A Cromwellian Warship wrecked off Duart Castle, Mull, Scotland, in 1653

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Chapter 7

SHIP'S ARMAMENT

7.1 The guns

Eight cast-iron guns have been identified on the wreck-site (Illus 195–6). With the exception of Gun 8 they have been left in situ in their concreted state, though some have undergone minor intrusive investigation to determine their corrosion potential and other physical characteristics (MacLeod 1995) (Illus 197–8). Because of variable thicknesses of concretion the only reasonably reliable measurements which can be recorded are the overall length, and length from base-ring to muzzle. In obtaining these measurements allowance has been made for concretion thickness, while the estimated bores are based on the general proportions of the pieces. The data for the unrecovered pieces should therefore be regarded as approximate (Table 7.1). Only Gun 8 has been accurately measured following recovery, the removal of concretion, and conservation. No data are given for the partly buried Gun 5, or for Gun 7 because of its fragmentary state. Neither of these guns has yielded meaningful measurements.

Guns 1, 3, 4 and 6 appear to form a broadly homogenous group, and their estimated bores of 89mm (3½in) are appropriate to the three cast-iron roundshot recovered from the wreck (2 × 84mm and 1 × 85.5mm diameter). It should also be noted that the cartridge-box 84 and powder-scoop 85 (see section 7.5 below) would comfortably hold a filled cartridge of this diameter. These observations combine to suggest that

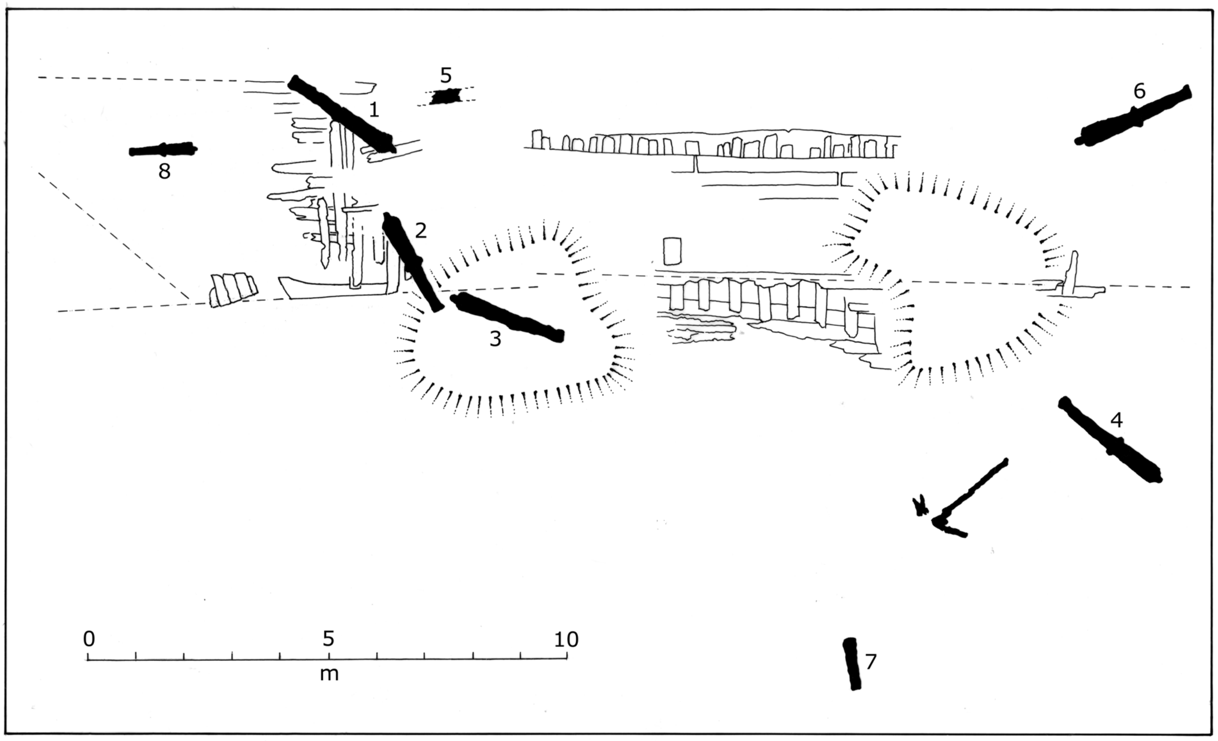


Illustration 195
Locations and identifying numbers of the guns (DP 174815)

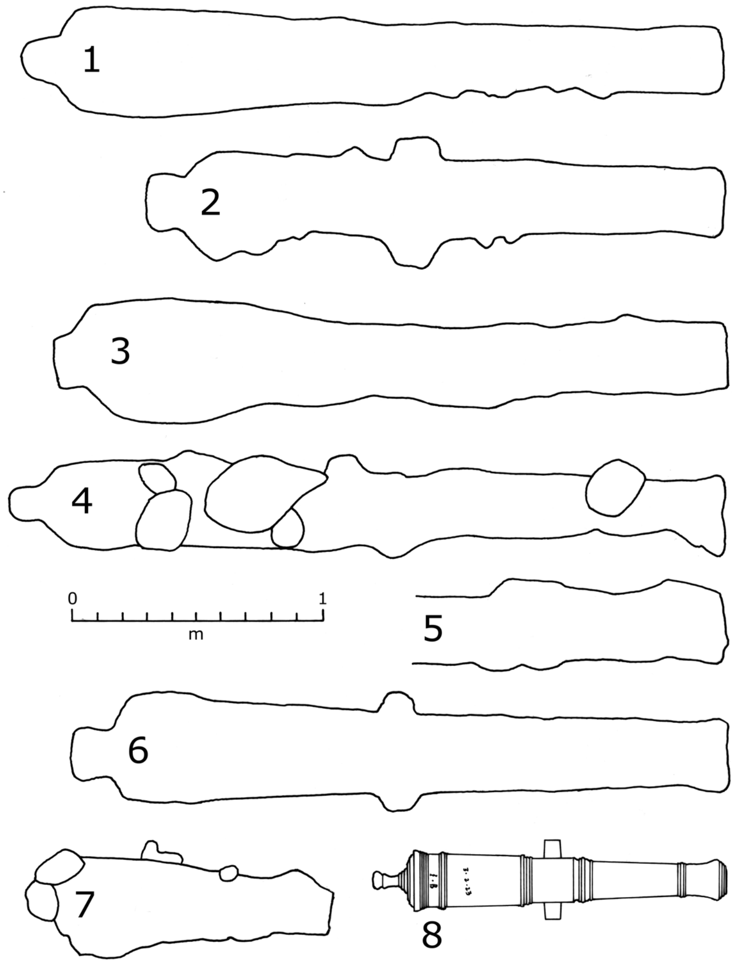


Illustration 196
Profiles of the cast-iron guns. Guns 1–7 are outlines of the still-concreted pieces which have been left in situ; Gun 8 [82] has been de-concreted and conserved (DP 174818)

Illustration 198
Attaching a sacrificial anode to Gun 2 to assist in stabilising corrosion (DP 174699)

the pieces are 5-pounder sakers (Norton 1628: 53; Ward 1639: 109; Eldred 1646: 15). Norton specifies the length and weight of such a piece as 9ft (2.74m) and 1400lbs (635kg), while Ward and Eldred give figures of 9½ft/1900lbs and 9½ft/2500lbs respectively. The Duart group as a whole appears to consist of guns a little shorter and consequently lighter than these figures indicate.

Gun 2 is significantly shorter and slimmer than the main group, and is best identified as a minion, for which Norton,

Illustration 197
Using an air-drill to test the thickness of concretion and to take pH and e_{corr} readings from the surviving metal (DP 174016)

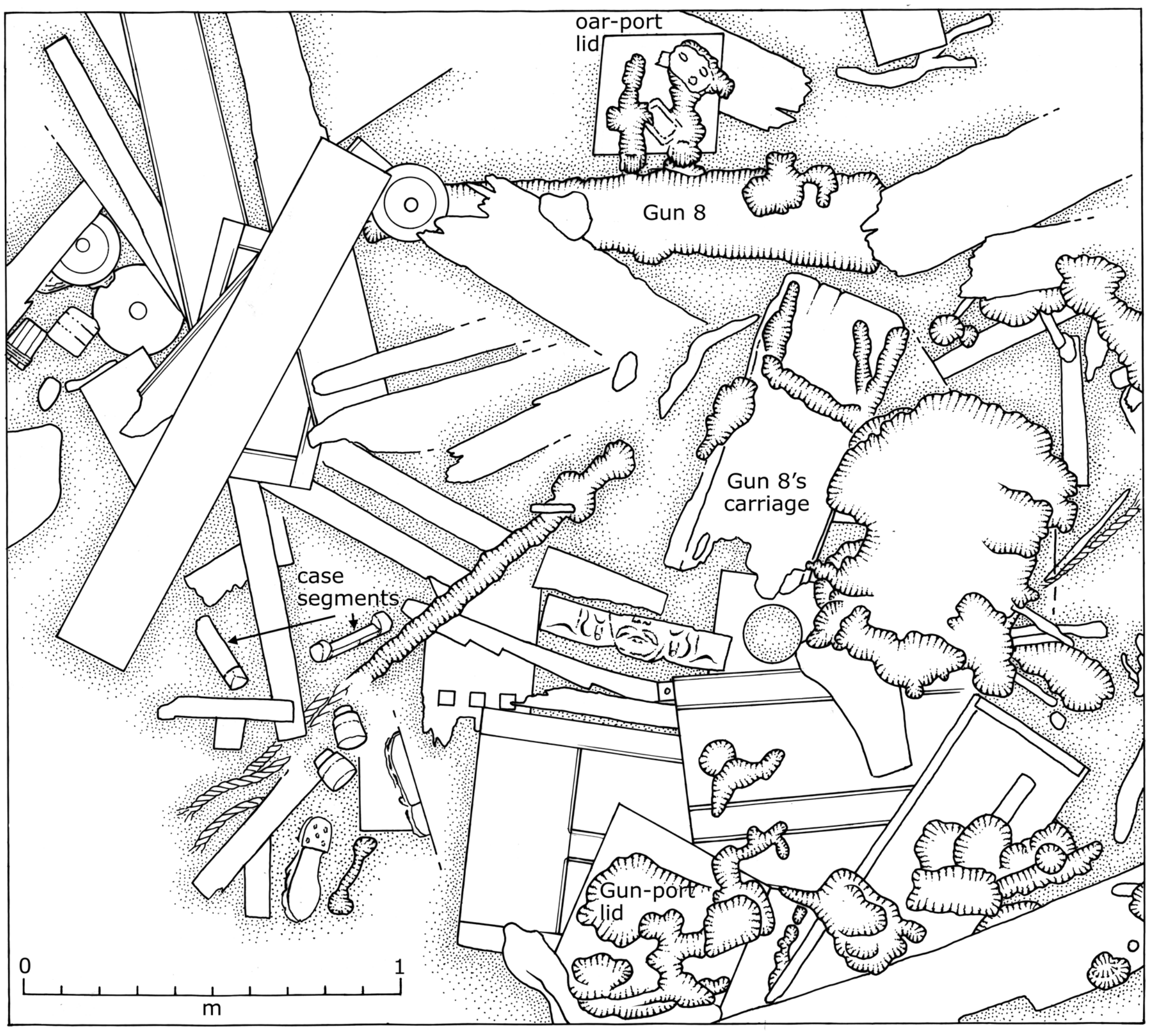


Illustration 199
The deposit associated with Gun 8, with key features labelled

Table 7.1
Specifications of the measured guns

Gun no	*L muzzle to base-ring (m)*	*L muzzle to base-ring (imperial)*	*L overall (m)*	*L overall (imperial)*	*Estimated bore (m)*	*Estimated bore (imperial)*	*Bore:length ratio*
1	2.45	8ft	2.65	8ft 8in	0.089	3½in	1:27.5
2	2.1	6ft 10in	2.3	7ft 7in	0.076	3in	1:27.6
3	2.45	8ft	2.6	8ft 6in	0.089	3½in	1:27.5
4	2.5	8ft 2in	2.7	8ft 10in	0.089	3½in	1:28.1
6	2.45	8ft	2.6	8ft 6in	0.089	3½in	1:27.5
8	1.24	4ft 1in	1.41	4ft 7½in	0.082	3¼in	1:15.1

Illustration 200
Gun 8 82, still in its concreted state, being prepared for transport to the conservation laboratory (Edward Martin, DP 174564)

Illustration 201
Gun 8 82 after conservation (DP 174285)

Illustration 202
Surface detail of Gun 8 82 at the breech, showing the initials of John Browne of Horsmonden and the weight in hundredweights, quarters, and pounds. These marks were cut with a chisel after casting. Note the marks which represent a final wiping of the clay surface of the mould pattern. Scale in centimetres (DP 174286)

Ward, and Eldred respectively give bores of 3¼, 3¼ and 3in; shot-weights of 3¾, 3¼ and 4lb; lengths of 7½, 8 and 8ft; and weights of 1200, 1100 and 1500lb (Norton 1628: 53; Ward 1639: 109; Eldred 1646: 15). Gun 5 is partly buried, so its full length could not be determined, but it appears to be of a girth appropriate either to a minion or a saker as described above. Gun 7 lies some distance from the main site, and may have been displaced and damaged during an abortive salvage attempt in 1979 (John Dadd pers comm). It does, however, appear to be of slight proportions, and is perhaps a companion to the stern-mounted minion drake, Gun 8, described below.

Cast-iron Gun 8

82 Gun 8, DP00/203, was found adjacent to its inverted carriage at **080.107/094.106** (Illus 199). It was completely buried when found, though its top surface was only a few centimetres below the present shingle level (Illus 79–80). The piece was raised and transported in its concreted state (Illus 49–50, 200) to the conservation laboratories of National Museums Scotland, where the concretion was removed prior to treatment (Illus 201). Its outer surfaces everywhere show no loss of material to abrasion or corrosion, and the wipe-marks of the final skim of clay on the mould-pattern are replicated crisply on the casting (Illus 202). The gun's overall length is 1.41m (4ft 7½in), and from muzzle to breech-ring it measures 1.24m (4ft 1in). Its bore is 82mm (3¼in) in diameter. This identifies the piece as a minion (Ward 1639: 109; Eldred 1646: 15), firing an iron ball *c* 76mm (3in) in diameter and weighing *c* 1.36kg (3½lb). The bore is 1.17m (3ft 10in) long, and the final 232mm (9in) of its breech end narrows from the full bore-diameter of 82mm to 55mm at the concave rear face of the chamber (Illus 203).

This characteristic identifies the gun as a tapered-chamber piece of the 'drake' family (Wilson 1988; Towes & McCree 1994). A mark '3–2–23' cut on the first reinforce after casting (Illus 202–3) indicates a certified weight of

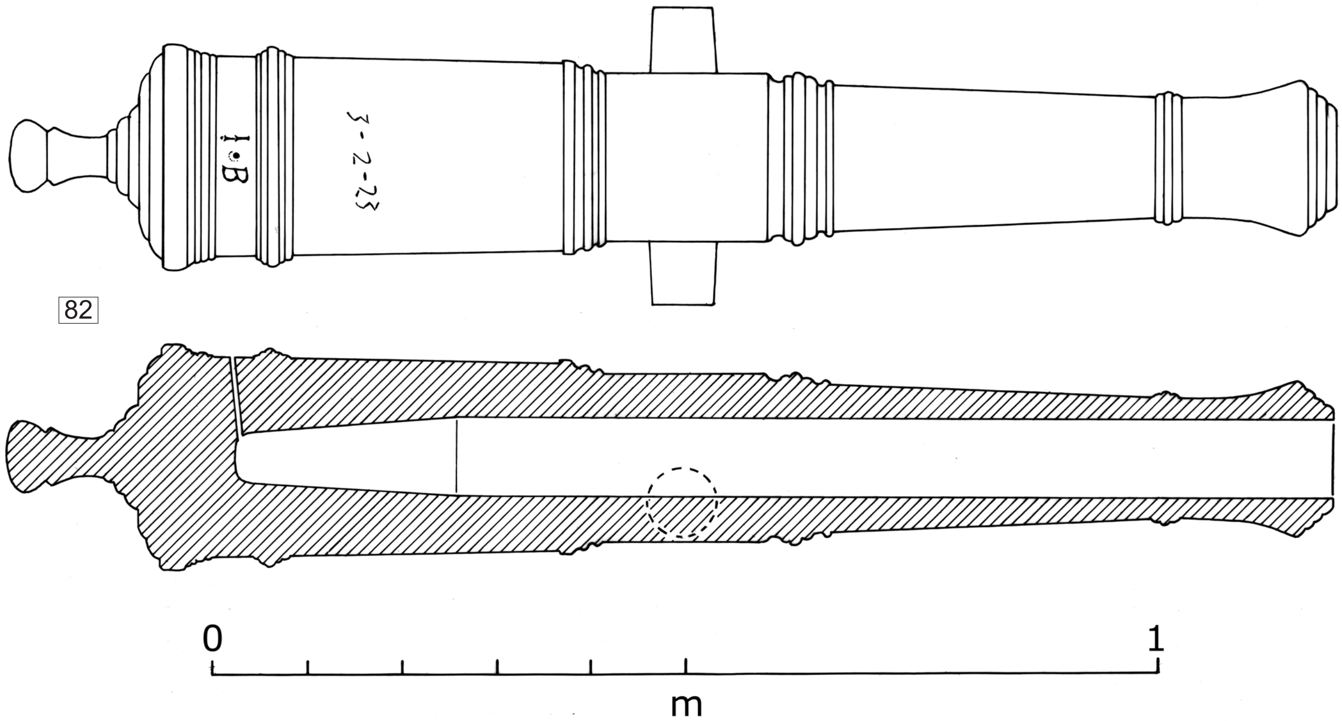


Illustration 203
Gun 8 [82]: top view and section (DP 174821)

3cwt (1 hundredweight = 112 English pounds of 454g), 2 quarters (each of 28lb), and 23 individual pounds, giving a total of 415lb (188kg). This figure, since the weighing of pieces was an officially controlled process, may be presumed to be accurate. The gun's present weight with the concretion removed is just under 185 kg, giving the metal an exceptionally low loss of weight to corrosion, during 348 years of immersion in seawater, of only 1.7% of its original mass.

John Browne, gunfounder

The letters 'I B' cut on either side of the touch-hole (Illus 202–3) identify the piece as having been cast by John Browne, gunfounder successively to James I, Charles I, and (after 1642), the Civil War Parliament. Browne was the foremost producer of drakes in England (Towes & McCree 1994). He was active in Kent and Surrey from at least 1613 until his death in 1652, operating mainly from furnaces at Brenchley and Horsmonden (Ffoulkes 1937: 118). The furnace-pond and adjacent wheel-pool, together with industrial debris from the foundry, can still be seen in woodland to the north-west of Horsmonden in Kent at NGR: TQ 694 412 (Illus 204) (personal visit, 15 December 2005). A similar gunfounding furnace and associated structures have been excavated at Pippingford in Sussex (TQ 450 316), 30 km west of Horsemonden (Crossley 1975). It is believed that the Duart Point gun is the only cast-iron drake by John Browne currently known, although four, perhaps five 'ordinary' castings carrying his initials have been identified. The best-known is now mounted on a replica

Illustration 204
Stratified industrial debris at the site of John Browne's foundry near Horsmonden, Kent

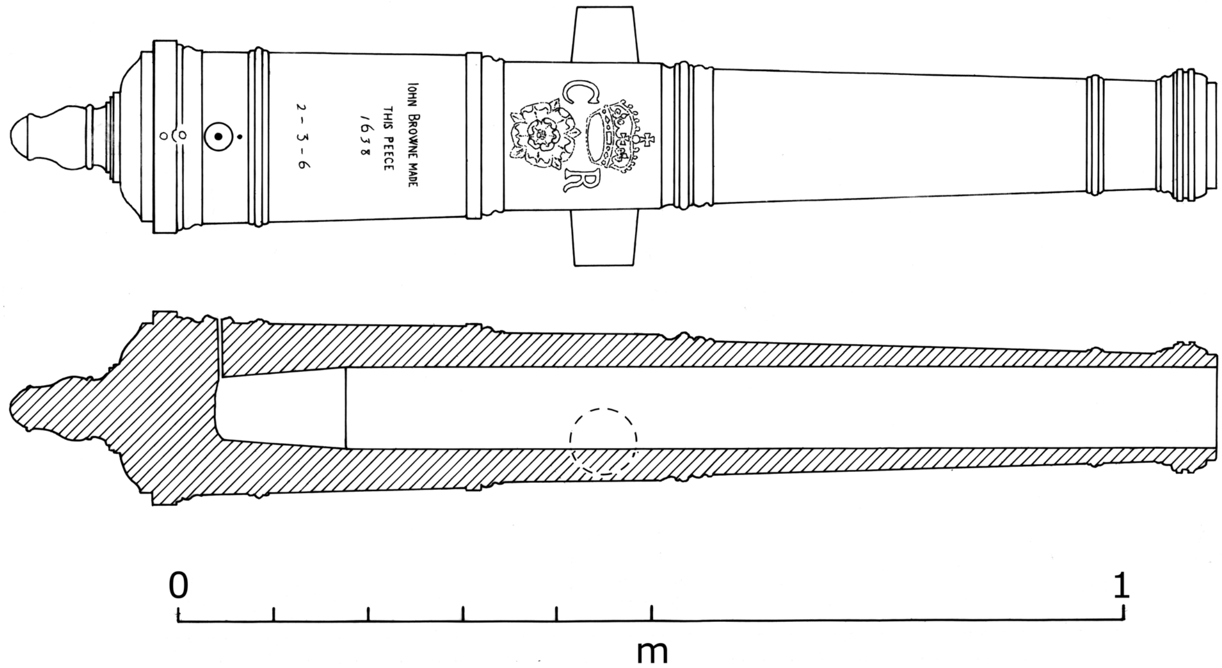


Illustration 205
The bronze minion drake now at Boston, Lincolnshire (after a drawing by R Roth 1994: 44) (DP 174822)

carriage on the walls of Derry/Londonderry in Northern Ireland (Scott et al 2008: 145–7). It is a demi-culverin, the proportions and weight of which (3,117lb or 1,414kg) make it clear that it is a full-weight parallel-chambered piece.

Other IB-marked pieces include one recovered from a wreck off Terschelling which bears a Dutch Admiralty mark and the date 1623 (Brinck 1996: 9); one associated with the Dutch West Indies Company (Brinck 1996: 43–5); and one from Mehrangarh Fort, Jodhpur, India (cat no 1780, Scott et al 2008: 49). There is another possible example at Mehrangarh (cat no 1732) but the mark is indistinct. None appears to be a drake. An iron demi-culverin bearing the ‘C R’ cipher of Charles I, and the Tudor rose-and-crown emblem, was recently discovered re-used as a bollard in the old Dockyard at Bermuda. Its marked weight of 1988lb (903kg) set against the 3248lb (1475kg) of an ‘ordinary’ demi-culverin (see below) suggests that it is probably a drake, although its ascription to John Browne on the basis of its proportions and mouldings is inconclusive (Horsmonden village website).

Four bronze drakes by John Browne are, however, known to survive. Two are in the Royal Armouries, Leeds. They are minions weighing 335lbs (142kg) and 305lbs (138.3kg) respectively (Blackmore 1976: 64–5, cat 38–9, pl 17). No 38 bears the remarkable inscription ‘CAST IN PRESENCE OF HIS MAJTY OCTO THE FIFTH 1638. MOUNTJOY EARLE OF NEWPORT MR GENERALL OF THE ORDNANCE. IOHN BROWNE MADE THIS PEECE’. A bronze demi-culverin drake by Browne, also dated 1638, is preserved in the Royal Artillery Museum at Woolwich, London. It carries the English rose entwined with a fouled anchor, trident and sceptre, with the inscription ‘CAROLVS EDGARI SCEPTRVM STABILVI AQUARVM’ (Charles has established Edgar’s sceptre on the waters). It was probably one of the drakes specially cast for *Sovereign of the Seas*, referring to the mythical King Edgar whose mounted effigy trampling seven kings formed her elaborate figurehead (Heywood 1637: 29–39). The final surviving Browne bronze drake is a minion in the Guildhall Museum at Boston, Lincolnshire, also dated 1638 (Illus 205). Like the two minion drakes in the Royal Armouries, this gun is shorter (1.127m from muzzle to base-ring) and lighter (314lbs marked weight, or 141.3kg) than the Duart Point piece, although it has a slightly larger bore (86mm or $3\frac{2}{5}$in). The Woolwich and Boston guns are illustrated by Roth (Towes & McCree 1994: 44–5). A list of guns at Ayr in February 1653, recently brought there from Argyll, included two bronze drakes, each weighing 278lb, and 4ft long (Clarke MS 3/5 unfol).

Historical context of the minion drake

During the 1620s a new type of lightweight gun called the drake was introduced to England. Its origins are obscure, but the use of such guns on the continent is recorded in 1622 when Prince Maurice of Nassau, marching to relieve Bergen-op-Zoom, included in his train ‘new devised pieces called Drakes’ (Firth 1992: 46). Drakes had evidently reached England by

1625, when they were employed against Cadiz during the abortive Anglo-Dutch attack on the city. 'We discharged upon them some of our drakes or field pieces loaded with small shot' wrote John Glanville, who was there (Towes & McCree 1994: 39).

By 1626 John Browne, then Charles I's master-gunfounder, was conducting experiments to reduce the weight of cast-iron guns by 'refining' the metal, though the process involved is not explained. But in a report dated November 1627 Browne provides a set of equivalence figures for three guns cast in 'ordinary' and 'extraordinary' ('refined') metal (Towes & McCree 1994: 39–40, citing TNA SP16/95) (Table 7.2).

Six guns cast by Browne in refined metal (for which he charged double the normal price for cast iron) were tested under the supervision of Charles I's proof-master, John Reynolds, at Millhall in Kent in April 1627. All the pieces 'endured the King's double proof and yet are lighter than bronze', reported Reynolds, although he added the rider that because of the guns' lightness 'their reverse [recoil] is so much that I doubt they may hazard the breaking of their tacklings and ringbolts and so deliver their shot uncertainly'. Nonetheless, he went on, 'for shooting at eleven or twelve score [yards, or *c* 200m] which is considered by most seamen to be far enough at sea, these pieces have done such execution … as more is not required'. In conclusion, Reynolds considered, such pieces could most profitably be used on the upper decks of ships 'where heavier guns could not be brought to bear' (Towes & McCree 1994: 39, citing TNA SP16/25/79).

Hitherto most English warships had been equipped with expensive bronze guns, and the introduction of the lightweight drake design, combined with Browne's successful experiments in producing iron guns cast using 'refined' metal, clearly appealed to the Navy Commissioners as a means whereby the King's ships could be equipped with lighter and cheaper guns without reducing the weight or effective range of the projectile fired. During a meeting in March 1627 the Commissioners took into consideration,

> the great inconvenience which many of His Majesty's ships do suffer by overweight of ordnance … when the upper tier lies high their overbalance makes the ship walty and cranksided where she bears small sail; and is unwholesome at sea … when they strive to lay them lower, they are forced to lay the Lower Tier so near the water that they cannot carry them out in any reasonable weather, but are driven to shut up their ports and so they become useless cumber.

The Commissioners recommended that two steps should be taken to remedy these defects. The first was to make use of 'metal refined', a clear reference to the high-grade cast iron with which John Browne was experimenting. Their second recommendation spelled out the attributes by which they defined drakes. The new guns were to be 'foundered in new measures both shorter and lesser in Diametrical Magnitude or in forming the metal of the Chamber by diminishing the same towards the touch-hole according to the nature of the Drakes'. Such guns, the Commissioners concluded, 'were more nimble and proper for their uses, as well through bulkheads as from the upper places of deck, half-deck, or forecastles' (Towes & McCree 1994: 40–1, citing TNA SP16/56/45). Another description of the type is included in the *Travels of Sir William Bereton* (cited by Thompson 1977), in a diary entry dated 23 July 1635 at Wexford when he 'went aboard one of the king's ships, called the ninth *Whelp*. He found it to be armed exclusively with drakes, which he describes as 'taper bored in the chamber, and are tempered with extraordinary metal to carry that shot; these are narrower where the powder is put

Table 7.2
Examples of the difference between the weights of guns made with 'ordinary' and 'extraordinary' metal, compared with the actual weight of the Duart Point minion drake

Gun type	*Length*	*Bore*	*'Ordinary' weight*	*'Extraordinary' weight*
Whole culverin	8ft 6in	5¼in	40cwt	33cwt 3qr†
Demi-culverin	8ft	4½in	29cwt	23cwt†
Saker	8ft	3½in	22cwt	18cwt†
Duart minion	4ft 0¾in*	3¼in		3cwt 2qr 23lb

* Length from muzzle to base-ring. Browne's measurements were probably the same
† Towes & McCree 1994: 40

in, and wider where the shot is put in, and with this kind of ordnance his majesty is much affected'.

By these criteria Gun 8 is a classic minion drake. Analyses by Dr MacLeod and Professor Preβlinger confirm that it was cast of 'refined' metal of exceptional strength and resistance to corrosion, while its tapered chamber fits the specifications given above. It should be noted that the modified chamber was not intended to reduce the weight of the propellant charge, for its dimensions accommodate the same volume of powder as specified for a conventional piece. The volume of Gun 8's chamber, the length of which is defined unambiguously by its tapered end (as it is not in a straight-bored piece), is 750cc. The constituents of gunpowder have a solid specific gravity of just over 2, but when granulated or 'corned' the near-spherical grains pack into a face-centred cubic lattice which occupies about 75% of the available space, reducing the weight/volume equation commensurately (Hall 1997: 69). Applying these figures to the chamber of the Duart Point minion drake gives a powder capacity of 1.125kg or 2lb 8oz.

Drakes have long caused confusion among historians. Lewis (1961: 25 n1) thought that the term 'taper-bored' meant 'decreasing more or less uniformly in bore from muzzle to breech', an interpretation followed by Lavery (1987: 90–1), who added by way of explanation that drakes 'were intended mainly to fire grape-shot … and a taper bore would spread such shot.' But while drakes undoubtedly were used for canister-shot they routinely fired roundshot too, for which a bore flared along its full length would be ballistic nonsense. As surviving examples show, it is the chamber only that flares, an arrangement unequivocally confirmed by the Navy Commissioners in their report of March 1627 (TNA SP16/56/45), which notes 'forming the metal of the Chamber by diminishing the same towards the touch-hole according to the nature of the Drakes'. Beyond the tapered chamber the bore-diameter is constant, as confirmed by the Duart Point drake and the surviving bronze examples.

Another long-standing drake *canard* (to which the writer succumbed in an earlier paper, Martin 2004: 85–6) is that Browne alloyed the iron in some way to form a lighter mix. This too is scotched by a careful reading of the Navy Commissioners' March 1627 report, which states: 'order be taken with the founder to fortify his pieces rather by the virtue and strength of the metal refined … than by adding plurality of ordinary stuff which increases the weight' (Towes & McCree 1994: 41 citing TNA SP1/56/45). In other words the metal was not *lighter* but *stronger*, so less of it was needed to achieve the required strength. This is borne out by the unusual composition which analysis has shown to characterise the metallurgy of the Duart Point drake (see below).

The widely held belief that drakes bore a lighter charge than their 'ordinary' equivalents is also a misconception. As we have seen, the taper was confined to the chamber and its capacity was the same as that of a full-bored gun. What the tapering achieves is to maintain the wall thickness of the barrel around the chamber, where the pressure stress is greatest, while allowing the outer circumference of the breech (its 'diametrical magnitude', as the Navy Commissioners put it) to be significantly reduced. The high internal pressure developed at this point by the expanding combustion of gases following ignition is well illustrated by a photo-elastic model analysis of internal stresses around the chamber of a gun replicated in resin, carried out at Princeton University (Guilmartin 1974: 287–8, fig 17). Less metal around the circumference of a tapered chamber was needed to achieve the requisite strength. More weight was saved by shortening the piece. Ward's specification (1639: 109) for a conventional minion indicates a bore:length ratio of 1:29.7, almost double that of the Duart Point piece. By applying all three factors – stronger 'refined' metal, a tapered chamber which allowed a reduction of the circumference at the breech, and reduced length – such a gun's weight could be reduced by more than half when compared with its 'ordinary' equivalents (Table 7.3).

Most guns produced for the navy during Charles I's reign were drakes (Caruana 1994: 56–68). Among them were 36 demi-cannon drakes, 40 culverin drakes, and 40 demi-culverin drakes, all of iron and all cast by John Browne, issued in 1628 to ten new pinnaces, the *Lion's Whelps* (arguably the Royal Navy's first 'class' of warships) (Caruana 1994: 59). A decade later John Browne and Thomas Pitt cast 102 bronze

Table 7.3
The specifications of two ordinary minions from 17th-century sources, compared with the specifications of the Duart Point minion drake

Gun type	*Bore*	*Shot weight*	*Length*	*Weight*	*Source*
Minion	3¼in	4lb	–	1,000lb	Monson 1913: 41
Minion	3¼in	3lb 12oz	8ft	1,000lb	Seller 1691:137
Duart Point minion drake	3¼in	4lb	4ft 1in	415lb	

guns, almost all of them drakes, for the King's ornate and expensive nautical showpiece, *Sovereign of the Seas* (Caruana 1994: 63; Rodger 1997: 388–9). Originally conceived as a two-decker mounting 90 guns, Charles had defied expert advice (and the recent disastrous precedent of *Vasa*) by insisting on an additional gun-deck to make the ship the first true three-decker, and increasing her armament to over 100 muzzle-loading guns – another first. This number of large-calibre guns could certainly not have been achieved without exploiting the weight-saving characteristics of drakes.

The Duart piece's short length, tapered chamber, and refined metal combine to give it, in the evocative technical jargon of its time, the full descriptive nomenclature 'bastard [= shortened] minion [= bore] drake [= tapered chamber] extraordinary [= cast from refined metal]'. It is a unique relic of a short-lived and probably unsuccessful phase in the development of naval ordnance, and its exceptional condition (metallurgically as well as physically) has made possible the important analytical work by Dr Ian MacLeod and others, presented below.

7.2 The composition and properties of 'refined' iron: a metallurgical analysis of Gun 8

Ian MacLeod

The piece's weight loss, determined after the removal of concretion after 350 years of immersion in seawater, amounts to only 3.24kg (1.72 wt%), or only 5×10^{-3}wt% per year of immersion. Given the remarkable degree of preservation and the questions posed by its resistance to corrosion, permission was granted by National Museums Scotland to take a sample from the gun for metallographic analysis. A full report on the archaeometallurgy and microstructure of the gun is published elsewhere (Preßlinger et al 2012).

From the measurements and description of the gun it is possible to calculate the wetted surface area of the piece, assuming that the tampion was not in place so that seawater could penetrate the bore. There was no evidence of a tampion and, had one been fitted, the pressure differential would probably have forced it up the barrel when the gun sank, where it would almost certainly have been preserved. Tampions were recovered from guns on the Dutch East India Company (VOC) ships *Batavia* (1629) and *Zuytdorp* (1712) (Green 1989: 54; WA Museum artefact database). From these data it was possible to use the weight-loss information to calculate the corrosion rate, assuming a uniform distribution of decay across the gun. Corrosion rates expressed in $mm.y^{-1}$ of metal loss are calculated according to the formula:

$$i_{corr} = 10 \times \{\delta/SA\rho t\}$$

where the 10-fold factor is to allow for conversion from cm of corrosion per year to $mm.y^{-1}$, the weight loss in grammes (δ), the surface area (*SA*) in cm^2, the density ρ is in $gm.cm^{-3}$ and the time of immersion (*t*) in years. The density used in the calculations was obtained from an un-corroded section of the solid metal which had been cut with a diamond-tipped metallographic instrument, which was approximately 20mm × 7.5mm × 7.5mm, and determined to be 7.17 $gm.cm^{-3}$, which is significantly higher than the initial bulk estimate value of 6.71 calculated from the displacement volume of the conserved gun (Martin 2004: 82). The metal sample has a density that is typical of a medium-carbon grey cast-iron (American Society for Metals 1983: 167, 172). A section of the gun that included an edge of corroded material had a density of 7 ± 0.02 $gm.cm^{-3}$, which shows that even a small amount of corrosion can significantly alter the apparent density. When attempting to determine the density of a large whole object such as a cast-iron gun special care needs to be exercised when taking readings on the corroded rough surfaces to ensure that all the areas have been thoroughly wetted, as entrained air can result in lower density readings.

From the conversion weight % loss to $mm.y^{-1}$ of corrosion, the John Browne minion drake can be seen to have an estimated uniform corrosion rate of 1.15×10^{-3} $mm.y^{-1}$ which amounts to a total depth of graphitisation of only 0.4mm after 350 years of immersion. A scanning electron micrograph of the leading edge of the sectioned gun is shown in Illus 206; the bar-scale is 1mm. The view of the metal was obtained using a backscattered secondary electron image which is atomic numbered contrast-sensitive so that light elements like carbon show up as black and heavier elements like iron are manifest by a light-grey to white tone. Corrosion has occurred in patches around the roseate-shaped graphitic clusters (dark-grey image areas). There is some solid metal to within 100µm of the seaward surface, which is in marked contrast to most iron

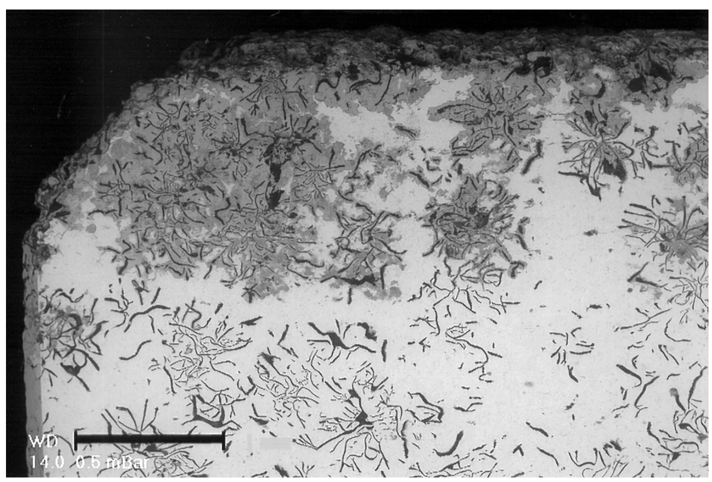


Illustration 206
Scanning electron micrograph of the leading edge of the sectioned Gun 8 [82]. The bar-scale is 1 millimetre

Table 7.4
Summary of the principal components of the alloy

ppm											
Element	Li/7	Be/9	B/10	Sc/45	Ti/48	51/V	Cr/52	Mn/55	Co/59	Ni/60	Cu/65
Canon	< 0.1	<0.1	<0.1	0.9	86	75	57	6200	20.5	59.4	2100
Element	Zn/66	Ga/69	Ge/74	As/75	Se/82	Rb/85	Sr/88	Y/89	Zr/90	Nb/93	Mo/98
Canon	761	12	1.1	53	0.3	0.1	0.3	0.4	158	43.5	3.9
Element	Ru/101	Rh/103	Pd/105	Ag/107	Cd/111	In/115	Sn/120	Sb/121	Te/126	Cs/133	Ba/138
Canon	<0.1	<0.1	0.1	<0.1	0.5	<0.1	8.0	3.4	0.3	<0.1	1.3
Element	La/139	Ce/140	Pr/141	Nd/144	Sm/152	Eu/153	Gd/158	Tb/159	Dy/162	Ho/165	Er/166
Canon	0.1	0.4	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1
Element	Tm/169	Yb/172	Lu/175	Hf/178	Ta/181	W/182	Tl/205	Pb/208	Bi/209	Th/232	U/238
Canon	<0.1	0.1	<0.1	4.7	2.4	6.1	<0.1	10.0	<0.1	0.3	<0.1

samples from marine contexts of similar age, where corrosion profiles are typically of the order of 35mm. Given that the gun appears to have been buried for most of the time since the vessel sank it is instructive to compare its corrosion rate with Gun 5 which had been partially buried at the foot of the cliff and had a corrosion rate of only 1.9×10^{-2} mm.y^{-1} which in itself is roughly five times less than the normal corrosion rate of iron in seawater of 0.1mm per year of immersion.

Thus Gun 8, which may be presumed to have been cast with John Browne's 'extraordinary' metal, has corroded at roughly one-sixteenth the rate of an apparently normal 17th-century cast-iron piece of ordnance. This level of corrosion rate is normally only obtained today by costly duplex stainless steels designed for performance in aggressive marine and chemical environments. For example the specialised steel SCS10 JIS duplex stainless steel containing 25% chromium, 7% nickel, 3% molybdenum, has a combined corrosion- and erosion-rate equivalent to 1.06×10^{-3}mm.y^{-1} (Yokota 2011), which is the same as that calculated for Gun 8, the product of a technology available nearly four centuries ago (the SCS codes relate to the Japanese Standards Association).

The incised markings on the surface of the gun showing its measured original weight recorded at the time of casting, 3cwt 2qr 23lb (415lb or 188.24kg), are seen against a surface detail which preserves the brush-marks from the mould used at the gun-foundry (Illus 202). The fine surface detail reveals even grains of sand, attesting to the remarkably small extent of corrosion since cast iron would normally lose this level of surface detail quite quickly. Metal swarf was obtained by penetrating the core sample with a drill-bit in the middle of the square-end cross-section after removing the surface 0.5mm of material and collecting metal shavings to a depth of 10mm. The metal was dissolved in nitric acid and analysed by inductively coupled plasma – mass spectrometry (ICP MS) at the University of Western Australia's micro-analytical service laboratory, and the carbon content was determined on duplicate solid samples in a Leco furnace. A summary of the principal components of the alloy is given in Table 7.4, and the full range of trace metals found in the alloy, which provides clues to the provenance of the ore body and the metallurgical processes used in the manufacture of the gun, are reported in detail in a separate publication (Preßlinger et al 2012).

The basic metallurgical composition of cast-iron objects is controlled by the phase diagram for iron and carbon. If the effective carbon content, or carbon equivalent, is on the low carbon side of the eutectic composition the alloy is referred to as being a hypo-eutectic grey cast iron, which is the appropriate description for Gun 8. One of the principal ways in which the presence of silicon and phosphorous is manifested is that they act as though they are carbon, in terms of modifying the melting-point and altering composition of the phase diagram. These factors in turn control the phases that are present in the solid materials when recovered from the marine environment. Using the formula

$$CE\% = \%C + 0.3*\%Si + ⅓*\%P - 0.027*\%Mn + 0.4*\%S,$$

where CE is the carbon equivalent, and using the weight % composition of the silicon and phosphorous recorded (see Table 7.4) it is possible to calculate what the effective concentration of carbon is in the alloy (Campbell 2008: 454). Thus the 1.04% Si and 0.378% P increases the analytical concentration of carbon from 2.76% to 3.22%, which may seem trivial, but an inspection of the phase diagram shows that this 'equivalence' alters the melting-point of the iron alloy by 125°C, which naturally makes it much easier to manage and to achieve a fine casting with less porosity. The small amounts of chromium and vanadium, which promote the formation of the iron-carbide phase cementite, are unlikely to have had any measurable impact on the microstructure. Manganese increases the hardenability and retards the softening and tempering of the cast iron. Mechanical testing of the metallographic coupon showed a Brinell hardness of 175 which is the same value as an ASTM 25 standard grey cast iron (Illus 207).

The phosphorous impurities react to form the iron phosphide which combines with the ferrite phase to form the eutectic phase called steadite, and this composition assists the fluidity by lengthening the solidification process (Abbasi et al 2007). The relatively low amount of silicon will tend to inhibit the formation of iron-carbide cementite, Fe_3C, and promotes the growth of graphite phases which are present in the metal structure as flakes (Smallman & Bishop 1999: section 9.3).

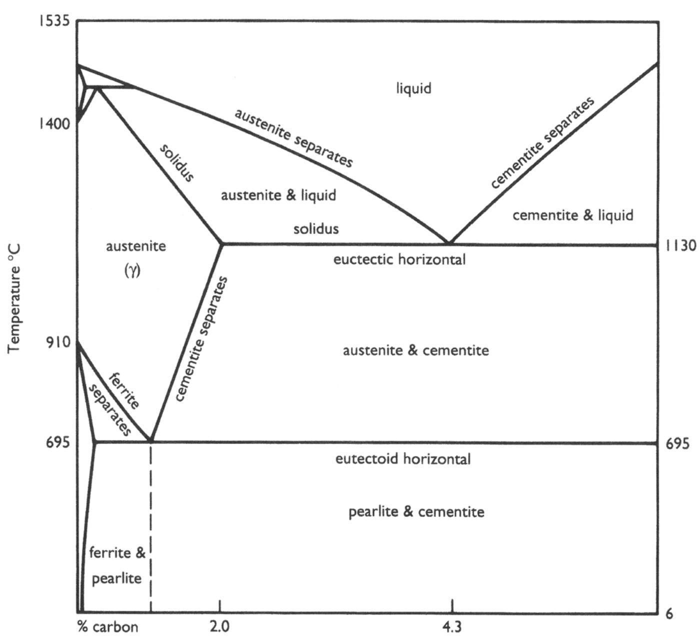


Illustration 207
The complete iron-carbon diagram for the sample from Gun 8 [82]

Corrosion of cast iron is strongly influenced by the level of impurities in the alloy and how they affect the microstructure, which in turn controls the corrosion mechanism. In most cast-iron guns and roundshot the principal phases are ferrite (pure iron), pearlite (a lamellar structure of ferrite with bands of iron-carbide cementite), cementite Fe_3C, and graphite. The electrochemical differences in reactivity of the phases ultimately result in the selective dissolution of ferrite in grey cast irons in the marine microenvironment. After the ferrite phase has been corroded the pearlite phases are next to go, which are followed by the cementite phases until only the graphite structure remains (Pearson 1972; Wu et al 1998).

Another source of localised corrosion for cast-iron objects is the presence of sulphur as an impurity, for in the molten state the sulphur reacts with iron to form iron sulphides like pyrite (FeS_2), which act as electrical conductors and have different chemical reactivity to the phases around them, and this in turn causes localised corrosion. Pyrite can also be present as inclusions from the parent ore body which was incompletely roasted to form an oxide mineral which could then be reduced to iron metal in the normal furnace operations. However the low level of sulphur (<0.1%) present in cast iron attests to its quality.

Chemical analyses of the underlying metal from cast-iron guns recovered from shipwrecks dating from 1622 to 1875 conserved in the Western Australian Museum showed that there were two distinct groupings that had the same rate of decrease in sulphur content for each year of the casting date(s) but different intercept values. In other words, the graph of sulphur content versus the date of the wreck or its build date consisted of two parallel lines, and the rate of the decrease in sulphur content per year was approximately 0.0011 ± 0.0003 wt% per year as the technology of manufacturing guns improved and the awareness of the impact of impurities began to be better understood. Using these data and the relationships discussed above it can be seen that Gun 8 fits to the lower sulphur content with a predicted sulphur content of 0.09% for a gun made *c* 1640 which is what the analytical results bear out for the Browne gun. It is of interest to note that this lower level of sulphur in cast-iron guns was found in examples from three Dutch East India Company shipwrecks from Australian waters, the *Batavia* (1629), *Vergulde Draeck* (1656) and *Zuytdorp* (1712), as well in the Duart Point Gun 8. It is most likely that the iron source minerals were based on oxide ores of hematite, goethite, or magnetite.

If the proposed casting-date of *c* 1640 for Gun 8 is used to calculate sulphur content from the upper linear relationship, derived from guns from the *Trial* (1622), *Sirius* (1790), *Cumberland* (1830) and *Fairy Queen* (1875), the theoretical value was 0.25% which is substantially higher than the analytical value of <0.1%. As previously discussed, the higher sulphur contents of these guns are probably due to contamination from pyritic ore bodies used in the production of cast iron. When pyrite FeS_2 is roasted sulphur dioxide is released and the iron product is based on Fe_2O_3 which can then undergo standard blast-furnace reduction (Carpenter & MacLeod 1993).

When the manganese and phosphorous contents of the Western Australian Museum cast-iron ordnance were examined it was found that for pieces from the *Batavia*, *Sirius*, *Rapid*, *Cumberland* and *Fairy Queen* there was a direct linkage between the amount of phosphorous present and the amount of manganese which had an R^2 of 0.975 for the linear regression, $\%P = 0.73xMn\% + 0.0899$, but this relationship does not correlate with the composition ratios found in the gun from the Duart Point wreck. It has been noted above that John Browne had used 'refined' iron (metal not directly smelted from the parent ore bodies) to make his special guns, and so this disjoint in composition ratios provides additional support for this supposition. At present a research programme looking at osmium isotope ratios in the gun and comparing them with slag residues from the foundry site in Kent is likely to be able to source the iron ore from which this unusual gun was made (Preßlinger et al 2012).

Other than the main impact on the melting-point, the presence of phosphorous is normally regarded as being deleterious in that the iron phosphide steadite phase, Fe_3P, makes the alloy increasingly brittle and subject to accidental damage during firing and reloading activities. Recently these effects have been superbly quantified in a study showing that increasing amounts of phosphorous make grey cast iron weaker through a combination of reduced tensile strength and reduced impact strength, while at the same time increasing the hardness and lowering the eutectic temperature (Abbasi et al 2007). The eutectic mixture of iron and iron phosphide is the last phase to solidify and so the impurities tend to be concentrated at the grain boundaries with concomitant negative effects on the corrosion and mechanical properties.

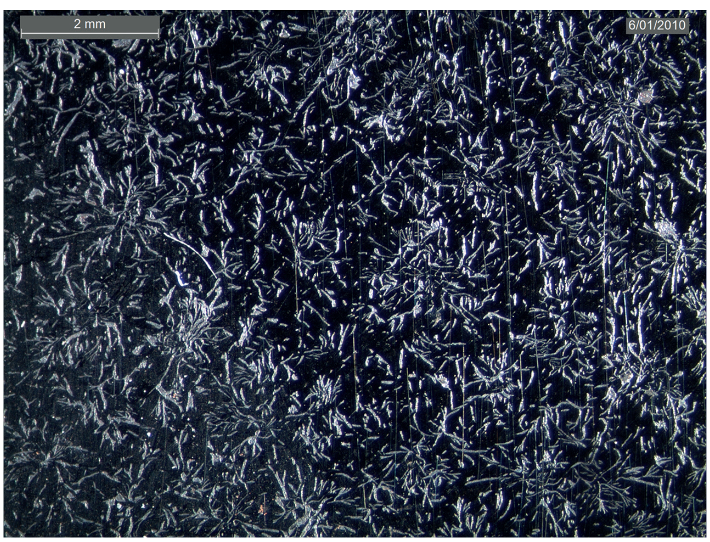


Illustration 208
The as-polished metal section of Gun 8 82

Analysis of the microstructure of the section of solid metal from Gun 8 showed that the cast iron has an unusual structure for 17th-century guns in that there is essentially no ferritic phase present. The un-etched surfaces showed up a characteristic roseate pattern of graphite which was visible to the naked eye. Part of the mystery for 'extraordinary' materials performance is explained by the major amounts of pearlite in the alloy, which will have greatly reduced the internal galvanic reaction between graphite, pure iron, and the surrounding seawater. Black malleable iron is made by annealing white iron in a neutral packing of iron-silicate slag when the cementite in the original white iron is changed into the rosette-shaped graphite nodules in a ferritic matrix (Campbell 2008) – see Illus 208 for the as-polished metal section of the gun. Especially to be noted is the remarkable way in which the lamellar structure of pearlite is formed in its different phases where the bands of iron carbide Fe_3C are laid down in a fashion that depends on the rate at which the molten metal cools (Campbell 2008). Closer bands of Fe_3C within the lamellae indicate cementite formation from graphite at a lower temperature such as 600° where the spacings are of the order of 0.1µm. Although iron carbide has low tensile strength it has great compressive strength and so the presence of the pearlite structure will explain in part why the guns were able to withstand the double proof-firing of contemporary testing (Towes & McCree 1994: 39, citing TNA SP16/25/79).

Another remarkable feature of Gun 8 is that the normally deleterious effects of sulphur have been eliminated through the formation of manganese sulphide inclusions which are electrochemically much less reactive than iron sulphides. The manganese sulphide inclusions appear as rounded grey particles at the dendrite boundaries of the alloy. Different surfaces of the alloy showed up structures that were indicative of interdendritic segregation with random orientation, while other areas showed up some preferential orientation of the phases. As previously mentioned the majority of the phosphorous present would react to form iron phosphide, Fe_3P, which solidifies out as the eutectic phase of ferrite and phosphide known as steadite which increases the hardness of grey cast iron, which is a beneficial effect for a piece of ordnance (Abbasi et al 2007).

In summary, the metallurgical structure of Gun 8 is most complex, as it consists of a quaternary phase system with graphite, manganese sulphide inclusions, the Fe_3P containing phase, as well as the pearlitic phases. Although the normal lamellae of pearlite I phase are present at about five times more abundant than the spheroidal form of pearlite II, it is believed that the complex and interacting structures of this alloy all contributed to its remarkable properties. John Browne appears to have been fully justified in charging double for his 'refined' metal (£26 13s 4d per ton instead of £13 6s 8d, Towes & McCree 1994: 39–40, citing BL Harleian MS429).

Acknowledgements

IAN MACLEOD

The assistance of Dr Bernard Pilcher, Professor Alfred Vendl and Professor Hr Preßlinger of the Technical University of Vienna in enabling the metallographic analysis of the core sample is gratefully acknowledged. The encouragement and support of Drs Colin and Paula Martin who brought the gun to my attention is happily noted. Without financial assistance from a grant by the J Paul Getty Trust to enable the author to work at the Getty Conservation Institute in Los Angeles this work could not have been effected.

Additional note

COLIN MARTIN

Since Dr MacLeod's analysis was carried out my attention has been drawn to research by Wertime (1962), who more than half-a-century ago reached much the same conclusion as Macleod & Preßlinger from oblique and intuitive study. He notes (1962: 168),

> though records and personal accounts reveal very little of the underlying chemical knowledge of the Sussex founders, it seems reasonable to believe … that masters of the Sussex tradition came to grasp in a limited practical way the majority of basic rules still applicable in iron-founding. These related to the positive role of certain phosphorus-bearing limonite ores; the negative role of sulphur; the central importance of gray iron; and the importance of proper pouring and moulding practice, including slow cooling without quenching. A superior gray cast iron resulted, as attested by metallographic results in firebacks cited by Schubert [1957: 246ff].

These pioneering conclusions by historians of technology are thus independently confirmed by MacLeod & Preßlinger's archaeologically based analyses, which were conducted without knowledge of the earlier work.

7.3 The drake carriage

83 DP00/013, **090.096/093.104** and fragment DP99/101 at **089.102**, a wooden carriage lay upside-down adjacent to Gun 8 (Illus 209–12). Mounted guns often invert themselves when they sink, because of the buoyancy of their carriages. Mechanical and biological degradation has severely damaged the exposed lower parts, and there is no sign of the forward trucks or axle, although the concreted

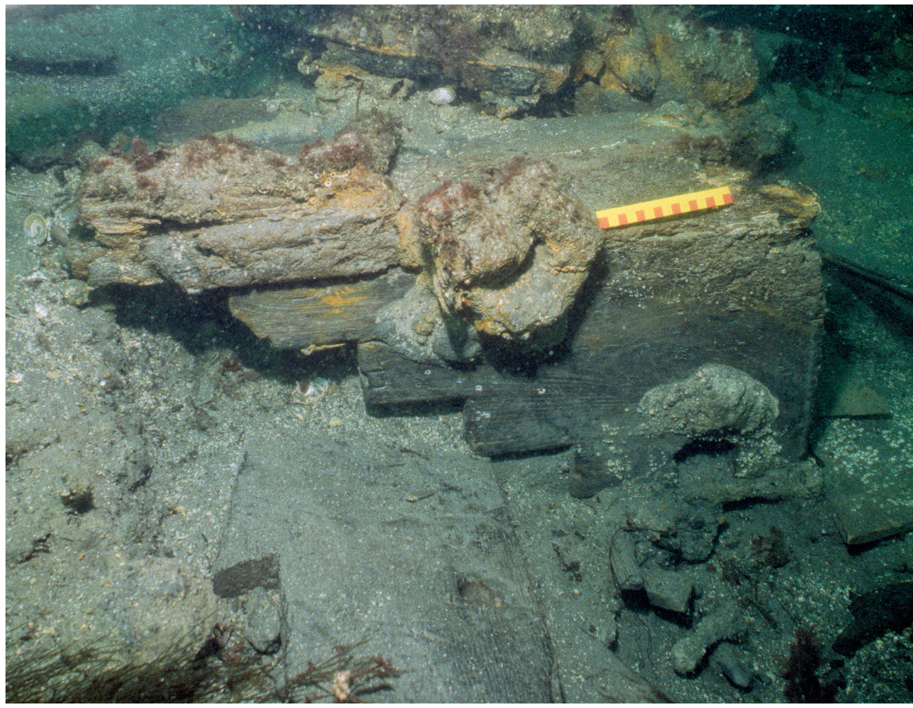


Illustration 209
The inverted drake carriage 83 at **091.101**. Scale 15 centimetres (DP 174310)

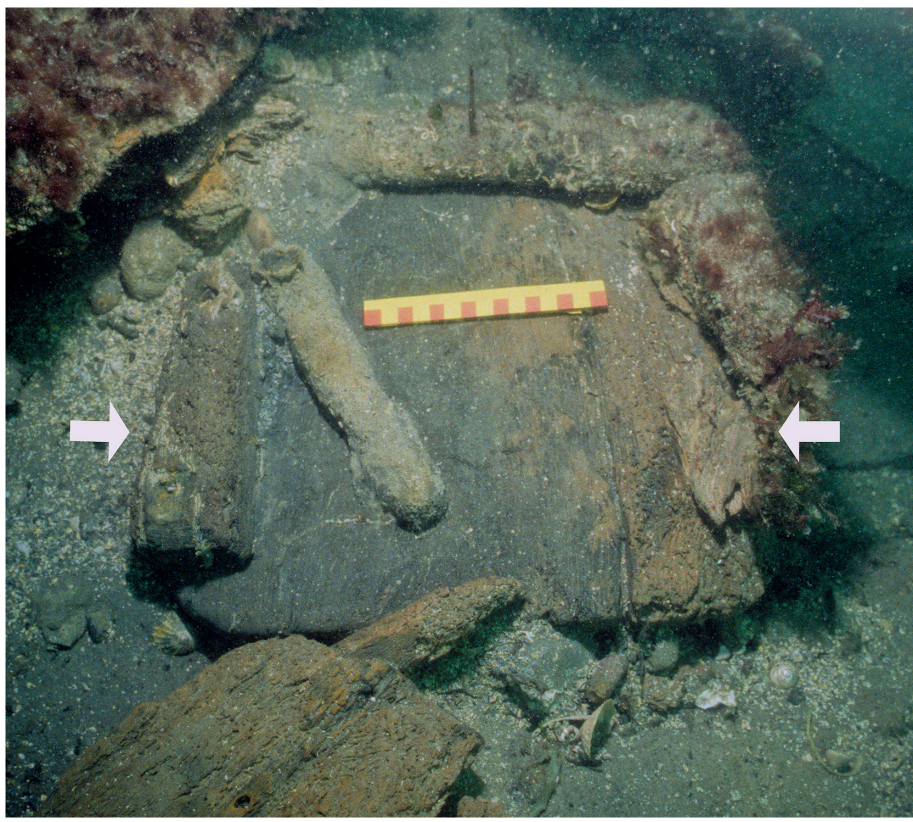


Illustration 210
The bottom rear part of the drake carriage-bed 83, showing the two abraded chocks (arrowed). The iron concretions are not part of the assembly. Scale 15 centimetres (DP 174317)

remains of iron fixing bolts for the front undercarriage are in place. At the rear end of the bed, however, there is no evidence of an axle or its fastenings. Instead the much-abraded remains of two pieces of wood, one fixed to each outer side, were noted. These can be identified as the vestiges of wooden chocks or skids (Illus 210).

The main body of the carriage consists of three components, a bed and two stepped cheeks, all of elm (*Ulmus* sp) (Illus 211). This conforms with contemporary practice: 'only elm doth make them', wrote Sir Henry Mainwaring of shipboard gun-carriages in the 1620s (Manwaring & Perrin 1922: 119). Elm is a resilient wood capable of withstanding shock. The bed is 60mm (2⅓in) thick and 0.9m (3ft) long, and tapers from a width of 0.388m (15¼in) at the rear to 0.324 m (12¾in) at the front. It is derived from the full width of the tree; that is, the central growth-ring of the parent log lies at the centre of the board, making it a tangential slice with balanced grain, and thus resistant to warping (McGrail 1987: 32–3). The cheeks are likewise of 60mm (2⅓in) elm board 0.66m (2ft 2in) long, falling from a level front portion 0.32m (12½in) high in four steps to the bed forward of its rear. The boards appear to be a handed pair derived from either side of the parent log's centreline, though they are placed in parallel without being reversed to mirror one another's grain, as might be expected. Just forward of the mid-point of the level foreparts of the cheeks, U-shaped recesses are cut to accommodate the full depth

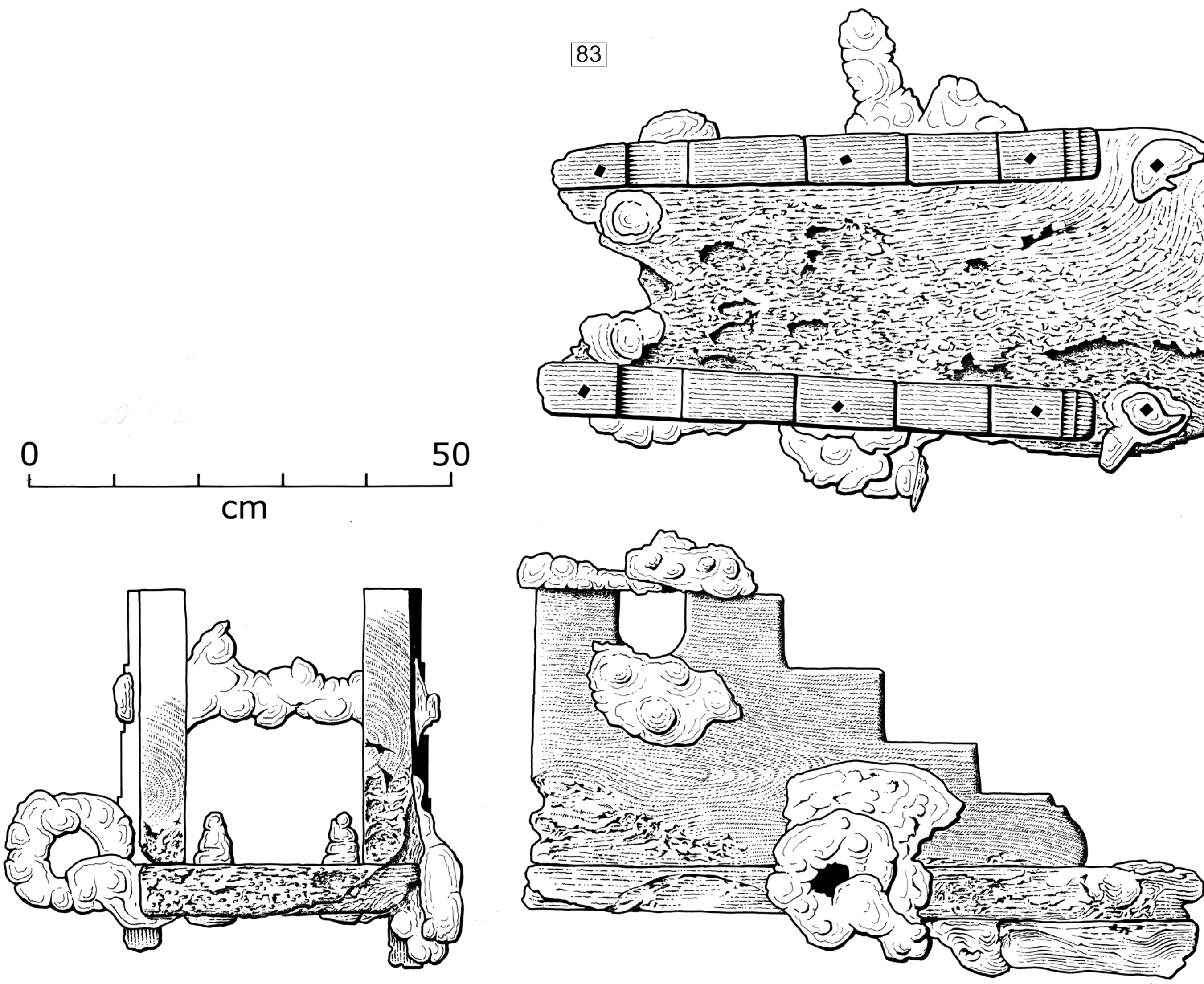


Illustration 211
Plan and front and side elevations of the drake carriage 83 (DP 174823)

of the minion drake's 72mm (2¾in) diameter trunnions. This is similar to the arrangement noted on truck carriages from *Mary Rose* (Hildred 2011: 99) but distinctively different from later practice, in which the recesses were generally semi-circular housings accommodating only the lower halves of the trunnions, with the capsquares arching over them, as on *Vasa*'s mounted guns (Padfield 1973: 66–9).

Flat iron capsquares hinged at the rear locked the trunnions to the carriage when the gun was bedded in place. The concreted left-hand capsquare remains in place but the one on the right has been thrown backwards, no doubt when the gun detached itself from the carriage during the wrecking process (Illus 212). Six through-bolts, three on each side, fix the cheeks to the bed, and were presumably secured at their lower ends by forelocks (slotted iron pins and locking wedges), though this detail was obscured by concretion. The front bolts also secure the capsquares, and it is presumed that iron spikes were provided to hold their rear ends in place. Two bolts at the forward end of the carriage indicate the position of the now-lost axle and fore-truck assembly. Close to the rounded rear corners of the bed two more bolts retain the rear chocks, which are secured at the front by the main bolts passing through the cheeks and bed. The rear bolts may also have been fitted with securing-rings.

The carriage was braced laterally by two transverse bolts. One joins the two cheeks just below the trunnion recess, and may have retained a wooden transom bracing the structure internally, although no evidence of this has survived. Another bolt, placed under the second cheek-step, runs through the full width of the bed to prevent it from splitting. At each end of this bolt breeching-rings 100mm (4in) in diameter are fastened.

In most respects the design of this carriage is typical of 17th-century practice (Moody 1952: 303–4), except for the solid wooden rear chocks in place of the more familiar rotating trucks. Evidence is, however, growing that rear-chocked carriages may have been more common than has been supposed, and frequently appear in association with drakes. Caruana (1994: 181–2) cites a document dated 1 May 1639 which refers to 'ship carriages for his Majesty's ship the *Sovereign* [*of the Seas*]', all of which are described as having 'whole trucks and half trucks'. Caruana also refers (1994: 182) to documents in the Library of the Royal Artillery Institute (RAI) at Woolwich which, although not quite contemporary, show carriages of this type. One of these is by a Dane, Albert Borgard, who joined the British artillery service in 1692 and made drawings of 'historic' ordnance and related equipment he found lying at Woolwich. These include several rear-chocked carriages, one of which Caruana has re-drawn (1994: 115). The RAI also possesses the notebooks of a Lieutenant James, which

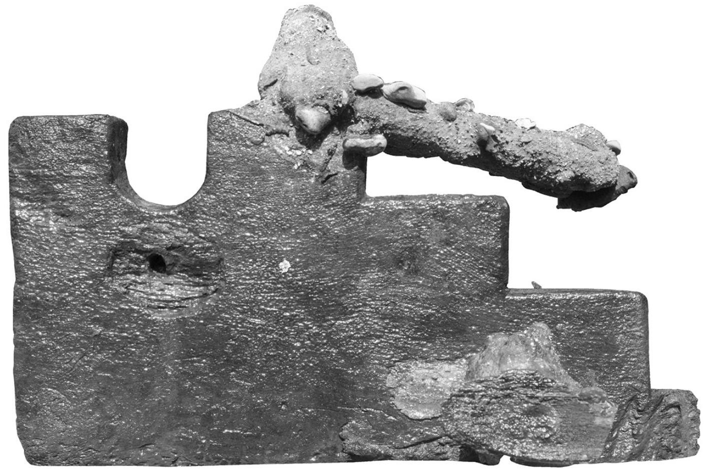


Illustration 212
Inside view of the right-hand cheek of the drake carriage 83 showing the rearwards throw of the concreted capsquare (DP 173431)

contain a drawing of a rear-chock carriage. Caruana (1994: 181) has redrawn this, believing it (on unstated grounds) to be for one of the *Sovereign*'s drakes. That drake ship-carriages were a recognisable type is indicated by an entry in an inventory listing ordnance in the Tower of London dated 20 March 1634 which records six 'drake shipp Carriages' – two for demi-culverins, and four for sakers (TNA WO55/1690, transcribed by Blackmore 1976: 303).

Puype (1990: 15–16) illustrates and describes two rather different rear-chock carriages. One is from a manuscript of *c* 1660 in the Netherlands Scheepvaart Museum. The other is a 1675 sketch by van de Velde the Younger which depicts a rear-chock carriage designed for a yacht (Robinson 1958: 370). In the 19th century carriages of similar design are sometimes encountered, particularly in association with lightweight heavily shotted pieces (for example Moody 1952: 309; Padfield 1973: 153, 155). At least two rear-chock carriages, evidently of 17th-century date, have survived on land. One is at Windsor Castle (Smith 2001), the other in Barbados (Charles Trollope pers comm).

Finally, mention should be made of the carriages associated with ten model guns presented to the future Charles II in 1638 and 1639, when he was Prince of Wales (Blackmore 1976: 65–6, pls 74–5). The five cast in 1638 were by John Browne, and the remaining five, cast a year later, by Thomas Pitt. All were mounted on wooden carriages which were destroyed in a fire at the Tower of London in 1841, although the guns survived. The new carriages made to replace them are so similar in design to the Duart drake's rear-chock carriage as to suggest that they are close replicas of the originals, which themselves must have been faithful representations of the real thing (Illus 213). The rear chocks are particularly clear, being semi-circular pieces of

Illustration 213
Model bronze gun and carriage. English, 1638. Cast by John Browne (XIX.24, © Royal Armouries)

wood with flattened bottoms and short rearward extensions. Since these models are static the flattened bottoms must have been intentional, and not the result of wear.

Drakes and rear-chock carriages

The replacement of the more usual rotating rear trucks with fixed semi-circular chocks with flattened bottoms on drake sea-carriages was clearly intended to increase friction on the deck and so contribute to the absorption of recoil. That modified carriages were needed for these light but heavily shotted guns is evident from Nathaniel Butler's *Dialogues* of *c* 1634 (Perrin 1929: 260–1) in which he presents an imaginary conversation between an admiral and a captain, with specific reference to drakes:

> ADMIRAL: What say you of those light kind of guns newly invented, called drakes?
>
> CAPTAIN: For these also, howsoever in regard of lightness and smallness, they may seem desirable, yet in respect of their violent reverse, occasioned by their over-lightness; so they are not to be used on ship-board, unless the trucks of their carriages be so framed, as by their straitness upon the axle-trees, their reverse may be regulated; and that, being thus straitened, they become as hard to be traversed as most of the heavier pieces; and besides that by reason of the thinness of their metal they are so soon overheated, as not to be made use of in any long fight. In these respects (I say) it is mine opinion of these drakes likewise, that they are not to be held in any great account for service at sea.

Butler's modern editor, W G Perrin, considered that 'straitness' should be rendered in modern English as 'tightness': in other words the trucks being tight on their axles would fail to rotate on recoil and so dampen the 'violent reverse' (1929: 260 n3). It seems more likely, however, that Butler's 'strait' trucks were none other than the fixed rear chocks with flattened bottoms now seen to be characteristic of drake carriages. Such an arrangement would help to mitigate the recoil problem. Since the gun's trunnions are set below the axis of the bore, recoil would push the breech downwards, so increasing the friction of the flat-bottomed chocks against the deck. This explains what Butler meant by the 'straitness' which regulated the 'reverse'. By the same token, such a carriage would be harder to traverse (to move its rear sideways).

Little is known of Butler's life and sea-experience, although in the abortive Cadiz expedition of 1625 (in which, as we have noted, drakes were first recorded in English sea-service) he was, apparently at Charles I's behest, commander of the *Jonathan*, a 371-ton hired merchantman in the Admiral's squadron. In 1627 he commanded the *Patient Adventure*, another auxiliary merchantman of 360 tons, in the Ile de Ré campaign. A year later he became captain of one of the King's ships, *Nonsuch* (600 tons, 40 guns), and took part in the relief of Rochelle (Perrin 1929: xiii; Rodger 1997: 347–63). Though these campaigns were far from successful (a consequence of Charles I's abysmal naval administration and his dreadful Lord Admiral, the Duke of Buckingham) they took place at just the time drakes were beginning to enter naval service, so

Butler's low opinion of them was probably rooted in first-hand and perhaps hard-won experience.

It seems likely that the drake, while no doubt excellent for use in the field (for which, apparently, it was originally designed), where its lightness would have been a virtue and its boisterous recoil much easier to manage, was from the outset problematic at sea. Contemporary land carriages, with their pairs of large-diameter spoked wheels and long downward-angled trails, were designed to operate without any form of tethered restraint. On recoil the heel of the trail tended to dig in, causing the coupling effect of the recoil axis along the barrel to lift the gun and its attached carriage bodily off the ground. This progressively and smoothly absorbed the recoil forces. Such a procedure would have been impossible to follow at sea, as discussed below. Yet no doubt the ingenious technology which lay behind the drake as a successful light field-piece, pushed by the vigorous entrepreneurship of English gunfounders led by John Browne, brought it to the attention of naval administrators (who would value the economy of such pieces) and of Charles I (who, because of the lighter weight of such guns, could cram more aboard his ships and so enhance his prestige). No one in a position of power and influence, apparently, thought to assess their actual shipboard performance or to consult the sea-gunners who would have to operate them. If so, it would not be the first or last time that political expediency and wishful thinking on the part of state authorities and bureaucrats has driven armament policies in ill-judged directions.

Nonetheless drakes continued to be manufactured into the second half of the 17th century, as shown by the recent recovery of a Commonwealth cast-iron culverin drake from the sea off Holland (Wilson 1988; it is now in the Royal Armouries). Probably a casualty of the battle of Schveningen between the English and Dutch fleets in 1653, the gun may have been cast in 1652 by George Browne, John's son and successor. As the century progressed, however, the term 'drake' became ever more vague, and the guns so described are increasingly heavy and lengthy, while their tapered chambers give way to 'home bores' (parallel-sided ones). It is beyond the scope of this report to examine the convoluted and rather mysterious demise of the drake over the second half of the century, although the subject has usefully been investigated by Towes & McCree (1994).

7.4 Disposition of armament

As argued in Chapter 4 the ship appears to have broken up in a relatively coherent and predictable manner, and most items have not moved far from where they were originally deposited. This will have been particularly so in respect of heavy objects such as guns, so their relative positions on the sea-bed today probably broadly reflect their original locations within the ship. A systematic metal-detector survey in 1997 recorded no hits which could be interpreted as buried guns, so the eight now identified probably represent the ship's full complement. *Swan* had five guns when she was purchased for the state in June 1653, but armament levels were frequently adjusted and we know that the Ayr-based contingent of Cobbett's fleet, which included *Swan*, had called at Knapdale to collect some pieces of artillery (Chapter 1.2). So we may therefore conclude that *Swan* mounted eight guns on her main deck, probably disposed as suggested in Illus 214.

Guns 4 and 6, provisionally identified as sakers, lie close to the port and starboard quarters of the forward ballast-mound, and were probably mounted well forward in the bow. Even allowing for a bluff shape to the bow, as argued in Chapter

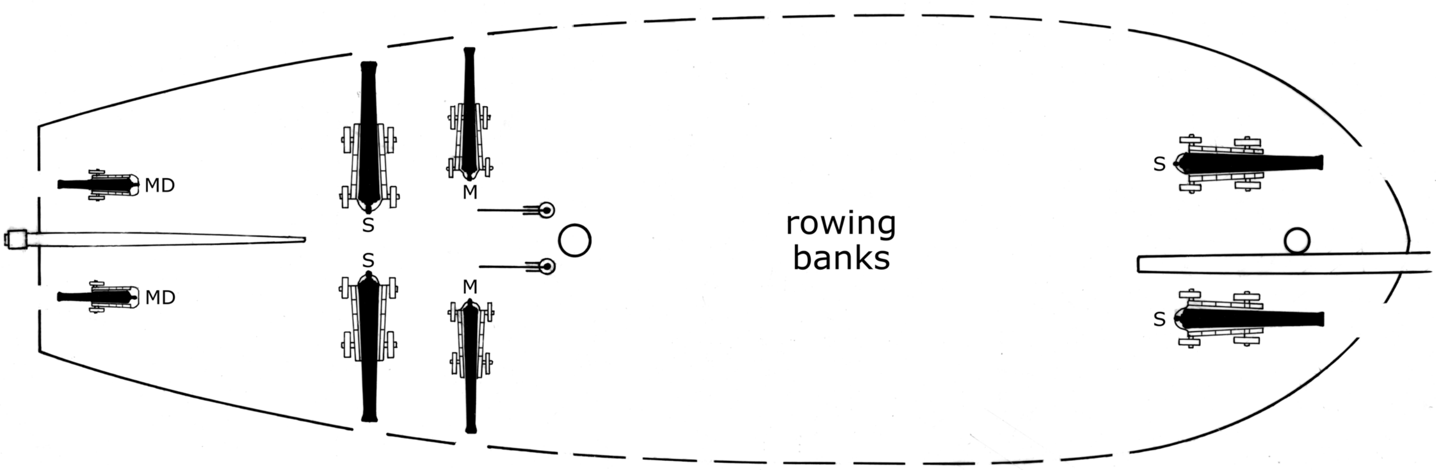


Illustration 214
Suggested arrangement of guns on the main deck. M = minion; S = saker; MD = minion drake (DP 174816)

5.1, there would scarcely have been room on the narrowing deck to operate long guns of this kind opposite one another on the broadside, which in any case would have been encumbered by the foremast, bowsprit, and galley structure. A more likely disposition would be in parallel, pointing forward through the bow on the port and starboard sides.

There are no guns in the midships part of the wreck, which suggests that none had been mounted there. This is best explained by the fact that the ship is known to have possessed auxiliary oar-power. Although some oar-assisted sailing ships combined sweeps and guns amidships, either by arranging them in tiers or by alternating oar-ports with gun-ports along the same deck, such solutions were not always practicable. Alternating guns and oars on a single deck would have raised problems of space, particularly in a small ship.

Four guns (Guns 1, 2, 3 and 5), however, cluster in the after part of the ship, on and around the aft ballast-mound. They presumably fell there from the collapsed upper deck. Two appear to be sakers, one a minion, while the fourth is of indeterminate type, though it is probably either a saker or minion too. We can reasonably suppose that these were mounted in pairs on the main-deck broadside, two to port and two to starboard, aft of the mainmast. The gun-port lid at **088.087** no doubt belongs to one of them. The identification of a cartridge-box 84 and powder-scoop 85 appropriate to guns of saker calibre with parallel-sided chambers strongly suggests that the four putative pieces of this type (Guns 1, 3, 4 and 6), and probably the pair of putative minions as well (Guns 2 and 5), were not drakes but 'home bored' guns – that is, they have untapered chambers of the same diameter as the bore.

Gun 8 82 is the small minion drake, complete with its carriage, which lay at the upper end of the transom complex. As argued above, its position and associations suggest that it was mounted at the aft end of the main deck, pointing through the stern on the port side as suggested in the general arrangement reconstruction of the ship (Illus 159). If this interpretation is correct there would probably be a matching piece on the starboard side, for which a candidate may be Gun 7, the small broken piece some way distant from the main site which appears to have been displaced in 1979.

7.5 Working the guns

There has been much debate about the working of guns at sea during the 16th and 17th centuries (Laughton 1928; Rodger 1996; Martin & Parker 1999). In particular it is unclear when loading on the recoil – that is, allowing a gun to travel inboard using the rearwards momentum generated by firing, restrained only by its mass and the friction of its breeching tackles and truck wheels – was first introduced. This brought the gun back into the loading position without effort from its crew, and led to the high rates of fire achieved by sailing navies of later eras (Rodger 2004: 539–42). Before this procedure was introduced guns were generally secured to the side of the ship by breeching-ropes before firing, a much less efficient process which not only placed considerable stress on the vessel's structure but also required the guns to be unhitched and manhandled inboard for reloading. Alternatively pieces could be left secured in the run-out position, and loaded outboard by a crew member perched precariously astride the muzzle (Konstam 1988: 19–20).

It is generally agreed that loading on the recoil through running tackles was introduced during the first half of the 17th century, but it was adopted gradually and, on smaller ships in particular, the older system continued until the end of the century and perhaps beyond. Laughton (1928: 340) cites an encounter between an English merchantman and five small pirate ships off the Cape Verde Islands in 1686 in which the former drove off the latter by picking the gunners off with musket fire as they attempted, somewhat unadvisedly, to load outboard.

It is unlikely that Gun 8, the minion drake, with its 'boisterous reverse' and strong upwards kick, could have been allowed a free recoil to carry the assembly inboard for reloading. It must therefore have been secured to the ship's structure during firing to restrain its upwards and backwards movement. Not all the strain would have been taken directly by the hull-timbers. It is likely that the breeching-rope was allowed some slack so that cushioning friction would be generated by the initial slide over the deck, as experimental firing tests on replicas of guns and carriages from the *Mary Rose* have demonstrated (Hildred 2011: 127–9). The elasticity of the breeching-rope after pulling taut would also absorb some of the recoil, as would the additional friction provided by the rear chocks. The low set of the trunnions, moreover, would create a downwards couple at the breech during recoil, which would increase the pressure of the chocks against the deck (I am indebted to Fred Hocker for this observation). We must suppose that such guns were manageable under battle conditions or they would surely have been discarded, though Butler's forthright Captain was probably right when he said they were tricky to handle, and 'are not to be held in any great account for service at sea' (Perrin 1929: 260–1).

We can be less sure of the operating procedures used for the ship's larger guns, but the restricted space available would have made it difficult to employ the recoil method. The two pairs of broadside guns aft of the mainmast, if mounted on truck carriages, would have extended at least 1.6m (5ft 3in) inboard when fully run-out, so between them they would occupy 3.2m (10ft 6in) athwartships, considerably more than half the gun-deck breadth available at this point. Brought fully inboard, whether by recoil or manhandling, they would have run foul of each other. If only one broadside was engaged at a time, recoil firing might have been possible, but the fixed-tackle option was probably a safer alternative. The same is likely to have been true of the forward-firing guns in the bow.

Gun-port lid

During the investigation of the collapsed after-castle a composite wooden object with concreted iron fittings was located at **088.087** (Illus 215). It was approximately square, 60mm (2⅓in) thick, with sides 0.51m (20in) long. A slightly smaller square piece of similar thickness was fixed to its underside to leave a flange of *c* 25mm around the outside. The grain of the two elements ran at right-angles to one another, and what appeared to be two wrought-iron straps were fixed to the outer face. The object was clearly a gun-port lid and the intention was to raise it for conservation and study, but unfortunately operational considerations at the close of the season precluded this. It was left protected by sandbags so that it could be located and recovered the following season, but the sandbagging became consolidated with fresh silting during the winter to such an extent that it was felt that the disturbance involved to retrieve it would not be justified. However the object had been photographed in situ and its primary measurements obtained, and this information is presented in Illus 216.

Mainwaring, writing in the 1620s (Manwaring & Perrin 1922: 200), prescribes a 30-inch port for a 9-pounder demi-culverin, so a 20-inch port would be for a significantly smaller piece. As argued above, the Duart Point ship's armament probably included full-bored 5-pounder sakers and 3½-pounder minions, and perhaps a pair of the smaller and lighter 3½-pounder minion drakes. One of the drakes seems the most appropriate candidate for the 20-inch port lid, a supposition reinforced by the fact that Gun 8 is the piece closest to the lid, which lies only 2m from it. The next nearest (Guns 1 and 2) are 4.5m away.

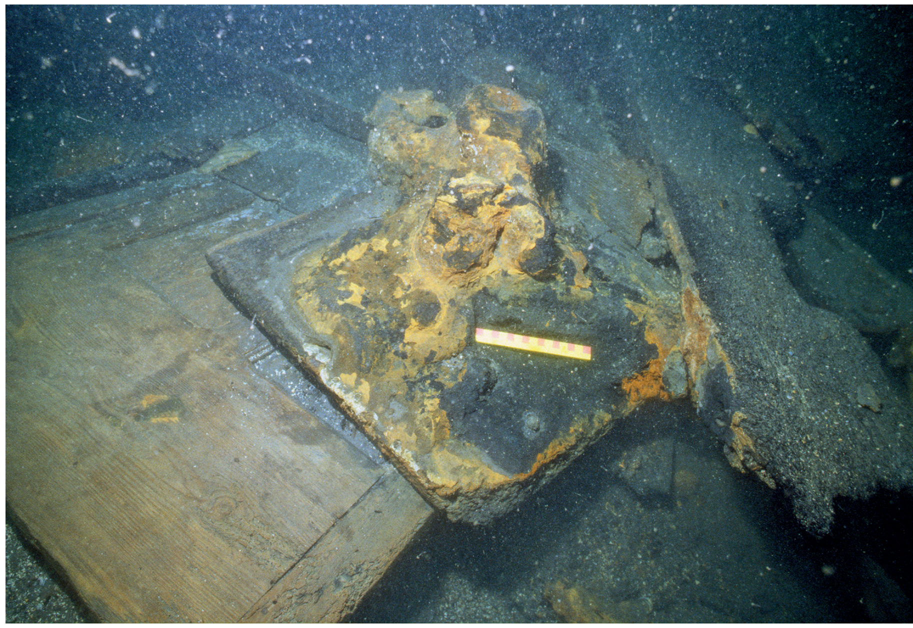


Illustration 215
Gun-port lid at **088.087** lying on top of the framed-and-panelled door [17].
Scale 15 centimetres (DP 173891)

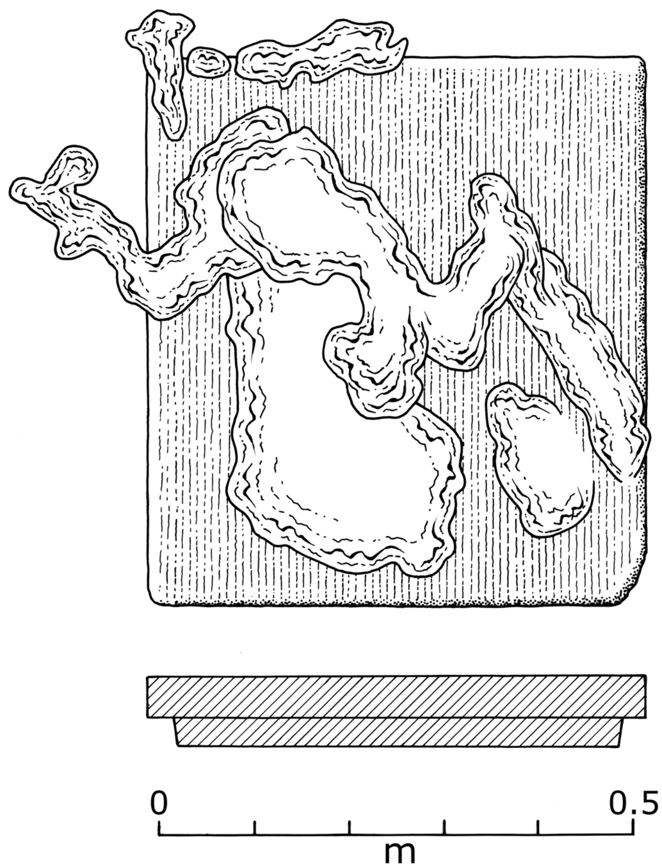


Illustration 216
Gun-port lid with concretion associated with its hinges. Drawn in situ and from photographs. Its dimensions are reliable but its geometry may not be precise.

Cartridge-box

[84] DP97/A009, **077.095**, a segment of a hollow cylindrical object with a solid base, turned from poplar (*Populus tremula*) (Illus 217–18). Its external diameter is estimated as 120mm and its internal diameter 94mm. The base is 78mm thick and its surviving overall height is 378mm, although the extreme top is missing. An external collar of semi-circular section surrounds the exterior 275mm from the foot, and four narrow beads are spaced at roughly equal intervals from the base upwards. The object is shown restored to its estimated diameter in Illus 218.

A substantial number of almost identical objects, most of them complete and with associated lids, have been recovered from the wreck of *Invincible* (1758) (Bingeman 2010: 107–10). These have been identified as the boxes in which gunpowder-filled cartridges of paper, parchment, or cloth were carried from the powder-room to the gun-decks during action. The *Invincible* boxes are in three sizes, appropriate to 9-, 24- and 32-pounder guns. Their flanged lids plug into the tops of

Illustration 217
Segment of a wooden powder-cartridge box 84 in situ. Scale in centimetres
(Steve Liscoe, DP 173946)

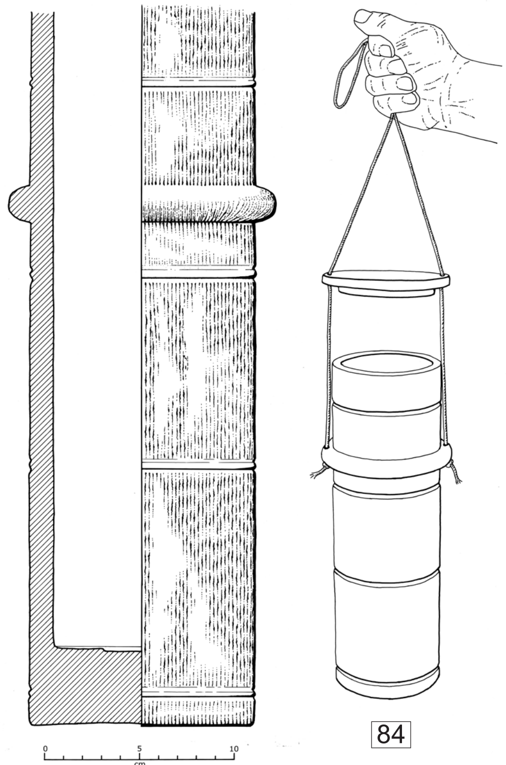


Illustration 218
Drawing and reconstruction of the wooden powder-cartridge box 84 (DP 174824)

the boxes. Looped lanyards anchored by terminal knots in holes drilled through the collars pass through holes in the flanges of the lids. Thus when a box was slung its lid was held secure, but when the lanyard was released the lid could quickly be opened and the cartridge extracted, although the lid would remain secured to the lanyard. A diagrammatic reconstruction of the system is shown in Illus 218. This simple procedure, well suited to the stresses and confusion of battle, is similar to that followed by musketeers with their bandolier-slung powder boxes.

The efficacy of this simple design is emphasised by the century that separates the *Invincible* and Duart Point wrecks, during which it remained essentially unchanged. It apparently continued in service until the end of the smooth-bore muzzle-loading era, as evidenced by a detail showing a wounded powder-monkey holding a lanyard-slung collared powder-box in Denis Dighton's well-known painting *The Fall of Nelson at Trafalgar*, painted in 1825 and now in the National Maritime Museum (BHC0552).

As far as I am aware the Duart Point find is the earliest recorded example of the collared type of cartridge-box, but earlier forms are known. Turned wooden cases without collars are known from *Vasa* (Cederlund 2006: 351), and while these have tentatively been identified as case-shot canisters I am informed that their exterior diameters are too great for the calibres of the ship's largest guns so they cannot have served this purpose. Their interior diameters do, however, match the guns' calibres, so they are more plausibly identified as powder-boxes (Fred Hocker pers comm). Sheet-copper powder-boxes with lids have been found on the *Batavia* wreck (1629). A loaded iron gun of culverin calibre (125mm) from *Batavia* contained a tampion, wadding, a 110mm roundshot, and a linen powder-cartridge (Green 1989: 54, 64–5, 67)

A 1665 inventory of ordnance stores in the Tower of London notes 2608 'Cases of wood for Cartouches' representing all calibres from 3-pounders to 'Cannon of 8 [inches calibre]' (TNA WO55/1699, transcribed by Blackmore 1976: 309). There are earlier indications of cartridge containers, though their forms are not specified. In 1558 William Wynter instructed that 'if he [the master-gunner] shall need to lade his brass or cast pieces, to do it by cartridge covered in mantles [a word meaning, in this context, some kind of protective container], or some other thing out of hazard of fire' (Corbett 1905: 367). Lord Wimbledon's Fleet Instructions of 1625 state that in every ship there should be men 'of good understanding and diligence … forthwith appointed to fill carthouses [cartridges] of powder, and to carry them in cases or barrels covered to the places assigned' (Corbett 1905: Lord Wimbledon 1625/3/19).

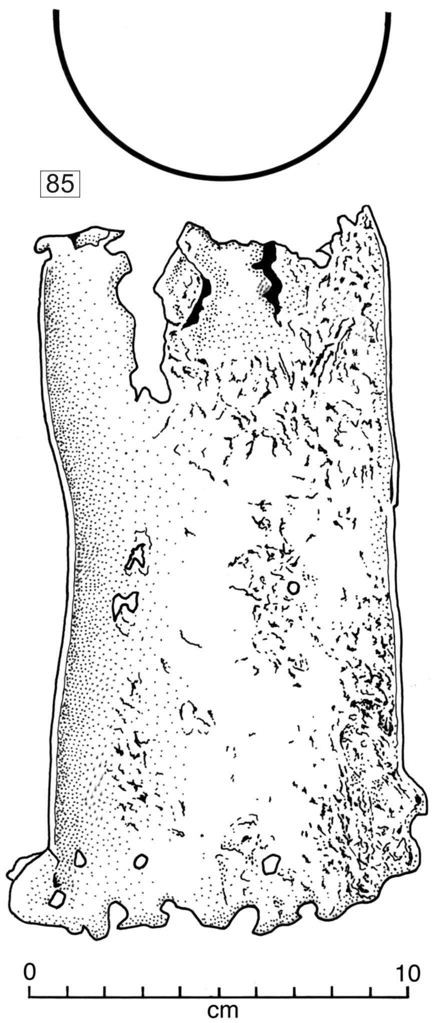
Sir Henry Mainwaring, writing in the 1620s, has much of relevance to say on these matters, and is here quoted in full:

> A cartridge is a bag made of canvas which is reasonable good, being made upon a former, the diameter whereof must be somewhat smaller than the cylinder of the piece, and of such a length or depth as that it shall contain just so much powder as is in the charge of the piece. This is wondrous necessary for our great ordnance in fight both for speedy lading our ordnance and also for saving the powder, which is in danger to be fired if in fight we should use a ladle and carry a budge barrel [an open powder-barrel] about the ship. These cartridges are many times made of paper, parchment, or the like, but are not so good as the other. There are also other cartridges, or more properly are to be called cases for cartridges, which are made of latten [brass], in which we put these other cartridges to bring alongst the ship so much the safer from fire, till we put them into the piece's mouth; which is a care that in fight there cannot be too much diligence and order used (Manwaring & Perrin 1922: 119–20).

Towards the end of the 17th century Thomas Binning (1676: 109) recommended that sea-gunners should have 'to every piece 24 cartridges at least, ready made, to wit 12 filled and 12 empty in sort', and keep them in marked chests or barrels.

The appearance of an item which suggests the application of such procedures on a small vessel of limited importance on a remote Scottish station in 1653 has wider implications. Ships largely constructed of wood, fibre, and tar were naturally combustible, and when gunpowder, the use of fire in battle, and the malign intentions of an enemy eager to exploit every weakness are added to the mix the dangers become real and immediate. The carefully designed powder-box from the Duart Point wreck hints at well-established procedures of risk-management, with secure gunpowder stowage, spark-resistant handling arrangements, and safe delivery to the guns when required in spark-proof containers which were easy to carry and operate. The sophisticated powder-handling routines of Nelson's era may have had earlier roots than has previously been supposed.

85 DP00/171, **106.079**, damaged semi-circular copper-alloy powder-scoop, 190mm × 88mm (Illus 219). Evidence of nail-holes for attaching to a wooden former along the rear edge. Appropriate to a bore of saker calibre (3½ins, firing a ball of *c* 5lb).



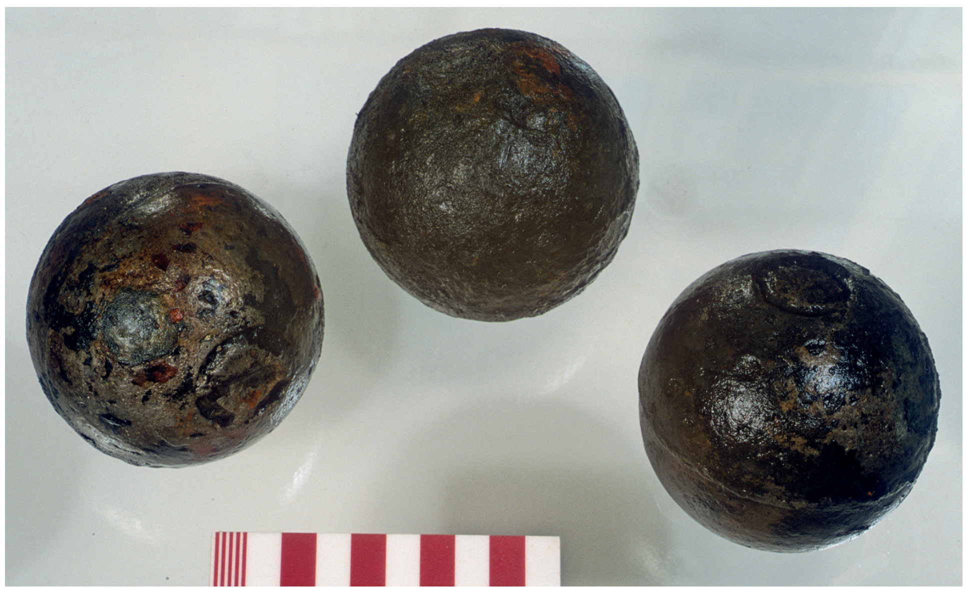


Illustration 220
Three cast-iron roundshot 86 of saker calibre (*c* 5-pounder). The piece on the right shows the flash of a two-part mould around its middle, and on the top the cut-off sprue scar. Scale in centimetres

Illustration 219
Copper-alloy powder-scoop 85

Illustration 221
Outside and inside views of two conjoining segments of a wooden shot-case 87
(DP 174293, DP 174294). Note the grooves for cord bindings

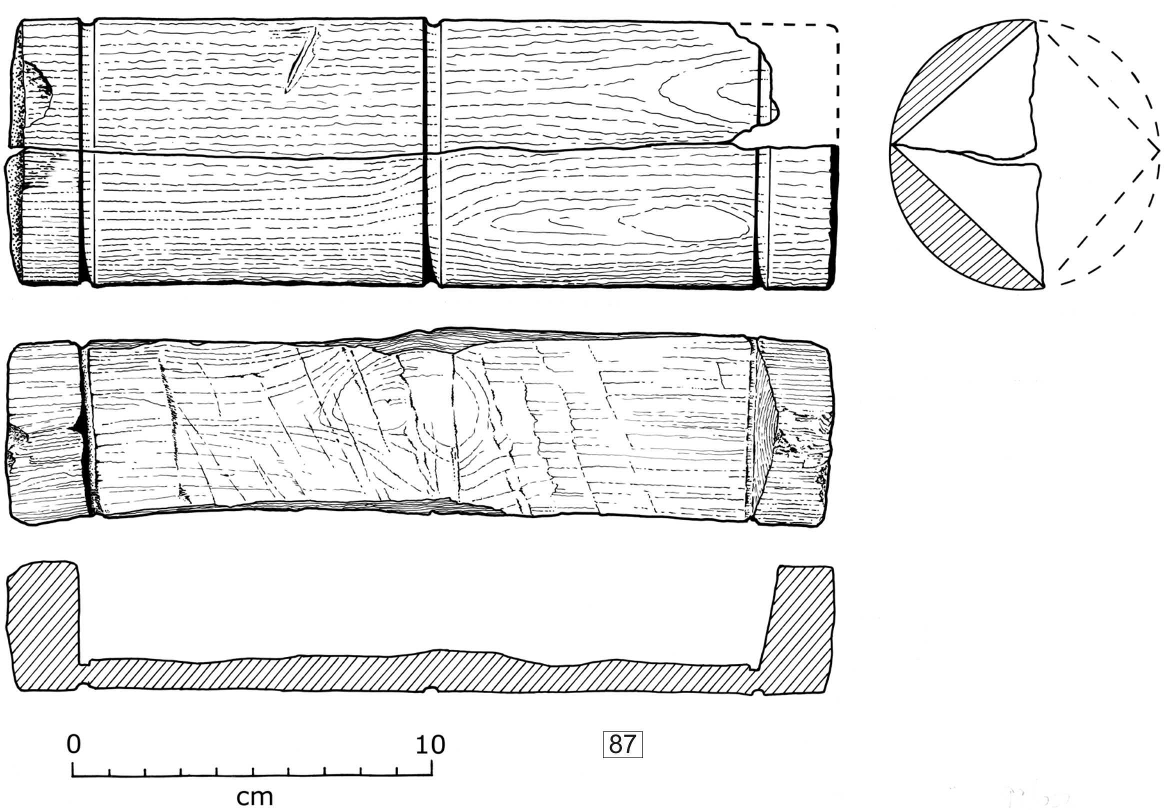


Illustration 222
The shot-case segments 87

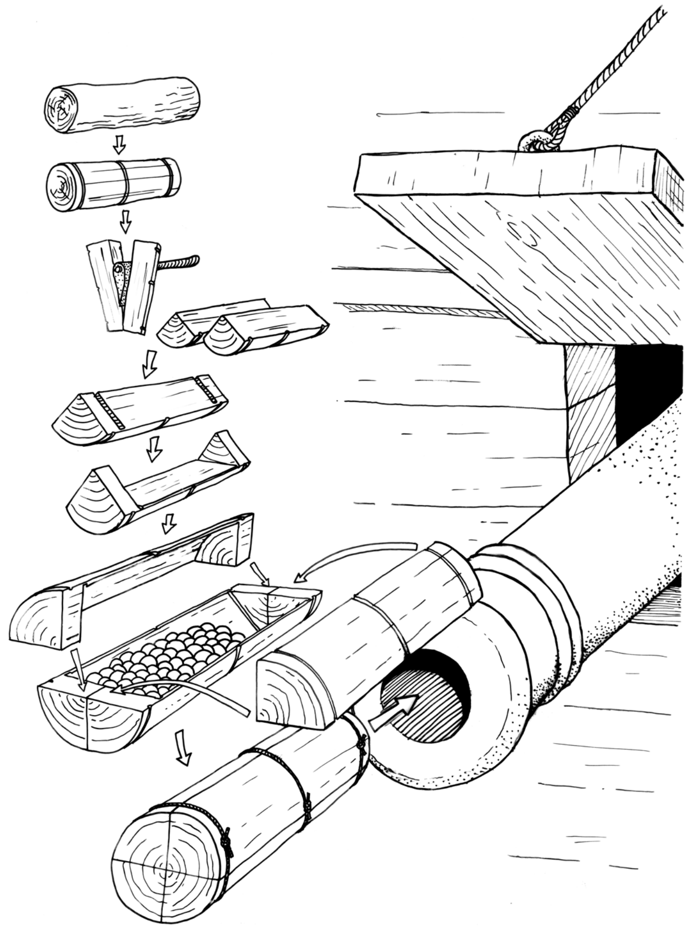


Illustration 223
Reconstruction of the processes involved in the manufacture and operation of case-shot (Graham Scott DP 174819)

7.6 Projectiles

Iron roundshot

86 DP99/122, inside wooden chest 110, **095.088**, three cast-iron roundshot (Illus 220). They were accurately cast in two-part moulds, leaving distinct mould-lines around their circumferences and scars where the sprue had been chiselled off. Their diameters are 84mm (3.3in) (two examples) and 85.5mm (3.4in). Their original weights, assuming a specific gravity of 7gm/cm^3, would be 4.8 and 5.05lb respectively (2.18kg and 2.29kg), straddling the 5lb saker median.

Wooden case and burr-shot

87 DP99/032, **075.094** and DP99/076, **079.096**, two conjoining segments of a four-piece cylindrical wooden container were found close to Gun 8 (Illus 221–2). The container had been turned from a small-diameter piece of alder roundwood (*Alnus* sp) (a round billet, probably from a straight branch), with growth-rings radiating from its centre. Such work would be well suited to a simple pole-lathe. Three grooves had been turned around the cylinder, one towards each end and one in the middle. The billet had then been quartered along the grain with an axe (the radial grain-structure facilitating this operation) and saw-cuts made close to the ends of each piece, allowing the central waste to be removed. Tool-marks suggest that the latter operation was carried out with a draw-knife, perhaps used in conjunction with a shaving-horse. These basic but effective processes are typical of a traditional woodland craftsman, probably working in the forest using green wood (Abbott 1989). Because the quarters had been split rather than sawn none of the wood would be lost to kerfs (the width of saw-cuts), and the pieces would reassemble as a true cylinder held together with cords around the grooves. The case would hold the projectiles secure in the barrel, but disintegrate during firing. Once clear of the barrel its load of lead balls would spread in an expanding cone of fire (Illus 223). Similar wooden cases of four conjoining pieces were found on the *Batavia* wreck (1629) (Green 1989: 60).

The reconstructed container is 76mm (3in) in diameter and 230mm (9in) long with an internal box, formed by the cut-out segments, 50mm (2in) wide and 180mm (7in) long, with a capacity of *c* 450cc. This would be sufficient to contain about 48 lead balls of 19mm (¾in) diameter, which is the 12-bore (12 to the pound) calibre of many of the musket balls found on the site. The diameter of the container, and its capacity for 48 balls with a total weight of 4lbs (1.81kg), match the projectile specifications of a minion drake.

Several musket-calibre lead balls recovered from the site have had their surfaces systematically gouged with a sharp implement (see Chapter 8). These were probably intended as dum-dum rounds to be fired from muskets (Foard 2012: 104) – captured royalists were executed at Colchester when found in possession of such bullets (Carlton 1992: 322–3). They might also have been intended for use in wooden cases like the one described above. An ordnance inventory of 1634/5 (TNA WO55/1690, cited by Blackmore 1976: 287–306) contains several references to wooden cases filled with burr shot, and while there is no positive indication that the projectiles were of lead, the term 'burr' might imply roughening or gouging in the manner noted on the Duart Point examples. However, recent experiments have shown that acceleration forces on a load of cased lead balls fired from a cannon barrel smoothed and distorted them (Foard 2012: 104; see Chapter 8). Contemporaries may not of course have been aware of this effect, so the question remains open. John Smith (1627:

86) describes cases made of 'two pieces of hollow wood joined together … fit to be put in the bore of a Piece', and filled with 'any kind of small Bullets, Nails, old iron or the like'. Two-part wooden cases filled with fractured flint have been recovered from the wreck of *Mary Rose* (Hildred 2009: 320).

Contemporary sources identify such projectiles as being particularly suited to drakes. The Navy Commissioners' detailed consideration of drakes during their meeting in March 1627 noted the difficulties encountered with the breech-loading guns previously used in an anti-personnel role, observing that they are 'subject to tumble out of their cases and to offend the Gunner that gives fire through the vent of their chambers which are worn or can seldom be fitted as they ought'. Closed-breech drakes, on the other hand, 'are more nimble and proper for their uses, as well through bulkheads as from the upper places of deck, half-deck, or forecastles' (Towes & McCree 1994: 41). The Duart ship's presumed rearward-firing minion drakes would have been well placed to fulfil such a role. It seems that the drake, for all its inadequacies as part of a ship's main armament, at least represented a significant if short-lived improvement in her close-quarter capability.