UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC DATA REPORT ON THE BLACK BUTTE HYDROFRAC HOLE, WESTERN SAN BERNARDINO COUNTY, CALIFORNIA

By

J. E. Springer[1] and G. D. Myren[1]

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ABSTRACT

The Black Butte hydrofrac hole was drilled to a depth of 2,134 ft (651 m) and is located adjacent to Black Butte, an intermediate to mafic stock of middle to late Mesozoic age. The upper 280 ft (85 m) intersect regionally extensive Cretaceous quartz monzonite and minor amounts of hornblende diorite and gabbro from the stock. Below 280 ft (85 m) the hole intersects only quartz monzonite. Borehole televiewer logs reveal 523 throughgoing fractures. Fracture density generally decreases with depth with the dominant fracture set striking roughly north and dipping steeply to the east. The distribution of fracture orientations is very different in the 585 ft (178 m) deep Sacks-Evertsen dilatometer hole only 1,214 ft (370 m) away.

During the course of the drilling activity, the dilatometer, which provides a continuous record of volumetric strain, recorded a high rate of strain until the range of the instrument was exceeded. A downhole temperature sensor also recorded spurious values. This unusual response ceased after cementing the hydrofrac hole between 320 ft (98 m) and 914 ft (279 m) in depth. Because this cementing appeared to solve the problem, it is likely that the fractures responsible for the unusual readings intersect the hydrofrac hole in the cemented interval. The anomalous readings are interpreted as a result of these fractures communicating fluid between holes. While the data quality does not warrant quantitative modeling, these events are discussed qualitatively.

INTRODUCTION

The Black Butte hydrofrac hole was drilled in order to perform deep hydraulic fracturing stress measurements for earthquake hazards studies. The hole is located on the south side of Black Butte, 27 mi (45 km) east of Lancaster in the western Mojave region of California (fig. 1). The hole was drilled with a 6-1/2 inch rotary air bit to a depth of 2,134 ft (651 m). Table 1 provides general drilling data.

The Black Butte site was chosen for two reasons. First, it is located near the Fort Tejon-Palmdale segment of the San Andreas fault which has remained locked since the great Fort Tejon earthquake of 1857. It is thought that the next great earthquake in California may occur along this segment

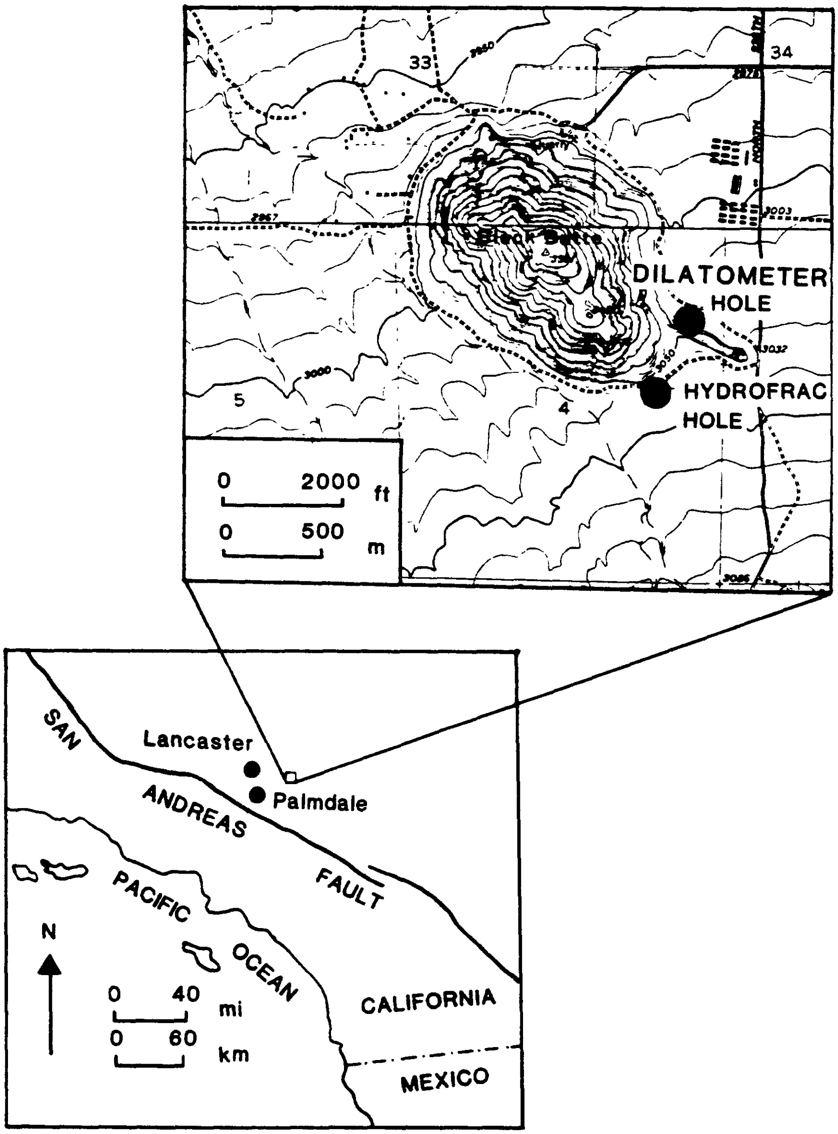


Figure 1. Location map of the Black Butte site.

(Allen, 1981). This site was also chosen because the non-porous nature of the local crystalline rock lends itself to hydraulic fracturing stress measurements.

Table 1

SUMMARY OF DRILLING DATA FOR THE BLACK BUTTE

HYDROFRAC HOLE

Date of drilling completion: June 18, 1984

Location: 34° 33' N, 115° 51' W
(middle of Sec. 4 T5N/R8W)

Drilling rate: Average 1 ft/min (.3 m/min)

Rock type: 0 - 40 ft (0 - 12 m) Alluvium
40 - 280 ft (12 - 85 m) Quartz Monzonite and Hornblende Gabbro
280 - 2,134 ft (85 - 651 m) Quartz Monzonite

Total depth: 2,134 ft (651 m)

Bit size: 6-1/2 in. (165 mm)

Casing: 0 - 170 ft (52 m)

Cement: 320 - 1,334 ft (98 - 407 m)
680 - 1,774 ft (207 - 541 m)

Logs run: Caliper, Televiewer

Water level: 225 ft (69 m)

A 585 ft (177 m) deep hole was drilled previously on the northeast side of Black Butte, about 1,214 ft (370 m) from the hydrofrac hole. It was drilled in order to monitor strain continuously with a dilatometer (volumetric strainmeter. This instrument was designed by S. I. Sacks and D. Evertsen of Carnegie Institute and is described by Sacks et al. (1971). During drilling of the hydrofrac hole, anomalous readings were recorded on instruments in the dilatometer hole. Because these large strains were not anticipated, the instruments were not set up to record the signal amplitudes that were encountered.

The purpose of this report is to document the geologic data associated with the hydrofrac hole. The results of the hydraulic fracturing stress measurements are to be presented in a later report. First we outline the geologic setting and describe the rocks encountered in the drillhole. Then we describe the fractures that were seen on the televiewer log. Finally, we discuss the correspondence between the drilling activity and the responses of the dilatometer.

GEOLOGIC SETTING

Black Butte is an intermediate to mafic stock located 20 mi (33 km) northeast of the San Andreas fault. Figure 2 is a generalized geologic map of the site. The stock consists of two rock types: a hornblende diorite and a hornblende gabbro or amphibolite. Both rocks are medium- to coarse-grained, equigranular, and phaneritic with some slight local lineations due to preferred

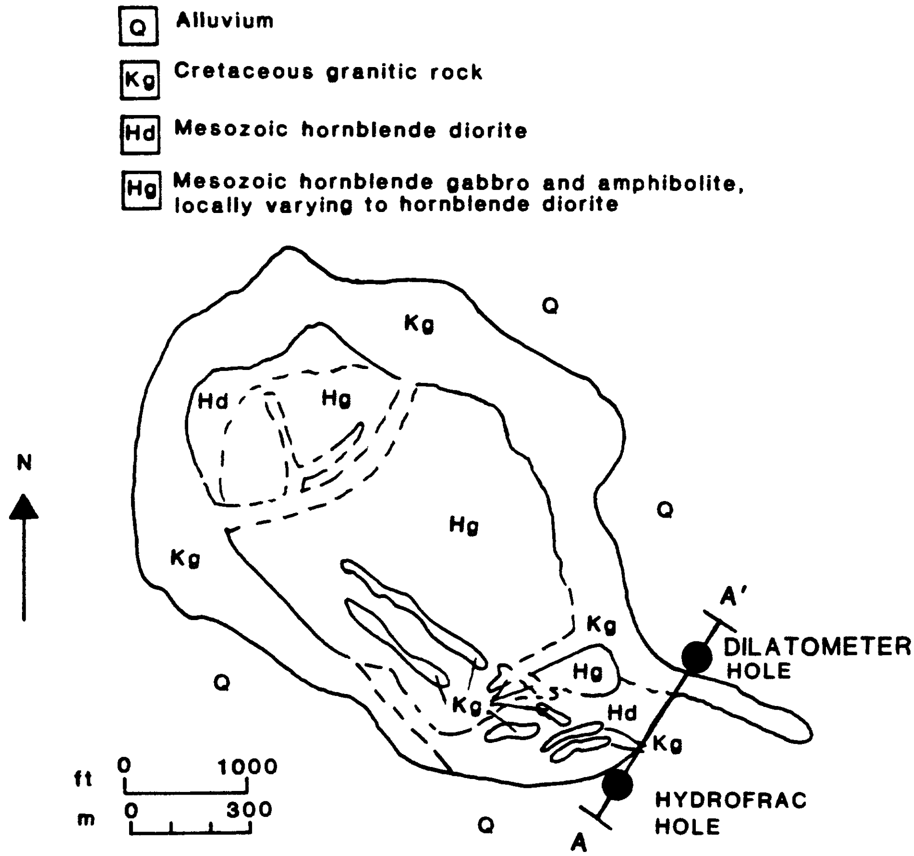


Figure 2. Generalized geologic map of the Black Butte site.

orientations of hornblende phenocrysts. The gabbro occupies the core of the stock while the diorite lies around the edges. The contact between the two is gradational and locally interfingering. Because of this gradational and interfingering nature, and because of a large amount of talus on the hill, the contact, as drawn in Figure 2 is only a rough approximation.

The dikes that cut the stock are granitic and are probably related to the locally extensive quartz monzonite. They have a variety of compositions and textures, including aplite, aphanitic quartzite, hypidiomorphic quartz monzonite, and pegmatite. Widths of the dikes vary from a few meters to 10 m and some of them cut completely across the stock.

The surrounding rock is phaneritic biotite quartz monzonite, locally varying to granodiorite. It is part of a regionally extensive batholith of Cretaceous age (Bowen, 1954; Noble, 1954). Near the site it is easily distinguished from the hornblende diorite of Black Butte because the hornblende in it occurs only in trace amounts.

From 0 to 280 ft (85 m) depth the drill encountered mostly quartz monzonite with about 10% to 15% of the cuttings being diorite and gabbro. A 20 ft (6 m) thick subhorizontal fracture zone occurs at 280 ft (85 m) and below the fracture zone only quartz monzonite was encountered.

The age of the stock is not known with certainty. A similar stock at Iron Mountain, 30 mi (50 km) to the northeast, cuts the probable Triassic Sidewinder Group (Bowen, 1954) and therefore post-dates it. Bowen (1954) interpreted the Iron Mountain Stock to be "Jura-Cretaceous". Similar intermediate rocks in the Victorville region yield K-Ar ages as old as 233 $\pm$ 14 m.y. (Late Triassic) (Burchfiel and Davis, 1981). The dikes that cut the stock at Black Butte may be as young as Late Cretaceous, so the age of the stock is between Late Triassic and Late Cretaceous.

Ditch samples were collected at 20 ft (6 m) intervals (one sample for each stand of drill pipe). Because air drilling returns cuttings rapidly to the surface, the samples are a good representation of the rock, averaged over the 20 ft (6 m) interval. The samples were analyzed with a hand lense and, in some cases with a low-powered binocular microscope. Descriptions of the samples are given in Appendix A. Because the samples were broken up by drilling, descriptions of textures are interpretations of what the rock looked like before drilling. Larger grain sizes are more difficult to interpret because the drill cuttings are small with respect to the average grain size. Because of the limitations of reflection microscopy, only a general classification was given for most of the non-hornblende-bearing rocks. For eight of the samples, feldspars were stained in order to obtain feldspar ratios. For these, the approximate range of compositions from visual estimation of ditch samples are:

15% to 45% quartz

20% to 52% plagioclase

18% to 46% K-feldspar

5% to 20% biotite

traces of hornblende, sphene, and hematite.

Although these estimates vary considerably, each individual sample had a plagioclase-to-total-feldspar ratio of quartz monzonite.

FRACTURES

Borehole Televiewer. Fractures in the Black Butte wells were analyzed using borehole televiewer data. The borehole televiewer is a sonic logging tool that produces an acoustic image of the borehole. It consists of a logging sonde with a rotating piezoelectric transducer that emits a 1.3 MHz pulse 2,000 times per second. It rotates three times per second. The televiewer describes a spiral as it is logged up the hole at a rate of 5 ft (1.5 m) per minute. The return pulse is electronically processed, output on a three-axis oscilloscope, and recorded on videotape. A flux-gate compass triggers the oscilloscope on magnetic north (see Zemanek et al., 1969, 1970). Each oscilloscope trace is recorded with magnetic north on the left. Polaroid pictures of the oscilloscope traces are taken as the trace moves up the scope.

The result is a sonic picture of the inside of the borehole (fig. 3) as if it were split down the middle and laid flat. The brightness of the image is a function of the reflectivity of the borehole wall. Planar features, such as fractures, describe a sinusoid on the image. By measuring the azimuthal location of the crest and trough and the amplitude of the sinusoid, the strike and dip of a throughgoing fracture can be calculated trigonometrically.

Observation of Fractures. Figure 4 contains lower hemisphere equal area plots of the fractures seen in the hydrofrac hole. Figure 4a contains all of the fractures, 4b, c, d, and e have fractures at depth intervals of 225 ft to 500 ft (69 to 152 m), 500 ft to 900 ft (152 to 274 m), 900 ft to 1,500 ft (274 to 457 m), and 1,500 ft to 2,115 ft (457 to 645 m), respectively. Figure 5 is a dip log or "arrow plot" of the fracture data. In this figure the dip angle is plotted against depth and the dip direction is displayed as an arrow or tail on the plotting symbol. Conventional oil industry dip logs have a log scale on the dip axis in order to compensate for poorer quality data near the high-angle end of the scale. With the televiewer data, we do not present a log scale on the dip angle axis because a horizontal exaggeration of about 8:1 actually makes the high-angle determinations more accurate than the low-angle ones. Nevertheless, vertical and very high-angle fractures are under-represented in this data set for two reasons. First, the vertical borehole is less likely to intersect fractures parallel and subparallel to it. Second, vertical and nearly vertical fractures are less likely to be seen as throughgoing fractures with a sinusoidal trace.

While Figures 4 and 5 show considerable scatter, it can be seen that the dominant fracture set strikes north-northwest to north-northeast and dips steeply to the east. In spite of the bias against very high-angle fractures, a significant number of those in this set have near vertical dips. Another minor set is subhorizontal.

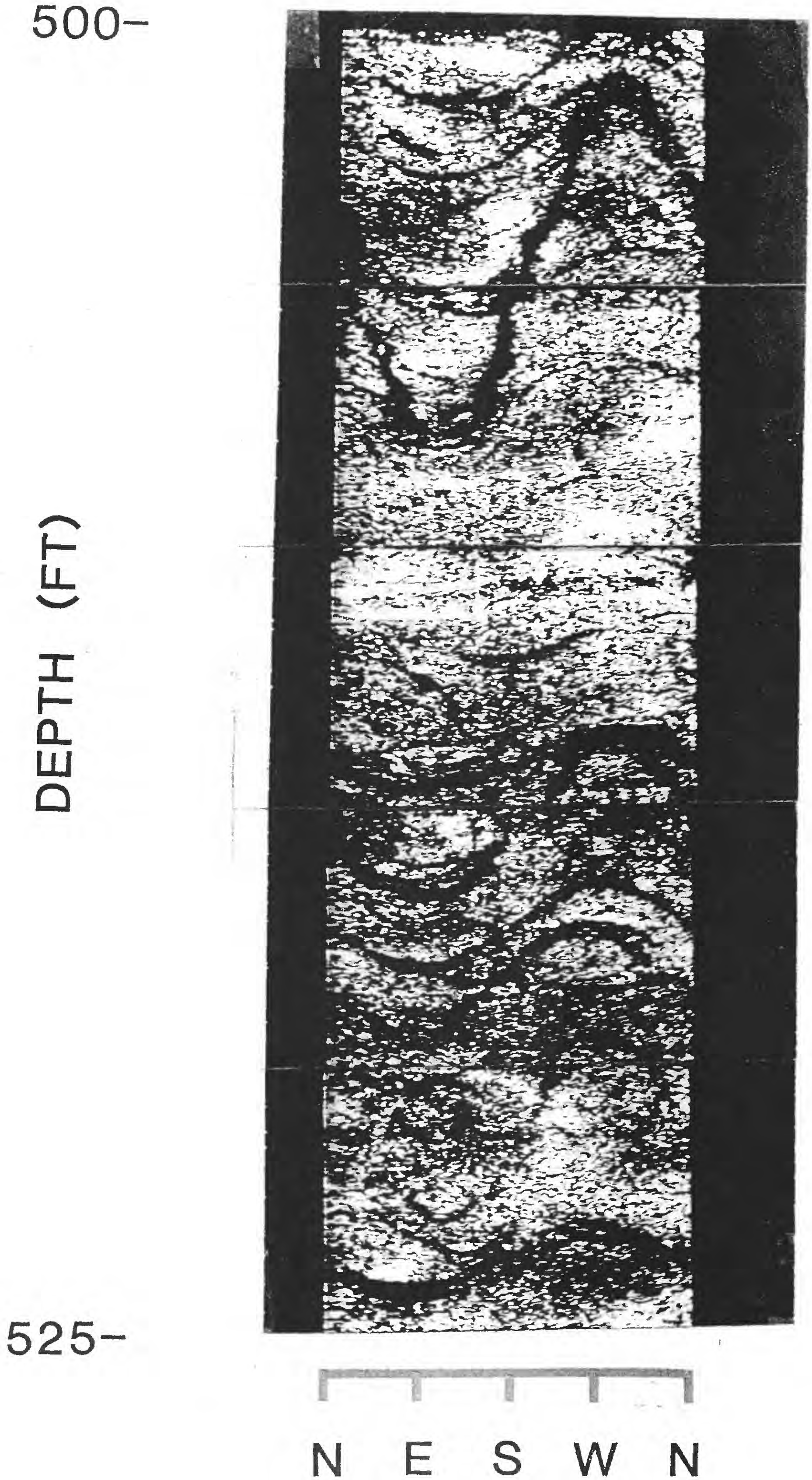
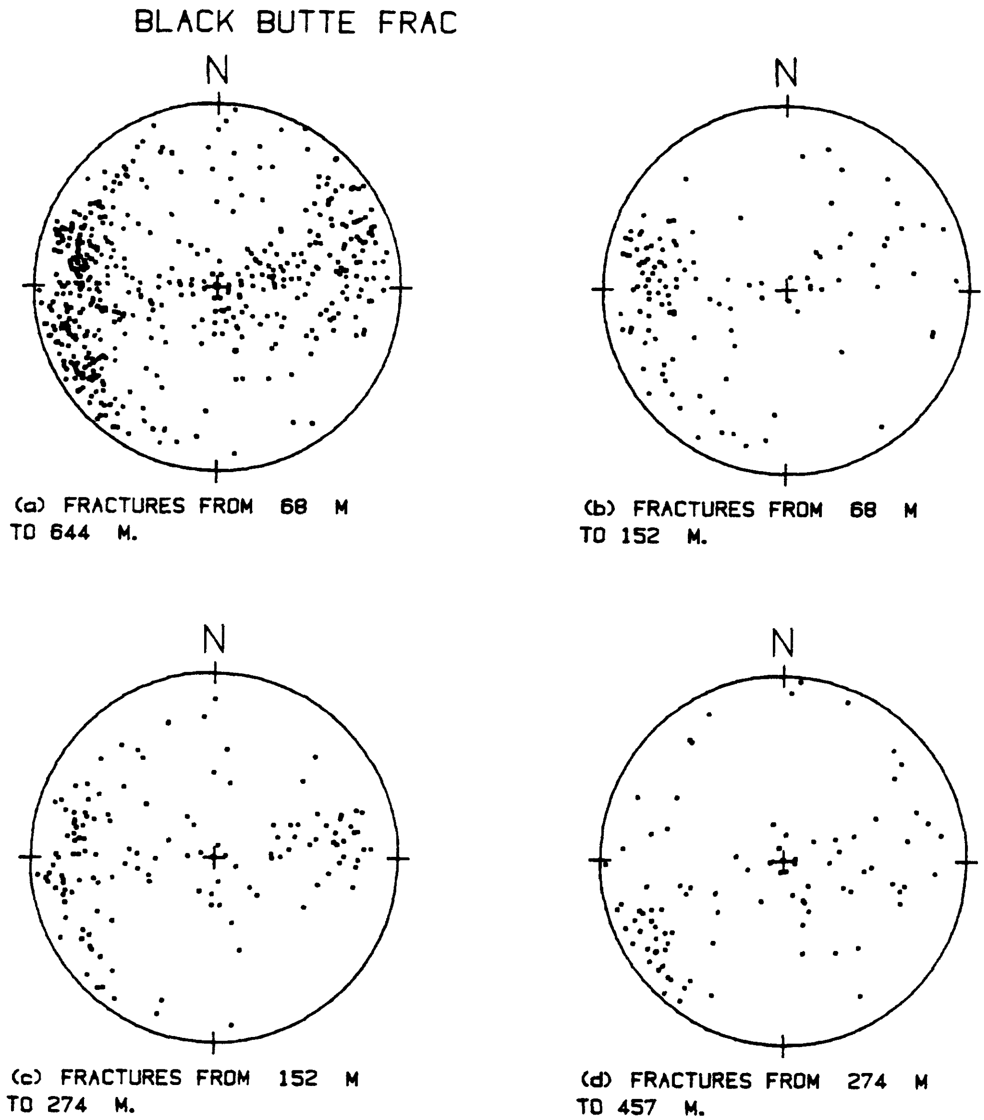


Figure 3. Example of a televiewer log showing throughgoing fractures.



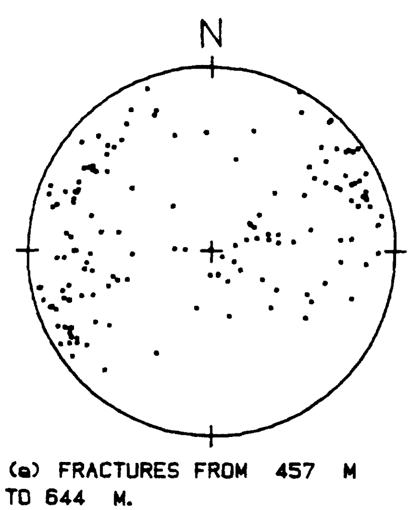


Figure 4. Lower hemisphere schmidt projections of poles to fractures in the hydrofrac hole. (a) shows all 523 fractures, (b) shows fractures from 225ft to 500 ft (68 to 152 m), (c) is from 500 ft to 900 ft (152 to 274 m), (d) is 900 ft to 1,500 ft (274 to 457 m), and (e) is 1,500 ft to 2,115 ft (457 to 645 m).

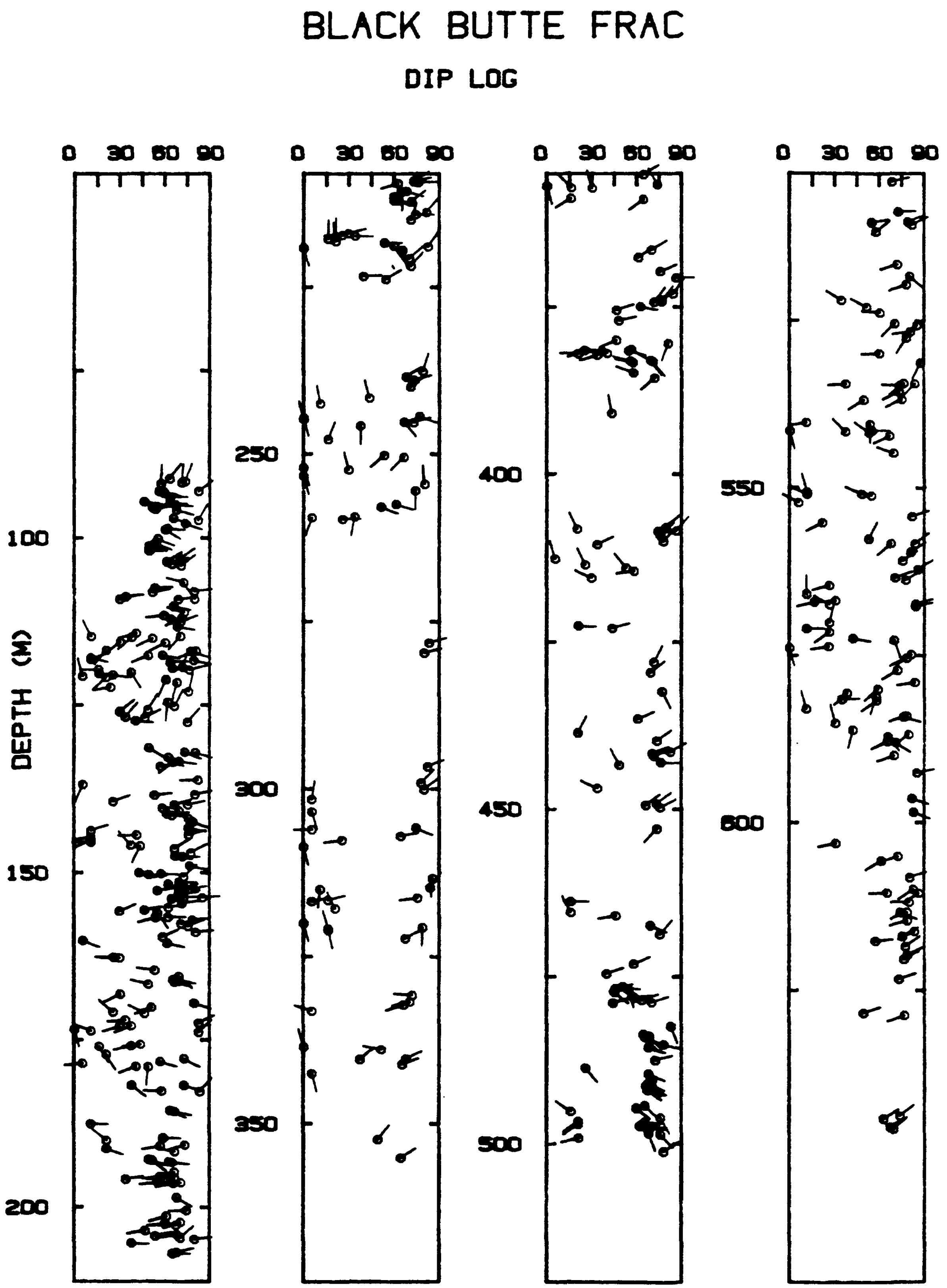


Figure 5. Dip log of fractures in the hydrofrac hole. Tails on the plotting symbols are in the direction of dip.

Figure 6 is a plot of cumulative fractures versus depth. The flat (near vertical) portions of the curve correspond to depth intervals that have few fractures. It can be seen from the slope of the curve in Figure 6 that fracture frequency tends to become less dense with depth. A similar observation was made by Seeburger and Zoback (1982) in four wells in the western Mojave region. It is unclear whether this is influenced by the increased confining pressures that keep fractures closed and make them more difficult to detect with the televiewer.

Figures 7 and 8 are a stereoplot and an arrow plot, respectively, of fractures in the dilatometer hole. The scatter is greater and low-angle fractures are much more common. In the bottom 200 ft of the hole there is a high-angle, northeast-dipping set that is partly coincident with the dominant set in the hydrofrac hole. This is the only similarity between the two data sets. It is surprising that the distribution of fracture orientations is so different between two wells that are only 1,214 ft (370 m) apart. Seeburger and Zoback (1982) found in the same region that there was almost no correlation between fracture orientations in the four wells that they studied. The distances between their wells, however, were between 3 mi (7 km) and 15 mi (25 km).

RESPONSE OF THE DILATOMETER HOLE INSTRUMENTS TO DRILLING ACTIVITY IN THE HYDROFRAC HOLE

During the drilling of the Black Butte hydrofrac hole, the Sacks-Evertsen dilatometer registered strains that caused it to go off scale. To a lesser extent, a temperature probe installed in the hole was also affected. The cause of the anomalous readings is probably related to water being transmitted through fractures from one hole to another. Since strain monitoring requires careful consideration of noise sources, it is important to document the problems that nearby drilling causes. Furthermore, the affect of drilling and related activities on the local strain field can be used to our advantage if it is carefully planned for (see, for example, studies by Evans and Wyatt (1984) and Evans and Holzhausen (1983)). The following discussion will document and attempt to evaluate the affect of drilling on the instruments in the dilatometer hole.

The temperature probe was placed in the dilatometer hole in sand within a large fracture zone at a depth of 337 ft (103 m). A pressure transmitter was installed alongside the temperature probe, but was not operating during the time of drilling. The dilatometer was set in an unfractured interval at a depth of 558 ft (170 m).

Table 2 is a summary of the drilling history of the hydrofrac hole. Figure 9a is a plot of time versus strain for the dilatometer from April 7 to May 19, 1984 and Figure 9b is a plot of time versus relative temperature for the same time period. Each tick mark on the horizontal axis of Figures 9a and b represents one day and corresponds to midnight Greenwich Mean Time (5:00 PM local daylight savings time). The regular oscillation between April 7 and 16 in Figure 9b is due to earth tides.

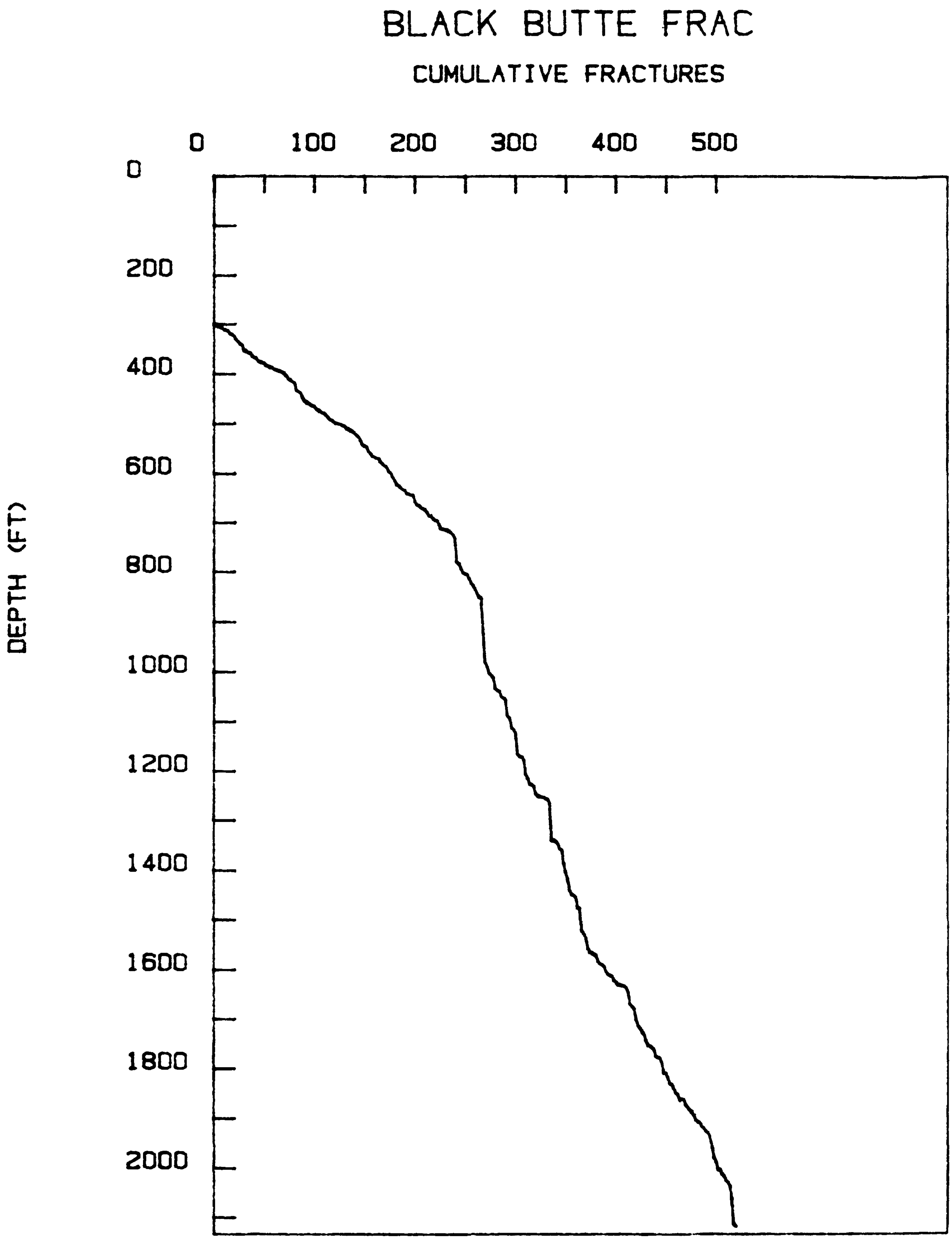


Figure 6. Cumulative fractures vs. depth for the hydrofrac hole.

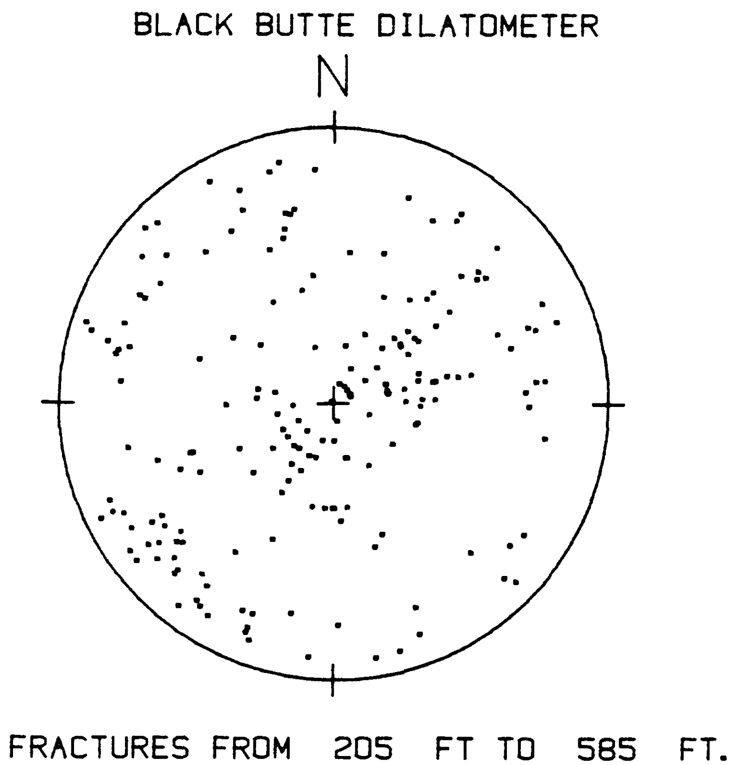


Figure 7. Lower hemisphere schmidt projection of poles to fractures in the dilatometer hole.

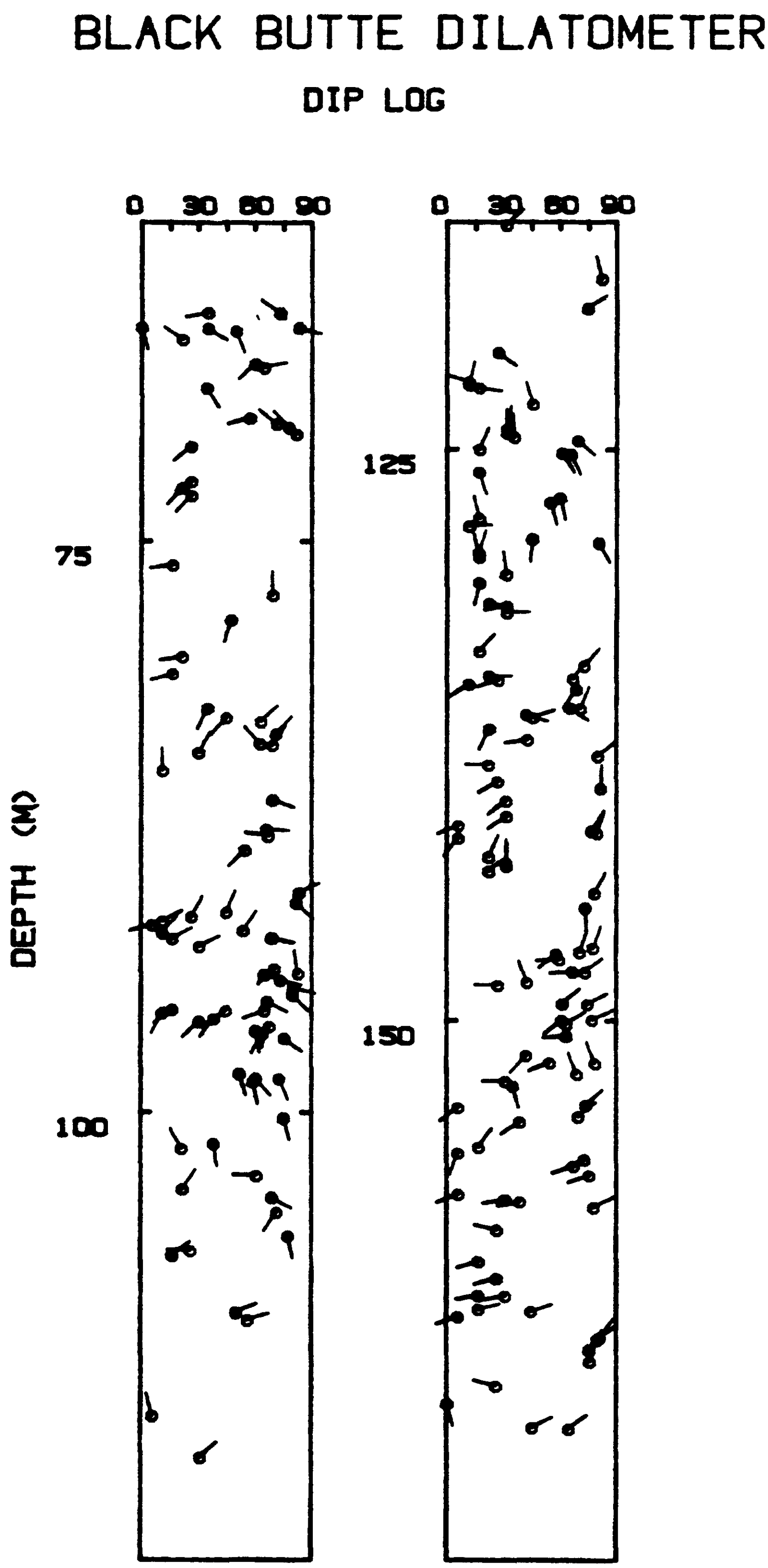


Figure 8. Dip log of fractures in the dilatometer hole.

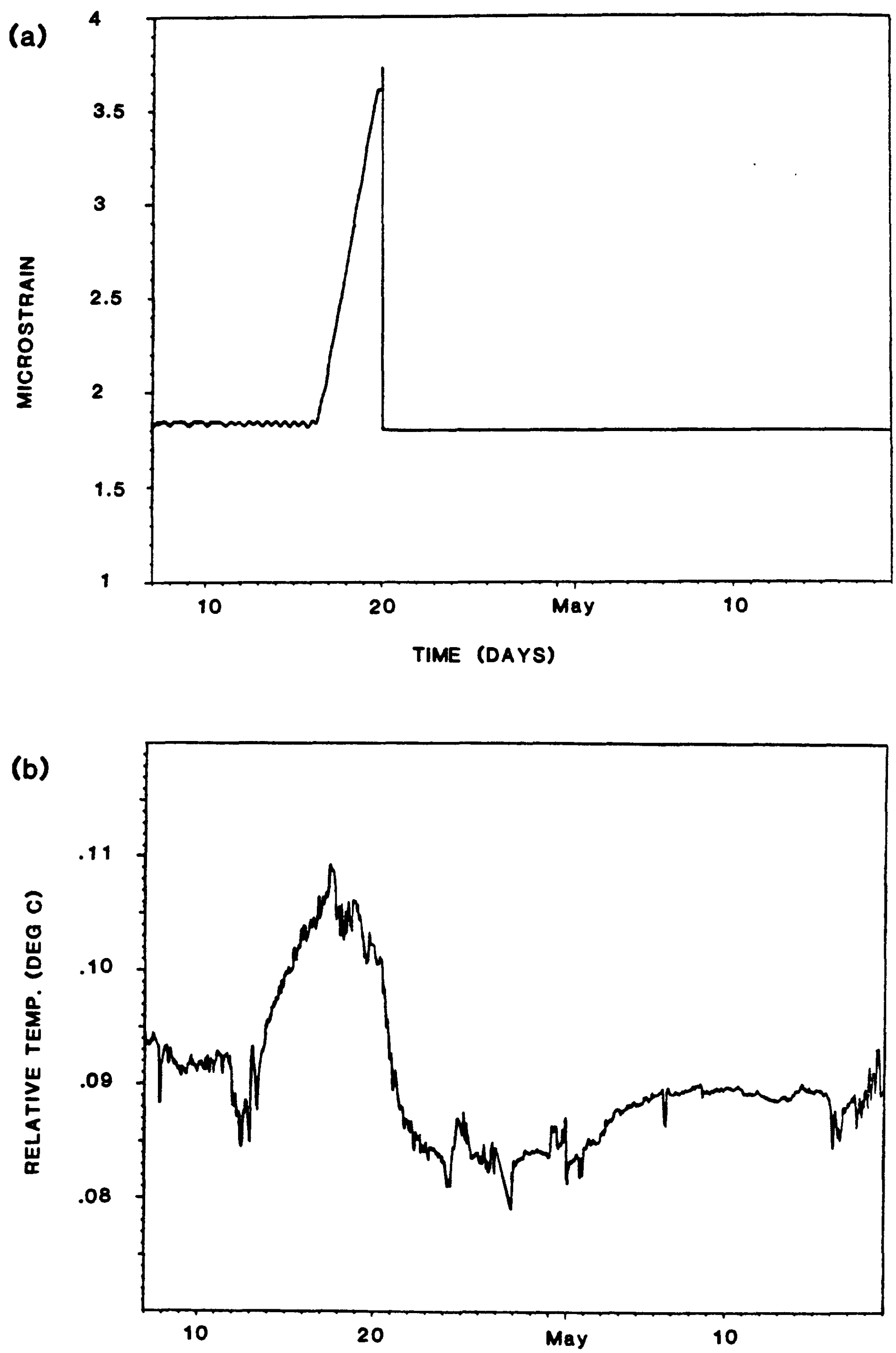


Figure 9. Plots of strain (compression upward) and temperature vs. time in the dilatometer hole from April 7 through May 19. (a) is strain vs. time and (b) is temperature vs. time. Each tick mark on the time axis represents a day and corresponds to midnight Greenwich Mean Time (5:00 PM local daylight savings time).

Table 2

GENERALIZED DRILLING HISTORY OF THE BLACK BUTTE

HYDROFRAC HOLE

April-June 1985

Date	Activity
April 6	Drilled 14 ft to 94 ft (4 to 29 m).
April 7	Drilled 94 ft to 294 ft (29 to 90 m).
April 13	Drilled 294 ft to 914 ft (90 to 279 m).
April 14-24	No activity.
April 25	Drilled 914 ft to 954 ft (279 to 291 m).
April 26	Drilled 954 ft to 1,334 ft (291 to 407 m).
April 27	Started to drill from 1,334 ft, then pulled out and cemented to 320 ft (98 m).
May 1	After cementing, drilled 320 ft to 1,334 ft (98 to 407 m).
May 2	Drilled 1,334 ft to 1,714 ft (407 to 523 m).
May 3	Drilled 1,714 ft to 1,774 ft (523 to 541 m).
May 5	180 ft (55 m) of hole caved in.
May 6-16	No activity.
May 17	Cemented to 680 ft (207 m). After cement, drilled to 920 ft (280 m).
May 19	Drilled 920 ft to 1,774 ft (280 to 541 m).
May 20-29	No activity.
May 31	Started to drill from 1,774 ft (541 m). Hole caved in.
June 7	Drilled through fault gouge 1,640 ft to 1,774 ft (500 to 541 m).
June 8-13	No activity. Hole caved in again.
June 14	Cemented hole.
June 15	Drilled 1,360 ft to 1,580 ft (415 to 482 m) (through cement).
June 16	Drilled 1,580 ft to 1,834 ft (482 to 559 m).
June 17	Drilled 1,834 ft to 1,934 ft (559 to 589 m).
June 18	Drilled 1,934 ft to 2,134 ft (589 to 651 m).
June 19	Packer test.
June 20	Tried to drill deeper--drill bit stuck.
June 21-23	Hydrofrac operation.

Around midnight (local time) on April 16, 1984, the strain began increasing dramatically. By April 20, the strain was beyond the range of the dilatometer, so the instrument was shut off to avoid damage to the sensor. The instrument was turned on again on the afternoon of May 24 and by May 25 it was again recording tidal cycles (fig. 10).

The beginning of the spurious readings was during a time when the drill rig was inactive (see Table 2). The temperature sensor, on the other hand, began to record spurious temperatures around April 13. From April 14 through April 24, when there was no drill activity, the temperature rose and fell by about 0.02°C.

The difference in timing of the spurious readings of the dilatometer and the temperature sensor is best explained by contamination of groundwater by drilling fluid. The thermal diffusivity of the rock is so low that heat transfer to the dilatometer hole had to be through fluid flow. The permeability of the rock is almost zero and groundwater only moves through fractures. One or more of the fractures encountered on April 13 (between 194 ft (90 m) and 914 ft (279 m)) probably allowed redistribution of the fluid regime. The dilatometer probably recorded a delayed strain change as the fluid pressures or temperature changed.

Figure 11 is a schematic structure section between the two boreholes. The locations of the dilatometer and the temperature probe are shown on the dilatometer hole. On the hydrofrac hole, the apparent dips of several large fractures are plotted. Any one, or several of these may have contributed to the observed perturbations in the strain state. One might suppose that the fracture conducting fluid toward the dilatometer hole would intersect the hydrofrac hole up-gradient from the position of the temperature probe. However, because the network of fluid-conducting structures is so complex, it is possible that the fracture(s) conducting the fluid intersect the hydrofrac hole at an elevation lower than that of the temperature probe. In that case, the fluid would have moved within the fracture system in response to drilling-related changes in hydrostatic head within the hydrofrac hole. Actual drilling fluid probably did not reach the dilatometer hole.

The subhorizontal fracture zone at 280 ft (85 m) in the hydrofac hole is a possible fluid conductor because it appears to be a major geologic discontinuity. On April 27, the hole was cemented to 320 ft (98 m) and drilled out in May. After cementing, there was no clear evidence of drilling-related noise on either instrument. Other likely fractures that occur at 362 ft (110 m), 403 ft (123 m), 431 ft (131 m), 484 ft (148 m), and 728 ft (221 m) are shown in Figure 11. Hydraulic fracturing performed at depths from 653 ft (199 m) to 2,082 ft (635 m) on June 21 to 23 apparently did not affect the instruments at the 10^{-2} microstrain level.

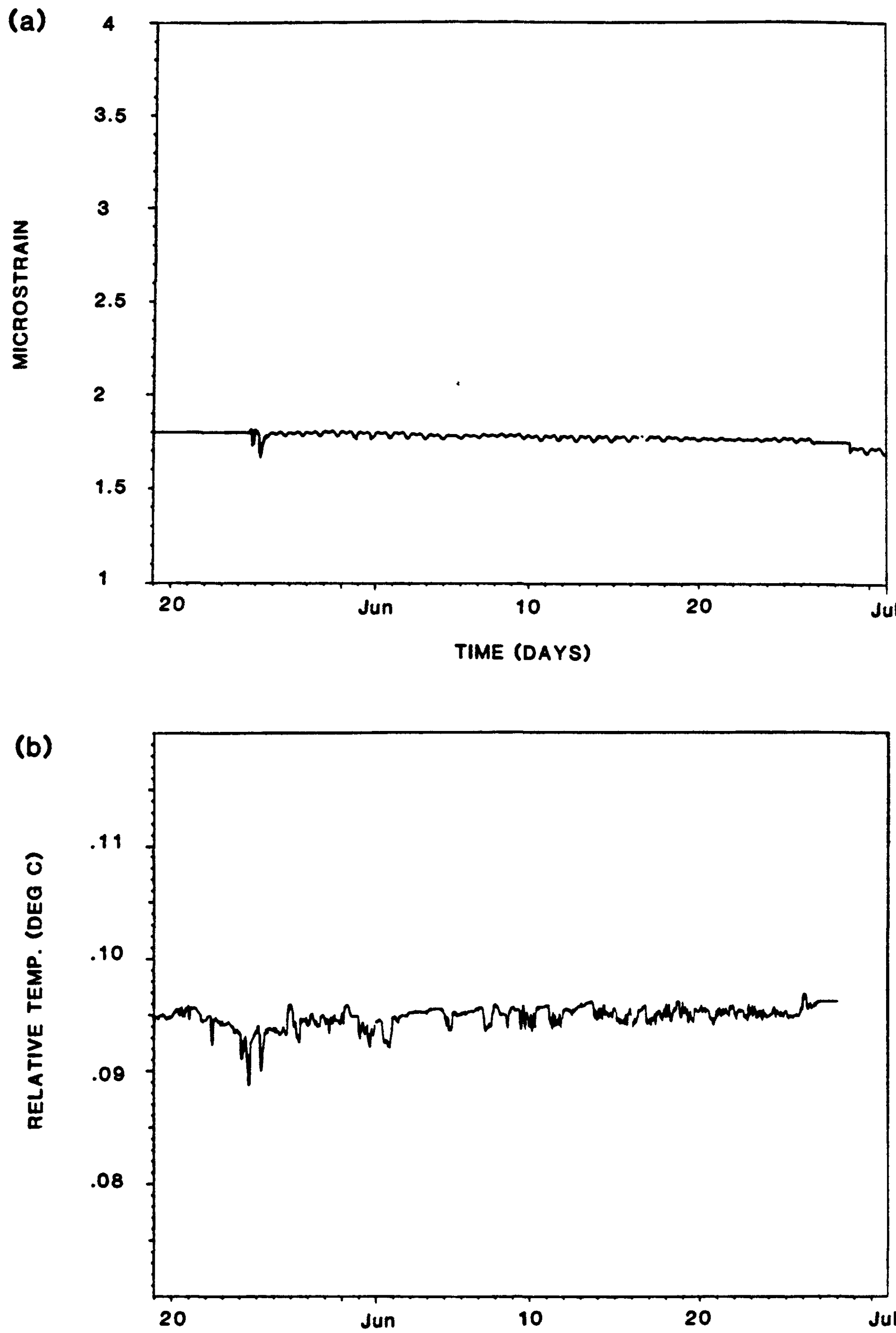


Figure 10. Plots of strain and temperature vs. time for the dilatometer hole from May 19 through July 2.

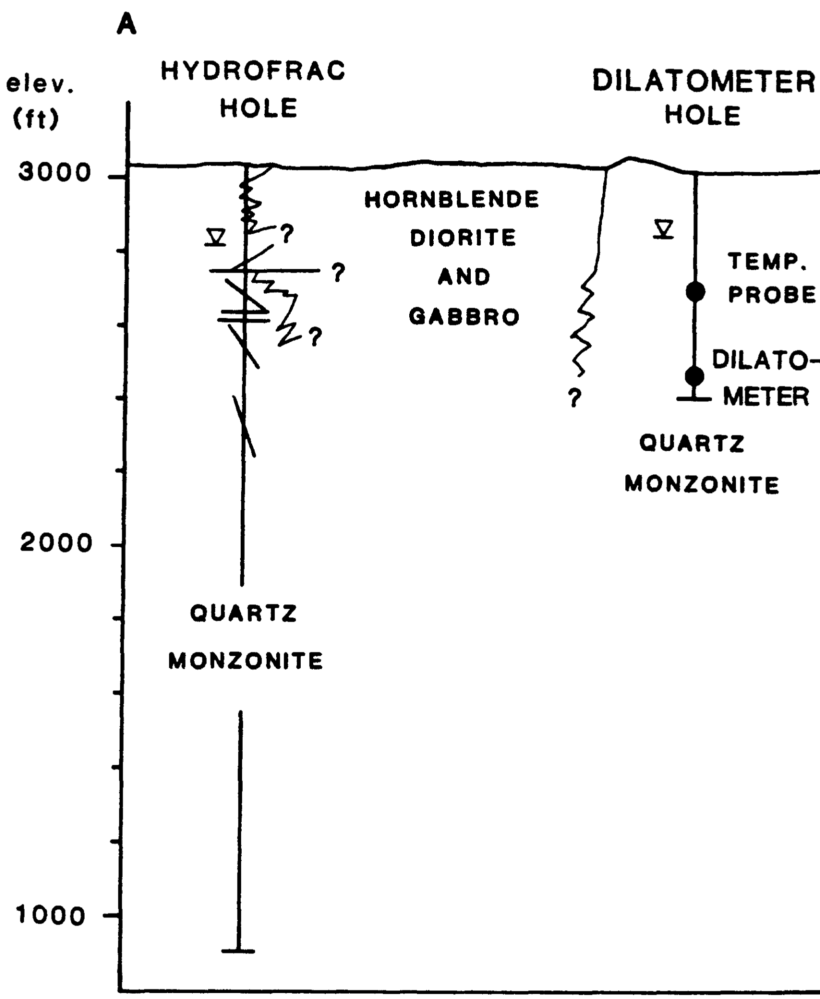


Figure 11. Schematic structure section A - A'. See Figure 2 for location.

ACKNOWLEDGEMENTS

We thank J. Healy for support and encouragement and M. Johnston and C. Mortensen for helpful comments and information about the instruments in the dilatometer hole. J. Stock and J. Svitek ran the televiewer log. D. Styles provided information for the drilling history and R. Harris helped collect and catalog the drill cuttings.

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APPENDIX A

LITHOLOGIC SUMMARY OF THE BLACK BUTTE HYDROFRAC HOLE

The well encountered mostly quartz monzonite varying to granodiorite. Hornblende only occurs in trace amounts in these rocks which makes them easily distinguished from the hornblende diorite associated with the stock. A small amount of hornblende diorite, gabbro, and amphibolite were encountered in the upper 280 ft of the well. This suggests that the well intersected the stock locally. Below 280 ft, hornblende-bearing fragments showed up in very few samples and probably represented contamination.

Several samples were stained and the feldspar ratios were estimated. The range of compositions are:

15% to 45% quartz

20% to 52% plagioclase

18% to 46% K-feldspar

5% to 20% biotite

traces of hornblende, sphene, and hematite.

Descriptions are from ditch samples.

0' - 20'	Alluvium containing pieces of weathered granite and black amphibolite. Matrix is light brown and sandy.
20' - 40'	Clean, sandy alluvium and pieces of granitic rock.
40' - 60'	Fresh, medium-grained, phaneritic granitic rock. Too finely ground to observe texture.
60' - 80'	Fresh, medium-grained, phaneritic granitic rock as above and some black amphibolite.
80' - 100'	Fresh, light-colored, phaneritic granitic rock and dark hornblende diorite.
100' - 120'	Pieces of fresh to moderately weathered granitic rock and pieces of fresh hornblende. Too finely ground to observe texture.
120' - 140'	Pieces of fresh granitic rock and black amphibolite. Too finely ground to observe texture.
140' - 160'	Pieces of fresh granitic rock. Too finely ground to observe texture.
160' - 180'	Fresh, fine- to medium-grained phaneritic granitic rock. A few pieces of black amphibole.
180' - 200'	Fresh to moderately weathered, medium- to coarse-grained, phaneritic granitic rock. Some pieces of black amphibolite.
200' - 220'	Fresh, medium-grained, phaneritic granitic rock. Contains 15% to 20% biotite which occurs in 2 to 4 mm "books". Much of the feldspar (plagioclase) is pink. There is some Fe-oxide staining.
220' - 240'	Pieces of fresh granitic rock with some Fe-oxide staining. Too fine-grained to observe texture.

240' - 260'	Most pieces are medium-grained phaneritic quartz monzonite, a few have aplitic texture, a few pieces are hornblende diorite and gabbro varying to amphibolite. Approximate modes are: 30% quartz 32% plagioclase 18% K-feldspar 20% biotite trace of hematite.

Quartz is generally anhedral and occurs in 2 to 3 mm irregular-shaped masses. Plagioclase varies from 1/2 to 3 mm and occurs as pink to white anhedral crystals. Some occurs as euhedral laths that are poikilitically enclosed in K-feldspar grains. K-feldspar is usually 3 to 5 mm and subhedral. Feldspars are generally fresh, but in a few pieces they are argillitized. Biotite occurs in 1 to 2 mm flakes and clusters of flakes. A few pieces of biotite are poikilitically enclosed in K-feldspar.

Pieces of diorite-gabbro contain 50% to 100% black amphibole. Plagioclase makes up nearly all of the feldspar component.

260' - 280'	Fresh, medium-grained, phaneritic granitic rock and pieces of fine-grained amphibolite.
280' - 300'	Highly weathered granitic rock. Probably gouge.
300' - 320'	Same highly weathered gouge as above.
320' - 340'	Highly weathered, medium-grained, phaneritic granitic rock.
340' - 360'	Completely decomposed rock flour. Probably fault gouge.
360' - 380'	Fresh, medium-grained, phaneritic granitic rock. No amphiboles.
380' - 400'	Weathered, medium-grained, phaneritic granitic rock. Abundant pink plagioclase.
400' - 420'	Slightly weathered granitic rock, similar to previous sample.
420' - 440'	Fresh, medium-grained, phaneritic granitic rock with minor Fe-oxide staining.
440' - 460'	Fresh, medium-grained phaneritic granitic rock.
460' - 480'	Fresh, granitic rock as in previous sample.
480' - 500'	Mostly fresh, medium-grained granitic rock as above. A few pieces of very fine-grained granitic rock.
500' - 520'	Light-colored, medium-grained, phaneritic granitic rock. Contains very little biotite or other mafic minerals.
520' - 540'	Medium- to coarse-grained phaneritic granitic rock.
540' - 560'	Highly micaceous granitic rock. Too finely ground to observe texture.
560' - 580'	Highly weathered granitic rock. Probably some gouge.
580' - 600'	Medium- to coarse-grained granitic rock and finely ground gouge.
600' - 620'	Fresh, highly micaceous granitic rock. Too finely groune to observe texture.
620' - 640'	Fresh, medium-grained, phaneritic granitic rock.
640' - 660'	More finely ground granitic rock.
660' - 680'	Fresh, medium- to coarse-grained quartz monzonite. Approximate modes are:

25% quartz
47% plagioclase
21% K-feldspar
7% biotite
trace of sphene(?).

Quartz occurs in 1 to 5 mm anhedral grains. White and pink plagioclase laths vary from 2 to 5 mm. K-feldspar is generally subhedral and varies from 3 to 8 mm in size. Biotite occurs in 1/2 to 2 mm flakes and clusters of flakes.

680' - 700' Fresh, micaceous, medium-grained granitic rock.
700' - 720' Fresh, micaceous, medium-grained rock as in previous sample.
720' - 740' Fresh, medium- to coarse-grained, phaneritic granitic rock.
740' - 760' Medium- to coarse-grained phaneritic quartz monzonite. Approximate modes are:

30% quartz
33% plagioclase
32% K-feldspar
5% biotite
trace of hematite.

Anhedral quartz varies from 3 mm to 1 cm. Pink to white plagioclase is subhedral to euhedral, 1 mm to 1-1/2 cm in size and the larger grains contain poikilitic inclusions of K-feldspar and biotite. K-feldspar is subhedral and has a maximum size of about 4 mm. Biotite occurs as 1 to 4 mm flakes and clusters of flakes.

760' - 780' Fresh to slightly weathered, medium- to coarse-grained, phaneritic granitic rock.
780' - 800' Medium- to coarse-grained granitic rock as above.
800' - 820' Some fresh, medium-grained granitic rock and some aphanitic granitic rock.
820' - 840' Fresh, medium-grained, phaneritic granitic rock.
840' - 860' Slightly weathered granitic rock, similar to previous samples. Too finely ground to observe texture.
860' - 880' Micaceous granitic rock with abundant pink plagioclase. Too finely ground to observe texture.
880' - 900' Same as last sample, but with very little pink plagioclase.
900' - 920' Aplitic, quartz-rich rock and some pieces of phaneritic granitic rock as above.
920' - 940' Fresh, micaceous, medium-grained, phaneritic granitic rock. A few pieces of aplite.
940' - 960' Same as previous sample, but with some slightly argillitized feldspars.
960' - 980' Fresh, medium-grained, phaneritic granitic rock with slight argillitization of feldspars.
980' - 1000' Fresh, micaceous, medium- to coarse-grained, phaneritic granitic rock. Similar to previous sample, but with more biotite and less argillitization.

1000' - 1020' Mostly fresh, equigranular, medium-grained, phaneritic quartz monzonite. A few pieces are decomposed and chewed up. These are possibly gouge. Approximate modes of the quartz monzonite are:

40% quartz
29% plagioclase
19% K-feldspar
12% biotite
trace of hornblende, trace of sphene(?).

Quartz is 2 to 4 mm and anhedral. Pink to white plagioclase is 2 to 5 mm and subhedral to euhedral. Some plagioclase laths are poikilitically enclosed in 3 mm to 1 cm anhedral K-feldspar grains. Some plagioclase is slightly argillitized. Biotite occurs in tiny (less than 1 mm) specs and 2 to 3 mm clusters of flakes. Some biotite crystals are poikilitically enclosed in larger feldspar crystals.

1020' - 1040'	Fresh, medium-grained, phaneritic granitic rock with slight argillitization of feldspars. A single piece of black amphibolite.
1040' - 1060'	Fresh, micaceous, medium-grained granitic rock similar to the previous sample. No amphibole.
1060' - 1080'	Fresh, slightly argillitized granitic rock similar to previous sample. Too finely ground to observe texture.
1080' - 1100'	Fresh, micaceous granitic rock. Too finely ground to observe texture.
1100' - 1120'	Finely ground micaceous rock as in previous sample.
1120' - 1140'	Finely ground micaceous rock as in previous sample.
1140' - 1160'	Fresh, medium-grained, phaneritic granitic rock with minor argillitization of feldspars.
1160' - 1180'	Moderately weathered granitic rock that is finely ground. A few pieces of aplite and a few pieces of black amphibole.
1180' - 1200'	Slightly weathered, medium-grained, phaneritic granitic rock.
1200' - 1220'	Fresh, fine-grained granitic rock with pink feldspars and medium-grained, granitic rock with white feldspars.
1220' - 1240'	Fresh, micaceous, medium-grained, phaneritic granitic rock. Minor Fe-oxide staining.
1240' - 1260'	Fresh, medium-grained, phaneritic grinite and weathered hornblende diorite and amphibolite.
1260' - 1280'	Mostly medium-grained, phaneritic quartz monzonite. A few pieces appear to be gouge. Approximate modes are:

25% quartz
24% plagioclase
46% K-feldspar
5% biotite

Quartz is 2 to 4 mm and anhedral. Plagioclase is pink to white, 1 to 5 mm, and generally euhedral. Some 1 to 2 mm plagioclase laths are poikilitically enclosed in 2 mm to 1-1/2 cm subhedral K-feldspar crystals. Some plagioclase grains are partly argillitized. Biotite occurs in small flakes and clusters of flakes that are less than 1 to 3 mm in size. Some biotite is poikilitically enclosed in larger feldspar grains.

1280' - 1300'	Fresh, medium-grained, phaneritic granitic rock. Slight argillitization of feldspars.
1300' - 1320'	Slightly argillitized granitic rock as in previous sample.
1320' - 1340'	Mostly argillitized phaneritic granitic rock. A few pieces of aplite. A few pieces of hornblende diorite.
1340' - 1360'	Missing.
1360' - 1380'	Hard, fresh, pink aplite with tiny specks of mica.
1380' - 1400'	Hard, fresh aplite as in previous sample. Some finely ground pieces of granitic rock.
1400' - 1420'	Mostly fresh, hard, light pink aplite. Some pieces of phaneritic granitic rock.
1420' - 1440'	Fresh, medium-grained, phaneritic granitic rock. One piece is very fine-grained (aphanitic).
1440' - 1460'	Fresh, medium-grained, phaneritic granitic rock. Some pieces of light pink quartz.
1460' - 1480'	Fresh, medium-grained phaneritic quartz monzonite. Approximate modes are: 45% quartz 20% plagioclase 30% K-feldspar 5% biotite

Quartz is 1 mm to 1 cm and anhedral. Plagioclase laths are pink to white and 1 to 3 mm in size. K-feldspar is subhedral, 3 to 6 mm and contains poikilitic inclusions of biotite. Most of the biotite occurs in small specks (less than 1 mm) although there are a few 2 to 3 mm clusters of flakes.

1480' - 1500'	Fresh, medium-grained, phaneritic granitic rock.
1500' - 1520'	Same granitic rock as previous sample, but with more biotite.
1520' - 1540'	Granitic rock as above, but highly weathered.
1540' - 1560'	Fresh, micaceous granitic rock. Too finely ground to observe texture.
1560' - 1580'	Finely ground granitic rock as in previous sample.
1580' - 1600'	Finely ground granitic rock as above.
1600' - 1620'	Fresh, micaceous, medium-grained, phaneritic granitic rock. Appears similar to previous three samples, but pieces are larger.
1620' - 1640'	Finely ground granitic rock as above. Some feldspar grains are highly argillitized.
1640' - 1660'	Fresh, fine- to medium-grained, phaneritic granitic rock. Some minor Fe-oxide staining.
1660' - 1680'	Granitic rock as in previous sample.
1680' - 1700'	Some rock flour and pieces of granitic rock. Too finely ground to observe texture. Possibly fault gouge.
1700' - 1720'	Fresh, medium- to coarse-grained phaneritic quartz monzonite. Approximate modes are: 15% quartz 50% plagioclase 27% K-feldspar 8% biotite trace of hematite.

Quartz is anhedral and 3 mm to 1 cm. Plagioclase is white to pink, anhedral to euhedral, and 2 to 4 mm in size. Some plagioclase is slightly argillitized. K-feldspar crystals are subhedral and 2 to 5 mm. They contain poikilitic inclusions of biotite and plagioclase. Biotite occurs in 1 to 3 mm flakes and clusters of flakes.

1720' - 1740'	Fresh, fine- to medium-grained, phaneritic granitic rock and some hard light pink aplite.
1740' - 1760'	Some phaneritic granitic rock as in previous sample.
1760' - 1780'	Fresh granitic rock. Too finely ground to observe texture. One piece contains an opaque black metalic sulfide(?) mineral.
1775' - 1795'	Fresh, fine- to medium-grained, phaneritic granitic rock. Abundant pink feldspars.
1795' - 1815'	Fresh, phaneritic granitic rock as in previous sample, but with less pink feldspar.
1815' - 1835'	Fresh granitic rock as in previous sample.
1835' - 1855'	Highly weathered granitic rock. Too finely ground to observe texture. Possibly fault gouge.
1855' - 1875'	Fresh, micaceous, fine- to medium-grained phaneritic granitic rock.
1875' - 1895'	Fresh granitic rock as in previous sample, but with more pink feldspar.
1895' - 1915'	Missing.

Note: A significant color change occurs from 1915' to the bottom due to increased pink alteration of plagioclase.

1915' - 1935'	Fresh, pink, fine-grained phaneritic to aplitic rock.
1935' - 1955'	Slightly weathered pink granitic rock. Too finely ground to observe texture.
1955' - 1975'	Fresh, medium-grained, phaneritic granitic rock. Some pieces have white plagioclase and some have pink plagioclase.
1975' - 1995'	Mostly fresh, medium- to fine-grained phaneritic quartz monzonite varying to granodiorite. A few pieces have aplitic texture. Approximate modes are: 15% quartz 52% plagioclase 23% K-feldspar 10% biotite

Quartz is 1 to 3 mm and anhedral. Plagioclase is pink to white, 2 to 3 mm, and generally subhedral to euhedral. K-feldspar is subhedral to anhedral and 1 to 4 mm. Biotite occurs in 1 mm flakes and 2 to 3 mm clusters of flakes. Some biotite is poikilitically enclosed in larger feldspar grains.

1995' - 2015'	Fresh, phaneritic granitic rock as in previous sample.
2015' - 2035'	Weathered, pink, micaceous granitic rock. Too finely ground to obsere texture. Possibly gouge.
2035' - 2055'	Some pieces of pink, phaneritic granitic rock and pink aplite.
2055' - 2075'	Mostly broken pieces of pink plagioclase.
2075' - 2095'	Missing.
2095' - 2115'	Fresh, medium-grained, phaneritic granitic rock. Some pieces have pink plagioclase, some have white plagioclase.