



A Ground Penetrating Radar (GPR) Survey of the Smith College Physics Department

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Introduction

Students in the course EGR 390, a seminar on remote sensing, have been exposed to the basic operating principles and some use cases of remote sensing technologies such as lidar, sonar, radar, and ground penetrating radar. Students have also read and discussed complex published journal articles detailing more advanced remote sensing applications and techniques. With this background, students are prepared to design and carry out their own survey or experiment that can be carried out with the Smith College Engineering Department ground penetrating radar equipment. The purpose of this report is to detail the methods and results of one such project.

Motivation

Scientific research labs can have a significant effect on the physical spaces they occupy. That can include cosmetic changes, such as wiring/ventilation renovations or furniture rearrangement. However, it can also include significant structural changes. Heavy equipment often requires a minimum thickness of concrete for support, and sometimes equipment must be partially buried or routed in the floor of a lab. The structural construction of a space can provide information about its current or past usage. McConnell Hall, home of the Smith College Physics Department, opened in 1967. Ground-penetrating radar (GPR) scans of the department's spaces could reveal interesting historical information about previous space usage and building practices in the 1960s.

Purpose and Scope

This project includes a ground penetrating radar survey of 3 rooms used by the Smith College Physics Department in McConnell Hall. Rooms included in the survey consist of room 206, a current research lab; room 201, a current teaching lab; and room 203/204, a current classroom. All rooms surveyed are located on the same floor of McConnell Hall. Preparation work for the project included interviews with long-standing members of the physics department on the history of space usage in McConnell Hall, comparison of current and original building floor plans to select survey candidates, and coordination with physics professors to obtain permission to survey the spaces in which they work. Fieldwork included 4-5 free-running GPR scans per room using a 900MHz antenna, prioritizing resolution over depth. The scope of the project was limited by only scanning three rooms on one floor, by not moving significantly heavy equipment to carry out scans, and by only surveying one building.

Site Conditions

Fieldwork was conducted indoors, in a heated building. Each surveyed site is in current use by the physics department, and contained furniture and equipment at the time of surveying. Room 206 is a research lab containing heavy equipment, and is also used for storage. It contained several lab tables, rolling chairs, and a filing cabinet. It had very little open floor space. Room 201 is a teaching lab containing light equipment, though it historically has also contained heavy equipment. It contained lab benches with oscilloscopes and function generators and rolling chairs. It had distinct aisles of open floor space. Room 203/204 is a single classroom that was originally two separate rooms, a storage room and a prep room. It contained classroom tables with computers and rolling chairs. It had the most open floor space of the three rooms surveyed.

Summary of Fieldwork Completed

At each survey site, the start and end points of each scan were marked with tape and labeled with a number and an arrow indicating scan direction. Each free-running scan was completed one after another with one person pushing a cart with a laptop and power source, one person pushing the 900MHz antenna at a steady rate across the floor, and a third person timing the duration of the scan. After all free-running scans were completed, a laser rangefinder was used to measure the length traveled for each scan, the position of the scan's start point relative to nearby walls, and the dimension of the room. More information on field work can be found in Appendix A.

Table 1. Survey details

Survey site	Equipment used	Measurement type	Measurements taken
room 206	GPR unit, 900MHz antenna	free-running GPR scan	4
"	phone stopwatch	scan duration	4
"	laser rangefinder	scan length	4
"	"	scan start point location	8
"	"	room dimensions	4
room 201	GPR unit, 900MHz antenna	free-running GPR scan	4
"	phone stopwatch	scan duration	4
"	laser rangefinder	scan length	4
"	"	scan start point location	8
"	"	room dimensions	2
room 203/204	GPR unit, 900MHz antenna	free-running GPR scan	5
"	phone stopwatch	scan duration	5
"	laser rangefinder	scan length	5
"	"	scan start point location	10
"	"	room dimensions	2

Table 1 summarizes the data collected at each survey site. For each room surveyed, the same equipment was used to collect the same types of measurements. However, depending on the size and configuration of the room, different numbers of scans and different dimension measurements were taken.

Summary of Data Collected

This survey was mainly qualitative in nature rather than quantitative. The most significant data collected consisted of GPR images. Scan locations, lengths, and durations were recorded, but not used in this project's analysis. Instead, GPR images were examined for significant features, such as rebar and pipes. The 900MHz antenna used is best for detail rather than depth, so only the first 10ns of data were examined. Features or patterns at depths greater than 10ns were assumed to be false detections.

Table 2. Data details

Survey site	Scan #	Location	Direction	Features / Notes
room 206	1	South wall	East	Rebar entire scan, 4ns
"	2	East wall	North	Rebar entire scan, 4ns
"	3	North wall	West	Rebar entire scan, 4ns
"	4	West wall	South	Rebar entire scan, 4ns
room 201	1	Center	South	Possible rebar at start and end of scan, 4ns. No rebar most of scan
"	2	South third	East	Rebar entire scan, 4ns
"	3	Center	North	Bad scan; unusable
"	4	North third	West	Rebar entire scan, 4ns
room 203/204	1	Center	East	Rebar at start and end of scan, 4ns. Pipes in center of scan, 4ns
"	2	East wall	North	Rebar entire scan, 4ns
"	3	North wall	West	Rebar at start and end of scan, 4ns. Regular parabolic features between pipes and rebar, 4ns. Pipes in center of scan, 4ns
"	4	West wall	South	Bad scan; unusable
"	5	South wall	East	Rebar at start and end of scan, 4ns. Regular parabolic features between pipes and rebar, 4ns. Pipes in center of scan, 4ns

Table 2 summarizes the GPR images collected from free-running scans at each survey site. Each site included some rebar. Room 201 included additional features, such as pipes and unidentified parabolic features. Out of thirteen total scans, two produced images that were not usable. All GPR images collected can be found in Appendix B along with annotated features.

Primary Findings

Data processing showed rebar present in the foundations of all three rooms surveyed. Room 206 had visible rebar across its entire length and width, indicating a lot of reinforcement in its foundation. It did not display any additional significant features. Room 201 had visible rebar across its width in the middle of the floor. It did not have any visible rebar down the center of its length. The edges of the room were not accessible to scan. Room 203/204 had visible rebar across its entire length. It had visible rebar across most of its width, with pipes visible in the center of width scans. The pipes were indicated by larger parabolic features with a characteristic ringing pattern. Width scans also showed unknown parabolic features interrupting the rebar. These features could be a side-profile scan of additional pipes, or some other irregularity in the foundation, such as cracked concrete or additional embedded materials.

Conclusions

The scope of this project was not great enough to draw conclusions about structural differences between different spaces and how that may correspond to their uses in the physics department. Interviews with faculty members suggest that there are few structural differences between rooms. In particular, faculty recalled extremely heavy equipment being moved between spaces with no concerns raised as to the structural soundness of one space versus another. To thoroughly examine this idea, scanning more rooms (including rooms on the third floor as well as the second floor) and scanning rooms in a more modern building could be included in a future project.

The data suggest that there could be structural differences between rooms in different parts of the building. It shows that the amount of reinforcement and rebar varies from room to room, with rooms on the edges of the building possibly containing more rebar in their foundations. Plumbing runs through more central rooms. This survey does provide some information about how McConnell Hall was built in the 1960s, and what kind of shape its foundations are in today.

Acknowledgements

I would like to acknowledge the assistance and support I received from the Clark Science Center, the Smith College Physics Department, and the Smith College Engineering Department in completing this project. In particular, Tom Richardson provided current building plans of McConnell Hall and valuable historical information on the original building plan. Dr. Nalini Easwar provided an interview, a candid history of the physics department, and insightful guidance in developing this project. Dr. Doreen Weinberger provided an interview and an informative tour of the physics department spaces in McConnell Hall. Ellie Martin-Eberhardt provided access to survey sites and measurement assistance during fieldwork. Dr. Aaron Rubin provided assistance with the ground penetrating radar equipment as well as feedback and support throughout this project.

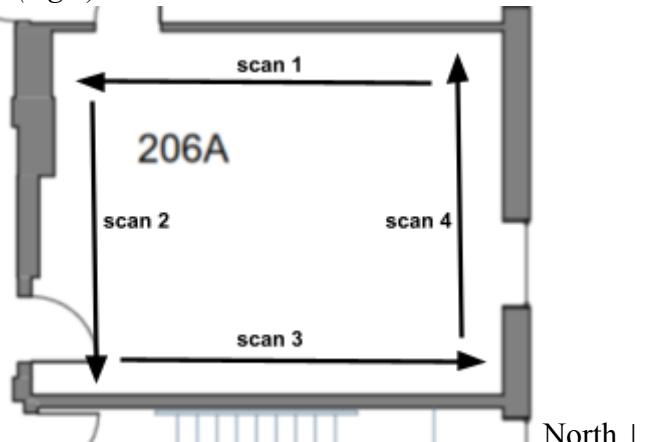
Appendix A: Field Report

Detailed Field Log

Date: Thursday December 1st
Location: McConnell Hall 2nd floor
Purpose: Collect ground penetrating radar scans of McConnell spaces
Equipment: GPR unit; laser rangefinder; masking tape; phone stopwatch;

Site: Room 206

Figure 1. Room 206 (left) and scanning pattern (right). North is indicated.



3:06 Finished marking planned scan locations
3:10 GPR power connected and computer turned on
3:15 Began scans of 206

Table 3. Quantitative data collected in room 206

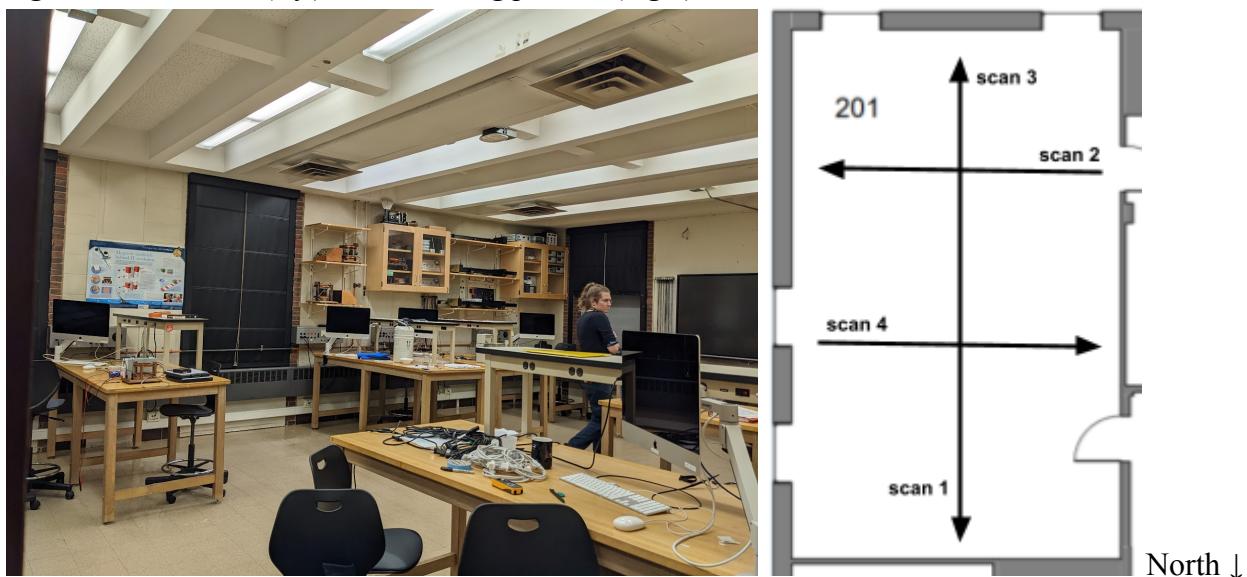
Scan	Duration (s)	Length (m)	Distance from scan start point to ___ wall (m)	Distance from scan start point to ___ wall (m)
1	18.18	4.545	West; 1.194	South; 1.177
2	10.3	3.893	South; 0.322	East; 0.506
3	18.71	4.556	East; 0.827	North; 1.714
4	10.41	2.734	North; 0.937	West; 1.150

Room 206 dimensions: 5.025m x 6.532m; 5.025m x 6.441m; 5.025m x 6.249m

3:27 Move to next location

Site: Room 201

Figure 2. Room 201 (left) and scanning pattern (right). North is indicated.



- 3:35 Finished marking planned scan locations
3:38 GPR power connected and computer turned on
3:40 Began scans of 201

Table 4. Quantitative data collected in room 201

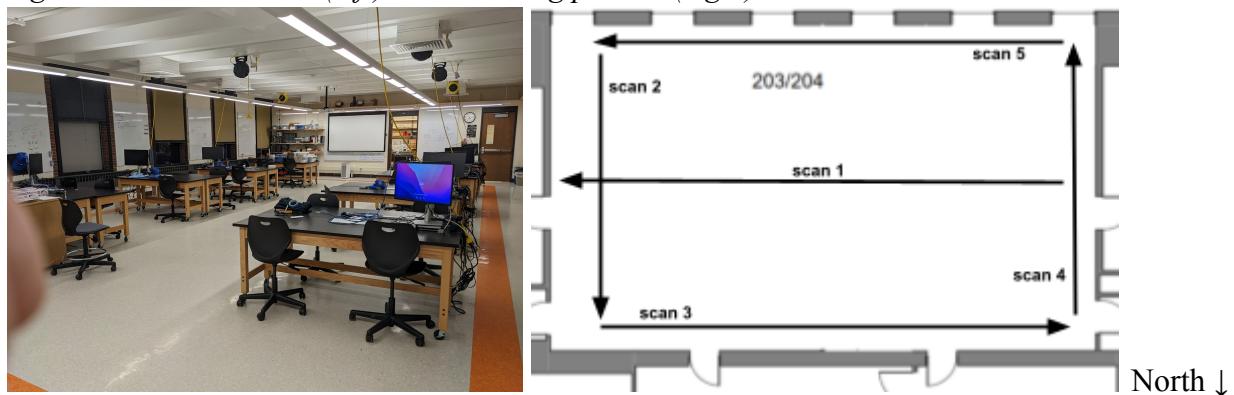
Scan	Duration (s)	Length (m)	Distance from scan start point to ____ wall (m)	Distance from scan start point to ____ wall (m)
1	27.11	9.579	North; 0.637	West; 3.173
2	20.22	5.478	West; 0.435	South; 2.466
3	28.19	9.579	North; 0.637	West; 3.173
4	18.89	5.696	East; 0.416	North; 4.464

Room 201 dimensions: 10.634m x 6.549m

- 3:52 Move to next location

Site: Room 203/204

Figure 3. Room 203/204 (left) and scanning pattern (right). North is indicated.



3:59 Finished marking planned scan locations
4:00 GPR power connected and computer turned on
4:03 Began scans of 203/204

4:13 Scans complete

Table 5. Quantitative data collected in room 203/204

Scan	Duration (s)	Length (m)	Distance from scan start point to ____ wall (m)	Distance from scan start point to ____ wall (m)
1	35.39	14.015	North; 4.563	West; 0.466
2	22.46	7.92	North; 0.611	West; 1.072
3	41.62	12.08	West; 1.076	South; 0.439
4	19.83	7.62	South; 0.428	East; 1.069
5	33.66	12.562	East; 1.284	North; 0.609

Room 203/204 dimensions: 14.926m x 8.967m

4:15 Began measuring scan distances and locations at each site

To measure distances, a laser rangefinder was used. It was placed on the ground, with the back of the instrument corresponding to the start of the measured distance. The laser was aimed at a solid target--either a cardboard box or a wall at the other end of the distance. Room dimensions were measured from the center of the relevant walls where possible.

Figure 4. Distance measurement with the laser rangefinder.



Appendix B: Annotated GPR Images

Figure 5. Room 206, scan 1

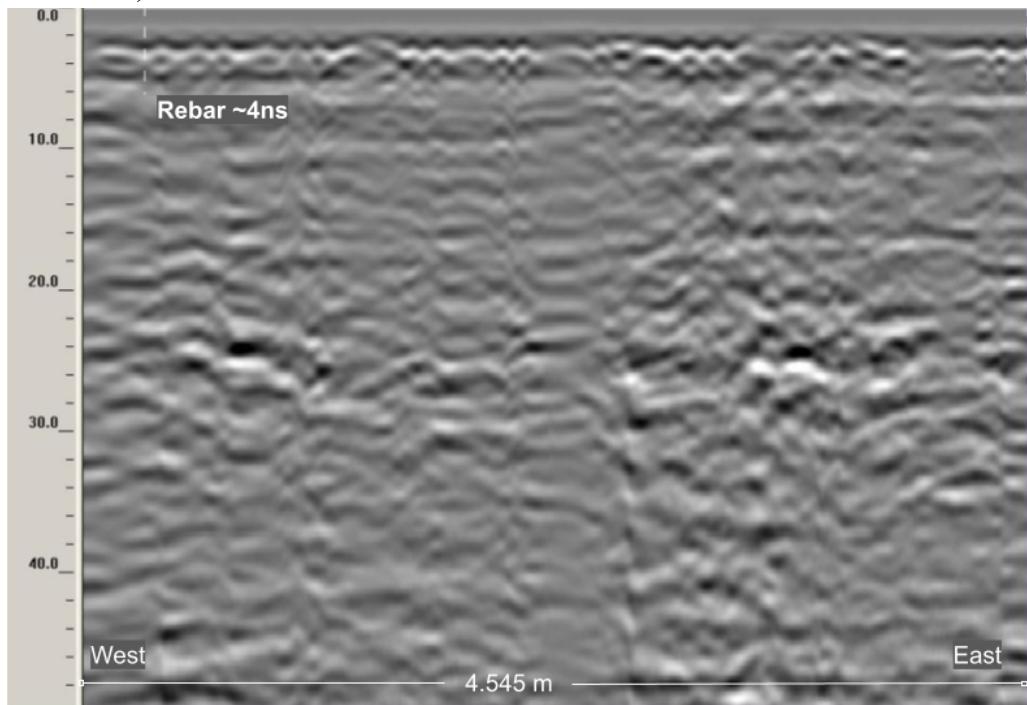


Figure 5 is of a West-East scan in room 206, spanning 4.545 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 6. Room 206, scan 2

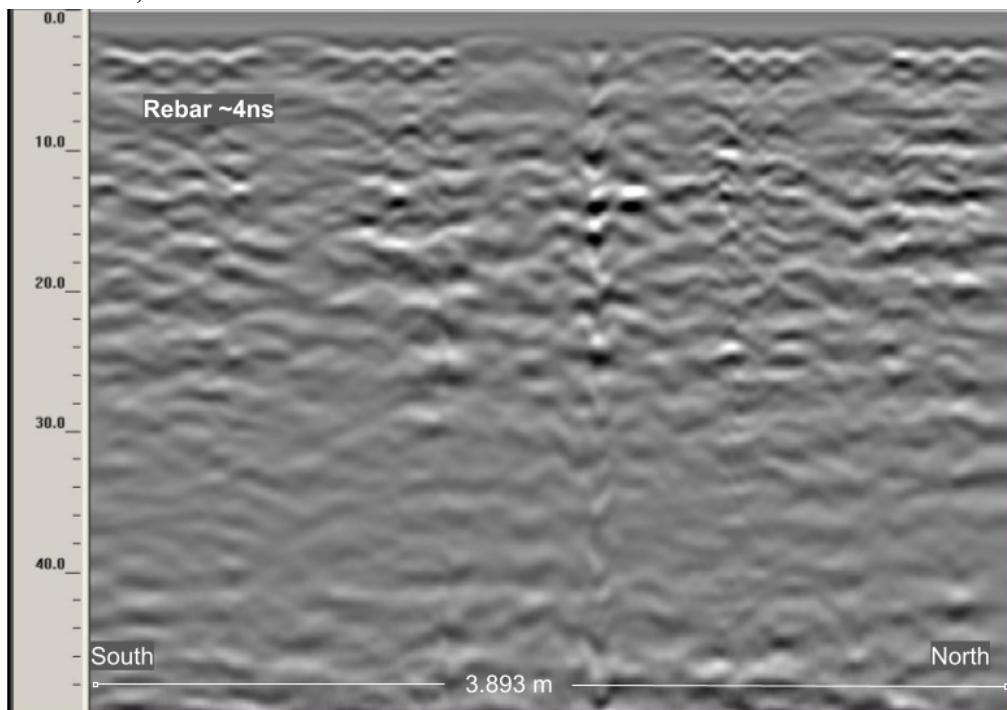


Figure 6 is of a South-North scan in room 206, spanning 3.893 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 7. Room 206, scan 3

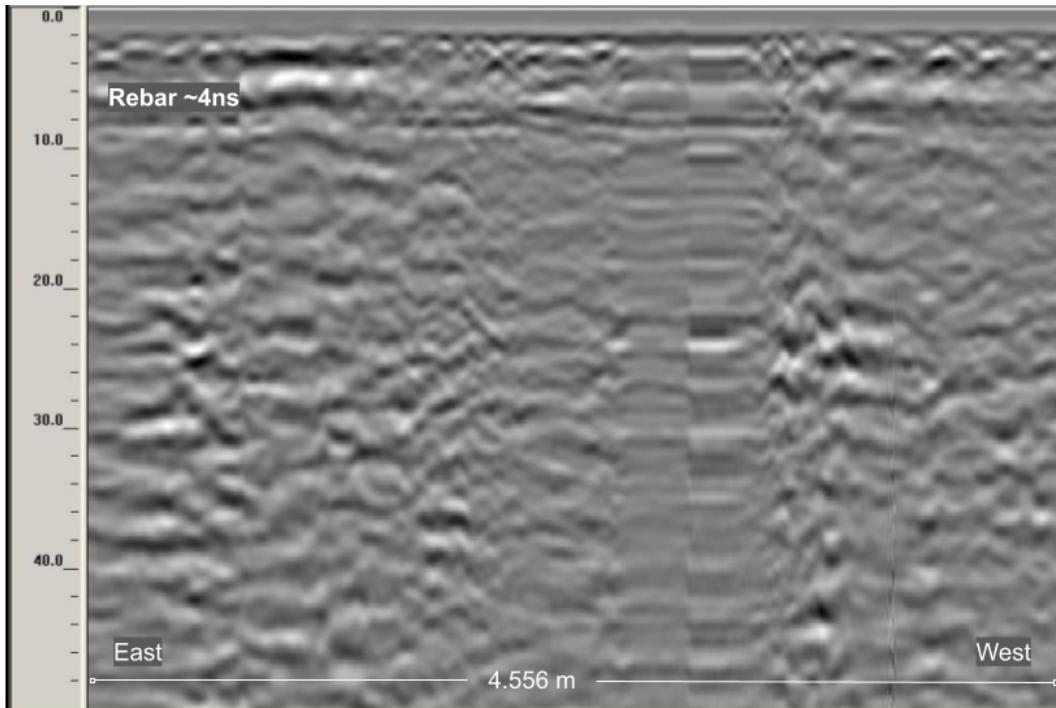


Figure 7 is of an East-West scan in room 206, spanning 4.556 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 8. Room 206, scan 4

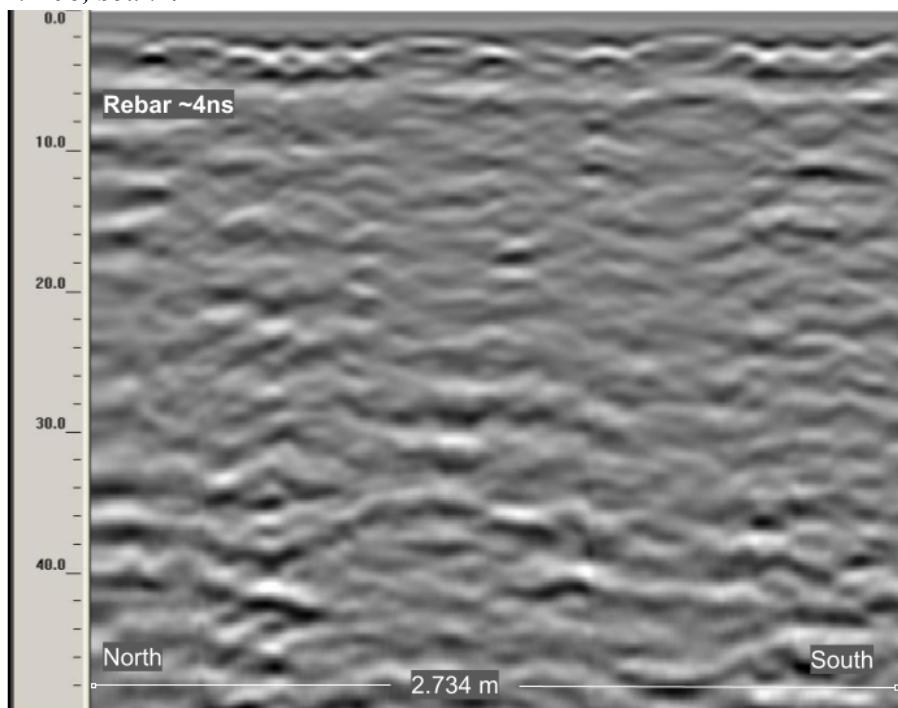


Figure 8 is of a North-South scan in room 206, spanning 2.734 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 9. Room 201, scan 1

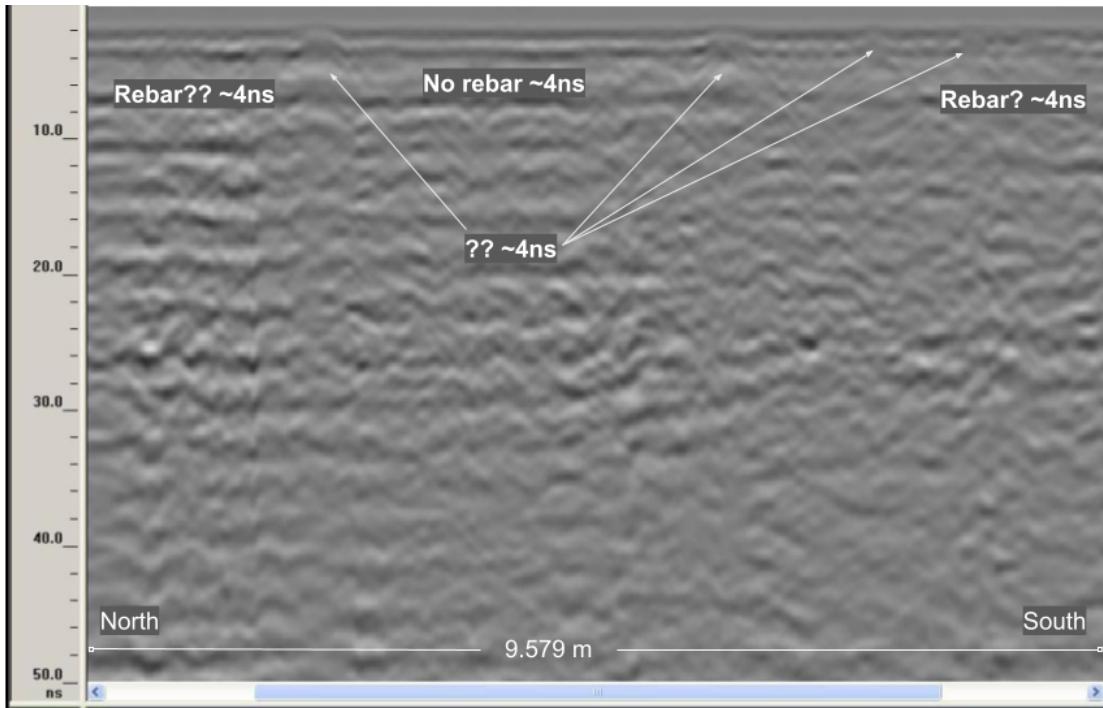


Figure 5 is of a North-South scan in room 201, spanning 9.579 meters. It shows possible rebar across the beginning and end of the scanned length at a depth corresponding to about 4 nanoseconds. In the center of the scanned length, there is no rebar. There are a few parabolic features that interrupt the sections of rebar--possibly pipes in side-profile, or sections of cracked concrete.

Figure 10. Room 201, scan 2

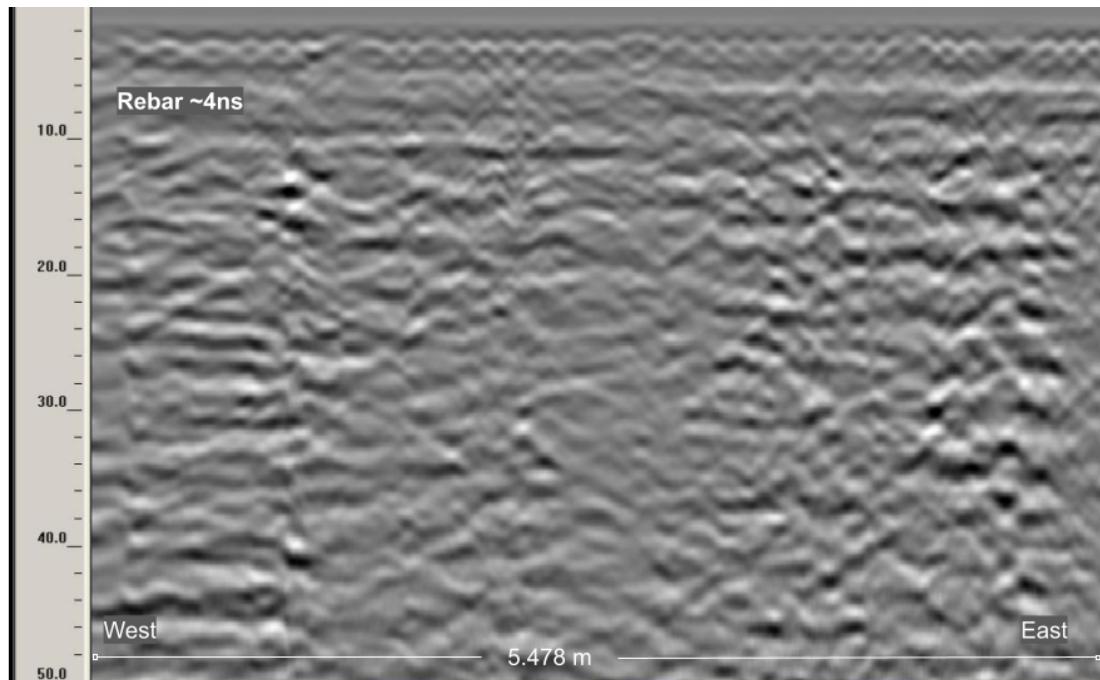


Figure 10 is of a West-East scan in room 201, spanning 5.478 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 11. Room 201, scan 3

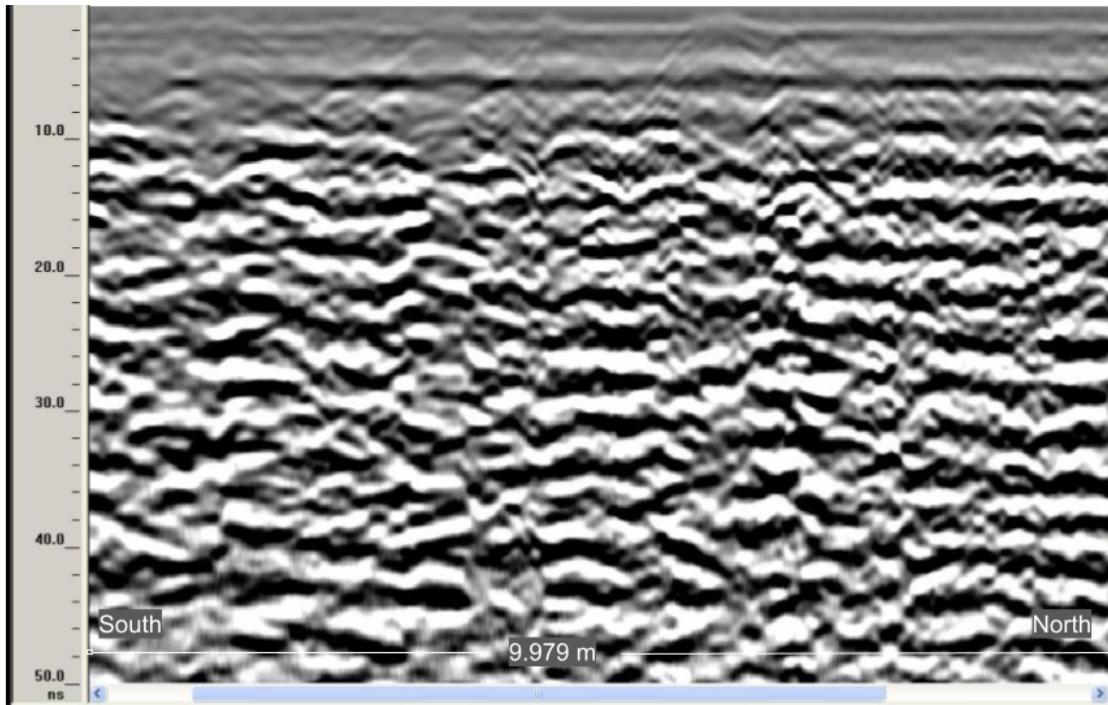


Figure 11 is of a South-North scan in room 201, spanning 9.979 meters. It shows an extreme dielectric constant at depths corresponding to greater than 10 nanoseconds, indicating that the scan was not performed adequately--likely the antenna was not fully in contact with the ground. This is not a usable scan.

Figure 12. Room 201, scan 4

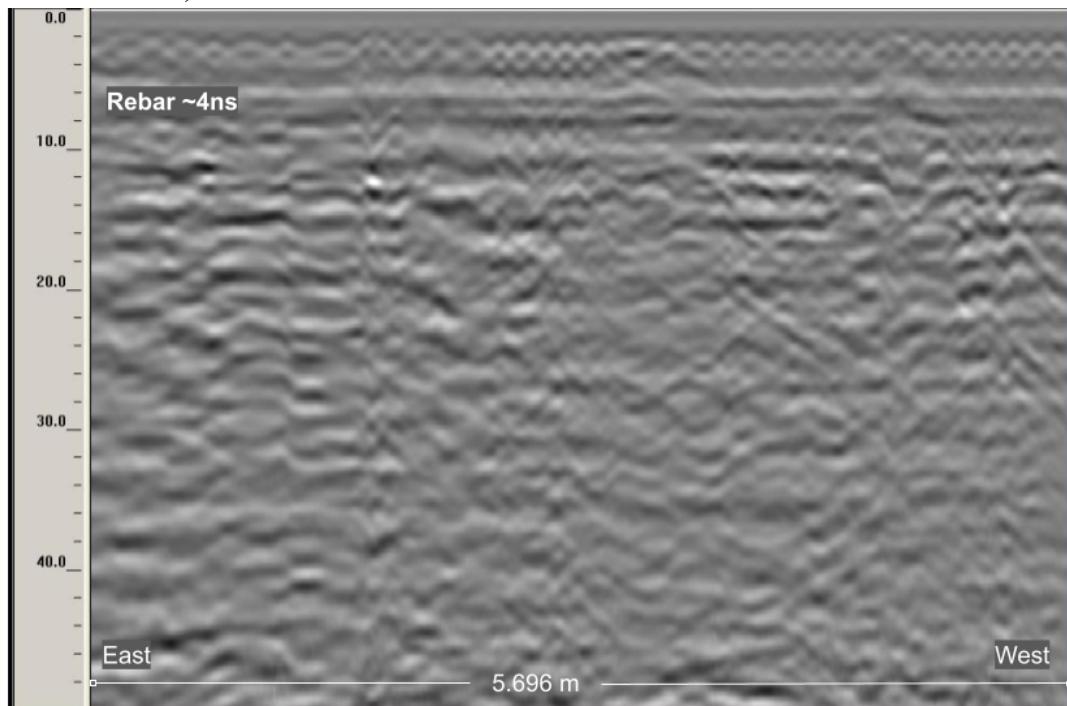


Figure 12 is of an East-West scan in room 201, spanning 5.696 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 13. Room 203/204 scan 1

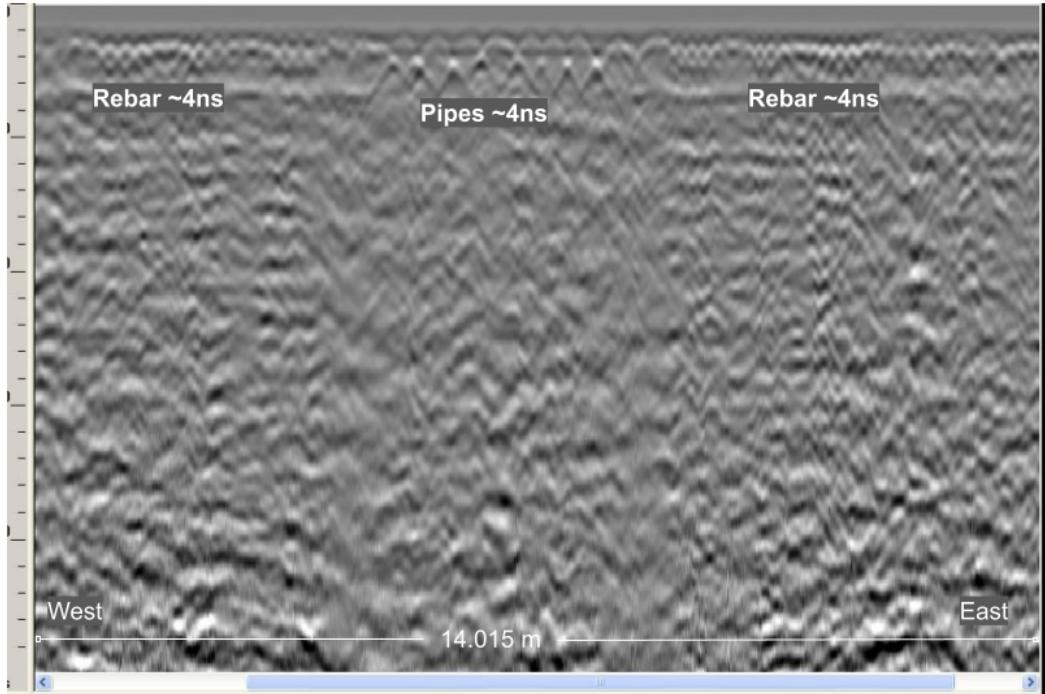


Figure 13 is of a West-East scan in room 203/204, spanning 14.015 meters. It shows rebar across the start and end of the scanned length at a depth corresponding to about 4 nanoseconds. In the center of the scanned length, there are larger parabolic features with ringing patterns indicative of pipes, also at a depth corresponding to about 4 nanoseconds.

Figure 14. Room 203/204, scan 2

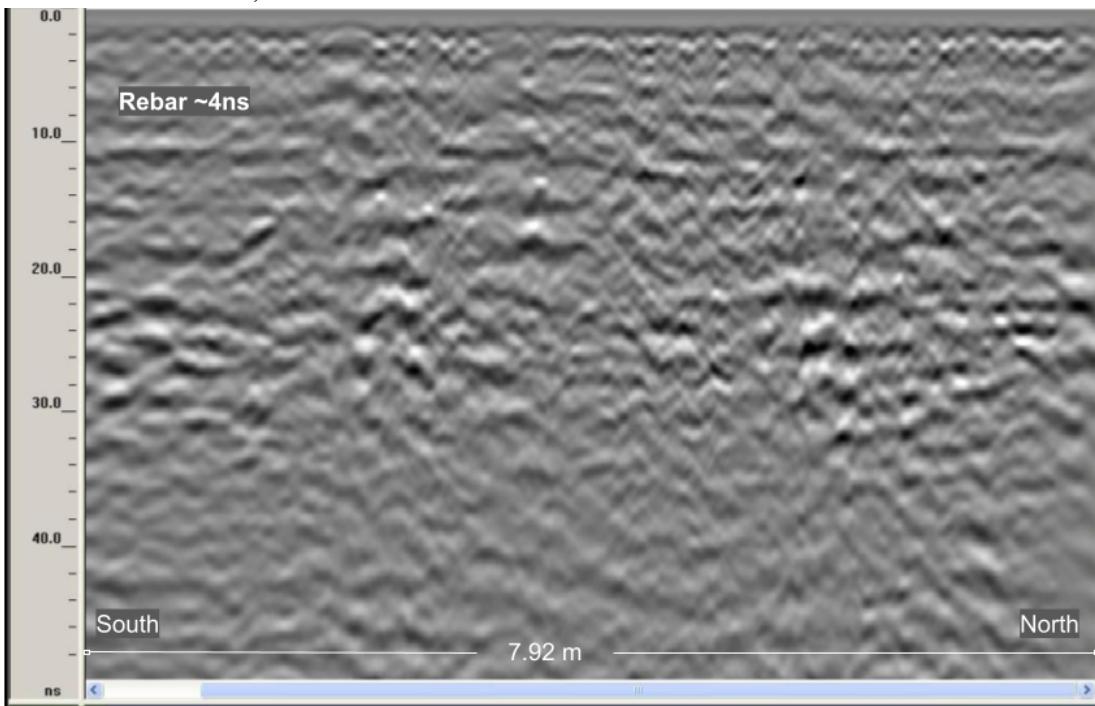


Figure 14 is of a South-North scan in room 203/204, spanning 7.92 meters. It shows rebar across the entire scanned length at a depth corresponding to about 4 nanoseconds.

Figure 15. Room 203/204, scan 3

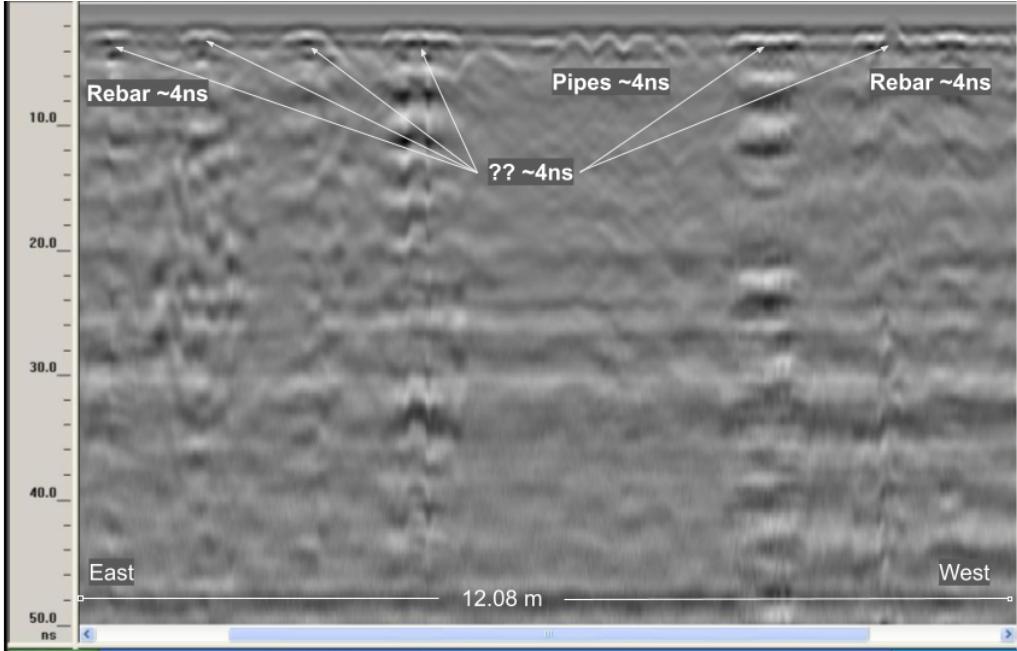


Figure 15 is of an East-West scan in room 203/204, spanning 12.08 meters. It shows rebar across the start and end of the scanned length at a depth corresponding to about 4 nanoseconds. In the center of the scanned length, there are larger parabolic features with ringing patterns indicative of pipes, also at a depth corresponding to about 4 nanoseconds. There are additional regular parabolic features interrupting the rebar--possibly pipes in side-profile, or sections of cracked concrete.

Figure 16. Room 203/204, scan 4

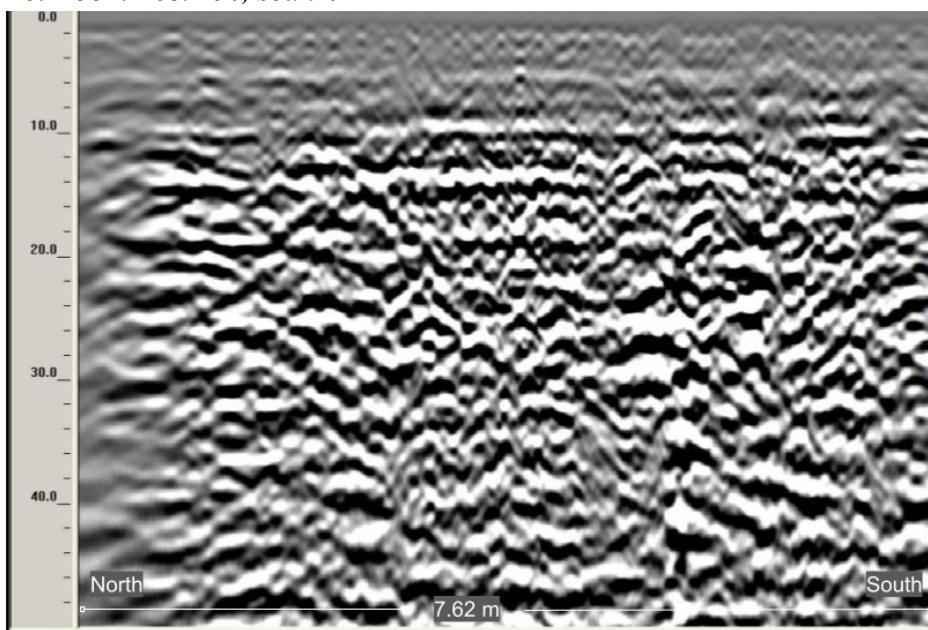


Figure 16 is of a North-South scan in room 203/204, spanning 7.62 meters. It shows an extreme dielectric constant at depths corresponding to greater than 10 nanoseconds, indicating that the scan was not performed adequately--likely the antenna was not fully in contact with the ground. This is not a usable scan.

Figure 17. Room 203/204, scan 5

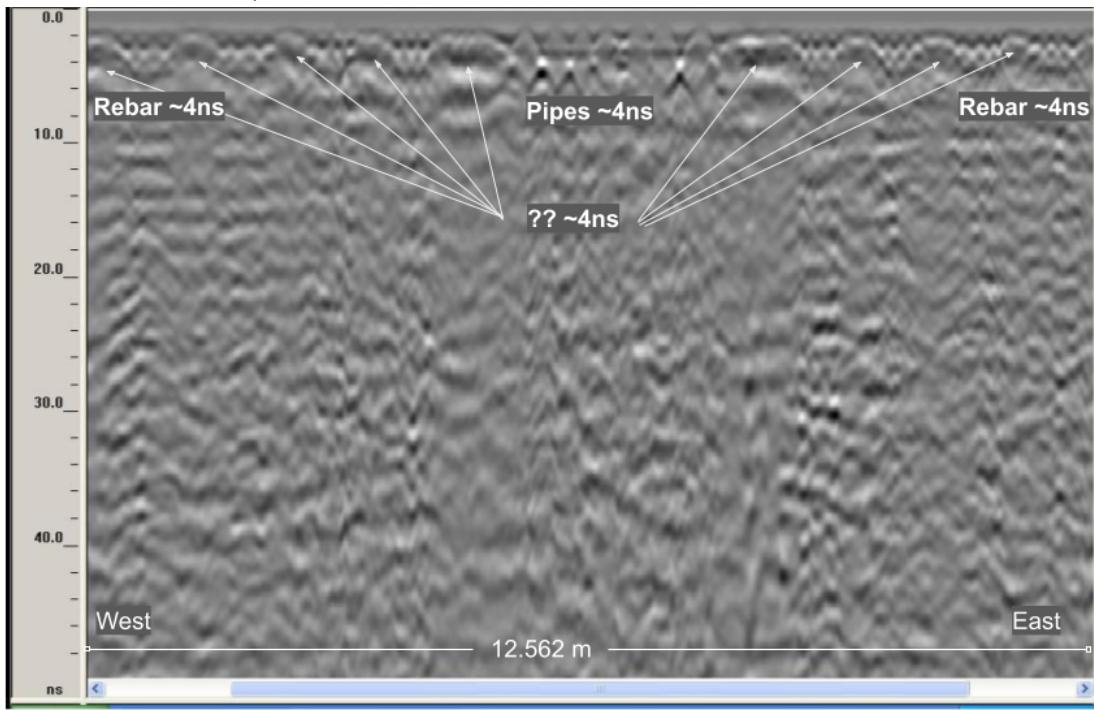


Figure 17 is of a West-East scan in room 203/204, spanning 12.562 meters. It shows rebar across the start and end of the scanned length at a depth corresponding to about 4 nanoseconds. In the center of the scanned length, there are larger parabolic features with ringing patterns indicative of pipes, also at a depth corresponding to about 4 nanoseconds. There are additional regular parabolic features interrupting the rebar--possibly pipes in side-profile, or sections of cracked concrete.