Spiral Fluted Columns and the Mechanical Screw: The History of a Mathematical Idea in Ancient Architecture and Mechanical Technology

by

Georgina Jane Henderson
B.A., University of British Columbia, 1964
B.L.S., University of British Columbia, 1965

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Supervisory Committee

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Abstract

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This thesis examines the stone-carved architectural spiral fluted column from second-millennium B.C. Mesopotamia to the fourth-century A.D. Roman Empire, and establishes its relationship to technological devices such as water screws, screw presses, and other machines. Evidence from literary sources and archaeological records shows the increasing architectural use of the helical spiral during that time, particularly in structures such as theatres, nymphaea, colonnades and decorative gateways. The use of spiral designs on coins, sarcophagi, pottery and wall paintings is also discussed.

The thesis presents: the mathematics of the spiral as applied in Mesopotamian architecture; spiral use in the Aegean Bronze and Iron Ages and the Greek and Roman worlds; and its use in technology and mechanical devices, specifically those of Archimedes and Hero. The conclusion summarises the evidence, demonstrating that the construction of the spiral fluted column evolved from that of the Archimedean water screw.

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All abbreviations for ancient texts are taken from the *Oxford Classical Dictionary*, ed. S. Hornblower and A. Spawforth, pp. xxix-liv. 3rd ed. Oxford: Oxford University Press, 1996.

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Dedication

To Win, Dave and Jane Henderson, and to the memory of my dear parents, Hartley and Bonnie Detwiller.

Chapter 1: Introduction to Terms and Problems

> [The spiral] has been said to represent the wanderings of the soul; why, or how, is not specified; nor why some souls should wander in circular spirals, others in oval spirals, some in spirals with ends, others in spirals that are endless. And what was a soul supposed to do when on the track of a triple diverging spiral, how it could go two ways at once, or which line it was to take - all these difficulties suggest that the theorist's soul was on a remarkable spiral (Petrie 1895: 17-18).

1. Definition and Description of Spiral Fluted Columns

At the site of ancient Apamea on the Orontes River in modern Syria there is a magnificent Roman colonnade of spiral fluted stone columns, constructed in the second century A.D. (Balty 1988: pl. 11.1, 1994). The columns are immediately eye-catching because they are arranged so that the flutes of each column twist in opposite directions to those of their neighbours. Having rarely, if ever, seen this uncommon type of ancient column, the viewer is naturally curious: what is the history of this impressive architectural style? The ubiquitous stone column used in building construction in the ancient Greek and Roman world generally was fluted; that is, it had parallel grooves or channels cut into its surface, but these were vertical, not twisted. Vertical fluting was used on buildings in Greece and Rome from the seventh century B.C. onwards, as, in the bright Mediterranean sunlight, fluting provided the shadows needed to soften the brilliance of the stone in order to show off volume and architectural details.

Spiral fluted columns are certainly striking (and are used even today in decorative and structural contexts) and thus it seems puzzling that Vitruvius, the late first-century B.C. Roman architect and military engineer, does not mention them. He wrote our only contemporary surviving handbook of ancient architecture, *De Architectura*, and, although he gives information on fluting in the Doric and Ionic architectural orders, he never mentions spiralling flutes. For fluting in the Ionic order, Vitruvius says (*De arch.* 3.5.14),

> (14) Columnarum striae faciendae sunt XXIIII ita excavatae, uti norma in cavo striae cum fuerit coniecta, circumacta anconibus angulos striarum dextra ac sinistra tangat acumenque normae circum rotundationem tangendo pervagari possit. Crassitudines striarum faciendae sunt, quantum adiectio in media columna ex descriptione invenietur (Granger 1962: 196).

> (14) The flutes of the columns are to be twenty-four, hollowed out in such a way that if a set square is placed in the hollow of a flute and moved round its ends, it will touch the fillets on the right and left, and the point of the square will touch the curve as it moves round. The width of the flutes is to be altered so as to suit the addition produced by the swelling of the column (Granger 1962: 197; Morgan 1914: 96).

His prescriptions for fluting in the Doric order are (*De arch*. 4.3.9),

> (9) Columnas autem striari XX striis oportet. Quae si planae erunt, angulos habeant XX designatos. Sin autem excavabuntur, sic est forma facienda, ita uti quam magnum est intervallum striae, tam magnis striaturae paribus lateribus quadratum describatur; in medio autem quadrato circini centrum conlocetur et agatur linea rotundationis, quae quadrationis angulos tangat, et quantum erit curvaturae inter rotundationem et quadratum descriptionem, tantum ad formam excaventur. Ita dorica columna sui generis striaturae habebit perfectionem (Granger 1962: 224, 226).
>
> (9) The columns ought to be fluted with 20 flutes. If the flutes are flat, the columns must have 20 vertical edges marked. But if the flutes are hollow, we must fix their form in this way: draw a square with equal sides as great as is the width of the fluting. Now in the middle of the square the centre of a circle is to be placed, and let a circle be described which touches the angles of the square; and the curve which comes between the circumference and the side of the square, will give the hollow of the flutes. Thus the Doric column will have the fluting proper to its order (Granger 1962: 225, 227; Morgan 1914: 113).

Was Vitruvius simply too conservative to accept the spiral style of fluting, or did he think this style would not last and was therefore not worth mentioning? Was it not discussed by the sources on which he based his work? Was this type of column too whimsical and thus not considered "serious" enough for "serious" purposes? We shall see later that spiral fluted columns were used in conjunction with particular sites and buildings that were "serious" indeed. This observation leads to geographical and architectural questions: where were spiral fluted columns used, and when and why did they arise? Why do we not see more of them at ancient sites? Archaeological evidence suggests that this remarkable deviation from the Graeco-Roman norm had become more common (though still a comparative rarity) by the first century A.D., and examples are found not only in Syria but also elsewhere in the eastern Mediterranean: Turkey, Jordan, Cyprus, Greece, Egypt, Libya, Tunisia and Italy (Benson 1956, 1959; Humphrey et al. 1998; Ratté and Smith 2004; Smith 1996; Smith and Ratté 1996; Wace 1954). The object of this thesis is to

examine in detail the spiral fluted column in the twin contexts of (a) the "normal" vertical fluted or unfluted stone column, and (b) the other forms of spirals that developed at the same time in mathematics and applied technology, such as the screw press and the water screw (Oleson 1984, 2008).

2. Definition and Description of Screw Presses and Their Technology

How does the screw press fit into an examination of spiral fluted columns? Since its mechanism depends on a spiral screw, the screw press is an example of a spiral being applied practically rather than decoratively, i.e., by being incorporated into a machine. From this development, then, more speculations arise: was the spiral fluted column associated with Archimedes' work on spirals, and, if so, was the later invention of the screw press directly descended from Archimedes' work? Or was the screw press invented on the basis of architects' and engineers' observations of spiral fluted columns, and the application of the concept to another medium? We shall examine Archimedes' ideas of spirals in Chapters 2 and 6 to investigate these questions, but it is necessary first to consider the processes involved in pressing olives and grapes and the construction and evolution of ancient presses.

Grapes can be crushed fairly simply either by human feet or with mechanical presses to extract the juice, leaving the skins and seeds to be used as animal feed. On the other hand, olive oil must be extracted from the fruit without crushing the pits as they give a bitter taste to the oil (White 1975: 225). Paton says there are two processes in olive-oil manufacture: grinding and pressing. For grinding, the olives are crushed by a roller on a flat stone or by a rolling millstone in a stone trough in order to soften the fruit and permit the pits to be removed. After the olives are ground, the oil must be separated from this crushed mass, the πυρῆνα, by pressing, so it is placed in bags and then pressed (Paton and Myres 1898: 209).

Simple oil-presses are made of a spouted trough of stone or wood to hold the bags "with a wooden plank above them, on which men stand to press out the oil" (Paton and Myres 1898: 209). With the application of the principle of leverage for increased pressure came the rise of the early lever or beam press. Pliny the Elder (A.D. 23/24-79) describes four types of presses in his encyclopedia, *Naturalis Historia*: the simple lever, the lever-

and-screw, the weighted screw and the direct-screw (White 1975: 230; *HN* 18.317). Presses thus evolved from the simplest style to the more complicated designs made possible by the use of the lever and, later, the screw. Each of these presses will be treated in more detail in Chapter 6 below. Descendants of the ancient world's simple trough-and-plank presses were being used in Anatolia in 1898 (Paton and Myres 1898: 209), and are no doubt still used today in remote rural areas.

3. Definition and Description of Water Screws and Their Technology

Another example of the principle of the spiral and its adaptation for use in a machine is Archimedes' water screw, a helical screw contained in a wooden cylinder, which was used to lift water for agricultural irrigation or for draining hard-to-reach areas such as ships' bilges (Turfa and Steinmayer 1999: 119, 124 n. 34) and mine shafts. In his description of the *Syracusia* (later *Alexandris*), the massive wheat-carrier built by Hieron II of Syracuse, Athenaeus says (Ath. 5.208.f), ἡ δὲ ἀντλία καίπερ βάθος ὑπερβάλλον ἔχουσα δί ἑνὸς ἀνδρὸς ἐξηντλεῖτο διὰ κοχλίου, Ἀρχιμήδους ἐξευρόντος (Gulick 1957: 442, 444); "The bilge-water, even when it became very deep, could easily be pumped out by one man with the aid of the screw, an invention of Archimedes" (Gulick 1957: 443, 445). Diodorus of Sicily (Diod. Sic. 1.34.2) notes that, in Egypt, τῶν δ' ἀνθρώπων ῥᾳδίως ἅπασαν ἀρδευόντων διά τινος μηχανῆς, ἥν ἐπενόησε μὲν Ἀρχιμήδης ὁ Συρακόσιος, ὀνομάξεται δὲ ἀπὸ τοῦ σχήματος κοχλίας (Oldfather 1961: 112, 114); "the inhabitants easily irrigate [the Nile Delta's] whole area by means of a contrivance which was invented by Archimedes of Syracuse and is called, after its shape, a screw" (Oldfather 1961: 113, 115). Vitruvius gives an excellent description of and instructions for building a water screw. As for draining mine shafts, several examples of Vitruvian water screws have been found in Roman mines in southern Spain (Rickard 1928: 130, pl. 12.2), and the water screw and Archimedes' part in its invention will be investigated in detail in Chapter 6.

4. Spirals in General: Archimedes and Hero

In order to understand the three applications of the spiral noted above, i.e., its uses in architectural column decoration, agricultural presses and devices for raising water, we

must examine the definitions and origins of the spiral. One definition (which is easy for a non-mathematician to understand) is that "a spiral is a flat curve, characterized by infinite twists that continuously increase in a mathematical progression around a point" (Geymonat 2010: 29), and an example of this type of spiral is found in a snail shell. A three-dimensional spiral is more complicated as the spirals do not "continuously increase in a mathematical progression" but wind without increase around a fixed axis; an example of this type is seen in the water screw. But there are other definitions and other forms of spirals which apply more particularly to this study, and, as Archimedes studied the mathematics of the spiral in detail in his work, "On Spirals," we shall discuss him and his work in Chapters 2 and 6. In Chapter 6 we shall also consider the work of Hero (also called Heron) of Alexandria, an inventor at the Museum of Alexandria in the mid-first century B.C., who used the spiral in some of his inventions, e.g., in his direct-screw press. This design, Humphrey says, was used centuries later for early printing presses, an example of the transference of an ancient technology to a modern use (Humphrey 2006: 26, 30-31, figs. 6-7).

5. Questions and Problems to be Examined in This Thesis

1. Where and when did the spiral fluted column originate? Middle Kingdom Egypt, Turkey and Greece have all been suggested as its starting-place, and I shall explore the architectural history of Mesopotamia, Egypt, the Levant, Greece and Rome to find clues about its chronological and geographical sources. Mediterranean trade expanded greatly between 200 B.C. and A.D. 200 as a result of Roman control of the sea, and thus the trade in luxury building materials expanded (Butcher 2003; Dodge 1988; Paton and Schneider 1999; Ward-Perkins 1951). Did this expansion increase the geographical spread of the spiral fluted column?

2. Why and how did the spiral fluted column develop? Was it a reflection of new technological processes and/or mathematical theories? Mesopotamian mathematics were certainly developed enough to permit the construction of the spiral mudbrick column by 1800 B.C. (Robson 1999: 144-46), and, as noted above, by the third century B.C. Archimedes is credited with inventing the spiral mechanisms of waterlifting devices

(Oleson 1984; Vitr. *De arch.* 10.6.1-4). There are connections between Archimedes' theoretical writings and practical inventions, and I will explore these connections. Therefore, what was the increased mathematical and technological knowledge that permitted the calculation and appearance of spirals in architecture in both Bronze Age Mesopotamia and Hellenistic Greece?

3. Was the spiral fluted column used in the construction of specific types of buildings? Was it built with or limited to specific materials, i.e., did it require certain types of stone for strength, did builders use local stone for economic or aesthetic reasons or did rich donors use imported materials to make a personal or political point?

4. Did the practical screw influence the decorative motif or *vice versa*, and what was the relationship to Archimedes' spirals? (Humphrey et al. 1998; Oleson 2008). Pliny the Elder (A.D. 23/24-79) (*HN* 18.74.317) says that the screw press, which involved a large central wooden screw with spiral threads, had been invented relatively recently: *intra C annos inventa Graecanica, mali rugis per cocleam ambulantibus* (Rackham 1950: 388); "but within the last hundred years the Greek pattern of press has been invented, with the grooves of the upright beam running spirally" (Rackham 1950: 389; Humphrey et al. 1998; Oleson 1984). This is approximately the same time that spiral fluted columns emerged in the Roman world.

5. How were spiral fluted columns made? Were most of them monolithic (made of one piece of stone), or were they made of individually cut and shaped stone drums piled atop each other? Architectural attitudes and preferences as well as construction techniques must be considered. The Greeks generally preferred columns built of drums, while the Romans preferred monolithic columns; is this true for spiral fluted columns as well as conventional ones? Another technological advance was the development and use of iron tools. How did the ancients design and construct these spiral flutes on stone columns? Were masons specially trained, and was this type of column therefore more costly than the standard vertically-fluted column? Were the same techniques used to cut spiral flutes and spiral screws? Is there a relationship between the decorative and the practical spiral?

6. Final areas to be examined are the representations of spiral fluted columns shown in frescoes and non-architectural goods such as furniture, pottery, coins and seals, and sarcophagi (particularly those of Anatolia) to see if these representations match the geographic extent of the spiral fluted columns used in architecture (Wace 1954; Von Bothmer 1985; Price and Trell 1977; Brants 1932).

The answers to these questions will advance our knowledge of Mediterranean society as a whole, with emphasis on the core areas of architecture in the ancient world and the history of Graeco-Roman technology and mathematics.

6. Sources

Building on the research done by earlier scholars (Balty 1994; Barletta 2001; Benson 1956, 1959; Chapot 1907; Oleson 1984), I propose to examine both ancient literary sources and archaeological records to answer the six main questions indicated above. As for chronological coverage of the topic, I shall consider evidence from second-millennium B.C. Mesopotamia to the fourth-century A.D. Roman Empire, showing the continuing artistic interest in and the increasing architectural and mechanical emphasis on the spiral.

As well, I include in two appendices compilations of data on spiral fluted columns and other spirals. The first compilation, Appendix 1, is based on my own field work and research on spiral fluted columns and includes information (where known) on their countries, cities, sites, their locations within the sites, the structure types and the cultures with which they are associated, their spiral directions, the materials from which they are made, their dates, and relevant archaeological and literary references. The second compilation, Appendix 2, includes similar information on Archimedes' water screw; ancient olive and grape presses (including both lever and screw presses); other mechanical screws, including some of Hero's inventions that depended on screws; and concludes with a list of ancient stone-working tools and machines for raising stone columns. I will analyse these data to find trends and comparisons and then use this analysis to examine the six questions noted above. Examples of trends so far noted include the following: spiral fluted columns occur primarily in four main types of Roman

structures: theatres (e.g., Sparta, Termessos, Hierapolis, Sabratha, Lepcis Magna and Kourion); nymphaea (e.g., Side, Kourion, Hierapolis and Perge); grand colonnades along important public thoroughfares (e.g., Perge, Ephesus and Apamea); and decorative entryways to sacred or civic precincts (e.g., Aphrodisias and Sardis). In these structures, spiral fluted columns are made primarily of marble, which may be a local stone easily available but hinting of grandeur, or may be brought to the site at great expense to reflect the same idea. More trends will be discussed in Chapter 5.

The use of ancient literary sources (see Bibliography - Primary Sources) is essential when investigating the ancient world, as these authors not only present contemporary facts and theories about ancient society but also give us ideas of how their world worked and what the people themselves were like, both as subjects and authors. However, there are gaps even in works that have survived: although Vitruvius' *De Architectura* is based on his own knowledge as an architect and military engineer, and he does give prevailing architectural ideas and standards, he does not note significant Roman architecture of his own period, the beginning of Augustus' reign. He does, however, include the work of Hellenistic architects now lost to us.

Archimedes' work on the screw and the mathematics of the spiral will be examined further, as noted above, and Pliny the Elder's descriptions of the screw mechanism help to determine the chronology of the agricultural use of the screw. Drachmann has translated and interpreted Hero's instructions for constructing a screwcutter, "an instrument for cutting an inside screw thread in wood," and built a reconstruction of it according to his own interpretation. Hero's documents have been translated and interpreted variously by other scholars and Drachmann's reconstruction has been criticized as "technically impossible" by Kenny (Hero *Mech.* 3.21; Drachmann 1936: 72 fig. 1, 76-7 figs. 4-8; Kenny 1933: 249-50). This is an example which shows another problem with ancient authors: how have their works survived and how can their works be interpreted and their instructions followed according to the authors' intentions when their original Greek or Latin texts have been lost? In this case, Hero's text survived only in an Arabic version which had been translated into German, and therefore shows us that translations into English may vary considerably and thus the resulting machine can be understood or built several ways.

The main secondary sources (see Bibliography - Secondary Sources), all from the 20th century A.D. and the only specific studies of spiral fluted columns, are by Chapot (1907) and Benson (1956, 1959). Their bibliographies, although dated, are helpful in finding original excavation reports and archaeological site guides, and both these sources are invaluable for finding the exact location of columns in a site and/or the present locations of the columns if they are no longer *in situ*. Their references to ancient literary sources are also helpful.

Other useful secondary sources, which include primary sources as well as descriptions and discussions of technological developments, are general surveys of ancient technology such as Humphrey et al. 1998, Humphrey 2006, and Oleson 1984, 1986 and 2008. Also helpful are histories of specific geographic areas, e.g., the Levant (Ball 2000; Butcher 2003; Sartre 2005); general architectural histories (Bretschneider 2007; Dinsmoor 1950); histories of mathematics (Robson 1999; Robson 2007); studies of trade patterns and the preferences for and uses of certain building materials (Ward-Perkins 1951); studies of particular architectural features (Balty 1994; Oates 1990); examinations of the development and technology of specific tools and machines (White 1975; Wilson 2008; Paton and Myres 1898); excavation reports of specific ancient sites or structures within a site (Waywell 1998; Oates 2007); and government- or institutionally-produced tourist guides to archaeological sites (Christou 1996).

Chapter 2: The Mathematics of the Spiral

To begin a discussion of the spiral in the ancient world, it is necessary to define exactly what a spiral is. Archimedes, the third-century B.C. Greek mathematician, scientist and technological genius, wrote a treatise "On Spirals," in which he defines a spiral as follows (*On spirals* 1.1),

> α. Εἴ κα εὐθεῖα ἐπιζευχθῇ γραμμὰ ἐν ἐπιπέδῳ καὶ μένοντος τοῦ ἑτέρου πέρατος αὐτᾶς ἰσοταχέως περιενεχθεῖσα ὁσακισοῦν ἀποκατασταθῇ πάλιν, ὅθεν ὥρμασεν, ἅμα δὲ τᾷ γραμμᾷ περιαγομένα φέρηταί τι σαμεῖον ἰσοταχέως αὐτὸ ἑαυτῷ κατὰ τᾶς εὐθείας ἀρξάμενον ἀπὸ τοῦ μένοντος πέρατος, τὸ σαμεῖον ἕλικα γράψει ἐν τῷ ἐπιπέδῳ (Thomas 1968: 182).
>
> a. If a straight line drawn in a plane revolve uniformly any number of times about a fixed extremity until it returns to its original position, and if, at the same time as the line revolves, a point move uniformly along the straight line, beginning at the fixed extremity, the point will describe a *spiral* in the plane (Thomas 1968: 183; Heath 1952: 483).

It is important to note that the spiral used in the three applications discussed in this thesis, i.e., the spiral fluted column, the water screw and the screw press, is not on a single flat plane, and is not one of infinite and increasing twists. It is rather a spiral which has a defined and constant diameter depending on the scale of the object in which it is used, and is stretched out along a line perpendicular to the plane of the spiral to form what might be called a spiralling prism, i.e., a spiral in three dimensions. In other words, the spiral is "a curve traced by a point moving round, and simultaneously advancing along, a cylinder…[it is] a helix…" (Onions 1973: 2077). Another term would be "cylindrical helix." This type of spiral is found, for example, in a water screw, and is not the same as a spiral on one flat plane, e.g., that which is found in a snail shell. The "cylindrical helix" is the definition which this thesis will apply in examining the monumental use of spirals in architecture and technology.

1. From Mesopotamia to the Classical Period

The spiral, both two- and three-dimensional, has captivated artists and societies for millennia. It was thoroughly examined in the Hellenistic period, as will be shown below, but what theoretical basis was there for spirals in the Bronze and early Iron Age, i.e., was the use of the spiral based on mathematical principles or the generally-accepted

(and continually evolving) procedures of workmen or artists? In this chapter we shall explore the use of spirals from Middle Bronze Age Mesopotamia through classical Greece and Rome by examining influences from the natural world, as well as the mathematics of the spiral used in each society. We shall consider three-dimensional (rather than flat) spirals, and their use in monumental architecture. Flat spirals, however, may occasionally be mentioned to support a cultural, geographic, chronological or ceramic argument.

In the ancient world, as in the modern one, the spiral form continually fascinated architects, potters, painters, stonemasons and sculptors. Since the spiral occurs in nature, artists enjoy the challenge of applying it to manufactured objects. Two examples follow, showing the adaptation in art of two common spiralled animal and plant species which are widespread in the Mediterranean. Firstly, the spiral appears in animal shells such as those of the land snails, gastropods in the phylum *Mollusca*, whose family name, *Helicidae*, comes from the Greek word ἕλιξ meaning spiral or coil. What has the snail shell to do with art? Being ubiquitous in the Mediterranean world, such shells could have been the inspiration for countless spiral designs in architecture and on pottery. Three excellent examples (Fig. 2.1) reproduce the spiral of the snail shell almost exactly: one dates from the late Neolithic period (4000-3000 B.C.) and was found at Dimini, Greece; a similar spiral comes from Mycenae and is dated about 1500 B.C.; and a third from Troy of the same date shows the same spiral. A Middle Minoan (2000-1600 B.C.) example from Knossos on Crete shows two spirals reminiscent of both the snail shell and the acanthus plant (discussed below), and it foreshadows the Ionic capital as well (Petrie 1930: pl. 29: LA 58, LA86, LA8; pl. 30: LC58).

Dimini Mycenae Troy Knossos

Fig. 2. 1 Reproductions of snail shell spirals

Since these are merely examples of the spiral form and are not cylindrical helixes, they are not discussed further below. In addition, I have not found any ancient literary sources that describe the artistic use of spirals.

Another possible influence of the snail shell on art is found in the spiral volutes of the Aeolic capital, a design favoured in Asia Minor, and also in the spiral volutes of the Ionic capital, which is thought to have arisen either on the Aegean island of Naxos (Barletta 2001: 101) or in Asia Minor. Vitruvius describes the design and proportions of the Ionic capital in detail (*De arch.* 3.5.5-7), and for his information he says he relied on the works of Greek architects in Asia Minor, now lost (*De arch.* 4.1.7-8, 7.*praef.*12-18; Barletta 2001: 9). Vitruvius mentions illustrations of the Ionic capital, but none has survived in the manuscript tradition. In concluding his discussion, Vitruvius says (*De arch.* 3.5.8),

> (8) De volutarum descriptionibus, uti ad circinum sint recte involutae, quemadmodum describantur, in extremo libro forma et ratio earum erit subscripta (Granger 1962: 190).
>
> (8) At the end of the book a diagram and formula will be furnished for the drawing of the volutes so that they may be correctly turned by the compass (Granger 1962: 191; Morgan 1914: 93).

The second example of a model spiral is from the botanical world. The acanthus is a thorny plant of the genus *Acanthus* (from the Greek ἄκανθα, meaning a thorn or thistle) which is also found throughout the Mediterranean. It has a spirally-twisted stem (Colling 1898: 144-45) that was used by sculptors intrigued by its shape, as it fitted neatly into different types of architectural elements. Two examples of this application can be cited: firstly, on a carved rectangular block from the precinct of the Hellenistic Temple of Apollo at Didyma, showing one spiral stem (Fig. 2.2) and, secondly, on an akroterion from the first century B.C. theatre at Aphrodisias which shows four spiral stems (Fig. 2.3).

Fig. 2.2

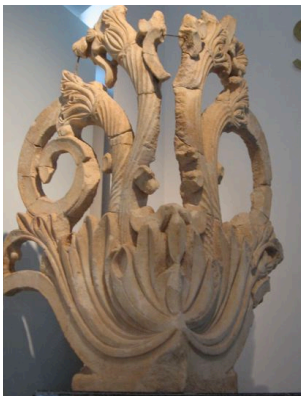
Fig. 2.3 

Fig. 2. 2 Acanthus, Didyma, Turkey
Fig. 2. 3 Acanthus, Aphrodisias, Turkey

A plate in Page's book on drawing the acanthus shows a scrolling acanthus with two fine spiral stems in the lower part of the plant and two vertically-fluted stems above; this plate is labelled simply "Grecian" and is otherwise unattributed and not discussed in the text (Page 1840: pl. facing p. 122: 122-23). The same book contains a plate of another scrolling acanthus, this time with two vertically-fluted stems, noted as a "Pilaster end from the Temple of Apollo, drawn suitable for a cornice." This plate is not described in the text either, but the style of the acanthus pictured is similar to that on the block at the Temple of Apollo at Didyma shown above, which may be the temple Page alludes to (Page 1840: 82-83 pl. 23). Both plates in Page's book show columnar-style fluted stems complete with almost Doric-style capitals out of which spring blossoms and more stems twining into volutes, reminiscent of the Ionic capital.

Vitruvius (*De arch.* 4.1.9-10) says that the acanthus is the inspiration for the Corinthian capital,

> (9) Eius autem capituli prima inventio sic memoratur esse facta. Virgo civis Corinthia iam matura nuptiis inplicata morbo decessit. Post sepulturam eius, quibus ea virgo viva poculis delectabatur, nutrix collecta et conposita in calatho pertulit ad monumentum et in summo conlocavit et, uti ea permanerent diutius subdiu, tegula texit. Is calathus fortuito supra acanthi radicem fuerat conlocatus. Interim pondere pressa radix acanthi media folia et cauliculos circum vernum tempus profudit, cuius cauliculi secundum calathi latera crescentes et ab angulis tegulae ponderis necessitate espressi flexuras in extremas partes volutarum facere sunt coacti.
> (10) Tunc Callimachis, qui propter elegantiam et subtilitatem artis marmoreae ab Atheniensibus *catatechnos* fuerat nominatus, praeteriens hoc monumentum animadvertit eum calathum et circa foliorum nascentem teneritatem, delectatusque genere et formae novitate ad id exemplar columnas apud Corinthios

> fecit symmetriasque constituit; ex eo in operis perfectionibus Corinthii generis distribuit rationes (Granger 1962: 208).
>
> (9) It is related that the original discovery of this form of capital was as follows. A freeborn maiden of Corinth, just of marriageable age, was attacked by an illness and passed away. After her burial, her nurse, collecting a few little things which used to give the girl pleasure while she was alive, put them in a basket, carried it to the tomb, and laid it on top thereof, covering it with a roof-tile so that the things might last longer in the open air. This basket happened to be placed just above the root of an acanthus. The acanthus root, pressed down meanwhile though it was by the weight, when springtime came round put forth leaves and stalks in the middle, and the stalks, growing up along the sides of the basket, and pressed out by the corners of the tile through the compulsion of its weight, were forced to bend into volutes at the outer edges.
> (10) Just then Callimachus, whom the Athenians called κατατηξίτεχνος for the refinement and delicacy of his artistic work, passed by this tomb and observed the basket with the tender young leaves growing round it. Delighted with the novel style and form, he built some columns after that pattern for the Corinthians, determined their symmetrical proportions, and established from that time forth the rules to be followed in finished works of the Corinthian order (Granger 1962: 209; Morgan 1914: 104, 106).

The above examples, then, show how these two widely-occurring natural spirals, one from the animal world and one from the plant kingdom, have influenced designs in the arts and architecture of the Greek world.

2. The Use of Spirals in Mesopotamian Art and Architecture

Excavations have shown that the spiral was used in Mesopotamia to decorate architectural columns as early as the Middle Bronze Age, i.e., by around 1800 B.C. This is the Old Babylonian period of Mesopotamian history, which is conventionally dated from 1900 to 1600 B.C. In this region, a land essentially without stone, the spirals were created in columns formed with specially shaped, sun-dried, mudbricks (Oates 1990: 388). These early columns have no direct chronological or technical connections with classical columns, but they show two important aspects of ancient cultures, and therefore a cultural connection with the later ancient world. Firstly, they are an early example of the appeal and adaptation of the spiral shape, formerly restricted to painted designs or twisted elements on pottery, which is now being used in architecture; in this way, spiral mudbrick columns can be considered as precursors to the classical stone-carved columns. Secondly, they show the progress being made in mathematics, specifically in geometry,

which is required for the design and construction of both the spiral and the palm trunk columns (discussed below), and which will eventually lead to the stone-carved spiral columns of the classical world. The evolution of the architectural spiral and its accompanying mathematics will be discussed further below.

In Mesopotamia, spiral mudbrick columns have been found at the sites of Tell al Rimah (ancient Karana), situated between the Tigris and Euphrates Rivers in northern Iraq, Tell Haddad (ancient Me-Turan) on the Tigris River in northeastern Iraq, Larsa (ancient Telloh) on the Euphrates River in southern Iraq and Tell Leilan (ancient Shubat-Enlil) in the Khabur River area of northeastern Syria. Thus they are not geographically limited to any specific area of the Mesopotamian world. A brief description of the columns, both spiral and palm trunk, found at each of the above sites helps to indicate the types of buildings in which they were located and to determine if there are any similarities in their settings. The excavation reports call these columns "spiral," "barley-sugar" or "twisted" columns.

A. Tell al Rimah

Excavations began at Tell al Rimah in 1964, and continued until 1966 under British and American teams, and British archaeologists carried on the project from 1967-1971 (Dalley 1997: 428). The Great Temple is thought to have been built by the Assyrian king Shamshi-Adad I (1813-1791 B.C.) around 1800 B.C., and this is the first site in Mesopotamia where spiral mudbrick columns were discovered, along with palm trunk columns in the same building complex (Oates 1990: 392 fig. 3, 393 pl. 1). This site has been called "one of the finest examples of Bronze Age monumentality" (Bretschneider 2007: 173), and the impressive plan and decoration of its mudbrick Great Temple suggest that it was built by skilled architects and a large number of craftsmen. Its outside and courtyard frontages featured 277 engaged columns, either single or in groups, 50 of which were constructed and decorated as spiral columns or palm trunks showing two styles of pruning, either scale-patterned or diamond-patterned (Oates 1967: 78-79, 84, 94, pl. 32 a-b, pl. 36; Oates 2007: 173; Robson 1999: 145; Postgate 1977: 63; Dalley and Oleson 2003: 8, 9 fig. 2). The palm trunk decoration found in Mesopotamian temples and ziggurats may represent the "Tree of Life" (Oates 1967: 78) and Woolley, who found this

decoration also at Ur, says that these columns are obviously "a translation into brickwork of an effect originally produced by timber construction" (Woolley 1939: 42, pl. 30 a-b). Weiss notes that this style is also found at Tell Leilan, as discussed below (Weiss 1985a: 10-11; Weiss 1985b: 278). Since palm trees are not native to northern Mesopotamia, this style of decoration was clearly transplanted to northern sites from the south, where the palm tree is a symbol of agricultural fertility (Weiss 1985a: 11). There is, however, a stylistic connection between spiral and palm trunk columns, as follows: at Tell al Rimah, there is a carved block showing a man between palm trees whose trunks have a herringbone pattern, and Weiss says this herringbone pattern is the same as the spiral patterns on the spiral columns at Tell al Rimah. Therefore, spiral columns at Tell al Rimah, Tell Leilan and Larsa (the latter two sites are discussed below) could also represent palm trunks "whose frond imbrications [overlapping edges] could be perceived and represented as diagonal cuts along the palm trunk" (Weiss 1985a: 11; Howard-Carter 1983: 67, pl. 3a). Some palm trees also have a spiralling pattern in their bark, as shown in "some stone and terra-cotta sculptures" (Dalley and Oleson 2003: 8; Dalley 2002: 71).

Cuneiform tablets from ancient Mari, southwest of Tell al Rimah on the Euphrates River and a site roughly contemporary with these three sites, reveal the use of palm trunks in building construction, as Shamshi-Adad I, ruler of Mari, wrote to his son, Yasmakh-Adad,

> The palms, cypresses and myrtles that have been brought from the town of Qatanum lie at present in the town of Subrum…. Send one-third of the palms, cypresses and myrtles to Ekallatum, one-third to Nineveh and one-third to Shubat Enlil [Tell Leilan] (Weiss 1985a: 11).

Qatanum, also known as Qatna or Qatana, is thought to be modern Homs in western Syria. It is situated on the Orontes River (Dalley 1984: 2, 7, 45; Heimpel 2003: 619) and thus is linked with the Mediterranean, so it could reasonably have been a centre for importing trees or lumber and exporting it to treeless inland cities, such as those mentioned on the tablet above. Subrum, or Suprum, is "within the kingdom of Mari," but its location is unspecified, and it is thought to be Tell Abu Hasan on the Euphrates River in western Iraq/eastern Syria (Dalley 1984: 71; Heimpel 2003: xxii-xxiii, 623). Ekallatum is north of Assur and on the Tigris River in northwestern Iraq (Dalley 1984: 31; Heimpel 2003: xxii-xxiii, 609); Nineveh is north of Ekallatum and also on the Tigris River in

northwestern Iraq (Dalley 1984: 2; Heimpel 2003: xxii-xxiii); and Shubat Enlil (Tell Leilan) is in northeastern Syria. All these settlements, therefore, are located in areas lacking wood for construction and would be dependent on importing it, so this text is important as it shows examples of the types of wood traded and the trade routes used.

In the temple courtyard at Tell al Rimah, at first inspection, four engaged half-columns near the southwest corner were thought to be simple semi-cylinders, but after deeper excavation, this appearance was found to be "the result of repeated replastering," and they were originally grooved spiral columns. Other plain-looking columns nearby were found to have the diamond- and scale-shaped patterns of palm trunks (Oates 1967: 79). Many other smoothly-faced columns on Mesopotamian sites may conceal spirals or palm trunks beneath coats of mud plaster. On the outside of the temple, similar spiral and palm trunk columns were arranged across its east front, and the decoration on the south front shows both undecorated and scale-patterned palm trunk columns (Oates 1967: 84, pl. 33, 36). A ziggurat to the west of the temple is only partly attached to the temple, as its east wall joins the temple's west wall ten metres above the temple floor. The ziggurat's west front has the same spiral and palm trunk columns as the temple's south face (Oates 1967: 85, pl. 38 a-b). Construction methods for both these types of columns will be examined in detail in the following section on Mesopotamian mathematics. Oates says that the Great Temple's ornate construction "is a statement of power and wealth" by King Shamshi-Adad I, who, although one of the most powerful kings of the second millennium B.C., placed this statement in a "minor city in his northern kingdom" (Oates 2007: 175 fig. 12, 176 fig. 13).

B. Tell Haddad

Tell Haddad, northeast of Tell al Rimah, was excavated quickly between 1977 and 1984 because it was due to be flooded, along with many other archaeological sites in the area, by the new Diyala River dam, to be built northeast of Baghdad. The Hamrin Dam Salvage Project began under international teams of archaeologists (Roaf 1997: 471). In 1984, spiral and palm trunk columns of similar styles to those at Tell al Rimah were found here in the temple or palace. Dated to the mid-18th century B.C., this building also contains engaged mudbrick columns which line the inner walls of two rectangular

courtyards, which themselves are similar to the Great Temple's courtyard noted above (Killick and Black 1985: 220).

C. Larsa

Excavation at Larsa was begun in 1933 by the University of Paris, ceased, then was continued from 1967-1991. Cuneiform texts from the beginning of the second millennium B.C. on document its history (Margueron 1997: 331-333). After the death of Shamshi-Adad I in 1791 B.C., his kingdom collapsed and southern Mesopotamia was taken over by Hammurabi (1792-1750 B.C.), king of Babylon. The southern city-state of Larsa, powerful since the 20th century B.C., was a rival of Babylon to the north, and Hammurabi's conquest of King Rim-Sim of Larsa in 1763 therefore secured Babylon's power in the south (Armstrong 1996: 458).

During the 1969-1970 field season at Larsa, six engaged spiral mudbrick columns were found in the excavation of a building bordering a courtyard in the southeast quadrant of the site (Margueron 1970: 274, 275 fig. 9, pl. 16.2). Although these columns were integrated into a wall, their bases rested on six mudbricks, each of which contained the name of the Kassite king, Kadasman-Enlil (also written as Kadashman Enlil). The Kassite period is conventionally dated from the 15th to the 12th centuries B.C. (Stein 1997: 271), and it is not known whether the ruler mentioned on the tablets was the 14th-century B.C. Kadasman-Enlil I or his 13th-century B.C. successor, Kadasman-Enlil II (Negahban 1991: 108). The inscriptions, which are identical on each brick, announce the reconstruction of the temple of E-Babbar, the Temple of the Sun, by the king:

> Kadasman-Enlil, roi fort, roi de Babylone, roi de Sumer (et) d'Accad….l'Ebabbar, l'ancien temple (?) de Samas (?) qui, depuis longtemps, était en ruines, il construisit (répara) (et) restaura (Birot 1968: 246-247; Margueron 1970: 274).
>
> Kadasman-Enlil, strong king, king of Babylon, king of Sumer (and) of Accad… Ebabbar, the ancient/former temple (?) of Samas (?)…which for a long time was in ruins, he built (repaired) (and) restored (Birot 1968: 243, 246-247; [trans. G. Henderson]).

Because of the small size of the cleared zone, it is impossible to know if these columns, which resemble those at Tell al Rimah, were part of a simple reconstruction by one of these rulers or if they resulted from a complete reorganisation of the whole temple

(Margueron 1970: 274; Oates 1967: pl. 32, pl. 36). The finding of these inscribed tablets is particularly significant as they show that, no matter which king had them placed beneath the columns, he was interested in maintaining or emphasizing architectural tradition and a connection with the past (and thus emphasising his own lineage and reputation) by rebuilding in the style of half a millennium before his reign.

In the next field season in 1970, a group of courtyards around the Temple of E-Babbar was discovered, among which Courtyard One included spiral columns like those at Tell Leilan (Weiss 1985a: 11; Calvet 1976: 4). In this courtyard, a group of seven engaged spiral mudbrick columns was found along the southwest wall, of which the first, fourth and seventh columns were made with semi-circular bricks laid horizontally, while the other four were built as spiral columns. This variation is not described in the text, but is plainly seen in the accompanying figure and photograph (Calvet 1976: 33 fig. 5, pl. 1.1), and this variation is repeated in the columns found along the northwest wall, which will be described below. The columns had later (the date is unspecified) been covered with a thick coating of mud plaster (this is speculation, as the excavator does not say what material was used), and were similar to the columns found at Tell al Rimah. These columns were comparable to the ones found here at Larsa in the previous season, but were so badly eroded that that it was difficult to distinguish their spiral pattern, and this time no stamped mudbricks were found at their bases (Margueron 1971: 274, 275 fig. 2, pl. 15.1; Calvet 1976: 4, 33 fig. 5, pl. 1.1-1.2). Four engaged spiral mudbrick columns were also found just south of the courtyard's central doorway, also covered with (probable) mud plaster, but which still allowed their spiral forms to be seen. This coating, along with the nearby wall, showed traces of burning (Calvet 1976: 5, pl. 1.3-1.4, pl. 2.1).

Another group of seven engaged spiral mudbrick columns was found along the northwest wall of the courtyard (Fig. 2.4), but, as on the southwest wall, erosion plus a coating of (probable) mud plaster made it difficult to discern the spirals, and again no stamped mudbricks were found under these columns (Margueron 1971: 276, 275 fig. 2, 277 fig. 3, 278 fig. 4, pl. 15.3; Calvet 1976: 16, 35 fig. 13, 38 fig. 18, 39 fig. 19, pl. 3.3-3.4).

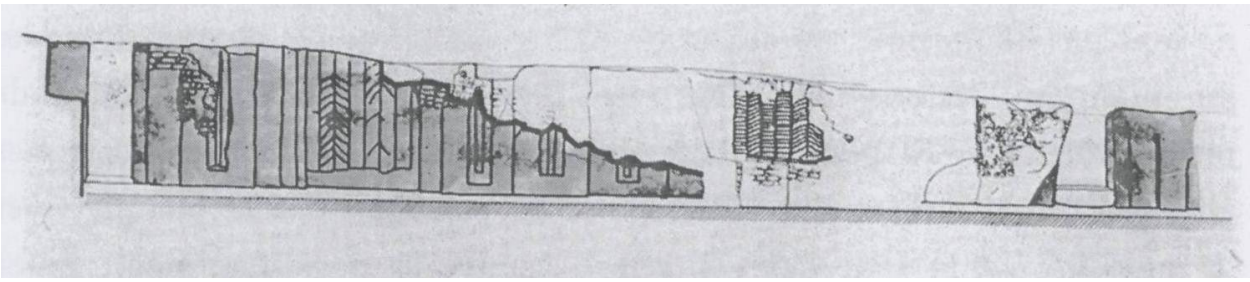


Fig. 2. 4 Northwest wall of courtyard, Larsa, showing torn-out wall and displaced columns

Here, too, as on the southwest wall, the first, fourth and seventh columns were made with semi-circular, horizontally-placed bricks and the others were built as spiral columns (Calvet 1976: 16, 34 fig. 12, 44 fig. 33). A similar group of columns was set between the central door and the door on the west side (Calvet 1976: 16).

D. Tell Leilan

Tell Leilan flourished by the beginning of the second millennium B.C., as documented by cuneiform tablets, and excavations by Yale University and New York's Metropolitan Museum of Art began here in 1978 and continued until 1991. The lower town's palace and the temple on the acropolis were thought to have been built during the reign of Shamshi-Adad I (Weiss 1997: 345). The northeast quarter of the acropolis was excavated in three levels, Level One being the first level under the surface and consisting mostly of the remains of a mudbrick platform or mudbrick paving; all three levels have been pottery-dated to the 19th century B.C. (Weiss 1985a: 7). A large earlier building, with its collapsed southern side abutting the platform or paving, has been identified as a temple. While excavating Level Three (the lowest level) the team found part of a courtyard with surrounding rooms. The north wall of this courtyard had spiral mudbrick engaged columns set against a central engaged column decorated as a palm trunk (Weiss 1983: 276; Weiss 1985a: 7, 13). On Level Two, to the north of and above Level Three, was a partial reconstruction of Level Three's building, and the reconstruction has been identified as a temple by cylinder seal impressions and cuneiform tablet inscriptions (Fig. 2.5). There was also a courtyard with both spiral and palm trunk engaged mudbrick columns, the latter on its south exterior and the former on its north (Ball 2000: 384).

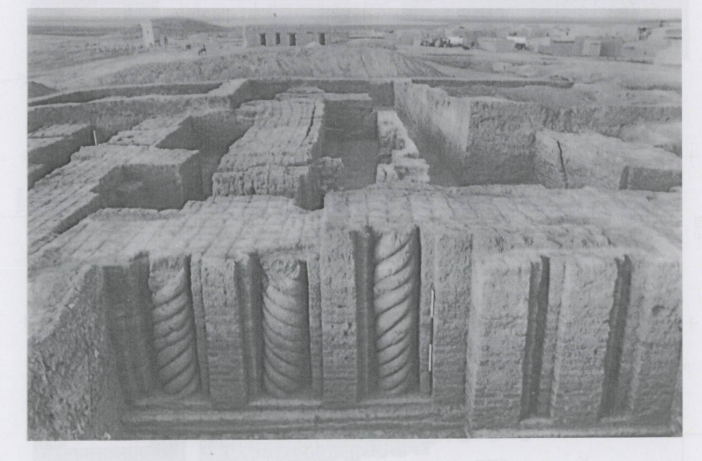


Fig. 2. 5 West side of the Building Level II temple on the Acropolis, Tell Leilan

Weiss notes the strong impression that must have been given by this "array of mudbrick architectural power" to the traders following the route past Tell Leilan, as these walls may have risen six or seven metres from the twenty-metre-high acropolis (Weiss 1985a: 12-13). The spiral columns at this site are very similar to those at Tell al Rimah and Larsa, and, as all three sites fall within the Old Babylonian time period (Weiss 1983: 276; Weiss 1985a: 8), these discoveries emphasise the geographical spread of this type of column and the probability of travelling architects and/or engineers spreading ideas of new construction techniques and their applications to old materials throughout the Mesopotamian world.

What was the significance, then, of these columns and their locations? They were not built and then carved with spirals, but rather made with mathematically-shaped bricks placed in position (the mathematics of construction are investigated below). The columns were expensive to make, requiring trained architects and meticulous builders, and therefore were used in areas for symbolic or honorific purposes. Oates says that when the function of the buildings featuring these columns is identifiable (one assumes by cuneiform writings on clay tablets, inscriptions on statues or architectural features, or attributable or dateable small finds), "they appear always to have been temples" (Oates 1990: 392). These columns also appear in the ziggurat at Tell al Rimah, which is partly physically attached to the Great Temple but is a religious structure in its own right, the ziggurat being a temple-tower symbolising divine power whose function is "to support

the temple of the city god" (Stone 1997: 391). The word "ziggurat" comes from the Accadian *ziqqurratu*, meaning peak or summit (Albright 1944: 303). Mesopotamian society was centred on the temple rather than a civic authority, and thus the spiral and palm-trunk columns, which required expensive construction designers and techniques, were suitable for a temple or ziggurat honouring local or regional deities.

3. The Mathematics of Spirals

A. Mesopotamia

How were these Mesopotamian spiral and palm trunk engaged columns constructed in mudbrick? Were the mudbricks shaped and decorated before the construction of the columns? Are these column designs based on mathematics, or simply laid out by eye? At Tell al-Rimah, Oates says that both spiral and palm trunk columns were composed of bricks with relief patterns on their outer sides, which, when arranged in layers as noted below, gave the necessary patterns to the columns. The basic shape of the brick was "a 60 degree sector of a circle of radius c. 29 cm." These bricks were manufactured either in special brick-moulds or cut from a brick made in the standard square mould which then had the ornament carved on the semi-circular outer surface of the brick. It is important to note that the brick faces were carved before the bricks were built into a column (Oates 1967: 79-80, 88). The spiral half-columns of Tell al Rimah's Great Temple and ziggurat were then constructed in a four-course sequence of shaped bricks as follows (Fig. 2.6):

> Two of these layers comprised three or four wedge-shaped bricks dividing the columns into 60 degree segments…alternating with courses of one central block surrounded by six roughly semicircular bricks continuing the spiral motif (Oates 1990: 392-396, 395 fig. 4 a-b; Robson 1999: 145 fig. 9.4).

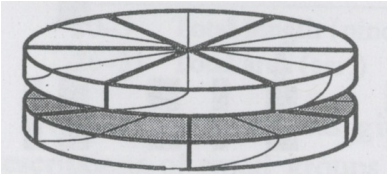


Fig. 2. 6 Construction of the Tell al Rimah columns

Oates says that the cutting of the bricks for the spiral columns was a more complex geometrical problem than the brick-cutting for the palm trunk columns, but "the basic

knowledge required was no greater." Each shaped brick had on its outer side "parts of two adjacent strands of the spiral separated by a slanting groove, the angle of which determined the twist [or slant] of the spiral," and the bricks were laid so that "their centres were 15° off the line of the sides of the brick, to right or left according to whether a right-hand or left-hand spiral was required" (Fig. 2.7) (Oates 1967: 88, pl. 40; Oates 1990: 395 fig. 4). The brick-laying was complicated by the fact that, as these bricks at Tell al Rimah were being used to construct engaged spiral columns, they had somehow to be connected to the wall behind them, and this was done as follows. Full-sized "sector bricks," i.e., the bricks cut so as to form the spiral shape, were laid in alternate courses, and between these courses were laid horseshoe-shaped bricks which ran into the wall behind the column. Then sector bricks cut in half widthwise were laid in front of the horseshoe-shaped bricks to continue the spiral pattern and brick pieces and mortar filled any gaps (Fig. 2.7) (Oates 1967: 89, pl. 40).

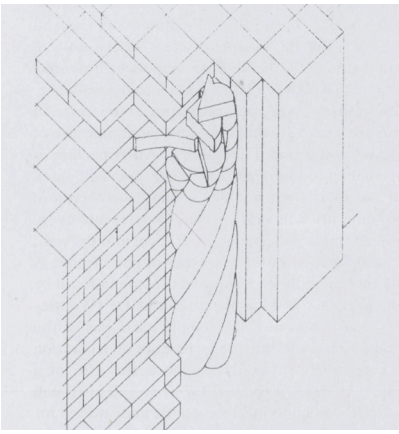


Fig. 2. 7 Reconstruction of a spiral column on the west façade of the Tell al Rimah ziggurat

Another example of the use of shaped bricks is seen at Larsa, as noted above, where groups of columns contained bricks laid in both spiral and horizontal patterns. The bricks used for the horizontal patterns were shaped so that their visible edge was formed into a semi-circle, and thus these shaped columns were not carved from standard bricks when laid *in situ* but custom-made with specifically-designed bricks (Calvet 1976: 16, 34 fig. 12, 44 fig. 33).

As for the two types of palm trunk columns, the ones with the scale pattern were made with one course of bricks, each of which was carved with three scales, and the

diamond pattern columns were made with four courses of bricks carved in four different patterns (Oates 1990: 395; Robson 1999: 145). Parallels to the Tell al Rimah diamond pattern columns have been found at Ur, where they are located at the entrance to Warad-Sin's bastion, built around 1830 B.C. Here they were also constructed of custom-moulded bricks, which were then covered with thin greenish plaster, similar to that on the columns at Tell al Rimah, and Oates says this similarity in technique resulted from "the employment of master builders trained in the same, presumably south Mesopotamian, tradition" (Oates 1967: 90; Woolley 1939: 43). Neither Oates nor Woolley says if the green colour was significant, but it could result either from the use of local clays or the wish to mimic a colour from nature. Woolley notes that the palm trunk columns at the bastion of Warad-Sin mark the most ornate style of building from the Isin-Larsa period (about 2100-1900 B.C.) at this site and, since some of them are almost free-standing, they are important in the history of Mesopotamian architecture (Woolley 1939: 42-43, pl. 30 a-b).

Later examples of columns fashioned from shaped bricks have been found, showing that the technique of building with the shaped brick continued in Mesopotamia, but the style and artistic quality of the decoration for which it was used declined as follows: Aqar Quf, west of Babylon in southern Mesopotamia, is ancient Dur Kurigalzu, built in the later Kassite period around the late 15th to early 14th centuries B.C. Although square-shaped bricks found here show cross-sections of spiral columns on their outer sides, they were "designed to be incorporated in… a wall [relief]" rather than into a column, and are not built to the same design or standard as the ones used in "the elaborately ingenious mud-brick [constructions] of Ur and Tell al Rimah" (Oates 1967: 90). Examples of these later bricks are found in wall reliefs from Uruk (modern Warka on the southern Euphrates River) in the 15th century B.C. temple of the goddess Inanna, built by the king Karaindash (Oates 1967: 90; Heimpel 2003: xxi; Parrot 1960: 316, 317 pl. 392). Here columnar-style figures, whose lower halves have either palm trunk decorations or wavy lines, alternate with panels of wavy lines running into rounded-arch shapes at the bottom of the panel (Fig. 2.8). This style, though not as complicated to construct, recalls the earlier spiral and palm trunk columns from the sites discussed above, and, indeed, Parrot says that both the plan and the decoration of this temple echo that of the previous

millennium (Parrot 1960: 316). A second example of this shaped-brick style of wall reliefs is seen on a wall panel from Susa (in southeastern Mesopotamia/Iraq), which features a god in the shape of a man-bull and a columnar-bodied goddess (Fig. 2.9). This panel has been dated to the second half of the second millennium B.C. and shows a palm tree with a stylised trunk between the two figures (Oates 1967: 90; Dalley 1984: 2; Parrot 1960: 328, 329 pl. 405). This panel shows this time period's simplifying of decorative elements as follows: the palm trunk with its large imbrications is much simpler than the detailed palm trunks of the sites discussed above**,** the artists show no desire to make the tree or its foliage realistic, and the goddess seems to be part of the wall, with only her top half having linear and stylised human characteristics.

Fig. 2.8

Fig. 2.9

Fig. 2. 8 Mural decoration from Temple of Karaindash, Uruk
Fig. 2. 9 Bull-god and goddess, Susa

Robson has studied Mesopotamian mathematics and compares mathematical theory at this time (the mid-Old Babylonian period, or around 1800-1700 B.C.), which is based on the information from cuneiform tablets (the "theoretical bricks"), with actual bricks from house plans and the measurements of construction materials revealed by excavation. It is important to note that in the following discussion Robson examines only baked, stamped bricks and excludes unbaked ones, so that bricks could be dated. There were twelve standardized sizes of brick in the mathematical records, which varied in size from 10 to 30 "fingers," i.e., 16-48 cm in length and generally a variant of five fingers (8 cm), the "ideal" width, in thickness. Although most bricks are square, there are also two-thirds bricks, where the width is two-thirds of the length, and half-bricks, where the width

is half the length. The bricks used at Larsa, although not showing the complete range of sizes, generally fit these proportions. Robson's work thus verifies the tablets' mathematical theory and its use in actual construction. There is only one size not mentioned in cuneiform mathematical records but found in excavations dated to the Larsa period: an 18-finger (approximately 28 cm) half-brick, so thus the tablet and construction information remains basically the same (Robson 1999: 145-147).

B. Greece

As for the influence of Babylonian mathematics on the later ancient world, Robson states that, when the Old Babylonian state fell in 1600 B.C., much of the scribal culture, which included Babylonian mathematics as well as Sumerian literature, was lost. In the second millennium B.C., "when cuneiform culture spread west to Egypt and the eastern Mediterranean coast…mathematics did not travel with it" (Robson 2008: 286), and thus it had no influence on early Greek mathematics. By the mid-seventh century B.C., however, it is posited that later Babylonian mathematics, i.e., from the Middle- to Neo-Babylonian periods or about 1300-500 B.C., could have had an influence on emerging Greek mathematics. Scholars differ on this point, with some believing that transmission did not happen until the fifth century B.C., and others saying that there is little or no evidence of direct transmission before the time of Alexander (Robson 2008: 286-87). Classical and later Greek authors understood Egypt to be the source of mathematics, and Chaldaean/Babylonian priests to be the source of astrology and astronomy. Robson mentions that Strabo notes three Babylonian astronomers, two of whose names have been found on cuneiform tablets. Direct contacts between Greek and Babylonian astronomy are attested in the Persian and Hellenistic periods, i.e., from about 550-150 B.C., but "there are no early Greek traditions about Babylonian mathematics" (Robson 2007: 58).

What about Greek mathematicians? How did mathematics develop in Greece so as to permit the advancement of its science, art and architecture? Perhaps the most famous of Greek mathematicians was Archimedes of Syracuse (287-212 B.C.), whose work included not only mathematics but also its practical applications to physics and engineering, as seen in such inventions as the winch and the screw pump (also known as

the water screw or water snail), and weaponry which included catapults and "burning mirrors" (Geymonat 2010: ix). Plutarch's description of Archimedes in his "Life of Marcellus" (Plut. *Marc.* 17.3-5) gives us a striking picture, fantastic or not, of the man and his work:

> (3) Τηλικοῦτον μέντοι φρόνημα καὶ βάθος ψυχῆς καὶ τοσοῦτον ἐκέκτητο θεωρημάτων πλοῦτον Ἀρχιμήδης ὥστε, ἐφ᾽ οἷς ὄνομα καὶ δόξαν οὐκ ἀνθρωπίνης, ἀλλὰ δαιμονίου τινὸς ἔσχε συνέσεως, (4) μηθὲν ἐθελῆσαι σύγγραμμα περὶ τούτων ἀπολιπεῖν, ἀλλὰ τὴν περὶ τὰ μηχανικὰ πραγματείαν καὶ πᾶσαν ὅλως τέχνην χρείας ἐφαπτομένην ἀγεννῆ καὶ Βάναυσον ἡγησάμενος, εἰς ἐκεῖνα καταθέσθαι μόνα τὴν αὐτοῦ φιλοταμίαν οἵς τὸ καλὸν καὶ περιττὸν ἀμιγὲς τοῦ ἀναγκαίου πρόσεστιν…(5) οὐ γὰρ ἔστιν ἐν γεωμετρίᾳ χαλεπωτέρας καὶ βαρυτέρας ὑποθέσεις ἐν ἁπλουστέροις λαβεῖν καὶ καθαρωτέροις στοιχείοις γραφομένας (Perrin 1961: 478, 480).

> (3) And yet Archimedes possessed such a lofty spirit, so profound a soul, and such a wealth of scientific theory, that although his inventions had won for him a name and fame for superhuman sagacity, (4) he would not consent to leave behind him any treatise on this subject, but regarding the work of an engineer and every art that ministers to the needs of life as ignoble and vulgar, he devoted his earnest efforts only to those studies the subtlety and charm of which are not affected by the claims of necessity….(5) For it is not possible to find in geometry more profound and difficult questions treated in simpler and purer terms (Perrin 1961: 479, 481).

Who began the mathematical examination of the spiral? About 225 B.C., Archimedes produced a definitive work called "On Spirals." The Greek mathematician, Pappus of Alexandria (A.D. 290-350), however, in his work the *Synagoge* (or, the *Mathematical Collection*, a compendium of his mathematical writings), attributed the definition of the spiral to the geometer Conon of Samos (280-220 B.C.) rather than to Archimedes. He states that the theory of spirals originated with Conon, and that Archimedes proved it ἀπέδειξεν δὲ Ἀρχιμήδης θαυμαστῇ τινι χρησάμενος ἐπιβολῇ (*Mathematical Collection* 4.21); "by means of a remarkable procedure" (Knorr 1978: 44). However, Archimedes says that he himself originated the theory of spirals and that he sent it to Conon for comment, but Conon died before he could reply. Archimedes says this in a letter to Dositheus of Pelusium, one of Conon's students, which is included in his introduction to "On Spirals" (1.2-10):

> Τῶν ποτὶ Κόνωνα ἀποσταλέντων θεωρημάτων, ὑπερ ὧν αἰεὶ τὰσ ἀποδειχίιας ἐπιστέλλεις μοι γράψαι, τῶν μὲν πλείστων ἐν τοῖς Ἡρακλείδα κομισθέντεσσιν ἔχεις γεγραννένας, τινὰς δὲ αὐτῶν καὶ ἐν τῷ βιβλίῳ γράψας ἐπιστέλλω τοι. μὴ θαυμάσης δὲ, εἰ πλείονα χρόνον ποιήσαντες ἐκδιδομες τὰς ἀποδείξιας αὐτῶν.

> Συμβαίνει γὰρ τοῦτο γεγενῆσθαι διὰ τὸ βοὐλεσθαιμ με πρ΄τερον διδόμεν τοῖσ περὶ τὰ μαθήματα πραγματευομένοις καὶ μαστεύειν αυτὰ προαιρουμένοις. Πόσα γὰρ τῶν ἐν γεωμετρίᾳ θεωρημάτων οὐχ ευμέθοδα ἐν ἀρχα φανέντα χρόνῳ τὰν ἐξεργασίαν λαμβᾳανοντι; Κόνων μὲν οὖν οὐχ ἱκανὸν λαβῶν ἐς τὰν μάστευσιν αὐτῶν χρόνον μετάλλαξεν τὸν βιόν (Heiberg 1972, vol. 2: l.2-10)
>
> Of most of the theorems I sent to Conon, and of which you ask me from time to time to send you the proofs, the demonstrations are already before you in the book brought to you by Heracleides; and some more are also contained in that which I now send you. Do not be surprised at my taking a considerable time before publishing these proofs. This has been owing to my desire to communicate them first to persons engaged in mathematical studies and anxious to investigate them. In fact, how many theorems in geometry which have seemed at first impracticable are in time successfully worked out! Now Conon died before he had sufficient time to investigate the theorems referred to…. (Heath 1952: 482).

Archimedes was in the habit of asking Conon for comments on his ideas, as is shown in another letter he wrote to Dositheus concerning his recent work on "The Quadrature of the Parabola" (l.3-10),

> Ἀκούσας Κόνωνα μὲν τετελευτηκέναι, ὁς ἦν οὐδὲν ἐπιλείπων ἁμῖν ἐν φιλία, τὶν δὲ Κόνωνος γνώριμον γεγενῆσθαι καὶ γεωμετρίας οἰκεῖον εἶμεν τοῦ μὲν τετελευτηκότος εἵνεκεν ἐλυπήθμες ὡς καὶ φίλου τοῦ ἀνδρὸς γεναμένου καὶ ἐν τοῖσ μαθημάτεσσι θαυμαστοῦ τινοσ, ἐπροχειριξάμεθα δὲ ἀποστείλαι τοι γράψαντες, ὦς Κόνωνι γράφειν ἐγνωκότες ἥμες, γεωμετρικῶν θεωρημάτων…. (Heiberg 1972: 262).
>
> When I heard that Conon, who was my friend in his lifetime, was dead, but that you were acquainted with Conon and withal versed in geometry, while I grieved for the loss not only of a friend but of an admirable mathematician, I set myself the task of communicating to you, as I had intended to send to Conon, a certain geometrical theorem….(Heath 1952: 527).

Knorr thinks it unlikely that Conon had "worked out the theorem on the area of the spiral" and was simply studying it in relation to solving the problem of trisecting angles (Knorr 1978: 69).

Pappus discusses the mathematics of spirals in the *Synagoge* (*Mathematical Collection* 4.21-25), and it is important to note that Pappus' and Archimedes' works on the spiral differ, as there is "different phrasing at crucial points [and] six propositions in Pappus instead of the twenty in Archimedes" (Cuomo 2000: 158). To explain these differences, some scholars have suggested that the fourth-century A.D. Pappus, living some six centuries after Archimedes, was able to work only from "excerpts and

summaries" of an earlier (now lost) version of Archimedes' ideas. Knorr dismisses this idea, as he has considered both Archimedes' and Pappus' works on spirals, and suggests that Pappus took his own discussion of the spiral "from an Archimedean work addressed to Conon" which was extant before Archimedes' final version of his "On Spirals." Thus Pappus was developing his own theories based on Archimedes' uncompleted work, and the *Synagoge* is useful as an examination of Archimedes' early ideas on this subject (Knorr 1978: 44-45, 48, 69). Cuomo suggests that the idea of crediting lost sources is unnecessary as the differences can be explained by the time lapse between the two mathematicians, and also by their dissimilar aims: Pappus gives a detailed example of a spiral curve, including specific reference points on a diagram (e.g., radius BA), while Archimedes presents a spiral in general terms (e.g., a line moves around a point). Cuomo states that, of the twenty propositions presented by Archimedes in his introductory letter to "On Spirals," only one does not occur in Pappus' work, and that actually "the theorems in Pappus' account of the spiral correspond…to the theorems Archimedes picks up for his introductory letter to the 'Spirals'" (Cuomo 2000: 158-160). Archimedes' theoretical work on spirals led to his practical inventions of the screw windlass and the water screw, both of which will be discussed in Chapter 6, along with other applications of the spiral to technology and mechanics.

Other mathematicians concerned with the spiral include the geometer Apollonius, born at Perge in Pamphylia about 262 B.C. He was a mathematician who specialized in conics and much of his work has been preserved in the writings of Pappus. Proclus Diadochus (A.D. 410-485), as well as writing about astronomy and theology, wrote a commentary on Euclid which included a history of Greek geometry. In it he describes the cylindrical helix, noting Apollonius' work as follows (On Euclid. *Definitio* 4, 105: l. 1-6),

> Τὴν περὶ τὸν κύλινδρον ἕλικα γραφομένην, ὅταν εὐθείας κινουμένης περί τὴν ἐπιφάνειαν τοῦ κύλινδρου σημεῖον ὁμοταχῶς ἐπ' αὐτῆς κινῆται. Γίνεται γὰρ ἕλιχ, ἧς ὁμοιομερῶς πάντα τὰ μέρη πᾶσιν ἐφαρμόζει, καθάπερ Ἀπολλώνιος ἐν τῷ Περί τοῦ κοχλίου γράμματι δεὶκνυσιν (Thomas 1968: 10: 350).
>
> The cylindrical helix is described when a point moves uniformly along a straight line which itself moves round the surface of a cylinder. For in this way there is generated a helix which is *homoeomeric* [having like parts], any part being such that it will coincide with any other part, as is shown by Apollonius in his work *On the Cochlias* (Thomas 1968: 10: 351).

The work of all these mathematicians, which was essential to the advancement of artistic and architectural theory as exemplified by the artists, architects and engineers of Greece, became the foundations of developments in Roman art, architecture and engineering as laid by Hellenistic mathematicians. The use of the spiral column as a building element could never have existed without this cross-connection.

C. Rome

The Romans were not as interested in mathematical theory as the Mesopotamians and the Greeks, being concerned primarily with practical applications of mathematics and geometry to engineering (e.g., aqueduct construction), architecture (e.g., amphitheatre design), and the arts (e.g., sculpture and painting). This attitude is best stated as follows:

> Vitruvius devoted his tenth book to "machines" and approached the topic with the Roman sense of the "practical." This attitude divides technology into three classes: useful, amazing or comfortable, and irrelevant. "Can it crush gravel and if not, can we bathe in it?" would be a typical Roman question (Brumbaugh 1966: 94).

Smith notes that, although the Greeks had laid the foundations for Rome to expand pure mathematics, the Romans "produced not a single mathematician of the first rank, nor did she produce a single treatise on this branch of the subject that showed the slightest originality" (Smith 1963: 10). Cicero describes this attitude as well (*Tusc.* 1.2.5),

> In summo apud illos [Graecos] honore geometria fuit, itaque nihil mathematicis illustrius; at nos metiendi ratiocinandique utilitate huius artis terminavimus modum (King 1971: 6).

> With the Greeks, geometry was regarded with the utmost respect, and consequently none were held in greater honour than mathematicians, but we Romans have restricted this art to the practical purposes of measuring and reckoning (King 1971: 7).

That said, we must not discount Rome's contributions to mathematics, as, according to Smith, Rome "made a more tangible use of it than the Greeks…. Hence Rome developed the applied side of the science" (Smith 1963: 11). An example of this applied science is the development and improvement of geometry-based land surveying, which the Romans expanded from the Egyptian model, and whose work in this field was never superseded in the ancient world. Some surveying information is preserved in the

writings of Hyginus, a surveyor of about A.D. 100, and more of the work of the *Gromatici,* the land-surveyors, was collected in the sixth century A.D. The textbooks used to train these surveyors included the basic geometry required for their work, and Geymonat notes that this "specific connection between geometry and land surveying" lasted throughout the Middle Ages (Smith 1963: 139-40; Geymonat 2009: 13-14). Two Roman engineer-architects who wrote handbooks on ancient technology are Vitruvius, who lived in the late first century B.C., and Frontinus, whose work on the aqueducts of Rome, *De Aquis Urbis Romae*, dates to A.D. 97 (Smith 1963: 138-39). In Book Three of his work, *De Architectura,* Vitruvius discusses the proper proportions of buildings and the calculations that are required to achieve these proportions (*De arch.* 3.3.6-7, 10-12). In 3.5.1-15, he prescribes the proportions for the Ionic order; in 4.1.1, 6-8, and 11-12, he explains the proportions for the Corinthian capital; and in 4.3.2-9, he specifies the proportions for the Doric order. Frontinus summarizes the various kinds of water pipes used in Rome's water system and their mathematical relationships (Frontin. *Aq.* 1.25-27, 38-63; Maher and Makowski 2001: 386-91). The technical and practical character of Roman mathematics, specifically in arithmetic and geometry (Geymonat 2009: 13), is thus exemplified in the writings of Hyginus, the *Gromatici,* Vitruvius and Frontinus, and their works demonstrate how complicated mathematical computations were necessary for common construction projects. It is therefore important to note that the Roman educational system prepared young men well to deal with projects of this magnitude:

> The achievements of Roman architecture are ample evidence of the success of the Romans in practical mathematics….Any educated Roman must have been able to do arithmetical problems as well or nearly as well as any educated person today (Maher and Makowski 2001: 391, 393).

Many of the principles described by these writers still stand today, and their works are essential to our understanding of the ancient world's technological theories and their applications to practical matters.

This chapter has explored the definition and the mathematics of the spiral, and how the spiral was applied to the construction of monumental architecture in Mesopotamia. It has presented as well a survey of the mathematicians who have worked on the spiral, and a summary of Greek and Roman mathematical theory. The next chapter

will explore the two types of spirals, the S-curve and the Z-curve, and examine their uses in the Egyptian, Minoan and Mycenaean societies. How was the spiral incorporated into daily life, i.e., in pottery, furniture, painted or mosaic decoration and carved seals? Was the interest in the spiral fluted column transferred from Mesopotamian mudbrick into Bronze Age Aegean stone architecture? These are the questions the next chapter will explore.

Chapter 3: The Decorative Spiral in the Aegean Bronze and Iron Ages

This chapter discusses the use and geographical distribution of spirals as decorative and architectural elements from the Bronze Age to the Early Iron Age in the Aegean. It includes a discussion of the standard classification of spirals, and considers examples of spiral use from the worlds of art and architecture, including textiles, pottery, wall paintings, seals and gemstones, and architectural columns.

1. Classification of Spirals

Several modern terms are used to classify spirals. Some citations use the term "twist," which gives a sense of dynamism, and others describe spirals in terms of their slant, thus implying steepness, while gauge (used for spirals on architectural columns) is the distance between the column ridges and the steepness of the spirals' slope. As for the direction of the spiral, there are two types, classified as "S" or "Z": S spirals twist downwards from left to right and Z spirals twist downwards from right to left, like the crossbars of the respective letters (Fig. 3.1).

Fig. 3. 1 S-spiral and Z-spiral columns, Priest's House, Aphrodisias, Caria, Turkey

As well as in art and architecture, S and Z spirals also appear in textiles in their spun threads or yarns: S-spun threads twist to the right, having a counter-clockwise spin; while Z-spun threads twist to the left, having a clockwise spin. There are often cultural preferences: Burke (Burke 2010: 7, 115) says that in Egyptian textiles, the threads were most often S-spun, but in European textiles of the same period (dates unspecified), the threads were Z-spun. Threads found at Phrygian Gordion in Turkey are all Z-spun, but, when they were twisted together to form a two-ply thread, the resulting strand had an S twist. Shamir adds that, in the ancient world, Z-spun yarns were uncommon in Israel, while they were customary "in Syria, Mesopotamia and Iran" (Shamir 2001: 99). But here again, scholars differ: Wild says that the Z spiral was the general norm in the western Roman Empire, while the S spiral was the norm for the eastern Empire (Wild 2008: 470). Compound ropes have strands spun in one direction, which then are wound together in the opposite direction, allowing the strands to lock in position. This process is shown in Egyptian evidence for rope-making, dating from about 4000 B.C.: after fibers were twisted into yarn, "several yarns were twisted together in the opposite direction; the resulting strands were then twisted back the other way into rope" (Humphrey 2006: 32). An example of this is seen in Roman-era rope strands from ancient Tebtunis, located in the Fayoum oasis southwest of Cairo: "These (right-laid) strands…each consist of two left-laid yarns" (Domning 1977: 58). Note that "lay" refers to the direction of twist; "right-laid" is a Z twist and "left-laid" is an S twist. There is as yet no research on cultural preferences for the direction of twist in ropes.

Were there also cultural preferences for spiral directions in art and architecture? In both Mesopotamian and classical times, architects and builders placed columns so that their spirals twisted in the opposite direction to that of their neighbours to add interest, emphasis and drama to their structures. The mathematics and techniques of carving a spiral around a column or setting mudbricks in a spiral pattern would be the same for either the S or Z spiral, simply involving a change of direction as with spun fibres. The spirals used in Mesopotamian mudbrick columns in the sites discussed in the previous chapter were almost equally S and Z spirals, with the columns having opposing spirals either set beside each other or separated by palm trunk or horizontally-marked columns. This is only a general estimate based on excavation photographs and diagrams, as in

some cases the site photographs are unclear, some columns are too weathered to determine their patterns, and many columns and, indeed, whole areas at some sites have yet to be excavated. As will be discussed below in Chapter 5, the Romans had a slight preference for the Z spiral when deciding how to design and where to place their columns.

We have seen that spiral columns were being constructed in Mesopotamia by the early second-millennium B.C. In the Middle to Late Bronze Age Aegean, as well, the spiral was a popular artistic motif. In this period, however, it appeared primarily in its two-dimensional form, as seen in painted decoration, rather than its three-dimensional form, as used in pottery, e.g., in twisted handles. Thus two questions arise: first, where did the stone-built spiral column of the classical period originate? Second, if this style of column did not arise in the Bronze Age Aegean, how and where did the spiral motif survive in the millennium separating its appearance in Mesopotamian mudbrick and its rebirth in stone in the classical period?

To investigate the first question, we turn first to Egypt as a possible source of classical inspiration, as its art and architecture were well developed by the mid-third millennium. Petrie presents a detailed study of the Egyptian spiral, noting its many different designs on scarabs, which appeared by the mid-third millennium, and used on these as "a detached ornament for a small surface." The spiral was also used on ceilings and furniture beginning in the early second millennium, as these required "a continuous decoration on borders and on large surfaces" (Petrie 1895: 28). Petrie notes the similarities between Egyptian and Mycenaean spiral decoration (the latter is discussed below), attributing its Late Bronze Age employment on the Greek mainland (specifically at Mycenae and Orchomenos) to Egyptian influences:

> We may well turn now to see the beginning of the course of European decoration at Mykenae [*sic*] and observe its close contact with that of Egypt….whole patterns with their detail are taken over complete from Egypt….the source of the designs lies in the two thousand years' start which Egypt had before Europe awoke (Petrie 1895: 38-40).

Petrie, however, does not mention spirals being used in any period of Egyptian history on architectural columns, either as surface decoration applied after the column was in place

or built in during its construction. Thus Egypt can be ruled out as the place of origin of the spiral fluted stone column.

Could this type of column have originated in the Aegean Bronze Age? Or, if the spiral fluted stone column was not employed architecturally during that time, how did the spiral motif survive in arts and crafts until its appearance on stone columns in the classical period? We have seen that the spirals Petrie discussed above have nothing to do with mechanical spirals but are included here to show the continued use of and fascination with the twisted shape and thus the persistent artistic interest in spirals. Some Early Helladic vases (3000-2000 B.C.) with spiral decorations produced by rolling a clay or wooden cylinder across the pot have been found in three separate sites in the Peloponnese: Lerna, Tiryns and Zygouries. A hearth at Lerna has an impressed pattern of spirals and animals (Boardman 1970: 22, 23, fig. 13, 92; Vermeule 1972: 39, 399, pl. 4B). As well, throughout the Aegean Bronze Age (and continuing throughout Roman times, to be discussed below), some pottery was made with handles twisted to resemble spirals. An early example of this type of pot comes from a shrine at Beycesultan, on the upper Maeander River on the west coast of Turkey. A bowl with a twisted handle was found here, which is dated to about 2500 B.C. (Lloyd and Mellaart 1957: 31, pl. 2a, 35 fig. 7.1).

Other indications of the artistic interest in the spiral form are spiral shapes carved onto seals and gems, and frequently used in painted decorations, to be examined below. But is there any evidence for the architectural use of the spiral fluted stone column in the Minoan or Mycenaean periods? This question will be examined next, beginning with the Minoan civilisation centred on the island of Crete.

2. The Aegean Bronze Age: The Middle and Late Minoan Periods (2000-1200 B.C.)

The flat spiral is an important element in Minoan design, appearing on pottery, seals and wall paintings. Evans suggests that sea-shells (and also, we may assume, the shells of land animals as discussed in Chapter 2) were an influence on Minoan design: “It is a moot point whether the simple coils that appear among decorative elements before the close of the Early Minoan Age may not have been simply due to the suggestion supplied by one or other of the common whorl-shells” (Evans 1964b: 110). Much of

Minoan design had international as well as local influences. From Peristeria in the Peloponnese comes an example of the fashionable Cretan pottery style which had become popular in the Mycenaean world by the Late Minoan I/Late Helladic I period (1700-1600 B.C.): the "Vapheio" or "Keftiu" style of cup, "a thin-walled tankard with a ribbon handle and floral, spiraled, or rippled patterns which is named after its Cretan prototype in gold" (Vermeule 1972: 117, [242] fig. 41d, 243; Higgins 1981: 144 fig. 176). From Knossos, a running spiral on the shoulder of an LM I pitcher matches those on imported spiral-decorated LM I vases from Grave Circle A at Mycenae (Vermeule 1972: 140, 141 fig. 26a). In LM Cretan pottery, the spiral was used not only as an ornament to fill space around other designs but also as a design by itself, and Higgins shows examples of these uses in two vases dated about 1550-1500 B.C. (Higgins 1981: 103, 104 figs. 112-113). The "Floral Style" vase has two registers (and the designs come from contemporary frescoes; see discussion below), of which the upper register is filled with painted plants and the lower is filled with a geometrical pattern of spirals. The body of the "Pattern Style" vase is completely covered with "spirals joined by tangents" sloping diagonally across the vase, and its lower zone, much smaller than that of the "Floral Style" vase above, is patterned with a single large running spiral. Also from Knossos, and from nearly the same period, comes the "tea-cup" shaped drinking vessel. Examples of this shape were found in precious metals: silver cups with spiral decoration came from a house of 1550-1500 B.C., and a slightly later (1500-1450 B.C.) gold cup from a tomb has "a band of double running spirals over an arcade pattern" (Higgins 1981: 147 fig. 181).

The spiral was important in Minoan fresco painting as well as in ceramics, and here it also had international influence: "The origins of Aegean fresco painting can be found on FN [Final Neolithic] and EM [Early Minoan] Crete" (Chapin 2010: 224), or approximately 4000-3000 B.C., and from there it spread throughout the Aegean. The city of Avaris in the Nile's eastern delta showed much Minoan influence in the wall paintings of its palace, the home of King Ahmose, founder of Egypt's 18th Dynasty, around 1570 B.C. A fresco fragment from this structure shows spirals on a griffin's wings and body (Bietak 1996: pl. 8c opposite p. 55, 80). "There can be no doubt that fresco painting was introduced fully developed from Minoan Crete to the mainland" (Mylonas 1966: 201),

and Vermeule says that "Knossos supplied the prototypes [to Mycenaean Greece] for processions, for architectural façades and shrines…[including] real architectural features such as timber frameworks and dadoes" (Vermeule 1972: 187-88). Pictorial painting in the Minoan world appeared first at Knossos in the MM IIIA period, about 1750-1700 B.C., perhaps inspired by the artistic conventions of the Near East and Egypt. Spiral designs accompanied the new human and animal representations gracing palace walls. Minoan windows and doorways often had fresco borders above them, many of which featured spiral patterns (Chapin 2010: 224). The wall paintings of Xeste 3, a large building at Akrotiri, included, on its ground level, a spiral-decorated door and a griffin with spirals on its wings and body, recalling the similarly-adorned creature noted above at Avaris. The first floor had a frieze with running spirals, and the second floor had a long and very complex frieze with "antithetical [opposing] white and blue double spirals in horizontal and vertical pairs that form colourful stylized ivy leaves" (Vlachopoulos 2008: 491, 493, 494, 496, fig. 41.10, 498 fig. 41.20, 503 fig. 41.43, 504 fig. 41.48-41.50; Chapin 2010: 227).

The spiral, therefore, was a standard and even essential motif in the inventory of Minoan architects and artists, and, according to its use at Xeste 3, Vlachopoulos suggests that it could be a motif with spiritual associations as well. At Xeste 3, it appeared throughout a building thought to have been "a centre of ritual activity for the community" (Vlachopoulos 2008: 494) because of its architectural plan and fresco themes of goddesses, young men and young women, as well as adults and animals, in ritual postures, and scenes hinting at sacrifices. This interpretation does not seem probable, however, as the spiral has been such a common decorative motif for millennia, and was used in circumstances which do not always include sacred connections. Spiral decoration can be used for almost any object, e.g., ordinary tableware, cooking pots, jewellery or wall paintings, as well as in sacred settings such as temples and votive areas.

Spirals also appear on Minoan seals and gemstones, as follows: from the MM III period (1750-1675 B.C.) come three- and four-sided prisms with hieroglyphs set in decorative patterns, and with floral, spiral or figure patterns placed around and between the hieroglyphic signs. Although the examples pictured by Boardman have only plant

motifs distributed among the signs, it is easy to imagine their places filled instead with spirals (Boardman 1970: 37, [72] pl. 43, 45-48, 99).

As for Minoan architectural columns, an early representation of a spiral fluted column appears on a fine Minoan seal/gemstone from Tomb 36 in the Zapher Papoura cemetery at Knossos (Fig. 3.2). This shows a sheep with handsome horns tied to a spiral fluted column; it is dated to the LM IIIA period, about 1400-1300 B.C. (Boardman 1970: 48, 103, [84] pl. 140).

Fig. 3. 2 Minoan seal, Knossos

A good example of a spiral fluted column in miniature is seen in a "columnar lamp" (Fig. 3.3) from the MM III period at Knossos (about 1750-1675 B.C.). Here the shaft, both spirally fluted and with carved leafy decorations between the flutes, supports an Egyptian-style palm tree capital (Evans 1964a: 344-345, 345 fig. 249; Oliver-Smith 1970: 49). This object, then, includes not only international motifs but also their religious and secular associations: palm trees (Mesopotamia and Egypt), plant decorations akin to the Egyptian sacred "papyrus sceptre" design (Evans 1964a: 345), and spirals carved on a pillar (Minoan seals and Near Eastern sacred baetyls; to be discussed further below). This lamp stand is an excellent indication of the continuing popularity of the spiral and its emerging adaptability to three-dimensional contexts.

Fig. 3. 3 Columnar lamp of purple gypsum from S. E. House, Knossos

Another example of Minoan architectural columns is found on one end of a clay ossuary chest from an undated chamber tomb at Milato in Crete, which has a motif on its left edge that might be intended as a spirally-decorated column; Evans accepts it as a representation of a column, but the photograph of the chest does not clarify his idea (Fig. 3.4). This column may be "supporting" the ceiling (or roof), which has short diagonal lines extending down from it (or perhaps they are meant to be painted on the back wall of the "room"; the drawing is unclear). There is a human figure holding a shield beside the column, and Evans describes this figure as a god because of the rays coming out from his neck and spreading above his shoulders (Evans 1901: 174 fig. 50, 174-175). This would be an appropriate figure to appear on an ossuary, and, as noted above, the spirally-decorated column may (or may not) imply spiritual associations.

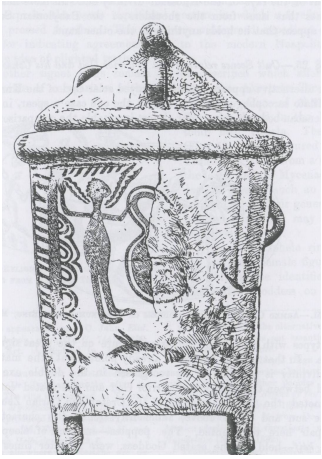


Fig. 3. 4 Ossuary chest, Milato, Crete

Reconstructions of Minoan buildings show columns as tapered and unfluted (Shaw 2011: 147 fig. 10, 149 fig. 11). At Knossos, the upper floors of the palace were held up by wooden columns tapered downwards which were set on gypsum bases. Stone

pillars were also found in the palace, though Higgins suggests these pillars "were evidently considered too unsightly for general use" (Higgins 1981: 22 fig. 9, 23). This statement is not explained in the text, but it may be based on the rarity of stone columns in the palace remains. In a study of Minoan halls, Shaw says that columns are used not only structurally but are also used on a small scale in areas such as lustral basins, where they are not architecturally necessary, to symbolize "strength and rule" (Shaw 2011: 148). Higgins shows a reconstruction of the west side of Knossos' Central Court in which two columns on the stairway appear to be vertically fluted: "The reconstruction, although imaginative, is soundly based on archaeological evidence" (Higgins 1981: 22 fig. 9), but this evidence is not discussed in the text. These two columns, also unexamined in the text, may be simply drawn with vertical lines to represent wood.

Excavations at Minoan sites have revealed no examples of spiral fluted columns in wood or stone, and thus we must conclude that the spiral fluted stone column so extensively used in the later classical period did not originate in the Minoan world. Although the wooden columns have all disappeared, spiral fluting would in any case have been very difficult to execute across the grain of a wooden column. It is not improbable, however, that wooden columns could have led to later stone columns, as shown in the case of the Temple of Hera at Olympia, built about 600 B.C., where the temple's original wooden columns were replaced with stone columns.

3. The Aegean Bronze Age: The Mycenaean Period (1600-1200 B.C.)

Petrie says that the spiral column appeared on the Greek mainland early on in Mycenae, but he does not mention it as an architectural element of a building. Instead, he pictures a seal carved with a Z-spiral column placed between two griffins, found in Chamber Tomb 58 (Fig. 3.5). The column rests on a pedestal (which Boardman calls an altar), on which the griffins have placed their front paws, and their heads are turned away from the column, facing the left and right sides of the seal (Petrie 1895: 7, pl. 4 fig. BC6; Tsountas and Manatt 1897: 254 fig. 131; Mylonas 1966: 172, fig. 124: 44; Evans 1901: 158 fig. 36; Boardman 1970: 58, pl. 177, 105).

Fig. 3.5

Fig. 3.6

Fig. 3. 5 Seal with Z-spiral column and griffins, Mycenae
Fig. 3. 6 Lion Gate, Mycenae

This seal is undated; Shelton notes that dating of Mycenae's chamber tombs is problematic, because of inconsistent and/or nonexistent excavation records, but dateable finds range from LH II to LH IIIC (ca. 1635-1050 B.C.) (Shelton 2003a: 35; 2003b: 35). We may therefore assume that this seal falls within this range. The arrangement of the figures on this seal evokes the composition of the Lion Gate panel at Mycenae, which is dated to the 13th century B.C. (Iakovidis and French 2003: 11), but there the lions are now headless (Fig. 3.6). (They were thought to have faced forward because of the space available). The column on the Lion Gate is plain and unfluted (Tsountas and Manatt 1897: 30). It is important to note that the columns on both the above-mentioned seal and the Lion Gate have capitals and support some entablature, and thus these columns represent actual architectural elements as well as religious symbolism. As for the column on the griffins-and-pillar seal, fluting was known on stone Mycenaean columns: Evans found part of a vertically-fluted marble column near the site of Kalamafka, in southeast Crete, which he dated to the Mycenaean period because of "the associations in which it lay…[and] the parallelism with the *kymation* [ribbon-like ornament] of the half-capital of the 'Grave of Atreus'" (Evans 1896: 54). This fragment is the first example of a Mycenaean fluted column to be found. It lacked distinctive Doric elements such as the "encircling channels" (these are probably the Doric necking rings at the top of the column shaft), and its flutes "overlapped on to the spring of the echinus." It is "an important link between the Mycenaean and Doric styles" (Evans 1896: 54; Tsountas and Manatt 1897: 323 n. 3). The column fragment is not illustrated in the text, and no more

details of its context are given so it is not possible to verify Evans' dating. It seems reasonable, however, given the evidence of the Mycenaean seals above and furniture inlays and wall paintings to be discussed below. This column, if it is truly Mycenaean, is several centuries too early for the Doric order, but could well be its precursor.

In discussing the Mycenean "tree and pillar cult" (symbolised by the griffins-and-pillar seal and the Lion Gate above), Evans explains the belief that the tree or pillar is the dwelling place of the "numen," the spiritual force, of the god (Evans 1901: 106), whose shrine can be established indoors or outdoors. He gives as an example the "hypaethral [roofless] shrine" at Mycenaean Goulas on Crete, which is thought to have included a sacred pillar as well as a sacred tree (Evans 1901: 100). The tree and pillar cult is also shown on a carved agate seal (date unspecified) from Mycenae (Fig. 3.7): it has two running animals facing opposite directions (the drawing suggests two ibexes, but the text says the figures are an ox and an ibex; the text and illustration do not seem to match) separated by two spirally fluted columns whose capitals also face opposite directions (Chapot 1907: 35 fig. 42).

Fig. 3. 7 Seal with spiral pillars and animals, Mycenae

Both columns have round bases and are topped with three-pronged decorations: do they represent actual palm trees? Or architectural spiral fluted columns with elaborate capitals symbolising palm trees? In either case, they are reminiscent of the Mesopotamian palm trunk columns in mudbrick discussed in Chapter 2, and thus they show the persistence of the spiral decoration in the two cultures, although no direct artistic connection between these cultures should be assumed.

Another example of the tree and pillar cult, this time including genuine spiral fluted columns, is a cylinder seal from Mycenae (date unspecified) which shows a human figure "in the act of adoration" (i.e., his right arm is raised towards the column closest to

him) before a group of five architectural columns (Fig. 3.8). All the columns have bases and capitals, and one column has spiral flutes, two have vertical flutes, and two have a combination of vertical and spiral flutes. Another column, also fluted half-vertically and half-spirally, stands behind the figure, thus making a total of six columns on this cylinder.

Fig. 3. 8 Cylinder seal, Mycenae

There is no ceiling or roofline above or groundline below these columns, so this grouping is not intended to suggest a structure. This arrangement recalls sacred baetyls from the Semitic world, where groups of two or three pillars (or trees) were considered "the visible embodiment of a single divinity" (Evans 1901: 140, 141 fig. 24; Chapot 1907: 36 fig. 43, 37), and Evans suggests a parallel Mycenaean belief in groups of aniconic pillars (Evans 1901: 140). Nilsson corroborates this idea, "It may be assumed with some probability that they are free-standing sacred columns" (Nilsson 1950: 257 fig. 126, 258).

The flat spiral was a popular decorative motif on painted Mycenaean pottery and wall paintings, as its circular form could be adapted to any size and shape of pot and could always be used to fill in areas of friezes either as background or a main image. Tiryns has a fine painted frieze whose up-and-down S spirals alternate with fan-shaped papyrus blossoms. This pattern is identical, except for its borders, to the design on the sculpted ceiling in the Treasury of Minyas at Orchomenos, which Tsountas and Manatt describe as "one rich composition of rosettes and spirals apparently reproducing a textile pattern" (Tsountas and Manatt 1897: 51, 52 fig. 13, 126-29, 128 fig. 48, 226; Vermeule 1972: 123; Mylonas 1966: 125; Schliemann 1886: 298-99, pl. 5; Immerwahr 1990: 142, 143 fig. 39d). These two friezes with the same design offer clear support for Petrie's theory of an Egyptian origin for the Mycenaean spiral, as noted above. Immerwahr says that a complicated pattern such as this, which exists in several Mycenaean locations,

suggests that itinerant craftsmen were working in the eastern Mediterranean (Immerwahr 1990: 143). Schliemann quotes Muller on the origin of the Mycenaean spiral:

> the spiral ornament…appears…very commonly in Egypt, both in the ornamentation of pottery and other objects, which were, in many cases, booty from the Phoenicians and other Oriental people…. In Phoenicia the spiral ornament is universal on a certain class of antiquities…. The origin of the spiral ornament must, therefore, be sought for far from Greece, in the Egypto-Phoenician domains (Schliemann 1886: 110-11).

Tsountas and Manatt say that "the genuine spiral pillar was not unknown at Mycenae," and they cite two examples of decorative (as distinct from architectural) spiral use there: the first is an ivory mirror handle decorated with spiral "winding bands" of rosettes and chevrons, which was found in the *dromos* of the Tomb of Clytemnestra. The second example is part of a column and its capital "richly carved in zigzags and spirals" from the doorway of the Treasury of Atreus (Tsountas and Manatt 1897: 119 fig. 44, 186 fig. 82, 187-88). This column was not a supporting part of the doorway, but simply used to embellish the entrance of the tomb. It has been suggested that these doorway columns are "the translation into stone of wooden pillars covered with richly embossed plates of metal." The authors say that, although this may be true, the spiral and ring decorations represent "actual bands binding together several slender stems to form the column" (Tsountas and Manatt 1897: 255). This motif recalls the papyrus-style columns of Ptolemaic Egyptian temples, the shafts of which were carved vertically to represent bundles of stems, though these bundles are not shown bound together, either spirally or otherwise, by carved bands on their shafts. Nonetheless, these columns do have five carved lines representing bindings at the juncture of the shaft and capital (McKenzie 2007: 122 fig. a).

Carved ivory furniture inlays were found at Mycenae in two private houses outside the citadel to the west, the House of the Sphinxes and the House of the Shields. A fine miniature example of a column with a Z spiral, including part of its shaft and capital (Fig. 3.9), was found in the House of the Sphinxes, along with a small dolphin, and some unfluted and vertically fluted miniature columns (Vermeule 1972: 404, pl. 39D).

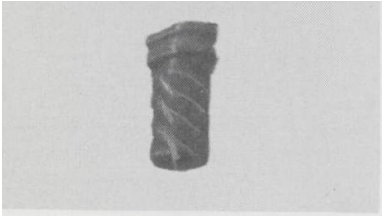
Fig. 3.9 

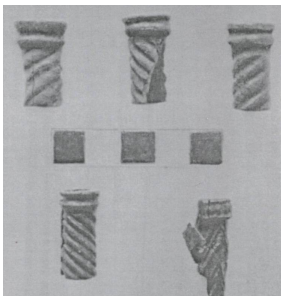
Fig. 3.10 

Fig. 3. 9 Model column furniture inlay, Mycenae
Fig. 3. 10 Model column furniture inlays, Mycenae

Five more model spiral fluted columns (Fig. 3.10), two with S spirals and three with Z spirals, were found in the House of the Shields (Wace 1954: pl. 40d). Though they were probably simply decorative, these ivories may have had a votive function, as those featuring columns were often shown in settings of possible "religious significance" (Rehak 1992: 45). Where did this ivory and its craftsmen come from? Ivory carving was widespread in Asia Minor and the Levant at this time, and Mycenaean trade reached all over the eastern and southern Aegean. Ivory-carving craftsmen could have brought their tools and knowledge to Mycenaean Greece and taught local workers, or locals could have travelled east and returned with the techniques of ivory-carving and eastern motifs, and then combined them with local designs. In any event, as Vermeule says,

> Most of the inlays were inset into furniture and chests of an elegant quality…. Mycenae was a major centre for ivory carving from the middle fourteenth century onwards…. The city imported raw tusks and finished articles from Syria and Canaan…[and] her craftsmen made local ivories sometimes copying foreign styles and sometimes inventing new designs in the mainland idiom (Vermeule 1972: 81-82, 219, pl. 24B).

Evidence for the Mycenaean use of the spiral column as a structural element is found in a fresco from Mycenae's Room 31, a shrine room dated to the LH IIIB period (1300-1200 B.C). It is located in Mycenae's "Cult Center," which is in the southwest area of the citadel and so-called because of the evidence of votive features in this area, such as altars containing ash, and painted or model double axes and "horns of consecration" (Burns 2010: 143; Rehak 1992: 42; Lupack 2010: 265-66). In this room, two platforms for offerings and cult equipment were built against one wall. A mural above and beside them shows, in two registers: three goddesses (or two deities in the upper register and a priestess in the lower one); two tiny floating male figures (souls? spirits? votaries?); and

an animal identified as a griffin or a lion (Fig. 3.11) (Rehak 1992: 43, 46, 48-9, 54-5; Marinatos 1988: 246-48). Burns describes the fresco's female figures, each one standing "before a column decorated with spiral carving and detailed bases and capitals" (Burns 2010: 142). Immerwahr, too, says that the columns are "spirally fluted" (Immerwahr 1990: 120).

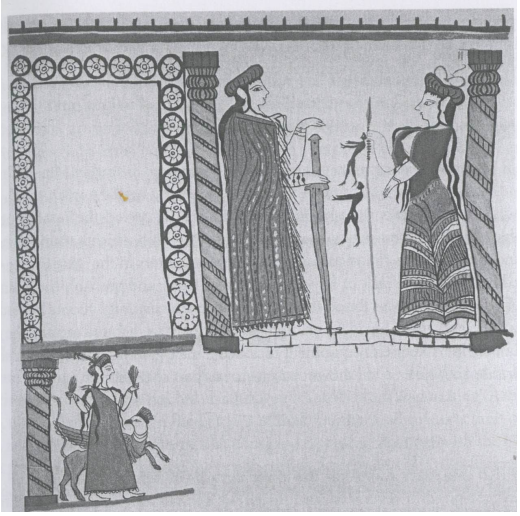


Fig. 3. 11 Room 31 fresco reconstruction, Mycenae

The reconstruction of the fresco (Lupack 2010: 267 fig. 20.2), however, does not clarify this decoration, as the spiral design may be simply painted on the column rather than carved into it. Marinatos says, describing the lower panel, "there is a column decorated with hands [*sic*; bands?] or ribbons or possibly, archaeological decorations such as the ones on the columns from the façade of the tomb of Atreus" (Marinatos 1988: 246). Since the photographs of the fresco fragments (Immerwahr 1990: pls. 59-61) show only incomplete columns and their spirals appear to lie flat against the surface of the column, i.e., there is no shading to suggest any depth of carving, the spirals should be interpreted as either painted or very shallowly carved.

Nevertheless, the columns are definitely embellished with flute-like spirals and, after the Mesopotamian spiral columns in shaped mudbricks, this fresco is the earliest representation we have found so far of the spirally-decorated column being used structurally. Two columns are shown in the upper register, the one on the left side of the painting standing beside a rosette-decorated doorway presumably leading into another room (perhaps the actual room beside this shrine room), while the column on the right

side stands by itself. The single column in the lower register also stands alone. The tapering shape of these columns suggests Minoan origins, but this style is also seen in many Mycenaean settings, e.g., Mycenae's Lion Gate. The three columns in Mycenae's Room 31 also resemble those decorating the entrances to the nearby mid-13th century B.C. Treasury of Atreus and the Tomb of Clytemnestra, built around 1220 B.C. (Burns 2010: 142; Rehak 1992: 45; Marinatos 1988: 246; Mylonas 1966: 122). The reconstruction of the fresco shows that its three columns all have S spirals and their bases rest on their rooms' "floors," but while the two in the upper register have capitals, they do not reach to the "ceiling" of their painted room. This may be because the upper register's ceiling is not shown and the possible ceiling line actually represents the roof of the building. The column in the lower register has a capital touching its room's "ceiling," which is the lower margin of the painted floor line directly below the upper register's rosette-studded doorway (Lupack 2010: 267). But here again there is a difference of scholarly interpretation: the reconstructed drawing accompanying Morgan's examination of Room 31 shows three steps leading to the rosette-decorated doorway, which in turn touches its room's ceiling (drawn in the form of an architrave). The two columns in the upper register also touch the ceiling/architrave (Morgan 2005: 167 fig. 10.5, pl. 24B). The fresco fragments obviously provide room for speculation and rethinking of previous design ideas, and it will be interesting to read the two forthcoming studies [as of 2005, but still not yet published] in the "Well Built Mycenae" series: Fascicule 11: "The Room with the Fresco Complex," by A.D. Moore and W.D. Taylour; and Fascicule 29: "The Painting from the 'Room with the Fresco'," by M.A. Cameron, N. Marinatos, D. Wardle et al. (Morgan 2005: 159 n.1).

What is the significance, then, of the use of the spiral column on this fresco and, by extension, on the above-noted two tombs, the Treasury of Atreus and the Tomb of Clytemnestra? "Architectural frames and decorated doorways originated in Minoan painting" and painted Mycenaean architectural representations are first seen in tomb architecture (Rehak 1992: 44). Although some scholars believe that these depictions are modelled on "house and palace architecture, which is not preserved," Burns suggests that this fresco is intended to bring to mind the exterior of a tomb, and thus the room which houses it may be a place for tomb rituals (Burns 2010: 142). Marinatos interprets the

person in the lower register as a priestess carrying wheat offerings to the shrine/altar, and thus she may mirror cult activity in Room 31 (Marinatos 1988: 247). While specific interpretations differ, by the LH IIIB period this style of spirally-decorated column was important enough (and unusual enough?) to be used in royal or sacred architecture, or in specific tomb or votive settings. Rehak notes that this fresco's "cutaway" view into another room in the building is "virtually unique in the Aegean," being reminiscent of Egyptian painting conventions for implying interior areas (Rehak 1992: 45). Thus this fresco also shows international connections in trade, decorative motifs and craftsmen, as well as conventions in local or regional architecture and religious rituals. The spiral has now advanced from pottery decoration to a dramatic architectural enhancement and is an element used to evoke cultural or spiritual associations.

4. The End of the Bronze Age and the Beginning of the Iron Age: 1200-1000 B.C.

Some examples of spiral pottery decorations from four different sites are discussed next. Although they are separated by several hundred years, they are presented here to show how the use of the decorative flat spiral continues from the Bronze Age into the Iron Age. The first example appears on the Linear B tablet PY Ta 711 from the Palace of Nestor in Messenia. This tablet lists two jugs: the first is described as *ko-ki-re-ja*, a word thought to be related to the Greek κόχλος, "a kind of shell-fish with spiral shell…[thus] 'decorated with a shell-pattern'" (Hooker 1980: 129). The second jug is "one ewer of the queen's set" decorated with a bull's head, *qo-u-ka-ra*, and a running spiral pattern, *to-qi-de-we-sa.* The latter word is connected with the Latin *torqueo*, "twist," and the Greek ἐπιστρέφεσθαι, "turn towards, revolve"; thus the jug is "decorated with a spiral pattern" (Hooker 1980: 129; Ventris and Chadwick 1959: 335-36). This tablet, then, is important in that it could be one of the very few literary mentions of a spiral pattern. The second example is the "Friendly Krater," found at the Iklaina excavation site, several kilometres south of the Palace of Nestor. Discovered in 2009 and dated to the LH IIIA period (1400-1300 B.C.), this krater has spirals painted on its outside just below the rim, and below these spirals are single lines that curve around the lower part of the spiral and end in three "fingers," seemingly waving at the viewer (Fig. 3.12) (Shelmerdine 2011: 252).

Fig. 3.12

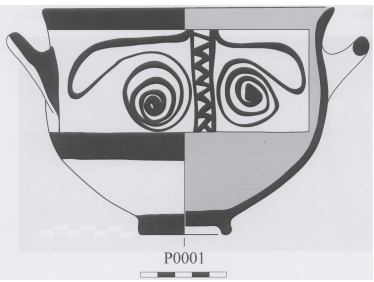
Fig. 3.13 

Fig. 3. 12 "Friendly Krater," Iklaina
Fig. 3. 13 Eleon bowl

The third example, showing a similarly imaginative use of spirals, appears on a recently-excavated deep bowl from Eleon in Boeotia, dated to the LH IIIC period (1200-1050 B.C.). On its outside, it has two antithetic spirals separated by a zigzag design, which could be interpreted as a "proto-spiral column," and which also breaks up the circular design with a lively linear image (Fig. 3.13).

The nearby settlement of Lefkandi on the island of Euboea, just across the Euripus Strait from Boeotia, is also dated to the LH IIIC period and provides our fourth example, a selection of pots from the transition period from the Late Bronze Age to the Early Iron Age. Here the site has yielded a cylindrical pottery lid whose spiral design starts on its side and continues up to its flat top, filling the whole top surface (Popham et al. 2006: 144 fig. 2.4 no. 9, 146). Running spirals, similar to those on the Eleon pot noted above, can be seen on the outside of a deep bowl (Popham et al. 2006: 171, fig. 2.12 no. 6), and there are several instances of a spiral design being painted on the inside bottom of a bowl (Popham et al. 2006: 156 fig. 2.8 no. 6, 182 fig. 2.15 nos. 4-5). A decorated deep bowl with a design on its outside almost identical to that on the Eleon pot noted above has the same antithetic spirals separated by a possible "proto-spiral column," but this bowl has added two circles of Mycenaean-style dots between the spirals and the column (Popham et al. 2006: 191 fig. 2.22 no. 1). Similarities between pottery designs of the LH IIIC period at Mycenae and Lefkandi include the use of "elaborately-filled antithetic spirals" as well as these decorative dots (Popham et al. 2006: 225).

This chapter has examined how the interest in the spiral form was transferred from Mesopotamian mudbrick spiral helix columns into Bronze Age Aegean arts and

crafts, where it was sustained, not by its translation into stone architectural columns, but by its incorporation into daily life: the flat spiral was painted on pottery, and the helical spiral was represented in textiles, furniture decorations, wall paintings and seals. We have seen, too, that the decorative spiral extended both geographically and chronologically throughout the Egyptian, Minoan, Mycenaean and Early Iron Age worlds. In summary, then, although there are painted representations of spirally-decorated columns and numerous examples of flat spirals as decorative motifs on architecture, frescoes and ceramics, no remains of an architectural spiral fluted column have been discovered in Aegean Bronze Age or Iron Age excavations. Could it simply be that columns were usually of wood and so have not survived? The next chapter will examine the use of the spiral in the Greek world, and continue to explore the problem of the origin of the spiral fluted stone column.

Chapter 4: Spirals in the Greek World From the Geometric to the Hellenistic Periods

This chapter plots the development of the decorative spiral in the Greek world from the Geometric period to the Hellenistic period (about 1100-31 B.C.). In this time frame, we will consider the transition from two- to three-dimensional spirals, as spirals were used not only as motifs in painted decorations but also appeared as architectural elements incorporated into built structures. We will also examine the use of spirally-decorated columns in art, e.g., in vase paintings, as monuments and on seals and coins, and try to determine when the spiral fluted stone-carved column appeared as an architectural element in structures in the Greek world.

1. The Geometric Period: 1100/1000-700 B.C.

In Greece's Geometric period, the spiral took second place to the meander as the most prevalent pattern in painted decoration (Dörig 1967: 119, 121), but it still remained a popular motif. A fine example of running spirals is seen on a clay model of a shrine from Archanes, near Heraklion on Crete, dated to about 800 B.C. (Fig. 4.1). Here, along with chevrons, the spirals cover the body of the shrine, and are used also on the lid around and between two human figures and an animal (Boardman et al. 1967: [61] pl. 1). An example of similar running spirals is seen on panels decorating the short sides of a larnax (Fig. 4.2), a footed wooden box-like container for funerary ashes, whose elaborate decoration emphasises the idea that "life is seen as a costly treasure" (Dörig 1967: 126, figs. 99-100). The findspot for the example discussed is unidentified, but it is from the same period as the model shrine.

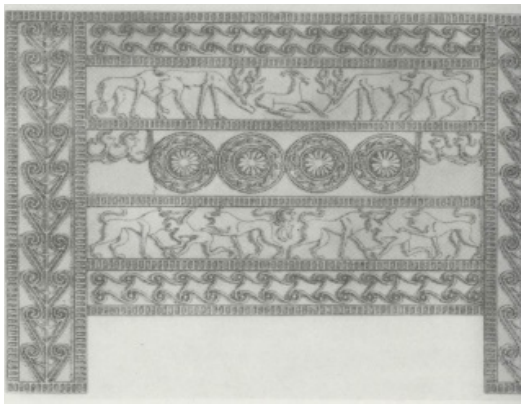
Fig. 4.1 Fig. 4.2 

Fig. 4. 1 Shrine model, Archanes, Crete
Fig. 4. 2 Larnax (findspot unidentified)

2. The Archaic Period: 700-500 B.C.

In the Archaic period, the three-dimensional architectural spiral began to appear in structures. Is there a connection between the two-dimensional and three-dimensional spiral, and, if so, how did the motif move from wall paintings and ceramic designs into architecture? We shall examine first the use of spirals in column capitals. As mentioned above in Chapter 4, both Ionic and Aeolic capitals echo the spiral shells of local snails, and were widely distributed throughout the eastern Mediterranean world. Although both these capitals feature the two-dimensional spiral rather than the "cylindrical helix," or three-dimensional spiral with which this thesis is concerned, it is still important to examine them and their origins: not only did they bring the spiral motif more prominently into public view, but they also showed that architects and builders were beginning to consider the spiral as an interesting and specialised architectural feature with historical and religious overtones. In previous eras, as discussed in earlier chapters, the spiral had appeared only on a limited range of items such as seals, frescoes, ceramics and furniture decorations. (This limitation is assumed, based on the lack of literary and material evidence for the structural stone-carved spiral fluted column). The next section begins with the advent of the Ionic column into Greek architecture.

The Ionic column originated with the Greek colonists who settled in Asia Minor (to be discussed further below) and was thought to have evolved from the local Aeolic capital (Fig. 4.3), also called the "proto-Ionic" capital (Boardman 1967: 16). How did this evolution occur? The Aeolic capital featured two separate spiral volutes separated by a

"leaf torus that represents the termination of the cylindrical column shaft" (Barletta 2001: 98 fig. 56, 100; Boardman et al. 1967: [102] pl. 42). In its early form, called "proto-Aeolic," it is said to be "a schematization of a palm tree," having fringe-like patterns set between the volutes to represent palm fronds (Shiloh 1976: [67] fig. 1, 68 fig. 2). This arrangement strongly resembles the palm-trunk Mesopotamian mudbrick columns discussed in Chapter 2 and is thus another indication of the continued use of designs from the natural world in ancient architecture. Shiloh says that the proto-Aeolic capital is a reproduction in stone "of the wooden capitals used in Mesopotamian-Syrian-Palestinian monumental buildings" (Shiloh 1976: 74), and thus has long historical connections.

Fig. 4. 3 Aeolic capitals (first half of sixth century B.C.), Larisa and Neandria

Another stage in the development of the classic Ionic capital is seen in a small Phoenician-style temple model said to be from Transjordan, or at least "the cultural area of ancient Syria-Palestine" (Fig. 4.4). It is dated to the Iron Age II period, or around the tenth-ninth centuries B.C. (Shiloh 1976: 69 fig. 3; Iliffe 1944: 91, pl. 21).

Fig. 4. 4 Iron Age temple, Transjordan/Syria-Palestine

A drawing and photograph of this model show two partly-engaged columns with simple Aeolic volute capitals, and above each volute is another one turned upside-down so that

the tops of the volutes rest on each other. "It would seem as if we had here that stage of evolution before the palm-tree motif had crystallized inevitably into the form which it eventually took as the Ionic capital" (Iliffe 1944: 92). There is a bird, probably a dove, set between the capitals above the doorway. Iliffe says that this style of shrine, with its bird decoration, was most likely sacred to Astarte and goes back "at least to the early third millennium in Mesopotamia" (Iliffe 1944: 91). A slightly later shrine model from Cyprus is dated to the seventh or sixth centuries B.C. and shows Syrian-Palestinian influences similar to those of the above-mentioned shrine, although it is thought to have been made locally. This Cypriot model also has Aeolic capitals set on "engaged columns or pilasters [which are located] at the interior of the doorway" (Betancourt 1971: 427, figs. 1-3). Thus these two small model shrines with their Aeolic capitals emphasise the long pedigree of the Ionic capital, with religious, historical and architectural associations begun in Mesopotamia and transmitted through Asia Minor into the classical Ionic column used throughout the Greek and Roman worlds. The spiral motif is now moving from primarily domestic situations with somewhat limited audiences into the wider public world.

Vitruvius (*De arch* 4.1.12) does not mention the Aeolic capital, simply noting, *Sunt autem, quae isdem columnis inponuntur, capitulorum genera variis vocabulis nominata* (Granger 1962: 210); "There are other kinds of capitals set upon these same columns [i.e., Doric and Ionic columns] and called by various names" (Morgan 1960: 106; Granger 1962: 211). Since the Aeolic capital is set on an unfluted shaft, Vitruvius' "other kinds of capitals" do not include the Aeolic style. Barletta says that either he may not have known about the Aeolic capital, which flourished in Asia Minor during the sixth century B.C. but "did not survive into later times," or this capital was not mentioned by the sources on which he based his work (Barletta 2001: 5). Where and when did the Ionic capital (Fig. 4.5) appear in buildings? Vitruvius (*De arch.* 4.1.4-5), says that the west coast of Asia Minor was settled by Greek colonists sent from Athens, who named this area Ionia after their leader, Ion:

> (4) Postea autem quam Athenienses ex responsis Apollinis Delphici, communi consilio totius Hellados, XIII colonias uno tempore in Asiam deduxerunt ducesque in singulis coloniis constituerunt et summam imperii potestatem

> Ioni….(5) Ibique deorum immortalium templa constituentes coeperunt fana aedificare (Granger 1962: 204).
>
> (4) The Athenians, in obedience to oracles of the Delphic Apollo, and with the general agreement of all Hellas, despatched thirteen colonies at one time to Asia Minor, appointing leaders for each colony and giving the command-in-chief to Ion….(5) [in their new cities] they set off precincts for the immortal gods and began to build fanes [temples] (Morgan 1960: 103; Granger 1962: 205).

Vitruvius (*De arch.* 4.1.7-8) states that the Ionic order was used first in the Temple of Artemis at Ephesus:

> (7) Item postea Dianae constituere aedem, quaerentes novi generis speciem…. Capitulo volutas uti capillamento concrispatos cincinos praependentes dextra ac sinistra conlocaverunt et cymatiis et encarpis pro crinibus dispositis frontes ornaverunt….(8) Id autem quod Iones fecerunt primo, ionicum est nominatum (Granger 1962: 206).
>
> (7) Afterwards also seeking to plan a temple of Diana in a new kind of style…. In the capital they placed the volutes, hanging down at the right and left like curly ringlets, and ornamented its front with cymatia and with festoons of fruit arranged in place of hair….(8) The Ionians, however, originated the order which is therefore named Ionic (Morgan 1960: 104; Granger 1962: 207).

Fig. 4. 5 Ionic capital, Propylaea, Acropolis, Athens

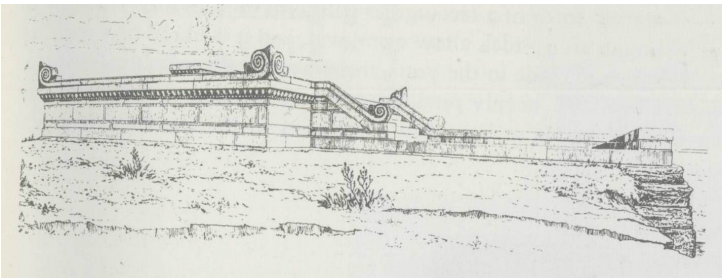
Pliny (*HN* 36.56.179) says that the Temple of Artemis at Ephesus (which was built under King Croesus, 560-546 B.C.) was the first to have moulded bases and capitals (Barletta 2001: 84):

> In Ephesiae Dianae aede, quae prius fuit, primum columnis spirae subditae et capitula addita (Eichholz 1971: 140).
>
> It was in the earlier Temple of Diana at Ephesus that columns were for the first time mounted on moulded bases and crowned with capitals (Eichholz 1971: 141).

A chronological problem arises here: although the Ionian settlement of western Asia Minor is generally dated to around 1000 B.C. (Barletta 2001: 4), the Temple of Diana/Artemis at Ephesus mentioned by Vitruvius was built in the sixth century B.C. Barletta suggests that the site could have been a sacred one for the Mycenaeans, and thus was considered consecrated ground even before the Ionian eastern movement (Barletta 2001: 5). There was, however, an earlier eighth century B.C. temple on the same site, but this is still too late for the modern accepted dating of the Ionian eastern migration. Thus we should accept that Vitruvius "allowed for an indefinite lapse of time" (Barletta 2001: 5) between the arrival of the Ionians and their building of the temple to which Vitruvius refers. The evolution of the classical Ionic capital on the Greek mainland is thus clear, with its predecessors having arisen in Asia Minor and the Levant and then been adapted by mainland artists and architects to local and regional tastes.

The Ionic capital has four deeply carved concave spiral volutes that extend well beyond the shaft of its column. The volutes, two on the front face and two on the back face of each capital, can be arranged in two ways: either horizontally joined together in pairs, so that they can be seen "satisfactorily" only from the front or back of the column; or one volute can extend diagonally outwards, e.g., on a corner column, so as to be seen from any angle (Boardman 1967: 17). In some cases, where columns are used for a dramatic effect or a column stands alone, all four volutes can be angled outwards.

By the sixth century B.C., the Ionic spiral began to appear in architectural decorations on other structures as well as columns. Ionic altars in Asia Minor were generally large sacrificial platforms, with wide stairs leading up to them and with large and elaborate carved Ionic scrolls set on the platforms' edges, in the manner of elongated Ionic capitals turned upside down. Two examples of this style are found at Miletos and at nearby Cape Monodendri. The Miletos altar is dated to the late sixth century B.C. and Boardman suggests that this style of stepped altar shows Egyptian influence. The Altar of Poseidon at Cape Monodendri (Fig. 4.6) dates to the second half of the sixth century B.C. and has "large volute acroteria" at its corners (Boardman 1967: 30-31 figs. 31, 33).



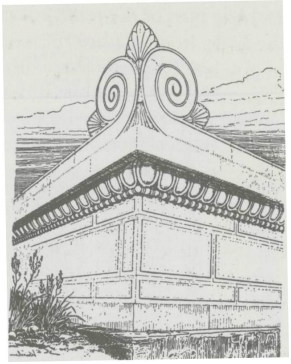


Fig. 4. 6 Altar of Poseidon, Cape Monodendri

The Aeolic and Ionic capitals, then, are early examples of the use of the flat spiral in architecture, with both originating in Asia Minor from the tenth through the seventh-sixth centuries B.C. Are there other influences on this style of decoration? Barletta says that "the Bronze Age spiral and the Near Eastern volute, as well as perhaps the Mycenaean and more likely the eastern leaf, are clear sources for the decoration of the Ionic capital" (Barletta 2001: 144). Another example of the survival of the Bronze Age spiral (and an early representation of the three-dimensional spiral) is found in a Doric capital from Kalapodi, in central Greece, west of Boeotia. It has "a spiral pattern of flutes in its necking" and, although the capital is dated to *ca.* 580-560 B.C., its design is believed to have originated in the Mycenaean period (Barletta 2001: 138; Felsch et al. 1980: 74 fig. 52, 76-77).

In Chapter 2, we mentioned the artistic influence of the acanthus plant in the ancient world, and noted the example of the Corinthian capital. The earliest instance of the Corinthian capital known in Greece, dated to the second half of the fifth century B.C., was found in the Temple of Apollo Epikourios ("Apollo the Helper") at Bassai in the Peloponnese (Fig. 4.7) (Boardman 1967: 21, fig. 15). Here the capital uses two forms of acanthus spirals, one in the stems curving out from the bottom to the top of the capital and extending diagonally out under the corner of the abacus (compare with Ionic volutes), and the other in the flat spiral stems carved on the body of the capital between the extended stems.

Fig. 4. 7 Temple of Apollo Epikourios, Bassai

Unlike the Ionic capital, the new Corinthian capital looked the same from all sides. This design was not particularly popular in Greece when it first arose, but it became more common in the fourth century B.C. and the Hellenistic period (Boardman 1967: 21). The Corinthian capital was used extensively during the Roman period both in Greece and throughout the Mediterranean world. The Temple of Zeus Olympios in Athens, in an almost permanent state of construction from the sixth century B.C. to the second century A.D., has "near classic" Corinthian capitals (Boardman et al. 1967: 22, pl. 28), with their fine spiral stems and volutes springing from the acanthus leaves carved around the capital bases.

3. Black-figure Vase Painting

Is there any evidence for the existence of architectural spiral fluted columns in Greek vase paintings? We shall begin by examining black-figure vase painting, which was invented in Corinth around 700 B.C. (Boardman 1991: 9), and in which spirals were often used as defining and decorative elements in the designs. The Attic painter and potter Exekias, who lived in the mid-sixth century B.C., sometimes used spirals to frame his subjects. For example, three of his amphorae show figures in the centre of the picture with three or four large vertical spirals on each side of the group: Achilles and Penthesilea (Fig. 4.8); Herakles fighting the lion; and a marriage procession, possibly of Herakles and Hebe (Boardman 1991: [80] figs. 97-98; Folsom 1975: [70] fig. 7b, [72] 7d). These spirals not only emphasise the picture but also fill the space beside and underneath the amphorae handles.

Fig. 4. 8 Achilles and Penthesilea, by Exekias

From the same time period comes another example of this use of the spiral: on an amphora by the Amasis Painter (of whom more below) three figures, Dionysos and two maenads, are framed on the sides by four large vertical spirals in almost the same design as that used by Exekias (Dörig 1967: [177] fig. 14; Boardman 1991: [75] fig. 85). Thus we see that the use of this type of large spiral decorations was an artistic convention for the vase paintings of this age, and again, artistic interest in and adaptation of the decorative spiral was still strong.

In the early sixth century B.C, "the first representation of a building" appeared on a vase (Fig. 4.9), painted in the black-figure style by the Attic artist Sophilos on a dinos, a mixing bowl (Beazley 1951: 18). The scene's theme is the wedding of Peleus and Thetis, and the house of Peleus is shown with its two Doric columns in the upper register of the dinos (Boardman 1991: [28] figs. 24, 25.1). Although these columns are not spirally fluted, the painting is important for this study, showing the new role of architecture in setting the scene of the story shown in the painting. A slightly earlier vase, the work of the Group of the Nessos Painter, simply suggests a temple by showing two columns (Beazley 1951: 18), but Sophilos' design on this vase shows a specific style of column used now as an architectural element to represent a realistic house with which its audience was familiar.

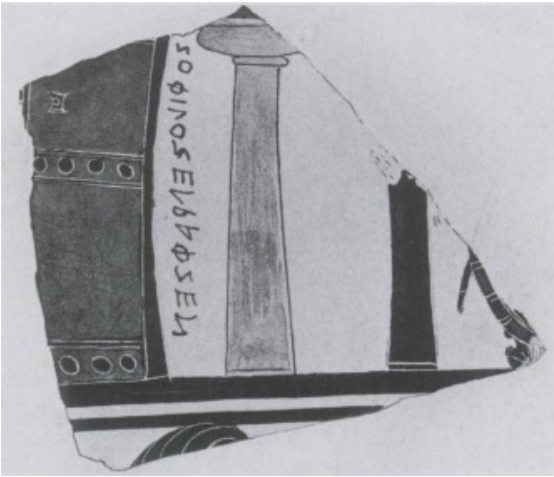


Fig. 4. 9 Doric column, Peleus' house, by Sophilos

By the mid-sixth century B.C., architectural elements with spiral decorations were beginning to appear on painted vases. Two spirally-decorated columns appear on an Attic black-figure lekythos attributed to the Amasis Painter and dated to around 550 B.C. The subject on the body of the vase is an Attic wedding (Fig. 4.10). It shows the procession of the bride and groom and their followers approaching the house of the groom, marked by an open doorway flanked by two Doric columns (von Bothmer 1985: 183 [fig. 3]).

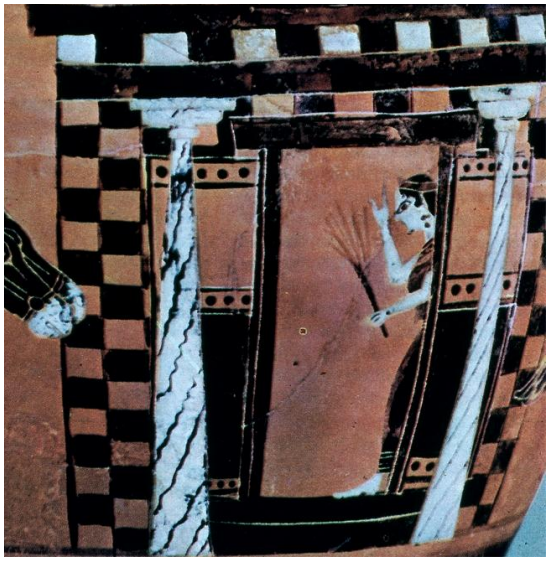


Fig. 4. 10 Doorway with spiral columns, by the Amasis Painter

The columns taper sharply from bottom to top (unusual for the Doric order; is this simply artistic licence?), and their capitals touch the transverse beam of the house's porch. The

columns sit firmly on the groundline of both the building and the painting, and there are two steps between them leading to the open doorway. Thus these columns have a specific architectural function as well as an artistic one, and probably mirror actual Athenian building practices. Benson says that the columns are "apparently garlanded" (Benson 1959: 254 n. 6). One assumes Benson said "apparently" because the spiral lines on the columns are slightly wavy, although, since it is difficult to tell from photographs, they could be shallowly carved spirals. Von Bothmer suggests that the columns may have been wooden, and that their spirals were incised decoration (von Bothmer 1985: 183). As mentioned previously, however, it would have been difficult to carve spirals across the grain of wooden columns. Both columns have Z spirals, which is unusual as most pairs or groups of spirally decorated columns have columns showing opposing spirals to those of their neighbours, as noted above. Still, since this image is both early and uncommon on painted vases, it is not surprising that this style of contrasting spiral directions, which later became conventional, had not yet been adopted.

Two more examples of vase paintings showing architectural spiral fluted columns are as follows: the first is a carved spiral fluted column which appears on a cup from Taranto (Fig. 4.11) painted by the Heidelberg Painter, who worked slightly later than the Amasis Painter in the same century (von Bothmer 1985: 183). The theme is either "Herakles in the Garden of the Hesperides (?) or the erotic pursuit of marriageable girls (?)." Near the cup's handle, a fountain-house is shown in profile view: it has one spiral fluted column topped by an unusual "globular capital" and is set on a plinth (Brijder 1991a: 376; Brijder 1991b: pls. 128a, 128c). There is an Aeolic column beside the cup's other handle, balancing the scene, and not only showing that this style of column is still fashionable, but also evoking historical connections.

Fig. 4. 11 Fountain house with spiral column, by the Heidelberg Painter

The second example is mentioned by Benson, who says "a representation which must undoubtedly be considered a spirally fluted column" is on an (undated) Apulian krater (Benson 1959: 254), and a drawing of this "representation" shows a spiral fluted column with an Ionic capital (Déonna 1938: 54 fig. 77.1). This drawing, though basic, shows spirals seemingly carved into the shaft rather than simply made with garlands twisted around it. The column is shown by itself, not in its place in the krater's decorated panel, and its architectural context is unexplained.

These vase paintings, therefore, show that the spiral fluted column was known and used architecturally, either in wood or stone, by the mid-sixth century B.C. As Oliver-Smith points out, "It hardly seems possible that the Heidelberg Painter invented the spiral shaft…[or] that he adapted the idea from a Mycenaean seal or furniture inlay, if he saw one, to the complex architecture of a fountain" (Oliver-Smith 1970: 50).

4. The Classical Period: 500-323 B.C.

After the Battle of Plataea in 479 B.C., the Greek allies dedicated a large bronze column topped by a gold tripod to Apollo at Delphi as a thank-offering for their victory against the Persians (Fig. 4.12). Herodotus (Hdt. 9.81) describes the offering as follows:

> Συμφορήσαντες δὲ τὰ χρήματα καὶ δεκάτην ἐξελόντες τῷ ἐν Δελφοῖσι θεῷ, ἀπ' ἧς ὁ τρίπους ὁ χρύσεος ἀνετέθη ὁ ἐπὶ τοῦ τρικαρήνου ὄφιος τοῦ χαλκέου ἐπεστεὼς ἄγχιστα τοῦ βωμοῦ (Godley 1969: 254).

> Having brought all the stuff together they set apart a tithe for the god of Delphi, whereof was made and dedicated that tripod that rests upon the bronze three-headed serpent, nearest to the altar (Godley 1969: 255).

Pausanias (10.13.9), who saw the monument in the second century A.D., describes it as follows:

> Ἐν κοινῷ δὲ ἀνέθεσαν ἀπὸ ἔργου τοῦ Πλαταιᾶσιν οἱ Ἕλληνες χρυσοῦν τρίποδα δράκοντι ἐπικείμενον χαλκῷ. ὅσον μὲν δὴ χαλκὸς ἦν τοῦ ἀναθήματος, σῶον καὶ ἐς ἐμὲ ἔτι ἦν; οὐ μέντοι κατὰ τὰ αὐτὰ καὶ τὸν χρυσὸν οἱ Φωκέων ὑπελίποντο ἡγεμόνες (Jones 1965: 442).
>
> The Greeks in common dedicated from the spoils taken at the battle of Plataea a gold tripod set on a bronze serpent. The bronze part of the offering is still preserved, but the Phocian leaders did not leave the gold as they did the bronze (Jones 1965: 443).

Although both these descriptions say that the Z-twist bronze column of the monument was constructed with one serpent (and three-headed only according to Herodotus in the quotations above), most scholars now think it consisted of three bronze serpents entwined spirally, with a gold tripod balanced atop their heads. Ridgway, however, suggests that the spiral appearance of the column shaft could have been achieved by casting a single serpent "without the misleading effect of the head finials" (Ridgway 1977: 378). The tripod had vanished by 353 B.C., stolen by the Phocians, and in the early fourth century A.D. Constantine the Great took the serpent column from Delphi to Constantinople, his new capital (Ridgway 1977: 374). The stone base of the column, however, is still *in situ* in Delphi before the Temple of Apollo. Only one of the serpent heads survives (now displayed in the Istanbul Archaeological Museum), but the extant column (29 coils, 5.35 m high) stands today in the Hippodrome in Istanbul (Ridgway 1977: 374, 376-377 figs. 1-3).

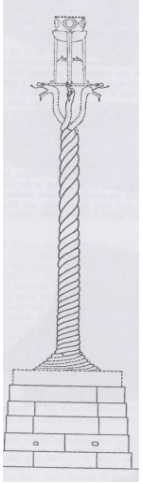
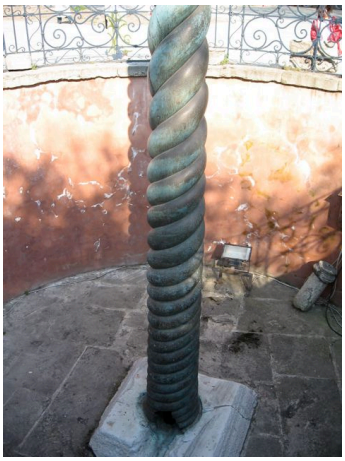
a.  b. 

Fig. 4. 12 a). Reconstruction of Serpent Column, Delphi;
b). Serpent Column in Hippodrome, Istanbul

The names of the 31 dedicators are inscribed on eleven spirals of the column shaft, "from the third to the thirteenth" spiral (Godley 1969: 255 n.1). Chapot points out that the "rings" created by the twisted serpents are not as regular as the carved fluted channels of a stone column would be, as the twists on the lower level of this monument are more crowded together and more horizontal than spiral, as if to represent the considerable weight of the three-serpent bronze column plus its gold tripod (Chapot 1907: 54 fig. 65). Single- or triple-bodied, in any case, the column's role in supporting the tripod, and thus the complete monument's original form, is still under discussion. The snake being sacred to Apollo, a serpentine column is a suitable shape for an offering to the god in his sanctuary at Delphi. I suggest that it was also an attempt to mimic an interesting architectural shape with religious and historical associations, often used in vase decorations and wall paintings and now copied in and adapted to architectural structures.

5. The Hellenistic Period: 323-31 B.C.

The spiral becomes an even more important design element in the Hellenistic period: Benson notes that there are Hellenistic copies of Minoan seals, as discussed in Chapter 3 above, and thus their subjects "(which include spirally fluted columns) were directly known and admired in the classical world" (Benson 1959: 254).

In vase paintings, examples of the continuing importance of the spiral come from two former Greek colonies in Sicily and Italy, by this time under Roman administration.

A late third-century B.C. krater from Centuripe in Sicily shows a group of three women flanked by two tall and slightly-curving lines ending in spirals, which act as frames for the scene. The long-stemmed spirals are not architectural elements, but merely framing devices, and they evoke the elongated acanthus stems of the Corinthian capital (Fuchs 1967: 524, pl. 52). Another example of the Hellenistic decorative spiral is found on a silver-gilt pyxis lid from Canosa di Puglia in southeastern Italy, dated to 130 B.C. It features a Nereid riding a sea-serpent and beneath them are stylised waves with spiral tops reminiscent of Ionic volutes and acanthus stems. Although the area was under Roman control at this time, this lid shows that Tarentine artists "retained their skill even during the period of Roman rule" (Fuchs 1967: 518, pl. 50).

6. Coins

Coins from the Archaic and Classical periods in Greece do not show spiral fluted columns used as architectural elements, but flat spiral designs were used on coins throughout the Greek world. In the last quarter of the fifth century B.C., two new mints began in Crete, at Knossos and Lyttos, east of Knossos, and some of the new issues showed a stylised spiral-like labyrinth (Sheedy 2012: 119 fig. 6.23). Two other issues from Knossos, and issued fifty years apart, show squared-spiral labyrinths: one is dated to 450 B.C. and has an eight-pointed star in the centre, and the other is dated to 400 B.C. and has a blank centre (Kraay 1966: 347, pl. 165.541-42, 165.544). A third Knossos issue, dated around 350-325 B.C., had a similar squared-spiral labyrinth with the spiral continuing into the centre of the design, leaving no space for further ornament (Kraay 1966: 347, pl. 165.544). A final example of the spiral-labyrinth type of coin design is also from Knossos, and dated to 350 B.C. It shows a woman's head, possibly Ariadne's, surrounded by a maeander pattern in a rather stretched-out spiral, which represents the labyrinth as well (Kraay 1966: 347, pl. 165.543). Whether or not the legendary palace labyrinth of King Minos was actually designed as a squared or rounded spiral, these coin designs show the adaptability of the spiral pattern when applied to architecture, mythological or real.

Other Greek coins featuring spiral designs include a Macedonian coin from the mint at Babylon (Fig. 4.13). It is dated to 325 B.C. and shows the young Herakles in a

lion skin on the obverse. On the reverse is a seated Zeus holding a spiral-patterned staff, on which the spirals could be either carved or formed by garlands; the spiral pattern is not discussed (Kraay 1966: 351, pl. 173.572). This coin uses typical Alexandrian motifs such as Zeus and Herakles, and thus both sides of the coin emphasise Alexander's connections with power and divinity, with the spirally-decorated staff adding religious and historical associations.

Fig. 4. 13 Macedonian coin: Zeus with spiral staff

7. The Architectural Spiral Fluted Column in Greece

Many spiral fluted columns have been found in Greece, but according to Benson they are all from the Roman period (Benson 1959: 254), i.e., after 146 B.C. Felsch (Felsch 1980: 76) says that part of an archaic Doric column with spiral fluting was found on the Athenian Acropolis, but he registers two problems with this discovery: spiral fluting on a Doric column is unconventional for the Doric order; and, this column could be a single example of a votive offering, an unprecedented architectural development. Benson catalogued four fragments of spiral fluted columns and one composite spiral fluted column from the Athenian Acropolis (Fig. 4.14; the top left column fragment is from the Odeion of Herodes Atticus in Athens), but they are no longer *in situ* as he described (Benson 1959: 263, pl. 45 a-d, pl. 47 a). As Felsch gives no details of the material or dimensions of his column piece, it is not possible to ascertain whether it is one of the column fragments mentioned by Benson. Dinsmoor, however, mentions two

spirally fluted "votive" columns, both of which are Doric, one from the Athenian Acropolis and one from Delphi. He says that these two columns "are the only forerunners of the spirally fluted columns of Roman times" (Dinsmoor 1950: 121), and Oliver-Smith dates them to the late sixth century B.C. (Oliver-Smith 1970: 49-50). No more information about these columns is given, but perhaps Dinsmoor's Athenian Acropolis fragment is the one noted by Felsch. In any case, it seems that only two or three stone-carved spiral fluted columns from this time period (i.e., Geometric to Hellenistic) have been found in Greece.

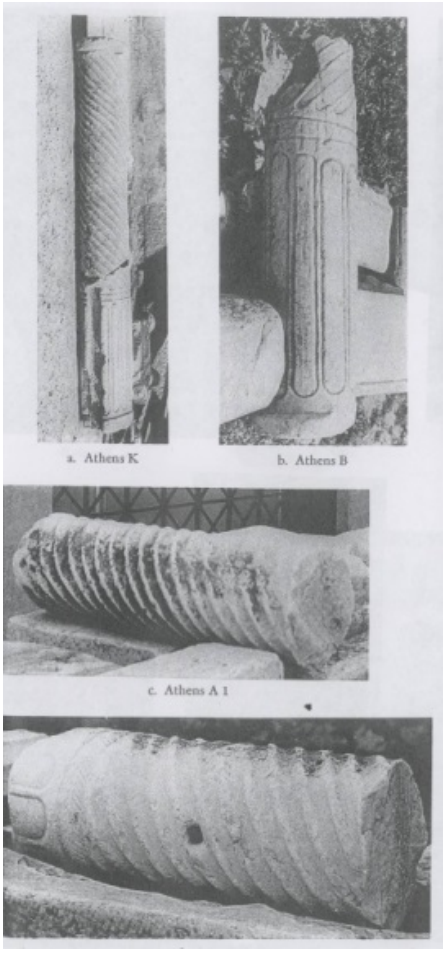


Fig. 4. 14 Spiral fluted column fragments, Acropolis, Athens

It is difficult to date sections of spiral fluted columns unless they are found in context within a structure, and Benson cites Roman theatres, temples, propyla, and ecclesiastical buildings as examples of such structures containing these columns (Benson 1959: 260-61). Conversely, the Acropolis columns could have been taken from an earlier

structure and reused, and therefore accurate dating of these columns or column fragments is not possible. Does the style of fluting give any clues as to its date? When did fluting begin on stone columns? Evans, as noted above in Chapter 3, dated a fragment of a vertically-fluted stone column found in Crete to Mycenaean times, but gave little information about its context, so it is not possible to verify his dating. Vertical fluting styles did indeed change over time. Flat, and sometimes faceted, vertical flutes are seen on early Doric columns (from the late seventh to the early sixth century B.C.) and gradually the flat flutes evolved into "concave grooves with pointed arrises" (the sharp edges where two grooves meet), which became the standard pattern of Doric fluting (Barletta 2001: 54, 63; Camp and Dinsmoor 1984: 19). On early Ionic columns, the flutes "rose in points or arrises, as with their Doric counterparts," and the arris was replaced by the flattened ridge, or fillet, about 530 B.C. This change appeared in the construction of the Polykratean Temple of Hera at Samos, and became the standard architectural convention for the fluting of the Ionic column from then on (Barletta 2001: 98; Camp and Dinsmoor 1984: 19).

Regarding the spiral fluted column in Greece, Benson says, "The use of spirally fluted columns and a composite variety related to composite Ionic columns is attested in Greece from Roman imperial times to the sixth century after Christ and possibly later" (Benson 1959: 261). There are different styles of spiral fluting on columns, and Benson describes the composite type, where the column has "vertical linear fluting on its lower part and spiral fluting on its upper part" (as shown above in Fig. 4.14: Benson 1959: pl. 45b). Here the vertical channels are not hollowed out, but instead are left convex or flat. The earliest example of this style was found at a seaside villa at Stabiae, on the Bay of Naples, the town destroyed during the eruption of Vesuvius in 79 A.D. (Benson 1959: 255, pl. 52b; Modianot-Fox 2007: 1, [figs. 1, 3]; D'Orsi 1954: 802 fig. 2). Other examples have been found in Athens and Corinth, although Benson dates them later, i.e., between the first and fifth-sixth centuries A.D. He suggests that the Athenian columns may have come from the mid-fifth century A.D. basilicas of the Asklepieion or the Olympieion, or possibly the basilica built in the middle of the Parthenon (Benson 1959: 255, pl. 45 a-d). Given these ambiguities concerning date, it is difficult to accept the spiral fluted columns on the Athenian Acropolis as Hellenistic.

An unusual variation on the lower section of the composite style column is seen at the first-third century A.D. Roman city of Volubilis in Mauretania Tingitana, now in modern Morocco. The House of Columns, dated to the early 200s A.D. (MacKendrick 1980: 303), is in the northern part of the city in the residential area. It has two Z-spiral fluted columns at the entrance to its courtyard. Here the channel in the centre of each spiral flute is convex, and each one of these flutes is separated from its neighbour by a wider and deeper plain spiral flute. There are 20-22 spiral flutes in total on each column, including both plain and convex-centred, and this is a rare example of spiral flutes in the Roman world having convex centres (Fig. 4.15). There is also a spirally-twisted band carved under the egg-and-dart design below the capital, and a similar twisted cable design occurs on the Syrian/Palestinian lead sarcophagi, which were popular in the second-fourth century A.D. throughout the Roman Empire. They will be discussed below in Chapter 5.

Fig. 4. 15 Spiral fluted column, House of Columns, Volubilis, Mauretania Tingitana

This chapter has examined the continued use of the decorative spiral from the Geometric through the Hellenistic periods. During this time, artists still used the painted flat spiral on pottery, and builders and architects began to use it in architecture, as shown in the rise and development of the Aeolic and Ionic capitals. The spirally-decorated column, both garlanded and carved, appeared on Greek vase paintings, seals, and coins,

but, except for the elusive "votive" columns noted by Felsch and Dinsmoor (as discussed above), no spiral fluted stone columns dated securely to the Greek period have yet been found in excavations. While this may lead us to believe that the creation and structural use of the spiral fluted stone column did not originate in Greek architecture, the evidence considered in this chapter suggests otherwise: the Amasis Painter's spirally-decorated columns; the Taranto cup's and the Apulian krater's spiral fluted columns; the Doric capital from Kalapodi and the archaic Doric column from the Athenian Acropolis, both with evidence of spiral fluting; Dinsmoor's spirally fluted "votive" columns from the Athenian Acropolis and Delphi; the spiral shaft of the Serpent Column at Delphi; and the continued use of the spiral as decoration on seals, coins and pottery; all these items support the idea that the architectural spiral fluted stone column did indeed have its beginnings in Greek structural design. Nevertheless, it clearly remained rare.

The next chapter will consider the use of the spiral fluted column in the Roman world, in Roman Greece, Italy and the wider Roman Empire. Was it tied to certain types of structures, functions, materials and/or geographical areas? We will also examine how, during the same period, the spiral changed from a common ornament found in domestic settings to a specialized design used on architectural columns intended for particular public areas such as theatres, colonnades, public fountains and decorative entryways to public and private areas.

Chapter 5: Spirals in the Roman World From the Etruscans to Constantine

This chapter considers the use of the spiral fluted column in design and construction in the eastern Mediterranean during the Roman period, by examining excavation reports and field study results. This chapter proceeds chronologically through the evidence, beginning with the Etruscans and continuing through the Constantinian period of the fourth century A.D., to see how and where the spiral fluted column was used. Having been developed in the Greek world, as seen in Chapter 4, the spiral fluted column was used as an important element in Roman monumental contexts. Cheilik states that "spiral fluted columns appear only on one or two provincial monuments of the first century A.D." and do not appear in Rome until the end of the second century (Cheilik 1963: 71). In Italy, however, the Porta dei Borsari, a city gate in Verona, is said to be from the Flavian era, and its second storey has spiral fluted columns supporting an entablature (Blake 1959: 143). But again, scholars differ on dating: a later scholar dates this structure to the Hadrianic period (Wilson Jones 2000: 116 fig. 6.14), which would support Cheilik's theory. Is there any evidence for an earlier use of the spiral fluted column in the provinces? From the chart of those found in my field study (Appendix 1), it can be seen that they were used mainly from the first century A.D. onwards in the eastern Mediterranean, although an earlier example, to be discussed below, is found in the Villa of Columns in Ptolemais, Cyrenaica, a structure dated to the late Hellenistic/early Roman period (Olszewski and Zakrzewski 2011: 665). Other examples will be sought in this chapter as well.

The chart also shows that spiral fluted columns were employed primarily in four types of Roman structures: theatres (e.g., Sparta, Termessos, Hierapolis, Sabratha, Lepcis Magna and Kourion); nymphaea (e.g., Side, Kourion, Hierapolis and Perge); grand colonnades along important public thoroughfares (e.g., Perge, Ephesus and Apamea); and decorative entryways to sacred or civic precincts (e.g., Aphrodisias and Sardis). Spiral fluted columns were included not only as architectural components of buildings, but also became an important element of Asiatic sarcophagus design by the second century A.D. This popular style of burial container originated in central Anatolian quarries and was then shipped to many areas throughout the eastern Mediterranean. In addition, coins,

particularly those of second to third century Asia Minor, occasionally showed temples with spiral fluted columns framing the figure of a deity in the temple. Each of these applications will be examined in this chapter. We will also look briefly at the later Roman period to see if and how spiral fluted columns continued to be used.

The investigation begins with the Etruscans. Although Petrie gives no opinions as to the origin of the architectural spiral column, he says that it was in use in Italy by at least 500 B.C. He depicts a twisted column with an S spiral on an Etruscan tomb altar panel from Chiusi, Etruscan Clevsin, in Tuscany (Fig. 5.1). Carved in limestone, this panel is dated to 550 B.C. and shows what has been interpreted as a funeral scene, with women making preparations for the burial and feast (Poulsen 1922: 55-56, fig. 42 opposite 56; Petrie 1930: pl. 56 fig. RY3). A spiral column frames the right-hand side of the scene and touches a plain architrave which provides the "ceiling" of the room and defines the top of the picture. The column stands on a plain "floor" which provides the bottom frame of the picture. There are vertical concave lozenges carved above the architrave and below the floor, thus serving to emphasise both the top and bottom of the scene. The left side of the panel is broken off, and we may assume that another spiral column framed the left side of the scene, and thus the combination of spiral and vertical designs as framing elements adds drama to otherwise standard funerary motifs. Here again the spiral column has not only a decorative function but also an architectural one, as we have seen in the Lion Gate panel and the fresco from Room 31 in Mycenae, and the Greek black-figure vase paintings by the Amasis and Heidelberg Painters.

Fig. 5. 1 Spiral column on Etruscan tomb altar panel, Chiusi

There were four types of Roman structures in which spiral fluted columns were primarily used: theatres, nymphaea, grand colonnades along important public thoroughfares and decorative entryways to sacred or civic precincts. Full details about each site, as well as sites not examined in this chapter, can be found in Appendix 1, which includes the locations of the spiral fluted columns within the archaeological sites, the structure types and the cultures with which they are associated, and the classifications of their spirals, as well as additional information.

1. Theatres

Spiral fluted columns have been found in many Roman-era theatres. I have documented them in nine Roman sites: one in Greece, three in Asia Minor (one example is in a bouleuterion which was also used as an odeion, and is therefore included in this section), three in Cyprus and two in North Africa. The seven examples described in this section come from these areas, and were selected to show the geographical and chronological range of this influential theatrical design.

A. Sparta

The Roman-period theatre at Sparta in Greece's southern Peloponnese was built in the first century B.C.; the location of Sparta's first Greek theatre of 465 B.C. is unknown (Waywell et al. 1998: 98). The original stage and σκήνη building may have been wooden, set on rollers although another opinion is that the remaining wheel-tracks were probably meant for moving stage scenery about (Bieber 1961: 122; Cartledge and Spawforth 1989: 128). When the wooden elements burned down, Vespasian had the "first architectural *scaenae frons*" built in stone, although a stone stage was not constructed until about A.D. 200 (Bieber 1961: 122, 217). The design for the new building included distinctive spiral fluted columns (Woodward 1930: 175, 190 fig. 13.1), having an acanthus design carved on the lower part of each drum and S spiral flutes above the acanthus (Fig. 5.2). Columns with a ring of acanthus leaves at the base are thought to have originated in Ptolemaic Egypt, and are seen in North Africa (the Severan basilica at Lepcis Magna) and Jordan (the Hadrianic Arch at Gerasa), among other sites (Ward-Perkins 1981: 341, 343). This style of column at Sparta, however, having the acanthus pattern carved at the base of each column drum, seems to be unique to this theatre. The

columns are thought to have been set in the central section of the upper façade, along with vertically-fluted and unfluted columns used in the same façade (Waywell et al. 1998: 98-9, 100 fig. 9.8, 111; Woodward 1930: 206), and thus would have provided a dramatic backdrop for the plays.

Fig. 5. 2 Spiral flutes and acanthus column drums from theatre, Sparta, Greece

In the second century A.D., Pausanias (3.14.1) admired Sparta's theatre, ἀπέχει δὲ οὐ πολὺ τοῦ τάφου τὸ θέατρον, λίθου λευκοῦ, θέας ἄξιον (Jones and Ormerod 1966: 82); "Not far from the cenotaph [of Brasidas] is the theatre, made of white marble and worth seeing" (Jones and Ormerod 1966: 83; Cartledge and Spawforth 1989: 171, 217). The spiral fluted columns set in this theatre's *scaenae frons* undoubtedly added to the visual impact because of their distinctive design.

B. Termessos

The theatre at Termessos in Pisidia**,** south central Turkey, is dated to the Antonine period (Bieber 1961: 219). As was generally the case in theatres of Asia Minor, its *scaenae frons* had five doors, while western theatres had three doors (D'Andria 2003: 158). Although the drawing in Bieber's account does not show any spiral fluted columns in front of the stage building (Bieber 1961: 219 fig. 740), the drawing in Chapot's description shows two of these columns framing its central doorway (Chapot 1907: 124 fig. 155). This arrangement is verified by a larger and more detailed drawing of the

central doorway in Lanckoronski's account (Lanckoronski 1892: 95 fig. 53, 97 fig. 55, pl. 11) which shows two spiral fluted columns flanking the doorway, one with a Z spiral and the other an S spiral. There are unfluted columns beside them, and all the columns have composite capitals (Lanckoronski 1892: 96), a mixture of Corinthian acanthus leaves and Ionic volutes, a favourite Roman combination. Two fragments of spiral fluted columns were seen in the rubble of the orchestra in 2012, one with an S spiral and the other with a Z spiral (Fig 5.3). This was the usual arrangement for two columns framing an entryway, and therefore these fragments must be the remnants of the doorway columns.

Fig. 5. 3 Spiral fluted column fragments from theatre, Termessos, Pisidia, Turkey

C. Hierapolis

The monumental façade of the theatre at Hierapolis in Phrygia, west central Turkey, had three courses of columns and friezes, although only one course still survives. The stage is about twelve feet high (Bean 1980: 208), and its lower *hyposcaenium*, at orchestra level, has twelve spiral fluted columns, with alternating S and Z spirals and composite capitals, placed between the niches and doors (Fig. 5.4). A theatre existed on this site in Flavian times, but the building presently being excavated and reconstructed is dated to the late second to early third centuries A.D., according to inscriptions dedicating it to Apollo Archegetes (Apollo as founder of towns or leader of colonies), and the Roman emperor Septimius Severus and his family (D'Andria 2003: 153 fig. 133, 154 fig. 135, 155-56, 157 fig. 138, [160] fig. 14, 181; Thomas 2007: 88 fig. 91a). The spiral fluted

columns in the *hyposcaenium* in this theatre combined with the monumental façade of the *scaenae frons* to frame the entryways and exits, and heighten the visual impact of the entire stage area. Thus they enhanced the dramas taking place on the stage.

Fig. 5. 4 Spiral fluted columns in theatre's *hyposcaenium*, Hierapolis, Phrygia, Turkey

D. North Africa: Sabratha and Lepcis Magna

In Roman North Africa, "Roman love of luxury and ostentatious display created architectural masterpieces" (Bieber 1961: 208), and the spiral fluted column became an important part of the display in several highly visible public locations. The theatre at Sabratha, west of Tripoli in Numidia, built about A.D. 200, is the largest Roman theatre in Africa. Bieber describes the 96 "colorful columns" of the three-storeyed *scaenae frons*: they were made of white marble (from Greece?) violet *pavonazzetto* (Docimeion, Asia Minor), green *cipollino* (Euboea, Greece), and black granite (Egypt), but gives no details about their fluting (Bieber 1961: 206 fig. 695; Benson 1956: 386). A 1988 photograph of the west side of the reconstructed *scaenae frons* shows three spiral fluted columns in the second storey, but without comment in the text (Onians 1988: 55 fig. 32). Wheeler mentions spiral fluted columns in his description of the columns in the theatre's *scaenae frons*: "others again (at the lateral angles) were spirally fluted, in an attractive fashion which the Renaissance was later to adopt." These columns, however, do not appear in the photograph of the theatre on the opposite page (Wheeler 1966: 84, [85] pl. 22). However,

a drawing of the reconstructed *scaenae frons* published in 2006 shows four spiral fluted columns in its second storey, and all the columns in this storey were made of white marble (Sear 2006: 284, fig. 26). In 2006, one fragment of a spiral fluted column in red sandstone was seen near the entrance to the archaeological site of Sabratha (fig. 5.5). Although it was unlabelled and unidentified, it may have come from an undescribed part of the theatre.

Fig. 5. 5 Spiral fluted column fragment from entrance to site, Sabratha, Numidia

The theatre at Lepcis Magna, east of Tripoli in Numidia, was begun under Augustus and rebuilt about A.D. 160. Its three-storeyed *scaenae frons,* though slightly smaller than the one in Sabratha's theatre, was constructed with similar brightly-coloured decorative marbles (Bieber 1961: 206-7). The proscenium level and the lower order have been reconstructed, but no spiral fluted columns are mentioned (Bieber 1961: 207; Sear 2006: 281-82). Two fragments of spiral fluted columns were seen in 2006 near the entrance to the archaeological site (Fig. 5.6). They were undescribed and unattributed, but may have come from the theatre where they would have fitted well into an upper level of the façade of the *scaenae frons*.

Fig. 5. 6 Spiral fluted column fragments from entrance to site, Lepcis Magna, Numidia

E. Cyprus: Kourion

At Kourion, the original Hellenistic theatre was remodelled under Nero, and, after earthquake damage in A.D. 77, was rebuilt under Trajan, with spiral fluted columns as an important part of the stage building's design (Christou 1996: 22-3; Soren and James 1988: 198). Three doorways were flanked by spirally fluted columns set on high podia (Sear 2006: 382), and Benson notes two nearly contemporary parallels for the use of spiral fluted columns in the *scaenae frontes* of the Roman provincial theatres at Termessos and Sabratha. In 1956, Benson said of the Kourion theatre, "One good-sized fragment of a rather large spirally-fluted column is lying in the orchestra of the theater" (Benson 1956: 385-86, pl. 126 figs. 1-2), and a photograph from 1961 shows a Z-spiral fluted column lying in the orchestra (Stillwell 1961: 53 fig. 19, 73). In 2012, this column was seen at the right side of the stage building (Fig. 5.7a). More fragments of spiral fluted columns "with an upper diameter of about 0.26 m to 0.27 m" were noted by Stillwell in or around the theatre. Stillwell does not specify if the spirals have an S or Z twist, and this diameter suggests a second storey of smaller columns on the *scaenae frons* (Stillwell 1961: 73). As of 2012, these fragments are no longer visible at the theatre. Benson does cite, however, a section of a smaller-diameter column, 0.93 m long and with an S spiral, lying one hundred yards south of the basilica (and therefore west of the theatre). The diameter was 0.26 m to 0.31 m (Benson 1956: 385-86, pl. 126 fig. 3; Benson 1959: 271), so it may be one of Stillwell's smaller column fragments. A search of the area in 2012 revealed no complete column, but only five very weathered S- and Z-spiral fluted column pieces, partly buried in soil and long grass. Without diameter measurements, however, it is not possible to know if any of them is part of Benson's "basilica" column. As of 1956, there was one Z-spiral fluted column section in the Kourion Museum courtyard, which Benson says was from the theatre, brought in by villagers around 1890-1900 to use in a house that was never built. It was 1.64 m long, with a diameter of 0.40 m (Benson 1956: 385, pl. 126 fig. 3), but it was not in the courtyard in 2012. But in 2012 two pieces of spiral fluted column were seen in a shelter opposite the Kourion Museum, along with other marble fragments belonging to the Museum (Fig. 5.7b). Their diameters are approximately 0.38 m and they are both Z-spiral, so they are likely to be the original "courtyard" column from the theatre, now broken in two.

a. b.

Fig. 5. 7 a). Spiral fluted column fragment beside stage of theatre, Kourion, Cyprus;
b). Spiral fluted column fragments near Kourion Museum, Kourion, Cyprus

F. Aphrodisias

At Aphrodisias in Caria in western Asia Minor, two fragments of spiral fluted columns were seen in 2011 and 2012 set up in the stage area of the bouleuterion (Fig. 5.8). This building is dated to the second half of the second century A.D. "with distinct Antonine and Severan sub-phases," according to its architectural ornament (Bier 2008: 159-60; Ratté 2001: 134 fig. 5-15). Both column fragments were of gray marble, and one had a Z spiral and the other an S spiral. Since the bouleuterion's *scaenae frons* was two-storeyed and included both unfluted (white marble) and spiral fluted (gray marble) columns (Bier 2008: 154), it is probable that these two fragments are parts of the original *scaenae frons*. There is a possibility that they may have been brought to this location from another site, as Ratté's 2001 photograph of the Late Roman stage-platform and orchestra does not show these fragments *in situ*. This possibility, however, seems unlikely, given that gray marble spiral fluted columns are known to have been in the *scaenae frons*, and archaeological examination continued here in 2000, 2002 and 2003 (Bier 2008: 145). No repositioning of spiral fluted columns is noted in Bier's account, but an examination and documentation of previously-stored architectural elements from the *scaenae frons* (Bier 2008: 153) may have brought these columns to the fore. In any case, since this building was used both as a council house and an odeion (Bier 2008: 162-3), the connection between the theatre and the spiral fluted column is emphasised in both the ancient and the present juxtapositions.

Fig. 5. 8 Spiral fluted column fragments in the bouleuterion, Aphrodisias, Caria, Turkey

2. Nymphaea

In the Roman Empire, from the first to the third centuries A.D., the funding for nymphaea came primarily from civic benefactors and city governments rather than from the central Roman administration. Expensive marbles and statues still represented the donors' wealth and status, but nymphaea were cheaper to build than aqueducts or baths because of their smaller size (Jacobs and Richard 2012: 28-9). Spiral fluted columns are often found in the monumental façades of nymphaea, and I have recorded them in five Roman sites: one in Jordan, one in Cyprus and three in Asia Minor. This section examines four of these sites in detail.

A. Side

At Side in Pamphylia, Asia Minor, there is a large nymphaeum just outside the main gate of the city. It is dated around A.D. 211-12, although Longfellow notes that it has also been dated to the Antonine period and suggests that the current *anastylosis* project will provide more clues to its building phases (Longfellow 2011: 180-81, 243 n. 79). It was a three-storeyed structure which had three two-storeyed *exedrae* in the back wall, through which the water came by way of three spouts into three basins. It then spilled from these basins into a long rectangular storage basin that ran the length of the nymphaeum between its side walls. Fifteen small basins were set across the front of the large basin, from which the public could draw water. Along with reliefs, and statues portraying local gods and people as well as mythological and imperial figures, the

monumental façade was elaborately decorated with columns (Longfellow 2011: 180-1, 181 fig. 61). Some of these were spiral fluted, as shown by numerous fragments lying in groups in front of the building in 2011 and 2012, ready to be replaced in the façade, which is presently being reconstructed. Some of these columns are attached to pilasters, and others are in the round (Fig. 5.9). There was formerly a large plaza in front of the structure for spectators to rest and admire the fountain. It is easy to imagine the impressive sight of this monumental fountain on a summer's day, with the water cascading from the spouts in the rear wall into the basins and then into the main storage basin.

Fig. 5. 9 Spiral fluted column fragments from nymphaeum, main gate, Side, Pamphylia, Turkey

B. Kourion

At Kourion, the Graeco-Roman city on the south coast of Cyprus, a single Z-spiral fluted column of blue marble, complete with base and Corinthian capital, rises above the blocks and low walls in the surrounding area. It is part of Kourion's Roman nymphaeum, begun in the early first century A.D. and enlarged under Trajan. With a length of 45 m and width of 15 m, this nymphaeum is one of the largest such monuments known (Christou 1996: 46; Soren and James 1988: 192). It provided the main water supply for Kourion and was elegantly decorated, having two marble columns at the entrance, one of which is the remaining spiral fluted column, seen *in situ* in 2012; the other is missing. The building had shell-shaped niches above three apsed fountains, two basins bordering the central apse, and other (undescribed) "impressive architectural members." In the third century A.D., a large hall with a geometric mosaic floor "of exceptional interest" was added, with colourful patterns of "lozenges, guilloches, spirals, meanders, concentric circles, rosettes, shields in circles and other motifs" (Christou 1996:

46-7; Swiny 1982: 113). Here again the spiral fluted column was used to add elegance to a popular public structure which was one of the opulent city buildings. The complex was finally destroyed by Arab raids in the seventh century A.D. (Christou 1996: 47).

C. Hierapolis

In ancient Phrygia, the city of Hierapolis was rich in water. Near the theatre are the remains of a large nymphaeum, called the Temple Nymphaeum, or Nymphaeum of the Sanctuary of Apollo, as it is situated just west of the sanctuary's *temenos* (Campagna 2006: 391). There is another nymphaeum as well, the Nymphaeum of the Tritons, located farther to the north near the city's agora. Both the Temple of Apollo and its nymphaeum are dated to the third century A.D. Campagna says that this nymphaeum was built "to give the sanctuary of Apollo a monumental façade towards the *plateia*" on the west, and the suggestion has been made that the nymphaeum was placed near the temple so that its waters would be used for aspersion (sprinkling of water) and purification rites in the sanctuary (Campagna 2006: 394). Several fragments of spiral fluted columns were seen lying in front of the nymphaeum in 2012, some of which were attached to pilasters. There were also some fragments of columns with unusual wavy fluting (Fig. 5.10). Similar wavy fluting can be seen carved on a wellhead block at Ephesus, near Kuretes Street, and there are several undated and unidentified column fragments with wavy fluting in the courtyard behind the Archaeological Museum of Peiraeus in Greece.

Fig. 5. 10 Spiral fluted and wavy columns from Temple Nymphaeum, Hierapolis, Phrygia, Turkey

The nymphaeum was U-shaped, with a back wall and two side walls, and had a large water basin on the front. The water came from a reservoir outside the eastern city wall and poured into the basin through a niche in the centre of the back wall. The elaborate

decoration of this building has been described, but spiral fluted columns are not mentioned in accounts of this nymphaeum. There were two courses of columns with entablature and niches for statues lined the walls (D'Andria 2003: 132, 133 figs. 114-15, 135 fig. 118). "The whole building was richly decorated, and many handsome architectural pieces have been excavated" (Bean 1980: 207), and spiral fluted columns would have been considered a fitting style of adornment for this impressive civic construction.

D. Perge

At Perge in Pamphylia there were three nymphaea, set at the ends of a long water channel, the *euripus* (2 m by 400 m), that runs from north to south down the middle of the city's colonnaded central street (Jacobs and Richard 2012: 58). Inscriptions on the colonnade state that the street was first given columns under Tiberius, but the main street with its canal and double colonnade (one on each side of the canal) was not finished until Hadrian's time (Fig. 5.11). The nymphaeum-gateway at the north end of the street was also Hadrianic (Abbasoğlu 2001: 174 fig. 7.2, 179). Its patron or civic benefactor may have been a local person of high rank, as shown by the central statue of a local god and the use of local craftsmanship in the imperial statues of Hadrian also set in the nymphaeum (Longfellow 2011: 157, 160). "Four granite and spirally fluted columns stretch across the first story of this central part of the monument" (Longfellow 2011: 157 fig. 55, 158), and fragments of several of these columns were seen in the rubble of the nymphaeum in 2012. The water arrived in the city from a stream via an aqueduct (Grainger 2009: 175), emerging from the nymphaeum below a statue of the local river-god Kestros and flowing down an open channel running the length of the main street (Longfellow 2011: 157 fig. 55).

Fig. 5. 11 Spiral fluted column fragments in *euripus*, Perge, Pamphylia, Turkey

This water channel provided an easily-accessible water source by means of drawing basins and a random series of terracotta pipes set into its sides, so that water could be piped directly into various nearby shops and houses (Jacobs and Richard 2012: 58). The open channel also supplied a method of cooling the city in the hot summers. In 2012, numerous fragments of spiral fluted columns were seen both beside and inside the water channel all along its length, suggesting that parts of the colonnades on each side of the channel were spiral fluted. As well, archaeologists have re-erected several unfluted columns along its length (Grainger 2009: pls. 4, 7).

At the end of the second century A.D., two more nymphaea were built at the south end of the city (though not connected directly to the earlier water channel), one of which contained statues of Septimius Severus and Julia Domna (Abbasoğlu 2001: 174 fig. 7.2, 182). This monumental fountain was called the Hydreion of Aurelia Paulina after its founder, a local woman who was priestess of the imperial cult as well as priestess of Artemis Pergaia, the Anatolian goddess of the city (Longfellow 2011: 185-6). It was situated beside the South Bath, the source of its water supply, and was dedicated to Artemis Pergaia and the Severan family. Several spiral fluted fragments seen in its rubble in 2012 probably belong to this monumental structure, although Longfellow's drawing does not show spiral fluted columns and the text does not mention any (Longfellow 2011: 185-8, 185 fig. 63).

3. Grand Colonnades Along Public Thoroughfares

Another characteristic of the Roman city is the colonnaded main street. I have documented those containing spiral fluted columns in four Roman sites: one in Cyprus, one in Syria and two in Asia Minor (one of which, in Perge, has been discussed above). This section examines two of these sites in detail to see how these distinctive columns were used in colonnades.

A. Ephesus

At Ephesus, in Ionia, western Asia Minor, a colonnade runs along Kuretes Street in the central area of the city. This street extends from the Library of Celsus to the Byzantine Herakles Gate (Scherrer 2001: 65 fig. 3.9, 81), a distance of about 350 m. On the north end of this street, near the site of the Terraced Houses and in front of the Alytarchs' Stoa, two spiral fluted columns, one with an S spiral and one with a Z spiral, stand today among the vertically-fluted ones (Fig. 5.12).

Fig. 5. 12 Spiral fluted columns beside Kuretes Street, Ephesus, Ionia, Turkey

This colonnade was rebuilt from elements taken from elsewhere in the city after the great earthquake of the fourth century A.D.: "Although the whole [of the street] was finely designed, most of the material was reused; hardly any two columns of the street are

matching" (Foss 1979: 69). Where did these two spiral fluted columns come from? To answer this question, it is necessary to examine the harbour area to the west of the city.

Around A.D. 83, the harbour area was enlarged, and under Trajan the harbour was enclosed, permitting construction of the new Sebaston Gymnasium (Gymnasium of the Emperors, or Harbor Gymnasium) and the new Sebaston Baths (Baths of the Emperors, or the Harbor Baths, and called the *Thermae Constantianae* in late antiquity when they were rebuilt by Constantius II) (Scherrer 2001: 64-5 fig. 3.9, 72 fig. 3.13, 74; Lessing and Oberleitner 1978: 118; Foss 1979: 59). A single Z-spiral fluted column, along with some pieces of a classical frieze decorated with garlands and *bucrania,* stands near the Sebaston Baths in a 19th century undated photograph, displayed in a nearby Selçuk hotel in 2012. In photographs from 1972 and 1979, the same column is shown standing beside the same frieze remnants. These frieze fragments were "re-used in the rebuilding of the Baths of Constantine" (Foss 1979: 59 fig. 18; Alzinger 1972: [150] pl. 120, 157). They are from the dismantled Parthian monument, built to commemorate Lucius Verus' victory in the Parthian Wars (A.D. 161-166), and here they were used as water basins, placed beside the entrance stairway to the baths. The column standing beside the frieze fragments is not mentioned in the accompanying texts. A 2012 photograph, however, shows two pieces of spiral fluted columns, one S-spiral and one Z-spiral, flanking the remains of the staircase, with another S-spiral fragment standing beside the S-spiral column, obviously part of it (Fig. 5.13) (Jacobs and Richard 2012: 19, 20 fig. 11). The single Z-spiral column seen in the three earlier photographs is the same Z-spiral column that is in the 2012 photograph.

Fig. 5. 13 Two spiral fluted columns beside staircase of Baths of Constantine

Since the columns by the Sebaston Baths as well the ones on Kuretes Street were re-used from other structures, where did they all come from? After a great earthquake in A.D. 262 and "subsequent plundering by Germanic sealords" (Scherrer 2001: 79), much of Ephesus lay unrestored until Theodosius I (A.D. 379-95) began to rebuild the city with re-used materials. The harbour's bath-gymnasium complex was connected to the main city area by a colonnaded street, the Arkadiane (Scherrer 2001: 79-80), which ran west from the theatre to the harbour. Both a drawing of a theoretical reconstruction and a photograph of the eastern end of the Arkadiane show unfluted columns along the street and vertically-fluted columns in its Hellenistic or Roman West Gate (Alzinger 1972: 106-7; Lessing and Oberleitner 1978: [97] pl. 55; Foss 1979: 56, 57 fig. 16, 58 fig. 17); therefore the spiral fluted columns now beside the Harbor Baths staircase and the ones from Kuretes Street could not have come from the Arkadiane colonnade. The most likely source is the Sebaston Gymnasium, which, along with the Sebaston Baths, was destroyed by fire in the third-century A.D. (Foss 1979: 60) and fell into ruins. A drawing in Alzinger's account shows a reconstruction of one of two *exedrae* in the gymnasium, opening off the *palaestra*. Each of these is called a "Kaisersaal or Marmorsaal" because of its ornate marble decorations, and the drawing shows two spiral fluted columns, one with an S spiral and one with a Z spiral, flanking a central niche (Alzinger 1972: 126 pl. 95, 133; Ward-Perkins 1981: 292-93, 294 fig. 191). Thus the spiral fluted columns beside the Sebaston Baths staircase and those in the Kuretes Street colonnade, all of which have similar proportions, may well have come from one of these Marmorsaal *exedrae*. The total number of spiral fluted columns in both *exedrae* is unknown, since the drawing of the reconstruction shows only one of the three sides of one Marmorsaal. If we assume that both Marmorsaals were identical in size and shape, there would be at least four spiral fluted columns available for re-use, enough to supply two for the Kuretes Street colonnade and two for the Sebaston Baths staircase.

B. Apamea

Apamea is situated in northwest Syria, on the Orontes River. It was first a Seleucid city, founded in 300 B.C., and then became a Roman one, and was the headquarters for the Roman Legion II Parthica in the third century A.D. Its great

colonnaded street is an impressive sight: it is almost two km long, and a magnificent part of its colonnade near the agora is composed entirely of spiral fluted columns with carved S or Z spirals set alternately in line (Fig. 5.14). The rest of its colonnade contains smooth or vertically-fluted columns (Sartre 2005: 169). This is the greatest concentration of spiral fluted columns still surviving in the ancient world. This colonnade has been partly reconstructed since antiquity, and some 44 columns were seen standing in 2009. Some entablature remains *in situ*, and many large pieces of spiral fluted column drums lie scattered around the colonnade.

Fig. 5. 14 Spiral fluted colonnade, Apamea, Syria

After a great earthquake in A.D. 115, reconstruction work began on the baths, the colonnade and the city's water supply. The new town-plan included enlarged colonnades on the main north-south street (Balty 1988: 91-2; Balty 1994: 98, 100). In front of the agora, three of the spiral fluted columns show a special feature, having small platforms on the side facing the street. These are designed to hold statues, in this case of the emperors Antoninus Pius, Marcus Aurelius and Lucius Verus, which were, according to inscriptions, donated by local benefactors, two brothers of the Apii family (Balty 1988: 93, pl. 11; Butcher 2003: 245). These column platforms, "a Syrian feature" (Ward-Perkins 1981: 305), are also seen on the main colonnaded street at Palmyra, and they

provided a way for local donors and benefactors to honour themselves, their families and the imperial family. Ward-Perkins notes that, "however upsetting [these brackets are] to the classical purist," they at least limited the clutter of statues on the ground (Ward-Perkins 1981: 360). Apamea, then, holds the honour of having the largest number of spiral fluted columns extant in one area, and the only spiral fluted colonnade. This monumental work is a testament to Roman engineering and to its visionary architects and craftsmen, as well as to Apamea's benefactors, who wanted to point out their own wealth and that of their city.

4. Decorative Entryways to Sacred or Civic Precincts

The monumental gateway is an important architectural element of the ancient city, both Greek and Roman. In the Greek world, the Lion Gate at Mycenae makes an impressive entrance to that Bronze Age city, as does the classical Propylaea to the Athenian Acropolis. The Romans continued this practice of the monumental gateway. I have documented two of them containing spiral fluted columns in two Roman sites in Asia Minor: one gateway leads to a sacred temple precinct, and one to a civic bath-gymnasium complex, both of which are discussed in this section.

A. Aphrodisias

At Aphrodisias, a monumental tetrapylon leads from the east into the precinct of the Temple of Aphrodite on the west. Dated to the mid- to late-second century A.D., it has four rows of four columns each, the first and third of which, seen from the front, or east side, of the monument, were spirally fluted (Fig. 5.15). The other columns either had vertical flutes (the second row from the east) or were left unfluted (the fourth, or west, row). As the gateway to the sacred *temenos*, the tetrapylon was connected to a perimeter wall, now missing. A paved road running from north to south passed between the second and third rows of columns (Erim 1986: fig. p. 60, 61).

Fig. 5. 15 Tetrapylon at Aphrodisias, Caria, Turkey

The tetrapylon today is a "rebuilt ruin" rather than a reconstruction, in that only "structurally or aesthetically essential" new parts were added (Smith 1996: 11, 12 fig. 2, 41; Paul 1996: 204 Abb. 3, 205 Abb. 4, 212 Abb. 10). Although no blocks of the perimeter wall remain, the rebuilt tetrapylon, standing alone, is an impressive sight, highlighting the importance of the sanctuary of Aphrodisias' tutelary deity.

There was a sanctuary of Aphrodite in Aphrodisias by the sixth century B.C., but the present Temple of Aphrodite is dated to the first century A.D. (Ratté 2001: 119). Two photographs taken by Gertrude Bell in 1907 show some spiral fluted columns and fragments in the temple: one photograph has two standing columns plus entablature, and is labelled "Temple of Aphrodite, Corinthian porch with spiral fluted columns" (Fig. 5.16a) (Bell 1907a: photo 1702). The second photograph shows three spiral fluted fragments and is labelled "Temple of Aphrodite - fragments of carved stone" (Bell 1907b: photo 1705). A published photograph from 1986 shows one spiral fluted fragment (undiscussed) in the temple rubble (Erim 1986: 56); another from 1990 shows two spiral fluted fragments (also undiscussed) lying in the temple (Cormack 1990: 83 fig. 5b); and photographs from 2011 and 2012 show several spiral fluted fragments also lying in the temple (Fig. 5.16b).

a. b.

Fig. 5. 16 a). Spiral fluted columns in Corinthian porch, Temple of Aphrodite, Aphrodisias, Caria, Turkey, 1907
b). Spiral fluted column fragments in Corinthian porch, Temple of Aphrodite, Aphrodisias, Caria, Turkey, 2012

Because of Bell's photograph of the spiral fluted columns standing in the Corinthian porch, it is probable that all these fragments are from the Temple of Aphrodite. Since, however, a Christian basilica was built on the temple site in the mid-fifth to the early sixth century A.D. (Ratté 2001: 130), there is a (faint) possibility that some of these fragments were brought from other structures to be incorporated into the basilica.

B. Sardis

At Sardis in Lydia, western Asia Minor, the bath-gymnasium complex had a monumental entrance "decorated with columns and pilasters, with a screen colonnade in front" (Foss 1976: 36; 184 fig. 4, 185 figs. 5-6). This entrance-gate is called the Marble Court, and it is an open-roofed, three-sided structure dated to the early third century A.D. as proved by its Severan dedicatory inscription. It was restored between 1964 and 1973 by the Harvard-Cornell Expedition, and may have been an Imperial Cult Hall, or Kaisersaal/Marmorsaal, similar to that at Ephesus, discussed above (Hanfmann et al. 1983: 148, 150). The two-storeyed, columnar façade has four spiral fluted columns flanking the central door (Hanfmann et al. 1983: 154), and the façade includes both vertically-fluted and plain unfluted columns (Wilson Jones 2000: 114 fig. 6.8). Like the

columns in the theatre's façade at Sabratha, the columns in the Marble Court were of coloured marbles, and many of them, including the spiral fluted ones, were made of North African *giallo antico*, the dark golden marble from Chemtou in modern Tunisia (Hanfmann et al. 1983: 154, figs. 222-25, 237). Thus this building was constructed not only with local marbles but also with expensive imports, which were used for the most expensive style of column. The column capitals were also in several styles: Ionic, Corinthian, palmette and lotus, and some Corinthian ones with sculptured heads of divinities; the two capitals pictured show one with a head of Dionysus (evoking Alexander the Great and Caracalla), and the other with the head of Zeus rising from the acanthus leaves (Hanfmann 1972: 278, 195 fig. 147, 278-9 fig. 208). "All this seems to fit very well with the taste and tendency for exuberance that one encounters in the Roman architecture of the second and third century A.D., especially in Asia Minor, Syria and North Africa…" (Hanfmann et al. 1983: 156).

5. Spiral Fluted Columns in Other Locations: Private Houses

Spiral fluted columns have been found in the public areas of luxurious private houses, three examples of which are found in Cyrenaica, North Africa, and Aphrodisias and Ephesus in Asia Minor. The Villa of Columns in Ptolemais, now in present-day Libya, is dated to the late Hellenistic/early Roman period. Some fragments of Z-spiral fluted columns in gray marble were seen lying in its atrium in 2006, and none had been re-erected. Ward-Perkins says that domestic architecture in Ptolemais (and also in nearby Apollonia, Cyrene's port) was influenced by that of Hellenistic Alexandria, and the Villa of Columns is "the most significant monument in this respect…[with colonnades] and a second storey over the main peristyle – an echo presumably of the vertical development imposed by the crowded urban conditions of Alexandria" (Ward-Perkins 1981: 368-69). Other fragments of spiral fluted columns, both Z- and S-spiral, were seen lying in the courtyard of the Ptolemais Museum. Although they are undescribed and unattributed, they may have come from the Villa of Columns, as they resemble (in material and size) the Z-spiral column fragments in its atrium.

In the southeast area of Aphrodisias is a structure called the "Priest's House" or the "Atrium House," dated to the fourth to fifth century A.D. (Campbell 1991: 22; Erim

1990: 14 fig. 6, 15, 16 fig. 7). Several spiral fluted columns are situated in the atrium of Room 3 (Figs. 3.1, 5.18), and, since the house is described as "opulent," with upper storeys and fine mosaic floors (Erim 1990: 15), it is an apt setting for this type of column.

Fig. 5. 17 Spiral fluted column, Priest's House, Aphrodisias, Caria, Turkey

Erim suggests that the house had three building periods: the Ionic columns and the atrium date it to the first century A.D.; the spiral fluted columns suggest the mid- or late-second century A.D.; and the mosaic floors date it to the fourth-fifth century A.D. (Erim 1990: 15; Campbell 1991: 22; Campbell 1996: 195). Scholars differ, however, about the dating of this house. Campbell says, "It appears that the house was imposed onto a pre-existing structure" (Campbell 1996: 192), and that the "obviously first century" Ionic columns and capitals were "reused" (Campbell 1991: 22). As well, some architectural elements were not custom-made for this structure: "The columns and capitals are of secondary use and may well have been brought in from elsewhere" (Campbell 1991: 22, pls. 78-79, 83, 85-6; Campbell 1996: 192, 194 figs. 12-13). It is probable that the spiral fluted columns are included in this statement, although Campbell does not mention them specifically. In summary, then, if we accept Erim's dating of the building's second phase according to the spiral fluted columns, i.e., the mid- or late-second century A.D., this house is a fine example of Roman provincial upper class style. If we accept Campbell's idea that the house is contemporary with its mosaic pavements (Campbell 1991; 22), we see that, by the fourth-fifth century A.D., earlier structures in Aphrodisias (possibly the Temple of Aphrodite or the tetrapylon) were being plundered

for their building materials. In either case, spiral fluted columns were thought to be the proper ornamentation for this stylish atrium house.

At Ephesus, there is also evidence for the use of spiral fluted columns in houses or shops, particularly in the group of private houses in the centre of the city beside the colonnade on Kuretes Street. These are called the Slope Houses or Terrace Houses, as they are built up the side of the hill beside the street, and are dated from the first century B.C. to the seventh century A.D. (Erdemgil 1991: 75-6, 77 fig. 69, 78 fig. 70, 80 figs. 72-3). In Terrace House 1, there is a spiral fluted column on the ground floor in front of what Lessing and Oberleitner call a "tavern" (Lessing and Oberleitner 1978: [108] fig. 69, 258 fig. 69), but which could equally well be part of the living quarters. In 2011 and 2012, several fragments of spiral fluted columns were seen inside some of the other terrace houses, standing or lying on the floors (Fig. 5.18).

Fig. 5. 18 Spiral fluted column fragments in Terrace Houses, Ephesus, Ionia, Turkey

They are not labelled on any of the site's information boards, but it is probable that they were found in or near the rooms where they are now situated. Since these houses were decorated with wall paintings and mosaics, and had peristyles with fountains as well as bathrooms with hypocausts, the spiral fluted columns fitted well into this style of upper class house, as discussed above in the Villa of Columns and the Priest's House.

6. Spiral Fluted Columns in the Later Roman Period

In Asia Minor, the Church of St. John, built in the sixth century A.D. on the hill of Ayasuluk near the Temple of Artemis in Ephesus, had four spiral fluted columns set around the tomb of St. John (Foss 1979: 88, 91 fig. 33). The tomb is in the central nave of the church, and the spiral fluted columns had originally supported a small dome over the

tomb. Both the dome and the iconostasis have now collapsed (Erdemgil 1991: 116), though the columns remain *in situ*. Although it is most likely that these columns were recycled from other pagan structures in the city, the fact that they were used in a sixth-century church shows that, at this time, this ancient style was still considered important enough to mark the sacred remains of St. John the Evangelist.

7. Sarcophagi

A. Anatolian Columnar Sarcophagi

In the Roman period, the spiral fluted column became an integral element in the design of the Anatolian columnar sarcophagus. In this section, we will examine its rise as a framing device on these sarcophagi, including the artistic influences on its design; the quarrying techniques that made the construction of these sarcophagi possible; the diffusion and continued popularity of this style in the eastern Mediterranean; and the trade routes that led to its distribution throughout the Roman world. Where and why did the preference for sarcophagus burial arise during the early Roman period when cremation was still generally preferred? Strong says that "the origins of the fashion for sarcophagi" were in A.D. 100 Italy, and this fashion had its roots in an earlier tradition in central Italy (third and second centuries B.C.) for two types of elaborately-decorated sarcophagi, the "house/tomb type and the box with effigy type" (Strong 1978: 679).

Fig. 5. 19 Anatolian columnar sarcophagus at Aphrodisias Museum, Aphrodisias, Caria, Turkey

Anatolian columnar sarcophagi are generally carved from stone, but some have been found which are constructed with moulded lead panels, to be discussed below. The

columnar style of sarcophagus is characterised by decorated panels on the sides framed by spiral fluted columns, which sometimes extend around the corners of the sarcophagus to frame the ornamentation on the end panels as well. Carved figures are usually placed in *aediculae* (niches or small shrines for the images of gods, mythological figures, or heroes) within the panels (Fig. 5.19). For example, a fine Z-spiral column from Italy, dated to A.D. 250, is one of several on a Roman or Anatolian sarcophagus, framing panels showing the labours of Hercules (Petrie 1930: pl. 56 figs. RY4, RY7; Gusman [1908-14]: [v. 1], pls. 10, 23, 48). Thus these sarcophagi are not only containers for bodies, but also miniature architectural constructions, and therefore they became small-scale monuments in their own right, suitable for "the resting-place of the soul" (Thomas 2011: 389). This style of sarcophagus "architecture" evokes more the façades of contemporary theatres and grand civic buildings (e.g., the Library of Celsus at Ephesus) than those of tombs or temples (Strong 1978: 677-78; Thomas 2011: 393-94). The construction of an elaborate façade on a public building heaped praise on its donor or founder, and, in the Anatolian columnar sarcophagus, the design using the spiral fluted column and its symbolism were now transferred to the glorification of the dead person and his or her family.

"The architectural ('columnar') sarcophagus of the Roman Empire is generally thought of as an Anatolian creation" (Strong 1978: 677). Are there any "outside" artistic influences on the design of these Asiatic sarcophagi, or are they strictly products of their local culture? Scholars differ about who influenced whom in the matter of Anatolian sarcophagus design: Thomas says that "some sarcophagi from western workshops seem to imitate Docimian [Asia Minor] types" (Thomas 2011: 390), but that it is more likely that these western ones had "earlier, Italic precedents," which suggests that Anatolian sarcophagi had incorporated designs from the west into their creations. On the other hand, a large number of Asiatic sarcophagi may have been imported into Rome and were so popular that local craftsmen copied them (Thomas 2011: 391-92). Anatolian columnar sarcophagi have a figure or two reclining, as if at a banquet, on their covers. This construction recalls not only Etruscan sarcophagi, the first to use this technique of lid decoration, but also later Attic and Hellenistic sarcophagi (Walker 1985: 23, 24 fig. 14, 25 fig. 15). Thus this aspect of columnar sarcophagi decoration shows no local Phrygian

influence, as it is not characteristic of earlier Anatolian sarcophagi (Cormack 1997: 146; Strong 1978: 678). Their local stamp, however, is evident in their use of marbles from local sources (primarily Proconnesus in the Sea of Marmara and Docimeion in central Phrygia), and some aspects of their decoration (spiral fluted columns framing panels of subjects).

Walker notes the three main quarries that produced sarcophagi for the long-distance trade: Mount Pentelicus at Athens; Proconnesus in the Sea of Marmara; and Docimeion in Asia Minor (Walker 1985: 18). Docimeion, also called Docimeum, Dokimeion, or Synnada (which was the administrative centre for the quarries), is in Phrygia, in west central Anatolia, and is generally considered to be the centre of columnar sarcophagus production. The quarry here flourished from the first century B.C. to the sixth century A.D., with the Docimeion columnar sarcophagi lasting from about A.D. 150-260 (Thomas 2011: 390).

As for shipping items from the quarries to their destinations, transportation by river, sea and oxcart was expensive, time-consuming, and difficult, and could result in damage to any carved designs. Docimeion's unfinished or partly-finished products would have been taken overland by ox-carts to nearby rivers, and then transported by boats and barges to the sea. River routes north and west led from Docimeion to both the Black Sea and the Mediterranean: a route north to the Propontis port of Nicomedia went via the Sangarios (Sakarya) River and Lake Sapanca (Öğüş 2004: 30). Another route, leading to the west and thus to the Mediterranean, followed the Maeander River to Miletus (Öğüş 2004: 30). A third route, suggested by Öğüş in the case of the Antakya Sarcophagus found at Antioch on the Orontes River, led overland from Docimeion to Pamphylia in the south. From there, the sarcophagus would have been taken by sea east to the Orontes River on the Syrian coast, and then up the river to Antioch (Öğüş 2004: 30-1).

Because of these often hazardous journeys, few fine details would be added to sarcophagi (or other building elements) at the quarrying site, as they would be finished at their destination, perhaps by artists or architects who accompanied them from the quarries. "Sarcophagi…were usually shipped with the design already blocked out; this is referred to as 'quarry-state'; some sculptures were also blocked out before shipment, others travelled as blocks" (Ward-Perkins 1992: 26, 132 fig. 116). The quarries at

Docimeion, however, often sent out sarcophagi and other items "in a finished condition," perhaps to reduce weight on a long haul overland, even though there was a greater risk of damage (Ward-Perkins 1992: 26 n. 20; Waelkens 1982: 50). No evidence for the construction of shafts for spiral fluted columns has been found in ancient quarries, as columns would usually have been simply blocked out and only roughly finished before transport. For example, a Late Hellenistic shipwreck at Kızılburun in western Asia Minor contained, with other cargo, eight marble and partly-finished Doric column drums, still unfluted, and a Doric capital. The marble came from the quarry at Proconnesus in the Sea of Marmara and the architectural elements were destined for the Temple of Apollo at Claros, northeast of Ephesus. They were probably custom-ordered for this project (Carlson and Aylward 2010: 147-48, 154) and would be completed on site.

B. Lead Sarcophagi

Lead sarcophagi originated in Syria and Palestine, and from the second to the fourth century A.D. were used both in the eastern and western Roman Empire (McCann 1978: 142). They were often decorated with spiral fluted columns (McCann 1978: 143 figs. 178-79, 145 fig. 181, 146 fig. 183), and twisted cable designs which were standard sarcophagus decorations for this period. Many lead sarcophagi were not intended for public display, however, but were found "hidden away from human sight" in undecorated stone or wooden coffins, or buried beneath the floor of a tomb (Toynbee 1971: 275; McCann 1978: 142). Since their designs were similar to those on Anatolian stone sarcophagi, which were intended for public display, these designs on the lead sarcophagi were intended not for public ostentation but simply "to please the dead" (Toynbee 1971: 275), and possibly to please the living who saw them at the burial.

Four sarcophagi made of lead panels, all with spiral fluted columns framing scenes on the sides and ends, have been found in Palestine and dated to the first and second centuries A.D. Two of the three described by Avi-Yonah are Christian and one is "pagan" (Avi-Yonah 1930: 309, 311, 312, pl. 12), whereas Brants is undecided about the attribution of the one she describes (Brants 1932: 263, pls. 11-12). To make these sarcophagi, which were sand-cast, small and repetitive decorative patterns were either stamped with wooden blocks into the wet sand mould or cast separately and attached to

the lead panels, which were then riveted together (Brants 1932: 263; Toynbee 1971: 276). Avi-Yonah says that this manufacturing technique "points to mass production" (Avi-Yonah 1930: 302). Because of the similarities in ornamentation, the style of decorations and the techniques of manufacture, Brants suggests that there was one Roman factory producing these sarcophagi, beginning in the third century A.D. and based in Syria (Brants 1932: 263). Later scholars, however, have dated the beginnings of this style of sarcophagus and its factory (or factories) earlier, i.e., to the second century A.D.

As for the symbolism of elements on lead sarcophagi (and, by extension, on stone sarcophagi as well), Thomas notes that columns on sarcophagi "establish scale, often a colossal one…when figures break the human scale implied by the height of an entablature…[and they also] provided adornment and were seen as appropriate and necessary indicators of status" (Thomas 2011: 394).

C. Sarcophagi in Ptolemaic and Roman Egypt

Egyptian tombs in Ptolemaic and Roman Egypt occasionally feature reliefs of banqueting scenes, and the sarcophagi themselves were sometimes the κλίνη type, with an effigy of the dead person, alone or with other family members, reclining atop the casket. The necropolis of Tuna el-Gebel (Greek Hermopolis) is situated in Middle Egypt on the edge of the Western Desert, and here a tomb dating to the early Roman period was found in Tomb House Number One. This tomb has an uncommon mixture of Greek, Roman and Egyptian characteristics, and, according to two inscriptions within the tomb house, was constructed for a young girl, Isidora. It featured a burial niche decorated with a conch shell at the top, a Greek symbol of Aphrodite. Two spiral fluted columns, both with S spirals and small unornamented capitals and bases, flank the niche. Inside it is a stone bed, on which the girl's mummy was found. There is no κλίνη here, but instead an Egyptian embalming bed is painted on the side of the stone bed. Lembke says that this construction links Greek and Egyptian funerary ideas: in Greece, the κλίνη was used for "eating, drinking and dying," and for Egyptians "it was the embalming bed…combined with the old idea of banqueting in the afterlife" (Lembke 2010: 264 fig. 22.6, 265). The presence of the spiral fluted columns adds an unmistakably Roman and monumental touch to the composite decoration used in this tomb.

D. Christian Sarcophagi

From the reign of Constantine, i.e., from the fourth century A.D. onwards, spiral fluted columns were often used on Christian sarcophagi. This was a suitable decoration as this style of column may have had an allegorical significance, with the helix being an emblem of eternity; Chapot says that this mystical interpretation of the spiral came from the "pagan art" of the age (Chapot 1907: 105).

8. Other Examples of Spiral Fluted Columns

A. Umm al-Biyara, Jordan: A Spiral Fluted Stand

A small spiral fluted column used as a piece of furniture, and comparable to the columnar lamp from Knossos described in Chapter 3, appears as a spiral fluted stand from the Nabataean site of Umm al-Biyara, situated on a mountain-top high above Petra in modern Jordan (Fig. 5.20). This stand was found in 2010 and its upper part was found in 2011; both came from Structure 20, a building with several rooms thought to be a bathing installation (Schmid and Bienkowski 2011: IIIc: 11, 12 fig. 20; Schmid and Bienkowski 2010a: IIIc: 1). The diameter of the stand is approximately 17 cm (Schmid and Bienkowski 2010b: 5, 17 fig. 14). It has a round hole cut vertically through its centre, which may have been used to fill a water basin on top of the column, though the basin has not yet been found.

Fig. 5. 20 Spiral fluted stand fragment, Umm al-Biyara, Jordan

Examples of this kind of stand have been found at Pompeii, although none has spiral fluting; these stands, therefore, were common by the first century A.D. (Schmid and

Bienkowski 2011: IIIc: 11; Schmid and Bienkowski 2010a: IIIc: 10, 11 fig. 14). The Umm al-Biyara stand fragments are particularly informative, as the area in which they lay is dated to the Nabataean period, though their design is essentially Roman. This area has an "almost complete lack of evidence for any other periods than the Edomite (7th-6th century B.C.) and the Nabataean (1st c. B.C. -1st c. A.D.)….no traces whatsoever of [the Roman, the Byzantine and the Medieval periods] were found on top of Umm al-Biyara" (Schmid and Bienkowski 2010b: 2). Was this spiral fluted stand, then, copied from a Roman design and made locally, or was it made by Roman craftsmen either in Italy or elsewhere and brought into this Nabataean settlement? The excavators say that the affluent building in which the stand was found, along with the other structures on top of Umm al-Biyara, is "out of the ordinary" for several reasons: its elevated location, which gave an overview of the valley and thus provided protection, but also meant that the necessary water and wood would be expensive; its elaborate decorations of marble, limestone and stucco; and the statue fragments found here which echo similar statues decorating Roman upper-class villas (Schmid and Bienkowski 2012: IIIb: 9, 10 fig. 20, IV: 1-2). In any case, either a local copy of a Roman basin stand or an imported original would be entirely proper in this building, adding to the elite status of the building and its owners.

B. A Roman Terracotta Savings Bank

Another example of a spiral fluted column decoration is found on a Roman terracotta savings bank dated to the second half of the first century A.D. It is 12.5 cm high and is now in the archaeological collection at Johns Hopkins University (Cheilik 1963: 70). Although its findspot is not given, it is similar to one found on the Esquiline Hill in Rome, and is thought to be from the same mould (Robinson 1924: 246, 247 fig. 5). The bank shows two columns flanking a figure of Mercury standing in an *aedicula,* with a slot for coins above this decoration (Cheilik 1963: 71, pl. 16). The columns have no capitals, and their ill-defined bases rest on a groundline formed by three carved lines representing steps up to the small shrine. The box is beehive-shaped, and may have been designed to be kept in a family *lararium*, many of which were of similar shape (Cheilik 1963: 70). The bank is dated not according to the use of the spiral fluted columns, which

Cheilik asserts appeared only in Rome in the second century A.D., but rather according to the clothed figure of Mercury, who generally appeared in heroic nudity. He is seen clothed, however, in a first century A.D. painting at Pompeii, and this fact has dated the bank.

C. Two Roman Funerary Reliefs

A first-century B.C. marble relief from Amiternum, in central Italy northeast of Rome, shows the funeral procession of a nobleman. The funeral bed on which he reclines is framed by two upright columns or poles, probably made of wood, as stone would be too heavy for the eight men carrying the bier. The two columns or poles are joined at the top by a crossbar, and all three are decorated with spiral carving. They are thought to support a canopy over the bed, which is decorated with the moon and stars, symbolising the dead man's "celestial apotheosis" (Toynbee 1971: [30] pl. 10, 46; Walker 1985: 9 fig. 2). The use of spirally-decorated poles suggests that they were generally included in the materials used at an upper-class funeral, and those pictured on this relief were probably used in the man's actual funeral procession.

A second marble tomb relief with spiral columns is dated to the late first-century A.D. It is on the Tomb of the Haterii in Rome, and shows a temple-tomb with four columns in its portico. They have Corinthian capitals, and their shafts are decorated with spiral bands carved in low relief (Toynbee 1971: [65] fig. 17, 81, 132). S-spiral columns are set alternately with Z-spiral columns across the front of the portico, which is the standard arrangement for architectural spiral fluted columns (Fig. 5.21). Here again, then, their appearance on an upper-class tomb shows that this style of column was well-known enough to be used in a setting where its significance would be recognized by passers-by, and the family's honour and status would thus be enhanced.

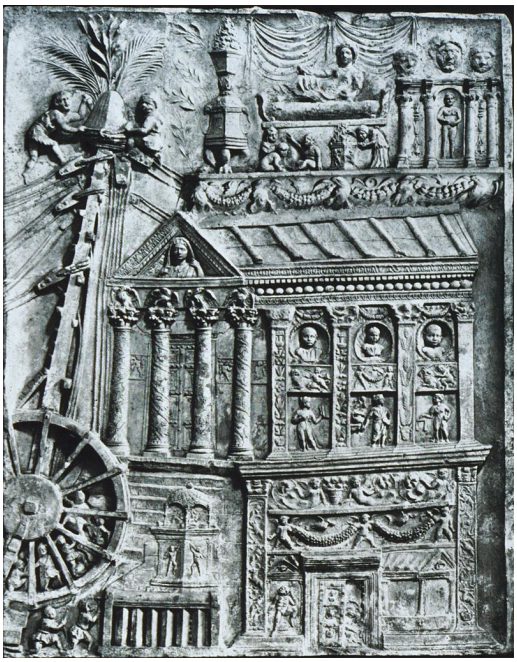


Fig. 5. 21 Relief on Tomb of the Haterii

D. Rome: The Columns of Trajan and Marcus Aurelius

The two columns of Trajan and Marcus Aurelius in Rome are exceptional examples of the second century A.D. use of the spiral on a column, showing its adaptability to external and internal architecture. Although neither column uses spiral fluting, nevertheless they deserve mention in this context as spectacular instances of the association of the spiral with the stone-carved column. Both columns are 100 Roman feet high, and have a narrative Z-spiral frieze carved on the outside, running from the bottom to the top: the frieze on Trajan's column is about 200 m long (Coarelli 2000: 27, 15 fig. 13), and on Marcus Aurelius' column the frieze is just over 200 m long (Beckmann 2011: 207). On both columns, a Z-spiral staircase cut into the inside leads to a viewing platform on the top, and, as well, Trajan's Column was a significant funerary monument as it contained the emperor's ashes in its base. Marcus Aurelius' ashes, however, were placed in Hadrian's Mausoleum (Beckmann 2002: 356). To contemplate the whole spiral frieze on Trajan's Column, which was difficult to see because of the surrounding buildings, the viewer would have had to walk around the column many times, and would thus "reenact and perpetuate rituals performed at the emperor's burial" (Davies 2004: 128).

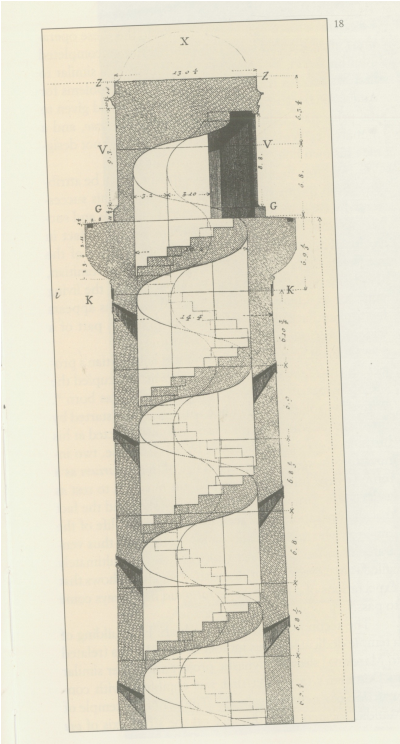


Fig. 5. 22 Trajan's Column and interior staircase

Beckmann notes that the term applied to these two columns, "*columnae coc(h)lides,*" comes from the Greek word κόχλος, a snail-shell (as noted in Chapter 3 in the discussion of Linear B tablets). The external spiral frieze and the internal spiral stairway of these columns could each be interpreted as a κόχλος, but scholars continue to differ on this attribution: some say it refers to the frieze alone, and some to both the frieze and the stairway, but Beckmann says that it refers only to the internal stairway (Fig. 5.22) (Beckmann 2002: 348). This stairway is similar in shape to the Archimedean water-screw, which consists of wooden strips fastened spirally around a pole and set inside a wooden cylinder; the water-screw will be examined in Chapter 6. Vitruvius (*De arch.* 10.6.2) describes the water-screw, with its wooden strips *faciunt canales et iustam cocleae naturalemque imitiationem* (Granger 1962: 308); "thus forming an accurate and natural imitation of a spiral shell" (Granger 1962: 309). "The aspect of the *cochlea* being imitated is the internal passage that forms the home for the animal" (Beckmann 2002: 350), and thus Beckmann believes that it is the spiral staircase inside these two columns

which is related to the *cochlea,* rather than the external frieze (Beckmann 2012: 251, 252 fig. 15.2).

The stairways in both columns would have been carved into the separate column drums before they were set in place, which would have reduced their weight (Lancaster 1999: 424, 425 fig. 4; Davies 2004: 31 fig. 22) and the friezes were carved after the columns had been set up (Beckmann 2011: 113). Both internal and external spirals, however, demanded careful construction, and these two monuments were remarkable even in the ancient world for their height, the statues atop the columns and their internal staircases, the last a notable technical achievement "never before attempted" (Beckmann 2002: 353). Small windows carved into the outside of the column drums in each column permitted some light to enter, and the viewer came out from the restricted light and space of the stairway into daylight on the column's viewing platform, "released from total restriction to utter freedom" (Davies 2004: 135). In Trajan's Column, the site of Trajan's remains, Davies says, "the staircase reflects a change of state from mortal to immortal" (Davies 2004: 223 n. 87).

E. Egypt: Hellenistic and Roman Alexandria

In Hellenistic and Roman Alexandria, little evidence remains for the structural use of spiral fluted columns. In 2008, one fragment was seen standing alone in the garden of the Kom el-Shuqafa cemetery, in the southwest part of Alexandria. It was out of context and undescribed, but it may have come from one of the tombs, similar to the spiral fluted columns found in the tomb at Tuna el-Gebel and discussed in the section on sarcophagi above. This would not be unusual in Alexandria, as tombs in Kom el-Shuqafa's Large Hypogeum, in use from the first to the fourth centuries A.D., show a mixture of Egyptian and classical decorations, with Egyptian religious scenes painted on the walls and Medusa heads and garlands carved on the stone sarcophagi. Similar combinations of Roman, Egyptian and Greek tomb decorations are seen in Roman-period cemeteries throughout Alexandria, including on Pharos Island, and are thus not unique to the cemetery at Kom el-Shuqafa (McKenzie 2007: 193-94, 197 fig. 340). It is odd, however, that spiral fluted columns do not appear more often in Hellenistic and Roman tombs in

Alexandria, where the Archimedean water screw was invented and was in constant daily use.

Another section of a spiral fluted column was seen in 2008 in the central part of Alexandria in the area called Kom el-Dikka. It was set beside the path leading from the mid-fourth century A.D. Roman theatre to the houses on its north and northwest. It, too, was out of context and undescribed, but may have come from a nearby Roman-period house, as the houses around and underneath the theatre are dated to the late first to second century A.D. Most had elaborate mosaic floors and some had not only colonnades around a courtyard, but also private baths (McKenzie 2007: 180, 183 figs. 309, 310 a-b). Thus spiral fluted columns enhanced the stylish decoration of the elegant houses in this neighbourhood, as they did in the atrium of the Villa of Columns in Ptolemais, Cyrenaica, as discussed above.

F. Coins

As already seen in this chapter, spiral fluted columns were a distinctive feature of the architecture of Roman Asia Minor, and they appear from time to time on coins from the second and third centuries A.D. showing temples. As well as sarcophagi, coins reflect ancient architecture, although sometime their details can be puzzling: temples are often shown in a distorted view as are figures within them, and examples of these distortions are considered below. Chapot discusses examples of temple-design coins that show spiral fluted columns, ranging from the time of Marcus Aurelius through the Severan period, with the majority dated to the third century A.D. (Chapot 1907: 123). Since the greatest collection of provincial imperial coins comes from Asia Minor, as compared to coins from other provinces, it follows that there are more temple-design coins from this area than elsewhere. Four examples follow, illustrating the chronological and geographical range of this coin design.

From Philadelphia in Lydia comes a coin dated to the time of Marcus Aurelius, whose design shows a temple of Aphrodite, with a cult statue of the goddess in the style of the “Venus de Médicis” in the centre. She is flanked by two spiral fluted columns, one with a Z spiral and the other with an S spiral, and Chapot notes that a similar image on a coin from a century later has the two columns’ spirals twisting in the same (unspecified)

direction. This, he says, shows that the moneyers cared only about "relative fidelity" in this detail (Chapot 1907: 118 fig. 138). Thus the fact that the spiral fluted columns were seen flanking the goddess was enough to emphasise her (and their) importance, and the direction of the fluting was unimportant.

A coin from Thracian Hadrianopolis (now Edirne in northwest Turkey) is dated to the reign of Septimius Severus. It is dedicated to Zeus, who is shown sitting in a spacious temple whose four columns have Z-spiral flutes. Two steps lead up to the temple, and the architrave is surmounted by a triangular pediment (Chapot 1907: 120 fig. 144). Although the figure of Zeus does not extend above the columns and there is thus no necessity for an arcuated lintel, his seated statue is emphasised by his attitude: his right arm is extended to the side and his hand holds a long staff; his raised left arm points to the columns on his left; his legs are also extended to his left. A wide space between the two groups of columns permits these extended limbs and adds emphasis to the seated god: Zeus does not need to stand to show his supremacy, and the spiral fluted columns frame his powerful image.

Thomas says that one purpose of Roman provincial coins was "to proclaim local identity through architectural form" (Thomas 2007: 62), and thus significant local or regional structures, whether rendered accurately or fancifully, often appeared on local coins. A coin from Phoenician Tripolis from the reign of Elagabalus (A.D. 218-222) shows the front of a temple with an unknown goddess (possibly Astarte) and Niké standing in its entryway (Fig. 5.23). A flight of four steps leads to the temple, and two tall slender spiral fluted columns flank the figures. Four unfluted columns extend to each side of the structure, and all the columns have capitals (undefined) and support entablatures and the temple roofs, set on two levels (Donaldson 1859: 102-3, pl. 29; Chapot 1907: 115 fig. 129).

Fig. 5. 23 Astarte? and Niké on coin from Tripolis

Although Donaldson believes that this unusual temple design actually shows three sides of the building at once (Donaldson 1859: 103), Chapot disagrees, saying that this hypothesis is "hazardous" and the architecture is structurally improbable. He does not offer an alternative interpretation of the design (Chapot 1907: 115). But realism on the imagery of coins varied: it was not necessary to show the exact number of columns on a temple façade, as they were intended only to represent the temple's columned portico. An equally important detail is that "the careful artist would never show more than the actual number of columns," so that it is possible to work out the number of columns in a building**.** The proportions of the temple and the image it contained could also be inexact, and the image of the deity was often enlarged to give the impression that the god was "appearing in person before his worshippers" (Price and Trell 1977: 19). On this coin the spiral fluted columns are clearly shown and highlight this religious setting, framing the images of the goddesses as on the coin from Hadrianopolis above.

A bronze coin from Samos, minted in the reign of Trajan Decius (A.D. 249-251), shows a cult statue of Hera in a temple whose façade has four Ionic spiral fluted columns. Two S-spiral columns are set on one side of the goddess and two Z-spiral columns on the other (Fig. 5.24). The statue is oversized, showing Hera much taller than the columns, with her head and head-dress extending into the space formed by an arcuated lintel (Thomas 2007: 62 fig. 57b; Chapot 1907: 119 fig. 143). Donaldson says that the coin shows not the outside of the temple but rather "the canopy over the statue of the goddess, inside the temple" (Donaldson 1859: 87, pl. 22), but Chapot says that the stairway

leading up to the façade shows that the structure is the temple itself (Chapot 1907: 120). In any case, whether the coin portrays the inside or outside view of the structure, the spiral fluted columns beside Hera call attention to her monumental statue and therefore to her presence in Samos.

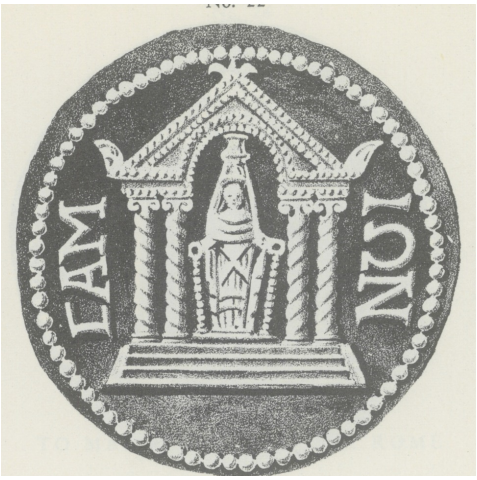


Fig. 5. 24 Hera on coin from Samos

Beyond the practical medium of exchange, then, coins showing easily recognised local and regional temples and deities had both realistic and instructive purposes, as they promoted their cities and their accompanying gods and goddesses, keeping them in the minds of anyone who used the coins. The spiral fluted column on the coins described in this section echoes local architecture in Asia Minor, with its attendant symbolism of religious and civic power, as well as imperial and local munificence. This style of coinage, therefore, had a spiritual as well as a monetary value.

9. Summary of Findings in Appendix 1

Before the next chapter's discussion of the relationship between spiral fluted columns and the mechanical application of the spiral, a summary of the archaeological evidence is needed. As mentioned in Chapter 1, I have prepared a chart of spirals and spiral fluted columns from the literature and my field work in Greece, Turkey, Syria, Cyprus, Jordan, Egypt, Libya and Tunisia, presented in full in Appendix 1. It includes information (where known) on the spirals' and columns' countries, cities, sites, locations within the sites, the structure types and the cultures with which they are associated, the classifications of their spirals, construction materials, dates, and some archaeological and

literary references. Similar information on mechanical screws and presses is presented in full in Appendix 2 and discussed at the end of Chapter 6. It is important to note that the sample considered here is small and includes only the eastern Mediterranean and four areas in North Africa (Ptolemais, Sabratha, Lepcis Magna and Volubilis).

The chart in Appendix 1 includes spirals and spiral fluted columns in both two and three dimensions: fashioned in mudbrick, carved in stone or carved as designs on stone or lead sarcophagi, as well as some painted representations of flat spirals or spiral fluted columns on pottery and wall paintings, and carved images on coins and seals. This range of images and structures shows how the spiral motif continued to be used two-dimensionally in the Roman era, even while, by this time, mathematics and technology permitted its extensive three-dimensional use in architecture and machines. Entries without information in column Q, "References," were used for statistical purposes only and are not discussed in this thesis. Table 1 below summarises only those structures and artefacts that contain helical spiral fluted columns or representations, and does not include any object featuring two-dimensional flat spiral designs. As it was not always possible to identify the material from which the columns or artefacts were made, or the directions of some spirals were unobtainable, there are some unknowns indicated in the chart.

Table 1: Summary of Findings in Appendix 1

Culture (in chronological order)	**No. of items with spiral fluted columns**	**S spiral**	**Z spiral**	**Z and S spirals in groups**	**Structures and artefacts with spiral fluted columns**	**Materials**
Mesopotamian: 1800-1400 B.C.	4	0	0	4	Temples or palaces	Mudbrick
Minoan: 2000-1200 B.C.	3	1	2	0	Seals, lamp, chest	Unknown stone, gypsum, painted clay
Mycenaean: 1600-1200 B.C.	5	2	2	1	Seals, furniture inlays, mural, column fragment	Agate, unknown stone, ivory, painted plaster, marble
Etruscan: 550 B.C.	1	1	0	0	Tomb altar panel	Limestone
Greek: 1100-323 B.C.	8	0	4	0 (4 not known)	Vase paintings, column fragments	Bronze, clay, marble, limestone
Macedonian: 325 B.C.	1	1	0	0	Coin	Bronze
Hellenistic/ Roman: 323 B.C.-4th c. A.D.	8	4	3	1	Column fragments	Black marble or basalt, marble
Nabataean/ Roman: 1st c. B.C.-4th c.A.D.	1	0	1	0	Basin stand	Unknown stone
Roman: 1st c. B.C.-4th c.A.D.	83	21	28	33 (1 not known)	Temples, houses, villas, nymphaea, colonnades, theatres, baths, gateways, tombs, savings bank	Marble, limestone, basalt, terracotta, bronze, brass

Culture (in chronological order)	No. of items with spiral fluted columns	S spiral	Z spiral	Z and S spirals in groups	Structures and artefacts with spiral fluted columns	Materials
Possibly Roman: 1st c. B.C.-4th c.A.D.	5	2	3	0	Column fragments	Marble, basalt, plastered mudbrick
Anatolian: 1st-3rd c. A.D.	26	2	2	22	Sarcophagi	Marble
Anatolian/ Roman: 1st-3rd c. A.D.	1	0	0	1	Sarcophagus	Marble
Byzantine/ Ottoman: 7th-15th c. A.D.	1	0	0	1	Door divider	Wood
Modern: 19th-20th c. A.D.	9	2	3	4	Gateways, door /window dividers, staircase, decorative supports	Concrete, wood, marble, steel
Totals:	156	36	48	67	xx	xx

What do these statistics show us and why are they important? First, the spiral fluted column was a favourite architectural element in the Roman world, where it was used primarily in monumental structures and on sarcophagi. The most common material from which it was made is marble, even in areas where marble was not available locally. Thus it was not only a distinctive design, but was considered important enough to carve from expensive imported stone. This choice of column style and material showed not only a person's upper-class status, but also emphasised his (or her: recall the nymphaeum donated by the priestess Aurelia Paulina at Perge) wealth, civic pride and good taste.

Secondly, as considered briefly in Chapter 3, there appears to be a slight preference for the S spiral in the Hellenistic/Roman period, and for the Z spiral in the Greek and Roman periods, including the "possibly Roman" items. Large numbers of the combined Z and S spirals in groups in the Anatolian period come from sarcophagi, where spiral fluted columns framed scenes on the side and end panels. The large number of the same in the Roman period comes from their monumental architectural settings, of which

many fragments have survived in archaeological sites or literary sources. These large numbers in both cases are not surprising, as columns in groups tended to be set with the spirals in alternating directions, though occasionally, as noted above on some coins, the spirals all turned in the same direction. Although it would have seemed more dramatic to have alternating spirals in one's architecture, sometimes it was simply enough to have spiral fluted columns present and the direction of their spirals was unimportant. It is important to remember, too, that the results of this informal compilation depend, as with all archaeological findings, on those columns which have survived in the field or have been documented in either ancient or modern sources.

This chapter has examined the use of the spiral fluted column in the Roman world from the Etruscans to the fourth century A.D. With the expansion of the Roman Empire in the new millennium, the Roman architectural stamp was put on both new Roman settlements and older Greek or Hellenistic cities that now came under Roman control. Ratté says that, particularly in first- and second-century Asia Minor, large building projects "served both to advertise through statues and inscriptions the generosity of their individual donors, and to clothe the city in that homogeneous 'international style,' instantly recognizable at archaeological sites throughout Turkey, and to a lesser degree throughout the eastern Mediterranean world" (Ratté 2001: 123). From the Etruscans to Constantine, then, the spiral fluted column became a characteristic element of Roman architecture and was used particularly in grand public monuments, as discussed above, such as theatres, nymphaea, colonnades and decorative gateways. Some upper-class private houses also incorporated it into their own designs, thus bringing public architecture into a private setting, with its attendant symbolism. The spiral fluted columns carved on the Asiatic columnar sarcophagus of the first and second centuries A.D. influenced sarcophagus preferences throughout the eastern Mediterranean and was later adapted by Christians for their own sarcophagi. Coins from Asia Minor show that the spiral fluted column was used in temples in that region, and other examples such as the Nabataean/Roman stand for a water basin, the Roman savings bank, the Roman funerary reliefs, and the monumental columns of Trajan and Marcus Aurelius all show the adaptability of the spiral design to a variety of purposes and projects.

The next chapter will consider the helical spiral as used in ancient technology, beginning with Archimedes' invention of the water screw, and continuing with an examination of the screw press and Hero's screw gear, along with other mechanical inventions by Archimedes and Hero. All these devices are examples of the spiral's practical and mechanical applications, rather than its decorative use, and show how it was being adapted for these new machines.

Chapter 6: The Use of Spirals in Technology and Mechanical Devices

How do the water screw, the screw press and Hero's screw gear fit into a discussion of spiral fluted columns? In these machines the spiral was adapted for a practical rather than a decorative use, as their mechanisms depended on a spiral screw. Did the spiral fluted column spawn the mechanical spiral used in machines, or *vice versa*? This appears to be a question which scholars have not yet addressed, and which this chapter will consider. The mathematical and production principles of the spiral water screw and spiral fluted column would have been the same, i.e., how to wind a spiral (either made of three-dimensional vanes or a carved ornament) around a pole, and therefore one may have influenced the other. In its construction, the screw mechanism of the screw press resembles a spiral fluted column, as both are basically solid shafts with grooves cut into them. Pliny's dates for the invention of the screw press, i.e., from the first century B.C. to the first century A.D., coincide with the rise in popularity of the spiral fluted column in Roman architecture, although it had appeared in various architectural and decorative contexts before then. This chapter will examine chronological, geographical and literary references to the water screw, the screw press and Hero's screw gear in order to investigate possible connections. The techniques of spiral fluted column design and carving will also be considered. Appendix 2 is a compilation of information on the mechanical spirals discussed in this chapter: Archimedes' water screw; ancient olive and grape presses (including both lever and screw presses); other mechanical screws, including some of Hero's inventions that depended on screws; and a list of ancient stone-working tools and machines for raising stone columns.

To begin, what machines were known in the ancient world, and how was the spiral mechanism used in them? Pappus of Alexandria, the fourth century A.D. mathematician, defined the five basic machines (*Mathematical Collection* 8.52.7-15):

> πέντε τοίνυν οὐσῶν δυνάμεων δι' ὧν τὸ δοθὲν βάρος τῇ δοθείσῃ βίᾳ κινεῖται, ἀναγκαῖόν ἐστιν τά τε σχήματα αὐτῶν καὶ τὰς χρείας ἔτι δὲ καὶ τὰ ὀνόματα ἐκθέσθαι. ἀποδέδοται δὲ ὑπὸ τοῦ Ἥρωνος καὶ Φίλωνος καὶ διότι αἱ προειρημέναι δυνάμεις εἰς μίαν ἄγονται φύσιν, καίτοι παρὰ πολὺ διαλλάσσουσαι τοῖς σχήμασιν. ὀνόματα μὲν οὖν ἐστιν τάδε. ἄξων ἐν περιτροχίῳ, μοχλός, πολύσπαστον, σφήν, καὶ πρὸς τούτοις ὁ καλούμενος ἄπειρος κοχλίας (Hultsch 1878: 1116).

> There are five machines by the use of which a given weight is moved by a given force, and we will undertake to give the forms, the applications, and the names of these machines. Now both Hero and Philo have shown that these machines, though they are considerably different from one another in their external form, are reducible to a single principle. The names are as follows: wheel and axle, lever, system of pulleys, wedge, and, finally, the so-called endless screw (Humphrey et al. 1998: 49).

"The wheel and axle, the lever, and the wedge were known by the Early Bronze Age, [and] the pulley by the eighth or seventh century B.C.," but the use of the screw is not verified until the mid-third century B.C. (Wikander 2008: 786). Pappus' "endless screw" is the basic machine used in Archimedes' and Hero's inventions.

1. Archimedes' Theory of Spirals and the Invention of the Water Screw

What permitted the invention of the water screw and the screw press? Diodorus (5.37.3) credits Archimedes of Syracuse, the Greek mathematician and inventor (about 287-212 B.C.), with the invention of the water screw during a visit to Egypt about 260 B.C. Rickard says he visited Egypt in 220 B.C. (Wikander 2008: 788; Rickard 1928: 130). Oleson says that Archimedes analysed the spirals and helixes in nature and applied their principles "to the solution of a human engineering problem," and thus developed the water screw (Dalley and Oleson 2003: 21). There is some dispute about attributing the invention of the water screw to Archimedes, but the most recent scholarship now accepts this attribution. In support of this, Oleson says that Archimedes may have been hired by Ptolemy II (283-246 B.C), who wanted to increase agriculture in the Delta area (Oleson 2004: 79; Simms 1996: 56). Both Drachmann and Oleson believe that Archimedes was indeed the inventor of the water screw (Drachmann 1958a: 280; Drachmann 1958b: 943; Oleson 1984: 291-301, figs. 36, 110-11, 145-49; Dalley and Oleson 2003: 1, 17-24), and Simms agrees with them, suggesting that "Vitruvius' description may well derive from Archimedes' own" (Simms 1996: 94; Oleson 1984: 298).

The water screw, as described briefly in Chapter 1, is a helical screw fixed within a wooden cylinder, which was used to lift water primarily for agricultural irrigation, but also for draining difficult-to-reach areas such as ships' bilges or mine shafts. Although it could only be used efficiently in areas where a low lift was desired, its advantages were

as follows: it was mechanically efficient, self-purging and therefore could be used effectively in silty or vegetation-clogged water, and it was portable and therefore easy to move around and install quickly wherever needed (Oleson 1984: 292). Strabo (*ca.* 64 B.C.-A.D. 21) describes its use in Egypt (17.1.52):

> νήσους δ' ὁ Νεῖλος κατεσπαρμένας ἔχει παμπόλλας, τὰς μὲν καλυπτομένας ὅλας ἐν ταις ἀναβάσεσι, τὰς δ' ἐκ μέρους, ἐποχετεύεται δὲ τοῖς κοχλίαις τὰ λίαν ἔξαλα (Jones 1967: 132, 134).
>
> The Nile has very many islands scattered along its courses, of which some are wholly covered at its risings and others only partly; but the exceedingly high parts of the latter are irrigated by means of screws (Jones 1967: 133, 135).

Of all the ancient literary sources, Vitruvius (*De arch.* 10.6.1-4) has the best description of the design and construction of a water screw (Fig. 6.1), and, indeed, has such clear instructions that a team was able to build two full-size working water screws for a BBC-TV program in 1997 (Oleson 2004: 75-80, figs. 10-14):

> (1) Est autem etiam cocleae ratio, quae magnam vim haurit aquae, sed non tam alte tollit quam rota. Eius autem ratio sic expeditur. Tignum sumitur, cuius tigni quanta rata est pedum longitudo, tanta digitorum expeditur crassitudo. Id ad circinum rutundatur. In capitibus circino dividentur circumitiones eorum tetrantibus et octantibus in partes octo, eaeque lineae ita conlocentur, ut plano posito tigno utriusque capitis ad libellam lineae inter se respondeant, et quam magna pars sit octava circinationis tigni, tam magna spatia decidantur in longitudinem….2) Eadem ratione per omne spatium longitudinis et rutunditatis singulis decusationibus oblique fixae regulae per octo crassitudinis divisiones involutos faciunt canales et iustam cocleae naturalemque imitationem….
> (3) Dextra autem ac sinistra cocleam tigna conlocantur in capitibus utraque parte habentia transversaria confixa. In his foramina ferrea sunt inclusa inque ea inducuntur styli, et ita cocleae hominibus calcantibus faciunt versationes (Granger 1962: 306, 308).
>
> (1) There is further an application of the screw which draws a large amount of water, but does not raise it as high as the wheel. The contrivance is as follows. A beam is taken as many inches thick as it is feet long. This is rounded to an exact circle. At the ends the circumference is to be divided by a compass into quadrants and eighths and so to eight parts; and the diagonals are so to be drawn that when the beam is horizontal the lines at either end correspond exactly. The whole length is to be marked off into spaces, equal to one-eighth of the circumference….
> (2) Throughout the whole distance of the length and the circumference, strips of wood are fixed obliquely at the several intersections and make channels which wind round through the eight divisions of the thickness: thus forming an accurate and natural imitation of a spiral shell….(3) On the right and left of the screw,

beams are placed at the ends, with cross-pieces placed on either side. In these are iron sockets into which the pivots of the screws are inserted, and so the screws are made to turn by a treadmill (Granger 1962: 307, 309; Morgan 1914: 295-97).

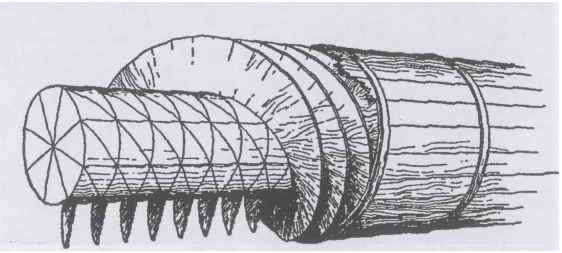


Fig. 6. 1 Reconstruction of Vitruvius' water screw

In constructing the water screw replicas, Oleson adapted Vitruvius' design by reducing the number of helixes from eight to two, as "all surviving water-screws have only two or – more usually – three helixes instead of eight, a detail which reduces weight, construction time, and presumably cost" (Oleson 2004: 79). Drachmann suggested that Vitruvius used eight helixes because he relied on Archimedes' original design (Drachmann 1963: 154), an opinion later emphasised by Simms (Simms 1996: 94).

Diodorus of Sicily (5.37.2-4), the first-century B.C. Graeco-Roman historian, gives an informative description of the water screw as it was used in Spanish mines:

> (2) οἱ δὲ κατὰ τὴν Σπανίαν μεταλλουργοὶ ταῖς ἐλπίσι μεγάλους σωρεύουσι πλούτους ἐκ τούτων τῶν ἐργασιῶν…(3) ἐνίστε δὲ καὶ κατὰ βάθους ἐμπίπτουσι ποταμοῖς ῥέουσιν ὑπὸ τὴν γῆν, ὧν τῆς βίας περιγίγνονται διακόπτοντες τὰς ῥύσεις αὐτῶν τὰς ἐμπιπτούσας τοῖς ὀρύγμασι πλαγίοις…ἀπαρύτουσι τὰς ῥύσεις τῶν ὑδάτων τοῖς Αἰγυπτιακοῖς λεγομένοις κοχλίαις, οὓς Ἀρχιμήδης ὁ Συρακόσιος εὗρεν, ὅτε παρέβαλεν εἰς Αἴγυπτον· διὰ δὲ τούτων συνεχῶς ἐκ διαδοχῆς παραδιδόντες μέχρι τοῦ στομίου, τὸν τῶν μετάλλων τόπον ἀναξηραίνουσι καί κατασκευάζουσιν εὔθετον πρὸς τὴν τῆς ἐργασίας πραγματείαν. (4) φιλοτέχνου δ' ὄντος τοῦ ὀργάνου καθ' ὑπερβολήν, διὰ τῆς τυχούσης ἐργασίας ἄπλατον ὕδωρ ἀναρριπτεῖται παραδόξως, καὶ πᾶν τὸ ποτάμιον ῥεῦμα ῥᾳδίως ἐκ βυθοῦ πρὸς τῆν ἐπιφάνειαν ἐκχεῖται. Θαυμάσαι δ' ἄν τις εἰκότως τοῦ τεχνίτου τῆν ἐπίνοιαν οὐ μόνον ἐν τούτοις, ἀλλα καὶ ἐν ἄλλοις πολλοῖς καὶ μείζοσι, διαβεβοημένοις κατὰ πᾶσαν τὴν οἰκουμένην, περὶ ὧν τὰ κατὰ μέρος ὅταν ἐπὶ τὴν Ἀρχιμήδους ἡλικίαν ἔλθωμεν ἀκριβῶς διέξιμεν (Oldfather 1961: 196, 198).

> (2) but the exploiters of the mines of Spain, in their hopes, amass great wealth from their undertakings….(3) And now and then, as they go down deep, they come upon flowing rivers, but they overcome the might of these rivers by diverting the streams which flow in on them by means of channels leading off at an angle….they draw out the waters of the streams they encounter by means of

> what is called by men the Egyptian screw, which was invented by Archimedes of Syracuse at the time of his visit to Egypt; and by the use of such screws they carry the water in successive lifts as far as the entrance, drying up this way the spot where they are digging and making it well suited to the furtherance of their operations. (4) Since this machine is an exceptionally ingenious device, an enormous amount of water is thrown out, to one's astonishment, by means of a trifling amount of labour, and all the water from such rivers is brought up easily from the depths and poured out on the surface (Oldfather 1961: 197, 199).

Strabo (3.2.9) also describes the water screw in Spanish mines: καὶ πρὸς τοὺς ἐν αὐταῖς ἀπαντῶντας ποταμοὺς πολλάκις τοῖς Αἰγυπτίοις ἀναντλούντων κοχλίαις (Jones 1969: 44); "and, as regards the streams that meet them in the shafts, [they] oftentimes draw them off with the Egyptian screw" (Jones 1969: 45). But since the water screw is useful only where a low water lift is required, mines and ships' bilges would have had to use a series of water screws. The disadvantage for bilge-drainage was that the water screw would need to be mounted along the ship's centre line, as it would not be effective when the ship was pitching or rolling. There is no archaeological evidence for its use in ships. The force pump does not appear in the archaeological record or ancient literary sources until the late first century B.C. (Oleson 2004: 72-73), so that, until then, the water screw was the only mechanical method of water-lifting that could be used in restricted areas.

Vitruvius (*De arch.* 5.12.5) describes the use of the water screw in the draining of cofferdams when building harbours and breakwaters:

> In quibus autem locis pulvis non nascitur, his rationibus erit faciendum, uti arcae duplices relatis tabulis et catenis conligatae in eo loco, qui finitus erit, constituantur, et inter destinas creta in eronibus ex ulva palustri factis calcetur. Cum ita bene calcatum et quam densissime fuerit, tunc cocleis rotis tympanis conlocatis locus qui ea septione finitus fuerit, exinaniatur sicceturque, et ibi inter septiones fundamenta fodiantur (Granger 1962: 314).

> But in places where this powder [*pozzolana*] is not found, the following method must be employed. A cofferdam with double sides, composed of charred stakes fastened together with ties, should be constructed in the appointed place, and clay in wicker baskets made of swamp rushes should be packed in among the props. After this has been well packed down and filled in as closely as possible, set up your water-screws, wheels, and drums, and let the space now bounded by the enclosure be emptied and dried. Then dig out the bottom within the enclosure (Morgan 1960; 163; Granger 1962: 315).

The Vitruvian/Archimedean water screw was turned as a whole by having a person stand on the cylinder and walk on its outside treads so that the entire device rotated (Fig. 6.2). This process is confirmed by two Hellenistic terracotta reliefs from Egypt, one from Alexandria and one from Memphis (Oleson 1984: 293, figs. 71, 86; Bowman, 1986: 16 fig. 7; Rickard 1928: pl. 12.1), and one fresco from the House of Menander in Pompeii (Oleson 1984: fig. 101; Dalley and Oleson 2003: 18).

Fig. 6. 2 Water screw representations from Alexandria and Memphis, Egypt; Pompeii, Italy

All three of these representations show a man walking on a water screw cylinder while holding onto a rod stretched above it. In contemporary Egypt, where the water screw is still used, the cylinder is turned by means of a crank worked by an individual sitting by the upper end. As the crank was little known in the ancient world, treading on the cylinder was the only way of turning it (Oleson 1984: 295). The true crank had appeared in the second century B.C., used in a basic form on rotary querns, but it was only occasionally used in ancient machinery (Dalley and Oleson 2003: 14).

2. The Screw Press

Pliny the Elder (*HN* 18.74.317) describes four types of presses in his encyclopedia, *Naturalis Historia*: the simple lever, the lever-and-screw, the weighted screw and the direct-screw (White 1975: 230). Details of Pliny's four presses are discussed next, in order to examine the role of the spiral screw in the screw press. Before that discussion, however, it is necessary to see how the olives are prepared for pressing.

The first operation in olive oil production is to crush the fruit by means of stone rollers, to soften it and permit the pits to be removed, as noted briefly in Chapter 1. After the fruit is ground, the oil is separated from the mass of pulp, the πυρῆνα, by pressing. The πυρῆνα is put into bags that are then soaked with hot water to make the oil flow more easily. Since oil-presses require a great deal of water to wet the bags both before and between pressings (they are usually pressed twice), oil-presses are generally located near a water source (Paton and Myres 1898: 209). The bags are then stacked several high on the oil-press, ready for pressing, which Columella (*Rust.* 12.52.3), the Roman writer on agriculture, says must be done without delay: *uniuscuiusque diei fructus molis et prelo statim subiciatur* (Forster and Heffner 1968: 308); "each day's picking should be immediately placed under millstones and the press" (Forster and Heffner 1968: 309). If the fruit is left too long, it will spoil.

The lever system for pressing, i.e., the system used in the first two examples in Pliny's list, consisted of a long wooden beam fixed at one end (Fig. 6.3). Bags of fruit were placed below the beam, which was then lowered to crush the bags by means of a rope attached around a capstan, by moveable weights hung from the free end of the beam, or, eventually, by a screw fixed in the free end of the beam and working through a nut that lifted stones. This press was later modified by adding two large vertical standards at each end of the press to take the strain of the press-beam (White 1975: 230; figs. 60-62; Drachmann 1932: 145-148, figs. 12-16). Pliny (*HN* 18.74.317) describes the beam press:

> premunt aliqui singulis, utilius binis, licet magna sit vastitas singulis. longitudo in his refert, non crassitudo; spatiosa melius premunt. antiqui funibus vittisque loreis ea detrahebant et vectibus (Rackham 1950: 386, 388).
>
> Some press the grapes with a single press-beam, but it pays better to use a pair, however large the single beams may be. It is length that matters in the case of the beams, not thickness; but those of ample width press better. In old days people used to drag down the press-beams with ropes and leather straps, and by means of levers (Rackham 1950: 387, 389).

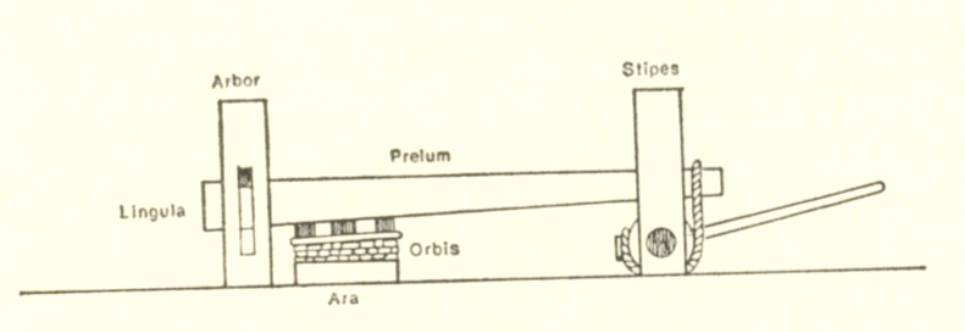


Fig. 6. 3 Pliny's lever-and-beam press

The lever-and-screw press, Pliny's second example, was developed as an easier way of moving the press-beam than by using a capstan or moveable weights (Fig. 6.4). Pliny (*HN* 18.74.317) describes an early form of this press:

> intra C annos inventa Graecanica, mali rugis per cocleam ambulantibus, ab aliis adfixa arboris stella, aliis arcas lapidum adtollente secum arbore, quod maxime probatur (Rackham 1950: 388).
>
> but within the last hundred years [thus from the late first century B.C. to Pliny's time] the Greek pattern of press has been invented, with the grooves of the upright beam running spirally, some makers fitting the tree [i.e., the large vertical supports at each end of the beam] with a star [i.e., four handles which fitted into the screw], but with others the tree raises with it boxes of stones, an arrangement which is very highly approved (Rackham 1950: 389).

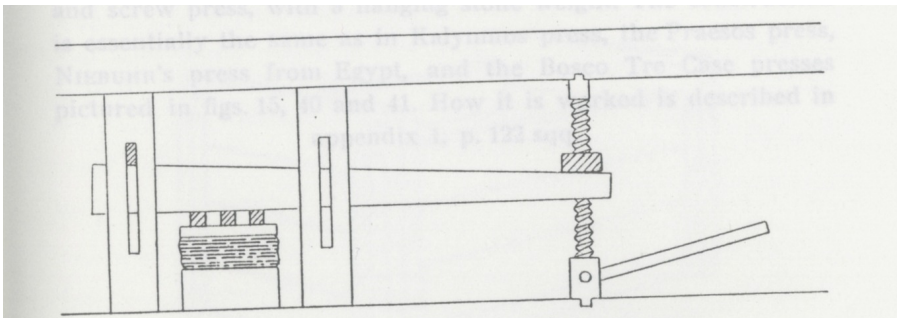


Fig. 6. 4 Pliny's lever-and-screw press

To summarise, then, a spiral-threaded pole was attached to the floor and passed through the beam's free end, and the lever was moved up and down by means of the four handles attached to the screw (White 1975: 230-231, figs. 61-62; Paton and Myres 1898: 211; Heron *Mech.* 3.2.15, 180-84 [original pagination], 182, fig. 57; Drachmann 1932: 146 fig. 14).

Pliny's third example (*HN* 18.74.317), the weighted screw press, a later form of the screw and lever press, had the screw attached to a large suspended stone weight instead of the floor, making it easier to move the beam by turning the screw and thus raising or lowering the weight (Fig. 6.5). This construction avoided the jamming of the screw due to the beam's arcing motion when being moved (White 1975: 230-231, fig. 62).

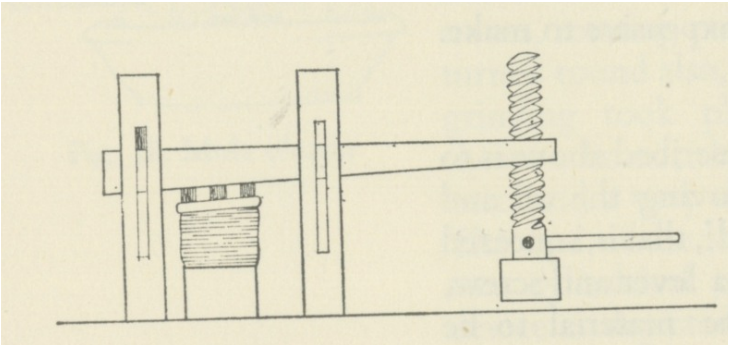


Fig. 6. 5 Pliny's weighted screw press

The fourth of Pliny's press types (*HN* 18.74.3170 is the direct-screw press (Fig. 6.6), invented, he says, as follows:

> Intra XXII hos annos inventum parvis prelis et minore torculario aedificio, breviore malo in media derecto, tympana inposita vinaceis superne toto pondere urguere et super prela construere congeriem (Rackham 1950: 388).
>
> Within the last twenty years a plan has been invented to use small presses and a smaller pressing-shed, with a shorter upright beam running straight down into the middle, and to press down the drums placed on top of the grape-skins with the whole weight and to pile a heap [*congeriem*] of stones above the presses (Rackham 1950: 389).

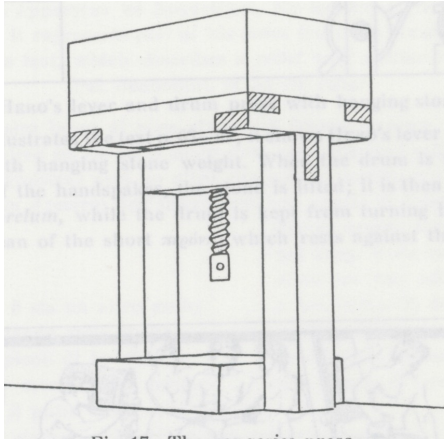


Fig. 6. 6 Pliny's direct-screw (*congeriem*) press

With this press, the screw gave direct pressure on the items to be pressed and thus the need for a lever was eliminated (Drachmann 1932: 149 fig. 17). Vitruvius (*De arch.* 6.6.3), in his description of how to build a pressing-room, discusses the dimensions of the new room and the amount of space required for a lever-type press and its workers:

> Ipsem autem torcular, si non cocleis torquetur sed vectibus et prelo premetur, ne minus longum pedes XL constituatur; ita enim erit vectiario spatium expeditum. Latitudo eius ne minus pedum senum denum; nam sic erit ad plenum opus facientibus libera versatio et expedita. Sin autem duobus prelis loco opus fuerit, quattuor et viginti pedes latitudini dentur (Granger 1962: 40, 42).
>
> The press, if it is not turned by a screw, but is worked by levers and a press-beam, is to be not less than 40 feet long. This will leave room for the man who works the levers. The width of the room must not be less than 16 feet, so that when the men are fully at work, their movements will be free and easy. But if two presses are required in the place, the width should be 24 feet (Granger 1962: 41, 43).

The screw press, therefore, had the significant advantage of allowing its installation in a smaller space than that required for a lever press. Because the pressing-room was such an important part of ancient society, it had to be built properly, as described by Cato (234-149 B.C.) (*Agr. Orig.* 31.1-2). He provides information on its construction, including harvesting requirements for the woods used in the building of both the press and pressing-room:

> (1) Vectes iligneos, acrufolios, laureos, ulmeos facito uti sient parati. Prelum ex carpino atra potissimum facito. (2) Ulmeam, pineam, nuceam, hanc atque aliam materiem omnem cum effodies, luna decrescente eximito post meridiem sine vento austro (Hooper 1967: 46).
>
> (1) Have oak, ilex, laurel, and elm levers ready. Make the press-beam preferably of black hornbeam [a type of beech tree]. (2) Take out elm, pine, nut and all other timber which you are felling, when the moon is on the wane, after noon, while there is no south wind (Hooper 1967: 47).

Hero of Alexandria's *Mechanika* (Hero 3.2.19, 187-94 [original pagination], 188, fig. 58) written about A.D. 50, describes two types of the screw press (Drachmann 1932: 83, 125-28): one has a single screw in the centre of the press and the other has one screw at each side of the press and is therefore called a twin-screw press (White 1975: 231, figs. 63-64; Drachmann 1988: 293-99, 294 fig. 50a). Hero's single-screw press is also called a "congeries press…a screw press built inside a frame, with a single screw in the middle,"

so-called because of the congeries, the heap or pile of stones noted above in Pliny's description (White 1975: 231-32, fig. 65; Drachmann 1932: 149, fig. 17).

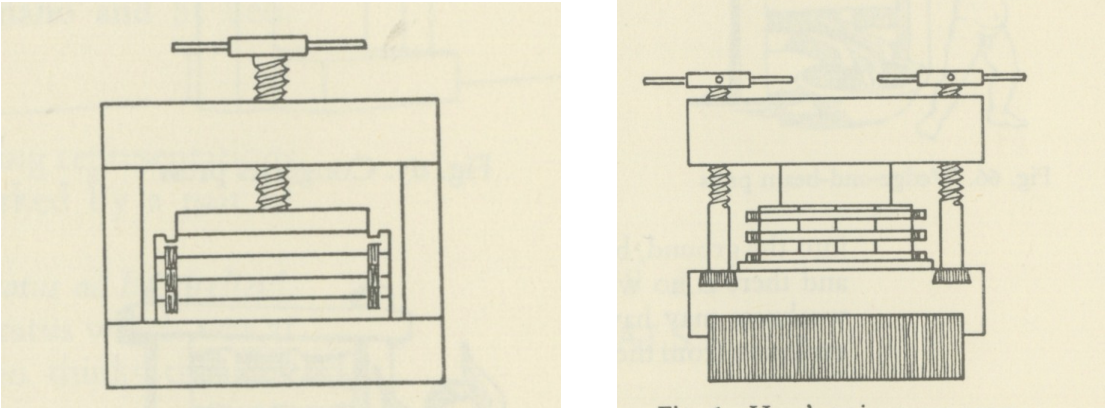


Fig. 6. 7 Hero's single-screw and twin-screw presses

White cites another type of press, the wedge-and-beam press (Fig. 6.8), constructed with a group of flat "floors" separated by rows of circular pieces of wood, but he says that this is shown only in two "fanciful" wall-paintings, one from the House of the Vetii in Pompeii and another from an unnamed location in Herculaneum. Wedges are driven between the horizontal timbers which then exert pressure on the container of fruit at the bottom of the wooden frame, but the two mural representations are not detailed enough either to understand the structure properly or to reproduce it. This kind of press is not mentioned in any literary sources, but this simple device was able to exert enormous pressure (White 1975: 232; fig. 66; Drachmann 1932: 52).

Fig. 6. 8 Wedge-and-beam press

Hero is also credited with the invention of the lever-and-drum press, where the lever is pulled up and down by means of a drum attached to the floor below one end of

the press-beam, the other end inserted into a hole in a wall (Fig. 6.9). A rope is wound round the drum and attached to two pulleys, one on the underside of the free end of the press-beam and the second pulley on the top of a stone weight hanging below the free end. When the drum is turned, the stone is lifted and the press-beam moves downwards to press the material placed beneath its other end (Drachmann 1932: 63-67, 151 fig. 20).

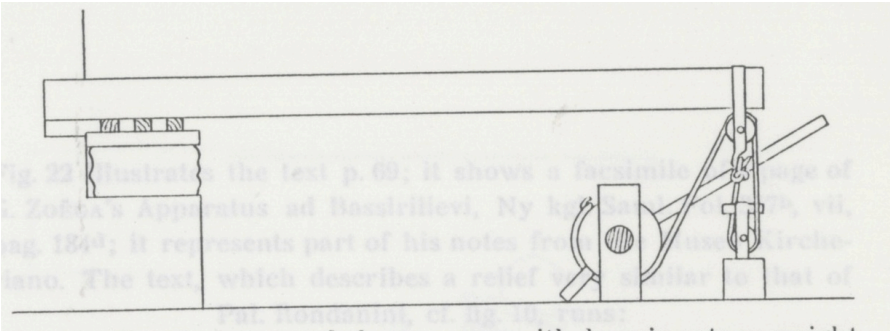


Fig. 6. 9 Hero's lever-and-drum press

The late first-century B.C. screw press, then, was an improvement on the earlier lever press, as the use of a screw allowed more pressure to be applied steadily to the material to be crushed and reduced the need for large, and therefore more expensive, pressing-rooms or dedicated outdoor areas for pressing (Wilson 2008: 359-60). Greene suggests that the development of the screw press, i.e., using a screw to pull down the press-beam rather than ropes, may be connected with Hero's "description of a thread-cutting device," to be discussed below (Greene 2008: 814; Humphrey et al 1998: 55). Two centuries after Archimedes, then, the spiral had been incorporated into the screw press, and described by Pliny and Hero as noted above.

3. Other Uses For the Mechanical Screw

A. Hero's odometer

The three-dimensional spiral was also an essential part of Hero's odometer, a machine designed to measure distances travelled. Here a combination of cogged wheels and worm gears reduced the revolutions of a vehicle's axle to a slow rate, and gradually rotated, over a measured distance, a plate through which marbles fell. The marbles could

then be counted to determine how far the vehicle had travelled (Humphrey 2006: 118-20, 121 fig. 4).

B. Hero's siphon

Hero (Heron *Pneum.* 4) also used a screw in his "Siphon which is capable of discharging a greater or less quantity of Liquid with uniformity." A basin full of water is placed in a vessel, and a tube to hold the siphon is soldered into the lid and bottom of the basin. A vertical wooden frame with grooved sides is placed in the vessel, and this frame supports a horizontal piece of wood. A long screw with a handle at the top runs through this piece of wood, which can now be raised and lowered along grooves in the side of the frame (Fig. 6.10). By this means, the amount of water in the vessel can be controlled and thus the amount of water let out through the siphon can be increased or decreased as desired (Greenwood 1851: 17-18, 17 fig. 4). Both this and the previous application involve screws in situations including stresses much lower than those of the screw press.

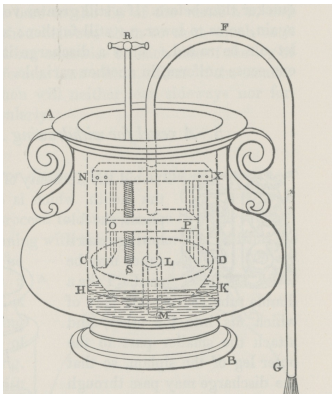


Fig. 6. 10 Hero's siphon

C. Hero's screwcutter

Hero (Heron *Mech.* 2.5) describes a screwcutter, which is essential to the production of workable screws (Carra de Vaux 1894: 101-4 [original pagination], 103 fig. 26; Drachmann 1963: 56-9, 57 fig. 17a, 58 fig. 17b), as well as one which cuts an inside screw thread, or nut (Heron *Mech.* 3.21; Carra de Vaux 1894: 192-94 [original pagination]; Drachmann 1963: 135-40, 136 fig. 52a, 137 fig. 52b, 138 fig. 53a, 139 fig. 53b, 140 fig. 54). Hero first defines a screw, and then describes how it is cut: as a point on the end of a line moves along the side of a cylinder and "takes one turn around the cylindrical shape and [returns] to the place from which its movement began, then the line

that is described by this point on the surface of the cylindrical shape will be one turn of a screw" (Drachmann 1963: 56-7). The screw is cut by a blade mounted in wooden slots set at varying distances from the cylinder to be cut, so that as the blade is moved closer to the cylinder, the wood is pared away a little at a time and the screw threads are cut (Fig. 6.11). The blade moves up and down by means of a rope with an attached weight, thus giving a standard cutting force, and the cylinder is rotated by means of a capstan attached to its upper surface. Thus both large screws used in screw-presses and smaller ones used in Hero's siphon and odometer can be cut with evenly-spaced spiral turns of any size and depth. There is a problem, however, that Hero does not address, namely, how to make the first cut on the smooth surface of the cylinder, where it seems that the rope plus its attached weight would simply pull the blade straight down, as there was no groove yet to keep it in place. Perhaps the first groove was cut by hand after the smooth pole had been marked, and the weight and rope were attached to the blade only after it was cut, or perhaps there was some mechanism that Hero does not discuss which inscribed the first cut.

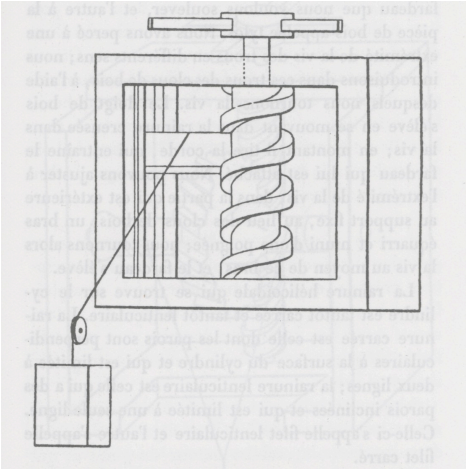


Fig. 6. 11 Hero's screwcutter

D. Archimedes' screw windlass

Another of Archimedes' inventions was the screw windlass (Simms 1996: 47-52, 48 fig. 1; Drachmann 1958a: 280-281), used during the launching of the massive ship *Syracusia*, commissioned by Hieron II of Syracuse (269-215 B.C.). It was designed to move the ship, and the process is described by Athenaeus (Ath. 5.207.b), a Greek writer

of ca. 200 A.D.:

> ὡς δὲ περὶ τὸν καθελκυσμὸν αὐτοῦ τὸν εἰς τὴν θάλασσαν πολλὴ ζήτησις ἦν, Ἀρχιμήδηςὁ μηχανικὸσ μόνος αὐτὸ κατήγαγε δι' ὀλίγων σωμάτων. κατασκευάσας γὰρ ἕλικα τὸ τηλικοῦτον σκάφος εἰς τὴν θάλασσαν κατήγαγε. πρῶτος δ' Ἀρχιμήδης εὗρε τὴν τῆς ἕλικος κατασκευήν (Gulick 1957: 434, 436).
>
> But after considerable discussion in regard to the method of pulling it into the water, Archimedes the mechanician alone was able to launch it with the help of a few persons. For by the construction of a windlass he was able to launch a ship of so great proportions in the water. Archimedes was the first to invent the construction of the windlass (Gulick 1957: 435, 437).

Drachmann amplifies this statement, saying that Archimedes had also invented the compound pulley, which was "worked by a windlass containing a screw" (Drachmann 1958a: 280), and by combining these mechanical contrivances, the *Syracusia* was pulled into the water.

4. Column Fluting and the Mechanics of Stone-Carving

This section examines how stone columns were constructed and set in place in structures, what materials were preferred, the tools and fluting techniques required for columns with vertical and spiral flutes, and the difficulties associated with the creation of the spiral fluted column.

A. Column construction

The Greeks preferred columns built with drums stacked atop each other, which made columns more resistant to earthquake damage than columns carved from one piece of stone. Cooper, however, says that more ancient Greek buildings were damaged by high winds than earthquakes, and that scavengers' desire for metal clamps and dowels caused the destruction of many more structures (Cooper 2008: 230, 233 fig. 9.3). The practice of building columns with drums continued in the Roman period, but the Roman preference for monolithic shafts gradually superseded the Greek way (Taylor 2003: 115; Fant 2008: 130-31). A possible reason for this was that, with the rise and expansion of the imperial marble trade in the first century A.D., builders and architects did not want to break up the patterns of the exotic stones now available to them from across the Empire (Taylor 2003: 113), although monolithic columns of gray or white unpatterned marble developed at the

same time (Fant 2008: 130). Fant suggests that another reason for the popularity of the monolithic column was the public impression made by the "utterly unnecessary additional effort involved in production and transport" (Fant 2008: 130). Compare Pliny's emphasis on Greek statues carved from one piece of marble, such as the Laocoön (*HN* 36.4.37), although Eichholz, in a footnote to his translation, says that this statue was actually composed of five blocks (Eichholz 1971: 30 n. a):

> Ex uno lapide eum ac liberos draconumque mirabiles nexus de consilii sententia fecere summi artifices Hagesander et Polydorus et Athenodorus Rhodii (Eichholz 1971: 28, 30).
>
> Laocoön, his children and the wonderful clasping coils of the snakes were carved from a single block in accordance with an agreed plan by those eminent craftsmen Hagesander, Polydorus and Athenodorus, all of Rhodes (Eichholz 1971: 29, 31).

The advances in construction of the massive Roman transport ships and barges during this period also meant that these enormous monolithic columns could be transported relatively safely. Centralized ownership and administration of quarries under the Roman Empire (Fant 2008: 126) meant increased efficiency and stimulation of production. At this time, too, there was an interest in stockpiling columns in standard heights and diameters at the quarries, so that there was a ready supply for builders and architects, thus lessening the time and expense required for construction projects and also streamlining production at the quarries (Wilson Jones 2000: 155). Column shafts in multiples of four, five or ten feet were generally stockpiled, all of which sizes were designed to achieve the perfect ratio of column shaft to the height of its base and capital. Other sizes, however, could be custom-ordered, if time and expense were of no concern to the patron, architect and builder. Although achieving "proportional harmony" was preferable in building projects, it was not an unbreakable rule: Wilson Jones cites the example of Perge, a city "where colonnaded streets consumed large numbers of prefabricated imports," and whose columns did not always follow orthodox proportions (Wilson Jones 2000: 155).

How were columns, both drum-built and monolithic, put into position in structures? Small monolithic columns could be set in place by treadmill cranes, such as the one seen in the funerary relief on the Tomb of the Haterii in Rome (Figs. 5.21, 6.12)

(Adam 1994: 46 figs. 92-5; Taylor 2003: 117 fig. 54, 118).

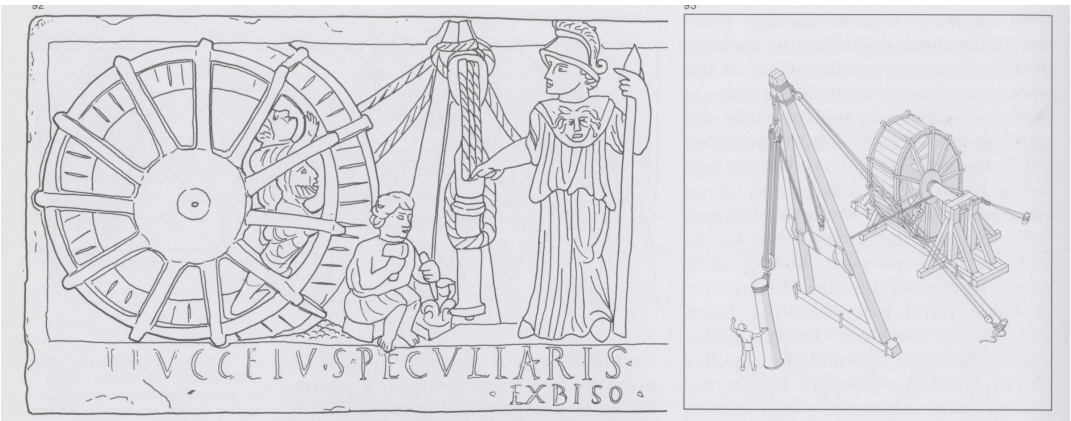


Fig. 6. 12 Treadmill crane relief from Capua, Italy (undated); reconstruction of treadmill crane

Large monolithic columns were erected by means of a "pivoting device" a frame that allowed rope-pullers to raise the column shaft in a controlled manner and then tilt it directly onto its base (Taylor 2003: 118-26, 120 fig. 56). Longer columns would need to be set in place by means of a pivoting arrangement to avoid the danger of their cracking in the middle of the shaft or damage to their bases as they were being hauled upright. Protective stone collars were generally left at each end of the shaft for protection against this type of damage, and removed once the column was in position. A triangular frame would support the column which was then winched into position and the shaft was "tilted into position directly onto its base" (Fig. 6.13) (Taylor 2003: 118, 120 fig. 56; Adam 1994: 47 fig. 98). An example of this machine's use is seen in the erection of the porch columns of the Pantheon, which were originally intended to have fifty-foot monolithic shafts. It was discovered, however, that there was not enough room around the porch to set up these columns, so they were reduced to forty feet, a shaft length which could be successfully erected in the space available (Taylor 2003: 129-31, 131 fig. 68).

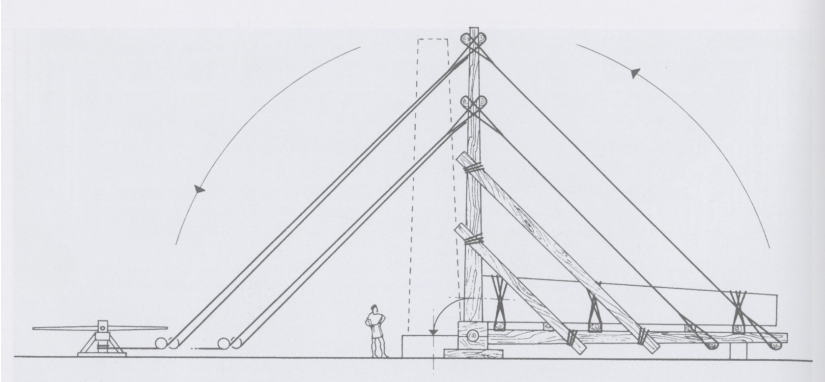


Fig. 6. 13 Tilting machine for raising large monolithic columns

The individual drums of drum-built columns could be hoisted into place by cranes lifting ropes looped around stone bosses on the sides of the drums; the bosses were then removed when the drums were in place (Taylor 2003: 115-16). Another method of lifting blocks, also used by the Greeks in the Classical period (Camp and Dinsmoor 1984: 13), was by using a "lewis block," an expanding device inserted into a specially-shaped hole on the top of a block. Ropes threaded through the lewis block then permitted the blocks to be raised by a crane (Adam 1994: 48-50, 49 figs. 102-5, 50 figs. 106, 110).

B. Materials

Why was fluting so popular on stone columns in the ancient world? Adam suggests that fluting on columns, which in early Greek structures were made of wood, "may well be only a memory of the grain of the wood or the long marks left by the squaring axe [adze]" (Adam 1994: 115). This idea appears fanciful, but fluting, ancestral memory or not, was obviously seen by early builders and architects as a way of providing shadows against the harsh Mediterranean sun, and thus emphasising not only the beauty of the stone, but also the cylindrical mass of the column. Marble was preferred for buildings, inscriptions and statues, although it was more expensive to carve than the ubiquitous limestone and sandstone in the Mediterranean world, because its crystalline structure and fine grain permitted very accurate and detailed carving (Hunt 2004: 112). The scientific explanation for the beauty of polished marble is that its "large calcite crystals allow light to penetrate without great absorption," thus giving depth to the stone (Hunt 2004: 113). Thus both ancestral memory and modern science clarify the dramatic

impact of the fluted marble column, so popular in the architecture of the ancient world. This dramatic impact was increased by the use of the uncommon spiral fluting rather than the usual vertical style, particularly when the spiral fluted columns were set in pairs framing a gateway, doorway or sacred statue.

C. Tools

As for the techniques of decorating columns, how did stoneworkers carve the fluting, vertical or spiral, on the column shaft, and what stone-carving tools were used? Tools used by Greek and Roman stonemasons were made of iron, or had iron heads with wooden handles, and were similar to those used by modern stonemasons: picks, hammers, mallets, punches, chisels, gouges, files and squares (Fig. 6.14) (Oleson 1986: 64; Blagg 1976: 158 fig. 1; Adam 1994: 32 fig. 45; Fant 2008: 122-23, 125, 129; Malacrino 2010: 38-9, fig. p. 39; Camp and Dinsmoor 1984: 10).

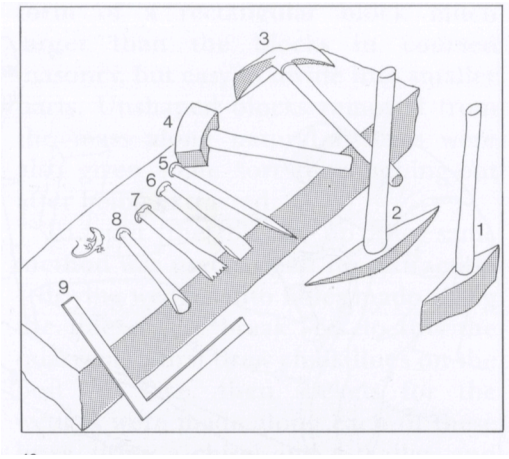


Fig. 6. 14 Roman stoneworkers' tools: 1. cutting hammer; 2. scabbling hammer (for roughly dressing stone); 3. kivel or stone-mason's hammer; 4. mallet; 5. punch or point; 6. straight chisel; 7. claw chisel; 8. gouge; 9. square

As stone-working tools quickly became blunt, most quarries had a forge on the site where worn tools were sharpened and repaired, as shown on archaeological sites by piles of cinders and the remains of hearths (Adam 1994: 26). Possible evidence for this type of forge has been found at the Roman quarries of Antinoopolis, founded in Egypt by Hadrian in A.D. 130. Two large jars set into the ground may have been used for activities at an on-site forge (Coli et al. 2011: 2704, 2705 fig. 12b). The Sanctuary of Poseidon at

Isthmia, Greece, also shows evidence of both a bronze and an iron foundry, dated to the fifth and fourth centuries B.C. They are important as examples of Greek metalworking practices before Rome's annexation of Greece in 146 B.C., and they also illustrate the continuity of the types of tools used for woodwork and stonework through the centuries. Three dumps near the temple contained, among much pottery and some marble sculpture, numerous pieces of bronze, lead and iron. Several tools were also found here: an iron chisel, bronze nails and an iron axe-adze head (Rostoker and Gebhard 1980: 347, 349, 352, pl. 107d and e, pl. 108c).

D. Vertical Fluting

Vertical fluting was common in ancient architecture: is there information on its construction that applies also to the carving of spiral fluting? How was vertical fluting carved? Wilson Jones describes masons' marks found on column shafts as guidelines for the position of vertical fluting, citing examples from Pompeii and Rome (Wilson Jones 2000: 7-9, 7 fig. 0.11, 8 figs. 0.12-0.14). He notes that "each set of marks is slightly different from its cousins," so that there were no standard fluting marks, which meant that "the Romans' attitude to design was flexible; it was a matter of applying principles rather than fixed rules or recipes" (Wilson Jones 2000: 7, 9). If fluting had to be carved on the column *in situ*, stonecarvers would work from scaffolding set up surrounding the column. Columns built with drums had only the grooves at the base cut first, with the drums being finely finished when the column was assembled *in situ*. In order to cut the *entasis* of the column, cords could be stretched from the top to the bottom of the shaft, aligned with the mouldings, and the column profile then carved parallel to the cords (Wilson Jones 2000: 130-32, fig. 6.34). Fluting placement down the length of the shaft could be established in the same manner, by running chalked cords vertically down the shaft and matching the masons' marks at each end. The channels would then be carved according to the marks left by the chalked cords. By this time, too, it was possible to use the lathe (discussed below) to check that the curve of each column drum was true before it was set in place.

E. Spiral Fluting

There is apparently no published research on the method of fluting spiral columns. Could Vitruvius' instructions for building the water screw correspond with the

procedures necessary for constructing spiral fluted columns? The marking of the spiral placement on the columns could certainly be done the same way: Vitruvius, as noted above, says that a rounded beam is divided and marked on its ends into eight parts, and lines drawn from one end of the beam to the other to join the marks. Diagonals are then drawn between the corresponding lines. For the water screw, the length is marked into eight sections and strips of wood are fixed obliquely to the beam along the diagonals, making channels, *iustam cocleae naturalemque imitationem* (*De arch.* 10.6.2); "thus forming an accurate and natural imitation of a spiral shell…." (Granger 1962: 309). To carve the spiral fluted column or column drum, the markings for the spirals could be measured on the column shaft or drum in the same way, and then the stoneworker would simply cut along the inscribed lines. Vitruvius' method gives his water screw eight helixes, but the divisions could be more for a spiral fluted column, depending on how many helixes were required to make a pleasing pattern. According to photographs taken at Apamea, Syria (colonnade), Kourion, Cyprus (nymphaeum), and Ghadames, Libya (single column in the Ghadames Museum), during my field work (Appendix 1), there are generally 20-22 spiral flutes on a column with a large diameter, and 14-16 on a column with a small diameter. Note that Vitruvius had prescribed 24 vertical flutes for a Ionic column and 20 for an Doric column (*De arch.* 3.5.14, 4.3.9; Granger 1962: 197, 224). He did not mention different numbers of flutes for different diameters of columns. Thus these numbers for spiral flutes on a large-diameter column fit within Vitruvius' range. Even numbers of flutes make it much easier to lay out the intervals.

Other more informal methods of marking the placement and carving of spiral fluting could have been as follows: a drum-built column could have chalked cords, probably of esparto, hemp or linen (Burke 2010: 8), wound spirally around each drum to mark the placement of the fluting while the drums were on the ground. The spirals to be carved would be marked on the column by the chalk left by the cords. Or, once the drums were set up in place, cords could be wound around the whole length of the column. The problem with this method would be if the cords were not wound firmly around the shaft or drum, they could slip and therefore the pattern would be irregular. If the cord fibres were slightly elastic, however, the cord would cling to the stone and make tracing the spiral pattern fairly easy. A monolithic column could be patterned by winding cords

around it when it was set up or still on the ground. One way to do this would be to raise each end in turn and wind the cords around the shaft to set the pattern accurately at each end. (Once the pattern was marked, the same procedure would be repeated as the carving was being done). So far there is no published information on procedures or techniques for the carving of the spiral flutes on columns, and thus some ideas are suggested next.

Ancient stoneworkers knew about and used the lathe. Of its origin, Pliny says, *normam autem et libellam et tornum et clavem Theodorus Samius* (*HN* 7.56.198; Rackham 1961: 640); "the square, the plummet, the lathe and the lever [were invented] by Theodorus of Samos" (Rackham 1961: 641). Theodorus, a Greek architect and sculptor whose writings are now lost, lived in the sixth century B.C. Vitruvius says that he wrote a treatise on the Temple of Hera at Samos: *de aede ionica Iunonis quae est Sami Rhoecus et Theodorus* (*De arch.* 7.Pref.12; Granger 1962: 70); "Rhoecus and Theodorus [wrote] on the Ionic temple of Juno which is at Samos" (Granger 1962: 71). Coulton says that the square, the level and the lathe "must have been known before," as the square and the level were essential for the construction of stone monumental architecture. He suggests that Theodorus was the first to describe them (Coulton 1977: 24).

Vitruvius (*De arch*. 10.1.6) mentions the lathe, but does not refer to its use on stone (Blagg 1976: 165)**:**

> Non minus quae sunt innumerabili modo rationes machinationum, de quibus non necesse videtur disputare, quando sunt ad manum cotidianae, ut sunt molae, folles fabrorum, raedae, cisia, torni ceteraque, quae communes ad usum consuetudinibus habent opportunitates (Granger 1962: 278).
>
> Besides, there are innumerable mechanical devices about which it does not seem needful to enlarge (because they are to hand in our daily use), such as millstones, blacksmiths' bellows, waggons, two-wheeled chariots, lathes, and so forth, which are generally suitable for customary use (Granger 1962: 279; Morgan 1914: 284).

Adam notes that, while turning is common in woodwork in the Roman period, stone elements in soft rock could also be turned, i.e., "column drums, capitals, Dorics and bases." He suggests that the design would be roughly carved in place, and then the stone element would be placed in a frame to be rotated, and the design finished with chisels (Adam 1994: 39-40). Although the date of its invention is unknown, the lathe was used for turning "stone columns, tabletops, and vessels" (Fant 2008: 132) by the time of Pliny

the Elder in the first century A.D., and Pliny (*HN* 36.19.90) describes its use in turning column drums thought to be for the Temple of Hera on Samos (Fant 2008: 132; Blagg 1976: 165): *quarum in officina turbines ita librati pependerunt ut puero circumagente tornarentur* (Eichholz 1971: 70); "the drums of which [the 150 columns] were so well balanced as they hung in the workshop that a child was able to turn them on the lathe (Eichholz 1971: 71).

How did the ancient lathe work, and was it possible to use it for monolithic columns as well as column drums? (Fig. 6.14) In order to wind the patterning cords around the column, mark the spiral pattern on the shaft and then carve the spiral fluting, the column could be mounted on a lathe frame similar to the one described by Blagg: "the column is mounted horizontally on a frame by means of a spindle at each end…[and] the spindle is here rotated directly…by turning a wheel at one end of the lathe, through which the spindle passes, with the handle offset to one side in the manner of a rotary quern" (Blagg 1976: 165, 168, 169 fig. 2B).

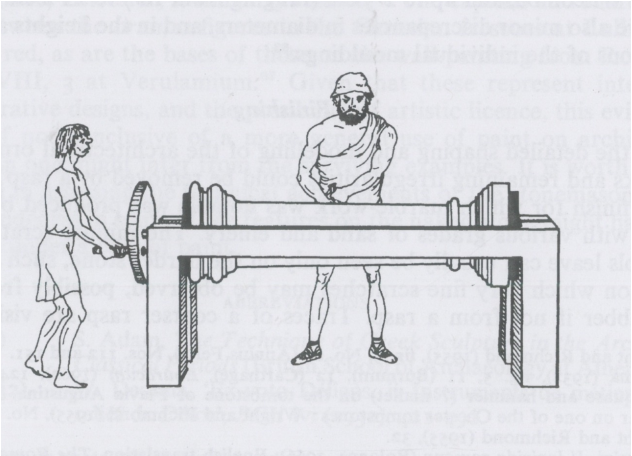


Fig. 6. 15 The ancient lathe

Note that the spindle and its socket would need constant lubrication with oil or water so that it would turn freely. (Olive oil is a very poor lubricant under stress). Once the pattern for the spiral flutes had been marked on the column, the lathe frame would have provided a practical way to carve the flutes as well, allowing the column to be rotated constantly while the spirals were being carved. The craftsmen would have carved the flutes by hand, turning the column as required, as it would not have been possible with Roman technology to carve spiral flutes on the column or drums with blades mounted on a lathe

frame. It was important to ensure that the flutes were evenly carved as well as accurately spaced. Using the lathe frame to hold the column depended on its length and weight, and thus the size and strength of the frame needed to hold it. It seems, therefore, that only short or slender columns could have been carved on this frame. The tallest complete spiral fluted columns standing today are in Syria and Cyprus: Apamea's columns are about nine m high and are made of drums. The one remaining column in Kourion's nymphaeum is about the same height, and is monolithic. Because of their height and weight, then, it is unlikely that columns such as Kourion's could have been carved while on a lathe frame, and therefore large columns must have been carved either *in situ* with the use of scaffolding, or on the ground, being turned when necessary, and then erected.

Another consideration is that, if the column were tapered or had *entasis*, then the carver would have to follow the taper, and it would not be possible to carve this kind of column with a lathe. It is theoretically possible that Hero's screwcutter, discussed above, could have been adapted to carve spiral fluted columns in stone if the column were monolithic and slender enough, and if the frame, as noted above, could support its weight as it passed through the cutter; perhaps column drums could be carved with this device as well. Hero's screwcutter had slots set at different distances from the object to be cut, so it would have been possible to vary the angles by moving or re-angling the blade, a time-consuming and detailed process, but necessary if the column or individual drums required tapering or *entasis*.

Could both columns and column drums have been spirally-fluted by the same method? Individual column drums could be set up fairly easily on this type of lathe frame, and then would have had to be placed carefully atop each other in the finished column so that the spirals lined up exactly, by matching the dowel and clamp holes cut into their upper and lower surfaces. It would be more efficient to face a drum's ends and cut its flutes without removing it from the lathe, thereby doing everything necessary at the same time. Any anomalies could be corrected when the drums were in place, if the very edges of the spiral flutes on the top and bottom sides of the drums had been left unfinished. A disadvantage to this method is that drums could knock against each other when they were being swung into place by the crane, and therefore damage their edges or the flutes, requiring either expensive repairs or entirely new drums. This problem is not

limited to spirally-carved drums, of course, as the same danger existed for vertically-fluted drums. It would seem, therefore, to be more efficient to have drums spirally-carved (or vertically-carved) when they were already set in place in the column.

No matter how the column was constructed and its spiral flutes carved, it would not have been easy to produce this style of column fluting, keeping the correct size, angle and spacing of the spiral flutes. It would have been far more work for stonecarvers to create spiral flutes, as opposed to vertical ones, as the total length of the spiral fluting would be much greater. For example, the columns of Trajan and Marcus Aurelius (as discussed in Chapter 5) are each 100 Roman feet high, but their spiral friezes are about 676 Roman feet long. Depending on the width, angle and number of turns of spiral fluting on a column, therefore, the craftsmen would have had to carve spiral flutes many times longer than vertical flutes. Along with the attendant expense of these spiral fluted columns due to the increased production time and the need for specialized equipment and stoneworkers, the significant difficulties of carving these columns could be another reason why they are less common in ancient sites compared to the columns with vertical flutes. An example of the stonecarver's work showing these difficulties is seen in the S-spiral fluted column in the Priest's House at Aphrodisias (Fig. 3.1), which has asymmetrical and irregularly-spaced spirals on its top portion, while the spirals on the Z-spiral column in the same photograph are symmetrical and evenly spaced. It is not known if these two columns were carved by the same craftsmen, as they may have been reused in this structure, as noted in Chapter 5. But their similar size and shape suggest that they were produced in the same workshop, whether or not they were constructed originally for use in another building.

5. Conclusion

The questions addressed in this chapter are as follows: how did the relationship develop between ornamental screws and working screws, e.g., how did the flat spiral design become three-dimensional, which led to its use in water screws, the screw windlass, olive and grape presses, and several of Hero's inventions such as the odometer, siphon and screwcutter; how were spiral fluted columns produced; and how did techniques from other crafts influence their production, *e.g.,* the Vitruvian measurement

method for constructing water screws could be used for the placement of column spirals, as a example of innovation rather than invention.

But the main question examined in this chapter is the possible relationship between the rise of the water screw in agriculture and machinery and the appearance and subsequent popularity of the spiral fluted column in Roman architecture. First, did the architectural spiral develop from Archimedes' invention of the water screw? The chronology shows that the spiral fluted column became popular mainly in the late first millennium B.C., although it appeared earlier in peripheral uses. The evidence shown in Chapter 4 indicates that the spiral fluted column was known and used, though rarely, from the Aegean Bronze Age through the classical Greek period. The ancient literature suggests Archimedes' invention of the water screw in the third century B.C., and Pliny (*HN* 18.74.317) declares that the lever-and-screw press and the direct-screw press were invented *intra C annos…intra XXII hos annos* (Rackham 1950: 388); "within the last hundred years…within the last twenty years" (Rackham 1950: 389) before his time. There is a relatively short period of time between the advent of the water screw and the rise of the screw presses, and this suggests a direct connection between the adaptation of the spiral design for use in the earlier Archimedean water screw and the later olive and oil presses, as well as Hero's inventions incorporating the screw. The fact that Vitruvius included instructions for the making of the water screw in his work shows that he considered it a helpful piece of equipment and an important subject for his compendium of architectural necessities. It is, therefore, a reasonable assumption that he had seen them in use, and consequently took his information from his own observations as well as Archimedes' work.

Secondly, did the spiral fluted column became fashionable as a result of the techniques developed for the production of the water screw? Again, the time-period is certainly right: the evidence from my field study (Appendix 1) shows that the spiral fluted column, having been used infrequently in the Greek world (see Chapter 4), became a favourite Roman architectural element from the turn of the millennium onwards. The helical spiral is an energetic and iconoclastic image, full of visual power. It is the sort of intentional variation on architectural canons that appealed to Romans of the Late Republic and Empire. Once the helical spiral became a well-known device in mechanics,

it was incorporated in architectural iconography. I suggest that the method of manufacturing the water screw, invented by Archimedes and written down by Vitruvius two hundred years later, led to the adaptation of both the marking and the carving of the spiral fluted column (Fig. 6.1). The use of the lathe, already known for turning woodwork and column drums, as noted above, made it possible to support the drums and small monolithic column shafts on its frame, and the advances in Greek mathematics by this time (see Chapter 2) permitted the calculation of the angles, slopes and directions of the spirals.

The evidence put forth in this chapter, therefore, suggests that the rise of the Archimedean water screw and its continuing popularity throughout the Mediterranean world led to a new Roman appreciation of the practical as well as the decorative possibilities of the spiral. Now with its adaptation to fresh uses in mechanical devices, the spiral opened up new architectural possibilities as well. With the application of mathematical principles similar to those used in the design of the water screw, the spiral fluted stone column, although costly in terms of equipment and manpower, became an integral element of Roman monumental architecture.

6. Summary of Findings in Appendix 2

Appendix 2 is a summary of the data used in this thesis on the use of the helical spiral in ancient technology and mechanical devices: the water screw, ancient olive and grape presses (both lever and screw presses), and other mechanical screws, including some of Archimedes' and Hero's inventions that incorporated screws. The appendix also contains data about ancient stone-working tools and machines for raising stone columns.

Included is information (where known) about each item's country of origin, city, archaeological site, its location within the site, the structure type and the culture with which it is associated, the classifications of its spirals, its construction material and time period, and some archaeological and literary references. The Appendix was compiled to give full information about each object studied for this thesis, and, as all the machines listed have already been discussed in this chapter, they are not considered further here.

Chapter 7: Summary and Conclusion

This chapter summarises the research done in order to answer the six questions posed in the first chapter, namely: where and when did the spiral fluted column originate? Why and how did it develop? Was it used in specific types of buildings? Did the practical spiral screw influence the decorative spiral motif or *vice versa*? How was the spiral fluted stone-carved column manufactured? How do other representations of the spiral, i.e., on furniture, pottery, coins and sarcophagi, match the geographic extent of the spiral fluted columns used in architecture? This thesis examined these questions chronologically, beginning with Middle Bronze Age Mesopotamia, and the answers to each question will be discussed next.

1. Where and when did the spiral fluted column originate? The investigations in Chapter 2 show that the spirally-decorated column was used in Mesopotamia by 1800 B.C., being fashioned by laying shaped mudbricks in specific mathematical patterns. These columns, as noted above, are not related chronologically or technically to the later stone-carved spiral fluted columns, but they do show the early beginnings of human interest in the spiral pattern, and therefore cultural and mathematical connections with the later Aegean Bronze Age, Greek and Roman worlds. The archaeological sites of Tell al Rimah, Tell Haddad, Larsa and Tell Leilan all contain spiral mudbrick columns, all of which are located in buildings identified as temples or palaces. Thus, although this style of column seems to be limited to a specific style of structure, probably because of the difficulty and expense of its construction, it is not confined to one geographic region of Mesopotamia, and therefore it was seen throughout the area as a distinctive architectural style suitable for honouring a ruler or god.

As for the Greek world, the evidence examined in Chapters 3 and 4 suggests that the architectural use of the stone-carved spiral fluted column, although rare, had its beginnings in Greek structural design. Such examples as Bronze Age representations on Minoan and Mycenaean seals; miniature columns designed as furniture inlays; spiral designs noted on a Linear B tablet; and painted spirals and spiral column designs on an ossuary chest, pottery and wall murals all show how the spiral form moved from Mesopotamian mudbrick spiral helix columns into Bronze Age Aegean arts and crafts

and was sustained by its incorporation into daily life. In the Greek and Hellenistic world, the spiral design emerged in the Aeolic and Ionic capitals. The architectural spiral fluted column appeared in structures shown on the Amasis Painter's lekythos, the Heidelberg Painter's cup, and the Apulian krater. Spiral fluted architectural elements from Greece, some unfortunately now lost, are the Doric capital from Kalapodi and the archaic Doric column from the Athenian Acropolis; the spirally fluted "votive" columns from the Athenian Acropolis and Delphi; and the spiral shaft of the Serpent Column at Delphi. All these objects support the idea that the architectural spiral fluted stone column did indeed begin in Greece.

An interesting discussion of the origin of the spiral fluted column appears in Avi-Yonah 1930: he attributes its source to Greece, Rome or the Orient (including Persia). After dismissing all the evidence from Greece ("isolated cases"), Egypt (one "doubtful" example), Asia Minor (numerous late coins: too many in relation to those of other provinces; and some early architectural remains), and Syria (only one example that can be dated either to the first century B.C. or the first century A.D.), and noting some early examples in the Roman west, he concludes that the spiral fluted column originated in Italy. Apart from the general migration of artistic ideas, it could have been taken east specifically by Syrian architects working in Rome, "the clearing-house of all the styles of the Empire," in the second century A.D. (Avi-Yonah 1930: 304-7). These arguments may have been convincing at the time (1930), but archaeological explorations and excavations in the eastern Mediterranean have yielded much more evidence of both decorative and architectural spiral fluted columns since then, and his conclusion is not tenable today. It is, however, instructive to follow Avi-Yonah's deductions and read his ideas, even though they have been superseded by modern scholarship.

2. Why and how did the spiral fluted column develop? As discussed in Chapter 2, Mesopotamian mathematics was advanced enough to calculate the required dimensions of the shaped mudbricks and then to arrange them in a spiral column. Mesopotamian mathematical theory is known from cuneiform tablets and is verified by bricks found in archaeological excavations, many of which were found to have standardized sizes. Classical and later Greek authors believed that Greek mathematics originated in Egypt

rather than Babylon. Although modern scholars differ about the influence of Babylonian mathematics on the Greek world, it is mainly a question of when this influence occurred: some date it as early as the mid-seventh century B.C., some to the fifth century B.C., and others say it was not felt until Alexander's time. In any case, by the third century B.C., Archimedes' work on mathematics (including the spiral) and its practical applications to physics and engineering was used by other mathematicians, such as Conon, Apollonius and Pappus. The work of these mathematicians became the basis for progress in Roman art, architecture and engineering, and the use of the stone-carved spiral column as a building element existed because of this cross-connection.

3. Was the spiral fluted column used in the construction of specific types of buildings? The information presented in Chapter 5 and Appendix 1, based on my research and field work, shows that the spiral fluted column was primarily used in four types of Roman structures: theatres, colonnades, public fountains and decorative entryways to public and private areas. From the Etruscans to Constantine, the spiral fluted column became a characteristic element of Roman monumental architecture. Spiral fluted column motifs became an integral part of the design of the Asiatic columnar sarcophagus of the first and second centuries A.D., influencing sarcophagus preferences throughout the eastern Mediterranean, and were later included on Christian sarcophagi. Coins from Asia Minor show that the spiral fluted column was used in temples, and other examples such as the Nabataean/Roman stand for a water basin, Roman savings banks, Roman funerary reliefs, and the monumental columns of Trajan and Marcus Aurelius show the adaptability of the spiral design to architectural public and domestic uses.

Was the spiral fluted column built with or limited to specific materials? Marble was the most commonly used stone for these columns, even in areas where it was not available locally. Thus the spiral fluted column was not only a distinctive design, but was considered important enough for execution in expensive imported stone. This choice of column style and material showed a person's upper-class status and emphasised his and his family's wealth, civic pride and good taste. There were exceptions, however: Termessos was so inaccessible (note that even Alexander made a treaty with the Termessians rather than try to invade the city) that it would have been impossible, as well

as impossibly expensive, to import marble. Thus its theatre (including its spiral fluted columns) and the other buildings in the city were made of the local grey limestone. The Roman control of the sea between 200 B.C. and A.D. 200 and the resulting increase in Mediterranean trade increased the use of imported marbles throughout the Roman Empire and also the geographical spread of the spiral fluted column.

4. Did the practical screw influence the decorative motif or *vice versa*, and what was the relationship to Archimedes' spirals? Chapter 6 examines these connections. In Archimedes' water screw, the screw press and Hero's inventions containing the screw gear, the spiral was adapted for a practical rather than a decorative use, as their mechanisms depended on a spiral screw. Pliny the Elder says that the screw press, which involved a large central wooden screw with spiral threads, had been invented within the last hundred years, which is approximately the same time that spiral fluted columns became popular in the Roman world. Vitruvius' instructions for constructing a water screw show its importance in the late first century B.C., and it is assumed that he wrote from his own observations as well as Archimedes' work. The relatively short period of time between the advent of the water screw and the rise of the screw presses suggests a direct connection between the adaptation of the spiral design for use in the earlier Archimedean water screw and the later olive and oil presses, as well as in Hero's inventions incorporating the screw. The spiral fluted column, therefore, became fashionable in the Roman world as a result of the following: the techniques developed for the production of the water screw, particularly its methods of measurement and use of mathematics; the use of the lathe, so prevalent by Vitruvius' time that he did not consider it worthy of description; the expansion of Roman maritime power; the imperial control of quarries and thus the availability and affordability of distinctive imported marbles; and the spiral fluted column's associated historical, religious and civic symbolism that made it suitable for both public and private use.

5. How were spiral fluted columns made? Chapter 6 discusses their design and the mechanics of stone-carving in the ancient world. Were these columns monolithic or made of individually cut and shaped stone drums piled atop each other? The Greeks preferred

columns built with stacked drums, which made the columns easier to erect and more resistant to earthquake damage. The Romans built some columns with drums (e.g., the spiral fluted colonnade at Apamea), but preferred monolithic columns. Several reasons have been suggested for this preference: the expansion of the imperial marble trade in the first century A.D. meant that builders and architects did not want to break up the patterns of the exotic coloured stones now available to them from across the Roman Empire; the newly-popular monolithic column made a grand public impression because of its huge size and the resulting expense of transporting it from its quarry to its final destination; the increased construction of massive Roman transport ships during this period meant that monolithic columns could be transported relatively safely; and centralized ownership and administration of quarries under the Empire meant more efficient production.

What tools were used? Were the same techniques used to cut spiral flutes and spiral screws? Tools used by Greek and Roman stonemasons were made of iron and were similar to those used by modern stonemasons: picks, hammers, mallets, punches, chisels, gouges, files and squares. Spiral flutes and spiral screws could have been cut by similar methods: the markings for the spirals could be measured on the column shaft or drum using Vitruvius' method for marking the spirals on the water screw, and then the stoneworker would simply cut along the inscribed lines. Hero's screwcutter could have been adapted to carve spiral fluted columns in stone if the column were monolithic and slender enough, and, since the lathe was known in the ancient world, its frame could have been used to hold the column or drum while it was being carved.

I suggest that the method of manufacturing a water screw, invented by Archimedes and written down by Vitruvius two hundred years later, led directly to the design, marking and the carving of the spiral fluted column. The mathematical and production principles of the spiral water screw and the spiral fluted column would have been the same: the screw mechanism of the screw press resembles a spiral fluted column, as both are basically solid shafts with incised grooves. The imperial *Pax Romana* provided the intellectual and political climate necessary for the development of new ideas in Roman art, architecture and engineering, and thus led to increased interest in the spiral fluted column as an important element in monumental Roman architecture. The new Roman appreciation of the practical as well as the decorative possibilities of the spiral was the

result of the continuing popularity and usefulness of the Archimedean water screw over the preceding three centuries in the Mediterranean world.

6. Throughout the chapters of this thesis, other non-structural representations of spiral fluted columns have also been examined: they are found in frescoes and non-architectural goods such as furniture, pottery, coins and seals, and sarcophagi. These motifs match the geographic extent of the spiral fluted columns used in architecture, having been found in the Aegean, Egypt, North Africa, Greece, the Levant and Asia Minor. They provide proof of the continuing interest in the spiral form, ranging from the Neolithic period's painted spirals to the Roman Empire's specialized constructions, and during this time, the two-dimensional spiral developed into the three-dimensional spiral used in ancient architecture and technology. The monumental masterpieces of the Mesopotamian and the classical world, e.g., the spiral mudbrick columns at Larsa and other Middle Bronze Age sites in the Fertile Crescent, the stone-carved spiral fluted columns of the Propylon at Aphrodisias in Turkey and the spiral fluted stone colonnade at Apamea in Syria all depended on mathematical ideas translated into mudbrick or stone by the direct and practical methods of the architect and the craftsman.

> "This is the shape, and with it ends the book"
> (Heron *Mech*. 3.21; Drachmann 1936: 77).

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Appendix 1: The Spiral and Spiral Fluted Columns

Please see attachment.

Appendix 2: The Spiral in Technology and Mechanical Devices

Please see attachment.