



Ravenglass Roman Bath House, Muncaster, Cumbria

Report on Geophysical Surveys, January 2024

Megan Clements and Neil Linford



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Walls Drive
Ravenglass, Cumbria, CA18 1SR

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Summary

A Ground Penetrating Radar (GPR) survey was conducted at the Ravenglass Roman Bath House, Muncaster, Cumbria, to determine whether overhanging masonry at the site had been subject to previous reinforcement to mitigate against collapse. Data was collected from a hand-held GPR antenna with profiles acquired across the standing walls of the Bath House. No convincing evidence was found to suggest the presence of ferrous reinforcement supporting the overhanging masonry. However, the survey did potentially reveal more extensive voiding in the vicinity of visible surface cracking on some elevations. A GPR survey (0.05ha) was also conducted over the accessible area surrounding the standing remains, although this was partially obscured by water-logging. The recorded anomalies are broadly consistent with the excavated Bath House remains extending to the east of the standing remains. The survey was conducted at the request of the English Heritage Trust through the Shared Services Agreement.

Contributors

The fieldwork was completed by Megan Clements and Neil Linford.

Acknowledgements

The authors are grateful for the help provided by colleagues from the English Heritage Trust in coordinating access for the survey to take place. The cover image shows the Bath House and the wider scheduled area viewed from the east (photograph taken by Neil Linford).

Archive location

Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth, PO4 9LD.

Date of survey/research/investigation

The fieldwork was conducted between the 30th and 31st January 2024. The report was completed on the 29th February 2024.

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Introduction

A Ground Penetrating Radar (GPR) survey was conducted at the Ravenglass Roman Bath House, Muncaster, Cumbria, to determine whether overhanging masonry at the site had been subject to previous reinforcement to mitigate against collapse. The survey was conducted in response to a request from the English Heritage Trust following anecdotal evidence suggesting the Ministry of Works may have added reinforcement during unrecorded consolidation works in the 1990s. While no evidence for any intervention is visible, it was hoped that a GPR survey of the walls would detect any ferrous reinforcement, thought to be the most likely means of structural support in use at the time. The work was agreed under the Shared Services Agreement and addresses Historic England corporate plan activity “5.2 Work with English Heritage Trust to support the National Collection”.

The walls of the Bath House (National Heritage List for England: 1009352) are of regularly coursed sandstone bonded with mortar and rendered internally with pink cement and concrete. Parts of the internal render are believed to be original Roman stucco. Excavations in 1881 located the foundations of a small room with solid floors to the east. Solid floors were also present in the southern most room that was heated with a hypocaust through the entire remaining length of the southern range (Historic England 1992). An analytic earthwork survey revealed linear topographic features extending to the east of the standing remains and this was investigated further through wider GPR coverage of the scheduled area to enhance the current understanding of the Monument (Blood 1998).

More recent works at the site introduced strengthening mesh to improve less able access and protect areas of high wear through doorways, together with replacing fencing with bollards, removal of cobbled surfaces, improved drainage, and the replacement of interpretive signage (Jepson 2011). There was no visible indication of any strengthening mesh or the drop-down bollard during the current survey, although the supposed location of the access path was more muddy and saturated with water than the surrounding grass.

The bedrock geology consists of Triassic Wilmslow Sandstone and the superficial deposits are Devensian, Diamicton Till deposits (Geological Survey of Great Britain 1999; British Geological Survey 2024). The soils are freely draining, slightly acidic and loamy, and are of the Wick 1 (k541r) association (Soil Survey of England and Wales 1983; Soilscales 2024). The ground was flat and comprised of grass with areas of standing-water within and around the Bath House following a period of heavy rain prior to the survey dates. It was cold, dry and sunny during the field work.

Method

GPR Survey of the Standing Remains

A Screening Eagle Proceq GP8000 Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a hand operated single channel antenna array and extension pole. Positional control was established through a photographic record of the start and end points for each survey profile that was subsequently matched to elevation drawings of the standing walls (Table 1; Brann 1985).

Data were acquired at a 0.005m m sample interval across a continuous wave step frequency range from 200MHz to 4GHz with the unspecified frequency step increment and dwell time set to depth over speed of acquisition. The single antenna element was monitored continuously to ensure data quality during acquisition. An average velocity of 0.08m/ns was assumed for the wall elevations following constant velocity tests on the data and was used as the velocity field for the time to estimated depth conversion.

Post-acquisition processing involved conversion of the raw data to time-domain profiles, adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Table 1 shows profiles from the full GPR survey data set together with a description and annotation of significant anomalies. To aid visualisation amplitude time slices were created from the profiles collected over Elevations 2 and 3 by averaging data within successive 1.0ns (two-way travel time) windows after 1D-Kirchoff migration and conversion to instantaneous amplitude through the application of a Hilbert transform (e.g. Linford 2004). Each of the resulting time slices therefore represents the variation of reflection strength through successive ~0.04m intervals from the outer surface of the elevation, shown as individual greyscale images in Figures 4 and 7.

GPR Survey of the Scheduled Area

A 3d-Radar (Kontur) MkIV GeoScope Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a hand operated multi-element DXG0908 ground coupled antenna array (Linford et al. 2010; Eide et al. 2018). A roving Trimble R8s Global Navigation Satellite System (GNSS) receiver was mounted on the GPR antenna array, that together with a second R8s base station was used to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 1. The GNSS base station receiver was adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and

gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise.

Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave step frequency range from 40MHz to 2.99GHz in 4MHz increments using a dwell time of 5ms. A single antenna element was monitored continuously to ensure data quality during acquisition together with automated processing software to produce real time amplitude time slice representations of the data as each successive instrument swath was recorded in the field (Linford 2013).

Post-acquisition processing involved conversion of the raw data to time-domain profiles, adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals.

Representative profiles from the full GPR survey data set are shown on Figure 12. To aid visualisation amplitude time slices were created from the entire data set by averaging data within successive 2.5ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.106m/ns was assumed following constant velocity tests on the data and was used as the velocity field for the time to estimated depth conversion. Each of the resulting time slices therefore represents the variation of reflection strength through successive ~0.13m intervals from the ground surface, shown as individual greyscale images in Figures 13 and 14. Further details of both the frequency and time domain algorithms developed for processing this data can be found in Sala and Linford (2012).

Results

GPR Survey of the Standing Remains

The names of the walls have been taken from previous measured drawings and a labelled view of the Bath House is displayed in Figure 2. Figures 3 to 10 display the location of the profiles against the measured drawings of the walls. Profiles have been named as Ravenglass_elevationprofilenumber (e.g. Ravenglass_e101 shortened to e101 in most cases and occasionally 01 where space is limited). The name of each profile traverse is displayed at the starting position. Profiles shown in red on Figures 3 to 10 were acquired vertically, while profiles shown in blue collected horizontally across the wall elevation. An attempt was made to acquire profiles in a sequential order across each elevation, however sometimes this was not always the case (Figure 7). Videos rather than still photographs were taken to record the location of profiles e224, e225 and e226.

Table 1 provides a photographic record of the beginning and end position of each profile, together with a greyscale image of the data and an annotated interpretation with a full list of anomalies. Anomalies have been named as Ravenglass_profilename_anomomalynumber (e.g. Ravengalss_e101_01 shortened to e101_1).

An indicative traffic light system has been used in the interpretation to indicate the subjective severity of anomalies: from green for those of less importance, orange where further investigation is recommended, to red where more immediate attention may be required (none recorded in the survey). Data acquisition artefacts, modern radio-frequency interference, and possible air-wave reflections from adjacent walls and HERAS fencing are shown in grey.

The profiles collected from all of the elevations mostly depict surface unevenness and irregularities (e.g. [e104_1], [e208_2], [e309_1] and [e401_1]), or the change in antenna coupling between the block masonry to concrete render (e.g. [e201_1], [e220_1], [e329_1] and [e413_1]). Some internal structure within the walls has also been identified, mostly in Elevation 2 for example at [e206_1] and [e219_1]. Air-wave reflections have also been recorded from immediately adjacent walls and overhangs, the protective HERAS metal fencing and the interface between the masonry and open air (e.g. [e207_1], [e313_1] and [e407_1]).

No convincing evidence for ferrous reinforcement has been identified in any of the walls surveyed. However, anomalies [e213_1] and [e226_1] may tentatively suggest a possible lintel or masonry support above Niche 49, although this is likely to be contemporary with the bath house construction.

Internal voids possibly due to gaps in the internal structure of the walls, near-surface delamination of the render, or through the weathering of external weaknesses in the fabric of the walls has also been identified. While some possible voiding has been identified in Elevation 2 at [e209], [e221_2] and [e223], the majority of void-type anomalies occur in Elevations 3 and 4 in the immediate vicinity of visible surface cracking or holes [e303_1], [e305_1], [e306_2], [e307 - e312] and [e402 - e405] (Figures 6 to 8). Anomaly [e332_2] might also indicate that the wall is thinner in this location around the hole. This suggests there may be some internal erosion of the walls linked to the weathering of the existing visible faults. Figure 7 shows the possible extent of voiding in the vicinity of the surface crack and between profiles [e307 - e312].

GPR Survey of the Scheduled Area

A graphical summary of the significant GPR anomalies, [gpr1 - 6] discussed in the following text, superimposed on the base OS map data, is provided in Figure 15.

Three wall-type anomalies [gpr1 - 3] extend north-east from the Bath House together with a possible fourth wall [gpr4] to the immediate south of the standing remains, and largely correlate with the results of the 1881 excavation. Fragmented anomalies [gpr5] to either side of [gpr2] might perhaps be associated with the excavated hypocaust. It is difficult to determine whether the high-amplitude anomaly [gpr6] to the north-east together with areas of diffuse response [gpr7] are related to the Bath House or possible back-fill from the excavation.

Conclusions

The GPR survey of the standing walls has found no convincing evidence to suggest the presence of ferrous reinforcement supporting the overhanging masonry. Tentative evidence for the presence of internal voiding has been found in the immediate vicinity of visible surface cracks and holes. However, there is no suggestion of any further significant deterioration. Given the inherent limitations of using a single technique such as GPR, further investigation and monitoring of the Bath House is advised. The survey of the wider Scheduled Monument has identified wall footings and the flooring of the eastern extent of the Bath House excavated in 1881, although there was no indication of any anomalies associated with the two linear banks recorded by Blood (1998).

List of Enclosed Figures

- Figure 1: Location of GPR instrument survey swaths superimposed over the base OS mapping data and an outline from a measured survey of the Bath House (1:250).
- Figure 2: Labelled diagram of the Bath House (1:100).
- Figure 3: Location of GPR profiles collected from Elevations 1 and 2: Wall 22.
- Figure 4: GPR amplitude time slice between 3.0 and 4.0ns (0.12 to 0.16m) superimposed over Elevation 2: Wall 22
- Figure 5: Location of GPR profiles collected from Elevation 2: Wall 20.
- Figure 6: Location of GPR profiles collected from Elevation 3: Wall 5.
- Figure 7: GPR amplitude time slice between 3.0 and 4.0ns (0.12 to 0.16m) superimposed over Elevation 3: Wall 5
- Figure 8: Location of GPR profiles collected from Elevation 4: Wall 28.
- Figure 9: Location of GPR profiles collected from Elevation 4: Wall 24.
- Figure 10: Location of GPR profiles collected from Elevation 5: Wall 27.
- Figure 11: GPR amplitude time slice between 25.0 and 27.5ns (1.32 to 1.46m) superimposed over the base OS mapping data (1:250).
- Figure 12: Representative topographically corrected profiles from the GPR survey shown as greyscale images with annotation denoting significant anomalies. The location of the selected profiles can be found on Figures 1, 11 and 15.
- Figure 13: GPR amplitude time slices between 0.0 and 25.0ns (0.0 to 1.32m) (1:500).
- Figure 14: GPR amplitude time slices between 25.0 and 50.0ns (1.32 to 2.65m) (1:500).
- Figure 15: Graphical summary of significant GPR anomalies superimposed over the base OS mapping data (1:250).



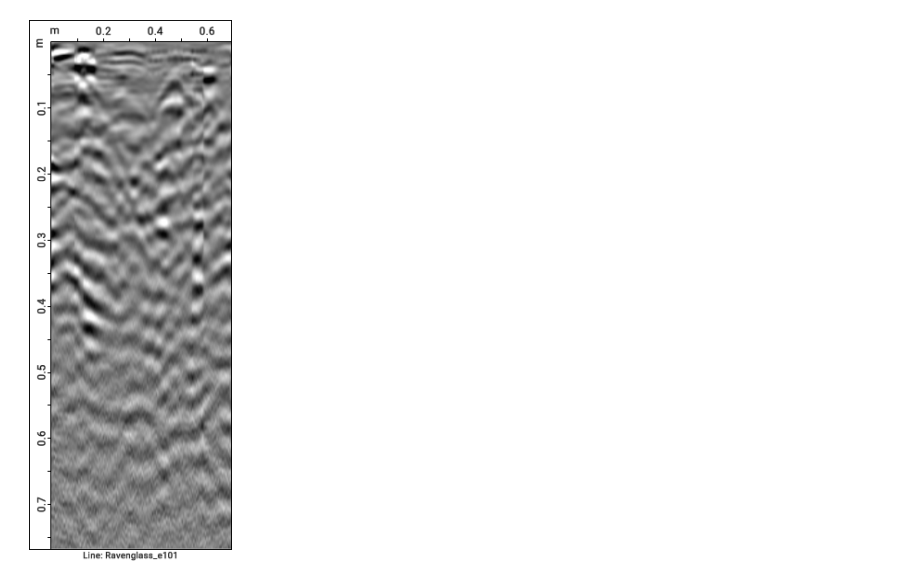

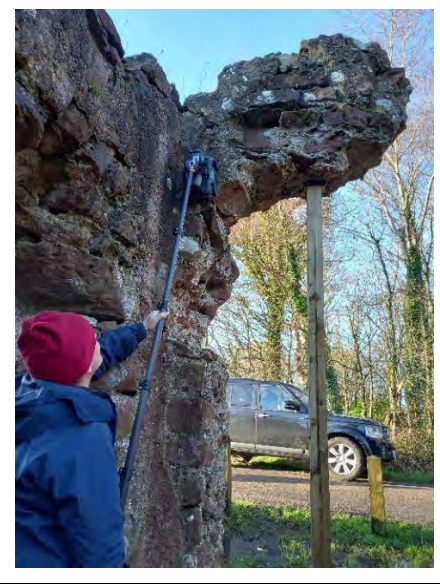

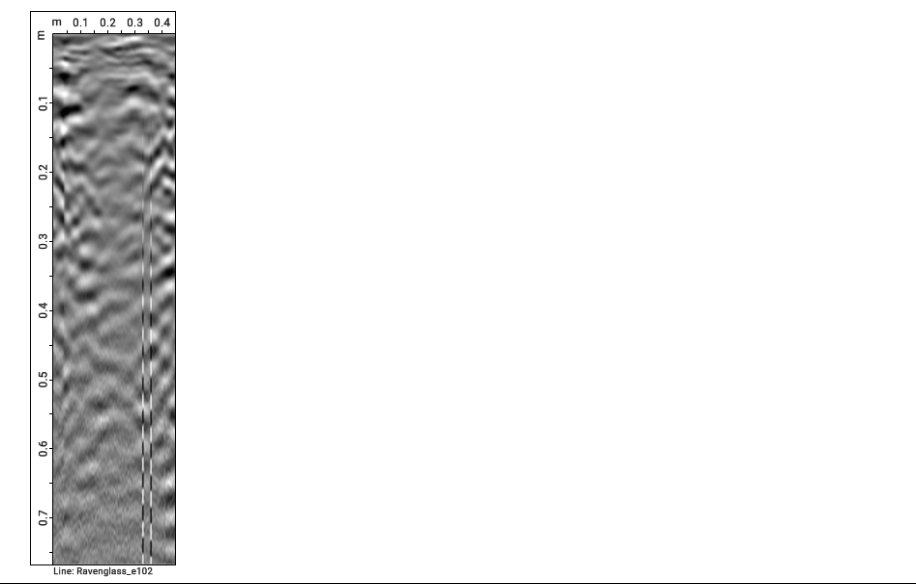

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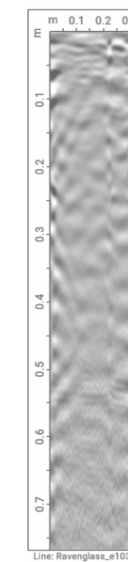
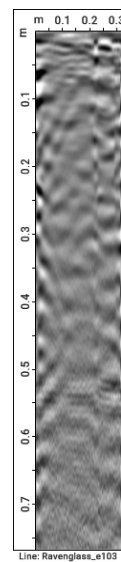
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Table 1 – GPR Survey Data of the Standing Remains

Elevation 1

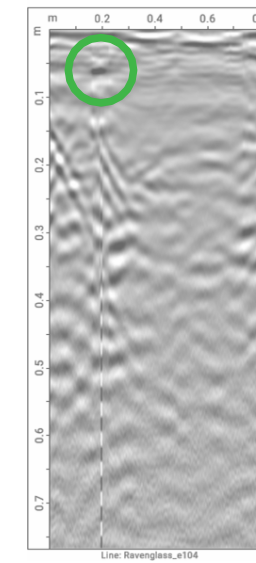
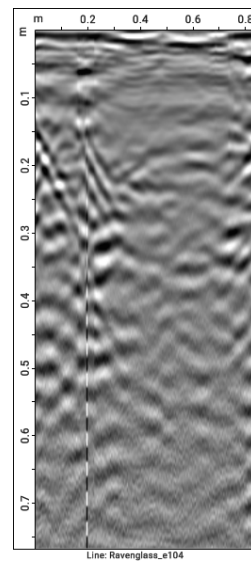
Ravenglass_e1**	Beginning	End	Data	Interpretation
<p>01</p> <ul style="list-style-type: none"> e101_1 = surface irregularity 				
<p>02</p>				

03



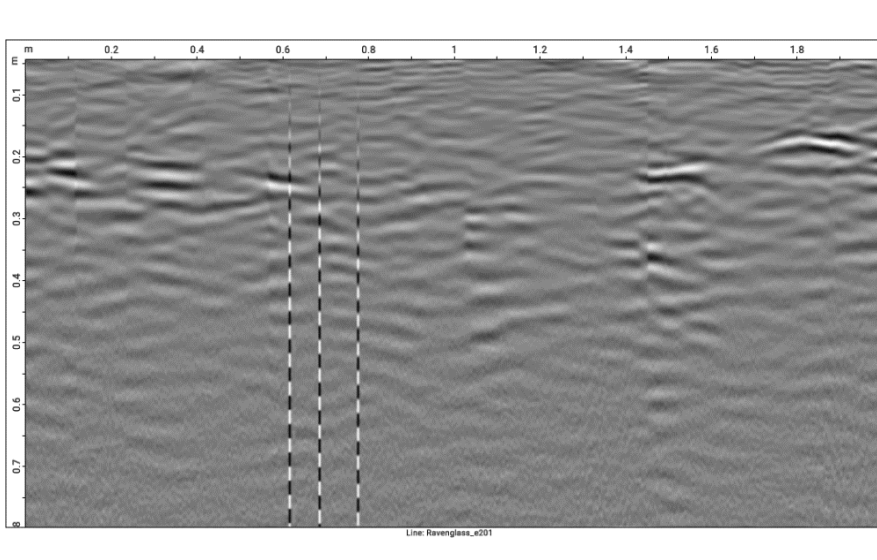
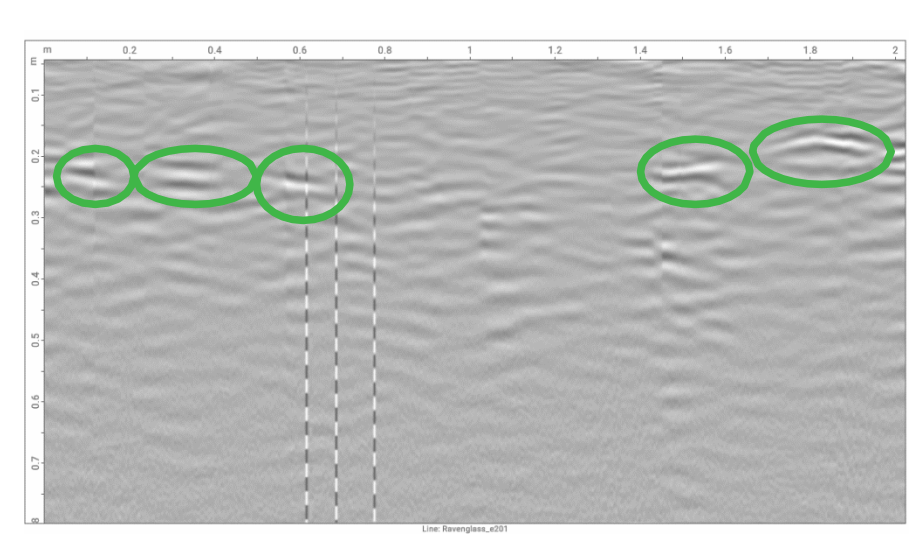


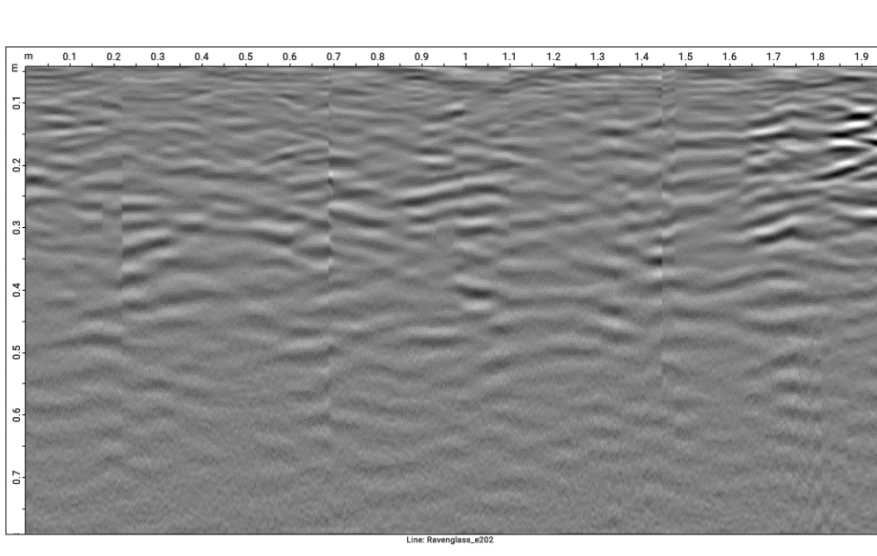
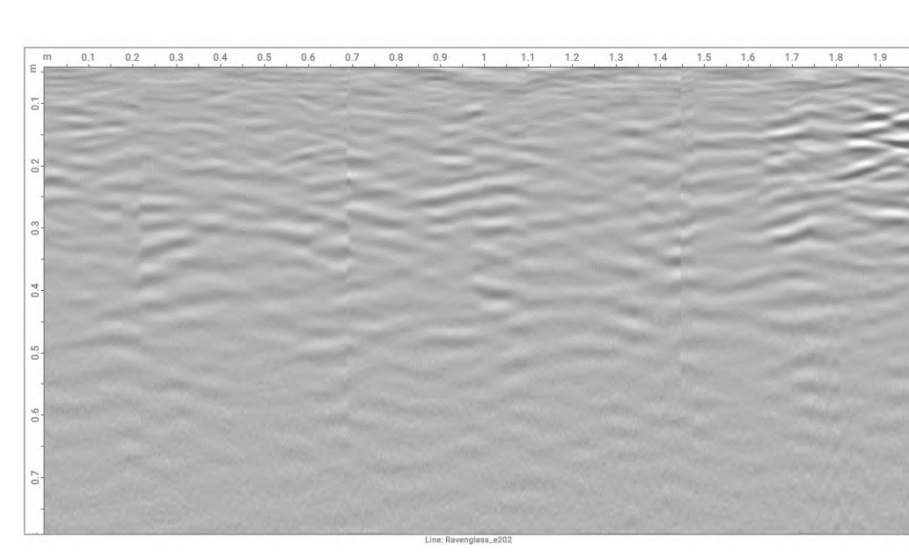


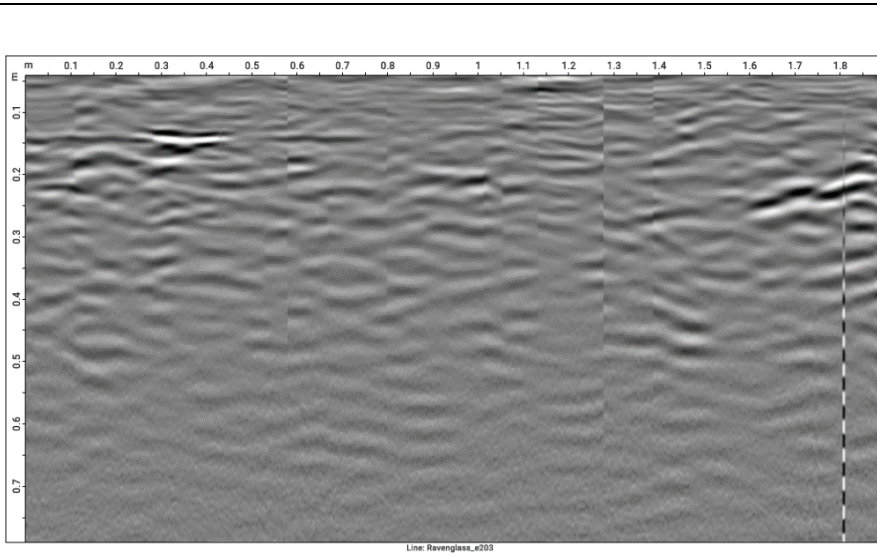
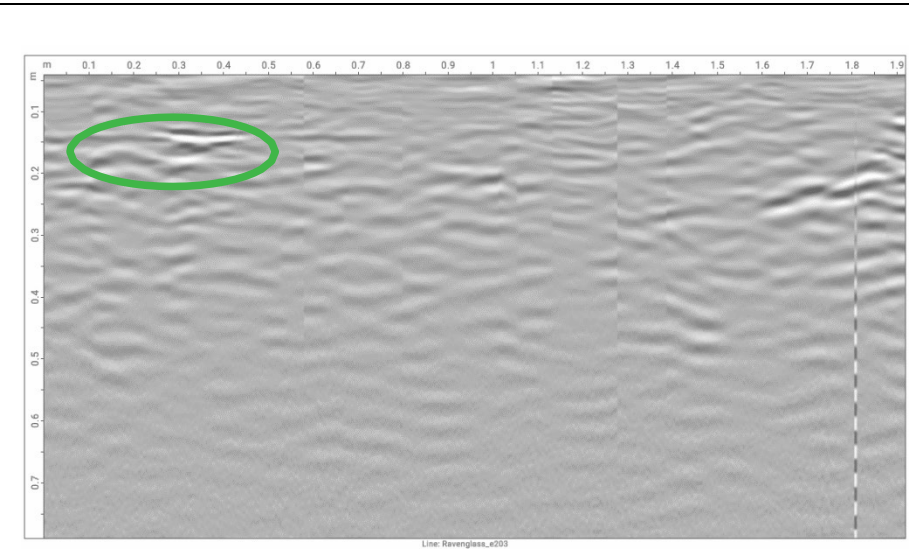


04

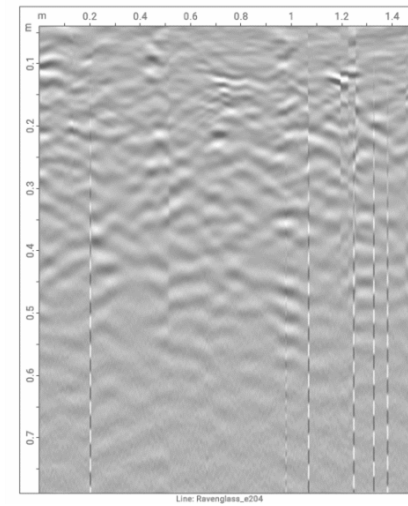
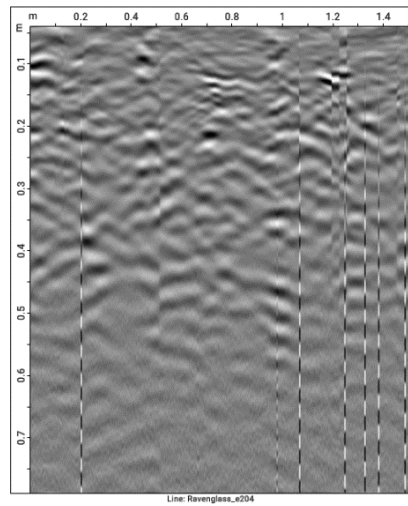
- e104_1 = surface irregularity



Elevation 2

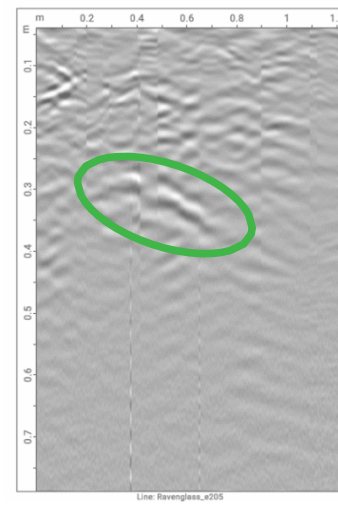
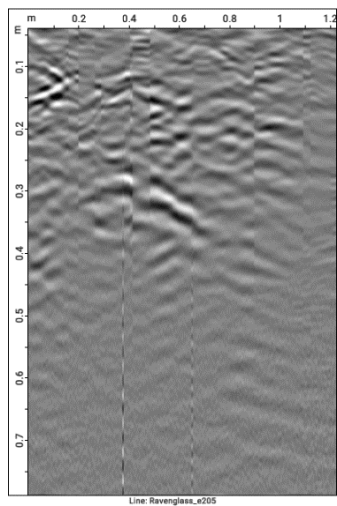
Ravenglass_e2**	Beginning	End	Data	Interpretation
<p>01</p> <ul style="list-style-type: none"> e201_1 = back of first masonry course 				
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<p>03</p> <ul style="list-style-type: none"> e203_1 = back of first masonry course 				

04



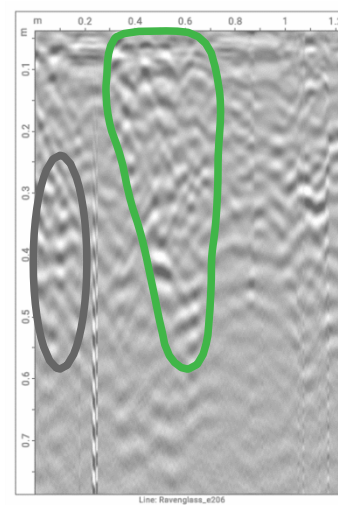
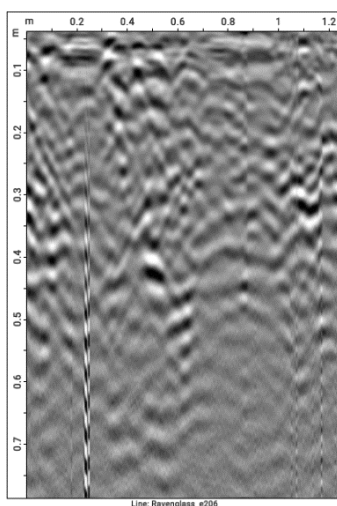
05

- e205_1 = bottom of niche 49



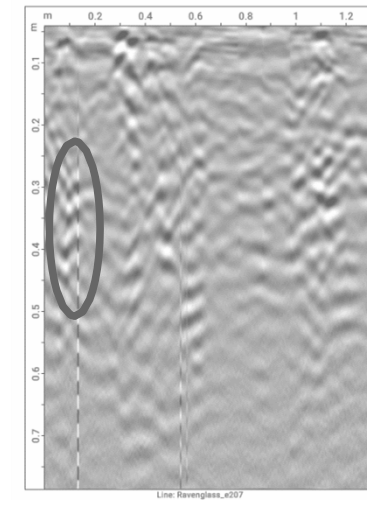
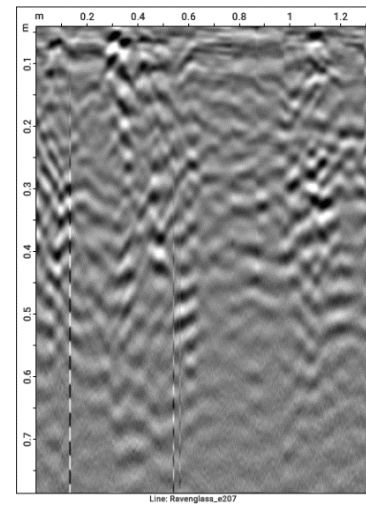
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- e206_1 = interna structure
- e206_2 = airwave reflection from overhang



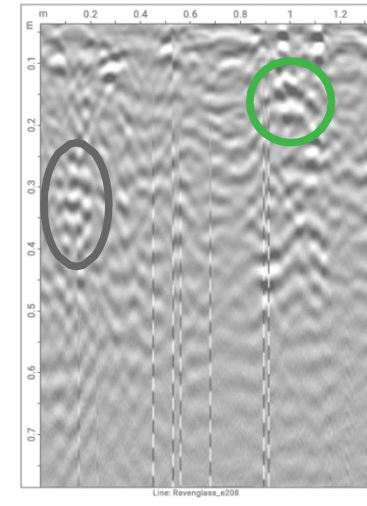
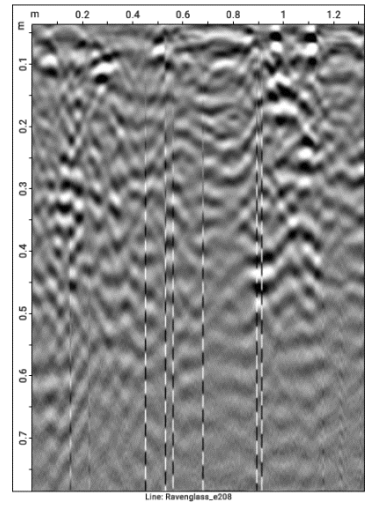
07

- e207_1 = airwave reflection from overhang



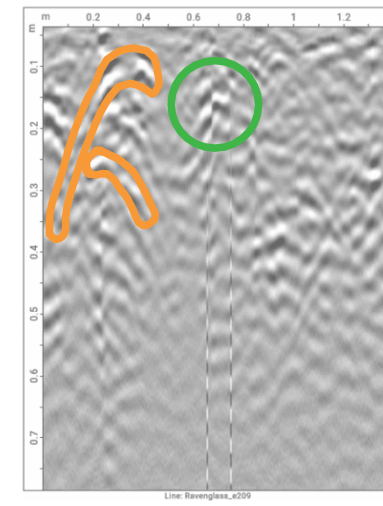
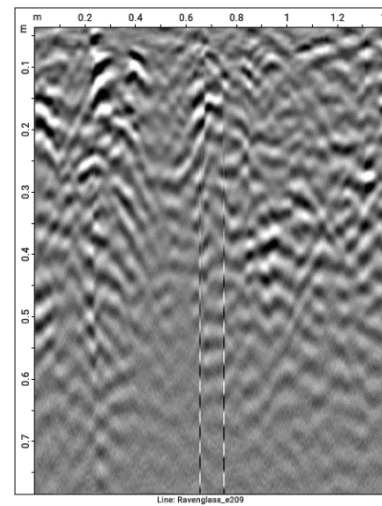
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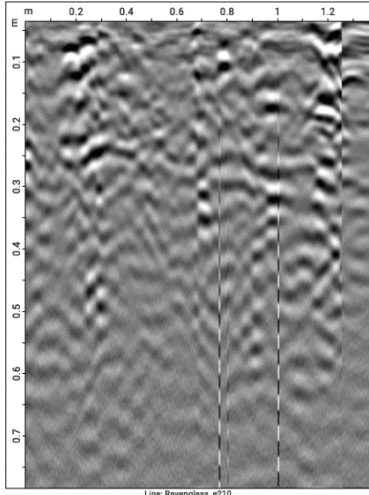
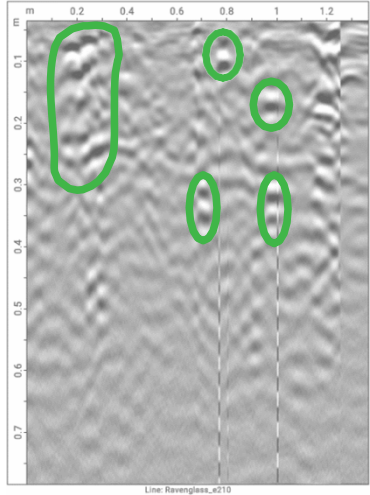


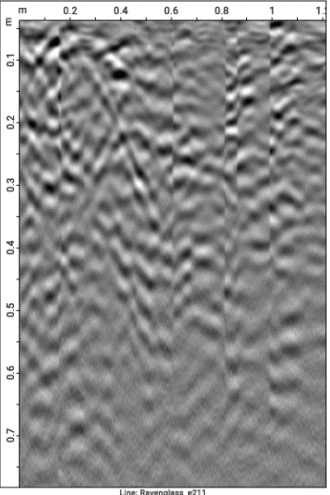
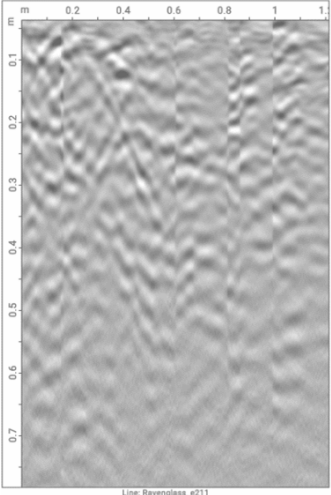


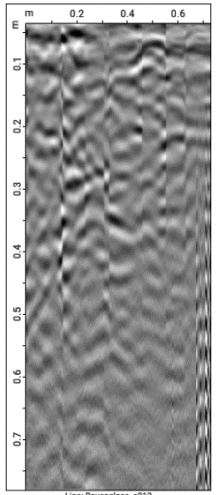
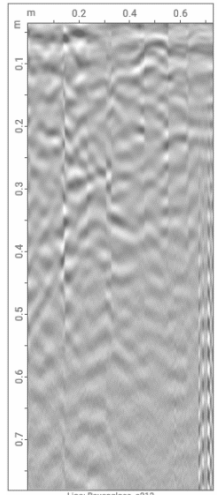
- e208_1 = airwave reflection from overhang
- e208_2 = surface irregularity



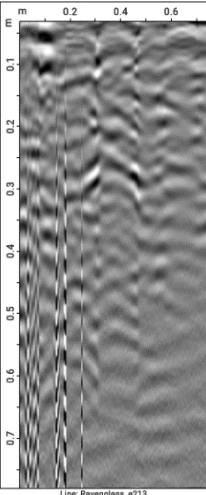
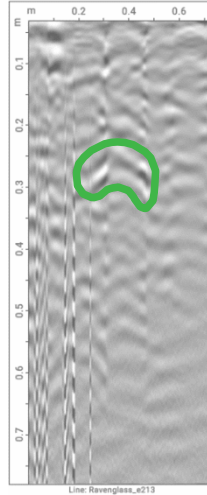


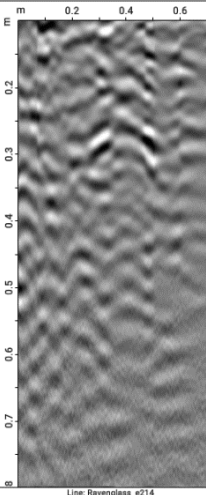
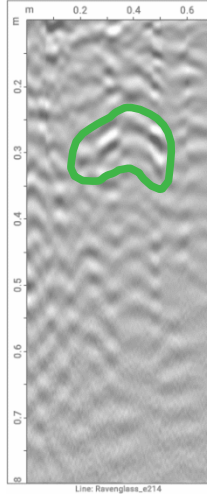


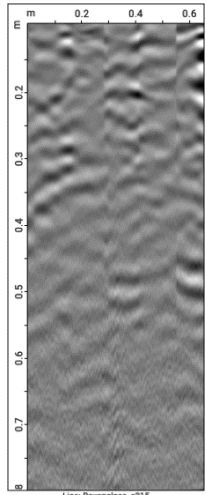
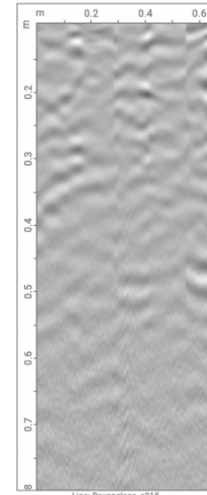


09

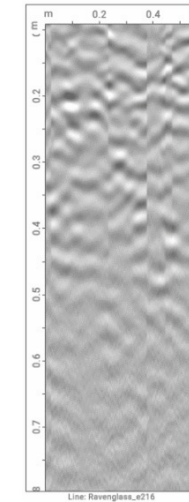
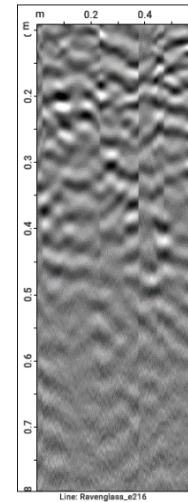
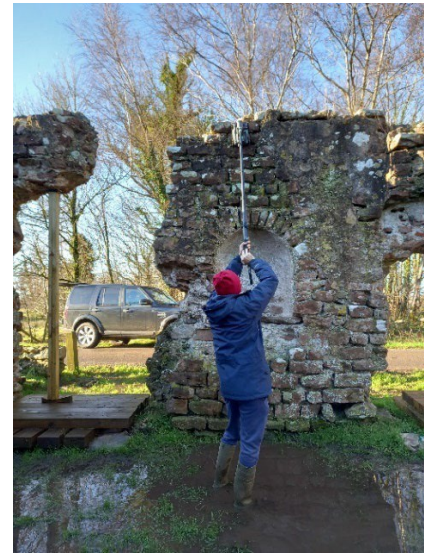
- e209_1 = internal voiding
- e209_2 = internal voiding
- e209_3 = surface irregularity



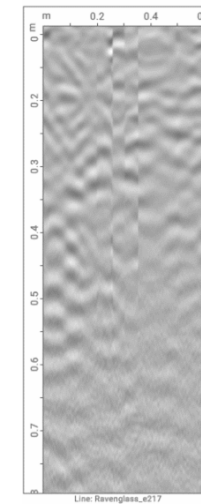
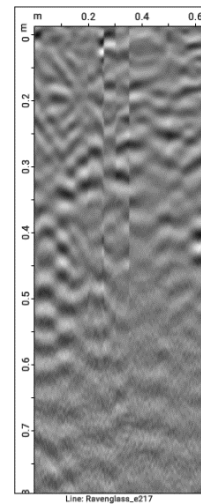
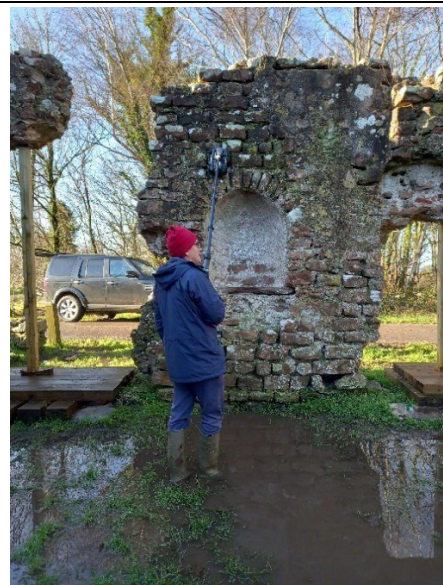
<p>10</p> <ul style="list-style-type: none"> e210_1 = internal structure 			 <p>Line: Ravenglass_e210</p>	 <p>Line: Ravenglass_e210</p>
<p>11</p>			 <p>Line: Ravenglass_e211</p>	 <p>Line: Ravenglass_e211</p>
<p>12</p>			 <p>Line: Ravenglass_e212</p>	 <p>Line: Ravenglass_e212</p>

<p>13</p> <ul style="list-style-type: none"> e213_1 = possible lintel/masonry support 			 <p>Line: Ravenglass_e213</p>	 <p>Line: Ravenglass_e213</p>
<p>14</p> <ul style="list-style-type: none"> e214_1 = possible lintel/masonry support 			 <p>Line: Ravenglass_e214</p>	 <p>Line: Ravenglass_e214</p>
<p>15</p>			 <p>Line: Ravenglass_e215</p>	 <p>Line: Ravenglass_e215</p>

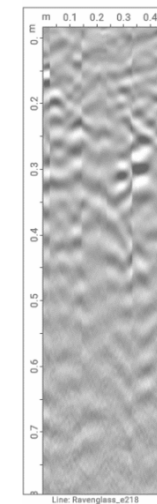
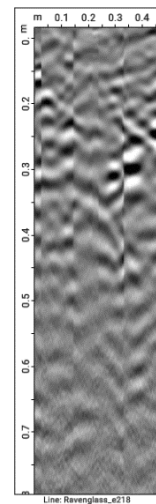
16



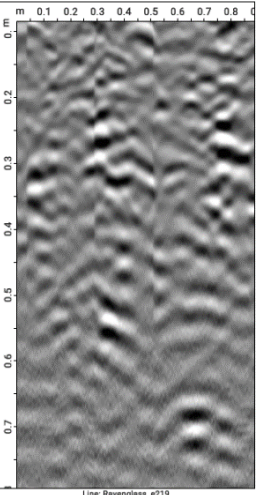
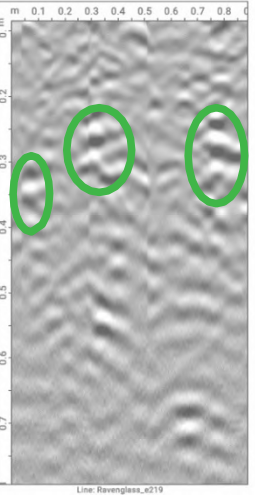


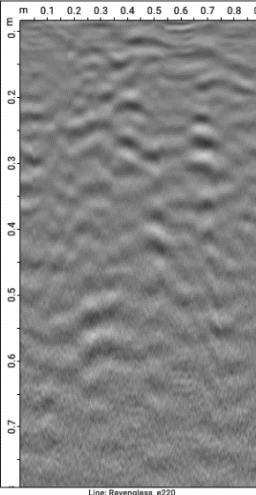
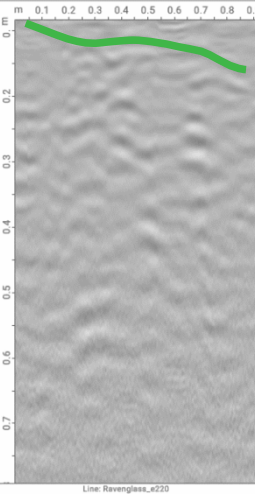


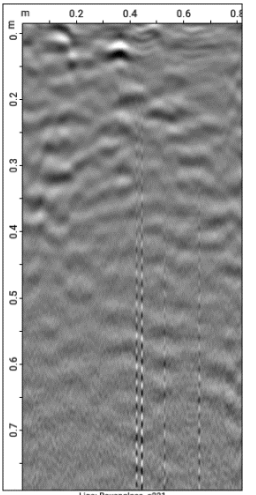
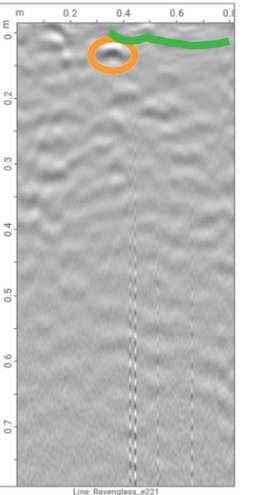


17

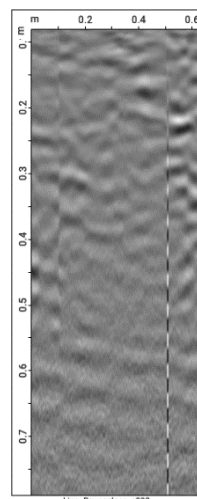


18

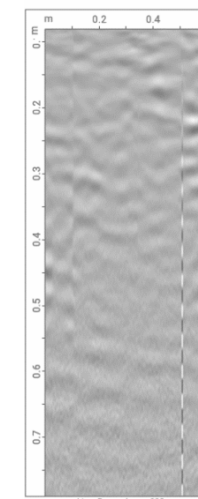


<p>19</p> <ul style="list-style-type: none"> e219_1 = internal structure 				
<p>20</p> <ul style="list-style-type: none"> e220_1 = delaminated render? 				
<p>21</p> <ul style="list-style-type: none"> e221_1 = delaminated render? e221_2 = internal voiding 				

22



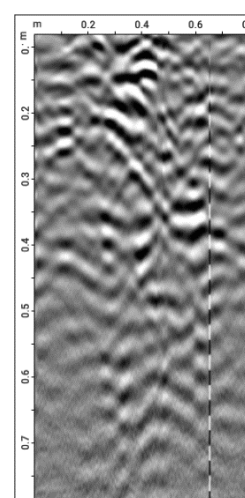
Line: Ravenglass_e222



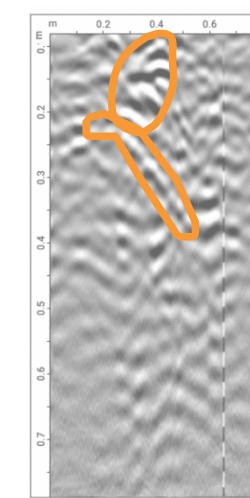
Line: Ravenglass_e222

23

- e223_1 = internal voiding
- e223_2 = internal voiding

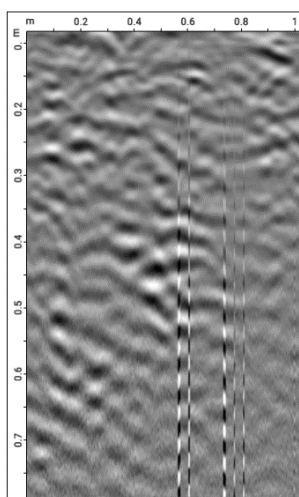


Line: Ravenglass_e223

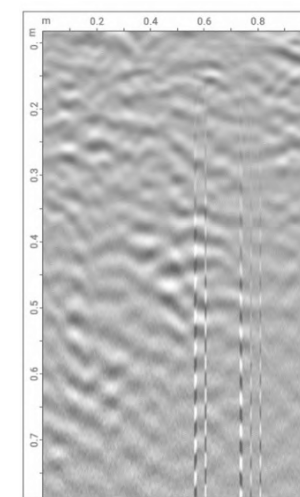


Line: Ravenglass_e223

24



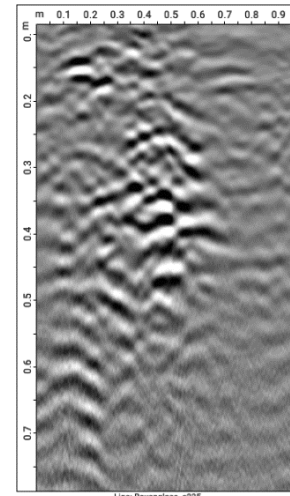
Line: Ravenglass_e224



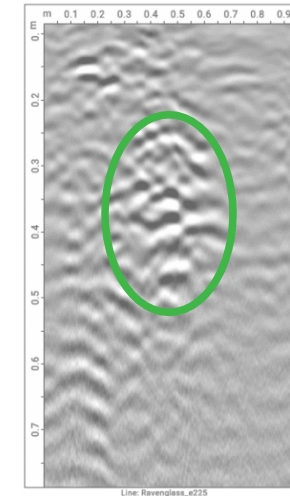
Line: Ravenglass_e224

25

- e225_1 = center of niche at the walls thinnest



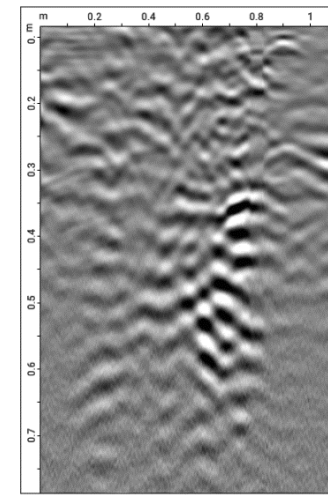
Line: Ravenglass_e225



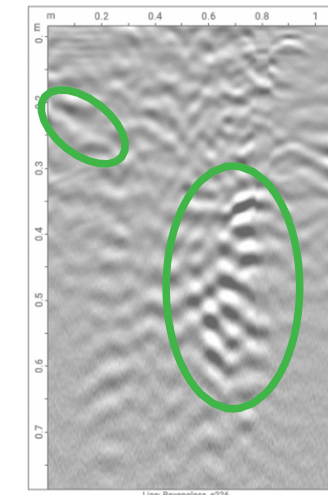
Line: Ravenglass_e225

26

- e226_1 = bottom-up view of possible lintel above niche / masonry support
- e226_2 = center of niche at the walls thinnest



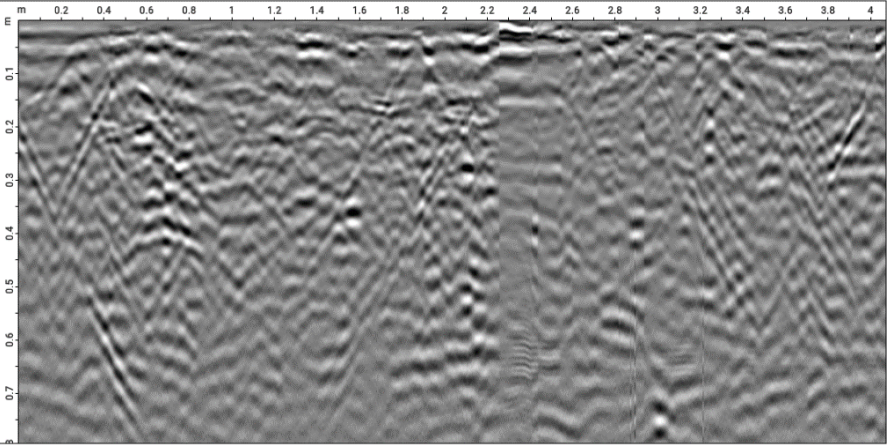
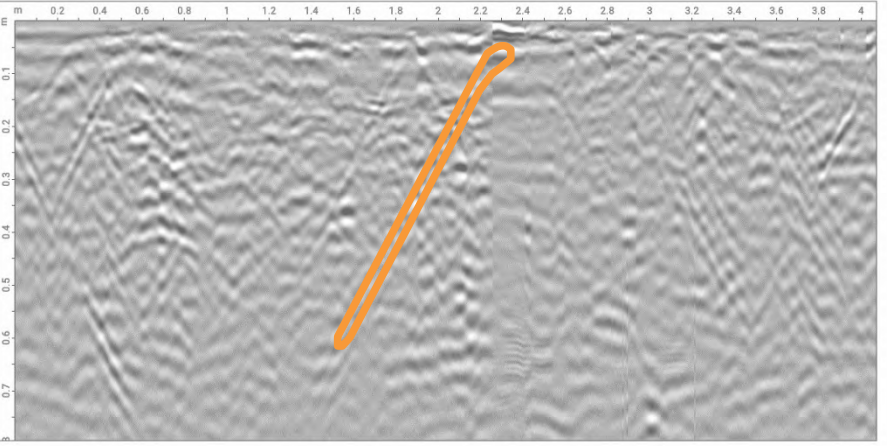


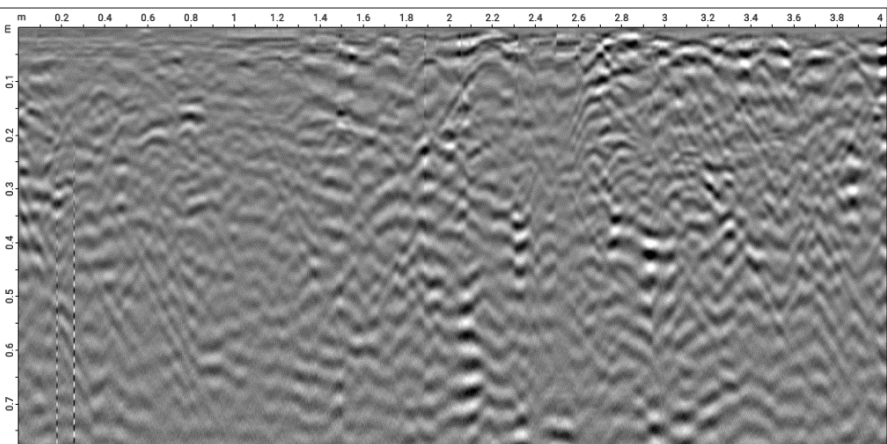
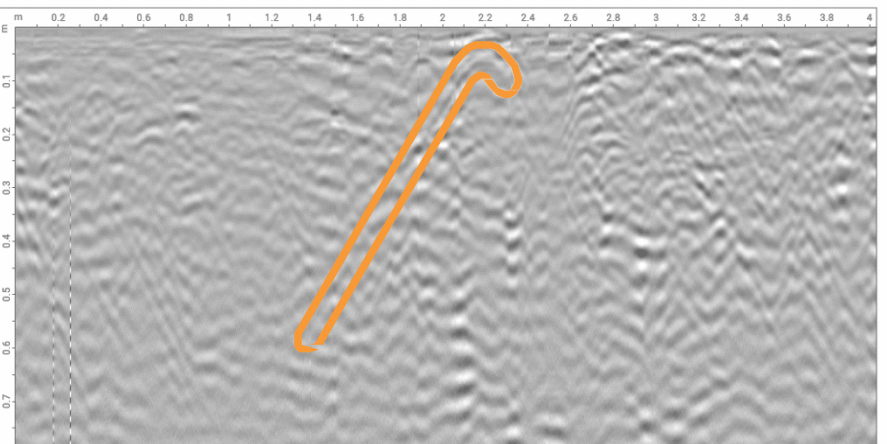


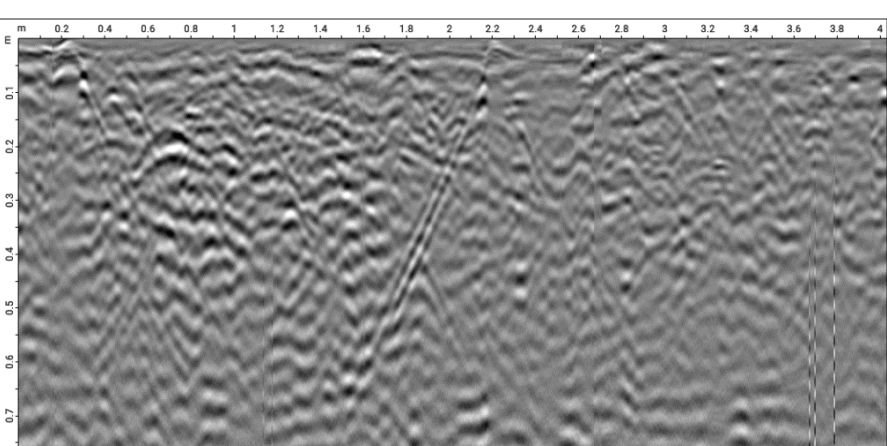
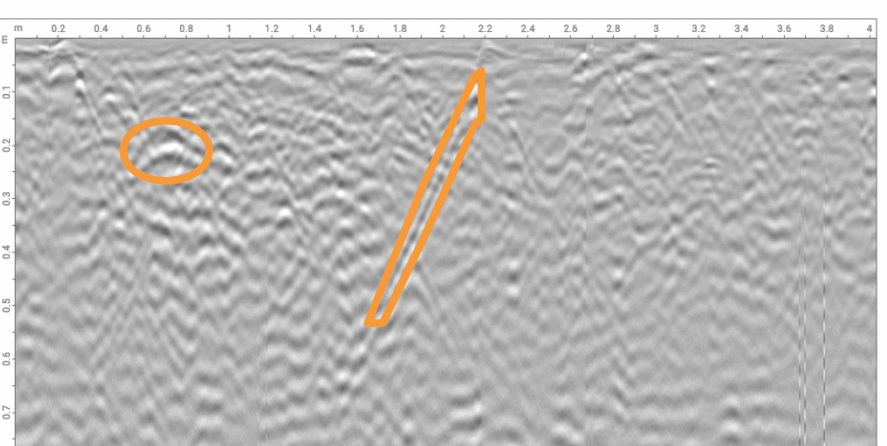


Line: Ravenglass_e226



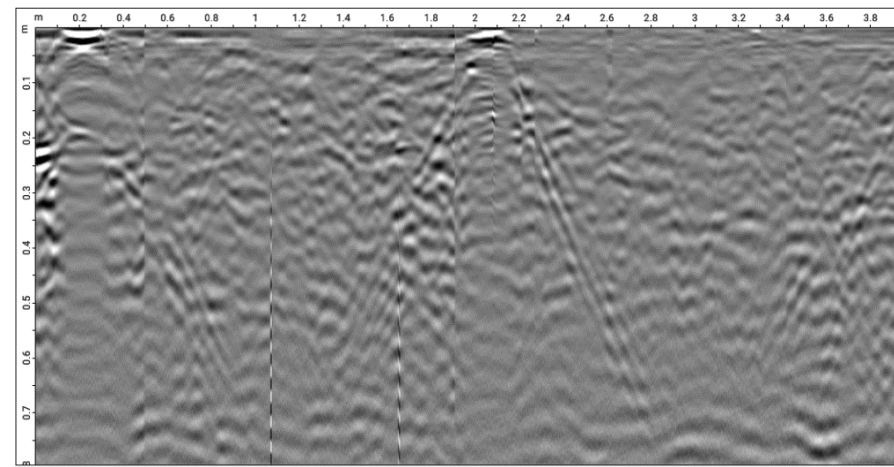
Line: Ravenglass_e226

Elevation 3

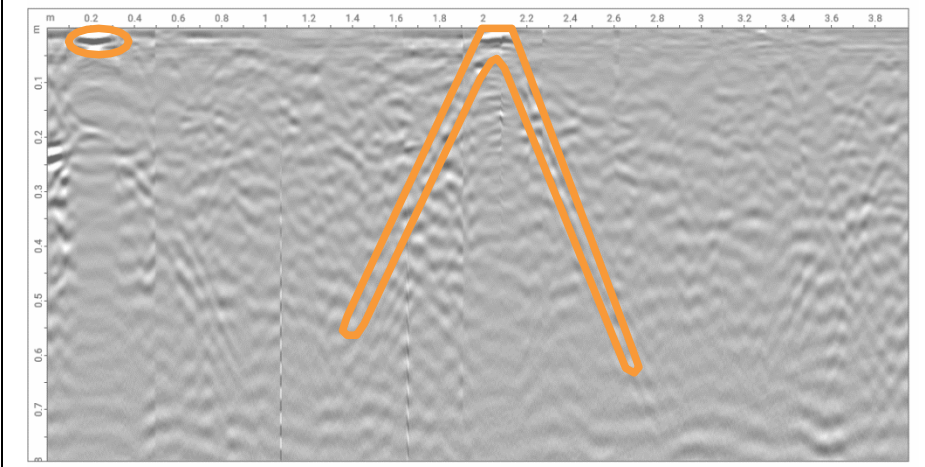
Ravenglass_e3**	Beginning	End	Data	Interpretation
<p>01</p> <ul style="list-style-type: none"> e301_1 = crack 			 <p>Line: Ravenglass_e301</p>	 <p>Line: Ravenglass_e301</p>
<p>02</p> <ul style="list-style-type: none"> e302_1 = crack 			 <p>Line: Ravenglass_e302</p>	 <p>Line: Ravenglass_e302</p>
<p>03</p> <ul style="list-style-type: none"> e303_1 = internal voiding e303_2 = crack 			 <p>Line: Ravenglass_e303</p>	 <p>Line: Ravenglass_e303</p>

04

- e304_1 = hole
- e304_2 = hole in middle of crack



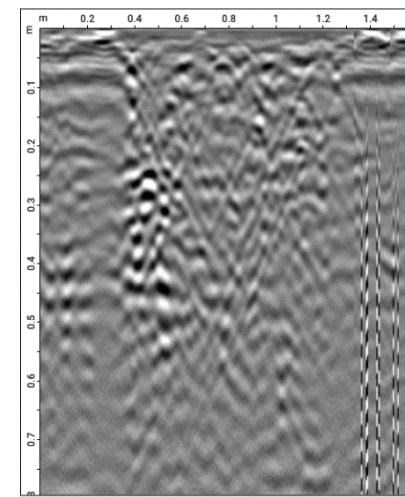
Line: Revenglass_e304



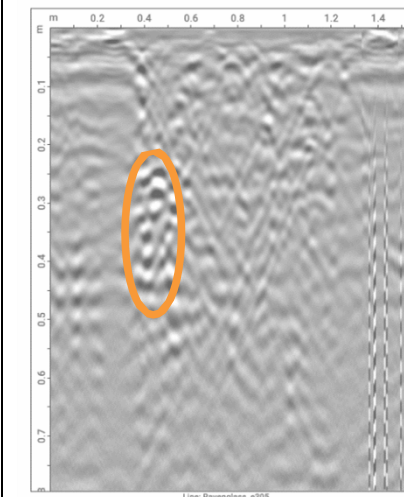
Line: Revenglass_e304

05

- e305_1 = internal voiding



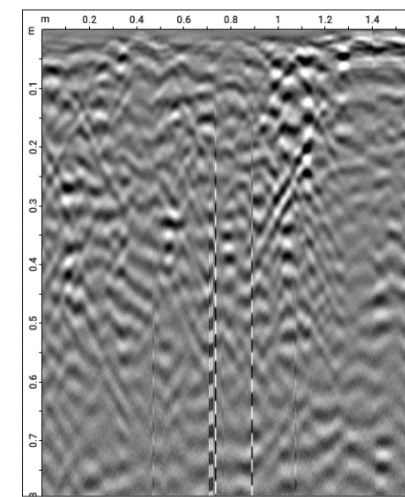
Line: Revenglass_e305



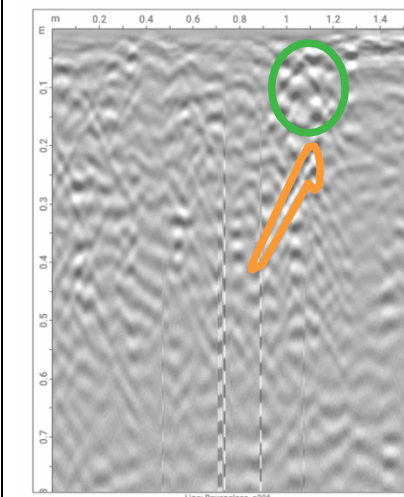
Line: Revenglass_e305

06



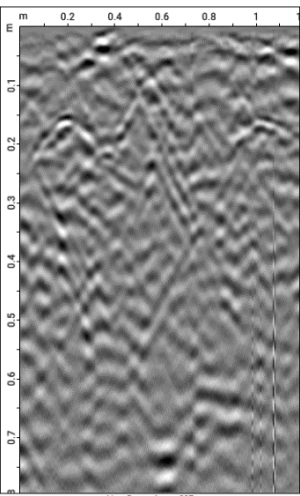
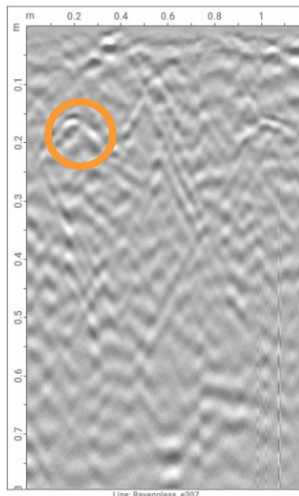


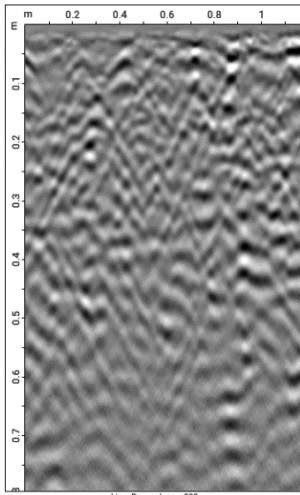
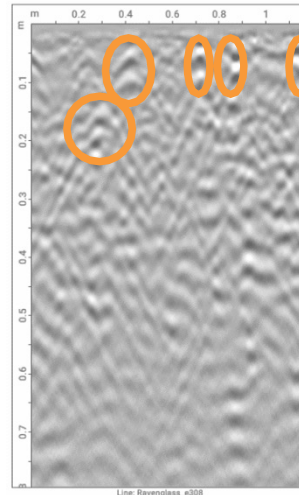


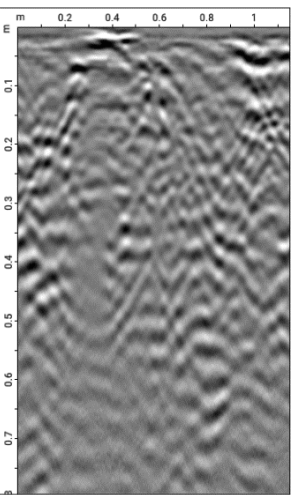
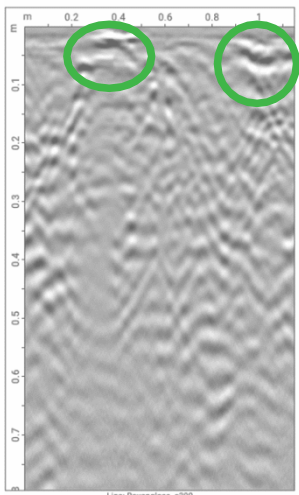
- e306_1 = change in building material
- e306_2 = internal voiding





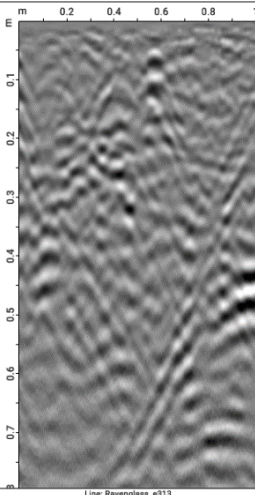
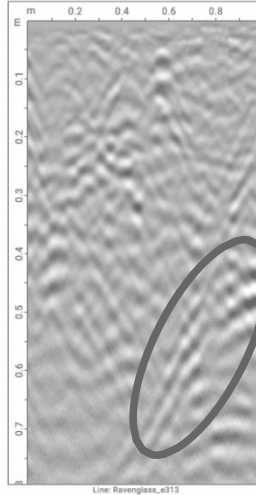


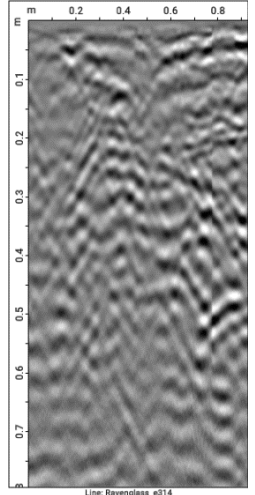
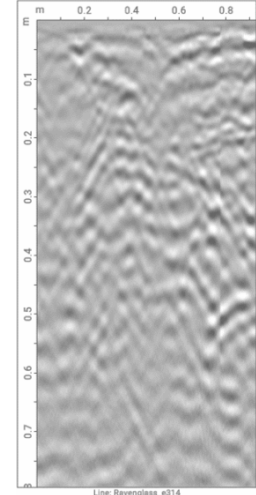


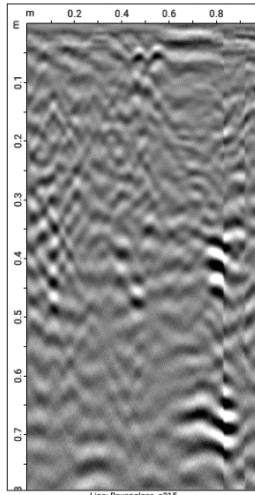
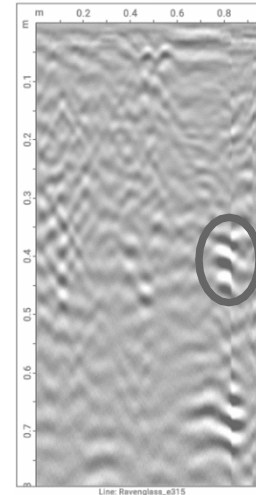
Line: Revenglass_e306



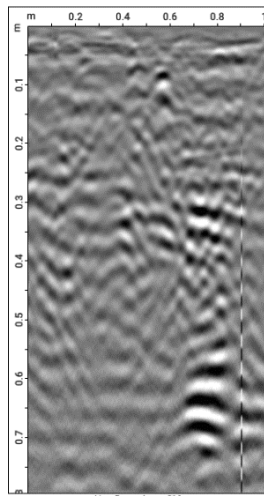


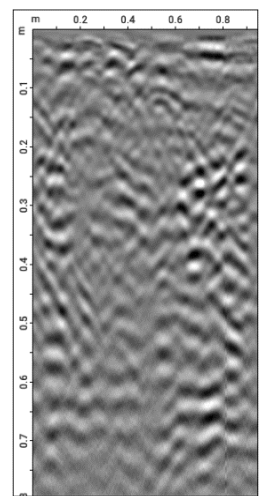
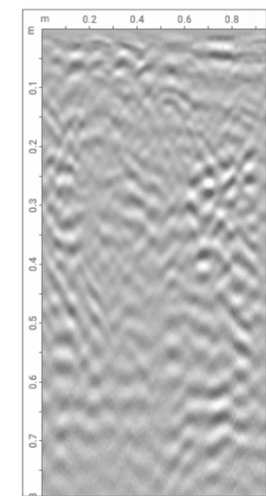


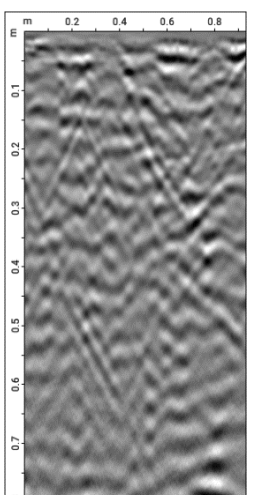
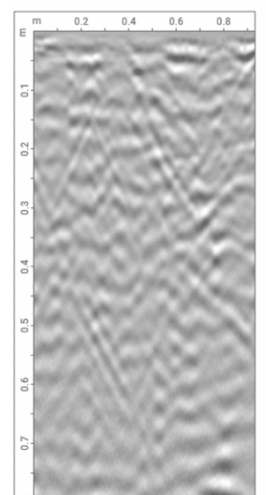



Line: Revenglass_e306

<p>07</p> <ul style="list-style-type: none"> • e307_1 = internal voiding 			 <p>Line: Ravenglass_e307</p>	 <p>Line: Ravenglass_e307</p>
<p>08</p> <ul style="list-style-type: none"> • e308_1 = internal voiding 			 <p>Line: Ravenglass_e308</p>	 <p>Line: Ravenglass_e308</p>
<p>09</p> <ul style="list-style-type: none"> • e309_1 = surface irregularity 			 <p>Line: Ravenglass_e309</p>	 <p>Line: Ravenglass_e309</p>

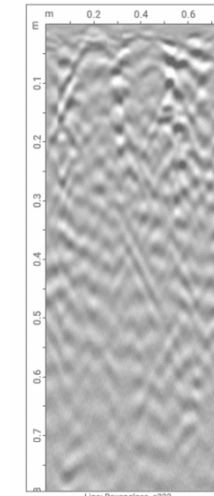
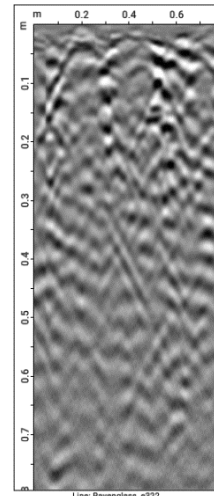
<p>10</p> <ul style="list-style-type: none"> e310_1 = hole 			<p>Line: Ravenglass_e310</p>	<p>Line: Ravenglass_e310</p>
<p>11</p> <ul style="list-style-type: none"> e311_1 = internal voiding 			<p>Line: Ravenglass_e311</p>	<p>Line: Ravenglass_e311</p>
<p>12</p> <ul style="list-style-type: none"> e312_1 = internal voiding e312_2 = air/metal fencing 			<p>Line: Ravenglass_e312</p>	<p>Line: Ravenglass_e312</p>

<p>13</p> <ul style="list-style-type: none"> e313_1 = air/metal fencing 			 <p>Line: Ravenglass_e313</p>	 <p>Line: Ravenglass_e313</p>
<p>14</p>			 <p>Line: Ravenglass_e314</p>	 <p>Line: Ravenglass_e314</p>
<p>15</p> <ul style="list-style-type: none"> e315_1 = air/metal fencing 			 <p>Line: Ravenglass_e315</p>	 <p>Line: Ravenglass_e315</p>

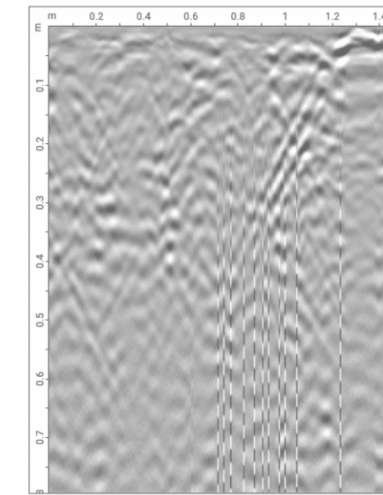
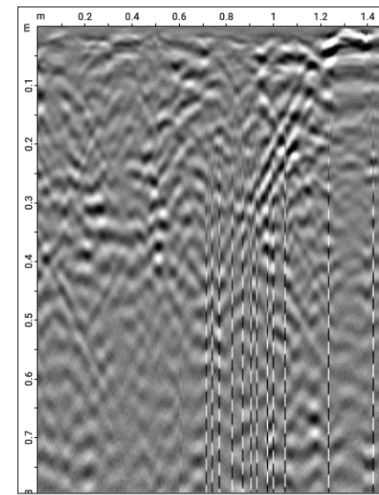
<p>16</p> <ul style="list-style-type: none"> • e316_1 = internal voiding • e316_2 = air/metal fence 			 <p>Line: Ravenglass_e316</p>	 <p>Line: Ravenglass_e316</p>
<p>17</p>			 <p>Line: Ravenglass_e317</p>	 <p>Line: Ravenglass_e317</p>
<p>18</p>			 <p>Line: Ravenglass_e318</p>	 <p>Line: Ravenglass_e318</p>

<p>19</p>			 <p>Line: Ravenglass_e319</p>	 <p>Line: Ravenglass_e319</p>
<p>20</p>			 <p>Line: Ravenglass_e320</p>	 <p>Line: Ravenglass_e320</p>
<p>21</p> <ul style="list-style-type: none"> e321_1 = internal voiding 			 <p>Line: Ravenglass_e321</p>	 <p>Line: Ravenglass_e321</p>

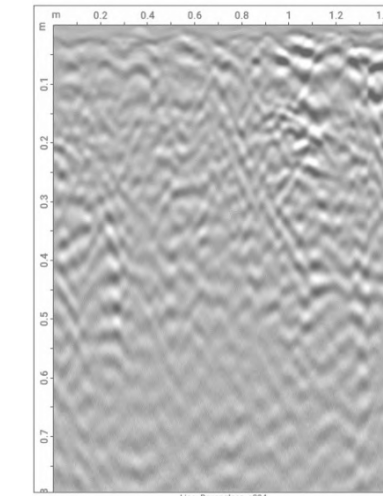
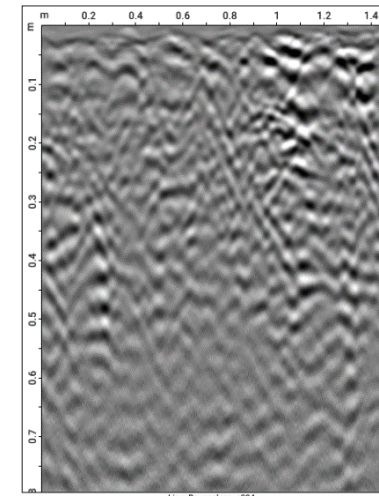
22



23

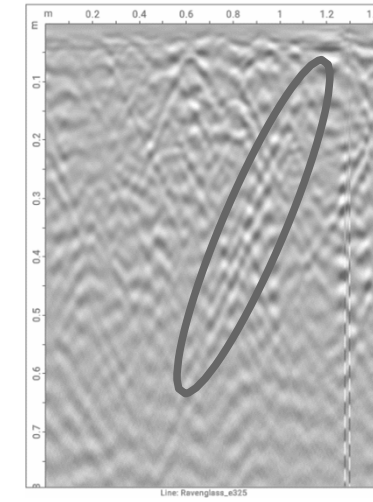
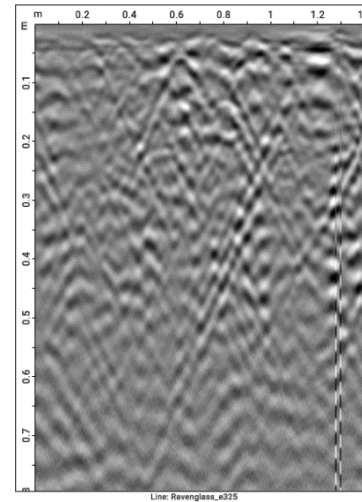


24

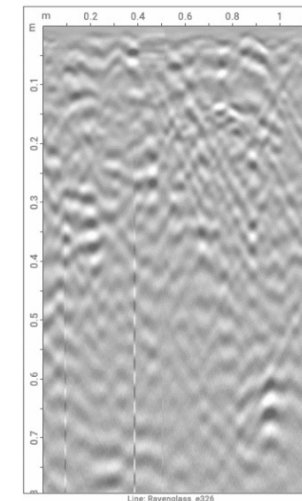
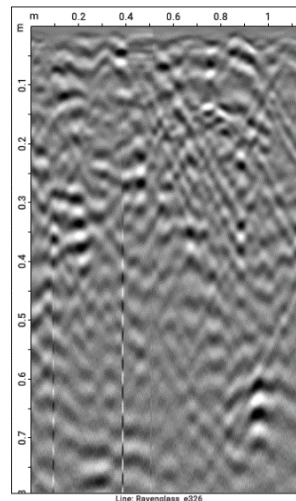


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- e325_1 = metal fencing

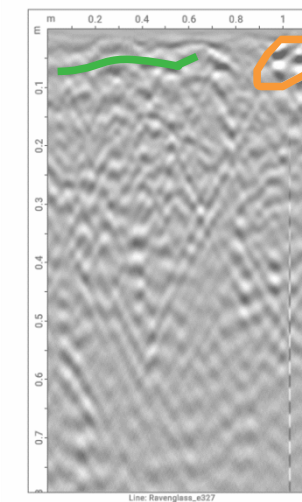
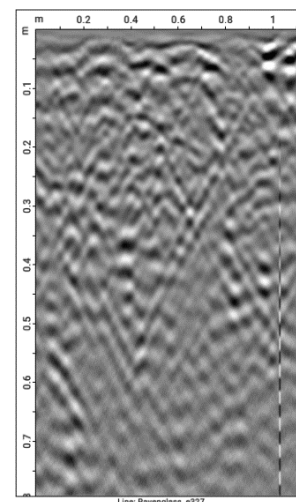


26

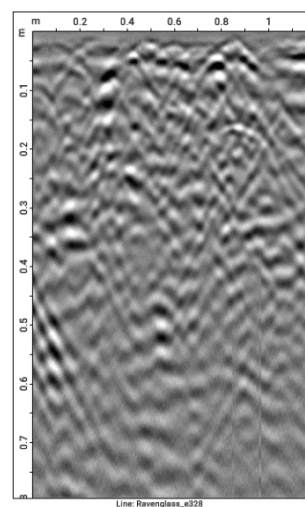


27

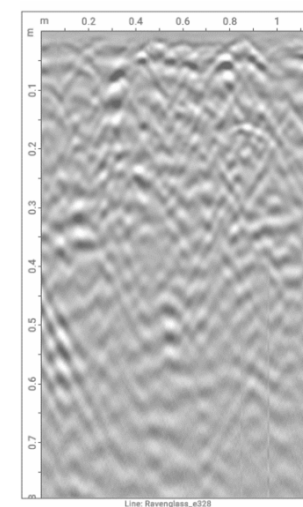
- e327_1 = back of concrete render
- e327_2 = internal voiding



28



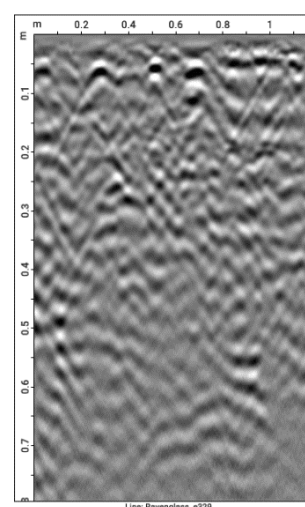
Line: Ravenglass_e328



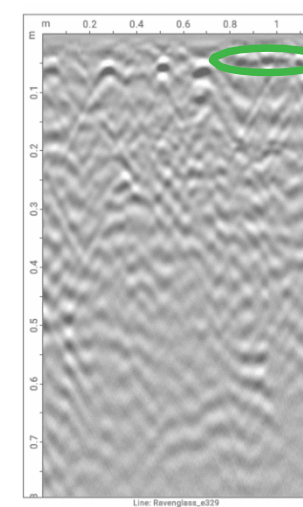
Line: Ravenglass_e328

29

- e329_1 = change in building material

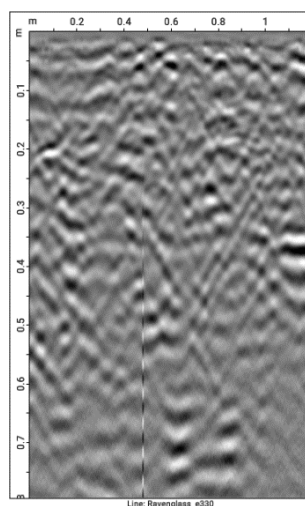


Line: Ravenglass_e329

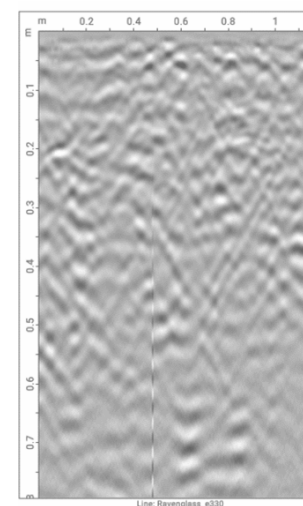


Line: Ravenglass_e329

30

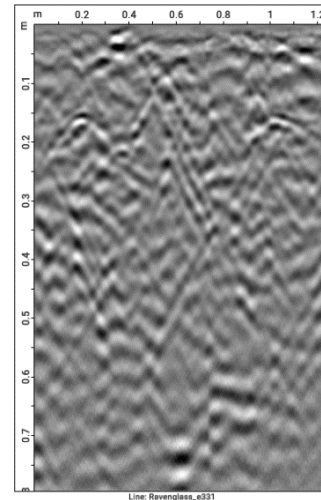


Line: Ravenglass_e330

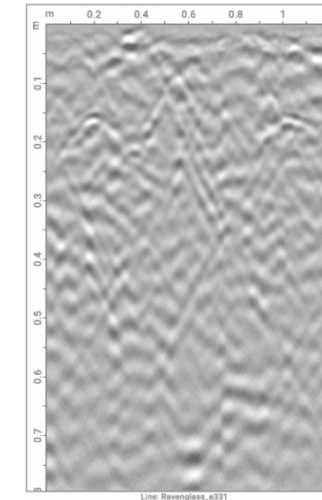


Line: Ravenglass_e330

31



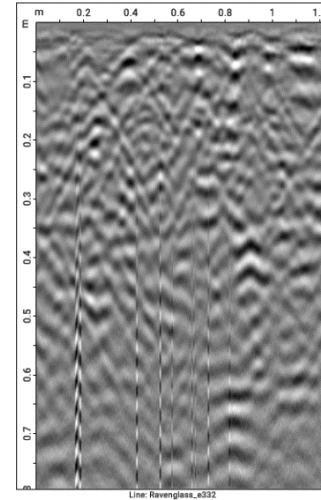
Line: Ravenglass_e331



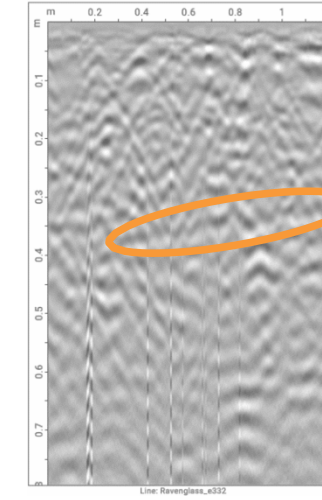
Line: Ravenglass_e331

32

- e332_2 = uncertain but consistent reflector, possibly from rear face of wall, possibly wall getting thinner in that location around the hole/void


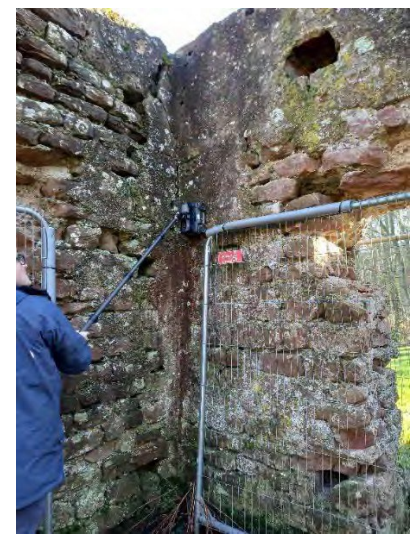
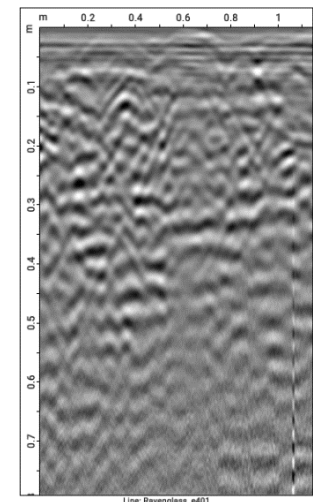
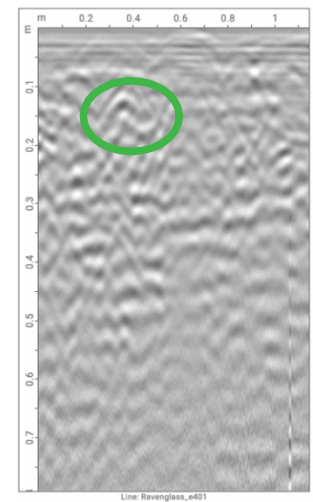

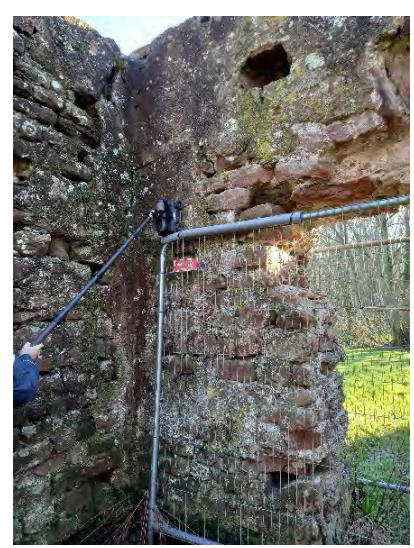
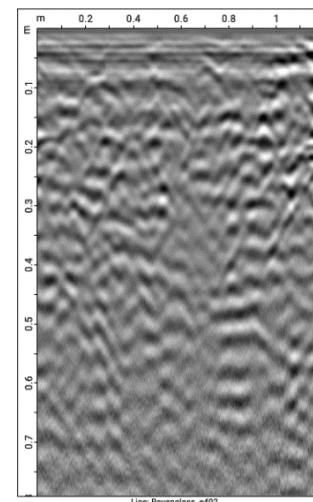
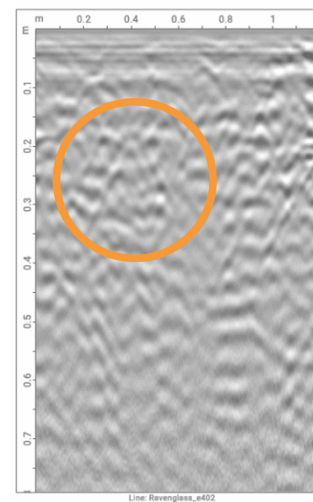


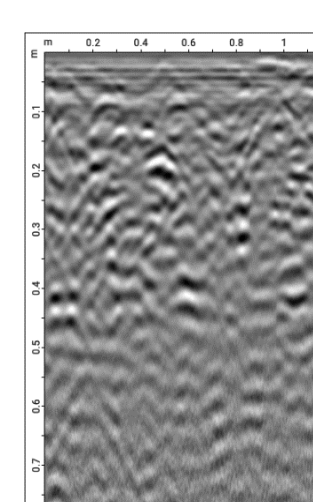
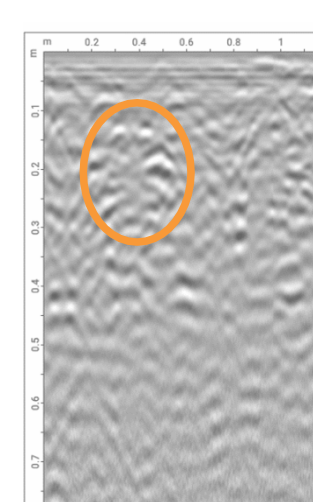


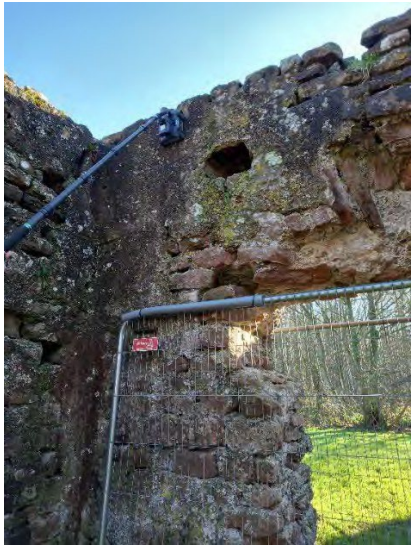

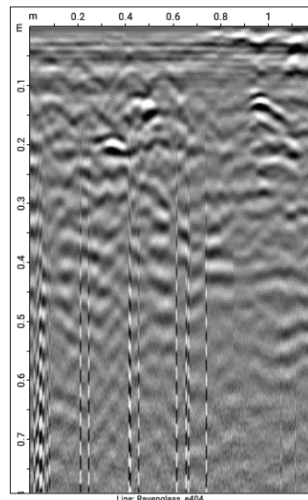
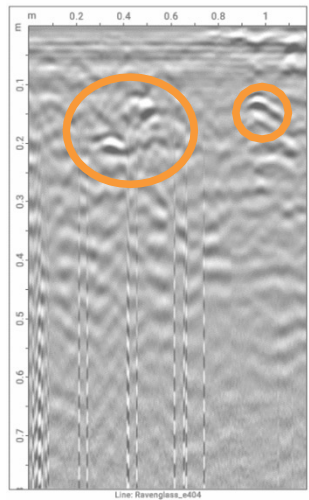


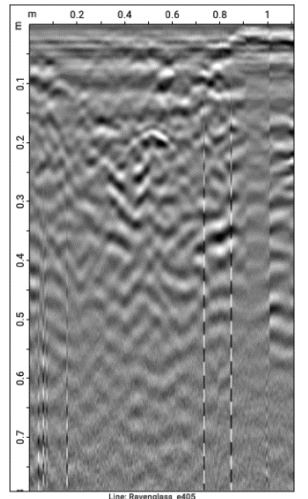
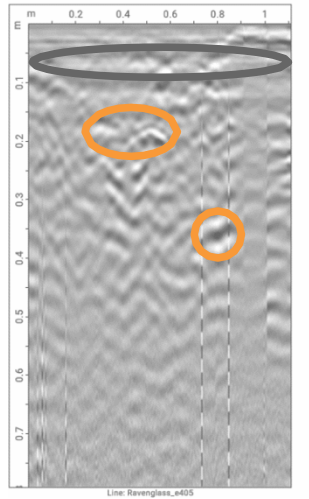

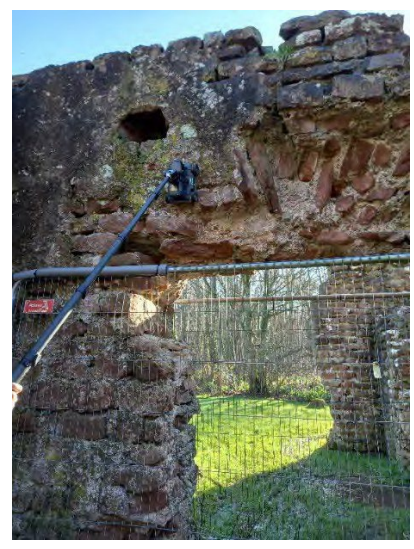
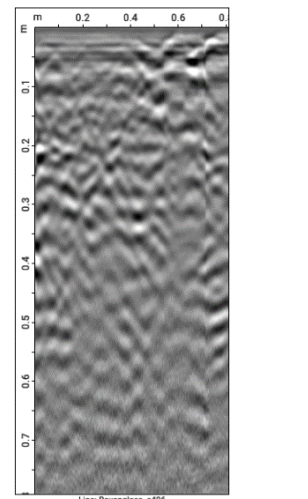
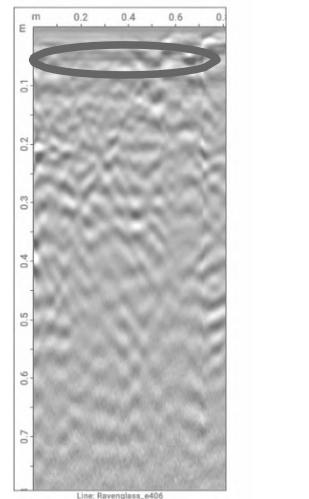
Line: Ravenglass_e332



Line: Ravenglass_e332

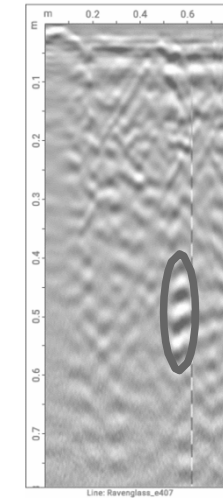
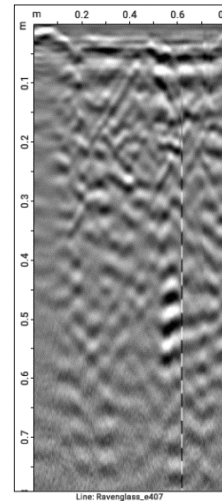
Elevation 4

Ravenglass_e4**	Beginning	End	Data	Interpretation
<p>01</p> <ul style="list-style-type: none"> e401_1 = surface irregularity 			 <p>Line: Ravenglass_e401</p>	 <p>Line: Ravenglass_e401</p>
<p>02</p> <ul style="list-style-type: none"> e402_1 = internal voiding 			 <p>Line: Ravenglass_e402</p>	 <p>Line: Ravenglass_e402</p>
<p>03</p> <ul style="list-style-type: none"> e403_1 = internal voiding 			 <p>Line: Ravenglass_e403</p>	 <p>Line: Ravenglass_e403</p>

<p>04</p> <ul style="list-style-type: none"> e404_1 = internal voiding 			 <p>Line: Revenglass_e404</p>	 <p>Line: Revenglass_e404</p>
<p>05</p> <ul style="list-style-type: none"> e405_1 = data artefact e405_2 = internal voiding 			 <p>Line: Revenglass_e405</p>	 <p>Line: Revenglass_e405</p>
<p>06</p> <ul style="list-style-type: none"> e406_1 = data artefact 			 <p>Line: Revenglass_e406</p>	 <p>Line: Revenglass_e406</p>

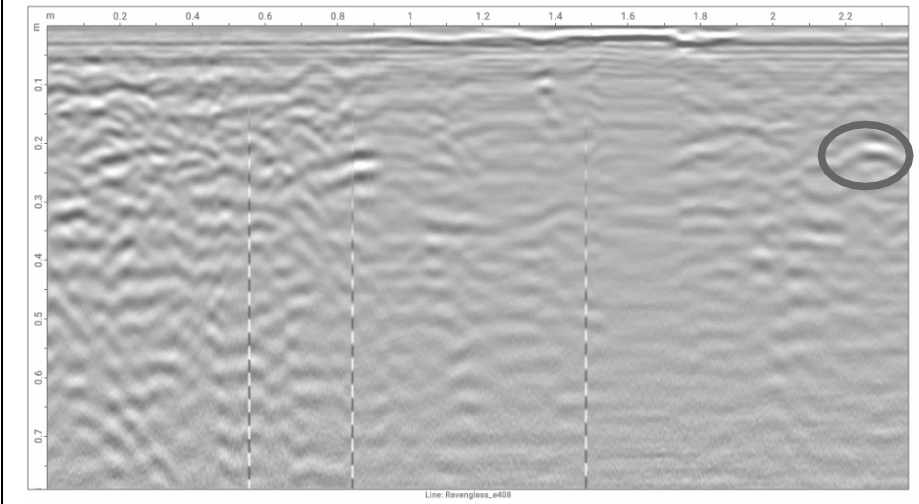
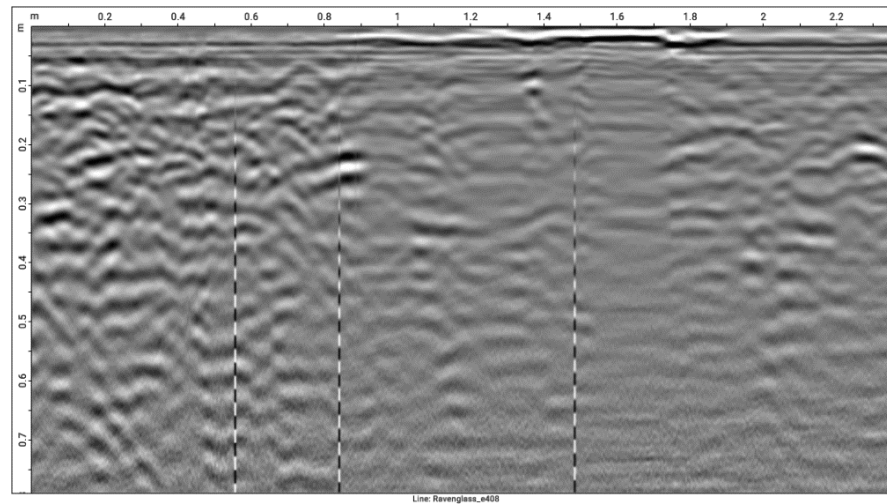
07

- e407_1 = air/metal fence

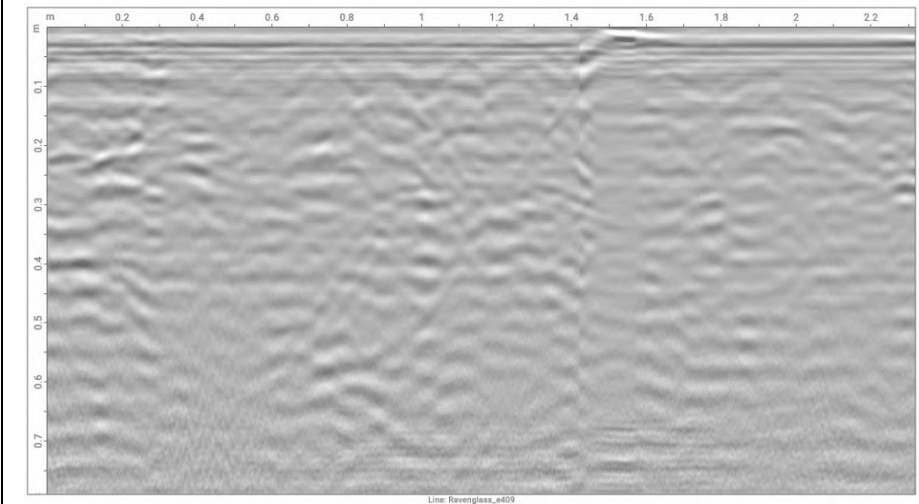
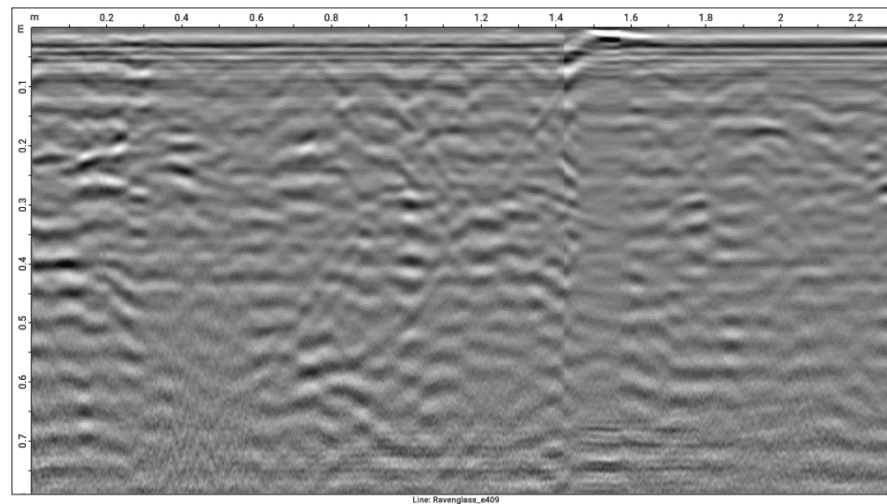




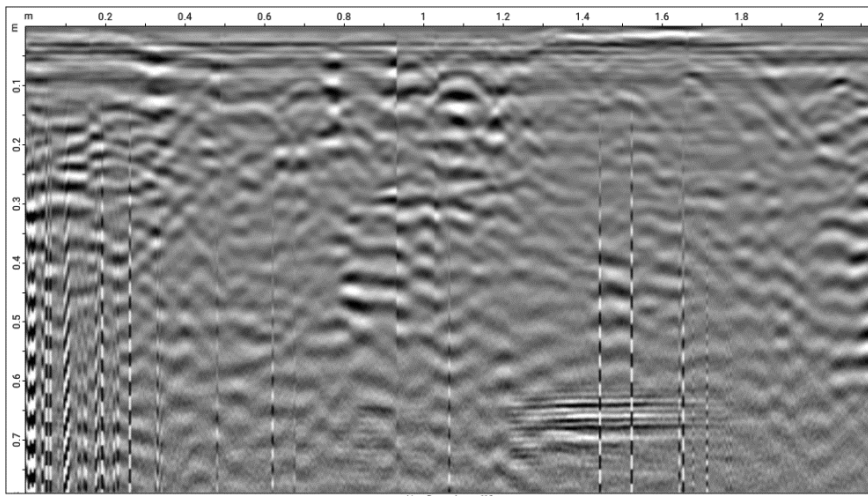
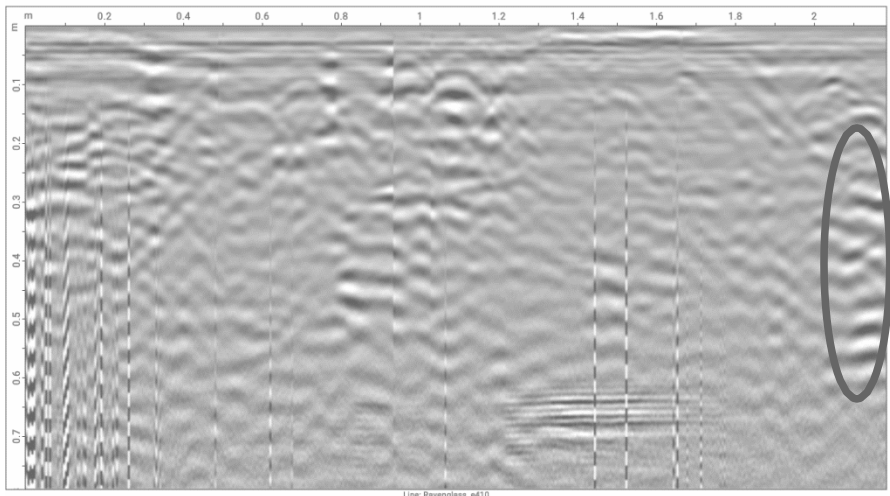


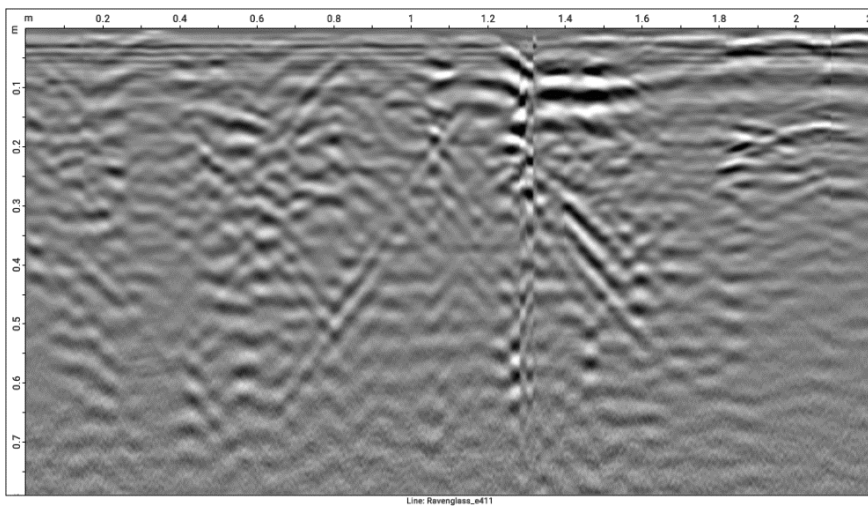
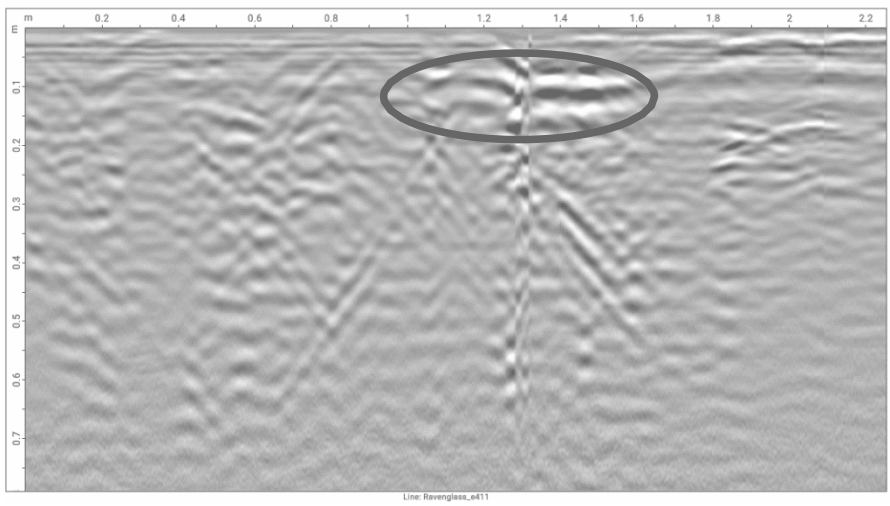

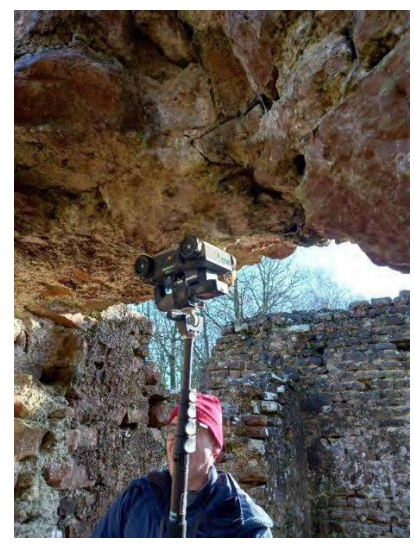
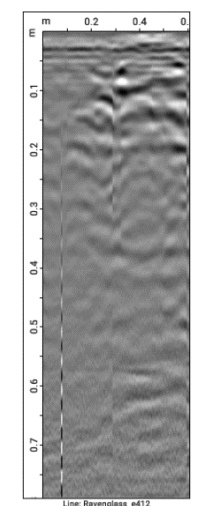
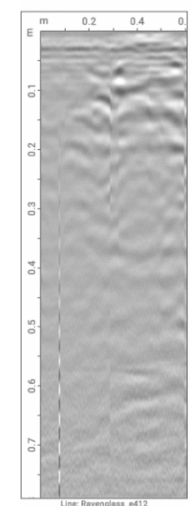
07

- e407_1 = air/metal fence



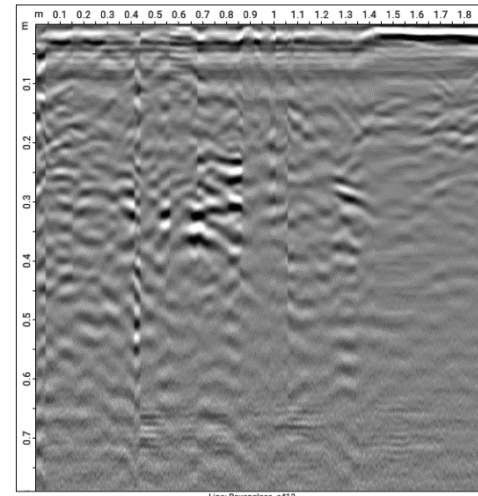
09



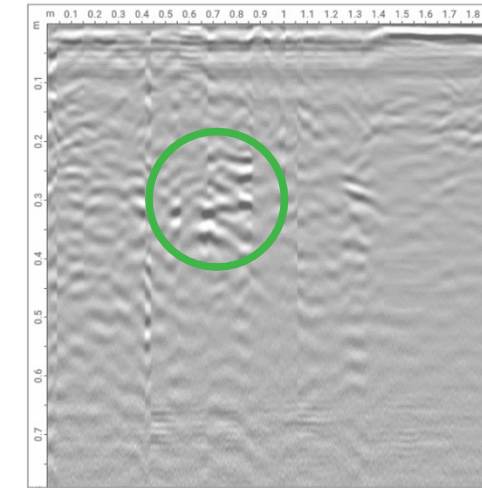
<p>10</p> <ul style="list-style-type: none"> e410_1 = airwave reflection from overhang 				
<p>11</p> <ul style="list-style-type: none"> e411_1 = data artefact 				
<p>12</p>				

13

- e413_1 = change in building material or direction of masonry



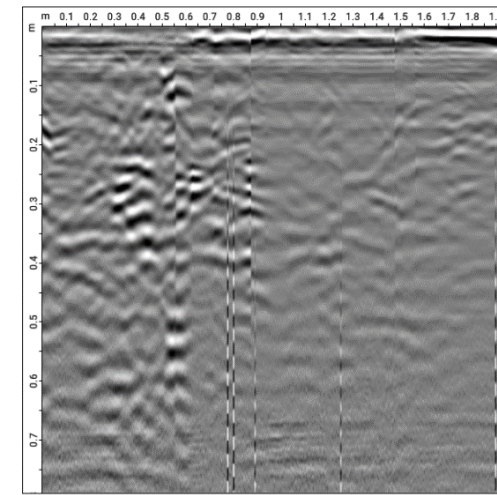
Line: Ravenglass_e413



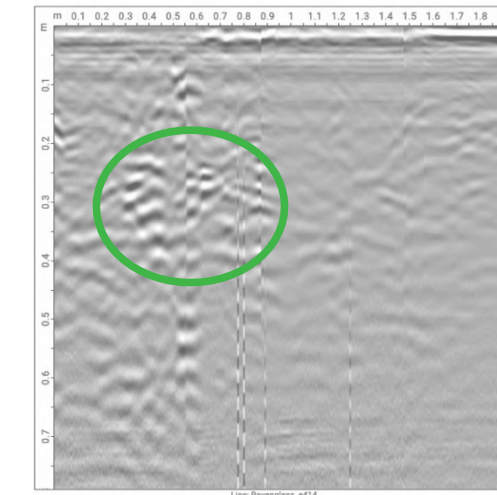
Line: Ravenglass_e413

14

- e414_1 = change in building material or direction of masonry



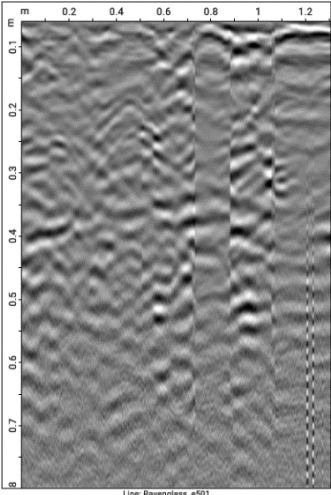
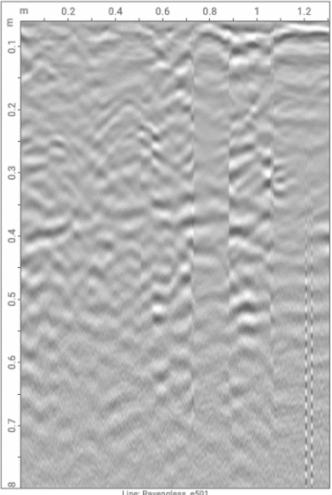


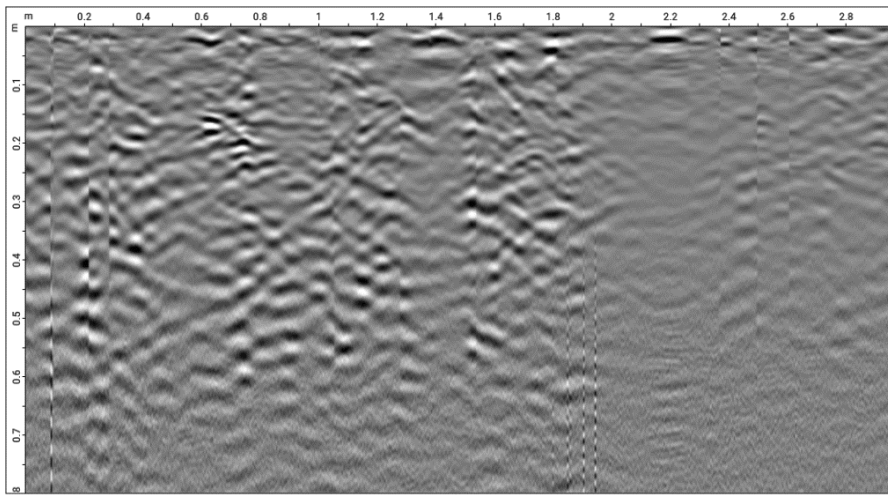
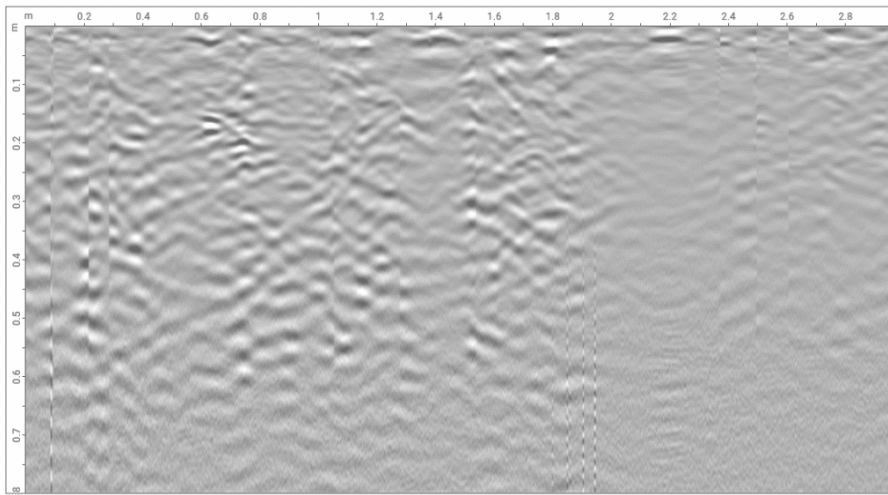


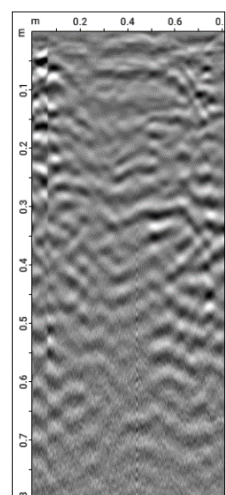
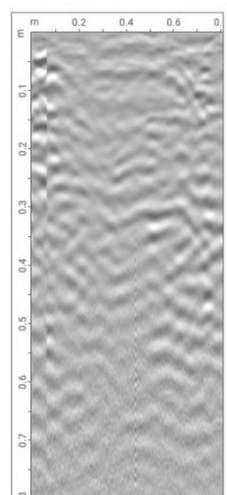


Line: Ravenglass_e414



Line: Ravenglass_e414

Elevation 5

Ravenglass_e5**	Beginning	End	Data	Interpretation
01			 <p>Line Ravenglass_e501</p>	 <p>Line Ravenglass_e501</p>
02			 <p>Line Ravenglass_e502</p>	 <p>Line Ravenglass_e502</p>
03			 <p>Line Ravenglass_e503</p>	 <p>Line Ravenglass_e503</p>

RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Location of GPR instrument survey swaths with measured survey plan of the Bath House



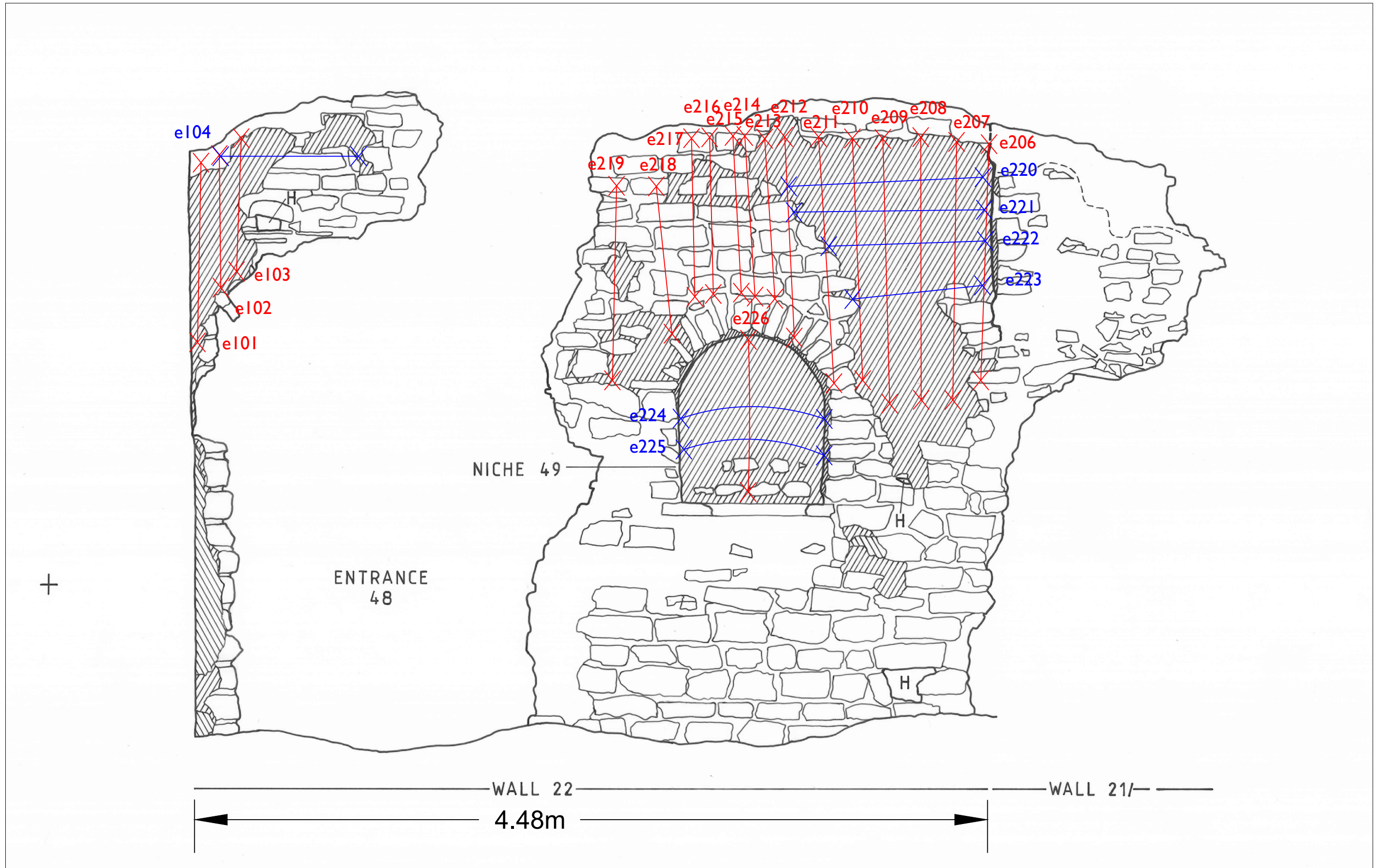
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Labelled measured survey plan of the Bath House



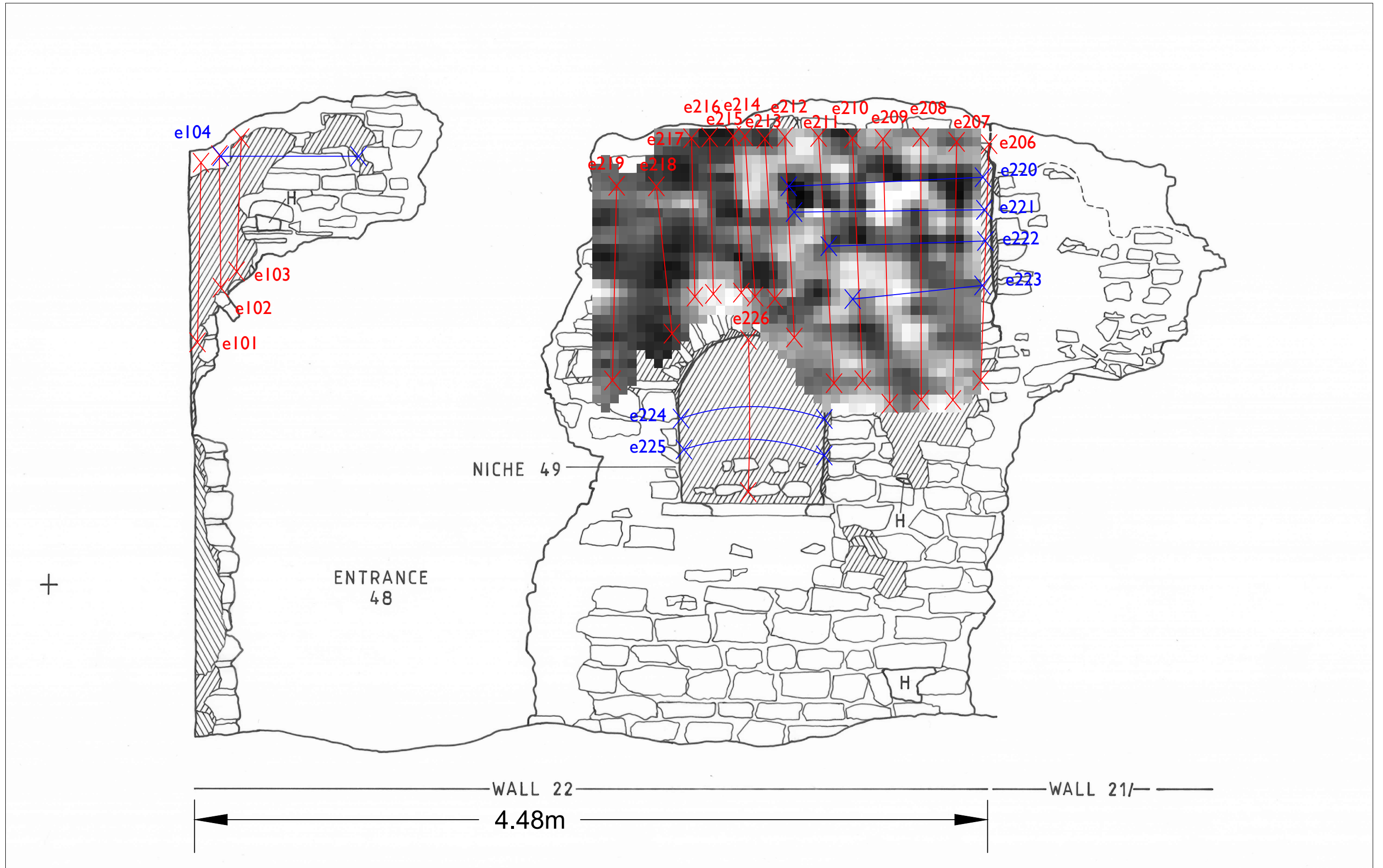
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevations 1 and 2: Wall 22



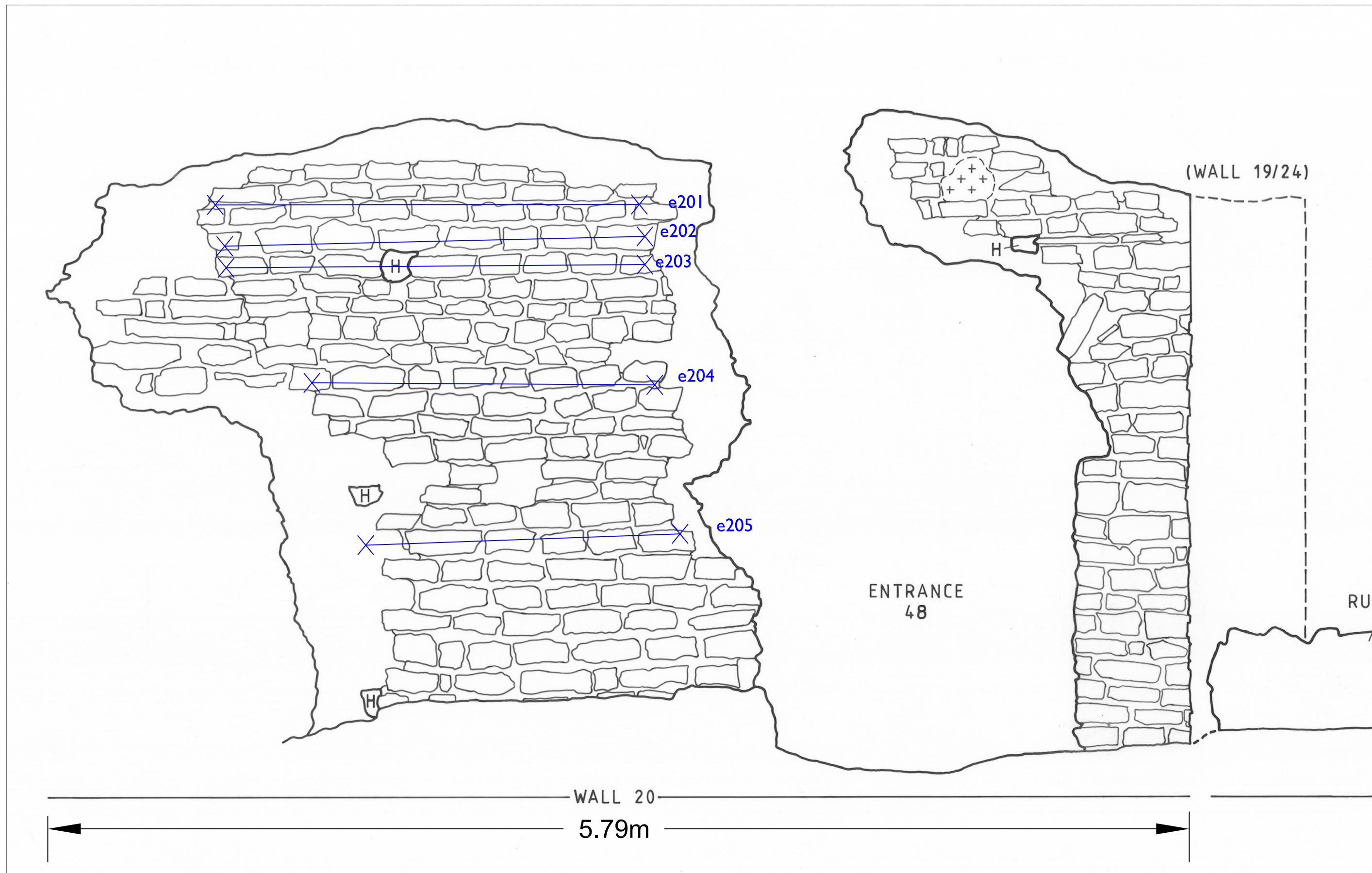
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

GPR amplitude time slice between 3.0 and 4.0ns (0.12 to 0.16m), Elevation 2: Wall 22



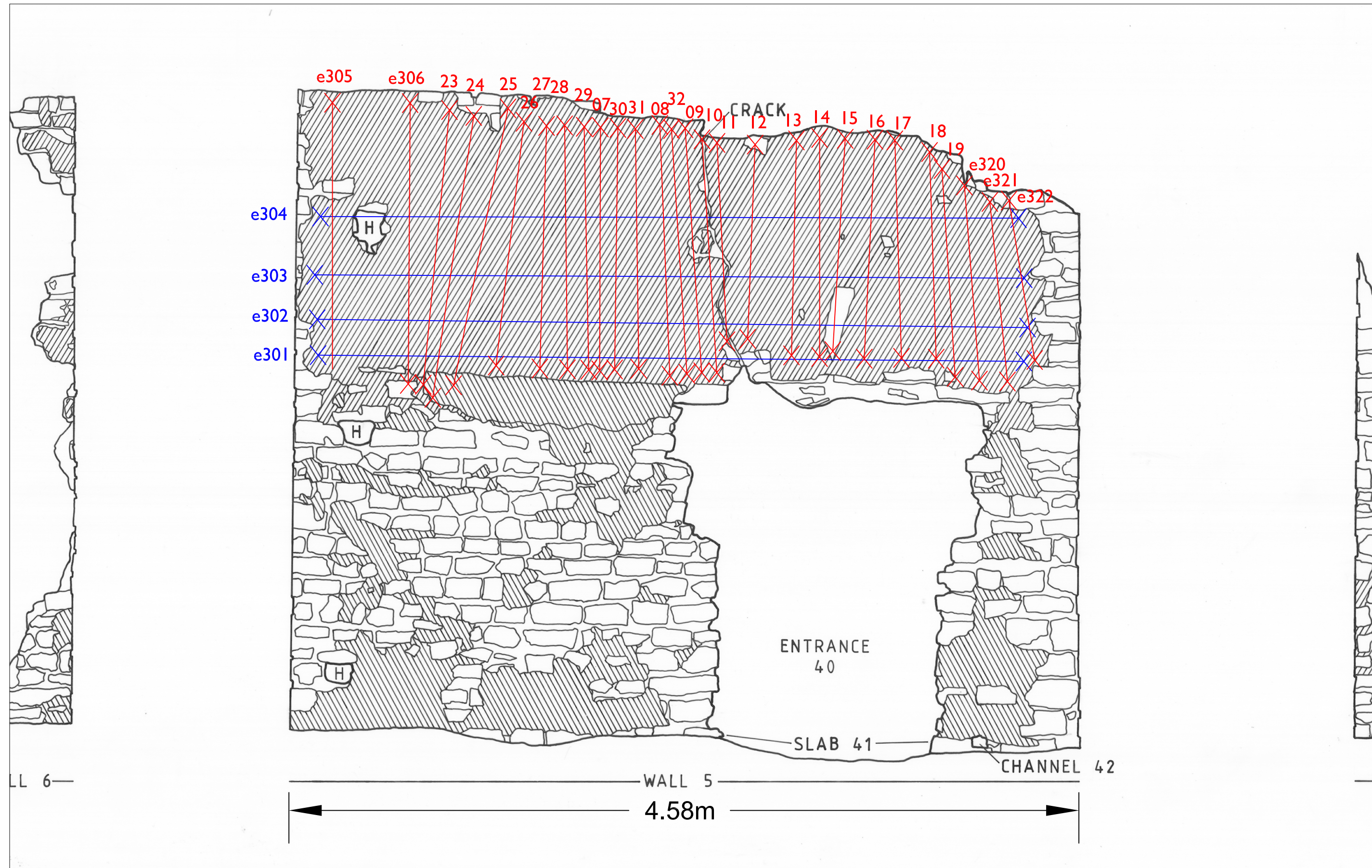
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevation 2: Wall 20



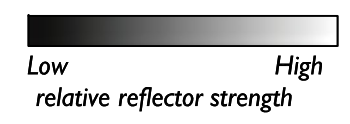
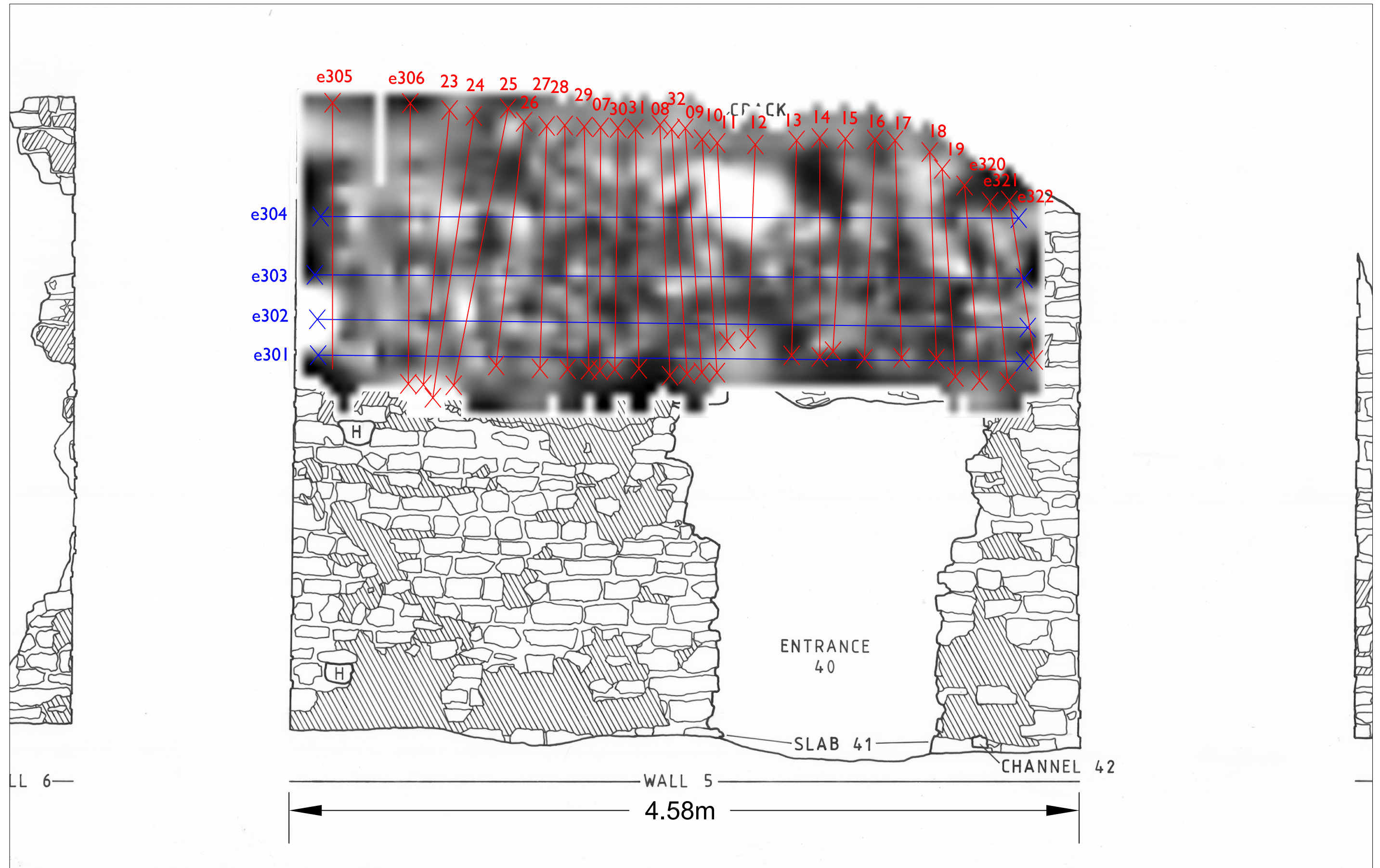
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevation 3: Wall 5



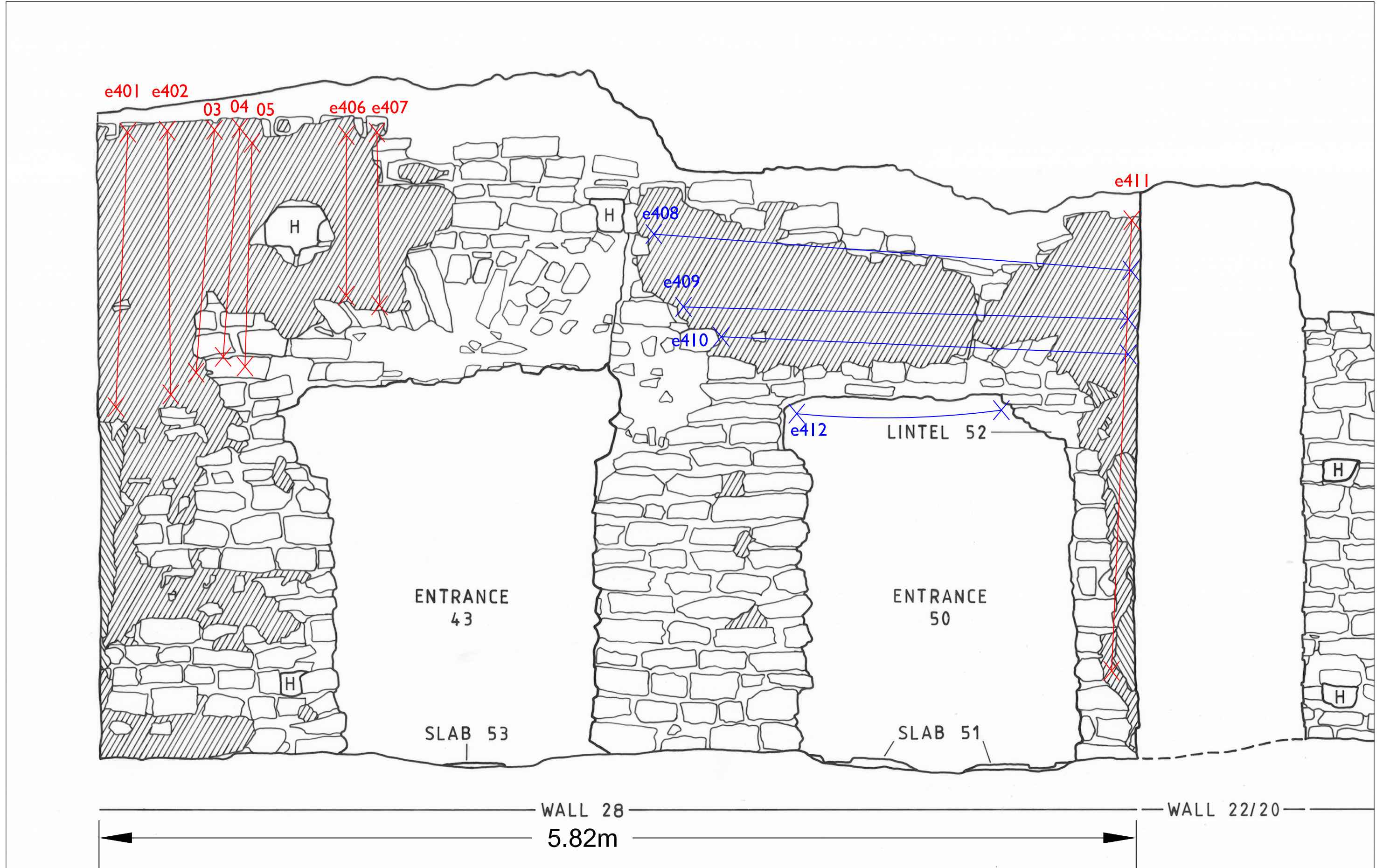
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

GPR amplitude time slice between 4.0 and 5.0ns (0.16 to 0.2m), Elevation 3: Wall 5



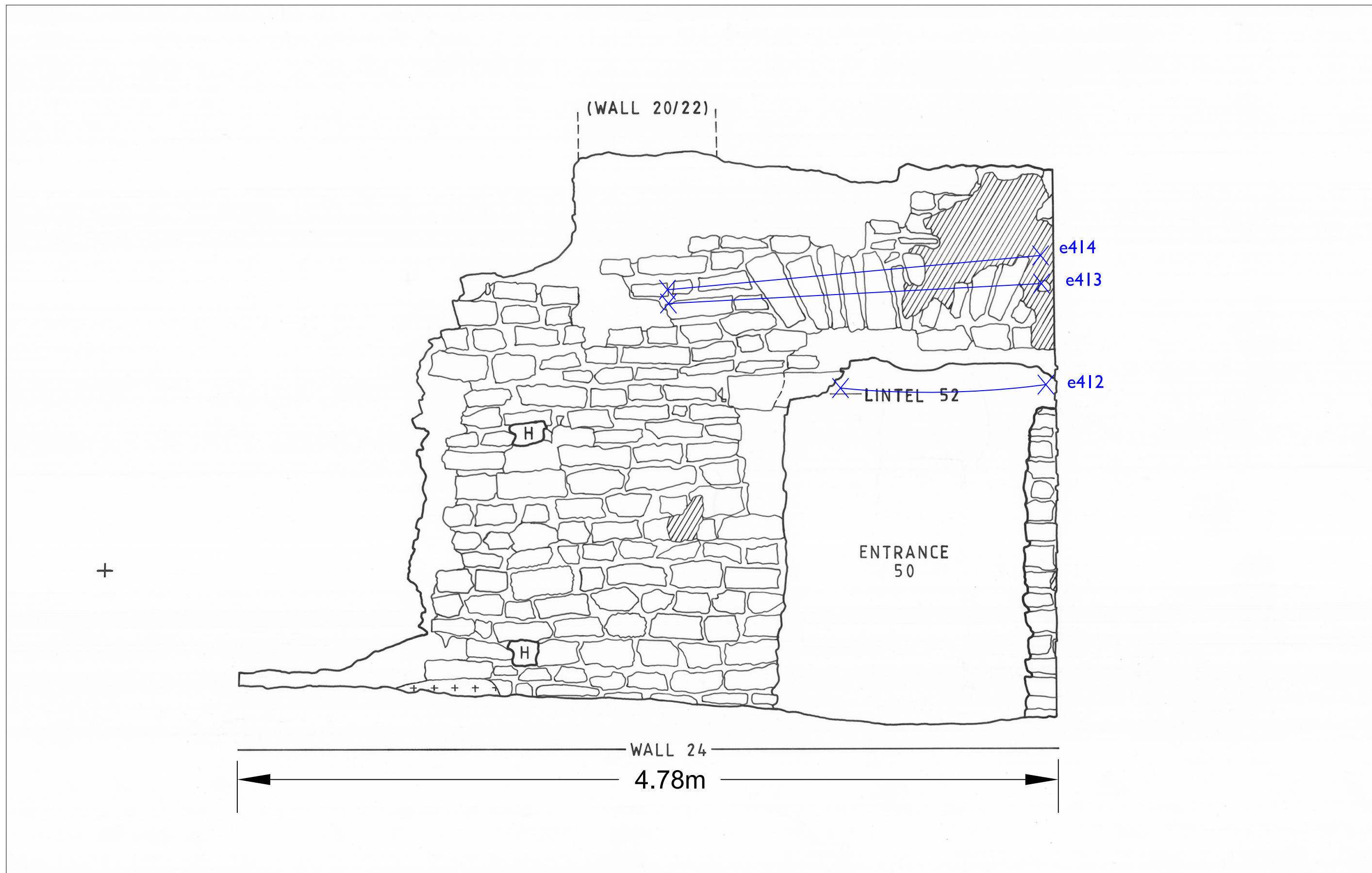
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevation 4: Wall 28



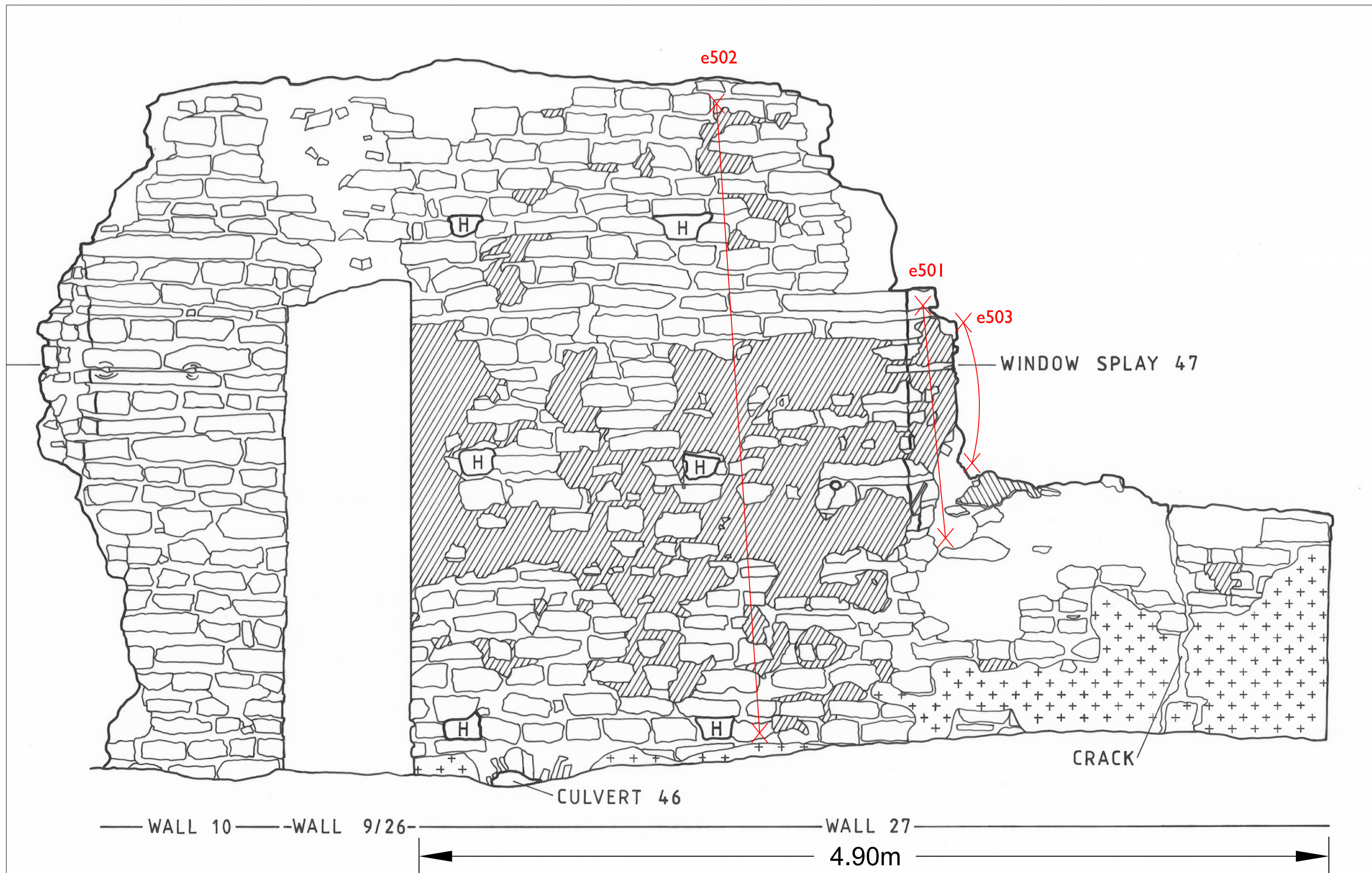
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevation 4: Wall 24



RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Elevation 5: Wall 27



RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

GPR amplitude time slice between 25.0 and 27.5ns (1.32 to 1.46m)



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— Location of selected
2024-01-31-016 GPR profiles shown
on Figure 12

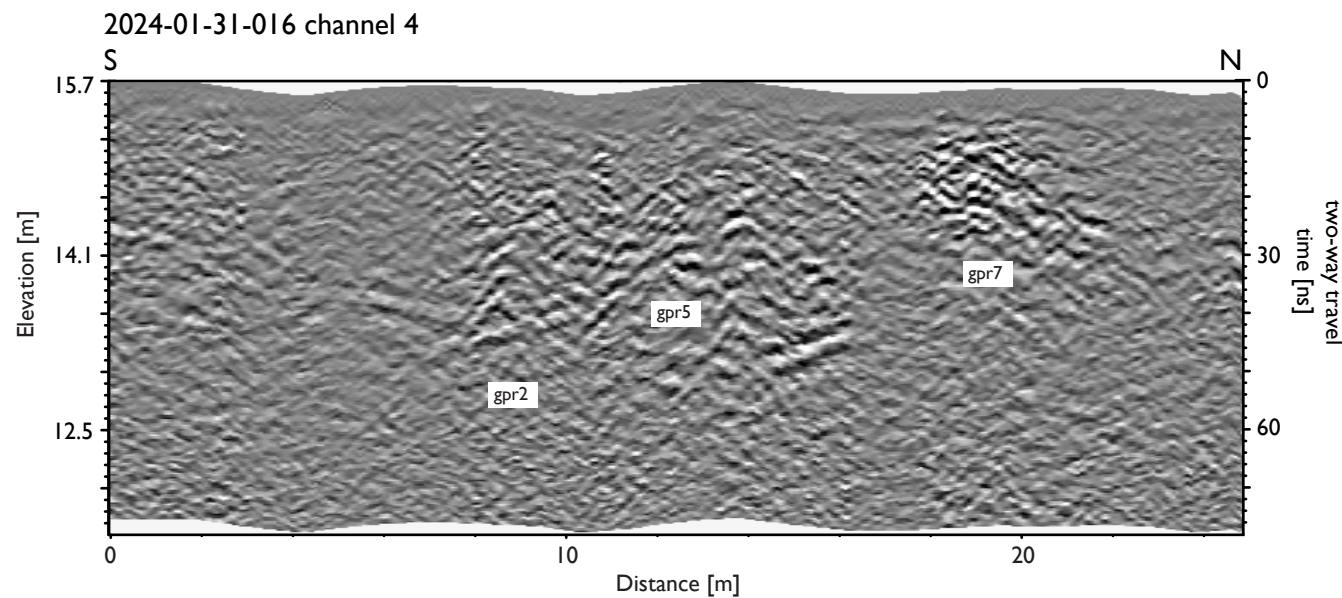
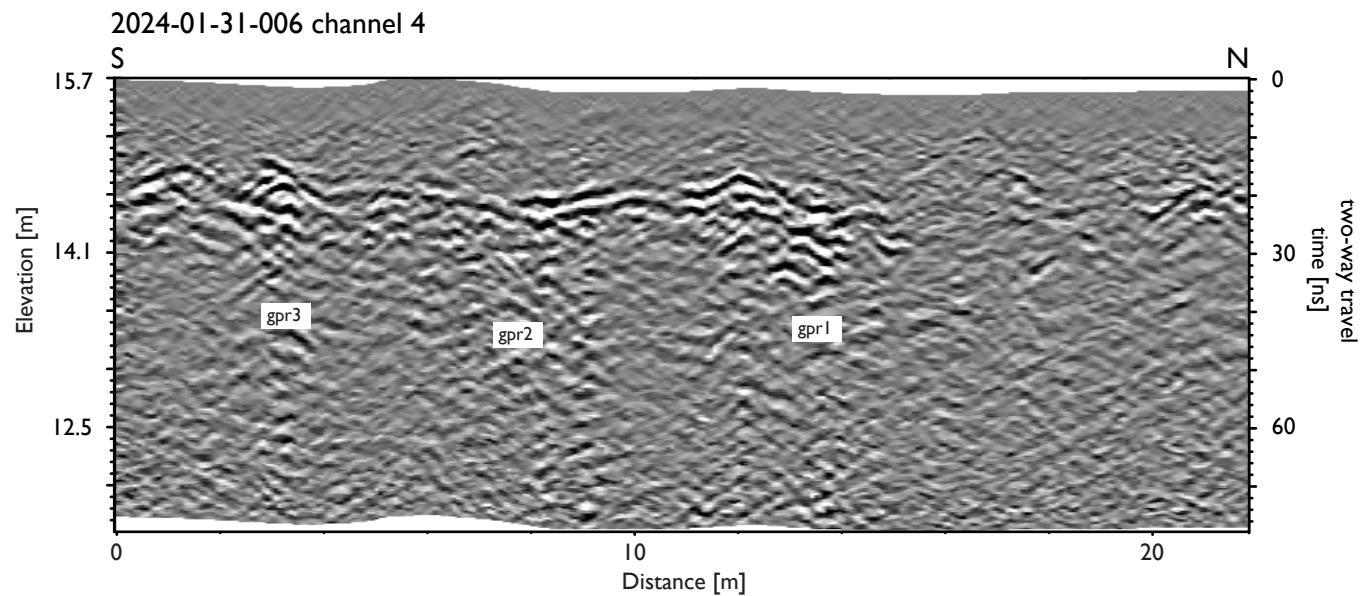
0 15m
1:250

Low High
relative reflector strength

RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Representative topographically corrected GPR profiles, January 2024

Figure 12



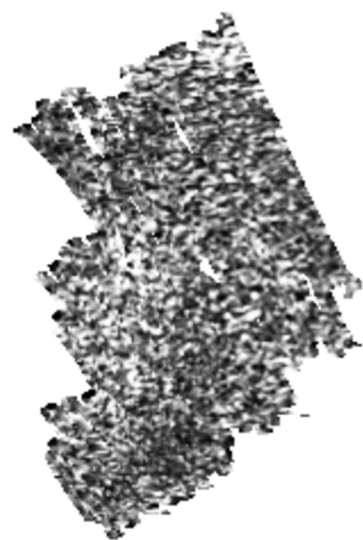
RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

GPR amplitude time slices between 0.0 and 25.0ns (0.0 to 1.32m)

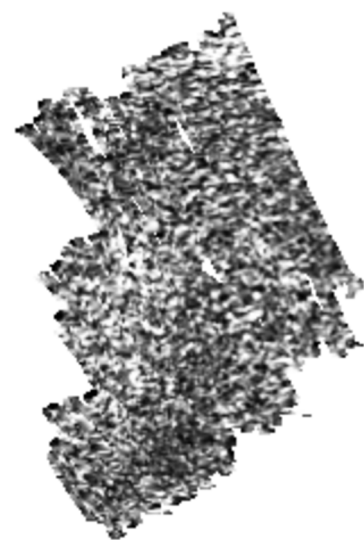
0.0 - 2.5ns (0.0 - 0.13m)



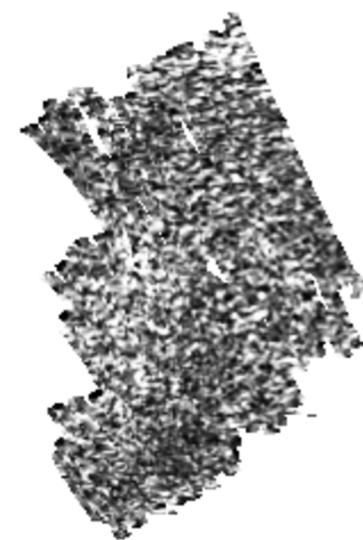
2.5 - 5.0ns (0.13 - 0.27m)



5.0 - 7.5ns (0.27 - 0.40m)



7.5 - 10.0ns (0.40 - 0.53m)



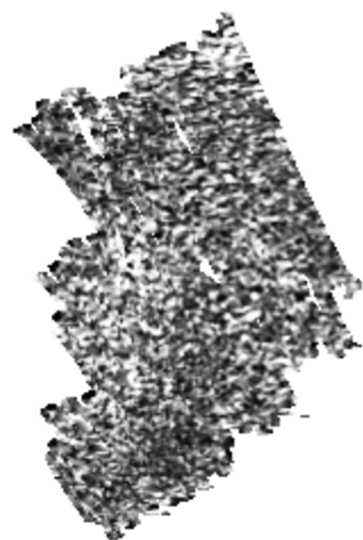
10.0 - 12.5ns (0.53 - 0.66m)



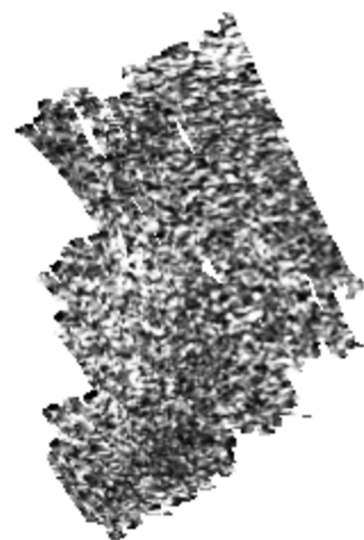
12.5 - 15.0ns (0.66 - 0.79m)



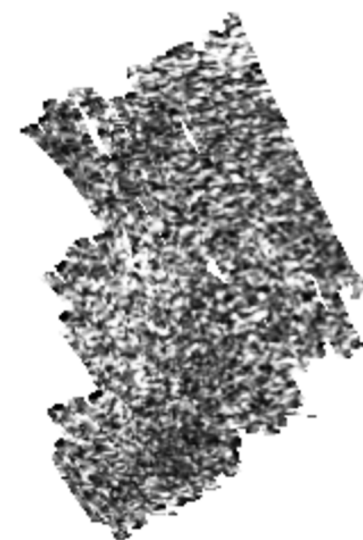
15.0 - 17.5ns (0.79 - 0.93m)



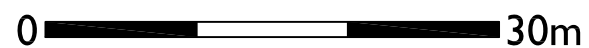
17.5 - 20.0ns (0.93 - 1.06m)



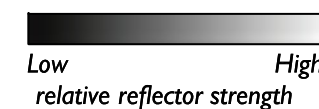
20.0 - 22.5ns (1.06 - 1.19m)



22.5 - 25.0ns (1.19 - 1.32m)



1:500



RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

GPR amplitude time slices between 25.0 and 50.0ns (1.32 to 2.65m)

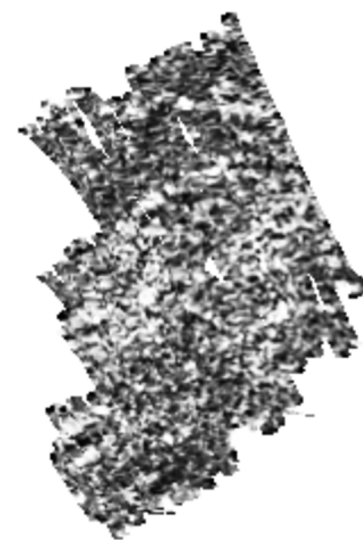
25.0 - 27.5ns (1.32 - 1.46m)

27.5 - 30.0ns (1.46 - 1.59m)

30.0 - 32.5ns (1.59 - 1.72m)

32.5 - 35.0ns (1.72 - 1.85m)

35.0 - 37.5ns (1.85 - 1.99m)



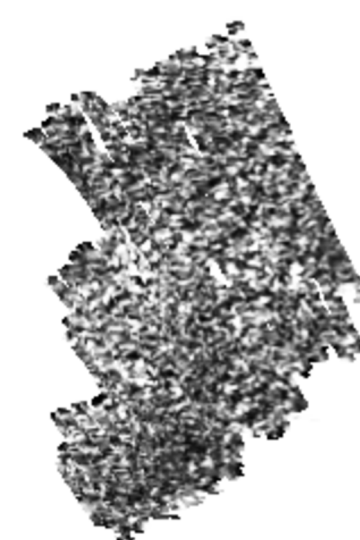
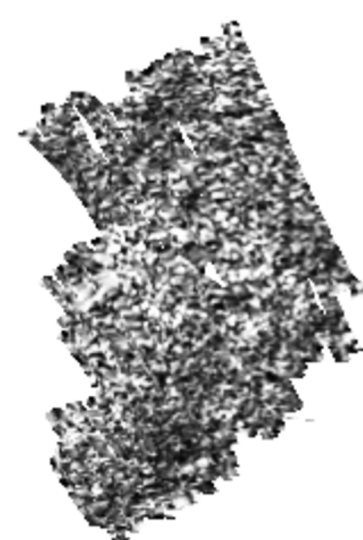
37.5 - 40.0ns (1.99 - 2.12m)

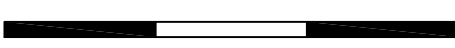
40.0 - 42.5ns (2.12 - 2.25m)

42.5 - 45.0ns (2.25 - 2.38m)


45.0 - 47.5ns (2.38 - 2.52m)

47.5 - 50.0ns (2.52 - 2.65m)



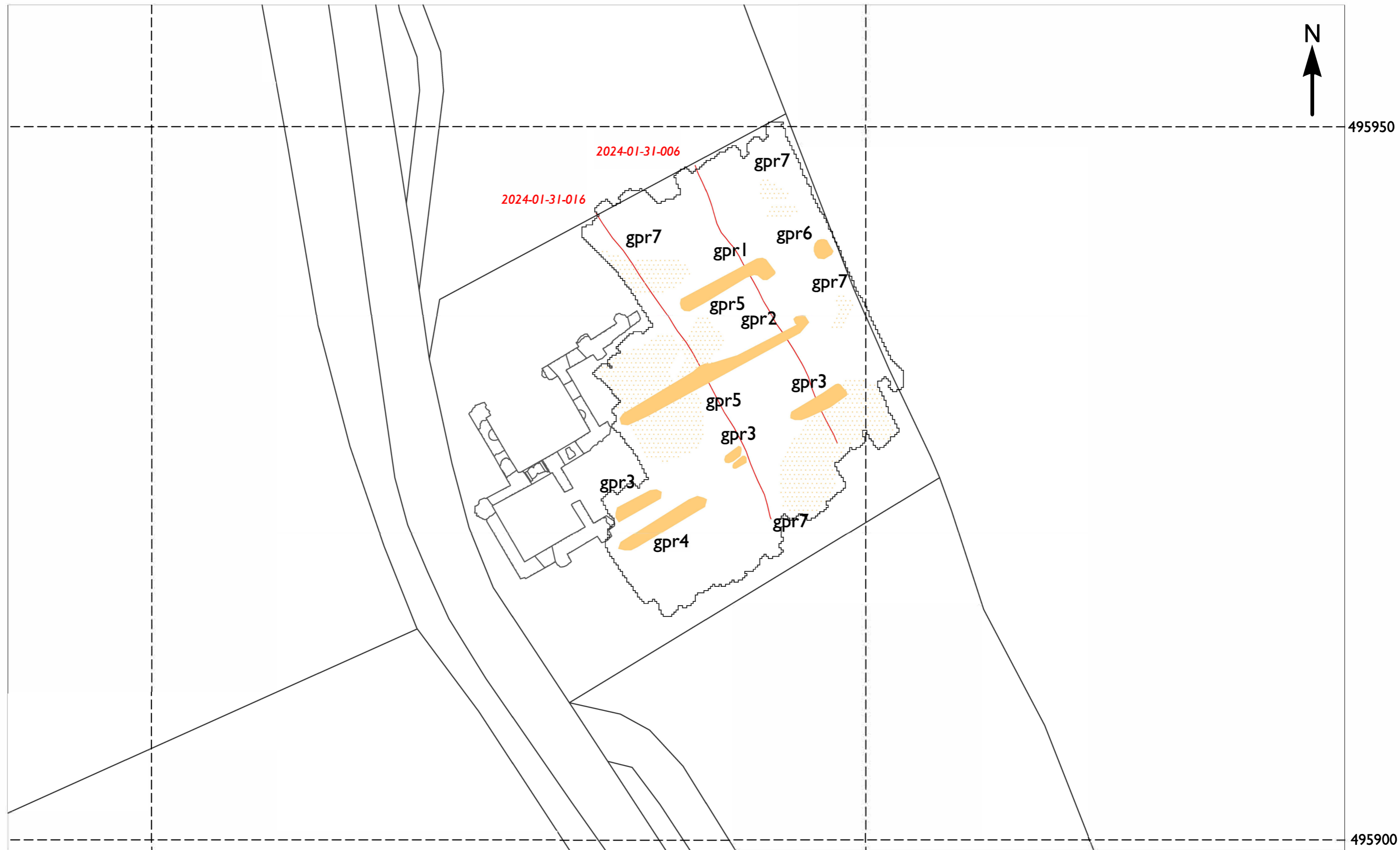
0  30m

1:500


Low High
relative reflector strength

RAVENGLASS ROMAN BATH HOUSE, MUNCASTER, CUMBRIA

Graphical summary of significant GPR anomalies





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