



Virtual Archaeology in a Material World:

NEW TECHNOLOGIES ENABLING NOVEL PERSPECTIVES

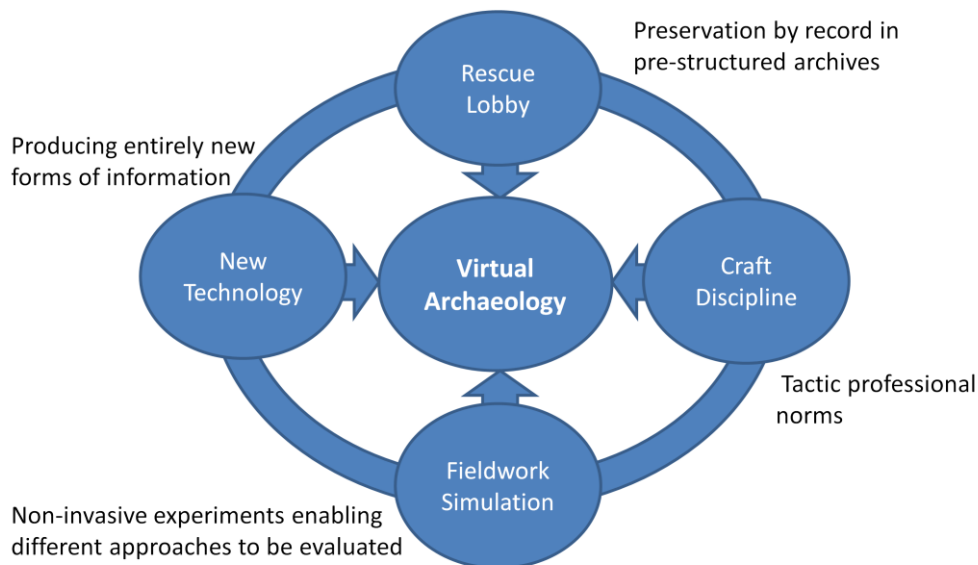
Gareth Beale & Paul Reilly

gareth.beale@york.ac.uk p.reilly@soton.ac.uk

CAA 2014, Paris

Paper presented to CAA 2014, Paris, 25th April 2014

Virtual Archaeology was conceived during a period of significant change in archaeological practice and tools



Four principal factors lead to the conception of virtual archaeology in 1990:

CLICK

Rescue archaeology lobbies had successfully positioned archaeological remains as priceless, irreplaceable resources under threat. If the remains could not be preserved *in situ*, a quasi-scientific system known as 'preservation by record' would be deployed; which involved recording observations into a *pre-structured* archive. *Archives that would become the foundation for all future interpretations and synthesis.*

CLICK

Archaeology, however, is a craft discipline. The use of tools, be they material, digital or conceptual, involves many tactic conventions that rarely get challenged; that is until new tools make possible the production of entirely new sorts of data, information, interpretation and, ultimately, archaeology

CLICK

In the 1980's archaeologists were embracing the rapidly expanding field of computer modelling and visualisation as vehicles for data exploration. Hypertext was also a very exciting emerging technology,

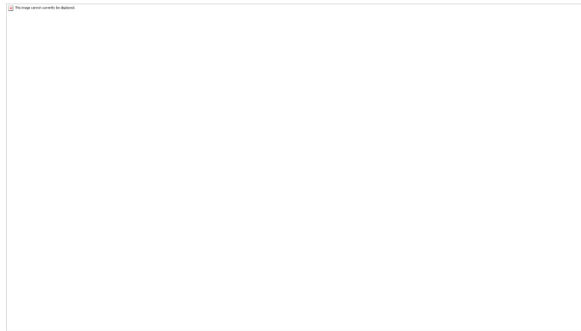
CLICK

Additionally, a number of innovative simulation studies evaluating survey methods and data processing had been published e.g., Fletcher & Spicer 's Clonehenge.

Virtual Archaeology was originally used to describe a multi-dimensional approach to the modelling of the primary physical structures and processes encountered in field archaeology

Modelling primary archaeological formations and processes to enable new ways of documenting, interpreting, annotating and narrating

Exploring the interplay between digital technologies and conventional archaeological practice



'Towards a Virtual Archaeology' CAA 1990 Revisited

In 1990, remember, excavation was acknowledged as an *unrepeatable experiment*. The challenge then was to demonstrate that the decisions on how to explore the raw archaeology have a decisive influence on the reported outcomes. We needed something that could be explored repeatedly in many different ways. The impasse was broken by invoking the concept of *virtuality*.

Virtual archaeology described the way in which technology could be harnessed in order to achieve new ways of documenting, interpreting and annotating primary archaeological materials and processes, and invited practitioners to explore the interplay between digital and conventional archaeological practice. The intent was to incite an epistemological rupture in conventional archaeological recording and representation of excavation data by demonstrating the arbitrariness of conventions, such as section- or plan- drawings and photographs, whilst demonstrating the possibility of developing new, radical, recording strategies, the relative advantages of which could be examined, discussed and evaluated in a non-destructive archaeological context.

In other words *Virtual Archaeology* was not only about 'what was' and 'what is' but a generative concept allowing for creativity and improvisation, in other words 'what might come to be'.

Virtual archaeology has become associated most strongly with the use of 3D computer graphics and VR in archaeological research. There can be little doubt that these activities form a part of what might be considered virtual archaeology but **they do not comfortably** define the limits of the original term. I must make clear that term *virtual reality* was deliberately avoided, and the non-graphical aspects of

modelling were highlighted.

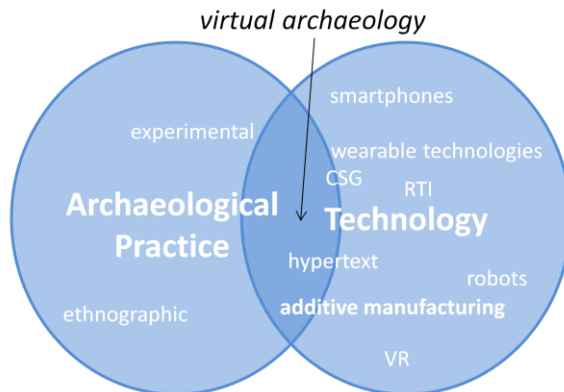
The *spirit of virtual archaeology* renders explicit the dynamic relationship between archaeological practice and technology

The spirit of virtual archaeology remains an adaptive concept

- Authentically archaeological
- Inherently changeable
- Technologically contemporaneous



Of paramount importance is the need to focus on the practice of adopting technology as well as the technology itself



Reifying virtual archaeology into a specific technology amalgam is to miss the point. The notion behind virtual archaeology was, and remains, useful for emphasising the intersection between technology and archaeological practice. For want of a better term, the *spirit of virtual archaeology* describes something which is inherently changeable, and which depends on the availability of technology and its potential utility within a specific situation.

Recent technological developments have led to a proliferation of devices and software which augment, and often enhance, the human experience of the world. Consider for example, wearable technology, the ubiquity of increasingly powerful smartphones and scanners, or the development of 3D printing.

The later especially is not synthetically haptic but authentically tactile and blended with the physical world, offering renewed sensorial prominence and perhaps more cognitive depth through material engagement.

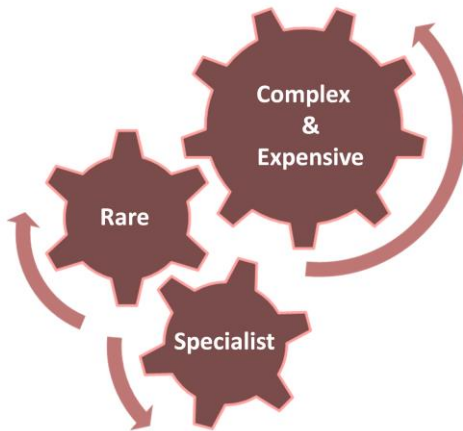
So, the specific technological emphasis says more about the state of technological development than it does about the essential meaning or relevance of the term.

CLICK

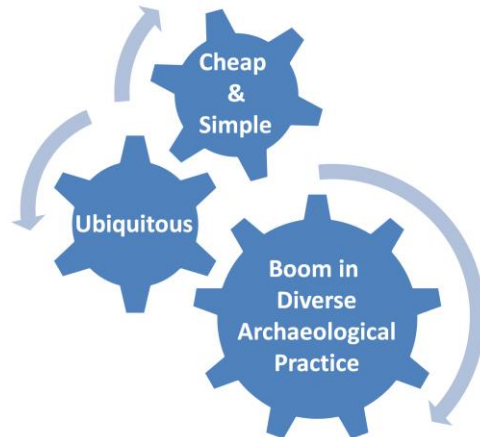
What remains of paramount importance is the need to focus on the practice of adopting technology as well as the technology itself.

Recent changes in archaeology-born digital imaging practice highlights some issues and opportunities in new technology adoption

2004 Restricted Specialism



2014 Unfettered Innovation



2 & 3D digital imaging is a useful case study through which to consider the restrictions and opportunities which the adoption of new technology can present to archaeological practice.

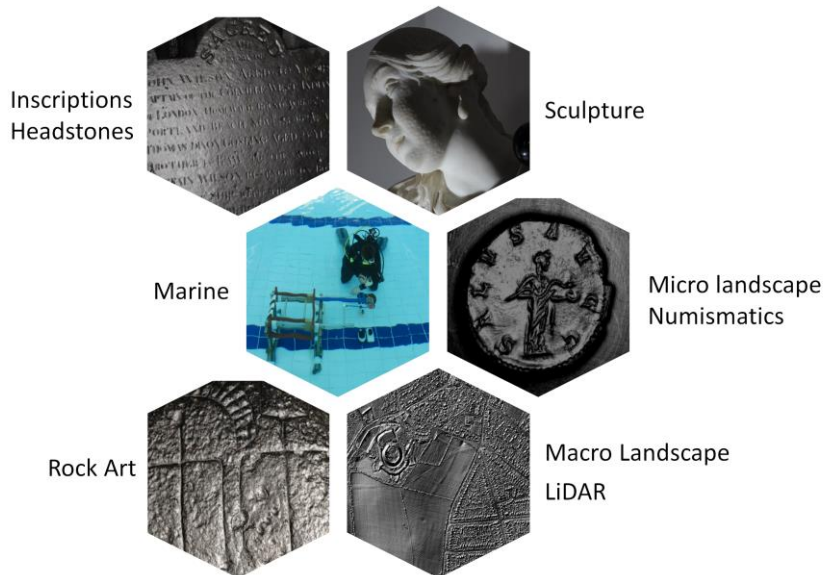
As recently as 10 years ago, digital cameras were comparatively rare and highly prized objects. We also had 'specialist devices' such as laser and structured light scanners which were dedicated to the creation of 3D data. The costs involved in these processes were enormous, requiring specialists to operate equipment and process data. This outsourcing of recording disrupts established patterns of archaeological practice. This is not to say by the way these specialists are not skilled archaeologists in their own right, but rather that we should not accept that the divide between technicians and archaeologists is inevitable.

CLICK TWICE

Consider computational photography. Today, almost everyone on site has a digital camera. Recent developments have sought to exploit the ubiquity of digital imaging devices in order to bring sophisticated digital imaging to the mass market. Sometimes this is a commercial process (as we have seen with Autodesk's 123D catch or Microsoft's Photosynth) and sometimes it is an open source, community driven process as we have seen with Reflectance Transformation Imaging?

The low resource burden associated with the use of these technologies has led to a boom in archaeological innovation.

RTI is an open source tool being developed organically by a community of researchers in order to suit their requirements



Images courtesy of Eleni Kotoula, David Selmo, Nicole Beale

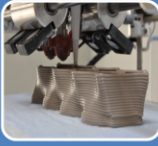
RTI (an open source computational photography tool) is a perfect example of this. Initial investment by cultural heritage organisations such as cultural heritage imaging has led to a tool which is:

- Developed by archaeological and cultural heritage organisations for their own uses
- Being widely adopted, not by those promoting digital archaeological but by those wishing to maximise the impact of their own research
- Being used in a wide range of unexpected ways by different researchers in different places according to need. E.g. the technique can be applied to surface models of remotely sensed data, such as large landscape survey using LiDAR, or micro-landscapes such as CT scans of buried coins. Marine housing have been designed and are under test.

What this shows is that if you give a community of skilled people a new tool THEY will tell YOU how, when and if it is useful to them. You only need to explain it and make sure that it is available.

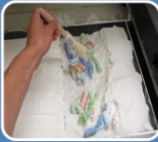
The original proposition of virtual archaeology was an expression of the need to focus on the interplay between archaeological practice and new technology. This example demonstrates that by focussing in this way we can maximise the impact of the limited resources which we have available and can develop technological approaches which not only reject the 'one size fits all'

Re-engagement with the *spirit of virtual archaeology* is possible through Additive Manufacturing technologies



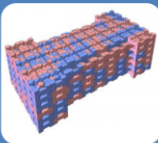
Selective extrusion deposition printers

Squirts, squeezes or sprays pastes or powders
Nozzles, Syringes, funnels



Selective binding printers

Fuse, bind or glue the raw materials

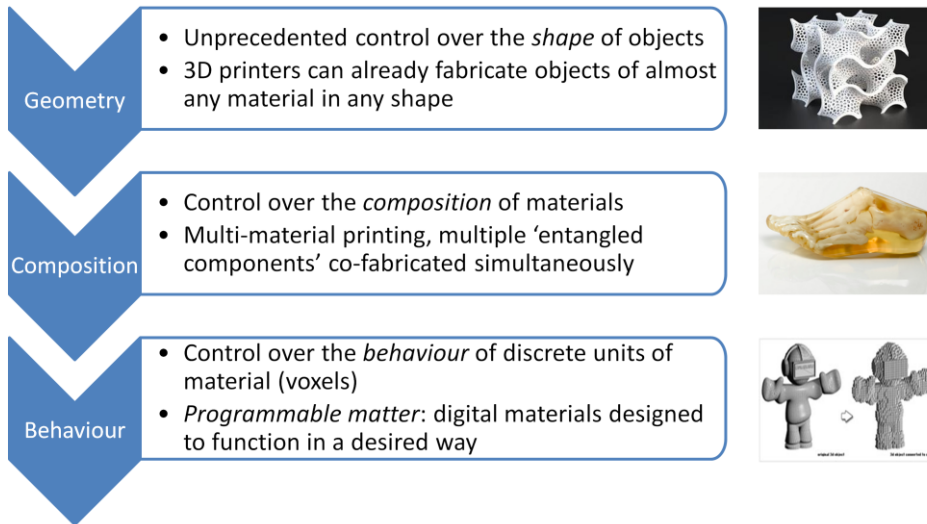


Digital assembly

Pre-manufactured multi-material physical voxels

Re-engagement with the *spirit of virtual archaeology* is possible through technologies such as Additive Manufacturing, by which we mean the general industry modes rather than the much over-hyped 3D printers and rapid prototyping.

The evolution of Additive Manufacturing can be summarised as three phases of gaining control over physical matter: geometry, composition, and behaviour



H. Lipson and M. Kurmar, *Fabricated: the new world of 3D printing*. Wiley, 2013.

Lipson and Kurmar summarise the evolution of additive manufacturing as three episodes *of gaining control over physical matter*.

First is an unprecedented control over the *shape* of objects. 3D printers can already fabricate objects of almost any material in any shape.

Next, comes control over the *composition* of matter. We are entering a new episode where we go beyond just shaping external geometries to shaping the internal structure of materials with unprecedented fidelity, with the possibility of printing multiple materials and 'entangled components' which can be co-fabricated simultaneously.

The final stage is control over the *behaviour* of materials, where they envisage programmable digital materials- made of discrete, discontinuous units - materials which are designed to function in a desired way, eg. Spongy, transparent, in shades of grey, perhaps even embedded with nano devices.

Voxel-based printing affords the notion of different types of voxels. Imagine, if you will, a library of archaeological material-voxel types.

Control over shape provides a bridge between existing 3D modelling formats and 3D printed physical objects



LANDSCAPE & TOPOGRAPHY

- Point clouds, TINs, and solid models, can be 3D (re)printed using the STL format, via CAD, GIS, etc., systems
- E.g., Topography and stratigraphic interfaces



Peter loewe, Jens klump (GeGIT), Jens Wickert 3rd April 2013

Control over *shape* provides a bridge between existing 3D modelling formats and the ability to repurpose them as 3D printed physical objects. Existing point clouds, Terrain and solid models, indeed any system that can output STL format files can be 3D printed.

For example at the top you see a 3D print of Mt. St. Helens, Washington, in the USA. It is available on Shapeways.com in 3 sizes!

The 3D printed stratigraphy you see is a stack of geology from north eastern Germany, prepared by geologists.

Although these are solid objects made of a single material, with the same density throughout, they still communicate in a tangible fashion.

Architects already design and 3D print model and full-scale buildings and architectural elements including prototype lunar bases



MONUMENTS

Image courtesy of Midwest Studios. Photo: Ed Watson



<http://www.digital-grotesque.com/#2>



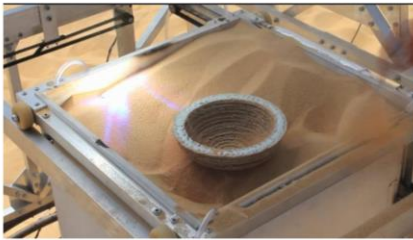
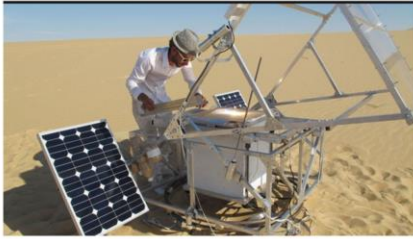
http://www.esa.int/Highlights/Lunar_3D_printing

The detailed architectural model in the top left was generated the architects' CAD files. In keeping with the Carmelite Rule, this new foundation is being built as a classic gothic monastery in Wyoming, USA.

The ultra-modern gothic-like interior below was assembled from 64 massive separate printed sandstone-like parts, and contains 260 million surfaces printed at a resolution of a tenth of a millimetre.

On the RHS, the space agencies are actively exploring the feasibility of building future moon bases using Fabricators exploiting local materials, that is the regolith or lunar soil. Of course, here – and this is central - they are using simulants (virtual properties).

**Example Additive Manufacturing materials case studies:
printing sand (glass), soil and organic materials (e.g., seeds)**



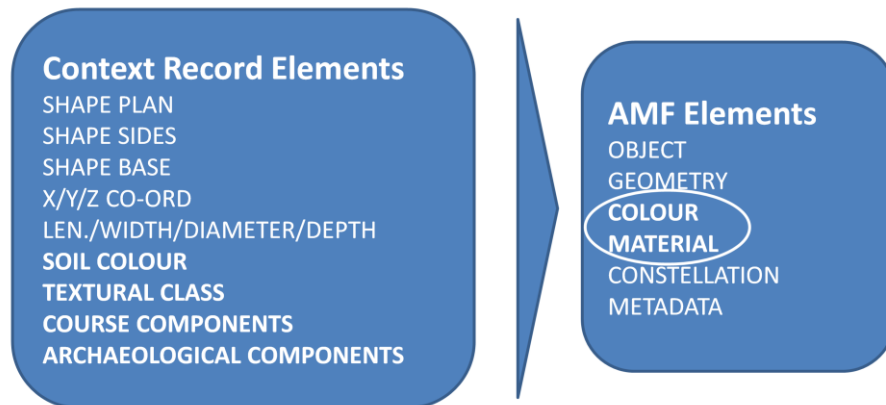
Solar Sinter - <http://www.markuskayser.com/>



© Tinkai Zedema
<http://www.treehugger.com/gadgets/students-create-3d-grass-printer.html>

Here you see sand being solar sintered into glass- ,and soil, containing seeds, formed into artistic vessels.

Materialisation: the Additive Manufacturing File (AMF) format encapsulates all the elements of an archaeological context record



make possible a closer alignment between virtual and physical worlds

As additive manufacturing evolved, from producing primarily single-material, homogenous shapes to producing multi-material geometries in full colour with functionally graded materials and microstructures, it created the need for the AMF standard interchange file format that could support these powerful new features.

CLICK

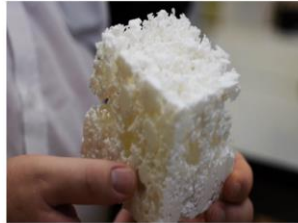
What is striking about the AMF format is that it encapsulates the typical archaeological excavation recording sheet, but in much finer *spatio-compositional* detail. If we did recast our recording method to generate contexts described in an AMF-like format, we suggest that archaeology would be a step closer to aligning the virtual and physical worlds, and a step closer towards the possibility of rematerialising archaeological *entities* found' in the field.

So what is to stop us from recording our excavations in such a way as they can be refabricated? Our current methods are clearly deficient here, but we're not suggesting 3D-printing all our excavations. We submit that if we recorded in such a way that we could (rematerialise/refabricate our excavations), then we would have improved substantively our practice.

Near *in situ* virtual (re)excavation of some contexts, soils and archaeological components revealing their intricate and detailed structure and form non-intrusively



Computer Tomography (CT) with 3D printing provide the ability to examine the structure of soil 'close up' and, for example, set-up multiple experimental investigations



W. Otten & R. Falconer, Abertay University

CT allows a detailed, non-intrusive investigation of a coin hoard *in situ* within a pot, with individual coins being isolated virtually from the fill and 3D printed



R. Boardman, G. Cox, M. Mavrogordato & J. Miles, University of Southampton
<https://vimeo.com/45452797>

Glimpses of *Additive Archaeology*, one particular essence of virtual archaeology materialised through additive manufacturing can be discerned 3D-printed soils and virtual excavations involving both scientific visualisations and 3D printing.

Combining CT and 3D printing, soil scientist have the ability to explore something so intricate and detailed as the structure of soil, close up, and set up multiple experimental investigations.

James Miles and Grant Cox in the Archaeological Computing Research Group and colleagues in the Mu-Vis CT Centre in the University of Southampton, have been able to disaggregate and re-aggregate non-intrusively a coin hoard found in one of two pots near Selby in the north of England. The CT data, which can be resolved as down as two microns, were processed to produce both this animation and 3D prints of some of the coins.

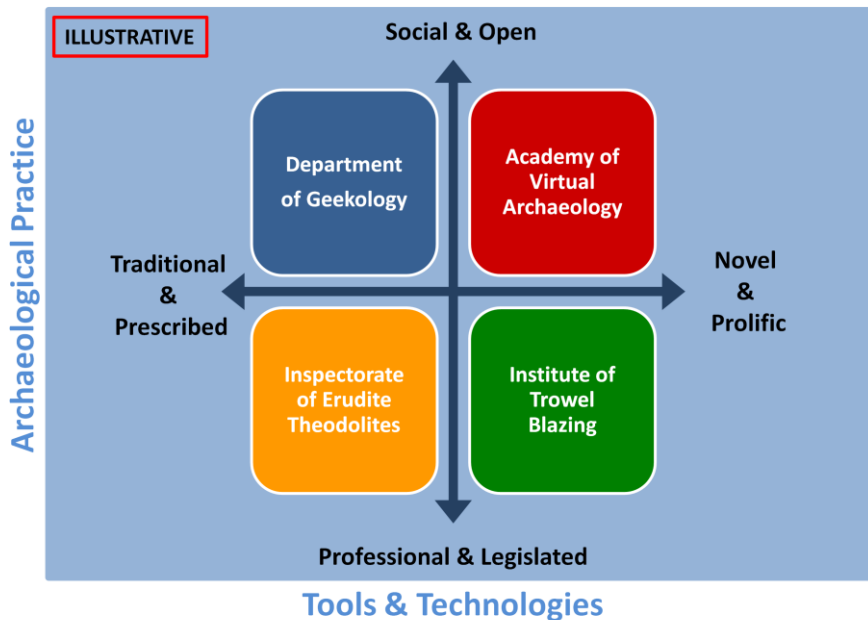
The *spirit of virtual archaeology* remains a useful way of introducing new and potentially disruptive technology to transform archaeological practice positively

- Emerging technologies such as Additive Manufacturing and 3D Imaging continue to refocus the spirit of virtual archaeology
- Digital literacy across diverse archaeological communities vastly expands involvement in processes of adopting, developing and using digital technologies
- The virtual archaeologist's role is changing from role of digital archaeology specialist to emerging technologies knowledge broker and mentor
- Requirement to introduce and develop approaches for strategic innovation in archaeological practice

In conclusion, Digital Imaging and additive manufacturing are just two technologies enabling the *spirit of virtual archaeology* to continue to generate new challenges to transform archaeological practice positively.

Printing artefacts, monuments and cultural landscapes is established. We contend that additive manufacturing provides a credible challenge to traditional archaeological practices of recording.

Scenario Planning Example Issue: how should we introduce new tools and techniques into future archaeological practice?

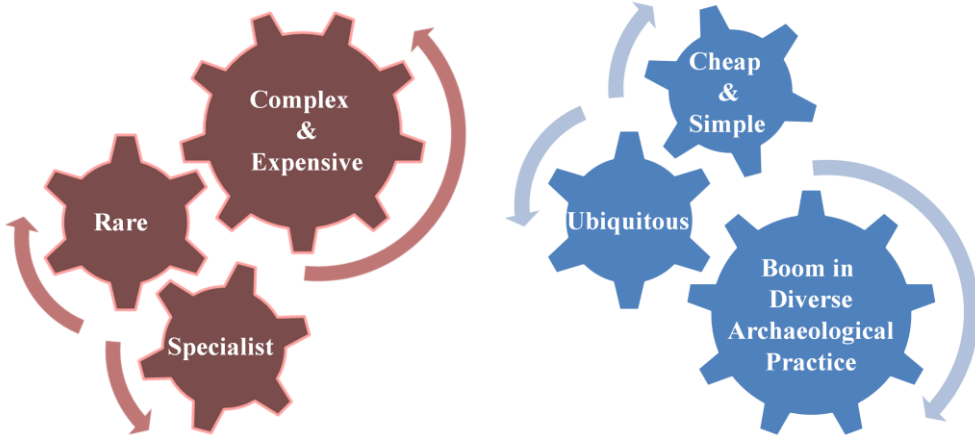


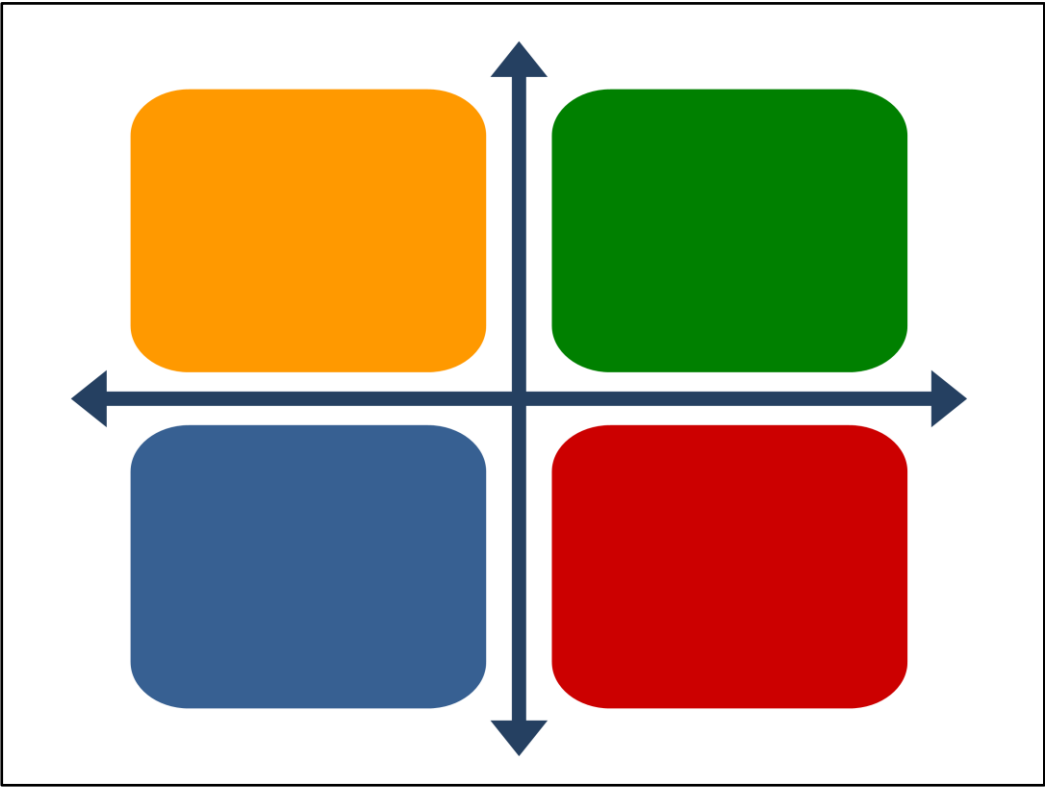
Scenario planning is one approach which has the potential to help us develop better *future-mindedness* or action with the future in mind. Put simply, we need to answer one key question: ‘what do we need to do now to be ready for all scenarios?’ The answers can inform the formulation of strategies to cope with contrasting pictures of the future.

We intend to elaborate the potential value of this approach to enhancing archaeological practice elsewhere.,

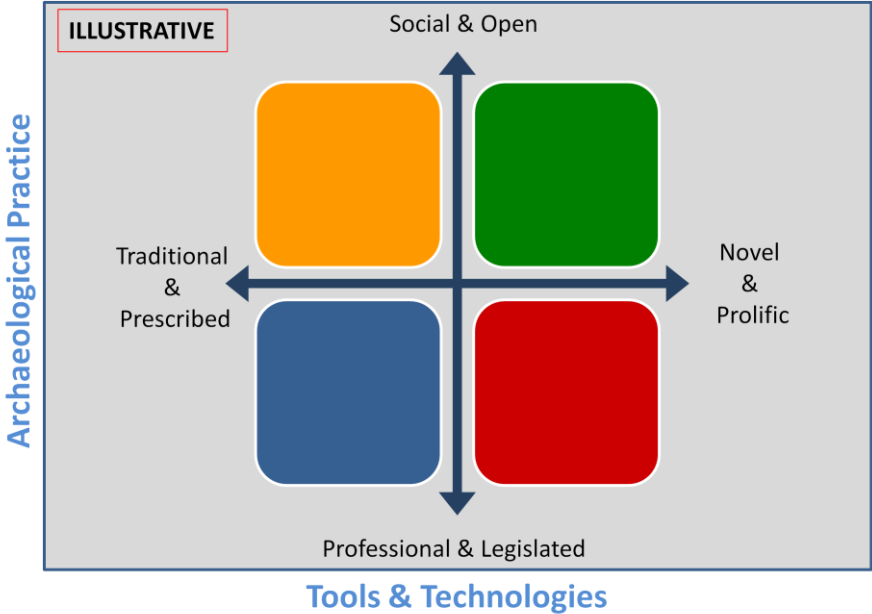


2004 Outsourced recording ➡ 2014 Unfettered innovation

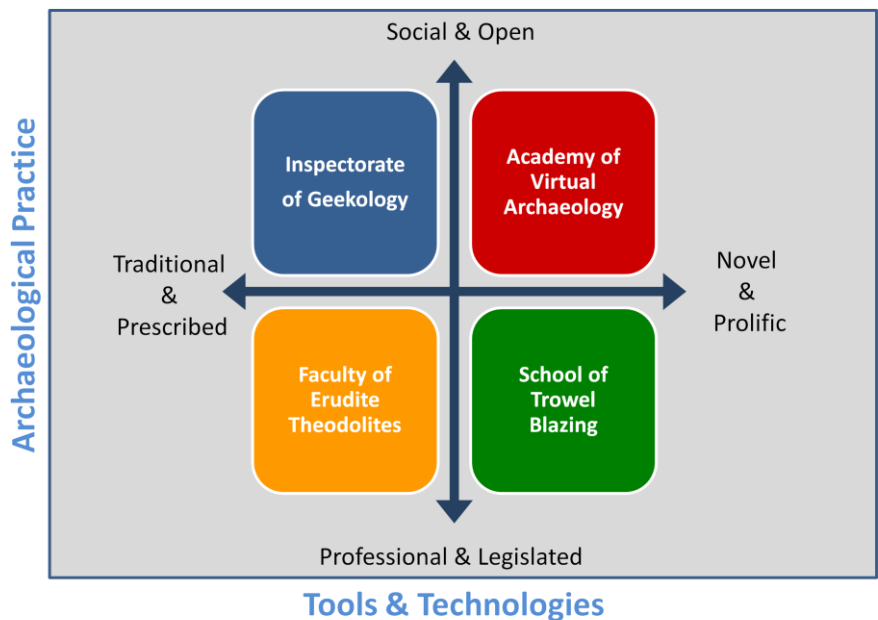




Scenario Planning blank template: e.g., introducing new tools and techniques into future archaeological practices



Scenario Planning template: e.g., introducing new tools and techniques into future archaeological practices



Scenario Planning Template: e.g., access to archaeology through tools and techniques

