ANALECTA PRAEHISTORICA LEIDENSIA 28

PUBLICATIONS OF THE INSTITUTE OF PREHISTORY
UNIVERSITY OF LEIDEN

INTERFACING THE PAST

COMPUTER APPLICATIONS AND QUANTITATIVE METHODS IN ARCHAEOLOGY CAA95 VOL. II

EDITED BY
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UNIVERSITY OF LEIDEN 1996

Graphic design: Henk de Lorm

Computer graphics: Peter Heavens

Copy editor: Marianne Wanders

ISSN 0169-7447

ISBN 90-73368-10-3

Subscriptions to the series Analecta Praehistorica Leidensia and single volumes can be ordered from:

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P.O. Box 9515
2300 RA Leiden
The Netherlands

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Remote Sensing and GIS in the Study of Roman Centuriation in the Corinthia, Greece

1 Introduction

During the last eight years a computerized architectural and topographical survey, the Corinth Computer Project, has been underway at the site of Ancient Corinth. The work is being carried out by a research team from the Mediterranean Section of The University of Pennsylvania Museum under the auspices of the Corinth Excavations of the American School of Classical Studies at Athens, Dr Charles K. Williams II, Director.[1] A brief summary of elements of this long-term and multifaceted project was presented last year at CAA94 as a part of the consideration of the overall methodology and techniques of the work (Romano/Tolba 1995). The overall project is under the direction of the senior author and was initiated in 1988. Since 1992 O. Tolba as a Research Intern has been working with remote sensing and GIS applications especially with respect to centuriation studies of the Corinthia.

One of the primary objectives of the project has been the definition of the plan of the urban Roman colony of 44 BC, *Colonia Laus Iulia Corinthiensis*. A separate element of the work is presented here, an aspect of the study of Roman agricultural land planning, centuriation, which has been documented in and around the colony, specifically the area between Corinth and the ancient city of Sikyon, 17 km to the northwest.[2] The area under present study, approximately 150 square kilometres, is roughly that found between the Helisson river to the north and west of Sikyon and the Xerias river to the east of Corinth, a stretch of mostly flat coastal land which, judging from its modern day fertility and intensive use, must have been highly prized and greatly utilized in antiquity.

The centuriation of agricultural land was a well-known aspect of Roman land planning and is documented from many parts of the Roman world (see, for instance, Dilke 1971; Clavel-Leveque 1983). In recent years a number of examples of Roman centuriation has been described in mainland Greece.[3] For the past few years we have been aware that the land between Sikyon and Corinth was centuriated and that much of the organization fits around the south side of the Corinthian Gulf so as to respect this natural topographic feature. To date, a number of systems of organization have been defined in this area, at least one of which appears to be linked in a series of grids. It has been our interest to define each of these systems, examining the size and relationship of the systems internally and in relation to each other.

2 Project Result Summary

The following is a preliminary summary of the results of the study to date. One system (Land Division System A) is characterized by a series of linked grids of 16 × 24 *actus* units (1 *actus* = 120 Roman feet).[4] This system is set out with respect to the topographical location of the Corinthian Gulf to the north and the plateau that borders the plain to the south (figs 1, 2). Some centuriation extends as far as seven kilometres to the south of the Gulf. Remains of other schemes of centuriation have been defined in the same areas, although the internal relationship between these grids is not as clear. There is reason to believe that these are successive systems in the same area of land.

2.1 Land Division System A

Five linked grids (A1-A5) composed of 16 × 24 *actus* units are identified between Ancient Sikyon and Ancient Corinth (fig. 1). Each grid is characterized by the fact that it meets its neighbouring grid at an angle of slightly more than 14 degrees (fig. 3). Outlines of the overall grid are present in the 1:5000 topographical maps, from the evidence of the field and property lines and roadways, as well as from the SPOT satellite image (see discussion below, Methodology). A principal element of this land division system A is found in grid A3 where there is a dominant line in the landscape, a *limes* of the 16 × 24 grid, found in a northwest-southeast direction. This dominant line extends *c.* 3400 m along the line of the land organization of grid A3 and then continues in a straight line, although at an oblique angle to the land organization system, across the neighbouring grid A2 for an additional *c.* 3500 m (fig. 1). Two corners of the 16 × 24 *actus* units of A2 are the end-points of the oblique line. A field examination of this line shows that it is a modern paved roadway for much of its approximately 9 kilometres of length although a 1.4 km section of the road remains unpaved as a dirt road. The road extends an additional 1200 m further where it crosses the

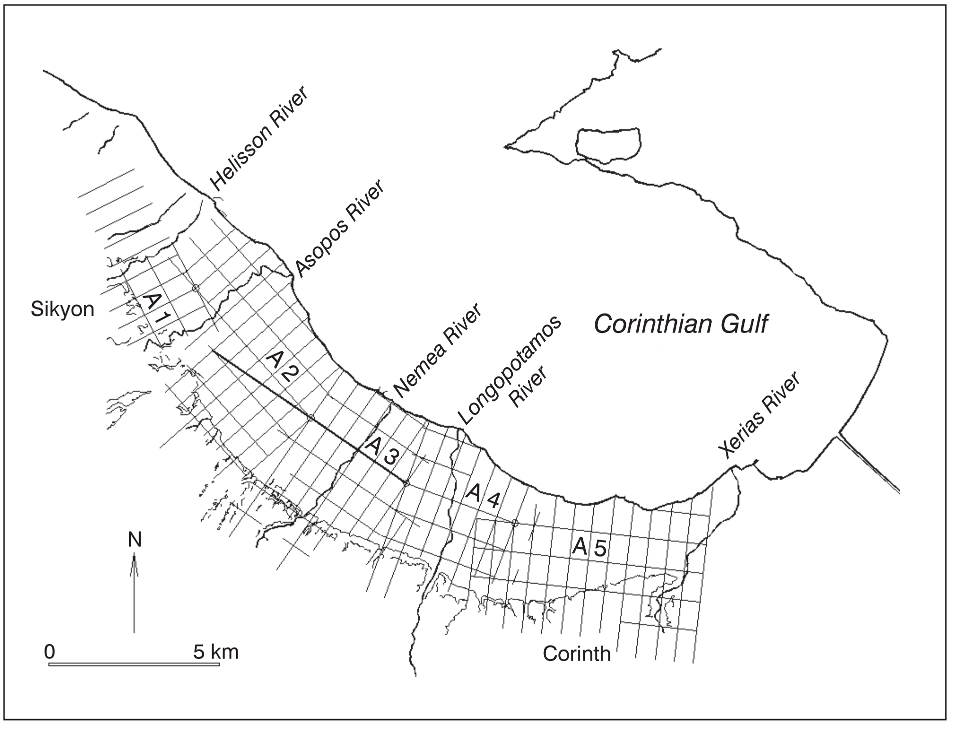

Figure 1. Region of the study between the ancient cities of Corinth and Sikyon illustrating Land System A.

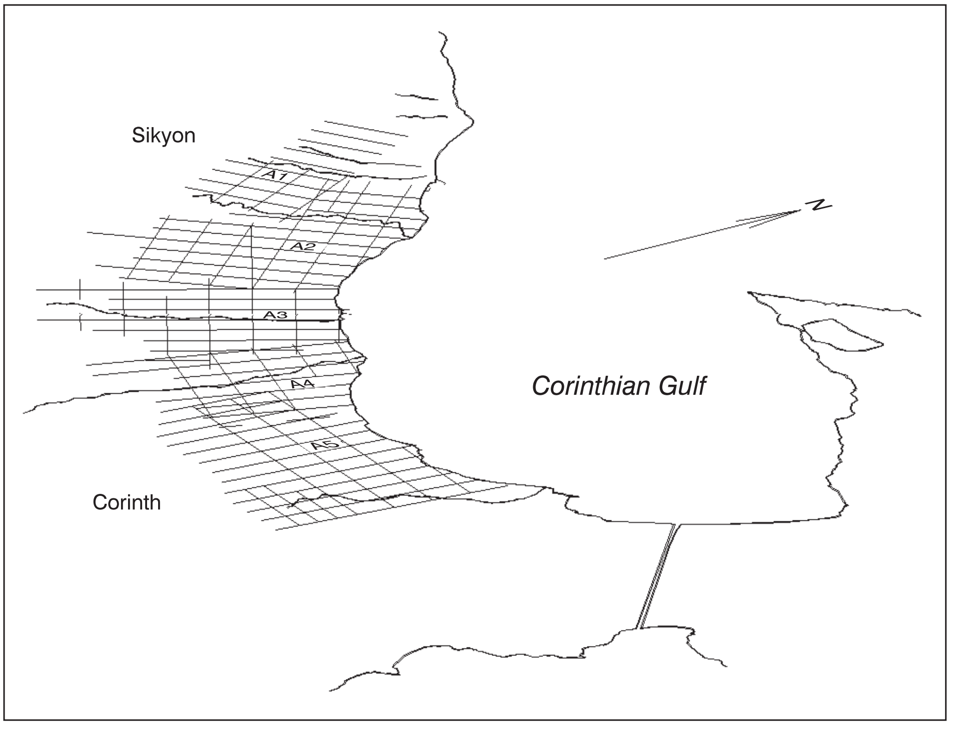

Figure 2. Simulated aerial view of the region of study from the southeast illustrating Land System A conforming to the south coast of the Corinthian Gulf.

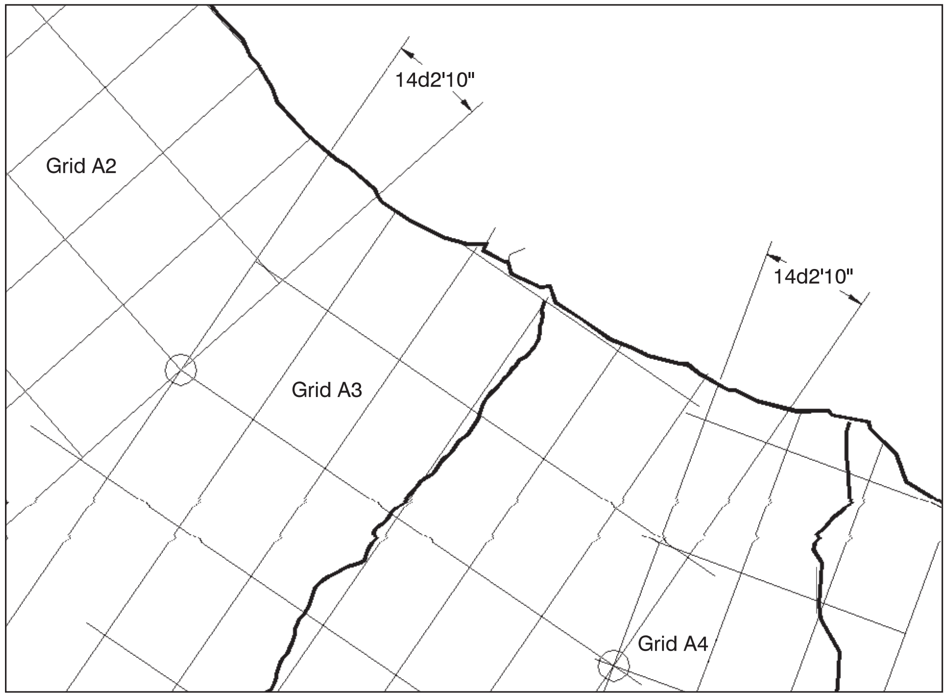

Figure 3. Detail of Land System A illustrating the linking of grids A2 with A3 and A3 with A4 showing, in each case, the joining angle of 14 degrees, 2 minutes and 10 seconds.

Asopos river, to the southeast of the ancient city of Sikyon. It is known in the modern day as the ODOS SIKYONOS, the Sikyonian Road. Besides its clear association with the Roman land division, two other facts suggest that this portion of the road is ancient. Firstly, there is a short section of the roadway that is no longer a thoroughfare of any kind since a church has been built in the line of the road. Secondly, it points in a direct line, in a generally southeast direction at the ancient city of Corinth (fig. 4).[5]

The area of meeting of grid A2 and A3 demonstrates the angle created by the joining grids (fig. 3). The angle of the intersection has been recorded from the modern property lines and roads of the topographical maps and the satellite image, in a number of instances, between 13 degrees 57 minutes to 14 degrees 20 minutes. The same angle of intersection is found in the joining of A4 with A3 as well as A5 with A4. The fact that the oblique line crossing grid A2 intersects two of the corners of the 16 × 24 *actus* grid suggests a trigonometric relationship between the oblique line and the centuriated rectangles. The relationship of the oblique line to the rectangles is 24:96 or 1:4.[6] This fits very well with our observations and indicates that the Roman surveyors used 1/4 relationships in laying out the grids.

The grid A5 which is found in the area of ancient Corinth has the same organization that has been identified and described previously (see discussion below) although some modification may need to be made with respect to the size of the centuriation module[7] (Romano 1993: 23-26).

The pattern of the modern fields and roadways that still retain the orientation of the Land Division System A are shown in figure 5. It seems clear that the Sikyonian Road, which is the oblique roadway of grid A2, is an important element of the linking of grids A2 and A3. In fact, the orientation of a certain portion of the fields to the south of the Sikyonian Road in grid A2 show that they continue to be oriented with the alignment of grid A3. From a preliminary analysis of the remaining land to the east of Corinth as far as Cenchreai it appears that the system of linking grids may continue to the Saronic Gulf.

2.2 Land Division System B

A second series of five grids (B1-B5) are being defined between Ancient Sikyon and Ancient Corinth, roughly the same area as that described above for Land System A. The study and analysis of this land division system is currently in progress.

3 Historical and Chronological Considerations

Although it is very difficult to accurately date the systems of centuriation defined in this study, it may be possible to eventually date the systems in relative terms. It would seem as a good possibility that system A was conceived of and layed out at a single time. The Sikyonian Road is an important element of the A system. It forms part of the A3 grid and it may be argued that the entire land organization system is dependent on its orientation. It is possible,

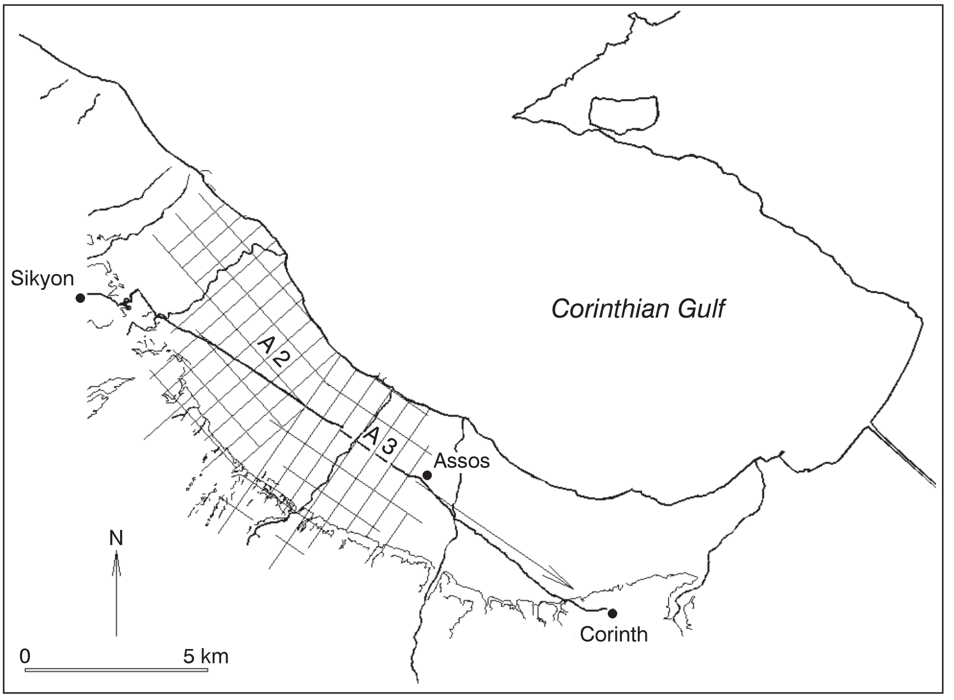

Figure 4. Grids A2 and A3, illustrating the line of the modern road from the location of Ancient Sikyon to near the modern town of Assos. The dashed line represents the portion of the ancient roadway that is no longer a thoroughfare. The arrow indicates the extended line of the roadway towards Ancient Corinth.

however, that when the oblique line, the Sikyonian Road, was layed out the grid was already in place. It is also possible that there existed a Greek road between Corinth and Sikyon that may have in part or in whole taken this orientation, and that the oblique road may have been a straightening out of this road. On balance it seems most likely that the A system and the oblique roadway, now known as the Sikyonian Road, were set out as a part of the same project.

It has been suggested previously that the portion of the A system that is found to the north of the city of Corinth, grid A5, is a portion of the land that was measured out in 111 B.C. as a part of the work described in the Lex Agraria (Romano 1993: 23-26). System A is related to the Sikyonian Road as reflected in the field lines found both to the north and south of the road. This would still seem to be a good likelihood based on the fact that the system seems to have been layed out all at the same time and that it may predate the B Land System.

4 Roman Surveyor's Techniques

The linking of the grids as suggested above conforms to a system of mathematics which may be inferred from observation of similar links in other centuriation systems. Although we have almost no evidence from any other source such as ancient documents, it seems to have been a standard practice of Roman surveyors[8] (Peterson 1992). The system involves the use of the ratio of small integers as a primary means of creating alignment of roadways between neighbouring and related grids. This appears to have been the system employed in the plain at Corinth. The ratio that is documented between grids A2 and A3, both 16 × 24 *actus* grids, is the ratio of 24:96 or 1:4. In a practical sense this would have meant that the *agrimensores* could have used whole multiples of one *actus* units, already employed to lay out the grid system, to determine the alignment of the straight road by measuring out one *actus* in a generally NE direction and 4 *actus* in a generally SE direction. Furthermore, the fact that the ends of the straight road segment intersect the corners of the grid suggests that this was a feature of organization that was an integral part of the centuriation system (fig. 1).

5 Methodology

The project's data set is composed primarily of AutoCAD drawing files. These include digitized 1:2000 and 1:5000 topographical maps, actual state plans, survey coordinates downloaded from the electronic total station, and all the analytical studies.[9] The results discussed in this paper have been achieved through the study of satellite imagery and topographical maps.

5.1 Satellite Imagery

It has been noted that SPOT satellite imagery has proven helpful in the identification of uniform grids of field sys-

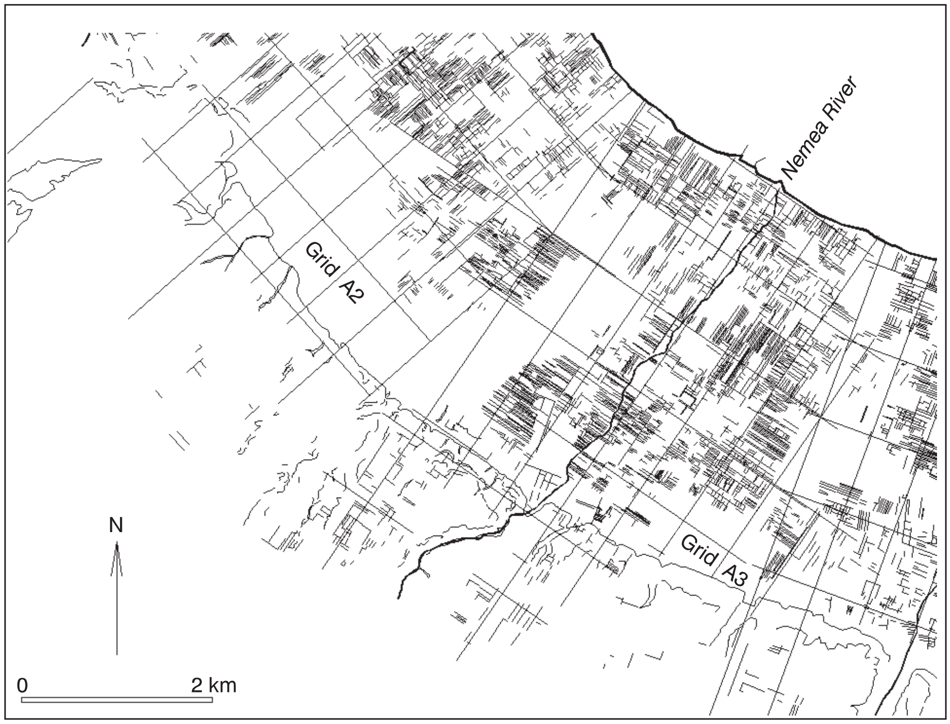

Figure 5. Detail of Land System A showing the digitized individual property lines, field lines, paths and roadways from the areas of grids A2 and A3. The oblique road of Grid A2 is visible where the field lines of Grid A2 are in keeping with the field system of grid A3.

tems possibly of Roman origin. The reason for acquiring these images was to expand on the study of the Roman colony and its territory begun by the main author in 1988, which showed evidence for centuriation in the area to the north of Corinth. It was crucial, therefore, that this new data set would be acquired in a format that matches the existing data sets. SPOT company rectified the images and delivered them in UTM projection as requested. UTM map projection is suitable for this study since the work requires accurate measurement of azimuth and distances. Additional image processing techniques, available in IDRISI, Clark University, were employed to enhance the visual clarity of the images. IDRISI's edge enhancement filter and contrast stretch functions were quite satisfactory.

5.2 Topographical Maps

Although the main roads and general pattern of agricultural fields are visible in the satellite images, it is not possible to distinguish the individual field boundaries and the minor paths. It was necessary, therefore, to verify and augment the initial results found by studying the satellite images with detailed maps of the study area. Since maps at 1:2000 scale were not available for the entire area extending from Corinth towards Sikyon, the project acquired more than thirty 1:5000 maps from the Greek Army Mapping Service extending west towards Sikyon and east towards Cenchreai on the Saronic Gulf. The entire area covered by these maps (26 × 22 kilometres) encompasses much of northern Corinthia.

The topographical maps were scanned using an 8.5 × 14 inches flatbed scanner in order to avoid the time needed to trace all the lines on a digitizer tablet. Each map was scanned in several smaller pieces at the resolution of 100 dpi, then the pieces were matched and merged into one larger TIFF file using CAD Overlay GSX. The calibration of the maps was possible since the coordinates are given for the corners of each map and marks are drawn at 500-metre intervals. It was also possible to print the maps and the satellite imagery on letter size paper to aid in field examination and navigation. The order of accuracy of these maps is approximately 5 metres, while the resolution of the satellite images is 10 metres.

5.3 Analysis and Model Testing

The study began by tracing over parallel roads, as seen in the satellite image, and measuring their azimuth and spacings. These lines were stored in AutoCAD drawings with the aid of CAD Overlay GSX, Image Systems Technology, which facilitates the display of images within AutoCAD. By comparing the spacings of the roads to multiples of the Roman *actus* it became evident that many of these measurements correspond to 16 and 24 *actus*. A hypothetical model of Roman centuriation was constructed as a grid of 16 × 24 *actus*. It was possible to rotate this grid and move it across the AutoCAD drawing in order to achieve the best match with the recorded evidence. In some areas it was easy to find the match; in others it seems that overlapping uses of the land have produced a very complex pattern. Therefore, it was necessary to compile a drawing of the field boundaries and paths that correspond with the alignment of the hypothetical grids (fig. 5). This drawing was useful in the identification of the spacings of the grids as well as their exact locations.

By constructing many of these grids, it was noticed that the field systems changed their orientation as they wrapped around the south coast of the Corinthian Gulf (fig. 1). The consistency with which their azimuth was changing alerted the project team to study the possible schemes the Roman surveyors would have used to lay out these rotating grids. At first, it was thought that the surveyors may have rotated the grids using fractions of the circle, for example 15 degrees. However, when a fifteen-degree rotation was imposed on the grids the accumulated error was unacceptable. An angle closer to 14 degrees was more favourable but could not be constructed using fractions of the circle. Therefore, an investigation of possible oblique surveying techniques started with comparing the measured angle with whole ratios. The closest ratio was determined to be the tangent of 1:4. Most of the gathered evidence fitted this hypothesis within one degree. This relationship did not only seem to be consistent with the grid dimensions, which are multiples of four *actus*, but also a simpler technique for the ancient surveyors than the division of circles.[10]

6 Future Directions

The study of the centuriation systems in the immediate area of Corinth is continuing towards the Corinthian port of Cenchreai on the Saronic Gulf. With the use of 1:5000 topographical maps and SPOT satellite images the areas shall be considered in the same way in which the area between Corinth and Sikyon has been presented.

Acknowledgements

The authors wish to thank Dr Charles K. Williams II, Director of the Corinth Excavations of the American School of Classical Studies at Athens and Dr Nancy Bookidis, Assistant Director, for helpful and generous assistance with this project. The Corinth Computer Project is supported by the Corinth Computer Project Fund of The University of Pennsylvania Museum of Archaeology and Anthropology and the 1984 Foundation. The project has also received generous support and educational grants and considerations from AutoDESK, Inc., Image Systems Technology, Inc., Softdesk, Inc., the Sokkia Corporation, the SPOT Image Corporation, and the Tektronix Corporation. We also thank the Greek Army Mapping Service (Geographike Yperesia Stratou) for permission to study and use the 1:5000 topographical maps of the Corinthia.

notes

1 During each summer of the survey project, the work has been carried out as a part of the architectural aspect of the Spring Training Seasons of the Corinth Excavations. The annual reports of the excavations appear in Hesperia, the Journal of the American School of Classical Studies at Athens.

2 The authors thank Mr Jeremy Hartnett of the Department of Classics, Wabash College, Crawfordsville, Indiana for assistance during the summer of 1994 concerning the definition and interpretation of the trigonometric relationship of the land systems described below.

3 Early notice of centuriation in Greece was made by R. Chevallier (1958). More recent articles include P. Doukellis (1988); P. Doukellis and E. Fouache (1992); A. Rizakis (1990).

4 The dimensions of the grid were determined from the computerized mapping process, specifically the measurement between significant roadways, field and property lines in the landscape. The result where 16 × 24 *actus* units is 566.4 × 849.6 m, gives a (local) Roman foot of 0.295 m.

5 The centuriation of a similar area of the Corinthian coastal plain has been recently studied and published by P. Doukellis (1994). Doukellis describes two schemes of centuriation, one of which he associates with the Lex Agraria of 111 BC (his fig. 9) and the other of which he associates with the colony of 44 BC (his fig. 3). Doukellis' grid of 111 BC roughly corresponds with the orientation of land system, A3, and his colonial grid roughly corresponds with the orientation of the Roman colony as previously published in Romano (1993).

6 This type of relationship is discussed in Peterson (1992), 185-196.

7 Above note 5.

8 See above note 6.

9 For a complete description of the project hardware, software, and data set see Romano and Tolba (1995).

10 This conclusion, on the most likely surveying technique, was reached independently of the suggestions made by Peterson, note 6.

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