REPORT OF SUBSIDENCE STUDY

LOCATED ON EAST MOUNTAIN ABOVE THE

DES-BEE-DOVE
COAL MINES

from October 1980
to August 1982

By

Intermountain Aerial Surveys
A Div. of Engineering Enterprises, Inc.

Salt Lake City, Utah

SUBSIDENCE STUDY

DES-BEE-DOVE COAL MINES

STATION	VABM OCT 80	JULY 82	AUGUST 82	DIFF. 80 to Aug 82
P-3	9239.89	9239.89	9239.89	Fixed
BS-21	9223.5	9223.60	9223.55	+0.1
BS-20	9210.2	9210.32	9210.27	+0.1
BS-19	9201.9	9202.00	9201.94	0
BS-18	9188.7	9188.74	9188.66	0
BS-17	9167.2	9167.14	9167.05	-0.1
BS-16	9147.1	9146.73	9146.61	-0.5
BS-15	9125.4	9124.75	9124.59	-0.8
BS-14	9106.7	9105.91	9105.73	-1.0
BS-13	9085.8	9084.81	9084.61	-1.2
BS-12	9062.3	9061.21	9060.99	-1.3
BS-11	9038.3	9037.15	9036.91	-1.4
BS-10	9016.5	9015.38	9015.11	-1.4
BS-9	8993.3	8992.14	8991.86	-1.4
BS-8	8962.8	8961.74	8961.44	-1.4

SUBSIDENCE STUDY

DES-BEE-DOVE COAL MINES

STATION	VABM OCT 80	JULY 82	AUGUST 82	DIFF. 80 to AUG 82
BS-7	8931.0	8930.08	8929.74	-1.3
BS-6	8900.6	8899.81	8899.45	-1.2
BS-5	8867.4	8867.45	8867.10	-0.3
BS-4	8846.5	8846.56	8846.19	-0.3
BS-3	8806.6	8806.76	8806.38	-0.2
BS-2	8795.2	8795.36	8794.98	-0.2
BS-1	8785.6	8785.67	8785.27	-0.3

SUBSIDENCE STUDY

DES-BEE-DOVE COAL MINES

STATION	VABM OCT 80	JULY 82	AUGUST 82	DIFF. 80 to AUG 82
BS-14				
#1 No.	9103.0	9102.16	9101.97	-1.0
#2 No.	9098.8	9097.88	9097.69	-1.1
#3 No.	9087.4	9086.34	9086.14	-1.3
#4 No.	9076.8	9075.74	9075.52	-1.3
BS-14				
#1 So.	9105.2	9104.46	9104.27	-0.9
#2 So.	9095.0	9094.32	9094.13	-0.9
#3 So.	9082.8	9082.18	9081.99	-0.8
#4 So.	9079.4	9078.88	9078.70	-0.7

SUBSIDENCE STUDY

DES-BEE-DOVE COAL MINES

STATION	VABM OCT 80	JULY 82	AUGUST 82	DIFF. 80 TO AUG 82
BS-9				
#1 No.	8983.8	8982.48	8982.19	-1.6
#2 No.	8973.9	8972.44	8972.15	-1.7
#3 No.	8960.0	8958.44	8958.15	-1.8
#4 No.	8946.8	8945.12	8944.82	-2.0
BS-9				
#1 So.	8995.7	8994.72	8994.44	-1.3
#2 So.	8992.6	8991.73	8991.45	-1.2
#3 So.	8980.6	8979.85	8979.57	-1.0
#4 So.	8958.3	8957.61	8957.32	-1.0

United States Department of the Interic

BUREAU OF MINES

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BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

December 10, 1981

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Review comp by 12/22
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MINING AND EXPLORATION

Mr. Don A. Dewey
Director of Mining
Mining and Exploration
Utah Power and Light Company
P.O. Box 899
Salt Lake City, Utah 84110

Dear Mr. Dewey:

Enclosed for your review is a draft copy of a report on the progress of the subsidence project at the Deer Creek Mine. This report will be published as a Bureau of Mines Information Circular.

In your review, pay particular attention to the facts relating directly to the mine such as panel dimensions, entry layout, face positions, etc. This type of information was obtained from several different sources including maps and personal communication with your staff. It is important that this information is correct and we hope that any inaccuracies will be identified and noted in your review.

We appreciate your assistance in reviewing this draft and welcome all comments you may have on any aspect of the report. At this time we are planning to have the final draft ready for printing in February. We will not, however, finalize the report without your input.

Sincerely yours,

Frederick K. Allgaier

Frederick K. Allgaier

Enclosure

Information Circular

Surface Subsidence Over Longwall Panels at the Deer Creek Mine, Utah,

by Frederick K. Allgaier, Denver Research Center, Denver, Colorado

UNITED STATES DEPARTMENT OF INTERIOR
James G. Watt, Secretary

BUREAU OF MINES

CONTENTS

SURFACE SUBSIDENCE OVER LONGWALL PANELS IN THE DEER CREEK MINE, UTAH

PROGRESS REPORT NO 1

by

Frederick K. Allgaier[1/]

ABSTRACT

This is the first in a series of technical progress reports on the longwall subsidence research program at the Denver Research Center. As part of this program the Bureau of Mines and the Utah Power and Light Company are cooperating on a study conducted at the Deer Creek Mine directed towards developing the capability to estimate the surface subsidence resulting from longwall mining in a geologic, topographic and mining environment common to coalfields in the western United States. Factors such as strong, massive sandstone members in the overburden, thick and multiple seams, deep cover, and extreme variations in overburden thickness over a single panel due to mountainous topography are common in the western U.S. and can have significant impact on subsidence characteristics.

The major objectives of the Deer Creek study are to measure surface subsidence caused by longwall mining in the Blind Canyon coal seam, determine the timing, rate and areal extent of subsidence, establish the final subsidence profiles, correlate mining and geologic variables with measured subsidence values, evaluate predictive capabilities with regard to actual, measured subsidence versus theoretical values, and determine the effects of subsidence on current and potential land use.

1/ Civil Engineer, Denver Research Center, Denver, Colorado

This report describes the study site, the methods and instruments used in subsidence surveys, the status of the monitoring program and a preliminary discussion of the surface subsidence measured through 1980. The final subsidence profiles and a complete analysis of the subsidence data will be contained in a project report to be prepared at the conclusion of this work.

Subsidence began as the first panel was being mined and continued for one year following completion of the panel during which time the adjacent panel was mined. A maximum of 2.7 feet of subsidence occurred over the two longwall panels mined at a depth of 1,500 feet. Due to the length of time during which subsidence continued after mining, the final subsidence profiles and angle of draw have not yet been determined. Monitoring will continue over two additional panels and will include measurement and analysis of horizontal strain as well as vertical displacement.

INTRODUCTION

Population density and surface development over active coal mines in Britain and other parts of Western Europe have dictated for many years that surface subsidence and its effects be thoroughly understood, and that mine engineering practices be developed to reduce these effects. It is only recently that the need to develop a subsidence data base representative of U.S. mining conditions has been recognized. In addition, longwall mining has only recently begun to gain substantial acceptance in the U.S., particularly in the West. Hence subsidence from longwall mining is still a largely unknown and unpredictable quantity.

The public sector and various government agencies which own the surface over much of the western coal deposits have become increasingly concerned about the effects of subsidence on future land use as well as impacts on surface and subsurface hydrology and surface structures. Consequently, mining companies are being required to more closely examine the possible surface impacts of underground mining.

A major problem now faced by mine operators and land owners in the western U.S. relative to the environmental impact of surface subsidence is the lack of actual case history data where subsidence was documented sufficiently to be of use in estimating subsidence values and environmental impacts for specific properties. As mine operators and environmental agencies attempt to address subsidence issues in the mine planning and permitting process, a lack of applicable subsidence information, experience and prediction capabilities becomes apparent. The Bureau's research in subsidence from longwall mining is directed toward the fulfilling of the needs of the industry in 1) premining evaluation of surface damage and 2) facilitating the permitting process.

ACKNOWLEDGMENTS

Utah Power and Light Company's Mining and Exploration Department provided valuable assistance in conducting this research. In particular, Don Dewey, Chris Shingleton, John Bootle, Jeff McKenzie and Roger Fry have made significant contributions to the project. Without the access they provided to company property, mine plans, survey data, drill logs and other information relating to the Deer Creek Mine, this study could not have been conducted.

The efforts of Bureau personnel who performed the field work for the project are also acknowledged. Laura Swatek, in the Bureau's Mine Engineering Division, prepared the geologic description of the study site for this report.

THE DEER CREEK MINE STUDY SITE

Site Selection

The Bureau selected the Deer Creek Mine, owned by Utah Power and Light Company, as one of the sites for monitoring subsidence over longwall panels because it contained specific features which would affect the character of the resulting subsidence for which little or no supporting field data exists. These features include 1,500 feet of overburden containing a significant percentage of strong sandstone members, an extraction height of 10 feet and a lower seam to be longwall mined which will present an opportunity to study subsidence from multiple seam mining. Also, the timing of the project was such that monitoring could begin over the first in a series of four adjacent longwall panels. This is important in that one of the questions to be answered by the study is how much area must be mined, either in terms of face advance or width over adjacent panels before subsidence occurs at the surface. The conditions at the Deer Creek Mine are somewhat representative of many western mines, therefore the results are expected to be applicable to mines in other western areas.

Site Description

The study site over the Deer Creek mine is located on East Mountain in Emery County, Utah approximately 10 miles west of the town of Huntington. The site includes parts of Sections 14, 15, 22 and 23; T17S; R7E on the Mahogany Point and Red Point 7.5 minute U.S. Geol. Survey quadrangle map. The project site location is illustrated in figure 1. Portions of the study site are within the boundaries of the Manti-LaSal National Forest and the remainder is controlled by Utah Power and Light Company. Approximately 500 acres are included in the monitoring area over four longwall panels.

The topography over the panels is generally rolling with no outcrops or vertical faces (fig. 2 and 3). The maximum ground slope in the area is approximately 45 percent with a maximum relief of 300 feet over the entire site. No unusual problems were encountered in either the installation or monitoring of the subsidence network due to topography.

The average surface elevation surface of the study site is 9,100 feet with vegetation consisting of mostly sage brush with some significant areas of pine and aspen (fig. 4). The location of the longwall panels is such that surface vegetation over three of the four panels is entirely sagebrush which alleviated line-of-sight problems and facilitated the monitoring surveys. Approximately one-half of the first panel (5E-fig. 2) lies under a wooded area and required cutting and clearing of survey sight lines.

Soil cover in the area ranges from a few feet to approximately 20 feet in depth. Although the soil is moderately rocky it is of adequate depth to permit the monuments to be installed with few problems. The area where any significant monument installation trouble occurred was near the center of the first panel on a topographic high in the area of the transverse line of monuments (fig. 2). Problems in this area were solved by changing the location of the monument by a few feet to an area which could be penetrated. In no case was a monument omitted from a planned location due to inability to drive it into rocky soil.

The elevation of the site is a significant factor in the monitoring program in that early and late snowfalls can make the site inaccessable from October into June. This prevented subsidence monitoring surveys from being carried out at equal intervals throughout the year. Therefore, the magnitude and timing of any subsidence occurring during the winter months must be interpolated between the last survey performed in the fall and first survey in the spring of the next year.

Regional Geology

The Deer Creek Mine is located in central Utah on the Wasatch Plateau. The Wasatch Plateau is a broad, linear structure that lies generally in a north-south direction (fig. 5). The strata dips gently westward in the eastern part of the plateau due to the presence of the west flank of the San Rafael Swell. The western part of the plateau marks the transition into the highly faulted and complex region of the Great Basin. (1)

Sedimentary rocks form the majority of the stratigraphic sequence within the Wasatch Plateau region. The sequence consists of one limestone unit and alternating sandstones, siltstones, and mudstones. The two major coal beds occur within the lower portion of the stratigraphic section. The rocks are subdivided into seven formations (fig. 6) and vary in age from early Cretaceous to Paleocene. (3)

Regionally, faults are a very prominent feature in this area (fig. 7), representing a transitional zone between the Wasatch Plateau and the Great Basin to the west. (1) These are high-angle, normal faults. Trending nearly north-south, vertical displacements of stratigraphy range from 0.5 foot to nearly 200 feet. Longwall operations involved in the subsidence study are being conducted between the Pleasant Valley Fault to the west and the Deer Creek Fault to the east (fig. 8). There are no known faults crossing the longwall panels.

Stratigraphy

Drill hole records supplied by Utah Power and Light Company were used to determine the stratigraphy of the overburden above the longwall panels. The generalized stratigraphic section (fig. 9) illustrates that sandstones and interbeds of siltstones, sandstones, and mudstones are predominant units within the section. The two major sandstone units are the Castlegate sandstone which is found in the lower Price River formation, and the Star Point sandstone which is located in the lower Blackhawk formation. In this area the Castlegate sandstone is described as a buff to grey, massive, fine-grained, well-cemented unit with occasional silty bands occuring throughout. The Star Point sandstone is a light-grey, fine-grained unit that is well-sorted and quartoze. The total percentage of sandstone in the overburden is between 35 and 45 percent with the 35 percent figure representing that occuring in thick beds and 45 percent including all thin beds and laminations.

The Deer Creek Mine produces coal from the Blind Canyon Seam in the coal-bearing zone of the Blackhawk formation. The Blackhawk formation consists mainly of medium to fine-grained interbedded sandstones, carbanoceous mudstones and siltstones. The Blind Canyon seam, with a coal thickness of 14.3 feet in the panel area, is described as a hard, dense, bright-attrital coal and is ranked as high volatile, B-bituminous. Figure 10 illustrates the general stratigraphy of the coal seam, the immediate roof, and the immediate floor as determined from drill hole records supplied by Utah Power and Light Company. The jointing pattern within the coal seam and surrounding strata consisted of vertical joints with an average trend of N21°W. The joints are very pronounced in the sandstone units and tend to be faint to undistinguishable within the mudstone units. Spacing of the joints is considered moderate with an average spacing of 10 feet to 20 feet.

Mine Plan

The mining plan for the longwall panels at the Deer Creek Mine is shown on figure 8. It consists of four adjacent panels oriented in an east-west direction to be retreat mined from the east toward the main entries to the west.

A room and pillar section north of the first panel was mined immediately prior to the development of the longwall panels. This section consisted of 20 foot wide entries on 100 foot centers with crosscuts on 80 foot centers. Pillar mining was not conducted, however 1-2 feet of floor coal was mined on retreat increasing the mining height to 10 feet. A 200 foot barrier pillar was left between third east section and fourth east section which contains the tailgate entries for the first longwall panel (5E).

The first panel was developed using a three-entry system while the remaining three panels were developed by two entries on 50 foot centers with crosscuts on 105 foot centers.

Mining height for the first two longwall panels averaged 10 feet. The lengths of panels 5E and 6E were 2,500 feet and 2,750 feet with face lengths of 480 feet and 540 feet respectively.

The depth of cover over the first two panels ranges from a maximum of 1,580 feet to a minimum of 1300 feet (fig. 11). The maximum overburden occurs near the center of the panels and decreases toward both ends. The seam dips only 1.3° to the NW and therefore has little effect on the depth of cover which is controlled almost entirely by the surface topography.

Mining of the first panel began in May 1979 and was completed in December. The second panel was mined between February and November 1980.

A 300-400 foot barrier was left between the end of the panels and the main entries to the west. Unmined coal remains between the east end of the panels and the Deer Creek Fault which lies approximately 300 feet to the east. There has been no previous mining either above or below the panels although the Wilberg mine will subsequently undermine this section of the Deer Creek Mine.

SUBSIDENCE MONITORING PROGRAM

Monitoring Program Design

Several factors influenced the design of the subsidence monitoring program at the Ceer Creek Mine. The most important consideration was that the information to be collected during the study would meet the established project objectives of determining the maximum subsidence, the areal extent of subsidence and the rate at which it progresses down the panels. In addition, final subsidence profiles would be developed and analyzed with respect to the overburden geology and mine layout then correlated with existing predictive techniques. Major items that affect the subsidence data being collected are: surveying accuracy and frequency; monument location, both in terms of spacing and layout over the panel; monument construction and surveying instrumentation. Constraints on the monitoring program due to the short field season and manpower limitations affect the number and type of surveys performed and thus the final project results.

Monument Locations

The locations of the subsidence monuments were established on the basis of coordinate survey data supplied by Utah Power and Light Company for points on the surface in or near the study site and for the location of the longwall panels. Both the underground and surface surveys are tied to the state plane coordinate system which allows direct correlation between surface and underground postions.

The monitoring network layout consists of one line of monuments approximately centered over the long axis of each panel and several transverse lines located at specific positions over the panel. This type of monitoring layout produces both transverse and longitudinal subsidence profiles. In addition, a diagonal line of monuments on the east end of the panels was included to provide more data on the angle of draw and the interaction of the combined subsidence at the corners of the two adjacent panels. The network layout used for this site is shown on figure 2. The transverse line of monuments running north-south at the center of the panels lies over the area of maximum overburden, the transverse line over the western end of the panels lies over the area of minimum overburden thickness and the transverse monument line just east of the panels is over an area expected to be affected by the angle of draw.

The location of stable, remote control points is governed by topography and vegetation which affect the line-of-sight to the subsidence monuments and also the location of the underground workings which dictate the areas that will remain stable throughout the life of the project. At the Deer Creek site it was not always possible to locate control points on stable ground because of the topography which blocked lines of sight to the subsidence monuments. In these instances control points were located over the panels and tied to a minimum of two stable points with vertical and horizontal surveys. The accurate location of these control points had to be established with each survey of the monitoring network.

Monument Spacing

Monument spacing on the subsidence monitoring network is 100 feet. This spacing was felt to be a practical compromise between the more accurate determination of strain and angle of draw which is possible with decreased spacing and the increased cost of installing and surveying the additional points. The 100 foot spacing averages 0.07 times the overburden depth which is somewhat larger than the 0.05 recommended by the National Coal Board Subsidence Engineer's Handbook. (2) However, they acknowledge that there is a practical limit to reducing monument spacing and that further research is needed before the optimum spacing can be defined. As part of the continuing work at the Deer Creek site, selected portions of the fourth longwall panel will be monumented with 50 foot spacing and the resulting angles of draw and direct strain measurements will be compared with similar measurements from the panels with monuments on 100 foot centers.

Monument Construction

Two different types of monuments were used on the project. One type consisted of 1-1/2-inch pipe cut to length with a bevel on one end to facilitate installation. The other type was 1-inch steel rod with a machined point (fig. 12). Both types of monuments were driven into the ground to a depth of 3 to 5 feet with either a gas powered hammer (fig. 13) or a sledge hammer. Approximately 6 inches of the pipe or rod extend above the ground to accommodate the target used in the horizontal position surveys. Minimizing the length of the monuments above the ground decreases the error in the horizontal position which results as the monuments tilt during subsidence. The only advantage of one monument type over the other that has become evident during the project is that the 1-inch rods are easier to drive into rocky ground to the required depth. Material costs for 6 foot long monuments were $8.80 for the pipe and $4.60 for the 1-inch rods.

Monument Installation and Survey Schedule

In the fall of 1978, monuments were installed over the first half of the first longwall panel (5E) and remote control points were located. The initial traverse survey, performed in October, before mining of the panel started, provided the baseline elevation and coordinate positions of the monuments.

The second traverse survey was performed in July 1979 when approximately 700 feet of the panel had been mined. At this time there was no subsidence detected over the mined out area of the first panel.

The second half of the first panel was monumented and the entire network surveyed in early September 1979. This provided initial monument positions for the second half of the network and the third survey of the first half of the panel which by the end of September had been mined to a length of 1,500 feet.

In September the decision was made to extend the monitoring program to the adjacent panels; however early snowfalls made the site inaccessable and work on the second panel was delayed until the next spring. At this time only 10 points had been located over the second panel. Based on the face advance per month for the first 3 months it was projected that the panel would be completed in another 8 months, however the face advance increased by an average of 150 feet per month and the panel was completed in 5 months. When the site again became accessible in 1980, mining of the second panel had progressed 1,200 feet.

A complete survey on the first two panels, run in early July 1980, indicated that subsidence had progressed down the first panel during the winter months. In 1980 the next two panels to the south (7E and 8E) were monumented and baseline positions were established on these networks. Five additional surveys including two direct level surveys were run on the first two networks at monthly intervals into the first of December.

During the 28 months of the project's duration between September 1978, when preliminary field work on the project began, and December 1980, when the last survey for the year was performed, the site was accessible in 14 of those months. Field work was performed at the site in 11 of the 14 months including 12 surveys on all or part of the monitoring network. Five of the twelve surveys were performed by the Bureau's contract surveyor during 1980 and the remaining seven surveys were performed by Bureau personnel.

All network layout and installation was done by the Bureau and required a total of 375 man-hours. This included reconnaissance, control point location, subsidence monument stakeout and monument installation. A total of 260 points have been installed at the Deer Creek site over the four longwall panels. Additional points will be installed over the fourth panel during 1981. The seven traverse surveys performed by Bureau personnel involved 205 man-hours. Man-hour totals are in addition to the travel time involved in reaching the remote study site.

Monitoring Procedures

The subsidence monitoring program at the Deer Creek mine was designed to measure both vertical and horizontal movement of the subsidence monuments. It was recognized that although the initial and final monument elevations showing the final subsidence profile and the associated horizontal strains was of prime importance, another objective of the study was to determine the timing and rate of subsidence development. This required several periodic surveys during the summer months when the site was accessible.

Based on the project objectives and the time and manpower constraints it was determined that traverse surveys would be run by Bureau personnel during the first year of the project. These surveys would provide both horizontal and vertical monument positons and allow the required number of surveys to be completed during the short field season. The Bureau was able to obtain a contract surveyor to perform approximately 50 percent of the surveys in 1980 and both traverse and direct level surveys were run on the monitoring networks.

The traverse surveys were run using an electronic distance measuring instrument (EDM) and a second order, optical reading theodolite with micrometer readings of one second (fig. 14). The accuracy of the EDM is ± 0.02 foot + 6ppm. For the traverse surveys, horizontal and vertical angles and slope distance were measured to each subsidence monument from instrument stations with known coordinates. The elevation and coordinates of the instrument stations were established from stable points beyond the influence of mining. To insure the stability of instrument stations located on non-subsiding ground and accurately determine the position of instrument stations located over the panels, a closed traverse survey was run through all instrument stations and control points as part of each survey.

To facilitate the surveying of the more than 250 subsidence monuments at this site, a target mounting unit was built for use in performing the traverse surveys. This target unit (fig. 15) which holds a prism for distance measurement and a target for angle measurement is clamped securely onto the subsidence pin and is then leveled. The unit requires minimal set-up time and is compact and lightweight for easy carrying over rough terrain. It provides a stable target and a constant target height. The standard mounting stud will accept any target assembly that may be required as well as vertical extensions to improve visibility.

Beginning in 1980 with contract surveys, two standard, direct level surveys were run on the monitoring networks. These surveys were run to third-order accuracy using an automatic, self-leveling level and a level rod with 0.01 foot graduations (fig. 16). The accuracy of the elevations from direct level surveys is greater than that of the elevations from traverse surveys which use vertical angles and slope distance in computing the elevations. The third-order level surveys have a maximum allowable closure error of 0.05 foot times the square root of the length of the level line in miles which resulted in a standard error calculated from several level surveys of 0.02 foot. The elevations computed from the traverse surveys yielded a standard error of 0.08 foot.

Although the direct level surveys produce more accurate results than the traverse surveys, consideration must be given to the substantial extra cost of running the level survey in addition to the traverse survey required to obtain horizontal positions. Continued monitoring at the Deer Creek site will utilize both level and traverse surveys with more emphasis placed on vertical displacement and thus the direct level surveys.

Measured Surface Subsidence

The longitudinal subsidence profiles for panels 5E and 6E as of December 1980 are shown on figures 17 and 18. Results of the last two surveys, run in October and December 1980, indicate that subsidence was still occurring over both of the panels. Therefore, the final subsidence profile for the first panel (5E) cannot be determined until the surveys are completed in 1981. Similarly, the final profile for panel 6E will be determined in 1982.

The maximum subsidence measured to date over the two panels was 2.7 feet which occurred near the midpoint of the panel lengths and just south of the longitudinal monument line over panel 5E, nearly over the chain pillars between 5E and 6E. This figure represents approximately 27 percent of the extracted seam height. The subsidence contours as of December 1980 are shown on figure 19. The maximum subsidence measured over the centerline of panel 5E was 2.6 feet while the maximum over panel 6E was 1.6 feet. This indicates that subsidence will continue over panel 6E and increase as the adjacent panel (7E) is mined during 1981.

The two longwall panels completed to date have face lengths of 480 and 540 feet. The total mined width for the first panel, including two 20 foot entries, is 520 feet which represents an average width-to-depth ratio of 0.36. This ratio is considerably less than that required for maximum subsidence and thus assures a sub-critical condition where the width of the opening is insufficient to allow the maximum possible subsidence to occur. A sub-critical condition is characterized by a U-shaped subsidence profile whereas a super-critical condition results in a flat-bottomed subsidence profile where more than one point near the center of the panel reaches maximum subsidence.

The subsidence profile across the two panels is shown on figure 20. The total mined width across both panels including entries and chain pillars, is approximately 1,200 feet which represents a width-to-depth ratio 0.80. This total width also produces the characteristic sub-critical U-shaped subsidence profile. At this point in the subsidence development there was no evidence in the subsidence profile of the two rows of chain pillars between the two mined panels.

Due to the fact that subsidence was not complete over the west end of the panels at the time of the last survey in December 1980, the east end of the first panel is the only location at which an angle of draw can be calculated at this time. As monitoring continues there will be a minimum of 10 separate locations at which the angle of draw will be measured. The calculated angle of draw for the east end of panel 5E is 27°. This figure is based on elevations from traverse surveys and will reflect the accuracy of this survey method. The angle of draw, determined by the limit of subsidence beyond the panel, is extremely sensitive to surveying error and therefore several measurements including some with greater accuracy will be required before the angle of draw for the Deer Creek site can be confidently stated. In addition, a major fault occurs beyond the east end of the panels in the area affected by the angle of draw. This fault could tend to decrease the angle of draw and may account for the 0.7 foot step in the subsidence profile between two adjacent points approximately 150 feet east of the panel. Continued measurements will also clarify the effect, if any, of this fault on the angle of draw.

Subsidence Development

The first indication of subsidence over panel 5E occurred in the elevations from the September 1979 survey. When compared to the initial survey run in October 1978, the first 1,400 feet of the panel shows approximately 0.25 foot of subsidence (fig. 21). At this time, (Sept. 1979) the longwall face had retreated 350 feet beyond the last point of measured subsidence. Per the July 1979 survey, subsidence had not occurred over this panel which indicates that the initial subsidence occurred between July 10, 1979 and September 18, 1979. At the midpoint of this time span, in August, the face had advanced 860 feet. At a minimum, the face had advanced 460 feet (as of July 10) prior to any subsidence being measured at the surface.

Following the September 1979 survey the site became inaccessable until July due to heavy snowfalls. Mining of the first panel (5E) was completed in December. The next survey was performed on July 9, 1980. At this time the subsidence over the 5E panel had increased to a maximum of 1.6 feet and progressed down the entire length of the panel (fig. 22). The adjacent panel 6E had been mined to a length of approximately 1,200 feet at the time of this survey.

Between July and December 1980, subsidence continued to occur over the 5E panel increasing in magnitude in the direction of mining (fig. 23). During November 1980 there was no additional subsidence over the first 700 feet of panel 5E; however continued settling of up to 0.4 foot occurred over the remainder of the panel.

Between July and December 1980 subsidence occurred over the 6E panel reaching a maximum of 1.6 feet near the midpoint of the panel length (fig. 18). As with panel 5E, there was no additional subsidence over the first 700 feet of panel 6E during November 1980. Up to 0.5 foot of subsidence occurred during November over the 2nd half of 6E at the same position on panel length as the 0.4 foot measured over panel 5E mentioned above. Mining of panel 6E was completed in late November 1980 and mining of the third panel (7E) began in February 1981.

Data Processing

All calculations and much of the plotting for the subsidence surveys is performed by computer. Although the calculation of coordinates and evaluations from field survey notes is not complex, the large number of points included in each survey along with the number of surveys to be performed over the duration of the study makes computer calculation and data storage advantageous.

Field data from the subsidence surveys is typed into a computer file, printed out, and then compared with the field notes so that obvious errors can be edited prior to computing position coordinates for the subsidence points. The raw survey data for the traverse surveys entered into the computer file consists of station names, horizontal and vertical angles, slope distances and the target and instrument heights. Before the subsidence point coordinates are computed, the instrument station positions are checked and adjusted if necessary. The northing, easting and elevation of each subsidence point is then computed and stored in a data file representing that particular survey. This information in the data file for each individual survey can then be accessed and used as input for programs which perform calculations such as coordinate or elevation differences between any two surveys to show changes in the position of the subsidence points. The coordinate data as well as the results of any calculations using the coordinate data can be printed out or plotted depending on the nature of the results and its intended use. In addition, the raw input data from the field books is held in storage and can be printed out any time questions arise involving the field data. If changes are required, the data can be edited and re-run to produce the corrected coordinate data.

Data input for the direct level surveys consists of station names and rod readings. The computer calculates point elevations and closure errors and then adjusts the elevations accordingly. Resulting elevations are stored on file to be accessed by the other programs in the same manner as the results of the traverse surveys. The input data is also stored and can be recalled for checks and editing.

CONCLUSION

Planned subsidence monitoring at the Deer Creek Mine includes the surface area over four adjacent longwall panels. To date only two panels have been mined, therefore, results presented herein are preliminary to the final subsidence conditions.

The maximum subsidence measured over the two mined longwall panels was 2.7 feet as of December 1980, some 27 percent of the extracted seam height. Subsidence was continuing over both panels at this time, therefore the final subsidence profiles could not be determined. The preliminary estimate of the angle of draw is 27°.

An appreciable impact of adjacent panel mining on the dynamics and final profiles of subsidence over previously mined panels has been established. The time lag between initial mining and measurable subsidence, along with the time during which subsidence continues to occur, results in the adjacent panel being mined before the subsidence over the previous panel is complete. This interaction precludes isolation or definition of subsidence from mining a single panel.

Any effect topography would have on the subsidence will not be evident at this site due to the rolling nature of the terrain with no abrupt changes in the overburden thickness relative to the depth of mining.

Through December 1980 there was no evidence of surface damage from subsidence over the two mined panels. No cracking or downwarping of the surface was visible during any of the surveys.

REFERENCES

1. Davis, F.D., and Doelling, H.H. Coal Drilling at Trail Mountain, North Horn Mountain, and Johns Peak Areas, Wasatch Plateau, Utah. Utah Geol. and Miner. Survey Bull. 112, 1977, p. 4.
2. National Coal Board Subsidence Engineers Handbook. 1975, p. 33.
3. Spieker, E.M. Guidebook to the Geology of Utah No. 4: The Transition between the Colorado Plateaus and the Great Basin in Central Utah. Utah Geol. Society, 1949, p. 52.

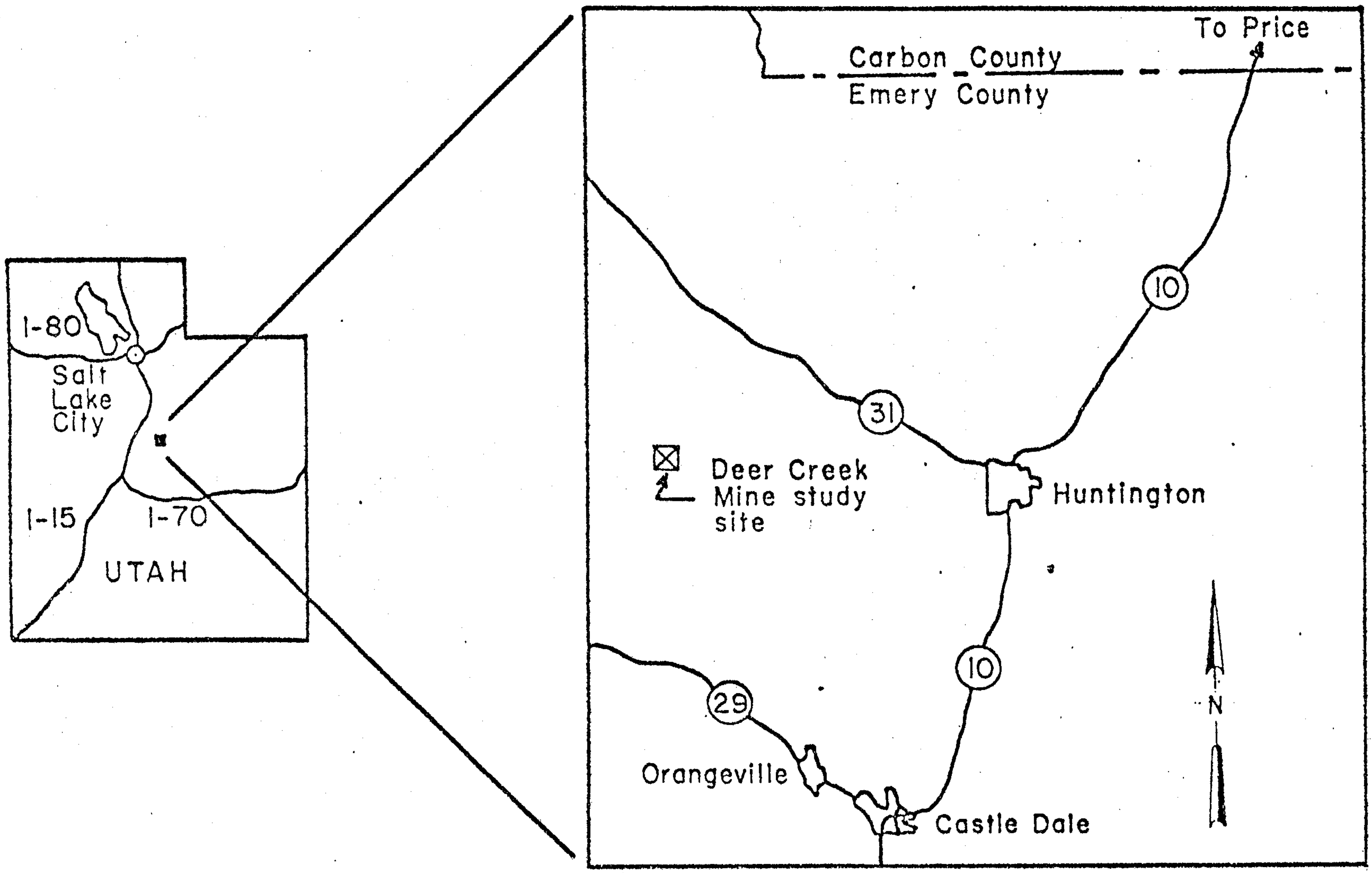


FIGURE 1. - Location Map

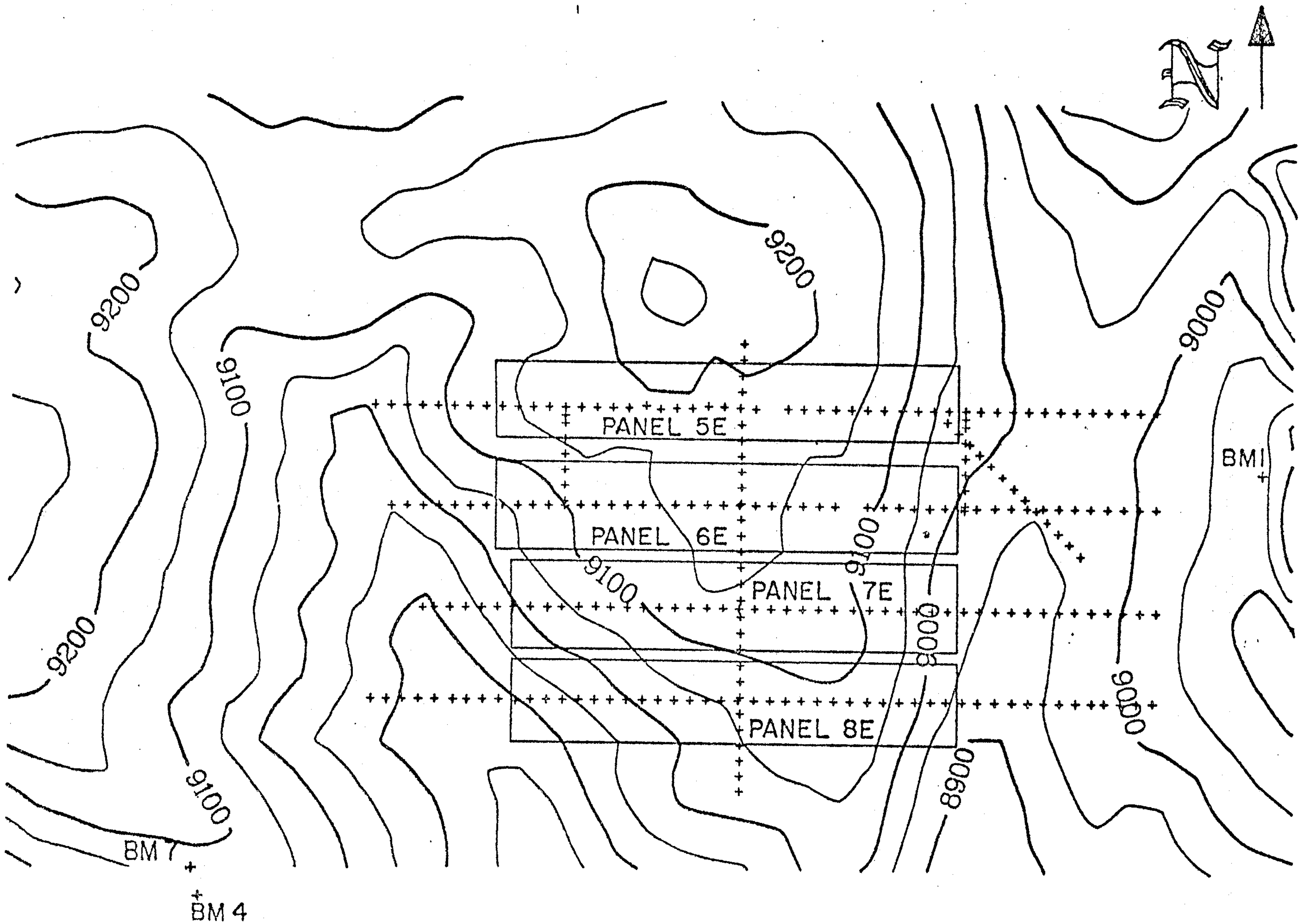


FIGURE 2. - Deer Creek Longwall Subsidence Study Site, surface topography and subsidence monitoring network.

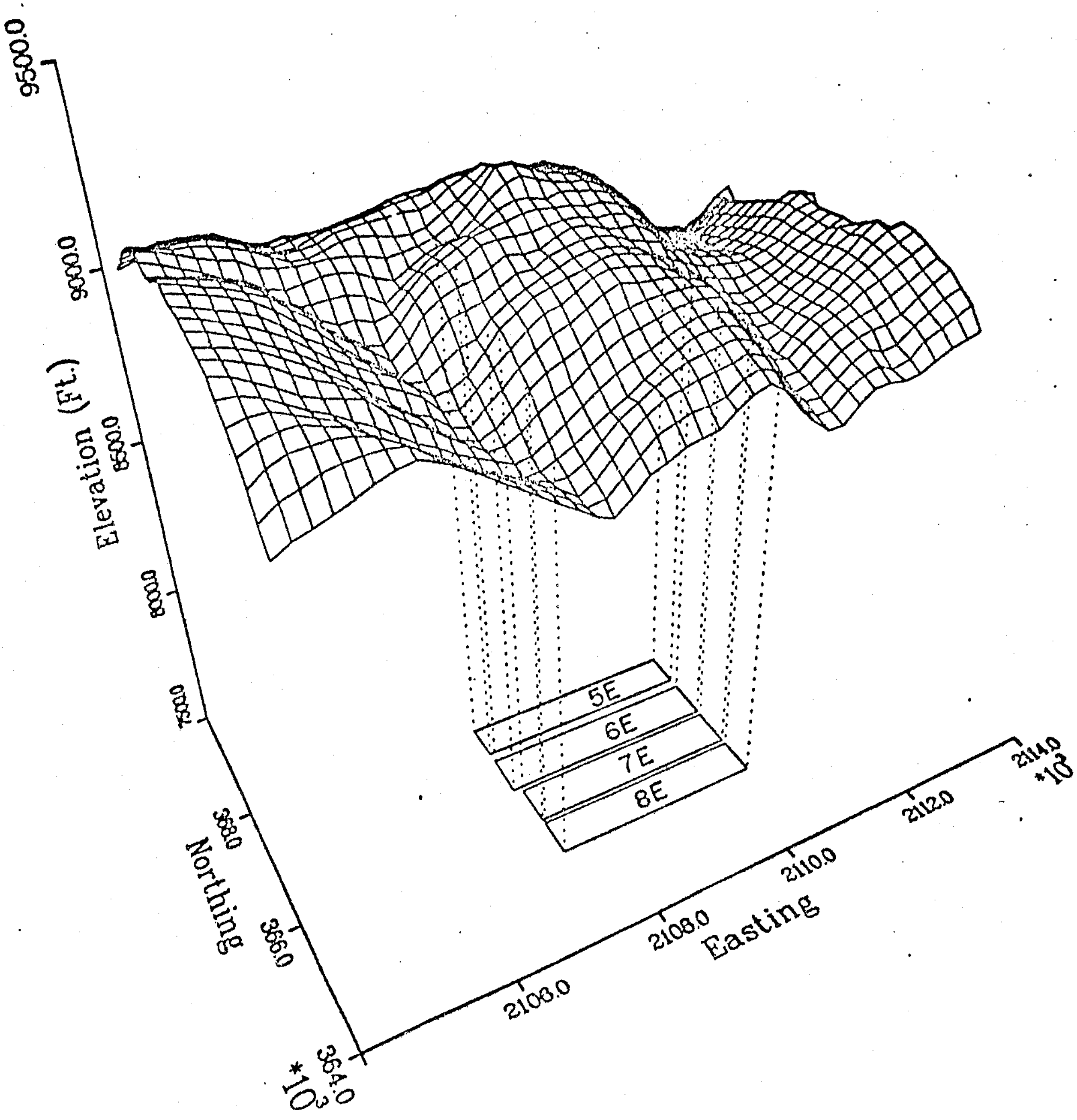
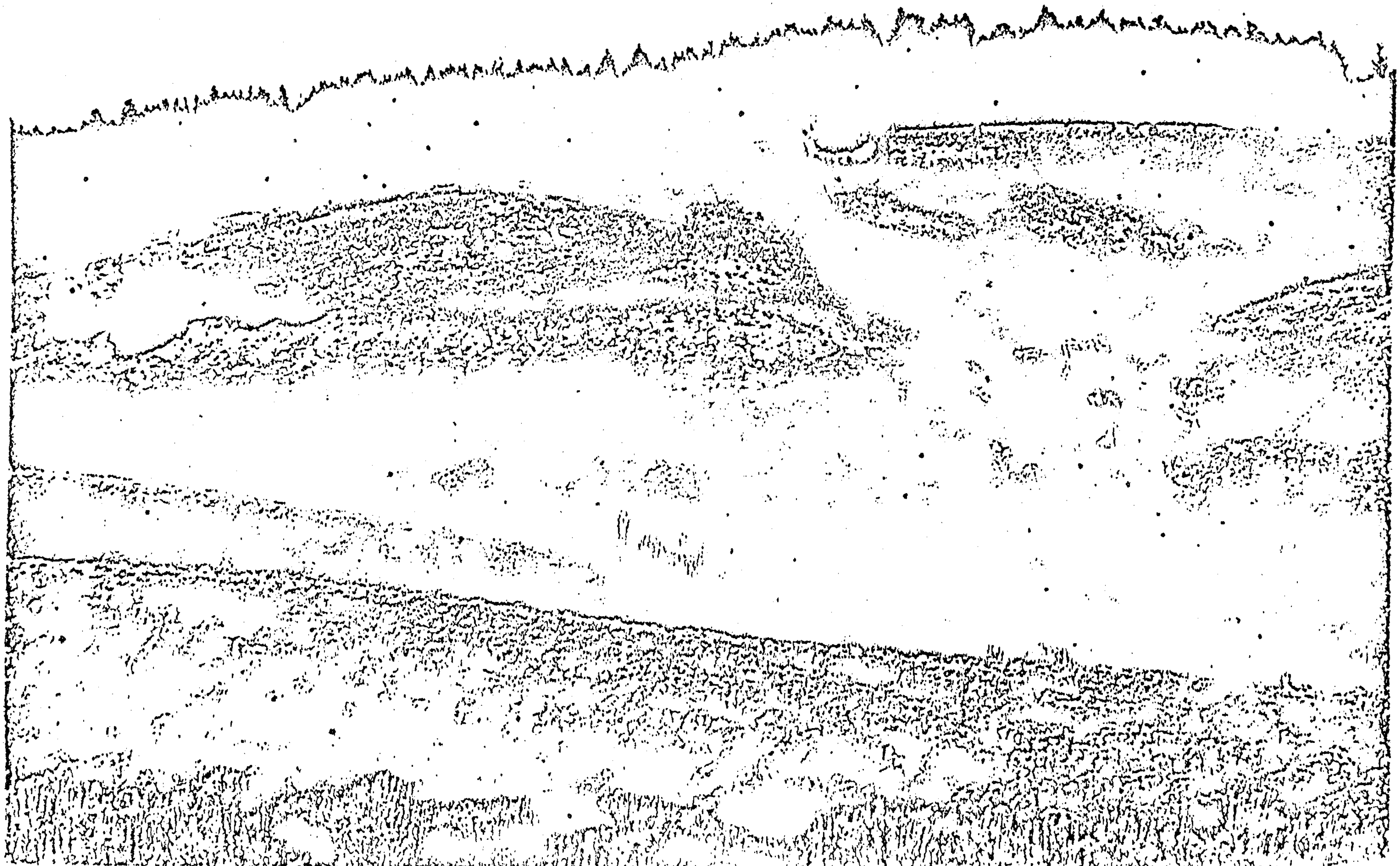


FIGURE 3. - Deer Creek Longwall Subsidence Study Site, surface topography.



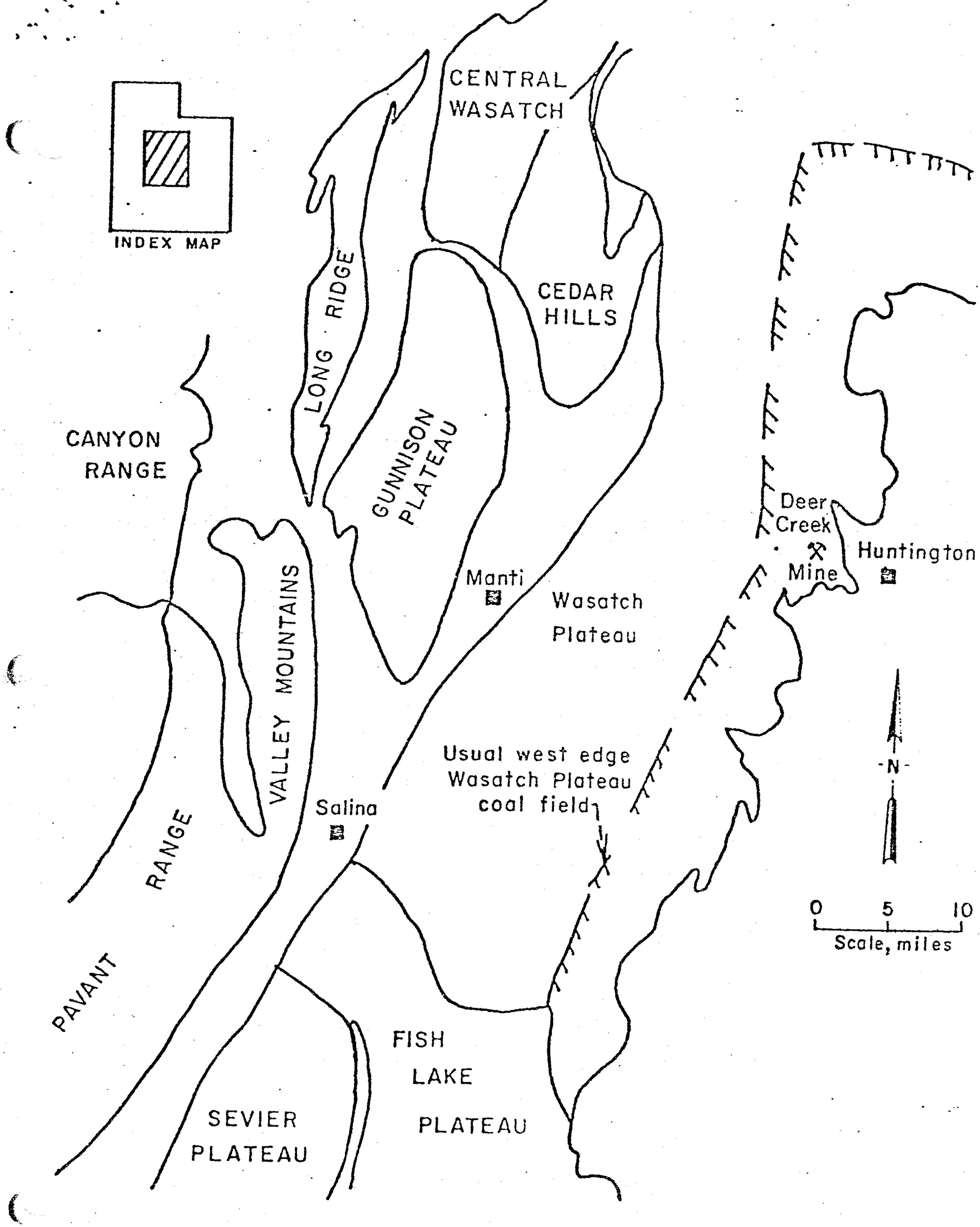


FIGURE 5. - Regional geologic structures.

System	Group	Formation		Thickness (feet)	Description
Tertiary	Wasatch	Flagstaff Limestone		100-1,000	Light gray to cream limestone; thin and even bedded; dense; fossiliferous; ledge- and cliff-forming.
Tertiary / Cretaceous	Wasatch	North Horn Formation		900-2,000	Mostly red-brown, and salmon colored shales; varying thicknesses of sandstone, freshwater limestone and conglomerate; slope-forming.
Cretaceous	Mesaverde	Price River Formation	Upper Price River Member	400-800	Mostly tan and gray, medium to coarse-grained sandstone and some gray shale and conglomeratic sandstone; ledge and slope-forming.
Cretaceous	Mesaverde	Price River Formation	Castlegate Sandstone Member	150-500	Light gray, yellowish brown and white, medium to coarse grained sandstone and conglomeratic sandstone; cliff-forming.
		Disconformity			
Cretaceous	Mesaverde	Blackhawk Formation		400-1,000	Light to medium gray sandstones; gray to black shale gray siltstones; important coal beds in lower half; sandstones weather tan, brown, yellowish brown; ledge and slope forming
Cretaceous	Mesaverde	Star Point Sandstone		200-1,000	Tan, light gray, and white massive sandstones separated by one or more shale tongue cliff-forming.
Cretaceous	Mancos Shale	Masuk Shale		300-1,300	Light gray to blue gray sandy marine shale; thins to west and south slope-forming.

Note: Modified from Utah Geological and Mineral Survey Bull. 112, 1977 P.4.

FIGURE 6. Regional Stratigraphy

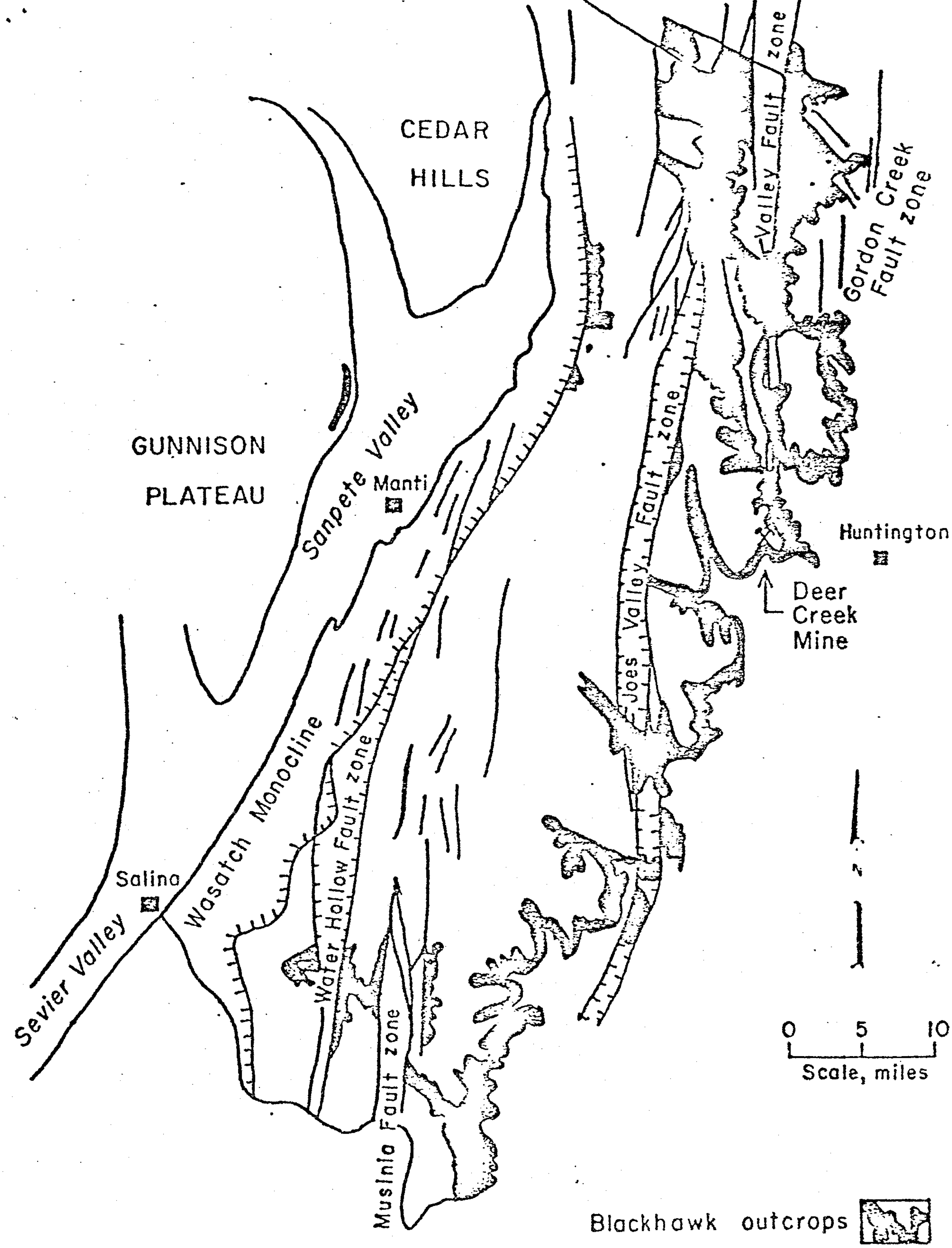


FIGURE 7. - Regional faulting map

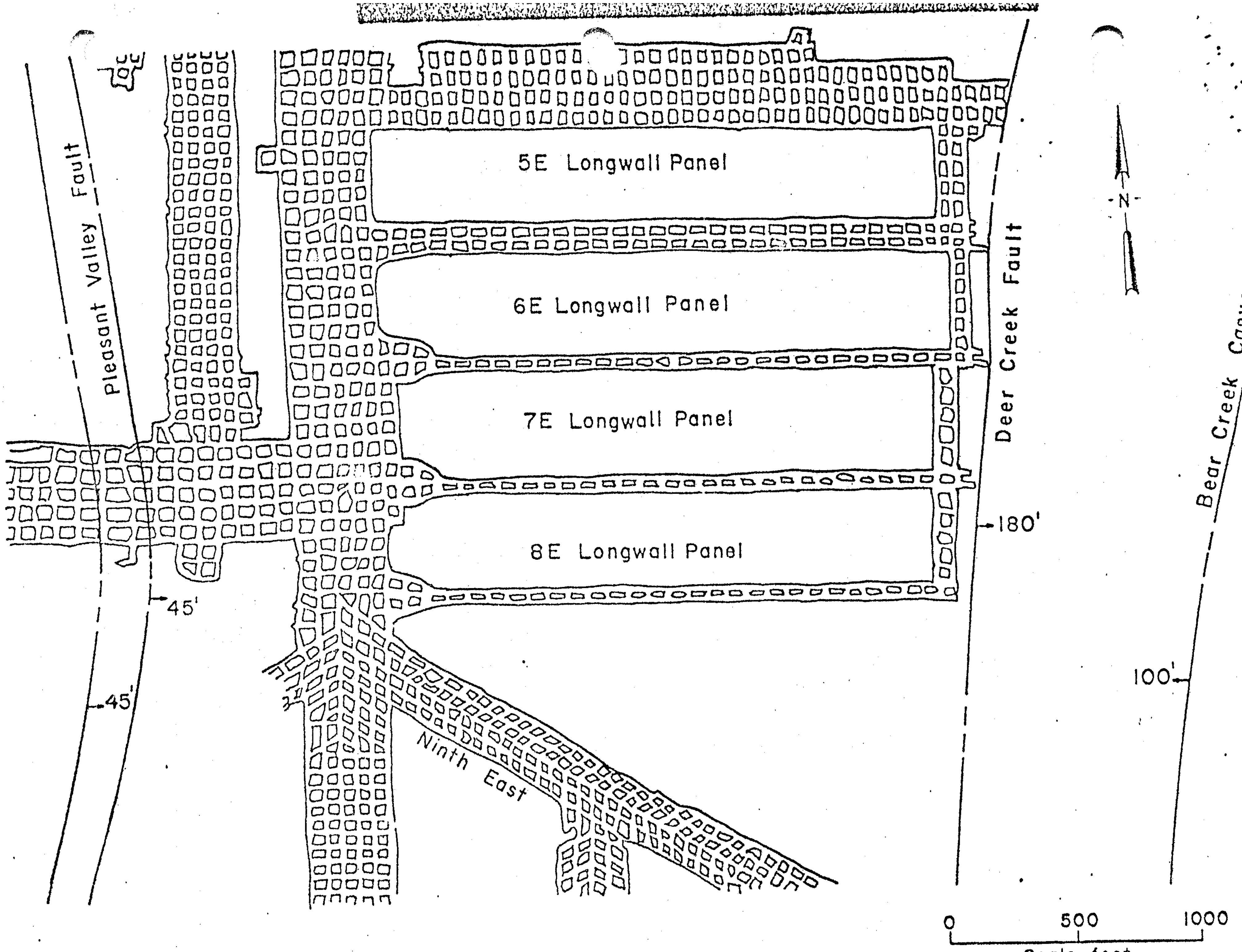


FIGURE 8. - Deer Creek Longwall Subsidence Study Site Mine plan and local faulting.

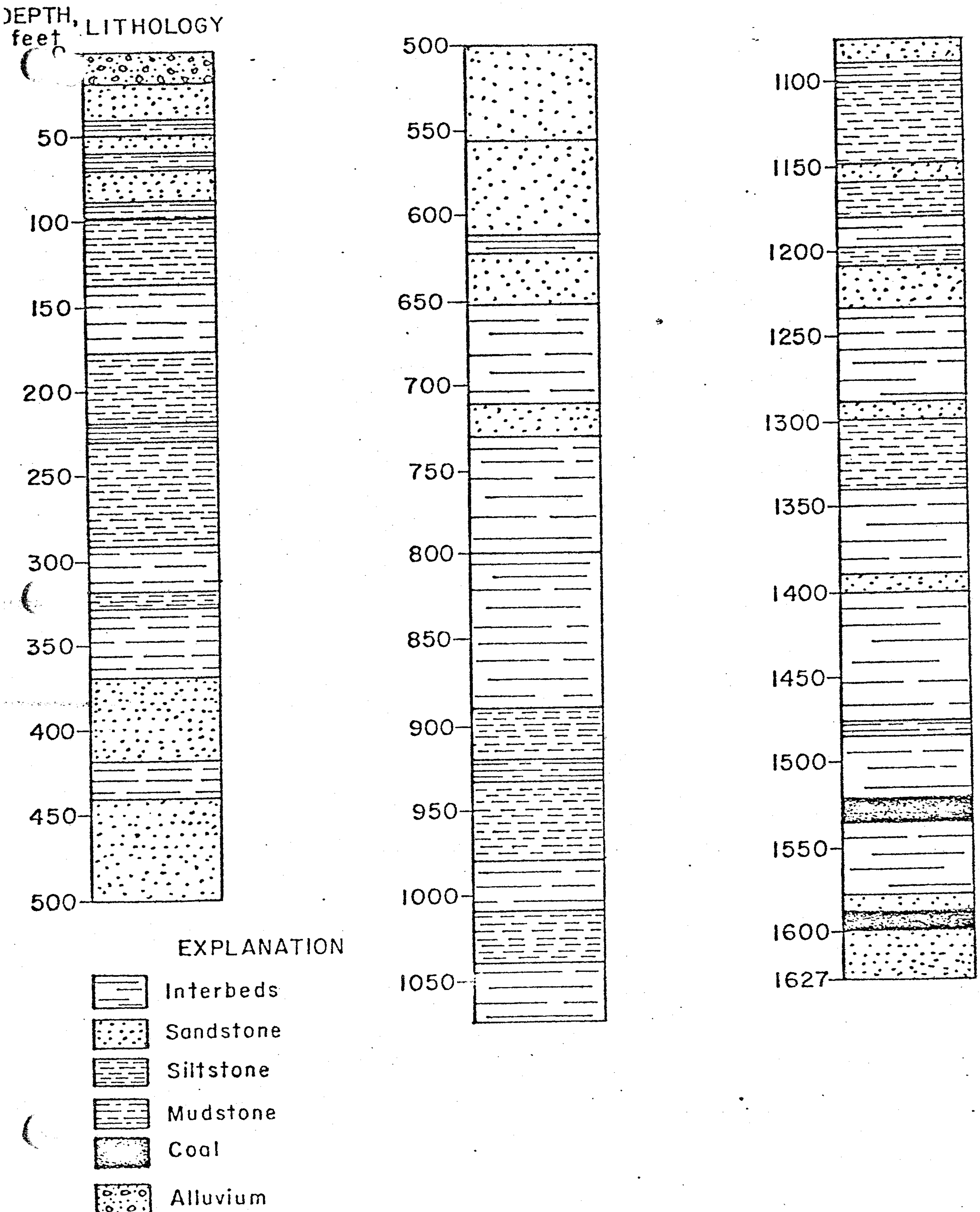


FIGURE 9. - Generalized overburden stratigraphy.

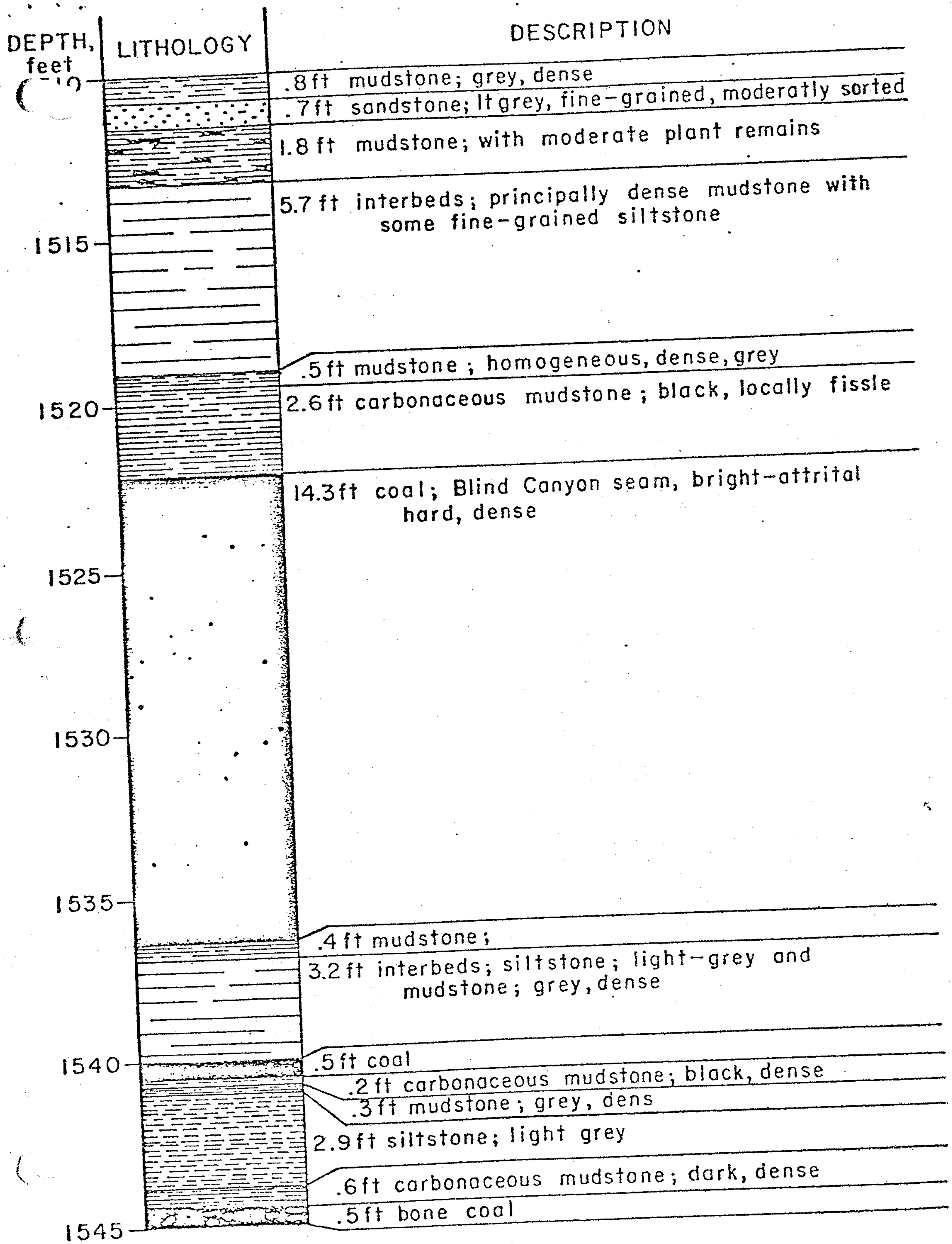
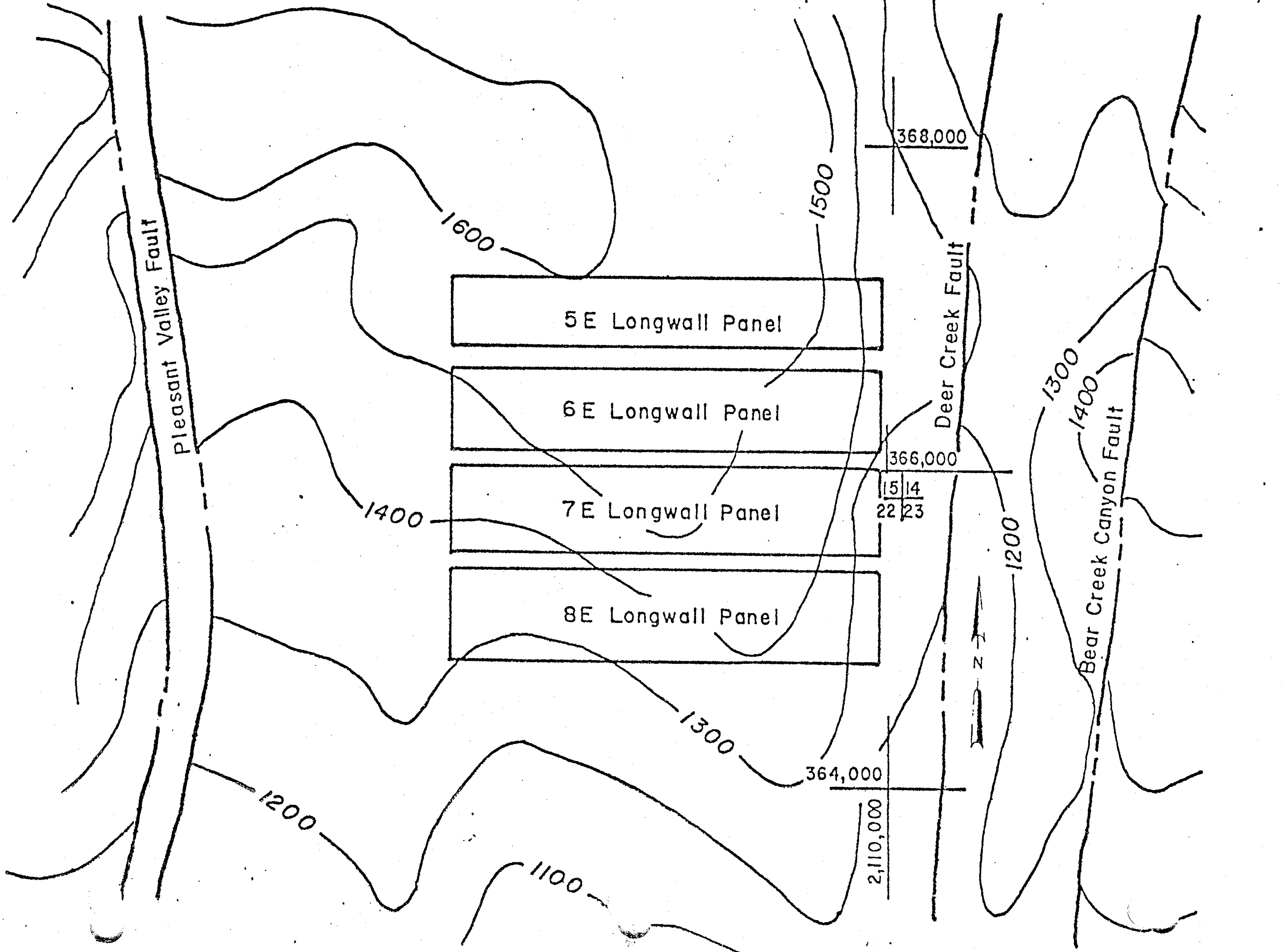


FIGURE 10. - Coal seam stratigraphy.

FIGURE 11. - DEER CREEK LONGWALL SUBIDENCE STUDY SITE - Overburden Isopach



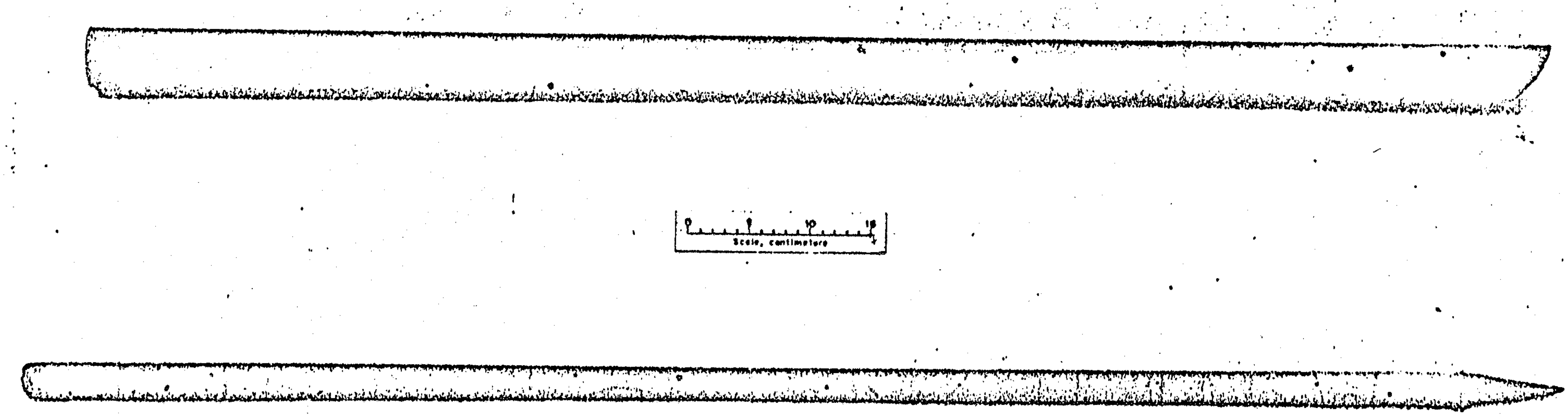


FIGURE 12. - Two types of monuments used at the Deer Creek Site 1-inch rods and 1½-inch pipe.

FIGURE 13. - Installation of a monument w/a gas powered hammer.

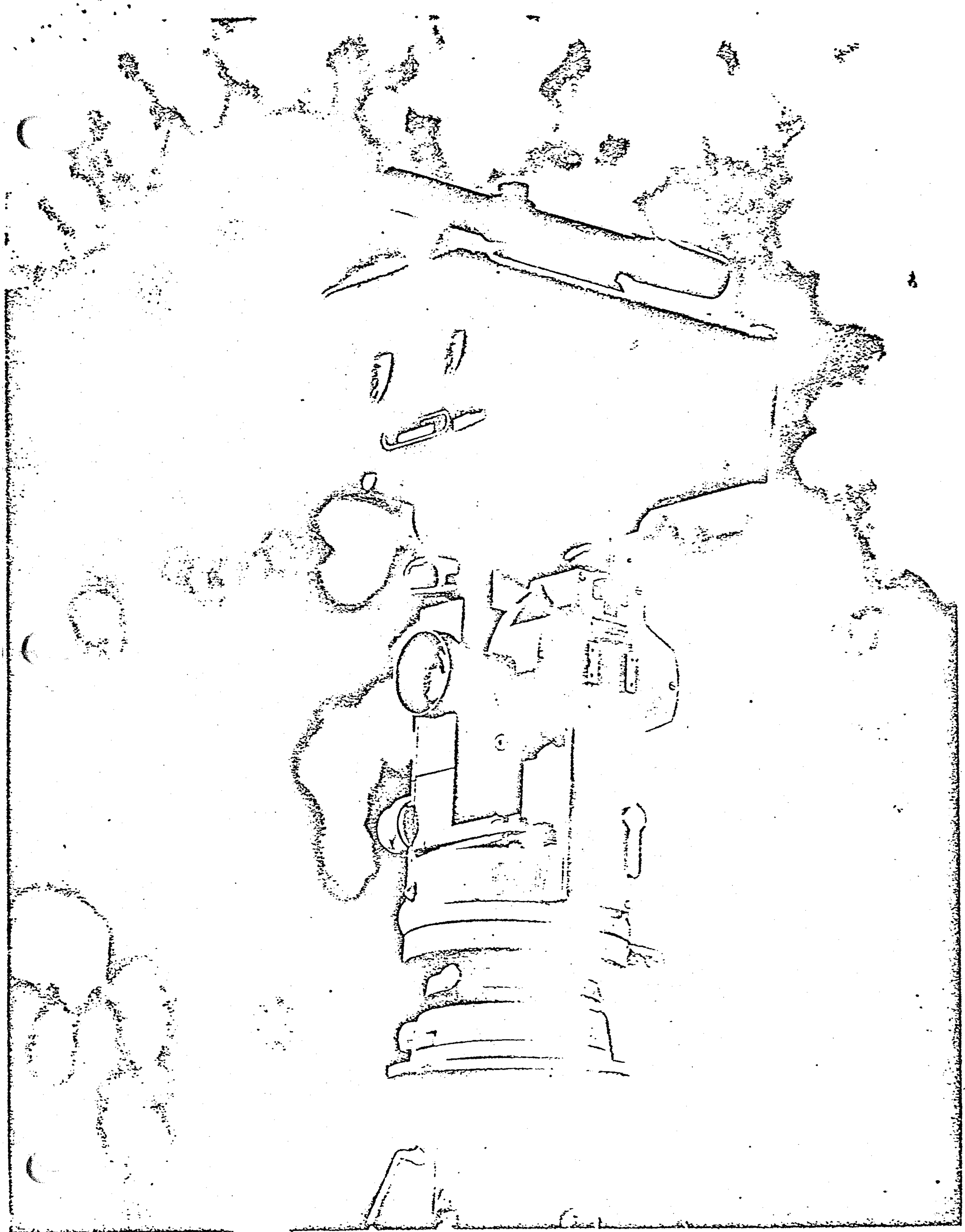


FIGURE 14. - Theodolite w/distance meter used in subsidence surveys.

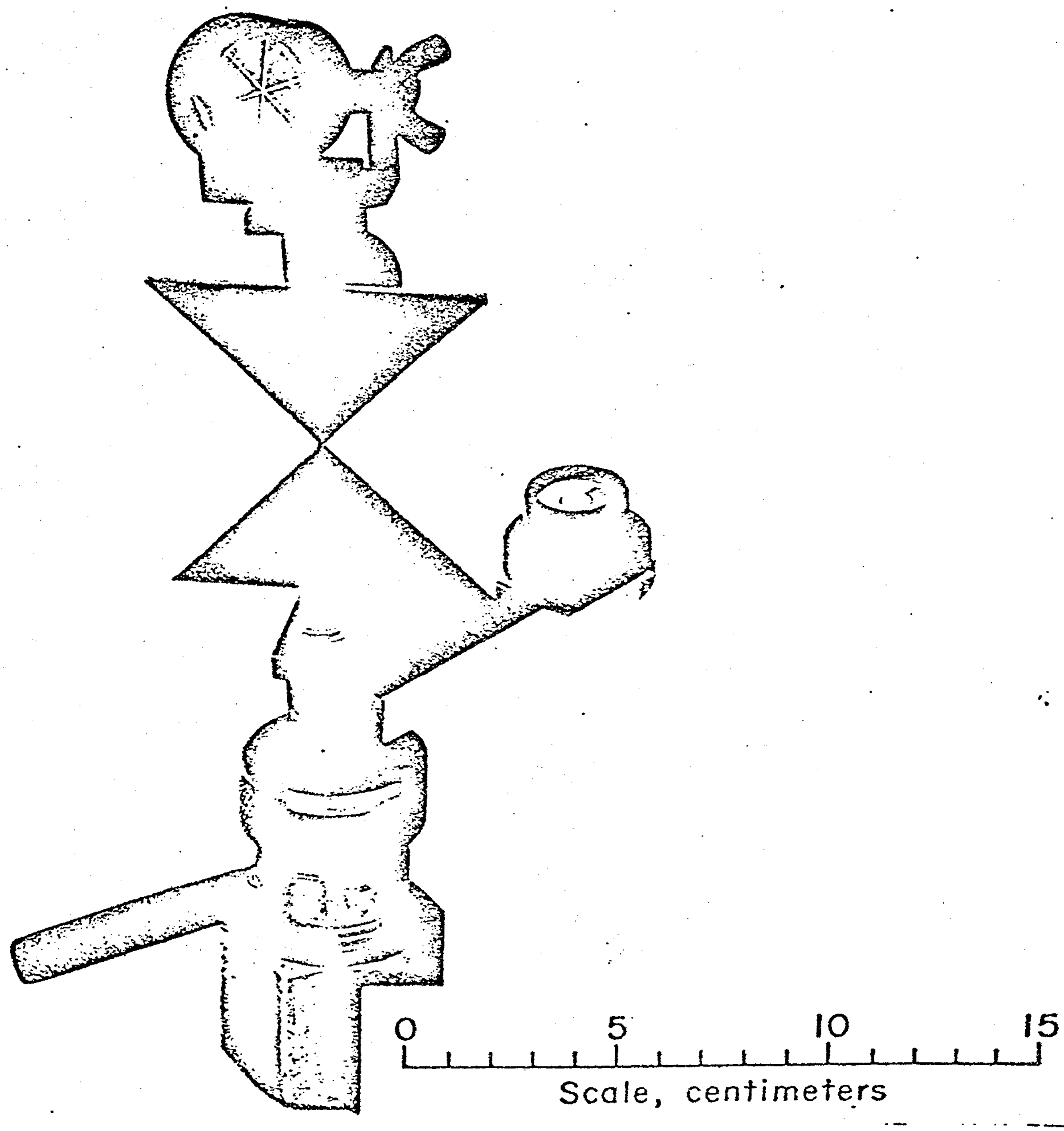


FIGURE 15. - Target/prism unit used in subsidence surveys.

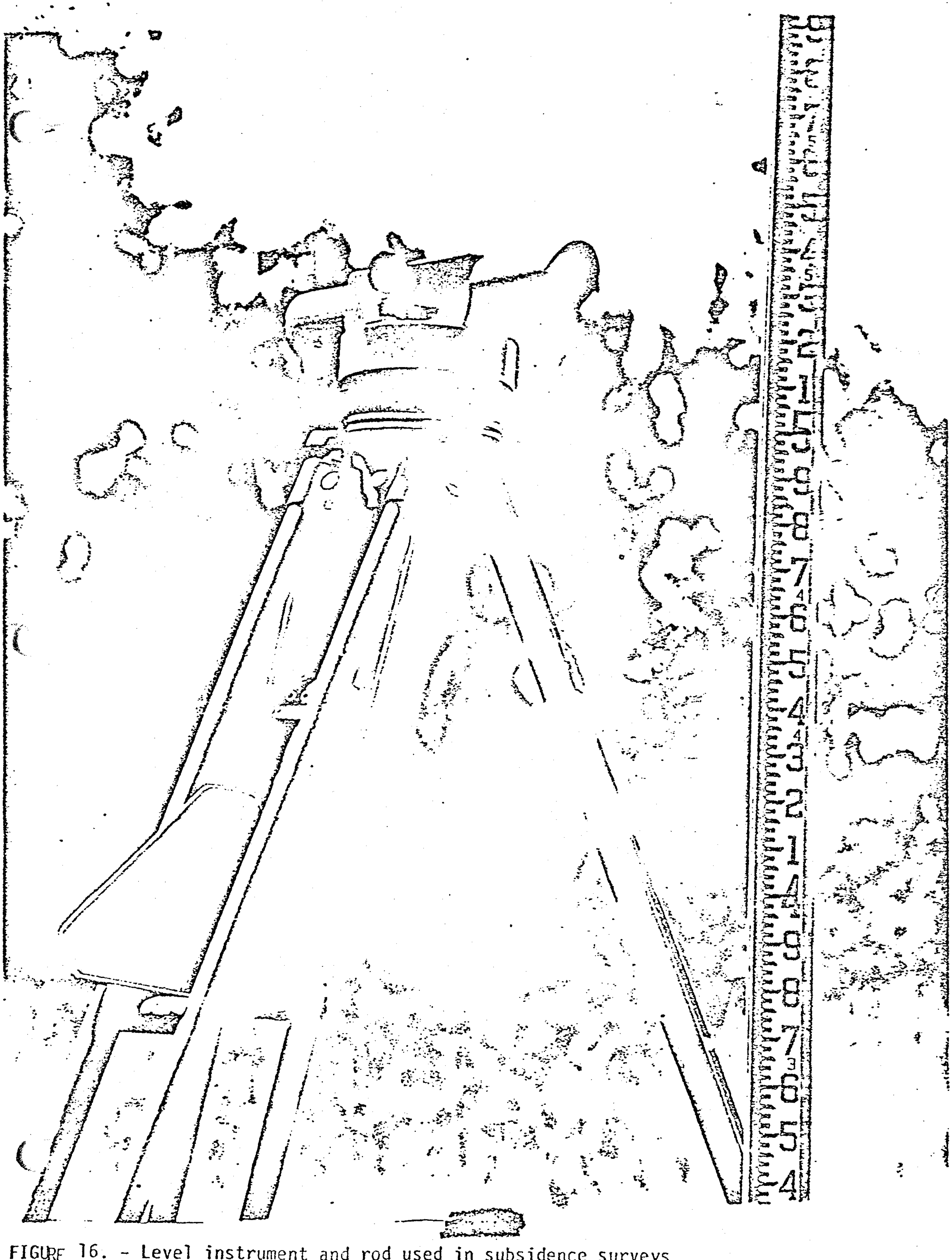


FIGURE 16. - Level instrument and rod used in subsidence surveys.

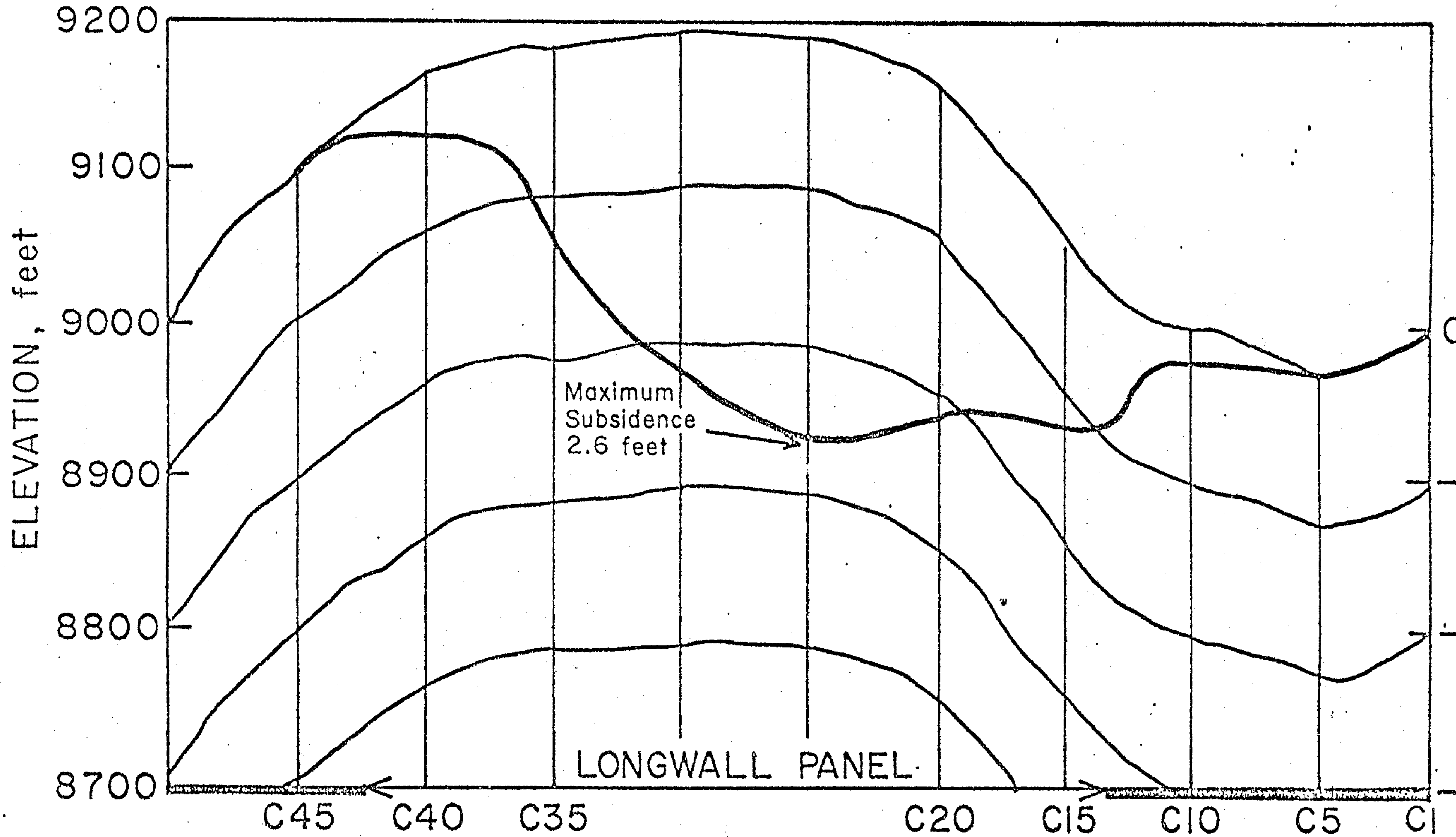


FIGURE 17. - Subsidence profile panel 5E
December 1980

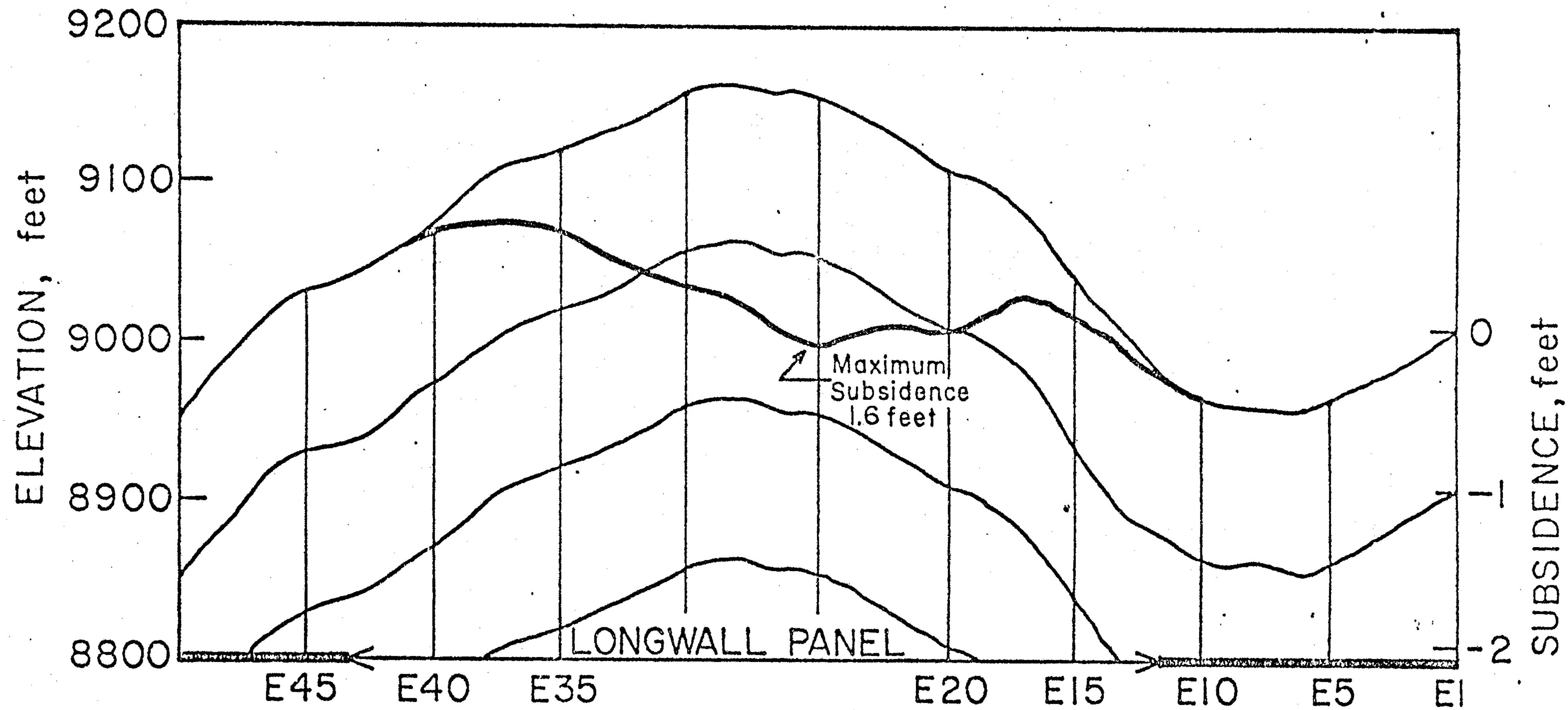


FIGURE 18. - Subsidence profile panel 6E
December 1980

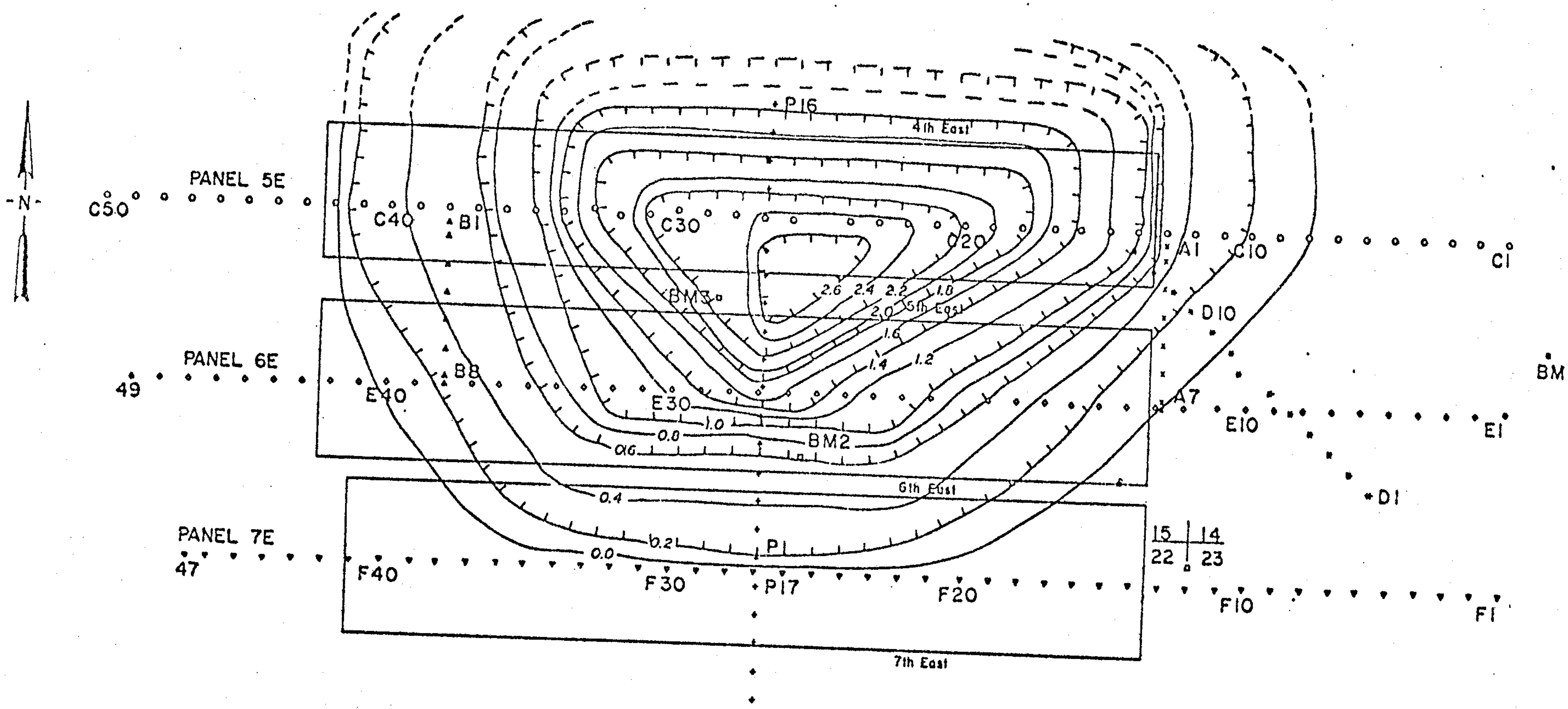


FIGURE 19. - Deer Creek Longwall Subsidence Study Site
Subsidence contours.

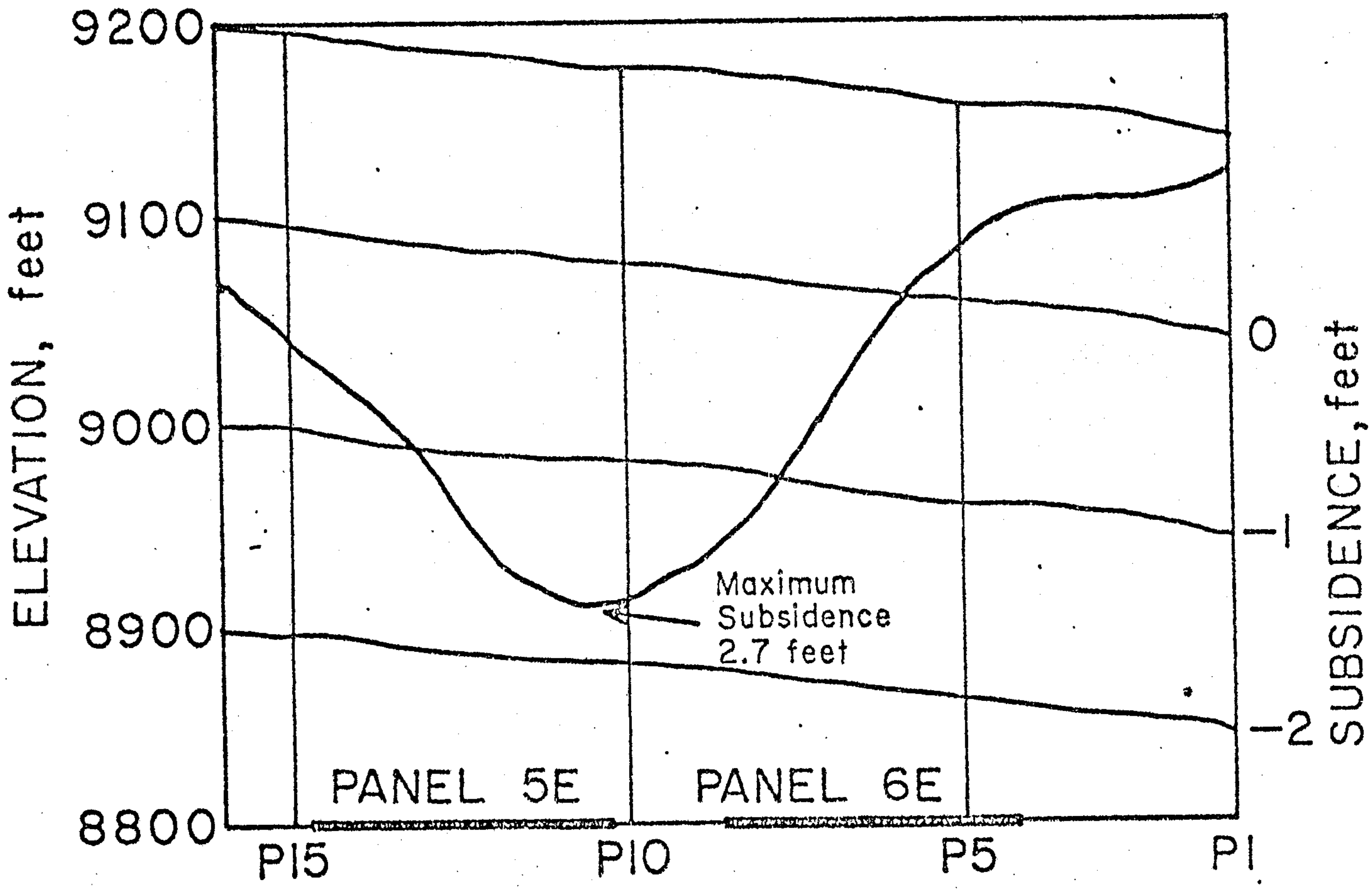


FIGURE 20. - Subsidence profile across panels 5E and 6E
December 1980

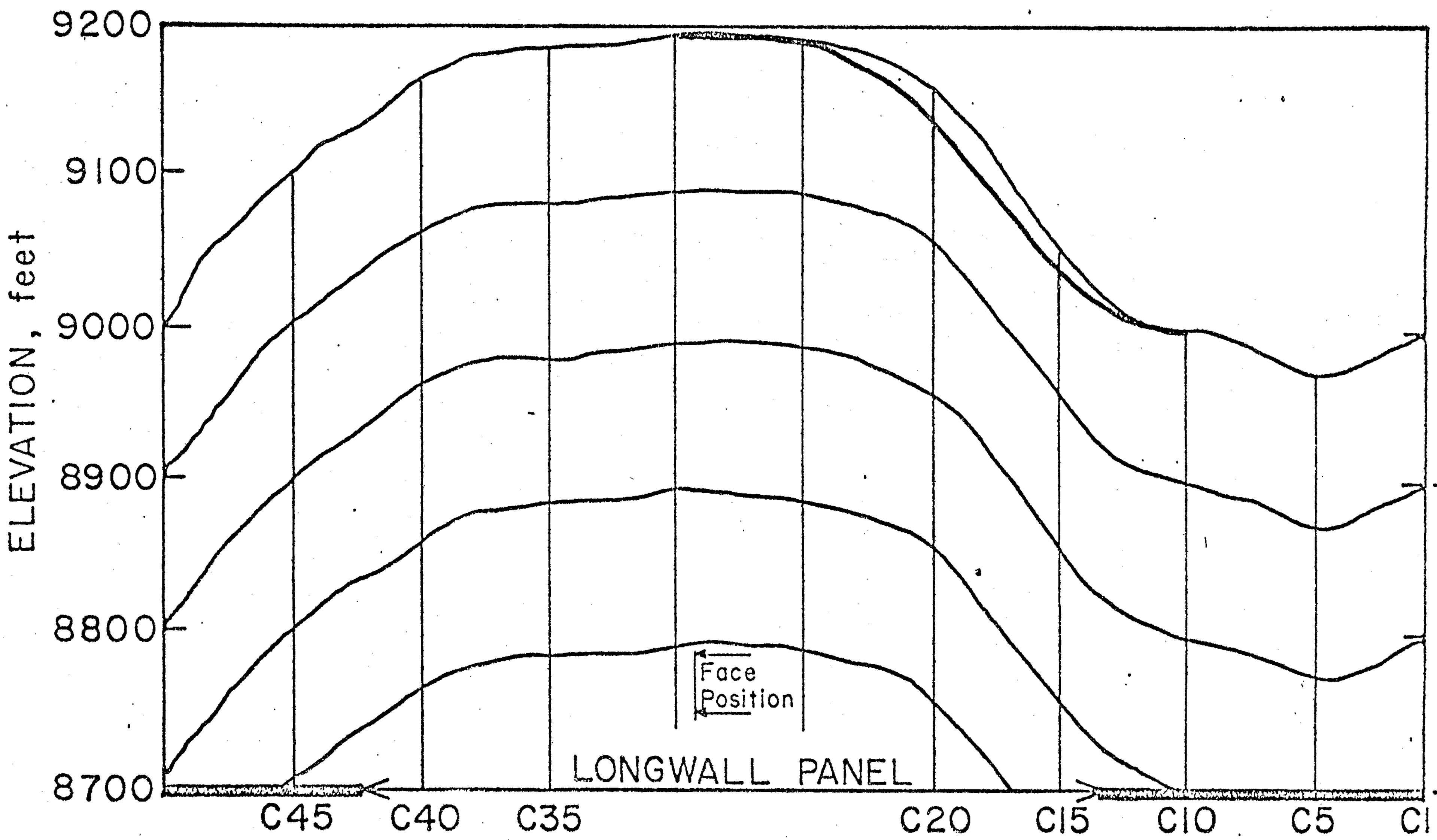


FIGURE 21. - Subsidence profile panel 5E
September 1979

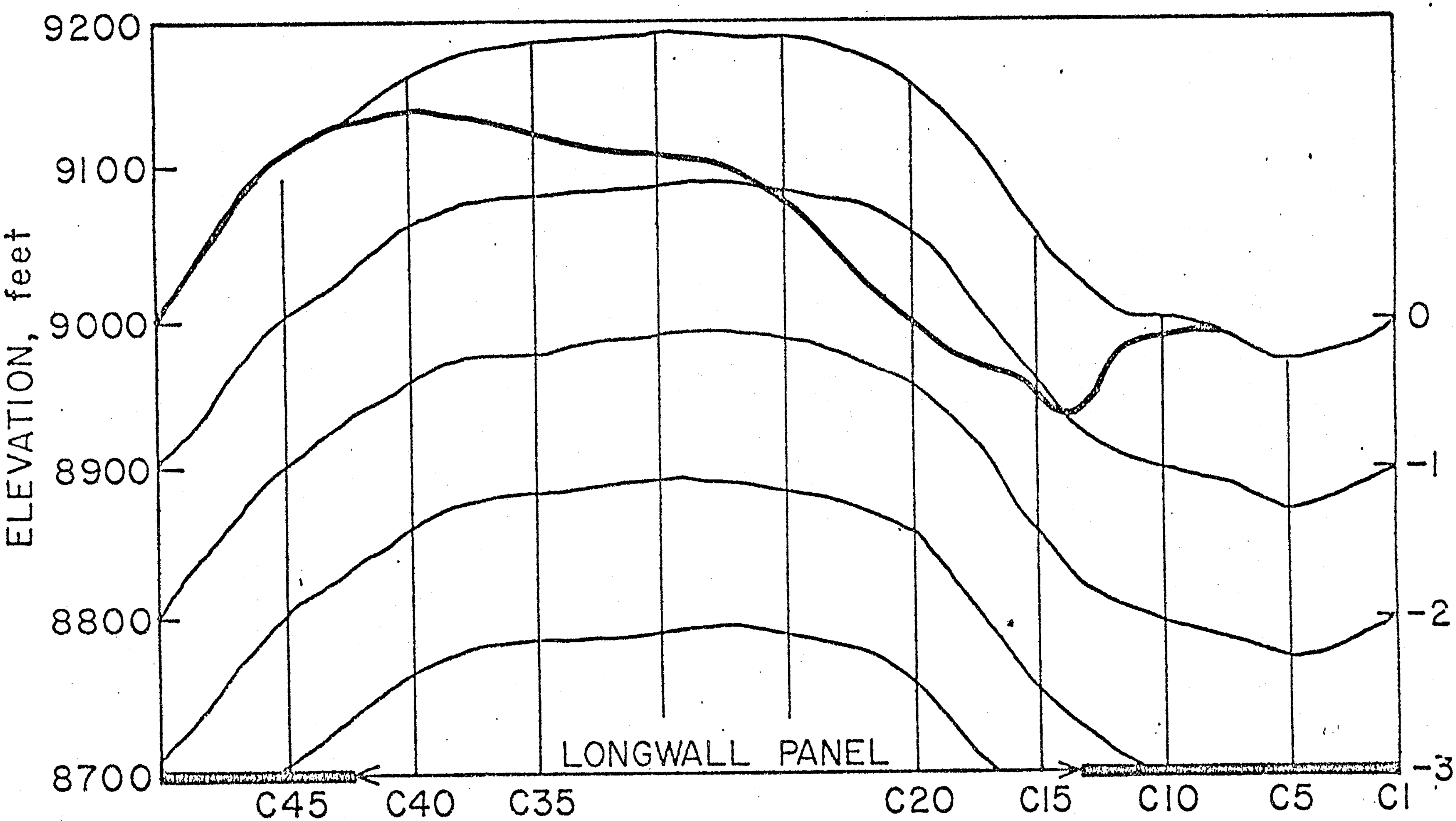


FIGURE 22. - Subsidence profile panel 5E
July 1980

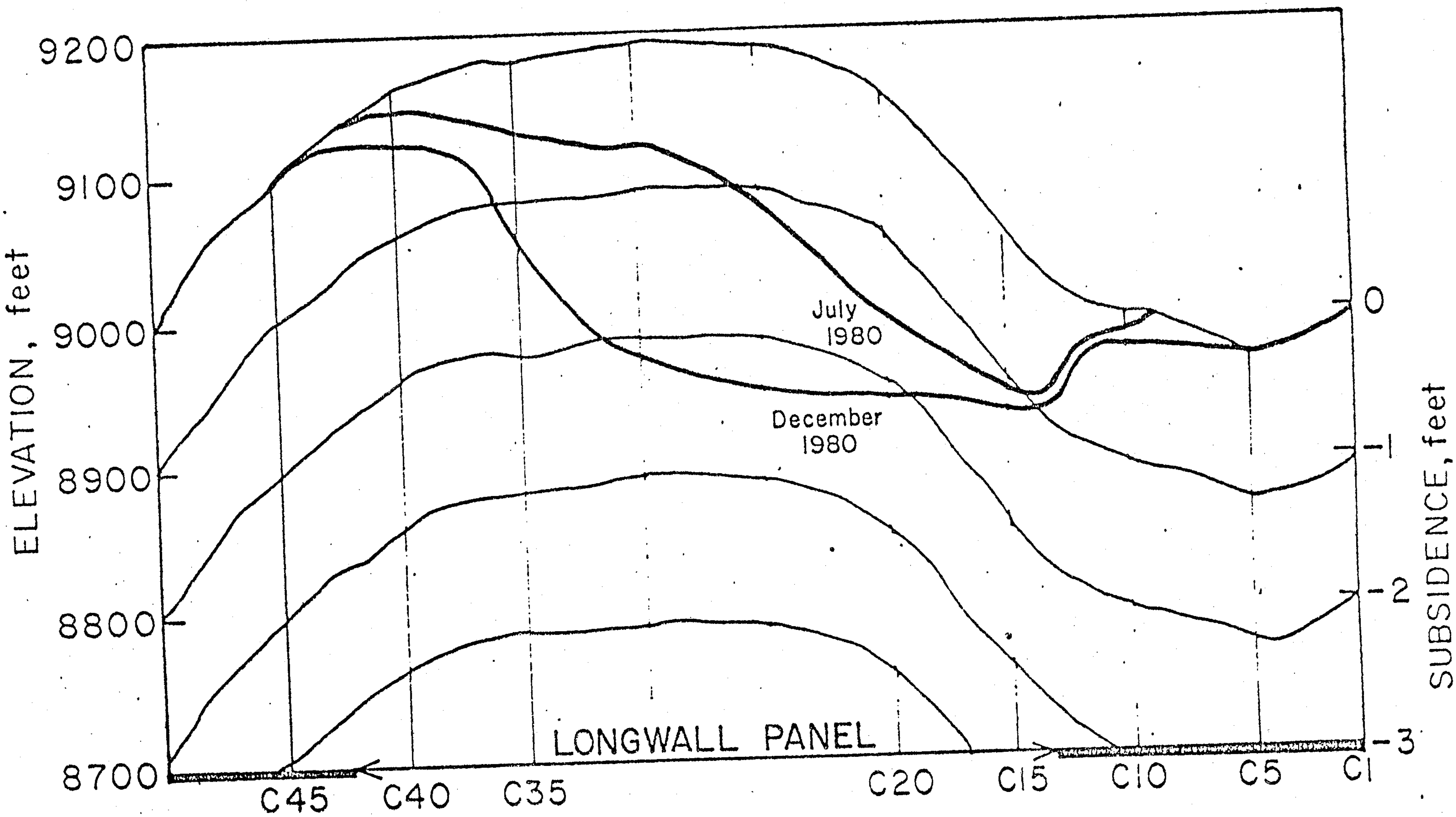


FIGURE 23. - Subsidence profiles panel 5E
July 1980 - December 1980