REPORT ON FAULTS AND SOIL FEATURES MAPPED
IN THE DISCHARGE TUNNEL EXCAVATION
MILLSTONE UNIT 3

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REPORT ON FAULTS AND SOIL FEATURES MAPPED IN THE DISCHARGE TUNNEL EXCAVATION, MILLSTONE UNIT 3

Introduction

Recent excavations for the Circulating Water Discharge Tunnel at Millstone Unit 3 exposed two fault zones on the floor and wall excavations of the cut and cover structure (Figures 1-4). Detailed investigations were undertaken to determine the seismic capability of the features. The faults were found to be similar in orientation and character to other faults previously mapped at the Millstone 3 site and are probably genetically related to them. The results of our investigation indicate that these faults are incapable as defined by 10CFR Part 100. The evidence for this conclusion is presented below.

Fault 2781

The first fault encountered, numbered 2781, showed 2.5 in. of reverse offset of a biotite-rich seam near the base of the north wall and 1.5 in. of apparent right lateral offset of a pegmatite vein on the floor. The fault trends N07W and dips 45^{o} to the W. Slickensides on the fault surface indicate movement directly up dip for the hanging wall. The fault zone is relatively narrow (0-4 in) with minor clay gouge and fractured rock. A sample of clay gouge was collected for radiometric age dating analysis but proved to contain insufficient illite for age determination. The clay analysis is included as Appendix A.

Unconsolidated soil deposits overlying exposures of the fault on the walls of the tunnel were examined and mapped. (See Figures 5, 6, and 7). Basal till was seen to overlie the fault directly and continuously with no offset, nor disruption of crude layering in the overlying ablation flow-till. Similarly, horizontally stratified outwash deposits were found to be continuous across the projection of the fault on the south wall and had no offsets of any kind (Figure 7). The evidence indicates tectonic movement prior to the last advance of ice about 15,000 to 18,000 yr. BP (Black, 1982 Appendix B; Caldwell, 1978).

Apparent shearing or drag of sandy layers in the ablation till adjacent to the glacially striated bedrock high on the north side of the tunnel is attributed to slumping and flow of till during deglaciation, the movement direction indicating gravitational sliding off the bedrock high (Black, 1982, Appendix B).

Fault Zone 2817-2819

The second fault zone uncovered is larger and more complex than the first and includes faults numbered 2817, 2818, and 2819. (See Figures 1, 3, 4, and 8). The zone strikes between N10-17E and dips 77-82 degrees NW. Measurable left and right lateral offset of pegmatite veins occurs along faults 2817 and 2818 to a maximum of 2.5 ft. Greater displacement is evident on 2819 as no continuity of structures could be identified across the fault in the width of the excavation. The 1.0 in to 1.5 ft wide zone is characterized as containing fractured rock, clay gouge, and drusy secondary quartz with heavy iron staining in some areas. Quartz crystals are found growing into the zone from most fault surfaces and may entirely enclose rock fragments in the zone. Previous studies of quartz crystals from Millstone indicated development at temperatures considerably higher than present surface conditions, meaning they are associated with hydrothermal activity. The last episode of hydrothermal activity in this part of New England is believed to be at least Cretaceous in age (NNECo, 1975).

A clay gouge sample was taken from the main fault zone for radiometric dating. Separated illite samples produced a K-Ar age of 142 million $\pm$6 million years for the material or Late Jurassic time. A copy of the age date analysis is included as Appendix C. This is the youngest reliable date so far determined for the Millstone site and could possibly represent an extension of tectonic activity of Late Triassic - Early Jurassic age. More likely, however, the age is a minimum resulting from argon loss during the hydrothermal activity associated with the quartz crystal development. The average of all previous gouge dates from the site is 179 million years.

The rock-soil interface above the fault zone has been carefully exposed and documented. (See Figures 9-12). On the south wall, offsets from 1 in. to 15 in. in the unconsolidated outwash material form a small fault-bound depression directly over fault 2819. Close examination of the till directly overlying the fault revealed synclinal but continuous layering within the till. Identification of the layering is enhanced by sand beds providing avenues for seepage of groundwater; these beds have subsequently been heavily iron stained and cemented (See Figures 9 and 10). The till-outwash contact was mapped above the fault zone and is not offset.

The basinal form of the faulted outwash in this area is believed to be the result of melting of a buried ice block with subsequent collapse and slumping of the overlying soil materials into the spaces left by the melting ice (Black, 1982, Appendix B). These features are quite common in glacial ice margin environments and are not of tectonic origin. Spatial correspondence of the soil structures and the bedrock fault is strictly coincidental.

The rock-soil interface above the north wall is not as well defined due to the more severe weathering and fracturing of the rock in this area. (Figures 11 and 12). No sharp boundary could be drawn where fault material ends and glacial material begins due to the heavy iron staining and abundance of clay from both glacial and tectonic origins. Basal till apparently was not deposited continuously over this area so lack of offset could not be verified. Crude stratification in the overlying flow till is not displaced, however.

Rock-Outwash Contact at Station 7 + 05

The bedrock surface drops sharply below tunnel grade near Station 7 + 05. From this point southeastward, the tunnel is primarily founded on till. Cursory inspection of the rock-soil contact at this point could possibly be interpreted as a fault contact due to the abrupt truncation of stratified outwash against the large, smooth joint face and the presence of small offset beds in the outwash sands.

Closer inspection reveals a glacially striated joint surface overlain with horizontally bedded deposits (except for cross-bedding) with no evidence of drag on any of the beds at the contact. (See Figure 13). The offsets are confined to particular beds, especially cross-bedded zones, and are not throughgoing. If the joint surface is a fault surface, last movement occurred prior to the formation of striations and deposition of the glacial material.

"Pseudo" Ice-Wedge Cast

Excavation of the soil-based section of the tunnel uncovered an unusual feature near Station 8 + 15. (See Figure 14 and 15.) It has been identified as an ice-wedge cast (Flint, 1964, p. 279) or a "pseudo" ice-wedge cast (Black, 1982). An ice-wedge cast is the cast of an ice wedge which has been filled with material which slumps and washes in from soil adjacent to the original opening. The original ice-wedge forms as a frost crack at the surface which gradually deepens and widens as more ice develops in the crack. Ice-wedges generally indicate the presence of permafrost during their formation. When the ice melts out as a result of warmer conditions, the hole created fills in with slumped material, creating the ice-wedge cast.

A "pseudo" ice-wedge cast can be formed in temperate climates and are formed by plastic flow of clayey material under differential overburden pressures. The displacement or flow of the subsurface clayey material creates a tension crack in overlying granular material which gradually slumps inward and fills the crack to form a "pseudo" ice-wedge cast. Black (1982) believes the features in Connecticut are of relatively recent origin, are not related to permafrost environments, and are still being formed today. Iron stained layers resulting from former groundwater levels were found to be displaced downward toward the central filled zone of the wedge at Millstone indicating formation after development of static groundwater levels. Whatever the timing of formation, the structure definitely is not of tectonic origin.

Other Faults

Two additional small faults were also identified in the excavation. Displacement was less than 1/2 in. on fault 2899 and about 3 in. on fault 2894. Displacements on both faults were observed to die out within the excavation. Neither fault had sufficient clay gouge for radiometric age dating.

Summary

The faults recently identified in the Discharge Tunnel excavation have been thoroughly investigated and documented. On the basis of the observable evidence, we believe that all the faults can be classified as incapable, according to the criteria set forth in 10CFR Part 100.

The faults are similar in orientation and character to other faults previously documented at the Millstone 3 site. The K-Ar age date of clay gouge in fault 2819 of 142 million ± 6 million years is compatible with other dates obtained for Millstone and falls within the generally accepted time frame of Triassic - Jurassic tectonic activity. This fault zone was also observed to contain undisturbed drusy quartz growths on the fault surfaces. Previous studies of fluid inclusions in fault zone quartz at Millstone suggested elevated temperatures for the quartz growth, conditions which have not been present at least since the Cretaceous.

The soil-rock interface above each of the larger faults was investigated in detail and found to be undisturbed. No movement has occurred since deposition of the glacial material between 15,000 and 18,000 years ago. All of the soil faults and disturbed bedding features have been attributed to glacial phenomena of one kind or another. There is no evidence for a tectonic origin for any of the soil structures.

REFERENCES

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Flint, R.F., 1964, Glacial and Quaternary Geology, John Wiley & Sons, Inc., N.Y., 892 pp.

Northeast Nuclear Energy Co., 1975, "Geologic Mapping of Bedrock Surface," Millstone Nuclear Power Station - Unit 3, Docket No. 50-423.

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May 28, 1982

Mr. Frank Vetere
Stone and Webster Eng. Corp.
P.O. Box 2325
Boston, MA 02107

Dear Mr. Vetere:

Samples analyzed by X-ray diffraction under Job No. 12179, P.O. No. E 21015, gave the following results.

Sample A contains ordered illite-smectite, ∿50% illite, randomly interstratified illite-smectite, ∿20% illite, and a trace of kaolinite. The two major phases are present in about equal amounts based on the areas of diffraction maxima between 15 and 17° 2 θ. No trace of feldspar was detected in the diffraction pattern. The sample is suitable for age measurement, and the dried < 2μ powder, flocculated with dilute HNO_3, is enclosed.

Sample B contains abundant potash feldspar and plagioclase in the < 2 and < 1μ fractions. A small amount of smectite and kaolinite is present, and abundant mica is evident. The mica is biotite-phlogopite, based on the very high intensity ratio of I001/I002. The sample appears to be comminuted metamorphic or igneous rock. It is unsuitable for dating fault movements, so no separation of the < 2μ fraction was performed.

Sample C is essentially pure smectite with minor (a few percent) amounts of ordered illite-smectite (50% illite) and kaolinite. The very small illite content makes it of doubtful utility for age determination. No separation was performed.

Diffraction patterns were obtained using a Siemens D-500 Diffractometer equipped with a copper tube and a graphite monochrometer. Standardization is based on the 26.66° line from a "Permaquartz" standard run with the same slit array, scanning direction, and time constant as the analytical runs. A check gave 26.64°2θ.

Clay suspensions (< 2 or < 1μ) were concentrated by ultracentrifuge, pipetted onto glass slides, dried at 90°C and analyzed dry. The slides were solvated by ethylene glycol vapor at 60°C for 24 hrs. and analyzed quickly to eliminate glycol evaporation. Mixed-layered clay interpretations are based on published work by Reynolds (Reynolds and Hower, 1970) Reynolds (1980).

Sincerely,

R.C. Reynolds, Jr.
Professor of Geology

RCR:sf

July 13, 1982
65 Sawmill Brook Lane
Willimantic, CT 06226

Mr. Frank Vetere
Lead Geotechnical Engineer
Stone & Webster Engineering Corporation
245 Summer Street
Boston, MA 02107

Dear Mr. Vetere:

At the telephoned request, June 28, 1982, of John H. Peck, I met with him and Richard Gillespie on July 2, 1982, at Millstone 3. The purpose was to check certain structures in the glacial deposits and soil in the trench excavated for the circulating water discharge tunnel. I was informed that detailed mapping had shown some narrow fault zones with very limited displacement and with clayey gouge whose radiometric age suggested Mesozoic. Underformed quartz veinlets in the gouge contained fluid inclusions that indicated elevated temperatures during crystallization. The temperature could be explained by considerable depth at time of formation or hydrothermal activity. Either source of heat, however, also pointed to considerable antiquity for the last activity of the bedrock faults. Yet, numerous small fractures, and other structures in the glacial deposits overlying or in the vicinity of the faults, were being suggested by some as possible evidence of post-glacial activity of the bedrock faults. If true, they would indicate activity in the last 15,000 years.

I examined the glacial deposits and soil for any possible evidence of post-glacial tectonic activity and to provide an explanation, if possible, for the small fractures and other structures in those unconsolidated deposits. In summary, I found no evidence of displacements in the glacial deposits and soil which can be related to bedrock fault activity. All the surficial structures seen are typical of normal complex movements occurring in sediments associated with wasting ice and of subsequent dewatering and compaction. These movements involved:

1. Water discharge from stagnant ice to all points of the compass,

2. Deposition of fluvial, lacustrine, and deltaic strata up to the angle of repose,

3. Penecontemporaneous deformation of susceptible beds by slump, flow, slide, creep, dewatering, and loading,

4. Deposition of flow till from ice masses into the stratified deposits with accompanying deformation,

5. Gravity movements from bedrock highs and ice highs of other kinds of glacial materials, and

6. The formation of sags, small kettles, with complex bordering faults over melting buried ice in topographic lows in bedrock and in glacial sediments.

Some structures, such as injection of till into joints in the bedrock, go back to the deglacial phase when considerable hydrostatic head was available, but the ice was not actively flowing. Other minor structures from piping and collapse are as recent as the dewatering brought on during the excavation of the trench. The others lie between those extremes.

Some specific details follow. Locations of features described along the trench are designated with respect to faults, to the rock-outwash contact at station 7+05, and a pseudo-ice-wedge cast. I understand you have photographs of all important structures except the one described next.

At fault 2781, on the north wall of the trench, a well polished and striated surface of the bedrock was exposed. On cleaning off a veneer of compact basal till that covered part of that surface the timing of displacement of small joint blocks of the rock became evident immediately. Two small joint blocks in the accompanying photo (Fig. 1) are separated from each other 1/4 to 1/2 in. by compact till; both are separated by about 1 in. of till from unjointed bedrock below. Moreover, the two joint blocks are offset horizontally up to an inch along the steeply inclined joint so that the south block (with 6 in. scale) juts to the west. The irregular edge of the joint is not worn or rounded in any way, nor is the block rotated as it would be if the ice were moving at the time of displacement. That displaced block would have been an obstacle to the moving ice that polished and striated the surface. The displacements and injection of till must have occurred after ice movement ceased, but while considerable hydrostatic head existed in the ice to inject the compact basal till into the joints. The displacements are typical of the spalling or fracturing that occurs during unloading of continental masses of ice thousands of feet thick. It is akin to rock bursts in mines. The unbroken rock below denies a deep-seated fault origin. The very dense compact basal till in the joints is often brittle enough to retain fractures if broken after unloading is completed. None were seen. In other places in the trench till was injected as much as 15 to 20 ft below the surface into small joints with various orientations.

At fault 2781 on the south wall, compact bouldery till covers the fault. Its finer portion is similar megascopically to that injected into the joints on the north wall. No breaks were seen in the till.

At fault 2819 on the south wall, compact basal till was seen locally in the fault zone on fractured ro[illegible] and was covered by stratified deposits. The sag structures in the stra[illegible]fied deposits are typical of those related to the melting out of small buried ice blocks to produce miniature kettles. It seemed reasonably clear in the trench extending southward along the fault that the southward moving ice had plucked irregularly the broken weak rock in the fault zone. The orientations of the sag structures and stratification in the sediments point to a bedrock low farther south. The orientation of the minor faults shows clearly that the sediments immediately over the fault have dropped like a graben. The fault would have to be a graben only 2 to 3 ft wide to generate the pattern of displacements seen in the drift. The kettle origin is commonplace and expected here.

The stratified drift at the rock contact at station 7+05 has numerous minor structures related to gravity movement and loading during deposition to small displacements related to collapse of piping conduits that formed probably by dewatering during excavation of the trench. Typical downdrag of sediments during compaction and dewatering appear along the rock face. All such structures are strictly normal and widespread in glacial deposits. I saw no reason to refer any of them to bedrock displacements.

The pseudo-ice-wedge cast is a term I have applied to similar features elsewhere in Connecticut. An abstract was published recently (copy attached), and a manuscript has been submitted for publication (a copy can be supplied if needed). In short, the wedge structure is typical of those produced by intermittent tension movements within the sediments. The opening produced allows blocks of stratified sediments on both sides to break loose from the host on small breaks inclined downward toward the apex or for material to simply flow into the void. Many wedges in Connecticut can be traced downward to their apices. The apices are mostly in finer sediments than the upper part or are at or in the water table. Typically, they are in polygonal array around kettles; single wedges commonly parallel topographic discontinuities, such as a stream or shore. Fluctuating water tables, loading, and creep of semi-rigid material over plastic material in the groundwater zone lead to their formation. Near Storrs, Connecticut, they are especially abundant in the upper part of kame terraces along streams where sediments are many tens of feet thick and are creeping intermittently toward a stream. The wedges disappear in the vicinity of the water table. In the one in the trench, the upper part of the wedge cuts dark brown iron-stained horizons and is younger than the oxidation. Near the apex, the iron stains swing out horizontally from the wedge into the sediments. The lowermost part of the wedge is in plastic fine sediments. Seemingly, the wedge has been extending itself downward as it widens. Movements are probably going on slowly but intermittently today. I see no reason why this wedge should be related to bedrock movements, nor do I know of any in Connecticut that are.

In conclusion, I reiterate my firm belief that no structures seen in the glacial deposits and soils in the discharge trench are related to post-glacial activity on bedrock faults. All structures seen are typical and normal for glacial complexes formed in proximity to wasting ice during deposition or later to normal gravity, compaction, dewatering, and related processes common to such sediments.

If a need to expand on these remarks arises, or if you have other questions, please feel free to contact me.

Respectfully submitted,

Robert F. Black
AIPG No. 1023

Enclosure 1 - photograph
Enclosure 2 - abstract

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA 02139 • (617) 876-3691

POTASSIUM-ARGON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

PRIORITY SAMPLE

Our Sample No. M-6233

Date Received: 6/4/82

Your Reference: P.O.#2199.073-480

Date Reported: 6/7/82

Submitted by: Frank S. Vetere
Stone & Webster Engineering Corp.
P.O. Box 2325
Boston, MA 02107

Sample Description & Locality: Sample A, less than 2 micron fault gouge, Millstone Nuclear Power Station - Unit 3.

Material Analyzed: clay sample, analysed as received.

Ar^{40*}/K^{40} = .008608 AGE = 142 +/- 6 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.02139	.752	.02133
.02127	.728	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
2.051	2.031	2.478
2.011		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

Table 1

List of Joints, Discharge Tunnel Floor Final Grade

Joint No.	Strike	Dip	Remarks
2780A	N68W	73N	Linear biotite seam 4 in. wide, parallel to foliation, weathered to soft, green clay, zone of shear.
2781	N07W	45W	Straight to sl. irregular, polished with slickensides, right lateral displacement of 1.5 in, 0 to 4 in. wide zone of fractured rock, minor clay, minor iron oxide stain.
2782	N30E	88S	Sl. irregular, dips to N and S, tight, iron oxide stain, soft, light green coating to 1/8 in.
2783	N03W	87E	Straight, smooth, clean, tight, minor iron oxide.
2784	N02E	80E	Straight, smooth, tight, thin white and lt. green, hard siliceous coating.
2785	N79W	70N	Linear, smooth to sl. rough, tight, thin siliceous coating, minor iron oxide.
2786	N12E	86W	Straight to sl. curved, smooth, soft lt. green filling to 1/4 in, minor iron oxide, dips to E and W.
2787	N21E	70W	Straight, tight, sl. irregular, thin siliceous filling.
2788	N10W	90	Curved to irregular, smooth, tight, clean.
2789	N82W	88 N&S	Straight to sl. irregular, smooth, tight, clean, sl. iron oxide.
2790	N12E	75E	Straight, smooth, clean, tight.
2791	N14E	90	Straight, smooth, clean, tight, set of 4, 6 to 12 in. spacing.
2792	N25E	88W	Straight, smooth, clean, tight.
2793	N14E	90	Straight to arcuate, smooth, clean, tight.
2794	N85W	85N	Straight, smooth, clean, tight, sl. iron oxide stain.

Joint No.	Strike	Dip	Remarks
2795	N11E	81N	Straight, very smooth, tight, white and green siliceous coating, minor iron oxide.
2796	N20E	79W	Curved to irregular, tight, sl. rough, soft green filling to 1/8 in.
2797	N02E	76W	Straight, smooth, sl. open, lt. green and white mineralization to 1/8 in, minor iron oxide.
2798	N01E	78W	Straight, smooth, sl. open, maroon coating.
2799	N02E	59W	Straight, tight, smooth, lt. green siliceous coating to 1/8 in, minor iron oxide.
2800	N60E	77N	Straight, tight, smooth, clean, minor iron oxide.
2801	N08E	78W	Straight to sl. en echelon, smooth, tight, clean, sl. iron oxide stain.
2802	N08E	78W	Straight, smooth, tight, soft lt. green coating to 1/16 in.
2803	N01E	78W	Straight to sl. undulatory, smooth, tight, thin lt. green and white filling, minor iron oxide.
2804	N24E	81W	Straight, smooth, tight, thin white coating, minor iron stain.
2805	N85E	83N	Linear to sl. irregular, smooth, soft lt. green coating, minor iron oxide.
2806	N10E	61W	Straight, smooth, tight, clean, minor siliceous coating.
2807	N05E	66W	Straight, smooth, tight, hard white mineral coating.
2808	N05E	78W	Straight, smooth, clean, tight.
2809	N21W	86W	Straight to curvilinear, smooth, clean, tight.
2810	N04E	61W	Straight, smooth, tight, fresh, thin white filling.

Joint No.	Strike	Dip	Remarks
2811	N04E	75W	Straight, smooth, clean, tight.
2812	N06E	90	Straight, smooth, tight, filled with quartz and soft siliceous material to 3/8 in.
2813	N17E	84W	Straight to sl. curved, smooth to sl. rough, tight, hard white siliceous coating to 1/16 in.
2814	N12E	83W	Straight, smooth, tight, thin white siliceous coating.
2815	N14E	87W	Straight, smooth, tight, thin white to lt. green siliceous filling.
2816	N10E	83W	Straight, smooth, tight, white to green siliceous coating, set of 2, 6 in. apart.
2817	N10E	83W	Sl. irregular zone 1.0 in wide, filled with drusy quartz, minor breccia, heavy iron stain, 1.3 ft left lateral displacement.
2818	N17E	77W	Sl. irregular to linear fault zone 1 to 6 in wide, filled with drusy quartz and fractured rock, 1.5 ft right lateral displacement, heavy iron oxide stain.
2819	N15E	81W	Linear zone of movement 2.0 ft wide filled with drusy quartz and breccia, minor clay, heavy iron oxide, unable to determine amount or sense of movement.
2820	N04E	84W	Straight to curvilinear, smooth, tight, white filling to 1/3 in.
2821	N21E	77W	Straight, smooth, tight, lt. green clay filling to 3/8 in.
2822	N12E	87E	Straight to discontinuous and en echelon, smooth to sl. rough, clean to filled 1/8 in. with green clay, set of 6, some drusy quartz, related to fault 2819.
2823	N05E	80E	Curved, smooth, tight, hard white siliceous coating to 1/16 in.
2824	N02E	85W	Linear, smooth, tight, clean.
2825	N06E	88E	Linear, smooth, tight, clean.

Joint No.	Strike	Dip	Remarks
2826	N10E	88W	Linear, smooth, tight, siliceous filling to 1/16 in.
2827	N05E	81W	Linear, smooth, tight, filled to 1/2 in. with siliceous material, some quartz crystal growth.
2828	N05E	82E	Sl. irregular, sl. rough to smooth, tight, thin siliceous coating.
2829	N10E	80W	Straight, smooth, tight, thin green coating.
2830	N02E	89E	Straight to sl. curved, smooth, tight, thin siliceous coating.
2831	N13E	6uW	Straight, smooth, tight, green and white siliceous filling to 1/8 in.
2832	N14E	80E	Straight, smooth, clean, tight.
2833	N13E	86E	Straight, smooth, tight to sl. open, green filling to 1/4 in.
2834	N12E	85W	Straight, smooth, tight, thin green and white siliceous filling.
2835	N13E	61W	Straight, smooth, tight, green and white filling to 1/2 in., surface vuggy with some quartz crystal growth, moderate iron stain.
2836	N08E	55W	Straight, smooth, tight, soft greenish fill to 1/4 in, sl. vuggy.
2837	N15W	81E	Straight, smooth, tight, clean.
2838	N04E	71W	Straight, smooth, tight, thin siliceous coating.
2839	N16W	87W	Straight to sl. irregular, smooth, tight, clean.
2840	N11E	67W	Straight, smooth, clean, tight, sl. iron oxide stain.
2841	N11E	79W	Straight, smooth, lt. green fill to 1/16 in., tight.
2842	N12E	72W	Smooth to sl. irregular, straight to curvilinear, tight, clean, minor iron oxide.

Joint No.	Strike	Dip	Remarks
2857	N20E	85SE	Straight to en echelon, smooth, tight, hard siliceous, crystalline coating with slight iron oxide staining.
2858	N10E	70NW	Straight, smooth, tight, dark green coating, minor iron oxide staining. Continuation of joint 2840.
2859	N05W	88E	Straight to sl. irregular, smooth, tight, hard dark green coating with moderate iron oxide staining.
2860	N12E	71SE	Straight to irregular, smooth to slightly rough, tight, clean.
2861	N06E	74SE	Straight, smooth, clean, tight, minor iron oxide staining.
2862	N18E	54SE	Straight, smooth, tight, very thin, hard siliceous coating, minor iron oxide staining.
2863	N06E	74SE	Straight, smooth, tight, white siliceous coating, minor iron oxide staining.
2864	N15E	75SE	Straight, smooth, tight, clean, minor iron oxide staining. Lies partially along the gneiss/granite contact.
2865	N09E	69SE	Straight, smooth to sl. rough, tight to sl. open, moderate iron oxide staining.
2866	N15E	65SE	Straight, smooth, tight, moderate iron oxide staining.
2867	N22E	84NW	Straight, smooth, tight, hard siliceous coating, moderate iron oxide staining.
2868	N10E	83SE	Straight to sl. irregular, white weathered coating to 1/16 in., moderate iron oxide staining.
2869	N15E	72SE	Arcuate, smooth, tight, clean.
2886	N23E	89SE	Straight, smooth surface, tight, dark green coating, very sl. iron oxide staining.
2887	N18E	65SE	Straight to curvilinear, smooth surface, tight, siliceous coating, slight iron oxide staining.

Joint No.	Strike	Dip	Remarks
2888	N08E	64SE	Straight, smooth surface, tight, clean, very slight iron oxide staining.
2889	N10E	77SE	Straight and irregular, smooth surface, tight, slight iron oxide staining.
2890	N15E	67SE	Straight, en echelon, smooth surface, tight, clean.
2891	N10E	56SE	Straight to sl. irregular and discontinuous, smooth surface, tight, clean, some iron oxide staining.
2892	N19E	73SE	Straight, smooth surface, open to 1/8 in, sl. iron oxide staining.
2893	N19E	73SE	Similar to joint 2892; sl. en echelon, open to 1/4 in.
2894	N20E	85SE	Straight, smooth surface, open to 1/8 in, filled with lt. green and white weathered material, minor iron oxide staining.
2895	N12E	61SE	Straight smooth surface, tight to open 1/8 in, minor iron oxide staining.
2896	N02E	69W	Straight, smooth surface, tight, iron oxide staining.
2897	N10E	62SE	Straight, smooth surface, tight to open 1/8 in., occasional greenish-grey siliceous coating, minor iron oxide staining.
2898	N11E	74NW	Straight, smooth surface, tight, clean.
2899	N14E	88NW	Straight, en echelon with a set of 2-4 about 5 in. apart, tight to open 1/4 in, white to greenish-grey siliceous coating, minor iron oxide staining.
2900	N20E	74SE	Sl. irregular, sl. rough surface, tight, white siliceous coating.
2901	N20E	77NW	Straight, sl. rough surface, tight to open 1/16 in, iron oxide staining.
2902	N28W	28NE	Irregular, rough surface, tight, minor iron oxide staining.
2903	N24E	80NW	Very straight, smooth surface, tight, clean.

Joint No.	Strike	Dip	Remarks
2904	N45W	62SW	Irregular, rough surface, tight, clean.
2905	N28E	63SE	Sl. irregular, sl. rough surface, tight, minor iron oxide staining.
2906	N08E	73NW	Straight, sl. rough surface, tight, minor iron oxide staining.

Table 2

List of Joints, Discharge Tunnel Walls

Joint No.	Strike	Dip	Remarks
956	N64W	63N	Sl. irregular, sl. rough, open to 1/4 in, minor iron oxide staining.
957	N05W	43SW	Same as floor joint 2781.
958	N73E	80S	Straight, sl. rough, tight, clean, very minor iron oxide staining.
959	N05E	85NE	Straight, smooth, surface filled with soft lt. green siliceous material to approximately 1/4 in, moderate iron oxide staining.
960	N20W	86S	Straight, smooth, tight, clean, very minor iron oxide staining.
961	N45W	86N	Straight, smooth, tight, clean.
962	N08E	78NW	Straight, smooth, sl. open with thin siliceous coating, moderate iron oxide staining.
963	N01W	77NE	Straight to sl. irregular, smooth to sl. rough surface.
964	N06E	55NW	Straight, smooth, tight, clean, moderate iron oxide staining.
965	N16W	84S	Straight, smooth to sl. rough surface, open to 1/4 in, clean, minor iron oxide staining.
966	N08E	78N	Same as floor joint 2802.
967	N10E	61N	Same as floor joint 2806.
968	N16E	83N	Straight, smooth, tight, minor iron oxide staining.
969	N69E	72S	Straight, smooth to sl. rough, open at top to 1/2 in, iron oxide staining.
970	N06E	65NW	Straight, smooth, tight, clean.
971	N01E	64NW	Straight, smooth, tight, clean.
972	N15E	79NW	Straight, smooth, tight, clean.

Joint No.	Strike	Dip	Remarks
973	N66E	85W	Straight to sl. irregular, smooth, open to 1/4 in, lt. green siliceous coating, minor iron oxide staining.
974	N06W	88E	Straight to curvilinear, smooth to sl. rough, tight to sl. open, thin siliceous coating and quartz filling to 1 in. Discontinuous set of six joints. Heavy iron oxide staining. Same as floor joint 2817.
975	N10E	76S	Similar to 974. Same as floor joint 2818.
976	N05	77W	Similar to 974. Same as floor joint 2818.
977	N03E	80W	Straight, smooth, open to 1 in, clay, siliceous filling, and crystalline quartz filling to 1 1/2 in, heavy iron oxide staining. Same as floor joint 2819.
978	N10W	86S	Straight, smooth, thin siliceous coating.
979	N01W	85S	Straight to irregular, smooth to sl. rough, tight with siliceous infilling to 1/16 in, moderate iron oxide staining.
980	N08W	89W	Straight, smooth, open to 1/4 in, clean, minor iron oxide staining.
981	N03W	89E	Straight, smooth, tight, clean, minor iron oxide staining.
982	N32E	83S	Straight to sl. irregular, smooth, tight, clean, minor iron oxide staining.
983	N10E	72S	Straight, smooth, tight, clean.
984	N23E	53N	Straight, smooth, tight, clean, minor iron oxide staining.
985	N48E	07S	Irregular, smooth to sl. rough, tight, clean, minor iron oxide staining.
986	N-S	72E	Straight to sl. curved, smooth, tight, thin siliceous coating, minor iron oxide staining.
987	N17W	83N	Straight, smooth, tight, clean.
988	N78W	86S	Sl. irregular, smooth to sl. rough, tight, clean, minor iron oxide staining.
989	N12W	42S	Same as floor joint 2781.

Joint No.	Strike	Dip	Remarks
990	N11E	65W	Curvilinear, smooth to sl. rough, open to 1/4 in, clean.
991	N01E	76E	Straight, smooth, tight, clean. Set of 3, 8 in. apart.
992	N86W	84N	Sl. irregular, smooth to sl. rough, tight, clean.
993	N03E	80E	Straight, smooth, tight, thin siliceous coating. Set of 3, 3-5 in. apart.
994	N08E	83E	Straight, smooth, tight, thin siliceous coating. Set of 3, 2-6 in. apart.
995	N25E	74E	Straight, smooth, tight, clean.
996	N83W	79S	Arcuate, sl. rough, tight, clean.
997	N15W	88N	Straight, smooth, tight, thin, lt. green soft siliceous coating.
998	N15E	85N	Straight to en echelon, smooth, tight, thin siliceous coating.
999	N18E	89NW	Straight, smooth, sl. open, lt. green coating. Irregular set of 6, 1-4 in. apart.
1000	N55W	90	Straight, smooth to sl. rough, open to 3/4 in, soft weathered siliceous fill to 3/4 in, heavy iron oxide staining.
1001	N20E	76NW	Straight, smooth, tight, clean, minor iron oxide staining.
1002	N13E	77NW	Straight to curved, smooth to sl. rough, open to 1 in, soft weathered lt. green fill up to 1 in.
1003	N16E	72NW	Straight, smooth, open to 1/2 in, lt. green soft weathered fill to 1/2 in.
1004	N50W	81S	Straight to undulatory, smooth, clean, forms face of excavation.
1005	N12E	75NW	Straight, smooth, open to 1/4 in, clean, iron oxide staining.
1006	N15E	82NW	Straight, smooth, tight, clean, iron oxide staining.

Joint No.	Strike	Dip	Remarks
1007	N10E	72NW	Straight, smooth, open to 1/4 in at top, clean, minor iron oxide coating.
1008	N06E	78NW	Straight, smooth, open to 1/8 in, clean, moderate iron oxide staining.
1009	N11E	87NW	Straight, smooth, open to 1/8 in, soft. lt. green siliceous fill, very minor iron oxide staining.
1010	N05E	80NW	Straight to sl. irregular, smooth, zone of quartz crystals, lt. green clay and rock fragments up to 1 in. wide. No offset detected.
1011	N12E	72NW	Straight, smooth, tight, clean, minor iron oxide staining.
1012	N03W	84NE	Straight to sl. irregular and discontinuous, smooth, open to 1/8 in, occasional lt. green coating, minor iron oxide staining.
1013	N10E	80SE	Zone of closely spaced fractures and discontinuous joints 1-6 in. wide. Smooth, tight to open 1/8 in. Some surfaces filled with soft green siliceous material, minor iron staining.
1014	N05E	82SE	Straight to sl. irregular, smooth to sl. rough, open to 1/4 in, soft green coating to 1/8 in, no offset.
1015	N13E	87SE	Straight to sl. irregular, 1/4-3 in. zone of gouge, rock fragments with quartz crystals growing on both surfaces of joint, smooth, apparent offset of 1.0 ft on vertical face with west side down.
1016	N13E	82NW	Zone of fractured rock and discontinuous joints. Gouge material from 4-8 in. wide in main zone of movement. Abundant clay, drusy quartz and crystals. Microcrystalline black zone of mineralization up to 3/8 in. wide on actual fault surface. Unable to determine amount or direction of offset. Several small left lateral offsets between joints 1015 and 1016. Same as floor joint 2819.

Joint No.	Strike	Dip	Remarks
1017	N21E	79NW	Straight, smooth, thin siliceous coating, tight, no offset.
1018	N10E	85NW	Straight, smooth, open to 1/8 in.
1019	N10W	86SW	Straight, smooth, open to 1/4 in, clean, minor iron oxide stain.
1020	N50E	84NW	Straight, smooth, open to 1/4 in, clean.
1021	E-W	04S	Sl. irregular, sl. rough, tight, thin weathered siliceous material.
1022	N44E	76SE	Straight to en echelon, smooth to polished, tight, white siliceous coating.
1023	N59E	75SE	Straight, smooth, tight to sl. open, clean.
1024	N55E	82SE	Straight, smooth, tight to open 1/4 in, clean, very minor iron oxide stain.
1025	N52E	80SE	Straight, smooth, tight to open 1/8 in, thin siliceous coating.
1026	N05E	67SE	Straight, en echelon with four joints at 10 in. spacing. Smooth surfaces, tight, white siliceous coating, moderate iron oxide staining.
1027	N25W	08NE	Irregular, rough, tight to open 1/4 in, heavily weathered, heavy iron oxide stain.
1028	N19E	66SE	En echelon with 3 joints at 4 in. spacings, sl. rough, tight, moderate iron oxide stain.
1029	N15E	84NW	Irregular, rough, open 1/8-1/4 in, clean.
1030	N14E	88SE	Straight, en echelon with 3 joints at 6 in. spacings, smooth, tight, clean.
1031	N12E	76SE	Very straight, smooth, tight, clean.
1032	N01E	83SE	Straight to sl. irregular, rough, tight to open 1/8 in, minor iron oxide staining.
1033	N15E	80SE	Straight, smooth, tight, iron oxide stain.
1034	N11E	66NW	Straight to sl. arcuate, smooth, tight, iron oxide stain.

Joint No.	Strike	Dip	Remarks
1035	N04E	79SE	Straight, en echelon with 8-10 joints at about 3 in. spacings, smooth but disjointed surfaces, tight, yellow-white siliceous coating, minor iron oxide stain.
1036	N35W	35NE	Irregular, rough and broken surface, tight to open 3/8 in, clean, approximately concordant to foliation.
1037	N20E	83SE	Straight, smooth, open 1/8-1/2 in, minor iron oxide stain.
1038	N80W	07N	Irregular, sl. rough, tight, iron oxide stained.
1039	N10E	76SE	Straight to en echelon, smooth, tight, minor iron oxide stain.
1040	N23E	76SE	En echelon with 4 joints spaced at about 5 in, sl. rough, open 1/4-1 in, iron oxide stained.
1041	N30E	81SE	Straight, en echelon with 4 joints spaced at 3 in, sl. rough, tight, clean.
1042	N10E	88SE	Straight, smooth to sl. rough, open 1/8 in and infilled with yellow-brown siliceous coating. Quartz stringers show 3 in. offset; 5 slickensides indicate normal faulting with east block down. One thin stringer and a 2-3 in. thick pegmatite vein show no displacement near top of south wall. Not traceable to north wall. Same as floor joint 2894.
1043	N18E	88SE	Straight to sl. irregular, sl. rough, tight, clean, minor iron oxide stain.
1044	N17E	86SE	Straight, smooth, open 1/8 in, filled with grey-green, soft, k-spar clay.
1045	N-S	65W	Straight, smooth, tight to open 1/16 in, minor iron oxide staining.
1046	N08E	70NW	Straight, smooth, tight to open 1/4 in. yellow-white to green-grey siliceous coating, minor iron oxide stain. Quartz stringers show 1/2 in. displacement at base of south wall but no offset near top of wall. Same as floor joint 2899. Offset not evident along floor.

Joint No.	Strike	Dip	Remarks
1047	N10E	63NW	Straight, rough, tight to open 1/8 in, white siliceous coating, iron oxide stain.
1048	N11E	74NW	Sl. irregular, smooth to sl. rough, tight, clean.
1049	N11E	84NW	Sl. irregular, sl. rough, tight, clean.
1050	N02W	76W	Irregular, rough, tight to open 1/8 in, clean.
1051	N12W	64SW	Straight, irregular, tight, clean.
1051A	N62W	77SW	Straight to sl. irregular, sl. rough, very tight, clean, 2 in.quartz vein along most of south end.
1116	N09E	63NW	Straight, smooth, tight, moderate iron oxide stain.
1117	N09E	63NW	Straight, smooth to sl. rough, tight to open 1/8 in, clean.
1118	E-W	84N	Arcuate, sl. rough, open 1/4", iron oxide stained.
1119	N51W	08SW	Sl. irregular and stepped, tight, heavy iron oxide stained.
1120	N86E	05SE	Straight, smooth, tight, iron oxide stain.
1121	N07E	61NW	Straight, sl. rough, tight, iron oxide stain.
1122	N10E	63NW	Straight but occasionally stepped 2-3 in, slightly rough, tight, iron oxide stained.
1123	N64W	84SW	Straight, smooth to sl. rough, iron stained.
1124	N15E	69E	Straight to curvilinear, smooth to sl. irregular, moderate iron oxide coating, glacial striae on surface.
1125	N21E	83NW	Straight, smooth, clean with some soil filling, open to 1/4 in, minor iron oxide.

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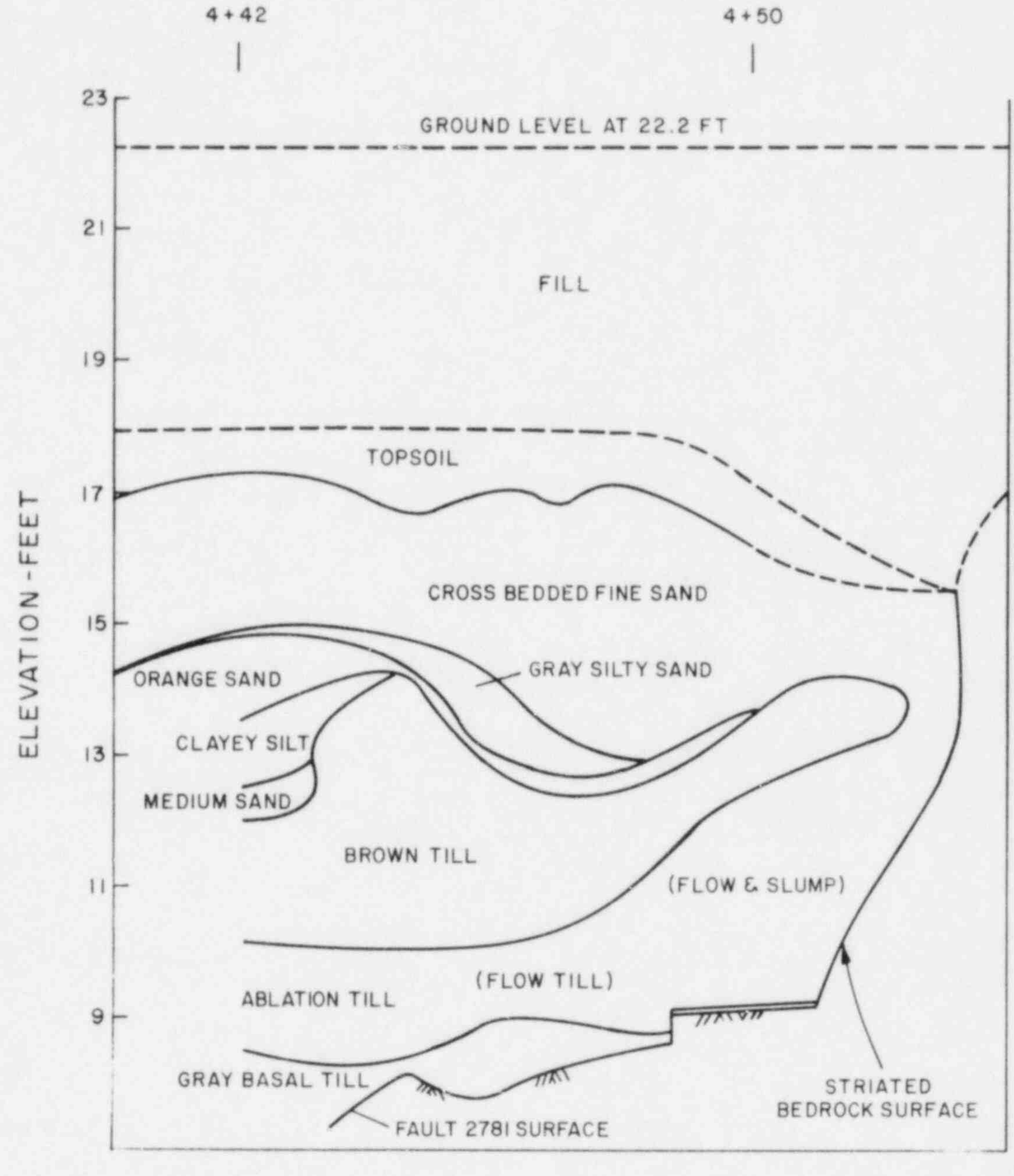

FIGURE 5
SKETCH MAP OF SOIL OVER FAULT 2781, NORTH WALL
MILLSTONE NUCLEAR POWER PLANT
UNIT 3

RULER IS ON FAULT SURFACE. NOTE CONTINUOUS GRAY TILL OVER FAULT

FIGURE 6

ROCK-SOIL CONTACT AT FAULT 2781, NORTH WALL

MILLSTONE NUCLEAR POWER STATION
UNIT 3

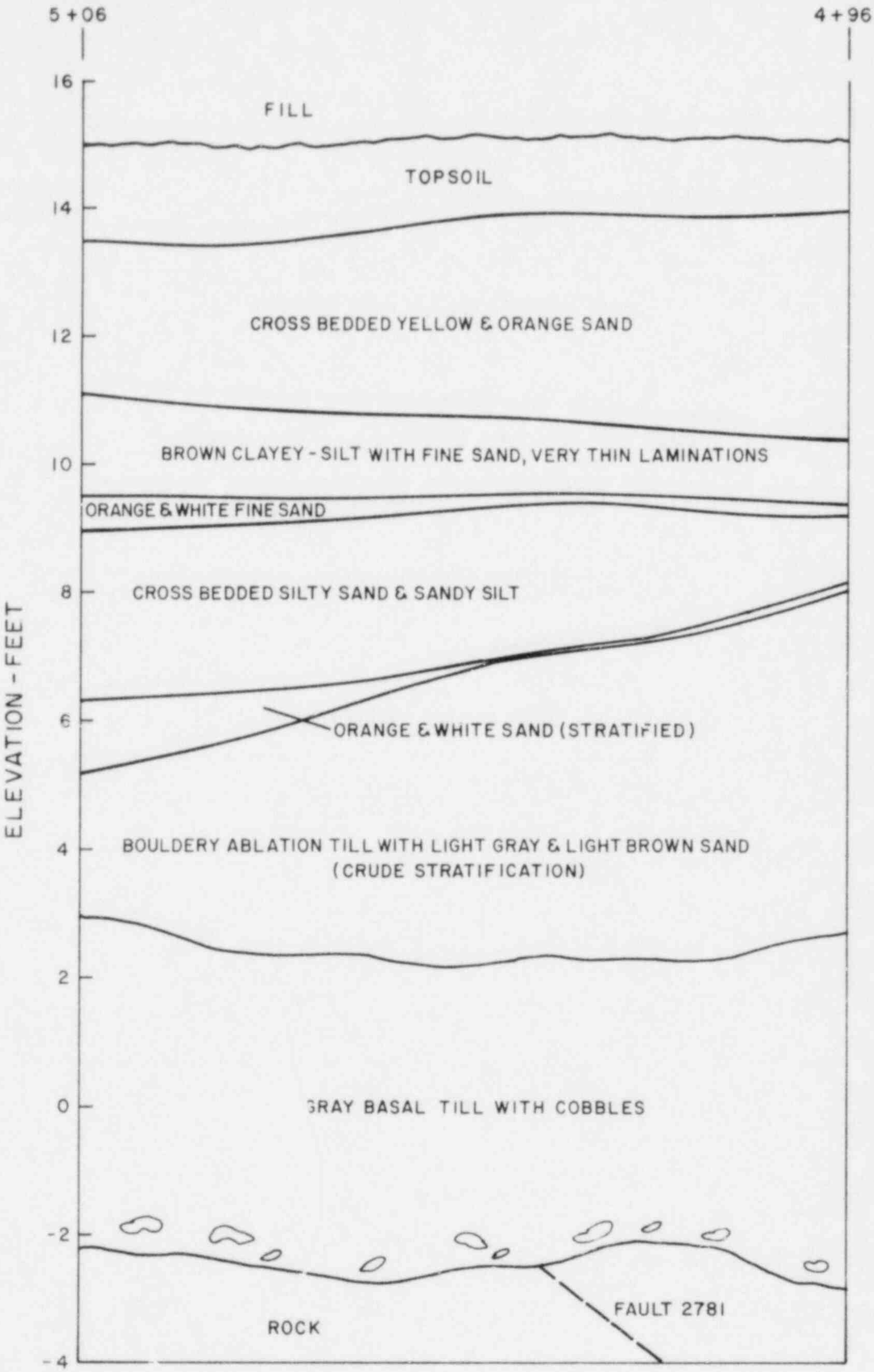

FIGURE 7
SKETCH OF SOIL STRATIGRAPHY
OVER FAULT 2781, SOUTH WALL
MILLSTONE NUCLEAR POWER PLANT
UNIT 3

LOOKING NORTH

LOOKING SOUTH

FIGURE 8
FAULTS 2817, 2818, AND 2819
LOOKING NORTH AND SOUTH
MILLSTONE NUCLEAR POWER STATION
UNIT 3

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PHOTOS OF SLUMPED SOIL OVER FAULT 2817-2819 ON SOUTH EMBANKMENT. NOTE CONTINUITY OF IRON-STAINED LAYERS OF SOIL.

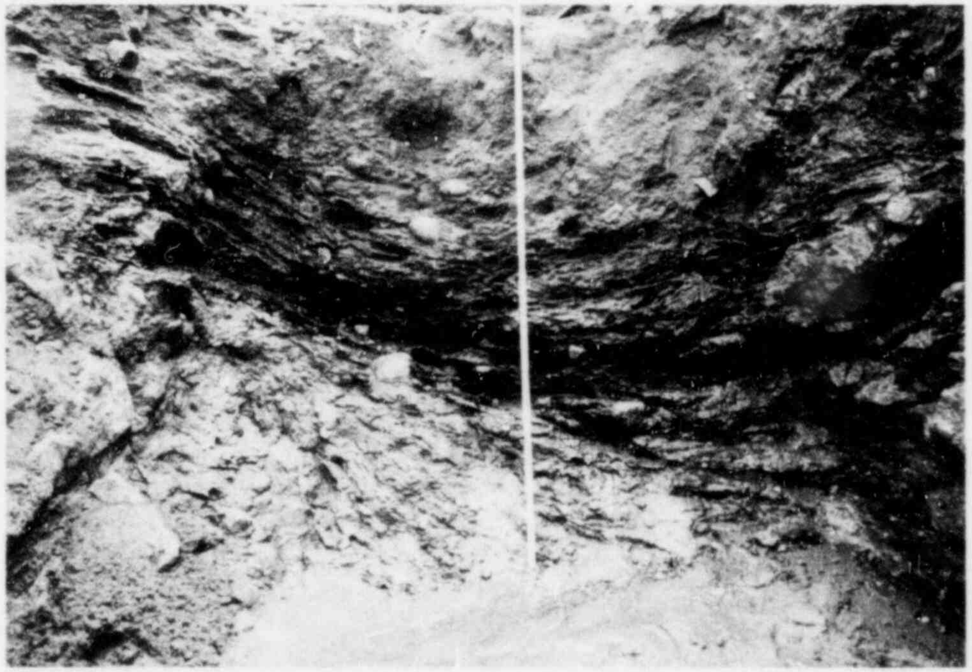

FIGURE 10

SOIL EXCAVATION OVER FAULTS 2817-2819, SOUTH WALL DISCHARGE TUNNEL

MILLSTONE NUCLEAR POWER STATION

UNIT 3

FIGURE 11

ROCK-SOIL CONTACT ABOVE FAULT ZONE 2817-2819, NORTH WALL

MILLSTONE NUCLEAR POWER STATION
UNIT 3

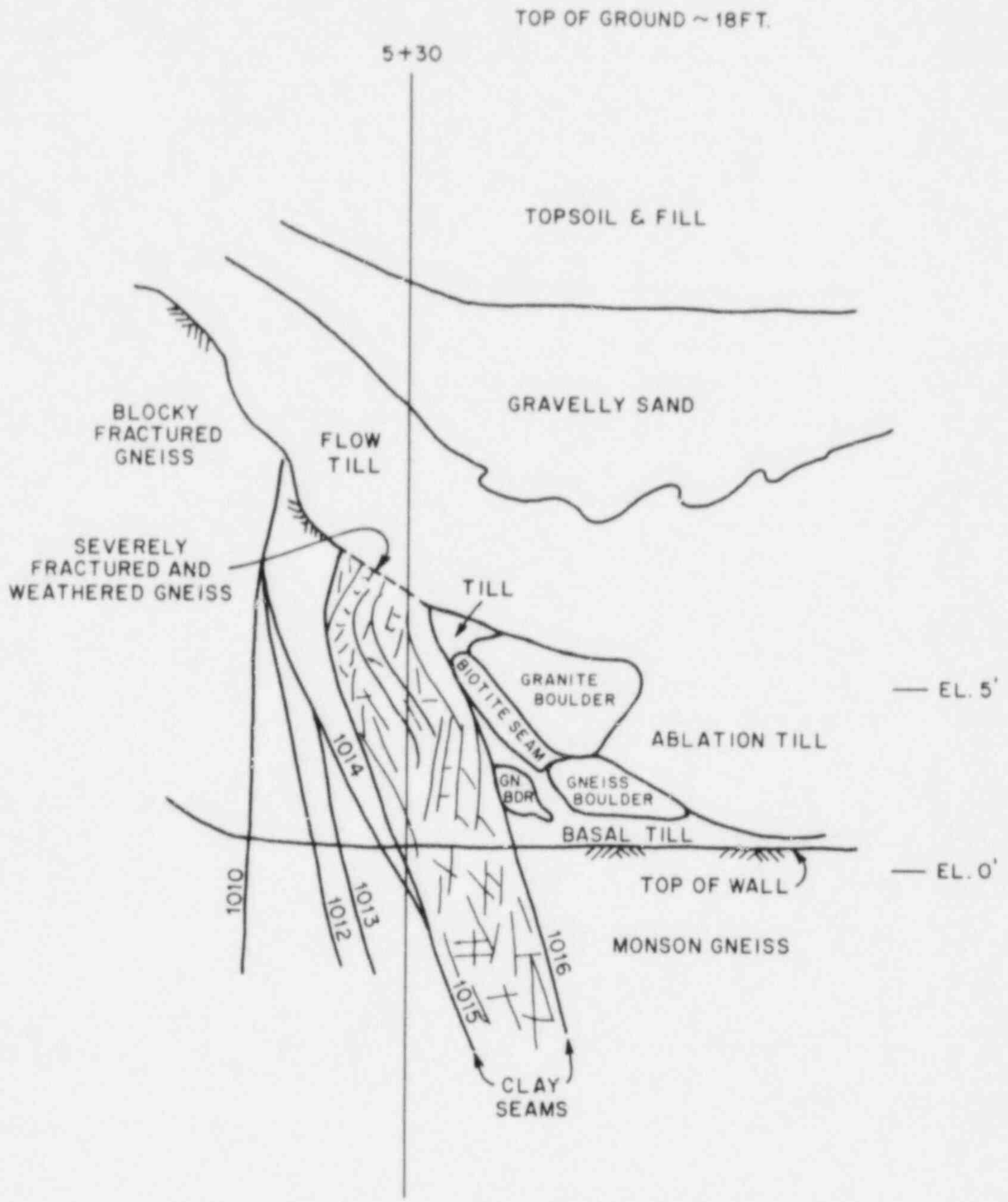

FIGURE 12

SKETCH MAP OF SOIL EXCAVATION ABOVE FAULT 2819, NORTH SIDE OF DISCHARGE TUNNEL

MILLSTONE NUCLEAR POWER STATION UNIT 3

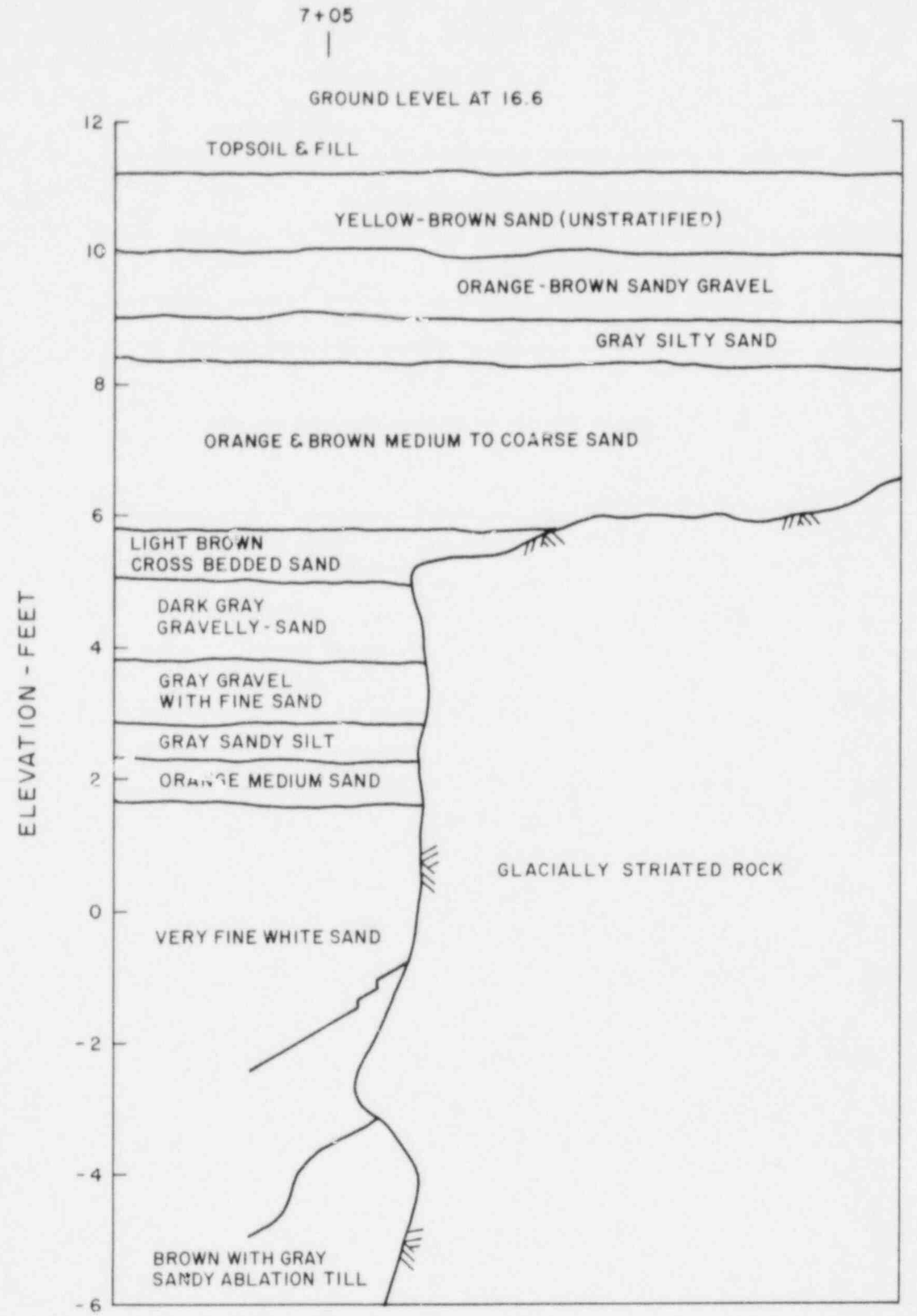

FIGURE 13
ROCK-OUTWASH CONTACT AT
STATION 7+05
MILLSTONE NUCLEAR POWER PLANT
UNIT 3

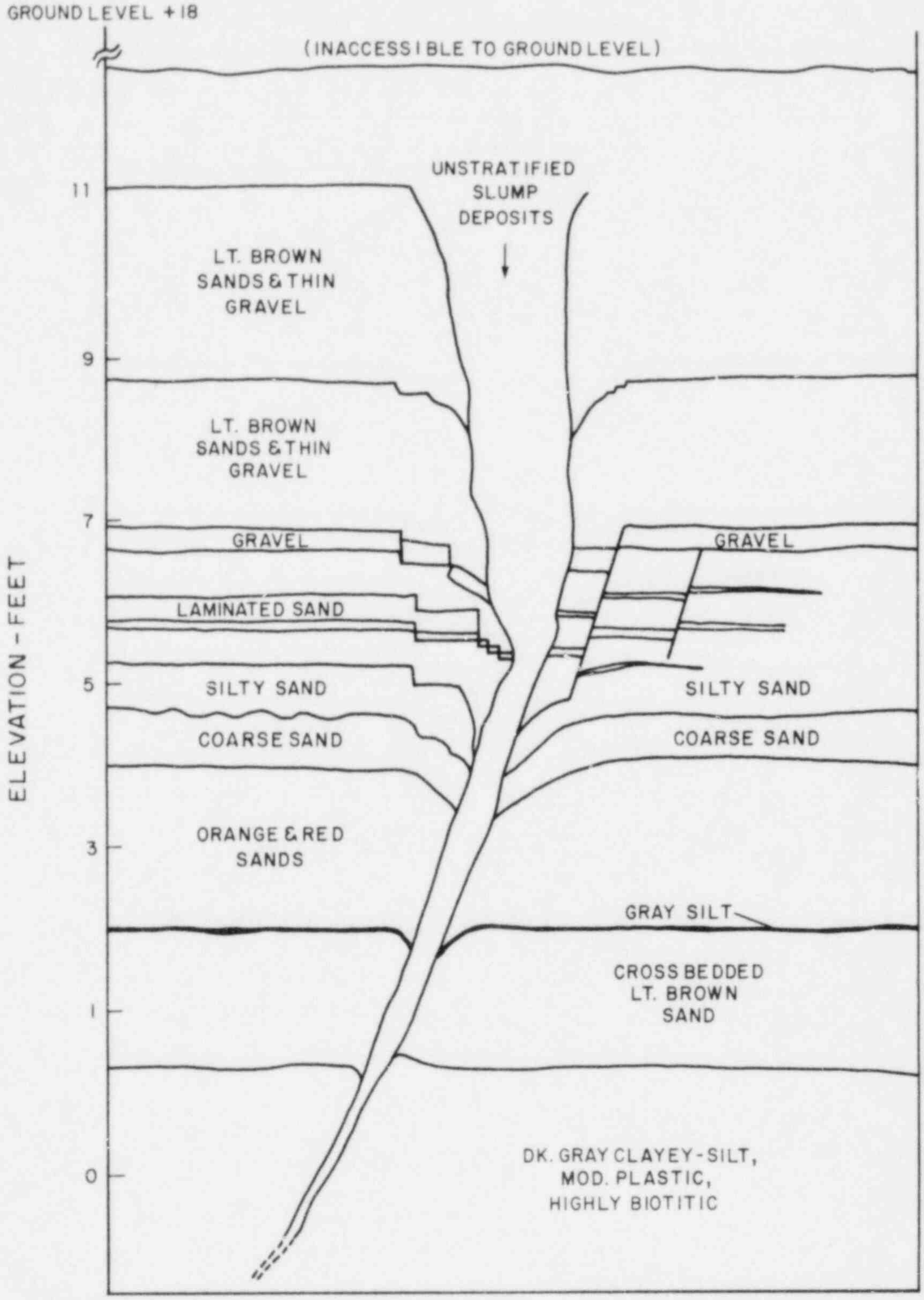

FIGURE 14
SKETCH MAP OF "PSEUDO" ICE WEDGE CAST AT STATION 8+15
MILLSTONE NUCLEAR POWER PLANT
UNIT 3

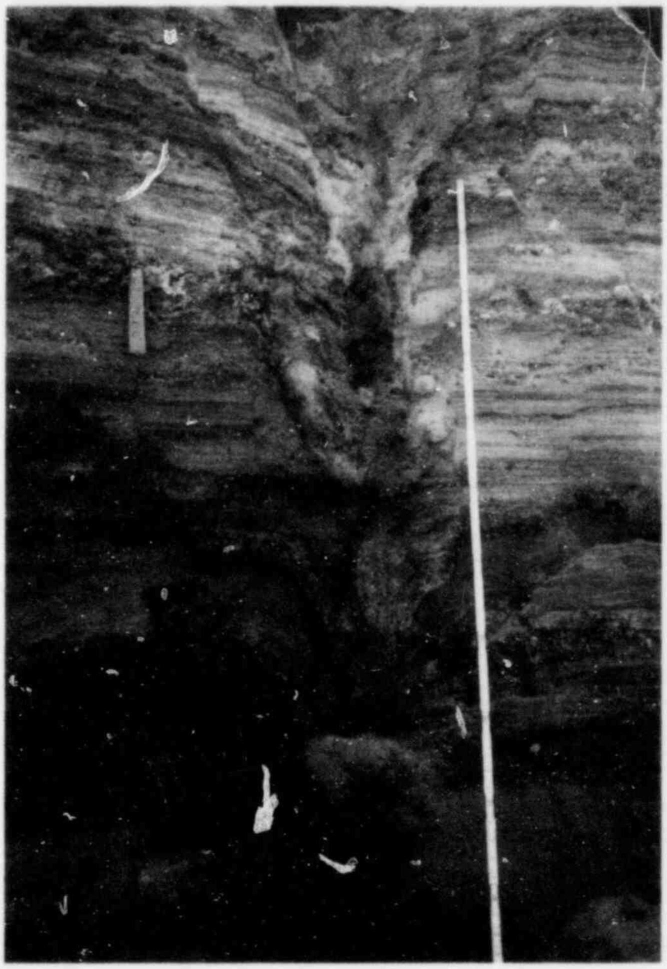

FIGURE 15
"PSEUDO" ICE-WEDGE CAST AT
STATION 8+15 OF DISCHARGE TUNNEL
MILLSTONE NUCLEAR POWER STATION
UNIT 3