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Stoneworking Tools and Toolmarks

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Stone carving is generally a conservative craft. There are only a limited number of ways to shape stone and broad similarities in technique can be noted all around the world and throughout history. In almost all stone carving traditions, one finds metal or stone chisels with pointed or flat ends, picks or axes for quarrying. Against this background, important regional differences in stone carving traditions can be observed. Exactly what tool a carver will use for a particular process will depend on the stone being worked, the final effect sought and the carver's own training: 'what is learned is the craft in its particular location, with certain materials and product requirements.'¹ Underlying geology has a certain role to play in the process of tool selection. The tooth chisel, therefore, a tool often used in marble carving, has a long history around the Aegean and Italy, areas rich in marble, but is almost entirely absent from Pakistan and India, where granite, sandstone and schist are the dominant stones.² There is considerably less chronological variation in stone carving techniques than there are geographical differences, however. The tools used within specific traditions have changed little over time. Experimentation is rare and even mechanized tools – such as the electric saw, drill, angle grinder and air hammer – were relatively late, twentieth-century introductions which are still only used sparsely.³ Granite carvers in India and marble carvers in Italy still use the same basic range of tools as their predecessors centuries earlier. What this means is that those familiar with the full range of stone carving tools and the history of carving traditions in specific areas can decipher toolmarks on sculpture of any age. What it also means is that dating sculpture based on toolmarks only is often impossible.

No attempt has been made to catalogue stone carving tools from all around the world but the *Art of Making in Antiquity* builds on several key publications examining stone carving tools and techniques in the Classical world and later Europe. Foremost among these are the various contributions of Rockwell, Bessac and Pfanner.⁴ All three of these scholars, as practising stone carvers and/or restorers, offer a new perspective on sculpture which complements and extends the bulk of art historical literature on this topic.⁵ Their work also demonstrates that practitioners are often the best guides for interpreting toolmarks on ancient carvings and how these were made because they are used to working in a wide variety of stones and are aware of the ranges of tools in existence.

Three main categories of stone carving tools can be distinguished: those that work by percussion, those that work by abrasion, and those that are used for measuring or laying-out but not actually removing stone. Within each of these classes a series of tool types can be identified and the purpose of this essay is to explain the basic form and function of these. It should be noted, however, that these tool types are by no means fixed. Tools of the same basic type come in a whole range of sizes and most carvers will own multiple versions of the same tool, collecting them over time, inheriting them, even swapping them with colleagues.⁶ Certain tools can also be shaped into other types of tools as

¹ Rockwell 1993: 3.

² On carving in Pakistan, see Rockwell 2006; observations on Indian carving are based on Rockwell's own analysis of pre-modern monuments in India as part of a project with Professor Vidya Dehejia at Columbia University.

³ While the air hammer is widely used for marble carving in Italy, for instance, many carvers working in limestone or sandstone in the UK and France choose not to use it (personal communication Andy Tanser).

⁴ Rockwell 1981–3; 1987–8; 1989; 1990; 1991; 1993; 2008; Bessac 1986; 1988; 1993; 2007; Pfanner 1989; Boschung and Pfanner 1988.

⁵ The key contributions dealing with sculptural production in antiquity are Blümel 1927; 1955; Adam 1966; Claridge 1985; 1988; Strong and Claridge 1976; Palagia 2006.

⁶ Personal communication Paul Jakeman and Andy Tanser.

required. A flat chisel, for instance, can be shaped into a round-headed chisel or roundel by cutting its corners back, or it can have teeth cut into its cutting edge, turning it into a tooth chisel. Since metal carving tools also need continual sharpening, blacksmiths and carvers have always had a very close relationship. In modern Carrara blacksmiths move from workshop to workshop collecting tools that need sharpening or altering.⁷ On the second-century AD *ostraka* from the Mons Claudianus granodiorite quarries in the Egyptian Eastern Desert large numbers of blacksmiths are recorded.⁸ In India, teams of twenty carvers are routinely accompanied by as many as three blacksmiths.⁹

Percussion tools

Most of the tools employed to carve stone are percussion tools, that is tools that are struck against the stone. These include picks and axes, tools with which the carvers hit the stone directly, and chisels, which are struck with a hammer or mallet. Percussion tools are used right through the stone carving process, for almost all tasks except polishing.

Quarry Pick

The pick is a tool used primarily during quarrying.¹⁰ With a wooden handle up to 70-80 cm long the quarry pick has a metal head with points on one or both ends.¹¹ The points themselves act effectively like a point chisel but the long handle allows the user to impart far more force, though less control, with each stroke. On quarryfaces the marks of the quarry pick are identifiable as long, often curved lines where the quarrymen struck the same spot repeatedly before moving along the rockface. Characteristic marks of the Roman quarry pick can be seen on extant quarry faces and especially in the channels excavated around blocks during quarrying. Very clear examples have been documented by Rockwell at Aphrodisias and in the Bacakale quarry at Iscehisar (ancient Dokimeion) {Fig. 1}.¹² At Carrara, where modern quarrying has destroyed many of the traces of Roman activity, a small section of quarry face on which marks of the Roman quarry pick can be seen has been preserved in the Museo del Marmo.¹³ In addition to actual quarrying, the pick was also used for squaring blocks and hollowing-out sarcophagi.¹⁴

In the Roman imperial period a heavier form of the quarry pick than had previously been used seems to have been introduced.¹⁵ This heavier pick allowed the quarryman to work quicker and with more impact but it also generated considerably more waste during what was already an exceptionally wasteful process.¹⁶ We are fortunate to have a small relief showing a carver using a quarry pick identical in form to those that have survived from antiquity. This relief comes from Istria, an area famed for its fine limestone in both the Roman and Medieval periods, and is now in the collection of the Archaeological Museum of Istria in Pula.¹⁷ The tool used by the carver depicted is almost identical to those still used by quarrymen who work by hand in areas of Turkey and Syria {Fig. 2}.¹⁸

Sculptor's Pick

The sculptor's or carver's pick is essentially a miniature version of the quarry pick, with a handle no more than 60 cm long and often more like 30-40 cm {Fig. 3}.¹⁹ The metal head of this small pick is usually pointed at either both ends or just one. The tool is held with two hands and its head strikes the stone vertically, leaving marks similar to the point chisel when used in this manner. How much this tool was used in the Roman period is unknown but it was widely used on marble and granite in Medieval Italy, as on Orvieto cathedral, where it was used in place of the tooth chisel for rough shaping.²⁰

Wedge

⁷ Personal observation, Peter Rockwell.

⁸ Hirt 2010: 211.

⁹ Personal observation, Peter Rockwell.

¹⁰ Rockwell 1993: 31–2, 66 (Drawing 12).

¹¹ Bessac 1986: 14–24. For Roman examples, from Felsberg and Carrara, see Bruno 2002d; 2002e.

¹² PR311_02_15, PR311_03_21.

¹³ PR228_02_01; for more on the collection of this museum, see Dolci 2006.

¹⁴ PR936_01_23, PR936_01_24, PR311_05_08.

¹⁵ Fant 2008: 129.

¹⁶ It is usually estimated that only 20–30% of marble extracted using traditional quarrying techniques would actually have been useable for carving projects (Röder 1971: 269; Attanasio, Bruno, and Yavuz 2009: 326).

¹⁷ Starac 2007: 136.

¹⁸ For photographs of quarrymen at work in the quarries at Aramel and Résafa in Syria, see Bessac, Abdul-Massih, and Vallat 1997: 166–76.

¹⁹ Rockwell 1993: 40.

²⁰ PR500_04_05, PR500_04_12; Martellotti and Rockwell 1988.

Another tool commonly used in the quarrying process, alongside the pick, is the wedge.²¹ Wedges can be either wooden or metal and are used to split stone. Several iron examples datable to the Roman period are known from the Felsberg granite quarries.²² Wooden wedges are obviously too weak to break the stone directly and are instead inserted into rectangular holes, usually carved with the point, and then soaked in water. As the wood becomes saturated it expands and forces the stone to split along its natural bedding lines or faults.

Holes made for the insertion of wooden wedges can be seen in several places in the quarries at Aphrodisias {Fig. 4}.²³ These are large holes and the wedges intended for them were at least 10–15 cm long and wide. Metal wedges are also inserted into specially carved cuts and are simply hammered into the stone. The plug-and-feathers is a particular form of metal wedge that is still used today but can be traced back to ancient Egypt.²⁴ This tool consists of three parts: a central wedge (the plug) and two shims, or tapered wedges (the feathers). The feathers are inserted into the socket first, their wider ends down, and then the plug is hammered down between them. The shape of the feathers helps to channel the force of this blow through the stone. By aligning a series of wedges the quarryman can control the line along which the stone will split.²⁵

Point

The point is a metal chisel consisting of a shaft, 20–30 cm long and 1–2.5 cm in diameter, with a pyramidal point at one end {Fig. 5}.²⁶ The length of the point varies depending on the material it is being used with. For marble and limestone the point tends to be elongated while for granite it is blunter. The other end of the point chisel is flat or rounded. This tool is hit against the stone with a metal hammer, sometimes a wooden mallet, and is the basic chisel used for most carving, especially roughing-out and basic shaping. As Rockwell puts it: 'This chisel is the workhorse of carving. At least 85% of the stone removed in the process of carving a statue is cut away using this tool.'²⁷ To quote Blagg, the point is 'the oldest, the simplest and the most versatile of the masons' iron tools.'²⁸

The way in which the point is applied to the stone varies according to the effect desired and the material. On granite and other hard stones it tends to be held perpendicular to the surface of the stone; a stroke at this angle effectively shatters the surface of the stone. At a shallower angle the chisel would simply bounce off these hard materials. For marble carving the point is only used at 90° for removing large amount of stone or for roughly squaring a block. At this angle, the point leaves behind a characteristic pock-marked surface.²⁹

For finer carving, especially on marble, the point is usually held at a shallower angle, around 70° or less, to cut into rather than shatter the surface of the stone. Working with successive strokes, lifting the chisel between each to cut a series of short grooves across the surface, a carver can remove large quantities of material quickly. This method is sometimes called the 'mason's stroke'.³⁰ Marks of the point used in both of these ways can be seen on the unfinished section of the entablature of the Temple of Vespasian now in the Capitoline Museums, where this tool was employed to rough-out the basic form of the block.³¹ On several monuments this kind of carving with the point is still visible in those areas which were hidden from view originally. The reliefs of the Sebasteion in Aphrodisias, for instance, usually have rough point chiselling on the upper surfaces of the planes on which the figures stand, and the same practice can be identified on the Arch of Constantine.³² On several reliefs from Aphrodisias the flat background plane behind the figures is even left in this state, as a roughly textured backdrop.³³ Held at this angle the point chisel can also be used to rough-out forms for finishing with finer chisels, such as the tooth and flat chisel.

²¹ Rockwell 1993: 34–5, 55 (Drawing 1).

²² Bruno 2002b: 507.

²³ See also PR309_09_21.

²⁴ Kirby *et al.* 1990: 23.

²⁵ For a modern example, see PR316_02_13 and PR316_02_15. For a photograph showing a worker using wedges in this way in a modern Syrian quarry, see Bessac, Abdul-Massih, and Vallat 1997: 175, fig. 19.

²⁶ Rockwell 1993: 39–40, 57 (Drawing 3); Besac 1986: 108–15. For Roman examples, from the Felsberg granite quarries, see Bruno 2002c: 510–11.

²⁷ Rockwell 1993: 39.

²⁸ Blagg 1976: 159.

²⁹ PR915_01_01, PR915_01_02, PR915_01_05.

³⁰ Rockwell 1993: 39; some British carvers call this "lift and place".

³¹ PR202_03_06.

³² PR301_03_07, PR301_08_07, PR210_03_18.

³³ PR303_01_24.

Working at a shallower angle, around 45°, and not lifting the point between each stroke a series of more controlled parallel lines can be created which help define the form of a shape. This stroke is known as the 'sculptor's stroke'.³⁴ Very clear marks of a point held at this angle can be seen on the inside of the Column of Trajan {Fig. 6}.³⁵

A slight variation on the point chisel is the limestone point or punch which tends to have a wider cutting edge, usually 0.5 cm long. This wider edge is better suited to softer stones which can be shattered by the point chisel.³⁶ Marks of the punch can be seen on the rear sides of many of the limestone reliefs from Palmyra.³⁷

Tooth Chisel

The tooth chisel –typically called a claw chisel in the United Kingdom– is a metal chisel consisting of a shaft, 16-22 cm long and 1-2 cm in diameter, with a toothed cutting edge at one end typically 0.5-10 cm wide {Fig. 7}.³⁸ It is usually hit with a metal hammer or sometimes a wooden mallet. The number of teeth on the cutting edge varies, usually between three and five, but a variation with two teeth also exists, referred to in Italian as a 'dente di cane' or dog-tooth chisel.³⁹

Typically the tooth chisel is held at 35-60° to the surface of the stone and leaves behind characteristic sets of shallow parallel lines. Sometimes it is held closer to the vertical to cut more deeply into the stone, in which case, the marks left behind are less regular.⁴⁰ The shape of the actual teeth on tooth chisels, which can be either pointed or squared, will also affect the marks they leave behind.⁴¹

The tooth chisel is usually used between roughing-out and finishing, to remove the rough marks left by the point chisel and prepare the surface for finer work with the flat chisel. However, it is also used for rough shaping of the stone. Marks of the tooth chisel can be seen very clearly on the head of the imperial statue abandoned in the Prokonnesian quarries and the same tool is used for shaping the figures on several of the Sebasteion reliefs from Aphrodisias {Fig. 8}.⁴²

While the tooth chisel is usually an intermediary tool it was occasionally used in the Roman period, and more so later, to create a roughly flat surface, especially on large expanses where a smooth finish was not required. Marks of the tooth chisel, consequently, are found on the interior of the Column of Trajan, on flat surfaces on both the Arch of Titus and the Arch of Trajan at Benevento, as well as on the background of some of the Sebasteion reliefs.⁴³

In general the tooth chisel is only widely used in marble carving. It is never used on granite because the hardness of the stone would cause the teeth to break. On softer stones, like limestone and sandstone, tooth chisel marks are sometimes found but usually carvers jumped straight from point to flat chisel. In Britain, Blagg notes that carvers typically used the drove, a wide flat chisel particularly suited to flattening surfaces, instead of the tooth chisel.⁴⁴

Flat Chisel

The flat chisel, like the point and tooth chisel, is a metal chisel which is struck with a metal hammer, or wooden mallet in some cases {Fig. 9}.⁴⁵ It typically consists of a shaft, 15-25 cm long and 1-2 cm in diameter, with a flat and sharpened cutting edge perpendicular to the line of the shaft. The width of the cutting edge can vary significantly, between 0.5 and 10 cm; the wider varieties are sometimes called bolsters or droves and are used for flattening surfaces.⁴⁶ Further variation is found in the profile of the corners of this cutting edge. Sometimes they are rounded so

³⁴ Rockwell 1993: 39; for the marks made by this process, see PR915_01_04, PR915_01_05.

³⁵ PR205_1_16_18.

³⁶ Rockwell 1993: 40; for a range of historical examples, see Petrie 1917: pl. XXII.

³⁷ Colledge 1976: 110.

³⁸ Rockwell 1993: 40–1, 58 (Drawing 4).

³⁹ In French, similarly, this tool is known as a 'dent de chien' (Bessac 1986: 140–1).

⁴⁰ PR915_01_06, PR915_01_09, PR915_01_11, PR915_01_12.

⁴¹ Bessac (1986: 138–48) distinguishes between two types of tool, the 'gradine' which has squared teeth and the 'ciseau grain d'orge' with pointed teeth, but in English both of these varieties are simply described as tooth or claw chisels.

⁴² PR301_01_15, PR301_04_23, PR316_05_15.

⁴³ PR204_04_23, PR205_1_16_19, PR225_03_03, PR301_02_13.

⁴⁴ Blagg 1976: 163.

⁴⁵ Rockwell 1993: 42–3, 59 (Drawing 5); Bessac 1986: 121–37.

⁴⁶ Rockwell 1993: 42; Blagg 1976: 163.

that they do not catch on anything during delicate work but often they are left squared and sharpened for the careful application of detail and especially for letter-cutting.⁴⁷

The flat chisel is usually held at 35-60° to the surface of the stone but like other chisels it can be employed in various ways and at different angles, depending on the type of material and whether it is being used carefully to smooth or more roughly to shape quickly. The traces left behind by the flat chisel tend to consist of almost smooth sets of parallel straight lines, sometimes barely noticeable when the carver has worked particularly carefully.⁴⁸

The flat chisel can be used for a wide range of processes, including fine shaping, applying detail and smoothing surfaces of finished forms. On the Column of Trajan, the flat chisel was employed before the rasp on figures and the marks of it can still be seen in the hair and beards of certain individuals.⁴⁹ However, it was also used as a finishing tool, for smoothing the background and occasionally for flattening surfaces on buildings and other structures {Fig. 10}.⁵⁰ In addition, there are examples where the corner of a flat chisel was used for incising details, such as the patterning on chain mail.⁵¹ On the Sebasteion at Aphrodisias, the flat chisel was used for shaping the forms of the figures, usually following work with the tooth chisel, and adding details to the hair, clothing or armour of figures. In many cases carving with the flat chisel was left as the final surface finish.⁵²

Roundel

The roundel is similar in basic form to the flat chisel except that its cutting edge is curved rather than flat {Fig. 11}.⁵³ For this reason it is also called a round-headed or bullnose chisel. It is a metal hand-held tool which is struck with a metal hammer or wooden mallet, and consists of a shaft, 15-25 cm long and 1-2 cm in diameter. The curve of the cutting edge varies considerably from a semicircle to a barely discernible curve and the marks that it leaves on the stone retain the same form.⁵⁴ It is difficult to differentiate between flat chisels with rounded corners and roundels and, as already noted above, a flat chisel could be turned into a roundel easily if required. Like the flat and tooth chisel, the roundel is usually held at 35-60° to the surface of the stone. It is often used on marble and is very common on softer stones but almost never on granite.

The roundel can be used for rough and smooth work and is well-suited to delicate areas of carving since it has no corners that might catch on anything. It is especially suited for carving hollows since its shape fits the curves. Occasionally it is also used for surface texture, especially on natural forms like trees, rocks or water.⁵⁵ The shape of the tool also makes it appropriate for the carving of hair or beards, a role for which it is commonly used on the Column of Trajan.⁵⁶ Occasionally, however, notably on the Sebasteion at Aphrodisias, the roundel is used interchangeably with the flat chisel as a finishing tool on the bodies of figures {Fig. 12}.⁵⁷

Channelling Tool

A range of chisels can be described as channelling tools, that is tools designed for the carving of narrow channels {Fig. 13}.⁵⁸ These are similar in form to narrow flat chisels or roundels, with a cutting edge of 0.5-1 cm and a shaft 15-25 cm long. The distinctive feature of most of these tools, when viewed from above, is the narrowness of their shaft immediately above the cutting edge. This allows the tool to be inserted into deep crevices and hollows. In profile the shaft thickens at this point so that the structural strength of the chisel is not compromised. This distinctive shape explains why this tool is often described as a 'fish tail' chisel in the UK.⁵⁹ This tool is used in the Roman period primarily for carving deep drapery or the grooves in hair, often following initial work with the drill, and outlining figures or other objects against flat backgrounds.⁶⁰

⁴⁷ On the carving of inscriptions, see Grasby 1996; 2002; 2009.

⁴⁸ PR915_01_10, PR915_01_11.

⁴⁹ PR205_1_07_10.

⁵⁰ PR205_1_06_18.

⁵¹ PR205_1_14_04.

⁵² PR301_04_23, PR301_05_22.

⁵³ Rockwell 1993: 43, 60 (Drawing 6).

⁵⁴ PR915_01_08, PR915_01_09.

⁵⁵ PR205_1_03_01, PR205_1_05_15, PR205_1_11_08, PR304_01_14.

⁵⁶ PR205_1_11_08.

⁵⁷ PR301_01_11, PR301_01_13.

⁵⁸ Rockwell 1993: 44-5.

⁵⁹ Personal communication Andy Tanser.

⁶⁰ For characteristic use of the channeling tool following drill use, see PR210_02_20 on the Arch of Constantine and PR202_03_04 on the Temple of Vespasian.

Hammer

All of these chisels are struck with a hammer {Fig. 14}. Most stone carving hammers are metal or wooden, though early hammers were probably simply stones; on Easter Island, where there are no sources of metal, hard stones were probably used for all carving.⁶¹ The size and shape of the head of a hammer, and the length of its handle, can vary considerably, depending on the stone being worked and the process being undertaken, and sometimes simply because different traditions have developed different hammer forms.⁶² Modern Italian marble carving hammers usually have a square head and a relatively short handle, 15–20 cm long. In Britain and France, hammers with a rounded head are found which are used for fine carving. Some of these have shorter handles, of 10–15 cm, while others can be much longer. Wooden mallets are also common in north-western Europe and indeed identical examples are known from Egypt, mainly from New Kingdom contexts.⁶³ These tend to have larger, rounded heads with handles of 15–20 cm. Most modern carvers will use just one type of hammer, depending on where they learnt to carve and the type of stone and tools they tend to use. Much marble and granite carving nowadays is also done with an air hammer. This is essentially a small pneumatic drill, attached to an air compressor, into which different chisel heads are inserted. The air hammer strikes the tool quicker than a carver using an ordinary hammer could but it does not hit it any harder: as Rockwell puts it, 'its value is the velocity of the blows, not their strength.'⁶⁴

Axe

Any of the cutting edges on the above list of chisels can also found in an axe form.⁶⁵ The quarry pick, in fact, is basically just an axe with a cutting edge similar to the point chisel. Axes with flat cutting edges can have them aligned with the shaft, like an axe used for cutting wood, or at 90° to it, a form sometimes called an adze {Fig. 15}.⁶⁶ Axes are traditionally used in north-western Europe and tend to be employed for either limestone or sandstone carving and sometimes in granite carving. Marks of axes are very common on Roman monuments in France and Britain and a lot of work has been done on identifying them in these areas.⁶⁷ Distinguishing between marks made by chisels and axes is often difficult but axes tend to produce more irregular marks. The axe is usually employed, as a result, more for rougher shaping or squaring than the corresponding form of chisel. How widely used axes were in the Roman period is not known due to the difficulty of identifying the marks made by them. They were probably not used for marble carving but marks that seem to have been made by axes can be found on carved limestone and sandstone objects throughout North Africa and the Levant, where these stones were the basic materials of building and sculpture {Fig. 16}.⁶⁸

Abrasion tools

After percussion tools the second main category of stone carving tools are those which effectively rub away at the stone. Some of these abrasion tools are used for cutting, like the saw, while others, like the rasp, are used for smoothing or polishing the surface of the stone. Drills, used to make holes or channels in the stone, also work by abrasion.

Saw

Saws can be used on almost all stones and were widely employed in the Roman period for creating thin panels for wall revetment or flooring.⁶⁹ Stone saws usually comprise a long, thin metal blade, typically no more than 0.5 cm wide and often over 2 m long. Normally these would have been operated by two workers pulling in sequence on each end. Smaller saws could have been operated by a single worker but only when they were used on soft limestone, sandstone or tuff. On these soft stones the blade tends to be toothed while on harder stones it is flat and used in conjunction with

⁶¹ Mulloy 1970.

⁶² Rockwell 1993: 32–3, 65 (Drawing 11); Bessac 1986: 158–71.

⁶³ There are a series of these from Deir el-Bahri in the collection of the British Museum (reg. no. 1899,1014.2, 1904,1008.287, 1905,1014.45) and for more examples, see Petrie 1917: pl. XLVI; Stocks 2003.

⁶⁴ Rockwell 1993: 32.

⁶⁵ Bessac 1986: 25–75.

⁶⁶ Blagg 1976: 157–8. For a Roman axe from quarries near Mayen, see Oesterwind 2002: 504–5. The bush hammer, a variety of axe that looks like a meat tenderizer, is commonly used in contemporary stone carving but there is no evidence for its use prior to the Roman period (Bessac 1986: 83).

⁶⁷ On France, see Bessac 1986; 1993. On Britain, Blagg 1976.

⁶⁸ See also PR252_02_08.

⁶⁹ Rockwell 1993: 45–7.

abrasives mixed in water. The blade cuts the stone by moving back and forth through this mixture of water and abrasives grinding away at it. Even now specialist sawyers used to working with hard stones, in the Italian *pietra dura* tradition, tend to favour iron over steel saw blades, since the relative softness of the iron allows the abrasives to embed in the metal making the whole process more efficient.⁷⁰

A relief from Ostia has been interpreted as showing a pair of marble sawyers in their workshop.⁷¹ They stand either side of a large block holding a flat-bladed saw. Half an amphora is propped against this block, perhaps containing the mix of water and abrasives, as is a long-handled spoon, which could have been used to apply this solution. Saw blades larger than the example depicted in this relief are usually fixed to wooden frames suspended above the stone by a system of pulleys and weights. This allows the operators to concentrate on the sideways motion of the saw without having to worry about keeping it level. This system also ensures that the saw blade rests gently on the stone, leaving just enough space for the water and abrasive mix to pass between them {Fig. 17}.

Saw blades, when used on hard stones, leave few traces aside from a very smooth surface occasionally with ripples in it where the blade has moved. Sometimes long straight lines can be identified. On the right end of the entablature block of the Temple of Vespasian which is now in the Capitoline Museums a small area of sawn surface can be seen {Fig. 18}.⁷² The saw seems to have been used in this case following quarrying to create a smooth, flat surface on which further carving work could be carried out, initially with the point and then flat chisel. Smooth sawn surfaces are also relatively common on sarcophagi, which were also usually shaped into a rectangular form before any work began on their decoration. A garland sarcophagus from Aphrodisias had its right end squared off with a saw before any detailed carving was begun.⁷³ The only reason that this sawn surface is still visible, as in the case of the Temple of Vespasian entablature block, is because carving on this end was never carried through to a final stage of finishing.

Long saws were also employed in quarries to remove blocks from the rock face. Marks of this saw type have been identified in the large Bacakale quarry at Iscehisar, ancient Dokimeion.⁷⁴ Similar traces have been discussed by Lambraki in the quarries at Kassamboli in Thessaly, where the distinctive green breccia known as *verde antico* was quarried in the Roman period and into Late Antiquity.⁷⁵

Modern stone saws tend to be operated by motors and there is evidence for the mechanization of these tools even in the Roman period. Water-powered stone saws are known at Ephesos and at Jerash in Jordan, both datable to the 5th or 6th centuries AD.⁷⁶ In the same period the poet Ausonius describes the noise made by these saws in the valley of the Moselle in north-eastern Gaul.⁷⁷ A depiction of a similar saw has recently been identified on a sarcophagus from Hierapolis in Phrygia, which dates back to as early as the 3rd century AD, indicating that these machines were not Late Antique inventions.⁷⁸ These saws were worked by waterwheels fed by channels of continually flowing water and the two archaeologically-attested examples both have multiple blades arranged on two arms so that two blocks of stone could be sawn at once into multiple panels. The job of the operator in this arrangement was to ensure that enough water and abrasives were present to maintain the grinding action.

Drill

The drill is one of the few mechanical tools to have a long history in stoneworking.⁷⁹ It is used to make a hole in the stone, usually at 90° to the surface, that has a uniform diameter its entire depth. In the Roman period the standard form of drill was the strap or cord drill {Fig. 19}.⁸⁰ This consists of a drill bit, usually a chisel-like metal tool, set into a shaft connected to a wooden handle within which it can rotate freely. The shaft is driven by pulling back and forth on a cord wrapped around it several times. The cord is operated by one person while another directs the drill itself, deciding where the bit is placed and applying pressure on the handle. The speed of rotation and the force applied can both be varied. Since the drill operator is free to use both hands to direct the drill and apply pressure the cord drill is

⁷⁰ Personal communication Goffredo de Tomassi.

⁷¹ Olivanti 2002: 499; Kessener 2012: 197, fig. 1. There is another example from Rome, now lost, which shows a seated male sawing a block on his own and guiding the blade with a stick, see Zimmer 1982, 154 (Cat. No. 76).

⁷² PR202_03_01.

⁷³ PR305_02_13.

⁷⁴ PR311_03_15, PR311_03_19.

⁷⁵ Lambraki 1982.

⁷⁶ Mangartz 2010; Seigne 2002.

⁷⁷ Ausonius, *The Moselle* 363–4.

⁷⁸ Ritti, Grewe, and Kessener 2007.

⁷⁹ Bessac 1986: 231–52.

⁸⁰ Rockwell 1993: 36–7, 64 (Drawing 10).

more flexible than most other types of drills –such as the staff drill or bow drill– which are operated by just one person. Rockwell notes that the cord puller was often an apprentice and had to work hard to keep up with the drill operators actions: 'I have been told by workers who were trained with this tool that the strap puller, usually an apprentice, learned quickly because he had his head slapped every time the cord slipped off the shaft, something which can happen quite easily' {Fig. 20}.⁸¹

The drill was used for a variety of tasks. These included creating holes for dowels or metal fittings but mainly it was employed to achieve depth in delicate areas of carving where the chisel might cause damage. On figures, single drill holes were used to give depth to nostrils, ear holes or curly hair, to mark out pupils in eyes or add texture to clothing, notably chain mail, emphasising the chiaroscuro of the finished piece.⁸² The drill was also commonly used to create deep channels. To achieve this a row of drill holes would be made next to each other, at 90° to the surface of the stone, and the bridges between them then knocked out with a fine flat chisel or channelling tool of some description. This process can be seen very clearly on a detail of a capital from the Temple of Vespasian {Fig. 21}.⁸³ The channel on the right has had the first stage of work done, and has a row of holes drilled along it, but only in the channel on the left have these been carved together to create a deep furrow. Rows of drill holes which were not joined together can be seen on a range of Roman monuments and become increasingly common from the third century AD onwards.⁸⁴ Sometimes these holes were just left in place because the final stage of carving was never undertaken.⁸⁵ However, a fourth-century AD pilaster capital from Aphrodisias also shows how drill holes could be used for deliberate decorative effect.⁸⁶

The cord drill could also be used as a so-called 'running' drill to create channels in the stone. Using a wooden support held in one hand to guide the drill bit, the drill operator would drill into the surface at a 35-45° angle, lifting the drill out and continually moving it slightly along to create a series of holes which are at such a shallow angle to the surface of the stone that they look like a channel. On his grave plaque from Rome which is now in Urbino, the Roman carver Eutropos depicted himself and his assistant using a cord drill in this way to finish the detailing on a sarcophagus.⁸⁷ This is the only visual representation of this tool in use to have survived from the Roman period. However, the marks on most Roman sculptures suggest that the drill was typically not used as a running drill but to create rows of vertical holes which were then joined together, with a narrow flat chisel or channelling tool.

Rasp

The rasp is a sort of file. Modern rasps tend to be double-ended tools, ranging in length between 12-40 cm, comprising a shaft in the middle and two flattened ends which are covered with sharp points {Fig. 22}.⁸⁸ The ends can be squared, rounded or pointed, flat or curved. The density of points varies between rasps depending on the fineness of the finish sought. Whether Roman rasps had one or two ends is unknown but this does not affect the marks left behind. The rasp is rubbed across the surface and is used for smoothing after the flat chisel or roundel and the range of shapes of the ends allows it to be a flexible tool for moving across and around complex forms. It can also be used for fine shaping on certain details. It is mainly used by carvers on marble since it would have little effect on granite, while scrapers are easier to use for smoothing softer stones.

Different grades of rasp exist, some used for actually shaping the stone and others just for smoothing. The marks left by the rasp consist of fine scratches crisscrossing the surface of the stone and often overlapping.⁸⁹ On Roman sculpture the rasp was often used as finishing tool. Clear rasp marks can be seen all over the Column of Trajan, where it was used to smooth the surfaces of clothing and skin on figures.⁹⁰ Similar marks are visible on clothing on the Arch of Trajan at Benevento {Fig. 23}.⁹¹

Scraper

⁸¹ Rockwell 1993: 37.

⁸² For examples of drill holes on faces and in hair: PR320_01_15 from Aphrodisias and PR208_01_21 from the Column of Marcus Aurelius. On armour: PR210_02_17 on the Arch of Constantine.

⁸³ PR202_03_04.

⁸⁴ PR305_03_05.

⁸⁵ For example, this garland sarcophagus from Aphrodisias: PR305_03_05.

⁸⁶ PR302_06_23.

⁸⁷ Strong and Claridge 1976: 200, fig. 327.

⁸⁸ Rockwell 1993: 47–8, 63 (Drawing 9); Bessac 1986: 201–9.

⁸⁹ PR915_01_13, PR915_01_14.

⁹⁰ PR205_1_04_17, PR205_1_11_08, PR205_1_12_03.

⁹¹ PR225_02_16, PR225_02_23.

The scraper is a toothed or flat-ended tool, much like a tooth or flat chisel, except that it tends to be curved at the end so that it can be dragged across the surface of the stone.⁹² It leaves behind characteristic parallel lines, different from the criss-crossed marks left by a rasp. Although its use on marble sculpture of Roman date is rare, patches of scraping are visible on the background and certain details of the Column of Trajan {Fig. 24}.⁹³ Scraper marks are also visible on sections of the reliefs of the Ara Pacis, though in this case they are assumed to be later, perhaps Hadrianic or Late Antique additions.⁹⁴

Abrasives

For achieving a very smooth finish on stone, various kinds of abrasive materials can be rubbed across the surface.⁹⁵ These range from relatively coarse materials, like emery, to softer ones, such as sandstone or pumice {Fig. 25}. These materials are applied to the surface of the stone with water which helps to remove the stone dust created during the abrading process. In order to achieve a high level of polish the carver will work from the rougher abrasives through to the finer ones, applying each in turn.⁹⁶ The carver can decide at what point to stop this polishing and in the Roman period it was relatively rare for this process to be taken beyond a smooth matt finish, though examples of high gloss polish are not unknown.⁹⁷ A high level of polish can only be achieved on certain types of stone, such as marble, granite or certain hard limestones. To judge from later building manuals, which provided labour figures for a wide range of tasks, polishing can be extremely labour intensive, especially when a high gloss polish is required.⁹⁸ Only one possible representation of a polisher at work seems to have survived from the Roman period. This is the fragment of a sarcophagus base from Ephesos, now in the Istanbul Archaeological Museum, on which four workers are shown at work, one at work on a statue, another polishing a marble table leg, a third finishing a bust and a fourth holding a series of tools.⁹⁹

Modern carvers use various manufactured abrasives to polish stone. These include sandpaper and emery paper, as well as different types of acid. Power tools have also helped to cut down the time that it takes to apply a polish. An artificial polish can also be applied by rubbing the surface of the stone with a thin layer of wax which reflects the light in much the same way as a high gloss polish. In the Renaissance a number of Roman statues and especially sarcophagi were given a fake polish in this way, though over time the wax has discoloured, giving them a yellowish hue.

Measuring tools

Ancient representations of stone carving tools almost always include measuring tools.¹⁰⁰ These are the tools used to help the carver lay out the design of the form they are carving, check the proportions or produce straight lines when needed {Fig. 26}.¹⁰¹ Several of these are very simple. A straight edge for example, often with measurements marked out on it, is an essential tool, as is a set square, the L-shaped tool used to check the angle and flatness of planes.¹⁰² Both of these tools are found on Roman reliefs depicting stone carvers' tools.¹⁰³ Basic and more complicated measuring is also done using callipers.¹⁰⁴ With callipers a carver can take measurements off a model, a sketch, or a set of guidelines and apply them to what they are carving, increasing or decreasing the measurements by set multiples as required. Callipers are a simple and effective tool for working out sets of proportions during the carving process {Fig. 27}. The measuring knobs that occur on numerous part-finished Roman statues were perhaps points from which measurements with callipers were meant to be taken. Since the carver would return to these points again and again during the carving process they were often left right until the end before being removed.¹⁰⁵ Callipers could also have

⁹² Rockwell 1993: 48, 62 (Drawing 8); Bessac (1986: 188–200) distinguishes between flat edged and toothed tools ('le racloir' and 'la ripe') which can both be described in English as forms of scraper.

⁹³ PR205_1_06_18.

⁹⁴ Conlin 1997: 49–50.

⁹⁵ Rockwell 1993: 48–50; Bessac 1986: 262–70.

⁹⁶ PR915_01_13, PR915_01_14.

⁹⁷ PR307_03_08.

⁹⁸ Barker and Russell 2012: 88–9.

⁹⁹ Mendel 1912–14: no. 13.

¹⁰⁰ For examples, see Zimmer 1982, 166–79; Bruno 2002a: 502–4; for a discussion of the iconography and meaning of the so-called carpenter's square, see Cuomo 2007, 84–98.

¹⁰¹ Rockwell 1993: 50–2, 67 (Drawing 13).

¹⁰² Borriello 2002a; 2002b.

¹⁰³ For an example, see Schraudolph 1993: 176.

¹⁰⁴ Borriello 2002c.

¹⁰⁵ PR246_01_04, PR301_01_12, PR312_03_19.

been used as compasses, to actually incise lines on the surface of the stone.¹⁰⁶ Marks probably made by callipers used in this way can be seen on the fluting of the columns of the Temple of Vespasian.¹⁰⁷ Other guidelines were incised into the stone using the point or flat chisel and probably also paint. Pencils are used by carvers today to mark out their designs as they work. Finally, in order to achieve straight vertical lines, Roman carvers certainly used plumb lines.¹⁰⁸ Again, this is a simple tool which can be used quickly and easily. Plumb lines would have been essential for the carving of fluting, which was usually done only once the column drums were in place. Lines made with the help of a plumb line are again visible on the columns of the Temple of Vespasian.¹⁰⁹

Conclusions

This account of tools is by its very nature general, using words to describe physical objects that are the essential medium by which stone is carved. These objects are a fundamental part of a physical and visual process which is why this description is accompanied by images and references, as links, to the evidence in our digital online catalogue. On the website itself are videos demonstrating the tools in use, which are there to aid the appreciation of stone working. The focus here is on the tools which feature in the sources and wider discussions. Therefore, this list is neither exhaustive and nor is it able to cover the different ways in which those tools were employed and with what intended effect. Although tools are largely universal, their choice and the way they are used is the result of a number of different factors, whether personal choice, material type, geographic location or historical moment. These contextual factors produce various permutations, or points of departure, within the practice of stone carving which can usually be identified with a good understanding of the variety of tools and methods. Tools only become participants in the act of making when they are picked up and applied to the material; their various applications, and the underlying function of these methods, are discussed in the next essay, on 'Stone Carving Techniques and Processes'.

References

- Adam, S. (1966). *The technique of Greek sculpture in the Archaic and Classical period* (Supplementary volume (British School at Athens) 3). Oxford.
- Attanasio, D., Bruno, M., and Yavuz, A. B. (2009). 'Quarries in the region of Aphrodisias: the black and white marbles of Göktepe (Muğla)', *Journal of Roman Archaeology* 22.1: 312–48.
- Barker, S. J., and Russell, B. (2012). 'Labour figures for Roman stone-working: pitfalls and potential', in S. Camporeale, H. Dessales, and A. Pizzo (eds). *Arqueología de la Construcción III. Los procesos constructivos en el mundo romano: la economía de las obras* (Anejos de Archivo Español de Arqueología 64). Madrid; Merida: 83–94.
- Bessac, J.-C. (1986). *L'outillage traditionnel du tailleur de pierre, de l'antiquité à nos jours* (=Revue archéologique de Narbonnaise supplément 14). Paris.
- Bessac, J.-C. (1988). 'Problems of identification and interpretation of tool marks on ancient marbles and decorative stones', in N. Herz and M. Waelkens (eds). *Classical marble: geochemistry, technology, trade*. (NATO ASI series, series E, applied sciences 153). Dordrecht: 41–53.
- Bessac, J.-C. (1993). 'Traces d'outil sus la pierre: problématique, methods d'études et interpretation', in R. Francovich (ed.). *Archeologia delle attività estrattive e metallurgiche: V ciclo di lezioni sulla ricerca applicata in archeologia, Certosa di Pontigliano (SI), Campiglia Marittima (LI), 9-21 Settembre 1991* (Quaderni del Dipartimento di archeologia e storia delle arti, Sezione archeologica, Università di Siena 32-33). Florence: 143–76.
- Bessac, J.-C. (2007). *Le travail de la à Pétra: technique et économie de la taille rupestre*. Paris.

¹⁰⁶ Borriello 2002d; 2002e.

¹⁰⁷ PR202_01_03; for more on these guidelines, see Rockwell 1987–8.

¹⁰⁸ Borriello 2002f.

¹⁰⁹ PR202_01_03.

- Wootton, W., Russell, B., and Rockwell, P. (2013). 'Stoneworking tools and toolmarks (version 1.0)', *The Art of Making in Antiquity*
- Bessac, J.-C., Abdul-Massih, J., and Vallat, Z. (1997). 'De Doura-Europos à Aramel: enquête ethno-archéologique dans les carrières traditionnelles de Syrie', in P. Leriche and M. Gelin (eds), *Doura-Europos, Etudes IV, 1991-1993*. Beirut, 159–97.
- Blagg, T. F. C. (1976). 'Tools and techniques of the Roman stone-mason in Britain', *Britannia* 7: 152–72.
- Blümel, C. (1927). *Griechische Bildhauerarbeit*. Berlin.
- Blümel, C. (1955). *Greek sculptors at work*. London.
- Borriello, M. (2002a). 'Unità di misura', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 510.
- Borriello, M. (2002b). 'Squadro', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 511.
- Borriello, M. (2002c). 'Calibro', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 505.
- Borriello, M. (2002d). 'Compasso', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 505.
- Borriello, M. (2002e). 'Compassi a chiave', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 507.
- Borriello, M. (2002f). 'Pesi per filo a piombo', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 508–9.
- Boschung, D. and Pfanner, M. (1988). 'Antike Bildhauertechnik. Vier Untersuchungen an Beispielen in der Münchner Glyptothek', *Münchner Jahrbuch der bildenden Kunst*, series 3, 39: 7–28.
- Bruno, M. (2002a). 'Piccolo piedistallo con dedica a Silvano', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 502–4.
- Bruno, M. (2002b). 'Tre cunei', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 507.
- Bruno, M. (2002c). 'Quattro subbie grande', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 510–11.
- Bruno, M. (2002d). 'Testa di piccone a doppia punta', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 512.
- Bruno, M. (2002e). 'Teste di piccone a doppia punta', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 512–13.
- Claridge, A. (1985). 'Sulla lavorazione dei marmi bianchi nella scultura dell'età romana', in P. Pensabene (ed.). *Marmi antichi: problemi d'impiego, di restauro e d'identificazione* (=Studi miscellanei 26). Rome: 113–26.
- Claridge, A. (1988). 'Roman statuary and the supply of statuary marble', in J. C. Fant (ed.). *Ancient marble quarrying and trade* (BAR international series 453). Oxford: 139–52.
- Conlin, D. A. (1997). *The artists of the Ara Pacis: the process of Hellenization in Roman relief sculpture*. Chapel Hill NC.
- Cuomo, S. (2007). *Technology and culture in Greek and Roman antiquity* (Key themes in ancient history). Cambridge; New York NY.

- Wootton, W., Russell, B., and Rockwell, P. (2013). 'Stoneworking tools and toolmarks (version 1.0)', *The Art of Making in Antiquity*
- Dolci, E. (2006). *Museo del Marmo, Carrara: catalogo-guida*. Pontedera.
- Fant, J. C. (2008). 'Quarrying and stoneworking', in J. P. Oleson (ed.). *The Oxford handbook of engineering and technology in the Classical world*. Oxford: 121–35.
- Grasby, R. D. (1996). 'A comparative study of five Latin inscriptions: measurement and making', *Papers of the British School at Rome* 64, new series 51: 95–138.
- Grasby, R. D. (2002). 'Latin inscriptions: studies in measurement and making', *Papers of the British School at Rome* 70, new series 57: 151–76.
- Grasby, R. D. (2009). *Processes in the making of Roman inscriptions: introduction to the studies*. Oxford.
- Hirt, A. M. (2010). *Imperial mines and quarries in the Roman world: organizational aspects, 27 BC–AD 235* (Oxford classical monographs). Oxford.
- Kessener, H. P. M. (2012). 'The mechanization of marble slab production', in R. Kreiner and W. Letzner (eds). *Spa: sanitas per aquam: Tagungsband des Internationalen Frontinus-Symposiums zur Technik- und Kulturgeschichte der antiken Thermen, Aachen, 18.-22. März 2009 = Proceedings of the International Frontinus-Symposium on the Technical and Cultural History of Ancient Baths, Aachen, March 18-22, 2009* (Bulletin antieke beschaving, supplement 21). Leuven; Walpole, MA: 197–205.
- Kirby, R. S., Withington, S., Darling, A. B., and Kilgour, F. G. (1990). *Engineering in history*. 2nd edition. New York NY.
- Lambraki, A. (1982). 'L'emploi de la scie lisse en tant qu'outil de carrier, en Grèce, à l'époque paléochrétienne', in *Troisièmes journées de l'industrie minérale: le marbre* (=Bulletin des Musées Royaux d'Art et d'Histoire, Bruxelles 53.2). Brussels, 81–8.
- Mangartz, F. (2010). *Die byzantinische Steinsäge von Ephesos: Baubefund, Rekonstruktion, Architekturteile* (Monographien Römisch-Germanisches Zentralmuseum Mainz. Forschungsinstitut für Vor- und Frühgeschichte 86). Mainz.
- Martellotti, G. and Rockwell, P. (1988). 'Osservazioni sugli strumenti della scultura nei rilievi della facciata', in L. Riccetti (eds). *Il Duomo di Orvieto*. Bari: 101–22.
- Mendel, G. (1912–14). *Catalogue des sculptures grecques, romaines et byzantines*, 3 vols. Istanbul.
- Mulloy, W. (1970). 'A speculative reconstruction of techniques of carving transporting and erecting Easter Island statues', *Archaeology and physical anthropology in Oceania* 5.1: 1–23
- Olivanti, P. (2002). 'Bottega di marmorari', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 498–9.
- Oesterwind, B. C. (2002). 'Ascia bipenne', in M. De Nuccio and L. Ungara (eds). *I marmi colorati della Roma imperiale*. Venice: 504–5.
- Palagia, O. (2006). 'Marble carving techniques', in O. Palagia (ed.). *Greek sculpture: function, materials, and techniques in the archaic and classical periods*. Cambridge: 243-79.
- Petrie, W. M. (1917). *Tools and weapons illustrated by the Egyptian collection in University College, London*. (British School of Archaeology in Egypt and Egyptian Research Account, 22nd year, 1916). London.
- Pfanner, M. (1989). 'Über das Herstellen von Porträts. Ein Beitrag zu Rationalisierungsmassnahmen und Produktionsmechanismen von Massenware im späten Hellenismus und in der Römischen Kaiserzeit', *Jahrbuch des deutschen Archäologischen Instituts* 104: 157–257.

- Wootton, W., Russell, B., and Rockwell, P. (2013). 'Stoneworking tools and toolmarks (version 1.0)', *The Art of Making in Antiquity*
- Ritti, T., Grewe, K., and Kessener, P. (2007). 'A relief of a water-powered stone saw mill on a sarcophagus at Hierapolis and its implications', *Journal of Roman Archaeology* 20.1: 139–63.
- Rockwell, P. (1981-3). 'Preliminary study of the carving techniques on the column of Trajan', in P. Pensabene (ed.). *Marmi antichi: problemi d'impiego, di restauro e d'identificazione (=Studi miscellanei 26)*. Rome: 101–111.
- Rockwell, P. (1987-8). 'Carving instructions on the Temple of Vespasian', *Rendicotti della Pontificia Accademia romana di archeologia* 60: 53–69.
- Rockwell, P. (1989). *Lavorare la pietra: manuale per l'archeologo, lo storico d'arte e il restauratore* (Beni culturali 7). Rome.
- Rockwell, P. (1990). 'Stone-carving tools: a stone-carver's view', *Journal of Roman Archaeology* 3: 351–7.
- Rockwell, P. (1991). 'Unfinished statuary associated with a sculptor's studio', in R. R. R. Smith and K. Erim (eds). *Aphrodisias papers 2: the theatre, a sculptor's workshop, philosophers and coin-types: including the papers given at the Third International Aphrodisias Colloquium held at New York University on 7 and 8 April 1989* (Journal of Roman Archaeology, supplementary series 2). Ann Arbor MI: 127–42.
- Rockwell, P. (1993). *The art of stoneworking: a reference guide*. Cambridge.
- Rockwell, P. (2008). 'The Sculptor's studio at Aphrodisias: the working methods and varieties of sculpture produced', in Y. Z. Eliav, E. A. Friedland, and S. Herbert (eds). *The sculptural environment of the Roman Near East: reflections on culture, ideology, and power* (Interdisciplinary studies in ancient culture and religion 9) Leuven: 91–115.
- Röder, J. (1971). 'Marmor phrygium. Die antiken Marmorrüche von Iscehisar in Westanatolien', *Jahrbuch des deutschen Archäologischen Instituts* 86: 253–312.
- Schraudolph, E. (1993). *Römische Götterweihungen mit Reliefschmuck aus Italien. Altäre, Basen und Reliefs* (Archäologie und Geschichte 2). Heidelberg.
- Seigne, J. (2002). 'A sixth-century water-powered sawmill at Jerash', *Annual of the Department of Antiquities of Jordan* 26: 205–13.
- Starac, A. (2007). 'A marble slab with relief of a stonemason', *Marmora* 3: 135–6.
- Stocks, D. (2003). *Experiments in Egyptian archaeology: stoneworking technology in ancient Egypt*. London.
- Strong, D. and Claridge, A. (1976). 'Marble sculpture', in D. Strong and D. Brown (eds). *Roman crafts*. London: 195–207.
- Zimmer, G. (1982). *Römische Berufsdarstellungen* (Archäologische Forschungen 12). Berlin.

Figures



Figure 1: PR309_08_06: Quarry pick marks on a quarry-face at Aphrodisias



Figure 2: PR936_01_23: Quarryman using a pick to square a block at Iscehisar (ancient Dokimeion)



Figure 3: PR948_01_05: Carver using a small pick in the Swat Valley, Pakistan



Figure 4: PR309_06_08: Wedge holes on a quarry-face at Aphrodisias

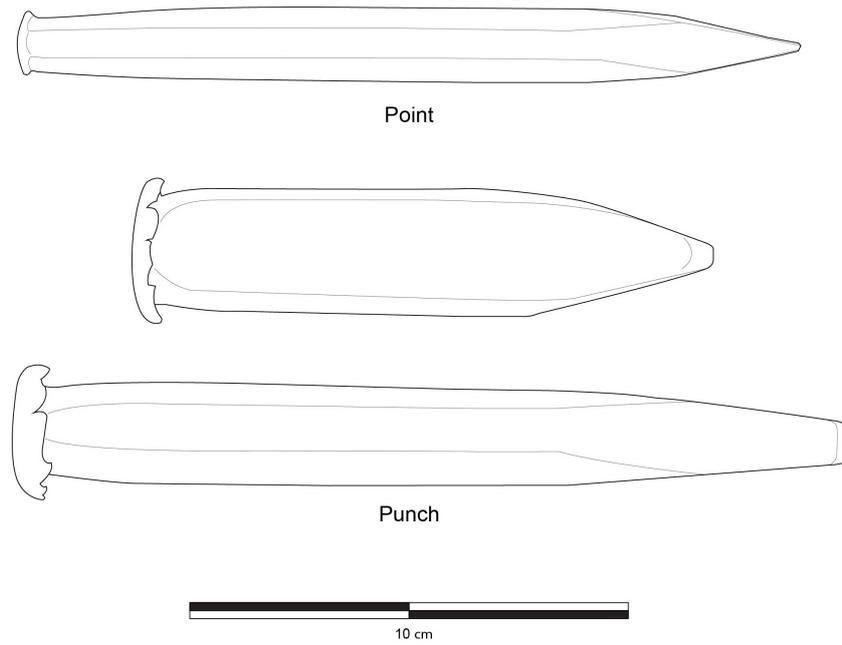


Figure 5: Point chisel and two varieties of punch (drawing: B. Russell)

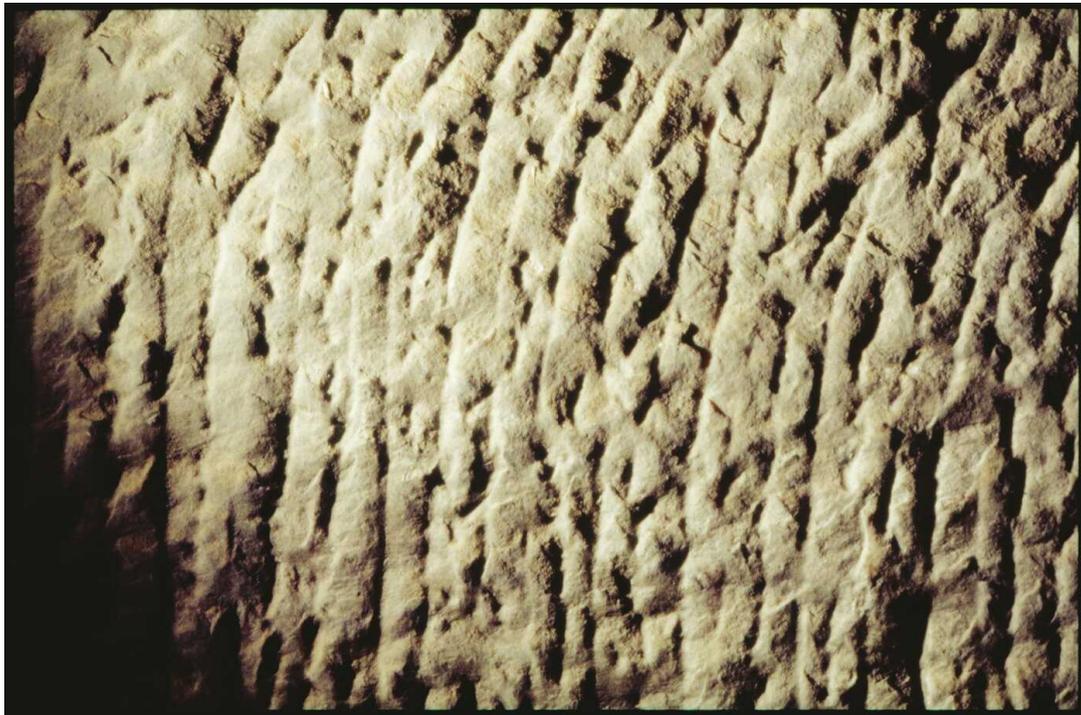


Figure 6: PR205_1_16_16: Point chisel marks on the interior of the Column of Trajan

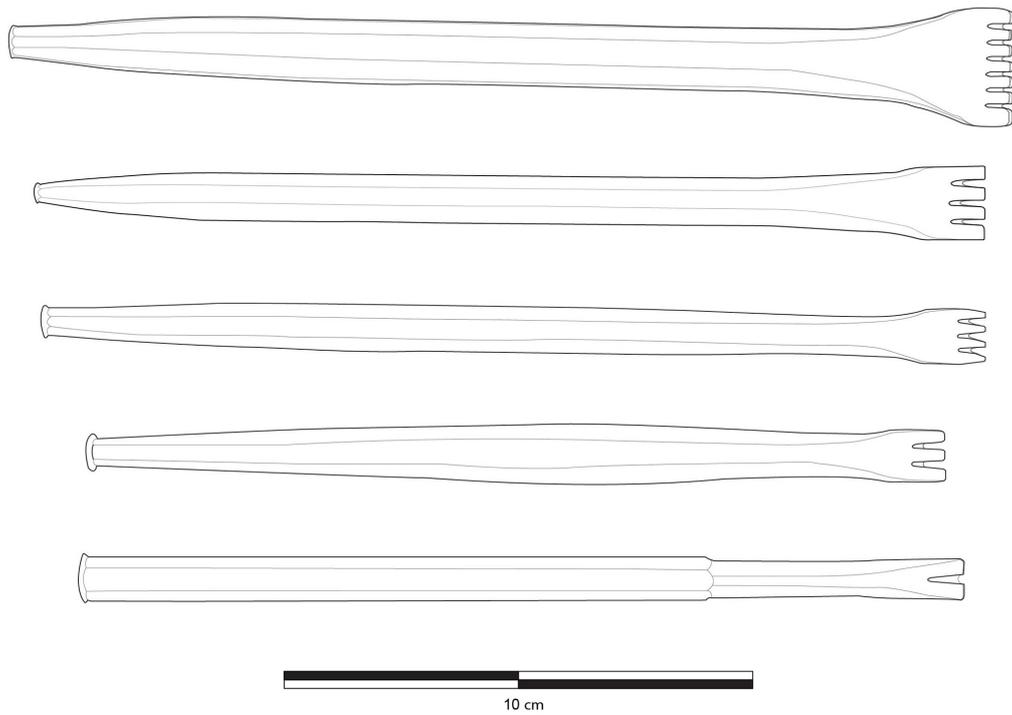


Figure 7: Five varieties of tooth chisel (drawing: B. Russell)



Figure 8: PR301_01_11: Detail of a panel from the Sebasteion at Aphrodisias depicting Tiberius with a captive

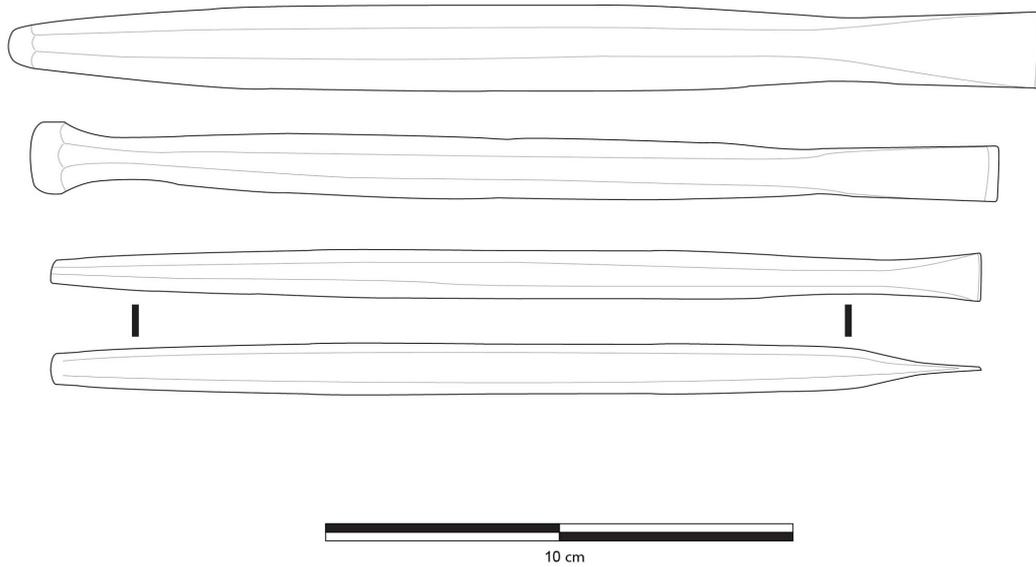


Figure 9: Three sizes of flat chisel (drawing: B. Russell)



Figure 10: PR205_1_03_01: Detail of the background on the frieze of the Column of Trajan on which marks of the flat chisel are visible

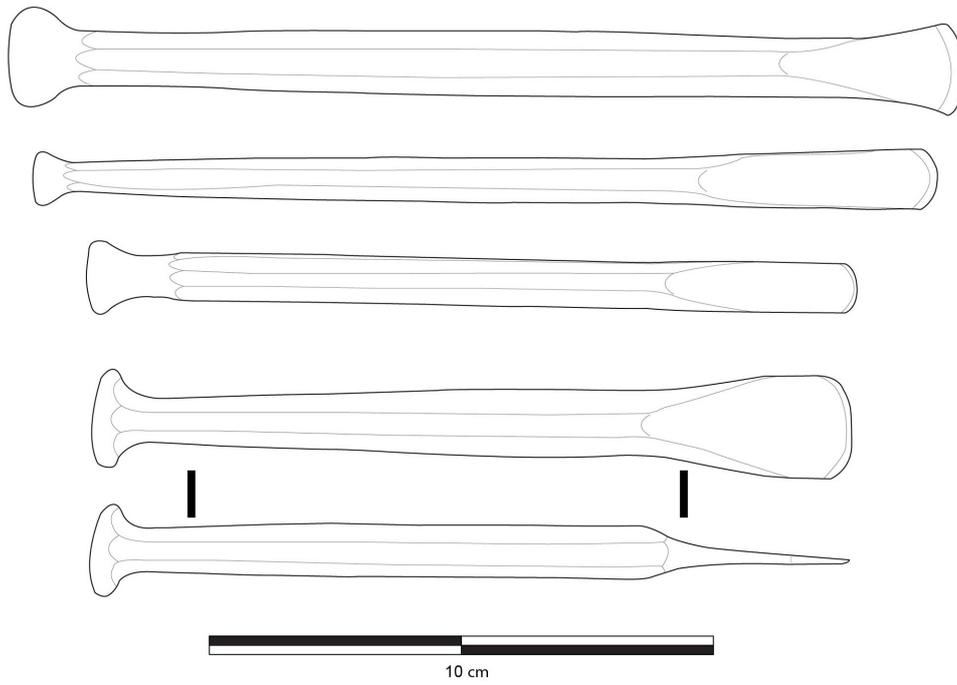


Figure 11: Four sizes of roundel (drawing: B. Russell)



Figure 12: PR301_01_13: Roundel marks on the leg of Tiberius from a panel of the Sebasteion at Aphrodisias

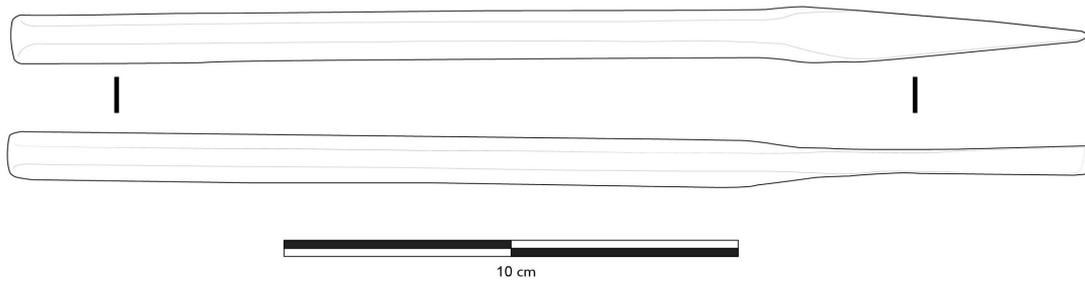


Figure 13: A channelling tool (drawing: B. Russell)



Figure 14: PR205_1_16_10: Stone carver at work as depicted on the frieze of the Column of Trajan



Figure 15: TE_2_2_11_4: Carver working with an axe in modern Palermo

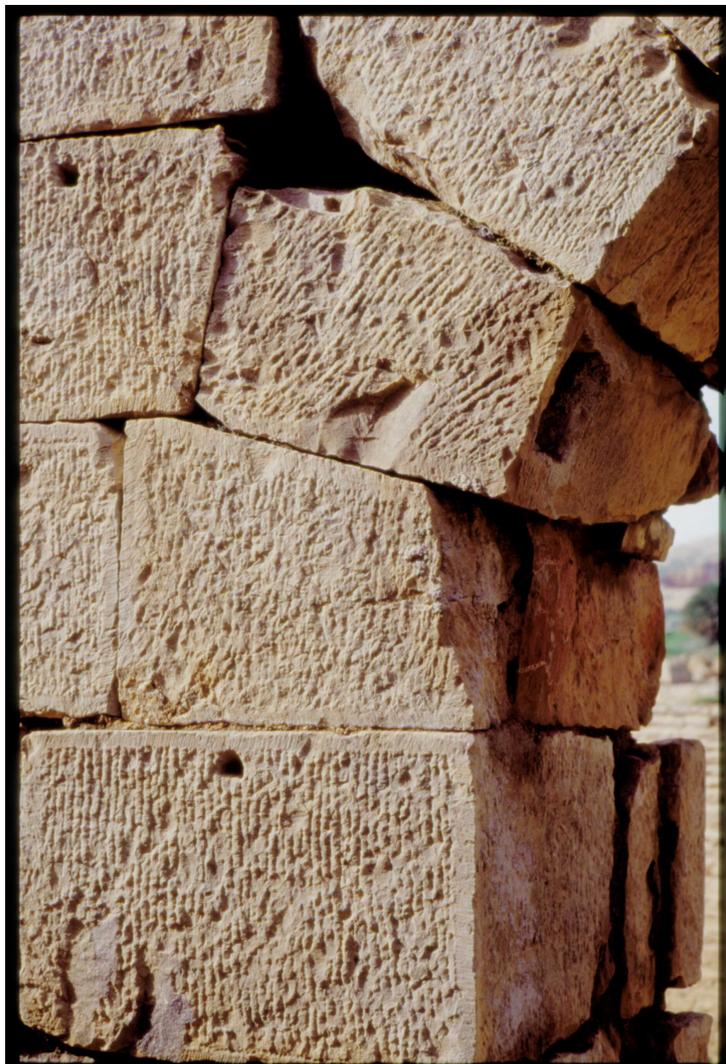


Figure 16: PR252_02_03: Axe marks on the amphitheatre at El Djem, Tunisia



Figure 17: TE_5_2_1_1: Modern marble saw constructed in a traditional manner, Rome



Figure 18: PR202_03_16: A sawn surface on the entablature of the Temple of Vespasian, Rome



Figure 19: A cord drill (photograph: B. Russell)



Figure 20: TE_2_1_1_2: Pair of carvers operating a cord drill in the De Tomassi workshop, Rome



Figure 21: PR202_03_04: Detail of one of the capitals of the Temple of Vespasian, Rome

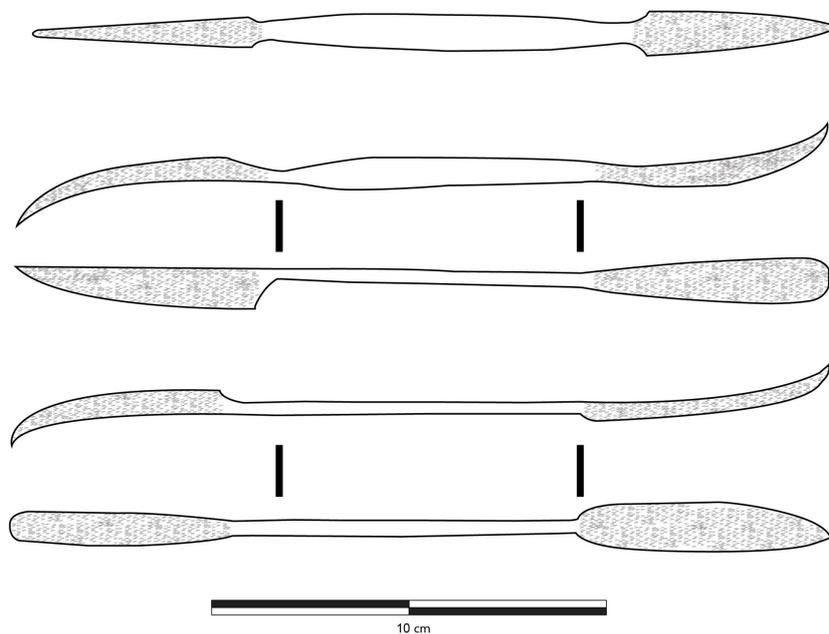


Figure 22: Three varieties of rasp (drawing: B. Russell)

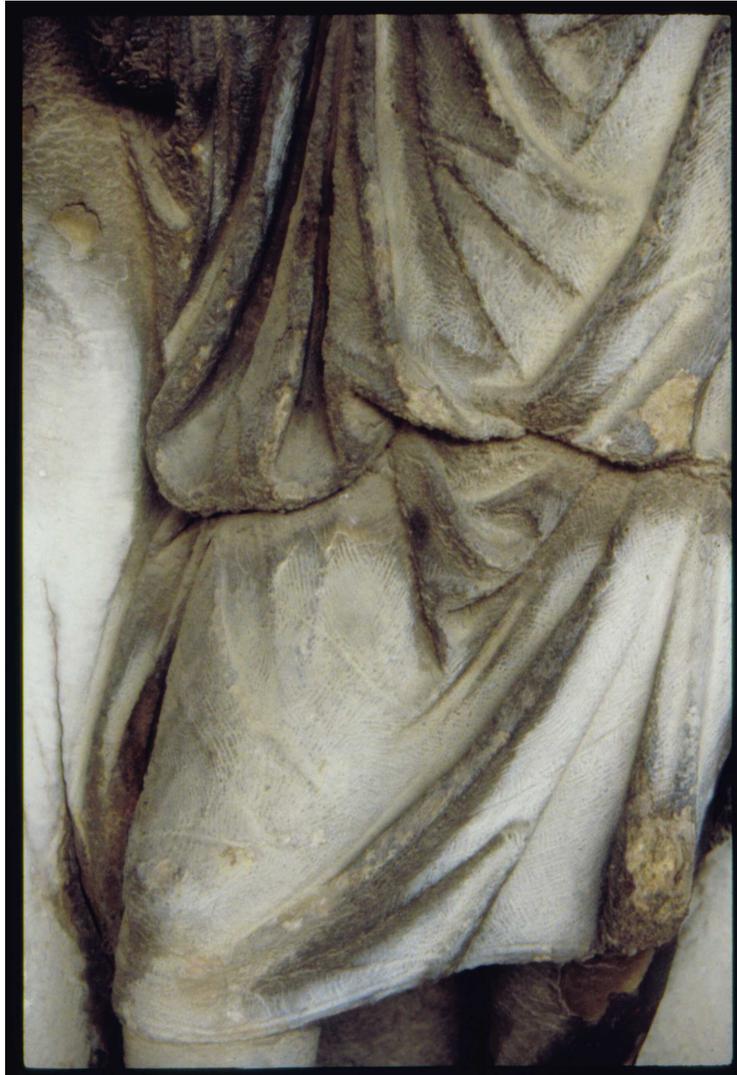


Figure 23: PR225_02_23: Rasp marks on a figure from the continuous frieze on the Arch of Trajan at Benevento



Figure 24: PR205_1_08_12: Scraper marks on the armour of a legionary on the frieze of the Column of Trajan, Rome



Figure 25: Pumice in use as an abrasive on white marble (photograph: B. Russell)



Figure 26: Two varieties of callipers, a set square and a ruler (photograph: B. Russell)



Figure 27: TE_5_3_5_1: Peter Rockwell using a straight edge and callipers to check measurements on a portrait head