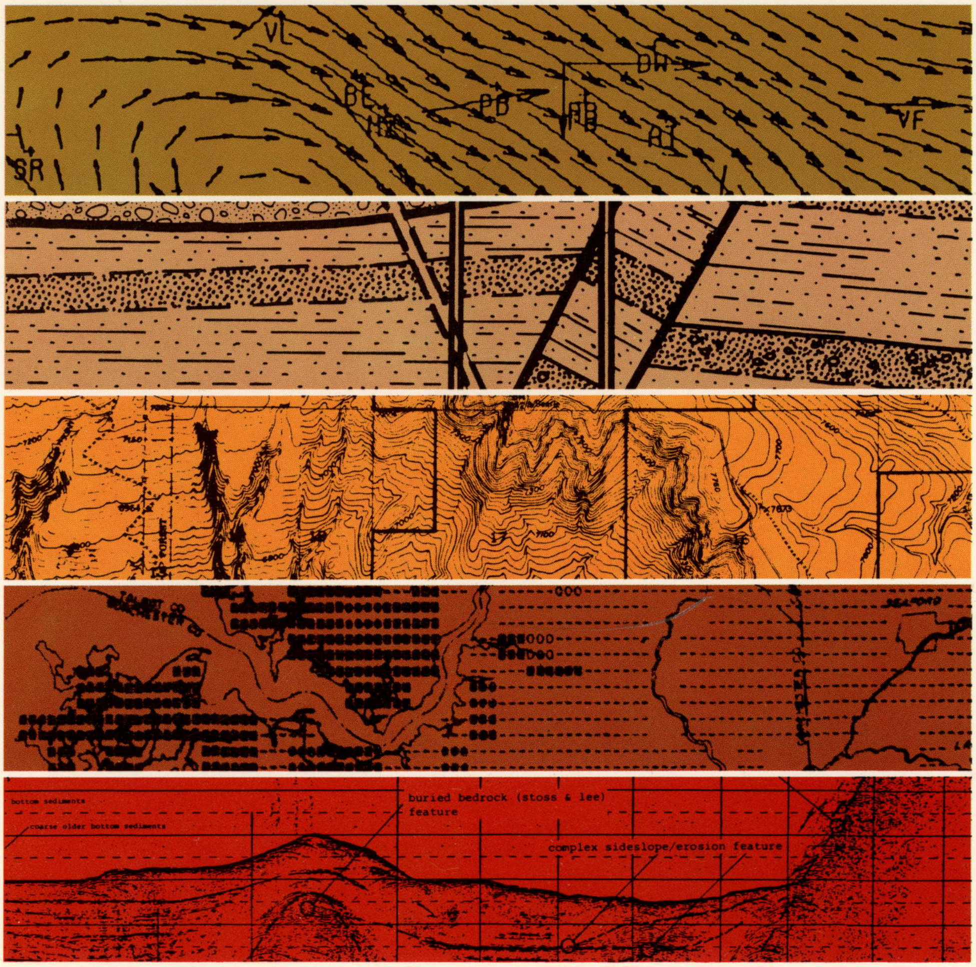
DAMES & MOORE JOB NO. 6701-023-06
SALT LAKE CITY, UTAH
March 17, 1982

REPORT
ENGINEERING GEOLOGY CONSULTATION
LANDSLIDE EVALUATION
SUFCO MINE
NEAR SALINA, UTAH
FOR COASTAL STATES ENERGY COMPANY

Dames & Moore

ACT/041/002



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March 17, 1982

Southern Utah Fuel Company
Highway 89 South
Salina, Utah 84654

Attention: Mr. Kerry A. Frame,
Chief Engineer

Gentlemen:

Report
Engineering Geology Consultation
Landslide Evaluation
SUFCO Mine
Near Salina, Utah
For Coastal States Energy Company

INTRODUCTION

Presented in this report are the results of our engineering geology consultation/landslide evaluation conducted at the SUFCO Mine near Salina, Utah. The mine site is shown on Plate 1, Vicinity Map. A landslide occurred on the afternoon of Friday, March 5, 1981. On March 9, Mr. Ken Payne of Southern Utah Fuel Company contacted us, requesting that this evaluation be performed. An engineering geologist from our office visited the site on March 10 and met Mr. Payne and Mr. Kerry Frame of SUFCO.

SUMMARY

A landslide occurred at the SUFCO Mine on Friday, March 5, 1982. The slide was first noticed when buried water lines broke releasing a large volume of water. The landslide occurred directly above the main entry and encompassed the electric substation. This slide is in the same area of, and extends uphill from, "Slide Area B" identified in our report dated May 2, 1975.[1]

[1] Dames & Moore report titled, "Slope Stability of Proposed Mine Portal Site, SUFCO Coal Mine at Convulsion Canyon, Sevier County, Utah, for Coastal States Energy Company," dated May 2, 1975, Job No. 6701-001-06.

On the basis of our site visit on March 10, 1982, it is our opinion that the main entry is not threatened but continued movement of the slope could interrupt electric service by tilting the substation out of tolerance limits.

We recommend that the slope and the existing retaining walls around the main entry be monitored to permit detection of increased rates of movement. We also recommend that immediate actions be taken to 1) fill depressions and cracks, 2) promote positive surface drainage, 3) try to dewater the slope by drilling holes into the roof of the main entry, and 4) restring overhead power lines which have been stretched by landslide movement.

Long-term action could include 1) relocating the buried water lines and 2) constructing a crib wall adjacent to the south side of the main entry.

PURPOSE AND SCOPE

The purpose of our consultation was to assess the nature of the landslide and to formulate remedial measures. The purpose and scope of this consultation were developed in response to an initial telephone conversation between Mr. Payne of SUFCO and Mr. Bill Gordon of Dames & Moore. Our scope consisted of 1) examining the landslide and mapping pertinent features, 2) interviewing mine personnel regarding the history of the slide, and 3) preparing this summary report.

SITE CONDITIONS

GENERAL

The site of the SUFCO Mine is located in sedimentary rocks consisting of sandstone, siltstone, claystone and coal of the Blackhawk Formation of Cretaceous age (approximately 100 million years old). The rocks are nearly flat-lying, dipping about 2 degrees to the northwest. Prominent canyons have been cut into these rocks.

The bedrock in the vicinity of the mine is covered in most places by up to 15 feet of surficial material (colluvial deposits) consisting of boulders and blocks of sandstone in a matrix of clayey and silty sand. In addition, fill soils have been placed by conventional "sidehill" construction methods adjacent to most cut areas.

The major facilities at the mine include mine mouth facilities (shop and warehouse, office and bathhouse, stacker and loader), mine entries, a 25 KV electric substation, and surface and buried utilities. Locations of most of these facilities are shown on Plate 2, Map of Landslide Features (March 10, 1982).

An abandoned entry exists between the main entry and the conveyor entry. The abandoned entry has been closed and a concrete retaining wall has been constructed across the portal. Three or four years ago, the abandoned entry caved in about 50 feet northwest of the existing substation. The abandoned entry was then supported by timber cribbing and the surface cavity was filled with soil and rock material. The cribbing was inspected on March 8, 1982 by SUFCO personnel and found to be providing adequate support for the abandoned entry roof.

LANDSLIDE DESCRIPTION

Key features of the landslide as of March 10 are shown on Plate 2. Sections through the slide are presented on Plate 3, Cross-Sections.

The landslide was first noticed Friday afternoon, March 5, because a large volume of water appeared around the entries of the mine. The water was found to be coming from two buried pipes about 55 feet above the entry elevation in the vicinity of the electric substation. The two water lines (4-inch and 6-inch diameters) separated at joints in the pipes between concrete thrust blocks inside the fenced area surrounding the substation. The 6-inch line also separated at a bell joint 10 to 15 feet farther south.

The 6-inch line is used to convey water from a spring near the bottom of Convulsion Canyon to a 10,000-gallon tank above the substation. At the time of the slide, the 6-inch line was flowing about 0.25 cubic feet per second (about 130 gallons per minute).

The 4-inch line is the supply from the tank to the bathhouse. Most of the water in the tank at the time the 4-inch line broke probably drained into the slope.

At the southern break, the water from the 6-inch line apparently went directly into the subsurface. At the northern break, the water from the pipes welled up out of the ground. The water ran about 20 feet to the west where it disappeared into the slope. It emerged at two locations about 50 feet to the west and 20 to 25 feet lower in elevation. The water flowed on the surface to the retaining wall and onto the working area below.

As the water emerged on the slope it carried soil particles from the point of emergence, creating subsurface tunnels (piping). Approximately midway between the point of emergence and the source of the water the slope above a tunnel collapsed, forming a 4-foot deep depression.

The water was shut off in both water lines within several hours after the breaks were noticed. The lines were repaired Saturday morning. At the time of our reconnaissance, zones of seepage were observed only in the vicinity of the main entry and north corner of the office building, as shown on Plate 2.

Surface cracking was observed at many locations between the main entry and the substation. The headscarp of the landslide extends for about 300 feet and passes about 20 feet east (uphill) of the substation. The maximum displacement at the headscarp at the time of our site visit was about 12 inches horizontal and 12 inches vertical at a location about 30 feet northeast of the substation. Displacements at the headscarp to the north and to the south of this point decrease until the scarp is no longer visible on the slope.

Minor surface cracking is present on the graded substation pad. The most prominent surface cracking, other than the main headscarp, is located over the main entry generally below an elevation of 7,600 feet. The surface cracking is located in the same area as the seepage zones mentioned above.

The slope adjacent to the south side of the main entry was actively sloughing during our reconnaissance. Water was ponded at the top of the retaining wall adjacent to the north side of the main entry and seeping from a construction joint near the bottom of the wall.

The concrete slab supporting the substation dropped 5-1/2 to 9 inches and the tension increased in the electric wires crossing the headscarp. A 3-1/2-foot high retaining wall adjacent to the south side of the main entry has rotated out about 1/2 inch. No damage has occurred to the main entry or to the conveyor entry and no seepage was observed in the roof of either entry.

A small landslide also occurred about 150 feet southeast of the main entry (about 50 feet northeast of the east corner of the office and bathhouse). This slide is about 50 feet across at the head and 40 feet long. The slide is thin and the toe is about at the midpoint of the slope, as shown on Section C on Plate 3. Water was seeping from the toe at the time of our reconnaissance.

DISCUSSION AND RECOMMENDATIONS

GENERAL

The following discussions are based on the observations documented above. It should be emphasized that no subsurface investigation or laboratory testing were performed in conjunction with this consultation. The remaining subsections of this report pertain to the probable cause of the landslide, the key aspects of the landslide, the consequences of continued movement, recommended immediate actions and recommended long-term actions.

PROBABLE CAUSE OF LANDSLIDE

We believe that the initial cause of landslide movement was related simply to infiltration of snowmelt causing increased weight of soil above and loss of soil strength at incipient failure planes. It is also possible that an undetected leak in the buried water pipes was contributing to initiation of failure. The initial movement was likely similar or smaller in magnitude to the small slide east of the office and bathhouse. The initial movement, however, was sufficient to separate buried water lines flooding the slope system with water. The addition of possibly 10,000 gallons of water then caused additional movement in the lower third or half of the slope.

KEY ASPECTS OF LANDSLIDE

Several aspects of the landslide are noteworthy with respect to recommended actions to correct or mitigate the landslide effects. The first is the segmented nature of the landslide movement. The main headscarp dies out about 150 feet northwest and 150 feet southwest of the point of maximum displacement. Surface cracking is not observable near the ends of the main headscarp, indicating that the slope did not move as a coherent block.

Most of the movement on the slope is concentrated on the lower third of the slope above the main entry. Subsurface water appeared to be concentrated in this part of the slope and the slope was actively sloughing during our reconnaissance. Continued movement of the lower part of the slope will tend to remove support from the upper part. lower slope still moving

Depressions and cavities caused by the landslide movement, especially the cavities caused by subsurface piping, provide direct conduits for surface water to enter the subsurface. Subsurface water tends to add weight and decrease the effective strength of the slope materials, thereby reducing the overall stability of the slope.

Water ponding at the top of the retaining wall is also significantly increasing the lateral active pressure acting on the wall. This existing pressure is probably significantly higher than the wall was designed to support. Surface water entering the substation pad tends to become ponded on the pad rather than to flow in a positive manner across it.

CONSEQUENCES OF CONTINUED MOVEMENT

The main entry does not appear to be significantly threatened by the landslide. No evidence was observed to suggest that the roof is taking additional weight. The retaining walls on both sides of the entry appear to be performing well; however, the presence of water at the top of the wall is very undesirable and could lead to severe difficulties and ultimate failure of the wall.

The substation clearly has the greatest risk of damage associated with continued movement of the landslide. The movements that occurred up to the time of our site visit were apparently within the tolerance limits of the equipment. Some power lines have been stretched very tightly but have not interrupted electric service to the mine. It is possible that continued movement of the slide could rotate the equipment to the point where service would be interrupted. We believe that it is doubtful that continued landslide movement could "break up" or cause the equipment to become unusable. If the tolerance limits were exceeded, we believe that the equipment could be releveled or moved to a level site and reconnected to provide the same electric service now being provided. Move it??

Continued ravelling of the slope adjacent to the south side of the main entry will cause debris to accumulate on the working surface at the base of the wall. We believe that the material will be primarily a nuisance and can be cleared up as quickly as it accumulates. However, continued movement of this part of the slope tends to remove support from the slope above, which can cause a progressive failure.

RECOMMENDED IMMEDIATE ACTIONS

We recommend that six actions be taken immediately. Two of these actions are monitoring and will help in making decisions if conditions appear to become worse. Three of these actions are related to minimizing the inflow of surface water or providing a means for draining subsurface waters. The sixth action pertains to immediate performance of the substation.

MONITOR SLOPE

Monitoring of slope movements at several places across the main headscarp in the vicinity of the substation began the day before our field visit. This monitoring is being done simply by measuring the distance between steel pins set on opposite sides of the headscarp. We recommend that these distances be measured and plotted daily at least until substantial drying of the slope has occurred, probably late May or early June.

If the distances between pins remain the same or increase only a small amount during the period, the measurements can be made on a weekly or monthly basis until next winter when additional water will likely be introduced into the slope. If the distances between pins increase at an increasing rate, we should be notified as soon as possible to reassess the slope conditions.

MONITOR WALL

We recommend that a system be established for monitoring movements of the retaining wall adjacent to the main entry. Failure of this wall could severely interrupt operation of the mine. A simple monitoring system could consist of reference marks on the top of the wall about 20 feet apart and a stable bench mark at a convenient location across the working surface from the main entry. Relative locations of the reference marks should be recorded and plotted once or twice per week in a manner similar to the slope monitoring system.

FILL DEPRESSIONS AND CRACKS

We recommend that all surface depressions and open cracks be filled to minimize direct inflow of surface water to the subsurface. Where the cracks and depressions are easily accessible by equipment, we recommend that they be wheel-rolled or track-rolled. Care should be taken to maintain the slope monitoring pins while the depressions are being filled.

Where the cracks are not accessible, we recommend that they be covered with plastic sheeting. The plastic must be weighted or fastened to the slope so that it will not be destroyed by strong winds.

PROMOTE POSITIVE DRAINAGE

Surface water should not be permitted to pond at any place on the substation pad or at the tops of retaining walls. Drainage on the substation pad could be improved by reestablishing a minimum gradient of two percent. Alternatively, surface water could be collected at several locations and conveyed to the bottom of the slope in corrugated metal pipes securely fastened to the slope. An engineering hydrology study would be needed to provide a basis for selecting pipe sizes.

At the tops of retaining walls, surface water should be collected in shallow ditches lined with continuous plastic sheeting, backfilled with free-draining gravel material and perforated plastic pipe. The ditches should be on the order of one foot deep and one foot wide and sloped to drain by gravity to a convenient location. A hole should be drilled in the wall at the low point of each ditch to permit water to drain. The plastic pipe should be 1- to 2-inches in diameter and slotted at 1-foot intervals. A sketch of the recommended ditch system is presented on Plate 4.

DEWATER SLOPE

The slope adjacent to the south side of the main entry is actively sloughing apparently due to seepage of subsurface water. We believe that most of the slope movement is confined to the zone of surficial material overlying bedrock. The clayey nature of the surficial material suggests that drainage of the subsurface water will not occur readily. However, we understand that it is relatively simple and inexpensive for SUFCO to have a few holes drilled with a jackleg. Therefore, we recommend that an attempt be made to dewater the slope using this method.

The holes should be drilled into the roof of the main entry beginning behind the lined section of the entry and extending as much as 150 feet to the northeast. The substation is above the main entry about 150 feet from the portal. We suggest that three holes be drilled in the roof in a "fan" pattern at about 10-foot intervals. We also suggest that the holes be drilled to within about 5 feet of the surface. Therefore, the holes should range in length from about 10 to about 40 feet.

SUBSTATION PERFORMANCE

As previously discussed, it is our opinion that the substation equipment would not be destroyed by continued landslide movement. However, some overhead wires have been stretched very tightly by the slope movement. We recommend that these wires be restrung in a slack condition as soon as possible so that electric service will not be interrupted by broken wires.

RECOMMENDED LONG-TERM ACTIONS

For uninterrupted operation of the mine, it is essential to protect the main entry and the electric substation. Since the landslide appears to be shallow and the entry roof does not appear to be taking weight, the main entry does not appear to be in danger. To reduce the risk of ravelling material falling into the mouth of the main entry, the lined section of the entry could be extended a few feet to the southwest into the working area. Extend Portal

The slope on which the electric substation is located has moved in a complex manner. Movement of the slope adjacent to the south side of the main entry will continue to remove support from the segment of the slope where the substation is located. This slope cannot be flattened because support for the slope above would be removed. Therefore, we recommend that the slope adjacent to the south side of the main entry be supported by a crib wall. The wall should be about 50 feet long and about 20 feet high. The crib construction could be timber, steel or concrete, whichever is more cheaply available at the mine. It is very important that free-draining material be used for backfill.

A temporary excavation will be required for construction of the wall; therefore, the wall should be built in the late summer or fall when water in the slope is at a minimum. We would be pleased to provide more specific recommendations for design of the crib wall; however, we would need more detailed topographic information (1 inch = 10 feet) in order to do so.

The influence of water on the stability of the slope is very clear. The initial cause of the slope problems could have been seepage from snowmelt; alternatively, an undetected minor leak from one of the buried water pipes could have been the initial cause.

Considering the importance of the substation to the operation of the mine and the relative cost of relocating the substation, relocation of the water lines might be warranted. Such a relocation would remove the water lines from the vicinity of the substation and significantly decrease the risk of renewed slope movement.

A possible relocation alignment could be near the south side of the new shop and warehouse. About 260 feet of new pipe would be required for each of the water lines but much of the existing lines probably could be reutilized.

DRAINAGE DEVICES

Many slope problems are caused by uncontrolled or partially controlled surface drainage. It is a common practice to collect surface water along a roadway or building pad and convey it to the nearest free face. The water is usually conveyed in a corrugated metal pipe for a few feet and then discharged onto the slope.

Prominent erosion gullies commonly lead from the point on the slope where the discharged water first strikes the slope to the stream channel at the bottom of the slope. Eventually, the gully head progresses upslope and part of the road surface or building pad fails into the gully.

Gullies below drainage devices can be minimized by extending the pipes to the stream channels at the bottoms of the slopes. An economical alternative to extending the pipe is to attach durable fabric sleeves to the ends of the steel pipes. The sleeves clamp onto the pipes and extend to the bottoms of the slopes and prevent discharge water from eroding gullies.

We recommend that these fabric sleeves be considered for use on all drainage devices at the mine and along the access road.

o0o

We trust that this report is sufficient for your present needs. If you have any questions, please contact us. The following are attached and complete this report:

Plate 1 - Vicinity Map
Plate 2 - Map of Landslide Features (March 10, 1982)
Plate 3 - Cross Sections
Plate 4 - Sketch of recommended ditch system at top of retaining wall

Very truly yours,

DAMES & MOORE

William J. Gordon
Partner
Professional Engineer No. 3457
State of Utah

Jeffrey R. Keaton
Engineering Geologist

WJG/JRK:si
6 Copies Submitted

REVISIONS
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Costal States
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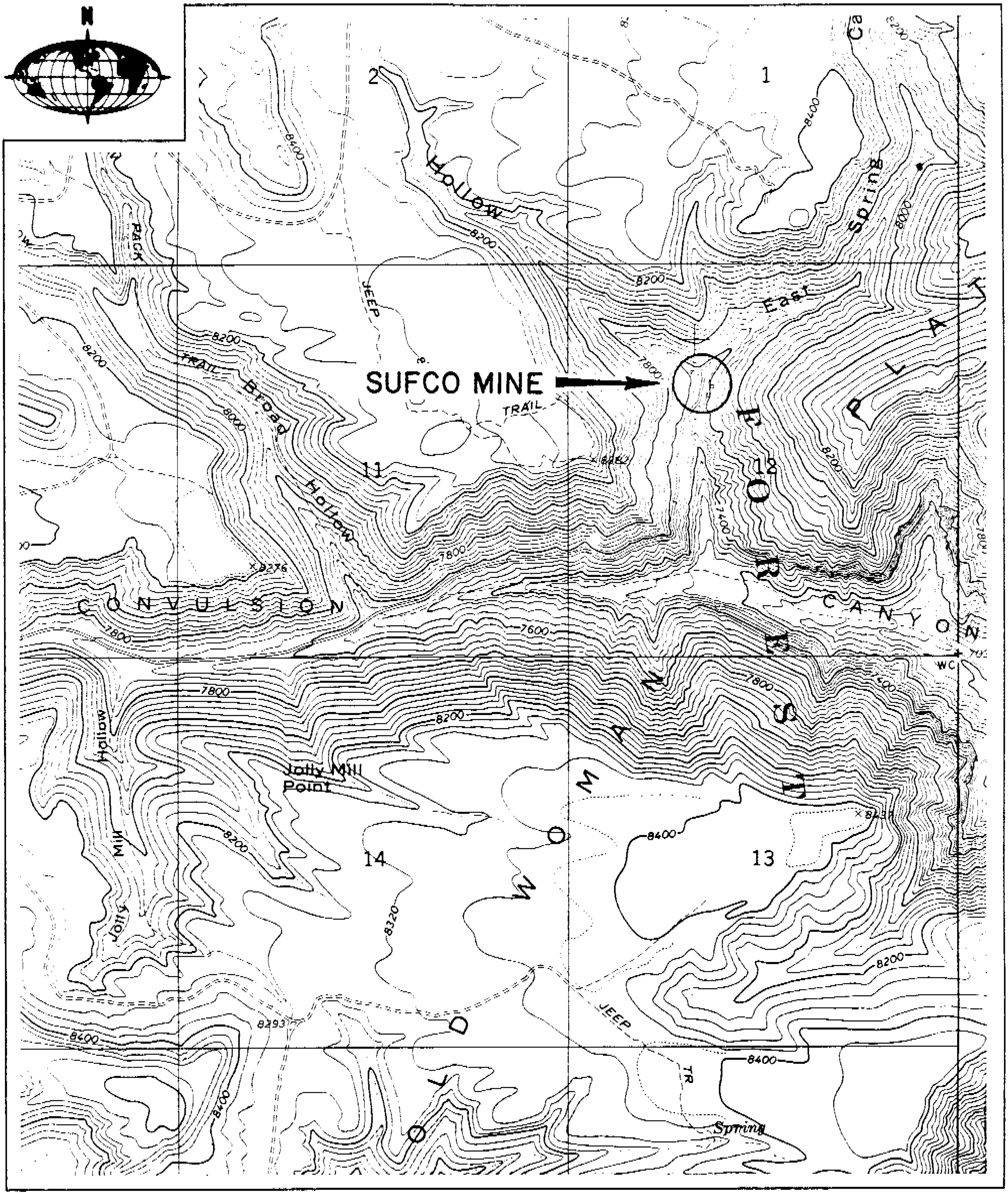

SCALE IN FEET
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VICINITY MAP

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"ACORD LAKES, UTAH" – 1968.

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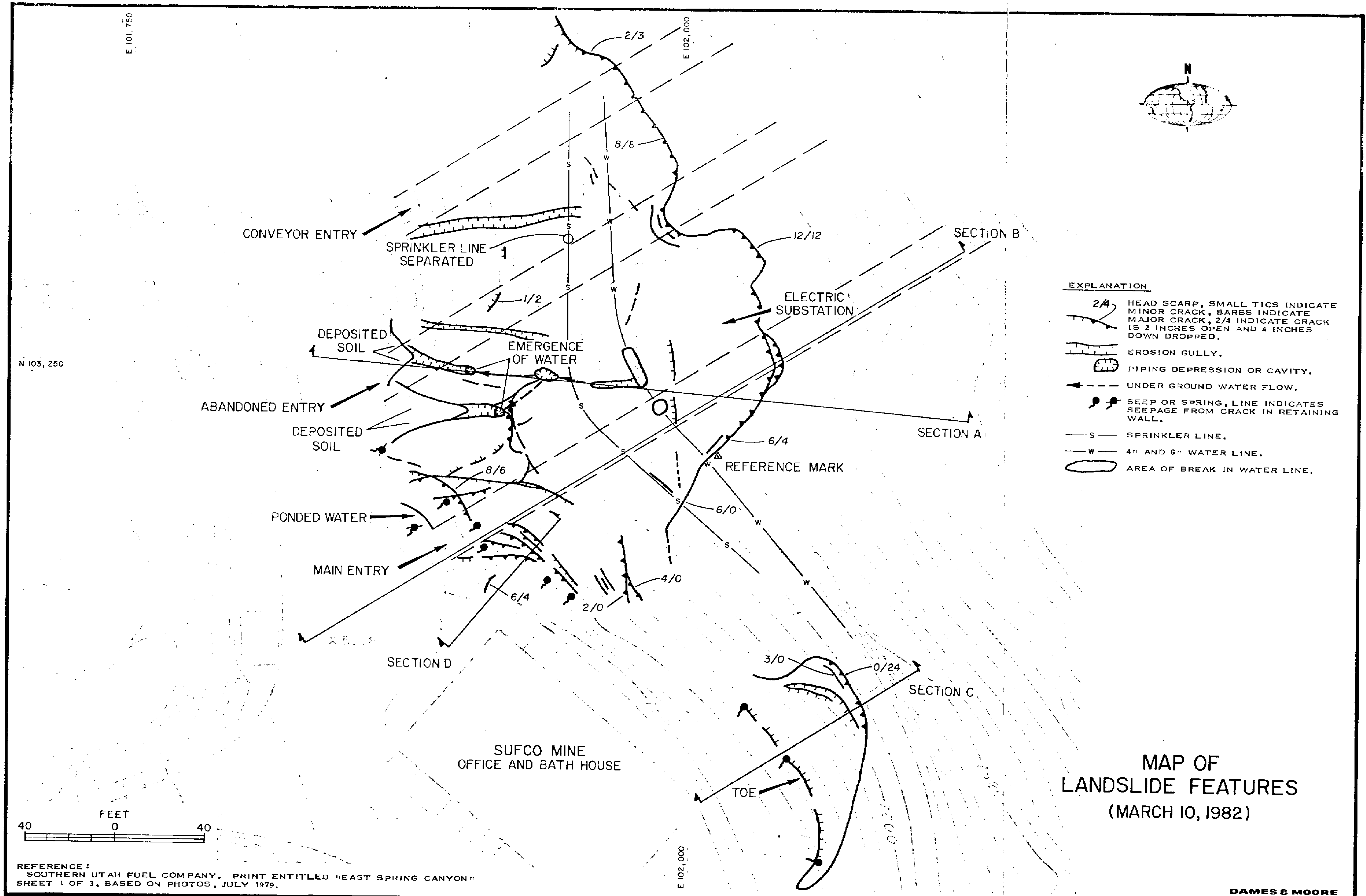
PLATE I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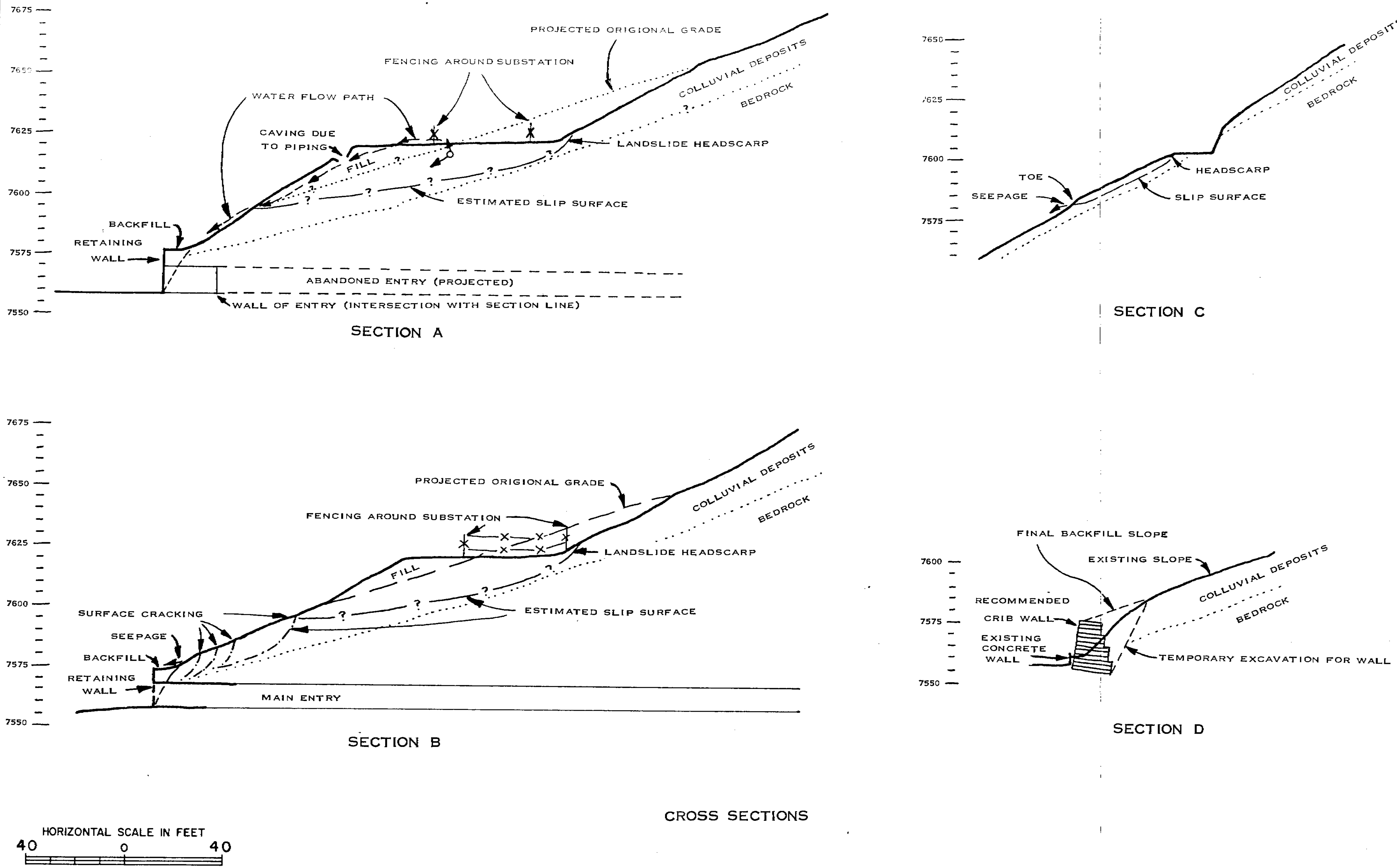
CONVEYOR ENTRY
SPRINKLER LINE SEPARATED
DEPOSITED SOIL
EMERGENCE OF WATER
ABANDONED ENTRY
DEPOSITED SOIL
PONDED WATER
MAIN ENTRY
ELECTRIC SUBSTATION
REFERENCE MARK
SECTION A
SECTION B
SECTION C
SECTION D
TOE
SUFCO MINE
OFFICE AND BATH HOUSE
FEET
40 0 40
EXPLANATION
HEAD SCARP, SMALL TICS INDICATE MINOR CRACK, BARBS INDICATE MAJOR CRACK, 2/4 INDICATE CRACK IS 2 INCHES OPEN AND 4 INCHES DOWN DROPPED.
EROSION GULLY.
PIPING DEPRESSION OR CAVITY.
UNDER GROUND WATER FLOW.
SEEP OR SPRING, LINE INDICATES SEEPAGE FROM CRACK IN RETAINING WALL.
SPRINKLER LINE.
4" AND 6" WATER LINE.
AREA OF BREAK IN WATER LINE.
REFERENCE:
SOUTHERN UTAH FUEL COMPANY. PRINT ENTITLED "EAST SPRING CANYON" SHEET 1 OF 3, BASED ON PHOTOS, JULY 1979.
MAP OF
LANDSLIDE FEATURES
(MARCH 10, 1982)
DAMES & MOORE

PLATE 2



CROSS SECTIONS

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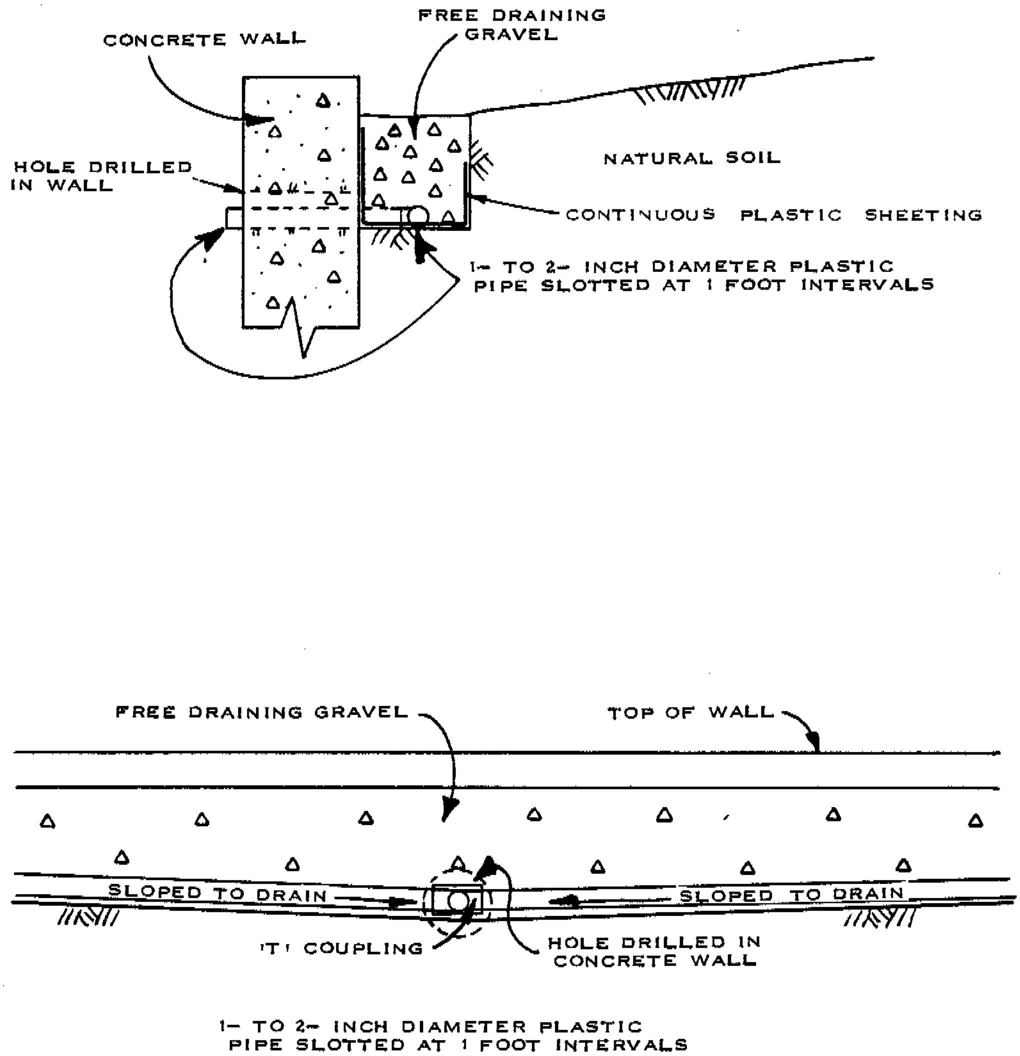
PLATE 3



SKETCH OF RECOMMENDED DITCH
SYSTEM AT TOP OF RETAINING WALL

BY LAA DATE 3-15-82 FILE 6701-023 REVISIONS BY ____ DATE ____
CHECKED BY JKK 16 Mar 82

FINAL REPORT

CONTRACT NO. DE-AC01-78ET122220

DESIGN AND DEMONSTRATION OF SUBSIDENCE MONITORING SYSTEMS

Prepared for

Department of Energy
Carbondale Mining Technology Center
P. O. Box 2587
Carbondale, Illinois 62901

by

Woodward-Clyde Consultants
Three Embarcadero Center
San Francisco, California

August 1982

Woodward-Clyde Consultants

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16. Abstract (Limit: 200 words)

Three instrumentation systems identified in earlier research were implemented to monitor subsidence at the SUFCO No. 1 Coal Mine in Salina, Utah. Principal objectives of the program were to demonstrate that the instrument systems could successfully monitor key parameters needed to evaluate subsidence for both caving and supported mining methods, and monitor surface structure response. The continuous mining method with pillar extraction utilized for mining the 1000 foot deep panel at SUFCO was compatible with the objective of monitoring subsidence associated with both supported and caving conditions, however, there was no opportunity to demonstrate monitoring of a surface structure. The instrumentation included combined borehole extensometer/inclinometer systems for full profile data from the surface to 800 foot depth, microseismic systems to monitor caving and subsurface fracturing over the mined panel, tape extensometers for surface strain, and ground surveys over the mined panel. Monitoring in the mine involved the use of borehole pressure cells, rod extensometers and convergence measurements as well as measurement of in situ stress by overcoring.

17. Document Analysis a. Descriptors

Subsidence, Underground Coal Mine, Instrumentation, Monitoring, Stress, Strain, Extensometers, Inclinometers, Borehole Pressure Cells, Microseismic Monitoring, Convergence, In Situ Stress, Faults, Rock Mechanics

b. Identifiers/Open-Ended Terms

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FOREWARD

This report was prepared by Woodward-Clyde Consultants, San Francisco under Department of Energy (DOE) Contract No. DE-AC01-78ET12220. The contract was initiated under the DOE Environmental Program. It was administered under the technical direction of the Coal Mining Division, and W. F. Eichfeld and Michalann Harthill acted as Technical Project Officers. Mr. Dave Williams was the contract administrator for DOE. This report is a summary of the work completed for this contract during the period September 1978 to September 1982. This report was submitted by the authors in September, 1982.

The Project Director for Woodward-Clyde Consultants was Dr. Ulrich Luscher and the Project Manager was John E. O'Rourke. Project Engineer was Barbara Ranson and Staff Engineers were Pamela Rey, Simon Kisch, Kevin O'Connor, Don Poulter and Mark Milani. Field Technicians included Jeff Shields and Brett O'Rourke. Prof. John Abel was a project Consultant. Drafting was done by Dante Tolosa and technical typing by Cheri King.

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Note: All tables are located at the end of each section.

LIST OF FIGURES

Note: All figures are located at the end of each section.

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LIST OF FIGURES (CONT)

1.0 INTRODUCTION

This report was prepared by Woodward-Clyde Consultants (WCC) for the U. S. Department of Energy (DOE) under Contract No. DE-AC01-78ET12220, entitled "Design and Demonstration of Subsidence Monitoring Systems." The project was initiated to demonstrate three systems for monitoring subsidence in an undermined area, (Table 1.1). These three systems were presented in a feasibility report prepared by WCC, entitled "Subsidence Monitoring Systems for Undermined Areas.*" Each system consists of (1) a set of measurements that are useful for a particular type of subsidence problem, (2) recommended instruments to make those measurements (Table 1.1) and (3) recommended monitoring layout and frequency. The systems are designated "Structural Performance," "Performance of Supported Systems," and "Performance of Caving Systems."

1.1 OBJECTIVES

In general, the systems were designed to help mine operators and public agencies in developing empirical relationships and in determining site parameters that can be used to control subsidence movements (for details of these objectives, see O'Rourke and others, 1977). Data recorded by these systems provide input for modeling and predicting ground movements to improve mine stability, minimize surface damage,

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*O'Rourke, J. E., Mabry, R., Ranson, B. B., and O'Connor, K., 1977, Subsidence monitoring systems for undermined areas: Contract No. USDOE ET-76-C-01-9123, U. S. Department of Energy, National Technical Information Service Publication No. FE/9123-1.

and aid productivity of future mining activities in adjacent seams. Certain instrumentation systems may also be used by private land owners or users who wish to monitor surface effects of subsidence on their land or on existing structures.

While such economic and social reasons may motivate mine operators and public agencies to implement instrumentation programs to monitor subsidence, legal and institutional guidelines, based on environmental protection, are the current impetus for monitoring. Many states, including Kentucky, Pennsylvania, Colorado, Wyoming, and Illinois, have enacted mining subsidence regulations. The federal Office of Surface Mining, created in 1977, has authority to regulate surface effects of underground mining and currently requires mines to provide a subsidence control plan (CFR 784.20).

1.2 DEMONSTRATION PROGRAM

With these objectives in mind, a demonstration of the instrument systems was undertaken to determine whether the monitoring systems and their component instruments can provide useful data on mining subsidence. The demonstration work included:

- Design of a test program
- Acquisition and installation of equipment
- Operation of instruments
- Evaluation of the effectiveness of the three measurement systems.

The demonstration program was conducted at the SUFCO No. 1 coal mine near Salina, Utah (Figures 1.1 and 1.2), where a selected panel was instrumented (Section 3.1). The panel is approximately 950 to 1,050 feet deep, 500 feet wide, and 2,100 feet long. The thickness of coal mined averaged 8 feet.

Because of delays, winter weather, and mining problems in the panel, the field demonstration program did not achieve all the objectives of evaluating the three subsidence monitoring systems. However, it did provide a good assessment of most of the instruments, case history data for the SUFCO mine panel, and a review of special mining problems at the panel. As a result of the evaluations, two monitoring systems that may prove more cost effective for monitoring subsidence at high-extraction coal mines are proposed.

1.3 ORGANIZATION OF REPORT

Section 2.0 of this report first discusses the planning phase for the demonstration program, site selection, the cooperative agreement with the SUFCO mine, permitting, and equipment and contractor selection. Site conditions and general field procedures are described in Section 3.0. Monitoring of basic operations are reviewed, and cleanup and reclamation procedures are reported in Section 4.0.

Field data are presented by instrument type in Section 5.0 and in Appendix A. A model developed from the field data to explain the mining problems at the panel is discussed. In Section 6.0, evaluations and ratings of the instruments and measurements for the most comprehensive of the three systems, "Performance of Supported Systems," are presented. From this information, two levels of effective subsidence monitoring programs are identified. Section 7.0 presents the summary and conclusions of this report.

TABLE 1.1

SYSTEMS AND INSTRUMENTS

MEASUREMENT \ MEASUREMENT SYSTEM	SYSTEM B STRUCTURAL PERFORMANCE	SYSTEM D PERFORMANCE OF SUPPORTED SYSTEMS	SYSTEM E PERFORMANCE OF CAVING SYSTEMS
Ground Surface Vertical Settlement	--	Precision Level	Precision Level
Ground Surface Horizontal Strain (Lines)	--	Steel Tape Extensometer	Steel Tape Extensometer
Ground Surface Horizontal Strain (Triangle)	--	Steel Tape Extensometer	Steel Tape Extensometer
Ground Surface Crack Movement	--	---	Steel Tape Extensometer
Ground Surface Tilt	--	Precision Level With Steel Tape or Tape Extensometer	Precision Level With Steel Tape or Tape Extensometer
Structure Differential Vertical Settlement	Precision Level	---	---
Structure Strain	Rod Extensometer with Micrometer	---	---
Structure Crack Movement	Dial Indicator Strain Gauge	---	---
Subsurface Vertical Deformation	--	FPBX with Electro-magnetic Torpedo	FPBX with Electro-magnetic Torpedo
Subsurface Horizontal Deformation	--	FPBI with Servo Ac-celerometer Torpedo	FPBI with Servo Ac-celerometer Torpedo
Extent of Subsurface Fracturing	--	---	Microseismic, with headphones
Mine Level Roof Sag	--	Precision Level	---
Mine Level Convergence	--	Steel Tape Extensometer	Steel Tape Extensometer
Mine Level Roof Strata Separation	--	MPBX, Rod Type, with Dial Gauge	---
Mine Level Prop Load	--	Hydraulic Load Cell	Hydraulic Load Cell
Mine Level Rock Bolt Load	--	Elastic Disc Load Cell	Elactic Disc Load Cell
Mine Level Pillar Stress (Absolute)	--	USBM Borehole Deformation Gauge	USBM Borehole Deformation Gauge
Mine Level Pillar Stress (Relative)	--	Encapsulated Flat Bore-hole Pressure Cell	Encapsulated Flat Bore-hole Pressure Cell
Mine Level Rock Noise	--	---	---

KEY: FPBX = Full Profile Borehole Extensometer
FPBI = Full Profile Borehole Inclinometer
MPBE = Multi-Point Borehole Extensometer

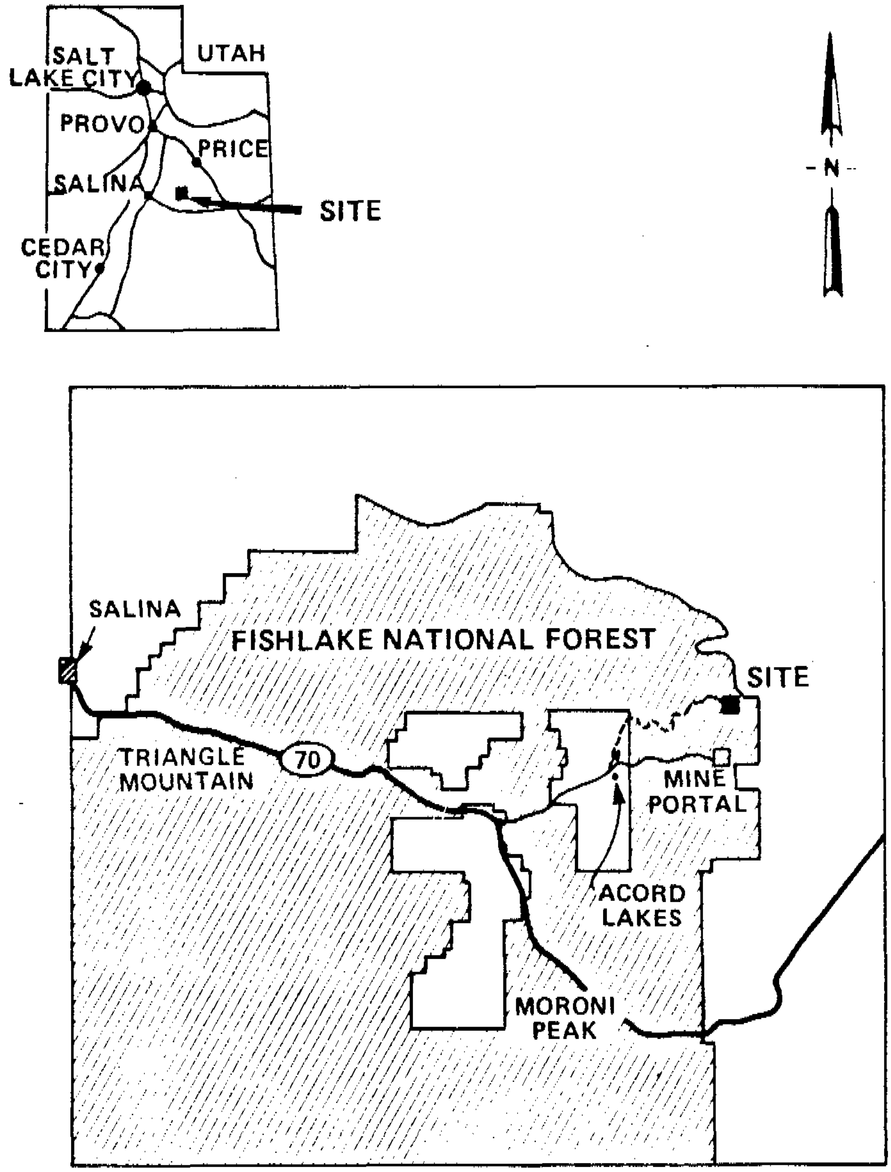

FIGURE 1.1

REGIONAL LOCATION MAP

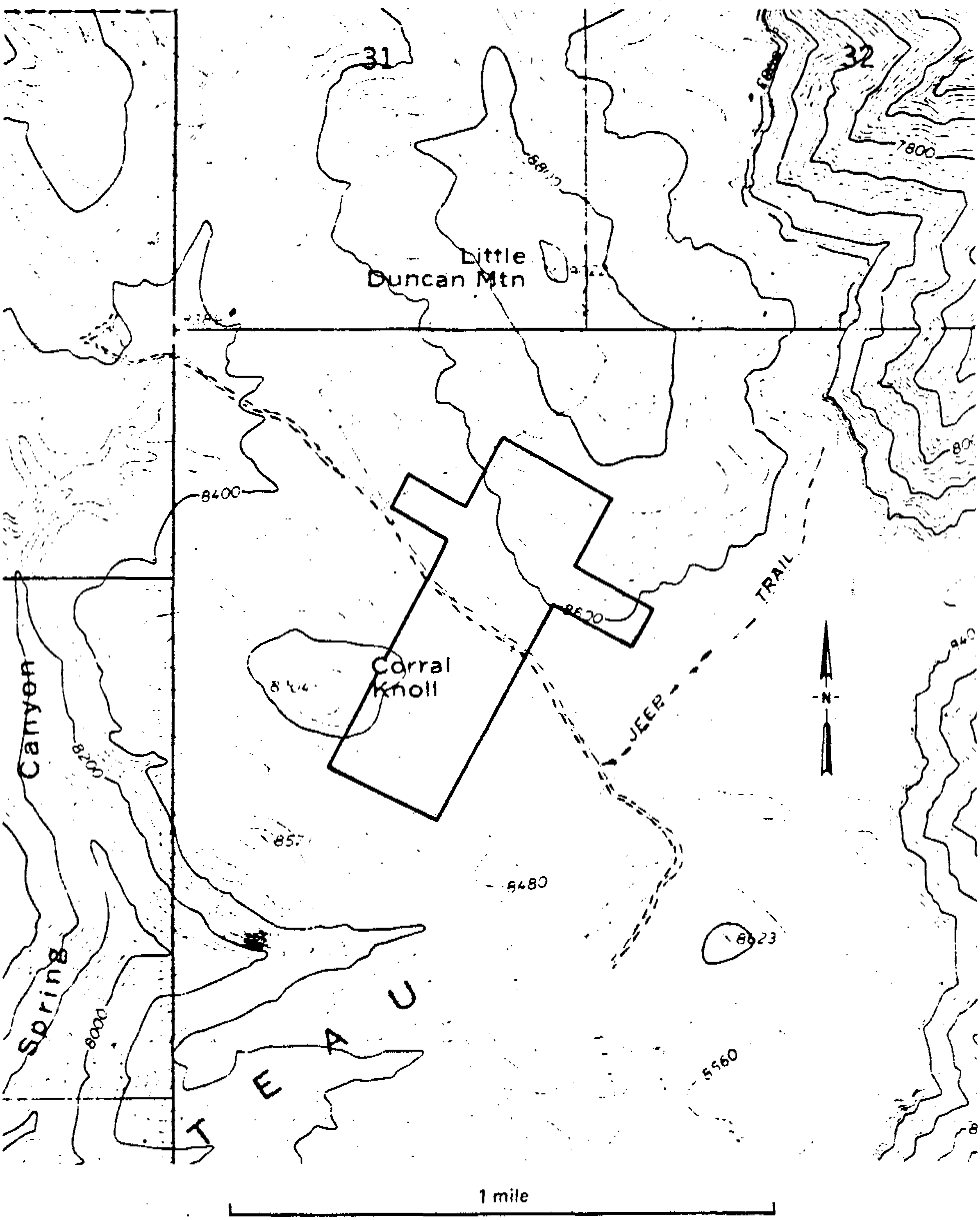

FIGURE 1.2

SITE LOCATION MAP

2.0 PREPARATIONS FOR FIELD OPERATIONS

2.1 GENERAL

In this section, the various tasks carried out prior to field work are briefly reviewed. The objectives of the section are: (1) present information on events that affected the evaluation of the instrument systems; and (2) assist future investigations and industry in setting up instrumentation programs. The following items are discussed:

- Site selection
- Cooperative agreement with a mine operator
- Permitting
- Equipment and contractor selection.

2.2 SITE SELECTION

Four room-and-pillar mines employing continuous miners and high extraction mining were visited and evaluated for this project after an initial screening of potential mines. Data were collected on topography, logistics, mine operations, interest in participation, overburden, coal seam characteristics, climate, and mining schedule. An evaluation matrix was developed (Table 2.1), and each candidate mine was rated. This procedure, which led to the selection (in December 1978) of the SUFCO No. 1 mine near Salina, Utah, was documented in the site selection report submitted for this project in December 1978.

Because of the depth of cover (1,000 feet) at SUFCO No. 1, DOE directed WCC to negotiate with the second-rated candidate mine. Although that mine made verbal commitment to sign a cooperative agreement, problems in their long-range planning ultimately prevented them from entering into a cooperative agreement for the research program. As a result, discussions were reopened with the SUFCO mine in June 1979. A cooperative agreement was concluded with that mine in August 1979.

2.3 COOPERATIVE AGREEMENT WITH A MINE OPERATOR

The cooperative agreement described the project and detailed the contractor's responsibilities, the owner's contribution toward program objectives, subcontractor's responsibilities and restrictions, duration of the project, publication rights, ownership of data, records and property, liability for accidents, damage, fines, procedures for notification of parties, and insurance. The cooperative agreement was comprehensive, and no disputes arose during the work.

2.4 PERMITTING

The permit application to install and operate instrumentation was filed with Fishlake National Forest under 36 CFR 252 FSM 2850 for review by the Forest Service. The Forest Service referred the application to the Office of Surface Mining (OSM) for approval. The OSM reviewed the program with respect to 30 CFR 741.11 and 30 CFR 815, and requested input from the U. S. Geological Survey (USGS) and the State of Utah. Approval to install and operate instrumentation was finally given on November 19, 1979.

Unexpected delays in permitting occurred in part because the initial permit application did not include provision for a short road to make several large hillside cuts for the drill pads. Furthermore, in the site selection and planning visits, a flat meadow was presumed to overlie the panel. Steeper terrain (Figure 2.1) over the panel was noted when the surveyors located the panel boundaries in September, after the initial permit application had been filed. A new permit application then was filed at the request of the Forest Service. This permitting experience points up the need for: (1) allowing a substantial period of time for permit acquisition; (2) surveying the site to delineate mine panels early in the planning stage, and (3) obtaining (if available) a topographic map with closely spaced contours during the planning stage.

The Forest Service assisted the applicant in preparation of the permit application and made suggestions for reclamation procedures. The final permit application included:

- Purpose of the project
- Names of the party seeking to drill and of the on-site representative
- Surface and subsurface ownership
- Duration of project
- Description of the study area, including topography, geology, and vegetation
- Site access and road needs
- Description of operations, including site layout
- Environmental protection measures
- Archaeological inspection report.

The Office of Surface Mining appended a list of additional environmental protection stipulations to the application and required a $5,000 performance bond.

2.5 EQUIPMENT AND CONTRACTOR SELECTION

Equipment was selected by soliciting quotations from manufacturers of the designated instrument types and evaluating the items in terms of cost, reliability, and quality. Some of the equipment was specially modified for this project. Drilling contractors were solicited by requests for quotations and were selected on the basis of cost, type of equipment, and experience in the area. The two major subcontracts for the deep hole and underground drilling were reviewed and approved by DOE, as required for subcontracts exceeding $10,000. The subcontractors selected were Northwest Air Drilling of Ogden, Utah, for the deep holes, and Earth Exploration of Salt Lake City, Utah, for the underground work. A third subcontractor, Anchor Services of Rangely, Colorado, drilled shallow holes for the survey monuments.

TABLE 2.1

SITE SELECTION

SELECTION CRITERIA	RATING 3 (DESIRABLE)	2	1 (UNDESIRABLE)
TOPOGRAPHY	flat, low vegetation, little surface water, little surface activity	INTERMEDIATE BETWEEN 1 AND 3	rugged, mountainous, tall vegetation, swampy, lakes, much traffic and other surface activity
LOGISTICS	facilities close (motels, restaurants, rental cars, airport, highway, suppliers), good surface access, good underground access (drift mine best), services available (power, water, air), experienced drilling contractors available, "close" to Denver/San Francisco		facilities farther than about 30 miles, surface access requires roadbuilding or foot travel only, underground access through shaft, services must be installed, experienced drilling contractors unavailable, far from Denver/San Francisco
MINING	continuous miners, room-and-pillar, pillar recovery, high production rates, large panels, high extraction		conventional mining, pillars not recovered, low production rate, small panels, low extraction
COOPERATION	interested, informed, needs data, willing to sign a cooperative agreement, able to divulge data, willing to provide on-site offfice facilities (or field office trailer space), non-union		tolerant, disinterested, unable/unwilling to assist, unwilling to sign a coop agreement, data proprietary, field office facilities not available, strong UMWA influence
OVERBURDEN	less than 300 ft, stable borehole walls, consistent and known geology, simple structure		thicker than 100 X coal thickness, boreholes require casing, complex/variable geology, geology not mapped, steeply dipping strata, highly faulted and jointed
COAL SEAM	more than 6 ft thick, thicker than overburden thickness ÷ 100, relatively flat, competent roof, clean coal (not bony, low sulfur)		less than 5 ft thick, less than OB ÷ 100, steeply dipping ($>10^{o}$), poor roof conditions, bony/rocky coal
CLIMATE	low precipitation, moderate temperatures, minimal wind, little snow		heavy precipitation, extreme high/low temperatures, much high wind, heavy snow accumulation
TIMING	Scheduling compatible		scheduling not consistent with program plan

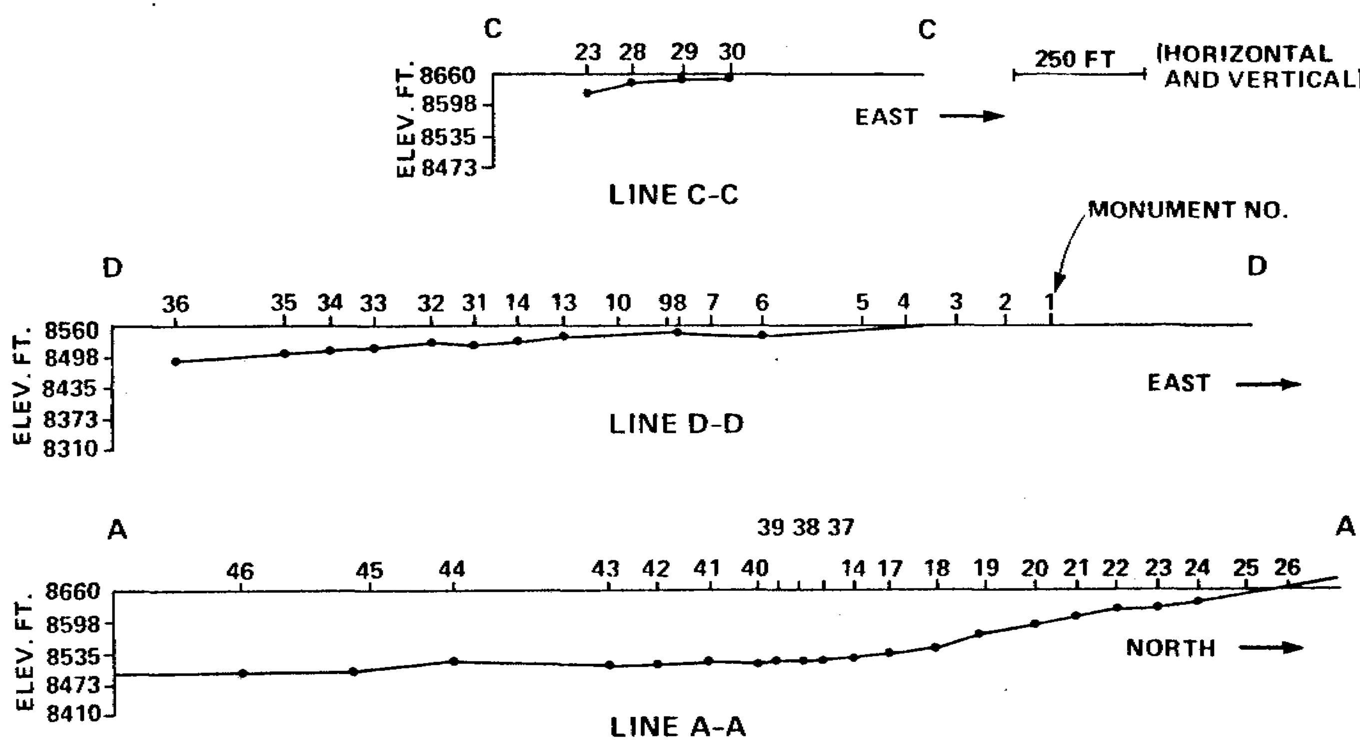

FIGURE 2.1

SURFACE ELEVATION PROFILES OVER MINE PANEL

3.0 INSTRUMENTATION AND INSTALLATION

This discussion of field operations includes a description of site conditions, instrumentation layout, and general installation conditions that affected program objectives. Further details of equipment installation are included in Appendix B. A detailed site design report covering this work was submitted for this project in October 1979. The major instruments installed at the site are summarized on Table 3.1.

The field work was conducted by Woodward-Clyde Consultants with the aid of the three drilling subcontractors. SUFCO mine personnel were not involved in the daily operations but provided assistance, advice and manpower when needed. They also assisted in some monitoring of underground equipment and conducted several surface surveys during the summer of 1980.

3.1 SITE DESCRIPTION AND MINING PLAN

3.1.1 Location

The study was conducted at the SUFCO No. 1 mine approximately 35 miles from Salina, Utah, in the Wasatch Plateau (Figures 1.1 and 1.2). The portal of the mine is located on East Spring Canyon, off Convulsion Canyon. The surface site is located at an elevation of approximately 8,600 feet on the slopes of Little Duncan Mountain, in a general area known as Old Woman Plateau. The topography is a moderate to steeply sloping hillside with an adjacent flat meadow. Access to the site from Salina, Utah, is by highway and by 10 miles of dirt road. Nearest support facilities are located at the mine, about 12 miles away by dirt road.

Access to the surface site was difficult during the operation phase, which began in winter. No on-site storage or surface radio communication was available. Both are recommended for future monitoring of remote sites, particularly under winter snow and spring thaw conditions.

The underground site is approximately 2 miles from the mine portal. The drive from the portal to the underground site by diesel boss buggy took about 30 minutes.

3.1.2 Stratigraphy

In the vicinity of the site, the Price River Formation overlies the Blackhawk Formation. The Castlegate Member, the basal member of the Price River Formation, forms the cliffs and plateaus near the mine. The Price River Formation is characterized by sandstones and sandy siltstones with relatively good drillability.

The transition from the Price River to the Blackhawk Formation occurs between 270 and 320 feet in SUFCO hole M-1 (Figure 3.1). Below this depth, siltstones, claystones, carbonaceous shales and occasional thin seams of coal predominate.

The borehole did not penetrate the mined seam, the Upper Hiawatha member of the Blackhawk Formation. Drillability in the Blackhawk Formation was frequently poor. The transition zone between the two formations was the site of strong differential displacement during undermining, resulting in shearing of some of the deep hole equipment.

Frequent faults, trending about N30°W at the site, have an almost vertical dip and can be mapped from satellites and observed at mine level.* Two of these faults are thought to be responsible for the heavy conditions at mine level that led to abandonment of a section of the 2E3L panel (Figure 3.2).

3.1.3 Mining Plan

A panel retreat mining method with continuous miners was used. This method included a three-entry system driven up the right side of the panel over a three-month period. Pillars in the entries are on 60-foot centers. After driving the entries the panel was mined from north to south. Initially three rooms on 60-foot centers were driven 500 feet across the panel, perpendicular to the entries, with crosscuts at regular intervals. The pillars were then mined between the northernmost pair of rooms. The next room to the south is then driven so that three rooms remained. The process is repeated, until the panel is completed. Approximately three rooms and three rows of pillars are mined per month. Chain pillars between 2L (previously mined) and 3L (current panel) were mined to the extent possible as 3L was mined.

3.1.4 Staffing Needs

Two WCC engineers/geologists generally were required for installation tasks. This same team would ordinarily suffice to obtain data immediately after installation is complete, but winter conditions limited post-installation data acquisition. Later, routine surface instrument monitoring generally required two people. Most of the underground equipment was monitored by a single, trained person. Technical personnel from the mine assisted WCC engineers when necessary.

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*Satellite photos trace unstable mine roof: Coal Age, September, 1978, p 60-69.

3.2 SURFACE INSTRUMENTATION AND LOGISTICS

3.2.1 Instrumentation

The above-ground installation was started in October, 1979 and was generally completed in early January, 1980. The completed permanent above-ground installations included:

- 43 survey points (33 for tape extensometer)
- Two deep cased inclinometer/Sondex holes
- Three microseismic installations (two holes with a total of four grouted-in-place geophones and one hole for a portable geophone assembly).

Locations of these instruments relative to the mine plan are shown in Figure 3.2. The instrumented brick wall planned for the program was not constructed because of permitting delays and the onset of winter weather.

Survey Points

The 43 survey points were used to measure surface vertical subsidence and horizontal strain. All were used for the level survey and 33 were used for the tape extensometer survey. The points were installed over the panel along three lines. Line AA (Figure 3.2) extended beyond the north end of the panel across the barrier pillar and line DD extended outside the mined areas above solid coal for a distance of 500 feet. These lines were designed to show the complete subsidence trough configuration caused by mining one panel with solid coal boundaries, as well as the effects of previous and possible subsequent mining of adjacent panels. Line CC was located closer to the barrier pillar than line DD in order to characterize subsidence processes in an area of partial subsidence.

Thirty-eight survey points were precision-machined cone monuments* installed in drilled holes; five points consisted of driven rebar installed on slopes greater than 10 percent where the auger could not be used (Figures 3.3 and 3.4). The machined cone points accommodated both the level rod and the extension rods used with the tape extensometer assembly (Section 4.1.2; Figure 3.5); the driven rebar rods were not stiff enough to tolerate the 40-pound horizontal pressure needed with the tape extensometer. A conventional driven or drilled survey point would be more economical if tape extensometer monitoring were not planned.

Combined Sondex/Inclinometer Assemblies

Two combined Sondex/inclinometer assemblies were installed to measure subsurface horizontal and vertical deformation, to provide insight into how the overburden adjusts as it is undermined. The Sondex system detects the vertical location of the wire rings fixed around the flexible casing which is keyed to the borehole wall with the grout backfill. The inclinometer system measures tilt and corresponding horizontal deflection along the two orthogonal axes defined by the casing grooves.

The assemblies, installed to 300- and 800-foot depths, consisted of nested, grooved ABS plastic inclinometer casing inside corrugated polyethylene casing. The latter was

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*Burland, J. B., and Moore, J .F. A., 1973, The measurement of ground displacement around deep excavations: Field Instrumentation in Geotechnical Engineering, British Geotechnical Society, Proceedings, John Wiley & Sons, New York, p 70-84.

outfitted with external metallic rings at 10-foot intervals (Figure 3.6). The assemblies were located over the rib and center of the panel in order to provide horizontal and vertical subsurface displacement data for full and partial subsidence conditions. The 300-foot installation over the panel rib was completed and operated successfully for a major portion of the monitoring period. The 800-foot hole was instrumented over the panel center. Initial readings were not obtained until nearly 3 months after installation, when only 500 feet of hole could be monitored. Hole depth loss may have been caused by mining movements or by installation problems.

Microseismic Installations

Microseismic activity such as grain fracture and slippage in soil or rock formations may be monitored by means of portable or permanent geophones. Highly stressed zones may emit detectable microseisms before large deformations occur, and monitoring of the microseismic activity can produce data tracking vertical extent of subsurface fracturing in relation to mine advance.

One portable microseismic system (Figure 3.8) and two grouted-in-place assemblies were installed (Figure 3.7). An 800-foot hole for the portable system (M-1), located over the panel center where maximum activity was expected, was cased with 4-inch heavy wall pipe. The annulus between the casing and the hole was grouted with neat cement. Two grouted-in-place geophone assemblies, consisting of two piezoelectric geophones each, were completed over the panel rib in holes drilled to depths of 300 (M-3) and 800 feet (M-2). The geophones were grouted at 144, 265, 472, and 672 feet. A constriction in the 800 foot hole stopped the portable geophone short of the full depth. The grouted geophone cables were greased and sleeved with rubber hose to prevent bonding to the grout and to allow the cables to adjust to mining movements.

3.2.2 Site Preparation and Drilling

The drilling program did not begin on schedule because of delays in the site selection and permitting procedures. As a result, most of the work was done in late fall and winter.

Site Preparation

Three drill pads were constructed for the deep hole installations. Mud pits were constructed for use as settling ponds for the cuttings, because the holes were air-drilled with foam that was not recycled. A short spur road across a steep hillside was constructed to hole M-1. The topsoil from these areas was stockpiled. Brush was cleared along the survey point lines as needed. A local contractor, Maurice Rasmussen Company, performed the surface earth work. Water for the drilling was hauled from a nearby pond until the winter freeze, when it was hauled from the mine.

Deep Hole Drilling

The deep hole work was performed by Northwest Air Drilling, Ogden, Utah. The deep holes (I-1, I-2, M-1, M-2, M-3) were drilled with a CP 1800 air rotary drill, which was equipped with a 600 cfm, 250 psi compressor. This rig, usually employed for water wells, was used because of the need for 8-inch diameter holes. An exploration rig, while capable of drilling to several thousand feet, usually cannot handle bits over 6 inches in diameter.

After initial drilling with a 7-7/8 inch button roller bit, a hammer bit was used. This bit proved more satisfactory in the shales and siltstones. The penetration rate ranged from

5 to 20 feet per hour with the hammer bit. A stiff foam was used for flushing out drill cuttings. Some minor inflow was encountered in the upper 300 feet of each hole, but in general the holes did not yield water.

Control of billable quantities was achieved by completion of a daily log with items listed as in the contract. See Table 3.2.

Shallow Hole Drilling

Thirty-eight 4-foot deep 8-inch diameter shallow holes were drilled with a Texoma truck-mounted auger. The auger was side-mounted and moveable. On slopes greater than 10 percent, the oil collected in the front of the oil pan and could not be cycled properly by the truck's oil pump. This problem limited the auger to slopes less than 10 percent. The shallow holes were drilled by Anchor Services of Rangely, Colorado.

Winter weather conditions caused daily delays. Diesel engines on the water truck and drill rig were difficult to start in low temperatures. Water had to be hauled daily because it would freeze overnight. A snow plow was kept at site and chains were required on all transport vehicles. The CP 1800 drill rig experienced several mechanical failures, possibly related to the stress from rapid temperature change from 0°F at night to the engine's operating temperature. Drilling was conducted on 12-hour shifts; a 24-hour work regime with two engineering and drilling crews, as is practiced in arctic climates, might have minimized these cold-related problems.

3.3 UNDERGROUND INSTALLATION

3.3.1 Logistics

Some general logistic considerations affected the installation and final location of the underground instruments. These considerations are a function of the requirements of a production operation in an underground environment and the special needs of a coal mine, as follows:

- Availability of power
- Availability of water
- Working space
- Dust
- Permissible equipment
- Transportation
- Communication
- Traffic
- Performance of roof and pillars
- Fire safety.

Availability of Power

The length of trailing cables for electrical face equipment is generally limited to 500 feet (CFR 30-CHI-18.35). Therefore, the power plant is located within 500 feet of the face in order to service continuous miners at the face. Electrical power for instrument installation is available from the plant, and 110 volt AC power is frequently an option.

Electrical cables must hang from the roof or from ribs by insulated J hooks attached to spads or rock-bolt-bearing plates. The cables cannot touch the roof or ribs. Trailing cables, which may trail on the ground, have stringent requirements that would be impractical for cables servicing installation tools. All power cables used underground must be grounded.

Some limitations caused by using electrical power may be avoided by using diesel equipment. Diesel can be an advantage for instrumentation work, because it permits work anywhere in fresh air using diesel compressors and air tools. Diesel equipment used for this project consisted of a Kubota diesel tractor for transport and a 600 cfm diesel compressor for drilling. Both engines were retrofitted with catalytic converters and were inspected by a State of Utah inspector for emissions prior to going underground. Diesel equipment use is regulated by 30 CFR 20-13.

Availability of Water

The SUFCO mine has an extensive system of water pipelines and standpipes along the belt line to bring water to the face. This system can be tapped for instrumentation drilling and installation; however, the nearest standpipe or valve was frequently several hundred feet from the work area. This separation and the routing of water lines around stoppings and pillars contributed to long runs of water hose. The water hose was hung from the ribs with spads and hooks to prevent traffic damage and a small hole was punched in the nearest stopping to allow direct hose access.

The discharge water from the drilling operations was directed into a depression in the floor, where it was then filtered and reused. This recycling measure reduced the load on the mine's pumping system.

Working Space

The panel had 6 to 8 feet of working height, but it was still necessary to use 1- and 2-foot long drill steel. A small depression in the floor and a small cutout in the roof were also required during the overcore tests in up-holes, to make room for all equipment.

The extensometer rods as shipped from the manufacturer were too long for the working space. They were cut and joined underground using butt-joints and an internal threaded stud.

Dust

Respirators were used at instrumentation sites for minor dust-producing operations such as hand drilling in coal and mixing cement. Heavy equipment used for instrument work at these sites had to be positioned carefully to avoid directing the exhaust stream at coal pillars. Dust from the compressor and air-drill exhaust at the work sites can cause increases in dust levels at the mining face. Coal and rock dust from the general mining operation eventually coats installed equipment, some of which (e.g., tape extensometer) proved sensitive to dirt. The reflectors used to mark the installations were coated and obscured during rock dusting operations and had to be cleaned frequently to maintain their visibility.

Permissible Equipment

All equipment used between the face and the last open crosscut had to be permissible (CFR 30-CH F-75.500) (i.e., formally approved by MSHA). A permissible instrument or machine must contain all explosion-proof components or be intrinsically safe, incapable of igniting an explosion in a methane atmosphere. Much of the instrumentation-related equipment was hydraulic or mechanically operated, to allow operation between the face and the last open crosscut.

Transportation

The need for frequent trips to the surface for supplies and to the mine face made special transportation necessary, and because of electrical limitations a Kubota tractor was used. It was modified with seats, hand rails and foot rests; the diesel engine was fitted with emission controls. The mine provided transportation for large equipment, such as the air drill and compressor.

Communication

Mines have a battery-operated phone system, which can be used to call other sections, the plant and the offices.

Traffic

Movements of mine vehicles underground must be considered both to avoid injury and to prevent delays in the mine operations. The operators of mine equipment generally sit to one side of the machine and have poor overall visibility. Trailing cables presented a hazard because they can whip across a room as the vehicle moves. Some damage to the installations was caused by mine equipment operations, despite precautions such as reflectors mounted on the installations to improve visibility.

Performance of Roof and Pillars

Instrumented mine areas commonly become unstable with time; spalling pillars and roof may damage equipment and supports may be lost. In the areas instrumented for this study, the roof was more stable than the pillars and was used for hanging equipment.

Fire Safety

As required by law, five sacks of rock dust were kept near diesel and electrical equipment in case of fire.

3.3.2 Instrumentation

The underground installation program, which lasted 2 months, included the following instruments or test apparatus:

- Survey and convergence points
- Deformation gauge
- Hydraulic borehole pressure cells
- Instrumented roof bolts
- Rod extensometers.

The locations of these instruments are shown on Figure 3.8. Details of the installation procedures for these instruments are shown on Figure 3.9 and are discussed in Appendix B.

Survey and Convergence Points

Mine level roof sag and convergence are measurements of initial subsidence deformation. Roof sag and convergence monitoring are typically used as an indication of the need for supplemental support installation.

The use of roof sag or convergence data for determining absolute roof or floor movements requires a stable reference point. One benchmark, six roof points and two floor points were installed between Rooms 6 and 27. Five pairs of convergence points were later installed in Room 23. The points consisted of rebar with SINCO spherical head reference points attached (Figures 3.13 and 3.14). Roof sag was monitored with a precision level; convergence was measured with the tape extensometer.

Deformation Gauge

Absolute stress measurements were made for comparison with relative stress changes that occur as stress is redistributed on pillars, roof and floor as the face advances.

The Irad USBM borehole deformation gauge measures radial deformations in three directions in a 1-1/2-inch diameter borehole when a concentric 6-inch diameter hole is overcored past it. Core samples retrieved during the overcore test were tested in a biaxial chamber to determine the modulus of elasticity, which was used to convert the borehole deflections, measured by the deformation gauge, into stresses. The principal stress was calculated assuming one principal stress to be vertical and equal to the weight of overburden.

Hydraulic Borehole Pressure Cells

Six Terrametries hydraulic borehole pressure cells (BPC) were planned to monitor pillar pressures. The cells were installed in horizontal holes in Rooms 6 and 13. A wire frame oriented two cells to measure vertical pressure and one to measure horizontal pressure in each hole.

The cells were oil-filled flatjacks (Figure 3.15), connected by a single steel tube extending from the cell to a terminal block located at the collar of the drillhole. A 3 percent accuracy Bourdon-tube type pressure gage was mounted on the valve block. The cells were pressurized after installation by connecting a pump at the valve block. Of the six cells installed, two failed to hold pressure immediately after installation and one would hold only nominal pressure.

Instrumented Roof Bolts

Three calibrated roof bolts, each outfitted with two pairs of bonded strain gauges (Figure 3.13), were installed in the regular bolting pattern (4-foot centers) to monitor stress buildup and bending. One additional bolt was damaged during installation, and wires to two strain gauges on one bolt were damaged.

The instrumented bolts were installed to study the stress transfer process and its relation to subsidence. Information on bending could indicate how the roof deforms in response to undermining.

Rod Extensometer

Two Interfels rod extensometers were installed to monitor mine roof strata separation. Four-point rod extensometers were planned, but the completed installations had fewer anchor points. The final installations consisted of a two-point assembly in Room 6 with anchors at 12 and 17 feet and a three-point assembly in Room 13 with anchors at 10, 20, and 50 feet. The rods connected to the anchors were sleeved with plastic pipe so that displacements measured at the head of the instrument would reflect movement of the roof relative to the anchors (Figure 3.17). The characteristics of roof strata separation can indicate active depth of roof beam support over the span and the competence of the roof; deformation data can be useful input to modeling studies.

3.3.3 Underground Drilling

Large Diameter Hole Drilling

Earth Exploration of Salt Lake City, Utah, drilled large (3- and 6-inch) diameter holes and assisted in installation of equipment associated with those holes.

The holes were drilled with a CP-8 air drill, powered by a 600 cfm diesel compressor. The intake of the compressor was turned toward the fresh air flow stream to prevent overheating. The exhaust was pointed away from the work area to prevent buildup of bad air in the drilling area. Water was taken from the mine's water supply system for drilling fluid and was discharged onto the mine floor. Because removal of this water burdened the mine's pumping system, it was reused for drilling whenever possible.

Timbers were set around the drill to stabilize the roof when drilling vertical up holes. Three rock bolts were installed by the mine about 12 inches from the hole center. A pipe dog was suspended from a chain attached to the bolts. To add a length of steel, the drillers supported the section of steel in the hole on the pipe dog while adding a new length. A recess in the roof and depression in the floor were excavated to provide needed working space to perform the overcore tests with the drill.

Small Hole Drilling

Small (1-inch diameter) holes for survey points were manually drilled in the roof with a 1/2-inch chuck, rotary hammer electric drill, which could handle bits up to 2 feet long. A jackleg drill powered by a 350 cfm compressor was used to drill 1-1/2-inch diameter holes in the floor for convergence points. The mine roof bolter was used to drill the holes and install the instrumented rock bolts.

TABLE 3.1

SUMMARY OF MAJOR INSTALLATIONS

INSTALLATION	NO. OF INSTALLATIONS	APPLICATION
Combined Level/Strain Stations	38	Ground surface vertical settlement, horizontal strain and tilt
Level Station	5	Ground surface vertical settlement
Microseismic Boreholes	3	Extent of subsurface fracturing
Combined FPBI/FPBX Boreholes	2	Subsurface vertical and horizontal deformation
Combined Level/Convergence Stations	13	Mine level convergence/roof sag
Mine Roof Extensometers	2	Mine level roof strata separation
Flat Borehole Load Cells	6	Mine level pillar stress (relative)
Borehole Deformation Gauge	3 tests in 1 hole	Mine level pillar stress (absolute)
Instrumented Rock Bolts	4	Mine level rock bolt load

TABLE 3.2
DAILY DRILLING LOG

DRILLERS ______________________________
DATE: ______________ HOLE: ______________ RIG: ______________
SIGNATURES ______________________ ______________________
(FOR DRILLER) (FOR WOODWARD-CLYDE)

TIME	ITEM	NO. HRS.	MATERIALS USED
	(Arrive on Site)		
	(Leave at Site)		

ITEM: PLEASE LIST:

MOBILIZATION Set-up at first hole; moves between holes; take down at last hole

DRILL Changing bit, drilling, circulating fluid before and after drilling, pulling up or putting in steel)

INSTALL Using rig to install equipment

GROUT Grouting holes; mixing cement

OTHER Please describe examples: get water, lunch, rig breakdown

STANDBY State reason

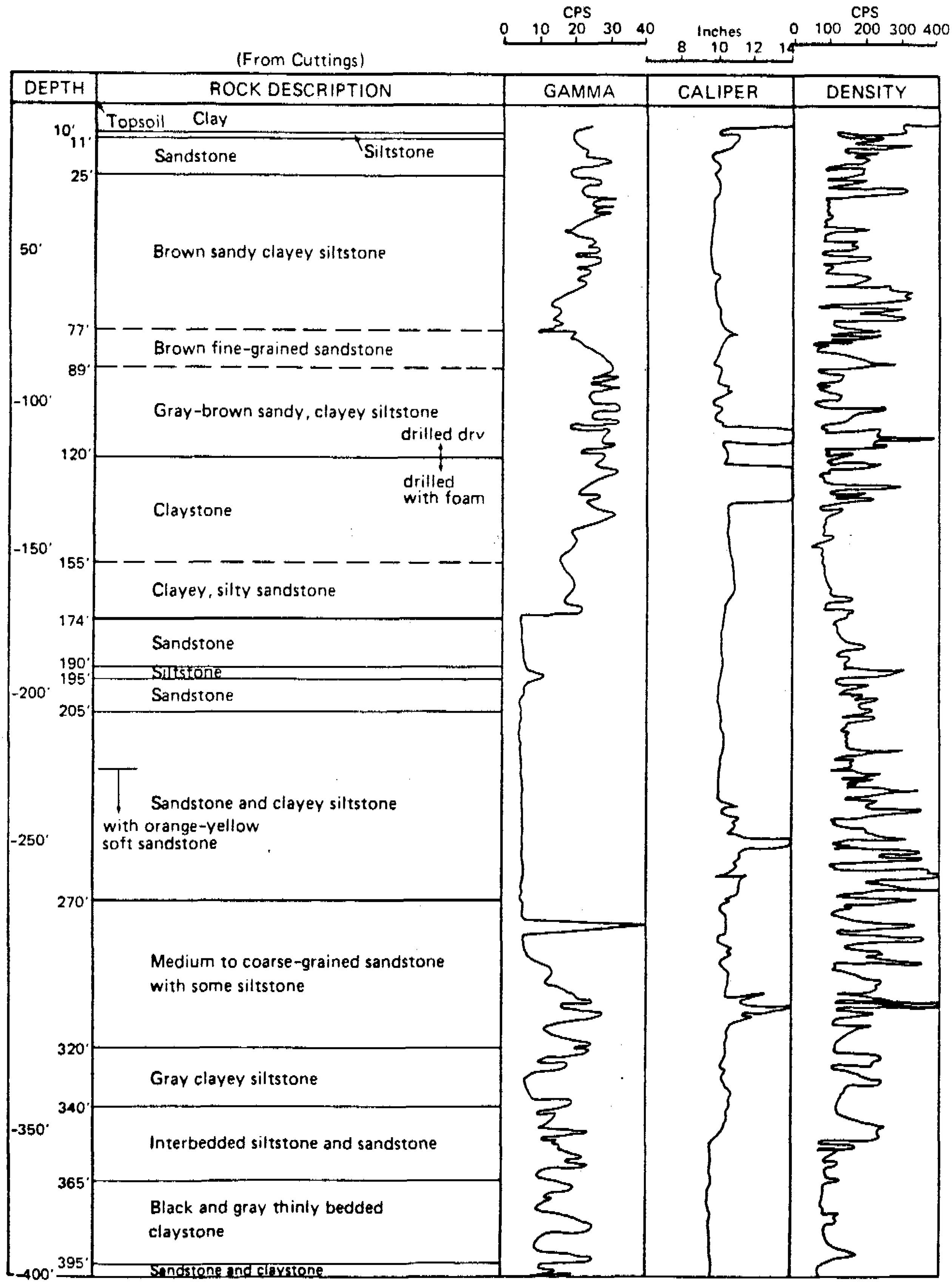


FIGURE 3.1a

BOREHOLE LOG FOR BH M-1
(Courtesy of SUFCO)

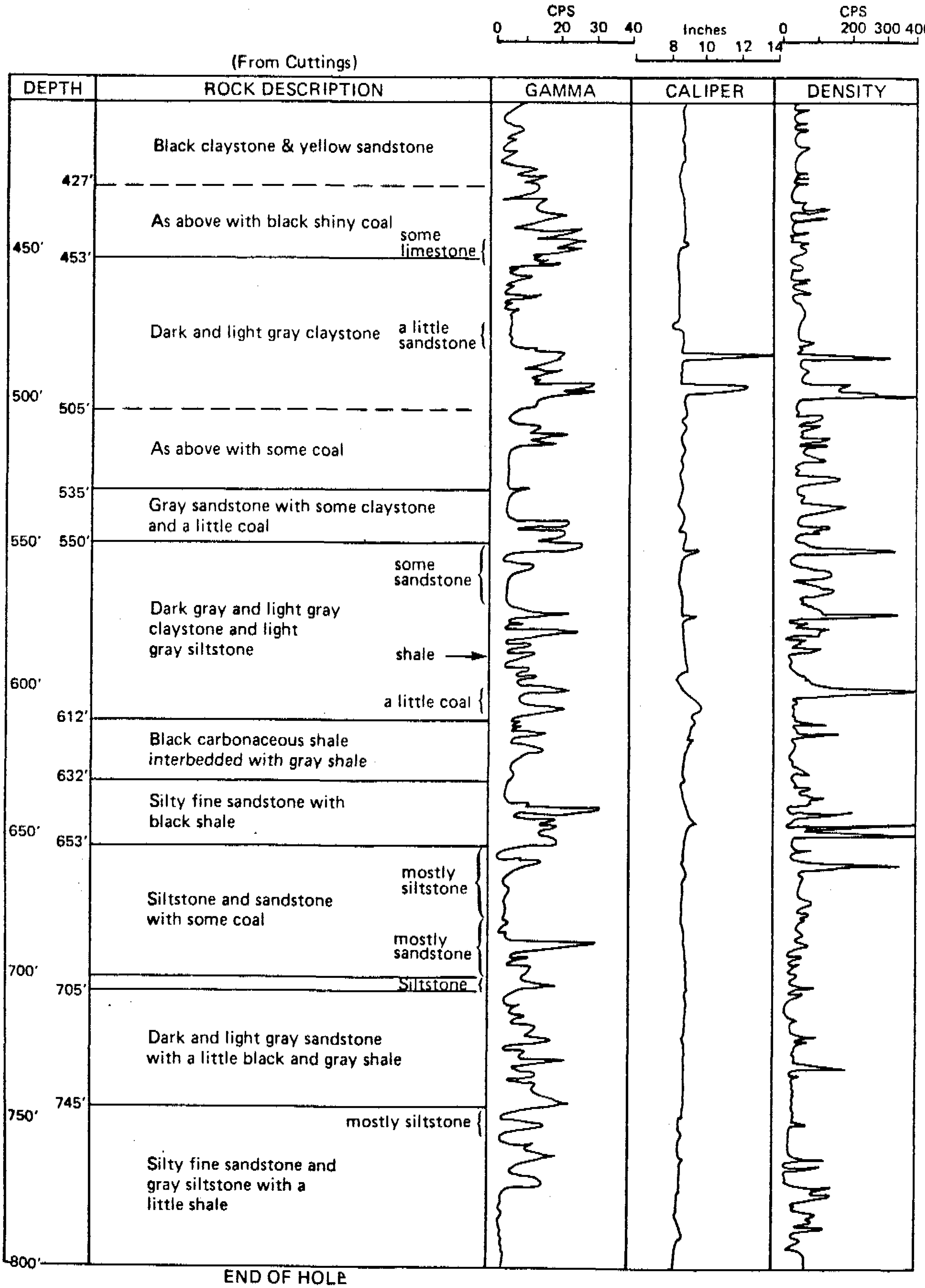


FIGURE 3.1b

BOREHOLE LOG FOR BH M-1 (contd.)

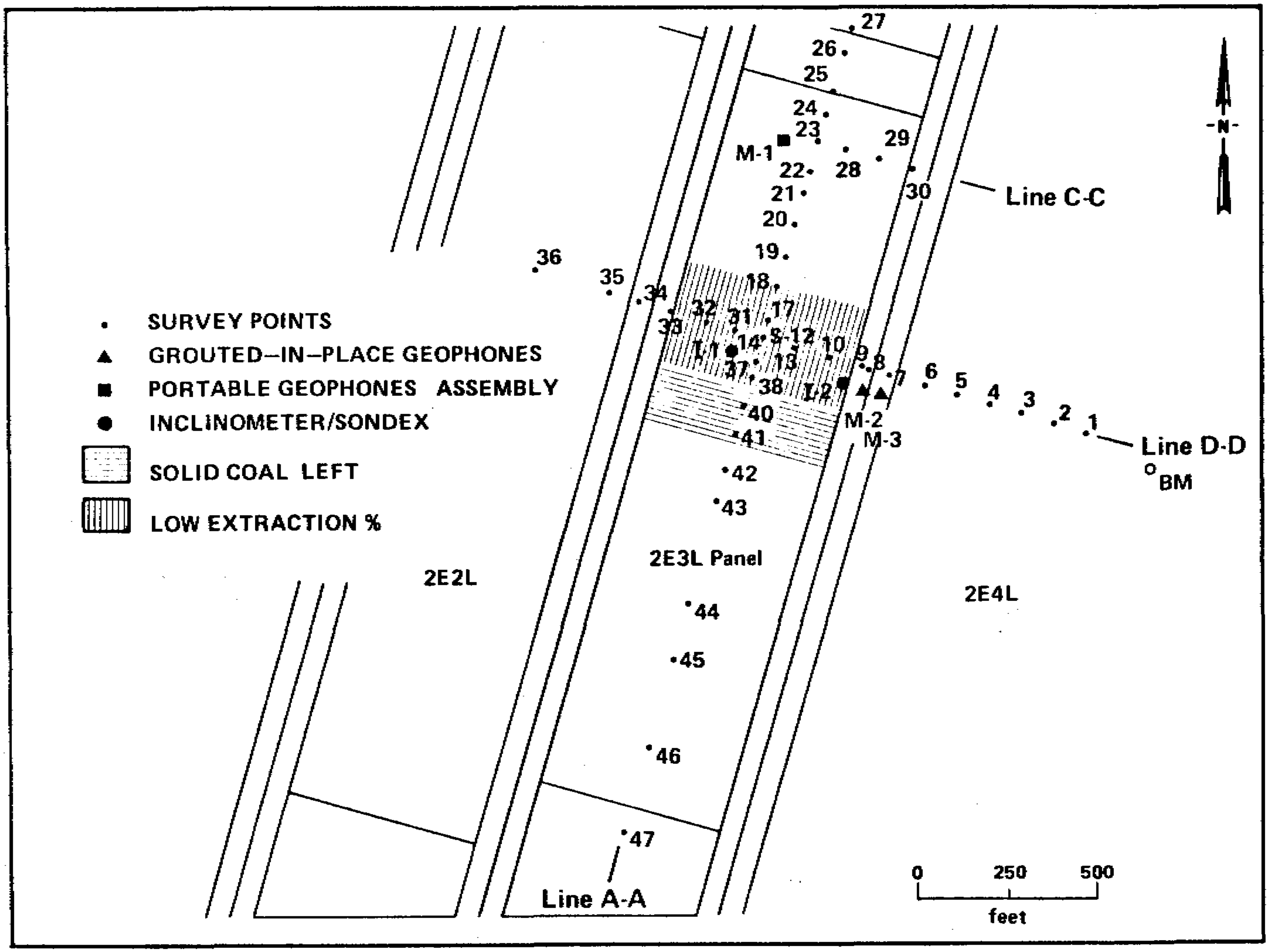
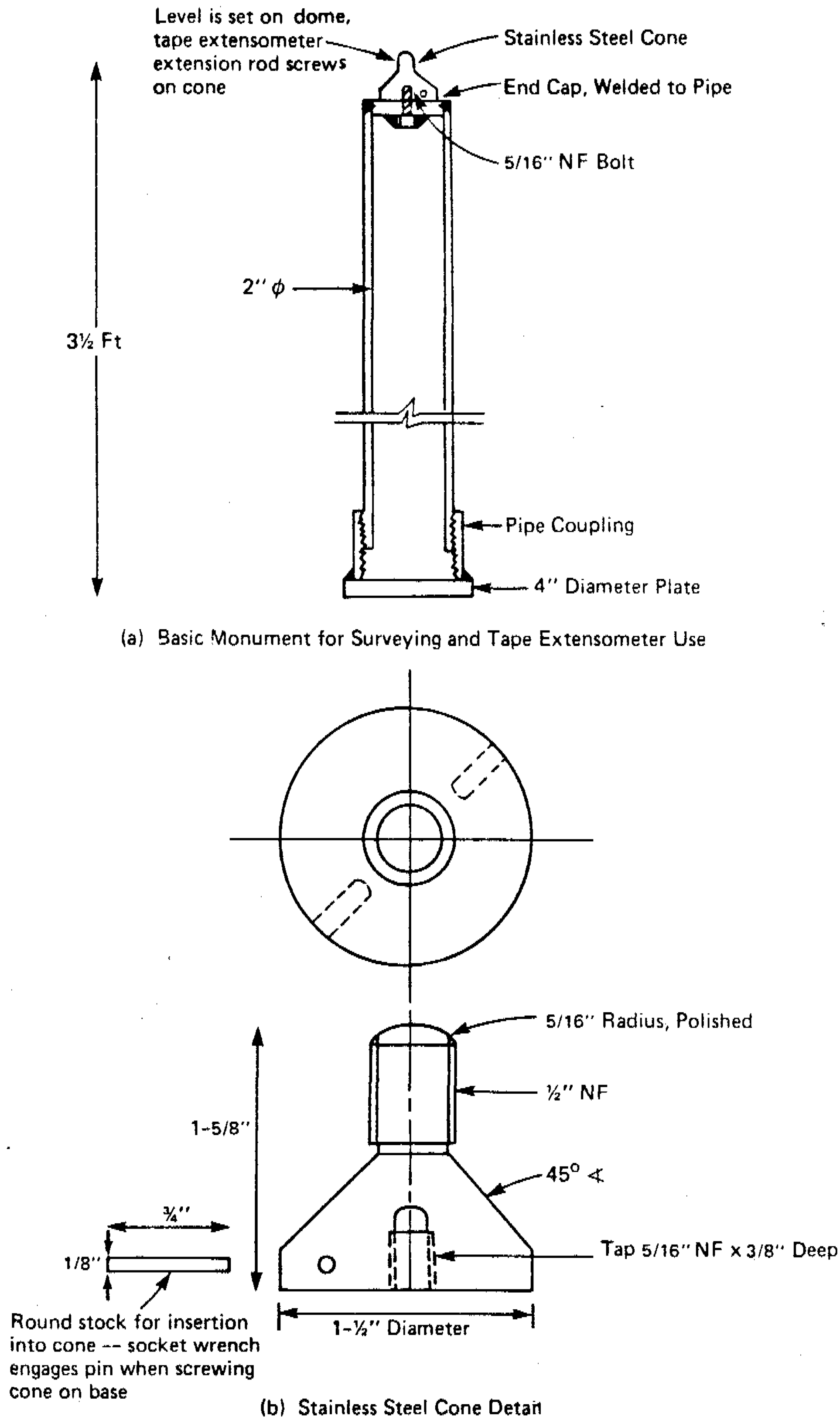


FIGURE 3.2

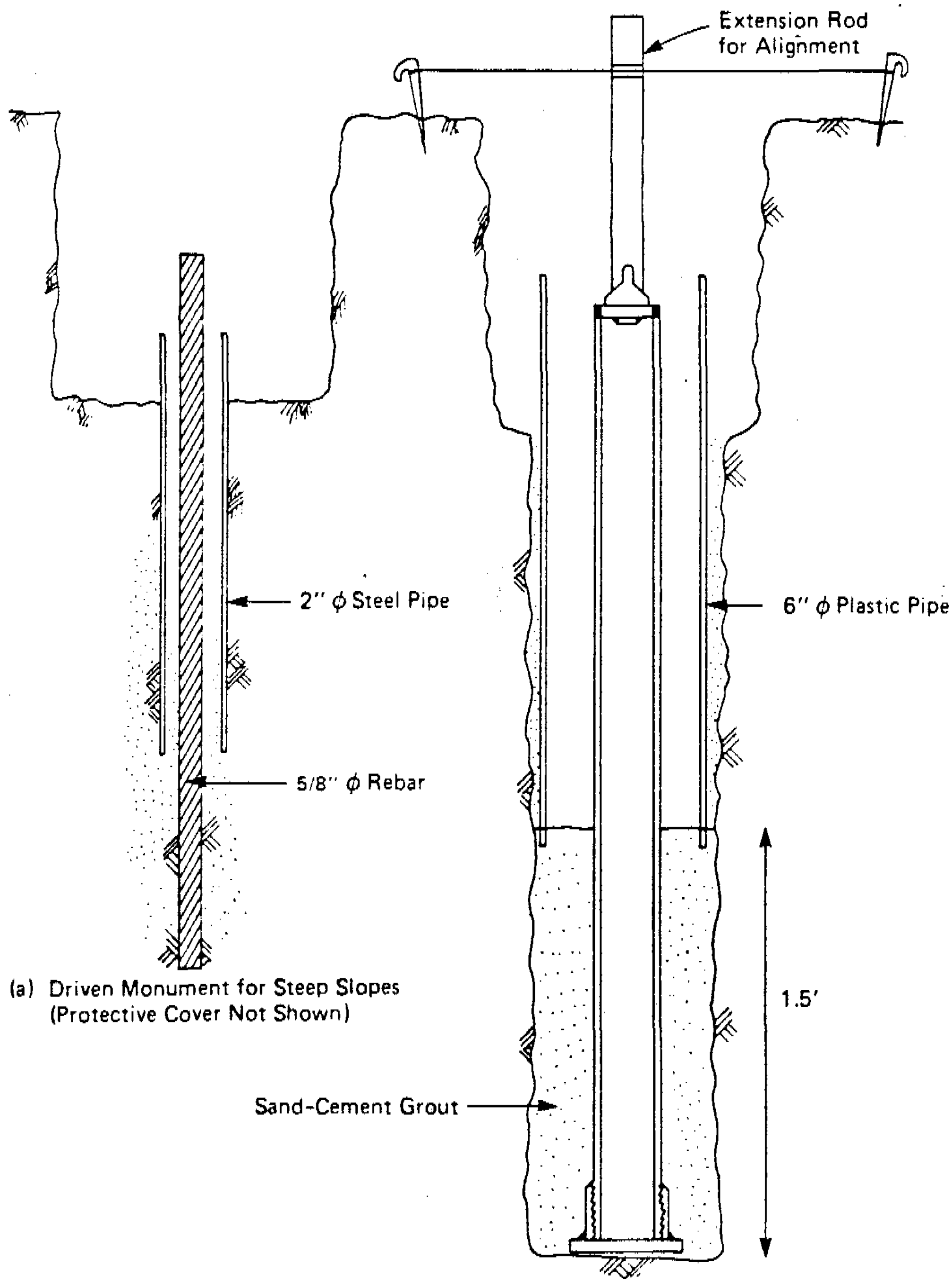
SURFACE AND BOREHOLE INSTRUMENTATION



Source: Burland and Moore, 1973

FIGURE 3.3

SURVEY MONUMENTS

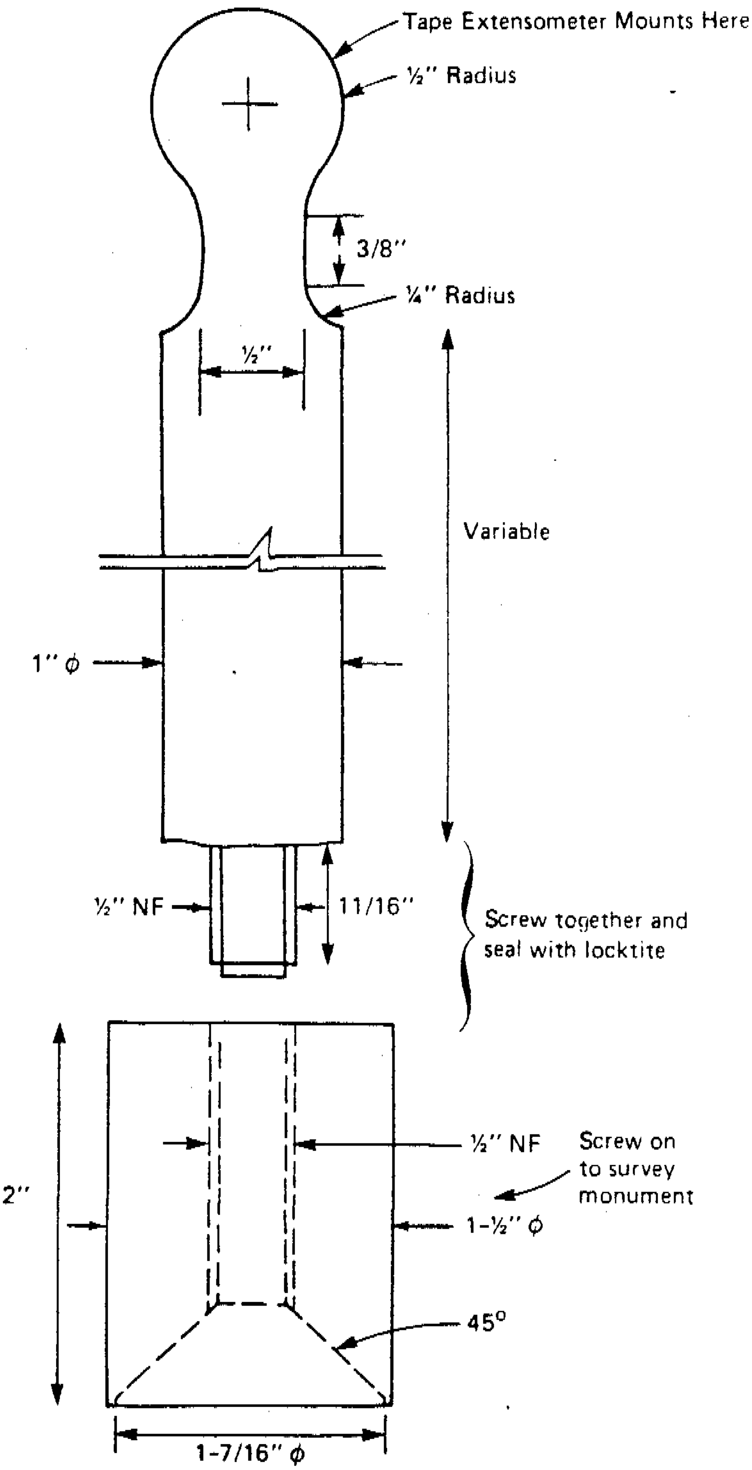


(a) Driven Monument for Steep Slopes
(Protective Cover Not Shown)

(b) Standard Monument
(Protective Cover Not Shown)

FIGURE 3.4

SURVEY MONUMENT DESIGN



Source: Burland and Moore, 1973

FIGURE 3.5

TAPE EXTENSOMETER EXTENSION ROD

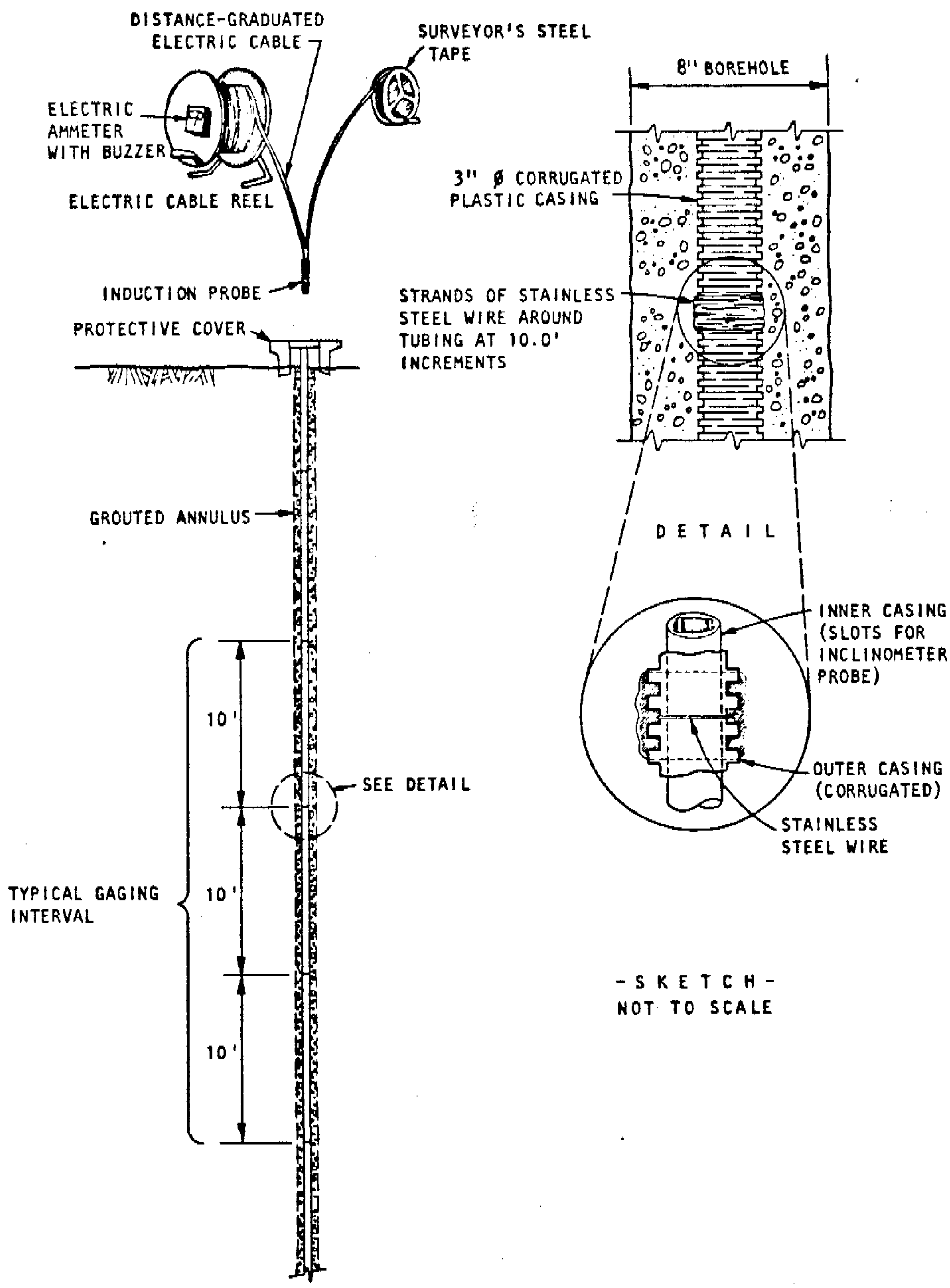
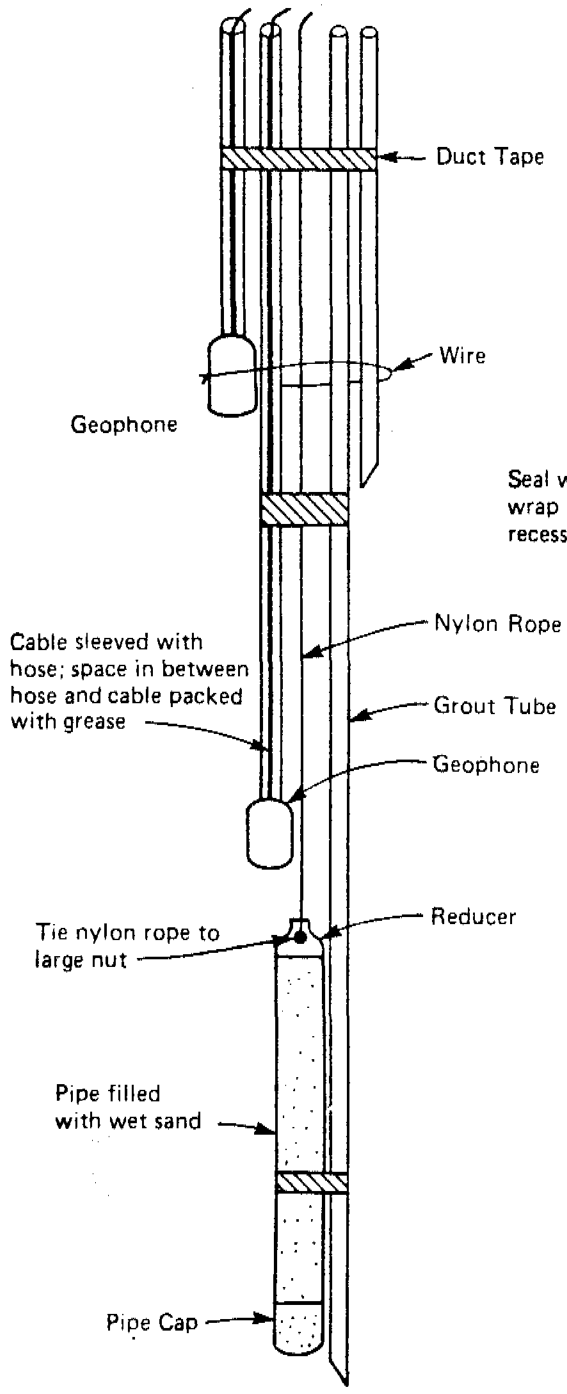
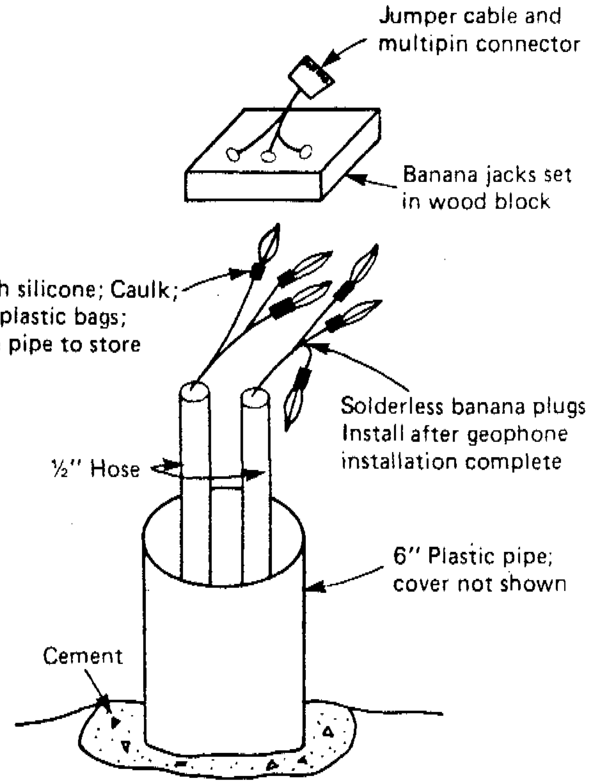


FIGURE 3.6

COMBINED BOREHOLE INSTALLATION FOR INDUCTION PROBE EXTENSOMETER (SONDEX) AND SERVO-ACCELEROMETER INCLINOMETER



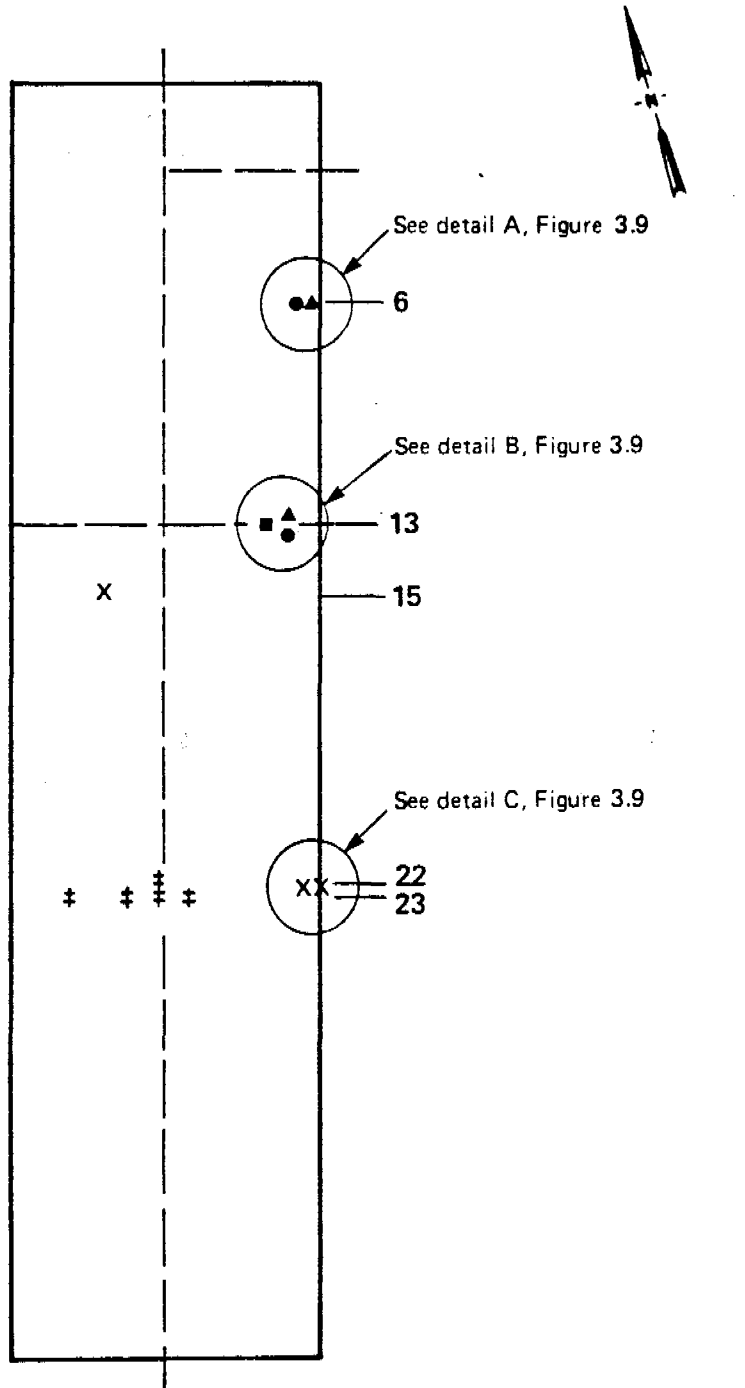
(b) Grouted-In-Place Assembly



(a) Above Ground Portion

FIGURE 3.7

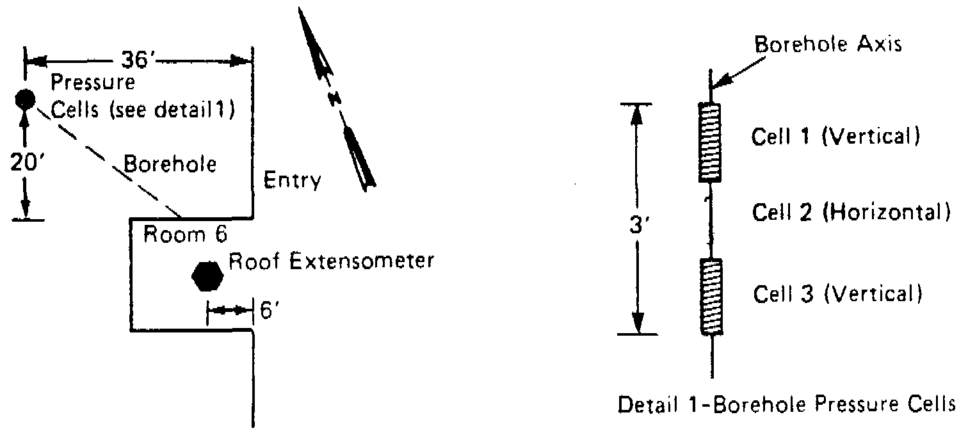
GROUTED-IN-PLACE GEOPHONE ASSEMBLY



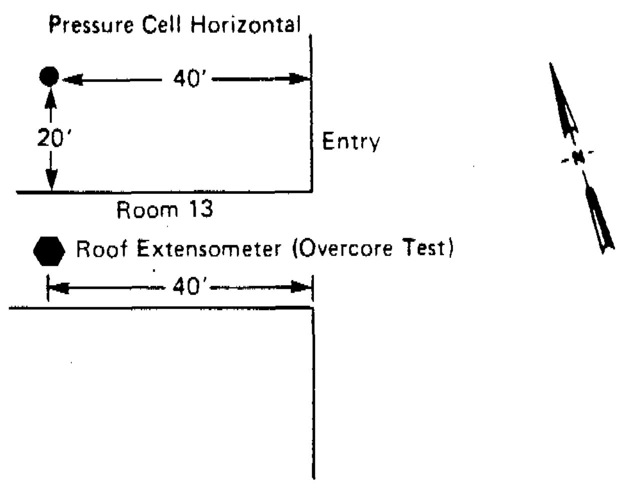
KEY

- **13** Room Number
- — — Surface Survey Lines
- ▲ Rod Extensometer
- ● BPC's
- X Instrumented Rock Bolt
- ■ Overcore
- ‡ Convergence

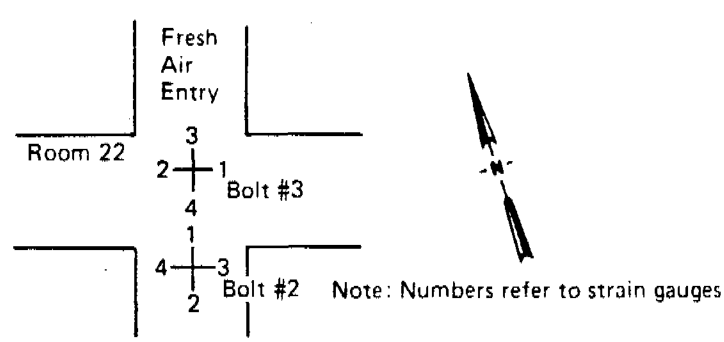
FIGURE 3.8
UNDERGROUND INSTRUMENTATION



DETAIL A-ROOM 6 INSTRUMENTATION



DETAIL B-ROOM 13 INSTRUMENTATION



DETAIL C-ROOM 22 INSTRUMENTATION

FIGURE 3.9

DETAILS OF UNDERGROUND INSTRUMENTATION LAYOUT

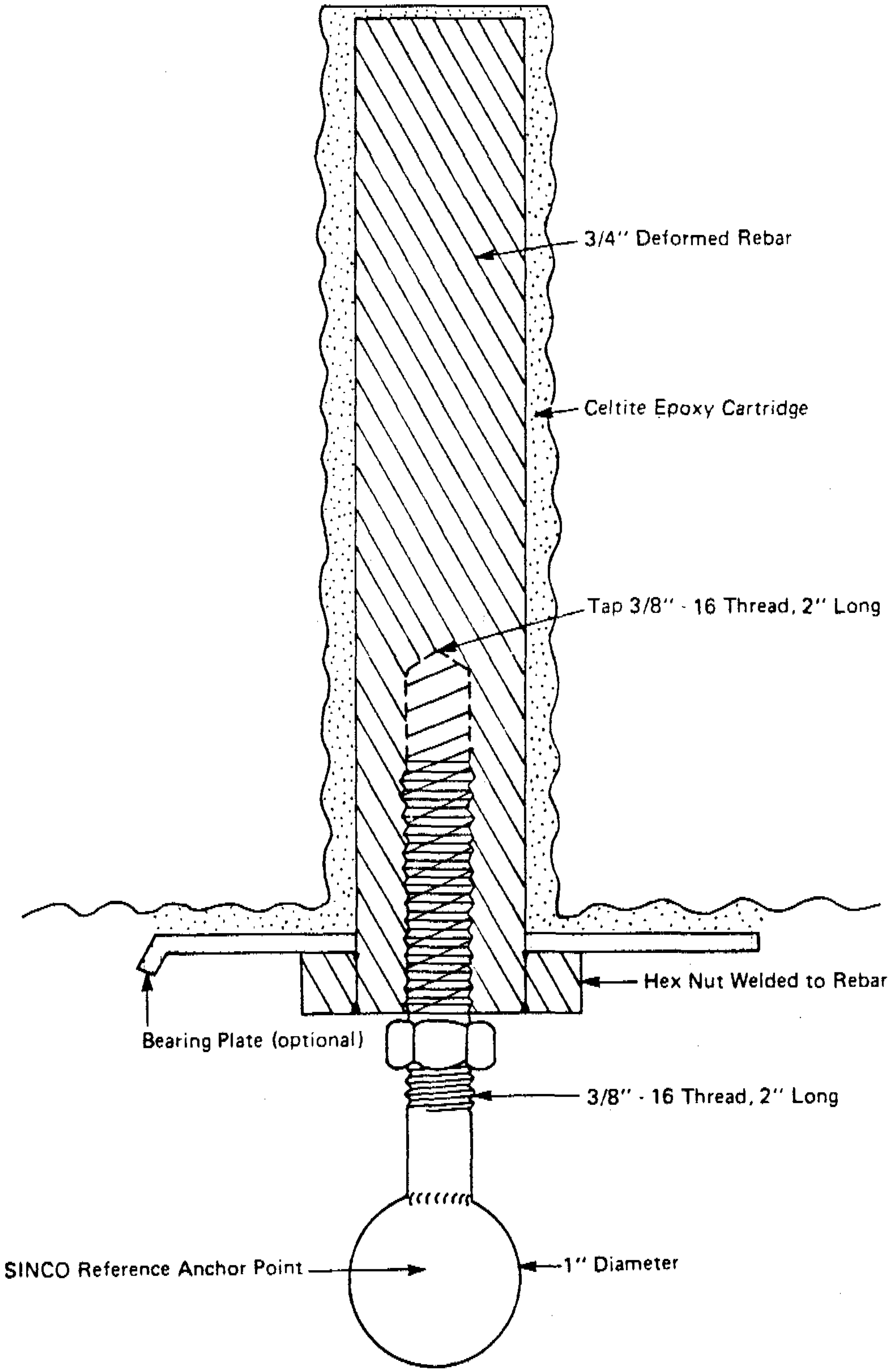


FIGURE 3.10
ROOF REFERENCE POINT DETAILS

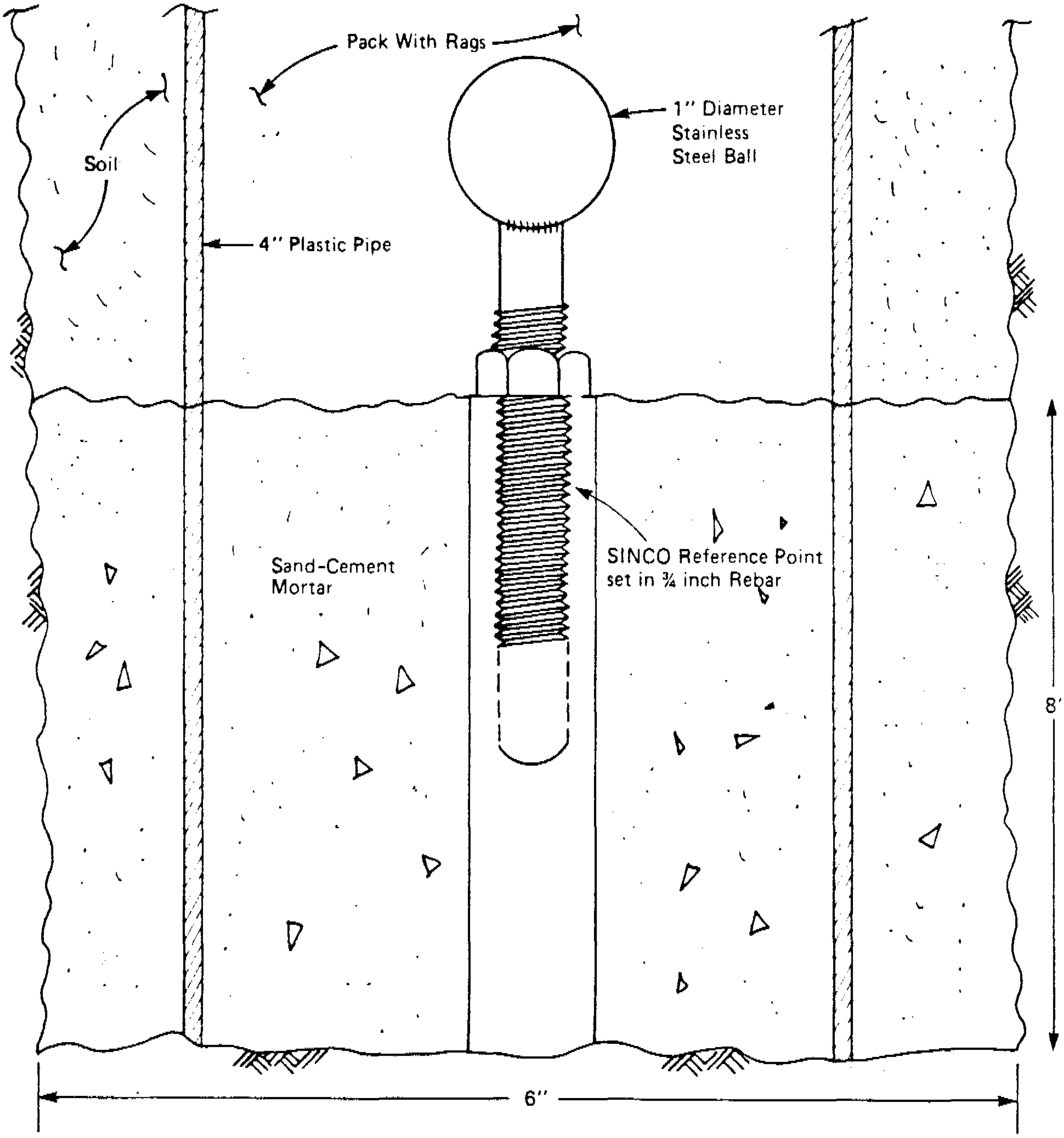
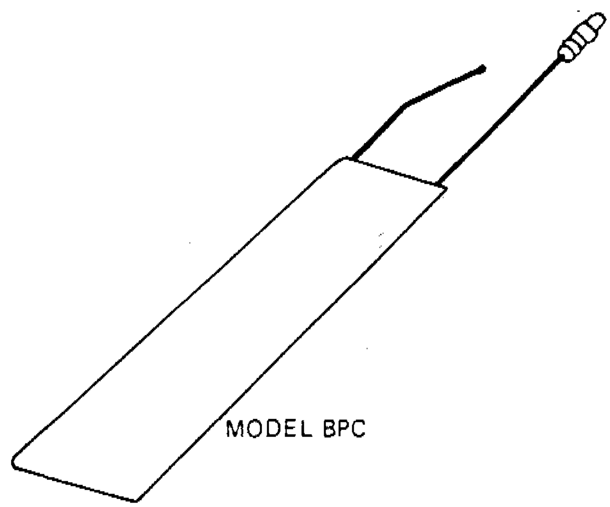


FIGURE 3.11

MODIFIED MINE FLOOR CONVERGENCE DETAILS



Borehole Pressure Cell
Terrametrics Model BPC-2.25

Capacity	0-4000 psi
Sensitivity	10-25 psi (depending on pressure gauge)
Size	10 x 2 x 1/4 inch (other sizes available on request)
Borehole Depth	0 to 50 feet
Weight	2 lbs

FIGURE 3.12

HYDRAULIC BOREHOLE PRESSURE CELLS

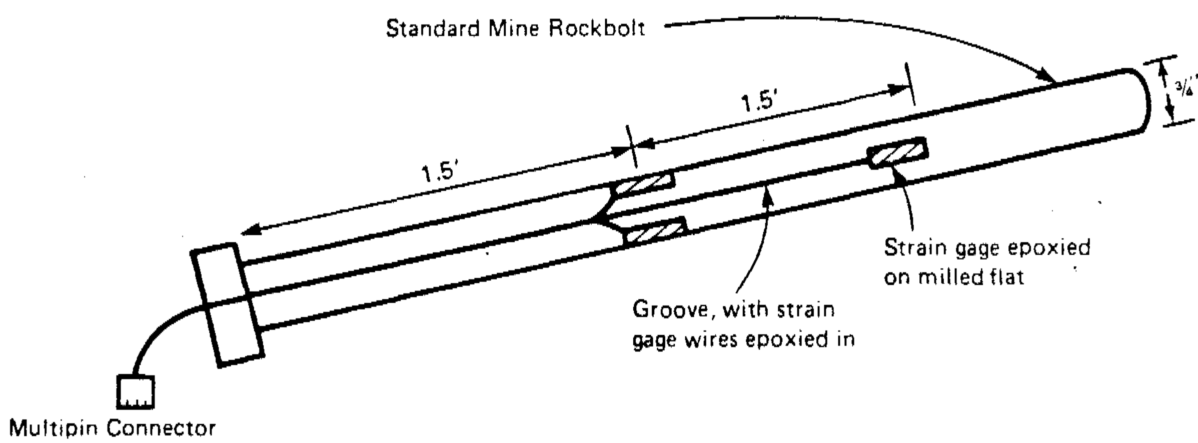
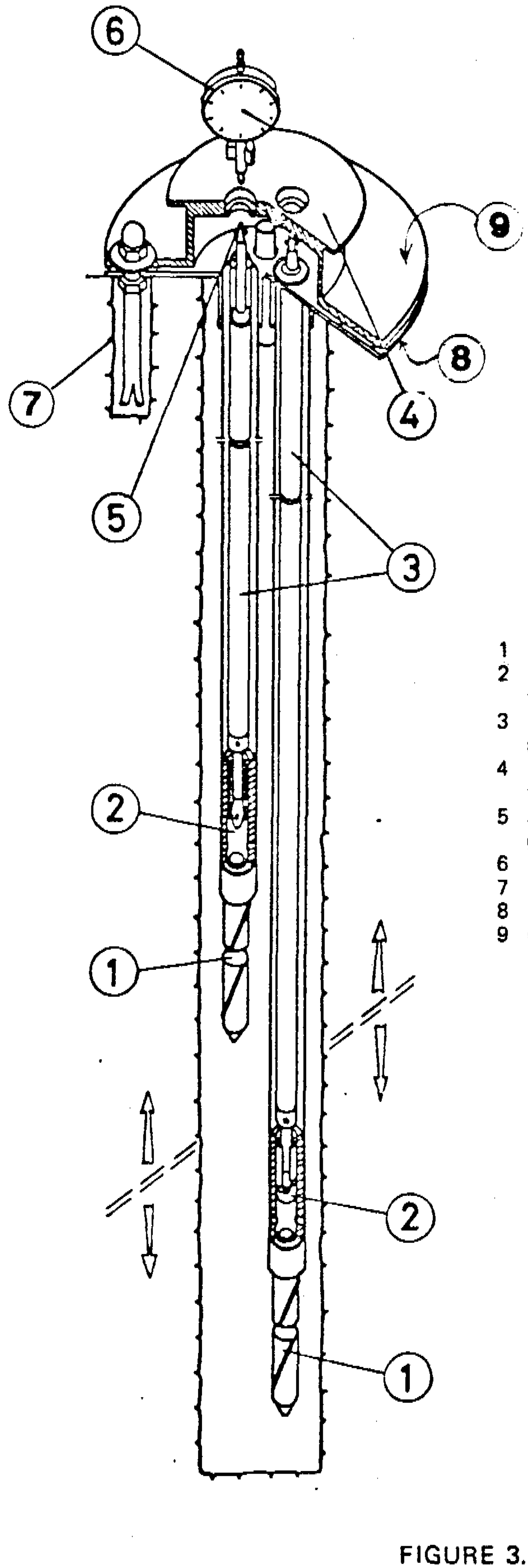


FIGURE 3.13

INSTRUMENTED ROCK BOLT



1 Ribbed steel anchor, fixed by grout injection
2 Anchor cone with measuring and calibrating notch for functional control
3 Extension rods in plastic protective tube, with lock mandril at anchor end, and with sensor bar at head end
4 Extensometer head with rod guides and rock bolts for fixation at borehole mouth
5 Sensor bar and dial gauge bar; recess for placing dial gauge or electrical sensor
6 Dial gauge with dial gauge bar
7 Rock bolt set up modified for use in top coal not shown
8 Inner cover plate
9 Outer measuring plate

FIGURE 3.14

INTERFELS MULTIPLE ROD EXTENSOMETER

to the instrument installations; this information may be difficult to reconstruct on a daily basis at a later date.

Refer to Figure 4.1 for a sample data sheet.

4.2 SURVEYS

4.2.1 Level Survey

A Wild NAK-1 Level and a 25-foot fiberglass rod were used for the level survey (Figure 4.2). An initial survey was done with a 3-m invar rod and an optical micrometer. Subsequent surveys were performed with the 25-foot rod to complete more quickly a level circuit across the steep terrain over the length of the panel. The invar rod would have been used exclusively if precision case history data was a key objective of the work.

The Wild Level was rugged and performed well under rough conditions of weather and topography. The in-place survey equipment, particularly the machined cone monuments, performed satisfactorily. The first two level surveys did not include several monument installations, which were later completed during the operations phase.

4.2.2 Tape Extensometer Survey

A SINCO Model 51885 Tape Extensometer with a 30-m tape and 5-cm dial guage was used for the tape extensometer survey (Figure 4.2). The tape is punched at 5-cm intervals. Because heavy snow blocked the clear space between monuments, the first tape extensometer survey was not completed until after the snow had melted on the site, at which time significant strain had taken place.

4.0 MONITORING AND RECLAMATION

4.1 GENERAL MONITORING REQUIREMENTS

Some general considerations that apply to all of the operations include:

- Data record needs
- Site access and shelter
- Staffing needs.

Data Record Needs

It was useful to have all of the data sheets arranged in computer form. Based on the field experience, the following procedure was developed for data documentation:

- Mail copies of the data to the office to be key-punched and loaded into a file on the computer.

- Process and review the data by phone using a portable CRT terminal.

- Have hard copy printed at the office.

This procedure could control costs by minimizing remote handling of data, while providing on-site review of the current results.
For underground data collection, data sheets should include:

- Description of the condition of the roof, floor, and pillars

- A sketch showing the location of the face relative

The tape extensometer survey required cone-type survey monuments. For each pair of monuments, an extension rod was screwed on each cone. The rods had precision conical mating surfaces for repeatability. Short, stiff rods, only long enough to clear the ground and brush, were used. The extension rods were labeled, and the same rod was used at a given monument on successive surveys. The tape extensometer was always oriented in the same direction for a pair of monuments on successive readings. A tape thermometer was attached to the tape near the moveable socket. The basic readout procedure included the following steps:

- Set the tape extensometer sockets on the rods and lock the tape in a punched hole

- Tension the tape to 40 pounds

- Read the dial gauge and thermometer.

Although the instrument is more sensitive, a limited analysis of the tape extensometer data showed the repeatability to be only 0.03 to 0.06 inch under severe weather conditions. Several problems with the system were noted:

- The danger of breaking the tape necessitated carrying a spare tape. The punched holes in any two tapes are not exactly identical and the difference can introduce an error to the data.

- The strain may be sufficient to cause the tape to lock into different holes on successive readings. The holes are not exactly 5 cm apart, causing a potential reduction in overall accuracy.

- When extended between two monuments, the tape was sensitive to wind vibrations, so it was impossible to obtain a good reading on a windy day.

Where the high degree of accuracy as provided by the tape extensometer system is not needed, an electronic distance measurement (EDM) survey might be more economical to operate. The expensive tape extensometer monuments and lengthy readout procedure could be substituted by conventional survey monuments and the rapid survey procedure associated with an EDM system. EDM equipment is fairly expensive and requires much more technical training for use, compared with a tape extensometer system. However, where it is convenient to contract for EDM services, these factors may present no special difficulty and the required accuracy may control the choice.

4.2.3 Crack Survey

In addition to the surface measurements described above, the instrumentation lines were walked at each monitoring session and cracks were noted on a map. These crack maps proved useful in data interpretation.

4.3 INCLINOMETER/SONDEX OPERATION

4.3.1 Sondex System

The full profile borehole extensometer system included a SINCO Sondex probe and readout (Figure 4.3) with corrugated polyethylene casing. The casing was outfitted with stainless steel rings at approximately 10-foot intervals. The depths to the rings were monitored with a probe containing a transformer-like sensor and a fully graduated steel tape.

The Sondex probe was adapted to operate on the same cable provided for the inclinometer. The cable was wound on a reel mounted on a portable skid (Figure 4.4) to allow operation of the system from the back of a pick-up truck (Figure 4.5). The skid had moveable extension booms that allowed the cable to be centered directly over the hole.

The original procedure used for reading of the system was to lower the probe, cable and tape to the bottom of the hole, allow the probe to come to temperature equilibrium and then make the readings on the way up. This procedure was modified when the tape twisted repeatedly around the cable, and kinked or broke when reeled in. The modified procedure was as follows:

- Lower Sondex probe without tape and note location of the rings relative to cable marks. Probe to determine total depth of hole, because the casing may shear as subsidence develops.

- Attach tape to probe. Lower tape and probe to just below deepest ring. Raise probe, taking weight primarily on the tape until the meter on Sondex readout reaches a maximum. Read tape. Repeat the procedure. If readings are not within 0.01 foot above 300 feet and 0.02 feet below 300 feet, repeat until good agreement is reached.

- Read next ring.

The Sondex instrument is simple in concept, but the separate tape is difficult to use in deep holes. The accuracy may be approximately 0.01 to 0.02 feet and smaller movements between rings are difficult to detect. Tape breakage problems and slow readout procedure were definite handicaps.

A major improvement in the system could be achieved by eliminating the separate tape. One alternative is to vulcanize a fully graduated fiberglass tape to the inclinometer cable. Another alternative is to improve the quality of the 1-foot marks already vulcanized to the cable and incorporate a scale at the top of the casing so that the offset from the nearest 1 foot mark could be read.

4.3.2 Inclinometer System

A SINCO Digitilt Model 50325 inclinometer probe (Figure 4.6) with 2.75-inch O.D. ABS plastic casing was used. The probe consists of force-balance accelerometers on two orthogonal axes. It is operated on a distance graduated strain reinforced multi-conductor cable.

The inclinometer was operated in the standard manner, reading both orthogonal channels every 2 feet on the way up. The probe was lowered to about 10 feet above the bottom of the hole (as indicated by the Sondex probe) to begin the readings, in case the casing was cracked at the bottom of the hole. To make readings easier, the skid was designed with an adjustable pointer which was aligned with a 1-foot mark on the cable near the readout set-up where the first 2-foot mark on the cable was aligned with the top of the casing. The pointer was then used to line up the cable marks for subsequent readings.

While the inclinometer survey was a repeatable and routine process, there were some equipment problems, possibly caused by vibration of the unit during daily transport. The servo-accelerometer type probe was repaired twice. The slip rings on the cable reel did not always maintain direct contact between the readout and the probe, resulting in zero readings until the problem was diagnosed.

Cracks in the casing caused by mining-induced shears could provide a trap for the spring-loaded wheels on the probe. To prevent loss of the probe into casing cracks, the bottom 10 feet of the hole was not monitored. To prevent trapping of the probe in bent or cracked casing, replaceable shear pins might be incorporated into the spring-loaded wheels of the probe. The wheels would be designed to collapse when the probe is pulled up at a near-damaging load.

4.4 MICROSEISMIC READINGS

The geophone readout for both the grouted-in-place system and portable system was a SINCO MS-3 with a meter, mechanical and digital event counters, earphone, high and low filters, and gain and trigger level adjustments (Figure 4.7).

4.4.1 Grouted-in-Place System

The grouted-in-place system was operated as follows:

- Connect the wires to the readout; set the filters on normal (wide band); find the combination of trigger level and gain that just eliminates the background noise and gives a reasonable count as determined from previous experience. Take a 10-minute reading. On subsequent readings, use this setting.

- Using various high and low cut filters, find the appropriate gain and trigger level settings that eliminate the background noise. Pick several filter settings and take 10-minute readings. Use these filter, gain and trigger level settings on subsequent readings for comparison with initial readings.

The grouted-in-place system was easy to operate. Attempts were made to allow the cables to slip with ground movements by providing a protective plastic tubing jacket over the cable so that the cement grout backfill would not bond to the cable. Three of the four geophones survived most of the subsidence period. The geophone at 472 feet failed early in the program, probably because of mining induced shears.

The readout used proved unreliable. The three event indicators--a meter, a mechanical total event counter and a digital rate counter--did not give compatible results. The reset button controlled reset of the display but not of the 10-minute digital counter. There was no scale on the trigger level adjustment or on the meter. It was not possible to assess and compare the magnitudes of events at different settings. Redesign of this model of readout is recommended.

4.4.2 Portable System

The portable system used a SINCO geophone on a strain-reinforced cable and an air-operated packer to force the geophone against the side of the hole. The system was used in a hole cased with 4-inch steel casing (Figure 4.8).

The basic readout procedure was as follows:

- Assemble and pressure-test packer assembly.
- Lower geophone and packer, with attached pneumatic line and cable, to a 100-foot depth.
- Inflate packer to press geophone against side of casing. Take a 10-minute reading, adjusting settings as described for the grouted-in-place system.

- Deflate packer, lower system 100 feet and repeat.

The portable system was tested successfully only once, at the end of the program. The packer, air hose and gas bottle system were fabricated especially for this project, and winter conditions delayed the resolution of several operational problems for these items. The handling of the air hose was simplified by devising a reel assembly with quick connects, and a pressure gauging system was improvised to prevent over-inflating and bursting the packer (15 psi mid scale). Once the monitoring procedure was finalized, the system operated smoothly. However, the undermining process was almost complete by this time.

4.5 UNDERGROUND SURVEY AND CONVERGENCE

The underground survey was done with a WILD NAK-2 level and a folding wood rod. The underground survey program was terminated after it became clear that the long distance between points and poor visibility reduced the accuracy of the survey beyond acceptable limits.

The convergence system used a SINCO tape extensometer with grouted-in reference points. The basic monitoring procedure was as follows:

- Locate and clean the points

- Place the tape extensometer sockets on the balls, lock the tape in a hole, tension to 40 pounds and read the dial gauge.

Reliable measurements require operator experience, and some of the readings made by mine personnel for WCC were difficult to interpret. The tape extensometer required cleaning and recalibration when coal dust and dirt prevented repeatable operation. The first two pairs to be installed were abandoned because the floor points could not be cleaned. Of the five pairs installed subsequently with an improved design, three survived routine traffic conditions and provided some data. The tape extensometer system appears reliable, but is dependent on stable reference points, clean conditions, and experienced operators.

4.6 OVERCORE TESTS

Three overcore tests were conducted 20, 33, and 34 feet into one up-hole in Room 13. The overcore tests were performed using IRAD equipment and standard USBM procedures. Cracked core in the 34-foot test limited the usefulness of the data from that test. Biaxial modulus tests of the core were completed following the overcore tests.

4.7 HYDRAULIC BOREHOLE PRESSURE CELLS

The pressure gauges for the hydraulic borehole pressure cells were read directly at the hole collar. The gauges were rehung from the roof when spalled pillar ribs loosened the spads that were initially used to support the pressure gauges.

4.8 INSTRUMENTED ROOF BOLTS

Strain-gauged, resin-grouted roof bolts made by GEOKON were monitored with a Vishay P-350 strain gauge readout. Successfully installed gauges gave reasonable, low working load values. It is suggested that a remote reading wire harness would enable reading of bolts near the face without danger to readers and after caving of the bolted area.

4.9 ROD EXTENSOMETER

The two rod extensometers were read with a dial gauge. The basic readout procedure was as follows:

- Remove cover.

- Place dial gauge on measuring stud and read, repeat; if reading not within one or two divisions, repeat until good agreement is reached.

- If dial gauge is near end of travel, reset; then reread all measuring positions in case of accidental disturbance.

An electrical remote readout system is available for this instrument and would allow additional data collection and remote reading when the face approaches.

4.10 CLEANUP AND RECLAMATION

All cleanup and reclamation work was done to the recommendations and subject to the approval of the United States Forest Service, Fishlake National Forest. A bond was posted with the Office of Surface Mining, to be released only when reclamation has been accepted by that office.

After the drilling phase, the mud pits were brought up to contour and reseeded. Topsoil from nearby cattle ponds was used to increase the fertility of the local topsoil. Water bars were placed in the roads to prevent erosion from spring runoff, and the surface of the reclaimed area was left rough to minimize erosion. Large unsightly boulders were buried and trash was removed.

After completion of the operation phase of the program, the roads and drill pads were brought up to contour, covered with original and supplemental topsoil, and reseeded.

The areas reclaimed the previous winter had reseeded successfully, except in a few limited areas where the soil was rocky. More topsoil was added to these areas and they were again reseeded. All deep holes were grouted to within 1 foot of the surface, and casings were cut back to that level. The holes were covered with fill and reseeded. The deep holes were marked with stakes giving the leaseholder's name (SUFCO) and the hole number.

PRESSURE CELL DATA

ENGINEERS ______________________________ DATE [ ][ ]–[ ][ ]–[ ][ ][ ] (1 2 3 4 5 6 7 8)

FACE LOCATION [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] (9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27)

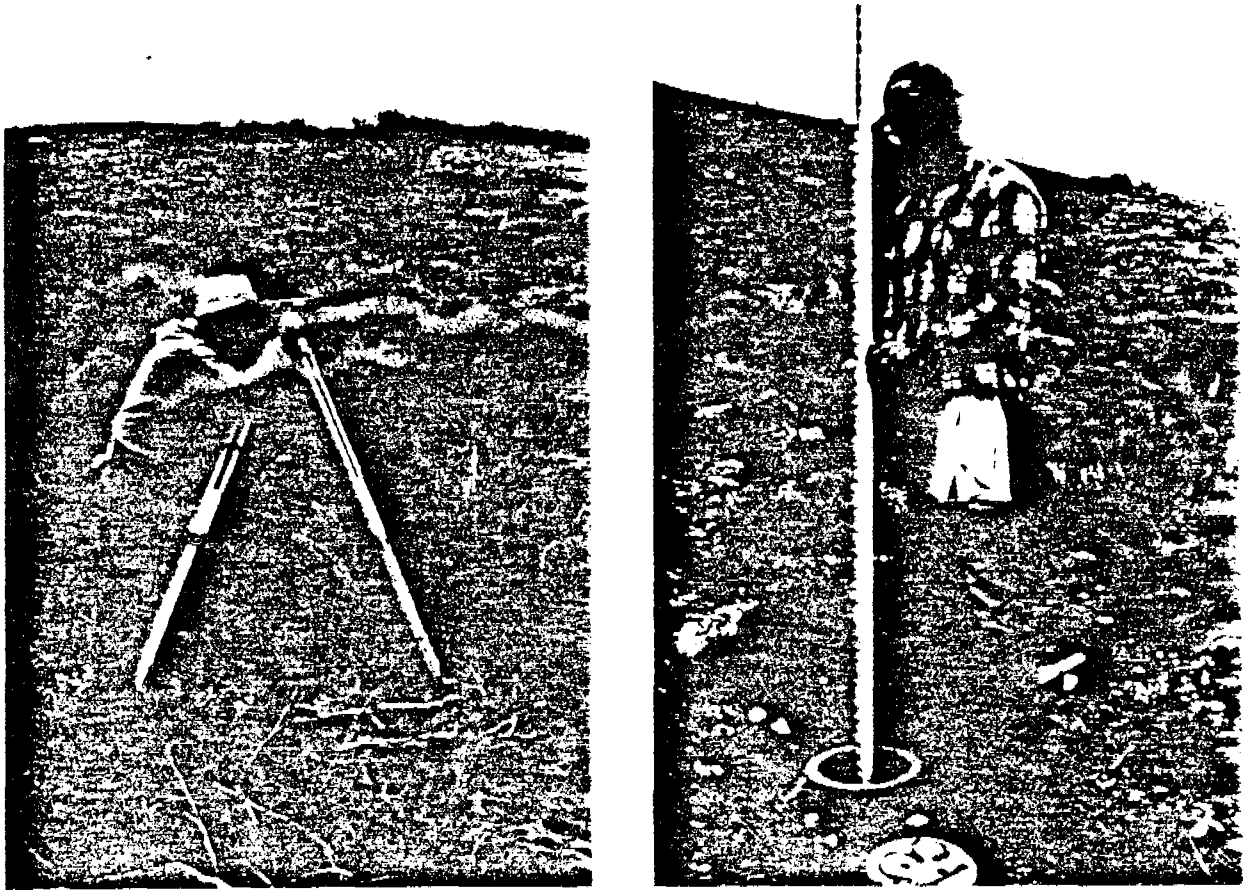
TIME	INSTALL-ATION NO.	CELL NO.	PRESSURE GAGE READING UNITS ______	CONDITION OF INSTRUMENTED AREA (Use Abbreviations)		
				INSTRUMENT HEAD	ROOF / FLOOR	PILLARS / RIBS
28 29 30 31 32	33 34 35 36	37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58	59 60 61 62 63 64 65 66 67 68 69	70 71 72 73 74 75 76 77 78 79 80

← SKETCH SHOWING FACE LOCATION RELATIVE TO INSTRUMENTS

COMMENTS ON MINING CYCLE: ______________________________

FIGURE 4.1

RECOMMENDED LAYOUT FOR UNDERGROUND DATA SHEETS



(a) Level Survey

(b) Tape Extensometer Survey

FIGURE 4.2

TAPE EXTENSOMETER AND LEVEL SURVEY EQUIPMENT

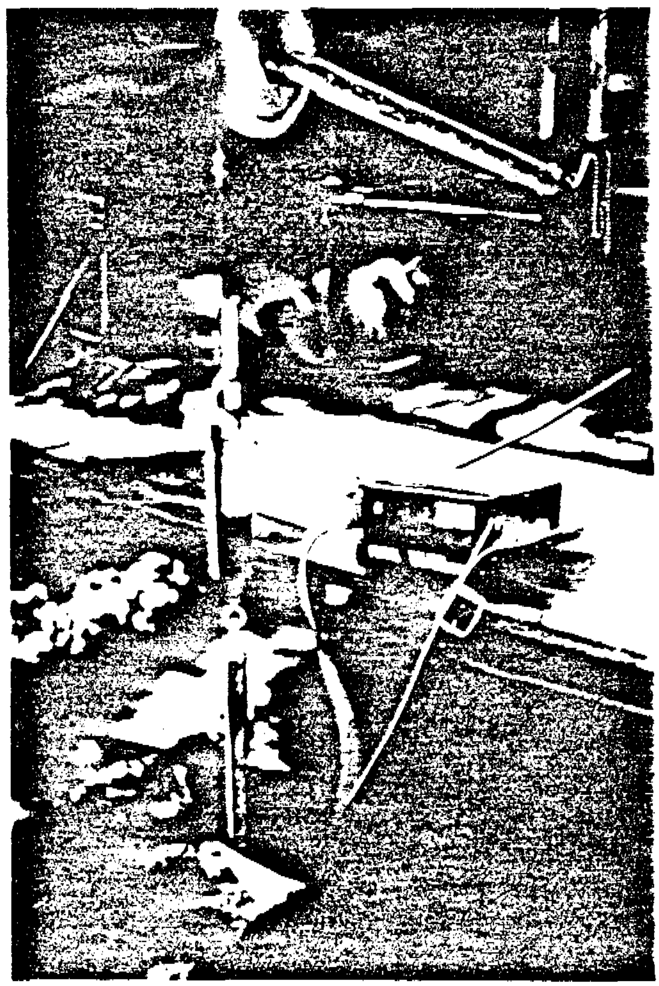
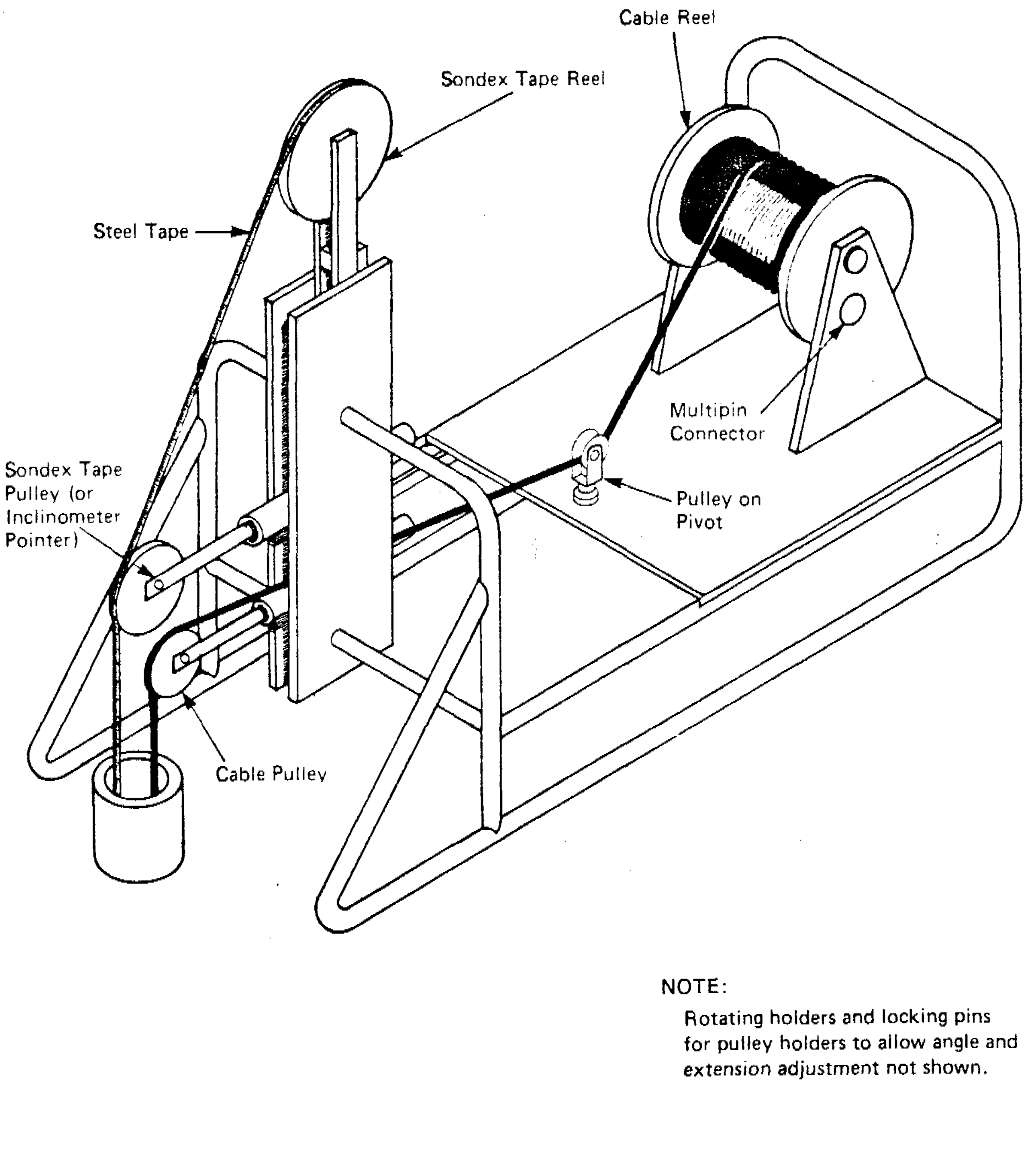


FIGURE 4.3

SONDEX PROBE AND READOUT



NOTE:

Rotating holders and locking pins for pulley holders to allow angle and extension adjustment not shown.

FIGURE 4.4

SKID WITH ADJUSTABLE BOOMS FOR SONDEX AND INCLINOMETER OPERATION

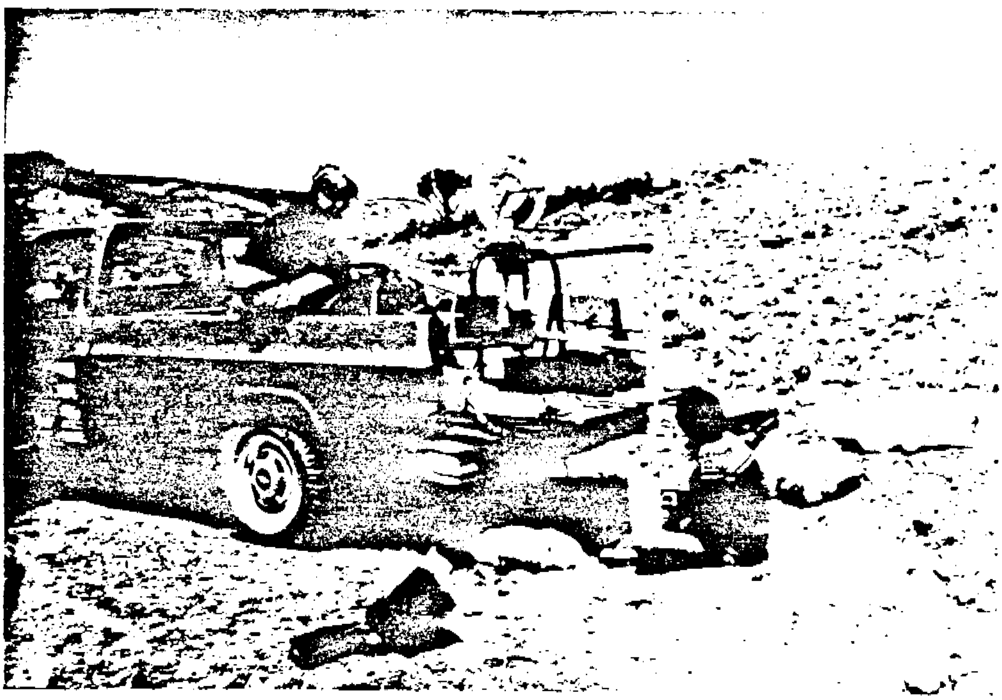


FIGURE 4.5
SONDEX OPERATIONS

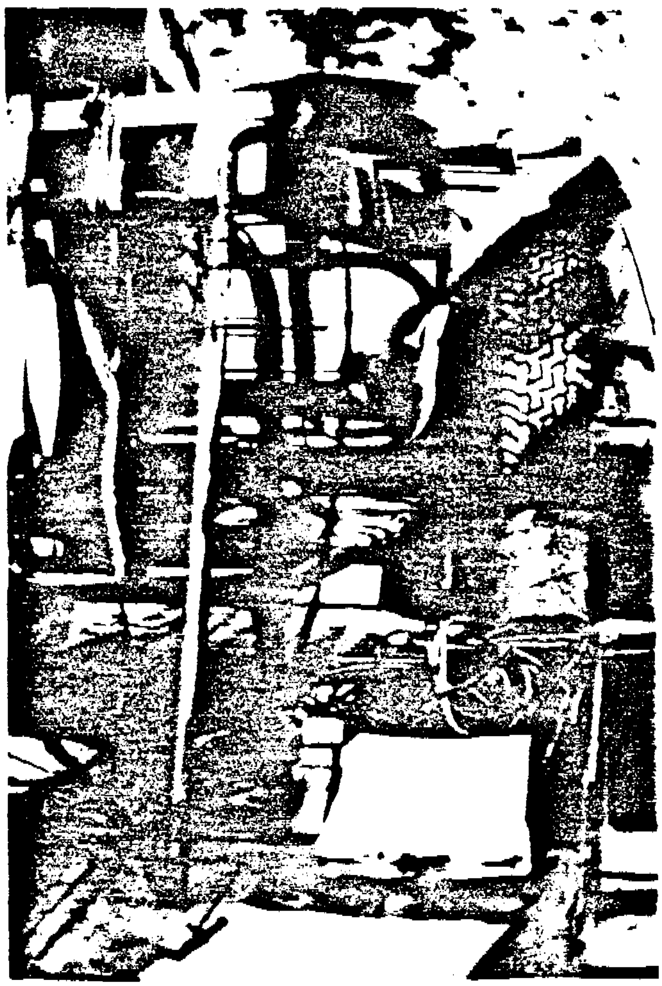
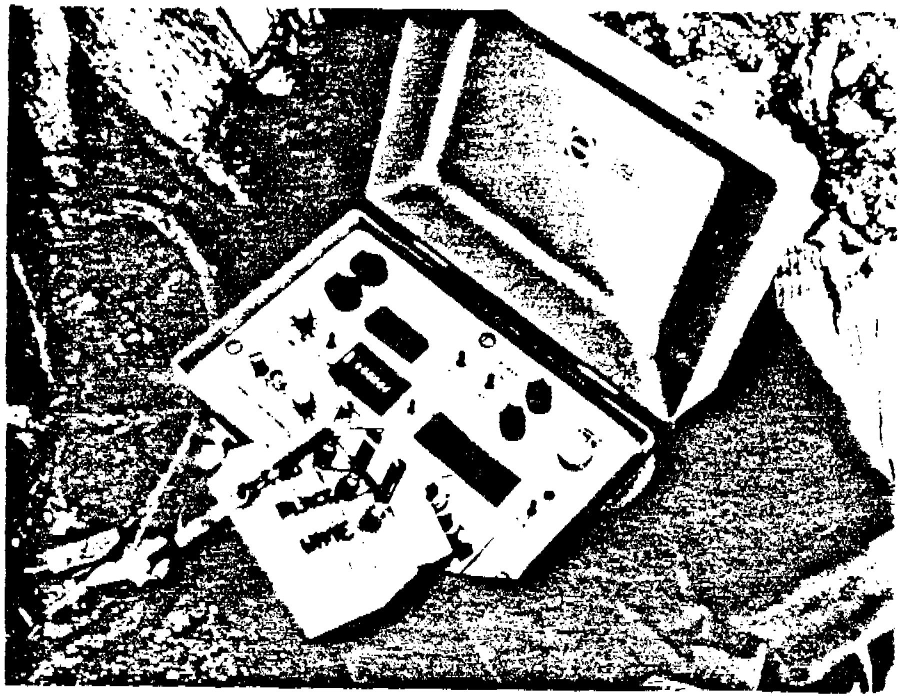
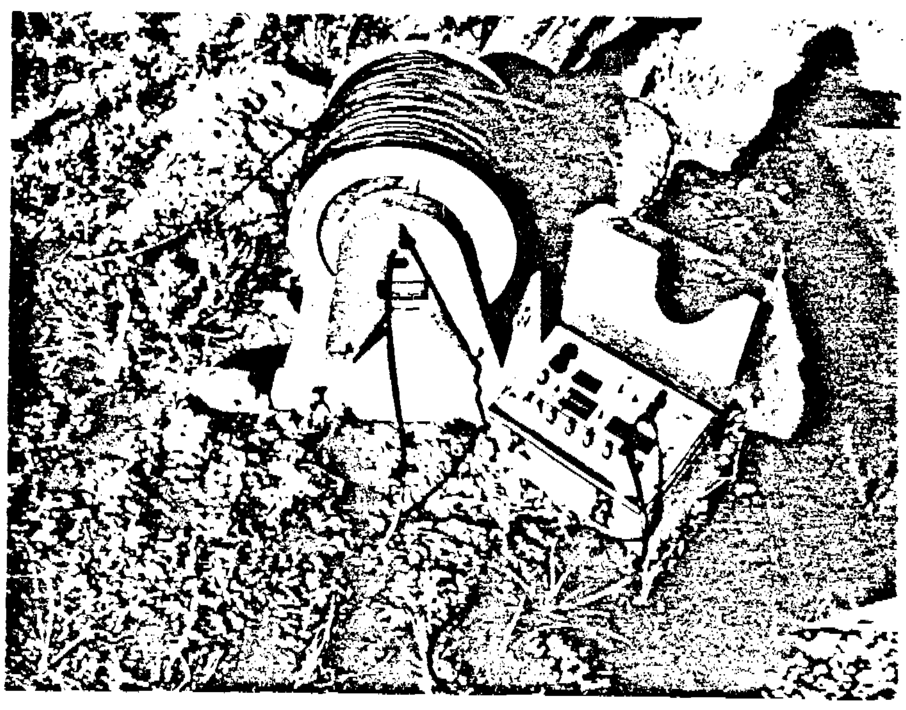


FIGURE 4.6

INCLINOMETER PROBE AND READOUT



(a) Grouted in place Geophone Readout Assy



(b) Portable Geophone Readout Assy

FIGURE 4.7

GEOPHONE READOUT AND TERMINAL EQUIPMENT

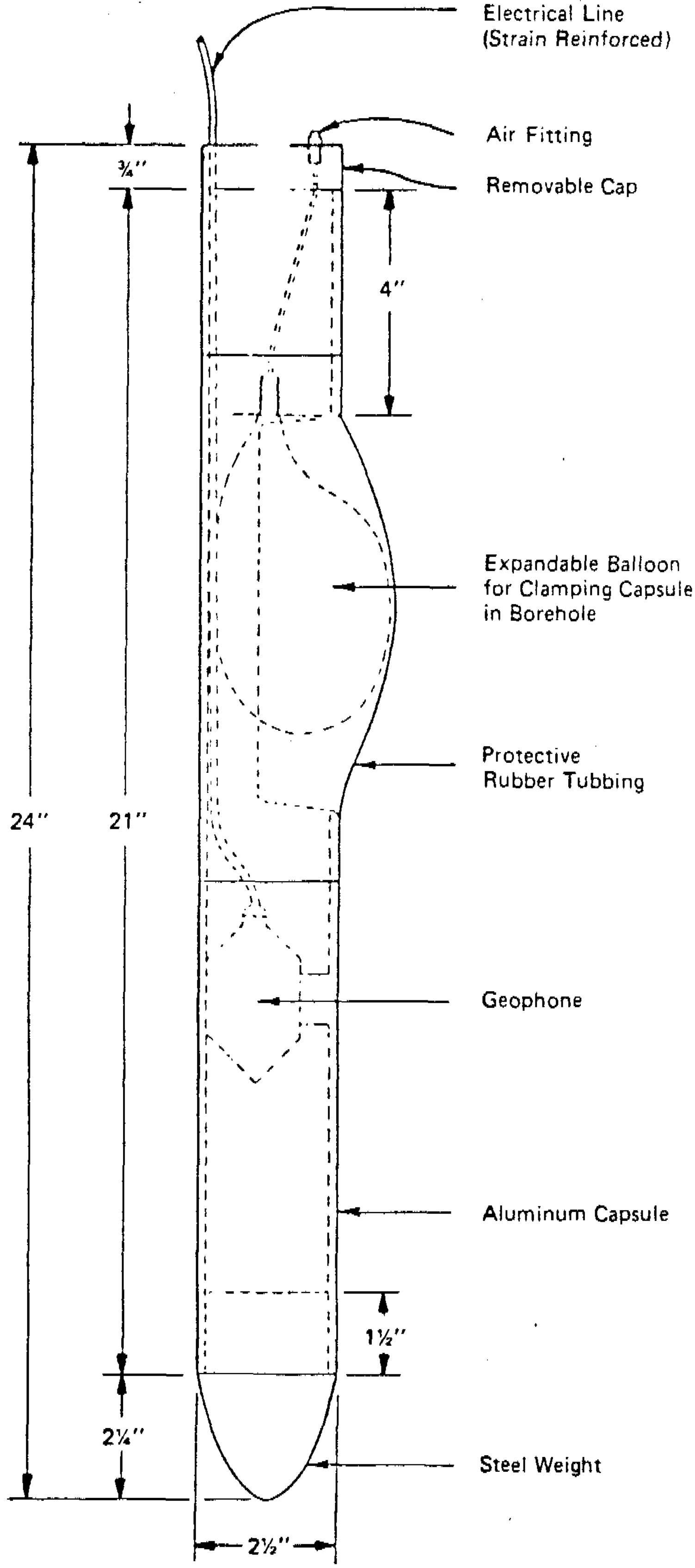


FIGURE 4.8

PACKER ASSEMBLY FOR GEOPHONE

5.0 FIELD DATA AND ANALYSIS

5.1 GENERAL

The purpose of this project was to test certain instrument systems. An important test for the instruments is whether they produce useful data. While the data resulting from this study do not comprise a comprehensive case study, the project achieved its purpose by characterizing some aspects of subsidence over a panel experiencing heavy ground conditions.

5.2 SURVEY DATA

5.2.1 Level Survey

Level survey subsidence profiles were affected by problems encountered during mining, which resulted in an area of low extraction and a solid coal pillar left in the center of the panel. See Figure 5.1 for extraction results and face progress for instrumented panel. The maximum subsidence observed was 2.6 feet. The survey profiles are shown on Figures 5.2 and 5.3.

The subsidence profile was compared (Figure 5.4) with the predicted profile based on National Coal Board (NCB) data.* NCB curves were calculated for the following conditions: W = 152 m, L = 610 m, h = 305 m, m = 2.44 m and adjusted for limited face advance and virgin ground conditions. The face

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*National Coal Board, 1975 Subsidence engineers handbook: Second Edition, Great Britain.

advance was 177 m in the north section of the panel and 312 m in the south end. Maximum slope was determined from 2.75 S_{max}/h using S_{max} corrected for limited face advance and virgin ground conditions. Subsidence in the area of low extraction was calculated using a superposition method and determining the subsidence for each room mined.

The NCB data were developed for somewhat different mining conditions, but the comparison is useful for general reference. Agreement is fairly good over the north end of the panel, but both the areal extent and magnitude of the predicted profile are larger than the actual profile at the southern end. Maximum tilt computed from level survey data reached 12.6×10^{-3} near survey point 43. For the same location, National Coal Board empirical formulas predicted a maximum of 9.3×10^{-3}, essentially the same order of magnitude. Tilts exceeding 3×10^{-3} are generally considered damaging to structures.

Figure 5.5 shows the time rate of subsidence for selected points. Plots of normalized subsidence data versus time (Figure 5.6) indicate that full subsidence developes at least 155 days after mining, and that at least 90 percent of subsidence develops within 155 days. The curves indicated that the time delay between mining and the start of major subsidence seems to increase from south to north along the panel. This phenomenon may be influenced by the length of time taken between surveys. The NCB recommends plotting normalized subsidence curves versus a face advance factor: face advance/depth. This plot is not presented because of the limited face advance. The total face advance was 580 feet and 1,025 feet in the southern half for a panel depth of 1,000 feet. The NCB plot is appropriate for conditions where the face advance factor exceeds 1.0 ahead of the point and 0.4 behind the survey point, when subsidence is complete.

Over a three-year period, panels 2E2L, 2E3L, and 2E4L were mined sequentially. Table 5.1 and Figures 5.1 and 5.2 show the additional subsidence that occurred over 3L when 4L was mined. The figures also show the additional subsidence over 2L resulting from mining both 3L and 4L. It should be noted that gate pillars between adjacent panels are extracted as part of the mining process. The additional subsidence resulting from mining of an adjacent panel is a large percentage of the original subsidence, probably because the individual panels appear to be significantly subcritical in width. A critical or super-critical width appears to be reached only when two or more adjacent panels are mined (recalling that chain pillars between panels are mined to the extent possible).

Baseline data for survey points 35 and 36 were not available for determining subsidence caused by mining 2L. The survey program began when subsidence over these points caused by mining 2L was 90 to 100 percent complete. At point 36 over the center line of 2L, subsidence of 0.62 feet was caused by mining 3L and an additional 0.02 feet was caused by mining 4L. At point 35, the mining of 4L caused a 0.08-foot increase in subsidence. The subsidence increase trends observed at SUFCO are consistent with data reported by the NCB, as shown in Table 5.2.

The limit angle (angle of draw) and critical width are two parameters generally used to characterize subsidence. The area of low extraction in the middle of the panel prevents accurate determination of these parameters for this study, but estimates may be given (Table 5.3). Angle of draw and limit are synonymous as used here. While this angle generally applies to affected ground above a newly-mined coal seam, it was also determined for ground above adjacent mined-out panels to show the greater extent of ground influenced.

When a panel is of critical width or wider, the points at the center of the panel should not subside further when the panel is widened. Level survey data yield the following implications:

- The panel width of 500 feet (650 feet including chain pillars) is substantially less than critical width, because subsidence (which had stabilized) continued to develop when adjacent panels were mined.

- One half of the critical width is probably greater than 850 feet, because mining of 4L appeared to increase the subsidence at point 35. This calculation assumes that point 35 is at the center of a critical width panel that extends just up to the western edge of 4L. Given the additional factors influencing subsidence at this location (the partial extraction zone), this number may be in error. The NCB predicts a critical width of 1.4 h = 1,400 feet. Given normal mining conditions, the data suggests that a number this large is appropriate.

- Different limit angles are appropriate for virgin ground and undermined ground. About 14 degrees is probably appropriate for virgin ground at SUFCO with about 45 degrees for undermined ground.

5.2.2 Tape Extensometer

A traveling strain wave typically consists of a tensile wave ahead of the face followed by a compression wave. The first tape extensometer survey was completed when 3/4 of the panel had been mined. As a result, most of the measured strains were compressive because the tensile part of the traveling wave had already passed the measuring stations (Figures 5.7 through 5.10). Residual tensile strains were measured above the block of solid coal left in the middle of the panel. Unexpected compressive strains were measured over one end of the unmined center portion of the panel and are discussed in Section 5.10. Because the strains measured in this program could not be compared to pre-mining profiles, it was not useful to compare SUFCO data with NCB predictions.

The profiles shown on Figures 5.7 through 5.10 are shown in conjunction with the ground cracking survey data for the same period.

Plots of strains computed from the level survey are shown on these figures for comparison with tape extensometer data. Strain computations derived from level survey data assume that points move only vertically, so horizontal strains computed from level survey data are only approximate. The computed strains are one order of magnitude less than the available strain data measured by the tape extensometer. When the level survey strains are increased by a factor of ten and plotted (Figure 5.7), the shapes of the curves are similar to the actual strain profiles but appear to be offset up to 250 feet downhill.

5.2.3 Crack Survey

In connection with the tape extensometer survey, the instrumented lines were surveyed for ground cracks on or near them (Figures 5.11 through 5.13). While extensive cracking occurred during active mining, the surface manifestation of all but one of the major cracks had healed by 8 months after the end of mining. The remaining open crack appears to be a result of subsidence over the pillar of solid coal left in the middle of the panel.

5.3 SONDEX/INCLINOMETER DATA

The Sondex data are plotted on Figures 5.14 and 5.15 as displacement per ring interval. In Borehole I-1, an upward migration of cracking can be observed. In Borehole I-2, no clear trend is apparent. The data suggests that no significant bulking or increase in rock volume occurred within the measured zones (Table 5.4). However, casing failure limited the amount of data collected. The Sondex data do not indicate serious potential casing distress before failure.

Profiles of horizontal offset with depth are shown on Figures 5.16 through 5.19. These profiles show that the upper strata tilt toward the gob in Boreholes I-1 and I-2. The tilt angle is small, ranging from 2 to 10 minutes. The tilted upper strata (Table 5.5) correlate between holes and with a distinct stratum, identified in the log of borehole M-1. The base of this unit, which is probably the bottom of the Castlegate Formation, may be correlated with several casing failures.

Borehole I-2 was sheared to a depth of 27 feet between October 1980 and May 1981. Substantial shear occurred prior to failure in I-2 at the exact depth at which the casing eventually closed off. Unstable surface terrain and substantial hillside slope were present at this site. Shallow slope instability was probably the cause of failure in this hole. This shallow slope movement is documented on Figures 5.16 and 5.18 and in Tables 5.6 and 5.7 for both Boreholes I-1 and I-2 and is downslope away from the gob.

In the upper part of the borehole, the uniform tilt suggests that the strata are bending as a beam. In the lower parts of the I-1 and I-2 boreholes, a slight tilt occurs toward the gob. Displacement towards the gob may occur below 200 feet in I-1 and I-2 as slipping between strata of the

Blackhawk Formation. Shearing between strata rather than beam bending appears to be the mechanism by which the ground adjusts to undermining in the lower parts of the holes.

The casing tilts in the Castlegate Formation were compared with the ground surface tilts to determine whether classical beam bending concepts applied (Table 5.8). The tilt directions were compatible, but no clear correlation could be concluded.

5.4 MICROSEISMIC DATA

Plots of microseismic data (Figure 5.20) show that two geophones failed at 472 and 672 feet, probably because of cable damage by the same shear processes that caused failure in the inclinometer casing. The geophone at 672 feet survived most of the subsidence period; the two shallow geophones survived to the end of the project. The greatest activity occurred in August, 1980, and rock noise was almost zero by October, 1980. The October date is about 155 days after undermining, and is consistent with the surface subsidence rate data from the level survey, which indicated that 90 percent of subsidence was completed within 155 days of mining.

5.5 CONVERGENCE DATA

The convergence data for Stations 1, 2, and 5 in Room 23 are shown on Figure 5.21. A significant room convergence of 23 and 35 mm was observed at Stations 1 and 2 respectively. Station 5 shows expansion between reference points. It is likely that damage to the reference points or operator inexperience caused this result.

5.6 OVERCORE DATA

Overcore results are summarized on Figure 5.20. The in situ stresses measured for the horizontal plane are 1768 psi for the maximum horizontal stress at N41°W and 883 psi for the minimum stress perpendicular to it. One-dimensional loading of an elastic material by a 1000 psi estimated overburden vertical stress would produce a uniform horizontal stress of 176 psi:

$$\sigma_{horiz} = \left(\frac{\nu}{1-\nu}\right) \sigma_{vert}; \text{ where n} = 0.15, \text{ approximately.}$$

The excess stress is defined as the amount by which the measured stress exceeds the predicted stress determined by the elastic equation above. The excess stresses are 1,592 psi for the maximum horizontal stress and 707 psi for the minimum horizontal stress. These stresses are plotted on a map of measured horizontal stresses for the United States (Figure 5.23). The stress orientation is consistent with regional trends. The magnitude is reasonable. No evidence of abnormally high horizontal stresses, such as floor heave or major coal bumps, was observed underground. The direction of maximum horizontal stress is approximately parallel to the fault orientation (Figure 5.24). The same phenomenon was observed in the Beckley coal seam where the maximum stress direction was parallel to a major thrust fault.*

5.7 BOREHOLE PRESSURE CELL DATA

Because borehole pressure cell grout and coal moduli were not matched, there is no assurance that the borehole

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*Aggson, J. R., 1978, Coal mine floor heave in the beckley coalbed, an analysis: U. S. Bureau of Mines Report of Investigation No. 8274, 32 p.

pressure cell records actual coal stress. While the trend of stress increases and decreases is correct the magnitude of the stresses may be high or low by some factor.

The trend in the pressure cell data (Figures 5.25 and 5.26) indicates that the cells lose pressure and then stabilize, suggesting the possibility that the coal and grout may creep until the cell pressure equals the in-situ pressure. This hypothesis implies that the in-situ pillar pressures in Room 6 may be 350 psi horizontally and 720 psi vertically. In Room 13, the horizontal stress may be 380 psi.

Stresses increased in Room 6 to a maximum of 1,080 psi vertically and 943 psi horizontally. The increased horizontal stress confines the central region of the coal pillar, and is thought to increase its vertical stress capacity.

The pressure decreased in Room 13 when the face was approximately 400 feet away. Movement on a nearby fracture or joint may have cracked the grout around the cell, reducing the pressure. However, the pressure decrease may also have been a true indicator of pillar loading conditions. It was apparent from the lack of pillar spalling that the pillar was not carrying much load. It is postulated that the area around the pressure cell was stress relieved, and that the stresses decreased over the general area around the installation. A mechanism for this stress relief is discussed in Section 5.10.

Heavy ground problems nearby resulted in abandonment of the Room 13 pressure cell installation.

5.8 ROOF BOLT DATA

Roof bolt loads and bending loads, calculated as the difference in loads between pairs of strain gages on opposite sides of a bolt, are plotted on Figures 5.27 and 5.28. Not enough data were available to determine a trend in the direction of bending.

The No. 1 roof bolt was located about 50 feet away from a major roof fall in Room 15. The bolt never carried much load, possibly because the load was transferred to a crib installed about 10 feet from the bolt. Bolts Nos. 2 and 3 carried moderate loads of 2,000 to 6,000 pounds. These loads are far less than the ultimate strength of about 24 kips for a 3/4-inch diameter 56 ksi bolt.

5.9 ROD EXTENSOMETER DATA

Approximately 10 mm of movement occurred in Room 6 between the roof and the anchor at 12 feet (Figure 5.29). Of this movement, about 8 mm occurred while the face was 120 to 180 feet away. Negligible strata separation occurred between 12 and 17 feet. For a comparable anchor depth in Room 13, less than 1 mm of movement occurred while the face was approaching (Figure 5.30). This observation is consistent with the low pressure cell readings discussed in Section 5.8. After the area was abandoned, slightly more than 2 mm of movement occurred between the roof and the 10-foot deep anchor. Closing of fractures between the 20- and 50-foot anchors may account for the small movement between the 50-foot anchor and the mine roof.

5.10 IMPLICATIONS OF DATA

Heavy ground loading conditions at mine level in the instrumented areas forced a change in the mining plan, which in turn limited subsidence development and therefore the degree to which the instruments could provide complete subsidence characterization data. However, because of the concentration of data in the problem area, instrumentation provided information on factors that may have produced high stresses at mine level.

The heavy ground conditions may be explained by a deflected fault block hypothesis (Figure 5.31). In the mine area, frequent faults, having an almost vertical dip, are present and can be mapped at the surface from satellite photographs. Two major faults, labeled P and Q on Figure 5.31, may have isolated a block of rock that deflected toward the gob at the north end of the panel as mining progressed. At mine level, and viewed as a three-dimensional elastic stress problem, this deflection could produce an addition to the compressive stress state near fault Q and relieve the compressive stress state near fault P. At the surface, tension cracks might develop in response to the forward deflection at fault Q and compressive strain would develop at fault P.

The following instrument data support this theory:

- At mine level (Figure 5.32), in the area of predicted stress relief, the Room 13 pressure cell showed a major drop in stress when the face was 400 feet away. The roof extensometer in Room 13 also indicated a low stress condition.

- At mine level, the absence of pillar spalling indicated a low stress condition in Room 13 along fault P. A roof fall near the northwest end of Room 15 just inside the fault block near fault Q indicated a high stress condition there (Figure 5.32).

- A 50-foot long open crack at the surface was mapped and identified as a fault. It corresponds with the trace of fault Q (Figure 5.33).

- As the face approached the fault block, the mining and caving process acted to decrease the in situ minimum horizontal stress that restrained the block in the north-south direction. As the face reached and passed fault P, removing all lateral restraint to the north above the mine level, the block remained loaded axially by the in situ maximum horizontal stress and transversely by the remaining minimum horizontal stress component south of fault Q. Once the block deflected in response to this unbalanced loading, the maximum horizontal stress continued to cause deflection.

- At the surface, the residual subsidence strains computed from the level survey data showed compression near the fault P location (Figure 5.33). In the absence of a fault, the area should have been subject to tensile strain (joint opening) caused by extension of the strata between the unmined pillar and the subsided gob.

The generalization of this deflection mechanism to other faults and a similar mining direction at the SUFCO site might be verified by observation of fault movement at the surface and at mine level.

TABLE 5.1

SUBSIDENCE INCREASE IN ADJACENT AND NEARBY PANELS DUE TO MINING 4 LEFT

Point	Percent of Subsidence Increase Due to Mining 4 Left[1]	Distance from 4 Left Centerline
20	85%	650 ft
22	87%	650 ft
24	133%	650 ft
35	6%	1100 ft
36	3%	1300 ft

1. Baseline includes surface subsidence caused by mining of Panel 3L.

TABLE 5.2

EFFECT OF INCREASING PANEL WIDTH ON MAXIMUM SUBSIDENCE (NCB STATISTICS)

Panel Width	Subsidence[1]/Seam Thickness	Percent Increase
500 ft	0.50	N/A
1000 ft	0.85	70%

1. Add correction for virgin ground and limited face advance at SUFCO site. Percent increase unaffected.

TABLE 5.3

LIMIT ANGLES

Location	Estimated Limit Angle[1] from mining 3 Left (angle from vertical)	Comments
Near 47, 46	-2°	Areas outside panel heaved
Near 24, 27	+11° minimum	Point of zero subsidence beyond surveyed area
Near 36	19° minimum	Over adjacent panel already undermined; point of zero subsidence beyond surveyed area

Location	Estimated Limit Angle[1] from mining 4 Left	Comments
Near 35	Approximately 40 to 48°	Extending over two adjacent panels already undermined
Near 2, BM	13° minimum	Subsidence only partially complete

Notes:

1. Limit area computation at this site affected by limited length of survey lines, narrow panels, limited face advance and variable survey frequency. All angles are approximate.

   Limit angles were calculated as angle from vertical between panel rib and point of zero subsidence.

TABLE 5.4

SONDEX DATA SHOWING LIMITED BULKING

Depth	Borehole	Increase in distance from surface to ring, from 3-5-80 to:			
		5-8-80	8-20-80	10-16-80	6-81-81
281 ft	I2	0.02 ft	0.08 ft	0.02 ft	---
183 ft	I1	0.01 ft	0.01 ft	0.02 ft	0.01 ft
328 ft	I1	0.03 ft	---	---	---

TABLE 5.5

LOCATION OF BENDING STRATA

Borehole	Depth of Tilting Strata	Elevation (if Top of M-1 = 0)
I-1	70 to 185 ft	180 to 295 ft
I-2	40 to 205 ft	127 to 292 ft
M-2	174 to 270 (sandstone)	174 to 270 ft

TABLE 5.6

SHEAR ZONE DEPTHS

Borehole	Depth of Shear Failure	Elevation (if M-1 top = 0)
M-1	270 ft	270 ft
I-1	181 to 187 ft	291 to 297 ft
I-2	205 to 222 ft (major shear; but no failure	292 to 309 ft

TABLE 5.7

SHALLOW SHEAR ZONE DEPTHS

Borehole	Depth to Shallow Shear Zone	Direction of Slope Movement
I-1	10 to 20 ft	South
I-2	27 to 35 ft (failed at 27 ft)	South

TABLE 5.8

COMPARISON OF SURFACE AND BOREHOLE TILTS[1]

Borehole	Axis	BH Tilt[2]	Surface Tilt[3]
I-2	A	3 min	---
	B	3 min	7 min
I-1	A	4 min	9 min
	B	6 min	3 min

Notes:

1. Tilts should be approximately the same if conventional mechanics of beam bending applies.

2. From vertical.

3. From horizontal.

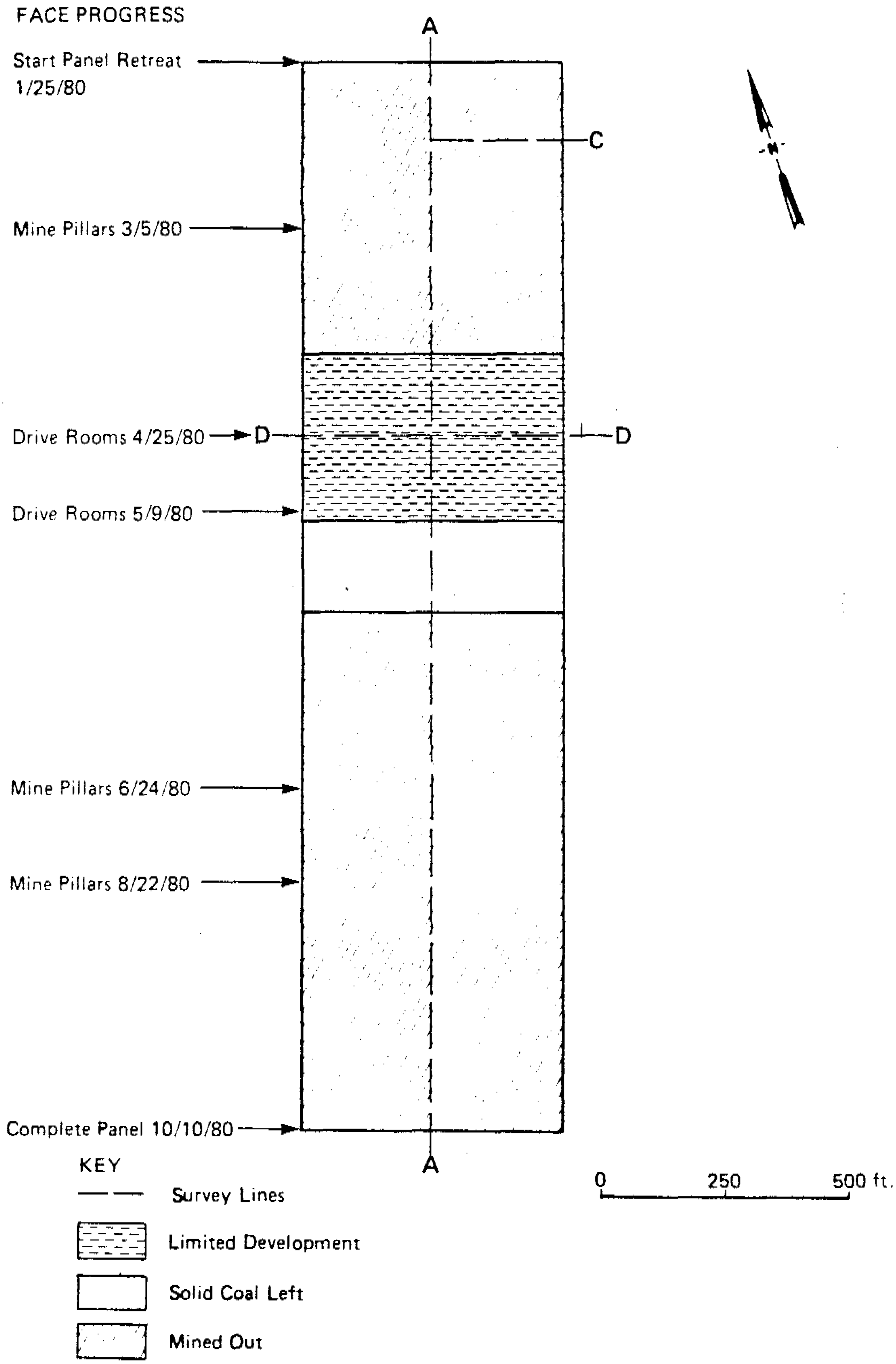


FIGURE 5.1

EXTRACTION RESULTS AND FACE PROGRESS FOR INSTRUMENTED PANEL

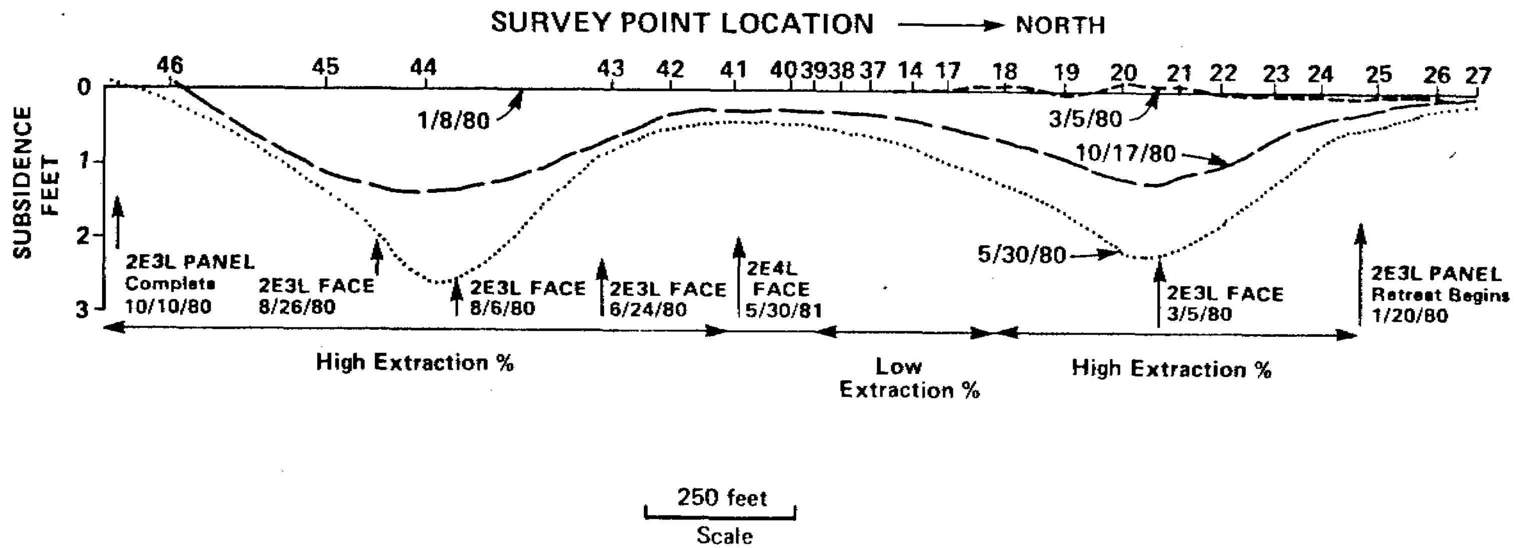


FIGURE 5.2

SUBSIDENCE PROFILES BASED ON 1/8/80 BASELINE PROFILE

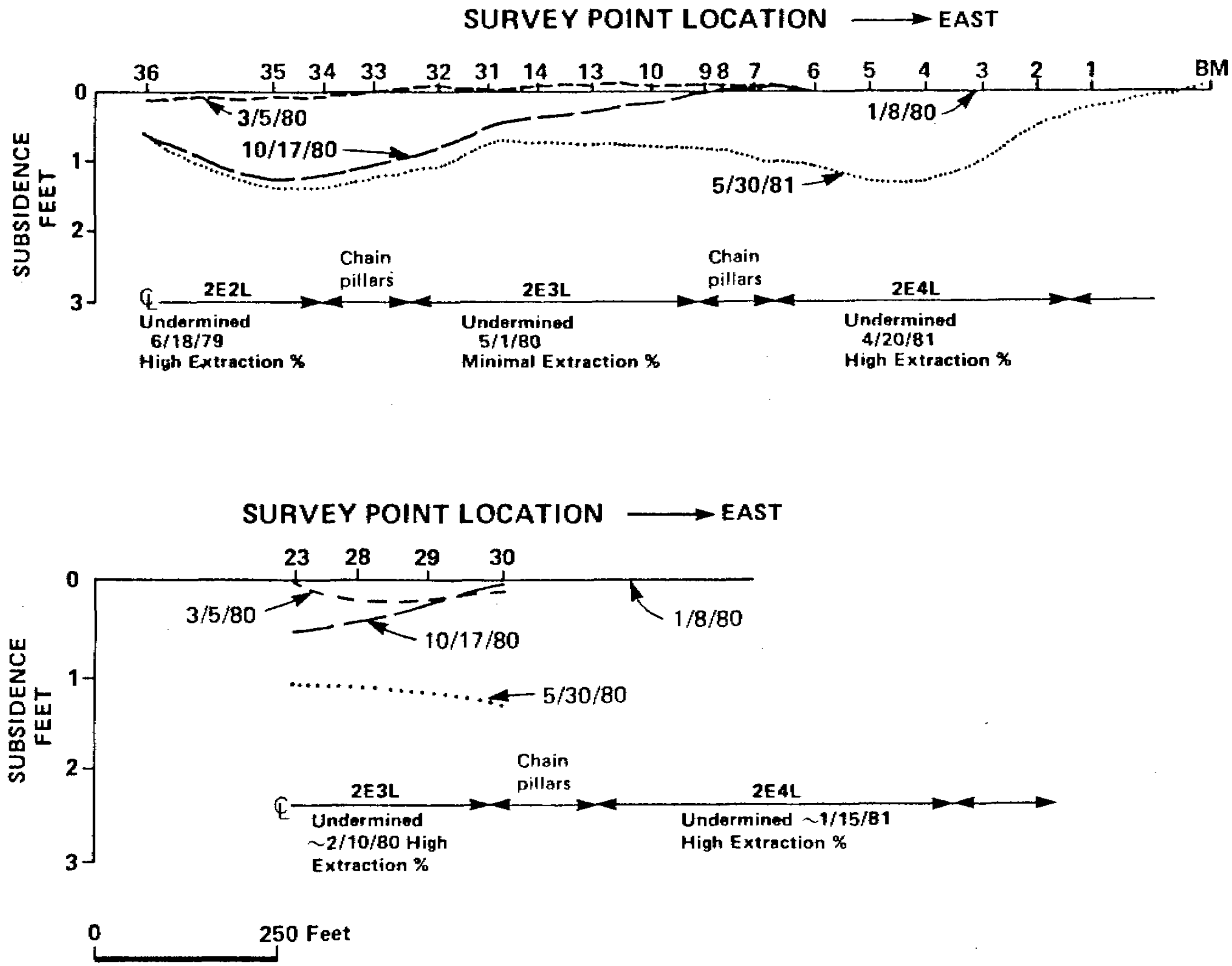
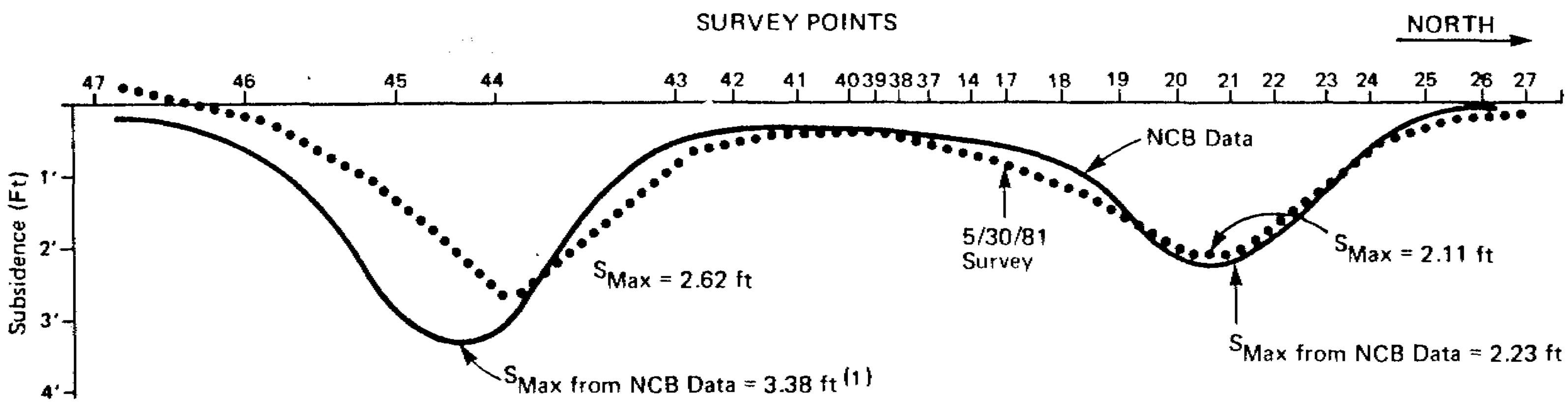


FIGURE 5.3

SUBSIDENCE PROFILES BASED ON 1/8/80 BASELINE PROFILE



Notes: Datum = 1/8/81 Survey
Slope Comparison: Southern portion of panel:
Max measured slope = 0.73° = 44 min
Max predicted slope = 0.53° = 32 min

Nothern portion of panel:
Max measured slope = 0.42° = 25 min
Max predicted slope = 0.35° = 21 min

(1) Curve for W = 500 feet, face advance = 1025 feet plotted along panel

FIGURE 5.4

COMPARISON OF ACTUAL AND PREDICTED SUBSIDENCE

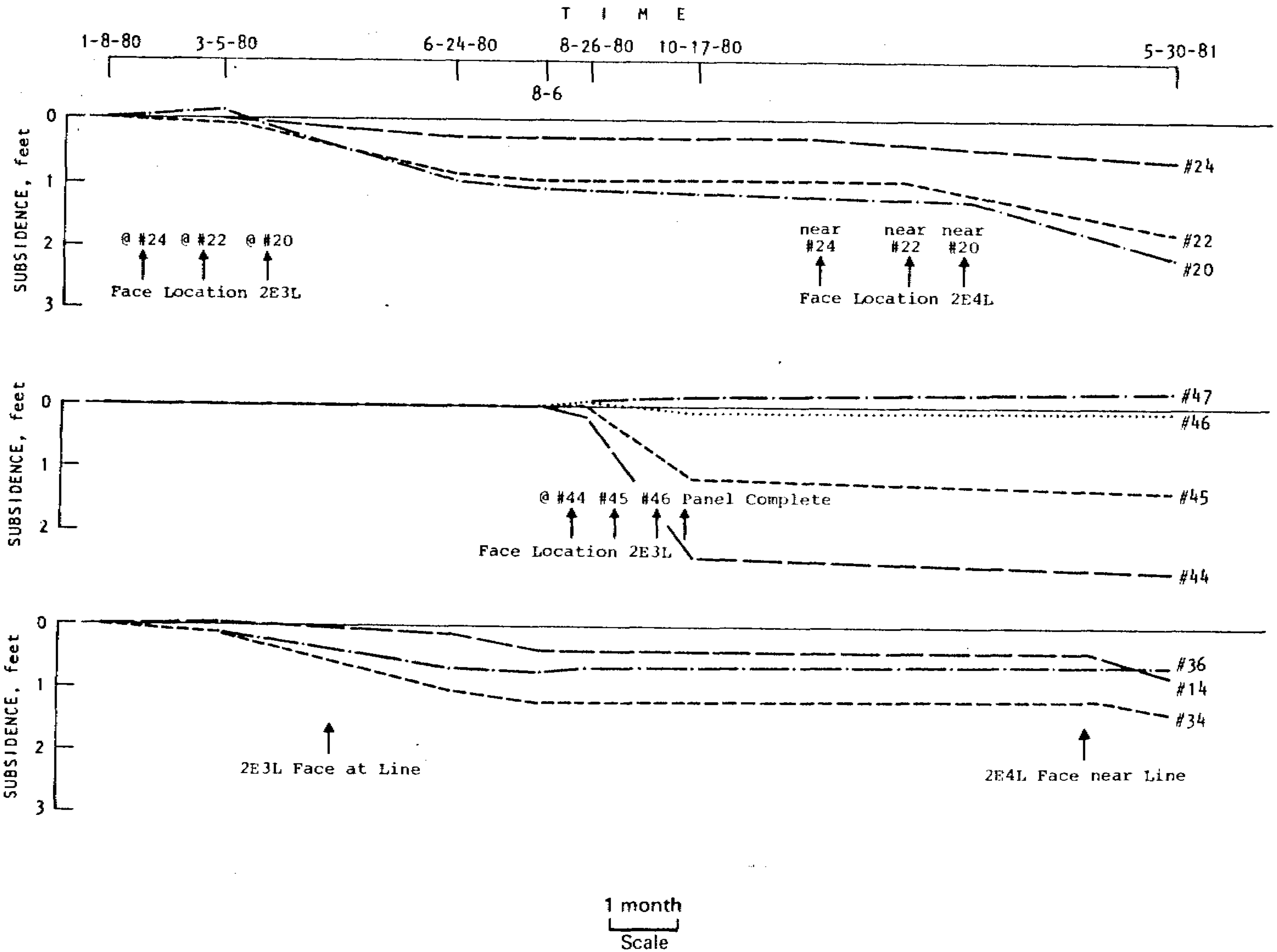


FIGURE 5.5

SUBSIDENCE PROGRESS WITH TIME

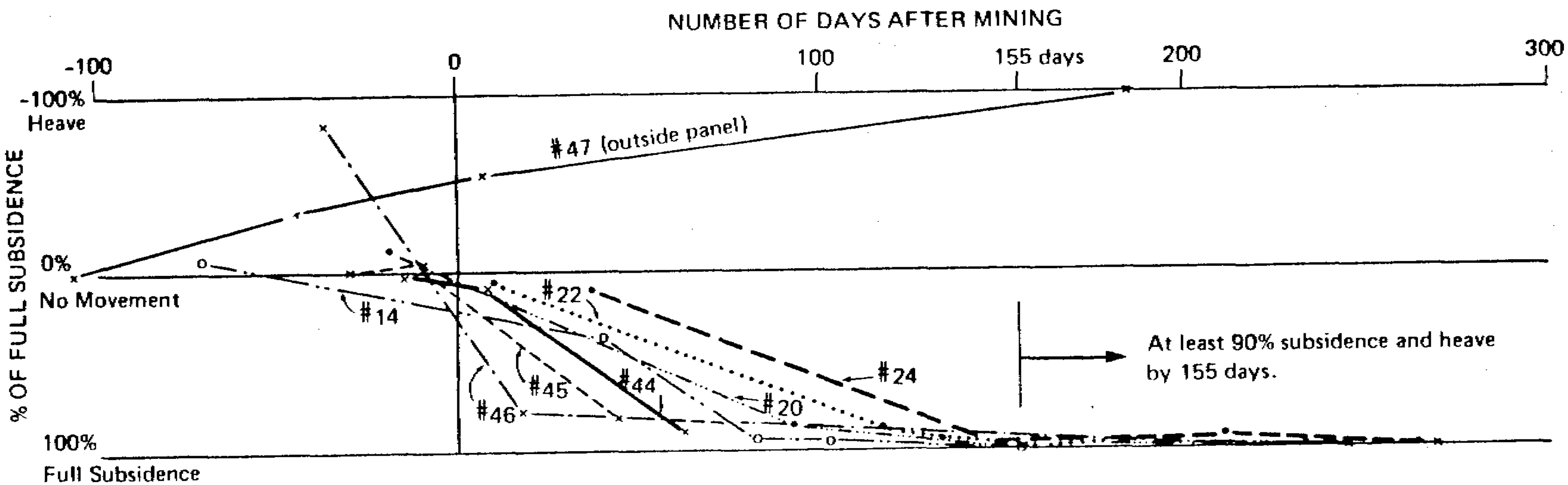


FIGURE 5.6

NORMALIZED SUBSIDENCE CURVES FOR SELECTED POINTS

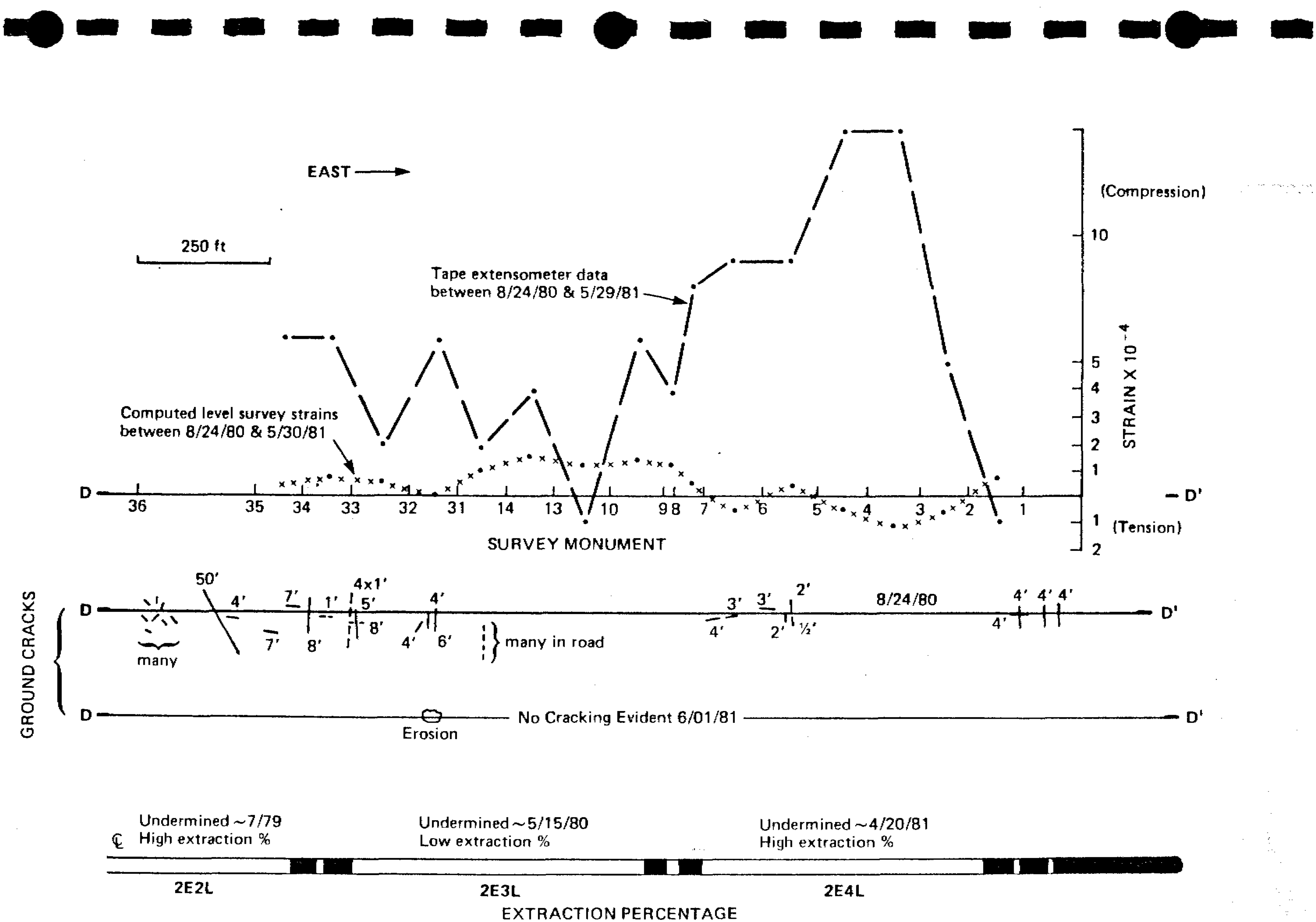


FIGURE 5.7

STRAIN PROFILE AND GROUND CRACKING ALONG LINE D-D, AUGUST 1980 TO MAY 1981

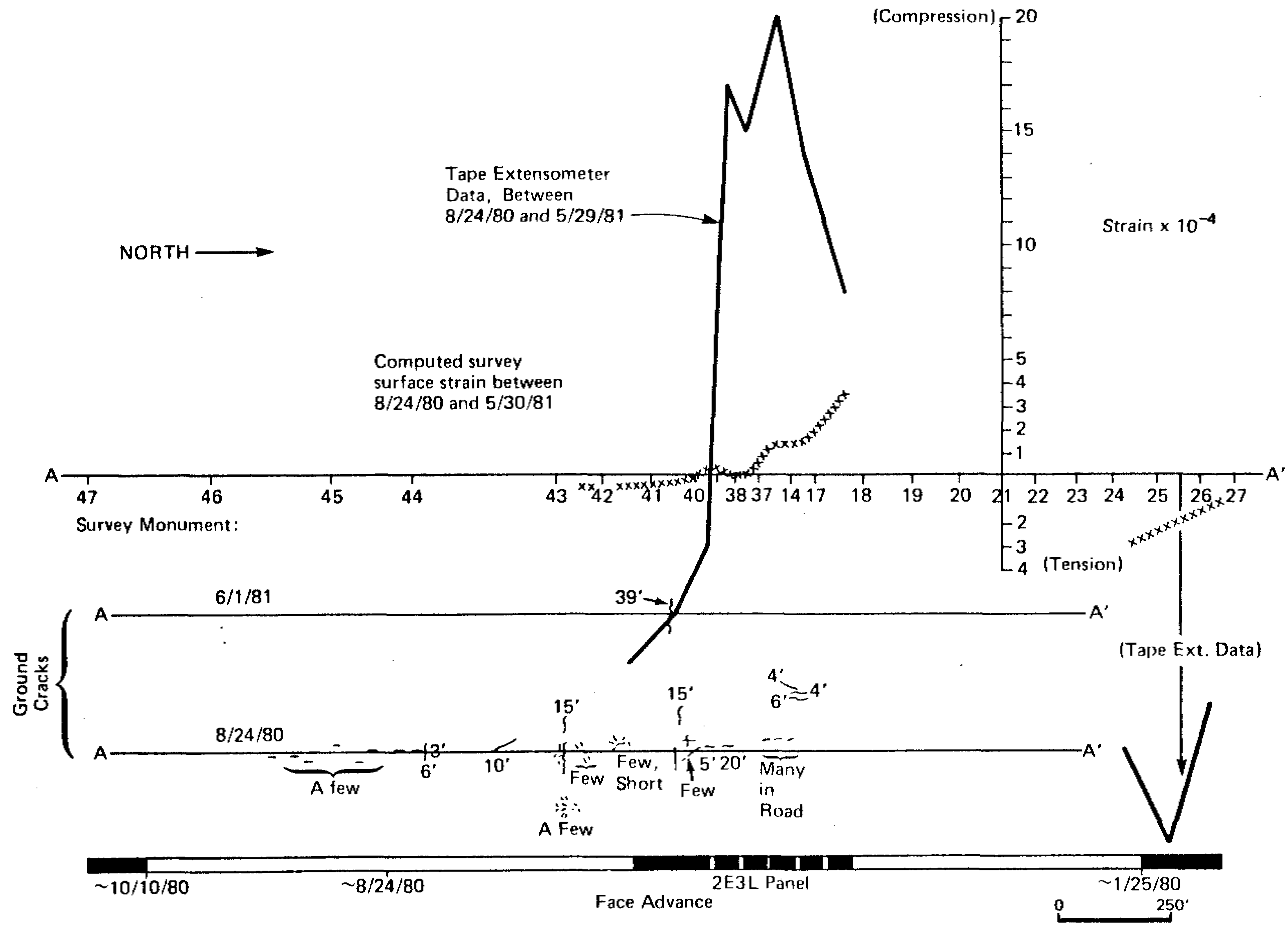


FIGURE 5.8

STRAIN PROFILE AND GROUND CRACKING ALONG LINE A-A, AUGUST 1980 TO MAY 1981

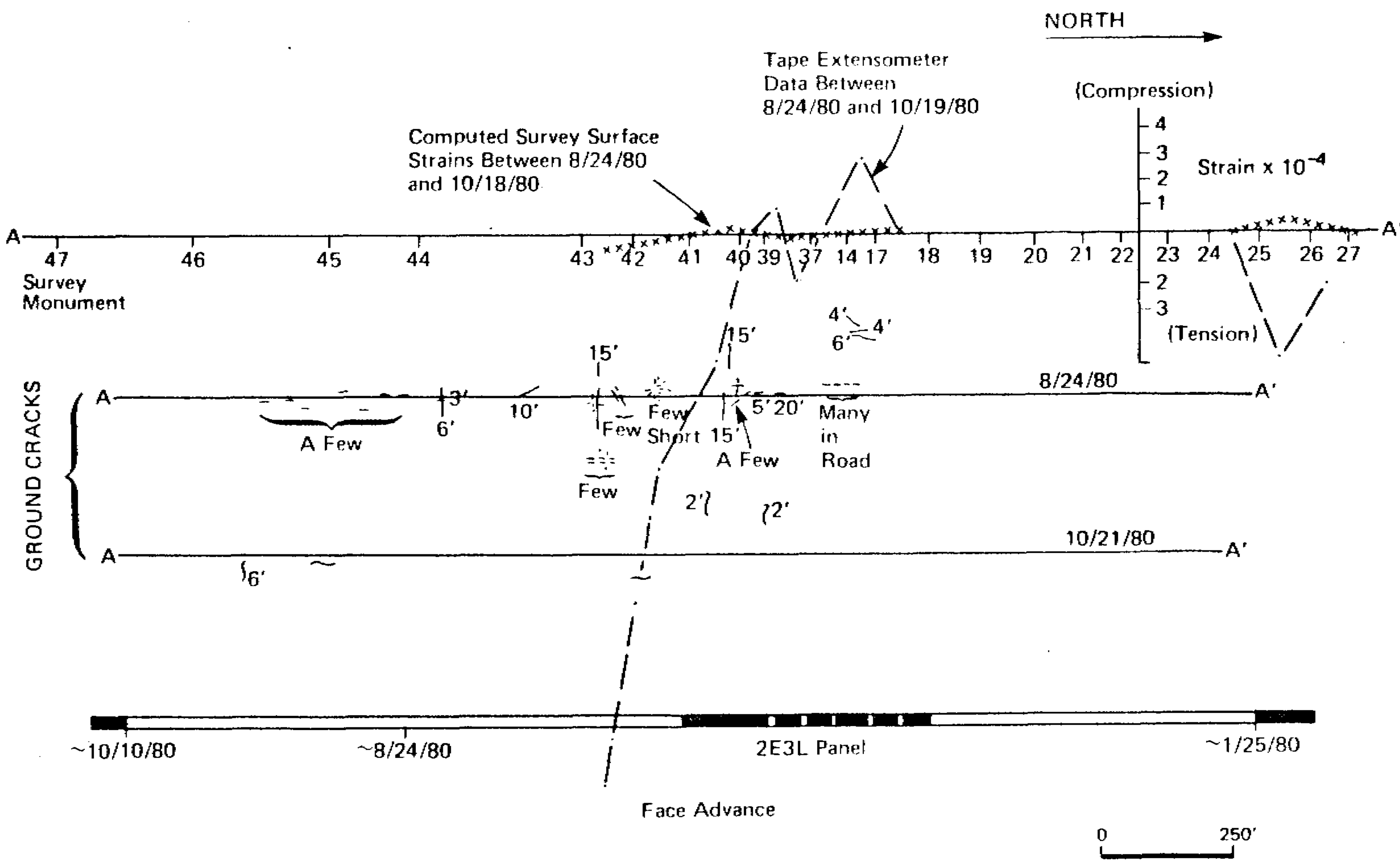


FIGURE 5.9

STRAIN PROFILE AND GROUND CRACKING ALONG LINE A-A,
OCTOBER 1980 TO MAY 1981

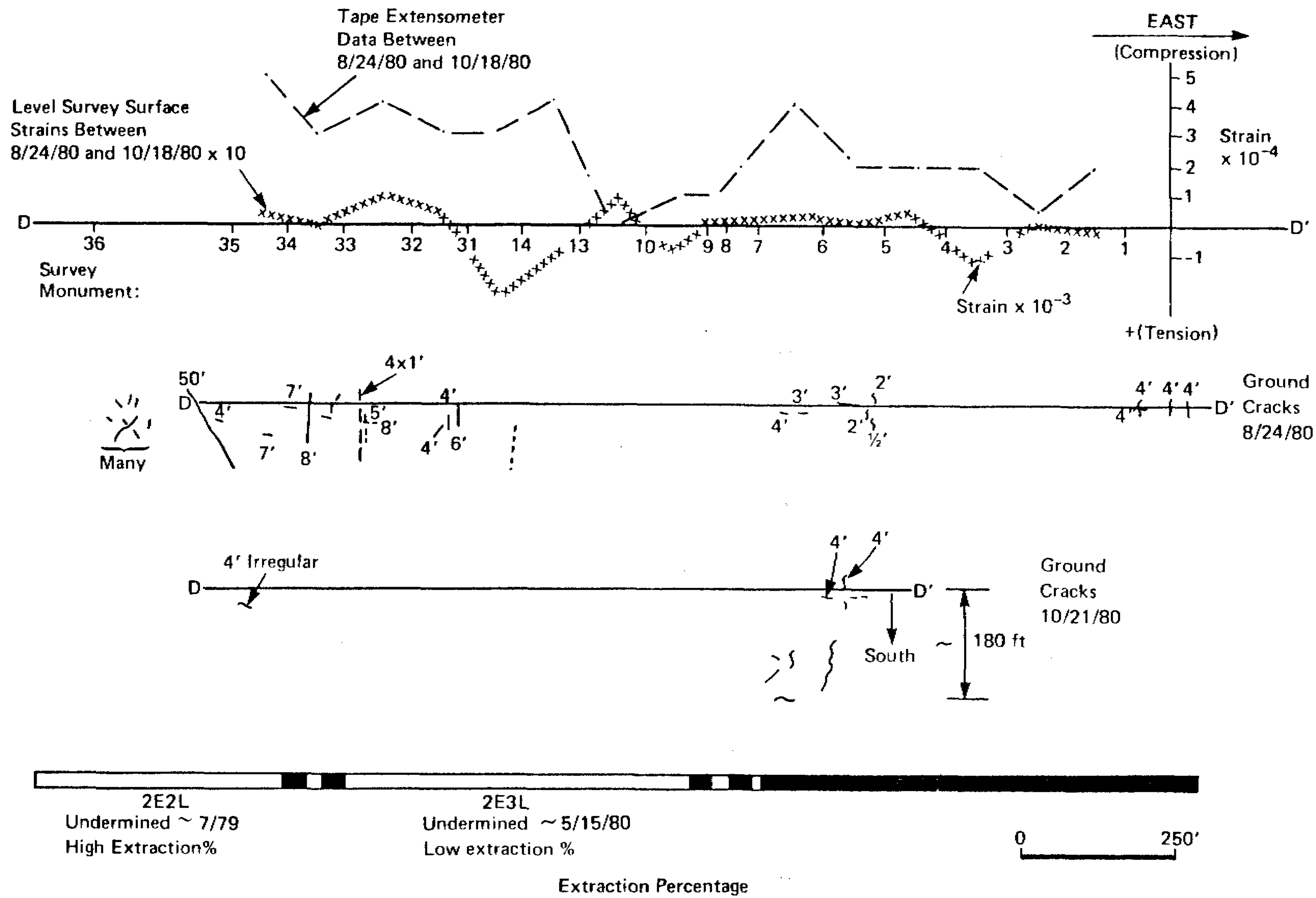


FIGURE 5.10

OCTOBER 1980 STRAIN PROFILE AND
GROUND CRACKING ACROSS PANELS

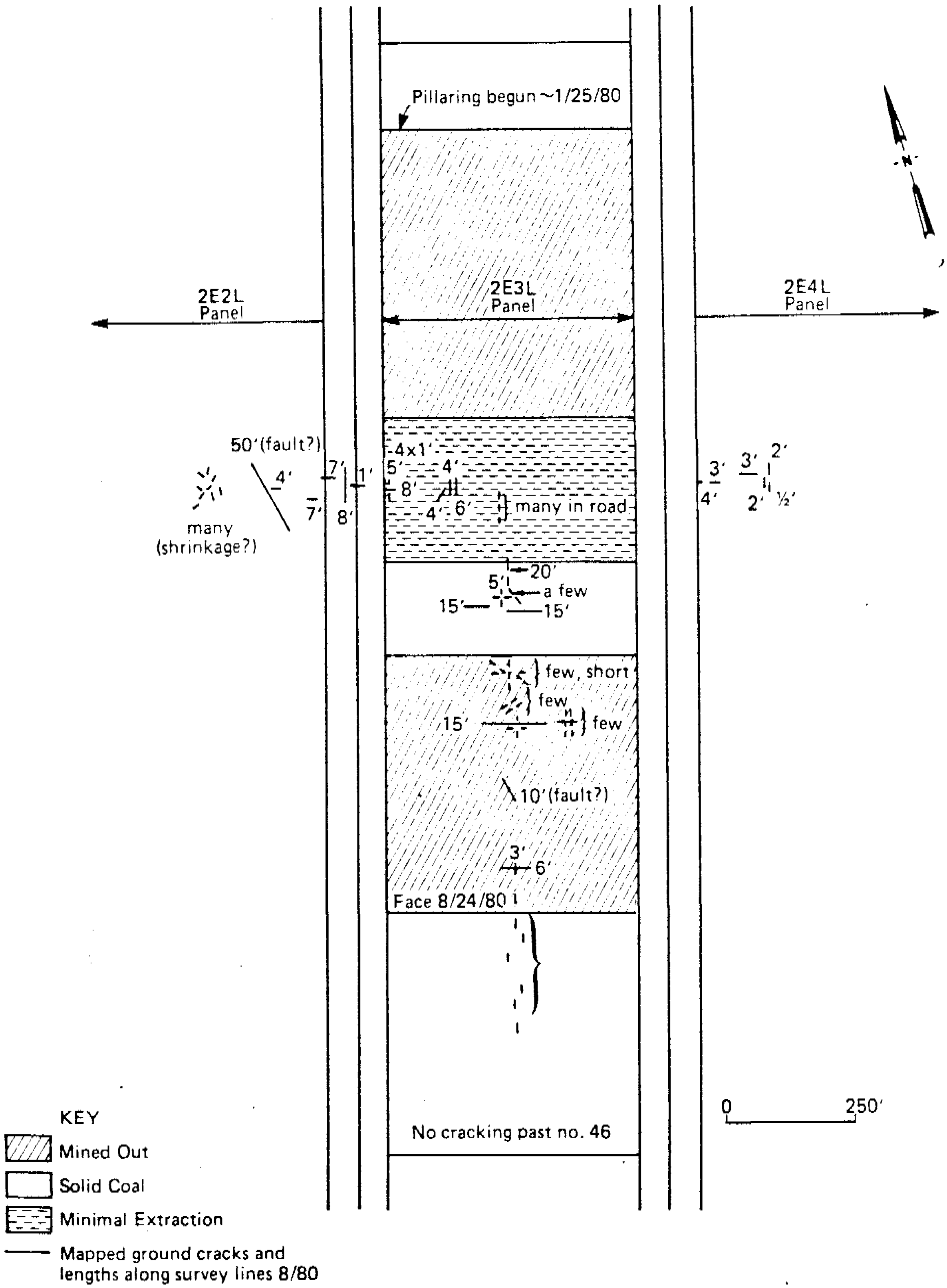


FIGURE 5.11

GROUND CRACKING 8/24/80

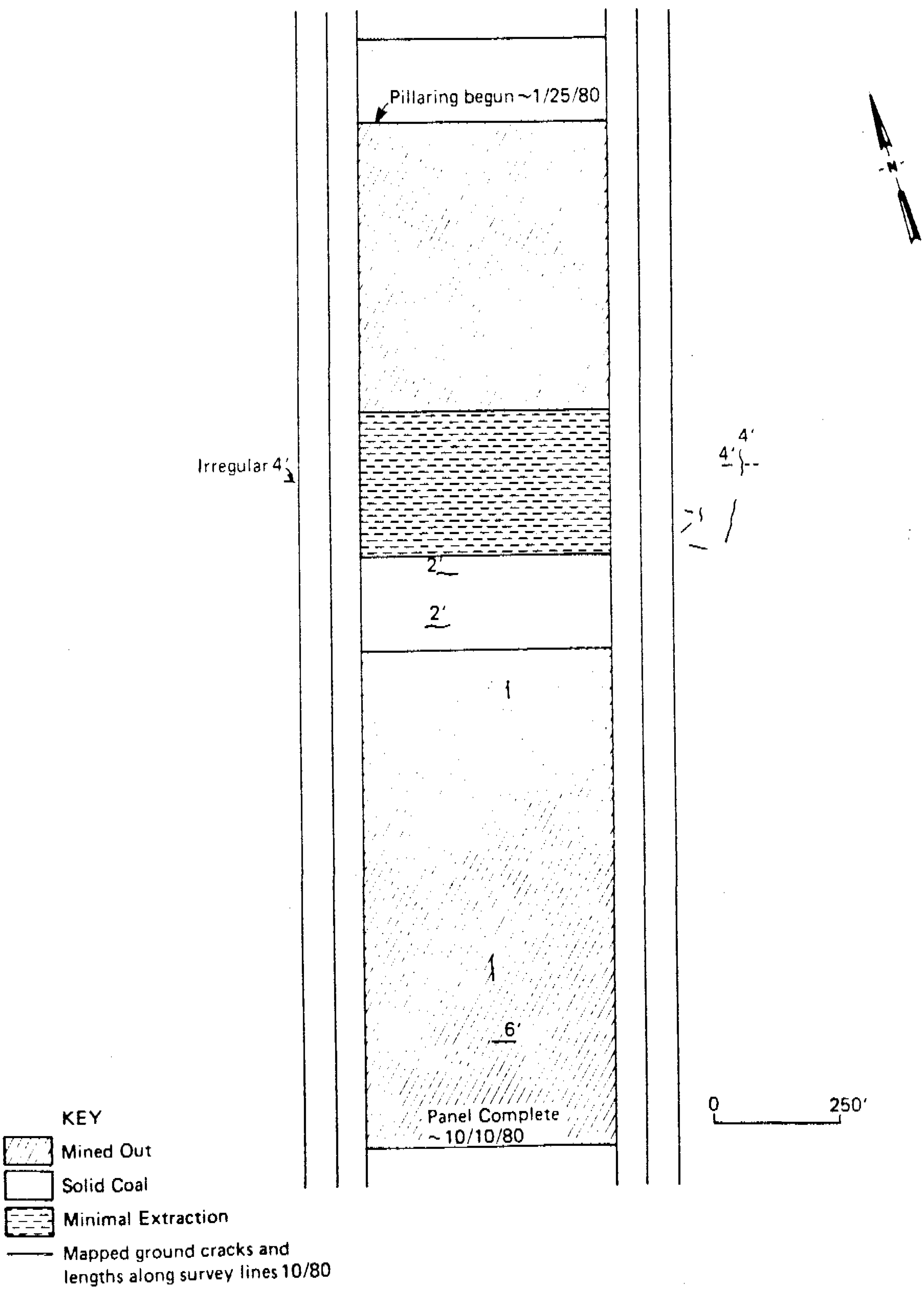


FIGURE 5.12

GROUND CRACKING 10/21/80

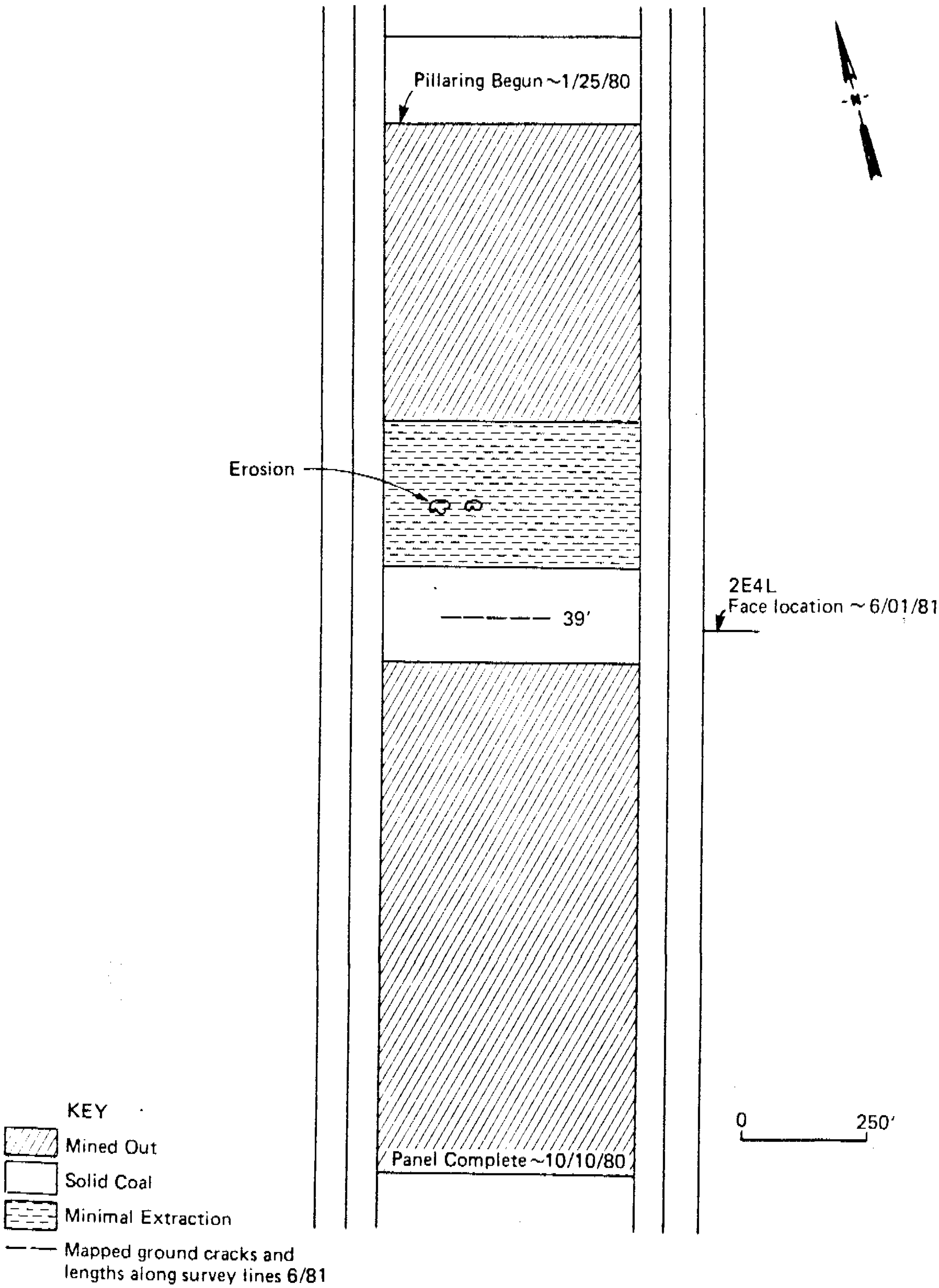


FIGURE 5.13

GROUND CRACKING 6/01/81

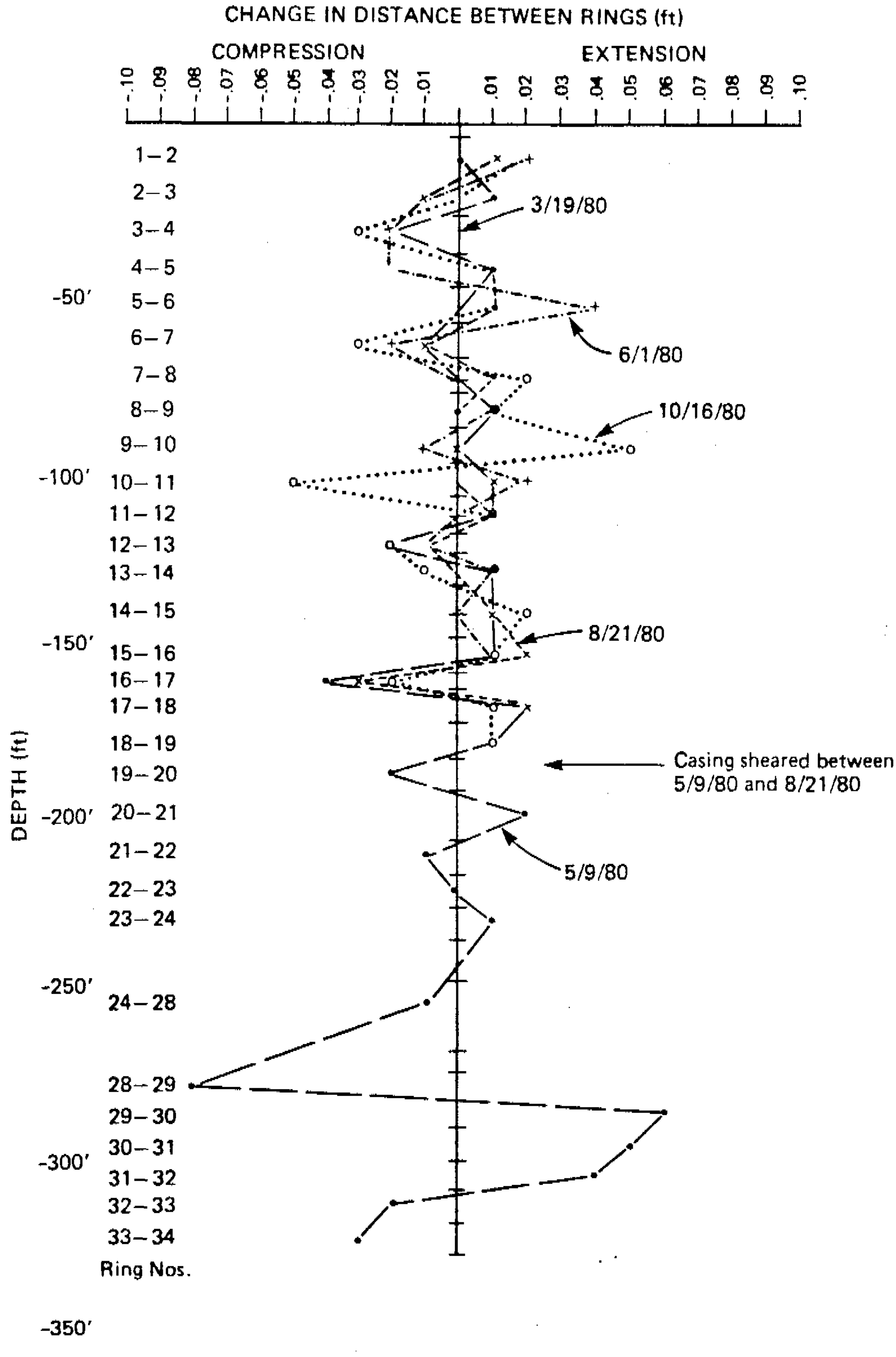


FIGURE 5.14

SONDEX DISPLACEMENTS I-1

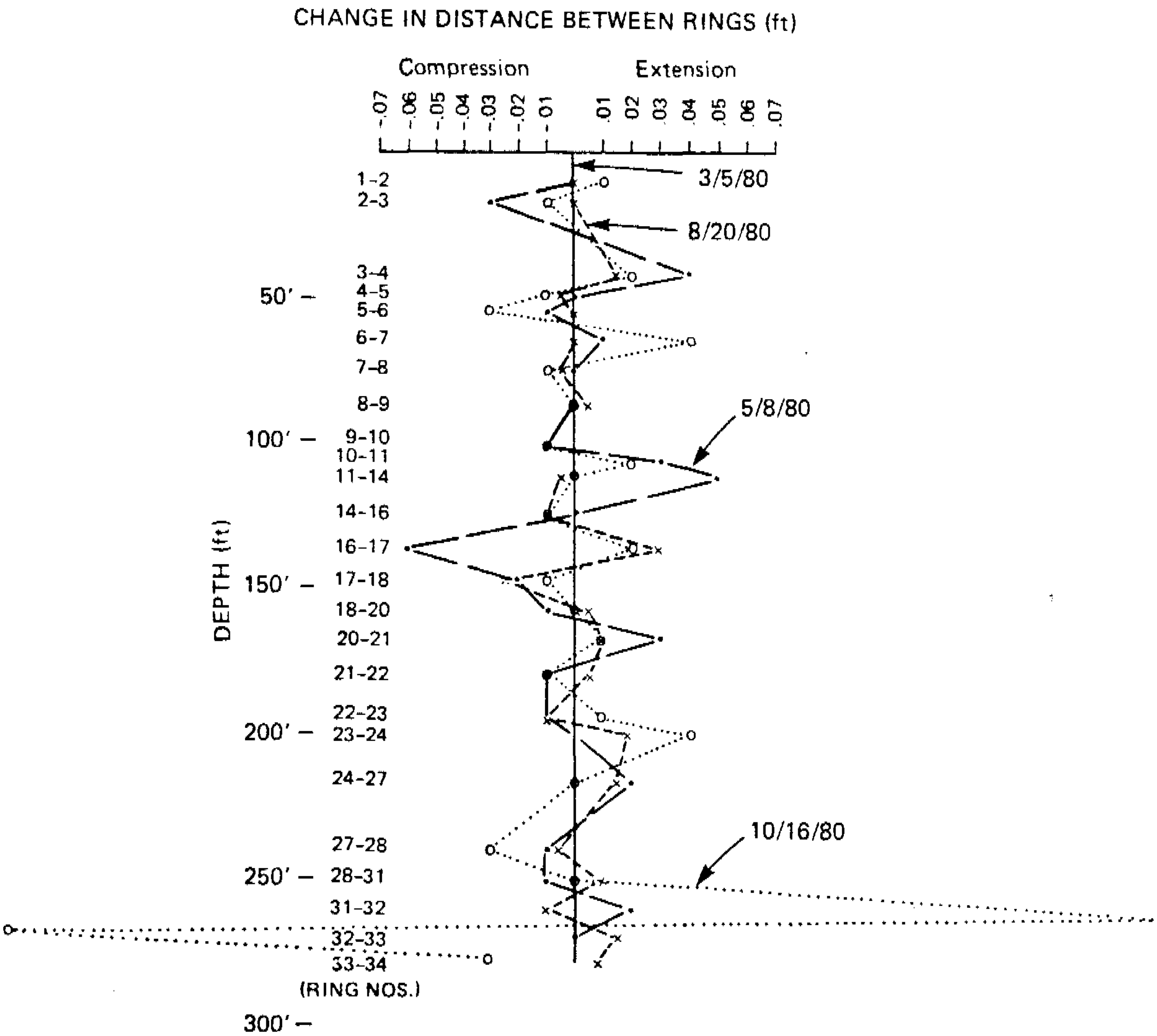


FIGURE 5.15

SONDEX DISPLACEMENTS, I-2

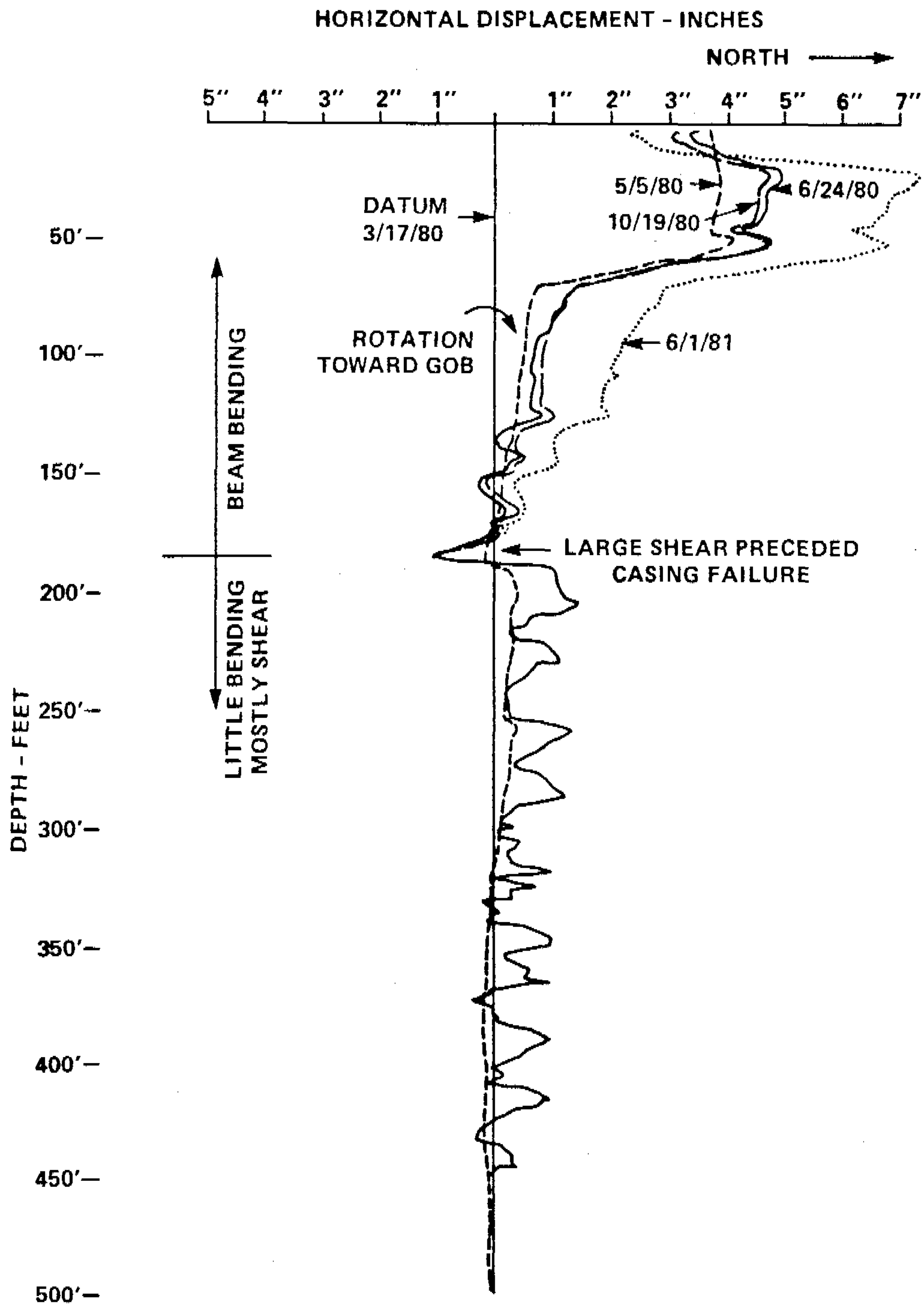


FIGURE 5.16

I-1 INCLINOMETER DATA
A-AXIS

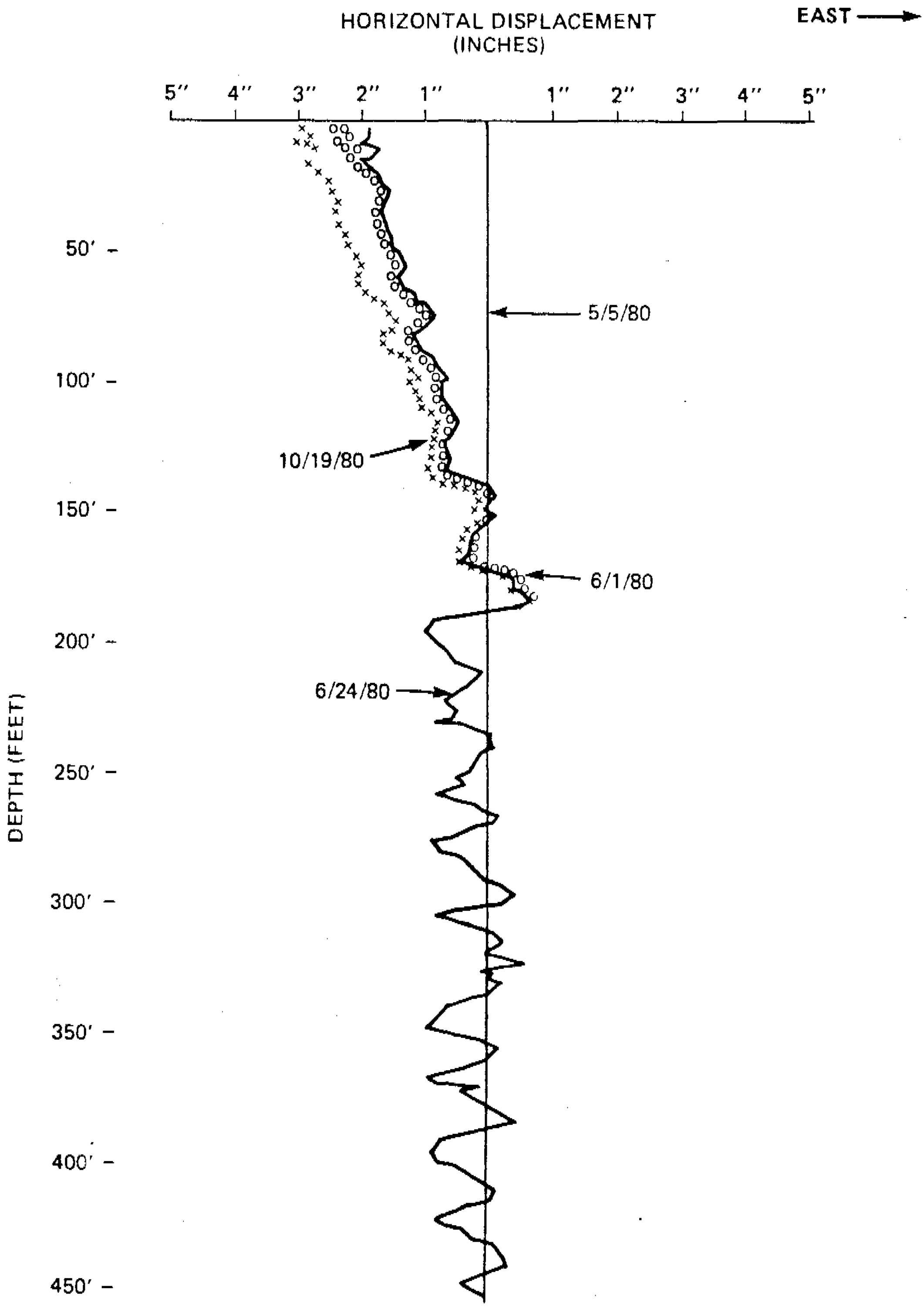


FIGURE 5.17

I-1 INCLINOMETER DATA
B-AXIS

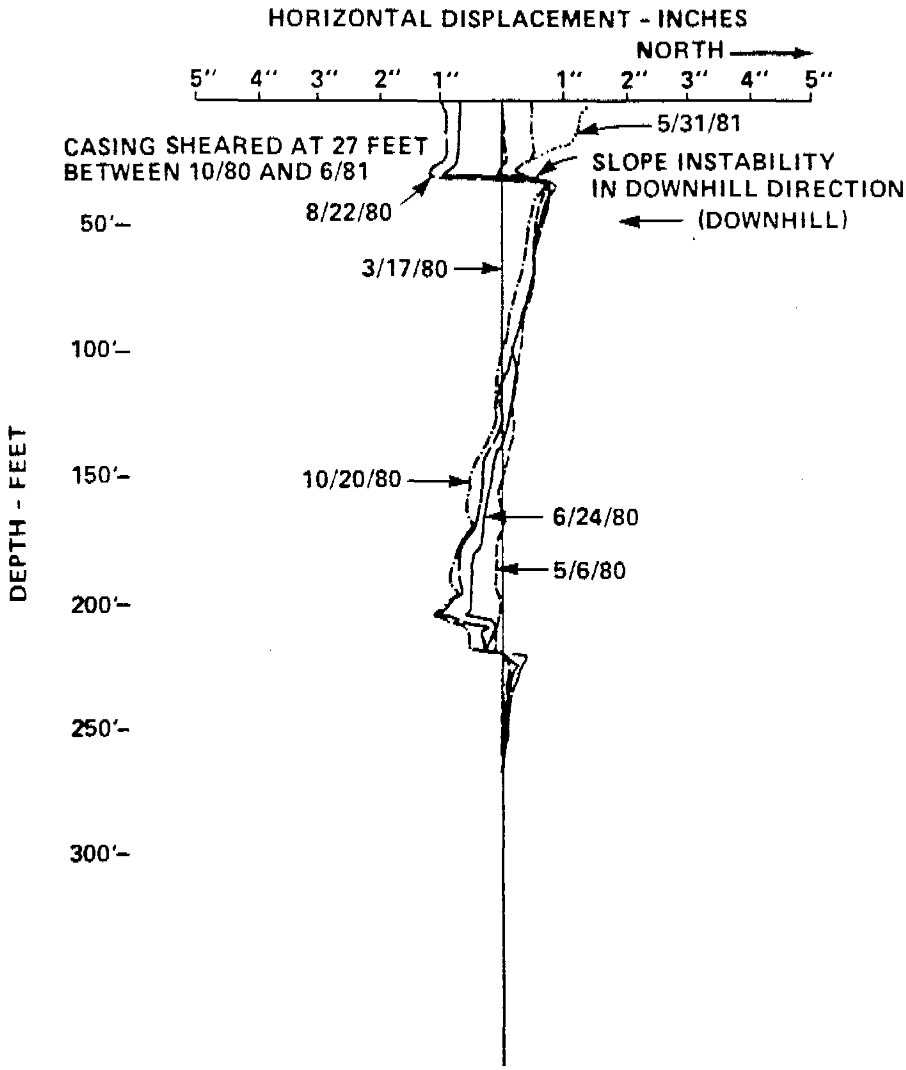


FIGURE 5.18

I-2 INCLINOMETER DATA
A-AXIS

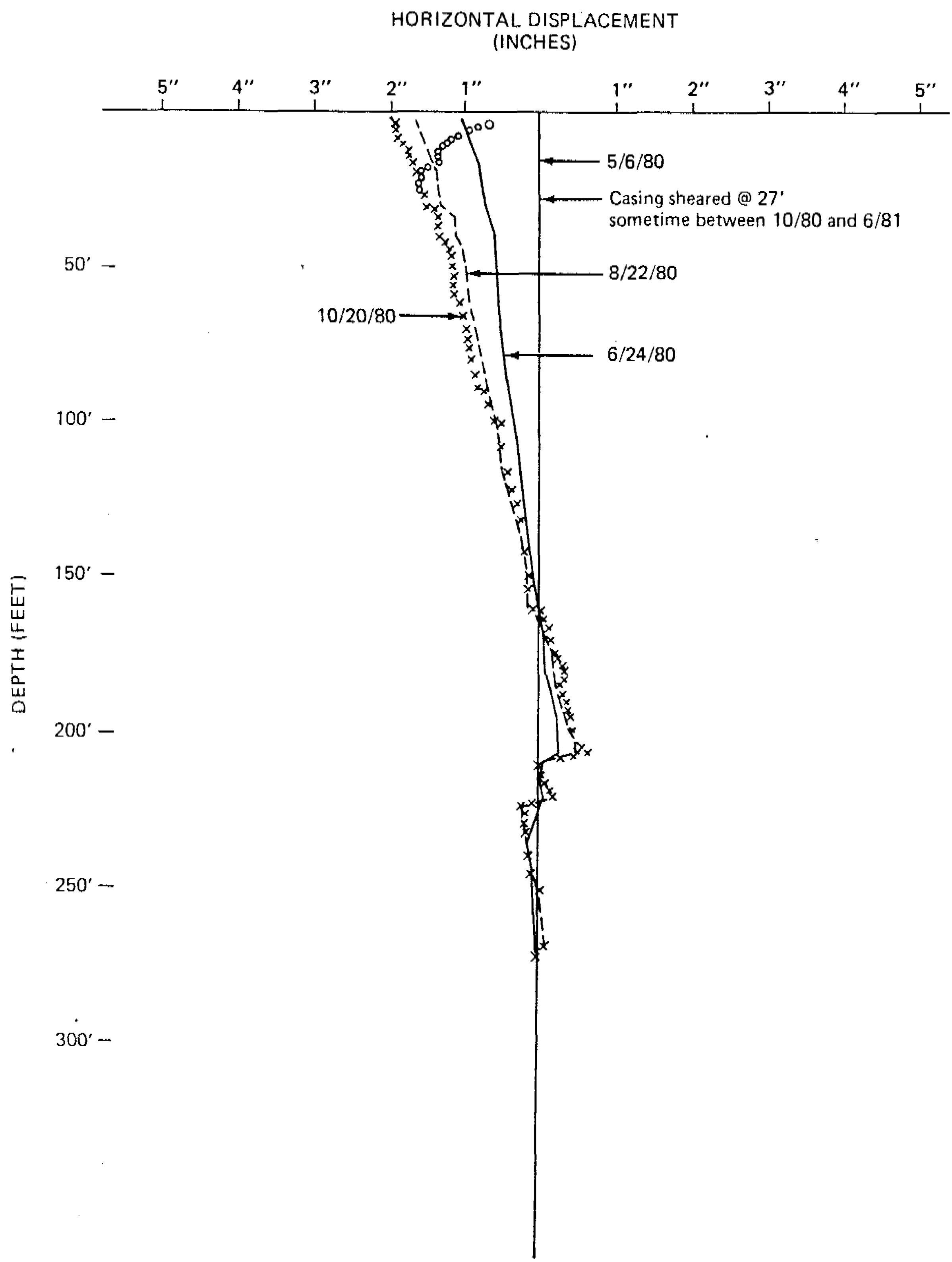
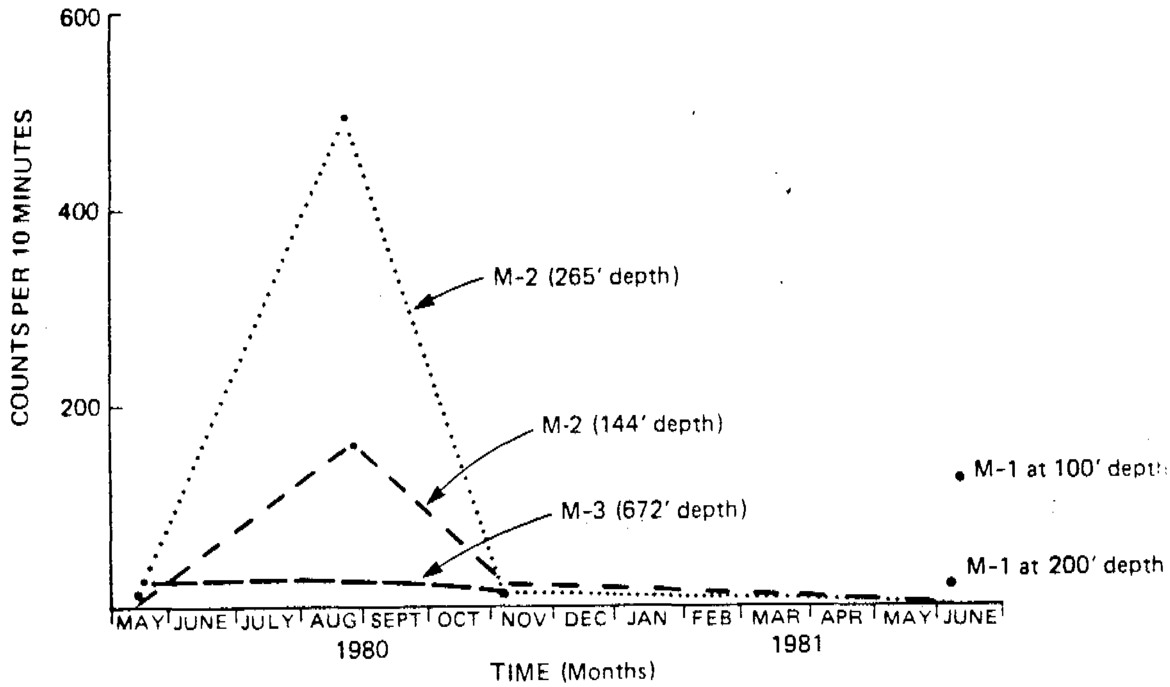


FIGURE 5.19

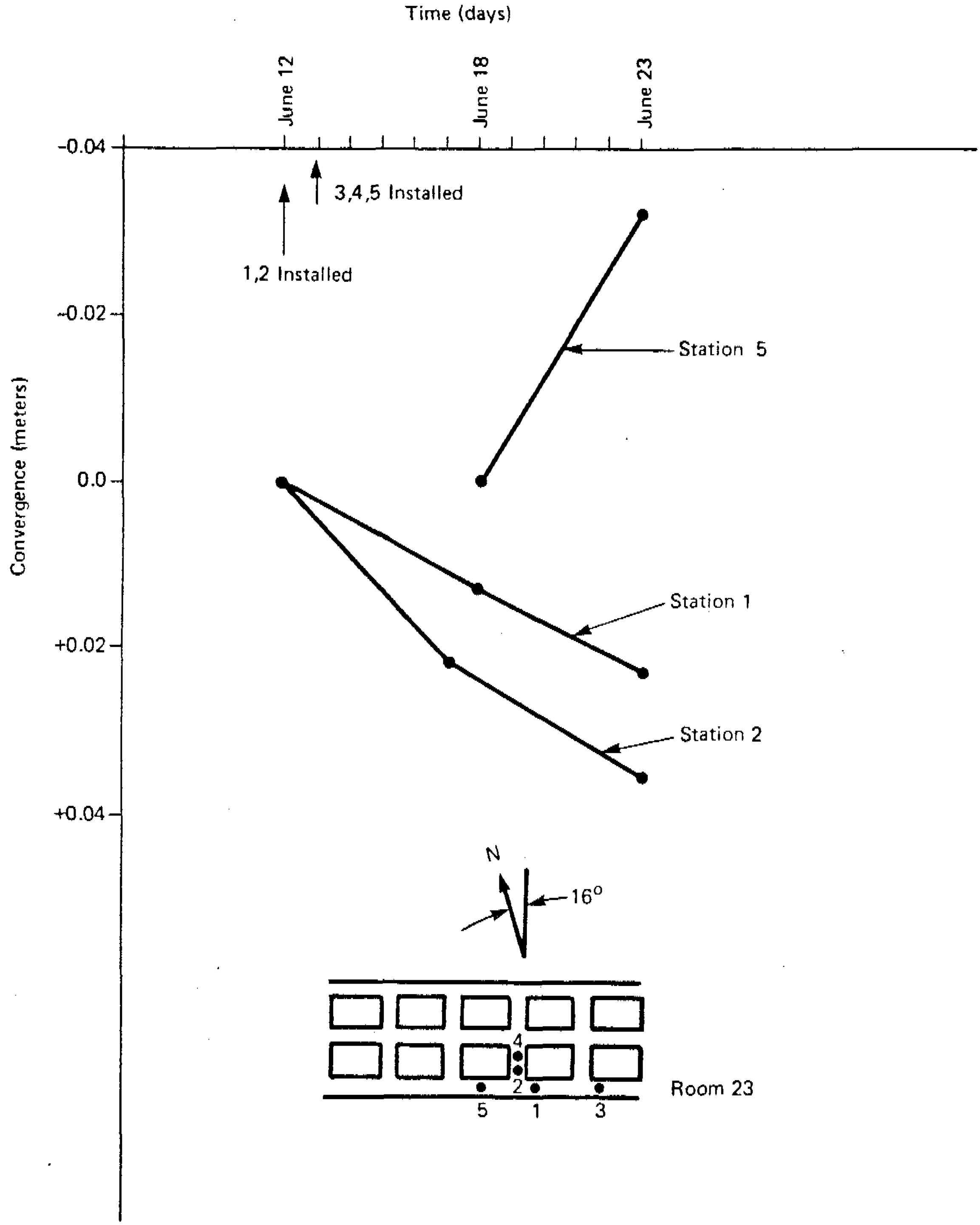
I-2 INCLINOMETER DATA
B-AXIS



NOTES: 1) M-1 data for portable system
2) M-2 and M-3 are grouted-in-place geophones
3) M-3 geophone at 472' depth failed by 8/80;
M-3 geophone at 672' failed by 6/81

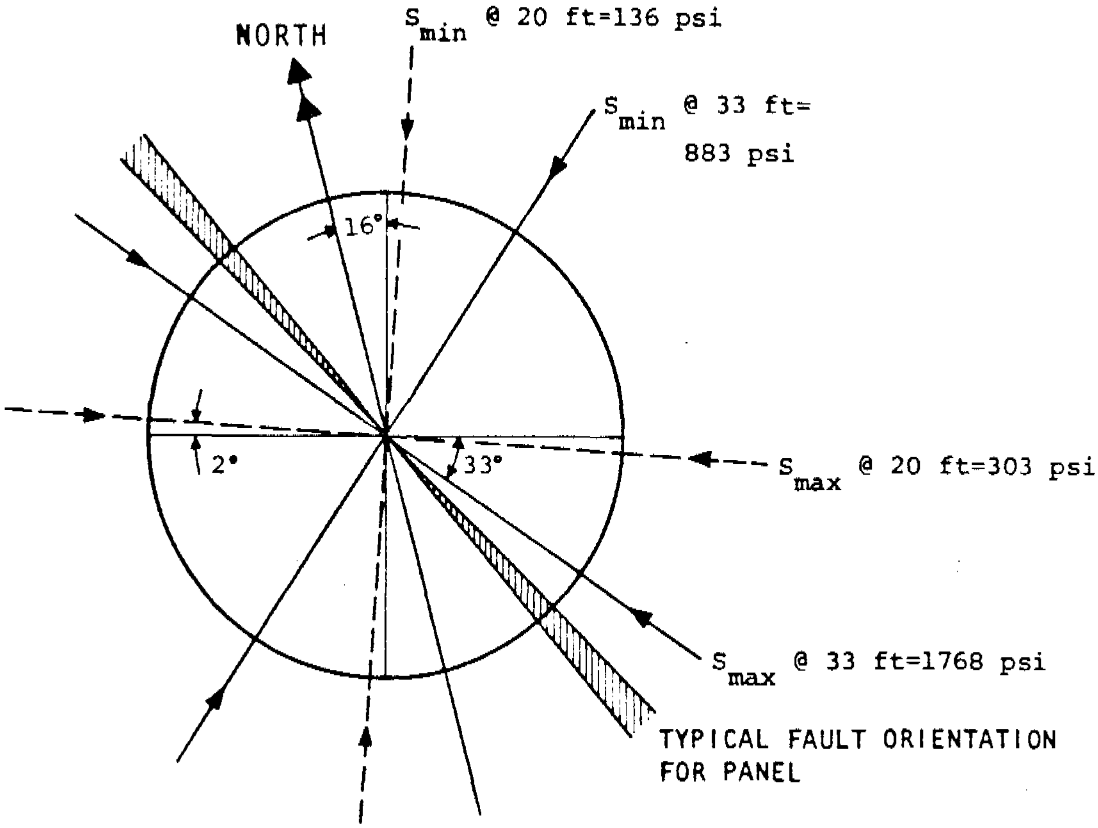
FIGURE 5.20

GEOPHONE DATA



Notes: No reading 6/13 on #5 since resin not set firmly
3,4 Lost on or before 6/18

FIGURE 5.21
CONVERGENCE DATA



DEPTH (ft)	S_{max} (psi)	S_{min} (psi)	Angle S_{max}
20	303	136	S88E
33	1768	883	S41E
34	S(ave)= 1540		Not determined

FIGURE 5.22
OVERCORE TEST RESULTS

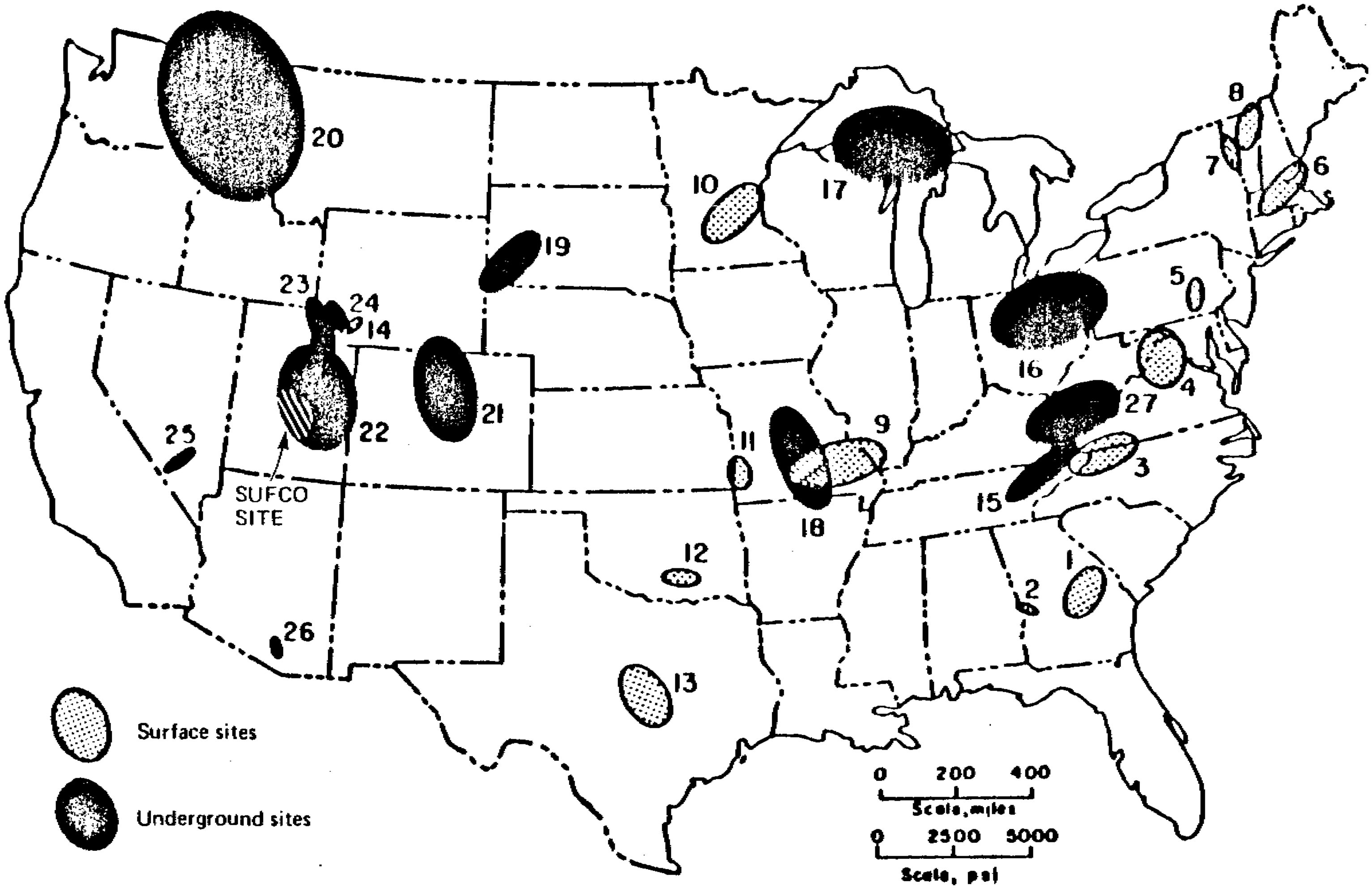


FIGURE 5.23

EXCESS HORIZONTAL STRESS MAP (after Aggson, 1978)

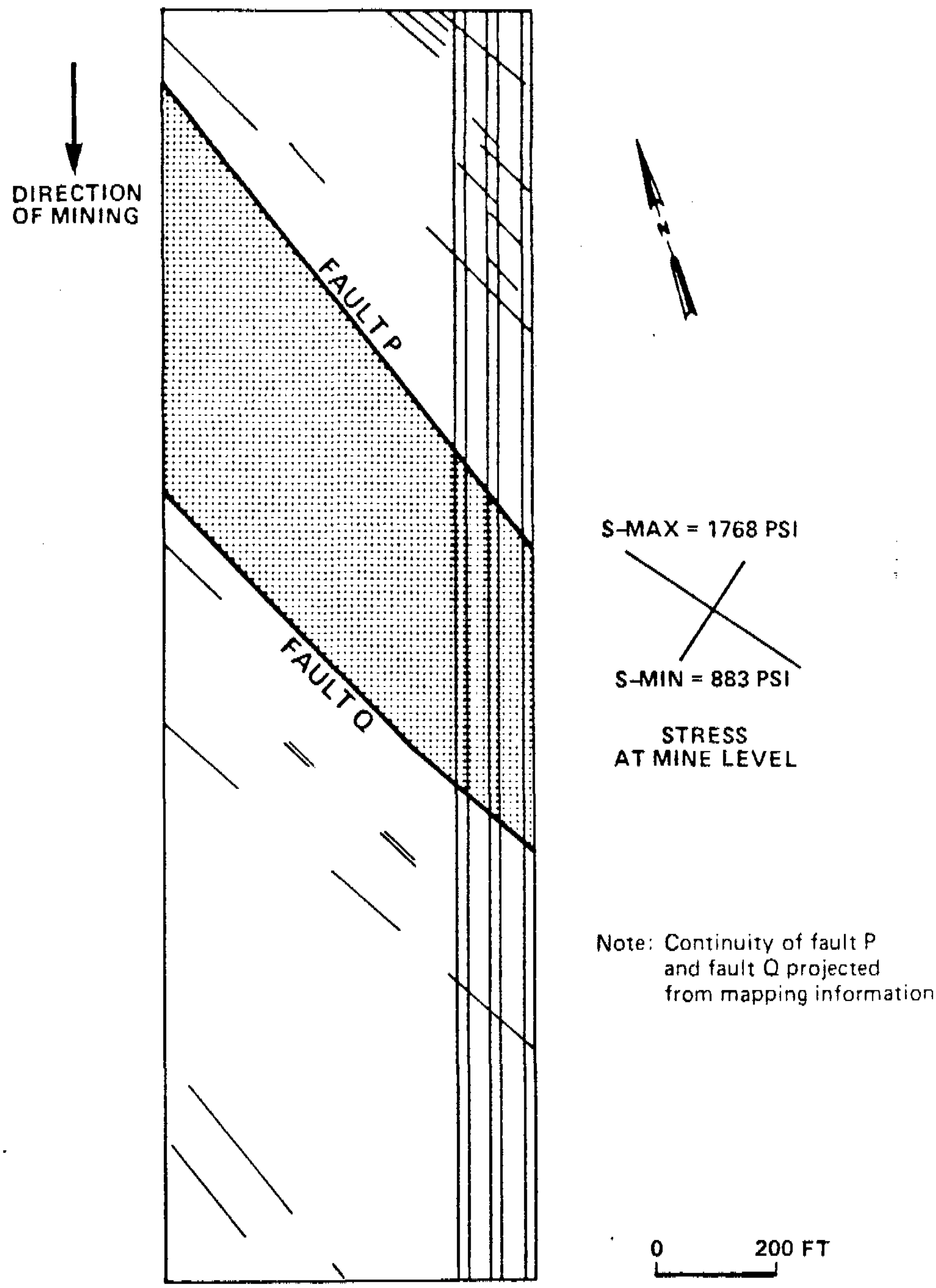


FIGURE 5.24

MEASURED IN SITU STRESS AND MAPPED FAULTS

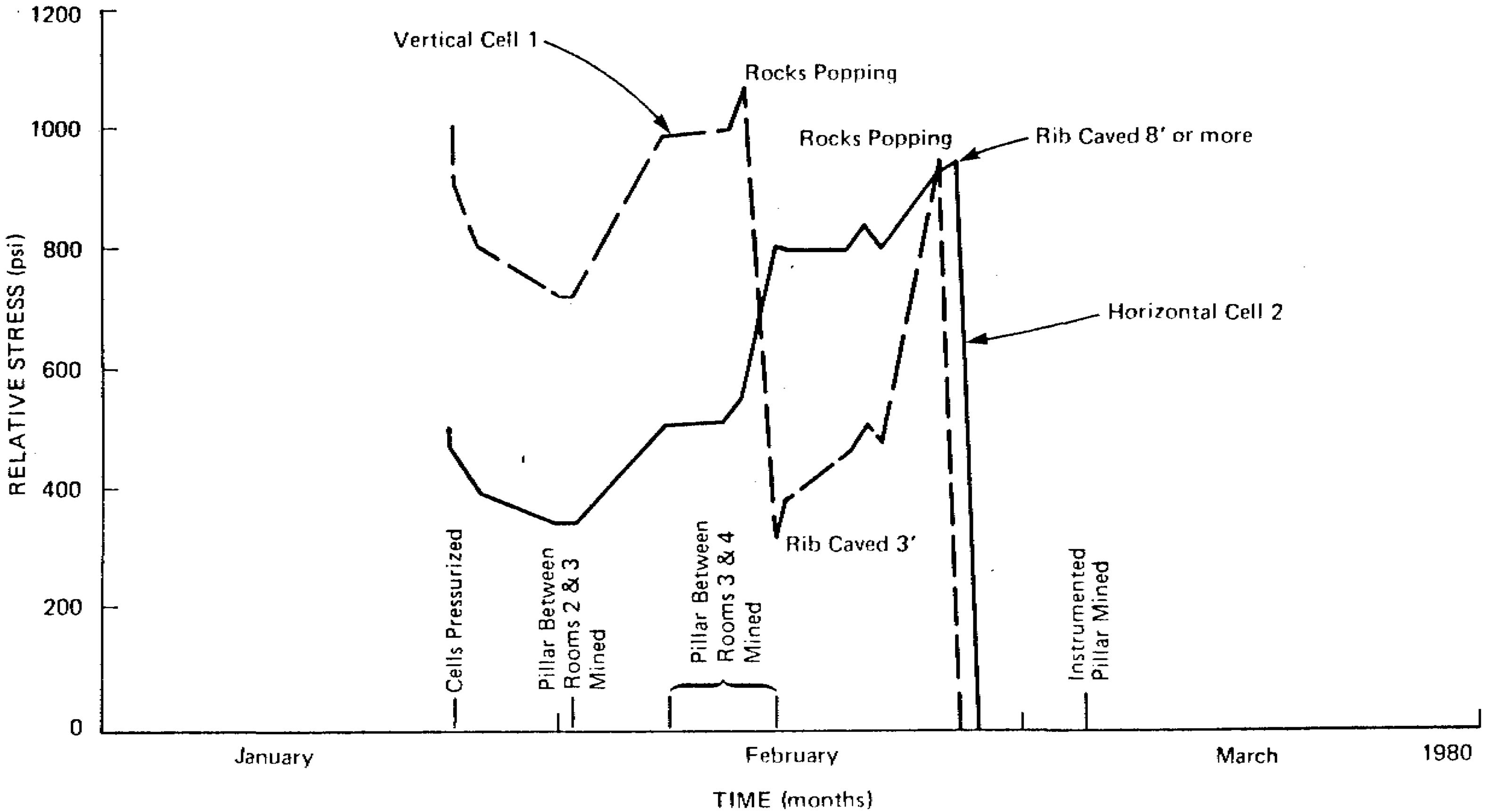


FIGURE 5.25
PRESSURE CELL DATA, ROOM 6

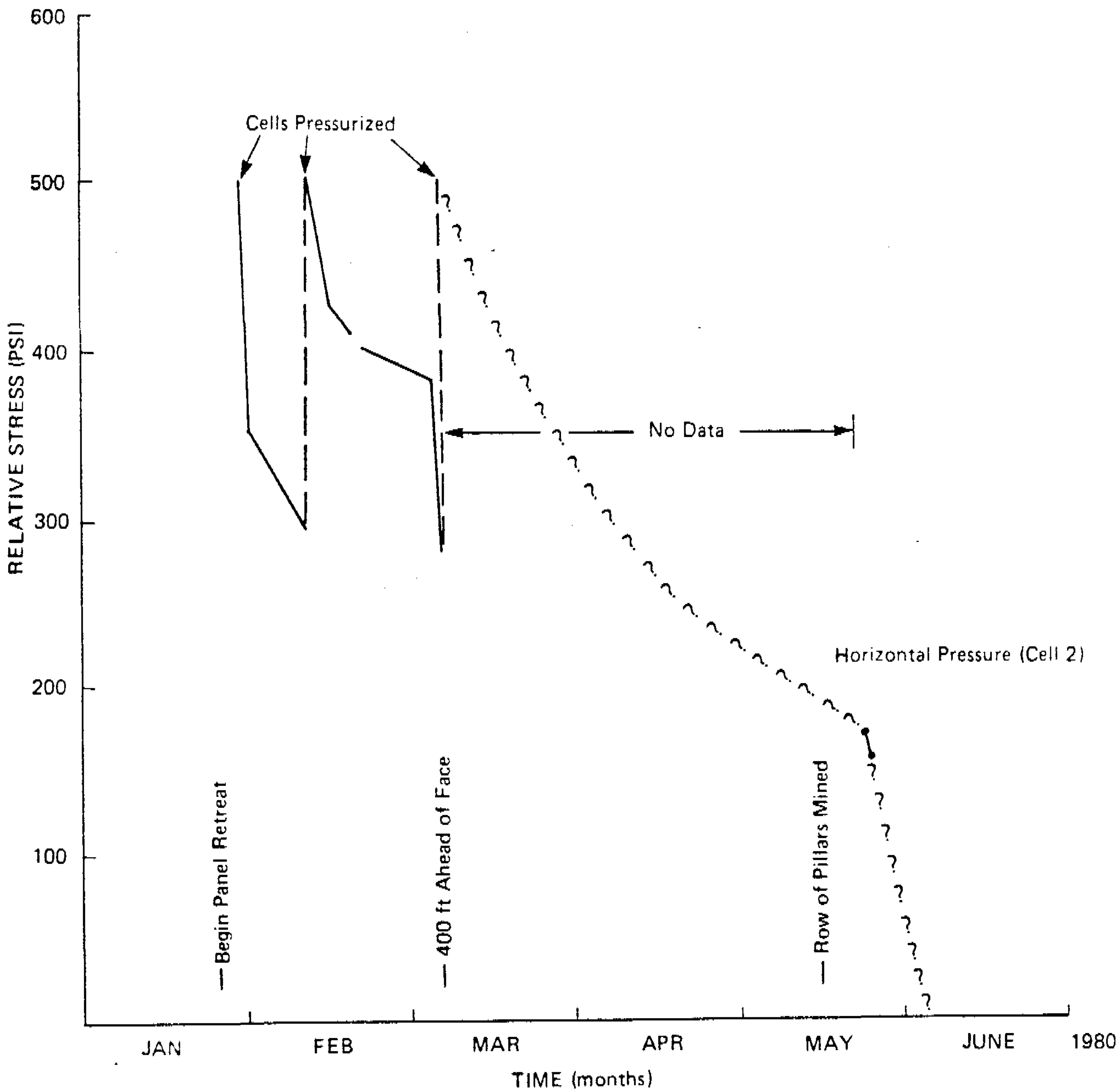


FIGURE 5.26

PRESSURE CELL DATA, ROOM 13

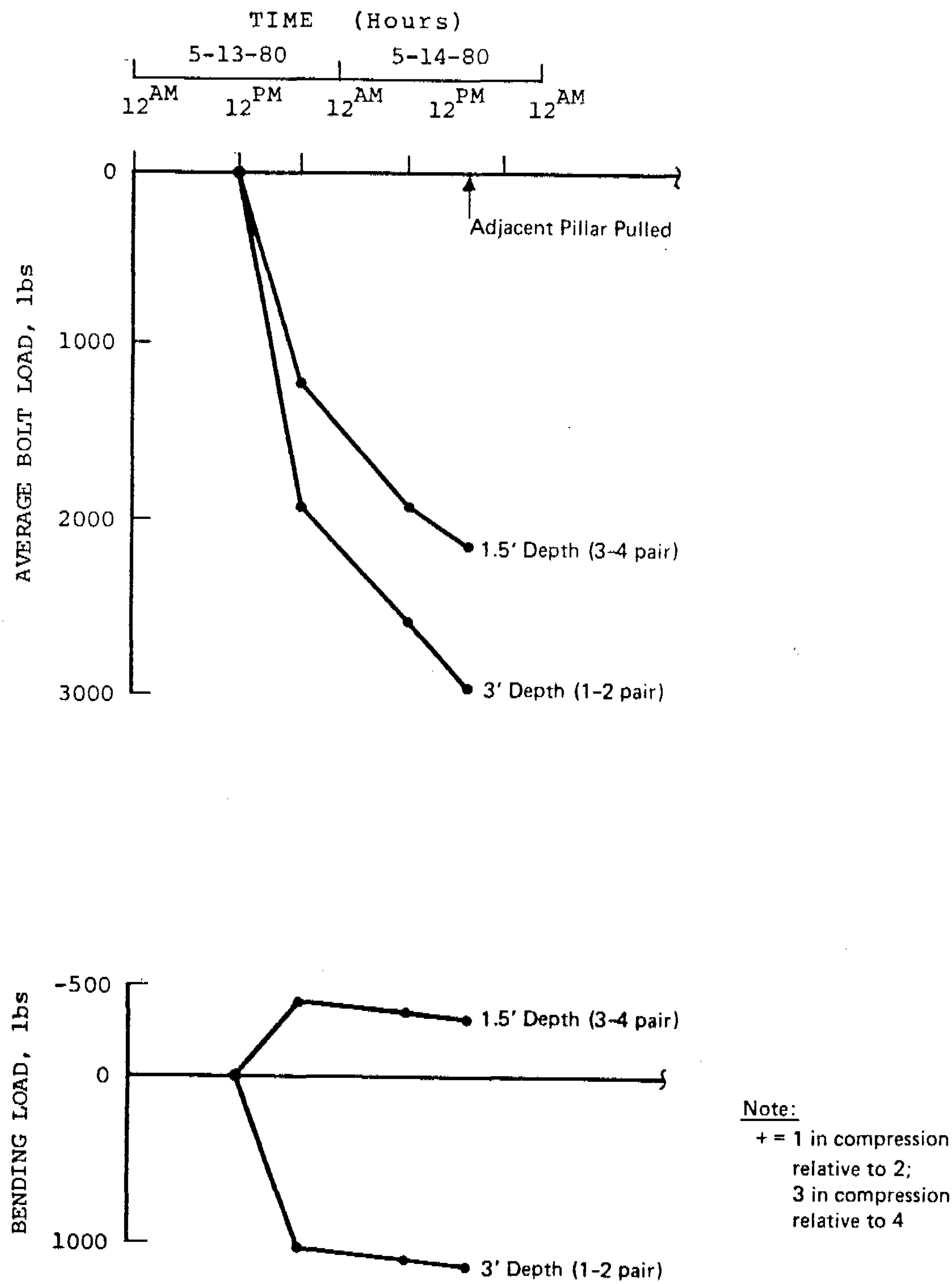


FIGURE 5.27

ROCK BOLT LOADS FOR BOLT No. 1

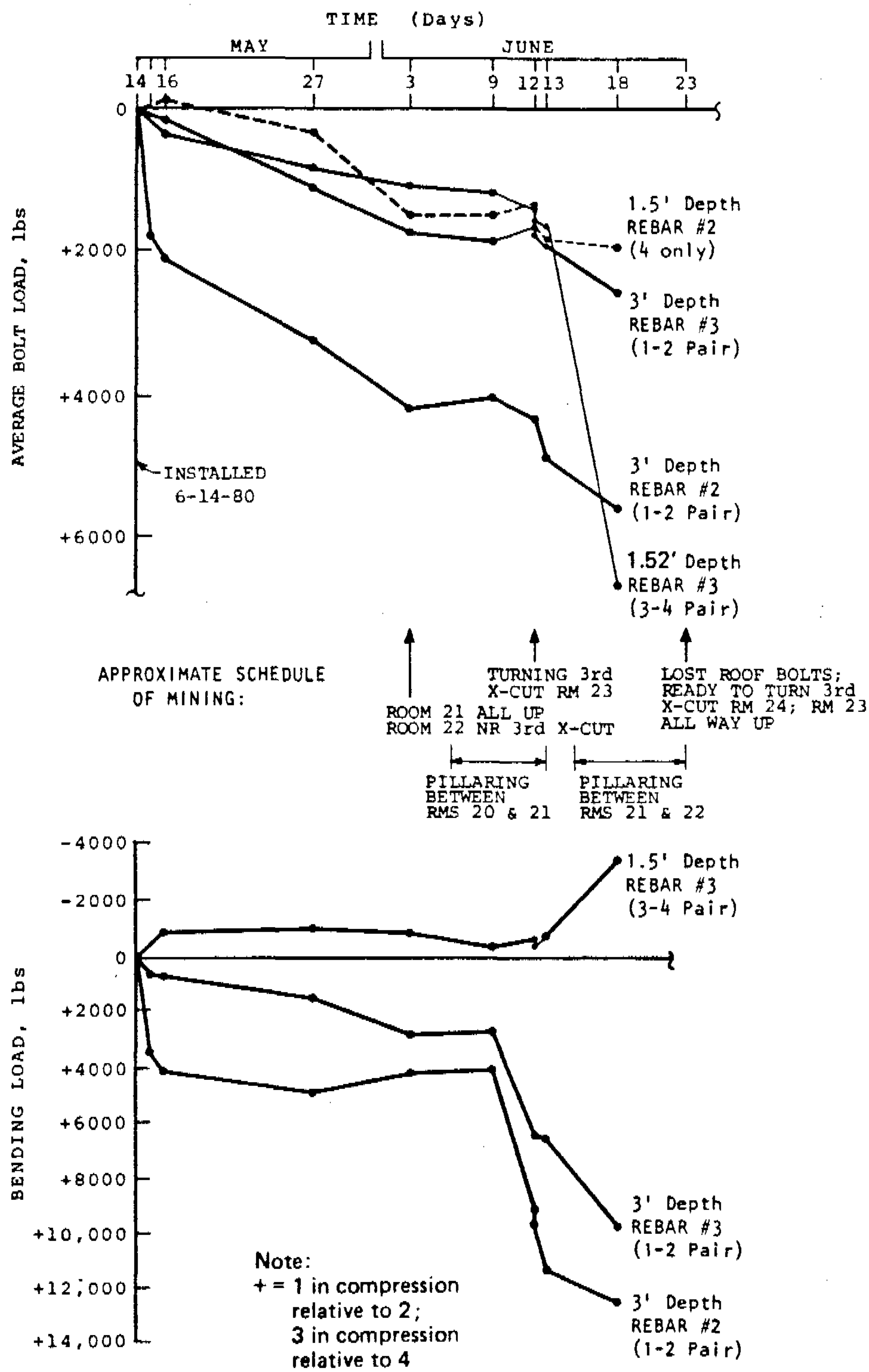


FIGURE 5.28

ROCK BOLT LOADS FOR BOLTS No. 2 AND No. 3

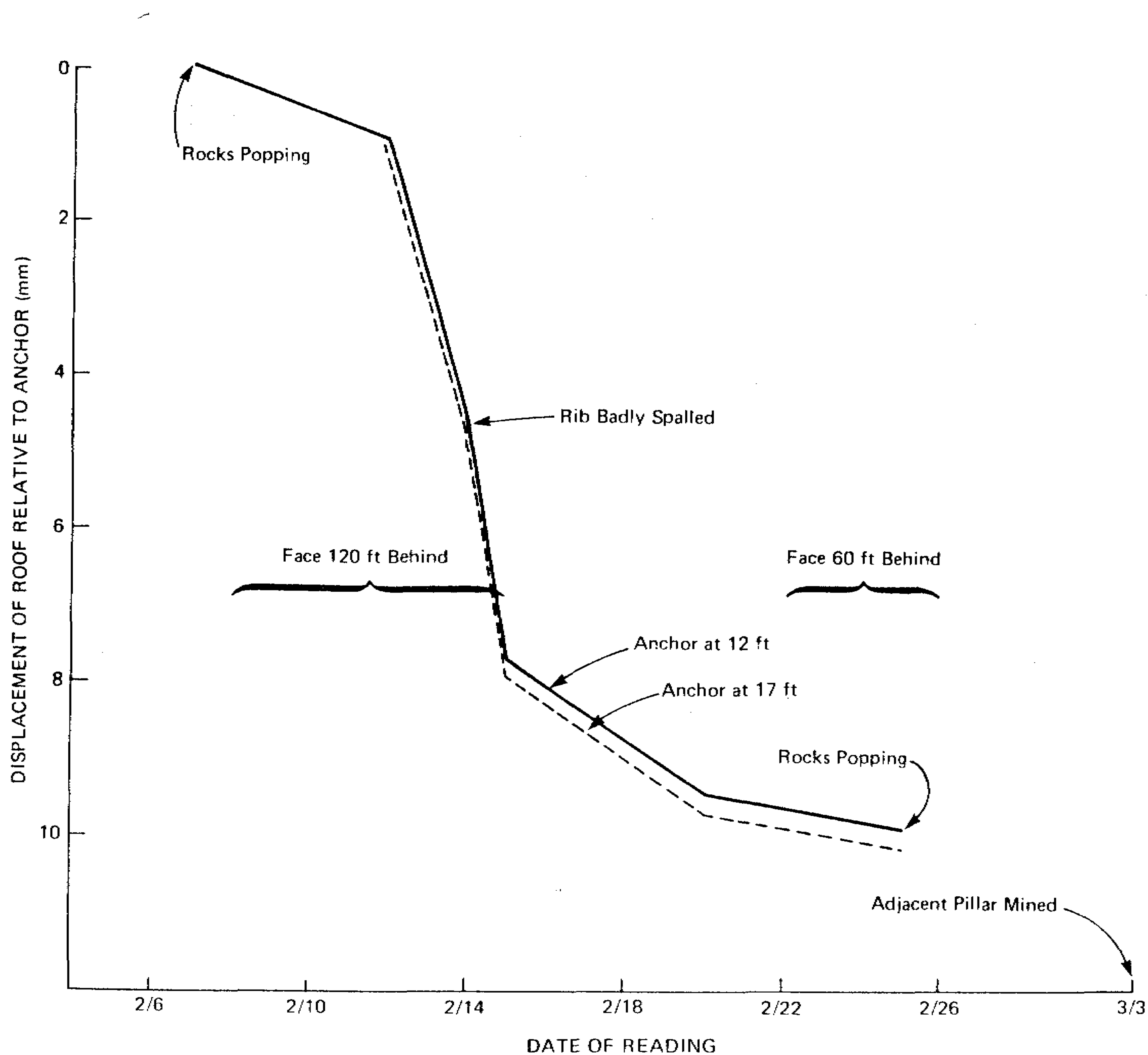


FIGURE 5.29
ROOM 6 EXTENSOMETER DATA

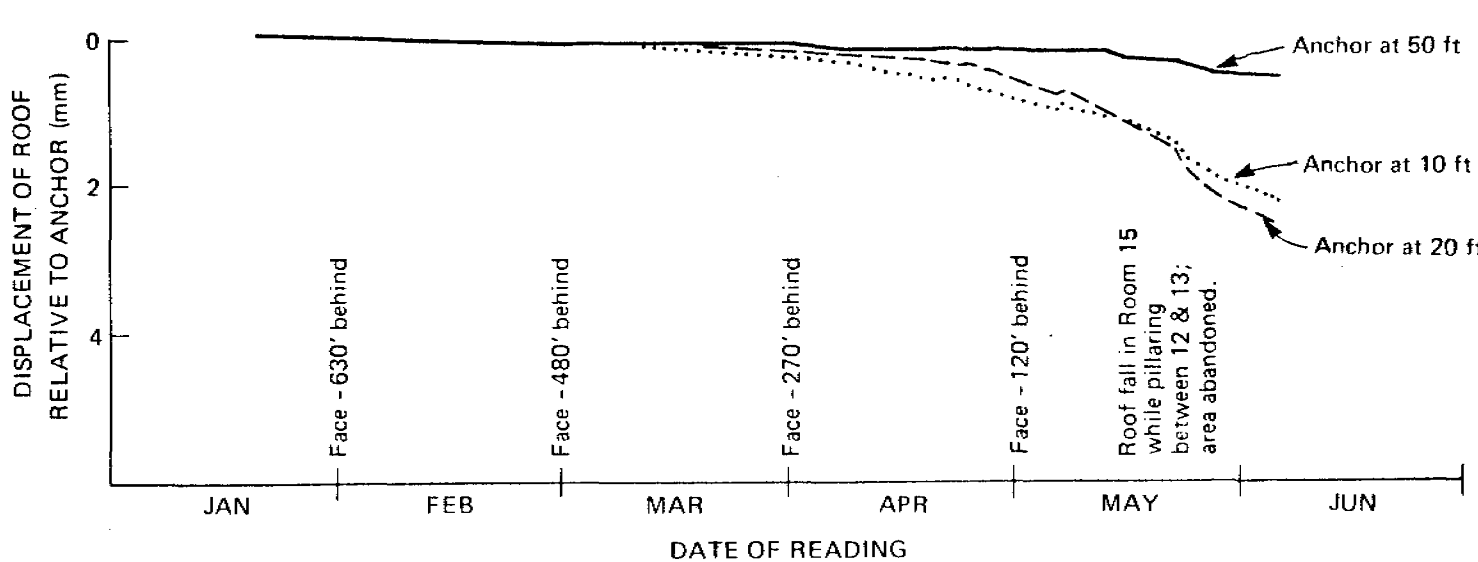


FIGURE 5.30

ROOM 13 ROD EXTENSOMETER DATA

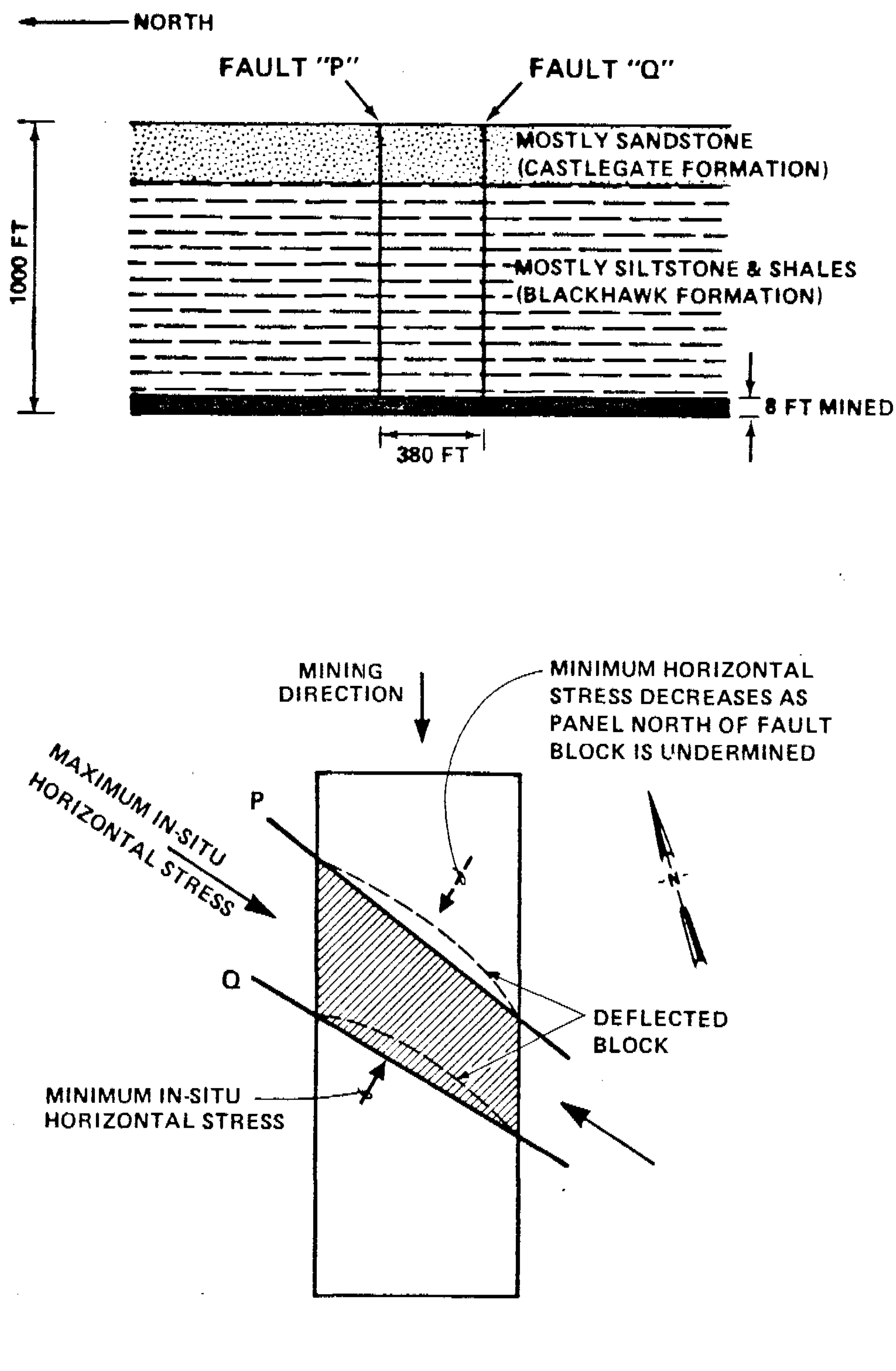


FIGURE 5.31

FAULT BLOCK DEFLECTION HYPOTHESIS

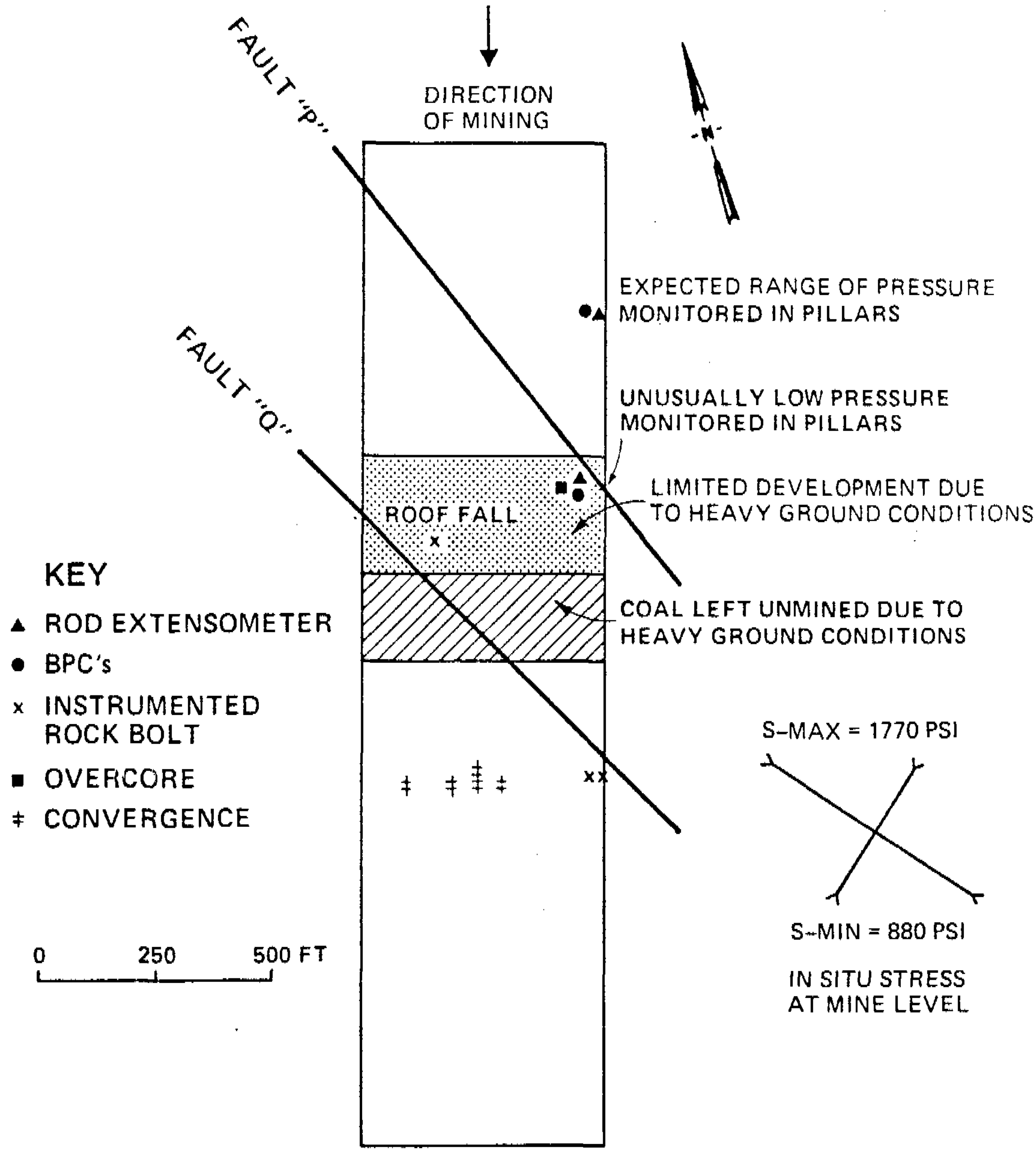


FIGURE 5.32

UNDERGROUND DATA SUPPORTING DEFLECTION HYPOTHESIS

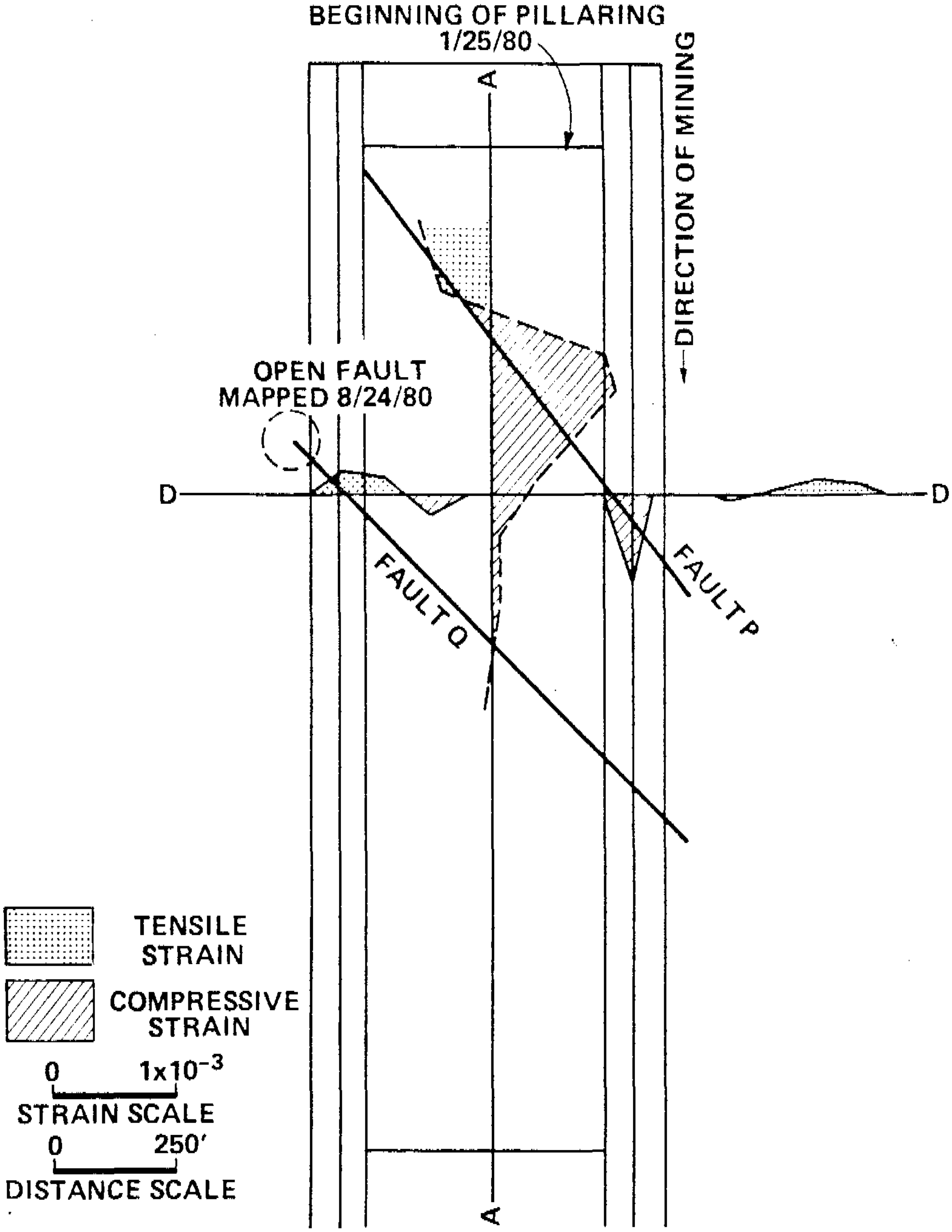


FIGURE 5.33

RESIDUAL STRAINS COMPUTED FROM LEVEL SURVEY DATA
(1/8/80 TO 6/1/81)

6.0 ASSESSMENT AND RECOMMENDATIONS

6.1 GENERAL

Field trial of the system designed to monitor "Performance of Caving Systems" was completed at the SUFCO mine and evaluated. On the basis of this field study, recommendations were developed for future subsidence monitoring of high-extraction coal mines.

6.2 EVALUATION OF INSTRUMENTATION

The major advantages and disadvantages of instruments used in this study and discussed in previous sections are summarized in Table 6.1. The format of the table has been adapted from O'Rourke and others (1977). A new category, "Usefulness of the Results," examines whether (1) the data are representative of the parameter measured; (2) the instrument biases the results; (3) the data are useful as input to or validation of analytic rock mechanics models; and (4) the data give insight into the physical processes of subsidence.

The category, "Major Cost of Items," assesses the approximate costs of using an instrument in a typical instrumentation program. The quantities are not necessarily the same as were used in this field program; and the costs are based on 1979 and 1980 rates. These costs are basic costs only and there are other field cost items, usually of a site-specific nature, associated with support of a field program.

The experience at the SUFCO mine indicated that redundancy is important in field and mine instrumentation where the conditions do not favor a high success rate such that sufficient reliable data may be obtained. In addition to the need to assure good quality data at a given point, the instrumented area must be adequately sampled to allow study of representative conditions. At the SUFCO mine, the instruments were concentrated in the vicinity of two faults, across which stress conditions were not uniform, resulting in collection of data representative of an unusual loading condition.

The instruments described in Table 6.1 were evaluated and rated numerically according to criteria listed in Table 6.2. The resulting matrix, Table 6.3, may be used as a basis for selecting types and quantities of instruments required to provide cost-effective data for subsidence characterization.

The numerical rating system is based on ease of installation, ease of monitoring, and usefulness of data and results. For example, the Interfels rod extensometer and hydraulic pressure cells were relatively easy to install, but required a large drill (ease of installation = 2). On the other hand, one person may read the instruments quickly (ease of operation = 3). In another example, the roof sag data provided by the instrument are generally not as useful as stress information in validating computer models. While this roof deformation data may not provide enough information to describe a model, it may be compared with trends in deformation results predicted by a model (usefulness of data = 2).

An examination of Table 6.3 points out that surface and underground instrumentation is less costly than deep hole instrumentation. Operation of some equipment in a deep hole (e.g., portable geophones) may also have an associated high level of difficulty and higher costs. Nevertheless, deep hole instrumentation is required for complete demonstration of the process by which subsidence develops from underground to surface. For example, the inclinometer/Sondex data collected at SUFCO suggests that in the top 500 feet (50 percent) of overburden thickness, slip between strata was a major mechanism for absorbing strains associated with undermining and that bulking was not significant in the upper strata.

6.3 EVALUATION OF MONITORING

6.3.1 Types of Program

Ratings (Table 6.3) suggest that a cost-effective basic subsidence program for a single panel at a high-extraction coal mine (Figure 6.1) would consist of:

- A surface level survey (approximately 100 points along 2 orthogonal lines; approximately 50-foot centers depending on panel dimensions and depth)

- A surface tape extensometer survey (approximately 100 points along 2 orthogonal lines using survey monuments)

- Mine level absolute stress measurement (two 35-foot deep holes, three USBM overcore tests/hole)

- Mine level hydraulic pressure cells (36 cells in 12 holes).

The basic program could be expanded to include more instrumentation where research on subsidence mechanisms is needed. In addition to the instrumentation listed above, such an expanded instrumentation program would include:

- Mine level rod extensometer (five 50-foot deep four-point installations in roof)

- Deep hole inclinometer (two installations)

- Deep hole Sondex (two installations, in same holes as inclinometers).

6.3.2 Duration of Program

The duration of both the basic program and the expanded program is essentially the same and depends on the completion of full subsidence and the mining schedule of the instrumented mine.

Estimated minimum times are as follows:

- Planning, design, purchasing and site selection: 6 months

- Field work begins 3 months before beginning mining. Allow 1 year for mining. Field work extends at least 9 months after completion of panel. Total duration: 2 years

- Data analysis and report preparation (only that portion scheduled after completion of field work): 3 months

- Total estimated minimum duration of proposed field programs: 2-3/4 years

6.4 COST CONTROL

A review of costs for this project suggests some measures where cost savings might be possible.

Efficient Use of Subcontractors. The use of surveying subcontractors might minimize investment in equipment and labor costs, because engineers who survey daily would be more efficient than those who survey intermittently. A local general contractor employed for mud pit construction, reclamation, plowing and other site construction tasks would reduce the time spent making arrangements for the individual items. The general contractor or other local workers can also assist as needed for labor-intensive operations such as grouting.

Good Quality Control. Daily field logs are suggested for all subcontractors. The logs should list the billable items specified in the contract, and they should be prepared and signed daily. Logs provided by the subcontractors themselves may not correspond exactly to contract items.

Instrument Testing. Instruments should be tested and calibrated as required in the laboratory before to beginning the field program. Modifications performed in the field are more costly than the same work done in a shop because all equipment must be transported to the field, and field conditions may affect efficiency of modification.

Winter Work. Installation in winter at some locations can greatly increase the cost of a project because snow and cold can cause low productivity and breakdowns. Installation, testing and initial operation at such locations should be completed in optimum weather conditions whenever possible.

TABLE 6-1a

INSTRUMENT PERFORMANCE

INSTRUMENT: PRECISION LEVEL

APPLICATIONS: SURFACE SUBSIDENCE; MINE LEVEL ROOF SAG

Manufacturer & Model	Wild NAK-1 Level
Availability	Readily available
Data Collection Characteristics	Portable, rugged; use with high quality survey points or with custom-made tape extensometer points
Range of the Instrument Used	Surface sight lengths 30 to 180 feet; rugged topography generally limited sight to 30 to 90 feet; mine level sights approximately 20 feet
Accuracy and Calibration Needs	Good closure at surface, approximately 0.01 feet for 2000 foot loop; 15 feet of 25-foot fiberglass rod used; poor accuracy at mine level due to unstable tripod footing, traffic, damage to points
Sensitivity to Environment and Damage of Permanent Equipment	Surface survey points were rugged; mine-level points were clogged with dirt, damaged by traffic
Sensitivity to Environment and Damage of Portable Equipment	After 1 year of intermittent but rough use, test of level showed well within specifications; surface survey difficult when windy; dust and traffic limited sight length underground; tripod set-up in mud difficult
Ease of Installation	Simple, repetitive installations; custom-made survey points required truck mounted auger for holes
Ease of Operation	Level easy to use, requires experience for rapid survey
Operation Power Requirement	None
Ease of Data Reduction	Standard procedure; easily stored and plotted by computer

TABLE 6-1a

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: PRECISION LEVEL

APPLICATIONS: SURFACE SUBSIDENCE; MINE LEVEL ROOF SAG

Usefulness of Results	Best measure of subsidence trough, angle of draw; usefulness of underground data dependetn on accuracy; cannot monitor roof sag after mining	
Major Cost Items (1979 prices--approximate)	Surface: Level and Tripod	$ 2,420
	2 Fiberglass Rods	300
	Installation of 40 monuments including labor and drilling	12,550
	40 monuments	2,200
	Operation: 8 Surveys	8,000
	Total Basic Costs (Surface)	$23,720
	Underground: Level and Tripod	$ 2,420
	2 wooden rods	300
	Installation of 10 roof sag points including bolter rent and labor	1,175
	10 reference points	130
	Operation: 20 surveys	2,000
	Total Basic Costs (Underground)	$ 6,025

TABLE 6-1b

INSTRUMENT PERFORMANCE

INSTRUMENT: TAPE EXTENSOMETER

APPLICATIONS: SURFACE HORIZONTAL STRAIN; MINE LEVEL CONVERGENCE

Manufacturer & Model	SINCO Model 51255
Availability	Readily available
Data Collection Characteristics	Portable extensometer and tape; permanent customized reference points
Range of the Instrument used	30 meters in 5 cm increments
Accuracy and Calibration Needs	±0.003 in. for measurements taken from same punched hole; accuracy better than needed for large strains measured; factory recalibration needed after cleaning
Sensitivity to Environment and Damage of Permanent Equipment	Surface points rugged; underground points subject to clogging and traffic damage
Sensitivity to Environment and Damage of Portable Equipment	Tape extensometer generally good on surface; tape subject to breakage; cannot be used when windy; underground, instrument sensitive to coal dust, required cleaning and factory recalibration
Ease of Installation	See comments on survey point, Table 5.1.a
Ease of Operation	Labor-intensive and slow; manual operation requires frequent personnel visits to site; 30 measurements required 5 hours for two men
Operation Power Requirement	None
Ease of Reduction	Straightforward; manual confusing; computerized data sheets convenient for reduction and plotting
Usefulness of Results	Shows strains due to mining and influence of faults on strain profile; strains one order of magnitude greater than strains computed from level survey

TABLE 6-1b

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: TAPE EXTENSOMETER

APPLICATIONS: SURFACE HORIZONTAL STRAIN; MINE LEVEL CONVERGENCE

Major Cost Items (1979 prices--approximate)	Surface: Tape Extensometer	$ 1,600
	Case, spare tape, thermometer	360
	Installation of 40 monuments	12,550
	40 monuments	2,200
	8 Surveys	6,400
	Total Basic Costs (Surface)	$23,110
	Underground: Tape Exensometer	$ 1,600
	Case, spare tape, thermometer	360
	Installation (10 convergence pair)	2,225
	Monuments (10 pair)	200
	20 Surveys	2,000
	Total Basic Costs (Underground)	$ 6,385

TABLE 6-1c

INSTRUMENT PERFORMANCE

INSTRUMENT: INCLINOMETER

APPLICATIONS: SUBSURFACE HORIZONTAL DEFORMATION

Manufactor & Model	SINCO Model 50325 with ABS plastic grooved casing (2.75-inch diameter)
Readily Available	Approximately four weeks construction and delivery
Data Collection Characteristics	Portable sensor and readout; permanently cased hole
Range of Instrument Used	Tilt range ±30°; minimum radius of bend that instrument can traverse is 9 feet
Accuracy and Calibration Needs	0.001 to 0.007 inches A-Axis; 0.009 to 0.013 inches B-Axis. Probe recalibrated when returned for repairs
Sensitivity to Environment and Damage of Permanent Equipment	Casing closed off when shear limit exceeded
Sensitivity to Environment and Damage of Portable Equipment	Sensor susceptible to damage during transport in truck, but tolerated cold and dampness. Readout rugged. Cable reel lock, ratchet and slip rings flimsy
Ease of Installation	Assembly tedious; plastic casing not rugged. No provision for external couplings if casing needs to be cut and repaired during installation; casing warps in sun
Ease of Operation	Requires two-man team, readings rapid but tedious. Must allow vibration to damp out (15 to 30 seconds) before making reading
Operation Power Requirement	Rechargeable battery on readout
Ease of Data Reduction	Lengthy; collect data on computer form and process by computer. Analysis complicated by some missing data from slip rings failure

TABLE 6-1c

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: INCLINOMETER

APPLICATIONS: SUBSURFACE HORIZONTAL DEFORMATION

Usefulness of Results	Shows slope instability as well as mining induced shears. Substantial horizontal off-set was recorded before casing failed	
Major Cost Items (1979 prices--approximate)	Inclinometer and readout	4,750
	1000 ft cable, cable reel, skids	2,965
	Casings, couplings for 1-800 and one 300 ft hole	3,990
	Grout hose fittings, nylon rope, support shoe	1,380
	Drill and install indicator labor	38,240
	Operate (8 readings)	3,840
	Total Basic Costs	$59,165

TABLE 6-1d

INSTRUMENT PERFORMANCE

INSTRUMENT: SONDEX (FULL PROFILE BOREHOLE EXTENSOMETER)

APPLICATIONS: SUBSURFACE VERTICAL DEFORMATION

Manufacturer & Model	Model 50812
Availability	Readily available; user must provide tape for lengths greater than 300 feet; casing was readily available but couplings may involve delay
Data Collection Characteristics	Portable sensor and readout; permanently cased hole
Range of the Instrument Used	Deformations ±0.02 to many feet; depth to 300 ft with tape, modification needed below this depth
Accuracy & Calibration Needs	±0.01 to ±0.02 ft; no better than 0.02 ft below 300 ft
Sensitivity to Environment and Damage of Permanent Equipment	Some sections of casing punctured during shipping prior to installation; casing closed off due to ground shears
Sensitivity to Environment and Damage of Portable Equipment	Probe was rugged; frequent tape repairs necessary; cable reel slip rings failed; cable reel ratchet and handle lock broke
Ease of Installation	Slow; casing hard to handle, easily punctured, and difficult to seal; glues do not work since polyethylene; installed in combined installation with inclinometer. Drill rig required for installation
Ease of Operation	Slow; tape tended to wrap around cable and kink when reeled up; labor intensive when using tape
Operation Power Requirement	Replaceable batteries in readout
Ease of Data Reduction	Simple; recommend collect data on computer forms and store on computer for ease in handling
Usefulness of Results	Indicator of bulking and strata separations; showed no significant bulking in top 500 ft; rod ext. might give same information at lower operation cost

TABLE 6-1d

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: SONDEX (FULL PROFILE BOREHOLE EXTENSOMETER)

APPLICATIONS: SUBSURFACE VERTICAL DEFORMATION

Major Cost Items (1979 prices--approximate)	SONDEX Probe and readout	$ 1,550
	Cable, cable-reel and skid	2,956
	Casing and Couplings for one 800 ft and one 300 ft hole	1,910
	Grout hose, fittings, support shoe	1,380
	Drill, installation, and labor	36,480
	Operate (eight readings)	5,120
	Total Basic Cost	$49,405

TABLE 6-1e

INSTRUMENT PERFORMANCE

INSTRUMENT: GROUTED-IN-PLACE GEOPHONE

APPLICATIONS: ROCK NOISE PROFILE

Manufacturer & Model	SINCO MS-3 readout, SINCO 53305 MS 1.75-inch diameter geophones
Availability	Some delay
Data Collection Characteristics	Portable readout; permanent geophone
Range of the Instrument Used	Wide band frequency; planned for use in holes to 800 ft; tested to 672 ft
Accuracy & Calibration Needs	The counters on the readout were not accurate; mechanical counter misses approximately 10% of events shown on meter; digital counter might record long event as several events
Sensitivity to Environment and Damage of Permanent Equipment	Geophones survived some ground movement, but eventually the deeper two of four failed due to mining displacements; not sensitive to weather
Sensitivity to Environment and Damage of Portable Equipment	Mechanical and digital counters did not agree; lack of reliability probably not related to environmental conditions
Ease of Installation	Greasing and sleeving the cables was time consuming but probably lengthned survival time. Placing in hole easy, but deep pairs of geophones would not descend past 670 ft in 800 ft 6-inch diameter hole
Ease of Operation	Fundamentally simple, but unreliable readout complicated the procedure
Operation Power Requirement	Drill for holes; rechargeable battery in readout
Ease of Data Reduction	Straightforward plot: count vs. time and depth
Usefulness of Results	Showed majority of rock noise occurring within 155 days of mining as did settlement data. Noise/depth profile over time was not obtained due to failures of geophones

TABLE 6-1e

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: GROUTED-IN-PLACE GEOPHONE

APPLICATIONS: ROCK NOISE PROFILE

Major Cost Items (1979 prices--approximate)	Four geophones plus cable @ 810, 610, 310, and 150 ft	$ 4,180
	Readout, earphones	1,180
	Protective surface housing	250
	Installation of geophones in 800 and 300 ft hole including drilling labor;	37,200
	Operate (eight readings)	640
	Total Basic Cost	$43,450

TABLE 6-1f

INSTRUMENT PERFORMANCE

INSTRUMENT: PORTABLE GEOPHONE

APPLICATIONS: ROCK NOISE PROFILE

Manufacturer & Model	SINCO MS-3 readout, 53305 MS tranducers--1.75 inch-diameter Pneumatic packer assy. was custom made
Availability	Some delay in obtaining geophone; major delays in getting packer assy. to operate properly. Many on-site modifications
Data Collection Characteristics	Portable readout and sensor; permanently cased hole
Range of the Instrument Used	Wide band frequency; planned for use to 800 ft tested to 300 ft.
Accuracy & Calibration Needs	See Table 5.1e. Calibration of meter and trigger level on readout was not provided by manufacturer
Sensitivity to Environment and Damage of Permanent Equipment	Steel casing in hole was sheared at 270 ft by mining induced movements
Sensitivity to Environment and Damage of Portable Equipment	See Table 5.1e. The pneumatic system was hard to handle due to stiffening of plastic air line; regulators rusted when stored outside
Ease of Installation	Installation of standard steel casing was straightforward
Ease of Operation	Debugging the system was very slow. The pneumatic packer assy required required many modifications; all testing and repair was done on site. Use is moderately easy, except handling air line in cold; air pressure regulators rusted when stored outside
Operation Power Requirement	Drill to install; readout has rechargeable battery
Ease of Data Reduction	Plot count vs. time and depth
Usefulness of Results	Surface noise (wind, footsteps, voices,) affected reading at 100 ft. Not tested for full depth due to delays in debugging and shearing of casing

TABLE 6-1f

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: PROTABLE GEOPHONE

APPLICATIONS: ROCK NOISE PROFILE

Most Cost Items (1979 prices--approximate)	Casing and caps	$ 3,867
	Geophone Cable reel (950 ft)	1,160
	Cable real	1,040
	Readout earphones	1,180
	Installation including drill of 800 ft hole	25,600
	Operate (8 readings)	3,840
	Total Basic Cost	$36,687

TABLE 6-1g

INSTRUMENT PERFORMANCE

INSTRUMENT: ROD EXTENSOMETERS

APPLICATIONS: DIFFERENTIAL ROOF SAG

Manufacturer & Model	Interfels Rex (Germany) 4-point rod extensometer
Availability	Readily available; allow time for shipping and for customs; instrument modified on site to provide broader and deeper support for readout head
Data Collection Characteristics	Direct readout with portable dial gage; permanently installed rods, anchors and heads
Range of the Instrument Used	Approximately 10 mm resettable; designed for about 5 cm total travel but could easily be modified to get 25 cm
Accuracy & Calibration Needs	Very accurate (±0.1 mm); can check for friction if desired by releasing rod at bayonet joint; dial gage comes with calibration jig
Sensitivity to Environment and Damage of Permanent Equipment	Very rugged
Sensitivity to Environment and Damage of Portable Equipment	Dial gage very rugged; provided in padded case
Ease of Installation	Well designed system requires slow and precise installation
Ease of Operation	Easy; well designed, repeatable dial gage mount; as face approaches, remote reading electrical sensor may be safer
Operation Power Requirement	None
Ease of Data Reduction	Straightforward plot: movement versus time
Usefulness of Results	Shows strata separation between roof and anchor, sag of roof relative to upper strata increases with time. Correlated with face advance mining problems. Can be used to estimate convergence of opening

TABLE 6-1g

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: ROD EXTENSOMETERS

APPLICATIONS: DIFFERENTIAL ROOF SAG

Major Cost Items (1979 prices--approximate)	Five 4-point Ext with anchors at 10, 20, 30, and 50 ft including shipping and customs	$ 9,850
	Installation including drilling and labor	28,200
	Operation: 20 readings	4,000
	Total Basic Cost	$42,050

TABLE 6-1h

INSTRUMENT PERFORMANCE

INSTRUMENT: BOREHOLE DEFORMATION

APPLICATIONS: ABSOLUTE IN-SITU STRESS MEASUREMENT

Manufacturer & Model	Irad Model BG-2 Vishay P-350 readout with added switch box
Availability	Readily available
Data Collection Characteristics	Portable; test only-no permanent installation
Range of the Instrument Used	Range limited by movement of pistons (approximately .0240 inch change in diameter of a 1.50-inch diameter hole)
Accuracy & Calibration Needs	Calibration of gage is standard part of pre-operation procedure
Sensitivity to Environment and Damage of Permanent Equipment	No permanent equipment; gage, left in hole during test, is very rugged; piston components may loosen
Sensitivity to Environment and Damage of Portable Equipment	Vishay readout and IRAD probe rugged. Biaxial cell well designed; membranes good quality
Ease of Installation	Moderately difficult procedure; requires competent zone for test in thinly bedded sedimentary sequence; wet procedure in up-hole
Ease of Operation	Easy; well designed, repeatable dial gage mount as full approaches, conversion to remote reading electrical sensor desirable
Operation Power Requirement	Battery-operated readout; drill rig required for test
Ease of Data Reduction	Reduce by hand for two-dimensional analysis; vertical stress is assumed a principal stress
Usefulness of Results	Stresses are basic input to computer models; horizontal stresses were consistent with regional trends

TABLE 6-1h

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: BOREHOLE DEFORMATION

APPLICATIONS: ABSOLUTE IN-SITU STRESS MEASUREMENT

Major Cost Items (1979 prices--approximate)	Borehole deformation gage, biaxial cell, spare parts, set rods, Vishay readout	$ 6,330
	Install, including drill, labor--two holes to 35 ft	8,280
	Drilling access	2,000
	Total Basic Cost	$16,610

TABLE 6-1i

INSTRUMENT PERFORMANCE

INSTRUMENT: BOREHOLE PRESSURE CELLS

APPLICATIONS: PILLAR PRESSURE

Manufacturer & Model	Terrametrics Model BPC-225
Availability	Readily available
Data Collection Characteristics	Permanent
Range of the Instrument Used	Stress: 0 to 4000 psi; select gage with middle range at expected stress level for application
Accuracy & Calibration Needs	Three percent gauge; accuracy of stress change depends on moduli of cell, grout, and coal; trend of stresses valid in any case
Sensitivity to Environment and Damage of Permanent Equipment	Sensitive to quality of grouting; hydraulic lines and gages may be damaged by rock spalling and by traffic
Sensitivity to Environment and Damage of Portable Equipment	Rugged hydraulic pump was only portable item; quick connects made it easy to use
Ease of Installation	Install in horizontal hole; moderately easy; made wire frame to hold cells; made holder to fit Irad setting rods to insert cells. Some cells failed during installation probably due to 1) leaks in hydraulic lines or cell and 2) gaps in grout leading to uneven strain
Ease of Operation	Easy; visually read pressure gages
Operation Power Requirement	None
Ease of Data Reduction	Easy; plot pressure vs. time; correct pressure for modulus ratio
Usefulness of Results	Shows build-up of both horizontal and vertical pressure as face approaches; provided assessment of in-situ pressure (pressure stabilized after some creep) basic data for computer model verification; correlated with mining problems

TABLE 6-1i

INSTRUMENT PERFORMANCE (CONT)

INSTRUMENT: BOREHOLE PRESSURE CELLS

APPLICATIONS: PILLAR PRESSURE

Major Cost Items (1979 prices--approximate)	Thirty-six cells in 12 holes--two vertical plus one-horizontal per hole; cells and gages	$ 10,400
	Metal frames	2,000
	Fittings, oil	100
	Hydraulic pump	250
	Installation, including drilling, labor	27,840
	Operation (20 readings)	1,600
	Total Basic Cost	$42,190

TABLE 6-1j

INSTRUMENT PERFORMANCE

INSTRUMENT: INSTRUMENTED ROCK BOLTS

APPLICATIONS: BOLT LOAD

Manufacturer & Model	Geokon with Vishay P-350 readout
Availability	Custom made
Data Collection Characteristics	Permanent installation, portable readout
Range of the Instrument Used	Designed for loads 12 tons
Accuracy & Calibration Needs	Accuracy not assessed; calibrated by manufacturer
Sensitivity to Environment and Damage of Permanent Equipment	Rugged during operation phase; heat due to friction during installation may anneal strain gage; two wires on one bolt sheared
Sensitivity to Environment and Damage of Portable Equipment	Vishay P-350 readout rugged
Ease of Installation	Use mine rock bolter with slow set resin; bolting skill required
Ease of Operation	Connect wiring harness; balance electric strain gage readout
Operation Power Requirement	Battery powered readout
Ease Reduction	Convert to load using manufacturer supplied calibration; moderately easy
Usefulness of Results	Provides support loading histories; too few bolts were instrumented to get a definite trend

Major Cost Items (1979 prices--approximate)	20 Bolts, resin, Vishay P-350 readout	$ 3,200
	Install using roof bolter including labor	690
	Operation (20 readings)	2,400
	Total Basic Cost	$ 6,290

TABLE 6.2

RATING CRITERIA FOR INSTRUMENTATION MATRIX

CRITERION	RATING	DESCRIPTION
Availability	1	Custom made
	2	Some delay or foreign manufacturer
	3	Readily available
Data Collection Characteristics	1	All permanent
	2	Major cost items portable, permanent items non-replaceable
	3	Major cost items portable, permanent items replaceable
Range of the Instrument Used	2	Movements exceeded instrument range
	3	Sufficient for instrumentation needs
Accuracy and Calibration Needs	1	Accuracy close to magnitude of measured parameter
	2	Moderately accurate ±50 percent, or very accurate but needs special calibration or recalibration
	3	Very accurate (±10 percent)
Sensitivity to Environment and Damage of Permanent Equipment	1	Easily damaged
	2	Damaged under severe conditions
	3	Robust
Sensitivity to Environment and Damage of Portable Equipment	1	Easily damaged or needs frequent adjustment
	2	Damaged under severe conditions
	3	Robust

TABLE 6.2

RATING CRITERIA FOR INSTRUMENTATION MATRIX (CONT)

CRITERION	RATING	DESCRIPTION
Ease of Installation	1	Requires large drill, complex procedure
	2	Requires large drill
	3	Requires hand tools only.
Ease of Operation	1	Complex operation; many adjustments; require two persons
	2	Several steps in readout procedure; may require two persons
	3	Easy for one person
Operation Power Requirement	1	Requires generator or a/c power
	2	Battery operated
	3	None
Ease of Data Reduction	1	Complex, computer generally used
	2	Some calculations
	3	Simple
Usefulness of Results	1	Data anomalous or difficult to interpret
	2	Intermediate between numbers one and three
	3	Standard subsidence data or typical output rock mechanics analyses or provides important insight

TABLE 6.2

RATING CRITERIA FOR INSTRUMENTATION MATRIX (CONT)

CRITERION	RATING	DESCRIPTION
Major Cost Items (1979 prices--approximate)	1	Less than $20,000
	2	Greater than $20,000
	3	Greater than $30,000

TABLE 6.3

INSTRUMENT EVALUATION MATRIX

RATING CATEGORIES \ INSTRUMENTS	WEIGHTS	Precision Level (Surface)	Precision Level (Mine Level)	Tape Extensometer (Surface)	Tape Extensometer (Mine Level)	Inclinometer	Sondex	Grouted-In-Place Geophones	Portable Geophone System	Rod Extensometers	Borehole Deformation Gage	Borehole Pressure Cells	Instrumented Rock Bolts
Availability	1	3	3	3	3	3	3	2	2	2	3	3	1
Data Collection Characteristics	1	3	3	3	3	2	2	2	2	2	3	1	2
Range of the Instrument Used	1	3	3	3	3	2	3	2	2	2	3	3	3
Accuracy & Calibration Needs	2	3	1	3	2	2	2	2	2	3	2	2	2
Sensitivity to Environment and Damage of Permanent Equipment	2	3	1	2	1	1	1	2	2	3	3	2	2
Sensitivity to Environment and Damage of Portable Equipment	2	3	3	2	1	1	1	2	1	3	3	3	3
Ease of Installation	2	2	2	2	2	1	1	2	2	2	2	2	2
Ease of Operation	2	2	1	2	2	2	1	2	1	3	1	3	2
Operation Power Requirement	1	3	3	3	3	2	2	2	2	3	2	3	2
Ease of Data Reduction	1	2	2	2	2	1	2	3	3	3	1	2	2
Usefulness of Data and Results	5	3	2	3	2	3	3	1	1	2	3	3	1
Basic Costs (Including Installation and Operation)	2	2	3	2	3	1	1	1	1	1	3	1	3
Weighted Total	-	59	46	55	46	41	41	38	34	50	55	52	43

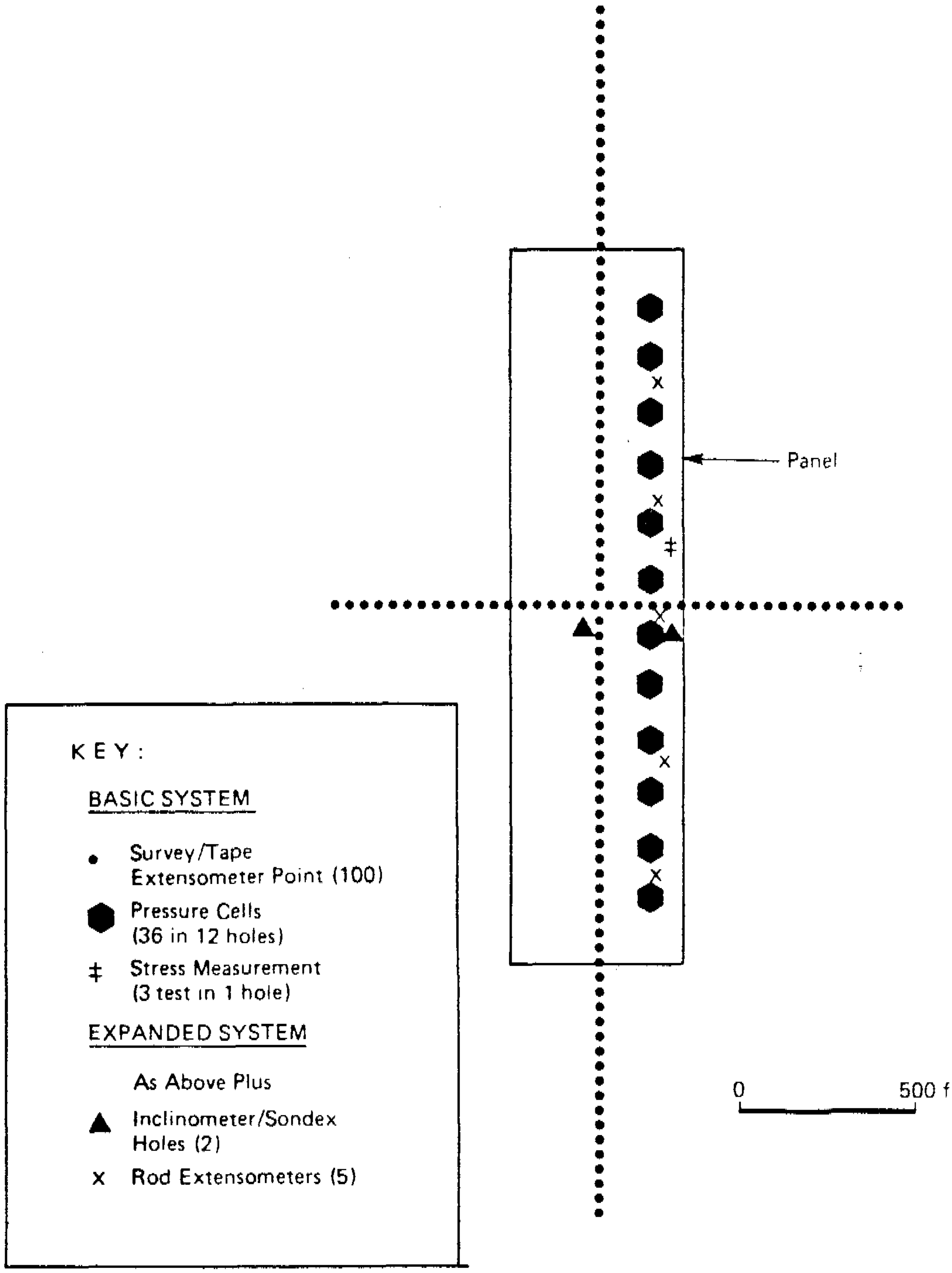


FIGURE 6.1

RECOMMENDED MONITORING PROGRAM

7.0 SUMMARY

This report summarizes the design and execution of a subsidence monitoring program conducted by WCC at the SUFCO No. 1 mine near Salina, Utah. The study tested the instrumentation system entitled "Performance of Caving Systems" and provided a partial test of two other systems, "Performance of Supported Systems" and "Structure Performance." The program was affected by delays, winter installation and mining plan changes in the instrumented panel.

The study developed a limited subsidence case history for panel 2E3L, which is approximately 1,000 feet deep, 2,100 feet long and 500 feet wide. A maximum subsidence of 2.6 feet was measured for an extracted seam thickness of about 8 feet. Subsidence increased when adjacent panels were mined. Angle of draw was approximately minus 2 to plus 19 degrees over virgin ground and 40 to 48 degrees over undermined ground. About 90 percent of total measured subsidence occurred within 155 days of mining.

Recorded horizontal strains were large over the panel ($\pm 2 \times 10^{-3}$) and were substantially affected by the presence of vertical faults. The tape extensometer recorded strains that were 10 times larger than those computed from the level survey profile. This disparity indicates that some form of direct strain measurement is necessary for accurate strain monitoring. Ground cracking caused by undermining healed over the panel after mining, except where a large pillar of coal was left unmined because of heavy ground conditions.

Deep-hole inclinometer data showed tilt of the strata in the top 500 feet toward the gob. They also revealed shallow slope instability in the downhill direction (away from the gob). Sondex data showed no major bulking in the top 500 feet. Geophone data and surface survey data confirmed that major adjustments to undermining as measured by rock noise occur within approximately 155 days.

At mine level, overcore data showed the principal horizontal stresses to be 1,770 psi at N41W and 880 psi at N49E. These stress magnitudes appear to be reasonably consistent with regional trends.

Borehole pressure cells showed pillar stress increases of 50 percent for vertical stress and 170 percent for horizontal stress under normal loading conditions. The failure to take load in another area where a pillar was monitored with borehole pressure cells was a precursor to difficult ground conditions encountered in mining. Roof bolt data showed low load conditions when a crib was installed adjacent to an instrumented bolt shortly after bolting. Bolts in other areas carried moderate loads of 2,000 to 6,000 pounds, substantially less than the design load. Rod extensometers showed roof sag relative to the anchors of about 10 mm prior to mining under usual loading conditions and only about 1 mm in a problem area.

The instrumentation was concentrated by chance in an area where mining problems developed. Although the unusual loading conditions and change in extraction plan reduced the completeness of the study as a subsidence case history, the study provided useful data for examination of the mining problems. Instrumentation data and visual observations suggested deflection of a block between two faults as the source of the unusual loading conditions.

The demonstrated instruments were evaluated for their usefulness to subsidence monitoring, and for their cost effectiveness. Two levels of subsidence monitoring programs were recommended: a basic program to develop case history data for a large number of mines, and an expanded program to develop an understanding of the physical processes of subsidence at key mines.

APPENDIX A
TABULATED FIELD DATA

DATA FORCED TO AGREE AT DEPTH 500.00A-ADJUST = .0000B-ADJUST = .0000

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
05-05-80 05-05-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
500.00	.0000		
498.00	-.0216		
496.00	-.0516		
494.00	-.0672		
492.00	-.0648		
490.00	-.0528		
488.00	-.0360		
486.00	-.0342		
484.00	-.0318		
482.00	-.0300		
480.00	-.0210		
478.00	-.0324		
476.00	-.0066		
474.00	-.0228		
472.00	-.0336		
470.00	-.0378		
468.00	-.0438		
466.00	-.0522		
464.00	-.0408		
462.00	-.0714		
460.00	-.1200		
458.00	-.1092		
456.00	-.1470		
454.00	-.1416		
452.00	-.1374		
450.00	-.1338		
448.00	-.1356		
446.00	-.1476		
444.00	-.1554		
442.00	-.1770		
440.00	-.1980		
438.00	-.2022		
436.00	-.1914		
434.00	-.1908		
432.00	-.1800		
430.00	-.1608		
428.00	-.1482		
426.00	-.1458		
424.00	-.1386		
422.00	-.1392		
420.00	-.1410		
418.00	-.1350		
416.00	-.1434		
414.00	-.1440		
412.00	-.1494		

58.	410.00	-.1524
59.	408.00	-.1530
60.	406.00	-.1422
61.	404.00	-.1296
62.	402.00	-.1272
63.	400.00	-.1356
64.	398.00	-.1256
65.	396.00	-.1212
66.	394.00	-.1092
67.	392.00	-.1062
68.	390.00	-.1098
69.	388.00	-.1014
70.	386.00	-.1134
71.	384.00	-.2130
72.	382.00	-.2544
73.	380.00	-.2418
74.	378.00	-.2268
75.	376.00	-.2190
76.	374.00	-.2178
77.	372.00	-.2058
78.	370.00	-.2100
79.	368.00	-.1854
80.	366.00	-.1728
81.	364.00	-.1758
82.	362.00	-.1752
83.	360.00	-.1716
84.	358.00	-.1704
85.	356.00	-.1644
86.	354.00	-.1464
87.	352.00	-.1152
88.	350.00	-.0888
89.	348.00	-.0624
90.	346.00	-.0150
91.	344.00	-.0162
92.	342.00	-.0144
93.	340.00	-.0456
94.	338.00	-.0930
95.	336.00	-.1110
96.	334.00	-.1224
97.	332.00	-.1392
98.	330.00	-.1350
99.	328.00	-.1218
100.	326.00	-.0942
101.	324.00	-.0792
102.	322.00	-.0702
103.	320.00	-.0318
104.	318.00	-.0126
105.	316.00	.0060
106.	314.00	.0120
107.	312.00	.0300
108.	310.00	.0504
109.	308.00	.0690
110.	306.00	.0792
111.	304.00	.0978
112.	302.00	.1128
113.	300.00	.1028
114.	298.00	.0990

115.	296.00	.0942
116.	294.00	.0960
117.	292.00	.1020
118.	290.00	.1110
119.	288.00	.1482
120.	286.00	.1950
121.	284.00	.2214
122.	282.00	.2490
123.	280.00	.2706
124.	278.00	.2766
125.	276.00	.2880
126.	274.00	.2766
127.	272.00	.2658
128.	270.00	.2676
129.	268.00	.2694
130.	266.00	.2796
131.	264.00	.3054
132.	262.00	.3378
133.	260.00	.3858
134.	258.00	.4506
135.	256.00	.3330
136.	254.00	.1932
137.	252.00	.2046
138.	250.00	.2070
139.	248.00	.1848
140.	246.00	.1830
141.	244.00	.1926
142.	242.00	.1872
143.	240.00	.1884
144.	238.00	.1974
145.	236.00	.2202
146.	234.00	.2538
147.	232.00	.2856
148.	230.00	.3084
149.	228.00	.3360
150.	226.00	.3600
151.	224.00	.3684
152.	222.00	.3702
153.	220.00	.3516
154.	218.00	.3324
155.	216.00	.3138
156.	214.00	.3108
157.	212.00	.3042
158.	210.00	.3216
159.	208.00	.3456
160.	206.00	.3720
161.	204.00	.4038
162.	202.00	.4302
163.	200.00	.4530
164.	198.00	.4680
165.	196.00	.4668
166.	194.00	.4614
167.	192.00	.4194
168.	190.00	.2778
169.	188.00	.0498
170.	186.00	-.1596
171.	184.00	-.2046

172.	182.00	-.1680
173.	180.00	-.1158
174.	178.00	-.0732
175.	176.00	-.0354
176.	174.00	-.0030
177.	172.00	.0270
178.	170.00	.0672
179.	168.00	.0978
180.	166.00	.1230
181.	164.00	.1368
182.	162.00	.1470
183.	160.00	.1482
184.	158.00	.1386
185.	156.00	.1320
186.	154.00	.1422
187.	152.00	.1530
188.	150.00	.1650
189.	148.00	.1782
190.	146.00	.1980
191.	144.00	.2196
192.	142.00	.2430
193.	140.00	.2628
194.	138.00	.2850
195.	136.00	.3132
196.	134.00	.3252
197.	132.00	.3354
198.	130.00	.3468
199.	128.00	.3624
200.	126.00	.3870
201.	124.00	.4014
202.	122.00	.4164
203.	120.00	.4332
204.	118.00	.4128
205.	116.00	.4218
206.	114.00	.4296
207.	112.00	.4416
208.	110.00	.4542
209.	108.00	.4692
210.	106.00	.4812
211.	104.00	.4962
212.	102.00	.5040
213.	100.00	.5112
214.	98.00	.5136
215.	96.00	.5172
216.	94.00	.5262
217.	92.00	.5364
218.	90.00	.5448
219.	88.00	.5496
220.	86.00	.5556
221.	84.00	.5670
222.	82.00	.5784
223.	80.00	.5934
224.	78.00	.6090
225.	76.00	.6216
226.	74.00	.6354
227.	72.00	.6480
228.	70.00	.7878

229.	68.00	1.1550
230.	66.00	1.6338
231.	64.00	2.0742
232.	62.00	2.5044
233.	60.00	2.9178
234.	58.00	3.3552
235.	56.00	3.7368
236.	54.00	3.9948
237.	52.00	4.1058
238.	50.00	4.0020
239.	48.00	3.7566
240.	46.00	3.7716
241.	44.00	3.7890
242.	42.00	3.8064
243.	40.00	3.8202
244.	38.00	3.8298
245.	36.00	3.8376
246.	34.00	3.8484
247.	32.00	3.8598
248.	30.00	3.8706
249.	28.00	3.8820
250.	26.00	3.8928
251.	24.00	3.8580
252.	22.00	3.8562
253.	20.00	3.8388
254.	18.00	3.8028
255.	16.00	3.7482
256.	14.00	3.7266
257.	12.00	3.7146
258.	10.00	3.7080
259.	8.00	3.6630
260.	6.00	3.6528
261.	4.00	3.6852
262.	2.00	3.6960

DATA FORCED TO AGREE AT DEPTH 450.00A-ADJUST = .1338B-ADJUST = .0000
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
06-24-80 06-24-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
450.00	-.1338		
448.00	.0444		
446.00	.1320		
444.00	.3864		
442.00	.3024		
440.00	.3684		
438.00	.2988		
436.00	.1386		
434.00	-.1392		
432.00	-.3156		
430.00	-.2592		
428.00	-.2658		
426.00	-.3012		
424.00	-.0006		
422.00	.2886		
420.00	.4338		
418.00	.6750		
416.00	.8922		
414.00	.9078		
412.00	.4164		
410.00	.3402		
408.00	-.0342		
406.00	-.0732		
404.00	.1422		
402.00	-.0420		
400.00	-.0846		
398.00	.1614		
396.00	.5334		
394.00	.6012		
392.00	.8952		
390.00	1.0140		
388.00	1.0284		
386.00	.7950		
384.00	.3634		
382.00	.0204		
380.00	.0708		
378.00	.0378		
376.00	-.1344		
374.00	-.3618		
372.00	-.0363		
370.00	-.1824		
368.00	-.1854		
366.00	.9204		
364.00	.4826		
362.00	.4866		

58.	360.00	.6306
59.	358.00	.4674
60.	356.00	.3348
61.	354.00	.2334
62.	352.00	.6018
63.	350.00	.8052
64.	348.00	.8952
65.	346.00	.9594
66.	344.00	.9366
67.	342.00	.5010
68.	340.00	.1950
69.	338.00	-.1536
70.	336.00	.0354
71.	334.00	.1014
72.	332.00	-.1595
73.	330.00	-.0570
74.	328.00	.3786
75.	326.00	.2940
76.	324.00	.8190
77.	322.00	.0054
78.	320.00	.2592
79.	318.00	.9732
80.	316.00	.3606
81.	314.00	.3216
82.	312.00	.2334
83.	310.00	.2256
84.	308.00	.3288
85.	306.00	.4212
86.	304.00	.0066
87.	302.00	.0636
88.	300.00	.3396
89.	298.00	.1248
90.	296.00	.1746
91.	294.00	.2262
92.	292.00	.2502
93.	290.00	.5022
94.	288.00	.9030
95.	286.00	1.2216
96.	284.00	1.2240
97.	282.00	1.0128
98.	280.00	.9150
99.	278.00	.7494
100.	276.00	.4440
101.	274.00	.2742
102.	272.00	.5604
103.	270.00	.6114
104.	268.00	.7272
105.	266.00	.8802
106.	264.00	1.0488
107.	262.00	1.0908
108.	260.00	1.2510
109.	258.00	1.3530
110.	256.00	.7908
111.	254.00	.3534
112.	252.00	.3630
113.	250.00	.3618
114.	248.00	.2758

115.	246.00	.3000
116.	244.00	.2808
117.	242.00	.2088
118.	240.00	.2976
119.	238.00	.3642
120.	236.00	.3972
121.	234.00	.3948
122.	232.00	.8142
123.	230.00	1.1196
124.	228.00	1.0416
125.	226.00	1.0584
126.	224.00	1.0458
127.	222.00	.8580
128.	220.00	.5568
129.	218.00	.3846
130.	216.00	.3264
131.	214.00	.5754
132.	212.00	.5958
133.	210.00	.7026
134.	208.00	1.2162
135.	206.00	1.4106
136.	204.00	1.4670
137.	202.00	1.2306
138.	200.00	1.1742
139.	198.00	1.1526
140.	196.00	1.1484
141.	194.00	1.1892
142.	192.00	1.1358
143.	190.00	1.0446
144.	188.00	.4704
145.	186.00	-1.0692
146.	184.00	-1.0458
147.	182.00	-.6000
148.	180.00	-.3966
149.	178.00	-.3258
150.	176.00	-.1332
151.	174.00	.0360
152.	172.00	-.0864
153.	170.00	-.0684
154.	168.00	.0258
155.	166.00	.2340
156.	164.00	.1922
157.	162.00	-.0258
158.	160.00	-.0678
159.	158.00	-.1350
160.	156.00	-.1422
161.	154.00	-.2742
162.	152.00	-.1662
163.	150.00	.0366
164.	148.00	.2202
165.	146.00	.3306
166.	144.00	.4374
167.	142.00	.2742
168.	140.00	.1848
169.	138.00	.1290
170.	136.00	.0636
171.	134.00	.0414

172.	132.00	.2010
173.	130.00	.3036
174.	128.00	.4206
175.	126.00	.8082
176.	124.00	.7960
177.	122.00	.5820
178.	120.00	.6144
179.	118.00	.6330
180.	116.00	.5916
181.	114.00	.6306
182.	112.00	.6726
183.	110.00	.7242
184.	108.00	.7494
185.	106.00	.6690
186.	104.00	.6744
187.	102.00	.7056
188.	100.00	.7152
189.	98.00	.7362
190.	96.00	.7836
191.	94.00	.7650
192.	92.00	.7974
193.	90.00	.8760
194.	88.00	.8784
195.	86.00	.8472
196.	84.00	.8712
197.	82.00	1.0686
198.	80.00	1.1832
199.	78.00	1.1832
200.	76.00	1.2030
201.	74.00	1.2444
202.	72.00	1.2846
203.	70.00	1.3452
204.	68.00	1.6068
205.	66.00	2.1438
206.	64.00	2.6616
207.	62.00	3.0882
208.	60.00	3.5220
209.	58.00	3.9618
210.	56.00	4.4004
211.	54.00	4.7076
212.	52.00	4.8450
213.	50.00	4.8084
214.	48.00	4.5426
215.	46.00	4.1886
216.	44.00	4.5306
217.	42.00	4.5696
218.	40.00	4.6350
219.	38.00	4.6068
220.	36.00	4.6194
221.	34.00	4.6530
222.	32.00	4.6956
223.	30.00	4.7292
224.	28.00	4.8084
225.	26.00	4.8930
226.	24.00	4.9866
227.	22.00	4.9032
228.	20.00	4.7412

229.	18.00	4.4526
230.	16.00	4.2168
231.	14.00	3.8430
232.	12.00	3.6750
233.	10.00	3.6432
234.	8.00	3.5784
235.	6.00	3.3144
236.	4.00	3.4794
237.	2.00	3.6162

DATA FORCED TO AGREE AT DEPTH 186.00A-ADJUST = 1.0692B-ADJUST = .0000
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
10-20-80 10-20-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
186.00	-1.0692		
184.00	-1.0248		
182.00	-.5670		
180.00	-.3588		
178.00	-.2784		
176.00	-.0774		
174.00	.1104		
172.00	.0390		
170.00	.0960		
168.00	.2004		
166.00	.4074		
164.00	.3654		
162.00	.1428		
160.00	.0954		
158.00	.0186		
156.00	.0090		
154.00	-.1272		
152.00	-.0330		
150.00	.1548		
148.00	.3264		
146.00	.3966		
144.00	.5388		
142.00	.3954		
140.00	.3318		
138.00	.3012		
136.00	.2652		
134.00	.2544		
132.00	.4206		
130.00	.5220		
128.00	.6756		
126.00	1.0380		
124.00	1.0032		
122.00	.7866		
120.00	.8028		
118.00	.8092		
116.00	.7512		
114.00	.7728		
112.00	.8040		
110.00	.8514		
108.00	.8760		
106.00	.7998		
104.00	.8028		
102.00	.8226		
100.00	.8209		
98.00	.9328		

58.	96.00	.8730
59.	94.00	.8520
60.	92.00	.8778
61.	90.00	.9522
62.	88.00	.9432
63.	86.00	.9042
64.	84.00	.9066
65.	82.00	1.0782
66.	80.00	1.1676
67.	78.00	1.1508
68.	76.00	1.1538
69.	74.00	1.1832
70.	72.00	1.2108
71.	70.00	1.2618
72.	68.00	1.5222
73.	66.00	2.0670
74.	64.00	2.5938
75.	62.00	3.0210
76.	60.00	3.4452
77.	58.00	3.8754
78.	56.00	4.3152
79.	54.00	4.6266
80.	52.00	4.7718
81.	50.00	4.7220
82.	48.00	4.4544
83.	46.00	4.0932
84.	44.00	4.4208
85.	42.00	4.4418
86.	40.00	4.4964
87.	38.00	4.4646
88.	36.00	4.4718
89.	34.00	4.5066
90.	32.00	4.5462
91.	30.00	4.5666
92.	28.00	4.6272
93.	26.00	4.6944
94.	24.00	4.7772
95.	22.00	4.6914
96.	20.00	4.5324
97.	18.00	4.2486
98.	16.00	3.9882
99.	14.00	3.5766
100.	12.00	3.3732
101.	10.00	3.3126
102.	8.00	3.2304
103.	6.00	2.9700
104.	4.00	3.0924
105.	2.00	3.2238

DATA FORCED TO AGREE AT DEPTH 182.00A-ADJUST = .5694B-ADJUST = .0000

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
06-01-198106-01-1981

DEPTH	A-OFFSET	B-OFFSET	ZZ
182.00	-.5694		
180.00	-.3246		
178.00	-.2124		
176.00	.0186		
174.00	.2352		
172.00	.1674		
170.00	.2880		
168.00	.4308		
166.00	.6858		
164.00	.6792		
162.00	.4872		
160.00	.4686		
158.00	.4224		
156.00	.4326		
154.00	.3084		
152.00	.4152		
150.00	.6282		
148.00	.8382		
146.00	.9600		
144.00	1.1418		
142.00	1.0332		
140.00	1.0026		
138.00	1.0020		
136.00	.9804		
134.00	.9954		
132.00	1.1862		
130.00	1.3146		
128.00	1.4580		
126.00	1.8930		
124.00	1.8990		
122.00	1.7172		
120.00	1.7688		
118.00	1.8042		
116.00	1.7736		
114.00	1.8258		
112.00	1.8900		
110.00	1.9716		
108.00	2.0334		
106.00	1.9824		
104.00	2.0109		
102.00	2.0574		
100.00	2.0862		
98.00	2.1234		
96.00	2.1912		
94.00	2.1960		

58.	92.00	2.2488
59.	90.00	2.3430
60.	88.00	2.3586
61.	86.00	2.3394
62.	84.00	2.3718
63.	82.00	2.5776
64.	80.00	2.6982
65.	78.00	2.7272
66.	76.00	2.7426
67.	74.00	2.8062
68.	72.00	2.8710
69.	70.00	2.9622
70.	68.00	3.2640
71.	66.00	3.8454
72.	64.00	4.4064
73.	62.00	4.8648
74.	60.00	5.3220
75.	58.00	5.7834
76.	56.00	6.2460
77.	54.00	6.5808
78.	52.00	6.7458
79.	50.00	6.7188
80.	48.00	6.4818
81.	46.00	6.1536
82.	44.00	6.5202
83.	42.00	6.5814
84.	40.00	6.6714
85.	38.00	6.6648
86.	36.00	6.7020
87.	34.00	6.7620
88.	32.00	6.8268
89.	30.00	6.8856
90.	28.00	7.0308
91.	26.00	7.2216
92.	24.00	7.3926
93.	22.00	7.2528
94.	20.00	6.7386
95.	18.00	5.6952
96.	16.00	4.4862
97.	14.00	3.2802
98.	12.00	2.7024
99.	10.00	2.5632
100.	8.00	2.5206
101.	6.00	2.2944
102.	4.00	2.4552
103.	2.00	2.5416

DATA FORCED TO AGREE AT DEPTH 450.00A-ADJUST = .0000B-ADJUST = .0000

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-05-80 05-05-80
06-24-80 06-24-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
450.00	.0000	.0000	0.
448.00	.1752	-.2502	0.
446.00	.2700	-.4128	0.
444.00	.5466	-.2070	0.
442.00	.4662	.0936	0.
440.00	.5676	.2778	0.
438.00	.5184	.3306	0.
436.00	.3456	.2706	0.
434.00	.0420	.3048	0.
432.00	-.1248	.1236	0.
430.00	-.0894	-.0264	0.
428.00	-.1236	-.2652	0.
426.00	-.1650	-.3672	0.
424.00	.1434	-.6522	0.
422.00	.4206	-.8052	0.
420.00	.5742	-.7374	0.
418.00	.8184	-.5388	0.
416.00	1.0218	-.3000	0.
414.00	1.0602	.0528	0.
412.00	.5616	.0420	0.
410.00	.4956	.1470	0.
408.00	.1218	.1866	0.
406.00	.0810	-.1230	0.
404.00	.2742	-.2112	0.
402.00	.0756	-.4794	0.
400.00	.0408	-.6510	0.
398.00	.3960	-.7404	0.
396.00	.6516	-.8862	0.
394.00	.7176	-.8814	0.
392.00	.9930	-.7704	0.
390.00	1.1178	-.7034	0.
388.00	1.1244	-.5070	0.
386.00	.8976	-.0588	0.
384.00	.4944	.4332	0.
382.00	.3336	.2910	0.
380.00	.3672	.3336	0.
378.00	.2676	.1104	0.
376.00	.0780	-.0492	0.
374.00	-.1500	-.2718	0.
372.00	.1812	-.4494	0.
370.00	.0120	-.1416	0.
368.00	.0294	-.8538	0.
366.00	1.0818	-.9744	0.
364.00	.6414	-.7008	0.
362.00	.6660	-.2922	0.

58.	360.00	.8058	-.1656	0.
59.	358.00	.6360	.0126	0.
60.	356.00	.5046	.1194	0.
61.	354.00	.3924	.1926	0.
62.	352.00	.7308	-.1092	0.
63.	350.00	.8898	-.3612	0.
64.	348.00	.9582	-.7014	0.
65.	346.00	.9960	-.9786	0.
66.	344.00	.9048	-.9972	0.
67.	342.00	.5199	-.9438	0.
68.	340.00	.2082	-.7254	0.
69.	338.00	-.0762	-.6378	0.
70.	336.00	.1764	-.3390	0.
71.	334.00	.2310	.0258	0.
72.	332.00	-.0252	-.0144	0.
73.	330.00	.0996	.2382	0.
74.	328.00	.5100	-.0048	0.
75.	326.00	.4032	.0708	0.
76.	324.00	.8862	-.1086	0.
77.	322.00	.0702	.5862	0.
78.	320.00	.3210	.1794	0.
79.	318.00	.9672	.0114	0.
80.	316.00	.3546	-.0252	0.
81.	314.00	.2976	.2682	0.
82.	312.00	.2160	.2202	0.
83.	310.00	.1782	.0798	0.
84.	308.00	.2586	-.2310	0.
85.	306.00	.3342	-.4200	0.
86.	304.00	-.0822	-.8172	1.
87.	302.00	-.0522	-.4296	0.
88.	300.00	.2124	-.0306	0.
89.	298.00	.0366	.2622	0.
90.	296.00	.0960	.4440	0.
91.	294.00	.1284	.4476	0.
92.	292.00	.1530	.2214	0.
93.	290.00	.3948	-.0186	0.
94.	288.00	.7836	-.0384	0.
95.	286.00	1.0368	-.2370	0.
96.	284.00	.9828	-.2844	0.
97.	282.00	.7656	-.4158	0.
98.	280.00	.6390	-.6456	0.
99.	278.00	.4578	-.7758	0.
100.	276.00	.1620	-.8292	0.
101.	274.00	-.0246	-.6360	0.
102.	272.00	.2358	-.2982	0.
103.	270.00	.3570	-.1992	0.
104.	268.00	.4584	.0816	0.
105.	266.00	.6096	.1392	0.
106.	264.00	.7596	-.1056	0.
107.	262.00	.6702	-.2148	0.
108.	260.00	.8814	-.4266	0.
109.	258.00	.9198	-.8102	0.
110.	256.00	.2760	-.7692	0.
111.	254.00	.1386	-.3576	1.
112.	252.00	.3102	-.5046	0.
113.	250.00	.1464	-.4062	0.
114.	248.00	.0870	-.3114	0.

115.	246.00	.1380	-.2946	0.
116.	244.00	.1002	-.2808	0.
117.	242.00	.0072	-.0546	0.
118.	240.00	.1164	.0864	0.
119.	238.00	.1752	.0924	0.
120.	236.00	.1914	.0234	0.
121.	234.00	.1524	-.0006	0.
122.	232.00	.5274	-.4374	0.
123.	230.00	.8028	-.8358	0.
124.	228.00	.7110	-.6114	0.
125.	226.00	.6954	-.4812	0.
126.	224.00	.6624	-.5765	0.
127.	222.00	.4818	-.7176	0.
128.	220.00	.1854	-.7248	0.
129.	218.00	.0522	-.5766	0.
130.	216.00	.0138	-.3774	0.
131.	214.00	.2809	-.3096	0.
132.	212.00	.2886	-.1128	0.
133.	210.00	.4056	-.1272	0.
134.	208.00	.8778	-.4842	0.
135.	206.00	1.0416	-.5784	0.
136.	204.00	1.0692	-.6504	0.
137.	202.00	.7956	-.7308	0.
138.	200.00	.7182	-.8076	0.
139.	198.00	.6774	-.8622	0.
140.	196.00	.6660	-.9294	0.
141.	194.00	.7242	-.9612	0.
142.	192.00	.6804	-.8502	0.
143.	190.00	.6678	-.8322	0.
144.	188.00	.3348	-.4116	0.
145.	186.00	-.8904	.4682	1.
146.	184.00	-.6762	.6126	0.
147.	182.00	-.3498	.5688	0.
148.	180.00	-.2646	.4704	0.
149.	178.00	-.2616	.3564	0.
150.	176.00	-.1020	.4122	0.
151.	174.00	.0342	.2724	0.
152.	172.00	-.1152	-.0930	0.
153.	170.00	-.1248	-.2706	0.
154.	168.00	-.0810	-.3960	0.
155.	166.00	.1062	-.3408	0.
156.	164.00	.0444	-.3234	0.
157.	162.00	-.1758	-.3349	0.
158.	160.00	-.2244	-.3288	0.
159.	158.00	-.2838	-.2658	0.
160.	156.00	-.2706	-.1752	0.
161.	154.00	-.3990	-.0006	0.
162.	152.00	-.3180	.1158	0.
163.	150.00	-.1266	.0510	0.
164.	148.00	.0438	-.0378	0.
165.	146.00	.1098	.0132	0.
165.	144.00	.2202	.0648	0.
167.	142.00	.0336	.0030	0.
168.	140.00	-.0810	-.0822	0.
169.	138.00	-.1530	-.2118	0.
170.	136.00	-.2430	-.4716	0.
171.	134.00	-.2994	-.7565	0.

172.	132.00	-.1356	-.7326	0.
173.	130.00	-.0414	-.7176	0.
174.	128.00	.0630	-.6558	0.
175.	126.00	.4308	-.6504	0.
176.	124.00	.3750	-.7152	0.
177.	122.00	.1668	-.6432	0.
178.	120.00	.1836	-.6042	0.
179.	118.00	.1836	-.5814	0.
180.	116.00	.1998	-.5172	0.
181.	114.00	.2004	-.5670	0.
182.	112.00	.2358	-.6462	0.
183.	110.00	.2712	-.6918	0.
184.	108.00	.2832	-.7212	0.
185.	106.00	.1854	-.7104	0.
186.	104.00	.1818	-.7566	0.
187.	102.00	.1950	-.7704	0.
188.	100.00	.2040	-.7830	0.
189.	98.00	.2184	-.6474	0.
190.	96.00	.2682	-.7416	0.
191.	94.00	.2448	-.7752	0.
192.	92.00	.2628	-.8748	0.
193.	90.00	.3300	-.9672	0.
194.	88.00	.3258	-1.0320	0.
195.	86.00	.2934	-1.0236	0.
196.	84.00	.3102	-1.0692	0.
197.	82.00	.4908	-1.1700	0.
198.	80.00	.5940	-1.0722	0.
199.	78.00	.5754	-1.0500	0.
200.	76.00	.5790	-.8882	0.
201.	74.00	.6108	-.8310	0.
202.	72.00	.6360	-1.0110	0.
203.	70.00	.6852	-1.1190	0.
204.	68.00	.6798	-1.1718	0.
205.	66.00	.6222	-1.1640	0.
206.	64.00	.5496	-1.3652	0.
207.	62.00	.5742	-1.4346	0.
208.	60.00	.5880	-1.4466	0.
209.	58.00	.6312	-1.3860	0.
210.	56.00	.6084	-1.3146	0.
211.	54.00	.5898	-1.2798	0.
212.	52.00	.5928	-1.3920	0.
213.	50.00	.5922	-1.4310	0.
214.	48.00	.6450	-1.4880	0.
215.	46.00	.6780	-1.4718	0.
216.	44.00	.7446	-1.4658	0.
217.	42.00	.7638	-1.5642	0.
218.	40.00	.8118	-1.5990	0.
219.	38.00	.7734	-1.6398	0.
220.	36.00	.7806	-1.6962	0.
221.	34.00	.8082	-1.6710	0.
222.	32.00	.8370	-1.6338	0.
223.	30.00	.8586	-1.5930	0.
224.	28.00	.9276	-1.6650	0.
225.	26.00	1.0002	-1.5720	0.
226.	24.00	1.0836	-1.6650	0.
227.	22.00	1.0806	-1.7040	0.
228.	20.00	.8874	-1.7298	0.

229.	18.00	.6318	-1.7304	0.
230.	16.00	.4506	-2.0118	0.
231.	14.00	.1590	-1.9008	0.
232.	12.00	-.0294	-1.7442	0.
233.	10.00	-.0588	-1.9920	0.
234.	8.00	-.1224	-2.1078	0.
235.	6.00	-.3239	-1.8036	0.
236.	4.00	-.1626	-1.8159	0.
237.	2.00	-.1008	-1.8936	0.

DATA FORCED TO AGREE AT DEPTH 186.00A-ADJUST = .8904B-ADJUST = -.4680
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-05-80 05-05-80
10-20-80 10-20-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
186.00	-.8904	.4680	0.
184.00	-.6552	.6486	0.
182.00	-.3168	.6174	0.
180.00	-.2268	.5016	0.
178.00	-.2142	.3672	0.
176.00	-.0462	.4092	0.
174.00	.1086	.2628	0.
172.00	-.0198	-.1446	0.
170.00	.0396	-.3114	0.
168.00	.0936	-.4506	0.
166.00	.2796	-.4140	0.
164.00	.2179	-.4086	0.
162.00	-.0072	-.4404	0.
160.00	-.0612	-.4374	0.
158.00	-.1302	-.3864	0.
156.00	-.1194	-.3072	0.
154.00	-.2520	-.1554	0.
152.00	-.1848	-.0462	0.
150.00	-.0084	-.1170	0.
148.00	.1500	-.2130	0.
146.00	.2058	-.1668	0.
144.00	.3216	-.1392	0.
142.00	.1548	-.2322	0.
140.00	.0660	-.3408	0.
138.00	.0192	-.4872	0.
136.00	-.0414	-.7362	0.
134.00	-.0864	-1.0092	0.
132.00	.0840	-.9654	0.
130.00	.1770	-.9378	0.
128.00	.3180	-.8682	1.
126.00	.6606	-.8574	0.
124.00	.5922	-.9234	0.
122.00	.3714	-.8586	0.
120.00	.3720	-.8310	0.
118.00	.3588	-.8274	0.
116.00	.3594	-.7902	0.
114.00	.3426	-.8574	0.
112.00	.3672	-.9570	0.
110.00	.3984	-1.0212	0.
108.00	.4098	-1.0674	0.
106.00	.3162	-1.0758	0.
104.00	.3102	-1.1310	0.
102.00	.3120	-1.1790	0.
100.00	.3096	-1.2024	0.
98.00	.3150	-1.2948	0.

58.	96.00	.3576	-1.1886	0.
59.	94.00	.3318	-1.2354	0.
60.	92.00	.3432	-1.3422	0.
61.	90.00	.4062	-1.4400	0.
62.	88.00	.3906	-1.5084	0.
63.	86.00	.3504	-1.5024	0.
64.	84.00	.3456	-1.5432	0.
65.	82.00	.5904	-1.6434	0.
66.	80.00	.5784	-1.5558	0.
67.	78.00	.5430	-1.5516	0.
68.	76.00	.5298	-1.4160	0.
69.	74.00	.5496	-1.3854	0.
70.	72.00	.5622	-1.5954	0.
71.	70.00	.6018	-1.7118	0.
72.	68.00	.5952	-1.7868	0.
73.	66.00	.5454	-1.7964	0.
74.	64.00	.4818	-1.9992	0.
75.	62.00	.5070	-2.0808	0.
76.	60.00	.5112	-2.0952	0.
77.	58.00	.5448	-2.0466	0.
78.	56.00	.5232	-1.9800	0.
79.	54.00	.5089	-1.9698	0.
80.	52.00	.5196	-2.1048	0.
81.	50.00	.5058	-2.1720	0.
82.	48.00	.5568	-2.2482	0.
83.	46.00	.5826	-2.2440	0.
84.	44.00	.6348	-2.2398	0.
85.	42.00	.6360	-2.3570	0.
86.	40.00	.6732	-2.3688	0.
87.	38.00	.6312	-2.4084	0.
88.	36.00	.6330	-2.4630	0.
89.	34.00	.6618	-2.4390	0.
90.	32.00	.6876	-2.4192	0.
91.	30.00	.6960	-2.4030	0.
92.	28.00	.7464	-2.4972	0.
93.	26.00	.8016	-2.4252	0.
94.	24.00	.8742	-2.5296	0.
95.	22.00	.8688	-2.5926	0.
96.	20.00	.6786	-2.6172	0.
97.	18.00	.4278	-2.6142	0.
98.	16.00	.2220	-2.9106	0.
99.	14.00	-.1164	-2.8212	0.
100.	12.00	-.3312	-2.6772	0.
101.	10.00	-.3894	-2.9376	0.
102.	8.00	-.4704	-3.0540	0.
103.	6.00	-.6474	-2.7906	0.
104.	4.00	-.5496	-2.8458	0.
105.	2.00	-.4932	-3.0168	0.

DATA FORCED TO AGREE AT DEPTH 182.00A-ADJUST = -.2214B-ADJUST = -.6948
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-1

NOTE ADFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-05-80 05-05-80
06-01-198106-01-1981

DEPTH	A-OFFSET	B-OFFSET	ZZ
182.00	.2214	.6948	0.
180.00	.3480	.5886	0.
178.00	.3924	.4824	0.
176.00	.5904	.5502	0.
174.00	.7740	.4032	0.
172.00	.6792	-.0084	0.
170.00	.7722	-.1770	0.
168.00	.8646	-.3348	0.
166.00	1.0986	-.3018	0.
164.00	1.0722	-.3042	0.
162.00	.8778	-.3420	0.
160.00	.8526	-.3516	0.
158.00	.8142	-.3054	0.
156.00	.8448	-.2244	0.
154.00	.7242	-.0624	0.
152.00	.8040	.0624	0.
150.00	1.0056	.0144	0.
148.00	1.2024	-.0630	0.
146.00	1.3098	-.0936	0.
144.00	1.4652	.0366	0.
142.00	1.3332	-.0288	0.
140.00	1.2774	-.1068	0.
138.00	1.2606	-.2334	0.
136.00	1.2144	-.4902	0.
134.00	1.1952	-.7770	0.
132.00	1.3902	-.7338	0.
130.00	1.5102	-.7188	0.
128.00	1.6410	-.6462	0.
126.00	2.0562	-.6384	0.
124.00	2.0286	-.7050	0.
122.00	1.8426	-.6360	0.
120.00	1.8786	-.5994	0.
118.00	1.8954	-.5862	0.
116.00	1.9224	-.5286	0.
114.00	1.9362	-.5886	0.
112.00	1.9938	-.6810	0.
110.00	2.0592	-.7386	0.
108.00	2.1078	-.7794	0.
106.00	2.0394	-.7746	0.
104.00	2.0580	-.8244	0.
102.00	2.0874	-.8520	0.
100.00	2.1156	-.8736	0.
98.00	2.1462	-.7488	0.
96.00	2.2164	-.8388	0.
94.00	2.2164	-.8732	0.

58.	92.00	2.2548	-.9744	0.
59.	90.00	2.3376	-1.0698	0.
60.	88.00	2.3466	-1.1280	0.
61.	86.00	2.3262	-1.1118	0.
62.	84.00	2.3514	-1.1484	0.
63.	82.00	2.5404	-1.2522	0.
64.	80.00	2.6496	-1.1592	0.
65.	78.00	2.6400	-1.1394	0.
66.	76.00	2.6592	-.9684	0.
67.	74.00	2.7132	-.9120	0.
68.	72.00	2.7630	-1.0992	0.
69.	70.00	2.8428	-1.1988	0.
70.	68.00	2.8776	-1.2540	0.
71.	66.00	2.8644	-1.2516	0.
72.	64.00	2.8350	-1.4580	0.
73.	62.00	2.8914	-1.5426	0.
74.	60.00	2.9286	-1.5594	0.
75.	58.00	2.9934	-1.4988	0.
76.	56.00	2.9946	-1.4268	0.
77.	54.00	3.0036	-1.3956	0.
78.	52.00	3.0342	-1.5078	0.
79.	50.00	3.0432	-1.5522	0.
80.	48.00	3.1248	-1.6074	0.
81.	46.00	3.1836	-1.5846	0.
82.	44.00	3.2748	-1.5744	0.
83.	42.00	3.3162	-1.6722	0.
84.	40.00	3.3888	-1.7154	0.
85.	38.00	3.3720	-1.7640	0.
86.	36.00	3.4038	-1.8264	0.
87.	34.00	3.4578	-1.7964	0.
88.	32.00	3.5088	-1.7520	0.
89.	30.00	3.5556	-1.6884	0.
90.	28.00	3.6906	-1.7274	0.
91.	26.00	3.8694	-1.6194	0.
92.	24.00	4.0302	-1.7268	0.
93.	22.00	3.9708	-1.8084	0.
94.	20.00	3.4254	-1.8756	0.
95.	18.00	2.4150	-1.9284	0.
96.	16.00	1.2606	-2.2638	0.
97.	14.00	.1278	-2.1930	0.
98.	12.00	-.4614	-2.0664	0.
99.	10.00	-.5982	-2.3202	0.
100.	8.00	-.6396	-2.4312	0.
101.	6.00	-.7824	-2.1678	0.
102.	4.00	-.6462	-2.2776	0.
103.	2.00	-.6348	-2.5309	0.

DATA FORCED TO AGREE AT DEPTH .00A-ADJUST = .0000B-ADJUST = .0000
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
05-06-80 05-06-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
268.00	.0000		
266.00	.0012		
264.00	.0102		
262.00	.0258		
260.00	.0180		
258.00	.0126		
256.00	.0180		
254.00	.0210		
252.00	.0258		
250.00	.0318		
248.00	.0222		
246.00	.0276		
244.00	.0222		
242.00	.0186		
240.00	.0174		
238.00	.0222		
236.00	.0330		
234.00	.0534		
232.00	.0732		
230.00	.0930		
228.00	.1026		
226.00	.1122		
224.00	.1008		
222.00	.0024		
220.00	-.1158		
218.00	-.1248		
216.00	-.1344		
214.00	-.1446		
212.00	-.1410		
210.00	-.1332		
208.00	-.1500		
206.00	-.1416		
204.00	-.1128		
202.00	-.0876		
200.00	-.0624		
198.00	-.0738		
196.00	-.0966		
194.00	-.1266		
192.00	-.1434		
190.00	-.1452		
188.00	-.1464		
186.00	-.1428		
184.00	-.1392		
182.00	-.1470		
180.00	-.1374		

58.	178.00	-.0810
59.	176.00	-.0570
60.	174.00	-.0390
61.	172.00	-.0144
62.	170.00	.0078
63.	168.00	.0234
64.	166.00	.0198
65.	164.00	-.0018
66.	162.00	-.0192
67.	160.00	-.0390
68.	158.00	-.0510
69.	156.00	-.0510
70.	154.00	-.0462
71.	152.00	-.0342
72.	150.00	-.0234
73.	148.00	-.0012
74.	146.00	.0210
75.	144.00	.0402
76.	142.00	.0606
77.	140.00	.1020
78.	138.00	.1374
79.	136.00	.1704
80.	134.00	.1842
81.	132.00	.1980
82.	130.00	.1962
83.	128.00	.2196
84.	126.00	.2046
85.	124.00	.1950
86.	122.00	.1902
87.	120.00	.1980
88.	118.00	.1992
89.	116.00	.2058
90.	114.00	.2214
91.	112.00	.2400
92.	110.00	.2568
93.	108.00	.2670
94.	106.00	.2688
95.	104.00	.2898
96.	102.00	.3108
97.	100.00	.3108
98.	98.00	.3198
99.	96.00	.3360
100.	94.00	.3444
101.	92.00	.3462
102.	90.00	.3624
103.	88.00	.3804
104.	86.00	.3948
105.	84.00	.3978
106.	82.00	.3882
107.	80.00	.3996
108.	78.00	.4290
109.	76.00	.4584
110.	74.00	.4776
111.	72.00	.4926
112.	70.00	.4968
113.	68.00	.5034
114.	66.00	.5076

115.	64.00	.5112
116.	62.00	.5172
117.	60.00	.5214
118.	58.00	.5268
119.	56.00	.5352
120.	54.00	.5436
121.	52.00	.5484
122.	50.00	.5538
123.	48.00	.5598
124.	46.00	.5682
125.	44.00	.5646
126.	42.00	.5778
127.	40.00	.6282
128.	38.00	.6912
129.	36.00	.7470
130.	34.00	.7662
131.	32.00	.5586
132.	30.00	-.0336
133.	28.00	-.0756
134.	26.00	.0138
135.	24.00	.0594
136.	22.00	.0744
137.	20.00	.0666
138.	18.00	.0504
139.	16.00	.0306
140.	14.00	.0162
141.	12.00	.0018
142.	10.00	.0096
143.	8.00	.0324
144.	6.00	.0492
145.	4.00	.0456
146.	2.00	.0168

DATA FORCED TO AGREE AT DEPTH .00A-ADJUST = .0000B-ADJUST = .0000

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
06-24-80 06-24-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
268.00	.0000		
266.00	.0036		
264.00	.0162		
262.00	.0390		
260.00	.0462		
258.00	.0492		
256.00	.0582		
254.00	.0666		
252.00	.0732		
250.00	.0816		
248.00	.0690		
246.00	.0738		
244.00	.0762		
242.00	.0834		
240.00	.0948		
238.00	.1092		
236.00	.1284		
234.00	.1548		
232.00	.1812		
230.00	.2064		
228.00	.2214		
226.00	.2466		
224.00	.2652		
222.00	.0570		
220.00	-.2592		
218.00	-.2190		
216.00	-.2028		
214.00	-.2028		
212.00	-.1878		
210.00	-.0786		
208.00	-.1764		
206.00	-.6348		
204.00	-.5568		
202.00	-.5274		
200.00	-.5142		
198.00	-.5136		
196.00	-.5118		
194.00	-.5184		
192.00	-.5226		
190.00	-.5088		
188.00	-.4998		
186.00	-.4854		
184.00	-.4710		
182.00	-.4470		
180.00	-.4150		

58.	178.00	-.3834
59.	176.00	-.3498
60.	174.00	-.3276
61.	172.00	-.2994
62.	170.00	-.2766
63.	168.00	-.2590
64.	166.00	-.2460
65.	164.00	-.2460
66.	162.00	-.2526
67.	160.00	-.2538
68.	158.00	-.2520
69.	156.00	-.2406
70.	154.00	-.2232
71.	152.00	-.2076
72.	150.00	-.1908
73.	148.00	-.1626
74.	146.00	-.1344
75.	144.00	-.1080
76.	142.00	-.0834
77.	140.00	-.0456
78.	138.00	-.0066
79.	136.00	.0312
80.	134.00	.0522
81.	132.00	.0702
82.	130.00	.0954
83.	128.00	.1044
84.	126.00	.1182
85.	124.00	.1464
86.	122.00	.1830
87.	120.00	.2178
88.	118.00	.2388
89.	116.00	.2538
90.	114.00	.2772
91.	112.00	.2850
92.	110.00	.2832
93.	108.00	.2640
94.	106.00	.2178
95.	104.00	.1986
96.	102.00	.1794
97.	100.00	.1656
98.	98.00	.1770
99.	96.00	.2046
100.	94.00	.2232
101.	92.00	.2298
102.	90.00	.2514
103.	88.00	.2742
104.	86.00	.2982
105.	84.00	.3126
106.	82.00	.3150
107.	80.00	.3234
108.	78.00	.3438
109.	76.00	.3780
110.	74.00	.4062
111.	72.00	.4410
112.	70.00	.4686
113.	68.00	.4914
114.	66.00	.5[illegible]4

115.	64.00	.4998
116.	62.00	.5246
117.	60.00	.5208
118.	58.00	.5394
119.	56.00	.5556
120.	54.00	.5676
121.	52.00	.5902
122.	50.00	.5958
123.	48.00	.6126
124.	46.00	.6252
125.	44.00	.6306
126.	42.00	.6450
127.	40.00	.6822
128.	38.00	.7386
129.	36.00	.8076
130.	34.00	.8724
131.	32.00	.6696
132.	30.00	-.9378
133.	28.00	-.8922
134.	26.00	-.7800
135.	24.00	-.7284
136.	22.00	-.7128
137.	20.00	-.7164
138.	18.00	-.7320
139.	16.00	-.7494
140.	14.00	-.7698
141.	12.00	-.7752
142.	10.00	-.7584
143.	8.00	-.7236
144.	6.00	-.6948
145.	4.00	-.6942
146.	2.00	-.7188

DATA FORCED TO AGREE AT DEPTH .00A-ADJUST = -.0998B-ADJUST = .0000
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
08-22-80 08-22-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
266.42	.0008		
264.42	.0020		
262.42	.0219		
260.42	.0621		
258.42	.0150		
256.42	.0065		
254.42	.0153		
252.42	.0216		
250.42	.0232		
248.42	.0386		
246.42	.0594		
244.42	.0985		
242.42	.1069		
240.42	.1213		
238.42	.1266		
236.42	.1491		
234.42	.1687		
232.42	.2120		
230.42	.2418		
228.42	.2865		
226.42	.3271		
224.42	.3562		
222.42	.2300		
220.42	-.2628		
218.42	-.2945		
216.42	-.2886		
214.42	-.3099		
212.42	-.3239		
210.42	-.2668		
208.42	-.2855		
206.42	-.9841		
204.42	-.8589		
202.42	-.7908		
200.42	-.8545		
198.42	-.6746		
196.42	-.6562		
194.42	-.6861		
192.42	-.7379		
190.42	-.7308		
188.42	-.7247		
186.42	-.7314		
184.42	-.7125		
182.42	-.7146		
180.42	-.6758		
178.42	-.6235		

58.	176.42	-.5569
59.	174.42	-.5254
60.	172.42	-.4980
61.	170.42	-.4628
62.	168.42	-.4139
63.	166.42	-.3677
64.	164.42	-.3660
65.	162.42	-.4057
66.	160.42	-.4342
67.	158.42	-.4477
68.	156.42	-.4551
69.	154.42	-.4306
70.	152.42	-.4353
71.	150.42	-.4060
72.	148.42	-.3901
73.	146.42	-.3550
74.	144.42	-.2946
75.	142.42	-.2611
76.	140.42	-.2502
77.	138.42	-.1746
78.	136.42	-.0972
79.	134.42	-.0537
80.	132.42	-.0310
81.	130.42	.0205
82.	128.42	.0480
83.	126.42	.0016
84.	124.42	-.0203
85.	122.42	-.0414
86.	120.42	-.0303
87.	118.42	-.0059
88.	116.42	-.0136
89.	114.42	.0049
90.	112.42	.0400
91.	110.42	.0690
92.	108.42	.1128
93.	106.42	.1261
94.	104.42	.1321
95.	102.42	.1679
96.	100.42	.2024
97.	98.42	.1766
98.	96.42	.2305
99.	94.42	.2360
100.	92.42	.2474
101.	90.42	.2364
102.	88.42	.2751
103.	86.42	.3135
104.	84.42	.3408
105.	82.42	.3388
106.	80.42	.3377
107.	78.42	.3586
108.	76.42	.3982
109.	74.42	.4335
110.	72.42	.4718
111.	70.42	.5116
112.	68.42	.5216
113.	66.42	.5341
114.	64.42	.5376

115.	62.42	.5453
116.	60.42	.5642
117.	58.42	.5762
118.	56.42	.5849
119.	54.42	.5933
120.	52.42	.6012
121.	50.42	.6154
122.	48.42	.6414
123.	46.42	.6590
124.	44.42	.6681
125.	42.42	.6575
126.	40.42	.6769
127.	38.42	.7437
128.	36.42	.8183
129.	34.42	.8986
130.	32.42	.8509
131.	30.42	-1.0773
132.	28.42	-1.1623
133.	26.42	-1.0194
134.	24.42	-.9345
135.	22.42	-.8968
136.	20.42	-.8811
137.	18.42	-.8894
138.	16.42	-.8984
139.	14.42	-.9033
140.	12.42	-.9058
141.	10.42	-.9106
142.	8.42	-.9132
143.	6.42	-.9336
144.	4.42	-.9854

DATA FORCED TO AGREE AT DEPTH .00A-ADJUST = -.0008B-ADJUST = .0000

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 6 INDICATES POSSIBLE DATA ERROR

03-17-80 03-17-80
10-20-80 10-20-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
266.42	.0008		
264.42	-.0058		
262.42	.0069		
260.42	.0291		
258.42	-.0240		
256.42	-.0349		
254.42	-.0273		
252.42	-.0186		
250.42	-.0128		
248.42	.0074		
246.42	.0452		
244.42	.0805		
242.42	.0865		
240.42	.0991		
238.42	.1050		
236.42	.1275		
234.42	.1447		
232.42	.1880		
230.42	.2178		
228.42	.1077		
226.42	.1495		
224.42	.1818		
222.42	.0512		
220.42	-.5286		
218.42	-.5567		
216.42	-.5514		
214.42	-.5727		
212.42	-.5855		
210.42	-.5290		
208.42	-.5349		
206.42	-1.0639		
204.42	-.9321		
202.42	-.8674		
200.42	-.9067		
198.42	-.7316		
196.42	-.7304		
194.42	-.7617		
192.42	-.8243		
190.42	-.8166		
188.42	-.8153		
186.42	-.8229		
184.42	-.8055		
182.42	-.8100		
180.42	-.7520		
178.42	-.6997		

58.	176.42	-.6325
59.	174.42	-.5986
60.	172.42	-.5646
61.	170.42	-.5222
62.	168.42	-.4865
63.	166.42	-.4505
64.	164.42	-.4590
65.	162.42	-.5089
66.	160.42	-.5296
67.	158.42	-.5467
68.	156.42	-.5523
69.	154.42	-.5260
70.	152.42	-.5343
71.	150.42	-.5116
72.	148.42	-.4945
73.	146.42	-.4534
74.	144.42	-.3972
75.	142.42	-.3703
76.	140.42	-.3486
77.	138.42	-.2664
78.	136.42	-.1836
79.	134.42	-.1401
80.	132.42	-.1180
81.	130.42	-.0695
82.	128.42	-.0510
83.	126.42	-.1070
84.	124.42	-.1247
85.	122.42	-.1482
86.	120.42	-.1329
87.	118.42	-.1085
88.	116.42	-.1204
89.	114.42	-.0965
90.	112.42	-.0626
91.	110.42	-.0365
92.	108.42	.0018
93.	106.42	.0097
94.	104.42	.0121
95.	102.42	.0407
96.	100.42	.0692
97.	98.42	.0410
98.	96.42	.0655
99.	94.42	.1010
100.	92.42	.1106
101.	90.42	.1008
102.	88.42	.1413
103.	86.42	.1821
104.	84.42	.2058
105.	82.42	.1957
106.	80.42	.1781
107.	78.42	.1936
108.	76.42	.2338
109.	74.42	.2757
110.	72.42	.3248
111.	70.42	.3688
112.	68.42	.3752
113.	66.42	.3787
114.	64.42	.3744

115.	62.42	.3797
116.	60.42	.3983
117.	58.42	.4082
118.	56.42	.4175
119.	54.42	.4283
120.	52.42	.4326
121.	50.42	.4499
122.	48.42	.4770
123.	46.42	.4936
124.	44.42	.4989
125.	42.42	.4811
126.	40.42	.4969
127.	38.42	.5649
128.	36.42	.6437
129.	34.42	.7324
130.	32.42	.6889
131.	30.42	.3555
132.	28.42	.2897
133.	26.42	.4254
134.	24.42	.5103
135.	22.42	.5462
136.	20.42	.5589
137.	18.42	.5488
138.	16.42	.5434
139.	14.42	.5433
140.	12.42	.5462
141.	10.42	.5444
142.	8.42	.5370
143.	6.42	.5154
144.	4.42	.4576

COMPARISON OF TWO INCLINOMETER READINGS--HOLE I-2
DATA FORCED TO AGREE AT 26.42 FT

5-06-80
5-31-1981

Depth	B-Axis Offset ZZ
26.42	-1.5642
24.42	-1.55
22.42	-1.55
20.42	-1.55
18.42	-1.44
16.42	-1.36
14.42	-1.34
12.42	-1.29
10.42	-1.24
8.42	-1.14
6.42	-.96
4.42	-.65

062BGE * 11

DATE [illegible]1681 PAGE 1

DATA FORCED TO AGREE AT DEPTH .00A-ADJUST = .[illegible]B-ADJUST = .[illegible]

COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-06-80 05-06-80
06-24-80 06-24-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
272.00	.0000	.0000	1.
270.00	.0000	-.0198	0.
268.00	-.0114	-.0180	0.
266.00	-.0096	-.0180	0.
264.00	-.0054	-.0138	0.
262.00	.0018	-.0234	0.
260.00	.0168	-.0252	0.
258.00	.0252	-.0240	0.
256.00	.0288	-.0216	0.
254.00	.0342	-.0192	0.
252.00	.0360	-.0216	0.
250.00	.0384	-.0234	0.
248.00	.0354	-.0300	0.
246.00	.0348	-.0438	0.
244.00	.0426	-.0564	0.
242.00	.0534	-.0732	0.
240.00	.0560	-.0846	0.
238.00	.0756	-.0978	0.
236.00	.0840	-.1152	0.
234.00	.0960	-.1242	0.
232.00	.0966	-.1266	0.
230.00	.1020	-.1206	0.
228.00	.1074	-.1146	0.
226.00	.1230	-.1158	0.
224.00	.1530	-.1362	0.
222.00	.0432	-.0768	0.
220.00	-.1548	.0864	0.
218.00	-.1056	.0648	0.
216.00	-.0798	.0330	0.
214.00	-.0696	.0162	0.
212.00	-.0582	.0192	1.
[illegible]	.0432	-.0096	0.
[illegible]	-.0578	.1530	0.
[illegible]	[illegible]	.0344	0.
204.00	-.4554	.2574	0.
202.00	-.4512	.2504	0.
200.00	-.4632	.2592	0.
198.00	-.4512	.2550	0.
196.00	-.4266	.2436	0.
194.00	-.4032	.2334	0.
192.00	-.3936	.2226	0.
190.00	-.3750	.2064	0.
188.00	-.3648	.1902	0.
186.00	-.3540	.1776	0.
184.00	-.3432	.1542	0.

58.	182.00	-.3114	.1358	1.
59.	180.00	-.3090	.1284	0.
60.	178.00	-.3128	.1200	0.
61.	176.00	-.3042	.1044	0.
62.	174.00	-.3000	.0954	0.
63.	172.00	-.2964	.0840	0.
64.	170.00	-.2956	.0726	0.
65.	168.00	-.2926	.0666	0.
66.	166.00	-.2772	.0582	0.
67.	164.00	-.2556	.0630	0.
68.	162.00	-.2448	.0534	0.
69.	160.00	-.2262	.0324	0.
70.	158.00	-.2124	.0120	0.
71.	156.00	-.2010	.0006	0.
72.	154.00	-.1884	-.0204	0.
73.	152.00	-.1848	-.0354	0.
74.	150.00	-.1788	-.0444	0.
75.	148.00	-.1728	-.0534	0.
76.	146.00	-.1668	-.0648	0.
77.	144.00	-.1596	-.0870	0.
78.	142.00	-.1554	-.0954	0.
79.	140.00	-.1590	-.1044	0.
80.	138.00	-.1554	-.1152	0.
81.	136.00	-.1566	-.0918	1.
82.	134.00	-.1434	-.0954	0.
83.	132.00	-.1392	-.1050	0.
84.	130.00	-.1122	-.0636	1.
85.	128.00	-.1266	-.1788	1.
86.	126.00	-.0978	-.1686	0.
87.	124.00	-.0600	-.1692	0.
88.	122.00	-.0186	-.1848	0.
89.	120.00	.0084	-.1944	0.
90.	118.00	.0282	-.2052	0.
91.	116.00	.0366	-.2250	0.
92.	114.00	.0444	-.2424	0.
93.	112.00	.0336	-.2562	0.
94.	110.00	.0150	-.2586	0.
95.	108.00	-.0144	-.2772	0.
96.	106.00	-.0624	-.2904	0.
97.	104.00	-.1026	-.3000	0.
98.	102.00	-.1428	-.3174	0.
99.	100.00	-.1566	-.3396	0.
100.	98.00	-.1542	-.3234	1.
101.	96.00	-.1428	-.3360	0.
102.	94.00	-.1326	-.3420	0.
103.	92.00	-.1278	-.3678	0.
104.	90.00	-.1224	-.3846	0.
105.	88.00	-.1176	-.4062	0.
106.	86.00	-.1080	-.4194	0.
107.	84.00	-.0966	-.4260	0.
108.	82.00	-.0846	-.423[illegible]	0.
109.	80.00	-.0876	-.438[illegible]	0.
110.	78.00	-.0966	-.4578	0.
111.	76.00	-.0918	-.4686	0.
112.	74.00	-.0829	-.4594	0.
113.	72.00	-.0530	-.4629	0.
114.	70.00	-.0396	-.4590	0.

115.	68.00	-.0234	-.4644	0.
116.	66.00	-.0185	-.4764	0.
117.	64.00	-.0228	-.4974	0.
118.	62.00	-.0240	-.4902	0.
119.	60.00	-.0120	-.4914	1.
120.	58.00	.0012	-.5214	1.
121.	56.00	.0090	-.5136	0.
122.	54.00	.0126	-.4974	0.
123.	52.00	.0204	-.4800	0.
124.	50.00	.0306	-.4728	0.
125.	48.00	.0414	-.4896	0.
126.	46.00	.0456	-.5028	0.
127.	44.00	.0546	-.5424	0.
128.	42.00	.0558	-.5646	1.
129.	40.00	.0426	-.5862	0.
130.	38.00	.0360	-.6000	0.
131.	36.00	.0492	-.5982	0.
132.	34.00	.0948	-.5892	0.
133.	32.00	.0996	-.6126	0.
134.	30.00	-.9156	-.7230	0.
135.	28.00	-.8280	-.7236	1.
136.	26.00	-.8052	-.7302	0.
137.	24.00	-.7992	-.7332	0.
138.	22.00	-.7986	-.7374	0.
139.	20.00	-.7944	-.7452	0.
140.	18.00	-.7938	-.7572	0.
141.	16.00	-.7914	-.7668	0.
142.	14.00	-.7974	-.7800	0.
143.	12.00	-.7684	-.7986	0.
144.	10.00	-.7794	-.8250	0.
145.	8.00	-.7674	-.8664	0.
146.	6.00	-.7554	-.9078	0.
147.	4.00	-.7512	-.9522	0.
148.	2.00	-.7470	-1.0110	0.

DATA FORCED TO AGREE AT DEPTH 270.42A-ADJUST = .0000B-ADJUST = .0042
COMPARISON OF TWO INCLINOMETER READINGS - HOLE 1-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-06-80 05-06-80
08-22-80 08-22-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
270.42	.0000	-.0042	0.
268.42	-.0637	.0674	0.
266.42	-.0763	.0847	0.
264.42	-.0825	.0847	0.
262.42	-.0768	.0738	0.
260.42	-.0337	.0740	0.
258.42	-.0749	.0639	0.
256.42	-.0865	.0759	0.
254.42	-.0812	.0696	0.
252.42	-.0793	.0459	0.
250.42	-.0834	.0590	0.
248.42	-.0617	.0082	0.
246.42	-.0432	-.0464	0.
244.42	-.0010	-.0655	0.
242.42	.0114	-.0809	0.
240.42	.0276	-.0852	0.
238.42	.0293	-.0979	0.
235.42	.0423	-.1106	0.
234.42	.0434	-.1153	0.
232.42	.0668	-.1044	0.
230.42	.0768	-.0832	0.
228.42	.1097	-.1118	0.
226.42	.1408	-.1351	0.
224.42	.1788	-.1904	0.
222.42	.1308	-.1802	0.
225.42	-.2479	.1410	0.
218.42	-.2477	.1020	0.
216.42	-.2323	.0475	0.
214.42	-.2436	.0251	0.
212.42	-.2583	.0354	1.
210.42	-.2081	.0026	0.
208.42	-.2151	.1334	0.
206.42	-.9168	.5315	0.
204.42	-.8162	.4757	0.
202.42	-.7733	.4804	0.
200.42	-.8630	.5386	0.
198.42	-.6793	.4269	0.
196.42	-.6505	.3792	0.
194.42	-.6419	.3618	0.
192.42	-.6742	.3540	0.
190.42	-.6621	.2951	0.
188.42	-.6547	.2933	0.
186.42	-.6640	.2950	0.
184.42	-.6487	.2354	0.
182.42	-.6454	.2586	1.

58.	180.42	-.6363	.3082	0.
59.	178.42	-.6130	.2607	0.
60.	176.42	-.5710	.2224	0.
61.	174.42	-.5587	.1770	0.
62.	172.42	-.5546	.1538	0.
63.	170.42	-.5421	.1215	0.
64.	168.42	-.5101	.0983	0.
65.	166.42	-.4644	.0682	0.
66.	164.42	-.4449	.0367	0.
67.	162.42	-.4663	-.0288	0.
68.	160.42	-.4755	-.0974	0.
69.	158.42	-.4754	-.1220	0.
70.	156.42	-.4803	-.0953	0.
71.	154.42	-.4595	-.1296	0.
72.	152.42	-.4747	-.1291	0.
73.	150.42	-.4565	-.1074	0.
74.	148.42	-.4604	-.1107	0.
75.	146.42	-.4474	-.1477	0.
76.	144.42	-.4070	-.1673	0.
77.	142.42	-.3936	-.1648	0.
78.	140.42	-.4196	-.1713	0.
79.	138.42	-.3807	-.1903	0.
80.	136.42	-.3368	-.1715	1.
81.	134.42	-.3112	-.2088	0.
82.	132.42	-.3023	-.2795	0.
83.	130.42	-.2523	-.2438	1.
84.	128.42	-.2428	-.3083	1.
85.	126.42	-.2823	-.3502	0.
86.	124.42	-.2935	-.3688	0.
87.	122.42	-.3088	-.4003	0.
88.	120.42	-.3028	-.4285	0.
89.	118.42	-.2810	-.4368	0.
90.	116.42	-.2941	-.4306	0.
91.	114.42	-.2894	-.4816	0.
92.	112.42	-.2723	-.4654	0.
93.	110.42	-.2604	-.5258	0.
94.	108.42	-.2282	-.5000	0.
95.	106.42	-.2185	-.4899	0.
96.	104.42	-.2294	-.5151	0.
97.	102.42	-.2146	-.5339	0.
98.	100.42	-.1845	-.5269	0.
99.	98.42	-.2174	-.5696	1.
100.	96.42	-.2082	-.5996	0.
101.	94.42	-.1828	-.6115	0.
102.	92.42	-.1746	-.6412	0.
103.	90.42	-.1988	-.6528	0.
104.	88.42	-.1776	-.7041	0.
105.	86.42	-.1544	-.7349	0.
106.	84.42	-.1325	-.7440	0.
107.	82.42	-.1276	-.7450	0.
108.	80.42	-.1356	-.7518	0.
109.	78.42	-.1453	-.7647	0.
110.	76.42	-.1301	-.7785	0.
111.	74.42	-.1162	-.7872	0.
112.	72.42	-.0938	-.7866	0.
113.	70.42	-.0604	-.7813	0.
114.	68.42	-.0565	-.8203	0.

115.	66.42	-.0487	-.8489	0.
116.	64.42	-.0490	-.8827	0.
117.	62.42	-.0467	-.8869	0.
118.	60.42	-.0325	-.8857	1.
119.	58.42	-.0256	-.9312	1.
120.	56.42	-.0247	-.9324	0.
121.	54.42	-.0247	-.9265	0.
122.	52.42	-.0224	-.9272	0.
123.	50.42	-.0134	-.9134	0.
124.	48.42	.0069	-.9421	0.
125.	46.42	.0154	-.9642	0.
126.	44.42	.0266	-1.0143	0.
127.	42.42	.0063	-1.0401	1.
128.	40.42	-.0168	-1.0758	0.
129.	38.42	-.0104	-1.0957	0.
130.	36.42	.0069	-1.0994	0.
131.	34.42	.0603	-1.0956	0.
132.	32.42	.1726	-1.1149	0.
133.	30.42	-1.2442	-1.2735	0.
134.	28.42	-1.1716	-1.2935	1.
135.	26.42	-1.0906	-1.2954	0.
136.	24.42	-1.0605	-1.2998	0.
137.	22.42	-1.0442	-1.3073	0.
138.	20.42	-1.0255	-1.3034	0.
139.	18.42	-1.0194	-1.3252	0.
140.	16.42	-1.0093	-1.3603	0.
141.	14.42	-.9986	-1.4029	0.
142.	12.42	-.9867	-1.4627	0.
143.	10.42	-.9948	-1.5211	0.
144.	8.42	-1.0169	-1.5889	0.
145.	6.42	-1.0554	-1.6342	0.
146.	4.42	-1.1079	-1.6223	0.

DATA FORCED TO AGREE AT DEPTH 270.42A-ADJUST = .0000B-ADJUST = .0042
COMPARISON OF TWO INCLINOMETER READINGS - HOLE I-2

NOTE AOFFSET,BOFFSET IN INCHES
PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE INITIAL READING
ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR

05-06-80 05-06-80
10-20-80 10-20-80

DEPTH	A-OFFSET	B-OFFSET	ZZ
270.42	.0000	-.0042	0.
268.42	-.1039	.1088	0.
266.42	-.1291	.1327	0.
264.42	-.1431	.1279	0.
262.42	-.1446	.1128	0.
260.42	-.1195	.1064	0.
258.42	-.1667	.0945	0.
256.42	-.1807	.0981	0.
254.42	-.1766	.0768	0.
252.42	-.1723	.0513	0.
250.42	-.1722	.0560	0.
248.42	-.1457	.0046	0.
246.42	-.1152	-.0470	0.
244.42	-.0718	-.0721	0.
242.42	-.0618	-.0959	0.
240.42	-.0474	-.1044	0.
238.42	-.0451	-.1201	0.
236.42	-.0321	-.1316	1.
234.42	-.0334	-.1417	0.
232.42	-.0100	-.1362	0.
230.42	.0100	-.1120	0.
228.42	-.1219	-.1346	0.
226.42	-.3896	-.1639	0.
224.42	-.0504	-.2252	0.
222.42	-.1008	-.1964	0.
220.42	-.5665	.2136	0.
218.42	-.5627	.1464	0.
216.42	-.5479	.0847	0.
214.42	-.5592	.0587	0.
212.42	-.5727	.0630	1.
210.42	-.5231	.0128	0.
208.42	-.5223	.1484	0.
206.42	-1.0554	.6389	1.
204.42	-.9422	.5675	0.
202.42	-.9035	.5686	0.
200.42	-.9680	.6028	0.
198.42	-.7891	.4743	0.
196.42	-.7675	.4320	0.
194.42	-.7703	.4062	0.
192.42	-.8134	.3984	0.
190.42	-.8007	.3479	0.
188.42	-.7981	.3422	0.
186.42	-.8074	.3382	0.
184.42	-.7945	.2846	0.
182.42	-.7936	.3030	1.

58.	180.42	-.7653	.3376	0.
59.	178.42	-.7420	.2793	0.
60.	176.42	-.6994	.2350	0.
61.	174.42	-.6847	.2112	0.
62.	172.42	-.6740	.1862	0.
63.	170.42	-.6543	.1557	0.
64.	168.42	-.6355	.1391	1.
65.	166.42	-.6000	.0958	0.
66.	164.42	-.5907	.0571	0.
67.	162.42	-.6223	-.0138	0.
68.	160.42	-.6237	-.0866	0.
69.	158.42	-.6272	-.0830	1.
70.	156.42	-.6303	-.0401	1.
71.	154.42	-.6077	-.0786	0.
72.	152.42	-.6265	-.0613	1.
73.	150.42	-.6149	-.0408	0.
74.	148.42	-.6176	-.0555	0.
75.	146.42	-.5986	-.0949	0.
76.	144.42	-.5624	-.1163	0.
77.	142.42	-.5556	-.1192	0.
78.	140.42	-.5708	-.1329	0.
79.	138.42	-.5253	-.1591	0.
80.	136.42	-.4760	-.1499	1.
81.	134.42	-.4504	-.2010	0.
82.	132.42	-.4421	-.2633	0.
83.	130.42	-.3951	-.2402	2.
84.	128.42	-.3946	-.2945	1.
85.	126.42	-.4437	-.3214	1.
86.	124.42	-.4507	-.3448	0.
87.	122.42	-.4684	-.3787	0.
88.	120.42	-.4582	-.4117	0.
89.	118.42	-.4364	-.4278	0.
90.	116.42	-.4537	-.4324	0.
91.	114.42	-.4436	-.4870	0.
92.	112.42	-.4277	-.4720	0.
93.	110.42	-.4188	-.5444	0.
94.	108.42	-.3920	-.5198	0.
95.	106.42	-.3877	-.5187	0.
96.	104.42	-.4022	-.5451	0.
97.	102.42	-.3946	-.5801	0.
98.	100.42	-.3705	-.5851	1.
99.	98.42	-.4058	-.6308	1.
100.	96.42	-.3960	-.6650	0.
101.	94.42	-.3706	-.6835	0.
102.	92.42	-.3642	-.7150	0.
103.	90.42	-.3872	-.7392	0.
104.	88.42	-.3642	-.8007	0.
105.	86.42	-.3386	-.8369	0.
106.	84.42	-.3203	-.8538	0.
107.	82.42	-.3232	-.8638	0.
108.	80.42	-.3480	-.8885	0.
109.	78.42	-.3581	-.9147	0.
110.	76.42	-.3473	-.9334	1.
111.	74.42	-.3268	-.9300	0.
112.	72.42	-.2936	-.9174	0.
113.	70.42	-.2560	-.9085	0.
114.	68.42	-.2557	-.9457	0.

115.	66.42	-.2569	-.9785 1.
116.	64.42	-.2650	-1.0213 0.
117.	62.42	-.2651	-1.0363 0.
118.	60.42	-.2515	-1.0423 1.
119.	58.42	-.2464	-1.0962 1.
120.	56.42	-.2449	-1.1046 1.
121.	54.42	-.2425	-1.1059 0.
122.	52.42	-.2438	-1.1036 1.
123.	50.42	-.2318	-1.0964 0.
124.	48.42	-.2104	-1.1317 0.
125.	46.42	-.2018	-1.1574 0.
126.	44.42	-.1954	-1.2069 0.
127.	42.42	-.2229	-1.2501 1.
128.	40.42	-.2496	-1.3032 0.
129.	38.42	-.2420	-1.3327 0.
130.	36.42	-.2205	-1.3340 0.
131.	34.42	-.1587	-1.3296 0.
132.	32.42	-.0422	-1.3513 0.
133.	30.42	.1358	-1.5214 0.
134.	28.42	.2186	-1.5527 1.
135.	26.42	.3014	-1.5642 0.
136.	24.42	.3315	-1.5746 0.
137.	22.42	.3460	-1.5839 0.
138.	20.42	.3617	-1.5866 0.
139.	18.42	.3660	-1.6084 0.
140.	16.42	.3797	-1.6441 0.
141.	14.42	.3952	-1.6963 0.
142.	12.42	.4125	-1.7645 0.
143.	10.42	.4074	-1.8331 0.
144.	8.42	.3805	-1.9027 0.
145.	6.42	.3408	-1.9348 0.
146.	4.42	.2823	-1.9007 0.

SONDEX DATA
HOLE I-1

Bottom Ring	Depth (ft)	Distance Between Rings (ft)	Change in Distance Between Rings (ft) 3/5/80-5/8/80	3/5/80-8/20/80	3/5/80-10/19/80	3/5/80-6/01/81	Average Depth to Ring Interval (ft)
1	6	--	--	--	--	--	--
2	16	9.9	0	+.015	.02	.02	11
3	26	10.5	.01	-.01	0	-.01	21
4	37	10.5	-.02	-.015	-.03	-.02	32
5	47	10.6	.01	+.005	.01	-.02	42
6	58	10.5	0	+.01	+.01	+.04	53
7	68	10.3	-.01	-.015	-.03	-.02	63
8	78	10.2	0	+.01	+.02	0	73
9	88	9.9	.01	0	.01	+.01	83
10	98	9.8	0	0	.05	-.01	93
11	108	10.0	0	.01	-.05	+.02	103
12	118	9.9	.01	.005	+.01	0	113
13	124	6.1	-.02	-.015	-.02	-.01	121
14	134	10.0	.01	0	-.01	+.01	129
15	148	13.7	+.01	+.005	+.02	0	141

Key: + indicates extension between rings

SONDEX DATA
HOLE I-1 (CONT)

Bottom Ring	Depth (ft)	Distance Between Rings (ft)	Change in Distance Between Rings (ft) 3/5/80-5/8/80	3/5/80-8/20/80	3/5/80-10/19/80	3/5/80-6/01/81	Average Depth to Ring Interval (ft)
16	158	10.0	+.01	+.02	+.01	+.01	153
17	163	5.7	-.04	-.035	-.02	-.03	161
18	173	9.5	.02	+.015	+.01	+.01	168
19	183	9.8	.01	+.005	+.01	+.01	178
20	193	10.0	-.02	hole sheared at 186 ft			188
21	207	14.0	.02				200
22	217	9.9	-.01				212
23	226	9.9	0				222
24	236	10.0	0.02				231
28	275	39.0	-.01				256
29	283	7.8	-.08				279
30	291	7.8	+.06				287
31	300	8.6	.05				296
32	309	9.2	.04				305
33	319	9.7	-.02				314
34	328	9.6	-.03				324

Key: + indicates extension between rings

SONDEX DATA
(HOLE I-2)

Bottom Ring	Depth (ft)	Distance Between Rings (ft)	Change in Distance Between Rings (ft) 3/5/80-5/8/80	3/5/80-8/20/80	3/5/80-10/16/80	Average Depth to Ring Interval (ft)
1	3	--	--	--	--	--
2	15	12.2	0	0	+.01	9
3	36	20.6	-.03	0	-.01	26
4	47	10.9	+.04	+.015	+.02	42
5	49	2.2	0	-.005	-.01	48
6	59	10.3	-.01	0	-.03	54
7	69	7.2	+.01	0	+.04	64
8	79	12.5	0	-.005	-.01	74
9	95	16.1	0	+.005	0	87
10	104	9.4	-.01	--	-.01	100
11	106	2.0	+.03	--	+.02	105
14	116	9.4	+.05	-.005	0	111
16	132	16.4	0	-.01	-.01	124
17	141	8.9	-.06	+.03	+.02	137
18	150	9.0	-.02	-.025	-.01	146
20	161	11.2	-.01	+.005	0	156
21	170	9.1	+.03	+.01	+.01	166
22	188	17.7	-.01	+.005	-.01	179
23	198	9.7	-.01	-.01	+.01	193
24	199	1.6	0	+.02	+.04	199
27	233	34.1	+.02	+.015	0	216
28	243	9.4	-.01	-.005	-.03	238
31	254	11.3	-.01	+.01	0	249
32	263	9.4	+.02	-.01	+.21	259
33	272	8.3	0	+.015	-.20	268
34	281	9.2	0	+.01	-.03	277

SUMMARY OF GEOPHONE DATA
HOLES M-2 AND M-3

Depth (ft)	Trigger Level	Count on date shown, for 10 minute period[1] 5/10/80	8/23/80	10/17/80 & 10/21/80	5/30/81
144	3				
	5				
	9	0	166	17-28	0
265	3				
	5				
	8		398-1178		0
	9	8-10		11-20	
472	3				
	5	1-2	dead	dead	dead
	9				
672	3				
	5	23	25	0-6	dead
	7			142	
	9			20	

[1]Band Pass = Normal/Normal, Gain = 100

BOREHOLE M-1, 5-29-81

Depth (ft)	Trigger Level	Band Pass	Gain	Count (10 min)
100	5	normal/normal	10	132
200	5	normal/normal	10	18
270	5	normal/normal	10	10

Hole sheared at 270 ft

OVERCORING DATA
ROOM 13

HORIZONTAL ROOF STRESS

Depth	S_{max} (PSI)	S_{min} (PSI)	Bearing of S_{max}
20 ft	303	136	N88W
33 ft	1768	883	N41W
34 ft	S (average) equal to 1540 psi; angle not determined Test incomplete due to core discing on bedding planes		

MODULI MEASURED

IN BIAXIAL TEST (10^7 PSI)

Depth	E_1	E_2	E_3	Remarks
20 ft	1.08	0.156	0.123	cores = sandy siltstone with shale partings
33 ft	0.271	0.581	0.239	

PRESSURE CELL DATA (PSI) ROOM 13

Date	Comment	13-1	13-2
1/29/80	Pressurize		
1/30		0	350
1/31	Try injection- seal blows out		
2/7		0	290
2/11	Repressurize		
2/12		0	480
2/14		0	440
2/15		0	425
2/19		0	410
2/20		0	410
2/21		0	400
2/25		0	395
3/4		0	380
3/6		0	280
3/6		580 and dropping	525
5/22	reset	0	175
5/23		0	160
6/6	Area unsafe		

PRESSURE CELL DATA (PSI)
ROOM 6

Date	Comment	6-1 (Vertical)	6-2 (Horizontal)	6-3 (Vertical)
1/16/80	Grouted			
1/23	Pressurize			
1/23		1000	500	350
1/23		900	480	190
1/25		800	400	190
1/31		720	360	250
2/1		720	350	250
2/7		990	505	320
2/11		1000	515	320
2/12		1080	550	350
2/14		320	805	200
2/15		380	800	170
2/19		460	800	150
2/20		510	840	150
2/21		480	800	120
2/25		950	930	200
2/26		0	943	217
2/27		0	0	188
2/28		0	0	0
3/3	Pillar pulled			

Comments:

2/1 Pulling pillar between 2 and 3 to within 100 ft from entry

2/7 Started pulling pillar between 3 and 4, rock popping

2/12 Finished third pillar within 100 ft of entry between 3 and 4

2/13 Finished pulling 3L chain pillar between Rooms 3 and 4 Drive Room No. 6

2/14 Rib caved badly

2/25 Rock popping

2/28 Low pressure; probably poor grout job or air bubble near cell; air bubble may be due to mercury tilt switch used to align cells

ROCK BOLT LOAD DATA
BOLT NO. 1

AVERAGE LOAD ON STRAIN GAGE PAIR (LBS)		
Gage Depth	3 ft	1.5 ft
Strain gages	1-2	3-4

Date	Time	Load	Load
5-13	12:00	0	0
	7:30	1,919	1,216
5-14	8:20 a.m.	2,667	1,920
	7:30 p.m.	2,945	2,112

BENDING LOAD[1] ON STRAIN GAGE PAIR (LOAD DIFFERENCE) (LBS)			
5-13	12:00	0	0
	7:30	+1,010	-431
5-14	8:20	+1,064	-392
	7:30	+1,106	-330

[1]Note: + indicates 1, 3 in compression relative to 2, 4.

ROCK BOLT LOAD DATA
BOLTS NOS. 2 AND 3

AVERAGE LOAD ON STRAIN GAGE PAIR (LBS)

Date	Time	Rebar No. 2 1-2 (3 ft depth)	Rebar No. 2 4 (1.5 ft depth)	Rebar No. 3 1-2 (3 ft depth)	Rebar No. 3 3-4 (1.5 ft depth)
5-14	8 pm	0	0	0	0
5-15	11 am	1,879	0	43	--
5-16	8 am	2,138	-139	69	336
5-27		3,331	+313	1,177	833
6-3		4,229	1,528	1,790	1,084
6-9		4,043	1,470	1,830	1,143
6-12		4,368	1,320	1,653	1,480
6-12		4,338	1,633	1,725	1,614
6-13		4,937	1,841	1,900	1,671
6-18		5,714	1,934	2,599	6,727

Note: + indicates an extension

ROCK BOLT LOAD DATA
BOLTS NOS. 2 AND 3 (CONT)

BENDING LOAD[1] ON STRAIN GAGE PAIR
(LOAD DIFFERENCE) (LBS)

	Rebar No. 2		Rebar No. 3	
Date	1-2	4	1-2	3-4
5-14	0		0	0
5-15	3,530		457	--
5-16	4,277		602	-839
5-27	4,855		1,429	-1,086
6-3	4,153		2,748	-923
6-9	4,039		2,667	-376
6-12	9,196		6,311	-718
6-12	9,596		6,387	-426
6-13	11,023		6,483	-809
6-18	12,433		9,683	-3,532

[1]Note: + indicates 1, 3 in compression relative to 2, 4.

EXTENSOMETER DATA
ROOM 6

1/23	Start installation
1/24	Grout
1/25	Unblock bent hose
1/28	Grout (finish)
2/1	Cut and tape ends
2/7	Secure plate; take first readings

Date	Anchor at 12 ft (x 0.01 mm)	Change	Anchor at 17 ft (x 0.01 mm)	Change
2/7	736		661.5	
2/11	659	77	582	79
2/12	641	95	559	102
2/14	268	468	171	490
2/14	781	Reset	753	Reset
2/15	475	774	453	790
2/15	737	Reset	879	Reset
2/19	596	915	734	935
2/20	564	947	698	971
2/20	802	Reset	--	--
2/21	800	949	694	975
2/25	763	986	652	1,017

End of recorded data--pillar pulled March 3, 1980

EXTENSOMETER DATA
ROOM 13

Date	Anchor at 10 ft (x 0.01 mm)	Change	Anchor at 20 ft (x 0.01 mm)	Change	Anchor at 50 ft (x 0.01 mm)	Change
1/20/80	Cut, tap and take first reading					
1/20	690		954		841	
1/21	693	-3	955	-1	841	0
1/25	688	2	952	2	841	0
3/4	680	10	943	11	840	1
3/6	677	13	942	12	838	3
3/6 Reset	686	Reset	949	Reset	857	Reset
4/2	666	33	939	22	855	12
4/10	658	41	938	23	852	15
4/18	645	54	934	27	850	17
4/21	641	58	928	33	849	18
4/22	639	60	927	34	849	18
4/23	634	65	924	37	848	19
4/24	636	63	922	39	849	18
4/28	624	75	912	49	852	15
5/5	606	93	885	76	848	19
5/6	606	93	879	82	847	20
5/7	610	89	885	76	848	19
5/12	595	104	862	99	846	21
5/13	592	107	857	104	846	21

EXTENSOMETER DATA (CONT)
ROOM 13

Date	Anchor at 10 ft (x 0.01 mm)	Change	Anchor at 20 ft (x 0.01 mm)	Change	Anchor at 50 ft (x 0.01 mm)	Change
5/15	584	115	846	115	840	26
?	578	121	839	122	839	27
5/22	552	147	805	156	831	36
5/23	538	161	782	179	827	40
5/27	512	187	747	214	817	50
5/28	505	194	742	219	815	52
5/29	502	197	735	226	818	49
6/5	477	222	704	257	813	54

CONVERGENCE READINGS (IN.)

	STATION				
Date	1	2	3	4	5
June 12	Turning 3rd crosscut in Room 24				
June 12	installed (0.74837)	installed (0.87063)			
June 13	?	?	installed ball broke	installed 0.50308	installed
June 18	0.73533	0.84884	lost	lost	0.52446
June 23	0.72597	0.83526			0.55722

Ready to turn third crosscut in Room 24, Room 23 all the way up.

CONVERGENCE[1] (METERS)

	STATION		
Date	1	2	5
6/12	0.0	0.0	--
6/18	0.01304	0.02179	0.0
6/23	0.02240	0.03537	-0.03276

[1]Note: + indicates shortening of span

SUBSIDENCE-LINE A (FEET)
FROM 1-10-80

Point No.	3-5-80	6-24-80	8-6-80	8-26-80	10-17-80	5-31-81
27	-.06	-.06	-.06	-.01	-.04	-.14
26*	--	--	--	--	--	-.17
25	-.06	-.18	-.13	-.16	-.18	-.40
24	-.03	-.26	-.26	-.25	-.27	-.63
23*	-.04	-.54	-.59	-.57	-.58	-1.14
22	-.05	-.82	-.92	-.89	-.93	-1.74
21*	+.05	-.89	-1.00	-.99	-1.04	-2.06
20	+.14	-.96	-1.07	-1.09	-1.14	-2.11
19	-.02	-.72	-.84	-.84	-.88	-1.67
18	+.08	-.53	-.63	-.63	-.66	-1.25
17	+.05	-.28	-.49	-.49	-.50	-.95
14	+.03	-.15	-.37	-.37	-.39	-.76
37	--	-.24	-.32	-.33	-.34	-.60
38	--	-.23	-.37	-.29	-.30	-.54
39	--	-.18	-.23	-.25	-.27	-.50
40	--	-.13	-.22	-.24	-.24	-.44
41	--	-.12	-.21	-.25	-.29	-.47

Key: * no 1-10-80 data; 1-10-80 data estimated

- indicates settlement

+ indicates heave

-- no data for date shown

SUBSIDENCE LINE A (FEET)
FROM 1-10-80 (CONT)

Point No.	3-5-80	6-24-80	8-6-80	8-26-80	10-17-80	5-31-81
42	--	-.07	-.18	-.26	-.36	-.53
43	--	-.06	-.19	-.36	-.69	-.87
44	--	-.01	0	-.16	-2.37	-2.62
45	--	0	0	+.05	-1.12	-1.36
46	--	0	0	+.11	-.10	-.13
47	--	-.04	--	+.09	+.14	+.25
APPROXIMATE FACE LOCATION						
	pts 21-22 Rms 5-6	pt 43 Rm 22	Approx. pt 44 Rm 26	pts 44- pt 45 Rm 28	Approx. pt 47 Rm 36	Approx. pt. 41 Rm 18 (4 Left)

Key: * no 1-10-80 data; 1-10-80 data estimated

- indicates settlement

+ indicates heave

-- no data for date shown

SUBSIDENCE (CONT)
LINE C (FEET)
FROM 1-10-80

Point No.	3-5-80	6-24-80	8-6-80	8-26-80	10-17-80	5-31-81
23	-.04	-.54	-.59	-.58	-.57	-1.14
28	-.20	-.38	-.44	-.39	-.44	-1.22
29	-.23	-.23	-.23	-.23	-.27	-1.26
29	-.11	-.12	-.10	-.12	-.15	-1.34
APPROXIMATE FACE LOCATION RELEVENT TO LINE DD						
	420 ft ahead	540 ft behind	780 ft behind	900 ft behind	1440 ft behind	300 ft behind 2E4L face

Key: - indicates settlement

+ indicates heave

SUBSIDENCE
LINE D (FEET)
FROM 1-10-80

Point No.	3-5-80	6-24-80	8-6-80	8-26-80	10-17-80	5-31-81
1	0	0	0	0	0	-.23
2	0	0	-.07	-.06	+.01	-.56
3	0	0	-.10	-.08	+.02	-.99
4	0	+.01	-.12	-.10	0	-1.22
5	0	+.01	-.14	-.12	+.01	-1.27
6	0	+.07	-.12	-.10	+.02	-1.12
7	+.03	+.07	-.22	-.19	+.03	-.96
8	+.04	+.06	-.28	-.26	+.04	-.84
9	+.08	+.06	-.01	+.01	0	-.82
10	+.08	-.08	0	-.15	-.17	-.82
13	+.07	-.11	-.29	-.30	-.29	-.79
14	+.03	-.15	-.37	-.37	-.39	-.76
31	0	-.33	-.42	-.47	-.51	-.77
32	+.04	-.52	-.71	-.74	-.79	-1.04
33	0	-.78	-.97	-.96	-1.00	-1.21
34	+.09	-1.00	-1.19	-1.16	-1.20	-1.36
35	--	-1.04	-1.25	-1.23	-1.26	-1.34
36	-.11	-.64	-.73	-.65	-.62	-.64

Key: - indicates settlement

+ indicates heave

TAPE EXTENSOMETER DATA
LINE A

STRAIN x 10^{-3}
FROM 8-24-80

Points	Slope Distance Between Points (ft)	10-18-80	5-29-81
27-26	90	+.2	+1.0
26-25	90	+.5	+1.6
25-24	92	0	+1.2
24-23	81	--	--
23-22	82	--	--
22-21	72	--	--
21-20	88	--	--
20-19	90	--	--
19-18	91	--	--
18-17	86	0	-.8
17-14	53	-.3	-1.4
14-37	84	+.1	-2.0
37-38	38	+.2	-1.5
38-39	45	-.1	-1.7
39-40	45	0	+.3
40-41	90	+.5	+.6
41-42	90	+.9	+.8
42-43	90	+2.1	+2.3
43-44	300	--	--

TAPE EXTENSOMETER DATA (CONT)
LINE A

STRAIN x 10^{-3}
FROM 8-24-80

Points	Slope Distance Between Points (ft)	10-18-80	5-29-81
44-45	150	--	--
45-46	249	--	--
46-47	251	--	--

Key: -- no data; interval not set up for taping

- indicates compression

+ indicates extension

TAPE EXTENSOMETER DATA (CONT)
LINE C
STRAIN x 10^{-3}

Points	Slope Distance Between Points (ft)	10-18-80	5-29-81
23-28	89	--	--
28-29	89	-.1	-1.1
29-30	89	-.1	-.7

Key: - indicates compression

+ indicates extension

TAPE EXTENSOMETER
LINE D

DATA: STRAIN x 10^{-3}
FROM 8-24-80

Points	Slope Distance Between Points (ft)	10-18-80	5-29-81
BM-1	210	--	--
1-2	90	-.2	+.1
2-3	90	-.1	-.5
3-4	88	-.2	-1.4
4-5	90	-.2	-1.4
5-6	89	-.2	-.9
6-7	91	-.4	-.9
7-8	64	-.2	-.8
8-9	25	-.1	-.4
9-10	90	-.1	-.6
10-13	90	0	+.1
13-14	90	-.4	-.4
14-31	90	-.3	-.2
31-32	90	-.3	-.6
32-33	89	-.4	-.2
33-34	89	-.3	-.6
34-35	89	-.5	-.6
35-36	231	--	--

Key: - indicates compression

+ indicates extension

APPENDIX B

INSTALLATION PROCEDURES

APPENDIX B

INSTALLATION PROCEDURES

1.0 SURVEY POINT INSTALLATION

The basic installation procedure for the cone-type monuments on slopes less than ten percent was as follows (Figures 3.3 and 3.4):

- Drill 7-inch diameter hole to depth of 4 feet. Ream top 1 foot of hole to seat large diameter valve box;

- Assemble monument. Screw on extension rod. Cover machined cone in monument with plastic.

- Place monument in hole. Slip 2-foot length of 6-inch diameter plastic pipe over monument. Align monument vertically and secure with rope and stakes.

- Pour moderately stiff sand-cement grout into hole so that grout fills bottom 1.5 foot of hole. Plastic pipe should sit on top of grout with its base just socketed in the grout. Allow grout to set.

- Remove alignment apparatus. Grout between bore-hole wall and plastic pipe. Place valve box in top of hole. Grout between cover and borehole wall. Allow grout to set.

The basic installation procedure for rebar-type monuments on steep slopes was as follows (Figure 3.4):

- Shovel out soil to sufficient depth to hold valve box, about 1 foot.
- Drive 18-inch section of 2-inch diameter pipe until three inches remain above the base of excavation.
- Drive 2-foot or 2 1/2-foot length of 5/8-inch (or heavier) rebar through pipe until about three inches remain above pipe.
- Mix a moderately stiff sand-cement grout. Grout valve box in place.

Limitations of the cone-type monument included:

- Auger could not work on slopes greater than 10 percent because the engine did not get proper lubrication.
- The site was windy and some of the augered holes filled partially with dirt before the monuments could be placed.
- Excavation of frozen, rocky soil was difficult. Some valve boxes were not flush with the ground as a result.

The rebar installations also had limitations:

- The rebar surface was not smooth and accurate enough for good leveling. The rebar was not stiff enough to be adapted to a tape extensometer monument.

2.0 SONDEX/INCLINOMETER

The pre-installation process included the following steps:

- Assemble, glue and rivet inclinometer casing to make 20 foot lengths.

- Wrap two nylon ropes (paired) around the sand line winch.

- Prepare weighted casing shoe (Figure B.1); attached nylon ropes; cap a 10 foot section of inclinometer casing and glue it into shoe. Slide on 8-foot length of Sondex casing; caulk annulus between casings; glue casings to shoe using plastic steel.

The installation was completed with the aid of a man on the mast, two persons assembling the casing at the hole and one man guiding the grout hoses.

- Thread the alignment-tool rope through a length of inclinometer casing. Lift the casing into place. With the mast-man supporting the casing, align the grooves, glue and rivet (Figure B.2 a and b). The mast man then pulls out the alignment tool. Raise a 20-foot length of Sondex casing. The mast-man threads it over the inclinometer casing (Figure B.2c).

- Spread caulking over the inclinometer casing near the Sondex joint. Butt the pieces of Sondex casing. Wrap the joint with tarry weatherstripping.

Place coupling over the joint. Fasten securely with auto ties. Tape with duct tape over full length of coupling plus six inches either side (Figure B.2d).

- Lower assembly, taping grout tube to Sondex casing (Figure B.3).

- Repeat procedure as needed. Add additional grout tubes as needed. Cut end of grout tube on a slant and tape dowels along side at end of grout tube to prevent plugging from scraping borehole wall.

- Tie Sondex casing to surface casing. For deep holes, support grout tubes on grout manifold. For all holes, stage grout casing in 150 foot lifts. Allow grout to set between lifts.

Limitations affecting installation were:

- The burst pressure of the casing was less than the pressure exerted by a column of fluid of the same height as the hole. This limitation required stage grouting and careful blancing of external grout pressure and internal water pressure. The use of accelerator and expansive agent would allow several lifts to be placed in one day and improve grouting efficiency.

- The cold weather and weight of the grout hose made it stiff and difficult to unroll; it was especially difficult to insert fittings to connect hose segments.

- The cold made glue, caulking and other materials unusable. Some sealants were found that worked, and a heating pad, attached to a generator and placed in a styrofoam cooler, was used to keep materials warm. The quality of the seals was not as good as it would have been if installed in warm weather.

- The quality control on the inclinometer casing couplings was poor. Some required hammering with a rubber mallet for installation. In addition, there was no provision for external couplings to mend casing breaks during installation.

- The Sondex casing is corrugated polyethylene drainage pipe and has little penetration resistance. Some obviously perforated sections were found, but minor damage, such as small punctures, probably went unnoticed. These punctures could let grout squeeze between the two casings and reduce the mobility of the Sondex casing. In addition, the casing is polyethylene and cannot be glued, making it difficult to guarantee a good seal.

- Stainless steel rings on the Sondex casing were placed by the manufacturer at 1 and 11 feet on some 20-foot lengths and at 5 and 15 feet on other lengths. It was not possible to get regular 10 foot spacings on the marker rings.

3.0 MICROSEISMIC INSTALLATION

The grouted-in-place geophone cables were greased and sleeved with light-weight hose before installation to allow some slip after grouting. A weight, supported on a nylon rope, was bundled with the geophones to sink the cables into the hole. Grout hoses were also bundled with the cables

(Figure 3.7). Originally one 8-inch diameter hole was planned for the installation of all four geophones. However, in drilling the hole, the bit broke off at 300 feet. In lieu of fishing for the bit, it was decided to drill a second, 6-inch diameter hole for the two deeper geophones and install two geophones in the 300 foot hole. Installed depths in the 300 foot hole were 144 and 265 feet. In the 800-foot deep hole, the geophones failed to descend to the bottom of the hole, perhaps due to caving of the hole. Installed depths in the deep hole were 672 and 472 feet. Banana plugs were installed on the ends of the cable after installation. Field soldering of the original multipin connectors was not possible in the 0°F temperatures.

The pre-installation procedure was:

- Grease cable and slide on protective hose.
- Bundle and tape cables, laying them out full length on the ground.
- Attached weight with nylon rope; rope is wrapped around sand line winch.
- Label cables with colored tape.

During installation, the procedure was:

- Lower bundle into hole, taping on grout hoses as needed; use nylon rope to ease bundle into hole.
- Grout hole through deepest grout tube, using shallower tubes if deep one plugs.
- Cut grout holes and nylon rope; install protective cover and grout in place; cut geophone cables and

label; solder on multipin connectors or screw on banana plugs.

4.0 UNDERGROUND SURVEY AND CONVERGENCE POINT INSTALLATION

One benchmark, six roof points and two floor points were installed initially and five pairs of convergence points were added later.

The benchmark was similar to the monuments installed as surface survey points. The monument was 11 feet long and set in a 12-foot deep hole. The bench mark was installed in Room 27.

The six roof points were installed by hand. The basic procedure was as follows:

- Drill a 1-inch diameter hole to 1-foot depth with the rotary hammer drill (in top coal).
- Insert celtite cartridge and special 1-foot rock bolt. Spin to mix glue.
- Screw in and secure stainless steel reference point into rebar.

A jackleg was used to drill a 1 1/2-inch diameter hole in the floor when the rotary hammer drill proved inadequate for drilling the hard floor. Rebar with a machined cone seat was grouted into the floor hole. This procedure was unsuccessful because it was not possible to clean off the cone seat in the 1 1/2-inch diameter hole. The cone must be clean so that the extension rod for the tape extensometer can be screwed on and seated properly. A final procedure which proved moderately successful was as follows:

- Drill 6-inch diameter hole with a masonry bit modified for use with a hydrualic drill to 2-foot depth.

- Set an 8-inch long rebar, containing a Sinco stainless steel ball, in grout in the base of the hole. Push a 18-inch long 4-inch diameter plastic pipe into the grout.

- Pack the top of the hole with rags for protection from dirt.

5.0 OVERCORING

Overcoring tests were conducted using a CP-8 air drill and a 600 cfm diesel compressor. The tests were run in Room 13 at depths of 20, 33, and 34 feet. The core disked (that is, separated along bedding partings) on the last test making that test's data valid only for estimating a lower bound on the stress level. A series of tests were planned in Room 6. However, due to drilling problems (loss of drill steel in the hole) and the rapid advance of the face, the stress test program was terminated.

The tests were performed using a 6-inch diameter masonry bit, a 1 1/2-inch diameter EX bit, IRAD borehole deformation gage, an IRAD biaxial modulus cell and a P-350 strain gage readout, modified with a switch box. The procedures for this test are given by Hooker and Bickell (1974).* The

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*Hooker, V.E., and Bickell, D. L., 1974, Overcoring equipment and techniques used in rock stress determination, U. S. Bureau of Mines Information Circular 8618.

tests were hampered by difficulty in finding a good test location where the core would not disk, washing of the core, and limited working height.

6.0 HYDRAULIC BOREHOLE PRESSURE CELL INSTALLATION

The CP-8 air drill with a 600 cfm compressor was used to drill two 3-inch diameter horizontal holes to 20 feet in coal pillars for the installation of the pressure cells.

The basic installation procedure was:

- Assemble pressure cells in wire space frame. Label gages. Bundle hydraulic lines. (Refer to Figure B.4)

- Insert space frame into holder at end of setting rods (Figure B.5). Loosely tape grout hose to setting rod. Grout hose extends past end of space frame.

- Insert assembly in hole, maintaining orientation.

- Mix grout; inject grout, withdrawing setting rods and grout tube taking care that the end of the tube remains well within the grout. Hold hydraulic lines so that pressure cells aren't displaced. When grout is visible near the mouth of the hole, remove the setting rods, leaving the grout tube still in the hole.

- Push a 4-foot long piece of rebar into the hole so that it protrudes a few inches. Pack the end of the hole with oakum. Continue to pump grout until oakum is sealed and there is some pressure on the grout. Bend grout tube, and wire closed.

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- Allow grout to set; suspend gages from end of rebar. Protect installation with reflectors.

- Pressurize cells to estimated in-situ pressure; 1000 psi for vertical and 500 psi for horizontal cells in this case.

The gages were suspended initially from spads on the pillar. Spalling of the pillar caused support problems. The gages were then suspended with wires from spads attached to the roof. A mercury tilt switch was used to verify orientation of the space frame. The setting tools successfully oriented the frame; withdrawal of the rods did not disturb the orientation. The switch may have contributed to one cell failure by creating a weak spot in the grout adjacent to a cell. The cell may have strained excessively near the switch when it was pressurized.

7.0 INSTRUMENTED ROOF BOLTS

Three of the four planned rock bolts were successfully installed, although the lead wires to two strain gages on one of these were damaged. The mine roof bolter was used to install the bolts in the regular bolting pattern. The installation procedure was:

- Cut bolt and special slow-set resin cartridge to length.

- Have bolter drill hole in standard pattern (bolts on 4 foot centers).

- Provide bolter with wrench modified for instrumented rock bolt installation. Put cartridge in hole. Slip end plate over bolt. Set bolt in wrench threading wires through slot in wrench. Tape wires to wrench.

- Install bolt. Spin slowly.

- Remove electrical tape; withdraw wrench. Allow to cool 1 hour; take initial reading.

The resin heated up due to friction during the spinning of the bolt and the chemical reaction of setting. This heat may have annealed the gage and altered the initial reading.

8.0 ROD EXTENSOMETER INSTALLATION

Two rod extensometer assemblies were installed. In Room 6 a two-point extensometer with anchors at 12 and 17 feet was installed. Due to drilling problems and the rapid face advance, the full four-point 50 foot deep installation planned for this room was not installed. In Room 13, a three-point assembly was installed with anchors at 10, 20, and 50 feet. The assembly was installed in a hole drilled for the overcore tests. The 6-inch diameter 35-foot deep hole was deepened to 50 feet in 3-inch diameter.

The basic installation procedure was modified for use in a coal mine, due to the poor load capacity of the immediate roof. The short anchor bolts provided with the instrument were inadequate for bolting the extensometer head to the weak immediate roof during first stage grouting. The extensometer head must temporarily support the rods and grout tubes during this initial grouting. To provide better support, conventional rock bolts were used to support the instrument head. Extension plates were made to connect the instrument head to the bolts (Figure B.6). The rock bolts were 3 feet deep and anchored in good rock. The bolts were also used to lift the drill rod when adding steel during drilling.

The basic installation procedure was:

- Drill hole to 50 feet + 3 feet (for grouting purposes)

- Prepare tubing bundles. Cut protective tubing for rods to length plus about 1.5 feet. Cement anchors on tubing. Label tube ends with colored tape. Cut grout tubes to length (3, 6, and 52 feet) plus about 6 foot and label. Cut borehole end of tube on a slant to prevent clogging. Layout tubing and bundle with tape and wire. The deepest grout tube should extend several feet past the deepest anchor. Over the longest grout tube, securely tape a 2-foot length of PVC pipe. The pipe keeps the tubing from bending as it is installed.

- Slide the tubing bundle into the hole. Slide on the cover plate arranging the tubes in the designated holes. Bolt on inner cover plate using the extension plates and rock bolts. Orient the cover plate perpendicular to borehole using a hand level. Paint rod depth designations on cover plate. Trim rod tubing to about 1 inch past inner plate.

- Screw rod bayonet onto end of rod segment and coat threads with locktite. Push rod into tubing, making up joints as rods are inserted. Subsequent joints should not be coated with locktite at this stage. Add one extra length of rod. Engage bayonet. Tie a wire around the threads of the extended rod and attach wire to rock bolt so rod is supported. Repeat for other anchor depths.

- Trim grout tubes to about 2 feet below cover plate. This short length allows tubes to drain as needed during grouting operations. Add fittings to grout tubes. Connect shallowest grout tube to pump. Pack area around cover plate and between tubes with oakum. Pack large gaps between the cover plate and roof with sand-cement mortar. Allow to set.

- Mix grout with expansive agent and quick set agent. Pump grout until it returns through the next grout tube. Pinch off grout tube (by bending) and tie off with wire. Allow next deeper grout tube to drain. Then clean it by running a 1/4-inch diameter piece of rebar or stiff tubing up, until air is easily blown into tube. Repeat in about 20 minutes, so that tube is clean.

- Allow grout to set 24 hours. Repeat process with next pair of grout tubes. Let set 24 hours.

- Slide a 1/4-inch tube, cut on a diagonal, into last tube. Pump in a thin grout in a small tube, until it runs back in outside tube. Pinch off both tubes; allow to set 24 hours.

- Mark rods about one and one-half inches from inner cover plate. Release one set of rods from bayonet joint and remove from tubing. Trim rod tubing and adjacent grout tubes about 1/8 inch past inner plate. Cut outermost rod at mark and tape rod end. Reinsert rod set into hole, adding one extra length of rod as a handle. Put locktite on all joints except the joint with the extra rod as the rods are joined. Engage bayonet joint and remove extra length of rod. Screw on measuring bushing and stud, holding rod securely so it does not rotate. Repeat for remaining rods.

- Bolt on measuring plate. Paint rod depths on plate. Take initial reading for each rod with dial gage. The dial gage should be almost fully compressed (about 7/8 of full reading); if not, adjust measuring stud. Initial movement will be opening of cracks, causing rod to recede into hole.

- Place protective cover plate and mark with reflectors.

Because the rods recede into the hole as the roof cracks, it is difficult to add extra rod lengths. A solution is to use an extra-long measuring stud or a threaded blank rod, as was used here.

The installation of the Interfels system was generally straightforward. Despite the adaptations made for the particular mine conditions, the quality of the overall system and the ease with which it is assembled was dependable and repeatable.

9.0 GROUTING PROCEDURES

Neat cement was used for most grouting. Bentonite was added to the grout in one hole (I-2) and made pumping extremely difficult. An air-operated double piston pump with a gas engine compressor was used to pump the grout into the holes. A 1/2-inch chuck drill fitted with a rebar bit was used to mix the grout in 55 gallon drums. A gas-operated centrifugal pump was used to shear the grout and transfer it between barrels. No accelerator was used in the mix. The holes were stage grouted in lifts of 150 feet, with 24 hours between stages. The use of an accelerator (and a nonshrink admixture) would reduce the set time and the total grouting time.

The basic grouting procedure for the deep holes was:

- Slowly add four sacks of Type II cement to a 55 gallon drum about 1/2 full of water and mix, for a 0.5 water/cement ratio.

- Using a small centrifugal pump, put discharge hose at top of barrel and intake hose at base; run for ten minutes until grout thoroughly mixed.

- Place a 2 x 4 lumber frame with window screen nailed across it over an empty barrel. Pump grout through screen into barrel.

- Connect pump, compressor, hoses and deepest grout tube. Pump into deepest tube until it is no longer possible to blow air into next shallower grout tube. (For nearly dry holes.) Let set 24 to 48 hours.

- Pour grout cylinder. Let cure and check that it sets before pouring next stage.

For the survey monuments, a sand-cement grout was mixed by hand in five gallon buckets.

Several underground installations were grouted, using small batches of neat cement mixed by hand and pumped with an Interfels grout pump. The pump was easily used and cleaned and could apply about 50 psi pressure without excessive effort.

APPENDIX C

MAJOR SUPPLIERS

MAJOR SUPPLIERS

Supplier	Products
Geokon, Inc. 10 Water Street Lebanon, New Hamshire 03766 (603) 448-1660	Instrumented Rock Bolts
Interfels GMBH A-5020 Salzburg Schwarzstrasse 27 Austria Telex: 84763872	Rod Extensometers
Irad Gage, Inc. Etna Road Lebanon, New Hamshire 03766 (603) 448-4445	Borehole Deformation Gage and Biaxial Cell
Slope Indicator Company (SINCO) 3668 Albion Place N Seattle, Washington 98103 (206) 633-3073	Geophone, Sondex, and Inclinometer Systems; Tape Extensometer Reference Points
Surveyors Service Company 2942 Century Place P. O. Box 1500 Costa Mesa, California 92626 (714) 546-0606 (213) 628-7119	Wild level, other survey equipment
Terrametrics 16027 West 5th Avenue Golden, Colorado 80401 (303) 279-7813	Borehole pressure cells

OTHER USEFUL SUPPLIERS

Anixter Industrial Park P. O. Box 726 Price, Utah 84501 (801) 637-4210	Spads, mine supplies
Celtite, Inc. 13670 York Road Cleveland, Ohio 44133 (216) 237-3232	Resin
Mine Safety Appliances Company 600 Penn Center Blvd Pittsburgh, Pennsylvaina 15235 (412) 273-5000	Mine safety equipment

APPENDIX D
LIST OF EQUIPMENT NEEDED FOR FIELD OPERATIONS

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LIST OF EQUIPMENT NEEDED FOR FIELD OPERATIONS

This appendix provides a check list for engineers preparing a subsidence monitoring field program. The checklist is based on the equipment used for this contract and on modifications and changes in instrumentation suggested by the performance of the instruments.

The tabulations are included as planning aids only, based on a specific study, and should not be considered comprehensive for other site studies.

The appendix includes the following tables:

- D-1 General Surface Supplies
- D-2 Level Survey and Tape Extensometer Survey Equipment
- D-3 Sondex/Inclinometer Equipment
- D-4 Microseismic Equipment
- D-5 General Underground Equipment
- D-6 Overcoring Equipment
- D-7 Convergence Points
- D-8 Borehole Pressure Cells
- D-9 Mine Roof Rod Extensometers
- D-10 Instrumented Rock Bolts
- D-11 Grouting Equipment

TABLE D-1

GENERAL SURFACE SUPPLIES

ITEM

Transportation

- 3/4 ton 4WD pickup with padded storage crates in bed
- Snowmobiles (for winter access)

Storage

- 8 x 32 foot office/storage trailer with electrical hookup
- 8 x 12 foot field trailer with tie downs and lightening rod (for remote site)
- 20-foot wide rolls of plastic

Communications and Recording

- Stationary supplies
- Telephone
- Data sheets (preferably in computer-input format)
- Site maps

Saftey Equipment (Many Items Usable in Mine)

- Flashlights (spark-proof), spare batteries, light bulbs
- Steel-toed boots, liners
- Hard hats, liners
- Rubber gloves
- First aid kit
- Fire extinguisher
- Axe
- Water jugs
- Salt tablets

TABLE D-1

GENERAL SURFACE SUPPLIES (CONT)

ITEM

Storage

- Orange safety vests
- Ear plugs

Writing Supplies

- Notebooks
- Mechanical pencils
- Grease pencils, metal markers
- Marking pens
- Paint
- Colored tape
- Expense forms, memo forms and other office forms

Hand Tools

- Tool box with adjustable wrenches, screw-drivers, hammers, pliers, vise-grips, and channel-lock pliers
- Wheel barrow
- Hand drill
- Rubber mallet
- 100-foot steel tape
- 6-foot pocket tape
- Compass
- Hacksaw and spare blades
- Assorted wire
- Oil can

TABLE D-1

GENERAL SURFACE SUPPLIES (CONT)

ITEM

<u>Glues and Lubricants</u>

- Epoxy (5-minute set)
- Plastic steel
- Duct tape
- Grease
- Locktite thread sealer
- Distilled water
- Teflon tape
- Joint compound
- Nylon rope

<u>Miscellaneous Supplies</u>

- Air thermometer
- Rags
- Matches
- Styrofoam
- Strainers
- Propane torch and striker
- Steel thermos

<u>Electrical Equipment</u>

- Electrical tape
- Heating pad
- Electric drill and bits
- Battery soldering iron, solder

TABLE D-1

GENERAL SURFACE SUPPLIES (CONT)

ITEM

Electrical Equipment (cont)

- Assorted crimp-type connectors
- Electrical wire
- 100 foot 3-wire, outdoor extension cord
- Multimeter

Power Equipment

- Arc welder/generator
- Welding rods, face shield, gloves, clamps.

TABLE D-2

LEVEL SURVEY AND TAPE EXTENSOMETER SURVEY EQUIPMENT

ITEM

Machinery

- Portable compressor
- Portable jackhammer or jack-leg drill (for rock)
- Two man auger or truck mounted auger (for soil)

Custom Monument Components (or Use Commercial First Order Survey Monuments)

- Custom precision survey monument adapted to take measuring cone
- Cone socket wrench
- Tape extensometer extension rods
- Plastic pipe and caps for sleeving monument
- Protective covers (valve box)

Hand-Installed Survey Points

- Rebar (5/8 inch x 2-1/2 foot) or commercial drivable monument
- 2-inch diameter by 18-inch pipe sections (for rebar protection)
- Valve boxes
- Sledge hammer

Materials

- Sand
- Cement, Type II

Tools

- Shovel
- Machetes

TABLE D-2

LEVEL SURVEY AND TAPE EXTENSOMETER
SURVEY EQUIPMENT (CONT)

ITEM

Tools (cont)

- Sledge hammer
- Pocket knife

Installation Accessories

- Five gallon buckets
- Five gallon cans for water
- Five gallon cans for fuel if power machinery used
- Plastic bags and tape

Alignment Accessories (for grouted monuments)

- Large nails or stakes
- Light rope
- 1-foot long stock drilled and tapped with 1/2-inch NF thread (for use with custom monument)

Initial Setting Out

- Lath
- Red paint
- Flagging

General Survey Equipment

- Survey notebooks
- Walkie-talkies (short-wave radios)

Level Survey

- Level, precision, self-leveling
- 25-foot fiberglass rod (two)

TABLE D-2

LEVEL SURVEY AND TAPE EXTENSOMETER SURVEY EQUIPMENT (CONT)

ITEM

Level Survey (cont)

- Air thermometer
- Crow's foot for turning points
- Hand level

Tape Extensometer Survey

- Tape extensometer
- Carrying case
- Spare tape
- Tape thermometer and refills

EDM Survey (Note--recommended to replace tape extensometer)

- EDM
- Theodolite
- Surveying Calculator
- Reflectors

TABLE D-3

SONDEX/INCLINOMETER EQUIPMENT

ITEM

Casing

- 4-inch diameter 20-foot long sections of corrugated drain pipe with rings at 10 foot intervals (use continuous lengths available from manufacturer if Sondex installed alone)
- 2 3/8-inch diameter plastic inclinometer casing in 10 foot lengths
- Couplings and end caps for above
- External couplings for inclinometer casing for repairs
- Spare stainless steel rings

Casing Installation Accessories

- ABS glue
- Support shoe for base of assembly
- Caulking
- Nylon rope--2 times length of casing plus 100-foot lengths
- Caulking gun
- Duct tape
- Tarry weather stripping
- Nylon auto ties (minimum two per Sondex coupling)
- Hand drill
- Bits
- Pop rivets
- Pop riveters (two)
- Inclinometer casing alignment tool (two)

TABLE D-3

SONDEX/INCLINOMETER EQUIPMENT (CONT)

ITEM

Grout Hose Installation

- Grout hose, 1/2-inch low pressure
- Male pipe ends (1/2 inch) designed to fit in grout hose
- Unions (1/2-inch pipe thread)
- 1/2-inch pipe caps
- Vice grips (two)
- Neoprene sheets or old inner tube

Grouting Equipment

- Window screen, 2 x 4's and nails to make frame to strain grout
- 50 gallon drums (five mininum)
- 1/2-inch diameter rebar X-mas tree bit
- Centrifugal gas pump and hose
- 1/2-inch chuck drill
- Generator
- Outdoor electrical extension cord
- Double piston pump and compressor, hose, reducers, pipe fittings (to pump grout into hole)
- Cement
- Accelerator and expansive agent (optional)
- Grout molds or concrete cylinders

Operation Accessories

- Sondex readout
- Inclinometer readout

TABLE D-3

SONDEX/INCLINOMETER EQUIPMENT (CONT)

ITEM

Operation Accessories (cont)

- Skid with cable reel and adjustable booms
- Jumper cable from readouts to reel
- Sunshade for readouts
- Charger/spare batteries for readouts
- Data sheets
- Tape for Sondex with accessories including:
  (1) Modified tape reel to mount on skid
  (2) Tape repair kit
  (3) Silver solder
  (4) Propane torch and striker
- External coupling with scale holder: 1 1/2-foot scale with 1/10-inch graduations, alternative to use of tape.
- 6-inch plastic pipe, cap, hasp loops, chain, two padlocks (protect lock installation).
- Sondex sensor
- Inclinometer sensor

TABLE D-4

MICROSEISMIC EQUIPMENT

ITEM

Permanent Geophone Equipment

- Wide frequency response (5 to 10,000 Hz) Piezo-electric geophone with envirnomental housing and strain-reinforced neoprene-covered cable
- 1/2-inch diameter low pressure hose to sleeve cable
- Grease to lubricate sleeve/cable contact
- 5/8- or 3/4-inch soft plastic hose as couplings for 1/2-inch hose
- Three 20 lengths of 3/8-inch rebar (to facilitate threading cable through hose)
- 3-foot length of 6-inch diameter plastic pipe and cap with lock (surface housing)

Readout Equipment

- Readout box
- Stopwatch or watch with second hand
- Charger/spare battery
- Earphones

Electrical Accessories

- Clear silicon caulking
- Archer TV tuner cleaner (dissolves above; cleans contacts)
- Solder
- Banana plug and jacks and Multipin Connector/ Banana Jack Adapter
- Plastic bags
- Electrical tape

TABLE D-4

MICROSEISMIC EQUIPMENT (CONT)

ITEM

Portable Geophone Assembly

- Wide frequency response piezoelectric geohpone with environmental housing and strain-reinforced neoprene-covered cable; cable marked at 100 foot intervals
- Packer housing
- Spare rubber ballons
- 1/4-inch diameter heavy wall nylon tubing
- Reel for above
- Pneumatic quick connects
- Valves, fittings
- Cable reel with attached geophone
- Jumper cables (reel to readout)
- Joint compound/teflon tape
- Nitrogen gas bottle with regulators
- Pulley and casing attachment (protects cable as geophone lowered)
- Cable jam cleat and casing attachment
- Soldering iron (battery-type)
- Vice grips
- Adjustable wrenches

TABLE D-5

GENERAL UNDERGROUND EQUIPMENT

ITEM

Surface Supplies, Table A-1

Transportation

- Boss buggy
- Battery charger
- Truck warning signs
- Adaptor to hang extension cord cable reel on boss buggy

Safety (In addition to General Surface Supplies)

- Reflective tape
- Reflectors
- Respirators and replacement filters
- Self-rescuers and one hour oxygen supply (latter is new MSHA regulation)
- Belts
- Lamps
- Chargers for lamps
- Water bottle for lamps
- Water bottle for lamps (or use horse-syringe)
- Distilled water
- Coveralls

Electrical

- 50-foot three-wire extension cord (outdoor type)
- 500-foot three-wire heavy duty waterproof cable and switch box on cable reel

TABLE D-5

GENERAL UNDERGROUND EQUIPMENT (CONT)

ITEM

Tools

- Spad hammer
- Spads

Other

- Equipment required by relevant mining laws

TABLE D-6

OVERCORING EQUIPMENT

ITEM

Drilling Equipment

- Drill
- 6-inch diameter core barrel, double-walled if possible
- 1 1/2-inch diameter double-walled core barrel; spare core barrel
- Bits for above
- Reamer for 1 1/2-inch diameter core barrel
- BQ drill rod; BQ to EW Sub (drill rod in 2-foot lengths)
- Wagon wheel centralizers to center BQ rod in 6-inch diameter hole
- 6-inch diameter starter barrel: 6-inch diameter core barrel with 1-1/2 inch mandrill
- EW starter barrel: 6-inch diameter wagon wheel that fits on EW core barrel
- Water swivel with added packing gland
- Silicon grease
- Piston pliers
- Vice grips
- Core breaker wedge (screws on drill rod)
- Spare packing for water swivel

Biaxial Tools

- Biaxial chamger with ends to fit core size
- Spare membranes

TABLE D-6

OVERCORING EQUIPMENT (CONT)

ITEM

Biaxial Tools (cont)

- Hydraulic pump
- Hydraulic oil
- Funnel
- Duct tape

Overcoring Tools

- Three-component deformation gage with cable
- Vishay P-350 readout with switch box
- Spare pistons, shims, screws, springs for deformation gage
- Reverse case
- Spare cables
- Setting rods (lengths 2-foot shorter than working height of mine); best with spring-loaded button lock
- Centering support for setting rods (for horizontal holes)
- Setting tool (fits on setting rods)
- Scoring tool (fits on setting rods)

TABLE D-7

CONVERGENCE POINTS

ITEM

Tools

- 1/2-inch chuck rotary hammer drill
- Socket and breaker bar for spinning roof rebar
- Drill or jackleg to drill 6-inch diameter hole to 24-inch depth
- Stud finder
- Shovel
- Five gallon buckets

Roof Points

- Sinco reference bolts
- Bearing plate for bolts
- Celtite cartridges (2 minute set-time)
- 2-foot long rebar with hex head (tapped to seat reference bolts)

Floor Points

- 4-inch diameter, 18-inch long plastic pipe
- Rags
- 8-inch rebar tapped to seat Sinco reference bolt
- Sinco reference bolt

Operation

- Tape extensometer
- Spare Tape
- Tape thermometer

TABLE D-7

CONVERGENCE POINTS (CONT)

ITEM

Safety

- Respirators (during installation)
- Wire and reflectors

TABLE D-8

BOREHOLE PRESSURE CELLS

ITEM

Pressure Cell Equipment

- Copper flat jack with 30-feet 1/8-inch diameter steel tubing
- Three-way valve block with quick-connect fitting at connection to pump
- 0 to 2,000 psi, 3 percent pressure gage (scale as appropriate)
- Hydraulic pump, hose with quick-connect

Pressure Cell Frame and Installation

- Irad setting rods in lengths 2 feet less than head room
- Pressure cell holder fitting above setting rods
- 1/8-inch wire for space frame to orient cells
- (Optional: mercury tilt switches, lead wires, multimeter)

Grouting Equipment

- 1/2-inch low pressure hose
- Male hose end
- Grout pump (manual-type)
- Hose from grout pump to grout hose in holes, with necessary fittings
- Cement
- Accelerator and expansion agents for cement
- 4-foot long 5/8-inch diameter rebar or rock bolt, for support of pressure gages
- Oakum
- Grout molds or concrete cylinders

TABLE D-8

BOREHOLE PRESSURE CELLS (CONT)

ITEM

Grouting Equipment (cont)

- Five gallon buckets
- Shovel
- Spare diaphragms for pump

Safety Equipment

- Protective box for pressure gages
- Spads
- Wire
- Reflectors

TABLE D-9

MINE ROOF ROD EXTENSOMETERS

ITEM

Basic Rod Extensometer Assembly

- Rods (length 2 feet less than mined height)
- Threaded studs
- Bayonet joints
- Protective tubing
- Anchors
- Bushings
- Measuring studs
- Bottom plate
- Cap bolt, nut and washer assembly to fasten on extension straps
- Extension straps to provide wider bearing area for readout head in weak roof
- Rock bolts (mechanical type) to connect to extension straps
- Cover plate
- Dial gauge with special seat
- 2-foot length 1-inch diameter PVC pipe (to sleeve top of uppermost grout hose)

Tools

- Shovel
- Metric taps for rods
- Vice grips
- Pipe wrenches
- Adjustable wrenches

TABLE D-9

MINE ROOF ROD EXTENSOMETERS (CONT)

ITEM

Tools (cont)

- Screwdriver
- Wire cutters

Accessories

- Five minute set epoxy
- Wire
- Paint and brush
- Marking crayons
- Colored tapes
- Locktite

Grouting Equipment

- Male pipe ends for grout hose
- Grout pump, hose, and fittings
- Oakum
- 1/4-inch rebar 10-feet long (to clean grout hose)
- 1/4-inch nylon tube, length equals 5-foot plus longest rod length)
- Grout hose for bundling with rod assembly (use closest American size approximately 1/2-inch diameter)

TABLE D-10

INSTRUMENTED ROCK BOLTS

ITEM

Basic Equipment

- Instrumented bolts
- Vishay P-350 readout
- Remote wiring harness

Installation Equipment

- Spads, J hooks for hanging wires
- Modified rock bolter wrench
- Celtite Resin Cartridges (2 minute set)
- Reflectors/wires
- Plastic bags and electrical tape (to protect multipin connector)
- Hacksaw/blades

TABLE D-11

GROUTING EQUIPMENT

ITEM

Surface Grouting Equipment

- Double piston pump (to pump into hole)
- Hose (100 feet) for pump
- Fittings to adapt to 1/2-inch pipe thread (assumes 1/2-inch diameter hose in hole)
- Centrifugal pump (for mixing)
- Two 10-foot lengths of hose for pump
- 2 x 4's (four 3-foot lengths), nails and window screen (to make frame to screen grout)
- Five 55 gallon drums
- 1/2-inch chuck electric drill
- Outdoor extension cords
- Generator
- Mixing bit (from rebar)
- Knife

Safety Equipment

- Rubber boots
- Rubber gloves
- Safety glasses or goggles
- Respirators

Underground Mortar and Grout Mixing

- Five gallon buckets
- Shovel
- Grout pump (manual-type)

TABLE D-11

GROUTING EQUIPMENT (CONT)

ITEM

Underground Mortar and Grout Mixing (cont)

- Spare diaphragms for above
- 20-foot hose and fittings to fit 1/2-inch hose and fittings to fit 1/2-inch male pipe thread (assmumes 1/2-diameter grout hose in hole)

APPENDIX E
COMPUTER PROGRAMS

```
C     ******************************************************************
C
C     THIS PROGRAM REDUCES INCLINOMETER DATA.IT WRITES THE BASIC DATA
C     ON FILE 8; THE REDUCED DATA ON FILE 10; AND THE TWO HOLE COMPARISON
C     ON FILE 6; FILE 11 HAS THE TWO HOLE COMPARISON ADJUSTED TO AGREE
C     AT A SPECIFIED DEPTH.  FILES 8,10 & 11 SHOULD BE PRINTED WITH SUITABLE
C     JOB CONTROL CARDS AT THE END OF THE JOB.
C
C     CARD FORMATS
C
C     CARD 1  COLS 1- 5  NO OF CARDS(NCARD,NCARD1)
C                        NCARD FOR 1ST READING MUST BE GREATER THAN OR EQUAL TO
C                        NCARD FOR SUBSEQUENT READINGS
C                  6-10  HOLE I.D. (HOLEN)
C                 11-55  TITLE
C     CARD 2  COLS 1-10  ZERO READING FOR A-AXIS (AZERO)
C                 11-20  ZERO READING FOR B-AXIS (BZERO)
C                 21-30  ALLOWABLE VARIATION IN ZERO WITHOUT BEING
C                        CONSIDERED AN ERROR (ZEROLK)
C                 31-40  CHANGE IN ELEVATION  FROM INITIAL  READING
C                        + MEANS TOP OF CASING MOVED DOWN (SURVEY)
C                 41-50  DATE OF READING (DATE,DATEE)
C     CARD 3  COLS 1- 5  HOLE NO (HOLEN)
C                  6-15  DATE OF READING (DATE,DATEE)
C                 16-20  DEPTH
C                        PROGRAM ASSUMES DATA AT DEEPEST POINT READ FIRST
C                 21-30  A-PLUS  READING
C                 31-40  A-MINUS READING
C                 41-50  B-PLUS READING
C                 51-60  B-MINUS READING
C     CARD 4  COL  1  0 IF NO FURTHER DATA & COMPARISON OF DATA NOT
C                          DESIRED
C                     1 IF FURTHER DATA SET
C                     2 IF NO FURTHER DATA & COMPARISION OF EACH  DATA SET WITH
C                       INITIAL DATA SET IS DESIRED
C                     3 IF SAME AS @2@ AND ALSO WANT TO FORCE DATA TO
C                       AGREE AT AN ARBITRARY DEPTH
C     CARD 5  COL  1-10 DEPTH AT WHICH CURVES TO BE FORCED TO AGREE
C                       MUST CORRESPOND TO DEPTH + SURVEY CHANGE IN
C                        SECOND DATA SET
C                 11-20  A-OFFSET  IF SPECIFIED
C                 21-30  B-OFFSET  IF SPECIFIED
C                        OFFSETS ARE SUBTRACTED
C                 41     OVERRIDE  IF=1, USE SPECIFIED OFFSETS
C                        USE THIS OPTION TO PRODUCE A NICE TABLE FOR HAND PLOTS
C                        SET OFFSETS TO 0 AND COL 41 TO 1
C
C     ***********************************Q****************************
C
      DIMENSION ACUM(3[illegible]),BCUM(3[illegible]),DEPTT(3[illegible]),Z1([illegible])
```

```
      DIMENSION JMAX(10),AST(10),BST(10)
      INTEGER X
      ICOUNT=0.0
      X=0.0
   20 IF(X.EQ.1) GOTO 25
      IF(X.GT.1) GOTO 50
C
C
C     INITIALIZE PARAMETERS
   25 ACUML=0.0
      BCUML=0.0
      DEPTHX=10000.0
      ATOTAL = 0.0
      BTOTAL=0.0
      ASQUAR=0.0
      BSQUAR=0.0
C     READ BASIC DATA FOR THE HEADINGS
C
      READ (5,101) NCARD,HOLEN,T1,T2,T3,T4,T5,T6,T7,T8,T9
      READ (5,102) AZERO,BZERO,ZEROCK,SURVEY,DATE,DATEE
C
      IF(X.NE.0.0) GOTO 15
      DATE1=DATE
      DATEE1=DATEE
      NCARD1=NCARD
      HOLEN1=HOLEN
      NPTS=NCARD
C
C     WRITE TITLES ON FILE 8 WITH BASIC DATA
   15 WRITE(8,103) HOLEN
      WRITE(8,104)
      WRITE(8,120)
      WRITE(8,104)
      WRITE (8,105) T1,T2,T3,T4,T5,T6,T7,T8,T9,DATE,DATEE
      WRITE (8,104)
      WRITE(8,106)
      WRITE(8,104)
C
C     GET NUMBER OF POINTS FOR PLOT FILE PART II
      IF(NCARD.LT.NPTS) NPTS=NCARD
C
C     WRITE TITLES ON FILE 10 FOR PROGRAM REPLOT
      WRITE(10,400)
      WRITE(10,401) HOLEN,DATE,DATEE
      WRITE(10,402) NCARD
      WRITE(10,104)
      WRITE(10,104)
C
C     WRITE TITLES ON FILE 10 WITH REDUCED DATA
C
      WRITE(10,110) HOLEN
      WRITE(10,104)
      WRITE(10,105) T1,T2,T3,T4,T5,T6,T7,T8,T9,DATE,DATEE
      WRITE(10,104)
      WRITE(10,112)
      WRITE(10,113)
      WRITE(10,114)
```

```
      WRITE(10,115)
      WRITE(10,104)
      WRITE(10,111)
      WRITE(10,104)
C
C     READ BASIC DATA
      DO 10 I=1,NCARD
      READ (5,100) HOLEN,DATE,DATEE,DEPTH,A1,A2,B1,B2
C
C     DEPTH ERROR CHECK
      IF(DEPTHX.LE.DEPTH) WRITE(6,180)
      IF(DEPTHX.LE.DEPTH) GOTO 95
      DEPTHX=DEPTH
C
      ADIFF=A1-A2
      BDIFF=B1-B2
      ASUM=A1+A2
      BSUM=B1+B2
      Z=0.0
C
C     ZERO ERROR CHECK
      IF(ABS(ASUM-AZERO).GT.ZEROCK) Z=1.0
      IF(ABS(BSUM-BZERO).GT.ZEROCK) Z=1.0
C
      WRITE(8,107)HOLEN,DATE,DATEE,DEPTH,A1,A2,B1,B2,Z
C
      ATHETA=(ASIN(ADIFF/4.0))
      BTHETA=(ASIN(BDIFF/4.0))
      ATHETA=ATHETA*180.0/3.14159
      BTHETA=BTHETA*180.0/3.14159
C
      ADEFL= ADIFF*6.0
      BDEFL= BDIFF*6.0
C
      ACUML=ADEFL+ACUML
      BCUML=BDEFL+BCUML
C
      DPTH=DEPTH+SURVEY
C
      WRITE(10,116)DPTH,ADEFL,BDEFL,ATHETA,BTHETA,ACUML,BCUML,Z
C**************************************************************************
C
C     STATISTICAL SECTION
C
      ATOTAL=ATOTAL+ASUM
      AMEAN=ATOTAL/I
      ASQUAR=ASQUAR+ASUM**2
      ASTDEV=SQRT(ABS((ASQUAR/I)-AMEAN**2))
      BTOTAL=BTOTAL+BSUM
      BMEAN=BTOTAL/I
      BSQUAR=BSQUAR+BSUM**2
      BSTDEV=SQRT(ABS((BSQUAR/I)-BMEAN**2))
      IF(I.NE.NCARD) GOTO 10
      WRITE(8,301) AMEAN,BMEAN,ASTDEV,BSTDEV
      ASTDEV=ASTDEV*6.0
      BSTDEV=BSTDEV*6.0
      WRITE(8,302) ASTDEV,BSTDEV
```

```
C
C**********************************************************************
C
   10 CONTINUE
C
C       WRITE END OF DATA SET MARKER
        WRITE(10,186)
C
C       KEEP TRACK OF NUMBER OF DATA SETS
        ICOUNT=ICOUNT+1.0
        IMAX=ICOUNT
C
C       DECIDE NEXT  STEP
        READ(5,190) X
        IF(X.EQ.0.0) GOTO 95
        IF(X.GT.0.0) GOTO 20
C
C
C
C       *****************************************************************
C
C       PART II  THIS PART OF THE PROGRAM COMPARES TWO SETS OF READINGS
C
C
C       PUT END OF FILE MARK ON FILE 10 SO ISN'T AFFECTED BY REWIND
   50 ENDFILE 10
        REWIND 10
        IF(X.EQ.3) READ(5,201) AGREE,ASET,BSET,IGREE
        II=1
C
C
C       READ DESCRIPTIVE DATA FOR  INITIAL MONITORING
        DO 500 I=1,5
        READ(10,104)
  500 CONTINUE
        READ(10,130) HOLEN1
        READ(10,104)
        READ(10,140) DATE1,DATEE1
        DO 60 I=1,8
        READ(10,104)
   60 CONTINUE
C
C
C       READ REDUCED DATA FOR INITIAL MONITORING
        DO 70 I=1,NCARD1
        READ(10,131)DEPIT(I),ACUM(I),BCUM(I),Z1(I)
   70 CONTINUE
C
C       READ DESCRIPTIVE DATA FOR SECOND MONITORING
        DO 501 I=1,5
        READ(10,104)
  501 CONTINUE
        READ(10,104)
   75 READ(10,130) HOLEN2
        READ(10,104)
        READ(10,140) DATE2,DATEE2
        DO 80 J=1,8
```

```
      READ(10,104)
   80 CONTINUE
C
      XI=0.0
C
C
C
C     WRITE TITLE ON PLOT FILE FORR PROGRAM REPLOT
      WRITE(9,400)
      WRITE(9,403) HOLEN,DATE1,DATEE1,DATE2,DATEE2
      WRITE(9,402) NPTS
      WRITE(9,104)
      WRITE(9,104)
C
C     WRITE HEADINGS ON OUTPUT
      WRITE(9,184) HOLEN
      WRITE(9,104)
      WRITE(9,192)
      WRITE(9,193)
      WRITE(9,195)
      WRITE(9,104)
      WRITE(9,183) DATE1,DATEE1,DATE1,DATEE1
      WRITE(9,183) DATE2,DATEE2,DATE2,DATEE2
      WRITE(9,104)
      WRITE(9,182)
      WRITE(9,104)
C
C
C     READ  REDUCED DATA FOR SECOND HOLE
C
C     INITIALIZE DATA FOR CALCULATIONS TO FORCE CURVES TO AGREE AT SPECIFIED
C     DEPTH
      J=0
      II=II+1
      AST(2)=10000.0
      BST(2)=10000.0
C
      READ(10,131) DEPTH2,ACUM2,BCUM2,Z2
      DO 90 I=1,NCARD1
C     ADJUST DEPTHS FOR CHANGE IN SURVEYED TOP OF HOLE
C
      FACTOR=0.0
C
C     CHECK TO SEE IF DEPTH FROM FIRST DATA SET MORE THAN 2.0 LARGER THAN
C     DEPTH FROM SECOND DATA SET
      IF((DEPTT(I)-DEPTH2).GT.2.0) GOTO 9
C
C     CHECK TO SEE IF DEPTHS FOR BOTH DATA SETS THE SAME
      IF(DEPTH2.EQ.DEPTT(I)) GOTO 94
C
C
C     CHECK TO SEE IF END OF DATA SET REACHED
   86 ID2=0
      IF(DEPTH2.GE.10000.0) GOTO 97
C
C
C     CHECK TO SEE IF DEPTH FROM SECOND DATA SET    ATER THAN 1ST ENTRY
```

```
C     FROM INITIAL DATA SET
      IF((DEPTH2-DEPTT(I)).GT.2.0) ID2=1
      IF(ID2.EQ.1) READ(10,131) DEPTH2,ACUM2,BCUM2,Z2
      IF(ID2.EQ.1) GOTO 86
C
C
C     CHECK TO SEE THAT DEPTH FROM 1ST DATA SET GREATER  OR EQUAL
C     TO DEPTH FROM 2ND
   89 ID3=0
      IF(DEPTT(I).LT.DEPTH2.AND.I.EQ.1) ID3=1
      IF(ID3.EQ.1) READ(10,131) DEPTH2,ACUM2,BCUM2,Z2
      IF(ID3.EQ.1) GOTO 86
C
C     CHECK TO SEE THAT 1ST DATA CARD  LESS THAN OR EQUAL TO 2ND
      IF(DEPTT(I).GT.DEPTH2.AND.I.EQ.1) GOTO 95
C
C
   93 FACTOR=(DEPTH2-DEPTT(I))/(DEPTT(I-1)-DEPTT(I))
C
   94 A=ACUM(I)-FACTOR*(ACUM(I)-ACUM(I-1))
      B=BCUM(I)-FACTOR*(BCUM(I)-BCUM(I-1))
C
C
      AOFFST=ACUM2-A
      BOFFST=BCUM2-B
      ZZ=Z2+Z1(I)
C
C     INITIALIZE DATA SO BOTTOM POINT ASSUMED STATIONARY
      IF(X1.EQ.0.0) A1=AOFFST
      IF(X1.EQ.0.0) B1=BOFFST
      AOFFST=AOFFST-A1
      BOFFST=BOFFST-B1
      X1=1.0
C
C
      WRITE(9,191) DEPTH2,AOFFST,BOFFST,ZZ
C
C     CALCULATE OFFSETS AT DEPTH=AGREE, I.E., DEPTH WHERE CURVES TO BE
C     FORCED TO AGREE.  DO ONLY IF REQUESTED
      IF(X.NE.3) GOTO 210
C
C     DETERMINE OFFSETS AT DEPTH = AGREE
C     IF(II.GT.2) GOTO 210
      IF(DEPTH2.EQ.AGREE) AST(II)=AOFFST
      IF(DEPTH2.EQ.AGREE) BST(II)=BOFFST
C
  210 J=J+1
C     J IS A C ARD COUNTER IN COMPARISON DATA SET
C
   85 READ(10,131)DEPTH2,ACUM2,BCUM2,Z2
C
   99 CONTINUE
C
   97 WRITE(6,800) J,II
      JMAX(II)=J
C
C     CHECK TO SEE IF ANOTHER DATA SET NEEDS PROCESSING
```

```
      ICOUNT=ICOUNT-1.0
      IF(ICOUNT.GT.1.0) WRITE(9,199)
      IF(ICOUNT.GT.1.0) GOTO 75
C
C     ****************************************************************
C     PART 3 -- FORCE DATA TO AGREE AT ARBITRARY DEPTH
C
      IF(X.NE.3) GOTO 95
      END FILE 9
      REWIND 9
C
C     PROCESS FOR EACH SET OF CALCULATED DATA OFFSETS
      DO 215 K=2,IMAX
C
C
      IF(IGREE.EQ.1) AST(K)=ASET
      IF(IGREE.EQ.1) BST(K)=BSET
C
      L=0.0
  205 READ(9,204) WORD,W1,W2,W3,W4,W5,W6,W7,W8,W9,W10
      L=L+1.0
      IF(L.LT.80.0.AND.WORD.NE.'COMPAR')  GOTO 205
      IF(L.GE.80.0) GOTO 95
C
C     COPY HEADINGS ONTO FILE 11
      WRITE(11,203) AGREE,AST(K),BST(K)
      WRITE(11,204) WORD,W1,W2,W3,W4,W5,W6,W7,W8,W9,W10
      DO 220 I=1,10
      READ(9,204) WORD,W1,W2,W3,W4,W5,W6,W7,W8,W9,W10
      WRITE(11,204) WORD,W1,W2,W3,W4,W5,W6,W7,W8,W9,W10
  220 CONTINUE
C
C     ADJUST DATA FOR SPECIFIED NO. OF POINTS IN DATA SET
      JSET=JMAX(K)
      WRITE(6,800) JSET,K
      DO 225 I=1,JSET
      READ(9,191,ERR=225) DEPTH2,AOFFST,BOFFST,ZZ
      IF(AGREE.GT.DEPTH2.AND.I.EQ.1) WRITE(6,802)
      IF(AGREE.GT.DEPTH2.AND.I.EQ.1) GOTO 96
      AOFFST=AOFFST-AST(K)
      BOFFST=BOFFST-BST(K)
      WRITE(11,191) DEPTH2,AOFFST,BOFFST,ZZ
  225 CONTINUE
C
C     CHECK TO SEE IF THERE IS ANOTHER DATA SET
      WRITE(6,802) I,K
      IF(K.EQ.IMAX) GOTO 215
  215 CONTINUE
C
C
C*****************************************************************
C
C     FIX UP DATA FOR HAND PLOTTING BY IDENTIFYING KEY CHANGES IN DATA
C     (GREATER THAN 0.5 INCH)
C
      END FILE 11
      REWIND 11
```

```
      DO 601 K=2,IMAX
      JSET=JMAX(K)-1
      WRITE(6,800) JSET,K
      WRITE(12,510)
      I1=0
C
  503 READ(11,600) WORD1,R1,R2,R3,R4
      I1=I1+1
      IF(WORD1.NE.'DEPTH'.AND.I1.LT.80) GOTO 503
      IF(I1.GE.80) GOTO 95
      WRITE(12,600) WORD1,R1,R2,R3,R4
      READ(11,104)
      READ(11,191,ERR=96) D,A,B,Y
      WRITE(12,522) D,A,B
C
      DO 502 I=1,JSET
      READ(11,191,ERR=96) DD,AA,BB,YY
      AAA=AA-A
      BBB=BB-B
      IF(ABS(AAA).LT.0.05.AND.ABS(BBB).LT.0.05) GOTO 502
      IF(ABS(AAA).LT.0.05) GOTO 505
      IF(ABS(BBB).LT.0.05) GOTO 506
      WRITE(12,522) DD,AA,BB
      A=AA
      B=BB
      GOTO 502
  505 B=BB
      WRITE(12,520) DD,BB
      GOTO 502
  506 A=AA
      WRITE(12,521) DD,AA
  502 CONTINUE
  601 CONTINUE
C
C
   95 IF(X.LT.3) READ(5,201) GAR,BAGE, F,ILLER
   96 STOP
C
C     *****************************************************************
C
C     FORMATS
C
  100 FORMAT(3A5,F5.0,4F10.4)
  101 FORMAT(I5,10A5)
  102 FORMAT(3F10.4,F10.3,2A5)
  103 FORMAT(1H1,10X,36H***BASIC INCLINOMETER DATA FOR HOLE ,A5,3H***)
  104 FORMAT(1X)
  105 FORMAT(5X, 3A5, 6H DATE=,2A5)
  106 FORMAT(3X,     7HHOLE NO,10H       DATE,10H    DEPTH ,
     110H    A-PLUS,10H   A-MINUS,10H    B-PLUS,10H   B-MINUS,
     110H ZEROCHECK)
  107 FORMAT(5X,3A5,5X,F5.0,4F10.4,5X,F5.0)
  110 FORMAT(10X,38H***REDUCED DATA FOR INCLINOMETER HOLE ,A5,3H***)
  111 FORMAT(3X,14HADJUSTED DEPTH,10H    A-DEFL,10H    B-DEFL,1X,
     19H  A-THETA,10H   B-THETA,10H     A-CUM,10H     B-CUM,3X,1HZ)
  112 FORMAT(5X,51HNOTE A-DEFL IS THE HORIZONTAL OFFSET OF 2-FT LENGTH,
     19H (INCHES))
```

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```
      113 FORMAT(10X,40HATHETA IS ANGLE OF CASING TILT (DEGREES))
      114 FORMAT(10X,46HACUM IS THE SUM OF HORIZONTAL OFFSETS WITH THE,
         133H DEEPEST POINT ASSUMED STATIONARY)
      115 FORMAT(10X,42HPLUS MEANS TOP OF 2-FT SECTION TILTS IN A+,
         110H DIRECTION)
      116 FORMAT( 7X,F10.2,6F10.4,F5.0)
      120 FORMAT(10X,45HIF ZERO-CHECK=1, PROBABLE ERROR IN BASIC DATA)
      180 FORMAT(2X,11HDEPTH ERROR)
      130 FORMAT(53X,A5)
      131 FORMAT( 7X,F10.2,40X,2F10.4,F5.0)
      140 FORMAT(56X,2A5)
      182 FORMAT(7X,10H      DEPTH,10H  A-OFFSET,10H  B-OFFSET,1X,2HZZ)
      183 FORMAT(17X,4A5)
      184 FORMAT(10X,*COMPARISON OF TWO INCLINOMETER READINGS - HOLE*,A5)
      186 FORMAT(7X,10H   10000.0)
      190 FORMAT(I1)
      191 FORMAT(7X,F10.2,2F10.4,F3.0)
      192 FORMAT(10X,*NOTE  AOFFSET,BOFFSET IN INCHES*)
      193 FORMAT(16X,*PLUS IS MOVEMENT IN A+,B+ DIRECTION SINCE  INITIAL*,
         1* READING*)
      195 FORMAT(10X,*ZZ GREATER THAN 0 INDICATES POSSIBLE DATA ERROR*)
      197 FORMAT(5X,*START PART 2*)
      198 FORMAT(5X,*READ DATA SET*)
      199 FORMAT(5X,*PROCESS ADDITIONAL DATA SET FOR CHANGES*)
      201 FORMAT(F10.2,F10.4,F10.4,10X,I1)
      202 FORMAT(13A6)
      203 FORMAT(16X,*DATA FORCED TO AGREE AT DEPTH*,F10.2,
         1*A-ADJUST =*,F10.4,*B-ADJUST =*,F10.4)
      204 FORMAT(10X,A6,10A6)
      301 FORMAT(5X,*AMEAN =*,F10.4,* BMEAN =*,F10.4,* ASTDEV =*,F10.4,
         1* BSTDEV =*,F10.4)
      302 FORMAT(5X,*ACCURACY/SINGLE READING NO BETTER THAN*,F10.4,
         1 * IN. FOR A $*,F10.4,* IN. FOR B*)
      400 FORMAT(10X,*PLOT CARDS FOR REPLOT*)
      401 FORMAT(5X,*INCLINOMETER HOLE PROFILE  HOLE*,A5,*DATE*,2A5)
      402 FORMAT(I5,10X,*  NO OF DATA POINTS*)
      403 FORMAT(5X,*OFFSET VS. DEPTH -HOLE *,A5,* FROM*,2A5,* TO*,2A5)
      510 FORMAT(5X,*HAND PLOTTING DATA*)
      520 FORMAT(7X,F10.2,10X,F10.2)
      521 FORMAT(7X,F10.2,F10.2)
      522 FORMAT(7X,F10.2,2F10.2)
      600 FORMAT(12X,A5,4A6)
      700 FORMAT(10X,*NO OF POINTS IN DATA SET =*,I5)
      800 FORMAT(7X,*NO OF POINTS = *,I5,5X,*NO  OF DATA SETS = *,I5)
      802 FORMAT(7X,*DEPTH FOR AGREEMENT NOT SUITABLE*)
C
C
          END
```

1983 SUBSIDENCE REPORT

Southern Utah Fuel Company