NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/300 ERIE BOULEVARD WEST, SYRACUSE, N.Y. 13202/TELEPHONE (315) 474-1511

October 3, 1980

Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Youngblood:

Re: Nine Mile Point Unit 2
Docket No. 50-410

Your letter of July 9, 1980 requested additional information regarding geology at Nine Mile Point Unit 2. Enclosed are Niagara Mohawk's responses to questions Q361.26 through Q361.35 contained in the enclosure to your letter.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

Gerald K. Rhode
Vice President
System Project Management

PEF:ja
Enclosures (25)

B001
S
1/25

8010070460

A

Q361.26 In your report entitled "Nine Mile Point Nuclear Station, Unit 2, Geologic Investigation," (Vol. 1, Section 4.7, paragraph 1), you state that the intensity of the shearing on the cooling tower fault does not appear to diminish toward the known extremities. However, it is not clear from your report where the southeastern extremity of this fault is and where either extremity of the drainage ditch fault is. Accordingly, provide data which will indicate the length of the cooling tower and drainage ditch faults and show their relationship, or lack of relationship, to each other. In your response, consider acquiring this information by running a detailed ground magnetic survey using a field magnetometer (e.g., a proton precession magnetometer). This approach could be followed by trenching, if necessary. If you choose to respond without doing a field survey using a magnetometer, indicate your reasons.

RESPONSE: Figure 361.26-1 summarizes all known observations relevant to the evaluation of the lateral extent of Cooling Tower and Drainage Ditch faults. The apparent west-northwest terminations of both faults are shown on Figure 361.26-1 as locations (1) and (2). Location (1) is considered to be the western extremity of the Cooling Tower Fault because trenches 1 and 2 revealed no evidence of faulting. These trenches were excavated 700 feet and 1750 feet west of the cooling tower piping trench. Location (2) is considered to be the western termination of the Drainage Ditch Fault because the lake water tunnels for Nine Mile Point, Unit II did not encounter the fault.

The east-southeast extremity of the Drainage Ditch Fault has been determined during investigations of the "compression buckle" disclosed during bedrock excavation for the James A. FitzPatrick Nuclear Power Plant. The report entitled, "Fault Study for James A. FitzPatrick Nuclear Power Plant" submitted as a supplement to the James A. FitzPatrick PSAR provided the following information concerning the extent of the feature:

> "Examination of aerial photographs showed a lineation crossing the plant area and corresponding to the projected trace of the fracture. This lineation was defined in some places by vegetation, probably because the fracture zone served to transmit water. In other places it was defined by a very slight depression probably due to some slight migration of soil downwards into the open jointing. This feature could be followed on the photographs approximately 6000 feet to the east of the plant site, at which point the lineation became indistinct

> and could no longer be seen. A test pit, No. 7, dug across the location of the lineation at this point showed only flat-lying beds with no evidence of disturbance.
>
> Refraction seismic surveys were able to define the trace clearly in the vicinity of the plant and to a distance of 2050 feet to the east. Beyond this point, the velocity decay by which the trace was identified was no longer evident. Several test pits were opened along this trace at locations shown on Figure 1. Near the plant the fracture zone was readily identified.
>
> Test Pit 5, (Ref. Figure 1) opened at the limit to which it could be traced by geophysical methods, revealed a fracture about 3 inches wide, containing shattered rock, but no gouge. The rock adjacent to the fracture or joint was closely jointed but did not exhibit the characteristic up-warp associated with the fracture in the station area. Test Pit 6, about 60 feet east of Test Pit 5, showed only intact rock with moderately closely spaced jointing. The evidence from these test pits indicates that between the plant and Test Pit 5 the buckling dies and the fracture resolves into a local system of close jointing.
>
> In a westerly direction, the trace was followed to within 90 feet of the shore of Lake Ontario, at which point it is obscured by artifical land-fill for a parking area on adjoining property."

On the basis of the above information it appears that it is appropriate to assume that the east-southeast extremity of the fault is somewhere around location (3) on Figure 361.26-1.

The minimum lateral extent of the Cooling Tower Fault as determined by our investigation is approximately 3000 feet. As shown on Figure 361.26-1, this corresponds to the distance between Pit 1 and the overcoring Borehole OC-2. With the data presently available, it is difficult to place the east-southeast extremity of the fault. However, the Cooling Tower Fault in terms of the magnitude of displacement and degree of cataclasis appears to be very similar to the Drainage Ditch Fault. Hence, it is difficult to envision the lateral extent of the fault as being significantly different than the length of its analog. This suggests that the Cooling Tower Fault does not extend beyond location (4) on Figure 361.26-1.

Investigating the length of the Cooling Tower Fault ana Drainage Ditch Fault by proton magnetometer survey had been considered. However, the nature of the faulting at Nine Mile Point does not lend itself to detection by this method. The displacement on the Cooling Tower Fault is small (5 feet of vertical offset at the bedrock surface diminishing to approximately 6 inches at a depth of 200 feet; and 3 feet of strike slip offset). Additionally, it is not believed that the fault extends to the basement. Consequently, the faulting does not bring rocks with highly contrasting properties in contact with each other and should not offer a distinct magnetic contrast or pattern by which the fault can be traced.

To illustate this, proton magnetometer surveys were conducted across the Cooling Tower Fault and Drainage Ditch Fault (Figure 361.26-1). As shown on the magnetometer profiles (Figure 361.26-2) no pronounced gradients are apparent that would suggest the location of the fault at the surface or at a hypothetical projection to the basement.

Examination of the Drainage Ditch Fault, undertaken during the 1977-1978 investigations for Nine Mile Point, Unit II, revealed that the structural development of the fault is essentially identical and contemporaneous with the development of the Cooling Tower Fault. This structural development has been summarized in the 1978 report as follows:

> "The study revealed that the fault (Cooling Tower) was initially developed as a vertical, left-lateral, strike-slip fault with 2 to 3 feet of stratigraphic displacement. The fracturing occurred selectively in the strongest rocks of the stratigraphic section, namely the massive part of the Oswego Sandstone. In contrast, the strike-slip fault zone did not develop within the softer rocks of the Transition Zone, and the underlying Lorraine Group. During the deformation, the fault zone was mineralized by calcite and sulfides. Analysis of fluid inclusions from this calcite indicates crystallization temperatures ranging from 170^{o}C to 120^{o}C (corresponding to a depth of burial of 3 to 3.5 kilometers). Moreover, fluid inclusions in quartz of the host rock indicated that the temperature reached during diagenesis was approximately 170^{o}C. From these data, it is interpreted that the fault was formed at the end of the Paleozoic Era, during the initial stage of regional uplift,

soon after the rocks reached a maximum depth of burial of approximately 3.5 kilometers (km).

At a later time, during the second episode of deformation, the fault plane was propagated downward as a normal fault through the Transition Zone and the Lorraine Group, with a northward dip of 55° to 65°. The displacement along this structure was small, not exceeding a few feet. At this time, the fault zone was also mineralized with calcite and sulfides. Fluid inclusions in the calcite yielded temperatures of homogenization ranging from 116°C to 73°C (corresponding to a depth of burial of approximately 2 to 3 kilometers). The age of the normal fault movement is interpreted to be Late Jurassic to Late Cretaceous.

The third episode of deformation on the Cooling Tower Fault was characterized by reverse-slip, bedding plane slip, and dilation within 200 feet of the bedrock surface. Field evidence clearly indicates that there were two phases of movement.

The first phase preceded the deposition of the overburden sediments, occurring prior to 12,500 years B.P.; whereas, the second phase post-dated the deposition of these sediments.

During the first phase of deformation, dilation of the bedrock strata on the hanging wall of the structure resulted in a reverse stratigraphic displacement that decreases from 5 or 6 feet near the ground surface to zero at a depth of 200 feet. This deformation is attributed to a mechanism of buckling, and is believed to have been initiated during crustal downwarping induced by glacial loading.

The deformation during the second phase is expressed as two types of structures:

1. fluidized flow structures in the overburden sediments, and;

2. folds and faults which deform the fluidization structures.

This phase of deformation is attributed to a mechanism of bedding plane slip which probably was caused by changes of fluid pressure in the

> bedrock associated with water level fluctuation in the Ontario Basin during the draining of glacial Lake Iroquois."

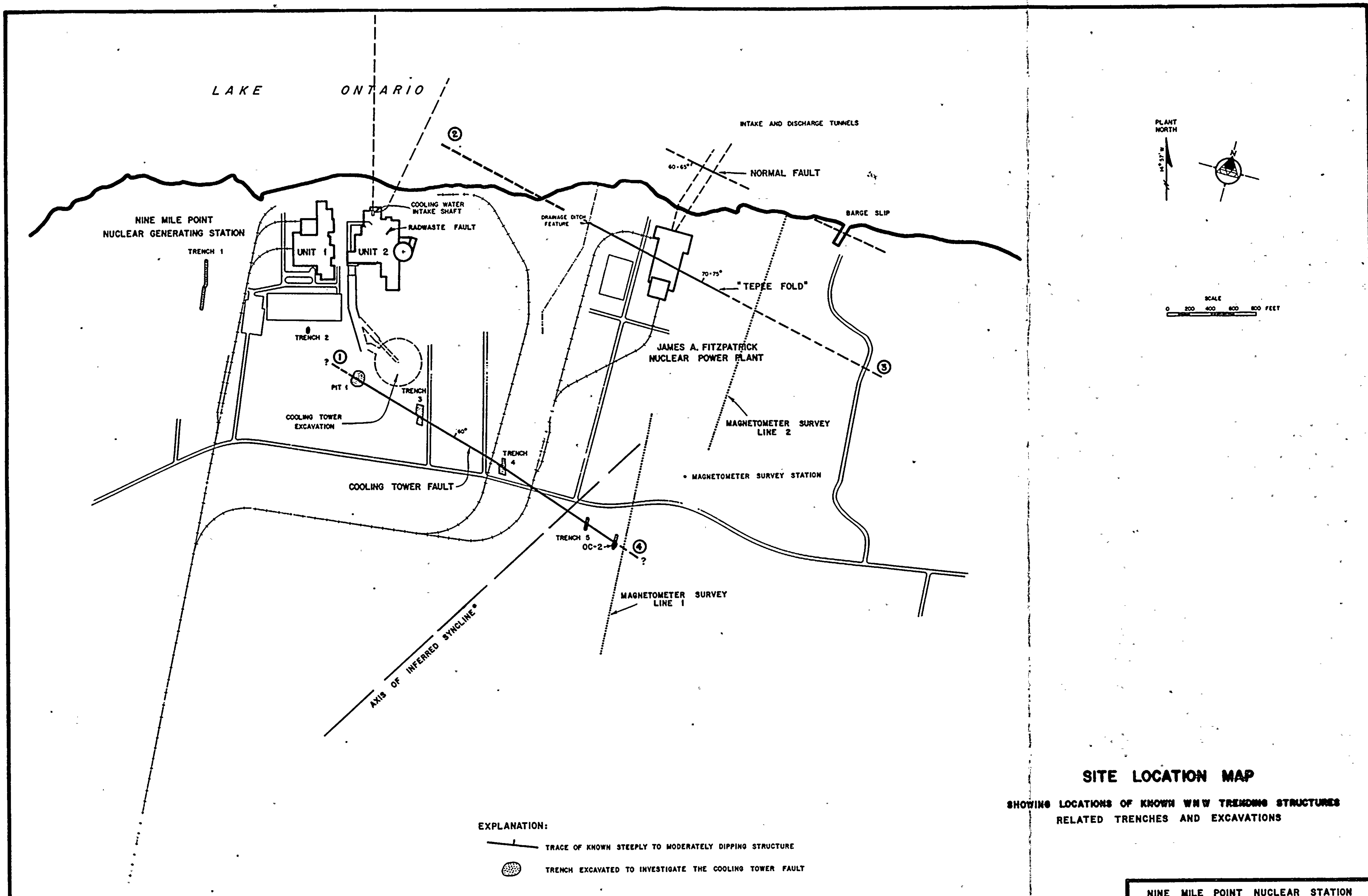
The identical structural character of both faults, coupled with their contemporaneous development, indicates that they are related to each other. Furthermore, both of these faults must be a part of an integrated deformational system which is linked to a common tectonic source and/or tectonic event(s). The April 1978 report linked the development of the faults with the tectonic development of the region. At that time knowledge concerning local geologic structure was more limited than at present. This knowledge was substantially enhanced as a result of geologic studies performed at the New Haven Site. Reference should be made to Figures 2.5-9 and 2.5-15 of the New York State Electric & Gas Preliminary Safety Analysis Report for New Haven Units 1 and 2. These figures present certain aspects of the local tectonic setting which are important in understanding the relationship among faults and possible linkage to a common tectonic source. It appears that the development of the Demster Structural Zone was accompanied by gentle warping of the sedimentary strata on either side of the zone. Particularly important is the occurrence, in the vicinity of the Nine Mile Point Site, of a broad syncline. As shown on New York State Electric & Gas Figure 2.5-9 the axis of this syncline trends north-northeast and its projection is located just east of the James A. FitzPatrick facility. Figure 361.26-1 presents a spatial relationship between the Cooling Tower and Drainage Ditch faults and the axis of the syncline. The axis appears to be situated half-way between the previously interpreted extremities of both faults. This suggests that there may be a causative relationship between the syncline and both the faults as indicated on Figure 361.26-3. It should be recognized that the relationship, as noted above, would account for the remarkable change in the character of deformation, that is, from strike-slip to normal. This change could be attributed to a local clockwise rotation of the trajectory of greatest principal stress in response to continued shortening. Once this trajectory assumed a position close to the previously formed left lateral shear fracture then conditions were favorable for development of normal faulting along this fracture.

REFERENCES

New York State Electric & Gas Corportation, 1979, New Haven Units 1 and 2, Preliminary Safety Analysis Report, Docket No. STN50-596 and STN50-597.

Niagara Mohawk Power Corporation, 1978, Nine Mile Point Nuclear Station, Unit 2, Geologic Investigation, Scriba, New York.

Power Authority of the State of New York, 1967, Fault Study for James A. Fitzpatrick Nuclear Power Plant, Appendix "F" Supplement to Preliminary Safety Analysis Report.



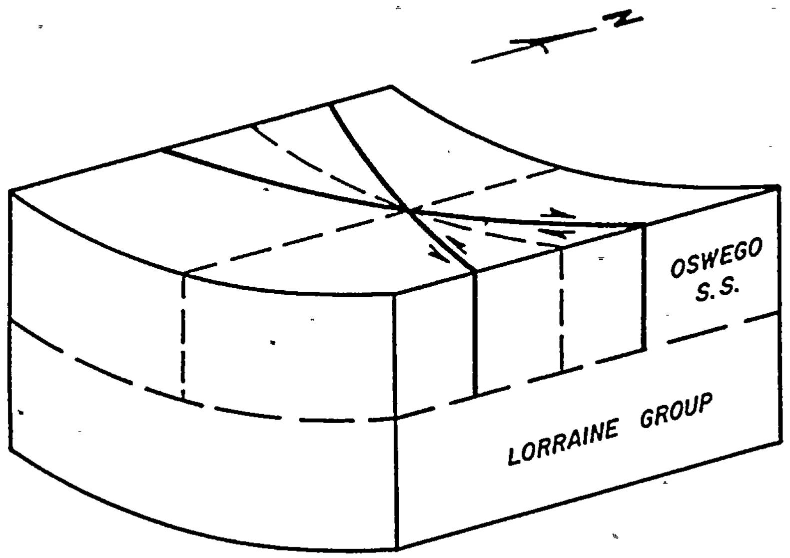
*Reference: Position of Inferred Syncline from N.Y.S. Electric and Gas Corp., 1979, New Haven Units 1 and 2 PSAR, Amendment 1, Fig. 2.5-9.

SITE LOCATION MAP

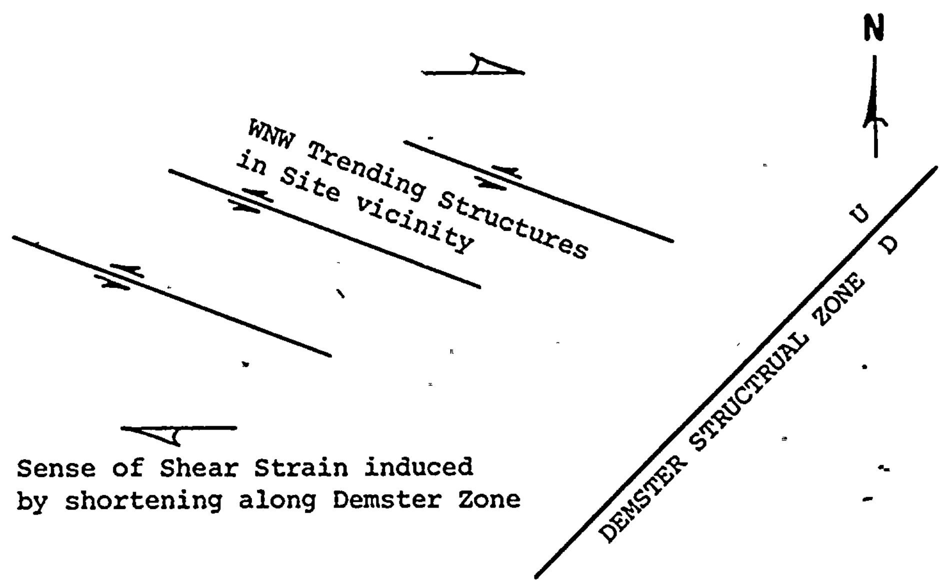
SHOWING LOCATIONS OF KNOWN WNW TRENDING STRUCTURES RELATED TRENCHES AND EXCAVATIONS

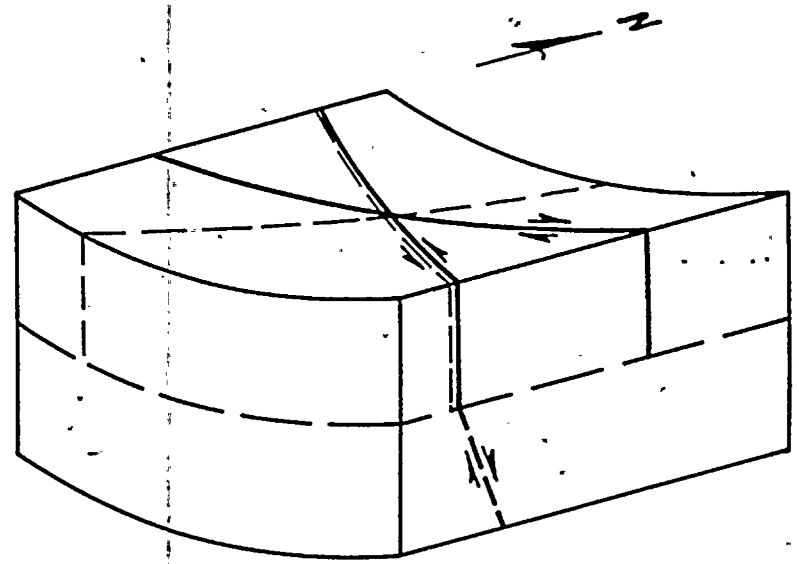
NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.26-1



REPRESENTATION OF INITIAL FOLDING AND
RESULTING SHEAR AND EXTENSIONAL FRACTURES





REPRESENTATION OF ROTATION OF PRINCIPAL STRESSES
SUCH THAT EXTENSION IS PARALLEL TO ORIGINAL WNW
TRENDING SHEAR FRACTURE RESULTING IN DIP SLIP
DISPLACEMENTS ON DISCONTINUITIES OF SIMILAR TREND

DIAGRAM OF FOLD / FAULT RELATIONSHIPS

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.26 - 3

Q361.27: Indicate spatial and age relationships of the faults at Nine Mile Point to the geologic structures at the site proposed for the New Haven facility and to other geologic structures in the region. Furnish a map and the necessary data to support your conclusions.

RESPONSE: In the region immediately around the Nine Mile Point Site (30 mile radius) there is only one structure known. This structure, located near New Haven, New York is known as the Demster Structural Zone. Figure 361.27-1 is a map showing the spatial relationship of the faults at Nine Mile Point to the Demster Structural Zone.

Presently, there are no data available from either site which would permit a direct, absolute determination of the age of development of structures at each site. Nevertheless, the existing data base permits a reasonable interpretation of the age relationship of the high angle faults at Nine Mile Point to the Demster Structural Zone. This interpretation is based upon results of fluid inclusion studies. These studies were performed independently at each site and are sufficiently broad in scope to warrant a meaningful comparison. Clearly, the faults at each site are mineralized, and the mineral assemblages are similar. Furthermore, at both sites the mineral assemblages yielded identical spectre of homogenization temperatures. Table 361.27-1 and Figure 361.27-2 present the results of fluid inclusion studies at both sites. It appears that at each site the minerals occurring within fault zones precipitated from fluids whose temperatures range from 170°C to 80°C. Based on this, it can be inferred that the development of the faults at Nine Mile Point (strike-slip and normal faulting) and movements along the Demster Structural Zone occurred under similar depths of burial (depth of burial ranging from approximately 3 kilometers to 2 kilometers) that is, in correlative geologic times. This conclusion is supported by movement plans (left-lateral) and the geometric arrangement of faults at Nine Mile Point relative to the trend of the Demster Structural Zone. The high angle faults at Nine Mile Point may be regarded as members of a systematic fracture set identified onsite. This fracture set consists of two conjugate strike-slip shear fractures trending west-northwest (left lateral) and northeast (right lateral). The trend of the acute bisectrix of the set indicates the direction of structural shortening required to produce the fractures in their present arrangement. It can be seen from Figure 361.27-1 that the direction of shortening indicated by the Demster Structural Zone is close to the trend of the acute bisetrix of fractures at Nine Mile Point. This coincidence suggests contemporaneous developments at each site and thus reinforces earlier drawn conclusions.

In summary, the presently available data indicate an age and causative relationship between the faults at Nine Mile Point and the geologic structures at New

Haven. These relationships appear to have been established in the distant geologic past (Late Paleozoic-Early Mesozoic). As noted previously (response Q361.14), evidence of Late Cenozoic bed-rock displacement has only been encountered at Nine Mile Point.

TABLE 361.27-1

HOMOGENIZATION TEMPERATURES

FOR

FLUID INCLUSIONS FROM A FAULT ZONE - NORTHWEST OF NEW HAVEN, N.Y.

SAMPLE #	TII 21A NH		TII 42 NH		TII 19 NH		TII 39 NH		TII 7 NH		TII 25 NH	
	Inclusion#	T°C	Inclusion#	T°C	Inclusion#	T°C	Inclusion#	T°C	Inclusion#	T°C	Inclusion#	T°C
1	38	157.2	24a	157.9	18b	159.9	55	179.6	44	148.5	6	170.4
2	35a	149.4	31a	155.4	15	158.3*	59	163.8	43	144.6	6b	170.4
3	37	138.8*	24b	154.3	16	147.8	56	155.6	45	128.8*	5b	155.1
4	40	137.8	23a	141.8	10	128.3	54	150.4	46a	118.9	9b	152.5
5	36a	121.7	31c	138.3	22b	127.2*	61c	135.2	49	93.1	5a	152.0
6	35b	103.1	31f	137.8	18a	124.6	50	132.5	46b	92.0	1	125.2
7	36b	101.0	31e	129.1	21	124.6	61b	116.2	42	75.7*	4	122.5
8	35c	99.2	31d	124.3	22a*	114.2*						
9	33	98.3										
Mean	122.9°C		142.4°C		135.6°C		147.6°C		114.5°C		149.7°C	
Std. Dev.	23.4		12.5		17.2		21.3		28.1		19.3	

*Inclusions found in milky areas.

Refer ..
Reference: New York State Electric & Gas, 1978, Preliminary Safety Analysis Report, New Haven Units 1 and 2, Amendment 1, Table 1.

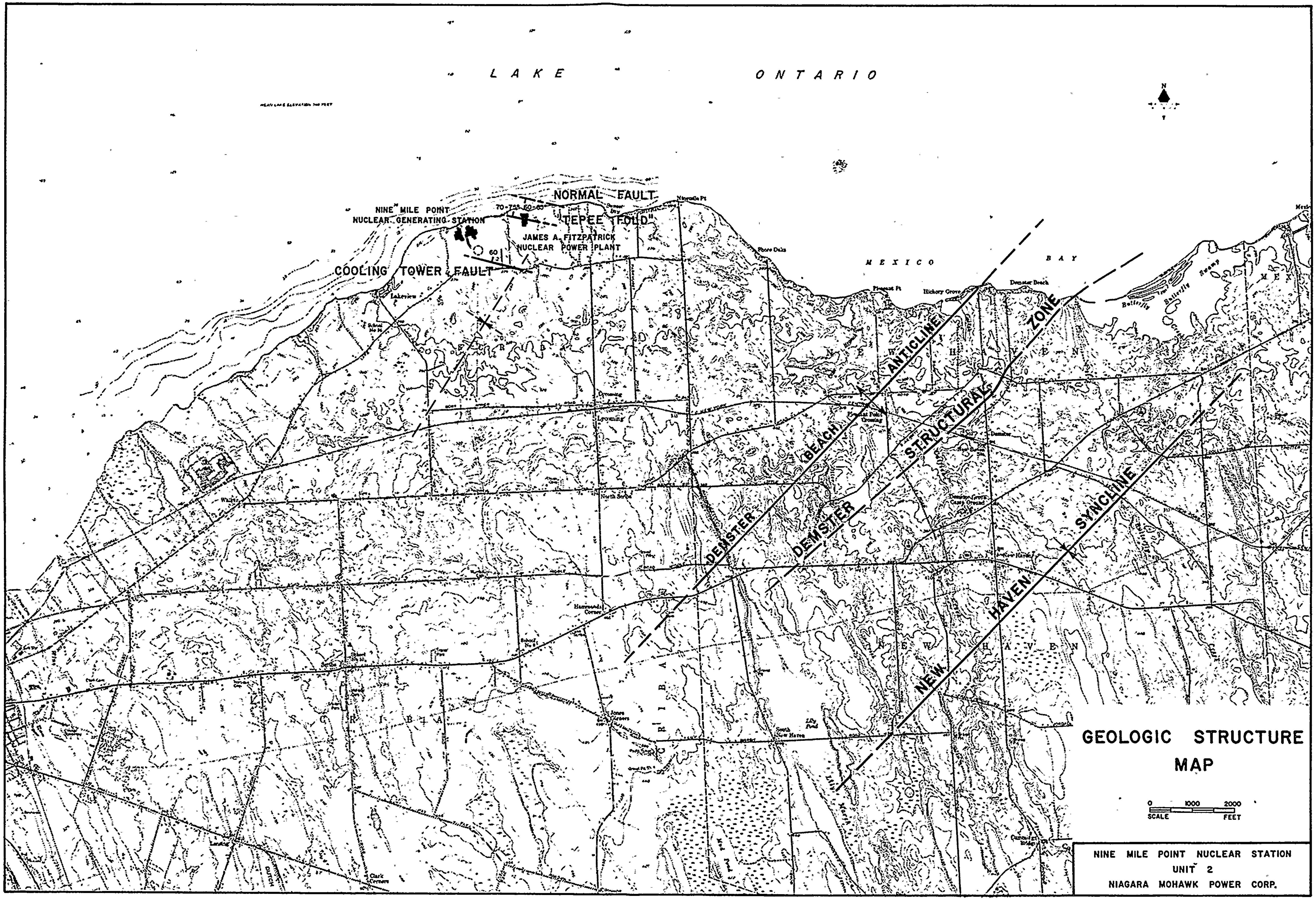
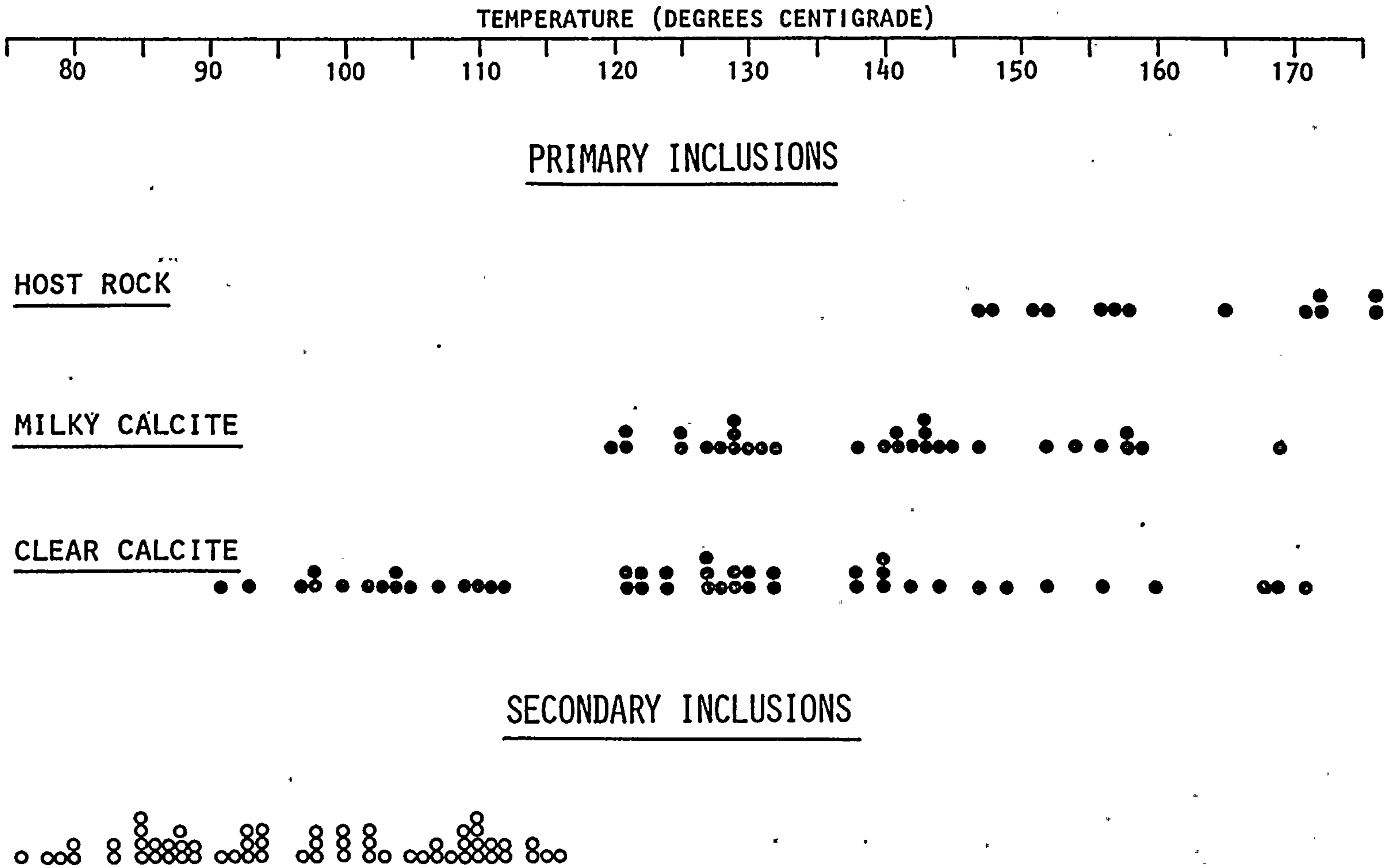


FIGURE 361.27-1



FLUID INCLUSION TEMPERATURE DISTRIBUTION

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.27-2

Q361.28 Indicate the relationship among the thrust faults, the cooling tower fault, and the drainage ditch fault. Specifically, indicate whether they connect as an integrated system and whether the thrust faults cut the the other faults.

RESPONSE: Thus far, no direct geologic evidence has been identified relevant to an unambiquous definition of age and spatial relationships among the "thrust" faults, the Cooling Tower Fault and the Drainage Ditch Fault. Presently, there are only a few exposures of the "thrust" faults known at the site. These are: the North Radwaste Trench, the Cooling Water Intake Shaft, Lake Water Tunnels and the Circulating Water Piping Trench. Figure 361.28-1 presents the location of all "thrust" structures known at the site. It can be noted that these structures were recognized only within a bedrock block bounded by the high angle faults. There is no single exposure wherein both types of structures are present. Furthermore, the absolute age of formation of the "thrust" faults, as well as their relative age with respect to the reverse slip deformation observed on the Cooling Tower Fault, cannot be determined with certainty. Consequently, the possible age and spatial relationships are inferred from the existing data base.

The "thrust" fault structures appear to have been formed as a result of relief of strain energy stored in the bedrock. The strain energy is inferred to be of remanent gravitational and/or tectonic origin. As such, in the time scale of concern and in the tectonic environment of the site region, the energy once relieved or reduced cannot be replenished. That is, it is only conceivable that either no change or a decrease in the amount of stored strain energy occurs after the initial movement has taken place.

The development of the "thrust fault" structures must have been triggered (initiated) by some environmental change (for example, glaciation) which reduced the ability of the bedrock to retain the strain energy being stored at the time such a change occurred.

The ability of a given block of bedrock to retain a given amount of strain energy is governed by the shear resistance of block boundaries and the lateral restraining forces. A reduction of one of these factors results in a reduction of the integrated restraining force and must be followed by a reduction of strain energy stored within the block. The latter reduction will be expressed on a lengthening of the block accompanied by the development of nonhomogeneous shear strains along the boundaries. The process, if continuous,

may be characterized as "leakage" of the strain energy induced by the reduction of the capability of the block to retain the stored strain energy.

Presently, there is no known direct geologic data permitting a firm definition of boundary conditions of the bedrock block whose lengthening is evident in the exposures of the "thrust" faults. However, with the information presently available, it is possible to postulate reasonable boundary conditions as presented on Figure 361.28-2. Once these boundary conditions are assumed then it is possible to perceive the nature of the environmental change which permitted the development of the instability.

With reference to the "thrust" fault structures, the factors which controlled the initial strain energy stored in the bedrock may be identified as:

1) the lateral restraining force provided by the bedrock which has been removed by erosion during the formation of the north-south trending erosional valley located between Nine Mile Point Units I and II (Figure 361.28-1);

2) the shear resistance of the boundaries of the block consisting of following elements (Figure 361.28-2):

   a) shear resistance along boundary 1

      $dS_1 = C_1 + \tan \phi_1 \cdot d\sigma n_2$;

   b) shear resistance along boundary 2

      $dS_2 = C_2 + \tan \phi_2 \cdot d\sigma n_2$;

   c) shear resistance along boundary 3

      $dS_3 = C_3 + \tan \phi_3 \cdot d\sigma n_1$.

      In the instance of the shear resistance of this boundary the shear stress acting along bedding planes (τ bed) should be accounted for and thus, $dS_3 = (C_3 + \tan \phi_3 \cdot d\sigma n_1) \pm \tau$ bed.

As indicated by the above equations the combined shear resistance of the block boundaries is controlled by the bedrock mass properties (C=cohesion and ϕ=angle of sliding friction), the normal stress perpendicular to the block boundaries (σn_1 and σn_2), and the shear stress acting along the plane of bedding (τ bed).

The latter two factors must have experienced significant changes in response to gravitational loading of the lithosphere by the continental ice sheet(s). Other related phenomena were also important. They include changes of water level in the lake (fluid pressure and reduction of σn_1) and shear straining of the lithosphere caused by glacially induced differential vertical movements (tilting during downwarping and tilting during rebound).

Considering the foregoing, the following scenerio of development of the "thrust fault structures can be outlined:

(i) Downwarping of the crust in relation to glacial advance created conditions favorable for buckling of the hanging wall blocks of northward dipping high-angle faults. This resulted in a reduction of σn_2 and hence reduction of dS_1 and dS_2;

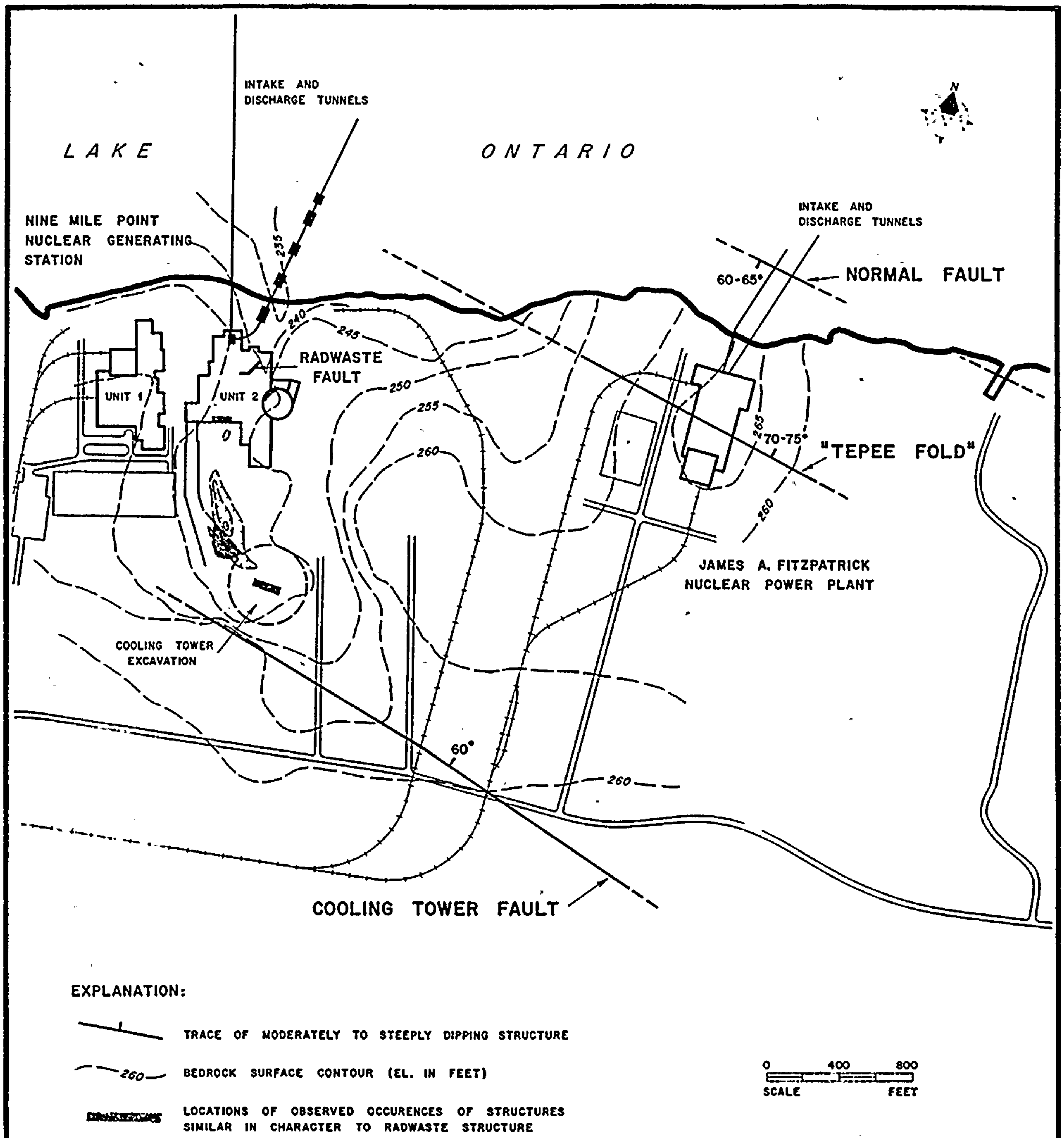
(ii) erosional formation of the valley reduced lateral restraining force, and;

(iii) removal of the load imposed by the continental ice sheet reduced σn_1 and, thus reduced dS_3. Further reduction of σn_1, and dS_3 may have occurred during the drainage of Lake Iroquois (development of high flüid pressure in the bedrock).

In summary, the present understanding of the site conditions strongly suggests that the "thrust faults do not cut the Cooling Tower and Drainage Ditch faults. It appears that the "thrust" faults together with the high angle faults form an integrated, but sequential system of bedrock deformation. The present understanding of the equilibrium conditions of the thrust structures implies that the development of buckling (Phase I of the reverse slip deformation) along the Cooling Tower and Drainage Ditch faults contributed to the instability of the bedrock block bounded by both faults. Additionally, it can be inferred that the development of the "thrust faults" post-dates the first phase (response 361.30) of reverse slip movement along the Cooling Tower Fault.

REFERENCE

Niagara Mohawk Power Corporation, 1978, Nine Mile Point Nuclear Station, Unit 2, Geologic Investigation, Scriba, New York.

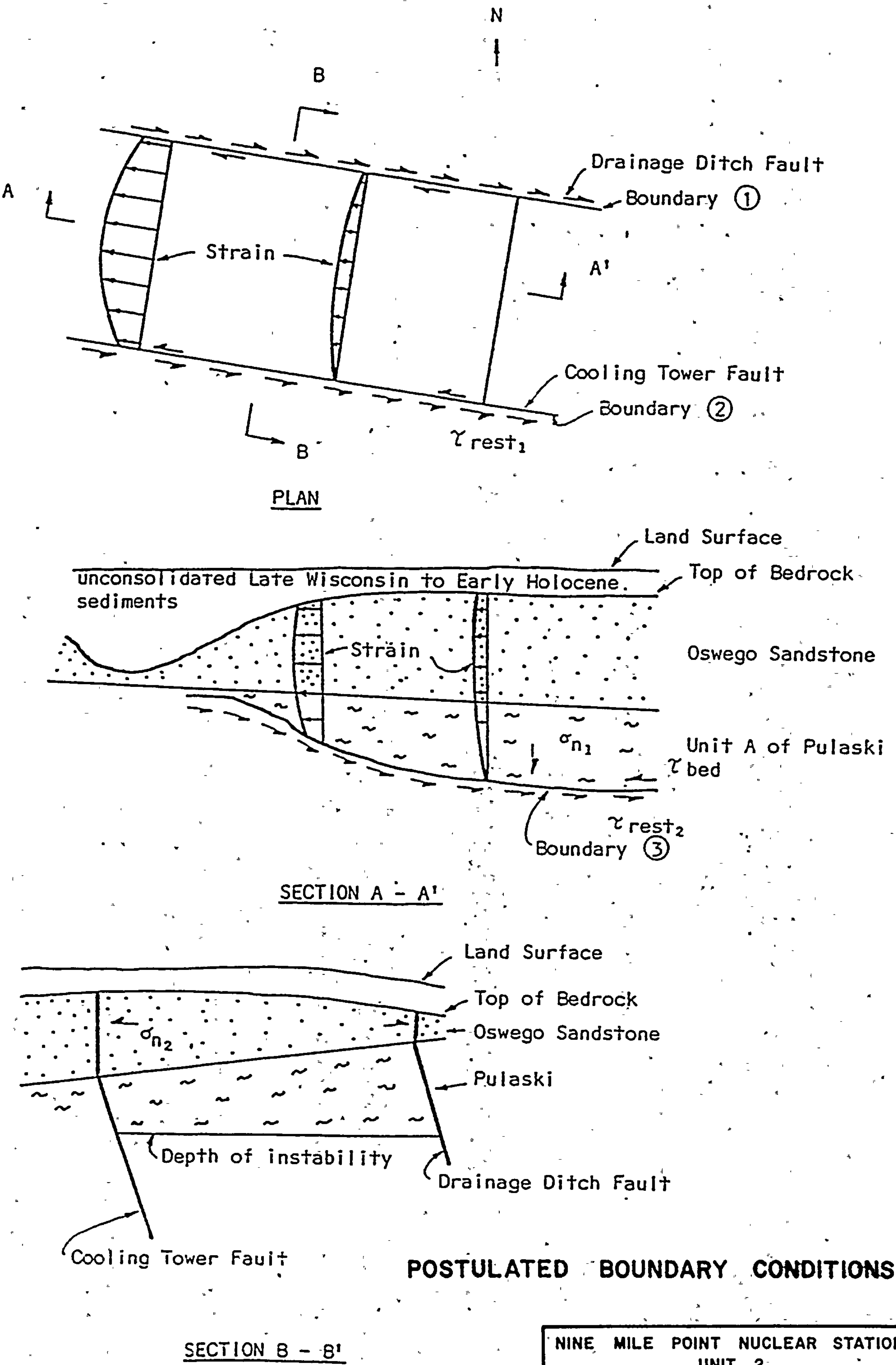


SITE LOCATION MAP

SHOWING GENERAL CONFIGURATION OF BEDROCK SURFACE AND LOCATIONS OF KNOWN GEOLOGIC STRUCTURES

NINE MILE POINT - NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.28-1



POSTULATED BOUNDARY CONDITIONS

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.28-2

Q361.29: Extend coverage of the lineament map (Volume II, Plate 1-1) out to a radius of at least 5 miles. Field check the lineaments to determine if they are reflections of unrecognized geologic structures.

RESPONSE: Figure 361.29-1 is a map of air photo lineaments identified within a 5 mile radius of Nine Mile Point Nuclear Station, Unit II. The air photo lineaments were identified by tonal variations on low altitude aerial photographs (approximate scale 1:20,000) flown in 1938 and 1939. No photo lineaments could be identified in many areas, including the area of the James A. FitzPatrick Nuclear Power Plant, because these areas were heavily forested. The lineaments were mapped on mylar overlays to the aerial photographs and then transferred to a 1:24,000 topographic base map. The lineaments were then checked in the field to determine whether or not they reflect unrecognized geologic structures.

Within the 5 mile radius, the majority of the bedrock surface is veneered with Late Wisconsinan and Holocene deposits. The surface topography reflects landforms related to Late Wisconsinan Ice. To the south of Nine Mile Point, long, parallel ellipitical hills or drumlins oriented approximately N20°W are the dominant topographic feature. The topography of the drumlins and inter-drumlin areas has been modified by erosion and deposition as evidenced by occasional knobs and ridges subparallel to the Late Wisconsinan ice margin. Further topographic modification occurred during Lake Iroquois and other pre-Lake Ontario lake stages as evidenced by lacustrine deposition and erosion, and weakly define fluvial terraces.

In general, the lineaments identified within the 5 mile radius may be related to the following non-cultural conditions: 1) surface topography such as streams and ridges not related to bedrock conditions, 2) surface topography related to discontinuities in the bedrock 3) joint or fracture patterns in the bedrock, 4) structural discontinuities such as folds or faults, and; 5) topographic variations on the bedrock surface produced by preferential glacial plucking.

Several lineaments identified on the lineament map can be related to previously identified geologic structure. A series of N40E to N45E trending lineaments were noted from east of Hammonds Corner to Demster Beach (Figure 361.29-1). These lineaments are coincident with the Demster Structural Zone and associated folds as mapped by Weston Geophysical, 1978. Location ① on Figure 361.29-1 shows three parallel N45°E-trending, linear, dark photo tones less than 1000 feet long.

Although there are no bedrock outcrops in the vicinity of these lineaments, trenching completed by Weston Geophysical in 1978 verified the existence of the Demster Structural Zone at this location (Figure 361.27-1). Several N40°E trending air photo lineaments were identified parallel to and north of and coincident with the axis of the Demster Beach anticline. The extent of N40°E to N45°E trending lineaments appears to be limited to the Demster Structural Zone as few N40°E to N45°E lineaments were identified to the west of the known extent of this zone.

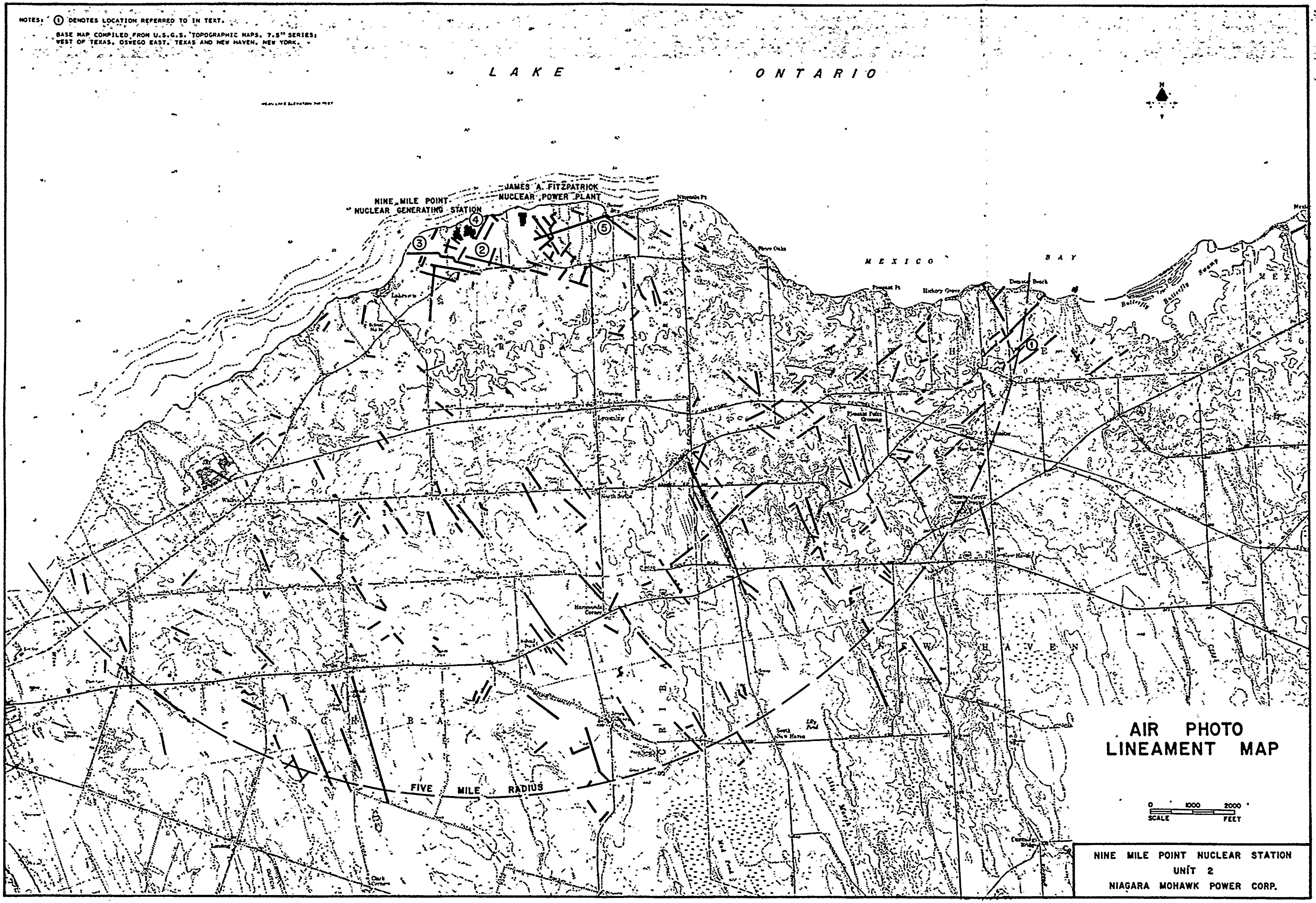
Location (2) (Figure 361.29-1) is a lineament nearly coincident with the Cooling Tower Fault. However, this area is now covered with fill and the natural surface conditions could not be field checked. This lineament is expressed on air photos as a linear, relatively dark photo tone, approximately 50 to 75 feet wide and 3000 feet long. The lineament appears not to be related to surface topography, as it crosses topographic highs and lows. It is not observed to extend toward the southeast beyond trench 5 and it only is noted to extend a few hundred feet northwest of pit 1 (Figure 361.26-1). The lineaments south of the main east-west road (Lake Road) and east of trench 5 (Figure 361.29-1) are related to topographic lows. No bedrock outcrops or anomalous surface conditions were found in this area. The same is true for the short lineament about 500 feet southwest of trench 5.

At location (3) on Figure 361.29-1, Unit 1, three west-northwest trending en echelon lineaments are connected by two north trending lineaments. This system appears to represent bedrock topographic variations because several bedrock outcrops were observed along the trace of these lineaments. No bedrock outcrops were found in the immediate area away from the lineaments. The glacial drift is apparently thinner along the trace of the lineaments. In general, the lineaments appear to be associated with a topographic high. However, the relationship is not consistent as some of the lineament segments cross topographic lows. The surficial evidence is not sufficient to determine if this lineament system represents structural discontinuities, joints, or bedrock topography produced by preferential glacial plucking.

The lineaments (Figure 361.29-1) south of the above discussed en echelon lineament system represent air photo tonal variations that cross topography. No bedrock outcrops or anomalous surface conditions could be found in this area. At location (4), a lineament approximately 1500 feet long and 100 feet wide, relatively dark, photo tone trends approximately N30°E and is located east and subparallel to the Heater Bay Structure. This area is excavated and the natural surface conditions could not be checked in the field.

At Sunset Bay (location ⑤, Figure 361.39-1) two lineaments were noted; one trending N60°E approximately 3500 feet long cutting across topography as a relatively dark photo tone and the second trending N45°W in part parallel to a small unnamed stream. No rock outcrops were located in the vicinity of these lineaments and dense forest plus fill at the James A. FitzPatrick Nuclear Power Plant Site prohibit checking the natural topography in this area. Surficial evidence is insufficient to determine whether these lineaments reflect structural discontinuities, joints, or bedrock topography produced by glacial plucking.

A distinct N20°W lineament trend was mapped. These lineaments are coincident with surface topography, such as drainages and ridges in the form of elongate drumlins. These lineaments are also coincident with the direction of Late Wisconsinan ice flow out of the Ontario Basin toward the southeast and do not reflect unrecognized geologic structure.



AIR PHOTO LINEAMENT MAP

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.29-1

Q361.30 Furnish additional discussion and documentation to support your conclusion that post-glacial reverse movement did not occur below 200 feet on the cooling tower fault. Our concern in this matter is that if this fault had previous normal movement as you suggest, and if the displacement on this fault is presently zero at the 200 foot depth, then it appears that reverse movement must have occurred below the 200 foot level to bring the net displacement to zero.

RESPONSE: All available documentation and discussions supporting the conclusion that "post-glacial reverse movement did not occur below 200 feet on the Cooling Tower Fault" have been presented in the April 1978 report. Development of additional documentation through subsurface exploration is considered to be unwarranted. By way of summary, some of the relevant arguments are given below.

The main conclusion of the April 1978 report was that the latest movements observed along the Cooling Tower Fault correspond to buckling of the near surface bedrock strata forming the hanging wall block of an old normal fault. This buckling, termed in our report the "reverse slip deformation", should be distinguished from "reverse movement". The reverse slip deformation occurred in two phases. The initial or the main phase corresponds to the development of buckling down to a depth of approximately 200 feet. This phase of deformation occurred "prior to the Wisconsinan glaciation and the deposition of overburden sediments," (that is, prior to "postglacial" time). The second phase of deformation has been recognized only in the near-surface bedrock strata and overburden sediments. It is not known whether deformation related to this phase extends all the way down to a depth of 200 feet. The age of this second phase of deformation is Holocene, (that is, "postglacial").

The data base relevant to interpretation of the depth of development of the reverse slip movements consists of:

(i) stratigraphic correlations across the Cooling Tower Fault;

(ii) relationships between stratigraphic separation and depth, and;

(iii) results of detailed examinations of rock cores extracted from the fault zone.

The data clearly indicate that:

(i) the stratigraphic separation resulting from the reverse-slip movements varies in a linear manner with depth. Figures 361.30-1 and 361.30-2 present

the relationship of stratigraphic separation and depth. It can be seen that downward the separation becomes progressively smaller. At a depth of approximately 200 feet there is no relative displacement of the strata;

(ii) below a depth of approximately 200 feet the sense of fault displacement is normal; and

(iii) the occurrence of a deformational fabric attributable to the reverse-slip deformation appears to be restricted to the upper 200 feet of the fault zone.

Combining the above observations, it can be concluded that the stratigraphic separation varies linearly with depth indicating that there must be a limiting depth below which the reverse-slip deformation is not present. Assuming that the normal fault separation is not large (smaller than 5 feet), it follows that this limiting depth does not exceed 400 feet. Additionally, the occurrence of deformation fabric (attributable to the reverse slip deformation), selectively within the upper 200 feet of the fault zone suggests that the limiting depth does not exceed a value of approximately 200 feet.

Further means of estimating a value of the limiting depth can be obtained from Figure 361.30-3. Before this can be accomplished the following points should be recognized:

(i) the reverse-slip deformation and/or separation is a result of buckling of strata forming the hanging wall block. The buckling occurred against the old fault whose inclination is approximately 60° toward the north, that is toward the hanging wall block;

(ii) the wavelength of each individual buckle is limited by the wavelength of the uppermost buckle (L_1 on Figure 361.30-3), and the inclination of the fault.

(iii) buckles whose wavelength $L_n \rightarrow 0$ require layer parallel normal stress $\sigma_{TOT} \rightarrow \infty$ in order to be formed. This relationship is depicted on Figure 361.30-4.

Considering the above points, it follows from Figure 361.30-3 that the maximum possible depth of occurrence of the reverse-slip deformation, D_r, is less than a value given

by the following equation:

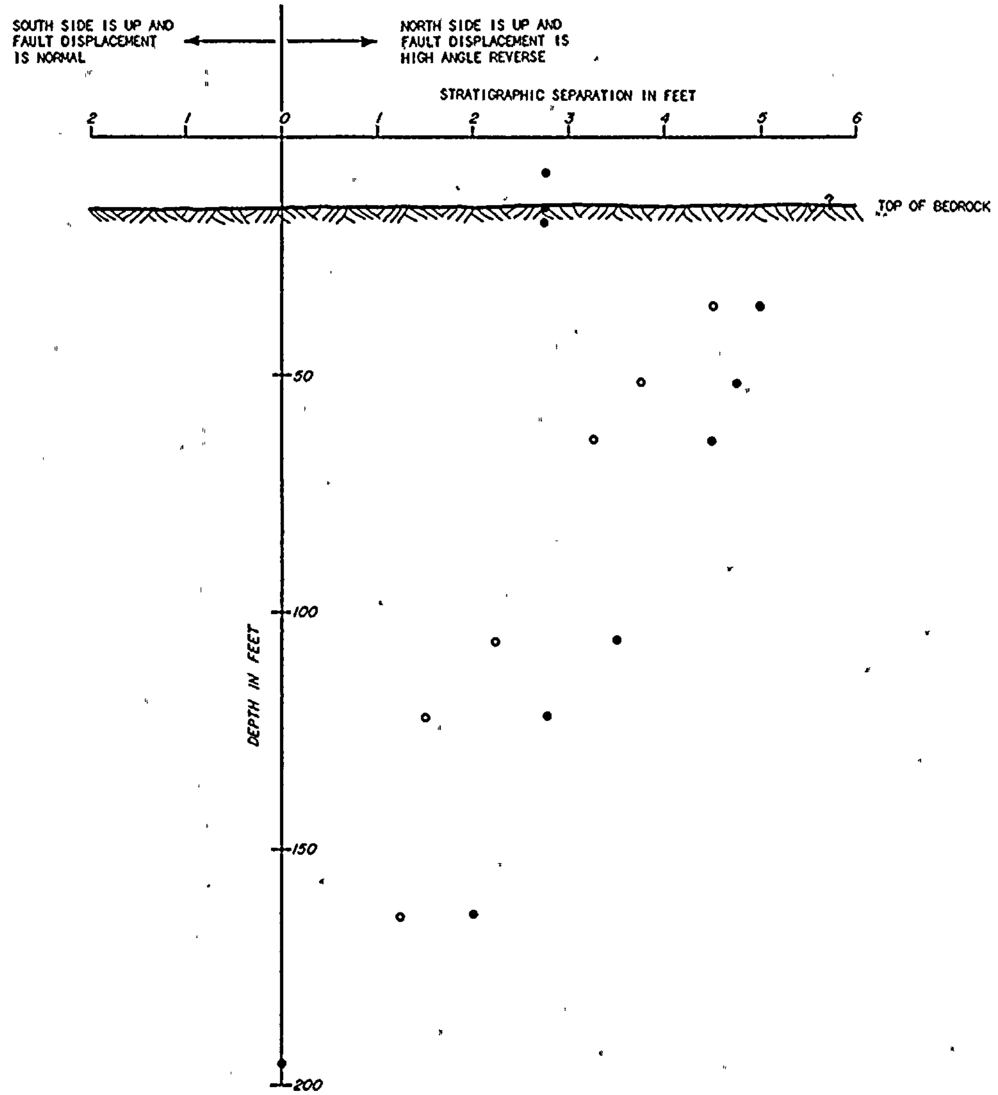
$$D = \frac{L_1}{\tan(90-\alpha)}$$

where:

α = inclination of the fault;

L_1 = wavelength of the upper deflections

From Figure 361.30-5 it can be seen that L_1 does not exceed a value of 130 feet. Hence, D_r is equal to approximately 225 feet. The actual depth of the reverse slip deformation must be less than this value.



EXPLANATION:

- ● Stratigraphic displacement measured adjacent to the fault plane.
- ○ Stratigraphic displacement measured 20 feet away from the fault plane.

NOTE:

(1) Displacements shown near top of the bedrock are based on observations made in trench 3.

(2) Displacements shown in unconsolidated sediments includes monoclinal flexure over the fault.

DIAGRAM SHOWING RELATIONSHIP BETWEEN STRATIGRAPHIC DISPLACEMENT AND DEPTH IN BORINGS T-3-1 THROUGH T-3-10

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.30-1

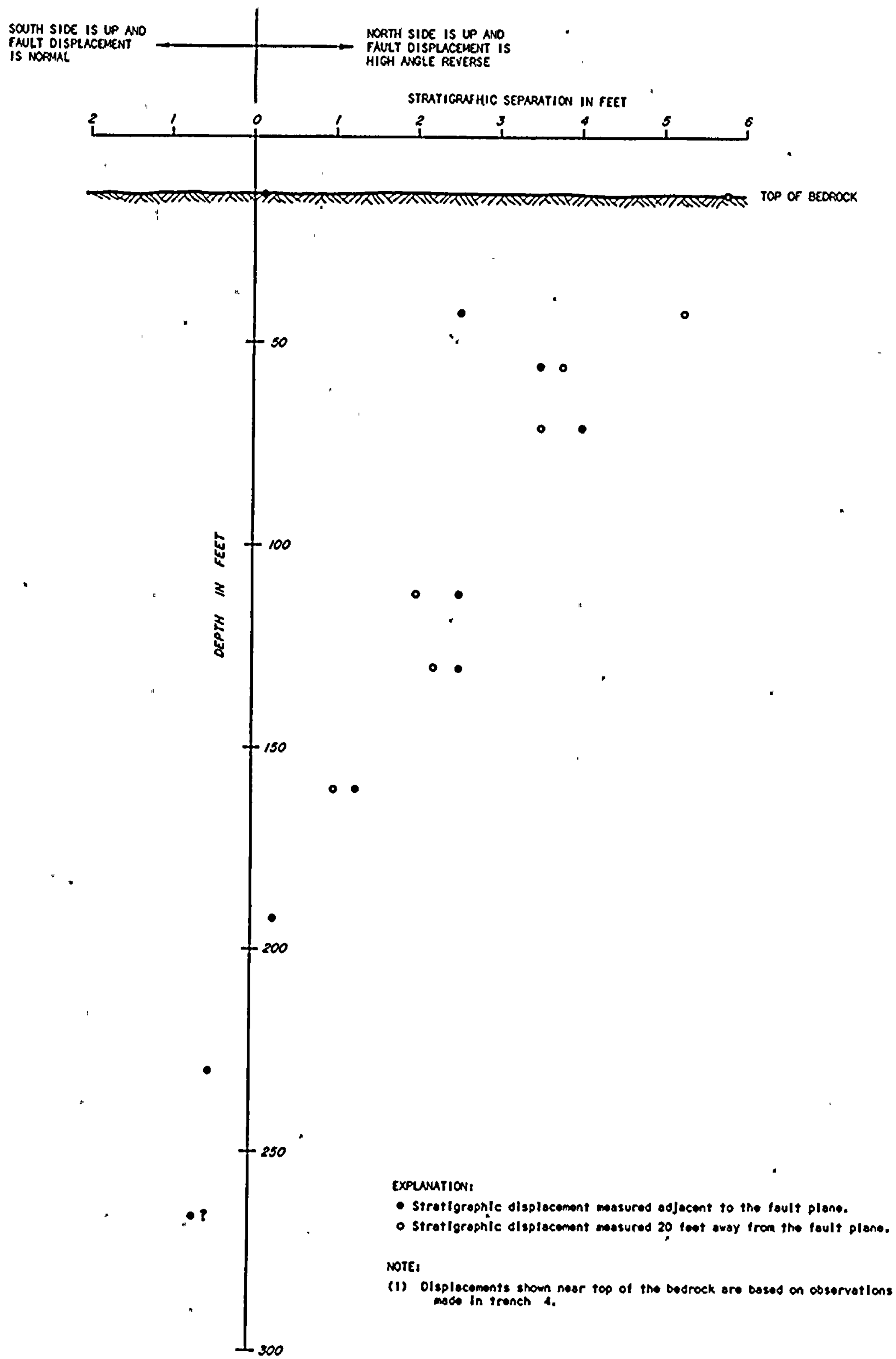
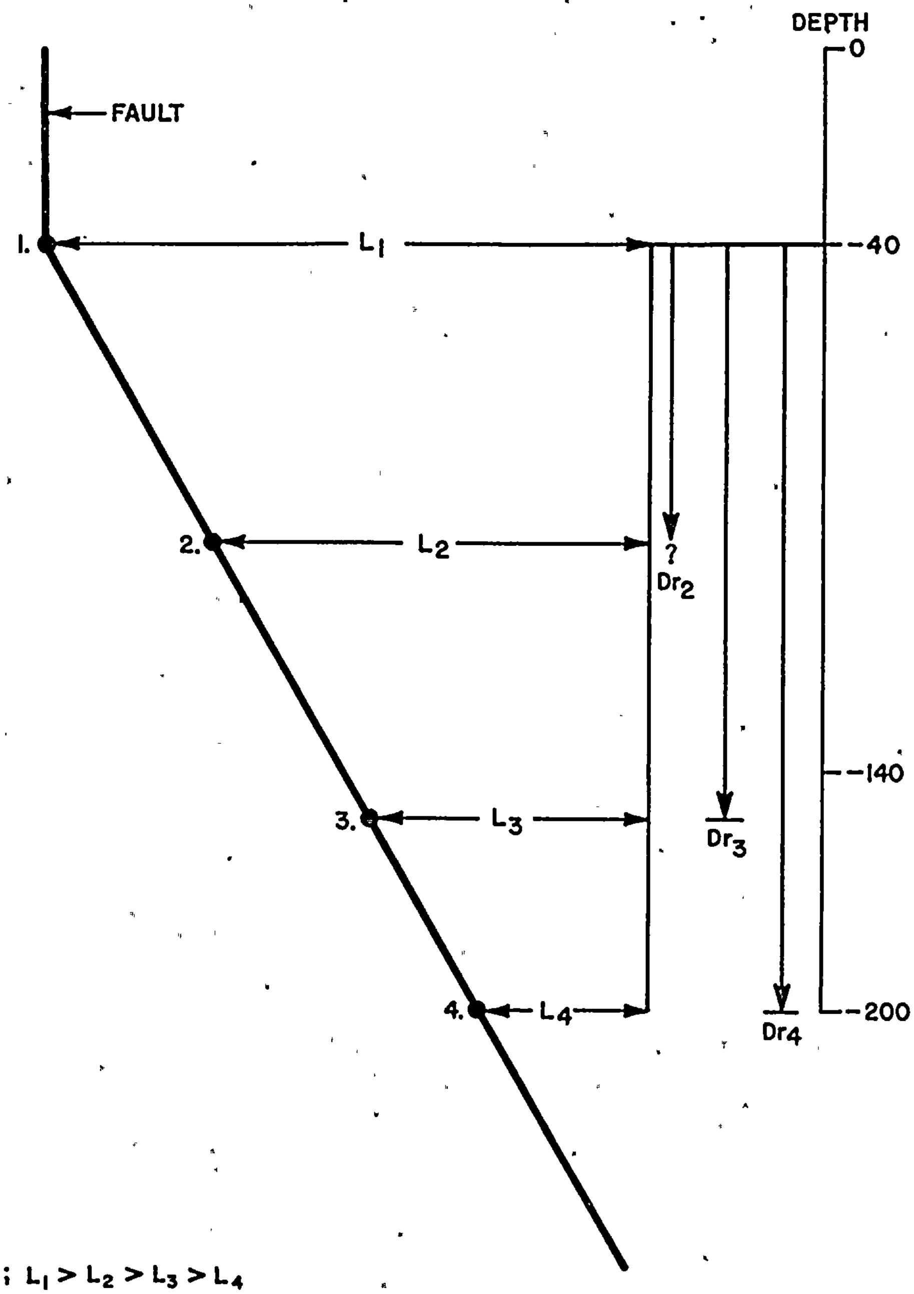


DIAGRAM SHOWING RELATIONSHIP BETWEEN STRATIGRAPHIC DISPLACEMENT AND DEPTH IN BORINGS T-4-1 THROUGH T-4-12

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.30-2



ASSUMING:

$t_1 = t_2 = t_3 = t_4$; $L_1 > L_2 > L_3 > L_4$

HENCE:

$L_1/t_1 > L_2/t_2 > L_3/t_3 > L_4/t_4$

Dr_4 = MAXIMUM POTENTIAL DEPTH OF REVERSE–SLIP DEFLECTION. (DEPENDS UPON L_1, AND IS CONSTANT FOR A SPECIFIC SYSTEM.)

L = WAVELENGTH OF DEFLECTION

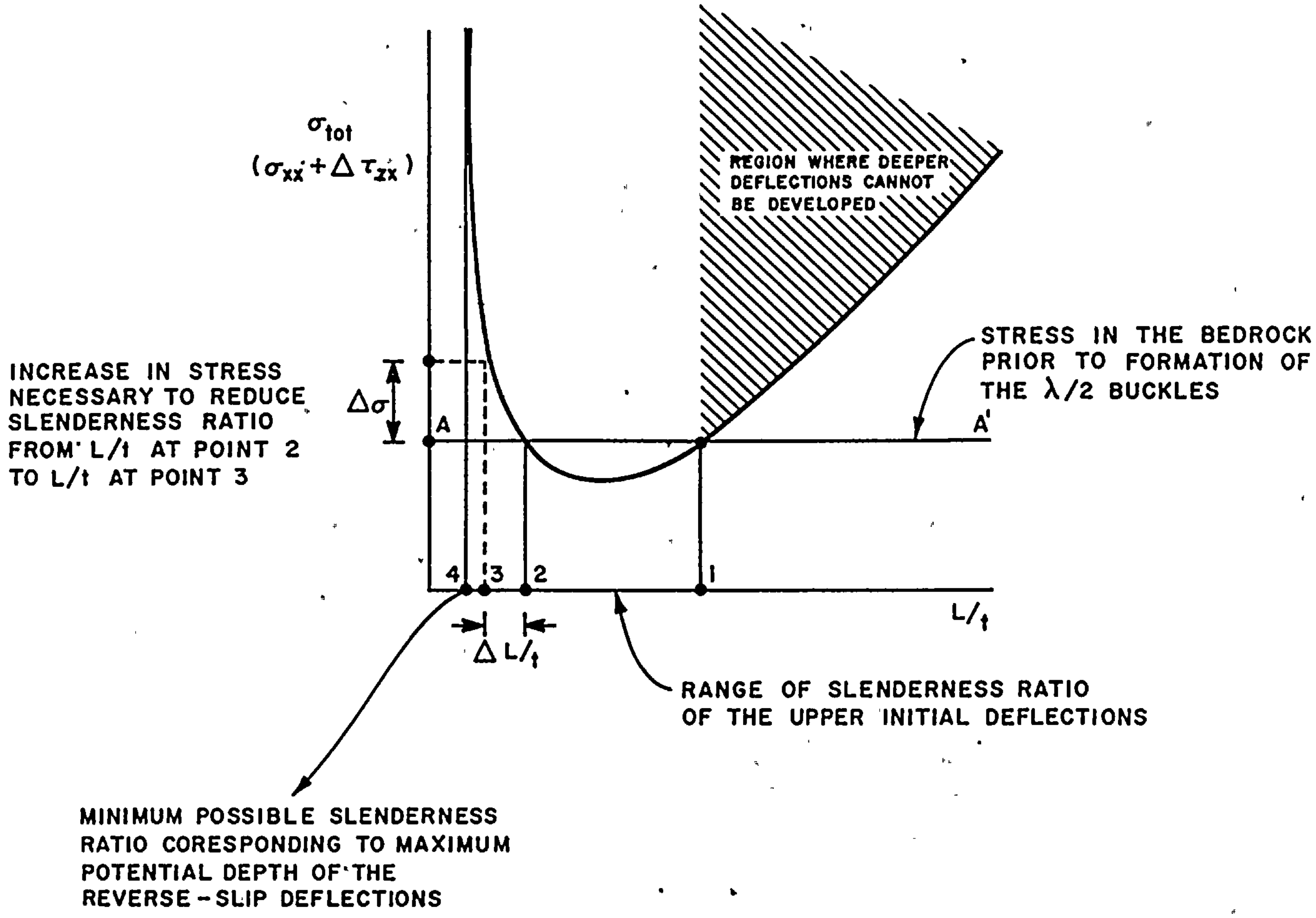
Dr = DEPTH OF REVERSE–SLIP DEFLECTION

t = THICKNESS OF STRATA

DEVELOPMENT OF MAXIMUM POTENTIAL DEPTH OF REVERSE–SLIP DEFLECTION

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

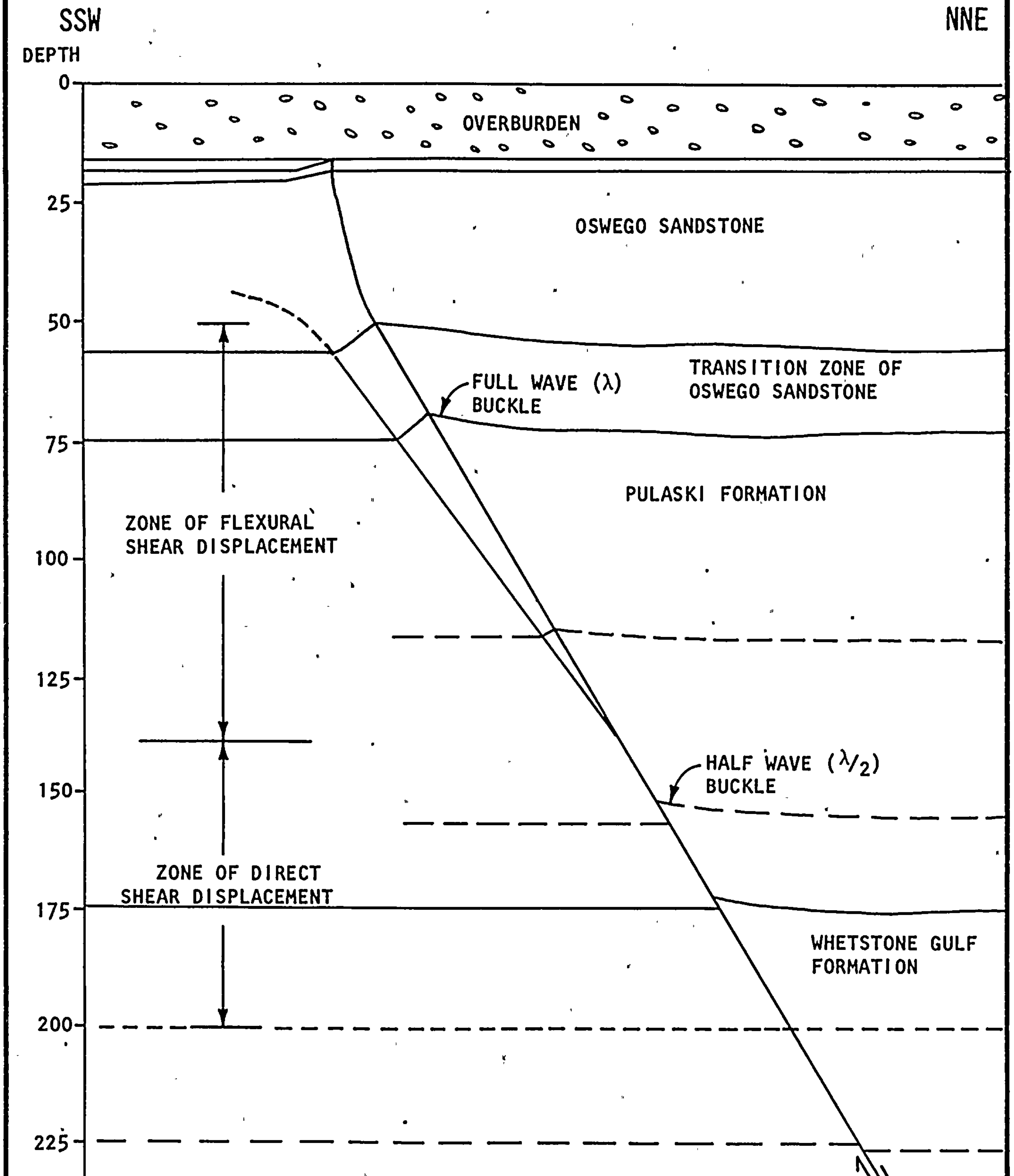
FIGURE 361.30-3



RELATIONSHIP OF LAYER-PARALLEL STRESS TO SLENDERNESS RATIO ASSUMED NECESSARY TO CAUSE BUCKLING ON THE COOLING TOWER FAULT

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.30-4



REVERSE SLIP DISPLACEMENTS DUE TO BUCKLING ON COOLING TOWER FAULT

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.30-5

Q361.31: In Section 3.2 of the Executive Summary, you conclude that future displacements along the deformation structures at the site will involve very low strain rates. Using the data available for these structures, provide a discussion as to why past Quaternary movements and possible future movements should be classified as slow (i.e., creep) versus rapid (i.e., seismic).

RESPONSE: The amount of seismic energy radiated as a result of slip along a fault in a given bedrock environment is a function of the stress drop and the source dimensions. Furthermore, for an earthquake to occur (the amount of seismic energy radiated is large) the stress drop must attain a value which is appreciably greater than zero. Typically, earthquakes are accompanied by stress drops ranging from 50 to 100 bars (approximately 750 pounds per square inch to 1500 pounds per square inch). Moreover, the earthquake related reduction of the in situ stress must be accomplished within a very small time interval, say 10^{-2} seconds. In other words, the change in stress with respect to time must be relativesly large.

In the April 1978 report it has been stated that the slip conditions accompanied by large, relatively fast stress changes can be only conceived during the development of the rotated bedrock sliver (see Sections 7.0 and 8.0, Volume I). Furthermore, it has been demonstrated that it is not possible to form another rotated bedrock sliver below a depth of approximately 160 feet.

From the present understanding of the site conditions and the mechanism of Quaternary deformation, it cannot be ruled out that minor, near-surface adjustments may occur in the future. These adjustments are considered to be related to:

(i) Further increase in amplitude of individual deflection within the depth interval of 140 to 200 feet, (below the rotated bedrock sliver where the stress drop was relatively small). The process will be arrested and/or mitigated by the higher deflections whose stress drop was significant.

(ii) Development of swelling strains in areas where the earlier deformational processes reduced the confining pressure below a given value of the first stress invarient (see response to Q361.34). It is expected that the occurrence of these strains will be limited to a rock mass above a depth of 160 feet.

(iii) Viscous "flow" of the bedrock in areas where the stress gradient is sufficiently large.

(iv) Reduction of the ability of bedrock, surrounding the perturbation, to maintain a given stress gradient. This reduction is related to the time dependent increase of the water level in the Ontario Basin. This increase will have a minor negative effect on the shear strength of bedding and thus, may facilitate further reduction of the existing stress gradient.

All the above mentioned processes are related to either rheological properties of the bedrock (viscosity and swell) or to the time dependent environmental changes (pore pressure). The resulting strains must also be time dependent. The strain rates, associated stress drops, as well as the rates of stress drops are infinitestimally small. The existing stress gradients will be decreasing, resulting in a time dependent reduction of the strain rates.

In summary, following the reasoning presented above, as well as that presented in the April 1978 report, it can be concluded that should any future adjustments occur in the vicinity of the Cooling Tower Fault, it is expected that they will involve very limited volumes of the bedrock as well as very low strain rates. These adjustments are of no consequence in the context of vibratory ground motion.

REFERENCES

Brune, J.N.,1970, "Tectonic Stress and the Spectra of Seismic Shear Waves from Earthquakes," Journal of Geophysical Research, Volume 75, pages 4997-5009.

Niagara Mohawk Power Corporation, 1978, Nine Mile Point Nuclear Station, Unit 2, Geologic Investigation, Scriba, New York.

Q361.32 Our position regarding the dating of the age of the last movement on the faults based on an apparent temperature of mineralization is that this method should be used with caution. Accordingly, provide your basis for discounting the possibility that frictional heat on the fault planes, generated during deformation, could cause the observed fluid inclusion temperatures. Further, indicate your basis for discounting the possibility that fluids which deposited the calcite were heated above the ambient geothermal gradient.

RESPONSE: We recognize and agree with your position regarding the need for caution when utilizing data from paleogeothermometry and paleogeobarometry to interpret the age of latest displacement along a fault. Indeed, the data by themselves do not provide direct information pertaining to their time of origin. Instead, one must infer this information based upon other data regarding the samples, their origin and local geologic (structural) relationships, and knowledge of the regional tectonic framework. Where these supplementary data are not available, paleotemperatures can be equivocal.

It was with this potential ambiguity in mind that the fault and fracture filling minerals were assessed as to their emplacement mechanism, environment and time of origin in the 1978 report (Niagara Mohawk Power Corporation, 1978; Geologic Investigations Nine Mile Point Nuclear Station Unit 2; Volume I).

Since the completion of that report all available fluid inclusion data for northern New York State and southeastern Ontario, Canada were reviewed. Additional data have been obtained from investigations for a Preliminary Safety Analysis Report for New Haven which is approximately 5 miles to the southeast of the Nine Mile Point Site. These newer data were reviewed and assessed in responses to Questions 361.13 and 361.14 which were submitted in June 1980. Comparison of these results with those reported in Section 2.2.4.2 of the 1978 report reveals that the majority of regional temperatures of homogenization are consistently in the range of 65°Centigrade (C) to 178°C. These values (a) are in excellent agreement with the data from the Nine Mile Point Site, and (b) represent temperatures obtained from specimens from a variety of specific settings including joints, beds, and stylolites, as well as faults. Intuitively, the quantity of frictional heat generated by shearing along these other features in comparison to faults would be minimal. Hence, one should be suspicious of the possible explanation that heat from frictional resistance to shear accounts for the high temperatures calculated from fluid inclusions.

There are two lines of evidence indicating that the temperatures of homogenization recorded by the calcite and quartz (in the host rock) represent heat from a source or sources different from the heat of friction. Dr. H.L. Barnes reported (Appendix E, Volume, I, Niagara Mohawk Power Corporation, 1978) the occurrence of certain euxinic sulfides accompanied with calcite along bedding as well as fracture planes; among them are mackinawite (Fe_9S_8) and troilite (FeS). These minerals are those to be expected from the aging of sedimentary iron sulfides, and have limited stability ranges. Mackinawite is unstable at temperatures above 140°-150°C (Appendix E, Niagara Mohawk, 1978); however, if buried to depths of 2 kilometers or more the stability limit increases to 155°C-160°C. This is completely compatible with the 160°C temperature values from fluid inclusions in recrystallized quartz from the host rock.

The other line of evidence is the discovery of calcite deposited by groundwater flowing along the Radwaste Fault, and Lake Water Tunnel faults as reported in the response to Question 361.1(d) submitted in June, 1980. As reported, this calcite contained fluid inclusions with decrepitation temperatures of less than 40°C. Dr. Barnes indicates that, in one specimen collected from the thrust fault in the tunnel, low-temperature calcite as matrix encloses breccia fragments of sandstone and milky calcite such as identified from the Cooling Tower Fault. Because the liquid-to-vapor ratio of the milky calcite inclusion clasts is approximately the same as that for the in situ milky calcite, no alteration or re-crystallization occurred when the low-temperature calcite was formed. Because the earliest generation of groundwater calcite always exhibits cataclastic texture, and because the texture, character of inclusions, their temperature values and the mineral paragensis all suggest that the groundwater calcite probably crystallized at temperatures less than 40°C, it is highly unlikely that frictional heat adversely affected inclusion entrapment temperatures in the calcite.

A further argument from a mechanical standpoint may be made that friction on the Cooling Tower Fault could not have contributed a significant quantity of heat such as would influence the entrapment temperatures of fluid inclusions. Price (Appendix L, Volume III, Niagara Mohawk, 1978) indicated that:

1) The rocks were saturated with brines.
2) The minimum fluid pressure likely to be attained over long time periods is that of hydrostatic head.
3) Mineralization of the fault can lead one to infer that the fluid pressure exceeded the hydrostatic state.

In other words, with progressive sedimentation in the Appalachian Basin, the ratio (λ) of fluid pressure to the vertical geostatic pressure commonly approached a value of 1.0 and locally could exceed this value under certain conditions. It can be shown that normal faults could develop and that the normal stress across such faults would be negative, that is the fault planes would be "open" thereby permitting flow of fluids along the faults with consequent precipitation of vein-filling minerals. Under these circumstances, the contribution of friction to the value of shear resistance would be minimal. One can extend this argument to include the thrust faults. These faults were formed later than the normal faults, and at higher levels in the crust as evidenced by abundant dilation of beds affected by the deformation. In this instance, the value of λ should have been much lower than at the time of normal faulting. Hence, one would expect the friction to have been relatively greater during thrust-type slip, than during normal-slip. However, the paleotemperatures were apparently less than 40°C. Therefore, one can only conclude, once again, that frictional heat had a negligible effect upon the inclusion entrapment temperatures. The temperatures more likely reflect the ambient geothermal gradient at the time the minerals were formed.

In the 1978 report, based upon the work performed by Dr. Barnes, it was concluded that the paleotemperatures recorded by the minerals were elevated initially due to increased heat flow caused by dehydration reactions typical of the zone of transition from hydrostatic temperature/pressure to lithostatic temperature/pressure conditions in the Appalachian Basin, analogous with the Gulf Coast Basin. It was postulated that these fluids of elevated temperature caused the development of a transient thermal gradient of as much as 40°C/kilometer for a period of a few tens of millions of years. It was also stated (pages 6-14 of Volume I) that there were two other potential causes of an elevated geothermal gradient: localized magmatic processes and crustal thinning associated with tectonic processes. The closest known evidence of paleo-magmatic activity is in Syracuse, New York where several Jurassic kimberlite dikes are known. Batholithic intrusions of the Monteregian Hills, Canada are known to be Cretaceous. However, no clear evidence of hydrothermal mineralization due to igneous activity was found in the site region. Similarly, because progressive sedimentation in the northern Appalachian Basin continued through the Mississippian period, it is improbable that crustal thinning was occurring beneath the basin rather than beneath the uplands. Therefore, no firm reason to support the supposition that the fluids from which fault-filling minerals precipitated could have been heated above the ambient geothermal gradient can be offered.

Q361.33 In Appendix I-G of your report, you present results of uranium/thorium (U/Th) disequilibrium dates from samples of fault-plane calcite. Indicate how this evidence affects your assessment of the most recent movements on the fault. Discuss why the ages of 80,000 and 170,000 years before the present as determined by this technique, are not consistent with ages of faulting determined by other methods. Our concern is that if there is sufficient uranium present in the sample to establish a U - Th disequilibrium date, then there should be sufficient uranium and lead for a U-Pb, Pb-Pb, or U-fission track date. Any one of these methods would be much more sensitive and meaningful if the calcite is older than 200,000 years. If possible, provide a reliable date by one or more of the methods cited above if the 80,000 year date is to be discounted as you claim.

RESPONSE: Conclusions regarding the nature and age of specimens SW-1 and SW-2 which yielded the Th/U dates of 80,000 and 170,000 years, have changed in light of detailed additional geological investigations performed at the Nine Mile Point Site since 1978. Subsequent work at the Nine Mile Point Site has revealed the occurrence of a generation of calcite which crystallized at a later time and at lower temperatures than the varieties of calcite identified in the 1978 report. The newer calcite has been found to be present in association with zones of deformation of the low-angle thrust faults in the North Radwaste Trench, in the Intake Shaft and East Lake Water Tunnel, as well as bedding plane slip zones elsewhere on site. The occurrence of this calcite has been documented, and specimens were collected for fluid inclusion and paragenetic analyses by Dr. H.L. Barnes.

Calcite specimens were collected from three locales:

1) the Circulating Water Piping Trench to the relocated cooling tower,

2) the North Radwaste Trench, and;

3) the East Lake Water Tunnel

Additionally, radiometric dates and stable isotope analyses were obtained to help interpret the absolute age of the calcite. Results are outlined herein and full details documenting the occurrence, analyses, and conclusions will be presented in a report to be submitted at a later date.

Dr. Barnes' paragenetic studies have distinguished as many as six varieties of calcite in the entire paragenetic sequence which is presented schematically in Figure 361.27-2.

Dr. Barnes also identified two additional stages of deformation based upon microscopic mineral textures. He termed these stages D_5 and D_6. The mineral types are briefly described below.

Types 1 and 2: These two types of calcite are equivalent, but Type 2 was only recognized at one locality, the Circulating Water Piping Trench. Type 1 consists of fine-grained clear calcite which has been brecciated and recemented by later calcite. Typically, clasts of broken bedrock are incorporated within it. Paragenetically, this group apparently is the oldest of this sequence, but its texture and isotopic composition indicate that it post-dates the clear calcite associated with Mesozoic normal faulting identified in the 1978 report. Fluid inclusions were rarely found in Types 1 or 2. The intense cataclasis of this calcite apparently liberated any inclusions which may have formed. This group of calcite is always found on shear planes of the Radwaste and East Lake Water Tunnel thrust faults, and along brecciated zones of bedding-parallel slip onsite. Dilated openings in the bedrock, associated with these zones of shear deformation where this mineralization occurred, suggested a near surface origin of Type 1 calcite.

Travertine: Many forms of very fine-grained, travertine were observed and this mineral group is paragenetically related to Type 1 calcite in that, although never found together with Type 1, it always underlies or is infilled by later forms of calcite, as in the case of Type 1. The travertine was deposited above the water table. Type 1 crystallized below it. The travertine is found on dilated bedding planes and joints in the zone of deformation of the Radwaste Fault, and has been deformed.

Silty Calcite: This calcite was seen as thin laminae of very fine-grained calcareous material containing abundant pyrite and siliceous detritus, deposited on travertine and covered by Type 3 calcite. This is not a dominant form of mineralization at the site.

Type 3: The sparry calcite is found in a variety of habits, and occurs in fractures and openings in the Type 1 breccias and travertines, and are therefore younger than the age of deformation of Type 1 (D_5). Type 3 calcite is the only one of the lower temperature calcites that commonly contained fluid inclusions. They are predominantly liquid-phase inclusions, but have high liquid-to-vapor ratios when a vapor phase is present. The fluid has a very low salinity, (5 to 6 percent NaCl by weight). The maximum filling temperatures of these inclusions is $40^{\circ}C$. Minor healed fractures in Type 3 have been observed (D_6) plus chips of Type 3 have been seen to be healed by brown calcite.

<u>Brown Calcite</u>: This mineral lies on top of sparry, Type 3 calcite, but is present only irregularly, being both discontinuous and of varied thickness. This mineral is interpreted to be younger than D_6, and is paragenetically the youngest variety of calcite.

<u>Age of the Calcite</u>: During the investigation, the absolute age of the major forms of calcite were analyzed and evaluated utilizing stable isotope ratios of ^{13}C and ^{18}O plus absolute dates by the ^{14}C and $^{230}TH/^{234}U$ methods. The results are summarized in Table 361.33-1.

Additionally, specimens of the drusy calcite dated by the Th/U method from the Cooling Tower Fault study were reassessed in light of the new data from the paragenetic studies on groundwater calcite. As a result of this work, the following conclusions can be drawn with respect to Type 1 calcite, Travertine, and Type 3 calcite.

1. Type 1 calcite is apparently the oldest of the groundwater calcites. It is younger than calcite found at the time of normal faulting (Mesozoic) because of its near-surface origin and lower inclusion temperatures. Carbon and oxygen isotope results (Table 361.33-1) indicate a typically marine source for the carbon, but a fresh water source for oxygen if the carbonate is younger than Triassic. A marine origin of the carbonate oxygen would be unlikely in Triassic time because the site area was emergent and eroding throughout the Mesozoic. Hence, fresh water apparently leached the older marine ^{13}C from the site bedrock, thereby explaining the greater than 36,000 year ^{14}C age (sample HK-1). For this reason a $^{230}TH/^{234}U$ date, to determine the actual age of calcite crystallization, was performed by Dr. T.L. Ku of the University of Southern California. His analysis yielded a less than 300,000 year age.

2. The travertine was found to be a vadose precipitate yielding a ^{14}C age of 14,180$\pm$550 year age. This age is somewhat compatible with that yielded by shells from sample SL-10 from the lacustrine overburden at the site (Table 361.33-1). The ^{13}C and ^{18}O ratios indicate a superficial source of both carbon and oxygen in fresh waters of relatively shallow circulation. Inasmuch as glacial ice covered the site 14,000 years ago, the travertine likely formed at a later time. This is because it formed above the water table.

Small quantities of older carbon leached from Paleozoic carbonate clasts by water percolating through till in the overburden could have been incorporated into the travertine, thus setting back the ^{14}C age. Nevertheless, the travertine is of Late Wisconsinan age, and the paragenetic studies showed that it is deformed and fractures in it are filled by Type 3 calcite.

3. An insufficient amount of Type 3 calcite was collected for a successful ^{14}C date, but the ^{13}C ratio shows that the carbon is also from a fresh water source (Table 361.33-1). This calcite is the same age or younger than the travertine, namely Late Wisconsinan.

Dr. Barnes re-examined the data from specimens JT-13, 43 and 44 collected from the same material which yielded the TH/U dates reported in the 1978 report (Samples SW-1 and 2). He has concluded that the clear calcite in these samples is actually Type 1 calcite for three reasons:

1. They contain single phase inclusions and inclusions with high liquid-to-vapor ratios, yielding temperatures well below 100°C.

2. The occurrence of sulfides (marcasite, pyrite) in JT-44 closely corresponds to those seen in the Type 1 calcites (Table 361.33-1).

3. Ku's analyses of Type 1 in TU-1 (analyzed recently) and SW-1 and 2 (analyzed previously) showed there to be excess ^{230}Th in the calcite because of the inheritance into Type 1 calcite of older clasts of milky calcite.

Additionally, fluorescence techniques applied to analysis of the Type 1 calcite has revealed that Type 1 consists of several compositional types of calcite indicative of the inheritance of older epigenetic calcites. This means that Type 1 calcite is prejudiced for older dates. Consequently, dating by the U-Pb, Pb-Pb, and probably the U-fission track methods is precluded because of the mixing of young and old calcite.

Hence, one can conclude from these new data that the clasts of breccia in Pit 1 were coated by a drusy form of low-temperature Type 1 calcite at the bedrock/till interface to be distinguished from the high-temperature epigenetic calcite which was found in every surface exposure of and throughout the cores obtained from the zone within the

Cooling Tower Fault. Moreover, the results of age-dating studies show that the Type 1 calcite is less than 300,000 years old. Therefore, the results of the 80,000 and 170,000 year dates are no longer discounted. Furthermore, the travertine and Type 3 calcite are approximately the same age as the later stages of glacial Lake Iroquois, (approximately 11,000 years before present).

From geological evidence (Niagara Mohawk, 1978, Volume 1, Section 4.0), it is known that the main stage of buckling occurred prior to deposition of the Wisconsinan overburden and that buckling caused dilation of the upper 200 feet of the bedrock section. It is known now that dilation and crystallization of Type 1 calcite are also associated with the development of the thrust faults. Therefore, the time of buckling on the Cooling Tower Fault could be correlative with the beginning of thrust fault development, which, because of the postulated mechanism of deformation for this sytem of structures, must have occurred during the final stages of an interglacial period (refer to response Q361.28; and to Sections 7.0 and 8.0, Volume 1 and Section 7.0 Volume III, Niagara Mohawk Power Corporation, 1978).

TABLE 361.33-1

RADIOMETRIC AND ISOTOPIC ANALYSES

Number:	HK-1, TU-1	HK-2	HK-3	SL-10*
Sample:	TYPE 1 Calcite Breccia	Travertine	TYPE 3 Sparry Calcite	Mollusk Shells
^{14}C Age (years)	36,000 (HK-1)	14,180 ± 550	-	12,545 ± 330
^{13}C ($^0/00$)	+ 3.1 (HK-1)	- 7.5	- 4.7	- 6.9
^{18}O ($^0/00$)	+ 21.1 ± 0.2 (HK-1)	+ 22.6 ± 0.2	-	-
$^{230}Th/^{234}U$ (years)	300,000 (TU-1)	-	-	-

*From Niagara Mohawk Report, 1978, Volume II. Collected from marl in overburden along Circulating Water Piping Trench.

Q361.34 Substantiate the argument presented in Section 2.6 of your Summary that swelling stresses may have resulted from fluctuations in water level in Lake Iroquois. Show that rocks at the site can develop a swelling stress under confined conditions with water pressure varying from 1 to 10 atmospheres. Estimate how rapidly Lake Iroquois must have drained so that residual pore pressues could approach lithostatic pressures. In this evaluation, use the permeabilities determined by pumping test in the upper 200 feet of rock in this area.

RESPONSE: In order to characterize the swell behavior of the bedrock at the Nine Mile Point site, various swelling tests were performed. These tests included free swell tests (unconfined swell) as well as oedometer ring swell tests (confined swell). The results of the free swell tests were presented and discussed in the April 1978 report. It was concluded that the development of swelling strains is conditioned by the accessibility of water, and the reduction of confining in situ stress below a given value.

The results of the oedometer ring swell tests are presented on Figures 361.34-1 through 361.34-8. The Figures show the relations of the swell rates as a function of the first stress invarient, which is the sum of the principal stresses. The rock units within which the Cooling Tower Fault is developed were tested for swelling potential. The following conclusions can be reached, based on the data presented:

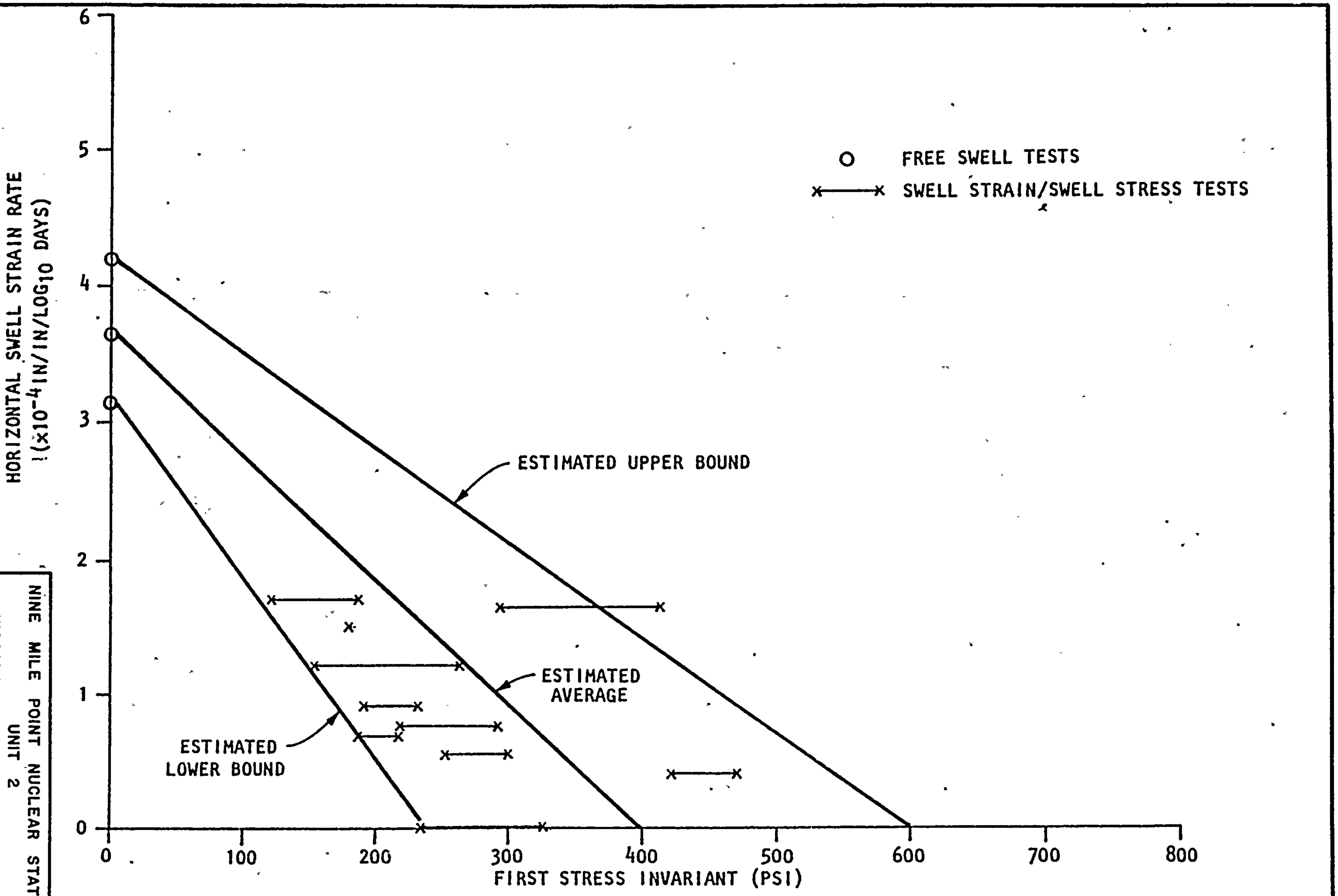
(i) the swell strain rates are dependent upon the first stress invarient. The rates decrease linearly with the increase of the stress invarient;

(ii) there exists a limiting value for the first stress invarient beyond which swell rate is equal to zero. The limiting value indicated by the results appears to be larger than approximately 450 pounds per square inch (first stress invarient corresponding to hydrostatic pressure equal to 10 atmospheres).

Hence, it follows that rocks present at the site can develop a swelling stress under confined conditions with water pressure varying from 1 to 10 atmospheres. However, in order to develop these strains, the in situ bedrock stress must be reduced below the limiting value of the stress invarient. From observations of bedrock dilations onsite, it is clear that the required reduction occurred simultaneously with the deformation. The residual pore pressure may have been important in triggering this deformation.

The deformation must have been accompanied with a stress drop and the development of a stress gradient. As a consequence of the deformation, permeability of the bedrock was substantially increased and the pore pressure was reduced. Following that, the swelling of the bedrock could have taken place, provided that access to water was maintained.

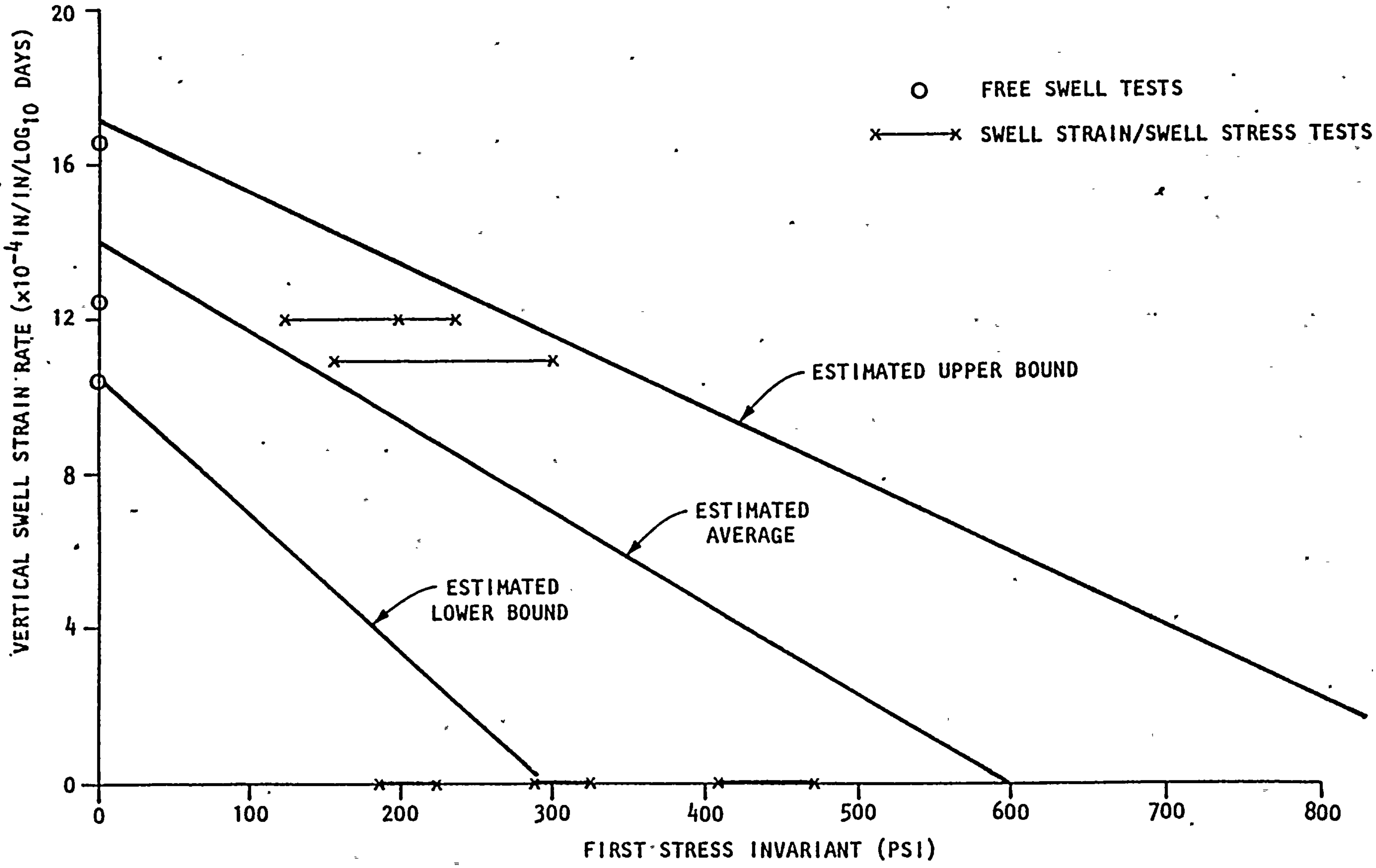
Available data regarding the drainage of Lake Iroquois do not allow a more precise estimate than already presented in Plate 1-14 of Volume II of the April 1978 report. Calculations of the rate of drainage would be highly speculative, requiring knowledge of the outlet cross sectional area and inflow rate. Additionally, changes in bedrock permeability occurred as a result of the draining of Lake Iroquois as evidenced by the presence of lacustrine deposits on bedding planes and fractures to below 200 feet. Therefore, it would be inappropriate to utilize present permeability values determined in the upper bedrock units. It is felt that the load casts and sand dikes observed in the Sandy Creek sediments above the Cooling Tower Fault provide sufficient evidence that Lake Iroquois drained relatively quickly and pore pressures probably did approach lithostatic pressures.



HORIZONTAL SWELL STRAIN RATE V.S. FIRST STRESS INVARIANT - TRANSITION ZONE

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

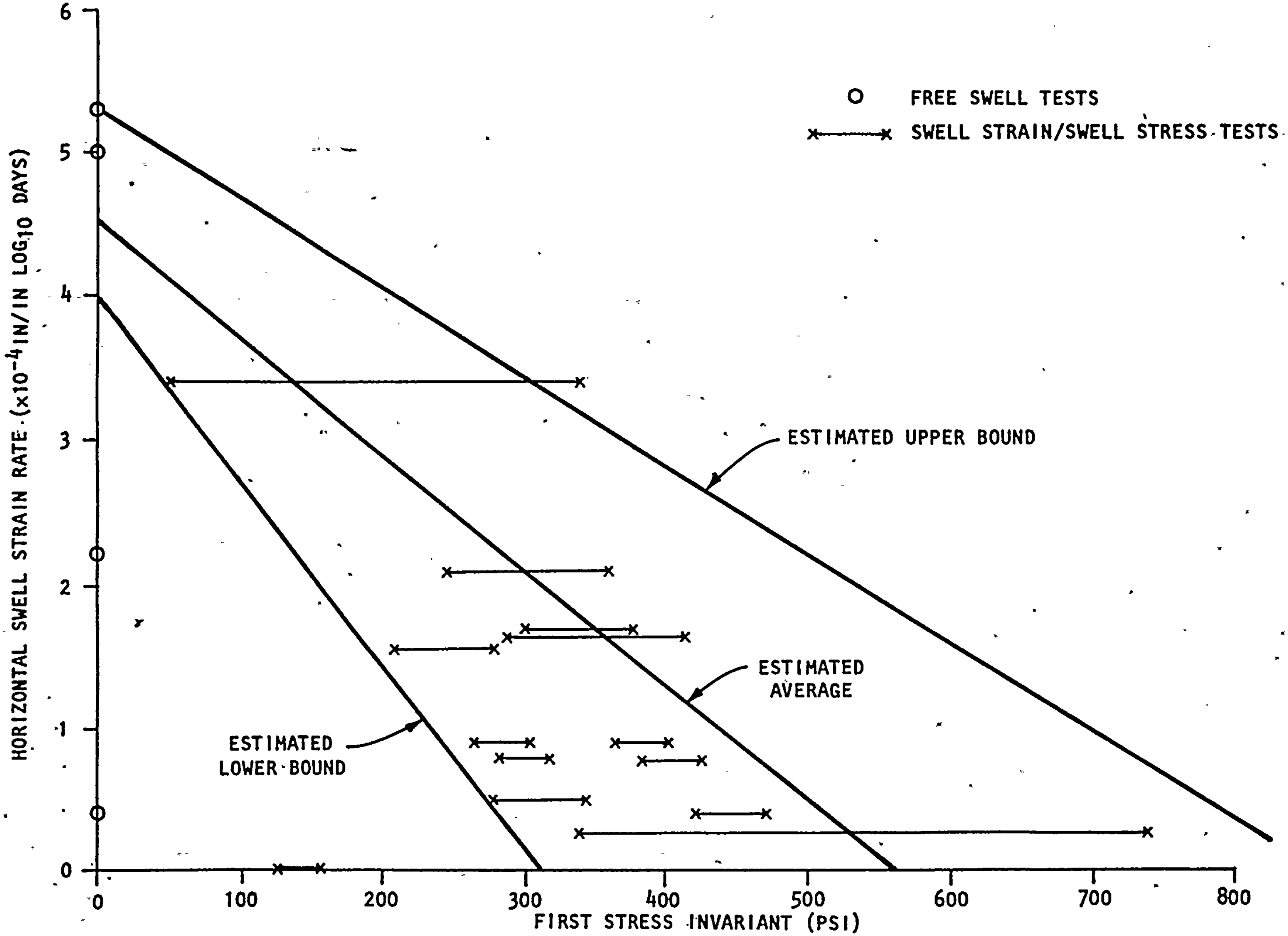
FIGURE 361.34-1



VERTICAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - TRANSITION ZONE

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

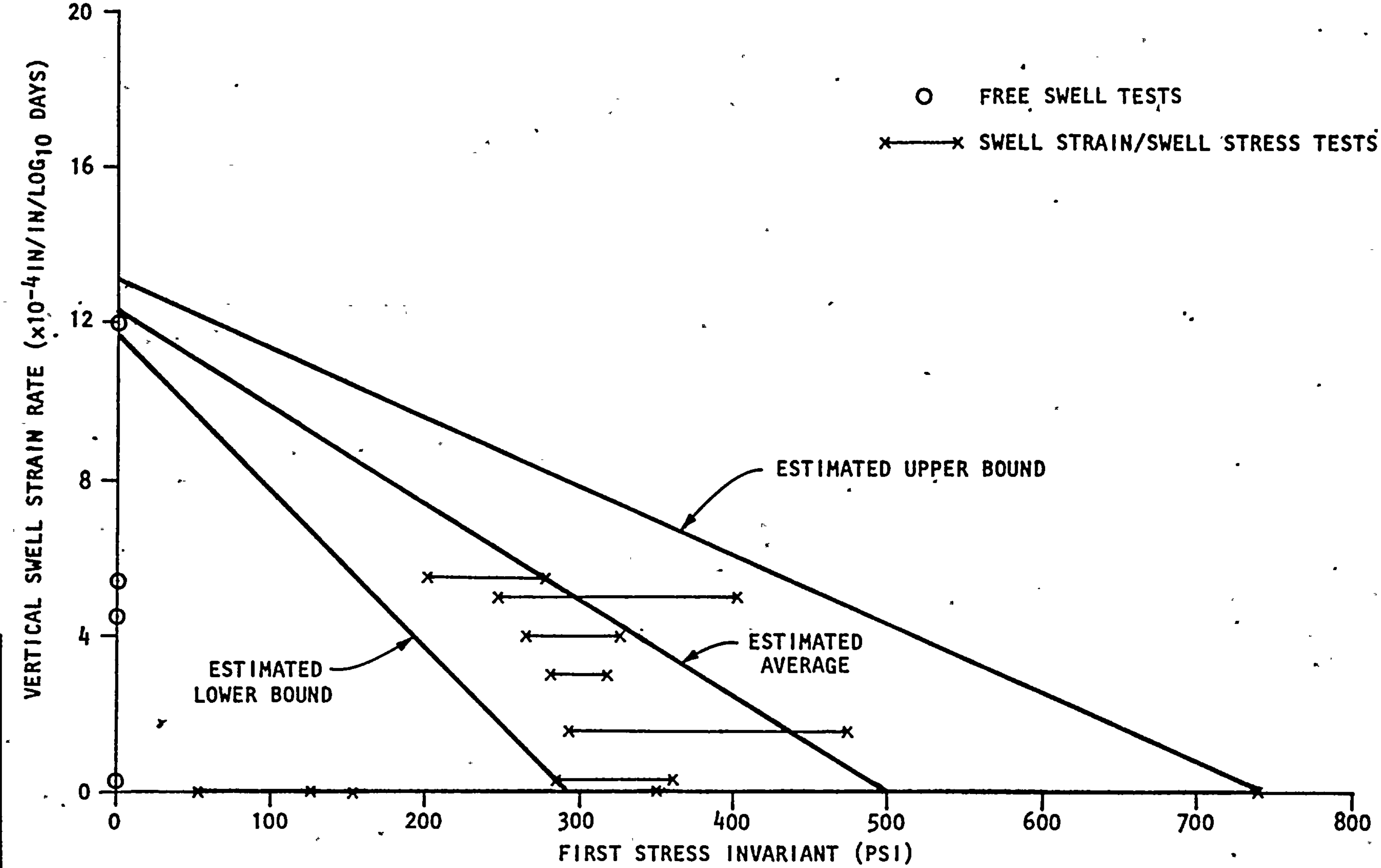
FIGURE 361.34-2



HORIZONTAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - GREYWACKE

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

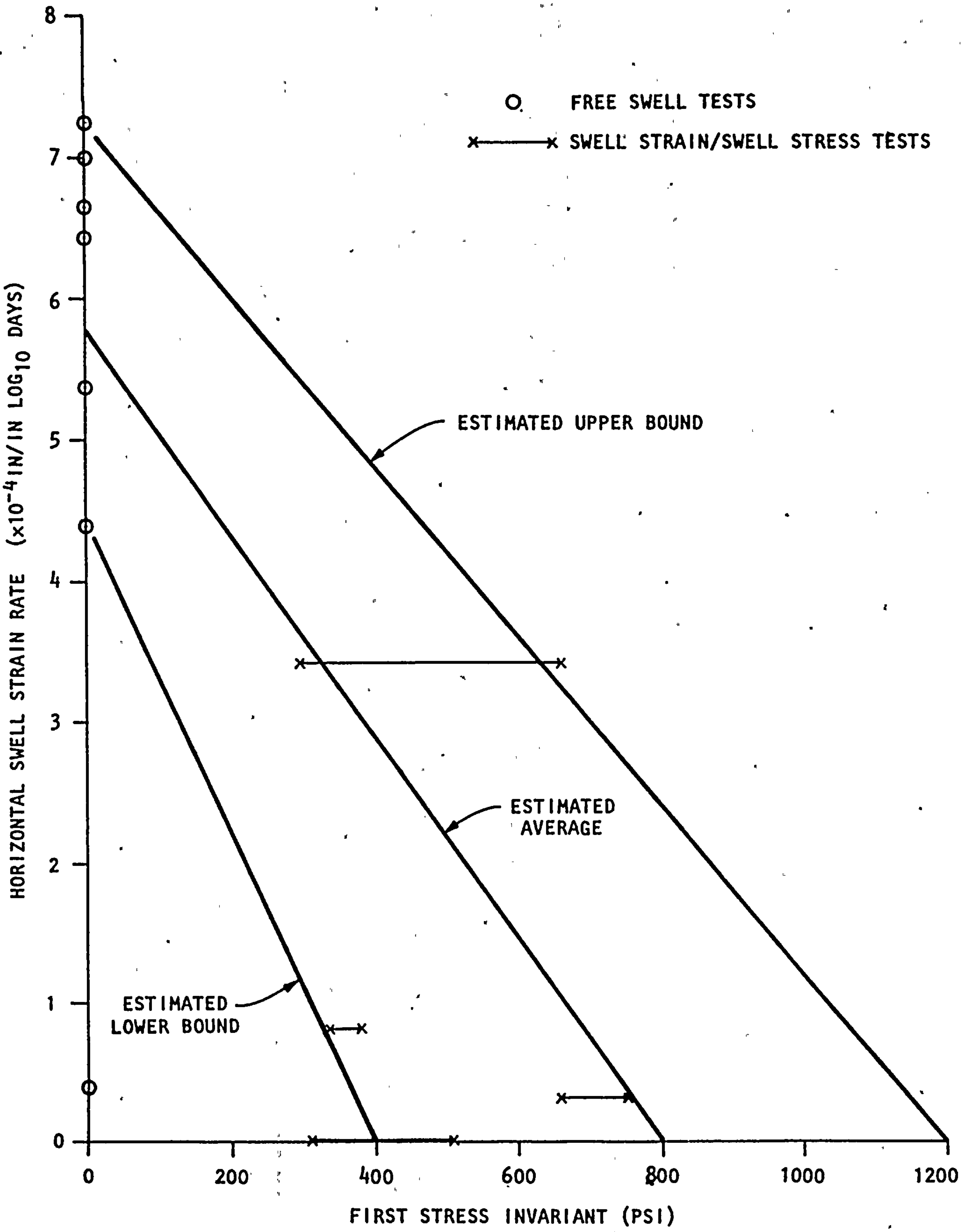
FIGURE 361.34-3



VERTICAL SWELL STRAIN RATE
V.S. FIRST STRAIN INVARIANT - GREYWACKE

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

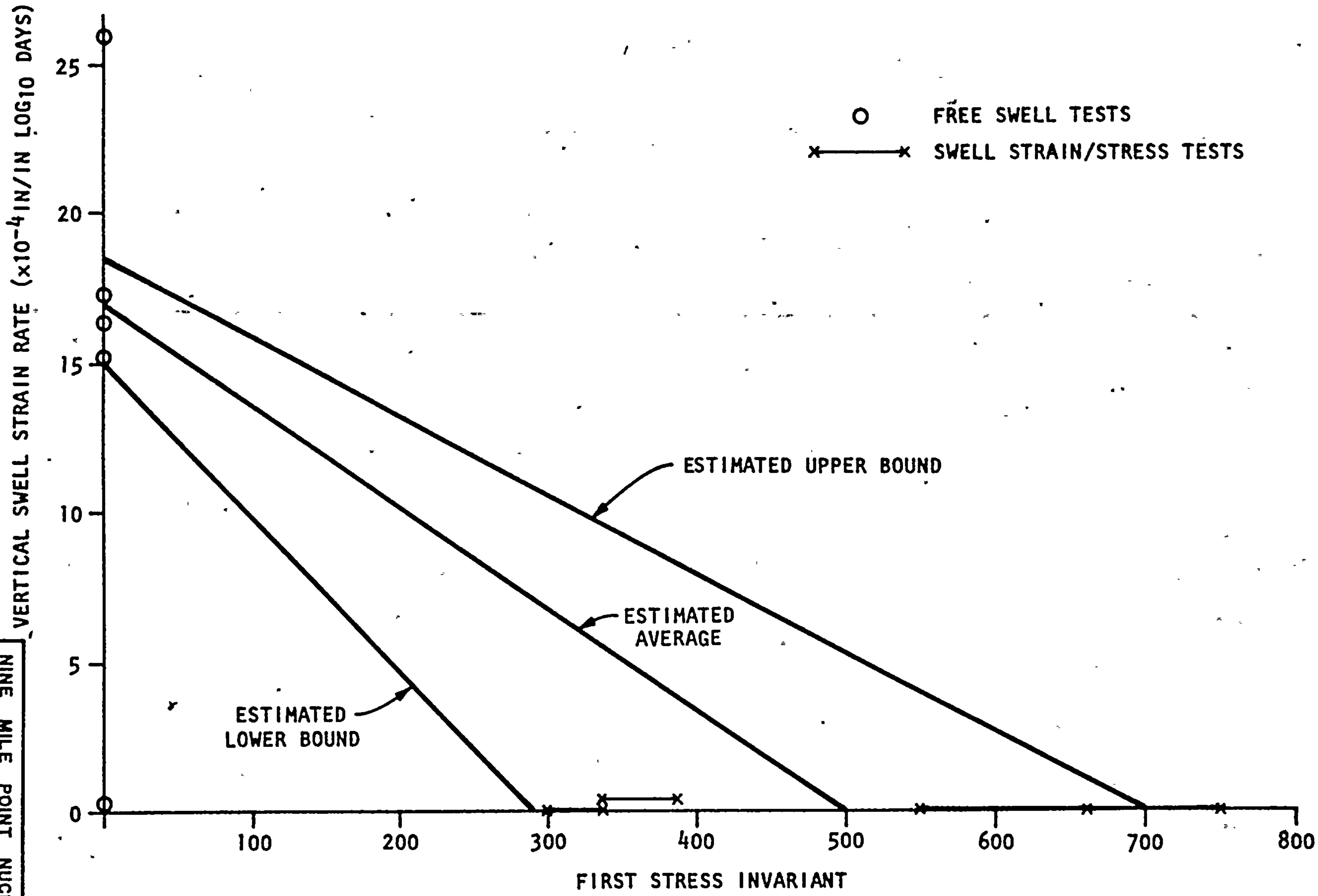
FIGURE 361.34-4



HORIZONTAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - PULASKI B & C

NINE MILE POINT NUCLEAR STATION UNIT 2 NIAGARA MOHAWK POWER CORP.

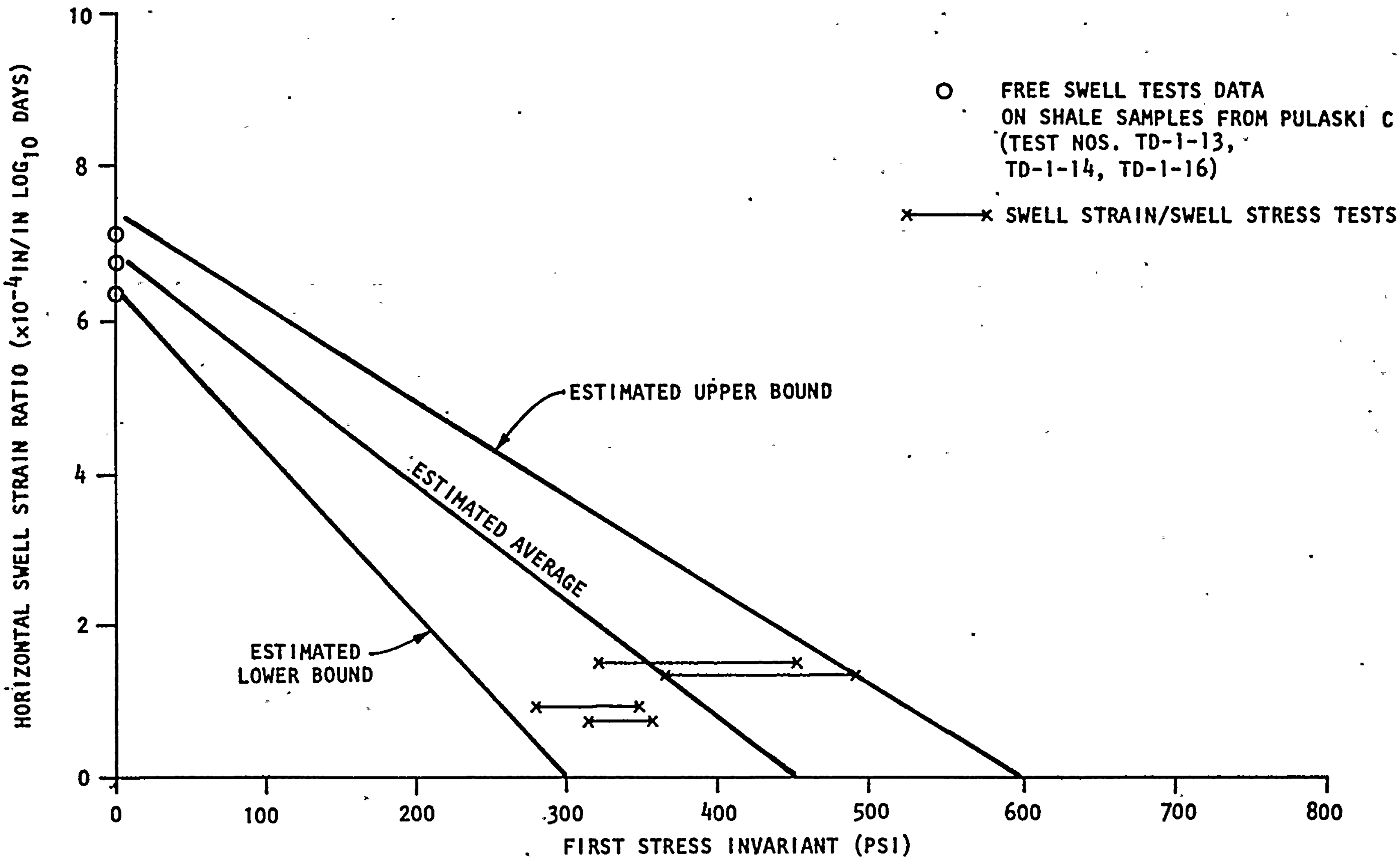
FIGURE 361.34-5



VERTICAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - PULASKI B & C

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

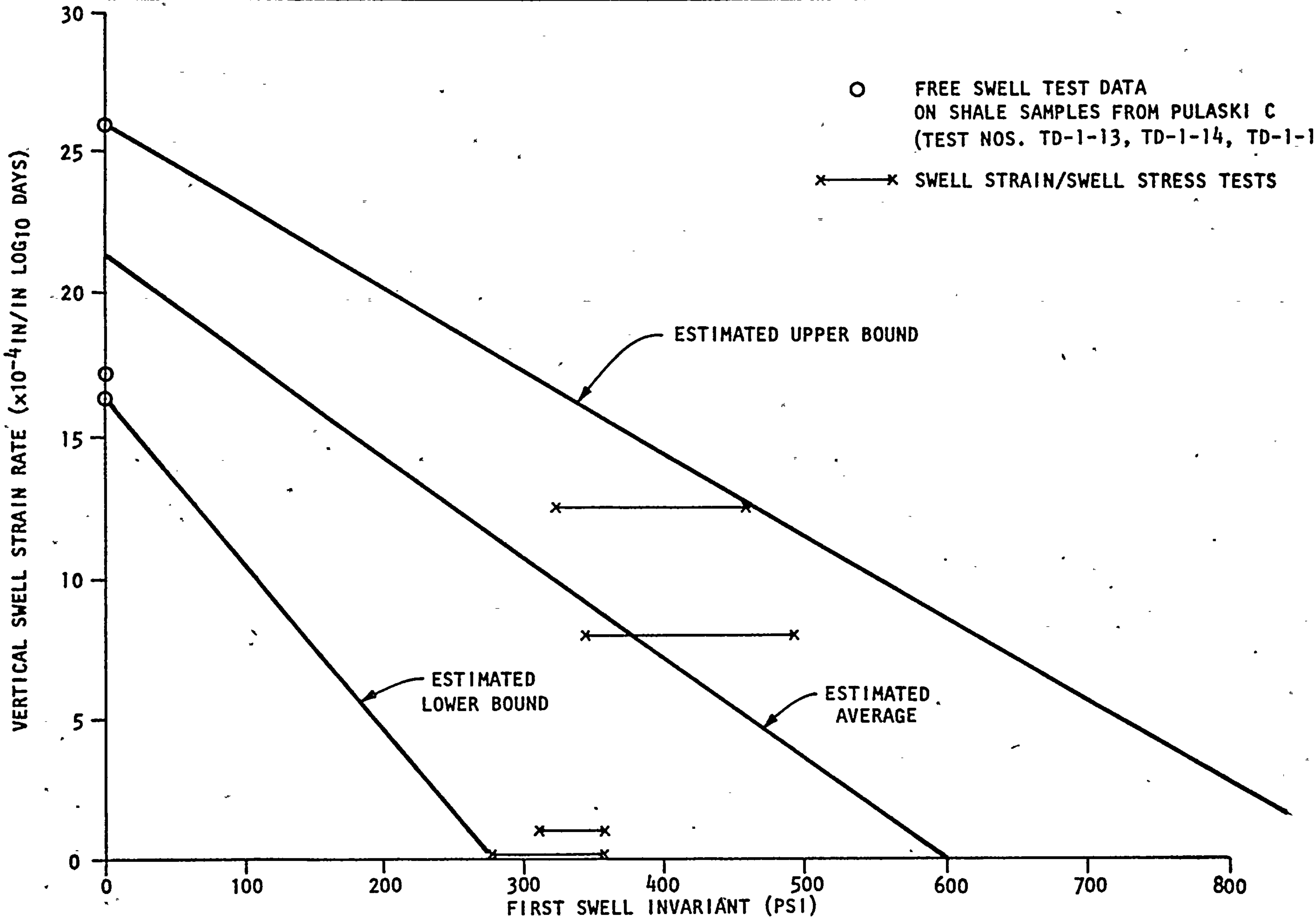
FIGURE 361.34-6



HORIZONTAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - WHETSTONE GULF FORMATION

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.34-7



VERTICAL SWELL STRAIN RATE
V.S. FIRST STRESS INVARIANT - WHETSTONE GULF FORMATION

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.34-8

Q361.35: If the draining of Lake Iroquois provides a plausible explanation for the Quaternary movement along the deformation structures at the site, then similar features should exist at other locations similarly affected by the draining of Lake Iroquois. The existence of similar structures only at such locations would provide evidence for your hypothesis. Accordingly, determine the known distribution of such structures from a literature search and present a discussion as to whether this distribution favors your hypothesis.

RESPONSE: In the region affected by the draining of Lake Iroquois, numerous buckles of postglacial age were reported (Niagara Mohawk Power Corporation, 1978, Volume I, Section 2.0, and Volume II, Section 3.0). It was also reported (Volume I, Section 2.2.3.5) that the buckles were of two types: chevron-style, and sinusoidal. Sutton's (1951) work in western New York State indicated that a chevon-style buckle:

> "typically coincides with a pre-existing fracture or fault, which is situated along the axial plane."

A classic example of the relationship between buckles and faults is the structure exposed at Thirtymile Point near Lyndonville, New York.

The locations of postglacial deformational features in the Lake Ontario region are illustrated on Figure 2-4, Volume I of the April 1978 report. None of the deformations reported appears to be as complex as that noted along the Cooling Tower Fault, but the lack of significant bedrock exposures along the southern shore of Lake Ontario precludes a detailed assessment of the distribution and complexity of similar structures.

REFERENCES

Niagara Mohawk Power Corporation, 1978, Nine Mile Point Nuclear Station, Unit 2, Geologic Investigation, Scriba, New York.

Sutton, R.G., 1951, Stratigraphy and Structure of the Batavia Quandrangle, Proc. Rochester Acad. Sci., v. 9, p. 348-408.