3.8. WHISTLE WASTE ROCK PILE MONITORING

Ken De Vos
Golder Associates

ABSTRACT

WHISTLE MINE
WASTE ROCK PILE MONITORING
FIELD AND LABORATORY MEASUREMENTS
MEND PROJECT: PWGSC FILE 0285SQ.23440-5-1125

KEN DEVOS: GOLDER ASSOCIATES, MISSISSAUGA
KARLIS JANSONS: GOLDER ASSOCIATES, SUDBURY

Considerable research has been carried out in the past decade related to the aspects of AMD from tailings, and many case studies have been documented. Due to difficult drilling and sampling conditions and the heterogeneous nature of waste rock, data collection and case studies in waste rock acid drainage environments are limited. To assist in establishing valuable sampling and Acid Rock Drainage (ARD) prediction techniques, more quality data on ARD is required. The scope of the Whistle Mine waste rock study is to assess the present chemical and physical conditions: determine proper sampling techniques, establish and implement laboratory and field programs to collect data; provide interpretation of the data; and to provide recommendations for future waste rock monitoring programs.

The Whistle ARD monitoring project was commenced in August 1995, by Golder Associates in association with Senes Consultants. The site and part of the funding was provided by INCO Limited. The Whistle ore deposit was discovered in 1897 and acquired by INCO in 1929, however, open pit mining only commenced in 1988. It has operated continuously since then except for a shut down period between September, 1991, to November 1994. The stripping ratio is close to 2 waste to 1 ore. Two waste dumps were developed, with non-reactive granitic rock being placed in the north-west dump and potential ARD producing rock in the north-east dump. During the initial site visit, the field program (in the north-east dump) of test pits and boreholes was laid out considering both current operations and the optimal areas of representative waste rock. The waste rock pile was found to be heterogeneous and generally very blocky. Although cut off grades for the mine should result in relatively low sulphur concentrations in the dump, there were areas of massive pyrrhotite, pyrite and gossan material. Three test pits were excavated in the waste rock to collect representative samples and establish the grain size of the material. Prior to backfilling the three test pits, lysimeters were installed to collect infiltrating water. Five boreholes were drilled to collect rock samples with depth and to allow the installation of instrumentation. The instrumentation consisted of sampling wells, thermistors and gas sampling tubes. Also, as part of the field work, an autopsy zone was selected to establish a typical, deep cross-section ,which might not be available from test pits. A freshly cut road along the edge of the pile was selected as the autopsy zone as sufficient rock was removed from the face to observe the layering and compositional heterogeneity within the pile.

Work subsequent to the field work during August to September 1995, has included laboratory testing, and field sampling. Most of the laboratory characterisation (chemical and mineralogical) testing has been completed. Column tests using an acid rain leach were conducted at the Lakefield Research laboratories in Peterborough for a period of months until they were stopped as the leachate chemistry stabilised very quickly. Field work in the form of sampling has continued to date with temperature readings being taken weekly, and samples of gases (O_2, CO_2), lysimeter leachate, seepage water and piezometer water are taken every 4 months. Current field data indicates that oxidation within the pile is resulting in acidic groundwater and seepage from the pile. Gas profiling indicates that the pile is well aerated, however, zones with slightly lower O_2 are observed and may indicate discrete areas of oxidation. Data collected to date is being analysed to determine if there are trends and to review the effectiveness of the installation and sampling procedures.

WHISTLE MINE WASTE ROCK MONITORING

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PROGRAM OBJECTIVES

- Assess Present Chemical and Physical Conditions
- Collect Quality Data on ARD Which May be Beneficial in Future Empirical Modelling Work
- Establish or Develop Sampling Protocols Which May Be Applicable to a Broad Range of Waste Rock Piles

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SITE BACKGROUND

- Base Metal Mine
- Discovered 1897 by Isaac Whistle
- Open Pit Mining from 1988 - 1991
- Actively Mined from 1994 to Present
- Production Rate of 2300 tonnes of Ore per Day
- Waste to Ore Ratio = 2:1
- Waste Rock Deposited in Two Locations
  - Northwest Dump - "Clean" Granitic Rock
  - Northeast Dump - Sulphide Minerals Present

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FIELD PROGRAM

- Drilling
- Instrumentation
- Test Pits
- Lysimeter Installation
- Autopsy Zone
- Monitoring
  - Gas Sampling
  - Temperature Measurements
  - Lysimeter Sampling
  - Groundwater and Seepage Monitoring

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DRILLING

- ODEX bit required (3 Bits Cycled)
- Successful Drilling Program Under Very Difficult Conditions

Borehole	*Order Drilled*	*Number of Samples*	*Borehole Depth (m)*
BH1	Fourth	8	32.9
BH2	First	3	36.6
BH3	Second	8	37.5
BH4	Third	18	31.1

- Sample Collection
  - Chip Samples (<10 mm dia.)
  - Poor Recovery due to Sample Loss into Waste Rock Void Space

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WELL INSTALLATION: INSTRUMENTATION

- Piezometers
  - Two Piezometers per Borehole to Assess Vertical and Horizontal Gradients
- Gas Sampling Ports
  - Composed of 6mm Polyethylene Tubing with Screened Tip
  - 10 to 15 per Borehole
  - Denser Spacing Near Surface
- Thermistors
  - Two Cables (one Deep, one Shallow)
  - Same Spacing as Gas Ports

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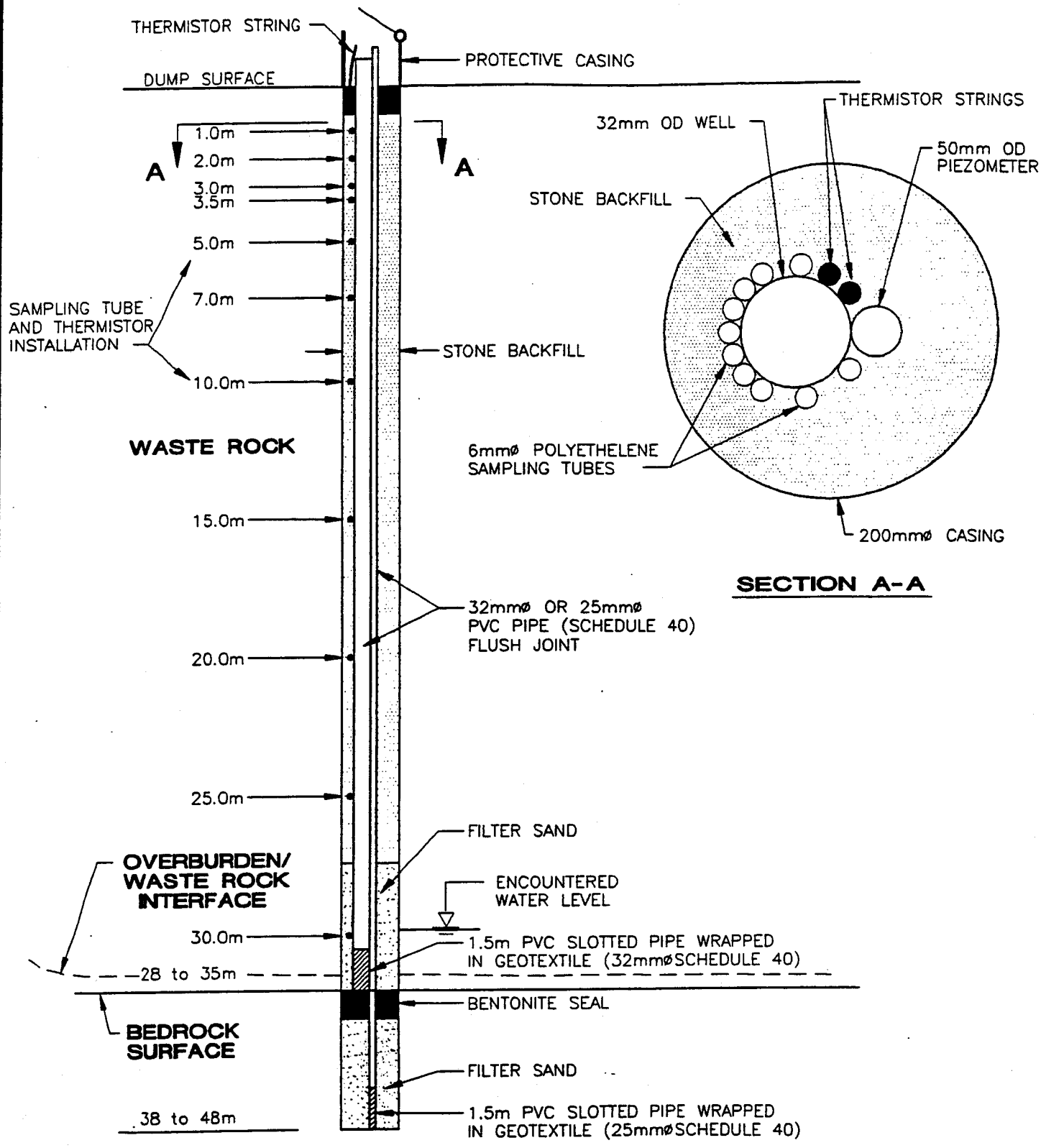
TYPICAL BOREHOLE INSTALLATION
WHISTLE MINE - ARD STUDY

FIGURE 3



Date JANUARY...1996..

Project .951-1952....

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Drawn ..JFC.....

Chkd ...KJD.....

ACAD FILE No.L1952003.DWG

TEST PITS / LYSIMETERS

- Three Test Pits
- Solid Samples Collected
- Porosity / Permeability Determination
- Lysimeters Installed
  - Infiltration
  - Chemistry

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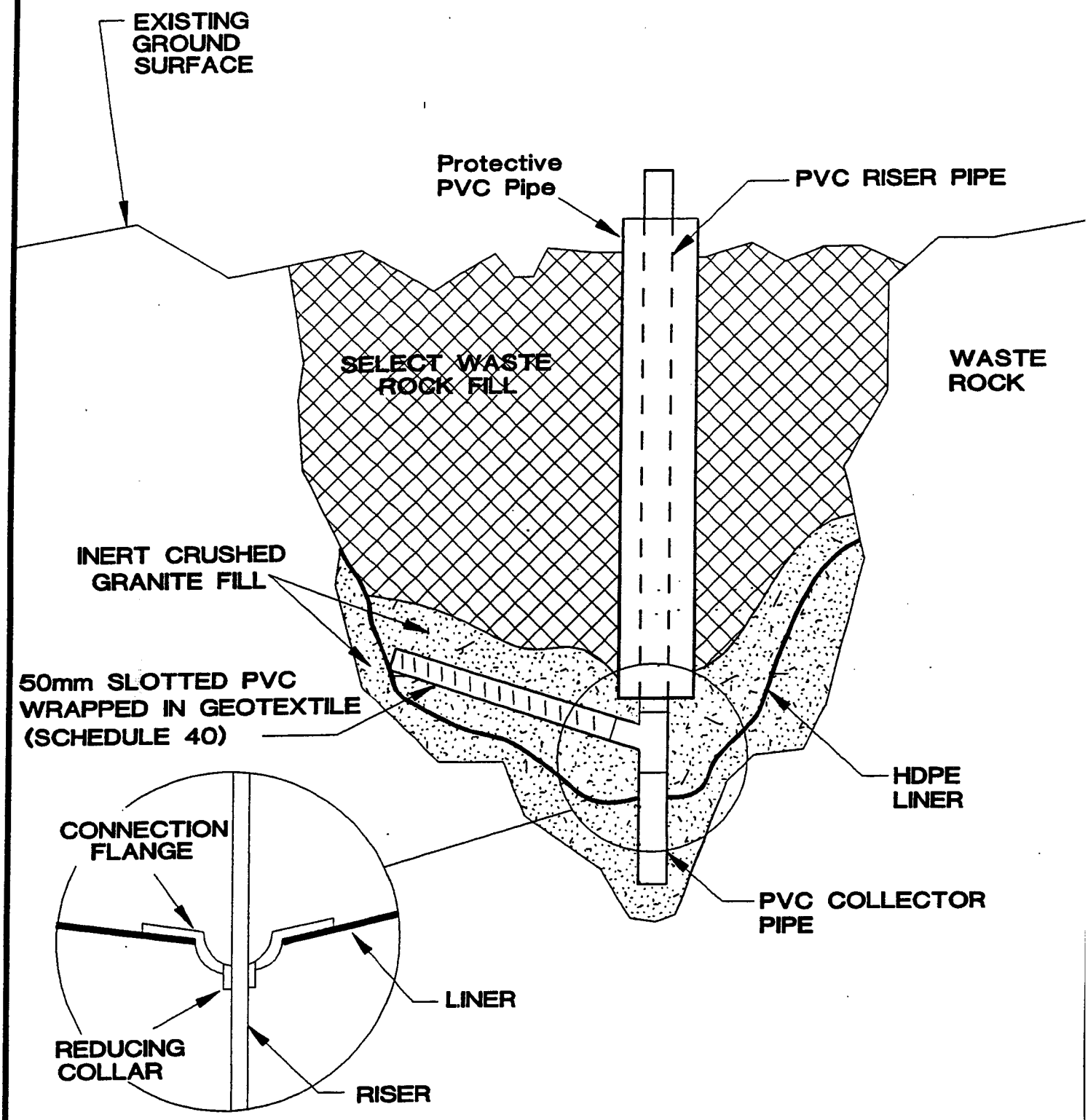
PLATE 2
TEST PIT EXCAVATION (TP-1)

TYPICAL LYSIMETER INSTALLATION
WHISTLE MINE - ARD STUDY

FIGURE 4



NOT TO SCALE

Date JANUARY...1996

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Chkd ....KJD.....

D FILE No. L1952004.DWG

AUTOPSY ZONE

- Deep Cut into Waste Rock Pile
- Recent Road Cut Selected
- Layering and Heterogeneity Observed

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Geology

- Northwest Dump
  - 20 % Mafic Norite
  - 80 % Granitic
- Northeast Dump
  - Very Heterogeneous
  - Average of About 3% Sulphide Minerals
  - 1% Gossan or Highly Weathered Minerals
  - 1% Pyrrhotite Blocks

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ESTIMATE OF THE QUANTITY OF WASTE ROCK BY TYPE IN NORTHEAST DUMP

Rock Type	*Quantity (tonnes)*	*Proportion of Pile (% by mass)*	*Estimated Sulphide Content (% by volume)*
Felsic Norite	200,000	4%	<1%
Granitoid	500,000	10%	generally <1%*
Mafic Norite	3,650,000	83%	variable, average 3%
Ore	50,000*	1%	>20%*
Gossan or Heavily Oxidized Waste Rock	50,000*	1%	>20%*
Sand/Overburden/Soil	50,000*	1%	nil
Total	5,000,000	100%	3%

Notes:

* Approximate quanitities

Estimate of sulphide content based on visual observation

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Porosity / Permeability

- Computer Program Goldsize Used
  - Coarse Fraction Determined ...
  - Fine Fraction Estimated from Sieve Analysis
- Fine Fraction Governs Acid Generation
- Approximately 2.5 % of pile < 5 cm
- Approximately 1.0 % of pile <1 cm

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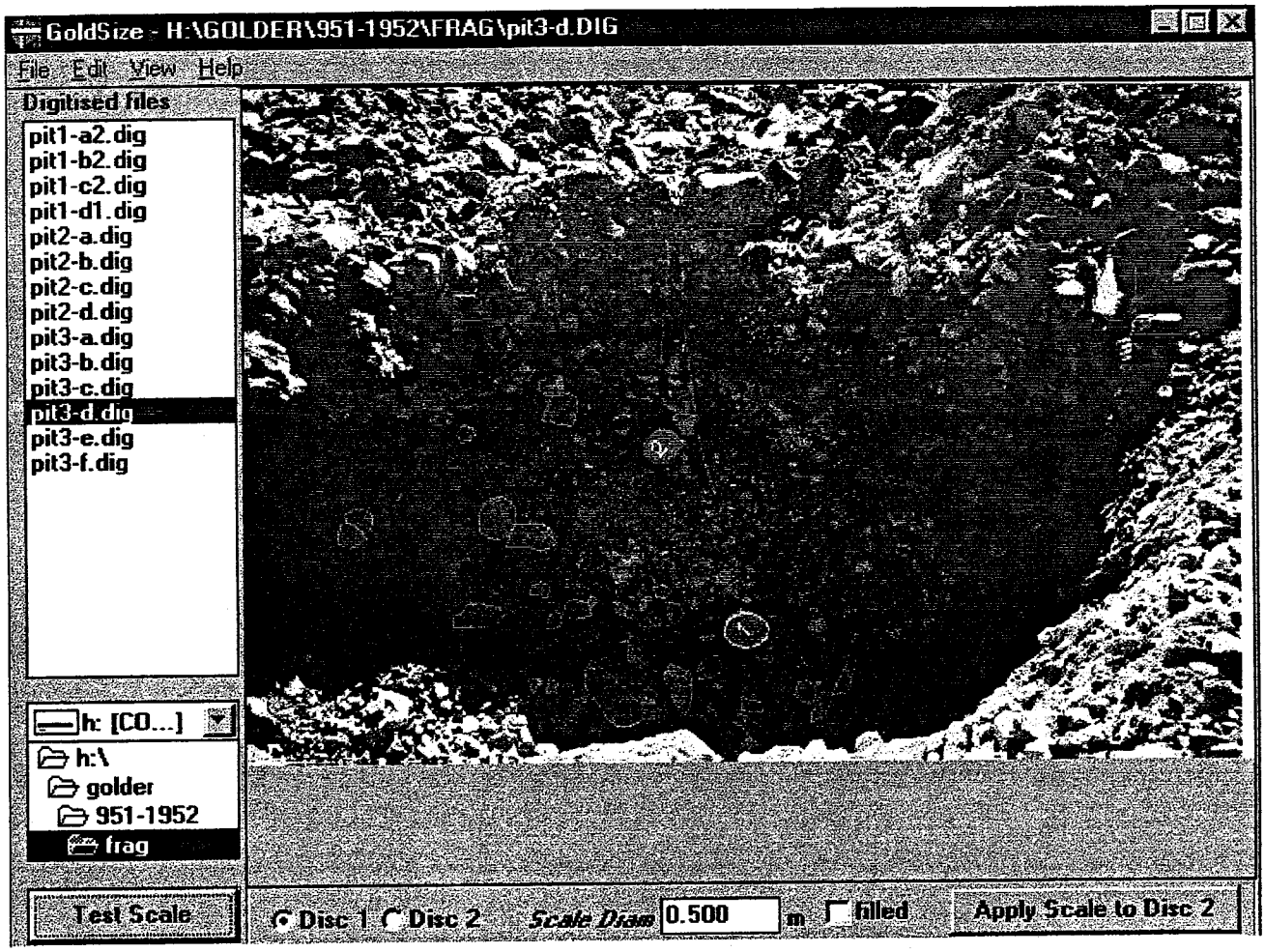
Photograph of Test Pit Showing Scale Disks



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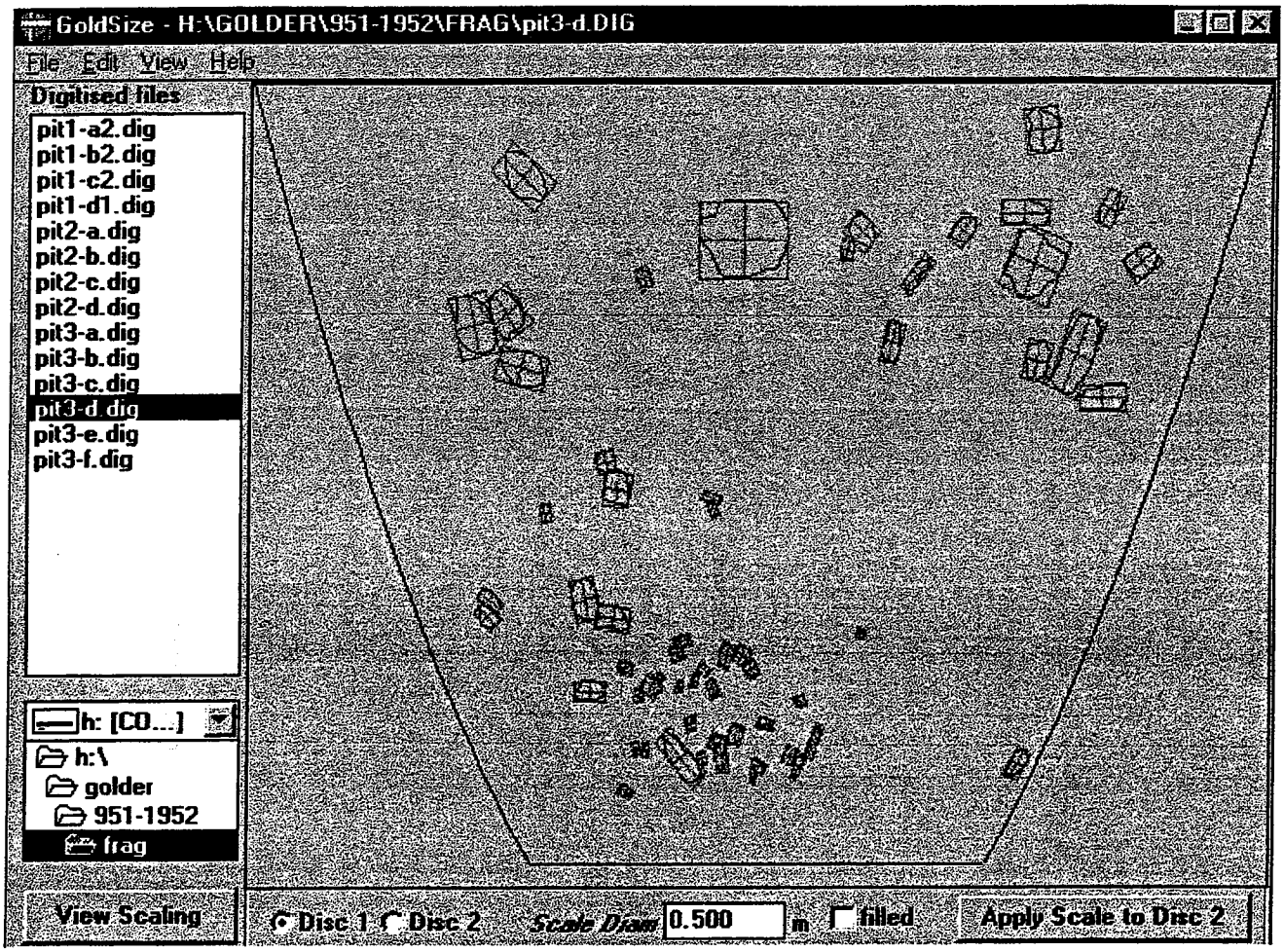
Calculation of Max. & Min. Chord Lengths



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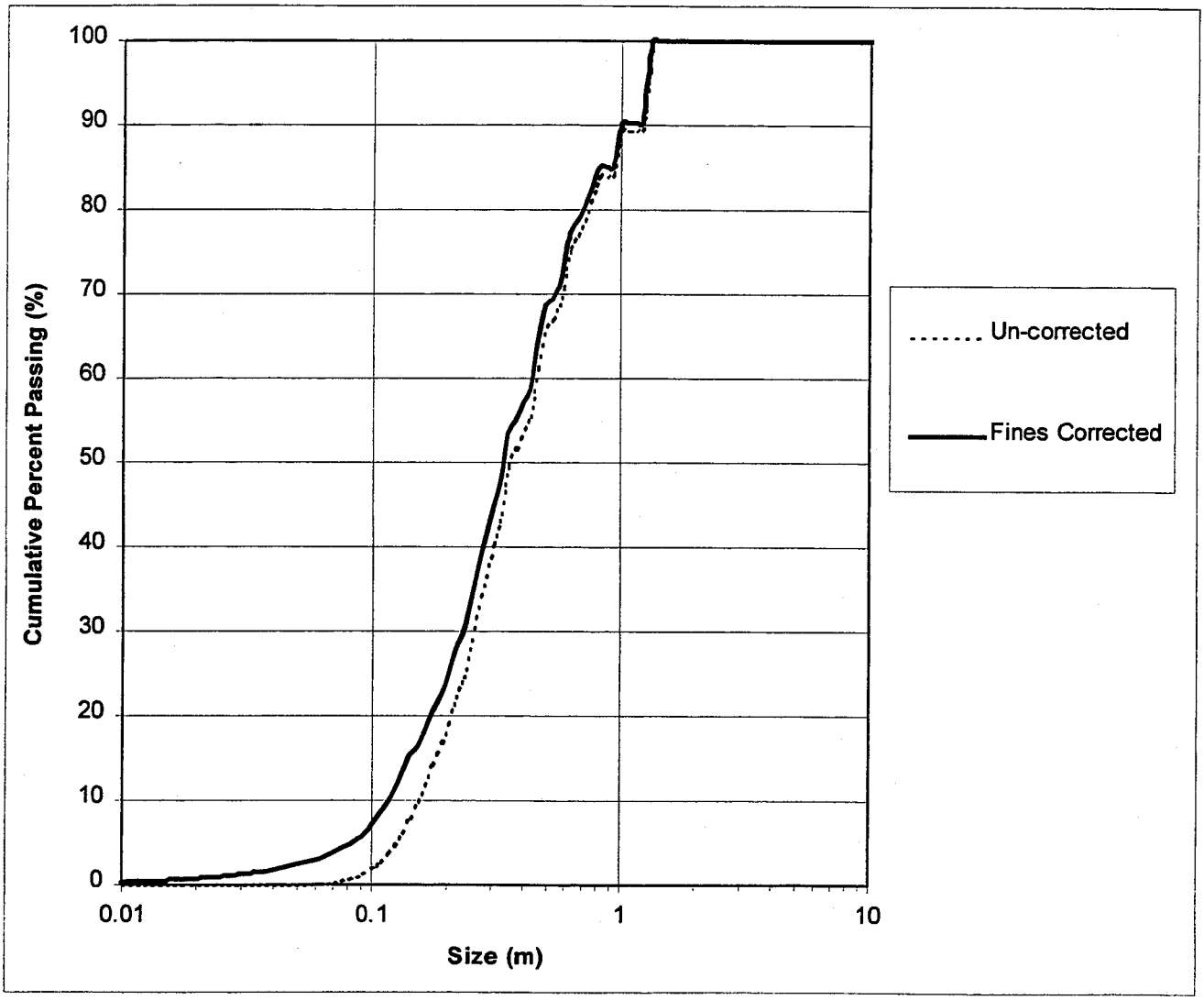
Plot of Rock Particle Size Distribution



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SOLID TESTING

- Paste pH
- Paste Conductivity
- Fizz Tests
- Mineralogy
- Static Testing
- Kinetic Testing - Ongoing

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SOLID ANALYSIS

- Paste pH = 4 - 7
- Paste Conductivity about 1000 μs/cm
- Mineralogy
  - <1% Carbonate Content
- Static Testing
  - Modified Sobek Method on 87 Samples
  - Average MPA = 103 kg $CaCO_3$ / tonne
  - Average NP from 10 to 24 kg CaCO3 / tonne
  - Average NNP is Negative
  - Most of the Waste Rock Samples are Acid Generating
- Kinetic Testing - Ongoing

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ONGOING MONITORING

- Groundwater Chemistry
- Seepage Chemistry and Volume
- Lysimeter Chemistry
- Water Levels
- Precipitation
- Lysimeter Infiltration

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GROUNDWATER

- Field Measurements
  - pH (4.05 to 4.3)
  - Eh (+400 to +500)
  - Conductivity (8000 to 9000 μS/cm)
  - Alkalinity (nil)
- Lab Analysis
  - Metals
    - Fe (90 to 210 mg/L)
    - Ni (500 to 700 mg/L)
  - Sulphate
    - 7500 to 10000 mg/L

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SEEPAGE WATER

- Field Measurements
  - pH (3.6)
  - Eh (+575)
    - oxidizing conditions
  - Conductivity (4000 μS)
  - Alkalinity (nil)
- Lab Analysis
  - Metals
    - Fe (7 - 10 mg/L)
    - Ni (200 mg/L)
  - Sulphate
    - 4000 mg/L
- Seepage is Collected and Treated at Base of Pile

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LYSIMETER RESULTS

- Field Measurements (shortly after rain event)
  - pH (6.2 to 6.8)
  - Eh (+450)
  - Conductivity (500 to 1700 μS)
  - Alkalinity (24 to 63 mg/L as CaCO3)
- Lab Analysis
  - Metals
    - Fe (0.1 to 0.3 mg/L)
    - Ni (3.7 to 8.6 mg/L)
  - Sulphate
    - 600 to 1000 mg/L

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TEMPERATURE MONITORING

- Temperature in the Pile are Measured Using Thermistors
- Temperature Distribution
  - 4° C Base of Pile
  - 8° C Mean Temperature
  - Ambient Air Temperature
- Seasonal Variation it Temperatures Pronounced at Surface

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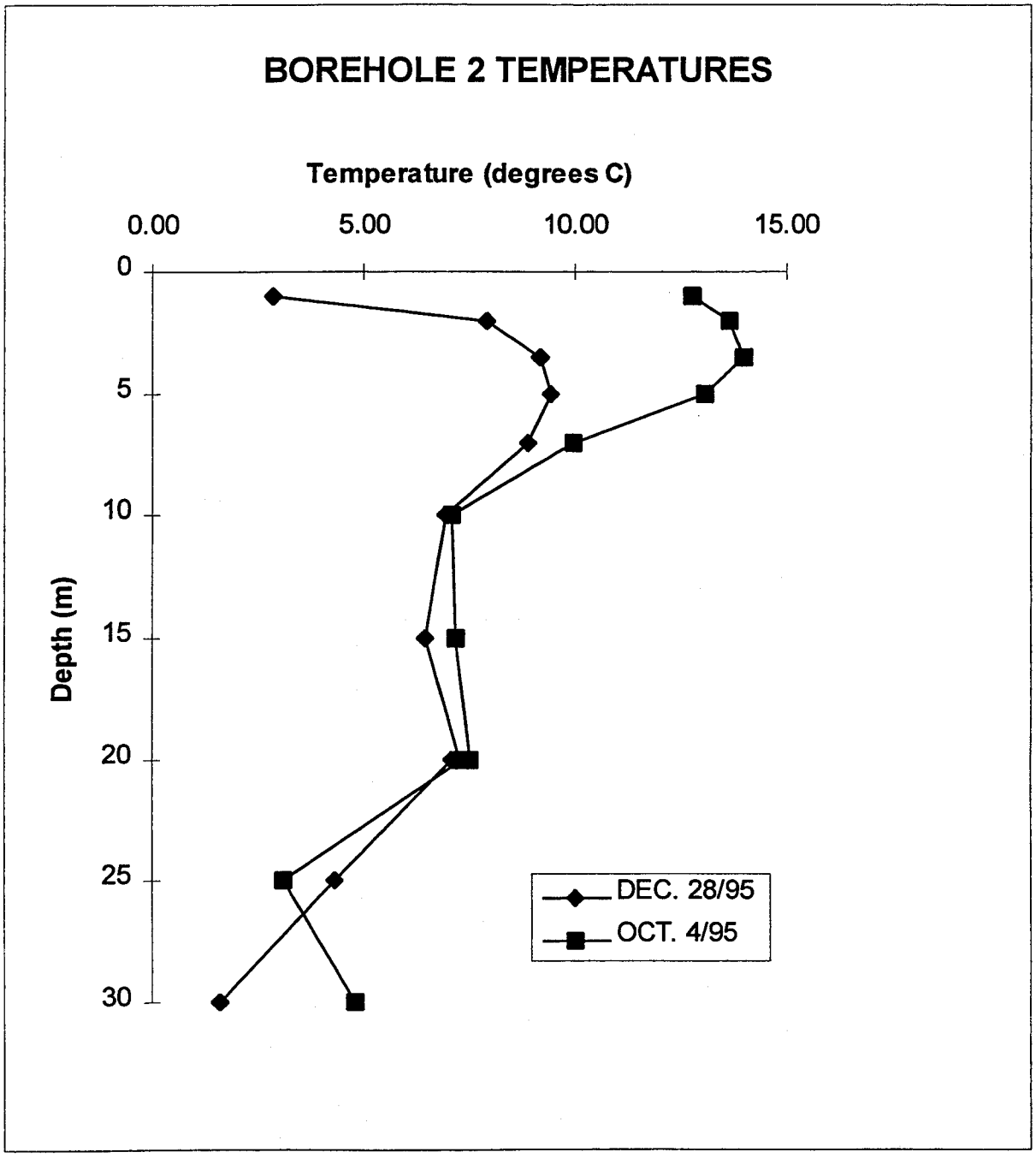
TEMPERATURE PROFILE



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GAS SAMPLING

- Concentration of Gaseous O_2 and CO_2 Measured
- Oxidation in the Waste Rock Results in Depletion of Oxygen and Increases in CO_2
- The Distribution of Gasses in the Pile May Indicate Zones of Active Oxidation
- In General Gas Distribution in the Whistle Mine Rock Pile is Homogeneous for a Given Borehole
- Some Depletion in Oxygen at Surface and Within the Waste Rock is Observed

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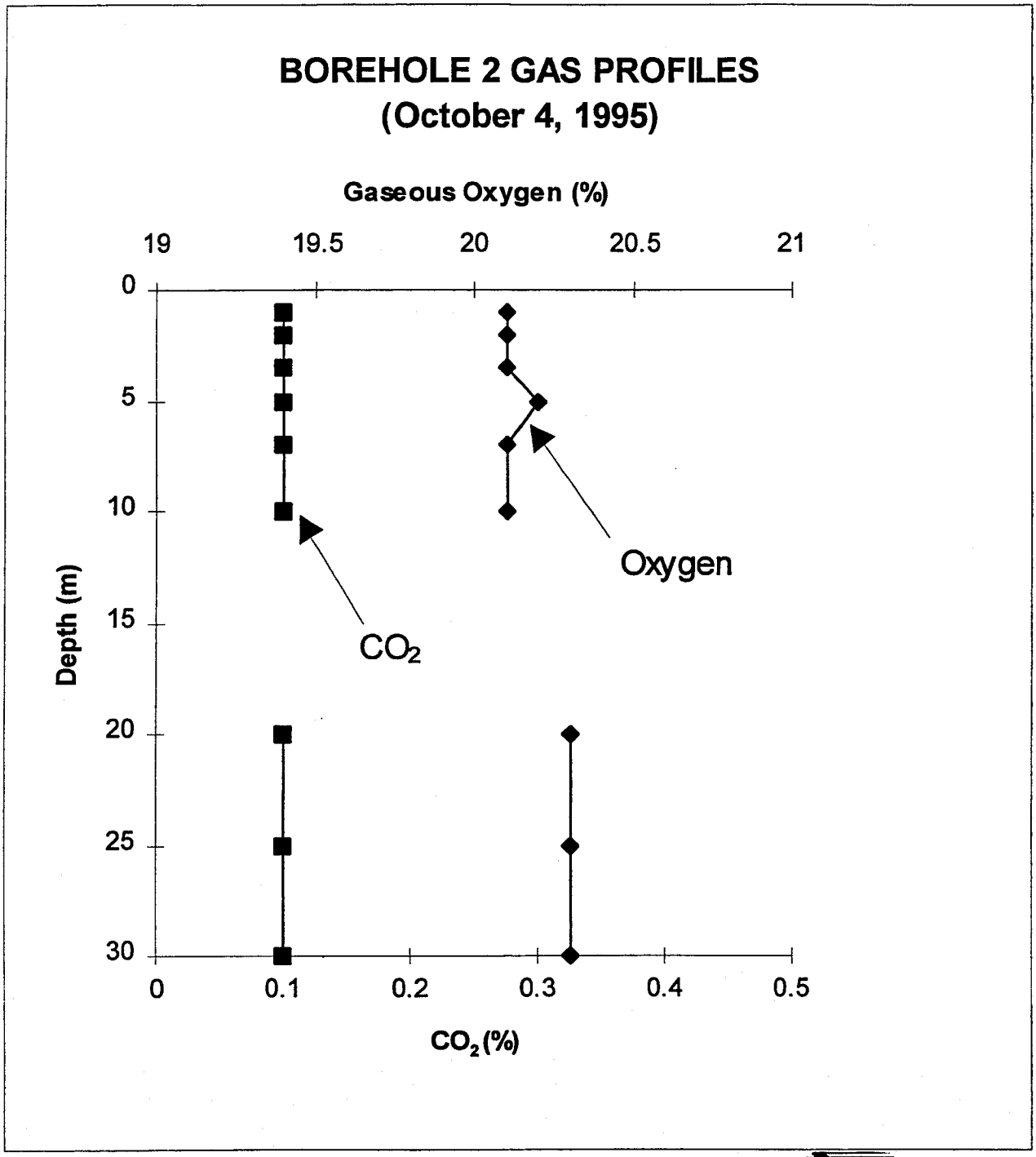
O_2, CO_2 PROFILES



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FLOW THROUGH PILE

- Permeability of Waste Rock Allows for High Infiltration Rate
- Maximum Flow Based on Precipitation
  - Average Annual Precipitation is approximately 700 mm/m/year for the Sudbury Area
  - Area of Infiltration is Approximately 4 Ha
  - Maximum Seepage Flow Based on Precipitation Recharge is Approximately 1 L/s

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CONCLUSIONS

- Very Heterogeneous
- Sulphide Content in Pile from <1% to 3%
- Local Areas of the Pile Contain Blocks of Pyrrhotite, Both Weathered and Intact
- Pile is Acid Generating
- Groundwater and Seepage have low pH and High Nickel Content
- Temperature Variations in the Pile Mainly Reflect Surface Temperature Variations
- Oxygen Concentration in the Pile May be Affected to Some Extent by Oxidation

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REMAINING WORK

- Assess Seasonal Variability of Chemistry and Flow Parameters
- Complete Kinetic Testing and Assess Results

ADDITIONAL OR SUPPLEMENTARY STUDIES

- Conduct a Tracer Injection Experiment Using Gas Sampling Ports to Confirm Permeability Estimates
- Continue Monitoring Geochemical Evolution of the Site
- Use Data Collected to Assess, and Assist in Modelling of Waste Rock Piles

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