**Interpreting mapping conventions in the diagrams of the *agrimensores***

> He had bought a large map representing the sea,
> Without the least vestige of land:
> And the crew were much pleased when they found it to be
> A map they could all understand.
>
> 'What's the good of Mercator's North Pole and Equators,
> Tropics, Zones and Meridian Lines?'
> So the Bellman would cry: and the crew would reply
> 'They are merely conventional signs'.
>
> 'Other maps are such shapes, with their islands and capes!
> But we've got our brave Captain to thank'
> (So the crew would protest) 'that he's bought *us* the best –
> A perfect and absolute blank!'
>
> Lewis Carroll *The Hunting of the Snark*, Fit the Second, Stanzas 2-4

## 1. Introduction

Maps may use different conventional signs for the same thing. A modern example – particularly relevant for our discussion – is the representation of the reference grid of kilometre squares on OS (British) and IGN (French) maps at a scale of 1:25,000. British maps show it by printed lines. French maps do not. They have small, almost invisible, crosses at the points where the grid lines would intersect. The reader must imagine the grid lines that join the points.

It is easy to understand inconsistencies between modern maps, but it not so easy to reconcile contradictions that seem to appear in the maps and diagrams of the *Corpus Agrimensorum*. Unlike modern maps, which have keys, these ancient documents do not tell us how we should read the signs. Furthermore, possible corruption in copying has an impact which, when compared with that arising from textual corruption, can be particularly severe. Errors in text can often be seen and plausibly corrected because words are normally used in other contexts, but diagrams often lack other illustrations with which they can be directly compared.

This lack of internal evidence and comparable material could explain why translations of the *Corpus* treat diagrams as they do. They give a meaning to the text, even if sources have to be amended, but they tend to leave the diagrams untouched - essentially without translation or correction. Prudent translators seem to avoid the diagrams because too much speculation would be needed to reconstruct, compare and translate them.

Furthermore, contradictions appearing in these illustrations have normally been dismissed as errors in one or other of them. This is not productive; it may be better to regard such contradictions as potential sources of information. Pathology - the study of malfunctioning organs - has greatly aided research in medicine. So, by analogy, the "bad" diagrams could also be informative and should not lightly be dismissed.

This approach will be taken to some illustrations in the *Corpus*. Although they may appear to contain contradictions, arguably because they use a variety of map conventions in contexts that we do not fully understand, it is possible to provide a coherent explanation of some of their discrepancies. This suggests that two of the authors in the *Corpus* are describing one method for survey and measurement of an area with an irregular boundary that could have been applied to an area of any size, from the smallest estate to the lands of a whole community.

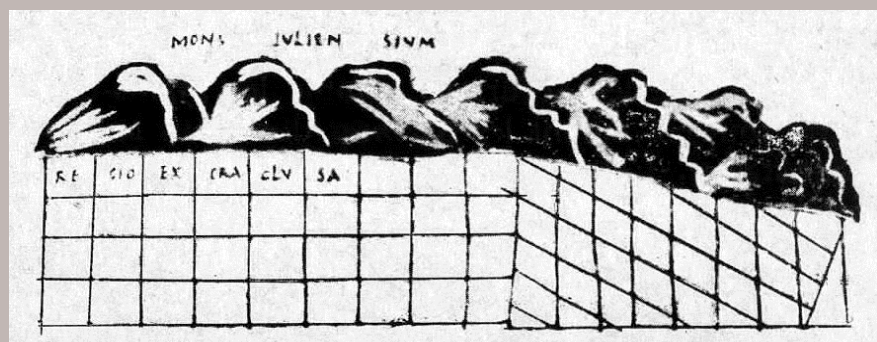## 2. Boundaries and survey lines in the *regio extra clusa*

The *Establishment of Limites*, by Hyginus Gromaticus, seems to contain a contradiction between two diagrams. They appear close to each other in a passage whose subject is an area not "divided and assigned" within a larger territory that has been so treated. This area is the *regio* (or *locus*) *extra clusa*.

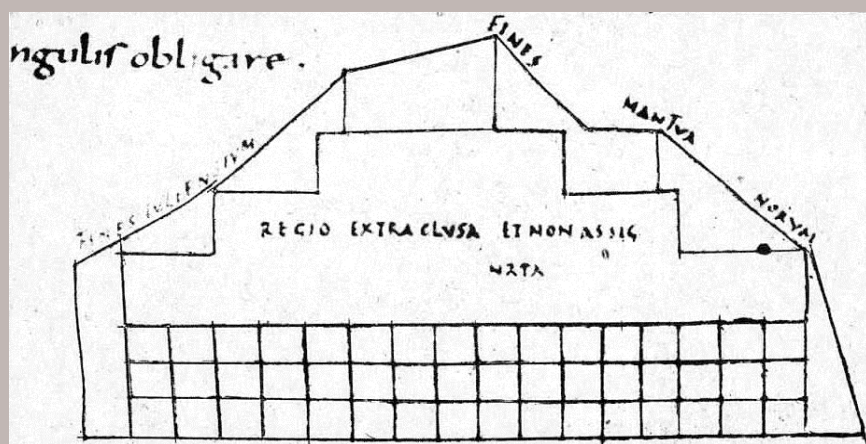| Latin text, with illustrations (in this case) from Thulin's photographs of manuscript P. | Suggested English translation. |
|---|---|
| si qua regio in extremitate limites non acceperit, eum locum uacantem significabimus hac inscriptione : LOCUS EXTRA CLUSUS. et extremitatem deinde terminis lapideis obligabimus, interposito ampliore spatio, et aris inscriptis conditoris nomine et coloniae finibus. (C 156.10-13).  | If a peripheral region has not received *limites* we will indicate that it is devoid of them with this inscription: EXCLUDED AREA. Then we shall embrace the outermost (area) with:<br><br>- boundary stones, with a generous gap between them<br><br>- altars inscribed with the name of the founder<br><br>- the outer boundaries of the colony. |

Figure 1. Hyginus Gromaticus, P 100 v

| | |
|---|---|
| extra clusa regio ideo, quod ultra limites finitima linea cluditur. linea autem finitima si limitibus comprehensa non fuerit, optimum erit extremitatem ad ferramentum rectis angulis obligare et sic terminos ponere. (C 156.13-15).  | It is an "excluded region" because it lies beyond the [area with] *limites* and is enclosed by the outer boundary line.<br><br>If the outer boundary of the colony is not included within [i.e. coincident with] *limites* it will be best to embrace [i.e. survey] the periphery with right angles using the *ferramentum* [groma] and place the boundary stones, thus. |

Figure 2. Hyginus Gromaticus, P 100 v

The first part of this text (*figure 1*) tells us how to mark out the *regio extra clusa*; the second part (*figure 2*) explains why it is given this name and how to survey the positions of its boundary markers. The word *sic* suggests that the second illustration was included in the archetype manuscript. We cannot be sure of this - as Brian Campbell has pointed out - but the illustration certainly seems to be relevant to the text immediately before it.

However, the illustration in *figure 1* appears to be a meaningless and contradictory interpolation. It does not show the boundary stones and altars referred to in the text. It includes the words *regio extra clusa* within the squares of an area apparently divided by *limites*. It also seems to be composed of fragments of illustrations found elsewhere in the same manuscript. What is more, manuscript P is dated to the early 9th century AD. The later copyist need not have used or understood the conventions employed in maps in the 1st/2nd century AD, when the text originated. The strong impulse to ignore this figure can therefore be understood.

Nevertheless it will be suggested that this diagram could make sense. We may suppose, for the sake of argument, that the original author of the diagram willingly included the words *regio extra clusa* within an area containing squares. If so he accepted the idea that lines forming squares could represent something in an area he defined as "beyond the *limites*". Since, by definition, they could not be lines of physical land division we must look for another meaning that he might have assigned to them.

### 3. *Limites* in lands that were surveyed but not divided and assigned

It is a fundamental contention of this article that lines on maps, apparently in the form of *limites*, could represent invisible survey lines and that the creators of *formae* could draw a square grid on the map when there was no corresponding physical division of the land it represented.

Two pieces of evidence support this claim. Firstly Frontinus in his *De Agrorum Qualitate* says:

| | |
|---|---|
| Ager est mensura comprehensus cuius modus uniuersus ciuitati est adsignatus, sicut in Lusitania Salmanticensibus aut in Hispania citeriore Palantinis; et in conpluribus prouinciis tributarium solum per uniuersitatem populis est definitum. Eadem ratione et priuatorum agrorum mensurae aguntur. <br><br> (C 2.12-15) | Land contained in a survey [across its extent] is [land] whose entire area has been allocated to a community, as for example at Salmantica in Lusitania or Palentia in Nearer Spain. Moreover in numerous provinces land subject to tax has been defined for communities on the basis of the entire area. <br> And surveys of private land are carried out using the same system. |



*Figure 3. Frontinus A 62*

| Hunc agrum multis locis mensores, quamuis extremum mensura comprehenderint, in formam in modum limitati condiderunt (C 2.15-17). | For many places, surveyors have represented this [type of] land on the *forma* in the same way as land that has received *limites*, although they have surveyed it across its extent. |
|---|---|



*Figure 4. Frontinus, A 62*

In the first part of this passage (*figure 3*) Frontinus is amplifying his definition, given near the start of his book, of lands *mensura per extremitatem comprehensi*. These are lands that, according to Campbell (C 3.4), are "contained in a survey throughout their extent". Frontinus also gives a motivation for such an overall survey: to calculate the area of land within the jurisdiction of the *ciuitas* and establish the amount of tax payable by the community as a whole (see C 319 note 6 for details).

But what does Frontinus mean when he says (*figure 4*) that in many cases such land is represented on the *forma* (i.e. mapped) in the same way as land divided by *limites*? The anonymous author of the *Commentum de Agrorum Qualitate* (possibly 5th-6th century) explains.

| Hunc ergo agrum ne in formis uideamus tantum modo conditum, continuo subiungit *'in modum limitatum'*, ut sciamus plenissime non posse formam cuiuslibet agri sine limitum rectura subsistere. (C 54.7-9) | In case we should see this land as merely inserted on maps, Frontinus immediately adds *'in the form of land that has received limites'*, so that we may fully understand that it is not possible for the map of any land to exist without the straight lines of the *limites*. |
|---|---|

So, a map of any land – even land that does not contain any physical *limites* – should show the survey lines. The illustration, placed immediately after Frontinus' text, must therefore be seen as a representation of the *forma*, and not of the land itself.

The second piece of evidence for the existence of such abstract survey grids comes from South Tunisia. An enormous *limitatio* is dated by a few of its *termini* discovered in the area bordering the Sahara. Four of them have remains of inscriptions stating that it was implemented by *Legio III Augusta* in the third proconsulate of *C Vibius Marsus,* i.e. 29-30 AD (Trousset 1978 p.131).

The inscriptions say that the surveyors established *limites* (*leimitauit*). However, no physical trace of *limites* can be seen on the ground or in aerial photographs. This cannot everywhere be blamed on the nature of the terrain. Although the area studied by Trousset includes steppe, salt flats and mountains, where the absence of traces can be understood, it also includes a fertile arable area where there is still no trace. Instead of centuriation, there are many signs of other forms of ancient cultivation. For Trousset (1978 p.134) these small dams on the oueds and terraces oriented according to contour lines "semblent relever beaucoup plus d'une tradition technique commune aux montagnes présahariennes que de l'histoire des centuriations romaines".

As Trousset says (1978 p.158), we have here, not a centuriation developed in detail, but an outline framework based on *termini quintarii* doubtless represented on a *forma* at Rome or Carthage. Furthermore, there is evidence that this *forma* was used to grasp the extent of the territory and allow strategic decisions to be made centrally and implemented at local level. This evidence comes from several stones, probably standing originally on the *decumanus* DDLXV (65 to the right of the *decumanus maximus*).

One *terminus* which stood at the intersection VKCCLXX (270 beyond the *kardo maximus*) has, in addition to the coordinate values, the inscription NYBG on one face; another, albeit rather doubtful, is on the summit of Jebel Terhendourt at about VK 350 with a reference in the fragmentary inscription to NYB. Two others, still on DD 65 at about VK 265 and 280, bear the inscription NYBG on one face and TAC on the opposite face, and the further inscription:

*ex auctoritate imperatoris Neruae Traini Caesaris Augusti ... secundum formam missam sibi eo posuit*

The surveyor set up the *terminus* by the order of the emperor Trajan according to the map sent to him (Trousset 1978 p.135).

These stones, in a line, mark part of the outer boundary (*fines*) of the Nybgeni, a boundary shared with the Tacapitani, the neighbouring tribe to the northeast. It is a strong possibility, but not certain, that this boundary – where it crosses the area between the tribal capitals – conformed consistently to the line of DD 65. In some places, where the points with surving markers lie only one or two *quintarii* apart, it is likely that the *forma*, representing *quintarii* (as Trousset suggests), would make it appear to be so. Certainly, none of the available evidence contradicts the idea that part of the *fines* of the Nybgeni, and plausibly a length of 60 km, lies on a *limes* of the south Tunisian *limitatio*. In the words of the text in figure 2, we have here an example of *linea finitima limitibus comprehensa*.

But what was the legal status of the territory of the Nybgeni? Their capital, Turris Tamelleni, was certainly not a *colonia*. Thus it seems almost certain that they and their neighbours in and around Aquae Tacapitani were *ciuitates* who were taxed on the basis of their lands *mensura per extremitatem comprehensi*.

Hence the archaeological evidence supports the view of Frontinus and the author of the *Commentum*. In the African case the *limites* drawn on the map seem to represent survey lines and nothing else. The land of these *ciuitates* was probably taxed on the basis of its whole area. It was not physically divided by the squares of centuriation but it was represented on the *forma* as if it was. The lines on the *forma* were an administrative and cartographic reality, but they were, like the kilometre grid lines of modern maps, not a physical reality on the ground.

## 4. *Limites* in lands divided and assigned

In the previous section we have considered the representation, on *formae*, of survey lines in the form of a square grid covering lands which Frontinus calls "contained in a survey throughout their extent". We now turn to the sort of land that he first describes, that "divided and assigned". The Arcerianus manuscript illustrates this (*figure 5*).

*Figure 5. Frontinus, A 61*

It may seem obvious that the square grid shown here represents *limites* in physical form, covering the whole territory and forming the basis of the colonial land allotment, but this assumption must, in some places, be false.

Within a sufficiently large territory there would almost certainly be some land unsuitable for allotment. Hence it is more likely that, although the grid lines often represent both the lines of the *limites* and their physical expression, there will be some places where the lines on a map of this sort of land have, like lines on the map of lands "contained in a survey throughout their extent", no corresponding physical reality.

It can therefore be concluded that several illustrations (in *figures 4 and 5*, and by analogy in *figure 1*), show grid lines – survey lines of *limitatio* - that are, in whole or in part, without physical reality on the ground.

## 5. The variable conventional meanings of the grid lines in these illustrations

It will now be argued that, using a different convention, the diagram in *figure 2* seems *not* to show, in some parts, survey lines that *are* present.

That diagram includes, around the edge of the *regio extra clusa*, a series of line segments at right angles (a stepped line) lying just within the outer boundary of the territory. According to Campbell (C 396 n. 43) "the excluded area has been prepared for survey by the creation of right angles". Hence, in his view, the area within the stepped line is blank because it had not yet been surveyed; the stepped line had been set up so that this could be done.

Examination of the stepped line reveals that 5 of the 6 vertical segments line up with the lines of *limites* in the allocated land. Discounting a minor drawing error, it is possible that this coincidence is not due to chance. It may perhaps be explained by the existence of an underlying grid that the scribe used to set out the diagram, but it is also possible that we are intended to imagine the lines of *limites* projected across the *regio extra clusa*, just as they are projected across lands "contained in a survey throughout their extent". This latter explanation suggests that the stepped line is the product of a grid survey across this area, not its future basis. Indeed, how could the stepped line be set up easily unless all the territory had already been surveyed?

The text confirms this. It says that the purpose of the establishing this series of right angles is to fix the outer boundary  (*extremitatem ad ferramentum rectis angulis obligare*) and so set up the boundary stones (*sic terminos ponere*). Therefore it seems that the stepped line is a first approximation to the territorial boundary itself.

Lines at right angles (normals) to this stepped lines pass through vertices of the outer boundary. A plausible interpretation of these normals is that they are the survey lines erected to the vertices of the polygonal boundary of the territory in order to determine their location.

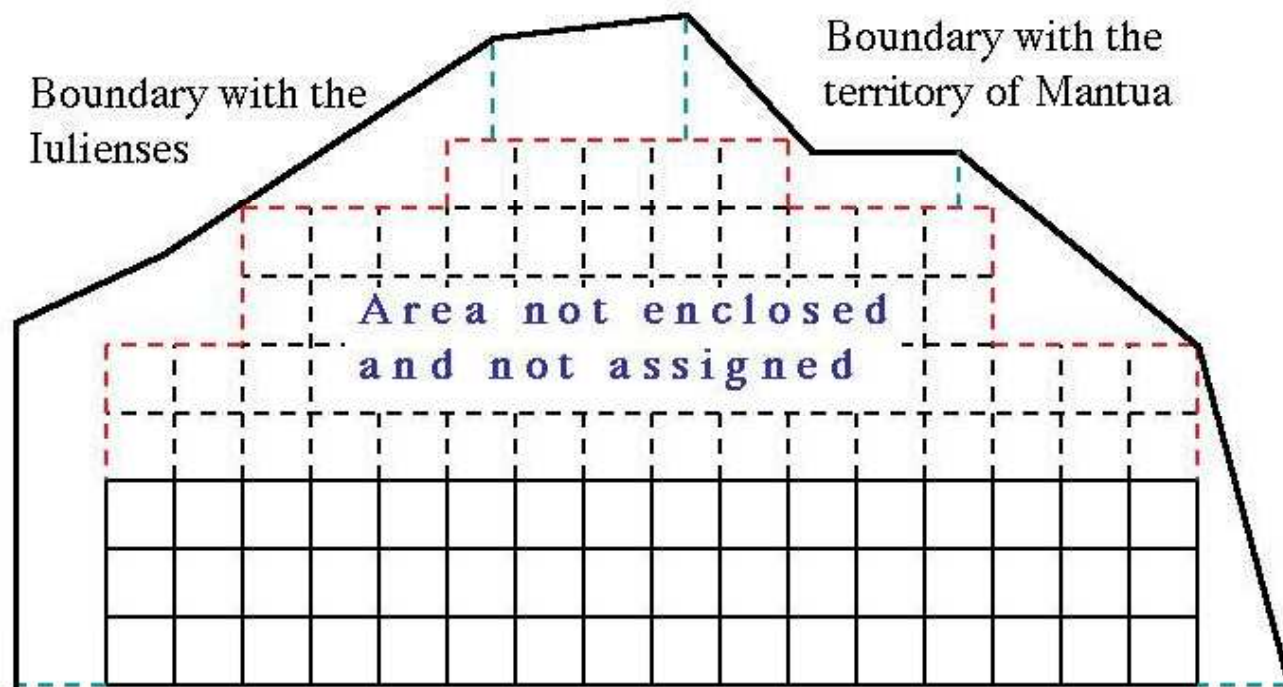This suggests an interpretation (*figure 6*) of the diagram shown in *figure 2*.



*Figure 6. Interpretation of diagram in figure 2.*

This interpretation introduces a convention, the dashed line, not used by the illustrators of the Land Surveyors' works, and perhaps unknown to them. For us, a dashed line on a map signifies a feature with a different, usually diminished, reality. The edge of a road shown in this way is unfenced, with little physical obstacle to movement. Administrative boundaries are also shown in this way. They are real but may not coincide with physical landscape features.

Perhaps the ancient surveyor and draftsman could not easily express what they had in mind. If so the blank space on the diagram is not to be interpreted as an area devoid of any feature. It contained survey lines, but the illustrator could not show them and also distinguish them from the lines of physical *limites*.

The dashed line, that expressive modern map convention, was not used in this case but other illustrations suggest that some illustrators were using a comparable convention. Another diagram (*figure 7*) shows land enclosed by the outer boundary (*terminatum per extremitatem*). A *regio extra clusa* is not explicitly labelled, but it may be represented by a large area between the area filled with squares, apparently the allocated area, and the outer boundary. This is filled with half the lines seen in the other area.
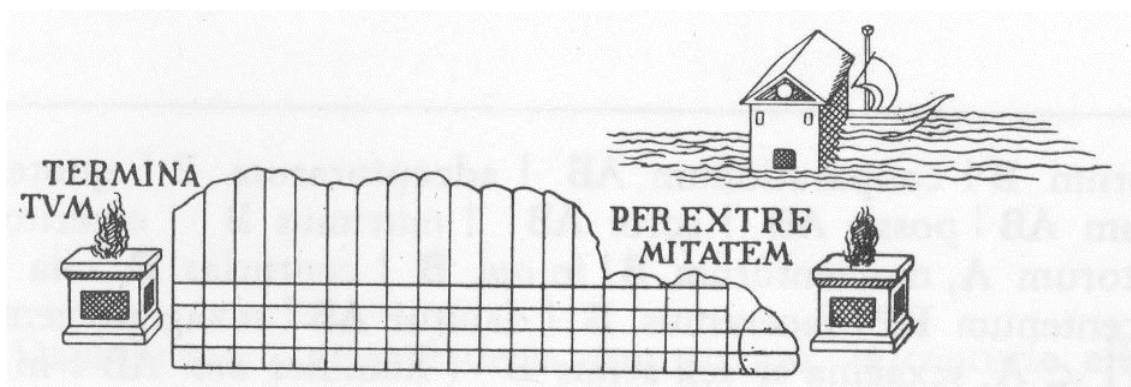
*Figure 7. Hyginus Gromaticus, J 27 r*

The same convention may also have been used in a different context (*figure 8*). The Faustinian farms (*fundi faustiniani*) are surrounded by land containing *limites*, but only half their lines are shown in the area.
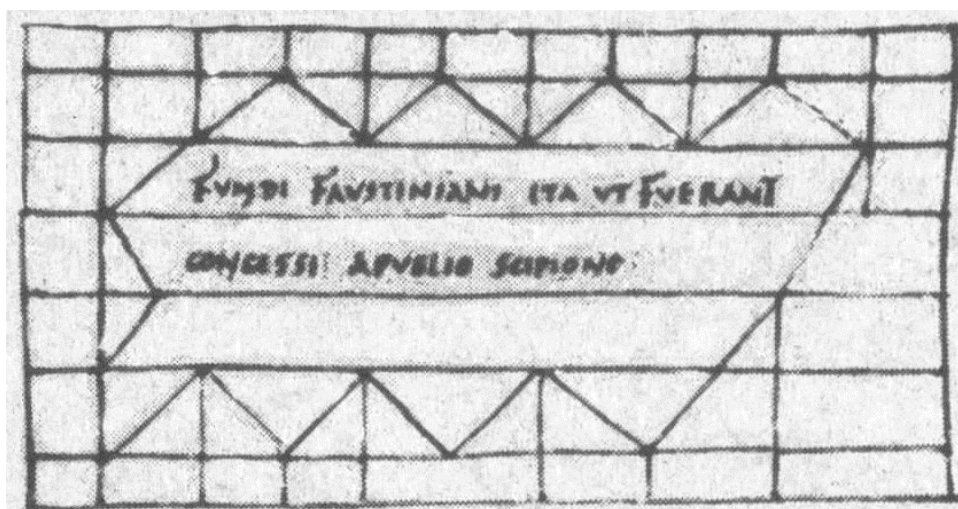


*Figure 8. Hyginus Gromaticus, P 99 v*

This use of lines, in one direction only, may then not be a drawing error. We have seen that whole territories that did not contain *limites* in a physical form were still covered in a grid of survey lines. Hence this diagram could represent a private estate that did not contain the physical *limites* of public land, but was still surveyed on the same system. The convention used to show these invisible lines is logically equivalent to the modern convention. The lines, which we in modern times half show by dashed lines, were in these two cases also half shown – by the lines in just one direction.

## 6. Surveying land with an irregular boundary

It has already been suggested that the stepped line shown by Hyginus Gromaticus (*figure 2*) is composed of segments of *limites*. If so it approximates the territory's outer boundary and also surrounds a whole number of squares of the *limitatio*. In consequence the number of these squares can be used to give a first approximation to the area of the territory. In the majority of cases, multiplication by 200 then gives the area in *iugera*.

This very simple, though inaccurate, method may also be represented in Balbus' *Systematic Description of all Figures*. Enigmatic shapes (*figure 9a*) may depict the sort of stepped boundary shown by Hyginus Gromaticus. They seem enigmatic because they are obviously out of place, having nothing to do with the passage (C 212.42, 43) in which they are found, and there is no reference to them in the surviving part of Balbus' text. Nevertheless, they should be familiar to modern readers who are accustomed to seeing figures produced by computers in just such a pixel form. We can

imagine the possibility that they could have been approximations to other figures, such as the irregular shape shown in *figure 9b*
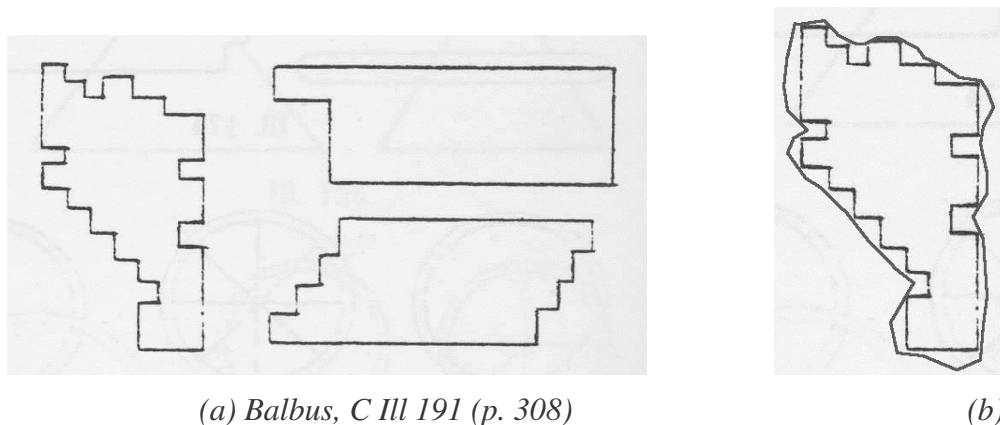


*(a) Balbus, C Ill 191 (p. 308)* (b)

*Figure 9.*

A more accurate determination of area requires that beyond the stepped line the territorial boundary is approximated by a polygon (a series of line segments) whose vertices can be accurately located by measurements.

Modern geographers and planners are familiar with this approximation. Computerised systems for mapping can hold numerical models of landscape expressed as (x, y) coordinates in a square grid. The information is generated by recording positions at points in the field, or by digitising existing maps. A boundary is represented in the model by a series of lines joining the points

It can be suggested how the irregular territorial boundary (*figure 6*) could have been surveyed. The stepped line, in red, is defined by the *limitatio*. From it the surveyor constructs normals, shown in light blue, which pass through the boundary's vertices. For each vertex, measurement of two distances: (a) the position of the foot of each normal from the nearest survey grid intersection and (b) the length of the normal, determines its position. In the field, setting up the normal could be done easily with a *groma*. With one arm aligned along the red line, the operator could move along that line until the other arm aligns with the vertex. We can also be reasonably confident that the normals between the stepped line and the vertices must have been surveyed from the stepped line to the vertices, and not vice-versa. Dropping a perpendicular from the vertex to the nearest red line would be extremely difficult in practice.

The measurements obtained in the field in this way can easily be used to draw a map, by plotting the position of each vertex. Once the scaled equivalent of the stepped line is drawn on the map, a setsquare (*norma*) can be placed on it with its corner at the scale position and a construction line drawn at right angles to it, with the scaled length determining the mapped position of the vertex.

These normals can also be seen in two other illustrations.

In one of them (*figure 3*) the diagram includes them, but only in the top half. This figure could be dismissed as merely confused, but it is also possible that its upper and lower parts show two aspects of a single reality. Its top half, containing the normals, represents a survey of the boundary of lands *mensura comprehensus*, while the bottom could be a depiction of *ager arcifinius*, with its bow shaped boundaries. The survey is regular, but the boundaries of physical land units are not. On a modern map this would be shown using conventions such as those described in the first paragraph of this article. Lacking such conventions, the Roman illustrator is obliged to draw a figure that seems self-contradictory.

Another diagram (*figure 10*) may also be relevant. Again, an area *terminatus per extremitatem* is shown. In this case a single straight line of a regular survey (and possibly also of land division, but we cannot be sure) approximates the sequence of oblique straight lines representing the outer boundary. The illustrator has not drawn normals through all vertices, but it is probably safe to suppose that this is an omission on his part.
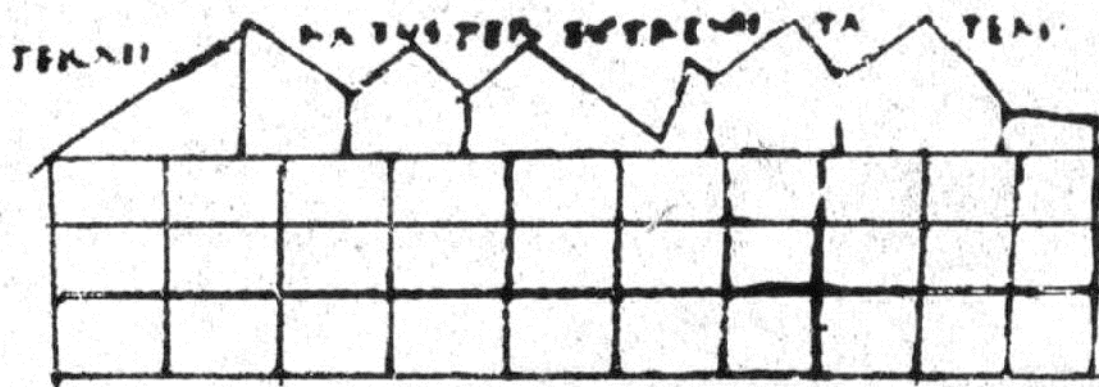


*Figure 10. Hyginus Gromaticus, P 101 r*

## 7. Interpreting a passage in Frontinus' *Science of Land Measurement*

Frontinus, in another book, deals in more detail with the survey and measurement of the area of land with an irregular boundary. It will now be suggested that his text, which is not illustrated, is referring to the surveying procedure already described, and seemingly so clearly illustrated by the diagram shown in figure 2.

He describes the mapping and measurement of land that has an irregular shape but whose outer boundary is composed of a series of straight line segments meeting at extremities (or angles).

Sed ut omnibus extremitatibus species sua constet et intra clusi modus enuntietur, agrum quo usque loci positio permittet rectis lineis dimetiemur ; ex quibus proximam quamque extremita*tiu*m obliquitatem per omnes angulos facta normatione complectimur, et cohaerentem mensuralibus <lineis> statutis certo procentema*te* spatio simil*i* futurae tradimus formae. Modum autem intra lineas clusum rectorum angulorum ratione subducimus. (Frontinus 1998 p.54. Equals, in most respects, C 12.7-12)

But in order to preserve the shape at all extremities, and specify the area of enclosed land, we shall measure the land with the straight lines as far as the arrangement of its features permits. Starting out from these lines we embrace each oblique (line in the) perimeter by making normals (from the straight lines) to all the angles. Then, thanks to the accurate digitisation linked to the survey lines that have been established, we transfer (the shapes) to the draft map, to scale. We calculate the area enclosed inside the lines using the system of right angles.

This version of the Latin text is that of the "Besançon" translation. It differs from that of Campbell in reading *procentemate* where Campbell prefers to follow Lachman and Thulin in replacing what is written in MS A – *procentemato* – by *praecenturiato*, which Campbell (C 328) suggests is a reference to "measurement akin to the measurement of *centuriae*, i.e., with a regular outline." This reading leads him to an interpretation of the method of survey that is, somewhat implausibly, dependent upon the establishment of a clear rectangular area - see below.

The reading of *procentemate* as a latinised Greek technical term, relating to a plan traced out by points (Frontinus 1998 n.76 pp.83-4), involves less modification of the text and leads to a more satisfactory

conception of the process The best modern equivalent word is "digitisation" because the process is the same i.e. the capture of the coordinates of points representing a series of line segments.

Also, this translation, line 2, takes *lineis rectis* to mean "the straight lines", that is the lines of conceptual *limitatio* used to survey any land which is to be represented on a *forma* (see above). The pre-existence of this survey grid is compatible with Frontinus' reference to "the system of right angles", *rectorum angulorum ratio*. This would be, in this interpretation, not be a series of right angles drawn arbitrarily, but the survey grid already set up to map the territory.

So the procedure is to prolong the lines of the survey grid as far as possible until some physical feature or the outer boundary stops us. Using these survey lines we construct a stepped line enclosing as many complete grid squares as possible. From this stepped line we erect normals to the nearest vertices (*anguli*) on the outer boundary of the area. We then measure the position of each end of each oblique boundary segment, with reference to the nearest survey lines. These points, located by these measurements, are then transferred to scale onto the draft map. We use the grid system to calculate the area inside the boundary. The further text, not shown here, goes on to explain that the areas of the non-rectangular pieces near the boundary must also be calculated to give a true account of the area.

Explanation of Frontinus' method requires a diagram. Two are considered, one published by Campbell (*figure 11*) and the other as an explanation of the hypothesis presented here (*figure 12*).

Without doubt Campbell has performed a very valuable service in bringing most of the text of the *Corpus* to an English-speaking readership in an intelligible form. However, we have to ask if his diagram 3 (*figure 11*) makes sense and if the suggested method would work.
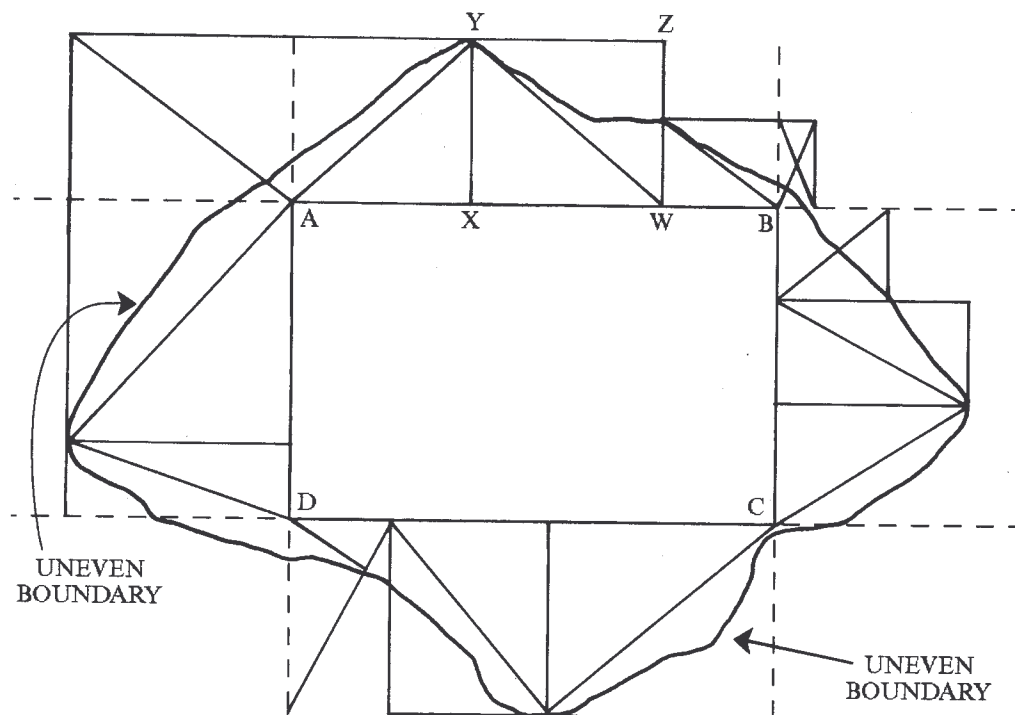


ABCD = central measured area

WXY }
WYZ } = examples of right-angled triangles for measurement on the boundary

*Figure 11. Campbell's diagram of Frontinus' method (C 486)*

Consider first the central measured rectangular area. It existence is not a logical impossibility but its reality depends on a particular interpretation of *procentemato*, as noted above. However, even if it did exist it would not, in practice, be a convenient basis for surveying the boundary. Territories, and smaller surveyed areas, need not approximate a rectangle. If a rectangle were inscribed in a large territory there could be some points on the boundary very far from it. This can be seen in the case of the territory shown above (*figure 5*). Assuming that the squares are the normal 710m on each side, the extreme points on the right hand side of the diagram would be at least 10km from a rectangle filling the centre of the territory. Constructing a normal over this distance would be a challenge. That is why the sort of stepped boundary shown by Hyginus Gromaticus (*figure 2*) seems much more useful.

Next consider the significant points on the boundary, such as point Y. They are related to the sides of the rectangle, but not in a consistent way. In four cases lines are drawn parallel to the sides of the central rectangle, and hence normal to its sides: and diagonal lines, such as WY, are also drawn. Another point, between Z and W, has normals but only one diagonal line. Yet another, to the right and down from point B, has two normals, but no diagonals. Finally, a point to the right and down from point D has two diagonals and no normals. This may be a misprint; perhaps it was intended to extend the diagonal passing through D to another point on the boundary where it is intersected by a normal that seems to have no function, but if that were so it is hard to see why the other diagonal has been drawn.

There are also some diagonal lines, a single one top left and a pair in the form of an X at top right, which are not related to any point on the boundary and could not be used to measure an area contained within it.

The logical errors in this diagram could perhaps be rectified, but that would not remove the practical difficulties. Triangles WXY and WYZ are supposed to be used for measurement on the boundary. Since they are congruent, and hence have the same area, we need only consider one of them, WXY. The problem facing the surveyor is how to measure the area between part of one side of the rectangle (XY), the two normals (XY and WZ) and the boundary. The triangle WXY is an extremely bad approximation to this area, representing only about 70% of it, and the diagram does not show how the part outside the triangle is to be measured. The approximation to the boundary near point D is even worse. For this reason alone the diagram does not demonstrate a workable method that would produce a reasonably accurate result.
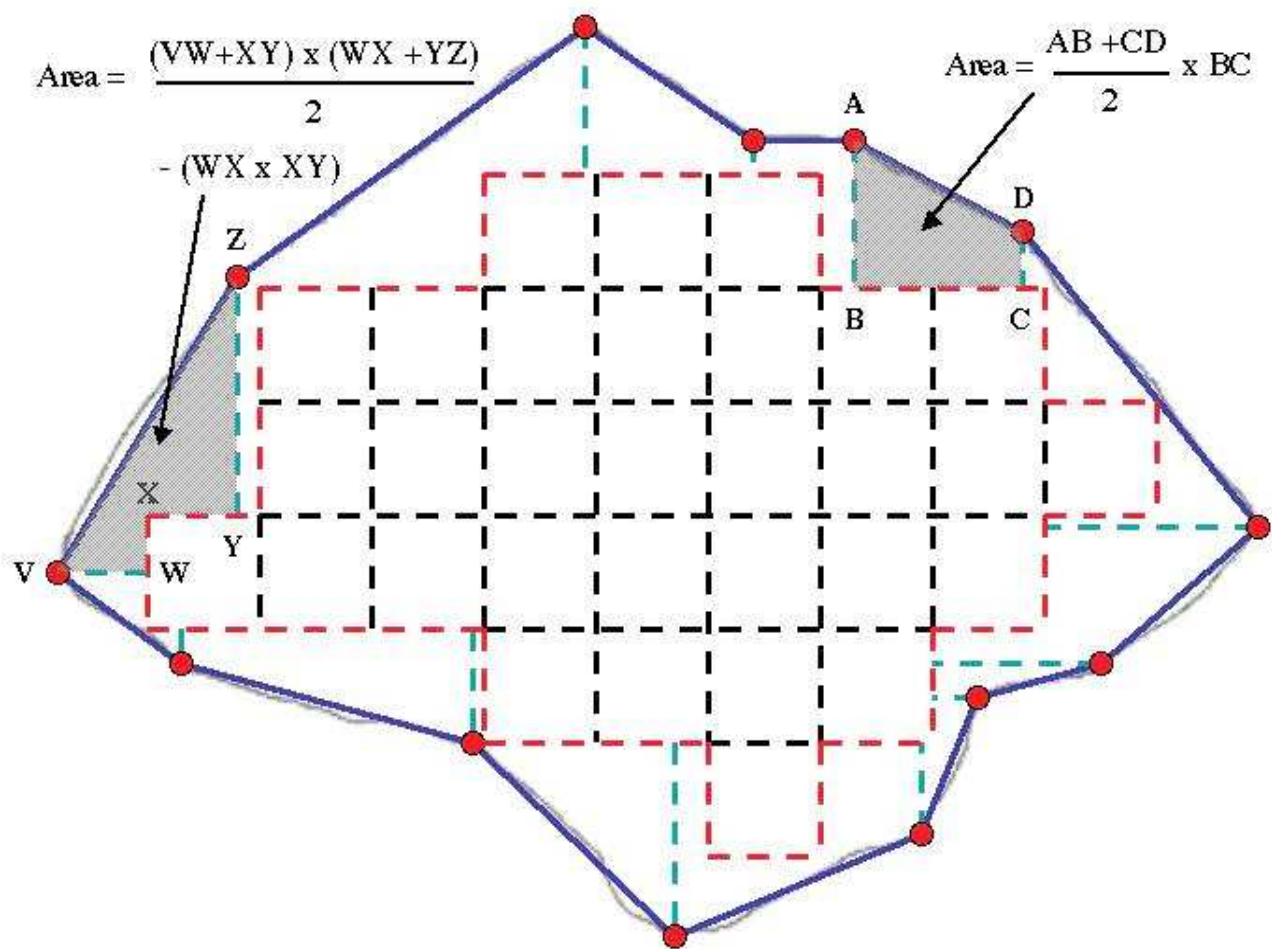
*Figure 12. Suggested alternative interpretation of Frontinus' method of surveying an irregular boundary*

In the alternative approach (*figure 12*) the same uneven boundary is used. The first and most important step is to choose and mark points on this boundary so that the straight lines joining them will closely approximate the boundary itself.

A stepped survey line is then constructed inside the boundary. It is based upon the grid survey that has already started. Normals are then erected from the stepped survey line to the vertices of the approximating polygon, and hence to both ends of each of its oblique segments. When the measurements have been made and recorded, the positions of the marked boundary points can be plotted on the map.

The size of the areas contained between the boundary and the stepped survey line can be calculated, as shown by two examples.

ABCD is a trapezium. Its size is the product of the length BC and the mean of the two parallel sides. The size of the other area, VWXYZ, can be calculated as that of the right-angled triangle, with corners at V and Z, minus the rectangle with three of its corners at W, X and Y.

With slight modifications as necessary, these formulae can be used to calculate the size of all the areas between the boundary and the stepped line. Their sum can then be added to the area of the squares to give the whole area included within the irregular boundary.

## 8. Conclusions

The suggestions made here may seem radical, and are offered not as certainties but as ideas for debate. In summary they are as follows:

- *Formae* used by the Romans for land administration (cadastral) purposes have similarities to modern maps based on kilometre grids. Like some modern maps, the *forma* could show the lines of the grid even if there were no corresponding physical land divisions.

- The legal status of the land was independent of the act of mapping. The author of the *Commentum* is stating a fact (possibly with some exaggeration) in saying that all maps must contain the lines of the *limites*. Whatever the legal status of the land, this implies the existence of the *limites* within it, if only in the form of survey lines. They may have no more physical reality than those of the south Tunisian system, but nevertheless they have a persistent administrative reality.

- The mapping conventions used in the *Corpus* do not allow the simultaneous illustration of the regular survey lines of *limitatio* and any irregular physical boundaries of land. One or other must be omitted, although it is possible that the diagram in figure 3 tries to evade this restriction. It is also possible that other diagrams use a convention - showing only half the *limites* - for land covered by them (as survey lines), but not divided by them.

- When some problematic – even pathological – diagrams are interpreted in the light of these suggestions they become harder to dismiss. A line may not necessarily represent a physical land division. Conversely, a blank may still signal an area containing survey lines, or even land divisions, in which the author has no interest.

If these ideas have any value they may illuminate Frontinus' method of surveying an area of land with an irregular boundary. The fundamental suggestion is that Frontinus and Hyginus Gromaticus (*figure 2*) are describing the same surveying and mapping procedure. The former is concerned with calculating an area, the latter with setting up boundary stones. Both tasks can only be accomplished by making a map.

A debate continues over the extent to which Greek practice influenced Roman land surveying. Lewis (2001 pp.122-3) tells us that "Some see connections between Hero's *Dioptra* and *Metrics* and some parts of the *Corpus*, notably in so far as Hero's method of calculating the area of irregular plots is not unlike those of Frontinus and Hyginus" but his overall conclusion is that the Roman tradition is basically independent. On the other hand, Roth Congès (2000 p.124-5) sees a connection between Hero's *Dioptra* and the passage of Frontinus considered here.

Whatever the truth of the matter, it does not seem essential to relate Frontinus' method to Greek technique. Hyginus Gromaticus' method of mapping, in order to place boundary stones, could equally well apply. The Roman approach of *limitatio* - which is "almost totally ignored by the Greek surveying manuals" (Lewis 2001 p.122) - provides the systematic frame of reference needed to construct accurate maps with ease.

Therefore interpretation of the illustrations in the works of the *agrimensores* should allow for the limitations imposed by the conventions they used. Perhaps some day we will have translations that transform the diagrams so that they conform to modern, consistent, map conventions. As long as these are not available, we are left in the position of Lewis Carroll's Snark hunters. We may indeed understand the map without knowing the territory.

**9. Thanks**

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