

# Ivy Tower, Clyne Arsenic Works, Clyne Country Park, Swansea

## Archaeological Building Record



Prepared  
For

City and County of Swansea

By



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<b>CONTENTS</b>	<b>PAGE</b>
<b>Summary</b> .....	<b>4</b>
<b>Acknowledgements and Copyright</b> .....	<b>4</b>
<b>1 Introduction</b> .....	<b>5</b>
<b>2 Background</b> .....	<b>5</b>
2.1 Archaeological and Historical .....	5
2.2 Clyne Wood Arsenic and Copperworks .....	8
2.3 Cartographic and archive review .....	9
2.4 Cadw Conservation Principles.....	12
<b>3 Location, Topography and Geology</b> .....	<b>12</b>
<b>4 Objectives</b> .....	<b>13</b>
<b>5 Legislative Framework</b> .....	<b>14</b>
<b>6 Methodology</b> .....	<b>15</b>
<b>7 Results</b> .....	<b>17</b>
7.2 Photogrammetric 3D Survey.....	17
7.3 Descriptive record.....	17
<b>8 Conclusions</b> .....	<b>22</b>
<b>9 Bibliography</b> .....	<b>25</b>
<b>10 Appendix I – Figures</b> .....	<b>27</b>
<b>11 Appendix II – Plates</b> .....	<b>35</b>

## **FIGURES**

Figure 1. Location plan showing Ivy Tower in relation to Clyne Arsenic Works (SMGm475/LB22562). Ordnance Survey maps reproduced under licence 100058761. ...	<b>27</b>
Figure 2. Ivy Tower Orthographic Photogrammetric Plan. ....	<b>28</b>
Figure 3. Ivy Tower Orthographic North Facing Photogrammetric Elevation. ....	<b>29</b>
Figure 4. Ivy Tower Orthographic South Facing Photogrammetric Elevation. ....	<b>30</b>
Figure 5. Ivy Tower Orthographic West and East Facing Photogrammetric Elevations. ....	<b>31</b>
Figure 6. Ivy Tower Orthographic North and South Facing Internal Photogrammetric Elevations. ....	<b>32</b>
Figure 7. Ivy Tower Orthographic West and East Facing Internal Photogrammetric Elevations. ....	<b>33</b>
Figure 8. 1845 Tithe Map of Oystermouth in the County of Glamorgan. Showing Clyne Wood Arsenic Works and Upper Chimney (Ivy Tower) © West Glamorgan Archives. ....	<b>34</b>
Figure 9. Ordnance Survey 1884, 1 <sup>st</sup> Edition map. Ordnance Survey © Crown Copyright. All rights reserved. Licence number 100058761.....	<b>34</b>
Figure 10. Ordnance Survey 1900, 2 <sup>nd</sup> Edition map. Ordnance Survey © Crown Copyright. All rights reserved. Licence number 100058761.....	<b>34</b>

## **PLATES**

Plate 1 – N facing elevation of Ivy Tower showing inserted Phase II folly door. Scale 2m.....	<b>36</b>
Plate 2 – Inserted Phase II folly door of Pennant sandstone with semi-circular stone arch. N facing elevation Scale 2m. ....	<b>36</b>

Plate 3 – W facing elevation of Ivy Tower showing external putlog holes. Scale 2m. ....	<b>37</b>
Plate 4 – WSW facing elevation of Ivy Tower showing external putlog holes and missing merlon on battlements. Scale 2m. ....	<b>37</b>
Plate 5 – SW facing elevation of Ivy Tower showing external putlog holes. Scale 2m. ....	<b>38</b>
Plate 6 – S facing elevation of Ivy Tower showing external putlog holes and Phase II inserted gothic round-topped window. Scale 2m.....	<b>38</b>
Plate 7 – SE facing elevation of Ivy Tower showing external putlog holes, Phase I Flue and Phase II gothic round-topped window. Scale 2m.....	<b>39</b>
Plate 8 – SE facing elevation of Ivy Tower showing external Phase II gothic round-topped window.....	<b>39</b>
Plate 9 – SSE facing wall of the Phase I Flue. Scale 2m.....	<b>40</b>
Plate 10 –E facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. GCP scale 0.3m. ....	<b>40</b>
Plate 11 – NNE facing wall of the Phase I Flue.....	<b>41</b>
Plate 12 –E facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. Scale 2m. ....	<b>41</b>
Plate 13 – NE facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. Scale 2m. ....	<b>42</b>
Plate 14 – N facing elevation of Ivy Tower showing inserted Phase II folly door, external putlog holes and remains of Phase I Flue.....	<b>42</b>
Plate 15 – Nadir view (E = top) of Ivy Tower Phase I chimney base, Phase II gothic battlements and internal staircase. Note missing merlon to WSW. GCPs scale 0.3m. ....	<b>43</b>
Plate 16 – S facing internal elevation of Ivy Tower showing inserted Phase II folly door, internal putlog holes and two sets of joist sockets. Scale 2m.....	<b>43</b>
Plate 17 – W facing internal elevation of Ivy Tower showing the Phase I Flue entrance. Scale 2m. ....	<b>44</b>
Plate 18 – N facing internal elevation of Ivy Tower showing internal putlog holes and two sets of joist sockets. Scale 2m.....	<b>44</b>
Plate 19 – E facing internal elevation of Ivy Tower showing Phase II inserted spiral staircase, internal putlog holes and two sets of joist sockets. Scale 2m.....	<b>45</b>
Plate 20 – Clyne Valley investment advertisement. The Cambrian 10 <sup>th</sup> September 1825.....	<b>45</b>
Plate 21 – Clyne Woods Mineral and Chemical Works sale notice. The Cambrian 12th April 1845. ....	<b>46</b>
Plate 22 – New Ironworks at Clyne. The Welshman 15 <sup>th</sup> January 1847.....	<b>46</b>

### **Summary**

*Comisiynwyd Archaeoleg Mynydd Du Cyf gan Ddinas a Sir Abertawe i gynnal cofnod adeiladu Lefel II ac arolwg ffotogrammetrig 3D (Historic England 2016) o Ivy Tower (LB22562), Clyne Wood Arsenic and Copper Works (SMGm475) i gefnogi ymdrechion cadwraeth i sefydlogi y twr. Nod yr arolwg yw cynhyrchu ‘dwin digidol’ ffotogrammetrig 3D manwl gywir o’r tŵr a disgrifiad manwl o’r adeilad.*

*Mae’r adroddiad presennol yn nodi canlyniadau’r arolwg ffotogrammetrig 3D a chofnod adeiladu Lefel II yn unol â Safon Sefydliad Siartredig yr Archeolegwyr a chanllawiau ar ymchwilio a chofnodi archeolegol o adeiladau neu strwythurau sy’n sefyll (cyhoeddwyd 2014, 2020); a Understanding Historic Buildings: A Guide to Good Recording Practice (2016) a Chanllawiau Arfer Da ar gyfer Ceisiadau Ffotogrametreg ar gyfer Treftadaeth Ddiwylliannol (cyhoeddwyd 2017). Cynhaliwyd arolwg o’r awyr (drôn) yn unol â’r rheolau a’r rheoliadau sydd wedi’u cynnwys yng Ngorchymyn Mordwyo Awyr 2016 a’i ddiwygiadau ar gyfer 2018 a 2019.*

*Black Mountains Archaeology Ltd were commissioned by City and County of Swansea to undertake a Level II building record and 3D photogrammetric survey (Historic England 2016) of Ivy Tower (LB22562), Clyne Wood Arsenic and Copper Works (SMGm475) to support conservation efforts to stabilise the tower. The aim of the survey to produce accurate, measured 3D photogrammetric ‘digital twin’ of the tower and detailed description of the building.*

*The present report sets out the results of the 3D photogrammetric survey and Level II building record in accordance with the Chartered Institute for Archaeologists Standard and guidance the archaeological investigation and recording of standing buildings or structures (published 2014, 2020); and Historic England’s Understanding Historic Buildings: A Guide to Good Recording Practice (2016) and Photogrammetric Applications for Cultural Heritage Guidance for Good Practice (published 2017). Aerial (drone) survey was undertaken in accordance with the rules and regulations contained within Air Navigation Order 2016 and its 2018 and 2019 amendments.*

### **Acknowledgements and Copyright**

The project was managed by Richard Lewis BA MCIfA. The 3D photogrammetric building survey was carried out by Richard Lewis and Libby Langlands BA MA. The report, photogrammetric 3D modelling and illustrations were prepared by Richard Lewis. The Welsh summary translation was provided by Dr Rhys Morgan. The authors are grateful to Mike Scott, Chris Lindley and Ian Kennedy (Swansea Council) for help and support during the project. Particular thanks to Ross Cook FSA (ArchaeoDomus) for helpful comments on the report.

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### **Report Reference**

Lewis, R, and Langlands, L, 2022, *Ivy Tower, Clyne Arsenic Works, Clyne Country Park, Swansea. Archaeological Building Record. BMA Report No.263.*

## Archaeological Building Record

### 1 Introduction

- 1.1.1 Black Mountains Archaeology Ltd/*Archaeoleg Mynydd Du Cyf* were commissioned by City and County of Swansea to undertake a Level II building survey (Historic England 2016) of Ivy Tower (LB22562), Clyne Wood Arsenic and Copper Works (SMGm475) to support conservation efforts to stabilise the tower (Figure 1).
- 1.1.2 In accordance with Scheduled Monument Consent granted on 23<sup>rd</sup> July 2021, Condition 4, e) states:
- No works including site clearance shall commence until Cadw has been informed in writing of the name of an appropriately qualified individual who will be carrying out an appropriate programme of historic building recording to HE level 2. This should record all details prior to and on completion of works including all masonry joints and lift lines, junctions between phases of construction and changes in stone type, quoins and other dressed stones, windows, doors and other openings, structural cracks and other faults, the extent of re-pointing and replaced or rebbed stones. This should be accompanied by a historic building report.
- 1.1.3 The present report sets out the results of the historic building recording in accordance with Condition 4 noted above. The historic building recording was carried out to a Level II standard in accordance with *Historic England's 'Understanding Historic Buildings: A Guide to Good Recording Practice* (2016) together with adhering to the standards of the *Chartered Institute for Archaeologists Standard and Guidance for the 'Archaeological Investigation and Recording of Standing Buildings or Structures'* (2014) and *Historic England's Photogrammetric Applications for Cultural Heritage Guidance for Good Practice* (Published 2017).

### 2 Background

#### 2.1 Archaeological and Historical

- 2.1.1 Ivy Tower (SMGm475; LB22562) is located within Clyne Country Park, around 700 acres of parkland and woodland formally belonging to Clyne Castle. The castle and grounds are a Registered Historic Park and Garden (PGW Gm 47) and the survey area lies within the essential setting of the parkland. Clyne Castle is a two-storey castellated mansion dating to around 1800 with gothic alterations made in 1819-20. The earliest house on the site was called Woodlands, a plain three gabled two storey house built for Richard Phillips in 1791. By 1800 Woodlands was substantially extended and altered by Col. George Warde from Kent. The Clyne Castle and estate was briefly owned by Sir Benjamin Hall of Llanover, famed for overseeing the construction of 'Big Ben' in the Elizabeth Tower, Westminster, who gave the castle and estate to his sister Charlotte Berrington. The castle and estate then passed to the Vivian family in 1860 with William Graham Vivian refurbishing and extending the house into an opulent mansion. By 1870 he had changed the name to Clyne Castle and by 1954 the Vivian family had sold the estate to Swansea Council (Cadw and ICOMOS 2000, 158-164; Newman 1995, 486-489).
- 2.1.2 Clyne Woods is a managed mixed deciduous woodland dating to at least middle of the

12<sup>th</sup> century when woodland here is inferred by de Newburgh's charter to Swansea in 1158-84 granting of the *boscus* (woodland) surrounding the borough (Leighton 1997, 140). Although, woodland here probably existed since the Mesolithic Period 6,000-10,000 years ago. By 1306 the De-Breos's charter of liberties to the lordship of Gower notes the woodland of Clyne to be made into parkland, probably as a hunting park, although no (deer) park boundary earthwork is known. Felling and hauling of timbers from Clyne Forest for the repairs works to the Swansea Castle are recorded in Hugh de Waterton's accounts of 1401-02 (Jones 1992) and a Parliamentary Survey from 1650 notes the 'Forrest of Clyn and Clyn Moor (as) a parcel of rough woody ground' as consisting of 400 acres (Leighton 1997, 135-159). Clyne Farm first appears in record in 1760, a plan attached to a lease held by the Duke of Beaufort (Badminton archives) and it is likely that enclosure of the common to the west of Clyne Woods was underway at this time. Although, there is some evidence of earlier 16<sup>th</sup> century illicit land occupation with parts of what is now Clyne Woods being enclosed. The Earl of Worcester made complaints in 1590 regarding illegal encroachment between 1549 and 1589 (Robinson 1968, 357-88; Leighton 1997, 145). In 1729 the Beaufort estate lands in Glamorgan listed timber valued at £4,500 of which two-thirds came from Clyne Wood (Leighton 1997, 151). The tithe map and apportionment (Plan of Oystermouth in the County of Glamorgan 1845) show Clyne Wood still owned by the Duke of Beaufort and Leighton (1997, 150-153) suggests a mixed regime of woodland management there at that time (cordage, tanning bark, coppicing and timber). The change of landowner to the Vivians in the 1860s marked a change in woodland management, with timber still important for mining and the planting of conifers both in Clyne Wood and on Clyne Farm. During the later 19<sup>th</sup> and 20<sup>th</sup> centuries large scale forestry work and felling was undertaken. Aerial photographs held by Air Photos Wales from 1946 through to the 1990s show many areas of Clyne Woods deforested and then slowly reforested to the extent of woodland visible today.

- 2.1.3 Industrial activity in the Clyne Valley has left a legacy of remains from the later medieval period to the 20<sup>th</sup> century. The valley boasts five scheduled ancient monuments (Clyne Valley Shaft Mounds SMGm455, Ynys Pit and Leat SMGm461, Clyne Wood Coal Level SMGm464, Clyne Wood Arsenic and Copperworks (including Ivy Tower) SMGm475, Clyne Wood Colliery Steam Winding Machine (SMGm469) and many other non-designated industrial sites.
- 2.1.4 The earliest industrial remains in the Clyne Valley are those concerned with the Clyne Valley Shaft Mounds (SMGm455). The 1306 De-Breos's charter mentioned above notes the earliest record of coal mining in the Swansea area with 'sea coal' being worked (*Et mineria carbonum maris juxta la lun*). Williams (1958, 18) notes this was likely outcrop workings for domestic purposes and it is not until the 17<sup>th</sup> century when large scale coal exploitation begins with a grant in 1642 to Richard Seys "for digging of coals in Clyn Fforest...". The coal was likely carried by packhorse down to Blackpill where Richard Seys had acquired a lease for a coaling place at Mill Dock (Swansea Common Hall Book 1658). Williams also notes a chart of Swansea Bay in 1795 showing a quay located opposite Blackpill where coal was loaded to ships of 'fairly large draught'.
- 2.1.5 Williams (1958, 18-19) recorded extensive early and later industrial remains in the Clyne

Valley area in the mid-20<sup>th</sup> century. At the time he noted 255 early workings or 'bell pits' together with ten large collieries of 19<sup>th</sup> and 20<sup>th</sup> century date and twelve smaller collieries and slants/levels. The 255 early 'bell pits' workings were then classified into six zones. Zone 1 on Fairwood Common, Zone 2 at Three Crosses, Zone 3 at Wern Fawr Farm, Zone 4 in Hen Parc Wood, and Zones 5 and 6 the north and south areas respectively of Clyne Wood. Williams recorded 24 bell pits in Zone 5 and 30 bell pits in Zone 6. These tended to follow a 'more or less' straight line down the valley side to the valley bottom. The bell pits ranged in size from 10 feet (3m) in diameter and 10 feet (3m) in depth to 6 feet (1.8m) in diameter and 6 feet (1.8m) in depth. Williams (1958, 18) suggests that the earliest bell pits are those identified in Zone 5, as these are one of two sets of bell pits referred to in the grant in 1642 to Richard Seys in Clyne Woods and of the two groups (Zones 5 and 6) are the most weathered.

- 2.1.6 Industrial activity accelerated in the 19<sup>th</sup> century, made possible by new communication routes into the valley. In 1804 the Oystermouth Tramway (Swansea and Mumbles Railway) was constructed, together with a branch at Black Pill serving quarries within the Clyne Valley and later (1855) the Clyne Wood Colliery (SMGm469), Rhydydefaid Colliery and Boat Level, and the Ynys Pit (SMGm461) (Barrie 1994, 214). The Llanelli to Swansea line through the Clyne Valley was completed in 1867 and became part of the LNWR main line from Swansea to Pontarddulais in 1873, the single track extended to double tracks by 1892. The line was closed in 1964 and incorporated into a cycle track in the later 20<sup>th</sup> century (Barrie 1994, 210-213).
- 2.1.7 Numerous large collieries and smaller levels were exploited in the 19<sup>th</sup> century, aided by the transport links provided by the Oystermouth Tramway and later LNWR main line. Ynys Pit and Leat (SMGm461) is located on southwest facing valley side and was developed by Sir John Morris between 1804-1807, with the colliery sunk in the 1840s and out of use by 1877. Towards to lower end of the valley on the northeast facing valley side is the Clyne Wood Coal Level (SMGm464), a rock-cut, stone lined coal level dating to around 1840 and connected to the Clyne Wood Canal. The latter dating to 1799-1803 as a mill leat for the corn mill in Black Pill but seems also to have been used for industrial transport for the Clyne Wood Arsenic Works (SMGm475).
- 2.1.8 To the north of the Clyne Valley a cluster of industrial sites is located on either side of the river and former railway. The Clyne Wood Colliery (SMGm469) was established in 1867 and had a small twin cylinder horizontal steam winding engine (SMGm469), the remains of which lies *in-situ*. Goldsmith (2012, 29) quotes a Cambrian Newspaper article for the Clyne Wood Colliery Company detailing the auction of the colliery, including the winding engine and boilers: *"All the new and valuable plant & materials, lately used by the Clyne Wood Colliery Company, comprising one horizontal steam engine, 14 in cylinder, 34 in stroke, egg end boiler about 27 ft by 4 ft 6 in diameter, both made by Waddle, of Llanelly, of the best material and workmanship, has only been used a short time, and equal to new; drum and winding gear, wire rope; lift of 7 in pumps complete with pump rods, V bob, stays and iron standards; several tons of colliery rails, 16 lbs to the yard; points and crossings; small lot flange rails, 72 lbs to the yard, lever points and crossings; two wood erections used as engine house and forge; tipping stage; quantity of sleepers. The colliery*

*is situated between Killay and Mumbles Road Station on the Llanelly Railway”.*

- 2.1.9 Rhydydefaid Colliery and Boat Level are located opposite Clyne Wood Colliery and adjacent to the Clyne Valley Brick and Tile Works. Goldsmith (2012, 29) notes that the Duke of Beaufort let the Rhydydefaid Boat Level to John Morris II in 1836, which was then later acquired and closed by the Rhydydefaid Colliery Company in 1856. The level brought coal out by means of an underground canal. The adjacent brickworks began trading in the 1870s and by 1959 went into liquidation and finally closed in 1960.

## **2.2 Clyne Wood Arsenic and Copperworks**

- 2.2.1 Located not far from the Clyne Wood Canal to the south of the Clyne Wood Coal Level is the Clyne Wood Arsenic and Copperworks (SMGm475), a well-preserved non-ferrous smelting works. Possibly built initially as a copperworks between 1825 and c1840 (1837?) by a Cornish company and closed in 1841 but later reopened by Henry Kingscote in 1844-45 and was in use by 1852 as an arsenic works under J. Jennings & Sons until final closure in 1860 (Newman 1995, 488-489; Hughes and Reynolds 1989, 15; Hughes 2000, 63).
- 2.2.2 The surviving buildings are of Pennant sandstone, quarried nearby in Clyne Wood, and represent a rare survival of an intact production plant of the period. The eastern side of the arsenic works is bounded by the Clyne Wood Canal and includes the remains of a retaining wall and canal basin. To the west, the main buildings are terraced into the gradually sloping valley side. While not having undergone an archaeological excavation, several surveys have been carried out on the site which enable a reasonable understanding of the layout and function of the buildings (Hughes and Reynolds 1989, 15; Hughes 2000, 63). John Hayman produced a measured sketch plan in 1985 that recorded the principle visible features of the former arsenic works. This plan most likely informed on Hughes (2000, Fig 95 63; Figure 1) detailed survey of the site for the RCAHMW. Michael Williams (1960, 29) notes that the works were ‘over three stories high, with at least eight furnaces connected by culverts to a strongly built chimney’.
- 2.2.3 A retaining wall defines the western extent of the site, where several tracks, one above and below the wall, provided ore tipping access from Blackpill Wharf. Eastward of the retaining wall was a large open sided ore storage shed and on the south side of this building a large chimney stack served by multiple flues. This chimney stack was the Lower Chimney Stack, the Upper being the Ivy Tower, and there is evidence for several large but now collapsed flues linking the calcining kilns and furnaces to this stack. On the south side of the lower stack is a very large flue that is carried westwards up the valley side 140m to the Upper Chimney Stack (Ivy Tower). The eastern end terminates at a large two/three storey east/west aligned building range. Hughes (2000, 64) suggests this to be a refined metal store and offices. The western end of this range may in fact be an engine house. An advertisement in The Cambrian newspaper dated 12<sup>th</sup> April 1845 lists a sale of the Clyne Woods Chemical Works and in the sale is a ‘...seven-horse power high-pressure steam engine, 20-inch stroke, 12-inch cylinder, with boiler...six roller clay mill, with four cog-wheels [and] several large fly-wheels for engine purposes...’. The boiler for this steam engine may have been positioned to take advantage of the large 140m flue that starts on the west side of the east/west aligned building range. An engine in this building would also be ideally placed to provide power to both the calcining (William Brunton type?) and

- reverberatory refining furnaces, which may have been located immediately to the northwest in the refining house (see Hughes 2000, 64-65, figs 95, 95a and 95b; Figure 1).
- 2.2.4 Arsenical ores were crushed to small pebble/pea sized pieces and calcined in rotating kilns, such as the Brunton Calciner, and the exhaust fumes led into long flues/chambers where they precipitated and condensed. The flues were then emptied and the collected arsenious oxide refined in the reverberatory furnaces. The Brunton Calciner was introduced by around 1835 and consisted of a revolving circular bed covered in fire bricks to form a hearth heated by two furnaces/fire boxes set at an angle. Ore was fed onto the hearth from the floor above and was calcined as it gradually worked its way out from the centre to the edge of the circular bed. Fixed iron paddles or rods stirred the ore as they passed on the rotating bed (Tylecote 2002, 159-160).
- 2.2.5 The Clyne Wood Canal also doubled as the (earlier) Blackpill Mill (corn) race before discharging into Swansea Bay near the location of the Blackpill Wharf. The advertisement in The Cambrian newspaper dated 12<sup>th</sup> April 1845 listed '*...a number of four wheeled iron waggons...twenty-seven new wheel-barrows [and] five canal barges...*'. The canal barges likely brought coal down from the collieries further up the valley, such as at Clyne Wood Coal Level which had direct access to the canal/mill race. It is not clear if the mill race was navigable by canal boat to Blackpill. The ore was loaded at the wharf here and carted up to the works along the track that looped around and above the west revetment wall and terminated at an ore tipping stage.
- 2.2.6 The reason for the closure of the works in 1860 is unclear. Certainly, financial viability may be a factor given the competition with the many copperworks (and associated arsenic works) along the River Tawe, such as the Hafod-Morfa Copperworks, which were rapidly expanding at this time. Perhaps more significant was that in 1860 the Woodlands Castle and estate passed to William Graham Vivian who refurbished and extended the mansion and by 1863 leased Clyne Woods from the Duke of Beaufort for the castle's pleasure grounds. Vivian may not have wanted a very toxic arsenic works pumping arsenic fumes from both the upper and lower chimneys across his parkland and mansion. After 1860 and by the publication of the Ordnance Survey 2<sup>nd</sup> Edition (1900) historic map (Figure 10) the upper chimney had been converted to a gothic castellated folly complete with inserted gothic (late-medieval styled) round-topped window, internal staircase and new semi-circular stone arched door. How much of the stack was demolished is unclear but only just over 6m of the original chimney stack survived the conversion. The main buildings at the arsenic works were converted to farm buildings and the 2<sup>nd</sup> Edition (1900) historic map depicts them as hay barns.

### **2.3 Cartographic and archive review**

- 2.3.1 One of the earliest maps of the Clyne Valley is 'Clyne Wood Farm in the parish of Oystermouth' dated to 1803 produced as part of a book of maps for the Duke of Beaufort lands in the Seigniories of Gower and Kilvey (held by the West Glamorgan Archives D/DBeau/E1&2). Clyne Wood Farm is depicted surrounded by an irregular enclosed fieldscape that ends with the vast stretch of Clyne Wood along the western side of the Clyne Valley. Clyne Wood Arsenic Works and Chimneys are not shown.
- 2.3.2 Clyne Wood Arsenic Works and Upper Chimney are first depicted on the 1845 Tithe Map,

Plan of Oystermouth in the County of Glamorgan, held by the West Glamorgan Archives (Figure 8). The canal is visible as are all of the main buildings and stack. The Apportionment records the arsenic works in Land Parcel 69: Clyne Wood Metallurgical; Occupier Henry Kingscote; Owner Duke of Beaufort. The Upper Chimney (Ivy Tower) is in Land Parcel 57: Clyne Wood with the Duke of Beaufort both the occupier and owner. The copy of the tithe map held by the National Library of Wales does not show the Upper Chimney. Likely an omission between the landowner and church held copies, which are can sometimes fractionally different.

- 2.3.3 The Glamorgan Archives also hold a rather lovely plan called “Plan of Woodland Castle Estate in the parish of Oystermouth”. The plan shows the extent of Woodland Castle and surrounding parkland and the fieldscape of Clyne Wood Farm. It also shows in the bottom left-hand corner a fairly large and beautiful drawing of the castellated Woodlands Castle set in a parkland with several cattle and trees. The bucolic scene was possibly illustrated at the time of the sale of the Woodlands Castle Estate in 1860 (D/D Z 177/2). The Clyne Wood Arsenic Works and Chimneys are not shown on the plan of the estate.
- 2.3.4 The Ordnance Survey 1<sup>st</sup> Edition dating to 1884 (Figure 9) depicts Clyne Wood Arsenic Works as ‘Old Buildings’ and the Upper Chimney as ‘Old Chimney’. But the buildings of the arsenic works are shown blacked out, or at least partially shaded as with the large range to the northwest, suggesting that they were still standing and roofed at the time of the survey. A quarry is noted to the northwest of the Upper Chimney together with a tank and filter bed. A circular coal pit is shown and old immediately northwest of the range of the former arsenic works buildings. Clyne Wood Level on the Clyne Wood Canal is shown as ‘Old Level’ at this time. The Clyne Valley Tramroad (Blackpill branch of Oystermouth Tramroad) is shown together with the newer Llanelli to Swansea line through the Clyne Valley, completed in 1867, and became part of the LNWR main line from Swansea to Pontarddulais in 1873. Only a single track is shown, which was later extended to double tracks by 1892.
- 2.3.5 The Ordnance Survey 2<sup>nd</sup> Edition dating to 1900 (Figure 10) depicts Clyne Wood Arsenic Works as ‘Hay Sheds’ and the Upper Chimney as ‘Ivy Tower’, suggesting the conversion to the castellated folly sometime between the publication of the surveys of the 1<sup>st</sup> and 2<sup>nd</sup> Edition Ordnance Survey maps. The quarry to the northwest of Ivy Tower is still shown and may still be active but the tank and filter beds are not shown. Usefully this edition of the Ordnance Survey maps shows roofed buildings with hachured lines and provides a fairly accurate representation of those buildings at the former arsenic works which were roofed, perhaps confirming the actual layout of original roofed buildings, which were a little ambiguous on earlier mapping. The circular coal pit immediately northwest of the range of the former arsenic works buildings is no longer shown as is the Clyne Wood Level. The Clyne Wood Canal is still shown as is the Clyne Valley Tramroad (Blackpill branch of Oystermouth Tramroad) together with the main LNWR Swansea line, now extended to double tracks.
- 2.3.6 No specific archives were found relating to the gothic folly, Ivy Tower, despite a search of the West Glamorgan Archives, the National Library of Wales and the RCAHMW. The Richard Burton Archives hold the William Graham Vivian and Family Collection (LAC/116),

which contains records about the Clyne Estate but does not appear to list anything specific relating to the Ivy Tower and the Clyne Wood Arsenic and Copperworks. They also hold a small collection of material relating to the Clyne Valley Industrial Archaeology Trail (SC/415) dating to the 1970s and created by John Hayman. Further investigation of these archives would be very interesting and may reveal some interesting documents relating to the works and Ivy Tower, however, this type of in-depth and exhaustive search would be time consuming and is beyond the scope of the Level II Building Record. The West Glamorgan Archives hold several more general documents mentioning Clyne Wood Arsenic and Copperworks dating to 1859. Archive D/D BF 679 is a 'Lease (copy) for 99 years, rent £20 and various duties yearly [dating] to 27 June 1859; George, Earl of Jersey, to Joseph and Nicholas Jennings of Clyne Wood Arsenic Works, Swansea' and D/D BF 1785 a 'Lease for 99 years from 25 Mar 1859 for £70 annual rent dated 27 June 1859; George Earl of Jersey to Joseph Jennings and Nicholas Jennings of Clyne Wood Works Arsenic Works.' These leases probably relate to the Jennings's holdings at Dan-y-Graig, Swansea, where they moved to after the closure of Clyne Wood Arsenic Works in 1860.

- 2.3.7 A review of newspaper archives revealed several interesting articles and one in particular that for the first time confirms the existence of a steam engine and its type together with other sales particulars.
- 2.3.8 The Cambrian newspaper carried an advertisement calling all 'Capitalists' on the 10<sup>th</sup> September 1825 (Plate 20) that "*Iron Mines and Collieries*" in Clyne Wood and Valley to be let including "*...all Seams and Veins of Iron Mine and Ore and Clay...and Limestone Rock...under Clyne Wood and Clyne Common containing about 2500 Acres...*". The advertisement further notes the excellent communication links with Swansea Port and "*...The proximity of Mine, Coal, and Lime, to each other renders the above property as advantageously sites for the erection of extensive Iron Works, as part of the Mineral Basin of South Wales. Any quantity of Building Ground may be had at nominal rents...*". This advertisement probably confirms that at this time no industrial works, such as the Clyne Wood Arsenic and Copperworks, were yet built as they are actively encouraging large scale industrial development (with nominal rents!).
- 2.3.9 Another advertisement in the Cambrian newspaper dating 27<sup>th</sup> February 1841 directly refers to "*Clyne Wood Chemical Works*" and encourages "*...persons Having Claims On This Establishment - Send To John Gwyn Jeffreys, Solicitor...*" directly confirming the existence of the works by 1841.
- 2.3.10 The Cambrian newspaper carried a sales advertisement on the 12<sup>th</sup> April 1845 (Plate 21) for the "*Stock, Trade Fixtures, and other materials, belonging to the Mineral and Chemical Works*". This advertisement is very important as it confirms the existence of a steam engine, which hitherto was only speculated, together with details of a smithy and carpenters workshop and all of the other machinery, tools, waggons and barges used at the works in 1845. The sales advertisement is detailed below (Plate 21):
- 2.3.11 "Clyne Wood Chemical Works near Swansea. MR DAVID HOWELL WILL SELL BY AUCTION on Monday, April 21st, 1845, and following days, at Clyne Wood, near Swansea, All the STOCK, TRADE FIXTURES, and other MATERIALS, belonging to the Mineral And Chemical Works there; comprising large quantities of wrought and cast iron; pipe, sheet, and pig

lead; zinc, tin, brass, copper; fire and other bricks; Stourbridge clay; copper, iron, lead, zinc, blackjack, and other ores; Bathurst's patent weighting machine; chains, ropes; about 40 fathoms of boring rods and bits; self-acting bellows, blow-pipe and stand; carpenters' shop, fixtures, and smithery, with three large extra forge bellows, anvils, vices, &c.; seven-horse power high-pressure steam engine, 20-inch stroke, 12-inch cylinder, with boiler and other appendages complete; six-roller clay mill, with four cog-wheels; several large fly-wheels for engine purposes, a number of four-wheel iron waggons; large quantities of Oak, Ash and Memel timber, sawed and seasoned, and fit for working; twenty-seven new wheel-barrow, five coal barges, with several hundred lots of other miscellaneous articles. Catalogues and conditions of the sale will be ready for delivery in a few days, on application to the Auctioneer; or at the office of Mr Jeffreys, Solicitor, Swansea. The sale is to commence at eleven 1 o'clock in the forenoon of each day".

- 2.3.12 An unusual notice was pasted in The Welshman on the 15<sup>th</sup> of January 1847 (Plate 22) declaring that a company of wealthy iron masters had taken the lease from the Duke of Beaufort at Clyne for the purposes of erecting furnaces. This may relate to the refurbishment of the Clyne Arsenic and Copper Works following Henry Kingscote's sale after 1845 to Jennings & Sons

## **2.4 Cadw Conservation Principles**

- 2.4.1 Cadw records the value of Ivy Tower (SMGm475/LB22562) folly and former chimney stack as follows:
- 2.4.2 Evidential value
- 2.4.3 Circular sandstone rubble tower comprising remains of the arsenic works mid-19th century flue, converted in the later 19th century to a gothic style folly within the Clyne Castle estate. The structure retains features associated with both phases of use, including industrial: the flue, and folly: putlog holes, round headed doorway, internal stone steps, embattled parapet and wall top walkway.
- 2.4.4 Historic Value
- 2.4.5 Well preserved example of non-ferrous metal industrial processing which strongly influenced the industrial revolution and led to the Swansea area and South Wales developing world dominating expertise. The later conversion of the flue into a gothic folly demonstrates the personal wealth accrued by industrial magnates and their impact on the domestic landscape.
- 2.4.6 Aesthetic Value
- 2.4.7 The ruin retains features which enable visitors to understand and appreciate both phases of use.
- 2.4.8 Communal Value
- 2.4.9 The monument is located within the publicly accessible Clyne Valley Park. However, chemical analysis of samples taken from the tower has shown it to be severely contaminated with arsenic, thus making the interior unsuitable for public access.

## **3 Location, Topography and Geology**

- 3.1.1 Ivy Tower folly and former chimney stack (LB22562) is positioned on the northeast facing

valley side of Clyne Woods, 140m west of Clyne Wood Arsenic and Copperworks, in the Clyne Valley Country Park, Swansea (centred on NGR SS 261338.540,190816.294, Figure 1). The chimney stack and later folly is located in the Gower Area of Outstanding Natural Beauty, the first AONB designated in the UK, and the Historic Landscape of Gower (HLW (Gt) 1), specifically within the historic landscape character area of Clyne Castle (HLCA078). Ivy Tower is wholly in the Clyne Castle Registered Historic Park and Garden (PGW Gm 47) and Clyne Wood Arsenic and Copperworks Scheduled Ancient Monument (SAMGm475).

- 3.1.2 The northeast facing valley is largely covered in deciduous woodland and bordered to the northeast by the River Clyne and the National Cycle Network Route 4. The ground rises the southwest from 15mOD at the valley bottom to 120mOD at Clyne Farm, with Ivy Tower at c50mOD.
- 3.1.3 The geology of the survey area is the South Wales Lower Coal Measures Formation, these are sedimentary mudstones and siltstones formed approximately 318 to 319 million years ago in the Carboniferous Period (BGS 2020). Superficial lithology includes Quaternary glacial sedimentary deposits of clay and silt. Soils belong to Brickfield 2 group (soil association 713f), consisting of slowly permeable and seasonally waterlogged fine loamy soils (Mackney *et al* 1983).

## 4 Objectives

- 4.1.1 The *definition* of an archaeological **Building Investigation and Recording** as set out by the *Chartered Institute for Archaeologists* (CIfA) is a programme of work intended to establish the character, history, dating, form and archaeological development of a specified building, structures, heritage assets or complexes and its setting, including buried components, on land, inter-tidal zone or underwater.
- 4.1.2 The *purpose* of an archaeological Building Investigation and Recording is to examine a specified building, structures, heritage assets or complexes, and its setting, in order to inform:
- the formulation of a strategy for the conservation, alteration, demolition, repair or management of a building, or structure, or complex and its setting.
  - or
  - to seek a better understanding, compile a lasting record, analyse the findings/record, and then disseminate the result.
- 4.1.3 (Chartered Institute for Archaeologists Standard and guidance for the archaeological investigation and recording of standing buildings or structures. Published 2014)
- 4.1.4 The programme of building recording has been implemented according to Level II (Historic England 2016). Historic England note "... a Level II building record will provide a descriptive record with the structures seen, described and photographed. The examination of the structures will produce an analysis of its development and use and the record will include the conclusions reached, but it will not discuss in detail the evidence on which this analysis is based. A plan and sometimes other drawings may be made included but the drawn record will normally not be comprehensive and may be tailored to the scope of a wider project. The presentation of these observations in a written report,

taking account of related documentary and historical evidence. The preparation of an archive of digital data recovered and records made as a result of the project, and the deposition of this archive in a suitable receiving museum or similar institution.”

- 4.1.5 The principal method of building survey utilised measured 3D photogrammetric techniques implemented in accordance with the standards set out in Historic England’s *Photogrammetric Applications for Cultural Heritage Guidance for Good Practice* (Published 2017).
- 4.1.6 The main objectives of the photogrammetric survey is to produce metrically accurate rendered photorealistic 3D modelling of the survey area, buildings and general scenes georeferenced with high accuracy. Modelling utilised Structure from Motion (SfM) photogrammetric techniques obtained through camera capable SUA (drone) to produce measurable 3D models of the photographed scene. The term photogrammetry was first coined by a Prussian architect Albrecht Meydenbauer in an 1867 article called ‘Die Photometrographie’ and Dominique Arago, a French surveyor, was using photographs to create topographic maps as early as 1840. Modern photogrammetric methods used flat lensed cameras to create photogrammetric montages of buildings or other methods such as stereoscopy using multiple aerial images to create the illusion of depth (3D) from 2D images. Present day photogrammetry uses sophisticated algorithms and workflows to digitally stitch each pixel together to create real world measured 3D representations of the photographed scene with outputs including dense point clouds (LAS), triangular meshes (OBJ) and orthophotography (plans and elevations – rasterised JPEG and TIFF). The accuracy or more appropriately the margin of error is calculated using the ground sampling distance (GSD), which is the distance between two adjacent pixel centres normalised to real world dimensions. Centimetre accuracy of photogrammetric outputs is reached by using Real Time Kinematic (RTK) GPS (satellite navigation systems) survey methods of control points within the surveyed area.
- 4.1.7 The *Research Framework for Wales* sets out the knowledge base of past research and sets out a rationale for future studies (<https://www.archaeoleg.org.uk/index.html>). The present investigations were undertaken considering the key themes and where there are limitations in current knowledge, particularly where the present investigations can enhance our understanding of some of these key areas. For example, current important Industrial themes for consideration where there are weaknesses in the knowledge base are: the significance and scale of technical change within the major industries of coal, iron, copper, tin, lead and slate, and the impact of that change within the landscape; their context and significance in terms of similar sites elsewhere in the world; their relationship with the markets they served. It has been noted that a gap still exists in our understanding of the ‘scientific’ elements of past industries, particularly metallurgical industries where limited scientific investigation has been undertaken as there has tended to be a reliance on contemporary documentary accounts to tell us ‘what we need to know’.

## 5 Legislative Framework

- 5.1.1 Any works affecting an ancient monument and its setting are protected through implementation of the *Ancient Monument and Archaeological Areas Act 1979*. In Wales

the 1979 Act has been strengthened by *The Historic Environment (Wales) Act 2016*. The 2016 Act makes important improvements for the protection and management of the Welsh historic environment. It also stands at the centre of an integrated package of secondary legislation (Annexes 1-6), new and updated planning policy and advice, and best-practice guidance on a wide range of topics (*TAN 24 Historic Environment*). Taken together, these support and promote the careful management of change in the historic environment in accordance with current conservation philosophy and practice. The *Ancient Monument and Archaeological Areas Act 1979* and *The Historic Environment (Wales) Act 2016* sets out a presumption in favour of preservation *in-situ* concerning sites and monuments of national importance (scheduled/listed), and there exists in the current *Planning Policy Wales (Chapter 6)* a presumption in favour of preservation *in-situ* of all types of heritage assets.

- 5.1.2 The *Civil Aviation Authority* (CAA) is the airspace controlling body for the United Kingdom (UK). The rules and regulations for the use of SUAs (drones) in UK airspace is set out in the *Air Navigation Order 2016* and its 2018 and 2019 amendments. The CAA publishes the ANO within CAP393 (Civil Aviation Publication). CAP382 details the safety occurrence reporting scheme for aircraft. CAP722 Unmanned Aircraft System Operations in UK Airspace – Guidance and Policy, is compiled by the Civil Aviation Authority's Unmanned Aircraft Systems Unit (UAS Unit). CAP722 is intended to assist those who are involved with the development, manufacture or operation of UAS to identify the route to follow in order that the appropriate operational authorisation(s) may be obtained and to ensure that the required standards and practices are met. Its content is primarily intended for non-recreational UAS operators and guides all commercial UAS activity, resulting in UAS pilots/operators needing to obtain an Operational Authorisation (OA), formerly the Permission for Commercial Operations (PfCO).
- 5.1.3 All UAS flights are operated within the limitations and conditions of the company Operational Authorisation (OA), Operations Manual and the applicable articles of the ANO (Articles 94, 94A, 94B, 95, 239, 240 and 241). In addition, from November 2019 AN(A)O 2018 Article 7 introduces new articles 94 C-F into ANO 2016 to ensure the correct certificates are held for both the company (The SUA Operator) and each individual remote pilot
- 5.1.4 The European UAS Regulatory Package was implemented on the 31<sup>st</sup> December 2020. *Air Navigation (Amendment) Order 2020* introduces some changes, with guidance provided in CAP2013. Full details of the UAS Regulatory Package and its implementation are published in CAP722 Edition 8. Three new operational categories have been introduced: Open (geared to hobbyists/some commercial users), Specific (mainly enterprise drone pilots), Certified (very high-risk operations).

## 6 Methodology

- 6.1.1 The investigations consisted of the historic building recording of Ivy Tower (SMGm475, LB22562), a former industrial arsenic chimney stack and later castellated folly. Conservation work included the removal of vegetation from the tower and its immediate environs. This provided an unfettered view of the former industrial chimney. The building

was recorded with a blend of RTK GPS measured survey, photogrammetry (3D modelling) derived from both aerial (drone) and terrestrial cameras and a descriptive account of the phasing of the building. The outcome of the survey a detailed 3D 'digital twin' of the folly/chimney stack. The survey was undertaken on the 7<sup>th</sup> March 2022 during low winter sunlight.

- 6.1.2 The programme of building recording was implemented in accordance to a Level II building survey as set out by Historic England's *'Understanding Historic Buildings: A Guide to Good Recording Practice'* (2016), the only nationally (UK) recognised building recording standard. The presentation of these observations is set out in this report, taking account of the related documentary and historical evidence.
- 6.1.3 The capture, processing and output of 3D models conformed to professional industry standard and best practice guidelines as set out by Historic England's *Photogrammetric Applications for Cultural Heritage Guidance for Good Practice* (Published 2017). The large size of the finished 3D photogrammetric necessitated a reduction to allow for online viewing. The decimated (from 3.5GB to 1GB in size) photogrammetric 3D model of Ivy Tower can be viewed here:
- 6.1.4 <https://cloud.pix4d.com/dataset/1164578/model?shareToken=e8c6fc65-26f0-46ee-8723-449fe985a484>.
- 6.1.5 The survey was carried out by multiple UAVs (drones) equipped with a Hasselblad 35mm equivalent 20mp, 1" sensor, 4k UHD camera, a 35mm equivalent 20mp, 1" sensor, fitted with a mechanical shutter and 4k UHD camera; a 35mm equivalent (24mm) camera with a 12mp 1/2.3" CMOS sensor and a terrestrial Canon EOS 2000D DSLR camera with a 24.7mp, 22.3mm x 14.9mm CMOS sensor. The ground investigations and aerial survey were tied into the Ordnance Survey National Grid and Datum using a GNSS/Glonass (GPS) Receiver and data logger with a 20mm tolerance. The 3D model was produced using proprietary photogrammetry software and aligned using known ground control points (GCPs). A total of 9,321 high resolution images were recovered and successfully calibrated. Dimensional control was then applied to each model and then reprocessed using the new parameters and optimised cameras to create dense point cloud of over 179 million points and a high face count mesh with a mean RMS error of 0.241cm. Models were then exported to OBJ format. Five GCPs were used with a sub-20mm error margin to OSGB36 (National Grid) and a high-resolution Ground Sampling Distance (GSD) of 0.02cm/pixel. High resolution orthographic renders (orthoplanes and orthomosaics) were exported and scaled in georeferenced raster (TIFF and JPEG) format (Figures 1-7).
- 6.1.6 A copy of the report and digital archive will be supplied to the client and their agents, the regional HER (GGAT) and the Royal Commission on the Ancient and Historical Monuments of Wales. Submission of photogrammetric images acquired by drone to the RCAHMW will follow *RCAHMW Unmanned Aerial Vehicle (UAV) Policy*. All data has been digitally stored in appropriate formats (SHP, DXF, TIFF, RAW, JPEG, PDF etc) with the archive destination in mind. All data will be submitted to the relevant archives in accordance with the RCAHMW's *Guidelines for Digital Archaeological Archives* (2015) and the regional HER's *Guidance for the Submission of Data to the Welsh Historic Environmental Records (HERs)* (published 2018).

6.1.7 All work has been carried out in accordance with the professional standards of the *Chartered Institute for Archaeologist (CIfA)*.

## 7 Results

7.1.1 The investigations consisted of the historic building recording of Ivy Tower (SMGm475, LB22562), a former industrial arsenic chimney stack and later castellated folly. Conservation work included the removal of vegetation from the tower and its immediate environs. This provided an unfettered view of the former industrial chimney. The building was recorded with a blend of RTK GPS measured survey, photogrammetry (3D modelling) derived from both aerial (drone) and terrestrial cameras and a descriptive account of the phasing of the building. The outcome of the survey a detailed 3D 'digital twin' of the folly/chimney stack.

### 7.2 Photogrammetric 3D Survey

7.2.1 The survey of Ivy Tower to create a 3D photogrammetric digital twin was undertaken using three UAV (drone) aircraft types and a handheld DSLR camera. The monument was photographed from all angles, including internal spaces. The resultant 9,321 high-resolution photographs were then processed in proprietary photogrammetry software and aligned using ground control points (GCPs), which were surveyed with a GNSS/Glonass (GPS) RTK Receiver with a sub-20mm error margin to OSGB36 (National Grid). All high-resolution orthographic renders (orthoplanes and orthomosaics) were exported and scaled in raster (TIFF) format from the detailed 3D model for the production of elevation and plan drawings (Figures 1-7).

7.2.2 The full high resolution photogrammetric 3D model (digital twin), orthoplane sections and orthomosaic plans (Figures 1-8) for Ivy Tower forms the primary record and has been supplied as individual OBJ files over 3.5GB in size and high-resolution PDFs. The 3D model was then decimated (reduced in size) by 66% to enable uploading to an online interrogable 3D viewer, which has a 1GB size limit, here <https://cloud.pix4d.com/dataset/1164578/model?shareToken=e8c6fc65-26f0-46ee-8723-449fe985a484>.

### 7.3 Descriptive record

7.3.1 The following forms a descriptive account of the monument and its phasing in accordance with a Level II Historic Buildings Record (Historic England 2016). Any descriptions of the deterioration of the tower are from a visual archaeological perspective as opposed to structural, as we are not qualified to comment on the structural stability, weakness or otherwise of any part of the building's standing masonry

7.3.2 Ivy Tower is a squat round stone tower/stack of roughly coursed Pennant sandstone standing to 6.3m in height and 6.8m in width, with walls generally (excluding internal Phase II staircase) 1.2m in thickness. The internal space or chimney flue area is 4.4m wide. A single round arched doorway provides entry to the tower from the north and is formed of rubble stone reveals and pennant sandstone voussoirs forming the arch. At first floor level, a round-headed window faces southwest, and is constructed of two large ashlar blocks to both the jambs and head. The mortar in the tower is generally a grey-white soft lime mortar with frequent unslaked lime inclusions, this tends to follow the Phase I

construction. A slightly harder grey-white lime mortar present on external elevations may represent repointing etc when the tower was converted to a folly. The tower was originally an exhaust chimney stack for the Clyne Wood Arsenic and Copperworks, connected by a 140m long stone flue set into the hillside. The flue, or what's left of it, measures 8.5m long x 2.5m wide before becoming submerged in the hillside. It is not clear how high the stack was originally as the stack was converted to a parkland castellated folly sometime after 1860 when the Clyne Wood Arsenic and Copperworks closed. Previous chemical testing of the tower identified significant arsenic contamination in the former chimney stack (Cadw Scheduled Monument Consent Letter 23<sup>rd</sup> July 2021).

- 7.3.3 A brief timeline for both the Clyne Wood Arsenic and Copperworks and Ivy Tower (Upper Chimney Stack) is set out below:
- 7.3.4 1825 – The Cambrian newspaper (see Section 2.3.8 above) carried an advertisement calling all ‘Capitalists’ on the 10<sup>th</sup> September 1825 (Plate 20) that “*Iron Mines and Collieries*” in Clyne Wood and Valley to be let. This advertisement probably confirms that at this time no industrial works, such as the Clyne Wood Arsenic and Copperworks, were yet built as they are actively encouraging large scale industrial development (with nominal rents!).
- 7.3.5 1825 to 1840 (1837?) – Clyne Wood Arsenic and Copperworks possibly built initially as a copperworks by a Cornish company. This reference has been regularly repeated and originated in the Glamorgan County History V (John and Williams 1980, 47-96).
- 7.3.6 1841 – An advertisement in the Cambrian newspaper dating 27<sup>th</sup> February 1841 directly refers to “*Clyne Wood Chemical Works*” and encourages “...persons Having Claims On This Establishment - Send To John Gwyn Jeffreys, Solicitor...”. This provides direct confirmation that the works must have been in existence by 1841, possibly the Cornish company referenced in the Glamorgan County History above.
- 7.3.7 1841-44 – the Clyne Wood Chemical Works was purchased by Henry Kingscote (Newman 1995, 488-489; Hughes and Reynolds 1989, 15; Hughes 2000, 63). It seems probable that the Upper Chimney Stack (Ivy Tower) was built at this time.
- 7.3.8 1845 – Clyne Wood Chemical Works, including the Upper Chimney (Ivy Tower), are first depicted on the 1845 Tithe Map, *Plan of Oystermouth in the County of Glamorgan*, held by the West Glamorgan Archives (Figure 8). The Apportionment records the arsenic works in Land Parcel 69: Clyne Wood Metallurgical; Occupier Henry Kingscote; Owner Duke of Beaufort. The Upper Chimney (Ivy Tower) is in Land Parcel 57: Clyne Wood with the Duke of Beaufort both the occupier and owner.
- 7.3.9 1845 – The Cambrian newspaper carried a sales advertisement on the 12<sup>th</sup> April 1845 (Plate 21) for the “*Stock, Trade Fixtures, and other materials, belonging to the Mineral and Chemical Works*”. This advertisement is very important as it confirms the existence of a steam engine, which hitherto was only speculated, together with details of a smithy and carpenter’s workshop and all of the other machinery, tools, waggons and barges used at the works in 1845.
- 7.3.10 1847 – An unusual notice was pasted in The Welshman on the 15<sup>th</sup> of January 1847 (Plate 22) declaring that a company of wealthy iron masters had taken the lease from the Duke

- of Beaufort at Clyne for the purposes of erecting furnaces. This may relate to the refurbishment of the Clyne Arsenic and Copper Works following Henry Kingscote's sale after 1845 to Nicholas Jennings & Sons.
- 7.3.11 1852 – Nicholas Jennings & Sons noted in Glamorgan County History (John and Williams 1980, 47-96) using the Clyne Wood Chemical Works for arsenic.
- 7.3.12 1859 – Nicholas Jennings & Sons take leases out on holdings at Dan-y-Graig, Swansea, suggesting the move away from Clyne Wood Chemical Works.
- 7.3.13 1860 – Clyne Wood Chemical Works closed and possibly formed part of the sale of Woodlands Castle purchased by William Graham Vivian.
- 7.3.14 1863 – William Graham Vivian refurbished and extended the Woodlands mansion (later renamed Clyne Castle in 1870) and by 1863 leased Clyne Woods and the Upper Chimney (Ivy Tower) from the Duke of Beaufort for the castle's pleasure grounds.
- 7.3.15 1884 – Upper Chimney Stack (Ivy Tower) noted as an 'Old Chimney' and the Clyne Arsenic and Copperworks depicted as 'Old Buildings' on the Ordnance Survey 1<sup>st</sup> Edition historic map (Figure 9).
- 7.3.16 1900 – by the publication of the Ordnance Survey 2<sup>nd</sup> Edition historic map (Figure 10) the Upper Chimney Stack has been renamed as Ivy Tower indicating a *terminus ante quem* for the conversion of the chimney stack to a gothic castellated folly complete with an inserted gothic round-topped window, internal staircase and new semi-circular stone arched door. The Clyne Arsenic and Copperworks depicted as 'Hay Sheds'.
- 7.3.17 1954 – The Vivian family sold the Clyne Castle Estate, including Clyne Wood, to Swansea Council.
- 7.3.18 Phase I – Figures 1-7, Plates 3-7, 9-13 and 17
- 7.3.19 The initial construction phase of Ivy Tower is that of a chimney stack connected by a 140m long stone-built flue to what was then called the Clyne Metallurgical Works. The chimney stack and flue are first depicted on the 1845 Tithe Map, *Plan of Oystermouth in the County of Glamorgan* (Figure 8). It is likely that the stack and flue was built by the Devonshire industrialist Henry Kingscote when he took over the works in 1841-44. Possibly suggesting a conversion from copper to arsenic at this time as the long flue would have been one method for precipitating and condensing the exhaust fumes from the calcining furnaces to obtain the arsenious oxide, which was then refined in the reverberatory furnaces.
- 7.3.20 The surviving structures (chimney and flue) are of roughly coursed Pennant sandstone, quarried nearby in Clyne Wood, with grey-white soft lime mortar and frequent unslaked lime inclusions. The chimney stands to 6.3m in height and 6.8m in width, with walls 1.2m, 4 foot, in thickness. The internal space or chimney flue area is 4.4m wide. The flue has collapsed in many places down the hillside and only stands to 1.8m in height where it joins the chimney stack at the flue entrance. The flue entrance is an integrally built aperture in the stack 1.85m in height from exposed rubble at floor level to a plain stone segmental arch. The flue opening is trapezoidal in section, 1.05m in width at the base and just over four foot, 1.25m, wide at the base of the arch. The flue and chimney stack are of one phase, the flue clearly having been built into the stack. This is particularly evident on the north side of the flue entrance where part of the flue and chimney stack have

collapsed outwards into the flue. A significant crack or defect is visible in the internal west facing elevation (Figure 7, Plate 17) that starts in the centre of the flue arch and extends northwards to 2m in height. The defect is not visible on the exterior elevation.

- 7.3.21 There are numerous putlog holes on the interior and exterior elevations. It is unlikely that many belong to the Phase I stack as industrial chimneys of the period tend to be built from the inside with scaffolding rising internally with the chimney. Animal and human gins (winding engines) would have provided the lift for the stonework. A four-foot-thick wall at Ivy Tower is fairly standard for industrial chimneys of the period. The original height of the chimney is uncertain, but it would not necessarily have been a tall chimney. Warburton (1987, 195-196) suggests that the height need only be sufficient to provide draught for the steam engine and be two and three times the height of the highest obstruction. He also suggests that cut and cover tunnels or flues, such as the one that connects the Upper Chimney stack with the arsenic works, help to provide additional draught and therefore the chimney that is usually placed upon a hill does not need to be as tall and is cheaper to build. Douet (1988, 12) suggests that it was common in the middle of the 19<sup>th</sup> century for the size of the chimney to be based on the horsepower of the steam engine. We now know that Clyne Wood Chemical Works, as it was known, had a “seven-horse power high-pressure steam engine, 20-inch stroke, 12-inch cylinder, with boiler” thanks to the 1845 sales advertisement (Plate 21; Section 2.3.10). Therefore, using an engineering table dating to 1866 (*ibid*, 12) the chimney height for Ivy Tower (Upper Chimney Stack) was likely no more than 60 feet/18m in height, and given it had a 140m, 460 foot, flue built into the hillside we can be reasonably confident that the stack may have been a lot lower.
- 7.3.22 Phase II Folly – Figures 1-7, Plates 1-8, 14-16, 18-19
- 7.3.23 Clyne Wood Chemical Works closed in 1860 and possibly formed part of the sale of Woodlands Castle purchased by William Graham Vivian, who refurbished and extended the mansion (later renamed Clyne Castle in 1870) and by 1863 leased Clyne Woods and the Old Chimney (Ivy Tower) from the Duke of Beaufort for the castle’s pleasure grounds. By the publication of the Ordnance Survey 2<sup>nd</sup> Edition (1900) historic map (Figure 10) the Upper or Old Chimney had been converted to a gothic castellated folly complete with inserted round-topped window, internal staircase and new semi-circular stone arched door.
- 7.3.24 How much of the stack was demolished is unclear but only just over 6m of the original chimney stack survived the conversion. A total of fourteen merlons were constructed into the chimney top, each measuring just over 1m in width. Crenels measuring 0.4m in width. Three to four courses of the merlons survive to 0.5m in height, the tops having been lost in the past. One merlon on the west facing side of the tower has been totally lost. A total of 25 putlog holes are visible on the exterior elevations of the tower and while likely that many were used to anchor scaffolding when the chimney stack was converted to a folly some may just be for ‘gothic’ effect.
- 7.3.25 A rather fine Pennant sandstone semi-circular arched doorway was built into the north facing elevation, the arch of chamfered ashlar blocks and an embossed trapezoidal

shaped keystone. The door jambs are not as fine and simply consist of the tidied up roughly coursed sandstone wall after the door had been inserted. The jambs have been damaged in the past with some quoins removed. The doorway is 1.3m wide at the base of the voussoirs and rises to a 0.6m high arch. The overall door height is 2.1m high from the existing ground level to the base of the keystone. This door perhaps providing a more genteel ingress to the folly than perhaps attempting to rework the flue, which would have been severely contaminated with arsenic and also 0.25m lower. The interior of the semi-circular arched doorway is not as fine, with most of the outer face of the arch lost. Three voussoirs survive on the west side and one on the east standing on its end more akin to a springer. The rough and ready appearance of the interior door arch would suggest that this was never meant to be seen and therefore the interior may have been plastered. This would certainly help with coming into contact with the arsenic contamination, which they would have been well aware of.

- 7.3.26 A Romanesque or Norman styled Pennant sandstone arched window was inserted into the southeast facing elevation. The window consists of a dressed moulded arched stone lintel (0.7m wide, 0.13m in depth, 0.25m high and with a 0.14m rise to the centre of the arch) and straight stone jambs (0.15m wide, 0.2m in depth and 0.75m long) on a large (0.95m wide, 0.4m depth and 0.05m thick) sandstone windowsill protruding 0.05m out from the tower. On the interior of the window a large flat stone lintel (0.8m thick, 0.4m in depth and 1.05m wide) has been removed, with the result several stones in the wall above the window have fallen out. The window has an overall depth of 0.6m including chamfered jambs 0.35m in width. Around 0.65m of the original Phase I chimney stack wall was removed to provide access for the window. Indeed, the upper part of the internal tower wall here has been stepped in and refaced to a thickness of 0.6m wide up to the castellated battlements. Perhaps this stepped area provided purchase for wooden steps or wooden wall walk?
- 7.3.27 Evidence for floors is unclear as is whether the tower had a roof or viewing platform. But as a folly one assumes there had to be some form of access to the battlements. There is the suggestion of two to three joist sockets (c0.2 x 0.3m) on the south facing internal elevation (above the inserted door) that may have carried floor joists over to the north facing internal elevation as there are two to three corresponding joist sockets there. However, the size of the north facing sockets are much smaller (0.2m x 0.15m) suggesting these are putlog holes instead. For the purposes of the report these have been labelled as potential joist sockets but the north facing set seem unlikely. Two courses above are two evenly sized joist sockets (c0.3m x 0.2m), one on each north and south facing internal elevations, 2.6m and 2.8m respectively above the undulating floor level. These two joist sockets are more believable and may suggest the first storey was maybe only half or two thirds floored supported by a single large joist, perhaps to allow for a spiral timber staircase on the west side. The south facing elevation has a further three large joist sockets 1.6m above the lower three. An alternate interpretation is that these larger sockets are in fact putlog holes for the Phase I internal scaffolding and perhaps larger timbers were needed to support a gin and winding gear to raise the stone as the chimney grew in height.

7.3.28 The east facing internal elevation has a winding stone staircase built against the inside of the tower, with surviving stonework standing to 2m in height and 0.9m (three foot) wide. Five steps are just about discernible from the floor level upwards, each step around 0.2m to 0.3m in height. The stone staircase is rounded as it terminates at the higher end where the tower wall has been stepped in at 2.7m high by 0.6m in depth to accommodate the spiral staircase. Here a patch of masonry has started to deteriorate with some loss of stonework (1.2m high x 1m wide). No stone steps survive perhaps suggesting that from here the spiral staircase was of timber construction. The spiral staircase must have either stopped before the round-topped window or bridge across it to the flat, stepped area in the wall beyond. There is currently no visible evidence (joist sockets, wall walk and drains etc) that the tower was roofed or had a second storey viewing platform covering the top of the tower, although if it did have a first floor, as suggested above, then it would be logical that this would be protected in some way. However, it maybe that all the tower had was a stone spiral staircase to first storey and then a timber spiral staircase to the battlements to provide a viewing location.

## 8 Conclusions

- 8.1.1 The investigations consisted of the historic building recording to Level II standard of Ivy Tower (SMGm475, LB22562), a former industrial arsenic chimney stack and later castellated folly. Conservation work included the removal of vegetation from the tower and its immediate environs. This provided an unfettered view of the former industrial chimney. The building was recorded with a blend of RTK GPS measured survey, photogrammetry (3D modelling) derived from both aerial (drone) and terrestrial cameras and a descriptive account of the phasing of the building. Section 6 and 7 above details the outcome of the photogrammetric survey, which includes details on the level of error that is used to determine the overall accuracy and quality of the survey. The Root, Mean, Square (RMS) error corresponds to the difference between the initial and computed positions of the GCPs surveyed by GNSS Glonass (GPS) RTK receiver, which was 3mm (RMS) across the 3D model with a Ground Sampling Distance (GSD – the distance between two adjacent pixel centres normalised to real world dimensions) of 2mm/pixel. An excellent outcome resulting in a high-quality georeferenced 3D photogrammetric model that will provide a detailed ‘Digital Twin’ against which future surveys and critically folly/chimney stack deterioration can be compared.
- 8.1.2 The initial construction phase of Ivy Tower is that of a chimney stack connected by a 140m long stone-built flue to what was then called the Clyne Metallurgical Works. The chimney stack and flue are first depicted on the 1845 Tithe Map, *Plan of Oystermouth in the County of Glamorgan* (Figure 8). It is likely that the stack and flue was built by the Devonshire industrialist Henry Kingscote when he took over the works in 1841-44. Possibly suggesting a conversion from copper to arsenic at this time as the long flue would have been one method for precipitating and condensing the exhaust fumes from the calcining furnaces to obtain the arsenious oxide, which was then refined in the reverberatory furnaces. The original height of the chimney is uncertain, but it would not necessarily have been a tall chimney. As noted above, Warburton (1987, 195-196) suggests that the height need only be sufficient to provide draught for the steam engine and be two and three times the

height of the highest obstruction. He also suggests that cut and cover tunnels or flues, such as the one that connects the Upper Chimney stack with the arsenic works, help to provide additional draught and therefore the chimney that is usually placed upon a hill does not need to be as tall and is cheaper to build. Douet (1988, 12) suggests that it was common in the middle of the 19<sup>th</sup> century for the size of the chimney to be based on the horse power of the steam engine. We now know that Clyne Wood Chemical Works, as it was known, had a “seven-horse power high-pressure steam engine, 20-inch stroke, 12-inch cylinder, with boiler” thanks to the 1845 sales advertisement (Plate 21; Section 2.3.10). Therefore, using an engineering table dating to 1866 (*ibid*, 12) the chimney height for Ivy Tower (Upper Chimney Stack) was likely no more than 60 feet/18m in height, and given it had a 140m, 460 foot, flue built into the hillside we can be reasonably confident that the stack may have been a lot lower, perhaps just above the tree line.

- 8.1.3 When Clyne Wood Chemical Works closed in 1860 it may have possibly formed part of the sale of Woodlands Castle, which was purchased by William Graham Vivian, who refurbished and extended the mansion (later renamed Clyne Castle in 1870) and by 1863 leased Clyne Woods and the Old Chimney (Ivy Tower) from the Duke of Beaufort for the castle’s pleasure grounds. By the publication of the Ordnance Survey 2<sup>nd</sup> Edition (1900) historic map (Figure 10) the Upper or Old Chimney had been renamed as Ivy Tower indicating a *terminus ante quem* for the conversion of the chimney stack to a castellated folly complete with inserted round-topped window, internal staircase and new semi-circular stone arched door. The Clyne Arsenic and Copperworks depicted as ‘Hay Sheds’. The conversion of the chimney stack to a folly would have been fashionable at the time. Another example can be found nearby across Clyne Valley at Sketty Park House (NPRN19974), where the industrial Morris family had built a similar gothic folly called Belvedere Tower (NPRN23067) in Mill Wood in the early part of the 19<sup>th</sup> century.
- 8.1.4 The interior of the tower may have been plastered or whitewashed as the rough and ready appearance of the interior of the inserted semi-circular door arch may suggest that this was never meant to be seen. This would certainly help with coming into contact with the arsenic contamination, which they would have been well aware of during the conversion of the chimney to a folly. It is uncertain whether the folly had internal floors but a set of joist sockets in the north and south facing internal elevations on the eastern side may hint at a first storey floor covering half or two thirds the internal space of the tower, perhaps to allow for a spiral timber staircase on the west side. Here a winding stone staircase was built against the inside of the tower at ground floor level, with surviving stonework standing to 2m in height. The stone staircase is rounded as it terminates at the higher end where the tower wall has been stepped in to accommodate a potential spiral staircase. No stone steps survive at this first storey level perhaps suggesting that from here the spiral staircase was of timber construction. The spiral staircase must have either stopped before the round-topped window or bridged across it to the flat, stepped area in the wall beyond. There is currently no visible evidence (joist sockets, wall walk and drains etc) that the tower was roofed or had a second storey viewing platform covering the top of the tower, although if it did have a first floor, as suggested above, then it would be logical that this would be protected in some way. However, it maybe that all the tower had was

a stone spiral staircase to first storey and then a timber spiral staircase to the battlements to provide a viewing location. The larger looking joist sockets visible in the internal walls are perhaps simply putlog holes for the Phase I internal scaffolding and maybe larger timbers were needed to support a heavier gin and winding gear to raise the stone as the chimney grew in height.

- 8.1.5 The Romanesque or Norman styled Pennant sandstone arched window inserted into the southeast facing elevation is an oddity as it would not have been particularly accessible from a potential first storey floor or the spiral staircase. It perhaps acted as a light well for the interior of the folly and perhaps was meant to be viewed as a Romanesque exterior feature.
- 8.1.6 Overall, the tower appears to be in reasonable condition considering how it has been affected by the intrusions of vegetation. That said, the long flue has long since collapsed and there are several areas where the masonry is now failing. A merlon is missing on the western battlements and the tops of the merlons have long since been lost, probably from vegetation intrusion. The Phase II western door jamb and internal voussoirs have been removed or fallen out. Internally the stone staircase is almost entirely robbed out and vegetation appears to have started the collapse of masonry at first floor level wall. Vegetation has also started to collapse the masonry around the inside of the parapet. A large crack is also visible in the west facing internal elevation running almost the entire height of the wall. The present removal of vegetation and stabilisation of the tower would appear to be a timely intervention to secure the future of the tower and arrest any further decay of the standing masonry.
- 8.1.7 The historic building record was carried out to Level II (Historic England 2016). The building was recorded with a blend of RTK GPS measured survey, photogrammetry (3D modelling) derived from both aerial (drone) and terrestrial cameras and a descriptive account of the phasing of the building.
- 8.1.8 The survey work has been carried out in accordance with the professional standards of the *Chartered Institute for Archaeologist* (CIfA).

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### 10 Appendix I – Figures

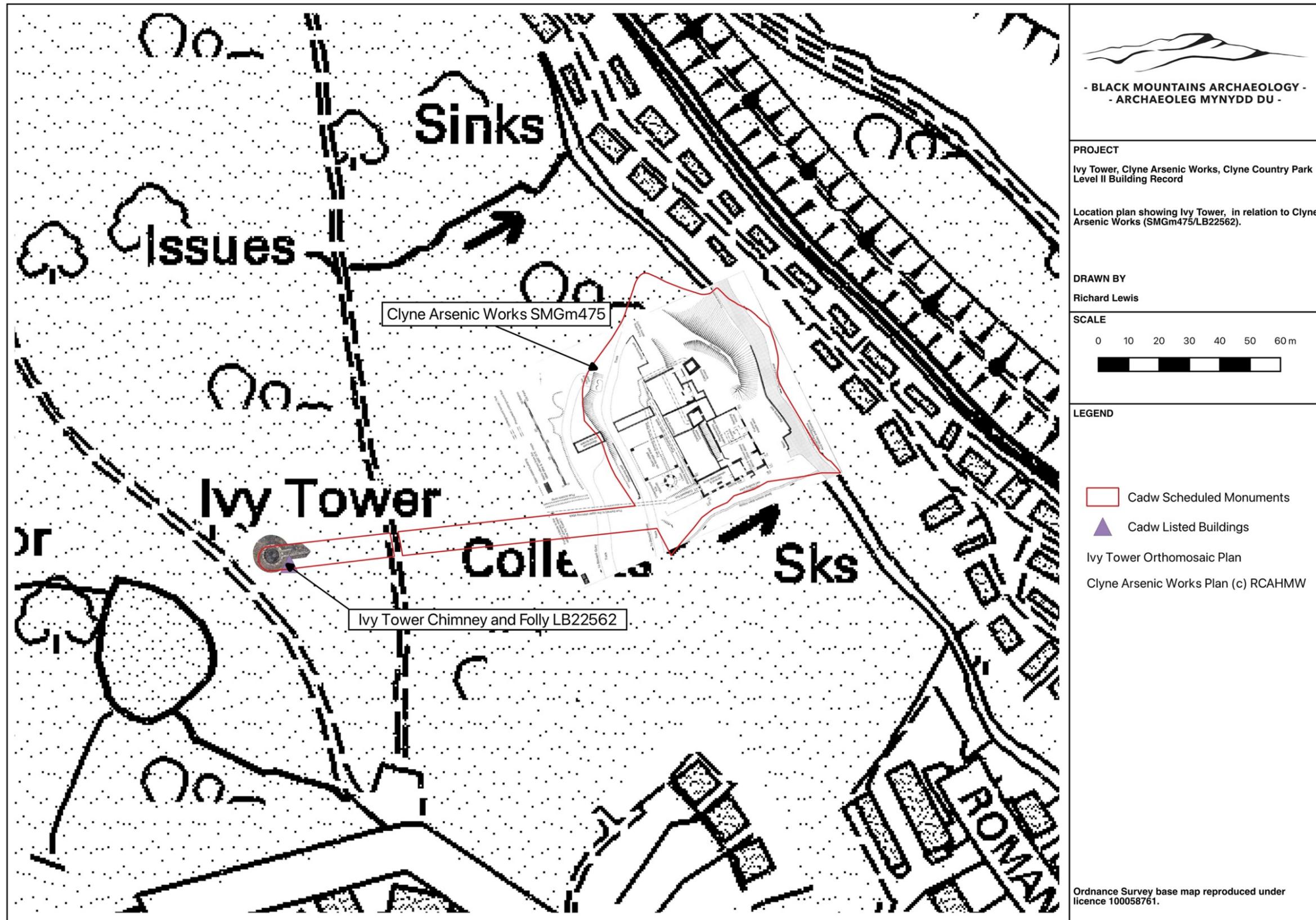


Figure 1. Location plan showing Ivy Tower in relation to Clyne Arsenic Works (SMGm475/LB22562). Ordnance Survey maps reproduced under licence 100058761.

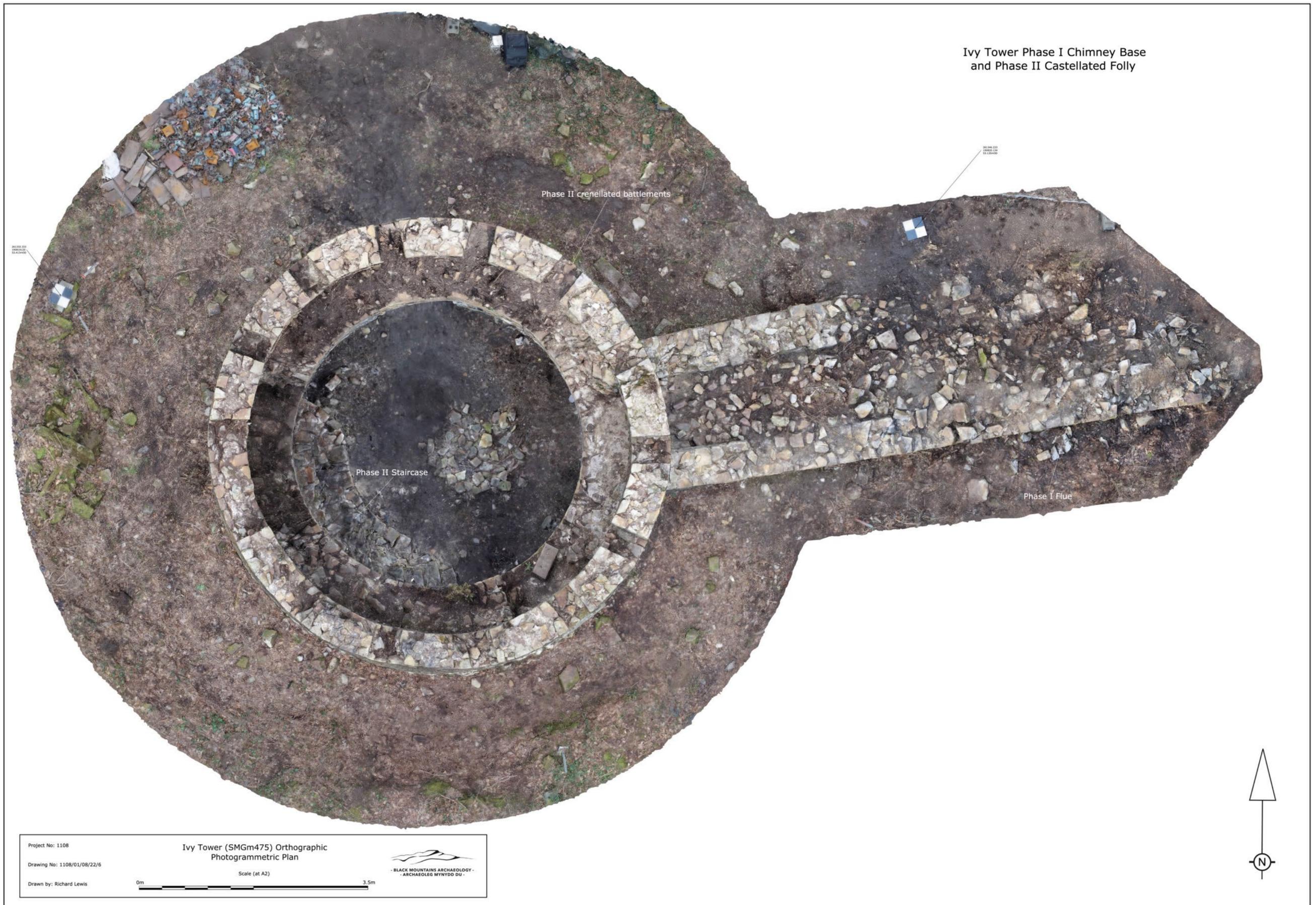


Figure 2. Ivy Tower Orthographic Photogrammetric Plan.

North Facing Elevation

Section A-A

Section A-A

Phase II crenellated battlements

Putlog Holes

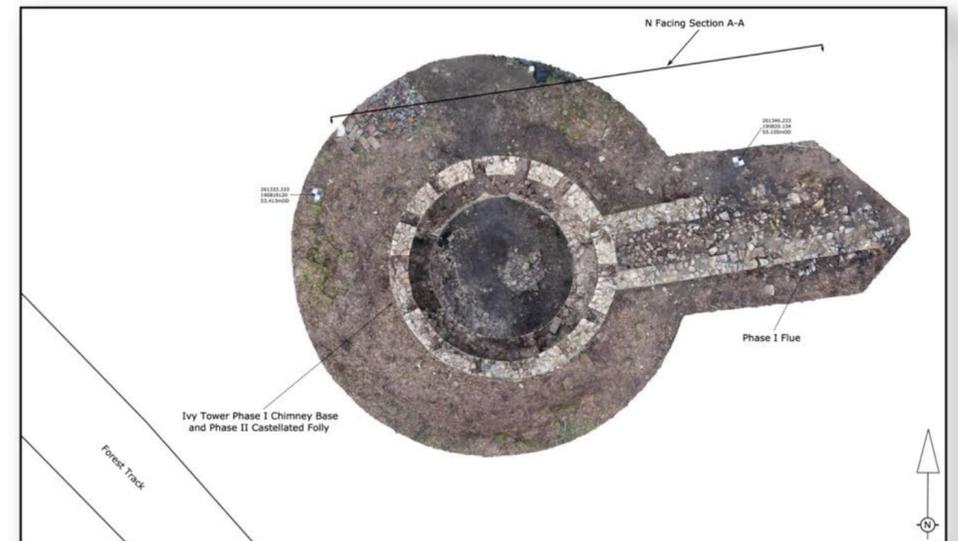
Phase I Chimney Base

56.010mOD

Phase I Flue

Phase II Pennant Sandstone Semi-circular Ashlar Arch

Phase II inserted door



Project No: 1108  
Drawing No: 1108/01/08/22/1  
Drawn by: Richard Lewis

Ivy Tower (SMGm475) Orthographic N Facing  
Photogrammetric Elevation

Scale (at A2)  
0m 2m



Figure 3. Ivy Tower Orthographic North Facing Photogrammetric Elevation.

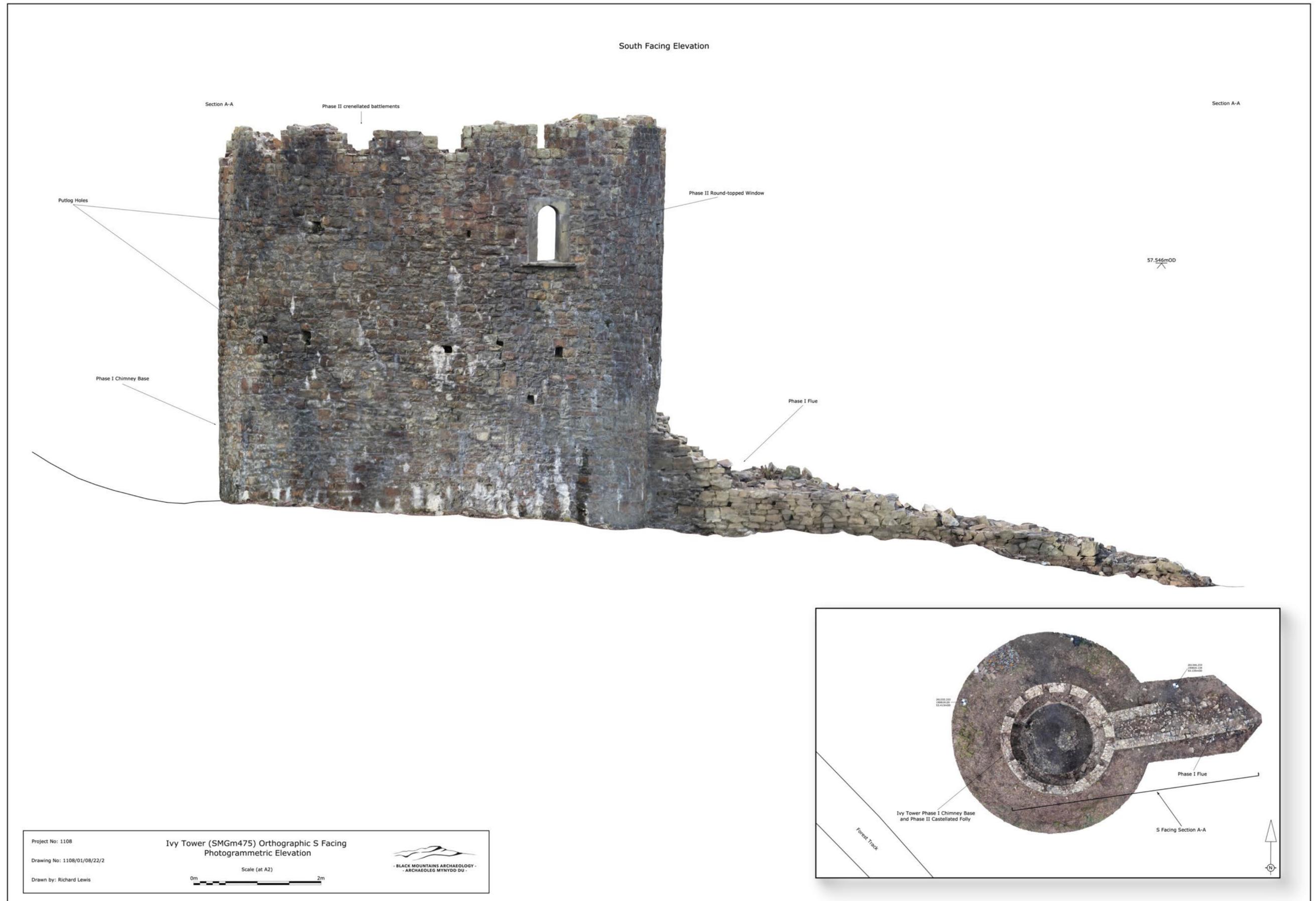


Figure 4. Ivy Tower Orthographic South Facing Photogrammetric Elevation.

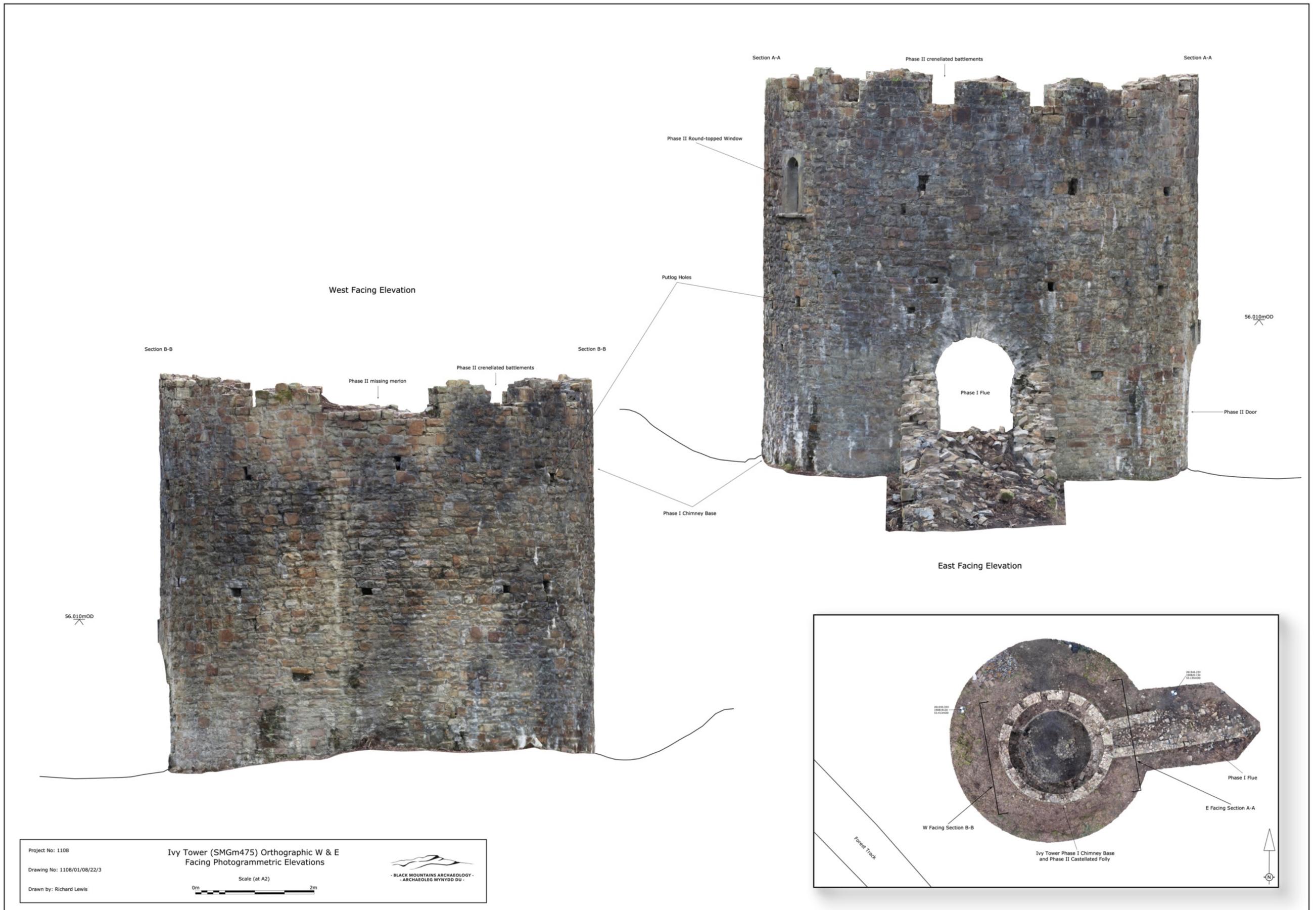


Figure 5. Ivy Tower Orthographic West and East Facing Photogrammetric Elevations.

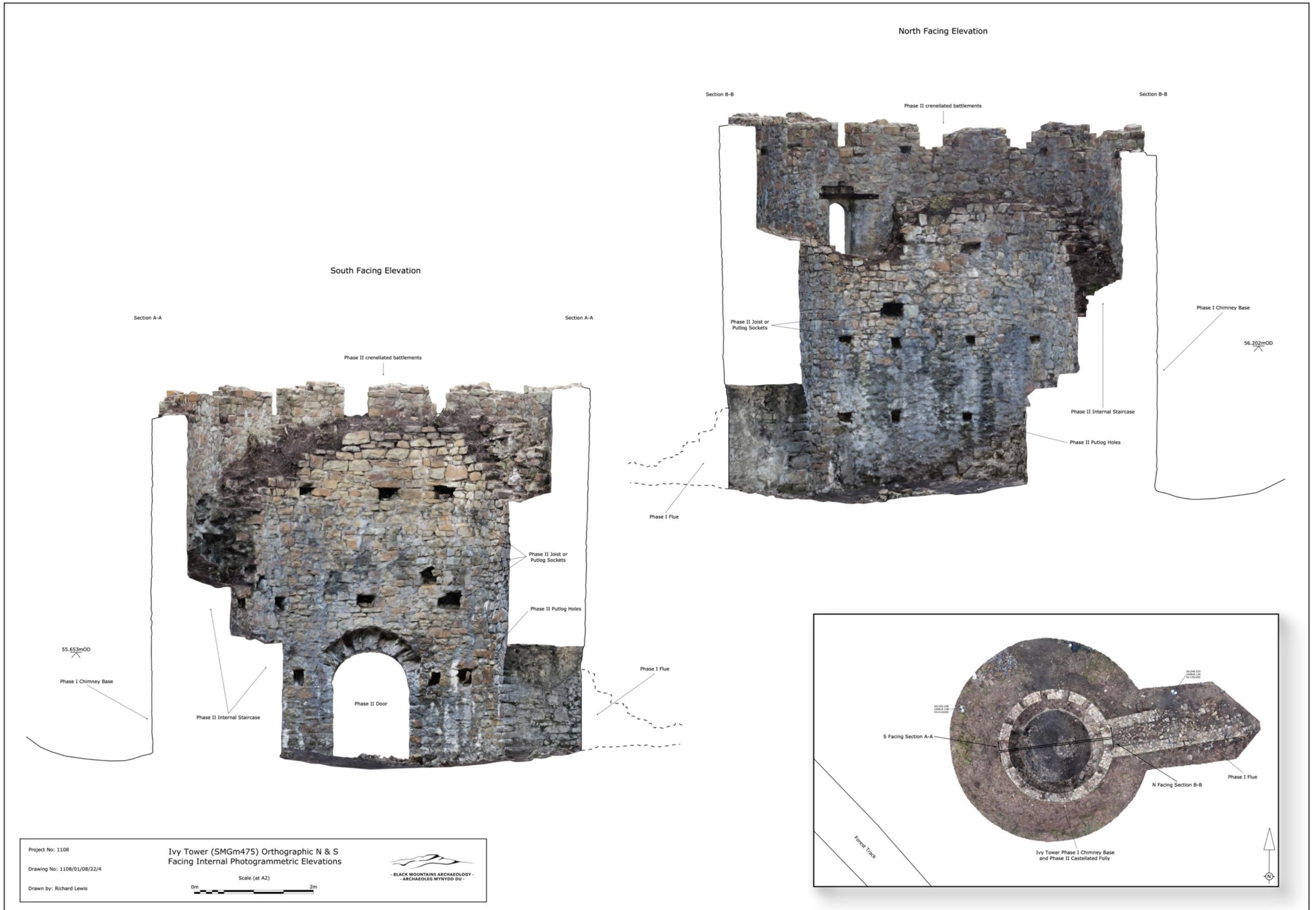


Figure 6. Ivy Tower Orthographic North and South Facing Internal Photogrammetric Elevations.

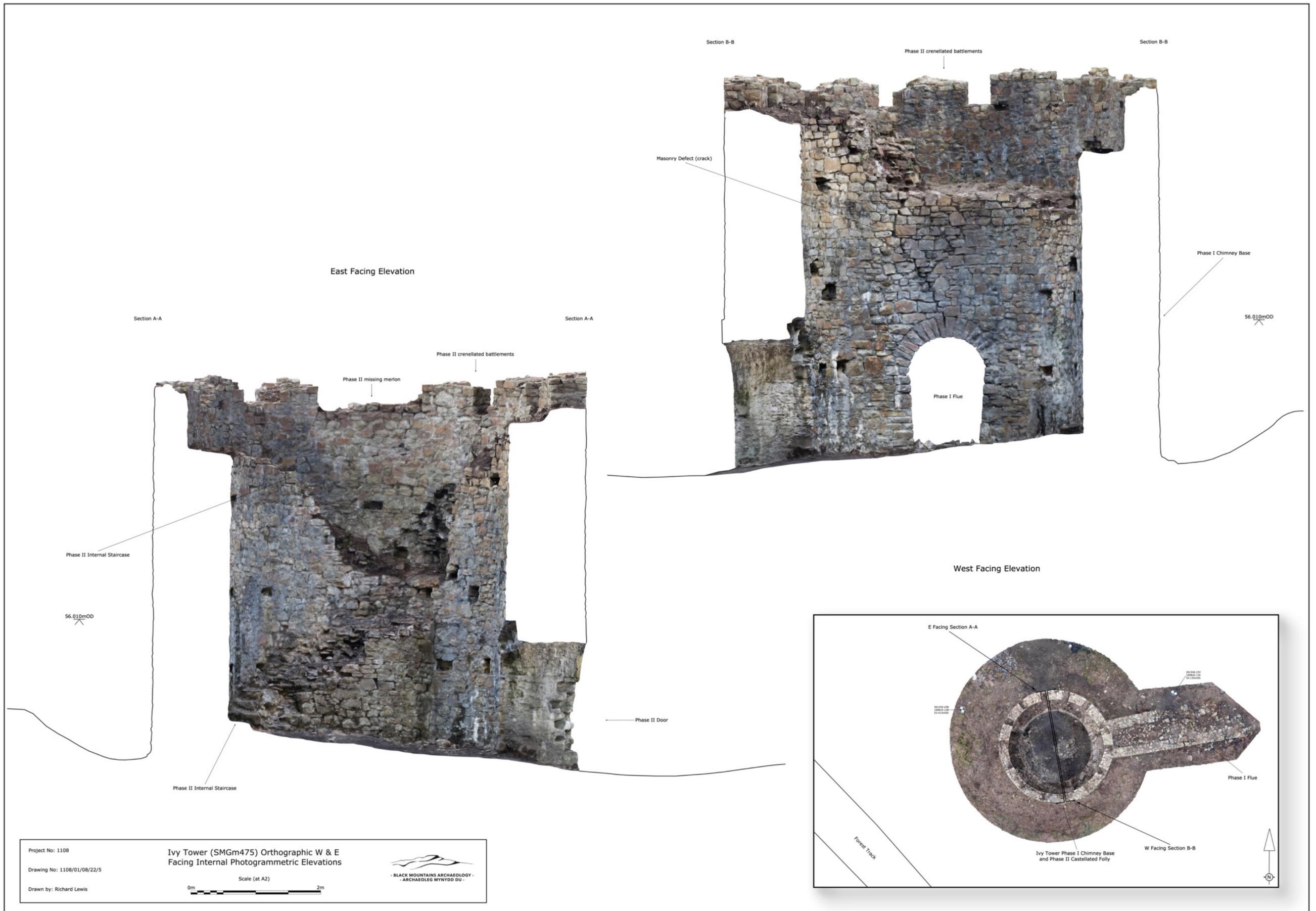


Figure 7. Ivy Tower Orthographic West and East Facing Internal Photogrammetric Elevations.



Figure 8. 1845 Tithe Map of Oystermouth in the County of Glamorgan. Showing Clyne Wood Arsenic Works and Upper Chimney (Ivy Tower) © West Glamorgan Archives.

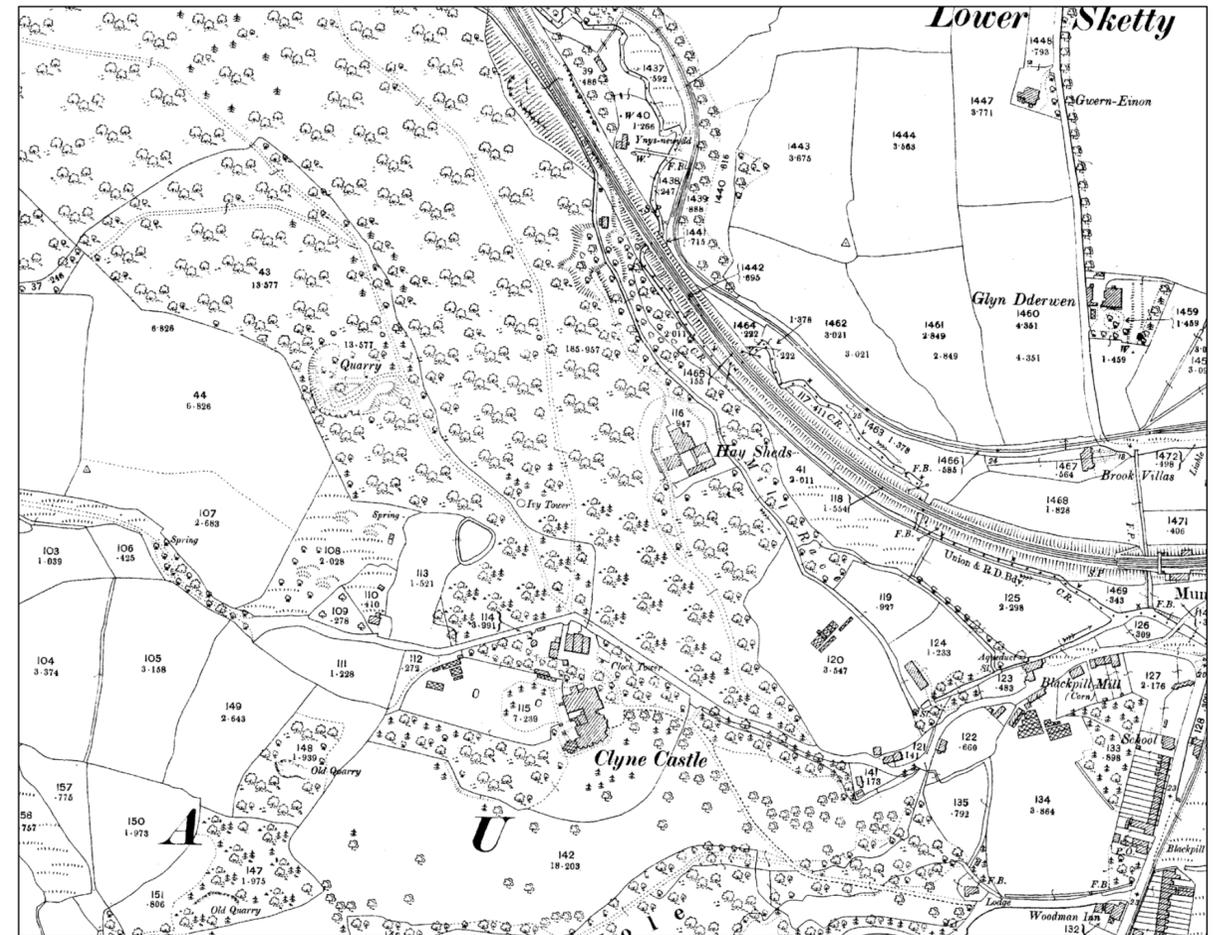


Figure 10. Ordnance Survey 1900, 2nd Edition map. Ordnance Survey © Crown Copyright. All rights reserved. Licence number 100058761.



Figure 9. Ordnance Survey 1884, 1st Edition map. Ordnance Survey © Crown Copyright. All rights reserved. Licence number 100058761.

## **11 Appendix II – Plates**

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Plate 1 – N facing elevation of Ivy Tower showing inserted Phase II folly door. Scale 2m.



Plate 2 – Inserted Phase II folly door of Pennant sandstone with semi-circular stone arch. N facing elevation  
Scale 2m.



Plate 3 – W facing elevation of Ivy Tower showing external putlog holes. Scale 2m.



Plate 4 – WSW facing elevation of Ivy Tower showing external putlog holes and missing merlon on battlements. Scale 2m.



Plate 5 – SW facing elevation of Ivy Tower showing external putlog holes. Scale 2m.



Plate 6 – S facing elevation of Ivy Tower showing external putlog holes and Phase II inserted gothic round-topped window. Scale 2m.



Plate 7 – SE facing elevation of Ivy Tower showing external putlog holes, Phase I Flue and Phase II gothic round-topped window. Scale 2m.



Plate 8 – SE facing elevation of Ivy Tower showing external Phase II gothic round-topped window.



Plate 9 – SSE facing wall of the Phase I Flue. Scale 2m.



Plate 10 –E facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. GCP scale 0.3m.



Plate 11 – NNE facing wall of the Phase I Flue.



Plate 12 – E facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. Scale 2m.



Plate 13 – NE facing elevation of Ivy Tower showing external putlog holes and remains of Phase I Flue. Scale 2m.



Plate 14 – N facing elevation of Ivy Tower showing inserted Phase II folly door, external putlog holes and remains of Phase I Flue.



Plate 15 – Nadir view (E = top) of Ivy Tower Phase I chimney base, Phase II gothic battlements and internal staircase. Note missing merlon to WSW. GCPs scale 0.3m.



Plate 16 – S facing internal elevation of Ivy Tower showing inserted Phase II folly door, internal putlog holes and two sets of joist sockets. Scale 2m.



Plate 17 – W facing internal elevation of Ivy Tower showing the Phase I Flue entrance. Scale 2m.



Plate 18 – N facing internal elevation of Ivy Tower showing internal putlog holes and two sets of joist sockets. Scale 2m.



Plate 19 – E facing internal elevation of Ivy Tower showing Phase II inserted spiral staircase, internal putlog holes and two sets of joist sockets. Scale 2m.

**TO CAPITALISTS.**

*TO BE LET,*  
**IRON MINES and COLLIERIES,**  
*In the Mineral Basin of South-Wales,*  
And within a quarter of a mile of the Swansea and Mumbles Tramroad.

**A**LL the SEAMS and VEINS of IRON MINE and IRON ORE and CLAY under *Clyne Wood* and *Glamorgan*, in the parish of Oystermouth, in the county of Glamorgan, containing about 2500 Acres.

Also, all the VEINS of COAL (being of coking quality), under the said Wood and Common.

And also, all the SEAMS and VEINS of IRON MINE and IRON ORE and CLAY, lying under *Fairwood Common*, in the several parishes of Lanridfan, Bishopston, Pennard, and Ilston, in the said County of Glamorgan, containing upwards of 2000 Acres, situate within one mile of the aforesaid Common.

And also, all the VEINS of COAL (being of coking quality), under the said last-mentioned Common.

*Clyne Wood* and Common are distant about two miles and a half from Swansea, and about quarter of a mile from the Oystermouth Tramroad, which communicates with the Town and Port of Swansea.

*Fairwood Moor* is distant about five miles from Swansea, and about two miles from the river Burry, which is navigable for vessels of large burthen.

Any quantity of Limestone Rock may be had with the above at a trifling tonnage, in the immediate neighbourhood of *Clyne Common*.

The proximity of Mine, Coal, and Lime, to each other, renders the above property as advantageously situate for the erection of extensive Iron Works, as any part of the Mineral Basin of South Wales.

Any quantity of Building Ground may be had at nominal rents

Apply at the Office of Messrs. L. and T. Thomas, Solicitors, Swansea; of Messrs. Perkins and Frampton, Gray's-Inn, London; or Mr. Edward Martin, Mineral-Surveyor, Morris-ton, near Swansea.

Plate 20 – Clyne Valley investment advertisement. The Cambrian 10<sup>th</sup> September 1825.

**CLYNE WOOD CHEMICAL WORKS,**  
*Near SWANSEA.*

—  
**Mr. DAVID HOWELL**  
**WILL SELL BY AUCTION,**

On **MONDAY, APRIL 21, 1845,** and following days, at **CLYNE WOOD, near SWANSEA.**

**A**LL the **STOCK, TRADE FIXTURES,** and other **MATERIALS,** belonging to the Mineral and Chemical Works there; comprising large quantities of wrought and cast iron; pipe, sheet, and pig lead; zinc, tin, brass, copper; fire and other bricks; Stourbridge clay; copper, iron, lead, zinc, black jack, and other ores; Bathurst's patent weighing machine; chains, ropes; about 40 fathoms of boring rods and bits, self-acting bellows, blow-pipe and stand; carpenters' shop, fixtures, and smithery, with three large extra forge bellows, anvils, vices, &c.; seven-horse power high-pressure steam engine, 20 inch stroke, 12-inch cylinder, with boiler and other appendages complete; six-roller clay mill, with four cog-wheels; several large fly-wheels for engine purposes, a number of four-wheel iron waggons; large quantities of oak, ash, and Memel timber, sawed and seasoned, and fit for working; twenty-seven new wheelbarrows, five canal barges, with several hundred lots of other miscellaneous articles.

Catalogues and conditions of the sale will be ready for delivery in a few days, on application to the Auctioneer; or at the Office of Mr. Jeffreys, Solicitor, Swansea.

The Sale to commence at eleven o'clock in the forenoon of each day.

Plate 21 – Clyne Woods Mineral and Chemical Works sale notice. The Cambrian 12th April 1845.

**NEW IRON WORKS AT CLYNE, NEAR SWANSEA.—**

We understand from good authority that a company of wealthy Ironmasters have taken a lease from his Grace the Duke of Beaufort of an extensive tract of iron and coal property at Clyne, and purpose immediately erecting furnaces on the bank of the Black-pill river, half-way between this town and Oystermouth. This we doubt not is but the commencement of what must result from the introduction of railways and the consequent development of the vast mineral resources of our district.—*Cambrian.*

Plate 22 – New Ironworks at Clyne. The Welshman 15<sup>th</sup> January 1847.



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