

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

**PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: OVERVIEW OF THE ROCK
MECHANICS PROGRAM**

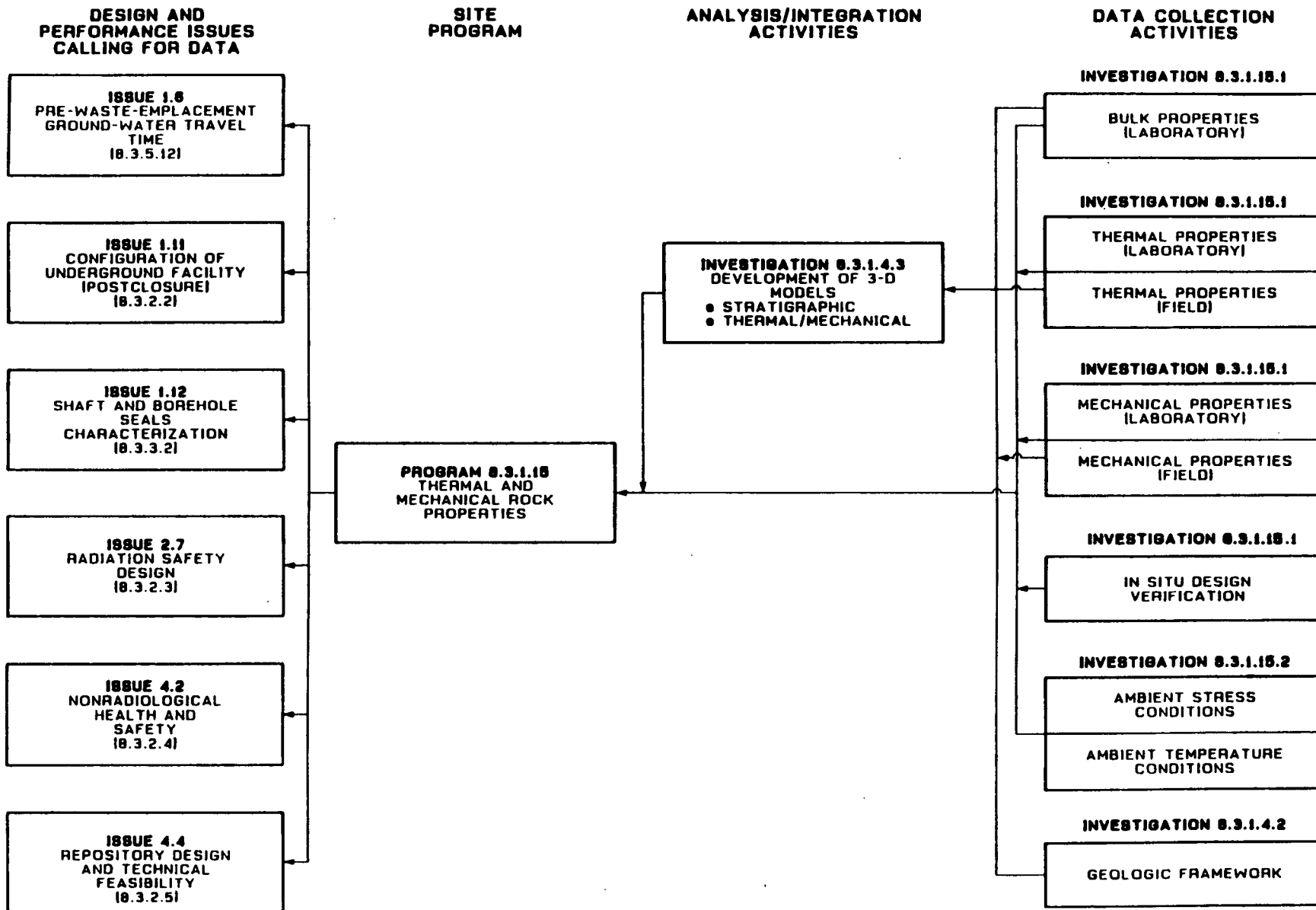
PRESENTER: DR. THOMAS E. BLEJWAS

**PRESENTER'S TITLE
AND ORGANIZATION: TECHNICAL PROJECT OFFICER,
SANDIA NATIONAL LABORATORY
ALBUQUERQUE, NEW MEXICO**

**PRESENTER'S
TELEPHONE NUMBER: (505) 844-9160**

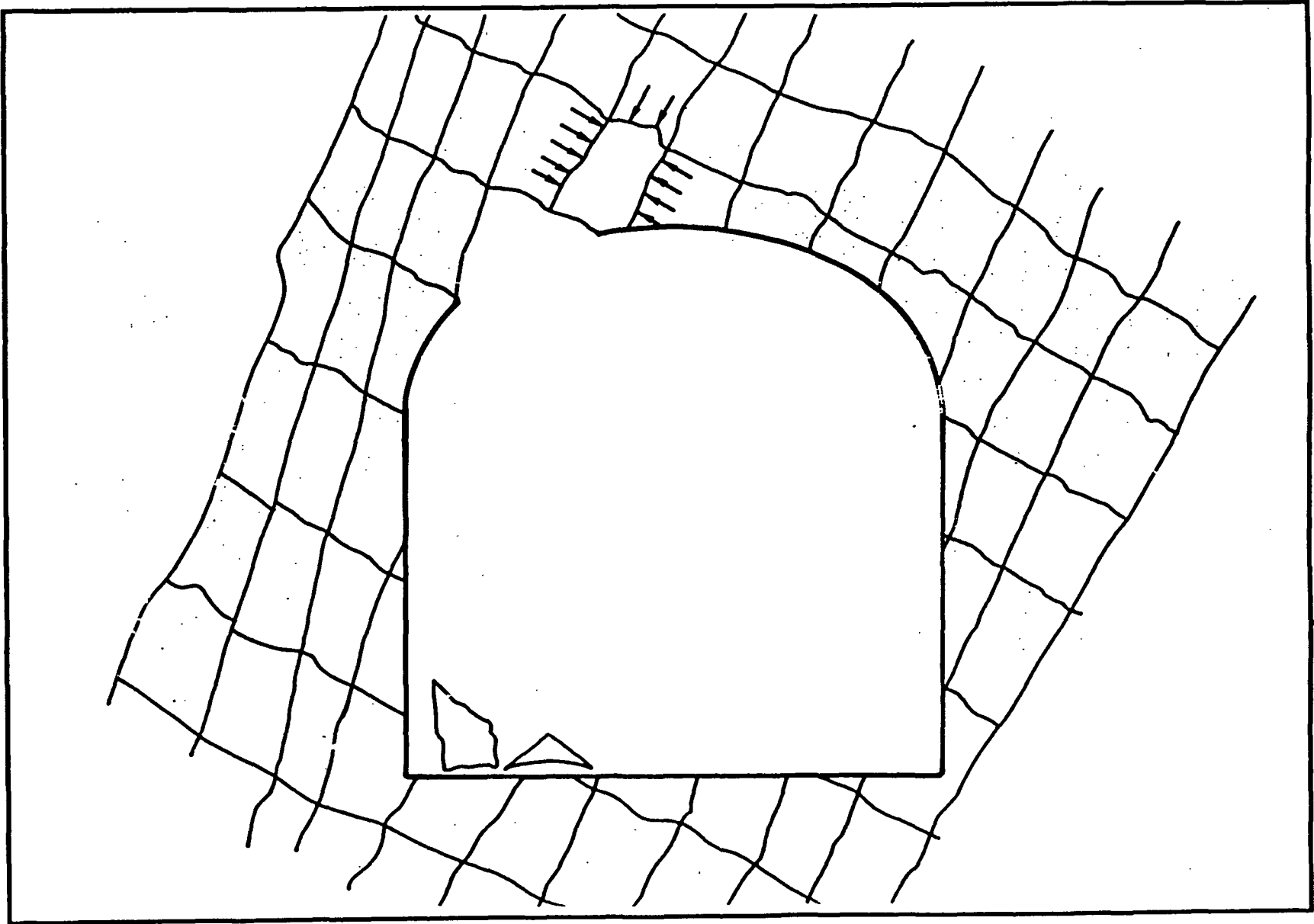
**REGISTRY HOTEL, DENVER, COLORADO
JUNE 25-27, 1991**

RELATIONSHIP BETWEEN DATA ACQUISITION FOR ROCK PROPERTIES AND ISSUES REQUIRING THE DATA

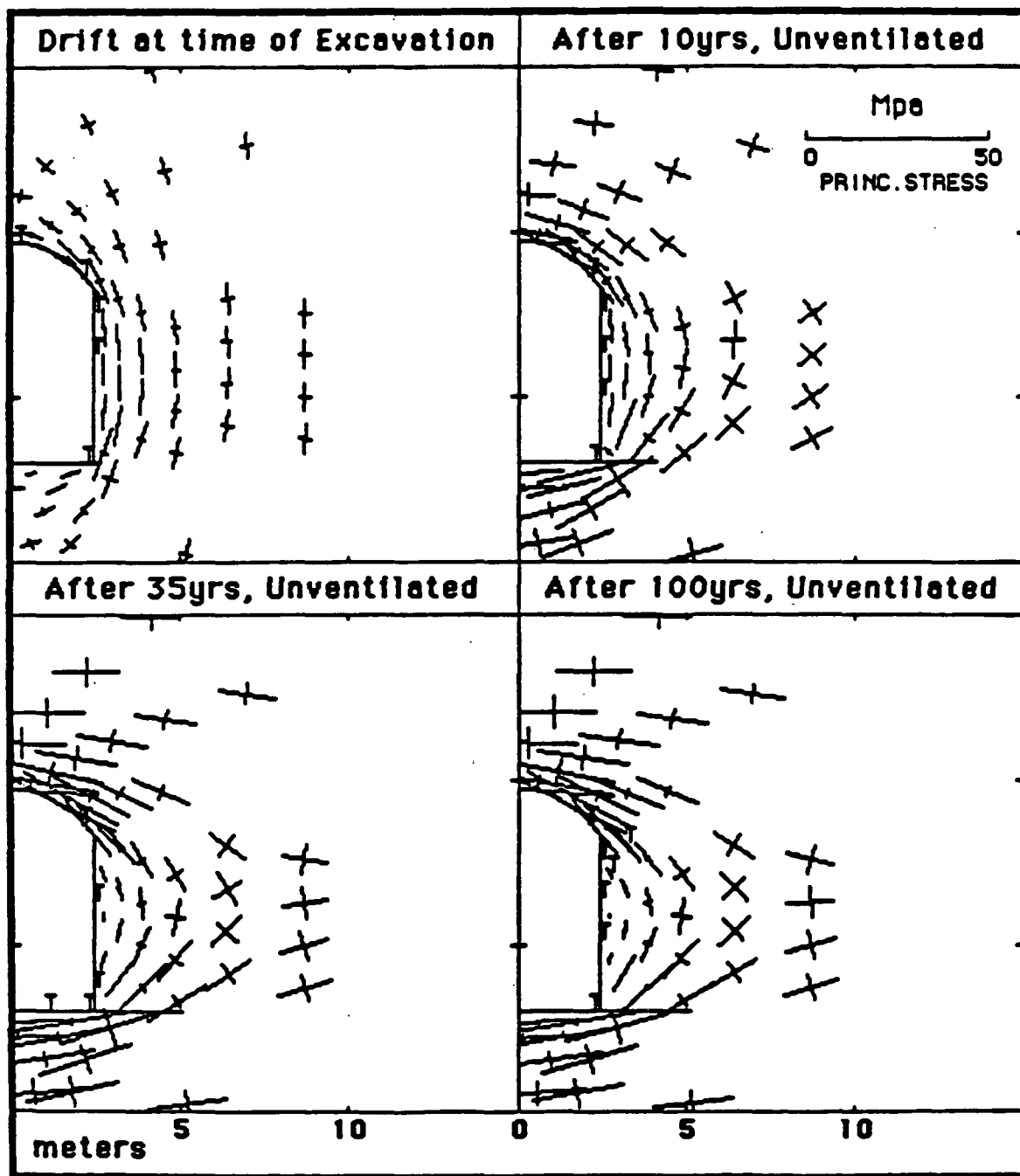


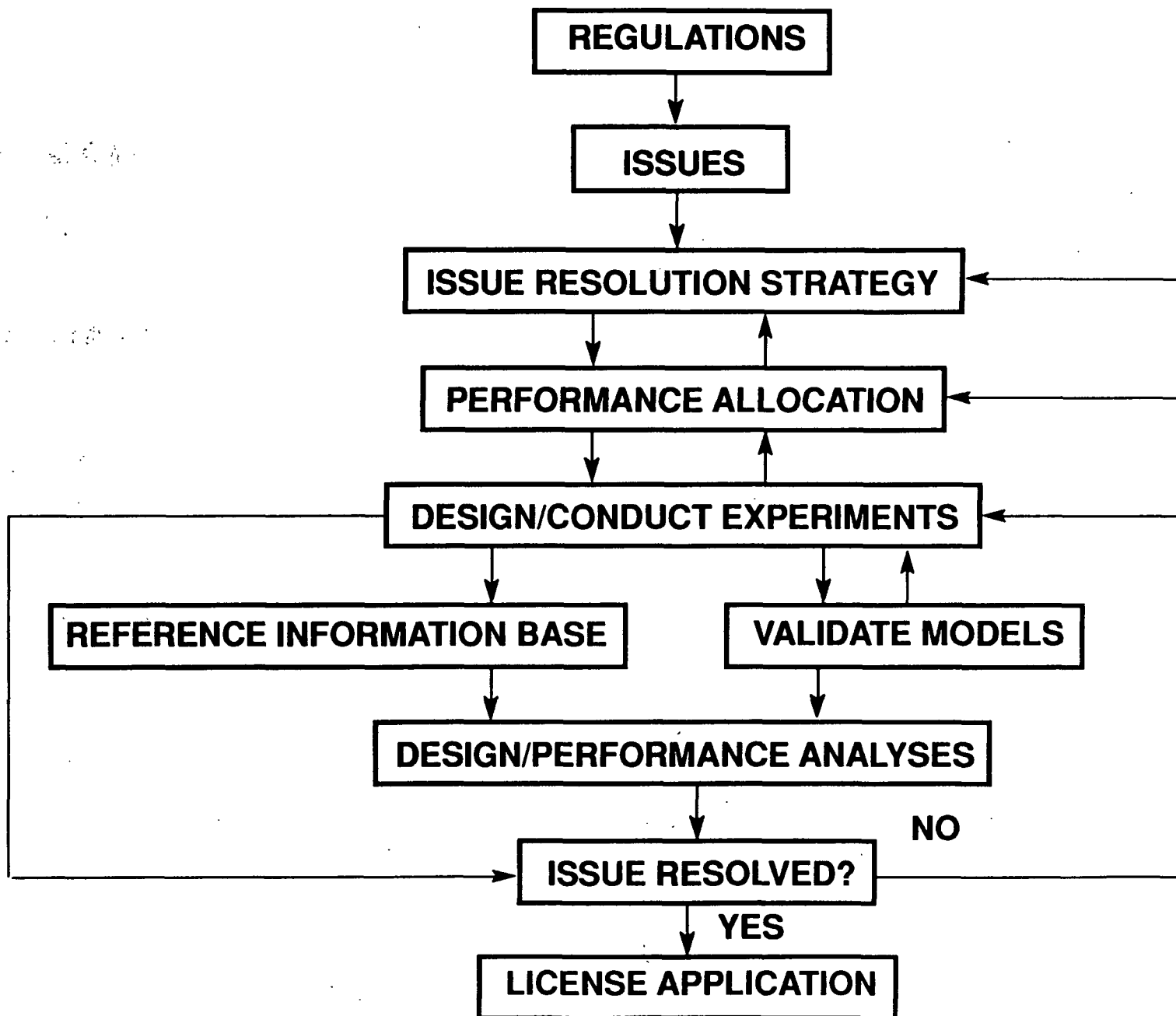
OVERALL OBJECTIVE

**CHARACTERIZE THE THERMAL AND MECHANICAL
PROPERTIES OF THE ROCK UNITS AT YUCCA MOUNTAIN**



BOUNDARY ELEMENT PREDICTION OF PRINCIPAL STRESSES IN THE VICINITY OF THE VERTICAL EMPLACEMENT DRIFT, AT TIMES UP TO 100 YEARS AFTER WASTE EMPLACEMENT (ST. JOHN, 1987)





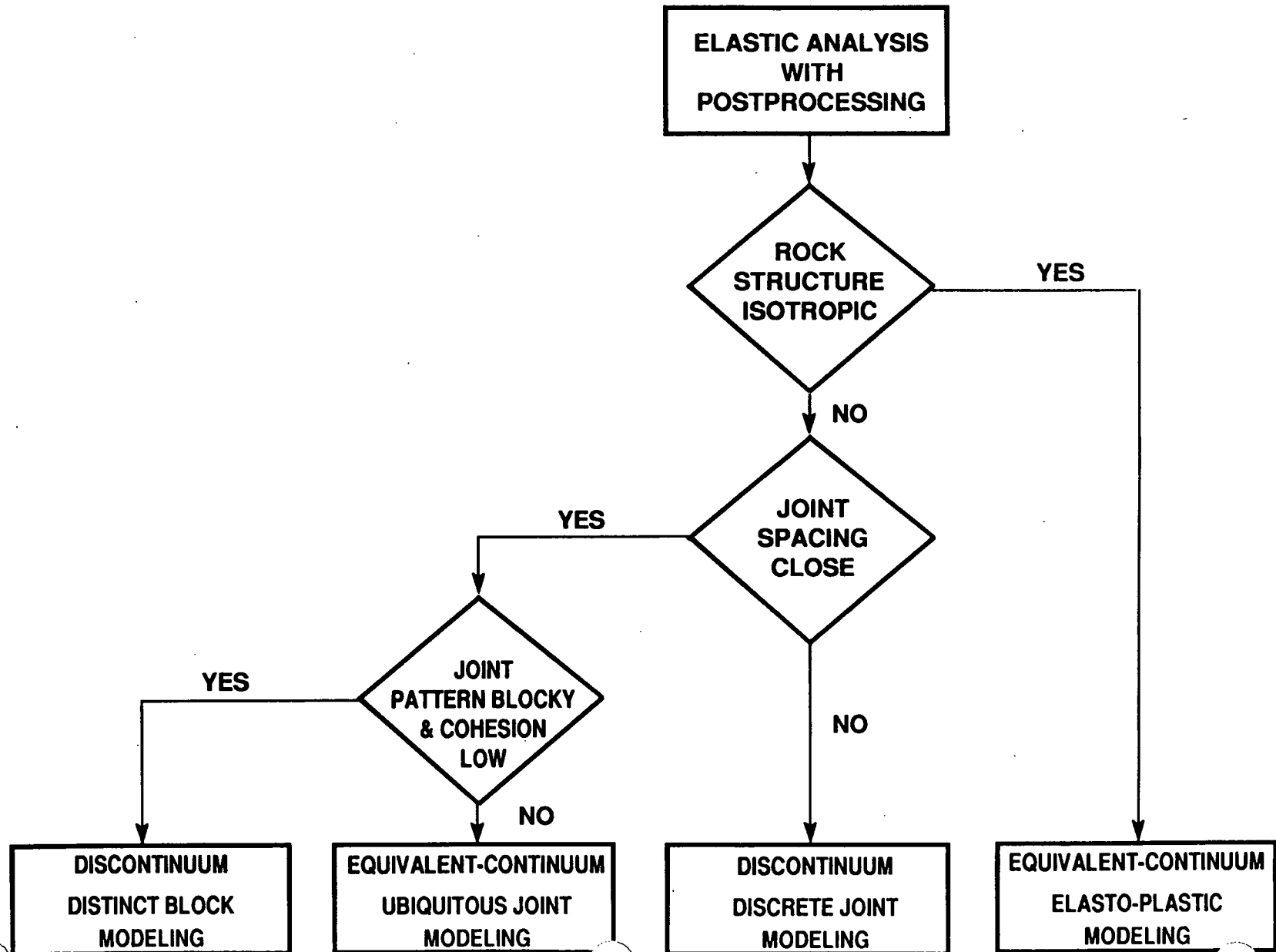
DATA NEEDS

- **PARAMETERS FOR THE DESIGN AND ANALYSIS OF THE REPOSITORY**
- **DATABASE FOR EMPIRICAL DESIGN METHODS**
- **VALIDATION OF ADVANCED ANALYTICAL METHODS**
- **CRITERIA FOR ACCEPTABILITY OR FAILURE OF OPENINGS**
- **DEMONSTRATIONS OF OPENING BEHAVIOR**

POTENTIAL DATA USERS

- **REPOSITORY DESIGNERS**
- **ANALYSTS OF PRE-CLOSURE PERFORMANCE**
- **ANALYSTS OF POST-CLOSURE PERFORMANCE**
- **STATE OF NEVADA INVESTIGATORS**
- **NUCLEAR REGULATORY COMMISSION STAFF**

DESIGN ANALYSIS AND MODELING



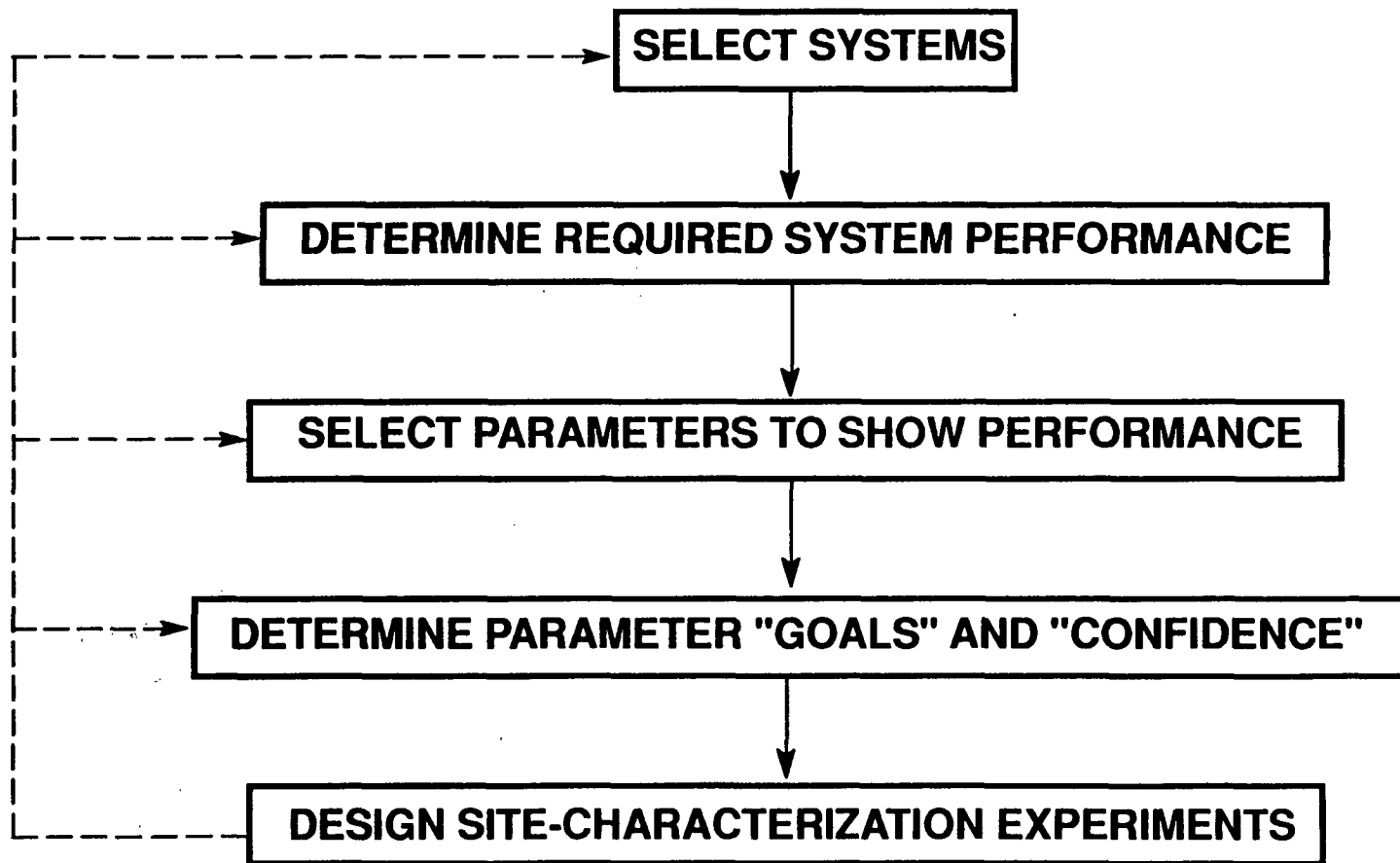
ROCK MECHANICS EXPERIMENTAL PROGRAM

**TRY TO COLLECT DATA OF SUFFICIENT
BREADTH TO SUPPORT A WIDE RANGE OF
ANTICIPATED AND UNANTICIPATED ANALYTICAL
AND EMPIRICAL ACTIVITIES**

PROGRAM HISTORY

- ~ 1980** **SCOPING EXPERIMENTS BEGIN IN LABS AND IN G-TUNNEL**
- 1982** **CONCEPTS FOR SUITE OF ESF TESTS**
- 1983** **EXPLORATORY SHAFT TEST PLAN (ESTP) FIRST APPEARS
IN DRAFT FORM**
- 1986** **PERFORMANCE ALLOCATION CONDUCTED. INTERNAL REVIEW
OF PLANNED TESTS**
- 1986 -
1988** **SCP WRITTEN, REVIEWED, AND ISSUED**
- 1987** **EXTERNAL REVIEW OF THE ESTP**
- 1985-
1989** **SIGNIFICANT ADDITIONS AND TURNOVER OF PERSONNEL**
- 1989 -
PRESENT** **PEER REVIEW PANEL FORMED AND REVIEWS CONDUCTED**
- 1990 -
1991** **LACK OF FUNDING LEADS TO ABSENCE OF FIELD-TEST SITE
AND STAFF TRANSFERS**
- 1991** **REVISION OF SOME TESTS FOR ALTERNATE ESF DESIGNS**

STEPS IN PERFORMANCE ALLOCATION



EXAMPLE OF THE PERFORMANCE - ALLOCATION PROCESS

- **NNWSI PROJECT ISSUE 2.4: "WILL THE REPOSITORY PRESERVE THE OPTION OF WASTE RETRIEVAL . . . ?"**
- **ISSUE- RESOLUTION STRATEGY: SHOW THAT ACCESS TO WASTE CAN BE MAINTAINED WITH NORMAL MAINTENANCE, i.e., DRIFTS ARE GENERALLY STABLE WHILE THE REPOSITORY IS HEATED BY THE WASTE**
- **MUST KNOW THE STRESS FIELD AROUND OPENINGS - PRELIMINARY ANALYSES SUGGEST STRESSES MAY BE HIGH (~50 MPa)**
- **MODULUS OF DEFORMATION FOR THE ROCK MASS MUST BE KNOWN WITH HIGH CONFIDENCE**
- **COMPLEX APPROACH TO DETERMINING MODULUS INCLUDING:**
 - **LABORATORY TESTING OF SAMPLES**
 - **PLATE BEARING TESTS**
 - **ANALYSES OF JOINTED ROCK MASS**
 - **VALIDATION EXPERIMENTS (LABORATORY & FIELD)**

PLANNING DOCUMENT HIERARCHY

SITE CHARACTERIZATION PLAN (SCP)

STUDY PLANS (SP)

EXPERIMENT PROCEDURES (EP)

TECHNICAL PROCEDURES (TD)

ROCK MECHANICS STUDIES

8.3.1.15.1.1 LABORATORY THERMAL PROPERTIES

**8.3.1.15.1.2 LABORATORY THERMAL EXPANSION
TESTING**

**8.3.1.15.1.3 LABORATORY DETERMINATION OF
MECHANICAL PROPERTIES OF
INTACT ROCK**

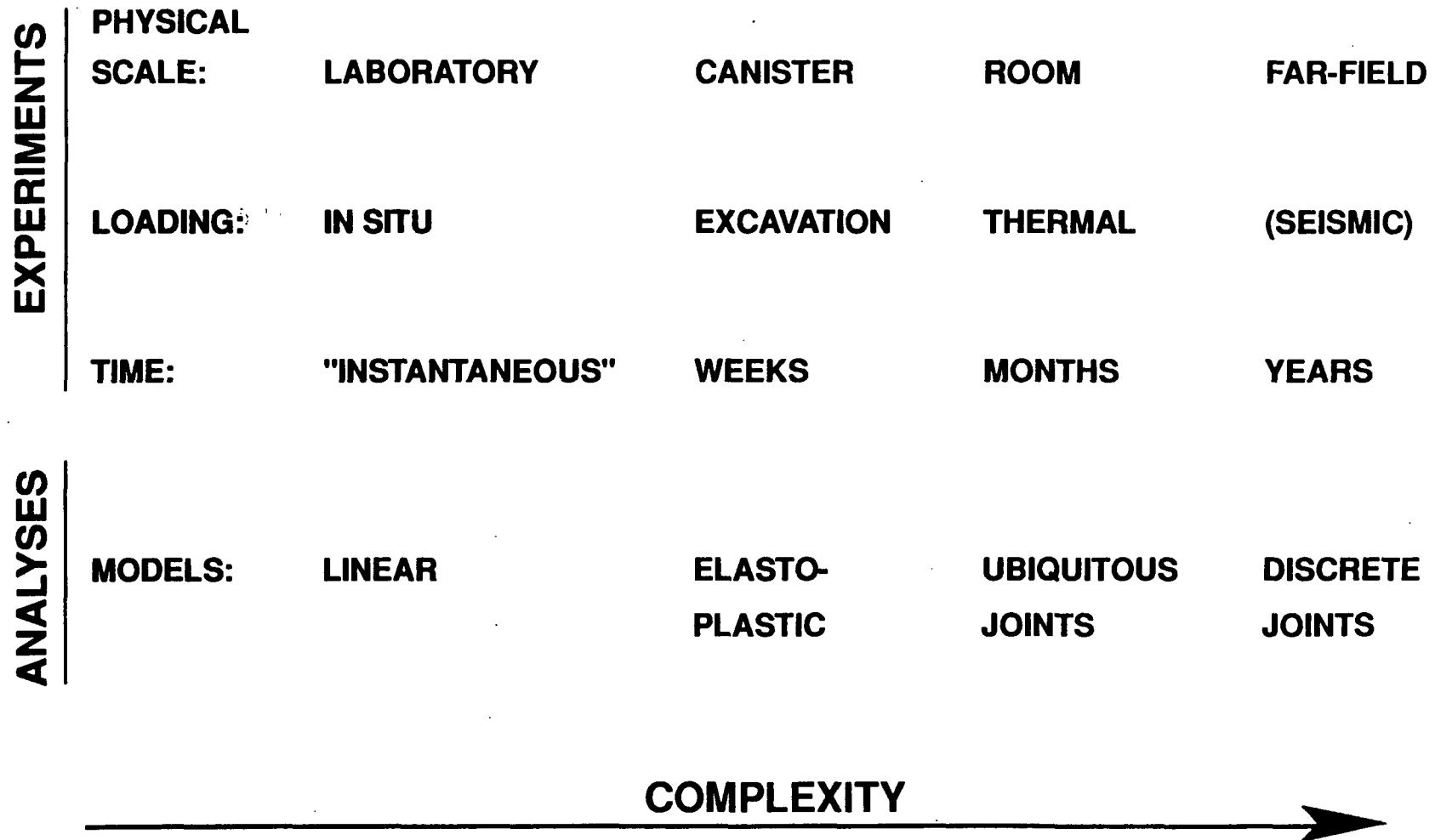
8.3.1.15.1.5 EXCAVATION INVESTIGATIONS

**8.3.1.15.1.6 IN SITU THERMOMECHANICAL
PROPERTIES**

8.3.1.15.1.7 IN SITU MECHANICAL PROPERTIES

8.3.1.15.1.8 IN SITU DESIGN VERIFICATION

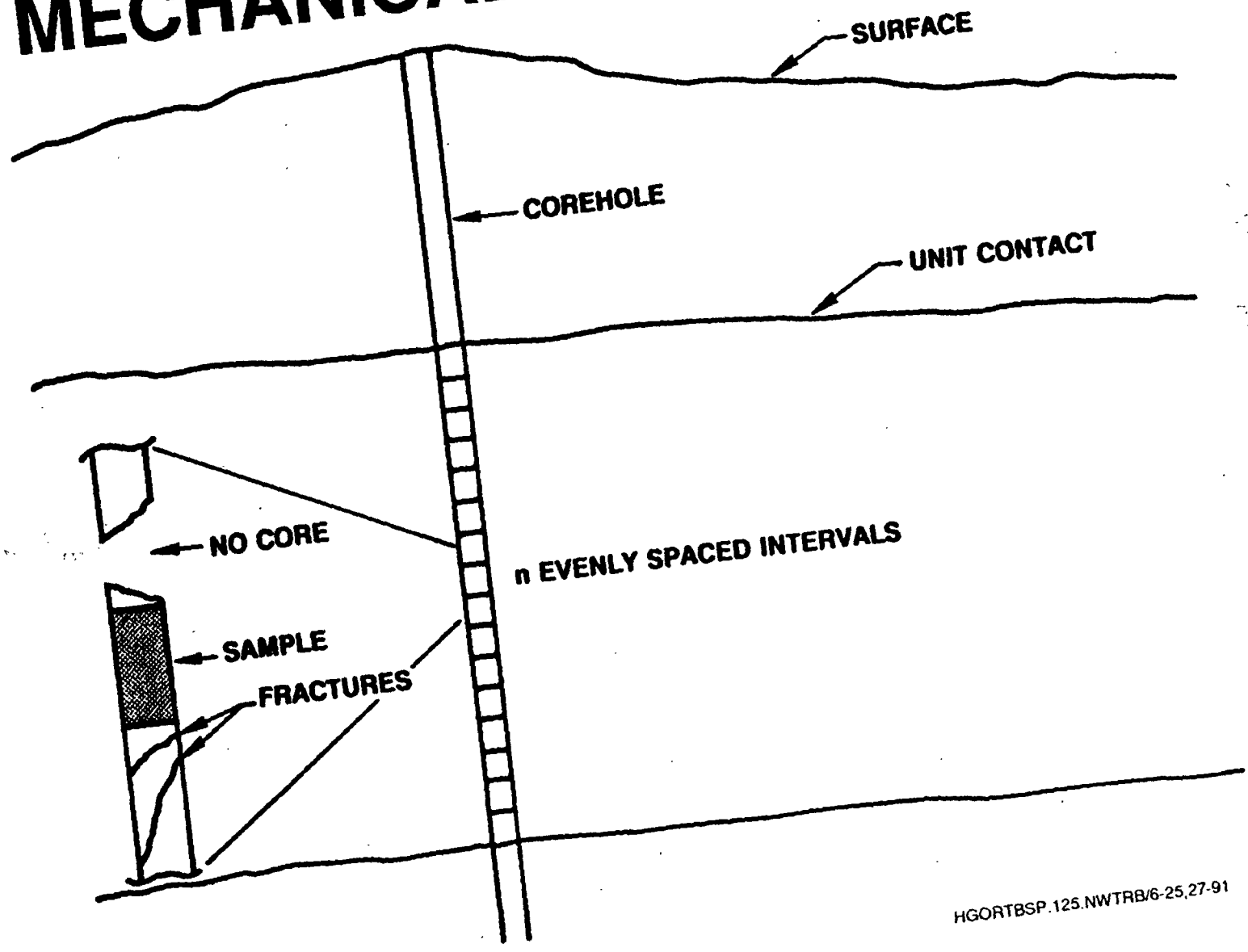
BUILDING BLOCK APPROACH

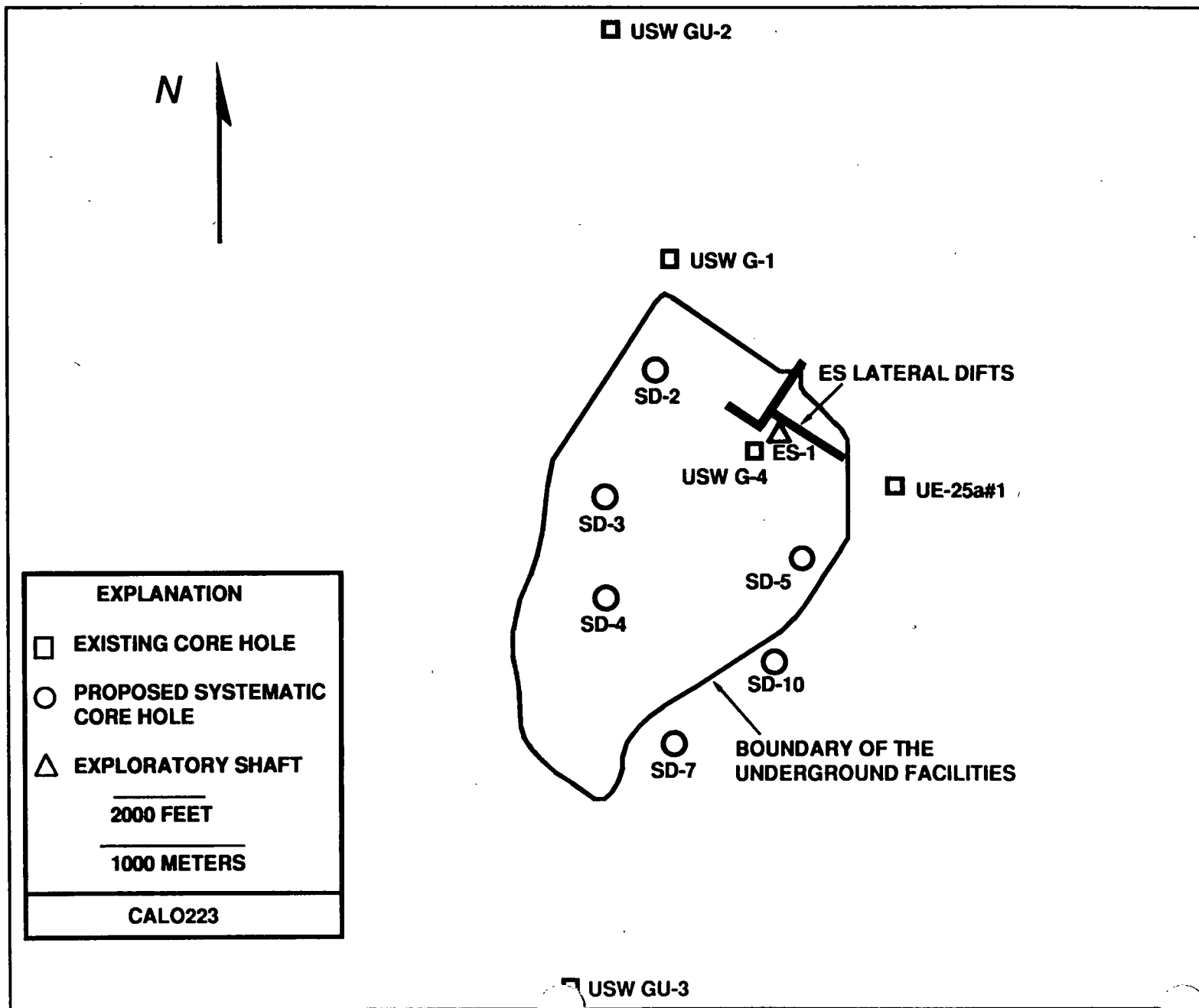


PLANNED LAB PROPERTIES TESTS

- **LABORATORY DETERMINATION OF MECHANICAL PROPERTIES OF INTACT ROCK**
 - **COMPRESSIVE MECHANICAL PROPERTIES AT BASELINE EXPERIMENT CONDITIONS**
 - **EFFECTS OF VARIABLE ENVIRONMENTAL CONDITIONS**
- **LABORATORY DETERMINATION OF MECHANICAL PROPERTIES OF FRACTURES**
 - **MECHANICAL PROPERTIES AT BASELINE EXPERIMENT CONDITIONS**
 - **EFFECTS OF VARIABLE ENVIRONMENTAL CONDITIONS**
- **LABORATORY THERMAL PROPERTIES**
 - **DENSITY AND POROSITY**
 - **VOLUMETRIC HEAT CAPACITY**
 - **THERMAL CONDUCTIVITY**
- **LABORATORY THERMAL EXPANSION TESTING**

SAMPLING FOR THERMAL AND MECHANICAL PROPERTIES





**PHOTOGRAPH OF
TRIAxIAL COMPRESSION APPARATUS**

**PHOTOGRAPH OF
SONIC VELOCITY MEASUREMENT
APPARATUS**

**PHOTOGRAPH OF
CORE SAMPLE FROM TSw1**

LABORATORY EXPERIENCE

INFORMATION FOR SOME UNITS OBTAINED ON:

- **INTACT MECHANICAL PROPERTIES**

- **COMPRESSION TESTS**
 - * **DRY AND SATURATED**
 - * **VARIOUS CONFINING PRESSURES**
 - * **STRAIN-RATE EFFECTS**
 - * **SAMPLE-SIZE EFFECTS**
- **TENSILE TESTS**

- **FRACTURE PROPERTIES**

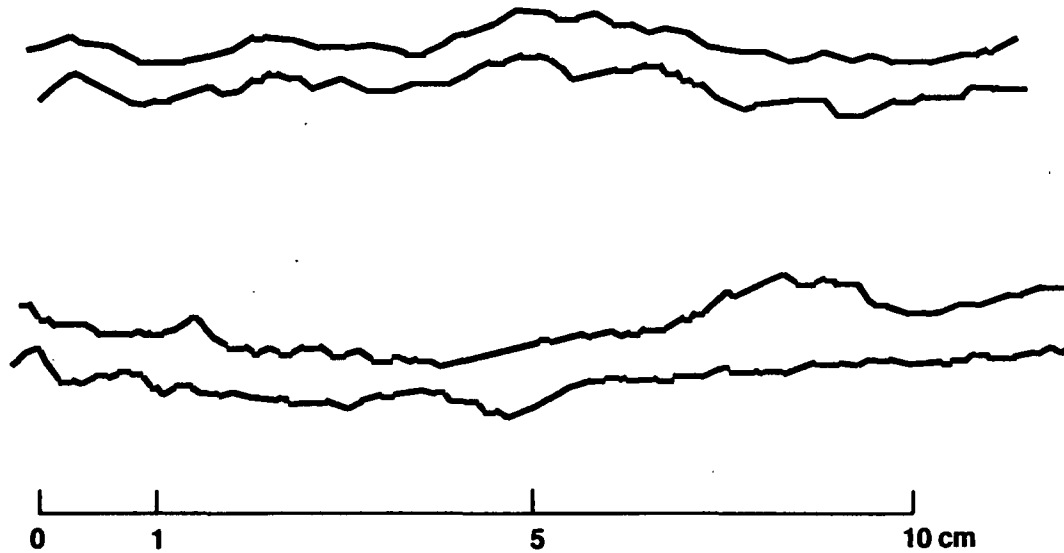
- **THERMAL EXPANSION**

- **THERMAL CONDUCTIVITY**

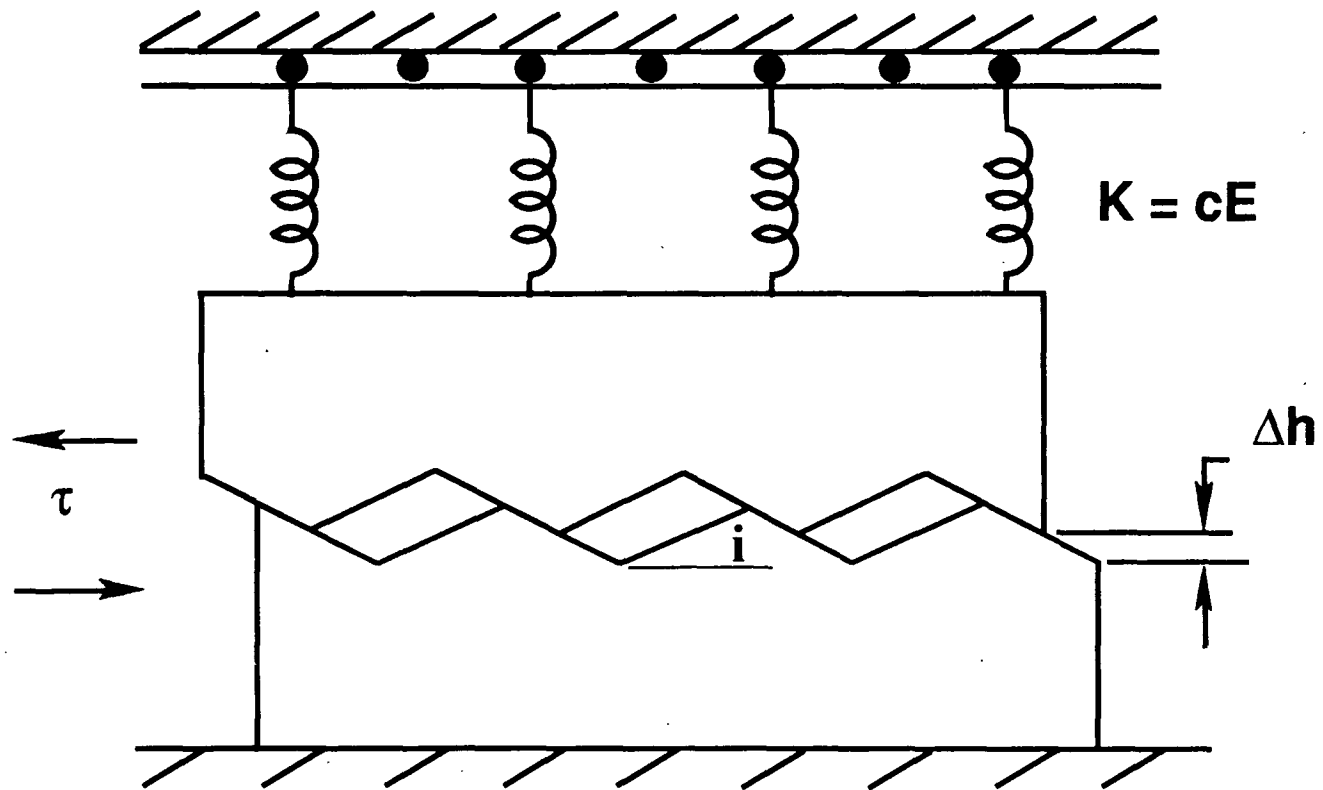
- **BULK PROPERTIES**

- **MINERALOGY AND PETROLOGY**

JOINT TRACES - WELDED TUFF TOPOPAH SPRING MEMBER

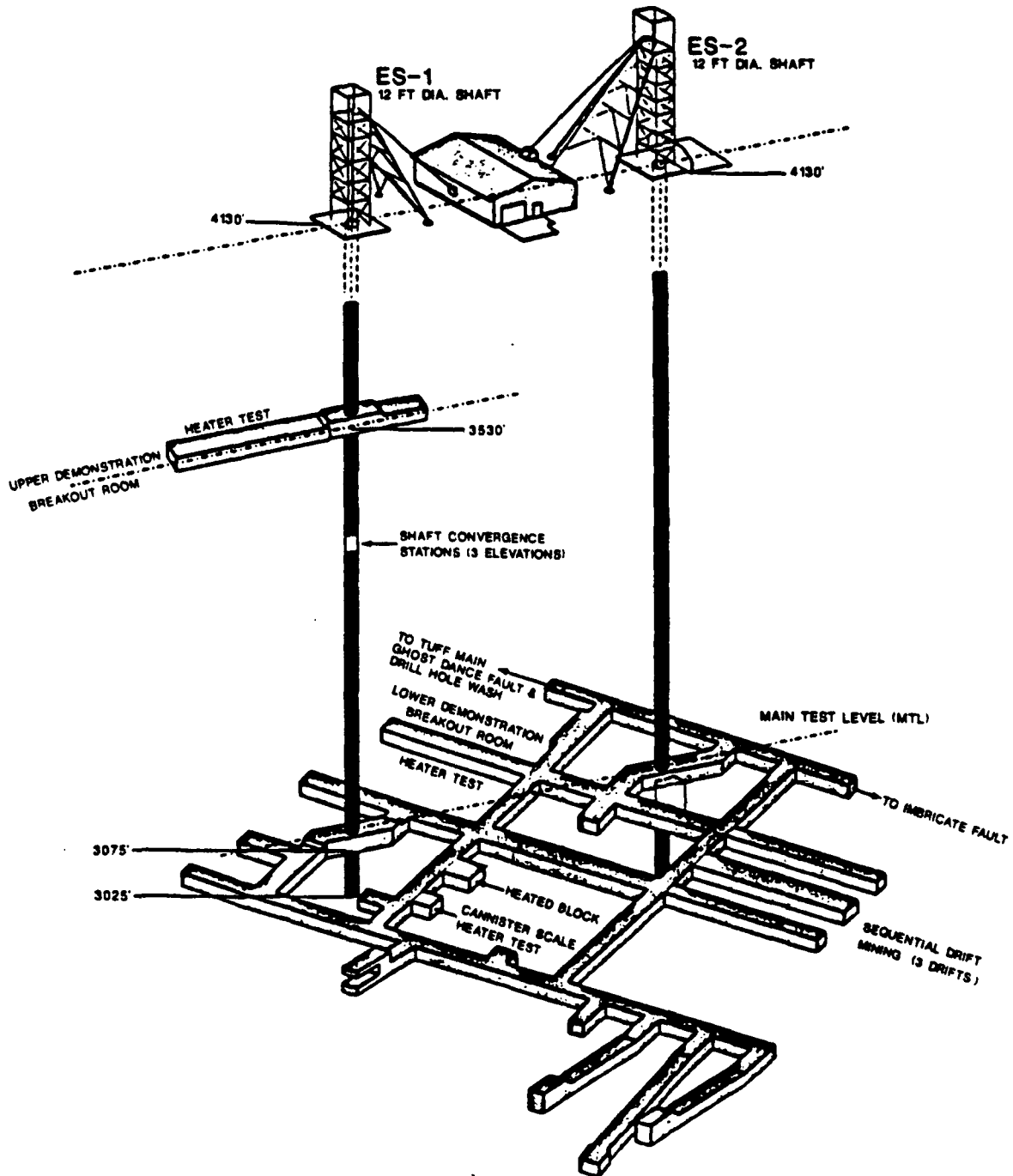


JOINT SHEAR IDEALIZATION



$$\Delta\tau = cE \Delta h \tan(\phi_\mu + i)$$

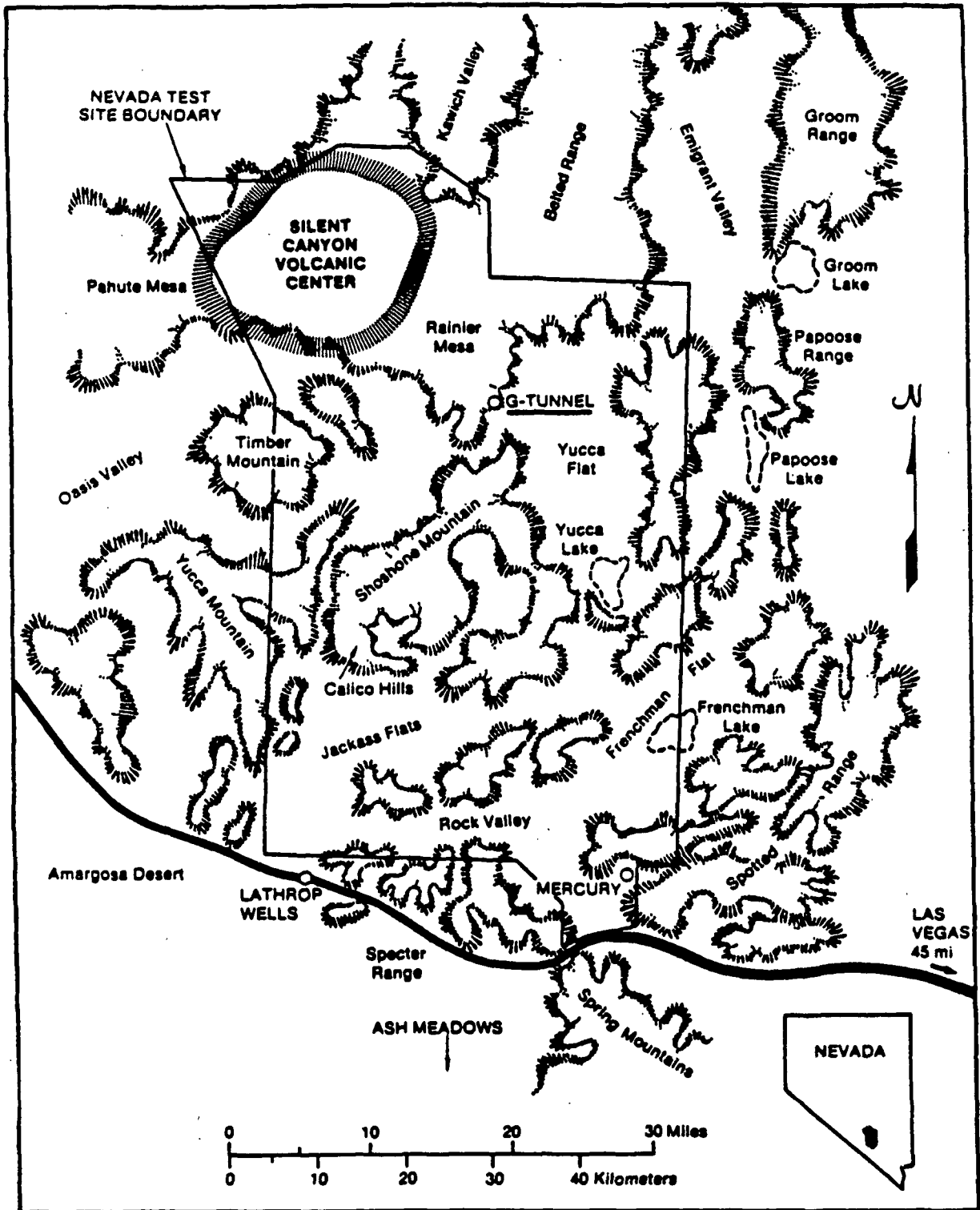
SCP ESF CONFIGURATION



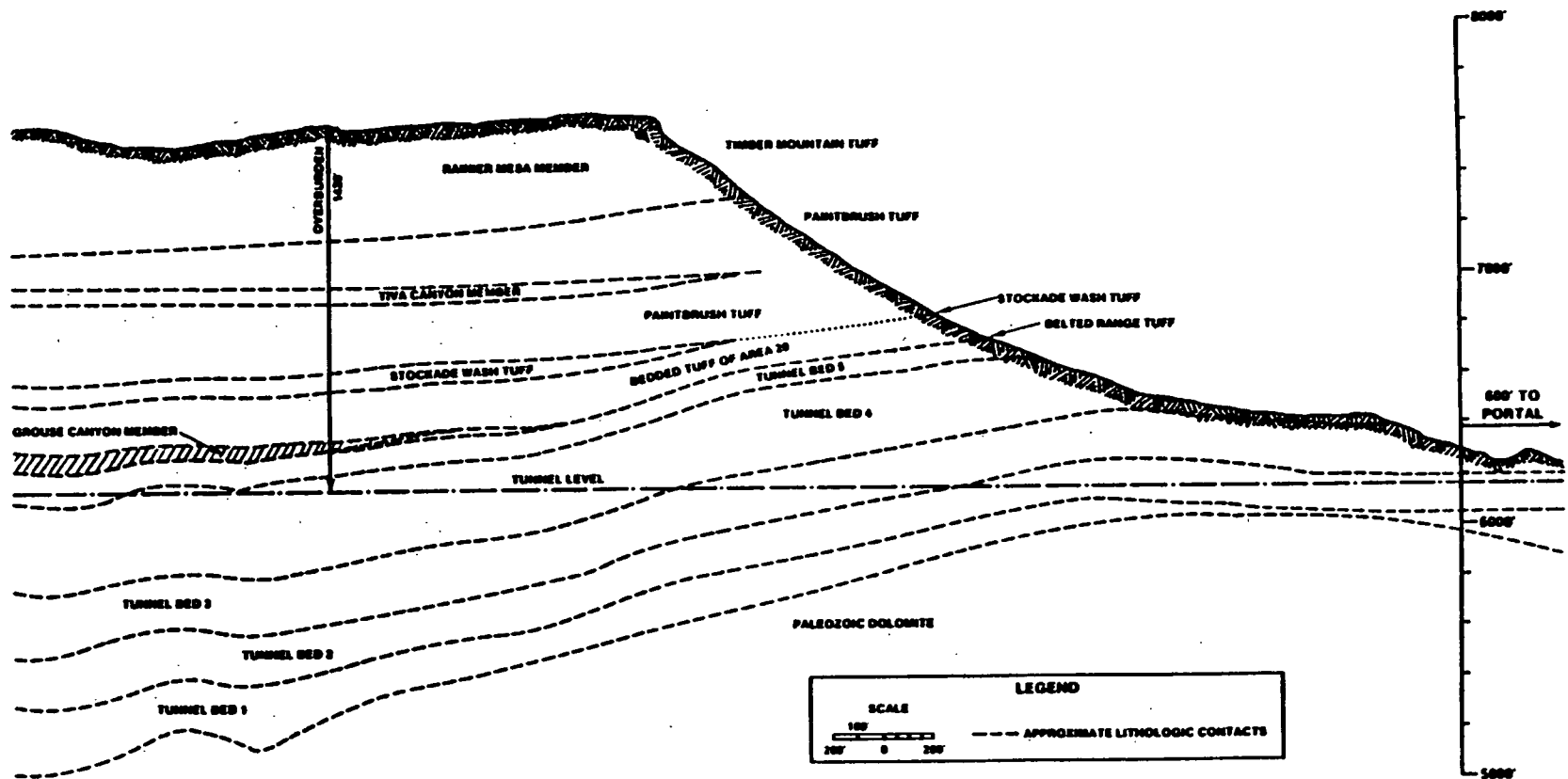
G-TUNNEL UNDERGROUND FACILITY (GTUF)

- **LOCATED ABOUT 25 MILES FROM YUCCA MOUNTAIN**
- **PROVIDED ACCESS TO A THIN UNIT OF WELDED TUFF**
- **OVERBURDEN (~1400 FT) SIMILAR TO YUCCA MOUNTAIN**
- **ABOVE THE WATER TABLE**
- **PROVIDED SUFFICIENT UNDERGROUND OPENINGS FOR
MANY EXPERIMENTS**
- **PROVIDED READILY AVAILABLE NTS SUPPORT**

NEVADA TEST SITE



CROSS-SECTION OF RAINIER MESA



**PHOTOGRAPH OF
DEMONSTRATION DRIFT IN G-TUNNEL**

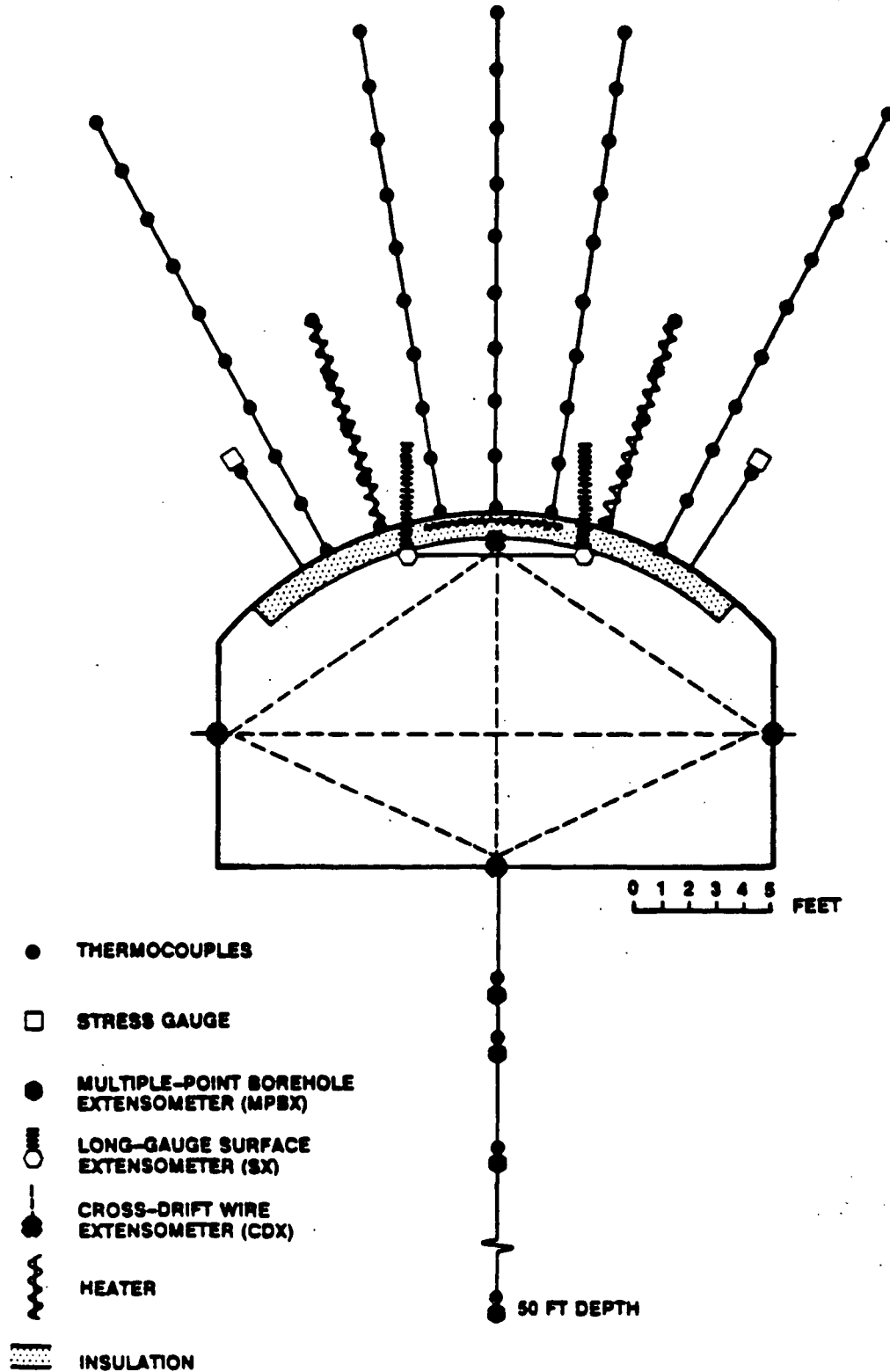
G-TUNNEL EXPERIENCE

- **HEATER TESTS IN WELDED AND NONWELDED TUFFS**
- **HEATED BLOCK EXPERIMENT**
- **MINING EVALUATIONS (MINE-BY)**
- **SLOT TESTS**
- **STRESS MEASUREMENTS**
- **EQUIPMENT AND INSTRUMENT EVALUATION**

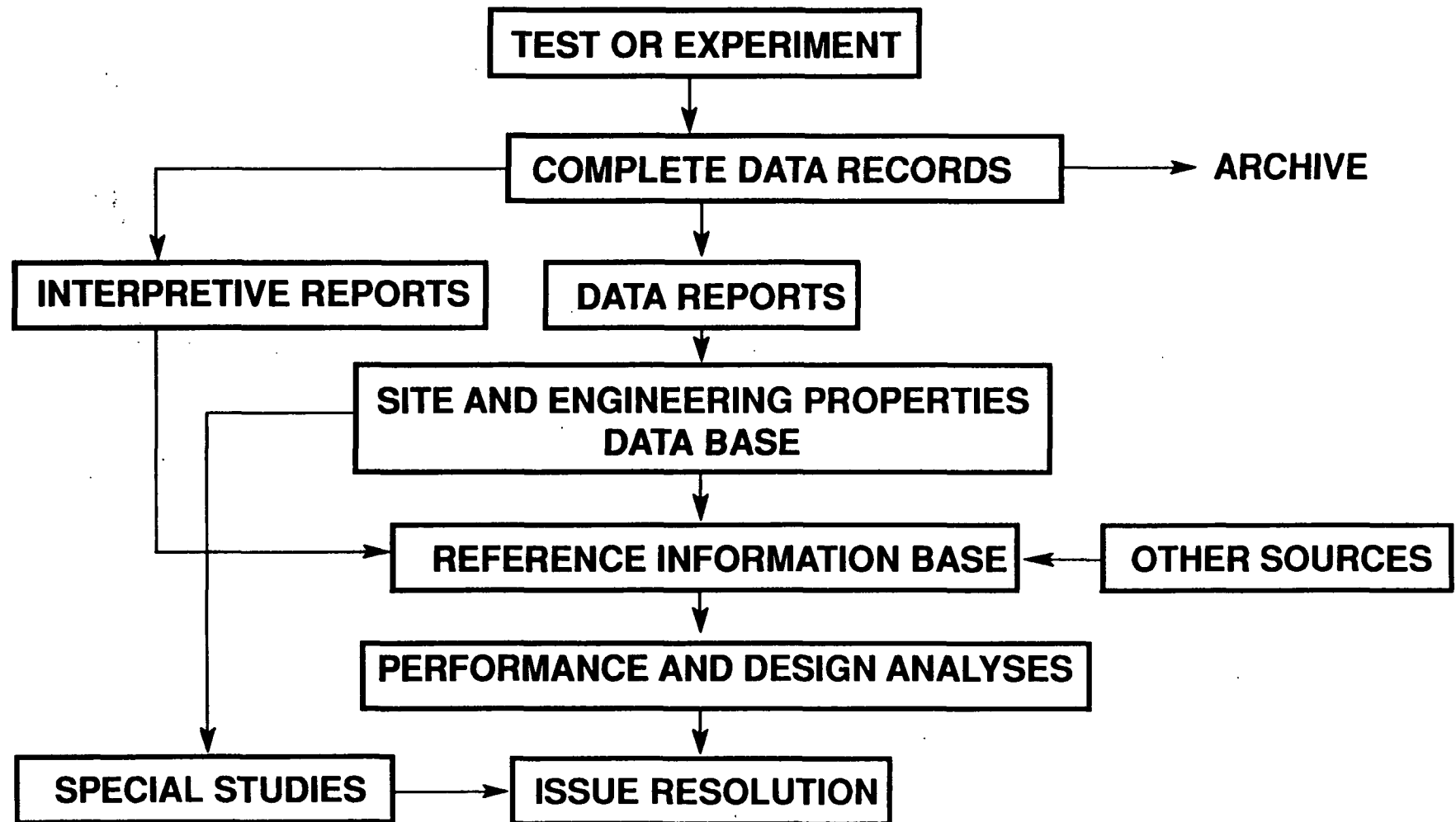
**PHOTOGRAPH OF
G-TUNNEL HEATED BLOCK
EXPERIMENT**

**PHOTOGRAPH
G-TUNNEL SLOT TEST**

SCHEMATIC OF THERMAL STRESS TEST



FLOW OF DATA



ROCK MECHANICS REVIEW PANEL

- DICK BIENIAWSKI - PENN STATE UNIVERSITY**
- STEVE CROUCH - UNIVERSITY OF MINNESOTA**
- HOWARD PINCUS - CONSULTANT**
- JIM RUSSELL - TEXAS A&M UNIVERSITY**
- CHRIS SCHOLZ - LAMONT-DOHERTY
GEOLOGICAL
OBSERVATORY**
- HANS SWOLFS - USGS**

EQUIPMENT AND INSTRUMENT DEVELOPMENT AND EVALUATION

- **CHAIN SAWS**
- **HIGH-PRESSURE FLATJACKS**
- **IMPRESSION FLATJACK**
- **MULTI-POINT BOREHOLE EXTENSOMETER
(MPBX)**
- **DATA ACQUISITION SYSTEM**
- **LASER INTERFEROMETER FOR DRIFT/SHAFT
CONVERGENCE**

**PHOTOGRAPH OF
ROCK CUTTING CHAIN SAW**

1989 VIEW OF NEAR-TERM FIELD ACTIVITIES

- **PROTOTYPE THERMAL STRESS EXPERIMENT**
- **SCOPING ROCK-MASS "STRENGTH" TESTS**
- **EQUIPMENT AND INSTRUMENT CHECKOUT**
- **UNHEATED BLOCK**