An Archaeological Study of *Zuiddorp*'s Lead Ingots

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Front cover: painting of *Zuiddorp* foundering on the reef by Stanley Hewitt, Western Australian Museum.

TABLE OF CONTENTS

List of Tables

List of Figures

Introduction

Lead (chemical symbol Pb) is a heavy, durable, comparatively soft and malleable bluish-grey metal; it is occasionally found native, but is more usually encountered within its principal ore, galena. Galena or lead sulphide (PbS), is a common heavy mineral with a dark lustrous appearance, similar to coal. Unlike coal, however, which has a specific gravity of 1.3, galena is significantly denser, with a specific gravity of 7.5 (Tylecote, 1962: 73). Galena is a mineral that is easily smelted by humans; lead melts at 327°C, and it is possible to smelt lead from crushed galena in a very hot camp fire. Due to this ease of extraction, coupled with the existence of silver yielding galena, lead is a metal that has been known to and exploited by humans since prehistory (Tylecote, 1962: 79).

An **ingot** (or **pig**) may be defined as:

The casting obtained when melted metal is poured into a mould (ingot mould) with the expectation that it is to be further processed (Macquarie Dictionary, 2006: 609).

The casting of metals into ingot form produces a convenient medium for their transport, trade and further processing. Ingots are usually cast in standard sizes, shapes and weights, and sometimes marked accordingly. The casting and trade of metal ingots is a practice that can be traced back to antiquity (Tylecote, 1976: 30).

Ingots found in archaeological contexts are generally cast from precious metals such as gold and silver, or else base metals intended for alloying or reworking, such as copper, tin, iron and lead. Metal ingots are rare finds in terrestrial archaeological contexts; being ephemeral, largely due to the fact that they were rarely stockpiled and melted down for recasting as tools, weapons, coins or other artefacts. In shipwreck contexts, however, finds of significant quantities of ingots have been made. A wrecked cargo ship provides the maritime archaeologist with the opportunity to examine a ‘time capsule’, which may have laid undisturbed on the seabed for centuries, or even millennia. For example, the discovery of a large number of copper and tin ingots on a Bronze Age shipwreck at Uluburun, located off the south Turkish coast, has proven to be an invaluable resource in the study of metallurgy and trade in the ancient Mediterranean (Pulak, 1991).

Lead ingots are typically heavy and bulky items, lending themselves to transport by sea. They also have the advantage of being ideal ballast for trimming sailing ships, a quality that mariners have exploited since the earliest boats of the Mediterranean. Studies of metal ingots from shipwrecks serve to document many aspects of the rapidly expanding and fast changing technologies and trading patterns around the world (Craddock and Hook, 1995: 67).

Project Background

On April 2nd 1595, three Dutch merchantmen, *Mauritius*, *Hollandia* and *Amsterdam,* accompanied by the small yacht *Duifje*, sailed from the Texel roadstead in the North Sea. The departure of these four ships marked the beginning of the era of Dutch–Asiatic shipping, an era that was to see the Dutch Republic reach its zenith, or ‘golden age’ in the mid-seventeenth century (Israel, 1989: 197).

In January 1597, *Amsterdam* was set on fire and lost near to the island of Bawean in the Java Sea (Bruijn, *et al.*, 1979: 3). In 1598, following the return of the remaining three ships, a large number of Dutch companies, keen to profit financially, jumped onto the bandwagon of the Asian spice trade. From 1602 onwards, however, nearly all ships sailing from the Dutch Republic to Asiatic ports were fitted out by a single, united concern, the United East India Company, or *Verenigde Oostindische Compagnie* (VOC). The Company’s principal objective was to profit from trade with and within Asia. To achieve this aim the VOC was engaged not only in trade. The VOC also built ships and fitted them out, it constructed warehouses, forts and even harbours and cities overseas; it conquered territories in Asia and sometimes interfered drastically with agrarian societies to obtain its desired results (Bruijn, *et al.*, 1987: 1).

Following the establishment of the VOC in 1602, for the next two centuries the Company’s ships plied the trade routes of the Indian Ocean from the Red Sea to Japan (Gaastra, 2003: 11). In response to threats to the initial VOC trading centre at Bantam on the island of Java in 1610, the VOC outpost Batavia was established for security reasons at the settlement of Jakarta. This went on to grow into the principal VOC trading centre in the East Indies (Gaastra, 2003: 40). By 1652 the VOC had also established a base at the Cape of Good Hope, where its ships stopped *en route* to the East Indies to take on supplies (Gaastra, 2003: 56).

Thus, by the mid-seventeenth century, the previously marginal commercial empire of the North Netherlands maritime provinces continued to expand and grow in vitality (Israel, 1989: 6). With the decline in Portuguese primacy, much of the lost leverage over the Asian spice markets was picked up by the Dutch. The Dutch maritime zone moved to the top of the global hierarchy of exchange, emerging as the hub of what may now be termed a mono-nuclear system, the first and for most of early modern times, the only true world entrepôt (Israel, 1989: 6). By the first quarter of the eighteenth century the VOC was at the height of its power, operating in effect as a self-contained state with the Dutch government's authority to negotiate with nations and to wage war. Its administration, shipyards, cargo procurement and operating protocols were highly systematised and relied upon maritime trading voyages to the Far East (Martin, 2005: 179).

Once the shipbuilding industry had become well-established in the mid-seventeenth century, the shipyards of the VOC Chambers were permanently in work. The Amsterdam and Zeeland Chambers had adequate facilities for building several large ships at one time (Bruijn, *et al.*, 1987: 27). The ship *Zuiddorp* was owned by the VOC's Chamber of Zeeland, who commissioned her construction on 2nd December 1700. *Zuiddorp* was built as a *retourschip,* or return-voyage ship, built specifically to undertake return trading voyages to the East Indies (Playford, 1996: 33; van Duivenvoorde, 2008: 29).

Due to the VOC's need for hard currency for the purchase of goods in the Indies, their ships typically carried large quantities of specie or gold and silver ingots on their outward-bound voyages. Similarly, on their homeward voyage the ships were laden with valuable cargoes of spices and other precious Asiatic commodities (Boxer, 1973: 769). For this reason, despite the fact that they were essentially trading vessels, the large Dutch East Indiamen were also armed so that they had the means to defend themselves from pirates and privateers. *Zuiddorp* was armed with 40 cannon made up of ten 12-pounders, twenty-two 8-pounders and eight 4-pounders, some of which were breech-loading swivel guns (NA, *Verenigde Oostindische Compagnie*, 1.04.02, nr. 10459, 17 July 1712, loose paper). East Indiamen differed from warships, however, in their hull dimensions and structural design. The Indiamen were *spiegelschepen,* or square-tuck ships, and were built with maximum cargo capacity in mind. The resultant broad aft end of the ship had the added advantage of providing additional space for officer and passenger cabins (Bruijn, *et al.*, 1987: 27).

Figure 1: The stern of Cees de Heer's model of *Zuiddorp*
(photograph by Patrick Baker, Western Australian Museum)

Zuiddorp was constructed in 1701 by the Zeeland Chamber of the VOC to specific guidelines that were laid down in 1697 by the VOC directors, the *Heeren XVII* or 'Gentlemen Seventeen' (van Dam, 1927: 476; van Duivenvoorde, 2008 484-498). The ship was one of the largest of the three classes of ships built by the Company at that time. *Zuiddorp's* dimensions are listed below.

Table 1: Dimensions of VOC ship *Zuiddorp*.

Length	Beam	Depth of hold	Tonnage
160 feet (45.28 m)	40 feet (11.32 m)	17 feet (4.81 m)	1152 tons

(van Dam, 1927: 476)

Zuiddorp made two successful voyages to Batavia, departing from Wielingen in 1702 and 1707 (Bruijn, *et al.*, 1979: 274, 296). Her fateful third voyage commenced on 27th July 1711, when she set sail from the port of Vlissingen on the south coast of the Zeeland island of Walcheren. After a brief stop at Wielingen, she put to sea on 1st August 1711, accompanied by the flute ship *Belvliet*; their destination was the VOC port and trading centre of Batavia (Bruijn, *et al.*, 1979: 312). *Zuiddorp's* principal cargo was some 250,000 guilders worth of newly minted silver specie, which was intended as capital for the purchase of spices and other commodities by the VOC in Batavia (Playford, 1996: 43).

By the time that the two ships reached the Cape of Good Hope, *Belvliet* had lost 60 crew of the 164 who had come on board in Flushing. *Zuiddorp*, arriving on 23rd March 1712, after seven months at sea, had lost 112 of her 286 crew (Bruijn, *et al.*, 1979:312). The length of the voyage and the number of dead were unusually high. After spending time at the Cape, *Zuiddorp* set sail again on 22nd April, accompanied by the VOC Chamber of Amsterdam's ship *Kockengen*. *Kockengen* arrived at Batavia on 4th July 1712 (Bruijn, *et al.*, 1979: 314), whereas *Zuiddorp* and her crew never reached their destination.

The *Zuiddorp* shipwreck is unique in that it is the only one of the four Dutch shipwrecks known along the Western Australian coast from which no survivors succeeded in reaching their countrymen at Batavia (McCarthy, 1998: 41); the other three wrecked Dutch East Indiamen being: *Batavia* (sank in 1629), *Vergulde Draak* (sank in 1656) and *Zeewijk* (sank in 1727).

The *Zuiddorp* wreck is located at the foot of the precipitous cliffs to which it has given its name (spelt Zuytdorp), on the remote, rocky Western Australian coastline between Gantheaume Bay and Shark Bay. The nearest settlement is the crayfishing and holiday town of Kalbarri, approximately 62 km to the south, at the mouth of the Murchison River (Playford, 1996: 68).

Local Aboriginal people would surely have had knowledge of the *Zuiddorp* wreck. There is evidence that the wreck's survivors lit at least one large signal fire on the cliff top in an attempt to attract a passing ship to rescue them (Playford, 1996: 206). This would have been visible for many kilometres, and not only in a seaward direction. However, it was not until the wreck site was discovered in the 1920's by stockman Tom Pepper that its attention was drawn to the larger Western Australian public (Playford, 1996: 99). Due to its remote location and the treacherous diving conditions that prevail, the *Zuiddorp* wreck has always proved to be a difficult archaeological site to investigate. A number of expeditions to the site have been launched, including: the *Sunday Times* sponsored expedition in 1941, the *Daily News* sponsored expedition in 1954, the *Daily News* sponsored expedition in 1958 and the expedition mounted by Tom Brady with Max and Graham Cramer, which resulted in the first successful dive and salvage of underwater artefacts from the wreck, in May 1964 (Playford, 1996: 101-145). In 1968, diver Alan Robinson made an announcement to the press of his finding of large quantities of silver bullion on the *Zuiddorp* (Playford, 1996: 155). The destructive looting of the wreck site that followed spurred the Western Australian Museum, as the responsible government agency, to intervene (Playford, 1996: 163).

Museum divers Harry Bingham, Geoff Kimpton and Colin Powell dived on the *Zuiddorp* wreck on 31st January 1971, succeeding in recovering a variety of artefacts, including 3300 silver coins (Playford, 1996: 165). During the course of the next four decades the Western Australian Museum has been actively involved in researching and protecting the site. Under the directorship of Jeremy Green and his successor Michael McCarthy, who took over as director of the *Zuiddorp* Project in 1986, the Western Australian Museum's Department of Maritime Archaeology has conducted an extensive programme of archaeological research on the wreck. This included archaeological excavations of terrestrial sites thought to be associated with survivors from the *Zuiddorp* wreck (Weaver, 1994). A study of shell middens on the cliff top adjacent to the wreck site concluded that the shell deposits are of indigenous origin (Morse, 1988). The fate of the *Zuiddorp* shipwreck survivors remains one of the most enigmatic questions in the history of Western Australia (McCarthy, 2006: 95).

In addition to directing ongoing research and monitoring of the site, McCarthy also directed two successful seasons of underwater archaeological excavations, which were undertaken in 1987 and 1996 (Kimpton and McCarthy, 1988; McCarthy, 1990; McCarthy 1998). A site plan and profile drawings of the *Zuiddorp* wreck site were prepared with the assistance of Museum volunteer Stanley Hewitt, a retired architect/draughtsman. Dimensions from a model of *Zuiddorp* built by Cees de Heer were used to establish the likely wrecking process of the stricken ship (McCarthy, pers. comm. October 2009). During the course of these excavations, and despite the extensive looting that had previously occurred, a large quantity of silver coin, a damaged bower anchor, cannon, as well as a variety of other artefacts were recovered from the site. Of an estimated 80 lead ingots observed on the wreck, with many more presumably lying buried beneath the sand (McCarthy, 1990: 37); 21 ingots, the subject of this dissertation, were successfully moved from the crevices of the reef using lifting bags, floated into deeper water and hoisted aboard a workboat (Western Australian Museum File, MA-460/71). The lead ingots recovered from the *Zuiddorp* wreck are presently on display or stored in the Western Australian Museum's collections in Fremantle and Geraldton.

Figure 2: Lead ingots lying on the seabed at the *Zuiddorp* wreck site

Figure 3: Lead ingots lying on the seabed at the *Zuiddorp* wreck site (photographs by Jeremy Green, Western Australian Museum)

To date, no detailed studies have been undertaken of lead ingots from the four Dutch shipwrecks along the Western Australian coast. The *Zuiddorp* ingots derive from an era when the ships of the European, and particularly Dutch traders created the first global economy in the seventeenth and eighteenth centuries. They are archaeologically significant in that they comprise the only significant assemblage of lead ingots from the four Dutch shipwrecks found in Western Australian waters, and therefore warrant analysis and study.

Archaeologically, metal ingots derive much of their value and from the context in which they are discovered. A known shipwreck, such as that of *Zuiddorp*, not only provides a terminal date for the ingots, but tells us from which port they came, as well as to where they were bound. This information is important in the accurate documentation and mapping of the expanding maritime commerce that was flourishing around the world in the Post-Medieval period (Craddock, *et al.*, 1995: 67).

Lead Ingots from Shipwreck Contexts: Literature Review

A number of archaeological studies of lead ingots deriving from shipwreck contexts have been undertaken to date. Those relating to Dutch East Indiamen and other contemporary or relevant shipwrecks are reviewed in this chapter.

Lead ingots of VOC ship *Hollandia* (1743)

One of the first and most prominent studies of lead ingots from VOC shipwrecks was conducted by Lynn Willies on those recovered from *Hollandia* (Willies, 1985). *Hollandia* was one of the largest ships of the VOC's fleet in the latter part of the eighteenth century and was constructed between 1742 and 1743. The ship was wrecked on her maiden voyage on 13th July 1743, off Gunner Rock in the Isles of Scilly. Amongst *Hollandia*'s cargo, archaeologists recovered 238 lead ingots, with a total weight of approximately 18,000 kg (Cowan, *et al.*, 1975; Gawronski, *et al.*, 1992).

In 1974, Willies studied the *Hollandia* ingots on St Mary's Isle in the Isles of Scilly. He used a block and tackle, suspended from a derrick, on which a set of scales were hung to measure and weigh the lead ingots. Each ingot was weighed to the nearest half kilogram and the maximum length and width dimensions were measured to the nearest half centimetre. The maximum thickness of each ingot was measured at its central point. Each ingot was assigned to one of ten typologies, called groups, based on its physical characteristics. The ingots were cleaned of marine growth as best as was practicable, prior to their inspection for any markings (Willies, 1985: 234).

Willies found that there was considerable variety in the form of the ten basic ingot groups. The majority of the ingots were likely to have been cast in stone or iron moulds, due to their well-formed mould (bottom) surfaces. In contrast, ingots cast in sand or earthen moulds typically have poorly-formed, irregular mould surfaces. The six ingots from Group 4 were the only exception to this, and these were probably cast in a basic sand mould that would have been formed by scooping a shallow trench by hand, or with a small scraper. Some of the ingots exhibited an overhanging lip at the margins of their cooling (top) surfaces, indicative of overfilling of the mould. Others (Groups 9 and 10), appear to have been deliberately cast with stepped ends to facilitate their handling (Willies, 1985: 234).

Any markings visible on historical lead ingots are a valuable addition to the archaeological record, and may assist with dating and determining an ingot's provenance. Willies noted that apart from two exceptions, the marked *Hollandia* ingots were stamped on their cooling surfaces after they were cast, using a hammer and die. Approximately a quarter of the ingots that were inspected appear to have no markings. Those with marks predominantly display a scatter of often repetitious motifs, whereas two sets from Groups 5 and 9 were marked clearly and precisely at one end, suggesting the same maker or merchant (Willies, 1985: 237).

The weights of the *Hollandia* ingots indicate that the lead smelters aimed to produce ingots of a fairly consistent mass. These vary from approximately 50 kg (110 lb) to 90 kg (198 lb) (Willies, 1985: 233). Lead, having a density of 11.3 g/cc, requires only small differences in the fill level of the mould to cause considerable variation in ingot weights. This variation is estimated to be in the order of 10 kg per cm depth (Willies, 1985: 234). Weight differences between similar sized ingots may also be attributed to internal contraction pipes, or else the presence of slag lead within the casting (Willies, 1985: 234). Willies considers the ingots' weights and their markings as significant indicators of their provenance, concluding that there are grounds for believing that they originated in Derbyshire in the north of England (Willies, 1985: 247).

Lead ingots of VOC ship *Kennermerland* (1664)

Another study of lead ingots deals with those found on the wreck of the Dutch East Indiaman *Kennermerland* (Price, *et al.*, 1980). This ship was wrecked on 20th December 1664, off Stoura Stack in the Out Skerries, Shetland. The wreck site was identified in 1971 and investigated by maritime archaeologists during the course of four seasons of excavations in the 1970s (Forster and Higgs, 1973; Price and Muckelroy, 1974, 1977, 1979). The 119 lead ingots that were recovered from the site comprise the total assemblage that was visible on the seabed; it is however possible that some ingots may have been salvaged shortly after the shipwreck. A letter from Mr. Partick Blair, dated 19th June 1665, writes of '*much iron and lead lying there,*' and mentions arrangements made with local boatmen for them to have a share in any goods that they could recover (Price, *et al*., 1980: 7).

The *Kennermerland* ingots were predominantly located at the bottom of a deep gully south of Stoura Stack, or else found piled up on the surrounding seabed. They were freed and lifted by divers by attaching each ingot to an empty metal barrel. The barrels were lashed together to form a string of between five and nine, and then sequentially filled with air to provide the necessary lift. Once that the string of barrels, with ingots attached, was floating free, the whole apparatus was towed into port at high tide by a workboat (Price, *et al*., 1980: 10). Once on shore, the ingots were recorded by measuring their dimensions, weight and markings. Detailed photographs were taken and scale drawings made (Price, *et al*., 1980: 10).

The 119 *Kennermerland* ingots are boat-shaped, a form that is easy to cast and convenient to sling (Price, *et al*., 1980: 10). With a mean weight of just over 140 kg (309 lb) (Price *et al*., 1980: 19), they are heavy ingots that conform to the typical English 'great pig' type, as opposed to the French 'salmons' or Spanish flat rectanguloids (Price, *et al*., 1980: 23). Marks are stamped on the ingots' flat cooling surfaces, and 37 different motifs were noted, of which a single ingot may display anything between none and six. Over half of the *Kennermerland* ingots displayed some kind of markings (Price, *et al*., 1980: 10). Thirteen shape classes were identified, as well as six ingots which do not fit into any class. Whilst recording the ingots' shapes and forms it became apparent to the researchers that some of the ingots were so similar that they may have been cast in the same mould, or at least from the same mould pattern (Price, *et al*., 1980: 10). In order to glean the maximum amount of information from the *Kennermerland* ingots, the researchers studied five attributes of the assemblage: ingot shape, weight, metallurgical constitution, markings and the ingots' locations on the seabed (Price, *et al*., 1980: 17).

Metallurgical analysis was not undertaken during the course of this work, although it was noted that such a study may help to identify the source of the lead that was used in the casting of the ingots (Price, *et al*., 1980: 17). Such analysis could also determine if *Kennermerland* was loaded with lead from a single source (Price, *et al*., 1980: 17). The ingots are generally of a relatively consistent mass, suggesting that the manufacturers tried to cast them at a standard weight (Price, *et al*., 1980: 19).

The researchers utilised the *CLUSTAN* software on Cambridge University's 370/165 computer to analyse the correlation between ingot shape class and markings. This data was plotted on a dendrogram which represents the relationship between a large number of items, showing how they come together in fewer and larger clusters at successively lower degrees of similarity (Price, *et al*., 1980: 22). The results of the cluster analysis show a close correlation between ingot shape and markings, suggesting that the markings are connected in some way with ingot production. In view of the fact that there is no relationship between ingot shape class and ingot weight, there is no correlation between ingot weight and markings (Price, *et al*., 1980: 21).

Lead ingots of VOC ship *Kampen* (1627)

One hundred and three lead ingots of varying form and with a wide variety of markings were recovered from the wreck of the VOC ship *Kampen* by the Needles Underwater Archaeology Group. The ship was lost off the Needles rocks on the Isle of Wight in 1627. Unfortunately the majority of the ingots were destroyed by a fire after only initial studies had been undertaken (Larn, 1985: 97). A number of the *Kampen* ingots that escaped the fire were sold at auction in Penzance, Cornwall in 1983 (Lane, 1983: 74-78).

The ingots were found to be lying *in situ* on the seabed in a compact, east – west aligned arrangement. They covered an area of the wreck site measuring approximately 10 m^2. The dense concentration of ingots appeared to reflect the way that they had been stacked in *Kampen*'s hold. Initial estimates of a total of approximately 60 ingots soon grew as excavations proceeded and more ingots were revealed. The mean weight of the ingots was 62 kg (137 lb), making it possible for them to be recovered by divers one by one, using a standard lifting bag (Larn, 1985: 97). The recording of the lead ingots from *Kampen* was conducted following the methods used on the ingots recovered from *Hollandia* 1743 (Cowan, *et al.*, 1975; Willies, 1980) and *Kennermerland* 1664 (Price, *et al*., 1980), described above.

Marine growth was removed from the ingots using a wire brush, taking care not to damage any marks. Each ingot was then drawn and photographed and details of any visible marks recorded. Measurements were taken along the maximum length and width on the cooling surface and the maximum thickness was measured to the nearest half centimetre. The ingots were weighed to an accuracy of half a kilogram. Metallurgical samples weighing approximately 10 g were taken from the mould surface of each ingot using a small chisel. The researchers intend to compare the metallurgical signature of the *Kampen* ingots with signatures from known lead sources, in an attempt to determine the origin of the metal (Larn, 1985: 98).

All of the ingots recovered from the *Kampen* wreck appear to have been open cast, most probably in clay or loam moulds. This has produced ingots of a boat-shaped, asymmetrical form which are rounded on the mould surface, with a flat cooling surface on which markings were scored or stamped. An interesting feature of the *Kampen* ingots, not seen on ingots from other shipwrecks, is the presence of cuts on their lateral edges. These notches are located opposite each other, towards the heavier end of the ingots and are likely to have been used to make the ingots easier to handle with ropes. Once secured by two half hitches, the notches prevent the ingot from slipping out of the eye of the rope (Larn, 1985: 98). It is also possible that the ingots were fitted with rope grommets that were left in place during their transportation (Larn, 1985: 100).

During the course of measuring and weighing the ingots, it became apparent to the researchers that although the bulk of the ingots were very similar, they could be categorised into well-defined groups. Once the data had been recorded, the ingots were grouped based on similarities in form, dimensions and weight. The classification highlighted a close correlation between ingot form and markings (Larn, 1985: 101). The researchers classified the ingots into eleven groups, including one unclassified group comprising a single ingot, with two forms, Groups 8 and 10 standing out as markedly different from the remainder (Larn, 1985: 100).

The *Kampen* ingots weigh between approximately 60 kg (132 lb) and 70 kg (154 lb), which is thought to relate to the sixteenth part of a fother, an English unit of account which was applied to lead. Ingots of this size are known as ‘pieces’. The fother varied per region, with values ranging from 991.5 kg (2186 lb) in London to 1280.3 kg (2823 lb) in High Peak Mill, Derbyshire (Larn, 1985: 107). The markings on ingots from Group 1 appear to have been struck individually using a chisel with an 8 cm wide blade (Larn, 1985: 101). The most common marking encountered was the stamped mark **AD**, which appears on 67 of the *Kampen* ingots, comprising 65% of the total assemblage (Larn, 1985: 101). Interestingly, ingot number 53 had a centrally located, 2 cm diameter hole bored through its heavier end, the purpose of which is unknown (Larn, 1985: 101).

In Group 2 the ingots were found to vary considerably in weight, despite having similar form and dimensions. This may be attributed to the use of inferior quality lead in the manufacturing process. Alternatively some of the ingots may have been adulterated with the addition of rocks or other material, to add bulk and cheat the purchaser. Internal casting pipes and the presence of slag from the smelting process are other possible explanations for the weight variation (Larn, 1985: 101). The ingots from Group 8 were notably different from the others, being narrow, deep and almost triangular in section. The mean weight for this group was 64.2 kg (141.5 lb) and all of the ingots had been struck with a chisel to form a six pointed star mark, depicted with three lines (Larn, 1985: 106). The ingots from group 10 were remarkable in that they lacked the **AD** marking, and were instead marked with a **B** crowned with a cross and star (Larn, 1985: 107).

Lead ingots of VOC ship *Adelaar* (1728)

In 1728 the Dutch East Indiaman *Adelaar* was outward bound from Middelburg to Batavia when she was wrecked on Greian Head, Barra, in Scotland's Outer Hebrides. Despite the fact that the wreck was extensively salvaged at the time, the site was found to retain a significant amount of archaeological integrity and was excavated by Colin Martin of the University of St Andrews in 1972 and 1974 (Martin, 2005: 179).

In December 1727, following two successful round trips to Batavia, *Adelaar* was commissioned for a third voyage under Willem de Keyser of Middleburg. The ship was carrying cloth destined for Japan, as well as a general cargo intended for Dutch consumption at the Cape of Good Hope and Batavia. A large consignment of yellow bricks and lead ingots was stowed in the ship's hull. Having served as ballast for the voyage, these building materials would have been used in VOC offices, warehouses and residences. *Adelaar* was also carrying a considerable amount of specie in seventeen numbered chests (Martin, 2005: 179). The ship set sail from the roadstead at Rammekens on 11th March 1728, heading into the North Sea and north around the British Isles. Two weeks later she was wrecked on a reef off the west Scottish coast and there were no survivors (Brujin, *et al.*, 1979: 400). Much of *Adelaar*'s valuable cargo, including almost all of the specie, was daringly salvaged by Captain Jacob Rowe during the summer of 1728. The wreck site was then rediscovered in March 1972 and archaeologically excavated over the course of two diving seasons (Martin, 2005: 184).

Fifty lead ingots were recorded from two underwater rock gullies on the *Adelaar* wreck site. Forty-two, comprising the majority of the assemblage, were found in one gully, with the remaining six in the other. A further two ingots were found outside the main excavation area. Four distinct typologies were identified and six ingots were recovered from the wreck for detailed recording (Martin, 2005: 201).

Table 2: Details of lead ingots from the VOC ship *Adelaar*

Ingot Group	Number of Ingots	Weight	Dimensions	Markings
I	21	65 kg (143 lb)	93 x 13 x 6 cm	**V**, **IB**, ‘Crowned’ **V**
II	27	61 kg (134 lb)	86 x 14 x 6 cm	**D**, **Q**, **IB**, **AD**
III	1	66 kg (146 lb)	67 x 16 x 6 cm	None
IV	1	50 kg (110 lb)	60 x 15 x 7 cm	None

(Martin, 2005: 201)

It is possible that the ‘**IB**’ marks on the Type I and II ingots are the initials of John or Joseph Bright, who were active in the lead industry in northern England’s Peak District during the earlier part of the eighteenth century (Willies, 1985: 245). Parallels in the markings on the *Adelaar* ingots exist with lead ingots studied from *Kampen*, *Hollandia* and the Poompuhar unidentified wreck, described below.

Lead ingot of VOC ship *Lastdrager* (1653)

A single lead ingot was recovered by archaeologists from the wreck of the Dutch flute ship *Lastdrager*, lost off the island of Yell in the Shetland Isles in 1653. The boat–shaped ingot measures approximately 80 cm in length, 25 cm in width, and 12 cm in thickness. There is a contemporary record of salvors recovering ‘*three slabs of lead weighing between 200 and 300 pounds each*’ from the wreck (Sténuit, 1974: 235; Green, 1977: 434).

Lead ingots of Poompuhar shipwreck, India

In 1991, archaeologists from India's Marine Archaeology Centre of the National Institute of Oceanography investigated a timber shipwreck approximately 3.5 km offshore from the ancient port of Poompuhar, Tamil Nadu, in the Bay of Bengal (Gaur, *et al*., 1997). Several artefacts were recovered from the wreck, including an iron cannon, a rudder pintle and gudgeon, gunpowder boxes and 18 lead ingots. The wrecked ship was partially buried on a seabed of coarse sand and it has been estimated that she was approximately 50 m in length, 15 m in beam and weighed between 100 and 150 tons (Tripati, *et al*., 2003: 227).

Approximately 50 lead ingots were visible on the wreck site, and the excavators believe that more may lie buried beneath the sand. A total of 18 of these ingots was recovered for study (Tripati, *et al*., 2003: 228). After cleaning, the ingots were classified into four typologies based on their shapes, weight and markings. The most striking and diagnostic of these markings is an inscription '**W. Blackett**'. Other markings noted include a '**D**' with a crown symbol and the numbers, presumably dates, **1791** and **1792** (Tripati, *et al*., 2003: 229).

Analyses of the lead ingots were carried out to identify their provenance and composition. Two techniques were used: trace element and lead isotope analyses (Tripati, *et al*., 2003: 230). These have revealed that the lead derives from the North Pennine lead mines in England and is of a high quality (~93%). Historical research has revealed that W. Blackett was a well known lead exporting company, owned by Sir William Blackett of Durham in the northeast of England (Tripati, *et al*., 2003: 225).

Lead ingots of United East India Company ship *Albion* (1765)

The ship *Albion* belonged to the English United East India Company, a rival and competitor of the VOC. She was wrecked in 1765 at the beginning of an outward-bound voyage to the East Indies, and lies southeast of Long Sand in the Thames Estuary (Redknapp, 1990: 23). The identity of the wreck was revealed using a combination of historical research, as well as an examination of salvaged material in 1985. Albion was loaded with 47 chests of silver at Gravesend on the south side of the Thames Estuary in December 1764.

Archaeologists from Marine Archaeological Surveys inspected the salvaged material from *Albion*, including a sample of 71 lead ingots, from a total of some 500 ingots that were stored at the Ramsgate Droit House (Redknapp, 1990: 26). The ingots are described as flat-topped and round-ended, corresponding to pieces (Whiting, *et al*., 1985: 107). All of the ingots bore at least one '**UEIC**' marking, indicating the United East India Company, the numbers **63** or **64** (repeated two or three times), as well as various other merchants' marks (Redknapp, 1990: 26).

A study of *Albion*'s original financial accounts indicates that 179,233 lb (81,298 kg) of lead was originally on board the ship. Considering that personnel from Marine Archaeological Surveys viewed an estimated 500 ingots at Ramsgate, weighing approximately 165.8 lb (75.2 kg) each; this would leave some 96,733 lb (43,878 kg) of lead, or approximately 586 ingots unaccounted for (Redknapp, 1990: 26).

Lead ingot from VOC ship *Huis te Kraaiestein* (1698)

Lead ingots are also known to have been recovered in South African waters from the wrecks of VOC ships *Huis te Kraaiestein* (1698) and *Merestein* (1702) (Willies 1985:233). One lead ingot recovered from the wreck of *Huis te Kraaiestein* is marked '***1631***'. Despite the fact that this mark appears to be a date, it would indicate that the ingot was marked 67 years prior to the ship's sinking (Price, *et al*., 1980: 19-20). This is unlikely, but may suggest that the ingot was only used as ballast and never offloaded from the ship.

The scant amount of information available about these two VOC shipwrecks may reflect the fact that the wrecks were commercially salvaged (van Duivenvoorde, 2008: 252), rather than archaeologically excavated.

Lead ingot from VOC ship *Waddinxveen* (1697)

A lead ingot was found on the wreck of *Waddinxveen* and is similar to those found on the wrecks of VOC ships *T'Vliegend Hart* (1735) and *Hollandia* (1743). The number **94** stamped on the *Waddinxveen* ingot may refer to its weight in pounds (Werz, 2004: 113).

Lead ingots from VOC ship *Merestein* (1702)

The cargo of this VOC ship wrecked in South African waters was salvaged and sold at auction in London in 1975. The artefacts from the wreck largely comprised silver coins and lead ingots, but there is no excavation report available for study (Green, 1998: 56).

Lead ingots from VOC ship *Reigersdaal* (1747)

Reigersdaal wrecked on an off-shore reef on the west side of the Cape of Good Hope. Much of her cargo, comprising specie and 30 tons of lead ingots was recovered following the wreck's discovery by salvage divers in 1979. No details of the salvaged material are available for study (Green, 1998: 58).

Lead ingots from VOC ship *T'Vliegend Hart* (1735)

The wreck of *T'Vliegend Hart* was discovered in 1981 by the North Sea Archaeological Group. The site was excavated under supervision by staff from the Rijksmuseum in Amsterdam. Lead ingots were amongst a variety of artefacts recovered from the site (Gawronski and Kist, 1983; 1984).

The VOC's Involvement in the Lead Trade in the Seventeenth and Eighteenth Centuries

During the seventeenth and eighteenth centuries lead was a common item of commerce and was used for a variety of purposes. These included the minting of coins, the production of water pipes, for sheeting, as sheathing for ships' hulls, for anchor stocks, seals, stamps, tablets, musket balls and shot cartridges (Tripati, *et al*., 2003: 225). The other important purpose of lead in maritime trade was as ballast for furnishing sailing ships. Heavy cargoes that served this dual purpose were called kintledge by the English East India Company (Whiting, *et al*., 1985: 110).

Evidence of ships ballasted with heavy commodities as paying cargoes is found in archaeological contexts, as well as in historical records. Heavy construction materials such as tin-glazed tiles, bricks, yellow and red copper sheets and lead were found by archaeologists on the wreck of the VOC ship *Ravestein* (1726). These were not only intended for the construction of Company houses in Ceylon, but also served as ballast for the outward bound Indiaman (Paesi, 1999: 51-53). Likewise, in 1725, the outward bound VOC ship *Stabroek* was loaded with ships' masts, coal and 205,222 lb (93,283 kg) of lead. Despite this substantial quantity of lead in her hold, *Stabroek* still took on more ballast after the masts were unloaded at the Cape of Good Hope (Paesi, 1999: 53). On her maiden voyage to Batavia in 1702, *Zuiddorp* was carrying several tonnes of lead as part of a varied cargo (Playford, 1996: 38).

A ready source of lead was, therefore, vital to the VOC for furnishing their ships, as well as for plumbing and roofing their buildings, and to a lesser extent, for trading in the Indies. Contemporary Dutch records show that the VOC employed plumbers to fit-out their ships, and records of transactions with both lead suppliers and plumbers were recorded. Despite this, relatively little is known about seventeenth-century lead production and marketing, in contrast to the quantity of information available concerning the eighteenth century (Price, *et al.*, 1980: 17).

In 1710, the maintenance of the lead gutters and roofing on the VOC's buildings was contracted to the plumber Jacob Crammer, who worked from Vijzelstraat in Amsterdam. In 1746 this contract was taken over by master plumber Abraham Smit, whose workshop was located on Anthoniebreestraat. The plumbers' duties were not limited to maintaining buildings, and they were also employed finishing ships. In the VOC's shipyards, jobs such as plumbing, fitting-out and copper sheathing ships' hulls were contracted to external companies. The master plumbers and their laborers installed lead piping, tanks, funnels and gutters for the drainage systems that kept the ships' decks and holds dry (Gawronski, 1996: 293).

In the mid-eighteenth century, around the time that the VOC appointed a new plumber, a supplier of lead ingots also appears in the Company's records. Initially, plumber Willem van der Bick of Warmoesstraat in Amsterdam supplied the VOC with lead. In 1747 however, bills appear from Coenraad van Vollenhoven, the accountant of a plumber working on Prinsengracht canal. The materials that the VOC purchased included rolls of lead sheet and *hulloot* (Gawronski, 1996: 293), which literally translates as 'hull lead'. This most likely refers to lead ingots, intended for loading into the holds of the Company's ships, in order to trim the vessels at sea (van Duivenvoorde, pers. com., September 2009). VOC records show that the plumber's accountant Coenraad van Vollenhoven charged 9182 guilders for 720 pieces of hull lead, which weighed a total of 112,917 lb (55,792 kg)[1]. In two other transactions, 30 ingots weighing 5024 lb (2482 kg) were sold for 3812 guilders, and 1120 ingots weighing 173,381 lb (85,668 kg) were sold for 14,098 guilders (Gawronski, 1996: 294).

[1] 1 Amsterdam pound = 0.4941 kilograms (Glamann, 1981: 304)

Due to the fact that the Netherlands lacks galena or native lead, the VOC relied heavily on imported lead. Lead was mined and smelted in most of the geologically older, mountainous areas of Europe. It is known that during the seventeenth century the Dutch generally imported lead from either England (especially Derbyshire), or else central Europe (Price, *et al.*, 1980: 17).

At this time, lead production occurred almost entirely in the ore hearth, a small blast furnace that was fuelled with wood chips, known as white coal, and ventilated by water powered bellows. Once up to temperature, the fuel and partially smelted ore floated on top of a pool of molten lead. This slowly overflowed into a reservoir, or sump pot, from where it could be ladled into a mould, known as a spurr. The spurr was usually made from stone or cast iron, however loam or sand moulds, formed up with a wooden pattern were certainly still in use when the *Kennermerland* ingots were cast, prior to 1664 (Price, *et al*., 1980: 24).

By the late eighteenth century, the techniques used for the smelting and casting of lead had advanced technologically. Engravings from a 1773 French book entitled 'the art of the plumber and the pipe fitter' depict men melting down lead pigs, or large ingots, for the production of rolls of sheet and lengths of pipe (Delgardette, 1773: Plate 1). The use of hand bellows to ventilate a brick blast furnace for the smelting of ore and casting of small lead ingots in rectangular iron moulds is also illustrated (Delgardette, 1773: Plate 22).

In the British Isles, most of the lead ores are found in carboniferous limestone regions (Tylecote, 1962: 73). The principal British lead production areas included the South-West and the Mendips, the product from which was shipped from Bristol. Lead from North Wales formed a fair proportion of Chester's trade, whilst that from the Peak and mid-Pennines was shipped from Hull. Further north, lead was transported east from the Pennines to the ports of Stockton and Newcastle (Whiting, *et al.*, 1985: 107). Archives in Amsterdam contain numerous references to lead being used as ships' ballast, from the ports of Hull, Newcastle and London (Willies, 1985: 233).

Lead was requisitioned from the Netherlands by the Dutch Governor General of the Indies. The amounts to be shipped varied and fluctuated, depending on the demand. In 1653, for example, 1,200,000 lb (592,920 kg) of lead was shipped, and annual orders often exceeded one million pounds (Green, 1977: 379). Table 3 provides details of VOC lead shipments to the East Indies for the years 1653-1657.

Table 3: Annual VOC lead exports 1653-1657

Year	Total Weight of Lead	Number of Ships
1653	1,200,000 lb	17
1654	1,600,000 lb	21
1655	1,000,000 lb	27
1656	1,600,000 lb	15
1657	1,000,000 lb	14

(Green, 1977: Table 6-18)

The markings on the lead ingots recovered from the wreck of VOC ship *Hollandia* indicate that they formed part of a well established lead trade from Derbyshire, via Hull and London to Amsterdam and Rotterdam. It was from here, as well as other Dutch ports, that the VOC shipped lead ingots to Batavia and other locations (Willies, 1985: 247). The Derbyshire lead industry was, at the time of the wrecking of *Hollandia*, the most important in Britain and possibly all of Europe.

According to VOC records, the average weight of lead ingots purchased in 1747 varied from 155 lbs to 167 lbs (approximately 77 kg to 82 kg) (Gawronski, 1996: 293). This is consistent with the weight of the lead ingots recorded from *Hollandia*, which vary from 50 kg to 90 kg, but mostly weigh between 69 kg and 85 kg (Willies, 1985: 236). In the eighteenth century, lead ingots were weighed by the fother (or fodder), the mass value of which varied from place to place. The trade practice was for lead to be ordered by the ingot, but paid for by the actual weight on the port's weigh beam, so it was in the interest of the smelter to overweigh his ingots (Price, *et al*., 1980: 24). The major groups of

Hollandia ingots appear to have weights with their modal values around those used in some of the Derbyshire foundries (Willies, 1985: 238). The *Hollandia* ingots display a wide diversity of shape, size, weight and markings. Willies infers that this may reflect the small-scale organisation of the lead industry that predominated in Derbyshire and other areas, prior to the adoption of the cupola smelting process in the late eighteenth century (Willies, 1971; 1975). The variety of marking on the ingots are therefore likely to derive from the lead smelting mills, or their custom clients, rather than from the metal merchants, who dealt in much larger quantities of lead (Willies, 1985: 247).

The dates marked on some of the *Hollandia* ingots range from 1732 to 1738. *Hollandia* wrecked in 1743, indicating that there were fairly considerable time delays in the movement of the ingots. On the smelting side of the industry, it was normal for the lead ore, or galena, to be purchased, smelted and sold within three months. There is, however, evidence that Derbyshire lead merchants held onto ingots, waiting for better market prices, but this probably would have only been for a matter of months and not years. Presumably the main delays occurred at the ports, whether English or Dutch (Willies, 1985: 248).

One *Kennermerland* ingot marked '***MR 1664***' would appear to have been marked in the ten months prior to the ship's sailing; however, as mentioned previously it should be noted that the mark '***1631***' has also been recorded on a lead ingot from the VOC ship *Huis te Kraaiestein*, sunk in 1698. It seems unlikely that the Company would keep lead in store for over half a century, so it is difficult to see this stamped number as indication a date. It may be possible that rather than representing a date, there is a relationship between marks and ingot shape, or weight class (Price, *et al*., 1980: 19-20). An alternative explanation may be that the ingot was never offloaded from the ship and remained as ballast in the hull for the duration of the ship's service.

Lead Ingots as Indicators of Shipwreck Site Formation Processes

The archaeological signature of historic timber shipwrecks is often a scatter of durable, heavy metal artefacts that survive long after ships' hull structure and rigging is gone. In this context, the maritime archaeologist may expect to find cannon, anchors, rudder pintles and gudgeons and metal ingots. Studies of the locations of these artefacts in relation to seabed topography and any surviving hull structure can yield valuable information about shipwreck site formation processes.

Colin Martin studied the locations of lead ingots on the seabed and used these as a means to interpret *Adelaar*'s wrecking process (Martin, 2005: 190). Having approached the site of her wrecking from the north-east in a severe gale, *Adelaar* would have been close hauled in an attempt to clear the approaching headland. She appears have struck bow first and lodged on a shallow submerged gully. The initial impact of the ship's hull hitting the reef released the majority of the ballast, lightening her enough that she was carried over the reef by the wind and heavy seas. Here she pivoted and lay broadside-on, stern to the west. At this location, the discovery of only a small quantity of ballast bricks and lead ingots suggests that *Adelaar*'s hull was still partially intact up to this point. Held against the reef by back-surge from the shore, the total break up of the hull would have followed quickly, depositing the majority of the ship's cannon and most of the heavy cargo into a second gully. The specie evidently remained intact in its chests in a localised area, facilitating its recovery by Captain Rowe and his associates in 1728. As *Adelaar* began to break up, the forward part of the ship was then pushed inshore, resulting in further deposition of the contents of her hold. Isolated pieces of timber structure were carried further off, taking with them attached heavy objects, particularly the deck mounted guns, which eventually sunk and stabilised on the sea bed (Martin, 2005: 190). This scenario of *Adelaar*'s wrecking is essentially recreated from the series of catastrophic events that were mapped out on the seabed with heavy artefacts such as lead ingots and guns.

The wrecking of *Adelaar* is paralleled in several respects with that of *Hollandia*. When *Hollandia* wrecked off Gunner Rock in the Isles of Scilly in 1743, the lead ingots spilled from her hold in two distinct locations (Cowan *et al.*, 1975: 281). The initial point of impact where the ship's hull struck rock and was holed is indicated by a deposit of lead ingots and iron bars. Some 60 m to the north, the main break up of *Hollandia*'s hull is marked by a concentration of cannon, anchors and the bulk of the cargo related material, including the specie. Thirty metres further on, a tertiary deposit of artefacts including scattered cannon, more lead ingots and two anchors indicates the final stage of the wreck's dispersal (Martin, 2005: 190).

From historical accounts it is known that *Kennermerland*'s hull was breached on the rocks off Stoura Stack in the Shetland Isles. At this moment, the majority of the ship's lead ingots were deposited on the seabed. The lightened ship then drifted off, depositing the remaining ingots to the west of the stack as she went (Price and Muckelroy, 1977: 199-201). Prior to their recovery from the seabed, the lead ingots from *Kennermerland* were numbered *in situ* using wax crayon. Their locations on the shipwreck were then plotted onto the site plan (Price, *et al*., 1980: 10). Assuming that the heavy ingots could not have moved on the seabed since the shipwreck event, the researchers hoped that their distribution would shed some light on the way that they were loaded in *Kennermerland*'s hold, and the way in which they spilled out when the hull was breached (Price, *et al*., 1980: 21).

The circumstances surrounding the wrecking of *Zuiddorp* were investigated by McCarthy and his team from the Western Australian Museum in the 1980s and 1990s (McCarthy, 1998: 49). Examinations of the wreck site indicated that the ship may have broken into two or more parts before coming to rest against the inshore reef platform. With the exception of isolated finds including navigational dividers and a brass adze used in the cooperage of gunpowder barrels; the entire shipwreck was found to lie in a shallow depression within a few metres of the reef-top at the foot of the cliffs.

Material from *Zuiddorp*'s stern has been recovered from as close as 2 m from the reef, in as little as 1.5 m of water, indicating that the ship sank close enough to the reef platform to allow some people to bridge the gap to apparent safety. This hypothesis was tested using measurements taken on the wreck site and the known dimensions of the ship. The results indicate that *Zuiddorp* first struck a shelving reef approximately 100 m offshore. The foundering ship then rolled onto her side in the shallow water, turning broadside to the cliffs with her bow pointing south-east. Loose material spilled from the ship in this position, as the surf pushed her further towards the cliffs and the inner reef platform. There, the hull would have been breached, allowing the lead ingots to fall through, lightening the ship sufficiently for her to be pushed further ashore where she finally came to rest (McCarthy, 1998: 49). The ship's hull would then have broken up into pieces. It is possible that the crew had no warning of the impending disaster, as no anchors appear to have been dropped prior to the wrecking. Eight anchors were found on the wreck site, grouped around the area where the ship's bow section is thought to have come to rest (see Figure 4). The following two figures illustrate *Zuiddorp*'s projected final location on the reef platform at the foot of the cliffs.

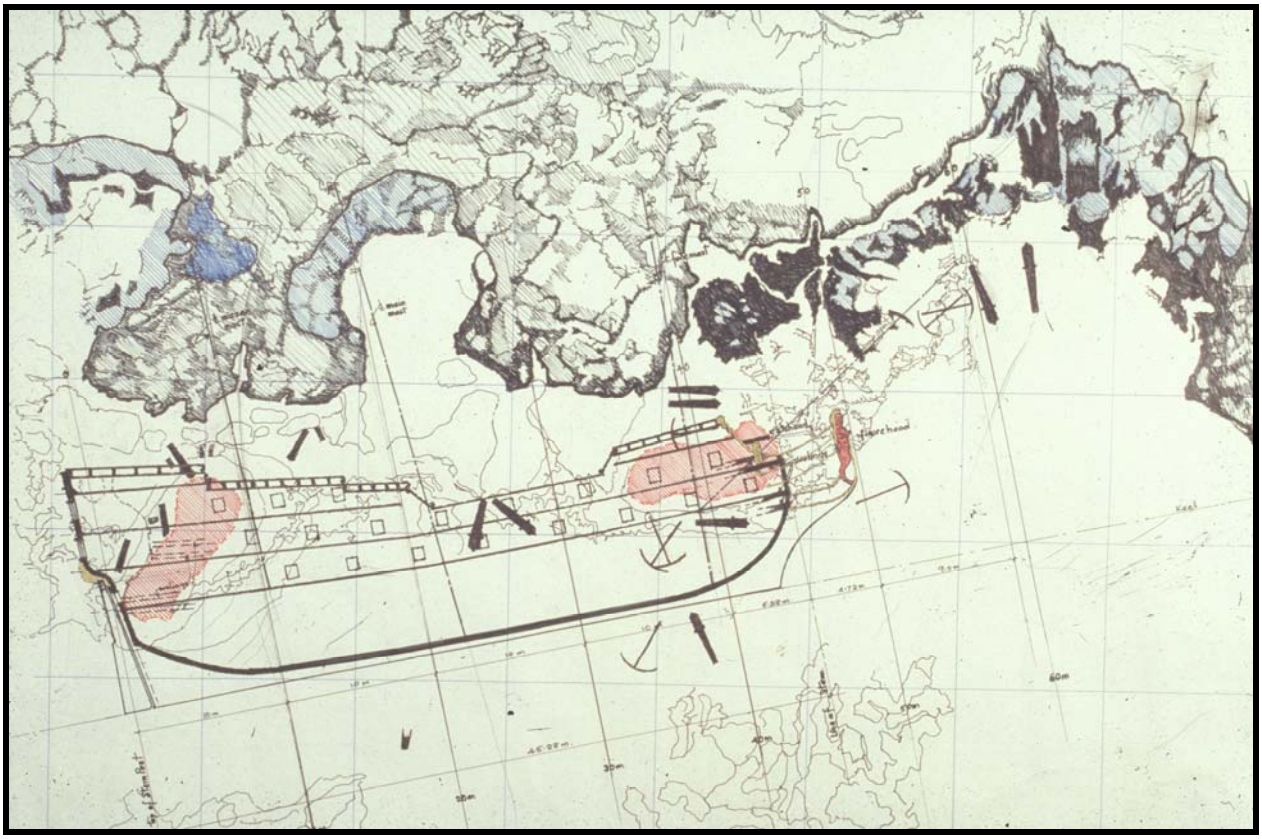

Figure 4: Plan showing the projected final position of the wrecked ship *Zuiddorp*

Drawing by Stanley Hewitt, Western Australian Museum

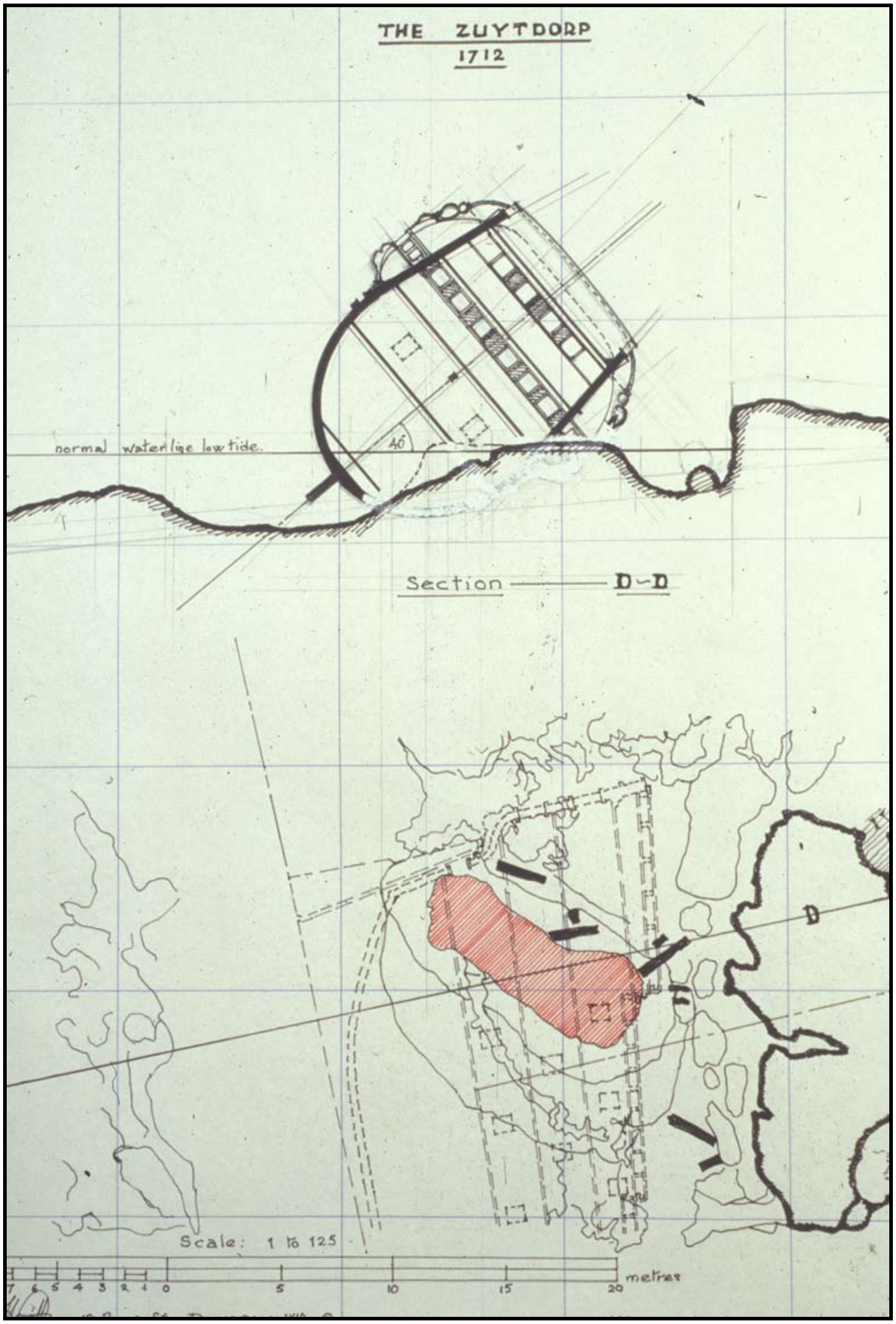

Figure 5: Profile showing the projected final position of *Zuiddorp*'s aft end
Drawing by Stanley Hewitt, Western Australian Museum

Previous Research Conducted on the Zuiddorp *Lead Ingots*

Prior to this study, previous research had been conducted on the 16 *Zuiddorp* lead ingots that were recovered by Museum divers in 1987 (Stanbury and Sawday, 1991: 18). These preliminary findings are reproduced in Table 4 below. The ingot numbers correspond with those in the Western Australian Museum Department of Maritime Archaeology's artefact register. Each registration number comprises the ZT prefix code, which refers to the *Zuiddorp* shipwreck, followed by a unique artefact number.

Table 4: Details of *Zuiddorp* ingots recovered in 1987

Ingot Number	Markings	Pre-conservation weight (kg)	Post-conservation weight (kg)	Length (cm)	Width (cm)
ZT3386	**1702** + 'star'	141.60	140.68	78	27
ZT3387	Various **EE J** *et. al*	140.57	139.77	73.5	29
ZT3388		141.14	140.45	79.5	26
ZT3389		114.75		78	24
ZT3390	**DD DD VOC**?	54.50	54.19	74.5	16
ZT3391	**EH EH FA**	52.10	51.86	78.5	15
ZT3392		44.67	44.55	76.5	15
ZT3393	**5**?	54.75	54.63	77.5	13-14.5
ZT3394		43.75	43.65	80	16.5
ZT3395		61.10	55.85	75	13.5-15
ZT3396	**DP**	61.10	51.45	77	18.5
ZT3397		38.04		77.5	14.5
ZT3398		43.92	43.85	79	15.5
ZT3399	**T**	57.86	57.75	77	16
ZT3400	**PK PK EF EF**	54.00	53.59	77	15.5
ZT3401	**DD DD**	57.08		76	16

(Stanbury and Sawday 1991:18)

In addition, David Kelly of the Western Australian Museum's Department of Materials Conservation took lead core samples of approximately 2 cm depth from ingots ZT3386, ZT3388, ZT3390, ZT3397 and ZT3401. The lead samples were dissolved in concentrated nitric acid and made up to volume in distilled water. Using a varian AA$ Atomic Absorption Spectrometer, the samples were analysed for: lead, copper, zinc, silver, tin, antimony, magnesium, calcium, bismuth and iron. Two samples of a few milligrams each were taken from each of the ingots. Due to some surface oxide contamination on the ingots, the total base metal analysis was between 80% and 90%. The base metal composition provided in Table 5 was recorded. The values are the normalised percentage values as an average of the two samples from each ingot (Stanbury and Sawday, 1991: 19). As the second column of Table 5 shows, the lead content of the six ingots is exceptionally high, with a mean value of 99.74 %.

Table 5: Results of varian AA$ Atomic Absorption Spectrometer Analysis on six *Zuiddorp* lead ingots.

	Pb	**Cu**	**Zn**	**Ag**	**Sb**	**Mg**	**Ca**	**Bi**	**Fe**	**Sn**
ZT 3386	99.74	0.05	<0.01	0.08	<0.01	0.02	0.09	<0.01	<0.01	<0.01
ZT 3388	99.74	<0.01	0.01	0.07	<0.01	0.02	0.11	<0.01	<0.01	<0.01
ZT 3390	99.71	0.08	0.01	0.05	<0.01	0.01	0.12	<0.01	<0.01	<0.01
ZT 3391	99.74	0.03	0.02	0.06	<0.01	0.02	0.12	<0.01	<0.01	<0.01
ZT 3397	99.75	0.01	0.01	0.08	<0.01	0.02	0.12	<0.01	<0.01	<0.01
ZT 3401	99.77	0.02	0.01	0.06	<0.01	0.02	0.12	<0.01	<0.01	<0.01

(Stanbury and Sawday 1991:19)

Project Aims and Methodology

The principal project aim is to attempt to provenance the source of the lead ingots that were aboard *Zuiddorp* when she was wrecked in 1712. The question of whether the VOC procured lead from a variety of manufacturers in the early eighteenth century, or else utilised a single lead source will also be addressed. In the process of addressing these questions, it is hoped that additional information concerning the VOC's involvement in the lead industry, and particularly the trade of lead to the Indies, may come to light. The initial objective of this dissertation is to compile a complete catalogue of the 21 *Zuiddorp* lead ingots currently held in the Western Australian Museum's collection. Using this catalogue as a data set, the project's key research aims will be addressed.

The principal methodology employed comprises a comparative study of lead ingot assemblages recovered from other relevant and contemporary shipwrecks. Studies that have been undertaken on such ingot assemblages are reviewed above. This dissertation will compare ingot forms, weights and markings, in an attempt to place the *Zuiddorp* lead ingot assemblage within a wider context of seventeenth and eighteenth century metallurgical studies, with particular reference to European lead production and trade with Asia. More specifically, the aim of the comparative study is to recognise similarities and differences between the *Zuiddorp* ingots and those from other relevant shipwrecks.

In order to produce a consistent and accurate data set, the *Zuiddorp* lead ingots in the Western Australian Museum's collection were recorded and catalogued. The results of this study will be used to update the Museum's Department of Maritime Archaeology's digital databases.

Unfortunately ingot ZT 3389 is currently in storage at the Geraldton Museum and was unavailable for study whilst this dissertation was in preparation. The ingot's weight, length and width were recorded after it was recovered from the *Zuiddorp* wreck site (Stanbury and Sawday, 1991: 18, Table 4). In addition, photographs of the ingot have been taken at the Geraldton Museum and were made available for study at the Museum in Fremantle. Further recording of this ingot will be undertaken as soon as it becomes available for study.

There are three principal characteristics that may be used to classify and compare metal ingots: form, weight and markings. The comparison of ingot form is certainly a valid study and enables a typology range to be established, to which ingot weight is closely correlated. Perhaps the most precise method of dating ingots is by a positive identification of their markings, although care must be taken, as demonstrated by the case of the VOC ship *Huis te Kraaienstein*, described above. A fourth feature, chemical and lead isotope analyses is also feasible, but reliable sampling methods must be employed and comparative signatures for lead smelting areas need to be established (Whiting, *et al*., 1985: 107).

Due to the fact that the *Zuiddorp* ingots were cleaned and treated by conservators from the Western Australian Museum's Department of Materials Conservation after their recovery from the wreck site, this process did not need to be repeated. Each of the ingots was weighed on a set of digital platform scales, accurate to within 50 grams. The ingots were then drawn, cooling surface upwards, at life size. A laser-guided drafting tool was used to accurately trace the edges of each ingot. Any markings visible on the ingots were then traced onto the drawings. The profiles of all accessible ingots were drawn at their central points using a profiling tool.

The maximum dimensions (length, width and thickness) of each ingot were measured to the nearest 0.1 centimetre. The following attributes were described for each of the ingots: mould surface (or underside), cooling surface (or topside), distal ends (a / b) and lateral edges (left / right).

The cooling surface of each ingot was photographed using a digital single-lens-reflex camera, mounted vertically and level on a tripod. Close-up photographs of prominent markings on the ingots were also taken. Where necessary, the ingots were numbered with white ink, sealed within a base coat of 25% paraloid B72 in acetone/ethanol and a top coat of 25% paraloid B67 in petroleum spirits. Having recorded the ingots, they were then classified into eight separate types based on their varying forms and attributes.

Type I (Great Pigs), total 3 ingots, mean weight 152.4 kg

ZT 4178
ZT 4179
ZT 4260

Large, boat-shaped pigs with flat ends and gently curving lateral edges. All three examples of this type have shallow central troughs on their cooling surfaces. The ingot sides are flat, almost vertical and well-formed. The ingots are thicker towards one end, which is typified by a lumpy, irregular mould surface. This indicates that Type I ingots were cast in a sand or earthen mould, that was damaged during the pouring of the molten lead. Ingot ZT4178 is approximately 2 cm broader than the other two ingots in this group, but was so similar in form and markings that it is included (and may be the result of a slight overfilling of the ingot mould).

Figure 6: Cooling surface of ingot ZT 4179, Type I. (Scale = 20 cm)

Type II (Great Pigs), total 2 ingots, mean weight 141.67 kg

ZT 3386
ZT 4176

Large, boat-shaped pigs with flat ends and gently curving lateral edges. The ingots are thickly cast and have flat, near vertical sides and well-formed smooth mould surfaces. The ends are square and have been cast with a convex to concave step forming ‘handles’. The cooling surface of Type II ingots is flat.

Figure 7: Cooling surface of ingot ZT 4176, Type II. (Scale = 20 cm)

Type III (Great Pigs), total 2 ingots, mean weight 139.54 kg

ZT 3387
ZT 4177

Broad, symmetrical boat-shaped pigs with rounded ends and curved lateral edges. Type III ingots have well-formed flat sides and a smooth, convex mould surface. The cooling surface of these ingots is generally flat.

Figure 8: Cooling surface of ingot ZT 4177, Type III. (Scale = 20 cm)

Type IV (Great Pig), total 1 ingot, weight 139.85 kg
ZT 3388

The single example of this ingot type is a large elongate pig with one flat end and one rounded end. The ingot is markedly thicker at its square end. The ingot's mould surface is smooth, convex and well-formed. The cooling surface is generally flat with blistering evident in a central, shallow trough. The ingot sides are smooth, shallow and flat.

Figure 9: Cooling surface of ingot ZT 3388, Type IV. (Scale = 20 cm)

Type V (Pig), total 1 ingot, weight 114.75 kg
ZT 3389

Type V has been assigned to a single ingot which is currently in storage at the Geraldton Museum and was unavailable for study. At 114.75 kg, the weight recorded for this ingot is unique in the assemblage (Stanbury and Sawday, 1991: 18, Table 4), falling in between the weights recorded for the remaining pigs and pieces. For this reason, ingot ZT 3389 has been assigned to Type V, of which it is the only member.

Photographs of this ingot supplied by the Geraldton Museum indicate that it is large, elongate and well-formed. It has a flat cooling surface, lacking any markings. The mould surface of this ingot is smooth and convex. The lateral edges and distal ends are rounded.

Figure 10: Cooling surface of ingot ZT 3389, Type V. (Scale = 20 cm)
(photograph James Thompson, Geraldton Museum)

Type VI (Pieces), total 8 ingots, mean weight 52.21 kg

ZT 3390	**ZT 3396**
ZT 3392	**ZT 3399**
ZT 3394	**ZT 3400**
ZT 3395	**ZT 3401**

Elongate, parallel sided, boat-shaped pieces. These ingots are generally well cast although some have been bent in transit. The ingots have flat cooling surfaces and convex, smooth mould surfaces. The ends are rounded, with one slightly broader than the other. Type VI ingots all measure approximately 75 cm in length.

Figure 11: Cooling surface of ingot ZT 3399, Type VI. (Scale = 20 cm)

Type VII (Pieces), total 3 ingots, mean weight 50.12 kg

ZT 3391
ZT 3393
ZT 3398

Type VII ingots are elongate boat-shaped pieces. These ingots are similar in appearance to Type VI ingots, but are all approximately 5 cm longer, and lack having one end broader than the other. The ingot's lateral edges are parallel and two ingots from the group (ZT 3391 and ZT 3393) are bent.

Figure 12: Cooling surface of ingot ZT 3391, Type VII. (Scale = 20 cm)

Type VIII (Piece), total 1 ingot, weight 38 kg

ZT 3397

Although similar in appearance to pieces from Types VI and VII, this ingot is markedly lighter. It is elongate with an irregular cooling surface and a smooth convex mould surface. At 77.5 cm long, this ingot's length falls in between those exhibited by Type VI and Type VII ingots. The distal ends of this ingot are rounded and slightly bulbous, with one thicker that the other.

Figure 13: Cooling surface of ingot ZT 3397, Type VIII. (Scale = 20 cm)

Table 6: Dimensions and characteristics of *Zuiddorp*'s lead ingots.

Ingot Number	Weight (kg)	Maximum Length (cm)	Maximum Width (cm)	Maximum Thickness (cm)	Marks (see Figure 14 below)	Ingot Type	Bent Yes/No
ZT3386	140.68	78.3	26.5	N/A	**1702**(4), **Star M**(4)	II	No
ZT3387	139.77	74	29.3	N/A	**E**(7), **CS**, **l**	III	No
ZT3388	139.85	79.9	26.5	10.9	**A**, ^, **RC**, **6**	IV	No
ZT3389	114.75	78	24	N/A	None visible in photograph	V	N/A
ZT3390	54.19	74.8	16.2	6.2	**D**(4)	VI	No
ZT3391	51.85	79	16.2	5.7	**EH**(2), **Pk**	VII	Yes
ZT3392	44.55	76.6	15.2	6.5	Not legible	VI	Yes
ZT3393	54.65	80.2	16.7	5.8	**5**, **t**	VII	Yes
ZT3394	43.60	75.5	15.5	6.4	**!**	VI	Yes
ZT3395	55.85	75.6	16.1	6.7	**L**, **D**(3), **u**, **H**(4)	VI	No
ZT3396	51.45	76	16.4	7.3	**pK**, **B**, **<**	VI	Yes
ZT3397	38.00	78	15.2	5.4	None	VIII	No
ZT3398	43.85	78.5	15.8	6	**[**, **C**(2)	VII	No
ZT3399	57.60	76.1	16.8	7.8	**I**(2), **i**(2)	VI	Yes
ZT3400	53.50	75.1	16.9	6.6	**PK**(2), **u**, ?(2)	VI	No
ZT3401	56.95	75.6	16.3	6.6	**U**, **LL**(4), **v**	VI	No
ZT4176	142.65	78	28	10.5	**1702**(4), **Star M**(3)	II	No
ZT4177	139.30	75.5	30.4	9.8	**CS**(7), **E**(3), **4**	III	No
ZT4178	154.70	81.3	32.2	9.8	**RC**(3), **X**(2), **XX**(5), **x**(1), **UU**(3), **RC9**(3), **W**(2)	I	No
ZT4179	147.90	83.5	29.4	9.5	**RC9**(8), **UU**(2), **69**(3), **H**(3), **HD**(2), **xx**	I	No
ZT4260	154.60	82.6	30	10.7	**Star** (4), **rc**(10), **xx**, **FH**(6), **FOUR**(3), **#**, **+**	I	No

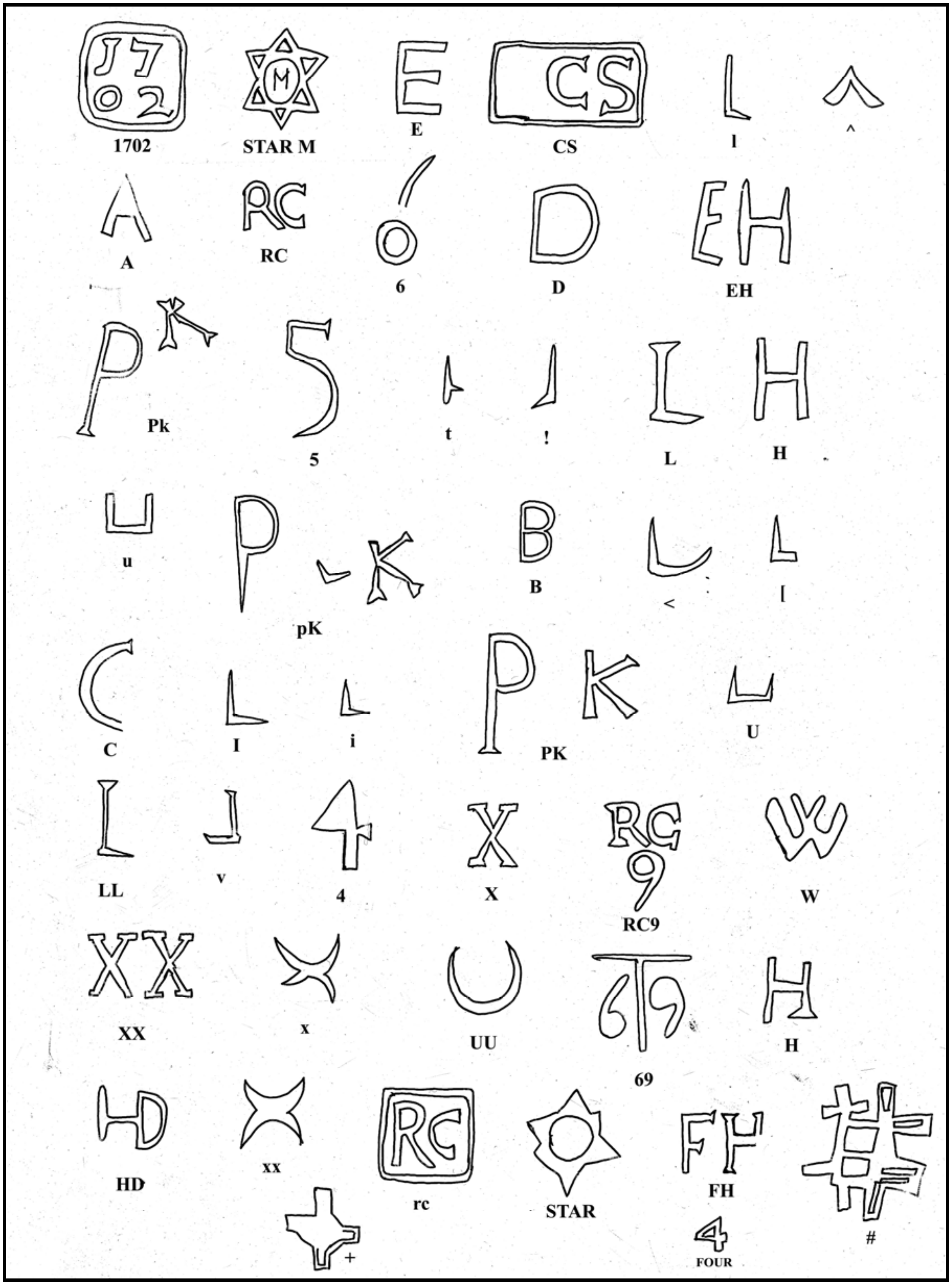

Figure 14: Key to Ingot Stamp Motifs

Catalogue of Zuiddorp's Lead Ingots

The catalogue numbers assigned to the ingots refer to the Western Australian Museum's Department of Maritime Archaeology artefact register and database.

ZT 3386 (Type II)

Maximum Dimensions: length 78.3 cm, width 26.5 cm, thickness N/A.
Weight: 140.68 kg.
Mould Surface: the mould surface of this ingot was not examined as it is currently on display in a purpose-built installation.
Cooling Surface: flat with a shallow, concave trough at the centre. Coated with epoxy resin for display purposes. Resin has filled and partially obscured some of the ingot's markings.
Distal A End: straight and stepped.
Distal B End: straight and stepped. Damaged.
Left Lateral Edge: flat to concave, intermittent overhanging lip.
Marks: 1702(4), **Star M**(4).
Right Lateral Edge: flat.
Notes: Longer and more slender than Type III ingots.

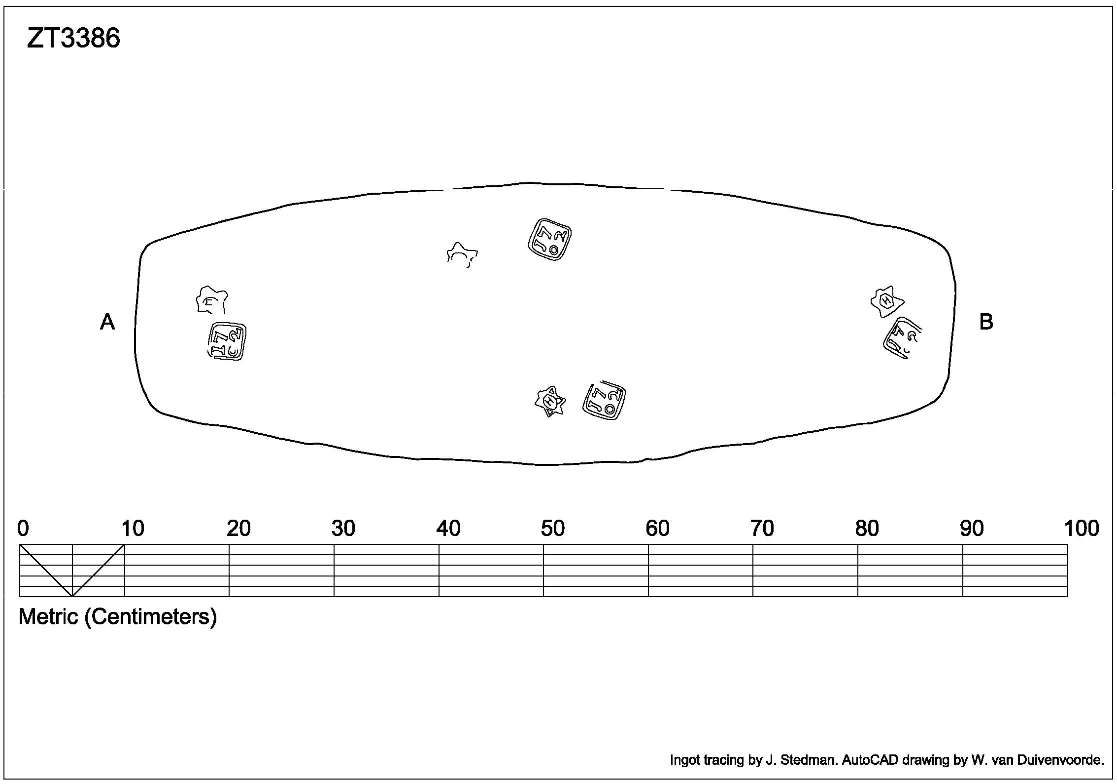

Figure 15: Ingot ZT 3386, Cooling Surface

ZT 3387 (Type III)

Maximum Dimensions: length 74 cm, width 29.3 cm, thickness N/A.
Weight: 139.77 kg.
Mould Surface: the mould surface of this ingot was not examined as it is currently on display in a purpose-built installation.
Cooling Surface: flat with a shallow, concave trough at the centre. Coated with epoxy resin for display purposes. Resin has filled and partially obscured some of the ingot's markings.
Distal A End: straight and flat to convex.
Distal B End: straight and flat to convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **E**(7), **CS**, **l**.
Notes: Large symmetrical ingot. Broader and shorter than Type I and II ingots.

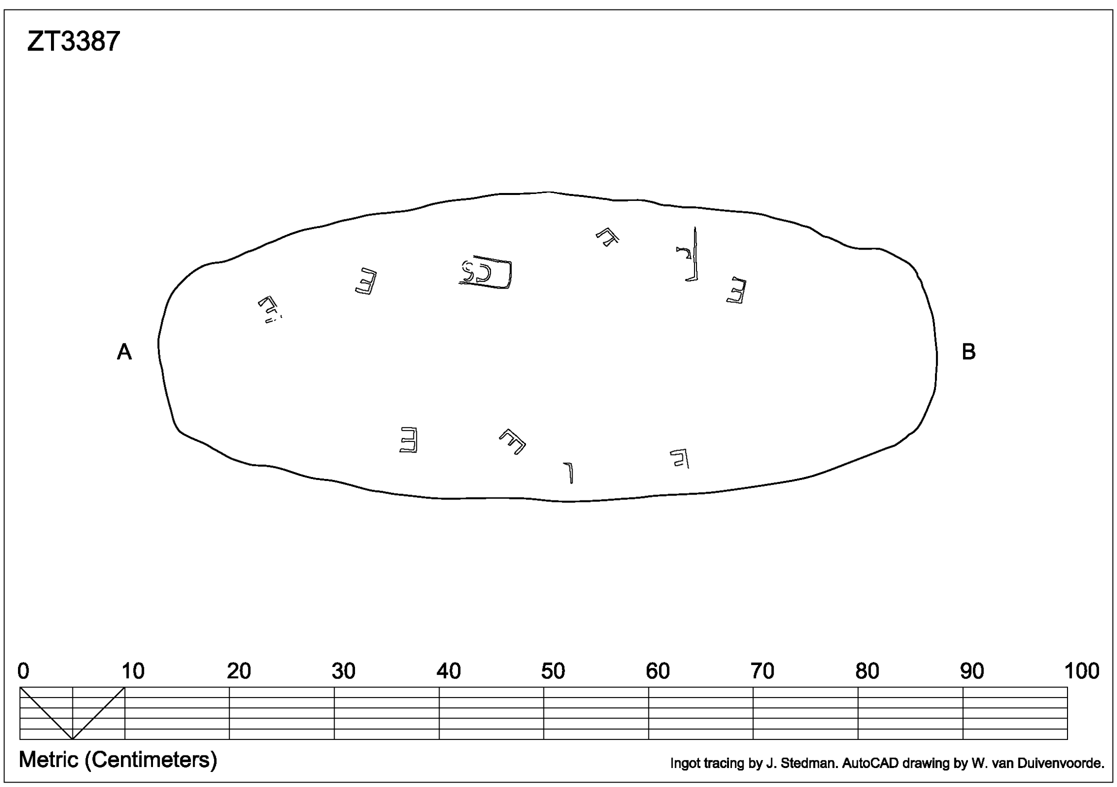

Figure 16: Ingot ZT 3387, Cooling Surface

ZT 3388 (Type IV)

Maximum Dimensions: length 79.9 cm, width 26.5 cm, thickness 10.9 cm.
Weight: 139.85 kg.
Mould Surface: flat and smooth, becomes convex towards distal B end.
Cooling Surface: irregular, blistered in central portion.
Distal A End: flat becoming convex at mould surface.
Distal B End: flat and stepped.
Left Lateral Edge: flat, becoming convex.
Right Lateral Edge: flat, becoming convex.
Marks: A, ^, **RC**, **6**.
Notes: the marking on this ingot are faint. This ingot is the only example of the Type IV form.

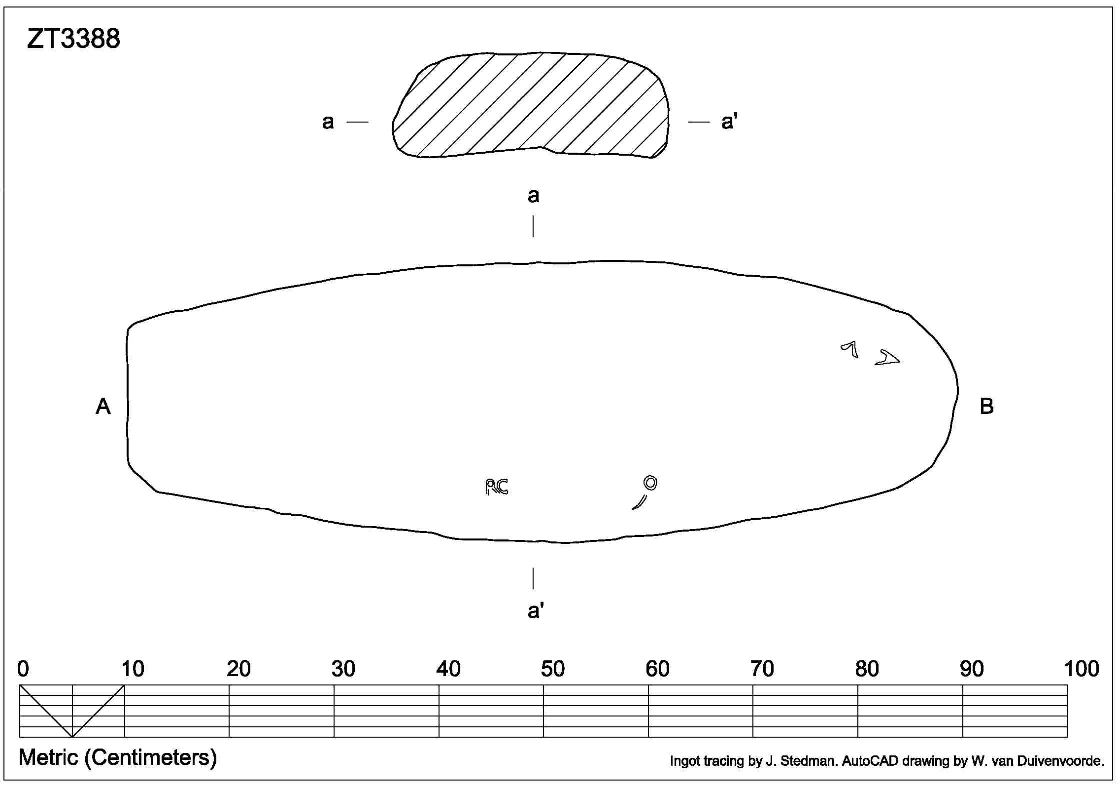

Figure 17: Ingot ZT 3388, Cooling Surface and Section

ZT 3389 (Type V)

Maximum Dimensions: length 78 cm, width 24 cm, thickness N/A.
Weight: 114.75 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: flat with no visible marks.
Distal A End: rounded and convex.
Distal B End: rounded and convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: None visible in photographs.
Notes: Ingot measurements (Stanbury and Sawday, 1991: 18, Table 4). Ingot attributes taken from photographs. Ingot requires further study.

ZT 3390 (Type VI)

Maximum Dimensions: length 74.8 cm, width 16.2 cm, thickness 6.2 cm.
Weight: 54.19 kg.
Mould Surface: convex.
Cooling Surface: flat with a shallow, concave trough at centre. Coated with epoxy resin for display purposes.
Distal A End: rounded and convex.
Distal B End: rounded and convex.
Left Lateral Edge: convex, dented in central portion.
Right Lateral Edge: convex, some damage towards distal B end.
Marks: D(4).
Notes: well formed ingot, wider at distal A end.

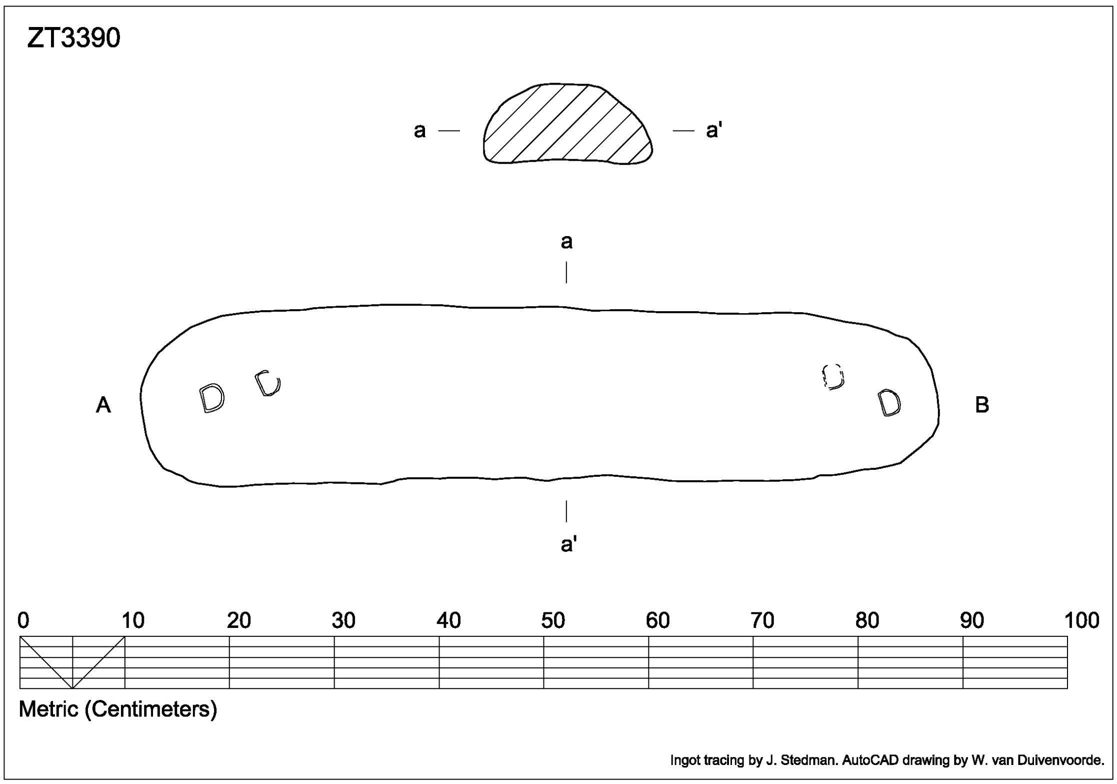

Figure 18: Ingot ZT 3390, Cooling Surface and Section

ZT 3391 (Type VII)

Maximum Dimensions: length 79 cm, width 16.2 cm, thickness 5.7 cm.
Weight: 51.85 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: irregular, concave in places.
Distal A End: convex, slight overhanging lip.
Distal B End: convex, slight overhanging lip.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: EH(2), **Pk**.
Notes: ingot is bent.

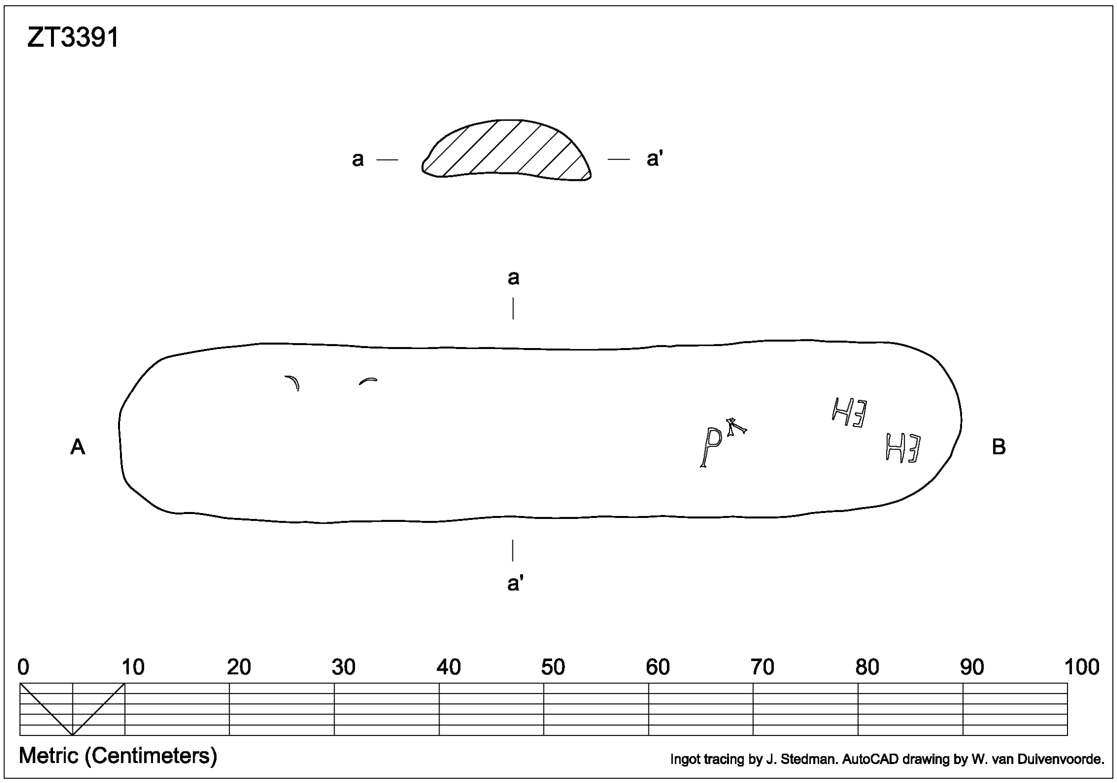

Figure 19: Ingot ZT 3391, Cooling Surface and Section

ZT 3392 (Type VI)

Maximum Dimensions: length 76.6 cm, width 15.2 cm, thickness 6.5 cm.
Weight: 44.55 kg.
Mould Surface: convex, smooth, well-formed.
Cooling Surface: flat.
Distal A End: convex, slight overhanging lip.
Distal B End: convex, slight overhanging lip.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: Not legible.
Notes: Ingot slightly bent.

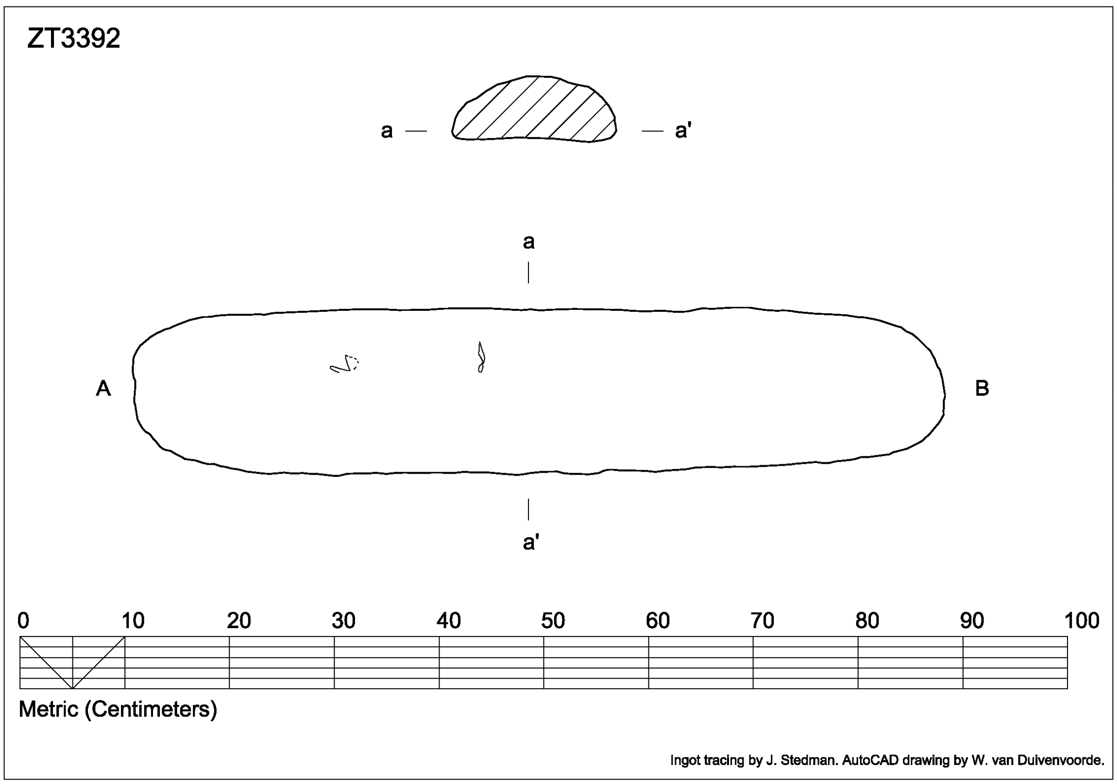

Figure 20: Ingot ZT 3392, Cooling Surface and Section

ZT 3393 (Type VII)

Maximum Dimensions: length 80.2 cm, width 16.7 cm, thickness 5.8 cm.
Weight: 54.65 kg.
Mould Surface: convex and smooth. Two dents close to distal B end.
Cooling Surface: irregular with two pronounced striations, slightly concave trough at centre, dent at distal A end.
Distal A End: convex.
Distal B End: convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex, damage at distal B end (see above).
Marks: **5**, **t**.
Notes: symmetrical ingot, bent.

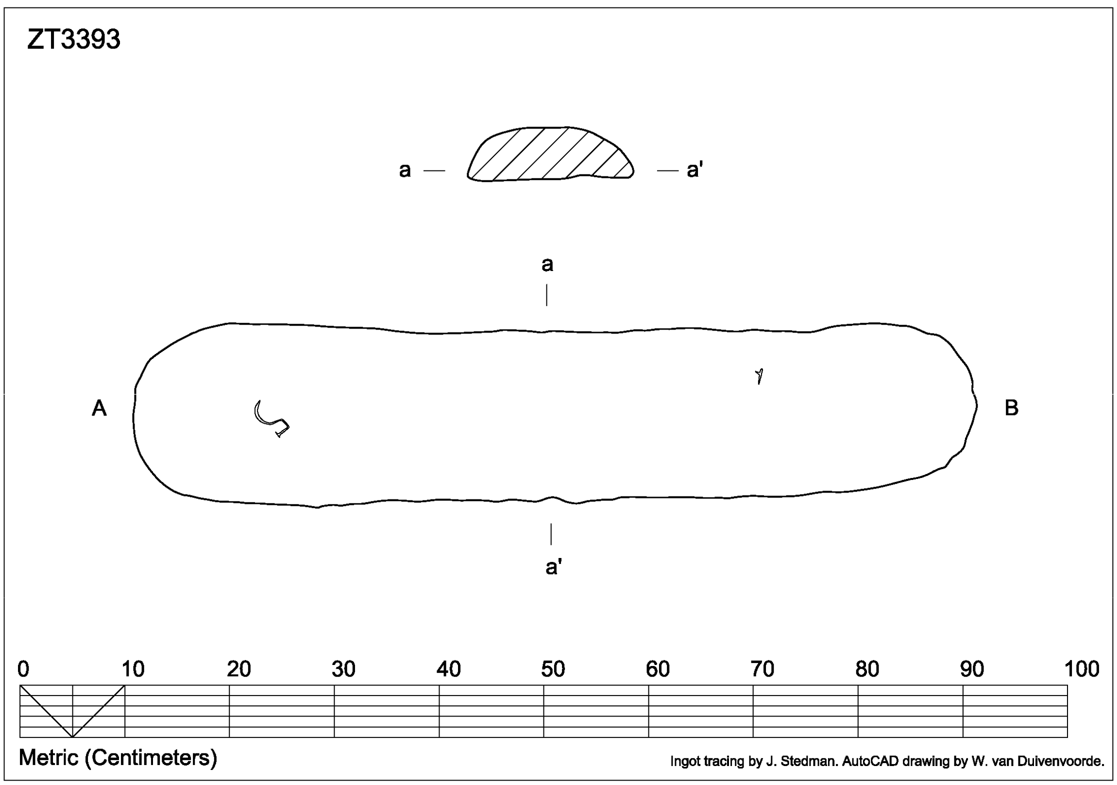

Figure 21: Ingot ZT 3393, Cooling Surface and Section

ZT 3394 (Type VI)

Maximum Dimensions: length 75.5 cm, width 15.5 cm, thickness 6.4 cm.
Weight: 43.60 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: flat with shallow concave trough at centre. Pronounced overhanging lip towards distal A end and right lateral edge.
Distal A End: convex.
Distal B End: convex, lip overhanging cooling surface.
Left Lateral Edge: convex.
Right Lateral Edge: convex, slight overhanging lip.
Marks: **!**.
Notes: ingot is bent and is wider at distal A end.

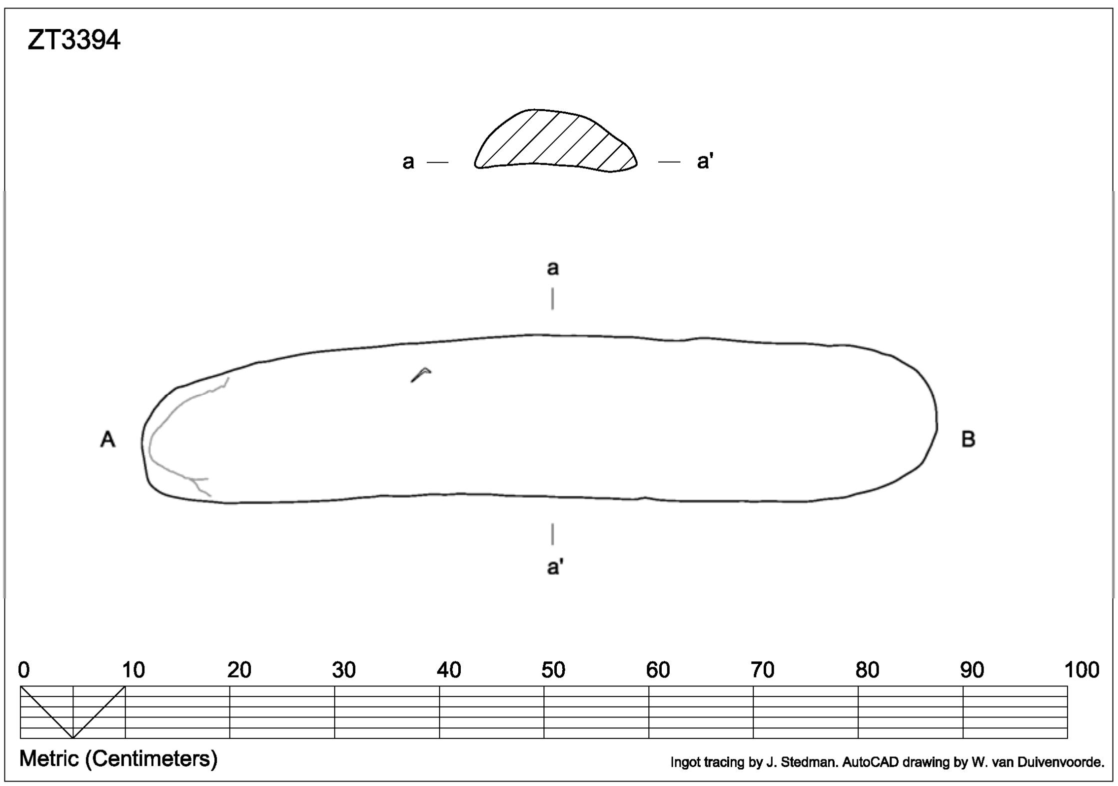

Figure 22: Ingot ZT 3394, Cooling Surface and Section

ZT 3395 (Type VI)

Maximum Dimensions: length 75.6 cm, width 16.1 cm, thickness 6.7 cm.
Weight: 55.85 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: flat with a shallow, concave trough at centre. Coated with epoxy resin for display purposes.
Distal A End: rounded and convex.
Distal B End: rounded and convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **L**, **D**(3), **u**, **H**(4).
Notes: well-formed ingot, wider at distal A end.

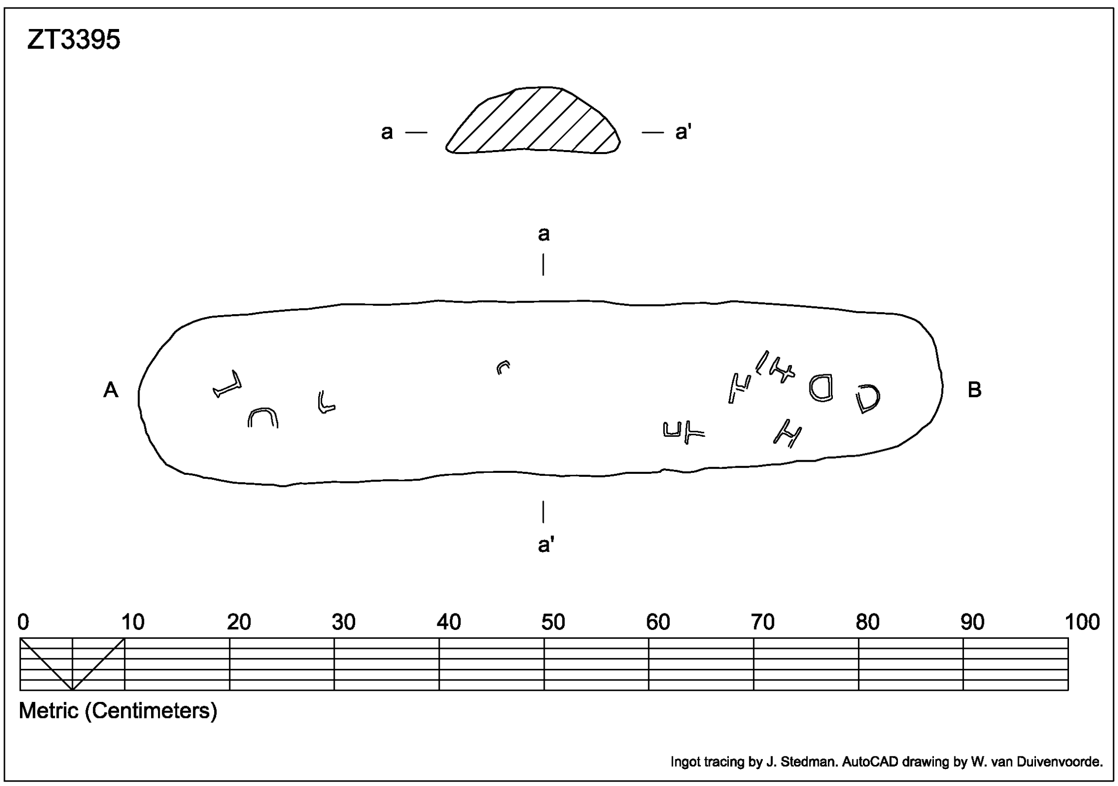

Figure 23: Ingot ZT 3395, Cooling Surface and Section

ZT 3396 (Type VI)

Maximum Dimensions: length 76 cm, width 16.4 cm, thickness 7.3 cm.
Weight: 51.45 kg.
Mould Surface: convex and smooth.
Cooling Surface: flat and pitted, shallow concave trough at centre.
Distal A End: convex.
Distal B End: convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **pK**, **B**, <.
Notes: ingot is bent.

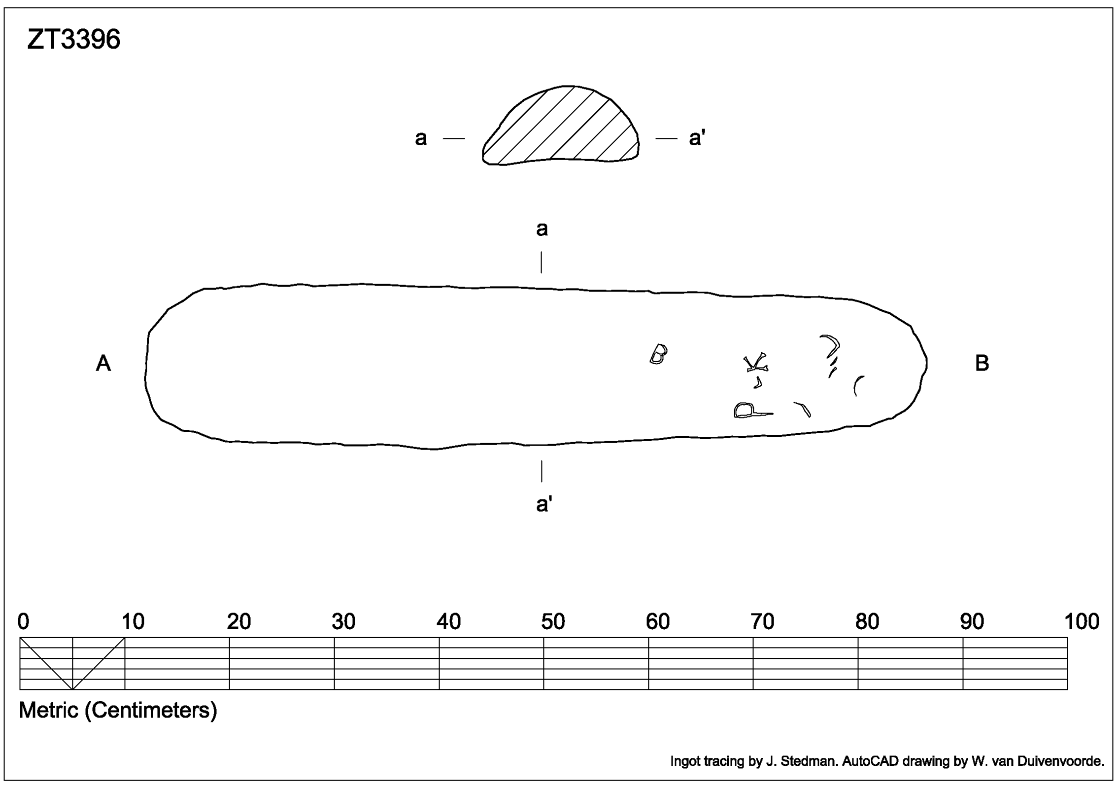

Figure 24: Ingot ZT 3396, Cooling Surface and Section

ZT 3397 (Type VIII)

Maximum Dimensions: length 78 cm, width 15.2 cm, thickness 5.4 cm.
Weight: 38 kg.
Mould Surface: convex and smooth. Void in central portion.
Cooling Surface: irregular, undulating and pitted.
Distal A End: convex, slight overhanging lip.
Distal B End: convex, flattened edge on left side.
Left Lateral Edge: irregular, flat in places.
Right Lateral Edge: convex.
Marks: None.
Notes: notable as the lightest ingot in the assemblage, also no visible marks. This ingot is the only example of the Type VIII form.

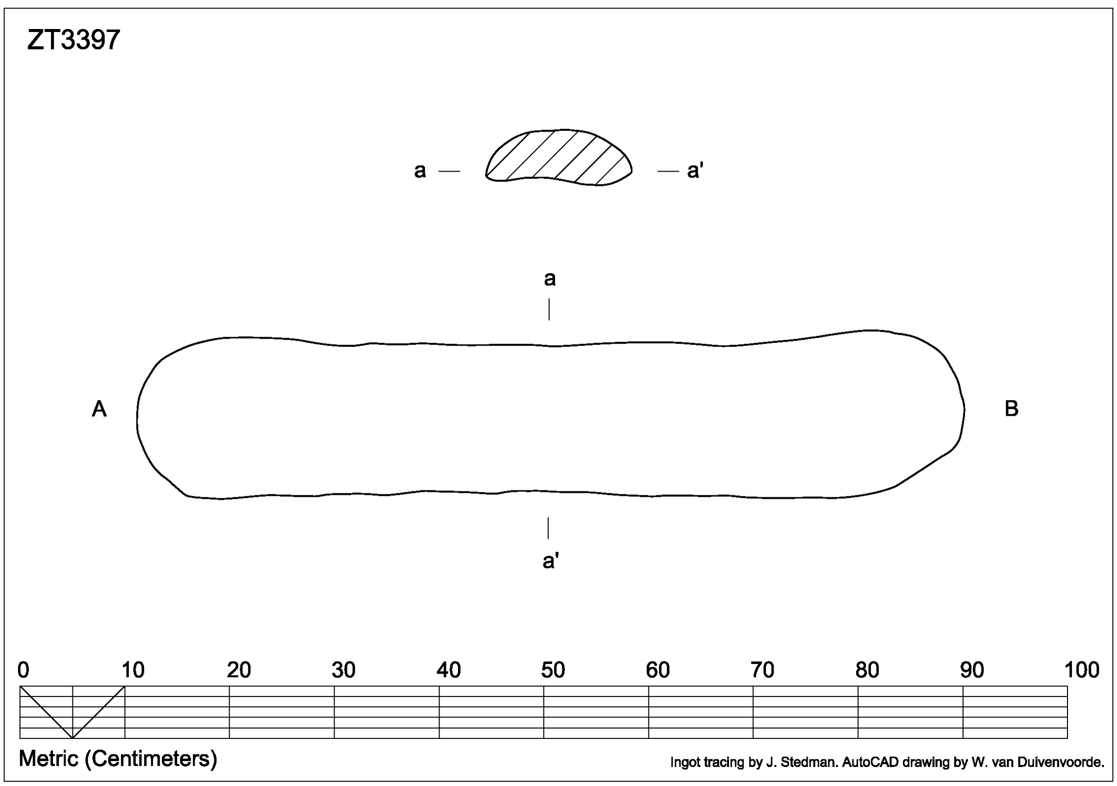

Figure 25: Ingot ZT 3397, Cooling Surface and Section

ZT 3398 (Type VII)

Maximum Dimensions: length 78.5 cm, width 15.8 cm, thickness 6 cm.
Weight: 43.85 kg.
Mould Surface: convex, smooth, well-formed.
Cooling Surface: irregular, slightly concave.
Distal A End: rounded and convex.
Distal B End: rounded and convex.
Left Lateral Edge: convex, pronounced step midway along.
Right Lateral Edge: convex and straight.
Marks: **[**, **C**(2).
Notes: parallel sided ingot.

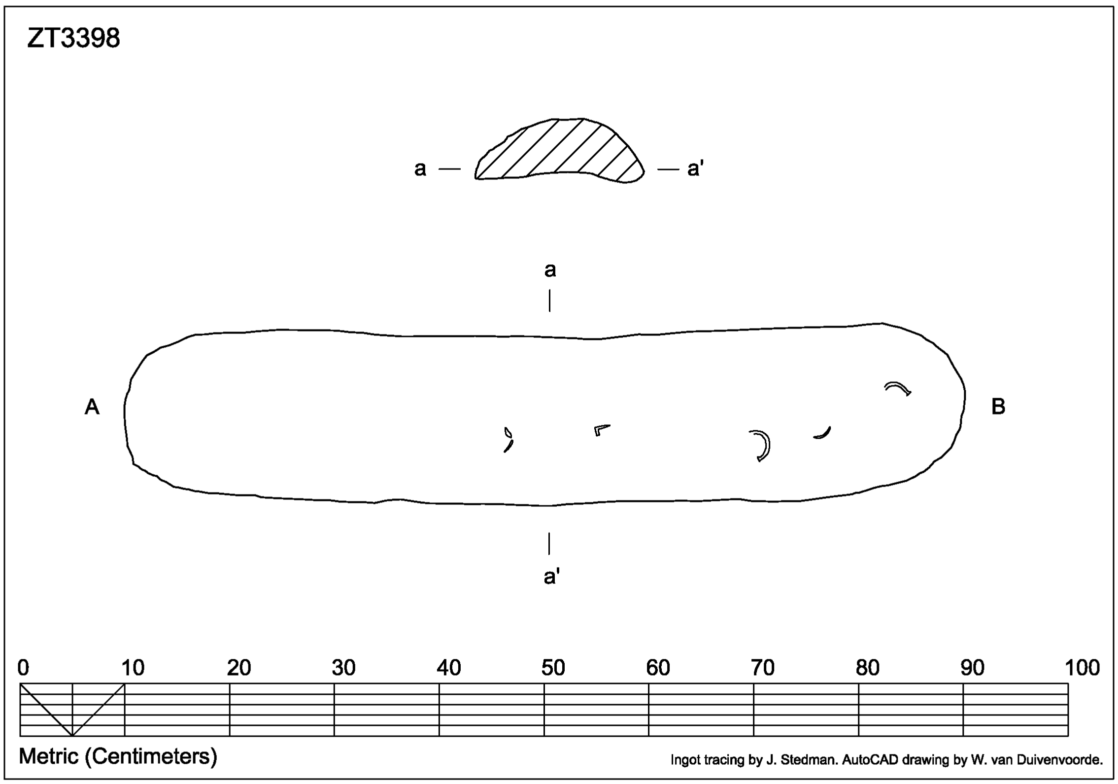

Figure 26: Ingot ZT 3398, Cooling Surface and Section

ZT 3399 (Type VI)

Maximum Dimensions: length 76.1 cm, width 16.8 cm, thickness 7.8 cm.
Weight: 57.6 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: flat with a slightly concave central trough. Some blistering visible.
Distal A End: flat to convex.
Distal B End: convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **I**(2), **i**(2).
Notes: Ingot is slightly bent.

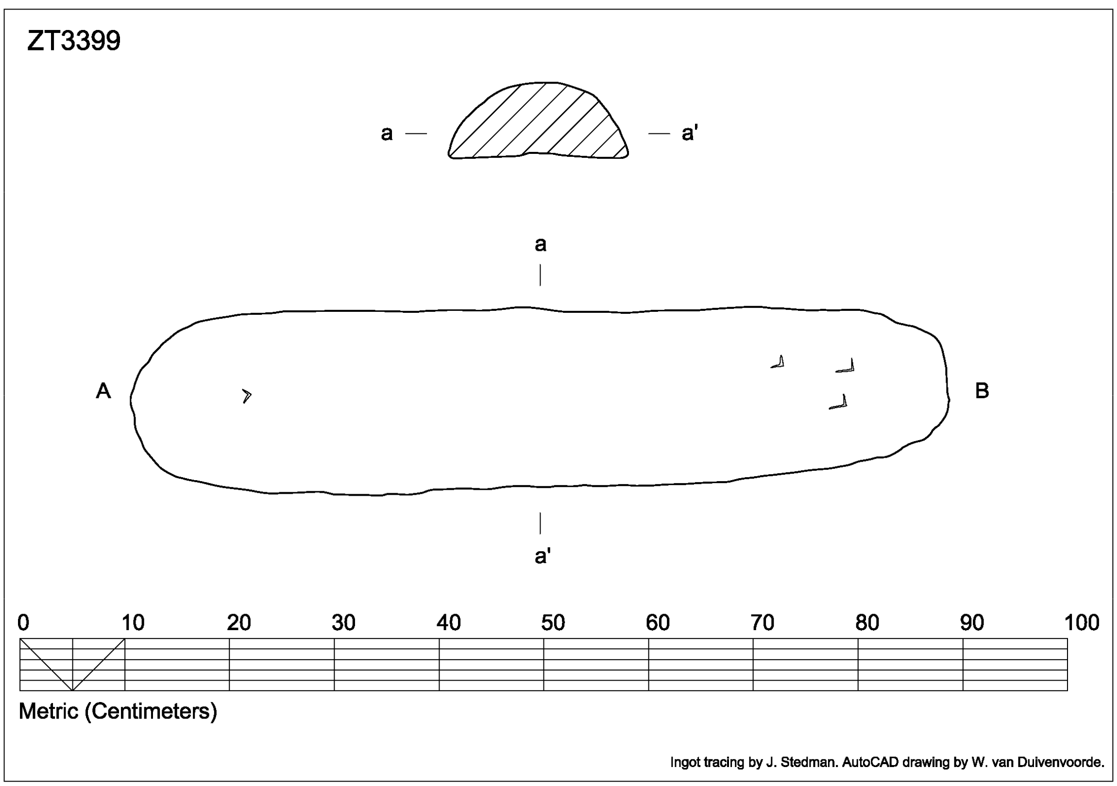

Figure 27: Ingot ZT 3399, Cooling Surface and Section

ZT 3400 (Type VI)

Maximum Dimensions: length 75.1 cm, width 16.9 cm, thickness 6.6 cm.
Weight: 53.50 kg.
Mould Surface: convex, smooth and well-formed.
Cooling Surface: flat with a slightly concave central trough.
Distal A End: convex.
Distal B End: convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **PK**(2), **u**, **?**(2).

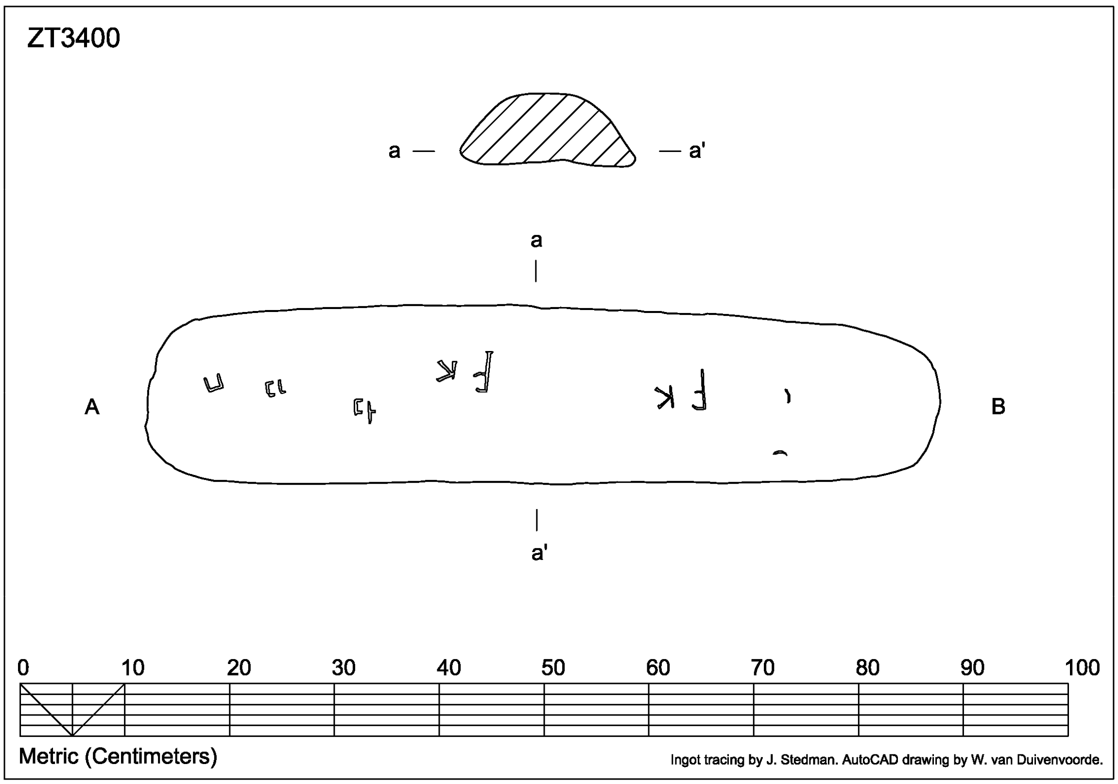

Figure 28: Ingot ZT 3400, Cooling Surface and Section

ZT 3401 (Type VI)

Maximum Dimensions: length 75.6 cm, width 16.3 cm, thickness 6.6 cm.
Weight: 56.95 kg.
Mould Surface: convex, some residual marine growth.
Cooling Surface: flat with shallow concave troughs at centre and towards distal ends.
Distal A End: convex.
Distal B End: convex.
Left Lateral Edge: convex.
Right Lateral Edge: convex.
Marks: **U**, **LL**(4), **v**.
Notes: Straight, well-formed ingot.

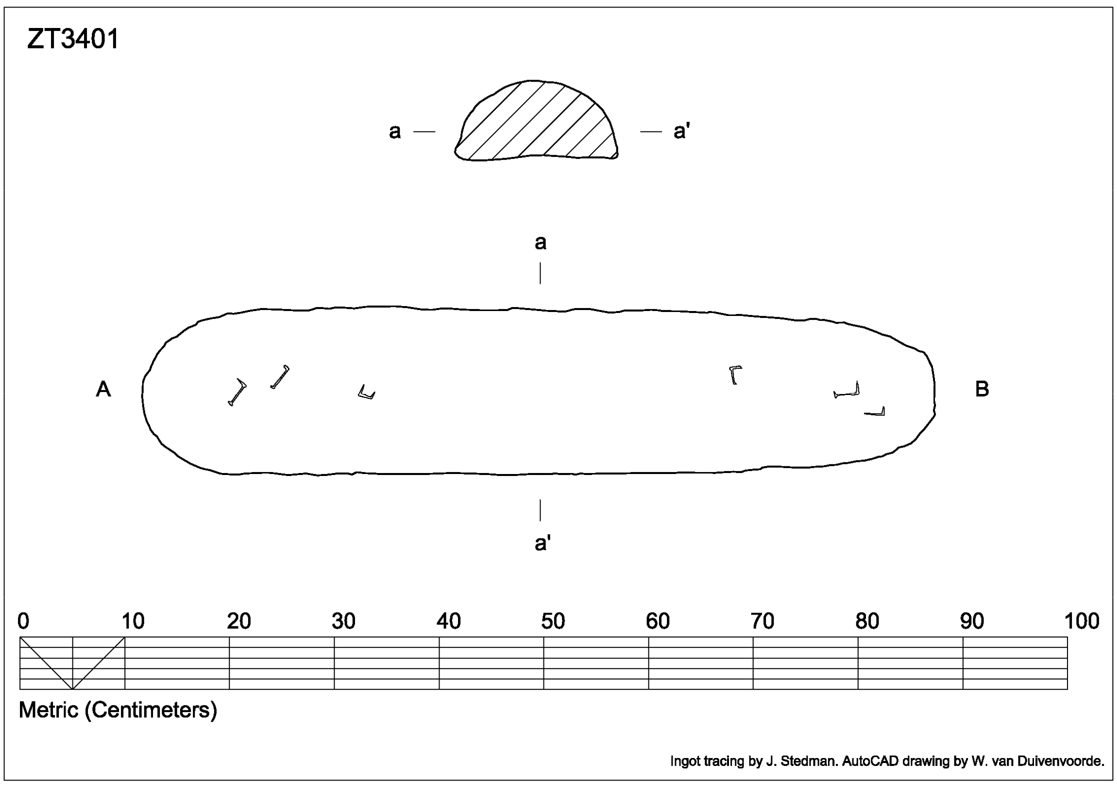

Figure 29: Ingot ZT 3401, Cooling Surface and Section

ZT 4176 (Type II)

Maximum Dimensions: length 78 cm, width 28 cm, thickness 10.5 cm.
Weight: 142.65 kg.
Mould Surface: concave to flat, stepped at distal ends.
Cooling Surface: irregular, although very smooth in places, some damage. Concave trough towards distal A end.
Distal A End: stepped, slightly damaged.
Distal B End: marginally concave with overhanging lip, some damage.
Left Lateral Edge: flat, deep and well-formed.
Right Lateral Edge: flat, deep and well-formed.
Marks: **1702**(4), **Star M**(3).
Notes: Symmetrical, square ended pig.

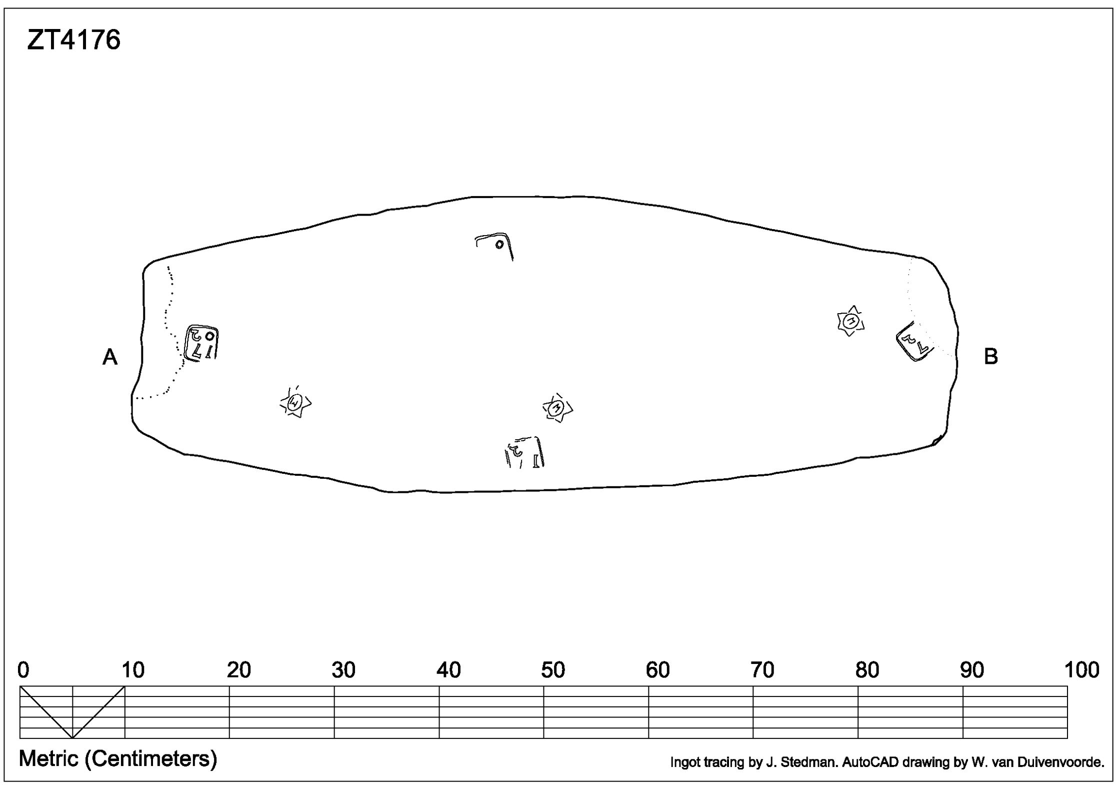

Figure 30: Ingot ZT 4176, Cooling Surface

ZT 4177 (Type III)

Maximum Dimensions: length 75.5 cm, width 30.4 cm, thickness 9.8 cm.
Weight: 139.30 kg.
Mould Surface: smooth, convex and well-formed.
Cooling Surface: generally irregular, shallow concave trough in central portion, some blistering.
Distal A End: flat, graduating to convex, slight lip, damaged.
Distal B End: flat, prominent overhanging lip.
Left Lateral Edge: flat, graduating to convex at mould surface.
Right Lateral Edge: flat, graduating to convex at mould surface. Intermittent overhanging lip.
Marks: **CS**(7), **E**(3), **4**.
Notes: Symmetrical ingot with flat ends.

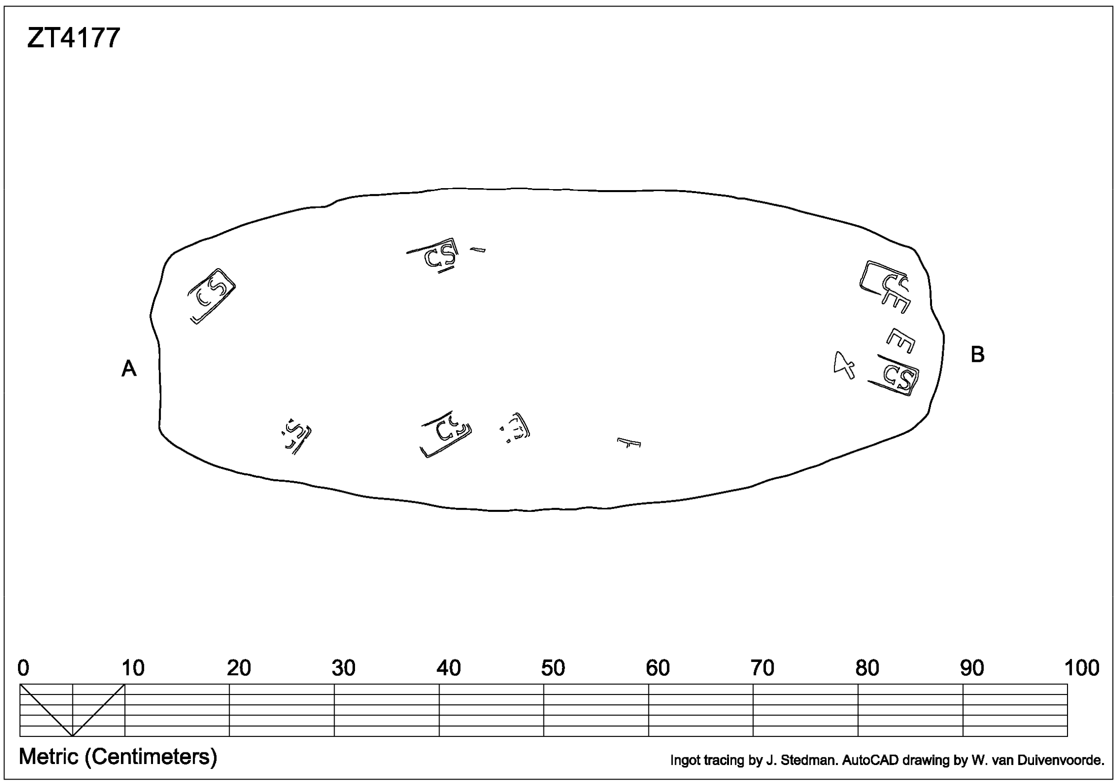

Figure 31: Ingot ZT 4177, Cooling Surface

ZT 4178 (Type I)

Maximum Dimensions: length 81.3 cm, width 32.2 cm, thickness 9.8 cm.
Weight: 154.70 kg.
Mould Surface: lumpy and irregular.
Cooling Surface: flat, shallow, concave trough at centre.
Distal A End: irregular, stepped.
Distal B End: irregular, damaged, stepped.
Left Lateral Edge: flat.
Right Lateral Edge: flat.
Marks: **RC**(3), **X**(2), **XX**(5), **x**(1), **UU**(3), **RC9**(3), **W**(2).
Notes: broad and symmetrical pig.

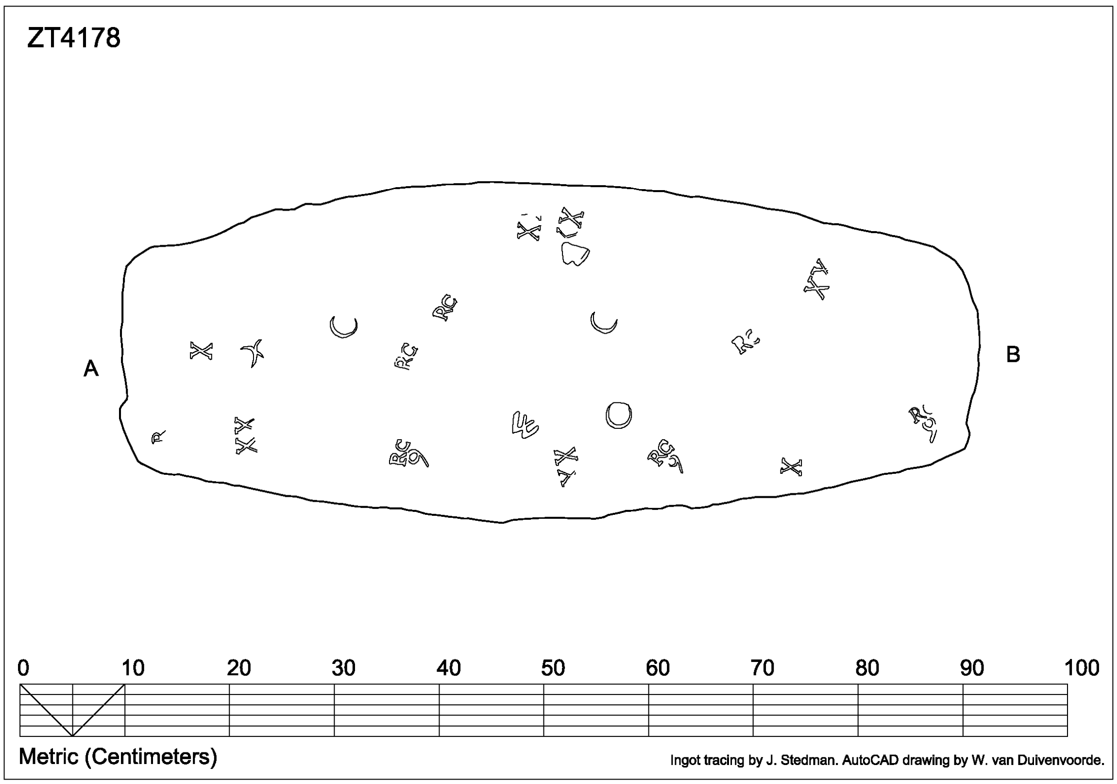

Figure 32: Ingot ZT 4178, Cooling Surface

ZT 4179 (Type I)

Maximum Dimensions: length 83.5 cm, width 29.4 cm, thickness 9.5 cm.
Weight: 147.90 kg.
Mould Surface: lumpy and irregular.
Cooling Surface: irregular and damaged in places. Shallow, concave trough at centre.
Distal A End: straight and thin. Damaged.
Distal B End: straight and thick.
Left Lateral Edge: flat with a slight lip.
Right Lateral Edge: flat with a slight lip.
Marks: **RC9**(8), **UU**(2), **69**(3), **H**(3), **HD**(2), **xx**.
Notes: this ingot displays a range of repeated markings.

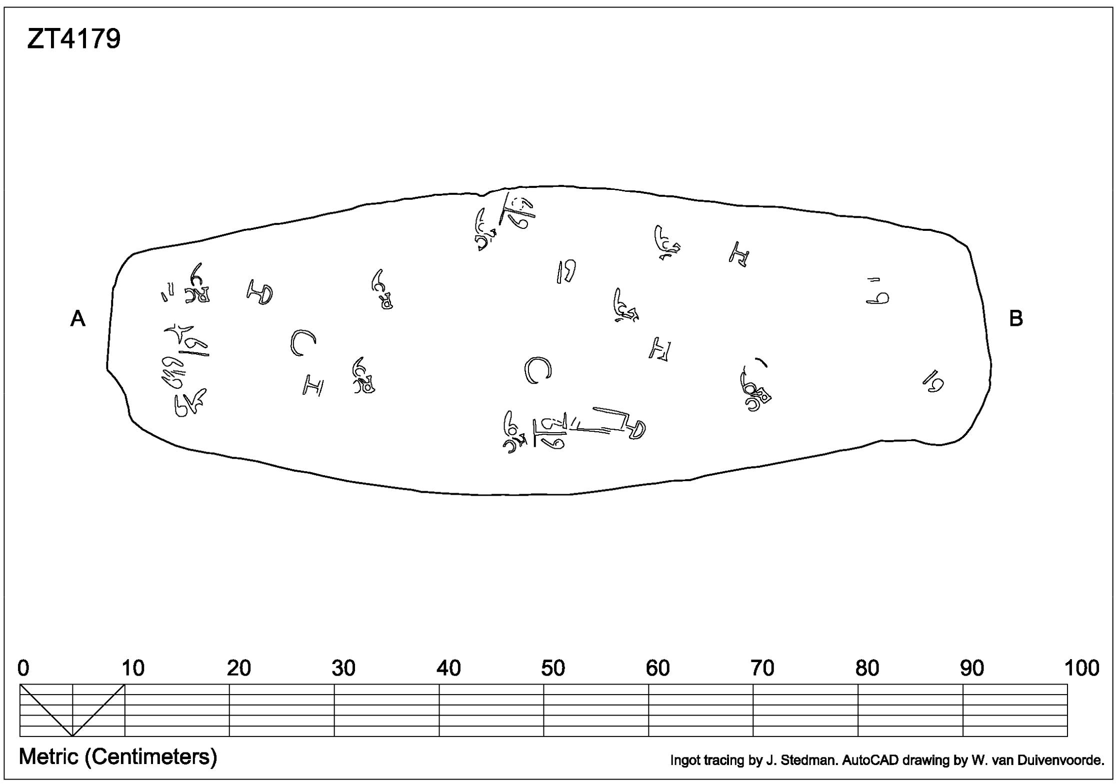

Figure 33: Ingot ZT 4179, Cooling Surface

ZT 4260 (Type I)

Maximum Dimensions: length 82.6 cm, width 30 cm, thickness 10.7 cm.
Weight: 154.60 kg.
Mould Surface: rounded and convex.
Cooling Surface: flat with a shallow, concave trough at centre. Surface has been heavily encrusted underwater and some of the markings are partially infilled with marine growth.
Distal A End: straight with an upturned lip.
Distal B End: straight with an upturned lip.
Left Lateral Edge: flat to slightly concave. Damaged towards distal A end.
Right Lateral Edge: flat to slightly concave.
Marks: **Star**(4), **rc**(10), **xx**, **FH**(6), **FOUR**(3), **#**, **+**.

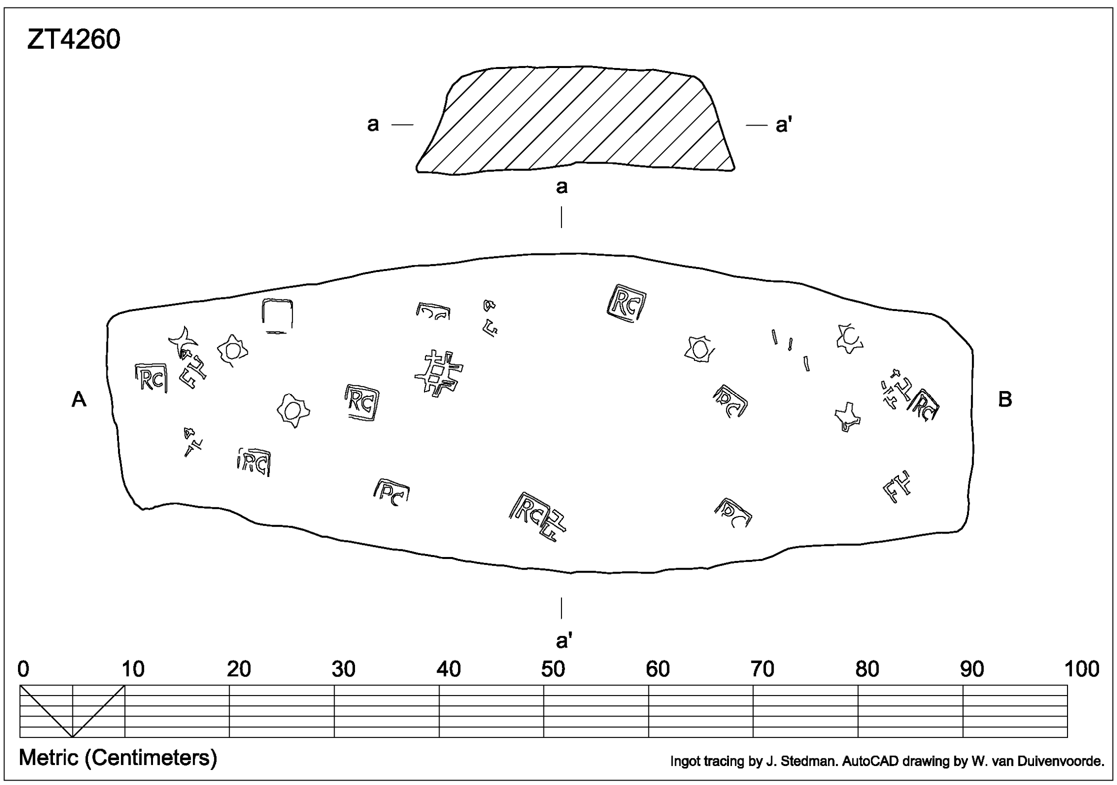

Figure 34: Ingot ZT 4260, Cooling Surface and Section

DISCUSSION

As stated above, there are three principal characteristics that may be used to classify and compare metal ingots: form, weight and markings (Whiting, *et al*., 1985: 107). The 21 *Zuiddorp* lead ingots are discussed in the following paragraphs, in relation to these three characteristics.

Form

The *Zuiddorp* ingots display a range of eight differing shape types, varying from the broad, great pigs comprising Types I, II, III, IV, and V, to the slender, elongate pieces represented by Types VI, VII and VIII. This considerable variation of form in the assemblage of 21 ingots is notable, as the ingots studied from *Kennermerland*, for example, are all great pigs (Price, *et al*., 1980: 23), whilst those from the wrecks of *Hollandia*, *Kampen* and *Adelaar* are all pieces (Willies, 1985: 235; Whiting, *et al*., 1985, 97; Martin, 2005: 201). The *Zuiddorp* ingot assemblage is therefore unique in that it spans the transition from the great pigs of the seventeenth century, to the pieces which became more common in the eighteenth century (Price, *et al*., 1980: 25).

There are definite similarities in form between the *Zuiddorp* pigs (Types I – V) and those from *Kennermerland*. Boat-shaped lead pigs are easily cast and convenient to sling (Price, *et al*., 1980: 9). They are, however, heavy items to handle and their shape means that they do not stack well. Once on board the ships it is likely that they were supported by either wooden chocks or stacked up against the ship's timbers (Price, *et al*., 1980: 24). Like the *Kennermerland* pigs, many of those from *Zuiddorp* have longitudinal striations visible in their sides, giving them a laminated appearance. This is a normal product of cooling and not necessarily indicative of multiple lead pourings. The shallow concave trough often seen on these ingots' cooling surfaces is caused by the cooling of the molten lead, and is usually centred over the deepest part of the ingot. Some of the *Kennermerland* pigs have prominent bumps on their mould surfaces, possibly reflecting damage to a sand mould during the lead pour (Price, *et al*., 1980: 17). This was certainly the case with the Type I *Zuiddorp* pigs, which have lumpy, irregular mould surfaces.

The sides of basic sand moulds would have been formed up with a wooden pattern, resulting in the flat ingot sides (Price, *et al*., 1980: 24). The remainder of the ingots in the *Zuiddorp* assemblage have well-formed, smooth mould surfaces, indicating that they were cast in stone or cast-iron moulds.

Parallels in form may also be drawn between Type VII *Zuiddorp* pieces and lighter examples from Group 5 ingots recovered from *Hollandia* (Willies, 1985: 235). Another similarity shared by the *Zuiddorp* and *Hollandia* assemblages is the presence of bent ingots. The examples from *Zuiddorp* are typically all pieces, and are bowed downwards when viewed with their cooling surfaces up. This would suggest that the ingots were stored, or perhaps stacked in ships' holds with their mould surfaces downwards.

Weight

Studying the weights of historic lead ingots can provide clues as to where they were made and for which market they were intended (Willies, 1985: 237). The total weight of the ingots recovered from *Zuiddorp* is 1880.5 kg (4146 lb). If it is taken that this comprises approximately a quarter of the lead ingots that were observed on the sea bed at the wreck site (McCarthy, 1990: 37); it can be estimated that *Zuiddorp* was carrying at least 7500 kg (16,535 lb) of lead. However, many more ingots presumably lie buried in the sand and were not visible to the Museum divers (McCarthy, pers. comm., November 2009).

During the eighteenth century, English lead ingots were weighed by the fother (or fodder), the value of which varied from place to place (Willies, 1985: 237). When dealing in lead ingots, two pieces equal one pig and eight pigs equal one fother. The exception to this rule was at Grassington where there were 10 pigs and 20 pieces to the fother (Willies, 1985: 238, Table 1). By comparing the weights of lead ingots recovered from shipwrecks to historic records of fother values, Willies considers the most likely source for *Hollandia*'s lead ingots to be Derbyshire.

This method of comparing ingot weights with fother values is not failsafe, however, and it may be possible that lead smelters cast ingots to specific weights for particular customers or markets (Willies, 1985: 238). A single lead ingot found in the Trent gravels near Colwick almost certainly originated from Derbyshire. In contrast to the expected local weights for lead pigs of 153 kg (337.3 lb) and 160 kg (352.7 lb), the Colwick ingot weighs only 134 kg (295.4 lb) (Price, *et al*., 1980: 24).

The weights of the fothers at various lead production areas and ports in England are listed below. The pig and piece weights are calculated as described above, with Grassington the only exception to the norm of eight pigs per fother.

Table 7: Fother, pig and piece weights at English lead production towns and ports.

Fothers	Fother weight (Lb)	Pig weight (kg)	Piece weight (kg)
London	2184	123.9	61.97
Birmingham	2240	127.1	63.56
Hull	2340	132.8	66.39
Newcastle	2352	133.5	66.74
Liverpool/Chester	2400	136.2	68.1
Stockwith	2408	136.7	68.33
Grassington	2450	111.1	55.56
Stockton	2464	139.8	69.92
Worksop	2520	143.0	71.5
Wirksworth	2700	153.3	76.6
High Peak	2820	160.0	80.02

(Willies, 1985: 238, Table 1)

Ingot ZT 3389 (Type V) is unique in the *Zuiddorp* ingot assemblage, weighing 114.75 kg (253 lb). This is considered too light to be a great pig, but markedly heavier that the Type VI – VIII pieces. If the ingot is of northern English origin, it may be that it derives from Grassington, where there were said to be 20 pieces to the fother. The Grassington fother of 10 pigs equated to 2450 lb (1111 kg), meaning that each pig would have weighed approximately 245 lb (111 kg). It was standard practice for lead ingots to be cast slightly over weight, but with a sample of only one ingot, this is only speculation. The closest known parallel is an ingot of 265 lb (120 kg), recovered from the *Kennermerland* wreck (Willies, pers. com. October 2009).

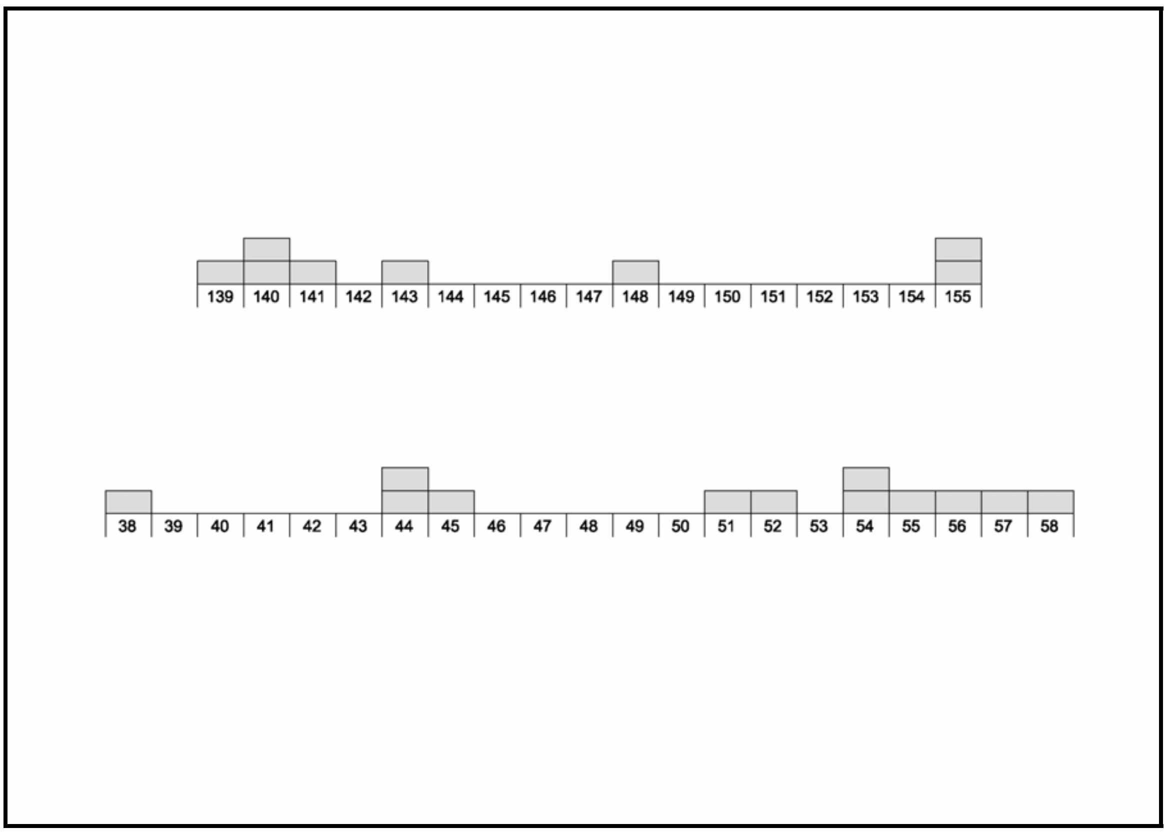

Figure 35: Histograms showing the spread of *Zuiddorp* ingot weights in kilograms. Pigs are represented on the top row and pieces on the bottom.

When the weights of the remaining 20 *Zuiddorp* ingots are compared with the English regional fother values, it is evident that the pigs could derive from Stockton, Worksop or Wirksworth. Lead was shipped down the River Tees out of Stockton (Price, *et al*., 1980: 24), which would have been a convenient departure port for ships bound for Amsterdam or Rotterdam. Worksop, not being a lead production area itself, was reliant on lead from mines in Derbyshire, which was shipped from Hull on the River Humber (Willies, 1985: 238); another English east coast port with close maritime links to the Netherlands. It is probable that lead from Wirksworth would have been traded along the same route. The Type VI and VII pieces, ranging in weight between 44 kg (97 lb) and 58 kg (128 lb), match best with the Grassington fother. Grassington lead ingots are also known to have been shipped out of Hull (Price, *et al*., 1980: 24).

Markings

The stamped markings on the cooling surfaces of the Zuiddorp ingots may at first appear to be a perfect diagnostic research tool to provenance the source of the lead. This however this is not the case. To date, very little historical information detailing exactly what or who the stamped marks represent has come to light. Marks on lead ingots are known to have been applied at the smelting mill, although the universality of this practice is unknown. Lead merchants may also have applied their own marks (Larn, 1985: 110). The stamps appear to be control marks applied by the lead producers, middle-men or perhaps even the VOC or other clients (Price, et al., 1980: 19). They include a wide range of motifs, including: numbers, letters, initials, ciphers and occasionally dates (see Figures below). The only comparative data about lead ingot stamps comes from other studies undertaken on lead ingots dating from the period, as reviewed above (Price, *et al.*, 1980; Willies, 1985; Larn, 1985; Tripati, *et al*., 2003; Martin, 2005).

Figure 36: Ingot ZT 3400, PK **motif, (Scale = 20 cm)**

Figure 37: Ingot ZT 4178, RC9 **motif, (Scale = 5 cm)**

Figure 38: Ingot ZT 4178, UU **motif, (Scale = 5 cm)**

Figure 39: Ingot ZT 4178, X **and** XX **motifs, (Scale = 5 cm)**

In the *Zuiddorp* ingot assemblage the pieces (Types VI – VIII) generally display fewer marks than the pigs (Types I – V). The marks on the *Zuiddorp* ingots were all stamped on the ingots' cooling surfaces, probably using a hammer and die. This appears to have been a standard method, and was used to mark ingots recovered from the wrecks of *Hollandia*, *Kennermerland* and *Adelaar* (Willies, 1985; Price, *et al.*, 1980; Martin, 2005). Some ingots recovered from *Kampen*, however, display crudely executed linear markings that may have been applied with a chisel (Larn 1985: 101). Only two of the 21 *Zuiddorp* ingots (ZT 3397 and ZT 3389) do not have any visible markings on them. Ingot ZT 3392 is marked, but the motifs are faint and illegible.

There are clear indications on the *Kennermerland* ingots of one mark consistently overlying, and therefore being applied after another. Unfortunately this does not occur frequently enough to form a comprehensive relative chronology of stamping (Price, *et al*., 1980: 19). The practice of stamping marks over existing marks is also seen on the *Zuiddorp* ingots, but as with the *Kennermerland* ingots, no relative chronology could be formed due to the limited data set.

Figure 40: Ingot ZT 4177, E **motif overlying** CS **motif, (Scale = 5 cm**

The cluster analysis undertaken on attributes of the *Kennermerland* ingots shows a close correlation between ingot shape and marks. This suggests that the marks were in some way connected with ingot production. The marks may have been applied soon after casting to identify ingot batches; or else may have been added by customers, middle-men or even by the ingots' recipients denoting their suppliers (Price, *et al*., 1980: 21). In view of the varying frequency of the marks on the *Kennermerland* ingots, it seems likely that they were applied at different stages along the trade line; the general feature being a relationship to the source of the ingots rather than any other attributes such as weight, quality, price or intended destination. Studies of the *Kennermerland* ingots prove a possible relationship between marking and shape classes, but not necessarily a strong one (Price, *et al.*, 1980: 20). In view of the lack of relationship between shape class and ingot weights, Price concludes that within the *Kennermerland* ingot assemblage, there is no correlation between ingot weight and markings (Price, *et al*., 1980: 21).

There are definite stylistic parallels noticeable between the marks on the pigs from *Kennermerland* and *Zuiddorp*. Initials, often within boxes are recurrent motifs. The markings are frequent, often repetitive and are clear and well-formed. There are similarities in the style of motifs between the two assemblages, with the initials **CS** and **RC** and **E** notably recurrent on the *Zuiddorp* pigs. It is not surprising that the stamp motifs differ somewhat, bearing in mind that *Kennermerland* sank 48 years before *Zuiddorp*. The **1702** motif that is stamped on Zuiddorp ingots ZT 3386 and ZT 4176 suggests that the Zuiddorp Type II ingots were cast, or perhaps sold, 10 years prior to the shipwreck event. Date marks ranging from 1732 to 1738 were stamped on some of the *Hollandia* ingots. *Hollandia* was wrecked in 1743 and Willies interprets these early date marks as an indication of delays in the trading sequence, when lead ingots may been stockpiled at ports on both sides of the North Sea (Willies, 1985: 248). On the Zuiddorp pigs the **1702** motif occurs in association with the **STAR M** motif.

Figure 41: Ingot ZT 4176, 1702 **motif, (Scale = 5 cm)**

Figure 42: Ingot ZT 4176, STAR M **motif, (Scale = 5 cm)**

Amongst the *Zuiddorp* ingots, the **#** motif that is stamped on ingot ZT 4260 is similar to the **DC** motif that was repeatedly stamped on 21 *Kennermerland* ingots. The **TR** motif that occurs on three of the *Kennermerland* ingots (Price, *et al*., 1980: 11-12, Table 1), although not identical, is similar in appearance to the *Zuiddorp* motifs **x** and **xx**, which occur on the pigs ZT 4178, ZT 4179 and ZT 4260.

Approximately a quarter of the lead ingots that Willies studied from *Hollandia* carried no marks at all. Most of the marked ingots displayed a scatter of often repetitious marks, apart from two exceptions in Groups 5 and 9. These ingots were marked clearly and precisely at one end, without repetition, perhaps suggesting the work of the same founder or lead merchant (Willies, 1985: 237). Ingot 268H from *Hollandia* is clearly marked with a single **L** motif (Gawronski, 1992: 288); a motif that is also seen on *Zuiddorp* ingot ZT 3395. This motif is also similar to the **LL** motif that is stamped on ingot ZT 3401. The **W** motif was also noted on *Hollandia* ingots (Willies, 1985: 246), and occurs on *Zuiddorp* ingot ZT 4178. The **W** mark was used by Samuel White, probably of Stoke Mill in Derbyshire's High Peak in the mid-eighteenth century (Willies, 1985: 246).

Figure 43: Ingot ZT 4178, W **motif, (Scale = 5 cm)**

The **B** motif that is stamped on the *Zuiddorp* ingot ZT 3396 may correspond to marks used by the Barkers, who were a prominent partnership in the English lead industry by the mid-eighteenth century. Interestingly, the **B** motif has also been recorded on ingots from the VOC ship *Huis te Kraaiestein*, which sank in 1698, prior to the establishment of the Barkers' partnership (Soonike, pers. comm. to Willies, in Willies, 1985: 247).

The **D** motif occurs on Type II *Adelaar* ingots (Martin, 2005: 201), and is also present on Zuiddorp ingots ZT 3390 and ZT 3395. Although not diagnostic by itself, on the *Adelaar* ingots, the **D** motif appears in association with an **IB** motif (not recorded on *Zuiddorp* ingots). This is thought to be the initials of John or Joseph Bright, who were active in the Peak District lead trade in the early-eighteenth century (Willies, 1985: 233).

CONCLUSION

The *Zuiddorp* lead ingot assemblage is diverse, with eight distinct types from a sample of only 21 ingots. This sample represents approximately a quarter of the ingots that Western Australian Museum divers observed on the wreck of *Zuiddorp*, with many more presumably lying buried beneath the sand (McCarthy, 1990: 37).

With the lack of historical information with which to positively identify the markings that are stamped on the ingots, it is very difficult to ascertain precisely from where they came. The only viable avenue of study is to conduct comparative analyses with other ingot assemblages, which only survive from shipwreck contexts.

There are certainly grounds for believing that the *Zuiddorp* lead ingots examined in this study are of English origin. Historical records indicate that the VOC procured large quantities of lead from English sources and there are known to have been well-established maritime trade links between English and Dutch ports by the beginning of the eighteenth century (Willies, 1985: 247).

The *Zuiddorp* ingot assemblage is significant in that it spans the transition from the great pigs of the seventeenth century, to the pieces which gained popularity in the eighteenth century (Price, *et al.*, 1980: 25). The *Zuiddorp* great pigs bear definite similarities with ingots recovered from *Kennermerland*, both in form, weight and the style of the stamped marks. The great pig was a typically English form of lead ingot that differed considerably in form from ingots cast in continental European foundries (Price, *et al*., 1980: 23).

The smaller ingots, or pieces, that make up the remainder of the *Zuiddorp* assemblage are similar in form, weight and to some extent marks, to those recovered from the wreck of *Hollandia*. Willies believes that the majority of the *Hollandia* ingots derive from Derbyshire, which was perhaps the most important lead producing region in Europe in the mid-eighteenth century (Willies, 1985: 247).

It is clear that metallurgical analysis may yield further information on the provenance of the *Zuiddorp* lead ingots. A future study using lead isotope analyses on samples from the *Zuiddorp* ingots, as was conducted on ingots from the Poompuhar shipwreck off the Indian coast (Tripati, *et al*., 2003: 230), may serve to locate the source of the lead ingots that *Zuiddorp* was carrying when she was wrecked on the Western Australian coast in 1712. Steps will be taken to undertake such analyses when funding permits.

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