Geotechnical Characterization of Highwalls with Downhole ATV

Presentation to
Professional Engineers in Mining

Cardno
Shaping the Future

Authors:
John E. Feddock, P.E., Senior Principal
Mark S. Smith, GLS Business Unit Manager
Phil Waters, Senior Supervisor - GLS

Lexington, Kentucky • August 26, 2016

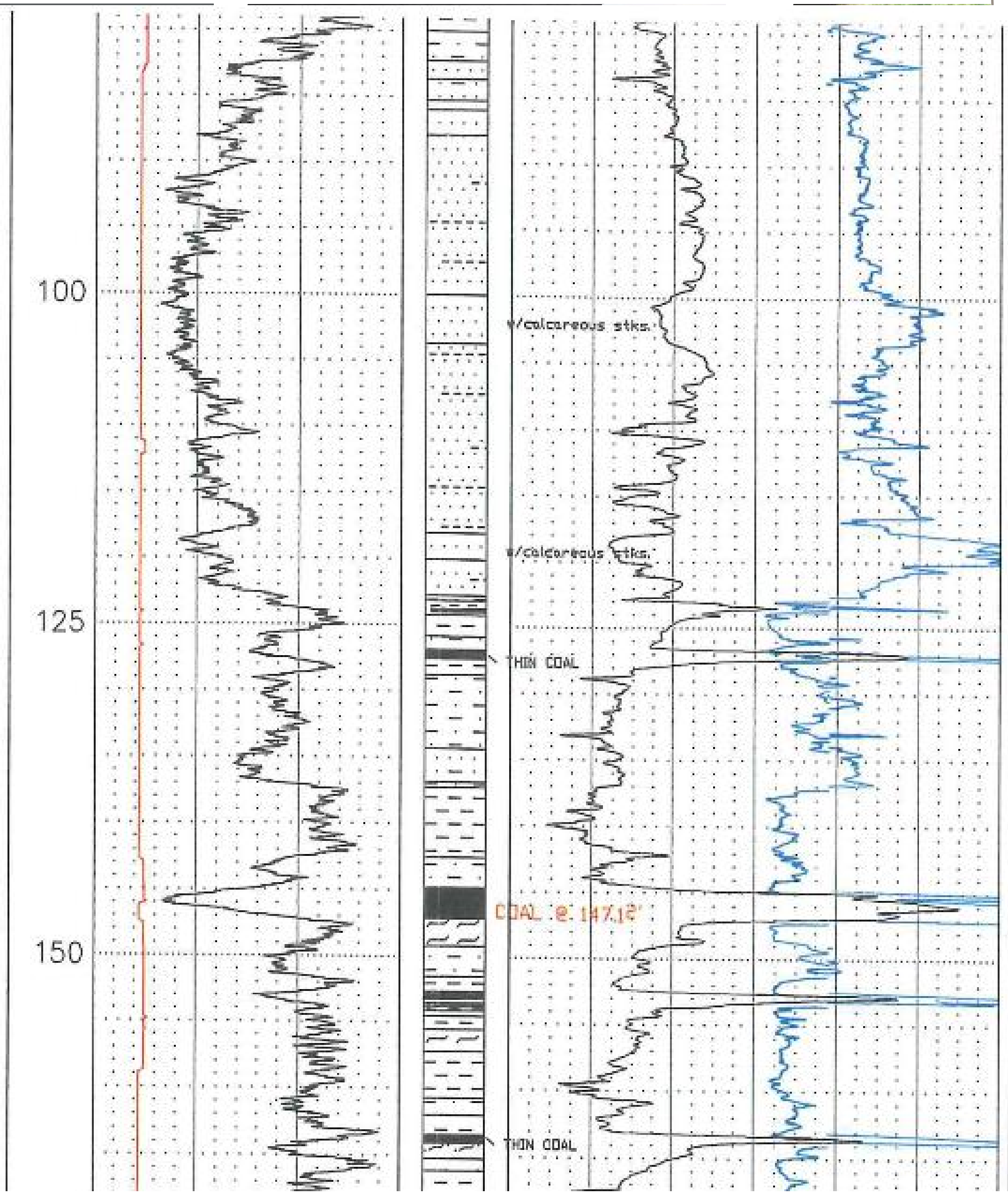
Abstract

This presentation deals with the design of slopes for open pits and highwalls at surface mines. Through properly located boreholes and the use of geophysical logging it is possible to identify and investigate fracture and bedding plane orientations and predict strata strength characteristics prior to excavation.

- Rock slopes and open pit excavations can be optimized by minimizing the risks of plane and wedge failures in constructed slopes.
- Through geophysical logging it is possible to identify faults and fracture patterns more accurately and at lower cost than oriented core logging, and with computer interpretation provide more detailed information to the geotechnical engineer for safe and economical excavation designs.

What is Geophysical Logging ?

Cardno



High Resolution Density Probe (Americium source)

Records natural gamma, caliper, guard resistivity (in fluid) and open hole density. Recording at 50 times/foot gives an accurate interpretation of lithology.

Geophysical Logging Probes	
0033 Density Probes	9051 Casing Collar Locator
9055 Deviation / Neutron Probes	9096 Gyro Deviation Probe
9041 Temperature-Fluid Conductvity-Res. Probes	Downhole Cameras – three models for various applications
9035 Compensated Density Probe	9511 Induction Probe
9136 Density Temperature Deviation Probe	9721 EM Flowmeter
9804 Acoustic Televiewer Probe	0026 Three-arm Caliper/ Deviation/Temperature
9321 Full-wave Sonic Probe	Discrete Interval Water Sampler

Cardno

Standard Working Depth to 4,000 Feet, Deeper upon request

Cardno

Acoustic Televiewer

Model No. 9804

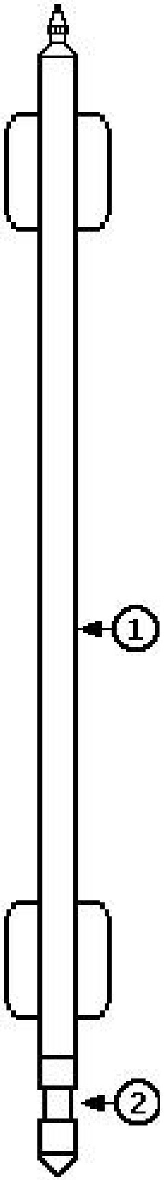
Provides Images of the borehole sidewall using high-resolution sound waves (similar to sonogram)

Picture displayed in both amplitude and travel time

Digitizes 256 measurements around the boreholes

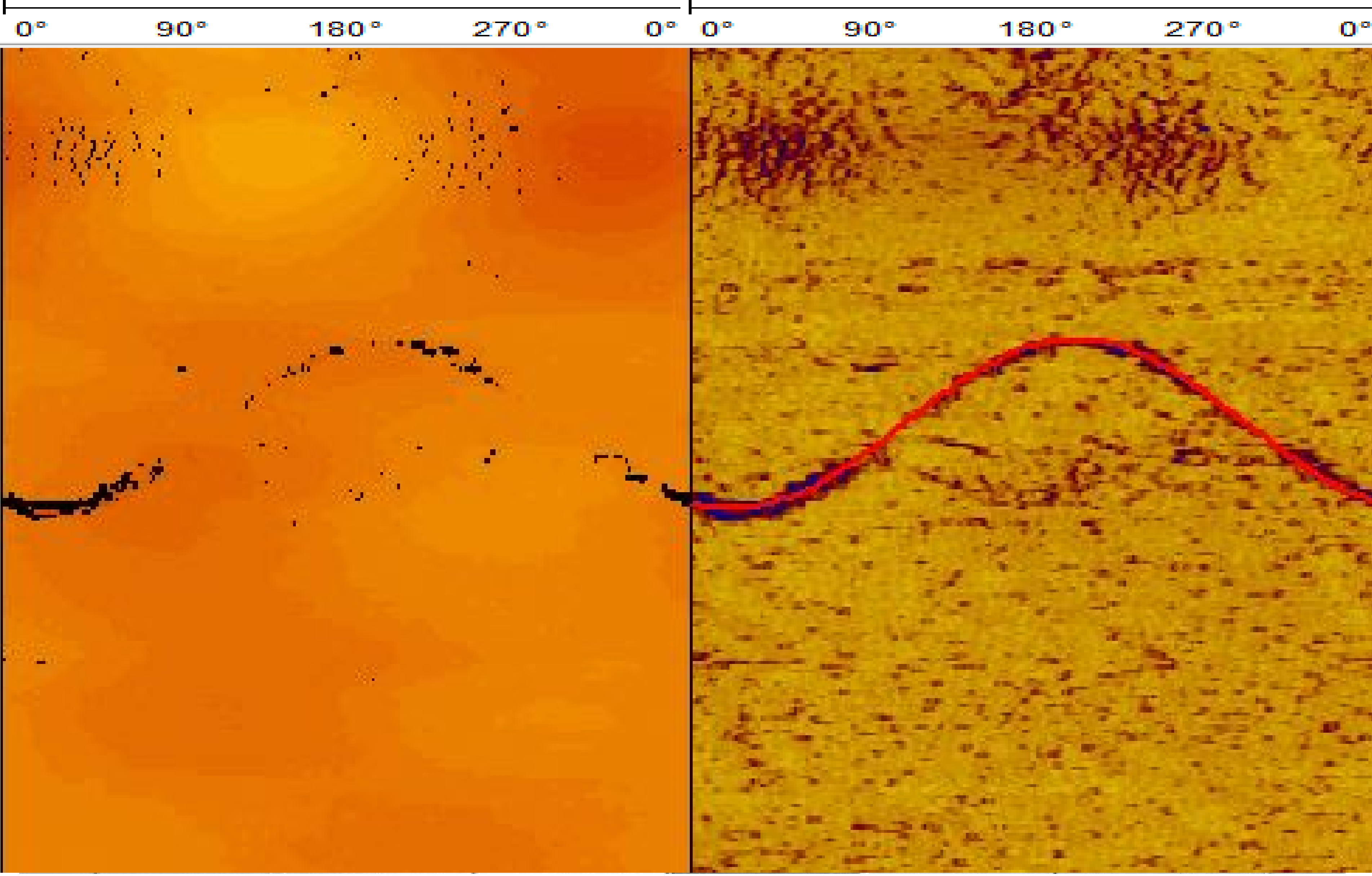
Sample interval (0.005 meters/0.02 feet)

Oriented directionally with magnetometers and inclinometers



Acoustic Televiewer

Features	
Properties Measured (see diagram)	**Tool Specifications**
1. **Deviometer:** Offset: 175 cm (69 in.) **X-Y Inclinometer (XYI):** 0 to 90 degrees, Accuracy +/-0.5 degrees **Azimuth (AZ):** 3-axis magnetometer 0 to 360 degrees, Accuracy +/- 2 degrees 2. **Acoustic Amplitude & Acousitic Travel Time:** Offset: 175 cm (69 in.), Accuracy +/- 2.55 mm (0.1 in.)	**Outside Diameter** 50.8 mm (2 in.) **Weight:** 14 kg (30 lbs.) **Length:** 193 cm (76.0 in.) **Pressure:** 105 kg/cm^2 (1500 psi) **Temperature:** 85 C (185 F) **Scan Rate:** 12 revolutions/second **Sample Rate:** 256 samples/revolutions **Borehole Size:** 50 to 230 mm (2.9 to 9 in.) **Logging Speed:** 2 m/min (6 ft/min.) **Tool Voltage Required:** 115 VDC



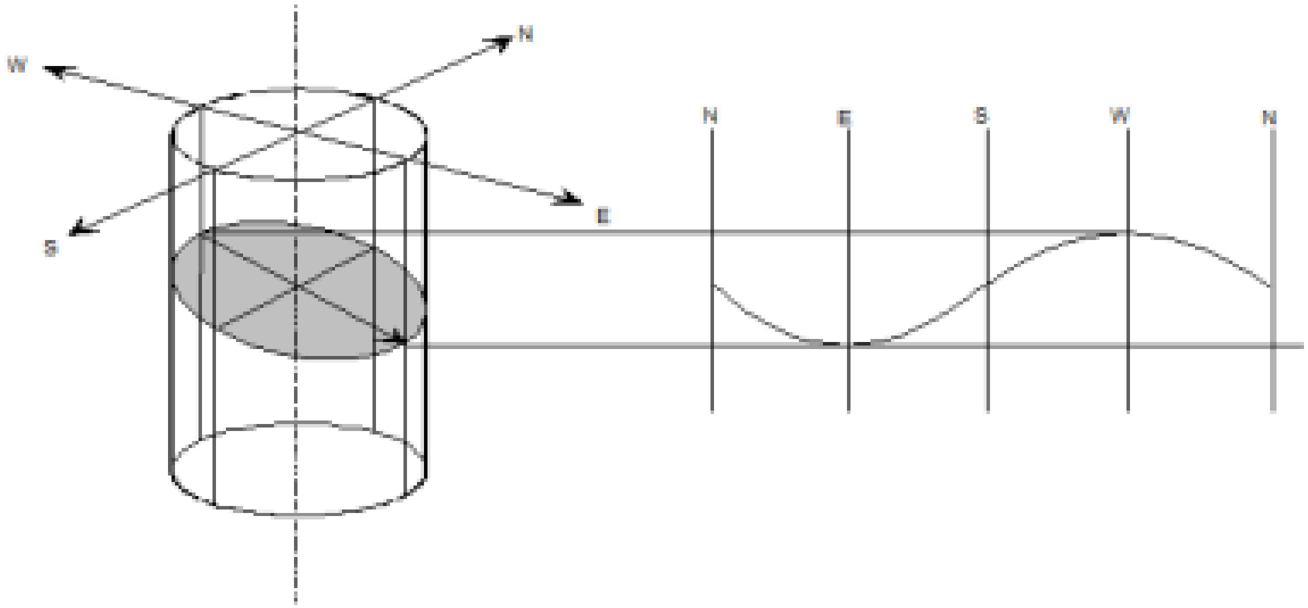
Televiewer Log – Travel Time

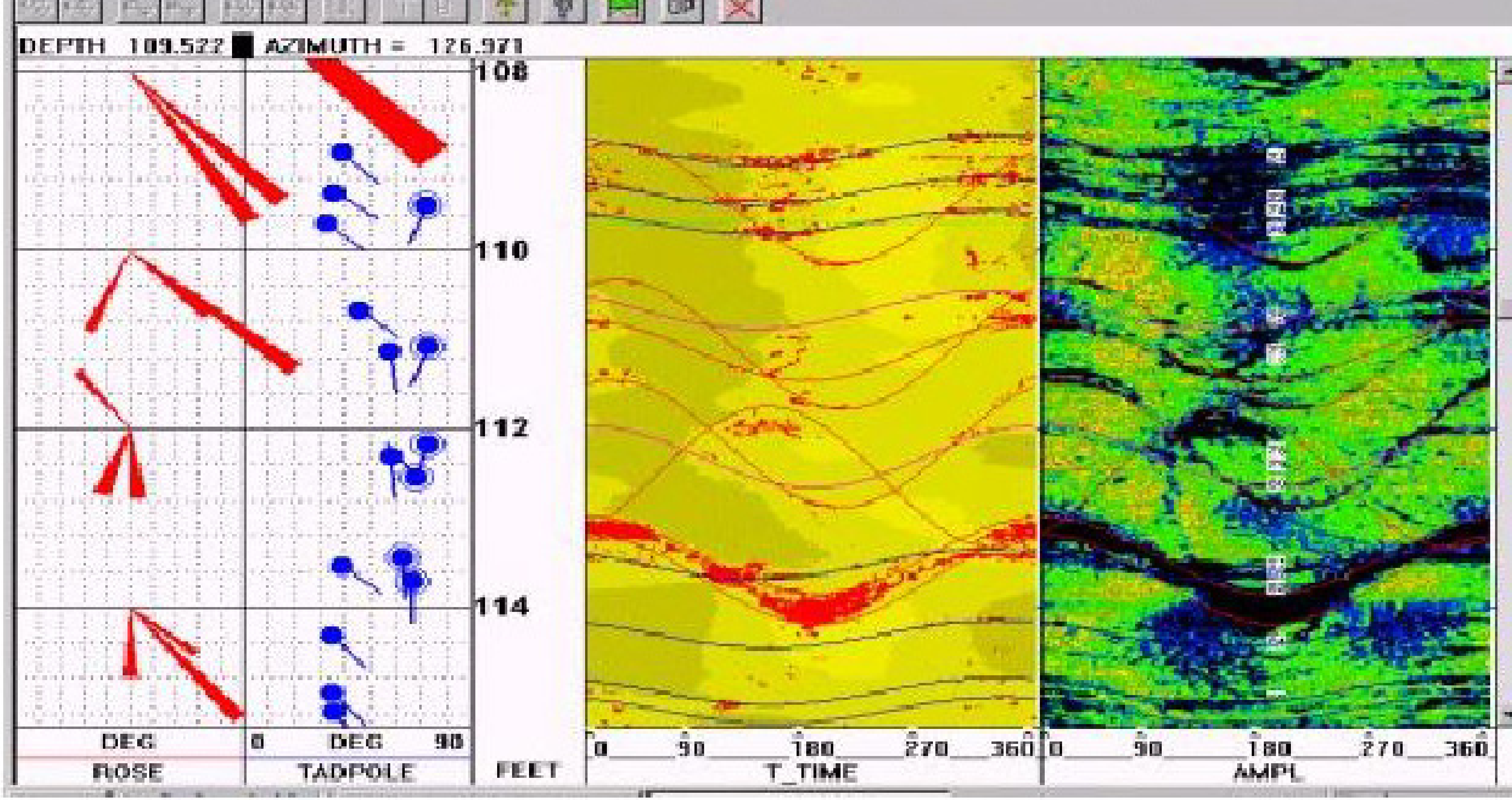
Televiewer Log - Amplitude

45º Fracture dipping North 10º East

Cardno

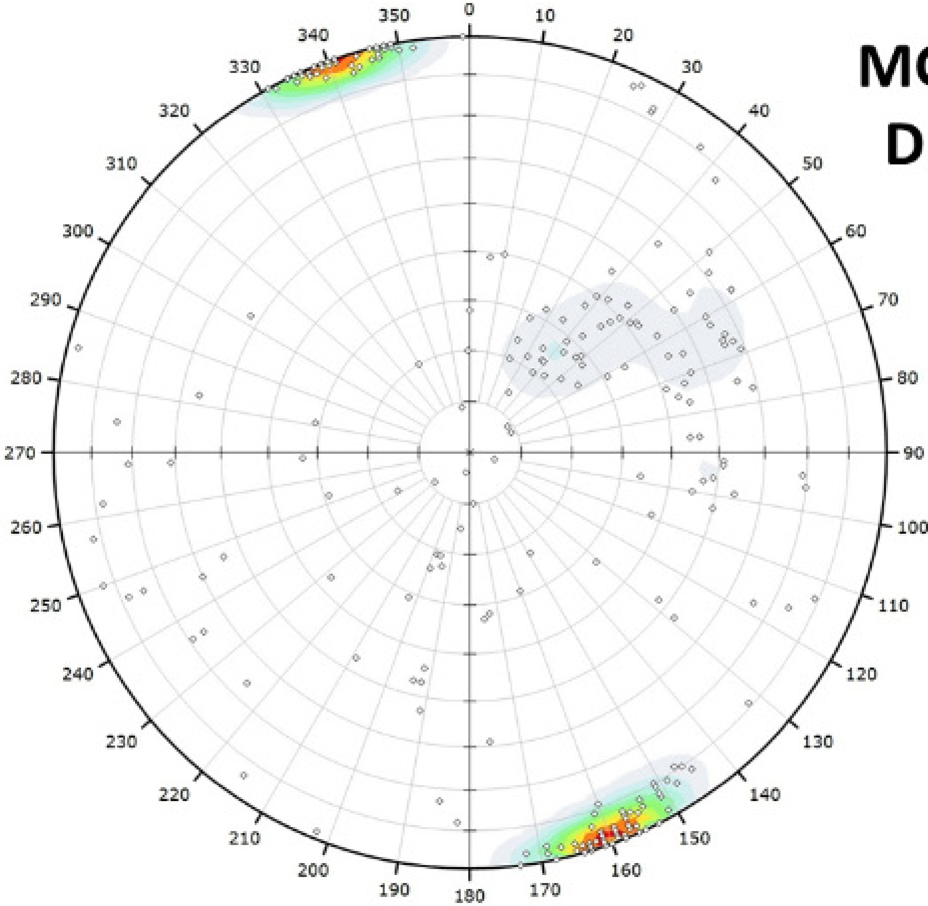
Acoustic Televiewer : The circle produced by the intersection of a dipping plane and borehole is “unrolled” and appears as sine curve



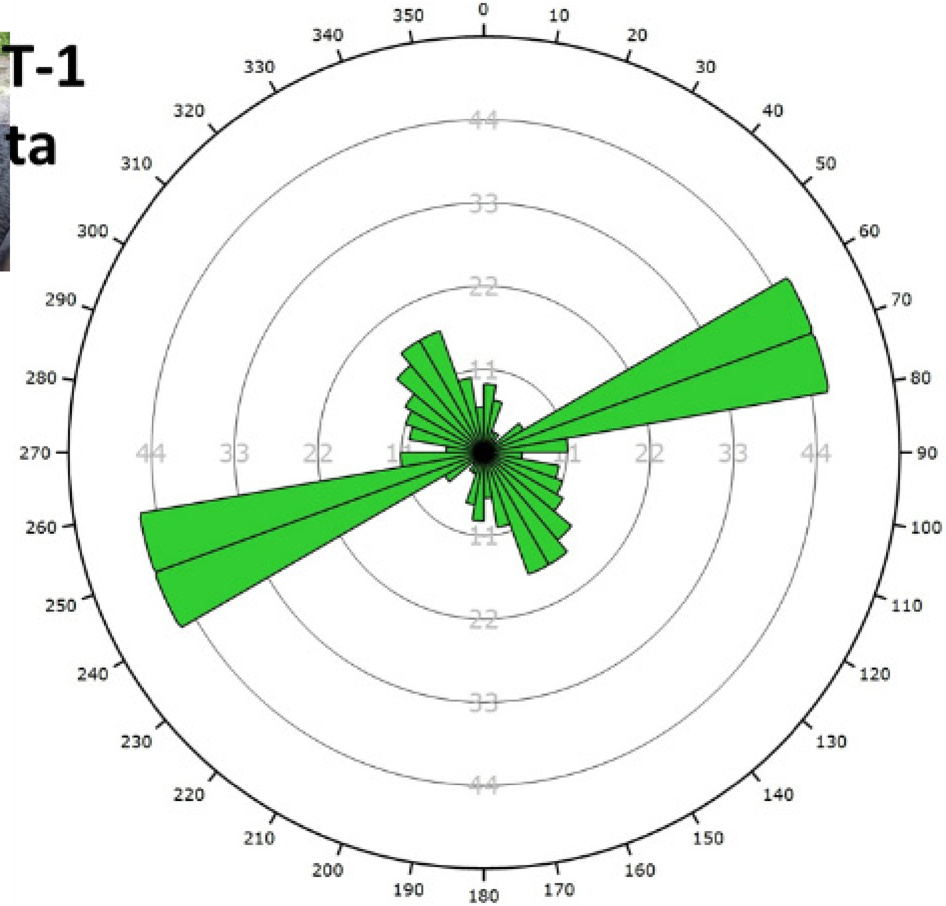


Televiewer Log Trace

Interpretation of a Highly Fractured zone over 8 feet



MGT-1 Data



From the log we can Plot Stereographs and Rose diagrams for wedge and plane failure analysis

Cardno

HIGHWALL_ A has strata dipping into the pit. A stable wall design was requested for the open pit mining of 7 different coal seams including Highwall Mining.

From Acoustic Televiewer logs in adjacent boreholes the dominant fracture patterns could be determined. Although Plane or wedge failure was not a risk, sliding was evaluated under varying phreatic surface conditions.

HIGHWALL_ A benches were placed to benefit from stronger strata with fewer fractures and joint sets, and to maximize the resistance to sliding in weak claystone. Sliding analysis identified risks in the shallow soil cover at the surface.

Highwall A Conclusions

The proposed highwall show themselves to be stable structures.

The proposed mining methodology does not appear to introduce unnecessary risk to the support of the surface or structures on them.

There is a risk of potential failure in the surface sediments based upon a significant reduction in the strength of the sediments due to possible weather conditions, to local sediment changes, or from water saturation.

A minor relocation of the pit was recommended to leave a stand-off distance between the protected structures and the west edge of the open pt.

Information Available

Knowledge of fractures and bedding planes allows prediction of possible unstable rock conditions in the shaft walls or the slope roof.

Prediction of rock strengths are an indicator of weak rock strata and provides information for rock bolting or secondary support.

In sedimentary rock, porosity is inversely proportional to the modulus of elasticity and the wave velocity, giving an indicator for water bearing strata.

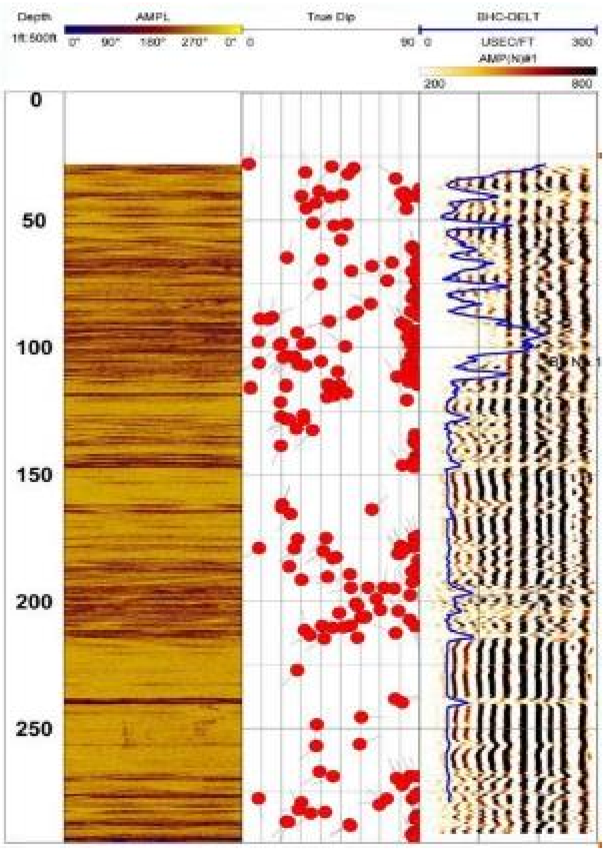
Ground water information gives the ability to predict potential water inflow and the design of water rings in shafts or effective grouting plans.

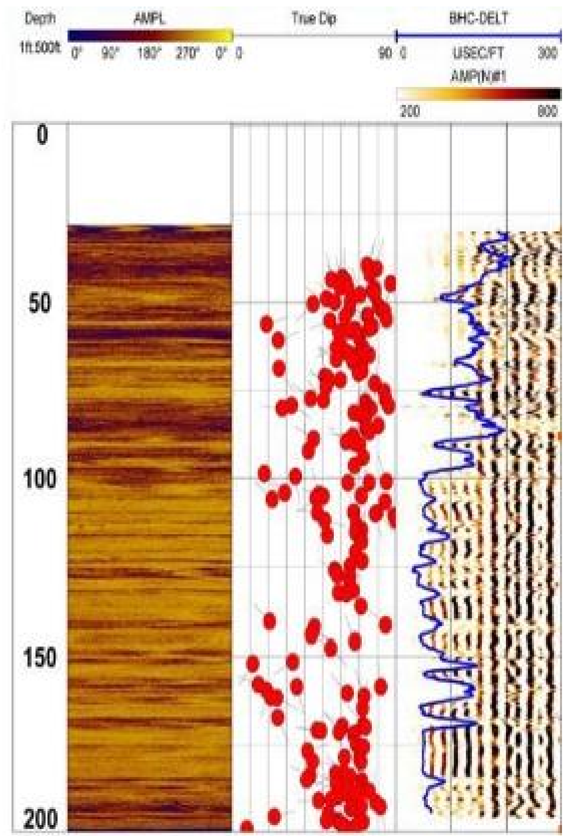
In sedimentary rocks sonic wave velocities can be treated as if they are isotropic, but in metamorphic and igneous rocks tectonic stress can have a large effect on sonic wave velocities.

Cardno

Testing the stability of a proposed pit design for the extraction of copper ore.

Cardno





Acoustic Televiewer identified rotation in the fractures patterns in the rock between the east versus the west side of the ore zone that would impact slope stability.

Cardno

Stereonet Analysis identified a risk of Plane Failure for Slope Orientation in a zone around 246 Degrees.

Redesign of the east side of the pit required locating the haulroad to minimize the east slope and the length of wall at the critical orientation of 246 degrees.

In addition to the Acoustic Televiewer, The Full Wave Sonic gives the ability to determine rock and strata strengths.

The Full Wave Sonic Tool

Model No. 9320

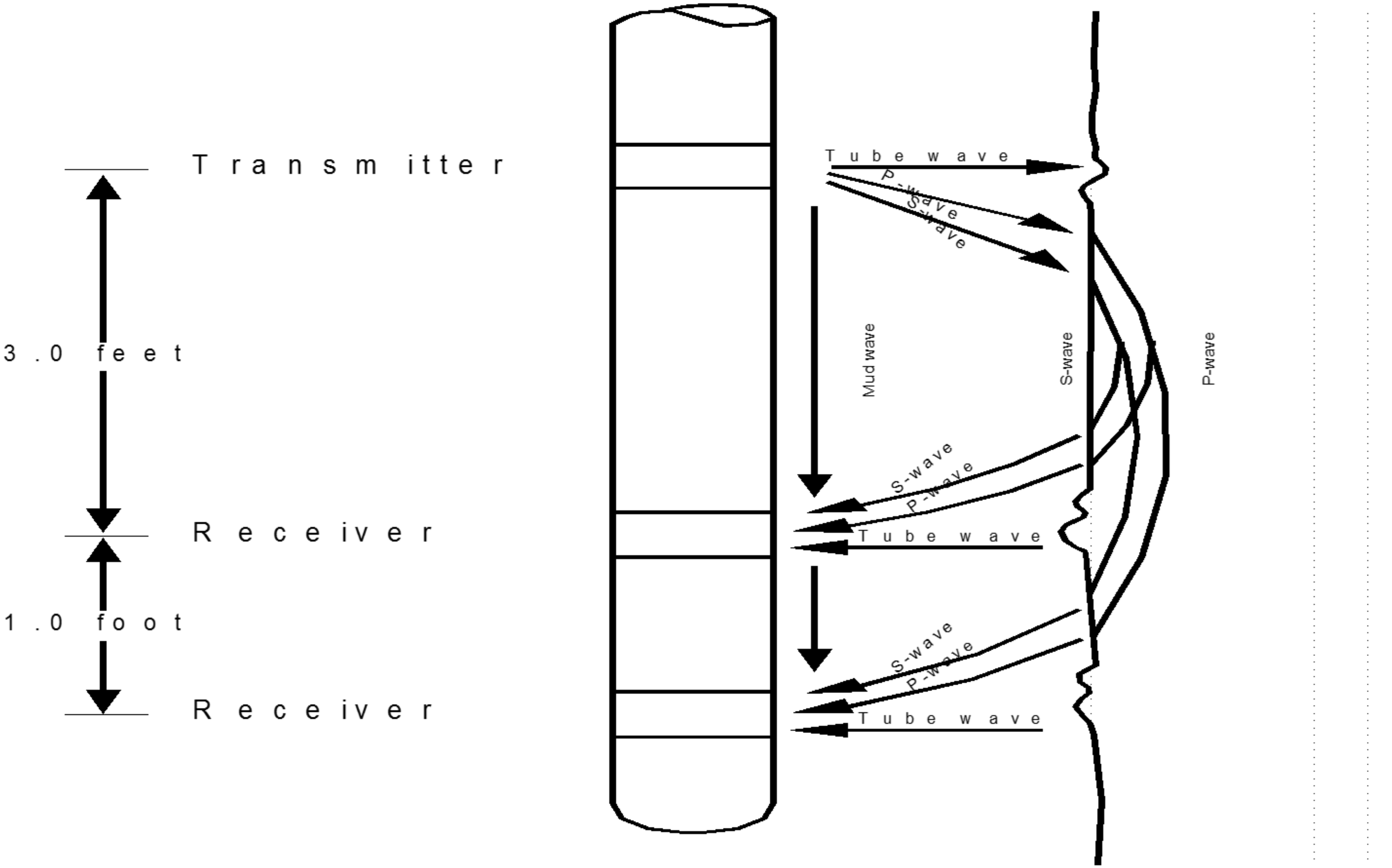
Single transmitter and dual receiver

Records 10 times per foot

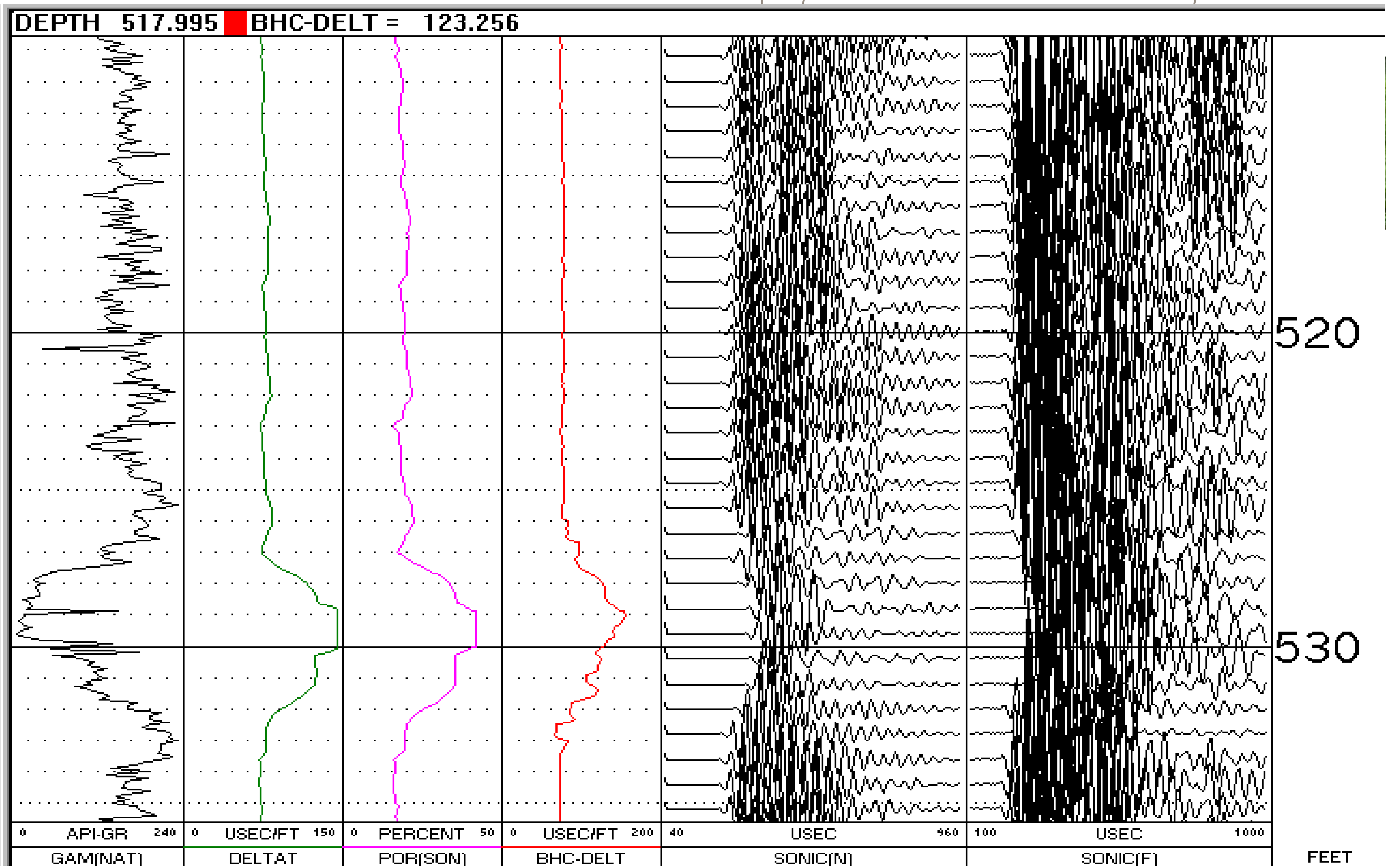
Sonic velocities are proportional to the compressional strength of the rock where the state of stress (σ) in a direction is proportional to the particle velocity (V) in that direction.

The sonic, density and the full wave sonic tool provide the ability to predict the weak rock areas and identify the necessary reinforcement such that the excavation can proceed with maximum safety and minimal interference.

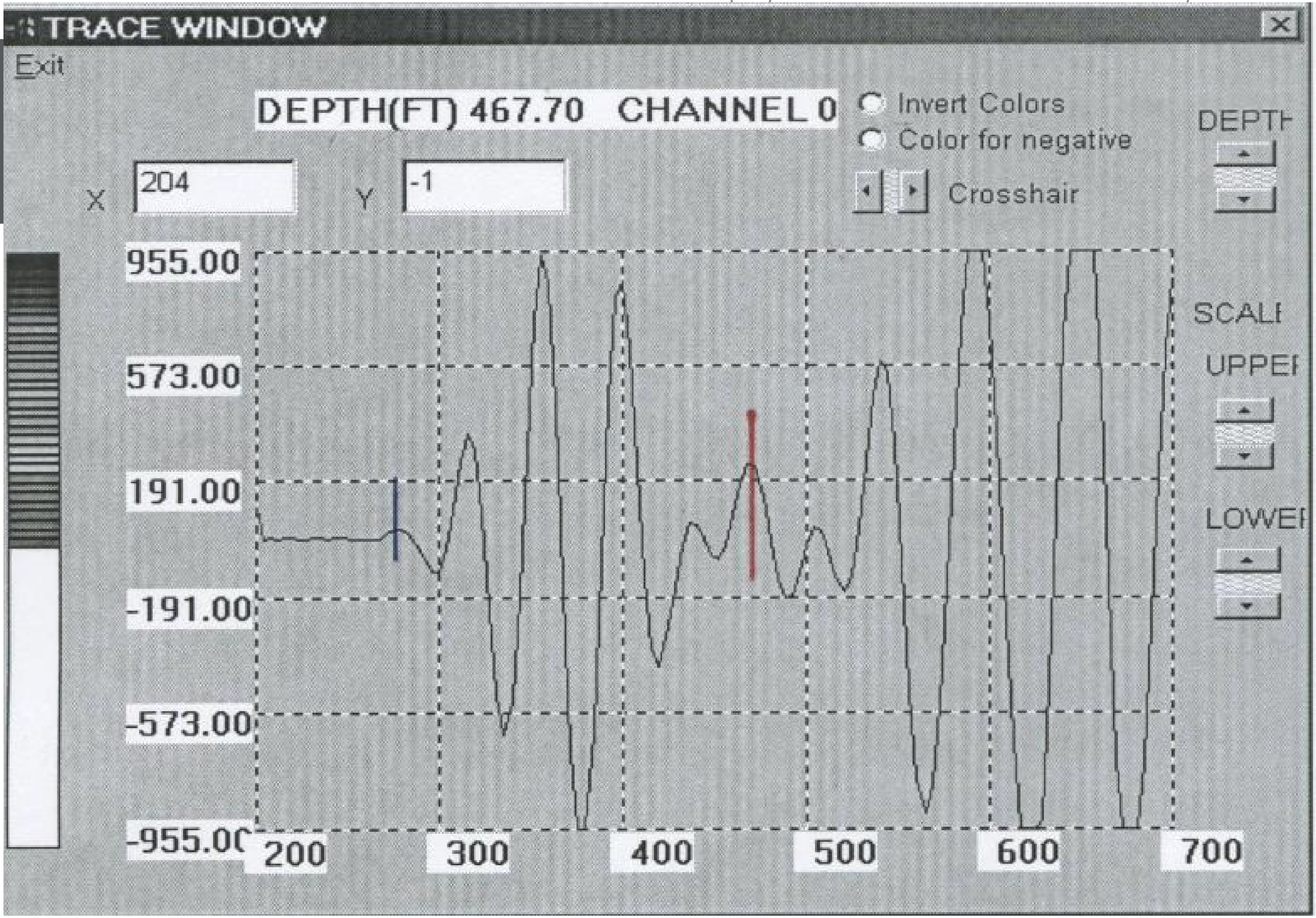
Cardno



Elastic-wave (acoustic) methods Propagation paths for P, S, mud, and tube waves. (After Lobo, 1987)



Sonic Log Traces



Trace of Acoustic Wave Train

Conclusions

- Geophysical logging with the acoustic televiewer documents
    - Fractures, bedding planes and other anomalies.
- and gives he engineer the information to
    - Design highwall orientations and the location of safety benches to minimize the risk of plane and wedge failures in rock highwalls, and
    - When coupled with sonic velocity of the borehole, strata strengths can be predicted for the design rock reinforcement,.

THANK YOU

Mining and Mineral Services

- Resource/Reserve Evaluations
- Geotechnical Evaluations (Subsidence)
- Geophysical Logging
- Hazard Prediction
- Field Exploration
- Water Resources Management
- Probable Hydrologic Consequences Evaluations
- Mine design and Plant Valuations

Cardno

Shaping the Future