**SURVEY RESULTS**

**2002 / 92 Appleby-in-Westmorland, Cumbria**

## 1. Survey Area

1.1 Four areas within the car park of the police station were investigated by GPR, as shown on Figure 1, at a scale of 1:250. As indicated Areas A and D were surveyed with both the 225MHz and the 450MHz antenna, while Areas B and C were investigated using only the 225MHz and the 450MHz antennas, respectively.

## 2. Display

2.2 The GPR data are displayed in two format as radargrams and time slice maps.

2.2.1 *Radargrams:* The data are displayed conventionally as profiles representing a vertical section through the ground. The time axis denotes the length of time required for a pulse to be emitted from the transmitter, travel down to a reflector and back up to the receiver. This is called the two-way-time. The GPR traces for each traverse are plotted side by side in their correct relative positions and the records are displayed with their two-way-time axes arranged vertically. For each area selected radargrams are displayed and annotated.

2.2.2 *Time Slice Maps:* The complex nature of urban deposits can present a complicated picture when viewed as individual radargrams. However, by collecting data along a series of closely spaced parallel traverses, in this case 0.25m, one can combine the data to form a series of time slice maps comprising horizontal slices through the ground at different time/depth intervals. This type of presentation enhances more subtle anomalies and enables relationships between features to be analysed more easily.

2.3 Numbers on the time slice maps and radargrams refer to specific anomalies noted in the text.

## 3. General Considerations

### 3.1 Physical Principles, Instrumentation and Data Collection

3.1.1 The Ground Penetrating Radar (GPR) method utilises the absorption and reflection of electromagnetic waves at contrasting interfaces. The transmitter induces electromagnetic pulses into the ground and reflection of these pulses occurs when there are abrupt changes in the dielectric properties of the material. GPR records detailed vertical time sections, which can provide a wealth of stratigraphic information and clearly define any discontinuities. The primary advantage of GPR is that it can provide an estimation of the depth of a target.

3.1.2 The Software & Sensors Pulse Ekko 1000 system comprises transmitter and receiver antennas connected to a control box via cables. The control box is linked to a computer, which controls all the data collection. A wide variety of parameters can be adjusted to best suit the ground conditions and targets being investigated. All the stored data are raw and any processing or gains applied to the data during collection are purely cosmetic. For archaeological sites 450MHz and/or a 225MHz antennas are used, with a wide variety of others being available if needed. The choice of antenna frequency is crucial; high frequency antennas produce high resolution near surface data but have a limited depth of signal penetration. Conversely, lower frequency antennas allow a greater depth of investigation but at the expense of resolution. However, this can be advantageous as it reduces 'clutter' from near surface material. For these investigations both antenna were used because of the varied depth of the archaeological deposits and the expected near surface rubble spread. The GPR set is powered from a 12V battery connected directly or via the cigarette lighter of a vehicle.

3.1.3 Data were collected along parallel traverses 0.25m apart. The traces were collected every 5cm along the traverses in all areas. Data collection was continuous with control markers every metre and the data aligned during processing.

### 3.2 Velocity analysis

3.2.1 It was not considered feasible to carry out on-site velocity analysis (CMP) in any of the survey areas as this method of estimating ground velocity is best suited to horizontal layers, which are not generally apparent in this kind of urban environment. However, graphical methods involving the fitting of curves to point source reflections can provide satisfactory results and thus were used to provide an estimate of a velocity of $0.09 m.ns^{-1}$ to enable time to depth conversion. It should be noted that as the velocity will vary down and across the section as the signal passes through different material, or slightly differing soils, and depths given are still an approximation.

### 3.3 Site Considerations

3.3.1 All geophysical techniques rely on a contrast between materials, in this case the dielectric properties of a material. A stone/brick wall surrounded by soil or silt will be relatively easy to detect compared to one surrounded by stone/brick rubble. As with all geophysical techniques, the lack of a response does not necessarily indicate the absence of features beneath the ground. It merely means that if a feature is present then it is invisible to the technique, either due to depth or insufficient contrast i.e. all geophysical techniques can prove a presence far more confidently than an absence.

3.3.2 Where there is a strong electromagnetic contrast, the GPR signal can be inter-reflected or reverberated and this produces a delay in the reflection of the signal. This is termed 'ringing'. This happens, to some extent, with all reflections and results in a greater apparent depth than actually exists. As a result, it is often not possible to detect the base of features; only the tops of buried features/deposits are detected with certainty.

## 4. Results of Detailed Survey

### 4.1 Area A (Figures 2 - 7)

*This area was investigated in an attempt to accurately locate the room that housed the treadmill used by prisoners. Both antennas were used in order to retrieve the most information from the area.*

4.1.1 As is to be expected the data with background removal is far clearer. The near surface data show discrete responses (1), which almost certainly relate to variations in the tarmac. By 0.3m – 0.6m a diffuse spread of high amplitude reflections is apparent, probably due to demolition debris and general landscaping.

4.1.2 In the 450MHz data, and to a lesser extent in the 225MHz data, relatively discrete linear anomalies (2) are apparent between about 0.45m and 0.9m. These appear to relate to modern drains. However, given the wealth of material revealed during excavation these could be composite responses of drains and foundation, especially in the 225MHz data where there is less resolution.

4.1.3 Other responses (3) may be significant but their lack of extent does not suggest the presence of wall footings. However, excavation revealed substantial foundations that are not readily apparent in the GPR data. It would appear that there was insufficient contrast between the foundation and the surrounding fill.

### 4.2 Area B (Figures 8 - 12)

*This area was surveyed in an attempt to accurately locate the range of buildings known to have occupied this section of the car park. The 225MHz antenna was used in order to suppress reflections from near surface demolition rubble.*

4.2.1 The clearly defined anomaly (4) in the 0.0m – 0.25m time slice map (with background removal) corresponds with a visible change in the tarmac.

4.2.2 In the 0.25m – 0.50m time slice map rectilinear high amplitude responses (5) are apparent though they are not especially well defined. Excavation revealed a complex series of walls, floors, rubble and other debris. Additional elements (6) are still clear in the 0.75m – 1.00m time slice map. Some of these may equate to deeper surviving foundations but others may be due to ringing (see section 3.3.2).

4.2.3 The data without background removal is not as clear, with the exception of the linear responses (7) near the eastern and western limits of the survey area. These are very well defined and may indicate surviving foundations although they were not excavated.

4.2.4 The lack of clarity in the GPR data is partly due to insufficient contrast between the surviving foundations and fill, together with the general spread of debris. Also the complex nature of the surviving archaeology is possibly beyond the resolution of the 225MHz antenna. Although this antenna was used to try to minimise clutter, the archaeology was a lot shallower than expected and this antenna does have reduced near surface resolution. There are few reflections, other than those due to ringing, below 1m in the time slice data and during excavation natural was encountered at about this depth.

**4.3 Area C** (Figures 13 – 15)

*This small area was investigated to confirm the extent of foundations associated with the woman's prison shown on plans. Only the 450MHz antenna was used given the results from Area B.*

4.3.1 Strong high amplitude reflections (8) in the 0m – 0.15m time slice maps coincide with inspection covers. The weak linear anomaly (9) coincides with a mark in the tarmac, which most likely indicates a buried service.

4.3.2 The 0.15m – 0.60m time slice maps show general zones of high amplitude response (10). It is not possible to say from the data whether these are due to intact features or spreads of debris. Excavation revealed a complex of walls and associated structures. Several 'rooms' were in-filled with rubble and this accounts for some of the observed anomalies.

4.3.3 A linear response (11) at the southern edge of the survey area may indicate a drain given its relationship to the manhole cover. However, it could be due to foundations/cellars associated with the extant building immediately south of the survey area.

4.3.4 The most striking response (12) appears at a depth of about 1m. The data suggested a possible void and excavation indeed revealed a stone floor approximately 1m below the modern ground surface beneath which was a void. This is thought to represent part of the heating system within the women's prison block.

**4.4 Area D** (Figures 16 – 18)

*This small section was investigated in the attempt to locate a possible tunnel thought to cross the area. Due to the unknown depth both antenna were used.*

4.4.1 As with previous areas the 225MHz data does show some variation but it is not possible to recognise any clearly defined structural responses in the data. The broad areas (14) of high amplitude response probably indicate drains.

4.4.2 The 450MHz data are similarly devoid of clearly defined anomalies indicative of foundation/structural remains or a tunnel.

## 5. Conclusions

5.1 GPR successfully detected elements of surviving foundations associated with the earlier prison, although numerous features revealed by excavation are not apparent in the GPR data. Undoubtedly the extensive network of drains across the site, and the amount of demolished rubble, has diminished the quality of the results.

5.2 Of particular interest was a strong reflection about 1m below the ground surface identified in Area C. Excavation revealed this to be a void associated with the prison heating system.

**Project Co-ordinator:** J Gater
**Project Assistants:** Dr S Ovenden, C Stephens and E Wood

**Date of Survey:** 9th – 11th October 2002
**Date of Draft Report:** 6th January 2003

**SITE SUMMARY SHEET**

**2002 / 92 Appleby-in-Westmorland, Cumbria**

**NGR:** NY 685 205

**Location and topography**

The area under investigation covers the car park of Appleby-in-Westmorland police station. Four areas, covering the majority of the car park, were investigated by ground penetrating radar. All areas were generally level and under tarmac.

**Archaeology**

Appleby police station occupies the site of the old town jail and court built in 1771 and demolished in the 1970s. Three prisons stood on the site during that time, although few extant structures associated with the earlier prisons survive.

**Aims of Survey**

A ground penetrating radar (GPR) survey was undertaken with the aim of identifying archaeological remains associated with the earlier prisons. The survey forms part of a wider archaeological investigation being undertaken as part of the **Time Team** series for Channel 4 television.

**Summary of Results ***

GPR successfully detected elements of surviving foundations associated with the earlier prisons, although numerous features revealed by excavation are not apparent in the GPR data. Undoubtedly the extensive network of drains across the site, and the amount of demolition rubble, has diminished the quality of the results.

*** It is essential that this summary is read in conjunction with the detailed results of the survey.**

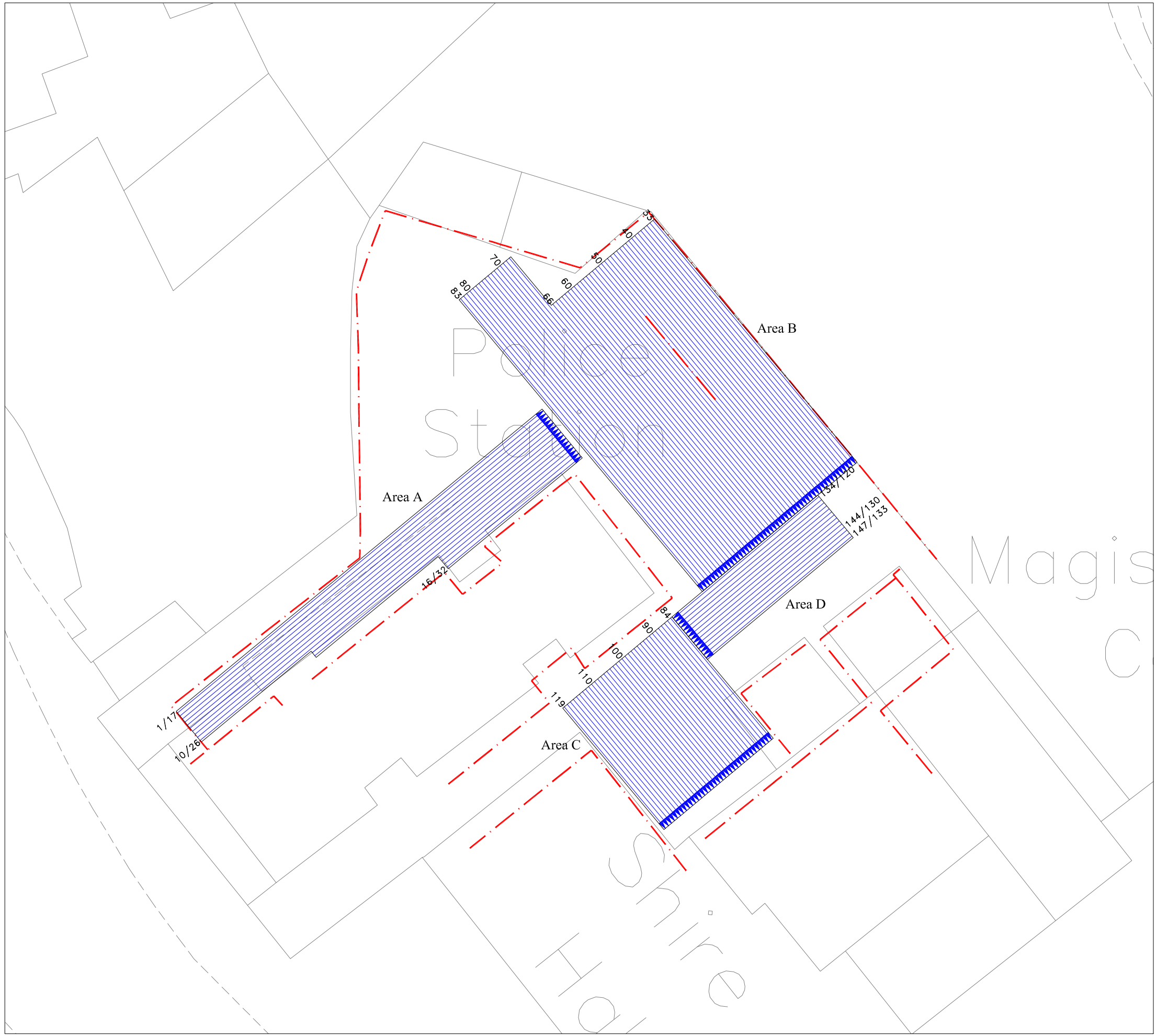
## List of Figures

**GSB PROSPECTION**

PROJECT: 2002/92 APPLEBY

TITLE: Location of GPR Survey

Based on map data provided by Time Team




GPR Traverse

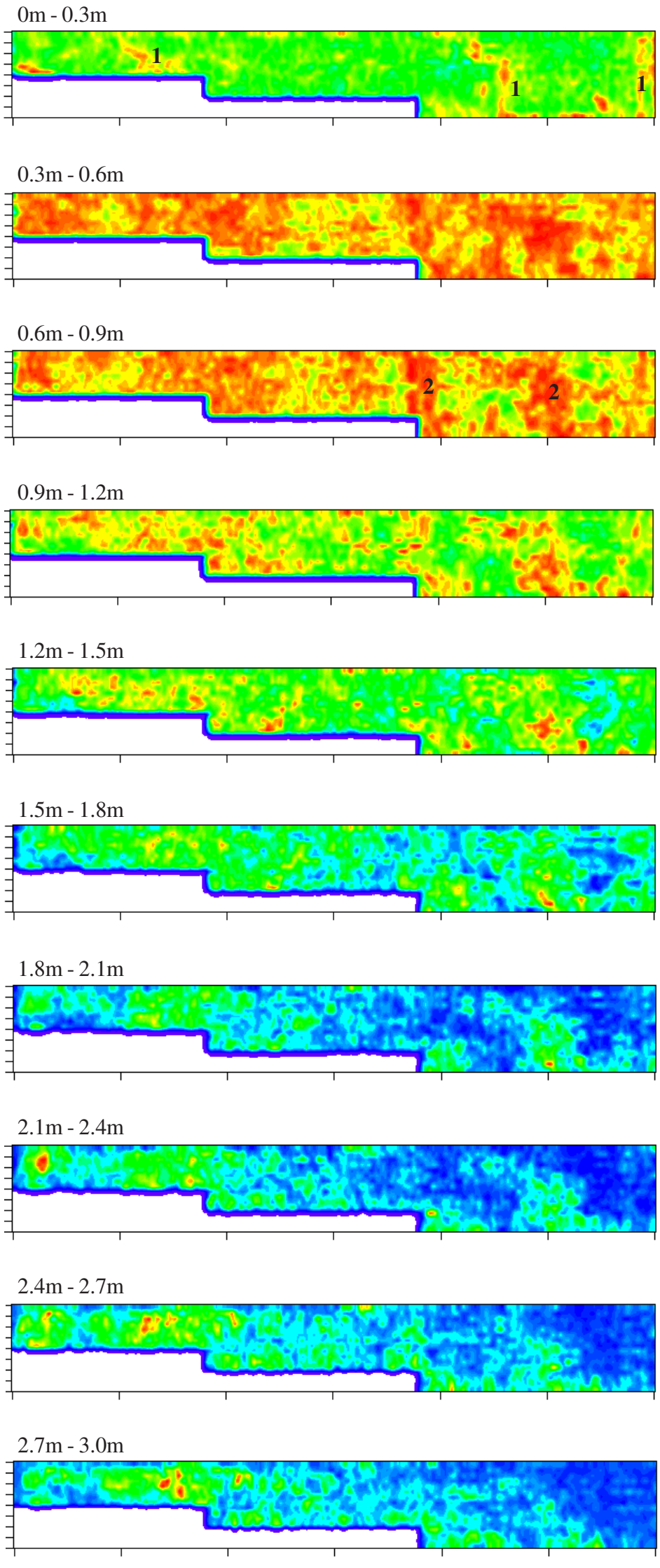
Existing Buildings/Walls as mapped by Time Team

Figure 1

# APPLEBY
# Area A

## GPR Time Slice Maps - 225MHz data

(with Background Removal)



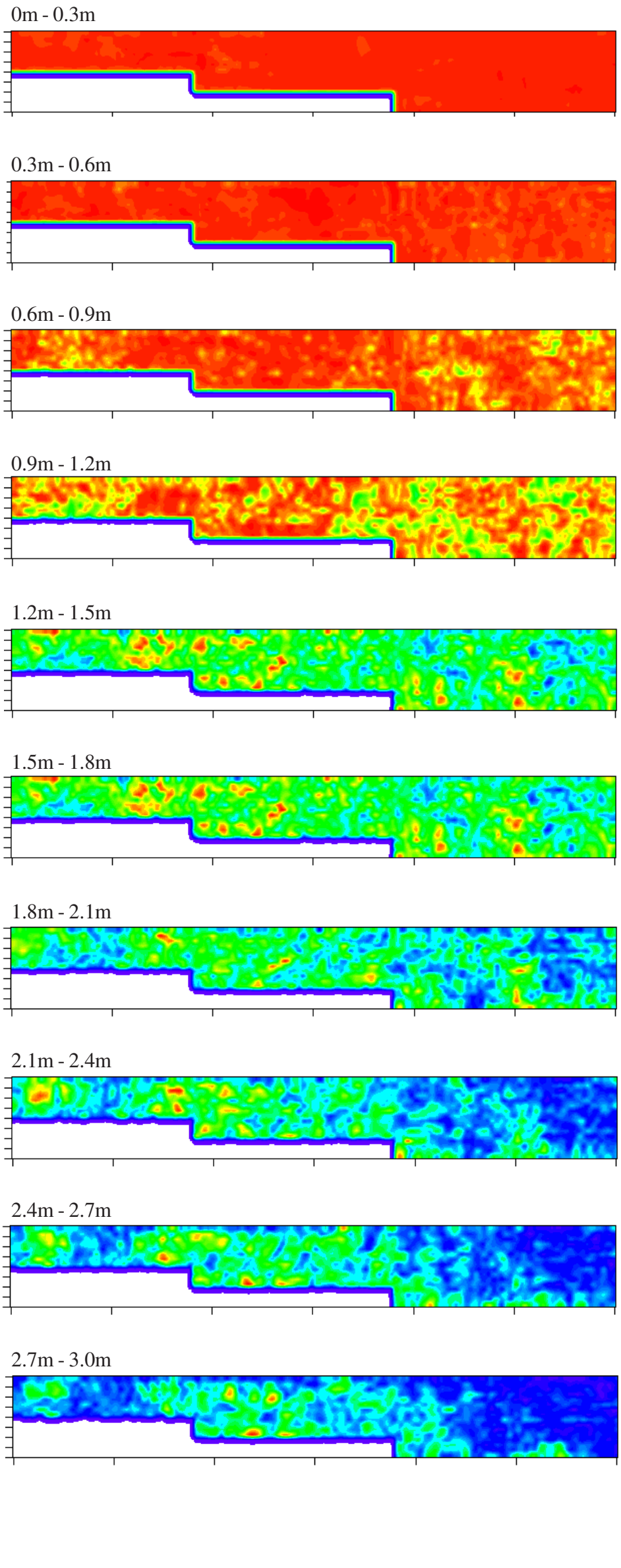

GSB Prospection 2002/92

**Figure 2**

# APPLEBY
# Area A

## GPR Time Slice Maps - 225MHz data

(No Background Removal)




GSB Prospection 2002/92

**Figure 3**

# APPLEBY
# Area A

## Radargrams - 225MHz data

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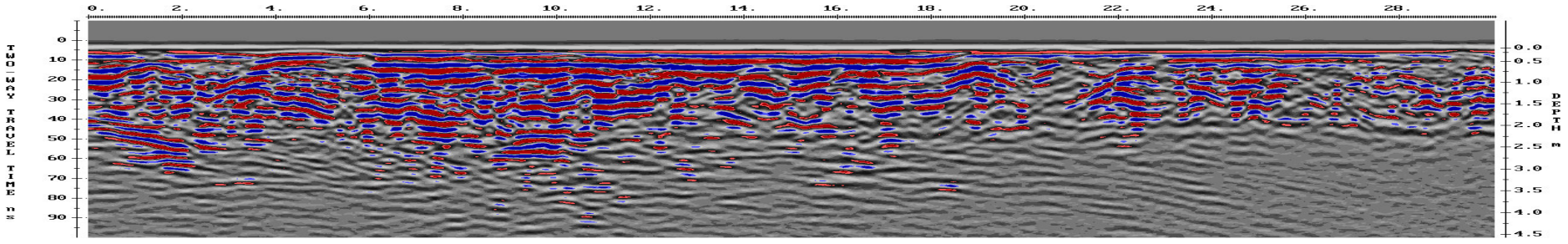


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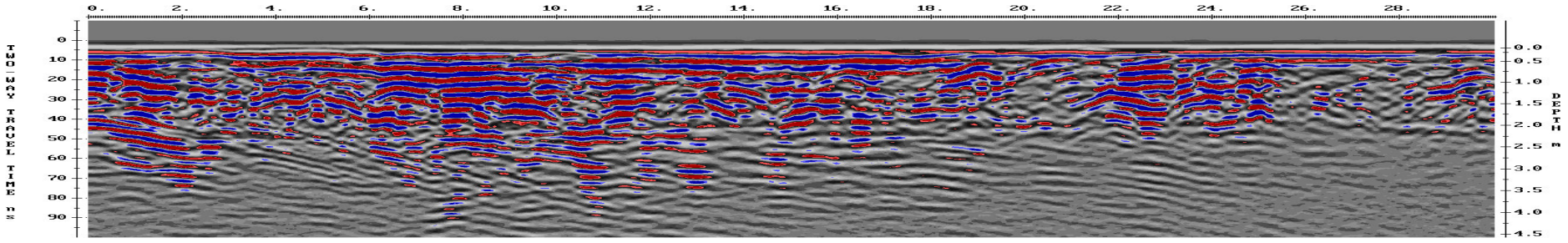


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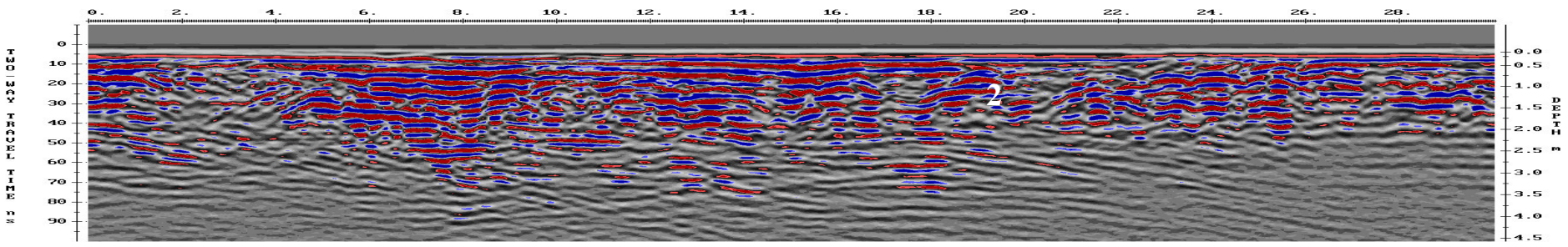


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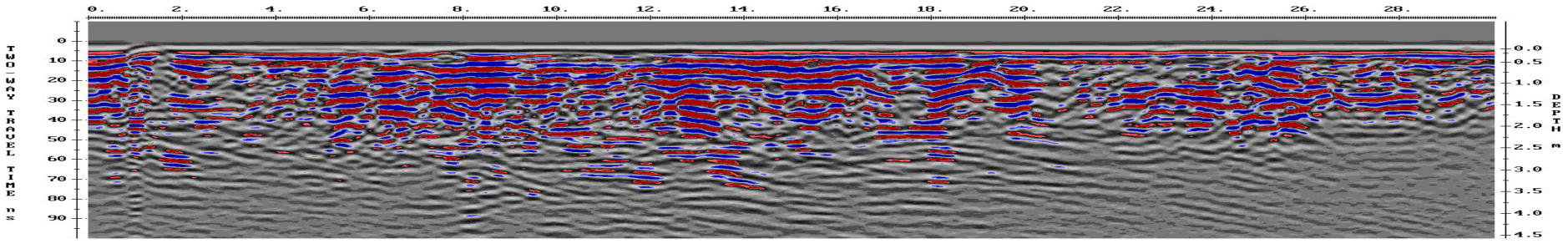


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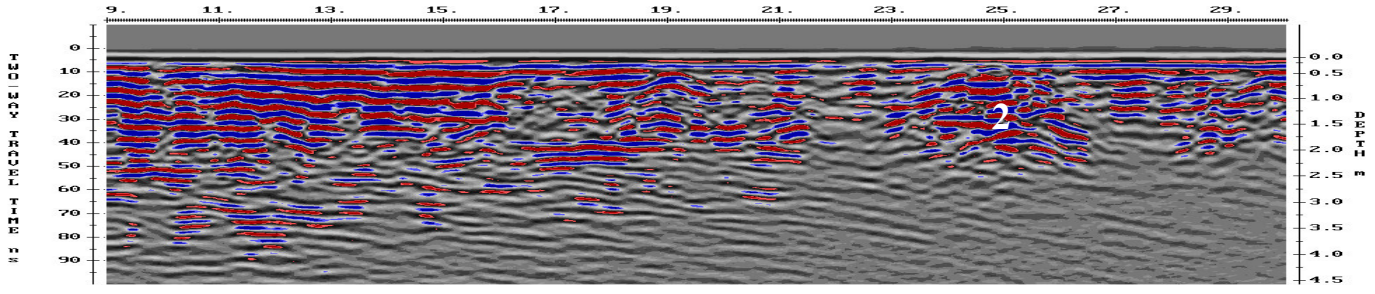


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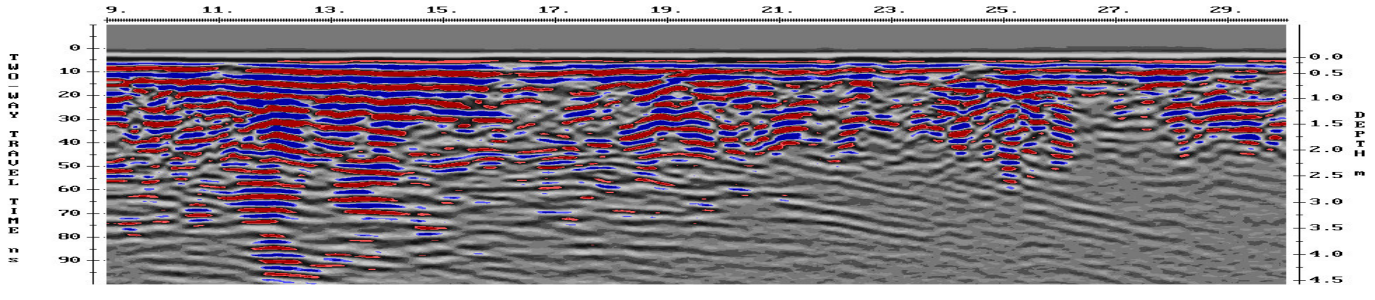




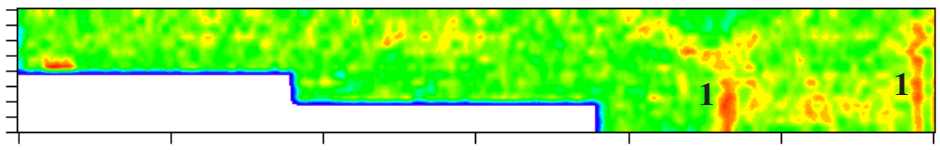

**Figure 4**

# APPLEBY
# Area A

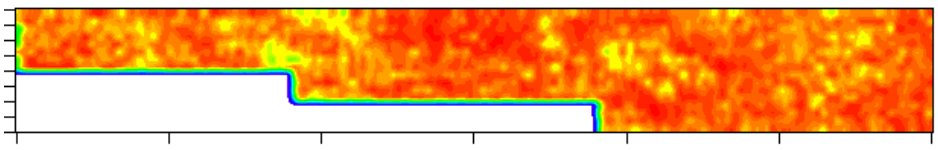
## GPR Time Slice Maps - 450MHz data

(With Background Removal)

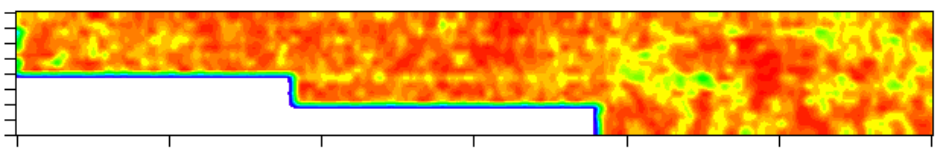
0.00m - 0.15m



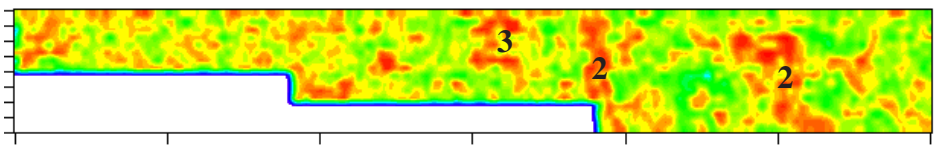

0.15m - 0.30m



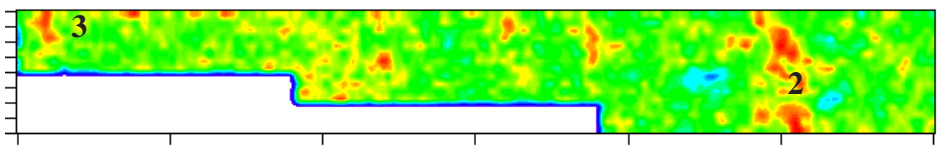
0.30m - 0.45m



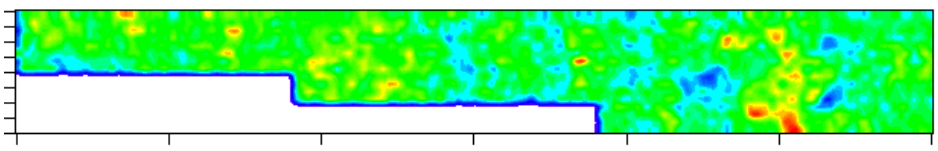
0.45m - 0.60m



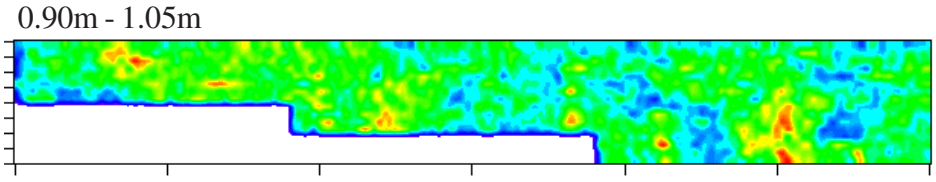

0.60m - 0.75m




0.75m - 0.90m



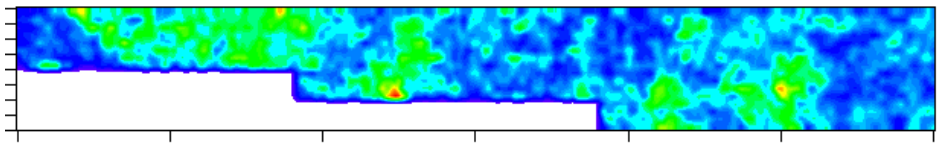
0.90m - 1.05m



1.05m - 1.20m



1.20m - 1.35m



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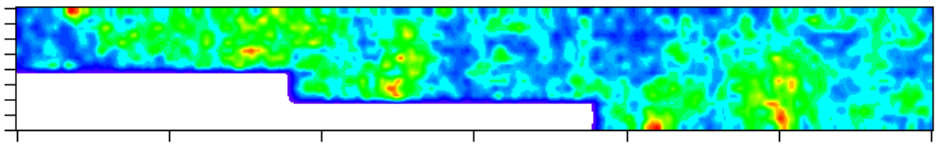

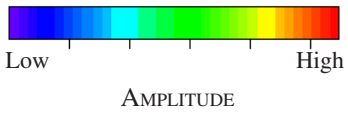


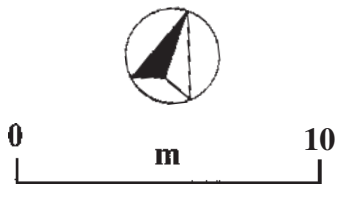


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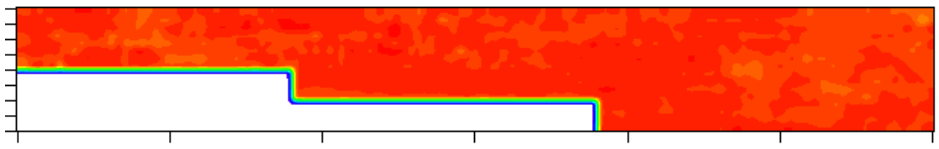
**Figure 5**

# APPLEBY
# Area A

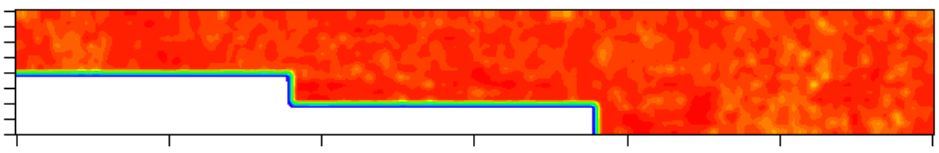
## GPR Time Slice Maps - 450MHz data

(No Background Removal)

0.00m - 0.15m



0.15m - 0.30m



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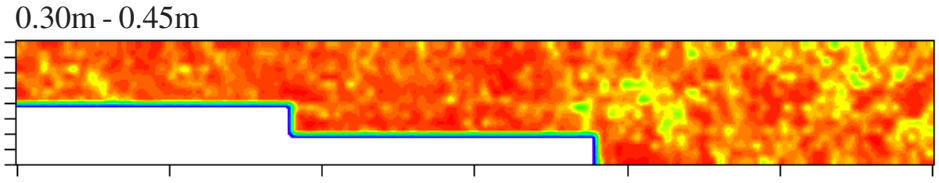
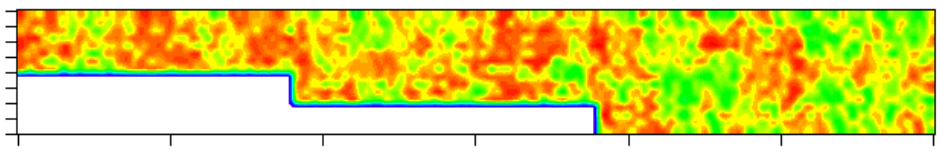
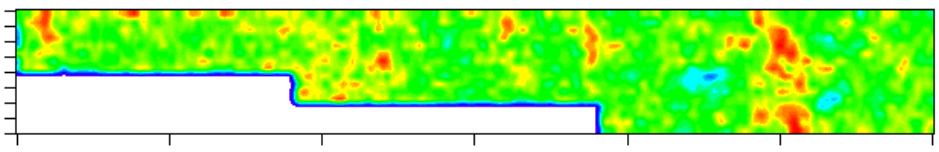


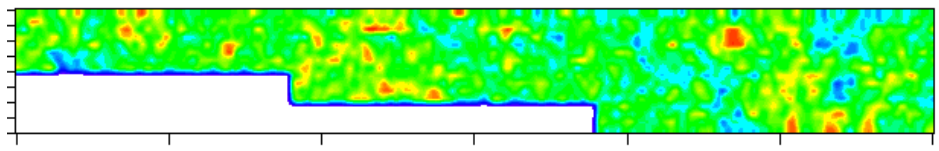
0.45m - 0.60m



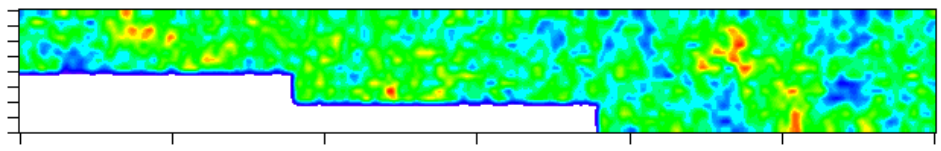
0.60m - 0.75m



0.75m - 0.90m



0.90m - 1.05m



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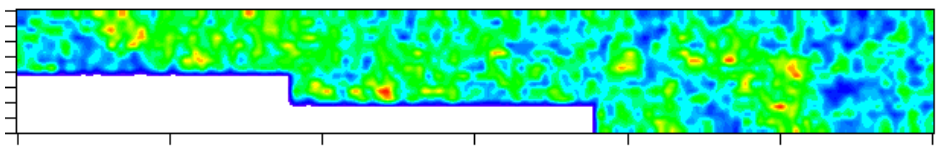

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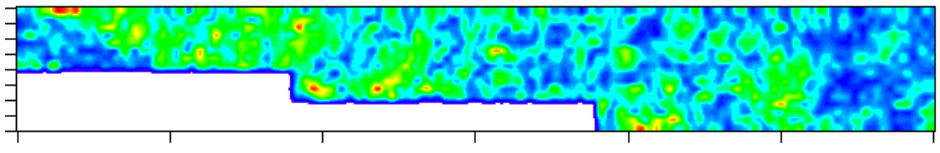

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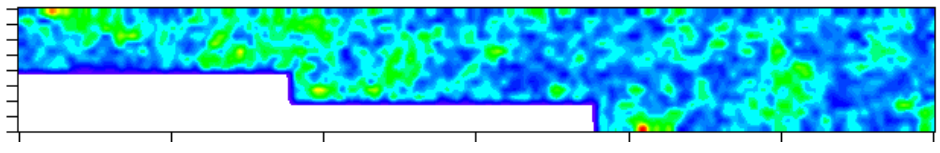

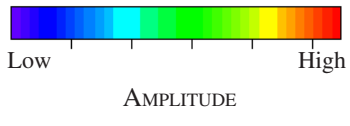


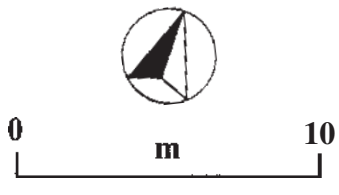


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**Figure 6**

# APPLEBY
# Area A

## Radargrams - 450MHz data

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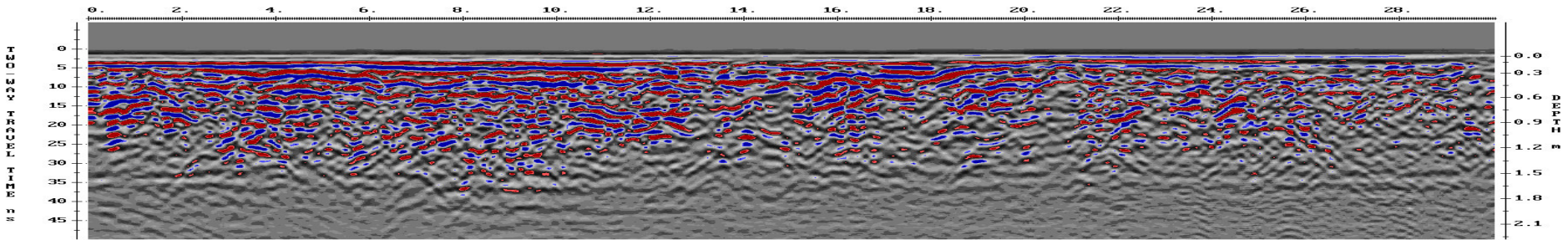


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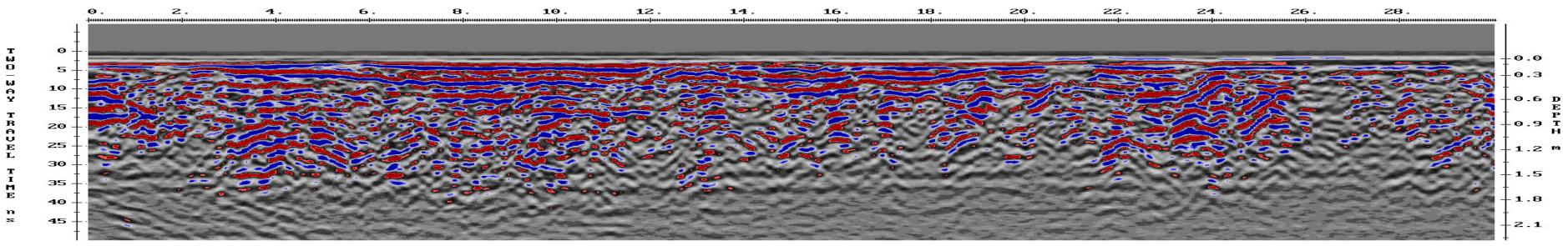


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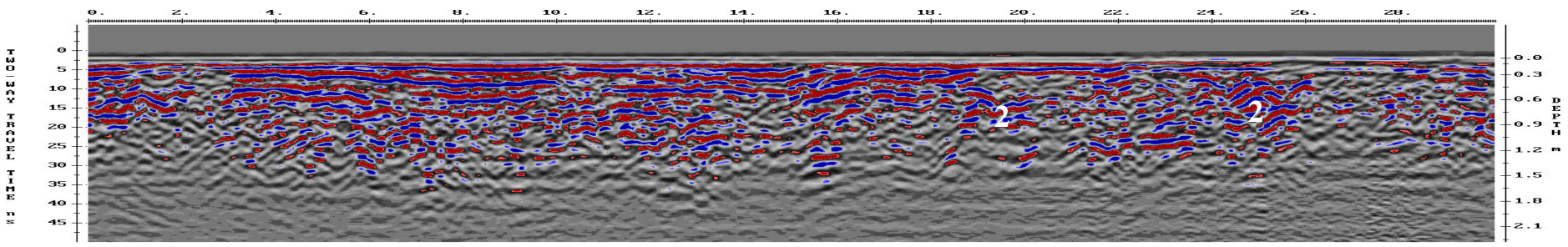


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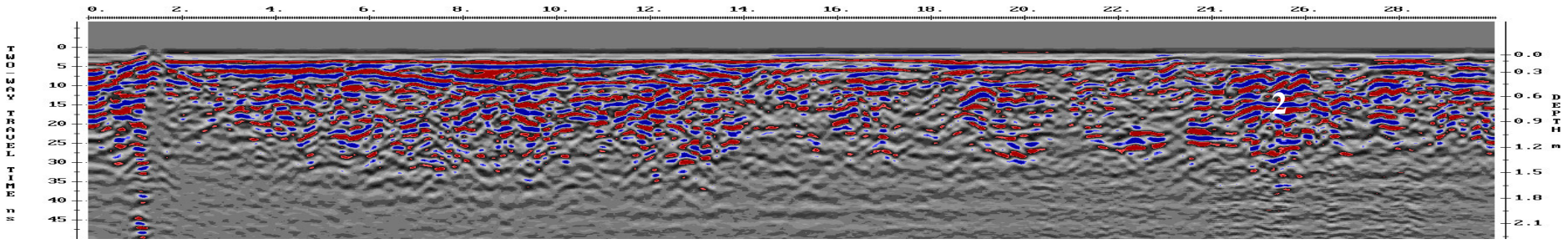


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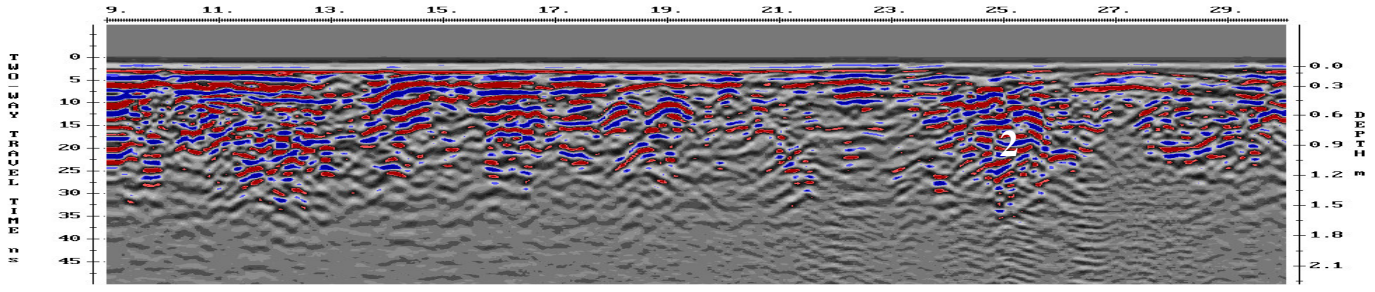



Line 28

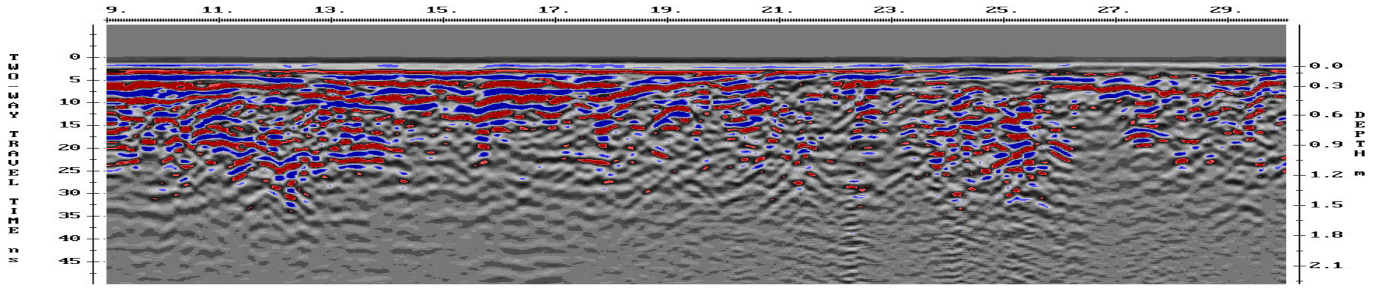


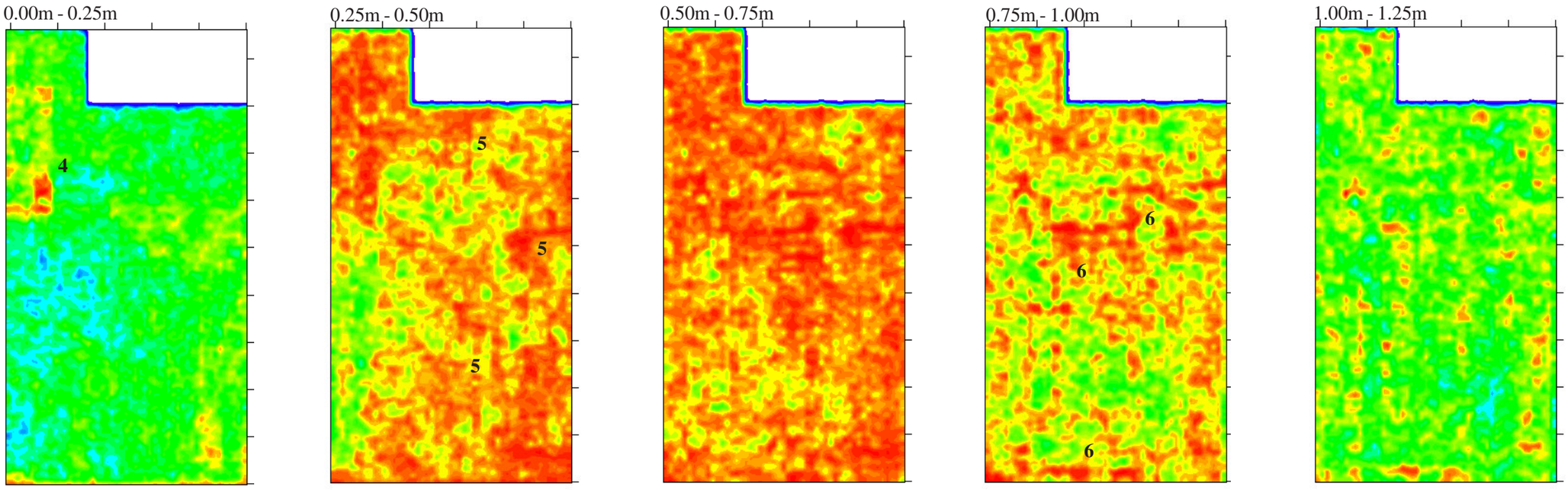



**Figure 7**

# APPLEBY
## Area B

## GPR Time Slice Maps - 225MHz data

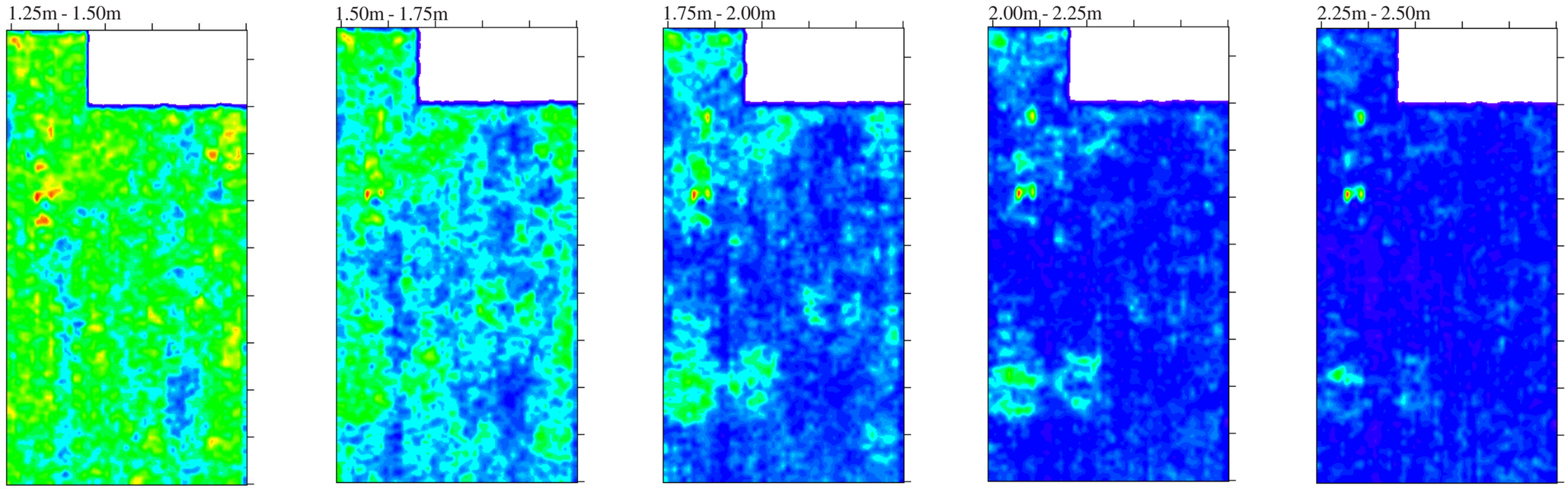
(With Background Removal)

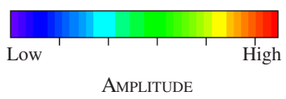


# APPLEBY
# Area B

## GPR Time Slice Maps - 225MHz data

(With Background Removal)



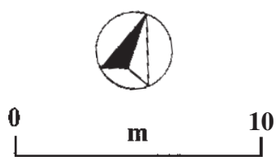



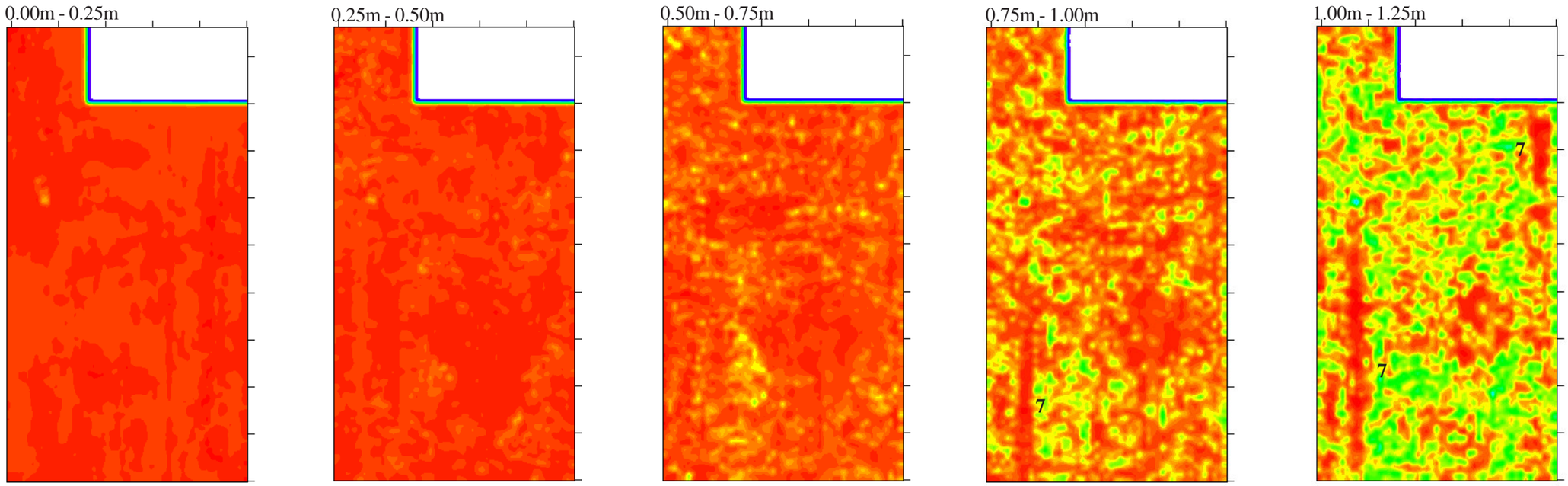



**Figure 9**

# APPLEBY
## Area B

## GPR Time Slice Maps - 225MHz data

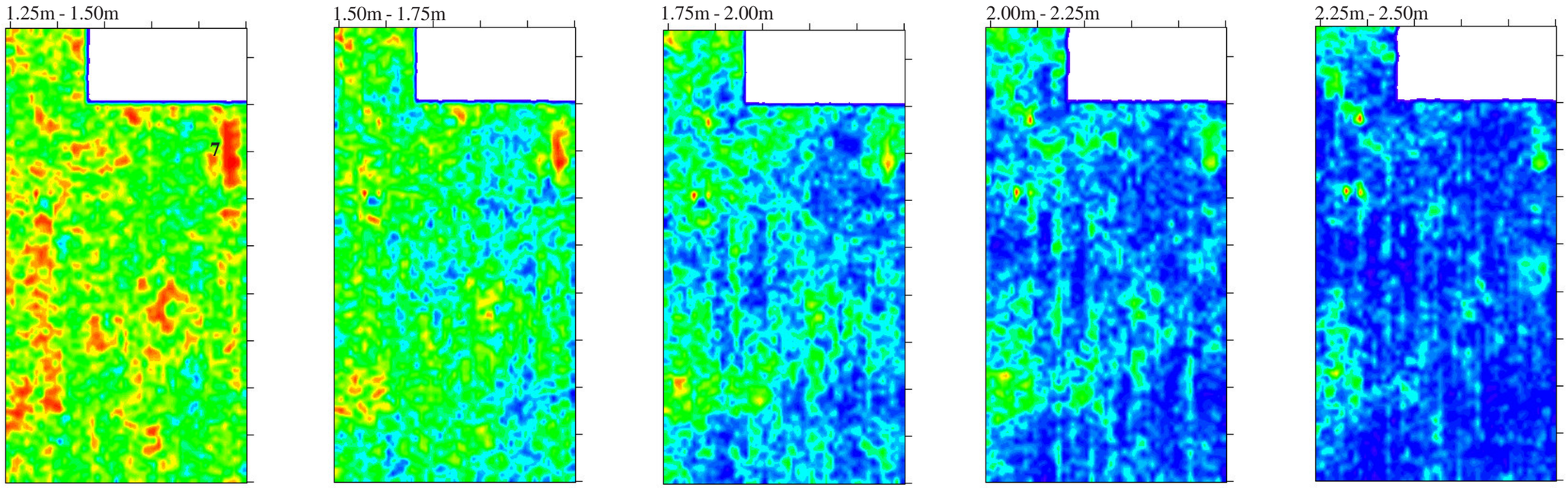
(No Background Removal)



# APPLEBY
# Area B

## GPR Time Slice Maps - 225MHz data

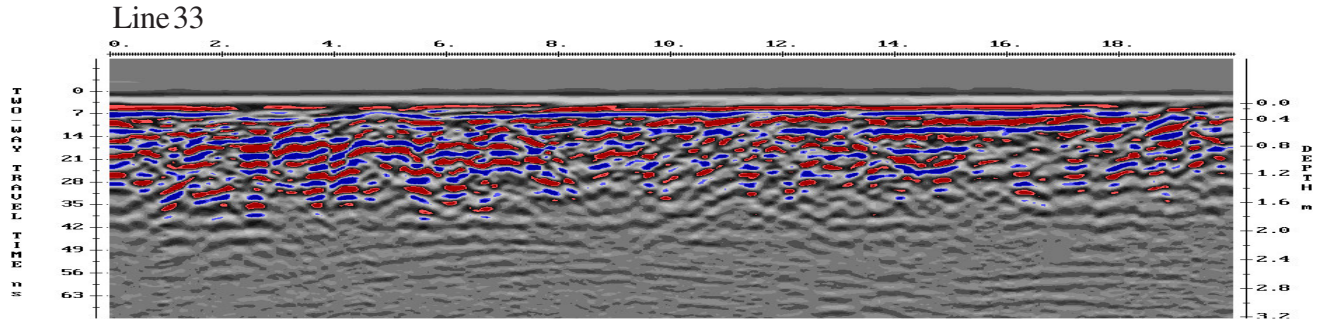
(No Background Removal)



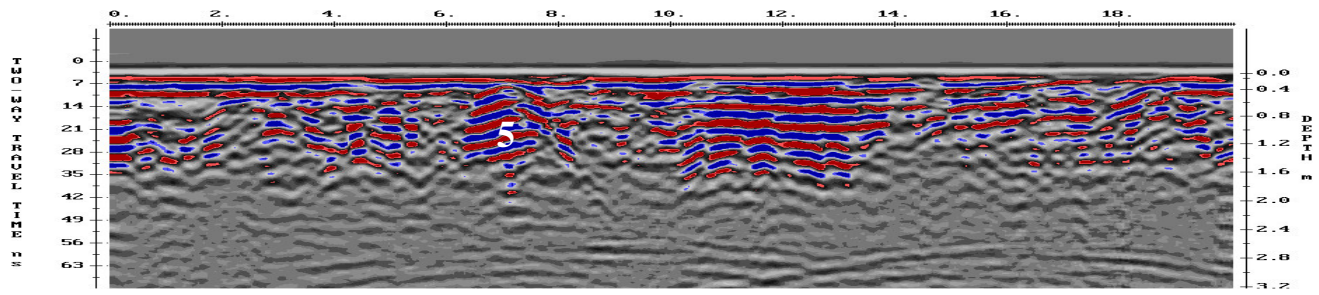
# APPLEBY
# Area B

## Radargrams - 225MHz data

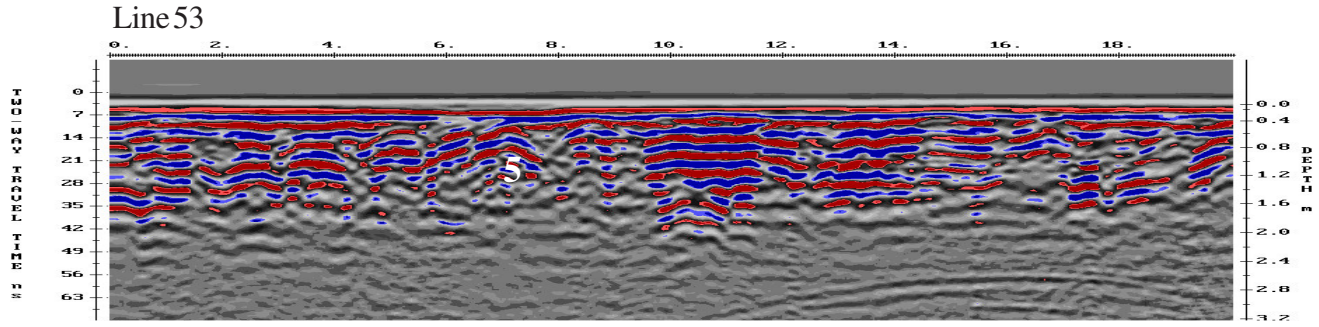
Line 33



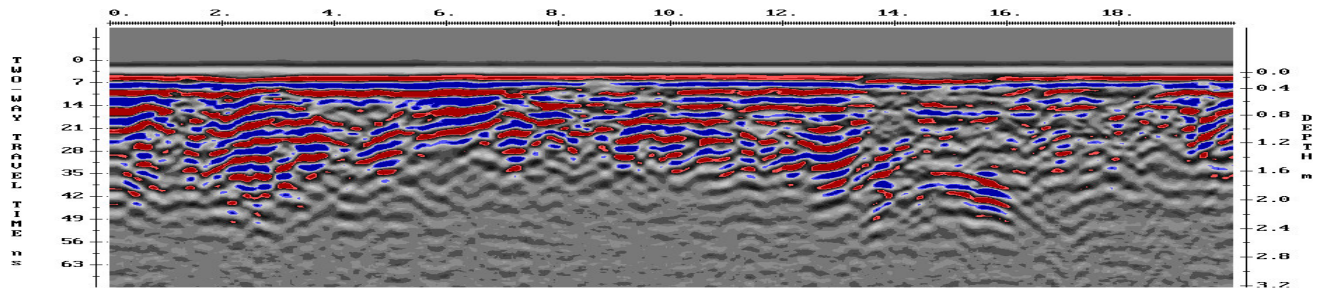

Line 43



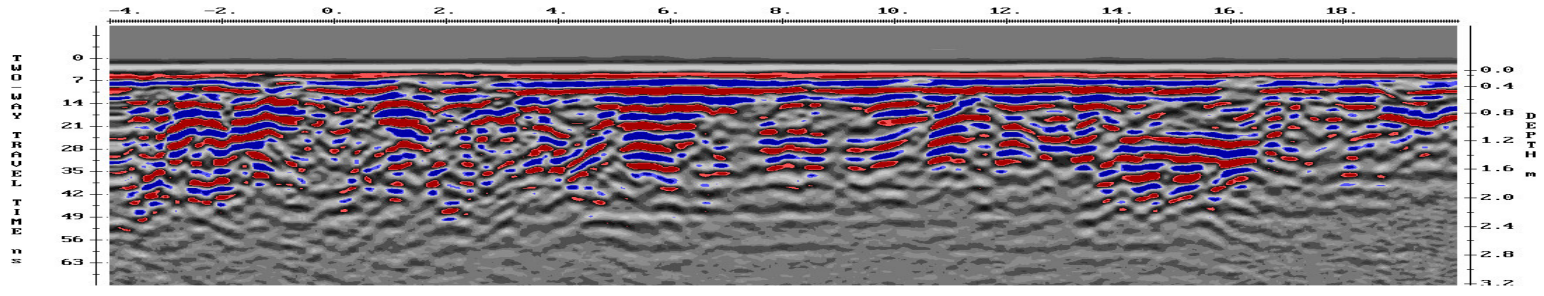

Line 53



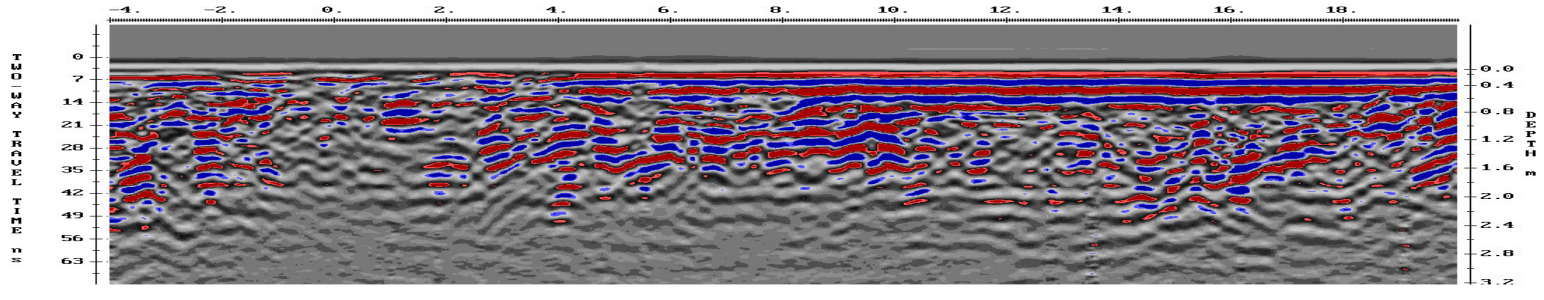

Line 63




Line 73



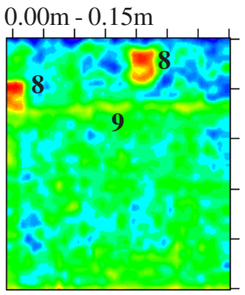

Line 83

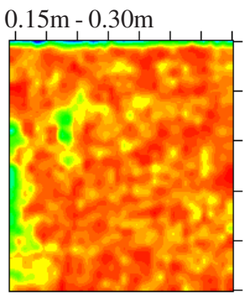


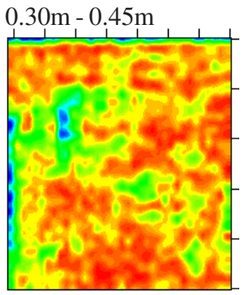
# APPLEBY
## Area C

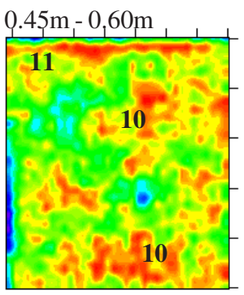
## GPR Time Slice Maps - 450MHz data

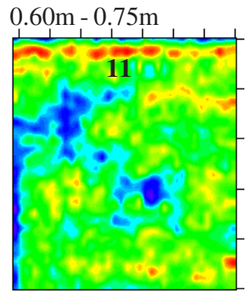
(With Background Removal)

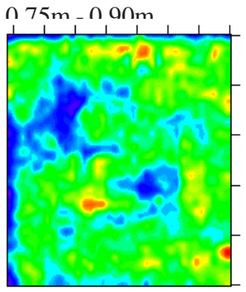


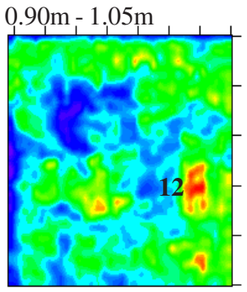



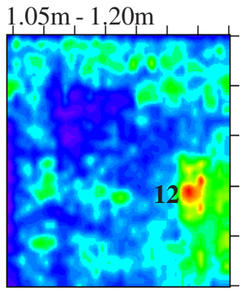



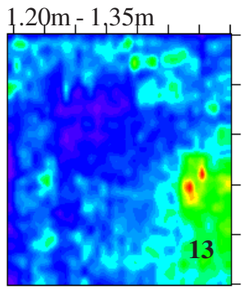



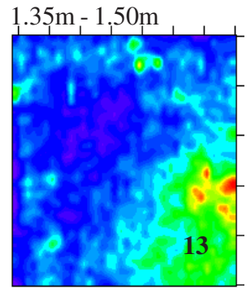



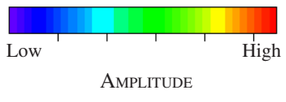



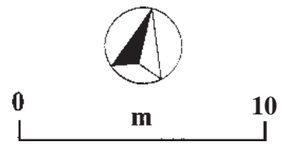



# APPLEBY
## Area C

## GPR Time Slice Maps - 450MHz data

(No Background Removal)

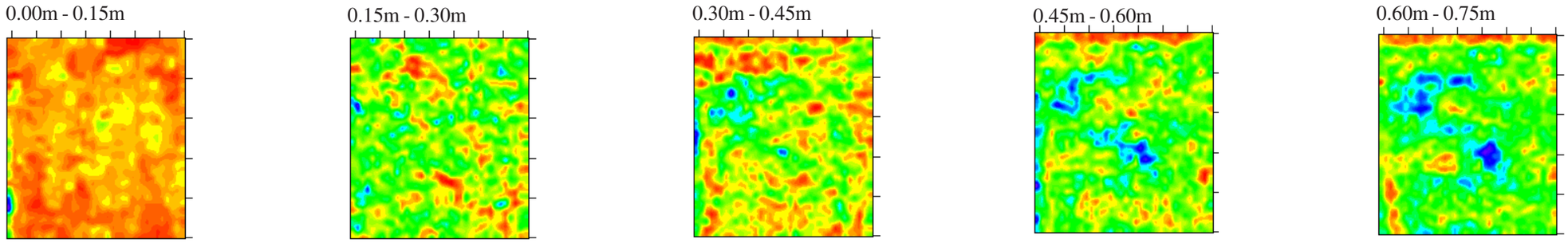



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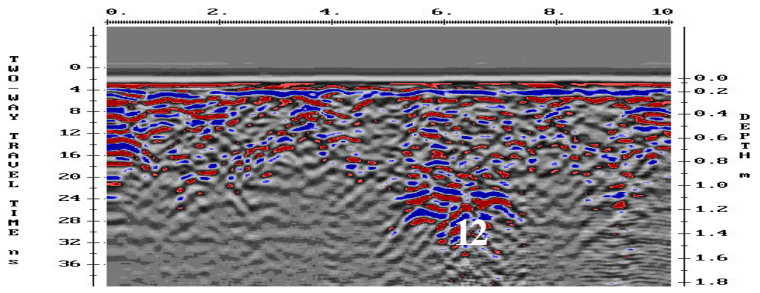
**Figure 14**

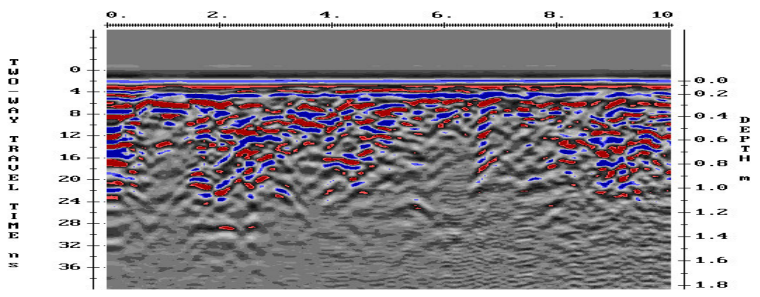
# APPLEBY
# Area C

## Radargrams - 450MHz data

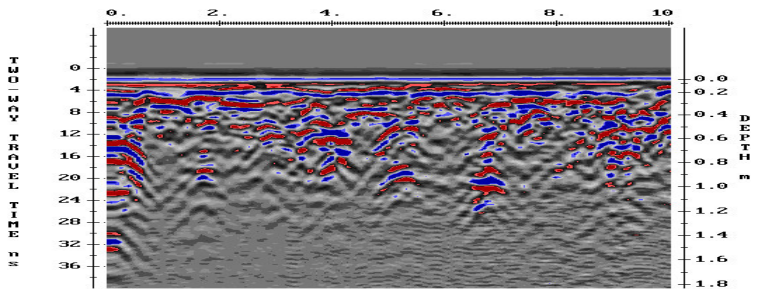
Line 90



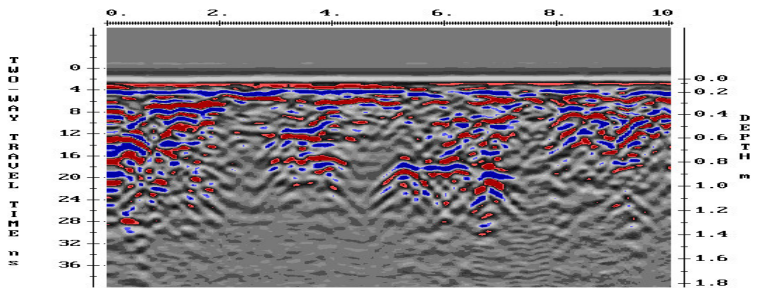

Line 95



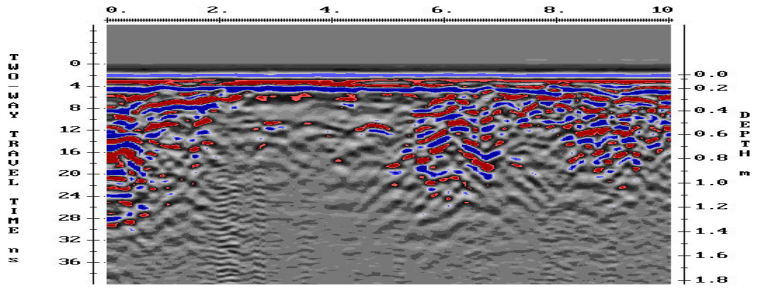

Line 100



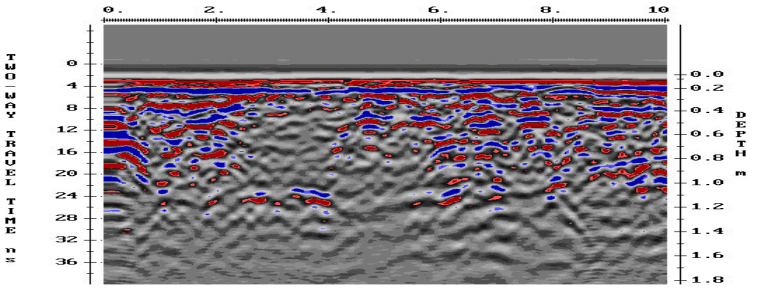

Line 105




Line 110



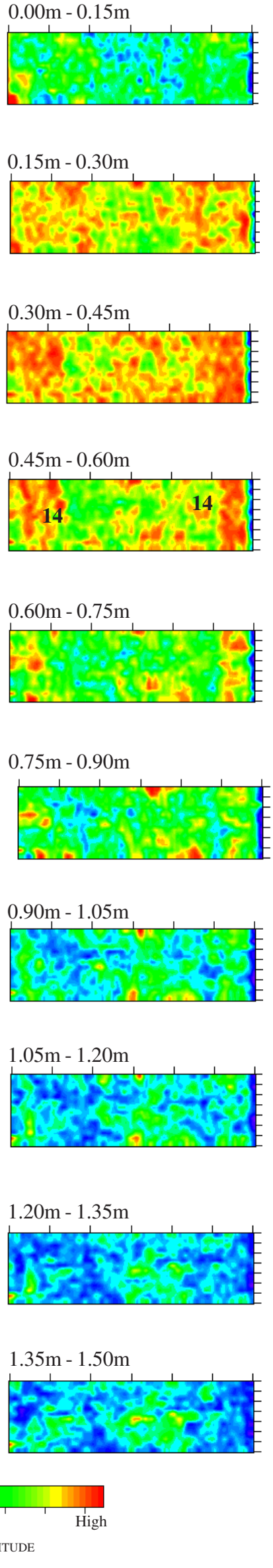

Line 115



# APPLEBY
# Area D

## GPR Time Slice Maps - 225MHz data

Background Removal




No Background Removal

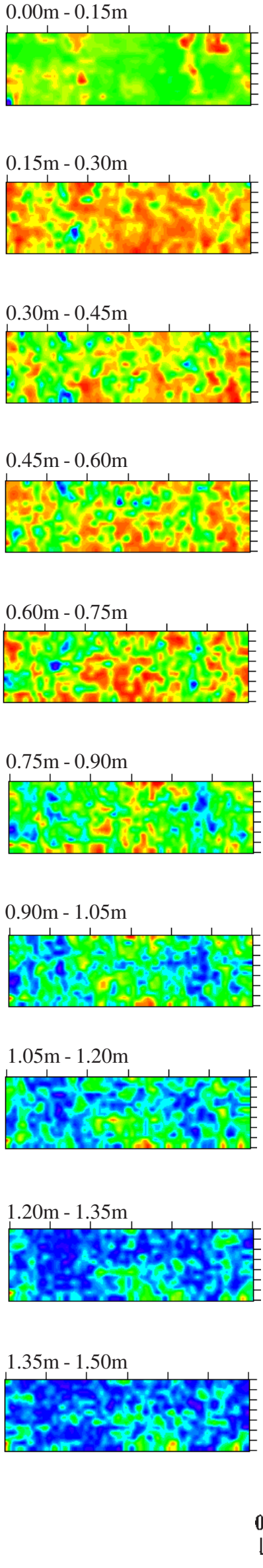



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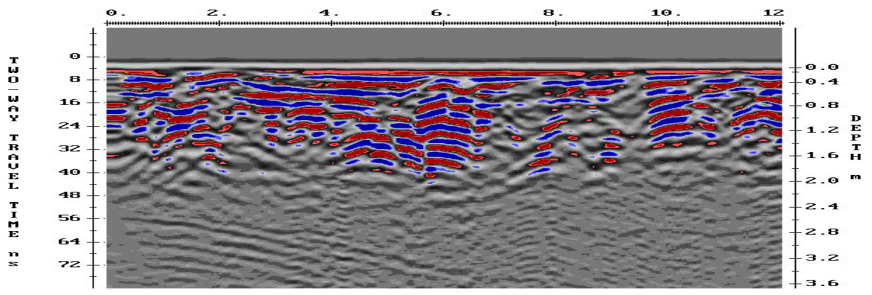
**Figure 16**

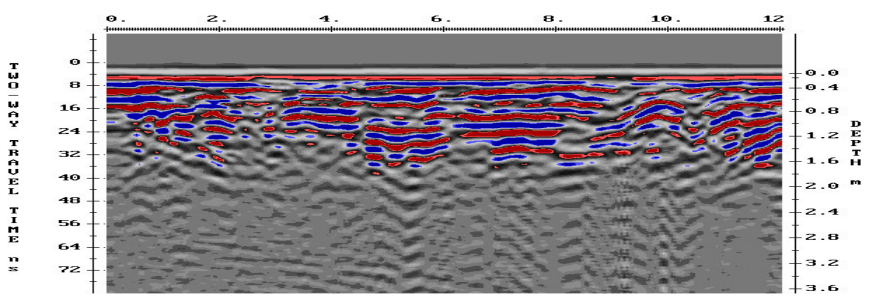
# APPLEBY
# Area D

## Radargrams - 225MHz data

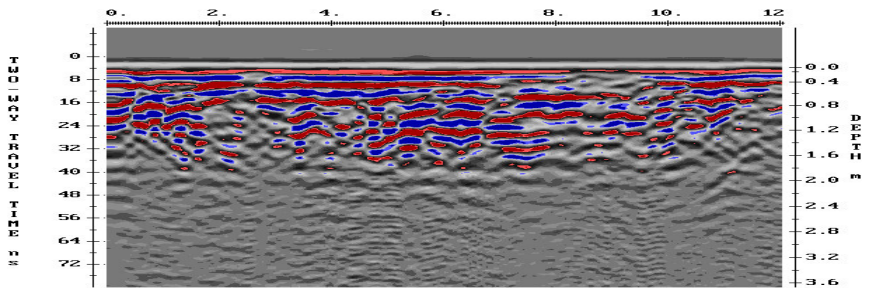
Line 135




Line 140

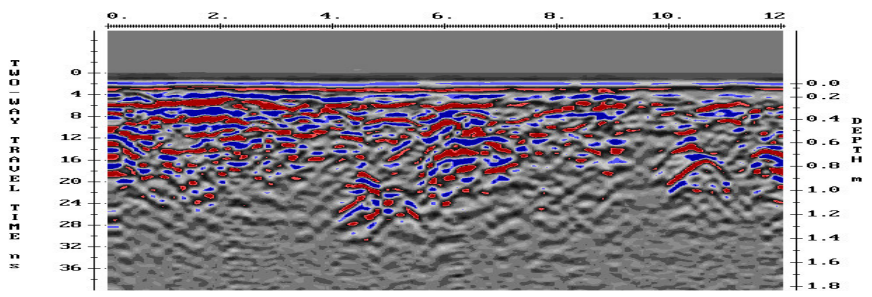



Line 145

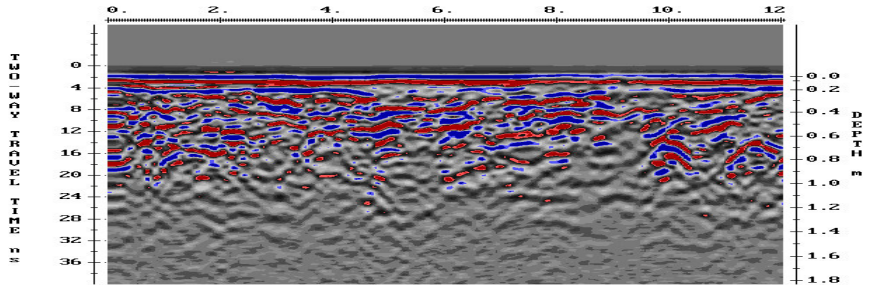



## Radargrams - 450MHz data

Line 120




Line 125




Line 130

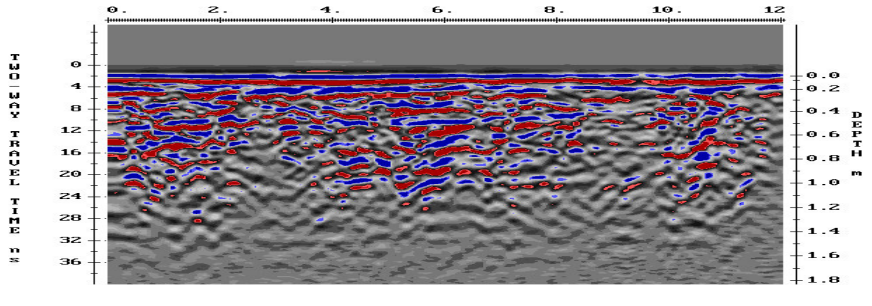


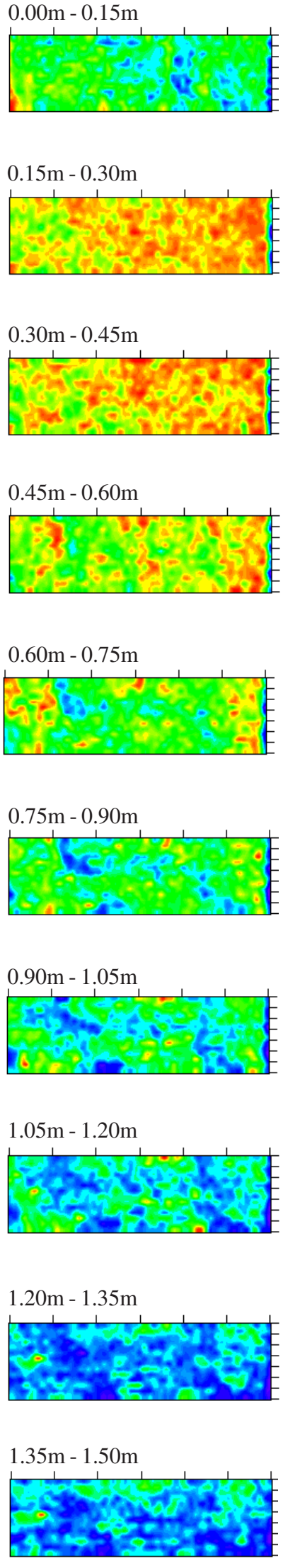



**Figure 17**

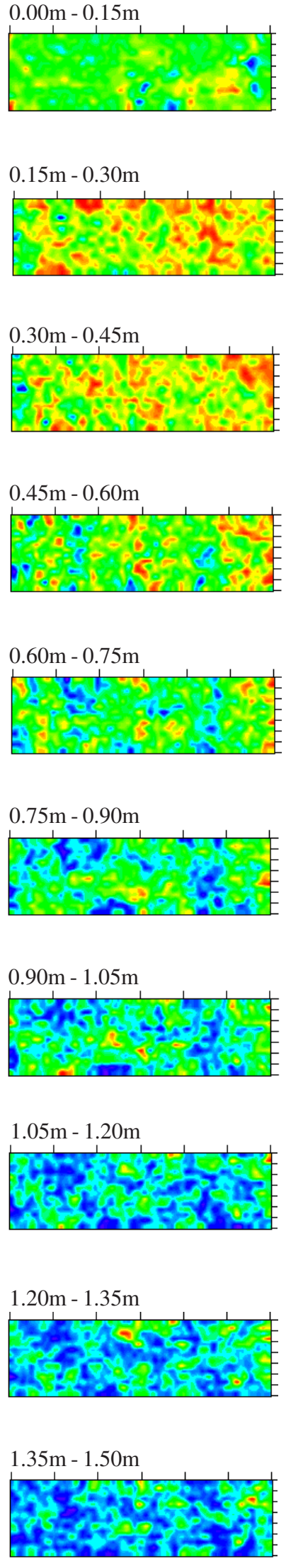
# APPLEBY
# Area D

## GPR Time Slice Maps - 450MHz data

Background Removal




No Background Removal



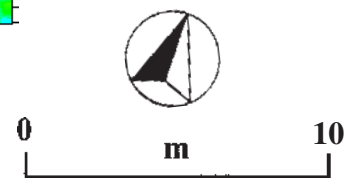




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**Figure 18**