Complex Archaeological Sites: An integrated stratigraphic framework for progressive knowledge acquisition and representation

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1. Introduction
Bringing back to light archaeological evidence already excavated in the past involves the development of methodological tools that enable its integration into current narratives. The application of stratigraphic interpretation to past and current excavations is enabled by use of the GIS platform. Notes, sketches, photos, surveys, materials - now considered historical documentary sources - must be read and transformed into elements of a stratigraphic sequence that can be connected with the new excavations, for the reconstruction of the history of the town based on objective criteria and on accurate chronology, possibly marked in intervals of generations and not centuries. It is a challenge faced not only by the archaeologists working in Adulis, but also those working on any site where excavations have preceded the birth of stratigraphic archaeology and the dissemination of this method1.

When Roberto Paribeni first dug Adulis in 1906 he didn’t yet have stratigraphic archaeology at his disposal. His major work, which included the survey of the area, test trenches and excavations, was targeted specifically at identifying the city walls and understanding its topographic organization and planning, as well as the cultural characteristics of the architecture and artifacts. This fieldwork is known to us thanks to a script published in 19072. It is a descriptive summary of the places and excavation sites and not an analytical daily excavation log containing drawings of the structures, layers and elevations. Fortunately, the text is very often accompanied by the citation of the material contained in the layers, and accompanied by a few but useful photographs in black and white3.

The location of walls, rooms, artifacts, elevation points, activities and events, is only to be found in the narrative of that precious writing, a topographic map of the site, annotated with some excavations details in the form of drawings. Pioneering archaeological excavations of the 19th century and the first half of the 20th century favoured, as usual, the monumental buildings of the site, works of art, precious artefacts, highlighting some élite elements of the ancient community. Almost unexplored is the social identity of non-elitist groups, which can be undertaken through the analysis of the stylistic variability of daily artefacts.

The monument to which Paribeni devoted most of his attention is a structure which he named “Altar of the Sun”. It is this edifice which prompted the new phase of archaeological work commenced in 2011 (Fig.1).
2. Geographic Information System

2.1. The knowledge of past excavations

The need to understand the Adultitan finds, including the “Altar of the Sun” monument, through the complex and heterogeneous records available in different places and nonetheless create a logical and comprehensive narrative, led to the adoption of the GIS platform. The scalability of the system proved its value not only for specific excavation sectors but also as a cartographic database for the management of the entire archaeological site.

All the elements described by Paribeni such as structures or layers - once reviewed philologically - have been isolated numbered and tagged as Stratigraphic Units. In those instances where the elevations were available, they were assigned to the Units. After having done that, a sequence of structures, activities and events has been defined in a relative chronology.

Where the layers and their related findings were described by Paribeni, they have been assigned to an absolute chronology on the basis of knowledge currently available for each of the various classes of materials.

With this procedure the main phases of construction, use, destruction and abandonment of the monumental basement, including the “early Christian church” that stands on top of it, have been identified, reconstructing a ‘stratigraphic’ sequence of 1907 excavations, in order to permit comparisons, on a like for like basis, with the stratigraphic sequence produced for the new excavations 2011-2012 (Fig.2, Table 1).

2.2. Needs and tasks

As previously explained archaeological activities on Sector 2 have to deal with the excavations led by Roberto Paribeni in 1906, excavations that were no longer visible in 2011, at the moment of the first investigations of the present research team: the monumental building was completely hidden by sand and dirt. At the present time the only source of information is Paribeni’s publication, and its contents are fundamental: it consists in a very accurate description of what came to light during excavations, supported by a detailed map of the structures. In this map each setting is named with a letter of the alphabet,
used by Paribeni in the text to “locate” his observations and descriptions. However this publication is not a systematic report: a specific theme may be debated suddenly switching from one setting to another, or stratigraphic descriptions may be incomplete. Beside these description, considerations and hypothesis are found, whose nonobjective nature is not declared. Since the very beginning it was necessary to organize all this information, to make it available to the present research and to integrate it in the full process. The proper instrument to fulfill this need is a 3D topographic database, focusing on a quite narrow area, with a specific “philological” nature, which could be then integrated in the Geographic Information System of the area and of the whole archaeological site, which, it is important to remark, includes other excavation sectors, as well as excavations left open and visible by other teams until the sixties of 20th century.

2.3. The reasons for choosing GIS
GIS environment has been chosen to set up the previously mentioned “philological” database. In fact GIS technology provides solutions to needs which became more and more important along with the analyses activity: first of all to understand and correctly organize and normalize the contents of Paribeni’s publication; detect all the gaps and the incoherence in order to better orientate part of the excavation activities; to make available these contents and to include them in the actual Geographical Information System. Along with the studies on Adulis many different operators with different skills and competences are involved, such as archaeologist, of course, topographers, architects, experts in Cultural Heritage Preservation, experts in traditional building materials and techniques. As GIS is a very versatile instrument, now used in many fields, it

Table 1 - Attributes of Philological database (on the right); Fig.2 - The GIS at high scale: comparison between topographic surveys (Paribeni 1907 - present 2011-13); layer for geolocated archive of photographs topographic matrix and 2D visualization of "philological" database (see below).
is familiar to all the experts involved in the excavations, thus enabling a real fruition of these data, their exchange and a deeply integrated and complex lecture of the site. At the same building up a GIS compels the normalization of data and the control on the information acquired. In the case of this “philological” topographic database, normalize, organize and geolocating each piece of information in their three coordinates, has been the main activity and soon a real guide in the process of reading Paribeni’s publication, and on the other side this process gave a new value to data by means of 3D visualization.

2.4. Theorical and practical aspects of a “philological” GIS
This activity of translating a publication into a topographical database, has actually provided new questions that the excavation must be asked about. In particular the detection of lacks and contradictions in information, especially when referring to elevation and position of layers, has already posed and will pose in the future new requests to the archaeological activity to understand the position and the relationship between stratigraphic events. This translation is strictly referred to Paribeni’s publication, and the Table of Attributes arranged for the specific layer of the GIS is made up of a set of fields suitable for the kind of information provided by the text, followed by a set of fields fitting the actual principles of identification and management of Stratigraphic Units.

2.5. Wide area GIS
A GIS can also manage multiscale information, thus including data about the wider area around Sector 2. This wide area will include an archaeological park and will be provided by itineraries connecting the various excavation sectors, as if they were rooms of an open air museum. The forthcoming planning of this park is the reason why, beside collecting all the photos taken during the excavation activity, this GIS also collects a set of 360° views, carried out to provide a friendly and exhaustive visual dataset. The dataset of the wide area (about 40 hectares) is made by a very accurate topographic survey map, carried out during Paribeni excavation (Fig.3): this is an important base, as it shows the position of artifacts now completely interred. At the same scale, the second map is a basic Satellite Remote Sensing image, in anticipation of the forthcoming orthophoto (Fig.4). A significant part of the analyses and study activity, is carried out after the conclusion of the excavation campaign. It is therefore important the availability of non-ambiguous, easy-to-use and complete documentation. This task is mainly fulfilled by photographs, as they can be taken any time, by any of the operators involved on the site, and any other operator involved can easily acquire and use them. But, at the same time, the overproduction of photos can prevent from easily referring to them. To enable an easier consultation, photos can be processed in two ways: 360° explorable panoramas, made up of a set of photos taken from the same point and stitched together by PTGui software; 3D views (without metrical purposes but only as visual documentation) generated by a close set of photos through 123D Catch application by Autodesk. In this second case it is interesting to remark that there is no need to take photographs on purpose to obtain a 3D model, so when the demand for a new model grows, it is just necessary to find
a valid set of pictures among all the photos taken. Panoramas and 3D views, together with photos from Paribeni’s excavations and from current campaigns, are georeferenced in order to make the whole archive easy to access and to interrogate. Each of them is therefore provided with information and details contained in the Attribute Table (Fig.5).

3. Surveying strategies
Surveying techniques applied to an Archaeological site require specific methods and expedients due to the demand for a sporadic but systematic documentation of the evidences dug out during the various steps of excavations. Every single Stratigraphic Unity, concerning both a structural element or a layer, must be recorded.

Photos are easy and fast to take, easy to use, but metrically useful only under restricted conditions: camera optic with well-known lens distortion, perfect nadirality between camera and surface of interest, which moreover must be
perfectly planar, and inclusion of a metrical reference. Orthophotos and photomaps are easy to use, but their processing is more complex, and it makes use of geometrical information acquired with topographic instruments or photogrammetric procedures. Electronic instruments, such as Total Station - for celerimetric survey - and Terrestrial Laser Scanner (TLS), permit fast and accurate acquisition of 3D data, but expert operators are necessarily required during the activity on the field and during the processing of data. These data can then be used by any other operator involved in the research only after their post-elaboration which is very time-consuming, especially in the case of the point cloud acquired by the TLS. In the specific case of Adulis site, the use of electronic instrument was strongly restricted by reasons of very high temperatures since the early morning, of impossibility of working at night-time, and of the presence of sudden breezes moving dust and dirt thus generating a second order of noise in the acquisition. In order to manage an effective collection of data, the use of TLS Leica HDS 6200 was limited to one scanning set at the end of excavations, both in 2012 and in 2013 (Fig.8).

The use of TLS is intended to provide geometrical bases, useful to refer all the other information and layouts, obtained through other techniques and methods, for example direct survey. In fact from the alignment of the single point clouds acquired, it is possible to derive standard layouts with high accuracy, such as plan, elevation orthoimages, sections. But it is also possible to extract control points to produce photomaps and other layouts useful to the preservation analyses, research and project.

4. TLS survey and preservation project
The accurate geometrical knowledge of the monument – which consists of

Fig.5 - A 360° explorable panorama and the same developed along its width, processed with PTGui software
two distinct structures: a base made of high steps, and the remains of a paleo-Christian church on the top — is a useful base to develop the preservation project, which aims to stop instability and deterioration of the most exposed structures and wall-ridges. In this case the survey layouts, in particular the drawings concerning the visible elevations, have been an important support for analyzing and studying construction techniques and stone installation solutions, for outlining the use of materials and to point out the relative position of stones in the corners. This is very important to make sure that the restoration activity is perfectly aware of the proper texture, and the adequate materials (Figs.7,9).

The high steps of the so called “Ara del Sole” were built according to stonework techniques which require expert workers in the skillful use of local materials, as schist plates and basalt stones lying on clay mortar. To this day, disrepairs and instabilities are mainly due to sudden and violent rains; local subsidence and wall-bloating are caused by water, as well, which have to be properly led out of the structure avoiding new damages. Detailed information about elevation are necessary. With an accurate re-orientation of the reference system of the point cloud, it is possible to produce an elevation map also for the fronts, in order to detect the position and the directions of the stresses operating on the walls. In this way it is possible to supervise and

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Fig.6 (on the left)- 3D view generated by a set of photos, using the application 123D Catch by Autodesk; the purpose of this elaboration is to provide an easy and effective way to display the various steps of the preservation works: here it is possible to see the north-western corner of the so-called Ara del Sole before and after the restoration

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Fig.7 - The corners are a fragile part in any structure, it is important to analyze the joint technique in order to detect and to anticipate structural problems in the future
Fig. 8 - Point cloud of “Sector 2”: in the first image the orthoimage from the TLS point cloud, with the orientation due to the Reference System of the scanning set, it is possible to see the point contrails due to common behaviour of the instrument and objects accidentally scanned (wheelbarrows). The second image has been processed to take away accidental or instrumental error points and to outline the artefact structures, the orientation is derived from the global Reference System, as provided by the Eritrean Survey Department team.

prevent new damages, and it is also possible to guarantee an adequate safety level on the excavation site. All the restoration activities carried out on the archaeological site comply with the precepts of the “International Charter for the Restoration of Historic Monuments”, and put them into practice. The most important principles that a conservative intervention must be inspired by, are: compatibility, revertibility, recognizability, long-lasting.

Consolidations were fulfilled by building the missing part of the wall a few centimeters away from the level of the wall itself, using the same clay mortar, schist plates and basalt stones, chiseled on the place and jointed together with the same masonry technique (Fig. 6). The survey is therefore important to provide both metrical information of the excavation steps, and static and material comprehension of the artifact. Each scanning session, determined ad hoc on the site records in a complete and accurate way the most relevant steps of the excavations and the before-and-after of conservation interventions. Eventually, just to mention the next steps of the research, the archaeological site of Adulis will be soon surveyed by a LiDAR flight, in order to have a detailed map of the whole area, supplied also by color and infrared orthophotos, and the possibility to explore and process the point cloud to detect the position of other archaeological evidences.

Acknowledgements
President of Eritrea Isaias Afewerki, Governor of Massawa Mrs. Tsegereda; Tedros Berhane, colonel Yesus Woldu, Josyef Liebsekal, Director of National Museum of Asmara; Yohannes Gebreyesus, Director of Regional Museum of Massawa and his collaborators: Naizgħi Kiflemariam, Dawit Tesfay, Tigesti Beidu, Weldetinsae Abraha, Ibrahim Musa; Department of Topography of Asmara, Nahom Welderfaiel, Bīemnet Libsu, Dawit Efrem; workers from Zula e Afta villages; Italian Foreign Ministry (MAE);
Fig.9 - Elaborations of the terrestrial laser scanner data to provide information about the northern front. From the top: orthoimage of the front extracted by using Cyclone 7.3 software by Leica; redrawing of the front to highlight the laying of the stones, with the use of black and white orthoimages and photomaps; elevation map of the front to highlight the stressed portions of the wall.

Alfredo e Angelo Castiglioni, Ce.R.D.O.; Officine Piccini, Perugia; Chiara Mandelli and Rosanna Nardi from Università Cattolica del Sacro Cuore di Milano; Chiara Zazzaro and Enzo Cocca from University L’Orientale di Napoli; Cristina Tedeschi from Politecnico of Milano.

Notes
1 The Danish archaeologists in the second half of the nineteenth century began to date strata with the artifacts contained in them, Ch. Thomsen, A guide to northern antiquities, English translation by Lord Ellesmere, London 1848; J. Lubbock, Pre-historic times, as illustrated by ancient remains, and the manners and customs of modern savages, Williams and Norgate, London, 1865. Milestones in the evolution of the modern approach are the stratigraphic excavations of Mortimer Wheeler at Maiden Castle in England in the thirties and the excavations of Nino Lamboglia at Albintimilium in Italy, in the fifties.
3 R. Paribeni, Ricerche nel luogo..., 1908, 463-511, tavv. VII, VIII, IX, X, XI.
Abstract
In ancient times the town of Adulis, Eritrea, was one of the most important harbours on the Red Sea and a fundamental gateway within the network of cultural and trade exchange between Mediterranean and Oriental civilizations. Ancient literary sources frequently refer to Adulis, which was destroyed and abandoned during the 8th century and rediscovered at the beginning of 19th century. Excavations led by various researches were carried out intermittently since 1867 up to the 1960s; in particular extensive excavations were conducted by Paribeni in 1906. In 2011 the archaeological and research activities started again, directed by Ce.R.D.O., in cooperation with the Eritrean Government, the National Museum of Asmara, the Regional Museum of Massawa, the Catholic University of Milan, the Politecnico of Milan, the “L’Orientale” University of Naples, the Museum of Rovereto. The research, also funded by the Italian Foreign Ministry, aimed at the valorisation of the ancient town, including the creation of an archaeological park. This paper outlines how the choice of the appropriate technologies in the fields of survey, documentation and analysis, can support various aspects and task of the project. The case study of Adulis has been a rich opportunity to test methodologies and practices about collection and management of data and knowledge related to various aspects and for different users, producing clear and easy-to-use information for complex archaeological sites. As in many other cases, the management of this site, besides facing logistical issues, has to deal with the involvement of experts from differing branches, each of which normally adopts its own strategies and tools in managing information. In order to maximize the richness of the data collected and its interpretation, the main benefit of this approach is to provide the entire team with a clear exhaustive framework and knowledge receptacle in a familiar environment.

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