Academic Science and Warfare in the Classical World

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No proposition Euclid wrote,
no formulae the text-books know,
will turn the bullet from your coat...
(Rudyard Kipling, 'Arithmetic on the frontier')

To a soldier in the front line, geometry or mathematics may not seem particularly useful in the face of his immediate problems. Nonetheless, the systematic application of science for military purposes is one of the key factors in the development of European warfare over the last three centuries—as K.G.H. Hillingsø points out in his contribution to this volume, pp. 167-68. While basic education prepared boys to be good soldiers when they were called up, theoretical science was applied to the study of ballistics, to engineering and to the development of new weapons.

What was the relationship between academic science and warfare in the ancient world? The fact that the ancient academies and the ancient educational curriculum were dominated by the arts and humanities, leaving little place for the 'hard sciences', does not mean that their lessons were *a priori* irrelevant to practical warfare. For instance, rhetoric, which formed an important part of the education of an upper-class Greek or Roman, was a prerequisite for success not only in the courtroom or in politics, but also as a military leader, since the commander was expected to give a speech to rouse the soldiers to battle.[1] Philosophy likewise played an important role in the formation of the educated Greek or Roman. The leisured and peaceful existence of the philosopher was seen as the antithesis of the soldier's life—witness, to take just one instance, the famous anecdote of Diogenes and Alexander. But if we read the *Stratagems* of Frontinus, a sort of empirical digest of the science of warfare down to the first century AD, we find that philosophical qualities are among the virtues of a commander. Indeed, the chapter headings of the fourth book of *Stratagems* could have been taken from a work of philosophy: *de continentia; de iustitia; de constantia; de affectu et moderatione.*[2]

The object of this paper is to examine another part of the academic curriculum, and one which underwent a dramatic development during the period under consideration, the last four centuries before our era: geometry.

Tradition has it that above the entrance to Plato's Academy were carved the words 'no one who is not versed in the science of geometry may enter here'. In ancient Greece, being geometrically literate was a prerequisite for the study of a wide range of subjects. Of course you had to know some geometry to study physics, or astronomy; or to practice cartography or city-planning; but geometry was an important part of music and philosophy as well. At a later date, Quintilian went so far as to say that without geometry, one could not learn rhetoric properly: '*nullo modo sine geometria esse possit orator*'. It also formed a basis for the study of mechanics, but this subject was not part of the academic curriculum; on the contrary, Plato is said to have rejected mechanics as a corruption of the purity of geometry, and furthermore involving *banausourgía*, manual work of a character entirely unsuited for the true scholar.[3]

We have a drama-documentary account of life in the philosophical school of Socrates preserved in Aristophanes' comedy *The Clouds*. In the first act, Strepsiades enters the Thinkery, the philosophical academy, and is shown around by a student who explains the various activities which are being pursued there. They concern, in the order in which they are mentioned in the play:

— measurement
— music
— astronomy
— geometry
— geology
— religion
— astronomy
— geometry
— cartography

Now the modern man in the street would probably consider most of these academic disciplines to be practical and possibly useful, but to the Athenian man in the street—a category which includes not only Strepsiades himself, but the audience for which the comedy was written—they are examples of pure and speculative, in other words largely useless, science. Not entirely useless, though: in one passage, the student explains that geometry can be used for surveying. 'Aha', the disingenuous Strepsiades replies, 'for confiscations'. Wrong again—for surveying the whole world, the student explains.[4]

In the following, I hope to trace the use of geometry and its related subjects in a military context from the classical Greek period to the early Roman Empire, and the extent of its application to reconnaissance and map-making, tactics, and castrametation. Artillery and poliorketics have been omitted, as they fall within the area of mechanics, and thus outside the scope of this paper. Hopefully, this brief survey can shed some light on the larger question of the relationship between pure science, warfare, and society in the ancient world. Along the way, some cases which have been cited as instances of an early use of geometry in a military context will be critically examined.

Tactics

As the first of these cases, let us take the battle of Leuctra near Thebes in 371 BC, where an expeditionary force of Spartans was defeated by the Boiotians and their commander killed. Instead of the traditional battle formation, where the hoplites would form two rectangles facing each other, the Theban force at Leuctra was drawn up as a wedge or triangle, producing a phalanx which was fifty deep at its widest point on the left. By concentrating their forces at one point, the Thebans were able to break the Spartan line and carry the day. Given the prestige of the Spartan hoplites and the dubious military reputation of the Boiotians, the outcome of the battle attracted considerable attention at the time, and even more in the centuries which followed. A tradition evolved, centred on the person of the Theban commander Epaminondas, who was credited with inventing the wedge-shaped phalanx and thus revolutionising Greek land warfare. In the biography of Epaminondas by Cornelius Nepos, we are told a good deal about his intellectual background, and how his studies included music and Pythagorean philosophy: he was, we are told, a pupil of the philosopher Lysis of Tarentum, who, when the Pythagoreans were expelled from Croton, sought refuge in Thebes (Nepos, 15.2). The combination of musical studies and Pythagorean philosophy, both of which involved geometry, with the tactical revolution brought about by the triangular phalanx is certainly suggestive; even more so when we are told that Philip, later king of Macedon and father of Alexander the Great, was also said to have been a student of Lysis. Did the two great tactical innovators, Philip and Epaminondas, go to school together? It sounds too good to be true; and so it is. Though Philip *did* spend three years in Thebes as a hostage, this was from 368 to 365, too late to have studied under Lysis. As for Epaminondas and his tactical revolution, this merits closer examination.

Around the middle of the fourth century, some twenty years after the event, the historian Ephorus wrote an account of the battle of Leuctra. The original is lost, but its character can be deduced from passages in Diodorus and Pausanias, both of whom seem to have found Ephorus a useful source.[5] Polybius, on the other hand, describes Ephorus' account of Leuctra as confused and incompetent (12.25f3-4).

In his account Diodorus, presumably basing himself on Ephorus, glorifies Epaminondas as a charismatic leader, a skilled rhetorician and gifted tactician, who achieves victory 'with a few soldiers against the Lacedaemonians and all their allies'[6] thanks to his tactical brilliance. Pausanias, writing two centuries later, and presumably likewise drawing on Ephorus, acknowledges the tactical brilliance of Epaminondas but soberly concedes that the armies were more or less evenly matched,[7] and that Sparta's allies contributed very little to the fighting, leaving the Spartans to fend for themselves.

An alternative to the Ephorus tradition is offered by Xenophon in the *Hellenika*.[8] At the time of Leuctra, he was between fifty and sixty years old and living in the western Peloponnese. After Leuctra, Xenophon moved to Corinth, not far from Thebes and the site of the famous battle. As a veteran soldier and contemporary of the events which he describes, his story deserves to be taken seriously—but the biographers of Epaminondas have not always done so. They have good reason to ignore Xenophon, since he does not mention Epaminondas at all! This omission, however, is no reason why we should not look closer at Xenophon's account of the battle itself. Describing the order of battle, he first mentions the cavalry, which was drawn up in front of the infantry. The Theban cavalry, we are told, was battle-hardened from recent conflicts; in any case, the Boiotians were known throughout Greece for the quality of their horses and horsemanship. The Spartan cavalry was 'in a sorry state' (6.4.10-11) due to lack of practice and the poor quality of the troopers. Only then does Xenophon go on to describe the infantry: drawn up twelve deep on the Spartan side, while the Theban formation was more compact (*elatton*) and up to fifty deep (6.4.12).

According to Xenophon, the cavalry made the first attack, and the superior Theban forces drove the Spartan cavalry back towards its own infantry. At this point the massed Theban infantry moved in, and the Spartan line broke (6.4.13-15).

As we can see, the accounts agree that the Thebans strengthened their left wing to make it fifty deep, but this tactic had been employed as early as 403 BC[9]—it was not as innovative as the biographers of Epaminondas claim. It was an application of the well-known military principle *frappez peu, mais fort*: concentrate forces at a few important points instead of dissipating them over a long front. Leuctra, in short, is not a convincing example of the application of abstract science to the realities of the battlefield.[10]

Geometry can, however, be used for other practical purposes: in reconnaissance, for taking bearings and estimating distances; and in cartography, for making sketch maps of the terrain.

Reconnaissance

Returning to Xenophon, we find among his works a short treatise *On the cavalry officer*. The text is preserved in its entirety, and in it there is no mention whatever of special qualifications or training for reconnaissance work—surprisingly to us, for in later times, reconnaissance becomes one of the key functions of cavalry.[11] One would think that being able to orient yourself by day and by the stars at night; to memorize the features of a landscape and describe them to others later on; or to draw a freehand map would be useful qualities for a cavalryman; but Xenophon does not mention any of these. Apparently, in the context of central Greece, first-hand familiarity with the terrain was a prerequisite for success, making drawn maps superfluous.

Indeed, reconnaissance does not seem to play any significant rôle in Greek warfare at this time. In the case of

Leuctra, a modern reader is struck by the fact that the battle-formation of the Thebans took the Spartans by surprise. Had they known where the Thebans intended to concentrate their attack, they could have redeployed their own forces accordingly—and removed the commander and his staff from the brunt of the enemy forces. In the event, it was the death of king Cleombrotus which sealed the fate of the Spartans.

Demetrius Poliorcetes imitated the oblique phalanx of Epaminondas at the battle of Gaza in 312 BC and placed most of his elephants, as well as his best cavalry, on his left wing. Ptolemy and Seleucus had already formed their line with a strong left wing and a weak right wing opposing Demetrius' forces, when spies, *kataskopoi*, reported how Demetrius had deployed his troops. They found time, however, to redeploy their army with a stronger right wing. Demetrius was less well informed and if he used scouts or spies at all, they failed to notice the soldiers of Ptolemy and Seleucus burying strange objects in the sand. When the order was given to advance, Demetrius' forces made good headway until his elephants were stopped by long rows of submerged spikes. 'Die Aufklärung hatte offenbar versagt', as Hermann Bengtson sarcastically remarks in his book on *Herrschergestalten des Hellenismus*.[12]

When he wrote his collection of *Stratagems* in the first century AD, Frontinus devoted a short chapter to reconnaissance and intelligence. The methods suggested for gathering information include kidnapping an enemy soldier and torturing him, but there are also examples of reconnaissance in a more familiar sense, one in the army of Aemilius Paulus in 282 BC, another under Scipio Africanus in 203 BC. A third example involves Quintus Fabius Maximus—not the Cunctator, but his great-grandfather of the same name, who served as commander against the Samnites in 322 BC and against the Etruscans in 310-308 BC.

Against the Samnites, Fabius was apparently victorious, since a triumph is recorded in his name; but his work was undone the following year, when his successors imprudently led a Roman army into an ambush laid by the Samnites at the Caudine Forks. According to Livy,[13] writing three centuries later, a Roman army on its way from Capua to assist Lucera (which was said to be under siege by the Samnites) attempted to march through two mountain passes, one after the other, only to find the Eastern exit blocked by the Samnites; turning back, they now found the Western end blocked as well. The consuls chose surrender as the only option available and were forced, along with their army, to march 'under the yoke' as a sign of their submission. While casualties were light, the damage to Roman prestige and self-esteem was enormous. Though it is easy enough to be wise two thousand years after the event, reconnaissance might have prevented this disastrous miscalculation; and the lesson will not have been lost on Fabius, who would be familiar with the country as well as with the enemy, and no doubt followed the events closely.

During his later command against the Etruscans, we are told, Fabius used his brother to scout ahead into the Etruscan forests, where no Roman had set his foot before. Frontinus comments that this took place *cum adhoc incognitae forent ... sagaciores explorandi viae*, 'at a time when more advanced methods of reconnaissance were as yet unknown' (Frontinus, *Stratagemata*, 1.2.2). So according to Frontinus—who, after all, had read more sources on ancient military history than any of us can ever hope to do, since most of them are now lost—reconnaissance in the modern sense of the word was not introduced until the early third century BC;[14] and possibly as a response to the Roman disaster at the Caudine Forks.[15]

In modern times, maps have been indispensable for land warfare and army staffs have gone to great expense and effort to map their national territory as well as the territory of other nations where they might have to wage a land war. The erstwhile Austro-Hungarian Empire produced topographic maps not only of their own territories, but stretching all the way from the Baltic coast and down into Central Greece. Ernst Kornemann, and some later scholars, believed that the Roman Army, too, had its 'map department' producing and storing maps. There is no evidence whatever to support this claim; neither in the literary sources,[16] in the form of preserved maps, or among the finds of Roman military equipment, where maps, map-cases and instruments used for orientation or map-reading are conspicuously absent. Where the Roman army *did* use survey instruments on a large scale was for castrametation, a point to which we shall return shortly.

The nearest parallel to the military cartographers of more recent times are the *bematistai*, who accompanied Alexander's army on its march eastward. The precise functions of the *bematistai* are not clearly defined in our sources; they seem to have been at one and the same time land surveyors, geographers, and ethnographers. The purpose of their work is not entirely clear either: was it to produce a catalogue of Alexander's conquests, or simply to ensure that the army could find its way back to Greece? The scanty fragments attributed to the *bematistai* by Jacoby are not sufficient to give a definite answer to this question. Since the presence or absence of *bematistai* is not recorded as having any impact on the military success of Alexander's army, we can hardly speak of a military application of cartography. We also note that later armies moving into unfamiliar territory—Caesar's army into Gaul, for instance, or Trajan's into Dacia—do not seem to have been accompanied by latter-day *bematistai*.

Though cartography may not have made any great contribution to the military campaigns of the fourth to first century, these campaigns made great contributions to the development of cartography. The conquests of Alexander and Caesar's expeditions to Germany and Britain increased the extent of the known world and acted as a stimulus to cartography, at the same time as contacts with the east brought new ideas to the science of astronomy. During the last three centuries before the beginning of our era, the science of cartography made greater advances than over the thousand years that followed.

These results were applied to practical map-making, as evidenced not only by the work of Eratosthenes, Marinus, or Ptolemy, but by the famous map which Agrippa had made and set up in the Porticus Vipsania in Rome. This map served a clearly political purpose, to illustrate and justify the achievements of Augustus, rather like the *Res Gestae*; and like the Res Gestae, it had counterparts elsewhere; we know that there was one in Autun (*Augustodunum*, in Central Gaul) and there may have been others.

Archimedes and the Siege of Syracuse

No account of geometry and warfare in the ancient world would be complete without a mention of the rôle of Archimedes during the Roman siege of Syracuse in 214-212 BC. The story is told by Polybius and in Plutarch's *Life* of Marcellus, the commander of the Roman force;[17] and by various later writers.

Archimedes, so the story goes, was living the peaceful life of a philosopher in the city of Syracuse when the king asked him to make some machines which could be used for practical purposes. According to Plutarch, Archimedes had accepted this task mainly as a chance to demonstrate geometry to the general public; and his first contrivance illustrated his famous proposition that if one would give him a place to stand, he could move the earth: using a system of compound pulleys, he demonstrated how one man could drag a large ship over land. Impressed by this, so Plutarch tells us (*Marcellus*, 14.8), the king asked Archimedes to produce some machines for the defence of the city, which he did; and by a happy coincidence, these were still at hand when, at a later date, the Romans attacked the city. It is more likely, and in accordance with the narrative of Polybius (8.3.5), that these machines were produced in response to the imminent threat of a Roman attack.

Plutarch's account has a certain 'Star Wars' quality; he delights in describing the high-tech contraptions used by both sides in the conflict. Marcellus, for instance, had a gigantic catapult mounted on eight Roman galleys lashed together (14.3).[18] One cannot help wondering if the ropes joining the galleys would hold up once the engine commenced firing, and how the machine was moved into the required firing position, as most of the oars would presumably be inoperable. Polybius does not mention this weapon, but he does speak of quinqueremes lashed together in pairs and carrying *sambucae*, an advanced form of scaling-ladder (8.4.2-3); in a later tradition this may have been elaborated into the large floating gun-platform of Plutarch.

In their description of the defensive machinery constructed by Archimedes, Plutarch is likewise more dramatic than Polybius; both tell us how cranes mounted on the battlements were used to overturn assault boats approaching the foot of the walls, but Plutarch goes further and graphically describes how the cranes could lift entire ships out of the water and whirl them around in the air, an obvious exaggeration.[19] We find a number of such tall stories about technical marvels in Roman literature; the tallest of them all in the *Natural History* of Pliny the Elder, who tells of an amphitheatre which could be turned on a pivot to form two theatres![20]

Both Plutarch and Polybius explain how, at the suggestion of Archimedes, the Syracusans had made slits in the walls for archers and light artillery.[21] This was not particularly innovative, but along with everything else, the stream of missiles raining down upon the attackers from the walls persuaded the Roman soldiers that 'Archimedes' was everywhere, aiming his diabolical machines at them. The Roman commander, Marcellus, ironically described his adversary as a 'geometrical Briareus' (Plutarch, *Marcellus*, 17.1); a reference to the son of Cronus and Gaia, who had fifty heads and a hundred hands.

Reading Plutarch's narrative, we should remember that he was writing at a time when the Greek city-states of Sicily were long gone, and there was no harm in glorifying the military prowess of this former enemy; at the same time, he was writing a biography of a Roman commander and would, naturally enough, wish to make him appear great by virtue of the opponents which he eventually overcame. For this was the sad and anticlimactic end of the siege of Syracuse: on a night during the festival of Artemis, when most of the defenders were drunk or asleep, the Romans set ladders against the city wall and climbed over. During the subsequent sack of the city, Archimedes was killed.

Looking back over the account of the siege of Syracuse, the only major innovation seems to be the crane arms mounted on the walls to pick up men and ships—and even these combined principles which had previously been used in the Roman *sambuca* and in the *corvus*, the boarding-bridge which the Roman navy used to such effect during the First Punic War. Cranes of a sort were already well known for other purposes, such as building. The innovation was primarily a matter of scale: Archimedes took the crane beyond the dimensions previously attempted, proving his famous assertion that with sufficient leverage, a small force can lift a large weight.

Castrametation

Let us turn now to an area where the practical application of geometry is self-evident: castrametation. Laying out a camp in a systematic manner has obvious practical advantages, not least if the troops may have to turn out in the dark. The standard, or perhaps we should say ideal, Roman camp is described in detail by Polybius; and we can identify its real-life counterparts in the field from Syria to Scotland, laid out with meticulous accuracy. In Gaul, Britain, and Germany, the characteristic forum-basilica complex of many civilian cities is thought to have been inspired by the *praetorium* of the army camp; and it is often assumed, following Oswald Dilke's magisterial study of *The Roman Land Surveyors* (1971), that civilian surveyors were veterans who had received their training in the army. At least in the Western provinces, town-planning and centuriation would seem to be an example of the civilian sector reaping the benefit of a military application of theoretical science.

On closer examination, the picture is more complicated, especially as regards chronology. The earliest securely dated Roman camps showing the characteristic, rectangular ground-plan are found in Northern Spain, and dated to the middle of the second century BC. The Roman standard camp is described in detail by Polybius, writing about the same time; but neither the archaeological evidence nor that of Polybius indicates that the technique of castrametation was new, only that it was already in use by this date. Frontinus writes that 'in days of old, the Romans and other peoples were accustomed to build their camp every which way, resembling a Punic village, since in antiquity only cities had walls' (4.1.14). He goes on to say that 'Pyrrhus, the king of Epirus was the first to keep the whole army behind one fortification'. In the first sentence, the word *murus*, wall, is used; in the second, *vallum* which can mean a wall, an earthwork or a palisade. At the Battle of Benevento in 275 BC, according to Frontinus, the Romans captured Pyrrhus' camp, studied its features and so, little by little, began to use the present method of camp layout: *paulatim ad metationem, quae nunc effecta est, pervenerunt.*[22]

There is a variant of this story in Plutarch's life of Pyrrhus. Before his first battle on Italian soil, at Heraclea in 280 BC, Pyrrhus looks down at Roman soldiers building a camp. The story is one of several in Plutarch which emphasize Pyrrhus' respect for his Roman adversaries. But if the Romans used systematic camp-building at their first encounter with Pyrrhus, as Plutarch claims, they obviously cannot have learned it from the same Pyrrhus five years later, as Frontinus claims. We should not ignore the possibility that the anecdote has been modified in transmission: in its original version Pyrrhus was impressed by some aspect or other of Roman camp-building—speed or discipline, perhaps—but at a later date this was reinterpreted to mean that the foreign invader was impressed by what was, by the time of writing, the distinguishing mark of a Roman legion: its regular camp layout.

Whatever our interpretation, we cannot rule out, even though archaeological evidence is lacking, that systematic castrametation was known to the Hellenistic world as early as the fourth century BC. This, however, would still be several centuries later than the first evidence for systematic, geometric town-planning in a civilian context. There are orthogonal town plans in Greek colonies of the seventh century BC; and in the fifth century, two hundred years before the arrival of Pyrrhus in Italy, Hippodamus from Miletus is credited with having perfected the geometric town-plan. The first Roman colonies on a regular plan—e.g., Ostia—also predate the arrival of Pyrrhus in Italy.

In the *Politics*, Aristotle gives an amusing character sketch of Hippodamus, emphasizing his vanity and excess of clothing, his long hair and his passion for philosophy. The Hippodamus depicted here is a very unmilitary type,[23] and if Greeks of the fourth century could attribute the geometric town-plan to him, this clearly indicates that they made no mental connection between geometric town layouts and military precision—that, to them, orthogonal town-planning was of a civilian and not a military origin.

But what of the surveyors themselves? Here, we need to distinguish between decision-makers, the land commissioners, who would be of equestrian or senatorial status, and the operatives who carried out the actual work in the field. Dilke suggests that in earlier times the land commissioners played a larger and more active role, but as time went by, a greater part of the work and the responsibility devolved to the operatives. As far as the decision-makers go, the land commissioners responsible for the numerous colonies of the second and first century AD, these seem to have had no technical background except the general education which the Romans considered equally suitable for the lawyer, the general, the admiral and the politician. As land commissioners, they were the arbiters of important cases, concerning property which would be passed on for generations. They must have had some idea of geometry in order to check the work of their subordinates, but Roman surveying, though precise, was not very advanced, and they could always obtain specialist advice when needed.

Turning to the operatives, the field surveyors, it has been asserted that at least in the Roman West, they typically received their initial training in the army. The epigraphic evidence does not support this claim. Among the 14 inscriptions cited by Dilke, 11 concern freedmen and one a slave; under normal circumstances, none of these could have served in the army.[24] Within the army itself, there is no evidence that surveyors (*mensores*) enjoyed a particularly exalted status; in the few inscriptions referring to them, and in Domaszewski's *Rangordnung*, they appear alongside bugle-players and the caretaker of the regimental exercise hall.[25] Cicero is generally taken to be a reliable source for the views and prejudices of the Romans on questions of social status, and in the ninth Philippic, he derides Saxa, a member of the opponents' party, as *castrorum antea metator, nunc, ut sperat, urbis*: 'earlier he was a surveyor of camps and now he hopes to be a surveyor of the city,' i.e., Rome.[26] One notes the implication that just because you are qualified to set out a military camp, this does not qualify you to measure a civilian settlement. The identification of Saxa as a former military surveyor comes immediately after the information that he is a barbarian *ex ultima Celtiberia*, and along with the epithet *honester condemnatus, turpiter res-*

titutus it is used by Cicero to characterize Saxa as a thoroughly bad character.

If geometric castrametation had been directly inspired by academic geometry, then we would expect it to date at least as far back as civilian town-planning on the orthogonal model; and if castrametation had been the inspiration for civilian planning, we would expect it to enjoy a status on the same or a higher level. But this is not what we find in our evidence—in fact, quite the contrary. The earlier date of civilian surveying, and the low status of army surveyors, are far more consistent with the hypothesis that castrametation was derived from civilian town-planning, not from a direct application of academic geometry in the military field.

Conclusion

As we have seen in this survey of the available evidence, the pure science of geometry, even its applied forms such as cartography, had a very limited impact on the planning, implementation or outcome of military operations during the last four centuries before our era. The most widespread application of geometrical method, castrametation, does not seem to have been derived directly from academic geometry, but via the applied science of city planning. This is all the more surprising as these four centuries were an age when the 'pure' sciences of geometry, astronomy and cartography were developing at a rapid pace.

Although contrafactual approaches tend to raise more questions than they answer, one cannot help asking oneself why the ancients made so little use of academic geometry in warfare. We will not venture into the debate on technological stagnation in antiquity, where the possible causes of technological stagnation are as hotly disputed as the question whether there was any stagnation at all. One notes, however, that the abundance of cheap slave manpower has often been invoked to explain the apparent lack of interest in labour-saving devices. While this may or may not be true for civilian society, it obviously will not account for the situation in the armies, where there were no slaves in active service, except in emergencies.

Two other explanations come to mind. One is that the pronounced social stratification of the army worked against the application of academic science. The men with a long liberal education were primarily found in the higher commands, which were filled not by promotion from the ranks, but by political selection and as part of a civilian career. In the Greek city-states as well as the Roman republic, the supreme commanders came and went; there were few career commanders and no officers' academies as we find them in later Germany and France. The rank and file, that is to say those who served as the repositories of the collective military experience, did not have a liberal academic education.[27]

Against this hypothesis, one can point to some instances of career commanders: Xenophon, for instance, or the great Hellenistic warlords such as Demetrius Poliorcetes, Pyrrhus or Mithridates. They had a higher education and few higher ambitions apart from warfare, yet they did not, as far as we know, apply one in pursuit of the other.

The other explanation which comes to mind is based on the contrast between the largely military development of the mechanical sciences and the non-military development of the pure sciences. Could it be a question of resources? Today, any new discovery in the exact sciences requires large resources to develop—and so science looks to the military, which at least until recently had large resources at its disposal, and could allow itself the luxury of long-term planning. Modern applied science, on the other hand, can be underwritten by civilian industry, as it will bring revenue within the short to medium term.

In antiquity, the situation was the inverse. Mechanics could be applied for civilian purposes, as we see in the water supply of Pergamon, the flour-mill of Barbegal, or the mines of Spain and Britain, to mention only a few instances. But given the structure of ancient society, capital and resources to finance such large-scale projects would be available at unpredictable intervals, insufficient to keep a civilian mechanical sector alive and inquisitive.

Warfare, on the other hand, was a recurrent activity involving the construction of large machines such as catapults, water-wheels, ships or siege-towers; and so the military sphere was where the mechanical sciences developed.[28] The pure sciences, which were less dependent on outside resources, could afford to remain apart and aloof from the world of warfare.

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Notes

1 Whether this always took place, and whether the commanders' speeches were nearly as good as the edited versions which have come down to us in the historical accounts, is another question altogether, which I shall not attempt to answer.

2 Some scholars are of the opinion that the fourth book is not an original part of the *Stratagems* but a later addition by another author. This does not, however, affect the general argument here.

3 Plutarch, *Marcellus*, 14.6.

4 Much of the first act of the comedy turns upon the contraposition of lofty and abstract concepts with concrete examples of a very earthy kind; with poor Strepsiades betwixt and between, never getting it quite right.

5 Pausanias, *Description of Greece, Boiotia,* 13.8-10; Diodorus, 15.39.2.

6 *oligois politikois stratiôtais pros pasas tas tôn lakedaimoniôn kai tôn symmakhôn dynameis*, Diodorus 15.39.2

7 *ex isou kathistê*, Pausanias, *Boeotia* 13.9

8 Xenophon, *Hellenika* 6.4.8-15.

9 At Munichia, in 403 BC, Kritias is said to have deployed his forces fifty deep.

10 For a detailed discussion, with references to older literature, see Hanson 1988.

11 In the *Cyropaedia*, on the other hand, Xenophon tells us how Cyrus uses scouts to spy ahead of the advancing forces and find out how the enemy formations have been drawn up, e.g., at the battle of Thymbrara (*Cyr.* 6.2.4-11).

12 Bengtson 1975, 46

13 Livy, *Ab urbe condita,* 9.1-6.

14 Of the nine examples cited in the chapter, five have Romans as protagonists; three have Carthaginians; one has a Greek, but he is a mythical character—Teisamenos, the son of Orestes. And while the other eight examples show the value of reconnaissance and intelligence, in the Greek example the reports of the scouts turn out to be valueless.

15 This did not prevent later disasters of a similar sort: e.g., the humiliating defeat of Lucius Cassius Longinus at the hands of the Tigurini in 107 BC, where the Roman survivors were likewise forced to march 'under the yoke' (cf. Caesar, *Bellum Gallicum*, 1.7.4); or Varus' defeat in the *Saltus Teutoburgensis*, where a vast Roman army was ambushed under circumstances reminiscent of the Caudine forks—except that in the case of Varus, the Roman soldiers did not get off with being humiliated, but were massacred by the enemy. Caesar made systematic use of reconnaissance units, both in his Gallic campaign and during the civil war (see Goldsworthy, 1996, 125-28 for details).

16 Sherk 1974, 559, quotes indirect literary evidence for two military maps, one of the Caucasus, the other of Ethiopia, i.e. outside the limits of the *Imperium Romanum* proper. If they existed, these maps will have been produced in the course of geographical exploration, not of ordinary military operations.

17 Polybius, *History*, 8.4ff.; Plutarch, *Marcellus*, 14-17.

18 On a smaller scale, Demetrius Poliorcetes had used catapults on ships during the siege of Salamis (307 BC) and Rhodes (305-304 BC). Marsden 1969, 169-73 offers a survey of the surviving evidence for ancient naval artillery and hypothesizes that 'the employment of artillery may have been one of the factors which led commanders to concentrate on boarding tactics and to build larger ships that could carry more catapults' and thus have been a contributory factor in the naval arms race of the third century BC.

19 Plutarch, *Marcellus,* 15.3; for a discussion, see Landels 1978, 96-98.

20 Pliny, *Natural History*, 26.116-21. The edifice in question was supposedly erected in the 50's BC by one Gaius Curio.

21 Polybius, *History,* 8.5.6; Plutarch, *Marcellus,* 15.5.

22 Frontinus, *Stratagemata,* 4.1.14. The account seems straightforward, yet the word *paulatim* is odd in this context. If the Romans found a fully developed, and superior, layout in Pyrrhos' camp, why would they not copy it immediately instead of *paulatim*, 'little by little'?

23 Aristotle, *Politics*, 2.8.1.

24 Similarly, among *c.* 100 *curatores viarum,* mostly of the Imperial period, studied by Ertman (1976), only two had previously held army commissions as *prafecti fabrum*.

25 The epigraphic evidence for the precise status of *mensores* within the army is sparse. An italian epitaph, CIL VI, 3606, commemorates a *L. Iulius Priscus miles leg(ionis) I Adiut(rix) mensor agrari(us).* From Lambaesis in North Africa, we have several inscriptions mentioning *mensores*, and in one (CIL VIII, 2564; AD 218) a legionary *mensor* is listed as a *duplicarius*, i.e. a soldier on double pay, alongside several *tesserarii*, the *custos armorum* and the *librarius*, implying that these functions were equivalent in rank. According to Watson (1969, 79) the rank of *tesserarius* roughly equals that of a sergeant in a modern army.

26 Cicero, *Phil.* 14.4.10. The *metator* was responsible for the general layout of the camp, which was then subdivided by *mensores*, one to each cohort (Bohec 1990, 52-53); a *mensor* was presumably inferior in rank to a *metator.*

27 A liberal education was expensive. In late fifth-century Athens, professors complained that the price had been forced down to a thousand drachmas—equivalent to the total earnings of a worker over a period of about four years.

28 Metrology was not very advanced at this time, and it was difficult to measure small units of force or mass with any sort of precision. Small-scale laboratory models as used in modern times were of very limited use for research purposes: on the contrary, the larger the machine, the more precise the empirical observations which could be drawn from its operation. For example, Philo of Byzantium, a pupil of Ctesibius, based much of his work on the study of military catapults.