FROM PRACTICE TO THEORY – EXPANDING THE STRATIGRAPHIC RECORDING INTO REAL 3D

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On many archaeological excavations world-wide latest technological equipment is in use for digital documentation of the excavation process. Digital cameras, total-stations, computer hard- and software speed up the documentation and enhance the quality as well. We worked for years mainly at the site Schwarzenbach-Burg on the problem of a complete digital documentation of the archaeological stratification destroyed by the excavation process. Our practical fieldwork showed that there is still no profound theoretical background defining the practical framework of documentation and therefore the efficient use of latest technology. As any archaeological excavation deals with a unique stratification - a four dimensional phenomenon - the complete three-dimensional documentation of any unit of stratification and its order in the time arrow by the means of a stratigraphic sequence is of crucial importance for a complete recording of the archaeological excavation process.

As shown by E.C. Harris in 1979 the arbitrary excavation process, still widely in use today, has to be avoided and replaced by the stratigraphic excavation process. The stratigraphic excavation process (Harris, 1989) aims in the unearthing of the single units of stratification (i.e. deposits and feature interfaces) along with the recording of all its attributes and relations to create a stratigraphic sequence or a Harris Matrix from this data. The Matrix is the fundamental diagrammatic representation of time for an archaeological site. It displays all uniquely numbered units of stratification in a sequential diagram representing their temporal succession. It provides a relative calendar, which is the testing pattern for any further analysis. However complete 3D recording of the units of stratification is upon demand, it is not yet the standard in archaeology due to theoretical shortcomings.

Three-dimensional recording of the stratigraphic excavation process by the means of a total-station to record the boundary polygons of the units of stratification and the location of finds at Schwarzenbach-Burg.

As Harris points out, any unit of stratification is formed by material deposits and immaterial aspects - feature interfaces or more generally surfaces - that have to be found and recorded by the excavating archaeologist. In the first instance these two aspects are the main objects to be recorded on a stratigraphic excavation. Any finds, samples or other information and observations have to be related to the deposits and surfaces. Single deposits are 3D volumes of material and can only be recorded partially as most of their mass is simply excavated. The material aspects of deposits can only be captured by sampling. For the stratigraphic record, each deposit is reduced to a unique number in the stratigraphic sequence. It imparts this number to all of the portable finds and samples found within its volume during the process of excavation and destruction. The finds or samples are isolated from the stratigraphic unit while excavating it. Their 3D position can be easily defined upon discovery or extraction. The finds and samples are recorded in 3D space as three-dimensional points or small volumes, thus reduced to a set of coordinates. All further data derived from the finds can be stored in a georeferenced database, photographs and find drawings.

The documentation of the uncovered surfaces is done by 3D Laser Scanner combined with a digital camera.

3D Laser Scanner Riegl LMS Z420i on a mobile scanning platform (MSP 250) in use to document the remains of the Iron Age workshops at Schwarzenbach-Burg.

Contrary to deposits, the immaterial aspects of stratification, the surfaces can be recorded in their entirety, which is the reason for their outstanding importance to stratigraphic analysis. Any material deposit is enclosed, or defined, by its immaterial outer surface. Thus an archaeological deposit is a material volume that can only be documented in 3D by mapping its surface. The access to the complete surface or hull is restricted as the deposits are buried volumes. Only its top surface once exposed to the atmosphere is unearthed by the stratigraphic excavation process and can be mapped. Its limitation can be represented by a 3D boundary polygon. The mapping of its bottom surface has been regarded as redundant so far.

At that point we add a vital and important expansion to the stratigraphic recording system as set out by Harris (1989). He identified the "feature interface" as an essential stratigraphic unit in its own right, as such surfaces have no deposits, e.g., the surface of a ditch after its construction. Having no deposit, he thought of them as "interfacial", that is between two faces, or surfaces.
It was appreciated that without the isolation and unique number of such interface units, a true stratigraphic sequence could not be compiled. Under our proposal, the feature interface is unique in that it, by its very nature, combines top and bottom surfaces into a single entity. We now propose that unless the top or exposed surface of a deposit and its secondary or underlying bottom surface are also isolated that the stratigraphic sequence cannot be fully compiled, nor can the full volume or definition of the associated deposit be captured in three dimensions.

The use of GIS for recording demands the adoption of these proposals, as does the full recording of the stratigraphic data of a site. Philosophically, this proposal brings the implications of the identification of surfaces by Harris as important stratigraphic units to a conclusion. Our proposals simply state that all surfaces must be identified and uniquely recorded, including also the overlooked bottom surfaces of deposits.

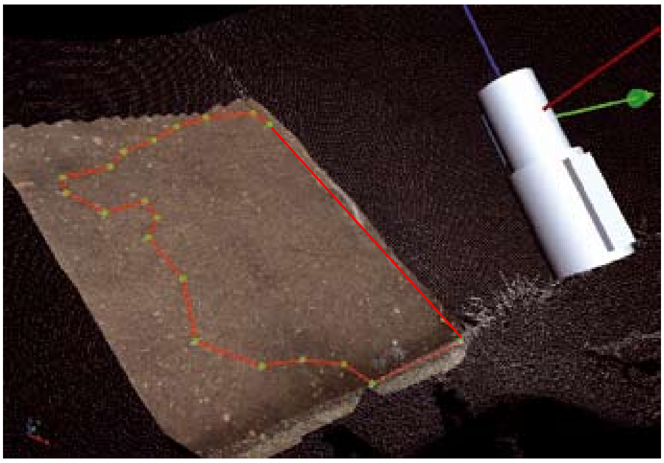
The bottom surface of a deposit is in superposition to the top surfaces of older deposits or interfaces. Upper or exposed surfaces represent the use periods of a site and thus account for far more time in the history of a site than do deposits and their bottom surfaces. Both surfaces have to be recorded entirely and in 3D. They are the primary elements for the reconstruction of the stratification and topography of the site through time. Single-surface recording provides the ability to reconstruct virtually the excavated volumes of deposits in three dimensions. Therefore, 3D recording of the top and the bottom surface of any single deposit as well as the 3D recording of feature interfaces is necessary to

The recording Laser Scanner is controlled remotely via a WLAN set-up on site. Additional vertical photographs complete the photographic record.

Triangulated and textured feature interface of a pit as recorded by the 3D Laser Scanner.

fully reconstruct the part of the site that was destroyed during the process of excavation. Every single unit of stratification - feature interface and deposits with their elementary surfaces - is given a unique number and documented by its boundary polygon as well as its topography. Therefore it is reduced to a set of coordinates. The collected sets of coordinates from feature interfaces and the top and bottom surfaces of the deposits are the primary raw data for further analysis in a GIS. All units of an archaeological stratification can be

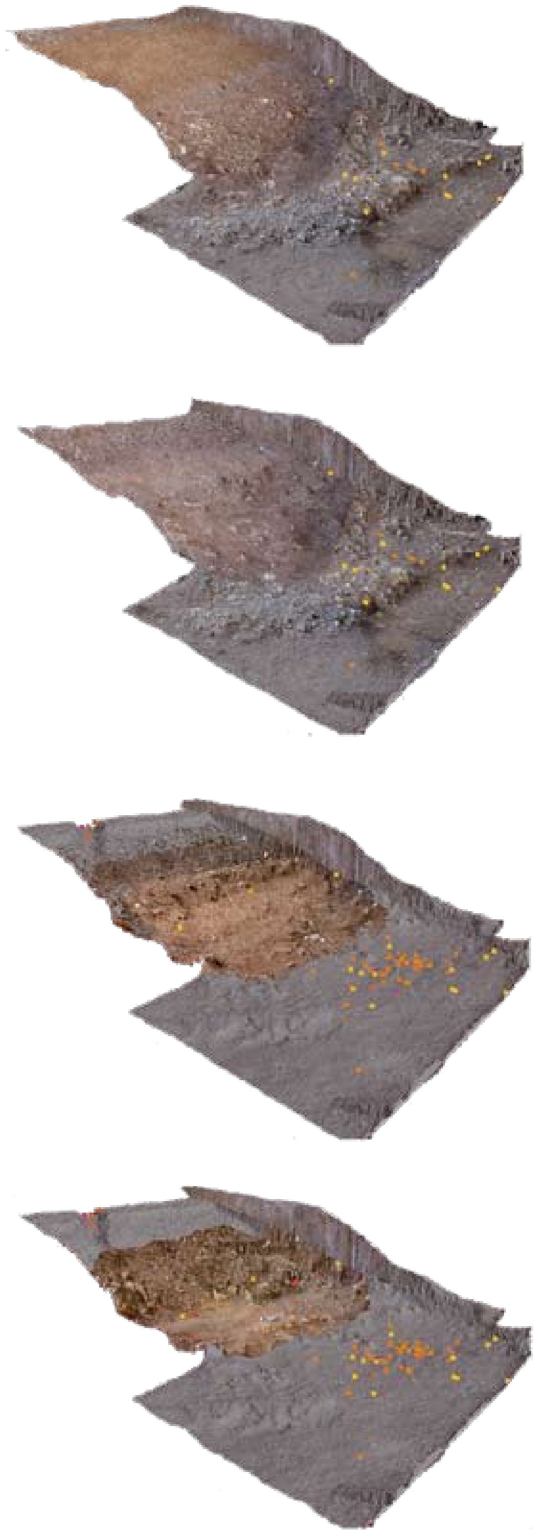
Feature interface of a Middle Neolithic pit integrated into the interface to geology.



The boundary polygon of a single deposit is marked by reflecting targets for direct recording by the scanner.

represented in 3D space by surfaces which have to be defined and recorded during the excavation process. Therefore stratigraphic recording is based upon 3D single-surface mapping. This forms the theoretical background for the application of terrestrial laser scanners, machines built for the efficient documentation of surfaces.

Stratigraphic recording ends in the creation of a stratigraphic sequence based on the spatial or topological relationship of the units of stratification. The stratigraphic sequence provides the ability to visualise time on archaeological sites. It is the fundamental diagrammatic representation of time for an archaeological site and provides its relative calendar, which is the testing pattern for any further analysis. The reconstruction of the site through time is achieved through the analysis of all artefactual data in relation to the stratigraphic sequence, and the placement of stratigraphic data in topographical order in conformity with the stratigraphic sequence using the information recorded and processed by GIS methods. Such reconstruction has often been impossible to achieve on most archaeological sites until the introduction of the Harris Matrix methods and the advent of GIS technology, and, we would add, the proposal made here for the complete identification of all surface stratigraphic units and their complete 3D recording as proposed below (see page 45-52). The most important concept to come out of what was mentioned before is an accurate and three-dimensional single surface planning (Neubauer 2007, Doneus & Neubauer, 2005) for a complete stratigraphic recording.



Sequential visualisation in the GIS of the surfaces and finds recorded during the stratigraphic excavation process at Schwarzenbach-Burg combining data from a Laser Scanner, digital camera, total-station and databases.

Three-dimensional visualisation of the scanned feature interface of an Iron Age oven combined with a real scene during the conservation of the hearth for exhibition purposes.

References

Harris, E.C. (1989): *Principles of archaeological stratigraphy.* London, 2nd edition.

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Zusammenfassung

Auf vielen archäologischen Ausgrabungen weltweit ist neueste technologische Ausrüstung für die digitale Dokumentation des Grabungsprozesses in Verwendung. Digitale Kameras, Totalstationen, Computer Hard- und Software beschleunigen die Dokumentation und erhöhen gleichzeitig deren Qualität. In den letzten Jahren wurde vor allem im Rahmen der stratigraphischen Ausgrabungen in Schwarzenbach-Burg an dem Problem einer vollständigen digitalen Dokumentation der durch den archäologischen Grabungsprozess zerstörten Stratifikation gearbeitet. Unsere praktische Arbeit hat gezeigt, dass für die effiziente Verwendung moderner Technologien die theoretischen Rahmenbedingungen für eine archäologische Dokumentation ungenügend sind. Da jede archäologische Stratifikation - ein vierdimensionales Phänomen - einzigartig ist, ist die vollständige dreidimensionale Dokumentation jeder einzelnen Stratifikationseinheit und ihre Einordnung im zeitlichen Ablauf in Form einer stratigraphischen Sequenz von grundlegender Bedeutung für eine komplette Dokumentation des archäologischen Grabungsprozesses. In Erweiterung der von E.C. Harris vorgeschlagenen ´single layer´ Dokumentation wurde ein neues Dokumentationsverfahren beruhend auf der hochauflösenden topographischen Erfassung einzelner Oberflächen der Stratifikationseinheiten entwickelt, das sowohl eine theoretische Präzisierung der stratigraphischen Grabungsmethode darstellt, wie auch in der Praxis effizient umzusetzen ist. Diese theoretische Erweiterung ist die wesentliche Grundlage für eine GIS-basierte stratigraphische Dokumentation und den standardmäßigen Einsatz von 3D Laser Scannern.