A case-study in Roman mathematics: the description of the analemma in Vitruvius' *De architectura*, book 9

Introduction

The text in this section is meant to exemplify Roman mathematics, by which we primarily mean mathematics written in Latin, rather than mathematical texts produced in the period of Roman dominance over the Mediterranean.

While there is evidence of early translations of the material contained in Euclid's *Elements* into Latin by at least the second century CE, if not before,[1] no original Latin treatise has survived that is structured along axiomatico-deductive lines. Moreover, the paucity of texts and the fact that none of the Latin mathematical texts appears to have acquired Euclid-like canonical status, it is difficult to generalize, or to indicate departures from the norm. As far as language or style are concerned, there is no norm. The sources are predominantly what has traditionally been called 'applied' mathematics, i.e. mathematics in the form of problems inspired or set in real-life contexts, such as measuring land, or, in the present case, building a time-keeping device. These problems are solved by deploying

[1] See the materials in Campbell 2000.

mathematical techniques or instruments which are often justifiable in 'theoretical' mathematical terms, but at the same time are presented in the treatise in a concrete, almost material way. On the whole, the language contains both borrowings from the Greek, sometimes transliterated rather than translated, and corporeal terminology, which evokes objects in the real world, rather than abstract geometrical entities. The passage below is one such example.

Vitruvius' *De architectura*, in ten books, is the only surviving treatise from antiquity devoted to the art of building, and related disciplines. It was produced between the late first century BC and the early first century AD, as we can infer, among other things, from the fact that Vitruvius dedicated it to the then emperor Octavian Augustus. Vitruvius also mentions that he had been a military engineer at the service of Julius Caesar, and that he had a patronage relationship with Augustus' sister Octavia. After claiming in the first book that the ideal architect should have at least some knowledge of an impressive array of forms of knowledge, ranging from mathematics to jurisprudence to astronomy, Vitruvius proceeds to cover building-related subjects such as materials, decoration, water supply, machines (including military machines) and, in book 9, astronomy, including the construction of time-keeping artefacts such as a sun-dial. The sun-dial is basically an object, of various shapes – extant examples include spherical, hemispherical, cylindrical – on which lines have been inscribed

which, together with a pole or stick called gnomon which casts a shadow on those lines, marks the time using the movements of the sun.[2] The analemma is a particularly sophisticated example of this kind of lines: it is a geometrical diagram which can be inscribed on an object, in order to make a sun-dial.

Unlike some of the clay tablets and papyri in this volume, Vitruvius' *De architectura* has not come down to us in the way in which it was originally written. Moreover, it has come down to us in different versions contained in manuscripts produced in different contexts, often at different times. There are some fifty-five manuscripts, and they all originate from a parent or archetype, now lost. Some manuscripts are considered to be very close copies of the archetype: primarily a 9th-century manuscript now in London (*Harleianus* 2767), taken by some to be the only direct copy of the archetype, but also two manuscripts in a German library (*Gudianus* 69 and *Gudianus Epitomatus* 132), and possibly more manuscripts housed in the Vatican Library, the Escorial and Sélestat in Alsace.[3] The various manuscripts have tiny and occasionally not so tiny discrepancies, which are resolved by following the manuscripts supposed to be closer to the original, and/or by emending the text on the grounds of consistency or

[2] See e.g. Gibbs 1976, Kienast 2007, Hannah 2009.

[3] Granger 1931, xvi-xxviii, xxxii; Fensterbusch 1964, 11-3.

coherence. The amount of subjectivity that enters these decisions cannot be overestimated.

Before even starting to translate, then, there are some decisions to be taken. Normally, the reader of a translation is not directly exposed to the preliminary choices that the translator has had to make. Information about them is relegated to the apparatus or the footnotes. Nevertheless, in my view the fact that some choices have been made even prior to the choice of language, needs to be highlighted, not just as a question of honesty - we should not pretend there is *one* version of the text, but also as a question of intellectual significance. Ancient Latin texts, with the possible exception of epigraphical and papyrological material, are the result of their reception as well as of their inception - they are never 'the original'.

One is how my translation ought to relate to the other extant translations of the same text. The question of course is meaningful only because Vitruvius has been translated into other languages since the Renaissance. A list of translations published in 1984 includes twenty-five items in eight different European languages.[4] I think it is naive to pretend that one's translation is produced in a vacuum, rather than being an interpretation not only of the text, but also, in a sense, of the other translations that have been given of that same text.

[4] The list in Callebat *et alii* 1984, xi-xiii; more recently Gros, Corso, and Romano 1997, Rowland 1999, Schofield 2009.

The second decision is even more radical, and concerns the text itself - which edition should we use? There is plenty to choose from. Leaving aside earlier efforts, including Renaissance editions, there are three different editions of *De architectura* published in the Teubner series alone, between 1867 and 1912,[5] plus an English edition for the Loeb series, a French edition with different editors for different books for the Budé series, and another German edition, by Fensterbusch. Most editions privilege a handful of manuscripts over the rest, on the basis of their being closer to the now lost 'original', from which they were copied.[6] The Loeb editor, Frank Granger, relied primarily on the *Harleianus* 2767, with only few references to other manuscripts. In disagreement with the Teubner editor, Granger thought that not only had the *Harleianus* been produced in England (rather than Germany), but he also believed that the main German manuscript, *Gudianus* 69, was "merely a recension of" *Harleianus*, rather than representing an independent tradition, as Rose and Krohn had maintained.[7] One cannot help but wonder if there is more to the debate than mere philology. Indeed, after years of considering philology of this sort almost an exact science, historians of mathematics are now starting to enquire more critically into the choices that enter the production of a

[5] Valentin Rose & Hermann Müller-Strubing (eds.) *Vitruvii de architectura libri decem*, Leipzig: Teubner 1867, *non vidi*; Rose 1899 and Krohn 1912. Successive editions were motivated by the consideration of further manuscripts.

[6] See the genealogical tree in Rose 1899, ix.

[7] Granger 1931, xvi, xviii.

'scientific' edition of a 'scientific' text.[8] Perhaps ownership of the true text of Vitruvius would be a good case-study.

For the passage here, I opted in the main for the text used in Gros, Corso & Romano (1997), because it is the most recent one and the authors, all well-established Vitruvius experts before they produced the edition, would have been able to benefit from the latest scholarship. Their Latin text is one of the Teubner editions – the earliest by Rose and Müller-Strübing – with a significant number of modifications.[9] All the same, I have introduced some changes from the Budé edition indicated in **bold** and some changes from the Loeb edition indicated in underlined when the alternative seemed more plausible in terms of meaning. I have also tended to choose alternatives which involved the least modification to the manuscripts, especially when at least some of the manuscripts agree. The Budé edition designates a virtual *übe*rmanuscript representing the consensus of "all or most' of the manuscripts with the letter ω; the second Teubner edition is even more explicit in denoting the consensus of the four main manuscripts with the letter *x*, which there also denotes the now lost parent manuscript.[10] Nevertheless, *every* text of Vitruvius that has been published is the result of some intervention, because even ω or *x* do not always make sense. What 'making sense' means, is of course an immensely

[8] See the papers contained in Chemla 2012.

[9] Gros, Corso, and Romano 1997, 1437.

[10] Soubiran 1969, lxxiii: "consensus codicum omnium vel plerorumque"; Rose 1899, ix.

subjective question, bound to be answered differently by different people. The fact that we are dealing with a mathematical text helps to narrow down the notion of 'making sense' quite considerably, but does not determine it entirely, especially if we are open to a historiographical approach where mathematical notions, and especially the ways in which they are communicated and expressed, changes through time.

The Budé editor for book 9, Jean Soubiran, is particularly explicit in describing the state of the manuscripts, and particularly so for the passage regarding the construction of the analemma. He tells us that the letters for the geometrical construction are all jumbled up, there are words that seem to have been modified or scrambled, and the text occasionally has little dotted circles in the text, but it is not clear what they denote.[11] Also, the apparatus does not tell you much about diagrams, which is common practice on the part of philologists until very recently. The diagram of the analemma as we commonly have it is a modern reconstruction. Reviel Netz argued that most of the diagrams in Greek mathematical manuscripts possessed two characteristics: overspecification (which is not of interest for us here) and indifference to visual accuracy (which might have applied in the case of our diagram). "The indifference to visual accuracy implies that the diagram was not meant to be a visual depiction of the objects under

[11] Soubiran 1969, lx-lxi.

discussion but rather to use visual cues to communicate the important mathematical relationships."[12]

If Netz's claims hold about diagrams in texts like *De architectura*, and there is no reason why they should not, then it could even be that some of the peculiarities of the lettering as it appears in the manuscripts could be resolved by looking at the (no longer extant) diagram. Perhaps the original diagram itself did not conform to our idea of visually accurate diagram.

There is also the problem of natural language *versus* 'technical' language, i.e. language that is specific to the practitioners of a discipline, usually to denote objects or concepts that occur more often in the practice of that discipline than they do in 'nature', i.e. everyday parlance. In a modern language like English, some 'technical' subsets such as business English or English for engineers, have become well-defined to the point where they can be taught separately to students. It is not clear to what extent that was the case with Latin at Vitruvius' time: was there a specialized architects' jargon? If yes, did it coin new terms, or did it use everyday words to denote objects or notions or actions specific to architecture, in such a way that the 'technical' sense would have been given by the context? The question is further complicated by the fact that Vitruvius draws at least in part on Greek sources, some of them at least written sources, so some of

[12] Nezt 2012, 157.

Vitruvius' language itself is translated.[13] Moreover, the only clues that may help us to recognize a term as a 'technical' term are firstly, when Vitruvius defines them (e.g. axon or meridian), and secondly, and more weakly, when they are unusual outside of this type of textual context (e.g. *circinatio* or *planitia*). There are also some very general terms, such as *ratio*, which I have tended to translate consistently (i.e. always with the same term), even though they had such a range of meanings that it would be justified to translate them in more than one way.

In sum, as a choice, I have tried to retain the 'naturality' of the language wherever possible, because I am not convinced that technical languages had cristallyzed (yet) within a knowledge tradition, such as architecture, which even on the Greek side was largely still oral rather than written. In other words, retaining the naturality of the language is for me a way to signal my belief that Vitruvius' knowledge of architecture stems from personal knowledge and direct practice, not just from books.

The text - Vitruvius, *De architectura* book IX, chapter 7*

1. Nobis autem ab his separandae sunt rationes et explicandae menstruae dierum **brevitates[1]**	1. Now, we must differentiate the accounts from these and explain the monthly shortenings and

[13] See the introductions to Gros, Corso, and Romano 1997.

itemque depalationes[2]. Namque sol aequinoctiali tempore Ariete Libraque versando, quas e gnomone partes habet[3] novem, eas umbrae facit VIII in declinatione caeli quae est Romae. Itemque Athenis quam[4] magnae sunt gnomonis partes quattuor, umbrae sunt tres, ad VII Rhodo V[5], ad XI[6] Tarenti IX, ad quinque <Alexandriae> tres,[7] ceterisque omnibus locis aliae alio modo umbrae gnomonum aequinoctiales a natura rerum inveniuntur disparatae.	demarcations of the days. For the sun, turning around in Aries and Libra at the time of the equinox, those parts which from the gnomon it has nine of, those it makes 8 of shadow at the latitude of Rome. And likewise in Athens the parts of the gnomon are as many as four, [but] they are three of shadow; in Rhodes 5 to 7; in Tarentum 9 to 11; in <Alexandria> three to five, and in all the remaining places different equinoctial shadows of the gnomons are found to have been made dissimilar by nature in different ways.
2. Itaque in quibuscumque locis horologia erunt describenda, eo loco sumenda est aequinoctialis umbra, et si erunt quemadmodum Romae gnomonis partes novem, umbrae octonae, describatur linea[8]	2. Thus in any places where dials will have to be traced out, in that place the equinoctial shadow has to be taken, and if the nine parts of the gnomon will be as in Rome, an octet of shadow, let a line be traced

in planitia et e media *pros orthas*[9] erigatur ut sit ad normam quae dicitur gnomon, et a linea quae erit planitia in linea gnomonis circino novem spatia dimetiantur, et quo loco nonae partis signum fuerit centrum constituatur ubi erit littera A, et diducto circino ab eo centro ad lineam planitiae ubi erit littera B, circinatio circuli describatur, quae dicitur meridiana.	on a level surface and from its middle let [a line] be erected perpendicularly so that it is at a right angle, which is called gnomon, and from the line which will be flat on the line of the gnomon let nine spaces be divided with the compass, and in the place where is the mark of the ninth part let the centre be established where the letter A will be, and having opened the compass from that centre to the line of the flat surface where the letter B will be, let a circular line be drawn, which is called meridian.
3. Deinde ex novem partibus, quae sunt a planitia ad gnomonis centrum, VIII sumantur et signentur in linea quae est in planitia ubi erit littera C. Haec autem erit gnomonis aequinoctialis umbra. Et ab eo signo et littera C per centrum ubi est	3. Next, of the nine parts between the flat surface and the centre of the gnomon, let 8 be taken and be marked on the line which is on the flat surface, where the letter C will be. This then will be the equinoctial shadow of the gnomon. And from

littera A linea perducatur, ubi erit solis aequinoctialis radius. Tunc[10] a centro diducto circino ad lineam planitiae aequilatatio signetur ubi erit littera E sinisteriore parte et I dexteriore[11] in extremis lineae circinationis, et per centrum perducenda <linea>[12], ut aequa duo hemicyclia sint divisa. Haec autem linea a mathematicis dicitur horizon.	that mark and the letter C through the centre where is the letter A let a line be drawn, where the equinoctial ray of the sun will be. At the same time, having opened the compass from the centre to the line of the flat surface let an area of equidistant width be marked where the letter E will be on the left side and I on the right [side] at the endpoints of the circular line, and through the centre <a line> has to be drawn, so that two semircircles be divided equally. This line then is called by mathematicians the horizon.
4. Deinde circinationis totius sumenda pars est XV, et circini centrum conlocandum in linea circinationis quo loci secat eam lineam aequinoctialis radius ubi erit littera F,[13] et signandum dextra ac sinistra[14] ubi sunt litterae G H.	4. Next, the 15th part of the whole circular line has to be taken, and the centre of the compass has to be situated in the circular line in the place in which the equinoctial ray cuts that line, where the letter F will be, and on the left and the right it

Deinde ab his lineae usque ad lineam planitiae perducendae sunt, ubi erunt litterae T R. Ita erit solis radius unus hibernus alter aestivus. Contra autem E littera I erit[15] quo secat circinationem linea quae est traiecta per centrum ubi est littera A, et contra G et H litterae erunt L et K, et contra C et F et A erit littera N.[16]	has to be marked where the letters G [and] H are. Next, lines have to be drawn from these to the line of the flat surface, where the letter T [and] R will be. Thus the ray of the sun will be one for the winter and one for the summer. Moreover, opposite E will be the letter I at the point where the line which is extended through the centre where the letter A is, cuts the circular line, and opposite G and H will be L and K, and opposite C and F and A will be the letter N.
5. Tunc perducendae sunt diametroe ab G ad L et ab H ad K.[17] Quae erit superior, partis erit aestivae, inferior hibernae.[18] Eaeque diametroe[19] sunt aeque mediae dividendae ubi erunt litterae M et O, ibique centra signanda, et per ea signa et centrum A[20] linea ad extrema lineae	5. At the same time diameters have to be drawn from G to L and from H to K. The one above will belong to the summer part, the one below to the winter part. And those diameters have to be divided equally in the middle, where the letters M and O will be, and in the

circinationis est perducenda ubi erunt litterae P Q[21]. Haec erit linea *pros orthas*[22] radio aequinoctiali, vocabitur autem haec linea mathematicis rationibus axon. Et ab eisdem centris diducto circino ad extremas diametros describantur hemicyclia, quorum unum erit aestivum, alterum hibernum.	same place the centres have to be marked, and through those marks and the centre A a line has to be drawn to the endpoints of the circular line, where the letters P [and] Q will be. This will be the line perpendicular to the equinoctial ray; then this line will be called in mathematical accounts the axis. And from the same centres having opened the compass to the endpoints of the diameters, let semicircles be drawn, of which one will be for the summer and the other for the winter.
6. Deinde in quibus locis secant lineae paralleloe[23] lineam eam quae dicitur horizon, in dexteriore parte erit littera S,[24] in sinisteriore V,[25] et ab extremo hemicyclio ubi est littera G,[26] ducatur linea parallelos axoni ad sinistrum[27] hemicyclium ubi est	6. Next, in those places where the parallel lines cut the line which is called horizon, on the right side the letter S will be, on the left [the letter] V, and from the outermost semircircle where is the letter G, let a line be drawn parallel to the axis

littera H.[28] Haec autem parallelos linea vocitatur **loxotomus**.[29] Et tum circini centrum conlocandum est eo loci quo secat eam lineam aequinoctialis radius, ubi erit littera D, et diducendum ad eum locum quo secat circinationem aestivus radius ubi est littera H. E centro aequinoctiali intervallo aestivo circinatio circuli menstrui agatur, qui menaeus[30] dicitur. Ita habebitur analemmatos deformatio.	to the semircircle on the left where is the letter H. This parallel line then will be called a *loxotomus*. And at the same time the centre of the compass has to be situated in the place where the equinoctial ray cuts that line, where the letter D will be[32], and has to be opened until the place where the summer ray cuts the circular line, where is the letter H. From the equinoctial centre with a distance [equivalent to the] summer [ray], let the circular line of the monthly circle be drawn, which is called monthly line (*menaeus*).[33] Thus the design of an analemma will be obtained.
7. Cum hoc ita sit descriptum et explicatum, sive per hibernas lineas sive per aestivas sive per aequinoctiales aut etiam per menstruas in subiectionibus[31]	7. Having thus described and explained this, in what is placed below the accounts of the hours from the analemmas, whether through the winter lines, or the

rationes horarum erunt ex analemmatis describendae, subiciunturque in eo multae varietates et genera horologiorum et describuntur rationibus his artificiosis. Omnium autem figurarum descriptionumque earum effectus unus, uti dies aequinoctialis brumalisque itemque solstitialis in duodecim partes aequaliter sit divisus. Quas [ob] res non pigritia deterritus praetermisi sed ne multa scribendo offendam, a quibusque inventa sunt genera descriptionesque horologiorum exponam. Neque enim nunc nova genera invenire possum nec aliena pro meis praedicanda videntur. Itaque quae nobis tradita sunt et a quibus sint inventa dicam.	summer lines or the equinoctial lines, or also the monthly lines, will have to be described, and many types and kinds of dials are below this and they are described by means of these artful accounts. Now, the outcome of all their illustrations and descriptions will be one, that the equinoctial day and the day of the winter solstice, as well as the day of the summer solstice, be divided into twelve parts equally. I omitted these things not discouraged by laziness but in order not to cause offence by writing a lot, and I will relate by whom the types and descriptions of dials have been found. In fact, neither am I now able to find new types, nor does it seem that things made by others should be declared as mine. Thus I will talk about those that

	have been transmitted to us and by whom they have been found.

Commentary

* At I.3.1[14] Vitruvius says that an architecture treatise must include three parts: *aedificatio, gnomonice* and *machinatio*. At I.6.4 he talks about the Tower of the Winds and then (I.6.6-7) has a construction with gnomon and compasses of a rose of the winds, which is more explicit possibly than the construction of the analemma. Ptolemy's *Analemma* survives mostly in Latin (in the 13th-century translation of William of Moerbeke) and only partly in Greek, addressed to Syrus, very different from Vitruvius. It starts with definitions of all the celestial circles, including a lettered diagram which is not about proving anything but just showing all the circles that have just been defined. Ptolemy's text contains proofs, plus (if I understand this correctly) instructions to trace out the dial on a drum (*tympanon*). But as far as I could see even the diagrams look quite different from what we find (reconstructed) in Vitruvius.

1. The manuscripts consensus has *separandae sunt rationes* (some have *et*) *explicandae … brevitates ….* The Budé goes for *separandae sunt rationes et explicandae brevitates*.

[14] Henceforth references to *De architectura* are organized by book, chapter and section. Thus, I.3.1 means book 1, chapter 3, section 1.

2. If I read the apparatus in the Teubner correctly, at least some of the manuscripts have "brevitates idemque depalationes" or even *depalatationes*. Confirmed by Budé: the manuscripts' agreement is on *depalationes*. I have opted for the manuscripts' reading – *depalatio* is used in a land-surveying context (Campbell 240.10, part of a very short text) for 'demarcation' or 'delimitation', which is in a sense what the gnomon does with the length of the days. We lose the other half of the pair (shortening and lengthening), but not at the cost of introducing a completely new term. Actually, the Loeb has *depalationes*, translated as 'marking'. For connections between *gnomonike* and land-surveying see McEwen (2003) 232.

3. Manuscript agreement is on *habent* – Budé has *habemus* which is too creative.

4. Manuscript agreement is *quae*. Rowland translates "a gnomon of whatever size".

5. Manuscript agreement is *XV*.

6. *XI* has been added but is not in the manuscripts.

7. This part has been amended – some of the manuscripts have different numbers, and none of them has Alexandria, so either this is tacit knowledge on the part of Vitruvius' reader, or of the philologist who knows through other means that the location must be Alexandria.

8. *Linea* not in the manuscripts. Budé has "octo, linea describatur", although the manuscript consensus is *octogenae*.

9. Several of the manuscripts had *prosorthas* or even *porthas* but in any case transliterated into Latin. This is confirmed by Budé. The other editions tend to 'return' the words to the Greek letters.

10. *Tunc* could indicate contemporaneity in the future, but also consecutivity.

11. "Et I dexteriore" is an emendation; the manuscripts have *in dexteriore* or mostly *inde alteriore*.

12. *Linea* not in manuscripts.

13. The consensus of the manuscripts is letter C.

14. The consensus of the manuscripts is "dextra sinistra".

15. The consensus of the manuscripts is not to have *E* after "contra autem".

16. This whole passage here is much more confused in the manuscripts in terms of what letters there are. The manuscript consensus basically is not this text – this has been amended, and is in fact different in the Budé, which has "Contra autem E littera I erit, quo secat circinationem linea quae est traiecta per centrum, ubi <est littera A. Item contra G> erunt litterae A et M, et contra H litterae erunt A et L, et contra C et F et A erit littera N." The Loeb retains the very strange passage "quae est traiecta per centrum, ubi erunt litterae Y K L G, et contra K litterae erunt K H X L", where it looks at the beginning as if the centre has more than one letter, which is why

most editors amend it. The Loeb then translates: "which cuts the circumference and passes through the centre. In this quarter are the points Y K L G. Over against K will be the points K H X L." The diagram in the Loeb does not have all the letters in the text, so it is difficult to see what this would correspond to.

17. Again letters messed up: the manuscripts' consensus has "ab C ad I" and nobody has what comes after "ab H" – Budé restores "ad M".

18. Budé calls this passage *locus desperatus* and has the zones switched around.

19. This and the one before in the manuscripts appear to have been simply *diametro*.

20. Again for the manuscripts this is centre C.

21. Some of the manuscripts have different or more letters.

22. Same as before: it seems that it is some editors' decision to transliterate into Greek.

23. This was *parallelon* in the manuscripts.

24. The manuscript consensus is letter E.

25. Letter not in the manuscripts: Budé has Y.

26. This sentence in the Budé is: "et ab littera S ducatur" etc. and I can't find anything in the apparatus to decide one way or the other.

27. *Dextrum* in the Budé.

28. This again is pretty much the editor's reconstruction. Budé has letter V plus a parallel construction on the left-hand side, with lines leading to letter X.

29. In the manuscripts this appears to be *locothomus* or *loco thomus*. Budé has *loxotomus*, which should mean 'that cuts the elliptical'. Gros, Corso, Romano (1997) have *logotomus*. The Loeb has *laeotomus*=cut to the left.

30. *Manaeus* or *maneus* in the manuscripts.

31. I have taken *subiecio* here to refer to the parts of the book, rather than parts of the dial. The Loeb seems to take the first *in subiectionibus* as a diagram ("in accordance with the annexed figure") and the second *subicianturque* as a different meaning ("there may be deduced"). Rowland goes with "the system of the hours should be inscribed along the form of the *analemma*. To these can be added". The Penguin goes straight out with a reference to projecting on a horizontal plane.

32. The future implies that the letter has been 'baptized' now, but it is not in sequence.

33. For the translation of this last paragraph I have looked at Gros/Corso/Romano.

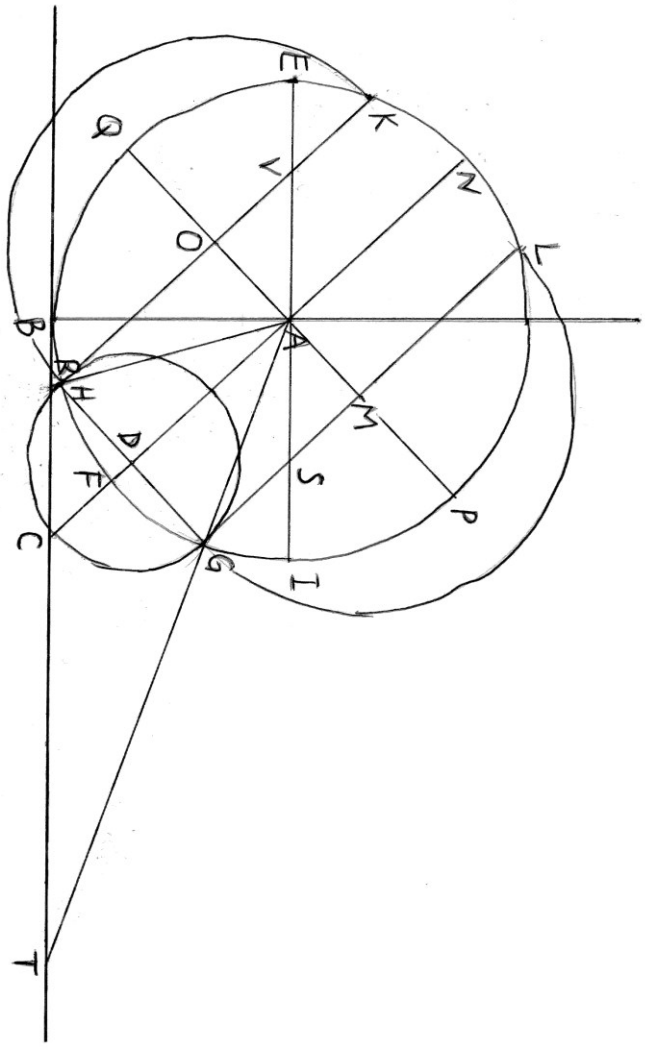
The diagram

The diagram you find below is my modern reconstruction, with compasses, a pencil, a ruler and a square. There are passages in *De architectura* where explicit mention of a diagram is made, generally to say that it will be found at the end of the book,[15] but we find no such mention here. Indeed, there has been some discussion of whether and why the text should have had more diagrams than it appears to have had. That is, if we limit the number of diagrams to the times where Vitruvius explicitly says there was a diagram in the text, we do not have many diagrams for a treatise about architecture. Pierre Gros has argued that the scarcity of diagrams is in fact part of Vitruvius' plan to move architecture from a praxis to a liberal art.[16] I am not too sure that was the case, and definitely here.

Vitruvius does not refer directly to there being a diagram in the case of the analemma, yet it seems obvious that there was one, if only one produced by the reader as they follow Vitruvius' instructions. The way in which the instructions are formulated, even if gaps have to be filled as we shall see below, implies an on-going construction – the diagram is, after all, the analemma itself.

[15] *De architectura* III.3.13; III.4.5; III.5.8; V.4.1, V.5.6; VIII.5.3; IX.preface.4-5; X.6.4.

[16] Gros 1996, 26.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Remarks about the grammar and style

The first thing to notice is that the geometrical construction is mostly in the future tense, which does not always come out in translation because you cannot use the future tense in a sentence like that in English. The future tense in constructions and descriptions of devices and objects is common throughout the book; that is how Vitruvius moves the account forward. A good parallel is the compass-aided construction of a wind rose, to be set at the centre of a town.[17] It also conveys a sense of constructing something in front of one's eyes. For letters in the diagram which are just being introduced Vitruvius uses the future tense; if the letter has already been introduced then he uses other tenses. The use of the future tense is common in ancient mathematical texts such as Euclid's *Elements*, but also, more to the point, in a couple of passages in Hyginus' *Constitutio* which describe constructions with the gnomon and with a *ferramentum*.[18] There is also a frequent use of the imperative, which again is common in Greek mathematical texts. The present imperative and the future indicative are combined so that one is commanded to construct a line, say, and then from that there will be consequences expressed in the future tense. Finally,

[17] *De architectura* I.6.6-8.

[18] Hyginus *Constitutio* (ed. Campbell) 150.3-21; 152.6-14.

there are frequent passive constructions, especially in a Latin form called the gerundive, which is basically a future passive participle with the idea of something that must be done. Again, the passive does not translate very well into English.

Overall, the construction comes across as rather impersonal - obviously, the reader has a role because of the imperatives, which imply addressing someone, but that is counterbalanced by the passives. There is no direct appeal to the reader in this passage.

There is some hybridity of language, between Latin words and Greek words which have been Latinized or at least transliterated. There is also at least one word which is a complete *hapax* (*loxotomus*). Most editions have re-transliterated the Greek words back into Greek characters, but retaining the reading of the manuscripts, and assuming of course that it reflects Vitruvius' way of writing, I think that one should retain a 'Latinized' Greek word. That says something significant about the extent to which Roman geometry was entirely comfortable with its Greek heritage, especially in fields like astronomy. In fields like land-surveying, we find an interesting mix of Greek terms for things like geometric shapes, and Latin terms for operations carried out in the process of surveying. Does the language mean that Vitruvius relied on a Greek textual source? I am not sure - you can learn the terminology and it can become everyday (albeit 'technical'),

so that the direct link to the written source need no longer be there - the connection to the source gets diluted through use.

To get back to the issue of 'natural' *v* 'technical' language, throughout *De architectura*, Vitruvius alludes to knowledge communities by means of his language. I would not call it 'technical' language however, because that label is too limiting. Much attention has been directed lately, for instance, to the literariness of Vitruvius' language. It has now been fully recognized that there are echoes of, and allusions to, Cicero and Varro in *De architectura*; in fact, the treatise itself may be using as one of its templates Cicero's *De oratore*.[19]

But we ought not to underestimate that Vitruvius' other, and arguably principal, knowledge community is other builders and more generally other practitioners whose knowledge falls under the vast umbrella of architectural knowledge. He references them by means of language in various ways: through nomenclature ('this thing is called that by the mathematicians'); through the occasional use of specialized language, as indicated above; yet another way is bringing up the issue of invention and tradition, establishing genealogies and chains of transmission where specialized knowledge plays a key role. At the same time, here as in other places,[20] Vitruvius is keen to construct an ethics for the discipline, for

[19] See e.g. Romano 1987, Novara 2005, Nichols 2009, Courrént 2011.

[20] *De architectura* VII.preface tells a story of plagiarism exposed in the context of the library of Alexandria.

instance by condemning plagiarism and praising respect for the achievements of other practitioners past and present.

Tacit knowledge - things that are *not* in the text

The main problem with this passage is that you cannot really build a dial on the basis of it. There are too many gaps. Things that have been said about the passage and about book IX in general include: "An exceedingly short treatment of gnomonics [...] the instructions as to how to draw the analemma are incomplete; Vitruvius glosses over how one should transfer the diagram onto a material object".[21]

And this from Soubiran, who is overall none too impressed by Vitruvius' abilities: "Cependant, à supposer même que le texte ne présentât aucune difficulté de lecture, nous ferions encore des réserves sur l'exposé de Vitruve, et le principal reproche que nous formulerions porterait sur son excessive brièveté. [...] On fera également à Vitruve le reproche de n'avoir pas toujours su distinguer, dans les pages spécialement consacrées à la gnomonique, le nécessaire du superflu. [...] Tout cela témoigne, chez Vitruve, de l'émerveillement un peu puéril d'un homme qui voit fonctionner sous ses yeux des mécanismes complexes, et qui s'attarde à en contempler l'extérieur, sans distinguer précisément les principes

[21] Gros, Corso, and Romano 1997, 1194: "[U]na trattazione sulla gnomonica eccessivamente breve [...]. [...] le indicazioni su come tracciare l'analemma sono incomplete e sulla maniera di riportare il grafico su un supporto materiale Vitruvio sorvola [...]."

fondamentaux et les simples détails de montage. En contrepartie [...] on constate des lacunes de divers ordres. [...] si l'on peut toujours pardonner à un exposé d'être incomplet dans le détail, il est beaucoup plus difficile d'admettre des omissions qui compromettent l'intelligence de l'ensemble; et sur ce point Vitruve n'est pas à l'abri de tout reproche. [...] il ne donne à son lecteur que des éléments tout à fait insuffisants pour la construction d'un cadran, l'obligeant à consulter des traités de gnomonique plus complets ou un spécialiste de cette science. Dès lors, il était inutile qu'il se donnât même la peine de construire si laborieusement l'épure de l'analemme."[22]

We could list the various types of things that Vitruvius takes for granted. According to Soubiran, Vitruvius doesn't explain that the ratio between length of the gnomon and equinoctial shadow has to be taken at midday.[23] Also, in order to do the thing with the equinoctial shadow, you need to have built a meridian line already. Plus, the analemma construction does not tell you how to project it on a three-dimensional surface; it only provides, in modern terms, the elevation. Soubiran notices further lacunae in Vitruvius' description of the construction of water clocks.

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[22] Soubiran 1969, lxi-lxv, 240. Cf. lxxi: "On eût aimé un génie scientifique, un nouvel Archimède, on ne trouve qu'un artisan. Mais il ne faut pas trop en vouloir à Vitruve de cette insuffisance: les Romains n'ont jamais eu 'la tête scientifique', et leur plus grand nom dans ce domaine, Pline l'Ancien, avec son goût des *mirabilia*, ses confusions et ses bévues, n'est pas tellement supérieur, pour la qualité intellectuelle, à notre modeste architecte...".

[23] Here Soubiran 1969, lxiv has a footnote 1 to explain that Pliny the Elder talking about the same subject does specify that it must be midday.

There are indeed 'missing' terms or concepts: in paragraph 1 he mentions the gnomon, the parts of the gnomon, the equinoctial shadow and the equinox without having previously defined them. Even the axis is first mentioned at 9.1.2 and then defined later.

There are steps in the construction which are not necessarily self-evident unless you *already* know what the diagram may look like. For instance, the fact that the first circle being drawn is in fact on a plane perpendicular to the flat plane is only clear if one already knows what an analemma is supposed to look like. Another example is where a certain geometrical object is referred to but not specified by means of the letters on the lettered diagram - the reader is supposed to understand which line (for instance) Vitruvius is referring to. Editors fill this gap sometimes by adding the letters, thus making the unspecified (and left tacit) mathematical object, specified. An example is at the end of 9.7.5.

There are procedures which are taken for granted: Vitruvius tells the reader to divide lines into nine equal parts or fifteen equal parts with the compasses, but does not explain how that is to be done. The compass is often used, or its use referred to, in the treatise as a whole, but at the same time it is taken for granted as, indeed, one of the things that the architect should know.[24]

[24] *De architectura* I.1.4.

The data for the length of the equinoctial shadow in different localities must have also come from common knowledge, because Vitruvius does not explain where those data come from. Most scholars think it must have been a written source, but again, we cannot be sure. Candidates include Eratosthenes and Hipparchus; Pliny the Elder must have used a different source because some of his data are different.[25] That would also assume that, unless Eratosthenes and Hipparchus were translated (not that there would have been a lot of translating to do, they are just lists of numbers), Vitruvius accessed his source in Greek.

The main gap, however, is how to go from this description to projecting the lines on an actual three-dimensional dial. This gap again has led to editorial decisions, on the part of those who have definitely seen *subiecio* in section 7 as a reference to the projection. Assuming tacit knowledge fills in the gaps in the text or the description, as in when Vitruvius has been criticized for omitting things, or for providing descriptions that do not work. Also, assuming tacit knowledge may help explain why seemingly unimportant or superficial details are included and apparently crucial information is not included - the crucial information would have been tacitly known. So the notion of 'tacit knowledge' may be useful in reading an ancient mathematical text (applied mathematical), because it prevents us from thinking that the author was somewhat incompetent. The gaps are

[25] See commentary in Gros, Corso, and Romano 1997, 1278-9.

not necessarily gaps in his knowledge or in his capacity to explain, but in-built in the way itself human beings communicate knowledge.

Different scholars have worked on tacit knowledge - among the first to articulate and discuss the concept in relation to science was Michael Polanyi. Basically, tacit knowledge includes the things that we know, and in particular we know how to do, but that at the same time are very difficult to communicate in words. The typical example is riding a bike, or indeed most craft activities like knitting or carving stone. Also, tacit knowledge can be tacit because it is assumed by everybody, it constitutes background noise rather than the explicit object of enquiry or discussion. Different scholars have different ideas as to whether tacit knowledge should, or indeed could, be fully articulated into words. Polanyi was convinced that some tacit knowledge cannot ever become 'spoken' knowledge, that it is essentially ineffable, and that it is fine that way.

More recently, Harry Collins has distinguished different kinds of tacit knowledge, some of which can be articulated but are only articulated when, usually in a situation of conflict, or dispute, or when there is a problem, the realization comes about that tacit knowledge is involved. Even then, Collins argues, based on his observations of how scientists operate, that the solution is often not in 'expliciting' the tacit knowledge, but in extending the circle of tacit knowledge through direct, personal contact between scientists, who can then observe how the other group do things. The idea

of 'being present' is indeed sometimes articulated in ancient texts - e.g. Apollodorus Mechanicus.[26]

If then decoding tacit knowledge helps to chacterize a community by building up a profile of what that community may have been expected to know, I think tacit knowledge could produce some interesting results in the case of Vitruvius. We could thus have a better idea of who Vitruvius' audience were. There is also the question of Vitruvius' sources. A lot of the scholarship (including Gros, Corso and Romano in their commentary) tends to attribute almost every piece of knowledge found in *De architectura* to a previous literary source. That may well be the case in passages that contain lots of detailed information (names of inventors with different types of devices, for instance), but there is no absolute need for that to be the case every time. The 'reservoir' of knowledge that Vitruvius is drawing from, need not be texts, and it need not be his own experience and knowledge - he could be tapping into his work community's tacit knowledge. Vitruvius was an architect/engineer before he wrote the treatise, and most of the things he describes in the treatise existed before the treatise, so it is a case of drawing on knowledge that is there, but is unrecognized (in Collins's sense of the term), and to turn it into recognized knowledge.[27] This leaves

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[26] Apollodorus, *Siege-matters* 137-138.

[27] Collins 2001, 73: "*Unrecognized Knowledge*: A performs aspects of an experiment in a certain way without realizing their importance; B will pick up the same habit during a visit while neither party realizes that anything important has been passed on. Much

open the case of explicit innovations, which are more difficult to describe because they require a combination of novel knowledge and background/tacit knowledge, but it also puts in focus the question of what particular unrecognized knowledge is identified by Vitruvius as a target for communication, and thus transformation into recognized knowledge.

For a start, we learn that knowledge of how to use the compass was taken for granted - it was unrecognized tacit knowledge and it remains so. This matches the passage on the wind rose in book I, and indeed cashes out what Vitruvius himself says about the knowledge of the architect again in book I. As in the case of the land-surveyor, mathematical knowledge seems to be deeply associated with the use of instruments.

In conclusion, this passage is clearly not teaching you to build a dial unless you already know how to build one. If you own a ready-made dial, it may teach you what's behind the dial in terms of geometrical construction. It also teaches you what's behind the dial in terms of astronomical knowledge and historical knowledge. In other words, it is at least partly an introduction by the expert to the non-expert, into the world of dial-making knowledge - introduction in the sense of unpacking some, but not all, of the unrecognized tacit knowledge contained in the object.[28] The bits that

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Unrecognized Knowledge becomes recognized and explained as a field of science becomes better understood, but this is not necessary."

[28] Cf. Soubiran 1969, xv-xvi: "Mais l'astronomie, objet des chap. I-VI, était-elle bien nécessaire à l'intelligence des développements relatifs à la gnomonique? Non, à

remain tacit (use of the compass, a basic idea of the diagram, how to do the projection, the fact that it must be midday) may have been a harder core of expertise than the rest. This distinction may help explain a couple of aspects of book 9 that otherwise remain puzzling.

It has often been observed that book 9 has more about the astronomical knowledge than about the actual construction of the dial, even though it is ostensibly about *gnomonike*. This could be because astronomical knowledge is not ineffable, but to an extent building a dial cannot be entirely described in words. So astronomical knowledge such as the one described here can be communicated to the non-expert, while the construction of the analemma, while clarified to some extent, remains the province of the expert. This is part of a more complicated game Vitruvius is playing in *De architectura*, about defining not just what architectural expertise is, but also what exactly an expert does or knows and where the boundaries are with other people - leaders, ordinary citizens, other people who get recognition for other reasons.

In this sense, the content of the chapter matches the preface about athletes and architects, which has also puzzled interpreters. The work that architects do is more valuable than what athletes do, but there is a parallel in that in both cases the public are to an extent spectators rather than

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l'exception de principes fondamentaux qui auraient pu être énoncés en quelques lignes. Vitruve a cédé, ici encore, à un desir d'étaler ses connaissances qui lui a fait rapidement perdre de vue son sujet."

participants, they are not entirely adopted into the group of the 'experts': the athlete does what he does, and the architect does what he does, in a way that does not necessarily invite complete participation.[29] Tacit knowledge is also a means of making sure that the expert will always be indispensable.

Conclusion

The aim of this exercise has been not so much providing a translation of Vitruvius' description of the *analemma* in book 9 of *De architectura*, but rather shining a light on what a translation rests on that is often left unsaid: the fact that even the source text is a composite, the editorial choices that enter any version of the text, the decisions to be taken at many points in the movement between Latin and English, and, finally, the fact that in a text such as this, describing the mathematical skeleton of an artefact to be built in three dimensions and out of real-life materials, there is the possibility that not all the knowledge about that artefact can be expressed in any language.

The exercise may thus have made things more difficult, rather than make them look easier, but that is not a bad thing. Translating a text from the original also means claiming, to some extent, ownership of that text, and

[29] Cf. Soubiran 1969, xv: "Passons rapidement sur le proemium: il est de toute évidence complètement hors du sujet."

that can only be accomplished if all the layers behind the text, which are often not made explicit in the name of simplicity, are not revealed and brought to bear over our interpretation and rendering of the ancient words, diagrams and thought processes.

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