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3.3. CSS for Success? Some Thoughts on Adapting the Browser-Based Archaeological Recording Kit (ARK) for Mobile Recording

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MOBILIZING the PAST for a DIGITAL FUTURE

The Potential of Digital Archaeology

Edited by

Erin Walcek Averett
Jody Michael Gordon
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FOR A
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Preface & Acknowledgments

This volume stems from the workshop, "Mobilizing the Past for a Digital Future: the Future of Digital Archaeology," funded by a National Endowment for the Humanities Digital Humanities Start-Up grant (#HD-51851-14), which took place 27-28 February 2015 at Wentworth Institute of Technology in Boston (http://uwm.edu/mobilizing-the-past/). The workshop, organized by this volume's editors, was largely spurred by our own attempts with developing a digital archaeological workflow using mobile tablet computers on the Athienou Archaeological Project (http://aap.toumazou.org; Gordon *et al.*, Ch. 1.4) and our concern for what the future of a mobile and digital archaeology might be. Our initial experiments were exciting, challenging, and rewarding; yet, we were also frustrated by the lack of intra-disciplinary discourse between projects utilizing digital approaches to facilitate archaeological data recording and processing.

Based on our experiences, we decided to initiate a dialogue that could inform our own work and be of use to other projects struggling with similar challenges. Hence, the "Mobilizing the Past" workshop concept was born and a range of digital archaeologists, working in private and academic settings in both Old World and New World archaeology, were invited to participate. In addition, a livestream of the workshop allowed the active participation on Twitter from over 21 countires, including 31 US states (@MobileArc15, #MobileArc).[1]

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[1] For commentary produced by the social media followers for this event, see: https://twitter.com/electricarchaeo/status/571866193667047424, http://shawngraham.github.io/exercise/mobilearcday1wordcloud.html, https://twitter.com/electricarchaeo/status/571867092091338752, http://www.diachronicdesign.com/blog/2015/02/28/15-mobilizing-the-past-for-the-digital-future-conference-day-1-roundup/.

Although the workshop was initially aimed at processes of archaeological data recording in the field, it soon became clear that these practices were entangled with larger digital archaeological systems and even socio-economic and ethical concerns. Thus, the final workshop's discursive purview expanded beyond the use of mobile devices in the field to embrace a range of issues currently affecting digital archaeology, which we define as the use of computerized, and especially internet-compatible and portable, tools and systems aimed at facilitating the documentation and interpretation of material culture as well as its publication and dissemination. In total, the workshop included 21 presentations organized into five sessions (see program, http://mobilizingthepast.mukurtu.net/digital-heritage/mobilizing-past-conference-program), including a keynote lecture by John Wallrodt on the state of the field, "Why paperless?: Digital Technology and Archaeology," and a plenary lecture by Bernard Frischer, "The Ara Pacis and Montecitorio Obelisk of Augustus: A Simpirical Investigation," which explored how digital data can be transformed into virtual archaeological landscapes.

The session themes were specifically devised to explore how archaeological data was digitally collected, processed, and analyzed as it moved from the trench to the lab to the digital repository. The first session, "App/Database Development and Use for Mobile Computing in Archaeology," included papers primarily focused on software for field recording and spatial visualization. The second session, "Mobile Computing in the Field," assembled a range of presenters whose projects had actively utilized mobile computing devices (such as Apple iPads) for archaeological data recording and was concerned with shedding light on their utility within a range of fieldwork situations. The third session, "Systems for Archaeological Data Management," offered presentations on several types of archaeological workflows that marshal born-digital data from the field to publication, including fully bespoken paperless systems, do-it-yourself ("DIY") paperless systems, and hybrid digital-paper systems. The fourth and final session, "Pedagogy, Data Curation, and Reflection," mainly dealt with teaching digital methodologies and the use of digital repositories and linked open data to enhance field research. This session's final paper, William Caraher's "Toward a Slow Archaeology," however, noted digital archaeology's successes in terms of

time and money saved and the collection of more data, but also called for a more measured consideration of the significant changes that these technologies are having on how archaeologists engage with and interpret archaeological materials.

The workshop's overarching goal was to bring together leading practitioners of digital archaeology in order to discuss the use, creation, and implementation of mobile and digital, or so-called "paperless," archaeological data recording systems. Originally, we hoped to come up with a range of best practices for mobile computing in the field – a manual of sorts – that could be used by newer projects interested in experimenting with digital methods, or even by established projects hoping to revise their digital workflows in order to increase their efficiency or, alternatively, reflect on their utility and ethical implications. Yet, what the workshop ultimately proved is that there are many ways to "do" digital archaeology, and that archaeology as a discipline is engaged in a process of discovering what digital archaeology should (and, perhaps, should not) be as we progress towards a future where all archaeologists, whether they like it or not, must engage with what Steven Ellis has called the "digital filter."

So, (un)fortunately, this volume is not a "how-to" manual. In the end, there seems to be no uniform way to "mobilize the past." Instead, this volume reprises the workshop's presentations—now revised and enriched based on the meeting's debates as well as the editorial and peer review processes—in order to provide archaeologists with an extremely rich, diverse, and reflexive overview of the process of defining what digital archaeology is and what it can and should perhaps be. It also provides two erudite response papers that together form a didactic manifesto aimed at outlining a possible future for digital archaeology that is critical, diverse, data-rich, efficient, open, and most importantly, ethical. If this volume, which we offer both expeditiously and freely, helps make this ethos a reality, we foresee a bright future for mobilizing the past.

* * *

No multifaceted academic endeavor like *Mobilizing the Past* can be realized without the support of a range of institutions and individ-

research and for allowing us to integrate mobile devices and digital workflows in the field.

The workshop itself benefitted from the help of Kathryn Grossman (Massachusetts Institute of Technology) and Tate Paulette (Brown University) for on-site registration and much more. Special thanks goes to Daniel Coslett (University of Washington) for graphic design work for both the workshop materials and this volume. We would also like to thank Scott Moore (Indiana University of Pennsylvania) for managing our workshop social media presence and his support throughout this project from workshop to publication.

This publication was a pleasure to edit, thanks in no small part to Bill Caraher (Director and Publisher, The Digital Press at the University of North Dakota), who provided us with an outstanding collaborative publishing experience. We would also like to thank Jennifer Sacher (Managing Editor, INSTAP Academic Press) for her conscientious copyediting and Brandon Olson for his careful reading of the final proofs. Moreover, we sincerely appreciate the efforts of this volume's anonymous reviewers, who provided detailed, thought-provoking, and timely feedback on the papers; their insights greatly improved this publication. We are also grateful to Michael Ashley and his team at the Center for Digital Archaeology for their help setting up the accompanying Mobilizing the Past Mukurtu site and Kristin M. Woodward of the University of Wisconsin-Milwaukee Libraries for assistance with publishing and archiving this project through UWM Digital Commons. In addition, we are grateful to the volume's two respondents, Morag Kersel (DePaul University) and Adam Rabinowitz (University of Texas at Austin), who generated erudite responses to the chapters in the volume. Last but not least, we owe our gratitude to all of the presenters who attended the workshop in Boston, our audience from the Boston area, and our colleagues on Twitter (and most notably, Shawn Graham of Carlton University for his word clouds) who keenly "tuned in" via the workshop's livestream. Finally, we extend our warmest thanks to the contributors of this volume for their excellent and timely chapters. This volume, of course, would not have been possible without such excellent papers.

As this list of collaborators demonstrates, the discipline of archaeology and its digital future remains a vital area of interest for people who value the past's ability to inform the present, and who

recognize our ethical responsibility to consider technology's role in contemporary society. For our part, we hope that the experiences and issues presented in this volume help to shape new intra-disciplinary and critical ways of mobilizing the past so that human knowledge can continue to develop ethically at the intersection of archaeology and technology.

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Jody Michael Gordon (Department of Humanities and Social Sciences, Wentworth Institute of Technology)

Derek B. Counts (Department of Art History, University of Wisconsin-Milwaukee)

October 1, 2016
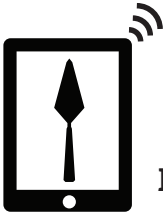
How To Use This Book

The Digital Press at the University of North Dakota is a collaborative press and *Mobilizing the Past for a Digital Future* is an open, collaborative project. The synergistic nature of this project manifests itself in the two links that appear in a box at the end of every chapter.

The first link directs the reader to a site dedicated to the book, which is powered and hosted by the Center for Digital Archaeology's (CoDA) Mukurtu.net. The Murkutu application was designed to help indigenous communities share and manage their cultural heritage, but we have adapted it to share the digital heritage produced at the "Mobilizing the Past" workshop and during the course of making this book. Michael Ashley, the Director of Technology at CoDA, participated in the "Mobilizing the Past" workshop and facilitated our collaboration. The Mukurtu.net site (https://mobilizingthepast.mukurtu.net) has space dedicated to every chapter that includes a PDF of the chapter, a video of the paper presented at the workshop, and any supplemental material supplied by the authors. The QR code in the box directs readers to the same space and is designed to streamline the digital integration of the paper book.

The second link in the box provides open access to the individual chapter archived within University of Wisconsin-Milwaukee's installation of Digital Commons, where the entire volume can also be downloaded. Kristin M. Woodward (UWM Libraries) facilitated the creation of these pages and ensured that the book and individual chapters included proper metadata.

Our hope is that these collaborations, in addition to the open license under which this book is published, expose the book to a wider audience and provide a platform that ensures the continued availability of the digital complements and supplements to the text. Partnerships with CoDA and the University of Wisconsin-Milwaukee reflect the collaborative spirit of The Digital Press, this project, and digital archaeology in general.

Abbreviations

AAI	Alexandria Archive Institute
AAP	Athienou Archaeological Project
ABS	acrylonitrile butadiene styrene (plastic)
ADS	Archaeological Data Service
Alt-Acs	Alternative Academics
API	application programming interface
ARA	archaeological resource assessment
ARC	Australian Research Council
ARIS	adaptive resolution imaging sonar
ASV	autonomous surface vehicle
BLM	Bureau of Land Management
BLOB	Binary Large Object
BOR	Bureau of Reclamation
BYOD	bring your own device
CAD	computer-aided design
CDL	California Digital Library
CHDK	Canon Hack Development Kit
cm	centimeter/s
CMOS	complementary metal-oxide semiconductor
CoDA	Center for Digital Archaeology
COLLADA	COLLAborative Design Activity
CRM	cultural resource management
CSS	Cascading Style Sheet
CSV	comma separated values
DBMS	desktop database management system
DEM	digital elevation model
DINAA	Digital Index of North American Archaeology
DIY	do-it-yourself
DoD	Department of Defense
DVL	doppler velocity log
EAV	entity-attribute-value
EDM	electronic distance measurement
EU	excavation unit/s
FAIMS	Federated Archaeological Information Management System
fMRI	functional magnetic resonance imaging
GIS	geographical information system
GCP	ground control point
GNSS	global navigation satellite system
GPR	ground-penetrating radar

GUI	graphic user interface
ha	hectare/s
hr	hour/s
Hz	Hertz
HDSM	high-density survey and measurement
ICE	Image Composite Editor (Microsoft)
iOS	iPhone operating system
INS	inertial motion sensor
IPinCH	Intellectual Property in Cultural Heritage
IT	information technology
KAP	Kaymakçı Archaeological Project
KARS	Keos Archaeological Regional Survey
km	kilometer/s
LABUST	Laboratory for Underwater Systems and Technologies (University of Zagreb)
LAN	local area network
LIEF	Linkage Infrastructure Equipment and Facilities
LOD	linked open data
LTE	Long-Term Evolution
m	meter/s
masl	meters above sea level
MEMSAP	Malawi Earlier-Middle Stone Age Project
MOA	memoranda of agreement
MOOC	Massive Online Open Course
NGWSP	Navajo-Gallup Water Supply Project
NeCTAR	National eResearch Collaboration Tools and Resources
NEH	National Endowment for the Humanities
NHPA	National Historic Preservation Act
NPS	National Park Service
NRHP	National Register of Historic Places
NSF	National Science Foundation
OCR	optical character reader
OS	operating system
PA	programmatic agreement
PAP	pole aerial photography
PARP:PS	Pompeii Archaeological Research Project: Porta Stabia
PATA	Proyecto Arqueológico Tuti Antiguo
PBMP	Pompeii Bibliography and Mapping Project
PDA	personal digital assistant

PIARA	Proyecto de Investigación Arqueológico Regional Ancash
PKAP	Pyla-Koutsopetra Archaeological Project
Pladypos	PLAtform for DYnamic POSitioning
PLoS	Public Library of Science
PQP	Pompeii Quadriporticus Project
PAZC	Proyecto Arqueológico Zaña Colonial
QA	quality assurance
QC	quality control
QR	quick response
REVEAL	Reconstruction and Exploratory Visualization: Engineering meets ArchaeoLogy
ROS	robot operating system
ROV	remotely operated vehicle
RRN	Reciprocal Research Network
RSS	Rich Site Summary
RTK	real-time kinetic global navigation satellite system
SfM	structure from motion
SHPO	State Historic Preservation Office
SKAP	Say Kah Archaeological Project
SLAM	simultaneous localization and mapping
SMU	square meter unit/s
SU	stratigraphic unit/s
SVP	Sangro Valley Project
TCP	traditional cultural properties
tDAR	the Digital Archaeological Record
UAV	unmanned aerial vehicle
UNASAM	National University of Ancash, Santiago Antúnez de Mayolo
UQ	University of Queensland
USACE	U.S. Army Corp of Engineers
USBL	ultra-short baseline
USFS	U.S. Forest Service
USV	unmanned surface vehicle
UTM	universal transverse mercator
XML	Extensible Markup Language
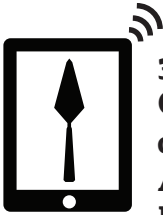
3.3.
CSS for Success? Some Thoughts on Adapting the Browser-Based Archaeological Recording Kit (ARK) for Mobile Recording

J. Andrew Dufton

The Archaeological Recording Kit (ARK) is an open-source system for flexible, Web-based archaeological data management. Designed in 2005 to facilitate simultaneous data creation and dissemination through a customizable Web interface, ARK faces new challenges with the growing use of tablets for on-site, paperless recording. At least two pressing questions have emerged: how do mobile devices interact with ARK's current codebase, which relies on a single Web server? And is now the time for the ARK team to develop a stand-alone, offline tablet application?

This chapter looks at the first 10 years of ARK's history to situate these questions within the wider trajectory of its development, and within broader trends of mobile computing. Understanding the initial goals of the project, and the background of the project team, helps to identify the underlying ideologies structuring ARK data and functionality, the projects that have historically shaped its growth, and the likely paths for future expansion. Detailed attention will then be given to different examples of projects—from the commercial sector, in academic research, and in community-based archaeological practice—that have chosen to employ ARK with tablets; these case studies demonstrate some strengths and weaknesses of such an approach for both paperless and paper/digital hybrid recording. In each example, the customization of the Cascading Style Sheet (CSS) controlling the HTML interface for ARK emerges as a cost-effective means of facilitating concurrent data recording and viewing on tablet-, phone-, laptop-, and desktop-based systems without a need for changes to the
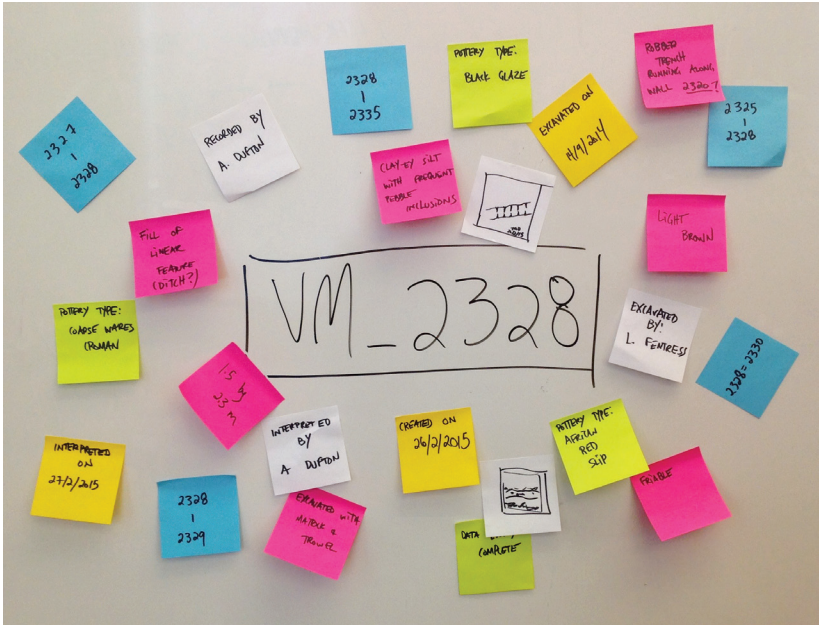
Figure 1: Paper illustration of ARK's EAV data structure, using Post-It Notes to represent individual data fragments.

existing data framework or core functionality. Further work toward a fully responsive design, rather than a focus on an offline application, is presented as one possible future for an ARK that respects the push toward sharing data online—a commitment that remains at its ideological core.

<p style="text-align:center">WHAT IS ARK?</p>

The Archaeological Recording Kit, or ARK, is a Web-based toolkit for the collection, storage, and dissemination of archaeological data (Archaeological Recording Kit 2015; the ARK system can be downloaded at: http://ark.lparchaeology.com). Developed using the Apache, MySQL, and PHP stack commonly used for Web applications, the system relies solely on open-source software, and it is also released on an open-source license—meaning the code is freely available to download and customize by individual projects for non-commercial use. The ARK system was originally released and is still maintained by L-P: Archaeology, a commercial partnership of archaeologists working within the United Kingdom (http://www.lparchaeology.com).

The ARK data is structured using an entity-attribute-value (EAV) data model, in which fragments of data are linked to a primary key—in most cases, the context record or stratigraphic unit (Eve and Hunt 2008). The SQL table structure abstracts these different data fragments into a series of basic data types, such as text, attributes, dates, actions, temporal spans, or uploaded files. These individual fragments are then pulled by a collection of PHP subforms, to be displayed or edited within a Web browser according to a series of configurable settings files. A context record, for example, could be attached to a number of different data fragments: text entries for color, compaction, or composition; various uploaded photographs; metadata surrounding the record author or its date of creation; or its stratigraphic relationship with other context records (FIG. 1). The user interface for entering or viewing these data is controlled by CSS, a programming language dedicated to styling the HTML output of Web documents and controlling things such as the font, spacing, background, or layout of a given page.

The configuration of ARK is organized using a modular structure, where each module represents a different type of archaeological record. The details of an individual context record, for example, are
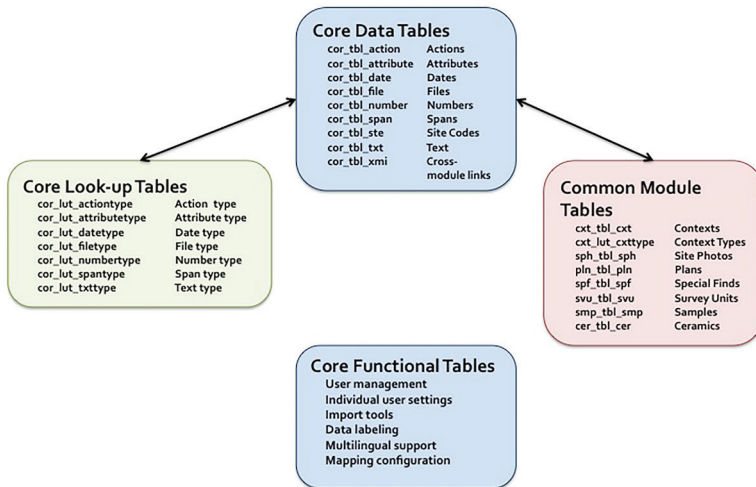
Figure 2: A simplified schematic representation of core and module-specific tables for ARK.

controlled by a dedicated PHP settings file with associated fields added to a series of MySQL tables. In the case of a pedestrian survey, contexts may be replaced by survey units. Some form of photographic module is usually included, as are modules for drawn plans, finds, and ceramic data. Although each module requires a single table to hold the primary record identifiers—the unique context number, photo number, or find number common in almost all recording systems— the core functionality and table structure is otherwise unchanged (FIG. 2). Thus ARK projects can install as many, or as few, modules as are needed simply by installing the relevant configuration files, and can also create new custom modules or edit existing ones according to the site conditions without additional programming (see Sobotkova *et al.*, Ch. 3.2, for a similar take on modular application development).

Entirely Web-based, ARK requires no external software beyond a Web browser to create, view, or share data—a use of Web tools for archaeological data management similar to other browser-based systems, such as the PKapp of the Pyla-Koutsopetria Archaeological Project (Fee *et al.* 2013; Fee, Ch. 2.1). This does not mean that ARK requires an active Internet connection to function, but rather that ARK relies on Web technologies to create and manipulate data. The basic Apache/MySQL/PHP package required for ARK can easily be installed in any Linux, Windows, or Apple operating system, essentially creating a local Web server on any computer. Users can then access this local Web server on laptops, phones, or tablets, either over a dedicated wireless network or connected directly to a wired local area network (LAN). Such a set-up is possible both in the lab or site museum for end-of-day data entry and also, in the case of many long-standing excavations, over a site-wide wireless network for on-site digital recording.

How Did We Get Here?

Much of the debate that emerged during the "Mobilizing the Past "workshop and throughout this volume focuses—quite rightly—on the ways in which archaeological practice is impacted by the technological choices we make in the field. Such a discussion is situated within a much wider dialogue about the relationships between new digital tools and the archaeologists who adopt them (Huggett 2000;
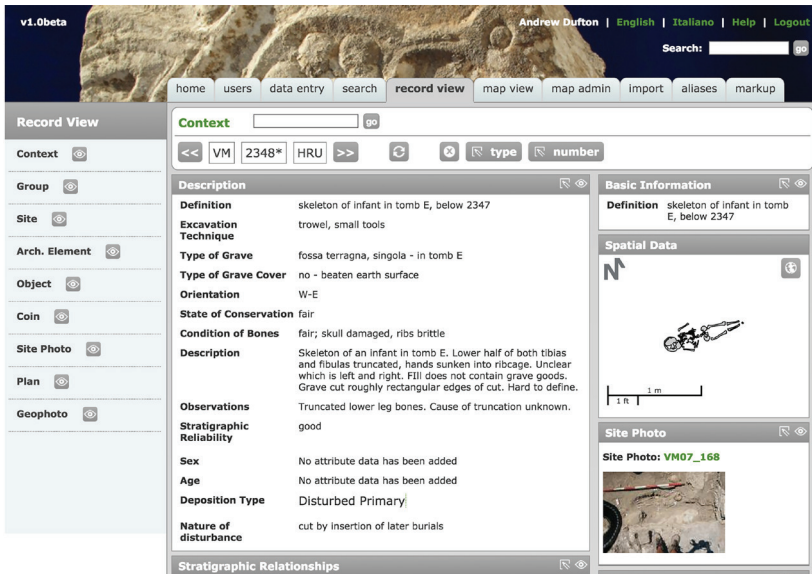
Figure 3: A screenshot of a basic context record from an early implementation of ARK at the Villa Magna Project, 2006–2010.

Zubrow 2006; Chrysanthi *et al.* 2012; Perry 2015). A shift from paper to tablet recording, like evolving digital data systems more generally, has great potential to increase fieldwork efficiency and introduce new ways of thinking about and with data "at the trowel's edge" (Chadwick 2003; Dufton and Fenwick 2012; Berggren *et al.* 2015). Yet without critical and ongoing reflection, these technologies risk the kind of technological determinism and unquestioned positivism that are described by Caraher (Ch. 4.1), and that also characterized adoption of similar "new" technologies within the past 25 years, such as geographic information systems, commonly referred to as GIS (Llobera 1996; Wheatley 2000; Huggett 2004; Hacıgüzeller 2012; Llobera 2012).

An acknowledgement that the tools archaeologists use, digital or otherwise, structure our relationships with resulting archaeological data—its creation, storage, and use in generating wider narratives about the past—has lead Jeremy Huggett to propose a new manifesto for an "Introspective Digital Archaeology" (Huggett 2015). Huggett suggests moving beyond solely the details or justification of the application of digital methods, to a "third wave" of digital archaeology (2015: 88): "which seeks to examine the ways in which digital technologies may have changed what we do, how we do it, how we represent what we do, how we communicate what we do, how we understand what we do, and how others understand what we do."

This introspection requires, in particular, a look at the choices made during the conception and application of various technologies. What research problem was the technology created or adapted to address? What were the goals of the original application? Who were the developers? These questions—and the underlying tensions between the sometimes conflicting needs of effective data collection, use, and dissemination—are best answered with an ethnographic examination of the development process (Huggett 2012: 546; 2015).

Any manner of deep ethnographic study of the origins and trajectories of the ARK system are well beyond the scope of this discussion. Nevertheless, a few details surrounding the early conception of ARK, and the backgrounds and theoretical leanings of the development team, will suffice as an introduction to subsequent consideration of the strengths and weaknesses of the system for tablet recording.

The initial creation of ARK, as well as the bulk of its ongoing evolution, was undertaken by a team of archaeologists with a strong digital focus, as opposed to programmers with specialized technical training

but little archaeological experience. The ARK codebase was compiled in 2005, drawing from existing data systems originally designed by L-P: Archaeology for various projects: the *FastiOnline* database of Mediterranean excavations produced by the International Association of Classical Archaeology (Rome); the excavations of the Institute of Classical Archaeology (University of Texas at Austin) at the National Preserve of Tauric Chersonesos (Rabinowitz *et al.* 2007); and private, developer-funded archaeology at various sites within the United Kingdom, such as the Prescot Street Project (Hunt *et al.* 2008; Morgan and Eve 2012). Continuing with bespoke solutions for these unrelated projects was proving increasingly ineffective given limited resources and manpower. A single, heavily customizable system that could be adapted to archaeological recording in research and commercial contexts, to site gazetteers and beyond, was thus created to streamline code development (FIG. 3).

The initial goals of the ARK system were fivefold: multivocality, reflexivity, data integration, openness, and flexibility (Eve and Hunt 2008). The first two goals, in particular, were heavily inspired by a sense of teamwork and camaraderie between excavators, supervisors, and digital specialists, which was fostered during months of excavation throughout a rainy, gray London winter. Rather than relying solely on the supervisor during the process of synthesis, we asked how a database system could facilitate contributions from all members of the team. How might the ongoing process of excavation and data recording feed more directly into emerging interpretations and site narratives? These questions from 2005 are still directly relevant to discussions of tablet recording in 2015. In the case of ARK, the frustrations of archaeologists working within the British commercial sector with the top-down, post-excavation analysis of fieldwork results led to a functionality allowing multiple interpretations—each attributed to individual team members, each informed by the latest site and laboratory findings, and each noting the date of interpretation to keep track of how these may change throughout the course of a project.

The other three goals for ARK revolved, at least to an extent, around more practical concerns. The integration of drawn, photographic, spatial, and textual materials into a single digital system mirroring the paper record saved time and resources on commercial projects. Research projects also benefitted from a digital archive incorporating spatial data and photographs, yet requiring no specialist software.

A need by early ARK projects to synchronically create and freely disseminate data, and to access these data from across the globe, was best met by a Web-enabled solution. Finally, developing a flexible data structure that could easily be adapted by international projects without restricting those projects to a specific (usually national) recording standard, and releasing the code for the system on an open-source license, encouraged contributions to the functionality of ARK. This flexibility and openness helped spread the costs of new features between a larger body of stakeholders than would have been possible with a more bespoke solution relying on proprietary software (see Sobotkova *et al.*, Ch. 3.2).

Where Do We Go Next?

The result of the early aspirations of the ARK project—to make an open, Web-based system for data entry and dissemination—is a platform that continues to evolve, even now over a decade after its initial creation. Yet ARK is also a system conceived before born-digital data recording became increasingly common practice with the widespread accessibility of tablets. The modification of the existing code for handheld devices, therefore, is an ongoing challenge for the core ARK development team. In a nutshell, the team must assess how ARK can—using limited resources and development time and causing minimal upgrade disruption for existing projects—be adapted to allow for tablet recording.

To understand the most likely trajectory of future advances requires a consideration of three characteristics common to those projects most invested in ARK, and therefore most willing to contribute time or funding to its further expansion. First, the majority of projects relying on ARK as part of their on-site practices are not making an active push toward a paperless archaeology. Most projects instead implement a hybrid recording practice of traditional paper records and hand-drawn plans, later digitized on laptops in the site hut or laboratory, with digital photography and born-digital registers of basic record metadata entered on tablets. It is important to remember in any discussion of tablet recording that many national or state guidelines still recommend paper archives for written, photographic, or drawn records for both research- and commercially-driven archaeological

work (see Spigelman *et al.*, Ch. 3.4). Furthermore, local organizations accepting digital-only data for archiving purposes may lack the robust infrastructure provided by centralized groups dedicated to creating stable digital resources—such as the Digital Archaeological Record (tDAR) in the United States, or the United Kingdom's Archaeology Data Service (ADS). Projects should thus consider not only whether to export their data into plaintext, Rich Site Summary (RSS), or comma separated values (CSV) formats, but also whether any of these digital formats can be sustainably archived.

Second, any changes to the ARK code to enable tablet use should respect existing and legacy projects, maintaining the data structure that has always been central to the success of the ARK system. The need for all new functionality to be abstract enough to work in many different contexts can make changes to the codebase more time consuming than would be the case in a bespoke, single-site system. New features also require a degree of backward compatibility with older releases, or a suite of upgrade tools for existing projects— expansive and expensive developments that are difficult to fund within individual project budgets. A solution to adapt ARK for mobile recording that does not require extensive changes to the existing system is preferred.

Finally, many ARK projects currently in the field take advantage of either an established, site-wide local wireless network, or reliable 3G access, to simultaneously enter data both on laptops in the laboratory and on tablets in the trenches using only a standard Web browser. As such, there has been no real impetus for development of a stand-alone ARK application for tablets to facilitate data collection in offline environments, nor a need to integrate existing (largely proprietary) systems with data storage and syncing functionality into ARK's open-source workflow. A desire to make data available as soon as possible from the field—to specialists, and to the general public—has often been the reason behind many projects' choice to use ARK. These projects already have the infrastructure needed to run "online," and they are unlikely to return to a model where data publishing and dissemination occurs only when fieldwork has been completed, or requires an additional step to convert from proprietary data formats used during field collection to open online systems for final archiving.

SOME LESSONS FROM THE TRENCHES

So where, then, does this leave the potential exportation of ARK's browser-based recording to mobile devices? It is ARK's primary use for paper/digital hybrid recording, desire for flexibility with minimal PHP coding, and goals of concurrent data entry and dissemination, that have thus far suppressed any great desire by the ARK user community for the development of a new, stand-alone mobile application. The easiest and most cost-effective solution to-date has, rather, been the modification of the HTML styling of ARK's interface, using custom CSS, to allow for concurrent tablet-, phone-, laptop-, or desktop-based data entry and viewing.

In a Web-based system such as ARK, a combination of changes to CSS and project-specific configuration files can display the same data in highly different ways while also requiring less intensive programming knowledge than modifying the existing codebase or creating new functionality. Creating a new theme or skin to change the display of data for various devices on-the-fly can in fact meet the needs of many fieldwork sites, does not require any additional software downloads beyond the Web browser already included on mobile equipment, and respects the existing data structure and stated development goals of the ARK system more generally.

This discussion will now turn to three types of project relying on custom CSS for ARK, representing the different project needs of commercial archaeology, academic research, and community archaeology.

Commercial Archaeology

A first example of the use of ARK for on-site tablet recording comes from the United Kingdom's commercial sector, at the site of 100 Minories in London's East End (http://100minories.lparchaeology. com). Excavations undertaken by L-P: Archaeology over the course of a year at the site—which is located less than 500 m from the Tower of London and the Thames River—recorded deposits up to 8 m in depth, and materials ranging in period from the defensive circuit of the Roman city, to medieval and Tudor housing, to a large 18th-century Georgian development (100 Minories 2014). Fieldwork at the
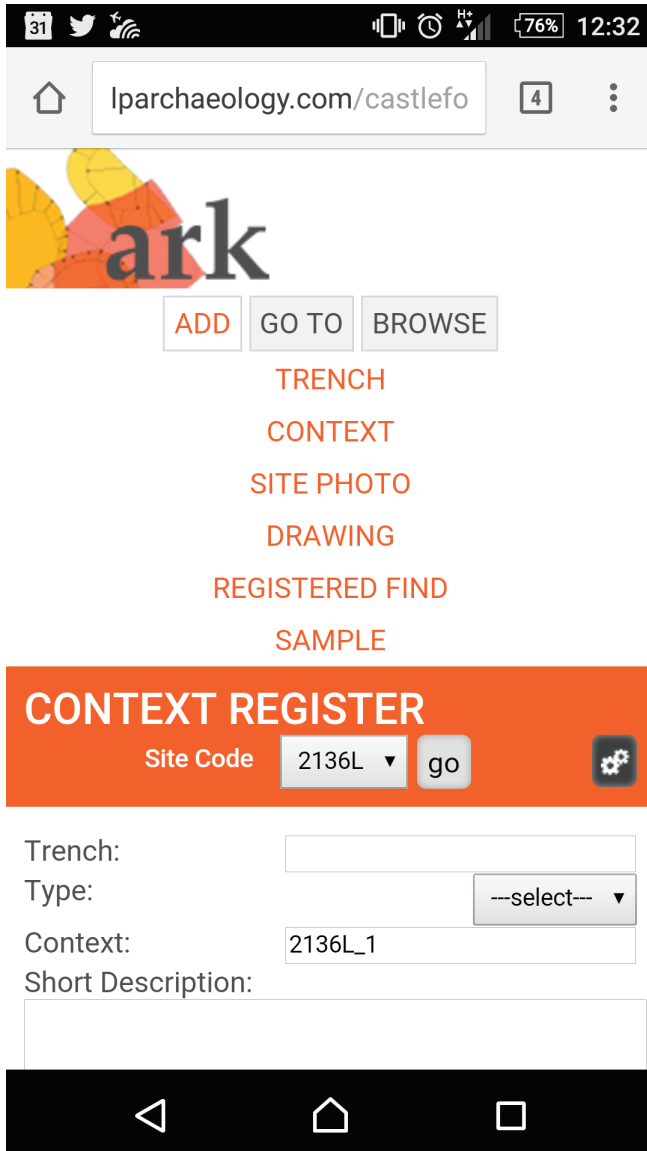
Figure 4: A simplified tablet stylesheet customized for data entry at the 100 Minories project.
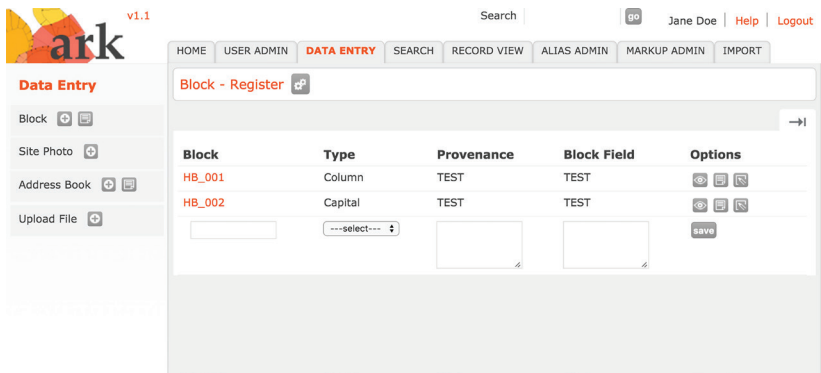
Figure 5: The default stylesheet of ARK when accessed through a desktop or laptop Web browser.

site was completed in advance of the construction of a new luxury hotel and funded by the developer, Grange Hotels. In addition to the full excavation of existing deposits, the site team completed a series of associated outreach activities, including a symposium of research talks by members of the project team, a number of pop-up museums displaying the latest recorded finds, and the online dissemination of live excavation data using ARK (100 Minories 2015a, 2015b).

The use of the ARK system for such a commercial enterprise within London comes as no great surprise, considering the British origins of ARK and its London-based development team. L-P: Archaeology had previously used ARK for a similar combination of developer-funded archaeology and public engagement at another East London site on nearby Prescot Street (Hunt *et al.* 2008; Morgan and Eve 2012; Prescot Street 2014). Fieldwork at Prescot Street was completed before the release of an affordable tablet robust enough to survive the archaeological trenches, and so mobile recording was not part of that project's digital strategy. However, Prescot Street's combination of a strong Web presence linking contributions from individual field staff to live archaeological data—facilitated by ARK's Web-based functionality— served as a template informing the work at 100 Minories.

Excavations at 100 Minories were completed under the guidance of the Greater London Archaeological Advisory Service at Historic England, and were thus subject to the archival requirements of all British archaeological practice (for an example of similar legal restrictions in a North American context, see Spigelman *et al.*, Ch. 3.4). These requirements dictate the need for a written paper record on standardized recording sheets, as well as bracketed photographs of individual contexts and drawn plans of the same on archival-quality gridded drafting film; all must be in accordance with the standards outlined in the site-recording manual of the Museum of London (Spence 1993). Tablet data entry was still possible for those items not restricted by Museum of London standards, such as the registering of new context, photo, or small find numbers at the trench. The 100 Minories site's central London location meant no local network or server was needed. Tablets on site were able to upload and access ARK data held in a remote location over a 3G wireless network—even at depths over 2 m below modern street level—using standard mobile broadband data provisions. The system's data entry functionality was simplified and streamlined using a custom mobile CSS, the new "skin" limiting the

more complex data entry or spatial tools but allowing for quick and easy creation of new context, find, or photo records (cf. FIGS. 4, 5).

The ARK system was also used to view context records and finds data from an earlier 2012 archaeological evaluation of the site. These older data, accessed on tablets in the field by excavators, assisted the ongoing processes of excavation and interpretation, and introduced an aspect of reflexive practice not often attempted within a commercial context (Howard 2013). Specialists working on the cleaning and consolidation of finds, a process handled off-site by Museum of London Archaeology, were able to view the latest excavated materials as they came out of the ground, connecting traditionally segregated excavation and post-excavation workflows.

The work at 100 Minories is but one example of a hybrid paper/digital system within the context of developer-funded work (see also Gordon *et al.*, Ch. 1.4, for a research-driven example). This hybrid approach increases the efficiency of site-recording practices—taking advantage of some of the basic benefits of a paperless system (see Wallrodt, Ch. 1.1)—while maintaining the archival standards required of sound commercial practice in a British context.

Academic Research

Research projects have been, in many ways, the early drivers of ARK development. The flexible parameters found in ARK were designed to suit its implementation in the highly varied circumstances of international research. Much of the current codebase was developed to meet the needs of disparate early adopters such as the Institute of Classical Archaeology at the National Preserve of Tauric Chersonesos (Rabinowitz *et al.* 2007; http://www.utexas.edu/cola/ica/projects/chersonesos/introduction.php), and the joint excavations of the University of Pennsylvania and the British School at Rome at the imperial Roman site of Villa Magna (Dufton and Fenwick 2012; http://villa-manga.org). The freedom often afforded to academic researchers to experiment with new methodologies or techniques is well suited to exploring novel ways to think about data creation, use, and dissemination. It is somewhat surprising, then, that such projects have been less instrumental in adapting ARK's existing functionality for use with mobile technologies (for a notable exception, see Opitz *et al.* in

Figure 6: Map of some of the sites featuring key research projects contributing to the ARK codebase.

press). Why are research projects already using the system not making a greater push for a paperless ARK?

There are a few reasons for this seeming discrepancy. Academic fieldwork is often planned and initiated with a specific time period or funding cycle in mind; the two projects listed above, for example, have moved on to a publication phase where tablet/ARK interoperability is less of a concern than tracking the evolution and use of project data (Esteva *et al.* 2010; Trelogan *et al.* 2013). Other projects currently in the field are content with a workflow of on-site paper recording and daily data-entry off-site, either due to a methodological loyalty to the perceived benefits of the paper record, or because experimenting with new digital data techniques is—quite understandably—not part of the research agenda.

A more significant barrier, however, is the absence of a stand-alone, offline, data-syncing alternative for ARK. The system's open-source codebase makes it difficult to track all projects currently using the system—at the time of writing, the latest version had been downloaded over 2,300 times in the one year since its release—but a look at the distribution of some of the higher-profile research projects using ARK shows a decidedly Mediterranean focus (FIG. 6). Unlike commercial excavations in the heart of London, rural sites in Sardinia, Tunisia, Turkey, or Jordan still lack the reliable network connectivity needed for tablet-based data entry over mobile broadband. Mediterranean fieldwork projects are content with data entry from paper records into the ARK system, but demonstrate an unsurprising reluctance to rely solely on on-site, born-digital recording when the possibility of establishing a site-wide wireless network, or the reliability of 3G coverage, is so hard to guarantee (see, e.g., the experiences of the Athienou Archaeological Project in Cyprus, Gordon *et al.*, Ch. 1.4). This is particularly the case for landscape survey projects covering a much wider study area—such as Brown University's Petra Archaeological Project—where regular 3G access to a remote server would be the only viable option but network coverage is not yet sufficient for such an approach (http://brown.edu/go/bupap).

Although individual devices can be configured to run a stand-alone system, there is at present no method for syncing a series of disparate ARK data tables into a single database at the end of a day's fieldwork—a function not as important to commercial excavations at a single, well-defined site, but essential for the use of tablets across multiple

excavation areas or between simultaneously active field survey teams, situations that characterize much academic research. Attempts to integrate ARK with stand-alone, offline data-capture systems such as FileMaker Pro have so far resulted in unwieldy workflows lacking the efficiency benefits that draw projects to paperless recording in the first place. Thus far, the combination of network concerns and other priorities for existing research using ARK has resulted in a slow uptake of born-digital data recording on many academic projects.

Public Outreach

A final example from the realm of public or community archaeology provides further insight into the use of ARK for mobile recording: the DigVentures social enterprise promoting crowdfunded archaeological fieldwork (http://digventures.com). The DigVentures team started in 2012 with a summer excavation season at the Bronze Age site of Flag Fen near Peterborough (United Kingdom). The project relied on existing public interest in this well-known monument—and in archaeology more generally—to fund the excavations, ultimately establishing a community of over 250 funders, many of whom also participated directly in work on-site (DigVentures 2015b).

In 2013, DigVentures fieldwork moved to the medieval site of Leiston Abbey, Suffolk, for a second season of crowdfunded and crowdsourced excavations. The Leiston Abbey project also established the *Digital Dig Team*, an online website/ARK hybrid to provide live data from the excavations at the moment of discovery. As with the 100 Minories example, a custom CSS was created for ARK to streamline data entry using tablets on-site, relying on existing 3G network access to connect to a remote Web server. These largely stylistic changes to the ARK system connected the archaeological data with broader Web content, such as daily blog entries by project participants, video updates, or news items.

Claims that this initiative should be seen as "the world's first entirely paperless recording system" are problematic (DigVentures 2015a; see Wallrodt 2011; Ch. 1.1, for earlier examples). Yet it does embody a very early attempt at combining paperless systems with online dissemination tools to make, in effect, all data public data from the moment of initial collection through analysis and interpretation. Although

designed primarily as an incentive to encourage donations to project funding, this approach also takes a valuable step toward a greater integration between digital data and other aspects of the archaeological process, such as documenting fieldwork practices, interpretation, and dissemination (Rabinowitz and Sedikova 2011).

The need to find effective, long-distance means of communicating archaeology has recently been highlighted, not least since geographic, financial, or physical restrictions can prohibit in-person involvement with archaeological sites or museums (Alcock *et al.* 2015). This is particularly relevant for a project such as DigVentures that is designed for, and funded by, the public. Web-based recording systems such as ARK provide an opportunity to connect field practices and the excitement of discovery more directly to a population eager to participate, either directly or virtually, in the archaeological process.

Mobilizing ARK for a Digital Future

Advances in mobile technology within the last decade have drastically changed the way archaeologists think about data collection. As a result, fieldwork projects now face a number of choices with far-ranging implications: to embrace paperless recording, or maintain some degree of traditional documentation; to develop a bespoke system, or adopt an existing archaeological database; to use an open-source platform, or licensed proprietary software; to prioritize data dissemination and reuse, or efficiency of on-site workflows.

The examples outlined above, when understood within the context of ARK development, provide some insight into the role of mobile recording using Web-based systems, such as ARK, in these wider debates. On the one hand, ARK's ability to eliminate the gaps between data collection and online dissemination has always been a major strength, and it is no surprise that those projects best deploying the system with mobile technologies include a substantial public-facing component. On the other hand, research projects are proving more hesitant to rely on a tablet system that can only function with local wireless or mobile broadband access, especially given the lack of such connectivity in many fieldwork settings. Yet research projects are not providing the funding for the majority of ARK development and, for better or worse, it seems unlikely that a syncing, offline version of ARK

will be produced in the coming years. A stand-alone, paperless system is not a priority for the projects actively developing the ARK platform at present, and existing software, such as FileMaker Pro, offers a less time-consuming alternative for bespoke, offline mobile recording.

More generally, a shift to Web-based site recording—on tablets or otherwise—also requires a broader paradigm shift within academic practice, encouraging open data not only as an afterthought to publication but as an active part of the fieldwork process. Advocates for the current trend toward open data stress the potential strengths of such an approach: reduced research costs, increased research quality, and better communication of archaeological findings (Kansa and Kansa 2011; Kansa 2012). Open data initiatives have traditionally worked with published or archival data sets, demonstrating the benefits of online publication for system interoperability or linked open data (LOD), text-mining, and data reuse (Isaksen *et al.* 2010; Atici *et al.* 2013; Kansa *et al.* 2014). Projects have been slower to adopt these principles for ongoing fieldwork, showing less willingness to sacrifice on-site efficiency for more unwieldy interfaces offering future data interoperability, nor to provide open access to data prior to its re-examination, possible correction, and traditional publication—a process that often takes years. Academic systems of appointment and promotion further contribute to an unwillingness to go digital by often placing a higher value on traditional print publications rather than on collaborative, open, and online initiatives (see Kansa, Ch. 4.2). An uptake in Web-based data creation on-site is unlikely unless it is accompanied by a change in the distinction we make between live and archived data, and a continued effort to make open-data systems more accessible to users with all degrees of technical competence.

This negative outlook does not mean that there is no potential for mobile, born-digital data collection using ARK. Longstanding excavation projects often have the resources necessary to establish local wireless infrastructure, and in some cases they have begun using ARK for paperless data capture (Opitz *et al.* in press). Furthermore, the latest figures provided by the International Telecommunication Union—the United Nations' specialized agency for information and communication technologies—show global access to 3G networks increased from 45% to 69% coverage in the period from 2007 to 2015 (International Telecommunications Union 2015). Industry projections suggest up to 85% 3G-network coverage worldwide by 2017 (Ericsson

2012). High-speed Long-term Evolution (LTE), often referred to as 4G LTE, has shown a similar expansion in coverage over the last five years; a 2015 survey of 68 countries demonstrated that in 53 (or 78%), users had access to LTE signals for over 50% of their total time connected to mobile networks (Open Signal 2015). Of course not all projects will be able to count on this coverage, particularly those working in highland or rural remote locations. It is reasonable to suggest, however, that reliable 3G/LTE coverage on archaeological sites will only become a more realistic expectation in the coming years. Future ARK development to streamline data entry on mobile devices is possible, and much can be accomplished with simple changes to ARK's CSS to create a responsive interface tailored to effectively display and enter data both on computers in the lab, and on tablets or smartphones in the trenches.

A significant strength of open-source software is that there is no single answer to the question of "where next?" Individual ARK projects will continue to follow their own trajectories based on individual project needs and research aims. This discussion presents only one perspective on the future of ARK and mobile technologies, a future where simple CSS customization takes advantage of the benefits of mobile, Web-based data collection while maintaining the goals of openness and flexibility that lie at the heart of ARK's development history.

https://mobilizingthepast.mukurtu.net/collection/33-css-success-some-thoughts-adapting-browser-based-archaeological-recording-kit-ark

http://dc.uwm.edu/arthist_mobilizingthepast/16

REFERENCES

100 Minories. 2014. "The 100 Minories Site." http://100minories. lparchaeology.com/about/

100 Minories. 2015a."100 Minories Pop Up Museum." http://100minories.lparchaeology.com/ research/100-minories-pop-up-museum/

100 Minories. 2015b. "The 100 Symposium." http://100minories. lparchaeology.com/about/symposium/

Archaeological Recording Kit. 2015. "About ARK." http://ark.lparchaeology.com/about

Alcock, S. E., J. A. Dufton, and M. Durusu-Tanrıöver. 2015."Who Are the People," in J. F. Cherry and F. Rojas, eds., *Archaeology for the People: Perspectives from the Joukowsky Institute. Joukowsky Institute Publication* 7. Oxford: Oxbow Books, 129-143.

Atici, L., S. W. Kansa, J. Lev-Tov, and E. C. Kansa. 2013. "Other People's Data: A Demonstration of the Imperative of Publishing Primary Data," *Journal of Archaeological Method and Theory* 20: 663–681. doi:10.1007/s10816-012-9132-9

Berggren, Å., N. Dell'Unto, M. Forte, S. Haddow, I. Hodder, J. Issavi, N. Lercari, C. Mazzucato, A. Mickel, and J. S. Taylor. 2015. "Revisiting Reflexive Archaeology at Çatalhöyük: Integrating Digital and 3D Technologies at the Trowel's Edge," *Antiquity* 89: 433–448. doi:10.15184/aqy.2014.43

Chadwick, A. 2003. "Post-Processualism, Professionalization and Archaeological Methodologies: Towards Reflective and Radical Practice," *Archaeological Dialogues* 10: 97–117. doi:10.1017/ S1380203803001107

Chrysanthi, A., P. Murietta-Flores, and C. Papadopoulos, eds. 2012. *Thinking beyond the Tool: Archaeological Computing and the Interpretive Process. British Archaeological Reports International Studies* 2344. Oxford: British Archaeological Reports.

DigVentures. 2015a. "Digital Dig Team." http://digventures.com/ digital-dig-team/

DigVentures. 2015b. "Our Story." http://digventures.com/about-us/

Dufton, A., and C. Fenwick. 2012. "Beyond the Grave : Developing New Tools for Medieval Cemetery Analysis at Villamagna , Italy," in A. Chrysanthi, P. Murrieta-Flores, and C. Papadopoulos, eds., *Thinking beyond the Tool: Archaeological Computing and the*

Interpretive Process. British Archaeological Reports International *Series* 2344. Oxford: Archaeopress, 155–167.

Ericsson. 2012. "Ericsson Mobility Report." http://www.ericsson.com/res/docs/2012/ericsson-mobility-report-november-2012.pdf

Esteva, M., J. Trelogan, A. Rabinowitz, D. Walling, and S. Pipkin. 2010. "From the Site to Long-Term Preservation : A Reflexive System to Manage and Archive Digital Archaeological Data," *Archiving* 7: 1–6.

Eve, S., and G. Hunt. 2008. "ARK: A Developmental Framework for Archaeological Recording," in A. Posluschnya, K. Lambers, and I. Herzog, eds., *Layers of Perception: Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin*. Kolloquien zur Vor- und Frühgeschichte 10. Bonn: Halbelt.

Fee, S. B., D. K. Pettegrew, and W. R. Caraher. 2013. "Taking Mobile Computing to the Field," *Near Eastern Archaeology* 76: 50–55.

Hacıgüzeller, P. 2012. "GIS, Critique, Representation and Beyond," *Journal of Social Archaeology* 12: 245–263. doi:10.1177/1469605312439139.

Howard, C. 2013. "Integrating Excavation and Analysis on Urban Excavations." http://urban-archaeology.blogspot.com/2013/02/integrating-excavation-and-analysis-on.html

Huggett, J. 2000. "Computers and Archaeological Culture Change," in G. Lock and K. Brown, eds., *On the Theory and Practice of Archaeological Computing*. Oxford: Oxford University Committee for Archaeology, 5–22.

———. 2004. "Archaeology and the New Technological Fetishism," *Archeologia e Calcolatori* 15: 81–92.

———. 2012. "Lost in Information? Ways of Knowing and Modes of Representation in E-Archaeology," *World Archaeology* 44: 538–552.

———. 2015. "A Manifesto for an Introspective Digital Archaeology," *Open Archaeology* 1: 86–95. doi:10.1515/opar-2015–0002

Hunt, G., C. Morse, and L. Richardson. 2008. "Watching the Past Unfold before Your Eyes," *London Archaeologist* 12: 41–45.

International Telecommunication Union. 2015. "ICT Facts and Figures: The World in 2015." http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

Isaksen, L., K. Martinez, N. Gibbins, G. Earl, and S. Keay. 2010. "Linking Archaeological Data," in B. Frischer J. Webb Crawford,

and D. Koller, eds., *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 37th International Conference, Williamsburg, Virginia, United States of America, March 22–26, 2009.* British Archaeological Reports International Series 2079. Oxford: Archaeopress, 1–8.

Kansa, E. C. 2012. "Openness and Archaeology's Information Ecosystem," *World Archaeology* 44: 498–520.

Kansa, E. C., and S. W. Kansa. 2011. "Toward a Do-It-Yourself Cyberinfrastructure: Open Data, Incentives, and Reducing Costs and Complexities of Data Sharing," in E. C. Kansa, S. W. Kansa, E. Watrall, eds., *Archaeology 2.0: New Tools for Communication and Collaboration.* Los Angeles: Cotsen Institute of Archaeology Press, 57–92.

Kansa, S. W., E. C. Kansa, and B. Arbuckle. 2014. "Publishing and Pushing : Mixing Models for Communicating Research Data in Archaeology," *International Journal for Digital Curation* 9: 1–15. doi:10.2218/ijdc.v9i1.301

Llobera, M. 1996. "Exploring the Topography of Mind: GIS, Social Space and Archaeology," *Antiquity* 70: 612–622.

———. 2012. "Life on a Pixel: Challenges in the Development of Digital Methods within an 'Interpretive' Landscape Archaeology Framework," *Journal of Archaeological Method and Theory* 19: 495–509. doi:10.1007/s10816-012-9139-2

Morgan, C., and S. Eve. 2012. "DIY and Digital Archaeology: What Are You Doing to Participate?" *World Archaeology* 44: 521–537.

Open Signal. 2015. "The State of LTE (September 2015)." *Open Signal*, http://opensignal.com/reports/2015/09/state-of-lte-q3–2015/

Opitz, R., M. Mogetta, and N. Terrenato, eds. in press. *A Mid-Republican House from Gabii.* Ann Arbor: University of Michigan Press.

Perry, S. 2015. "Changing the Way Archaeologists Work: Blogging and the Development of Expertise." *Internet Archaeology* 39, doi:http://dx.doi.org/10.11141/ia.39.9

Prescot Street. 2014. "The 2008 Excavations." http://www.lparchaeology.com/prescot/about

Rabinowitz, A., S. Eve, and J. Trelogan. 2007. "Precision, Accuracy, and the Fate of the Data: Experiments in Site Recording at Chersonesos, Ukraine," in J. T. Clark and E. M. Hagemeister, eds., *Digital Discovery: Exploring New Frontiers in Human Heritage. CAA 2006: Computer Applications and Quantitative Methods in*

Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006. Budapest: Archaeolingua, 243–255.

Rabinowitz, A., and L. Sedikova. 2011. "On Whose Authority? Interpretation, Narrative, and Fragmentation in Digital Publishing," in E. Jerem, F. Redo, and V. Szevérenyi, eds., *On the Road to Reconstructing the Past: Computer Applications and Quantitative Methods in Archaeolgy (CAA). Proceedings of the 36th International Conference, Budapest, April 2–6, 2008*. Budapest: Archaeolingua, 134–140.

Spence, C., ed. 1993. *Archaeological Site Manual.* 3rd ed. London: Museum of London.

Trelogan, J., A. Rabinowitz, M. Esteva, and S. Pipkin. 2013. "What Do We Do with the Mess? Managing and Preserving Process History in Evolving Digital Archaeological Archives," in F. Contreras, M. Farjas, and F. J. Melero, eds., *CAA2010: Fusion of Cultures. Proceedings of the 38th Annual Conference on Computer Applications and Quantitative Methods in Archaeology, Granada, Spain, April 2010*. *British Archaeological Reports International Series* 2494. Oxford: Archaeopress, 597–600.

Wallrodt, J. 2011. "Why Paperless?" *Paperless Archaeology*, http://paperlessarchaeology.com/2011/01/03/why-paperless/

Wheatley, D. 2000. "Spatial Technology and Archaeological Theory Revisited," in K. Lockyear, T. J. T. Sly, and V. Mihailescu-Birliba, eds., *CAA 96 Computer Applications and Quantitative Methods in Archaeology. British Archaeological Reports International Series* 845. Oxford: Archaeopress, 123–132.

Zubrow, E. B. W. 2006. "Digital Archaeology: A Historical Context," in T. L. Evans and P. Daly, eds., *Digital Archaeology: Bridging Method and Theory*. London: Routledge, 10–31.