A mining research contract report
JULY 1983

AN EVALUATION OF THE FIRE AND EXPLOSION HAZARDS OF OIL SHALE MINING AND PROCESSING

VOLUME 2: DATA SUMMARY OF ANVIL POINTS RAW SHALE WASTE PILE COMBUSTION

Contract J0275001
Tosco Corporation

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

DISCLAIMER NOTICE

FOREWORD

This report was prepared by the Oil Shale Division of Tosco Corporation, 10100 Santa Monica Boulevard, Los Angeles, California, under U. S. Bureau of Mines Contract No. JO275001. The contract was initiated under the Metal and Nonmetal Health and Safety Research Program and was administered under the technical direction of the Pittsburgh Research Center with Mr. J. Kenneth Richmond acting as the Technical Project Officer. Mrs. Darlene F. Wilson was the contract administrator for the Bureau of Mines. This report is a summary of the data collected during the period August 1979 to July 1980 and of observations made at various subsequent times until June 1982. This report was submitted by the authors on July 15, 1983.

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EXECUTIVE SUMMARY

In June 1979 traces of crude oil were found in a tributary to the Colorado River that were determined to have originated from the Anvil Points raw shale pile. Closer examination showed a small flow of crude oil coming from the base of the raw shale pile as a result of high temperature retorting and combustion. As a result, the Department of Energy (DOE), owners of the property, and Paraho Development Corporation, operator, undertook certain measures to stop the combustion and flow of oil into the tributary. Prior to instituting these measures, the DOE requested that Tosco Corporation, under its current Bureau of Mines contract on the fire and explosivity of oil shale dust and retorting vapors, monitor the extinguishment of the raw shale combustion.

During July 1979 Tosco installed over 70 thermocouple measuring points in the raw shale disposal area of the pile. These points consisted of 1/2-inch-diameter steel pipes driven into the pile on 50-foot centers to depths ranging from 10 to 35 feet below the surface. A survey of the topography of the pile was also completed, and the pile thickness was estimated from the original contours prior to mining and processing operations.

In addition to the temperature monitoring, gas monitoring of H_2S, O_2, and CO concentrations was done to determine combustion products and if toxic gas concentrations were present. This monitoring provided data on the extent of retorting within the pile, the effect of mitigating procedures on combustion, and if gas concentrations were too high for the health and safety of those individuals working in the area.

Work on extinguishing combustion in the raw shale pile was terminated by Paraho in December 1979 due to weather conditions. Mitigating attempts up to that time included uncovering hot spots and reducing temperatures with high pressure water, covering gas vents with compacted earth to cut off air supply, and preparation of the valley bottom for moving the pile to a new location. In March 1980 a decision was made to end Tosco's involvement in monitoring and to summarize the data collected up to that time. However, a lack of contract funds prevented Tosco from preparing any more than a draft interim report. As a result of obtaining additional funding in April 1982, Tosco was able to prepare this report.

Evaluation of the history of the raw shale and spent shale pile development since Paraho retort development began raised certain questions as to the origin of pile combustion. Verbal accounts indicate that original raw shale fires probably originated from the hot spent shale dumped from the retorts. This hot shale was spread over raw shale from crusher undersize/oversize and was probably the early ignition source. However, spontaneous combustion cannot be ruled out completely because some of the hot spots do not appear to be related to spent shale from the retorts, although they may have been the result of thermal migration along "chimneys" or other favorable paths from existing to what appeared to be new and separate combustion. The methods of mitigating the combustion did not make it possible to trace the migration of combustion.

Definite conclusions as to the sources of each area of combustion cannot be made. It was recommended in the draft interim report issued July 7, 1980, that as the pile was moved it be inspected to determine if spontaneous ignition could have actually occurred. Sufficient data should have been collected for determination of what possible conditions of raw shale size, pile porosity, moisture content, etc. were present to cause retorting temperatures.

As of early June 1982 the surface evidence of combustion was eliminated by excavating the burning material, thoroughly wetting it with water, and cooling it by exposure to excess air. The material was spread in shallow lifts at the disposal site, compacted, allowed to dry, and temperature monitored by drive-pipe thermocouples before the next lift was placed. The thermocouples were left in place at a depth of 12 feet below the final surface, and thermocouple monitoring indicated that ambient temperatures were being maintained.

Appended to this report are plots of raw thermocouple data, cross-sections of the pile, photographs of shale combustion and field operations, a description of extinguishment and stabilization action taken by Paraho, and an informal description of the Anvil Points research operations history.

1.0 INTRODUCTION

Work performed under this portion of the contract is a result of an interagency agreement between the Bureau of Mines and the Department of Energy (DOE). The responsible individual within DOE for reporting and contract purposes was Mr. Bruce Sudduth of LETC.

An area recognized by Tosco as requiring additional investigation is spontaneous combustion in coarse and fine ore oil shale storage piles. If large piles of stockpiled oil shale, such as coarse ore storage piles, are in fact subject to spontaneous combustion or auto-ignition, design measures should be implemented to mitigate this potential. Factors such as moisture in the pile; pile porosity; presence of pyrite, sodium, and other minerals; temperature; sources of heat or ignition; pile mass; etc. are related in some manner to the potential for fire and retorting within oil shale storage piles. Evaluation of temperature profiles within the raw and spent shale dumps at the Anvil Points facility provided an opportunity to investigate some of the characteristics of combustion in large, miscellaneous piles of oil shale. However, it was considered a possibility at the outset of the investigation that the origin of the Anvil Points fire was not spontaneous combustion, but may have been started by dumping hot retorting material from experimental retorts near waste raw shale and then inadvertently distributing this material onto the raw shale portion. Because combustion was observed from time to time for much of the life of the operations at Anvil Points, a single incident during the Paraho operation should not be construed as the episode responsible.

1.1 Scope of Study

At the start of this investigation little time was available to design a detailed data-gathering program. Paraho Development had been instructed by DOE to eliminate the flow of retorting products from the raw shale pile into the tributary stream drainage system as soon as possible. Tosco was then asked to monitor temperature changes and movement, both before and during the mitigation of the problem. The scope of work consisted of collecting raw field data such as present and original surface profiles, temperature profiles within the pile, and the composition of combustion gas before and after mitigating measures conducted by Paraho. This data was presented on a weekly or bi-weekly schedule to representatives of DOE and Paraho. A program of gas monitoring for CO, H_2S, and O_2 levels to protect the health and safety of Paraho and Tosco employees working on or near the pile was also implemented at the request of DOE. A brief, final report was to have been prepared at the conclusion of the extinguishment of the rubble fire. It was expected that this procedure would be completed by early May of 1980. However, by this time the mitigation measures had not been completed, and the available funding had been used; therefore, the field portion of the work was terminated, and a draft interim report was issued.

1.2 Report Contents

This report contains a summary of the pertinent data developed from monitoring combustion in the raw shale pile at Anvil Points and the field procedures developed for monitoring temperature gradients within the pile. A preliminary analysis of the data and conclusions and recommendations for further work complete the report. Appended material includes thermocouple data, iso-temperature contours, photographs, a description of extinguishment and stabilization action taken by Paraho, and an informal description of the Anvil Points research operations history.

2.0 HISTORIC BACKGROUND

In the process of investigating the fire, Tosco interviewed several individuals with long association with the experiments, tests, and investigation of retorting oil shale at Anvil Points from the late 1940's to 1979. From these conversations and pictures taken during these years, it is possible to conclude that on several occasions hot, even burning, raw shale was dumped proximate to, and upon occasion on, the growing pile of raw shale which was crusher oversize and screen undersize. In fact, it has been impossible to accurately define a dividing line between raw and spent shale piles for many years. See appendix E for a more detailed history of operations.

One positive conclusion easily reached is that there has been active combustion in the raw shale pile since very early in the long history of retorting experiments at Anvil Points. A significant conclusion, although without positive proof, is easily inferred: if combustion has not been continuous, it has been restarted several times over the years. It is not known whether all of the combustion resulted from direct contact with burning material or if some fires were the result of the critical conditions that are precursors to spontaneous combustion, such as those conditions observed from 1966 to 1975 in stockpiles of rich oil shale at Colony Development.

3.0 FIELD PROCEDURE

3.1 Transit Survey of Shale Pile

A transit survey was conducted to establish the area of pile, provide cross-section data from the original 1949 ground surface to the present 1979 surface contours, and provide reference lines for thermocouple placement.

A base line was established at the toe of the pile extending from approximately 100 feet north of the edge of raw shale south to the surface expression of the contact between the raw and spent shales. The line was taped and marked every 50 feet from station 0+00 to 5+50. A Brunton compass was used to keep lines straight. Stations were established at 50-foot intervals from station 1+00 to 5+50. Lines extending to the top of the pile were established at 90° angles from the base line. All roads, cuts, and other surface irregularities were included on the topographic map and the cross-sections. An area map was prepared using a 1949 topographic map of the area, and cross-sections were drawn to overlay the 1979 lines established from station 1+00 to 5+50.

3.2 Drive-Pipe and Thermocouple Wire Installation

Thermocouples were used to obtain temperature data at several predetermined depths throughout the raw shale pile. One-half-inch-diameter steel pipes, cut in 5-foot lengths, were driven into the shale using a welded point on the first section. As each length was driven, a coupling was threaded onto it and another 5-foot section was driven down. This process was continued until the pipe refused to be driven any further. The thermocouple wire was then inserted into the pipe. Several methods of getting the wire down the pipe were tried, including weights. The most successful method was to use only the wire, which was stripped on the end, tightly twisted and doubled back over itself. This method worked well and was used on all temperature points.

Pipes were first driven at 50-foot intervals on all section lines. After reading temperatures and locating points of combustion, additional pipes were driven to determine the size, shape, depth, and thickness of fires.

3.3 Data Collection Program

3.3.1 Temperature

At first, temperature data was taken every day for several weeks. As more was learned about the intensity, size, and rate of movement of the fires, data collecton was reduced to two or three times a week and finally to once a week. The data was reduced and plotted on cross-sections, temperature profiles, and progress charts.

3.3.2 Gas

Gas samples at the shale pile surface were taken daily as crews moved about the area. Direct-reading instruments were used to monitor CO, O_2, and H_2S. All the data were reported to Anvil Points safety personnel and recorded on data sheets. See table 3.1 for results of the H_2S monitoring with direct-reading instruments.

TABLE 3.1. - H_2S concentrations at Anvil Points raw shale pile area[1], ppm

DATES	LOCATIONS G-1	G-2	G-3	G-4
9/5/79	100	2-5	50	6
9/6/79	100	ND	9	2
9/7/79	60	0-9	45	4
9/10/79	100	3-14	5	4
9/13/79	100	3-6	20	3
9/18/79	100	ND	40	50
9/19/79	50-100	0	0	15
9/21/79	22-100	0	15	40
9/24/79	100	0	4	50
9/26/79	100	0	2	7
9/28/79	5-100	0	5	6
10/1/79	3-100	3	3	7
10/2/79	100	0	5	8
10/3/79	100	0	3	5
10/5/79	100	0	6	0
10/8/79	25-100	0	7	6
10/9/79	100	0	8	4
10/17/79	100	0	2	0
10/22/79	100	3	5	0
10/23/79	65-100	6	5	0
10/25/79	100	5	7	0
10/26/79	100	5	100	0
11/6/79	100	7	9	0
11/14/79	100	4	100	0
11/21/79	50	9	2	0
11/27/79	100	7	100	0
12/7/79	100	8	100	0

[1]Ground level measurements made with hand-held, direct-reading instrument utilizing length of stain tubes; H_2S TWA = 10 ppm and STEL = 15 ppm.

ND Not determined.

Gas concentrations were measured with direct readout instruments in the work areas of the pile every day that work was done. The oxygen concentration did not get below 20.1 percent. Carbon monoxide concentrations ranged from 0 to 1 ppm in all areas except in the vicinity of a fire or chimney. Fire zones averaged from 4 to 7 ppm, and the areas around chimneys averaged 10 to 20 ppm. Hydrogen sulfide could only be detected at ground level at chimneys; however, concentrations as high as 100 ppm were measured at location G-1.

Gas samples were taken with gas sampling containers (bombs) three times a week at four locations near the top of the pile and at specific event locations shown on figures C.11 to C.15 during August 1979. Sampling was stopped due to winter weather in December 1979. These locations were chosen because of the probability that there were gas and vapor chimneys connected to active fires. The four primary gas sampling locations were:

G-1 Chimney NE of primary crusher near top of pile on Station 2 + 00 line.

G-2 Chimney about 100 feet east of G-1 on wide bench near Station 2 + 00 line.

G-3 Chimney on edge of road near top of pile on Station 4 + 00 line.

G-4 Chimney on narrow bench below upper road on Station 4 + 00 line.

These locations are shown on figure A.0.

The gas samples were taken with the apparatus set up as shown in figure 3.1. For sample consistency the wind screen box was placed over the chimney. The sampling funnel was held at about the center of the box to prevent dirt from being pulled into the sampling pump. The Coleman[1] sampling pump was powered by a 12-volt d.c. motor and had a capacity of 7,000 milliliters/minute (mL/min). The gas sample containers (bombs) had a capacity of about 300 mL.

After the sampling apparatus was set up, the following procedure was used for taking each sample to preclude differences in gas composition due to sampling technique:

1. The box was set over the chimney, and the gas was allowed to equilibrate for one minute. Since the placement of the box was considered to have a concentrating effect on the gas, one minute was judged adequate to let the box fill with gas and purge the ambient air.

2. Both stopcocks on the bomb were opened, the pump was turned on, and the bomb was purged for 30 seconds.

3. After 30 seconds of sampling, the stopcock on the bomb nearest the pump was closed first to prevent sucking the sample out of the bomb and creating a vacuum in it.

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[1]The U.S. Government does not endorse products or manufacturers. Trade or manufacturers names appear herein solely because they are considered essential to the object of this report.

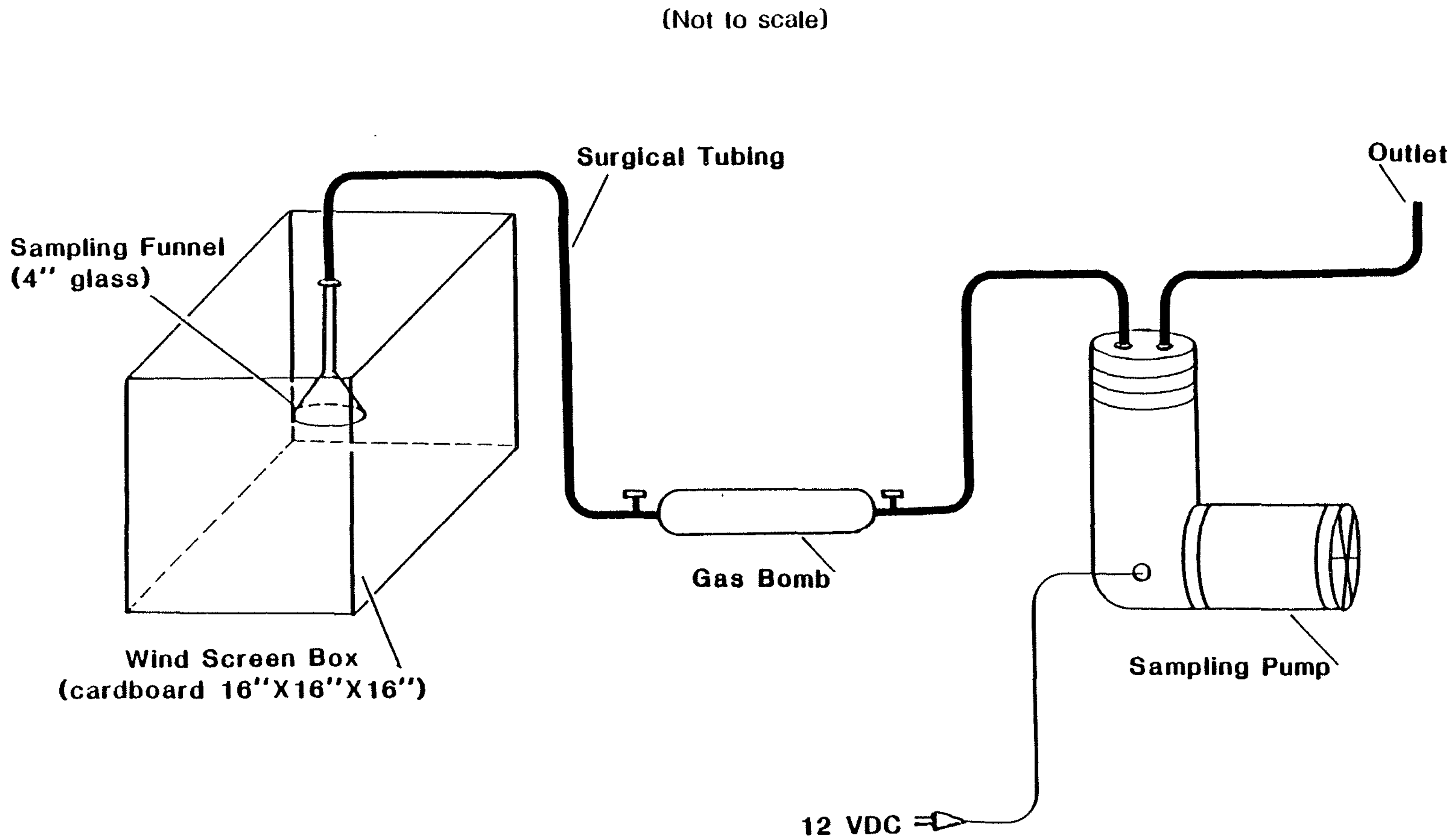


Figure 3.1. — Gas sampling apparatus arrangement.

4. The stopcock on the funnel side of the bomb was then closed, and the pump was shut off.

The ambient air temperature was not recorded at the time of sampling for analysis standardization as the need for this information was not deemed necessary for these particular samples.

3.4 Pictorial Record

Pictures which show all phases of work, including data collection, were taken thoughout the entire project. A composite picture showing the entire pile was also made. Appendix C contains photographs taken during the project. The pictures and observations made during the operation were expected to provide additional information about the origin, mode of occurrence, progression, and the paths of the fire or fires being observed.

4.0 DATA ANALYSIS

4.0 The activity on the pile was limited to thermal and gas monitoring. During this time the changes in subsurface temperatures, the movement and changes in temperatures, and appearance of fires on the surface were observed. This data, together with the increased venting of gases from so-called "chimneys," provided ample evidence of the thermal activity in a large portion of the pile.

4.1 Shale Pile Profile

The raw and spent shale disposal site for the Paraho Development operation is located on the west side of a north-south trending draw extending up to East Anvil Point. Original topography is shown in a series of 12 east-west cross sections, figures A.2 through A.13, appendix A. These sections extend from the Paraho retort dumping points to the north edge of the crusher oversize/undersize dumping point.

An approximation of the 1949, 1974, and 1979 slope contours was made for all sections where data was available. Inspection of these sections shows the pile thickening toward the south where the spent shale was dumped. Shale pile thickness in the northern end appears to be a maximum of 25 feet (1974 and 1949 surfaces are about the same). At the spent shale-crushed shale interface the pile thickness increased to about 80 feet at the thickest points. The southern portion of the shale pile contained a mixture of spent shale and crushed shale resulting from prior leveling of the pile to increase the dumping capacity in the vicinity of the retorts.

The texture of the pile, ratio of void space and particle size, and air permeability varied widely along with the temperature, rate of movement, thickness, and intensity of the combustion zone. The first indications of internal pile combustion and retorting were seen on the surface and at the toe of the pile. The combustion temperatures varied from 200° to over 1600°F. Combustion temperatures in the 400°-600°F range were very common. Evidence of combustion at the surface of the pile was indicated by an accumulation of moisture, sometimes smoke, occasional short-lived outbreaks of fire, and at times, accumulations of heavy hydrocarbons, which were the most common fuel associated with surface fires.

The fires progressed up the slope at about one foot per day; however, not all of the pile material was being consumed. Areas that were well graded, containing fines and coarse without segregation, were usually left as unburned "islands" in the pile. Although the pile contained mostly minus 1/2-inch material, there were many large pieces, and in some areas there was an accumulation of large "crusher oversize." This coarse material was totally consumed when the fire reached it. The pile was randomly constructed of fine and coarse waste.

The fire had been burning for a long time as indicated by the fact that the entire mass of many thousand tons was warm enough to cause retorting. The oil shale vapors were rising toward the top of the pile, condensing, and seeping downward, generally at the interface of the shale and the original ground surface to emerge at the base of the pile as heavy oil.

4.2 Temperature Profile

Figures A.1 through A.12 also contain the temperature data from August

1979 to July 1980. When possible, the thermocouples were read at 5-foot increments from the pile surface to the bottom of the pipe. In some cases, the thermocouple measuring points were destroyed by heavy equipment and are so marked on the section.

4.3 Iso-temperature Contour Plots

In order to evaluate the temperature relationship between data collection points, contours of equal temperature were constructed for 5-, 10-, and 15-foot depths. Insufficient data were available to construct contours at deeper elevations.

Figures B.1 through B.3 (appendix B) are iso-temperature contours as of October 17, 1979. Overlaying the contour maps indicated a tendency for the temperature concentrations to form "chimneys" to the surface. Data collected around these hot spots were insufficient to determine if vapor venting near the top of the pile actually came from lower buried hot spots.

In figures B.4 through B.6, the iso-temperature contours were taken about one month later on November 13, 1979. No great differences were noted except for the emergence of two more hot spots on the north edge of the raw shale pile.

4.4 Gas Sample Analyses

The gas bomb samples were analyzed at the Tosco Rocky Flats Research Center by gas chromatography using the thermal conductivity method. The results of the analyses are shown in tables 4.1, 4.2, 4.3, and 4.4.

TABLE 4.1. - Gas chromatographic analyses, mol-pct, location G-1

SAMPLE DATES	COMPONENTS										
	O_2 [1]	N_2	H_2	CO	CO_2	H_2S [2]	C_1	C_2	C_3	n-C_4+	Total
9/11/79	2.8	66.9	3.3	1.4	24.6	0.01	0.8	0.1	<0.1	T	100.0
9/19/79	21.9	78.0	T	0	0.1	0	0	0	0	0	100.0
9/21/79	15.7	74.7	2.0	0.1	7.1	0	0.4	<0.1	<0.1	T	100.0
9/24/79	11.2	72.2	3.3	0.4	12.2	0	0.6	0.1	0.1	<0.1	100.1
9/26/79	15.3	76.3	1.2	0.1	7.0	0	0.2	<0.1	T	T	100.1
9/28/79	18.2	77.2	0.5	0.1	3.9	0	0.1	0	0	0	100.0
10/1/79	19.7	77.4	0.5	<0.1	2.2	0	0.1	T	T	0	99.9
10/3/79	19.5	77.4	0.5	<0.1	2.5	0	0.1	<0.1	T	0	100.0
10/5/79	21.6	77.5	0	0	0.9	0	0	0	0	0	100.0
10/9/79	20.1	77.6	0.3	0.1	1.8	0	0.1	T	T	0	100.0
10/11/79	20.9	77.9	0.2	<0.1	1.0	0	0.1	T	T	0	100.1
10/12/79	21.4	78.2	0	0	0.4	0	<0.1	T	0	0	100.0
10/17/79	17.3	76.6	1.1	<0.1	4.8	0	0.2	<0.1	<0.1	T	100.0
10/19/79	21.7	78.0	T	T	0.3	0	<0.1	T	0	0	100.0
10/22/79	18.5	77.7	0.7	<0.1	3.5	0	0.2	<0.1	0	0	100.0
10/25/79	17.0	76.2	1.1	0.1	5.3	0	0.3	<0.1	<0.1	T	100.0
10/26/79	16.9	76.2	1.1	<0.1	5.3	0	0.3	0.1	<0.1	T	99.9
10/31/79	19.5	77.2	0.5	<0.1	2.7	0	0.1	T	T	0	100.0
11/6/79	19.1	76.9	0.6	<0.1	3.2	0	0.2	<0.1	T	0	100.0
11/14/79	20.7	77.6	0.3	0	1.3	0	0.1	T	0	0	100.0
11/21/79	18.5	76.6	0.8	0	3.9	0	0.2	<0.1	<0.1	T	100.0
11/28/79	20.3	77.5	0.4	T	1.6	0	0.1	T	0	0	99.9
12/7/79	21.3	78.0	T	0	0.7	0	<0.1	0	0	0	100.1

T Trace; response indicated but below 0.05 percent detection limit.
ND Not determined because glass sample bomb broken in transit.
[1]Mole percentage of oxygen includes argon.
[2]Lower detection limit of H_2S was 0.05 mole percent.

TABLE 4.2. - Gas chromatographic analyses, mol-pct, location G-2

SAMPLE DATES	COMPONENT										
	O_2 [1]	N_2	H_2	CO	CO_2	H_2S [2]	C_1	C_2	C_3	$n\text{-}C_4+$	Total
9/11/79	20.3	77.5	0.3	0.1	1.6	0	0.1	0	0	0	99.9
9/19/79	19.7	75.2	1.3	0.1	3.6	0	0.2	<0.1	T	T	100.1
9/21/79	21.3	78.0	0	T	0.7	0	<0.1	0	0	0	100.0
9/24/79	21.4	78.1	0	T	0.5	0	<0.1	0	0	0	100.0
9/26/79	21.7	78.1	0	0	0.2	0	0	0	0	0	100.0
9/28/79	21.7	78.2	0	0	0.1	0	0	0	0	0	100.0
10/1/79	21.8	78.1	0	0	0.1	0	0	0	0	0	100.0
10/3/79	21.6	78.1	0	0	0.3	0	T	0	0	0	100.0
10/5/79	21.9	78.0	0	0	0.1	0	0	0	0	0	100.0
10/9/79	21.6	78.0	0	0	0.3	0	T	0	0	0	99.9
10/11/79	21.6	78.1	0	0	0.3	0	T	T	0	0	100.0
10/12/79	21.9	78.1	0	0	<0.1	0	0	0	0	0	100.0
Discontinued											

T Trace; response indicated but below 0.05 percent detection limit.
ND Not determined because glass sample bomb broken in transit.
[1] Mole percentage of oxygen includes argon.
[2] Lower detection limit of H_2S was 0.05 mole percent.

TABLE 4.3. - Gas chromatographic analyses, mol-pct, location G-3

SAMPLE DATES	COMPONENT									
	O_2 [1]	N_2	H_2	CO	CO_2	H_2S [2]	C_1	C_2	C_3	n-C_4+	Total
9/11/79	11.3	77.6	0.7	0.3	9.4	0	0.6	0.1	0.1	T	100.1
9/19/79	18.1	77.2	0.6	0.1	3.7	0	0.3	<0.1	<0.1	T	100.0
9/21/79	18.7	77.6	0.4	0.1	2.9	0	0.2	<0.1	<0.1	0	99.9
9/24/79	17.8	77.3	0.5	0.1	4.2	0	0.2	<0.1	<0.1	T	100.1
9/26/79	18.0	77.6	0.4	0.1	3.8	0	0.2	<0.1	<0.1	T	100.1
9/28/79	19.9	77.9	0.2	<0.1	1.8	0	0.1	<0.1	T	0	99.9
10/1/79	18.8	77.7	0.4	0.1	2.8	0	0.2	<0.1	<0.1	T	100.0
10/3/79	17.4	77.4	0.5	0.1	4.4	0	0.2	<0.1	<0.1	0	100.0
10/5/79	17.1	77.2	0.6	0.1	4.7	0	0.3	0.1	<0.1	T	100.1
10/9/79	19.6	77.8	0.2	0.1	2.2	0	0.1	<0.1	T	0	100.0
10/11/79	19.9	78.0	0	0.1	1.9	0	0.1	<0.1	T	0	100.0
10/12/79	20.1	78.0	0.1	<0.1	1.6	0	0.1	<0.1	T	0	99.9
10/17/79	20.4	78.1	T	<0.1	1.4	0	0.1	T	T	0	100.0
10/19/79	18.7	77.8	0.2	0.1	2.9	0	0.2	T	T	T	100.1
10/22/79	18.0	78.0	0.2	0.1	3.5	0	0.2	<0.1	T	0	100.0
10/25/79	19.1	78.1	0.2	<0.1	2.5	0	0.1	T	T	0	100.0
10/26/79	18.8	78.0	0.2	<0.1	2.9	0	0.1	<0.1	T	0	100.0
10/31/79	19.1	77.9	T	<0.1	3.0	0	0.1	T	0	0	100.1
11/6/79	21.9	78.1	0	0	<0.1	0	T	0	0	0	100.0
11/14/79	17.2	77.5	0.2	<0.1	4.9	0	0.2	T	T	0	100.0
11/21/79	15.9	76.7	0.4	0.1	6.6	0	0.3	<0.1	T	0	100.0
11/28/79	20.5	77.9	T	T	1.5	0	0.1	0	0	0	100.0
12/7/79	19.8	77.7	T	T	2.4	0	0.1	0	0	0	100.0

T Trace; response indicated but below 0.05 percent detection limit.
ND Not determined because glass sample bomb broken in transit.
[1]Mole percentage of oxygen includes argon.
[2]Lower detection limit of H_2S was 0.05 mole percent.

TABLE 4.4. - Gas chromatographic analyses, mol-pct, location G-4

SAMPLE DATES	COMPONENT										
	O_2 [1]	N_2	H_2	CO	CO_2	H_2S [2]	C_1	C_2	C_3	$n\text{-}C_4+$	Total
9/11/79	13.8	79.5	0.3	0	6.3	0	0.1	0	0	0	100.0
9/19/79	15.3	78.2	0	T	6.2	0	0.3	<0.1	T	0	100.0
9/21/79	19.9	78.1	0	0	1.9	0	0.1	0	0	0	100.0
9/24/79	15.3	74.3	0	0	10.4	0	<0.1	0	0	0	100.0
9/26/79	18.2	78.2	0	0	3.5	0	0.2	<0.1	T	0	100.1
9/28/79	15.9	77.4	T	0	6.3	0	0.4	<0.1	<0.1	T	100.0
10/1/79	ND										
10/3/79	17.7	77.6	T	0	4.4	0	0.3	<0.1	<0.1	T	100.0
10/5/79	20.0	78.1	0	0	1.7	0	0.1	T	0	0	99.9
10/9/79	ND										
10/11/79	17.7	78.0	0	0	4.0	0	0.3	<0.1	T	0	100.0
10/12/79	19.4	78.2	T	0	2.3	0	0.1	T	T	0	100.0
10/17/79	20.4	78.4	T	T	1.1	0	<0.1	T	0	0	99.9
10/19/79	19.9	78.4	T	T	1.5	0	0.1	0	0	0	99.9
10/22/79	20.7	78.3	0	0	1.0	0	<0.1	T	0	0	100.0
10/25/79	18.1	78.7	0.2	T	2.9	0	0.1	T	T	0	100.0
10/26/79	20.0	78.4	T	0	1.5	0	<0.1	0	0	0	99.9
10/31/79	20.7	78.3	T	0	1.0	0	<0.1	T	0	0	100.0
11/6/79	ND										
11/14/79	20.3	78.4	T	0	1.3	0	<0.1	T	0	0	100.0
11/21/79	21.3	78.1	T	0	0.6	0	<0.1	T	0	0	100.0
11/28/79	20.7	78.3	T	0	1.0	0	<0.1	0	0	0	100.0
12/7/79	20.9	78.3	0	0	0.8	0	<0.1	0	0	0	100.0

T Trace; response indicated but below 0.05 percent detection limit.
ND Not determined because glass sample bomb broken in transit.
[1] Mole percentage of oxygen includes argon.
[2] Lower detection limit of H_2S was 0.05 mole percent.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Evaluation of the temperature profiles and iso-temperature contours in the Anvil Points raw shale pile did not identify an ignition source or establish that spontaneous combustion is or was a factor. It was obvious that numerous hot spots were present, and that extensive retorting had taken place in the past. If spontaneous combustion was possible, identification of factors which may have controlled combustion such as porosity, moisture content, and subsurface air flow was not possible at the time. A relatively small area of the pile appeared to be undergoing combustion during the spring of 1980. The combustion process was greatly affected by the weather. During hot, dry periods, the rate of combustion increased greatly. Conversely, during the winter months, the rate of combustion was reduced. It appeared that some areas of the pile which had high porosity did not have combustion. Areas which had high density or packing also seemed lacking in evidence of combustion. A region of sufficient porosity allowing adequate combustion air and temperature insulation (along with adequate oil shale grade) appeared to be required before combustion could be initiated or maintained.

A combustion phenomenon was the occurrence of low temperature combustion at 200^{o} to 600^{o}F. Concentrations of approximately 1/2-inch x 1/2-inch particles were noted to be completely consumed without an increase in temp- erature or the rate of combustion. It was concluded that particle size, grade, void spaces, air supply, and perhaps other factors provided the crit- ical conditions for this and numerous other unique events.

5.2 Recommendations

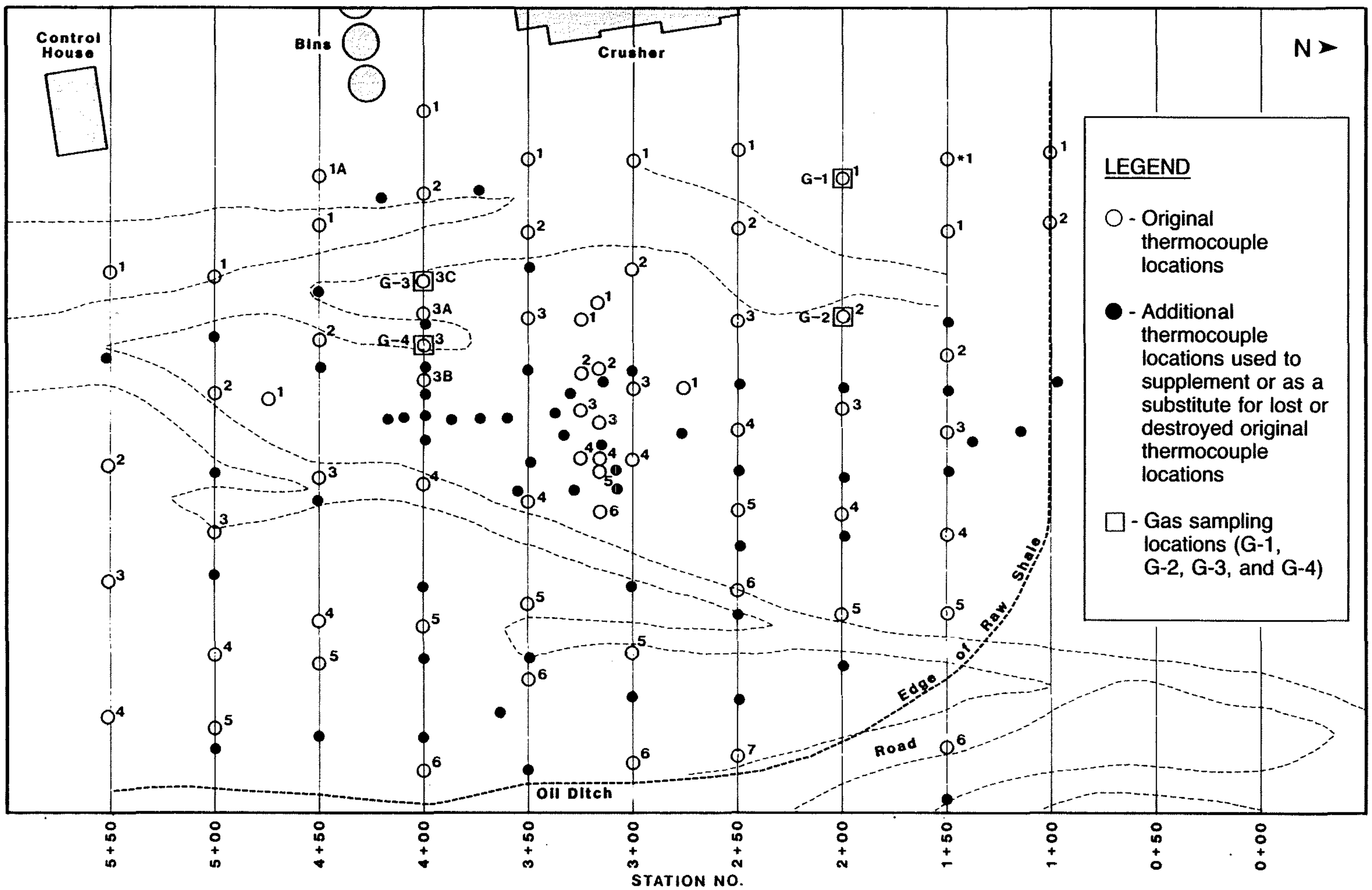
Further mitigating actions concerning the Anvil Points raw shale pile should have been preceded by a program to identify the characteristics of combustion areas. This program should have included determination of moisture, grade, and pile porosity along with possible identification of ignition sources and tracing by excavation of the fire paths in order to locate the sources and routes of numerous and possibly separate combustion events. Continuation of the gas monitoring program was recommended to identify potential for health and safety hazards to individuals working on the pile.

The low-temperature-combustion phenomena which has been observed in crushed oil shale should be further studied in order to define and quantify to the extent possible the conditions necessary for such events to occur.

Anvil Points Raw Shale Pile

CROSS SECTIONS AND TEMPERATURE PROFILES

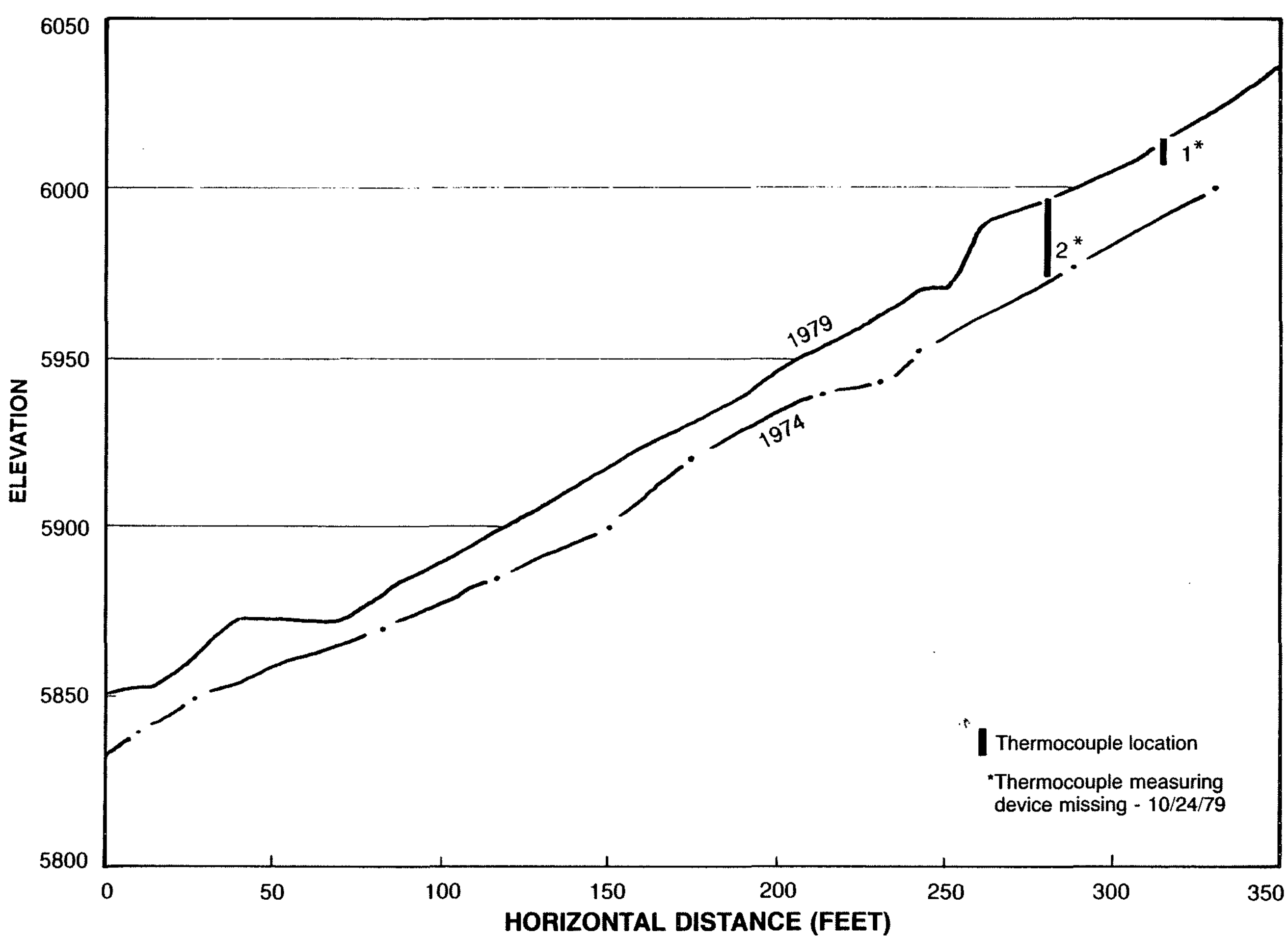
August 1979 to July 1980



Anvil Points Raw Shale Pile

THERMOCOUPLE LOCATIONS AND STATION INDEX FOR CROSS SECTIONS TO RAW SHALE PILE

Fig A.0

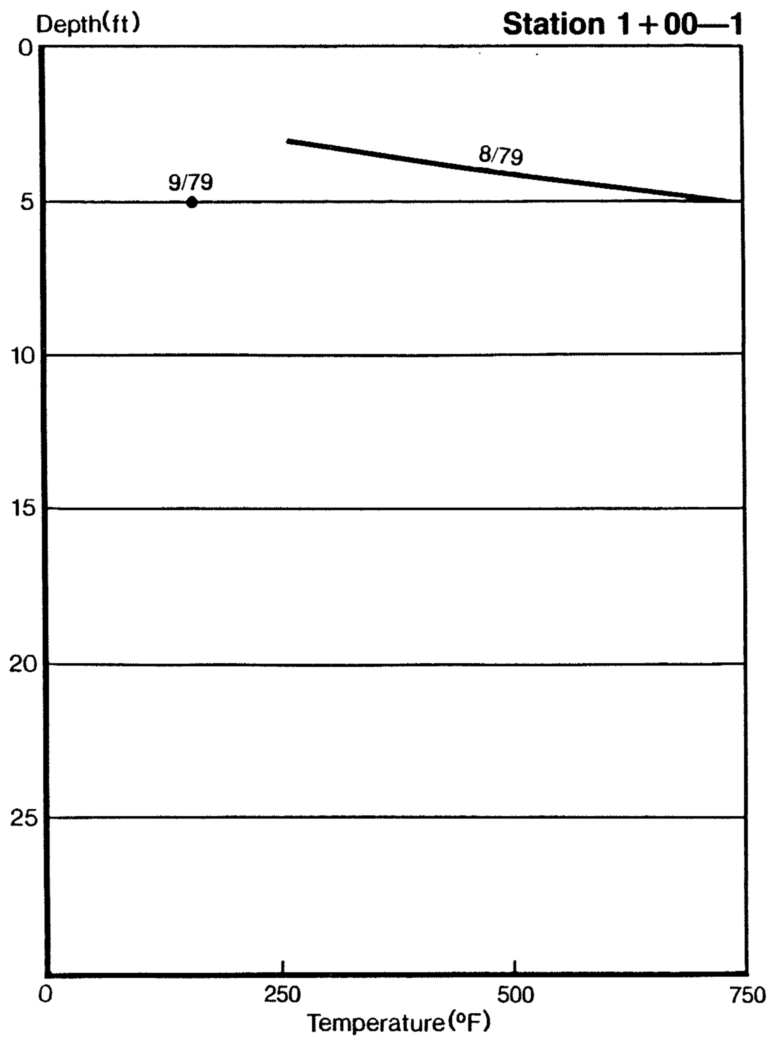


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

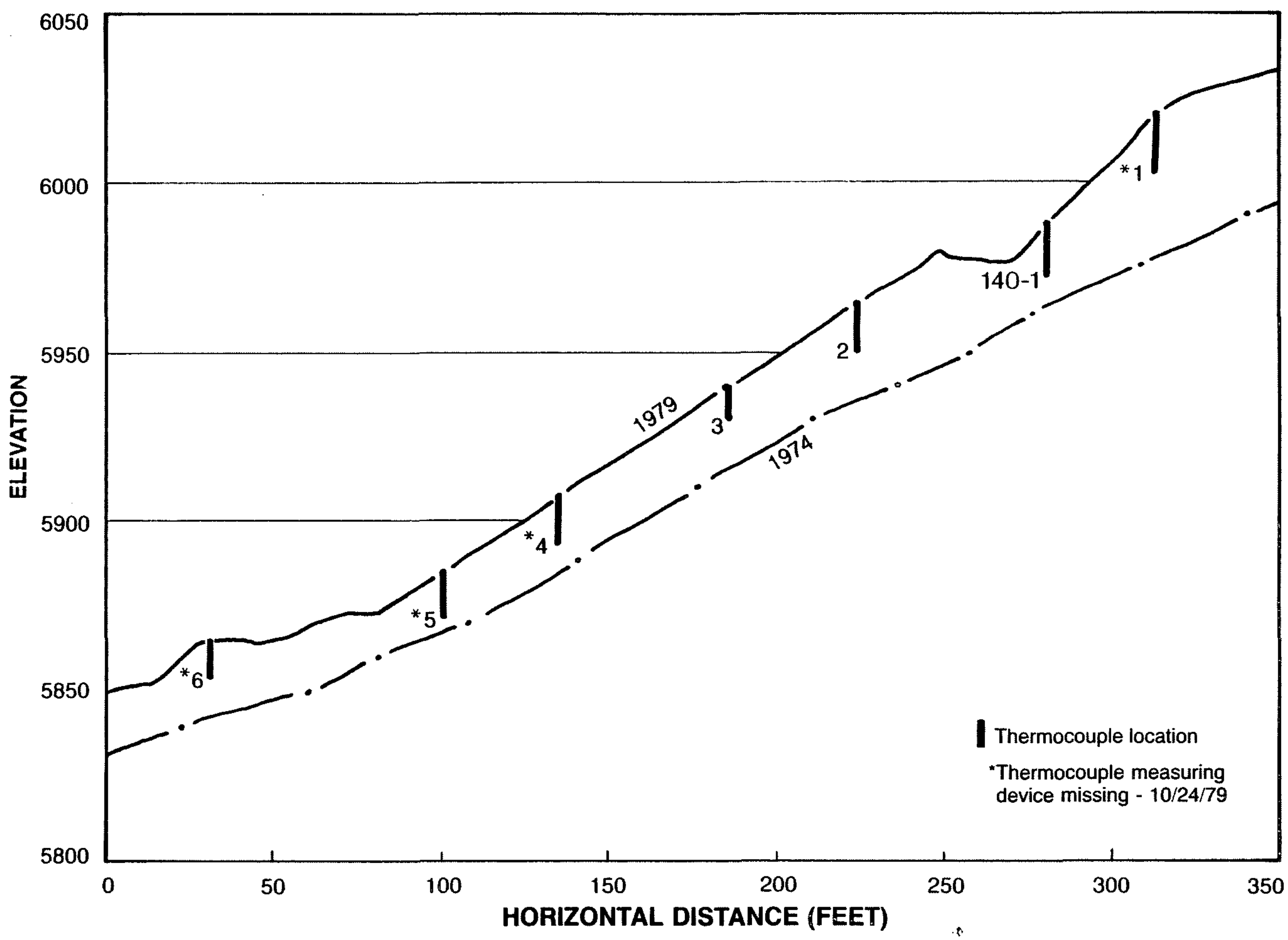
STATION 1 + 00

Fig A.1



MONTHLY TEMPERATURE PROFILE

Fig A.1 (continued)

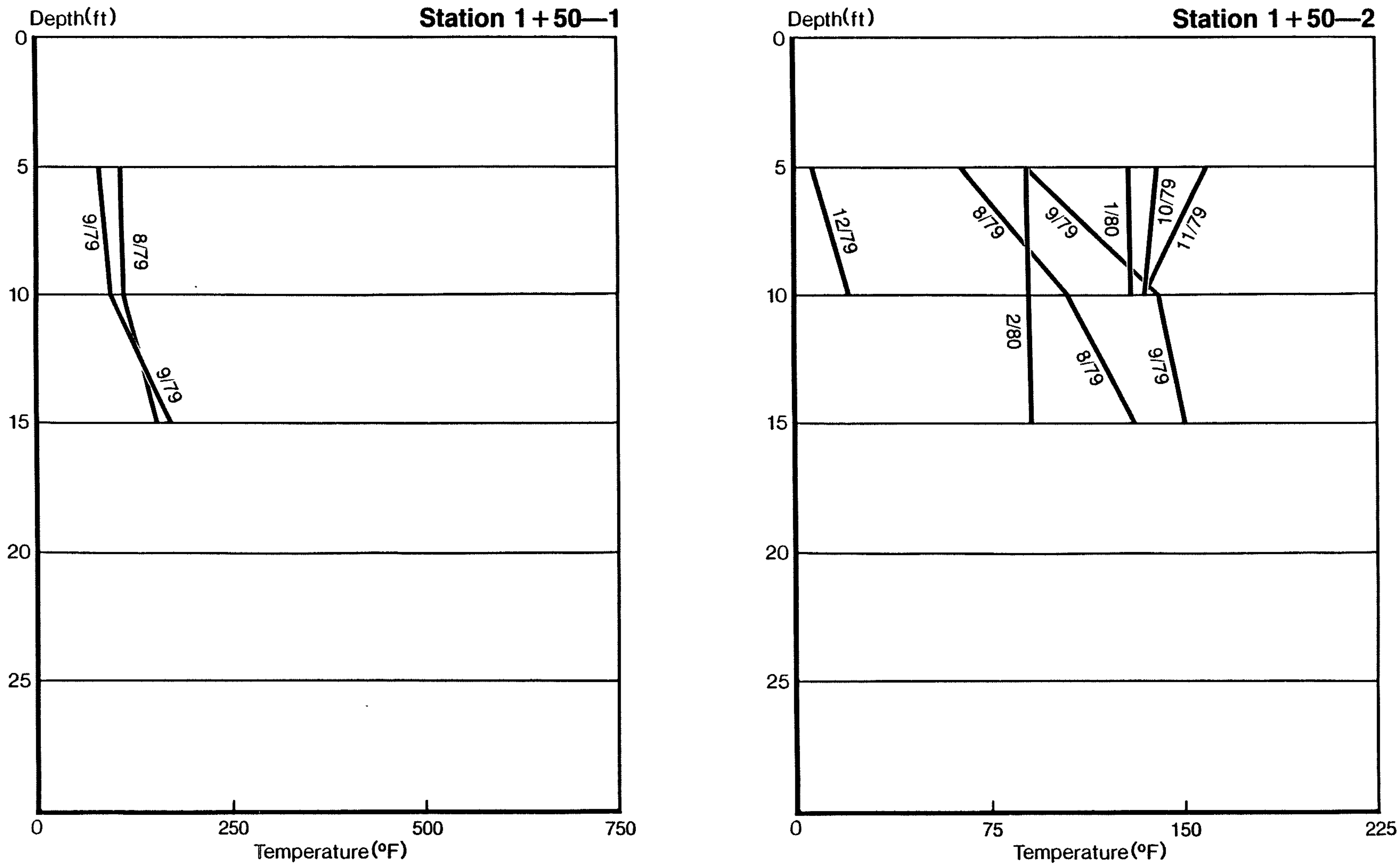


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

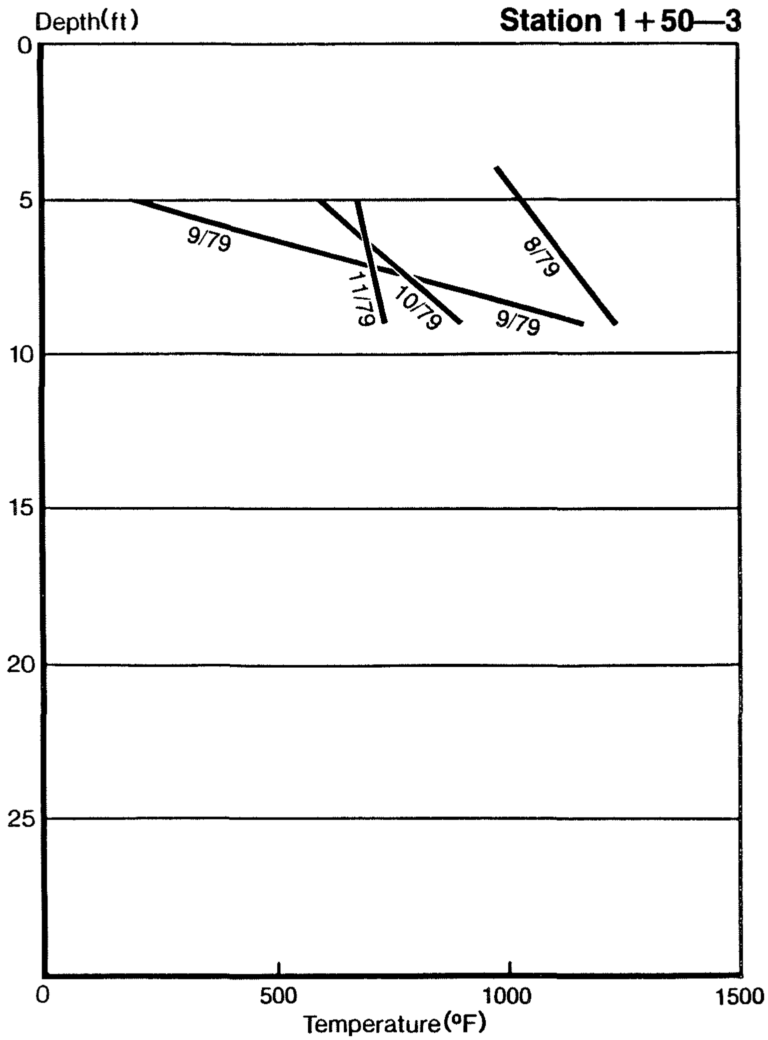
STATION 1 + 50

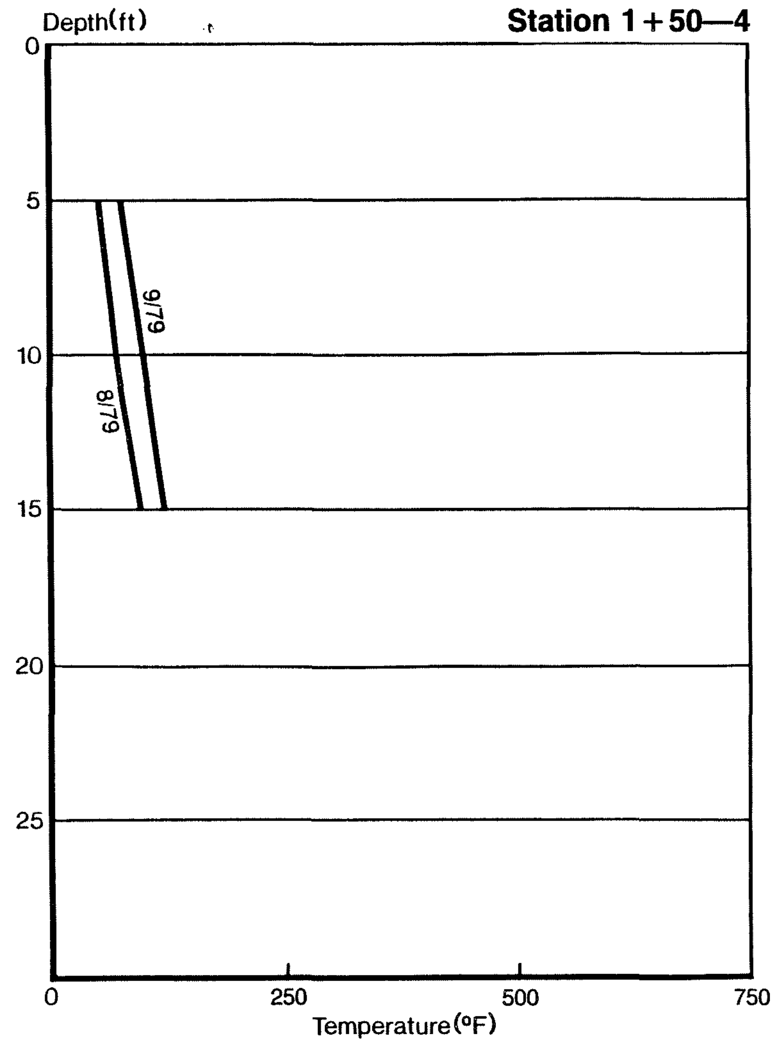
Fig A.2



MONTHLY TEMPERATURE PROFILES

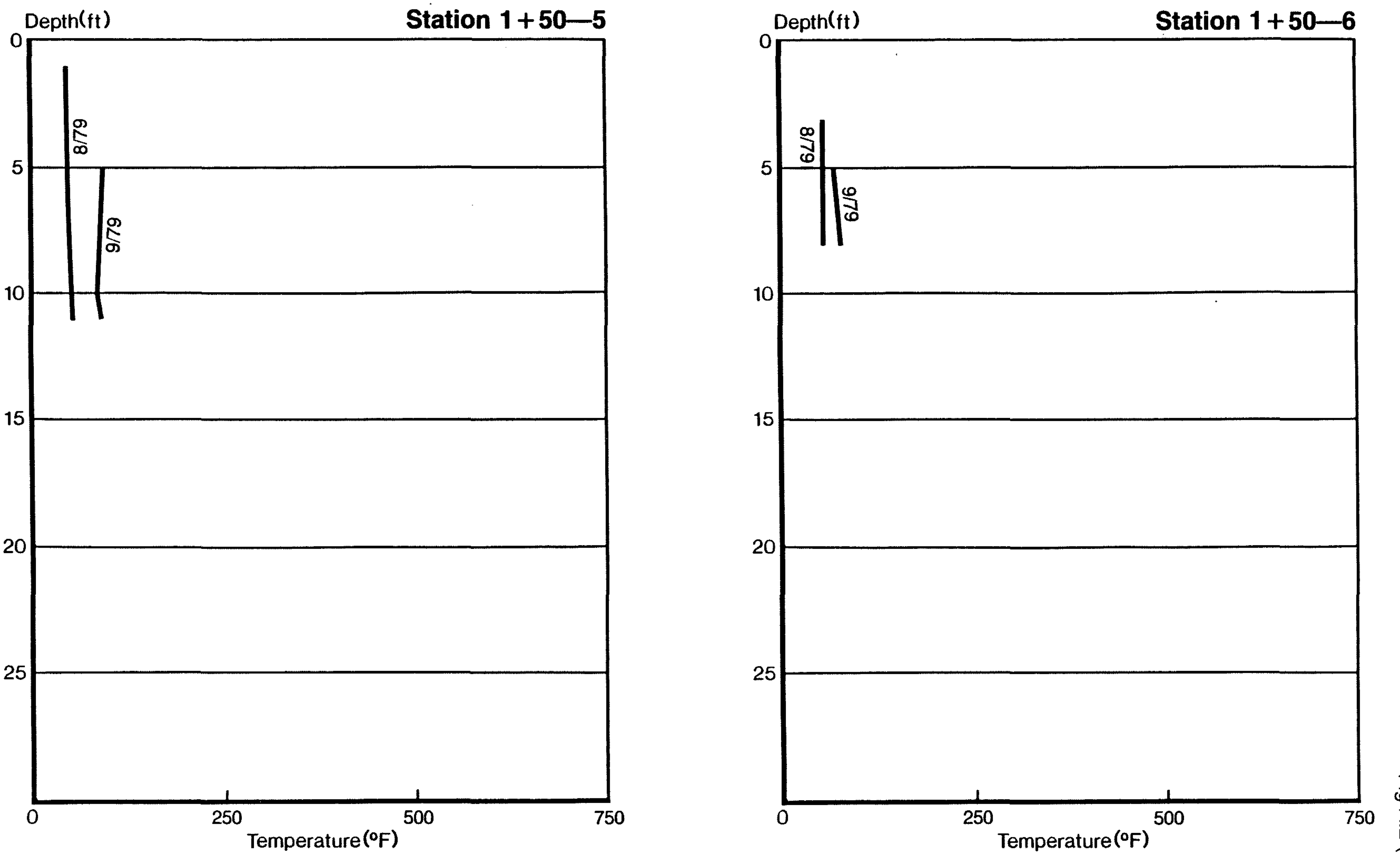
Fig A.2 (continued)





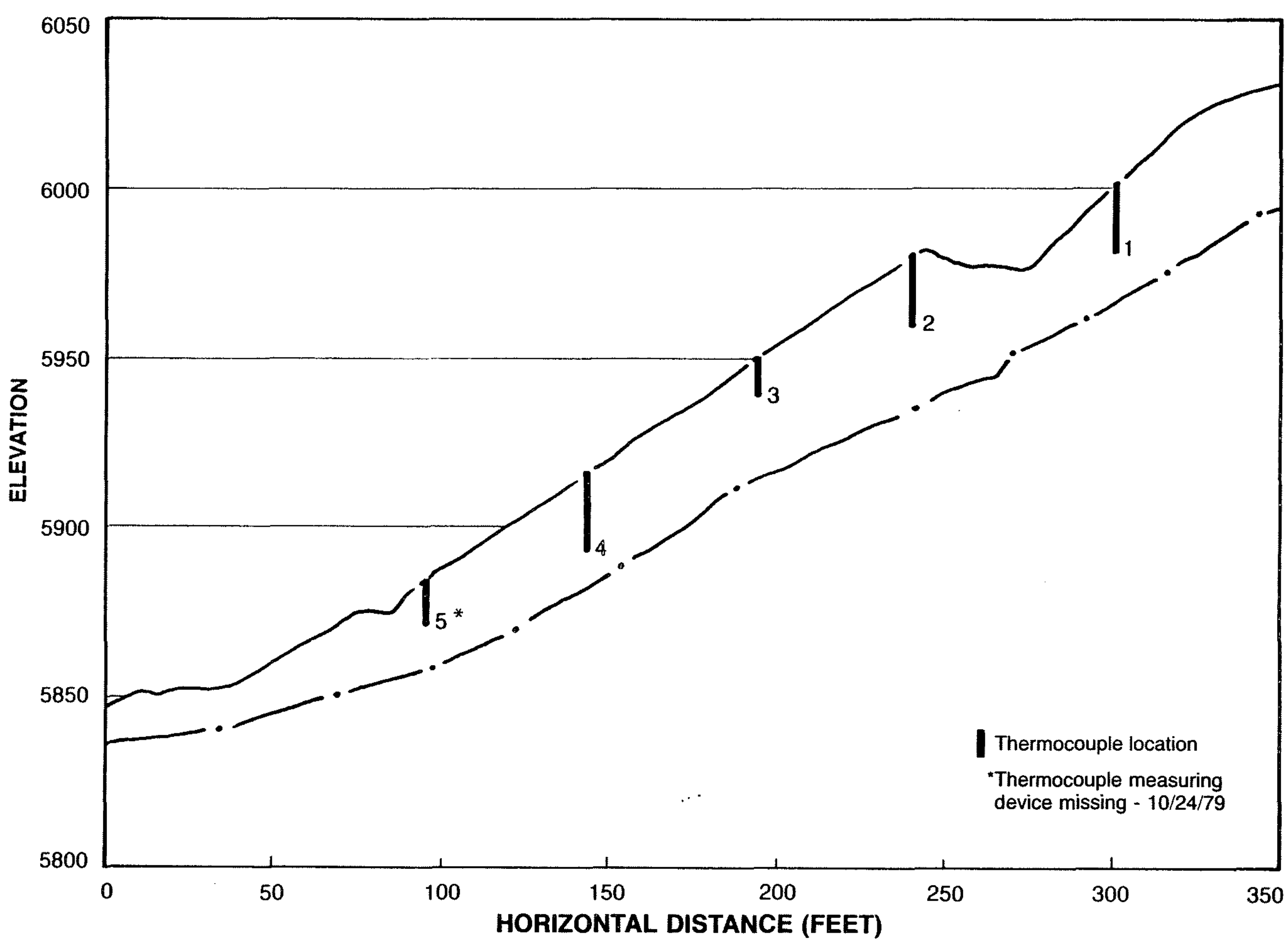
MONTHLY TEMPERATURE PROFILES

Fig A.2 (continued)



MONTHLY TEMPERATURE PROFILES

Fig A.2 (continued)

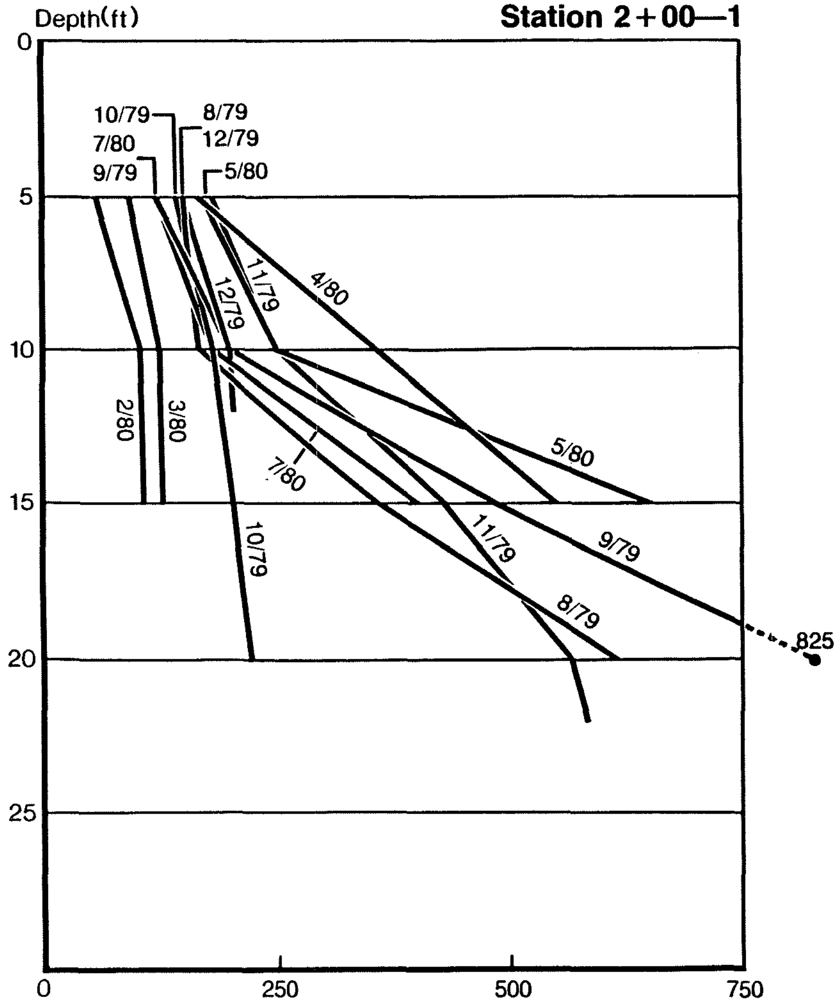


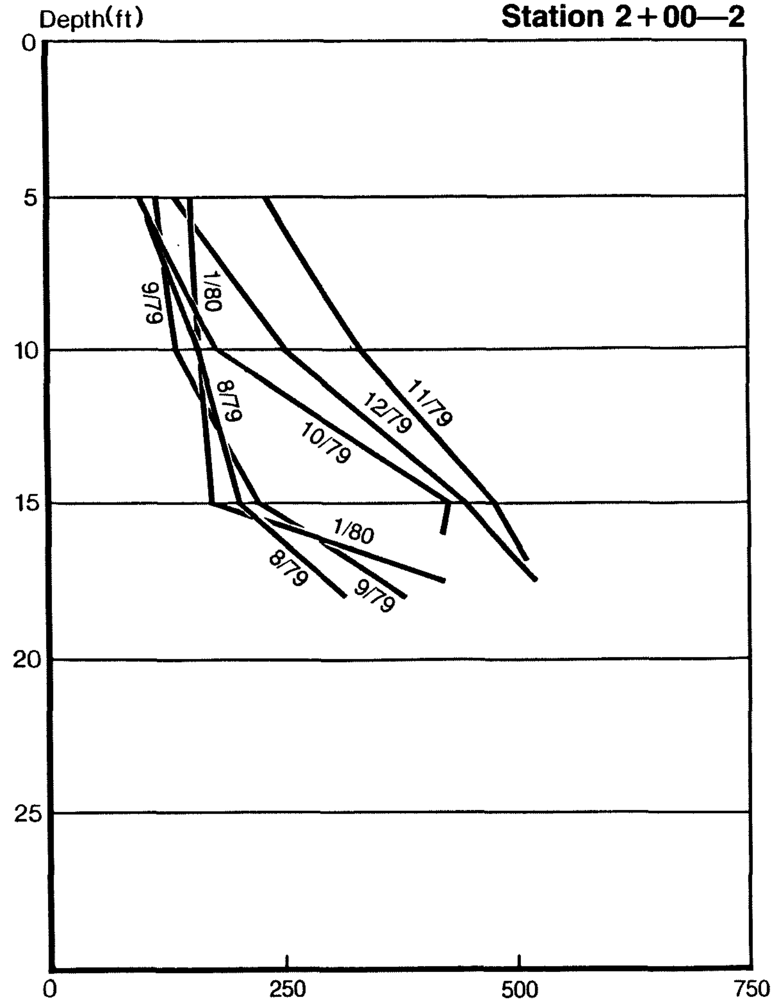
Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

STATION 2 + 00

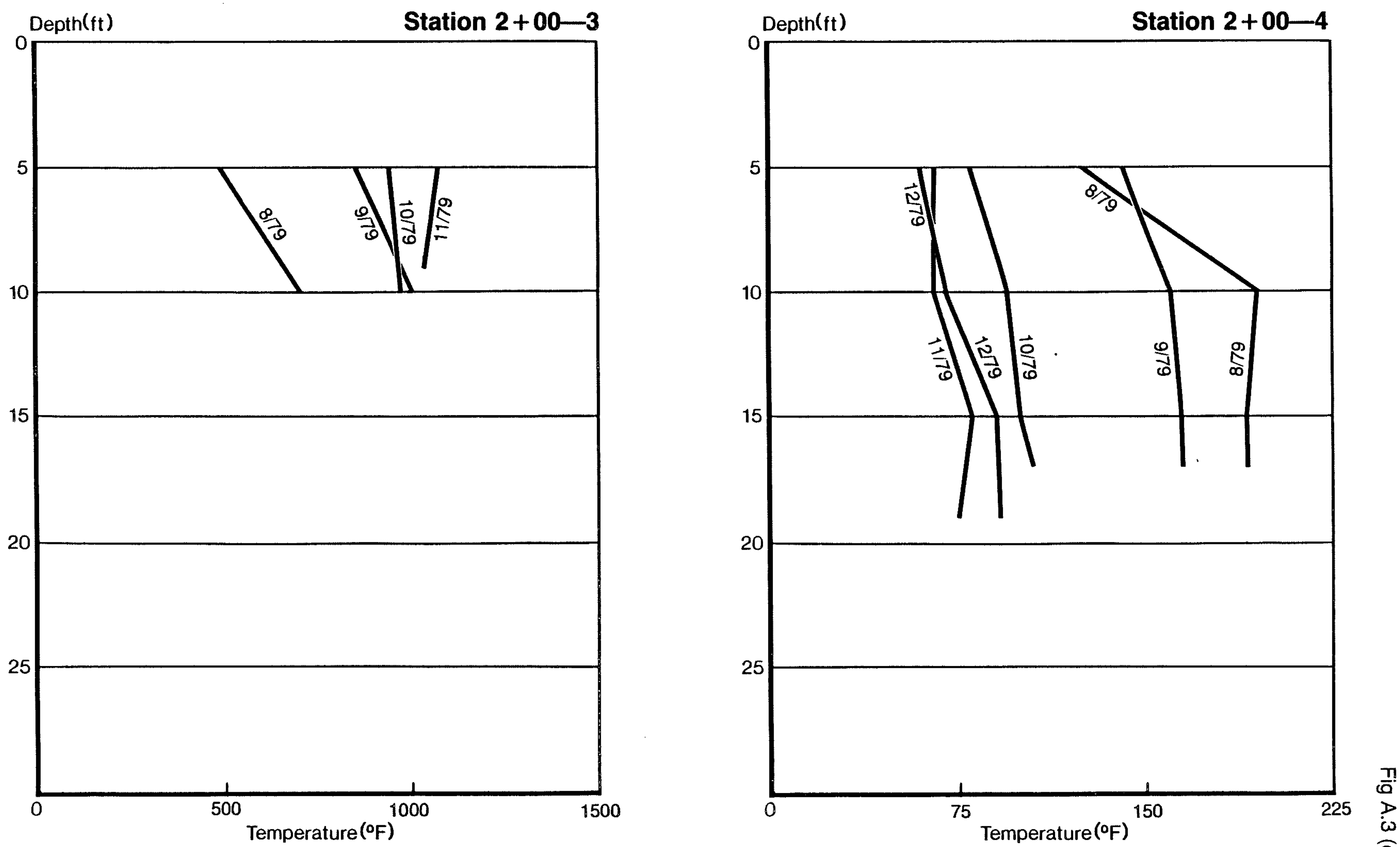
Fig A.3





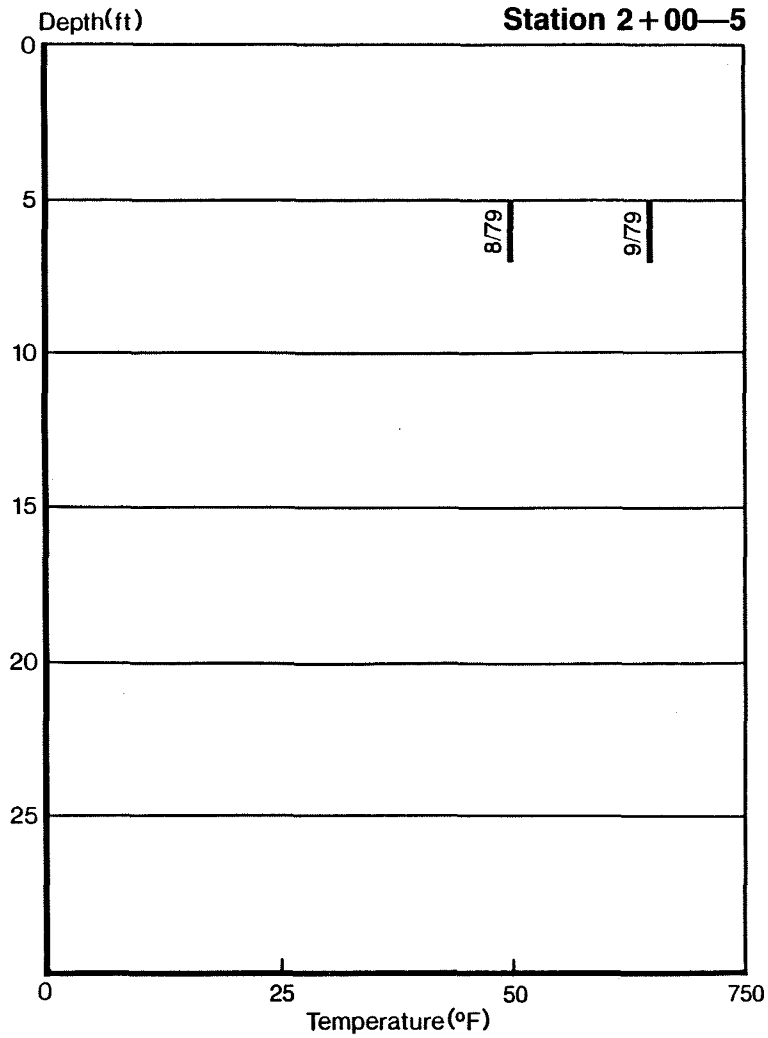
MONTHLY TEMPERATURE PROFILES

Fig A.3 (continued)



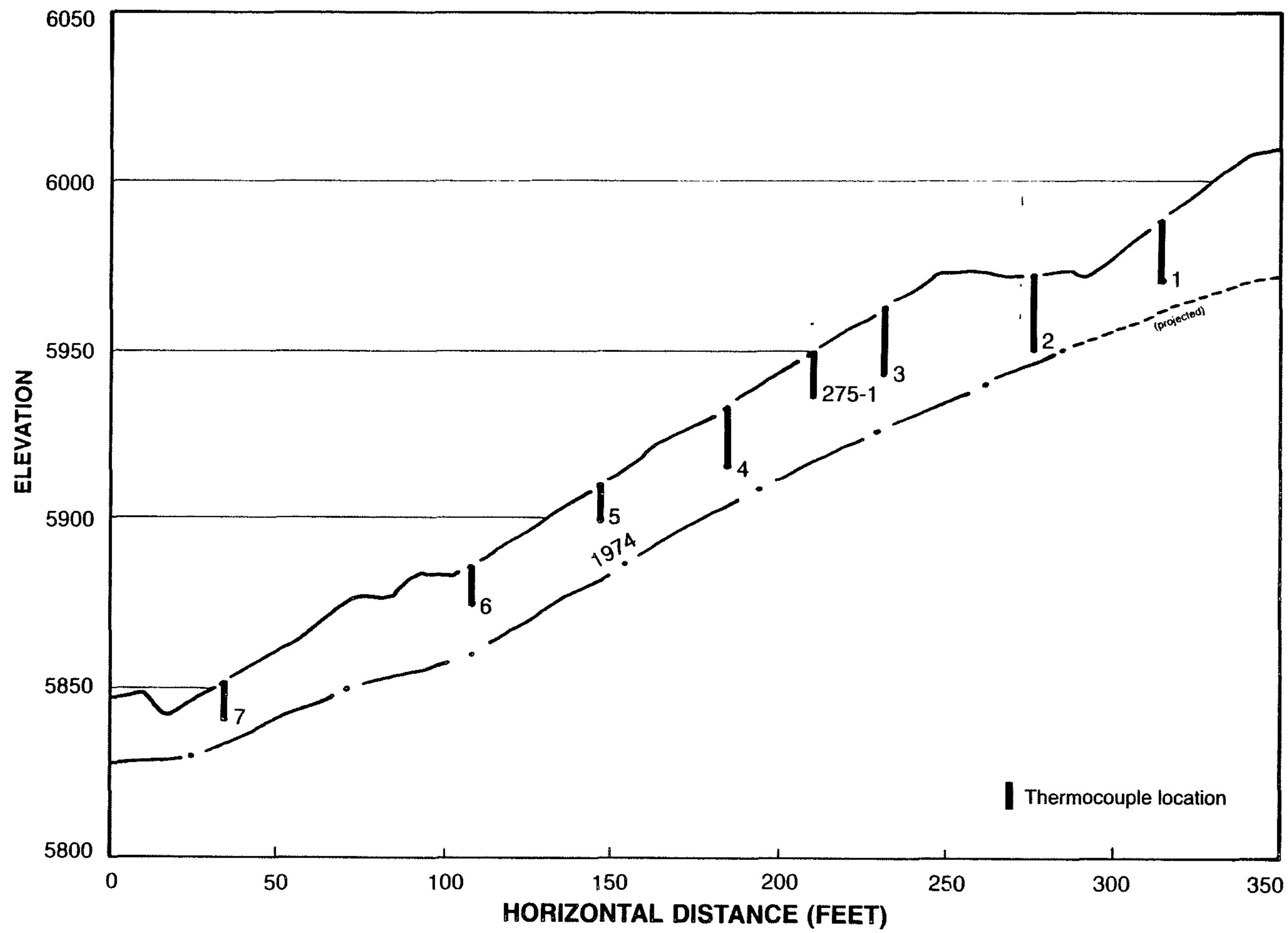
MONTHLY TEMPERATURE PROFILES

Fig A.3 (continued)



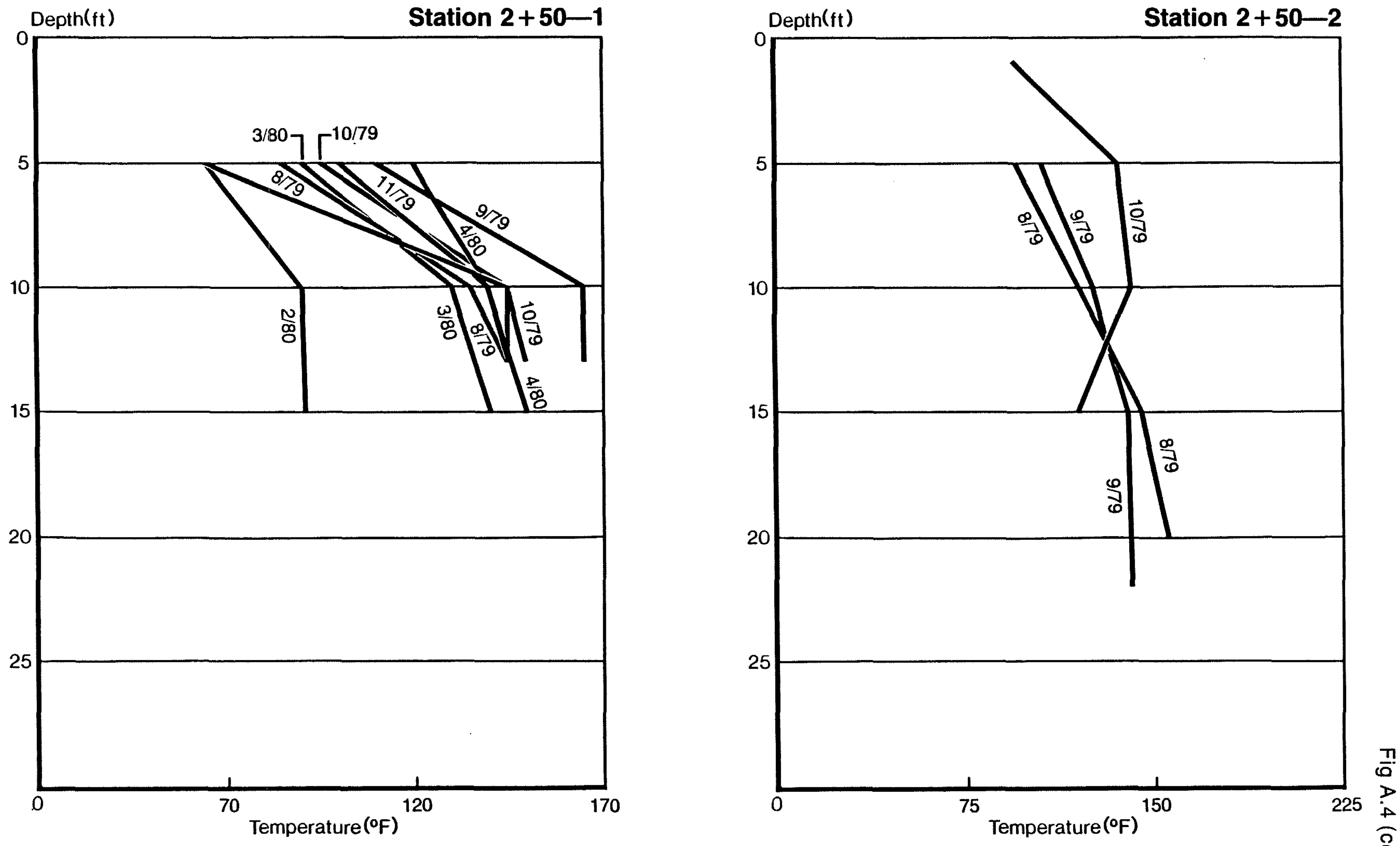
MONTHLY TEMPERATURE PROFILES

Fig A.3 (continued)



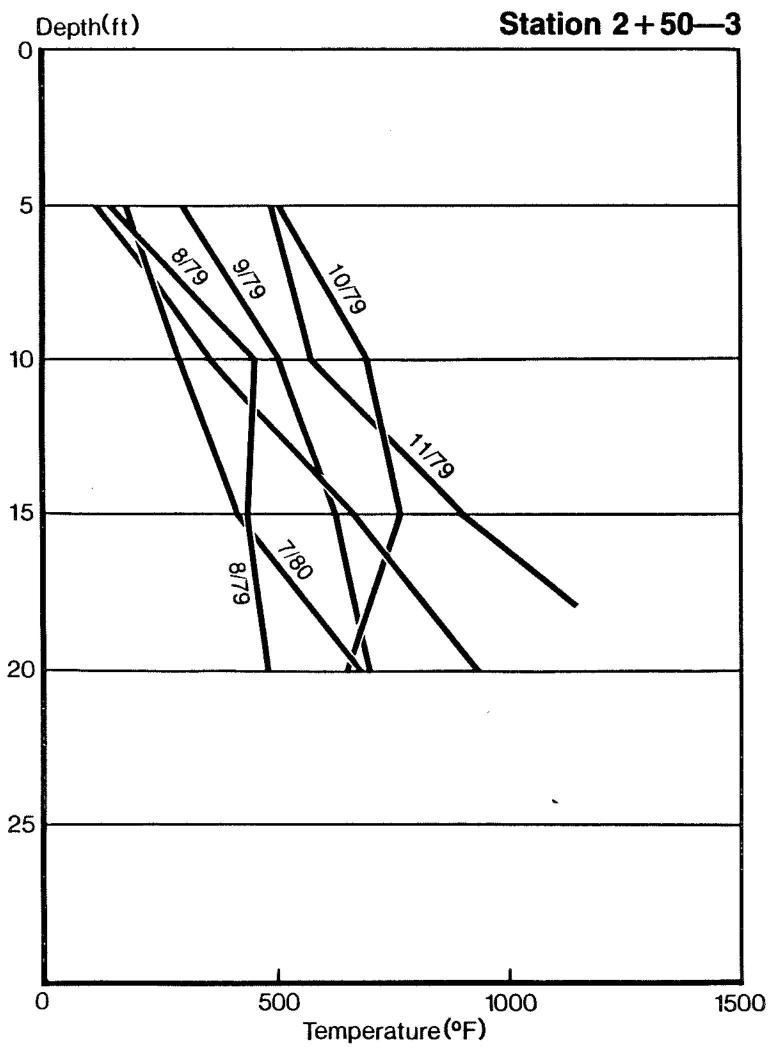
Anvil Points Raw Shale Pile
CROSS SECTION AND THERMOCOUPLE LOCATIONS
STATION 2 + 50

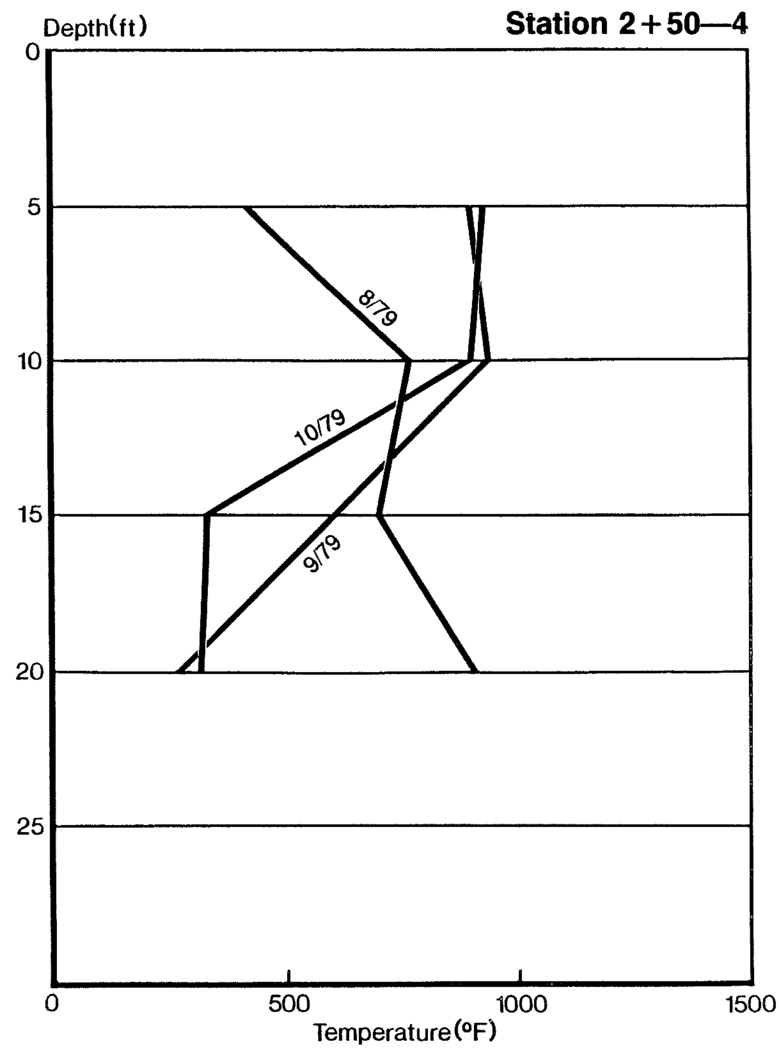
Fig A.4



MONTHLY TEMPERATURE PROFILES

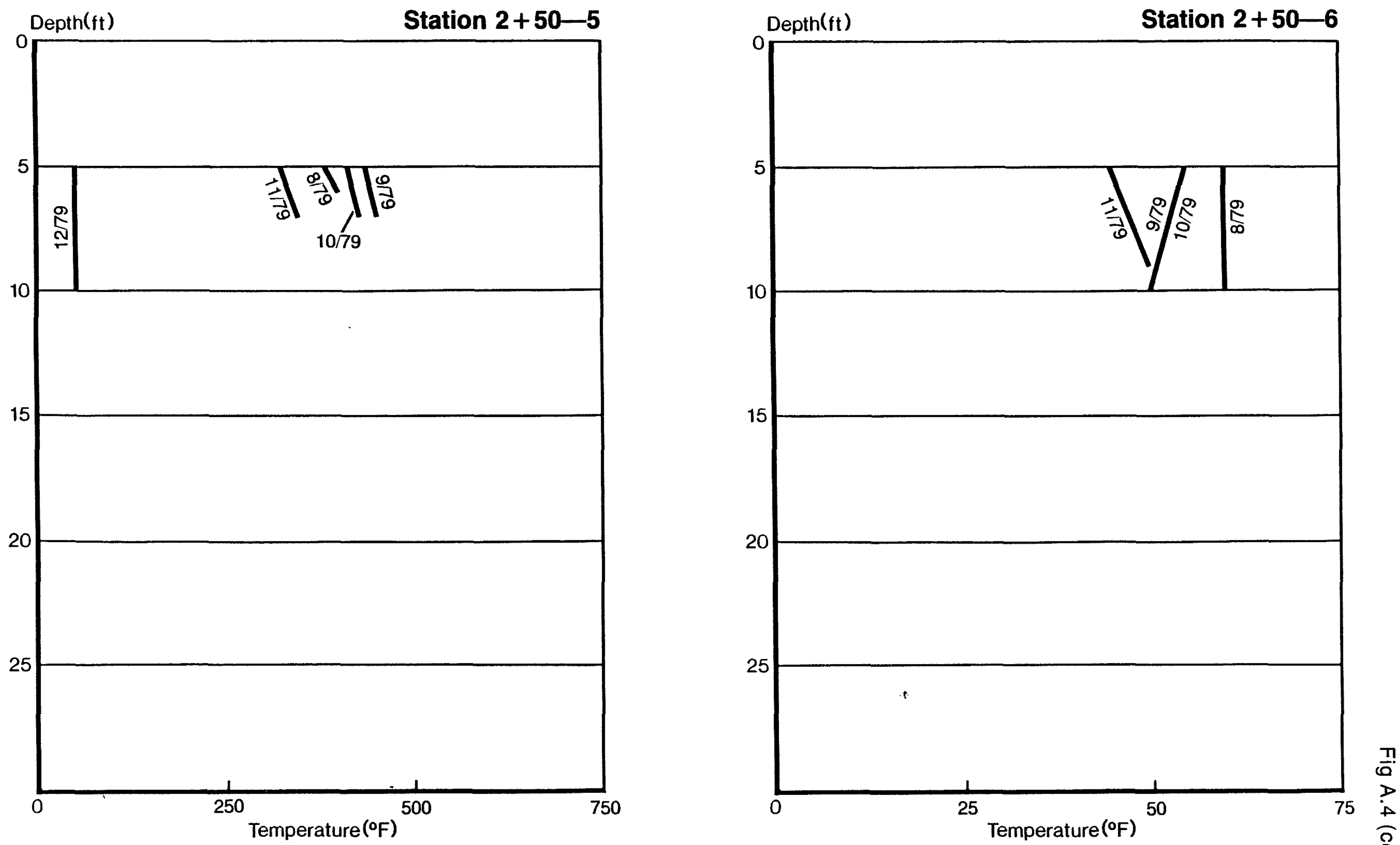
Fig A.4 (continued)





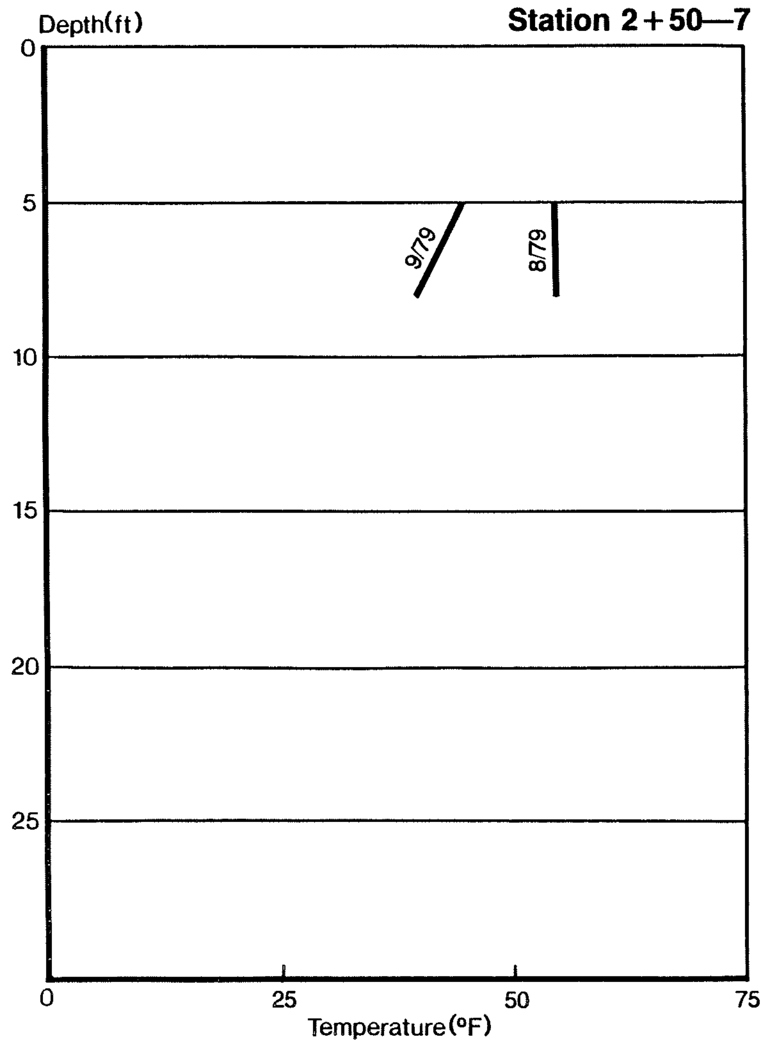
MONTHLY TEMPERATURE PROFILES

Fig A.4 (continued)



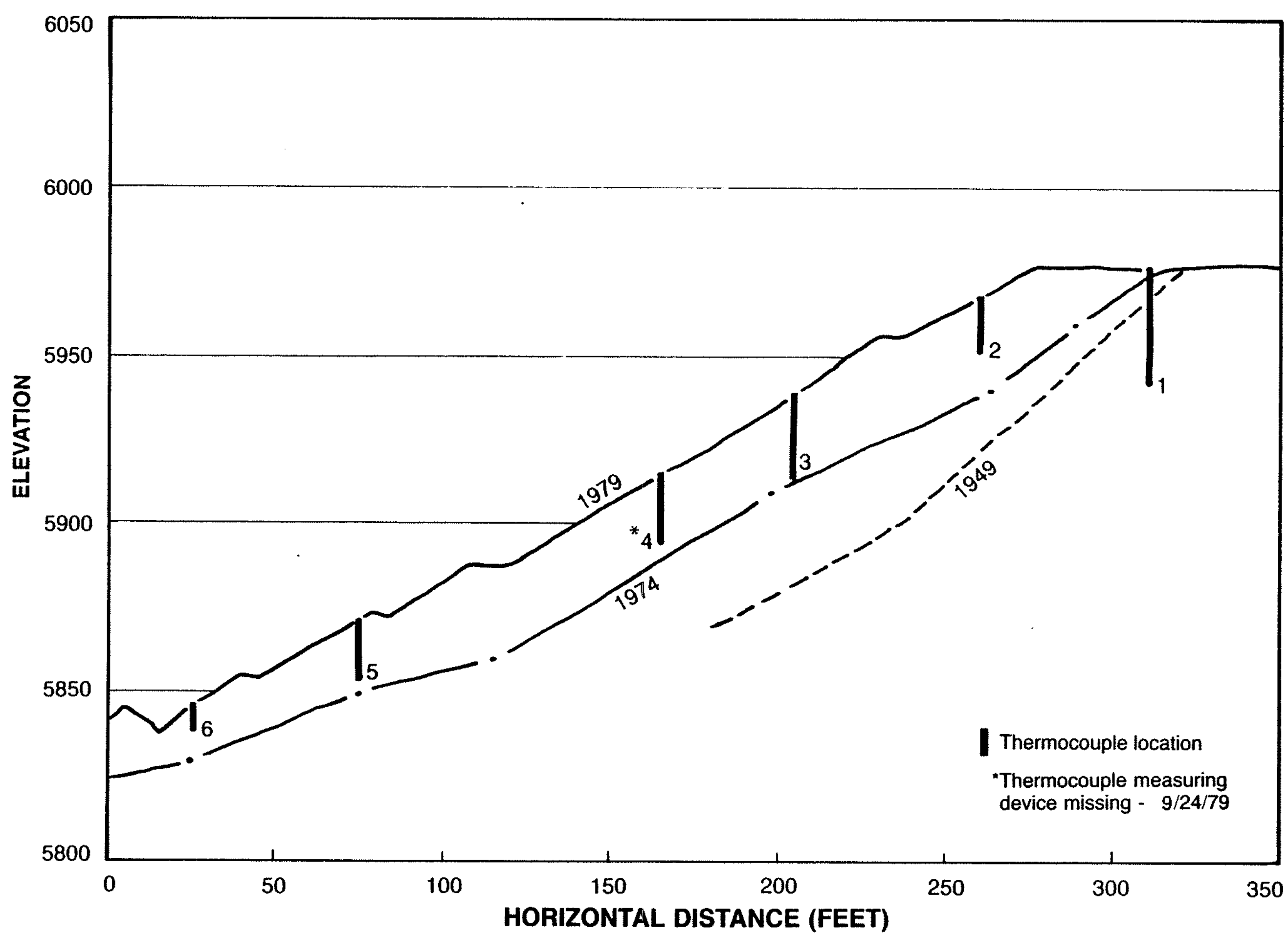
MONTHLY TEMPERATURE PROFILES

Fig A.4 (continued)



MONTHLY TEMPERATURE PROFILE

Fig A.4 (continued)

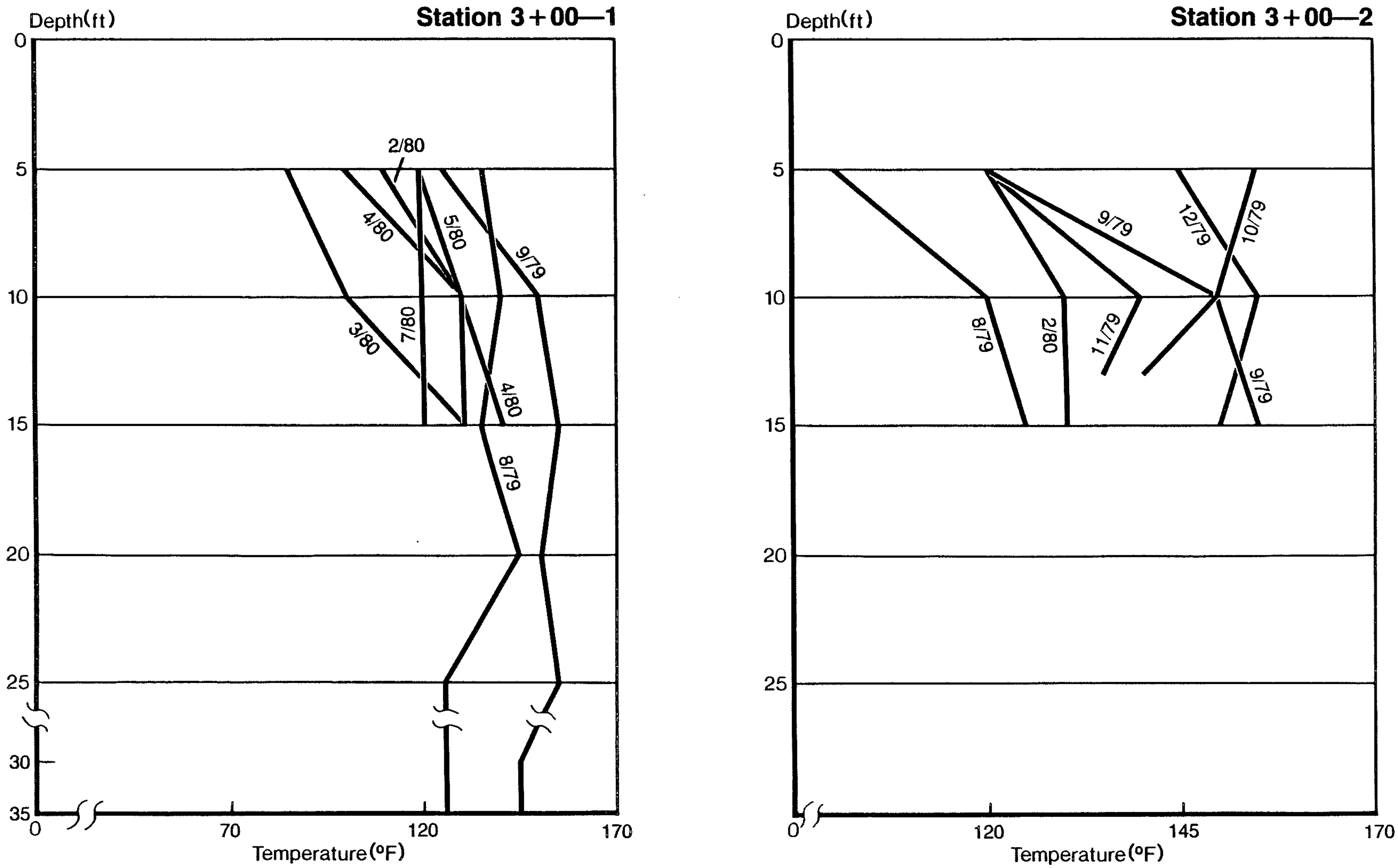


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

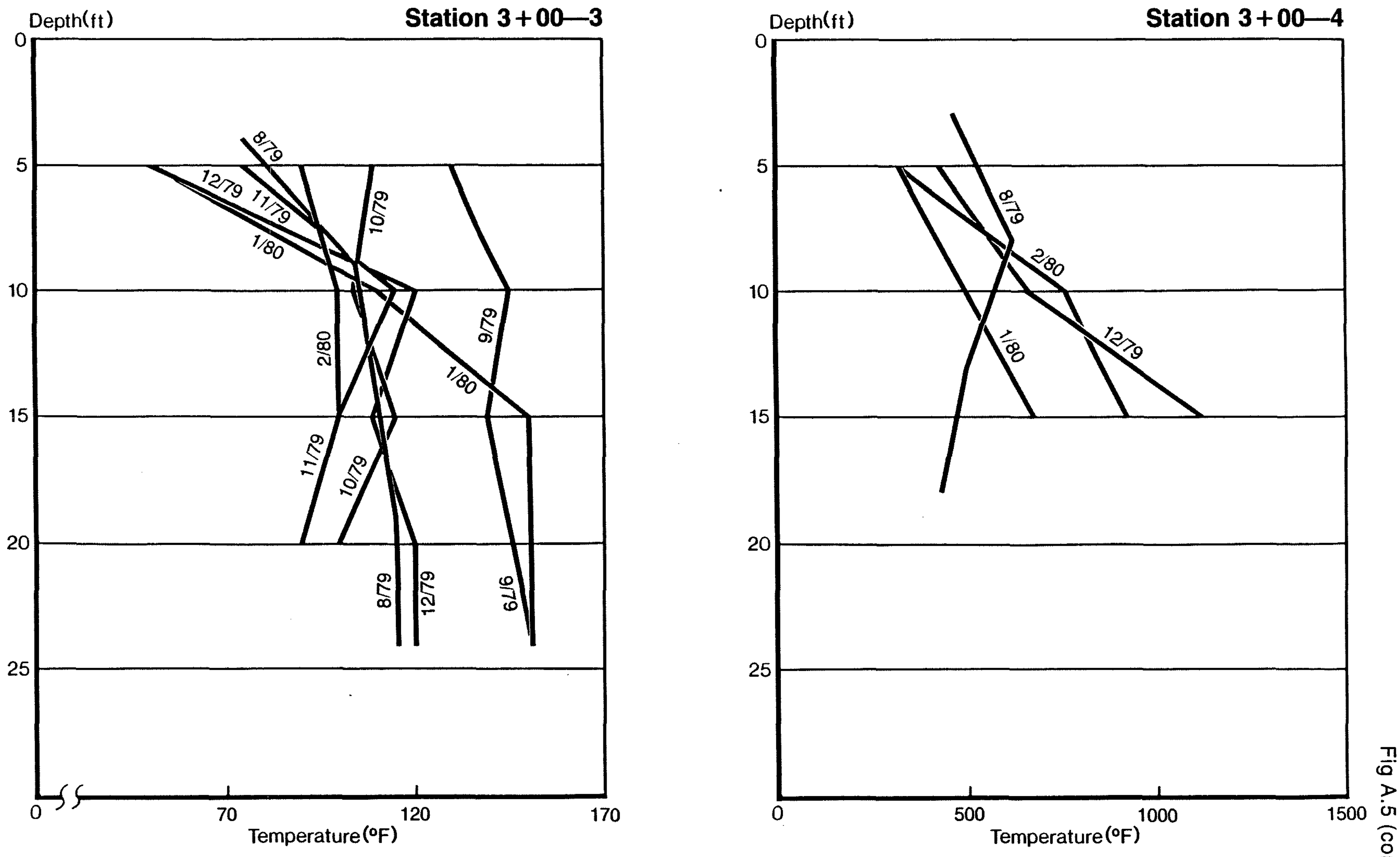
STATION 3 + 00

Fig A.5



MONTHLY TEMPERATURE PROFILES

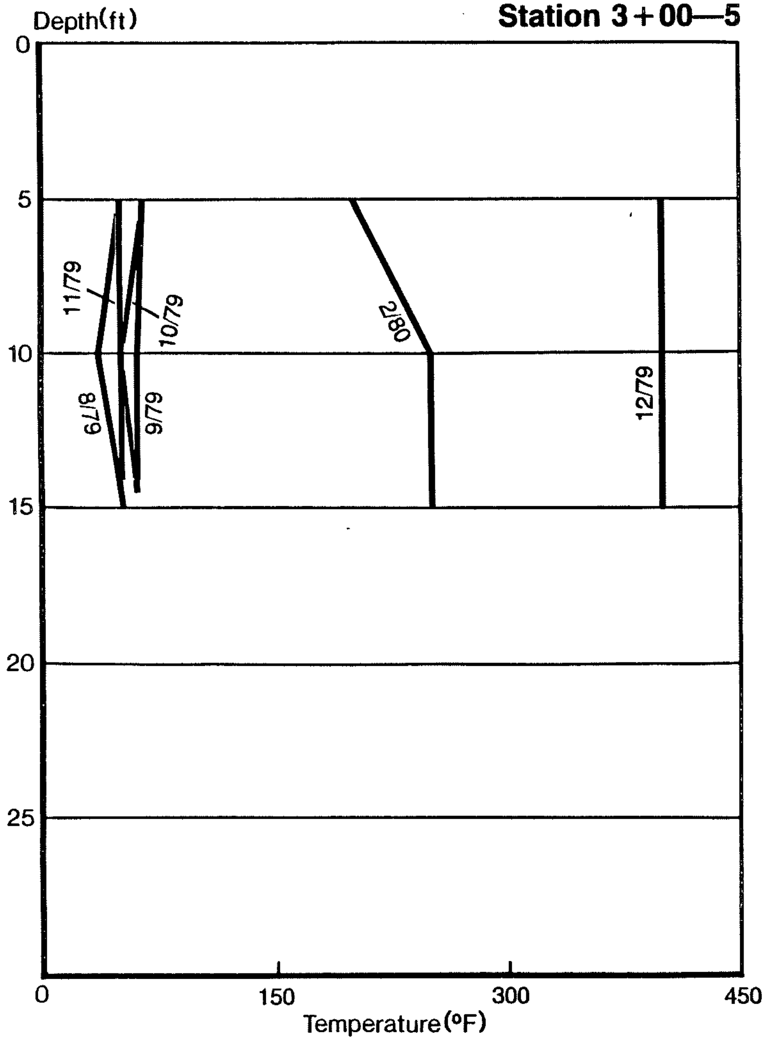
Fig A.5 (continued)



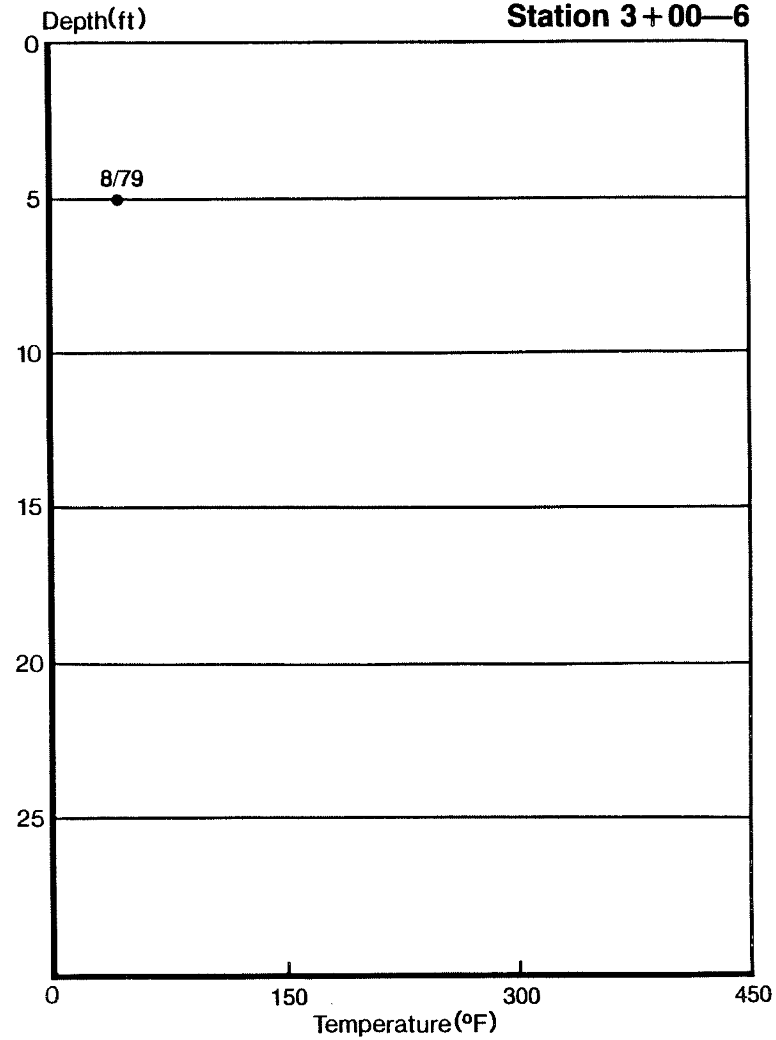
MONTHLY TEMPERATURE PROFILES

Fig A.5 (continued)

Station 3+00—5

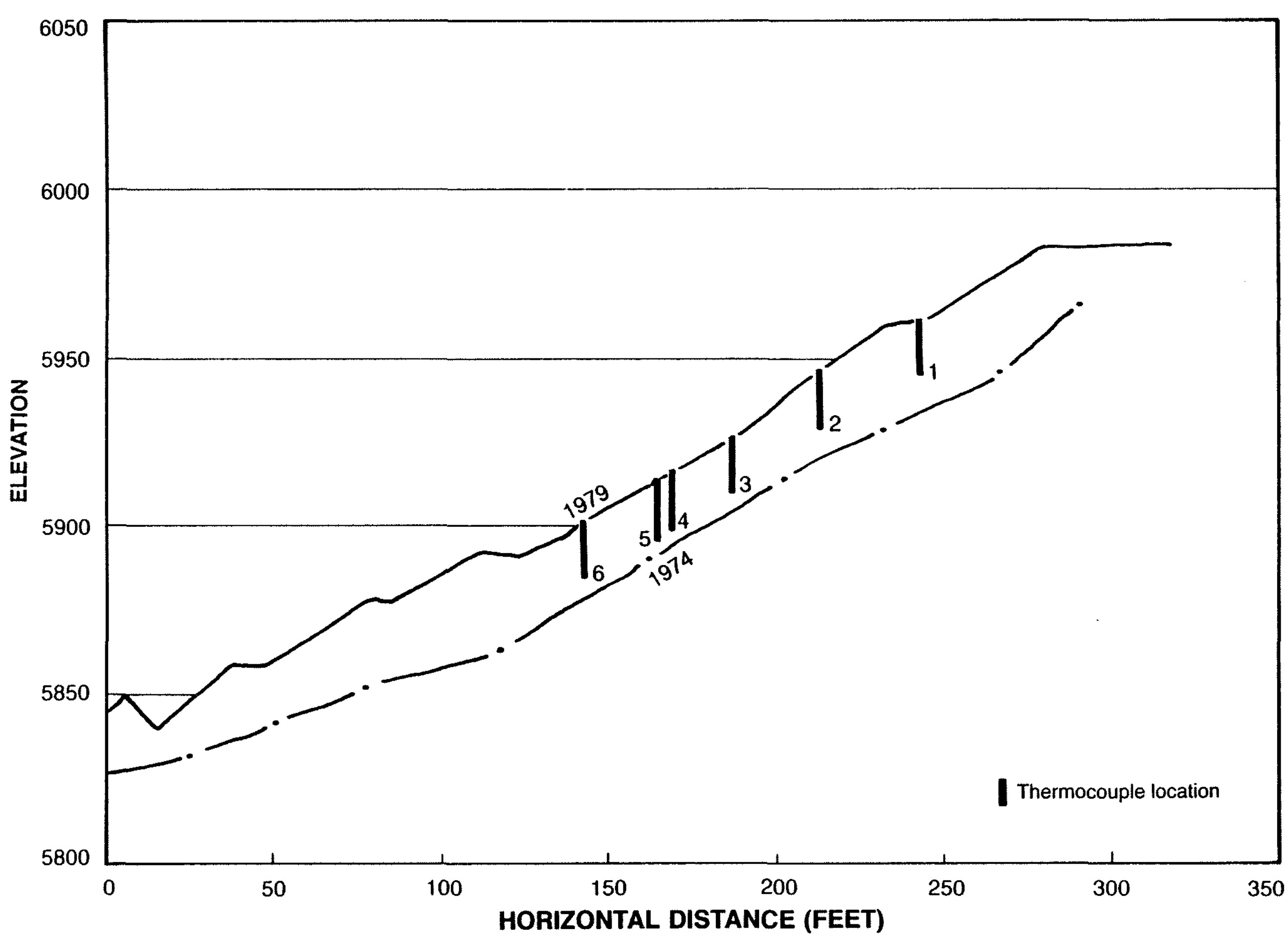


Station 3+00—6



MONTHLY TEMPERATURE PROFILES

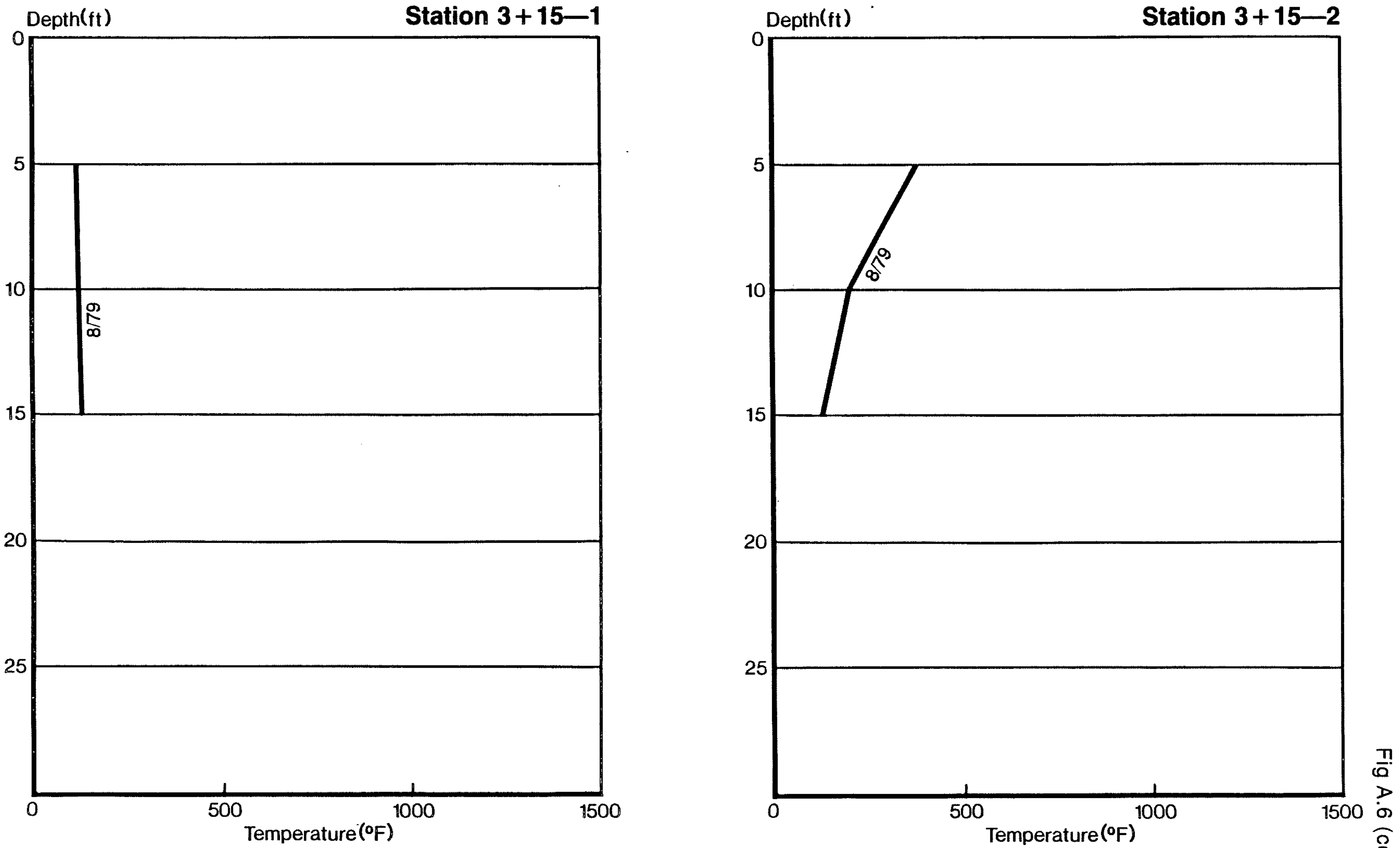
Fig A.5 (continued)



Anvil Points Raw Shale Pile

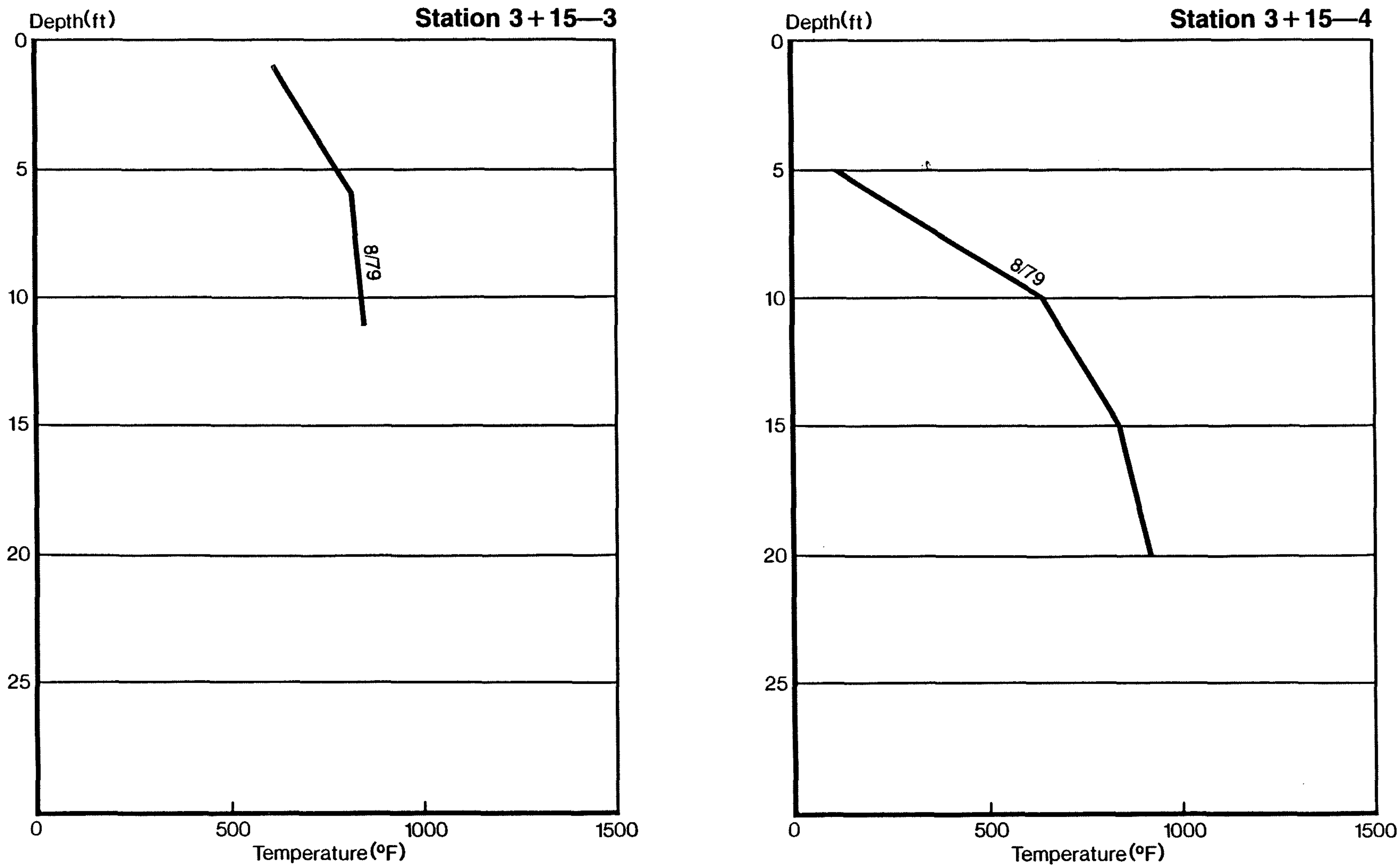
CROSS SECTION AND THERMOCOUPLE LOCATIONS
STATION 3+15

Fig A.6



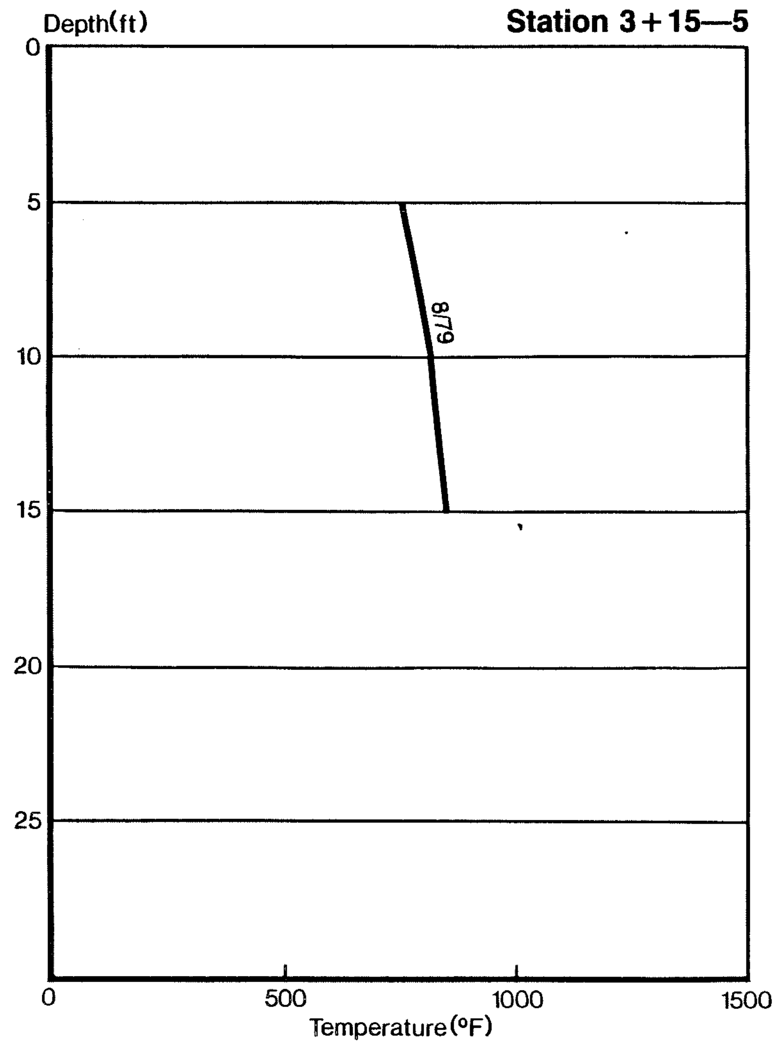
MONTHLY TEMPERATURE PROFILES

Fig A.6 (continued)



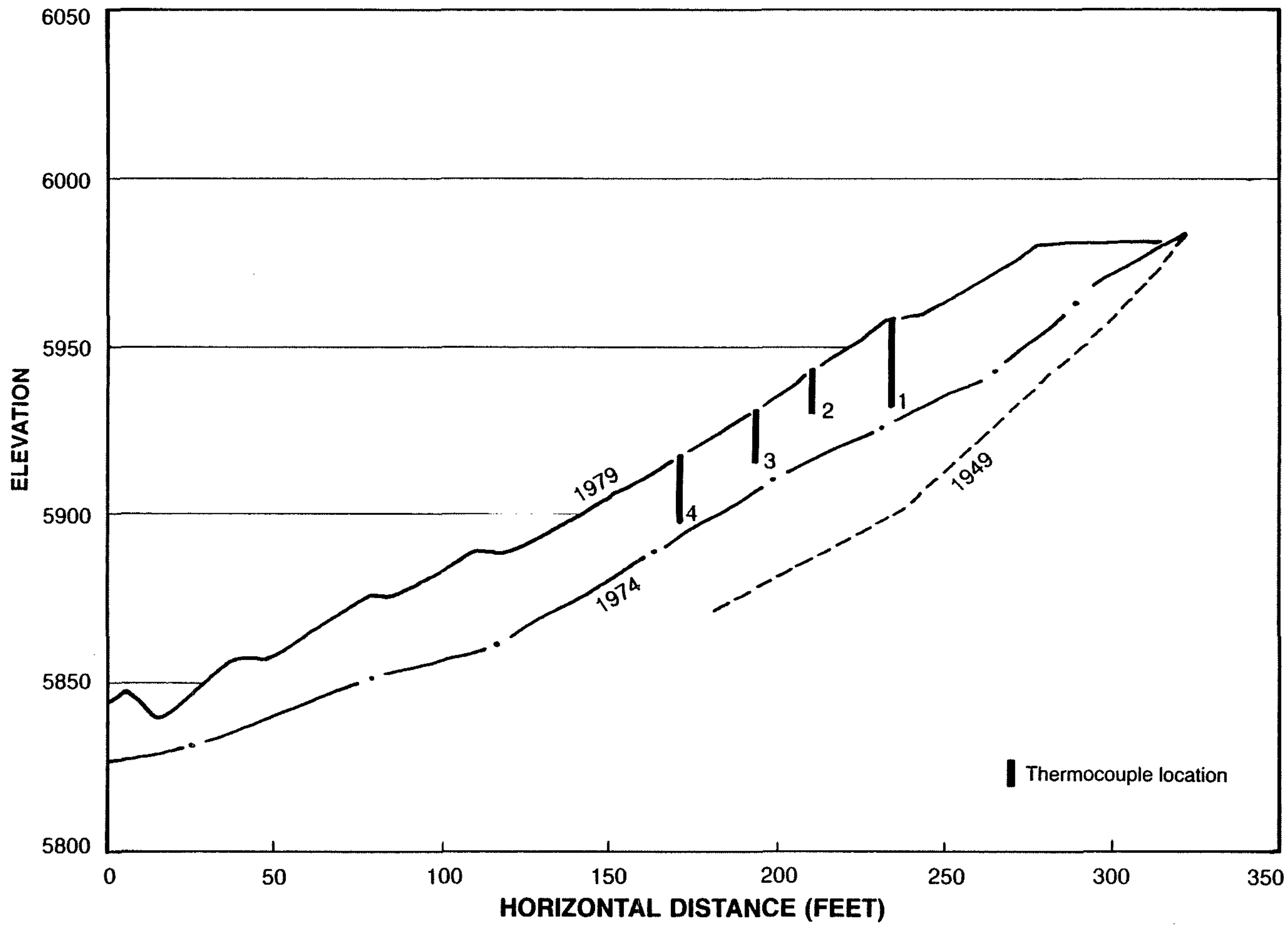
MONTHLY TEMPERATURE PROFILES

Fig A.6 (continued)



MONTHLY TEMPERATURE PROFILES

Fig A.6 (continued)

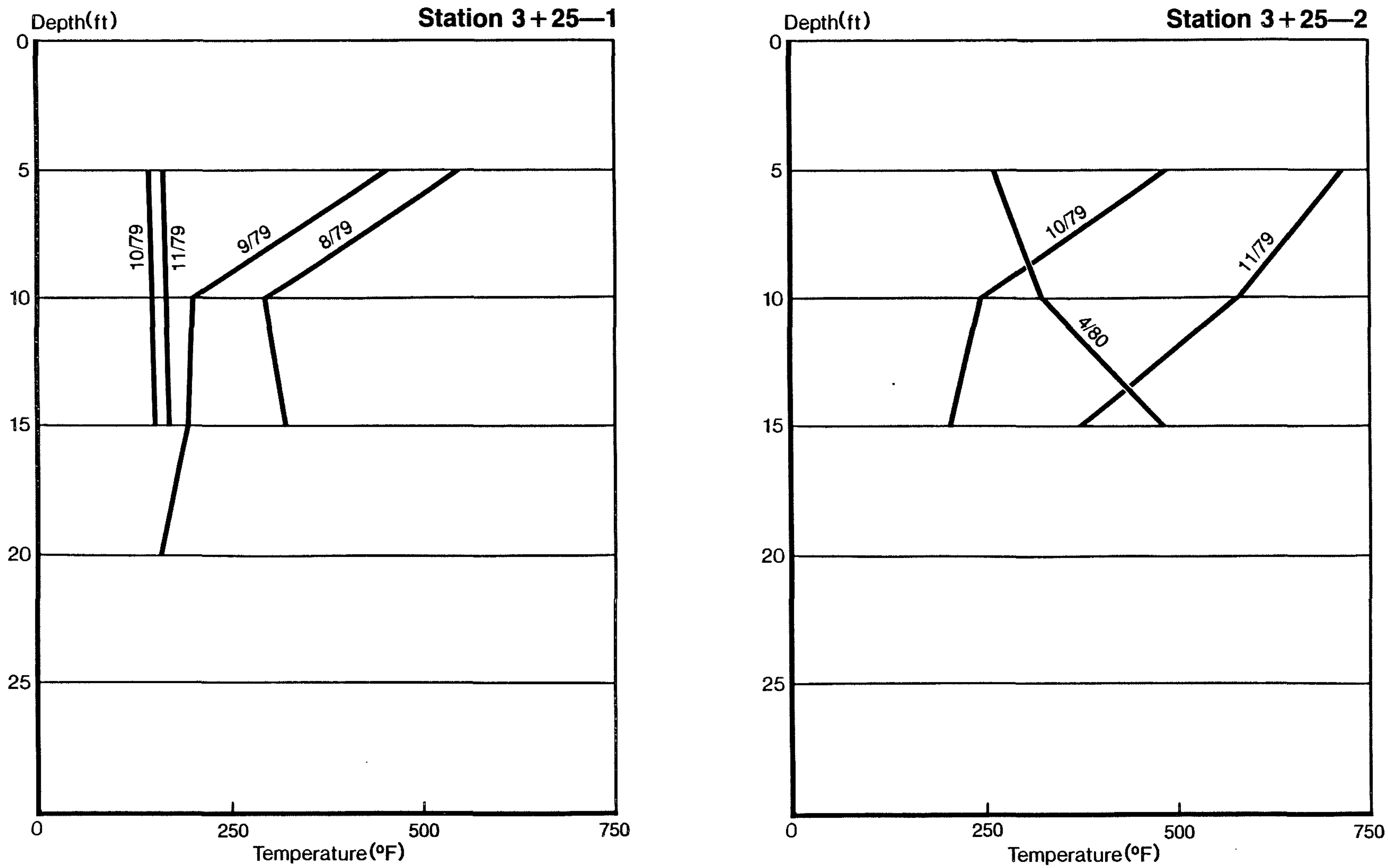


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

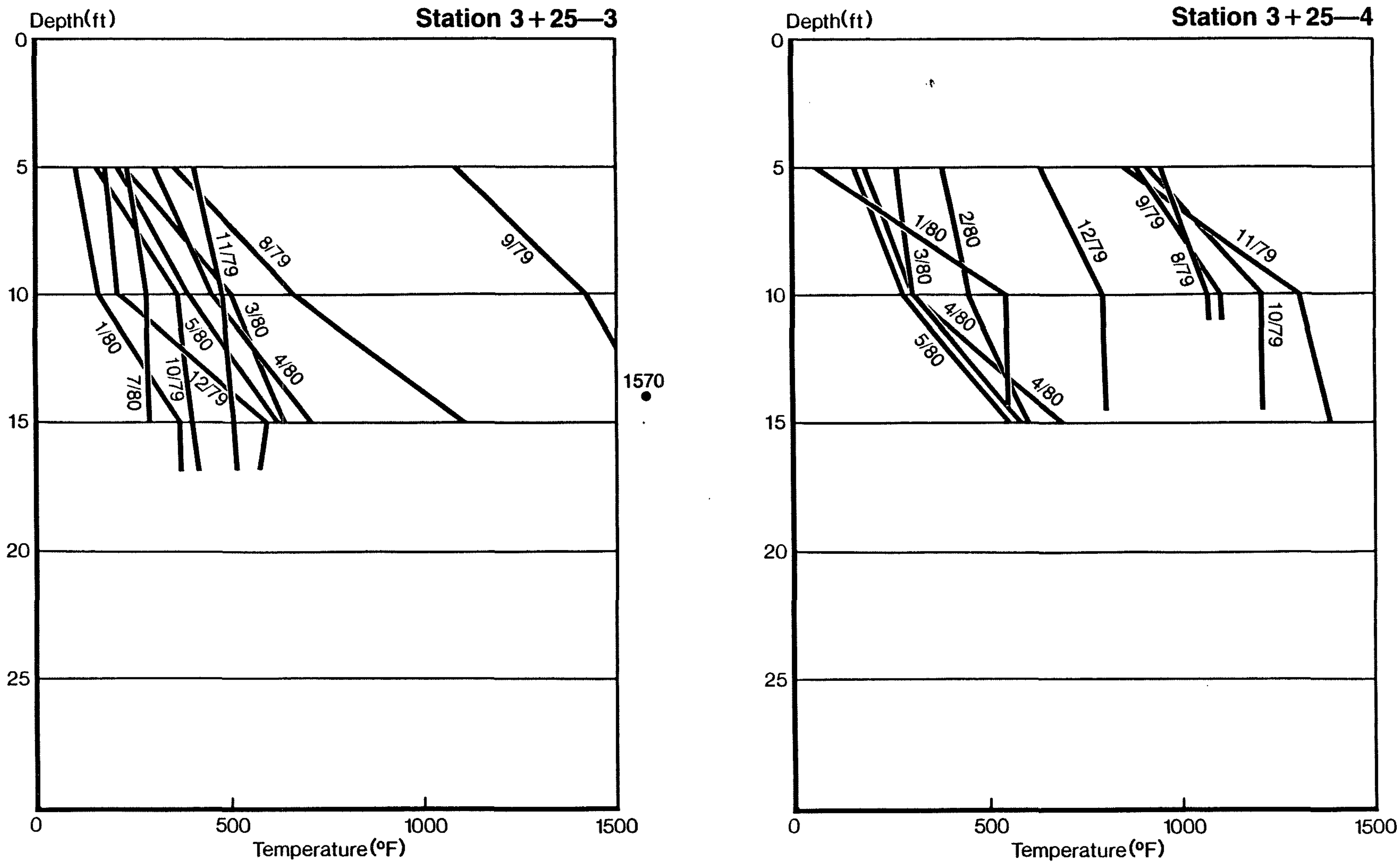
STATION 3+25

Fig A.7



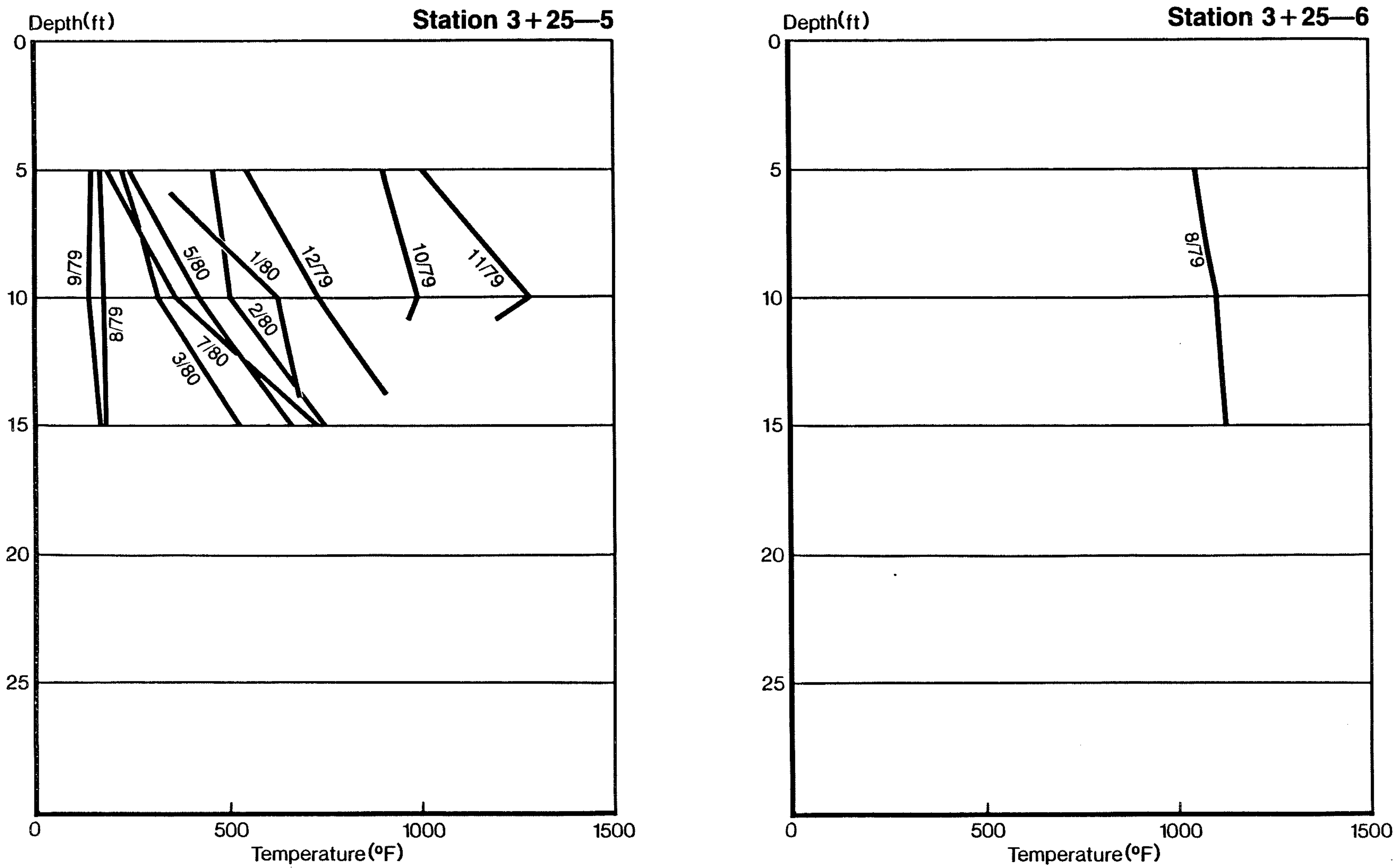
MONTHLY TEMPERATURE PROFILES

Fig A.7 (continued)



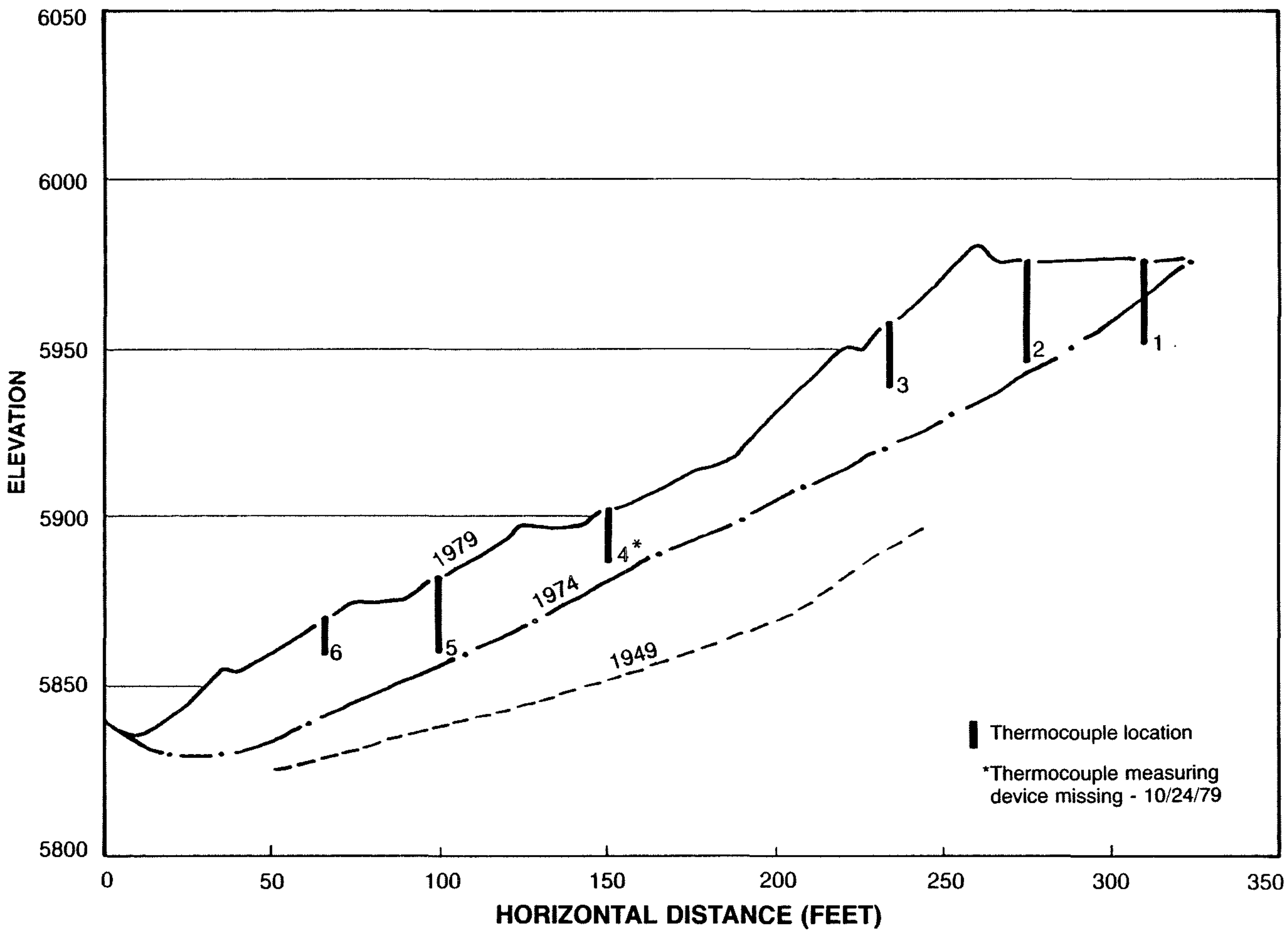
MONTHLY TEMPERATURE PROFILES

Fig A.7 (continued)



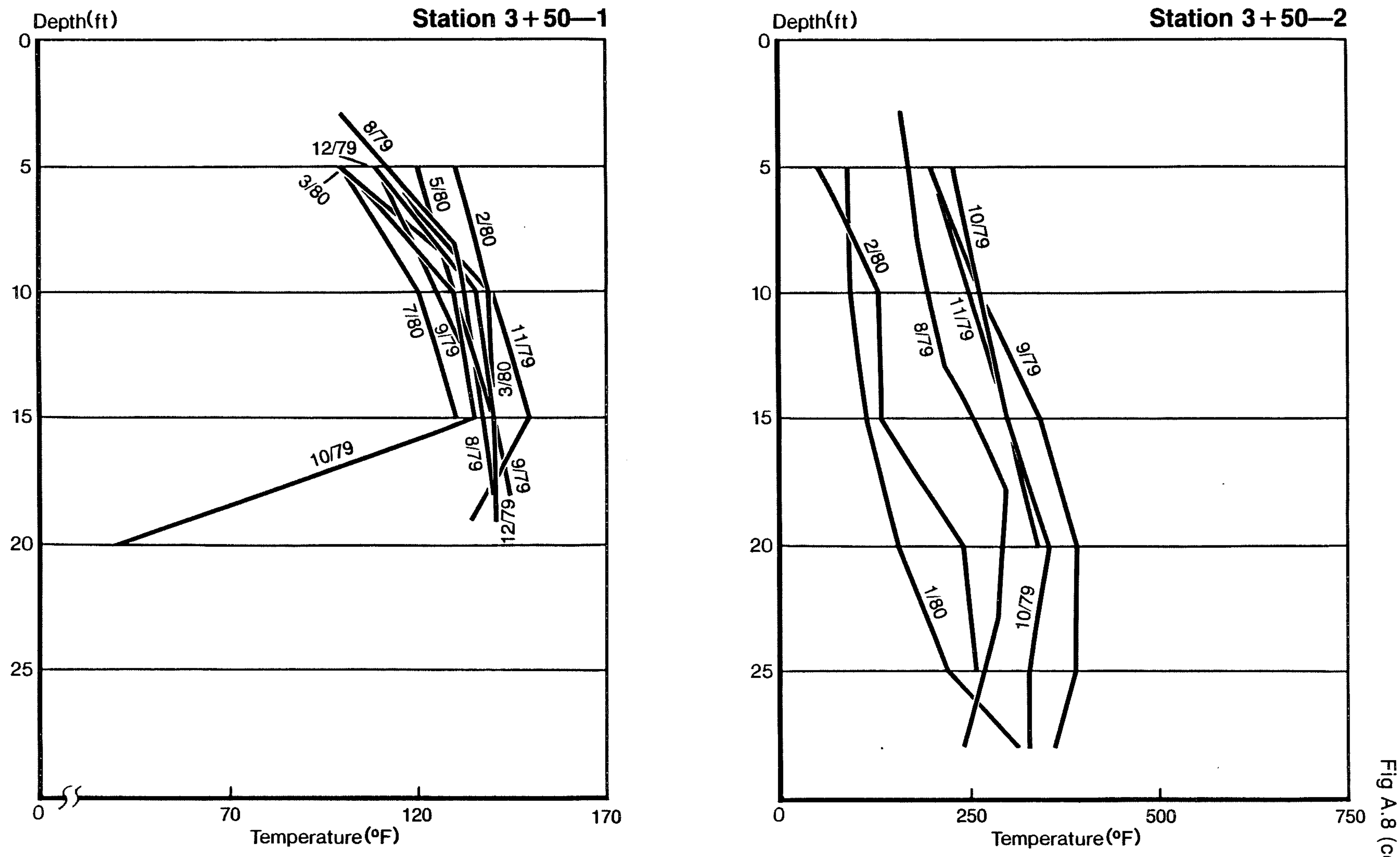
MONTHLY TEMPERATURE PROFILES

Fig A.7 (continued)



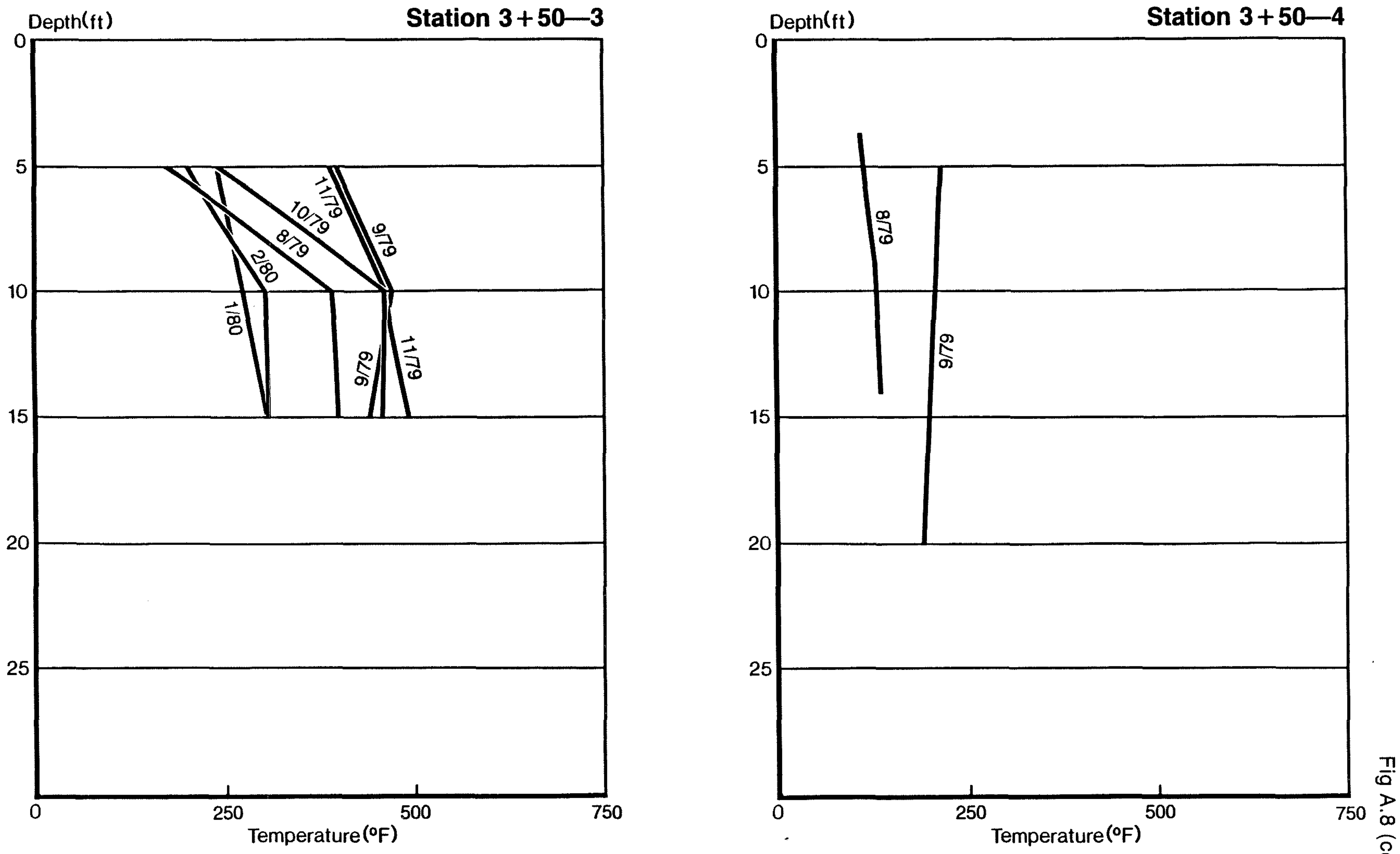
Anvil Points Raw Shale Pile
CROSS SECTION AND THERMOCOUPLE LOCATIONS
STATION 3 + 50

Fig A.8



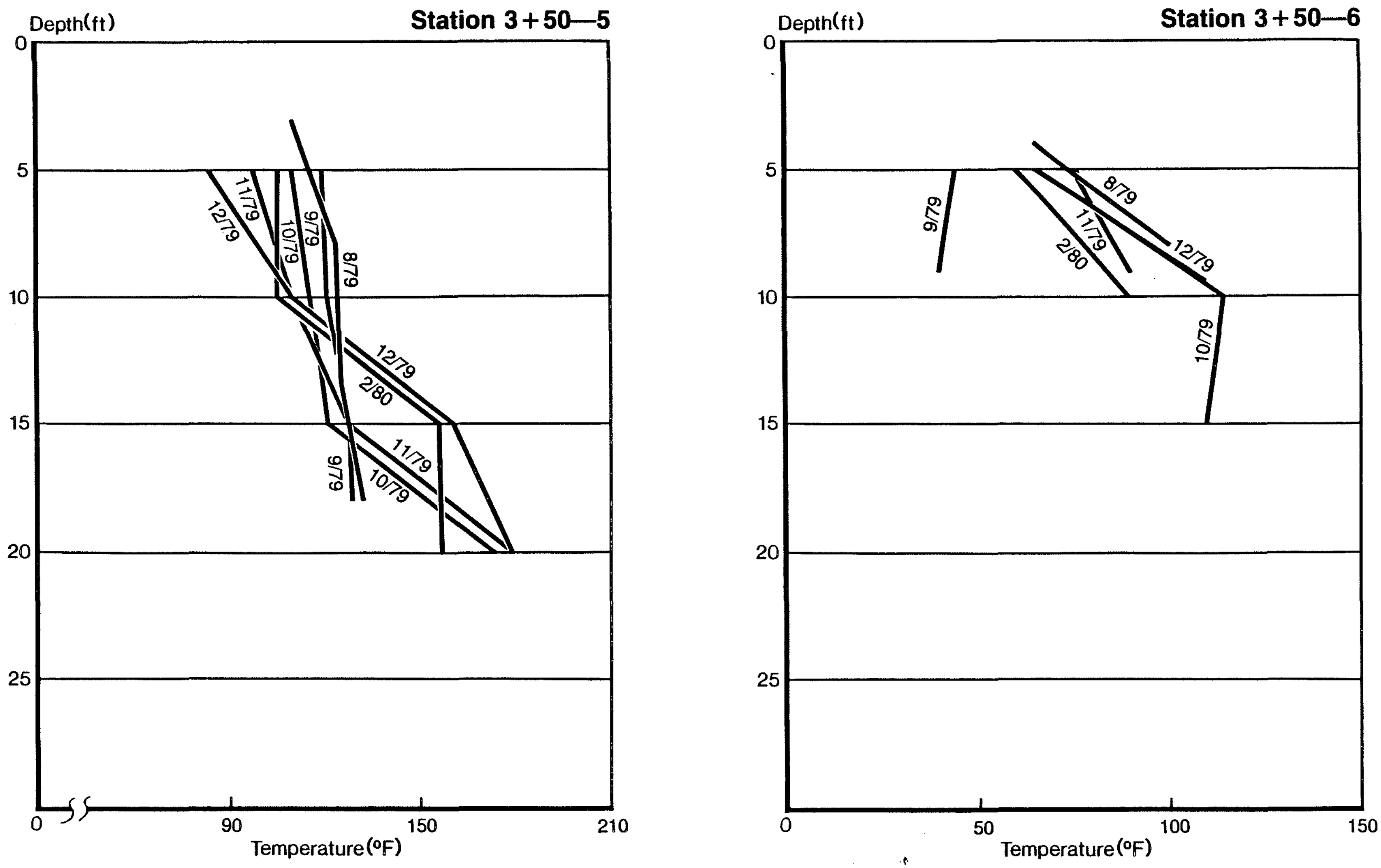
MONTHLY TEMPERATURE PROFILES

Fig A.8 (continued)



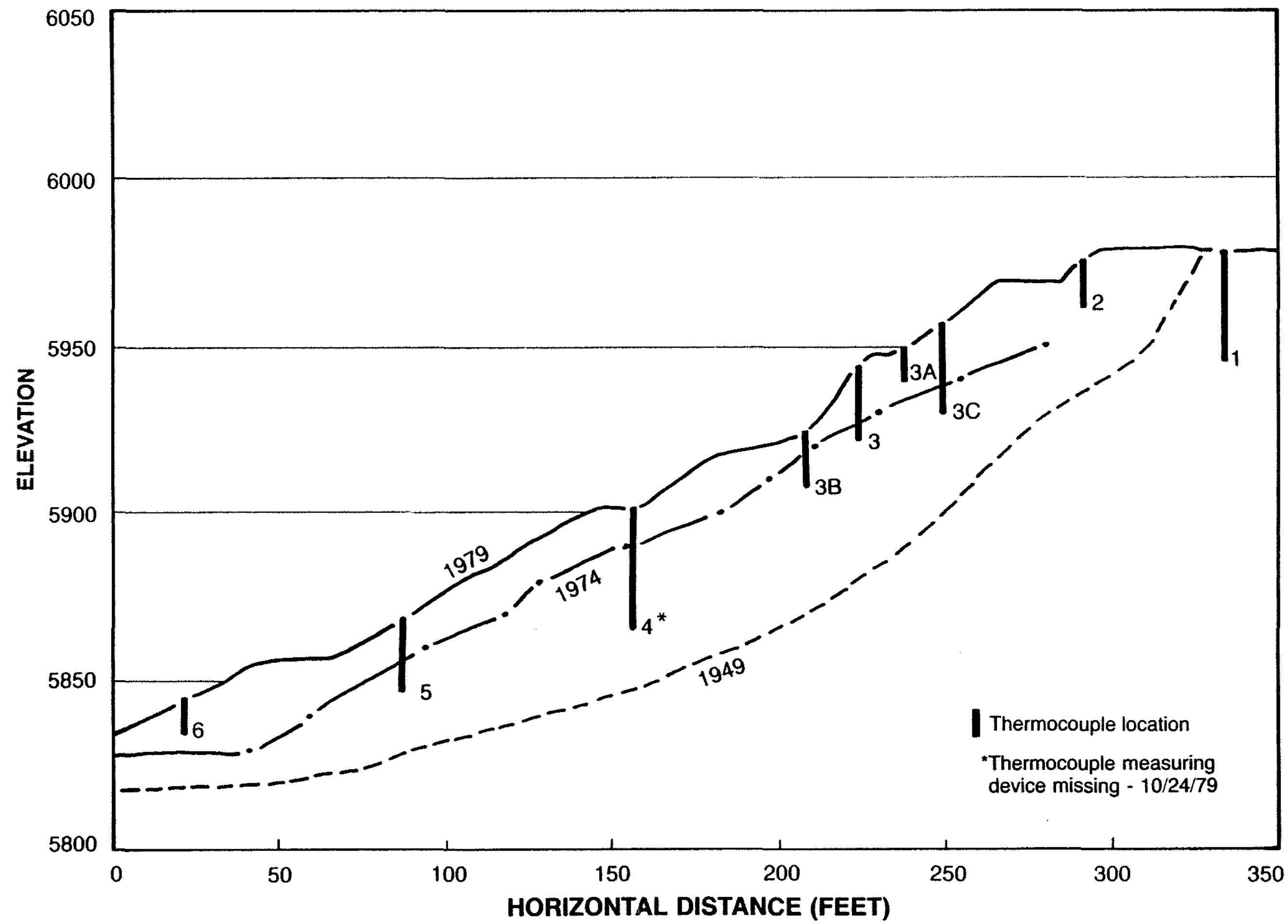
MONTHLY TEMPERATURE PROFILES

Fig A.8 (continued)



MONTHLY TEMPERATURE PROFILES

Fig A.8 (continued)

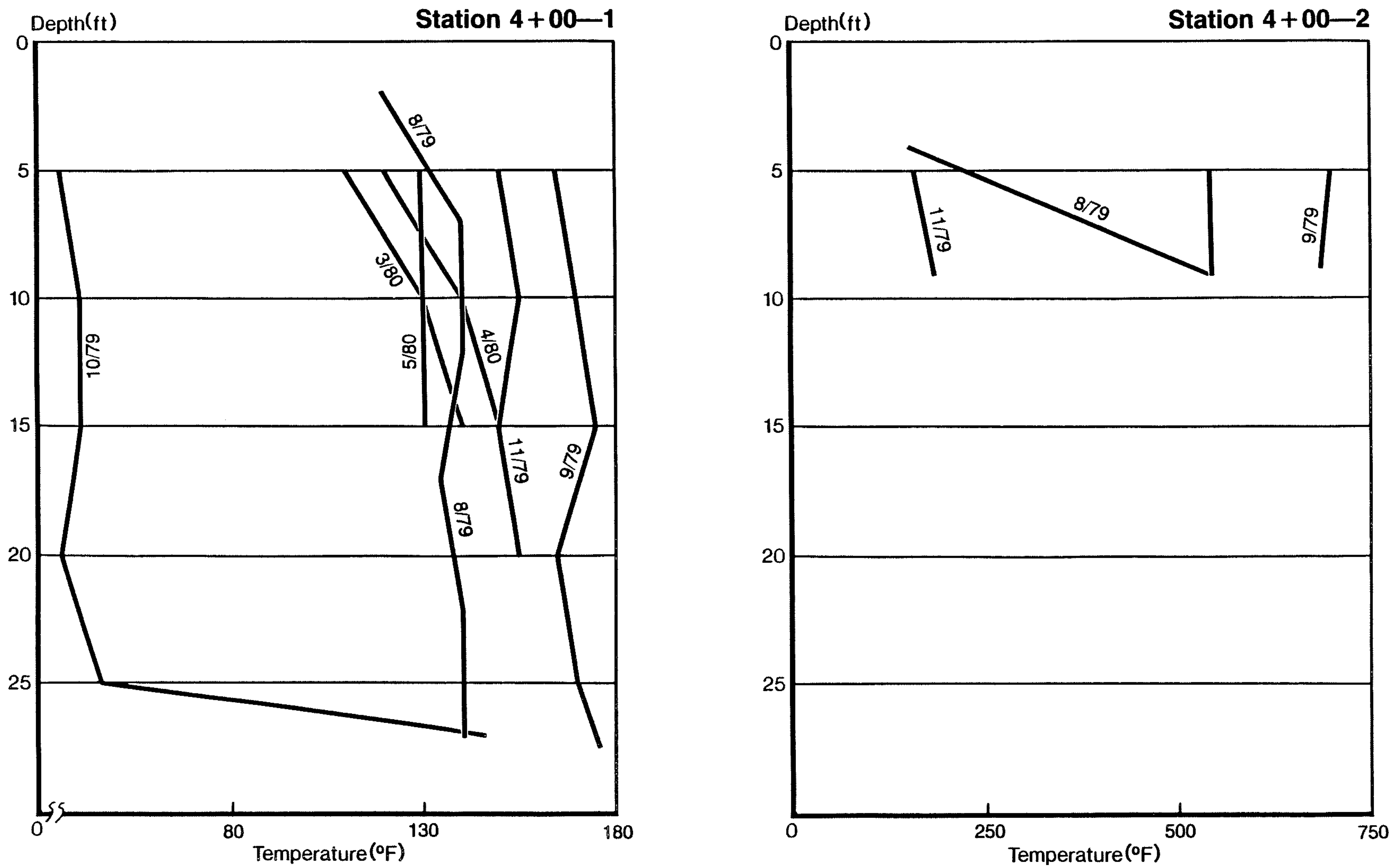


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

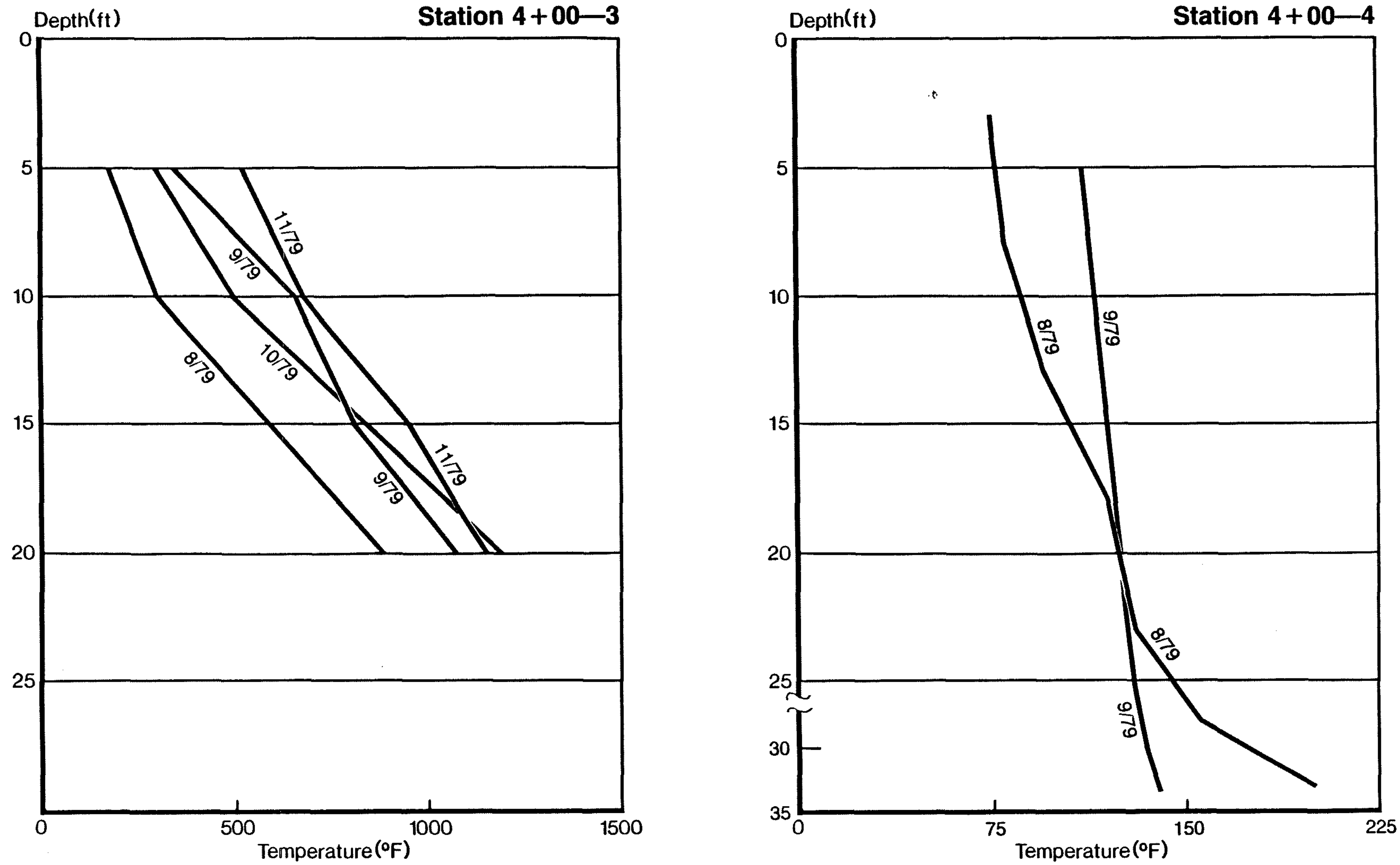
STATION 4 + 00

Fig A.9



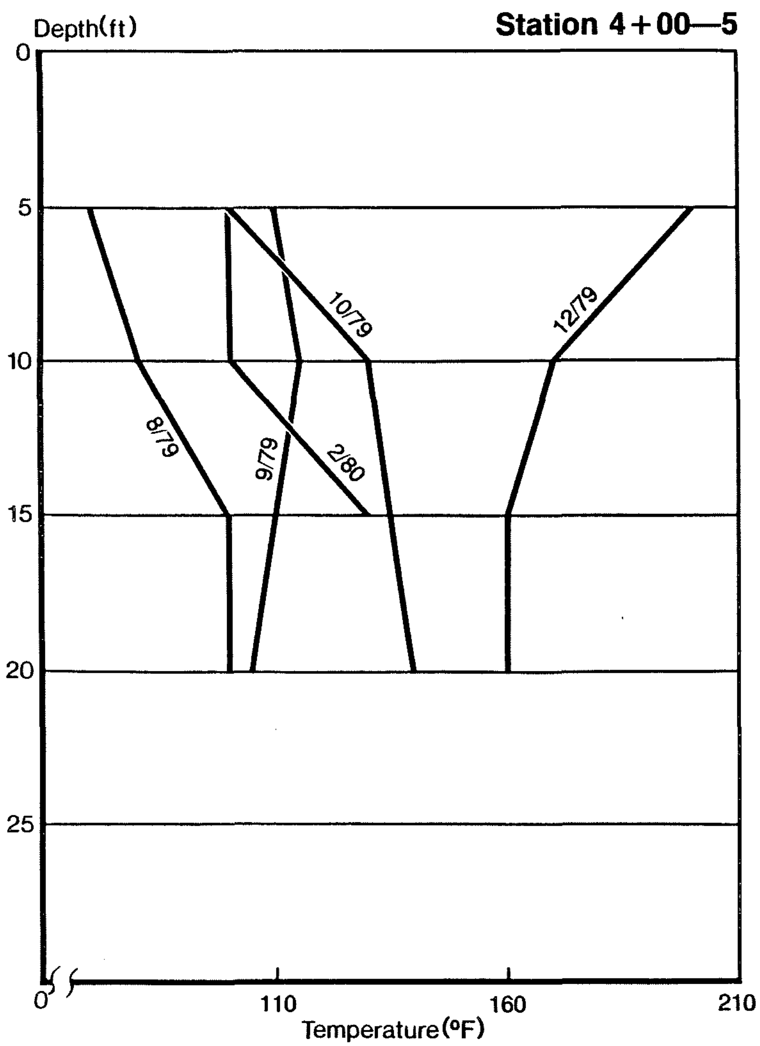
MONTHLY TEMPERATURE PROFILES

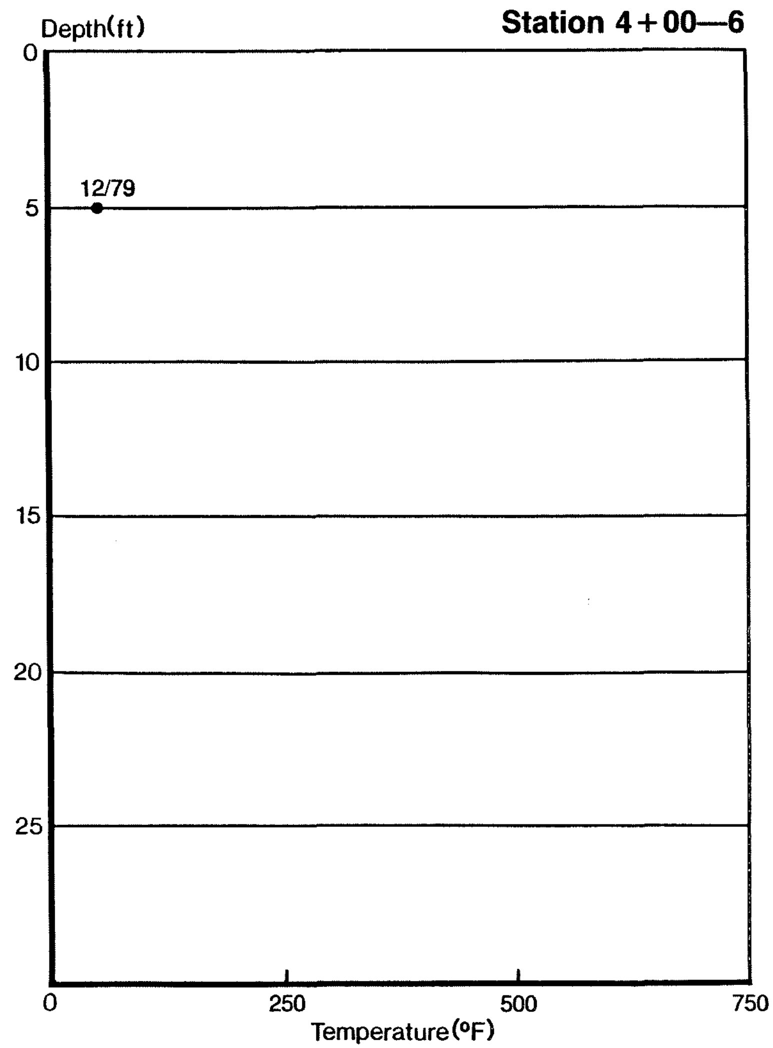
Fig A.9 (continued)



MONTHLY TEMPERATURE PROFILES

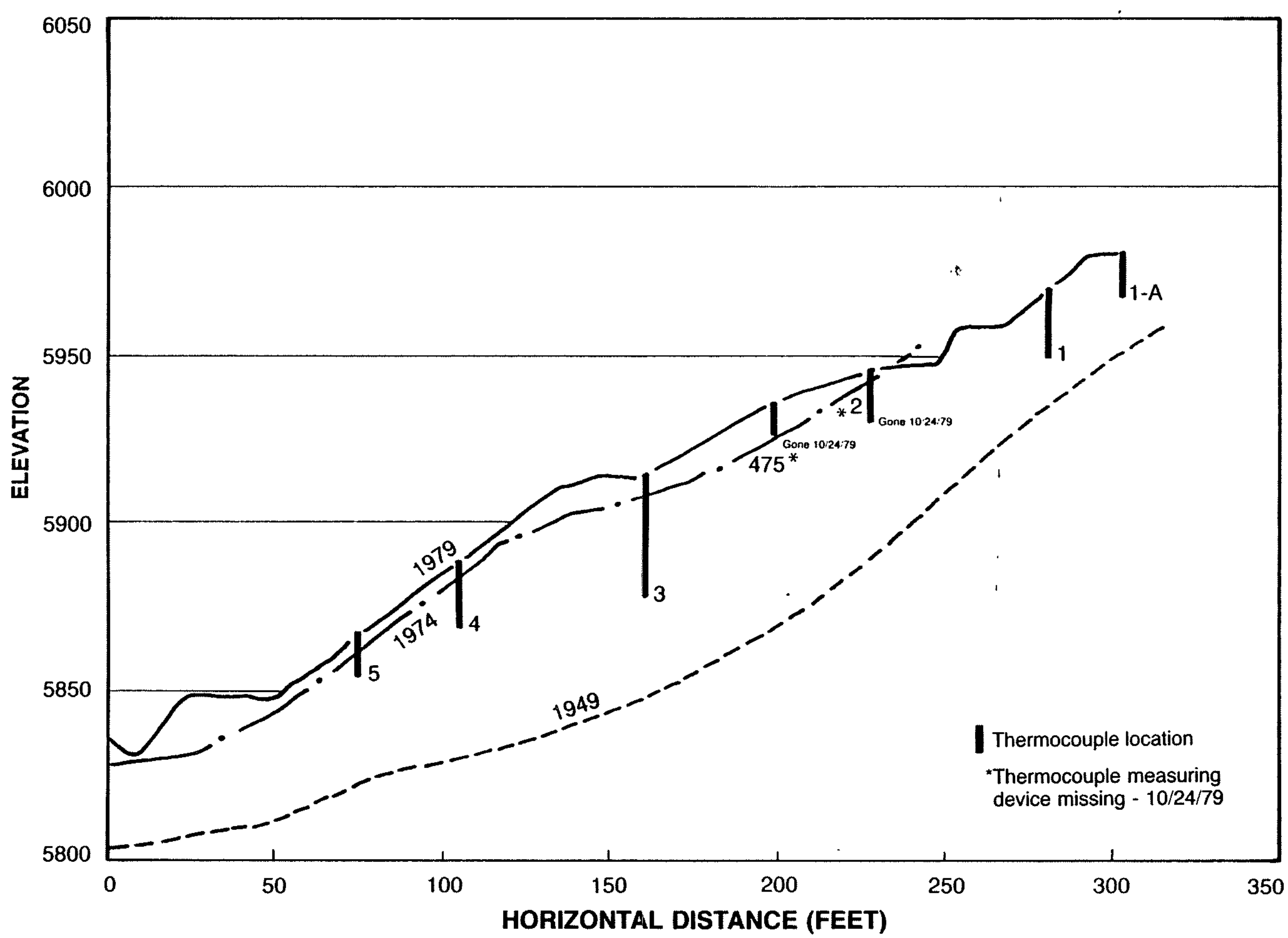
Fig A.9 (continued)





MONTHLY TEMPERATURE PROFILES

Fig A.9 (continued)

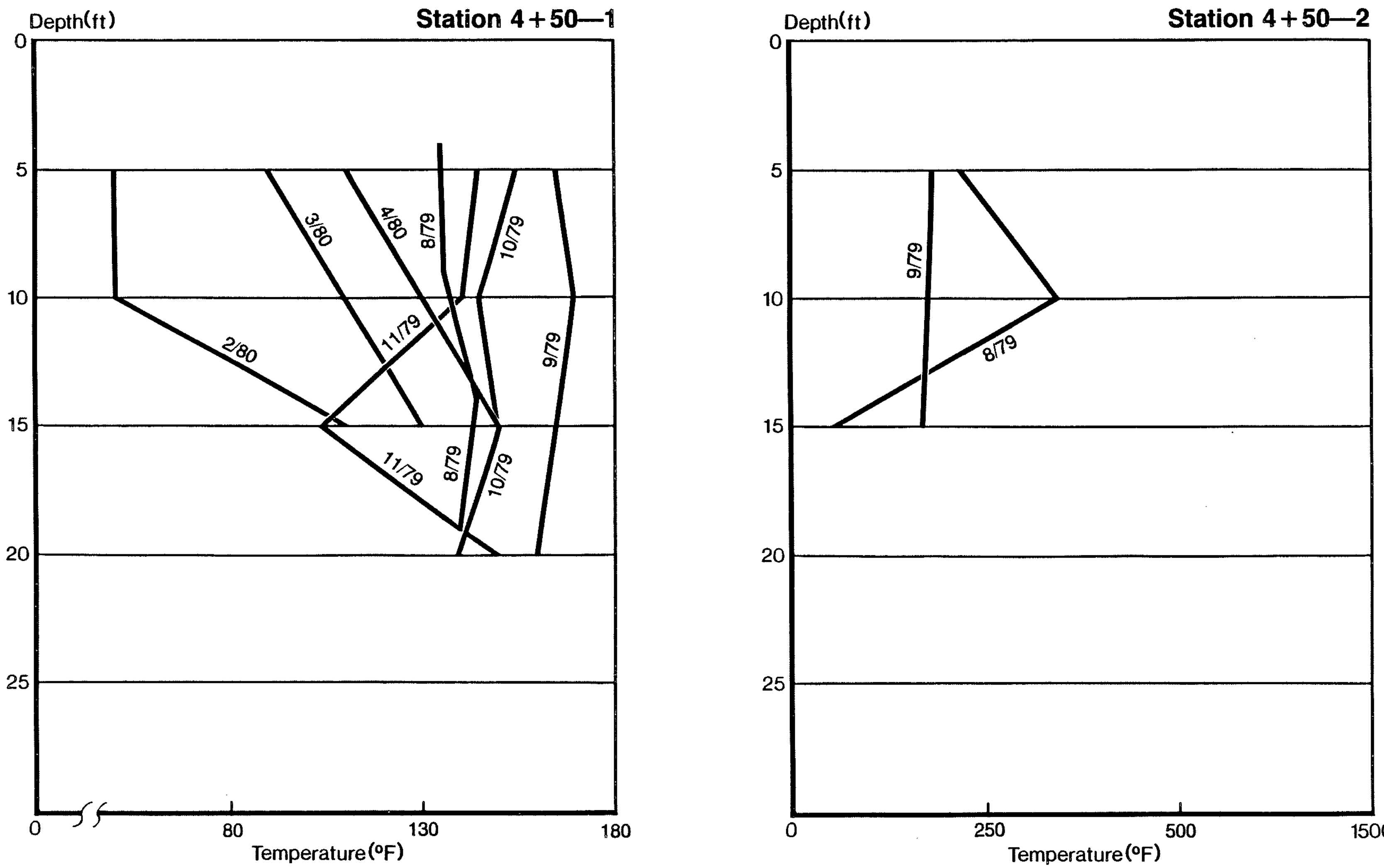


Anvil Points Raw Shale Pile

CROSS SECTION AND THERMOCOUPLE LOCATIONS

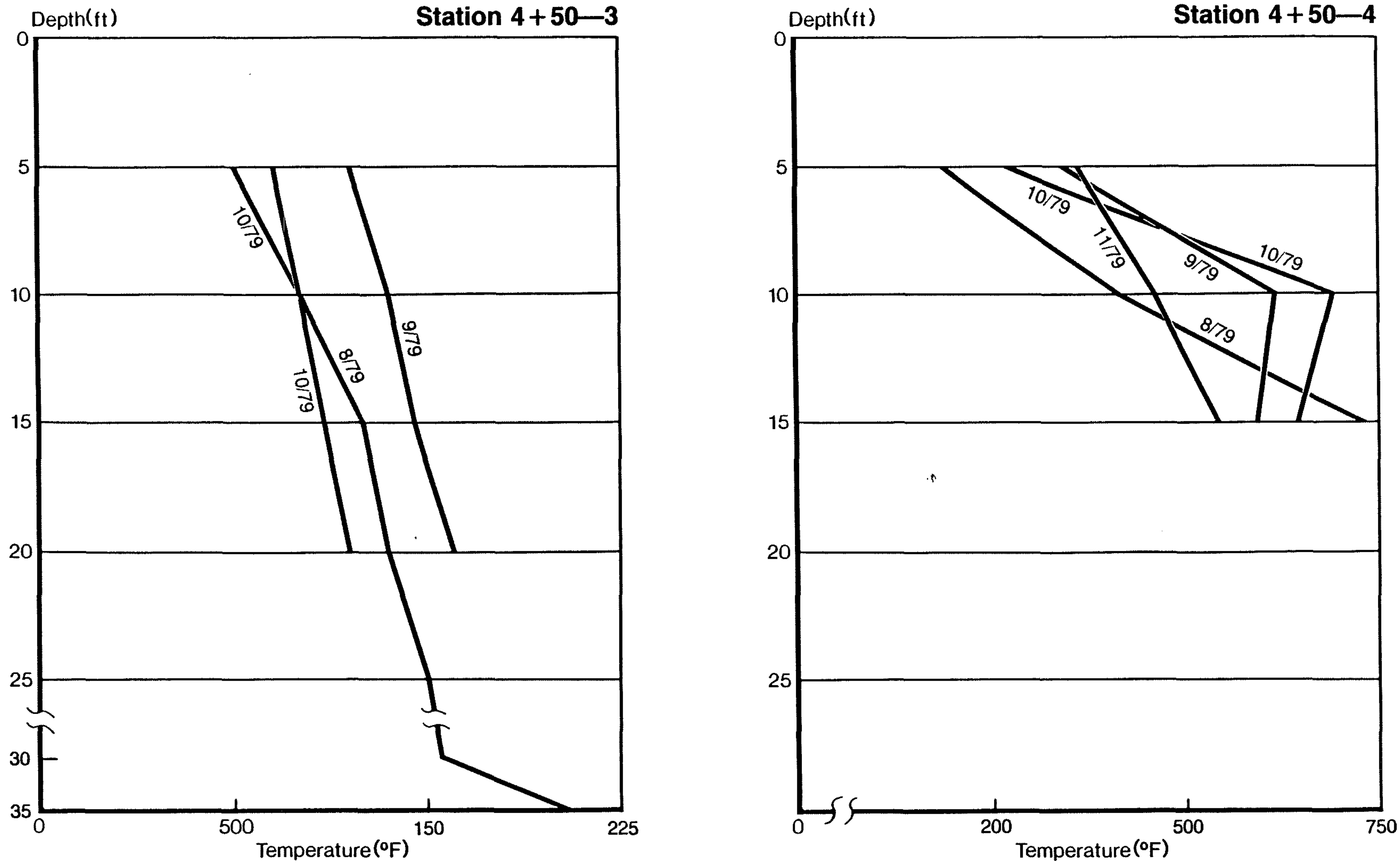
STATION 4 + 50

Fig A.10



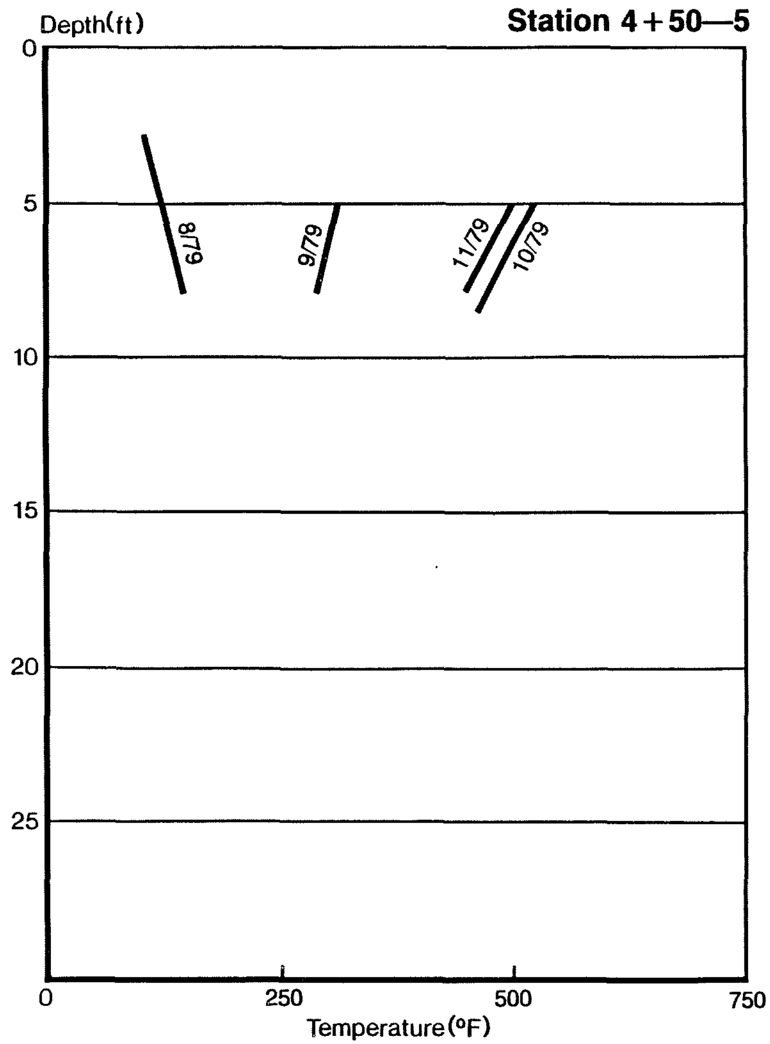
MONTHLY TEMPERATURE PROFILES

Fig A.10 (continued)



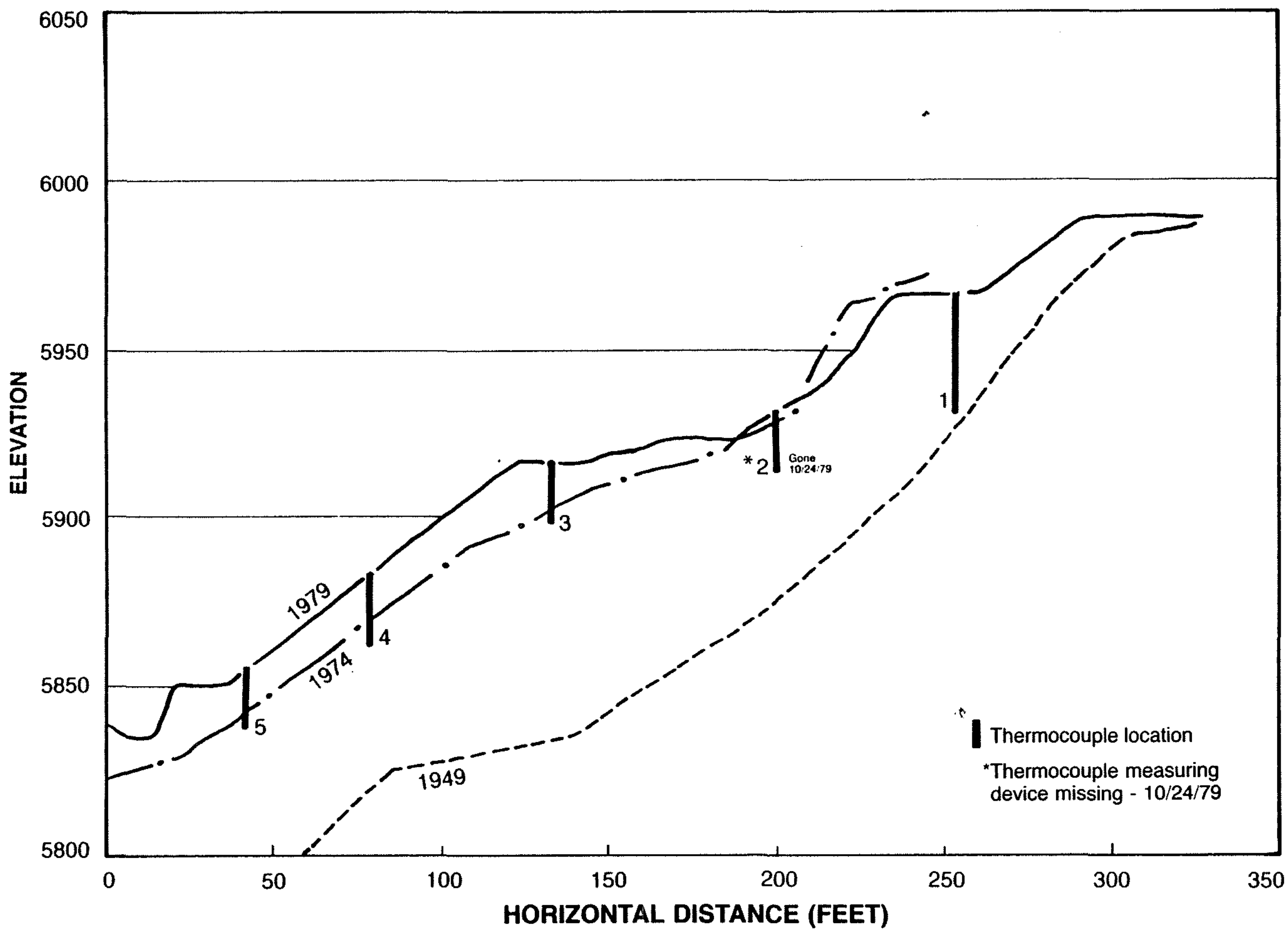
MONTHLY TEMPERATURE PROFILES

Fig A.10 (continued)



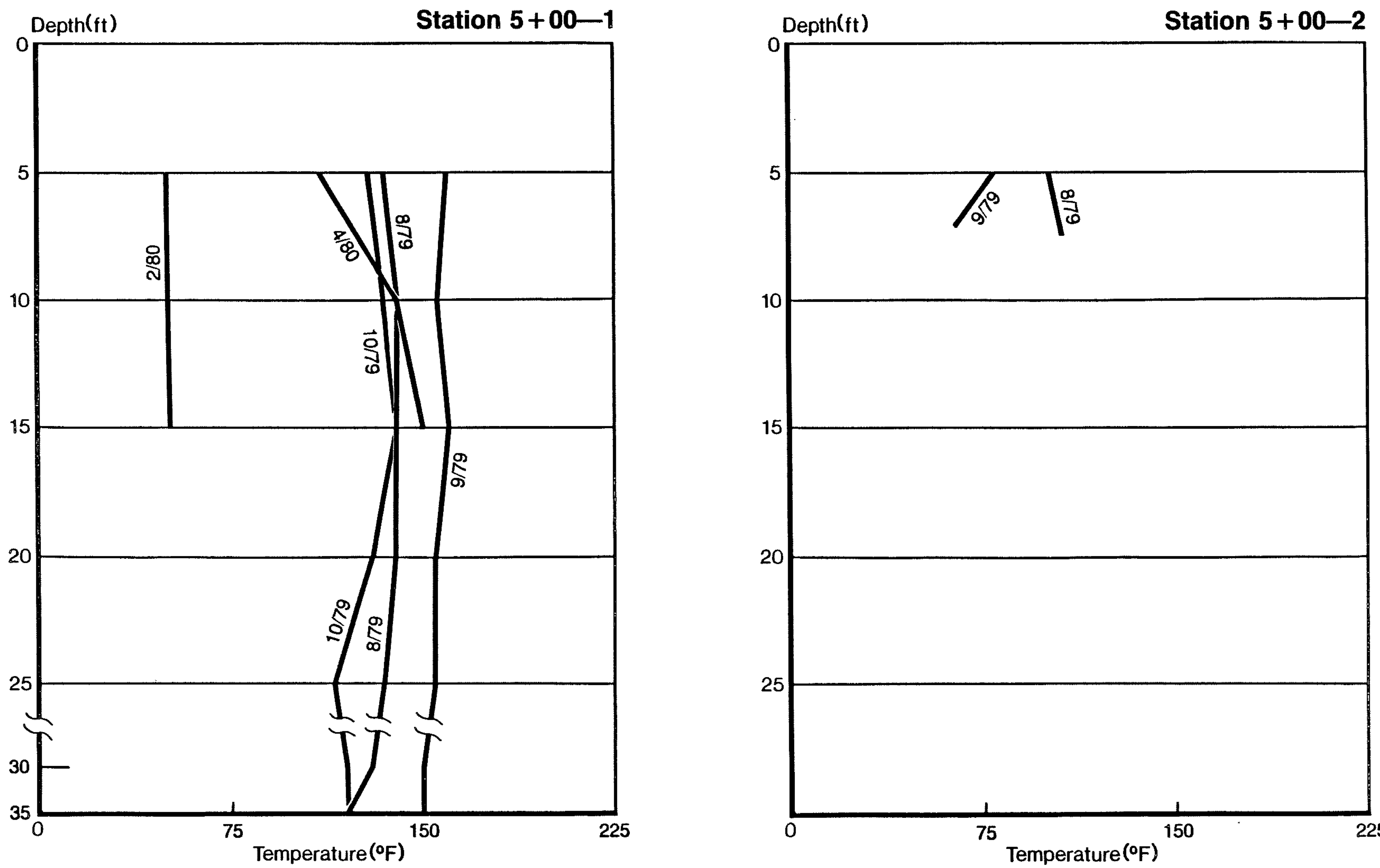
MONTHLY TEMPERATURE PROFILE

Fig A.10 (continued)



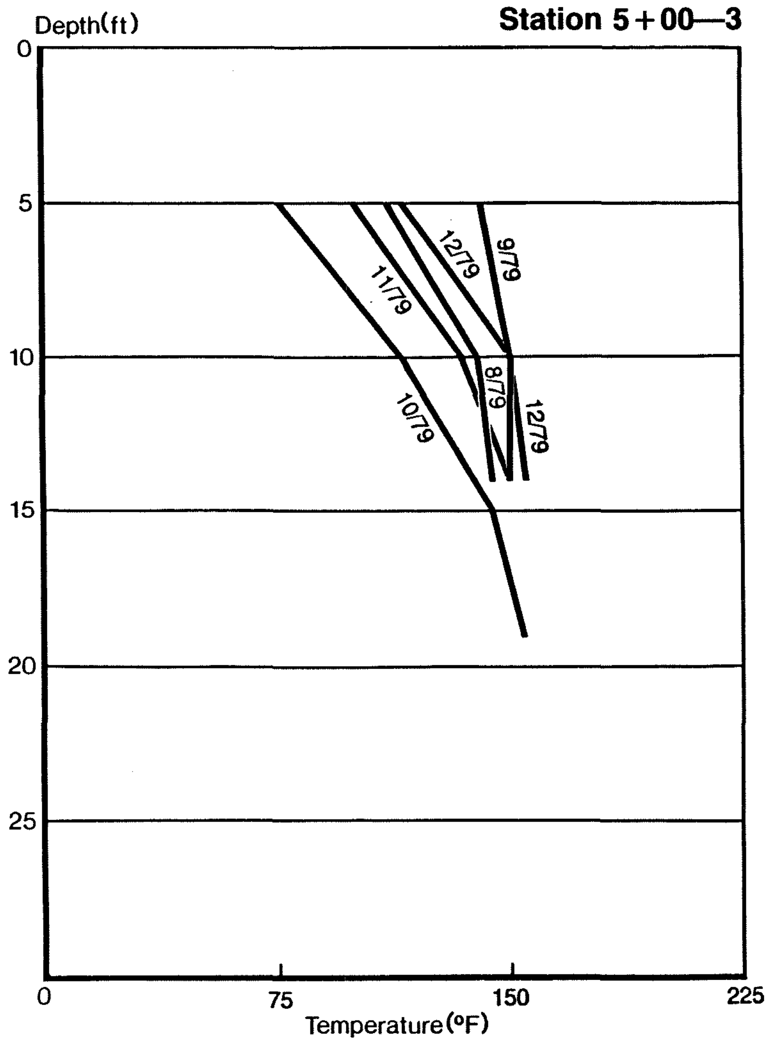
Anvil Points Raw Shale Pile
CROSS SECTION AND THERMOCOUPLE LOCATIONS
STATION 5 + 00

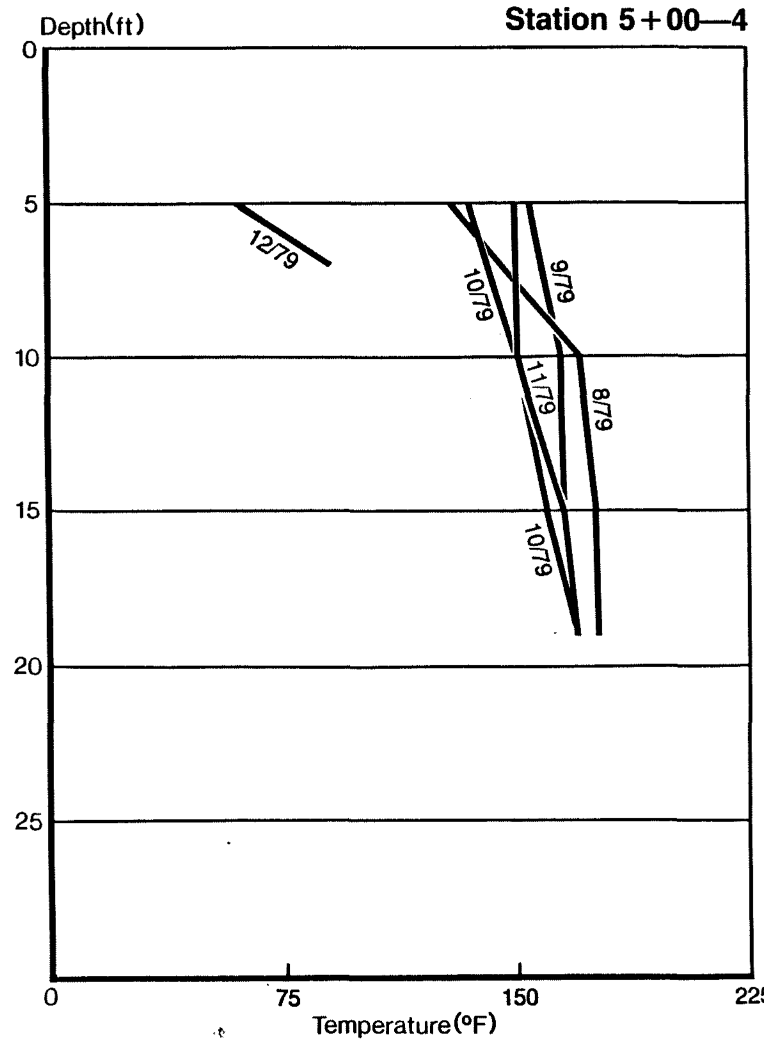
Fig A.11



MONTHLY TEMPERATURE PROFILES

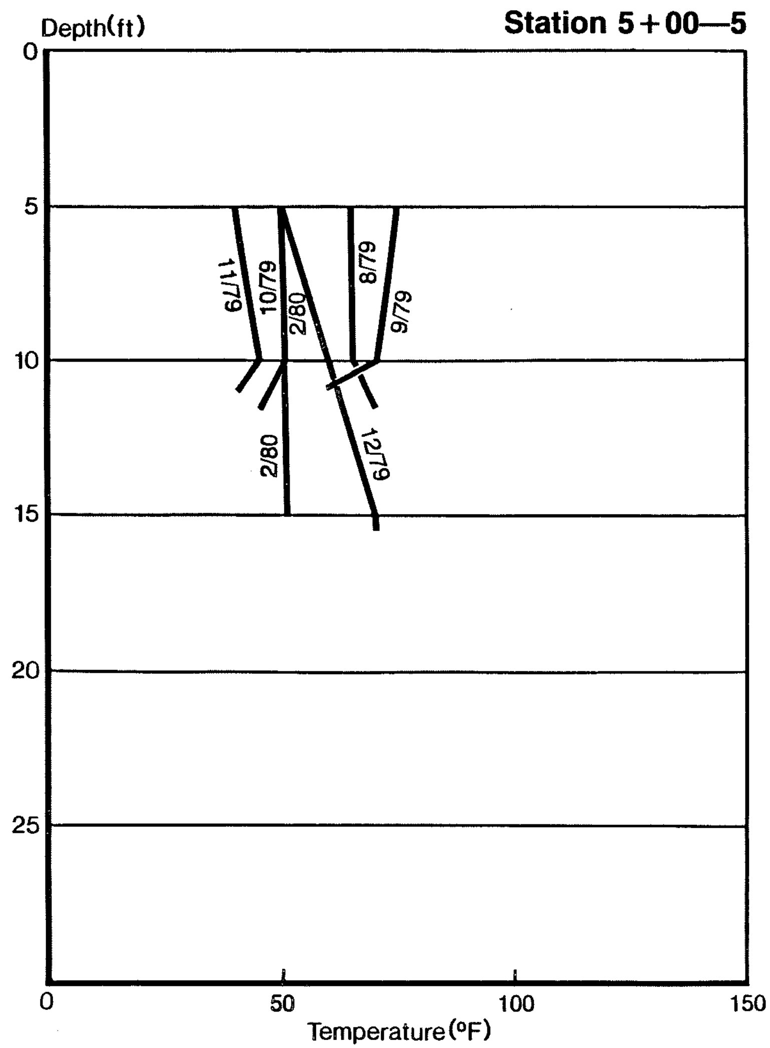
Fig A.11 (continued)





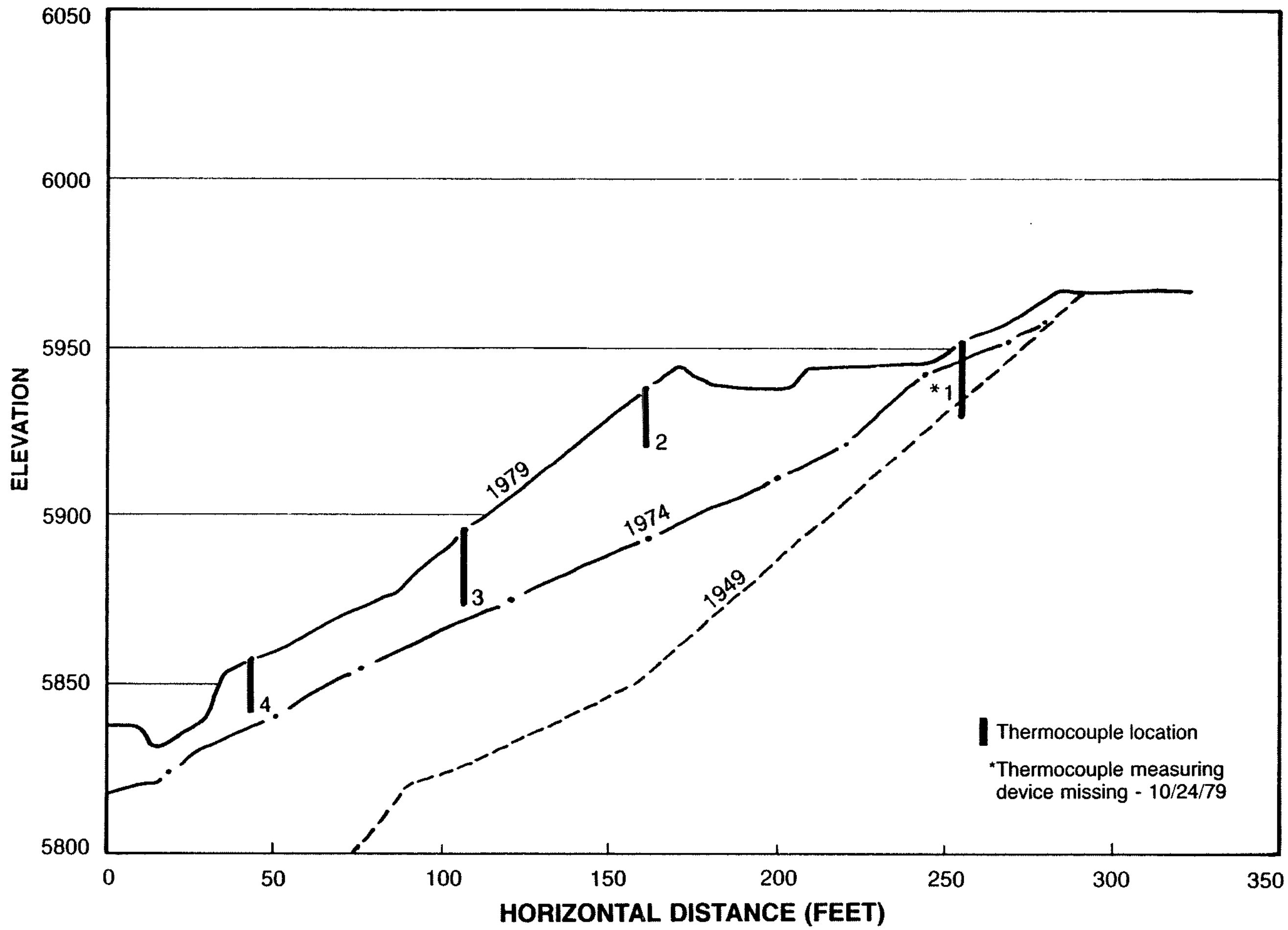
MONTHLY TEMPERATURE PROFILES

Fig A.11 (continued)



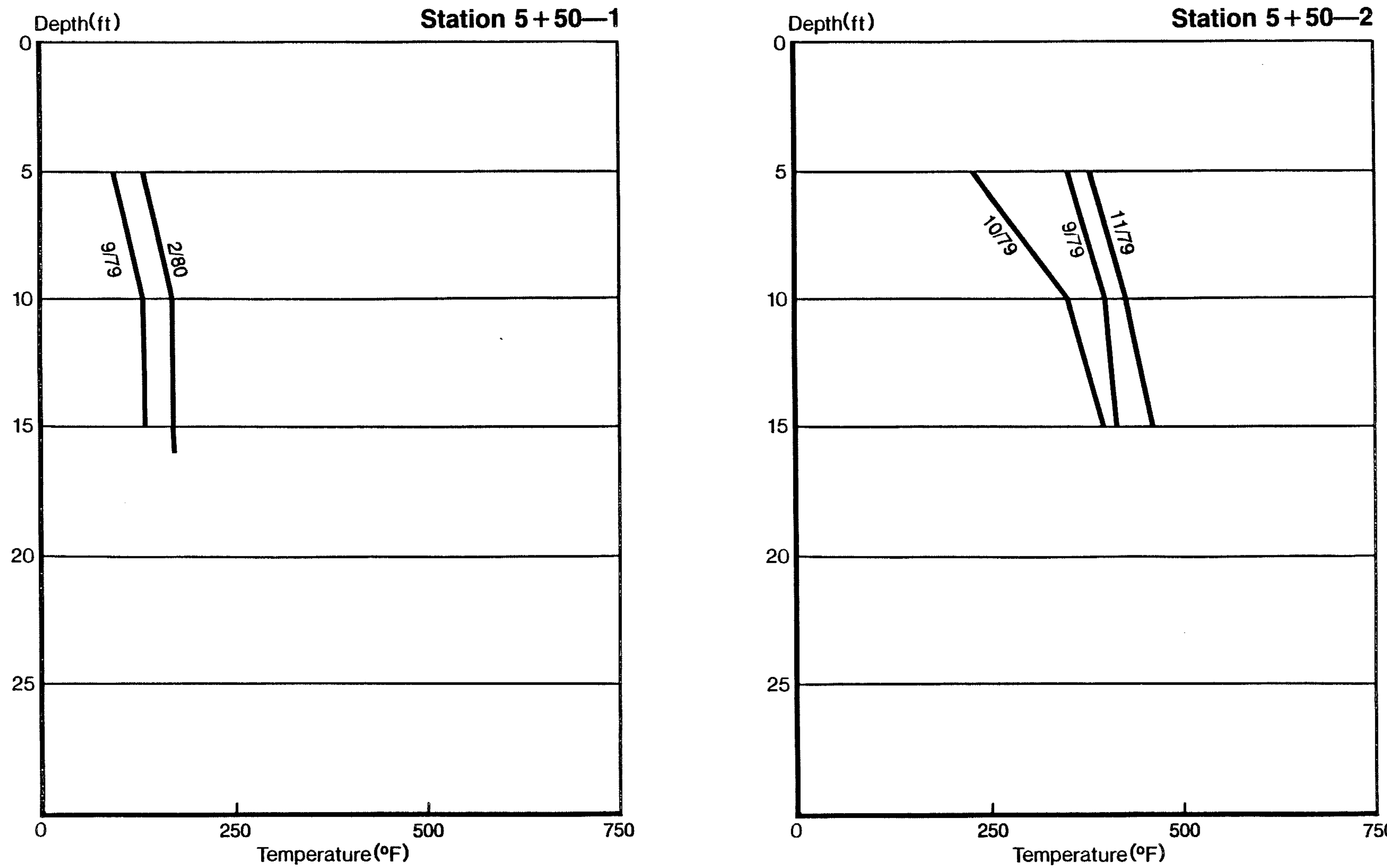
MONTHLY TEMPERATURE PROFILES

Fig A.11 (continued)



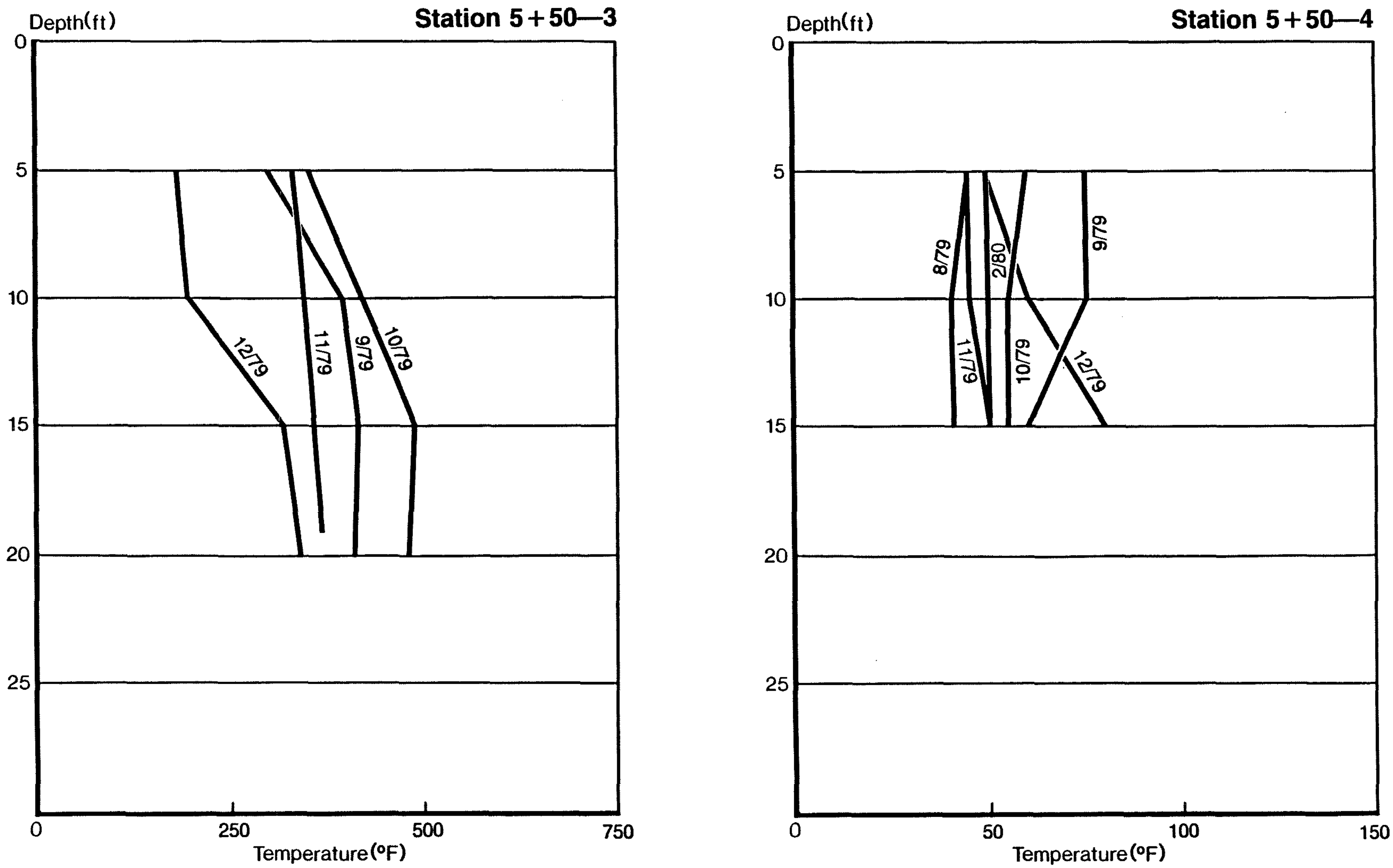
Anvil Points Raw Shale Pile
CROSS SECTION AND THERMOCOUPLE LOCATIONS
STATION 5 + 50

Fig A.12



MONTHLY TEMPERATURE PROFILES

Fig A. 12 (continued)



MONTHLY TEMPERATURE PROFILES

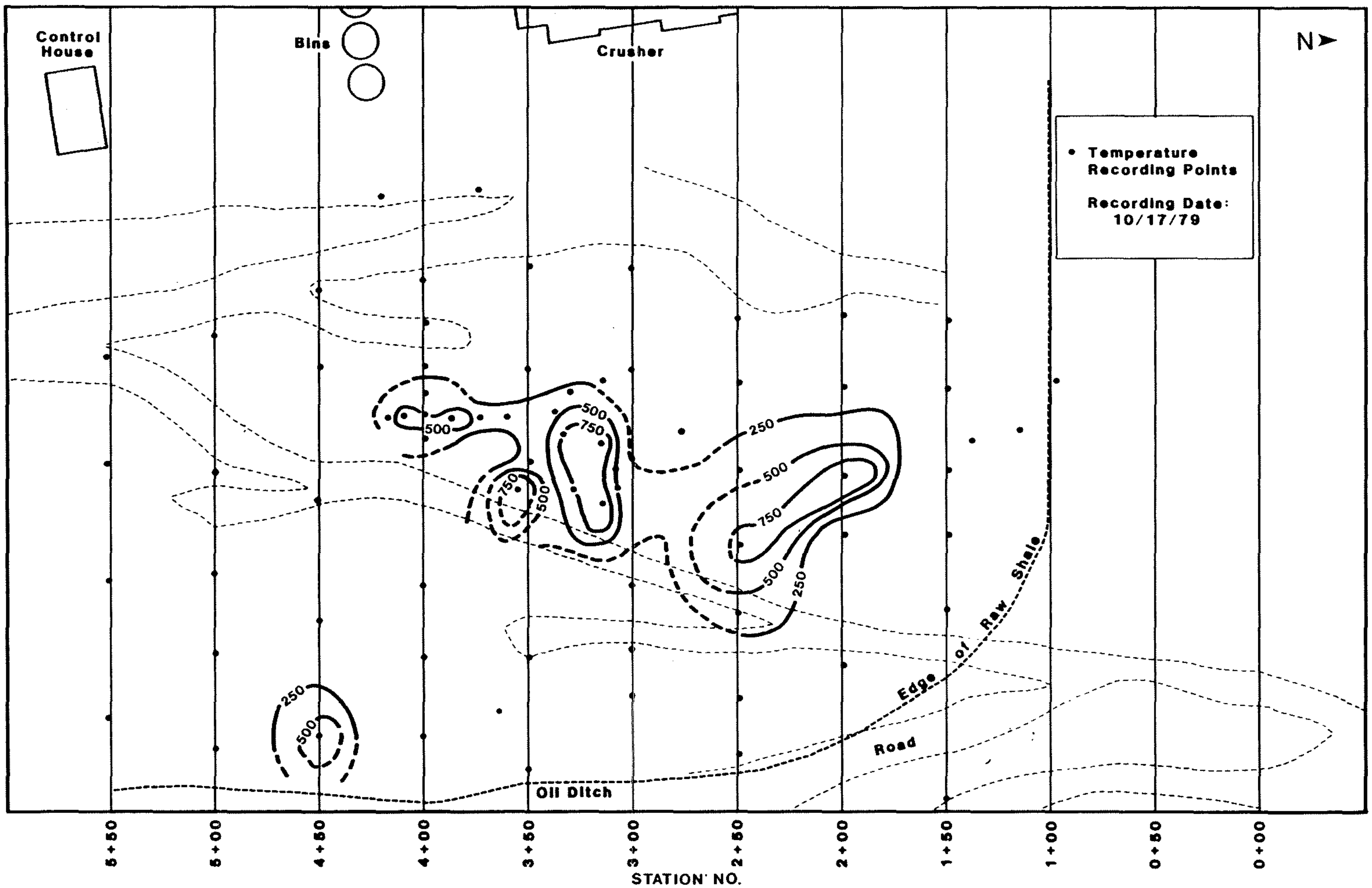
Fig A.12 (continued)

APPENDIX B

Anvil Points Raw Shale Pile

ISO-TEMPERATURE CONTOURS

October and November 1979

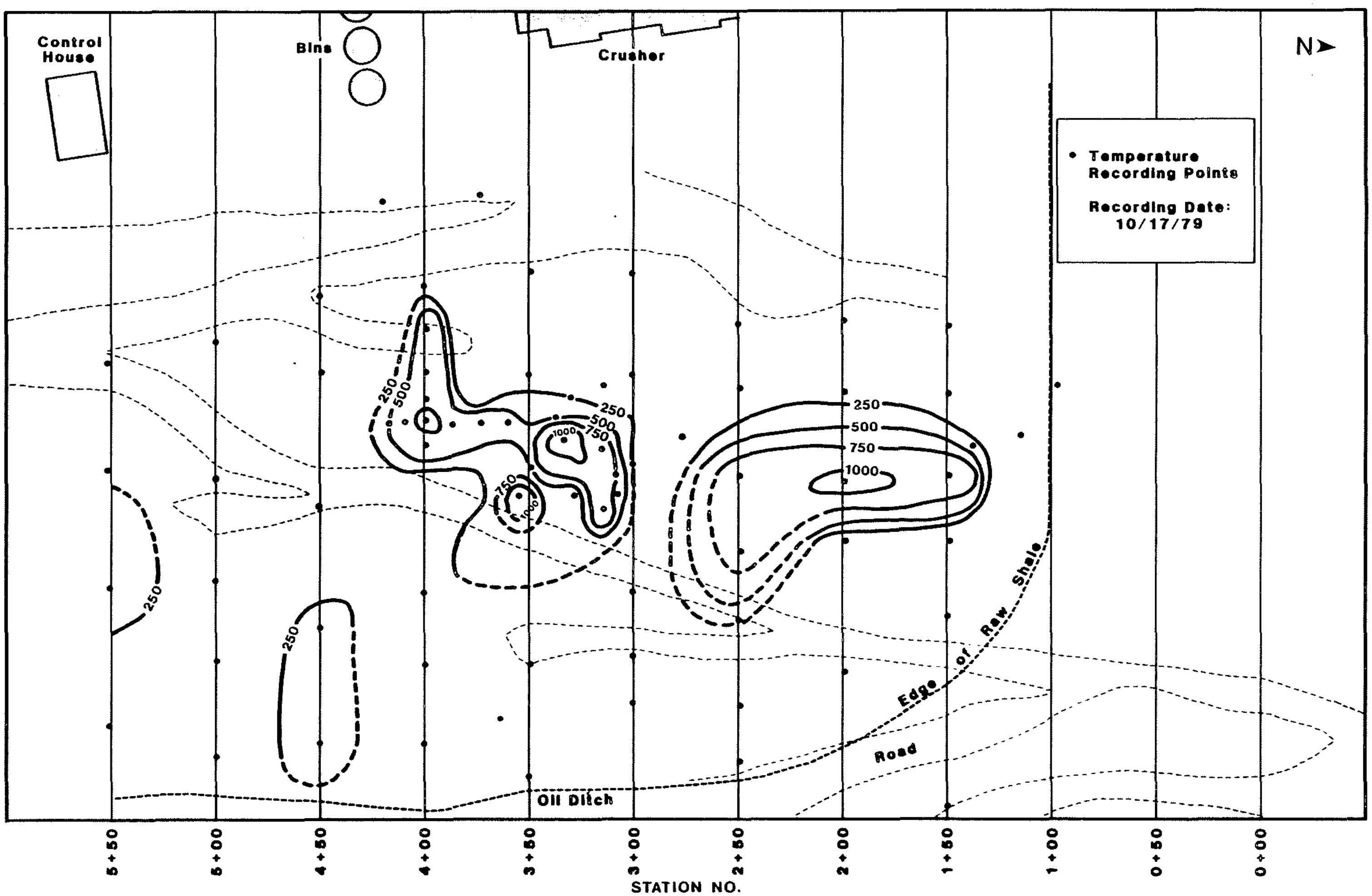


Anvil Points Raw Shale Pile

PLOT OF ISO-TEMPERATURE CONTOURS - 5′ DEPTH

Contour Interval 250°F

Fig. B.1

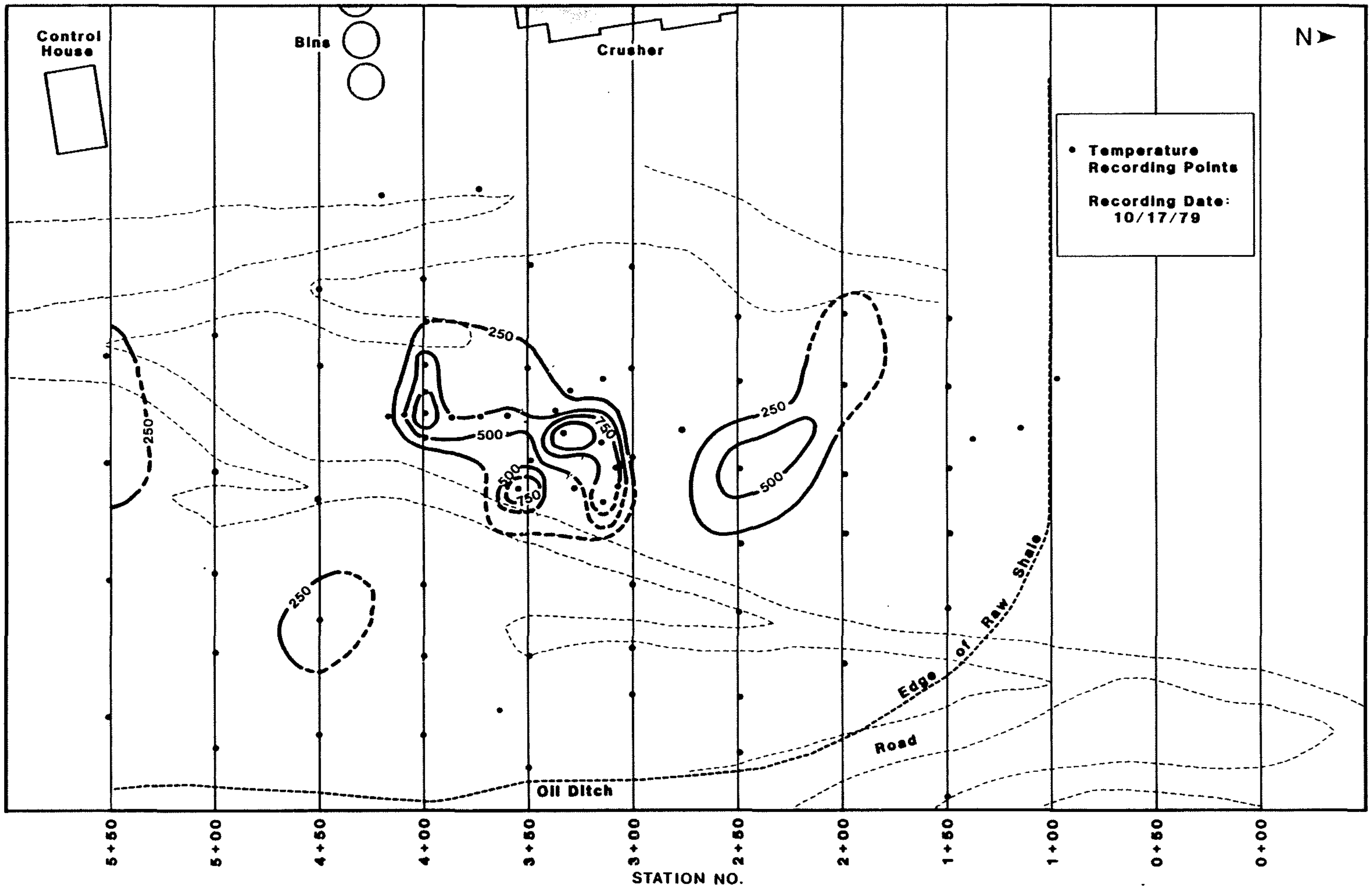


Anvil Points Raw Shale Pile

PLOT OF ISO-TEMPERATURE CONTOURS - 10′ DEPTH

Contour Interval 250°F

Fig B.2

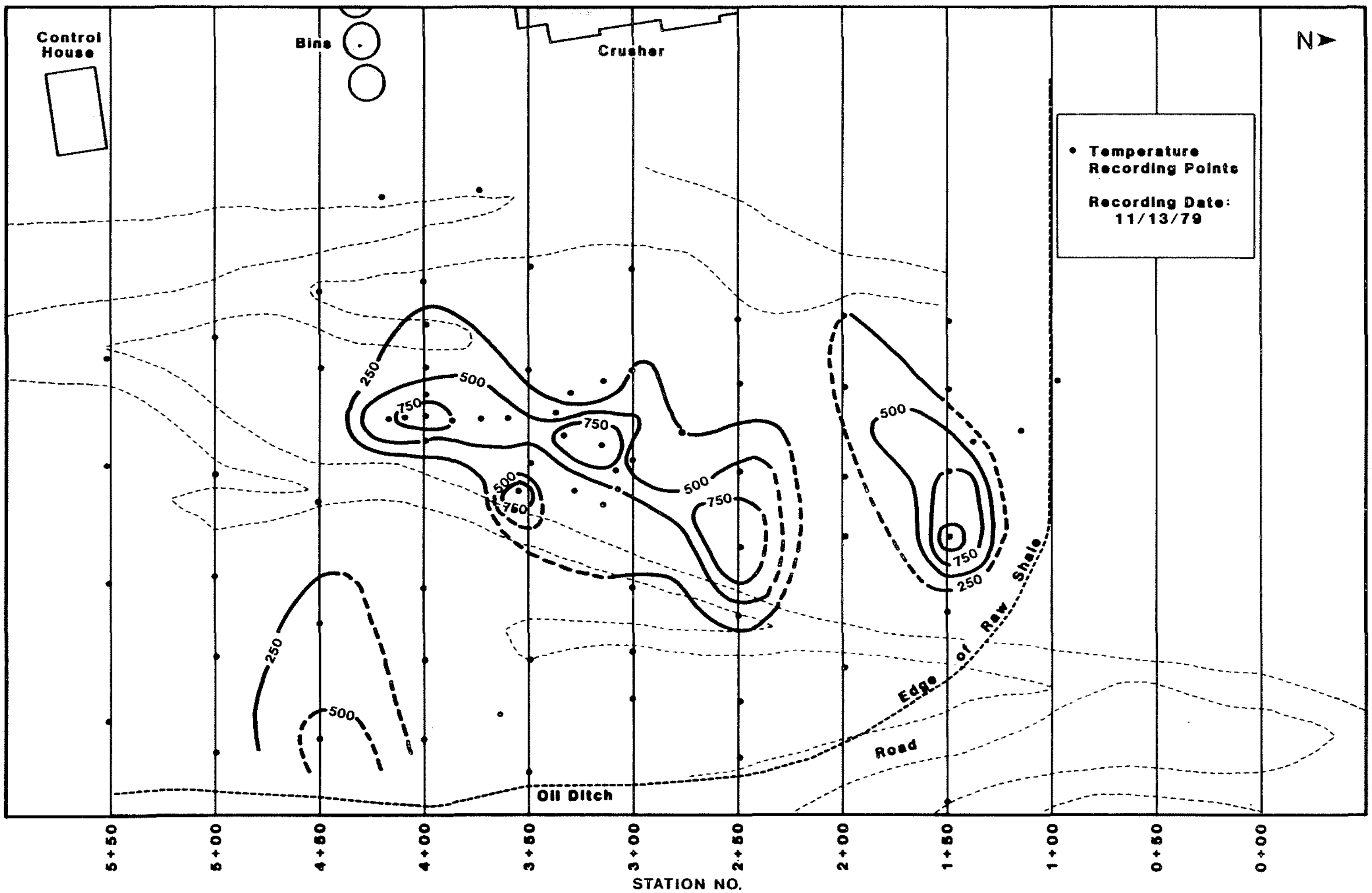


Anvil Points Raw Shale Pile

PLOT OF ISO-TEMPERATURE CONTOURS - 15′ DEPTH

Contour Interval 250°F

Fig B.3

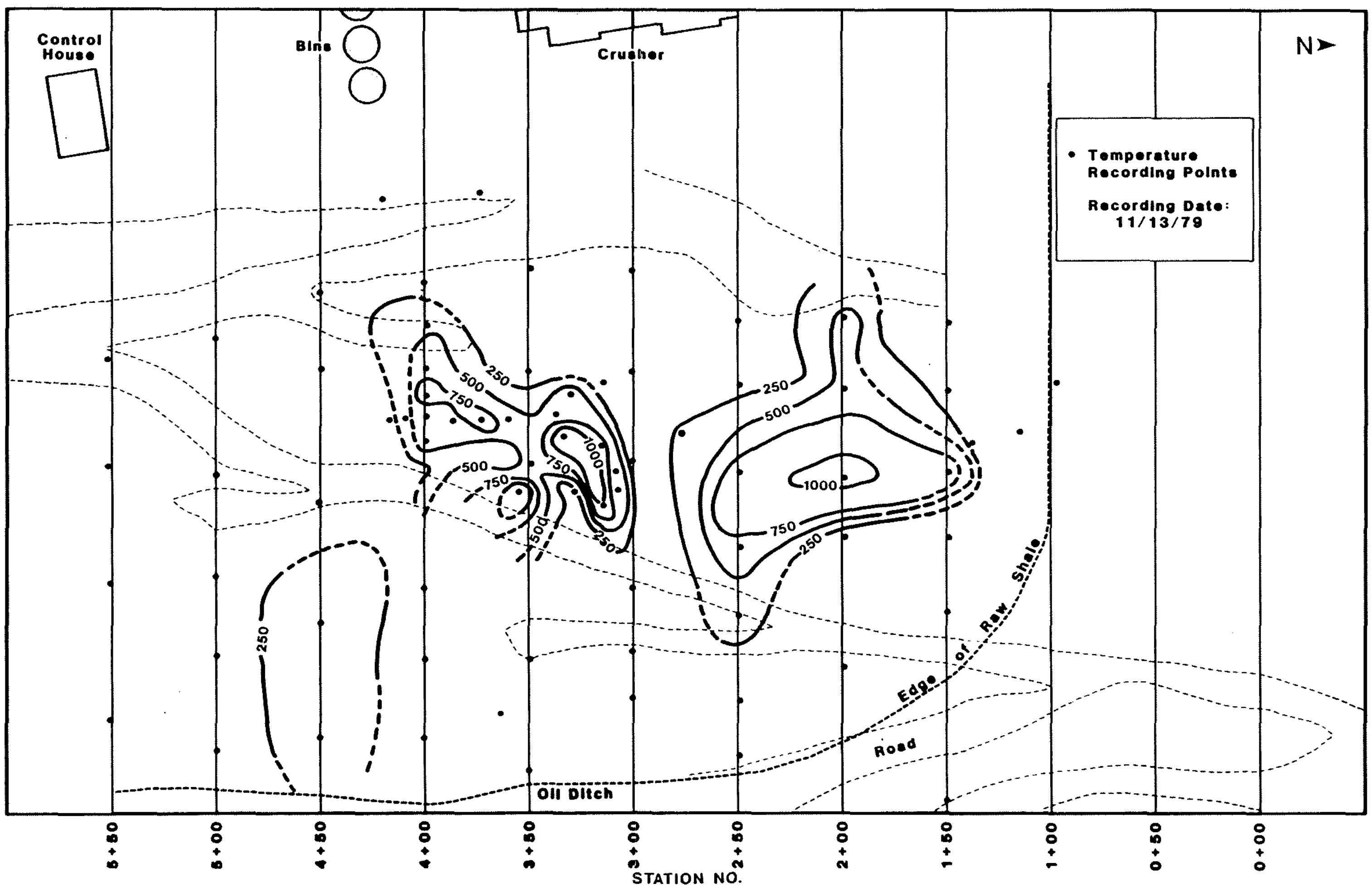


Anvil Points Raw Shale Pile

PLOT OF ISO-TEMPERATURE CONTOURS - 5′ DEPTH

Contour Interval 250°F

Fig B.4

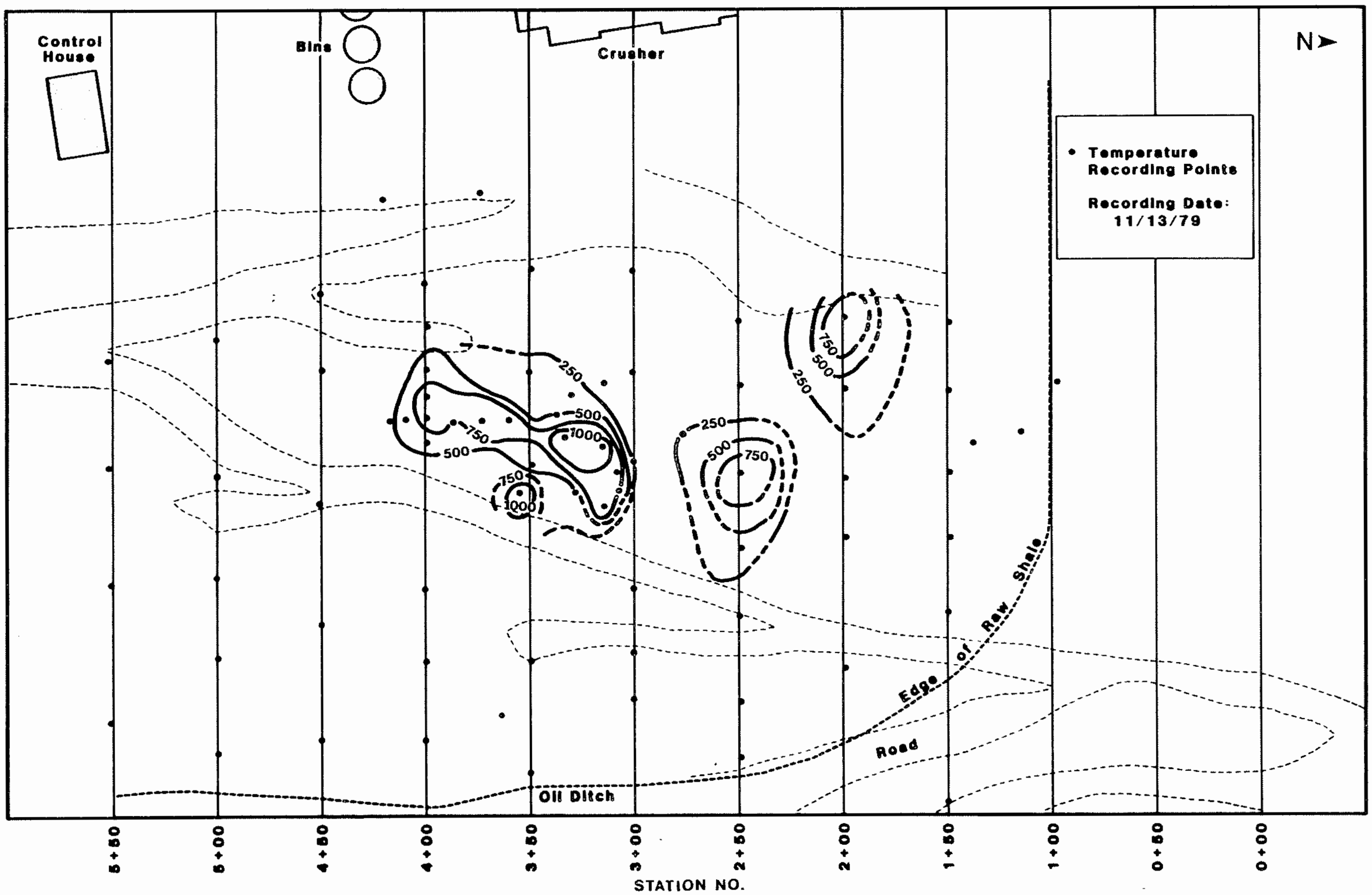


Anvil Points Raw Shale Pile

PLOT OF ISO-TEMPERATURE CONTOURS - 10′ DEPTH

Contour Interval 250°F

Fig B.5



Anvil Points Raw Shale Pile

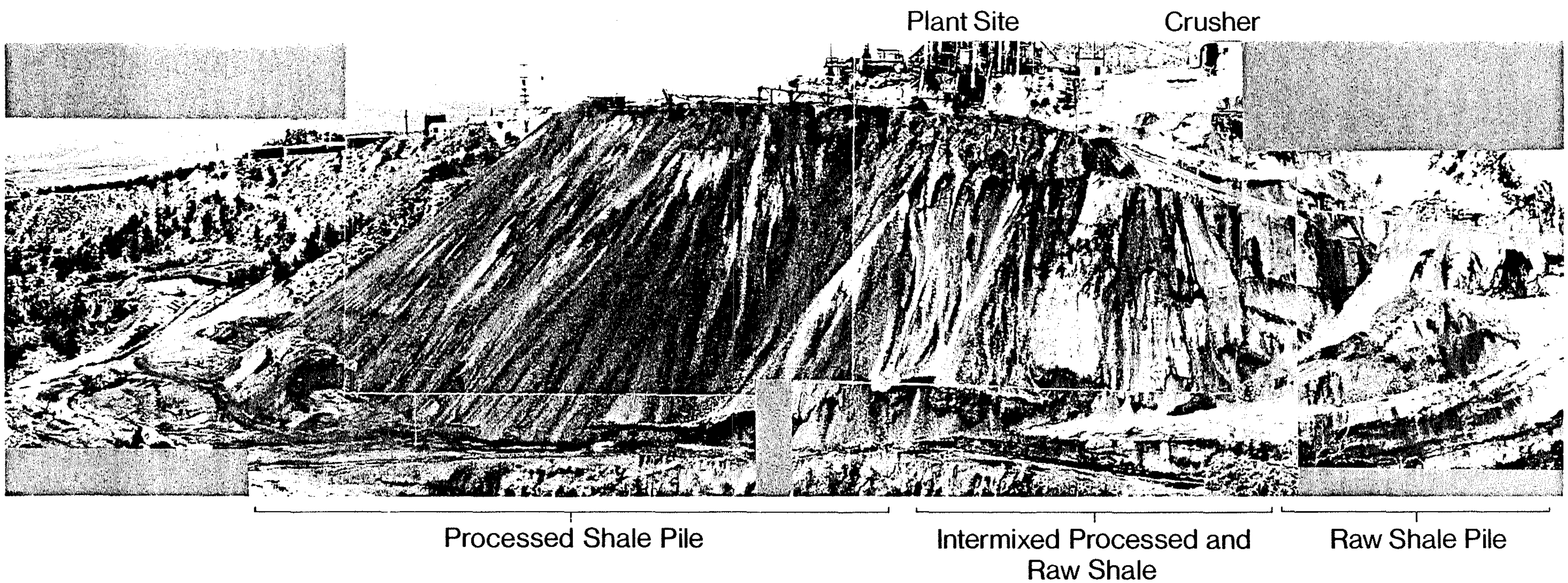
PLOT OF ISO-TEMPERATURE CONTOURS - 15′ DEPTH

Contour Interval 250°F

Fig B.6

Anvil Points Raw Shale Pile

PHOTOGRAPHS TAKEN DURING PROJECT

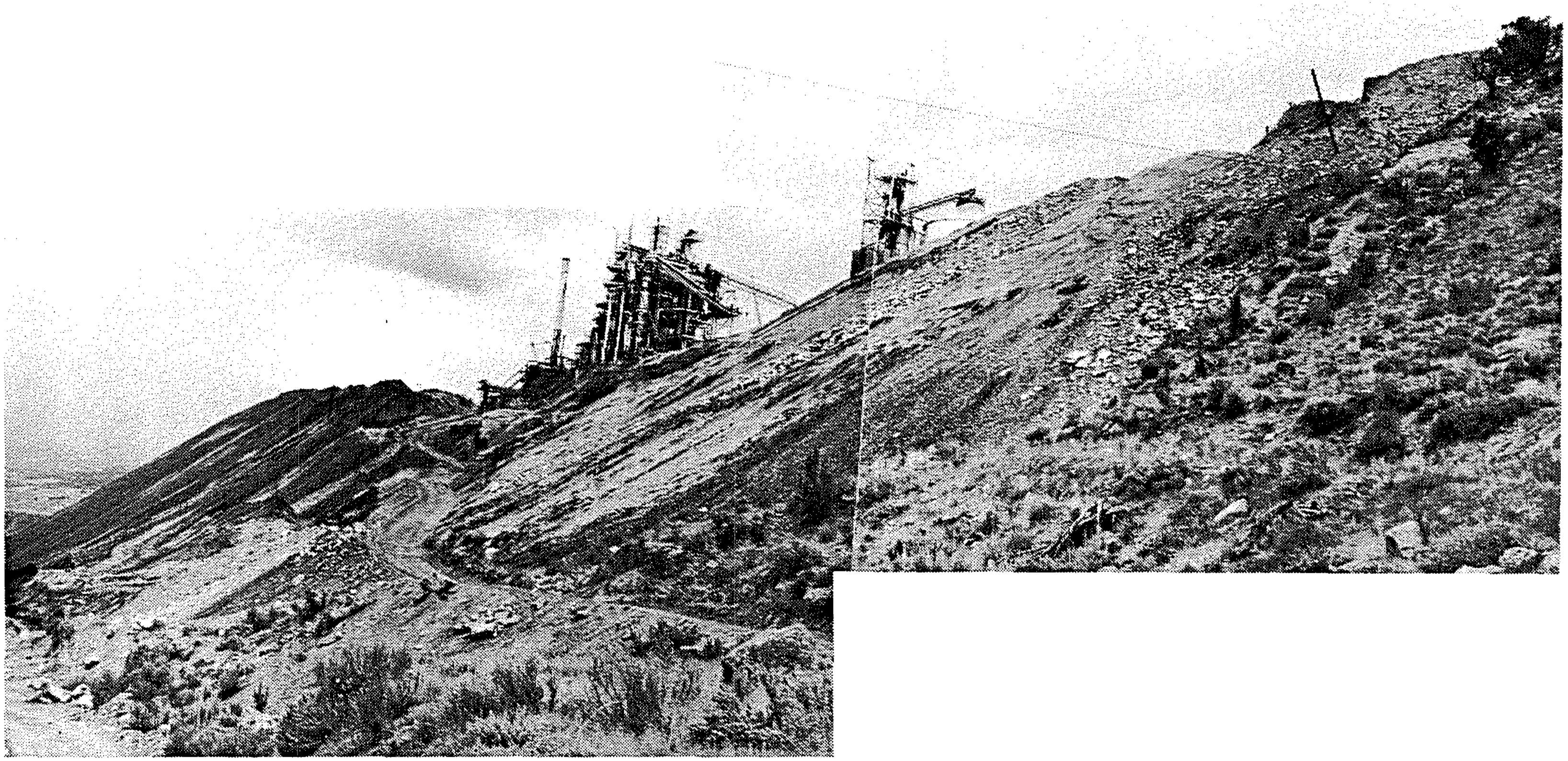


View looking southwest towards processed and raw shale piles
September 10, 1979

Fig C.1

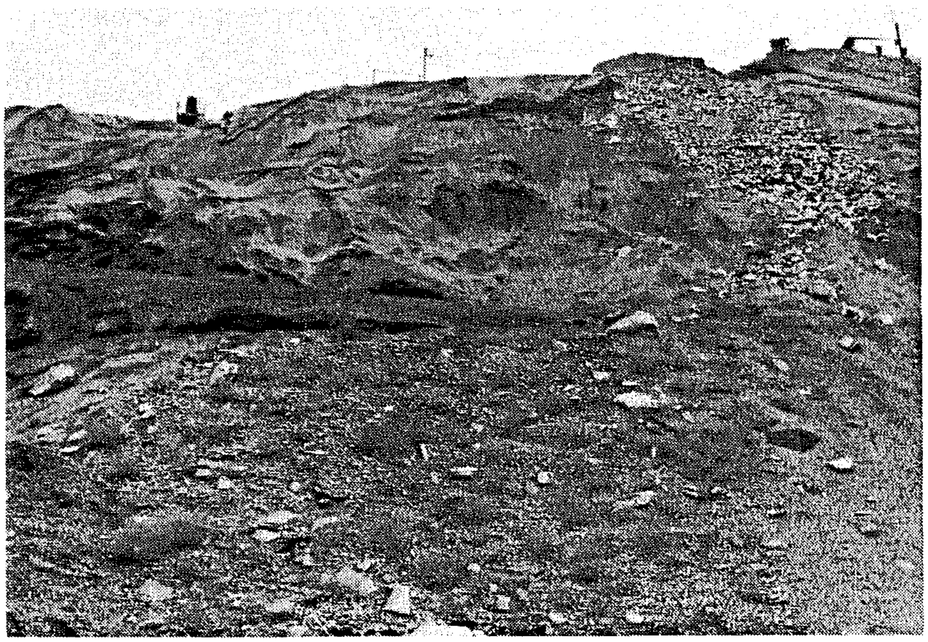
View looking northwest across processed shale pile towards raw shale pile

Fig C.2

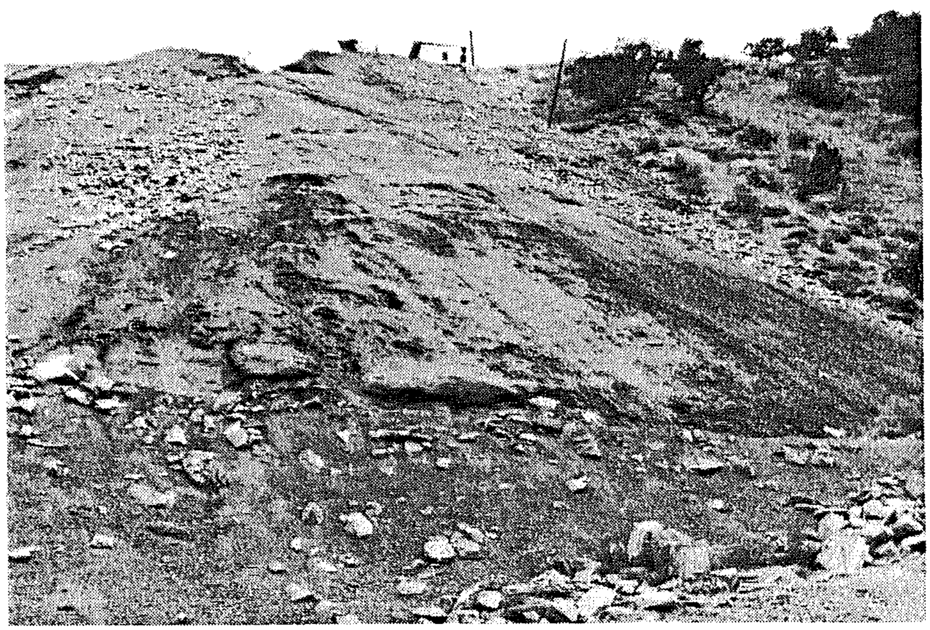


View looking southwest towards raw and processed shale piles

Fig C.3

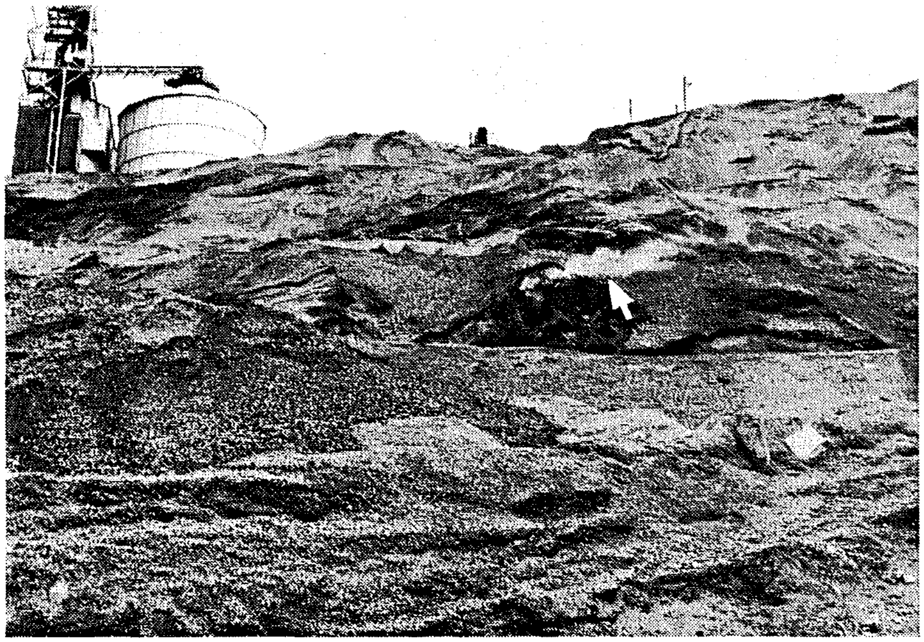


View looking west across raw shale pile
(Stations 2 + 50 and 3 + 00)

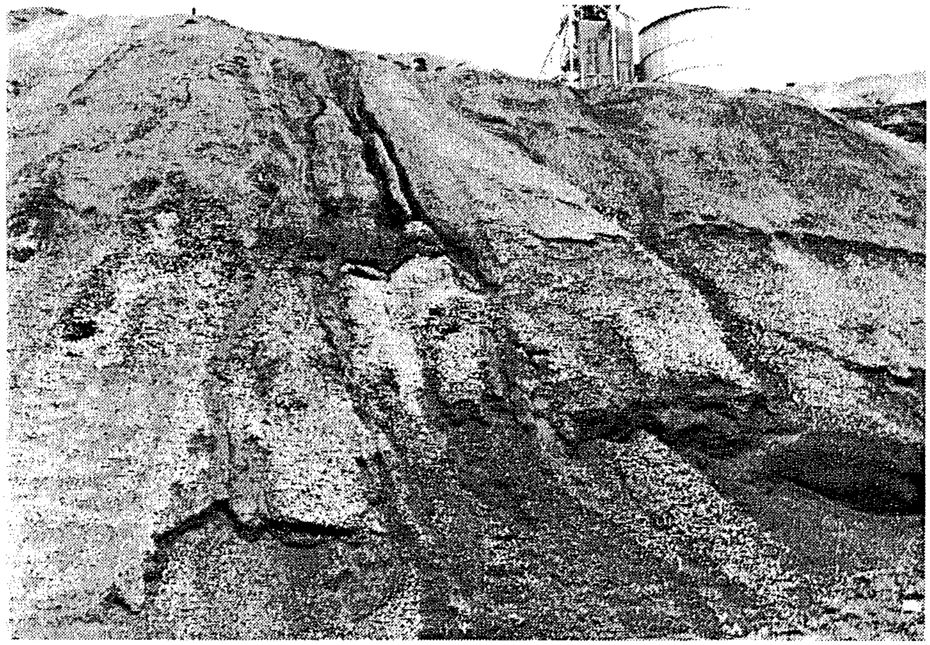


View looking west across raw shale pile
(Stations 1 + 00, 1 + 50 and 2 + 00)

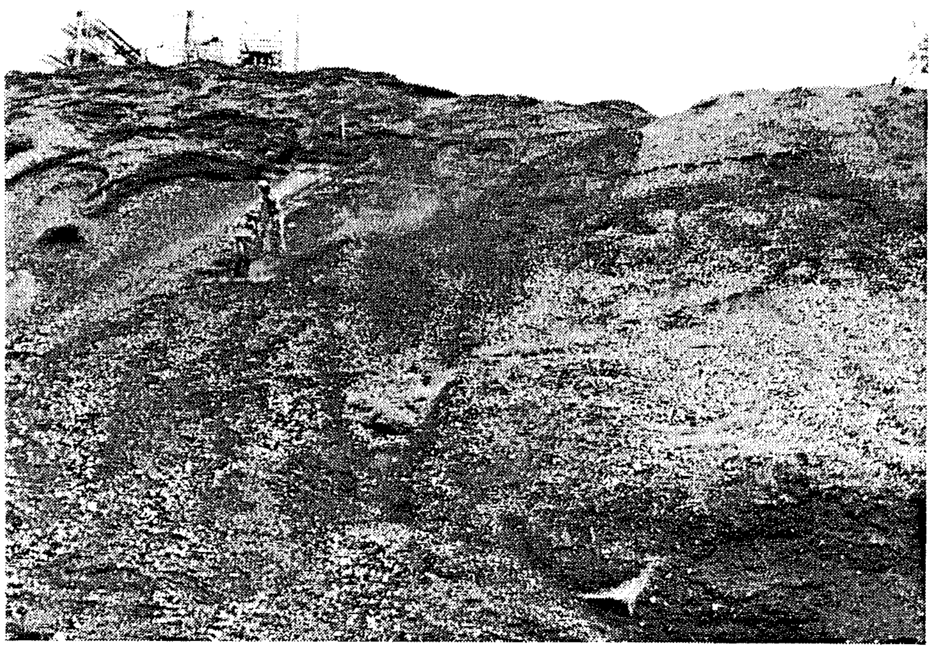
Fig C.5



View looking west towards raw shale pile
(Note fires above roadway - arrow)



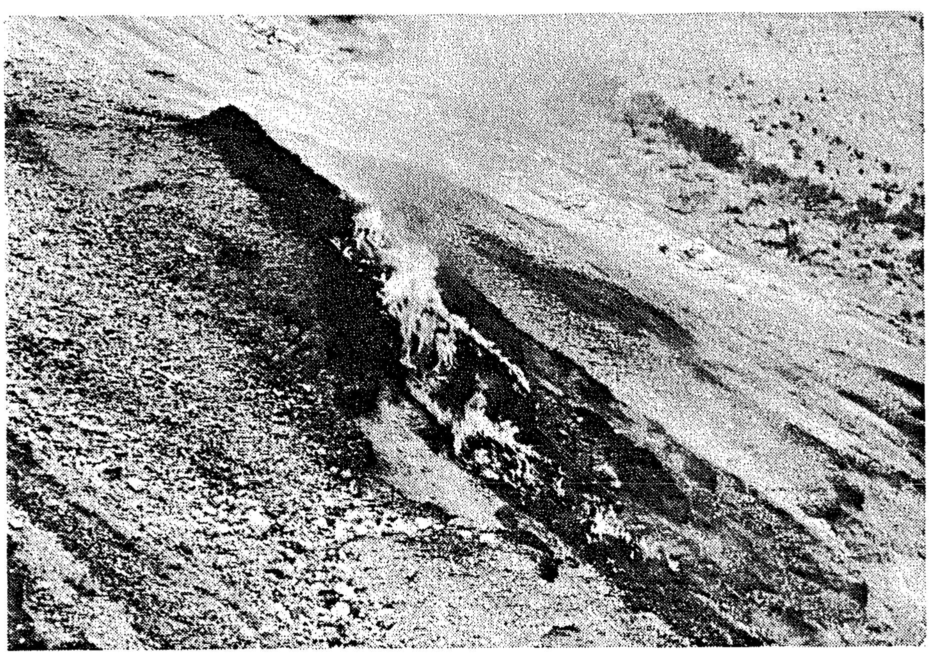
View looking west toward raw shale pile (Station 4 + 00)



View looking west toward raw shale pile (Station 5 + 50)

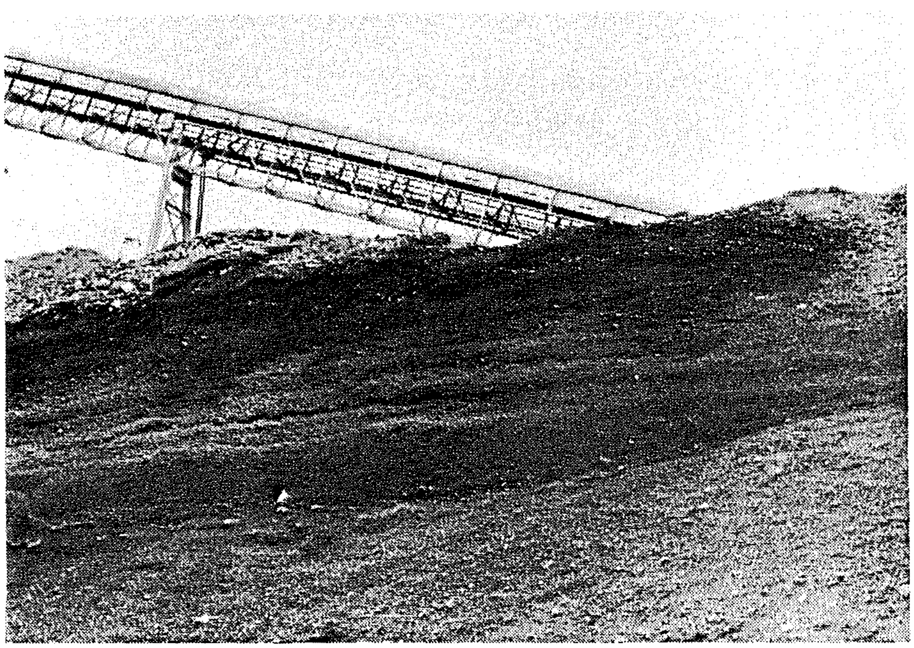
Fig C.7

View looking down across raw shale pile slope
(Stations 3 + 00 and 3 + 50)



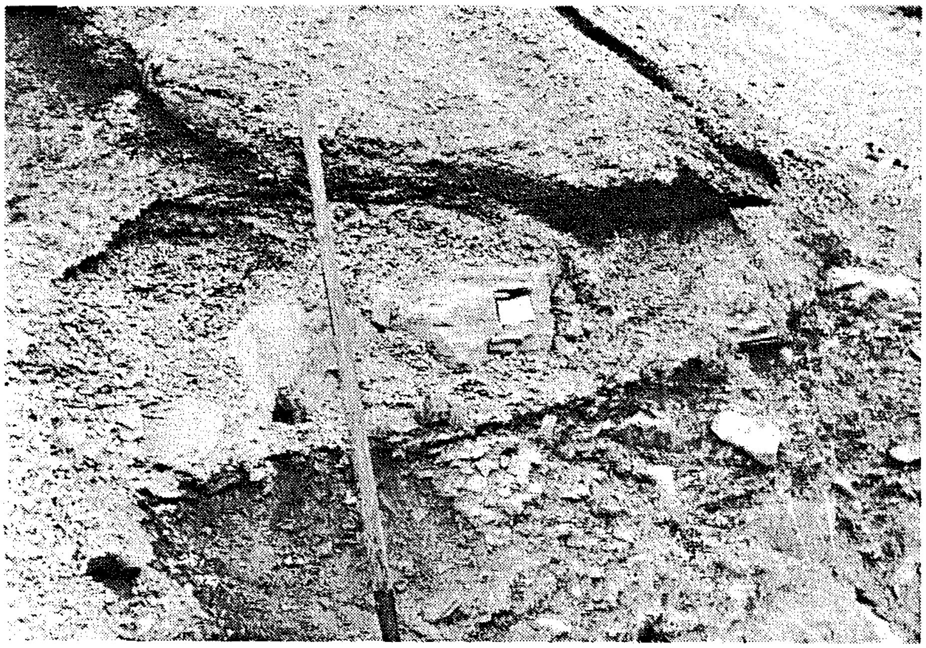
Raw shale pile fire at station 3 + 20

View of shale pile looking southwest (Note chimney remote from combustion - arrow)

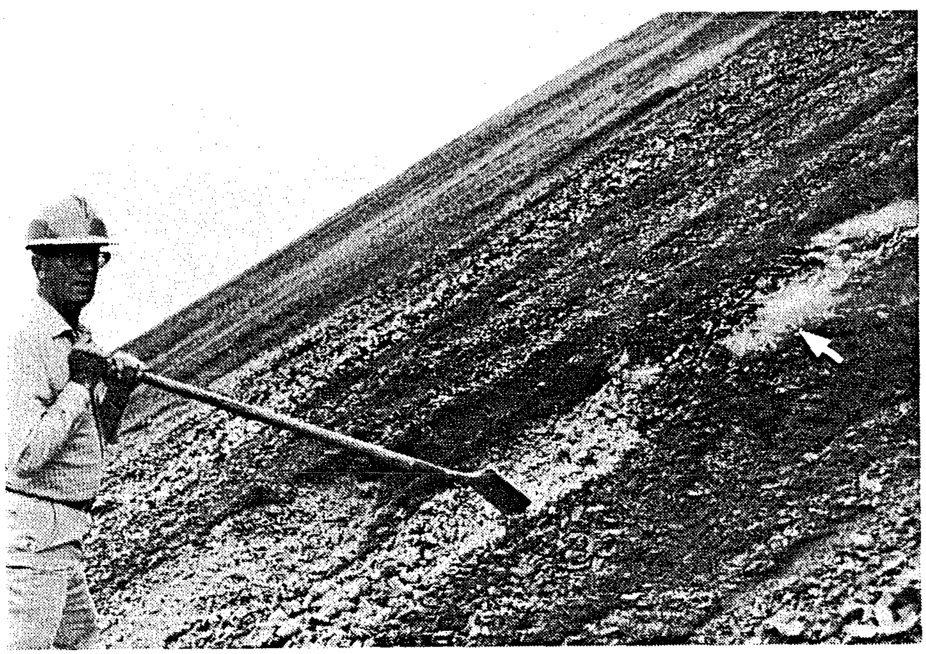


Closeup of chimney

Fig C.9

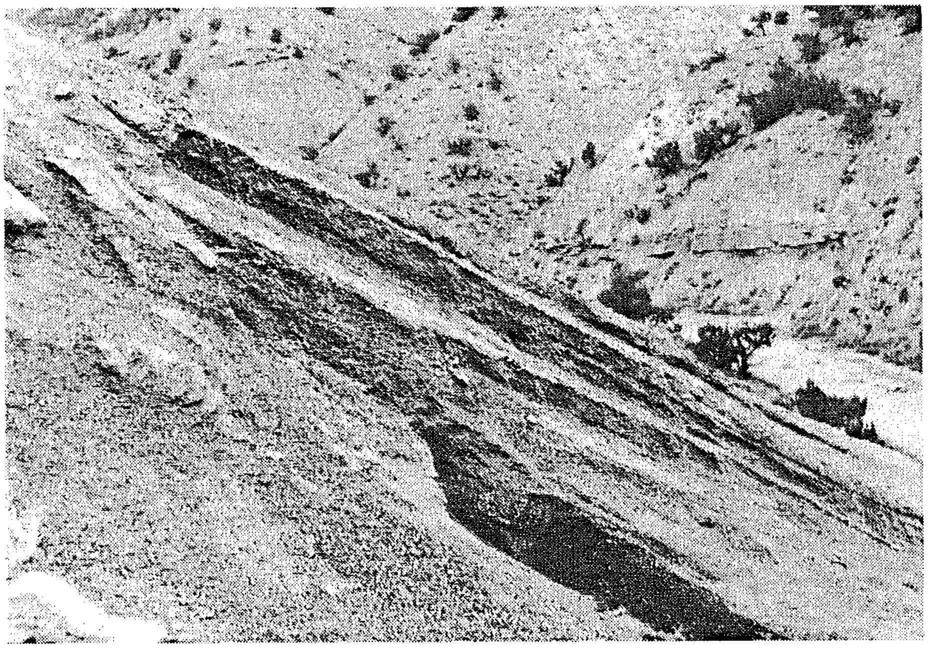


Spent shale ash in crusher oversize



Spent shale ash and combustion in segregated material
(Note smoke - arrow)

Fig C.10



Typical size segregation of shale

Burned and unburned shale

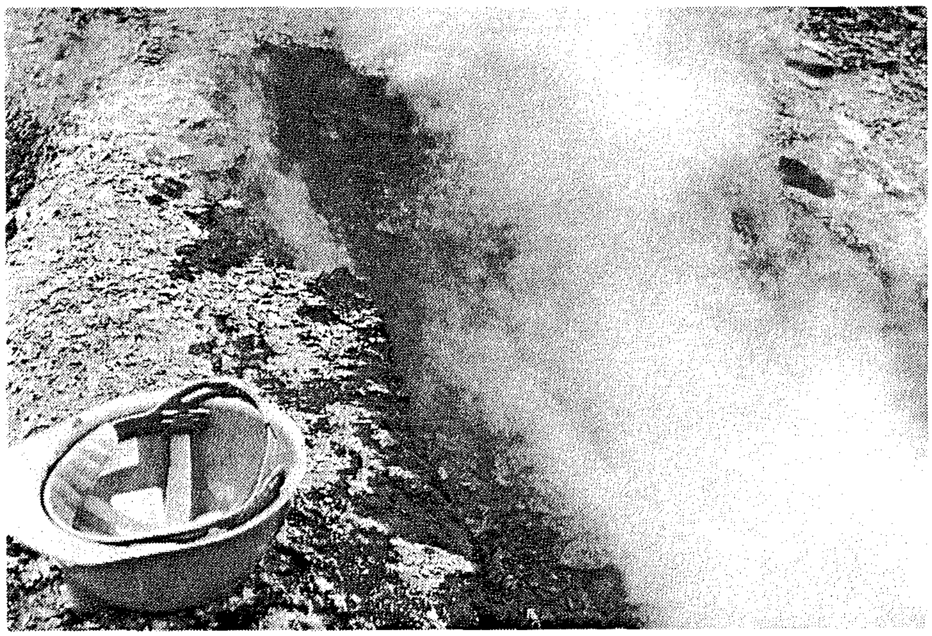
Fig C.11

Vapor chimney below crusher at station 3+50-3 (arrow).

Analyses of gas sample taken over vapor chimney

O_2 — 11.7%
N_2 — 76.4%
H_2 — 1.1%
CO_2 — 9.7%
Methane — 0.4%
Ethane — Trace
Propane — Trace

Fig C.12



Analyses of heavy yellow smoke gas sample

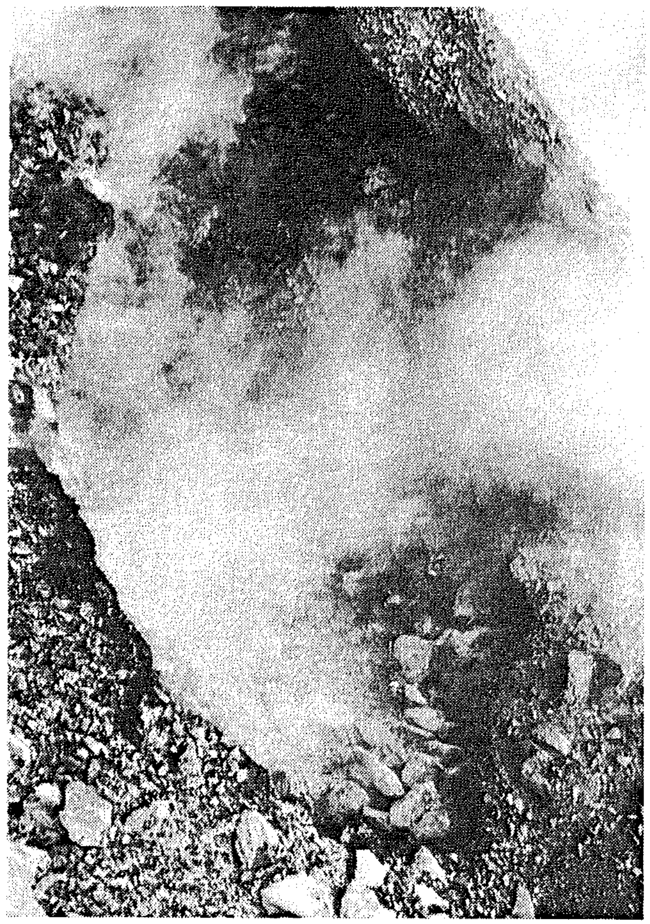
O_2 — 21.5%
N_2 — 77.2%
CO_2 — 0.2%
CO — Trace

Fig C.13

Gas sample being taken above vapor chimneys (station 4+00-3).

Analyses of vapor chimney gas sample

O_2 — 21.3%
N_2 — 76.9%
CO_2 — 0.3%
Methane — Trace



Analyses of smoke gas sample

O_2 — 21.5%
N_2 — 77.1%
CO_2 — 0.5%
CO — 0.1%

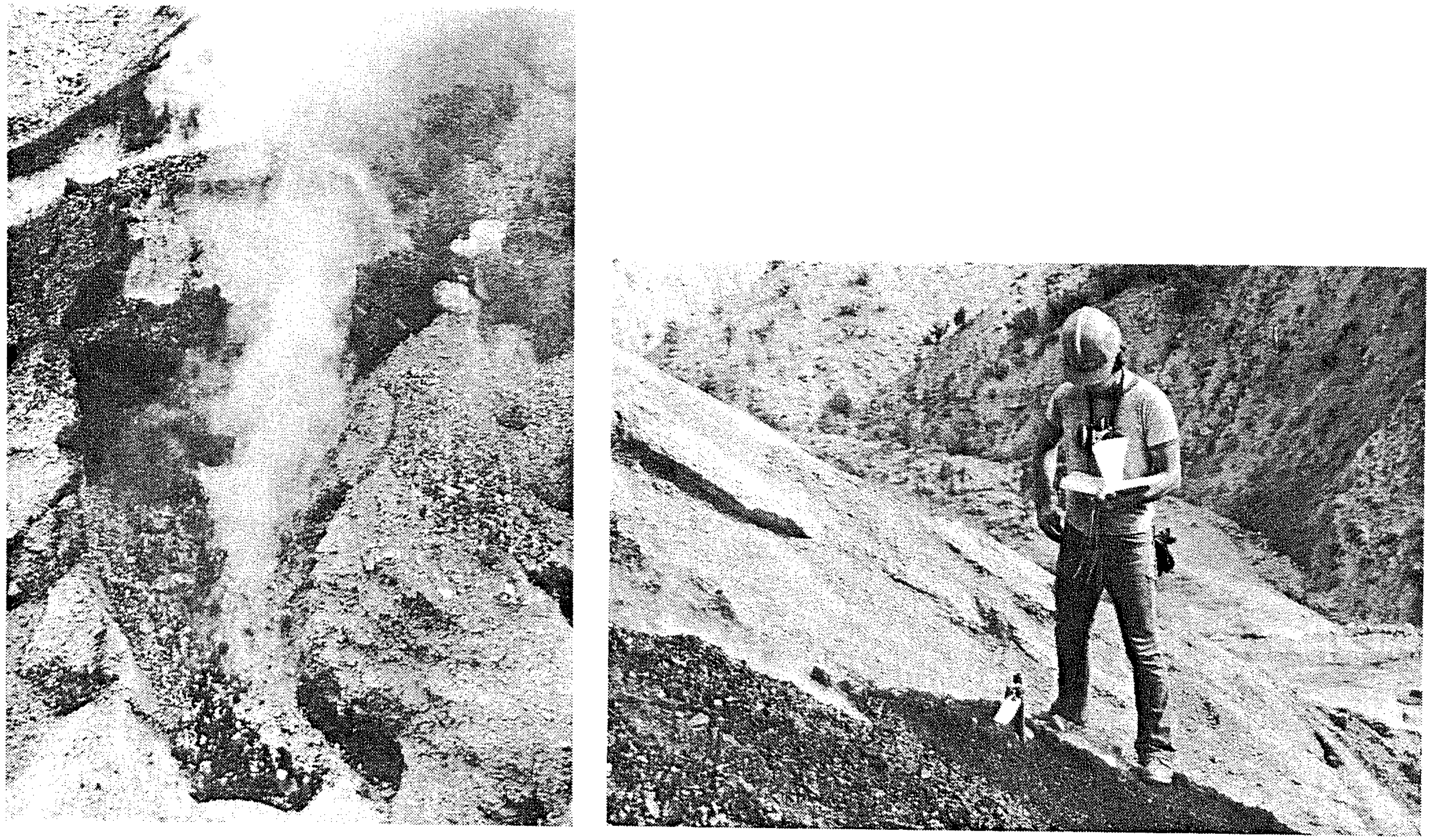
Fig C.15

Fire at station 3 + 20

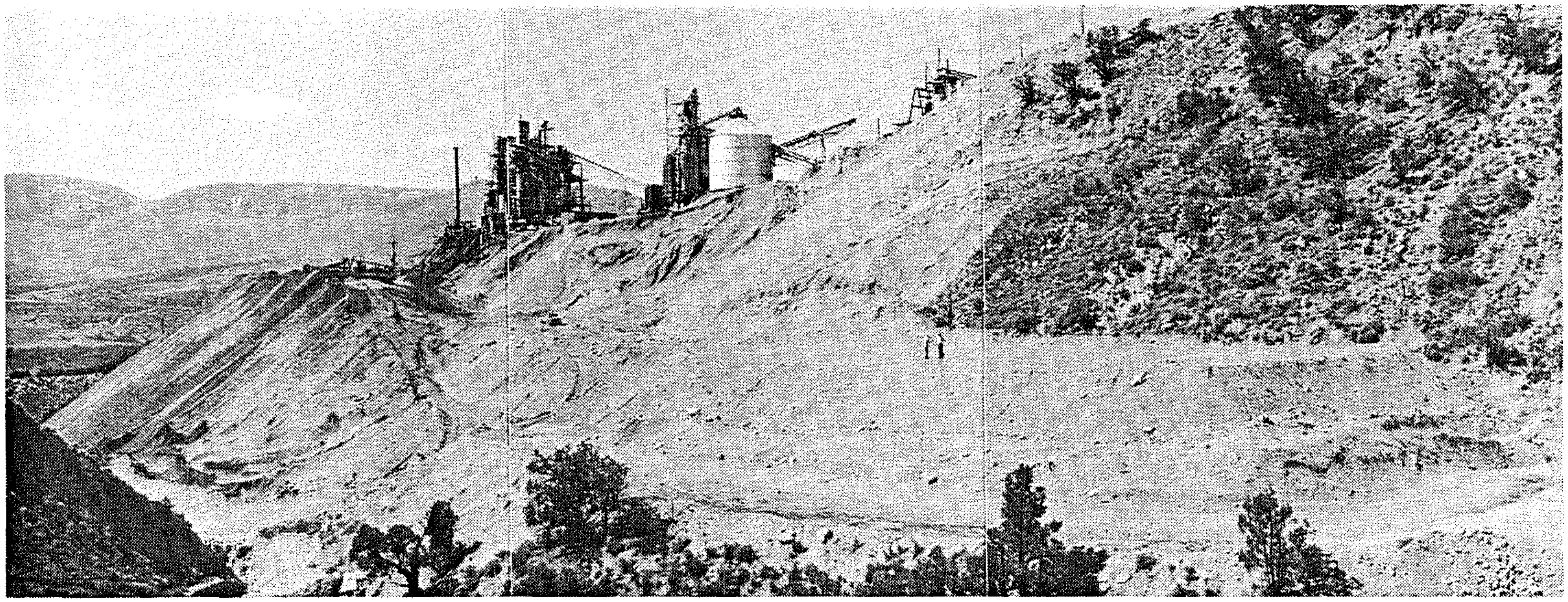
Analyses of gas sample taken above fire

O_2 — 21.3%
N_2 — 77.3%
CO_2 — 0.3%
CO — Trace

Fig C.16



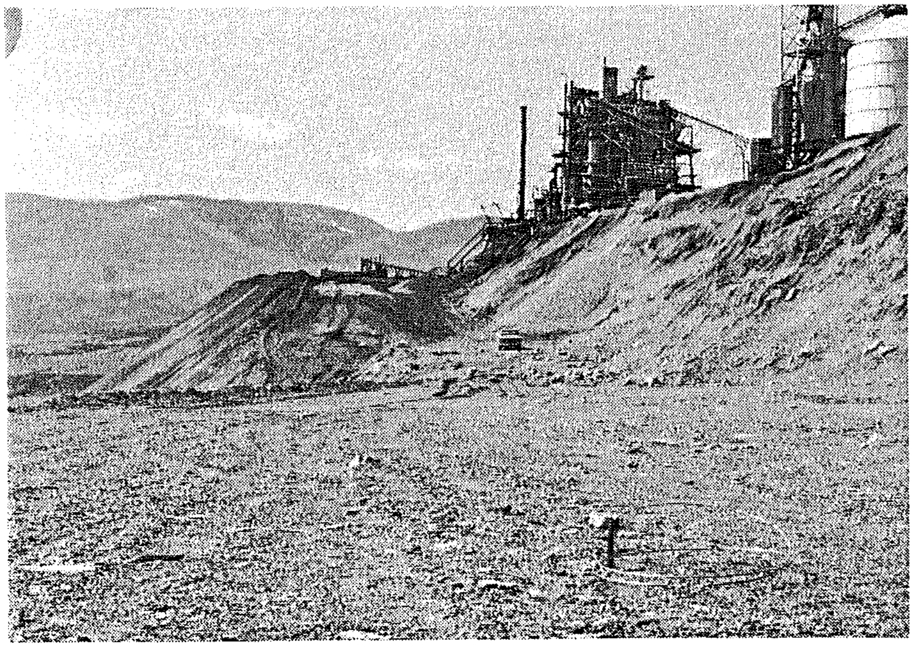
Visible signs of low temperature combustion
(Approximately 700°F)



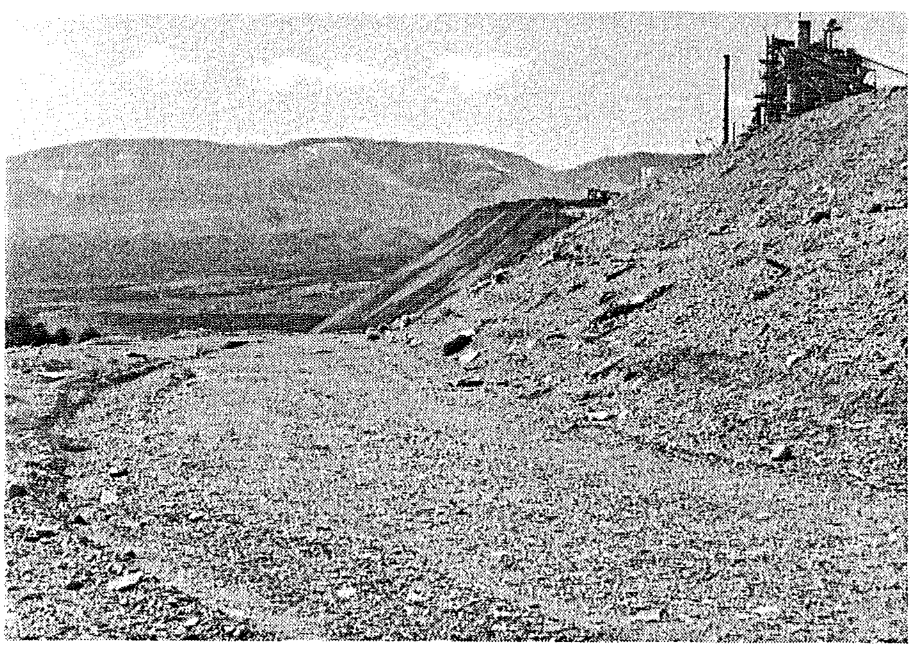
View looking southwest towards shale piles. June 2, 1982
(Compacted raw shale pile on right - processed shale pile on left)

Fig C.17

Fig C.18



View south along top of compacted raw shale pile.
June 2, 1982 (Note thermocouple installations)



View south along middle bench in raw shale pile.
June 2, 1982 (Note rock size distribution)

Anvil Points Raw Shale Pile

EXTINGUISHMENT AND STABILIZATION OF THE ANVIL POINTS RAW SHALE FINE STORAGE PILE

by F. E. Cooley

Vice President

Operations and Plant Manager

Paraho Development Corporation

EXTINGUISHMENT AND STABILIZATION

OF

THE ANVIL POINTS RAW SHALE FINES STORAGE FILE

In April 1979 oil was found to be discharging from the raw shale fines storage pile at Anvil Points. This oil was a product of combustion within the raw shale fines pile. Immediate action was taken to divert the oil flow to a nearby evaporation pond to avoid contamination of adjacent streams.

TOSCO Corp., under contract with the United States Bureau of Mines, set up a program to monitor temperatures in the raw shale fines pile. Aerial infra-red photographs were taken by the United States Department of Energy to identify the areas of combustion within the pile.

Development Engineering, Inc. contracted Woodward-Clyde Consultants of Denver, Colorado, to prepare a plan for a disposal area to hold combusted material from the pile. The plan called for a bowl-shaped area lined with a 24-inch clayey liner, compacted in three 8-inch layers. The bowl was constructed to drain to one end, with a perforated drain pipe discharging to a collection trench which drained to a lined evaporation pond. The disposal site was designed to hold approximately 60,000 yards of material.

Once the disposal site was prepared, Development Engineering, Inc. started activities to extinguish the pile. Using the infrared photographs from DOE and temperature profiles from the TOSCO studies, Development Engineering personnel identified the main hot spots in the pile and concentrated their efforts in extinguishing the fire in these areas.

By using high-pressure fire hoses, much of the material covering the hot spots was hydraulically mined and slurried to the lower end of the pile. This material was then transferred by front-end loader to the disposal site, spread in lifts, and compacted. As hot spots were uncovered, water was sprayed directly on the burning material to cool it and control dust as it was removed. A bulldozer was used to remove the material that was too large for hydraulic mining. The dozer operator approached the hot spots from the side and pushed across the hot spots. To protect the operator and equipment, one fire hose was aimed in front of the dozer to wet and cool material as it was being pushed. Another fire hose trailed the dozer to cool material that was exposed as already cooled material was pushed away. Fire hose operators kept a constant watch on the dozer operator so as to deluge both the operator and equipment with water in case of a flare-up.

Gas samples were taken routinely by safety personnel in the area to assure that no one was exposed to unsafe concentrations on gases. These samples were taken at ground level and at the equipment operator level. If, at any one time, concentrations approached an unsafe level, operators were removed from the area, water from fire hoses was directed on pile to cool the material, and gas was allowed to vent until tests indicated it was safe to resume removal of material by equipment. During the recovery operations work was suspended whenever intense smoke and dust were encountered, the area was thoroughly wet down with water, and work was not resumed until the adverse conditions abated.

Almost two years of elapsed time were required to remove approximately 60,000 yards of burned material and to extinguish the fire. Cold weather caused operations to be curtailed several times because water was used to cool the fire, and freezing conditions made operations unsafe. When areas of extreme heat were uncovered, several days were required to cool material before equipment could be used to remove large boulders.

To avoid over-exposure to the environment associated with extinguishing a fire where heat, smoke, and gas were involved, two basic crews were used on a rotated basis. Also, periods of non-involvement by both crews were allowed. During these periods of non-involvement, equipment was maintained, and the fire site was studied to see if a new approach should be taken to enhance the extinguishment effort.

As the pile was methodically disassembled to extinguish hot spots, several thousand yards of material that had not been affected by burning were transported to another area, spread, and compacted. This allowed an opportunity to study the material to see if any heat build-up would occur and also made more space for burned material in the prepared storage area. (No heat build-ups had been measured as of July 1982). The hot spots in the original shale waste pile ran in veins which developed from dumping material on a hillside from conveyor belts. This method of dumping creates segregation of material by forming fine and coarse layers. The coarser layers allow air to be updrafted through the pile to supply oxygen for combustion of the finer particles. The coarse layers also provide a chimney once combustion has started. An attempt was made to cool hot spots by saturating the chimney areas with water. Initially, it appeared this was working; but within a few days after pumping water into a chimney area, the hot spots became hotter and started to spread. A possible reaction scenario is that the water temporarily cooled the combustion until the water boiled off. Then the combustion became hotter because the water had made a better chimney passage which allowed more air to enter. The only way to extinguish the hot spots was to physically move the material, wet it, and cool it with excess air. Material that was dozed out of the pile wet and spread over the disposal site became almost a cement after being compacted and allowed to dry.

As the new disposal pile grew in depth, sufficient time was allowed between lifts to detect any heat build-up which might cause future combustion problems. At the time of this report, monitoring by thermocouples has shown only ambient temperatures exist in the disposal area.

Anvil Points Raw Shale Pile

HISTORY OF ANVIL POINTS

RESEARCH OPERATIONS

An Informal Description

Submitted by

Paraho Development Corporation

HISTORY OF ANVIL POINTS RESEARCH OPERATIONS

AN INFORMAL DESCRIPTION

TABLE OF CONTENTS

HISTORY OF ANVIL POINTS RESEARCH OPERATIONS

AN INFORMAL DESCRIPTION

TABLE OF ILLUSTRATIONS

INTRODUCTION

Knowledge of the vast oil shale deposit in the Piceance Basin, located in western Colorado, has been identified since the advent of the first white settlers into the region nearly 100 years ago. Before that, Indians were aware of the "rock that burns".

In 1916 a portion of these oil shale lands was set aside as Naval Oil Shale Reserve No. 1 for a future source of oil for the U.S. Navy. In 1924 an adjoining parcel of land was set aside as Naval Oil Shale Reserve No. 3 to provide land for processing plants and related facilities. These Naval Oil Shale Reserves Nos. 1 and 3 (NOSR 1 and 3) are located in the region known as Anvil Points at the southeast edge of the Piceance Basin about 10 miles west of Rifle, Colorado (see map, Figure 1).

The Rifle Oil Shale Project was started in 1944 as a result of the Synthetic Liquid Fuels Act (Public Law 78-290). This project was located at Anvil Points on the NOSR 1 and 3. Research facilities were developed by the Department of Interior, Bureau of Mines. In 1962, under Public Law 87-796, the Secretary of the Interior was authorized to lease the facilities to private companies to encourage further research and development work on oil shale and shale oil. Since 1973, through various reorganizations in the executive branch of the federal government, administration of these research facilities has been transferred from the Bureau of Mines (BOM) to the Energy Research and Development Administration (ERDA) to the Department of Energy (DOE).

In this paper the history of the research operations at Anvil Points will be described briefly. Although the proper name for the facility is the DOE Rifle Oil Shale Facility, in this paper the more familiar term, Anvil Points Facility, will be used. The history of the research operations will be presented to show the general impact of those operations on the ground and surface water quality - particularly as it pertains to the unnamed gulch adjacent to the east of the retorting operations. Since that gulch drains into an area identified as Sharrard Park (see map, figure 1), the term "West Drainage - Sharrard Park" will be used in this paper to describe that area. There are two other drainages mentioned in this paper. One is Balzac Gulch (see map, Figure 1) which lies below and to the south of the Anvil Points mine.

The other is the area between Balzac Gulch and West Drainage - Sharrard Park. Since this area represents the drainage from the Anvil Points formations (see map, figure 1), the area will be termed "Anvil Points Drainage" in this paper.

In order to present the impact of various research operations conducted at the Anvil Points Facility, the following information (when available) will be presented:

- Mining Operations
- Retorting Operations
- Disposal Operations
  - -mined (raw) shale, tonnage
  - -retorted shale, tonnage
  - -location of disposal sites

- o Dates of Mining, Retorting, and Disposal Operations
- o Utiltiies Affecting Water Quality
- o -domestic sewer
  - -industrial sewer
  - -plant water

The research operations conducted at the Anvil Points Facility include the following:

o	United States Bureau of Mines	1944-1956
o	Six Company Group	1964-1968
o	Paraho	
	-Paraho Oil Shale Demonstration	1972-1976
	-ONR/DOE Operations	1977-1978

Details of these research operations will be presented in the following section "ANVIL POINTS OPERATIONS". In the final section of this paper, "UTILITIES", a historical description of the domestic and industrial sewer and the plant water systems will be presented.

ANVIL POINTS OPERATIONS

To assess over 35 years of periodic research operations at Anvil Points, it is necessary to make some assumptions due to the fact that detailed records are not available in all areas of past operations. Three tables have been prepared to assist in this assessment. These include: table 1, Summary of Research Operations; table 2, Summary of Raw Shale Disposal; table 3, Summary of Retorted Shale Disposal. In addition to these tables, figures are provided to show historical surveys conducted in the disposal areas of the West Drainage - Sharrard Park.

United States Bureau of Mines (USBM). Development work started in 1944 at the Anvil Points site to provide underground selective and demonstration mines and an above-ground plant for the purpose of advancing oil shale research toward a viable commercial industry. Mining operations started in early 1946 and were conducted until June 1956 (see table 1). The first retort operations at Anvil Points started in 1947 on the two N-T-U batch units and continued until 1951. Research work in the pilot plant building on the Royster retort began in January 1948. The Royster operations were followed by the Gas Flow operations in late 1948. These pilot plant operations preceded the development and subsequent operations of the Gas Combustion No. 1 retort in 1950. Positive results of Gas Combustion retorting on Colorado shale created the need for research on a larger scale, and in July 1953 operations began on the newly constructed 150-ton/day Gas Combustion No. 3 retort. The Gas Combustion No. 3 retort was incorporated into the existing superstructure after dismantling of the N-T-U units. Gas Combustion No. 3 operations were carried out until July 1955. Gas Combustion No. 2 retort was constructed in the pilot plant building, and operations on this unit began in 1954. All retort operations at Anvil Points ceased in July of 1955. A breakdown of the USBM operations and amounts of shale retorted is shown in table 1.

USBM mining operations (1945-1956) were aimed at developing commercially feasible mining practices for oil shale. In the process of developing mining methods, much more shale was mined than could be utilized by the retorting facilities. Four hundred seventy-five thousand tons of shale were mined from the selective mine and the demonstration mine by the USBM. It can be estimated that 315,000 tons of this shale were disposed of in the Anvil Points Drainage (see figure 1). Thirty-five thousand tons were stockpiled.

Disposal of oversize mine run shale and crusher rejects, along with retorted shale from the N-T-U units and Gas Combustion No. 3 retort was in the West Drainage - Sharrard Park. Available records do not identify the amounts of raw shale disposed of in this area; but due to the nature of work carried out during this program, an estimate of at least 50,000 tons is made. Records do show at least 38,000 tons of shale were retorted in the N-T-U units and 30,000 tons in the Gas Combustion No. 3 retort (see Tables 2 and 3). These totals do not include shale used for cold flow studies or startups and shutdowns. Surveys made in 1949, 1974, and 1979 could be used to verify amounts of shale in the West Drainage - Sharrard Park Gulch disposal areas. Originally, the raw and retorted shale disposal areas in this gulch were separated; but, as research continued, by 1955 (as shown by photograph in U.S.B.M. Report of Investigation No. 5119) the separated disposal areas had come in contact with one another.

Disposal of shale from the Royster, Gas Flow, and Gas Combustion No. 1 and No. 2 retorts, all housed in the pilot plant building, was in the area west of the maintenance shops. The total amount from these operations is estimated at 15,000 tons.

Six Company. Under the authorization of P.L. 87-796, the Anvil Points Research Facilities were leased to the Colorado School of Mines Research Foundation from 1964 to 1968. Research work funded by six companies from private industry was carried out during this time.

Records show that at least 25,000 tons of shale were retorted in the period 1964-1968 (see table 1). Five thousand tons of the above amount were used in Retorts No. 1 and No. 2 and disposed of in the area west of the maintenance shops. The remaining 20,000 tons were used in Retort No. 3 and disposed of in the West Drainage - Sharrard Park Gulch disposal area (see table 3).

Mining during the period 1964-1968 produced 35,000 tons from the existing USBM mine and 530,000 tons from the newly developed Mobil mine located west of the No. 1 Adit of USBM mine on property owned by Mobil. By using available records and reasonable estimates, it can be surmised that 455,000 tons of mine run shale were added to the USBM disposal area east of the USBM mine. Based on the scope of work carried out during the Six Company program (special crusher studies and mechanical model studies), another 50,000 tons of raw shale are estimated to have been disposed of in the West Drainage - Sharrard Park Gulch (see table 3). Thirty-five thousand tons were stockpiled.

Operations from 1964 to 1968 increased the volumes in the West Drainage - Sharrard Park Gulch disposal areas to the point where the raw and retorted shale piles were overlapping one another (photos taken during construction of Paraho retorts, April 1974).

Paraho. In 1972 Development Engineering, Inc., a wholly-owned subsidiary of Paraho Development Corporation, leased the Anvil Points Facilities. The original privately-funded program (1973-1976) was for the demonstration of Paraho's technological advances in above-ground retorting. During this period 100,000 tons of shale were mined from the USBM mine. Retorting consumed 65,000 tons during these operations and produced about 54,000 tons of retorted shale. About 30,000 tons of this shale were transported from the Anvil Points Facilities and used in field compaction and vegetation studies, leaving only 25,000 tons for disposal in the southern portion of the retorted shale disposal area of the West Drainage - Sharrard Park Gulch. Seven thousand tons of the mined shale were held in stockpiles in the plant area for future use. Twenty-eight thousand tons of raw shale fines from the crusher operations were added to the existing raw shale disposal area. The success of the 1973-1976 operations led to a ONR/DOE contract for 1977-1978 to produce up to 100,000 barrels of oil for refining and testing as military fuels. During the 1977-1978 production operations 195,000 tons of shale were mined. Retorting operations consumed 132,000 tons and produced 108,000 tons of retorted shale for disposal. In September 1978 the Anvil Points facilities were put on a standby status, and all mining and retorting activities ceased. Thirty-thousand tons of shale remained in storage at the plant and mine for future use. The 1977-1978 crushing operations generated another 33,000 tons of raw shale fines in the existing raw shale disposal area of the West Drainage - Sharrard Park Gulch. Tabulation of Paraho operations are shown in tables 1, 2, and 3.

UTILITIES

Domestic Sewer. A drawing of the domestic sewer system for the Anvil Points plant area is shown in figure 4. This system was installed as part of the original construction of the facility and was increased as needed during USBM operations. No changes have been made to this system since the 1950's. Since the septic system and leach field are located so as not to affect the West Drainage - Sharrard Park Gulch, they are not shown.

Industrial Sewer. Figure 5 shows the Anvil Points Industrial sewer system. The industrial sewer system was installed by the USBM and the only known modifications to this system were made by Paraho during the 1970's. Paraho improved the drainage of the disposal area with dikes and lined the evaporation pond. The industrial sewer drains to the retorted shale disposal area were removed from the system and all industrial drains routed to the lined evaporation pond. As new oil storage tanks were added to the facilities during Paraho's operations, the system was enlarged to encompass the new dike areas for this tankage.

Plant Water. The potable water system built by the USBM consists of a water treatment plant located at the Colorado River, supply line from the river to the plant and housing area, tankage, and distribution systems. Many changes have been made to the total water system over the past 30-plus years. Because of a collapse of part of the plant water storage tanks in 1965, a new 3,000-barrel tank was installed by the Six Company Group. Due to deterioration of the water supply tank for the housing area and the need for more storage capacity for fire protection due to increased oil storage, a new 10,000-barrel water tank was installed next to the existing 3,000-barrel plant water tank (1978).

The system was modified to provide service to the housing area from the plant storage system, thereby abandoning the existing storage tank for the housing area. During construction of the new oil storage tanks, some of the old water lines in the refinery area were capped off and abandoned (see figure 6). Also, some other areas no longer in use were abandoned to avoid possible line failure. Considerable maintenance is required on the water system due to age, and repairs are made as soon as leaks in the lines are detected.

REFERENCES

Data used in this report were obtained from a variety of sources. These sources included many United States Government reports, Paraho documents, photographs, and personal communications with present and former employees of the Anvil Points facilities.

Paraho Documents:

Lease Agreement between the United States of America and Development Engineering, Inc. for the Anvil Points Experimental and Demonstration Facilities near Rifle, Colorado. May 1972.

Final Environmental Statement, Oil Shale Retort Research Project, Anvil Points, Colorado. Department of the Interior, February 1972.

Quarterly Reports. 1973-1978.

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SUMMARY

Intermittent research operations have been carried out at Anvil Points since 1944. These operations include:

United States Bureau of Mines (USBM)	1944-1956
Six Company Group	1964-1968
Paraho	1972-1978

Based upon available records, surveys and photographs, it is estimated that the following mining/retorting activities were carried out:

	Mined (Thousand Tons)	Retorted (Thousand Tons)
USBM	475	83
Six Company Group	565	25
Paraho	295	197

Although records are not available for all periods, it is estimated that the following quantities of shale were placed in the disposal area located in the gulch adjacent to the crushing-retorting operations (West Drainage - Sharrard Park):

	Raw Shale (Thousand Tons)	Retorted (Thousand Tons)
USBM	50	68
Six Company Group	50	20
Paraho (Dem)	28	24
(ONR/DOE)	33	108

Water and sewer systems were installed by the USBM. These systems were modified by Paraho and improved as necessary.

TABLE 1

SUMMARY OF RESEARCH OPERATIONS

Research Operations	Mined (In Thousand Tons)	Retorted (In Thousand Tons)
United States Bureau of Mines 1946-1956	475	
NTU-Gas Combustion #3 1947-1955		68[a]
Royster, Gas Flow, Gas Combusion #1, 2 1948-1955		15[a]
Six Company Group 1964-1968	565	
Gas Combustion #3		20[a]
Gas Combustion #1, 2		5[a]
Paraho Oil Shale Demonstration 1973-1976	100	65
ONR/DOE 1977-1978	195	132

Notes:

(a) Does not include shale used for cold flow studies, startups, and shutdowns.

TABLE 2

SUMMARY OF RAW SHALE DISPOSAL

Research Operations	Mine[a] (In Thousand Tons)	Gulch[b] (In Thousand Tons)
United States Bureau of Mines 1944-1956	315	50[c]
Six Company Group 1964-1968	455	50[c]
Paraho Oil Shale Demonstration, 1973-1976		28
ONR/DOE, 1977-1978		33

Notes:

(a) Area below and east of mine, Anvil Points Drainage.

(b) West Drainage - Sharrard Park.

(c) Estimate - no data available.

TABLE 3

SUMMARY OF RETORTED SHALE DISPOSAL

Research Operations	Disposal[a] (In Thousand Tons)	Disposal[b] (In Thousand Tons)
United States Bureau of Mines		
N-T-U/Gas Combustion #3, 1947-1955		68
Royster, Gas Flow, Gas Combustion #1, 2 1948-1955	15	
Six Company Group		
Gas Combustion #3		20
Gas Combustion #1, 2 1964-1968	5	
Paraho		
Oil Shale Demonstra tion, 1973-1976		24
ONR/DOE, 1977-1978		108

Notes:

(a) Area west of maintenance shops.

(b) West Drainage - Sharrard Park Gulch.

FIGURE 1

ANVIL POINTS AREA

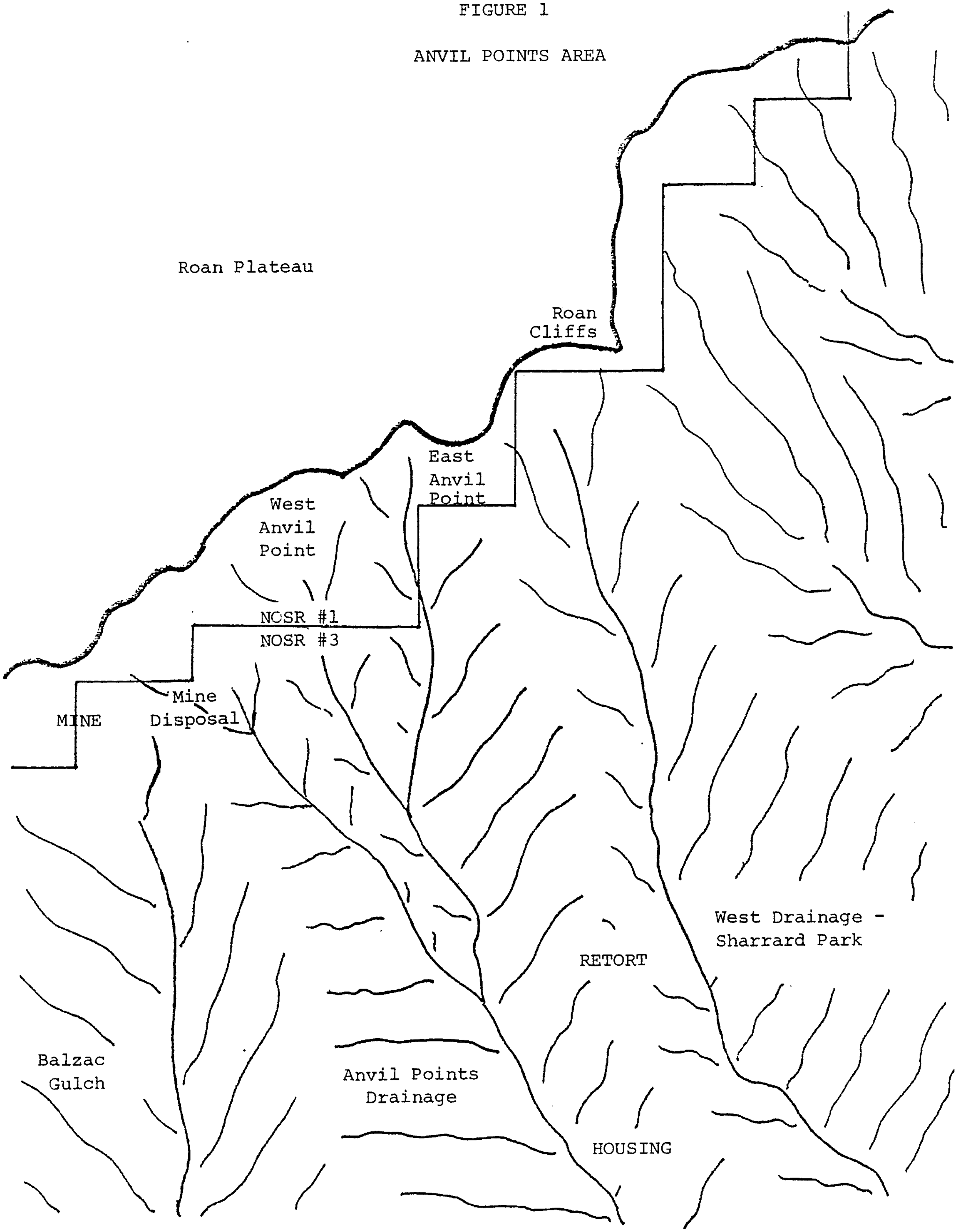


FIGURE 2

Historical Survey Profiles

West Drainage - Sharrard Park

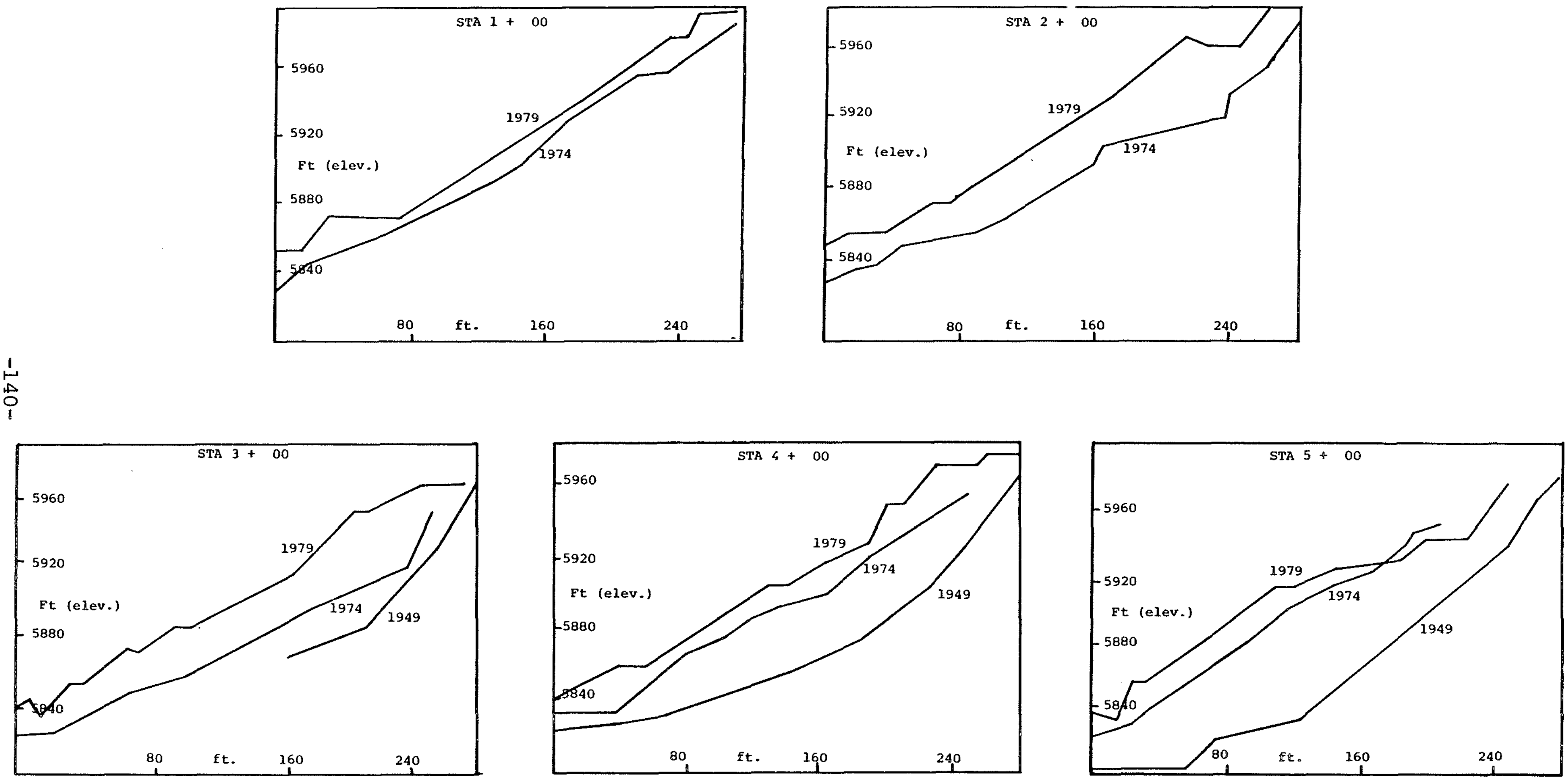
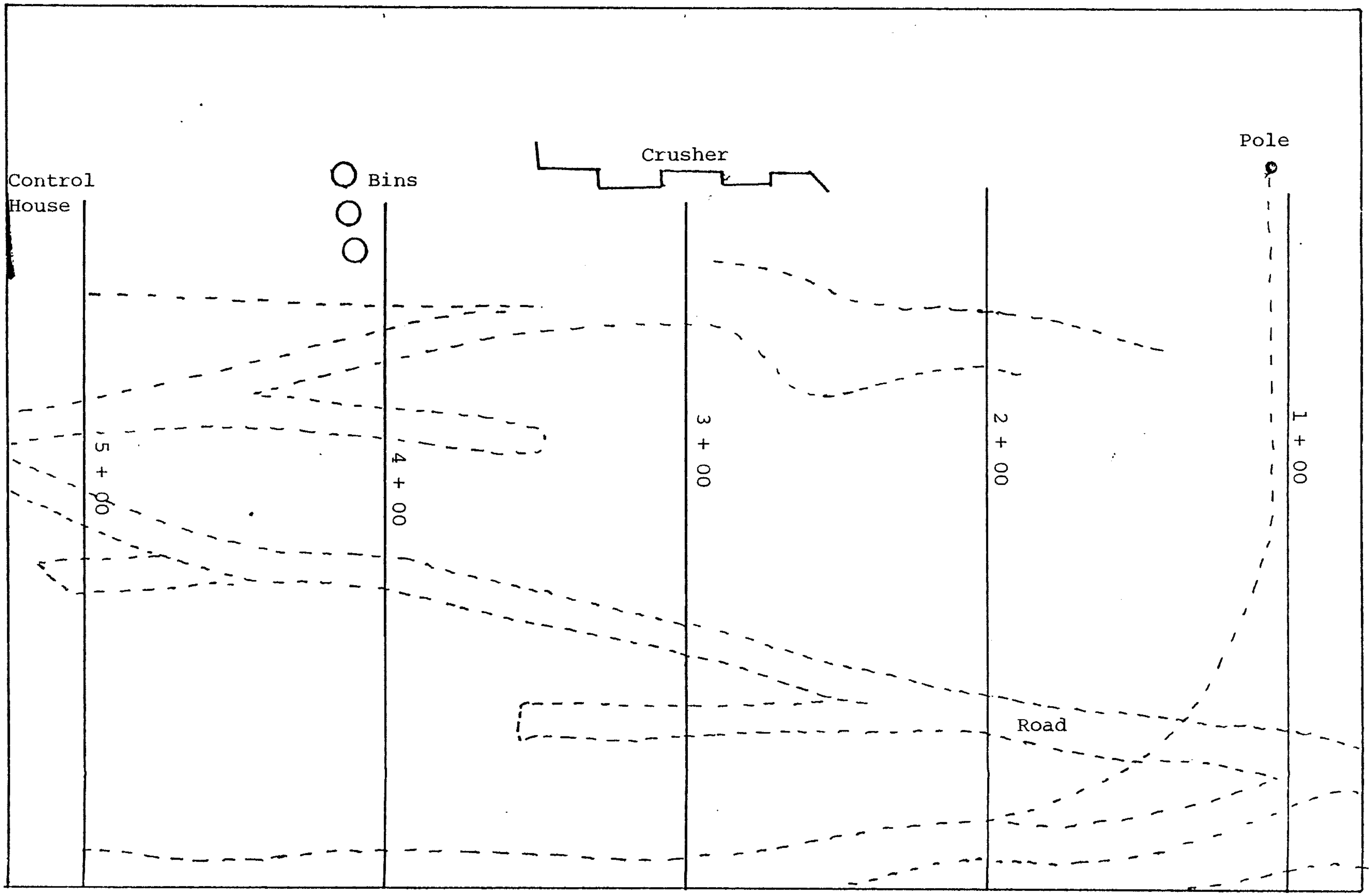


FIGURE 3

SURVEY LOCATIONS, WEST DRAINAGE - SHARRARD PARK



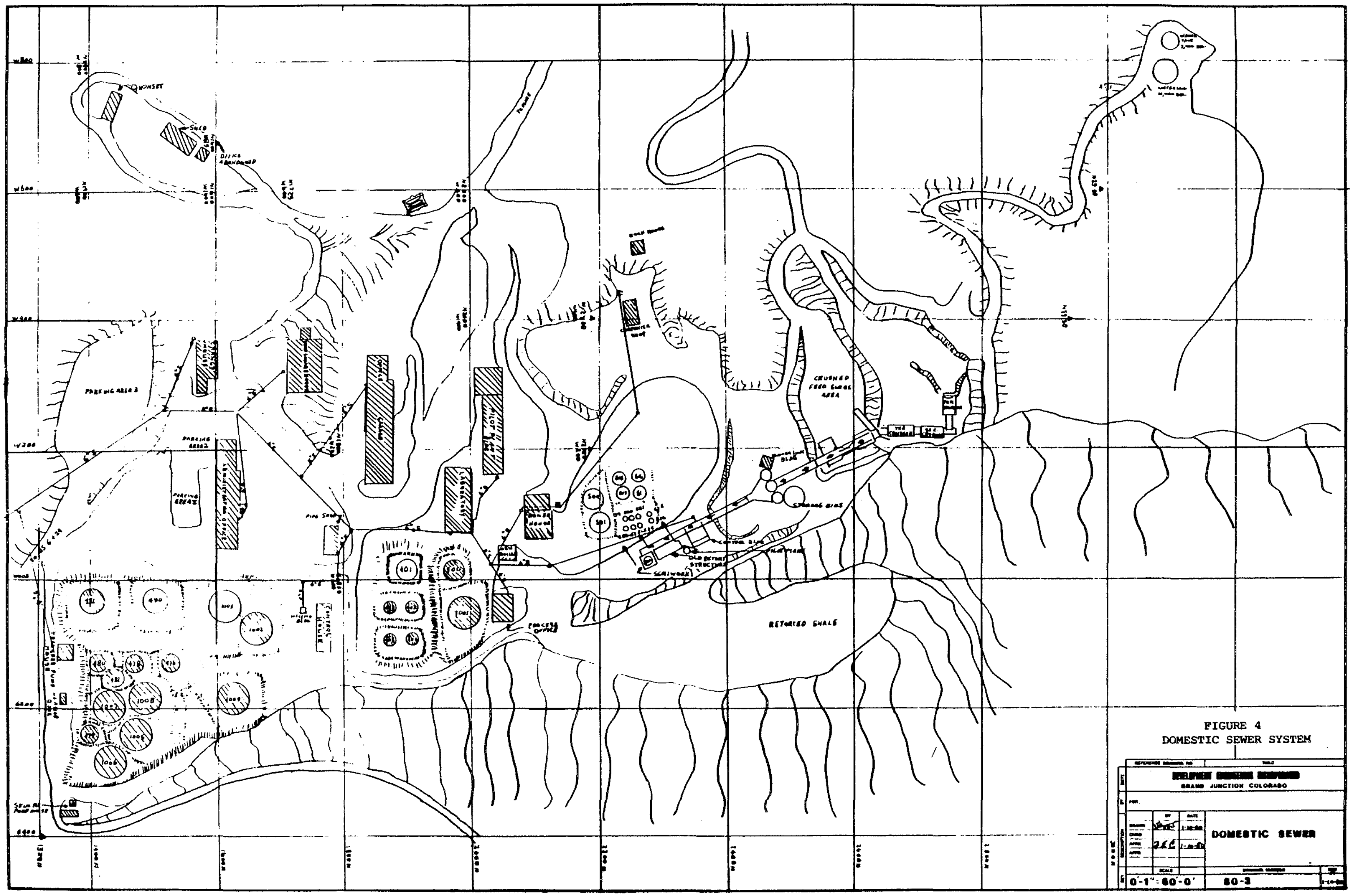


FIGURE 4
DOMESTIC SEWER SYSTEM

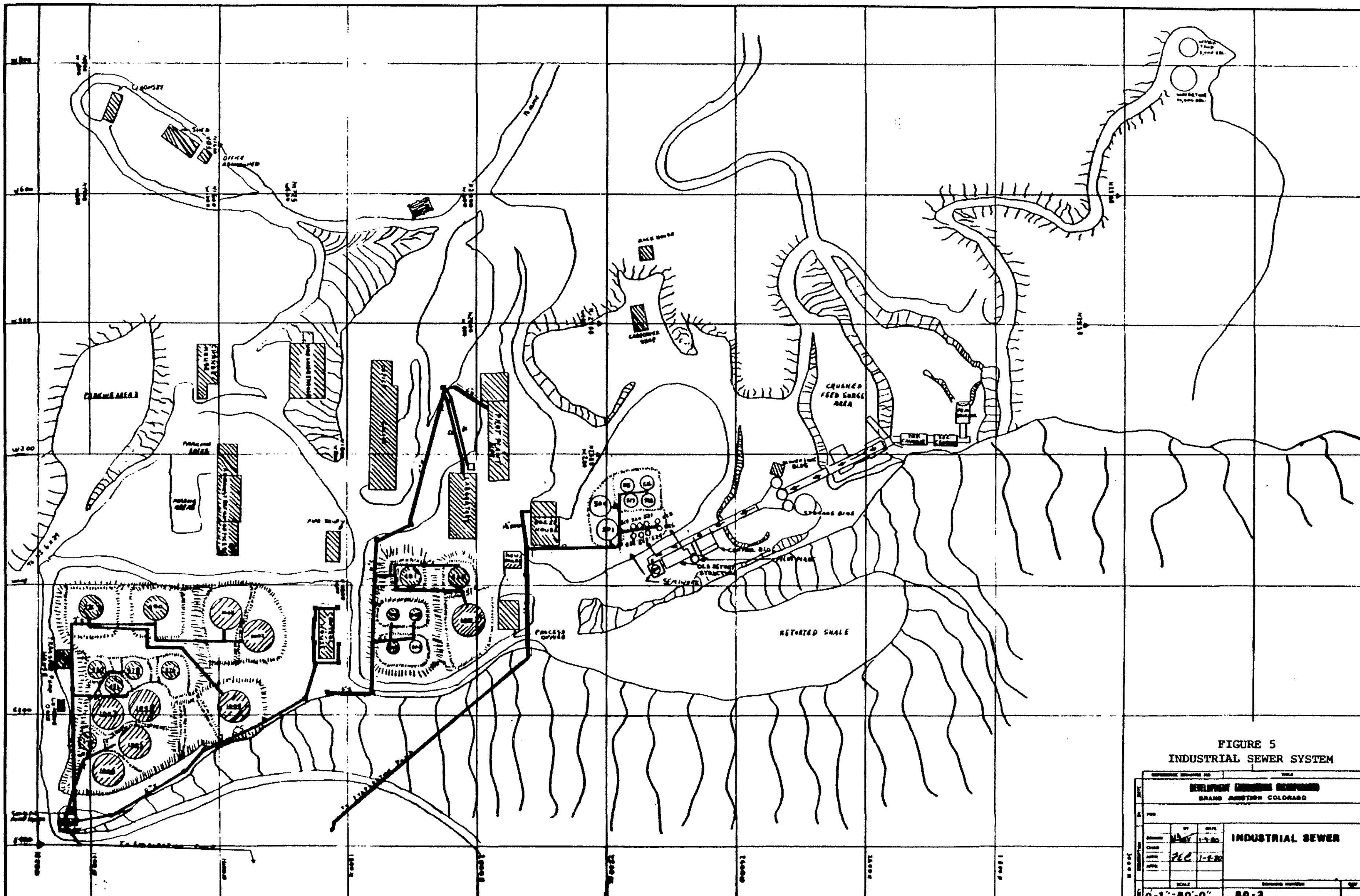


FIGURE 5
INDUSTRIAL SEWER SYSTEM

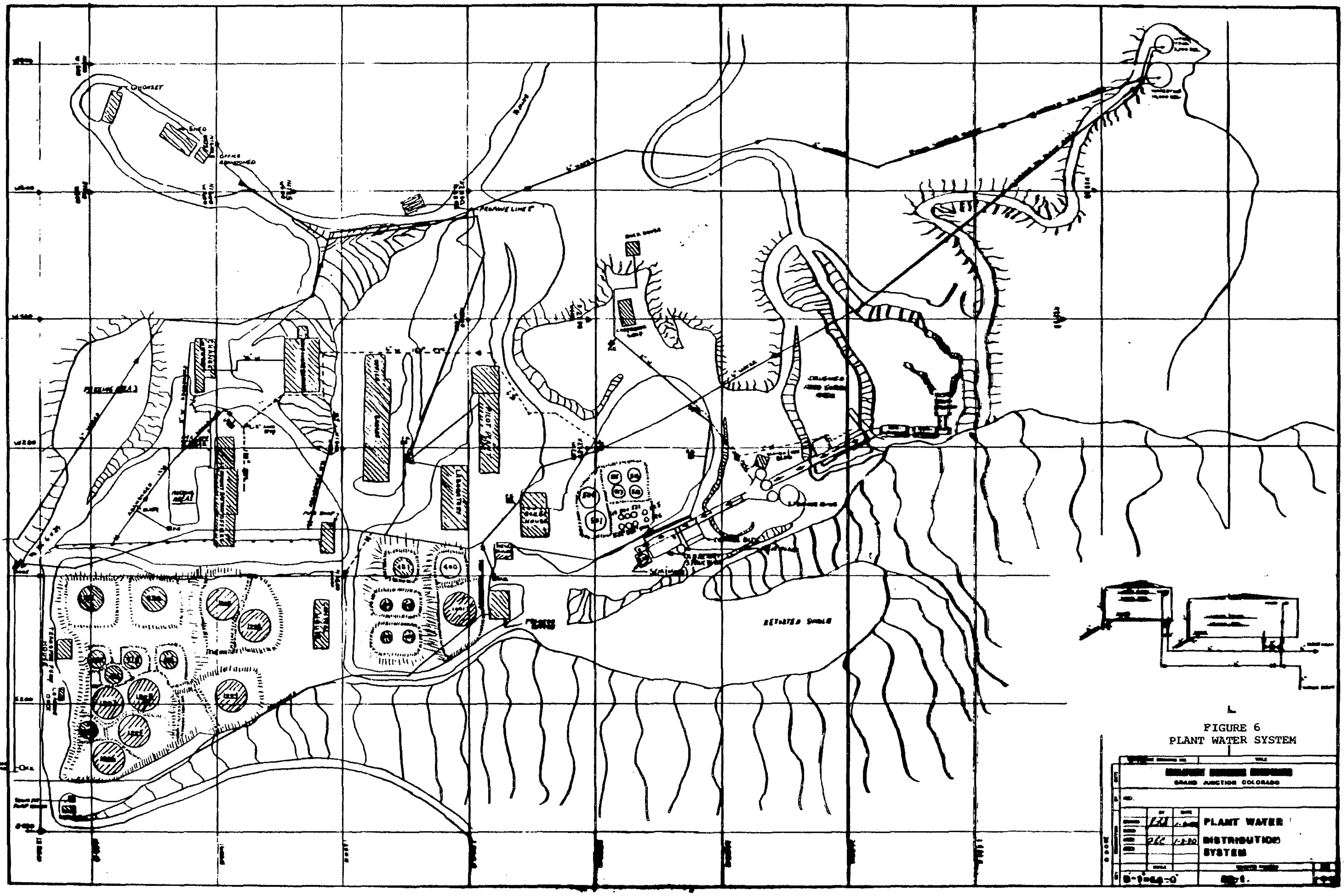


FIGURE 6
PLANT WATER SYSTEM