CHAPTER 1

ANCIENT WRITTEN SOURCES FOR ENGINEERING AND TECHNOLOGY

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THERE are four types of written evidence for engineering and technology in Greek and Roman antiquity: texts dealing solely or mainly with technical knowledge and/or written by people who identify themselves as technical practitioners; nontechnical texts, that is, any other text that provides us with information about technical knowledge and its practitioners but whose main aim is not the communication of technical knowledge and whose author's primary identification is not as technical practitioner; inscriptions recording technical activities or providing information about the lives of technical practitioners; and papyri with the same content. There are several published collections of translations of ancient sources relevant to engineering and technology. The only relatively comprehensive survey is Humphrey et al. (1998), but some more specialized sourcebooks are available: Cohen and Drabkin (1948), J. B. Campbell (1994), Sage (1996), Irby-Massie and Keyser (2002). The index of 138 ancient authors and inscriptional sources quoted in Humphrey et al. (1998: 601–12) is striking evidence for the pervasive presence of technological information in Greek and Latin literature. Only about eight Greek and ten Latin authors, however, wrote works that survive (at least in part) and can be considered handbooks of a particular technology or group of technologies: Aeneas Tacticus (military), the anonymous author of *De rebus bellicis* (military) and *Periplus Maris Erythraei* (navigation), Apicius (food preparation), Biton (siege engines), Cato (agriculture), Columella (agriculture), Dioscorides (pharmacology), Frontinus (water supply), Hero (mechanics, hydraulics, surveying, siege engines), Hesiod (agriculture), Hyginus (military), Palladius (agriculture, veterinary medicine), Philo of Byzantium (mechanics, hydraulics, siege engines), Varro (agriculture), Vegetius (military), Vitruvius (architecture, machinery), and Xenophon (horsemanship, hunting, agriculture). Many fragments or short works on surveying have been collected in the *Corpus Agrimensorum* (Thulin 1913; B. Campbell 2000). The following authors wrote works that contain significant information relevant to technology but are not themselves handbooks of technology: Archimedes (mathematics and geometry), Aristotle (various sciences), Galen (medicine), Oribasius (medicine), Pappus (mathematics), Pliny the Elder (human civilization and the natural world), Ptolemy (geography), Strabo (geography), and Theophrastus (natural materials). Numerous short works and fragments of works concerning geography and navigation have survived, collected in Müller (1855–1861).

These varied textual sources present different problems for the historian. Technical and nontechnical texts have survived in the form of manuscripts, and have thus been subject to repeated selection and copying, which has often affected not only the form in which they survive, but also their content. The first phenomenon has led to the formation of technical *corpora*, “bodies” or collections of works that deal with related topics but are not necessarily related in their composition. For instance, the *Corpus Hippocraticum* consists of treatises that early on were grouped under the name of Hippocrates, but were in fact produced by different authors, writing between the fifth and second centuries B.C., and not only with very diverse views, but also perhaps different professional identities. While some Hippocratic texts were manifestly produced in a context of medical practice, some could equally well be classified as philosophy or rhetoric—above all, *On Ancient Medicine* and *On Techne* (Lloyd 1987; Schiefsky 2005). Another example is the *Corpus Agrimensorum Romanorum*, comprising a wealth of material on land-surveying, dating from possibly the first century B.C. to at least the fourth century A.D. (B. Campbell 2000; M. J. T. Lewis 2001). Finally, manuscripts concerning subjects of little interest to the literate elite could be left uncopied, and thus ultimately lost. It is no accident that most of the surviving handbooks concern agriculture and military technology.

In the second kind of transformation frequently undergone by manuscripts, the contents of a technical work can be changed in ways that range from scribal errors (especially in copying numbers) to the modification of diagrams or the addition of explanations, corollaries, or lemmas that eventually become incorporated into the main text. These issues are particularly acute in the transmission of mathematical manuscripts (Fowler 1999).

Both technical and nontechnical texts tend to offer a perspective on technical knowledge that, unsurprisingly, depends on the agenda and circumstances of individual writers. In the case of nontechnical authors, the historian ought to ask how well informed they were about the technology they present, and what attitude they had toward technology in general. In the case of technical authors, again the historian ought to wonder for whom the text was written—whether it was meant to be read by colleagues, pupils, or patrons—and what function it was meant to have: manual of instruction, celebration of the subject, or codification of knowledge that up to that point had been transmitted orally.

Inscriptions and papyri avoid some of the pitfalls of manuscript transmission, in that they come to us more or less directly from the past. We must not forget, however, that inscriptions were public documents designed to be displayed, so they again offer a particular, somewhat biased perspective. Papyri, on the other hand, coming as they do in their great majority from Egypt, do not necessarily allow generalization to other parts of the Mediterranean world.

With these words of caution in mind, in what follows I aim to give readers an idea of the range of extant ancient textual sources for engineering and technology. At the same time, I will try to sketch a broad outline of how the production of texts dealing specifically with technical matters changed in the course of antiquity (see Meißner 1999). In order to combine the two aims, I will proceed chronologically, focusing on two or three examples from each period, chosen to represent both different types of textual evidence and the technological practice of the period in question.

Classical Athens

Our earliest surviving technical texts from Greek and Roman antiquity date to the fifth century B.C., and form part of the *Corpus Hippocraticum* (Nutton 2004: 60–61). We know that treatises on rhetoric, as well as on architecture, sculpture, and possibly many other forms of technical knowledge, were also written at this time, but none have survived (Lanza 1979). The emergence of a written tradition for forms of knowledge that had thus far existed only in an oral context can be linked to various phenomena that characterized the cultural and social life of Athens in the fifth and fourth centuries B.C. The increased importance of literacy is one, along with the connected significance of putting information into a form that was perceived as more stable and longer lasting than simple oral transmission (Thomas 1992). The presence of the sophists, and their claim to be able to teach pretty much anyone pretty much anything for a fee, can also be linked to the production of texts for instruction, particularly manuals of rhetoric. The existence of a widespread agonistic ideal, by which bearers of knowledge were prepared and expected to defend their ideas in public against opponents, may also have contributed to the articulation of some forms of knowledge into a written format, where arguments could be developed in a more systematic and comprehensive fashion. Several of the works in the *Corpus Hippocraticum*, for instance, have a marked polemical tone, and discussions about the status and nature of technical knowledge abound in the works of philosophers like Plato and Aristotle (Cambiano 1991).

A very different kind of text, although one equally meant for public fruition, deserves our attention, however: a marble stele inscribed on four sides with the accounts for the construction of one of the most iconic buildings of classical Athens, the Parthenon, completed around 432 B.C. after many years of work (*IG* I^3 436–51). There are comparable accounts for the Erechtheum (*IG* I^3 474–49; Randall 1953), also on the Acropolis, and for the temple of Asclepius at Epidaurus (*IG* IV.1^2 102; Burford 1969). We know from later sources (Plutarch, *Per.* 13.9, 31.2) that financing such a massive and luxurious enterprise was fairly controversial, and that Pericles, effectively the political leader at the time, was accused, if not of embezzling funds, at least of promoting his own interests and glory, and of favoring his own friends (the sculptor Phidias, for instance) in allocating the work.

A written document such as the accounts of the Parthenon provides us with useful information about the individuals involved with the building site. For instance, we know that the works were supervised, in terms of administration, by a board of five trustworthy citizens, called *epistatai*, appointed by the assembly. The workforce consisted of people with various levels of expertise, from the architects responsible for the design (apart from Phidias, later tradition has transmitted the names of Callicrates and Ictinus) and general technical supervision, to the headmen of various teams, to the workers who specialized in tasks such as fluting the columns or quarrying the marble, to nonspecialized laborers in charge of transporting or clearing materials. The workforce was diverse also in its geographical origin: even a large city like Athens would not have been able to provide enough specialized technicians for the jobs required, and when workers are named, as in the accounts of the Erechtheum, we find several metics (resident foreigners) among them (Randall 1953; Burford 1963; Korres 1995).

Although the inscriptions do not provide us with details about how the Parthenon was built, we can reconstruct the various phases of construction by following what is recorded each year (cf. Burford 1963: 29–32). First the foundations of the temple were laid, and payments were made not only to quarrymen and builders, but also to people who carted the marble from the Mount Pentelicon to Athens, and specifically to the highest point in the city, the Acropolis. From then on, we find that for several years wood was among the materials being bought, for use in scaffolding and roof beams. One year's account specifies that work was being conducted on the columns, and later precious materials (ivory, silver, and gold) are mentioned, for decoration—including perhaps the massive cult statue of the goddess Athena. As time passed, surplus material and even equipment were sold off, perhaps to working teams producing monuments at other sites. The inscription also provided information about the costs, but great chunks of the text where the figures would have been are missing.

The stele was found in the Athenian marketplace, the agora, and was evidently meant to provide public information about exactly how the money had been spent; this tells us that the production of monuments at the time was viewed as a matter of collective concern, and that the community was expected to be directly or indirectly involved in it.

would have been familiar with, exposed to when not directly practicing it, and ready to reflect on from a historical and moral point of view.

Hellenistic Kingdoms

The main factor that differentiates technical texts produced in the fifth and fourth centuries B.C. in classical Athens from those written from around the third century B.C. onward, and around the Hellenistic metropoleis—Alexandria, Pergamon, Rhodes—is above all the presence of patrons. The agonistic context of some of the medical treatises in the *Corpus Hippocraticum*, where the author could address a general public, real or ideal, as if he were giving a speech against an opponent, does not disappear, but it somehow loses prominence in favor of a more or less direct relationship between the technician and a powerful addressee, often a political leader. Hellenistic kings were prepared to invest heavily in culture by founding libraries, financing institutions such as the Alexandrian Museum, and supporting individual poets, philosophers, and various other "intellectuals" who often lived in relatively close contact with them at what have been called Hellenistic courts. At the same time, the practical necessities of ruling states that were much larger than the classical Greek polis called for experts in land-surveying, water-supply, architecture (including fortifications), navigation, and military engine-building.

Sometimes a strong administrative structure preexisted the formation of the Hellenistic kingdoms, and traditions, including technical traditions, merged. A good example of the intermingling of tasks, knowledge, and people in Ptolemaic Egypt is provided by a group of papyri about the *architekton* Cleon, who lived in Crocodilopolis/Arsinoe in the Fayum in the third century B.C. (*P. Petrie* II.4.1–13; N. Lewis 1986: chap. 2). As is the case for a surprising number of papyri, a good deal of Cleon's correspondence consists of complaints. For instance, a group of documents dating from 255 to 253 B.C. informed him of the problems some Egyptian men, working in a quarry, were having with one of the supervisors, Apollonius. The men, who were free and presumably on a corvée, complained through their headmen that they had not been properly and sufficiently equipped with iron tools, including wedges, and that they lacked wheat for sustenance and slaves to do some of the clearing work (*P. Petrie* II.4.1–5, 13.1; *P. Petrie* II.4.6–9 may relate to the same quarrymen). Throughout the documents, Cleon is presented as responsible for procuring materials and specialized personnel for works relating to water supply. One letter mentions a canal or conduit that was dug the year before but had now silted up; another discusses sluice-gates, bridges, and even prison walls (*P. Petrie* II.4.10–11, 13.2–5, 13.8–16, 13.18a–b; on water supply works see also *P. Lille* 1 (259–58 B.C.), with a diagram). Kleon acted through a number of delegates, at various levels of authority and presumably of expertise: we come across Greek names such as Diotimus and Clearchus, but also Egyptian ones such as Petesnites and Armas (*P. Petrie* II.11.1–2; no date is given). We also hear about Cleon's two sons, Polycrates and Philonides (Philonides at *P. Petrie* II.13.19, II.42.c, III.42.H.7; perhaps both brothers at II.16; Cleon's wife Metrodora at III.42.H.8). Polycrates wrote to him in what the papyri editor calls "a beautifully clear and correct hand," asking to be introduced to the king with a view to employment, and telling him that he was going to train as *geometres* (here probably land-surveyor). We thus learn that Cleon knew the king personally, and that technical knowledge may have run in families, although father and son were not necessarily in a master-and-apprentice relationship.

It is interesting that Cleon's main duties as they appear from these papyri seem to be administration and supervision, rather than design or even personal care of the works. Indeed, his successor, Theodorus, is called "architect" and *oikonomos* (steward/manager), and his tasks appear to have been very much the same (*P. Petrie* II.9.1–5, 15.1–3 [341–39 B.C.]; also II.42.a, III.43.2–3). No specific reference is made to Cleon's or Theodorus' specialized knowledge, but that does not mean that it did not play a crucial role in forging their identity, or that it was not determinant in procuring them jobs. Rather, we need to adjust our view of what ancient engineers were expected to do, and include administrative and management capacities alongside technical skills.

Another technician at the service of the state common in the Hellenistic period is the military expert. Kings and urban communities of the period invested heavily in city walls, weapons, ships, and the hiring of professional mercenaries, and it is not surprising that the majority of technical treatises extant from this period are war-related. We have texts dealing with what to do in the case of a siege (e.g., Aeneas Tacticus), texts teaching how to be a good general (e.g., Asclepiodotus, *Tactica*), and texts explaining how to build fortifications or machines suitable for offense and defense. A good example of the latter is the *Construction of Catapults* (*Belopoeica*) by Philo of Byzantium (ca. 240 B.C.; Marsden 1971; Garlan 1974).

Philo was a practicing technician and addressed both the *Belopoeica* and another text on fortifications to an otherwise unknown Ariston, who appears to be, rather than a fellow technician or a total layman, a member of the educated elite, whose interest in military-related technology could at the time almost be taken as a given. Biton (perhaps 241–197 B.C.) addressed his treatise on siege engines to one of the kings of Pergamon (Marsden 1971: 6, 78 n. 1; M. J. T. Lewis 1999).

Philo's treatise on catapults was part of a larger *Mechanice syntaxis* (*Synthesis of Mechanics*), and it combines engineering and geometry with epistemology and history of science. Philo begins by explaining how confusion still reigns among technicians, who often produce very different results even starting from the same principles and using the same materials. His aim is to provide a reliable method for building different kinds of catapults, and for modifying the dimension of a catapult according to the size of the projectile. This latter procedure was based on the facts that all the components of a catapult were in proportion to each other, that one of these pieces (specifically, the cylinder holding the torsion spring) was taken as a module or standard, and finally that a simple numerical relation could be established between projectile and module. In other words, in order to modify the dimension of a catapult an ancient engineer had to know how to modify the dimension of the cylinder holding the torsion spring, and he then had to increase or decrease all the other pieces accordingly. Philo and, later, Vitruvius refer to complete tables of specifications for catapults of various sizes. Philo also provides suggestions on the materials to use, and hints at the existence of accompanying diagrams.

He is quite explicit on the criteria a good catapult should satisfy: it should shoot far and be powerful, but also present an awesome appearance to the enemy, and be not too costly. Philo prizes novelty of design, and he presents himself as having improved on some of his predecessors, including Ctesibius. On the value of discovery, he says (*Belopoeica* 58.26–59.1; trans. adapted from Marsden 1971: 121):

> One must praise those who at the beginning discovered the construction of these instruments, for they were the originators of the thing and of its shape; they discovered something superior to all other artillery, I mean like the bow, javelin, and sling, in length of the shot and weight of the projectiles. To devise something at the beginning and to realize the device is of a superior nature; to bring to correction or adaptation something that exists seems rather easy. But, although very many years have passed since the putting-together [of the machine] happened to be discovered and there have been, as usual, both many machine- and artillery-makers, no one has dared to depart from the established method. We were the first to do so.

Most importantly for the historian, Philo also provides precious information on the past and the present of his discipline: he reports how former technicians experimented with their machines and through trial and error came to the realization that one piece of the catapult could be used as a module, so that all the other components could be expressed in proportion to it. Moreover, the modification of the cylinder holding the torsion spring could be carried out according to mathematical principles, because it basically amounted to a geometrical problem known as duplication of the cube. In the *Belopoeica*, Philo provides a solution to this problem, complete with proof, thus giving the stamp of ultimate mathematical stability to a result that had been arrived at empirically.

The image of technology that emerges from Philo's treatise is that of a discipline in expansion: growing through time from trial and error to a kind of mathematical certainty, accumulating knowledge, again through time, while learning from previous mistakes, and spreading geographically over the Mediterranean. Philo informs us about the existence of what we can call a network of catapult builders across Hellenistic kingdoms and cities, and he comments on the largess and *philotechnia* (love of technical knowledge) of the Ptolemaic kings, thanks to whom particular progress had been made by the engineers in Alexandria.

On the whole, Philo may be considered representative of the Hellenistic breed of technicians: emboldened by their newly found importance in military operations, they address a public beyond their immediate circle of peers or fellow citizens. Their audience can be said to include figures of political relevance, as well as colleagues or apprentices; their perspective has widened in space (together with their travels) and in time. Philo is able to look back in order to trace the journey his form of knowledge from a past of uncertainty to a present of mathematical reliability, and to point to a future of further innovation. He comes across as aware of the importance of what he does, and aware that he is part of a group. His work has to be understood against this background: Philo's *Belopoeica* does not simply provide information on how to build catapults. Indeed, the treatise implies much tacit knowledge, so that its actual usefulness as a manual of instruction, especially to a complete beginner, is doubtful. Rather, in an environment where, with the rise of Hellenistic scholarship and the foundation of big libraries, written sources were being collected and canonized, the text provides respectability, both for the discipline of mechanics in general and catapult-building in particular, to which it gives a history and epistemological and mathematical ratification, and also for its author, to whom it offers a platform for his claims and his designs.

It is then all the more intriguing that most of the evidence for the technological feats of possibly the most famous Hellenistic engineer of all, Archimedes of Syracuse, should be provided by nontechnical sources. Famously, and despite the survival of many of his other works, no treatise by Archimedes is extant about catapults, burning-mirrors, giant ships, or astronomical globes, all of which he is reported to have built. Plutarch later (notoriously) explained that Archimedes' all-consuming passion was mathematics, and that he engaged in machine-building only at the behest of his king, Hiero of Syracuse, and later on in order to help his city when it was besieged by the Romans. Polybius (8.3–7) and Livy (24.34), as well as later historians (Plutarch, *Marc.* 14.9–17.3), give accounts of how versatile and impressive Archimedes' catapults were, and how they managed to strike terror into the hearts of the numerically superior Roman army. When Syracuse fell, it was thanks to treason, not technical superiority (Dijksterhuis 1987).

Perhaps Plutarch's description of Archimedes is historically accurate, and he did not deem mechanical matters worthy of written treatment—a situation that would make him even more unusual among Hellenistic technical experts than he already is, thanks to his outstandingly sophisticated mathematical achievements. The circumstances of his life and even of his death, however, also mark him as typical of engineers contemporary with him: working in the service of a patron (he addressed a treatise on astronomy and arithmetic to king Gelon of Syracuse), providing for the safety and welfare of his community, and eventually being assimilated by the new world power, in the shape of the Roman troops who killed him when Syracuse was taken in 212 B.C.

The Roman Empire

The rise of the Roman Empire coincides with the advent of an even bolder breed of technician, well exemplified by Vitruvius Pollio and his *De architectura*. In ten eclectic books that deal with styles of architecture, materials, and planning, but range as well from what we would call ethnography to the construction of catapults, to that of sundials, to methods for finding water, Vitruvius not only provided information useful to the specialist, but also, and especially, strengthened the claim that technical experts like himself played a fundamental part in the empire. In the opening chapter, Vitruvius famously claimed that architects were well-rounded, well-educated individuals: he said that they ought to be competent in, among other things, philosophy, law, astronomy, music, and medicine (*De arch.* 1.1–10). His treatise is scattered with anecdotes about the ethical virtues of technicians, and even contains a potted history of humankind from its brutish origins to the advent of civilization (*De arch.* 2.1.1–7). This passage, marked by stepping-stones such as the accidental discovery of fire, is essentially a tribute to technology, which, far from being contrary to nature, imitates the cosmic order and is a part of it (Romano 1987).

Vitruvius dedicated *De architectura* to the newly installed Octavian Augustus (1, preface), the man who allegedly turned Rome from a city of bricks to one of marble, and the treatise can indeed be seen as a celebration of his empire. Not coincidentally, Vitruvius explicitly drew on a wealth of earlier Greek architectural manuals, none of which survives. The Roman *De architectura* erased previous efforts in more senses than one. By comparing throughout, directly or indirectly, Roman achievements with those of the Greeks or the barbarians, Vitruvius established the former as dominant, not only in deeds, but in accumulated knowledge.

A slightly different perspective comes from the works of Hero of Alexandria. On the one hand, he writes in the mold of Philo of Byzantium and inserts himself explicitly in the Greek tradition of geometry and mechanics, to the point where some historians would tend to classify him as Hellenistic, although he lived around the mid-first century A.D. On the other hand, his treatises contain scattered clues to the fact that he lived in a world now under Roman rule. Hero's devices, with the possible exception of his catapults, have often been described as gadgets or toys, but a more correct interpretation of his contribution to technology would emphasize their capacity to produce wonder, and to engage the observers in the philosophically validated act of curiosity. For instance, he provides several designs for *automata*, that is, things that move apparently by themselves, and in particular for a device that opens the gates of a temple when someone lights a fire on an altar (*Pneum.* 1.38–39). The point of the device for Hero is that it enables him better to reflect on the properties of matter, in particular of hot air, down to the presumed characteristics of particles and void, and that it also enables him to produce a wondrous effect, which will cause amazement in the audience and by reflection empower the technician, who alone knows what is going on behind the scenes (Tybjerg 2003). This particular configuration of knowledge and power, achieved through manipulation of reality that involved building machines, returns in the introduction to Hero's own *Belopoeica* (71–73.11; trans. adapted from Marsden 1971: 19):

> The largest and most essential part of philosophical study is the one about tranquility [*ataraxia*], about which many researches have been made and still are being made by those who pursue learning; and I think research about tranquility will never reach an end through reasoning [*logoi*]. But mechanics has surpassed teaching through reasoning on this score and taught all human beings

> how to live a tranquil life by means of one of its branches, and the smallest—I mean, of course, the one concerning the so-called construction of artillery. By means of it, when in a state of peace, they will never be troubled by reason of resurgences of adversaries and enemies, nor, when war is upon them, will they ever be troubled by reason of the philosophy which it provides through its engines.

One could hardly be more explicit: pitting himself against the most prestigious form of knowledge of all, philosophy, Hero asserts the right of his own discipline and by extension of technicians as a whole to claim a crucial role in society.

As with Philo in the third century B.C., technical treatises in the Roman imperial period were not just about conveying information or instructing the novice. In fact, if we assume that the sole aim of ancient technical treatises was to enable the reader to build a house, supervise the water supply, or divide up a piece of land, we would have to come to the conclusion that many of them simply do not work. This has led some historians to say that some ancient technical writers did not know what they were doing or produced pipe dreams, detached from reality. But the incapacity of some technical treatises to enable the reader to produce a technical artifact just on the basis of the text should not be a surprise to anyone who has ever grappled with the instructions that accompany unassembled furniture kits. Technical training in antiquity relied primarily on oral teaching and on direct experience through apprenticeship. Even the simplest technical treatises often imply tacit knowledge—about how to fit pieces together, or how to choose materials, or how to turn a two-dimensional geometrical description into a working structure—that needs to be supplied independently of the text. Some scholars (e.g., Oleson 2004, 2005) propose the existence of a class of subliterary technical manuals, how-to-do-it booklets concerning metalworking, water-lifting, or agriculture that were lost as Roman imperial culture withered away. Unlike the surviving technical literature, such booklets most likely would have lacked both literary and philosophical pretensions.

We thus have to come to the conclusion that technical texts have to be seen not only as providing information, but also as constructing a certain way of knowledge, and a certain identity for their authors. In the Roman period even more than at earlier times, technical knowledge was presented as useful to the commonwealth, epistemologically solid thanks to its links with mathematics and/or philosophy, and essential to the establishment or maintenance of the political order. The technician was correspondingly represented not only as competent and able to carry out specialized tasks, but also as honest and virtuous, or even as an upright Roman citizen contributing to the welfare of the empire.

Vitruvius is but one example of this posture; another is Sextus Julius Frontinus, author of *De aquaeductu urbis Romae* (*On the Aqueducts of the City of Rome*; see now Rodgers 2004). Whereas Vitruvius seems to have been, generally speaking, an upwardly mobile member of the lower middle classes who had come up through the army, Frontinus, who also had a strong military background, was a senator and a sometime consul. He was charged in A.D. 97 with the supervision of the water supply of the empire's capital city, and *De aquaeductu* stems from that experience. It can be seen as an administrative pamphlet, written by Frontinus for his successor and possibly as a report to the Senate. It provides invaluable information on the aqueducts of Rome, their foundation and maintenance; it also provides figures on their capacity. Above all, Frontinus creates a certain image of the technically-minded high-level civil servant, who equates expertise with efficiency, good rule, and the welfare of the people of the *urbs* (DeLaine 1996; Rodgers 2004: 12–14).

A similar tone is found in many of the writers in the collection now known as the *Corpus Agrimensorum Romanorum*, which includes texts attributed to Frontinus (B. Campbell 2000; M. J. T. Lewis 2001). One author, Balbus, writes for his addressee, Celsus, a treatise titled *Description and Analysis of All Figures*, an explanation of systems of surveying and measuring. Not only does Balbus mention his apprenticeship (*tirocinium*) and his and Celsus' shared *professio*, but also the fact that he has been on a campaign to Dacia (ca. A.D. 101–6) with the emperor, here probably Trajan (B. Campbell 2000: 204). Again, we find references to training, to self-awareness as a group, and to vicinity to the top echelons of political power. The *Description* is basically a short treatise on elementary geometry, presenting roughly the same material as the beginning of the first book of Euclid's *Elements*, but in a narrative form rather than an axiomatico-deductive one. Given that Celsus, implicitly presented as more senior than Balbus, would have already known the contents of the treatise, why did Balbus write it at all? The answer is clear from the introduction: he was keen to have his name circulate among people that Celsus could indirectly introduce him to, and he wanted to show that he had some theoretical knowledge to support his technical skills (trans. B. Campbell 2000: 204–7):

> It seemed disgraceful to me that if asked how many kinds of angle there were, I should reply "many." Therefore in respect of those points relevant to our profession, as far as I could in my work, I have set out the types, characteristics, conditions, measurements, and numbers. If you, a man of considerable influence, think that this work will benefit those learning [the profession], that will be sufficient recognition of my modest talent.

It is only appropriate that a conquered province, Dacia, should be the implicit background to the exchange between Balbus and Celsus. The presence of occupied territories, non-Roman units of measurements, and pre-Roman land management traditions is very strong in the *Corpus Agrimensorum*. Surveyors inevitably had to negotiate between local realities and the demands of imperial administration. In their texts, imperial control is often equated with geometrical order, to be imposed, if only in the form of a map, on an often recalcitrant nature, full of mountains, ridges, and other obstacles to overcome.

That the Roman Empire was identified with its technical achievements is confirmed by some nontechnical sources. For instance, *Agricola*, the biography Tacitus wrote of his father-in-law around A.D. 98, describes the Roman colonization of Britain thus (21; trans. from Lewis and Reinhold 1990: 279):

> In order that people who were scattered, uncivilized, and hence prone to war might be accustomed to peace and quiet through comforts, Agricola gave personal encouragement and public assistance to the building of temples, forums and

> houses. . . . He likewise provided a liberal education for the sons of the chiefs, and . . . he so encouraged them that although they had lately disdained the Roman language they now eagerly aspired to rhetoric. Hence too, our style of dress came to be esteemed, and the toga became fashionable. Step by step they turned aside to alluring vices, porticoes, baths, elegant banquets. This in their experience they called "culture," whereas it was but an aspect of their enslavement.

As well as the imposition of tribute and the institution of assize circuits and law courts, the presence of Roman power was made tangible by baths and forums, which were, ambiguously, both a means to an easier and more peaceful life and an instrument of servitude, a way through which the Britons were won over and ultimately Romanized. Similar sentiments are echoed by a passage from the *Babylonian Talmud* (*Shabbath* 33b; Lewis and Reinhold 1990: 333–34):

> Rabbi Judah began and said: "How excellent are the deeds of this nation [Rome]. They have instituted market places, they have instituted bridges, they have instituted baths." . . . Rabbi Simeon ben Yohai answered and said: "All that they have instituted they have instituted only for their own needs. They have instituted market places to place harlots in them; baths, for their own pleasure; bridges, to collect tolls."

The Roman reaction to the dissenting rabbis is appropriate to their degree of technological appreciation: Judah is praised by the authorities, whereas Simeon is condemned to death. Evidently, criticism of the Roman infrastructures is perceived as criticism of the empire. The identification of Rome with its forums, baths, and bridges appears complete, and puts a dent in interpretations that see technological achievements, ancient or modern, as "objective" or "neutral." Roman technological achievements were arguably meant, and arguably perceived, as politically charged.

Inscriptions

Apart from the architectural monuments that represent the most visible legacy of ancient Roman technology, the empire left its mark in the form of inscriptions. We have long texts, often celebrating conquests or reminding the public of a rich individual's benefactions, and we have shorter texts, often on milestones, boundary stones, or tombstones. As was the case for classical Athens, epigraphy provides some of the most interesting written sources for the history of Roman technology, not only for the content of some inscriptions, but also for their location (when that can still be reconstructed).

For instance, a set of inscriptions recording the settlement of boundary disputes between Delphi and neighboring communities, in which a surveyor was involved, was displayed on the walls of the temple of Apollo in the sanctuary. The documents record how a Roman public officer had resolved disputes between Greek communities, and are thus appropriately bilingual, in Greek and Latin.