Ground Penetrating Radar Survey at Dalgety Bay

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P107 312

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Contents

1. Introduction

Following the initial Ground Penetrating Radar (GPR) survey of the Dalgety Bay Headland area on the 5th September 2011, forming part of the Dalgety Bay Headland Investigation (Tyler, 2011), and the subsequent discovery of particles by SEPA in 2011/12, it has been hypothesised that other areas of made ground continue to act as source(s) of particles onto adjacent beaches. To test this hypothesis, a second GPR survey was undertaken to identify and map (where possible) areas of made ground adjacent to the beach area and to hypothesise on the relative ages of the successions observed.

2. Methodology

Appendix A summarises the theory behind the GPR surveys. The second survey was undertaken on the 24th and 25th March, 2012 and augments the survey work undertaken on the 5th September.

Transects were laid out using 50 m tapes. Each transect was surveyed and georeferenced using a Leica real time kinematic DGPS. Total gamma counts were collected at a 1m resolution along each transect by SEPA using 50 mm x 50 mm NaI detectors. A Mala Geoscience GPR system was deployed for the GPR survey (Figure 1). This system comprises a tablet-type computer viewer (XV11), connected to a backpack control unit (CU11), via parallel-port printer cable. All antennae used connect to the CU via fibre optic ports. Three antennae were deployed: 100 MHz and 200 MHz unshielded, and 500 MHz shielded. The majority of lines were gathered using 100 200 MHz antennae. 59 lines were gathered in total: a GPS location map of these transects is included in the attached figures. The 500MHz shielded antenna was deployed in the area boats are stored in, although in interpretation, the presence of these craft appears to have had little effect on the unshielded antennae.

Figure 1. GPR, DGPS and Gross Gamma counting along predefined transect

Figure 2 shows the transects undertaken across the site and Figure 3 shows more detail in areas A and C.

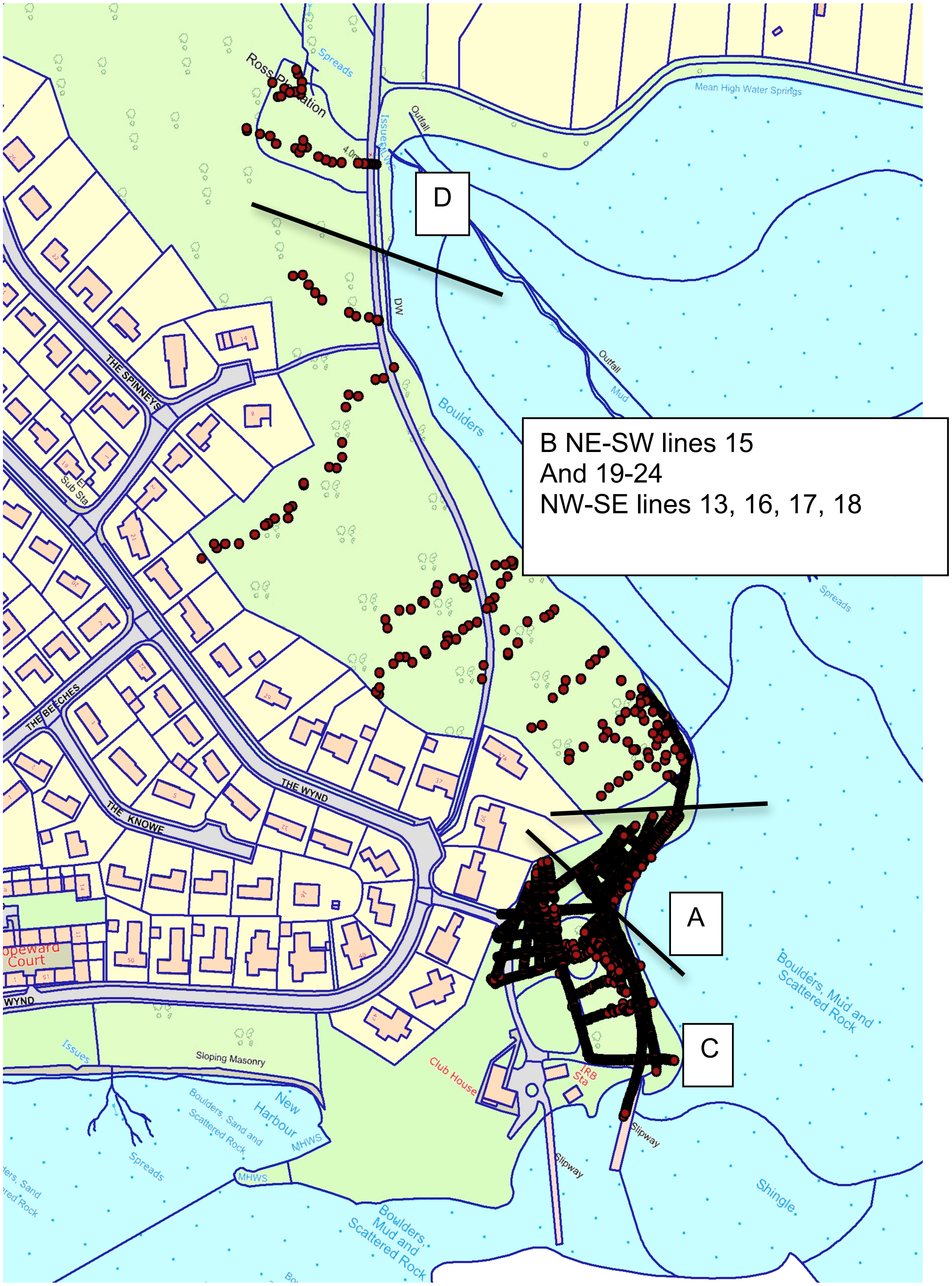


Figure 2. GPR transects at the Dalgety Bay, using the 100-200 MHz system

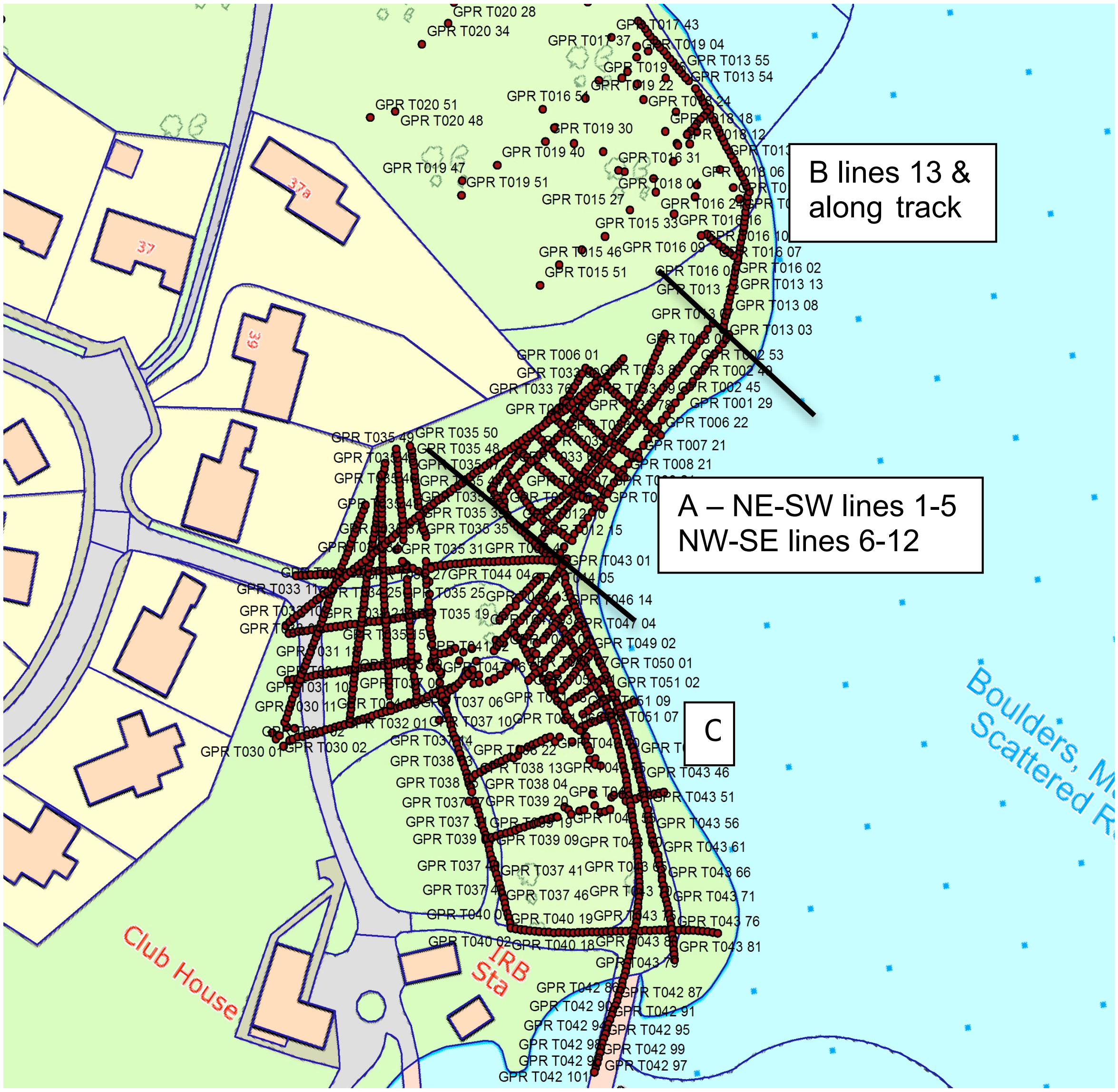


Figure 3. GPR transects in Areas A & C (see Figure 2), using the 100-200 MHz system

3. Results and Discussion

An excellent to satisfactory set of GPR transects were gathered. Four areas were surveyed, defined arbitrarily as A (grass and rough ground north-east of the Boat Club) (Figure 3); B (the wooded area east and north east of the Dalgety Bay urban area) (Figure 2); C (the area of boat storage) (Figure 3) and D (the bog known as Ross Plantation) (Figure 2).

Area A. 15 lines were gathered in this area, 12 at 100MHz and 3 at 200MHz, in a NE-SW and NW-SE grid (Figure 3). A track lies to the east of the grassed area and rough ground and is underlain by a basin of material, some 1m thick that is interpreted to be made ground. This basin is seen on three lines and thus has a high confidence of its existence (Appendix B; Figure 4). No anomalies were observed within this basin, so it is interpreted to be a well-made infill of a previous depression. Two areas occur in Area A, a grassed area to the SW and rough ground to the NE. These have very different subsurface makeup, with the grassed area comprising a 1m-thick infill, changing to very different material under the rough ground (seen clearly on Line 4 [565] and Line 5 [566]; Appendix B & Figure 5). Each area has a different infill, the nature of which could be revealed by coring or excavation. These would be two target areas for excavation to determine the nature of the infill.

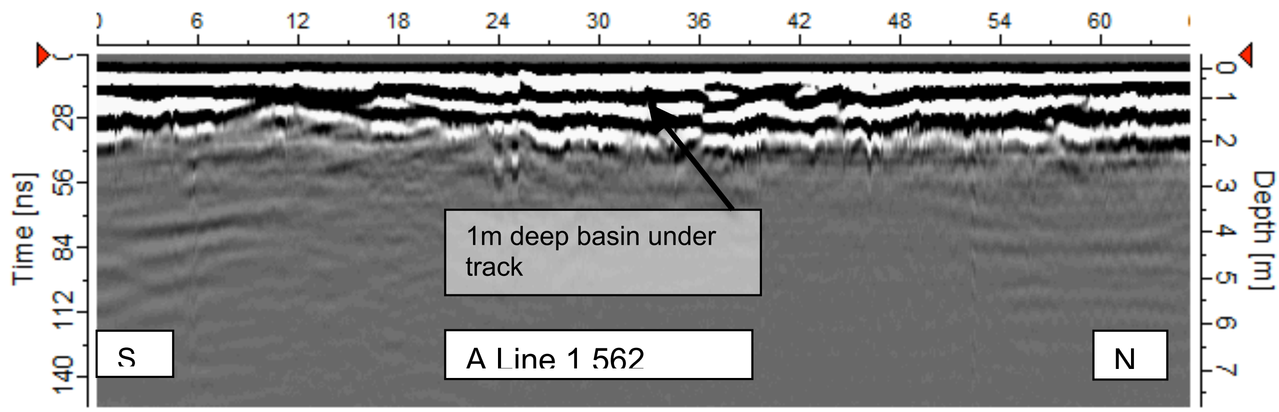


Figure 4. Transect A 1, illustrating the 1 m deep basin in area A (Figure 3)

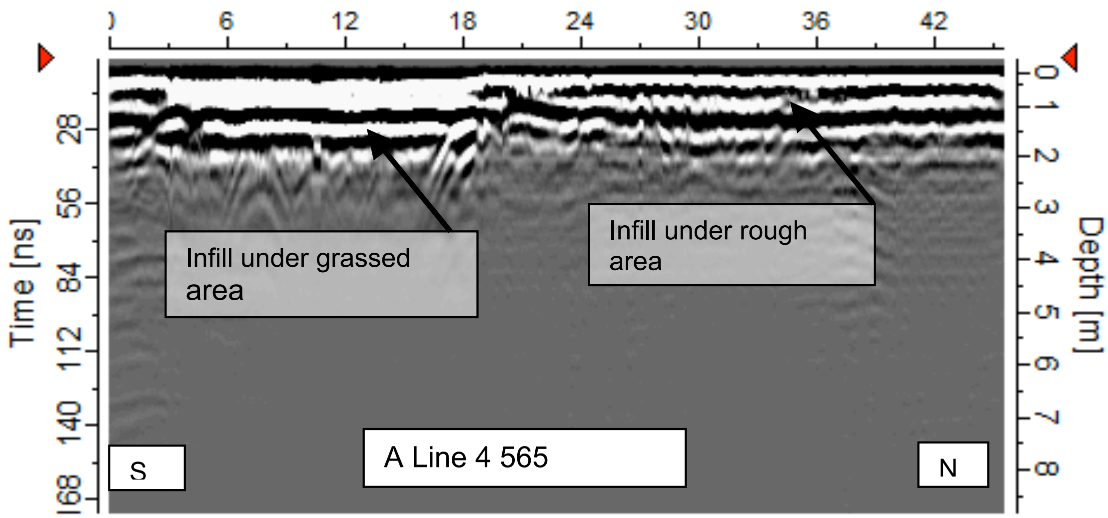


Figure 5. Transect A 4, illustrating two different areas of infill in area A (Figure 3)

Area B. Seven NE-SW and four NW-SE lines were gathered at 200 and 100MHz through this area (Figure 2). The northeast of the area along the coastal path comprises shallow surficial deposits on bedrock, with one area of infill (nature not known). The forested area comprises solid geology at 1m depth, with solid geological features apparent on the GPR profiles (Appendix B; Figure 6 & 7). Surficial deposits thicken toward the SW, in line with the houses, and a contour map, based on the interpreted base of the surficial material (i.e. depth to rock head) is included. An excavation in the area close to the back gardens of the houses would be ideal to reveal the nature of this infill. A secondary excavation could be undertaken on the path at the location of infill. Figure 8 provides a sketch map interpretation of the GPR data in this area.

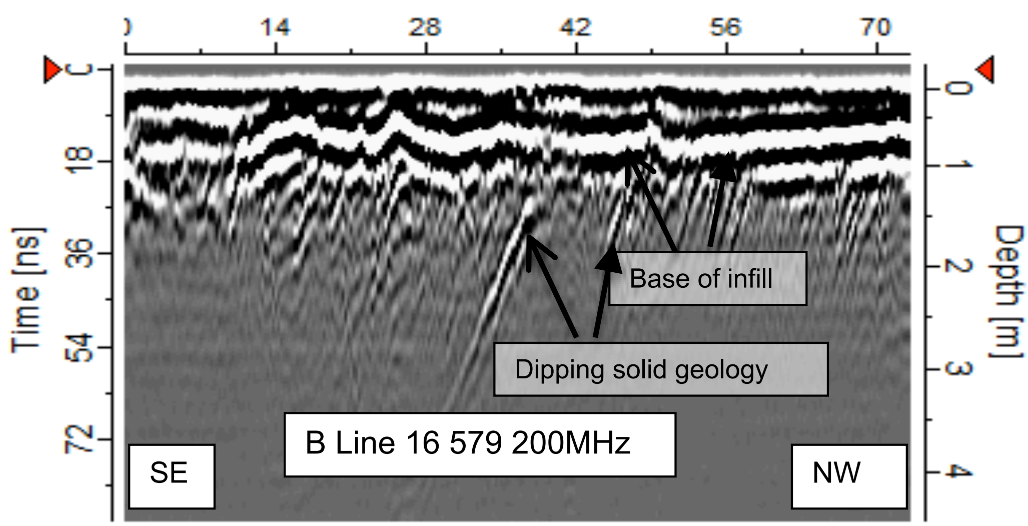


Figure 6. Transect B 16, illustrating dipping geology and basing infill in wooded area (Figure 2)

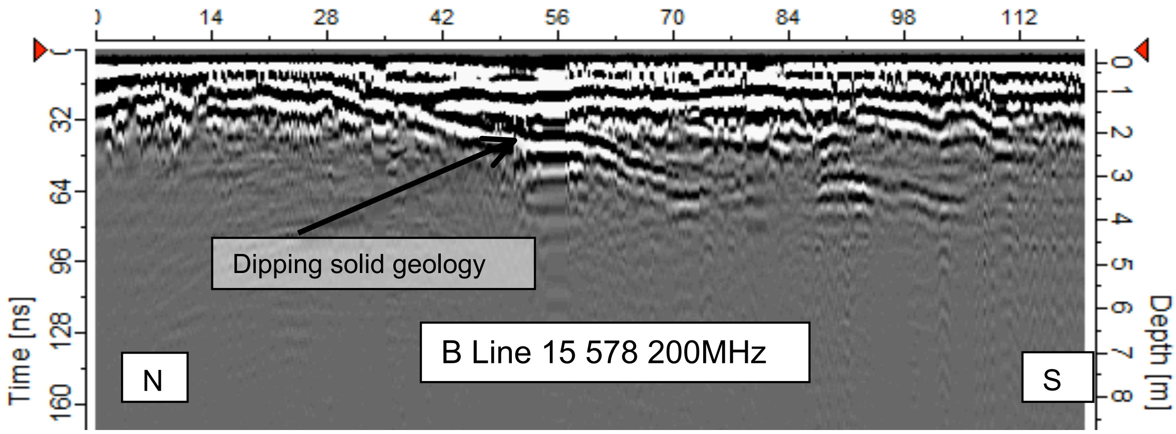


Figure 7. Transect B 15, illustrating dipping geology and basing infill in wooded area (Figure 2)

Figure 8. Sketch contour interpretation of the GPR data in area B

Area C. A 1-3m infill of surficial material underlies the area the boats are stored on. This infill is thickest between GPR TO43 46 and GPR TO43 71 (labelled 'infilled area' Figure 9) under the path parallel to the shore in Area C. A thinner (1m) mantle of drift/surficial material underlies the mound and slope the boats are stored on. An excavation along the track would be required to determine the nature of the infill, somewhere between the GPS points noted above.

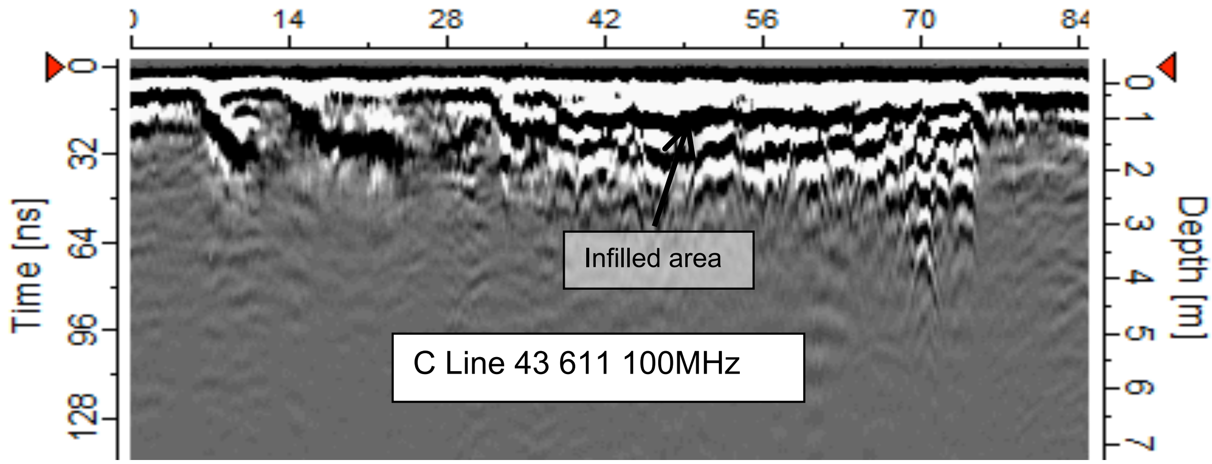


Figure 9. GPR data under boat standing area C (Figure 3), showing area of infill.

Figure 10 provides an interpretation of the GPR data and summarises the surface thickness of the areas identified as made ground in area C. This ranges from less than 0.5m underneath the car park area to over 1.5 m under the boat standing area.

Area D. This peat bog is inland from the sea, with a track separating the two. The base of the bog was successfully imaged on Line 25, 592, as being about 2m deep with no major anomalies recorded (Figure 11). A more complete survey of the area would be required for full evaluation, but on the information on the three lines gathered, no major anomalous bodies are present.

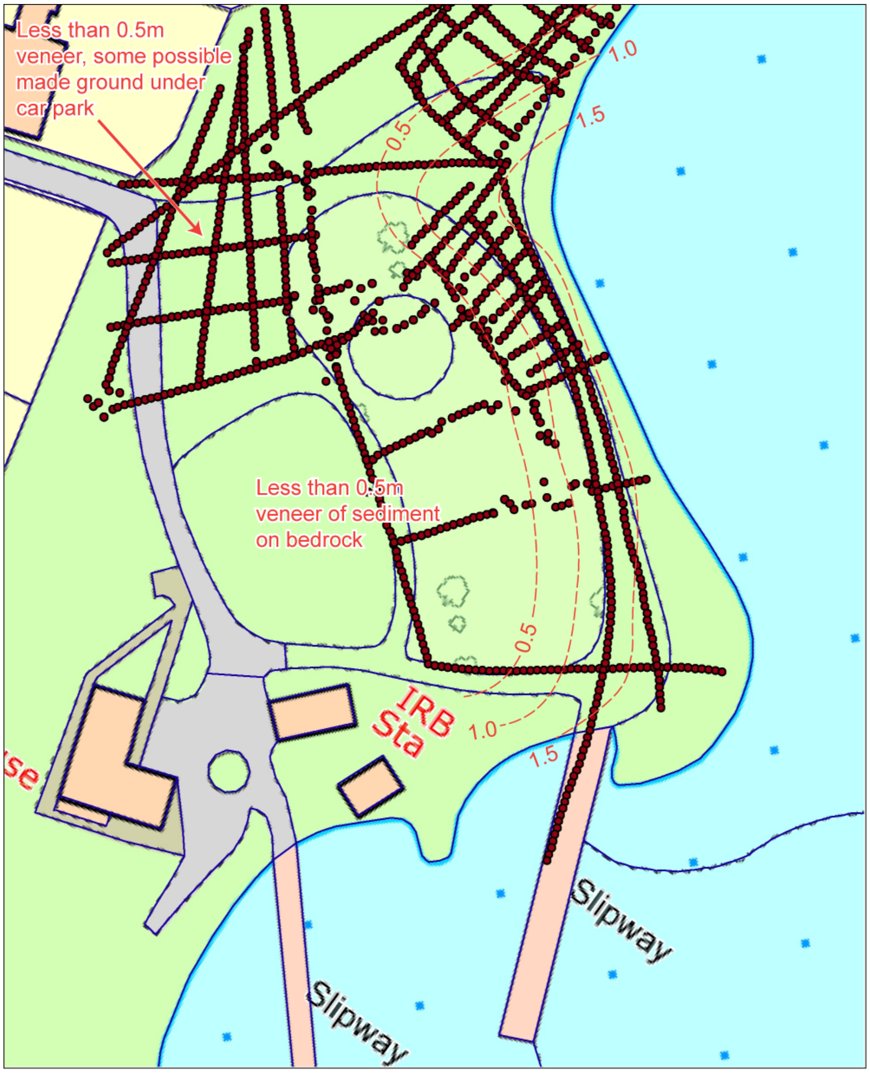


Figure 10. Sketch contour interpretation of area C (Figure 3).

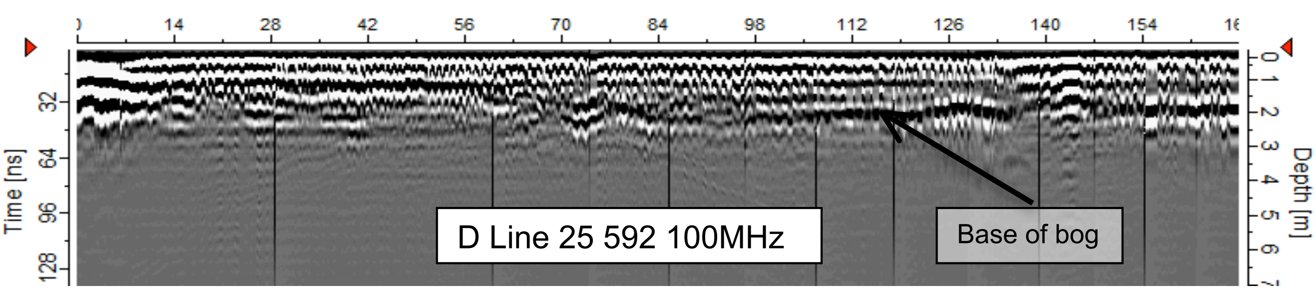


Figure 11. GPR data under boat standing area C (Figure 3), showing area of infill.

4. Conclusions

High quality GPR survey results were obtained from four areas identified around Dalgety Bay. Areas of made ground were clearly identified in three of the four areas and warranting further investigation through trial pitting. The areas identified were typically of between 1m and 2m thickness.

References

Tyler, A.N. (2011). Dalgerty Bay Headland. ERL (Striling) report to SEPA. P088 311.

Appendix A

GPR – How the method Works

GPR uses the transmission and reflection of radio waves (typically 25 to 2GHz) in imaging the subsurface. Radar waves, introduced in the ground, may reflect back to surface when they intersect objects or surfaces of varying dielectric permittivity. Thus a GPR system requires a source antenna and receiving antenna (built to measure the same frequency). The transmitting antenna generates a pulse of radiowaves that the receiver detects at a set time interval: the longer the time interval, (potentially) the deeper the waves will have travelled into the ground and back again. When the ground has a slow radarwave velocity, so a buried object may appear deeper than in ground with a fast transmissive velocity. As the antennae pass over discrete objects with different dielectric properties to the surrounding medium (boulders, pipes, coffins), they may generate hyperbolae, or arc-like reflections.

Radar waves also travel horizontally from the transmitting antenna, which in open ground simply dissipate with distance. However, in areas with upstanding structures, especially those that have a significant dielectric contrast to their surroundings, interference from such surface objects can create artifacts on the radargram. When such isolated objects (powerlines, telegraph wires, metal poles, trees) are passed during a traverse, a series of hyperbolae may be generated that appear like a subsurface object but are simply out-of-plane reflections. Radar antennae are commonly elongate, generating radar waves in a widening arc from their long axis. Thus when moved in parallel to the antennae axis, the radar waves may reflect from a larger subsurface area in front and beyond the antenna, (the so-called footprint) than when moved with the antennae at right angles to survey direction. Antennae may be shielded with radio-wave attenuating materials that reduce such out-of-plane interference.

Unlike other forms of electromagnetic radiation used in geophysics, radio waves have far higher rates of attenuation, and thus penetration and reflection depths are typically low, but horizontal accuracy is high, coupled with rapid, real-time results, unlike all other geophysical techniques bar metal detectors and magnetometer raw data. The receiving antenna has either electronic or fibre-optic link to a recorder that converts incoming radiowaves to digital format and displays these graphically as wavelets. As the transmitter-receiver array is moved, so these wavelets are stacked horizontally to produce a radargram, a kind of x-ray slice into the Earth, but recorded in the time taken for radar waves to penetrate and reflect, as opposed to real depth. The speed of radiowave propagation is determined by the makeup of the transmitting medium: in this case the speed of light and dielectric permittivity. Magnetic properties can also influence radar wave speed. Changes in dielectric permittivity can cause radar wave reflection, without which GPR profiling would be impossible. Radarwave attenuation, or signal loss is extreme in conductive media such as seawater, clays (especially hydrous) and some leachate. GPR has good depth penetration (tens to hundreds of metres) in ice (with minor fracturing/interstitial water), hard rocks like limestone and granite and clay-poor quartz silts or sands. Vertical resolution *vs.* depth penetration is of major concern when choosing antenna frequency. Low frequencies (15-50MHz) achieve deep penetration with poor vertical resolution in the received signal, due to the long wavelength. High frequencies (500-1000MHz) show high resolution with weak penetration (centimetres to metres). Low-frequency antennae are large (a few metres long), high frequency antennae are small (tens of centimetres). Again, this can influence the use of the method, as deeply-buried targets in enclosed spaces are virtually impossible to survey.

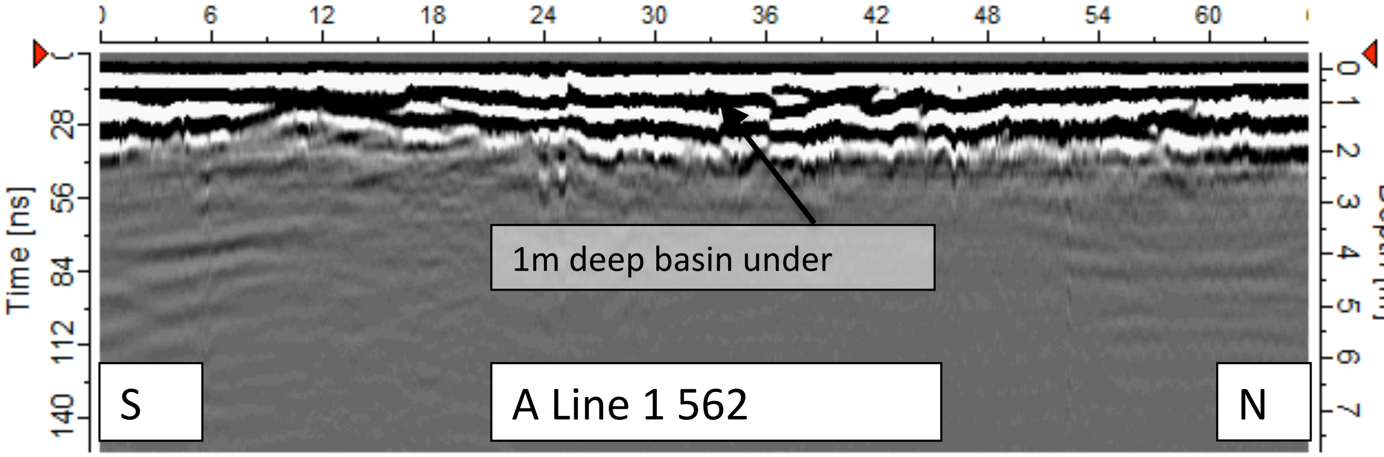
As with all geophysical methods, some intelligence concerning the likely size and makeup of the target is useful: where unknown or questioned, then a range of antennae should be used, and in very poorly understood locations, with other geophysical and invasive techniques (Blunderbuss Approach). Moisture contents influence radar wave velocity because in homogenous media porosity has a direct relationship to dielectric permittivity. Thus dry sand will allow increased wave propagation: sand with high freshwater content will give improved vertical resolution.

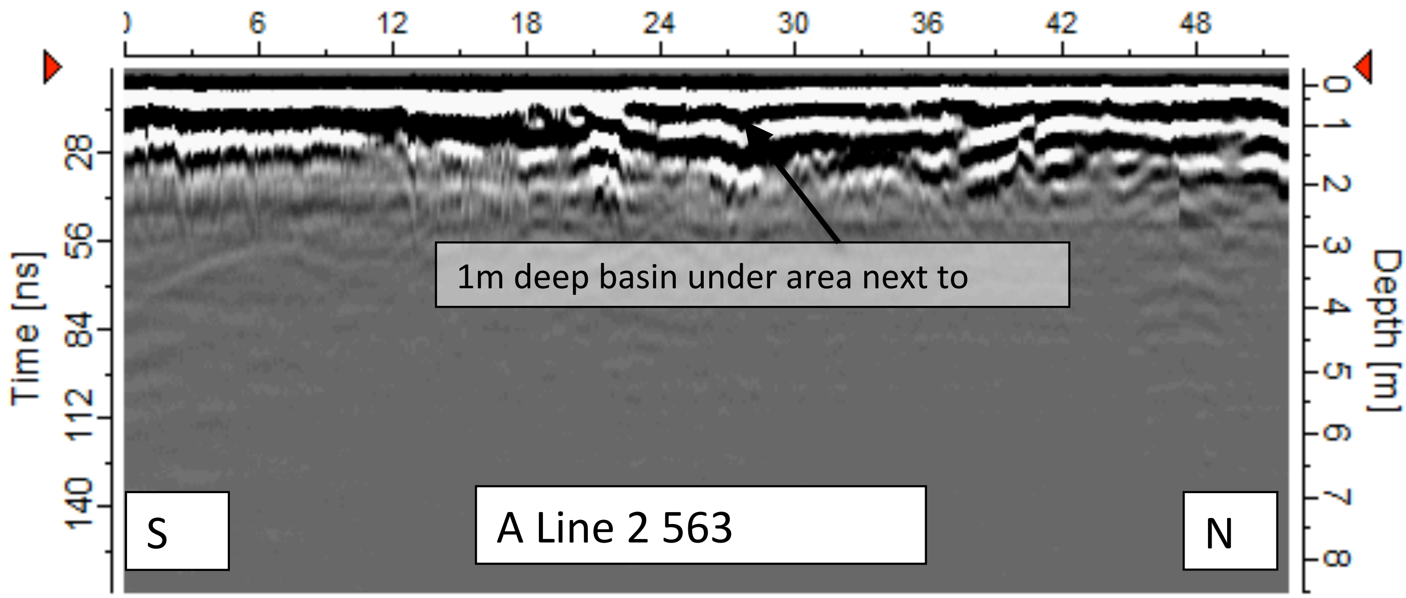
A major problem with early antennae was the effect of 'out-of-plane' reflections. It is easy to think of the radar wave as a focused beam (the ray-path at right-angles to the wave) when in fact the radar wave as it travels into the subsurface is more like a bubble, hemispherical at first, expanding and becoming distorted as it travels at different speeds into the ground. Thus lateral to the antennae, on or in the ground surface may be structures (buildings, posts, drains) that cause reflections at ground level. The effect of these surface features can be diminished by altering the orientation of the antennae, or by shielding the above-ground portion of the antennae, such that the radio wave is only allowed to penetrate the ground. GPR has found it's best uses in imaging glaciers, frozen ground, sand deposits (river deposits, non-saline coastal sands), aquifers (porous nature), archaeological features (moats, buried buildings) and concrete/pavements.

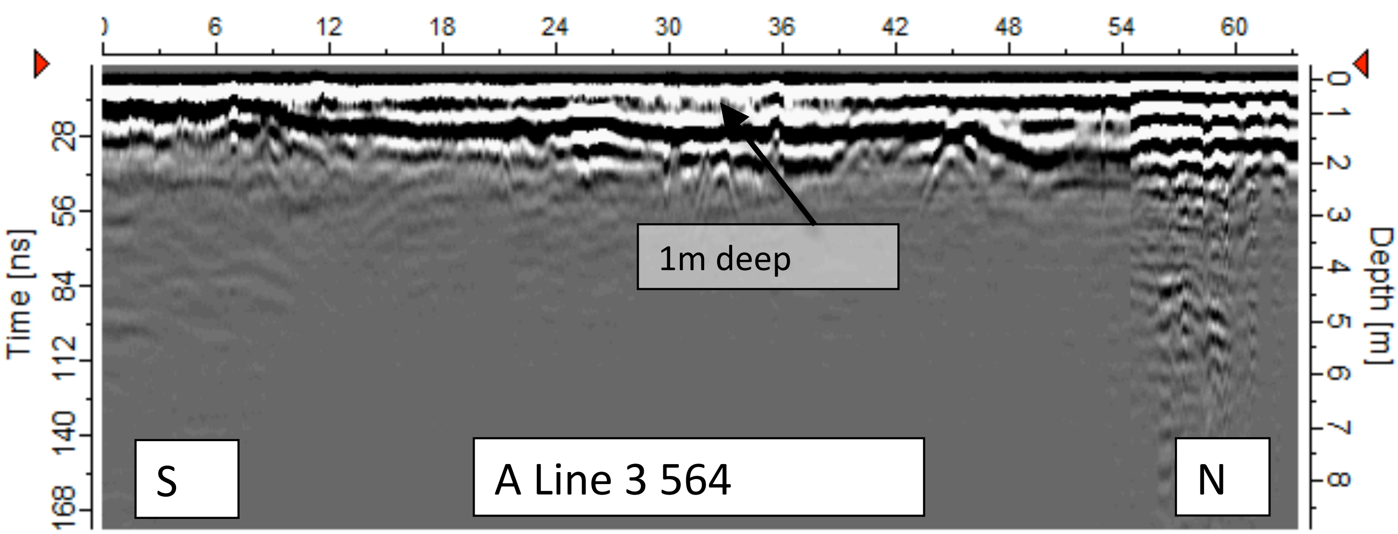
Alastair Ruffel, Queens University Belfast (September 2011)

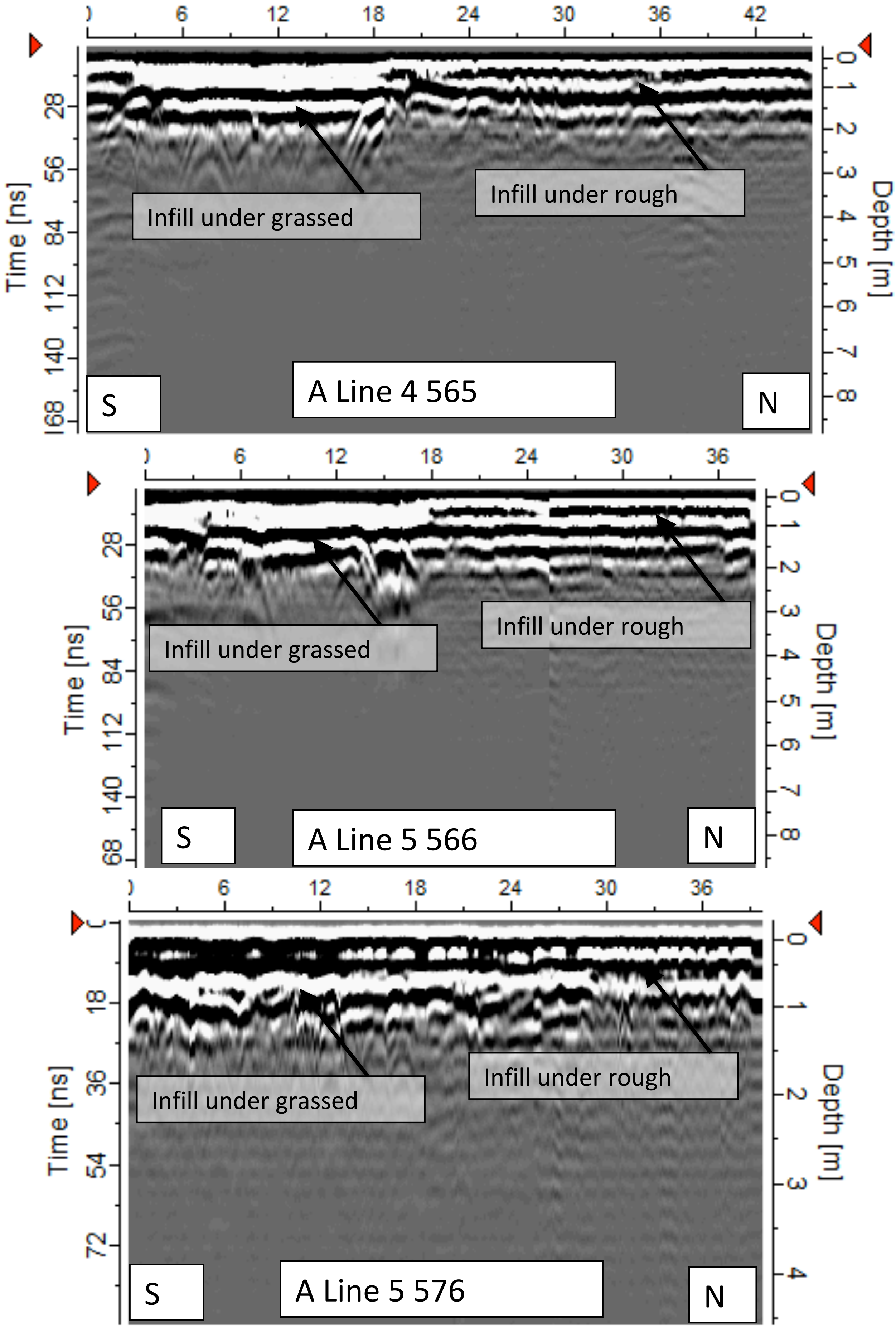
Appendix B

Example GPR Profiles





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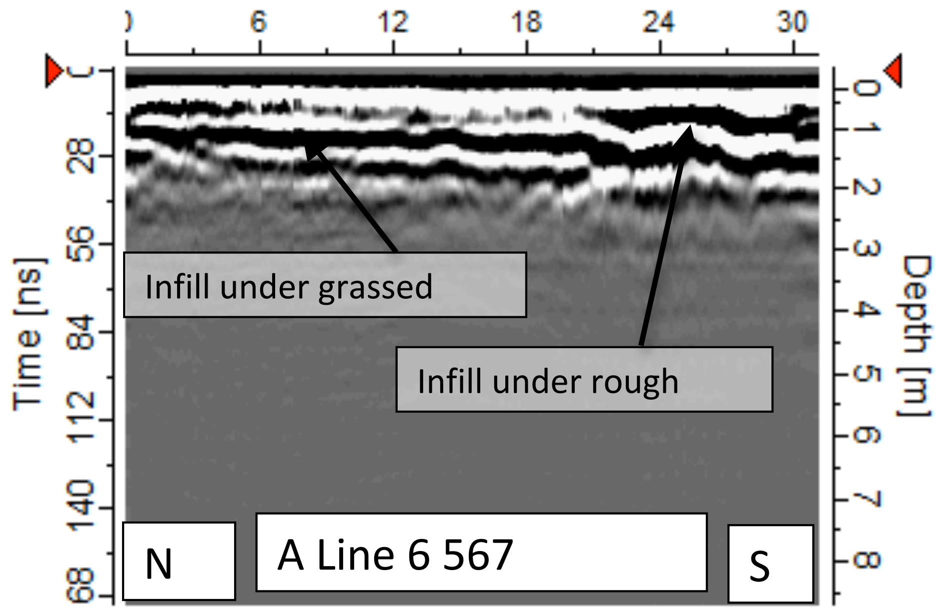
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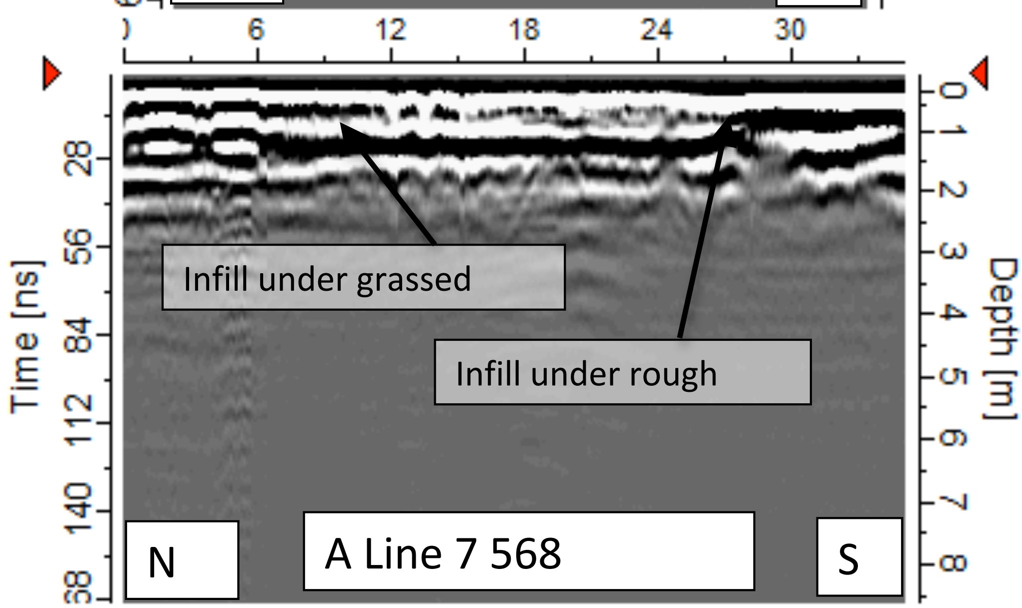
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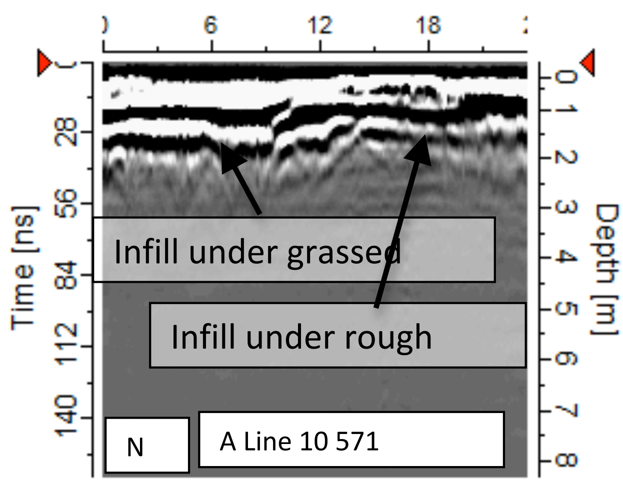
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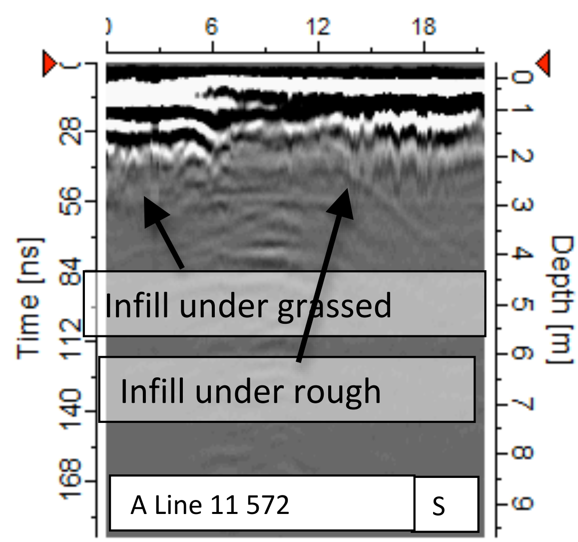
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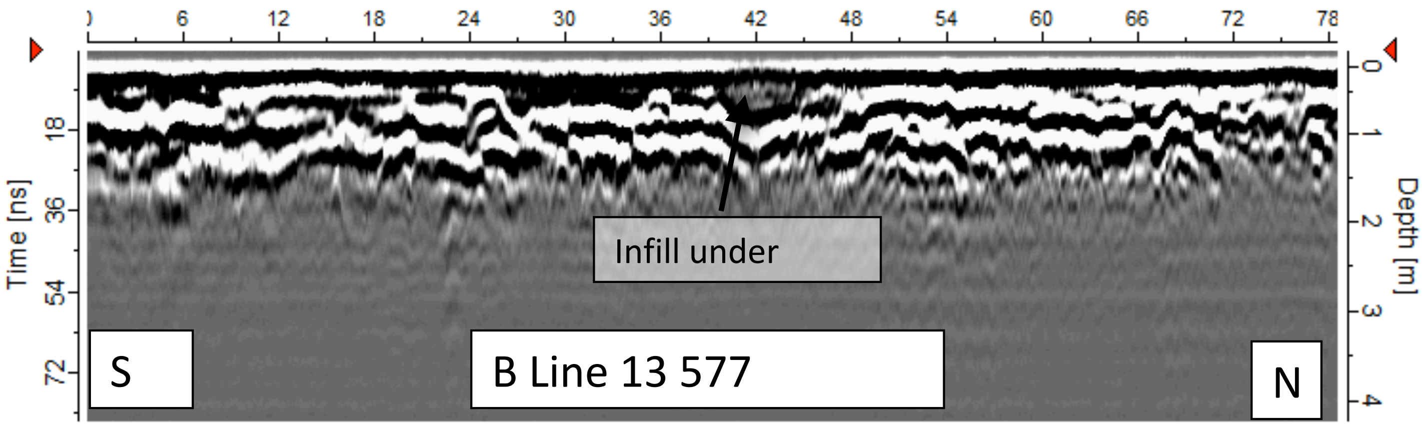

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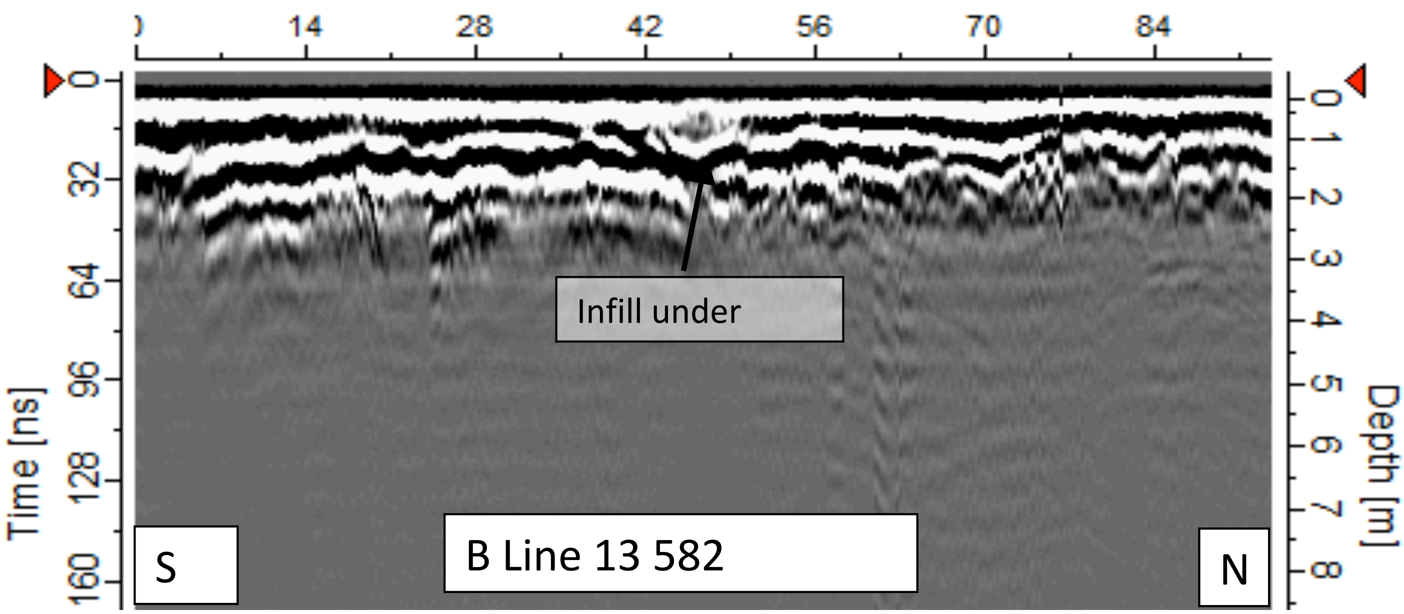

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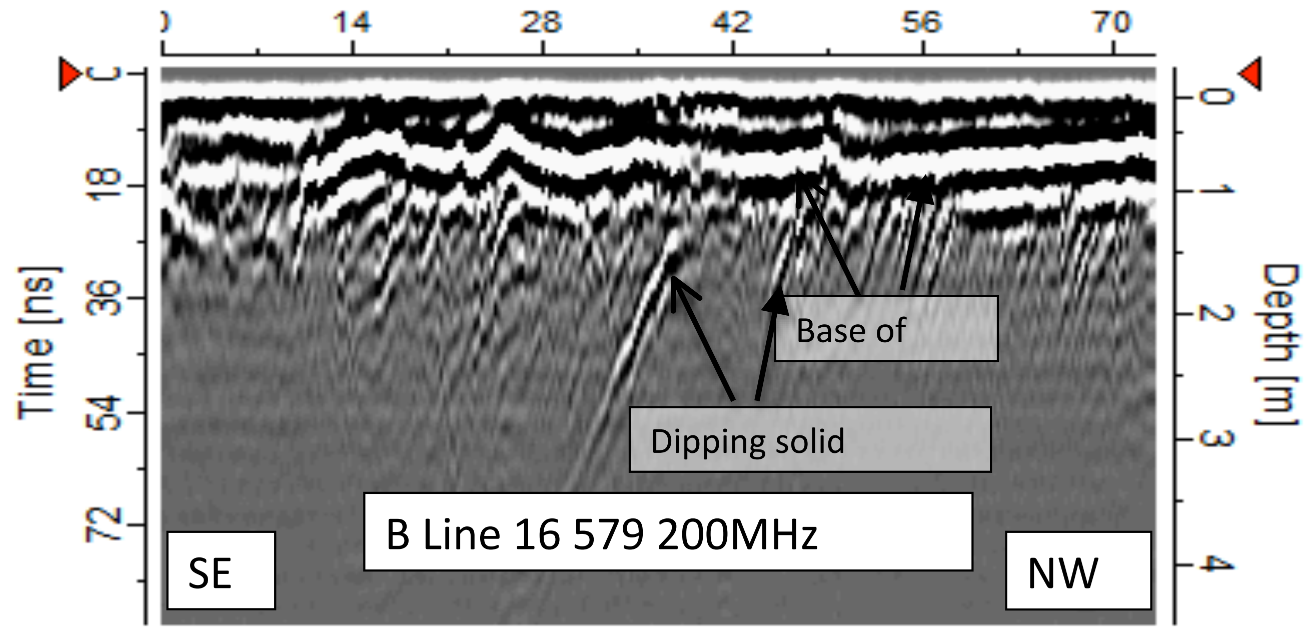

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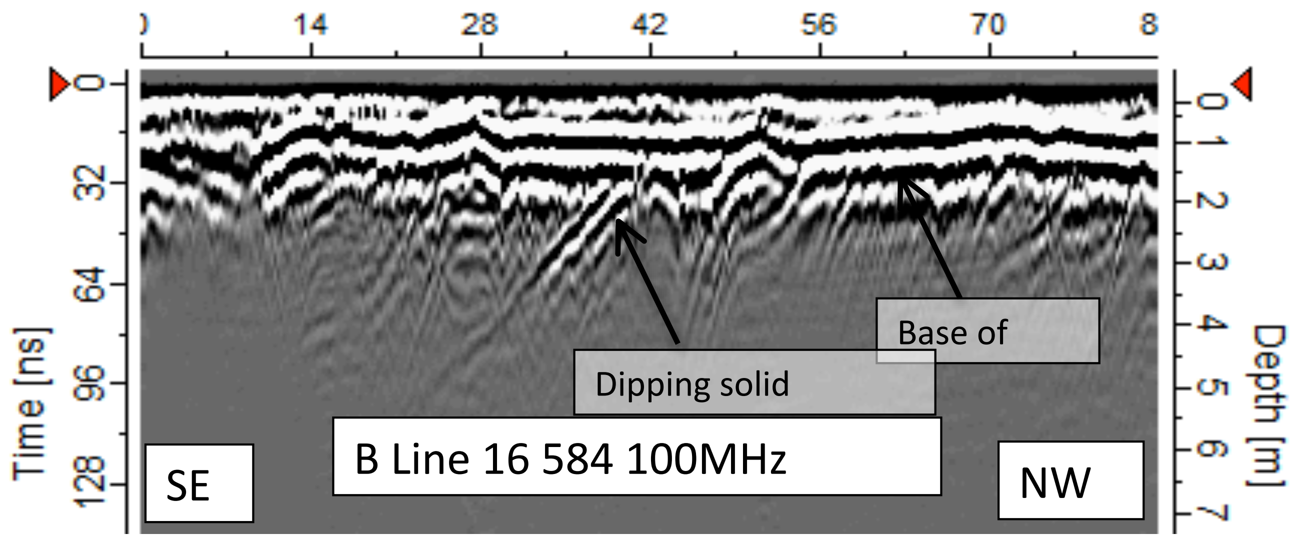

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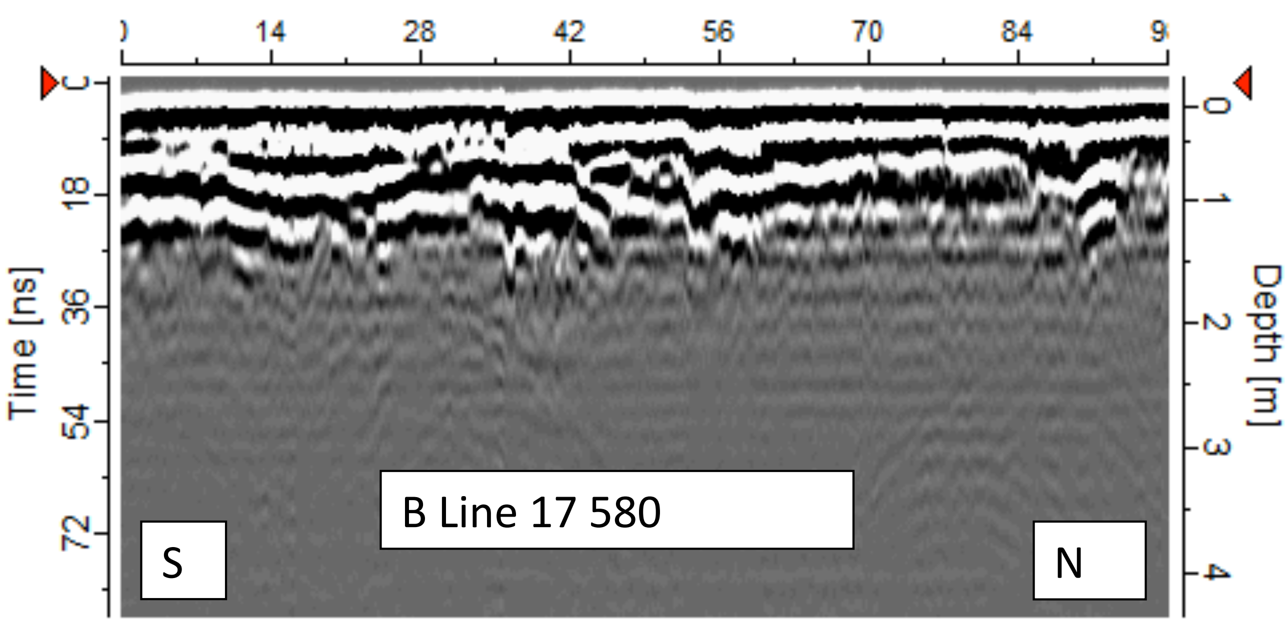

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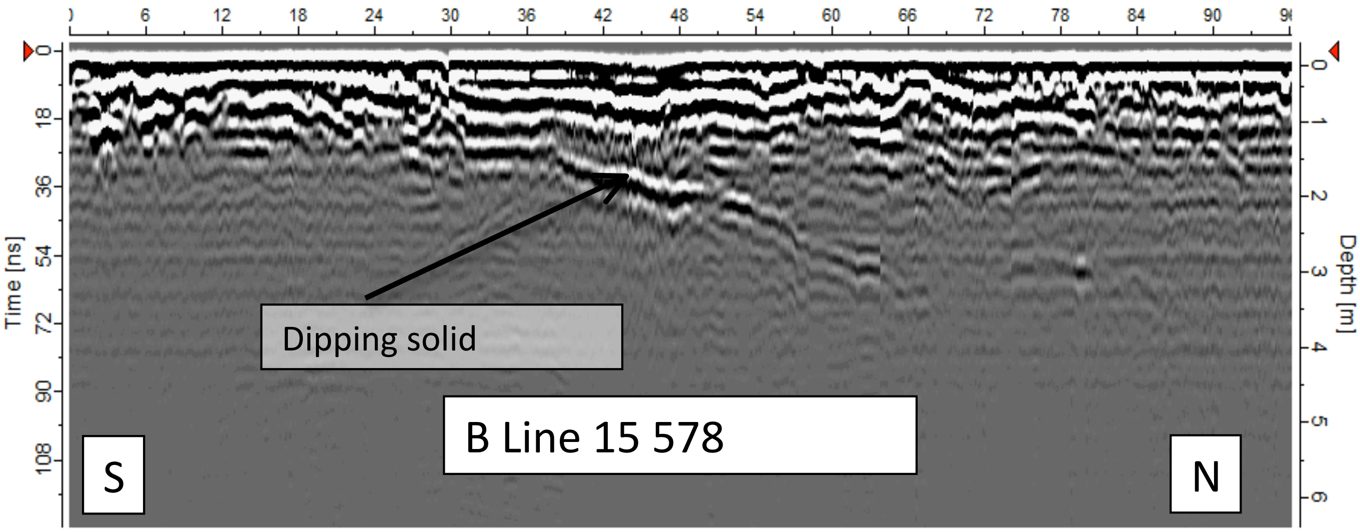
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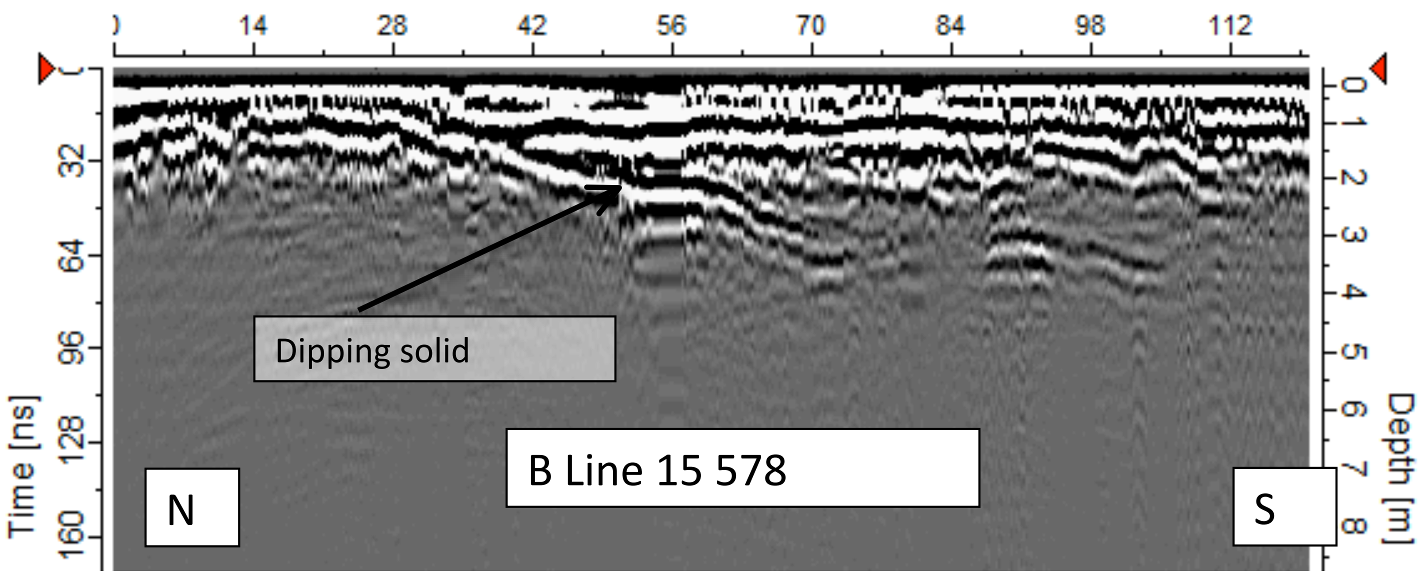
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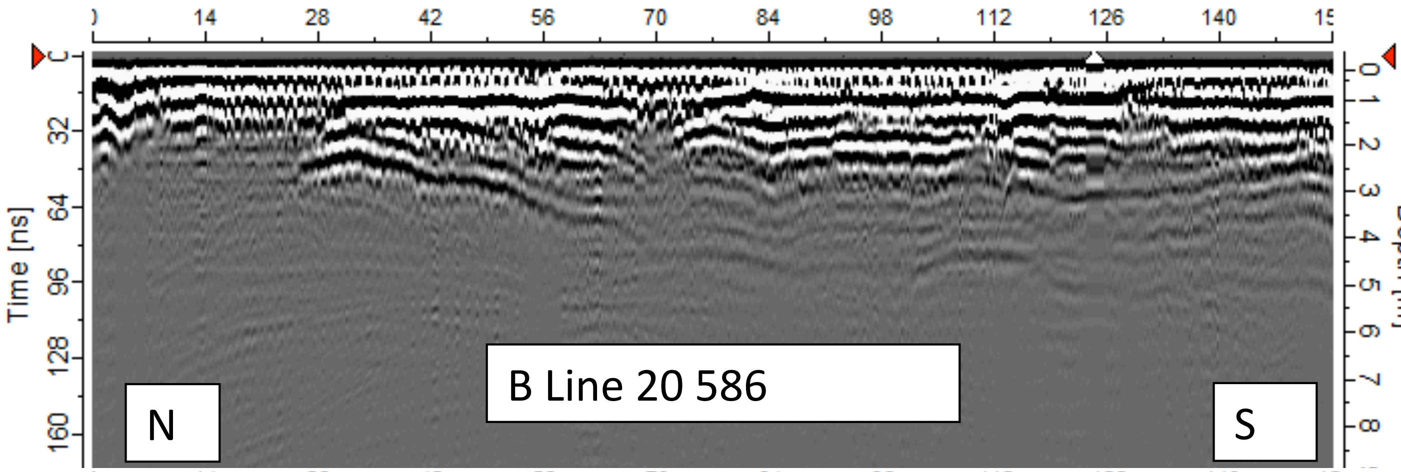
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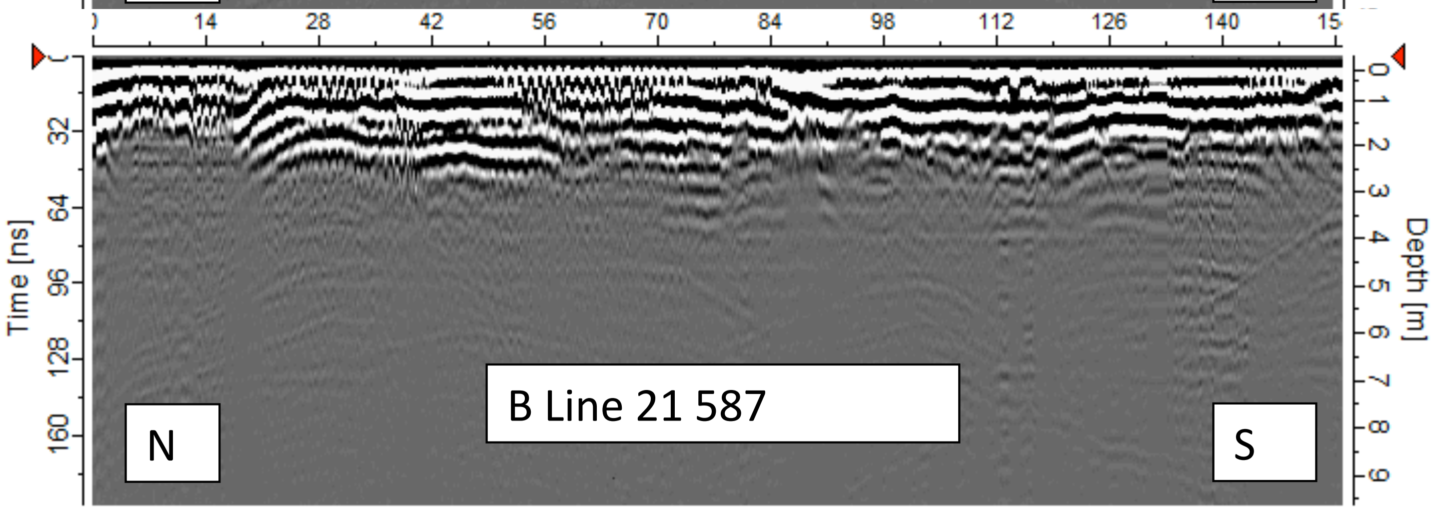
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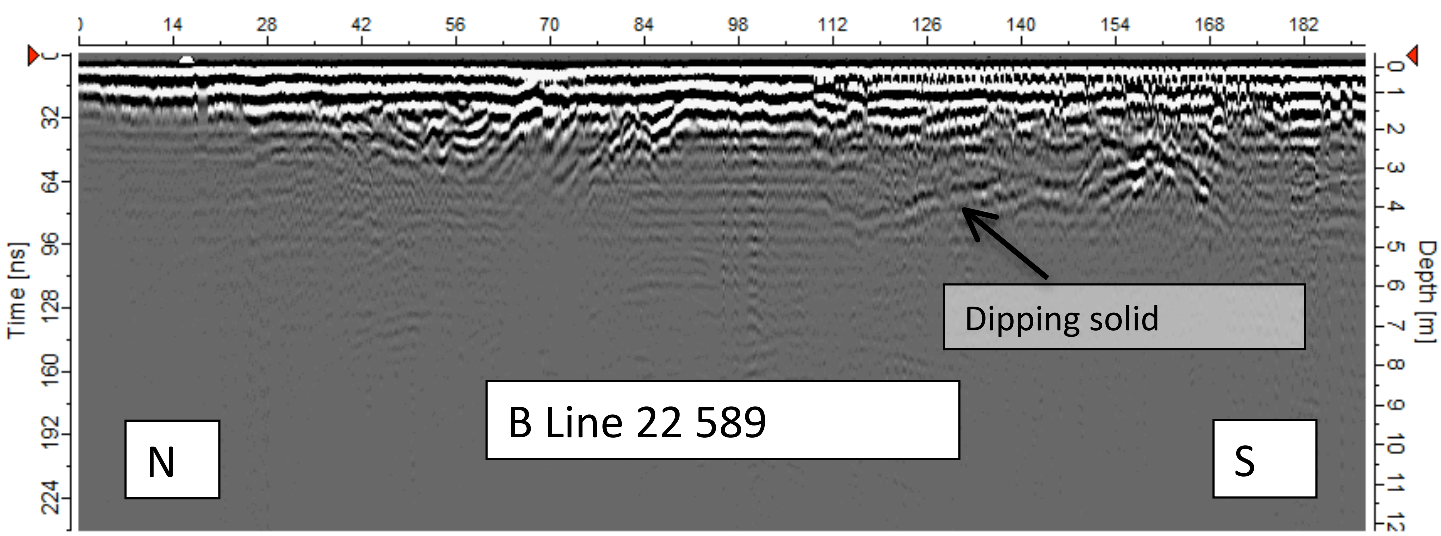
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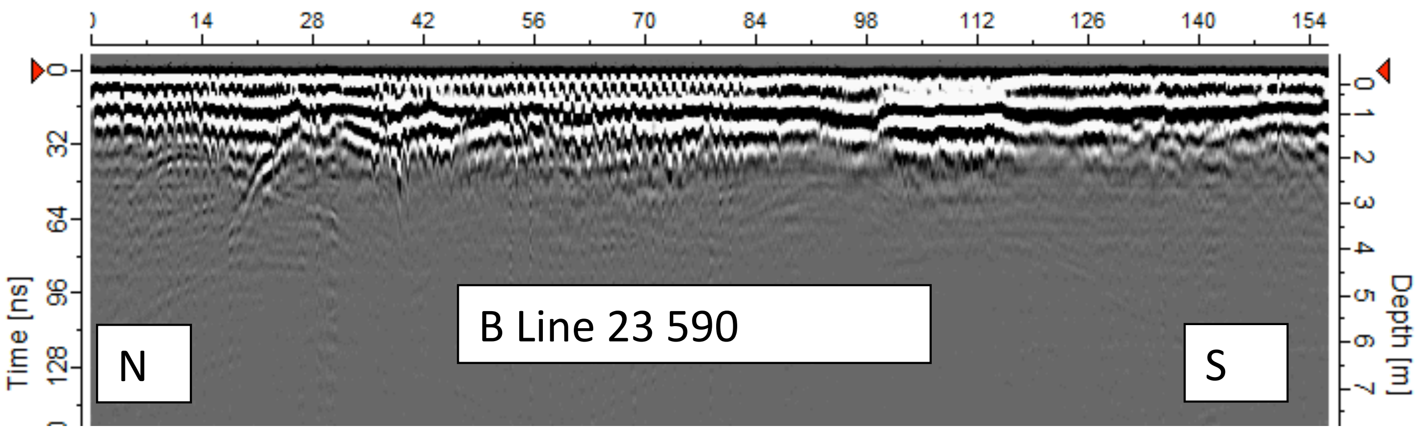

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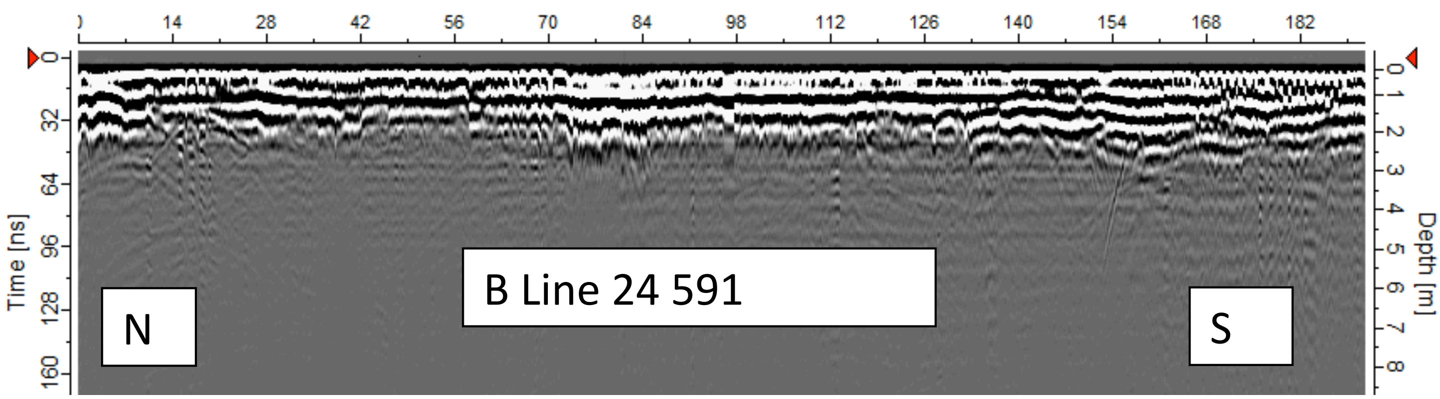

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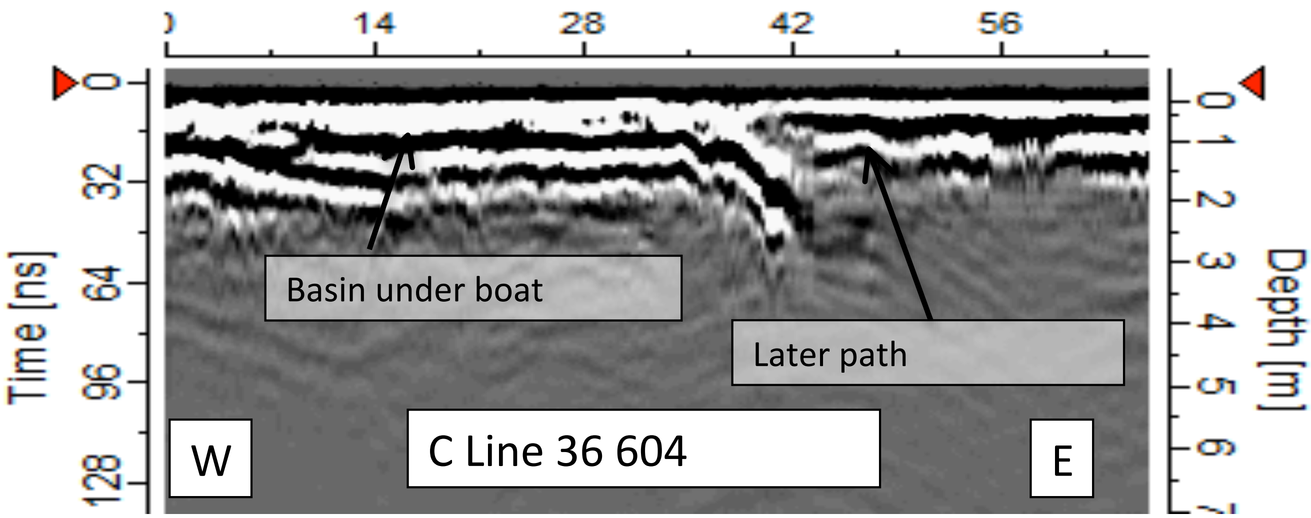
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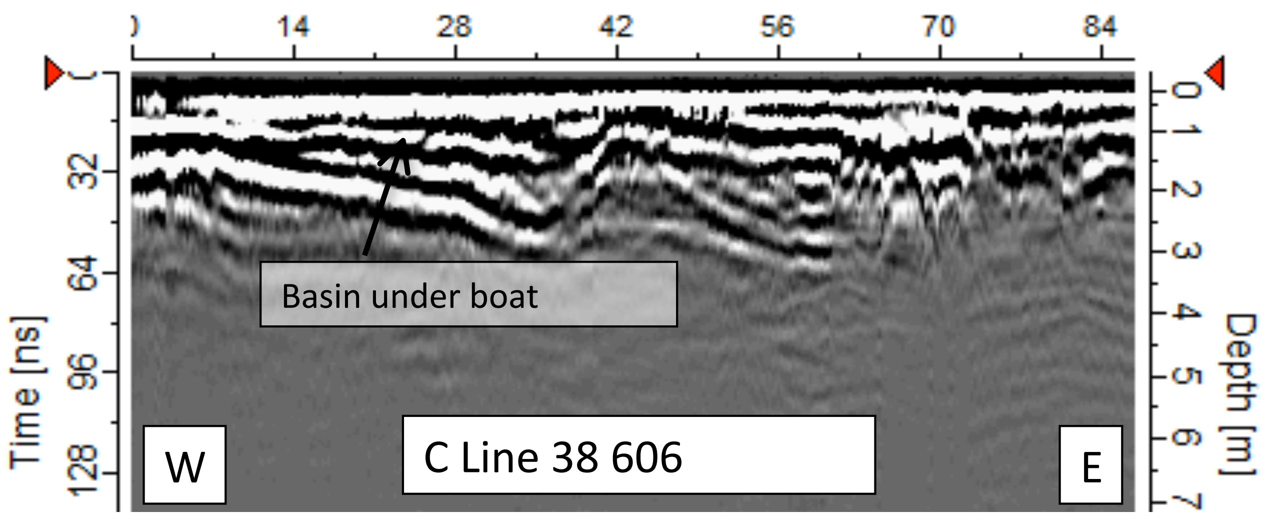
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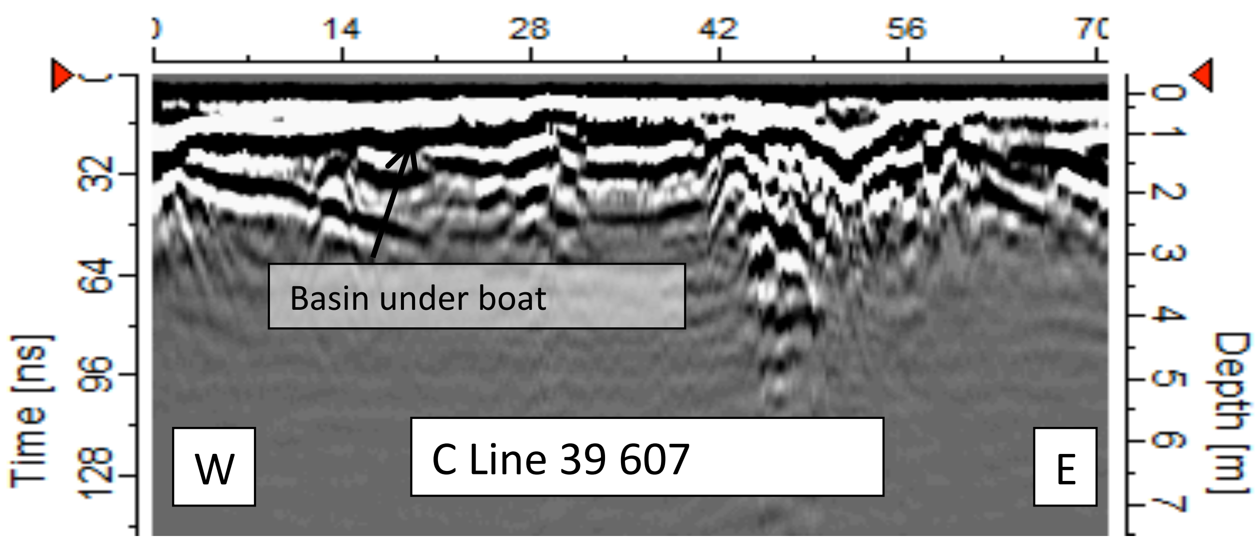
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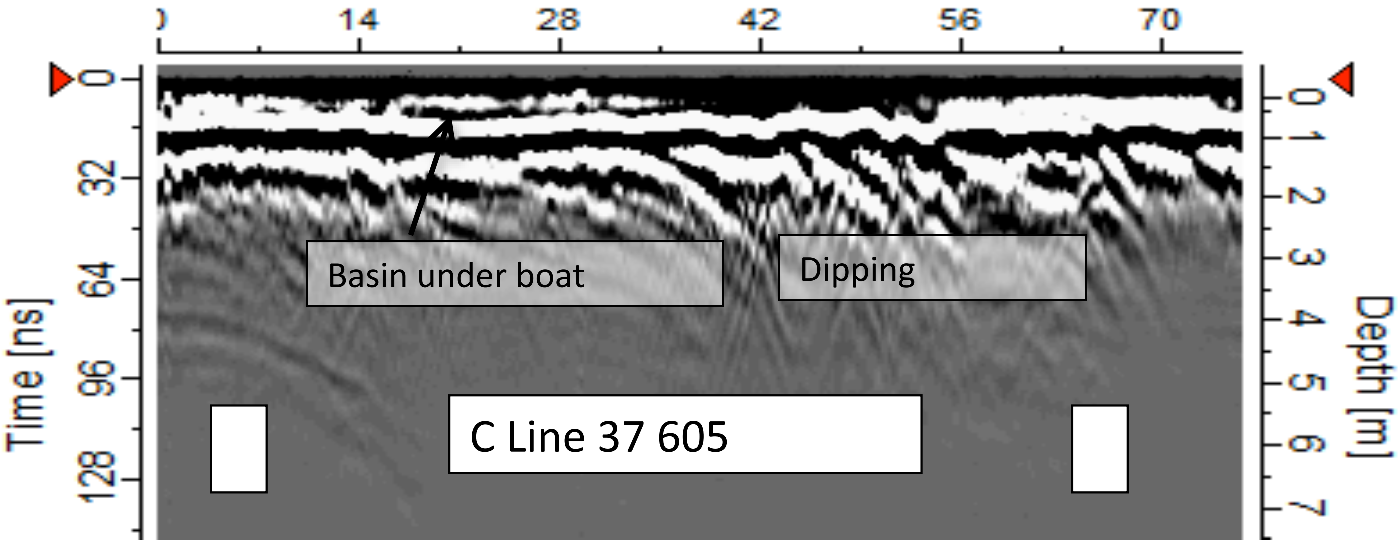
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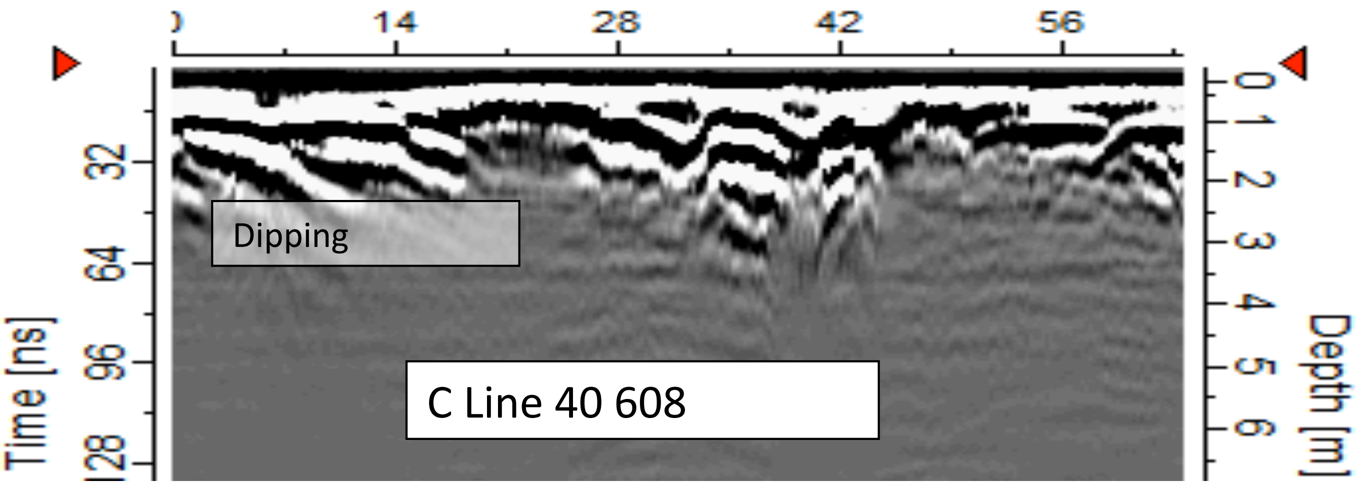
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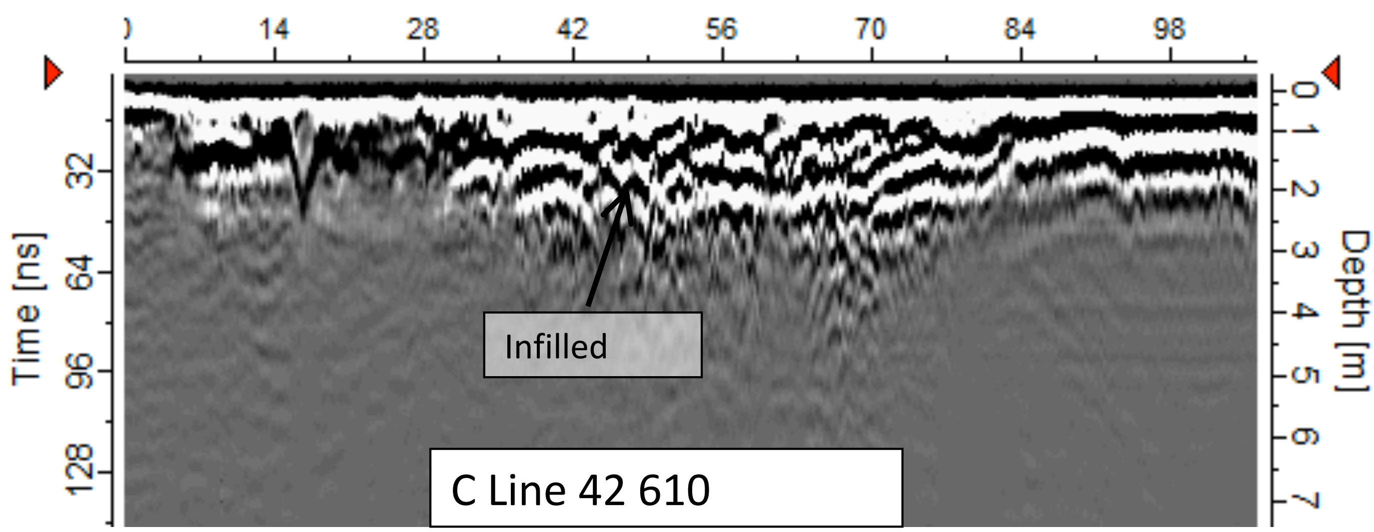
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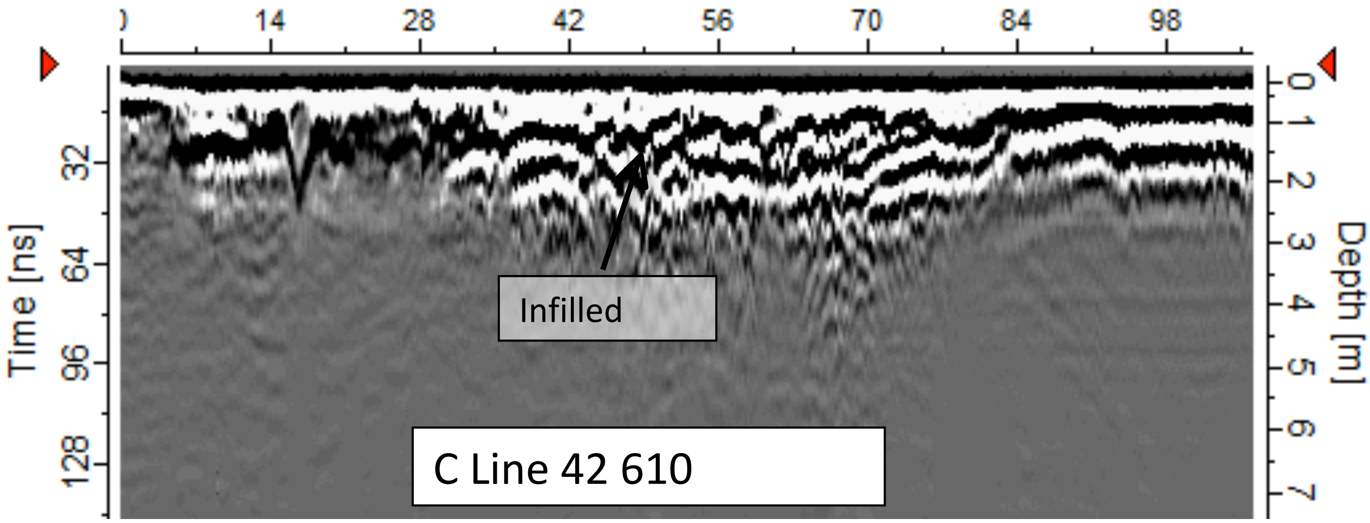

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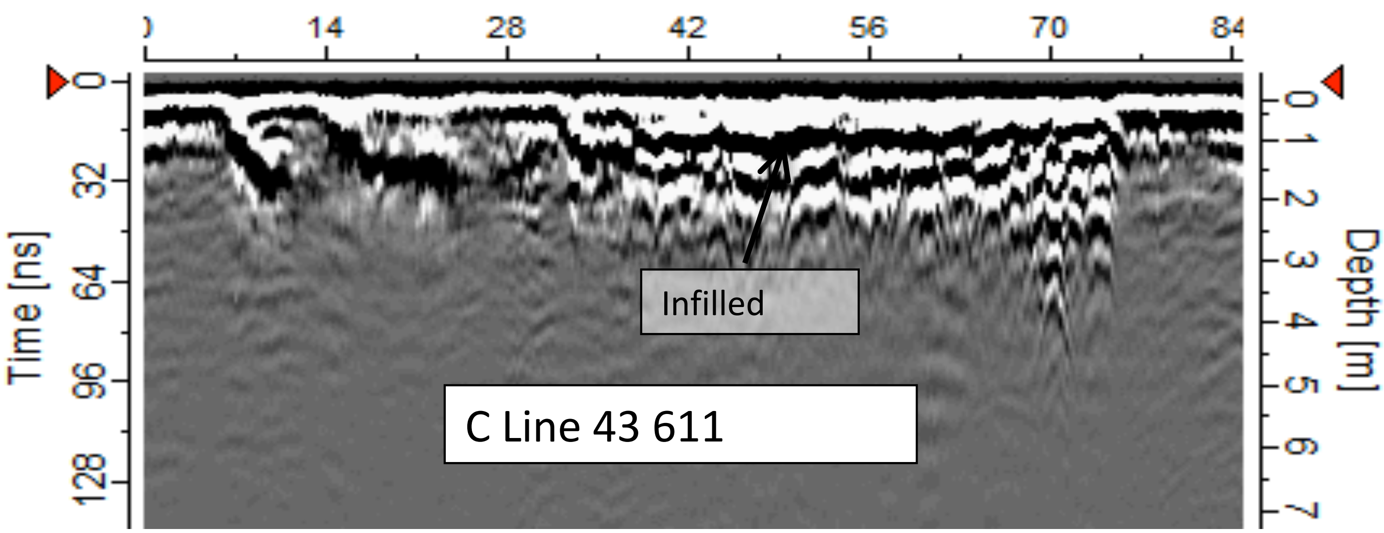

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1
2
3
4
5
6
7
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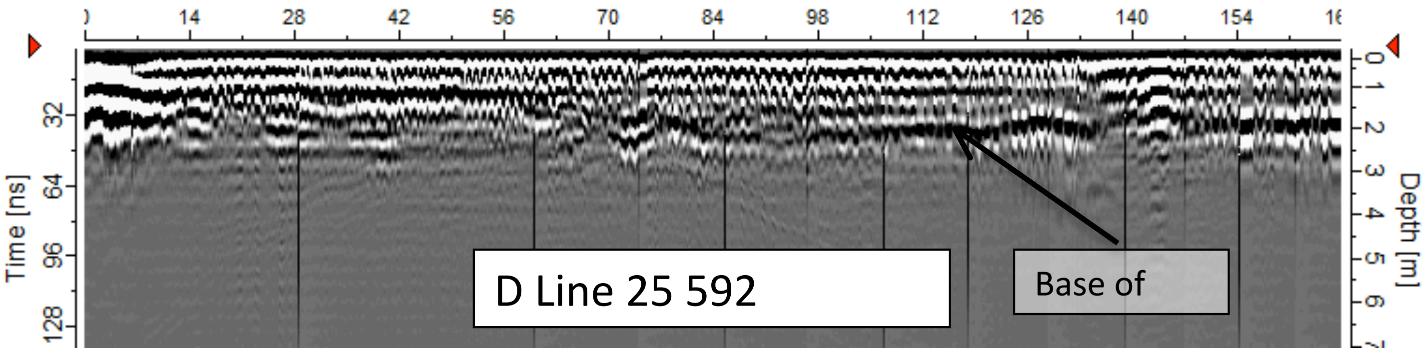
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Base of
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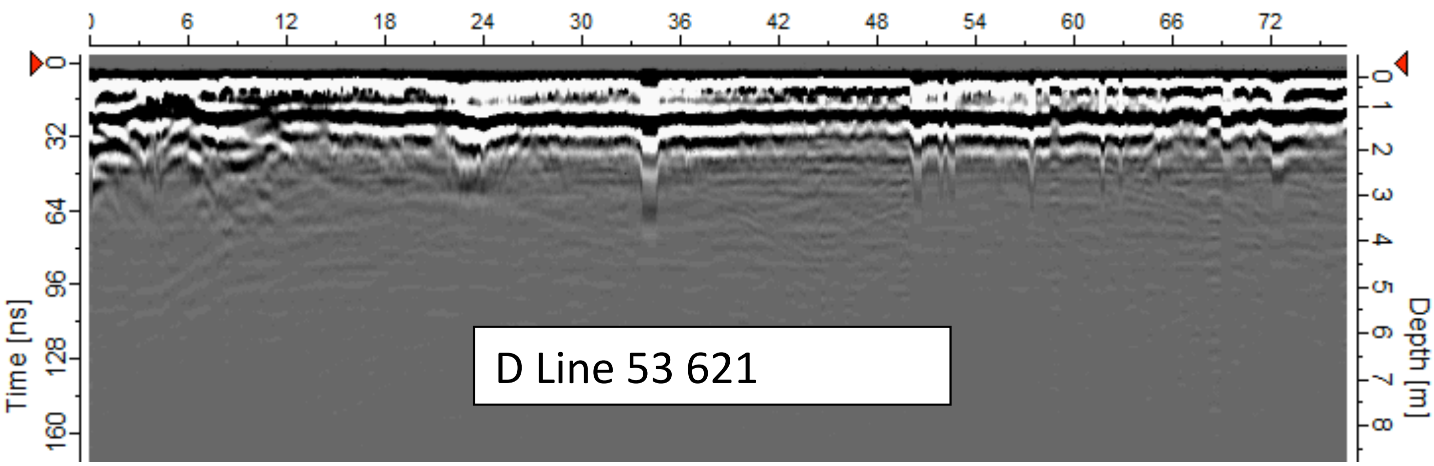
Depth [m]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Time [ns]
Depth [m]