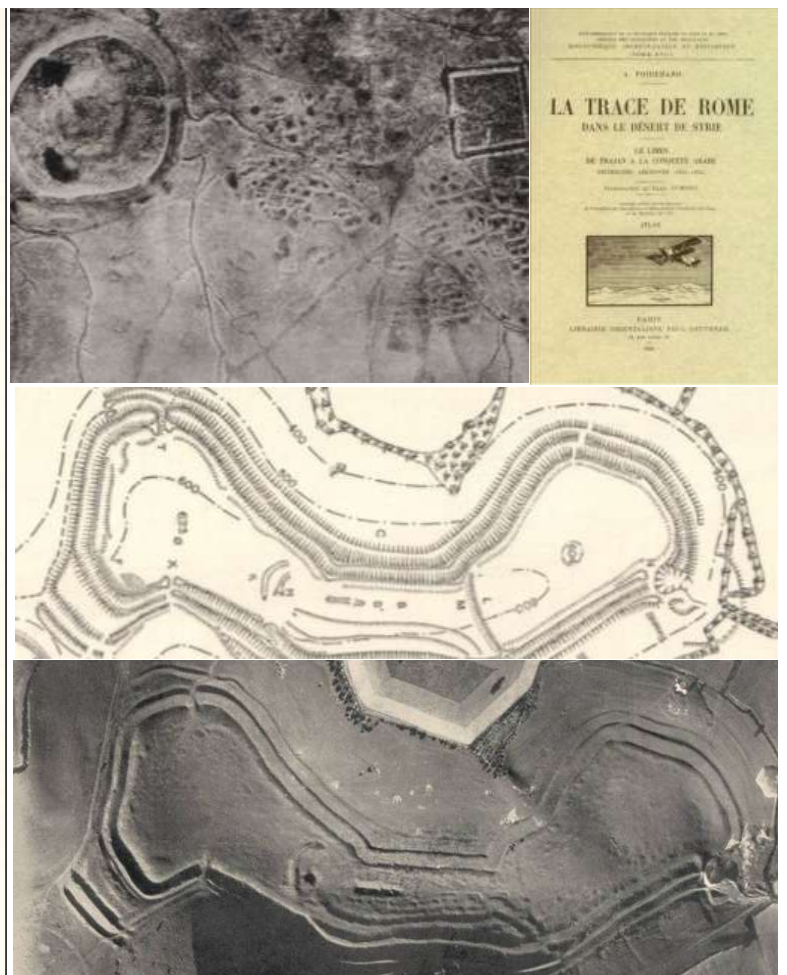
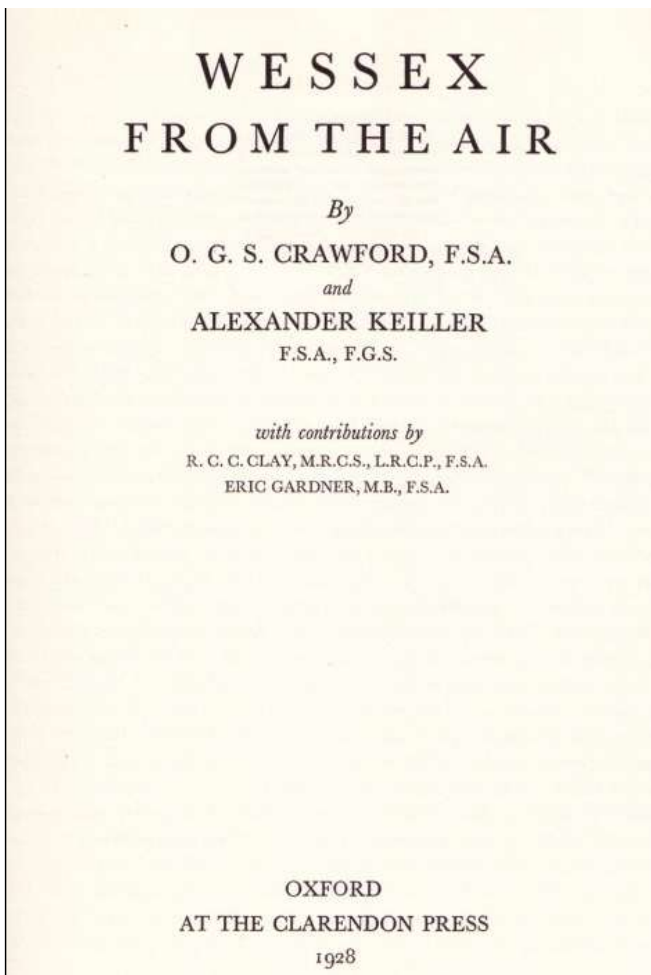


Stonehenge-UK 1906



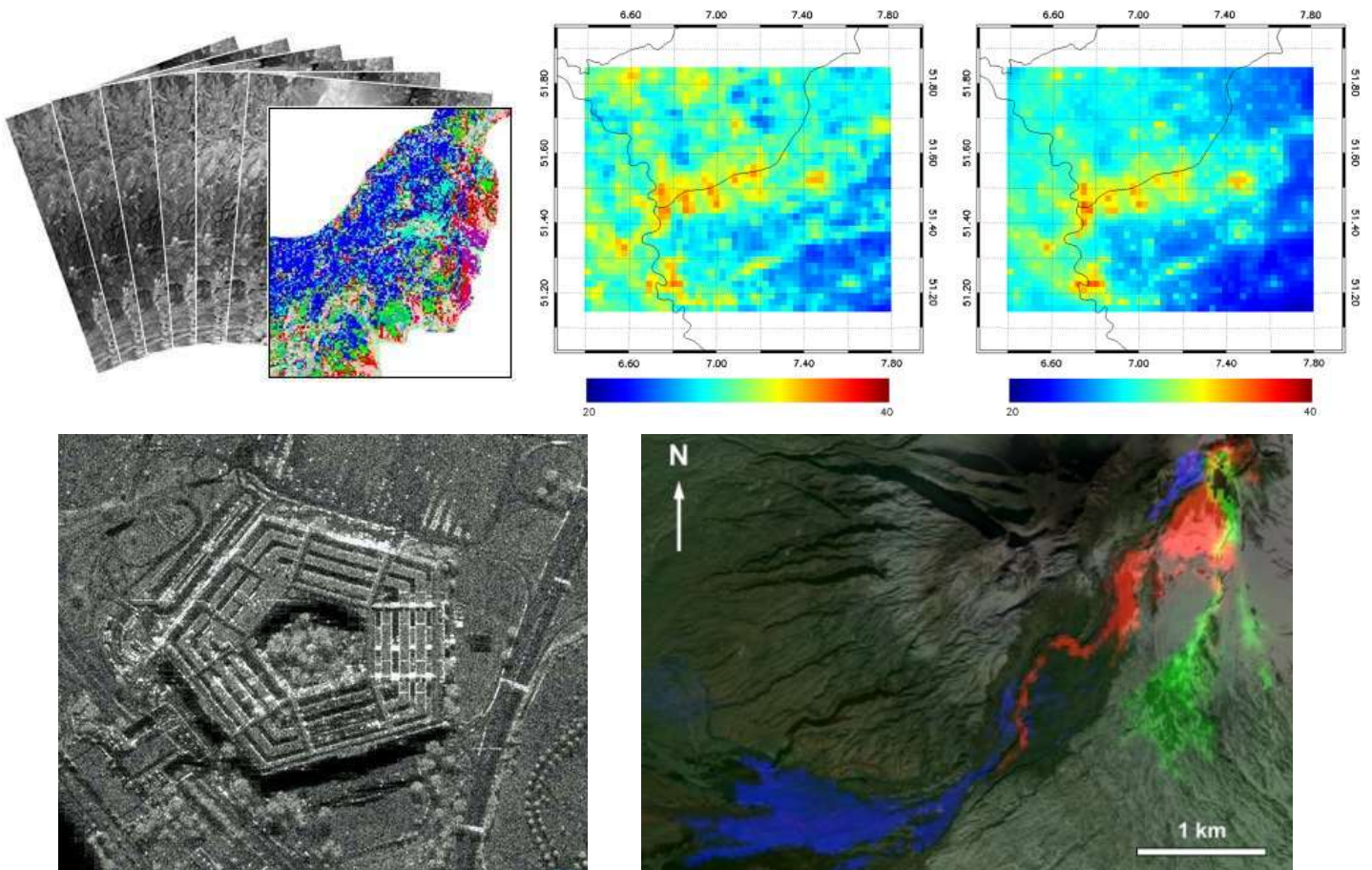
Introduction

past



Introduction

past



Introduction

past

Remote Sensing is now commonly used to describe:



THE SCIENCE OF IDENTIFYING, OBSERVING, INTERPRETING AND MEASURING OBJECTS OR SURFACES WITHOUT COMING INTO DIRECT CONTACT WITH THEM.

The European archaeological community has taken at least two different approaches to the definition of Remote Sensing:

Some archaeologists define it as the technique of obtaining information about objects through the analysis of data collected by sensors (cameras, scanners, imaging radar systems etc) that are not in physical contact with the objects under investigation, using spaceborne and airborne instruments.

Introduction

past/present

Some other archaeologists define remote sensing as:
any **non invasive** approaches to viewing the buried and
nominally 'invisible' evidence of past activity should be
included within remote sensing for archaeology.

These approaches include space and air borne sensor platforms
- these might be traditional air photographic sensors as well as
technology based multi-spectral or hyper spectral scanners, as
well as ground based geophysics, under sea remote sensing
and other non-invasive techniques such as surface collection; in
essence any method that facilitates observation of the buried
evidence **without impacting the surviving stratigraphy** is
encompassed within the remit of remote sensing.

however...

Introduction

past/present

What happened in the archaeological scientific community?

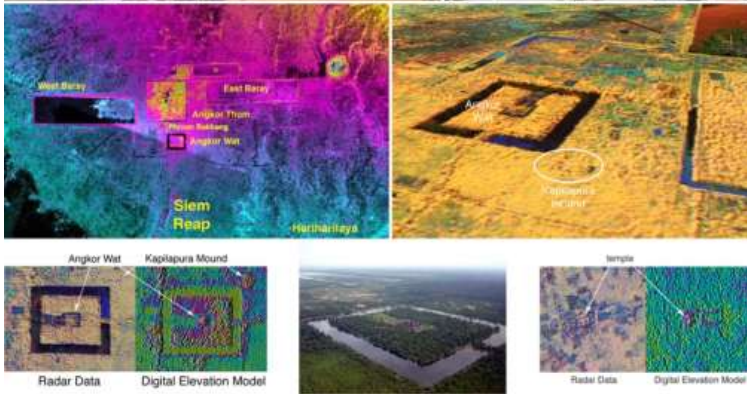
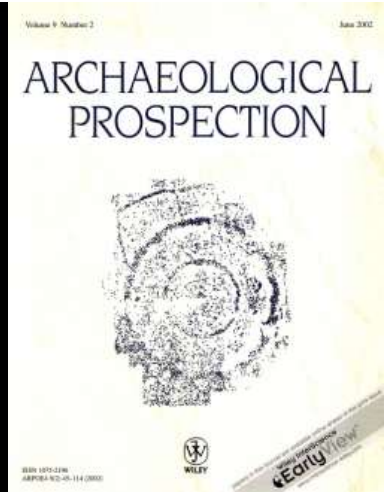
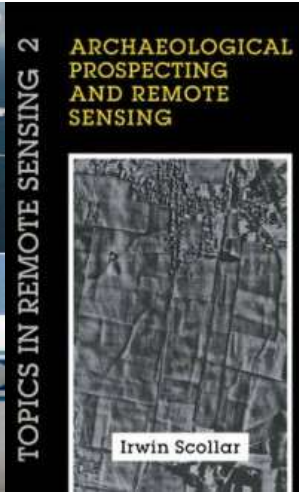
For a long period the technologies involved in Remote Sensing were
considered to be '**leading edge**' and it was fairly unusual for
archaeologists to access them.

It must be acknowledged, too, that the relationship between
archaeologists and technology has not always been **free of pain and
frustration**.

Despite this, in the last thirty years technology has become more and
more common in the archaeological laboratory and also in the field.

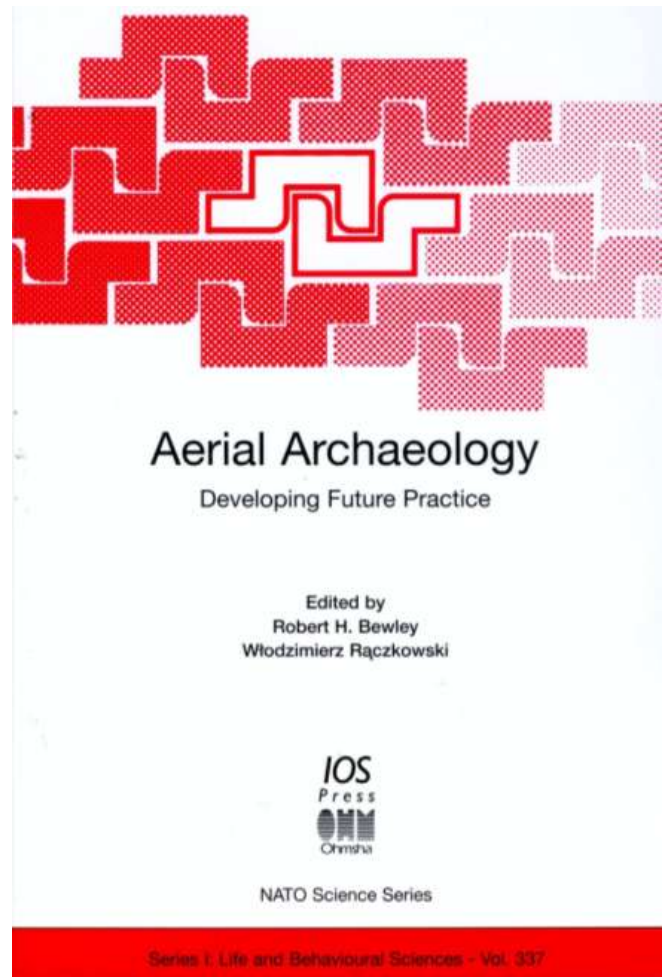
Introduction

past



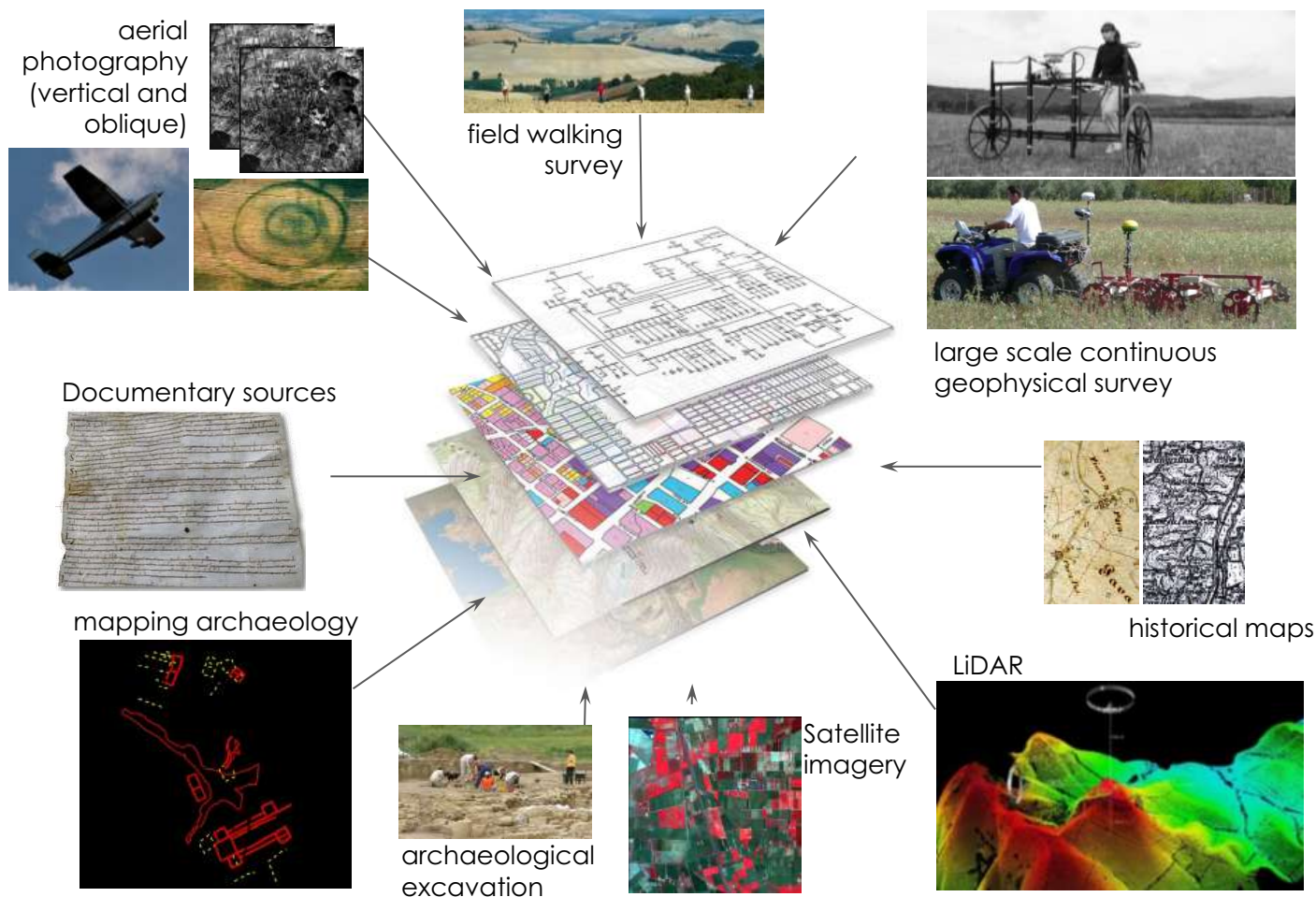
Introduction

past



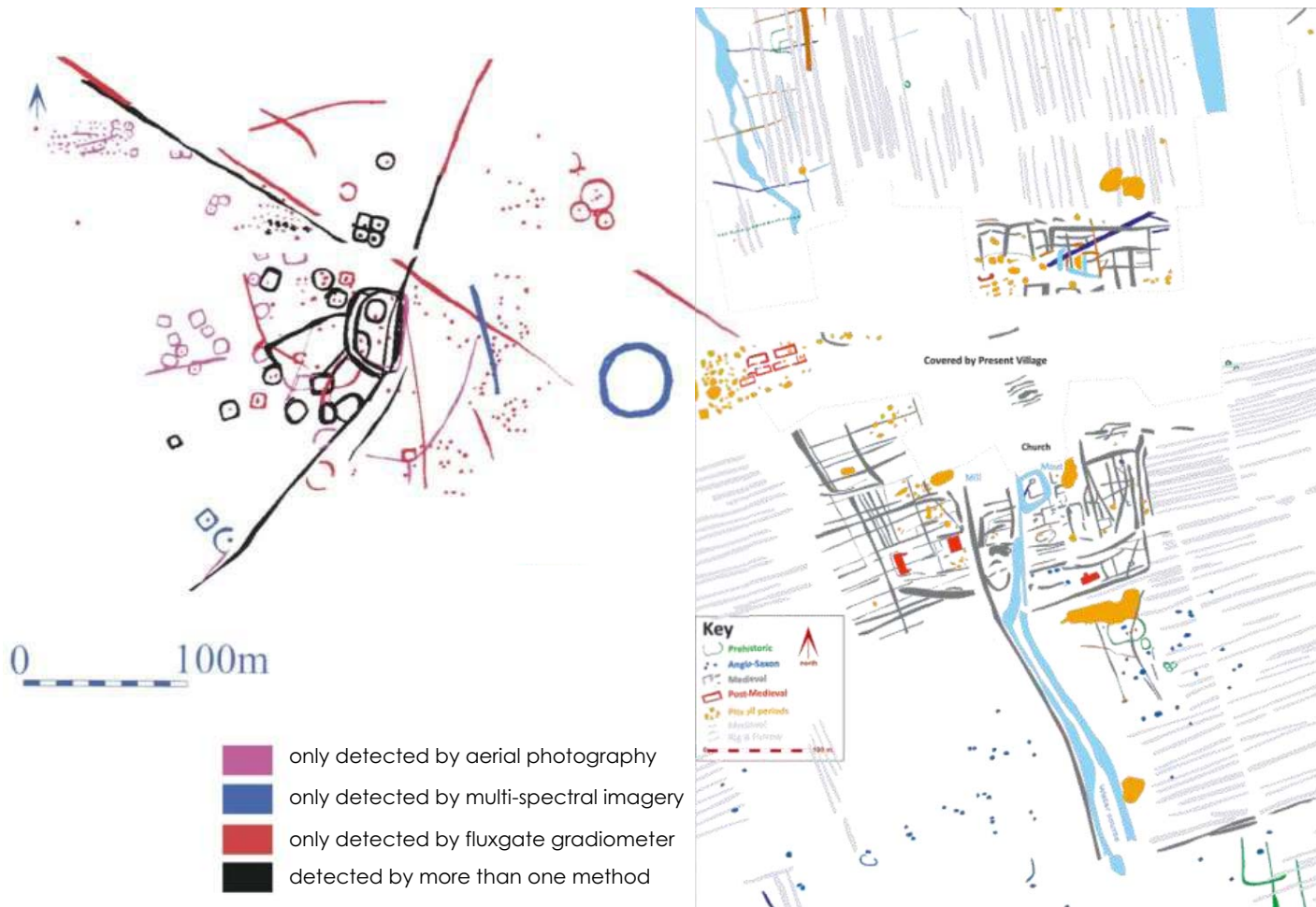
Introduction

past



Introduction

past/present



Introduction

past/present



Over the past ten years have been developed many innovative technologies in remote sensing. The leading news and most significant advances (from the archaeological perspective) have been achieved from my point of view in the following macro areas:



In absolute terms, all this tools are likely to be effective although it should be noted that not all macro-areas have the same level of impact in the increase of archaeological process.

main development

present

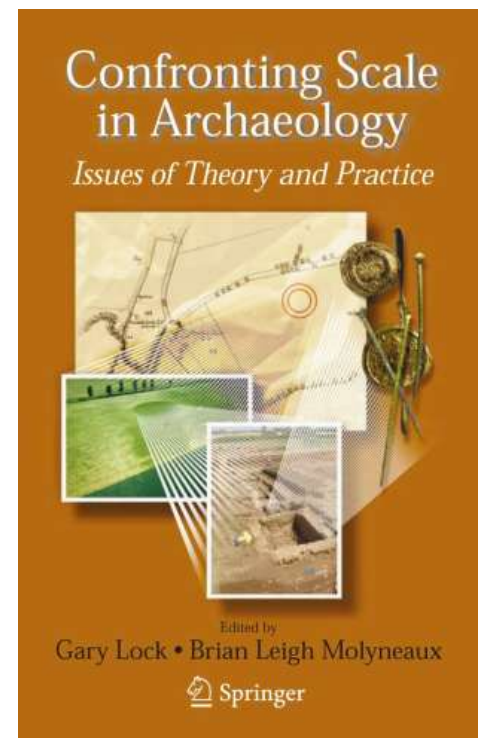
Archaeological research and scale of detail

Various basic levels of scale have been recognized in archaeology:

Clarke (1977), for instance, identified three: 'macro', 'semi-micro' and 'micro'.

Butzer (1982) proposed a more detailed graduation of scales, including 'mid-scale'.

However, no one scale that is better than the others; the key point is that it is the purpose of the mapping that should determine its scale.



main development

present

Archaeological research and the issue of scale of detail

1:200.000

In topographical mapping, for example, an **increase in detail** involves the revision or **supplementing of the contour lines** and spot heights.



In this case the **difference of scale** does **not affect the strategy** of work in any substantial way, nor the technical means or **basic methodology** for achieving it.

The archaeologist who has to cope with the transition to a more detailed scale must, however, give thought to the availability or **introduction of instruments** that are barely applicable today at the smaller scale.

1:25.000



1:5.000



main development

present

Archaeological research and the issue of scale of detail

'MACRO' SCALE – it is the higher scale, depending for its support most of all on literary, bibliographical and documentary sources, on place name, iconography, epigraphy, historical cartography, aerial photography, **SATELLITE IMAGERY**.

'MICRO' SCALE – it is the smaller scale, traditionally concerned with archaeological excavation; in the past decade, however, it has also drawn heavily on the contribution of **GEOPHYSICS** and **UAV**.

'LOCAL' SCALE, a term used here to indicate the shadowy zone between micro- and macro scale. I believe that currently **AIRBORNE LIDAR** and **LARGE SCALE GEOPHYSICS** represent the most innovative methodologies to explore that level of scale.



main development

present

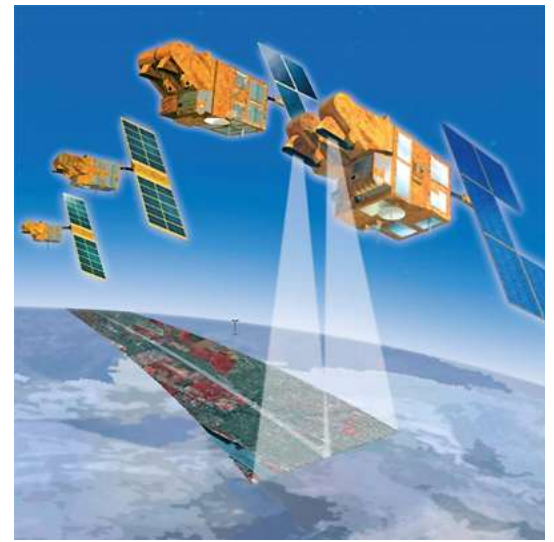


satellite

Over the past fifteen years, the resolution of the satellites increased from 20 m/pixel (Spot) to 0,40 m/pixel (GeoEye1) which represents an increase of about 2500 times.

The opportunities of application are therefore greatly increased although there are still some significant limitations including:

- DATA CAPTURE SCHEDULING
- SPECTRAL RESOLUTION
- GEOMETRIC RESOLUTION



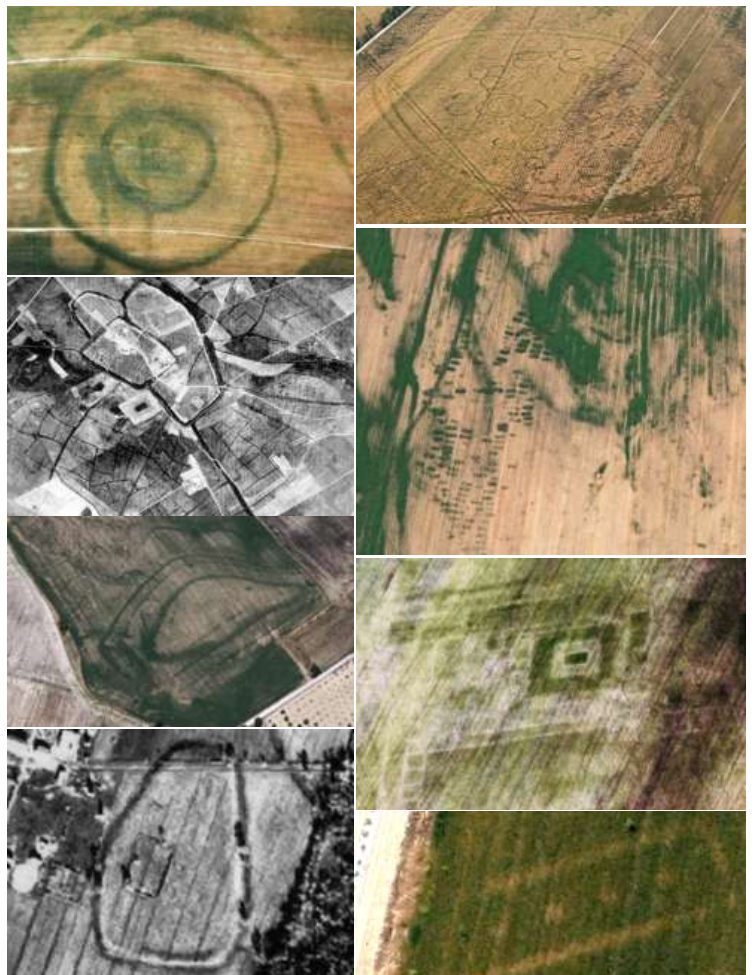
satellite

present

From the prospective of a **European observer** wandering through a library, **might be forgiven for believing** that **satellite remote sensing** is the **prime application for archaeological remote sensing**.

This is of course not the case in Europe:

“FOR EVERY ‘SITE’ IDENTIFIED FROM SPACE THOUSANDS HAVE BEEN IDENTIFIED THROUGH AIR-PHOTOGRAPHY”

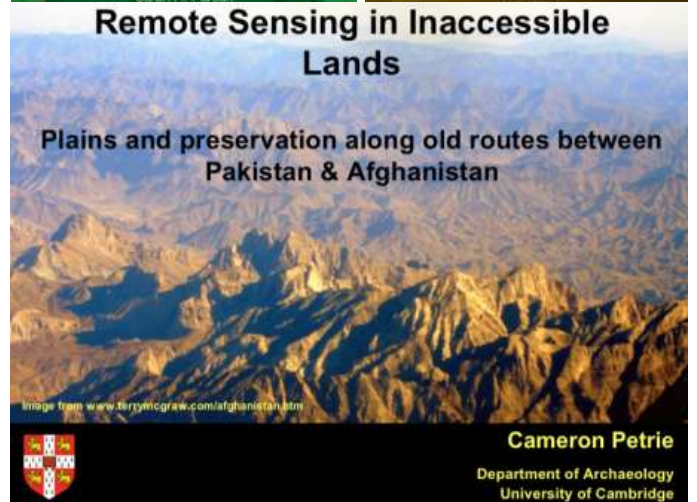
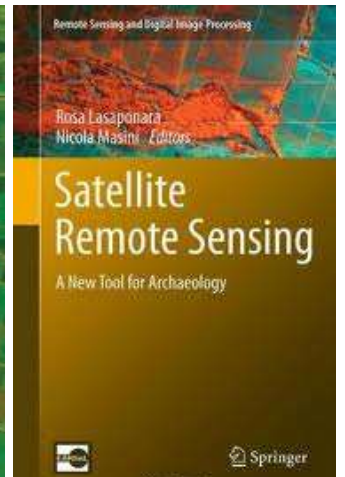
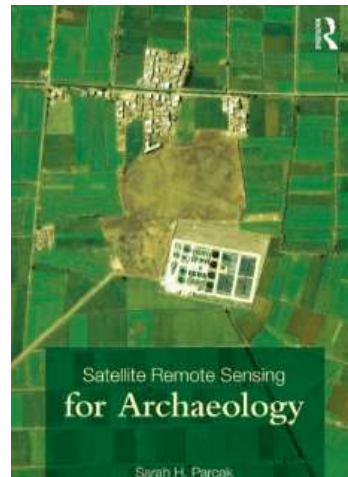


satellite

present

The outcome from the European perspective, in the practice of archaeological research, is the use of satellite imagery **IN ABSENCE OF OTHER DATA AVAILABILITY** that today should be still often considered superior (quality, costs, results):

- aerial photography
- geophysical prospection
- LiDAR
- Airborne Multi-Spectral Scanner
- Airborne Iper-Spectral Scanner



satellite

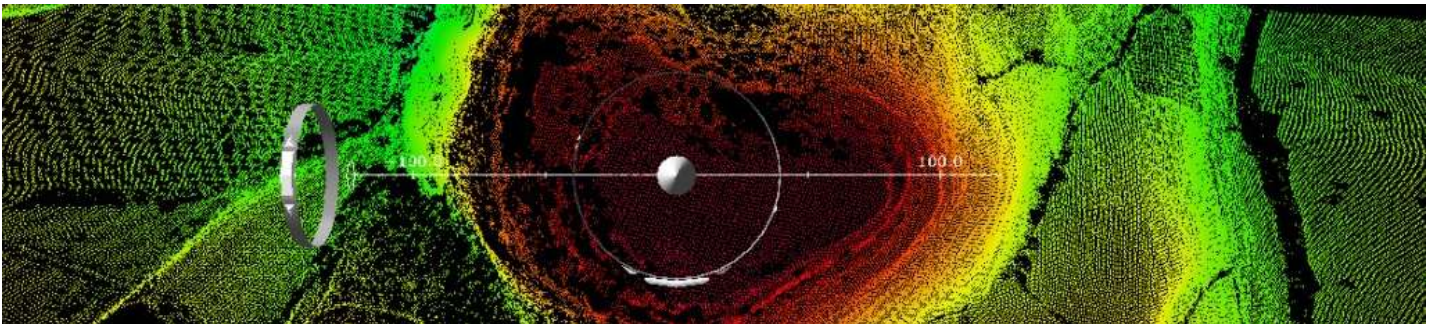
present



satellite

present

LiDAR



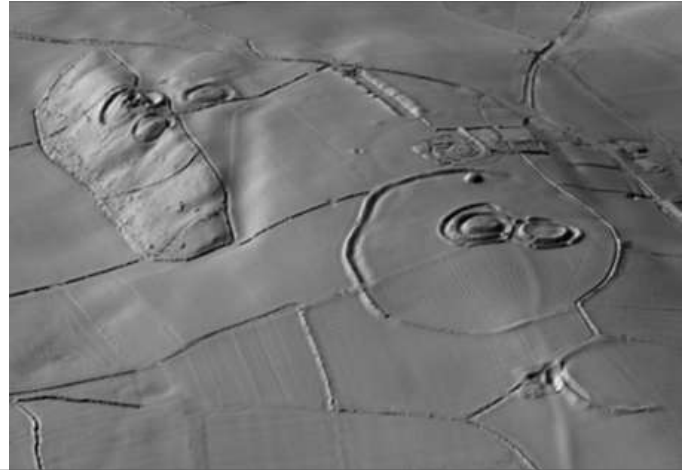
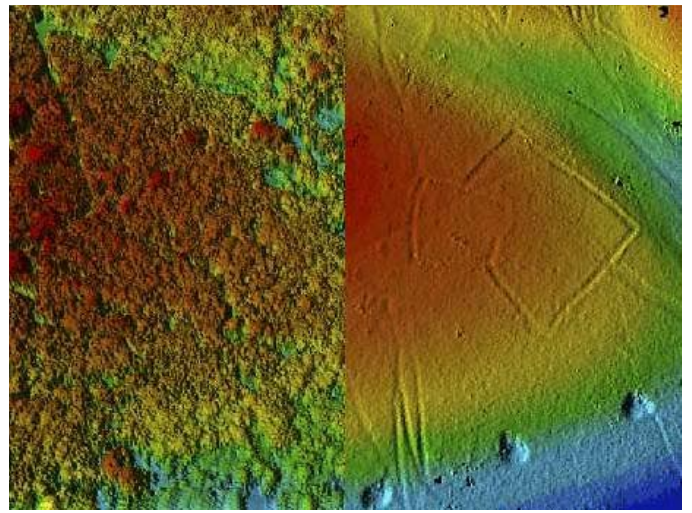
In the 2003, at Gent University in Belgium Robert Bewley, then Head of English Heritage's Aerial Survey Unit, argued that "**...the introduction of LiDAR is probably the most significant development for archaeological remote sensing since the invention of photography**" (Bewley, 2005).

Currently, the archaeological application of Lidar technology is **growing quickly** and the results are definitively exciting **opening new perspective** in the field of **detection** (with particular regard to under canopy and leveled landscapes) and **monitoring** archaeological evidence.

In the following years LiDAR applications have been **developed widely around Europe** and particularly in the UK, Austria, France, Germany, Norway and Italy.

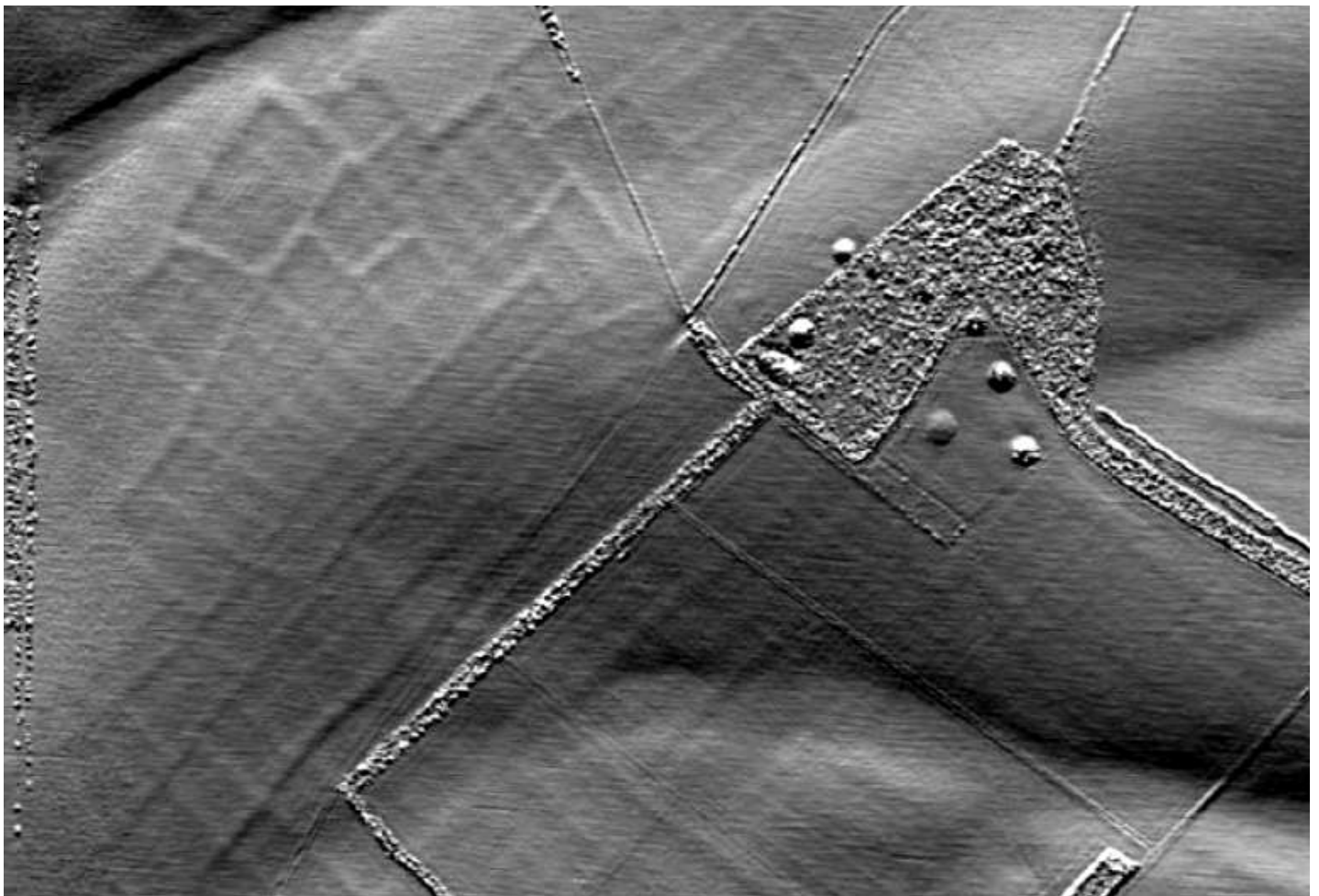
Currently the principal advantage of LiDAR survey for archaeologists should be recognized in:

- **provide a high-resolution DEM revealing micro-topography** which is virtually indistinguishable at ground level.
- **Removal of trees** so as to produce an under canopy DTM.



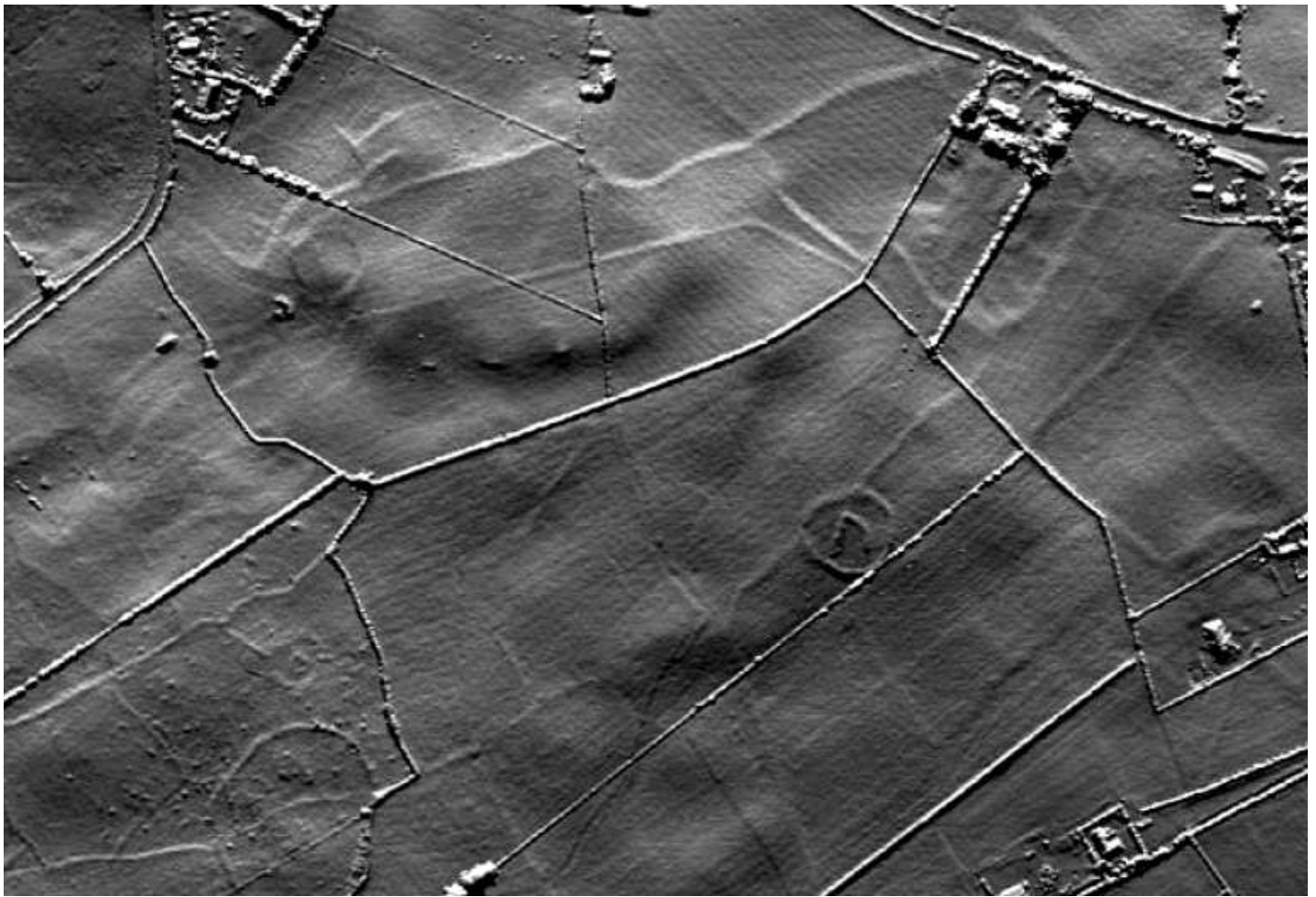
LiDAR

present



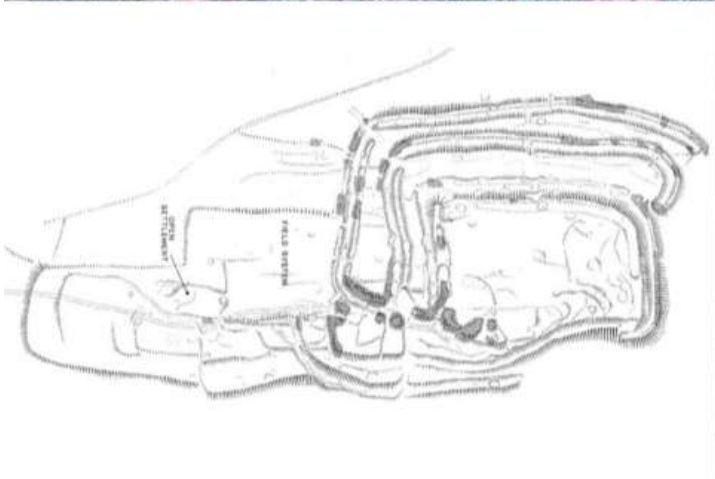
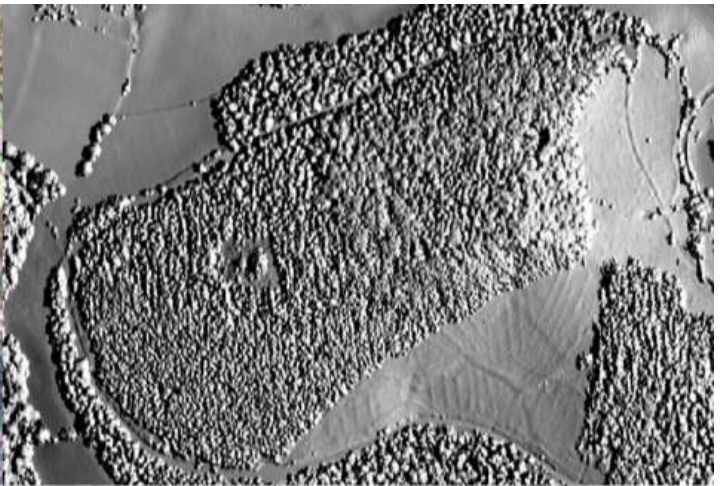
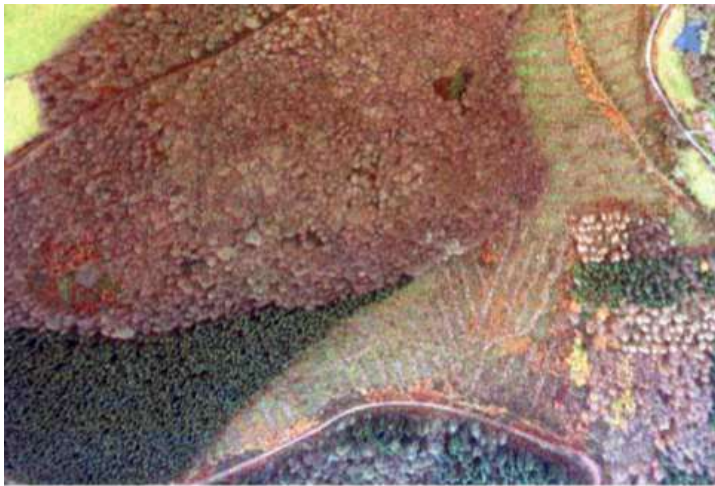
LiDAR

present



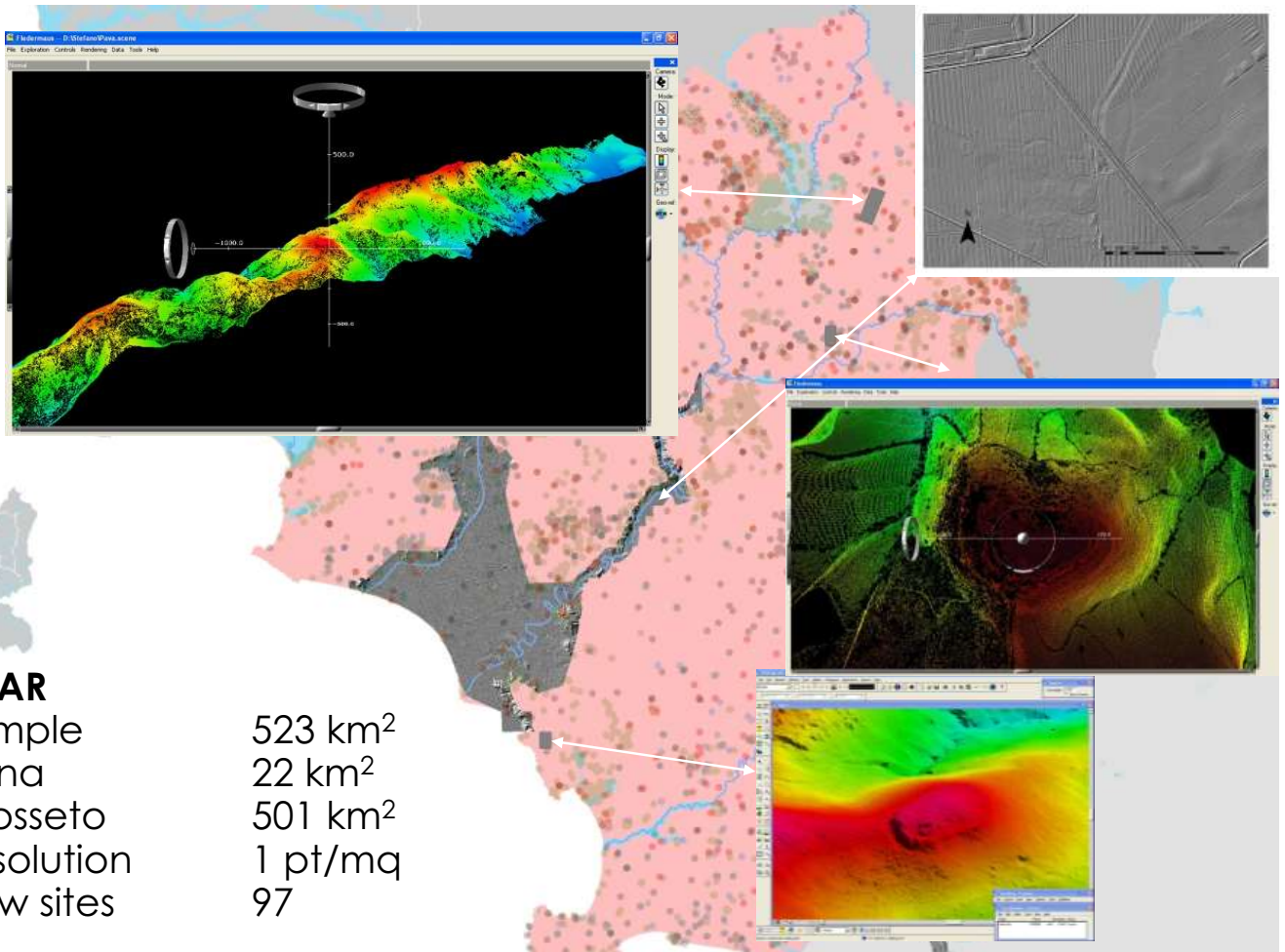
LiDAR

present



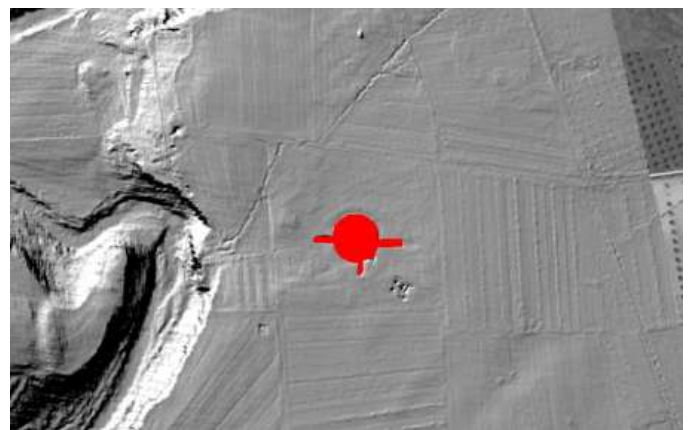
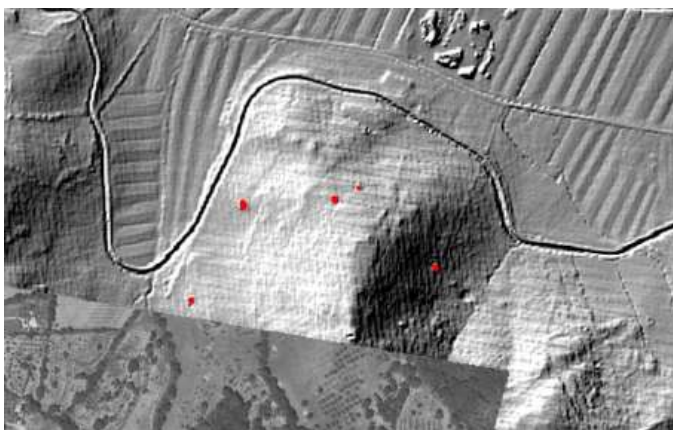
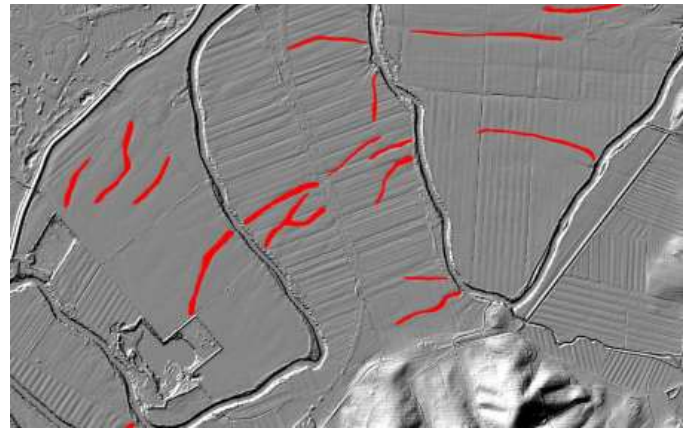
LiDAR

present



LiDAR

present

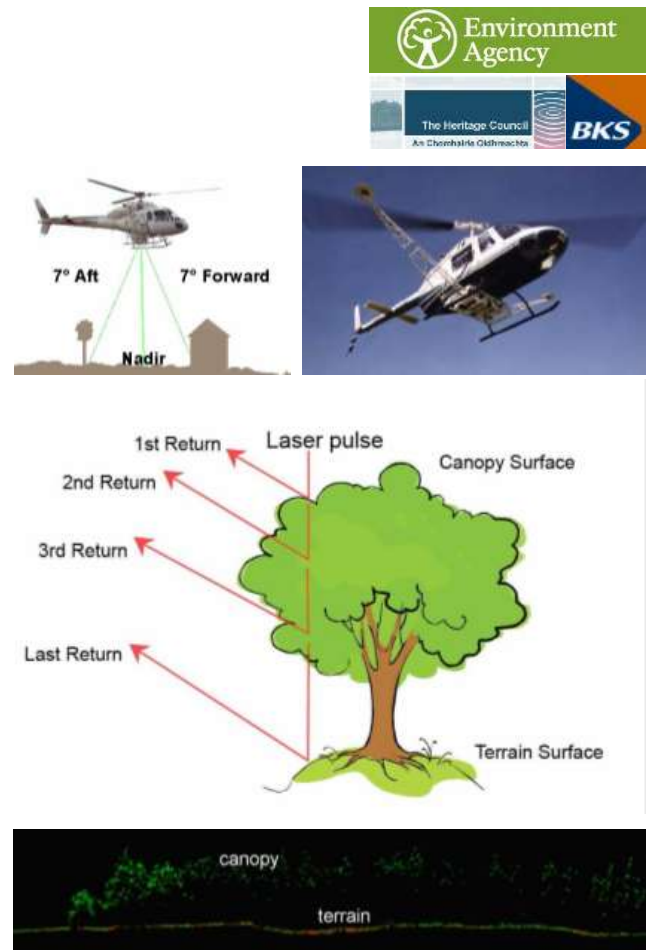


LiDAR

present

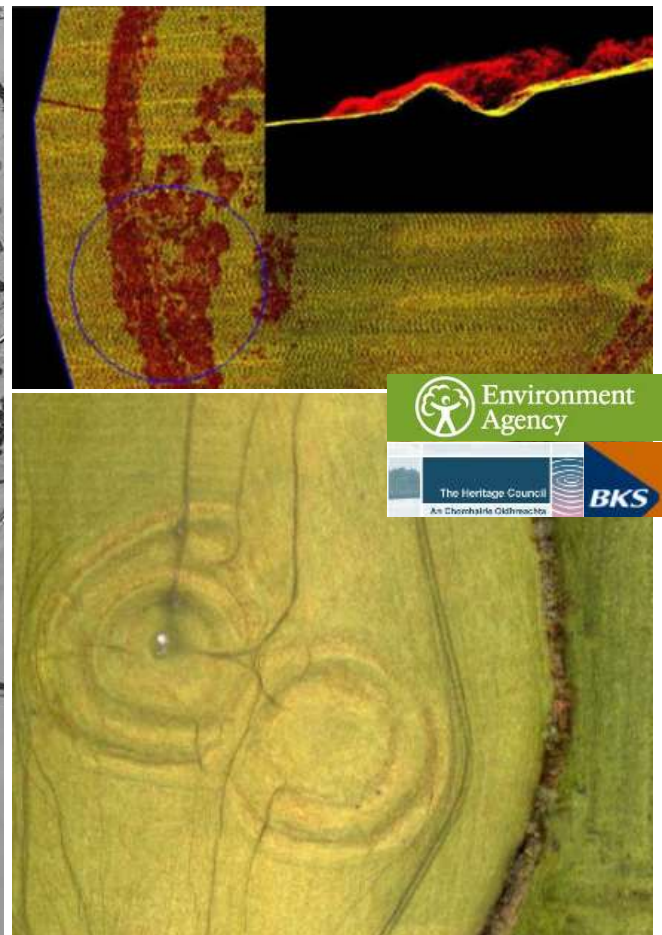
Helicopter based LiDAR FLI-MAP 400 (slower speed and lower flying), multiple return feature, combined with ultra high frequency enables:

- Much **higher resolution** up to 60 pts/m² (about 10 cm resolution);
- **Effective under-canopy visibility** also in the most densely vegetated areas;
- Very high resolution enable to record **micro-topographic element** even where the remains of archaeological sites are severely degraded.



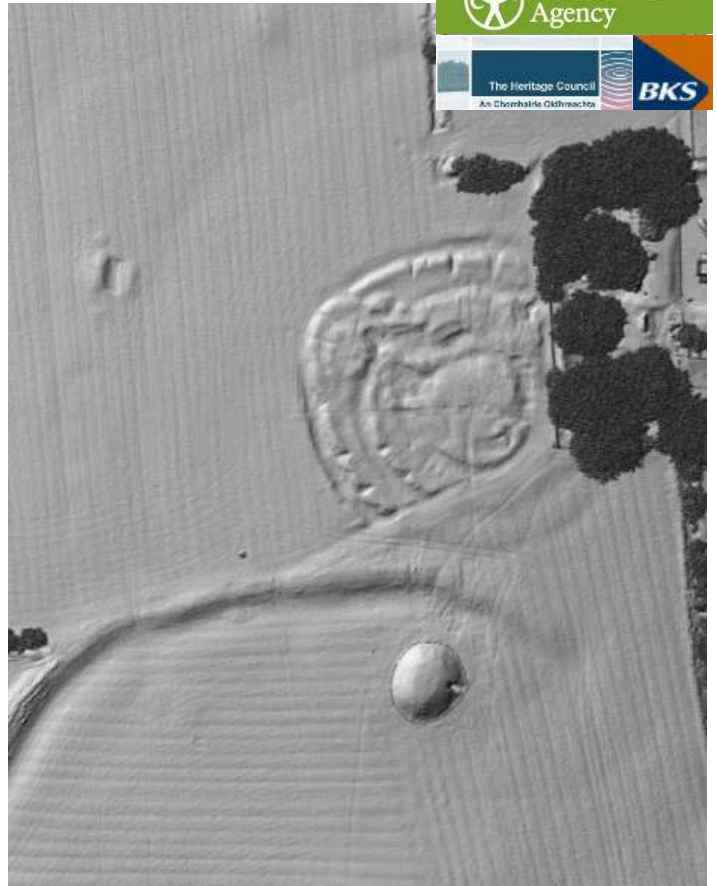
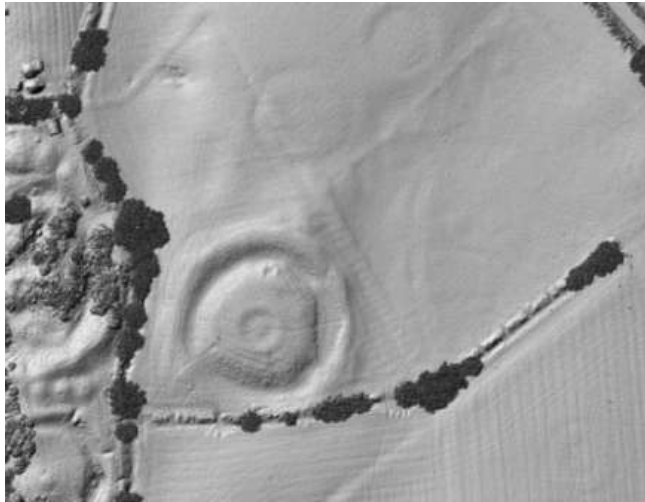
LiDAR

present/future



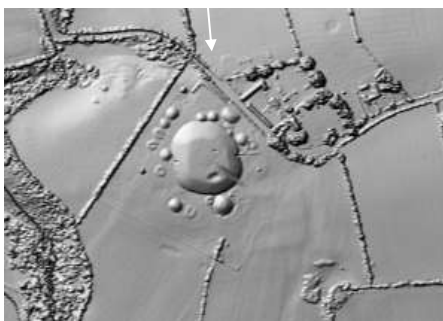
LiDAR

present/future



LiDAR

present/future



LiDAR

present/future

- **Cost is the major determining factor BUT THE VALUE** in terms of research and heritage management has been recognized.
- From our perspective the only reservation would be the LIMITED AREA HAVE BEEN ABLE TO COVER by this technique given the funding available and the MASSIVE amount of data collected per sq km.



	Brú na Bóinne	Tara
Survey area	85km ²	2.38km ²
Resolution	0.5m	0.1m
Total No. Points	85 Million	150 million
Accuracy Z	±7cm	±3cm
Accuracy X, Y	±15cm	±5cm
Focus	Landscape	Monument

LiDAR

present/future



UAV

Unlike technologies we have discussed so far, the main aims of this kind of system is addressed at the diagnosis of very specific areas or more frequently to 2D and 3D documentation of archaeological excavation, archaeological park or monuments.



UAV

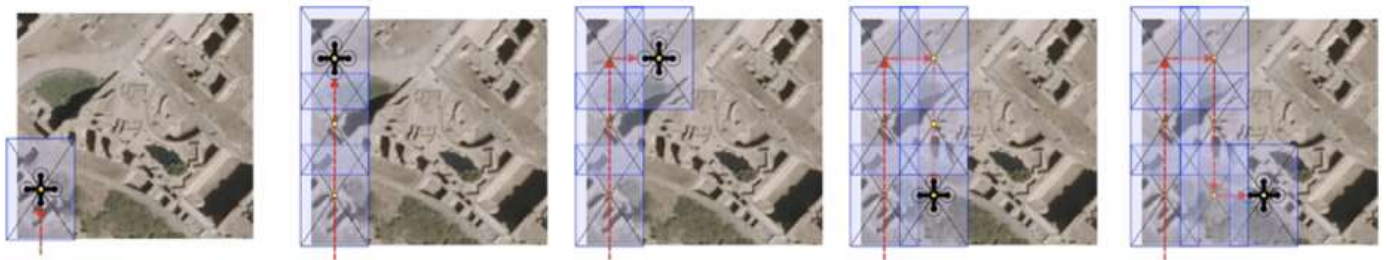
present

Commercial UAV are also currently available. My lab i.e. in collaboration with FBK foundation and Zenit started a project – ArcheoDRONE project - with to develop a semi-automatic system to achieve stereo pairs addressed produce a 3D documentation of archaeological excavation.



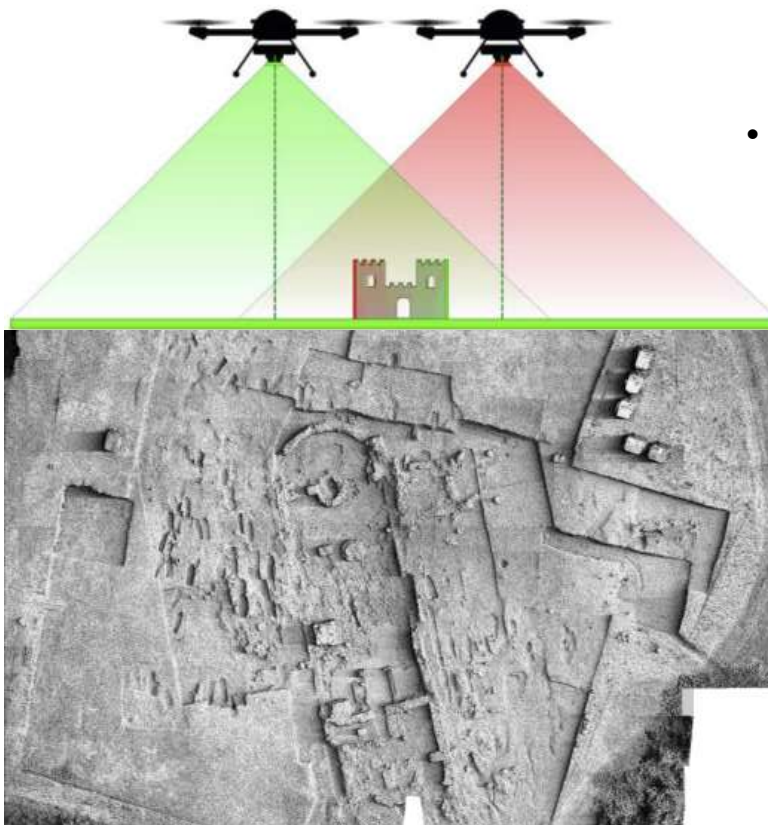
UAV

future



UAV

future



- The project started in summer 2007 when we did the first test on archaeological excavation.
- On this occasion several limits have emerged:
 - ✓ lack of experience of piloting and in the evaluation of field conditions
 - ✓ heavy dependence by wind condition
 - ✓ poor reliability of the system
 - ✓ take-off weight allowing only compact camera
 - ✓ Difficult to extract metric data from compact camera

UAV

future

The availability of a **more advanced UAV system** (MD4-1000 microdrones <http://www.microdrones.com>)

allows using:

- **full frame reflex camera,**
- **flight time** up to 70 minutes (dep. on load/wind /battery)
- operate in a **more wide range of environmental conditions**

temperature
humidity max.
wind tolerance

flight radius
Cooperating altitude
take-off altitude

0-40 C°
80%
steady pictures
up to 6m/s
up to 1000m
up to 1000m
up to 4000m
above sea



UAV

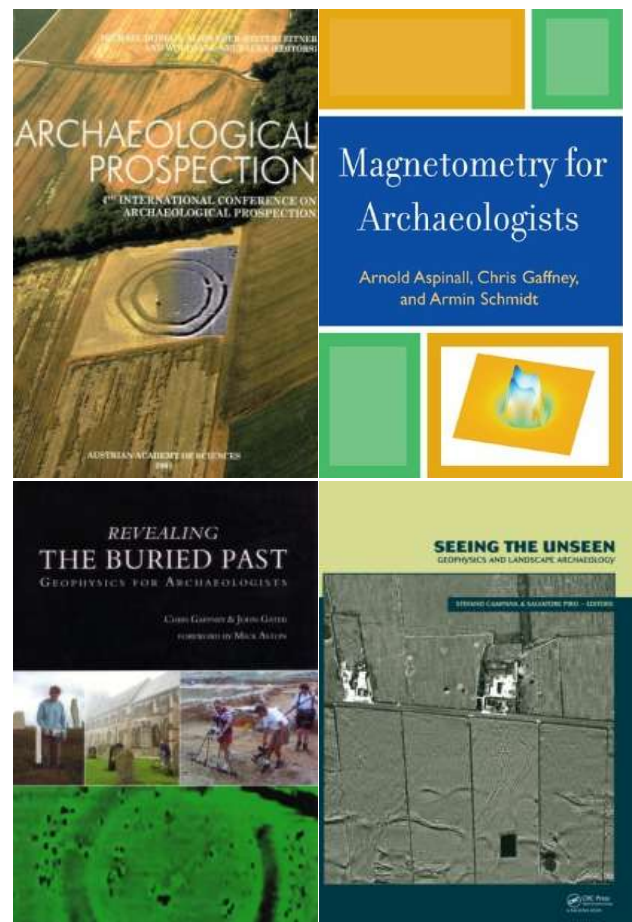
future

geophysics

Over the past ten years we have seen a major improvement of all key-geophysical instruments commonly applied to archeological research.

More sensitive and faster resistivity meter and magnetometer, multi-channel radar, however, in our opinion it happens in that period three most significant changes:

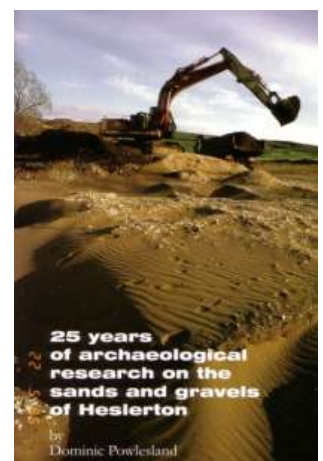
- **Direct involvement of archaeologists** in the management of geophysical data from data collection to the interpretation
- Extending survey from site to “off-site” and landscape: the discovery of the **archaeological continuum**
- Development of new system aimed to **collect large scale data**



geophysics

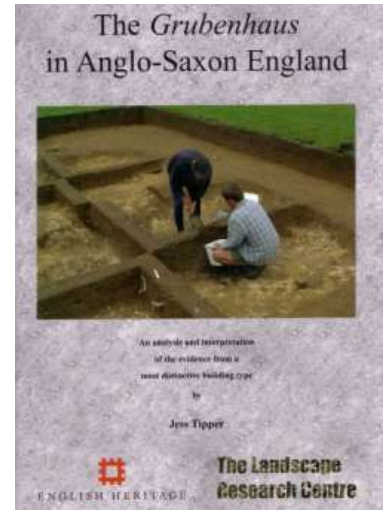
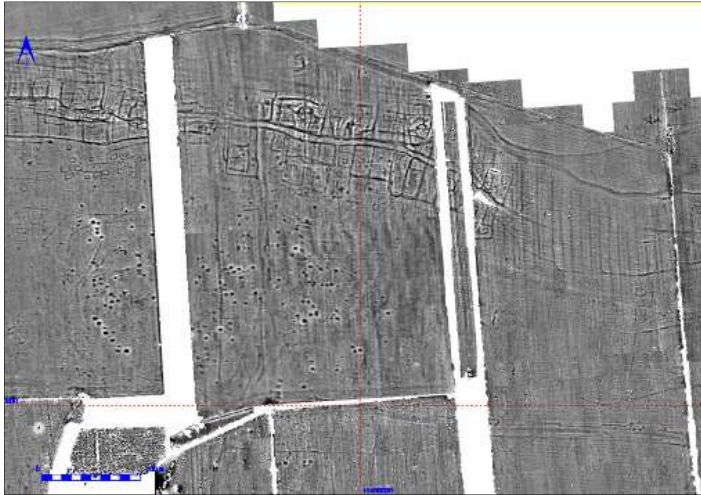
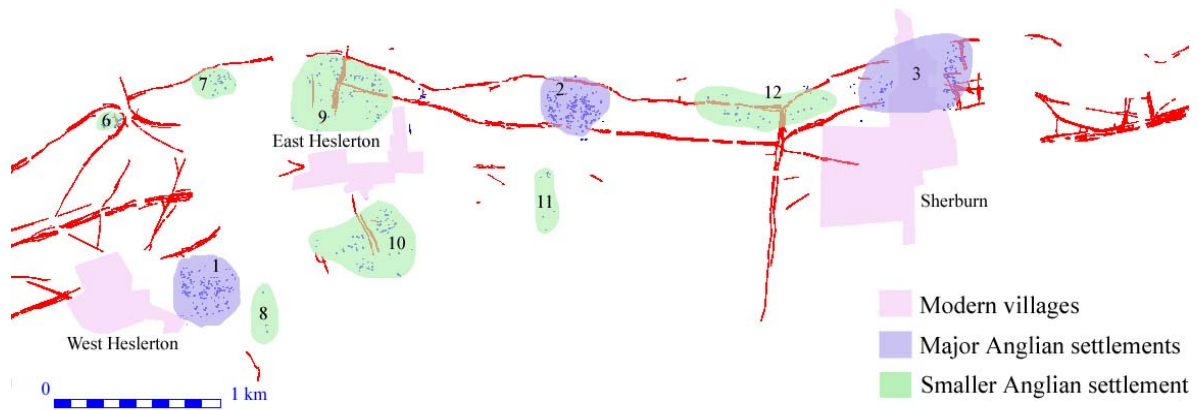
present

In the Vale of Pickering, North Yorkshire, England, The Landscape Research Centre has been engaged in remote sensing since the mid 1970's, focused upon a single landscape employing conventional air photography, airborne multi-spectral and hyper-spectral scanners, Lidar and ground based geophysics and other ground based surveys in addition to about 30Ha of open area excavation.



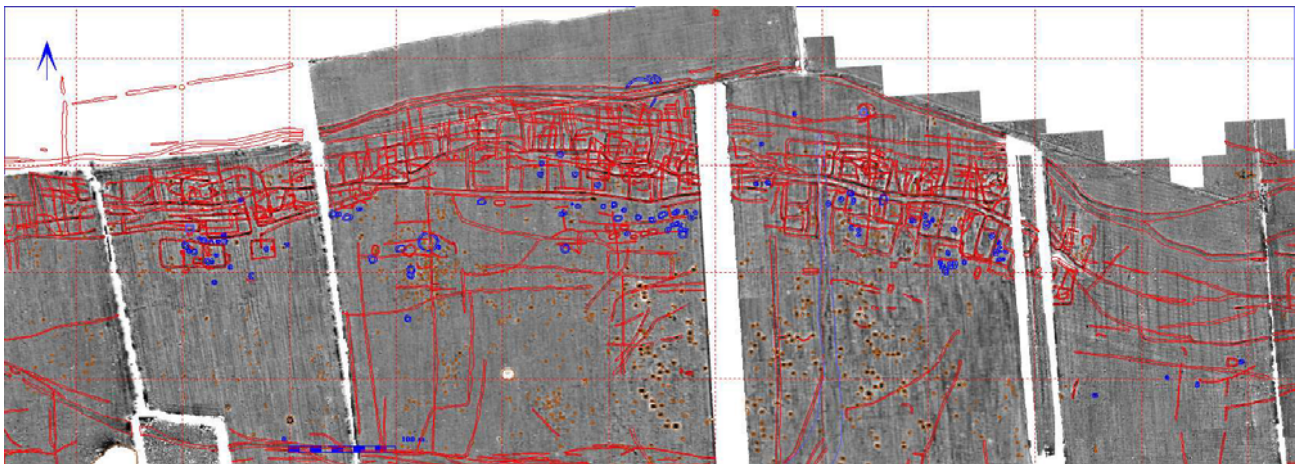
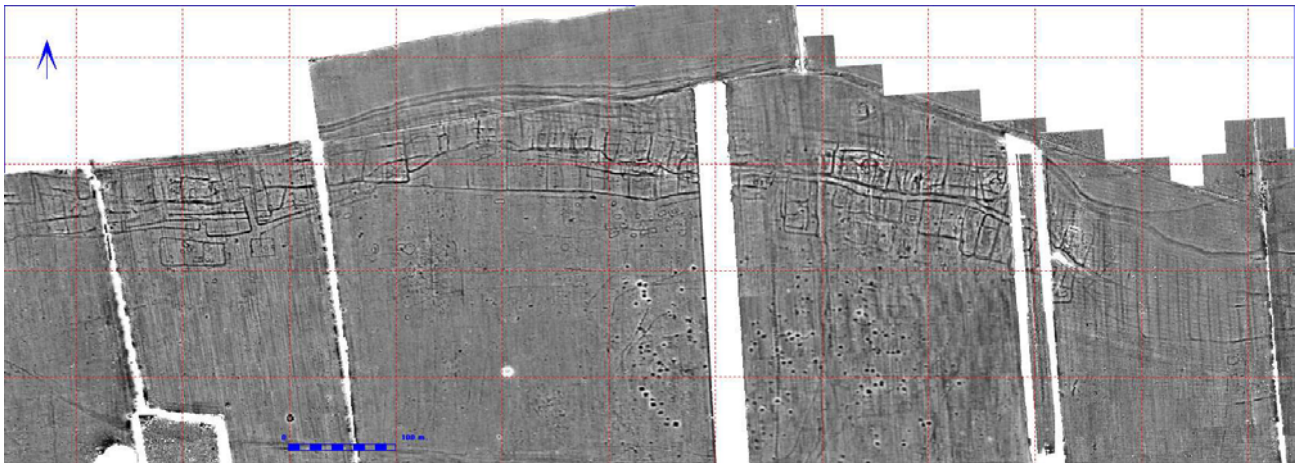
geophysics

present



geophysics

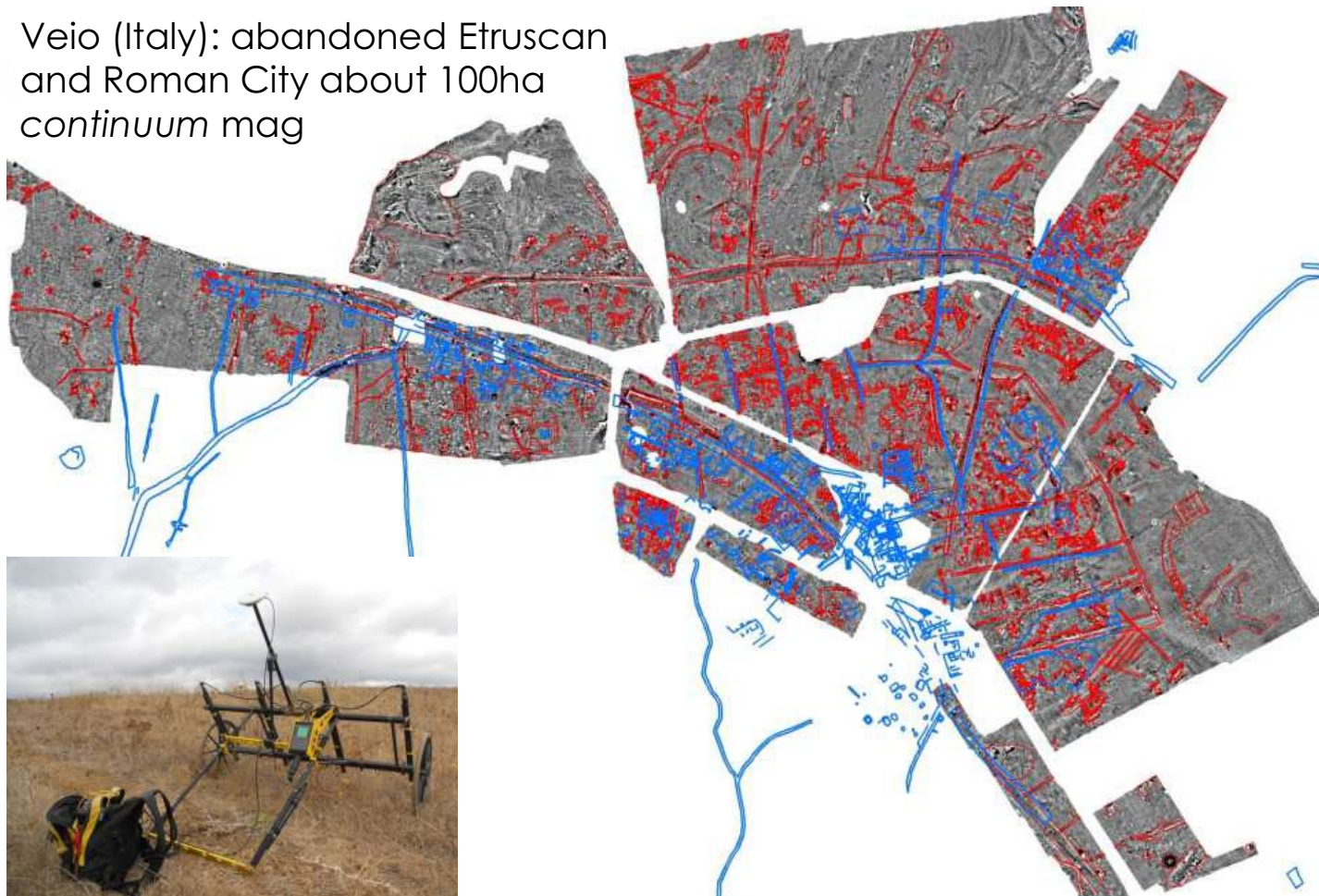
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geophysics

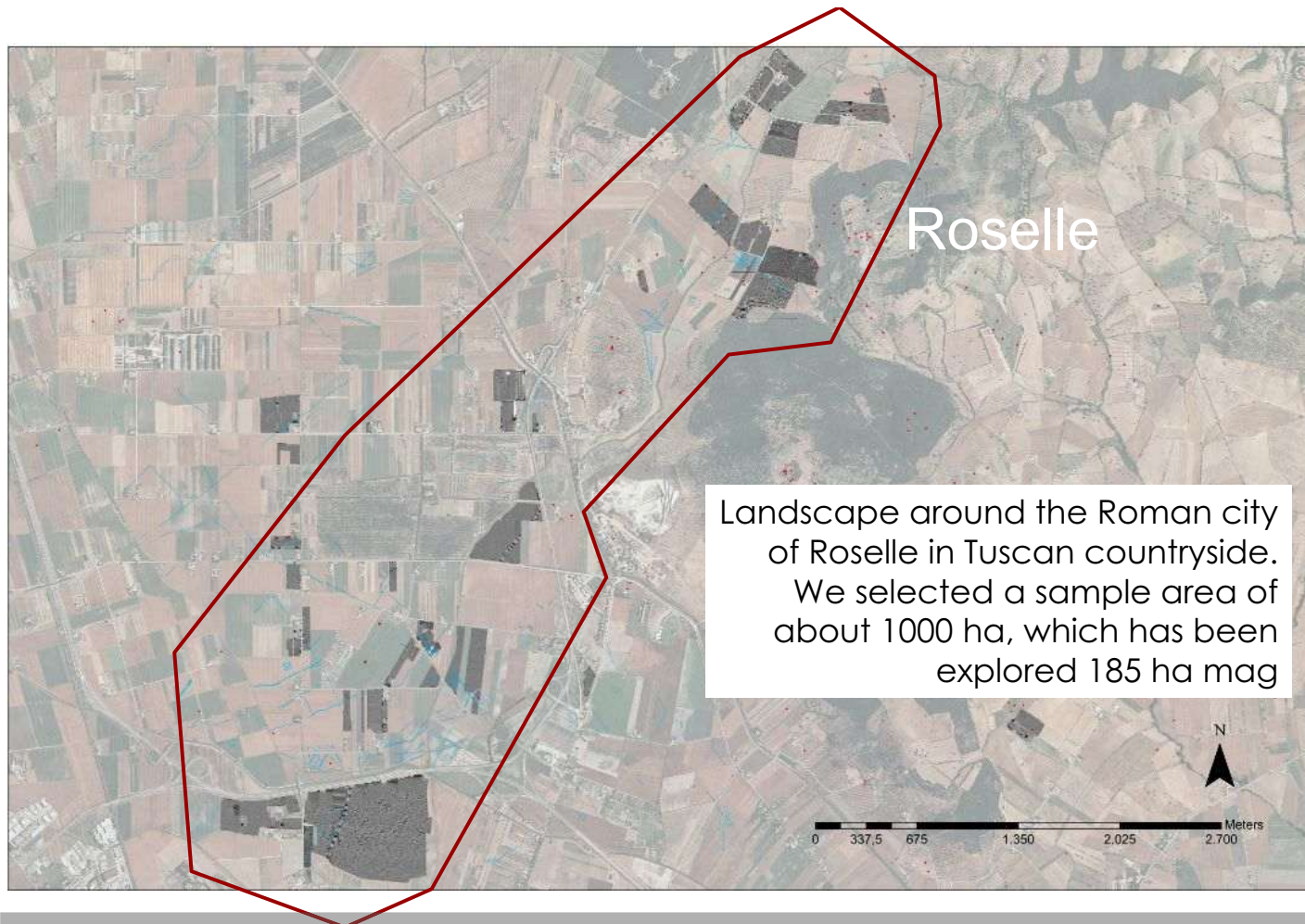
present

Veio (Italy): abandoned Etruscan and Roman City about 100ha
continuum mag



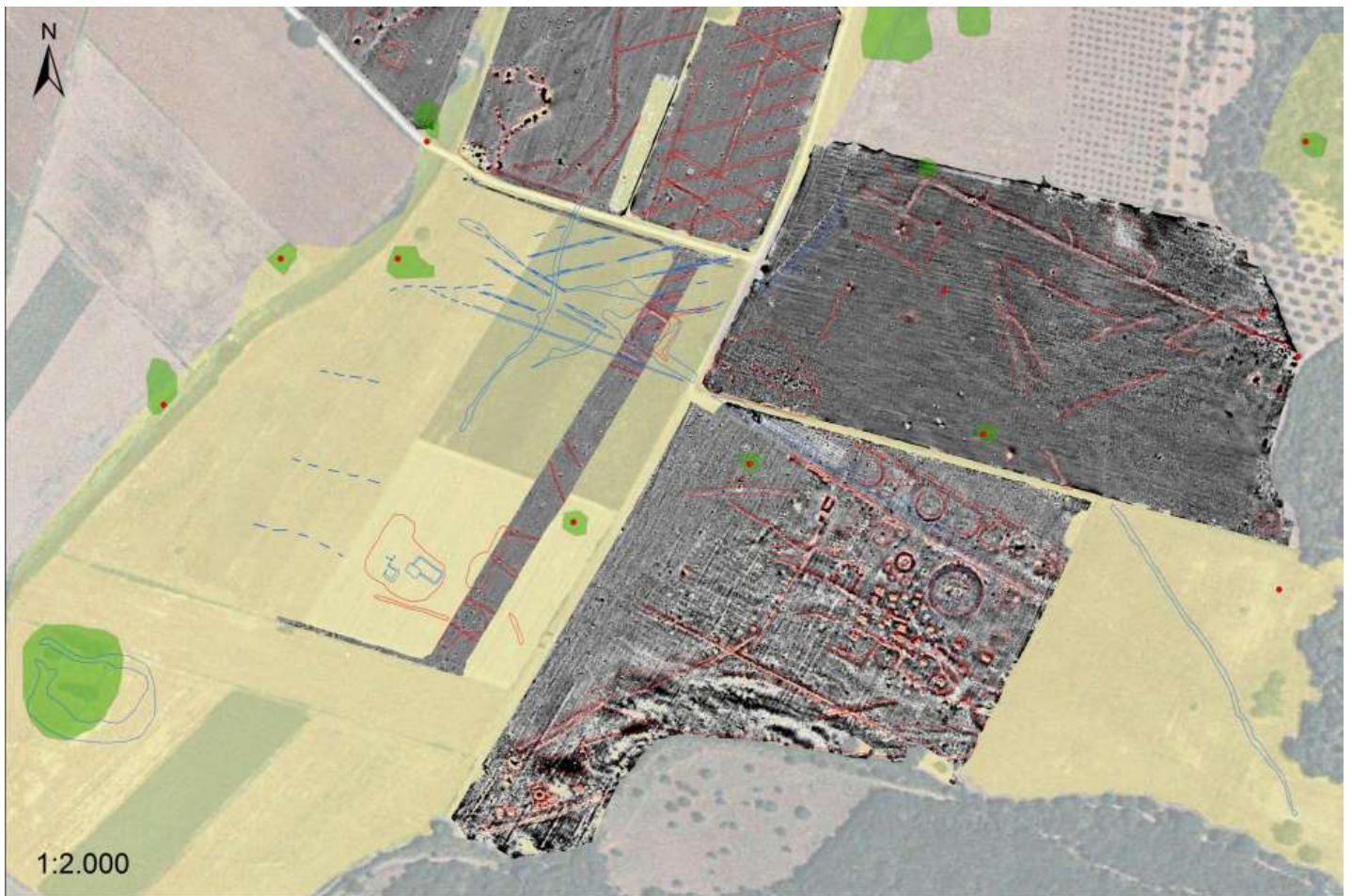
geophysics

present



geophysics

present



geophysics

present

- In the **past** geophysical prospection has been used to get information about **relatively small areas**. Most of archaeological survey cover about 1 or 2 ha notwithstanding sometimes has been surveyed larger areas.
- However a common trend is to **investigate only archaeological areas**. Archaeologist don't survey off-site.
- **Time has progressed changes in geophysics**. Gradiometers, resistivity meters and GPR can achieve in a day to around three hectares.
- The **area covered could be greatly enhanced** by constructing a new cart or trolley that **could be pulled by a quad bike**;



1ha/day

3 up to 4 ha/day



geophysics

present



geophysics

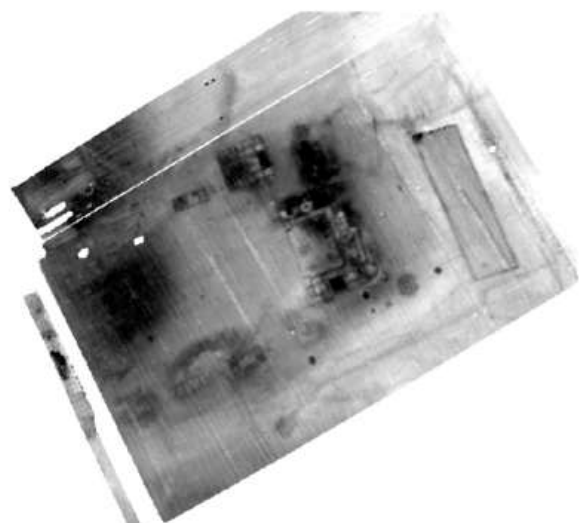
present



Automatic Resistivity Profiler - ARP©



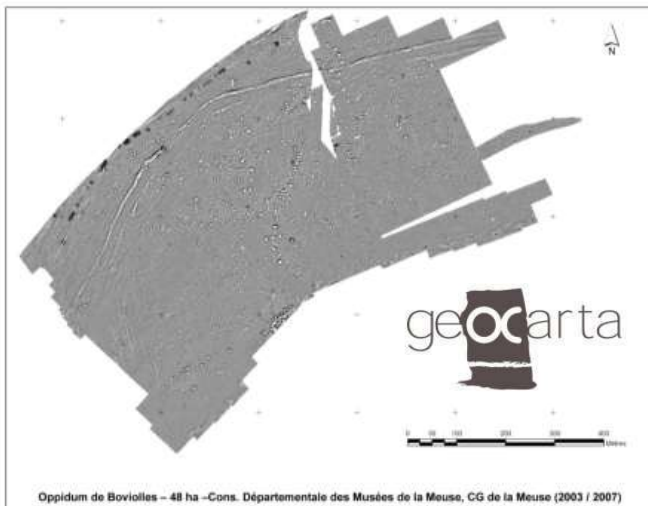
Carte de résistivité 0-2m – Méthode ARP
Site de Berthouville (12 ha – 2005 – CG27)
Mise en évidence du sanctuaire & du Théâtre



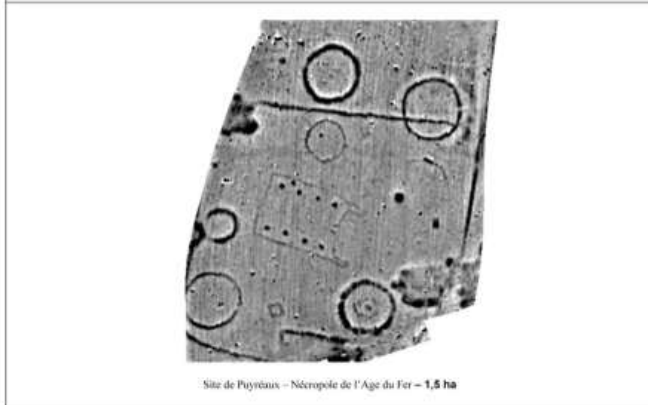
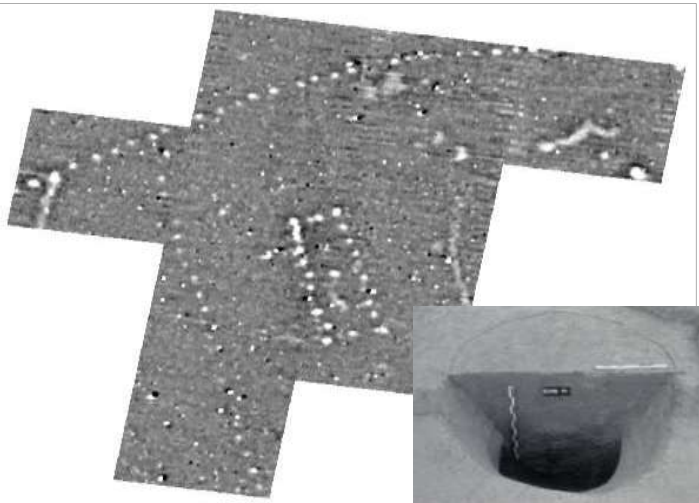
Carte de résistivité 0-1m – Méthode ARP
Site de Vaudoncourt (16 ha - Meuse)
Cartographie électrique d'une importante villa gallo-romaine

geophysics

present



Oppidum de Boviollles – 48 ha – Cons. Départementale des Musées de la Meuse, CG de la Meuse (2003 / 2007)



Site de Puyréaux – Nécropole de l'Âge du Fer – 1,5 ha



geophysics

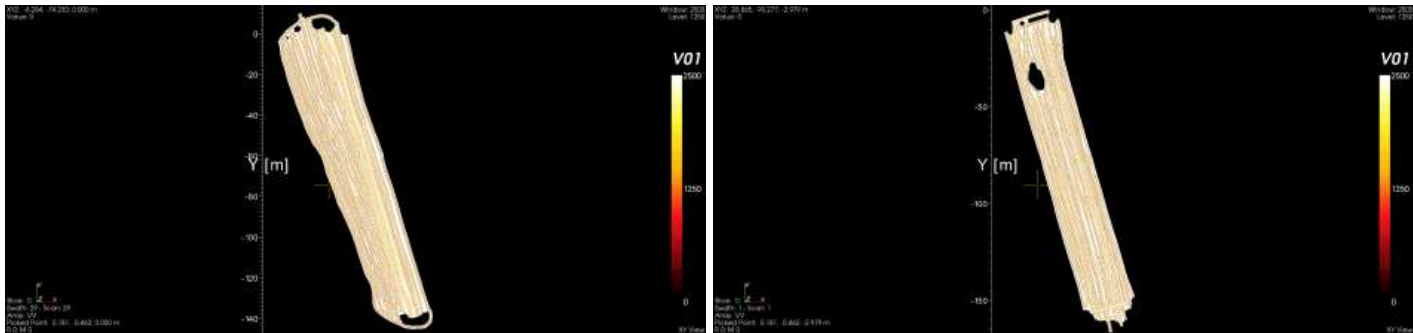
present/future



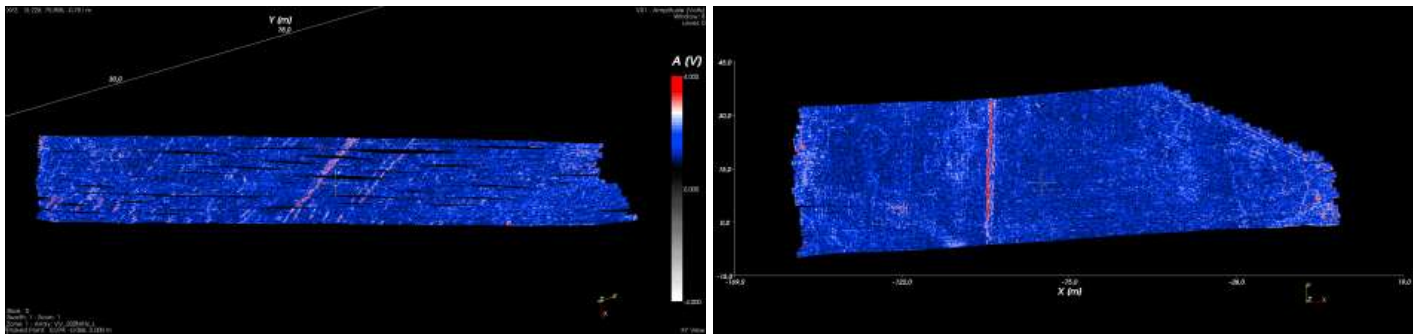
geophysics

present/future

Empuries (Girona – Spain)



Vieil-Evreux (France)



geophysics

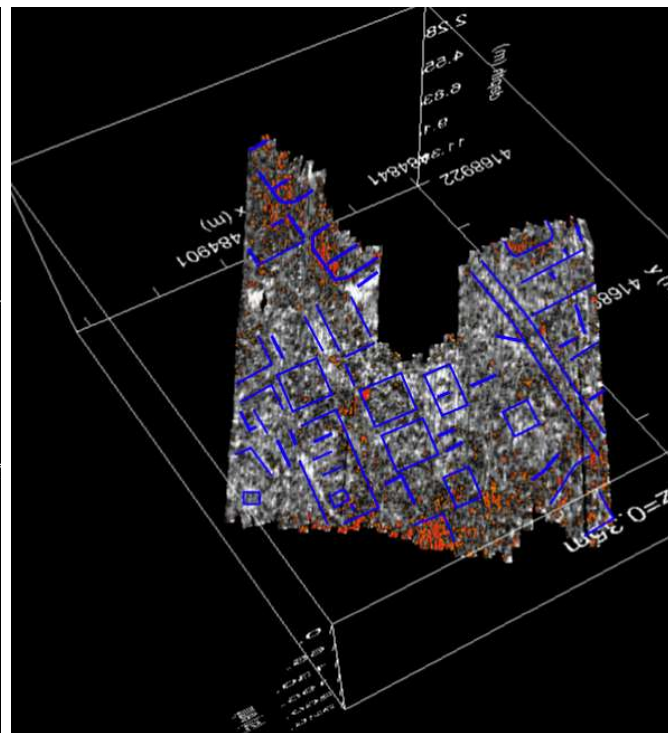
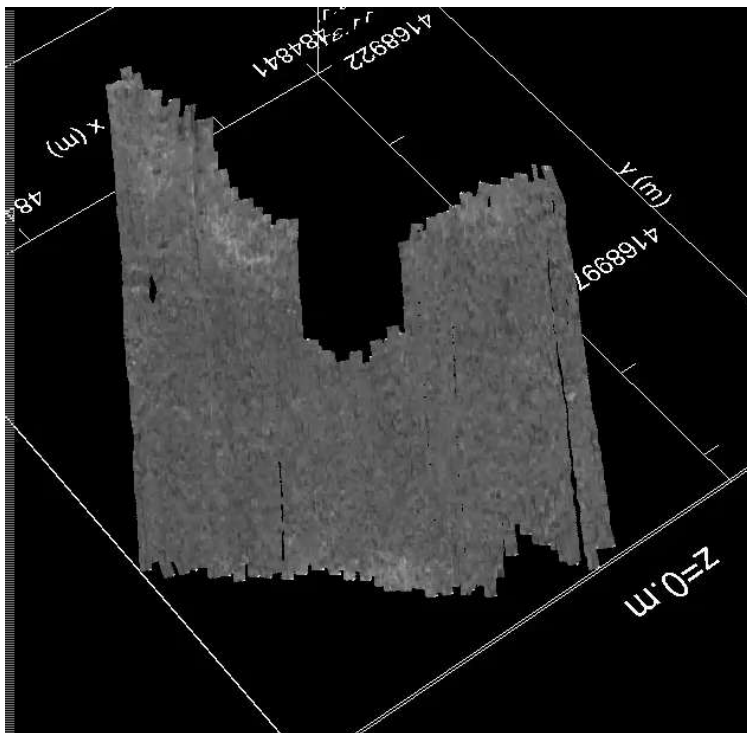
present



geophysics

present

Çatalhöyük (Turkey)



geophysics

present

NOW IT'S POSSIBLE TO APPLY
GEOPHYSICAL PROSPECTION ON
VERY LARGE SCALE IN A VERY SHORT TIME



=

THAT'S A
SCALE JUMP

FROM SITE-SCALE TO LANDSCAPE-SCALE

geophysics

future/present

That's a real innovation!

A real change in the practice and theory of archaeological process ... perhaps we could define this approach as a “revolution” in archaeology with consequence over at least:

- **CONSERVATION**
- **ARCHAEOLOGICAL ISSUES**
- **THE FUTURE**

geophysics

future/present

Final remarks

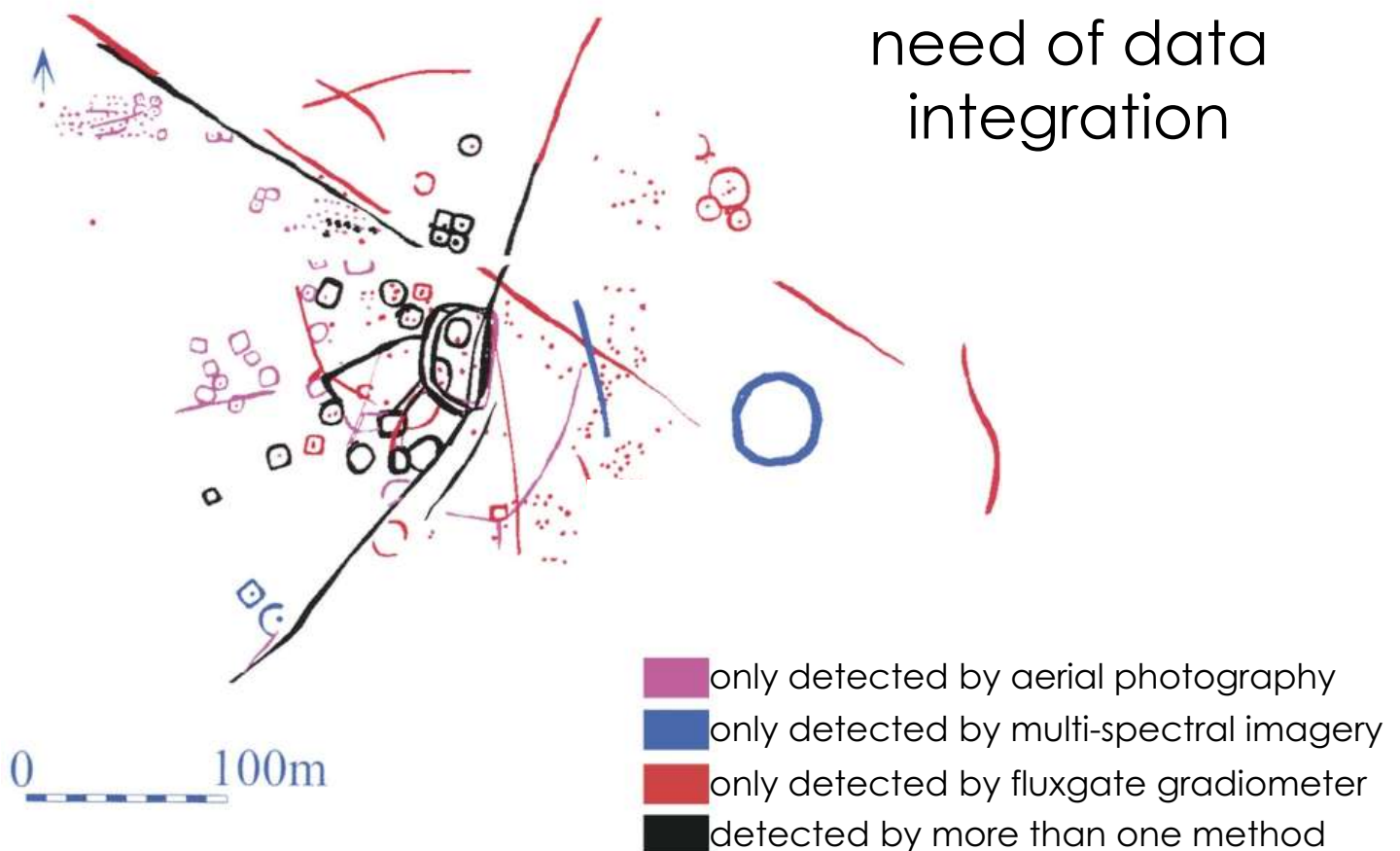


From this short presentation I hope it is clear how remote sensing is progressively increased from an **aseptic instrument aimed at documentation**, to an original methodology very effective for the **identification of archaeological sites**, to be become currently in the most advanced case histories the **key to overcome an outdated approach to archaeological research and conservation**, focuses on site and then on find.

It should be recognized that currently **WITHOUT INCLUDING REMOTE SENSING IN THE FRAMEWORK OF ARCHAEOLOGICAL RESEARCH** it is not possible to explore large sites and landscape in its complexity.

final remarks

future



final remarks

future

BUT ... WE ALSO Need integration of skills, experience and aims

1. Associations

Aerial Archaeology Research Group (AARG):

<http://www.univie.ac.at/aarg>

International Society for Archaeological Prospection:

<http://www.brad.ac.uk/archsci/archprospection/>

...



2. Universities and research centers

3. Networking remote sensing in archaeology

(Archeolandscapes EU project)



final remarks

future

thank you for your attention



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