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The aim of this paper is to summarize progress in the development of reflexive methods at Çatalhöyük over the past 20 years, and to describe some recent innovations that have used digital and 3D technologies to enhance the original reflexive aims. While digital technologies were not at the forefront of the methods described in an initial account of reflexive methods published in *Antiquity* (Hodder 1997), it has become clear that many of the original aims can be enhanced by the use of new generations of computer assisted technologies for visualization, recording and planning. The paper does not describe the full use of digital technologies at Çatalhöyük; for example laser scanning is being used as part of the documentation for conservation evaluation. The wider use of digital technologies is discussed by Forte et al (2012). The aim in this paper is to discuss those aspects of digital technologies that relate to the reflexive aims of the project, thereby adding to the continuing discussion of reflexive archaeological practice (see Bender et al. 2007; Berggren 2001; Berggren & Hodder 2003; G. Carver 2011; M. Carver 2011; Castaneda 2008; Chadwick 2003; Edgeworth 2006; Hodder 2003; Silliman 2008; Yarrow 2003). While we recognize the widespread use of digital technologies in archaeology (see, for example, Levy 2013), our focus here is on their use not only to increase the accuracy and detail of recording methods, but also to further reflexive aims, defined in general terms as the situating of recording within its social and interpretive contexts.

The evolution and evaluation of reflexive methods at Çatalhöyük.
While the main struts of reflexive method consist of emphases on interpretation at the trowel's edge and documentation of the documentation process (Hodder 1997, 2000b, 2005), Berggren and Nilsson (in press) have more recently evaluated twelve components of reflexive methods as they have been used at Çatalhöyük since the project began in 1993 (Hodder 2000a).

The twelve components (Table 1) were conceived as interwoven parts of the methodology of investigation at Çatalhöyük. However, some of them have been difficult to integrate, while others have become part of the archaeological practice on site. In short, the implementation of these components has been both more and less successful than expected. A reason for these rather inconsistent results may be that reflexivity at the beginning of the project was regarded as a methodological matter, with reflexive methods added as an envelope surrounding excavation and recording. More recently there has been a shift in the project towards the view that a reflexive stance may be achieved directly within the excavation and recording methods, and the digital methods discussed below have contributed to this change.

As an example of the varied responses to the twelve components, anthropologists (Table 1 component 8) worked closely with the field team in the early years of the project (eg Bartu 2000; Hamilton 2000). More recently studies of knowledge production have shifted towards evaluation of the documentation process rather than of the people (Berggren and Nilsson in press; Mickel in press). Much of the anthropological work has instead focused on the local community (eg Yalman 2005) and on public engagement and multivocality (eg Atalay 2010, 2012, in press). The project has also had longstanding collaborations with artists and illustrators, both in terms of enhancing research and developing ways in which the site is presented to the public (Earl 2013; Moser et al 2010; Perry 2013; Swogger 2000).

Web-based information has become standard since the 1990s and is a part of how the project has published its results. The integrated database (component 5) was meant to emphasize fluidity and flexibility. However, the Access database that was built has not allowed the fluidity that was sought, and attempts are underway to move to a web-based system, Open Linked Data, and a long-term 'living archive' (Grossner et al 2014; Esteva et al 2010).

Project teams of different nationalities and archaeological traditions have participated in the project. These different windows into Çatalhöyük have indeed resulted in different perspectives (eg see Tringham and Stevanovic 2013), but they have also resulted in a fragmentation of the project, on both geographical and scientific levels. Lately, the different teams have been mixed

and brought into closer dialogue, resulting in homogenization, but also in a better understanding of the various perspectives.

The priority tours

In evaluating the twelve components, Berggren and Nilsson (in press) found that the on-site interactions taking place during the priority tours have become integrated and central parts of the work process (components 1-4 in Table 1). This is where interaction, communication, negotiations, breaking down barriers and feedback take place. The priority tours have been an important source of communication between excavators and laboratory staff. However, they have also illuminated an imbalance or faultline between laboratory and field staff (Hamilton 2000). There is a structural imbalance and hierarchy embedded in the project, with excavators mainly from the developer-funded world and with academic researchers in the laboratories. To some degree, every laboratory is encouraged to develop its own research questions, a structure related to the funding strategies of the project. As a result, the laboratory staff may be regarded as independent researchers while the excavators are the paid labour of the project. Lately, the project has tried to bridge this faultline by involving excavators in the research of the project, a strategy also pursued by a team from the University of California at Berkeley (Tringham and Stevanovic 2012).

The diary.

The diary has provided a particularly important counterpart to the otherwise strict and codified documentation system that uses single context recording. In the early years of the project, under-communicated objectives and an imbalanced participation resulted in an uneven use of the diary, both in making entries and in using the information. Initially only the excavators were supposed to write entries, to expose their assumptions and preconceptions, while laboratory staff were not. This added to the separation between the two groups. Lately, everyone in the project is expected to participate in writing the diary. All team members are informed at the beginning of each season that they should aim to create two entries each week. Moreover, since 2012, an excerpt from one diary entry each day has been posted in highly visible areas of the dig house, making the diary database a conspicuous, tangible, and ever-changing aspect of the project's environs. After beginning this initiative, the number of entries jumped from 7 entries by East

Mound team members in 2011 to nearly 150 entries in 2012 and 2013—an increase which can only be partially explained by the fact that 2011 was a study season, entailing less extensive excavation. These results suggest the efficacy of the 'Diary Entry of the Day' for increasing participation in this recording medium.

The content of the diary has likewise varied over the years. Not only do recent diaries include diverse perspectives on the research process—representing excavation supervisors, laboratory heads, and students—but the platform for writing diary entries has also been altered. Participants are now given brief guidelines for diary entries. They are also given the opportunity to tag their entries with topics, as well as to respond to entries written by other team members—creating digital links between records and encouraging researchers to contribute to each other's work. The diary medium thereby serves the dual purposes of providing broader, more nuanced context regarding the research process, and enhancing communication and dialogue between team members.

An extension from the original methods but closely linked to diary writing and the documentation of the documentation process has been the introduction of the daily sketch. This at first involved a daily sketching on a printed photo of the area being excavated at the moment by the excavator (see Figure 1). With the introduction of tablet PCs the daily sketch is now produced digitally in the same way on a photo on the screen of the tablet. Explanations of the work done and the interpretations of the object being excavated, and its relations to other features or layers, are drawn and written on the photo. The daily sketch is integrated into the database and can be searched by the object being excavated, e.g. the building, the feature or the layer. This has shown to be very helpful as a record of work progress as well as in the interpretation process, both as a visual aid for the excavator to remember the various steps of work, and for other excavators that need to understand a certain area, e.g. when taking over the excavation from someone else or when excavating a nearby area.

Figure 1.

The application of 3D visualization.

Over recent years, the use of 3D scanning and image based 3D modelling has been developed at Çatalhöyük. This is another effort in a long line of digital experimentation on site (Tringham and Stevanovic 2012) and it has become clear that these techniques facilitate various aspects of a reflexive approach. In particular, in conjunction with the use of on-site tablets (see below), they allow more information to be concentrated at the moment of excavation and interpretation in the trench. We have tried to develop 3D techniques in the field in order to bring information to trowel's edge more effectively, quickly and interactively.

In 2009-10, an on-site digital experiment was started with the scope of recording every phase of excavation of a Neolithic house (Building 89) in 3D using laser scanning, image based 3D modelling and photogrammetry. The goal is to make the excavation process virtually reversible in a simulated environment at different levels, from laptop computers to virtual immersive systems. Indeed the entire excavation strategy of Building 89 was designed with these immersive systems in mind, and the simulation involves a virtual browsing of all the layers and stratigraphy (Figure 2) within a collaborative virtual environment. 3D recording has been implemented at two main levels. At the micro-scale, all of the stratigraphy of a single Neolithic house (Building 89) is recorded using image based modeling. Image based modelling allows for the creation of accurate 3D visualizations of the archaeology within the time frame of the excavation (Forte et al. 2012). Despite the large range of software available (commercial and open source), we decided to use Agisoft Photoscan, (http://www.agisoft.ru/; Verhoeven 2011; Dell'Unto 2014; Dellepiane 2013; Callieri et al. 2011). Image based 3D modelling has since been utilized by other excavation teams at Çatalhöyük, although unlike the strategy in Building 89 these areas are only modelled several times per season at significant points in the excavation process (ie. pre-excavation, post-excavation, and mid-season models, which are created when buildings are in phase). Despite the large number of pictures acquired and processed every day on site, this product proved to be efficient. At the macro-scale all of the key excavation areas are laser scanned in their entirety (Figure 3). These scans started in 2012 in the East Mound with the aim of recording the status of the excavation annually. The survey has been implemented using a Faro Focus 3D Shift Phase laser scanner. This makes the visualization of each area of the excavation possible in high resolution with the aim of taking measurements or calculating

volumes, while also allowing us to visualize specific details of the archaeology in different seasons and therefore monitor the decay of features, walls, or buildings. Irrespective of the technique used, all of the 3D data are integrated into the intra-site GIS (see below).
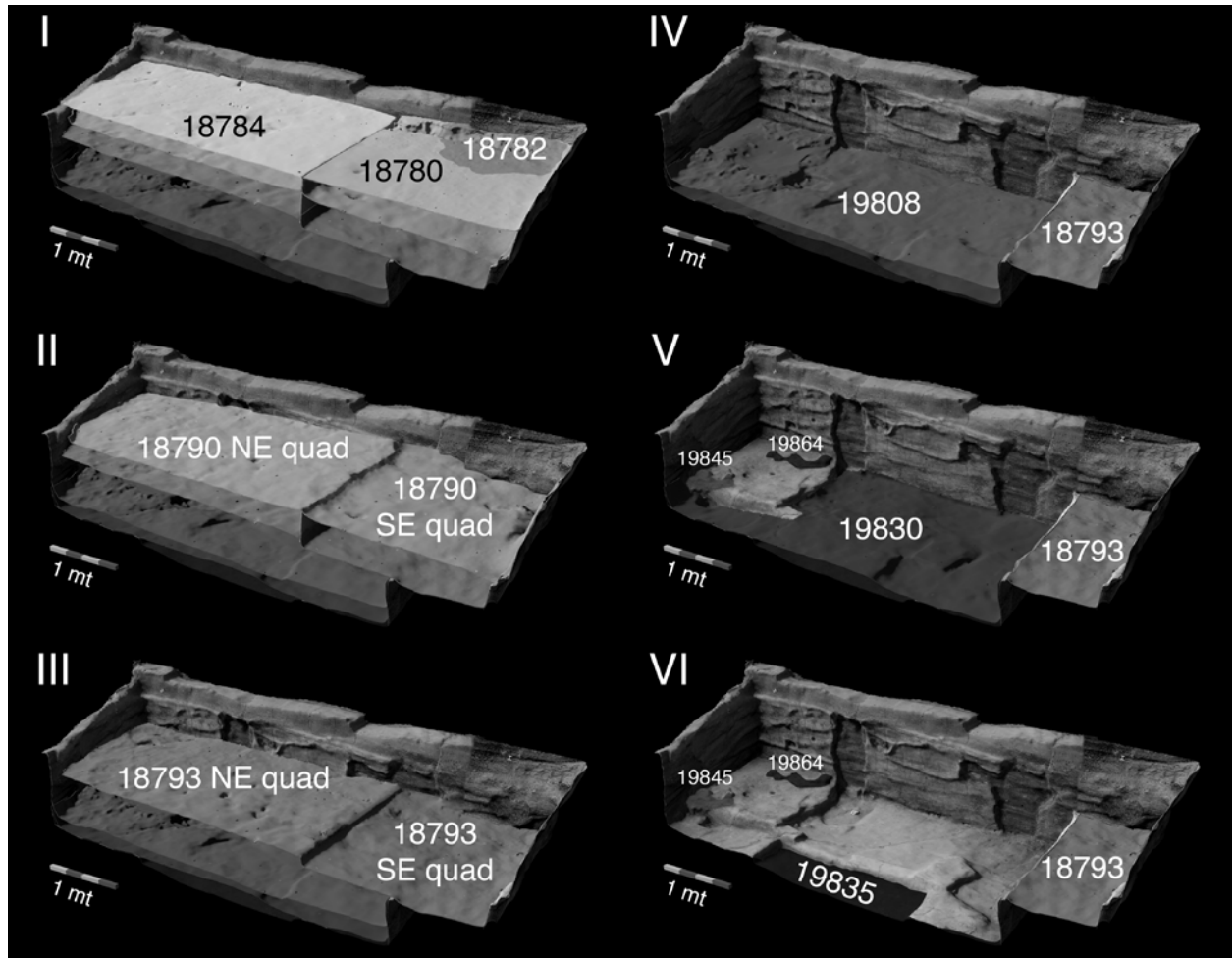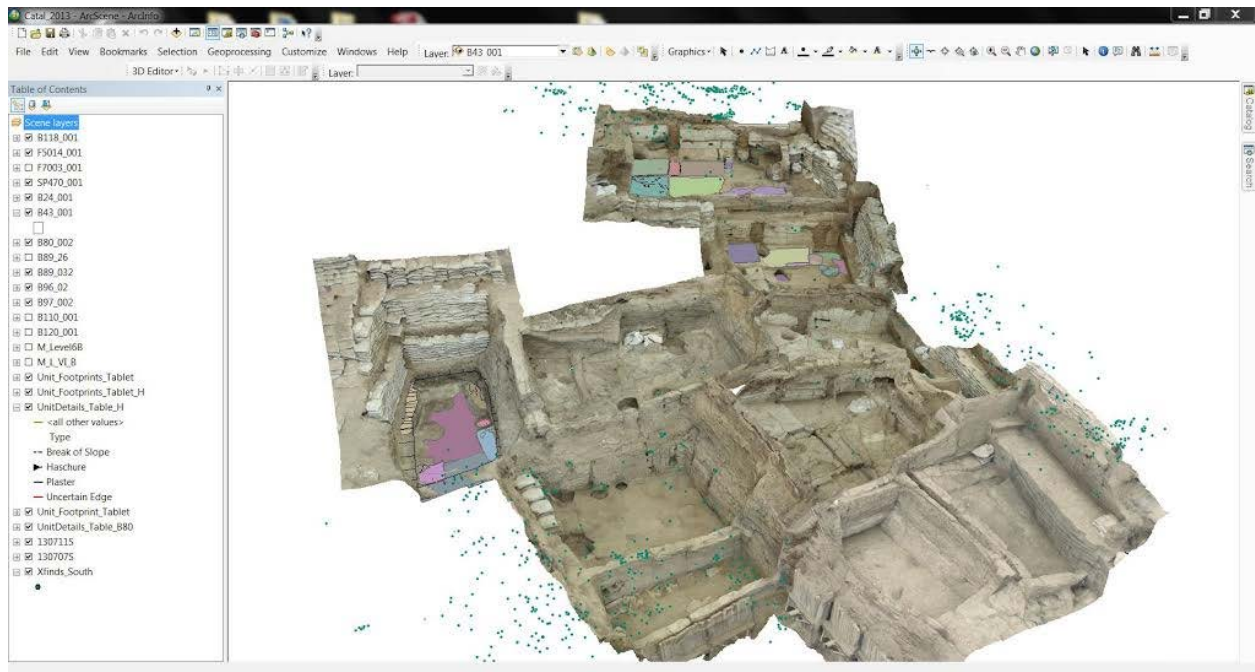

Figure 2.

Figure 3.

In an effort to extend the application of 3D recording techniques at Çatalhöyük, a program of 3D burial recording using image based 3D modelling was initiated in 2012. After a brief training session on proper photo recording techniques and use of the software, members of the Human Remains team began to produce 3D models of burials independently. Initially the technique was used only to document completely exposed skeletons, but by producing geo-referenced models at each stage of the excavation process the team could virtually reconstruct the often-complicated sequence of interments underneath house floors. Consecutive sub-floor burials at Neolithic Çatalhöyük frequently occur within a single house platform. As such, earlier interments are often disturbed by the grave cuts for later ones, a process which results in truncated skeletons and an abundance of co-mingled bone within grave fills. In addition, burials were sometimes reopened in order to retrieve and/or redeposit crania and other bones. In these situations, 3D modelling has greatly improved our ability to reconstruct and interpret mortuary practices.

As an example of reflexive re-interpretation based on 3D digital modeling, an initially perplexing sequence of co-mingled bone and partially disturbed primary skeletons was uncovered in 2012 (Figure 4). The uppermost layer consisted of a circular deposit of disarticulated limb bones and

several crania. Directly beneath this deposit was the tightly flexed headless skeleton of an adult male and just below this was an earlier primary adult burial that had been heavily disturbed. It was unclear at the time of excavation whether the cranium and mandible of the adult male had been removed prior to burial or whether the grave had been reopened some time later to retrieve them. By recording 3D models at each stage of the excavation process, however, we were able to see that the circular deposit of bones lay in a small cut directly above the area where the head of the earlier skeleton would have been located. Thus, we were able to positively identify a "skull retrieval pit" for the first time at Çatalhöyük and to show that after the removal, loose bones from at least two additional individuals had been carefully placed in the pit before it was resealed. This finding confirms that skull retrieval at Çatalhöyük was intentional and targeted, rather than being the result of accidental disturbances to earlier burials.
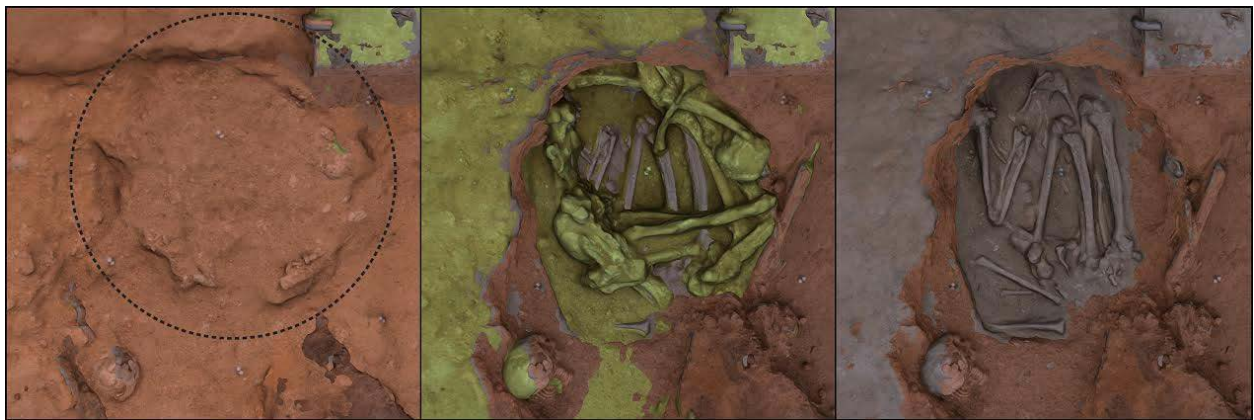

Figure 4.

Intra-site GIS as a tool for data integration and visualization.
Under-appreciated components of integrated and reflexive methods at the start of the project were Geographic Information Systems; these were not initiated until 2009. One of the main objectives of the use of GIS on the project more recently has been to develop a tool for integrating different types of data, produced by different participants in the project, both field and laboratory staff. In order to meet these goals, the GIS team and various members of the Çatalhöyük Research Project have worked closely together on the creation of a GIS geodatabase (Esri ArcGIS), which now forms, together with the database, the core of the Çatalhöyük digital archive. The geodatabase provides meaningful structure to the spatial data produced by the project, and its flexibility allows the organic incorporation of an increasing range of data

collected on site, including three-dimensional spatial data. During the past year, the increasingly central role played by the Çatalhöyük GIS both during the excavation process and laboratory staff work convinced us to migrate our personal geodatabase to an ArcSDE geodatabase in order to allow multiple users access and editing of the GIS data.

Since the 3D recording project was initiated, the Çatalhöyük GIS geodatabase has served as the main repository and display space for the image based modelling data recorded on site. During the course of excavation, geo-referenced image based models are imported to the GIS geodatabase and seamlessly integrated with other spatially related data, providing instant feedback to the field team (Figure 6). However, a number of technical issues needed to be addressed before a reliable workflow could be produced. This ultimately involved the creation of multi-patch feature classes in the GIS whose attribute tables were arranged in meaningful fields in order to make the models easily queryable (see ESRI, ArcGIS 10 Manual http://help.arcgis.com/en%20/arcgisdesktop/10.0/help/index.html#//00q8000000mv000000). The Çatalhöyük intra-site GIS has significantly enhanced our ability to present and interpret archaeological data, serving as a virtual space in which barriers between diverse data sets are broken down. An important step in the development of the Çatalhöyük GIS as a reflexive tool has been the implementation of GIS packages on tablet PCs used in the field.

'Information at the Trowel's Edge': the role of tablets in the production of knowledge.
In 2013, the systematic use of tablets in the field was introduced in three different excavation sections in the South Area as part of the broader goal of moving towards paperless recording. The sufficiently affordable cost of tablet technology, the wider development of the hardware technology itself, and the availability of tablet PCs robust enough to cope with the physical pressures of site work (specifically heat and dust), have allowed the expansion of tablet use at sites like Çatalhöyük. Pompeii, for example, is well known for pioneering efforts at using mobile technology in digital recording, replacing field notebooks and pro forma entirely with Apple iPads (Ellis and Wallrodt 2012). The success of the mobile recording initiative at Pompeii has inspired other projects, such as the Proyecto de Investigación Arqueológico Regional Ancash in Peru, which similarly employs iPads and has experimented with software and workflows to streamline data collection (DeTore and Bria 2013). Other projects, such as the Temple of the

Winged Lions Cultural Resource Management initiative, are using tablets specifically to enhance visualization and educational possibilities (Levy et al. 2013). The choices made at Çatalhöyük in terms of hardware, software, and methodology, drew on the successes and stumbling points of such initiatives in order to integrate the various intertwined forms of data we produce at the site. Moreover, our particular focus was on revising and improving Çatalhöyük's reflexive methodology, while keeping three central goals in mind:

- Ensuring no data would be lost in the transition from paper to digital;
- Creating a workflow with a manageable learning curve that could be utilized by team members with diverse technological backgrounds;
- Ensuring an increased overall efficiency when compared with traditional paper drawing.

The release of the Windows 8 operating system provided a software platform that would enable us to capitalize upon existing software solutions utilized by the project (i.e. the Microsoft Access Site Database and ESRIs ArcGIS 10 intra-site GeoDatabase), without reliance upon bespoke software solutions or app technology. Despite the desire to move towards total paperless recording, the main emphasis to date has been upon the use of tablets to create digital drawings of excavated features. This preliminary focus on the graphic archive was in part due to several logistical issues preventing database access on site. The three areas selected for tablet recording in 2013 were Buildings 80 and 118, which developed a workflow incorporating ESRI's ArcGIS 10.1, and Building 89, utilizing the open source QGIS as the main digitizing solution; although both workflows use vector points collected by the total station and raster ortho-photos taken with the site SLR camera as source data.

Figure 5.

As this workflow was developed and implemented, it soon became clear that tablet recording was a suitable replacement for the traditionally hand-drawn graphic archive and even exceeded initial expectations on several levels.

In addition to enabling the archaeologist to produce a robust, accurate, and ultimately efficient graphic archive, the tablet allowed an improved engagement between excavation and recording. The tablets became an indispensable repository of all past and present information relevant to the excavation, channeling a variety of data types. Archive reports containing relevant information about previous excavation seasons became available at the touch of the finger; older plans (including Mellaart's excavation plans) could be successfully imported into the GIS and superimposed upon recent plans and drawings; running matrices as well as relevant matrices from past seasons could be edited and annotated with ease; field notes and sketches were also organized and housed on the tablet; finally the integrated 3D models could be easily accessed within the GIS.

By combining tablets, GIS and 3D models the excavator has a unique opportunity to review the whole excavation process while in the field; the technologies serve as a useful reflexive tool in their own right. This instant and convenient availability of information has a direct influence on the archaeologist and allows better-informed decisions and interpretations. As such the tablets offer a number of potential ways to improve excavation recording methodologies by facilitating the reflexive engagement of the excavator in the archaeological process.
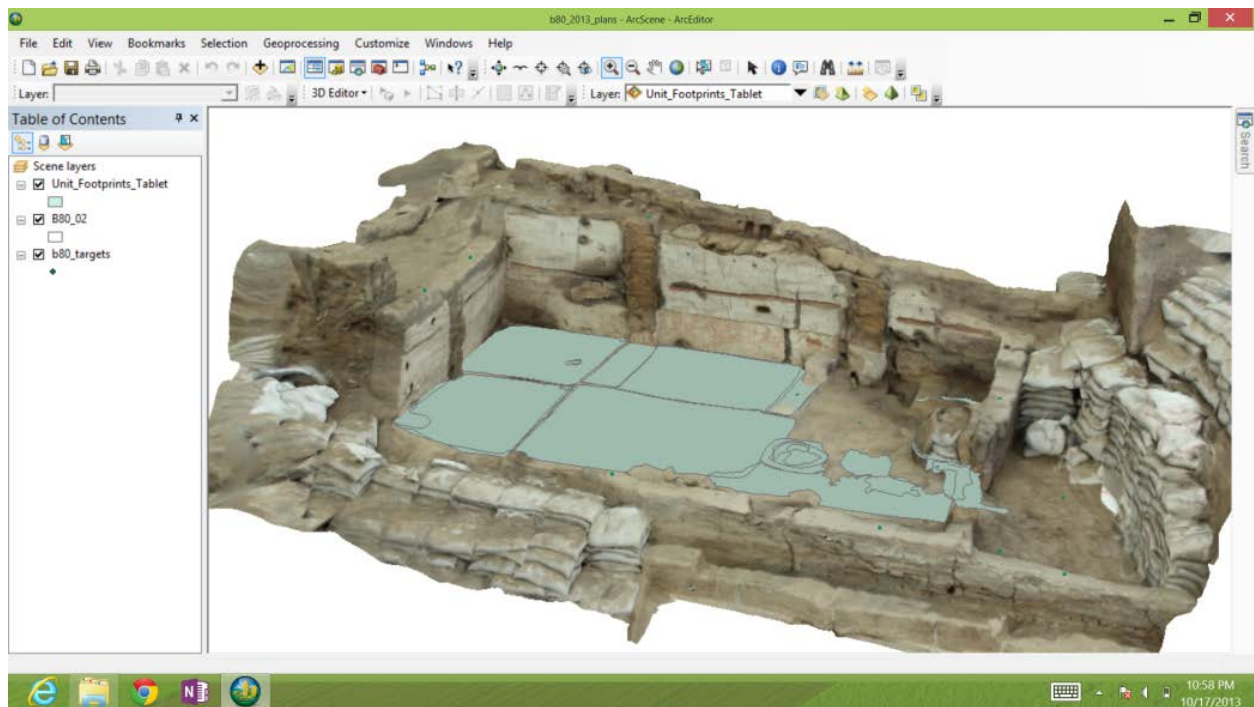

Figure 6.

Conclusions.

Figure 7 attempts to summarize the generation of knowledge at Çatalhöyük from the acquisition of field data, through the archaeologist as an agent for recording and interpretation, towards the generation and dissemination of output, both as an archive resource and in terms of publication. This structure is perhaps necessarily hierarchical because it is related to the recording system, which is based upon single context recording methodologies (Spence 1993). However the diagram also demonstrates how the various stages of knowledge production are impacted and

informed recursively by the application of the various reflexive methods employed by the project as they have developed and been added to in the ways outlined above.
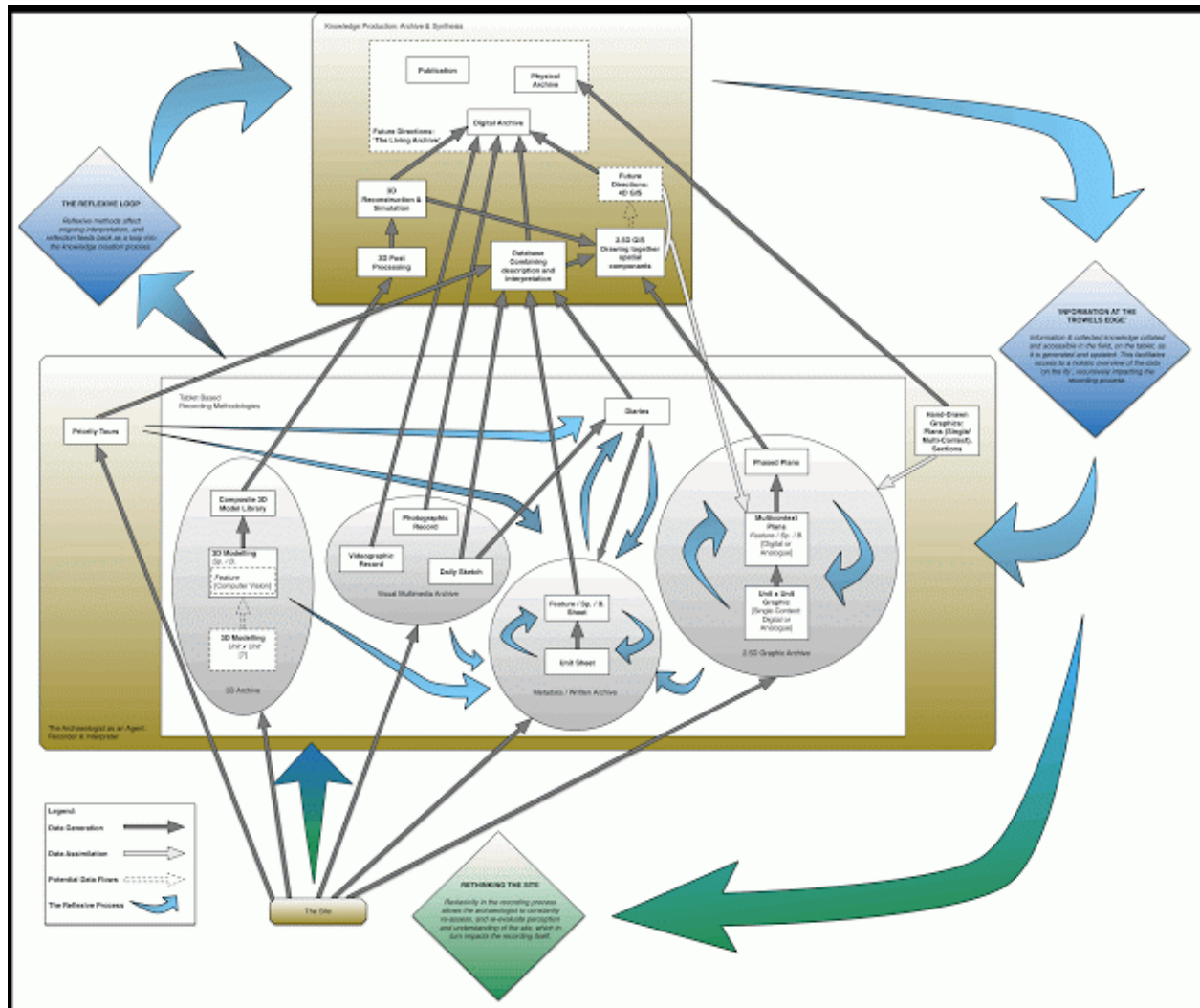

Figure 7.

The 'reflexive loop' might be seen as an ideal, and historically it has been difficult to implement fully (see above and Berggren and Nilsson in press). There are several factors which deserve some further consideration here – since, in a very real way the use of the tablets in the field addresses some of these problems. One impact of the tablets is in mitigating some of the social and structural faultlines identified above. Their use forces all members of the field team to train in and develop a range of 'non-traditional' skill sets (3D modeling, georectification, digitization and GIS data manipulation), historically reserved for specialist team members. Whilst the

coordination and management of this technology still requires a degree of specialization, the knock-on effect of the diversification of skills is an overall democratization of the knowledge creation process. Everyone on site is contributing, and recursively benefitting from the easy, integrated flow of data and interpretative information through the tablets.

This democratization is further reinforced by the fact that team members very quickly begin to develop a much deeper understanding of the digital data structure of the project, and by implication, what happens to the data once it leaves the site, and how it fits into the process of interpretation. The tablets bring many aspects of data manipulation, validation and interpretation, which are ordinarily reserved for certain 'privileged' individuals during the post-excavation process, into the field 'at the trowels edge.'

The tablets also directly address a number of issues arising from the fragmentary nature of various components that make up the recording system as a whole: entering data into the database was separated from recording on paper on site, diaries and certain levels of interpretative analysis were completed digitally in the evenings distanced from the field, and even within the field different logs and recording sheets were often stored in different files, kept on different boards and filled in at different times (both on and off site) - such are the practicalities of most 'paper' excavations.

At Çatalhöyük, the recording documentation was developed to try and accommodate this fragmentation, but it is fair to say that nothing has had such an integrative impact upon the recording process as the adoption of tablet PCs. This can be clearly seen in Figure 7 which gives some indication of the degree to which the tablet facilitates a more reflexive approach to recording by allowing the operator to switch at will between graphics, written observations and interpretations, stratigraphy and 'old data' or publications. The result is a more holistic overview of the data collation and interpretative process, on the fly, in the field, as the action unfolds. This 'deep integration' of data and interpretation inevitably informs and supports the process of generating knowledge output.

More specifically the tablets, and the suite of associated digital technologies which they allow in the field, serve to realize a number of the original twelve components of reflexive archaeology (see Table 1). As discussed above they have a democratizing effect, and therefore serve to breakdown barriers (component 3) and hierarchies between various team members. They integrate data (component 5) both from the database, the GIS, and the 3D models. Many of the technologies referred to in components 9, 10 and 11 seem dated in the light of these modern technologies; but for precisely this reason, the tablets and the technology they harness can be seen to dramatically supersede and improve upon the technologies envisioned when these steps were originally conceived. Finally the different visions of the site which flourish within the international teams (component 12) are drawn together as the tablets, diaries, and the increasing emphasis upon free interpretation of the various digital datasets by all team members, facilitates a subtle form of digitally based multivocality.

It remains the case, however, that as archaeology as a discipline becomes ever more fragmented into specialized areas of knowledge, challenges to integrated interpretation and contextual understanding within the field process increase. As noted above, a good reflexive methodology will try to institute a recording structure which places "the individual archaeologist at the forefront of a recursive, interactive web of interpretation and discussion" (Chadwick 1998). It will emphasise interpretation as part of the primary recording, it will allow for easy reflection and dialogue, preferably on site, and will allow all members of the project access to a holistic overview of the data so that interpretations about individual artefacts, or stratigraphic units, or higher order stratigraphic groupings and features, can be made in their broader context (Carver 2009). At Çatalhöyük there have been successes and failures in the implementation of reflexive methods. Many of the problems have derived from faultlines between field and laboratory staff, or from the practical separation of ever more complex forms and types of data. While it might have been thought that GIS and 3D visualization would encourage further fragmentation and distancing from the trowel's edge, in practice their use, especially when combined with the adoption of tablet PCs in the field, has led to a maturing and expansion of the original reflexive objectives.

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FIGURE CAPTIONS

Figure 1: Example of a daily sketch at Çatalhöyük. Photo and annotation by Burcu Tung.

Figure 2: Geo-referenced virtual reconstruction of the Western stratigraphy of B89 based on computer vision models. Source: Nicola Lercari.

Figure 3: 3D GIS of the south shelter visualized using Arcscene. The buildings displayed in the screenshot have been excavated in different years by different teams. The screenshot shows the field documentation realized by the archaeologists working in Building 80, 89 and 118 imported and visualized in spatial relation with the models of the buildings.

Figure 4: False colour 3D models produced in Meshlab showing stages of the excavation of a skull retrieval pit in Space 77: (left) upper burial layer showing circular fill of skull retrieval pit (dotted circle) above a primary flexed adult burial; (centre) middle burial layer after removal of soil from skull retrieval pit revealing disarticulated skeletal elements placed in cut for skull

retrieval pit. Parts of the underlying primary flexed adult skeleton are now visible; (right) lower burial level after full exposure of the primary flexed adult headless skeleton.

Figure 5: Using the tablet in the trench. Photo by Nicolo Dell'Unto.

Figure 6: 3D GIS of Building 80 visualized using Arcscene. The screenshot shows the field documentation (2D polygons in green) recorded by the archaeologists working in Building 80 imported and visualized in spatial relation to the model of the building created using image based modelling. Source: Justine Issavi.

Figure 7: Workflow summary diagram. Source: James Taylor.

TABLES

Table 1. Twelve components of a reflexive archaeology at Çatalhöyük as defined by Hodder 2000a.

Step/component	Description/aim
1. on site interaction	Tours on site to facilitate interaction and communication between excavators and laboratory staff
2. negotiations of priorities	Discussions between excavators and laboratory staff on the tours result in decisions of what to prioritize for immediate analysis by all relevant labs
3. breaking down barriers	Breaking down barriers between categories on different levels, e.g. barriers between find categories, to avoid decontextualization.
4. fast feedback	Fast track of results of prioritized analyses from labs to the field, to influence further work and decisions
5. integrated database	An integrated and fluid database to facilitate integration.

6. diary	An addition to the database, the diary situates the data within its context of production and provides an opportunity for reflection. Both an integrated part of the process of interpretation as well as a record of it.
7. videos	The interpretation process on film. Summaries of priority discussions and interpretations of areas in phase are filmed. To function as a key to the database in addition to the diary.
8. anthropologists	Three different kinds of anthropological studies of the construction of knowledge. 1, The study of the archaeological interpretation process to illuminate unrecognized assumptions. 2, The study of visual conventions that are a part of the record. 3, The study of the impact of the project on the local community.
9. web based database	The database made available on the Internet to enable a multivocal engagement in the project.
10. hypertext, multimedia	The use of hypertext and multimedia, to avoid linearity of archaeological narrative.
11. virtual reality	Virtual reconstructions as a gateway to the database, mainly for the general public and to allow for experimentation with reconstructions and visualizations.
12. teams/windows	Teams of different nationalities excavate different parts of the site, open different window into the site, leading to different versions of Çatalhöyük.