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CORE LOGGING FOR SITE INVESTIGATION AND INSTRUMENTATION

Spent Fuel Test-Climax

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ABSTRACT

As an integral part of the Spent Fuel Test-Climax 5150 ft (1570 m) of granite core was obtained. This core was diamond drilled in various sizes, mainly EX and NX. The core was taken with single tube core barrels and was unoriented. Techniques used to drill and log this core are discussed, as well as techniques to orient the core. Of the 5150 ft (1570 m) of core more than 3645 ft (1111 m) was retained and logged in some detail. As a result of the core logging, geologic discontinuiti . were identified, joint frequency and spacing characterized.

Discontinuities identified included several joint sets, shear zones and faults. Correlations based on coring alone were generally found to be impossible, even for the more prominent features. The only feature properly correlated from the exploratory drilling was the fault system at the end of the facility, but it was not identified from the exploratory core as a fault. Identification of discontinuities was later helped by underground mapping that identified several different joint sets with different characteristics.

It was found that joint frequency varied from 0.3 to 1.1 joint per foot of core for open fractur s and from 0.3 to 3.3 /ft for closed or healed fractures. Histograms of fracture spacing indicate that there is likely a random distribution of spacing superimposed upon uniformly spaced fractures.

It was found that a low angle joint set had a persistent mean orientation. These joints were healed and had pervasive wall rock alteration which made identification of joints in this set possible. The recognition of a joint set with known attitude allowed orientation of much of the core. This orientation technique was found to be effective.

1.0 INTRODUCTION

The Spent Fuel Test-Climax (SFT-C) is being conducted at the Nevada Test Site in the Climax Stock quartz monzonite (Fig. 1). The test facilities consist of three drifts constructed at the 1400 ft (427 m) level specifically for the SFT-C. These facilities are an extension of previously existing workings that had been constructed for weapon effects testing (Fig. 2).

The overall geology was well understood from work that had been done earlier for the weapon effects testing. The stock dimensions, interpreted from geophysical techniques (Allingham and Zietz, 1962), were sufficiently large to accommodate the SFT-C investigation. The mineralogy of this unit had been reported to be somewhat uniform (Maldonado, 1977), but the exact area contemplated for the SFT-C had not been drilled or studied. Therefore, four exploratory boreholes were drilled from the previously existing Pile Driver facilities to evaluate the geology in the alternative drift locations. We chose the location for the test based on the logging of the core from these holes, and on surface topography constraints. After the facilities were constructed, many boreholes were drilled to allow the installation of various instruments and to perform additional geotechnical and geologic investigations.

This report discusses the drilling of cored boreholes (but not boreholes drilled by methods that did not yield core), core logging and its results, and the current disposition of the core and boreholes. Subsequent reports will discuss geologic interpretations. A total of 5150 ft (1570 m) of coring was performed in the SFT-C, none of which was oriented. More than 3645 ft (1111 m) of this core was retained and will be discussed in this report; the remainder was recovered incidental to drilling, was not useful to furthering geologic understanding, and was therefore discarded.

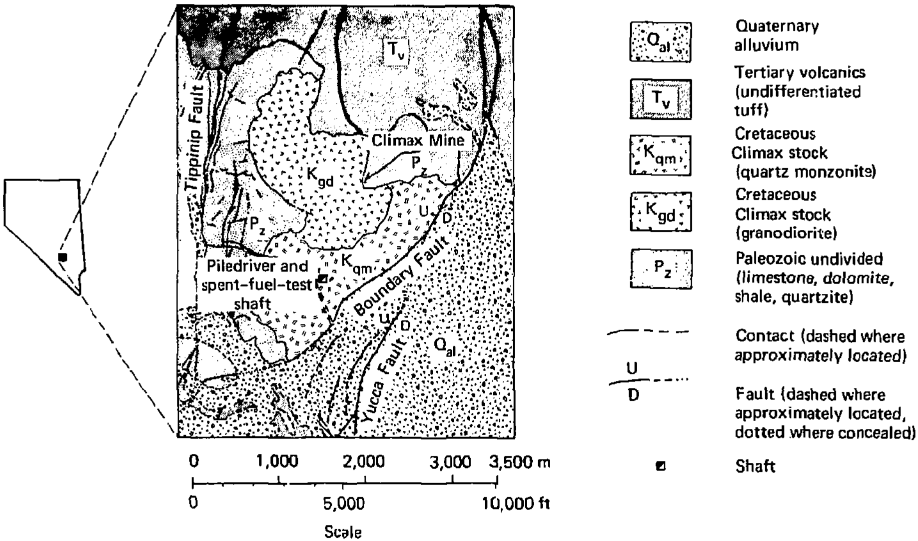

Figure 1. Geology of the Climax Stock.

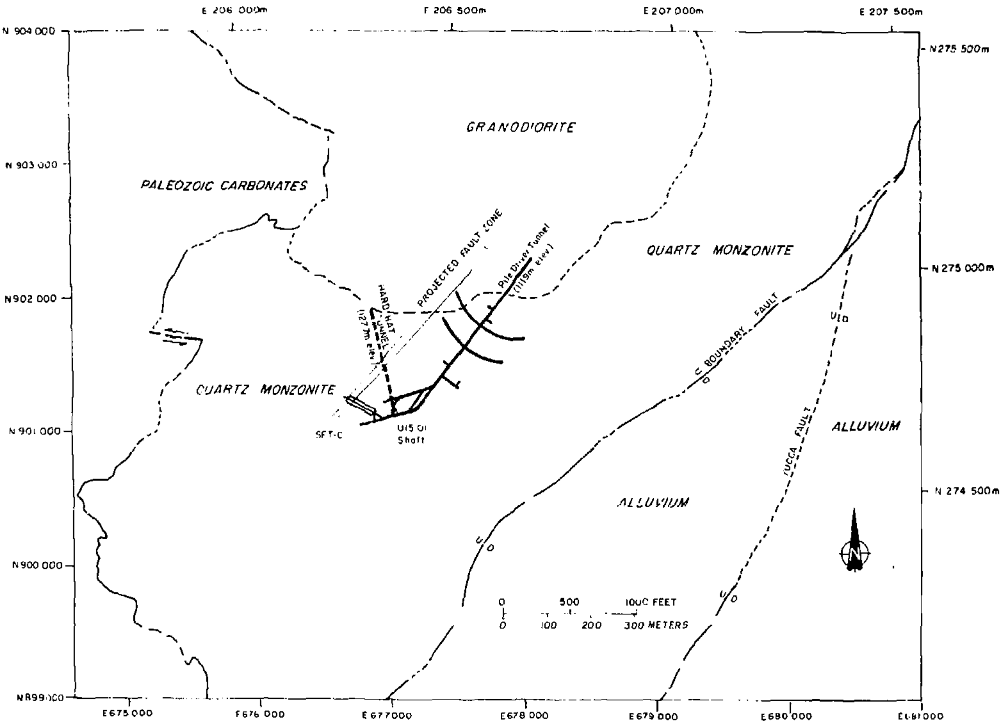

Figure 2. Pile Driver and SFT-C Facilities.

2.0 BOREHOLE DRILLING AND CORE LOGGING

2.1 Exploratory Boreholes (called UGs)

Underground development began with the drilling of four NX* exploratory holes, UG-1 through UG-4, from an existing drift west of the main 1501 shaft, with locations and orientations as shown on Fig. 3. A total of 1575 ft (480 m) of coring was performed using a Longyear 44 coring rig. Core recovery was high, averaging well over 95% (usually 99-100%) except for localized highly fractured zones. Core runs were tabulated and recoveries noted by Fenix and Scisson drilling inspectors. Core was boxed and shipped to the U.S. Geological Survey (USGS) core library in Mercury, where it was logged by LLNL engineering geologists, who emphasized open joints and alterations in their descriptions. Prior investigators (Maldonado, 1977) found that, with the exception of alteration along jointing and in localized ares, Climax Stock mineralogy was quite uniform. Therefore, mineralogical descriptions were made for the core as a whole; only notable variations were reported in detail. Open joints were described in terms of inclination from the core axis to the nearest 5°, intensity of jointing, alteration of the surrounding rock material, and any joint filling materials. Either rock quality designation (RQD) or fracture frequency was noted on the log sheets. A typical log sheet is shown in Fig. 4. A letter report (Emerson, 1978) on this core logging was

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*The diameters of the exploratory holes are as follows: AX=51 mm; EX=38 mm; HQ=76 mm; and NX=76 mm.

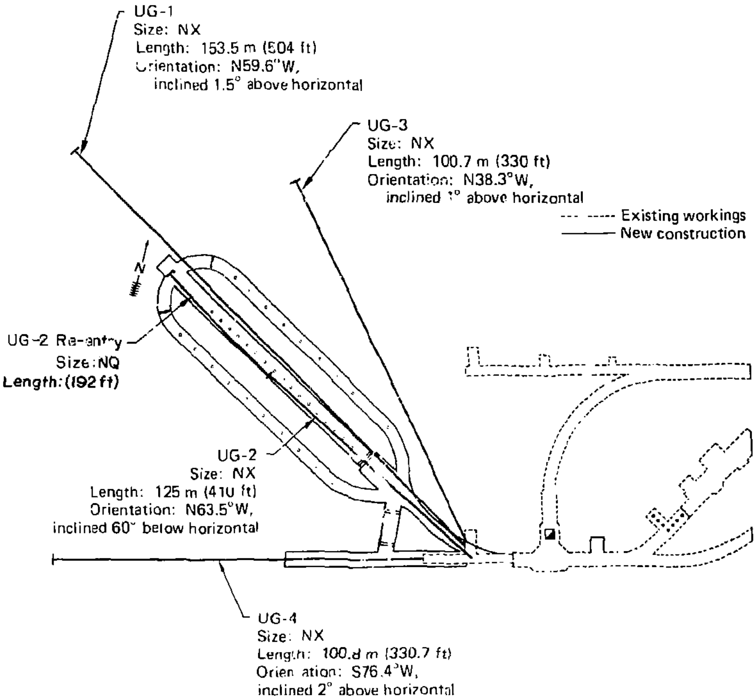


Figure 3. Exploratory borehole locations and orientations.

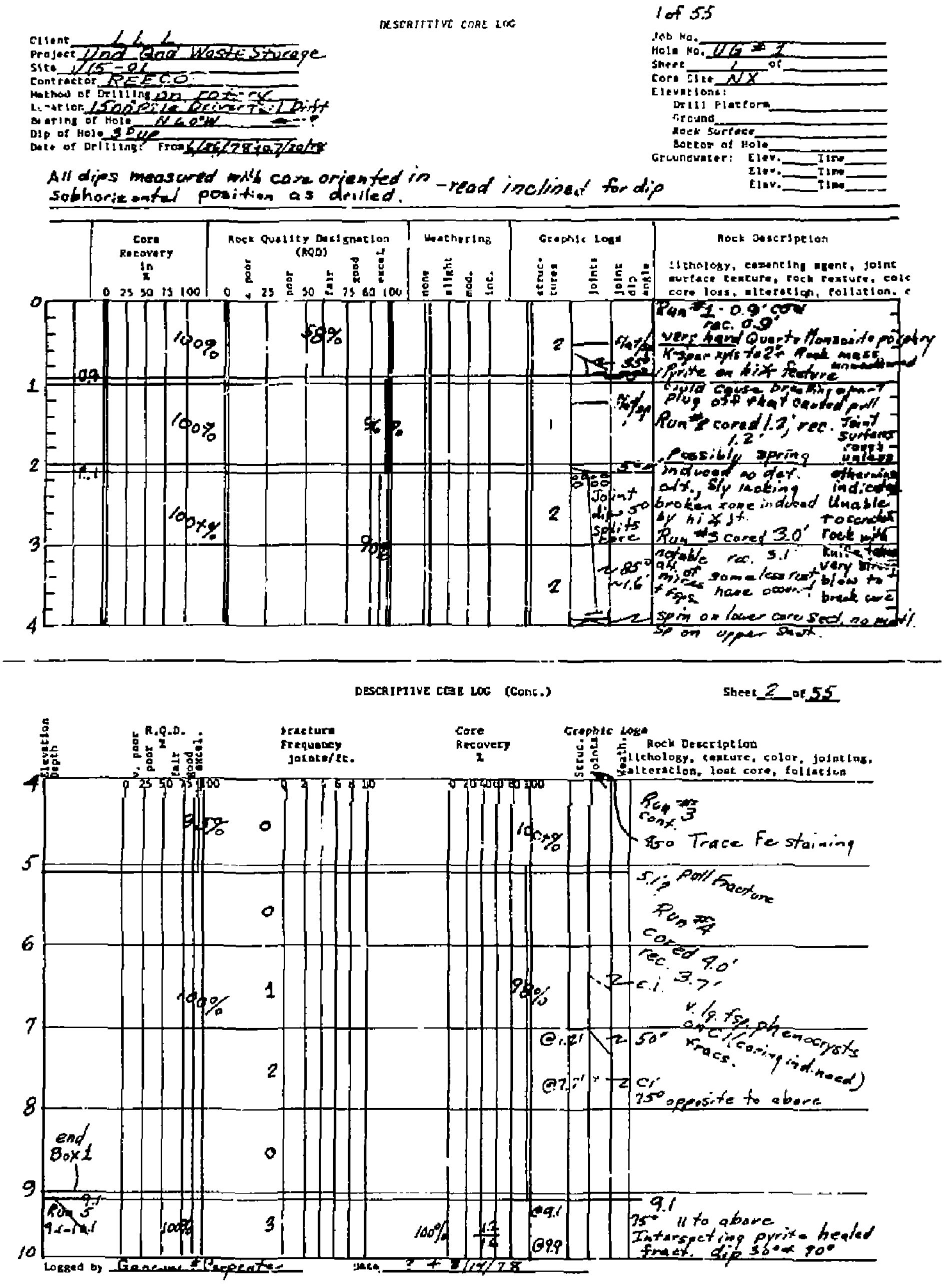


Figure 4. Example of UG log sheet.

transmitted to agencies involved in the SFT-C (Appendix A). Complete sets of photographs were taken of both wet and dry core, and directional surveys were run in all four exploratory boreholes. The directional surveys were performed using multishot magnetic techniques, the results of which are shown in Figs. 5 through 8.

After completion of the SFT-C drift excavation and facility construction, UG-2 was re-entered and deepened from 410 ft (125 m) to the final total depth of 602 ft (183 m). This deepening was accomplished by use of a Longyear 34 coring rig, using NQ wireline core barrels. The core was logged using criteria similar to those used in the original core logging except that all features were described and orientation of the core was attempted using techniques described in Section 3.0.

2.2 Instrumentation Holes For Monitoring Canister Drift Mining (MBIs)

Fourteen 76-mm (NX) diam. holes were drilled and cored from the heater drifts, prior to the excavation of the canister drift, for the emplacement of multiple-position rod extensometers. These boreholes, called mine-by instrumentation holes (MBI), were oriented horizontally or inclined upward toward the canister drift, as shown in Fig. 9, and were located in the pillar area between the heater drifts. The MBI holes in both heater drifts were drilled by a Joy 22 core drill, with drill rods limited to 5 ft sections because of drift dimensions. These holes were drilled at an average rate of about 1.4 ft/hr (0.43 m/hr). The total footage of holes drilled for extensometers was 498.1 ft (151.8 m).

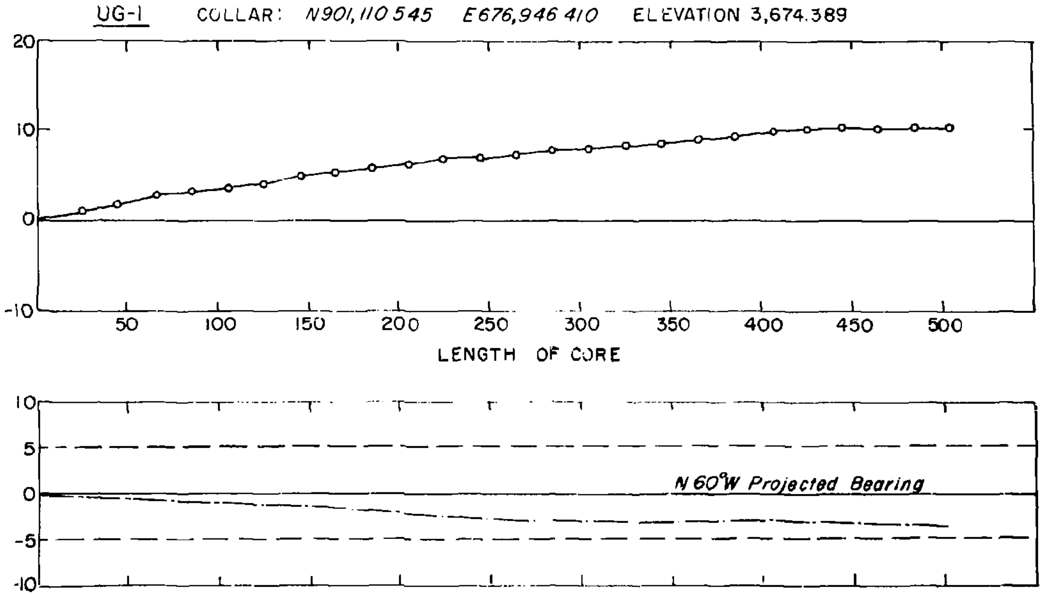


Figure 5. UG-1 directional survey.

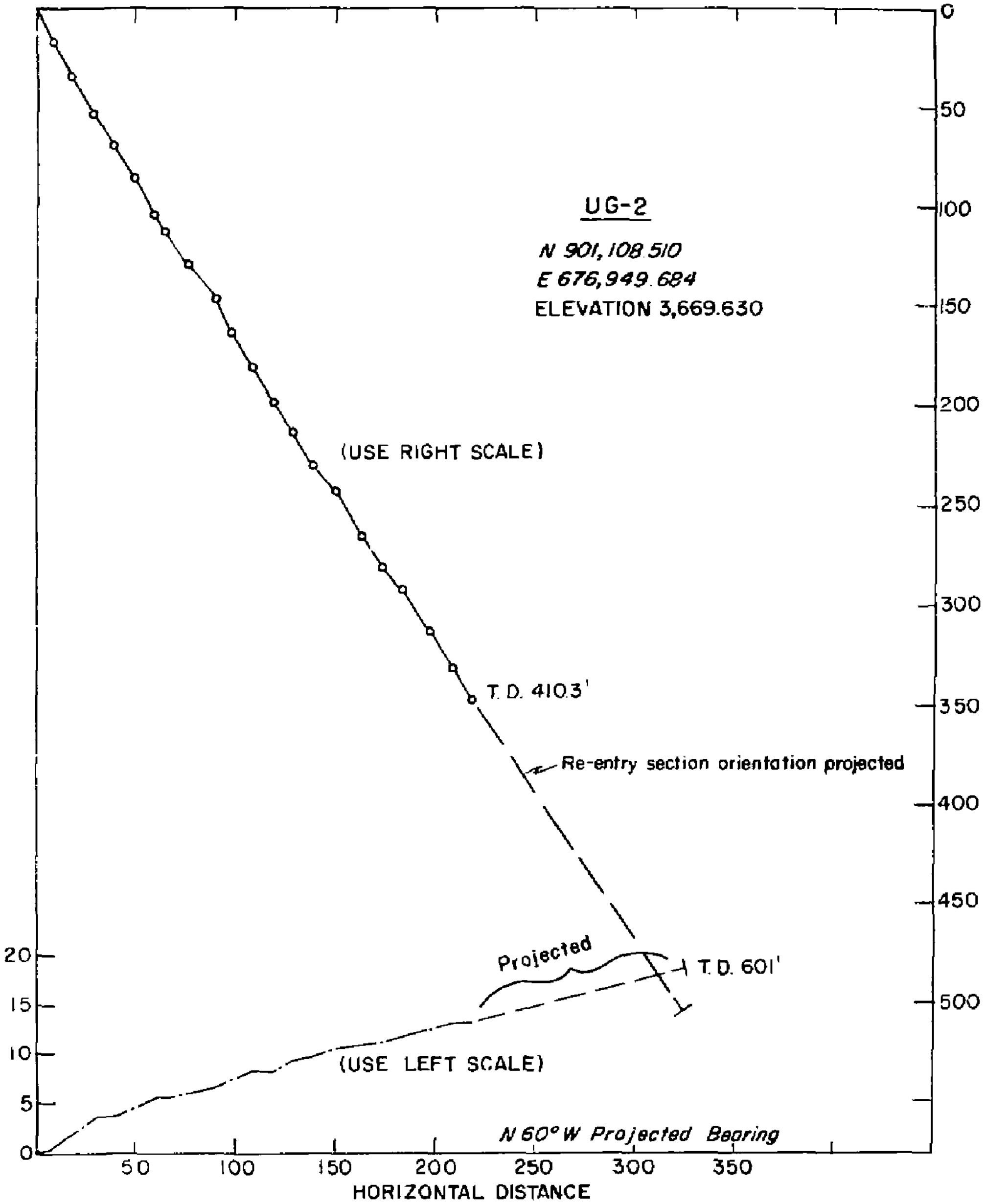


Figure 6. UG-2 directional survey.

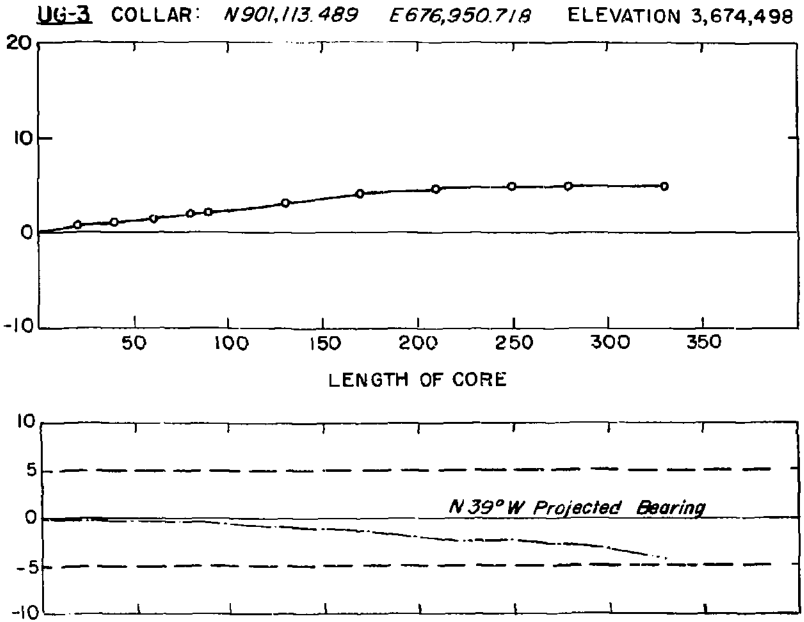


Figure 7. UG-3 directional survey.

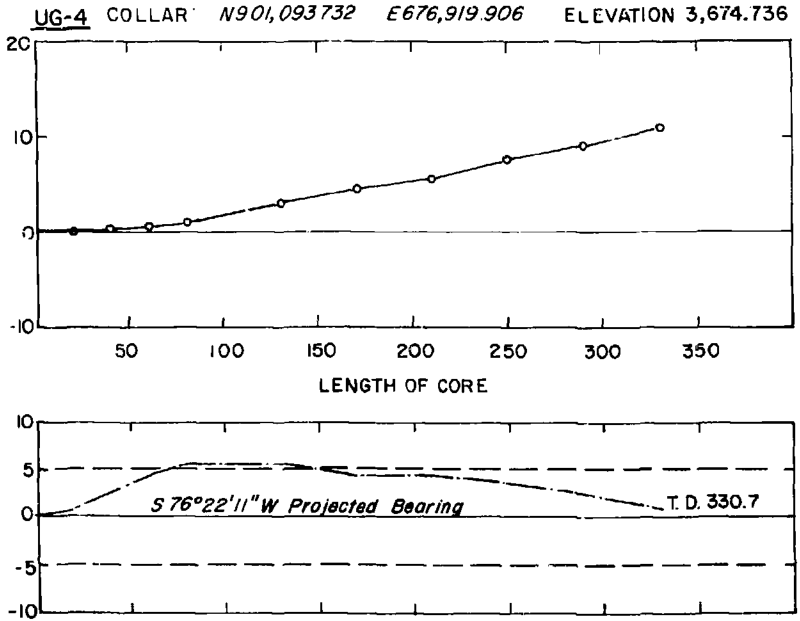


Figure 8. UG-4 directional survey.

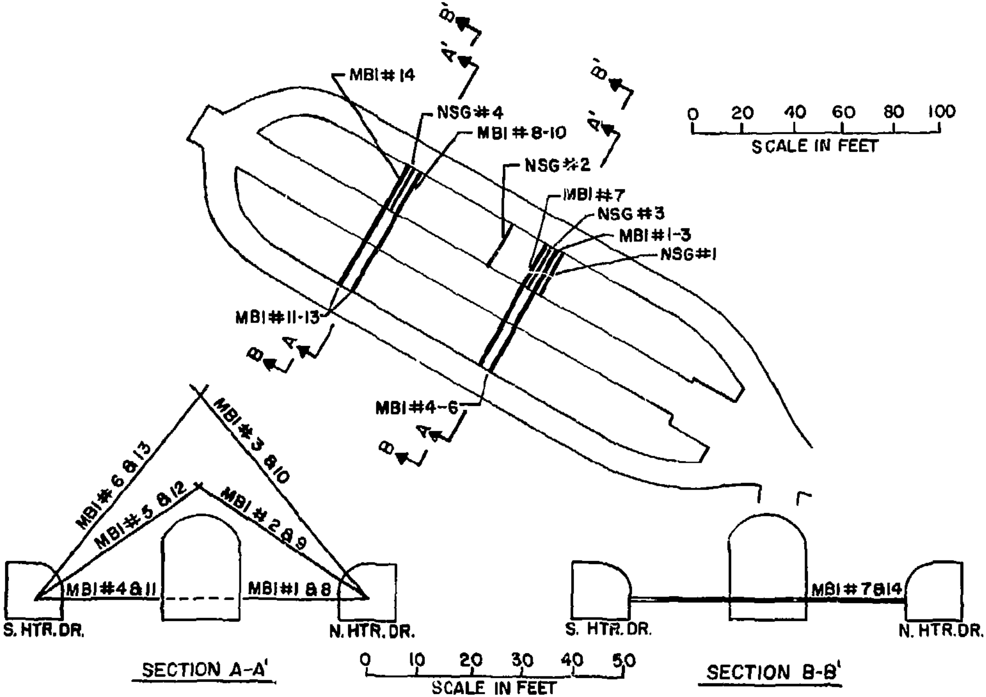
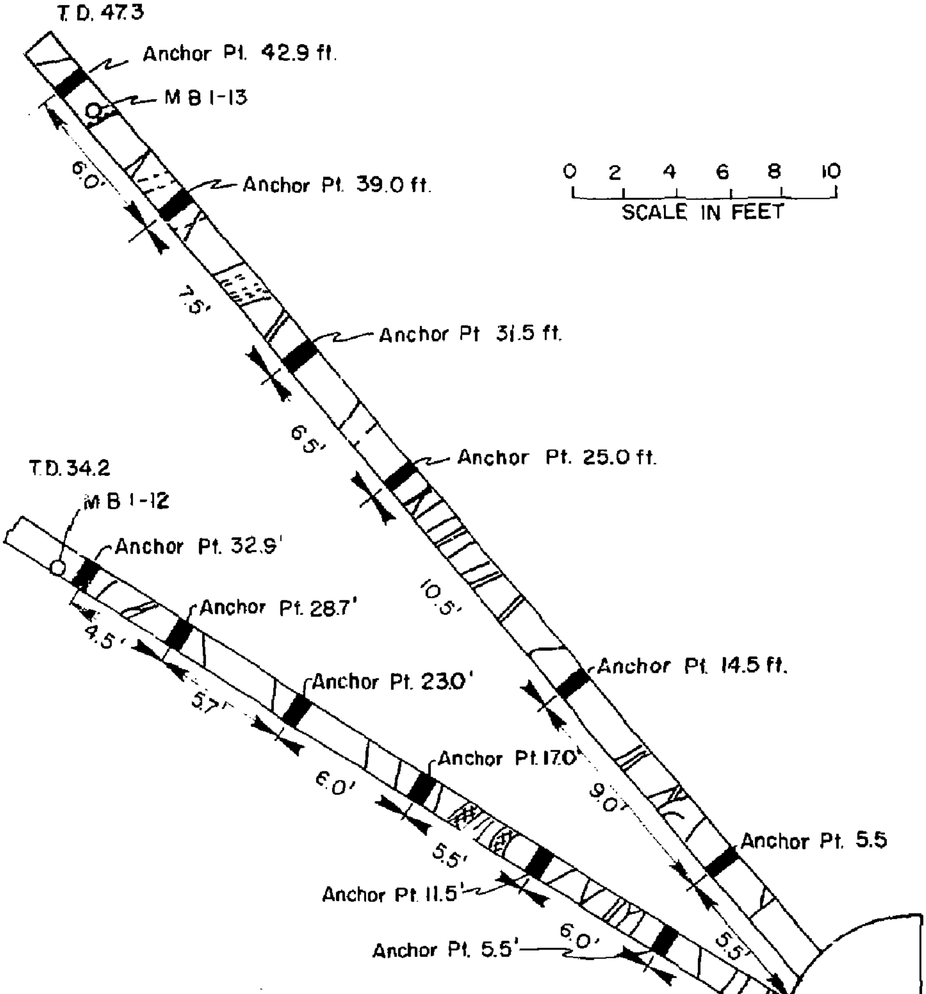


Figure 9. Location and orientation of MBI boreholes.

The core from these holes was initially logged underground to assist in selecting competent rock areas for extensometer anchors. This logging was performed concurrent with the excavation and drilling operations. To facilitate the construction schedule, some of this logging was simplified to include only the zones where anchors were to be placed. Based on this core logging, sketches were made (e.g., Fig. 10) to show the specified anchor locations relative to geologic features. When partial core logging was performed for anchor locations only, the complete logging of the core was done later in the USGS core library. The same logging criteria used on the exploratory boreholes were used for the MBI holes, except that all features were logged, including veins and healed joints. Core logging was performed by project engineering geologists assisted by a geology graduate student. The core logging included scaled sketches of the features within the core (e.g., Fig. 11).

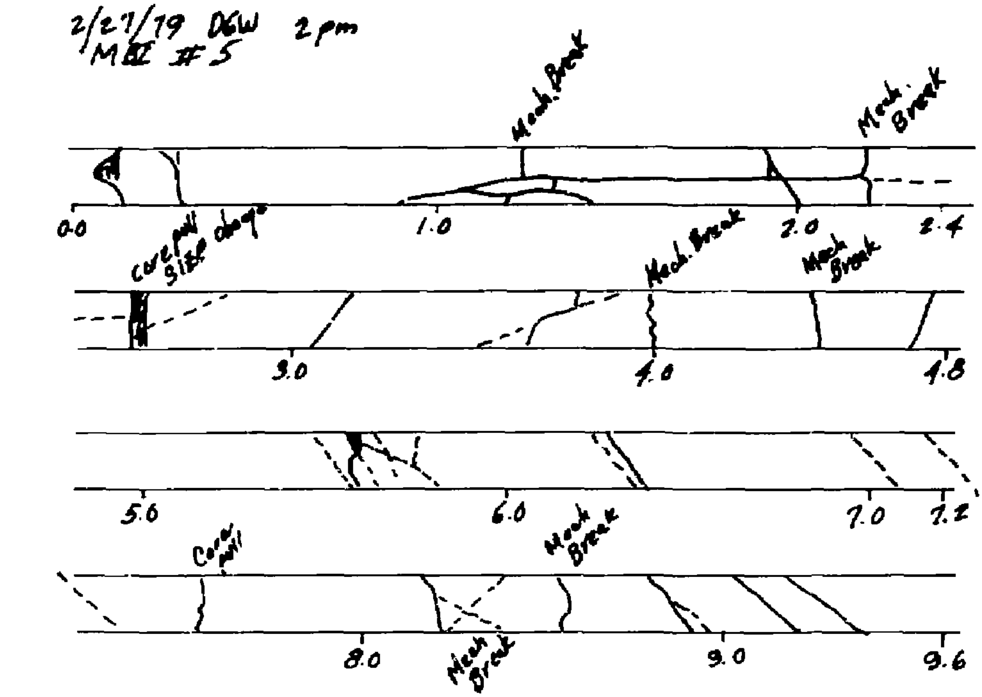
2.3 Heater Holes (NHHs & SHHs)

Twenty holes were drilled in the heater drifts for the emplacement of electrical heaters. These holes were diamond core drilled vertically down from the floor (invert) of the heater drifts in the locations shown in Fig. 12. These holes, 10-in. the north heater drift (NHH) and 10-in. the south heater drift (SHH), were drilled to a depth of 8 to 9 ft (2.4-2.7 m) with a 76 mm (NX) core bit, and then continued to a total depth of 16-17 ft (4.9 m) with a 51 mm (AX) bit. The difference in diameters provided a shoulder for the heating elements to rest on. A post-mounted CP-65 core drill was used to



NOTES: *Locations are measured from collar at time of drilling. Hand mining of loose rock to give solid head location may be required; this will change depths accordingly.*
Anchor locations are shown at approximate locations because of the scale of boring. Depth values are correct.

Figure 10. Sketch of anchors vs. fractures for MB1 extensometers.



	0.25 - 0.3	Sericite covered jt (broke) @ 60° to core
	0.95 - 2.25	Break along clean jt running parallel to core
	2.25 - 2.6	Jt (no break) continues parallel to core
	1.9 - 2.0	Sericite covered jt @ 60° to core (broke)
	2.6 - 2.82	Pyrite jt @ 45° to core axis (no break)
4/19/79	3.05 - 3.15	Break along sauceritized jt @ 60°+ to core
	3.5 - 3.9	Jt healed w/calcite-wavey-broke along jt in middle- 1/64" or less thick, approx. 30° to core axis
	4.7 - 4.77	Break along clean, planar jt - one small ridge - no gouge minerals
	5.55	Break along intersecting jts - one with calcite & mica the other with pyrite infilling
	5.5 - 5.55	Pyrite & calcite - healed jt - no visible breakage on jt
	5.55 - 5.65	Calcite & pyrite healed jt with mica-broke along part of jt
	5.55 - 5.7	Pyrite vein
	6.25 - 6.35	Pyrite vein
	6.26 - 6.36	Pyrite vein healed jt broke along jt
	6.95 - 7.07	Pyrite vein (not constant thickness varies from paper thin to 1/8") some calcite
	7.17 - 7.3	Pyrite vein - very thin - some calcite
	8.15 - 8.4	Jt filled w/clay - minor carbonate - broke abt 1/4 sample length
	8.2 - 8.4	Jt filled w/clay - minor carbonate - broke abt 1/4 sample length
	8.8 - 8.92	Carbonate & clay filled jt (paper thin) broke
	9.05 - 9.2	Jt - phylite shear - no carbonate - isolated pyrite - broke
	9.18 - 9.4	Jt - smooth - minor carbonate - broke

Figure 11. Typical core log sketch.

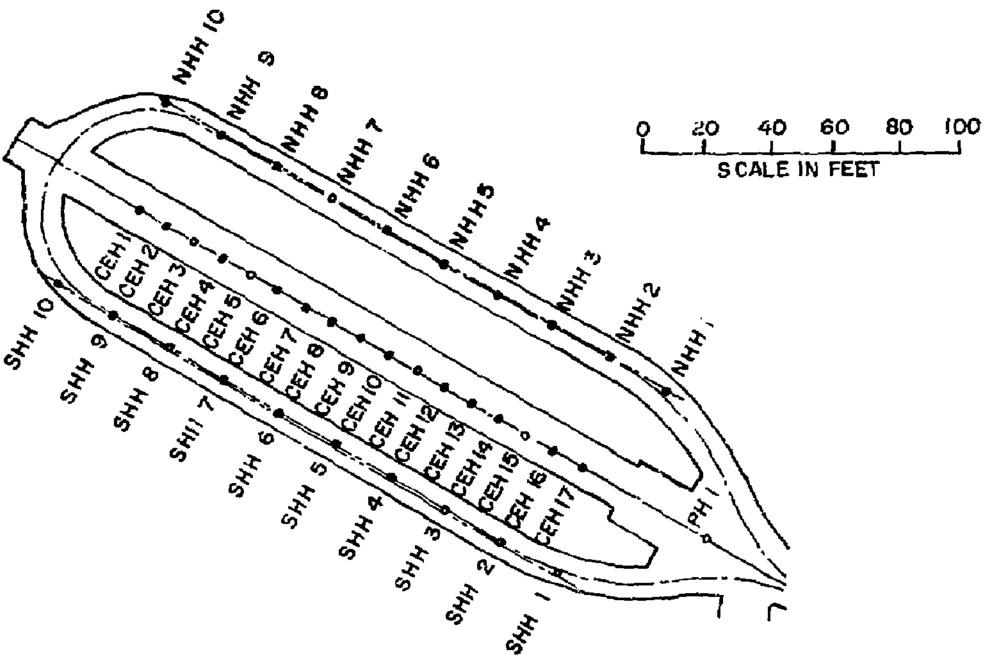


Figure 12. Location of heater and canister emplacement boreholes.

drill these holes. One heater hole was drilled each day, giving an average drilling rate of about 2.5 ft/hr (0.76 m/hr) for a one-shift operation. Because the drifts had limited clearance for drill rods (11 ft maximum height), 5-ft drill rods were used.

The total footage of core taken during the drilling of heater holes was approximately 322 ft (98 m). Logging of these heater holes was performed by geology student summer employees. The logging was performed in the same fashion as the MBI holes, with the exception that all of the logging was performed in the USGS core library. The results of the core logging on these vertical holes has been reported (Tewes, 1982). Figure 13 is a typical log sheet from that report.

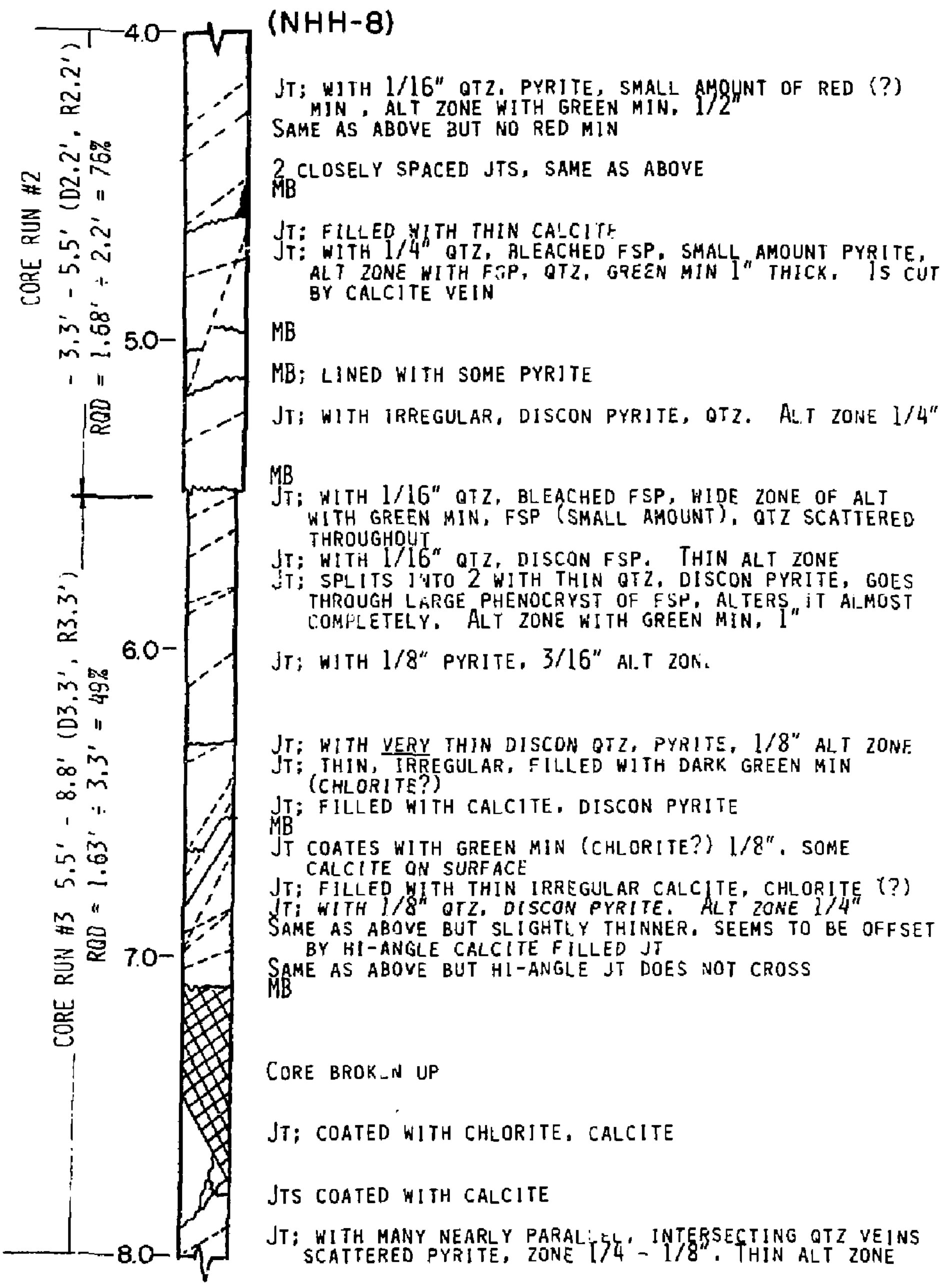


Figure 13. Typical heater borehole log (from Tewes, 1982).

2.4 Canister Core Holes (CCHs)

Four different methods were investigated for drilling the canister emplacement holes, which were to be 24-in. (610 mm) in diam. and 17 ft (5.2 m) deep:

1. Blind hole rotary drilling using a system of roller cone bits. The drill setup is similar to that in raise drilling, but there is no pilot hole and thrust is applied downward.
2. Line drilling which would require drilling 20 to 30 overlapping, small diam. holes in a circular pattern around the periphery of the planned hole.
3. Core drilling with a 22-in. (560 mm) diam core bit. This method was tested in an alcove constructed for an earlier heater test experiment. Slow progress was made because of rig breakdowns, excessive bit wear, and the difficulty of removing large core, which forced suspension of this method after drilling 6.9 ft (2.1 m)-in. the test section.
4. Hammer drilling with a 24-in. (610 mm) diam Ingersol-Rand downhole hammer, similar to that used on the 30-in. (762 mm) diam canister-access hole.

The hammer drill method was selected on the basis of the earlier success of similar drilling for the access hole. However, drilling canister emplacement holes with a hammer drill would not yield core from these areas of primary interest. Therefore, a 76 mm (NX) record core was drilled vertically downward from the floor of the canister drift the full length of each proposed emplacement hole prior to the hammer drilling operation, and each canister storage hole was photographed using a fish-eye lens before installing the liner. The core boreholes were drilled just inside the perimeter of each of the 17 canister emplacement holes using a Longyear 44 rig. The general locations of these holes are shown in Fig. 12 above; the detailed location relative to the emplacement holes is shown in Fig. 14. A total of approximately 290 ft (88 m) of core was drilled.

The unlogged CCH core was sent to the USGS core library in Mercury, where it will be held for logging during the later stages of the project. At that time a 6-in. (150 mm) borehole will be drilled just outside the perimeter of each canister emplacement hole and exactly opposite the area where the record core borehole had been drilled. The core from both sets of boreholes will be logged at the same general time by the same personnel to allow for a detailed comparison of the before- and after-storage mineralogy and fracturing. The two sets of cores will facilitate evaluation of changes in rock characteristics caused by the intense thermal and radiation fields imposed on the emplacement hole walls. This evaluation will help in differentiating between three potential sources of damage to the sidewalls of emplacement holes: damage caused by drilling, that caused by heat, and that caused by heat combined with intense radiation.

2.5 In Situ Stress (ISS) Determination Holes

Four holes were drilled for overcore tests to determine the in situ stress conditions in the SFT-C area. These holes, designated ISS holes, were drilled approximately vertically and horizontally from the south heater drift (Fig. 14) using a Longyear 44 rig. Approximately 80 ft (24 m) were drilled. No logging of this core was performed by SFT-C personnel. The core was shipped to the Special Projects group of the USGS, Denver, which had performed the overcoring.

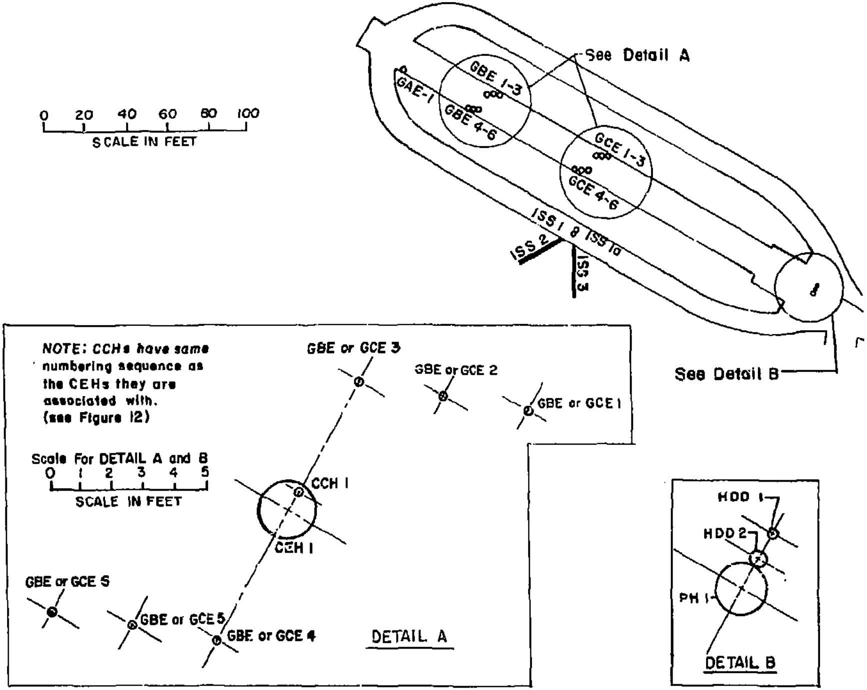


Figure 14. Location of boreholes.(Canister record core, hammer drill damage assessment, *in situ* stress overcoring, and thermal phase extensometers)

2.6 Stressmeter Emplacement Holes (NSG & CSG)

Six 38 mm (EX) boreholes were diamond core drilled to provide smooth holes for the installation of stressmeters. However, the core was prone to break into small pieces, because of its small size and drill-rod vibrations, and no attempt was made to log this core. Sections were examined to try to locate sufficiently sound rock for instrument anchorage, but the typical length of intact core recovered was less than 3-in. Therefore, the only features that could be routinely identified were alteration zones, which were avoided during instrument installation. Additional problems with the EX core were encountered in the mechanism for removal of the core, which often jumbled the core coming out of the barrel.

Four boreholes were drilled horizontally from the north heater drift toward or into the canister drift to provide for the installation of stressmeters, as shown in Fig. 9. These boreholes, designated north stress gauge (NSG) holes, were drilled at two different times. The first two were drilled prior to the construction of the canister drift and extended to within 2-3 ft (1 m) of the eventual canister drift rib. The other two were drilled after the excavation of the canister drift was completed and extended through the pillar into the canister drift. These holes were cored as EX-sized boreholes with a Joy 22 rig. A total of 72 ft (22 m) of borehole was drilled.

Two boreholes were drilled vertically from the canister drift for the installation of stressmeters. These holes, designated canister stress gauge (CSG) holes, were located in the instrumentation arrays around canister emplacement holes 3 and 9, as shown in Fig. 6. A total of about 26 ft (8 m) were cored as EX- sized boreholes using a turret-mounted Longyear 44 drill rig described below.

2.7 Thermal Phase Extensometer Holes (GxE)

Fourteen 76 mm (NX) boreholes were continuously diamond cored vertically downward from the canister drift to provide for the installation of borehole rod extensometers for monitoring thermal phase deformations. These boreholes were located as shown in Fig. 14.

These instrumentation holes (GxE series) were drilled with a Longyear 44 core drill mounted on a turret, attached to a railcar. To position the drill, the railcar was rolled to a hole location and the turret rotated over the collar. This shop-built rig allowed quick and easy drill movement from hole to hole. Drilling rates ranged from 3.6 ft/hr (1.1 m/hr) for 38 mm diam EX holes to 2.1 ft/hr (0.64 m/hr) for 76 mm diam NX holes. No restrictions on drill rod length were imposed by the 20 ft (6.1 m) high canister storage drift. A total of 630 ft (192 m) of NX core was drilled for this canister drift instrumentation.

By the time the GxE series core was taken, project engineering geologists had observed that the low-angle joints had a consistent mean orientation. Therefore, the orientation techniques described below in Section 3.0 were used to orient this core. The core logging was performed largely in the USGS core library with all features being described. This core was also used for alteration studies (Connolly, 1981).

2.8 Hammer Drill Damage (HDD) Assessment Holes

A practice hole was drilled in the railcar room with the drill rig that would be used to drill the canister emplacement holes. This provided a hole for railcar operation practice, and a test of the feasibility of drilling both the large diameter emplacement hole and the 6-in. (150 mm) core along the emplacement hole wall. After the practice hole was completed, two core holes were drilled vertically downward from the floor of the railcar room and adjacent to the practice canister-emplacement hole, as shown in Fig. 6. The first was a 6-in. (150 mm) hole drilled along the wall of the practice hole, and the second was a 3-in. (76 mm) NX cored hole some distance out. Both holes were diamond cored to a depth of about 17 ft (5 m), for a total cored footage of about 34 ft (10 m). The dual purpose of these holes was to examine the success of coring a 6-in. (150 mm) hole along the emplacement hole wall and to evaluate the damage experienced during the percussion drilling. No attempt has been made to log this core, although microscopic examinations of the core for damage during percussion drilling is in progress.

2.9 Other Boreholes

Many holes were drilled for installation of thermocouples, stressmeters, acoustic emissions sensors, or for other purposes. These holes are not reported here because they were either not cored, or the core was not retained.

All holes drilled for the entire test were surveyed by an optical line-of-site method to accurately determine the location of the hole bottom. The cores, however, were not conventionally oriented.

3.0 CORE ORIENTATION TECHNIQUE

A technique for orienting the core was developed based on information gained during the geologic mapping of the drifts. During this mapping, we observed that the low-angle joints were consistently healed with quartz, pyrite, or calcite or were filled with sericite. In nearly every instance there was wall-rock alteration that varied from barely perceptible widths to as much as 0.75-in. thickness. In contrast, the high-angle joints were never observed to have wall-rock alteration or hydrothermal mineralization within the joints. Some of the high-angle joints had secondary minerals such as clays and limonite in them or had iron oxide stains, but none was filled with the same mineralization as the low-angle joints. These observations allowed some assumptions to be made to assist in the orientation of the core from boreholes. It was assumed that any joints identified in the core that were hydrothermally altered (or were filled with quartz, pyrite, calcite, or sericite) belonged to the low-angle set of joints. Therefore, other features could be oriented with reference to the low-angle set, and their orientations could then be calculated based on the mean orientation of the low-angle joint set. This technique was first used on core taken for some of the instrumentation holes, then applied to the core taken during the deepening of UG-2. Similar techniques have been suggested by Goodman (1976).

In the earlier applications of this technique, an arbitrary line was drawn on the core after it had been pieced together. The orientations of all features were then related to this arbitrary line. Each feature was described by its inclination to the core axis and by the degrees of rotation, using a right-hand rule with thumb extending down hole, between the reference line and the apparent dip azimuth or direction of maximum inclination with the core axis. The mean orientation of the low-angle joints was then related to the reference line. Because the mean orientation of the low-angle joints was known from field mapping, orientation of the reference line could be calculated. Orientations of all other features could then be related to the calculated reference line orientation.

A similar procedure was used to orient the entire UG-2 core, including the last 200 ft of reentry core. The technique for this was modified slightly from that used during the earlier orientation attempts. A section of core was removed from the core box and reconstructed into a continuous piece of core using a length of angle stock as a core trough. The low-angle joints were then identified by their attitude, usually 50° to 60° to the UG-2 axis, and by their distinctive wall-rock alteration. Using another length of angle stock, an ink line was drawn down the core roughly through the average location of the lower-most point of intersection between the outer core wall and the dip azimuths of these low angle joints, as shown in Fig. 15. A reference drilling depth, usually the top of a drill run, was assigned to each section of reconstructed core to determine the depth of each discontinuity.

Once the orientation line was established for a given core length, the orientations of all other features were referenced to it. The method for doing this followed that of Rosengren (1970) and consisted of defining the orientation of a discontinuity with two angles. Angle α between the core axis and the major axis of the ellipse of intersection (Fig. 15) was measured with a protractor to the nearest degree. Angle β (Fig. 15) is the azimuth

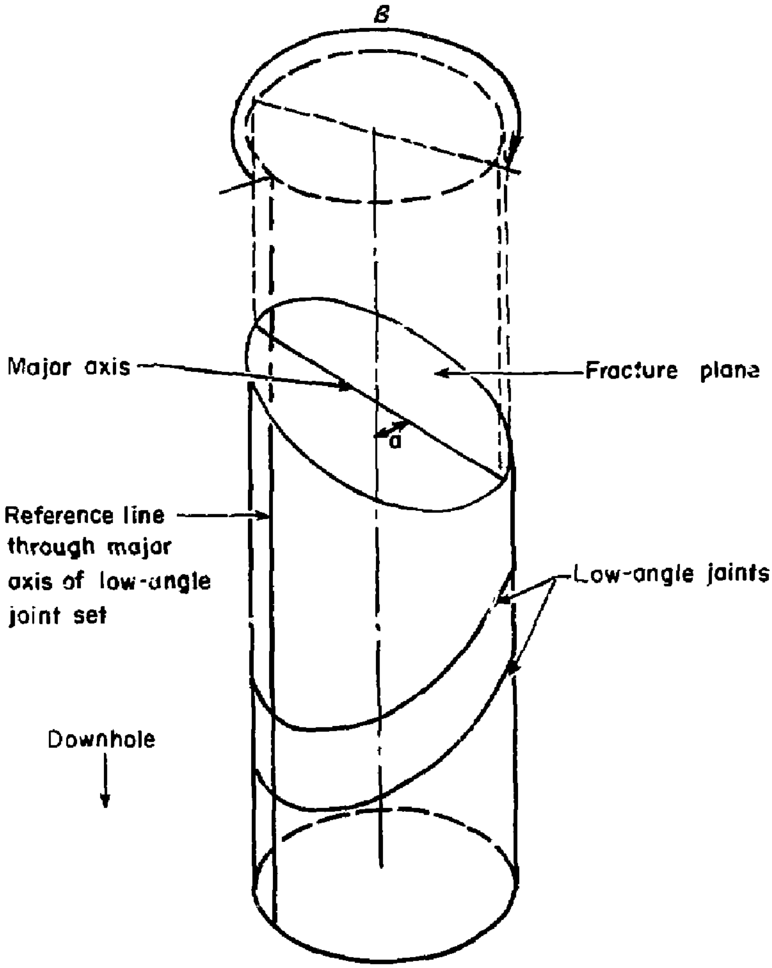


Figure 15. Core orientation technique.

of the downward end of the major axis relative to the orientation line and was measured to the nearest 5° with a scaled or calibrated 360° band wrapped clockwise around the core (looking downhole). Knowing the direction of the borehole, the orientation of a feature can then be determined from these two angles by means of stereographic projection (Goodman, 1976) or spherical trigonometry (Lau and Gale, 1976).

These procedures allowed most of the UG-2 core and much of the instrumentation hole core to be oriented. Even if the core were discontinuous or could not be pieced together over the entire length, segments of the core could be oriented by determining a new reference line. Because the low-angle joints had a frequency of at least one joint per foot, any core that could be reconstructed for more than one foot could usually be oriented. Obviously, the usefulness of this technique depends on the orientation of the low-angle set remaining constant throughout the hole. The orientations have remained constant over several long sections, of up to 65 ft (20 m), of fully reconstructed core, it therefore seems likely that the orientations are constant over the entire length of core. The presumption of constant mean orientation is further supported by the fact that the low-angle joint orientations obtained during taildrift mapping differ very little from those mapped in the Pile Driver drift (Wilder and Patrick, 1981).

4.0 INVENTORY OF CORES, LOGGING, AND HOLE STATUS

A total of about 5150 ft (1570 m) of core was drilled during the SFT-C project. More than 3500 ft (1067 m) of this core was logged by LLNL, as shown in Table 1. The orientation of holes and depths is also shown in this table. Most of the core that was logged was NX size, but a small percentage was AX size. A significant amount of EX core was obtained, but because of its smaller size it was not useful in core logging; therefore, it was either not retained or not logged. All of the core that was retained was sent to the USGS core library in Mercury, NV, where it is available for further reference as needed; the logs themselves are kept at LLNL. Table 2 shows the availability of core with indication of portions that have been removed for laboratory testing and analysis. The CCH is being kept for future logging and comparison studies with post-storage core; therefore, it is not available for inspection or sampling without permission of the project leaders.

Most of the SFT-C boreholes were drilled for the installation of instruments. The notable exceptions to this are the exploratory boreholes that were drilled to provide geologic information. Most of the boreholes are not available for further studies or experiments because of the instruments that have been installed in them. However, there are some boreholes that could be used for further studies. These boreholes are listed in Table 3.

Table 1. SFT-C core logging inventory.

Hole designation	Total depth, ft	Hole size	Hole orientation	By[a]	Logged Date	Fracture frequency Open	Closed	Total
Underground exploratory boreholes (UGs)								
UG-1	503.7	NX	+3°	DWC	6/26-7/20/78	0.61[b]	NA[c]	NA[c]
UG-2	410.3	NX	-58°	DWC	7/24-8/04/78	0.45[b]	NA[c]	NA[c]
deepen	602.3	NX	-58°	RKT	1/29-2/25/82	0.66	2.2	2.8
UG-3	330.3	NX	+1°	DWC	8/18-8/24/78	0.64[b]	NA[c]	NA[c]
UG-4	330.9	NX	+2°	DWC	8/17-8/24/78	0.67[b]	NA[c]	NA[c]
Total	1767.2							
Mine-by instrumentation boreholes (MBIs)								
MBI 1	18.4	NX	Horiz	DGW	2/9/79	0.38	0.4	0.8
MBI 2	34.0	NX	+33.5°	DGW	2/15/79	0.35	0.3	0.7
MBI 3	47.5	NX	+50.0°	DGW	2/15-16/79	0.27	0.3	0.6
MBI 4	17.1	NX	Horiz	DGW	2/23/79	1.0	0.5	1.5
MBI 5	33.4	NX	+33.5°	DGW/JAC	2/27/79	1.1	2.1	3.2
MBI 6	47.2	NX	+50.0°	ARE	2/20-21/79	0.51	1.5	2.0
MBI 7	53.6	NX	Horiz	JAC	6/20/79	0.73	1.2	1.9
MBI 8	18.0	NX	Horiz	DGW	2/9/79	0.67	0.4	1.1
MBI 9	34.2	NX	+33.5°	DGW	1/25/79	0.7	0.3	1.0
MBI 10	47.3	NX	+50.0°	DGW	1/26&2/8/79	0.74	0.4	1.1
MBI 11	17.2	NX	Horiz	JAC	6/20/79	1.1	1.5	2.6
MBI 12	32.4	NX	+33.5	ARE/BJQ	2/79&4/82	0.43	2.05	2.4
MBI 13	43.8	NX	+50.0°	ARE	2/27-29/79	0.46	1.5	2.0
MBI 14	54	NX	Horiz	BJQ	5/21/82	0.61	1.5	2.18
Total	498.1							
North heater drift stress gauge boreholes (NSGs)								
NSG 1	17	EX	Horiz		Logging was not attempted			
NSG 2	17	EX	Horiz		Logging was not attempted			
NSG 3	19	EX	Horiz		Logging was not attempted			
NSG 4	19	EX	Horiz		Logging was not attempted			
Total	72							

[a] *See Acknowledgements for identification of personnel.*
[b] From the first 150 ft.
[c] NA - closed fractures were not logged.

Table 1. SFT-C core logging inventory (Continued)

Hole designation	Total depth, ft	Hole size	Hole orientation	By[a]	Logged Date	Fracture frequency Open	Closed	Total
North heater drift heater holes (NHHs)								
NHH 1	16.0	NX/AX	-90°	PJG	7/16/81	0.76	2.75	3.51
NHH 2	16.0	NX/AX	-90°	PJG	7/28/81	0.56	2.52	3.08
NHH 3	16.0	NX/AX	-90°	PJG	7/29/81	0.62	2.64	3.26
NHH 4	16.3	NX/AX	-90°	PJG	7/30/81	1.06	2.82	3.88
NHH 5	16.0	NX/AX	-90°	PJG	7/30/81	0.49	3.08	3.57
NHH 6	17.0	NX/AX	-90°	PJG	2/29/81	0.41	2.83	3.24
NHH 7	16.0	NX/AX	-90°	PJG	8/5/81	0.83	3.31	4.14
NHH 8	16.0	NX/AX	-90°	PJG	8/15/81	0.83	3.08	3.91
NHH 9	16.5	NX/AX	-90°	PJG	8/6/81	0.64	3.93	4.57
NHH 10	16.0	NX/AX	-90°	PJG	8/11/81	1.06	2.12	3.18
Total	161.8							
South heater drift heater holes (SHHs)								
SHH 1	16.0	NX/AX	-90°	MCD	7/29/81	0.27	2.12	2.39
SHH 2	16.0	NX/AX	-90°	MCD	7/30/81	0.30	1.26	1.56
SHH 3	16.0	NX/AX	-90°	MCD	7/30/81	0.34	2.72	3.06
SHH 4	16.0	NX/AX	-90°	MCD	8/4/81	0.21	1.78	1.99
SHH 5	16.2	NX/AX	-90°	MCD	8/3/81	0.21	2.57	2.78
SHH 6	16.3	NX/AX	-90°	MCD	8/4/81	0.34	2.75	3.09
SHH 7	16.1	NX/AX	-90°	MCD	8/5/81	0.46	2.58	3.04
SHH 8	16.0	NX/AX	-90°	MCD	8/5/81	0.40	2.93	3.33
SHH 9	16.0	NX/AX	-90°	MCD	8/5/81	0.68	2.20	2.88
SHH 10	16.0	NX/AX	-90°	MCD	8/6/81	0.74	3.04	3.78
Total	160.6							
In situ stress (overcore) boreholes (ISSs)								
ISS 1	18.2	6"	-90°	Core shipped to USGS in Denver for analysis				
ISS 1A	19.7	6"&EX	-76.5°	Core shipped to USGS in Denver for analysis				
ISS 2	18.0	6"&EX	+3°	Core shipped to USGS in Denver for analysis				
ISS 3	24.6	6"&EX	+3°	Core shipped to USGS in Denver for analysis				
Total	80.5							
Canister core hole (CCHs)								
				Core not logged at time of report.				
CCH 1	17.0	NX	-90°	"	"	Core not logged		"
CCH 2	17.0	NX	-90°	"	"	At time of Report		"
CCH 3	17.0	NX	-90°	"	"	"	"	"
CCH 4	17.0	NX	-90°	"	"	"	"	"
CCH 5	17.0	NX	-90°	"	"	"	"	"
CCH 6	17.0	NX	-90°	"	"	"	"	"
CCH 7	17.0	NX	-90°	"	"	"	"	"
CCH 8	17.0	NX	-90°	"	"	"	"	"

Table 1. SFT-C core logging inventory (Concluded)

Hole designation	Total depth, ft	Hole size	Hole orientation	By[a]	Logged Date	Fracture frequency Open	Closed	Total
CCH 9	17.0	NX	-90°	NA	NA		NA	NA
CCH 10	17.0	NX	-90°	NA	NA		NA	NA
CCH 11	17.0	NX	-90°	NA	NA		NA	NA
CCH 12	17.0	NX	-90°	NA	NA		NA	NA
CCH 13	17.0	NX	-90°	NA	NA		NA	NA
CCH 14	17.0	NX	-90°	NA	NA		NA	NA
CCH 15	17.0	NX	-90°	NA	NA		NA	NA
CCH 16	17.0	NX	-90°	NA	NA		NA	NA
CCH 17	17.0	NX	-90°	NA	NA		NA	NA
TOTAL	289.0							
Canister drift extensometer borehole (GxEs)								
GAE 1	45.0	NX	-90°	JS	8/25-27/80	0.92	1.86	2.78
GBE 1	45.0	NX	-90°	BJQ	3/4-4/5/82	0.72	1.81	2.53
GBE 2	45.0	NX	-90°	JS	8/27-28/80	0.41	2.00	2.41
GBE 3	45.0	NX	-90°	JS	8/29-9/3/80	0.44	2.11	2.55
GBE 4	45.0	NX	-90°	BJQ	4/6/82	0.41	1.33	1.74
GBE 5	45.0	NX	-90°	JS	9/4-5/80	0.54	2.28	2.82
GBE 6	45.0	NX	-90°	JS	9/5-10/80	0.65	2.28	2.93
GCE 1	45.0	NX	-90°	BJQ	4/6-7/82	0.53	1.80	2.33
GCE 2	45.0	NX	-90°	JS	9/10-11/80	0.74	1.88	2.62
GCE 3	45.0	NX	-90°	JS	9/11-12/80	0.62	2.49	3.11
GCE 4	45.0	NX	-90°	BJQ	4/7-8/82	0.48	2.31	2.79
GCE 5	45.0	NX	-90°	JS	9/15-16/80	0.55	2.06	2.61
GCE 6	45.0	NX	-90°	JS	9/16-17/80	0.53	2.45	2.98
GDE 1	45.0	NX	-90°	BJQ	4/8-9/82	0.46	2.03	2.49
TOTAL	630.0							
Hole drilling damage assessment boreholes (HDDs)								
HDD 1	17-appr	NX	-90°	No logging performed-Microcrack analysis only				
HDD 2	17-appr	NX	-90°	No logging performed-Microcrack analysis only				
Canister drift stress gauge (CSG)								
CSG 1	13.0	EX	-90°	Logging was not attempted				
CSG 2	13.0	EX	-90°	Logging was not attempted				
TOTAL	26.0							

Table 2. Core removed from USGS core library

Hole	Interval ft	Core removed By	Date
MBI 1	0.4 - 0.9	LLNL - D. Isherwood	3/12/80
	10.6 - 11.2	LLNL - D. Isherwood	3/12/80
MBI 7	22.0 - 25.4	LLNL - D. Wilder	8/29/79
	25.8 - 26.68	LLNL - D. Wilder	8/29/79
ISS 1A	15.0 - 17.4 Wax	USGS-Denver - W. Ellis	
	17.6 - 19.65	USGS-Denver - W. Ellis	
2	4.2 - 9.4	USGS-Denver - W. Ellis	
	10.65 - 14.4	USGS-Denver - W. Ellis	
	14.6 - 18.0	USGS-Denver - W. Ellis	
3	20.0 - 23.25	USGS-Denver - W. Ellis	
HDD 2	16.4 - 16.5	LLNL	2/12/80
GBE 1	8.88 - 9.51	LLNL - J. Connolly	6/28/79
GBE 2	28.01 - 28.16	LLNL - J. Connolly	7/26/79
GBE 4	11.60 - 11.73	LLNL - J. Connolly	7/26/79
	21.75 - 22.05	LLNL - J. Connolly	7/26/79
	30.54 - 30.67	LLNL - J. Connolly	7/26/79
UG 1	12.32 - 13.52	LLNL - J. Connolly	6/29/79
	88.33 - 88.88	LLNL - J. Connolly	6/29/79
	107.5 - 108.3	LLNL - D. Isherwood	3/12/80
	254.2 - 254.97	LLNL - J. Connolly	6/29/79
	319.2 - 319.82	LLNL - J. Connolly	6/29/79
	347.65 - 348.8	LLNL - J. Connolly	6/29/79
	471.56 - 472.32	LLNL - J. Connolly	6/29/79
UG 2	59.7 - 60.7	Terra Tek - S. Steele	2/27/79
	224.3 - 225.0	LLNL - D. Wilder	1/15/79
	329.0 - 329.8	LLNL - D. Wilder	1/15/79
	118.9 - 120.0	Terra Tek - S. Steele	2/27/79
	262.4 - 263.4	Terra Tek - S. Steele	2/27/79
	279.8 - 280.8	DNA - M. Baldwin	1/31/80
	390.4 - 391.5	Terra Tek - S. Steele	2/27/79
	385.9 - 387.0	LLNL - D. Isherwood	3/12/80

Table 2. Core removed from USGS Core Library (concluded)

Hole	Interval ft	Core removed By	Date
	19.2 - 20.4	Waxed core sections remaining at the USGS Core Library	
	37.6 - 38.8		
	77.9 - 79.0	"	
	98.0 - 99.2	"	
	141.6 - 142.8	"	
	164.0 - 166.0	"	
	183.4 - 184.4	"	
	202.7 - 204.0	"	
	227.7 - 223.8	"	
	243.2 - 244.2	"	
	302.6 - 303.6	"	
	321.4 - 322.4	"	
	340.0 - 341.0	"	
	359.9 - 361.2	"	
	378.1 - 379.1	"	
	390.4 - 391.5	"	
UG 3	21.8 - 23.7	LLNL - L. Page	8/18/80
	27.7 - 29.1	LLNL - L. Page	8/18/80
	41.7 - 42.3	LLNL - L. Page	8/18/80
	49.17 - 49.53	LLNL - J. Connolly	6/28/79
	50.8 - 51.3	LLNL - L. Page	8/18/80
	76.6 - 77.4	LLNL - D. Wilder	1/15/79
	142.5 - 143.0	LLNL - J. Connolly	6/28/79
	268.4 - 269.1	LLNL - D. Wilder	1/15/79
	273.5 - 274.1	LLNL - J. Connolly	6/28/79
	298.64 - 299.4	LLNL - J. Connolly	6/28/79
	231.7 - 232.2	LLNL - J. Connolly	6/28/79
	217.4 - 217.5	LLNL - J. Connolly	6/28/79
	303.1 - 303.5	LLNL - J. Springer	2/28/80
	328.9 - 329.5	LLNL - J. Springer	2/28/80
UG 4	52.75 - 54.1	LLNL - E. Ziegler	3/19/79
	62.05 - 62.8	LLNL - E. Ziegler	3/19/79
	115.6 - 116.1	LLNL - D. Wilder	1/15/79
	242.6 - 243.75	LLNL - D. Wilder	1/15/79

Table 3. SFT-C open boreholes.

Hole	Open interval, ft
UG-1	357.0-503.7[a]
UG-2	All
UG-3	All
UG-4	All
NSG-1	All
NSG-2	All
ISS-1	All
ISS-1A	All
ISS-2	All
ISS-3	All

[a] - portions of UG 1 were destroyed during excavation.

5.0 RESULTS AND APPLICATIONS

Core logging was used for two purposes: to identify sufficiently competent rock for instrument installation, and to understand the structural geology of the Climax stock. Initial geologic interpretations of the SFT-C were based heavily on bo drift mapping in the Pile Driver drift (Maldonado, 1977) and mapping of the drift of the SFT-C (Wilder and Patrick, 1981), and somewhat on the logging of -C exploratory core. After the SFT-C drifts were excavated, the geologic inte ation was based mainly on the mapping of the drifts (Wilder and Yow, 1981). C logging of holes other than the exploratory holes was used only slightly in geologic interpretations. The mineralogy of the Climax stock does not vary greatly except near the low-angle joints where there is pervasive wall rock alteration, or in areas of intense jointing. Therefore, core logging was mainly used to identify joints and shear zones. Details of the joint identification varied both with the logging conditions and with the purpose for which the logging was performed. In subsequent reports, we will present our analysis of the fracture frequency and the resolution of the data into joint sets with orientations. An analysis of the geologic structure will also be made combining the mapping and the coring information. Furthermore, statistical methods of analyzing the joint sets from the core logs will be presented in subsequent reports to assess the utility of the core logging and methods of understanding crystalline rock masses.

5.1 Identification of Geologic Discontinuities

The major attempt to use the core logging for geological interpretation was made early in the project before the facilities were mined. Because the core was not oriented, interpretation of specific geologic features was largely impossible. Exploratory core logs were used to ascertain that there were no adverse stability conditions within the area of the SFT-C. Generalized interpretations were made on the basis of projections, between boreholes, of zones of highly altered materials. These interpretations were used, recognizing that the correlations were quite conjectural, to alert project personnel to possible major features, and to give them a general impression of the possible structure of the stock in the project area.

The most notable example of the successful use of the exploratory core logs to locate an important feature was the identification of a feature in the receiving room-heater drift intersection area. We identified a narrow shear zone with slickensides and highly altered core (Fig. 4) in the UG-1 core, near this location. A similar zone of alteration was identified in UG-3, but no slickensides were identified. On this basis, a through-going feature was interpreted to project at N45-55°E through the canister drift-receiving room area (Fig. 16). This feature was interpreted to be an intensely jointed and altered zone, potentially a shear zone, and was later identified during drift mapping as a fault zone with clay gouge in excess of 12-16 in. (300-400 mm) in thickness. While the general feature was identified from the core, it was not recognized as a significant fault that contained this thick clay gouge. During core logging, no clay gouge or readily recognizable fault zone was identified; nor were there significant core losses. Figures 17 and 18 are photographs of the UG-1 core, including the section identified as a shear zone. Subsequent re-examinations of the core and of fault exposures within

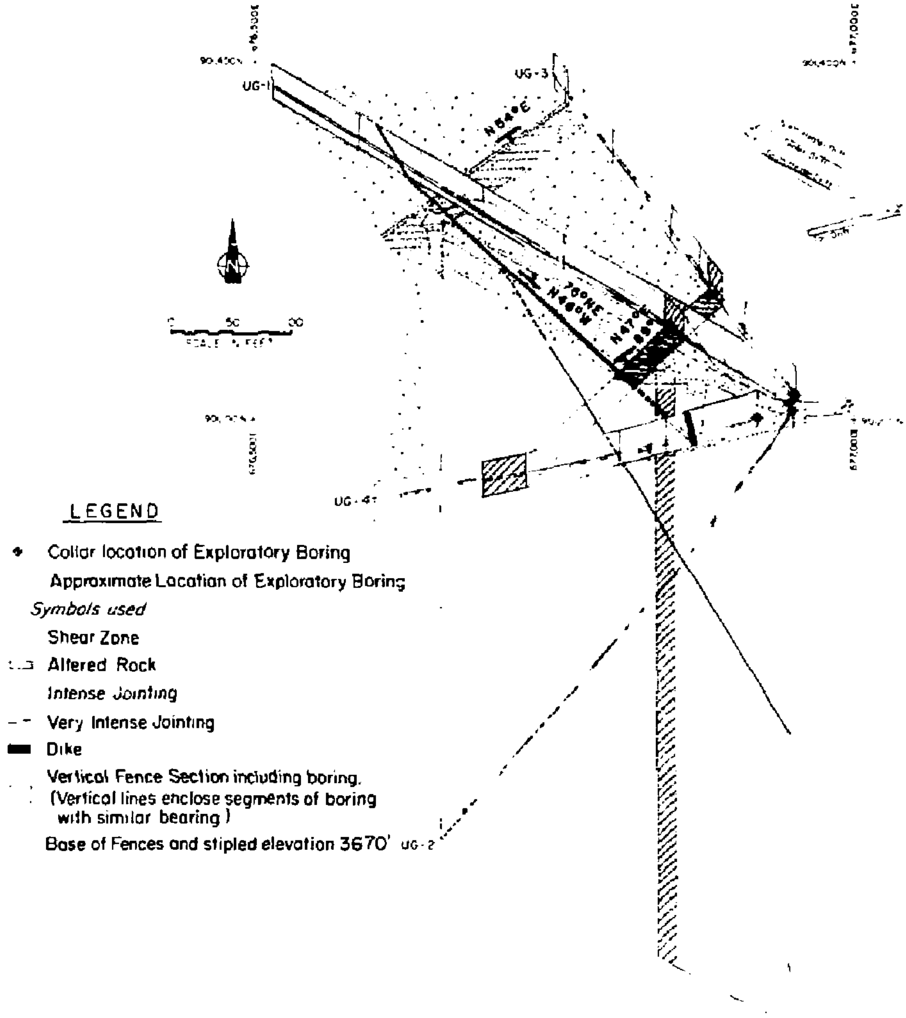


Figure 16. Fence diagram of the SFT-C showing significant features interpreted from exploratory core logs.

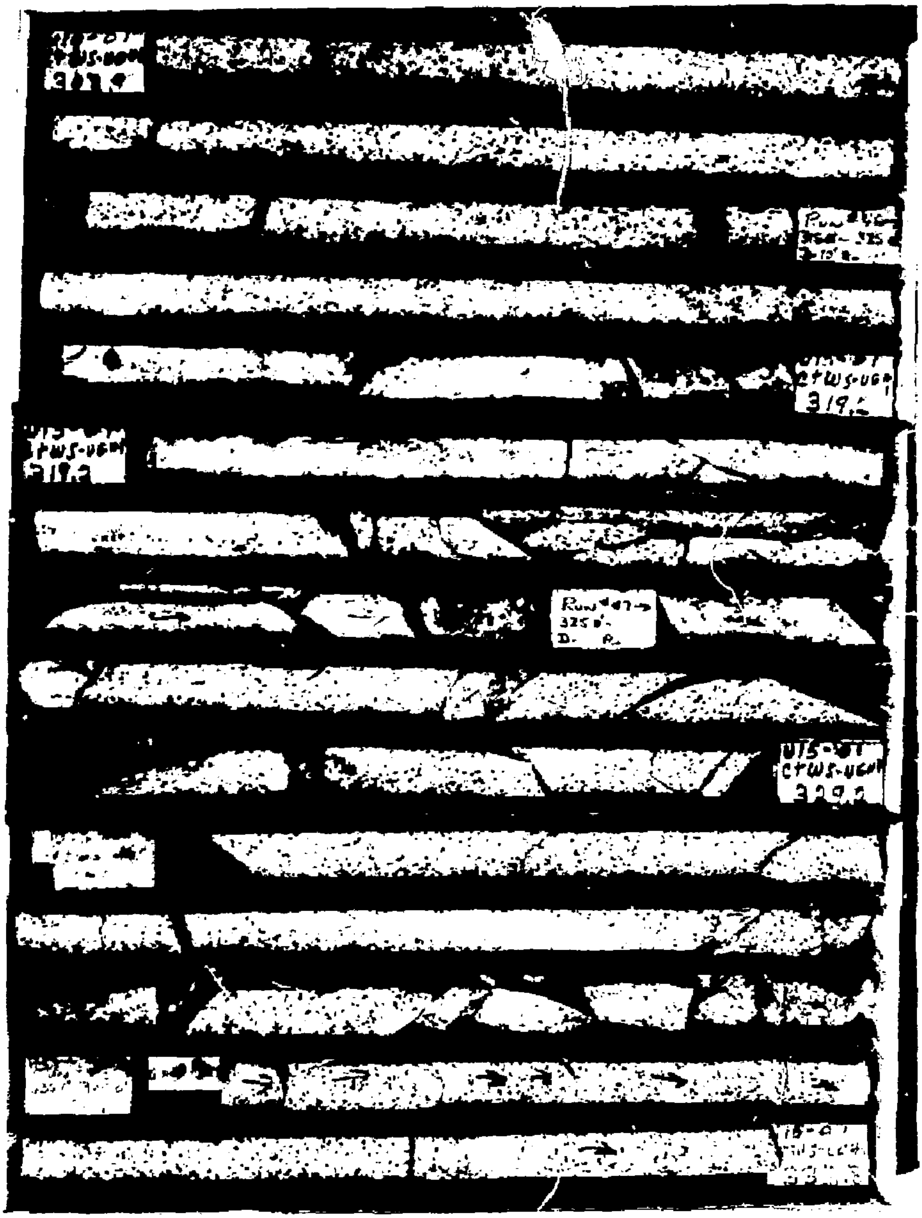


Figure 17. Photograph of UG-1 core, 308.9 to 338.8 ft.

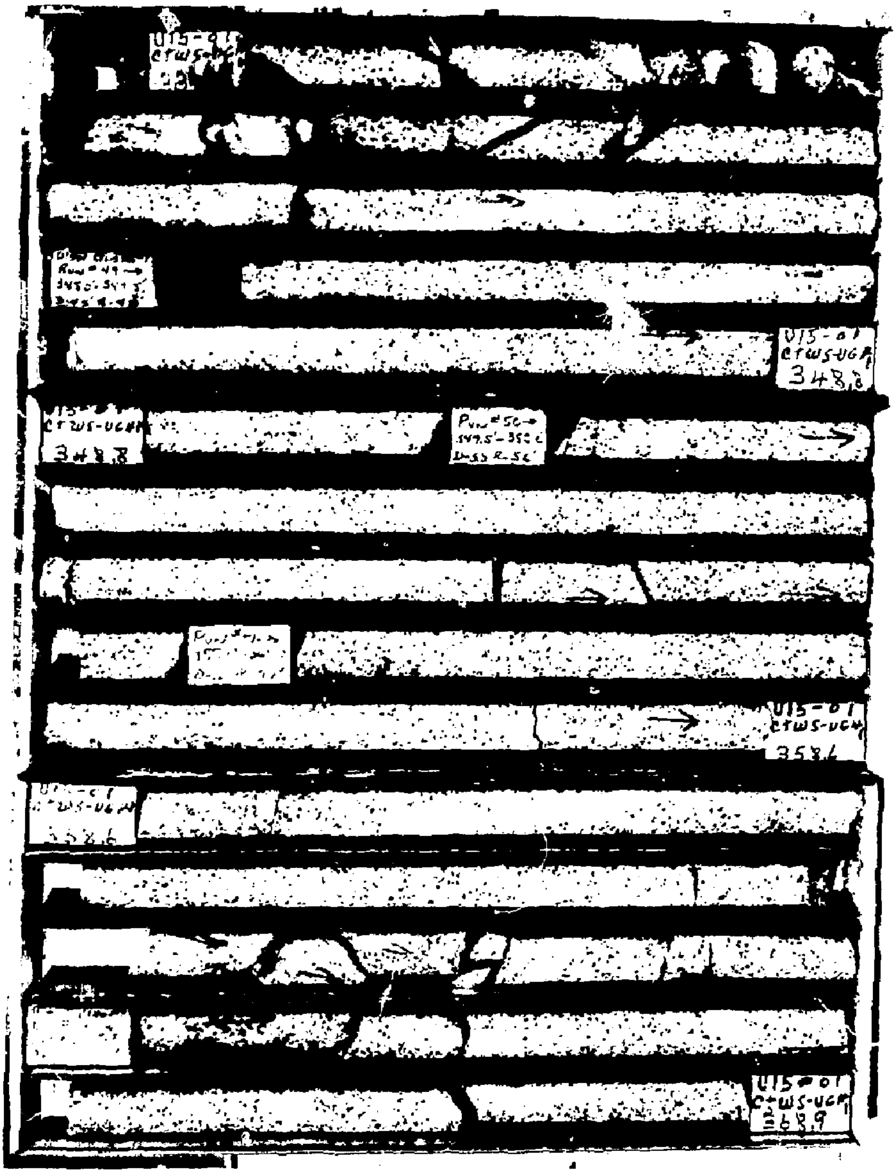


Figure 18. Photograph of UG-1 core, 338.8 to 368.9 ft.

the drifts have led us to the conclusion that spatial changes in fault character are such that one would not anticipate being able to identify this fault from the UG-1 core as anything other than an intensely jointed, highly altered, possibly sheared zone.

We attempted to correlate other major features, that might be encountered during the excavation, by considering possible orientations for these features. We did this by assuming that the features would be one of the joint sets or faults reported by Maldonado. We compared possible orientations of each feature, based on the inclination to the core axis, with the orientation of the known joint sets and faults to identify probable orientations. Table 4 is an example of the analysis. We tried to correlate between boreholes using these probable attitudes. This was facilitated by use of a fence diagram showing the four boreholes with the major features having the assumed orientations. When we projected features to similar features in other boreholes with the same probable orientations, we could identify potential correlations.

There were large numbers of possible correlations, but we could not substantiate any of them, and superimposing them on each other caused much confusion. Therefore, we removed correlations of all features except those with the strongest, and therefore most probable correlations from the diagram. These features, as interpreted at that time, are shown in Fig. 16. Figure 19 shows features that were later mapped in the drifts in comparison with these probable correlations. As can be seen, the major feature (the fault) was identified, but in general there was no overall correlation between the core interpretations and actual mapping. This highlights the difficulty in correlating multiple sets of similar features without the aid of oriented core.

Table 4. Example of Detailed Possible Fracture Attitude Analysis for UG-1 Core.

UG-1 Core

Depth to feature, ft	Geologic description of feature	Inclination of feature to core axis	Bearing of core axis	Inclination of core axis	Possible attitudes of feature	Remarks
101-105	Moderately jointed with Fe oxide stains, slight feldspar alteration	75-80°	N60W	+1°	N30E-75-80° SE/NW	Correlates with fence dia. except that the dips are too low Matches a regional Joint set
					N45W-vertical	Correlates with fence diagram
					N15E-vertical	No correlation
101-105	Same	40-65°	N60W		N30E-40-60°SE/NW	Dips too low To match regional
					N55E-89°	No match
					N80E-89°	No match
					N05E-89°	No match
					N20W-89°	No match
101-105	Same	10°	N60W	+1°	N50W-vertical	Weak match
					N70W-vertical	Matches regional
					N30E-10°SE/NW	No match
107-109	Very intense jointing. Occasional iron stains	70°	N60W	+1°	N30E-70°	No match
					N40E-vertical	No match
					N10E-vertical	No match

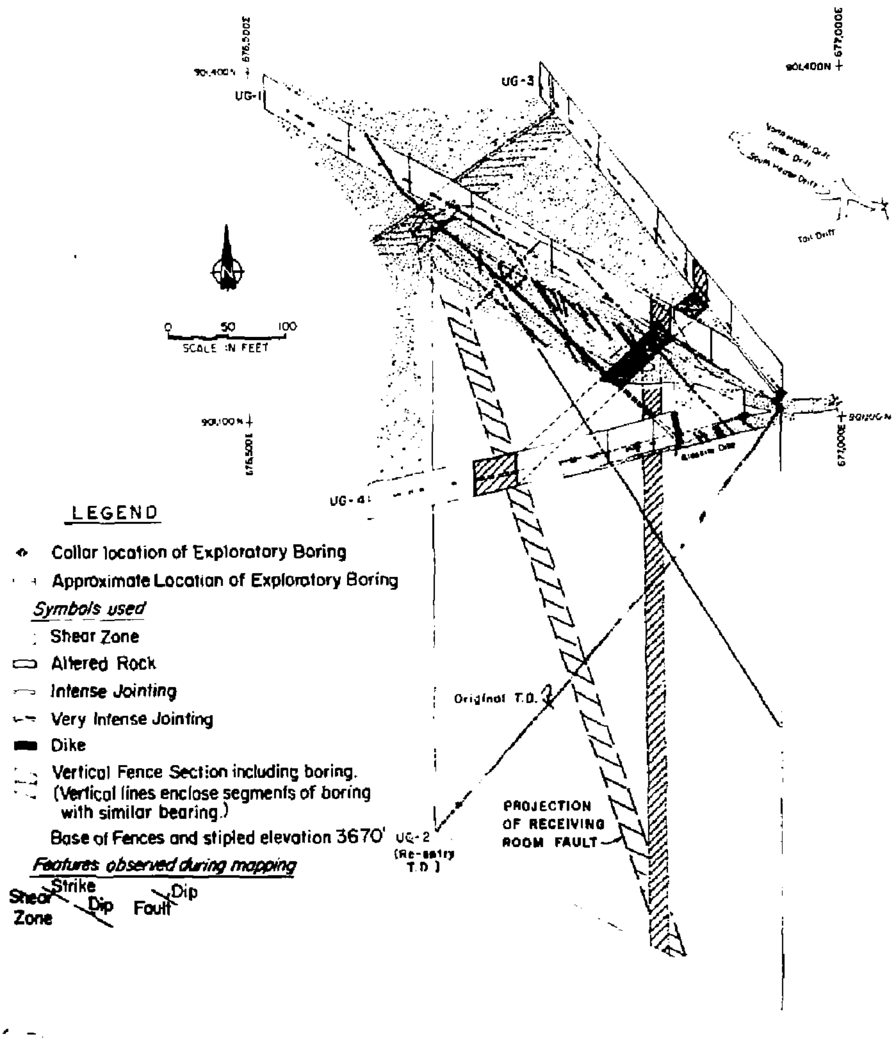


Figure 19. Fence diagram of SFT-C showing geologic interpretation from exploratory coring and drift mapping.

5.2 Characterization of Joint Frequency

In addition to the geologic interpretation from the core logging, some geotechnical insight can be gained from RQD and joint frequency information from the core. A complete and detailed analysis of these parameters, which is beyond the scope of this report, will be presented in subsequent reports. Fracture frequencies for entire boreholes and some analyses of these frequencies are included here for information.

Table 1 listed joint frequencies for cored holes from the SFT-C. Frequencies are presented separately for open joints and for healed joints. Open and healed joints were tallied over the length of each hole, excluding excavation-induced rubble zones sometimes encountered at the hole collar or open fractures judged to have been induced by drilling and core removal. The complete counts of open and healed joints were then divided by the length of the hole to obtain the frequencies shown in the table. To avoid length biases, only the first 150 ft of the four UG-series holes were tallied for this presentation; furthermore, only open joints were logged for these four holes during SFT-C exploratory drilling.

In addition to analyzing borehole fracture frequencies, we performed a statistical analysis of fracture frequencies within the exploratory boreholes. We chose the exploratory boreholes because they were sufficiently long to contain a meaningful number of fractures. We prepared tallies for 150 ft intervals of each UG hole because each of the UG holes could be easily broken into two, three or four such intervals for evaluation of fracture variations with hole depth. A 150 ft interval usually contained roughly 100 open joints, whereas smaller intervals did not always contain enough open features for statistical analysis, and larger intervals would prevent division of UG-3 and UG-4 into separate segments of equal length.

As can be observed (Table 1), fracture frequencies exceed one fracture per foot in most of the exploratory core. The frequency of open fractures varied from 0.3 to 1.1/ft, whereas the frequency of closed fractures varied by more than an order of magnitude, from 0.3 to 3.3/ft. There are several possible explanations for the range of fracture frequencies and especially for the much larger range of frequencies of the closed joints.

One possibility is that the individuals logging the core used differing criteria for identifying the features. Logging criteria should have less effect on the open fractures, which would explain the greater variation in the closed fractures, and therefore this explanation seems quite likely. A similar variation between mapped sections has been noted (Wilder and Yow, 1981). However, the variation in mapping was greater for the high-angle or open fractures than for the low-angle or closed fractures, whereas the core shows greater variation in the closed fractures.

A second possibility is that jointing varies throughout the SFT-C and that the core data accurately reflect the joint systems. It is interesting to note that the holes that have a lower frequency of closed joints also have a lower number of open fractures. The open fractures are readily identifiable, and therefore their fracture frequencies are insensitive to the level of skill or criteria used. Because observed fracture frequencies for open fractures vary, it appears likely that there are differences in joint frequencies within the stock. Figure 20 shows the location of MBI boreholes in relation to the location of shear zones. This comparison is interesting, but it should be pointed out that a borehole could cross a shear zone but be located mainly in unsheared rock so that the overall joint frequency would still be low. This comparison between fracture frequency and geologic features of limited thickness would be more valid if joint frequencies were calculated over

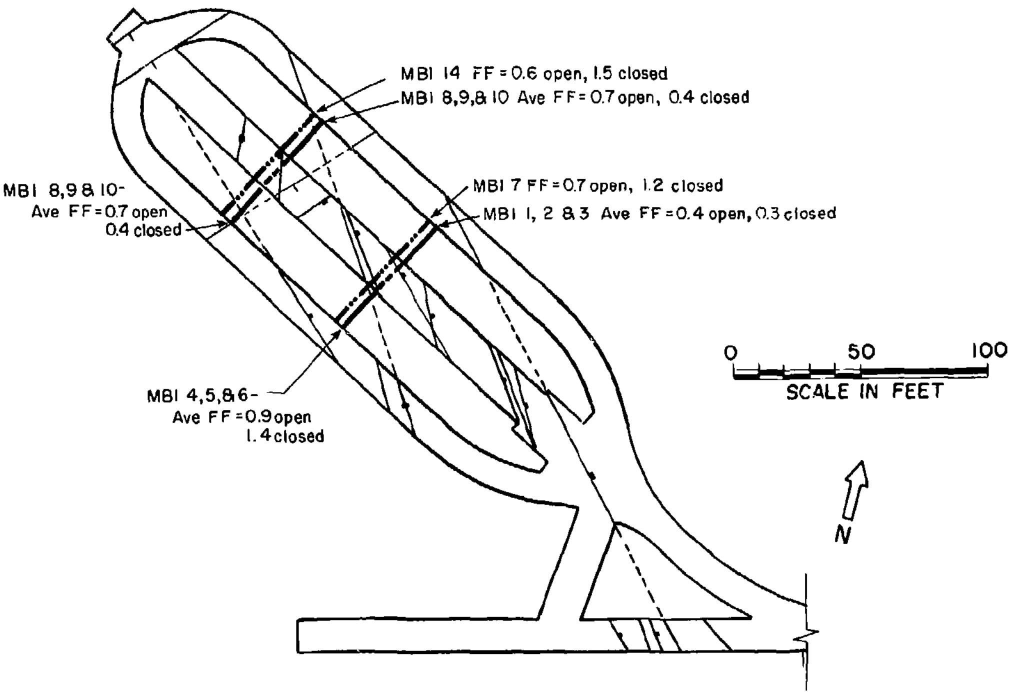


Figure 20. Joint frequencies related to geology.

smaller intervals. Furthermore, unless a relationship can be identified between the formation of the low-angle joint sets (which tend to be closed) and the formation of high-angle joint sets and shear zones, the fact that both open and closed frequencies are low in the same holes must be considered coincidental. To date, no such relationship has been demonstrated, and indeed there are strong indications that the different joint sets were formed at different times under differing stress fields so that this explanation must be considered tenuous.

A third possible explanation is that the conditions under which the logging was performed influenced the results. Of the three explanations suggested, this one is considered the most likely to be correct, especially for the closed or healed joints. The boreholes that show low fracture frequencies, mainly some of the MBI holes, were logged underground under less than ideal lighting conditions and without adequate facilities to clean or wash the core. In general, the core that exhibits the higher frequencies was logged at the USGS core library under good lighting conditions and with adequate facilities and water for cleaning the core. This would explain why the closed features, many of which are quite small and tend to be masked by dirt, would show up more frequently in core logged at the USGS. It was noted during drift mapping that the closed fractures would not show up unless the ribs were damp. However, as can be seen in Fig. 20 and Table 1, there is also a higher frequency of open joints in the MBI holes that were logged at the USGS core library (MBI 5, 7, 11, and 14) than in those logged underground (MBI 1-4, 6, 8-10, 12, and 13). Because open joints are readily distinguishable, however, the increased open joint frequency cannot be adequately explained by the better logging facilities at the USGS. It is possible that some of the healed joints were broken open during transport so that there were more open joints in the cores logged at USGS. On the other hand, there is not enough variation in the frequencies of the open joints to conclude that the variation is other than real.

If closed joints were not identified because of less than ideal logging conditions, than the mapping likely had similar problems because conditions were basically similar for both mapping and the core logging performed underground, except that the ribs were washed down which may have helped in the mapping. The fracture frequency for high-angle features identified in the mapping averaged 0.64/ft, which is in the mid range of the frequency indicated by the core logging. The fracture frequency for low-angle (closed) features averaged 0.5/ft, which is considerably less than most of the core logging indicates. This frequency lends support to the explanation that the logging of low-angle (closed) joints in the core library facilitated the identification of these small and often subtle features. If logging conditions caused the variations, then it appears that variations in open fractures may reflect actual stock conditions, while variations in closed fracture frequencies may result both from variations in the stock and in logging conditions.

A fourth possible explanation is that the orientation of boreholes had an influence on the fracture frequency. As observed during mapping of drifts, the joint spacing for low-angle joints is less than the joint spacing for high-angle joints. Therefore, vertical boreholes should exhibit higher joint frequencies than horizontal boreholes. However, there does not seem to be a relationship between low-joint frequency and orientation in that many of the boreholes that show low joint frequencies have some vertical orientation components and the horizontal boreholes have as great or greater frequency as those with a vertical component. Therefore, even though it is quite likely that borehole orientation has some influence, it is not considered a major factor in the observed variation between fracture frequencies from different boreholes.

5.3 Characterization of Joint Spacing

Figures 21 thru 24 show the distribution of spacing of open joints encountered in the first 150 ft of the four UG holes. Figure 25 shows the aggregate distribution of spacings of open joints encountered in holes GAE 1, GBE 1, GCE 1, and GDE 1. Each histogram is normalized so that the height of each bar indicates a percentage rather than the actual count of open joints. The original tables from which these histograms were prepared counted intervals to the nearest 0.1 ft; a 0.2 ft class interval was selected for preparation of the histograms. Joint spacings greater than 7 ft are lumped into the last bar on each histogram.

Although analysis of joint spacing distribution from the histograms is not yet complete, at least two observations can be made now. First, the general shape of the distribution of joint spacings appears to be similar for holes oriented horizontally (Figs. 21, 23, and 24), vertically (Fig. 25), and at an angle from horizontal (Fig. 22). In each case, the spacings are concentrated at the low or left-hand end of the histogram. Very few large spacings were found, which is not surprising considering the pervasive nature of the jointing as indicated by mapping (Wilder and Yow, 1981). Second, in each case the distribution appears to be a negative exponential combined with some degree of clustering at the smallest spacings, similar to that reported by Priest and Hudson (1976). Because these histograms are only for exploratory holes, they do not include the closed fractures. These distributions and an analysis of the fractures will be elaborated upon in a subsequent report.

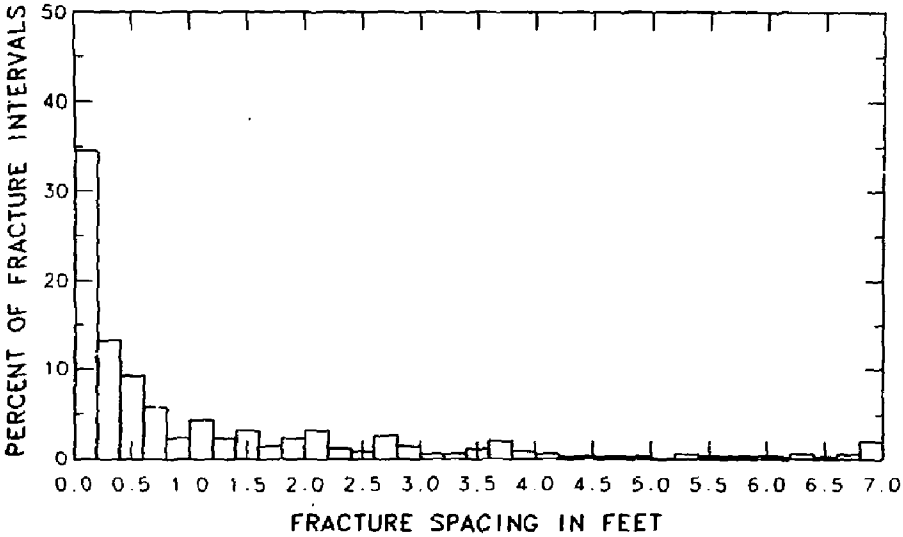


Figure 21. UG-1 joint frequency histogram.

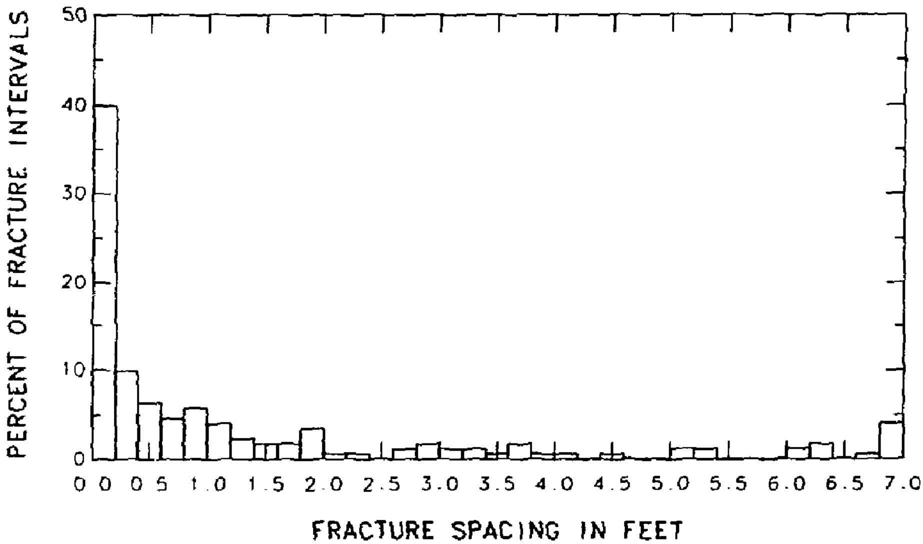


Figure 22. UG-2 joint frequency histogram.

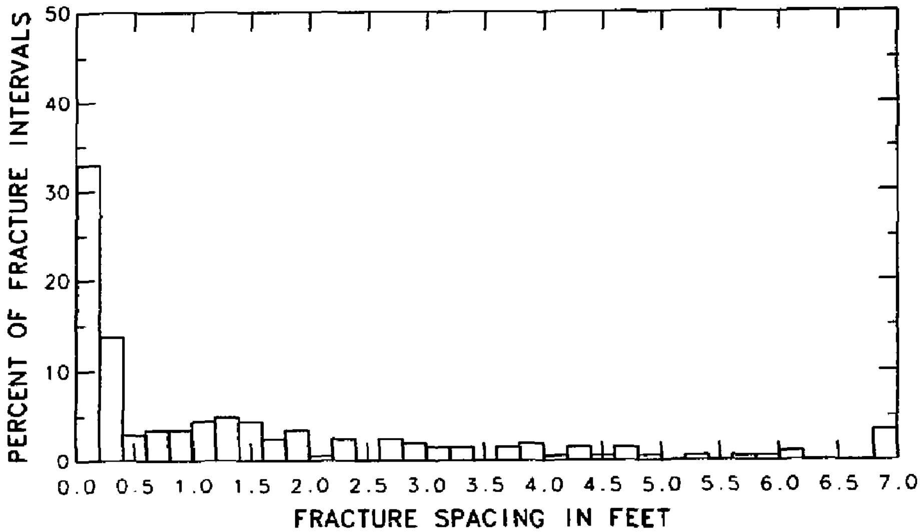


Figure 23. UG-3 joint frequency histogram.

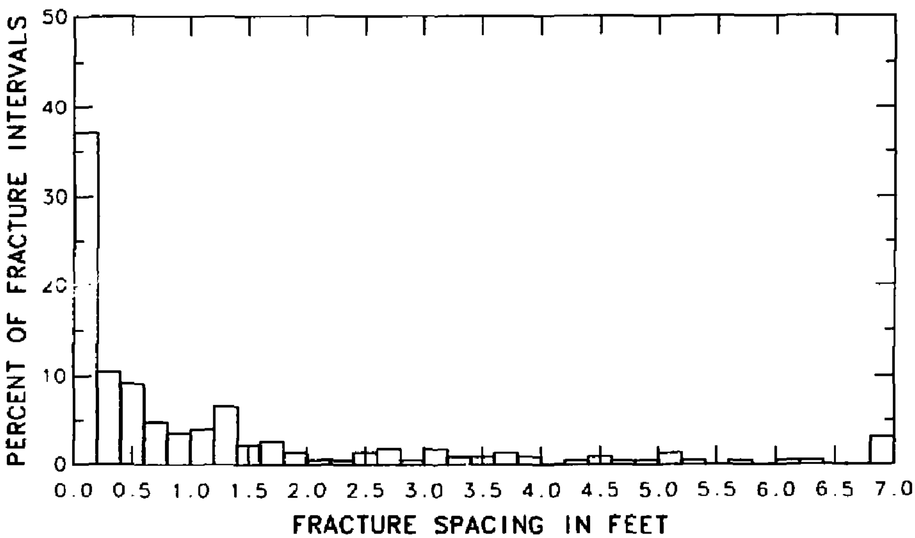


Figure 24. UG-4 joint frequency histogram.

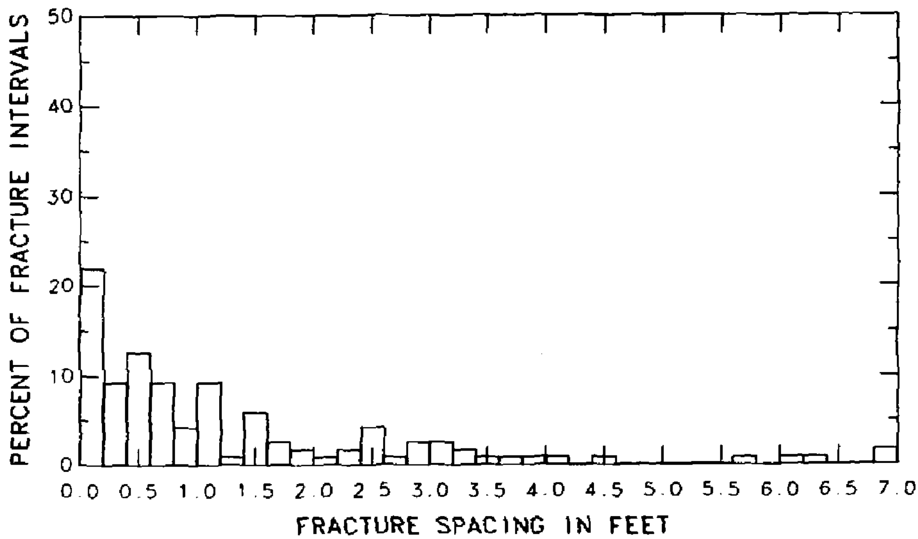


Figure 25. G x E-ls joint frequency histogram.

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APPENDIX A

EXPLORATORY CORE LOGS, UR-1 THROUGH UG-4

NOTE: Mineral originally identified on core logs as hornblende is biotite.

Summary Log

DH: UG-1

Drilled: 6/26 - 7/20/78

Location: Sta. 0+66, 1501 Tail Drift, Pile Driver Shaft

Bearing: Avg. N58^{o}W

Coordinates: N 901,110.545
E 676,346.410

Inclination: Avg. 1^{o} above Horizontal

Elev: 3674.389

Logged by D. W. Carpenter

0-503.7 Quartz Monzonite Porphyry

Medium gray igneous rock, hornblende, plagioclase, quartz dominant, variable percentage of pink K-feldspar phenocrysts to 3" max. size. Rock mass unweathered, dominantly unaltered, mostly very hard, unable to scratch rock with knife, very strong hammer blow required to break NX core.

Joint spacings variable as listed below, dominant inclinations 5-20^{o}, 40-45^{o}, 50-60^{o}, 70-80^{o}. Minerals on joint surfaces dominantly pyrite, calcite, sericite, some iron oxides; occasional quartz, clay, molybdenite.

0-4.0 Moderately to Intensely Jointed: Trace of iron oxide.

4.0-9.9 Moderately to lightly jointed.

9.9-53.3 Predominantly lightly jointed:

16.4-17.0 Very Intensely Jointed
@ 19.0 Feldspar slightly altered adjacent to pyrite vein inclined 15^{o}.
20 -29 Unjointed.
29.1-32.2 Moderately to Intensely Jointed.
39.5-39.8 Very Intensely Jointed: Feldspar partly altered adjacent to joint surfaces, iron oxide stains.
40 -49 Unjointed.

53.3-54.7 Intensely Jointed: Traces of iron oxide, slight feldspar alteration 1/4" into rock from joint surfaces.

54.7-100.7 Predominantly lightly jointed:

60.4-62.1 } Rock slightly altered, no loss of strength, abundant
63.9-64.0 } disseminated pyrite, scattered iron oxide stains.

71.7-73.3 }
75.3-75.6 } Moderately jointed, slight feldspar alteration on joint
78.6-79.3 } surfaces, some traces of iron oxide.

82.3-82.8
90.5-94.0

100.7-104.7 Moderately jointed: Traces of iron oxide, feldspar slightly altered 1/4" into rock from joint surfaces.
@ 103.2 1/2" pyrite vein inclined 40°, slightly vuggy.

104.7-107.5 Lightly jointed.

107.5-108.6 Very Intensely Jointed:

108.6-119.4 Predominantly moderately jointed.
116.2-116.8 Very Intensely Jointed: occasional iron oxide stains.

119.4-123.9 Predominantly Very Intensely Jointed: Feldspar partly altered 1/4" into rock from joint surfaces, some joints partly healed by calcite, pyrite, iron oxide.
@ 122.3 1/4" iron oxide filling on joint inclined 20°, scattered voids, filling fractured, possible shear.

123.9-166.5 Lightly jointed.
@ 137.1 Feldspar altered along joint inclined 60°.

166.5-172.2 Moderately jointed.
1/8" thick pyrite, sericite mineralization along 20° inclined joints, local voids.

172.2-186.6 Lightly jointed.

186.6-190.6 Moderately jointed:
Mineralization as 166.5-172.2 on 10 - 15° inclined joints.

190.6-211.6 Lightly jointed:
195.0-197.4 Core split on joint inclined 5°, hornblende alteration in adjacent rock, no loss of rock strength.
@ 201.5 Feldspar altered on surface of joint inclined 30°.
202.3-203.1 A few 1/16" dia. voids along joint inclined 15°.

211.6-219.3 Moderately jointed: Some joints partly healed by iron oxide.

219.3-219.6 Very Intensely Jointed: Rock partly altered, disseminated pyrite.

219.6-244.6 Predominantly lightly jointed:
223.3-223.6 / 229.3-230.2 > Intensely Jointed.
239.8-240.8 Intensely Jointed: Hornblende altered to 1" from joint surfaces, iron oxide stains.

244.6-252.6 Intensely to Very Intensely Jointed:
Core loss zone, rock altered adjacent to joint surfaces, occasional 1/16" dia. voids.

252.6-255.7 Unjointed.

255.7-258.0 Predominantly Very Intensely Jointed:
255.7-256.5 Iron oxide stains on joint surfaces.
257.6-258.0 Rock partly altered.

258.0-303.5 Predominantly lightly jointed:
267.1-269.1 Moderately jointed.
273.2-273.3 / 280.7-281.0 > Very Intensely jointed.
@ 286.5 Joints intersect, trace iron oxide.

303.5-304.6 Very Intensely Jointed: Scattered iron oxide stains.

304.6-322.0 Predominantly lightly jointed:
308.0-308.4 / 318.8-319.2 > Intensely jointed.

322.0-329.2 Predominantly Intensely Jointed: Scattered iron oxide stains on joint surfaces, hornblende, feldspar altered.
326.5-329.2
325.6-325.7 Shear Zone, inclined 60°, faint slickensides parallel inclination.

329.2-332.8 Moderately jointed.

332.8-336.8 Intensely to Very Intensely Jointed:
Iron oxide stains on joint surfaces, local hornblende alteration, no loss of rock strength.

336.8-338.8 Moderately jointed.

338.8-341.9 Predominantly Very Intensely Jointed:
Abundant iron oxide; rock highly altered, chalky, core easily scratched with knife.
@ 340.8 1/2" joint filling, calcite, iron oxide, voids to 1/8" dia, inclined 80°.

341.9-419.5 Predominantly lightly jointed:

362.7-364.4
368.1-368.9 > Intensely Jointed.

381.8-382.2 Granodiorite Dike: Fine to very fine grained, greenish grey, inclined 50°. Flow bands in 1/4" zones parallel tight contacts with Quartz Monsonite Porphyry.

386.1-386.2 Intersecting joints inclined 60° to 85°, 1/8" thick iron oxide coating on 85° joint.

386.2-390.2 Moderately jointed.

392.7-392.9 Very Intensely Jointed.

397.3-398.5 Core split on joint inclined 10°, tabular voids 1/16" x 1/2" max.

419.5-420.2 Very Instensely Jointed: Iron oxide on joint surfaces.

420.2-423.5 Moderately jointed: Iron oxide on joint surfaces.

423.5-424.2 Very Intensely Jointed: Iron oxide on joint surfaces.

424.2-431.5 Moderately jointed. Scattered iron oxide on joint surfaces.

431.5-438.4 Intensely to Very Intensely Jointed: Heavy iron oxide coatings on most joint surfaces.

438.4-440.1 Moderately jointed.

440.1-440.7 Very Intensely Jointed: Iron oxide on joint surfaces.

440.7-444.4 Unjointed.

444.4-445.2 Very Intensely Jointed: As 440.1-440.7.

445.2-474.2 Moderately to lightly jointed.

460.7-461.0 Very Intensely Jointed.

463.9-465.0 Intensely Jointed.

472.9-473.3 Very Intensely Jointed.

474.2-477.6 Predominantly Intensely Jointed. Joints mostly parallel, inclined 40-50°.

477.6-491.8 Moderately to lightly jointed.

485.7-486.1 Intensely jointed.

491.8-503.7 Lightly jointed.

EXPLANATION OF TERMS USED TO DESCRIBE JOINT FREQUENCIES

Lightly Jointed: Joint spacings dominantly exceed 1.5 feet, intervals with joint spacings in excess of 3 feet common.

Moderately Jointed: Joint spacings dominantly 0.5-1.5 feet, includes some short intervals with joint spacings as close as 0.3' and as wide as 2 feet.

Intensely Jointed: Joint spacings dominantly 0.25-0.5', includes some short intervals with joint spacings as close as 0.1' and as wide as 1 foot. Slight alteration often penetrates 1/4"-1/2" into rock mass from joint surfaces.

Very Intensely Jointed: Joint spacings dominantly less than 0.25', occasional spacing to 0.5' may exist. Rock mass usually partly altered, locally highly altered.

Summary Log

DH: UG-2 Drilled: 7/24 - 8/4/78

Location: Sta. 0+66, 1501 Tail Drift, Pile Driver Shaft

Bearing: Avg. N65°W

Coordinates: N 901,108.510
E 676,949.684

Inclination: Avg. 58° below horizontal

Elev: 3669.630

Logged by D. W. Carpenter

0-410.3 *Quartz Monsonite Porphyry*

Medium gray igneous rock, hornblende, plagioclase, quartz dominant, variable percentage of pink K-feldspar phenocrysts to 3" max. size. Rock mass unweathered, dominantly unaltered, mostly very hard, unable to scratch rock with knife, very strong hammer blow required to break NX core.

Joint spacings variable as listed below; dominant inclinations 5-20°, 40-45°, 55-70°, 75-85°. Minerals on joint surfaces dominantly pyrite, calcite, sericite, iron oxides as noted below, occasional clay, molybdenite.

0-3.5 Very Intensely Jointed: Poor core recovery.

3.5-40.5 Lightly jointed.
@ 20.4' 1/4" calcite filling on joint inclined 85°.
36.9-37.6 Intensely jointed.

40.5-41.9 Very Intensely Jointed:

41.9-49.3 Predominantly moderately jointed: slight feldspar alteration 45-49.2.
44.8-45.5
47.6-47.8 } Very Intensely Jointed.
49.0-49.3

49.3-135.7 Predominantly lightly jointed:

52.1-52.6
54.6-55.2 > Moderately jointed.

74.9-75.1 Very Intensely Jointed.

82 -92 Unjointed.

95.2-95.4 Very Intensely Jointed.

99.9-100.1 Rock altered, feldspar chalky, abundant pyrite, sericite; scattered tabular voids 1/16" x 1/4" max.

102 -129 Unjointed.

135.7-142.8 Very Intensely Jointed:

Joints coated with up to 1/8" clay, sericite, pyrite, iron oxide.

@ 137.0 Faint slickensides on joint, rake 45° to inclination.

142.8-145.7 Moderately jointed.

145.7-204.0 Predominantly lightly jointed.

152 -161
162 -172 Unjointed.

173.4-173.7 Core sr[illegible] on joint inclined 20°, heavy iron oxide c[illegible]ing; local faint slick[illegible]s, rake 80° to inclination.

196.1-198.7 Moder[illegible] jointed.

197.1-202.5 Granod[illegible]te Dike, tight contacts with Quartz Monzonite Porphyry subparallel core axis.

204.0-212.8 Moderately jointed.

212.8-248.4 Pre[illegible]ominantly Very Intensely Jointed: Rock highly altered, chalky, core [illegible]sily scratched with knife, fragments crumble on edges. Iron oxide, chalcocite(?) coat some joint surfaces. Alteration decreases below 220 ; some joints healed 226.5-244.2

213.1 Faint slickensides on fragments.

223.4-226.5 Moderately to intensely jointed.

244.2-247.0 Moderately jointed.

248.4-263.4 Predominantly lightly jointed:

252.2-253.7 Moderately jointed.

263.4-265.2 Predominantly Very Intensely Jointed: Iron oxide on some joint surfaces.

265.2-297.0 Predo[illegible]ntly lightly jointed:

277.6-278.0 [illegible]ately jointed, trace of iron oxide on joint surfaces.

284.8-287.6 Moderately jointed.

297.0-298.2 Intensely Jointed.

298.2-327.0 Predominantly lightly to moderately jointed:

300.6-301.2 Very Intensely Jointed.

@ 305.0 Pinhead sized voids along joint inclined 70°.

327.0-365.0 Predominantly Very Intensely Jointed: Rock altered similar to 212.8-248.4' interval; iron oxide on some joint surfaces, traces of chalcocite(?) to 344.5'.

@ 339.3 3/4" gray calcareous clay fills joint inclined 70°. no slickensides.

342.5-344.5 Rock heavily altered, recovered entirely as fragments.

344.5-349.4 Lightly to moderately jointed.

365.0-393.5 Predominantly lightly jointed:

379.1-379.9 Moderately to intensely jointed.

380.5-381.0 Very Intensely Jointed: Traces of iron oxide on joint surfaces.

386.3-387.0 Joint inclined 15°, healed by iron oxide.

393.5-394.5 Very Intensely Jointed:

394.5-410.3 Predominantly lightly jointed:

403.7-407.0 Moderately to intensely jointed, core frequently split on joints inclined 10°-25°.

EXPLANATION OF TERMS USED TO DESCRIBE JOINT FREQUENCIES

Lightly Jointed: Joint spacings dominantly exceed 1.5 feet, intervals with joint spacings in excess of 3 feet common.

Moderately Jointed: Joint spacings dominantly 0.5-1.5 feet, includes some short intervals with joint spacings as close as 0.3' and as wide as 2 feet.

Intensely Jointed: Joint spacings dominantly 0.25-0.5', includes some short intervals with joint spacings as close as 0.1' and as wide as 1 foot. Slight alteration often penetrates 1/4"-1/2" into rock mass from joint surfaces.

Very Intensely Jointed: Joint spacings dominantly less than 0.25', occasional spacing to 0.5' may exist. Rock mass usually partly altered, locally highly altered.

Summary Log

DH: UG-3 Drilled: 8/18 - 8/24/78

Rig Location: Sta. 0+70, 1501 Tail Drift, Pile Driver Shaft Bearing: Avg. N37°W

Coordinates: N 901,113.489 E 676,950.718 Inclination: Avg. 1° above Horizontal

Elev: 3674.498 Logged by D. W. Carpenter

0-330.3 Quartz Monzonite Porphyry

Medium gray igneous rock, hornblende, plagioclase, quartz dominant, variable percentage of pink K-feldspar phenocrysts to 3" max. size. Rock mass unweathered, dominantly unaltered; very hard, unable to scratch rock with knife, very strong hammer blow required to break NX core.

Joint spacings variable as listed below, dominant inclinations 0-30°, 40-55°, 60-65°, 70-80°. Minerals on joint surfaces dominantly calcite, sericite, pyrite quartz, occasional clay, molybdenite; iron oxides locally noted as listed below.

0-5.0 Moderately to Intensely Jointed: Pyrite commonly tarnished, occasional iron oxide stains.
1.5-2.0 Recovered as fragments, possible core loss.

5.0-13.7 Predominantly moderately jointed:
6.4-6.8, 13.6-13.7 > Very Intensely Jointed, iron oxide stains on joint surfaces.

13.7-72.4 Predominantly lightly jointed:
@ 25.5 Iron oxide stained joint inclined 80°.
@ 42.4 1/4" quartz-pyrite zone along joint inclined 45°.
58.2-59.5 Rock partly altered, hornblende chloritized, feldspar chalky, abundant quartz phenocrysts, no loss of rock strength.
70.0-70.5 Intensely Jointed.

72.4-79.4 Predominantly moderately jointed:
73.8-74.2 Intensely Jointed.
76.9-79.4 Core split on joint inclined 0-10°, local 1/16" x 1/8" voids.

79.4-100.0 Lightly jointed.

100.0-102.4 Very Intensely Jointed: Slightly altered, feldspar chalky.

102.4-107.3 Lightly jointed.

107.3-109.3 Predominantly Very Intensely Jointed: Slightly altered as 100.0-102.4

109.3-232.0 Predominantly lightly jointed:
124 -132, 135 -141, 146 -153, 213 -221: Unjointed.
130.8-132.0, 141.4-143.9, 156.4-158.0: Abundant disseminated pyrite, quartz.
145.0-145.4, 163.3-163.7: Very Intensely Jointed.
187.1-189.1 Moderately to Intensely Jointed.
207.8-208.3 Very Intensely Jointed.
226.6-227.0 Quartz-pyrite vein with inclusions of altered Quartz Monzonite Porphyry; tightly healed then refractured at 45°.

232.0-234.1 Very Intensely Jointed:
Possible core loss; voids to 1/8" dia. on some joint surfaces.

234.1-244.1 Moderately jointed.
@ 243.4 1/8" dia. voids on joint inclined 45°; trace of iron oxide.

244.1-266.0 Lightly jointed.

266.0-268.1 Intensely Jointed:
Occasional iron oxide stains.

268.1-269.9 Moderately jointed.

269.9-271.7 Very Intensely Jointed: Possible core loss.

271.7-273.7 Intensely Jointed:
@ 272.5 Heavy iron oxide stains on joint inclined 25°.

273.7-287.5 Lightly jointed.

287.5-291.7 Intensely Jointed.

291.7-293.7 Very Intensely Jointed: Rock partly altered, feldspar chalky.

293.7-302.8 Lightly jointed.

302.8-311.8 Predominantly moderately jointed:
309.3 > 309.6 Parallel iron oxide stained joints inclined 50°.

311.8-313.5 Very Intensely Jointed: Rock highly altered, core fragments break in hands, easily scratched with knife. Joints heavily iron oxide stained, possibly open.

313.5-315.0 Moderately jointed: Joints iron oxide stained.

315.0-327.7 Lightly jointed.

327.7-330.3 Moderately jointed.

EXPLANATION OF TERMS USED TO DESCRIBE JOINT FREQUENCIES

Lightly Jointed: Joint spacings dominantly exceed 1.5 feet, intervals with joint spacings in excess of 3 feet common.

Moderately Jointed: Joint spacings dominantly 0.5-1.5 feet, includes some short intervals with joint spacings as close as 0.3' and as wide as 2 feet.

Intensely Jointed: Joint spacings dominantly 0.25-0.5', includes some short intervals with joint spacings as close as 0.1' and as wide as 1 foot. Slight alteration often penetrates 1/4"-1/2" into rock mass from joint surfaces.

Very Intensely Jointed: Joint spacings dominantly less than 0.25', occasional spacing to 0.5' may exist. Rock mass usually partly altered, locally highly altered.

Summary Log

DH: UG-4 Drilled: 8/17 - 8/24/78

Rig Location: Sta. 1+05, 1501 Tail Drift Pile Driver Shaft Bearing: S76°W

Coordinates: N 901,093.732 Inclination: 2° above Horizontal
E 676,919.906

Elev: 3674.736 Logged by D. W. Carpenter

0-330.7 Quartz Monzonite Porphyry

Medium gray igenous rock, hornblende, plagioclase, quartz dominant, variable percentage of pink K-feldspar phenocrysts to 3" max. size. Rock mass unweathered, dominantly unaltered; very hard, unable to scratch roc with knife, very strong hammer blow required to break NX core.

Joint spacings variable as listed below, dominant inclinations 0-20°, 0-50°, 60-70°, 75-85°. Minerals on joint surfaces dominantly calcite, sericite, pyrite, occasional clay, quartz, molybdenite; iron oxides locally noted as listed below.

0-5.4 Moderately to Intensely Jointed.
@ 5.4 Joint inclined 20°; abundant sericite, some pyrite disseminated in rock mass to 1" out from joint surface.

5.4-11.7 Lightly jointed.

11.7-15.1 Predominantly Intensely Jointed.

15.1-20.0 Moderately jointed.

20.0-23.0 Intensely to Very Intensely Jointed.
@ 20.1 Joint inclined 75°, faint slickensides, iron oxide stains.
21.1-21.6
22.9-23.0 > Feldspar altered, chalky, to 1/4" into rock from joint surfaces.

23.0-79.6 Lightly jointed.

30-51 > Essentially unjointed.
59-79

54.0-58.5 Alaskite(?) Dike: Hard, brittle, tight contacts with Quartz Monzonite Porphyry inclined 90° to core axis.

79.6-80.9 Very Intensely Jointed:
Joints mostly inclined 65°. Rock altered, chalky up to 1/2" from joint surfaces.

80.9-92.1 Moderately jointed.

92.1-95.0 Predominantly Very Intensely Jointed:
Dominant joint inclinations 35-45°, 60-65°. Rock altered, similar to 79.6-80.9.

95.0-130.6 Predominantly lightly jointed:
102.2-103.1 Intensely Jointed, rock altered, feldspar chalky, abundant quartz phenocrysts, no loss of rock strength.

110-116 > Unjointed.
118-126

130.6-135.4 Predominantly Intensely to Very Intensely Jointed.

135.4-148.2 Lightly jointed.

148.2-149.5 Intensely Jointed.

149.5-150.7 Very Intensely Jointed: Dominant joint inclinations 20° & 60°.
Rock altered throughout, fragments friable with difficulty, core easily scratched with knife.

150.7-200.5 Predominantly lightly jointed:
164.2-166.1 Moderately jointed.
181.5-181.9 Intensely Jointed.

199 -209 *Quartz Monzonite Porphyry* grades to dark, greenish gray facies.
203.0-204.9 Granite Dike, tight contacts about 90° to core axis.

200.5-207.7 Predominantly Intensely Jointed.

207.7-223.6 Predominantly moderately jointed:
@ 212.0 Joint inclined 85°, pinhead sized voids, trace of iron oxide on surfaces.

223.6-225.7 Very Intensely Jointed.
@ 225.7 Joint iron oxide stained, rock altered 1/4" in from joint surface.

225.7-231.2 Lightly to moderately jointed.

231.2-233.1 Intensely to Very Intensely Jointed:
Iron oxide stains on many joint surfaces.
@ 233.1 1/4" calcite, iron oxide filling in 25° inclined joint.

233.1-237.1 Unjointed interval.

237.1-237.6 Very Intensely Jointed.
Rock altered throughout.

237.6-242.7 Predominantly Intensely Jointed.

242.7-293.5 Predominantly lightly jointed.
257.4-258.3 Intensely Jointed, iron oxide stains on 70° inclined joint @ 257.4.
284.3-285.3 Intensely Jointed, slight feldspar alteration, iron oxide staining.

293.5-295.5 Very Intensely Jointed, abundant pyrite.

295.5-304.6 Predominantly moderately jointed:
@ 304.1 Heavy iron oxide stain on joint inclined 35°.

304.6-309.1 Predominatly Very Intensely Jointed, rock slightly altered, some iron oxide stained joints.

309.1-312.5 Predominantly moderately jointed:
@ 312.5 Iron oxide stained joint inclined 70°.

312.5-330.7 Predominantly lightly jointed.
322.2-323.9 Moderately jointed, joints dominantly inclined 10°, step-like surfaces.

EXPLANATION OF TERMS USED TO DESCRIBE JOINT FREQUENCIES

Lightly Jointed: Joint spacings dominantly exceed 1.5 feet, intervals with joint spacings in excess of 3 feet common.

Moderately Jointed: Joint spacings dominantly 0.5-1.5 feet, includes some short intervals with joint spacings as close as 0.3' and as wide as 2 feet.

Intensely Jointed: Joint spacings dominantly 0.25-0.5', includes some short intervals with joint spacings as close as 0.1' and as wide as 1 foot. Slight alteration often penetrates 1/4"-1/2" into rock mass from joint surfaces.

Very Intensely Jointed: Joint spacings dominantly less than 0.25', occasional spacing to 0.5' may exist. Rock mass usually partly altered, locally highly altered.