Attachment C-1

Geophysical Survey Results
(on CD included with this document)

Geophysical Investigation SWMU 20-001(c) Landfill and SWMU 53-005 Former Waste Disposal Pit

Los Alamos National Laboratory, Los Alamos, New Mexico

ARM Project No.: 10348

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1.0 INTRODUCTION AND SCOPE

ARM Geophysics (ARM) performed a non-intrusive geophysical investigation at Solid Waste Management Unit (SWMU) 20-001(c) Landfill and SWMU 53-005 Former Waste Disposal Pit on September 9 through 12, 2010. The objectives of the investigation were to delineate the lateral extent of the landfill and disposal pit. To achieve these objectives an integrated geophysical investigation was performed using high-sensitivity metal detector (EM61), terrain conductivity (EM31), and ground penetrating radar (GPR) geophysical techniques. This report details the methods of the investigation in Section 2. A discussion of the results is presented in Section 3. Finally, the conclusions of the investigation can be found in Section 4.

SWMU 20-001(c) Landfill is a 400 x150 ft former disposal area located on the far west end of former TA 20 north of East Jemez Road. The site is believed to have been used to dispose of a number of 3-5 inch bore guns, which were cut into sections and buried in a trench. The site was excavated and contents reportedly removed in 1948.

SWMU 53-005 Former Waste Disposal Pit is an inactive liquid waste disposal pit located southeast of the TA 53 Building 53-2 equipment test laboratory. The pit was approximately 8-ft x 8-ft x 6-ft deep and was excavated directly into the volcanic tuff. The pit was allegedly constructed in 1970 and used until 1986.

2.0 METHODOLOGY

2.1. *GEODETIC POSITIONING*

All geophysical instruments were integrated with a differential global positioning system (GPS) to allow real-time navigation along planned survey routes, to provide accurate location of geophysical measurements, to eliminate the need to establish a local reference grid, and to allow direct data integration with LANL's geographic information system (GIS). The geographic positions of all measurement points were acquired at 1-s intervals as the geophysical data were collected. The data were acquired using a differential system, which allowed accurate positioning with real-time accuracy of less than 1 meter. All geographic data are presented in New Mexico State Plane Coordinate System, North American Datum 1983, Central Zone, US survey feet.

2.2. *HIGH-SENSITIVITY METAL DETECTOR (EM61)*

Buried metal objects can be effectively located using a Geonics EM61-MK2 High-Sensitivity Metal Detector. The EM61 is a time domain electromagnetic (EM) system that can discriminate between conductive soils and metal objects. It has numerous advantages over other commonly used metal detection devices. For example, it is significantly less sensitive to cultural interference.

The EM61 generates rapid electromagnetic pulses and measures the subsurface response between pulses. Secondary EM fields are generated in the ground after each pulse. These fields dissipate rapidly in earth materials but remain for a longer time in buried metal objects. The EM61 measures the prolonged metal response only after the earth response has dissipated. This response is measured and displayed in millivolts (mV).

For this investigation, data were collected at less than 1-ft intervals along lines spaced approximately 10-ft apart. Higher resolution coverage was completed in selected areas using a 5-ft line spacing. Line and station separation sometimes varied depending upon surface obstructions. Geodetic coordinates were recorded at 1-s intervals using an integrated GPS so each measurement point could be accurately located.

2.3. *TERRAIN CONDUCTIVITY (EM31)*

The EM31 method uses the principle of electromagnetic induction to measure the electrical conductivity of the ground. Lateral changes in terrain conductivity can indicate the presence of disturbed ground, disposal areas, buried metallic and non-metallic waste, and impacted ground water. In addition, the method is also useful in detecting linear metal objects such as utilities.

A Geonics EM31-MK2 was used to conduct the survey. The EM31 operates in accordance with the theory of operation at low induction numbers. An alternating current is passed through a transmitter coil to induce eddy currents into the ground below the instrument. These eddy currents generate a secondary magnetic field. The quadrature-phase component of the induced secondary magnetic field is detected by a receiver coil and measured by the instrument. The measured response is linearly related to the terrain conductivity. The instrument converts the measured signal and displays it as terrain conductivity in millisiemens per meter (mS/m).

For this investigation, EM31 data were recorded approximately at less than 1-ft intervals along lines spaced approximately 10-ft apart. Higher resolution coverage was completed in selected target areas using a 5-ft line spacing. Line and station separation sometimes varied depending upon surface obstructions such as the presence of cultural interference, buildings, and dense vegetation. Geodetic coordinates were recorded at 1-s intervals using an integrated GPS. A base station free from cultural interference such as aboveground metal objects and overhead power lines was occupied at the beginning and end of each survey day to calibrate the instrument and perform system functional tests. During these tests, battery, phasing, and sensitivity checks were performed.

Terrain conductivity (EM31) data are commonly used to map the lateral changes in electrical conductivity that can indicate the presence of disturbed ground and both metallic and nonmetallic buried waste. The character of EM anomalies can be complex when produced by buried metal objects. Anomalies can be positive, negative, or both depending upon the depth, location, and orientation of the object with respect to the instrument orientation. If sufficient lateral resolution is achieved, shallow anomalies caused by large metal objects typically produce a negative anomaly directly over the object that is surrounded by a "halo" of elevated conductivity.

2.4. GROUND PENETRATING RADAR (GPR)

The GPR technique uses the transmission and reflection of radio waves to image objects beneath the ground surface. The technique responds to changes in the electrical properties of the earth or buried materials. A GPR target must possess electrical characteristics that are different from the surrounding media in order to be detected. When the transmitted wave encounters an anomalous object or layer, the wave is reflected back to the surface where it is recorded and analyzed. The waves are transmitted rapidly such that a continuous subsurface image is generated as the transmitter is pulled along the ground surface.

The GPR survey was performed using a digital SIR-3000 Subsurface Interface Radar System, manufactured by Geophysical Survey Systems, Inc. Following initial field tests to determine maximum penetration and sufficient resolution, a 400 MHz transducer was chosen to perform the detailed survey. Data were digitally recorded, displayed, and analyzed during acquisition to allow real-time interpretation. Line locations were chosen based on the results of the EM31 & EM61 surveys.

In-field signal velocity calculations and depth calibrations were performed by recording two-way signal travel times over objects with known depths. In addition, hyperbolic fitting was performed by computer to calculate signal travel time and more accurately estimate target depths.

3.0 RESULTS AND DISCUSSION

3.1. SWMU 20-001(C) LANDFILL

The results of the terrain conductivity survey are presented in Figure 1. This map was constructed using the quadrature-phase component from 30,038 locations. Terrain conductivity data are commonly used to map the lateral changes in electrical conductivity that can indicate the presence of disturbed ground and both metallic and nonmetallic buried waste. Areas of generally elevated conductivity were observed in the northeast and southwest portions of the survey area. The diffuse character of the anomaly boundaries suggest these changes are due to natural conditions. Specifically, they are coincident with drainage areas identified by visual observations of surficial deposits.

A broad linear anomaly is observed near the center of the survey area. The anomaly shape and amplitude is consistent with a buried cable or pipe. A metal guy-wire anchor was identified near the southern end of the anomaly. This type of anchor is typically associated with utility poles.

Figure 2 presents a plan map of the EM61 data, which represents the lateral variations in the instrument's response to metal objects. Theoretically, if no metal objects were present, the instrument reading would be zero. The amplitude of any anomaly is a function of the distance (depth) to the object and the amount of metal present. Several data channels are recorded at each measurement point in millivolts (mV). The presence of buried metal will produce elevated responses from background.

The map shown in Figure 2 represents the contoured EM61 data from 67,780 measurement locations. All anomalies shown on this map are caused by metal objects. Several anomalies are caused by metal objects observed at the surface such as barbed wire. The suspected utility interpreted from the EM31 data is also observed in the EM61 data.

Numerous other anomalies were identified that could not be attributed to objects at the surface or interference. However, they appear to be buried only a few feet below ground and are generally small. By comparison, note the areas of barbed wire shown on the map.

GPR data were collected over selected EM anomalies. The line locations are shown in Figure 3. The GPR profiles are provided in Appendix A. In general, the GPR data confirm the presence of small, shallow buried objects. Figure 4 presents a profile acquired over the linear EM anomaly shown in Figures 1 and 2. This laterally consistent hyperbolic anomaly corroborates the interpretation that the source is a buried pipe or cable. The estimated depth of burial is 1 to 2 feet.

Digital files containing the coordinates of detected anomalies are included with this report.

3.2. SWMU 53-005 FORMER WASTE DISPOSAL PIT

EM data were collected over the SWMU 53-005 area but was adversely impacted by cultural interference. Specifically, a large metal I-beam was partially exposed in the center of the suspected pit location and a fire hydrant, utilities, and a metal dumpster were located in the northwest portion of the survey area.

Figure 5 presents a plan map of the EM61 data that shows the locations of potential interference and reference points. Although the I-beam that is partially exposed at the surface does produce a significant anomaly, the extent of the anomaly is caused by additional buried metal objects.

Closely-spaced GPR lines were run over the suspected SWMU 53-005 survey area. GPR data quality is typically unaffected by interference from adjacent surface metal objects. Figure 6 presents the GPR line locations. The GPR profiles are included in Appendix A. The results show laterally discontinuous features and chaotic reflections often associated with disturbed ground.

An example GPR profile over the target area is shown in Figure 7. The chaotic reflections and underlying interface depression suggests the presence of a former excavation. The depth of the interpreted excavation is estimated at approximately 5 ft. This depth is consistent with historical information that indicates a depth of 6 ft.

Digital files containing the coordinates of detected anomalies are included with this report.

4.0 CONCLUSIONS

The results of the terrain conductivity survey performed at SWMU 20-001(c) show a broad linear anomaly near the center of the survey area. The feature is interpreted as a buried utility and is corroborated by EM61 and GPR data. Numerous discrete anomalies were identified that was attributed to buried metal objects. However, no large trench or other features that appear to be fill boundaries were identified. The detected metal objects appear to be buried less than 3 ft below ground surface.

Although cultural interference was encountered at SWMU 53-005 Former Waste Disposal Pit, the results suggest the presence of a former excavation coincident with historical information. The depth of the suspected former excavation estimated from GPR profiles is 5 ft. The depth reported in historical documents is 6 ft. Although the geophysical data indicated the presence of a former excavation and non-native materials, the data cannot be used to confirm the presence of disposal pit wastes. The same GPR anomaly character could be produced if the disposal pit contents were removed and the excavation was backfilled with non-impacted sediments.

FIGURES

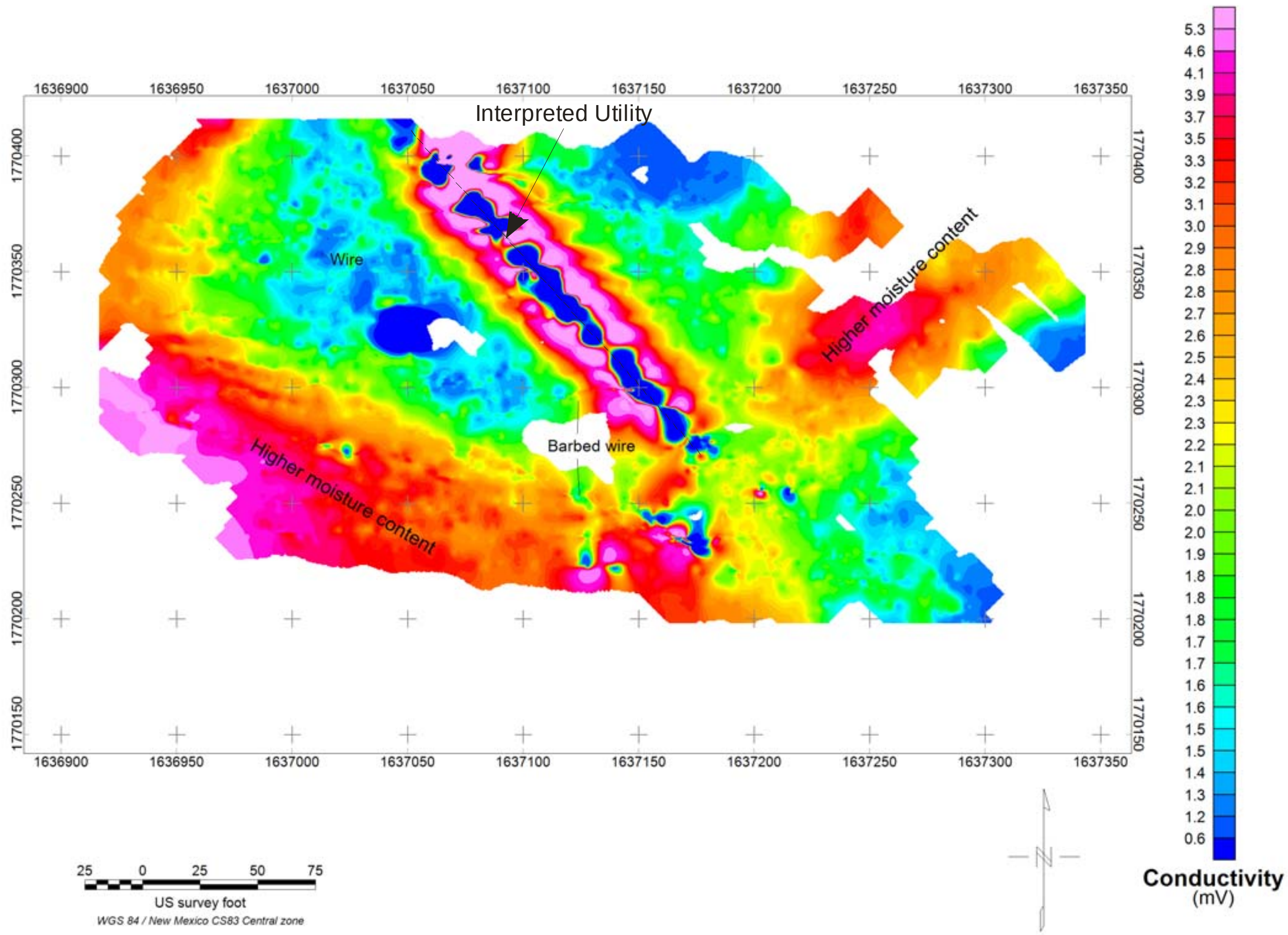


Figure 1: Terrain conductivity (EM31) map of SWMU 20-001(c) survey area.

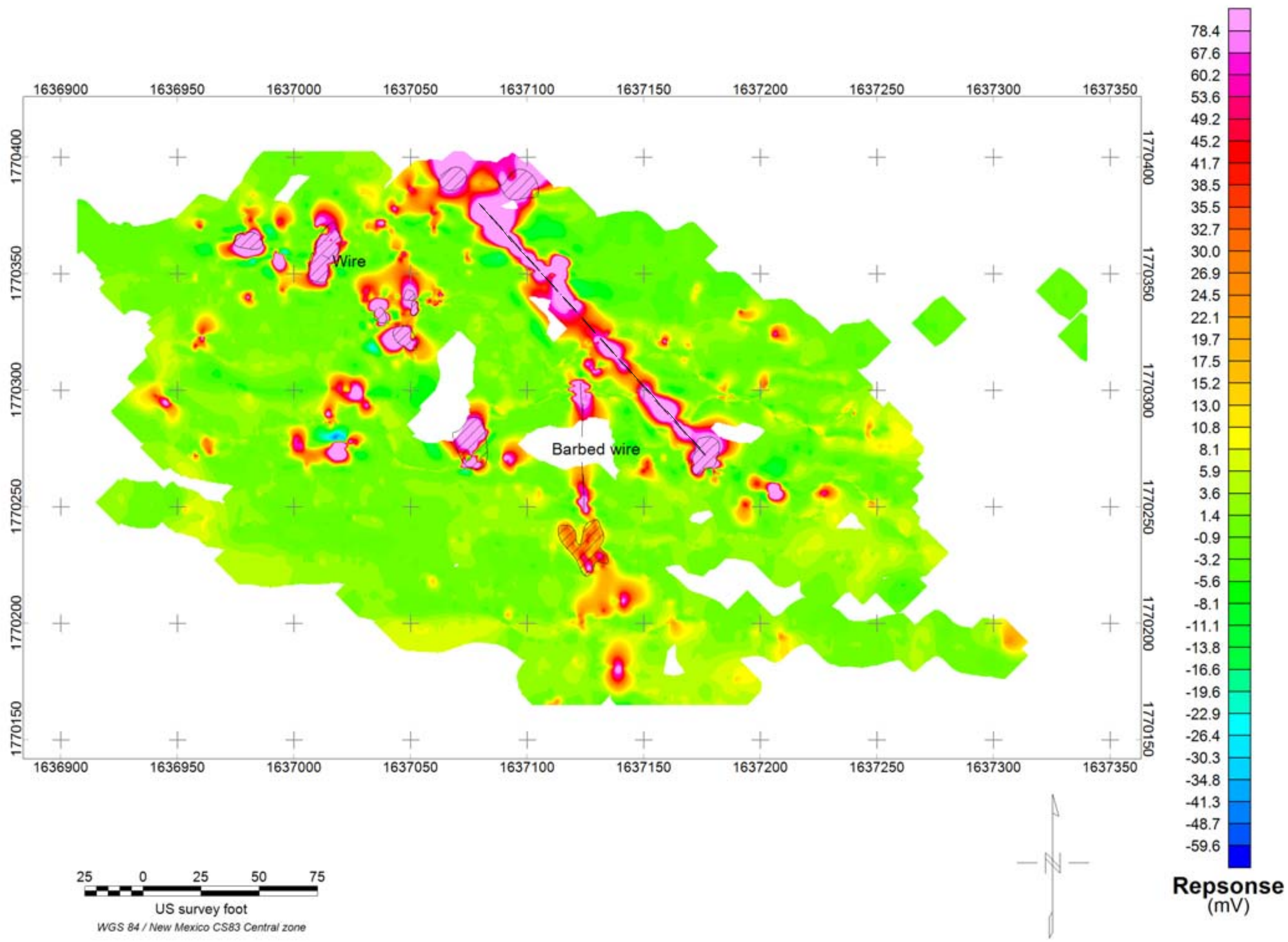


Figure 2: Buried metal anomaly (EM61) map of SWMU 20-001(c) survey area.

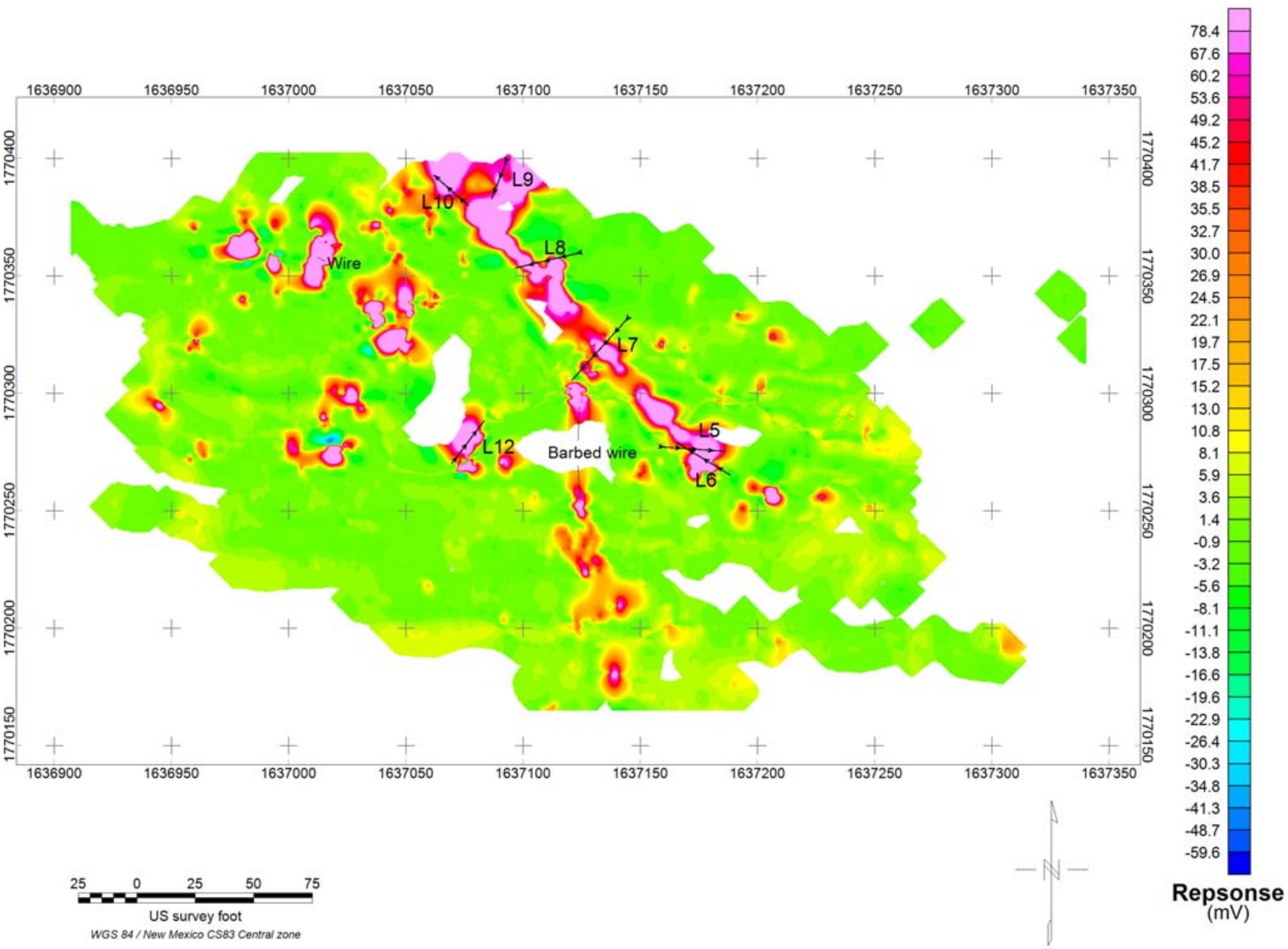


Figure 3: SWMU 20-001(c) GPR line location map.

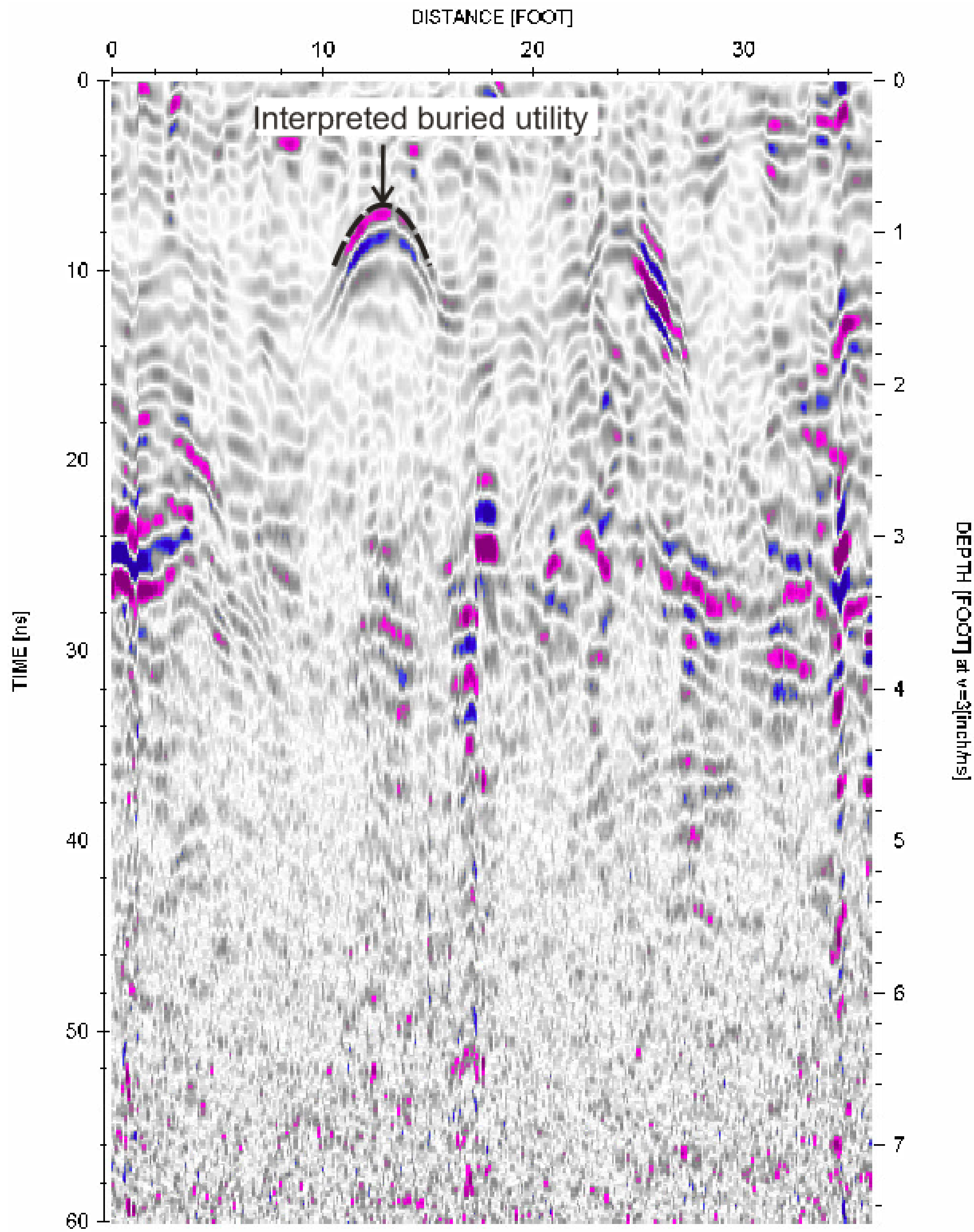


Figure 4: GPR profile of suspected buried utility at SWMU 20-001(c).

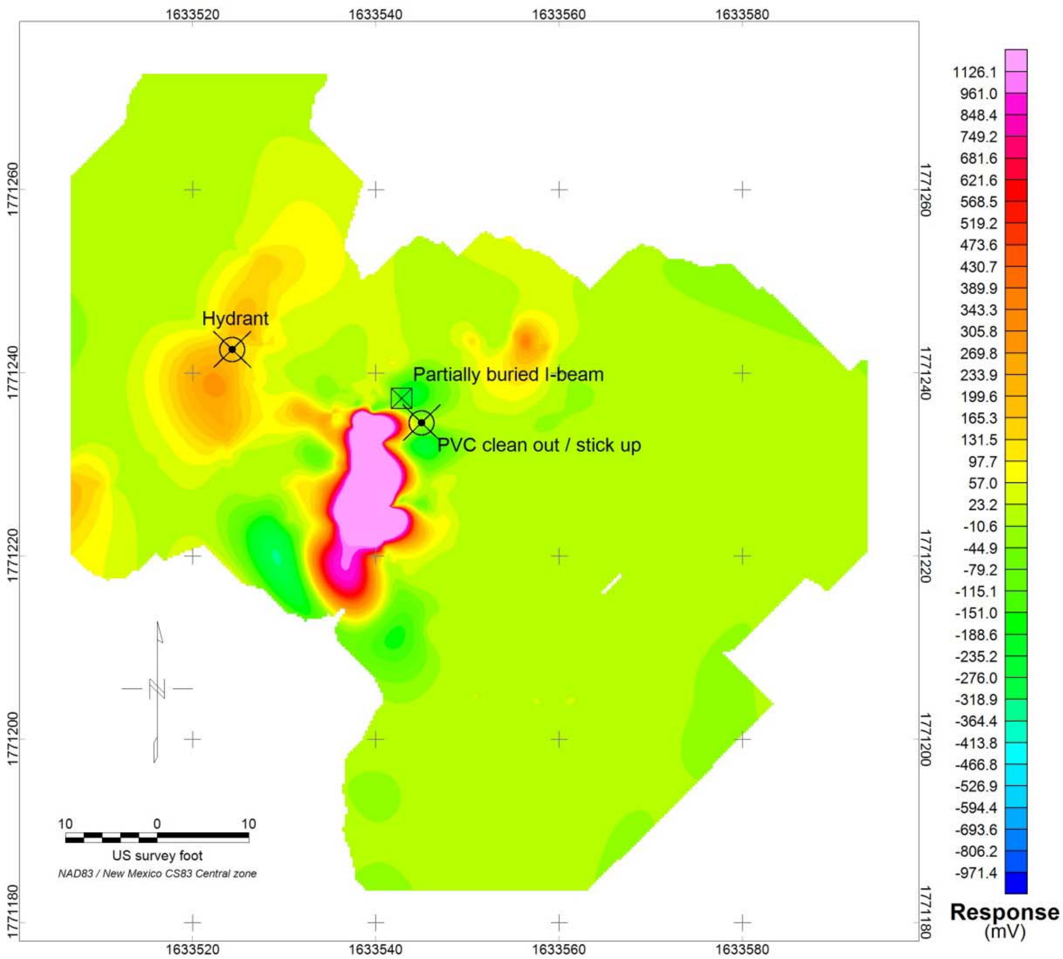


Figure 5: EM61 anomaly map of SWMU 53-005 survey area. Anomaly in the center of the survey area is only partially caused by the exposed I-beam shown there.

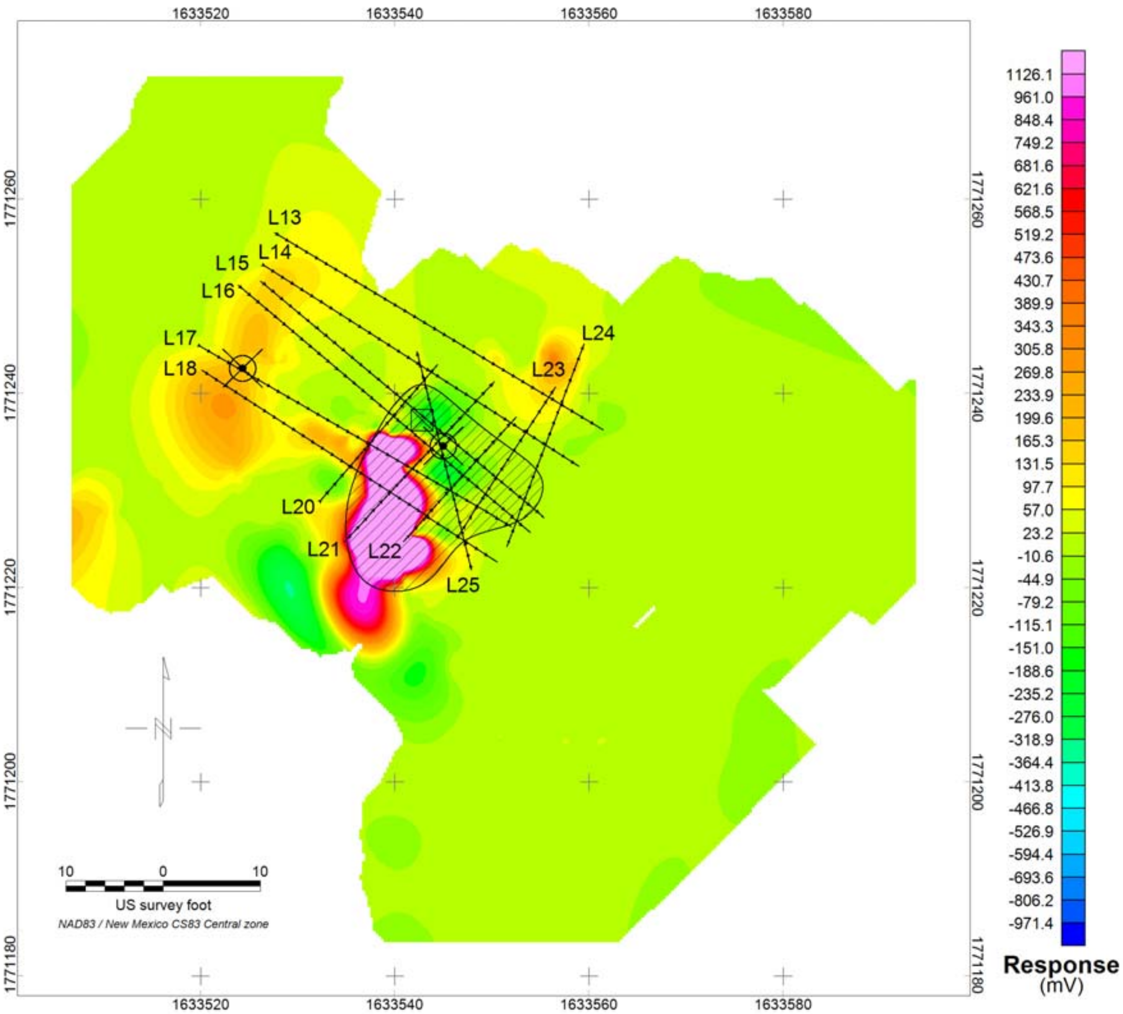


Figure 6: GPR line map and interpreted extent of former excavation (hatched area) at SWMU 53-005

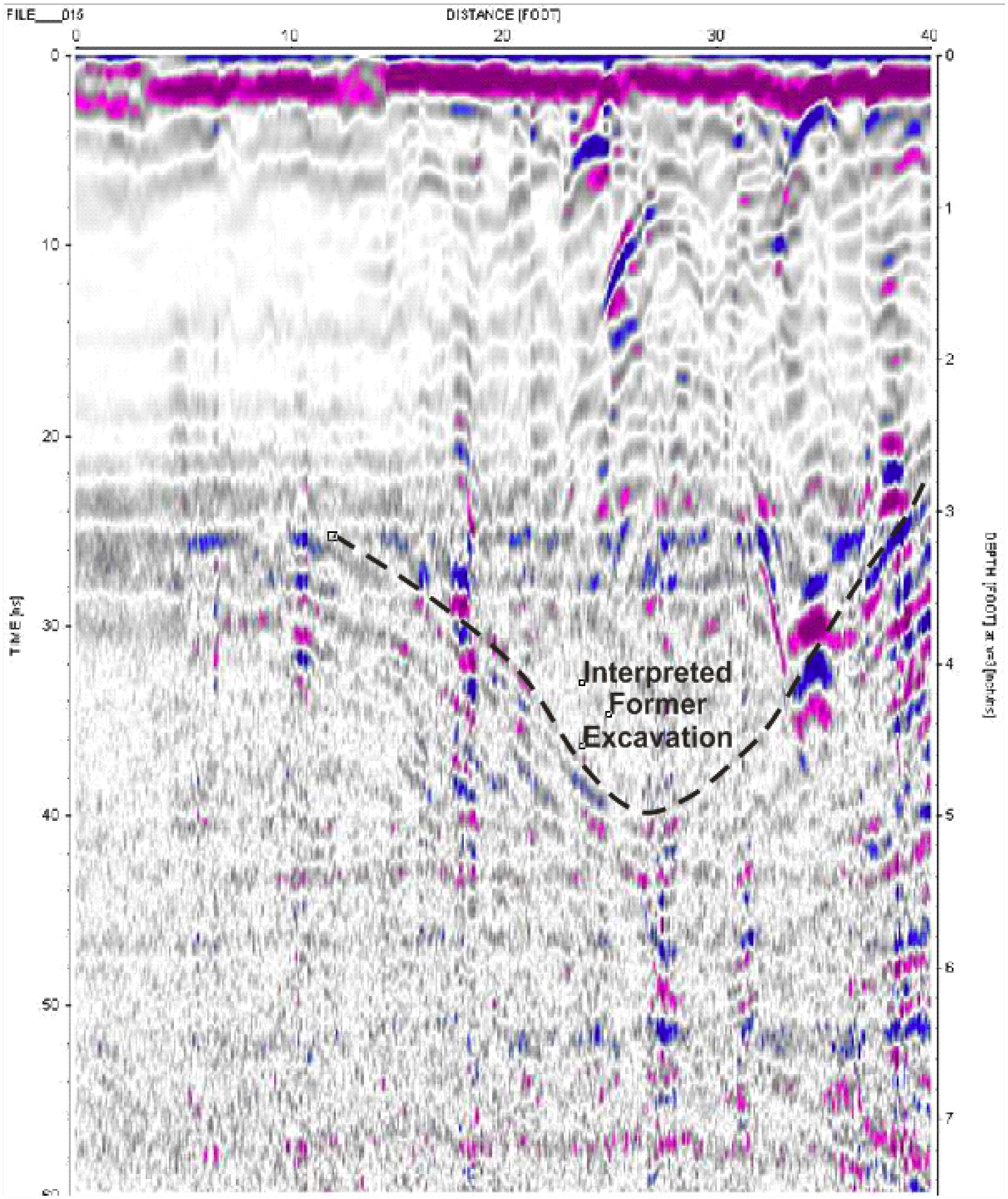
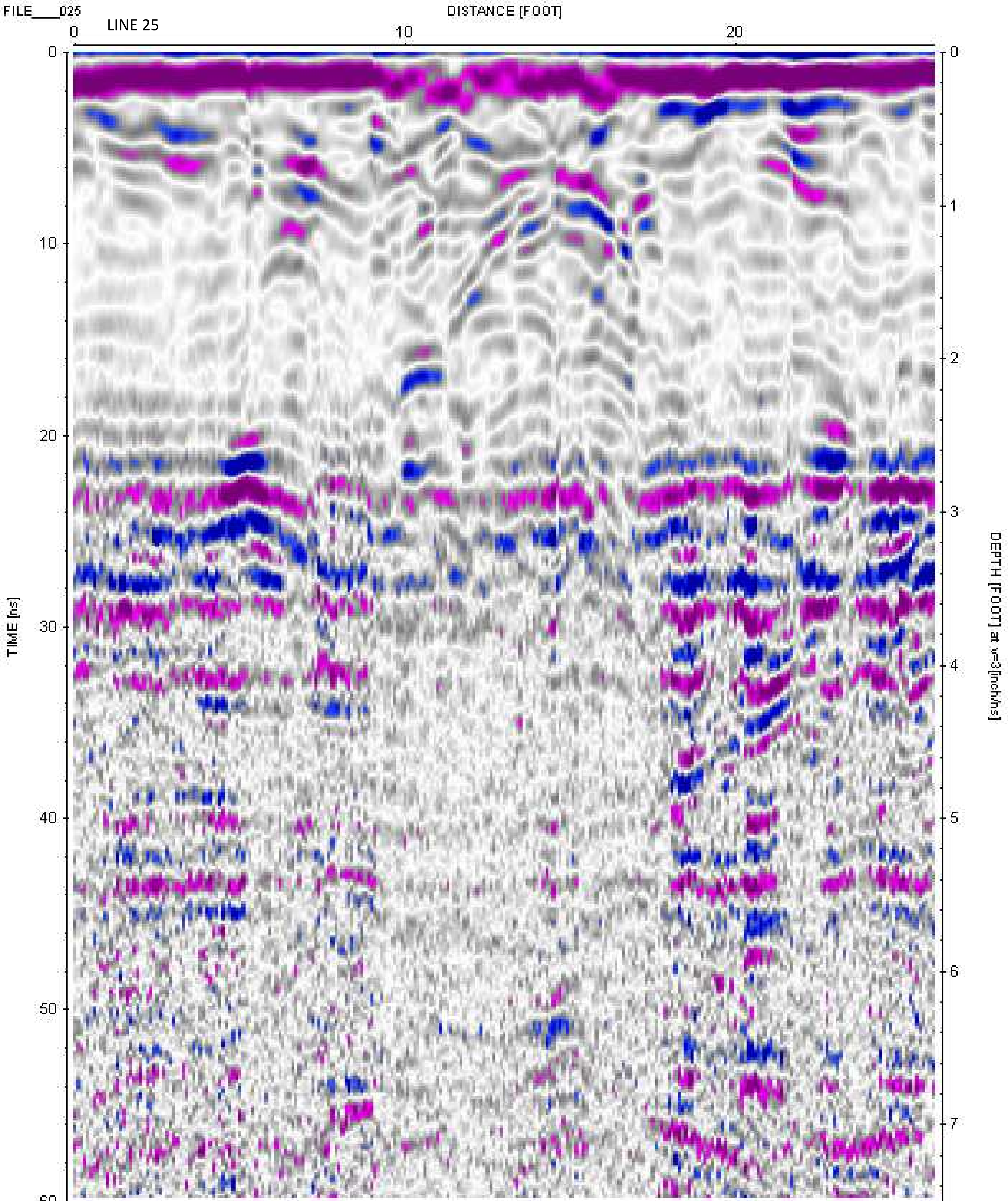


Figure 7: GPR profile of interpreted former excavation area at SWMU 53-005.

APPENDIX A
GPR PROFILES



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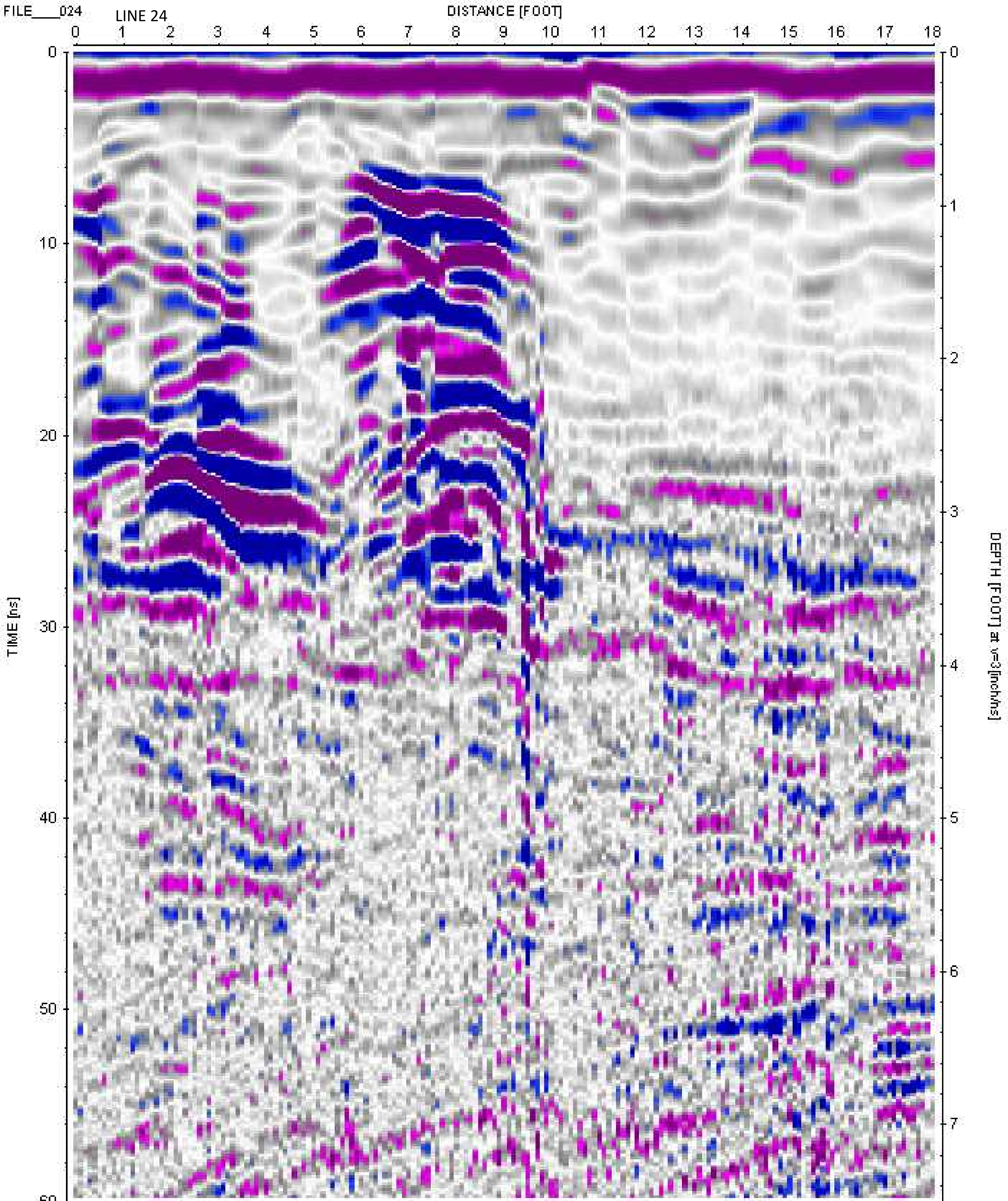
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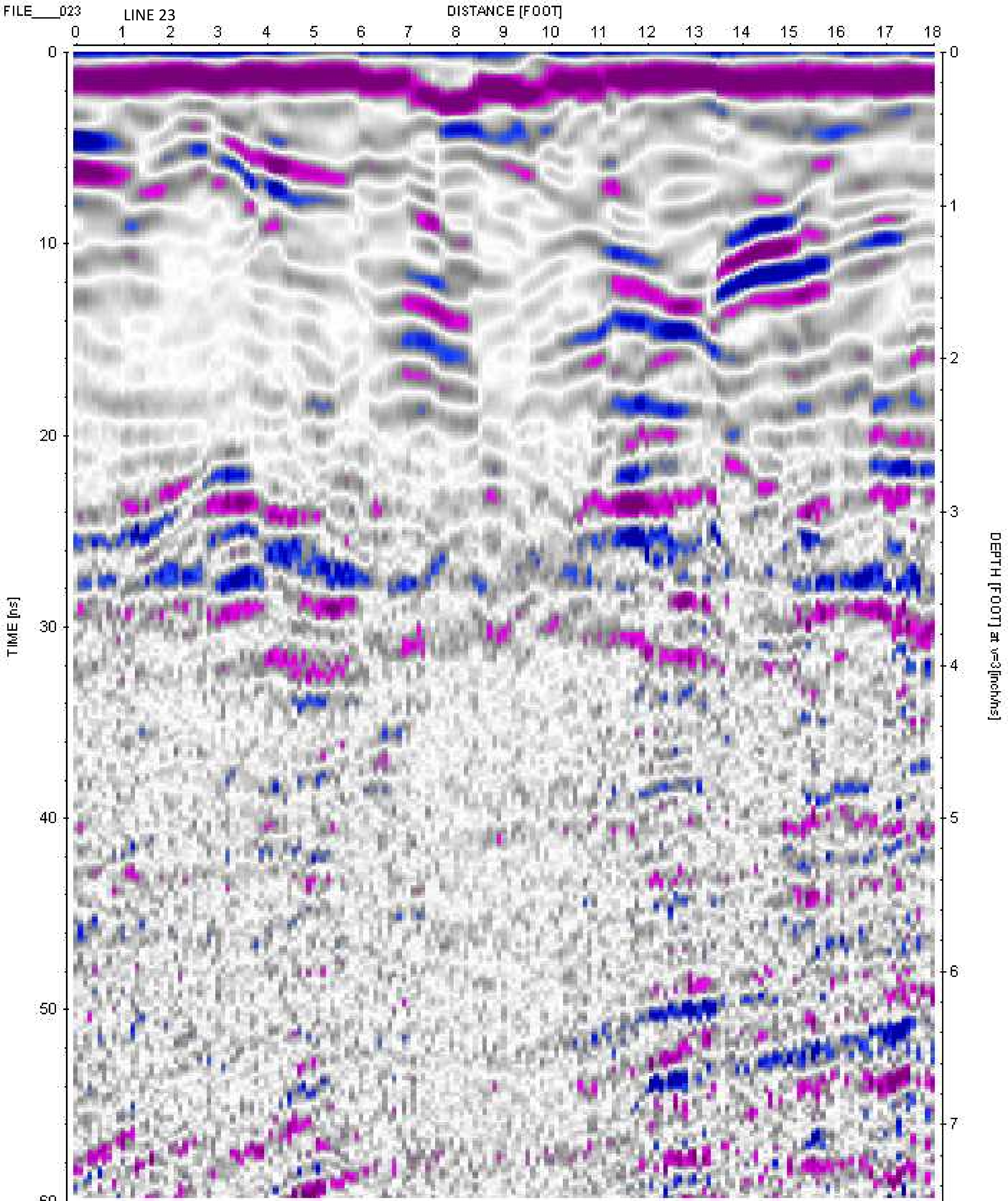

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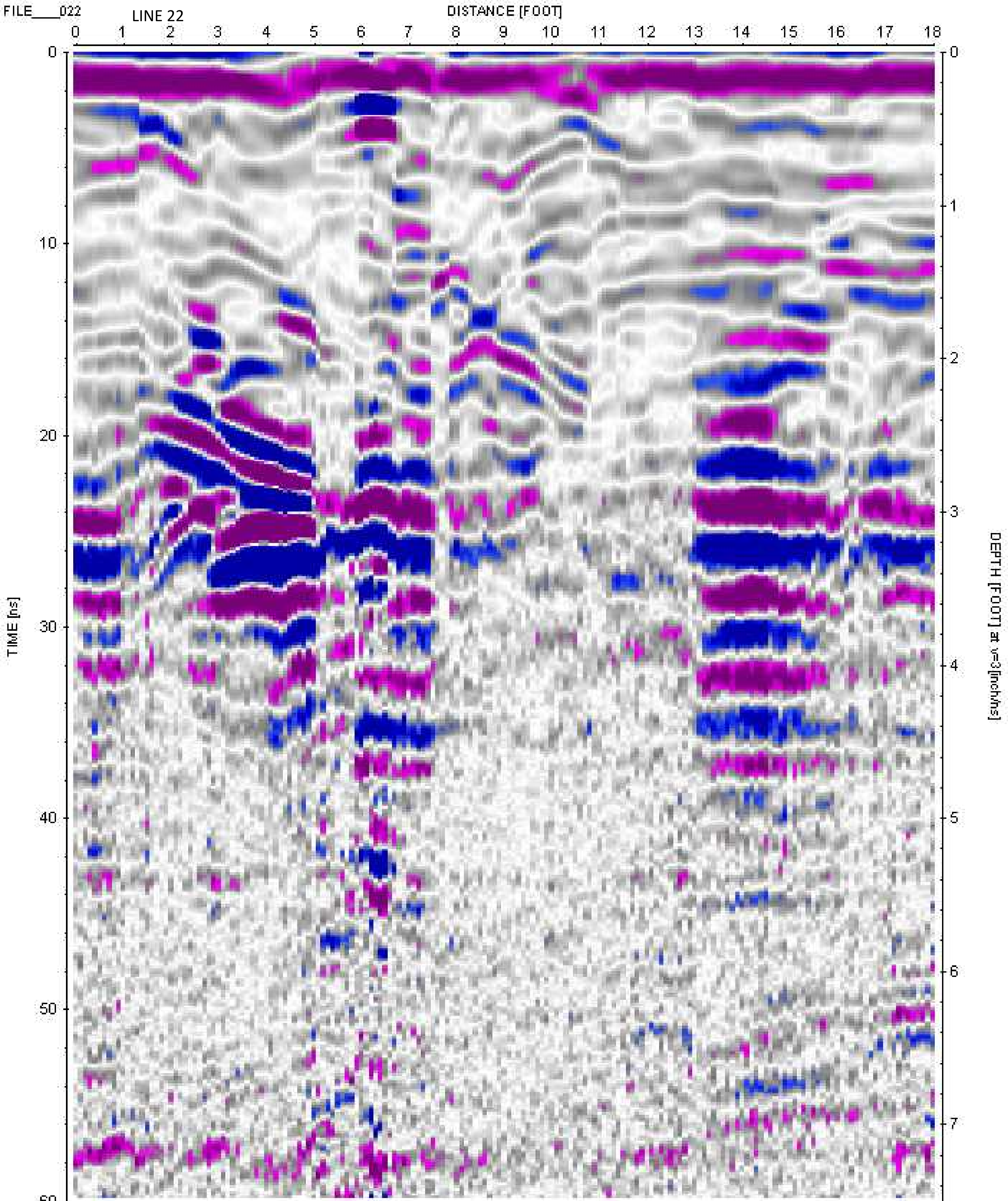
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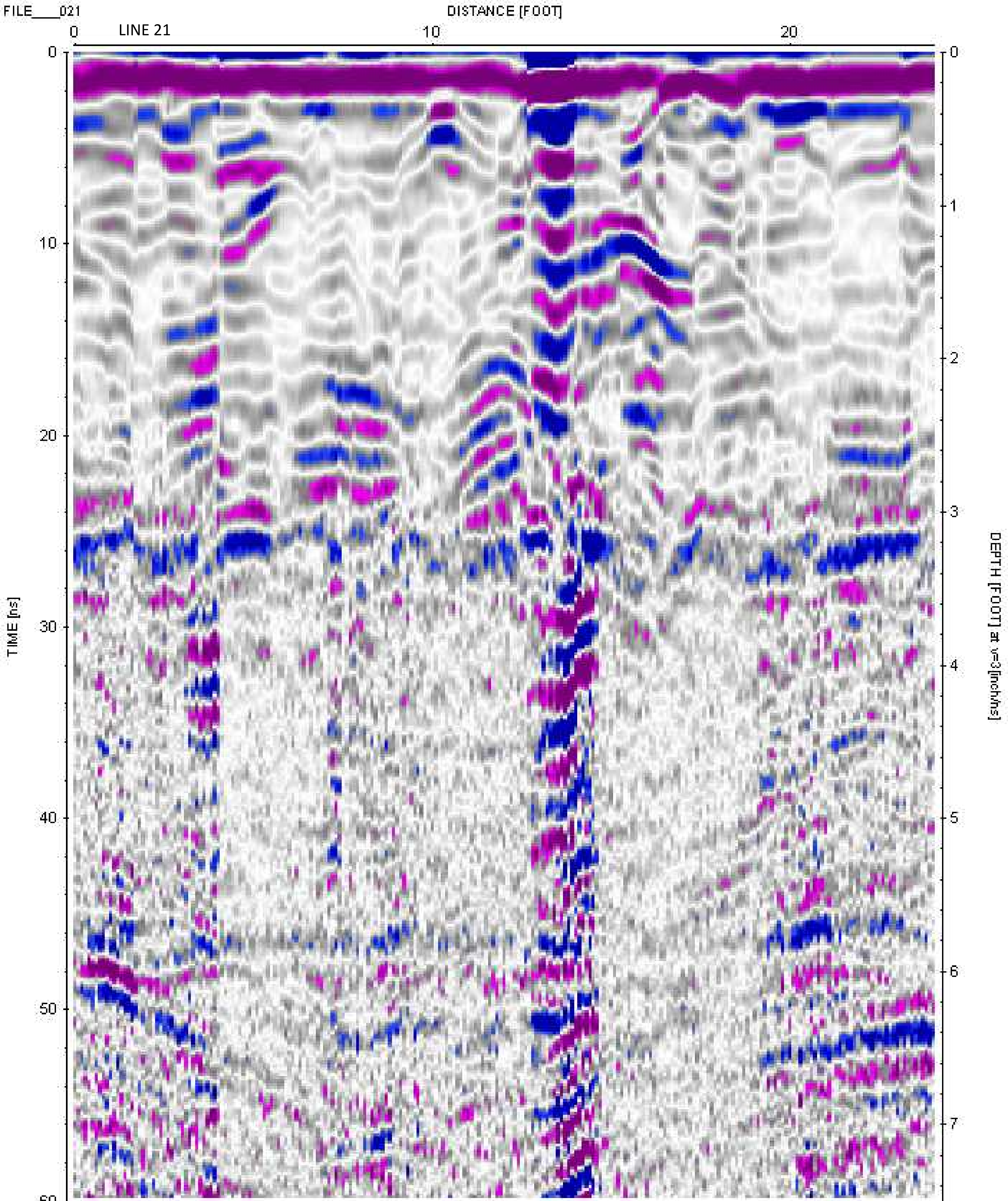
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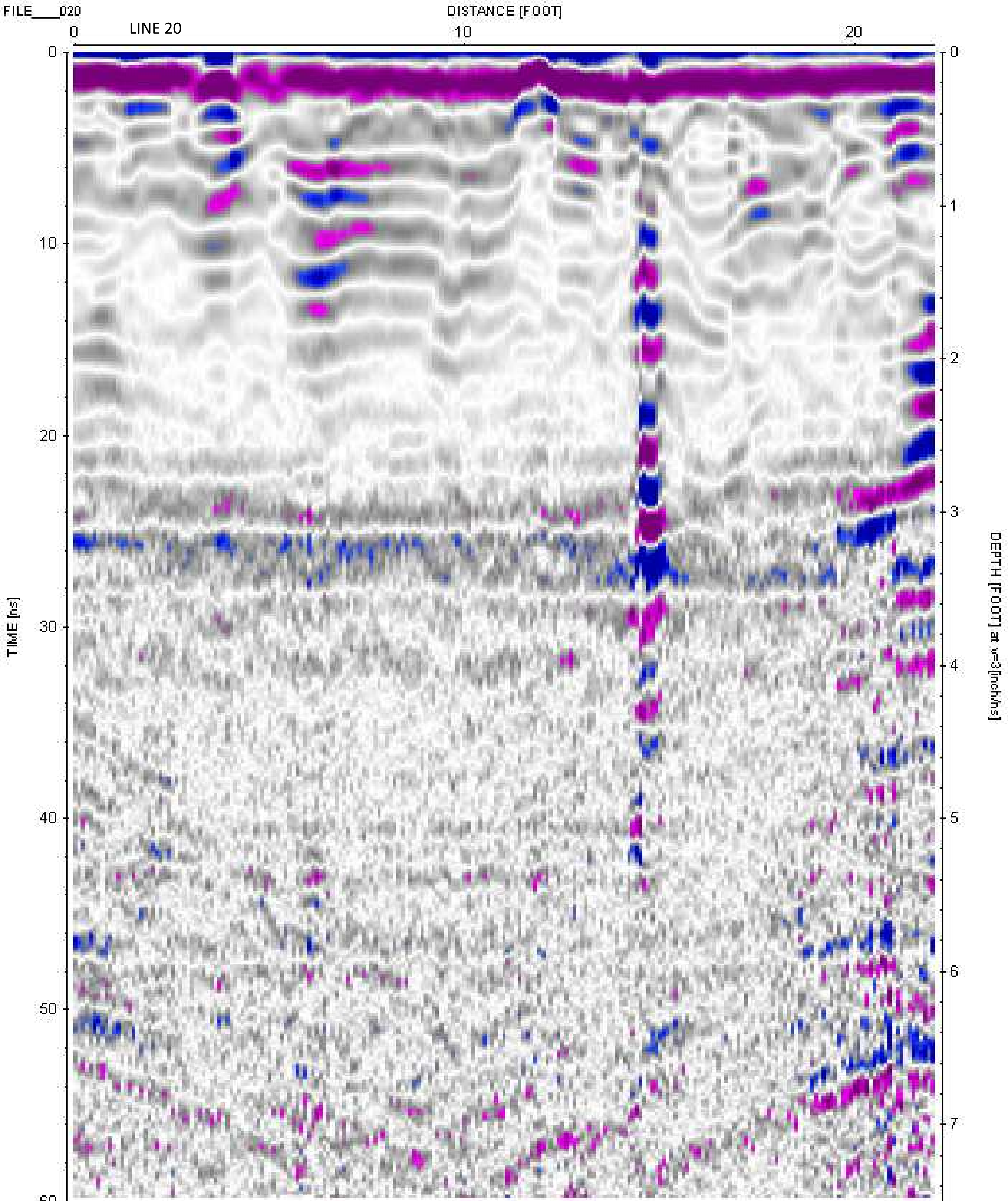

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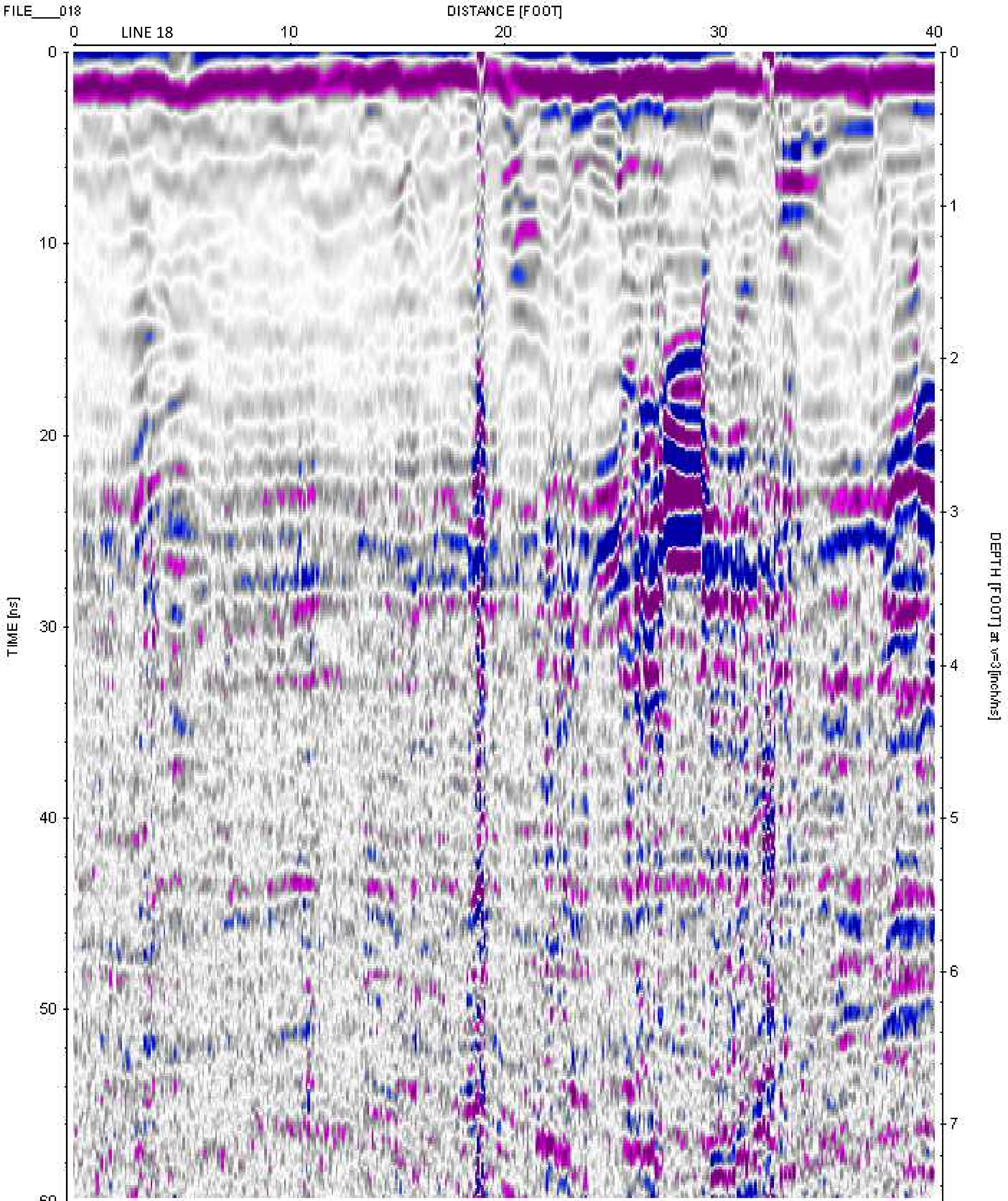
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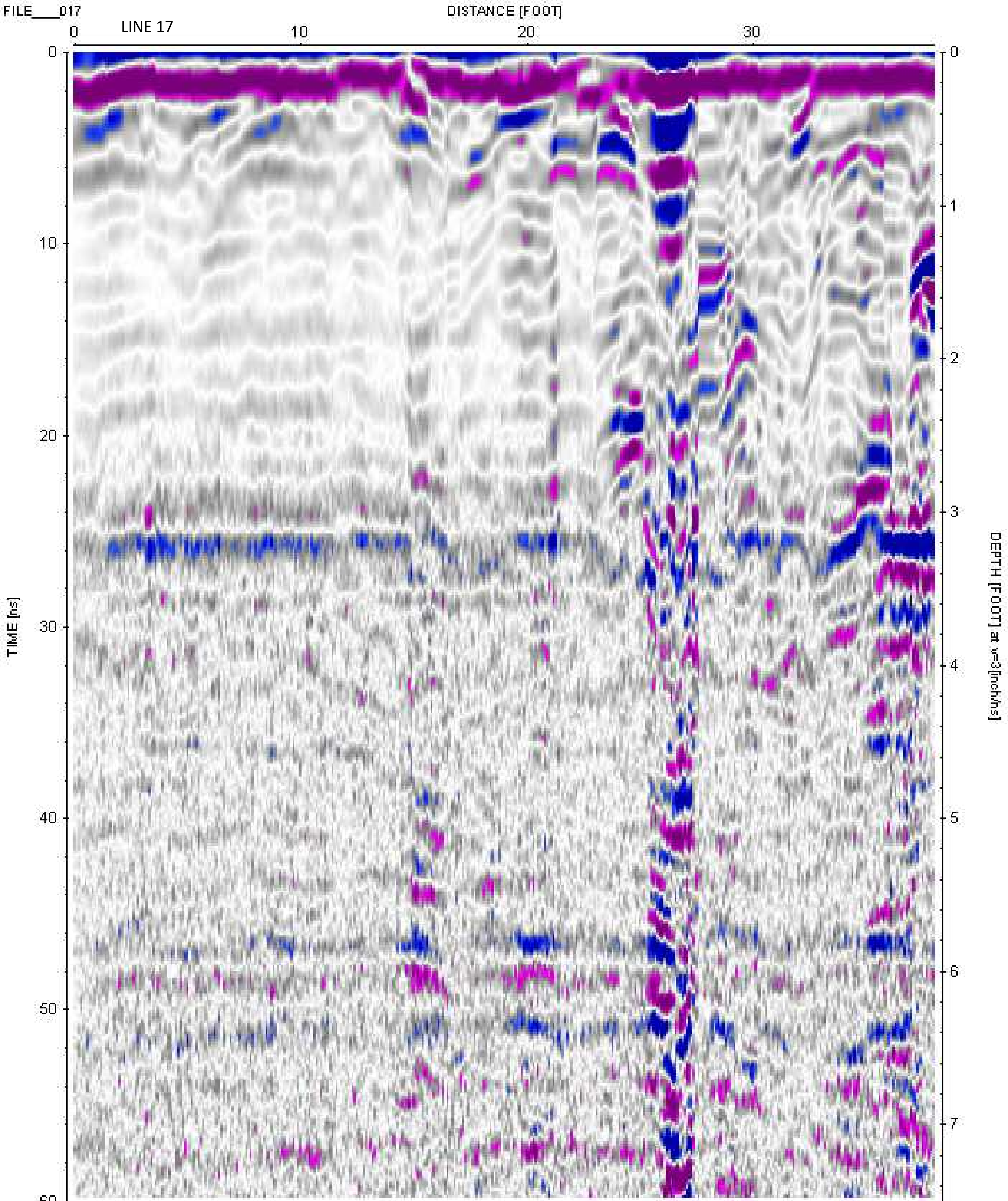
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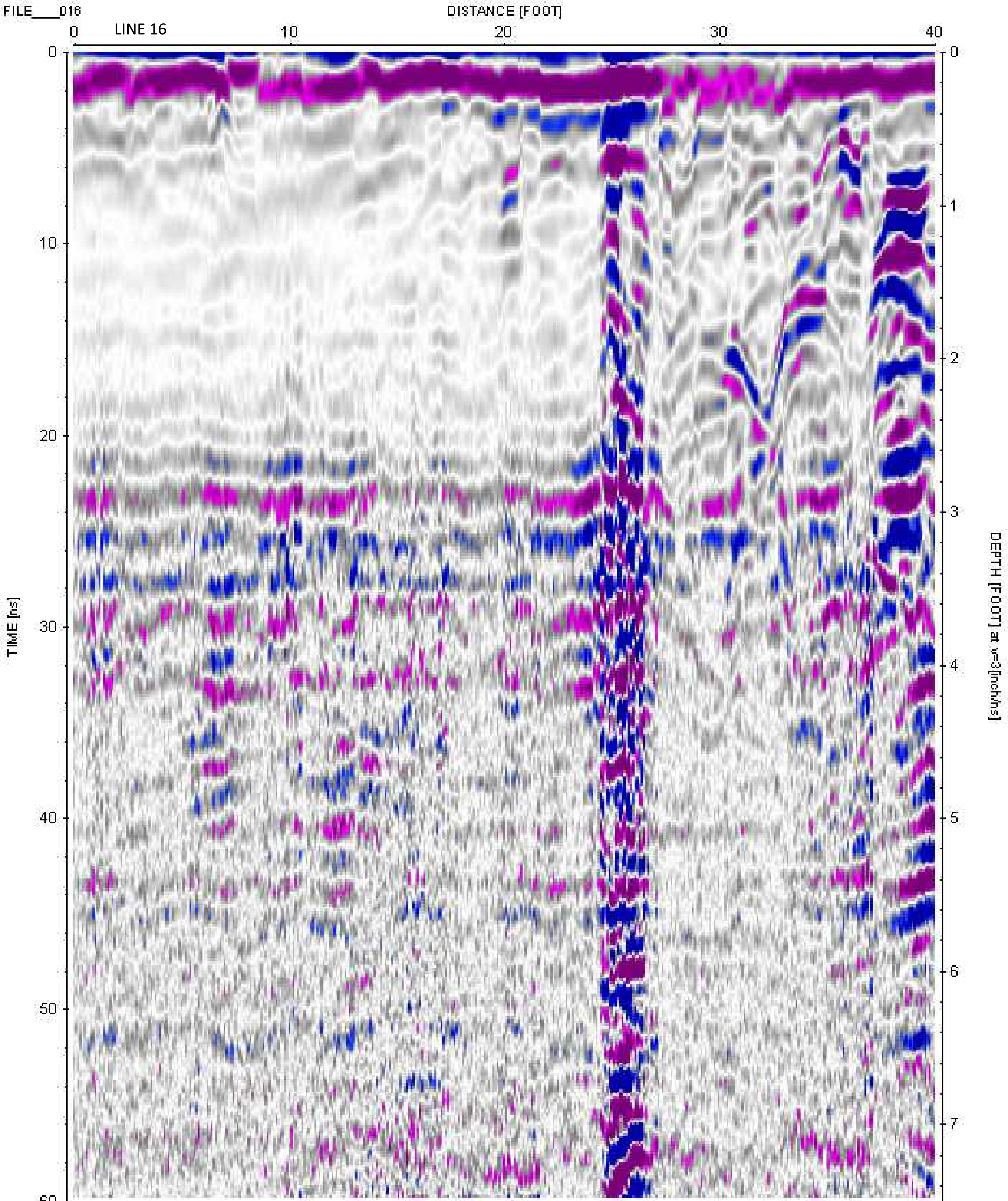
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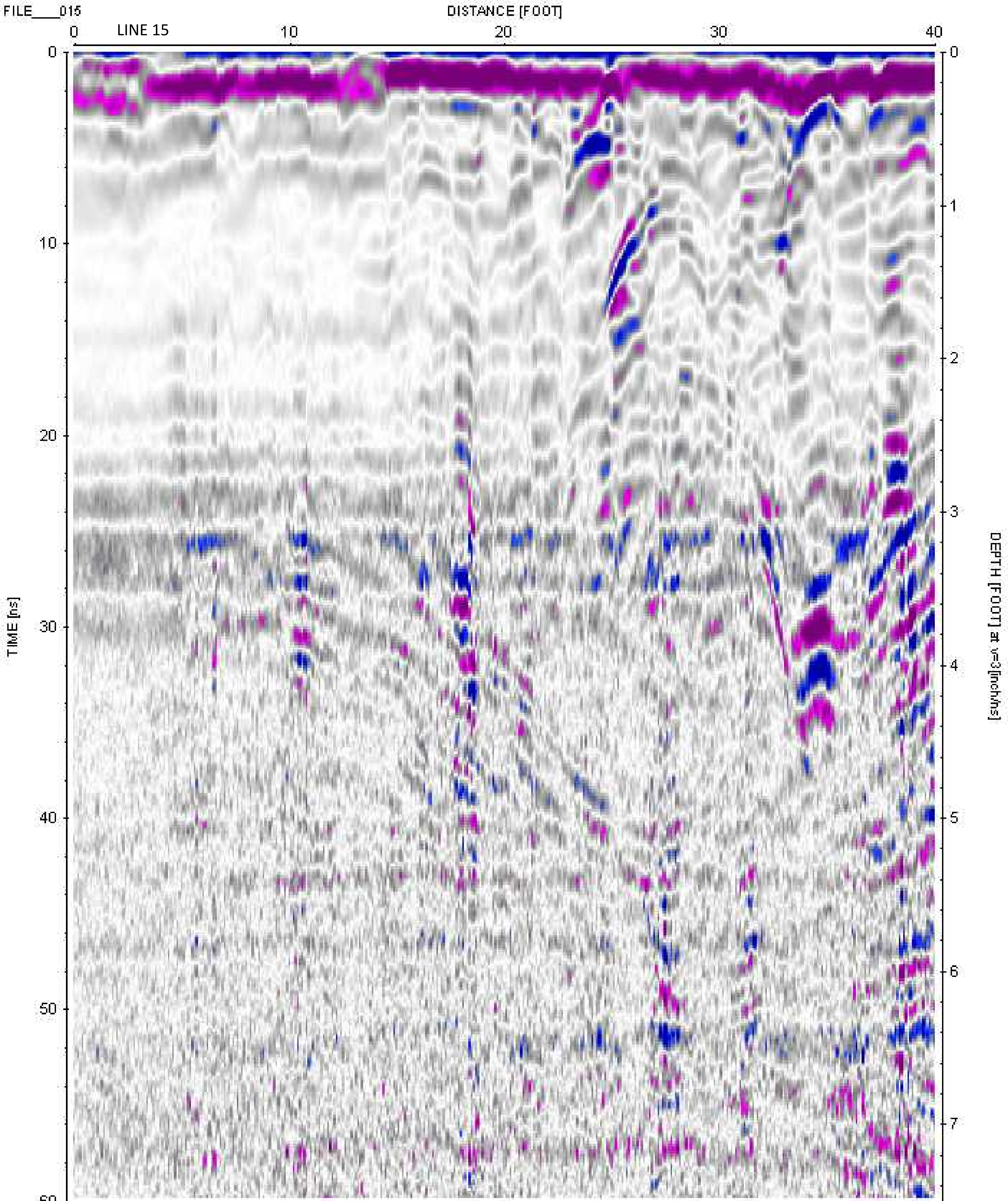
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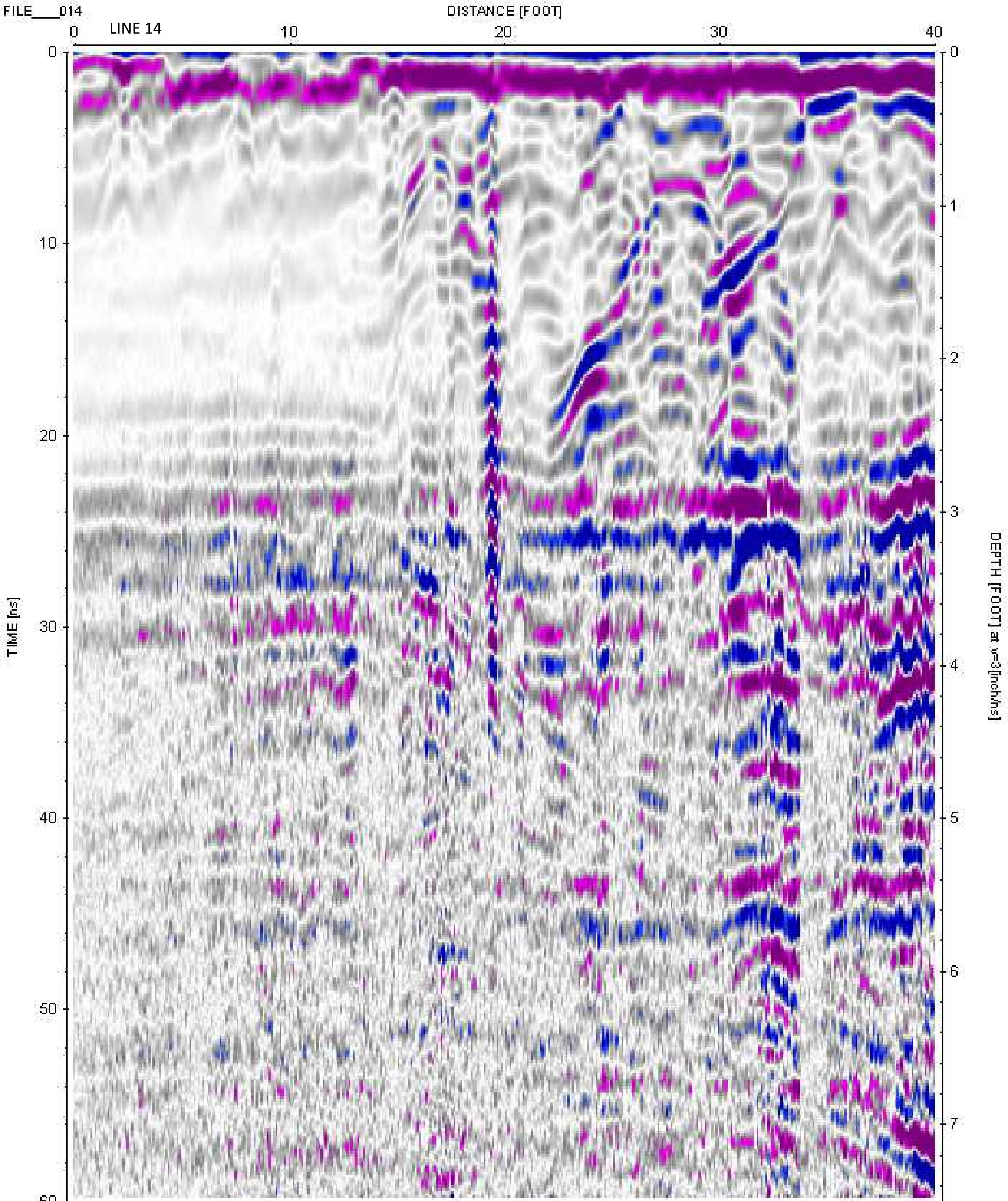
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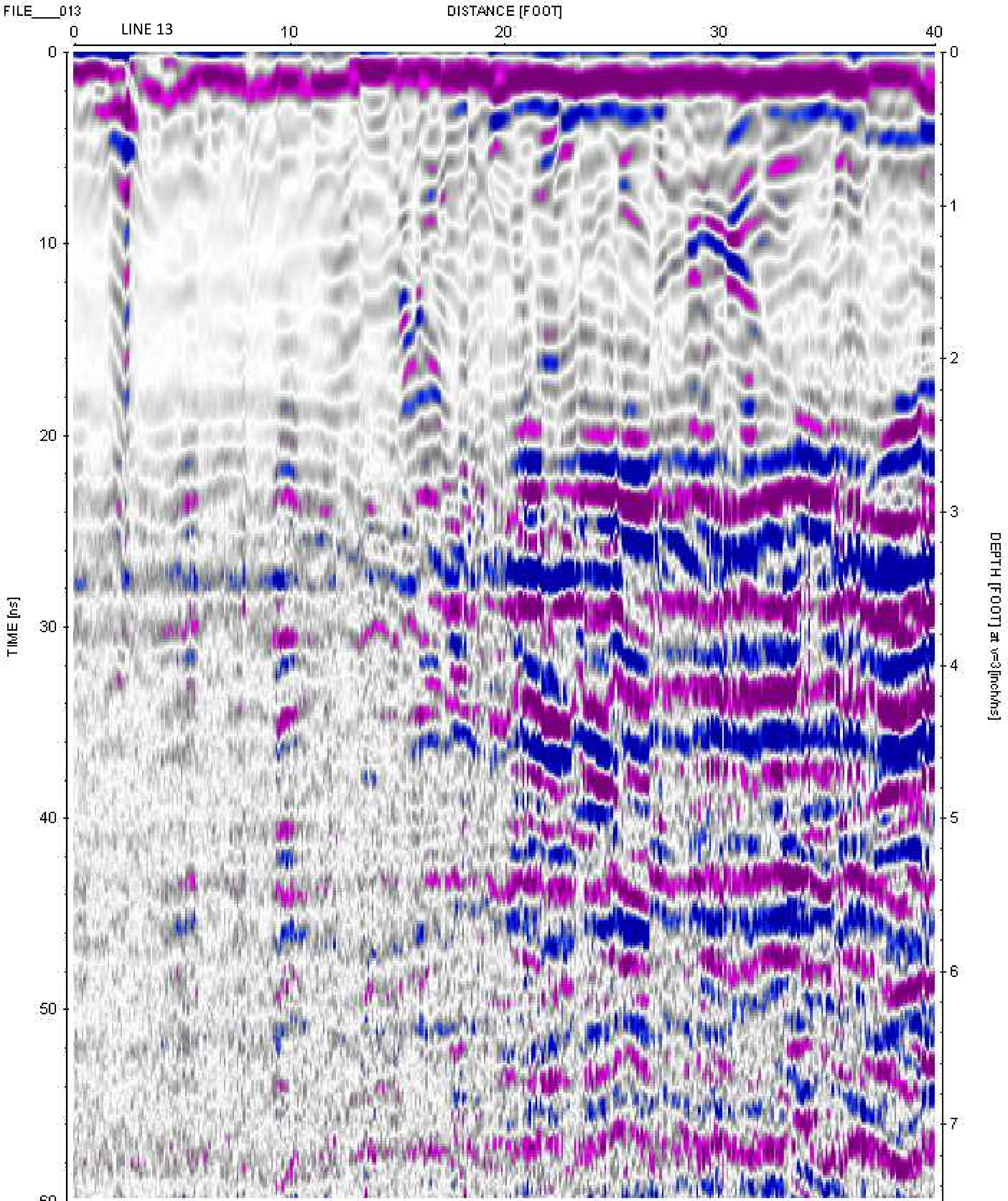

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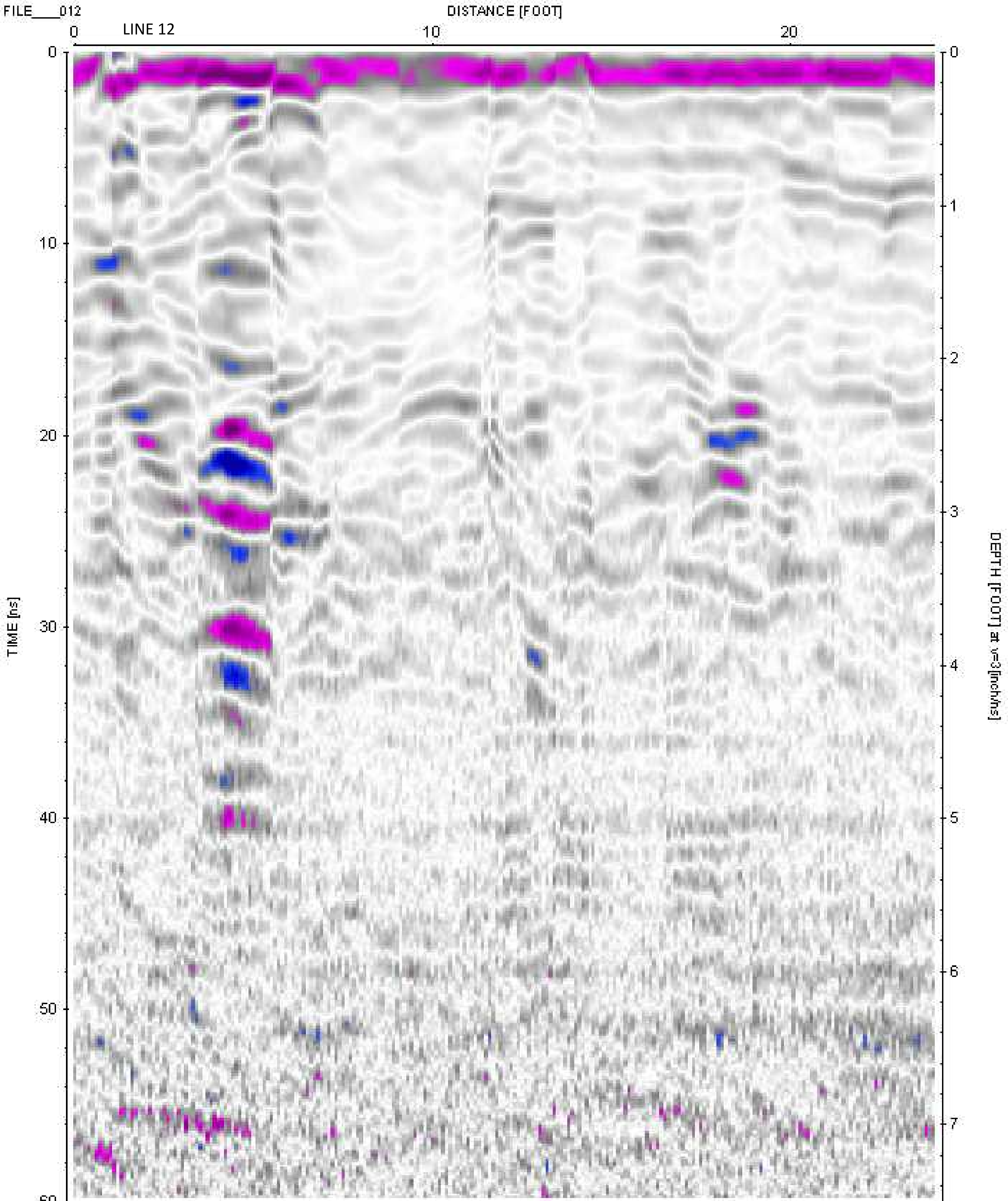
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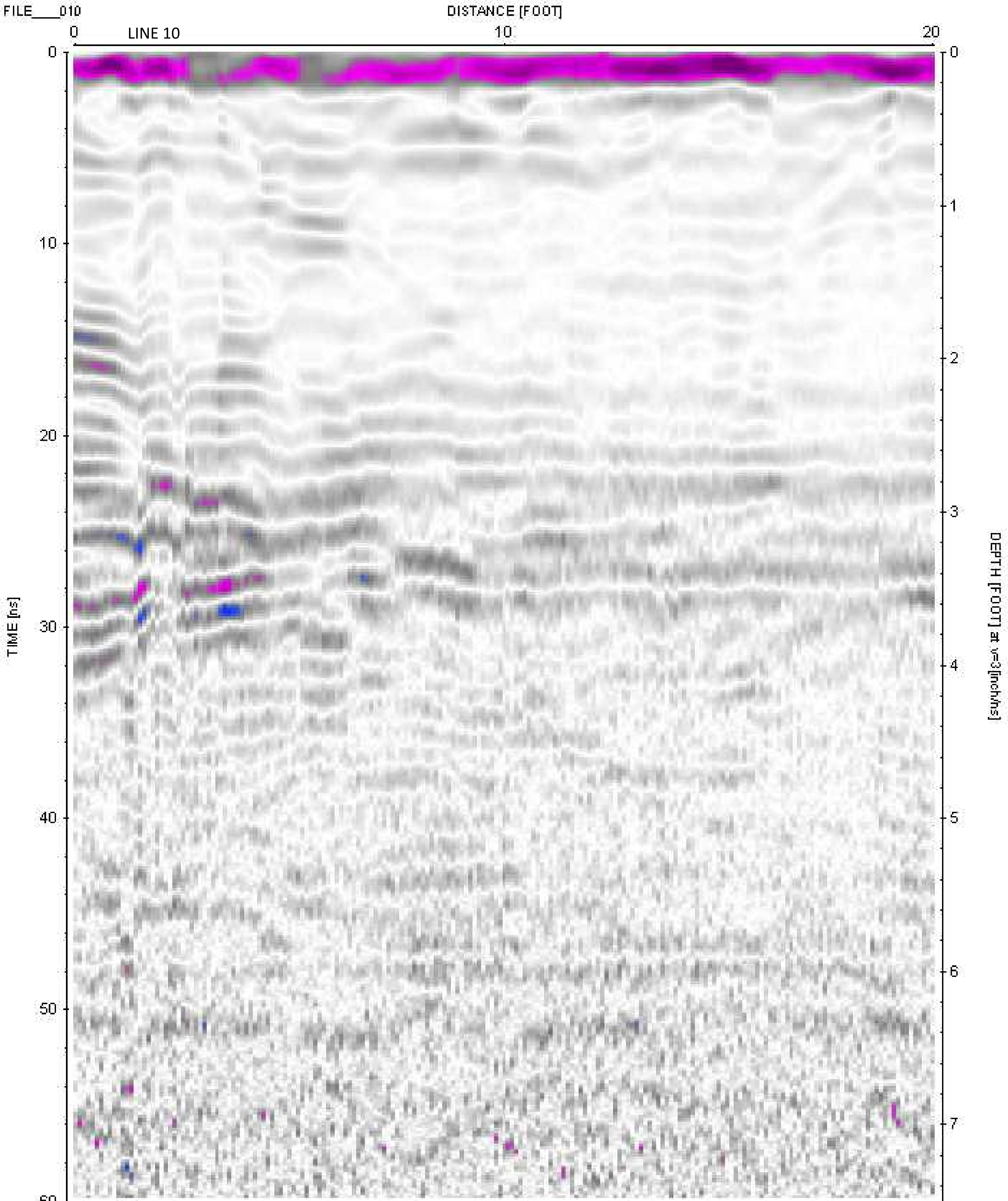
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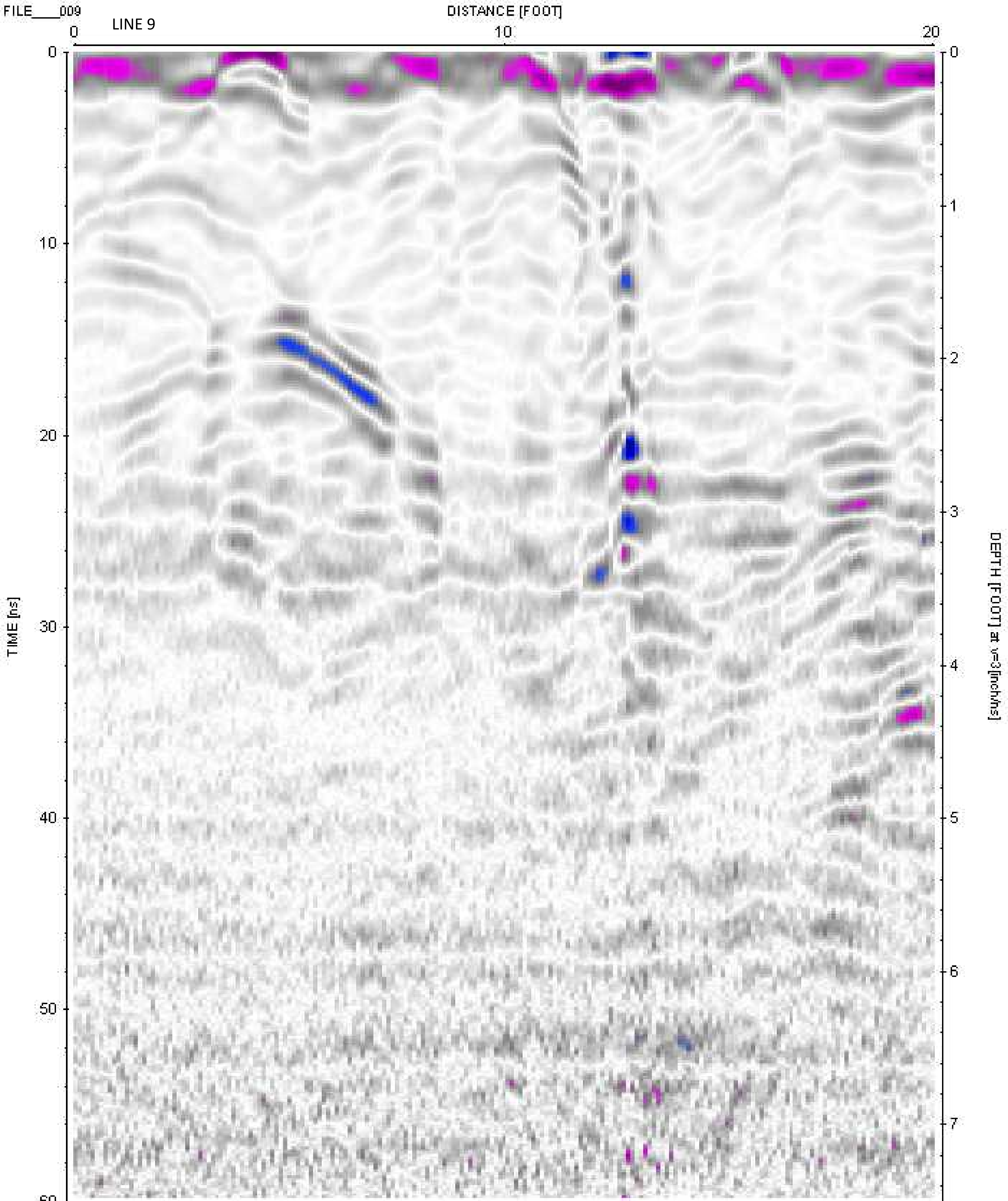
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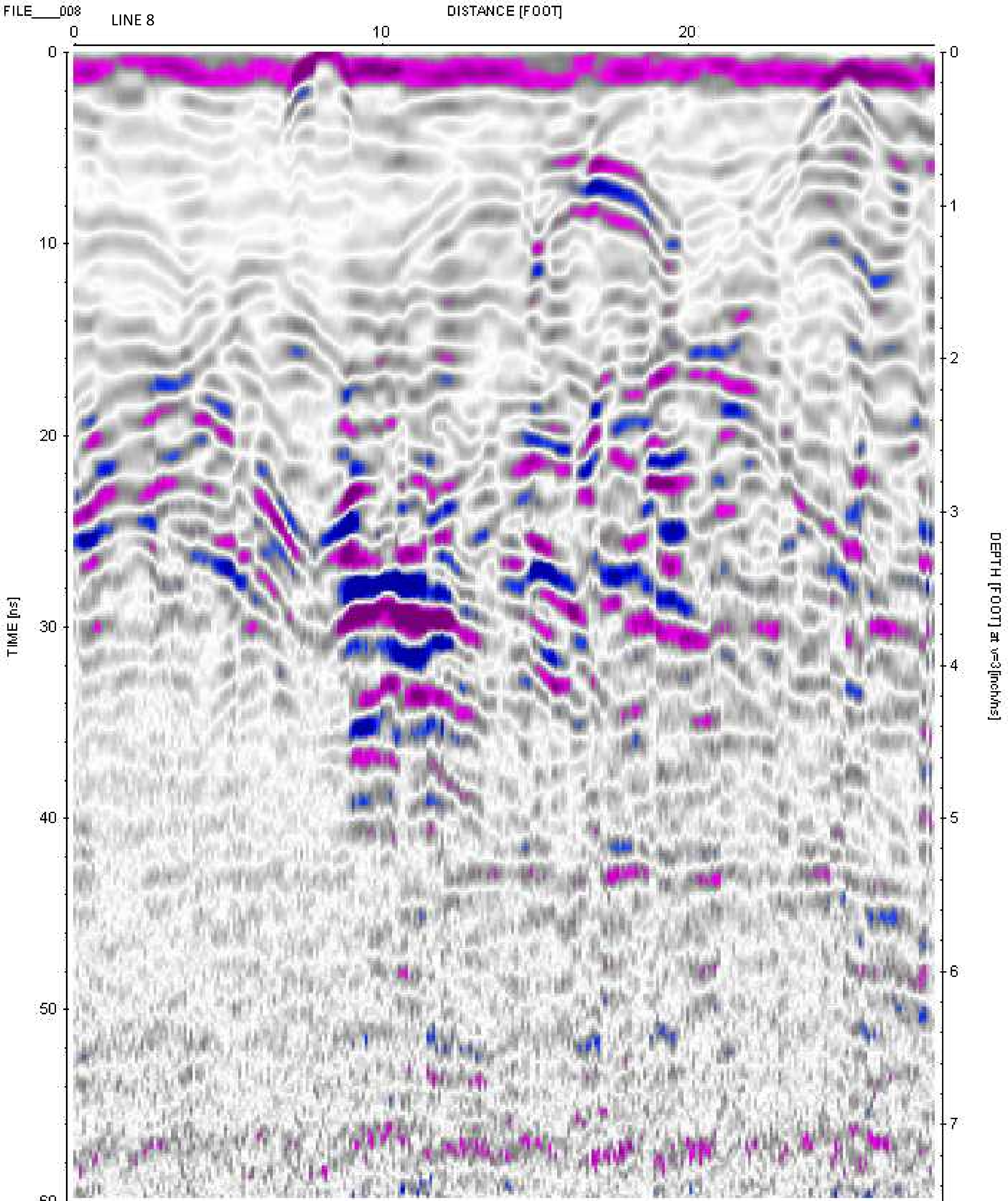

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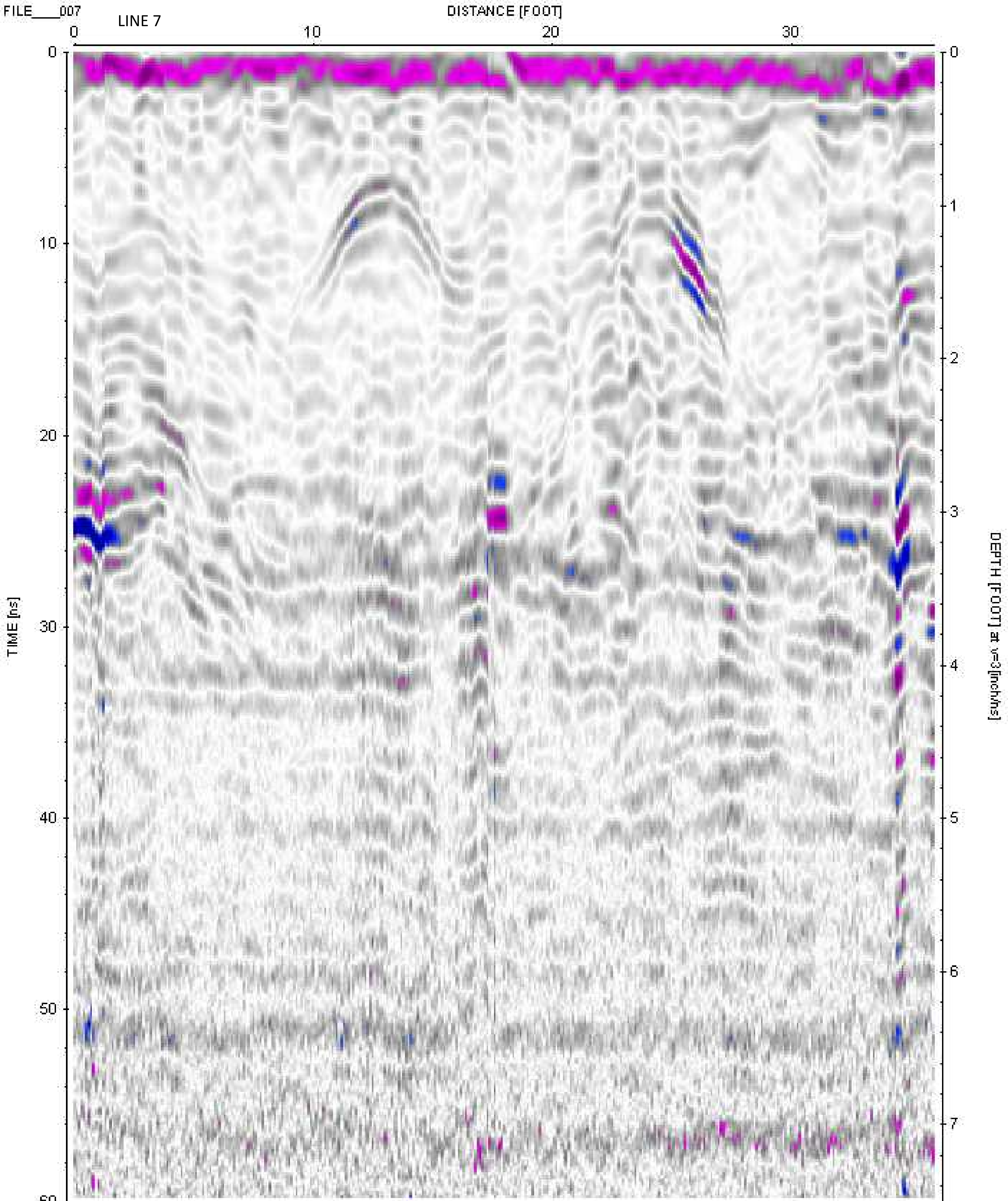
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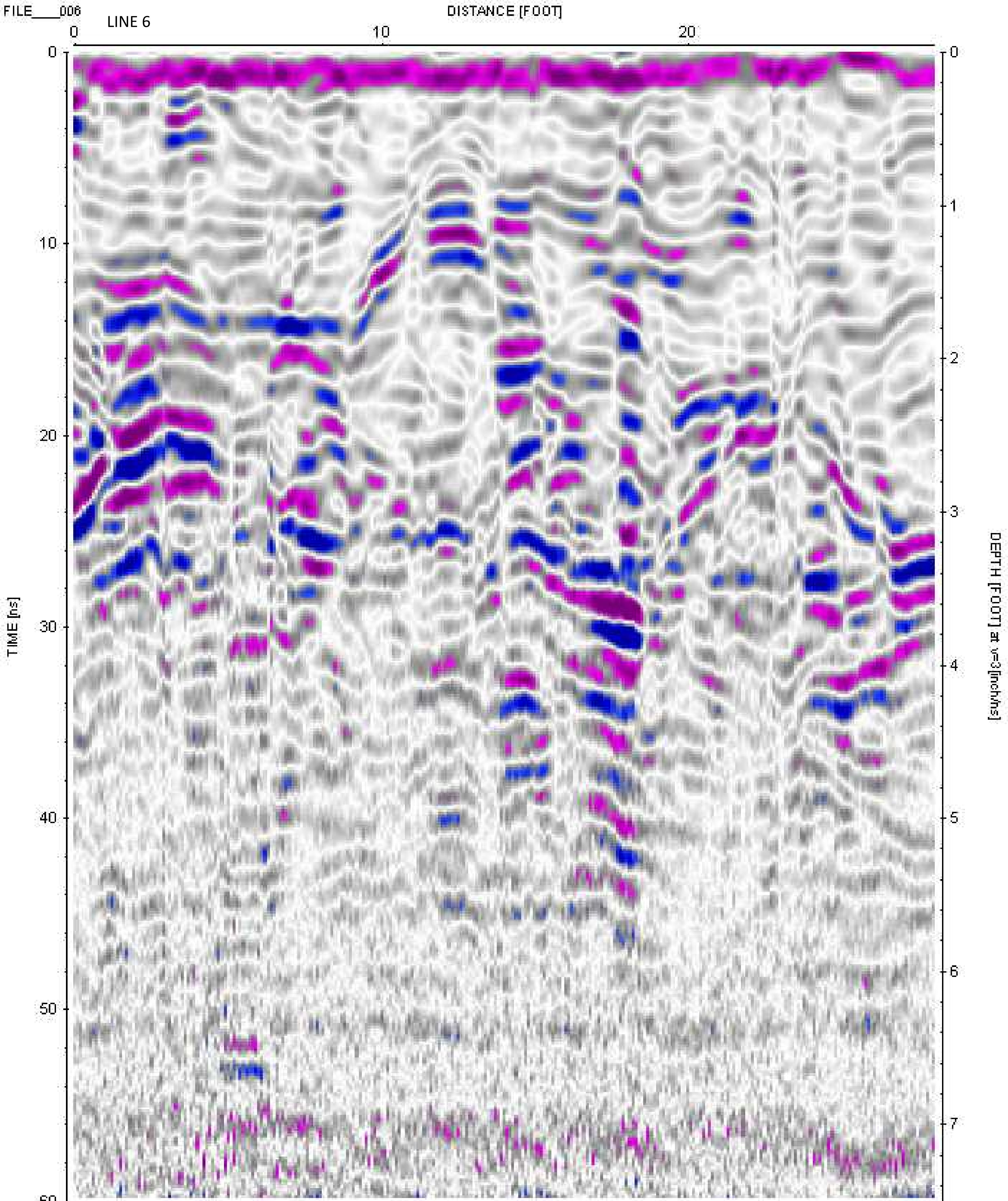
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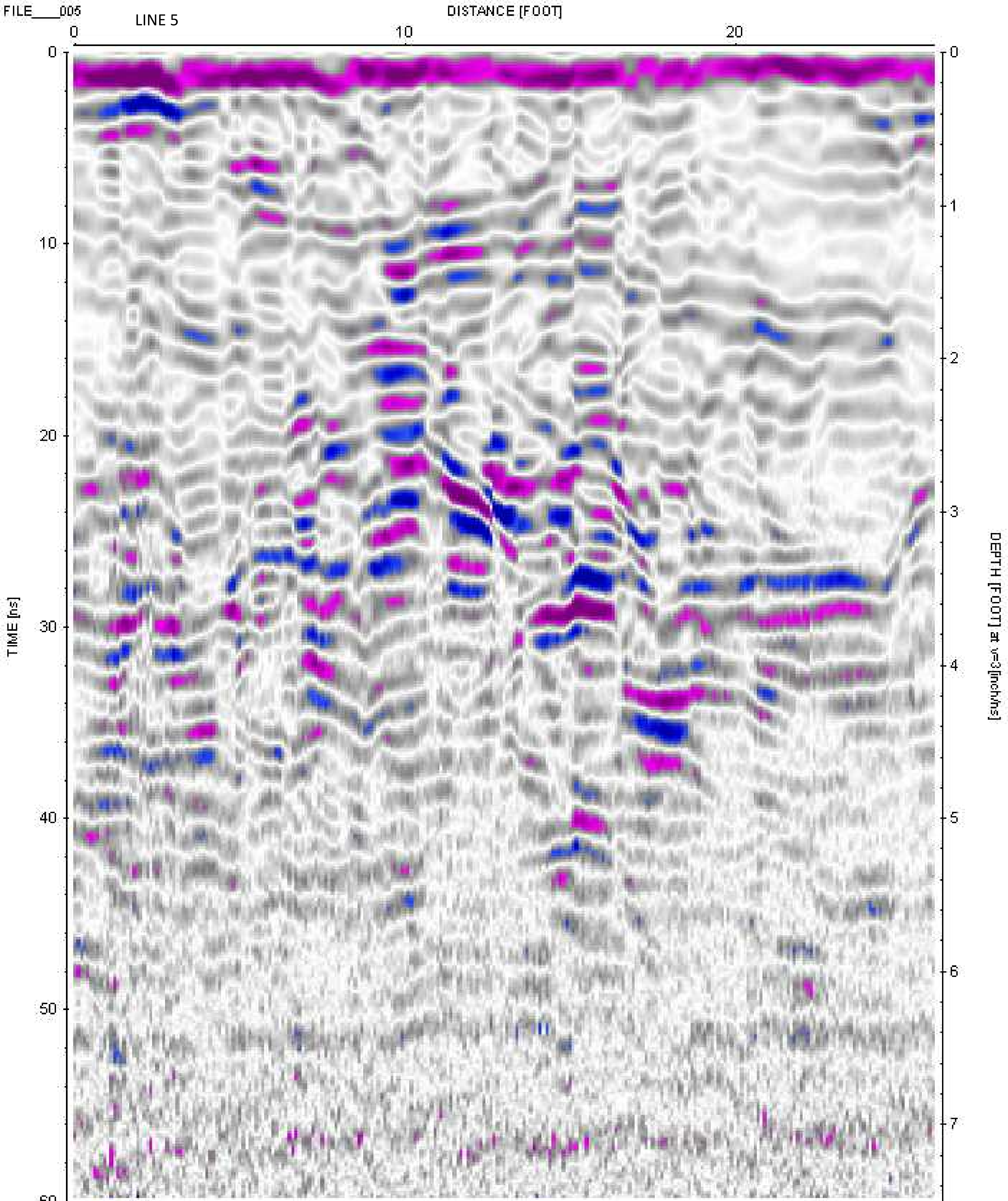
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