DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

In-Situ Stress Project
Technical Report Number 1:
Televiewer Data Report for the Test Interval 6000-6250 ft, Cajon Pass Well, California

by

Mark Ader and James Springer

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UNITED STATES
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TELEVIEWER DATA REPORT FOR THE TEST INTERVAL 6000-6250 FT, CAJON PASS WELL, CALIFORNIA

Mark Ader and James Springer

ABSTRACT

Two televiewer logs were run in the interval between 6000 ft and 6250 ft (1829 m and 1905 m) in the Cajon Pass well. The first log was run from 6000 ft to 6250 ft (1829 m to 1905 m). A second log was run from 6000 ft to 6230 ft (1829 m to 1899 m) in order to check the depths on the first log and to improve the image quality. The depths of all features in the two logs agreed to within 0.7 feet and within 2.4 feet of the drillers' depths. Televiewer coverage spanned six cored intervals. Although much of the core was badly broken and the depths were constrained to within only a few feet, four correlations could be made between fractures and veins on the core and on the televiewer log. The depths of these features agreed to within three feet.

Twenty-five fractures were logged on the core. The most common mineralization in these fractures was a white fibrous zeolite (?) with crystal growth perpendicular to the fracture surface and chlorite with fibrous crystals parallel to the fracture surface. Two slickensided surfaces were found. Our conclusion is that the sense of motion on them is reverse.

Eleven borehole breakouts were found, adding up to a total of 59 feet of the hole. The average orientation of these was N40-45W indicating a N45-50E maximum compressive stress. This direction is approximately normal to the average (N57W) trend of the San Andreas fault in this area. It is 40 to 50 degrees from the east-west trend of the Cleghorn fault and is consistent with left-lateral movement on it.

INTRODUCTION

During the first phase of the Cajon Pass drilling experiment, a 12 inch- (30 cm) diameter well was drilled and cased to a depth of 6000 ft (1829 m). A 6-1/2 inch- (16.5 cm) diameter hole was drilled and cored 250 feet (76 m) below the casing to be used for open hole hydrologic, geochemical, and in-situ stress measurements. In order to characterize this section of open hole and choose intervals for hydraulic fracturing stress measurements, a borehole televiewer log (BHTV) was run. This report describes the televiewer log and core, and provides a preliminary interpretation of the data.

The BHTV (Zemanek, et al. 1970) is an ultrasonic logging tool that scans the inside of the hole. It is capable of showing fractures that intersect the borehole, holes and washouts in the well, and stress-induced borehole breakouts (Zoback et al., 1985, Plumb and Hickman, 1985).

Six cores (Table 1) were taken from the 6000-6250 ft (1829-1905 m) section of the well. These cores were collected and cataloged by the USGS. The core was examined in order to locate fractures (existing or drilling induced) or any veins which might show on the BHTV log.

The first part of this report presents the borehole televiewer data and describes fractures, breakouts, and the condition of the well. The core is then described and tentative correlations are made between features in the core and features on the televiewer records.

TABLE 1

Recovered Core

Core No.	Depth Interval (feet)	Recovered (feet)	Percent Recovered
21	6050-6054	3.5	87.5
22	6059-6062	0.8	26.7
23	6073-6087	3.8	27.1
24	6150-6155	2.1	42.0
25	6180-6182	1.9	95.0
26	6240-6254	13.2	94.3

TELEVIEWER LOG

A BHTV log was run from 6000 ft to 6250 ft (1829 m to 1905 m) on March 4, 1987. The depth reference was ground level, located 32 ft (9.8 m) below the drill rig floor. The images from the complete log are represented in Appendix A. The tool stuck and jumped in the hole due to the stiffness of the centralizer springs which diminished the image quality somewhat. Our procedure is to log upward at 5 ft/min (1.5 m/min). We also tried logging downward to determine if the sticking could be reduced and found no significant improvement. To obtain a better image and to re-check the depths from the first log, a second log was run on March 9, 1987. The centralizer springs on the tool were modified and, for the second run, the interval from 6000 ft to 6230 ft (1829 m to 1899 m) was logged. Table 2 gives the depths of recognizable features recorded by the two runs of the tool and compares them with the drillers depth. The second log provided a better image.

TABLE 2

Depth Correlations from the Televiewer Logs

Feature	Drillers Depth(Ft)	First Run in (ft)	First Run out (ft)	Second Run in (ft)	Second Run out (ft)
Bottom of Casing	(6000)	6002.4	6001.9	6001.9	6001.7
Bottom of Hole	6257	6253.9*	_____	_____	_____
Rezero	0000	_____	-6.3	_____	-6.4

* Depth reference is the transducer which is 3 ft above the bottom of the tool.

The BHTV information was recorded on black and white polaroid pictures which represent the inside of the hole as if it were split down the middle along the magnetic north azimuth and laid flat. The brightness on each picture is a function of the amplitude of the reflected sonic pulse. The left and right sides of the image are magnetic north and the directions are clockwise from left to right on the picture; that is north, east, south, west, and north. Planar features, such as fractures, show up as dark sinusoidal traces on the pictures (Zemanek, et al., 1970). Paired dark vertical bands that appear 180 degrees apart are probable borehole breakouts.

Geologic Features

Few fractures were visible on the log. Most of those were subhorizontal and some were associated with intensity drops that may be lithologic changes. Table 3 is a list of the features seen on the log. The interval from 6010 ft to 6067 ft (1832 m to 1850 m) yielded a very low intensity thus making fractures more difficult to identify. The fracture frequency seen on the televiewer log was much lower than that found in the core, suggesting that many fractures opened up as the core was extracted from the ground.

Probable Borehole Breakouts

Borehole breakouts are stress-induced elongations of the well bore (Bell and Gough, 1979; Zoback et al., 1985). They

TABLE 3

Geologic Features found on the Televiewer Logs

Depth (Ft)	Feature
6002 - 6003	Hole below casing.
6005 - 6011	High-angle fracture.
6014	Sub-horizontal fracture.
6054	Low-angle fracture.
6062	Abrupt intensity change; probable lithologic change.
6082 - 6083	Pair of sub-horizontal fractures.
6085 - 6091	Change in intensity; probable lithologic change. Probable breakouts occur within the interval.
6102	Sub-horizontal fracture.
6113	Sub-horizontal fracture.
6139 - 6152	Sub-vertical fracture terminated by a horizontal fracture at 6152 ft.
6154 - 6166	Probable sub-vertical fracture.
6175 - 6190	Drop in intensity; probable lithologic change. Breakouts in lower part of interval.
6184	Low-angle fracture.
6231	Low-angle fracture.
6244	Probable low-angle fracture.

result from the distribution of stresses around a vertical hole in rock that is subjected to unequal horizontal stresses and they cause the hole to become elongated in the direction of the minimum horizontal stress. On a televiewer log, breakouts appear as paired vertical dark bands that are 180 degrees apart. Similar dark bands can be caused by a "shadow" effect from an off-centered logging sonde in an otherwise circular hole (see Plumb and Hickman, 1985). We believe that the dark bands in these televiewer pictures are breakouts for the following reasons: 1) The bands have a consistent orientation throughout the logged interval. 2) The bands appear in two different runs of the tool with centralizer springs of different stiffnesses. 3) The hole deviation (which is the most common cause of tool eccentricity) was less than three degrees as determined from the dip log run by Schlumberger.

Eleven breakouts were logged for a total of 59 feet. They were tabulated and plotted on histograms (figs. 1 and 2). In fig. 1, the frequency of breakouts was plotted as a function of azimuth. In fig. 2, the length of hole affected by breakouts is plotted as a function of azimuth. The mean orientation, when breakouts are taken as discreet observations (fig. 1) is N45W and the standard deviation is 17 degrees. When the breakouts are weighted according to their length (fig. 2) the mean is N40W and the standard deviation is 18 degrees. These breakouts then,

Fig. 1. Breakout frequency vs azimuth.

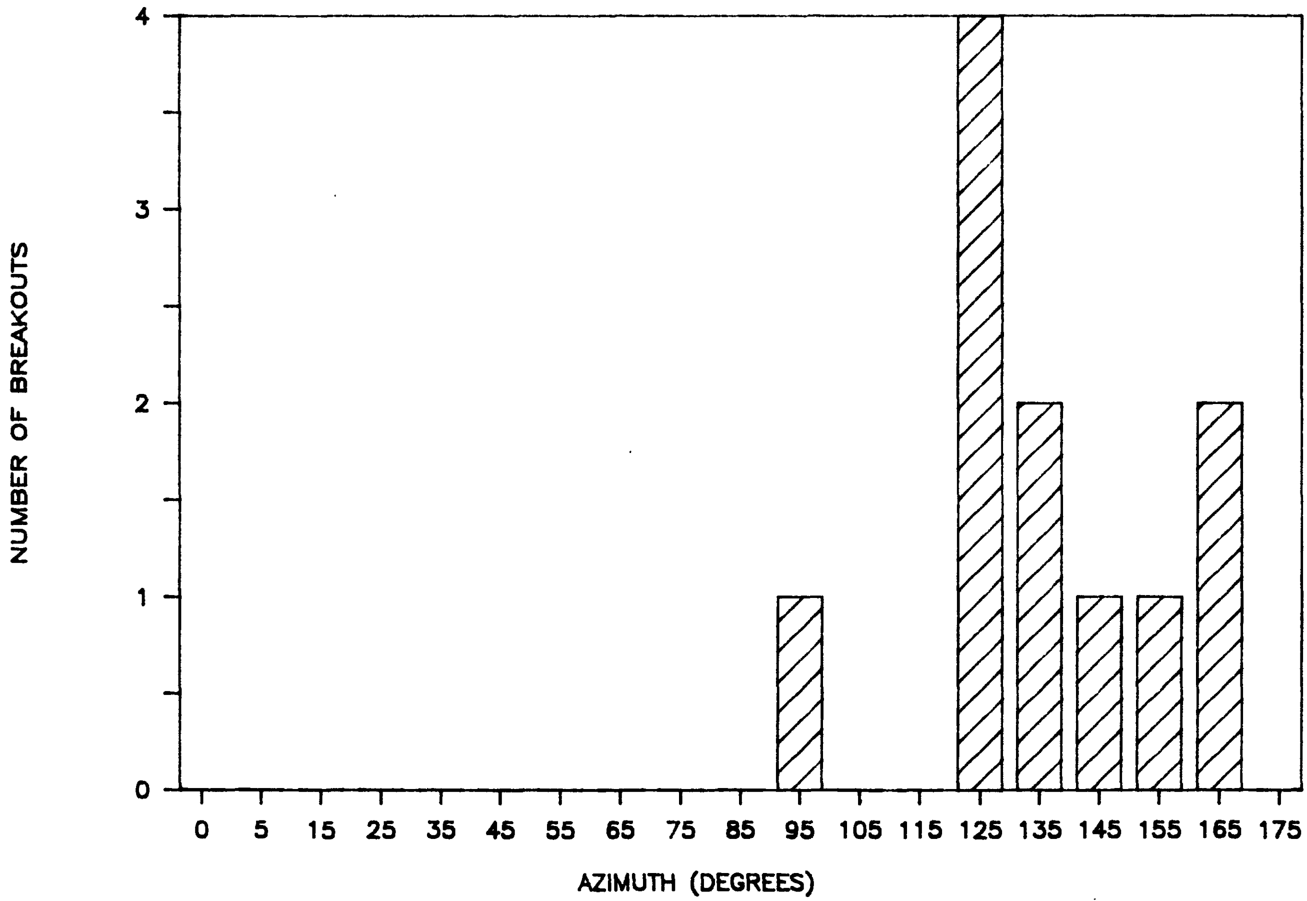
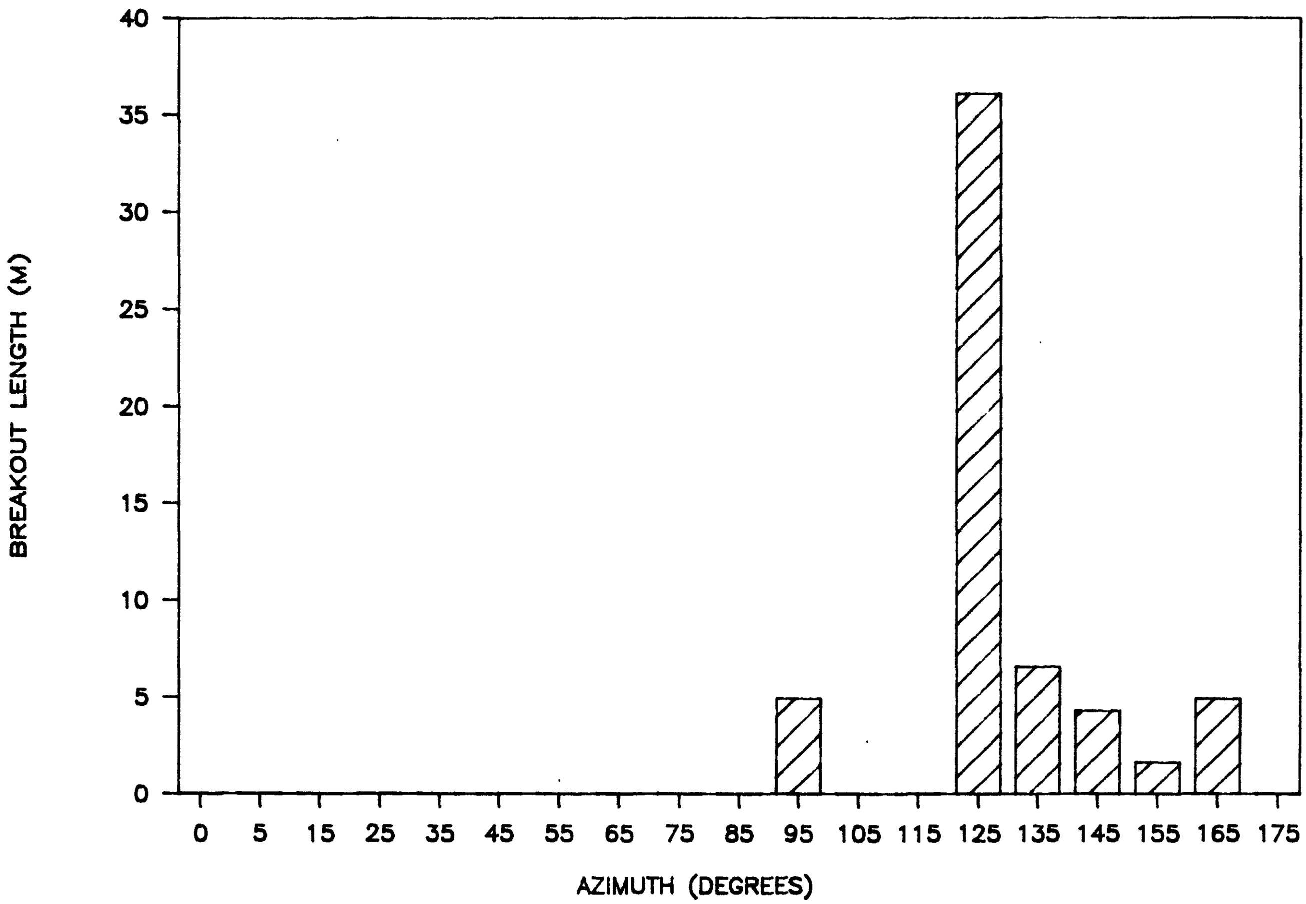


Fig. 2. Breakout length vs azimuth.



indicate a maximum horizontal compressive stress direction of N45-50E which is 73 to 78 degrees counter clockwise from the average trend (N57W) of the San Andreas fault in the Cajon Pass area.

This direction does not support the observation of right-lateral movement on the San Andreas fault. The Cleghorn fault, on the other hand (fig. 3), is an east-west-trending fault with recent left-lateral movement (Weldon et al., 1981; Meisling and Weldon, 1982). The maximum horizontal stress direction is 40 to 45 degrees counter clockwise from its trend and therefore consistent with its sense of motion. Other stress studies in this region (Stock et al., 1986) indicate that the stress directions are not uniform. The broad region of active tectonism along the San Andreas fault, with both extensional and compressional featurs is consistent with the observed non-uniformity in the stress field.

CORE DESCRIPTION

When assigning depths to the recovered core, the bottom of the core was assigned to the lower depth of the coring interval. In accordance to the drillers record, footages were marked ascending the core. The cores were inspected for fractures and veins that might show up on the televiewer records (Table 3). It was also noted whether the fractures were pre-existing or if they had a high probability of having been drilling induced or stress relief features.

Core recovery ranged from 26.7 percent to 95.0 percent. The cores with lower recovery rates were composed of gneisses with low angle to subhorizontal foliation. The poor recovery rate in these gneisses is inferred to be caused by the core disking, or breaking off, along the foliation due to drill bit rotation. The core was then ground up with further rotation within the core barrel.

There were 25 logged fractures in the core samples. These are listed in Table 4. Most of the fractures are mineralized and therefore predated drilling. Due to this secondary mineral growth, many of the fractures were not open. The main mineralization occuring in the fractures was a white to clear zeolite(?) that had fibers growing perpendicular to the fractures. The other fracture filling mineral that occured in great abundance was chlorite. It's habit was fibrose growing parallel to the fractures. The two minerals only occured together on one instance. Two fractures had slickensided surfaces indicating dip-slip motion. Our interpretation of the slickenside stepping is that it indicates reverse motion.

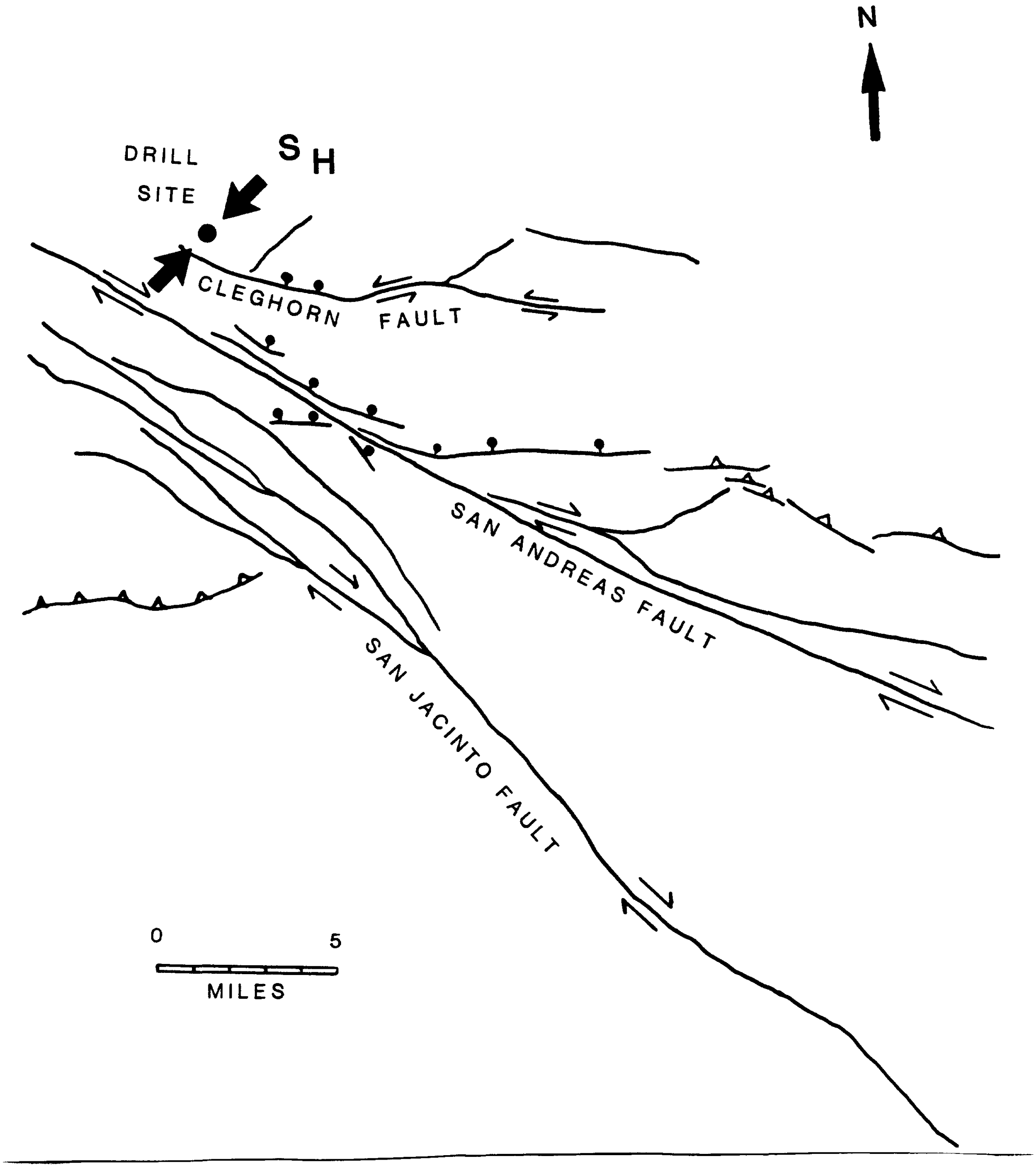


Figure 3. Generalized fault map of the Cajon Pass area (modified after Weldon, 1986).

TABLE 4

Fracture Log of Core

Interval (feet)	Mineral Growth	Fracture Angle	Comments
		CORE NO. 21	
6051.8-6052	zeolite(?)	sub-vertical	1mm wide, partly open.
	none	sub-vertical	perpendicular to 1st frac. (stress relief?)
6051.2	zeolite	sub-horizontal	
6052.5	zeolite	sub-vertical	branching fractures.
6054	zeolite	sub-vertical	intersect top of frac w/core wall, very coarse grained surface.
		CORE NO. 22	
6059.6	none	sub-horizontal	two parallel fractures, core severely disced.
		CORE NO.23	
6084.6	none	sub-vertical	in coarse-grained zone, probably stress relief.
6085.2	none	sub-horizontal	very tight, did not disc in heavily disced area.
6087	none	sub-horizontal	
		CORE NO. 24	
6150.4-6152	none	sub-vertical	frac intersects core wall at 6150.4. frac along coarse-grained rock w/ biotite, epidote, chlorite, and plagioclase.
		CORE NO. 25	
6180-6182	zeolite	sub-vertical	wall rock altered. frac follows core axis.
6180.4	zeolite	sub-vertical	
6181.1	none		leucocratic vein 3.56 cm wide.
		CORE NO. 26	
6240.8	chlorite	sub-horizontal	frac at mafic/leucocratic high k-feldspar boundary.
6241.1	none	low-angle	frac in coarse-grained, leucocratic, k-feldspar zone.
6241.4	none	low-angle	mafic band in leucocratic zone 1.27 cm wide.
6241.6	chlorite	high-angle	leucocratic/mafic zone boundary. slickensides (reverse?).
6241.9	chlorite	high-angle	slickensides indicate probable reverse motion.

6242	none	low-angle	frac parallel to leucocratic vein in mafic zone. Stress relief (?).
6242.3	chlorite/ zeolite	high-angle	frac branches. possible movement w/later fluid.
6242.5	chlorite	high-angle	frac branches to 6242.3. contact between fine-grained mafic/ coarse-grained leucocratic zone.
6243	none	high-angle	contact between coarse-grained leucocratic/fine-grained mafic zone.
6243.4	zeolite	low-angle	closed.
6243.7	none	low-angle	break on foliation w/some drill rotation rounding.
6246.1	zeolite	low-angle	partially disced.
6246.6	zeolite	low-angle	partially disced.
6248.8-6249.2	none	low-angle	leucocratic/mafic banding.
6248.9	chlorite	low-angle	parallel to banding.
6249.8	none	low-angle	frac at contact.

CORE-BHTV LOG CORRELATION

The core and BHTV logs were compared to identify any correlations. Five correlatable features were found and are given in Table 5. The correlated features averaged 2.7 ft (0.82 m) deeper on the BHTV record than on the core. This is consistant with the BHTV record as compared to the drillers records for depth of bottom of casing and bottom of hole.

TABLE 5

Comparison of Core to Televiewer Log

Feature	Core Depth(ft)	BHTV Depth(ft)	Difference (ft)
sub-horizontal fracture	6051.2	6054	2.8
two sub-horizontal fractures	6059.6	6062	2.4
sub-vertical fracture	6150.4-6152.0	6150 - 6155	--
low angle leuco. vein	6181.1	6184	2.9

SUMMARY

Two televiewer logs were run in the interval from 6000 to 6250 ft (1829 to 1905 m). The second one was run with modified centralizer springs in order to improve image quality and check depths from the first log. The depths agreed with each other to within 0.7 ft (0.2 m), they agreed to within 2.4 ft (0.7 m) of drillers depths, and they agreed to within 3 ft (0.9 m) of features that could be identified on cores.

Twenty-five fractures were identified and described on the core. Fibrous zeolite (?) and chlorite were the most common fracture filling minerals. Two fractures had slickensides on them and the sense of motion was probably reverse.

Eleven borehole breakouts were found, covering a total of 59 feet of the interval. These had an average orientation of N40-45W, indicating a maximum horizontal stress direction of N45-50E.

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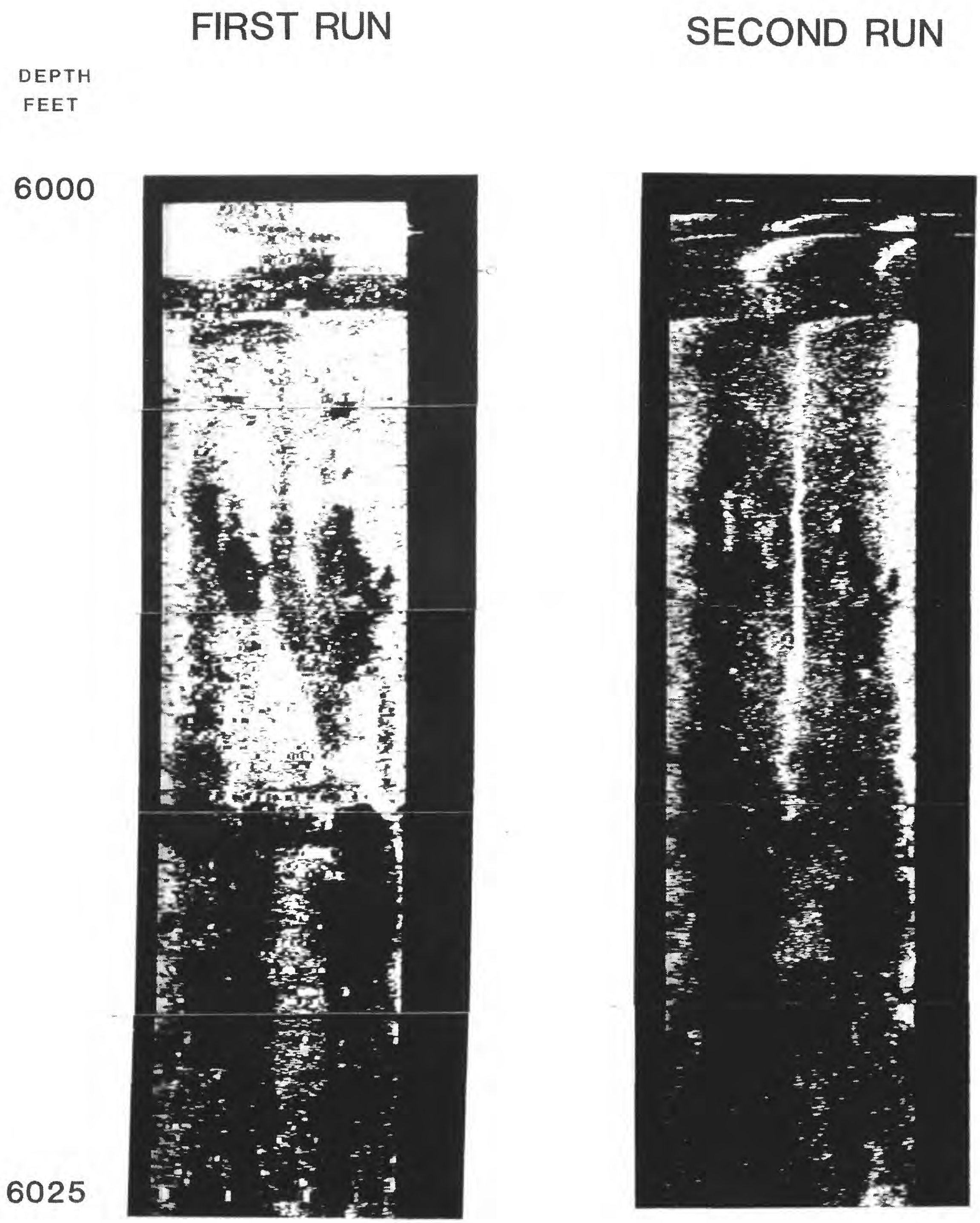
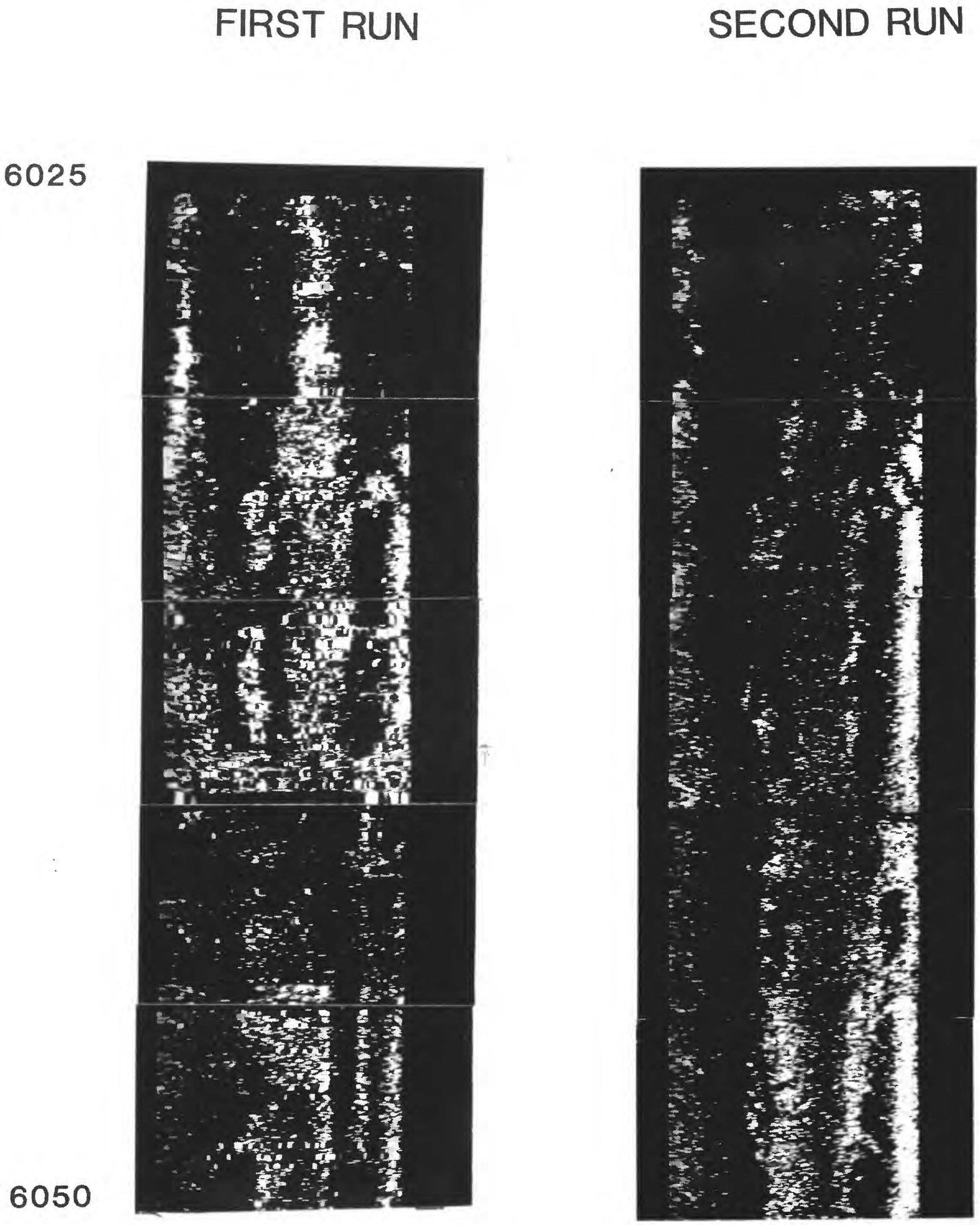
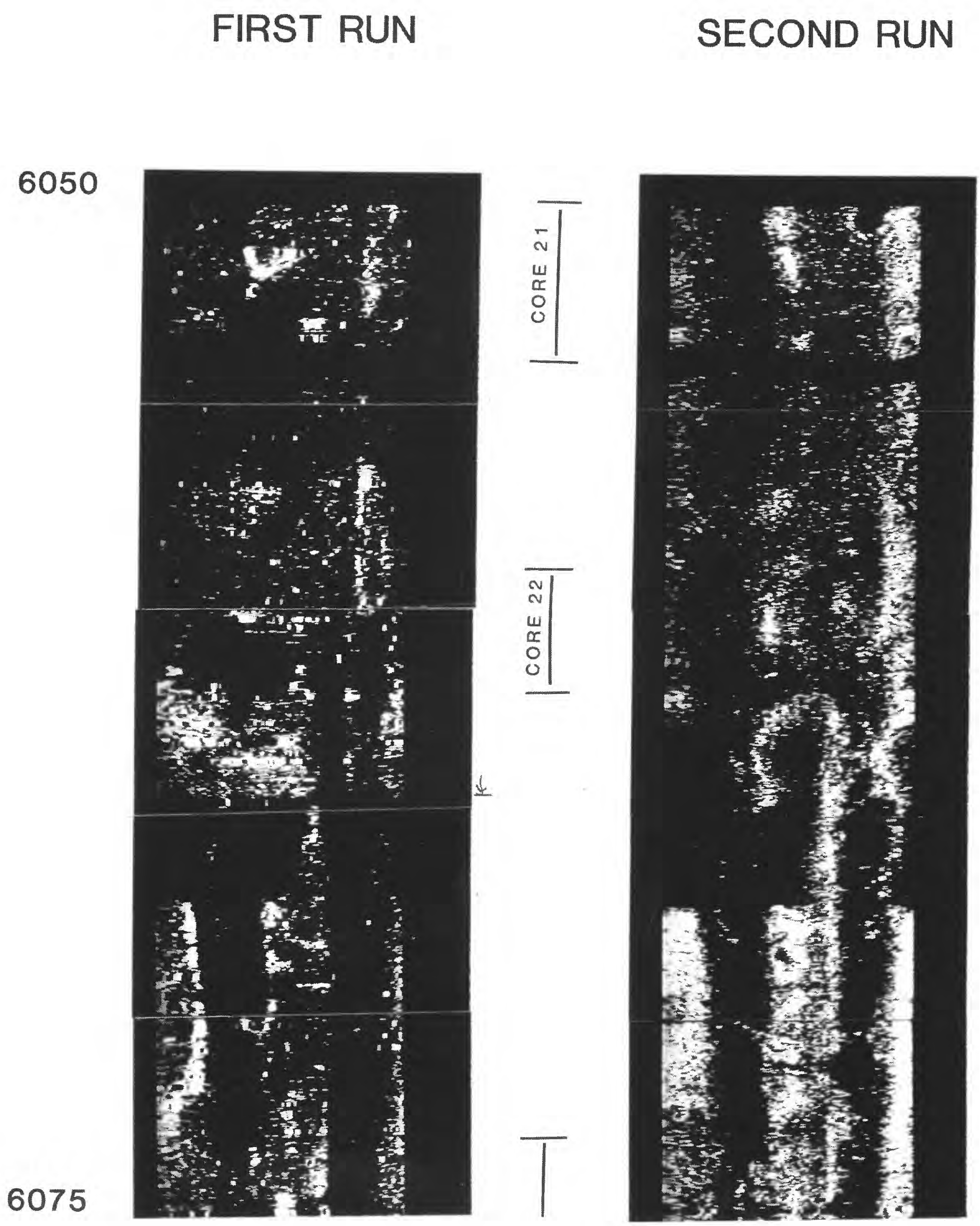
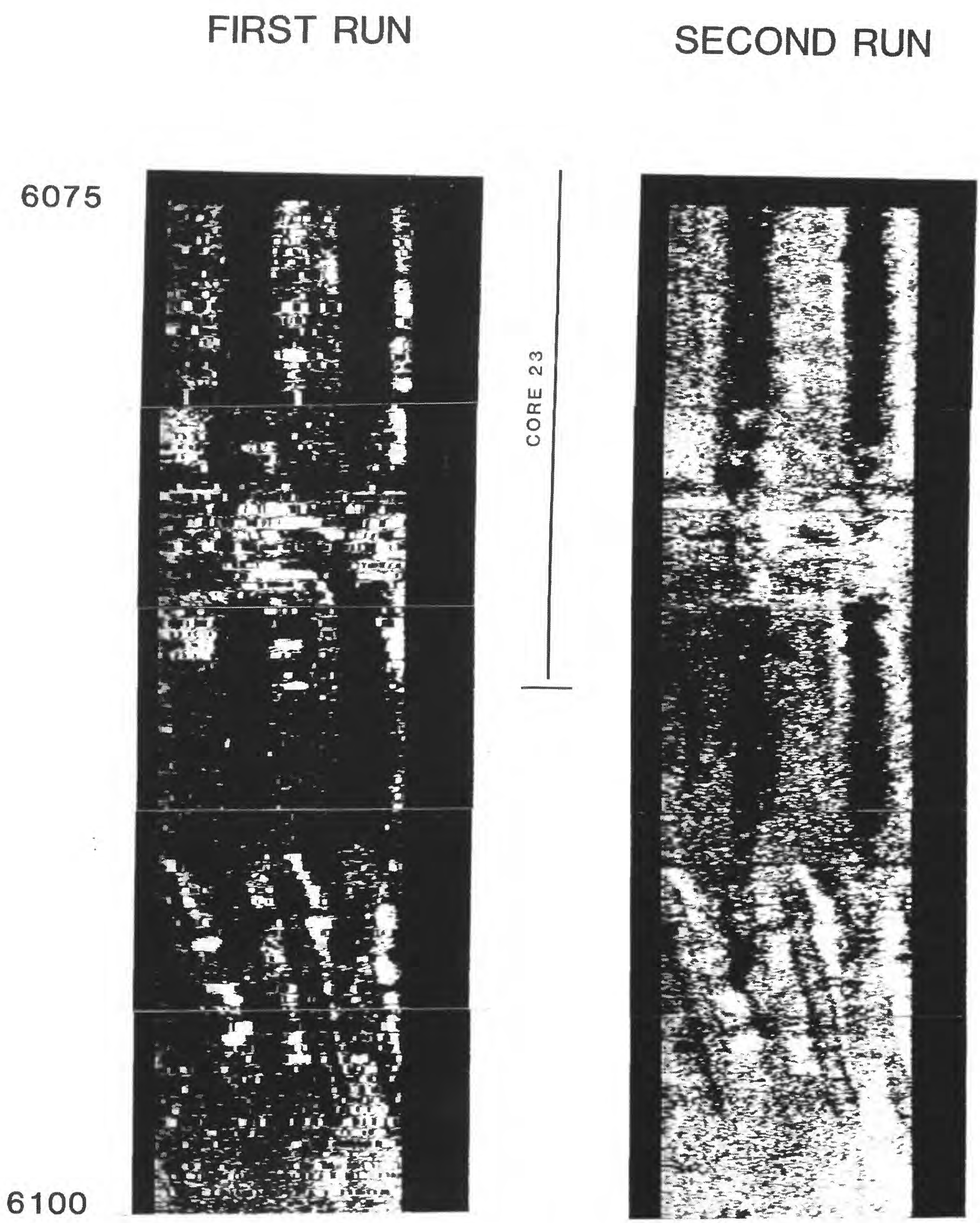
APPENDIX

TELEVIEWER LOGS


FIRST RUN
SECOND RUN
DEPTH
FEET
6000
6025


FIRST RUN
SECOND RUN
6025
6050


FIRST RUN
SECOND RUN
6050
CORE 21
CORE 22
6075

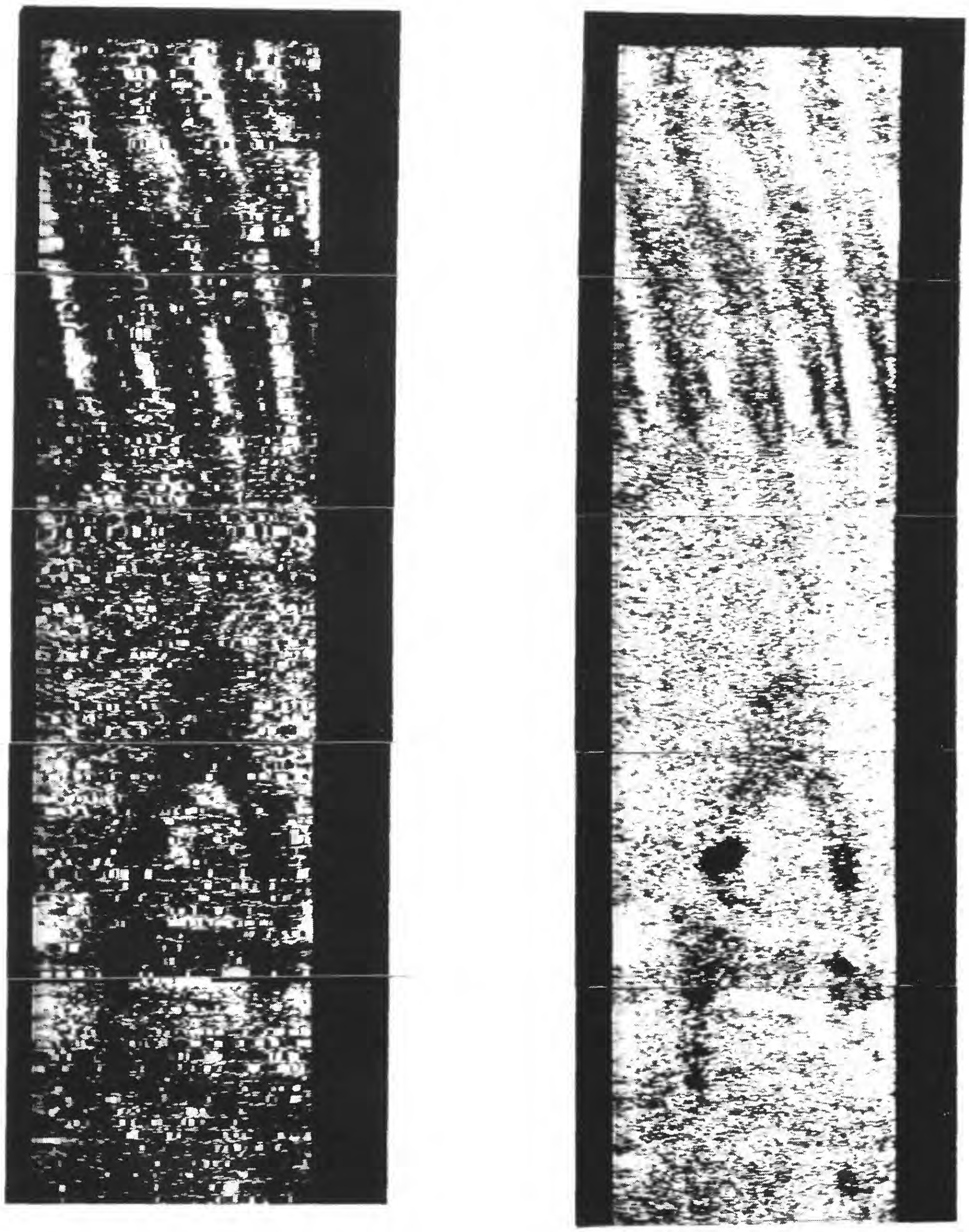

FIRST RUN
SECOND RUN
6075
CORE 23
6100


FIRST RUN
SECOND RUN
6100
6125

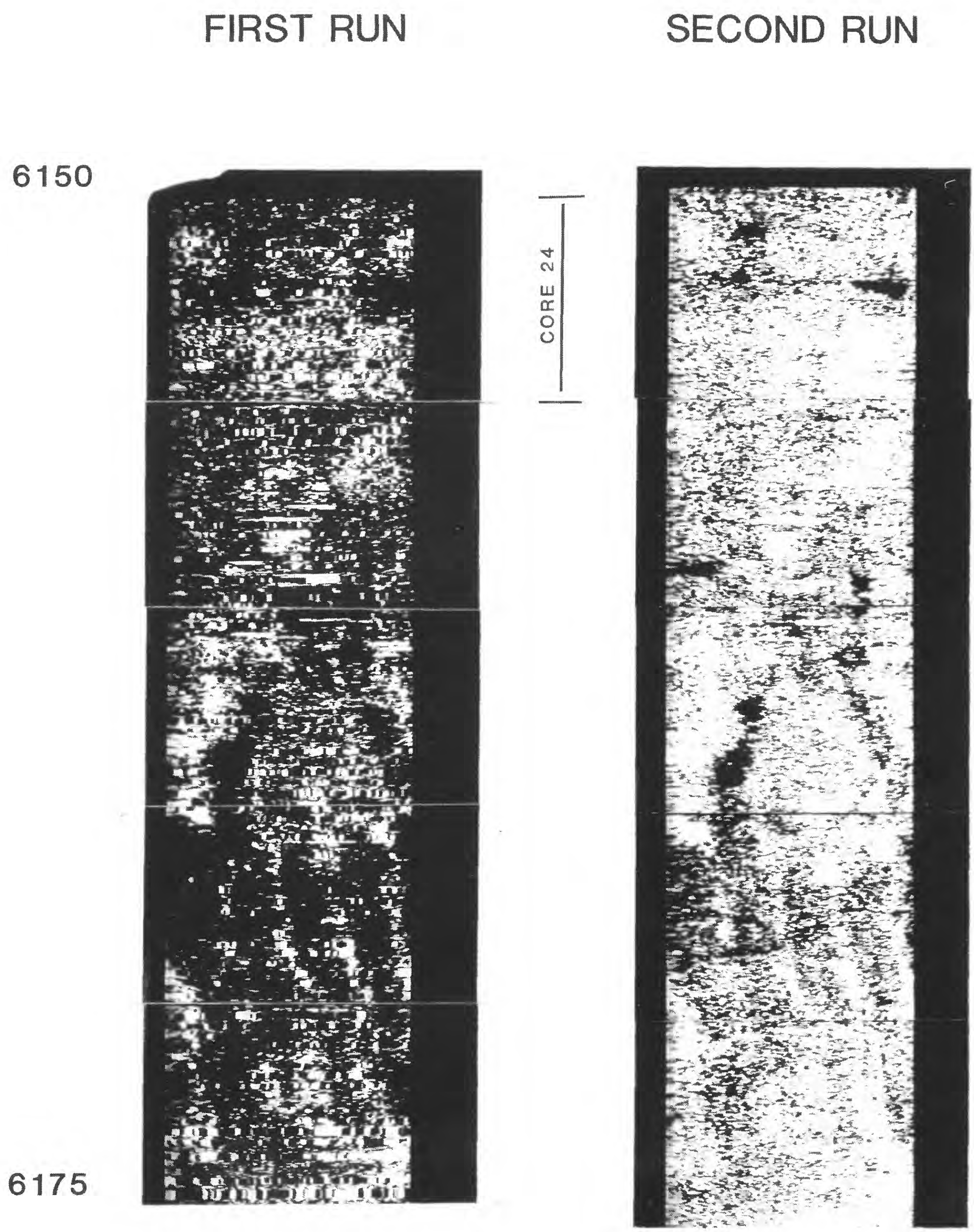
FIRST RUN

SECOND RUN

6125



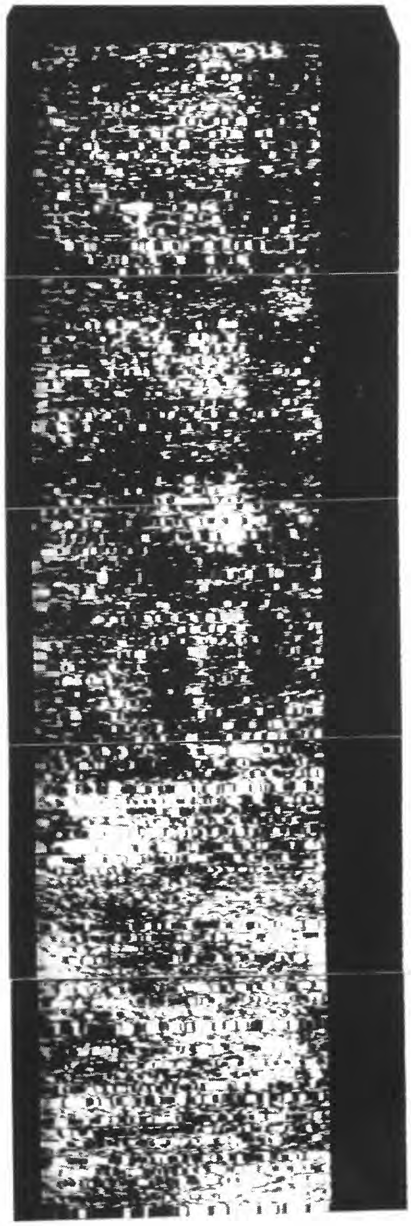
6150


FIRST RUN
SECOND RUN
6150
CORE 24
6175

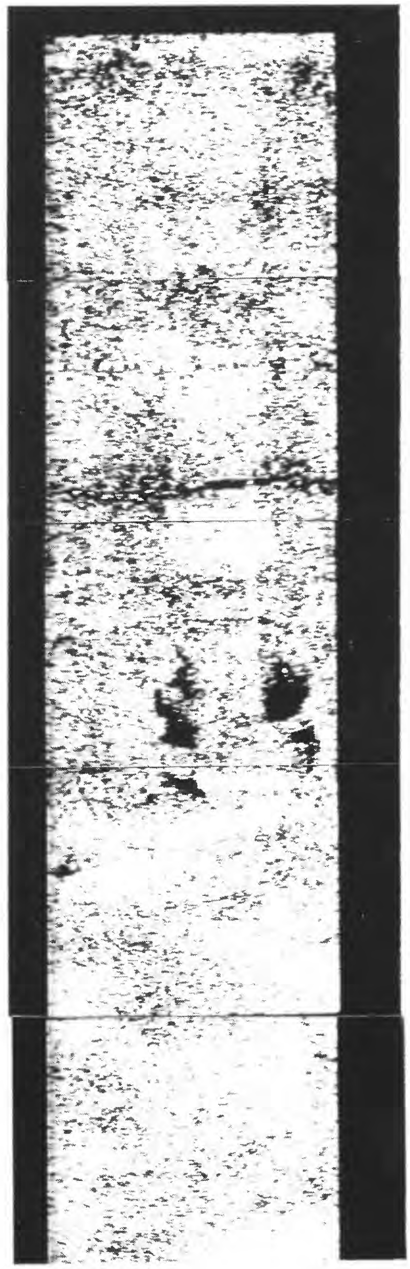
FIRST RUN

SECOND RUN

6175



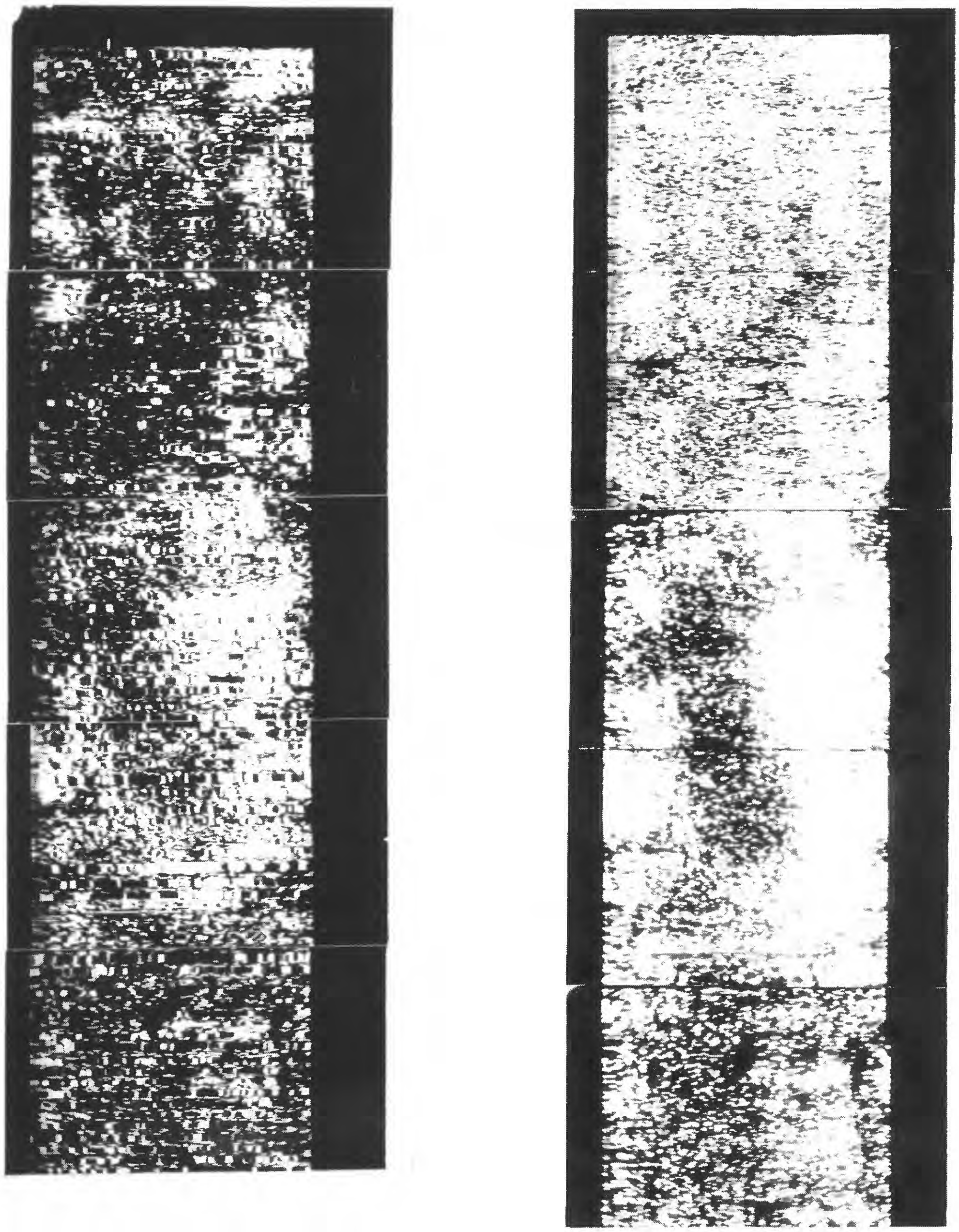
CORE 25



6200

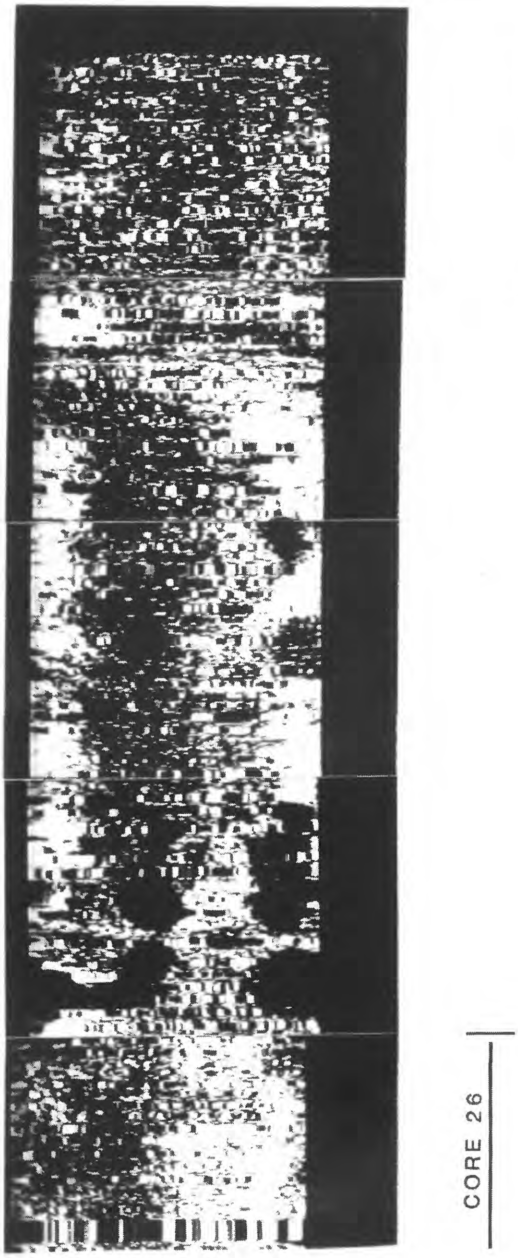
FIRST RUN SECOND RUN

6200



6225

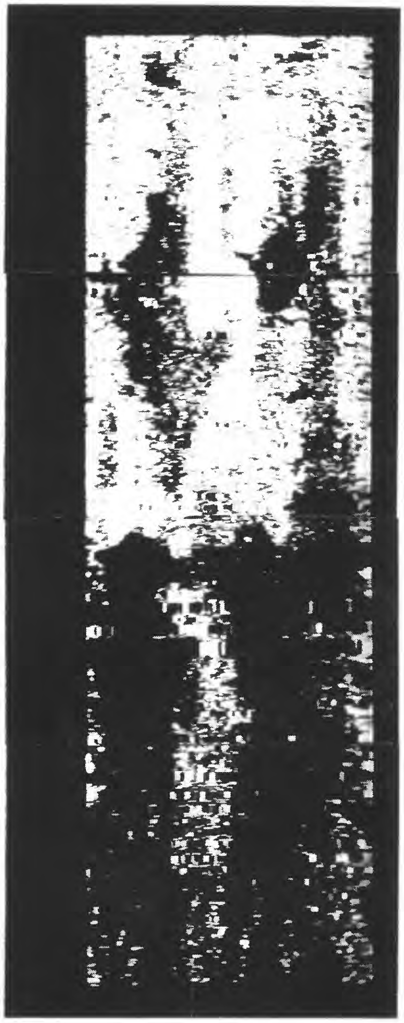
FIRST RUN



SECOND RUN

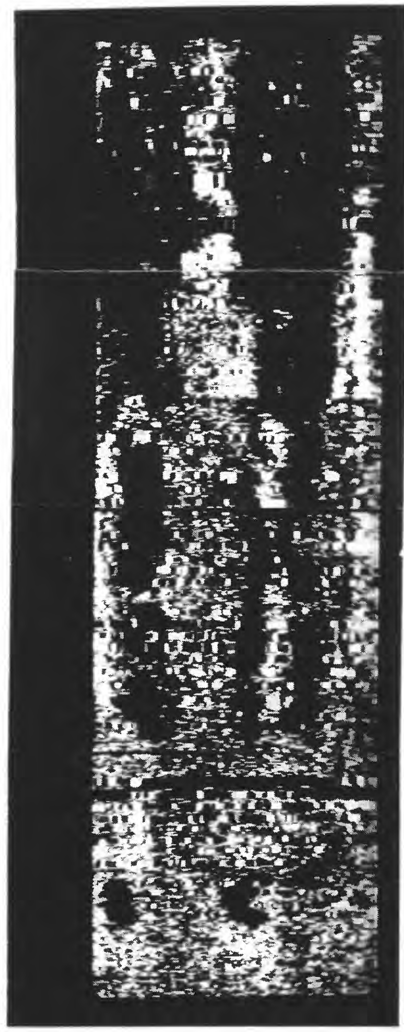
LOGGING DOWN

6005



6025

6025



6045