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From landscape to excavation: using new smart tools for multiscale archaeological investigations.

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Abstract –**The world of geomatics today provides new tools, smart and low cost, for archaeological research, from geographical positioning to detailed survey of past evidence. These instruments, light and not bulky, interface directly with tablets, I-Pads or smartphones via intuitive applications and speed up the data collection in the field. However, to what extent these tools, beyond their apparent effectiveness, are precise and reliable and in which frameworks work better or worse? Using the *Trimble Catalyst DA2* system for centimetric georeferencing at the *Curiae Veteres* in Rome (Italy), at the Sun Temple of Niuserra, in Abu Ghurab (Egypt) and inside the ancient site of Eridu in Iraq, was a good chance to test the accuracy of this new tool, especially when associated to detailed and close-range survey activities, related to landscape archaeology and stratigraphic excavations.**

I. INTRODUCTION

The world of geomatics and digital technology provides today new tools, smart, low cost and easy-to-use for archaeological research in the field, from geographical positioning to detailed survey of past evidence [1].
These instruments, light and not bulky, interface directly with tablets, I-Pads or smartphones via intuitive applications and speed up the data collection in the field, making the spatial and typological integration of archeological record increasingly faster and easier. However, to what extent these tools, beyond their apparent effectiveness, are precise and reliable and in which frameworks work better or worse?
In the last 2 years, using the Trimble *Catalyst DA2* system for centimetric georeferencing in various ancient sites of the world, facing different logistic and environmental situations and following distinct purposes and targets, was a good chance to test the efficiency and accuracy of this tool; in all cases I had to set different procedures to find a correct method, considering also collected data and disposable information.
The main on-field configuration was made by a *DA2* GNSS receiver mounted on a pole and connected via Bluetooth to a smartphone to get the *Catalyst* centimetric service by the application *Trimble Mobile Manager* and using *Mapit Spatial* for mapping data, an easy-to-use sofware working with OGC *geopackages* and EPSG codes for coordinate systems and projections.

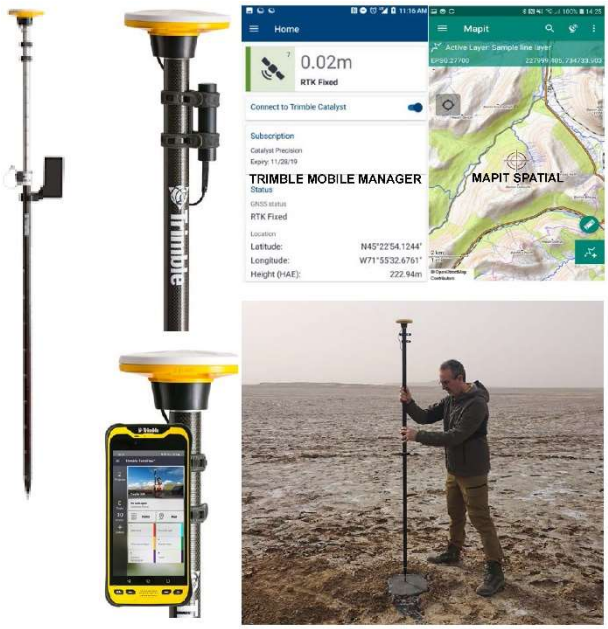


Fig. 1. The system configuration and the collecting data applications

The places where this configuration has been tested are: the *Curiae Veteres* in Rome (Italy), the Sun Temple of Niuserra, in Abu Ghurab (Egypt) and the ancient site of Eridu (Iraq).
It must be added that the use of this new geo-positioning system was always associated to detailed and close-range survey activities, related to landscape-archaeology investigations and stratigraphic excavations.

II. ACTIVITY AT THE *CURIAE VETERES* – ROME

The *Curiae Veteres* are located between the northeast slopes of the Palatine hill and the Colosseum valley: here a long archaeological research activity has been carried out since 1986 by Clementina Panella, Professor of *Sapienza University of Rome.* During more than 30 years of excavations and survey activities many ancient buildings have been discovered, bringing to light a topographical and urban continuum of architectural complexes, distributed over time, from Iron Age to the end of the antiquity: these important finds make this sector one of the most important

of the ancient Rome [2-4]. The excavations are finished and now the area is included in a new restoration and exposition project, carried out by the *Parco Archeologico del Colosseo*. One on the first activity to do was a new general survey to plan the future restoration activities: this new survey, of course, had to be linked to all previous archaeological documentation and at the same time georeferenced in the new topographical network set in 2020 by the *Parco Archeologico del Colosseo* inside the Roman Forum and the Palatine, using GNSS technology and the ETRF2000 geographic system.

This was an excellent opportunity to test the *Catalyst DA2* because the 2020 topographic network has integrated some already existing IGM95 benchmarks previously used to geo-reference the excavation; moreover, it was possible use the excavation area benchmarks as control points.

It must be added that the *Trimble Mobile Manager* software, which provides satellite data correction, is essentially web-based so it is necessary to connect to the online service to have access to the centimetric precision system; we have also detected that with a continuous connection, the data correction is faster and safer: in Rome the mobile line is excellent, so we worked in optimal conditions.

The results obtained were very satisfactory, with deviations contained within 1 centimeter for the topographic benchmarks and with discrepancies of 2-4 centimeters between the new photogrammetric survey and previous digital close-range drawings, which are physiological in consideration of the different analysis scales adopted.

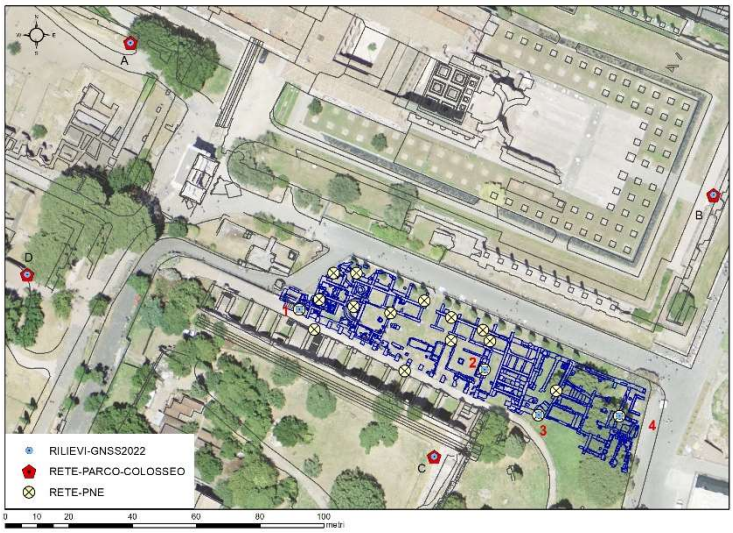


Fig. 2. The new georeferencing of the Curiae Veteres excavation area using the Colosseum Archaeological Park topographical network: benchmarks A-B-C-D

Table 1. Archaeological Colosseum Park benchmarks values compared with Catalyst DA2 new measurements: benchmarks A-D (only last 2 integer coordinates numbers are reported; decimal values are rounded to two digits).

Colosseum Park benchmarks values			
Benchmark	X	Y	Z
A	31.13	41.61	26.27
B	14.18	93.94	31.67
C	26.49	11.90	47.19
D	98.72	68.97	38.81
Catalyst benchmarks values			
Benchmark	X	Y	Z
A	31.12	41.61	26.25
B	14.18	93.94	31.65
C	26.48	11.89	47.19
D	98.72	68.96	38.81

It must be added that the *Trimble Mobile Manager* software, which provides satellite data correction, is essentially web-based so it is necessary to connect to the online service to have access to the centimetric precision system; we have also detected that with a continuous connection, the data correction is faster and safer: in Rome the mobile line is excellent, so we worked in optimal conditions.

The results obtained were very satisfactory, with deviations contained within 2 centimeters for the topographic benchmarks and with discrepancies of 2-4 centimeters between the new photogrammetric survey and previous digital close-range drawings, which are physiological in consideration of the different analysis scales adopted.

III. ACTIVITY AT ABU GHURAB – GIZA

The archaeological investigation in Abu Ghurab, inside the Memphite necropolis area, has been carried out since 2010 by an international team, today composed by the *University of Turin*, the *Orientale University of Naples*, the *Polish Academy of Sciences*, and the *Uninettuno University*. The investigations are focused on the Solar Temple of Niuserra, King of the V dynasty during 2460-2430 Before the Common Era.

The topographical survey of the general territory and the archaeological detailed graphic documentation of the excavation are managed by a multi-scalar GIS, following an intra-site/extra-site approach and connecting the stratigraphic information to the ancient landscape: from the smaller site of Niuserra's Sun Temple it is possible to move via GIS into the broader zone of Abusir and Saqqara necropolis, including all the Memphite area [5-6].

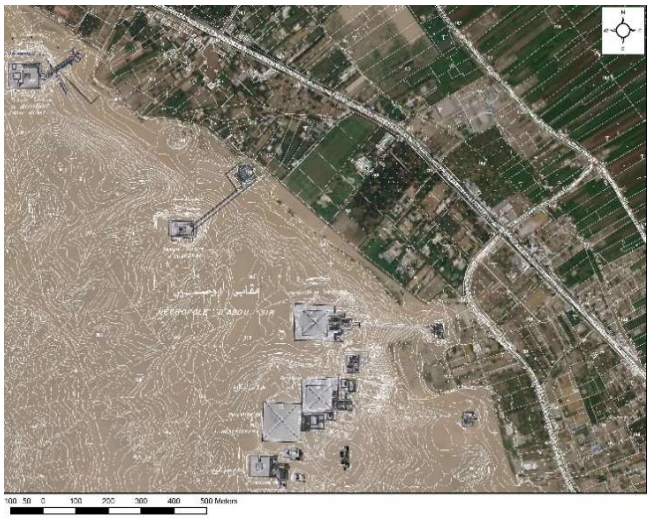


Fig. 3. The Abu Ghurab and Niuserra's Sun Temple area

For this purpose, at the beginning of the activity, a traverse around the temple was set by total station; later,

during the years of investigation, to a local topographic network was including a wider external area.

Unfortunately, georeferencing has been for long a concern: national geographic benchmarks are not visible in the surroundings while the use of conventional GNSS/DGPS devices normally is not permitted in Egypt for military reasons: for long it was possible georeferencing the data only using very high-definition satellite images and performing on them a manual roto-translation of spatial data by a best-fitting procedure.

Concerning elevations, it was not possible to assign absolute sea-level values and we had to use our conventional values; this was a big concern because our GIS base map is composed by the sheets of the *Survey of Egypt Topographical Series* of 1978 (together with several satellite images) reporting detailed contour lines (drawn every 1 meter) and elevations which cover the entire Memphite Necropolis: this map is used not only to locate all excavation drawings but also to reconstruct their ancient landscape by DEM and DTM. The *Catalyst DA2* survey was then essential to link the archaeological documentation to the orthometric heights reported in the French maps and transform all conventional elevations of the excavation to absolute values.

Since the centimeter accuracy of the system in Africa is not fully guaranteed by Trimble, considering also that the mobile line is not constant on site, we have repeatedly measured all the benchmarks of our topographic network, for many times; apart from gross errors easily detectable, multiple measurements varying of two centimeters on X, Y and Z axes, were obtained.

A further control of these values by total station (assuming the first benchmarks coordinates as a starting point) has detected a similar error range.

In this way the excavation and has been correctly placed in its geographic context; in addition, a new topographical network made of absolute value coordinates benchmark can now support the archaeological documentation.

Table 2. Multiple measurements of the topographic network benchmarks in Abu Ghurab.

	X	Y	Z
Benchmark A			
1	67.31	61.04	35.14
2	67.32	61.02	35.13
3	67.33	61.03	35.12
Benchmark B			
1	91.12	30.61	36.20
2	91.13	30.60	36.22
3	91.14	30.61	36.21
Benchmark C			
1	18.01	84.02	36.98
2	18.01	84.04	36.99
3	18.02	84.03	37.00
Benchmark D			
1	78.55	87.58	36.70
2	78.55	87.57	36.69
3	78.55	87.58	36.68

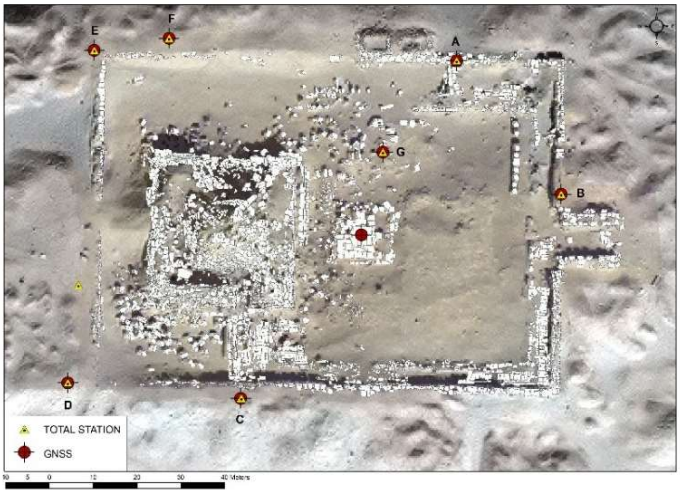


Fig. 4. The benchmarks around the excavation area

Table 3. Comparison between measurements taken inAbu Ghurab by Catalyst DA2 and total station

Catalyst DA2	Total station
BMA-X 67.32 Y 61.02 Z 35.13	BMA-X 67.32 Y 61.02 Z 35.13
BMB-X 91.13 Y 30.61 Z 36.21	BMB-X 91.13 Y 30.61 Z 36.21
BMC-X 18.01 Y 84.03 Z 36.99	BMC-X 18.02 Y 84.03 Z 37.00
BMD-X 78.55 Y 87.58 Z 36.69	BMD-X 78.55 Y 87.58 Z 36.70
BME-X 84.59 Y 63.46 Z 35.58	BME- X 84.59 Y 63.45 Z 35.59
BMF-X 50.48 Y 40.23 Z 34.43	BMF- X 50.48 Y 40.23 Z 34.44

IV. ACTIVITY AT ERIDU – IRAQ

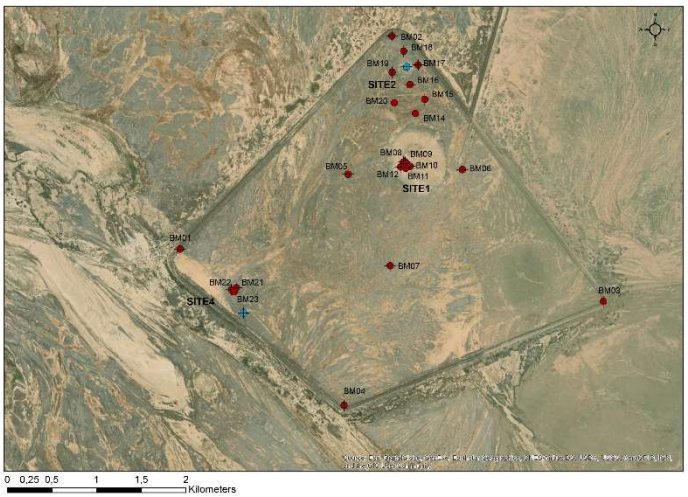


Fig. 5. The new topographic network in Eridu

Eridu is one of the first urban agglomeration recorded in the *Sumerian King List*, located in lower Mesopotamia, and probably raised around the 5th millennium BCE, about 19 Km southwest of Ur. The life of the site begun during the protohistoric *Ubaid* culture (at the beginning of the Chalcolithic in Mesopotamia) and lasted for millennia, in a vast area of hundreds of hectares characterized by the presence of distinct *tells* where structural evidence of different periods was found.

The site was partially excavated by an Iraqi mission in the mid-1900s and only in 2022 new systematic research started again, including activities of surface investigation and stratigraphic excavation, carried out by a team made up of the *Sapienza University of Rome*, the *University of Strasbourg,* and the *Uninettuno University* [7-9].

Starting a new investigation, the first operation to be implemented was the creation of a new topographical network, embracing the ancient site and thickening the benchmarks near the excavation area.

Fig. 6. The benchmark around the excavation area

Since the mobile line in Eridu is practically inactive, the use of the *Catalyst DA2* was more difficult, and the control operations had to be repeated many times; we have decided then to use a bipod to fix the antenna pole to the ground and to take repeated measures in the best precise way.

The positions of reference points around the excavation area, used to support detailed archaeological graphic documentation made by *close-range* digital photogrammetry, were measured many times again by total station, to check their accuracy: the results were satisfactory also in this case, having deviations of 2-3 centimeters and we could proceed to make detailed surveys and documentation of stratigraphic evidence using the new benchmarks with total station.

Table 4. Multiple measurements of the topographic network benchmarks in Eridu.

	X	Y	Z
Benchmark 8			
1	39.61	93.82	10.39
2	39.61	93.81	10.36
3	39.61	93.81	10.36
Benchmark 9			
1	73.66	77.28	11.83
2	73.66	77.29	11.80
3	73.67	77.30	11.81
Benchmark 10			
1	11.78	44.75	12.11
2	11.77	44.74	12.10
3	11.78	44.74	12.13
Benchmark 11			
1	64.15	25.45	11.24
2	64.15	25.43	11.26
3	64.14	25.44	11.25

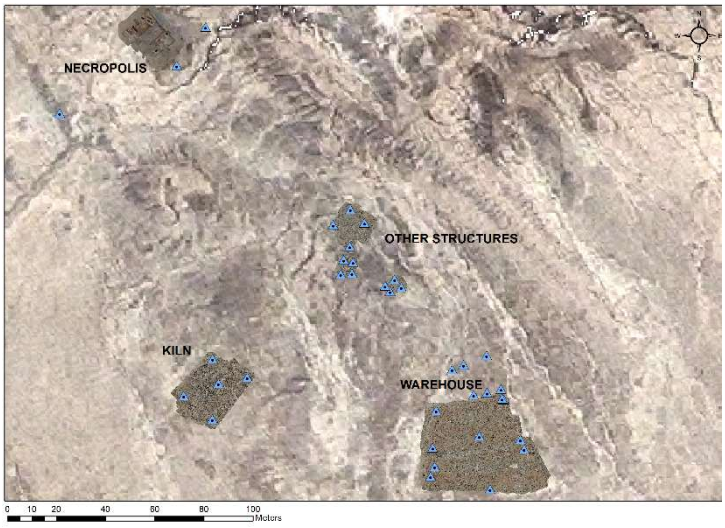
Table 5. Comparison between measurements taken in Eridu by Catalyst DA2 and total station

Catalyst DA2	**Total station**
BM8-X 39.61 Y 93.81 Z 10.38	BM8-X 39.61 Y 93.81 Z 10.38
BM9-X 73.67 Y 77.29 Z 11.81	BM9-X 73.68 Y 77.29 Z 11.77
BM10-X 11.78 Y 44.74 Z 12.12	BM10-X 11.79 Y 44.74 Z 12.10
BM11-X 64.15 Y 25.44 Z 11.25	BM11-X 64.14 Y 25.43 Z 11.26
BM13-X 09.51 Y 74.92 Z 13.38	BM13-X 09.52 Y 74.92 Z 13.36

Fig. 7. General map of Ubaid houses and necropolis in Eridu: spring 2023 excavation mission.

Near the *Ubaid* necropolis it was necessary to carry out a wider exploration to understand the residential zone of this primaeval occupation: we have then investigated an area of 8900 m2, using the Catalyst in association with a UAS *DJI Mavic Air 2*, flying at low altitude (about 5 m) and making high-definition photos, to produce a new photogrammetric detailed plan of this sector [10].

Fig. 8. The Ubaid residential are, S-E of the necropolis.



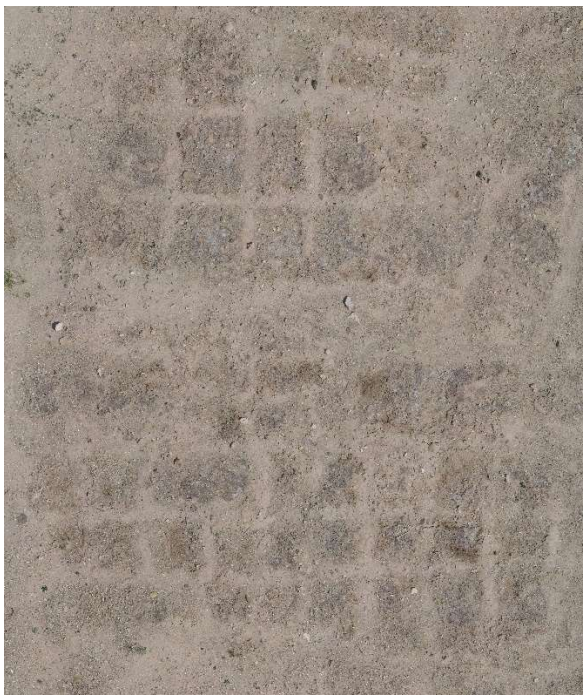


Fig. 9. Soil-marks highlighting a rectangular-shape structure, with an area of about 180 sqm, divided into squared rooms: probably a warehouse.

After our investigation this zone, beside the strong presence of pottery sherds mainly belonging to *Ubaid* period, results to be characterized by the presence in its west sector of a homogeneous pile of slag (ceramic but also metallic) covering an area of about 300 square meters, probably the clue of a buried kiln; in the eastern quadrant instead, about 75 m to east, a rectangular-shape buried structure, having an area of about 180 sqm, was highlighted by very clear soil-marks: it is divided into little and similar square-rooms, each with a surface between 75 and 90 cm2, arranged in chess. The shape and the internal layout suggest the presence, under the superficial sand, of a storage building.

For the future campaign it's our intention to carry out an intensive and systematic survey of this area.

V. CONCLUSIONS

During this various experience, the use of the Trimble *Catalyst DA2* was satisfactory: it is necessary anyway to highlight some not negligible aspects during field operations.

First, it is preferable to operate in areas where the mobile line is present and efficient, otherwise it is necessary to connect to the Trimble web service before entering areas without a line: in this second case it is advisable to use a support to fix the pole of the antenna on the ground and take as many repeated measurements as possible for each

point. Secondly, one must pay attention to gross errors and repeat the same measurements for few days. In other words, the system, to date, does not allow millimetric precision and cannot replace a total station for measuring numerous detail-points. However, there are more positive aspects: the system agility, simplicity and lightness (which also can avoid permits and customs passages problems in particular countries), the very low cost, the ease of use and the accuracy, which is centimetric even in unfavorable contexts.

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