

U.S. DEPARTMENT OF ENERGY  
OFFICE OF CIVILIAN RADIOACTIVE WASTE  
MANAGEMENT

**NUCLEAR WASTE TECHNICAL REVIEW  
BOARD**

**SUBJECT: THERMAL AND UNDERGROUND  
TESTING UPDATE**

**PRESENTER: WILLIAM J. BOYLE**

PRESENTER'S TITLE  
AND ORGANIZATION: PERFORMANCE CONFIRMATION TEAM LEAD  
FOR THE ASSISTANT MANAGER FOR LICENSING  
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PAHRUMP, NV  
JANUARY 28, 1997

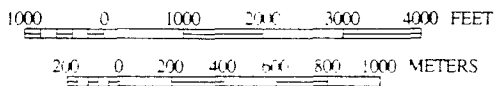
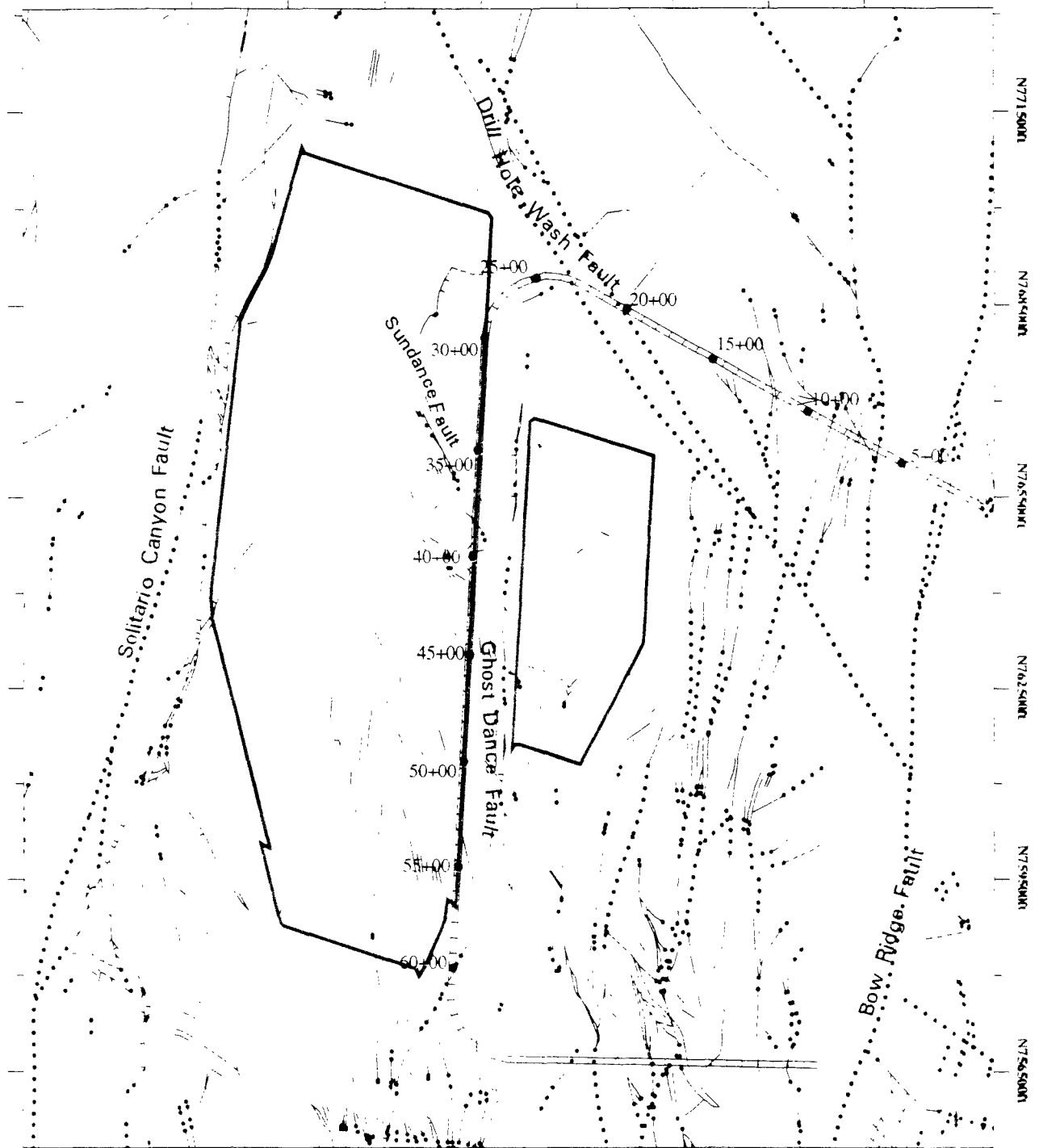
E556000ft

E559000ft

E562000ft

E565000ft

E568000ft



Yucca Mountain Site  
 Characterization Project

Legend

- |  |                   |  |                |  |                            |
|--|-------------------|--|----------------|--|----------------------------|
|  | Known Fault       |  | Inferred Fault |  | Potential Repository Block |
|  | Approximate Fault |  | Dike           |  | ESF Tunnel                 |

WARREN DAY FAULTS

# Sketch of Possible Fault at Station 71+31

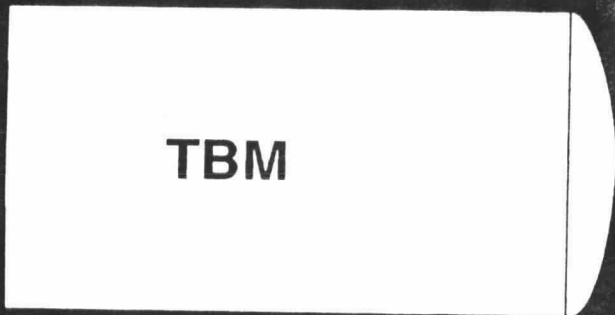


TBM

Side View

Tptpmn

Tptpul



TBM

Top View

Tptpmn

Tptpul

# EXPLORATORY STUDIES FACILITY - TEST LOCATIONS

## TBM TESTING

- HYDROCHEMISTRY TESTS IN THE ESF
- CONSOLIDATED SAMPLING
- UNDERGROUND GEOLOGICAL MAPPING
- PERCHED-WATER TESTING IN THE ESF (CONTINGENCY)
- CONSTRUCTION MONITORING

## POSSIBLE NORTH RAMP EXTENSION

- DIFFUSION TESTS IN THE ESF
- PERCOLATION TESTS IN THE ESF
- CONSOLIDATED SAMPLING
- UNDERGROUND GEOLOGICAL MAPPING
- RADIAL BOREHOLE TESTS IN THE ESF
- HYDROCHEMISTRY TESTS IN THE ESF
- CONSTRUCTION MONITORING

## THERMAL TESTING FACILITY

- THERMAL/MECHANICAL PROPERTIES
- NEAR-FIELD HYDROLOGIC/GEO-MECHANICAL PROPERTIES
- EXCAVATION INVESTIGATIONS
  - SEQUENTIAL DRIFT MINING
  - SINGLE-ELEMENT HEATER TESTING
  - PLATE-SOURCE THERMAL TESTING
  - EMPLACEMENT DRIFT THERMAL TESTING

NORTH PORTAL

ALCOVE #1

- HYDROCHEMISTRY TESTS
- RADIAL BOREHOLE TESTS (ANISOTROPIC)

ALCOVE #2

- HYDROCHEMISTRY TESTS
- HYDROLOGIC PROPERTIES OF MAJOR FAULTS (BOW RIDGE)

9 DEFERRED ALCOVES  
IN THE NORTH RAMP

ALCOVE #3

- HYDROCHEMISTRY TESTS
- RADIAL BOREHOLE TESTS (TIVA CANYON/PTn CONTACT)

ALCOVE #4

- HYDROCHEMISTRY TESTS
- RADIAL BOREHOLE TESTS (PTn/TSw CONTACT)

ALCOVE #5 (CURRENTLY DEFERRED)

- HYDROCHEMISTRY TESTS
- HYDROLOGIC PROPERTIES OF MAJOR FAULTS (DRILL HOLE WASH)

ALCOVE #6

- HYDROCHEMISTRY TESTS
- HYDROLOGIC PROPERTIES OF MAJOR FAULTS (SUNDANCE/GHOST DANCE)

ALCOVE #7

- HYDROCHEMISTRY TESTS
- HYDROLOGIC PROPERTIES OF MAJOR FAULTS (GHOST DANCE)

SOUTH PORTAL

MAIN DRIFT

13 DEFERRED ALCOVES  
IN THE SOUTH RAMP

4 DEFERRED ALCOVES  
IN THE MAIN DRIFT

## FINAL DECISIONS ON DEFERRAL

NOTE: TEST EXCAVATION AND TESTING IN DEFERRED ALCOVES IS DEPENDENT ON OBSERVATIONS DURING EXCAVATION, EVALUATION OF EARLY TEST RESULTS, AND PROGRAM PRIORITIES

## FY-97 ACTIVITIES TO BE CONDUCTED IN THE ESF

COMPLETE INSTRUMENTATION SET-UP ON LARGE BLOCK	1/27/97
COMPLETE HEATED DRIFT EXCAVATION	2/12/97
CONSTRUCT 12.5 METER CAST-IN-PLACE LINER (CIP)	3/3/97 - 3/26/97
COMPLETE INSTALLATION AND SET-UP OF DATA COLLECTION SYSTEM (DCS)	3/17/97
DATA COLLECTION SYSTEM (DCS) INSTALLATION AND SET-UP	4/1/97 - 11/14/97
DRILL 60 METER BOREHOLE IN HEATED DRIFT TEST DANCE FLOOR AREA	4/13/97
HEATED DRIFT TEST BOREHOLE DRILLING/CORING	4/12/97 - 7/1/97
HEATER TURN-ON AT LARGE BLOCK	TBD by DOE (February 97)
COMPLETE PREPARATION OF SOUTHERN REAR CROSS DANCE ACCESS DRIFT	5/9/97
COMPLETE TESTING IN SOUTHERN REAR CROSS DANCE ACCESS DRIFT	7/1/97
COMPLETE EXCAVATION OF SOUTHERN REAR CROSS DANCE ENTRY ROOM	10/1/97
BEGIN TESTING IN SOUTHERN REAR CROSS DANCE ENTRY ROOM	11/19/97
HEATED DRIFT HEATER TURN-ON	12/8/97

# Purpose of Testing in Alcoves 6 & 7

Determine the flow properties through

- Pneumatic monitoring
- Pressure tests
- Gas chemistry
- Temperatures

E560000

E565000

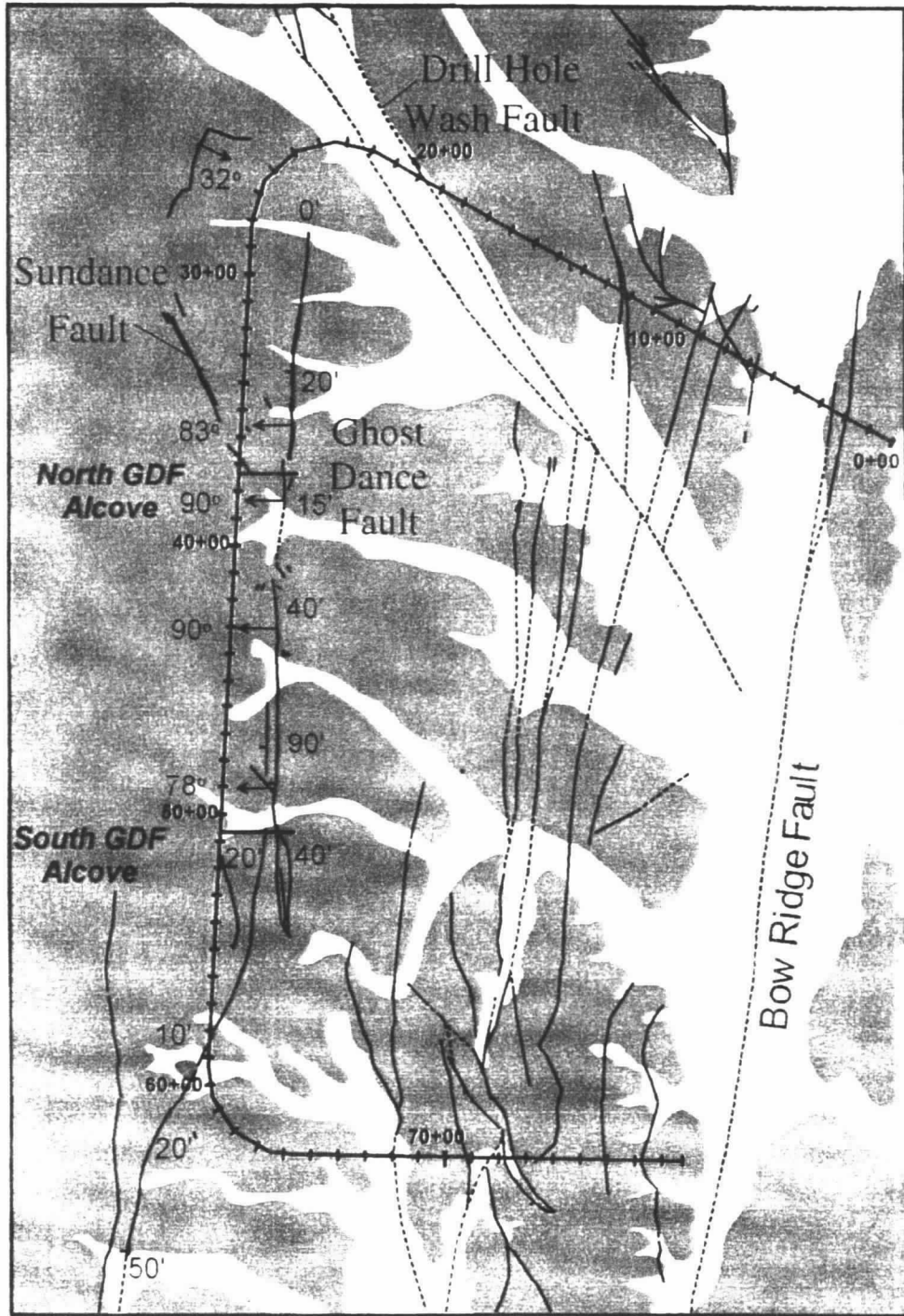
E570000

N770000

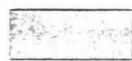
N765000

N760000

N754750



### EXPLANATION



Volcanic Rock

20'

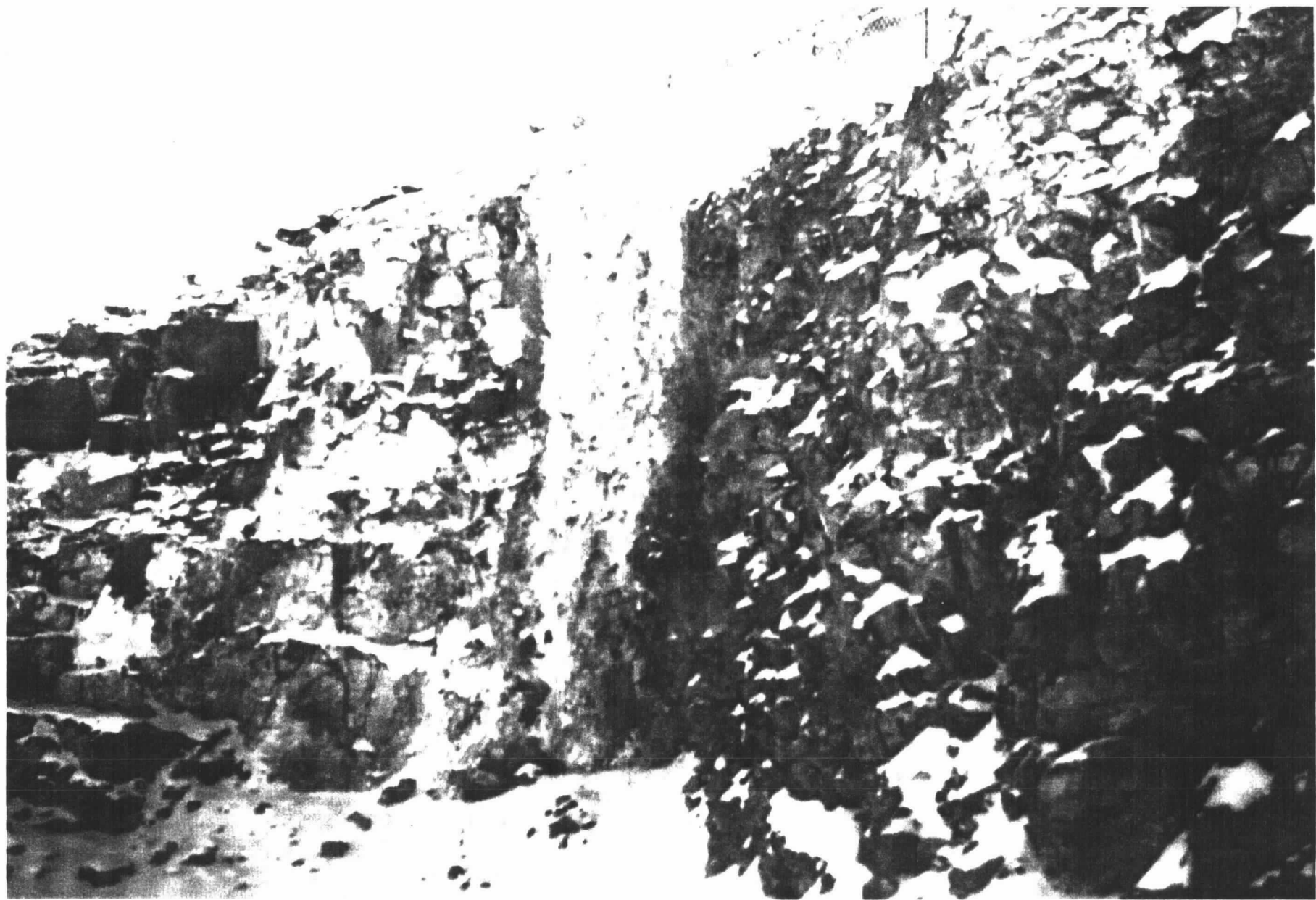
Amount of Offset on Fault



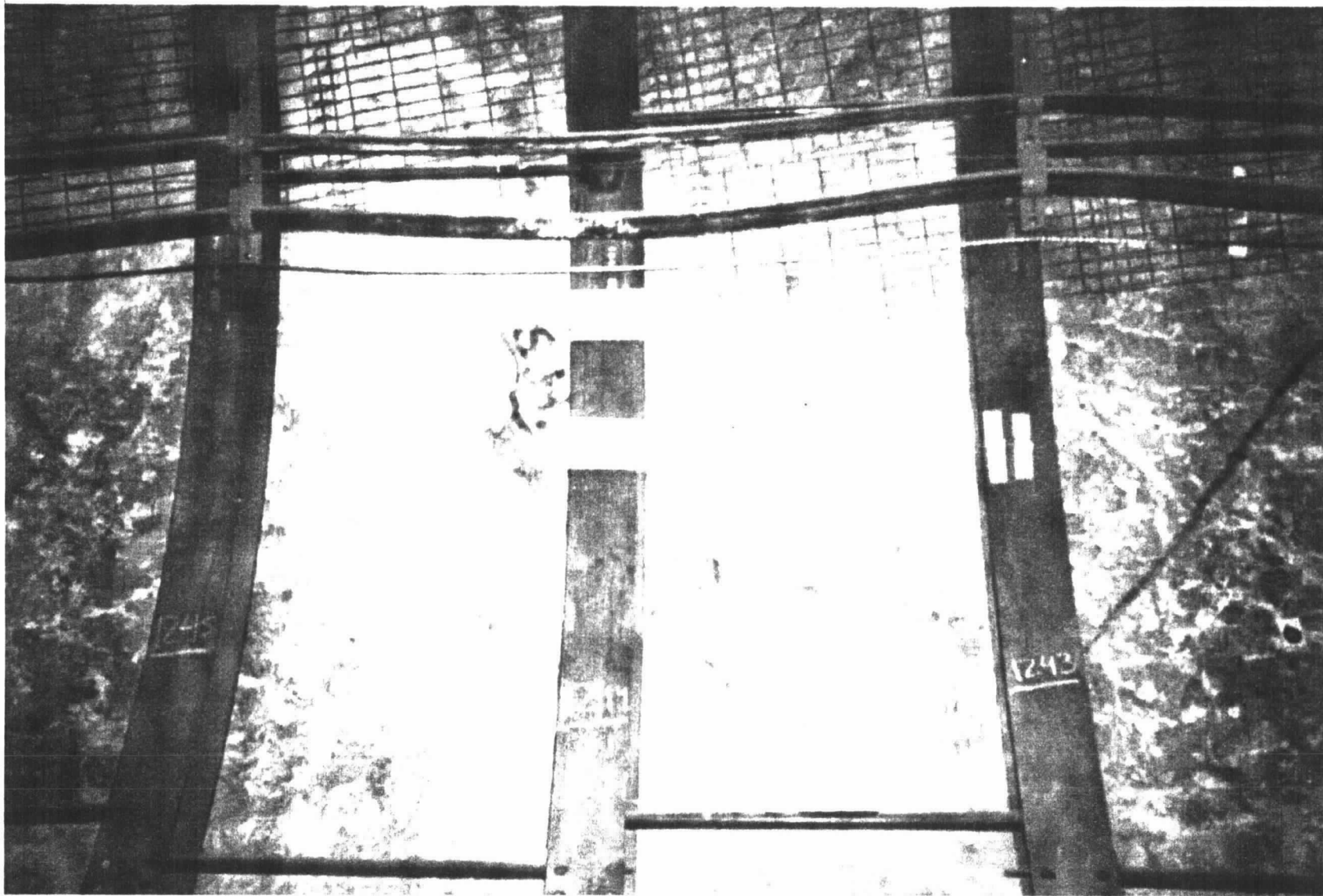
Fault

80°

Dip of Fault

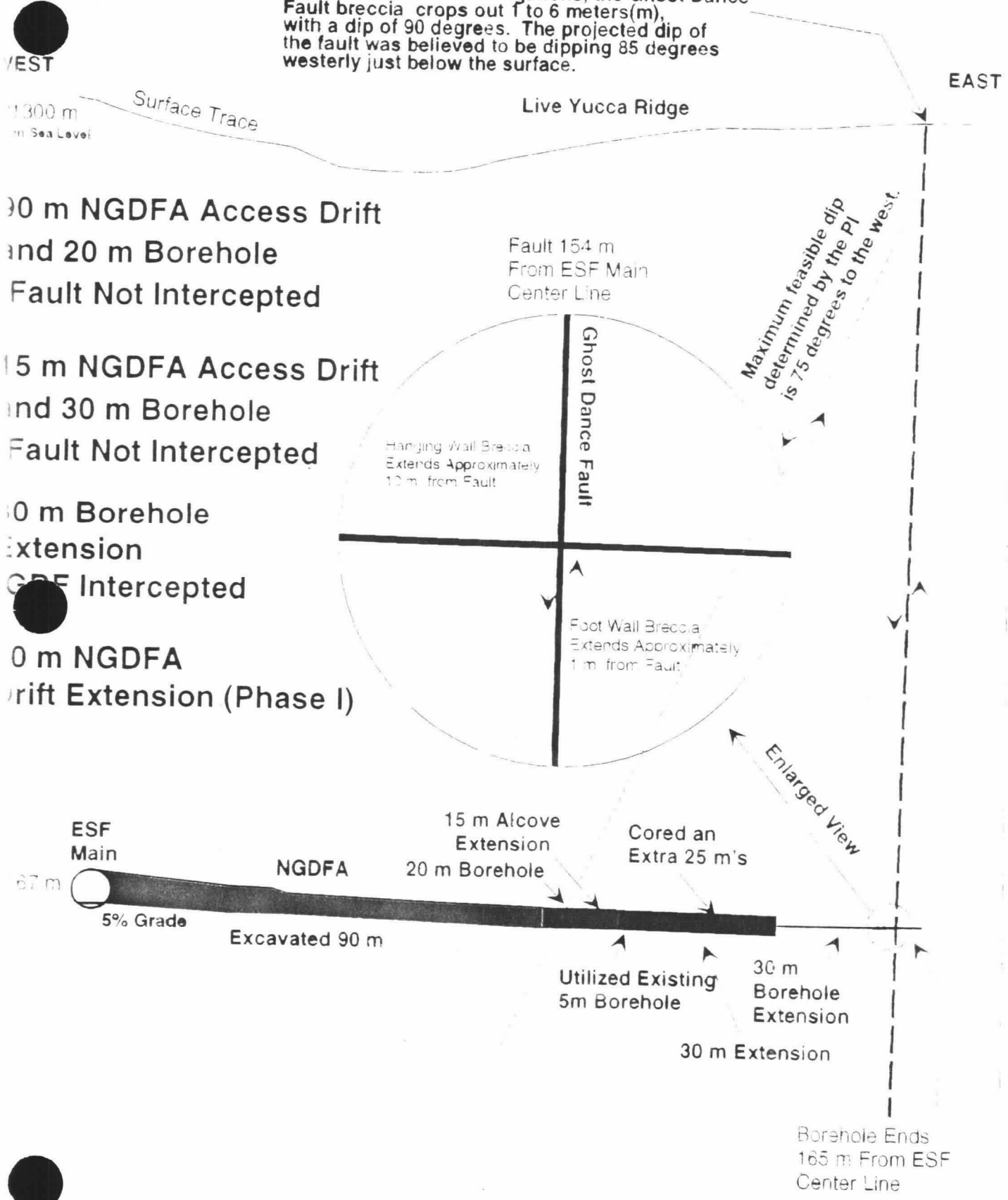






# GHOST DANCE FAULT (IN NORTH)

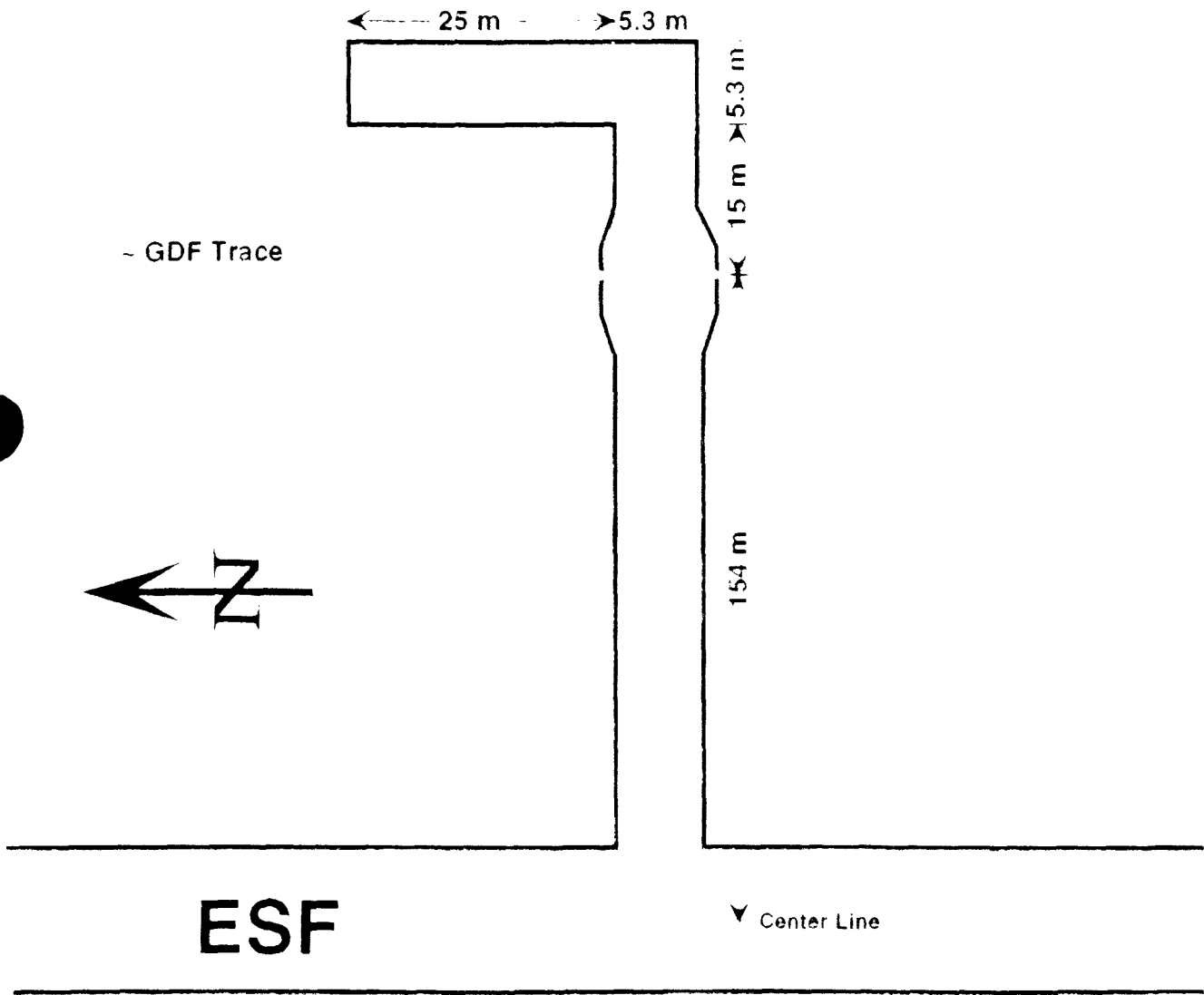
Based on surface investigations, the Ghost Dance Fault breccia crops out 1 to 6 meters(m), with a dip of 90 degrees. The projected dip of the fault was believed to be dipping 85 degrees westerly just below the surface.



NOT TO SCALE

ESF-TCO Administrative Drawing

# PRELIMINARY Northern Ghost Dance Fault Alcove Drill Room Layout (Alcove #6)

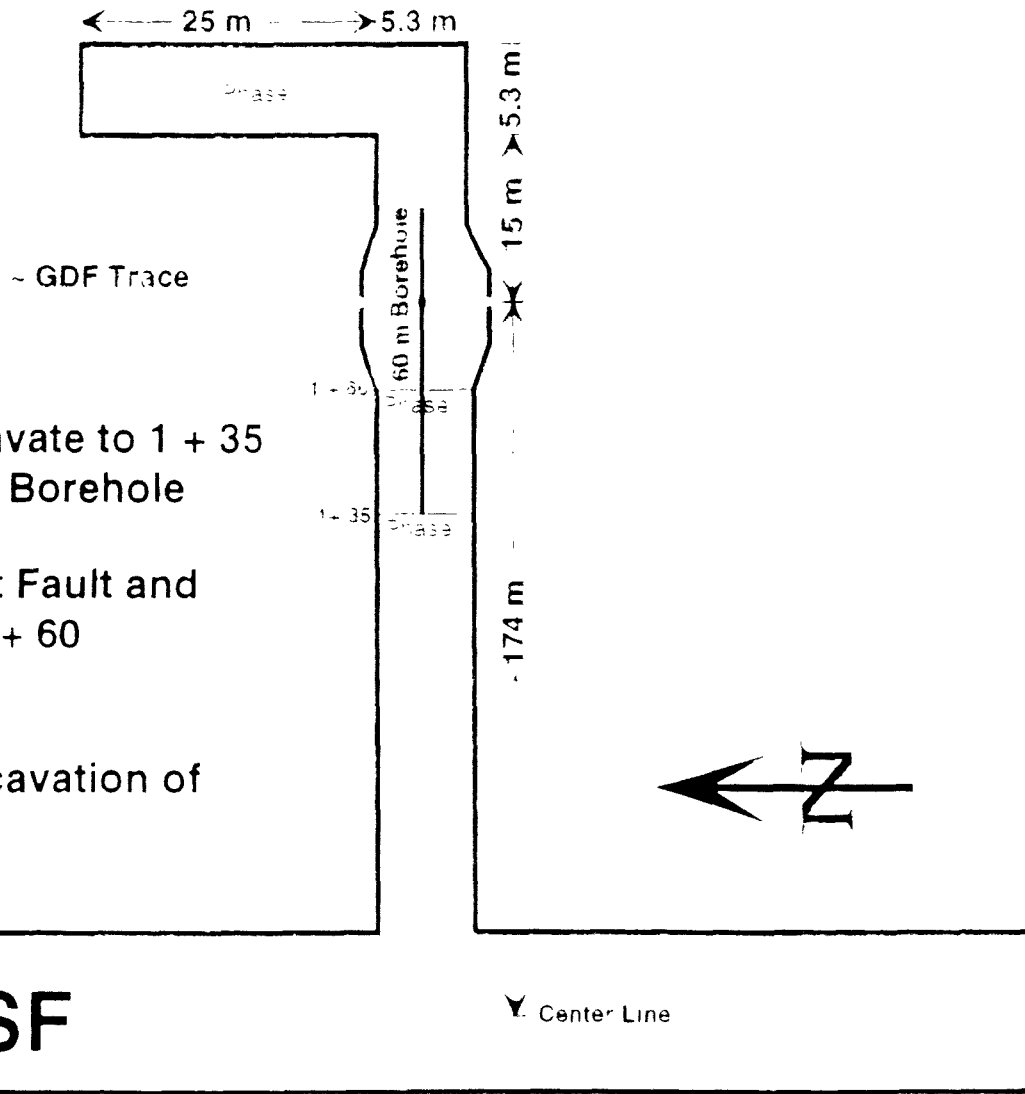


NOT TO SCALE

ESF-TCO Administrative Drawing

# PRELIMINARY

## Southern Ghost Dance Fault Alcove Excavation Logic and Drill Room Layout (Alcove #7)



**Phase I** - Excavate to 1 + 35  
and Drill 60 m Borehole

**Phase II** - Test Fault and  
Excavate to 1 + 60  
(~ 4 months)

**Phase III** - Excavation of  
Drill Room

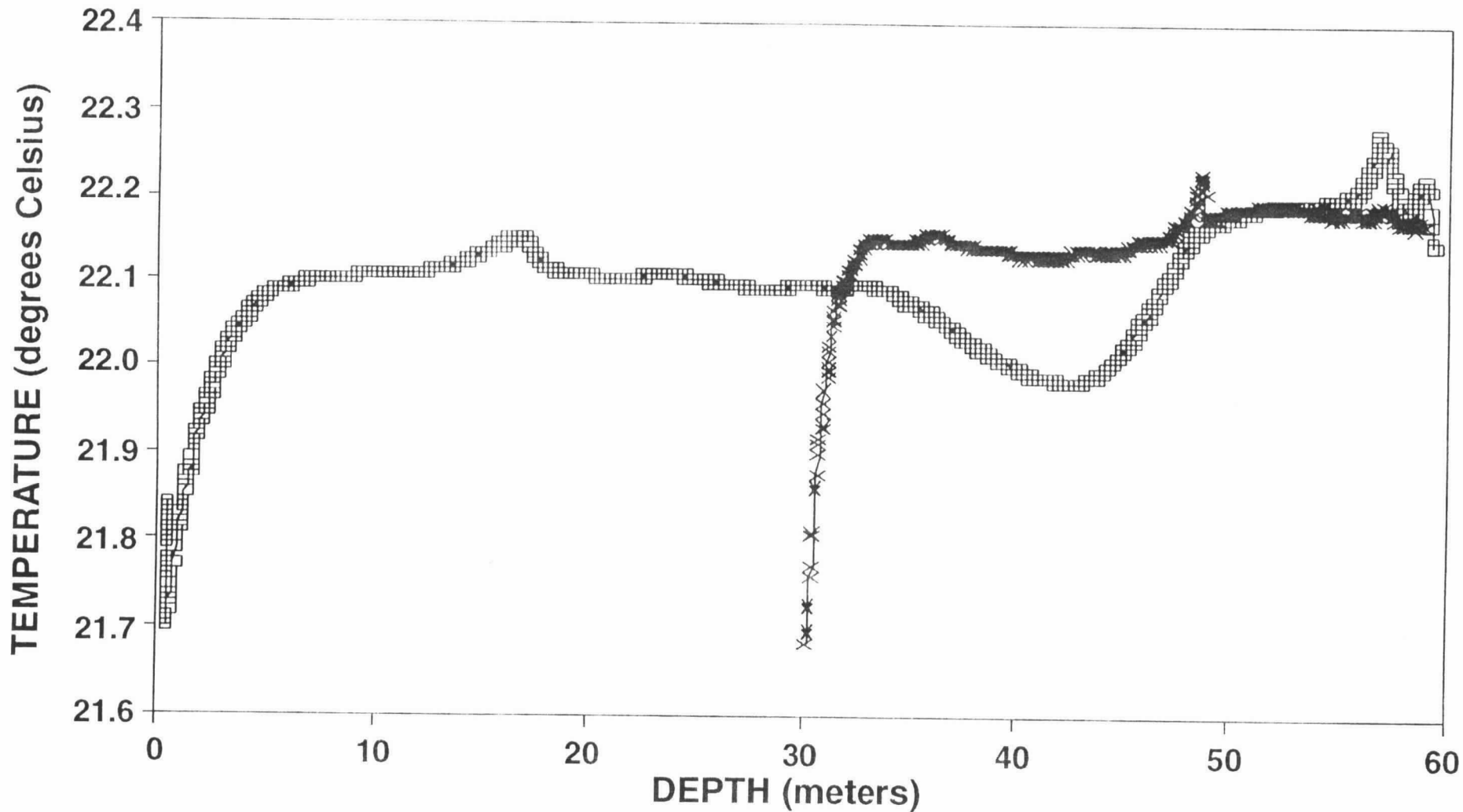
**ESF**

Y Center Line

NOT TO SCALE

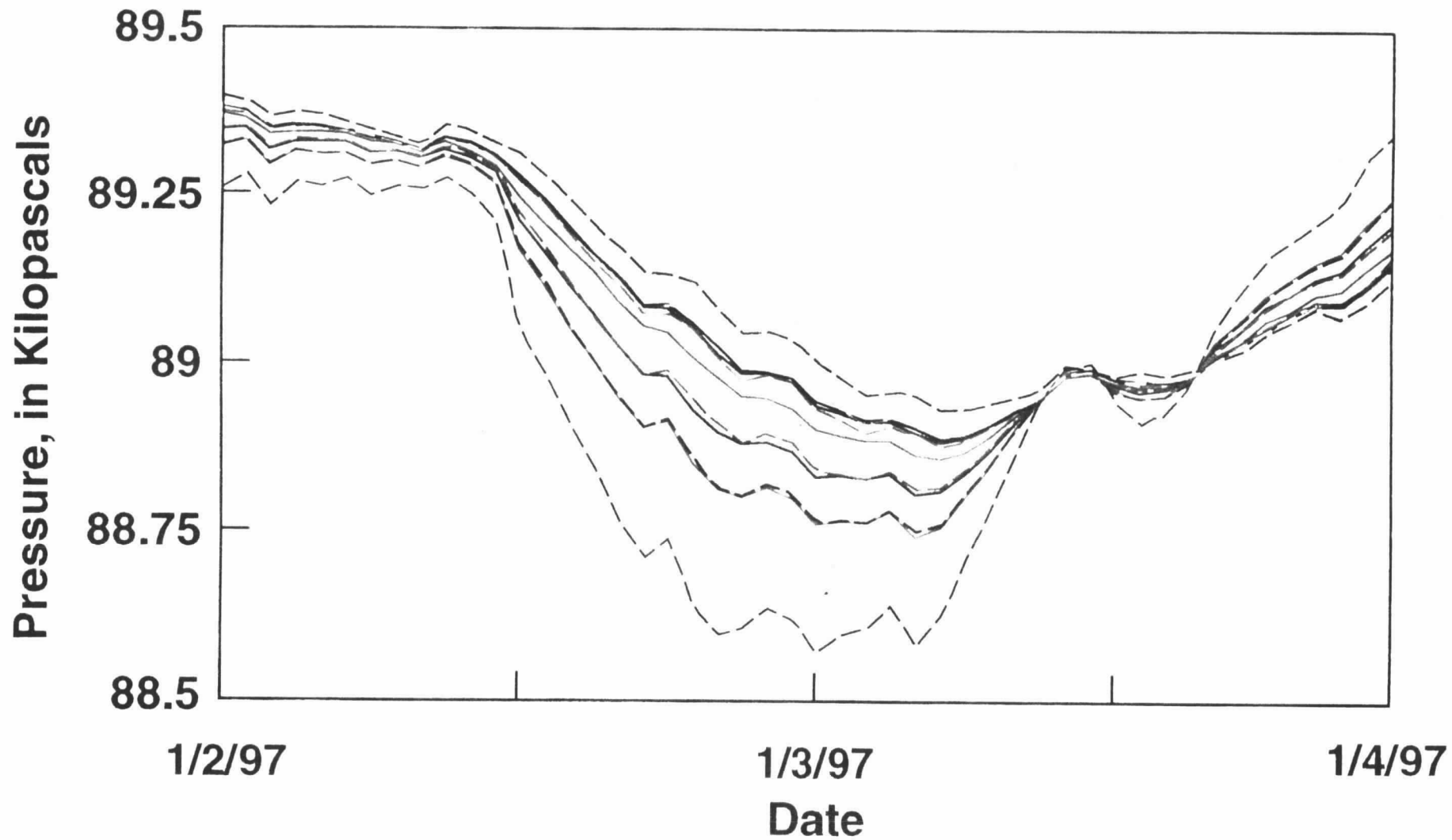
ESF-TCO Administrative Drawing

# Northern Ghost Dance Fault Alcove Geothermal Log



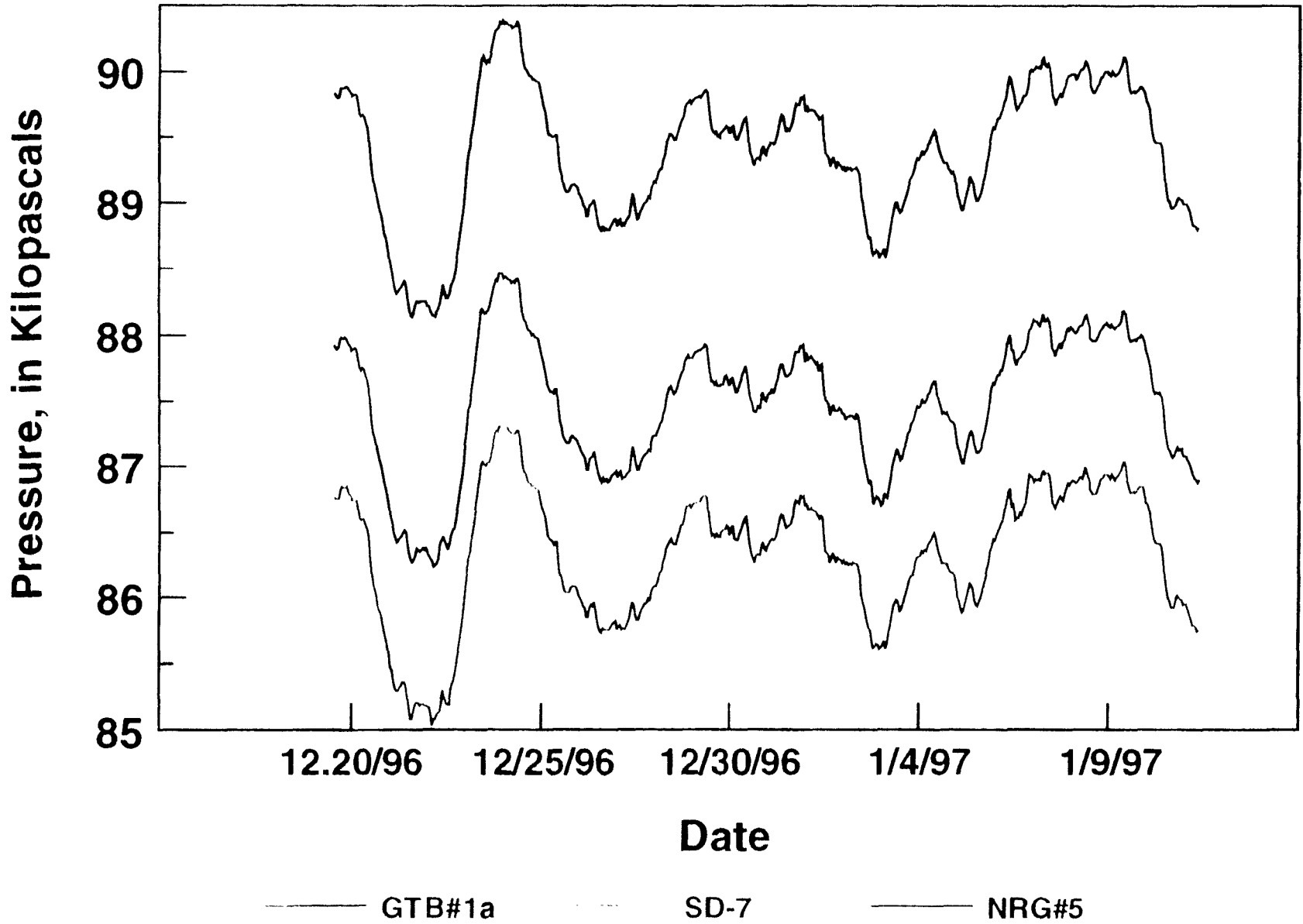
—□— LOGGED 7 NOV 1996    —x— LOGGED 3 DEC 1996

# Pneumatic Pressure Monitoring in Borehole GTB#1a



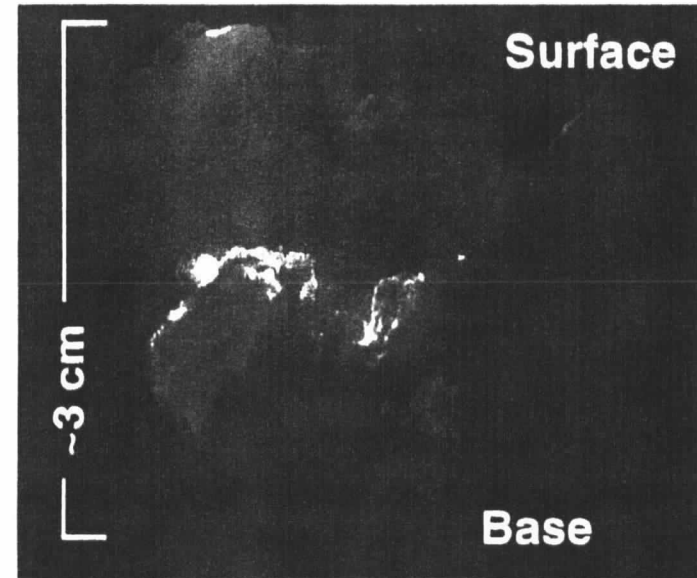
-----	Barometer	-----	Zone 1	-----	Zone 2	-----	Zone 3
-----	Zone 4	-----	Zone 5	-----	Zone 6	-----	Zone 7
-----	Zone 8	-----	Zone 9	-----	Zone 10		

# Barometer Comparison



# MINERAL RECORDS OF PERCOLATION IN THE ESF

Calcite ( $\text{CaCO}_3$ ) and Opal ( $\text{SiO}_2 \cdot \text{H}_2\text{O}$ ) are deposited in fractures and cavities by downward-percolating water.



Calcite (gray or blue-fluorescing) and opal (green-fluorescing) coatings in open cavities from the ESF.

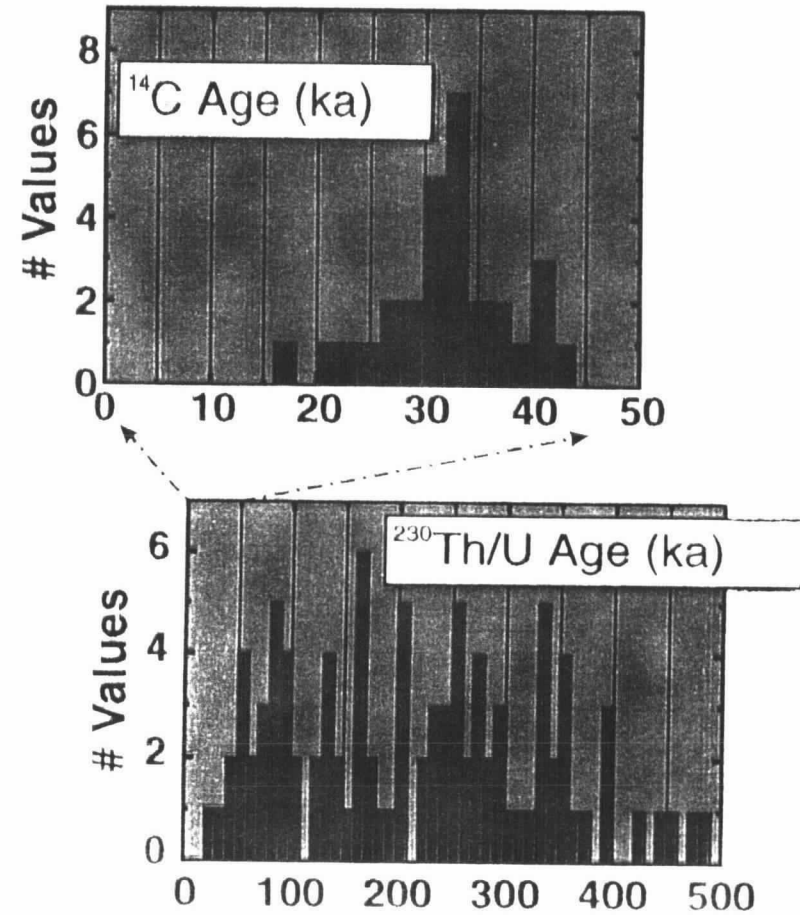


# MINERAL RECORDS OF PERCOLATION IN THE ESF

## AGE DETERMINATION

Depositional ages are determined by isotopic dating (U-series,  $^{14}\text{C}$ , U-Pb).

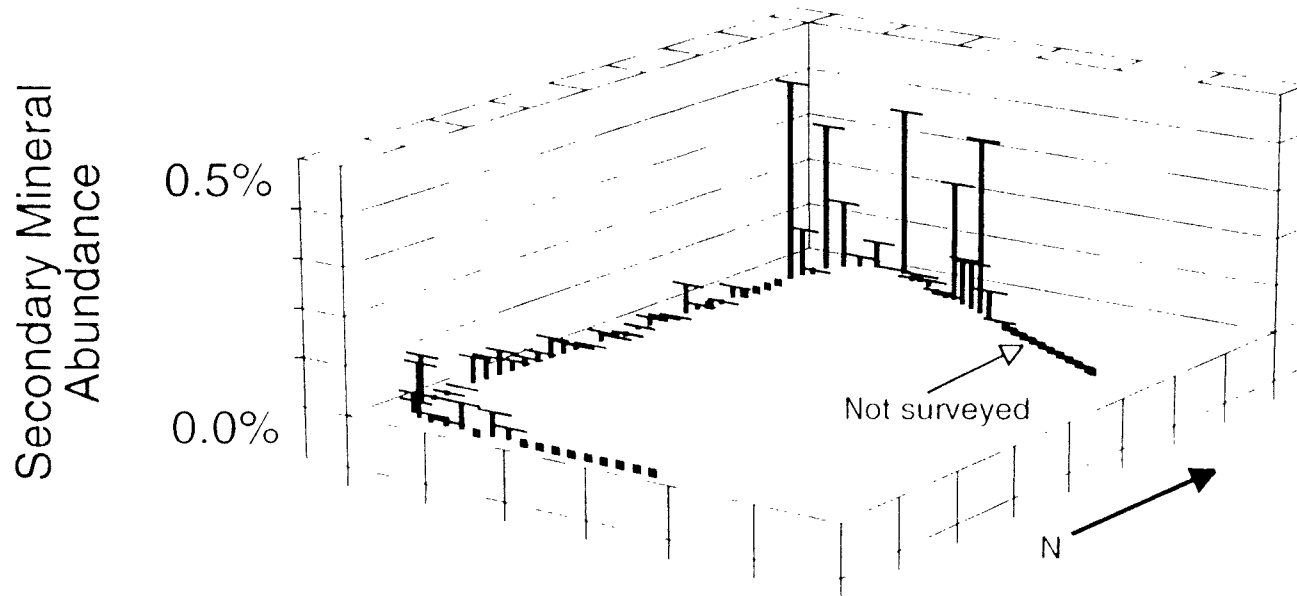
Results indicate a protracted history of deposition extending to relatively recent time, but at *very slow* growth rates.



# MINERAL RECORDS OF PERCOLATION IN THE ESF

## *MINERAL DISTRIBUTION*

Distribution of secondary minerals in the ESF identifies zones of past percolation.



## *CALCULATIONS OF PAST FLUX*

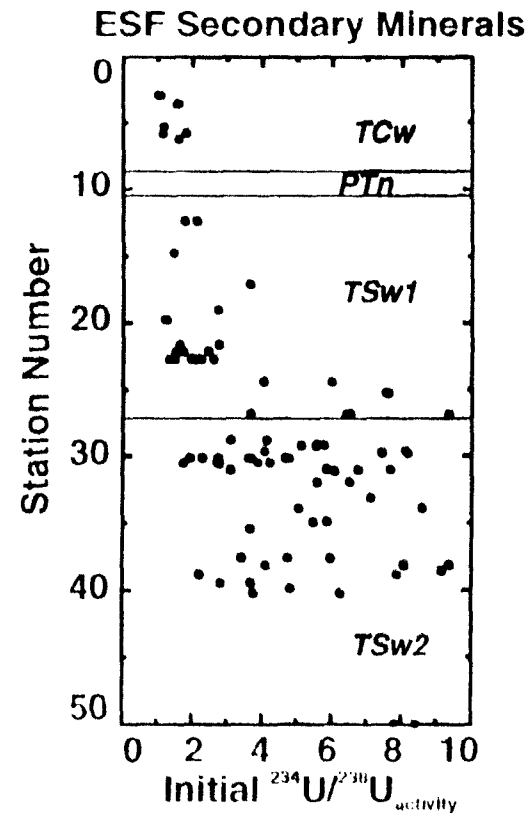
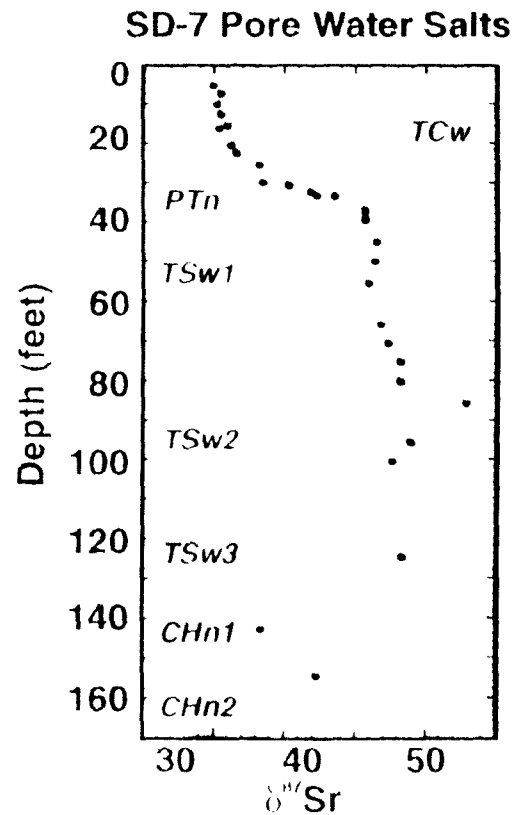
Amounts of water required to precipitate the secondary minerals are derived from mineral distributions and ages.

- Discrete flux estimates range from 0 to 20 mm/yr for 5 m intervals
- Spatially averaged minimum values range from 0.1 to 1 mm/yr
- Estimates are dependent on hydrochemical evolution models

# Mineral Records of Percolation in The ESF

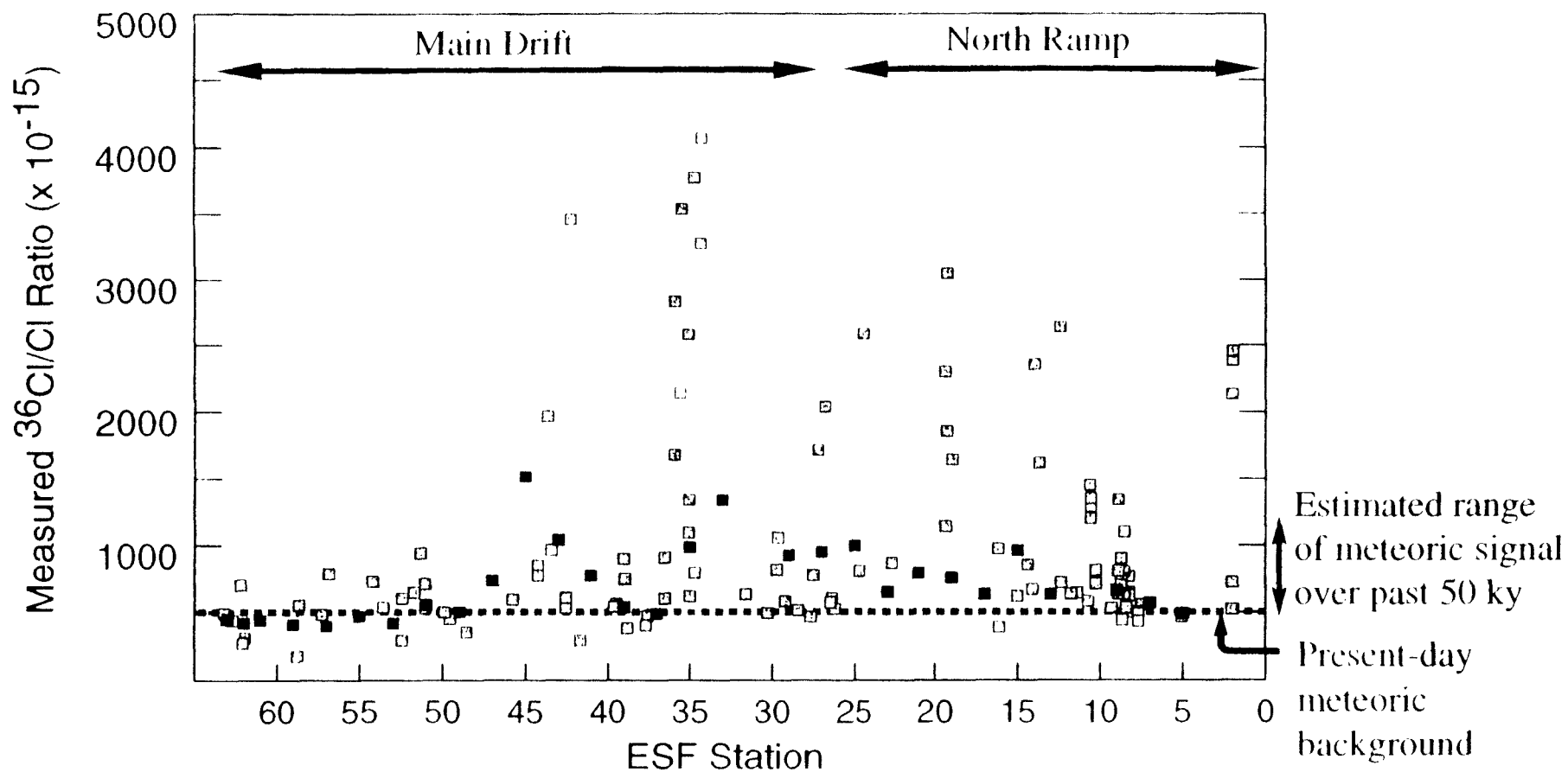
## *additional isotopic evidence of flux*

Possible diversionary role of the PTn on percolating waters. Isotopic compositions for both Sr and U indicate major differences above and below PTn.

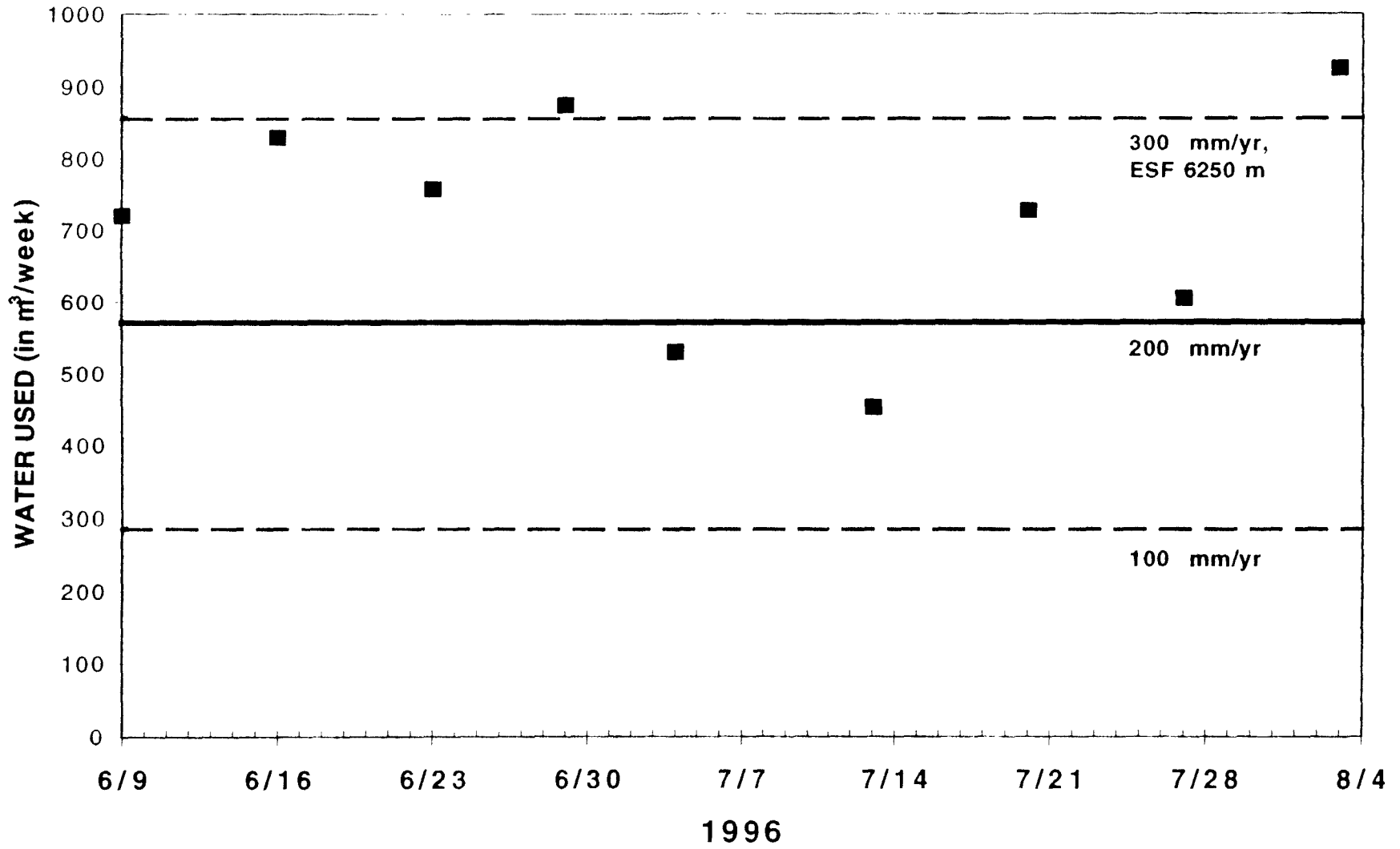


# DISTRIBUTION OF $^{36}\text{Cl}/\text{Cl}$ RATIOS MEASURED FOR ESF SAMPLES

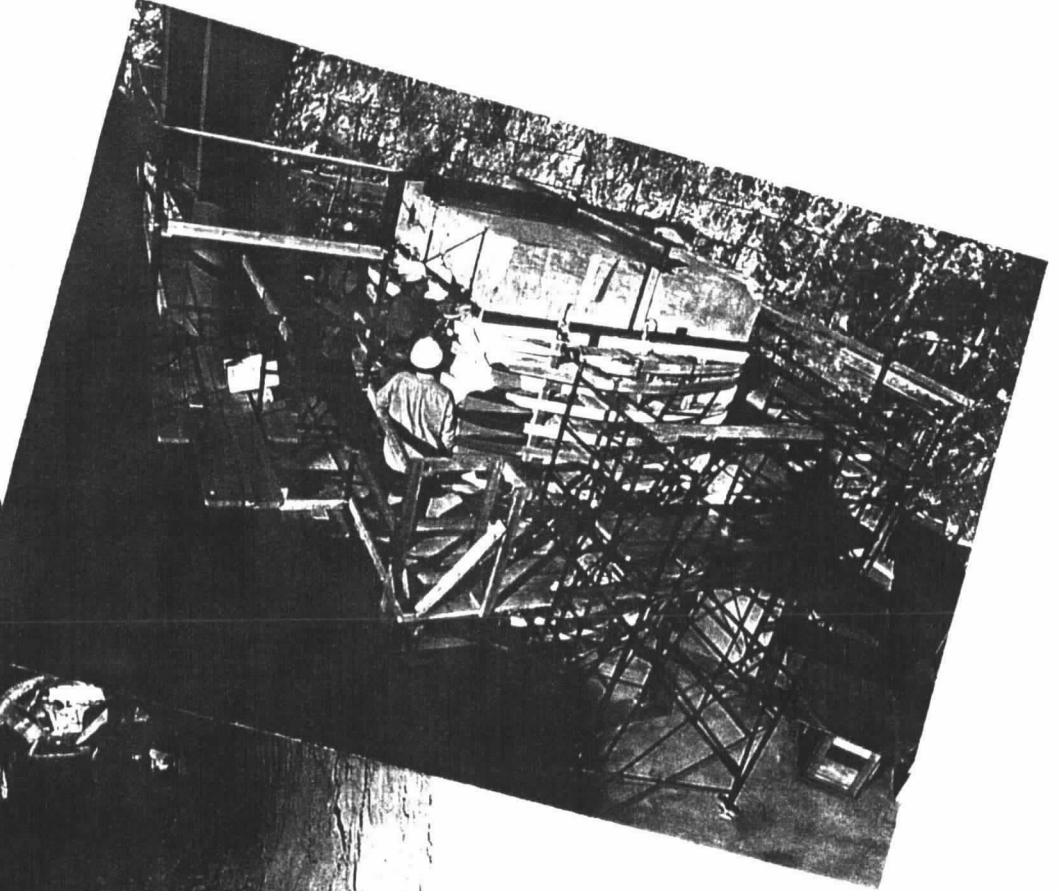
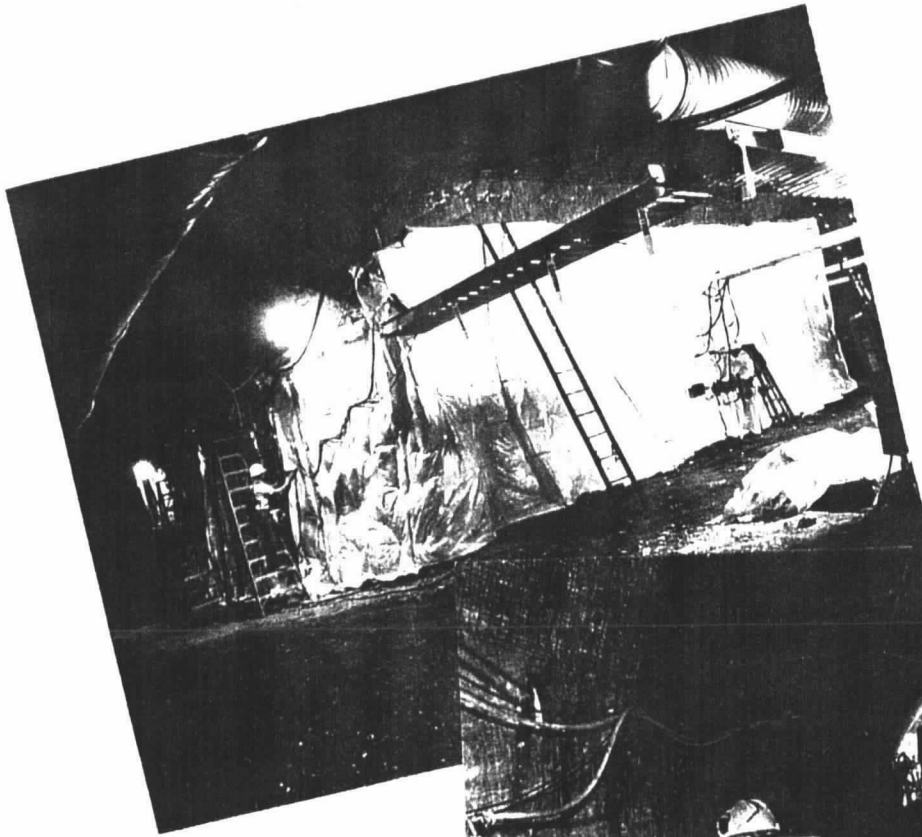
- Feature-based samples (fractures, faults, breccia, unit contacts, etc.)
- Systematic samples



# WATER USAGE IN ESF



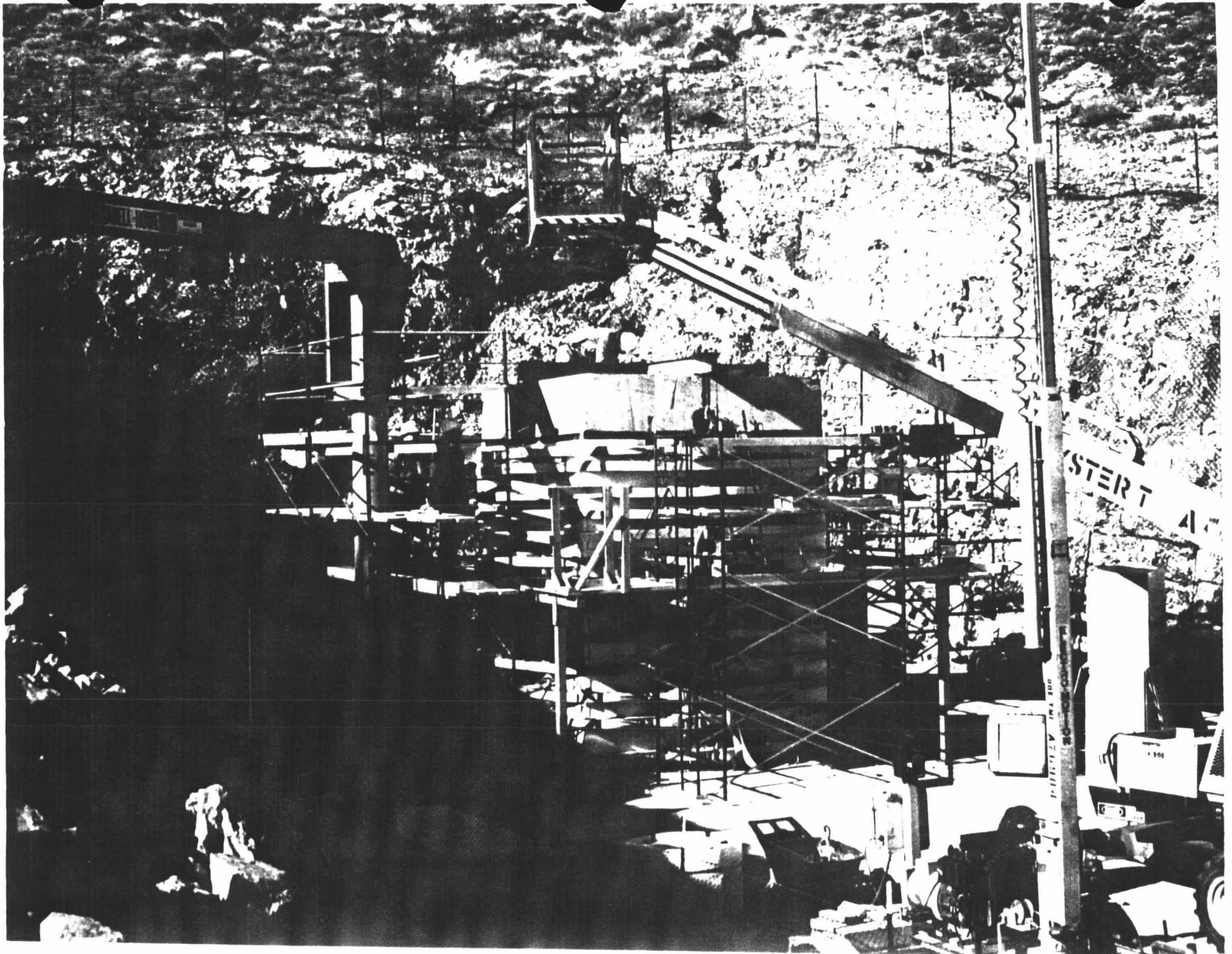
# Thermal Studies



# **LARGE BLOCK TEST**

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- **To Study the coupled TMHC processes in a medium of**
  - **controlled thermal boundary**
  - **controlled moisture boundary**
  - **large scale**
  - **multiple fractures and inhomogeneities**
  - **well pre- and post-test characterizations.**
- **To test instrumentation in a quasi in situ environment.**
- **To test waste package materials in a quasi in situ environment.**

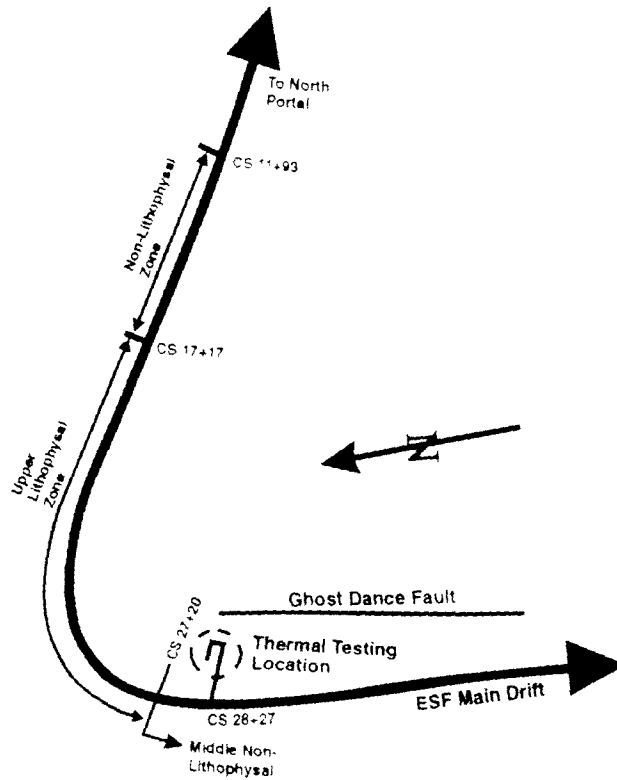




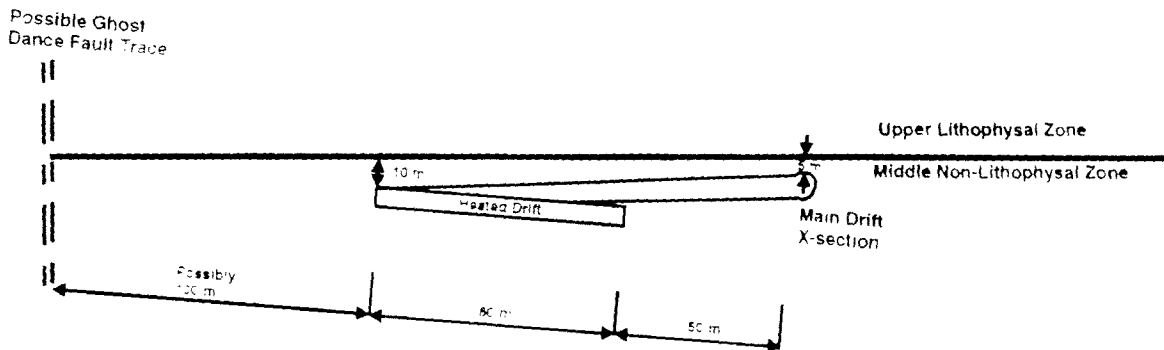
# **Exploratory Shaft Facility Thermal Test**

- **Drift Scale Test**
- **Single Heater Test**

# General Location of the ESF Thermal Test



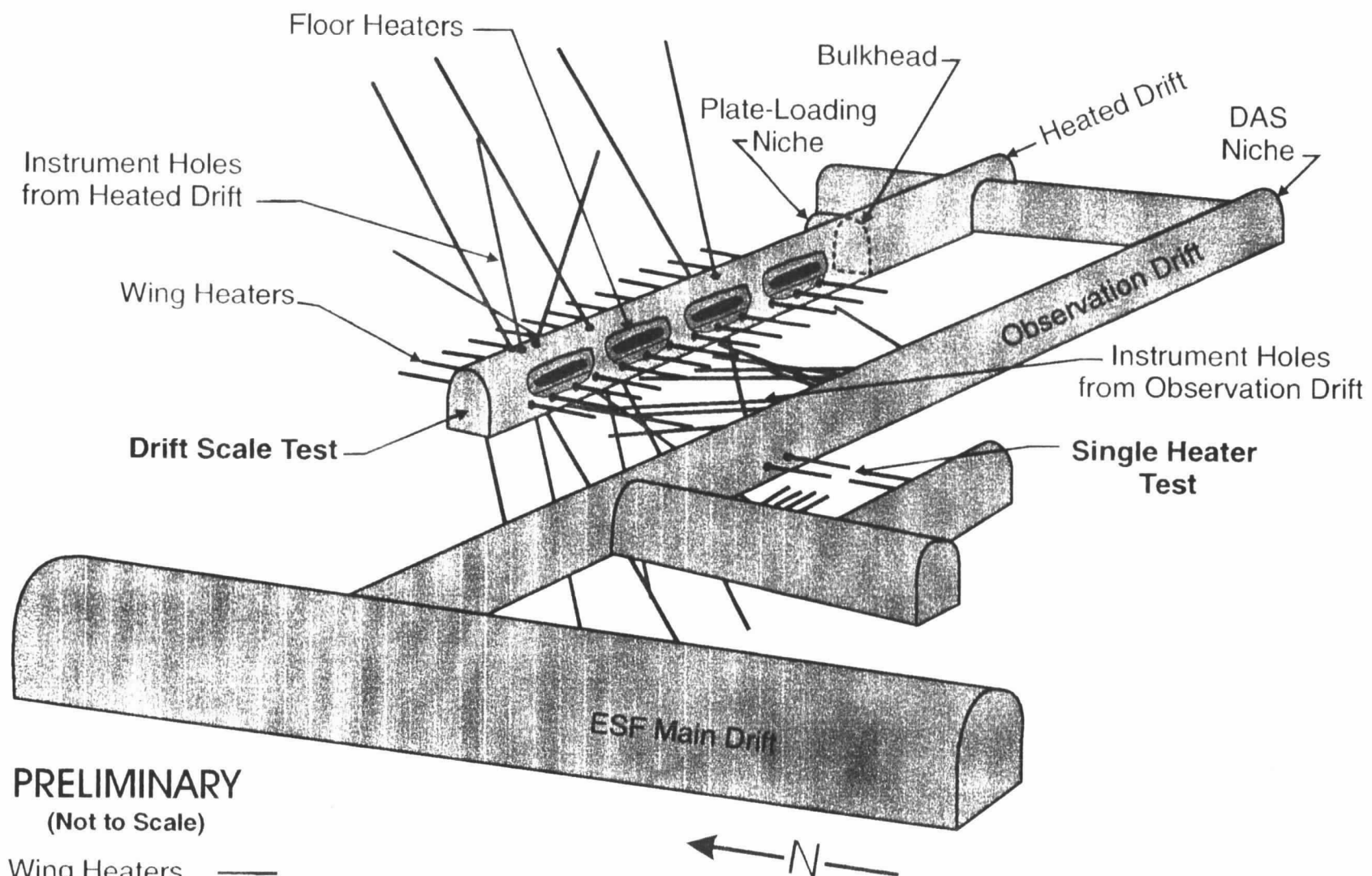
(a) Plan View



(b) Profile View

**REFERENCE ONLY**  
(Not to Scale)

# Schematic of ESF Thermal Test Facility



**PRELIMINARY**  
(Not to Scale)

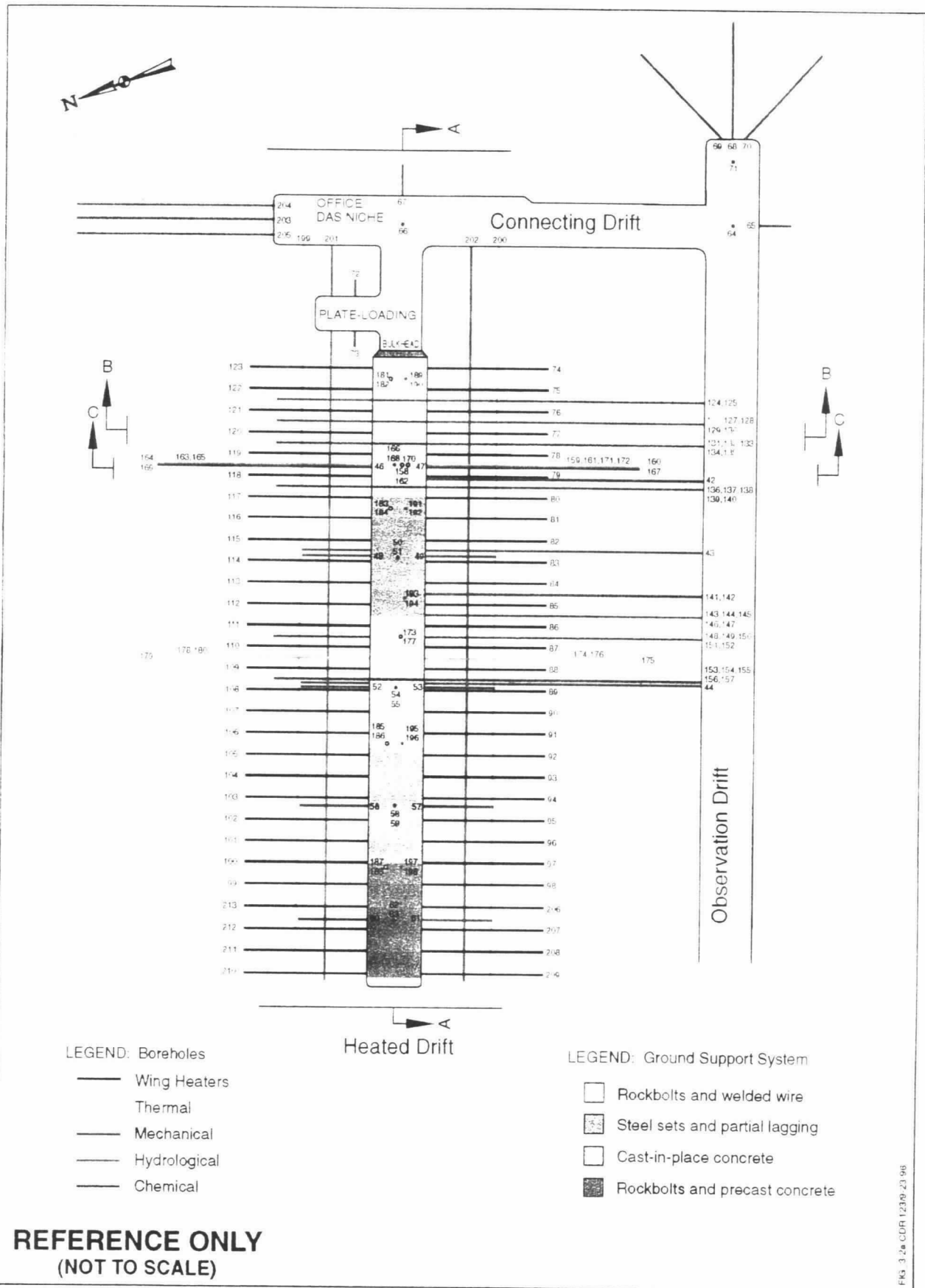
- Wing Heaters ———
- Instrumentation ———
- Boreholes ———

# Why the Drift Scale Test?

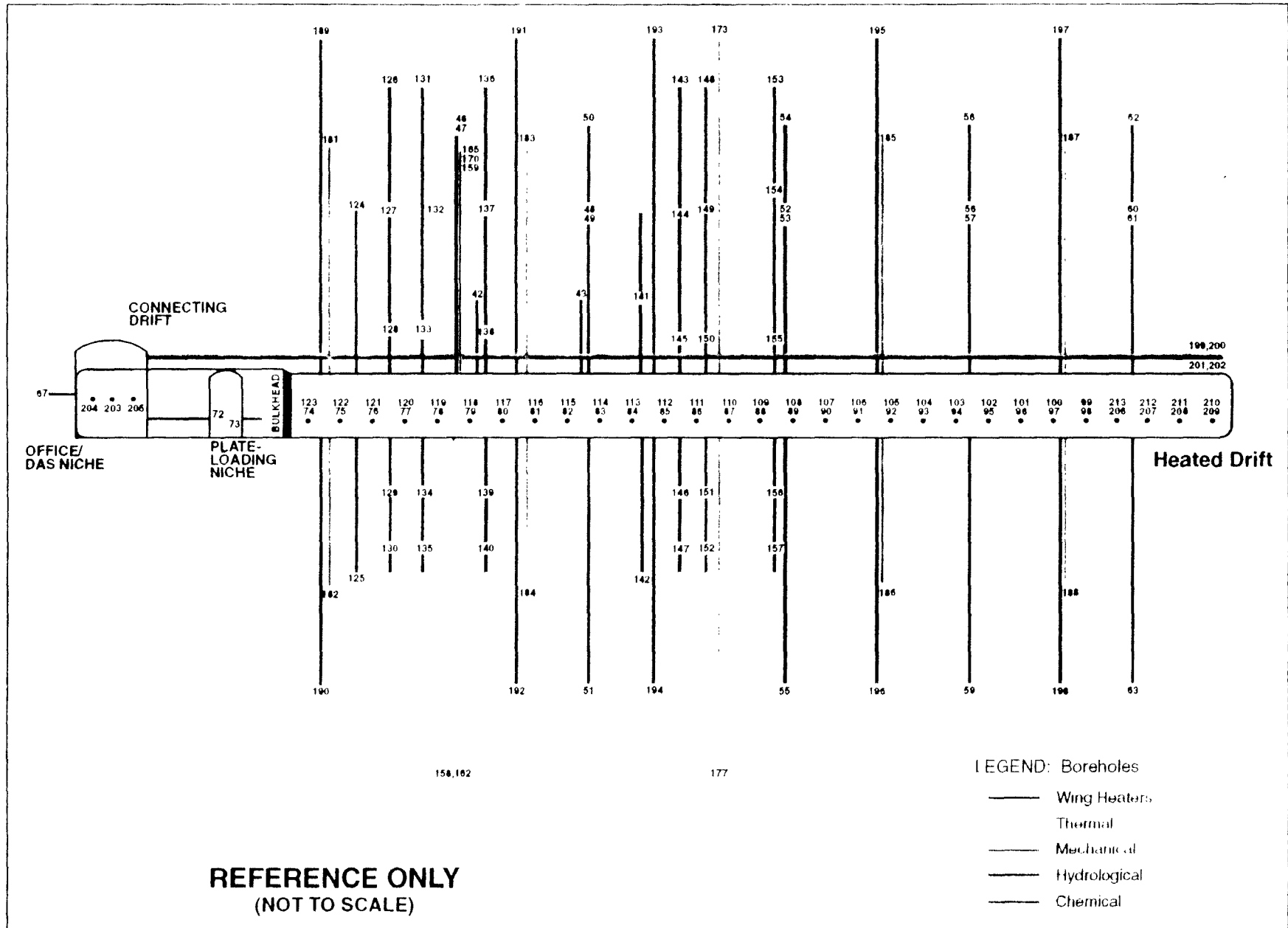
**Predict and measure coupled T-M-H-C processes at an appropriate scale**

- **Temperature distribution and heat transfer modes**
- **Propagation of the drying and re-wetting regions**
- **Changes in water chemistry and mineralogy**
- **Thermal expansion and deformation modulus**

# Layout of Drift Scale Test



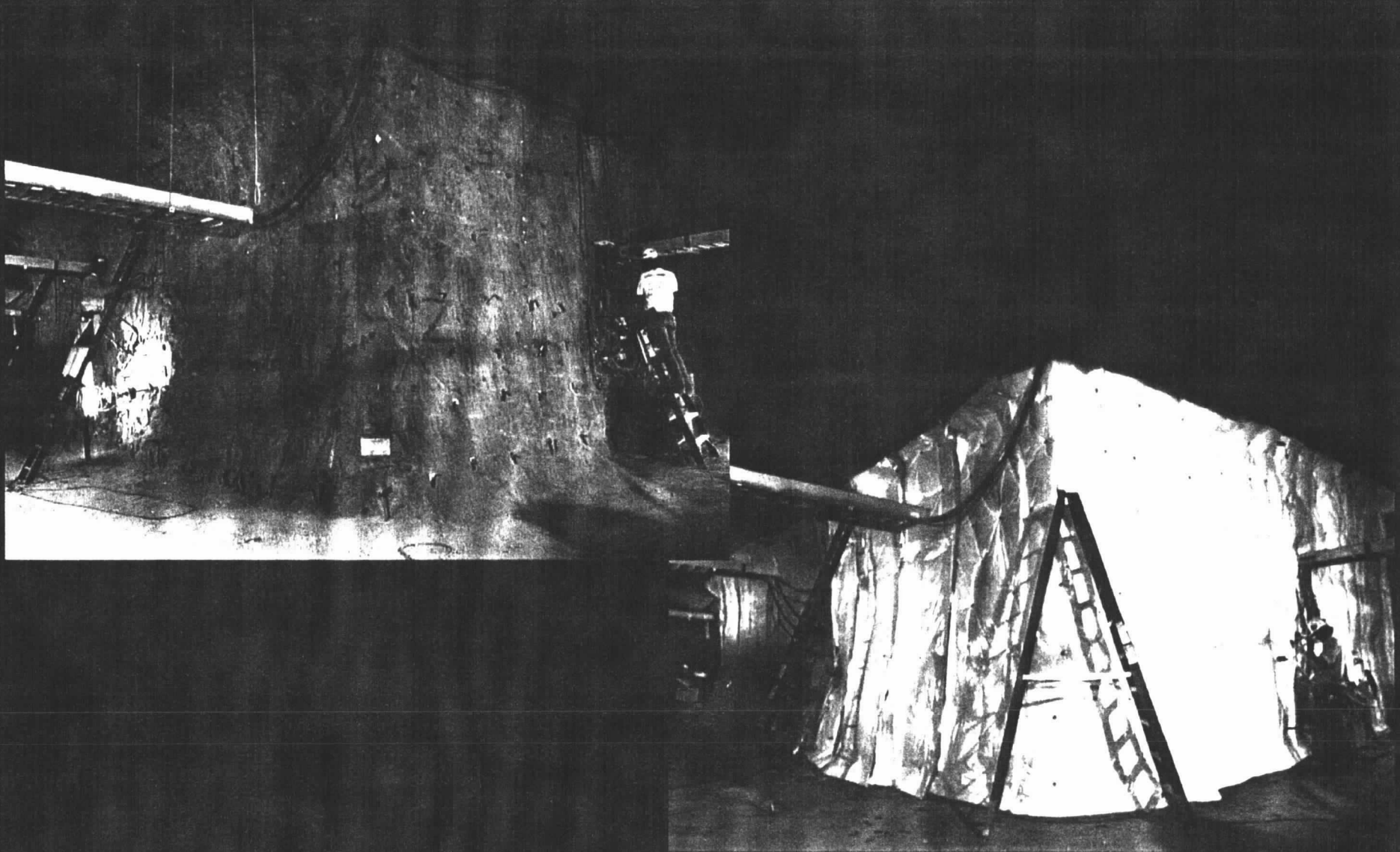
# Cross-Section of Drift Scale Test



# Schedule for the Drift Scale Test

- **Initiate Heating** **December 8, 1997**
- **Terminate Heating (min.)** **December 8, 1999**
- **Terminate Cooling** **December 8, 2001**
- **Submit Final Report** **July 1, 2002**

# Single Heater Test



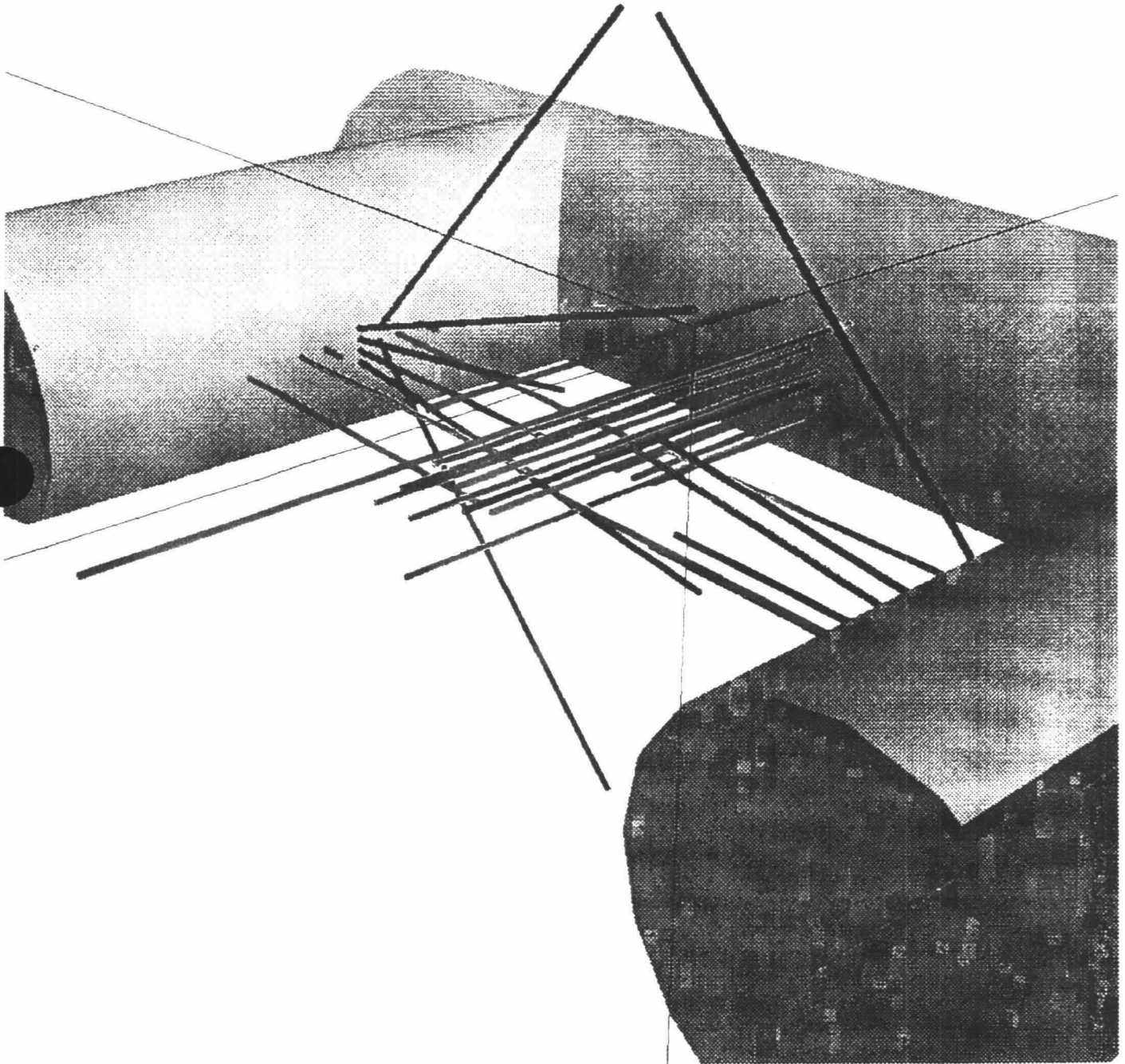
THE THERMOMECHANICAL TEST BLOCK WAS COVERED WITH INSULATION IN LATE AUGUST IN PREPARATION FOR AN AUGUST 26, 1996 HEATER TURN ON.



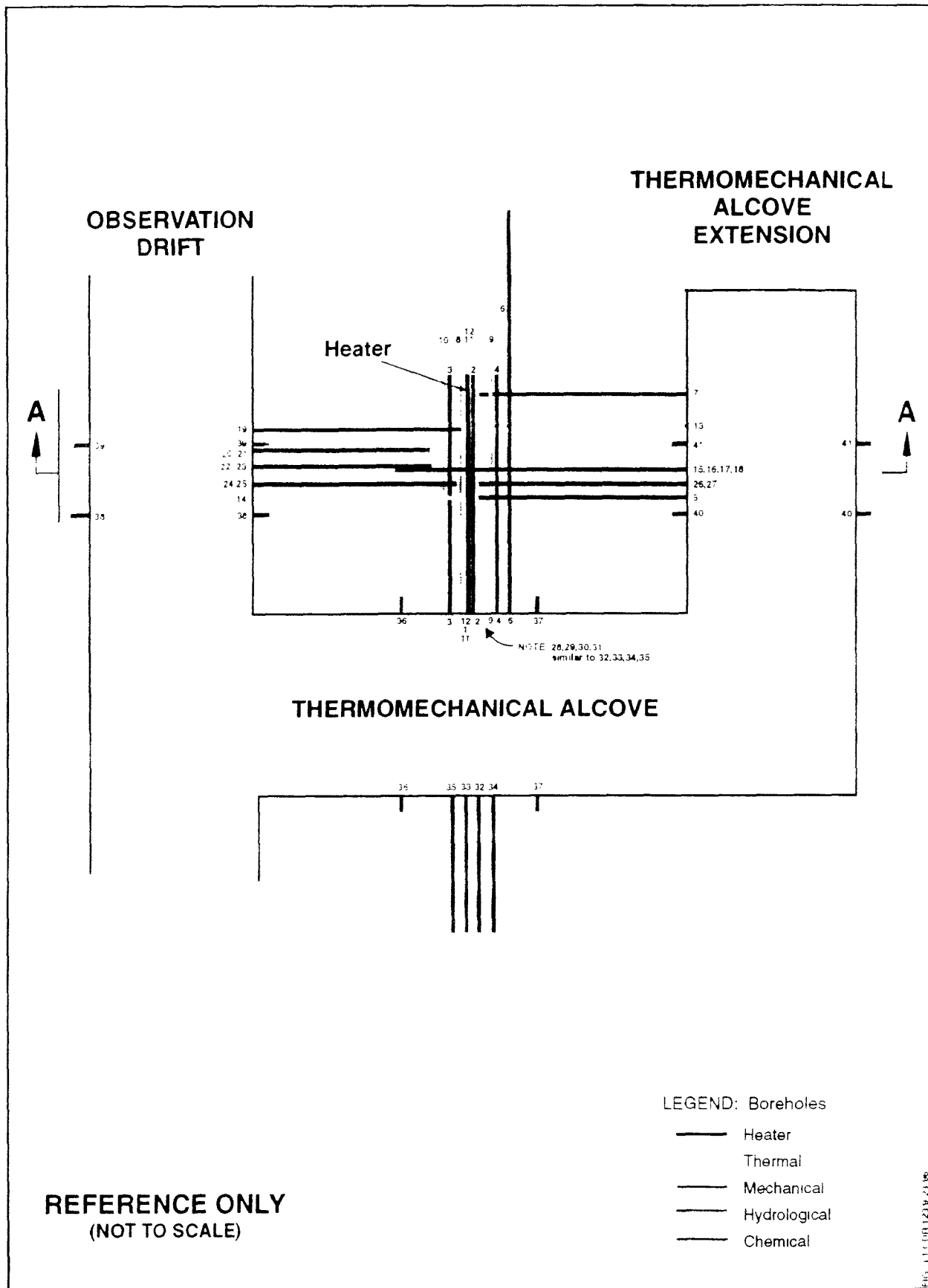
# Why the Single Heater Test?

- **Shakedown**
- **Simpler-Smaller-Shorter**

# Perspective Northeast View Single Heater Test



# Layout of Single Heater Test



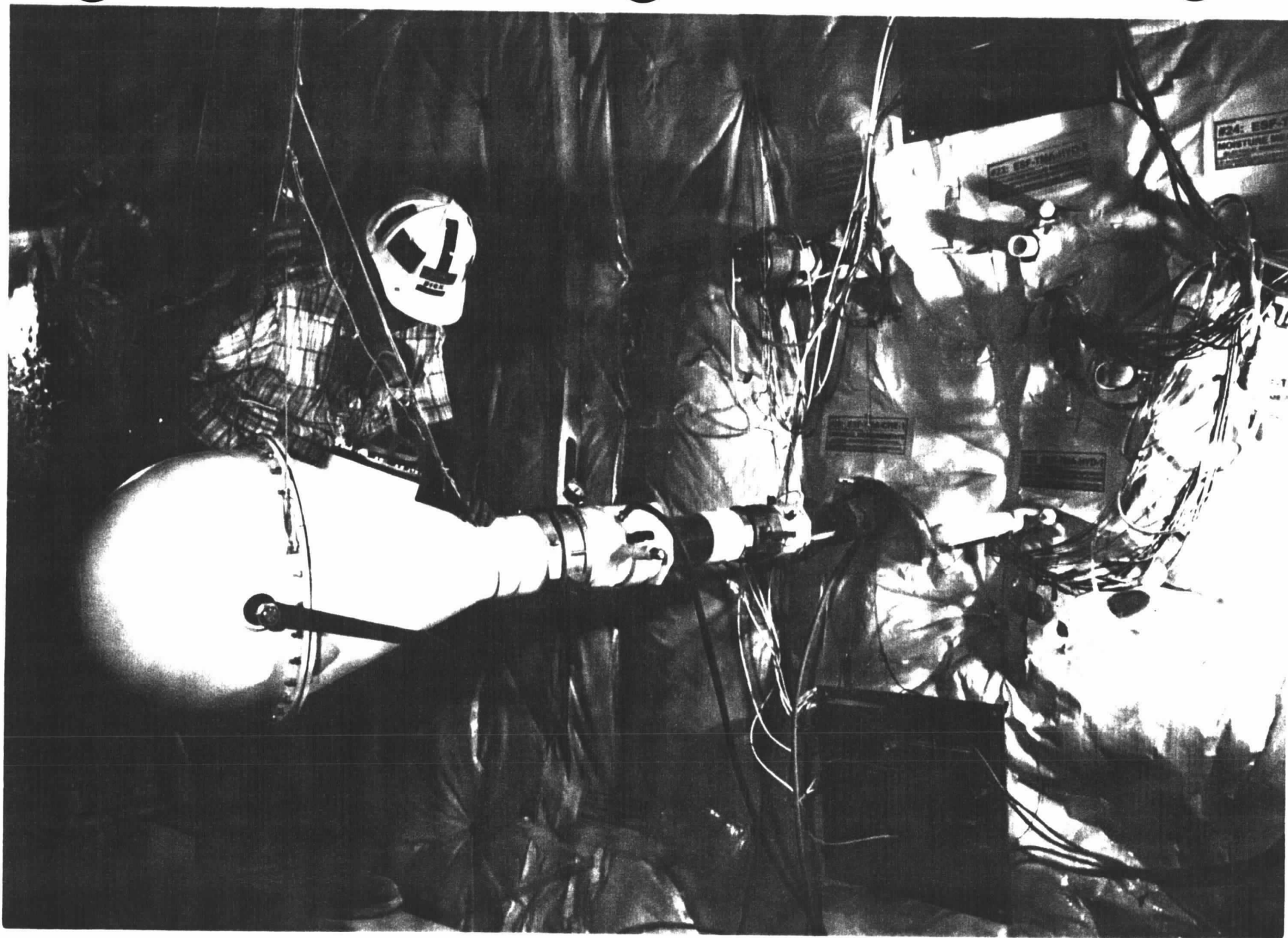
REFERENCE ONLY  
(NOT TO SCALE)

- LEGEND: Boreholes
- Heater
  - Thermal
  - Mechanical
  - Hydrological
  - Chemical



# Schedule for the Single Heater Test

- **Initiate Heating (on time)**                      **August 26, 1996**
- **Terminate Heating (min.)**                      **May 26, 1997**
- **Terminate Cooling**                              **February 26, 1998**
- **Submit Final Report**                              **June 30, 1998**





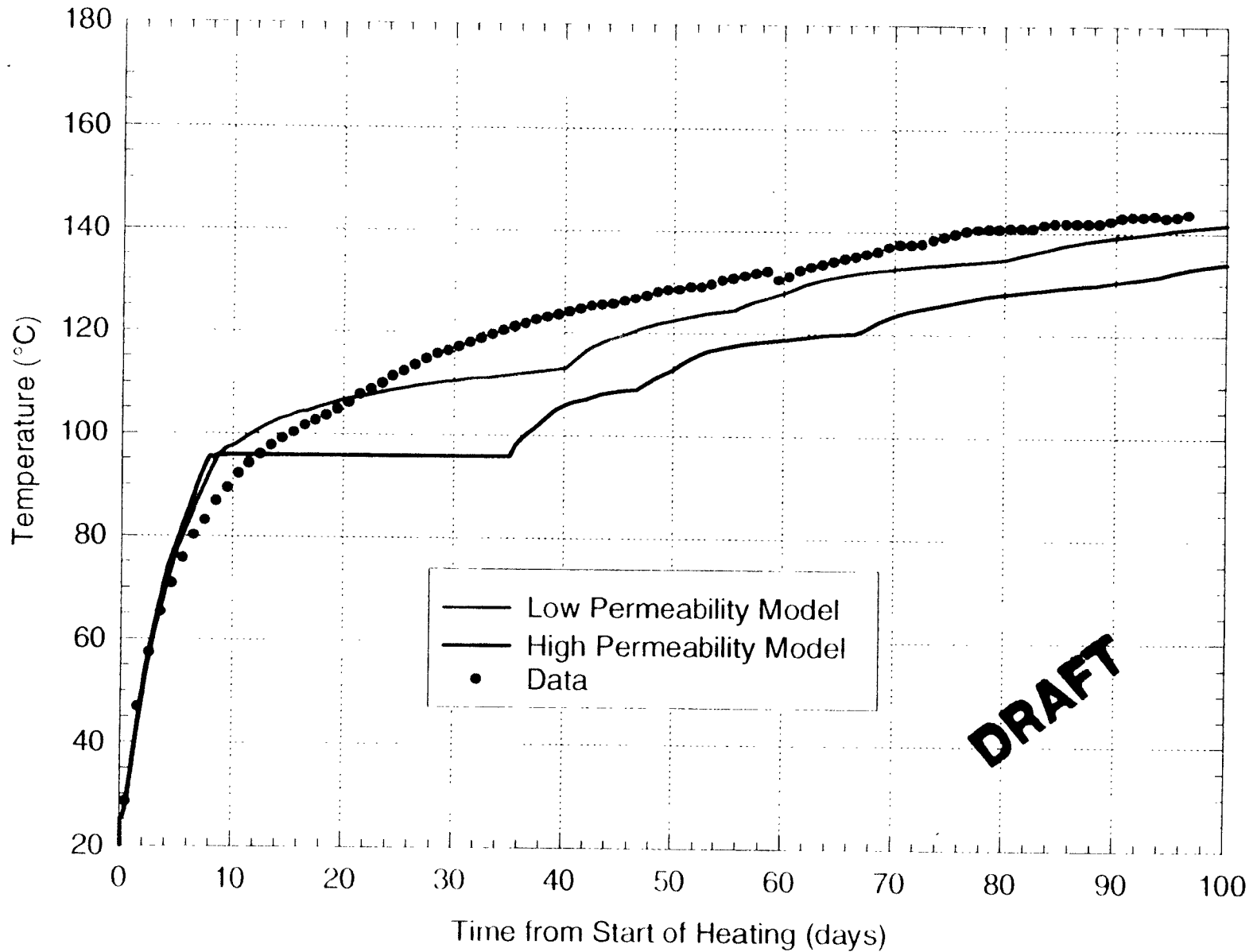


# **Results to Date Single Heater Test**

- **Test Proceeding as Planned**

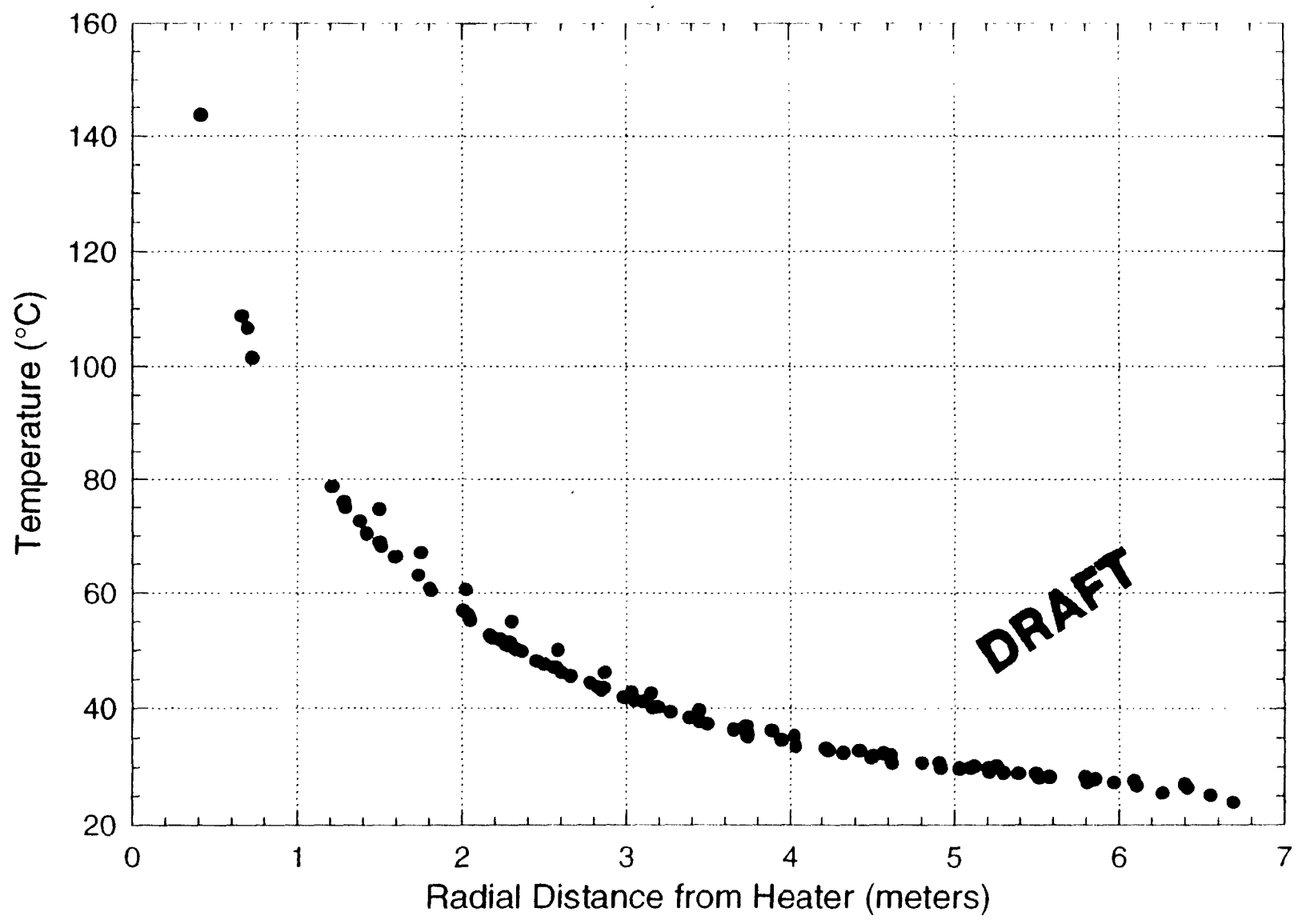


# TMA-TC-1A-7 Single Heater Test



**DRAFT**

# Temperature Measurements Near the Heater Mid-length Single Heater Test



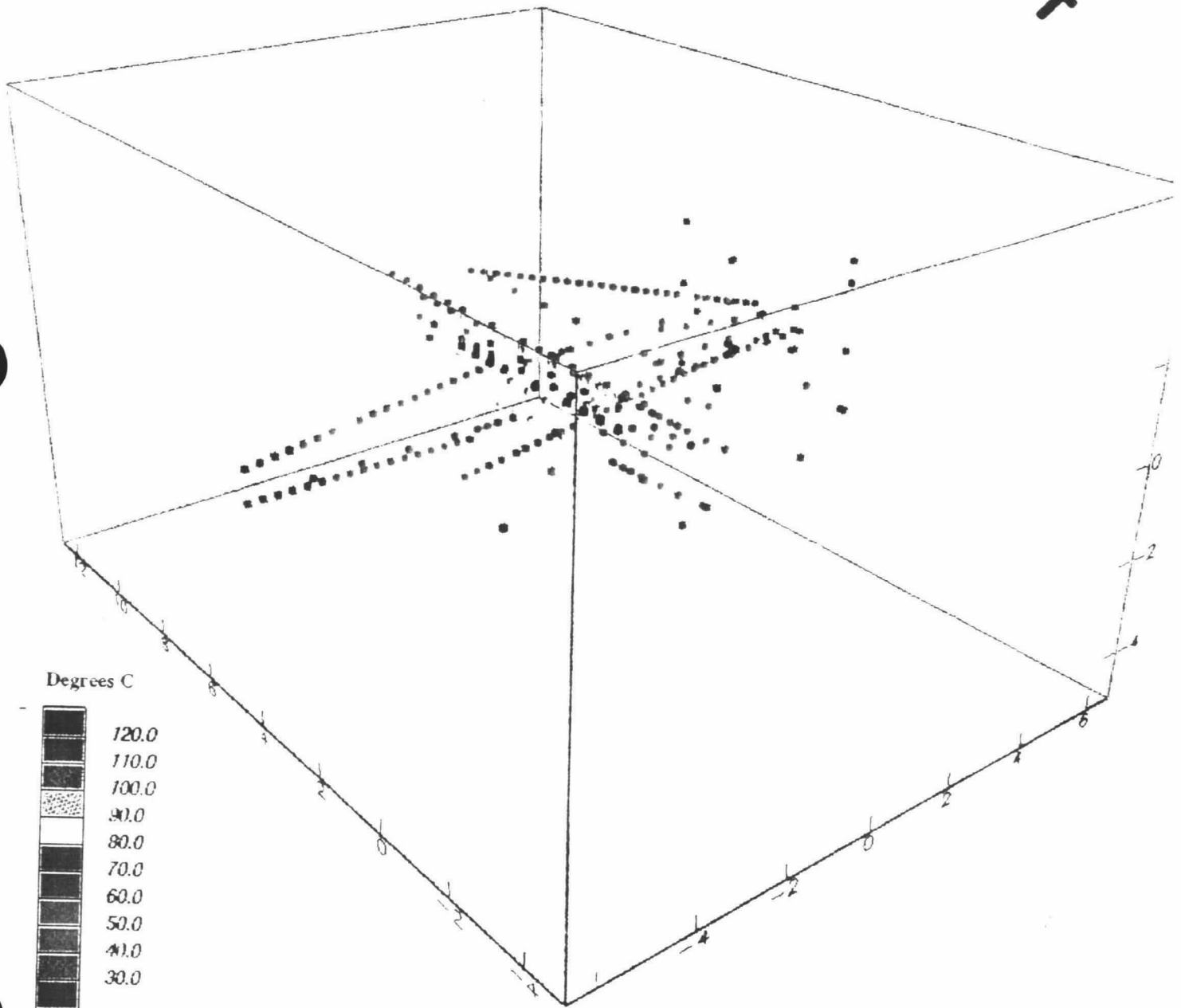
# Single Heater Test: Measurements

Perspective View

Input Sensor Locations

November 30, 1996 (Day 96)

**DRAFT**



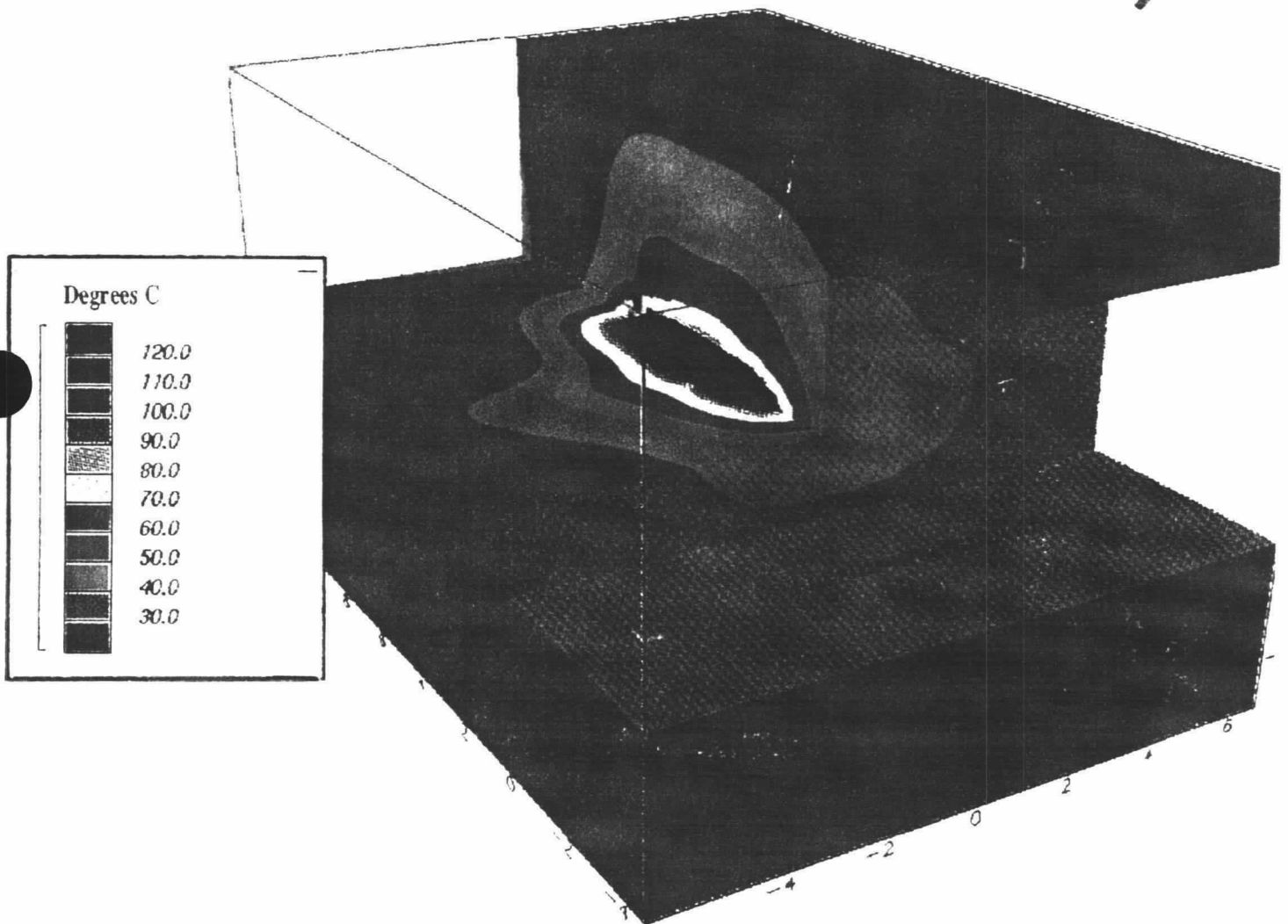
# Single Heater Test: Measurements

Perspective Isotherms

Cutaway Along Heater

November 30, 1996 (Day 96)

**DRAFT**



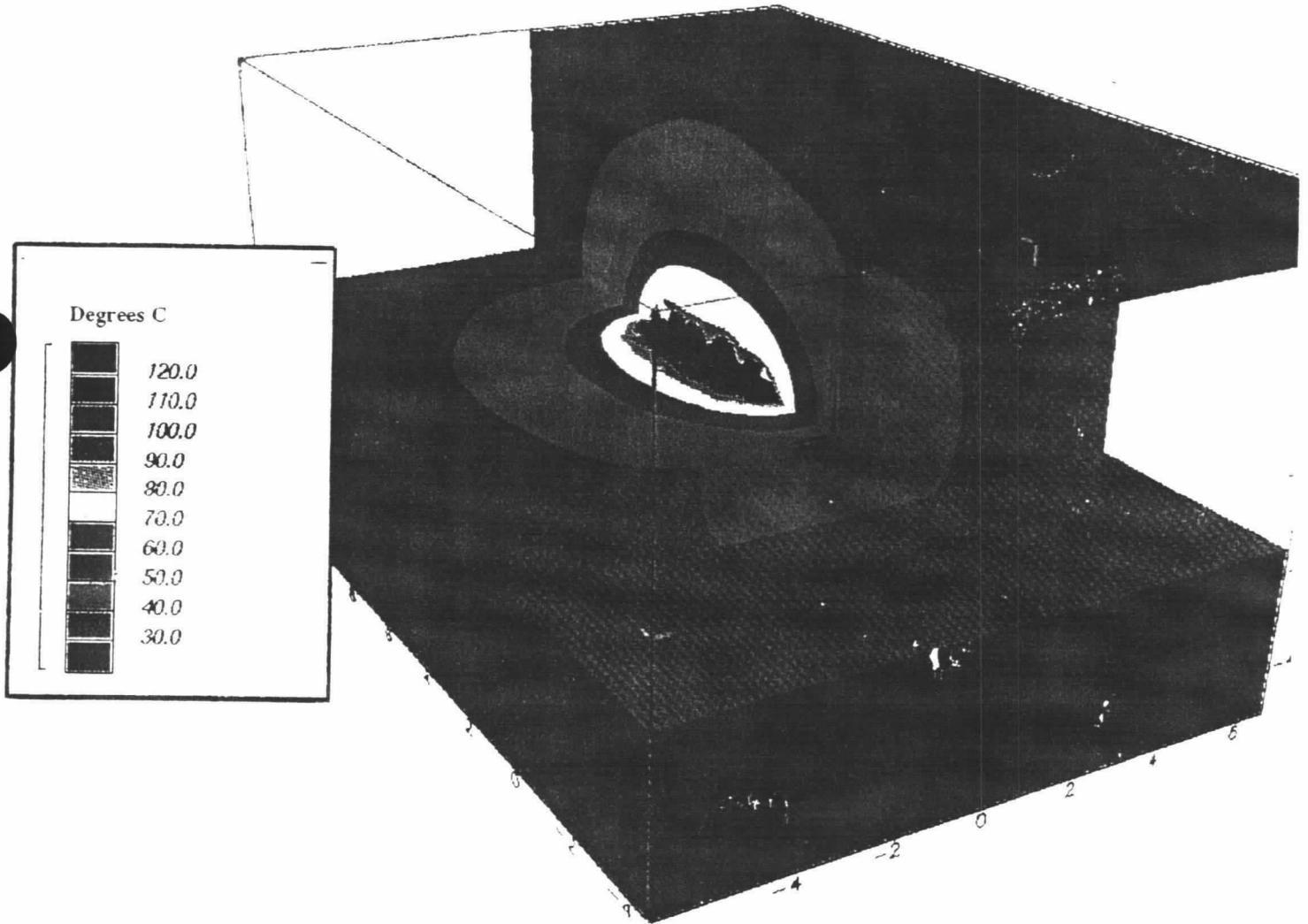
# Single Heater Test: Predictions

Perspective Isotherms

Cutaway Along Heater

November 30, 1996 (Day 96)

**DRAFT**



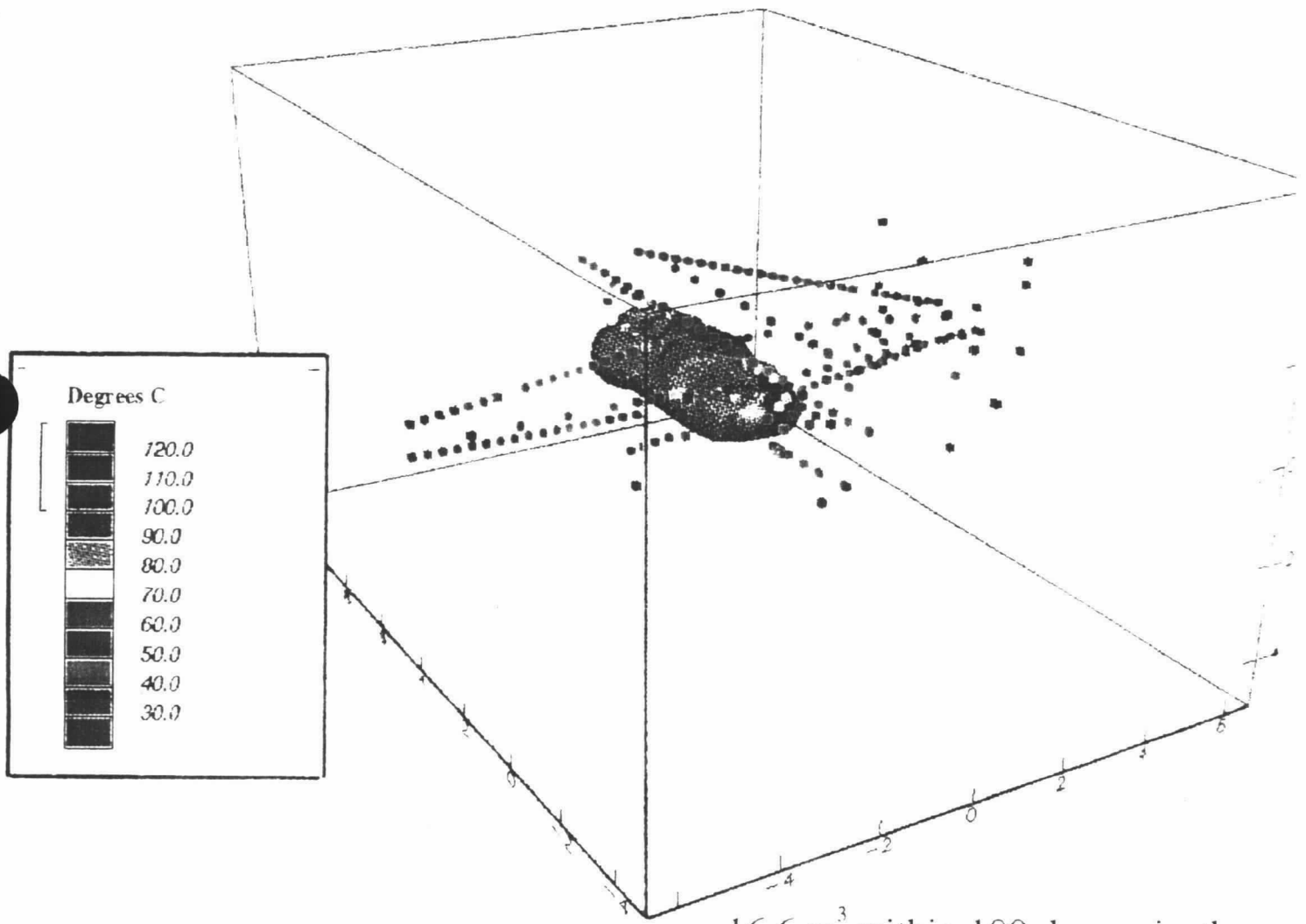
# Single Heater Test: Measurements

Perspective Isotherms

100 Degree C Isotherm and Data Points

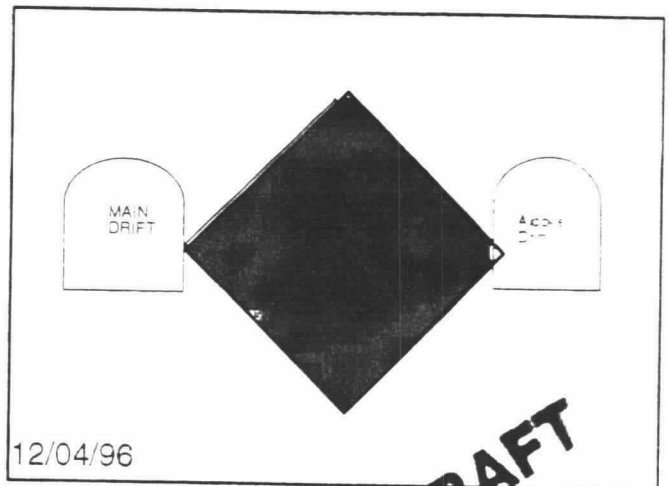
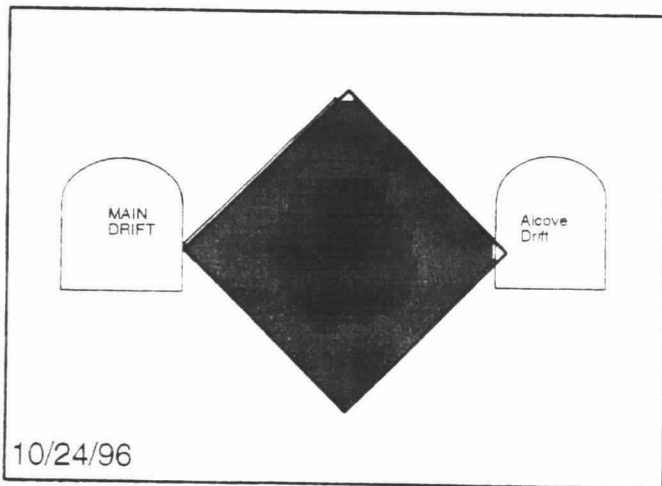
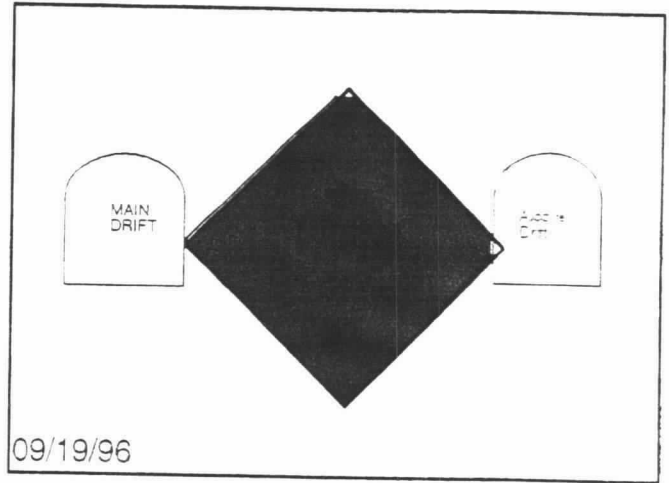
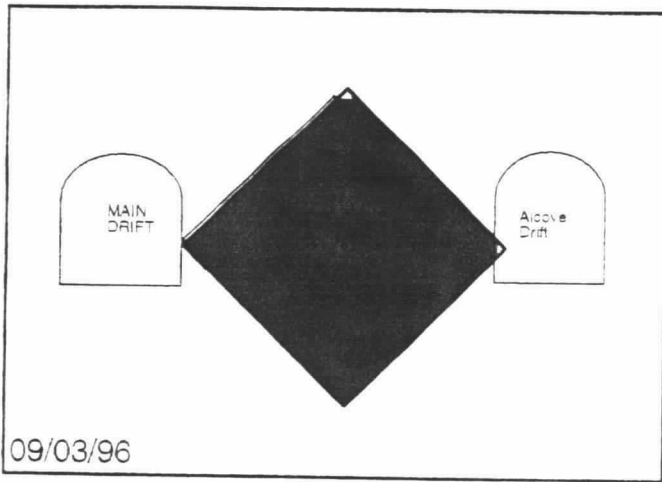
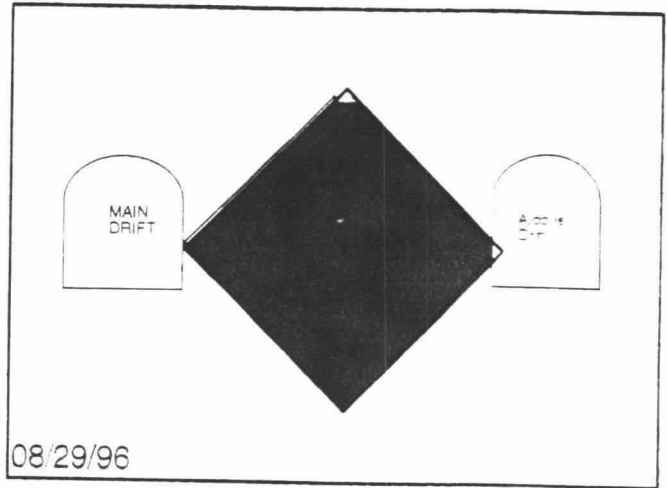
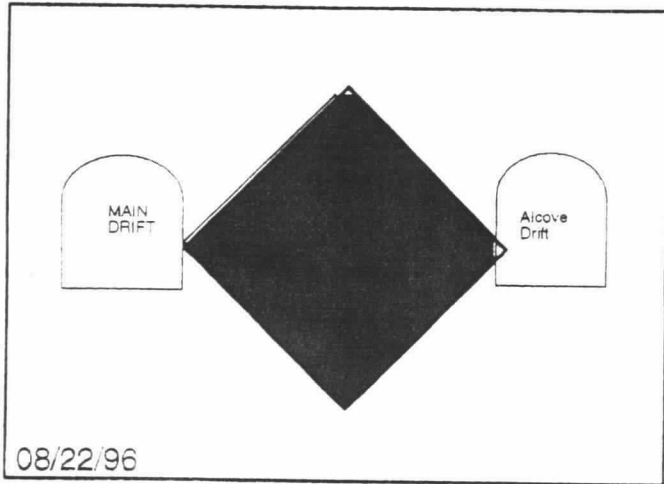
November 30, 1996 (Day 96)

**DRAFT**

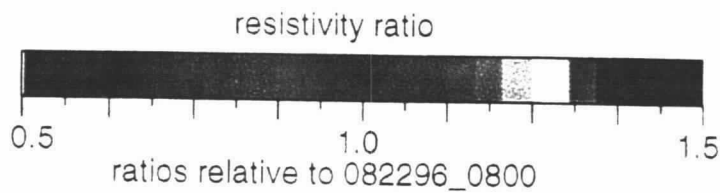


16.6 m<sup>3</sup> within 100 degree isotherm

# Chronology of Measured Resistivity Ratios Single Heater Test

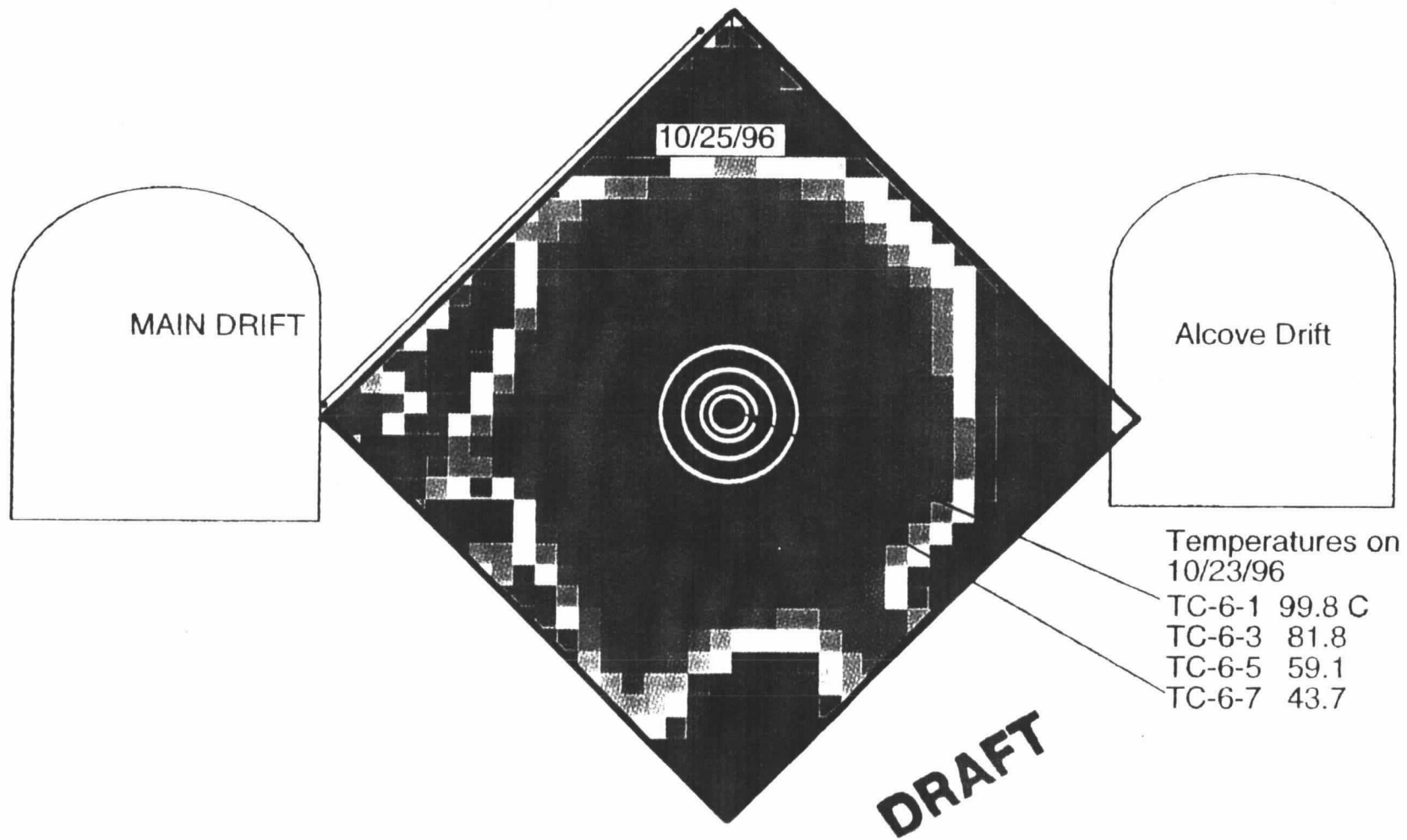


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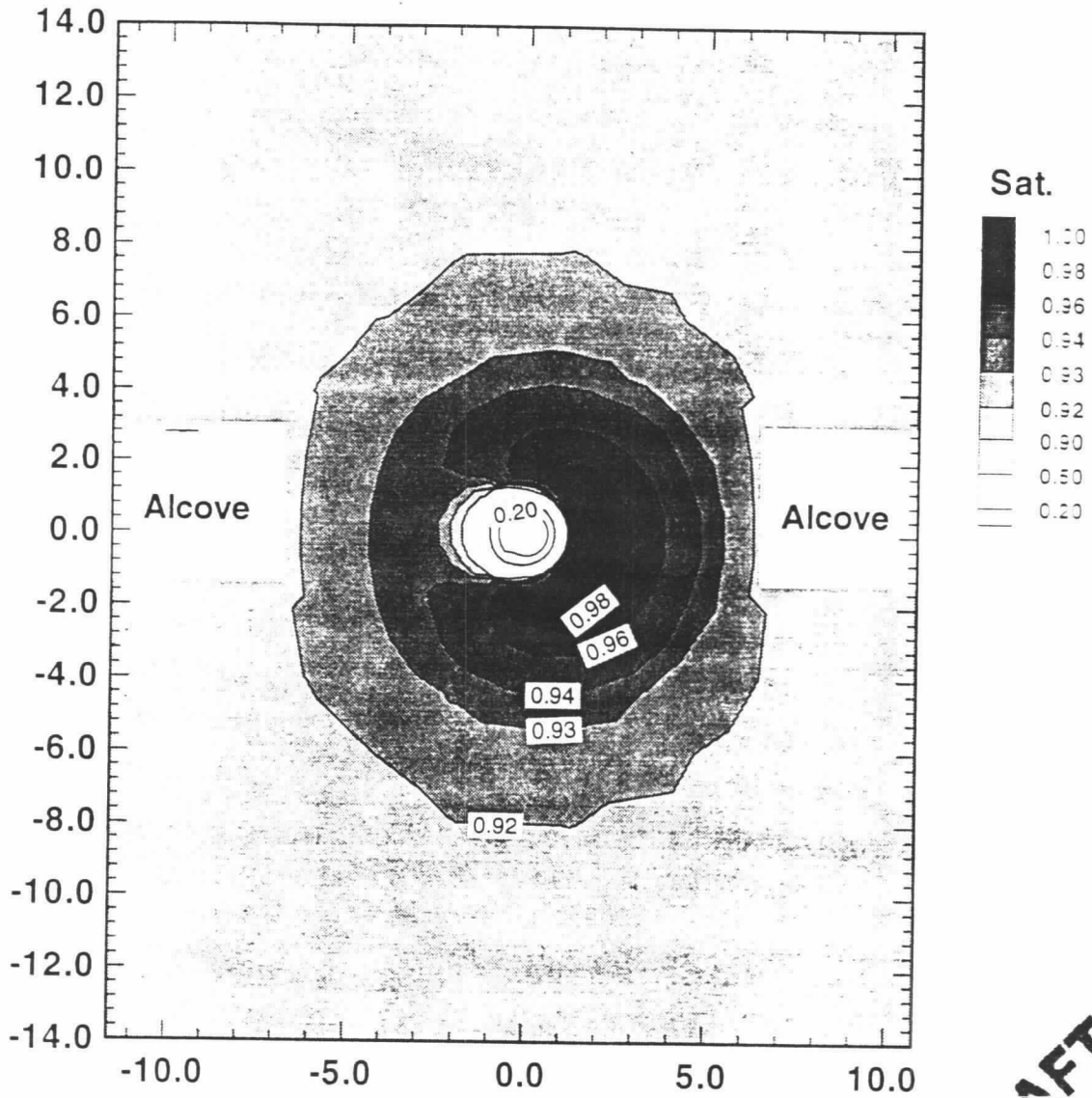
# Measurements of Resistivity Ratios Single Heater Test

Vertical Slice Along ERT Boreholes  
October 25, 1996 (Day 60)



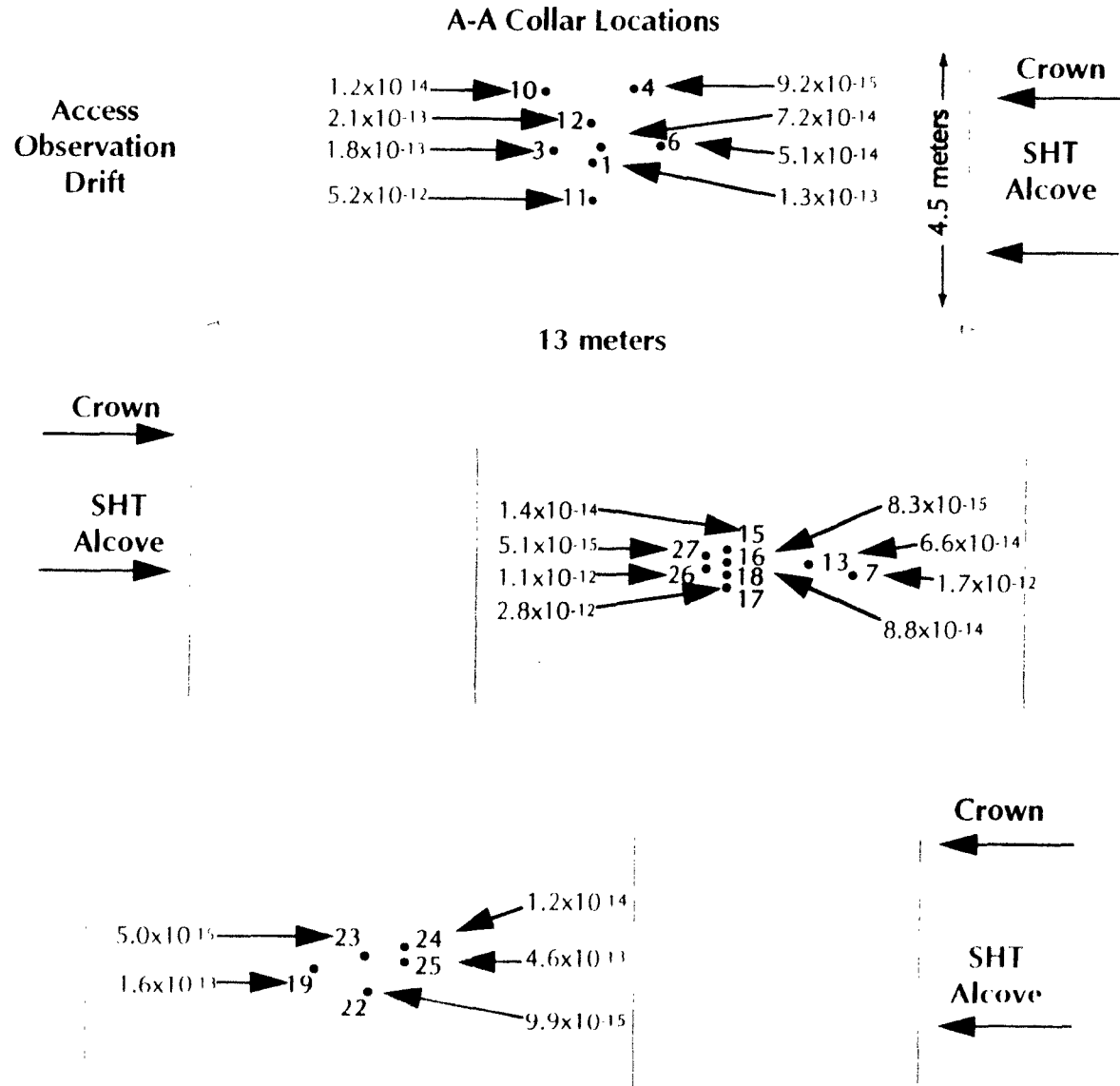


# Predicted Liquid Saturation at Year 1 (Base Case) Single Heater Test

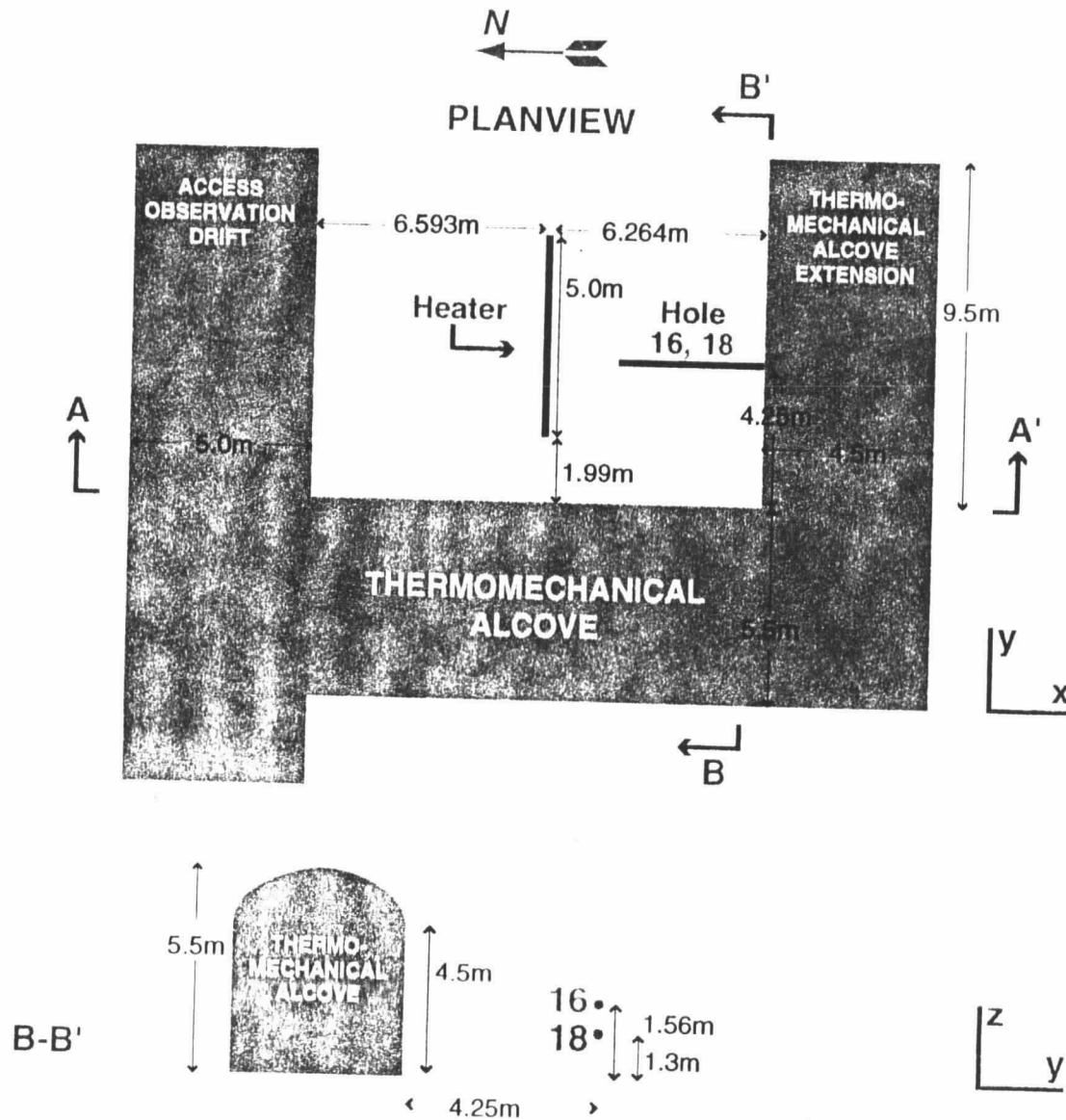


**DRAFT**

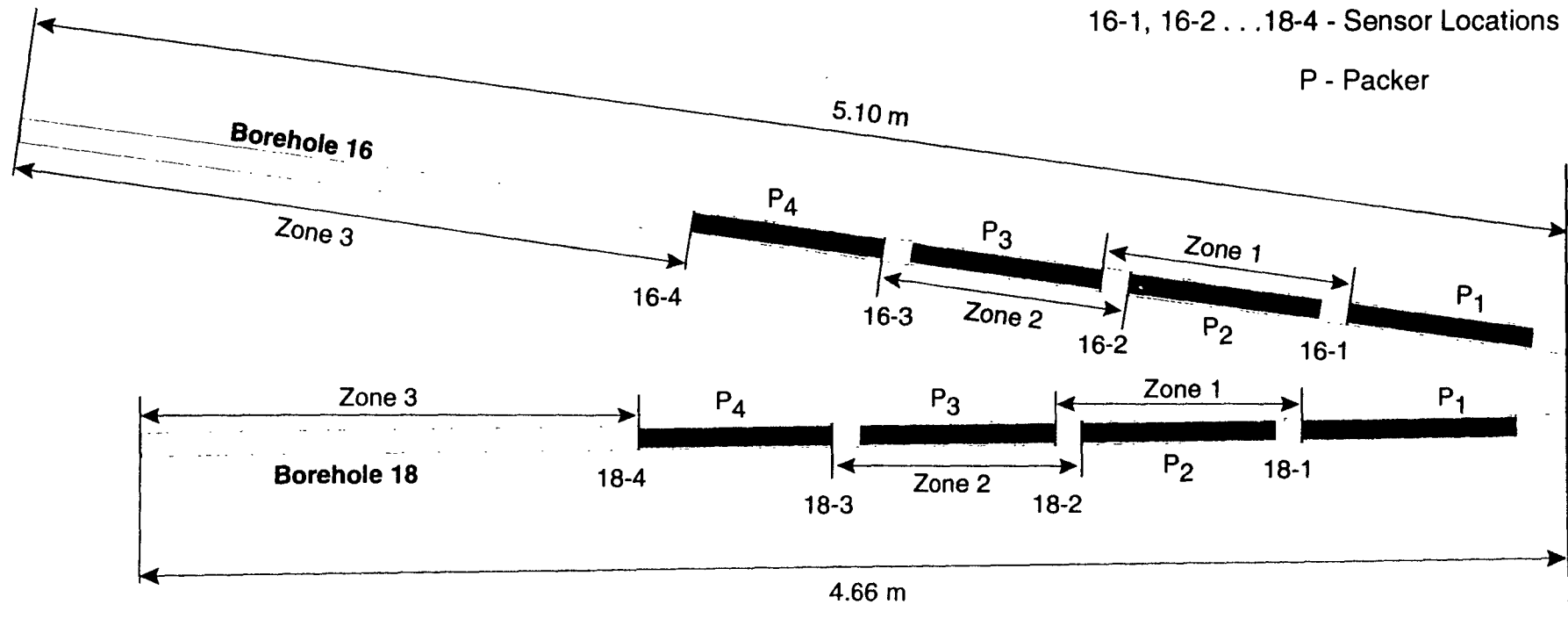
# Permeability Values From Test Conducted in May 1996 Single Heater Test



# Configuration of the Single Heater Test



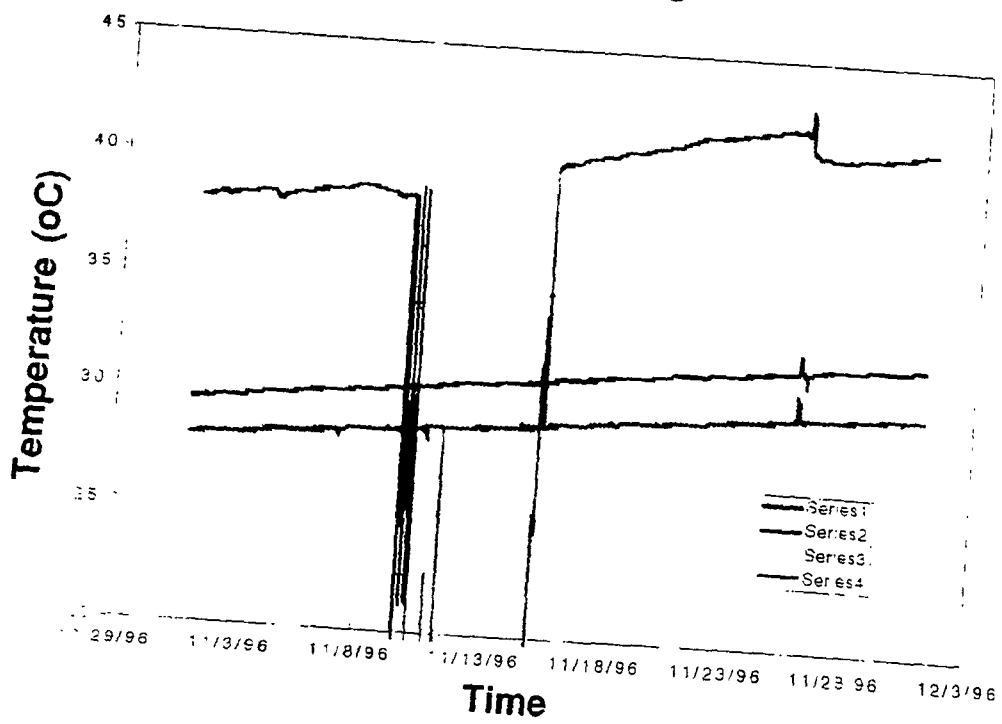
# Geometry of the Air Injection Test in Boreholes 16 and 18



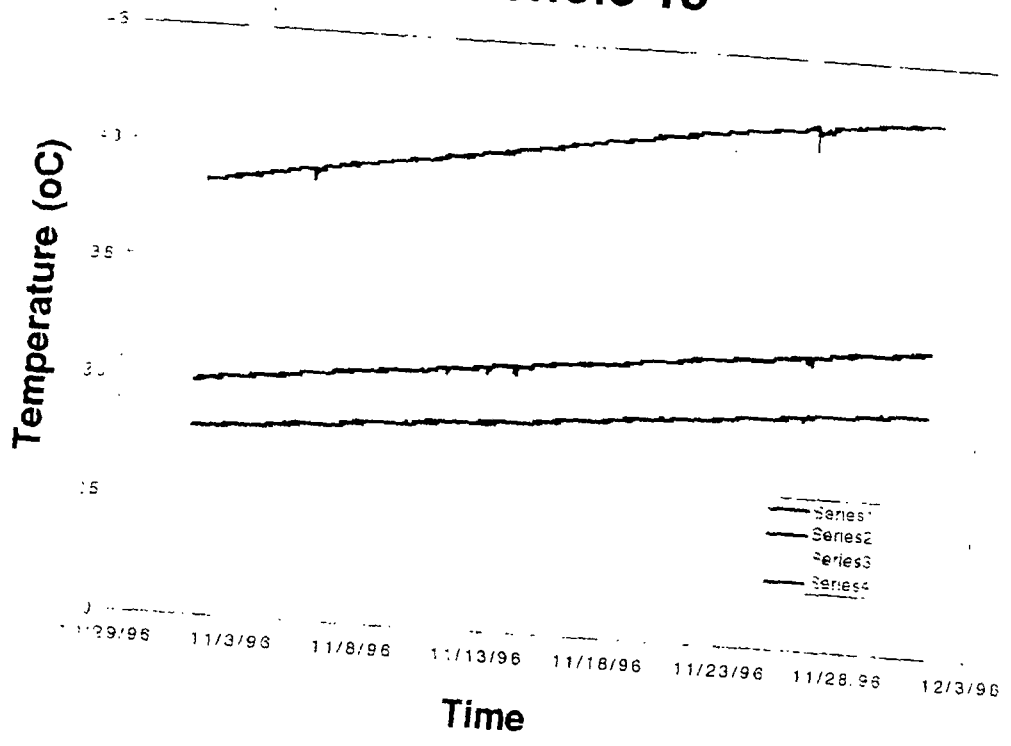
# Borehole 16 Observations

- **5.5 liters of water collected in zone 4 on November 25, 1996**
- **Zone 4 (before test)**
  - **Relatively low air permeability**
  - **Fracture at low angle lined with white mineral(s)**
- **Zone 4 (during test)**
  - **Temperature and relative humidity dropped significantly before water collection**
  - **Air permeability was lower after water collection**

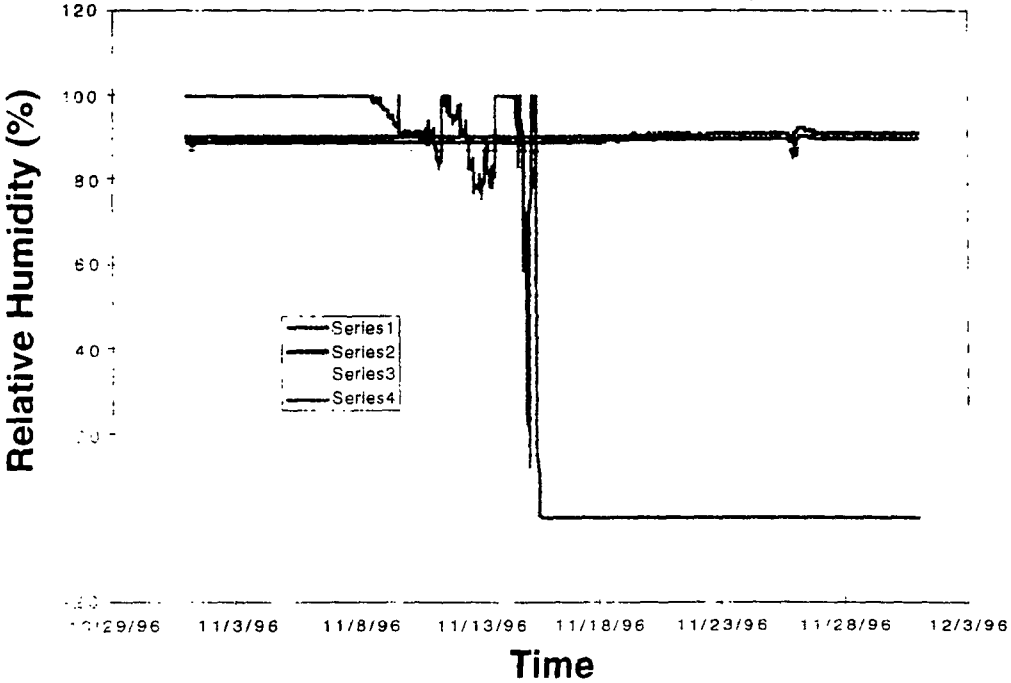
# Borehole 16



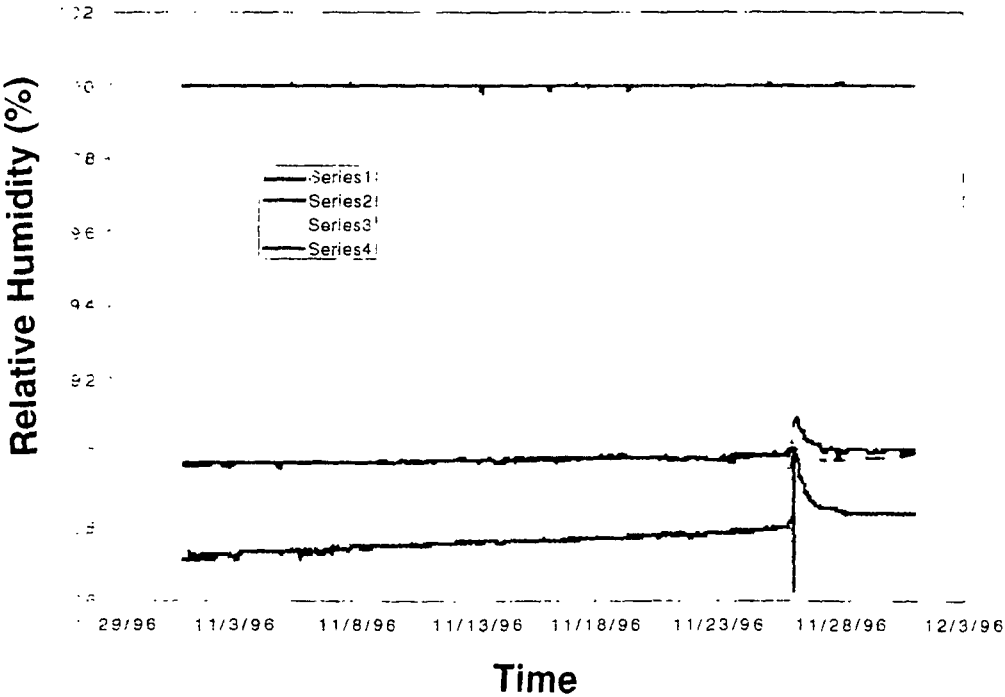
# Borehole 18



# Borehole 16



# Borehole 18



# **Borehole 16 Observations**

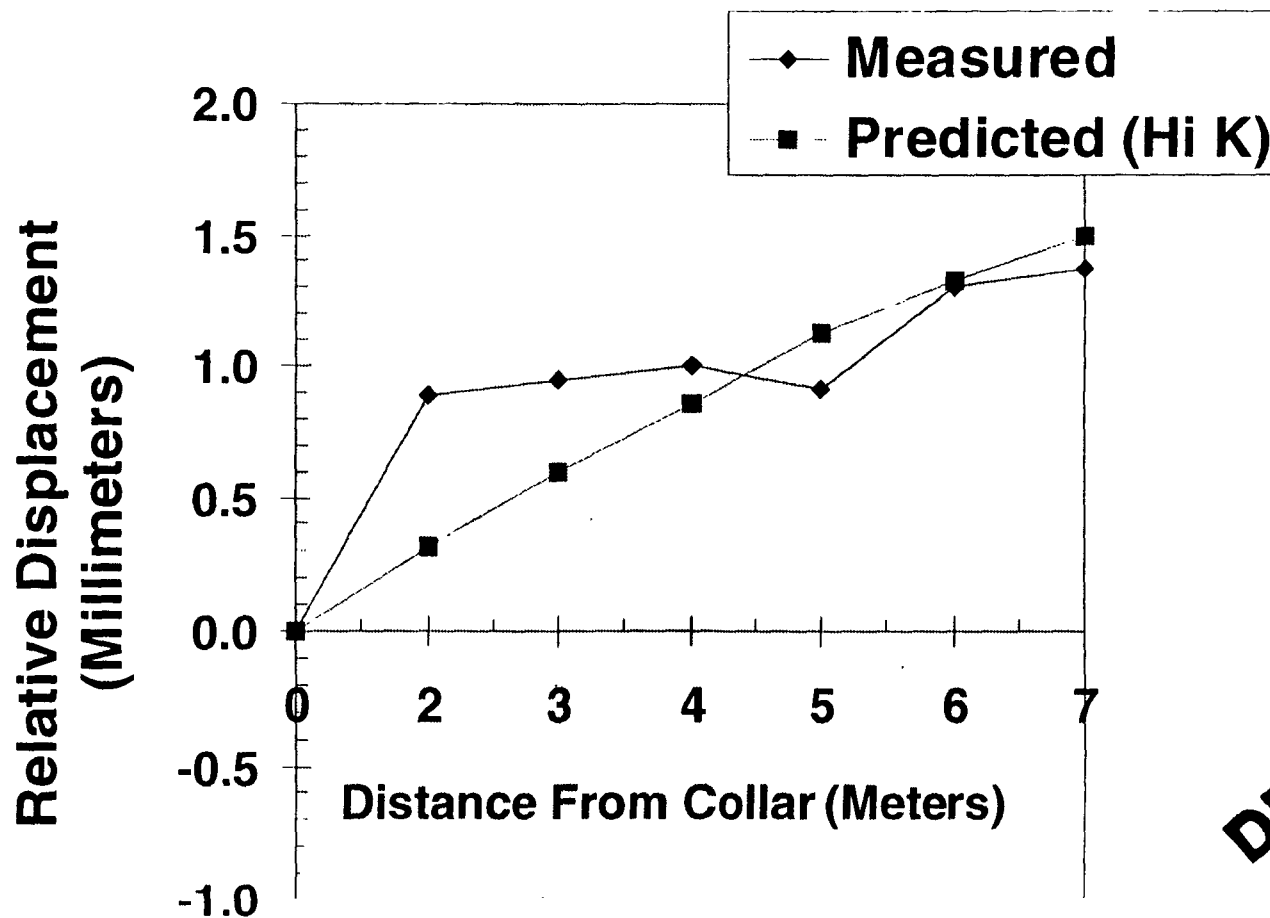
(Continued)

- **Comprehensive suite of chemical and isotopic analyses are ongoing**
  - **Preliminary data suggests water is not drilling fluid**
  - **Preliminary data suggests water is condensate exposed to fracture minerals**
  - **Confirms anticipated water mobilization**



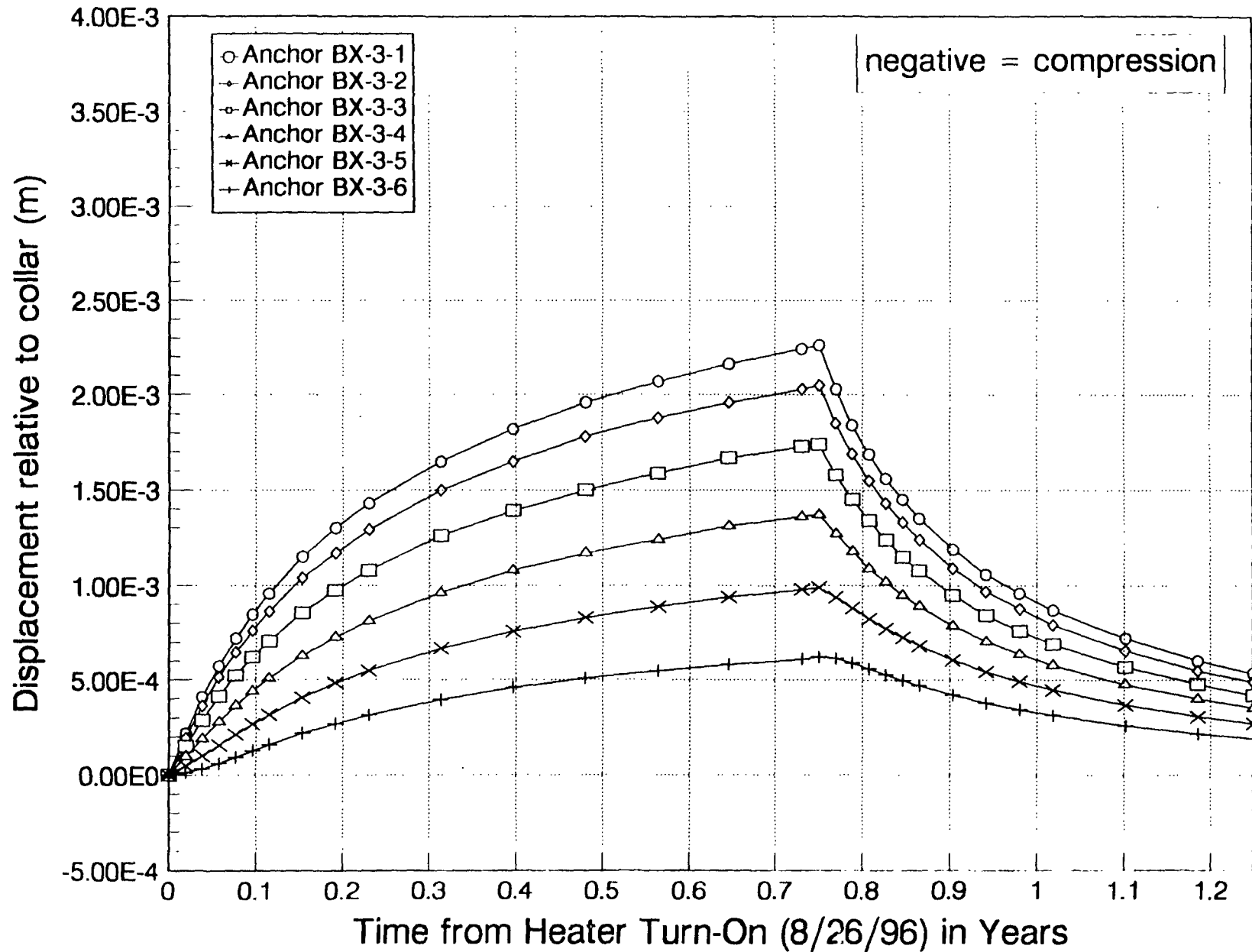
# Single Heater Test: Displacement Comparison

for MPBX-3 on November 30, 1996 (Day 96)

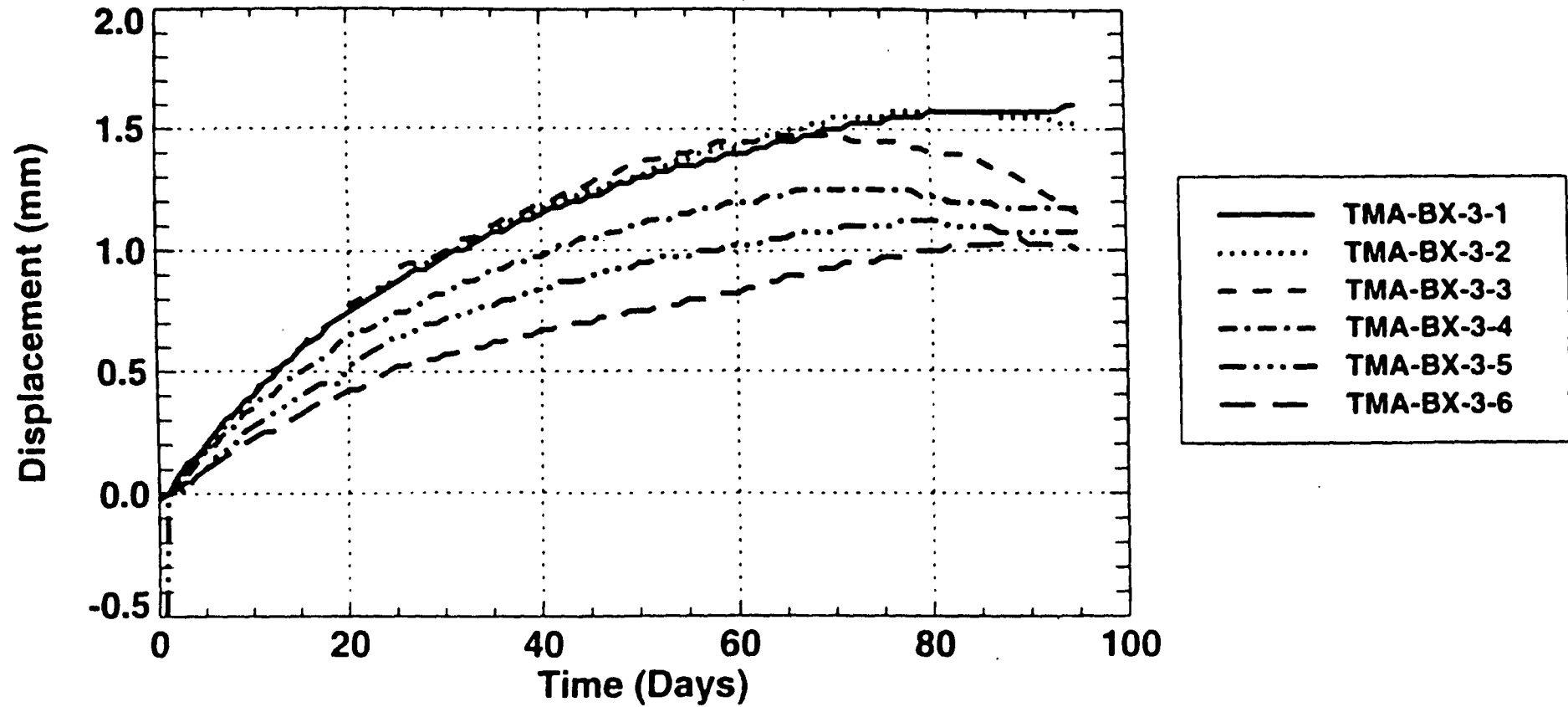


**DRAFT**

# Predicted Displacement for MPBX-3 Single Heater Test



# Measured Displacements for MPBX-3 Single Heater Test



# **Chemistry: Single Heater Test**

- **Chemical sensors are faulty**
- **“SEAMIST” sampling pads and water samples are primary sources**