LISTING ARCHAEOLOGICAL SITES WITH A TOTAL STATION TACHOMETER

DATA PROCESSING OPPORTUNITIES FOR SURVEYED SITES

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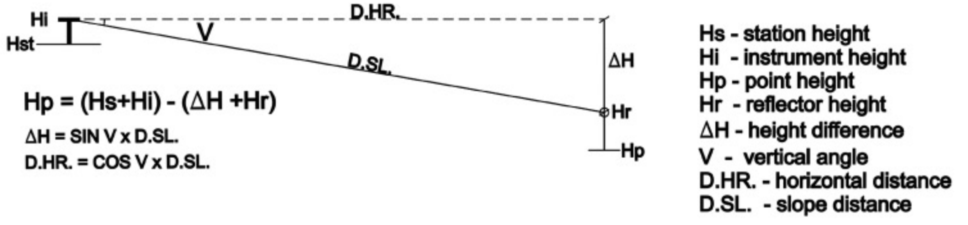
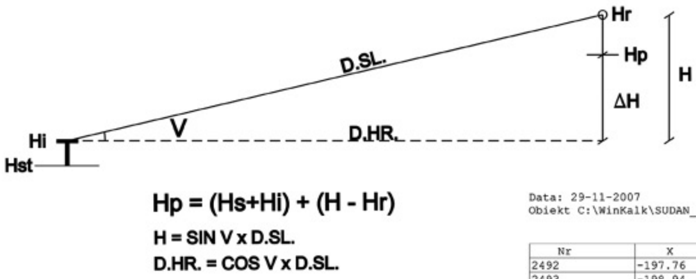
A geodetic survey and mapping of three sites in the vicinity of modern Karima in Sudan was carried out as part of the 2006 spring archaeological fieldwork of the Early Makuria Research Project (MtoM) directed by Prof. Dr. Włodzimierz Godlewski from the Polish Center of Mediterranean Archaeology of the University of Warsaw. The survey covered topographical measurements of the fortifications at Merowe Sheriq and the sites in the immediate vicinity of the fortress, as well as of a tumulus cemetery at Tanqasi; at el-Zuma, an existing plan of the tumulus cemetery at the site, prepared in 2004, was now supplemented with contour measurements. Digital maps were prepared subsequently for all three sites. The purpose of this paper is to discuss the usefulness of the planimetric digital method, hence the following remarks on the method and on the theory behind a broader application of digital maps in archaeological research.

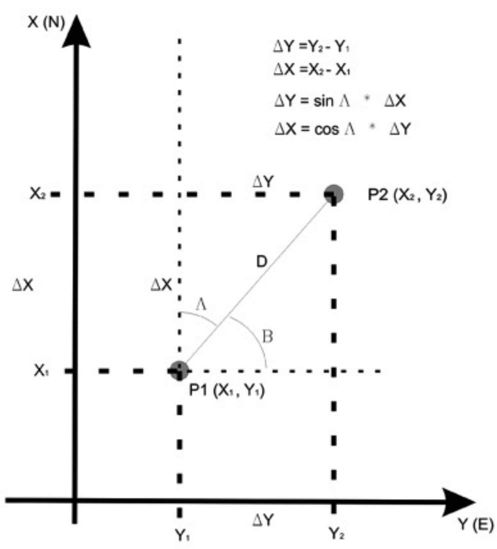
Geodetic site surveying with total station equipment and the resultant digital mapping can be done directly on the site, providing that the essential input for data processing is arranged and a multi-layer digital model of a given archaeological site is developed.

DIGITAL MAP

In principle, digital maps are computer vector drawings (in two or three dimensions) reflecting a specific fragment of measured surface. The process is largely dependent on computer systems drawing data from a variety of measuring instruments (tachimeters, GPS) and photogrammetric images, like adjusted aerial and satellite photos. Digital technology in current instruments for direct measurements and data processing technology have increasingly facilitated and accelerated the process of obtaining precise field or archival data. In archaeology, the application of digital cartographic methods has offered a different and frequently new approach to archaeological sites, the key benefit being a digital data model, best imagined as a multi-layer interactive presentation that is near in origin, as well as evaluation to the GIS system. Listing all potential data is of key importance for digital models of archaeological sites, followed by placing the obtained data on a digital platform, meaning a graphically uniform environment, and subsequent processing in order to generate the maximum amount of information about the area. Field data computer processing is accomplished usually through the addition







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Nr	X	Y	H
2492	-197.76	-123.30	270.557
2493	-198.94	-119.61	270.799
2494	-203.50	-116.64	270.796
2495	-209.43	-116.19	270.252
2496	-206.97	-117.81	270.547
2497	-206.60	-120.79	270.434
2498	-202.60	-120.96	270.974
2499	-204.43	-123.24	270.840
2500	-201.29	-123.75	270.951
2501	-202.11	-121.48	270.951
2502	-203.13	-123.86	270.879
2503	-201.73	-122.69	270.771
2504	-185.60	-150.29	269.058
2505	-171.91	-149.99	269.061
2506	-174.49	-139.87	269.115
2507	-173.43	-128.76	269.134
2508	-159.31	-132.43	269.104
2509	-159.24	-148.94	269.142
2510	-166.56	-162.72	269.090
2511	-164.04	-172.96	269.150
2512	-153.57	-164.86	269.184
2513	-142.56	-147.87	269.110
2514	-126.01	-145.79	269.139
2515	-120.52	-143.27	269.138
2516	-118.12	-137.45	269.101
2517	-123.48	-134.17	269.128
2518	-131.87	-134.06	269.086
2519	-131.61	-142.34	269.134
2520	-128.74	-139.11	269.209
2521	-124.52	-141.90	269.211
2522	-121.40	-139.46	269.221
2523	-126.17	-137.78	269.229
2524	-128.76	-152.90	269.095
2525	-118.30	-152.02	269.103
2526	-117.45	-162.29	269.104
2527	-124.08	-165.70	269.106
2528	-111.94	-164.88	269.130
2529	-110.98	-177.22	269.114
2530	-108.23	-186.10	269.133
2531	-100.42	-175.54	269.128
2532	-65.05	-209.72	269.573
2533	-79.18	-205.85	269.357
2534	-95.40	-202.97	269.188
2535	-109.96	-201.30	269.141
2536	-125.09	-201.72	269.112
2537	-131.20	-194.69	269.133
2538	-134.00	-180.27	269.132
2539	-132.72	-161.94	269.032
2540	-145.18	-161.26	269.137
2541	-157.04	-165.24	269.168

Fig. 1. Basic topographical measurement scheme (based on the author's original documentation from the Tanqasi cemetery, 2006)

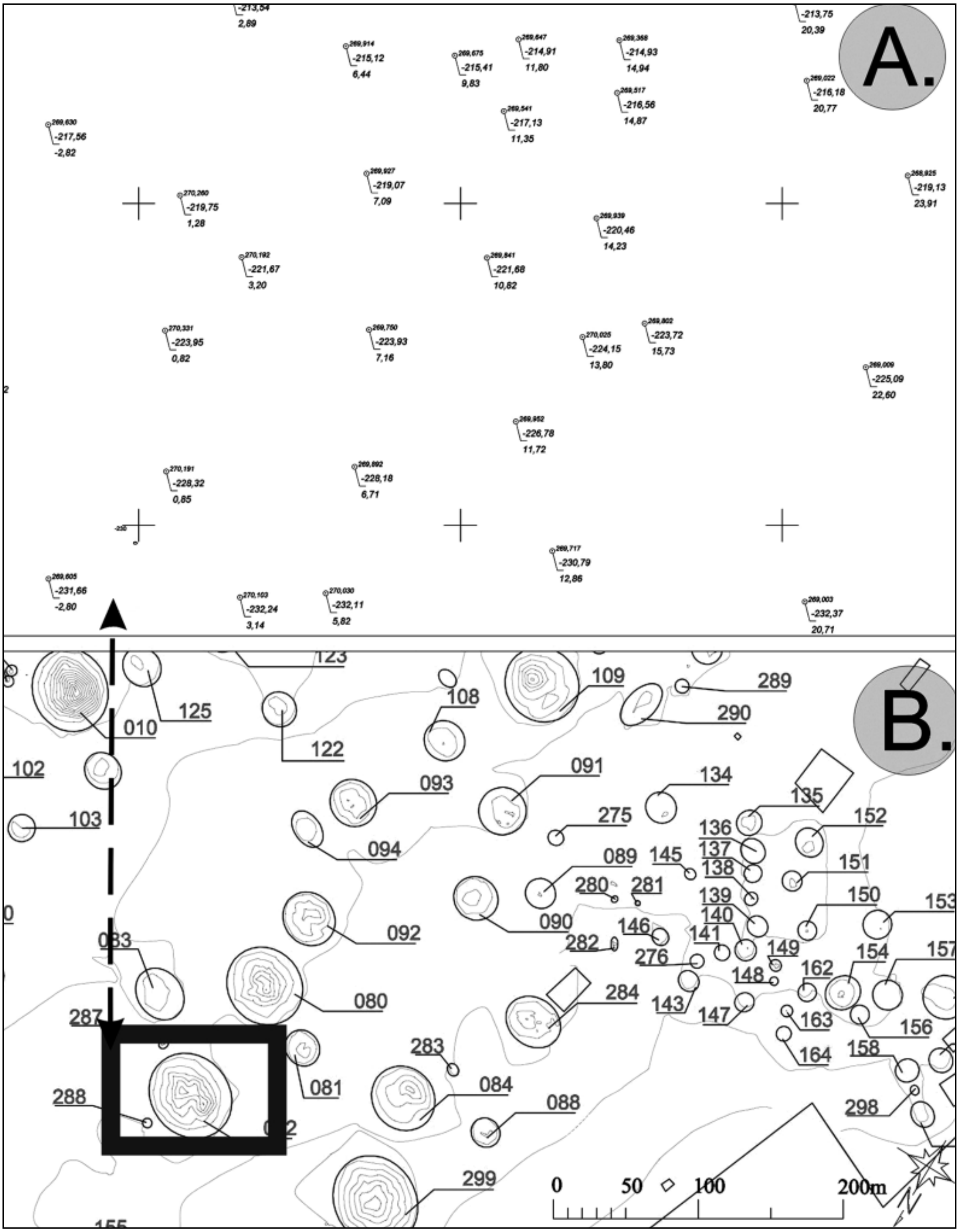

Fig. 2. *A – measured points with X,Y,H coordinates drawn after calculation in Winkalk software; B – topographical digital map drawn in AutoCad using measured coordinates (including numbers – links to database) (based on the author's original documentation from the Tanqasi cemetery, 2006)*

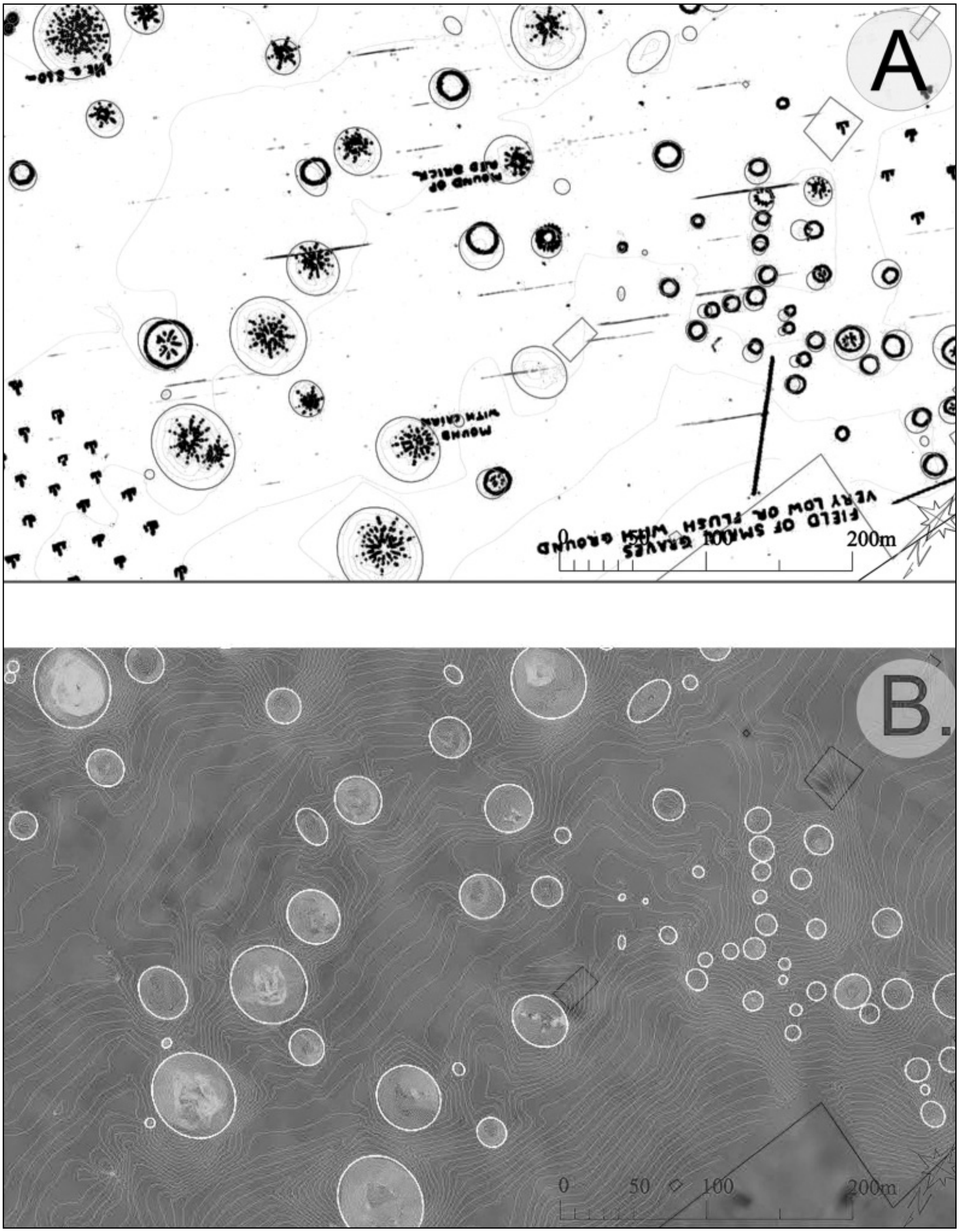

Fig. 3. A – digital map merged with captured archival drawing (P.L. Shinnie, 1953); B – digital topographical plan merged with satellite image from www.flashearth.com portal (based on the author's original documentation from the Tanqasi cemetery, 2006)

or separation of appropriate amounts of data and formulating questions, the outcome being quick and clear answers to specific issues. One of the benefits of an archaeological measurement record in the form of a digital map is the opportunity for continuous error assessment. Digital site mapping provides an image of measured features virtually at once, eliminating the risks inherent to the traditional method where protracted elaboration of results often makes it impossible to check for measuring errors. Properly prepared digital maps are often much clearer than the traditional paper version, while multiscale outprinting permits zooming in on selected parts of an archaeological site and presenting them in maximum resolution.

ARCHIVAL DATA SEARCH AND PROCESSING

Whenever a traditional plan on paper is available for an archaeological site, the data can be processed and incorporated in the new digital documentation. The source for digital maps in such cases is a raster image. This is a bitmap, that is, scanned or photographed traditional drawing, map or other archival source, which needs to be processed before it can be used [*Fig. 3A*]. This process of adaptation is called calibration and vectorization of the raster image.

Calibration adjusts image scale, eliminates distortions from scanning or photographing, and vectorizes the image. Once the map has been calibrated, it is then vectorized, bringing out geometric elements by contouring them on screen with broken, straight or curved lines. Some computer software will do this automatically or semi-automatically, but it is much better to interpret the image manually, based on observation of features in the field. This permits a proper layering of the map, that is, attributing recognized features to particular layers for the purposes of a clear presentation. Critical selection of map details at this stage facilitates work with the map, making it convenient with proper layer order management to work on whichever elements of the vectorized image are currently required.

FIELD MEASUREMENT WITH TOTAL STATION TACHIMETER

Increasingly often geodetic instruments are used for listing and mapping archaeological features in the field, during excavations, as well as fieldwalking. These instruments record data necessary for mapping structures in an inbuilt or external memory storage unit. The planimetric surveying method used in archaeology has undergone transformation in effect of the introduction of new technologies. Electronic total station tachometers are being used with growing frequency on archaeological sites. Modern electronic sub-assemblies and software favor broad application during fieldwork for the purposes of tachometric measurements, tracing stakeout points in three dimensions x, y, h; measuring surface area, etc.

The below listing presents stages of the work involved in preparing planimetric documentation during archaeological fieldwork.

I. Fieldwork

a. Current topograhical plan for planned archaeological works

b. Contour map for the excavated area

c. Tracing archaeological squares (kilometer, hectare, are divisions), trenches, grids for mapping archaeological top-plans and section drawings

d. Surveying features on the surface and excavated features

e. Measuring reference and datum points for the field documentation staff.

Tachometric measurement recording all data necessary for mapping the site later always begins with setting up the instrument. The total station instrument is oriented based on at least two reference points, from which the basic azimuth is calculated. This is the angle between the x coordinate of the geodetic grid (North) and the reference line. Taking up geodetic measurements on a site where previously such surveying was done requires the grid coordinates of at least two points identifiable in the field to be known. On this basis, it is possible to adjust the instrument to an existing system of coordinates [*Fig. 1*]. The coordinates system should be oriented to the north; the orientation should be checked with a regular compass. Having oriented the instrument, we can proceed with surveying features visible on ground surface. Data recorded during this stage of the work will serve to prepare a map of the measured features for archaeological purposes. Calculating coordinates for specific points is possible by adding or subtracting successive values of the horizontal angle (Hz – Horizontal) from the known basic azimuth value and measuring the distance to these points. The instrument automatically records the following data for each point: Hz – horizontal angle, V – vertical angle, and SD - slope distance, as well as HD – horizontal distance. Measuring successive points scattered with regard to the oriented reference line provides the opportunity to calculate coordinates increase (x,y), which are then added to the initial coordinates of a point with known coordinates [*Fig. 2A*].

II. Drawing stage

a. Data transfer and import of data to mapping and visualization software

b. Drawing topographical and contour maps, field sketches, based on measured points

c. Multiscale outprints

III. Data processing

a. preparing multi-layer digital model based on topographical map, contour map, photography, orthophotography and other kinds of data necessary for archaeological site analysis, e.g. geophysical maps, three-dimensional documentation etc.

b. attaching arbitrarily configured and prepared data bases on archaeological objects, geographical features etc.

c. data search: identifying archaeological issues and appropriate data model management in order to obtain satisfactory answers;

d. publishing and updating (editing) research results, using all kinds of available media.

The purpose of this particular work is to prepare an integral digital data model that is maximally useful from the archaeological point of view. Specific thematic layers should be mutually complementary and explanatory [*Fig. 2B*]. Model components include data obtained from above the site: all kinds of photography – kite, balloon, aerial, satellite [*Fig. 3B*]; additionally combined with surface measurements (Total Station, GPS), supplemented with geophysical prospection (electroresistivity, magnetic, ground penetrating radar).

Each of these non-destructive methods has its benefits in discovering and tracing the extent of an archaeological site and in making decisions concerning the localization and logistics of field excavations.

Combining a digital model with external database about recorded features facilitates textual queries to the model, producing substantive and statistical information about observed features. Quick access to data, use of modern technologies and the dynamics of data processing make this effective method very useful in archaeological research.

Connecting a database about objects recorded on the map permits textual queries to the digital model in real time, meaning that a graphic preview is presented of the selected group of objects. The selection is then cached in the computer's memory or printed on paper for confrontation in the field. Combining graphic and textual data is a fundamental characteristic of the Geographical Information System (GIS). Simultaneous review of drawing documentation and textual data base gives a very broad field of analysis and subsequently presentation of the digital model. The software for connecting a vectorical map and external data base needs to have interface permitting specific link definition between data base records and objects recorded in drawing so that selection of a database record calls up the corresponding graphic element on the map.

Automation of field data measuring and mapping reduces the time required normally by traditional planimetric techniques (keeping a journal of measurements and manual mapping) while increasing precision of both measurements and drawing, because mapping precision matches the precision of measurements in the field owing to direct data transfer of point coordinates to the map-generating software. Thus, the concept of the map itself is slowly changing, the analog paper map that was the result of mapping field measurements directly on paper or other available carrier being now replaced by a digital map that can be updated directly in the field using the hugely useful Total Station or GPS equipment. The analytical potential of the digital map thus generated is enormous thanks to interaction with external data bases and adaptation to other sources of information, like air photography, geophysical prospection, 3-D documentation, etc.

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