CHAPTER FIVE

Society and Environment: *The Alteration of the Ancient Landscape*

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EGYPT

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In order to avoid the recurrence of famines caused by the whims of the Nile (flooding or droughts), the Pharaonic kinship group had to establish an efficient organization. The objective was to improve the standard of living of a gradually increasing number of people, to meet their essential needs (e.g. food and consumer goods), and to respond to the demands of the aristocracy for imported products and artifacts for funeral uses or liturgical purposes.

Through the creation of departments, each responsible for a specific economic sector, the hierarchy of working methods grew. New techniques of craftsmanship for the manufacture of goods were developed, impacting to a greater or lesser extent on the environment, in accordance with the growth of the population and the improving standard of living. These new techniques considerably increased the production of artifacts (metal, mineral, glass), with several peaks in the importation of substances during the Middle and New Kingdoms, witnessing the domination of Egypt over the Near East and Lower Nubia. The availability of a great diversity of materials allowed more sophisticated technologies to develop, for armaments in particular, which mobilized techniques in a number of different fields, including metallurgy, quarrying, and woodwork. The study of the techniques used for weapon-making and shipbuilding showed that materials were selected because of their resistance or flexibility, the end point being improved performance.

The manufacture of chariots, bows, arrows, and javelins brought these complex technologies to their peak. Their manufacturing processes not only enhanced the proliferation of craft experiments and the control of the chemical processes involved, but also led to the overexploitation of both nonrenewable resources like ores and renewable resources like wood. Indeed, the scarcity of wood in the lower Nile valley and in Mesopotamia compelled the Egyptians to obtain wood from the forests of Lebanon – oak, cedar, juniper, and Cilician pine – whose exploitation largely contributed to the deforestation of this region.

As the information available in texts does not cover the wide range of trades involved in the transformation of materials and substances used in chemical processes, a brief overview will be presented here. Archaeological and textual data indicate both the short- and long-term impacts of this activity on the environment in Egypt and abroad. Among the methods mastered to build monuments, ranging from civil architecture to pyramids, the making of mud-bricks was the most important, since it was inexpensive and did not require skilled staff (Kemp 2000: 83–4). Mud-bricks were made from a mixture of mud and straw as well as mineral and vegetable residues that ensured their cohesion. The wet mud was packed in wooden shape-molds then dried to obtain bricks to build walls. Some of these bricks were stamped with the cartouches of builder-pharaoh. Gaps between bricks were filled with a mortar made of sand and mud (Kemp 2000: 92–3). The outside of mud-brick structures had to be covered with roughcast, then covered with a thin layer of plaster to ensure additional protection against the elements and to prevent the upward movement of salt.

Made of natural elements, the mud-brick was not reusable, but it did not pollute the environment. Remnants of old monuments were exploited by the *sabakhin* (in the nineteenth and twentieth centuries BCE) who collected the *sebakh* (i.e. a decomposed dry organic material rich in nitrates) in order to fertilize cultivable soils. In ancient times, the mud foundations of old buildings were not evacuated – other levels were simply rebuilt on them, creating kom-shaped (Greek *kome*, "village") structures. When reddened by fire, the remains of mud-brick structures polluted the soil. The use of clay-bricks, which also polluted the soil, appeared in the New Kingdom.

It should be pointed out here that thanks to a process invented in the Third Dynasty (2700–2625 BCE; see Chapter 4), the hand-hewn stone used for divine and funerary architecture was sometimes reusable. Many monuments that were partially built with such materials in Egypt still exist. Monuments of the great burial sites could be stripped. For example, in the reign of Ramses II and owing to the unavailability of cut stone – limestone, sandstone, or granite – the engineers had recourse to the stripping of ancient monuments at Giza for new architectural projects. Such a detail calls into question the myth of a political will to maintain the structures of the past. However, Khaemouaset, the fourth son of Ramses II and high priest of Ptah in Memphis, distinguished himself in this regard, because he restored several old monuments (Aufrère 1998e), thus gaining posterity in Egyptian literature under the name of Setne (Charron and Barbotin 2016).

Mining and stone-quarrying operations showed that, when necessary, the administration was capable of mobilizing a large workforce both in the Nile valley and in the surrounding deserts. This makes us conscious of the impact of human activities in this desert environment. As shown in documents like the *onomastica* (see Chapter 2), the Egyptians tried to control this impact by creating new functions such as those of the steward of the treasury of gold and silver, the steward of the desert in the foreign country of Syria, and the steward of the deserts of the Land of Kush. But the texts also mention that among the Theban priestly titles there was that of the "Great of the Gebels of the Gold of Amon," testifying to the omnipotence of the clergy in the New Kingdom (Ziegler 1981). From this one can infer that Egyptian political and religious systems were based on the plunder of the vegetable, animal, and mineral (especially auriferous) resources of a subjugated Nubia, mainly those of Wadi Allaqi. Thus, the Viceroys of Kush ensured that the royal capitals (Thebes, Memphis, etc.) received important yearly tributes (see Chapter 6), which probably required bonded labor in gold mines as attested in the classical texts. The interpretation of the written texts as well as the observation of the mining and quarrying sites exploited in antiquity show that, even though the first miners did not intend to ravage divine resources in order to carry out their necessary rituals, they nonetheless modified the environment by overexploitation of these resources in the long term. Thus, to facilitate the settlement of people in those deserted areas, if only episodically, the availability of vegetal resources was more important than the transformation of these materials.

Massively exploited without any control until the materials were exhausted – not only by the Egyptians themselves but also by the late Greek and Roman conquerors of Egypt – the desert became a place of fear and irrationality (Keimer 1944). In spite of the shortage of wood and water resources, men and animals could be settled to labor if a network of fortified wells or water tanks along with new means of transporting heavy loads were made available. Over time, most operating sites contemporaneous with the Pharaonic and Greco-Roman periods laid bare whole sections of the mountains and emptied veins to the smallest nuggets or mineral pellets, while mounds of accumulated waste rocks and erratic blocks of rock were discarded in the quarries. Moreover, close to the gates of Roman forts, there were discharges of all forms of waste related to daily life (Reddé 2018).

Ceramic production was a highly polluting activity resulting first from the combustion of kilns and then from the processing of the material itself. Indeed, once crushed, the material had little chance of being recycled. However, some shards of ceramics could be used to spread the mud-bricks of arched vaults, as well as employed as ostraca (surfaces for writing). However, this reuse was very limited and did not solve the problem of waste. Since ceramics were indispensable in everyday life, detritus was thrown on isolated mounds outside villages, making the wasteland infertile. As food consisted mainly of bread, tooth enamel was prematurely abraded by the fragments of silica detached from the querns and grinding wheels during the milling of flour. Dental attrition was observed even in the ruling classes.

In the Nile valley, the copper-melting industry, which mobilized significant numbers of workers, polluted the air with toxic fumes released from open or closed furnaces. The use of toxic substances and cow urine in tanneries and the workshops of curriers produced a stench and polluted the waters of the Nile. Tanned leather was widely used for the manufacture of cloth and weapons. The use of vegetable tanning limited pollution to a certain extent. Dyeing tanks also emitted unpleasant smells, as reported for madder in the *Trades Satire* (IV 5–7), but this also applied to many other dyes like woad (see Chapter 2). Moreover, according to the classical authors, embalmer workshops around Thebes, located on the west bank of the Nile and far from inhabited areas, were known to release appalling smells caused by the preparation of bodies for embalming after evisceration and desiccation (Riggs 2014). This industrialized postmortem activity required the involvement of a large number of specialized personnel and the use of large quantities of chemical substances such as natron, widespread in the environment. The preparation of bodies to safeguard their passage to eternity required that linen strips be woven, that coffins be made to standards required by the nobility, and that floral ornaments be prepared (David 2000). This industry around death applied broadly to sacred animals as well, as is revealed from animal necropolises in Saqqara and elsewhere.

If Egypt was considered by tradition to be a country in which simple drugs were prepared to relieve pain, it was also famous for making poisons (Cumont 1937: 174–7). During the Roman period, this reputation was mainly attached to the legend of Cleopatra (Marasco 1995). However, plants containing alkaloids – the opium poppy (*Papaver somniferum* L., 1753) or common henbane (*Hyoscyamus niger* L., 1753) – though not very toxic, and mineral poisons such as arsenic sulfides (orpiment and realgar), mercury sulfides (cinnabar), and copper sulfates were well known as poisons. In ancient times, these poisons were generally unstable, and it is not until the Renaissance that they were stabilized and really became highly toxic (Collar 2007). Nonetheless, Alexandrian Egypt was considered the land of poisoners (*pharmakoi*), also known for its love potions and aphrodisiacs. During this period, poisoning was part of daily life. For rulers, the risk of death by poisoned foods could be prevented by using the services of pretasters (Kaufman 1932: 106; Cumont 1937: 174–6).

MESOPOTAMIA

Cale Johnson

Unlike today, when raw materials are bought, containerized, and shipped around the world, the acquisition of rare or precious raw materials in antiquity was a difficult proposition. And while it can be easy to apply an anachronistic model to the ancient Near East, in which peaceful trade predominated, two particularly important modalities for acquiring raw materials are often left out of such accounts: the direct acquisition of metals through mining carried out by an expeditionary force and the acquisition of materials through military force, whether as tribute or plunder (Englund 2006). While the acquisition of raw materials through trade is deferred to the next chapter, this section first looks at these two methods of acquiring raw materials through direct action, and then turns to both archaeological and literary evidence for waste, pollution, and recycling.

Because we do not expect ores and other raw materials to be readily found in an alluvium like Mesopotamia, it is little wonder that nearly all discussion has focused on the extraction of ores and metals from well-known mining centers to the northwest and to the east of Mesopotamia. Copper and other raw materials from or via the Gulf, especially Oman, play a role later on, and in the Amarna Age in the second half of the second millennium BCE trade becomes central. By contrast, in the earliest phases, the Mesopotamians looked to eastern Anatolia or the Iranian plateau (see generally Potts 2007; Weeks 2013), and only at the end of the third millennium BCE to sources beyond Iran, perhaps as far as the Bactria Margiana Archaeological Complex (BMAC; see Steinkeller 2016). There is extensive evidence for ancient mining and metallurgical work in eastern Anatolia, prior to the intervention of southern Mesopotamian states during the Uruk Expansion (Lehner and Yener 2014: 536); as Lehner and Yener point out, "important developments in extractive metallurgy occur … at the beginning of the fifth millennium BC … in Cilicia (Garstang 1953), [including] the development of casting technologies and the possible smelting of ores into metal," but the best early evidence for extractive metallurgy is from the site of Degirmentepe at the beginning of the fourth millennium BCE (539). Of course, mining activities were not limited to this site: "Amongst Anatolia's 91 recorded copper ore deposits, 36 reveal evidence of prehistoric mining" (Wagner and Öztunalı 2000: 31; Kassianidou and Knapp 2005: 218).

Likewise on the Iranian plateau, certainly in greater proximity to Mesopotamia, there is a long history of mining and metallurgy that extends back to the fifth millennium BCE (see generally Thornton 2009; Weeks 2012; Weeks 2013). Much of the literature focuses on Talmessi/Meskani near Anarak, but the centrality of this area for the early extraction of copper ores is now disputed (Pernicka 2004; Weeks 2013: 278). The earliest evidence for crucible smelting of copper is from the fifth-millennium BCE site of Tal-i-Iblis in the southeast. Over the course of the fourth millennium BCE, this technological tradition continues to develop, as evidenced in the archaeological sequence at Arisman, culminating in copper-smelting furnaces in the Proto-Elamite period at the end of the fourth millennium BCE (Helwing 2011; Steiniger 2011; Weeks 2013: 279). Although the proto-cuneiform sources (ca. 3300–3000 BCE) include administrative documents dealing with small amounts of metals, especially copper, only in the third millennium BCE sources do we find evidence for the movement of metals between major urban centers (Englund 2006). Despite the efforts of much later literati to claim technological priority for Uruk, we can be fairly certain that in the Uruk period (ca. 3800–3000 BCE), the Mesopotamians were on the receiving end of this long metallurgical tradition.

One of the most important innovations, at the beginning of the third millennium BCE, was the development of tin bronzes, and it is telling that scholarly opinion on the nature and sourcing of materials for tin bronzes in Mesopotamia has changed dramatically in the last decade. It was long argued that tin bronzes, in contrast to arsenic bronzes, were intentional alloys and that tin sources must have been sought far off in Central Asia, but both of these ideas have been challenged in the last decade. There is "some evidence for the intentional (if uncontrolled) production of arsenic-rich materials for deliberate alloying purposes" such as arsenide-rich slags from Arisman and iron–arsenic speiss slags in Hissar (see Weeks 2013: 280 for an overview). Moreover, recent work in the central Zagros mountains, at the Deh Hosein mine in Luristan, suggests that tin-copper ores were mined in this region, in between Mesopotamia and the Iranian plateau, on the eastern edge of the Zagros in Iran, in the early second millennium BCE (Nezafati et al. 2009; Weeks 2013: 280), and consequently "a naturally mixed source of copper and tin [like] Deh Hosein" may have been the source of tin bronze artifacts in the third millennium BCE (Nezafati et al. 2009: 225). If so, the production processes for arsenic bronzes and tin bronzes may have been more alike than previously suspected. This possibility tends to undercut the idea of taking the Old Assyrian trade at the beginning of the second millennium BCE as a model for what was happening in the third millennium BCE (even if recent finds of a Bronze Age palace at Kültepe/Kaneš offer further support for this; see Ezer 2014), namely that tin was moving from Central Asia, via the Iranian plateau and the Mesopotamian alluvium, into Anatolia, while gold and silver from Anatolia were moving in the opposite direction.

Steinkeller (2016) has emphasized the enormous amounts of gold and silver that were given by Ebla, on the Euphrates in western Syria, as tribute to Mari on the middle Euphrates, and he goes on to postulate that during this period of massive political centralization in the Old Akkadian and Ur III periods, it was an influx of gold and especially silver into southern Mesopotamia that served as the distinctive economic medium of that imperial age. But some elements of Steinkeller's overall model seem to be contradicted by new findings such as the discovery of tin-copper ores in the Zagros and Archi's argument that Durgurasu, which Steinkeller, following Biga, identifies with Egypt, is actually a place in western Iran (Archi 2016).

The one well-documented instance of mining in the early cuneiform textual record, from the Ur III period (ca. 2112–2004 BCE), involves neither trade nor local specialists, but rather a team of "metalworkers (who) dig (in) the mountains" or "miners" (Sum. simug hur.sag ba.al), presumably sent from the southern Mesopotamian city of Lagash to extract ore, on site, in the Iranian foothills to the east of the alluvium (Lafont 1996). This is probably in the same region and also roughly contemporary with the Deh Hosein mine studied by Nezafati and coworkers. The text itself is a flour distribution record from a single day, in which a team of ostensibly 100 miners each receive 6 liters of flour while on their way to the city of Adamdun, or better Adamshah (we cannot assume that the team consisted of 100 individuals, since Ur III bureaucrats did occasionally use simplified summaries like this for smaller groups of workers over a number of days). Lafont reviews two other allusions, in literary texts from the nearly contemporary Gudea inscriptions, to "digging (Sum. ba.al) copper (Sum. uruda)" in the cities of Abullat and Kimaš (Statue B vi 21–3 and Cylinder A xvi 17), and on the basis of this data argued for a route from Lagash, through Adamshah, as a transit point rather than source, and on to Kimash in the Iranian plateau. This prompted a substantial literature on the locations of both Adamshah and Kimash, which has been admirably synthesized and evaluated by Potts (2010). Alongside a renewed investigation of a wide variety of cuneiform textual sources as well as Layard's mid-nineteenth-century investigation of the Tiyari mountains in Iraqi Kurdistan, Potts also points to the archaeological evidence for mines in the northwestern Zagros (2010: 251), and ultimately favors locating both Adamshah and Kimash in this region. Of the three regions briefly discussed here (Anatolia, the Iranian Plateau, and the northwestern Zagros), it is presumably no accident that the one cuneiform tablet that directly reports on mining activities refers to Adamshah, which is probably located in the northwestern Zagros, the closest of these three regions to southern Mesopotamia.

Although we speak of trade networks easily, under the influence of present-day models, Englund has emphasized that the most readily available source of raw materials in ancient Mesopotamia would have been the finished goods kept in the temples, palaces, and storerooms of competing or antagonistic urban centers. The historical record makes it quite clear that temples were one of the major beneficiaries of military campaigns and often received a great deal of the spoils from other conquered cities, and that one of the most widely used techniques for the extraction of raw materials was, as Englund has described it, the "simple plunder" of other people's temples and palaces.

> The violent removal of desired goods from Anatolia, Persia and other Gulf regions such as Bahrain and particularly Oman (ancient Magan), or their removal under threat of annihilation, was a preferred means of Babylonian elites to satisfy their needs for goods not native to Mesopotamia … . This threat of violence stood squarely behind the more benign extortion of taxation of domestic populations and close neighbours, and the demand of tribute from those more distant from Babylonian seats of power.
>
> (Englund 2006: 40)

In recent years, the clearest example of this process (now enshrined in Steinkeller's model of the silver-based economy that emerges at the end of the third millennium BCE) is the conflict between Ebla and Mari at the end of the Early Dynastic period.

Just prior to the emergence of the Old Akkadian empire, we have quite detailed evidence for more than four decades of conflict and diplomacy (ca. 2380–2334 BCE) between Ebla and Mari. Earlier in that period of time, Mari was ascendant and Ebla was forced to pay more than 1,000 kg of silver and 60 kg of gold in tribute (Archi 2017: 165). Mari would eventually fall to Ebla (and this entire zone of conflict would be subsumed within the Old Akkadian empire almost immediately afterward), but the cuneiform textual record makes clear that the acquisition of metals, whether through plunder or tribute or diplomatic "gift," was a central preoccupation of these city states. As Archi puts it:

> War was, therefore, a primary way to obtain valuable goods. The documents prove that the Eblaite army left for war nearly every year (a custom well exemplified in the following centuries by the Hittite and the Assyrian annals), but only a single document (ARET XIV 56) registered the booty collected during these campaigns.
>
> (Archi 2017: 164)

Although we do not have such clear documentation of subsequent Old Akkadian-period extractions, we do see this practice registered in Sumerian literary compositions, likely composed in the Ur III period, such as *The Curse of Agade*. No doubt written by Sumerian literati in southern Mesopotamia in order to shame their colonial overlords, especially Old Akkadian rulers like

Naram-Sîn, *The Curse of Agade* depicts the flourishing new capital of the Akkadian empire, Akkad, with Inanna as the key deity there, in contrast with the traditional religious center of Mesopotamia, the Ekur temple in Nippur. The booty and other wealth, especially in the form of precious metals and stones, which had previously found its way to Nippur was now diverted to Akkad, and Naram-Sîn's efforts to rebuild the Ekur temple in Nippur would even be misrepresented as a kind of unholy recycling of the raw materials held in the Ekur temple. This story is reacting against a central belief in Mesopotamian temple-building ideologies, namely that the raw materials for a new temple ought to be sourced from the full extent of the state (or macrocosm) that the palace represents and should not be recycled from previous incarnations of the temple or palace (Liverani 2001; Johnson 2014), an idea that probably stood in stark contrast to the usual state of affairs.

The most frequent types of waste or pollution in the archaeological record are various forms of nonchemical debris, such as the flakes produced in the production of stone tools, but slags and other waste products from the production of metals and glass are the most prominent debris from chemical processes. Potter's kilns and metal- and glass-making sites are generally swamped with all manner of discards, slag, and other debris from the production process. The best, almost literary, example of this kind of debris field may be found in Woolley's description of a potter's workshop in Pit F at Ur:

> At varying levels there were found, buried in the mass of wasters, the actual kilns in which they had been fired. The kilns had been used each many times and constantly repaired … [They] were circular and though differing in size were all approximately the same pattern … . The kiln proper was 1.30 m. in diameter, the ledge 0.20 m. wide round the rim of the furnace-pit serving as a support for the roof of the latter; the walls were of bricks … these were set in clay mortar and were liberally plastered with fire-clay which had been burnt by the heat to a greenish-white, while the soil round was deep red, shewing that the kiln was in part buried so as to preserve longer the heat of the furnace; the roof of the kiln was rebuilt for each firing and destroyed so as to remove the pots when the firing was complete.
>
> (Woolley 1956: 65–6: Moorey 1994: 146)

The reality is that the entire site consisted of waste products or one kind or another.

Certain kinds of waste products from the smelting process were distinctive and, in more recent descriptions, have acquired a kind of identity. In his description of the smelting of nonsulfurous copper ore, for example, Forbes describes zinc oxide residues "condensed against the furnace-roof" and known as "Ofenbruch" by early modern German metallurgists. Agricola describes it as "a kind of white liquid [that] flows from the furnace which is noxious to silver because it burns the metal" (Forbes 1950: 281). Other well-known processes such as cupellation (in order to separate silver from lead, for instance) would have led to residues, although evidence of this has only been identified in a couple of sites in the ancient Near East (Kassianidou and Knapp 2005: 226–7 mention only Habuba Kabira South in Syria [Pernicka et al. 1998] and Mahmaltar in Anatolia [Wertime 1973: 883]). By far the most important domain for complex procedures involved in the production of refined metal (and the corresponding precipitation of all manner of residues and slags) is the refining of sulfurous copper ore. In summarizing Roman through early modern metallurgy, Forbes even remarks that "from Roman times to the days of Biringuccio and Agricola the main struggle was the perfection of the method of dry extraction of copper from sulphide ores" (Forbes 1950: 306), yielding as residues primarily sulfur, arsenic, and antimony. Forbes summarizes the five-step procedure outlined in Agricola: (a) roasting the ore, (b) smelting the roasted ore into a mixture of copper and iron known as copper matte, (c) smelting the coarse materials with charcoal (coke) and siliceous fluxes, (d) resmelting the blue metal, and (e) refining the black copper. We do not know how much of this complex process was known to ancient Near Eastern smelters, but if the smelters had to use a simpler process they would have had "to sacrifice efficiency and extract a smaller percentage of the copper present in the ore and leave more copper in [their] slags. In fact, if the earlier processes may seem simpler, they were so at the expense of efficiency" (Forbes 1950: 310). There was, in other words, a continual trade-off between relatively simple procedures that produced large amounts of heterogeneous waste (including still-useable metal) and more complex procedures that yielded more refined metal and discrete types of slag. It has even been suggested that the shift from arsenic to tin bronzes was motivated, in part, by the toxicity of arsenic fumes, but others have found this argument unconvincing (see Charleston 1978: 30 and Pare 2000: 7; Steinkeller 2016, however, cites counterarguments from both the Near Eastern [McKerrell and Tylecote 1972] and Andean metalworking traditions [Lechtman 1979]).

In recent years, increasingly global and scientific approaches to pollution have focused on the *longue durée* evidence for pollution that can be identified at metal-refining sites or even, via atmospheric dispersal, in the Greenland ice sheet. As Grattan et al. frame the question, "the broad conclusions from investigations of lead and copper from cores from the Greenland Ice Sheet, as well as mires at high latitudes or high altitudes in Europe … indicate that many of the primary contributions of metalliferous pollutants to the global atmosphere from late prehistory to the modern day reflected changes in both the manner and intensity of mining, ore processing and smelting in the ancient Classical World" (2007: 87).

FIGURE 5.1 Pollution visible in a Greenland ice sheet core. Photograph by Jeff Overs/ BBC News & Current Affairs via Getty Images.

Since ancient Near Eastern workshops do not seem to have registered in the global environment in this way, the only method available is to test the chemical composition of on-site residues. Gratten and coworkers have conducted a number of studies of both human bone remains and smelting-site residues in the Feynan valley in western Jordan and found major toxic residues in both (see Gratten et al. 2002 and Gratten et al. 2005 for the skeletal evidence). In a study of toxic residues in three smelting sites, for example, Grattan et al. (2007: 100) identified concentrations of lead (~45,000 parts per million [ppm] at one site, ~14,000 ppm lead at another) and thallium (~90, ~35, and ~145 ppm at three sites) that were "clearly hazardous." For some perspective on these numbers, the US Environmental Protection Agency limits the amount of lead in a playground to 400 ppm, so the amount found in the smelting residues were more than 100 times above this limit.

Present-day concerns with toxicity or pollution can easily lead us to misunderstand how "waste" or "pollution" were viewed in antiquity. Rather than focusing on the deleterious health effects of these "additives," the primary concern in Mesopotamian and early Mediterranean antiquity was the fraudulent debasement of precious metals (or other ingredients). Already in the second half of the third millennium BCE at Ebla, and in the Ur III state at the end of the third millennium BCE, both gold and silver could be purified and classified on the basis of their purity. During the Amarna Age in the second half of the second millennium BCE, when precious goods again circulated among elites throughout the Mediterranean, Syria, and Mesopotamia, questions of purity and artificial creation come to the forefront. This was the same time frame within which recipes for producing artificial lapis lazuli were first written down, and in the famous Amarna Letters (ca. 1360–1330 BCE), we find explicit discussions of the debased gold that the Pharaoh of Egypt would send as gifts to his "brothers" (other kings of major kingdoms), including the rulers of Babylonia, the Hurrians, and the Hittites.

Though only a topic of epistolary conversation among the great kings (and thus limited to the first thirty letters in the corpus), the word "gold" appears more than 500 times in the first thirty letters in Moran's translation; it can be judged without hesitation as one of the chief obsessions of the Amarna Age. The belief of the non-Egyptian rulers, especially in the letters from Burna-buriash of Babylonia (to Amenhotep IV) and the Mitanni ruler Tushratta (to Amenhotep III), was that "in my brother's country [= Egypt], gold is more plentiful than dirt" (EA 19 rev. 20–1; Moran 1992: 44; Rainey 2015: 144–5), although we know from the map of the Wadi Hammamat gold mines and other sources that the gold-mining operations in Egypt were massive undertakings under direct control of the state (see Stierlin 2007: 74–5; Van de Mieroop 2009: 172). In letters from both Babylonia and the Mitanni Empire in Syria we repeatedly hear about debased gold coming from Egypt. In EA 10, Burna-buriash writes to Amenhotep IV:

> As for your messenger whom you sent to me, the 20 minas of gold that were brought here were not all there. When they put it into the kiln, not 5 minas of gold appeared. [The … th]at did appear, on cooling off, looked like ashes.
> (EA 10 obv 18–24; Moran 1992: 19; cf. Rainey 2015: 96–7)

There is no mention of melting down the Pharaoh's golden gifts in kilns in the correspondence from Tushratta, the ruler of the Mitanni state, but there as well he complains that the gold in question "was not gold and that it was not solid" (EA 29 obv 71; Moran 1992: 95; cf. Rainey 2015: 308–9). Elsewhere, in an inventory of wedding gifts, one total reads "1200 minas of gold" (EA 14 ii 34; Moran 1992: 30; cf. Rainey 2015: 118–19), which is at roughly the same order of magnitude as the huge amounts of precious metal that Ebla gave to Mari as tribute a millennium earlier, but now of gold rather than silver.

The most important literary commonplace for waste products and pollution in ancient Mesopotamian literature is the physical character and environs of the washerman, both in pieces of comedic literature in Akkadian, such as *At the Cleaners*, and in earlier Sumerian and Sumero-Akkadian bilingual lists of humorous professions and embarrassing physical characteristics. We will look

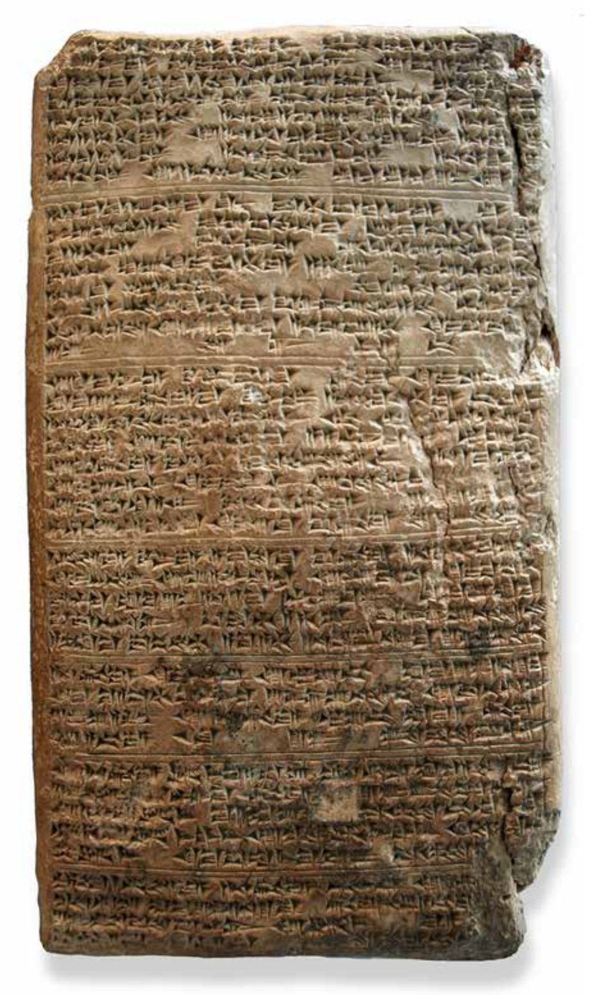

FIGURE 5.2 EA 19 letter from Tushratta. Courtesy of www.BibleLandPictures.com/ Alamy Stock Photo.

more closely at the literary form of *At the Cleaners* in Chapter 7; the crucial point here is that, although Mesopotamian fullers and washermen do seem to have made use of beer and other fermented liquids in their work, there is no evidence that they used stale urine, in particular for the ammonia that it contains, as a cleaning agent, so the horrendous smell associated with washing garments in later Greco-Roman texts should not necessarily be extended back to earlier Mesopotamian sources (as emphasized in the most recent edition, Wasserman 2013: 263–4, where he references a wide variety of possible cleaning agents in the Mishnah: “tasteless spittle, water from boiled grits, urine, nitre, soap, Cimolian earth and lion’s leaf” [m. Niddah 61b–2a]). Even if they did not make use of stale urine, fullers and washermen necessarily did use a wide variety of alkalis, animal fats, and dyes, so their chemical stews may already have gained attention. Unlike the well-known lists of professions that extend, in several forms, back to the origin of writing at the end of the fourth millennium BCE, the list known by its incipit as Lu-azlag (viz. Sum. lu_2.azlag = Akk. *ašlāku* “fuller, washerman”) is first attested in the Old Babylonian period and most exemplars are bilingual (Veldhuis 2014: 161–2). As Veldhuis goes on to say, “terms for professions are exceedingly rare in Lu-azlag, which concentrates on physical characteristics (including illnesses), psychological states, and human activities.” But it is probably no accident that lexical elements derived from the Lu-azlag list also served as building blocks for humorous scholastic dialogues such as *The Class Reunion*, so it is likely that the list served as a compendium of humorous motifs in the Old Babylonian period (Johnson and Geller 2015: 10–11).

GRECO-ROMAN WORLD

Matteo Martelli

Deforestation represented a critical result of the urban, economic, and technological development of the Greek and Roman civilizations. Several factors, such as large-scale agriculture, urbanization, and ship- and house-building, certainly contributed to an intense exploitation of wooden areas and forests, which resulted in depletion of these natural resources in various districts and regions of the Mediterranean (Williams 2006: 62–86; Hughes 2014: 68–87; Hughes 2017). Deforestation of Attica is mentioned in a well-known passage of Plato’s dialogue *Critias* (111b–c). In its mythical past, the region was unspoiled and full of forests, while in Critias’ days, the mountains of Attica could only sustain bees (Harris 2011). The shortage of timber (in particular tall trees for ship- and house-building) was also reported by other classical sources: in Plato’s *Laws* (IV 706b), Attica is said to lack shipbuilding wood, which in mainland Greece was only produced in Macedonia and some parts of Thrace, as Theophrastus observes in his *Enquiry into Plants* (IV 5.5).

Metallurgy (especially ore smelting) and metalworking – along with other pyrotechnical activities, such as ceramic production, glassmaking, tanning, and dyeing processes – were often considered among the prime factors in deforestation, even if recent studies tend to reduce the scale of their impact to the local situations (Rehder 2000: 153–9; Williams 2006: 77–80). Wood and charcoal represented the most important fuel for ancient furnaces, and they were in high demand in mining regions. A much-discussed case study is the Athenian silver mines at Laurion, where, according to Hughes’ calculations, the need for fuel exceeded the annual forest growth of the whole of Attica (Hughes 2014: 136–42; Hughes 2017: 204). Copper ore smelting must have contributed to the deforestation of Cyprus, according to the Hellenistic multitalented scholar Eratosthenes of Cyrene (third century BCE). Strabo's *Geography* (XIV 6.5) partially linked the destruction of forests on the island to the activities of the local mines, important suppliers of copper sulfate (*chalkanthos*), iron oxide, and other medicinal products.

Intensive mining activities could certainly reshape the landscape of exploited areas. Enormous heaps of spoil and discarded rocks were sometimes piled up next to the mines, such as the gold mines of Thasos, where Herodotus (VI 46–7) saw a mountain turned upside down by the Phoenicians. According to Pliny's account (*NH* XXXIII 70–6), galleries were dug in the mines by crushing the rocks with fire, vinegar, and iron picks, and supported by arches. When the vein was exhausted, the arches were knocked down, so that the fractured mountain collapsed with a tremendous crash. In order to wash this deposit away into the sea, a large supply of water was required. Pliny claims that "the land of Spain owing to these causes has encroached a long way into the sea" (*NH* XXXIII 76; Rackham 1952: 61). Water was collected in large reservoirs set above the mine, often being brought from distant sources through a net of artificial channels that rutted the ground for kilometers (Craddock 2016: 208–11). Ancient authors often embellished their accounts on these environmental transformations with moral judgments. Pliny denounces how the earth was violated by human workers who penetrated its bowels and dug deep tunnels, seeking gold, silver, electrum, copper, iron, pigments, gems, and medicines. "We trace out all the fibres of the earth," Pliny writes, "and live above the hollows we have made in her, marveling that occasionally she gapes open or begins to tremble" (*NH* XXXIII 1; Rackham 1952: 3). Along similar lines, in the seventeenth pseudo-Hippocratic letter (§ 5) Democritus harshly attacks those who run mining and extracting enterprises:

> They have no shame at being called happy for digging gaping holes in the earth using the hands of chained men, some of whom have died from the collapse of porous earth, and others of whom stay on in endless bondage … They search for gold and silver, seeking out tracks and scrapings of dust, gathering sand from here and there and excising earth's veins for profit, even turning mother earth into lumps. But it is one and the same earth that they walk on in wonder.
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> (Smith 1990: 81)

In the second century CE, the copper mines of Soli, an ancient Greek city in Cyprus, were visited by the Greek physician Galen, who traveled in various regions of the Roman Empire (Palestine, Lycia, the island of Lemnos) in order to collect and purchase the best-quality medicines. Galen was troubled by the working conditions of the miners, chained slaves (probably condemned criminals) who were accustomed to quickly running naked through a passageway that, starting from the building at the entrance of the mine, led down to an underground pond of green, thick, warm water (Galen, *On the Capacities of Simple Drugs*, IX 3.34 = XII 239–40 Kühn). In the tunnel it was almost impossible to breathe because of the dense warm air, which also prevented the lamps from burning for any length of time. The water of the underground pond was brought to the surface and poured into square ceramic basins, where it evaporated and left copper concretions settled in the receptacles (Mattern 2013: 101–3). All the mining work was carried out under the strict control of a procurator of equestrian rank, who allowed Galen to collect as much copper ore as he wanted from the multilayered deposit in the mine (*On the Capacities of Simple Drugs*, IX 3.21 = XII 226–7 Kühn).

Ancient miners often worked in dreadful conditions, of which ancient authors have left vivid accounts. The Greek historian and geographer Agatharchides (second century BCE) described the dangerous working conditions in the gold mines of Nubia. Only excerpts of his work on the Red Sea have been preserved by later authors, in particular Diodorus Siculus (III 12–18) and the Byzantine scholar Photius (*Bibliotheca*, codex 250). Photius' excerpts were also copied in the oldest alchemical manuscript, the *Marcianus* gr. 299 (tenth century CE), which also includes a list of gold mines in Egypt (*CAAG* II 26–7; Letrouit 1995: 66–8). Greco-Egyptian alchemists, indeed, were interested in mining activities. Zosimos of Panopolis, in particular, says that in Egypt the mining and working of precious metals were under the strict control of the kings (*CAAG* II 239–40; Festugière 1944: 363–4); according to the commentary by the late antique alchemist Olympiodorus (*CAAG* II 69–73; Viano 2018), Zosimos himself would have discussed how to wash and treat auriferous sand in his lost work *On the Action*.

Miners were certainly exposed to toxic fumes, as recorded by the Latin poet Lucretius (*DRN* VI 808–15): the noisome stench of sulfur and bitumen was heavy in the underground, and after breathing these vapors the pallid workers in the silver and gold mines in Scaptensula, a Thracian town, invariably died. Pliny observes that the exhalations from the silver mines were dangerous to all animals, but especially to dogs (*NH* XXXIII 98). Because of the toxic vapor of the ores extracted in the mines of Mount Sandarakourgion in Asia Minor – probably a mine for arsenic-based ores, from *sandarachē*, "realgar" – the 200 workmen (mostly enslaved criminals) often fell sick and died (Strabo XII 3.40). In order to reduce these risks, ventilating shafts were opened in the mines, which dispelled the toxic fumes (Plin. *NH* XXXI 49).

Poisonous exhalations were also produced in the workshops where the mined ores were processed. Dioscorides (V 94), for instance, warned against the noxious properties of cinnabar, which he identified with the Spanish *minion* (from the

Latin *minium*, usually referring to red lead) and distinguished from *kinnabari* or "dragon's blood," namely the exudation from the oriental plant *Dracaena* (see also Plin. *NH* XXXIII 116). While the vegetal substance had many medical applications, cinnabar was toxic, as was evident from the suffocating smell it produces when heated in the furnaces (Trinquier 2013; Martelli 2014b: 39–42). Pliny was skeptical about the recipes that prescribed cinnabar for medical uses and urged those who treated cinnabar in the workshops for the production of red pigments to protect their faces "with masks of bladder skin in order to avoid inhaling the dust which is highly pernicious" (*NH* XXXIII 122; Caley 1928: 424). Likewise, workers were advised to avoid breathing the toxic fumes of lead that was processed for medical purposes: in fact, when the lead was smelted in earthen vessels with sulfur, deadly vapors leaked from the furnaces (Plin. *NH* XXXIV 167). Ancient alchemists tried to seal their devices (e.g. alembics and the *kērotakis*) and make them airtight in order to prevent dangerous fumes from escaping. Lutes of different compositions (*lutum sapientiae* or "lute of wisdom"), in fact, were used to coat alchemical devices. In his commentary on Zosimos' alchemical work, Olympiodorus mentions a glass cup used to burn arsenic ores, which Julius Africanus called an *asympton* (F72 in Wallraff et al. 2012: 185): Olympiodorus specifies that another vessel was set on the top of the *asympton* so that the arsenic could not dissipate as a vapor (*CAAG* II 75,19–22; Beretta 2009: 116). Tubes or funnels could also be used to draw noxious fumes out of the furnaces. Strabo (III 2.8), after praising the unique variety of metals mined in Spain, mentions the local silver-smelting furnaces that were equipped with high chimneys "so that the gas from the ore may be carried high into the air; for it is heavy and deadly" (Jones 1921: 43).

The emission of gases and fumes had consequences both for human health and for the environment. Various lakes near mining areas were contaminated in antiquity. During the Roman period, especially the silver–lead deposits in southeastern Spain were exploited (e.g. the Rio Tinto region; Richardson 1976). Laguna de Río Seco in southern Spain, for instance, records a marked peak in lead content between 2100 and 1700 years ago, which can be associated with Roman metallurgy (García-Alix et al. 2013: 454). Northwestern Spain was especially abundant in gold deposits; analysis of the water in Laguna Roya, a small glacial lake 35 km south of Las Médulas mines, has shown high concentrations of lead, antimony, bismuth, and arsenic, probably due to the extraction and processing of gold ores (Hillman et al. 2017). The significant atmospheric effects produced by ancient metallurgical industries can be still detected in the ice layers of Greenland (see Figure 5.1), which represent "unique frozen archives of past changes in large scale atmospheric fluxes of metals" (Hong et al. 1996b: 191). Recent studies have shown that the concentrations of lead and copper in Greenland ice cores were significantly higher during the Greco-Roman era than in the previous and following centuries (Hong et al.

1994; Makra 2015: 31–3). Atmospheric copper emissions increased between 200 BCE and 350 CE, with a peak at the height of the Roman Empire (Hong et al. 1996a; Hong et al. 1996b). High levels of lead emissions are registered especially between the mid-fourth century BCE and the second–third centuries CE, as shown by Greenland's ice sheet that dates back to between 2500 and 1700 years ago: lead is present at concentrations four times greater than natural values (Hong et al. 1994; Capasso 1995). Fluctuations are recorded in conjunction with plagues, wars, or periods of political instability (especially during the Roman Republic), which probably caused temporary declines in mining activities (McConnel et al. 2018).

During wars, water could be intentionally poisoned, an underhand strategy particularly effective in siege craft. During the First Sacred War (ca. 595–585 BCE), for instance, in order to defeat the city of Kirrha under siege for ten years, Athenians used hellebore to poison a canal that supplied water to the city (Grmek 1979: 146–7; Mayor 2003: 100–4). According to a pseudo-Hippocratic treatise (*Embassy*, § 4 in Smith 1990: 114), it was the doctor Nebros (lit. "Fawn"), ancestor of Hippocrates, who planned to pollute the water with unspecified poisons (*pharmaka*). Poisonous fumes were also used in sieges, when pitch, sulfur, and bitumen were employed both as incendiary accelerants and to produce noxious smoke (Mayor 2003: 207–50). For instance, the Spartans defeated Plataia (427 BCE) by fueling a massive fire in front of the city's walls with pitch and sulfur (Thucydides, II 77). The same substances could also be used underground, as has been revealed from the archaeological evidence in the eastern Roman city of Dura Europos, besieged by the Persians in 256 CE. Here, a net of tunnels was dug under the city walls by both Romans and Persians; the latter, however, burned sulfur and bitumen to kill their enemies trapped in the galleries (James 2011). Indeed, in the East, petroleum products had military applications: in Samosata (on the Euphrates), a local inflammable mud (called *maltha* by Pliny; perhaps containing naphtha) was used as an incendiary weapon against Lucullus' army (Plin. *NH* II 235; Partington 1999: 3–5). Sulfur, quicklime, bitumen, and other ingredients are combined in the recipe for a "self-lighting fire" given by Julius Africanus in the *Cesti* (fr. D25 in Wallraff et al. 2012: 116–19), a multivolume "encyclopedia" that included, among other topics, military literature and alchemical recipes (Partington 1999: 5–10). These incendiary weapons anticipated the infamous "Greek fire," namely a "fluid fire" of crude inflammable oils (naphtha or petroleum) that was projected by a sophisticated device with siphons, pipes, cauldrons, and pumps, which could be accommodated in Byzantine ships (Haldon 2006).

Along with the extraction and processing of metals, other activities, such as brick and glass production and textile industries (which included both fulling and dyeing processes), polluted the air and water in urban areas as well.

Polluting smoke was produced by Roman glassworkers who often blew molten glass: the process required a sophisticated pyro-technology with furnaces that could reach constant high temperatures (ca. 1050–1150°C; Stern 1999: 450–4). Sometimes recycled material was remelted, as can be inferred from scattered references to the barter of broken pieces of glass by various Flavian poets, in particular Martial (*Epigrams*, X 3,3–4), Statius (*Silvae*, I 6,73–4), and Juvenal (*Satires*, V 47–8). It is difficult to locate glassmaking workshops in Rome: a *Vicus Vitrarius* (an area that took its name from glassmakers) in nearby Porta Capena is recorded by the fourth-century *Regionary Catalogues* (Holleran 2018: 461), and Martial mentions a Transtiberine street peddler who exchanges sulfur for broken glass (*Epigrams*, I 41,3–5). Scholars have sometimes interpreted this passage by Martial (along with the related passages by Statius and Juvenal that are referred to above) as a reference to the use of sulfur to remelt or glue broken glass (see, for instance, Post 1908: 21; Kardos 2002: 122). However, this interpretation, already questioned by several scholars (Leon 1941; Harrison 1987; Santorelli 2013: 93–5), does not seem to be confirmed by ancient sources.

Already in the second century CE, glassmaking was probably moved to the suburbs of Rome in order to remove the nuisance of its smoke from the city center (Douglas and Frank 1972: 4). Similar restrictions were applied in Palestine, at least according to the short sixth-century CE treatise on urban planning by Julian of Ascalon (Saliou 1996), who prescribed setting up workshops that produce polluting fumes – particularly the shops of glassmakers, blacksmiths, statue-makers, dyers, and fullers – on the outskirts of cities (Dell'Acqua 2004: 138; Saliou 2012: 44–5). Likewise, the *Mishnah* (Jewish exegetical oral traditions that began to be collected in the first century CE) includes restrictions on the location of workshops: a dyeing shop could not be located under another person's storehouse, while tanneries were to be relocated outside the town (Mamane 1987; Saliou 2012: 47).

Tanning was among the crafts that the ancients considered responsible for water pollution; the use of urine along with various astringent mordants, both vegetal (e.g. oak gall, pomegranate, or sumac) and mineral (especially alum), could contaminate the rivers where the treated leather was soaked. A fifth-century BCE inscription (*IG* I^3 1.257; 430 BCE) found in Athens reports a decree that prohibits using the waters of the river Ilissos, upstream from the temple of Heracles, to rinse skins or wash away the waste produced by tanners (Rossetti 2002; Beazot 2017: 55–6). The application of this decree had beneficial effects, if we rely on the testimony of Plato, who some decades afterwards praised the fresh waters and the scented air of the region (*Phaedrus*, 230b–c). Fulling and dyeing workshops often raised similar issues. *Fullonicae* were commercial laundries that washed used cloths and, less often, finished new textiles. Even though we find some fulleries at the margins of the city (e.g. the large *fullonica* excavated in Casal Bertone; Musco et al. 2008), they were more often situated in the centers of towns, as archeological evidence in Pompeii and Ostia clearly shows (Flohr 2013a: 229–36). The use of urine and sulfur in the processes could harm the workers (especially because of ammonia; Bresson 2017: 186–7) and produce unpleasant smells, ubiquitously mentioned in literary sources (Flohr 2003). The impact on health and the environment was probably more serious in the case of dyeing workshops, where chemicals were processed in heated cauldrons (Flohr 2013a: 184–6). Strabo (XVI 2.23), for instance, refers to the polluting dyeing shops on the island of Tyre:

> The city was also unfortunate when it was taken by siege by Alexander; but it overcame such misfortunes and restored itself … by means of their dye-houses for purple; for the Tyrian purple has proved itself by far the most beautiful of all; and the shell-fish are caught near the coast; and the other things requisite for dyeing are easily got; and although the great number of dye-works makes the city unpleasant to live in, yet it makes the city rich through the superior skill of its inhabitants.
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> (Jones 1930: 269)

Martial (*Epigrams*, I 49,32; II 16,3; IX 62) often mentions the unpleasant smell of purple-dyed garments, probably caused by use of urine in the dyeing procedure (see also Plin. *NH* IX 127). Perhaps in order to solve this problem, a recipe on purple dyeing included in Pseudo-Democritus' alchemical books (Martelli 2013: 80–1) prescribes using an aromatic substance to fumigate the wool that had been left to soak in urine for two days.

The textile industry is often associated with women in literary sources, especially with reference to weaving and spinning. However, the real involvement of female workers in the different steps of textile production is difficult to assess. Fulling and dyeing are especially opaque fields. Latin inscriptions do mention *purpurariae*, women who produced or retailed purple dyestuff or purple products (Larsson Lovén 2013: 115–16; Larsson Lovén 2016: 203–7); we also find two female perfume dealers (*unguentariae*; *CIL* VI 10006; X 1965), and a woman is mentioned among five jewelers (*gemmarii*; *CIL* VI 9435: see Larsson Lovén 2016: 204). The frescos in Pompeii's *fullonicae* display some women at work, usually associated with the last phase of the production process and with works physically less demanding (Clarke 2003: 116–17; Flohr 2013a: 282–3). Greco-Egyptian papyri refer to female fullers (*knaphissa* or *gnaphissa*; see, e.g., *P.Mich*. IV 359; *P.Oxy* XXIV 2425; *P.Iand* III 43), and the papyrus *P.Oxy*. XIV 1648 (second century CE) preserves a contract in which three women (a mother with two daughters) sell their dye shop equipped with a leaden pot and an earthenware cask (Wipszycka 1965: 148). Some letters from the archive of

Apollonios, a *strategos* (ca. 113–120 CE) who ran a large weaving enterprise in Upper Egypt, mention his wife Aline and his mother Eudaimonis engaged in purchasing purple dyestuff and assessing its quality (Martelli 2014c: 118–20; see Chapter 6, p. 184).

The recipes on purple dyeing included in the chemical papyri of Leiden and Stockholm do not explicitly mention the possible users of the copied instructions. In general, however, Greek alchemical literature often refers to women as significant actors in the early development of this art in Greco-Roman Egypt. As already seen in Chapter 3, Maria the Jewess was counted among the earliest authorities in the field, especially for her accurate descriptions of various devices, such as alembics, the *kērotakis*, and furnaces. Zosimos of Panopolis wrote his own alchemical writings for Theosebeia, a wealthy upper-class woman perhaps of Roman lineage, who is addressed as "purple-robed lady" and "my mistress" by the alchemist (*CAAG* II 226, 246; Hallum 2008). For a while she joined the Egyptian priest Neilos and his alchemical circle, to which the Egyptian woman Taphnoutia also belonged (*CAAG* II 190–1; Letrouit 1995: 22, n. 49).

Women were, after all, the first to receive the book on *chēmeia* that was revealed by the fallen angels, according to Zosimos' account, and the angel Amnael disclosed to the goddess Isis the secrets of the preparation of silver and gold (*CAAG* II 28–9; see Chapter 4, p. 132). Likewise, *chēmeia* is defined as the preparation of gold and silver in the Byzantine Lexicon *Suda* (χ 280) too, which also refers to the Roman emperor Diocletian (244–311 CE), who destroyed all the books on this subject. The same story was already recorded by John of Antioch in his *Universal History* (fr. 191 Mariev):

> Diocletian full of hatred and grudge against those who rebelled against his power in Egypt, was not satisfied with ruling the country unfairly and cruelly, but traversed it and damaged Egypt with proscriptions and murders of distinguished people. He tracked down and burnt the books on the *chēmeia* of silver and gold, which had been written by their ancestors: so Egyptians would have no longer gained money out of this art and thenceforward they would have no longer had confidence in the abundance of their substances and risen up against Romans.

Diocletian's hostility against alchemy does not seem to have been maintained by early Byzantine emperors. Indeed, the table of contents of the oldest alchemical manuscript (*Marcianus* gr. 299, fol. 2r; Saffrey 1995: 4–5) lists works on alchemy ascribed to the emperors Justinian (ca. 482–565 CE) and Heraclius (ca. 575–641 CE); to Heraclius, moreover, the alchemist Stephanus of Alexandria addressed his own *Lectures* on the sacred art of gold-making (Papathanassiou 2017: 213–8).

CONCLUSIONS

Marco Beretta

The increasing value attached by ancient civilizations to commodities that were the product of chemical manipulation such as metals, minerals, precious stones, and glass impacted on their society and environment in two ways: (a) territorial expansion and (b) environmental changes.

When they were not able to trade valuables, Egyptian and Mesopotamian rulers expanded their territories to where sources of new richness could be found. Tin, which was needed to alloy with copper for bronze, was imported from Anatolia. Even less valuable materials like wood, which were scarce both in Egypt and Mesopotamia and essential to keeping going the batteries of the furnaces implemented by chemical workshops, were imported from Lebanon (particularly cedar wood), Nubia (ebony), and from other areas rich in woods situated in the Near East.

The systematic exploitation of these resources led to deforestation, probably the most visible and extended form of alteration of the landscape. Although the polluting effects of the chemical arts became rapidly apparent, they did not lead to any attempt to mitigate these effects. Moreover, the dreadful conditions of workers such as miners, mostly slaves, were regarded as normal. Pollution and waste were not yet perceived as environmental problems, but the situation began to change with the Greco-Roman authors who, in a few texts, denounced both the greed and the dangers of exploiting the earth without any control. The progress made in medicine raised the awareness of the toxic properties of certain substances and chemical processes: tanning and dying manufactures poisoned the water and toxic fumes exhaled from the metallurgical and glassmaking workshops and noxious airs often filled the mines. The large-scale employment of the chemical arts introduced by the Romans encouraged the authorities to take some measures to mitigate the effects of the pollution. The growing output of waste in the chemical arts also inspired the first techniques enabling reuse by recycling.