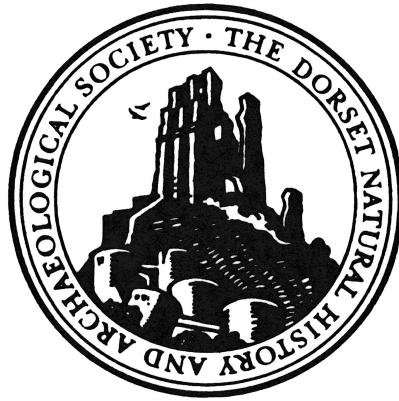


INVESTIGATIONS AT KIMMERIDGE BAY
BY THE DORSET ALUM AND COPPERAS
INDUSTRIES PROJECT

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Offprint from the

Proceedings of the Dorset Natural History & Archaeological Society

Volume 135

2014

Hon. Editor, Paul Lashmar

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Abstract

Archaeological investigations were carried out on behalf of the Poole Harbour Heritage Project in Kimmeridge Bay between 2009 and 2010, as part of a project researching the Dorset Alum and Copperas industries. There is documentary evidence for alum production at Kimmeridge in 1569 by John Clavell and 1605-1617 by William Clavell, but the precise location of their works is not known.

Earthwork survey revealed the remains of three linked ponds with associated dams and sluices, industrial deposits, and a number of stone and timber structures along the shoreline. The ponds were most likely constructed as part of the early-seventeenth-century alum works. Examination of eroding industrial deposits along the shoreline (at SY 9088 7880) revealed buried beach deposits overlain by an extensive layer of burnt shale and shale ash that may have derived from the earliest alum works. This was sealed by clay and stone structures that may have formed part of a former quay or jetty perhaps also related to William Clavell's industrial ventures. This was buried beneath tips of burnt shale waste, probably relating to nineteenth-century activity.

Exploratory excavations and geophysical survey were undertaken around the toilet block (centred on SY 9103 7878) where brick-built furnaces had been previously discovered, but this revealed that the archaeological remains were not extensive. Part of two flues and associated firing pits were found, probably related to the previously discovered furnaces, but they appeared unused. No dating evidence was recovered and no definite link to alum production was found.

Introduction

It has been argued by Dr William Sheldrick that the birth of the chemical industry in England can be traced to the attempts by Lord Mountjoy to produce alum and copperas at Poole in the mid-sixteenth century (Sheldrick 2006). The history of this industry in Dorset is little known and poorly understood and so the Dorset Alum and Copperas Project was set up by the Poole Harbour Heritage Project to investigate the social, economic and historical factors relating to these industries through documentary research and

limited archaeological investigation into three sites, at Kimmeridge, Studland and Brownsea Island, that had been suggested as having links with Alum/Copperas production. The archaeological project was supported by English Heritage with the aim of providing data to help characterise the remains of this industry. In the event, the link between the three excavated sites and the alum/copperas industry was not established to an appropriate degree of certainty. Without a common thread between these three excavations, it has been decided to publish each site separately.

The technical aspects of alum and copperas production have been described elsewhere in the literature (e.g. Rout 1997, Miller 2002, Allen *et al.* 2004) and will not be repeated here. Briefly, the historical process of alum manufacture consisted of the burning of alum shales followed by steeping in water to extract the soluble salts, which were then boiled to concentrate the liquor. Alkali, normally in the form of urine, was then added and the mixture allowed to cool in order to crystallise out the alum.

Historical background

In the later medieval and early post-medieval period alum and copperas were widely used in the textile, tanning and papermaking industries. The primary use of alum was in the textile industry where it was used as a mordant, or fixative, for dyes. In the sixteenth century the main source of alum was from the Papal States in Italy. Increasing Papal control over both the price and importation of alum into England led to moves to produce domestic supplies. By the reign of Elizabeth I these endeavours were being actively encouraged and supported by the Crown.

Some of the earliest recorded attempts to manufacture alum and copperas in England stem from a 1566 patent granted to Cornelius de Vos, a London merchant originally from Liège (State Papers, Dom. 1547-80; Patent Rolls 1563-66, C. 119). This patent granted him the rights to open and work mines in connection with the production of copperas and alum over the whole of England. Before long, de Vos assigned his patent to James Blount, the 6th Lord Mountjoy, the owner and Lord of the manor of Canford (Patent Rolls 1563-66, C. 119). The Canford estate was

already enjoying benefits from copperas recovered from Durley Cliffs and around 1564 Mountjoy started to mine and boil alum shale at Parkstone. A monopoly for the manufacture of alum and copperas was conferred on Mountjoy for twenty-one years from April 1567. By 1580 two factories producing copperas were operating in Parkstone based on alum shale mined nearby. Soon there were also works at Brownsea Island, Alum Chine and Boscombe.

Documentary sources indicate that manufacture of alum at Kimmeridge began when Lord Mountjoy and John Clavell (the owner of the Kimmeridge Estate) experimented using local shale in about 1569, but it was Clavell's son, Sir William Clavell, who commenced production on a commercial scale c. 1605 (Betsey 2001, 7-8; Brachi 2008). However, this soon ran into legal difficulties as the Crown deemed the enterprise to be in breach of a previous monopoly issued by James I. Clavell gained permission to recommence alum production, but came into conflict with the Crown once again, after which his plant was forcibly closed. A surviving document details the legal arguments Clavell presented hoping either to be granted production rights or to be or be recompensed for his work. He states that in the space of eight months he had built not only two alum houses but also a strong huge pier of stone, 100ft long and 60ft broad (Betsey 2001, 7-8). An inventory taken 1616(?) lists the contents of the two alum houses (WYL100/PO/8/VIII/4).

Clavell turned to salt manufacture and to glassmaking using local shale as fuel in 1617-23. His glass house was found close to the quay and its remains have been excavated (Crossley 1987). Sir Robert Mansell had already unsuccessfully tried window glass manufacture at Kimmeridge in 1615.

Exploitation of the shales at Kimmeridge recommenced in the nineteenth century. In 1848 the 'Bituminous Shale Company' obtained a lease to quarry and ship oil shale to its works at Weymouth for the production of naphtha, varnish, grease, pitch, paraffin wax and paint. In 1849 the 'Mineral Spirit Company' built a factory at Wareham to produce oil, grease and manure from Kimmeridge Shale. The Weymouth factory was closed in 1854 and shortly afterwards the Wareham works were sold. In 1858, Wanostrocht & Co. obtained a contract to light the city of Paris with gas from Kimmeridge shale. They converted the factory at Wareham and extended shale extraction at Kimmeridge by driving adits into the cliffs, as well as constructing a stone pier and an iron

jetty. By 1862, Wanostrocht & Co. were in financial difficulties and sold the business to the Wareham Oil and Candle Company, who survived until 1872 when the factory was destroyed by fire. In 1883, the 'Kimmeridge Oil and Carbon Company' extracted shale to make filters for the purification of sewerage but this ended in 1890. Further leases were granted until 1916, when exploitation of the shale ceased (Brachi 2008; Mansel 2000, 24).

The precise location of Clavell's alum works is not known, but a number of features perhaps associated with alum production have been identified by David Brachi. Possible alum furnaces were exposed during construction of the public toilets in 1976. The stream had been artificially diverted north-westward into its present course, perhaps to control the flow of water and allow the washing of alum. Also, the glassworks were built in a former shale quarry, which may have been associated with the alum works (Brachi 2008; Crossley 1987).

Site description

The archaeological investigations were focussed on the east side of Kimmeridge Bay, a wide curving bay facing roughly south west with a series of reefs or ledges formed by dolomite beds and hard bituminous shale (Fig. 1). A small stream runs from near Smedmore House down into the eastern part of Kimmeridge Bay. The edge of the bay is formed by vertical cliffs, except on the east side where there is a level terrace between the foot of the cliff and the shore, where a large number of blocks of Yellow Ledge Dolomite are found on the beach. The terrace is occupied by a series of boat sheds and a Marine Centre. At the southern end is a projecting, stone-revetted platform used as a quay, car park and turning area. This is accessed from a metalled road approaching from the east, set in the base of a narrow defile and overlooked on the north by a car park.

Methods

The investigations comprised an earthwork survey, geophysical survey, sample excavation, and the recording of the eroding shoreline deposits, together with associated geoarchaeological recording.

The earthwork survey was undertaken by Mark Corney and Nik Morris, using a total station tied into the Ordnance Survey grid, and covering an area of about five hectares on the eastern side of Kimmeridge Bay (Fig. 2). Dense vegetation prevented detailed

recording to the east of the Marine Centre, south of the access road, and west of the public toilets.

Electrical resistance and magnetic geophysical surveys of the paddocks to the east and northeast of the car park area was carried out by ArchaeoPhysica Ltd in February 2009 (Fig. 1). These surveys did not identify any features that were likely to be associated

with alum and copperas production and are not discussed further in this report.

Archaeological investigation was undertaken in two separate phases. In May 2009, the area around the public toilets (SY 9103 7878) where David Brachi had recorded the remains of kilns or furnaces in 1976 was investigated. Four trenches were opened, two in

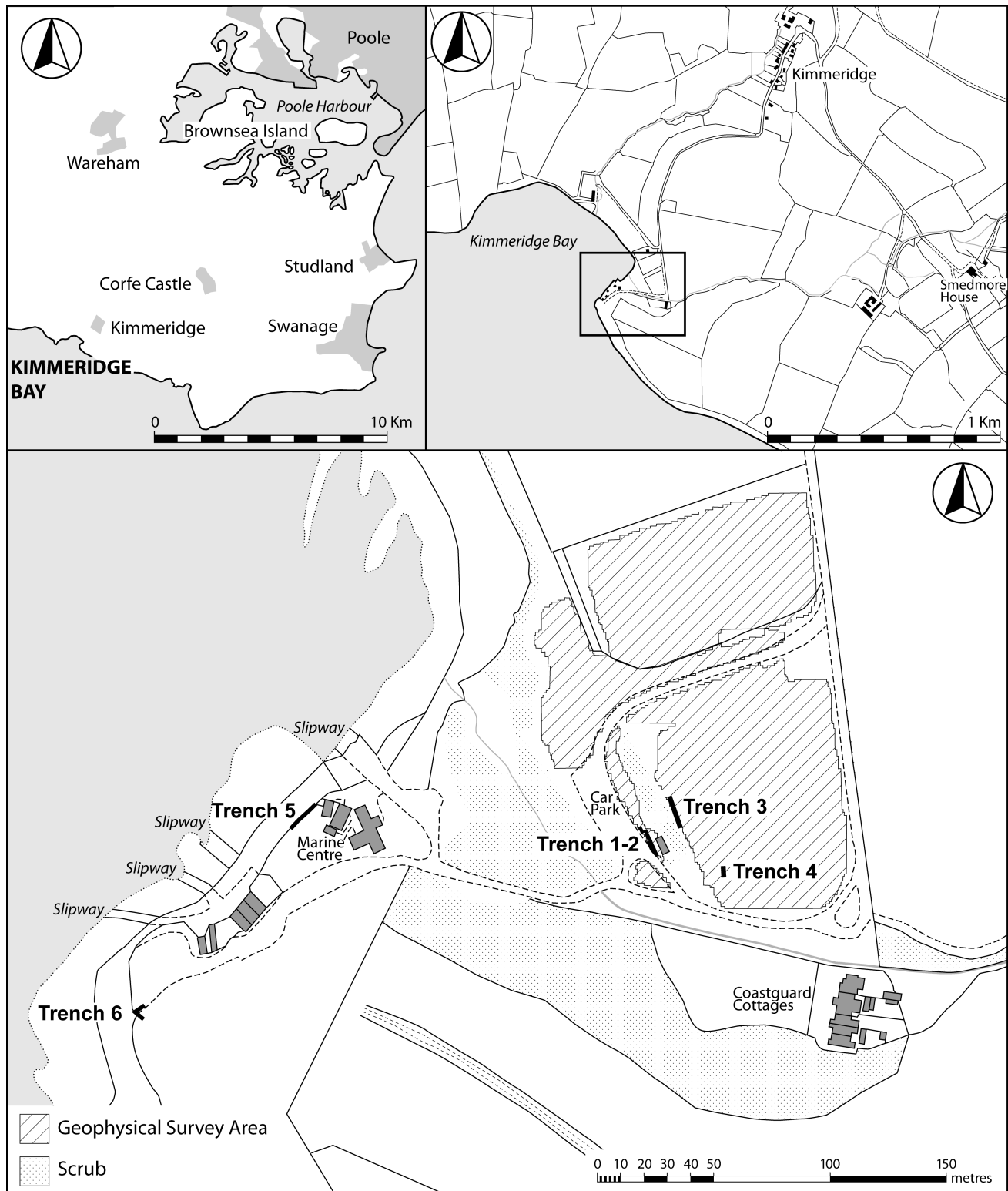


Figure 1: Location plan of the Kimmeridge Bay excavations and survey.

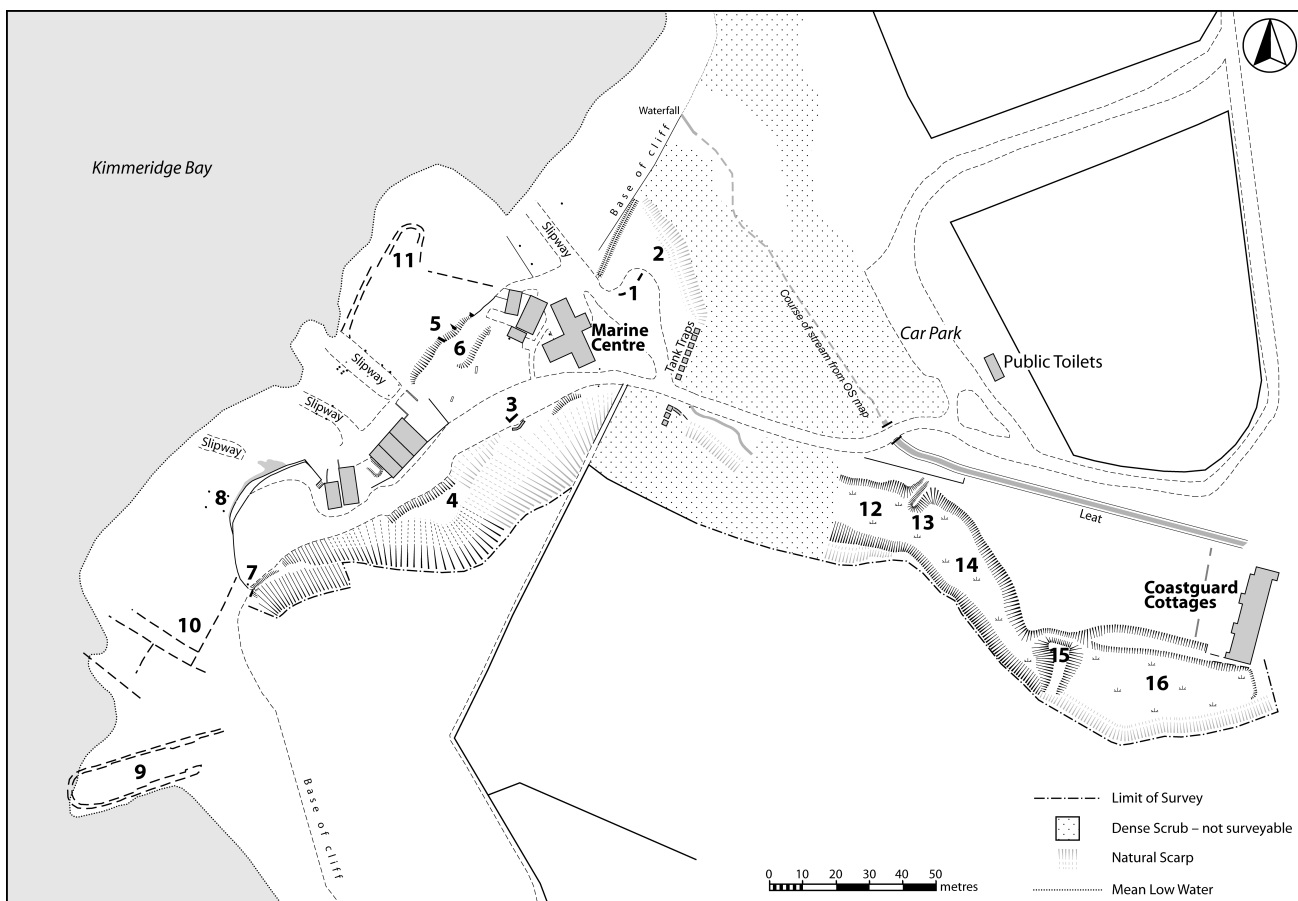


Figure 2: Plan of earthworks and other historic features on the east side of Kimmeridge Bay.

the upper car park (Trenches 1 and 2) and two in the adjacent paddock (Trenches 3 and 4) (Fig. 1).

In February 2010 the eroding shoreline deposits along the quay at SY 9088 7880 (Trench 5) and SY 9081 7871 (Trench 6) were recorded. The methods of investigation were constrained by the need to minimise potential erosion and only minimal clearance of vegetation and loose soils was undertaken. Trench 5 was an approximately 20 m long section of the exposed eroding industrial deposits along the shoreline (Fig. 1). A narrow strip of beach at the base of the section was also temporarily cleared of superficial beach shingle. The exposed section of Trench 6 was severely undercut by erosion, making it impossible to record safely. Previous investigation of this area has identified it as the remains of William Clavell's early-seventeenth-century saltworks (Brachi, 2008, 40; Valentin 1997). It will not be considered further in this report.

Geoarchaeological recording was undertaken by Dr Clare Wilson, SBES, University of Stirling, to characterise the nature and origin of the deposits. The soils and deposits were examined and described using standard Soil Survey of England and Wales terminology (Hodgson 1976). A Bartington MS2

meter and MS2-F field probe were used to investigate patterns of magnetic susceptibility in the field in order to investigate potential burning and buried soils.

Earthwork survey

The earthworks and other topographical features can be divided into two discrete groups: the quay and intertidal zone; and ponds and associated water management features between the quay and Coastguard Cottages.

The quay and intertidal zone

The features in this area include the remains of buildings, quarry scarps, and former piers, hards and slipways, which appear to represent a wide range of activities spanning some 400 years (Fig. 2). None of these features can be dated on purely morphological grounds.

The building remains include two lengths of stone wall (1) within the area of the excavated Clavell glass house (Crossley 1981) and L-shaped stone wall remains visible in the road along the quay (3).

The quarry features include a steep scarp up to

10 m high forming an arc around the northern end of the quay (2), probably the remains of a former oil shale quarry, within which the glasshouse of 1617-23 was built. The upper part of the scarp and any archaeological features beyond are masked by very dense scrub. The eastern edge is occupied by World War II concrete anti-tank 'dragon's teeth'. Along the cliff forming the south-eastern limit to Kimmeridge Bay (4) is irregular scarping, probably partly the result of ongoing landslips, but the presence of burnt debris in exposures also indicates former industrial activities including dumping and possible quarrying.

Along the edge of the shore is a low cliff face 26 m in length and up to 1.6 m high (5) with eroding archaeological deposits comprising much burnt shale material and three walls aligned NW-SE exposed towards its northern end. Behind the low cliff is a scarp aligned SW-NE 15 m long and up to 0.2 m high (6), which may mark the position of another wall.

Further industrial deposits were identified at the southwestern end of the quay (7), where a bank and scarp, 8 m long and up to 1.5 m high composed of burnt clay and shale with walling exposed at the southwest end. This short length of walling is of similar character to the glasshouse remains, and is probably the remains of the early-seventeenth-century saltworks (Brachi 2008). The exposed walling on the quay at (3) is parallel to alignments of stone blocks in the intertidal zone approximately 7m to the east at (10).

The remains of a series of piers and hards can be seen in the intertidal zone west and south of the quay. Two pairs of posts about five metres apart, the first pair approximately 3 m from the quay wall (8), coincide with the position of a wooden pier built in 1883 and depicted on the 1889 Ordnance Survey 25-inch map. To the south are the remnants of a substantial stone structure (9) about 12 m wide and approximately 50 m long with a rounded terminal at the western (seaward) end, aligned roughly WSW-ENE. It is constructed of carefully laid unmortared battered outer walls with coursed rubble infill core. This is the pier built in 1860 by Wanostrocht and Co. for the shipment of shale (Brachi 2008).

Between these two piers is a group of stone block alignments in the intertidal zone, which comprises at least four related alignments comprising unmortared walls a single stone block wide, associated with roughly lain rubble (10), which are probably the remains of piers or breakwaters and what may be a

narrow dock. The southern part of this group has been suggested as being the remains of Sir William Clavell's pier of 1620 (Brachi 2008). To the north are further stone block alignments in the intertidal zone (11). These run parallel to the shore, about 30 m from the high water mark. This structure has a battered, coursed unmortared face on the west with roughly-lain rubble to the east. To the north is a rounded terminal up to 10 m wide. From the terminal a single line of unmortared stones run to the shore and are aligned with a short length of walling running from the north-west corner of a small stone structure. This is of unknown date, but may be the remains of the 'large key or cobb' noted by Hutchins (1861, 555; Brachi 2008).

Ponds and water management features

A series of irregularly shaped ponds with dams and leats were surveyed over a distance of 160 m from the Coastguard Cottages to a point just east of the 'dragon's teeth'. The ponds are now silted up and little more than muddy hollows.

The westernmost pond (12) is of rectangular plan, but the full dimensions are unknown due to very dense vegetation masking the western end. The visible remains measure 25 m E-W and 15 m N-S and up to 2.2 m deep. Twenty-five metres beyond the accessible western limit of the pond, a narrow leat emerges from the dense vegetation and flows parallel to the modern access road for 25 m before entering a culvert under the road. It is presumed that the leat marks the original outflow from the pond complex. A bank (13) projects 7 m from the north side of the east end of pond 12, where there is a marked change of alignment to the southeast. The bank is 3 m wide and up to 2.3 m high with a shallow ditch on the west side as the feature ascends the north side of the pond. This feature has the appearance of a former dam, subsequently removed to link ponds 12 and 14. Pond 14 measures 60 m long with a maximum width of 15 m tapering to 6 m at the southeast end. The northern scarp is up to 2 m high and the southern side 1.5 m high. This pond is separated from the next pond to the east (16) by a substantial earthen dam (15) 15 m long and 12 m wide at the base and 4 m wide at the top. At the north end the bank turns through 90° to the west to form a platform 3 m by 3 m. North of the dam is a channel 1.5 m wide linking ponds 14 and 16. It is likely that this channel would have originally been equipped with a sluice gate to control water flow. No trace of a sluice was found, although the most likely position

may be marked by the platform at the northern end of the dam. The easternmost pond (15) measures 55 m long with a maximum width of 22 m. This pond has a maximum depth of 1.2 m and the northern edge is terraced with a further scarp, 1.0 m high, five metres north of the pond edge. The eastern end of the upper scarp has been truncated by the construction of the Coastguard Cottages.

The ponds are located along the bottom of a coombe draining land east of the bay. The current stream has been diverted via a leat, partly stone-lined, to flow north of the ponds, passing under the access road, at which point its course is obscured by dense vegetation, before ultimately issuing into Kimmeridge Bay as a waterfall over the cliff approximately 90 m north of the Marine Centre.

Investigations in the car park area

Introduction

The work in the car park area (centred on NGR SY 9103 7878) was designed to further investigate and provide context to the discovery by David Brachi of three furnaces revealed during the construction of the toilet block in 1976 (Figures 1 and 3). Geophysical survey of the paddocks to the east and around the margins of the car park was undertaken to try to locate further structures or industrial activity. As permission was not granted to excavate close into the toilet block and septic tank, the excavations were carried out on the adjacent grassy margins west of the earlier discoveries (Trenches 1-2). Two small evaluation trenches (Trenches 3-4) were dug in the paddock in order to test a geophysical anomaly and to see if the archaeology beneath the toilet block continued into this area. No archaeology was discovered in Trenches 3 and 4.

Geophysical survey

The geophysical survey identified twenty separate anomalies. None of these appeared to represent kilns, furnaces or industrial residues, or any other features which might represent the remains of alum processing (Roseveare 2009). Only one anomaly was tested by excavation and this did not prove to be archaeological.

Toilet block recording, 1976

David Brachi undertook salvage recording in July/August 1976 during the construction of the toilet block (Brachi 2008). He uncovered parts of two furnaces

in the area of the septic tank north of the toilets and another less well located furnace probably under the northern part of the building (Fig. 3). All three furnaces appeared to be of similar construction. They comprised a channel or flue oriented roughly WSW-ESE cut into the natural clay with brick sides and end, and with a natural or puddled clay base, measuring roughly 0.35 m wide by about 0.35 m deep. Two of the furnaces had a single iron fire bar surviving across the top of the flue. Up to five courses of brick survived in the flues. These furnaces were within a floor formed of bricks set on edge. Not enough of the floor was exposed to determine whether the furnaces were within a building. The bricks used in the structures appeared to be handmade and of consistent size (222-28 mm x 96-102 mm x 45-63 mm).

The furnaces were sealed beneath a layer of brick rubble disturbed by ploughing. A number of vitrified brick fragments were present and there was some evidence for blackened and burnt clay and burnt shale. A number of other features and deposits were present in this area. However, the circumstances of the salvage recording mean it is difficult to interpret what they represent and how they related to the furnaces.

David Brachi interpreted these furnaces as possibly belonging to William Clavell's alum house. Unfortunately, the rescue nature of the recording work means that clear evidence of the nature of the manufacturing process and the date was not obtained.

Excavation adjacent to the toilet block

The 2009 excavations were undertaken to elaborate the context of the earlier discoveries. The end of two brick flues and parts of the associated firing pits were discovered and can be related to two furnaces recorded in 1976 (Fig. 3). The two flues (112, 204) were parallel and set about 1.8 m apart. They were constructed in linear cuts about 0.45 m deep, with brick lining along both sides, creating a flue 0.35 m wide. The bricks were laid in a stack bond and six courses survived in the northern flue, with seven in the southern one. The upper two courses in the southern flue were offset slightly to the outside, possibly to allow seating for a capping.

To the west, the flues opened up into wider and deeper scoops (111, 206) about 1.25 m long, up to 1.0 m wide and 0.5 m deep, with concave profiles. These have been interpreted as possible firing floors.

The remains were filled with deposits of mid

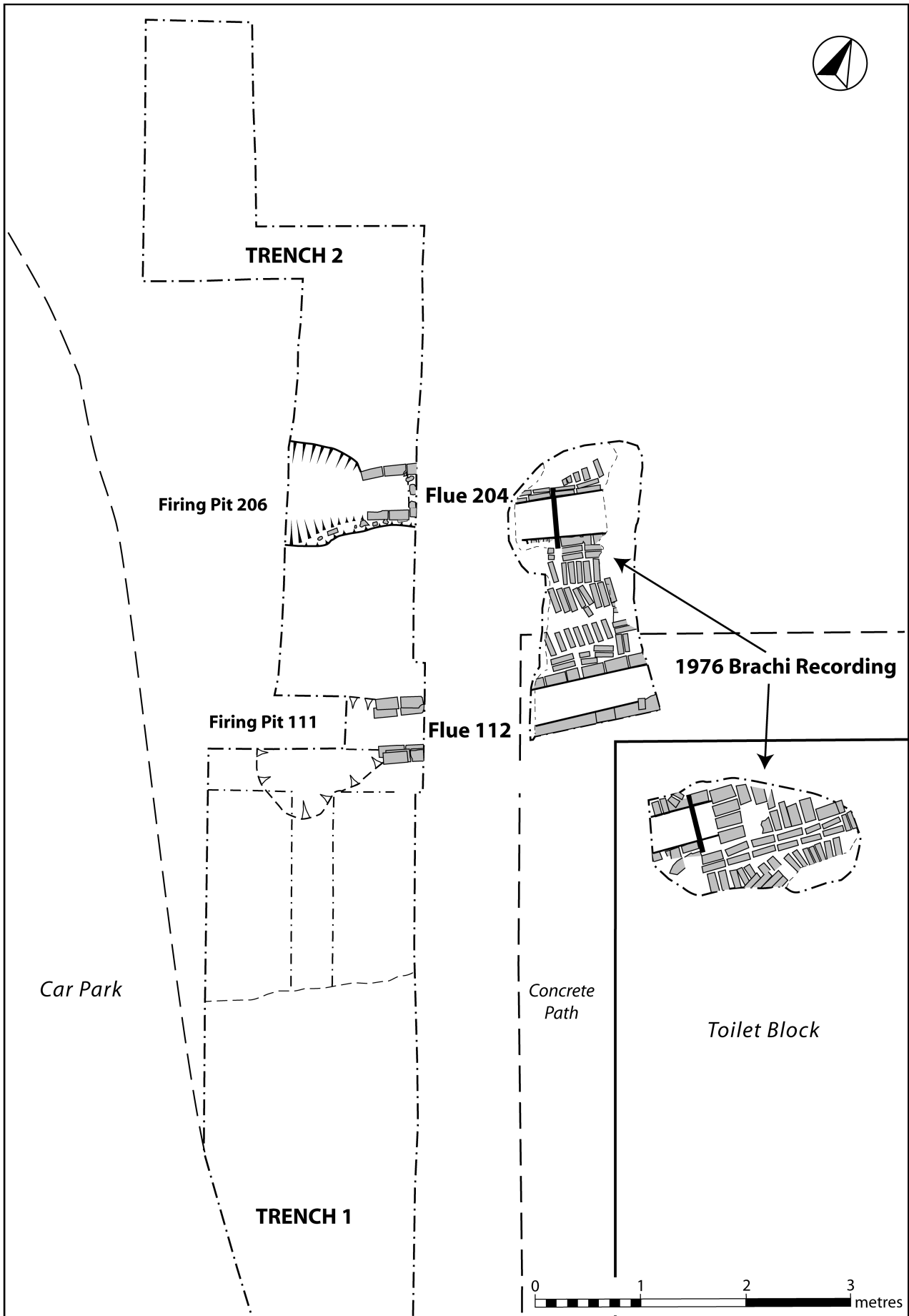


Figure 3: Plan of the excavated area (Trench 1-2) adjacent to the Public Toilets at Kimmeridge, in relation to the 1976 observations by David Brachi.

yellowish-brown silty clay, containing variable quantities of fragmented brick, probably derived either directly from demolition/dismantling of a standing structure, or from the rapid disintegration and erosion of un-reclaimed structural remnants. The remains were sealed by a plough-soil layer, containing brick and shale fragments, which was sealed by deposits related to the construction of the toilet block in 1976.

No manufacturing debris was found and neither structure had any visual evidence for thermal alteration of the natural clay. Enhanced magnetic susceptibility values for deposits filling the flues and firing floors appeared to be caused by the large amount of fragmentary and particulate brick detritus within them, rather than heating processes, particularly as no ash or fuel remains were found. This suggests that these two furnaces were never used. This appears to contradict the original Brachi evidence, though the surviving photos from the earlier works do not show much evidence for burning or any significant burnt deposits.

No secure dating evidence was found for the construction, use or abandonment of the features, but the character of the bricks does not rule out a sixteenth- or seventeenth-century date, so they could be associated with either John or William Clavell's industrial ventures.

Finds

A restricted assemblage of finds was recovered. Only brick was found below the plough-soil and recent levelling layers.

A total of 388 pieces (49,678 g) of brick were retained from the excavation. The bricks from flues 112 and 204 are lightly sanded, handmade bricks without frogs, with irregular faces and irregular rounded arrisses. All except the upper face of the brick are rough and irregular with crease marks; the upper face has strike marks and the large majority have sunken margins, often on all four sides, formed when the edges of the brick, having been pulled up when the mould was removed, were tamped down with the bottom of the moulding frame (Betts 1996). Occasional bricks have the pulled-up edges still surviving. The bricks are of consistent size (222-25 mm x 102-07 mm x 51-8 mm). It is likely they were all produced in the same mould and the difference in measurement is due to deformation after removal from the mould.

The bricks are all made from the same fabric, a fairly well wedged clay with poorly sorted quartz and flint sand temper, firing to a dark orange to red colour. They range from one under-fired example with raw clay surviving in the core to burnt vitrified bricks, including one example where two adjacent bricks have become fused together during firing. It is likely these bricks derive from a single clamp firing and the differences reflect the position of individual bricks within the clamp. It is entirely possible that the bricks were manufactured locally specifically for use in the furnaces.

The date of the bricks is uncertain, but similar bricks with sunken margins have been found in London dated from the mid-late fifteenth to the seventeenth century (Betts 1996). A date in the sixteenth or seventeenth century would be plausible for the bricks from Kimmeridge.

Recording of the shoreline exposure west of the Marine Centre

The recording of the eroding industrial deposits and exposed stone structures along the low sea-cliff west of the Marine Centre (Figs 4-5) was undertaken to try to characterise the nature of the activity in this area, to see whether it was possible to isolate the deposits of different industrial processes, and to date the sequence of deposits. Four major stratigraphic units were identified: (i) beach deposits, (ii) industrial shale waste, (iii) clay and stone structural remains and (iv) shale waste tips.

Beach deposits

The earliest phase in the sequence is represented by relatively unmodified beach-type deposits of shale and marine shell reworked by low-energy fluvial processes, probably from the stream that originally ran into the north-east part of Kimmeridge Bay.

The basal deposit is a moderately well sorted very dark grey shale gravel in a silty clay matrix (502) with many fine shell fragments, a few rounded flint, quartz and limestone gravels, and with rare fine reddened shale inclusions. It appears to represent a beach deposit, similar in nature to that found today between the large stone blocks and along the ledges elsewhere in the bay.

Overlying layer 502 was a 0.5 m thick very dark grey stratified deposit (503) of platy, rounded, shale

and silty clay with many fragmented shell inclusions (including oyster and limpet) and rare limestone and degraded reddened shale fragments. The coarse component of each stratum is well sorted and the gravel shows a strong preferred parallel orientation — larger clasts have a preferred dip southwards of about 5°. The upper 10 cm is more mixed and without any preferred orientation.

Layer 503 contained (or covered) two groups of dolomite cobbles and boulders projecting onto the beach. Those at the northeast end of the section (504) appeared superficially to form a very crude north-south alignment (Fig. 4) and could represent part of a footing, or perhaps an early episode of foreshore

consolidation, but equally may be little more than a coincidental arrangement exposed by erosion.

Layer 503 appears to represent a beach-type deposit as well, although its stratified nature and the greater proportion of silty clay is indicative of a significantly lower energy environment than 502. The fine reddened shale inclusions in both of these deposits have enhanced magnetic susceptibility and suggest a level of industrial or domestic activity using oil shale as a fuel, although the size and rounded nature of inclusions means this may not have been local activity. David Brachi found a sherd of pottery with red and yellow internal glaze from this layer just south of Wall 508.

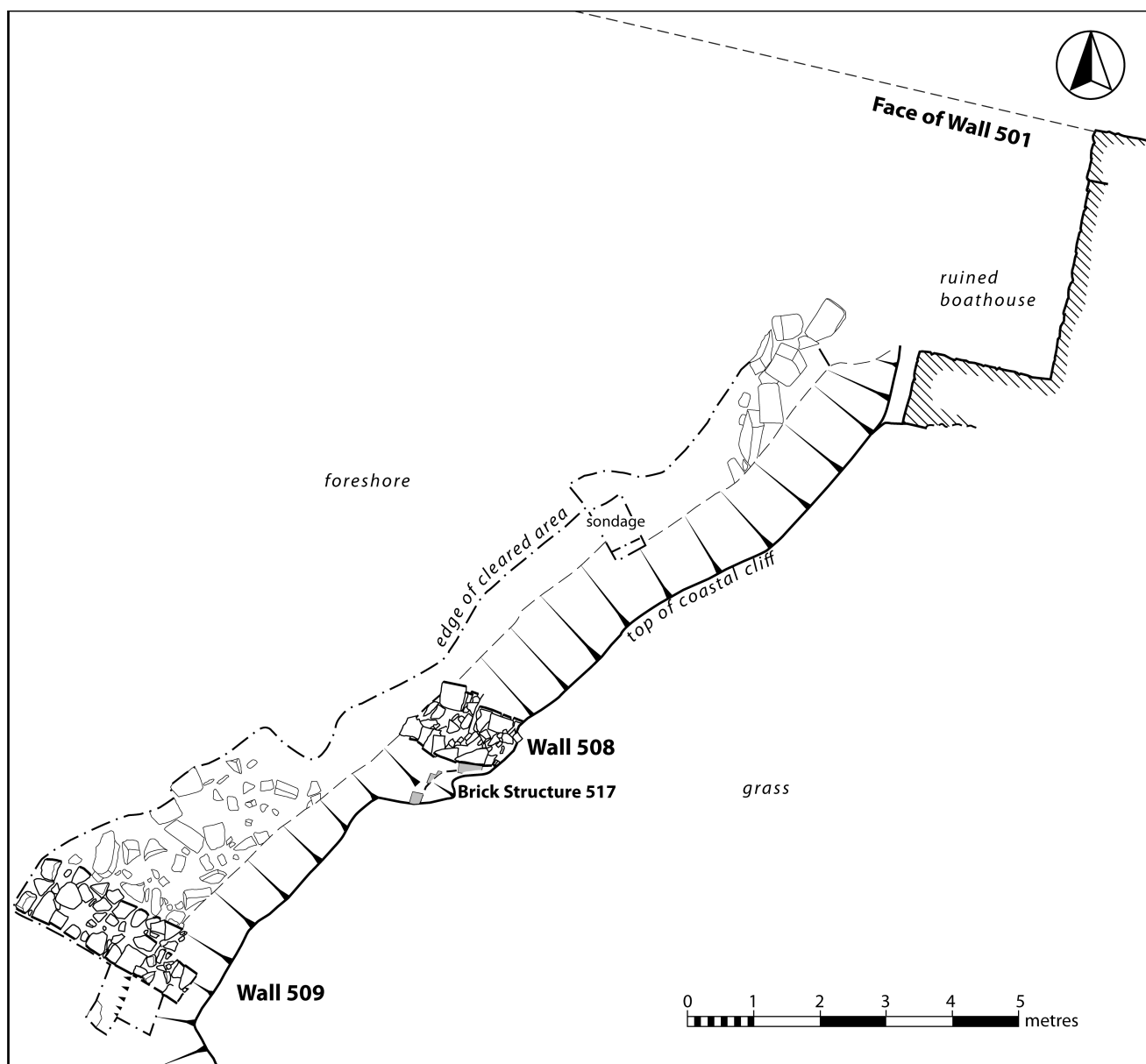


Figure 4: Plan features eroding out of the sea cliff on the east side of Kimmeridge Bay (Trench 5).

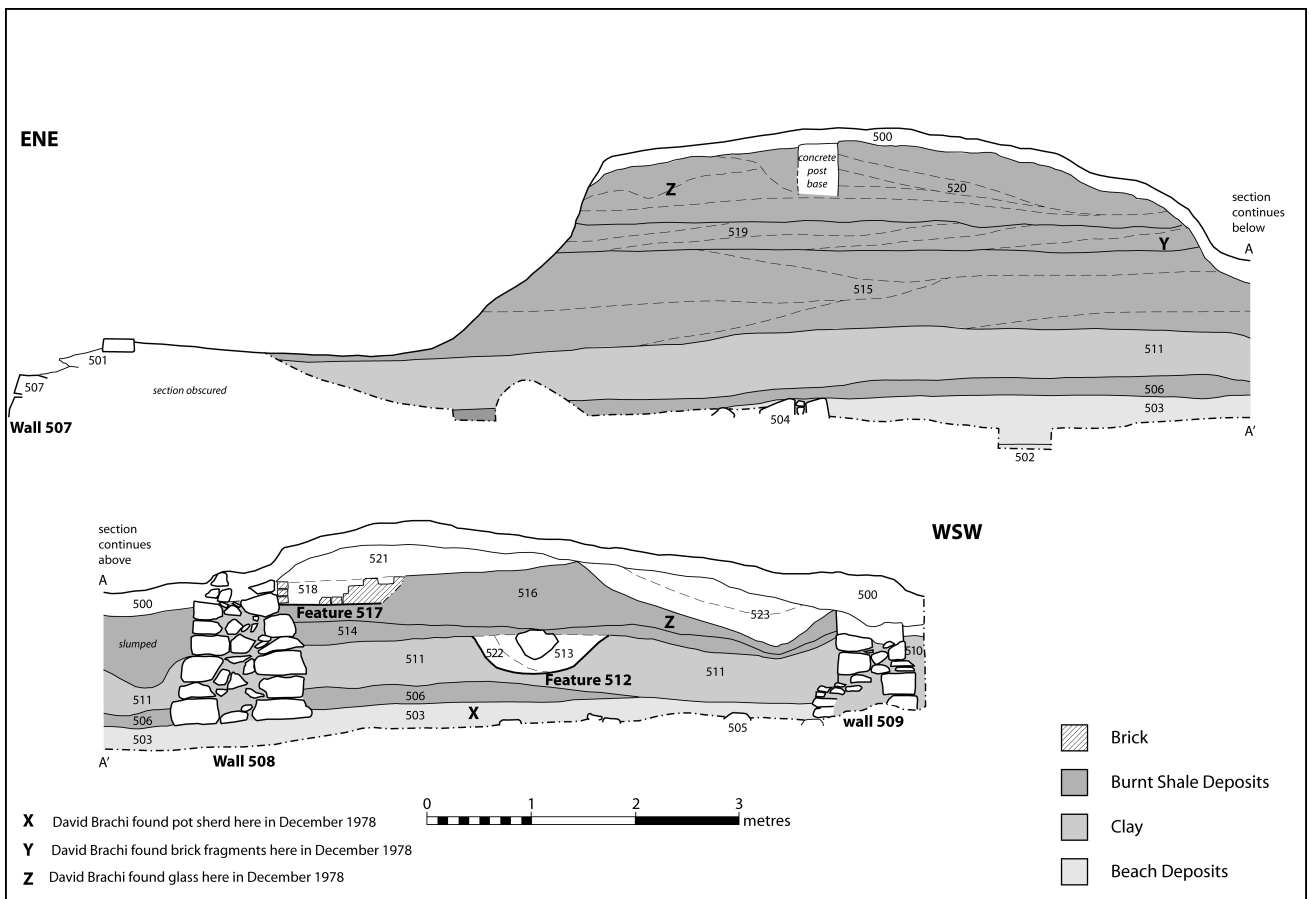


Figure 5: Section of the stratigraphy exposed in the eroding sea cliff on the east side of Kimmeridge Bay (Trench 5).

Shale waste deposit

The second phase sees the beach and stream outflow covered by tips of burnt shale waste. Beach deposit 503 was covered a 0.25 m thick tip of relatively pure shale waste (506) comprising a poorly sorted mixed deposit of loose reddened (burnt) and black (unburnt) oil shale with very little fine silty clay matrix. The coarse shale clasts showed little evidence of a preferred orientation but tended to dip seawards with an angle of 20-40°. The magnetic susceptibility readings throughout this layer were amongst the highest recorded in the section, similar to those of individual fragments of burnt shale, suggesting this was a relatively 'pure' deposit, probably derived from a single process. There was no scorching of the underlying material, suggesting that 506 was dumped 'cold', and the layer thinned southwards before tailing-out altogether near the south west end of the section. The sharp dip of the clasts seawards could indicate an advancing front of tipped waste material. It also indicates there was little or no reworking of the deposits by the sea. This tailing out of the deposit to the southwest, suggests it may be related to activity to the northeast. No dating evidence was recovered.

Structural Remains

The third phase is represented by clay and stone structures constructed over the shale waste. A 0.5 m thick layer of unburnt greenish-yellow structureless silty clay (511) containing occasional inclusions of shale waste sealed the burnt shale deposit 506. The upper surface of this clay appeared worn in places and the in-working of burnt shale in the top 10 cm suggests trampling and trafficking of the surface. Layer 511 appears to have been a single-phase deposit forming a deliberately raised base or platform between two stone walls (509, 507) with a third stone wall (508) incorporated within it.

The eroded stubs of the three walls were aligned WNW-ESE and were constructed from weathered dolomite beach boulders and cobbles, bonded with yellow clay. The north-eastern wall (507) comprised at least six courses of boulders, laid to give a steep batter to its northeast edge (Fig. 5). At the time of excavation most of this wall-stub was obscured by modern concrete and stone and it had been re-used as the base for a later boathouse. However, a clear linear 'kerb' of laid boulders can be traced from the outer face of the

stub across the beach to meet a perpendicular stone kerb near the low-water mark (Fig. 2, 11).

Thirteen metres to the south-west, was a wall (508) comprising a footing of dolomite boulders with a clay and rubble core measuring about 1.2 m wide and 0.6 m high, upon which was a wall of similar construction, up to 0.8 m wide (Fig. 5). Wall 508 appears to be associated with the use of the clay surface as the top of the footings of this wall is at the same level. The function of the wall is unclear; it does not appear to be part of a building and no other structural remains can be associated with it.

Five metres further southwest was a one metre wide wall footing of dolomite boulders with a clay and rubble core (509), upon which was constructed a stone wall about 0.7 m wide. This structure was traced for just over two metres out from the foot of the cliff-section and seemed to demarcate the end of clay layer 511. To the south of wall 509 was a stiff yellow clay deposit (510), over 0.7 m thick, the top of which was at the same level as 511.

A concave-sided, broad-based scoop or pit (512) was cut into the upper surface of 511. It was filled with mid yellowish-brown silty clay (522), containing burnt limestone, brick fragments and a single large burnt beach boulder (513). The surface of scoop 512 was examined in detail but no evidence of any alteration of the surface was found and the magnetic susceptibility was low, suggesting the burnt material was dumped into the feature when cold.

The clay and stone structures may have formed part of an extensive hard or quay, the stone facing stones of which survive in the intertidal zone (Fig. 2, 11). The dating of this is unclear but it has been suggested that it represents the remains of the large quay or cobb mentioned by Hutchins (Brachi 2008). Wall 509 appears to be associated with another eroding wall stub about four metres to the south, which has a similar yellow clay dump against its northern face.

Shale waste tips

The final phase is represented by the dumps of burnt and unburnt shale waste sealing the stone and clay structures. To the northwest of wall 508 were tips of burnt and unburnt oil shale and silty clay forming a deposit (515) up to 0.8 m thick. The individual tips showed little evidence of mixing and no evidence of soil formation indicating a rapid sequence of deposition. Above these was a relatively mixed deposit of burnt and unburnt shale waste (519) comprising a

loose, unconsolidated, stratified dark greyish-brown deposit of unburnt and occasional burnt pieces of oil shale and rare rounded limestone clasts in a silty clay matrix. The individual tip lines and lenses are 5-10 cm thick and gently dipping to the southwest. Above 519 was a mixed deposit, of loose mid brown and mid grey silty clay and shale ash (520), up to 0.65 m thick, which contained many inclusions of brick, reddened burnt oil shale, and few fragments of unburnt oil shale.

To the southwest of wall 508, there was a 0.2 m thick deposit of burnt shale (514) similar in character to 515. This was sealed by a 0.5 m thick deposit of loose, finely laminated dark and mid dark greyish-brown silty loam (516), containing common small burnt shale pieces and shale ash. Overlying the south end of layer 516 were some tips and dumps of moderately loose mid brown and greyish-brown silty loam (523) containing shale ash and burnt shale, which may be a relatively recent infilling of an erosion hollow formed within layer 516.

Protruding obliquely from the section was the damaged corner of a crudely constructed rectilinear brick structure (517), cut into the top of shale dump 516 and against wall 508 (Fig. 5). Not enough of this structure was exposed to be certain of its form or function, but it survived up to three courses high and appeared to have a brick or clay floor. It was filled with light yellow silty clay (518) with brick and heat-spalled limestone fragments. This material may form part of a single filling and levelling event along with the similar overlying layer 521.

Discussion

The investigations at have advanced our understanding of the development and layout of the industrial area at Kimmeridge Bay, confirming and amplifying observations made by David Brachi (2008). Unfortunately, positive identification of the alum works, one of the major aims of the project, is still elusive.

The basal deposits of the shoreline exposure indicate that initially this area was part of the foreshore, probably where a stream flowed out on to the beach. Examination of the topography of this part of Kimmeridge Bay suggests that the stream running down from Smedmore should drain into the bay roughly in the area of the Marine Centre. This stream has undergone significant modification. A series of artificial dams and ponds adjacent to the Coastguard Cottages were undoubtedly created to

control and utilise its waters. The most likely context for this is part of Sir William Clavell's alum works, as it is only alum production (of the recorded industries at Kimmeridge) that required large quantities of water as part of the manufacturing process. The agreement drawn up between Sir William and Crown in 1613 with regard to the alum works at Kimmeridge included the promise that Clavell would "at his charge [...] bring down the spring from Kimmeridge House unto the said works" (WYL100/PO/8/I/4). This implies that the water supply had not been fully developed before this date and suggests that the ponds were constructed as part of Clavell's building programme in the period between 1613-17. John Cole's 1720 map of the manor of Kimmeridge (DHC Ph910) shows the eastern pond forming part of a paddock, with the two western ones reduced to a small oval pool. The course of the stream then ran roughly along the south side of the present road, where there is still a drainage ditch visible, before taking a sharp turn northwards via a couple of sluices to run into the bay north of the Marine Centre near the existing slipway.

The location of John Clavell's alum works of 1569 is not known, but it is plausible that it was adjacent to the shale quarry in which the later glassworks was built, and close to the original course of the stream. It can also be argued that the later alum houses of William Clavell dated to the period *c.* 1605-15 were most likely built in the same area, in order to make use of controlled water supply provided by the ponds. The indication of sluices and the sharp change in direction of the stream outflow shown on the Cole map might suggest this was an overflow: perhaps originally the water also continued straight on to feed the alum works. It may be pertinent to note that immediately south of the recorded shoreline section were the remains of a clay-lined stone channel, which may be the outflow of the water channel which fed the alum works. If this is the case then the alum works may have been in the area south of the Marine Centre. It is possible the wall remains visible in the road in this area are part of the alum works.

The earliest layer of burnt shale waste recorded on the beach appears to have been dumped from the northeast, in other words, from the direction of the glassworks and the suggested location of the alum works, but it is unclear which industry created this waste. It is sealed beneath an extensive stone and clay structure, which suggests a change in the use and arrangement of this part of Kimmeridge Bay. This is most probably part of the extensive works undertaken

by William Clavell for his alum manufactory following his agreement with the Crown in 1613. The structure appears to be part of a land reclamation scheme to enlarge the available working area and perhaps was a hard or quayside. If this is the case then the earlier burnt shale waste deposit is most likely to have been derived from William Clavell's first alum works. Hutchins records that the quay was largely destroyed by a storm in 1745 (Hutchins 1861, 556).

The thick deposit of shale waste tips overlying the structures possibly constructed by William Clavell, probably relate to the mid- to late-nineteenth-century industrial activity. The nineteenth-century industries were based on the mining and quarrying of oil shale and shipping it out to factories in Weymouth and Wareham, rather than burning it at Kimmeridge. Curiously, the latest dumps were a mixture of burnt and unburnt shale, however a number of sherds of glass and crucible fragments were previously recovered from these deposits (Fig. 5; McMahon 2000), perhaps indicating the tips were a mixture of material derived from the nineteenth-century shale mining and from the earlier glassworks. If this is the case, then they are probably the result of levelling earlier waste tips to form a level platform for the tramways to the pier, and for storing the mined shale prior to shipping.

The only remains that do not fit easily into the known sequence of industrial works at Kimmeridge are the furnaces under the public toilets. These are set away from the main industrial area and above the level of the stream, both its original course and its later nineteenth century diversion. This suggests the processes associated with these furnaces did not require large quantities of water and, therefore, are not associated with the alum works. Also the furnaces lie above the probable area of the sixteenth- to seventeenth-century shale quarries, which would imply that the raw shale would need to be moved uphill for processing and the finished alum brought back downhill for shipping, which implies a very inefficient process.

This leaves a puzzle over what the furnaces actually represent. No identifiable industrial residues have been recovered and the recent work has suggested that not all were used. Could they represent another undocumented abortive attempt at exploiting the Kimmeridge oil shale? On present evidence we are no closer to determining their function or date. It is extremely unfortunate that the toilet block was recently rebuilt and extended over the whole of the known extent of the site. No planning condition for

archaeological investigation was placed on the works and the opportunity to answer these questions through further excavation has now been lost.

ACKNOWLEDGEMENTS

The Dorset Alum and Copperas project team would like to thank the site supervisor Mike Trevarthen and the excavators: Laurence Bartlett, Wendy Devlin, Barry Hennessy, Maureen and Malcolm Houghton, Roger Luffman and Nicki Tutton. The work could not have taken place without the support and permission of Dr Philip Mansel, the Smedmore Estate and their agent Piers Chichester of Chichester Land Agents. We would also like to thank Terry House for his help and cooperation during the fieldwork.

Mrs Joan Brachi and Peter Brachi have been of great help to the project, sharing their knowledge of the area and allowing access to the late Dr David Brachi's archive.

The project was grant-aided by English Heritage and we would like to thank our project officer Dr David Dungworth for his advice and guidance. The Project was monitored by the Poole Harbour Heritage Project under the chairmanship of Professor Timothy Darvill. Finally, this project would never have got off the ground without the efforts of Dr William Sheldrick, who guided the direction of the project with his knowledge and enthusiasm of the Alum and Copperas industries, and the support of Bernard Dyer. It is a great sadness that neither has lived to see the completion of the work they set in motion.

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