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

# PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

## SUBJECT: INFLUENCE OF THERMALLY-INDUCED EFFECTS ON REPOSITORY DESIGN


**PRESENTER:** DR. THOMAS E. BLEJWAS

**PRESENTER'S TITLE AND ORGANIZATION:** SUPERVISOR,
PERFORMANCE ASSESSMENT DEVELOPMENT DIVISION
SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

**PRESENTER'S TELEPHONE NUMBER:** (505) 846-0541


MARCH 19-20, 1990

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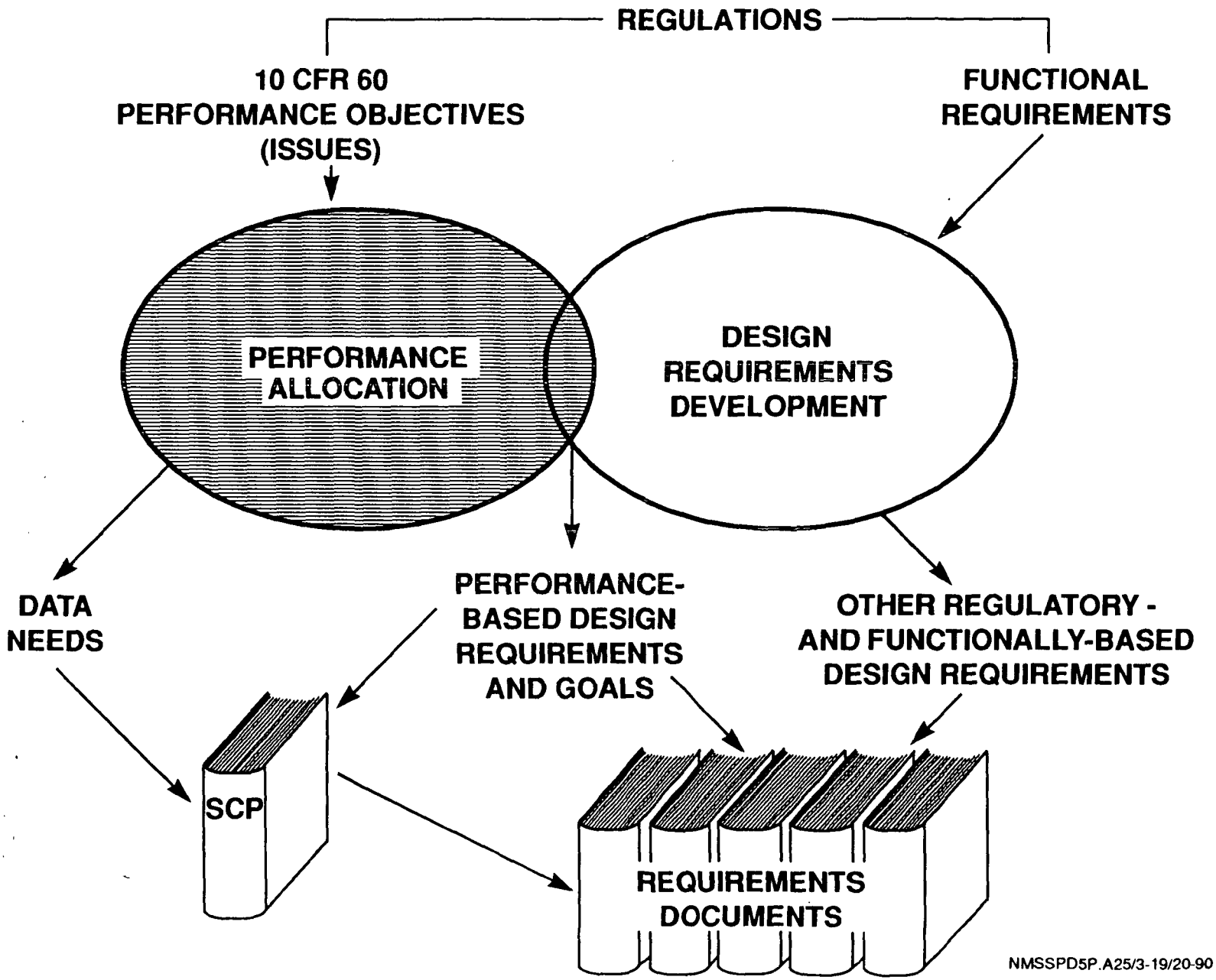
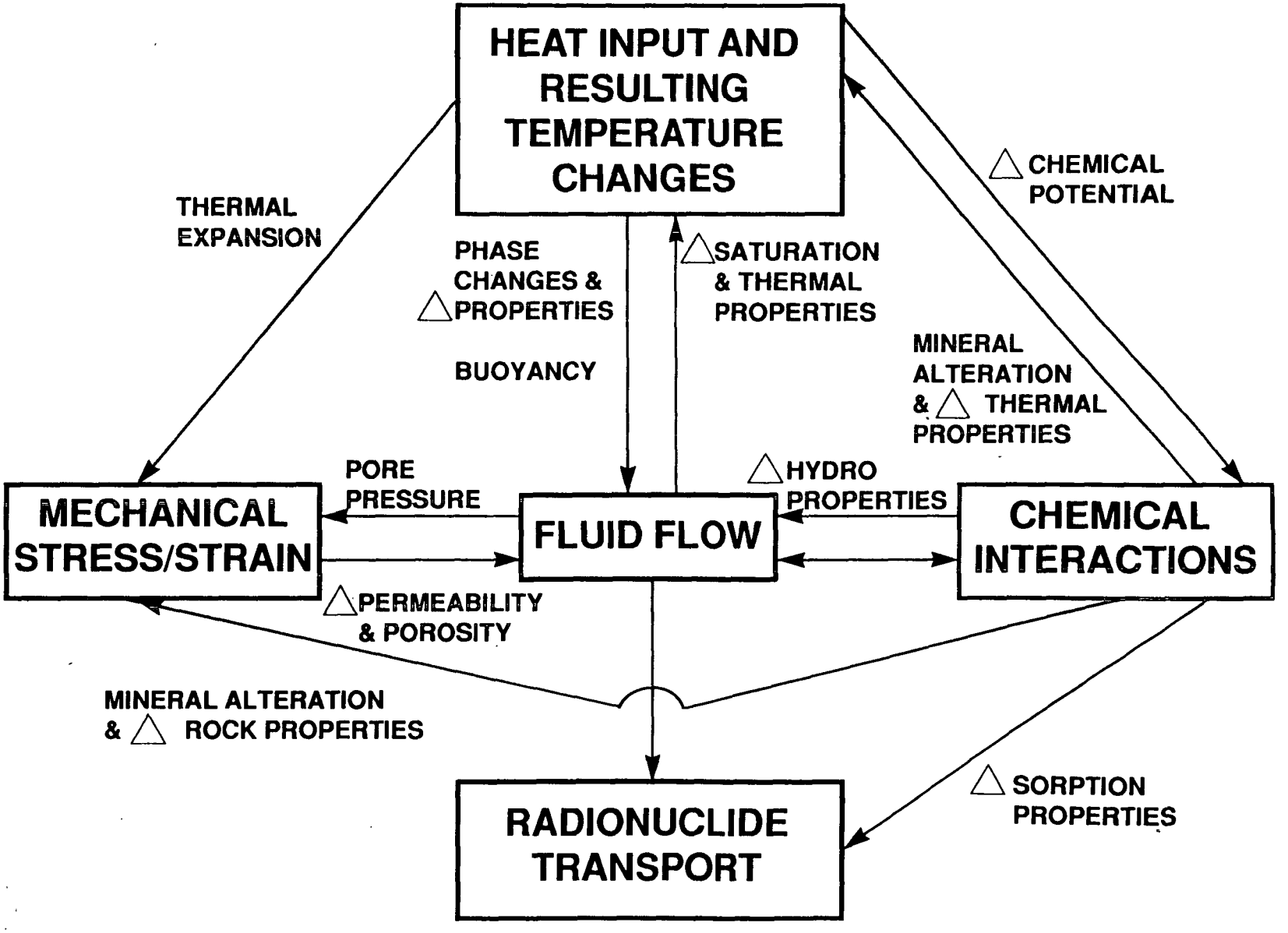
# THERMAL INFLUENCES ON THE REPOSITORY

- ROCK TEMPERATURE CHANGES AND THERMAL STRESSES
- HYDROLOGIC CHANGES
- GEOCHEMICAL CHANGES
- DESIGN GOALS

# DERIVATION OF DESIGN REQUIREMENTS



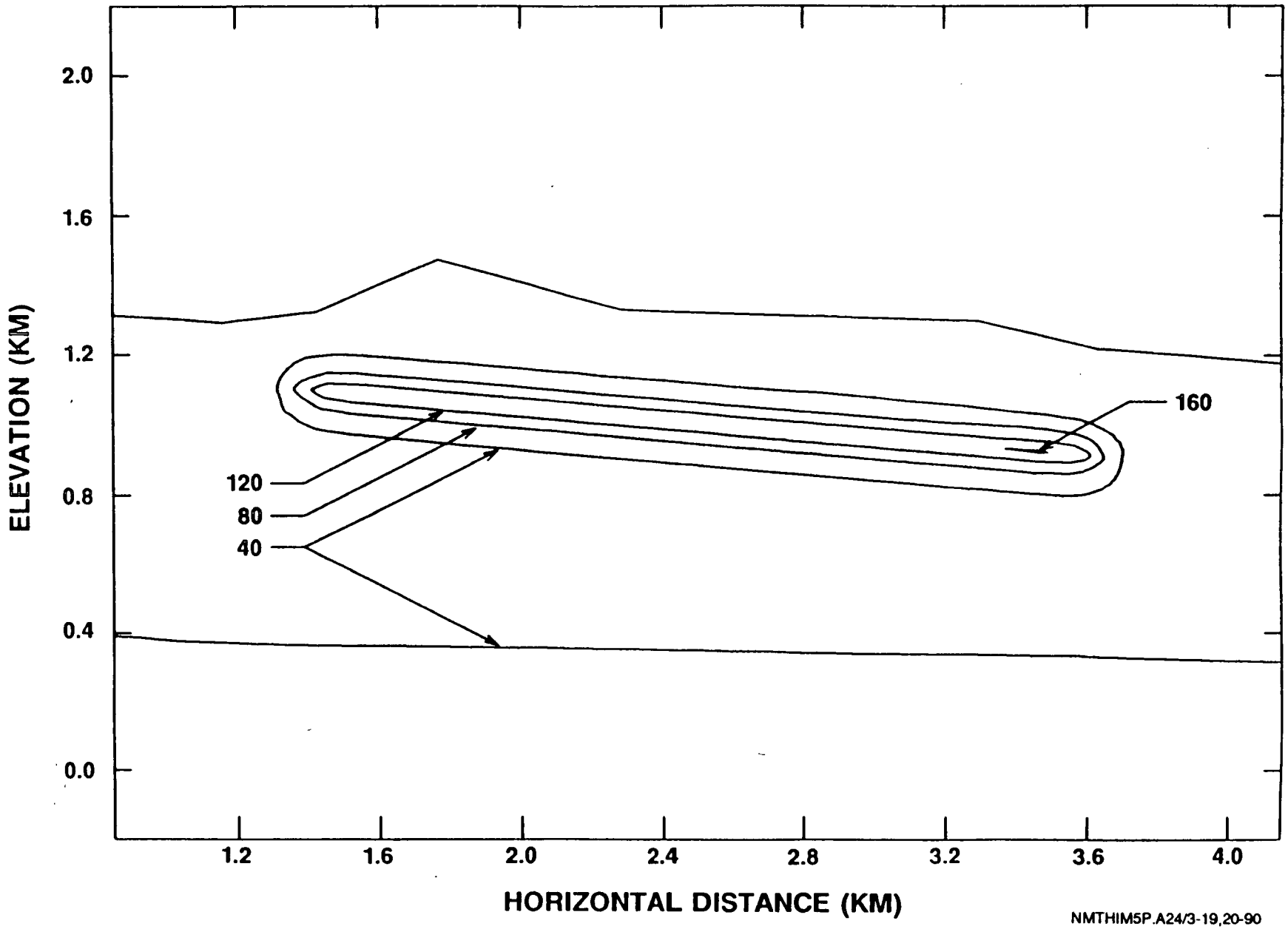

HEAT INPUT AND RESULTING TEMPERATURE CHANGES
THERMAL EXPANSION
PHASE CHANGES & △PROPERTIES
BUOYANCY
△SATURATION & THERMAL PROPERTIES
△CHEMICAL POTENTIAL
MINERAL ALTERATION & △ THERMAL PROPERTIES
PORE PRESSURE
△HYDRO PROPERTIES
MECHANICAL STRESS/STRAIN
FLUID FLOW
CHEMICAL INTERACTIONS
△PERMEABILITY & POROSITY
MINERAL ALTERATION & △ ROCK PROPERTIES
△SORPTION PROPERTIES
RADIONUCLIDE TRANSPORT

# ROCK TEMPERATURES AND RESULTING THERMAL STRESSES

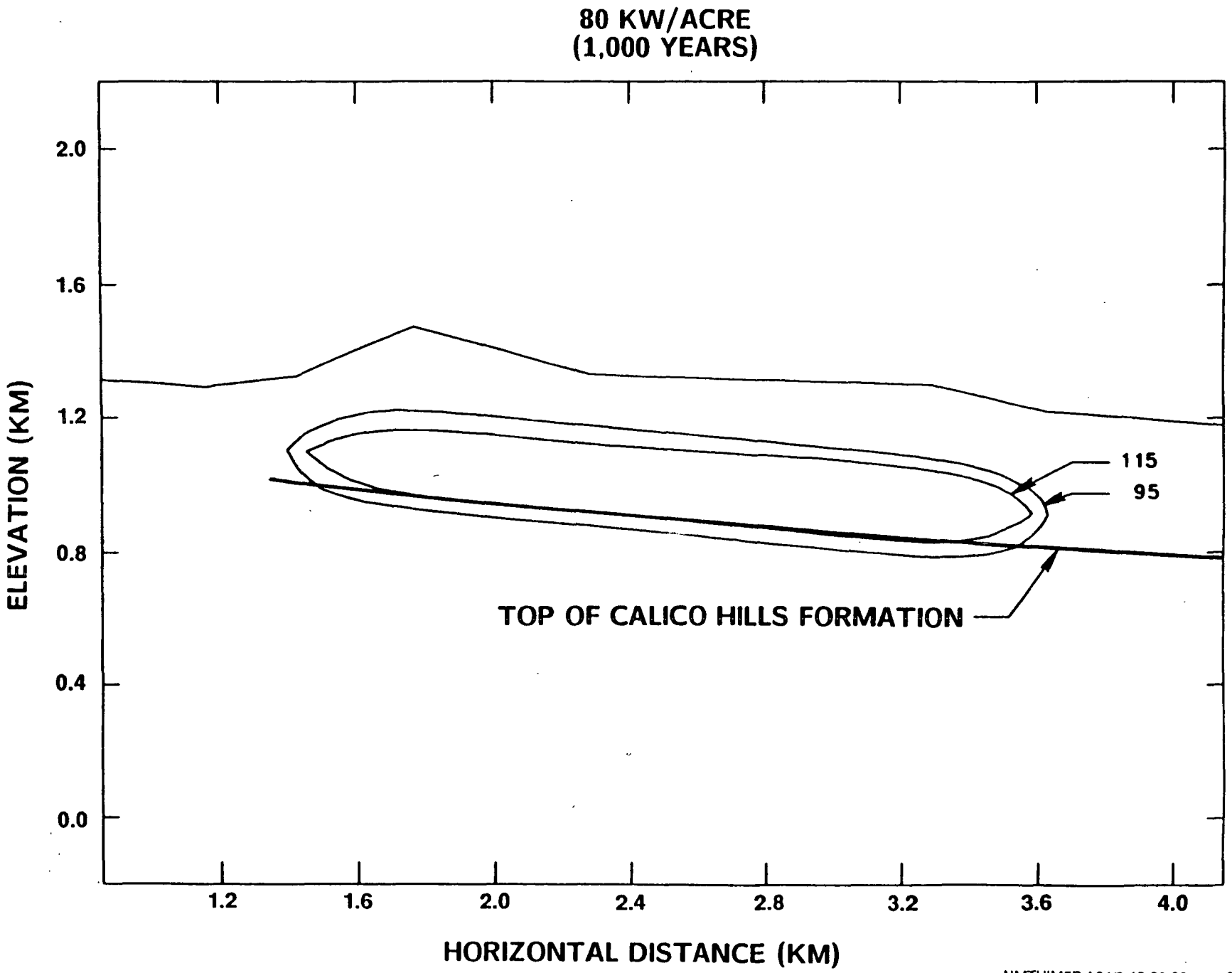
- DESIGN ANALYSES USE CONDUCTION MODELS
  - G-TUNNEL EXPERIMENTS
  - MODELS WITH VAPOR TRANSPORT
  - HIGH TEMPERATURE CONSTRAINTS
  - LOW TEMPERATURE CONSTRAINTS
- ANALYSES AT THREE SCALES
  - CONTAINER
  - DRIFT
  - FAR-FIELD
- THERMAL-MECHANICAL ANALYSES
  - LINEAR-ELASTIC
  - CONTINUUM JOINT
  - DISCONTINUUM

# TEMPERATURE (°C)

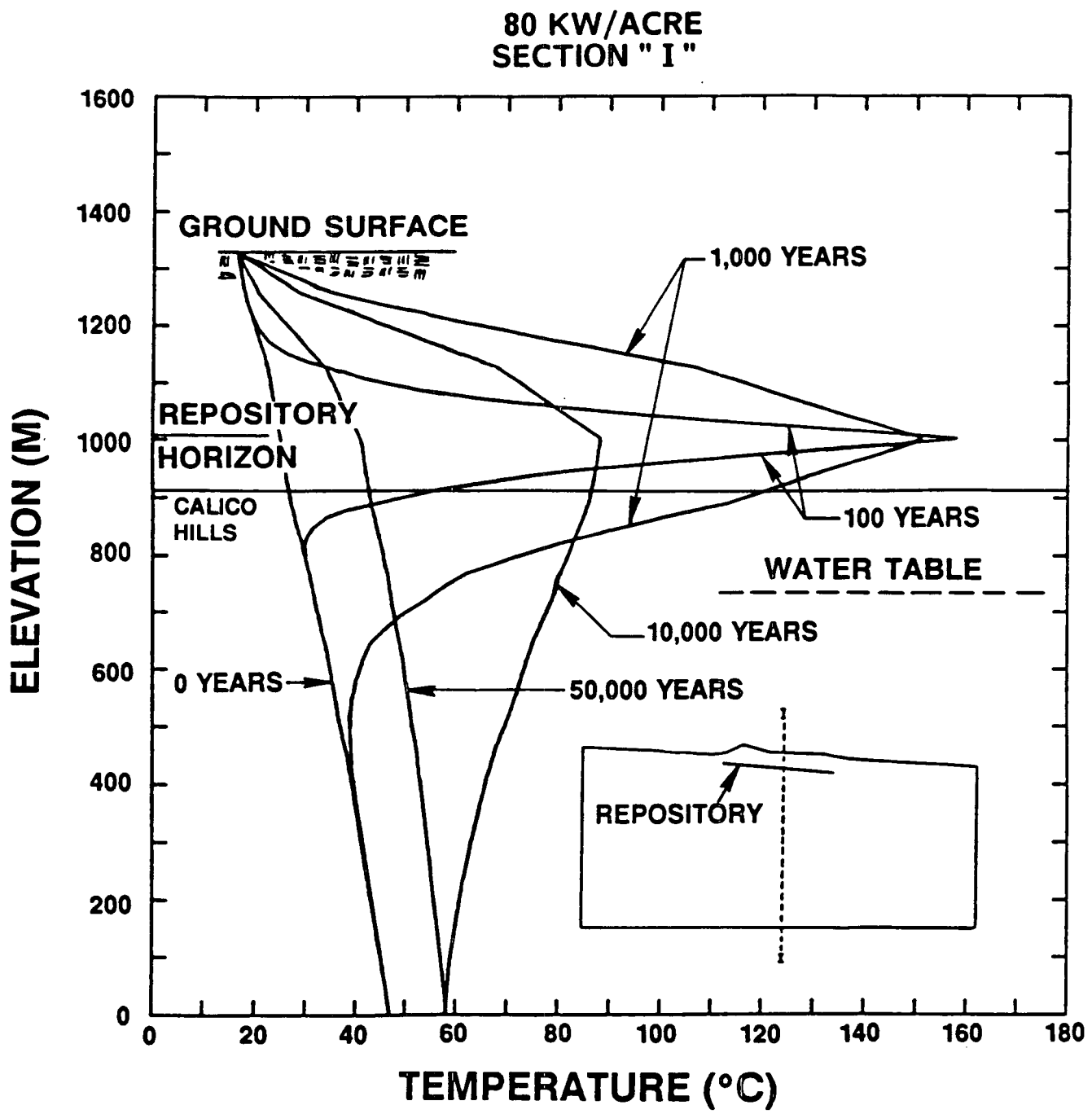
## 80 KW/ACRE
## (100 YEARS)



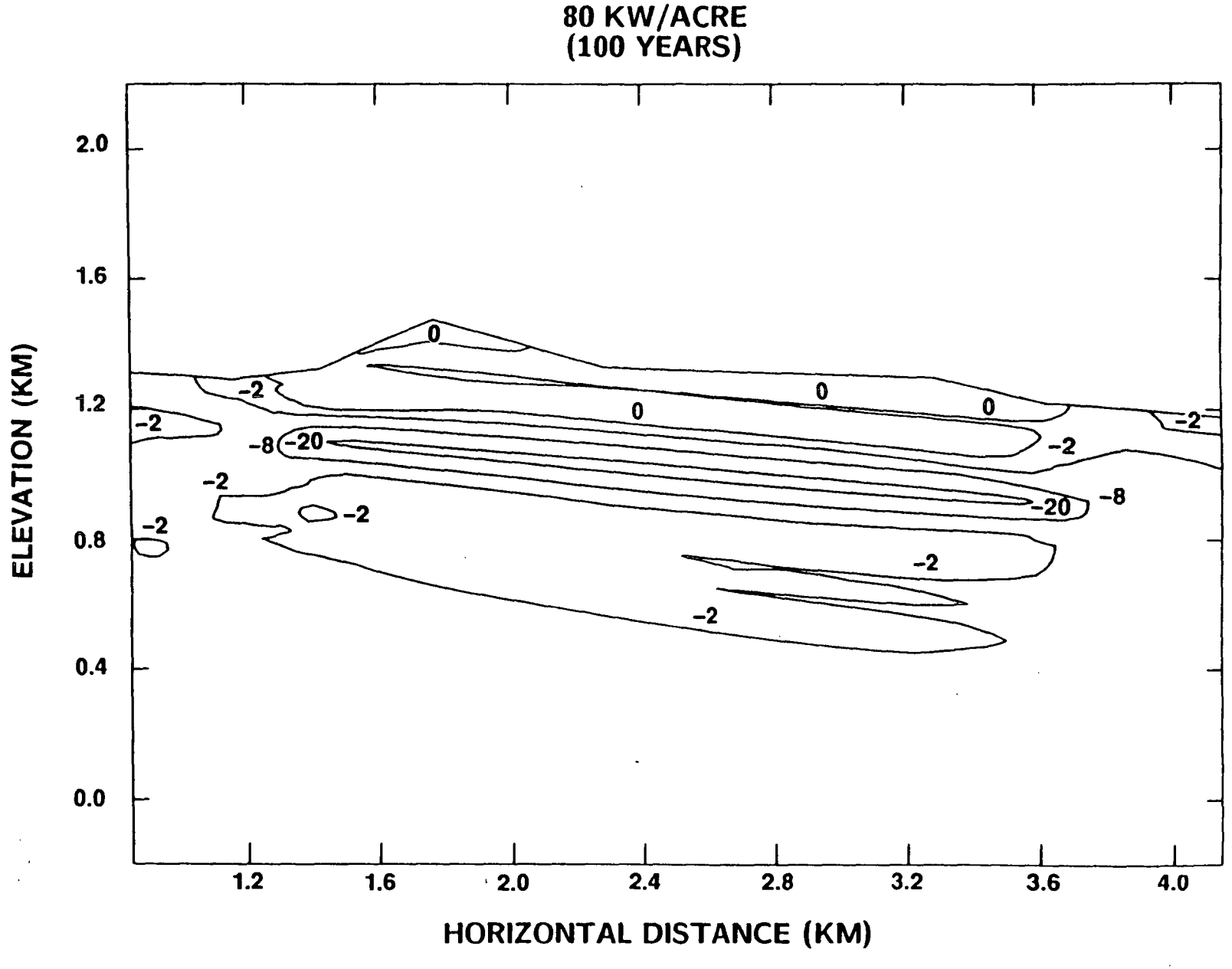
# TEMPERATURE (°C)



# PREDICTED TEMPERATURES

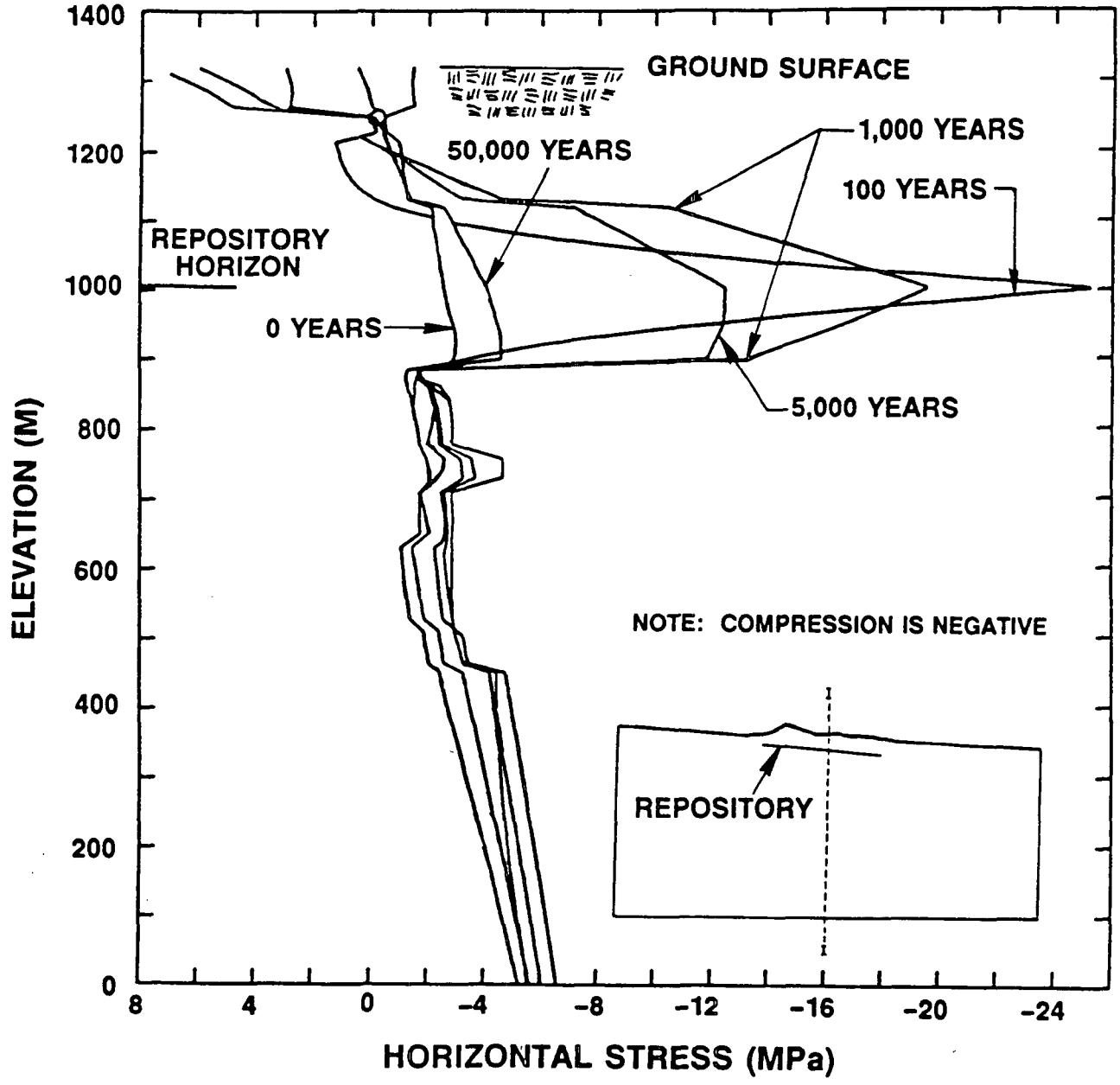


# HORIZONTAL STRESS (MPa)



# PREDICTED HORIZONTAL STRESS ELASTIC ANALYSIS,

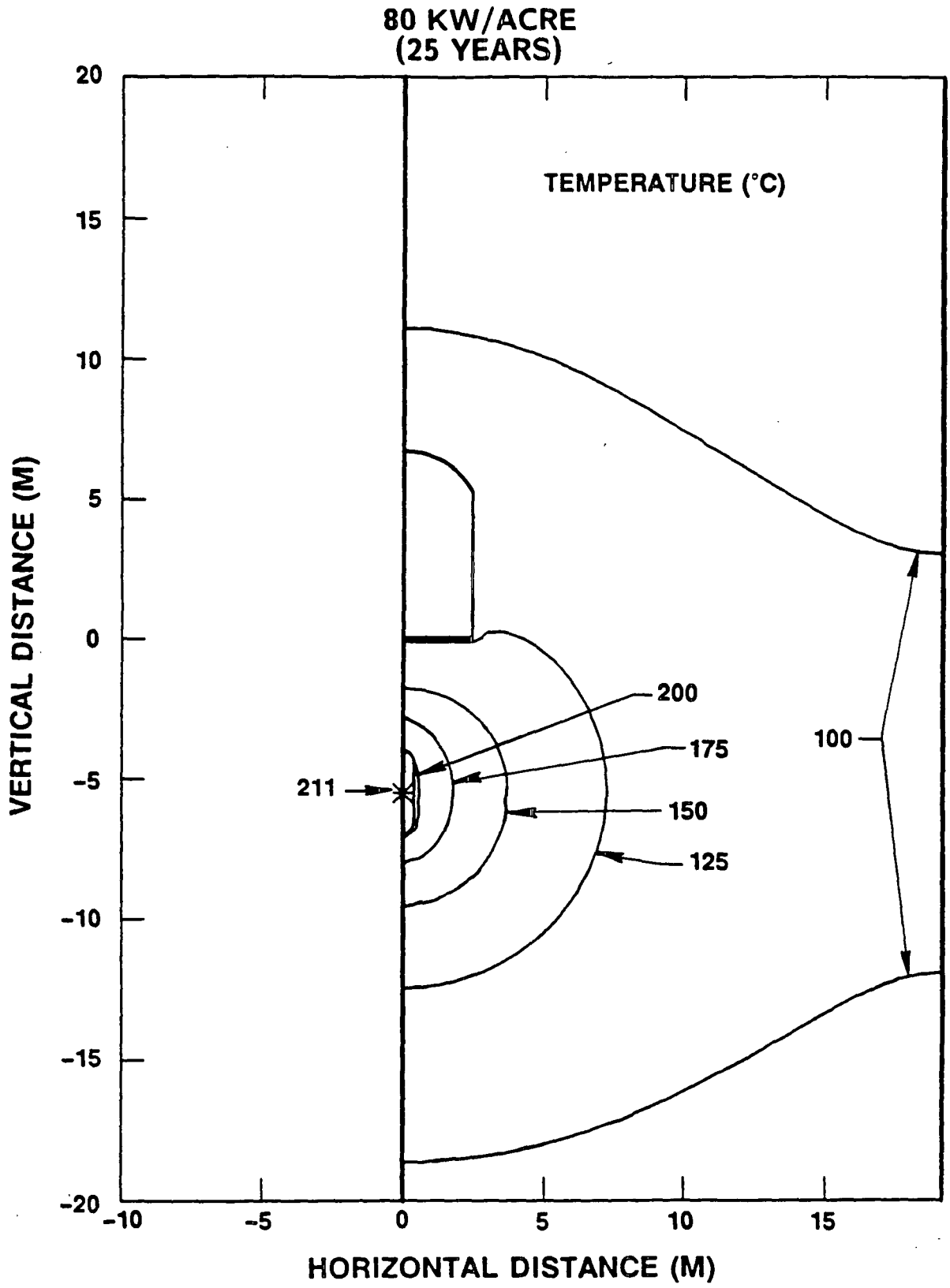
## 80 KW/ACRE
## SECTION " I "



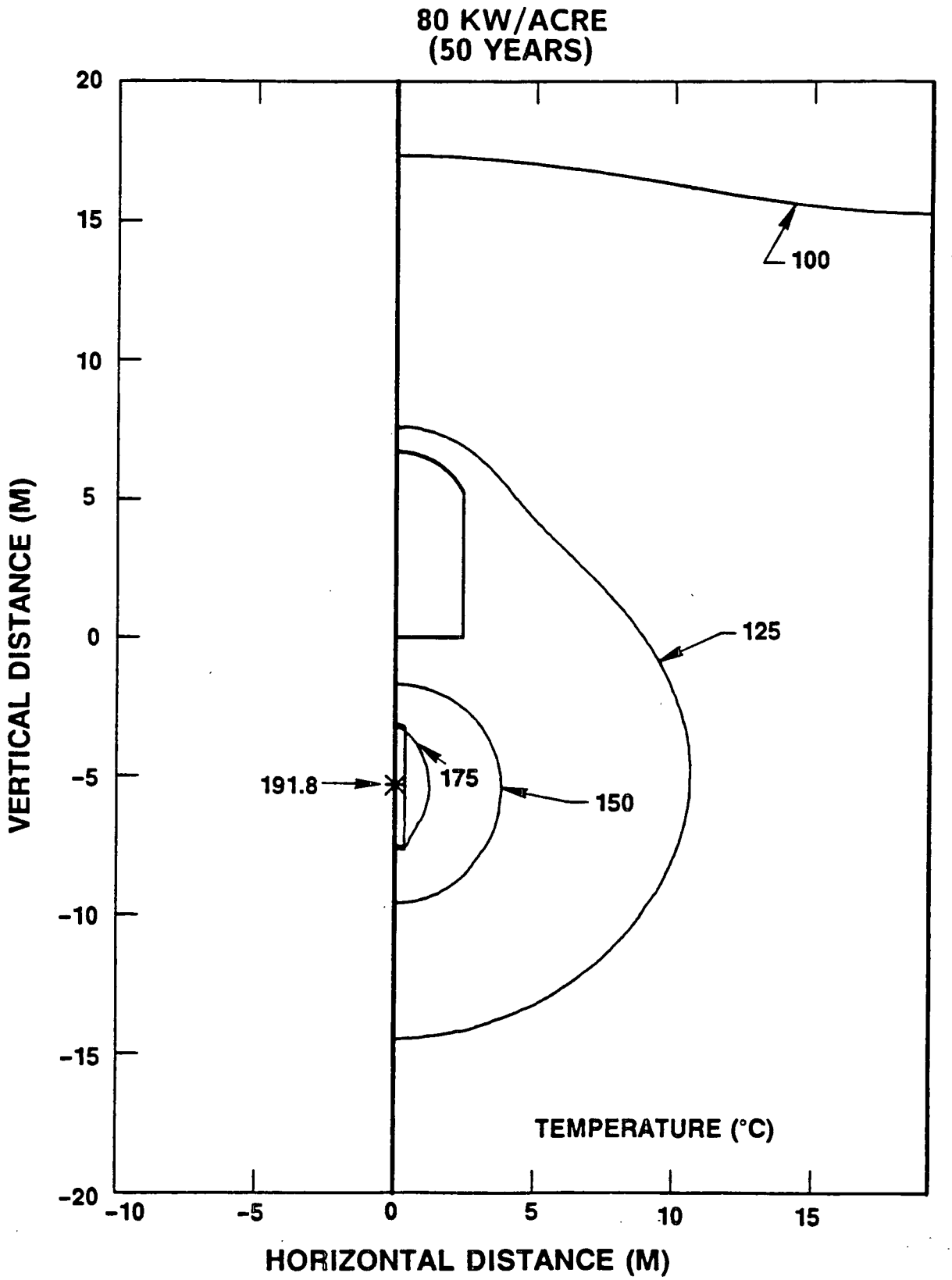
# THERMAL ANALYSIS OF BENCHMARK PROBLEM



NMTHIM5P.A24/3-19,20-90



# THERMAL ANALYSIS OF BENCHMARK PROBLEM



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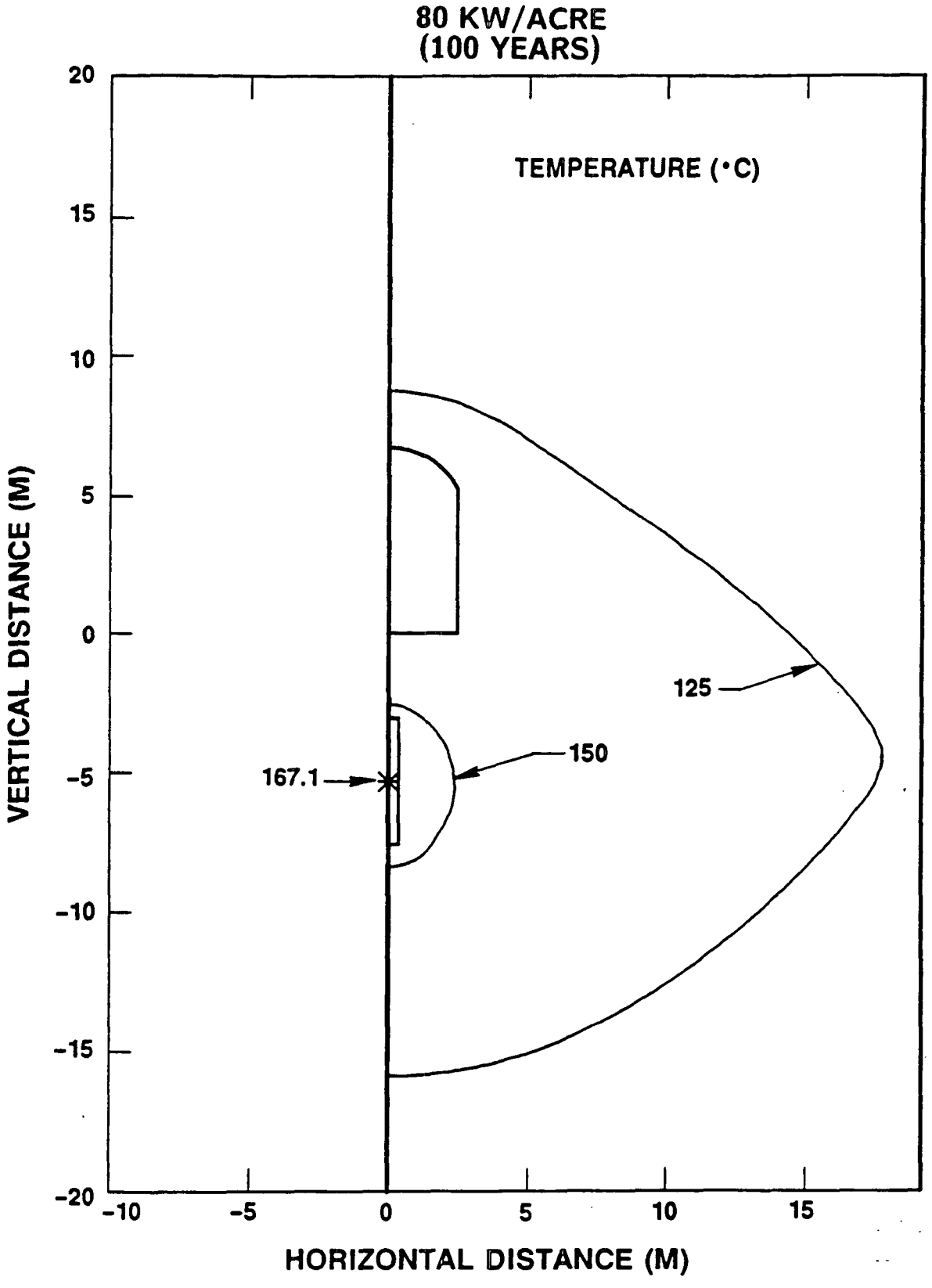
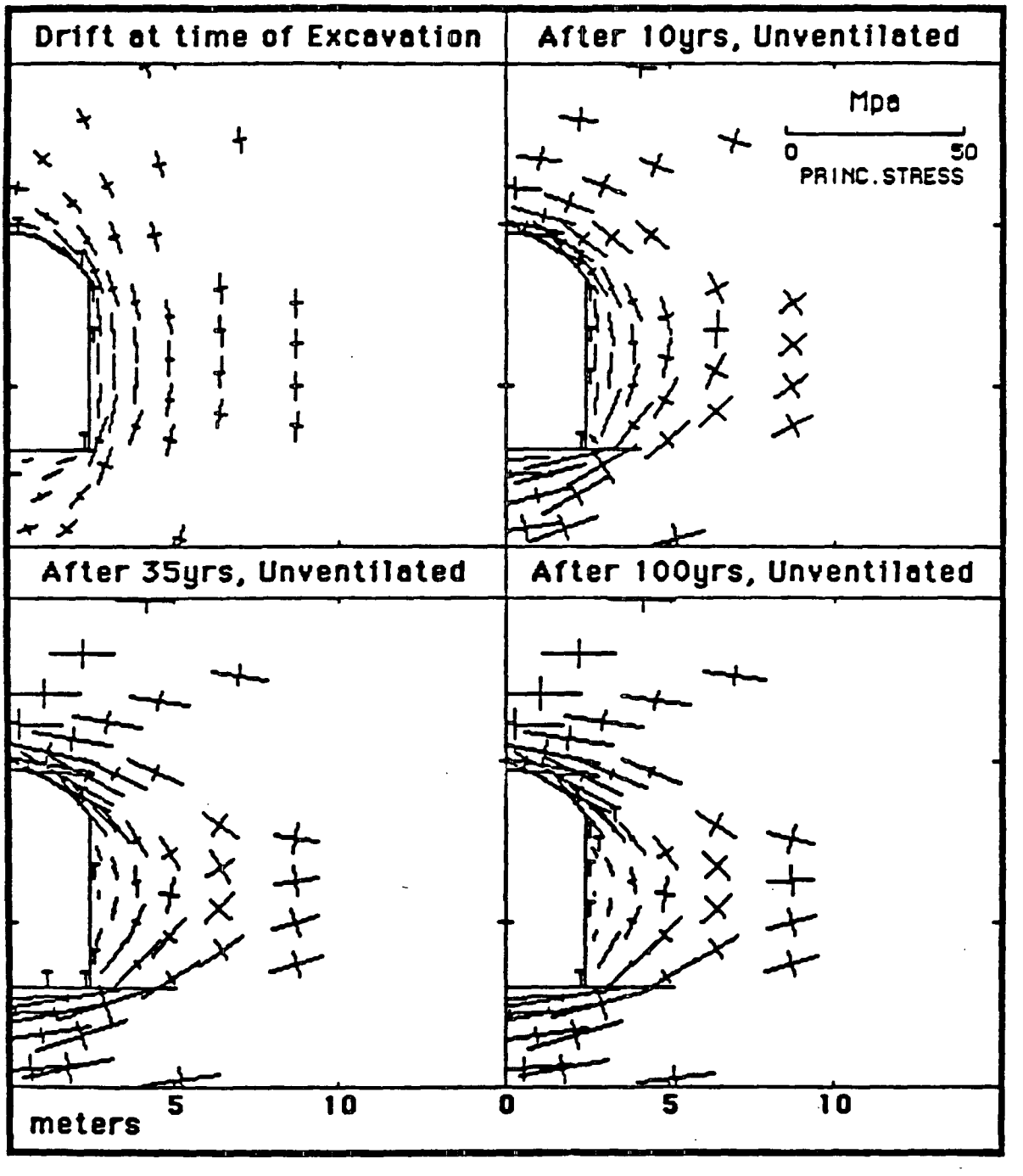
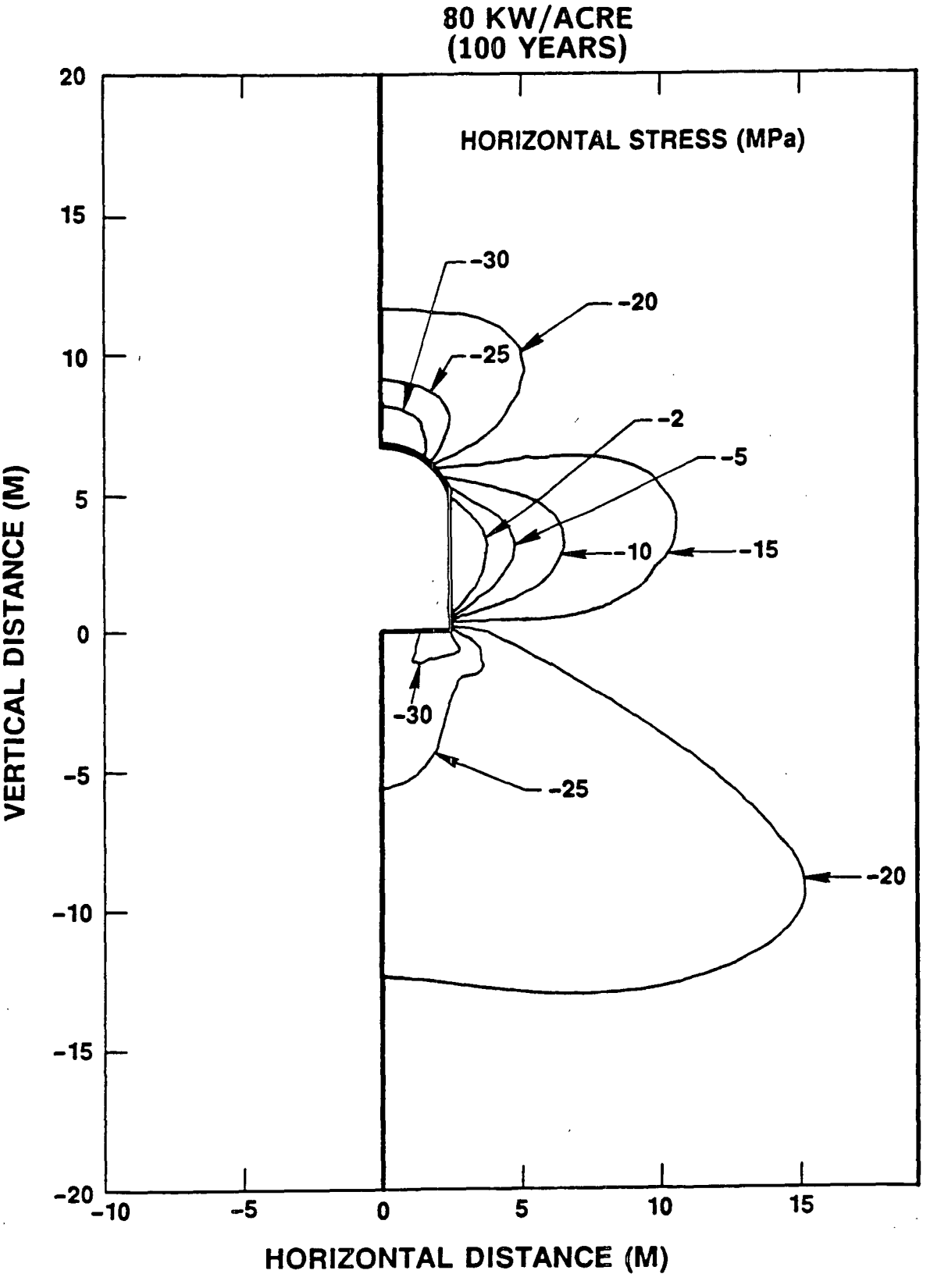


# PRINCIPAL STRESSES IN THE VICINITY OF A VERTICAL EMPLACEMENT DRIFT

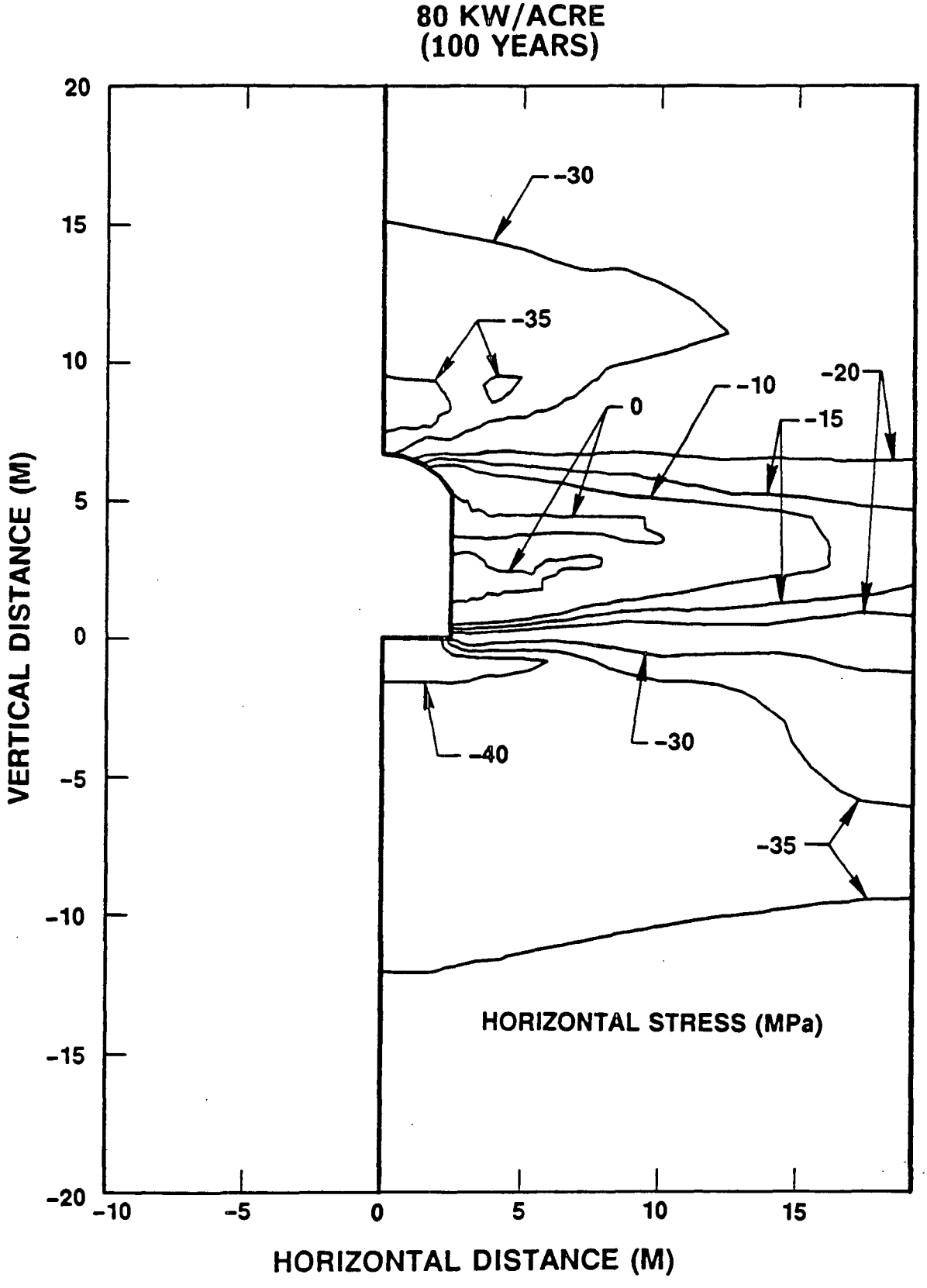


# ELASTIC ANALYSIS OF BENCHMARK PROBLEM



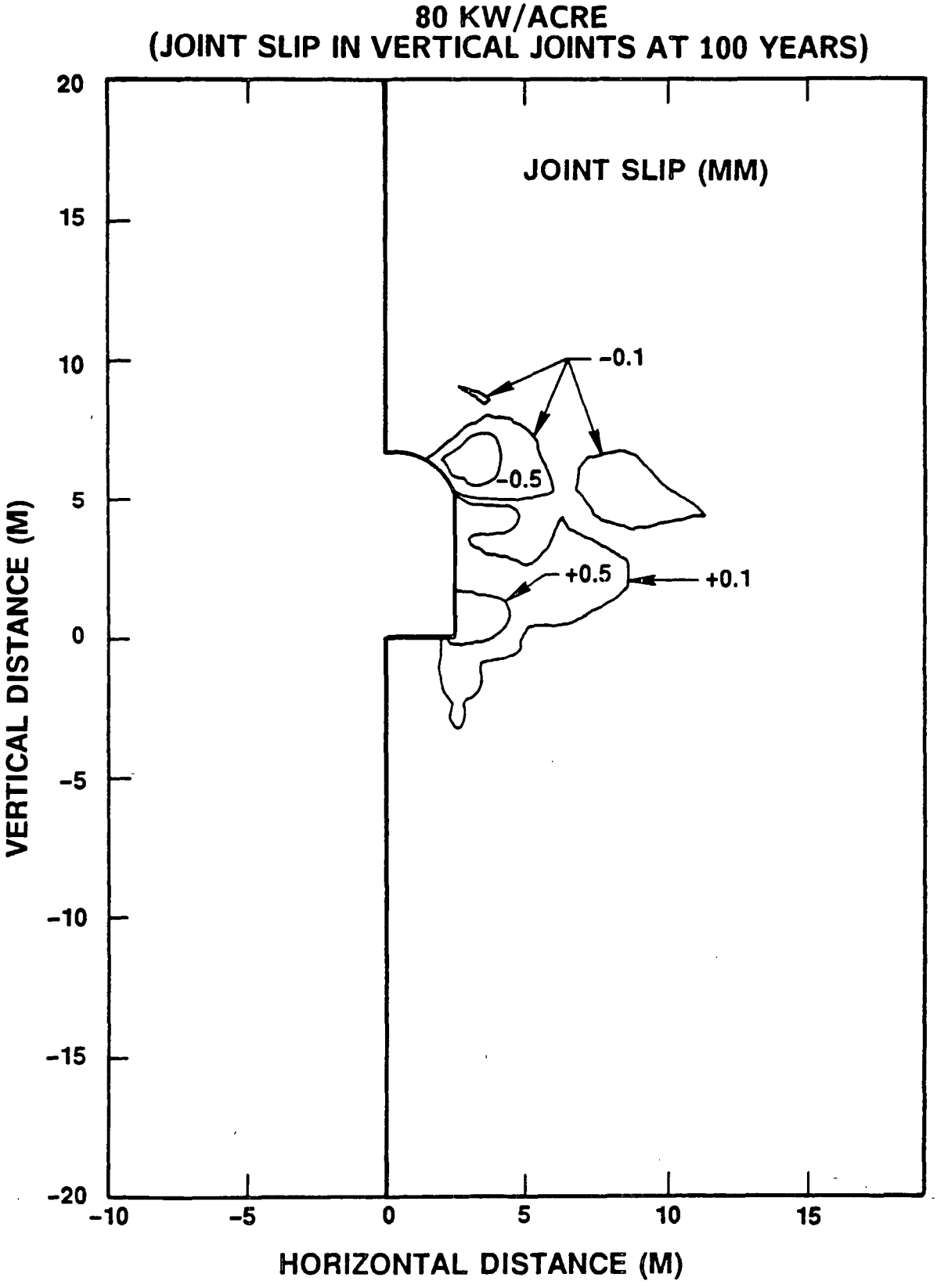


# ORTHOGONAL JOINT ANALYSIS OF BENCHMARK PROBLEM



# ORTHOGONAL JOINT MODEL ANALYSIS OF BENCHMARK PROBLEM





# THERMAL STRESS DESIGN GOALS

- **LIMIT TEMPERATURES NEAR BOREHOLES**
  - T < 200°C ONE METER FROM BOREHOLE WALL
  - NEAR-FIELD ROCK-MASS INTEGRITY
  - G-TUNNEL HEATER EXPERIMENTS
- **LIMIT TEMPERATURE OF CONTAINER AND BOREHOLE WALL**
  - T < 350°C CONTAINER
  - T < 275°C BOREHOLE WALL
  - CLADDING INTEGRITY

# THERMAL STRAIN DESIGN GOAL

- **LIMIT SURFACE TEMPERATURE RISE AND UPLIFT**
  - $\triangle T < 6^{o}C$ ON SURFACE
  - SURFACE UPLIFT < 0.5 cm/yr
- **NO INTACT ROCK FAILURE OR CONTINUOUS JOINT SLIP**

# THERMAL INFLUENCES ON HYDROLOGIC IMPACTS

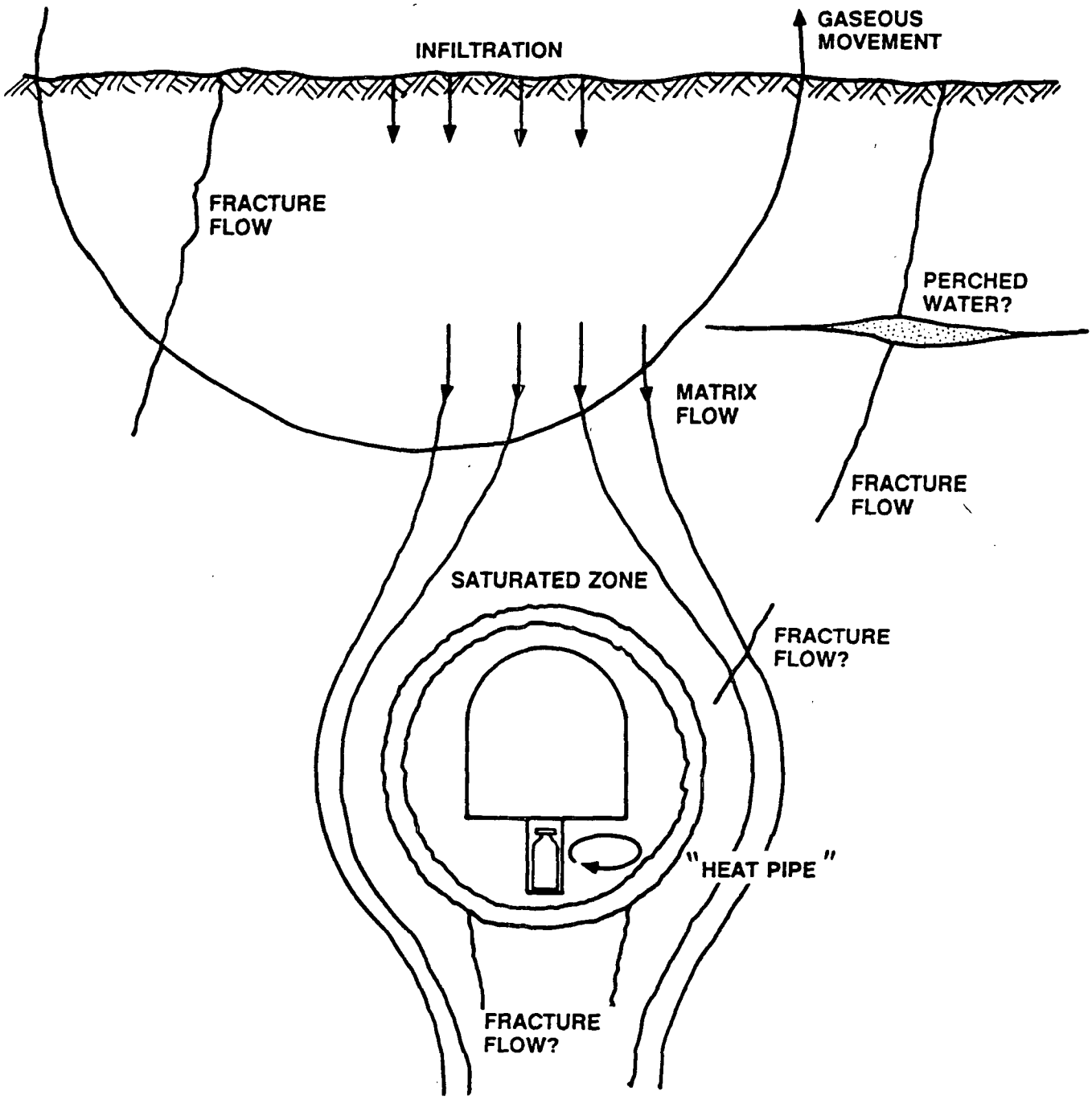
## MECHANISTIC

- "HEAT PIPE"
  - DRY-OUT NEAR PACKAGE
  - SATURATED ZONE
  - ALTERED FLOW FIELD
  - FRACTURE FLOW
  - WATER VAPOR AROUND PACKAGE
- GASEOUS MOVEMENT

## PROPERTIES

- FLOW PARAMETERS
- FRACTURE COATINGS AND FILLINGS

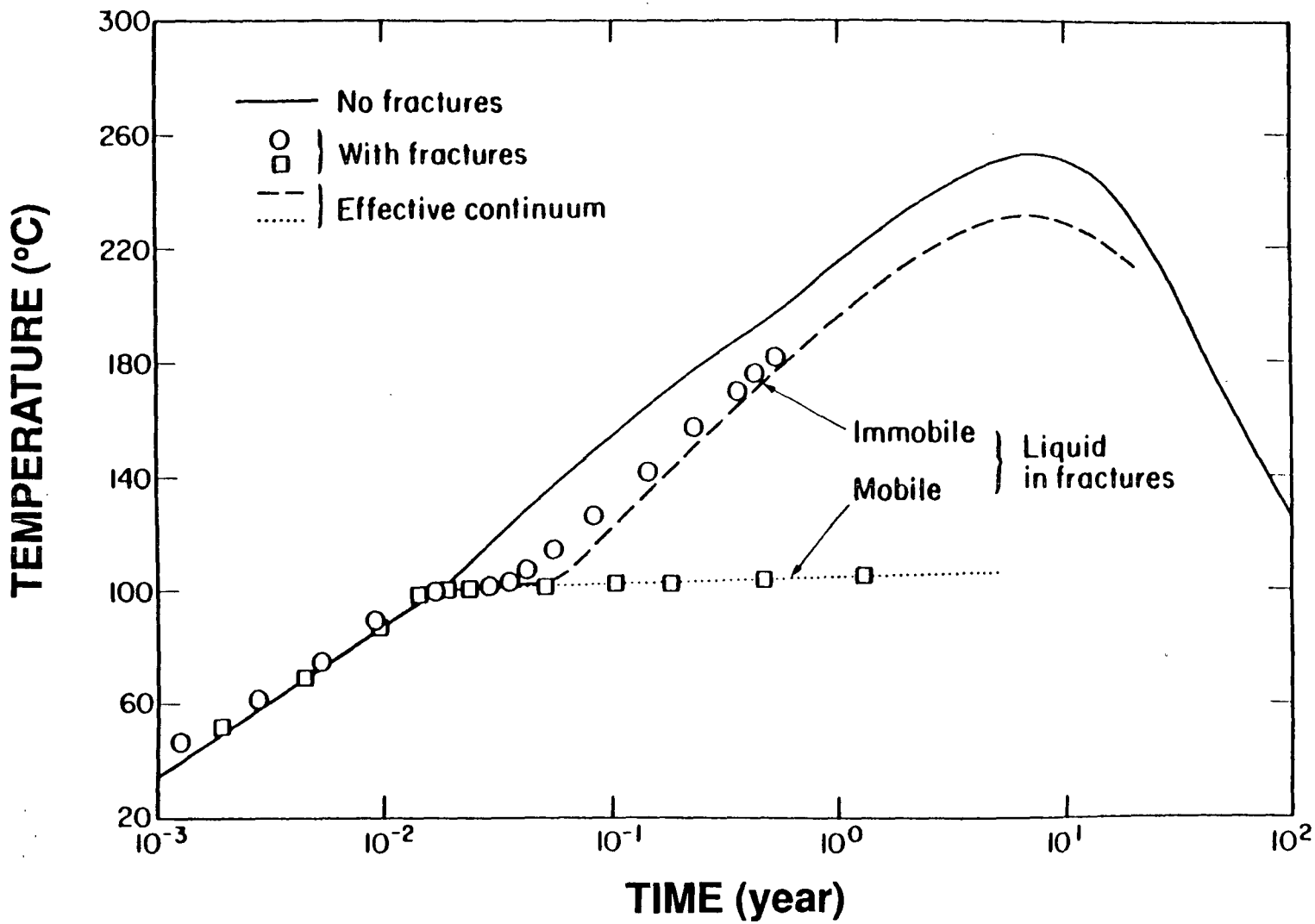
# DISTURBED HYDROLOGIC SYSTEM



# NONISOTHERMAL HYDROLOGIC SCOPING CALCULATIONS

- **NEAR-FIELD CALCULATIONS - SINGLE WASTE PACKAGE**
  - NO FRACTURES
  - EXPLICIT FRACTURES
  - CONTINUUM APPROXIMATION
- **FAR-FIELD CALCULATIONS**
  - EFFECT OF REPOSITORY LOADING ON FLOW
  - STUDY OF EFFECTS OF SURFACE BOUNDARY CONDITIONS ON FLOW

# TEMPERATURES NEAR A SINGLE WASTE PACKAGE




REFERENCE: SAND86-7016J

# HYDROLOGIC DESIGN GOALS

- **LIMIT THE EXTENT OF SATURATED CONDITIONS**
  - LOCAL SATURATION < 90%
  - CONTROL USE OF FLUIDS DURING CONSTRUCTION AND OPERATION
  - REDUCES THE POTENTIAL FOR FRACTURE FLOW

- **LIMIT THE CORROSIVENESS OF THE CONTAINER ENVIRONMENT**
  - MAJORITY OF BOREHOLE WALLS ABOVE BOILING FOR > 300 YEARS
  - REDUCES THE POTENTIAL FOR LIQUID WATER CONTACTING CONTAINERS
  - DESIGN FOR DRAINAGE AND CONVECTION AWAY FROM CONTAINERS

# THERMAL INFLUENCES ON GEOCHEMISTRY

## MINOR INCREASES (TO BELOW 95°C)

- LARGE VOLUMES WITH SMECTITE, VOLCANIC GLASS, AND CLINOPTILOLITE
- REVERSIBLE DEHYDRATION (MINOR, IF ANY)

## SIGNIFICANT INCREASE (ABOVE BOILING)

- REMOVAL OF PORE WATER
- POSSIBLE LONG-TERM EFFECTS:
  - IRREVERSIBLE COLLAPSE OF CLINOPTILOLITE
  - LOSS OF OSMOTIC SWELLING CAPACITY OF SMECTITE
  - DEHYDRATION OF SMECTITE, CLINOPTILOLITE, AND GLASS
  - DIFFERENTIAL STRESSES DUE TO VOLUME CHANGE
  - EFFECTS OF LONG-TERM EXPOSURE TO STEAM CONDITIONS
  - CLINOPILOLITE AND MORDENITE TO ANALCIME
- EFFECTS ON SORPTION

# TEMPERATURE vs. ELEVATION AT 100 AND 1000 YEARS, CENTRAL PORTION OF REPOSITORY BLOCK



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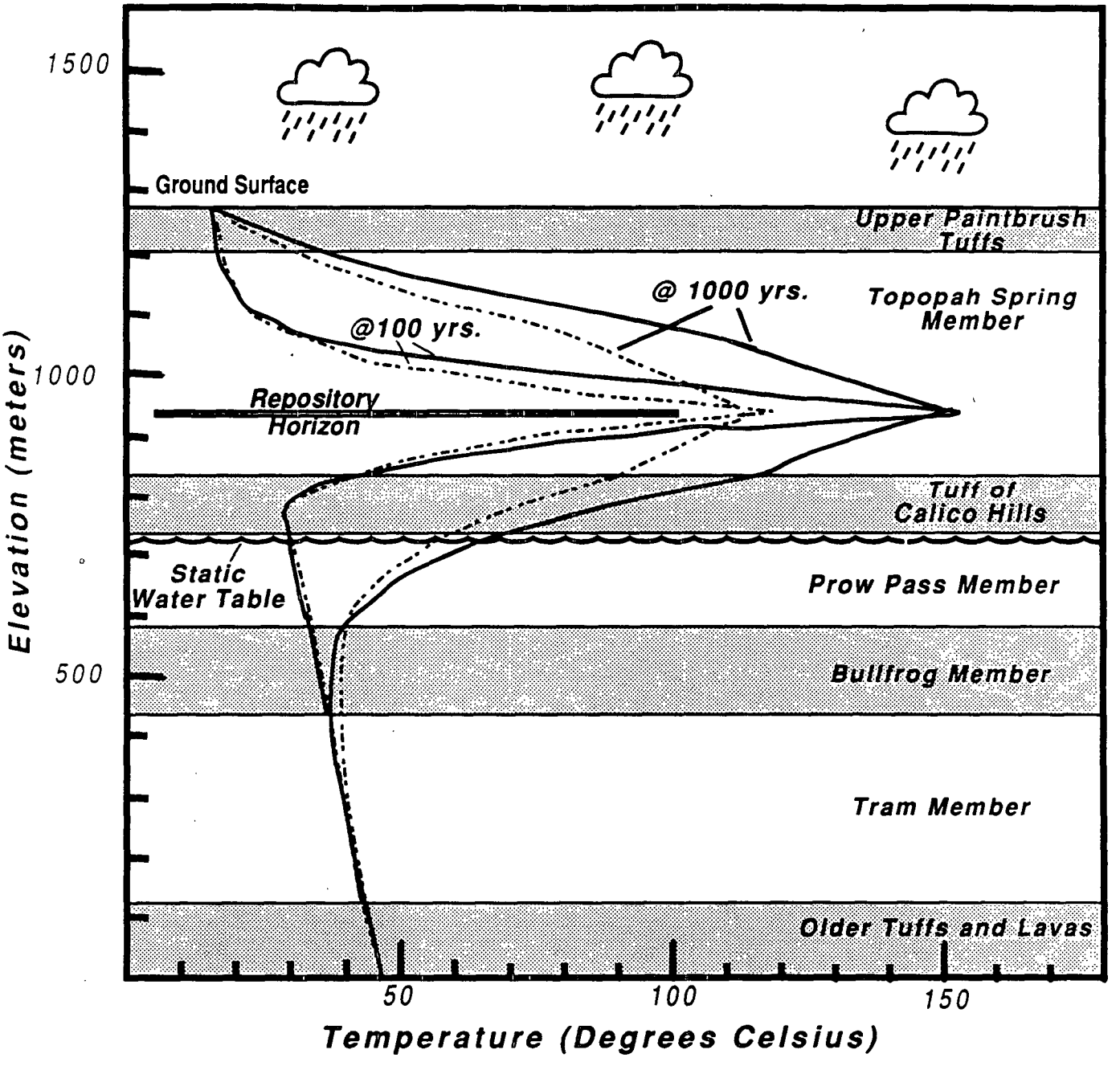


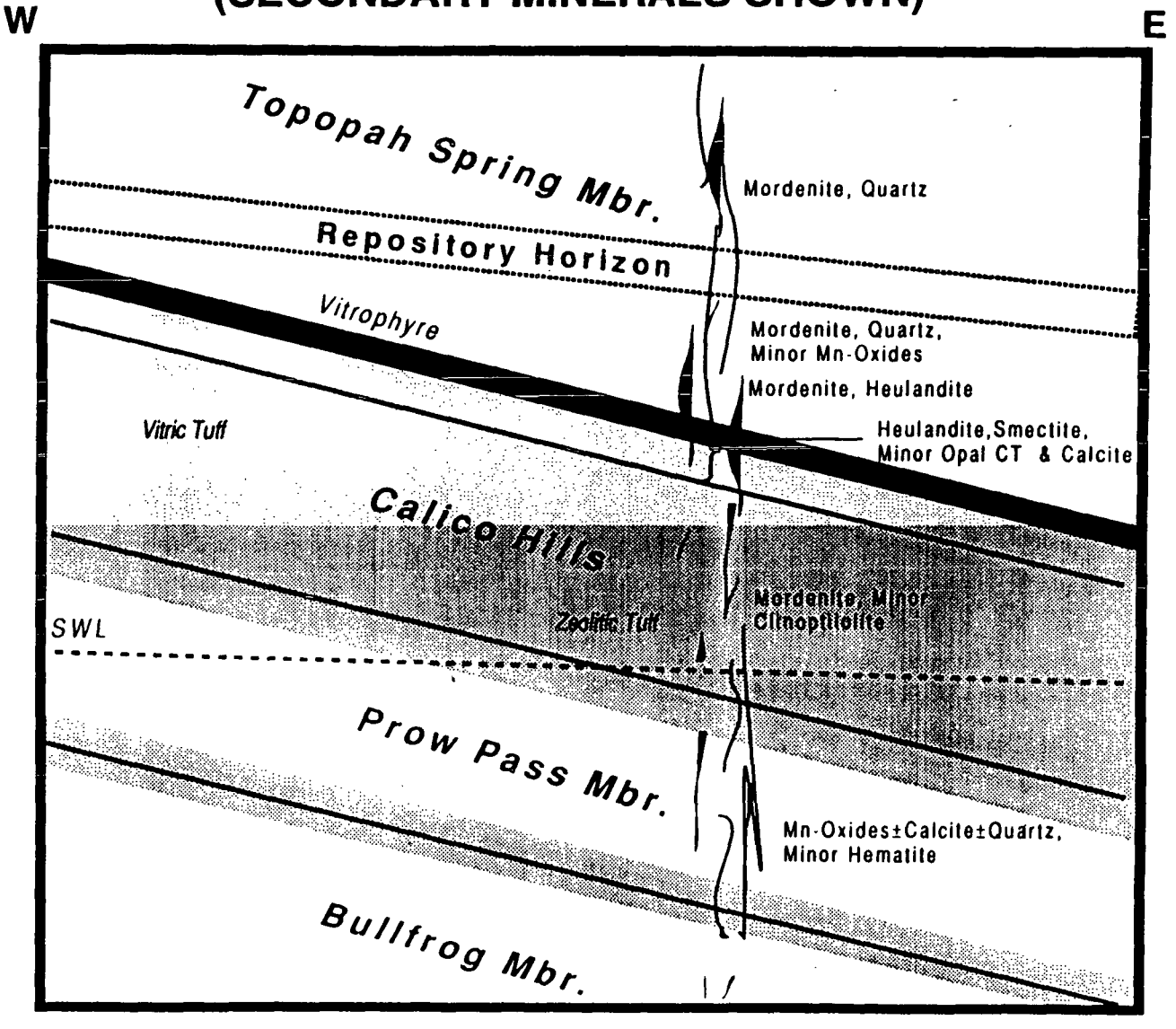

APD = 57 kW/a

APD = 80 kW/a

*Modified from Brandshaug (Figs. 6-1 and 6.2, SAND87-7079). Geologic contacts for USW G-4; Position of repository and geotherms adjusted to stratigraphy in USW G-4.*

# SCHEMATIC CROSS SECTION IN CENTRAL PORTION OF REPOSITORY BLOCK

## (SECONDARY MINERALS SHOWN)



# GEOCHEMICAL DESIGN GOALS

- **LIMIT TEMPERATURE IN UNITS BELOW THE EMPLACEMENT UNIT, TSw2**
  - **T < 115°C IN TSw3, CHnz AND CHnv**
  - **REDUCE THE POTENTIAL FOR MINERAL ALTERATION AND DEHYDRATION**
  - **INDIRECTLY RELATED TO CHANGES IN POROSITY AND PERMEABILITY**
  - **INTENDED TO LIMIT THE EXTENT OF THE DISTURBED ZONE**

# SUMMARY OF DESIGN GOALS FOR THERMAL LOADING

| GOAL | POSSIBLE EFFECT ON DESIGN |
|---|---|
| T < 200°C ONE METER FROM BOREHOLE WALL | VARY PACKAGE LOADING, BOREHOLE AND DRIFT SPACING; LIMIT APD |
| T< 275°C AT BOREHOLE WALL AND T < 350°C AT CONTAINER CENTERLINE | VARY PACKAGE LOADING, BOREHOLE AND DRIFT SPACING; LIMIT APD |
| △T < 6°C ON SURFACE AND SURFACE UPLIFT < 0.5 cm/yr | LIMIT APD |
| NO INTACT ROCK FAILURE OR CONTINUOUS JOINT SLIP | LIMIT APD |
| LOCAL SATURATION < 90% | LIMIT USABLE AREA |
| BOREHOLE WALLS ABOVE BOILING > 300 yrs | RAISE PACKAGE LOADING AND APD |
| T < 115°C IN TSw3, CHnz, AND CHnv | LIMIT APD |