8

Information systems and the interpretation of Roman cadastres

J. W. M. Peterson*

8.1 Introduction

This paper gives examples of the application of Information Systems theory and practice to the study of Roman planned landscape.

The first part, sections 2–5, describes the Roman cadastre, a system for recording and controlling the allotment and taxation of land. A hypothesis is presented that it was also, in many instances, the spatial basis upon which subsequent planning of oblique features took place. It is suggested that the grid points, or *termini*, of the cadastre provided a convenient means of specifying the position and orientation of such features, but that a constraint was imposed by the limitations of the Roman number system. Such a constrained system should have predictable outputs. Many segments of Roman road could be expected to be related to Imperial cadastres in this way.

The second part, sections 6–11, describes how, given two parallel sections of straight road, preferably known to be Roman, which appear to be distant by some multiple of the grid distance, the orientation of a grid to fit the roads can be calculated. If one orthogonal grid line can be perceived, then a computer program can calculate the grid references of a large number of potential *termini* which can be used to locate existing features which may be grid remnants. Tests on the location of point features, such as river crossings and road junctions have been performed in one of the areas, whose results appear to support the idea that a Roman cadastre was established.

Grid points can be plotted onto known Roman roads to see how well they conform to the oblique planning model. Given that such coincidences do occur, work is in hand to estimate their significance by means of a simulation which is also described.

8.2 The purpose of Roman cadastres

A cadastre is a system for demarcating, allotting, recording and taxing land. The word 'cadastre' has been used in English to refer to land registers, of which Domesday Book is an example, but it has also been used to refer to the physical divisions on the ground. Following current French practice this paper will use the word in both these ways.

* School of Information Systems,
University of East Anglia
Norwich

Although in the past cadastres, and particularly centuriations (see below), were most often associated (at least my mind) with the foundation of *coloniæ*, it is now clear (see Clavel-Lévêque 1983c) that they played a more fundamental and all-embracing rôle in the process of imperialism. They were a tool of conquest, a way of gaining control of the most productive parts of a conquered territory, whether it initially contained *coloniæ* or not. The territory which had been seized became *ager publicus*, or state land.

The Roman cadastre was a most comprehensive information system. The ground was demarcated by clearly visible boundary ways and markers, and a central registry was established. The records of one such registry, partially preserved at Orange, appear to have covered three cadastres occupying a large part of the lower Rhône valley. In this case maps were carved on stone; each section was identified by its grid coordinates; and details of the land holding were entered. Presumably there were also more perishable records since it was the duty of a land surveyor to make two copies of a map of each newly surveyed area.

One remarkable feature of Roman cadastres, particularly those recently discovered in southern Gaul, is that they were often superimposed. The land was reorganised,[1] in one place five times. This can be compared with such superimpositions in parts of Tunisia (Dilke 1971, p. 155).

8.3 Centuriation

As Bradford 1957 showed, using numerous examples from many parts of the Roman empire including Italy, Dalmatia, Tunisia and France, centuriation is a persistent feature of many former Roman territories. This was a grid system for which the most common basis was the square with sides of 20 *actus*, 2,400 Roman feet. Bradford gave 776 yards as the most common dimension, normally equated to 710 metres, but more recent work has shown that some centuriations had a module as small as 704 metres, although, in what is now southern France (Clavel-Lévêque 1983a), these seem to date from the earliest phase of imperial expansion.

Such systems were based on two orthogonal principal roads: the *kardo maximus* and the *decumanus maximus*. These were at right angles and formed the basis of the grid which was then laid out as minor roads, about 3–4 metres wide,[2] at regular intervals of 20 *actus*, the *kardines* being parallel to the *kardo maximus* and the *decumani* being parallel to the *decumanus maximus*. These roads, collectively called *limites*, were probably of bare soil (Chevallier 1976, p. 16).

Each corner of the squares so formed was marked with a carved stone, when this material was available. These are known as *termini*. It is clear from the surviving roman surveyors' manuals, and from their descriptions of actual centuriations, that intermediate divisions, especially from points halfway along the sides, could also be marked by *termini*, see Favory 1983, p. 121–2 for an example. A more complete treatment of this topic is given by Dilke 1971.

[1] But not totally, otherwise we would not have visible evidence of different orientations.

[2] The *decumanus* and *kardo maximus* were, in theory, wider. The figure is taken from Bradford's report of actual widths found from aerial photography.

8.4 Some evidence for oblique planning

I am aware of only one previous suggestion that linear features may have been planned in oblique relation to a centuriated grid. Clavel-Lévêque 1983b suggests (as an example) that a section of the via Domitia (voie domitienne) between Béziers and St-Thibéry forms the diagonal of a series of rectangles of 3x4 squares and that this section of road was rearranged to fit the cadastre. In this paper such a relationship will be referred to as 3:4.

Another example may perhaps be seen in Bradford 1957. The centuriation of Salona (Dalmatia) of 20 × 20 *actus* squares covered at least 7 × 20 kilometres. According to Bradford, it is likely that the centuriation dates from the time when Salona was raised to the status of a colonia in the latter half of the first century BC. It is overlain by Diocletian's palace at Spalatum (Split), on the coast near Salona, constructed at the end of the third century AD. Bradford suggests (Bradford 1957, p. 186) that a new road, oblique to the grid, was constructed to Salona because the *limites* provided only a somewhat roundabout route.

Fig. 8.1, traced from Bradford's plate 44, shows the remains of the grid and the linear features which share the new orientations defined by the palace and road. The palace, its associated enclosure, the water front and the first portion of road issuing from the Porta Aurea is at 3:2 to the grid. At 20 *actus* from the Porta Aurea the road turns onto a new alignment at 3:4, which would (if projected) pass through the mid point of the grid square to the North of the palace. Note also that there appears to be a small area of rearranged cadastre based on this road

There are other oblique linear features in Bradford's illustrations which seem to exhibit similar relationships. Unlike the road to Salona, they are not dated by Bradford. However, whatever the date of their construction, it seems reasonable to suggest that they may have been planned from the grid if their relationships with the grid are ratios of small integers.[3] The case for their relationship is even more strong if they pass through *termini*. Table 8.1 lists these features together with the confidence that the author feels about the relationship. Similar data are also listed in Table 8.2 for the cadastres depicted in Clavel-Lévêque 1983a.

8.5 Constraints on the angles

Many of these linear features have a rational relationship with the cadastres. In some cases this is clearly not accidental, either because the angle is consistently maintained for a large number of grid squares, as in Bradford's Plate 38 (which shows a road at 1:1 to the centuriation near Cesena, now known as Rimini III), or because the alignment clearly passes through *termini*. Thus it can only be concluded that many of these relationships are the result of planning.[4] Furthermore it appears that in 20 *actus* grids the relationship could not be any ratio. This suggests a way in which the orientation may have been specified.

[3] All observable straight features have been included, even if they may well be modern, in order to avoid accusations that there has been selection of data which fits the theory.

[4] This statement is not meant to imply that all oblique features with a rational relationship must postdate the grid. The oblique road cited in this paragraph is a counter-example, see Clavel-Lévêque 1983c, pp. 217–221.

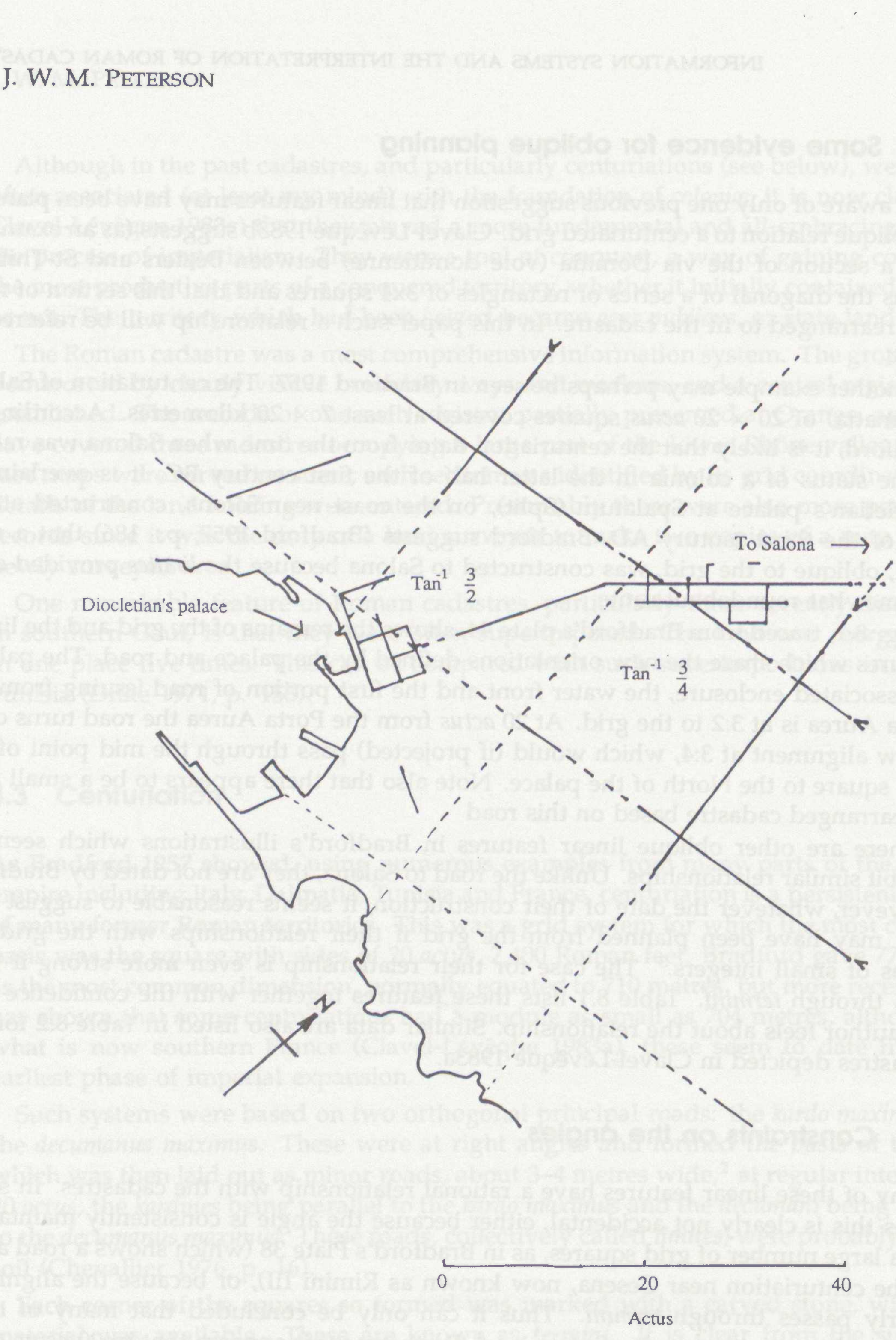


Figure 8.1: Some of the features at Split related to the Centuriation; traced from Bradford 1957, Pl. 44

Bradford Illustration	Feature	Ratio	Through termini?	Confidence	Notes
Fig 13, Pl 38	Road to NE	1:1	No	Very high	But road postdates grid
Pl 39	Road, N corner	1:1	—	High	15 *actus* grid,
	Road, N corner	1:1	—	Moderate	see note below
Pl 42	?Path N of 'G'	2:3	No	Moderate	
	Road to top left	3:1	Yes	High	Cont. by road in fig. 16
	Road lower right	1:1	No	Moderate	
Pl 43	Road lower left	6:5	Possibly	Low	
	Long diagonal road	1:1	No	Very high	Cont. by road in fig. 16
Pl 44	Diocletian's palace	3:2	No	High	
	Road to Salona	3:4	Yes	Very high	
	Road W of harbour	1:2	No	High	
	Streets E of Palace	1:2	No	Moderate	
	Roads E corner	5:2	Yes	Moderate	
Fig 16 excluding Pl 42, Pl 43	Road SE corner	—	No	—	Not 1:1
	Road SE corner	9:4	Yes	Moderate	
	Road NW corner	1:3	No	Moderate	
Pl 49a	Diagonal road	—	No	—	Alignment arbitrary

Table 8.1: Orientation of linear features in Bradford illustrations

Note: in Pl 39 the position of the *cardines* in the 15 *actus* grid is not totally clear. However, there is a position for the *cardines* in which both alignments of this road pass through the corners of grid squares, and the road bends at one of these. The oblique road on the E side fits at 3:5 through these grid square corners, but the portion shown is too short for certainty. The road in the SW corner appears not to be grid-related.

Clavel-Lévêque Illustration	Feature	Ratio	Through termini ?	Confidence	Notes
p 133, fig 30	Road, N side	4:3	Yes	Moderate	
p 140, fig 3	2 Field Systems	1:1	Yes	High	Other relationships under investigation
p 202, fig 3	Straight Roads to Elche	—	—	—	Relationship unclear
p 203, fig 4	Road to SW, lower part	2:3	?	Low	
p 204, fig 5	Road to NE, upper left	2:3	Yes	Low	
	Road to NW, upper centre	?	?		
	Road in SW corner	—	—	—	?Not related
p 205, fig 6	Sect of Roman road, lower right	3:1	Yes	High	
	Sect of Roman road, top right	11:4	Yes	Low	
p 268, figs 8, 10,11	Voie domitienne	1:3	Yes	Very high	
	Road to NE from Nimes	4:11	Yes	Moderate	
p 280, fig 2	Road N of Arausio	10:1	Yes	Moderate	
	Arausio, streets	—	—	—	?Arbitrary
	Road DD18 & 19, CK1	?5:1	Yes	—	See note 1
p 285, fig 4	Road NE from Ernaginum	1:1	Yes	High	
p 286, fig 6	Road NW from Ernaginum	3:2	Yes	High	
	Voie domitienne	1:10	Yes	Moderate	
	SD8VK2–DD4CK1	2:1	Some	Moderate	See note 2.
	Avignon to DD13CK4	3:1	Yes	High	
	Via Aurelia	—	No		Not related
p 288, fig 7	Via Aurelia	—	No		Not related
p 313, fig 1	Via Appia	?	?		Relationship unclear

Table 8.2: Orientation of linear features in Clavel-Lévêque 1983a

Notes:

1. Inspection of a photograph of the Roman engraving shows this represented as 5:1. See, for example, Wacher 1974, p. 39.
2. Road passes through 2 out of 3 corners. It appears to have been made to bypass Ernaginum.

Units	*(actus)*	Fraction
4		1:5
	5	1:4
8		2:5
	10	1:2
12		3:5
	15	3:4
16		4:5
	20	1:1
24		6:5
	30	3:2
	35	7:4
	45	9:4
	55	11:4
	60	3:1

Table 8.3: Multiples of 4 and 5 *actus* expressed as fractions of 20 *actus*

As Smith 1951, vol. 2, p. 208, points out, the Romans represented ratios less than unity as a whole number of smaller units. For example, the only fractions into which the *as* (12 *unciae)* could be divided, without going to units smaller than the *uncia*, were multiples of divisors of twelve. They could talk and write about a fraction but specified it in mathematical notation as a whole number of parts. So *quadrans*, one fourth (of an as, twelve *unciae)* was notated as =- (three *unciae)*. In this notation certain fractions could be expressed, but others, e.g. 2/5, could not, at least not in *unciae*.

For an oblique feature a similar notation could have been employed to specify one side of a right angled triangle with hypotenuse at the desired orientation, given that the (implicit) other side was one grid distance (in this case 20 *actus*). In this case the only specifiable angles would be those of the form mxd:20, for m integral and d a divisor of 20. By using multiples of four and five *actus*, it is possible to represent all the relationships observed so far, as Table 8.3 demonstrates. It may be significant that this inferred method of specification corresponds precisely to that used by the Egyptians to specify the slope of pyramids at so-many palms and fingers per cubit, documented in the Rhind papyrus, see Dilke 1987, p. 9.

This restriction on the observed relationships may imply that they were specified in writing. The hypothesis is that on the ground there would be nothing to stop a surveyor drawing a grid-related straight line between any two *termini*, or a line parallel to such a line, but if the construction had to be specified by someone else, in writing, using the method described (or some functionally equivalent method), then this latter person could specify only certain angles. This constraint, in the sense that the word is used in Cybernetics (Ashby 1964, pp. 127–34), leads to outputs which are predictable and testable.

There are some potential grid-related alignments which should not be observed in practice in a 20 *actus* grid. The simplest (those with the lowest sum of numerator and denominator), and the most distinguishable, would be 3:7, 6:7, 7:9, and 7:11. The theory would be weakened if these alignments were observed; it would be falsified if the alignments passed through *termini*.

Note that this theory is in two parts. Firstly it suggests that there is a 'black box' which appears to produce, with few exceptions, orientations of linear features which are constrained to a small number of angles with rational tangents; this can be tested by examination of more examples. Secondly it suggests a mechanism which may have produced this constraint. Documentation of this appears not to have survived, or may be unrecognised, and further research is needed on this and other, possibly more plausible, mechanisms.

8.6 Calculating the orientation and location of a hypothetical centuriation

An initial idea of the existence of a possible centuriation can be obtained by using a transparent overlay, ruled with grid lines to scale, to fit ' by hand' to roads, tracks and footpaths on topographical maps. However, even when computer-ruled grids are used, this method can present problems because map sheets may not be to precisely the nominal scale and it is difficult to trace from one map sheet to the next. A more precise method can be employed if two linear features,[5] which appear to be parallel and separated by some multiple of 20 *actus*, can be picked out. Given arbitrarily chosen points, one on each of two linear features, it is possible to calculate the orientation of two straight lines that satisfy these conditions exactly. This calculation is described in Fig. 8.2.

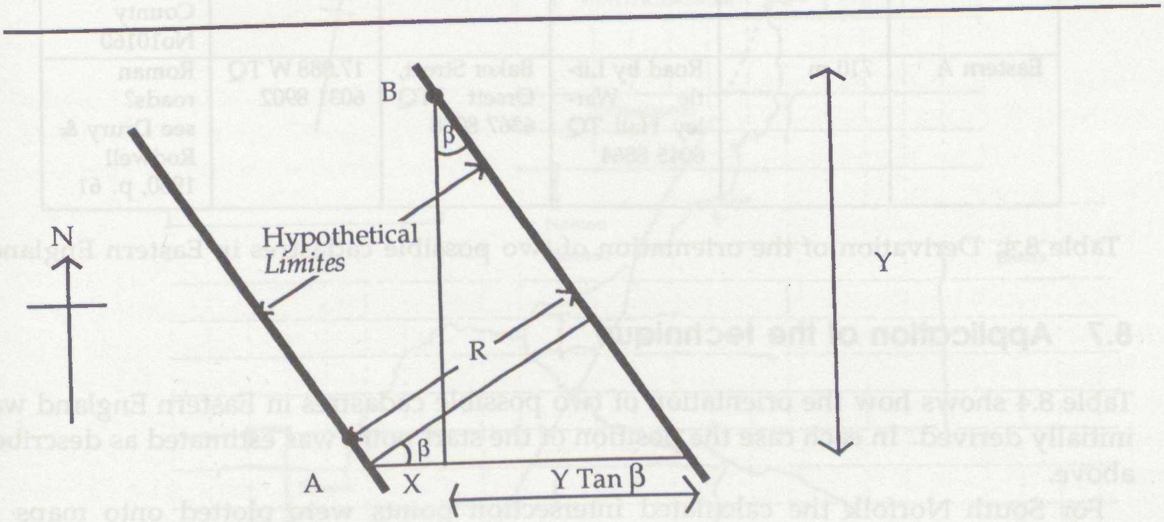
If the two features could, in fact, fit a hypothetical centuriation the position of the orthogonal set of *limites* needs to be determined. If strongly defined linear features are not apparent in this direction then a position must be selected subjectively by moving a transparent grid up and down the initially-defined set of *limites* until a best fit is found. This choice was supported in one case by the fit of nearby sections of Roman road. When this has been done, the position of any number of hypothetical grid points can be calculated, starting from an origin within the area first inspected.

Although the calculation of the possible grid intersection coordinates is trivial in principle, I have developed and used a computer program, designed to produce tables of coordinates, starting from any arbitrary point on the grid. This has saved a considerable amount of work, since many known centuriations covered large areas.[6] Without computer aid, such an examination would be hardly worth contemplating.

Given that the possible grid points have been determined, features which are near the grid lines, on a number of topographic maps, can be traced and joined together to produce a synopsis of possible centuriation remnants in the area concerned. The author would accept that such a map does not constitute quantifiable evidence for the existence of the centuriation, but other tests can be employed, particularly the relationship between the grid and Roman roads, which one would expect to conform to the oblique planning model.

[5]If such features appear to be too straight, then some evidence should be found that they are not the result of recent enclosure. If possible, some independent suggestion should have been made that they are likely to be of Roman origin.

[6]The area examined examined for traces of Eastern A is covered by several thousand squares.



To find the angle, β, that the line through B, lying at a perpendicular distance R from A, makes with grid North:

X = difference of X coordinates

Y = difference of Y coordinates

$$sec\beta = \frac{X + Y\tan\beta}{R}$$

$$R^2(1+\tan^2\beta) = X^2 + 2XY\tan\beta + Y^2\tan^2\beta$$

$$\tan\beta = \frac{-XY + R\sqrt{(X^2+Y^2-R^2)}}{Y^2 - R^2}$$

Figure 8.2: Calculating the grid angle

Provisional identification of cadastre	*Assumed module*	*First linear feature & point A*	*Second linear feature & point B*	*Angle to National Grid north & 'Start Point'*	*Notes*
South Norfolk A	709.5 m (776 yards)	Norwich Broadway & Parish Bdy TM 2417 8658	Brooke / Shotesham Parish Bdy TM 2704 9777	11.077 W TM 2417 8658	Second linear feature is a suspected Roman road, County No10160
Eastern A	710 m	Road by Little Warley Hall TQ 6045 8864	Baker Street, Orsett TQ 6367 8058	17.088 W TQ 6031 8902	Roman roads? see Drury & Rodwell 1980, p. 61

Table 8.4: Derivation of the orientation of two possible cadastres in Eastern England

8.7 Application of the technique

Table 8.4 shows how the orientation of two possible cadastres in Eastern England was initially derived. In each case the position of the start point was estimated as described above.

For South Norfolk the calculated intersection points were plotted onto maps at 1:25,000, and features extracted which were nearly coincident with the possible *limites*, see Fig. 8.3; each feature represents a road, track, footpath or parish boundary.[7] The roads are virtually all shown on Faden's map (Faden 1973, first pub. 1797). The dotted lines represent such features not shown on the modern map but present in either Faden's map, Williamson's (T.Williamson 1986, Fig. 2) or Addington's (Addington 1983, Fig. 4).

A portion of the features corresponding to the hypothetical Eastern A cadastre is shown in Fig. 8.4. Investigation of this possible centuriation is still in progress.

8.8 The relation of points to the hypothetical grids

A computer program has also been written to help perform a Kolmogorov-Smirnov single sample test against the expected distribution of points scattered uniform randomly in two dimensions. On the assumption of a uniform random two dimensional scatter of points, the cumulative probability that a point will lie within a distance d of a grid line is $1 - (1 - d)^2$, where d is expressed as a fraction of half the grid size. The program calculates this distance for a grid of given angle, size and location, then sorts the distances and calculates the D values for the cumulative observations.

In the possible South Norfolk A centuriation two sorts of features were tested, with the results which can be seen in Table. 8.5. Although the position of the river crossings is not statistically significant, it is interesting that one of the crossings (of a hypothetical kardo at Newton Flotman) appears to coincide with the crossing of the main Roman road. This supports the idea that parts of the road were planned to fit the grid, see

[7]Parish boundaries which are not also roads form a very small part of the features shown.

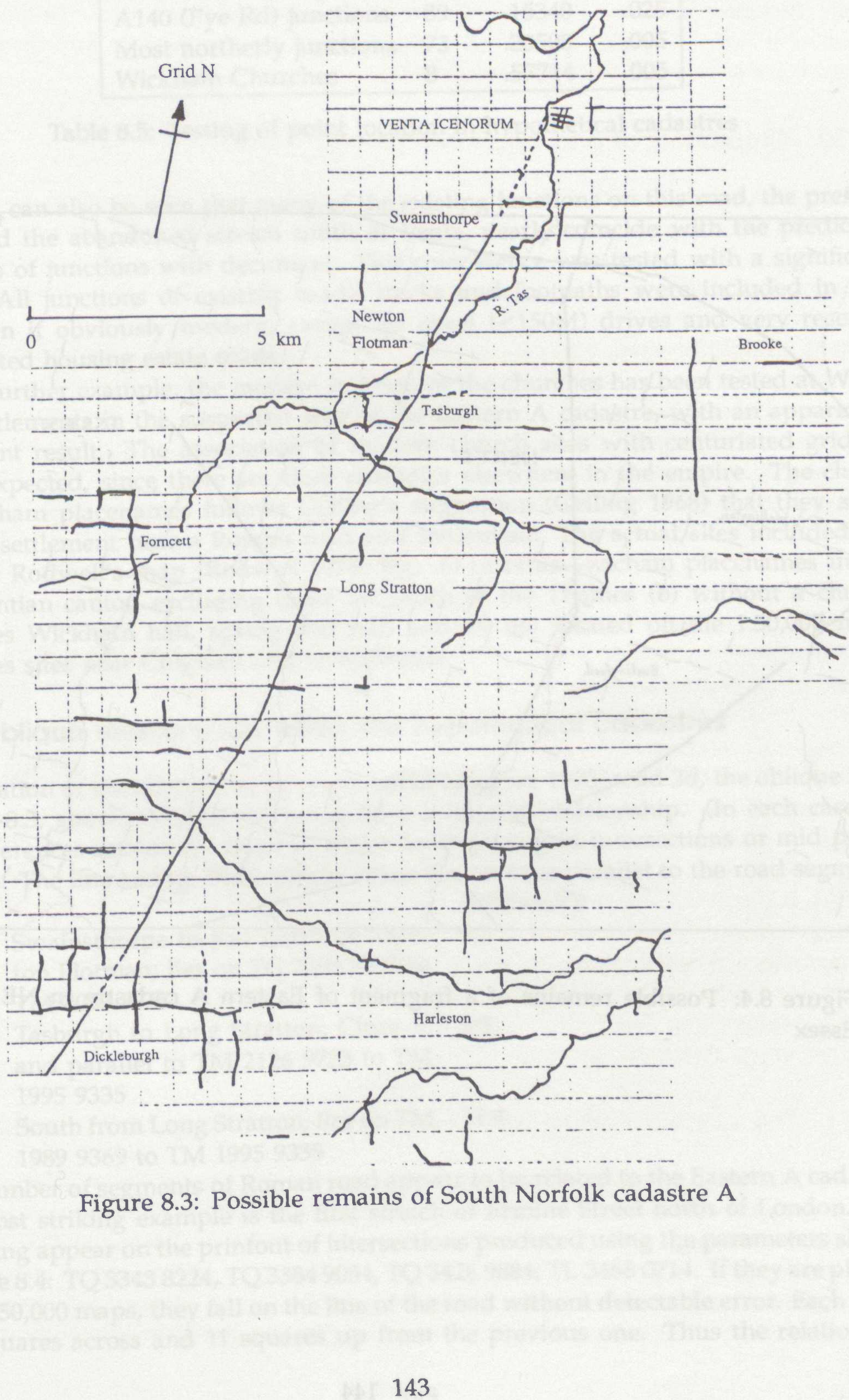
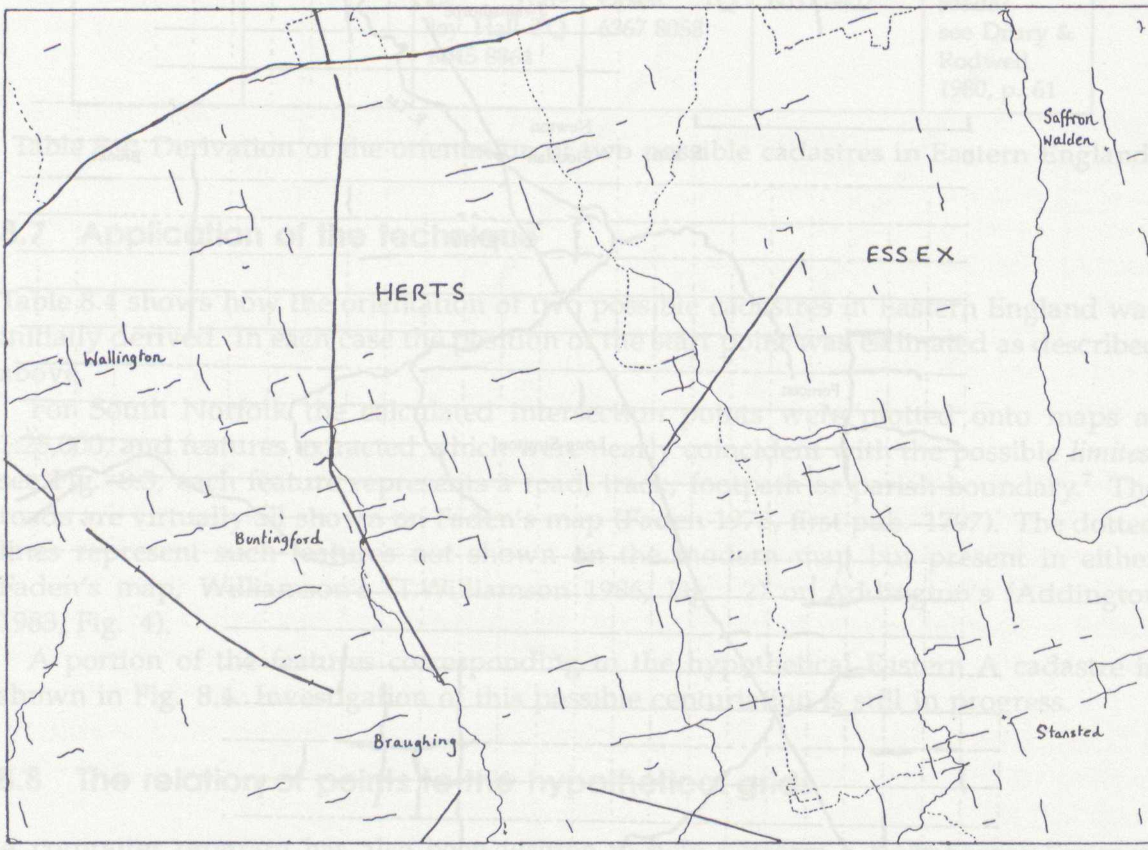


Figure 8.3: Possible remains of South Norfolk cadastre A

TL 28 55

42



22

Figure 8.4: Possible remains of a fragment of Eastern A cadastre in NE Herts/NW Essex

Kolmogorov-Smirnov Test			
Type of Points	Pop.	Max. D	P<
River Tas Crossings	28	.18543	
A140 (Pye Rd) junctions	89	.15340	.025
Most northerly junctions	73	.20508	.005
Wickham Churches	8	.57714	.005

Table 8.5: Testing of point location in hypothetical cadastres

below. It can also be seen that many of the existing junctions on this road, the present A140 and the abandoned stretch south of Venta, nearly coincide with the predicted positions of junctions with decumani. This coincidence was tested with a significant result. All junctions of existing roads, tracks and footpaths were included in this test, even if obviously modern, except for short (<150M) drives and very recently constructed housing estate roads.

As a further example, the modern location of the churches has been tested at Wickham settlements in the suspected area of the Eastern A cadastre, with an apparently significant result. The association of modern church sites with centuriated grids is not unexpected, since there are clear examples elsewhere in the empire. The choice of Wickham placenames follows Gelling's suggestion (Gelling 1968) that they are a type of settlement near a Roman road and settlement. The actual sites included are those in Rodwell's map (Rodwell 1975, Fig. 6) of *vicus*—wicham placenames in the Trinovantian canton excluding those (a) south of the Thames (b) without a church (excludes Wickham hall, spring and hill) and (c) not located on the 1:50,000 maps (excludes sites near Chigwell and Lt Waltham).

8.9 Oblique relationships within the hypothetical cadastres

Examination of the alignments of segments of Margary 1973, road 3d, the oblique road in Fig. 8.3, shows that the following have a rational relationship. (In each case the grid references quoted are those of major *termini, i.e.* grid intersections or mid points of sides. The line joining these points either lies on or is parallel to the road segment.)

		Relationship
i)	Swainsthorpe to just north of Newton Flotman; lies on TG 2305 0345 to TM 2093 9751	5:3
ii)	Tasburgh to Long Stratton; Close to and parallel to TM 2126 9723 to TM 1995 9335	5:3
iii)	South from Long Stratton; lies on TM 1989 9369 to TM 1995 9335	11:4

A number of segments of Roman road appear to be related to the Eastern A cadastre. The most striking example is the first stretch of Ermine Street north of London. The following appear on the printout of intersections produced using the parameters shown in Table 8.4: TQ 3343 8224, TQ 3384 9054, TQ 3426 9884, TL 3468 0714. If they are plotted onto 1:50,000 maps, they fall on the line of the road without detectable error. Each point is 4 squares across and 11 squares up from the previous one. Thus the relationship between road and grid is 11:4. It is notable that this relationship is maintained for 30 km.

These relationships look too good to be true. I share the uneasy feeling of McClure's hero (McClure 1974, p. 171) that 'flukes (are) seldom to be trusted'. In these circumstances it appears necessary to ask if they would be observed in any case. To what degree are such relationships significant?

8.10 Simulation of grid relationships

As far as I know, there has been no analytical treatment of this problem, so work is in progress on a computer-based simulation which 'throws' lines of varying orientation and length onto a grid of points, represented as small circles. The size of the points, in relation to the grid module, is parameterised in order to simulate different degrees of precision in the measurement of the coincidence.

It is straightforward, and probably an acceptable representation of reality, to select the orientation of the lines from a uniform random distribution in the range 0° to 90°. The selection of their length is more problematic since no data has been collected on the distribution of lengths of segments of Roman road. For an initial trial, for simplicity, the lengths were selected from a uniform random distribution in the range 3 to 23 times the grid module. With no loss of generality, a start point can be chosen with x and y taken from a uniform random distribution in the range 0–1. The program then checks, for each ordinate, if the grid point lies within the point radius of the line. If two such points are found, then the line is regarded as a hit (unless corresponding preceding or succeeding points do not fit).

For a point radius of 2.8% (which corresponds to 0.4 mm on 1:50,000 maps), two trials of 1000 lines indicated that about 3.5% of the total length of lines will conform to the oblique planning hypothesis. In 1000 trials of 20 lines, the sum of the lengths of fitting lines never exceeded 22% of the total. Further work needs to be done to refine this model, but it is probably true to say that it is very unlikely that more than 25% of the length of 20 straight segments of road will fit a centuriation by chance.

Fig. 8.5 shows the frequency distribution of angles which fit the oblique planning hypothesis. The dark bars show the frequency of observations in the sources cited in Tables 8.1 and 8.2 above. The light bars shows the distribution for the same angles obtained from 40,000 trials of the simulation, the 1207 'hits' being scaled down for comparison. It can be seen that the simulated coincidences seem to be more uniformly spread than the observed perceived relationships. This may be due to mis-perception, but it seems more likely that this difference is real, in which case the significance of the observed relationships is qualitative as well as quantitative.

8.11 The contribution of information systems theory and practice

In this work, the practical value of information technology is apparent. With a computer as a tool, a large area can be studied, since the problems inherent in manipulating overlays and maps are greatly reduced. In this way this technique is akin to the that of optical filtering of aerial photographs (Chevallier *et al.* 1970) used so successfully to discover the cadastres of southern France. Secondly, given the map references of point features, their distribution with respect to the grid can be examined without drawing

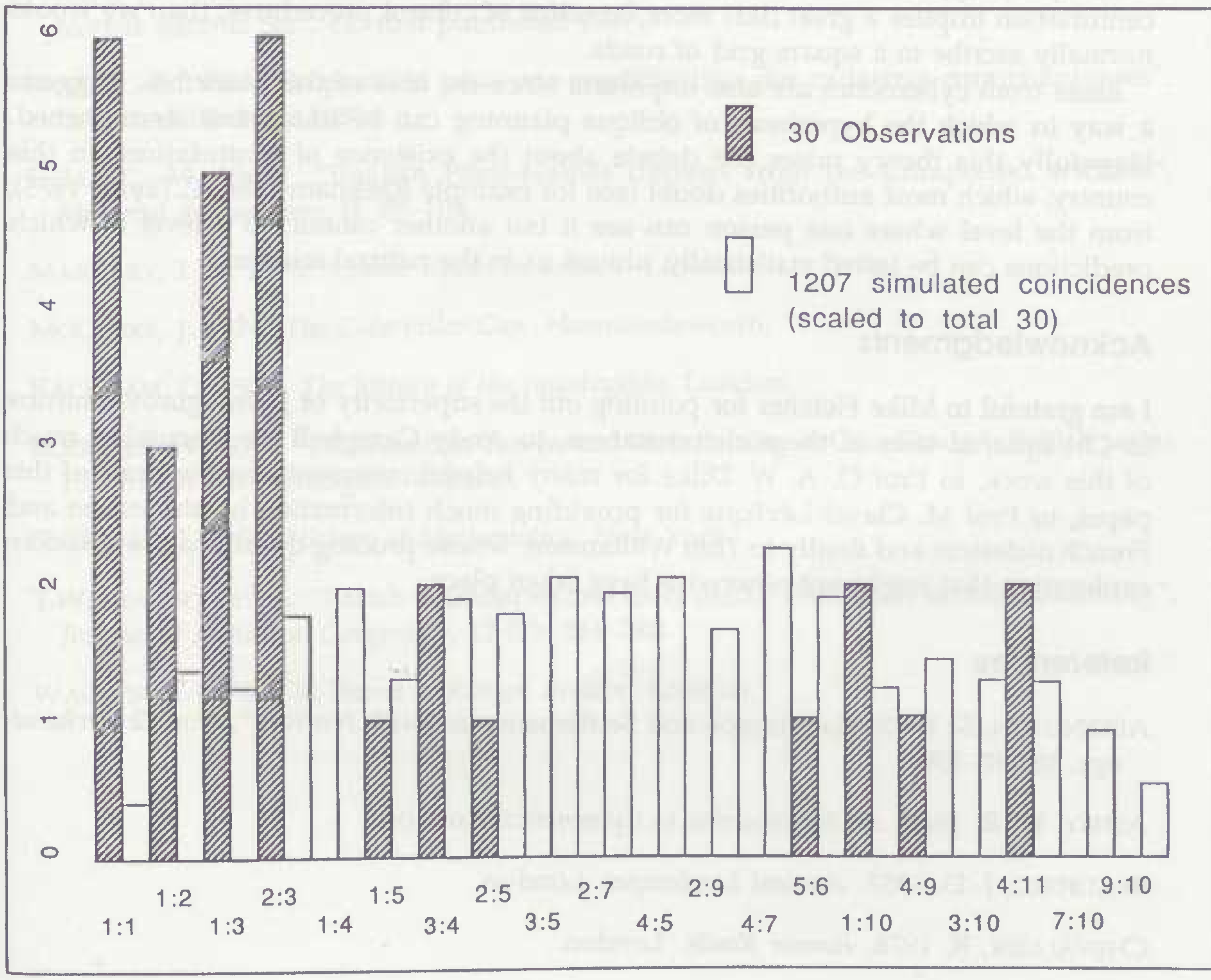


Figure 8.5: Coincidence of Oblique Features

a single line on a map. This is a considerable aid to objectivity, because, once the lines are drawn, the experimenter tends to see those features which fit, and to overlook those that do not. Thirdly, simulations allow us to attach some approximate measure to apparently unlikely coincidence, and thus decide whether or not the oblique planning theory is truly falsifiable.

However, I consider that in some ways information systems theory is even more relevant. An information system is essentially an instrument of control, and the Romans developed them to a high degree. Among these systems the cadastre was very important, since it controlled the major part of the primary production within its area. By trying to understand it as an information system, I begin to appreciate that a centuriation implies a great deal more, in terms of control procedures, than we would normally ascribe to a square grid of roads.

Ideas from cybernetics are also important since the idea of the 'black box' suggests a way in which the hypothesis of oblique planning can be tested and strengthened. Hopefully this theory raises the debate about the existence of centuriations in this country, which most authorities doubt (see for example Rackham 1986, C.Taylor 1975), from the level where one person can see it but another cannot, to a level at which predictions can be tested statistically, almost as in the natural sciences.

Acknowledgments

I am grateful to Mike Fletcher for pointing out the superiority of Kolmogorov-Smirnov to Chi squared tests in these circumstances, to Andy Campbell for discussing much of this work, to Prof O. A. W. Dilke for many helpful comments on the draft of this paper, to Prof M. Clavel-Lévêque for providing much information on the Italian and French cadastres and finally to Tom Williamson, whose probing questions provoked an exploration that might not otherwise have taken place.

References

ADDINGTON, S. 1983. "Landscape and Settlements in South Norfolk", *Norfolk Archaeology*, 38: 97–139.

ASHBY, W. R. 1964. *An Introduction to Cybernetics.* London.

BRADFORD, J. D. 1957. *Ancient Landscapes.* London.

CHEVALLIER, R. 1976. *Roman Roads.* London.

CHEVALLIER, R., A. FONTANEL, G. GRAU, & M. GUY 1970. "Application of optical filtering to the study of aerial photographs", *Photogrammetria*, 26: 17–35.

CLAVEL-LÉVÊQUE, M., (ed.) 1983a. *Cadastres et Éspaces Rural.* Paris.

CLAVEL-LÉVÊQUE, M. 1983b. "Cadastres et Voie Domitienne", *Dialogues d'Histoire Ancienne*, 9: 87–122.

CLAVEL-LÉVÊQUE, M. 1983c. "Pratiques impérialistes et implantations cadastrales", *KTEMA*, 8: 185–251.

C.TAYLOR 1975. *Fields in the English Landscape.* London.

DILKE, O. A. W. 1971. *The Roman Land Surveyors.* Newton Abbot.

DILKE, O. A. W. 1987. *Mathematics and Measurement—Reading the past.* London.

DRURY, P. J. & W. RODWELL 1980. "Settlement in the later Iron Age and Roman periods". *in* Buckley, D. G., (ed.), *Archaeology in Essex to AD 1500,* Reseach Report 34. CBA, London.

FADEN, W. 1973. "Faden's Map of Norfolk [with an introduction by J.C.Barringer]", *Norfolk Records Soc.,* 42. first published 1797.

FAVORY, F. 1983. "Proposition pour une modélisation des cadastres ruraux antiques". In Clavel-Lévêque 1983a.

GELLING, M. 1968. "English Place-Names derived from the Compound wicham", *Medieval Archaeology,* II: 87–104.

MARGARY, I. D. 1973. *Roman Roads in Britain.* London.

MCCLURE, J. 1974. *The Caterpillar Cop.* Harmondsworth.

RACKHAM, O. 1986. *The history of the countryside.* London.

RODWELL, W. 1975. "Trinovantian Towns and their Setting: a Case Study". British series 15. British Archaeological Reports.

SMITH, D. E. 1951. *History of Mathematics.* New York.

T.WILLIAMSON 1986. "Parish Boundaries and early fields: continuity and discontinuity", *Journal of Historical Geography,* 12 (3): 241–248.

WACHER, J. 1974. *The Towns of Roman Britain.* London.