BEDROCK DEFORMATION IN THE
COOLING WATER SYSTEM
INTAKE TUNNEL, PERRY NUCLEAR POWER PLANT
NORTH PERRY TOWNSHIP, OHIO

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GAI Report No. 1986

THE CLEVELAND ELECTRIC ILLUMINATING COMPANY

PERRY NUCLEAR POWER PLANT - UNITS 1 AND 2

BEDROCK DEFORMATION IN THE COOLING WATER SYSTEM INTAKE TUNNEL

MAY, 1978

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ABSTRACT

Flat-lying Chagrin shale strata exposed in the tunnel excavations at the Perry Nuclear Power Plant, Ohio, are interrupted by a low-angle thrust fault. Maximum measured apparent displacement is approximately 22 inches with a throw of approximately 12 inches. The fault plane is oriented nearly normal to the tunnel bearing and dips less than 17 degrees to the southeast. A small synclinal fold with an amplitude less than three feet is exposed contiguous to the fault plane. These structures presumably are genetically related to lateral compression, and their development is attributed to glacitectonic deformation initiated and completed during the Pleistocene Epoch.

The tunnel fault was produced either in response to glacial ice-shove and/or time-dependent stress relief, the latter subsequent to glacial unloading. Both are acknowledged modes of glacitectonic deformation and herein are classified as "active" and "passive" respectively. Proximity respective of distance and physical resemblance between tunnel bedrock deformation and active glacitectonic structures exposed in the onshore excavation suggests a common origin. In either case the tunnel fault as well as those identified onshore conform with the noncapable criteria set forth and defined in Appendix A, 10 CFR, part 100, Seismic and Geologic Siting Criteria for Nuclear Power Plants.

INTRODUCTION

Consistent with PSAR (Preliminary Safety Analysis Report) commitments respective of the PNPP (Perry Nuclear Power Plant) and its owner, CEI (Cleveland Electric Illuminating Company), this submittal to the NRC (Nuclear Regulatory Commission) provides information pertinent to a bedrock fault recently exposed during excavation of the plant intake tunnel.

Verbal and written notification as well as photographic documentation of the fault was accomplished by the PNPP resident geologists consistent with their responsibilities implemented for the geologic mapping program. Documentation prepared by the resident geologists provides a chronological reference of events relevant to the fault identification and is attached as Appendix A. The resident geologists are responsible to the Project Geologist as well as being integrated within the structure of the site organization. Consequently, the Project Geologist and a project consultant, (author of this report), confirmed the presence of a bedrock fault in the intake tunnel as reported by the resident geologists in the cited Appendix documentation.

The intake tunnel, one component of the plant cooling water system currently under construction, was excavated initially by conventional "drill and shoot" methods, subsequently by a Dosco Roadheader MK·2A tunneling machine for more than 426 feet and finally by a Jarva circular bore tunneling machine. Each successive method of advancing the tunnel heading was implemented at the

contractor's discretion (S&M Construction Company) subject to owner concurrence in the interest of increasing production. This action was warranted on the basis of bedrock conditions previously experienced in the intake tunnel as well as in other plant tunnel segments, vertical shafts and foundations excavated on site.

The geological record of bedrock deformation for northeastern Ohio, as reported in the literature, is discussed in the PNPP PSAR (Preliminary Safety Analysis Report). New data including comprehensive descriptions of specific structures exposed south of the PNPP site along Grand River and several of its tributaries are contained in Appendix 2L of the PSAR. Foundation excavations at the PNPP site through the glacial drift cover into the Chagrin shale exposed both primary and secondary structures. The secondary structures were thoroughly investigated and the results communicated to the NRC (see especially Geologic investigation of a portion of the PNPP foundation and supplemental addenda). The subject structure of this submittal was intersected by excavation during the week of April 17, 1978, but could not be observed until April 25, 1978 subsequent to sufficient advancement of the Jarva tunneling machine beyond the tunnel segment containing the fault trace.

The various modes of bedrock deformation contributing to observed structures in northeastern Ohio as reported in the PNPP PSAR include 1) penecontemporaneous slumping of unconsolidated or partially consolidated sediments during late Devonian or early Mississippian time, 2) comparatively recent joint controlled slumping along the high valley bluffs of present day stream courses, and 3) lateral

compressive stresses either glacially induced during the Pleistocene Epoch or tectonically active during the Paleozoic Era. Summarily, none of the structures, including the intake tunnel fault, is evaluated as a capable fault.

The existence of high horizontal stresses is reported in portions of northeastern United States and adjacent Canada (see especially Lee, 1978; also Voight, 1967; Oliver, Johnson and Dorman, 1970; Sbar and Sykes, 1973; and Herget, 1973 and 1974). It has been demonstrated by Lee (1978) through mechanistic analysis that the origin of these high horizontal stresses, as measured in bedrock throughout much of Ontario as well as adjacent areas including Ohio, is a viscoelastic response of cyclic glacial loading and rigid confinement experienced in this region during the Pleistocene Epoch. "Compression failures in the form of buckles, pop-ups, and high-angle, reverse faulting" are interpreted by Lee as an active manifestation of this in situ state of stress.

Non-tectonic deformation exposed in the Chagrin shale and Lower Till to bedrock transitory interval during the excavation phase of PNPP foundations is identified as glacitectonic and is attributed to late Wisconsinan glaciation. Briefly stated, the mode of deformation occurred at the ice-front margin of advancing continental ice sheets in accordance with models presented by DeSitter (1956), Moran (1971), and Banham (1974). The superficial nature of glacitectonic structures apparently restricts their development to depths on the order of 200 meters (see especially Wickenden, 1945; Byers, 1959; Rutten, 1960; Kupsch, 1962; Coates, 1964; and Banham, 1974).

The intake tunnel fault is interpreted as a compressional feature for which the maximum and minimum stress components were oriented horizontally and vertically respectively. The state of high horizontal stresses operative for this fault are attributed to Pleistocene glaciation most likely of the late Wisconsinan substage. The structure closely resembles others exposed in the onshore foundation excavations and can be interpreted as a feature of the ice-margin deformation model. Nevertheless, it is difficult to refute the repeated, confined glacial-loading hypothesis advanced by Lee. It is possible that elements of both models contributed in the development of the fault.

DESCRIPTION OF TUNNEL BEDROCK DEFORMATION

The fault plane trace intersects the tunnel at approximate elevation 455 ft. between stations 10+48.5 and 10+87 along the tunnel invert and crown respectively. It is preceded by a gentle synclinal fold with a vertical axial plane located at station 10+42.5. Reference base for all tunnel stationing is centered in the intake vertical riser shaft of the Service Water Pumphouse. Prior and subsequent to the exposure of the fault and fold, the tunnel bedrock essentially consists of flat-lying fissile shale interbedded with thin siltstone beds. All these spatial relationships are depicted on an intake and discharge structure plot plan (Fig. 1) and a drafted reproduction (Fig. 2) taken from the original log prepared by the resident geologists (see Appendix A for original log).

Measurements made in the tunnel indicate that the fault plane is oriented nearly normal (N47°E) to the tunnel heading and dips southeast at approximately 17 degrees. Effects of frictional drag of strata

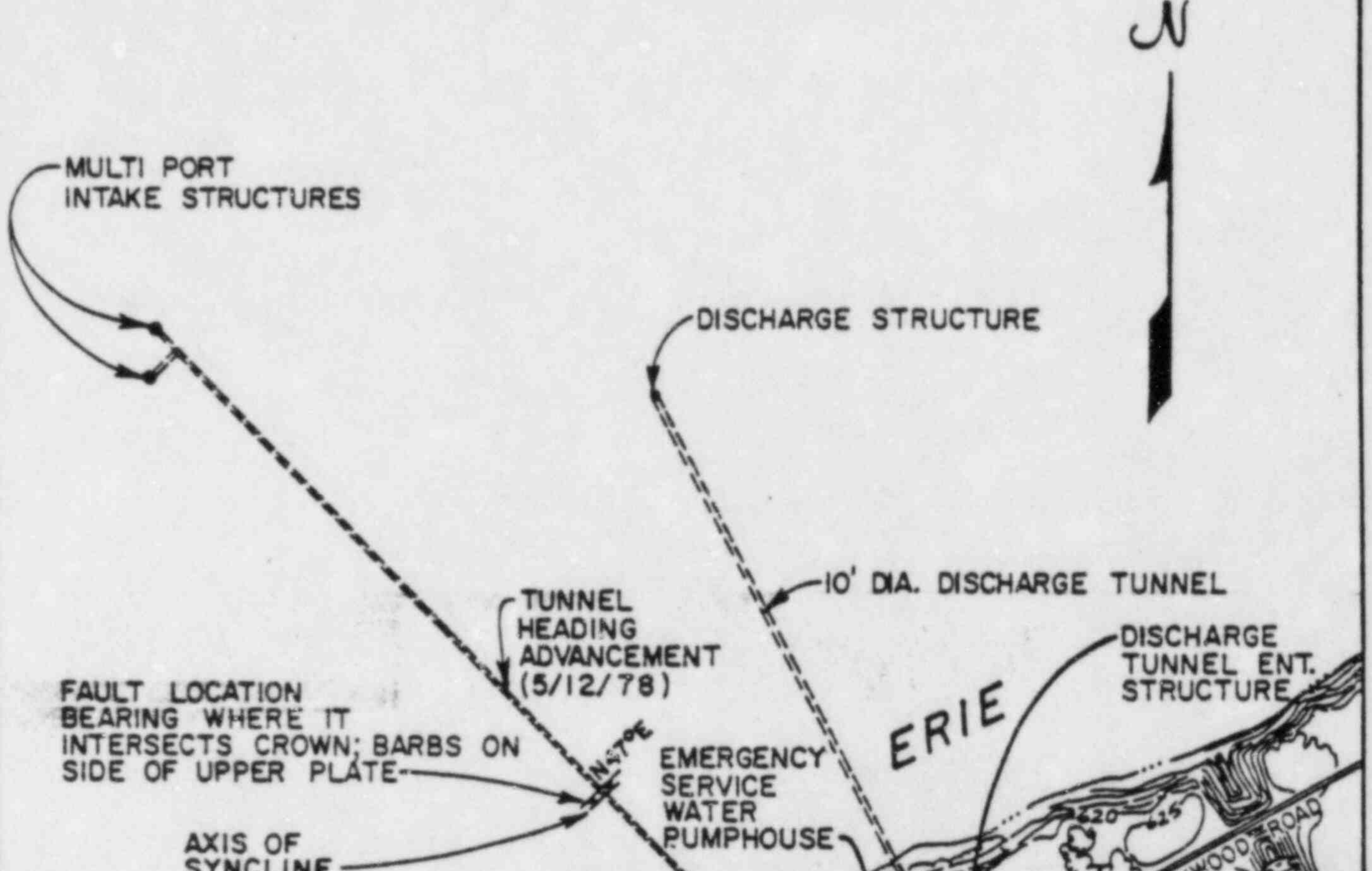


FIGURE 1. PLOT PLAN OF INTAKE AND DISCHARGE STRUCTURES
SHOWING LOCATIONS OF BEDROCK DEFORMATION
PERRY NUCLEAR POWER PLANT
NORTH PERRY, OHIO.

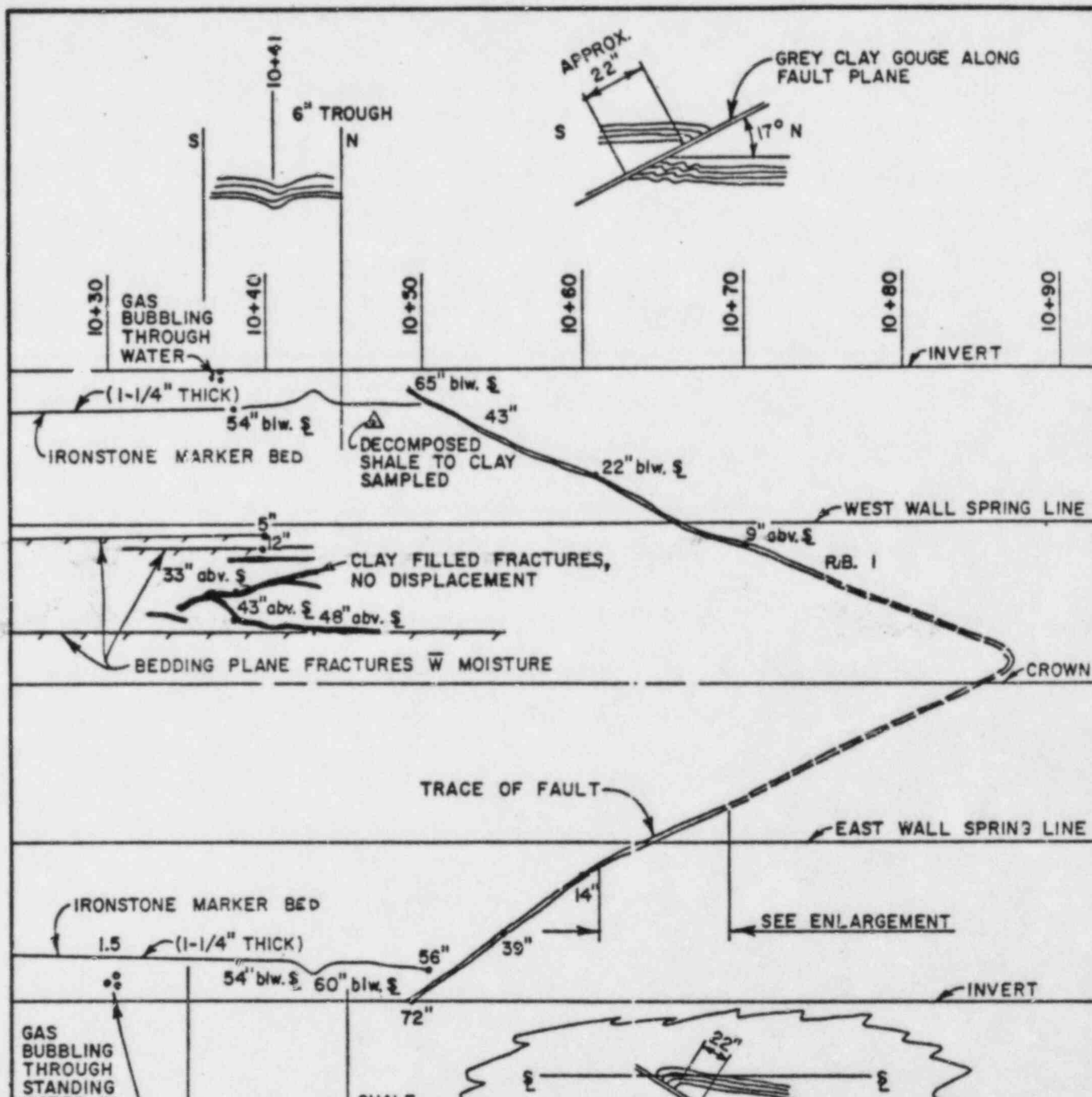


FIGURE 2. GEOLOGIC LOG OF INTAKE TUNNEL BETWEEN STATION LOCATIONS 10+30 AND 10+90 PERRY NUCLEAR POWER PLANT NORTH PERRY, OHIO.

adjacent to the fault plane and probable marker bed correlations are interpreted as rather substantial evidence of a low-angle reverse or thrust fault. Maximum apparent displacement was measured on the west wall at station location 10+61 to be approximately 22 inches accompanied by 12 and 18 inches of throw and heave respectively.

Geometric relationships of tunnel bedrock structures may be examined on Figs. 3 through 10 which comprise a series of photographic enlargements reproduced from 35mm. color slides. The tunnel diameter including overbreak rarely exceeds 12 feet thereby greatly restricting the area coverage normal to tunnel wall. Consequently, the photographer had to resort to non right angle views which contribute to apparent scale distortions on several figures.

The fault plane varies in width from 1/2 to 18 inches, although the latter is more indicative of gently flexed and/or abruptly kinked or otherwise simply fractured rock. Typically, a gray-clay gouge of tough leathery consistency containing small angular shale fragments occupies the fault zone separating adjacent hanging and foot walls. As shown on several photographs there is a slight splaying of the fault resulting in a subparallel fracture ranging up to three feet in length with an apparent displacement on the order of a few inches (see Figs. 3, 4, 5, 7 and 8).

A general sense of symmetry between the east and west tunnel wall is quite good for most fault features discussed above except for kinking (see Figs. 7 and 8). Presumably, kinking of the bedrock is limited laterally. Nonetheless, it is considered representative of

the somewhat ductile behavior demonstrated by the Chagrin shale in response to the high state of horizontal stress operative for this portion of northeastern Ohio. Kinking is evaluated as contemporaneous with respect to the faulting. No significance is attached to kinking either on the basis of its presence or asymmetrical characteristics with respect to the intake tunnel excavation.

A conspicuous absence of characteristic kinematic features and forms of mineralization commonly associated with faulted bedrock attributed to nonglacial tectonic crustal disturbances is noteworthy. Included within this category are slickensides, en echelon faults and/or fractures, euhedral crystal growth within fault plane or fractures in proximity to fault, or mineralized fault and/or joint surface coatings, quartz, calcite or other mineralization within veins, and inter-formational large-scale displacements. As the intake tunnel provides considerable exposure southeast and northwest of the fault, it is unlikely that fault-related kinematic features or mineralization could have gone undetected.

Horizontal exploratory boreholes were drilled in advance of the tunnel preceding its excavation through the portion intersected by the fault plane. These borings yielded gaseous emissions, essentially methane, and some connate water. Both conditions are not unique for the faulted tunnel segment, inasmuch as ample documentation of each from PNPP onshore and offshore exploratory programs, regional experience and/or the geologic literature can be cited. Gaseous emissions have been detected intermittently by other exploratory probes since commencement of underground excavation and most recently at considerable

distance beyond the faulted tunnel segment. These occurrences are not considered anomalous in spite of their potentially hazardous nature, especially in the case of methane. In fact the impact of these conditions as well as the total impact of the faulted bedrock tunnel segment have not necessitated deviations from tunnel design.

LABORATORY ANALYSIS OF FAULT GOUGE

Fault-plane material includes fractured or otherwise brecciated rock (Chagrin shale) and a gray-clay gouge of tough leathery consistency. None of the constituent shale-fragment and gouge minerals can be identified by megascopic techniques. The fault gouge which contains clay and small angular shale fragments is derived from the contiguous hanging and foot wall blocks which produced this material during faulting between station locations 10+50 and 10+60.

Samples of the tunnel fault gouge were collected and submitted to the Department of Geological Sciences, Lehigh University, Bethlehem, Pennsylvania for complete X-ray mineralogical identification and quantitative analysis of the two micron and smaller size fraction. The results of these analyses are attached as Appendix B. Summarily it is reported that the clay gouge predominantly consists of illite clay, approximately 80 percent, with a characteristic muscovite structure. The other principle clay minerals are chlorite and kaolinite contributing 10 to 11 and 8 percent respectively. Quartz and plagioclase comprise the other principle constituents. One peak slope differentiated on the diffractogram, representing less than one percent, may have been masked by a chlorite structure but was tentatively identified as smectite.

The mineralogy of the fault gouge clay is virtually identical to that of the Chagrin shale as documented in the PNPP PSAR and geologic literature. If this information is evaluated in consideration of the fault plane kinematics, it is readily apparent that the fault plane source was intraformational with respect to the Chagrin shale and did not involve interformational displacements. In conclusion, the fault gouge mineralogical analyses are interpreted as further evidence of the relatively minor displacements experienced along the fault segment exposed during excavation of the intake tunnel.

DISCUSSION ON MODES OF DEFORMATION

The ensuing discussion includes an abstraction of information respective of glacitectonic structures previously assembled and evaluated in the interpretation of the onshore structures and other supplemental evaluations (for earlier evaluations see Geologic investigation of a portion of the PNPP foundation and addenda). Moran (1971) and Banham (1974) have contributed data and glacially induced deformational models which are evaluated for structures exposed in both the onshore as well as tunnel excavations. Most recently, Lee (1978) has postulated that stress relief mechanics are operative at considerable depth well beyond that of the intake tunnel invert. He attributes much of the brittle and plastic deformation, identified in the glaciated areas of Ontario and adjacent northeastern United States of the Interior Lowlands physiographic province, to relief sought by soil and rock rigidly confined under repeated ice loadings during the Pleistocene Epoch. The

applicability of the Lee hypothesis is evaluated for the deformation identified in the intake tunnel and onshore foundations.

Glacitectonics

Glacitectonic structures are synonomous with glaciotectonic or cryotectonic ones defined as "complicated and deranged features and deposits found at glacier borders and consisting of material that has been overturned, inverted, folded, and transported by the shoving action of glaciers" according to the AGI Glossory of Geology (1974). Moran (1971) identifies three fundamental glacitectonic structures: (1) simple in situ deformation, (2) large-scale block inclusion, and (3) transportational stacking within single till sheets. The PNPP onshore deformation, previously cited, falls predominantly into the first category, in situ deformation, although lateral transport for an indeterminable distance along a basal glide plane or "décollement" was most likely involved.

The mode of deformation as described by Moran for relatively small, in situ deformation was caused by normal stresses exerted on the upstream faces of protuberances from the bed (ice push), shear exerted by moving ice along its bed, or a combination of both. This concept is augmented by lateral transport along a décollement characterized by reduced resistance to frictional drag and shear strength. The nature of the décollement probably represents a material property contrast such as: (1) bedrock overburden-bedrock, (2) weathered-unweathered rock, (3) abrupt, vertical density change in soil profile, or (4) the presence of a fluid interface.

Shear strength reduction which is attributed to a corresponding reduction in the effective normal stress corresponds to elevation porewater pressure, as defined by Terzaghi and Peck (1967) according to the following expression:

$$\bar{\sigma} = \sigma - U$$

where

σ = total normal stress
$\bar{\sigma}$ = effective normal stress
U = porewater pressure

The above represents an extrapolation of the Generalized Archimedes Principle applied by Hubbert and Ruby (1959ab) in their classic solution of overthrust faulting in the southern Appalachian Mountains and elsewhere. On a considerably reduced scale, this mechanism in part accompanied by lateral compression is presumed to have been active in principal at the PNPP where the development of glacitectonic structures consisting of upward thrusting, singular and imbricated, and downward under thrusting along décollements was accompanied by intra-fault block folding and fracturing. The specific mechanism for loss of shearing strength along a given décollement has received considerable attention subsequent to the work cited above. The salient methods of analysis include: (1) bench-scale experimentation, (2) computer-mathematical simulation, (3) mechanics, (4) petrofabric analysis, and (5) kinematics and (6) various combinations of two or more of the preceding. Contributory conditions for the onshore PNPP deformation are as previously cited (Gilbert Associates Inc., 1975).

The compressional model of Banham (1974) for glacitectonic deformation is an excellent summarization analogous in many aspects to that reported upon for the PNPP. Banham is in agreement with Moran and both argue persuasively in favor of porewater fluid pressure build-ups. More importantly, it is suggested that the relative rapidity of loading attributable to glaciation precludes the extremely deeply seated failures,

such as the Rubey and Hubbert overthrust style of faulting, to much shallower depths, probably less than 200 meters.

Stress Relief

As documented in the INTRODUCTION, independent data collection, analysis and evaluation by a host of cited investigators strongly indicate the existence of a high state of horizontal stress, albeit uneven, for crustal materials throughout the world. In response, affected rocks and soils strive toward re-equilibration in newly imposed stress environments. Lee (1978) demonstrates through mechanical analysis that repeated glacial loading and unloading during the Pleistocene Epoch in Ontario imposed heavy loads possibly exceeding 4000 psi. Under conditions of rigid confinement and fairly uniform loading (σ_v) distribution of lateral stress (σ_h) is given by:

$$\sigma_h = \frac{\nu}{1-\nu}\sigma_v$$

where ν = Poisson's Ratio

Subsequent to deglaciation in the context of elasticity, horizontal stress (σ_h) should be fully recoverable. However, Lee submits that creep or visoelastic compression of the confined rock mass accompanies elastic compression such that

$$\Delta\sigma h = \frac{E}{2(1-2\nu)}\Delta\varepsilon_v$$

where

E = isotropic elastic modulus

ν = Poisson's ratio

$\Delta\sigma_h$ = incremental stress] subsequent to initial

$\Delta\varepsilon_v$ = incremental strain] elastic response

Under rigid confinement, $\varepsilon_h = 0$.

This incremental stress component being time dependent is cumulative

throughout at least 4 major stages of glaciation as well as substage sequences of retreat and readvance. The sum of successive incremental stress build-ups is retained as a "residual" horizontal stress even subsequent to elastic rebound of crustal rocks. Rock mass accommodation of a high state of horizontal stress build-up may not be possible resulting in anisotropic adjustments, or simply "stress relief" manifested by post-glacial bedrock deformation.

Herget (1974) found that the vertical component of in situ stress measurement data with a global distribution exhibited a linear relationship respective of depth demonstrated by the equation:

$$\sigma_v = (19 \pm 12.6)\ kg/cm^2 + (0.266 \pm 0.028)\ H\ kg/cm^2$$

where

σ_v = vertical stress

H = depth in meters

The preceding expression is applicable to a depth of 2400 meters on the basis of overburden weight.

The horizontal stress component shows considerable variation with depth including values of parity as expected but also increased and decreased magnitudes respective of vertical stress. Moreover, 75 percent of Herget's data indicate a higher horizontal than vertical stress as given by his expression of average horizontal stress and depth:

$$\sigma_h = (83 \pm 5)\ kg/cm^2 + (0.407 \pm 0.023)\ H\ kg/cm^2$$

where

σ_h = horizontal stress

H = depth in meters

This expression is applicable to a depth of 800 meters.

Horizontal stresses which exceed vertical stresses cannot be explained on the basis of overburden weight. Heavy loading attributed to glaciation succeeded by erosion, assuming rigid confinement, is an alternative explanation where $\sigma_h > \sigma_v$ even when $\sigma_v > \sigma_h$ during glacial loading of the same rock mass.

Additional mechanistic analyses may be performed to graphically portray brittle deformation employing envelopes of limiting stress conditions determined either experimentally or empirically. Although Herget only considered elastic properties it is presumed that his working hypothesis on stress data should be applicable in principle to the viscoelastic behavior of a rock mass as presented by Lee. Admittedly, allowances for the dependency of creep behavior on time must be satisfied. Nevertheless, the collective works of Lee and Herget demonstrate "stress relief" through elastic and/or viscoelastic behavior of a rock mass as a viable passive glacitectonic deformational model. Further, the stress relief model of bedrock deformation exceeds by several times the limiting depth of 200 meters generally associated with the classical "active" glacitectonic deformational models of Moran and Banham.

Depth of Permafrost and Loss of Shear Strength

The behavior of soil and rock under temperature conditions presumed operative during Pleistocene glaciation is evaluated as a factor, presently of indeterminate magnitude, for development of glacitectonic deformation. Tystovich (1975) reports that permafrost depths in soil exceeding 300 meters in contemporary polar climates are typical and may reach the 1000 meter range. Although these depths are representative of soil, it is reasonable to assume that the depth of perennial

subzero C temperatures at the PNPP during the Pleistocene prevailed beneath the depth of bedrock weathering and probably much deeper. Ice coatings and wedges, undoubtedly, occupied some bedding planes and fractures as well as the overlying soil particle interstices.

It has been experimentally determined that the strength properties of frozen soils while exceedingly complex are dependent upon temperature, external pressure (loading) and especially time. Generally, strength properties increase with negative temperature but decrease with loading and time. The time dependent plastic-creep behavior of ice is well established from existing knowledge on the physics of ice flow as well as from empirical data gathered by glaciologists monitoring existing alpine and continental glacier movements. Further, frozen soils will exhibit a considerable loss in ultimate strength properties. For example, Tystovich documents a 90 percent reduction from initial to ultimate shearing strength for a frozen clayey soil. Apparently, a considerable portion of time dependent strength loss is attributable to reduced cohesion.

The behavior of glaciated rock during the Pleistocene similarly is characterized by reduced strength properties and especially shear, parallel to planes of weakness. Flat-lying bedding in the Chagrin shale is interpreted as the most likely rock mass defect susceptible to incipient shear failure. Saturated, bedding-plane separations probably were enhanced due to the ten percent volume increase incurred as H_2O solidifies below its melting temperature. Discontinuous ice wedges along bedding fulfilled a function similar to that of joint plane rock bridges. Ice wedge strength properties, however, would be considerably less

than rock bridges. The two conditions described above are presumed to be exemplary rather than exclusionary.

Glacitectonic deformation initiated along décollements in the soil and bedrock at the site of the PNPP in response to compression has been previously discussed. It is suggested that these zones of uncoupling may owe their origin to the behavioral properties of soil and rock affected by permafrost. It should be emphasized that the role of fluid pressure is not negated by permafrost, rather, the actual mechanism of failure may well have involved complex interaction of both phenomena.

CONCLUSION

Throughout this report considerable discussion of glacitectonic deformation has been presented in terms of active and passive styles. Several salient conclusions of a general nature are reviewed below:

(1) Lateral compression was operative in the deformation of soil and rock at the PNPP and induced either by in situ horizontal stress buildup subsequent to glacial unloading or direct contact along the advancing ice margin front.

(2) Glacial loading has received considerable attention for its contribution to the vertical stress component required in the stress relief model discussed in this report. It is equally appropriate to assume its capacity to directly induce plastic and/or brittle deformation of soil and/or rock in proximity to the basal contact of thick, glacial ice sheets.

(3) Pore pressure generation along décollements as described by Hubbert and Rubey in their classic solution of the "thrust fault paradox" to overcome a frictional resistance is considered to have direct application for the thrust fault observed in the intake tunnel. This is also probable for the onshore PNPP deformation. Factors involved in pore pressure generation are controlled by the pressure and thermal environment imposed on subglacial H_2O.

(4) Soil and rock strength properties were effectively reduced by permafrost conditions to an indeterminable depth in competent rock respective of time and ice sheet loading thereby contributing to the general state of material behavioral response optimum for glacitectonic deformation.

(5) Most importantly and in spite of the complex interaction of conditions, principles and material properties briefly outlined above but imperfectly understood, the precipitant deformation agent was continental glaciation.

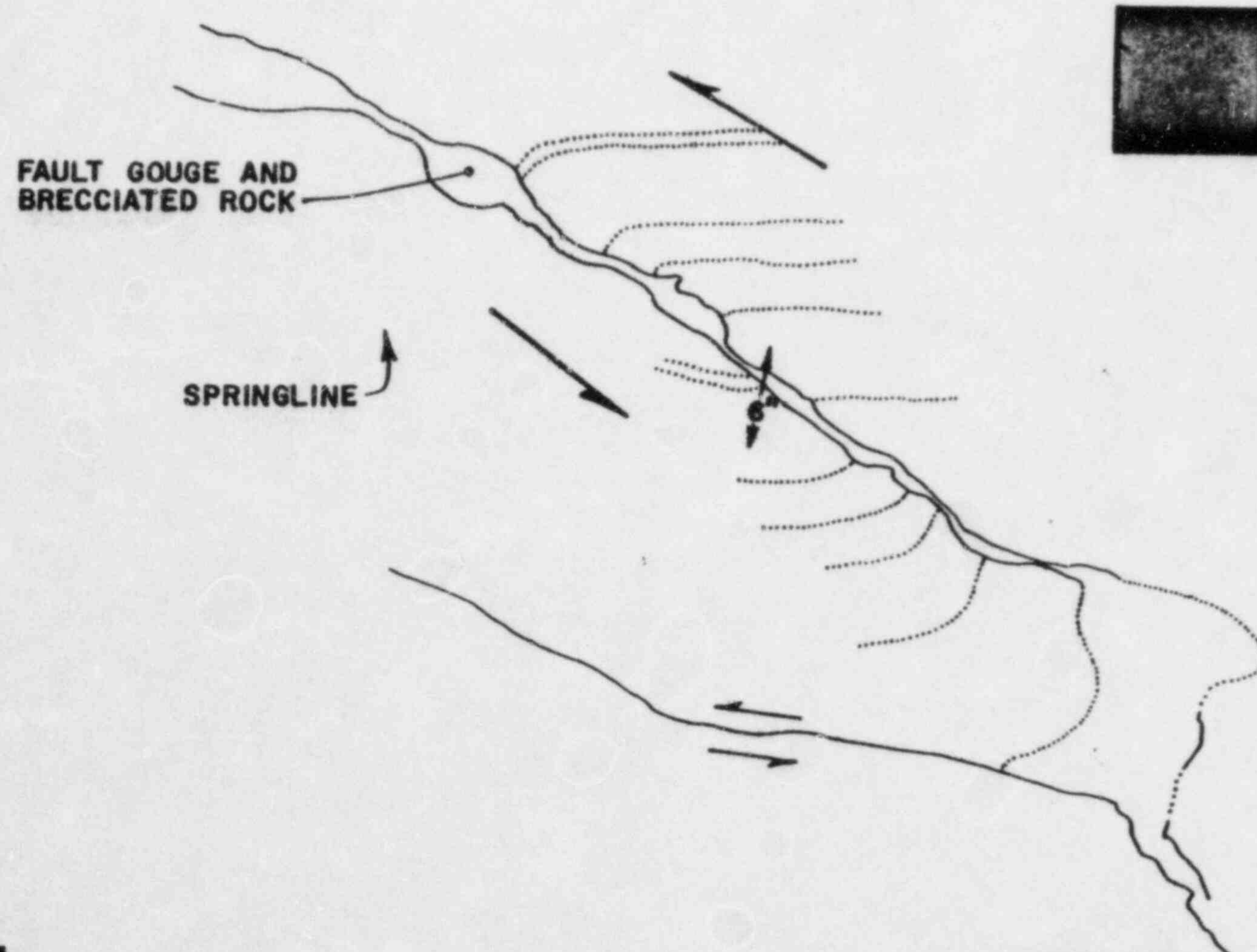
Interpretation of Tunnel Deformation

On the basis of all available information, the tunnel structures are interpreted to have been formed as a consequence of glacitectonic deformation during the Pleistocene Epoch. Movement along the fault was completed either in response to "active" or "passive" glacitectonic deformation as discussed in the literature and this report. The fault and fold exposed in the intake tunnel are presumed to be genetically related and the result of lateral compression. The similarity of

these structures as described in this report with the structures exposed in the onshore excavations also suggests a genetic correlation.

The elevation differential between the intake tunnel and onshore founding grade structures is on the order of 100 feet (30.5 m). Limiting depth for "active" glacitectonic deformation is on the order of 200 meters while that of the "passive" style is considerably greater, perhaps as much as 800 meters. Some of the onshore structures are known to extend nearly 30 feet (9.1 m) below their respective founding grade elevations or less than 70 feet (21.3 m) above the intersection of intake tunnel crown and fault. This elevation differential is relatively minor in context of either the 200 or 800 meter depth restrictions. It is not readily apparent on the basis of depth which model best fits the tunnel fault.

In consideration of all data the tunnel fault most likely is attributable to active glacitectonic deformation as defined in this report. This conclusion is submitted on the basis of field evidence, laboratory analysis, literature research, qualitative analyses, postulated models, speculation, interpretation as well as the similarity of the tunnel fault to those identified onshore. Alternatively, passive glacitectonic deformation cannot be dismissed and remains a viable candidate. In either case, the tunnel fault is neither earthquake related nor capable and therefore will not experience movement of a recurring nature.



GURE 3. CORRELATION OF STRATUM ON EAST WALL INTAKE TU
RE DISPLACED ALONG FAULT; APPROXIMATE STATION LOCATION I
NOTE FLAT-LYING STRATUM ABOVE AND BELOW FAULTED INTERV

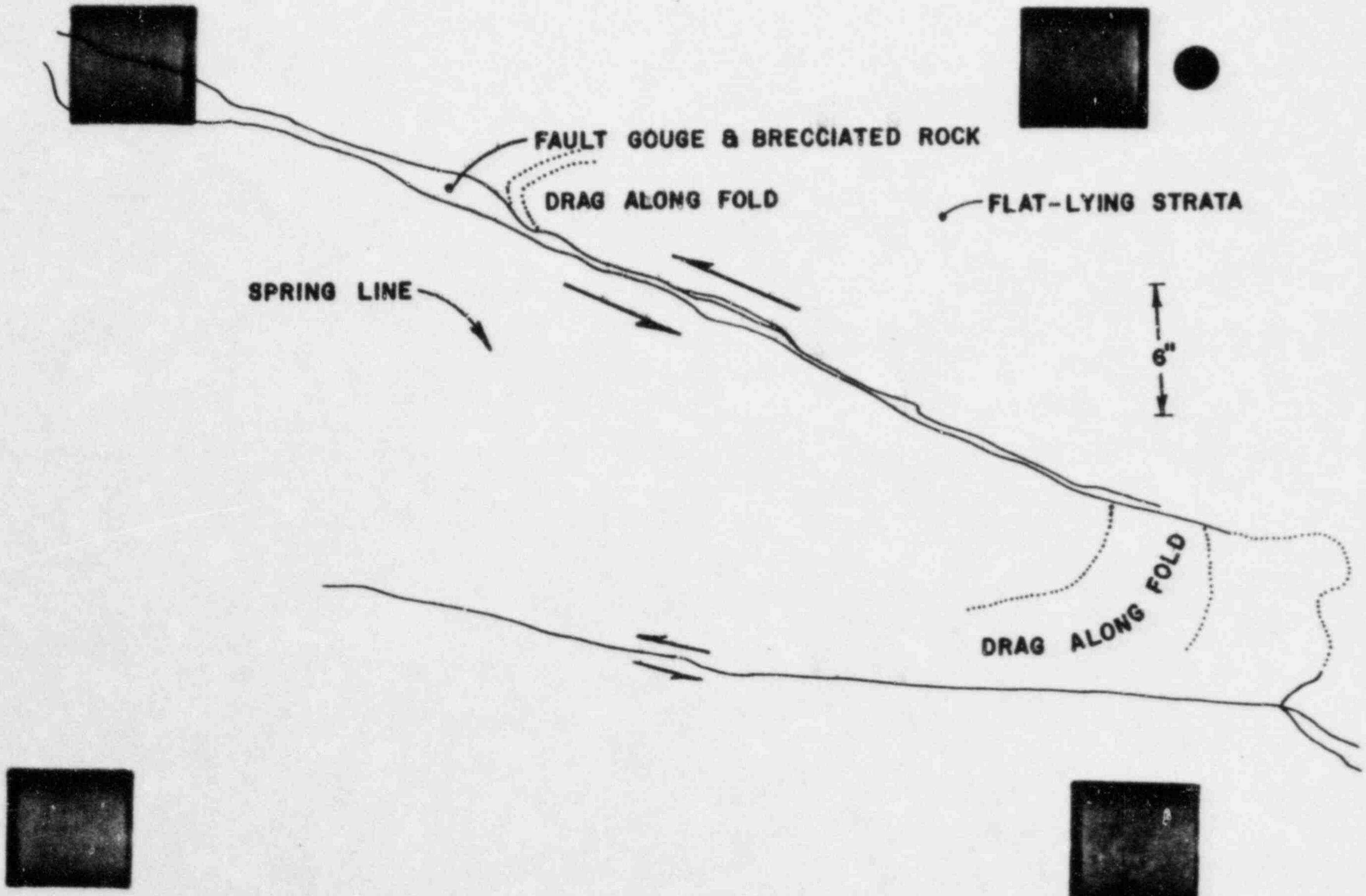


FIGURE 4. EAST WALL OF INTAKE TUNNEL WHERE FAULT CROSSES SPRING LINE AT STATION 10+65.

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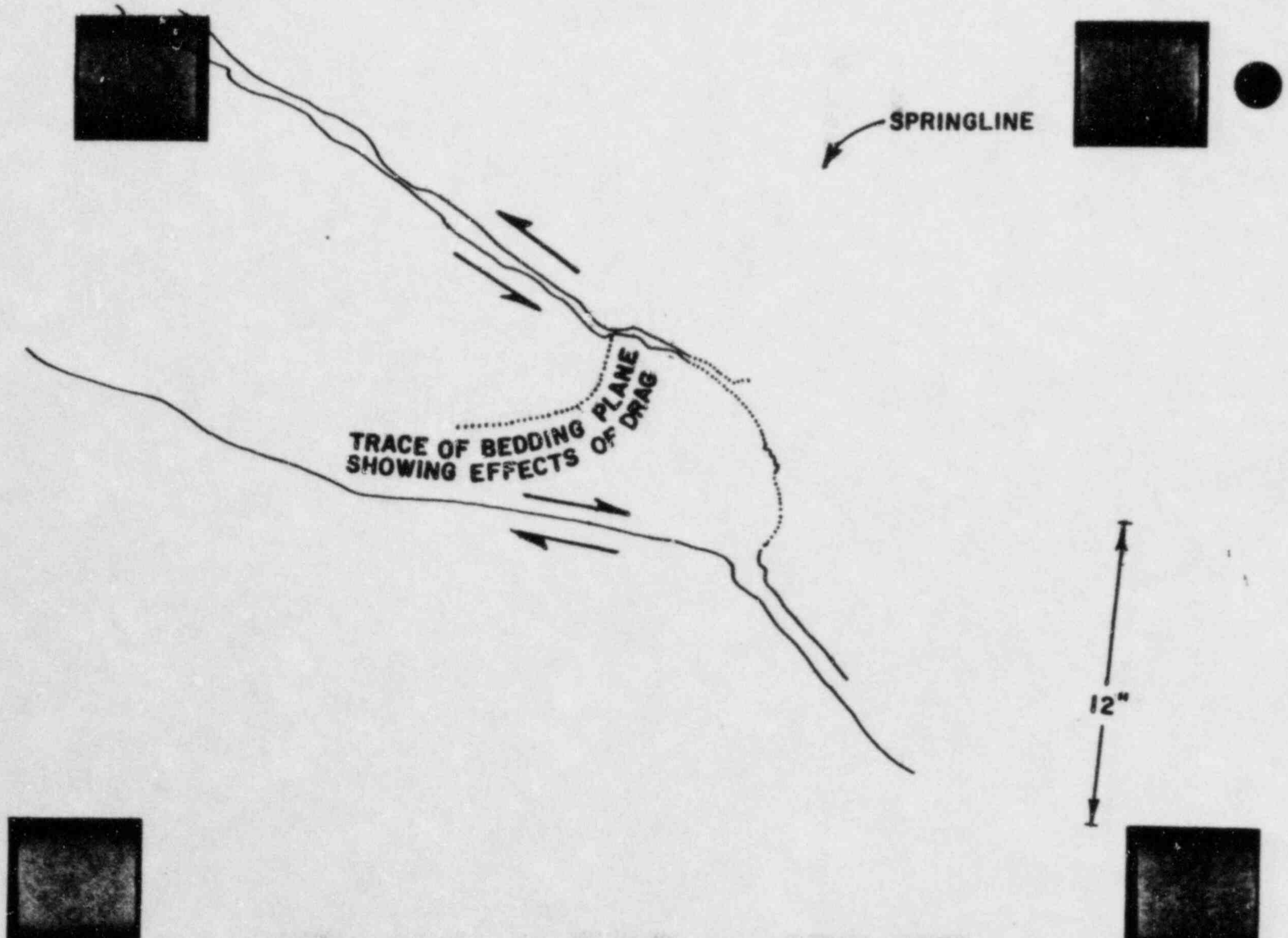

FIGURE 5. FAULT ON EAST WALL OF INTAKE TUNNEL;
NOTE DEFLECTION OF BEDS ADJACENT TO FAULT.

PNPP 4/27/78

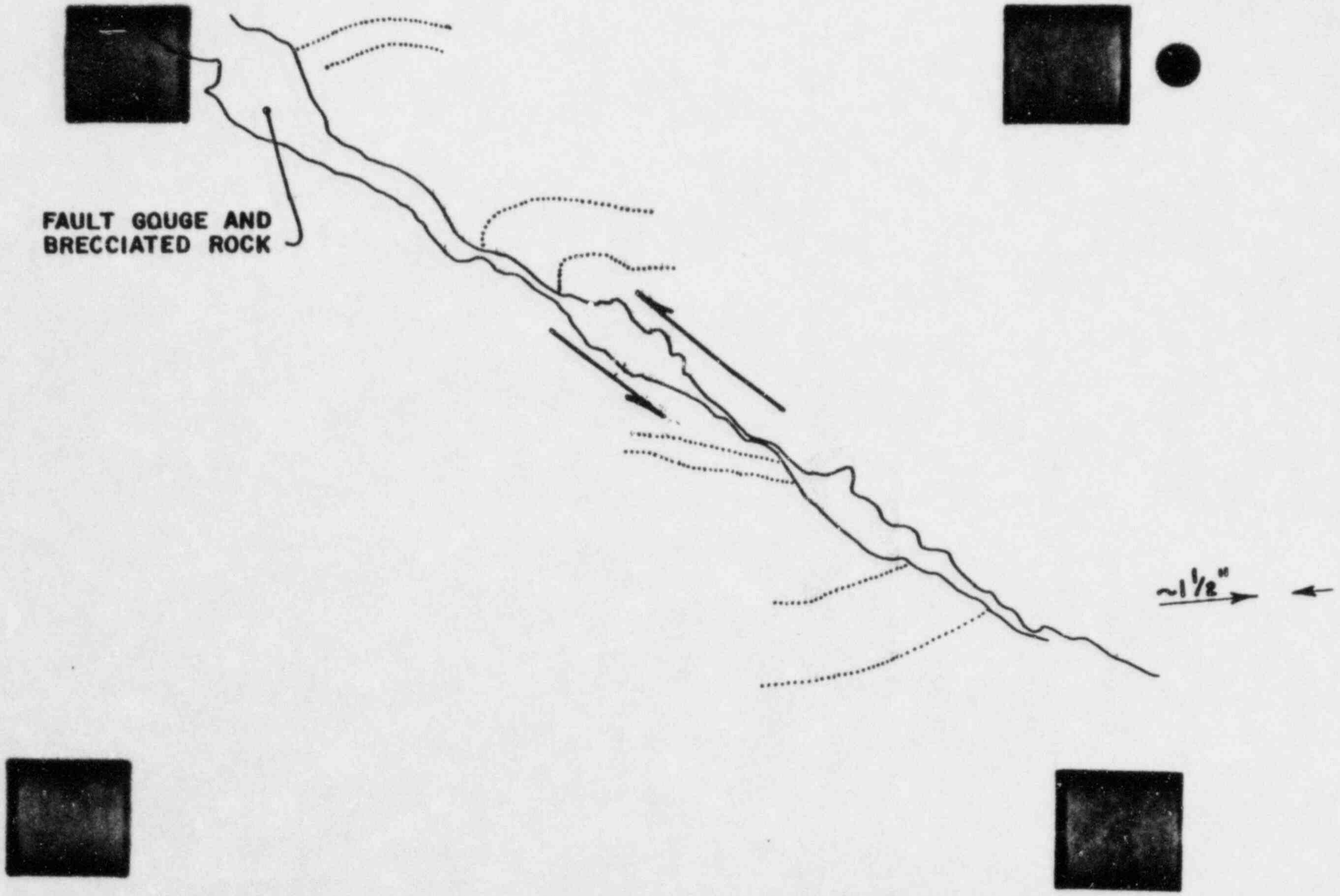

FIGURE 6. EAST WALL INTAKE TUNNEL FAULT SHOWING DRAG, ANNOTATED STRATUM BEDS ARE INTERPRETED AS A PROBABLE CORRELATION DEMONSTRATIVE OF DISPLACEMENT (~22 INCHES).

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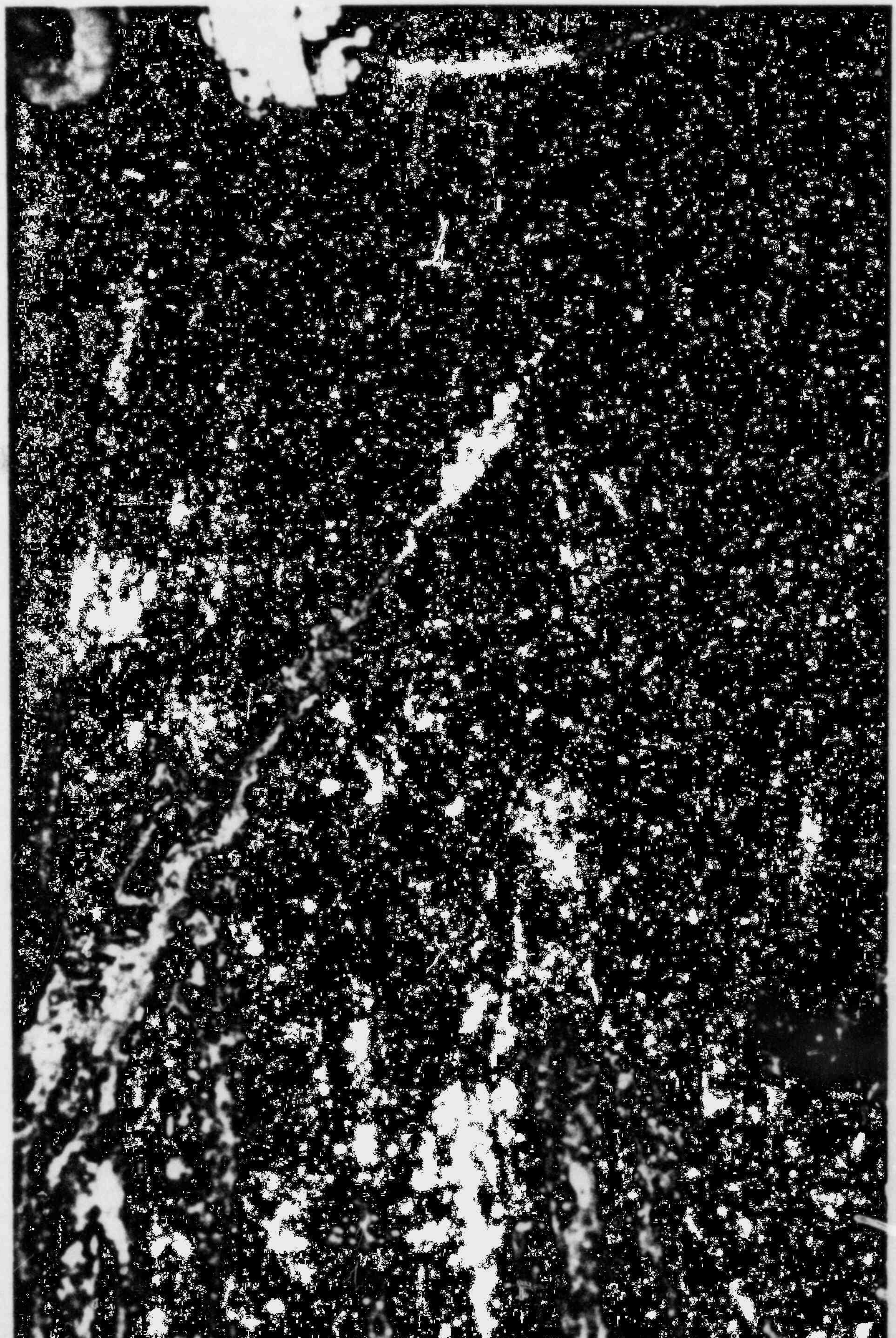
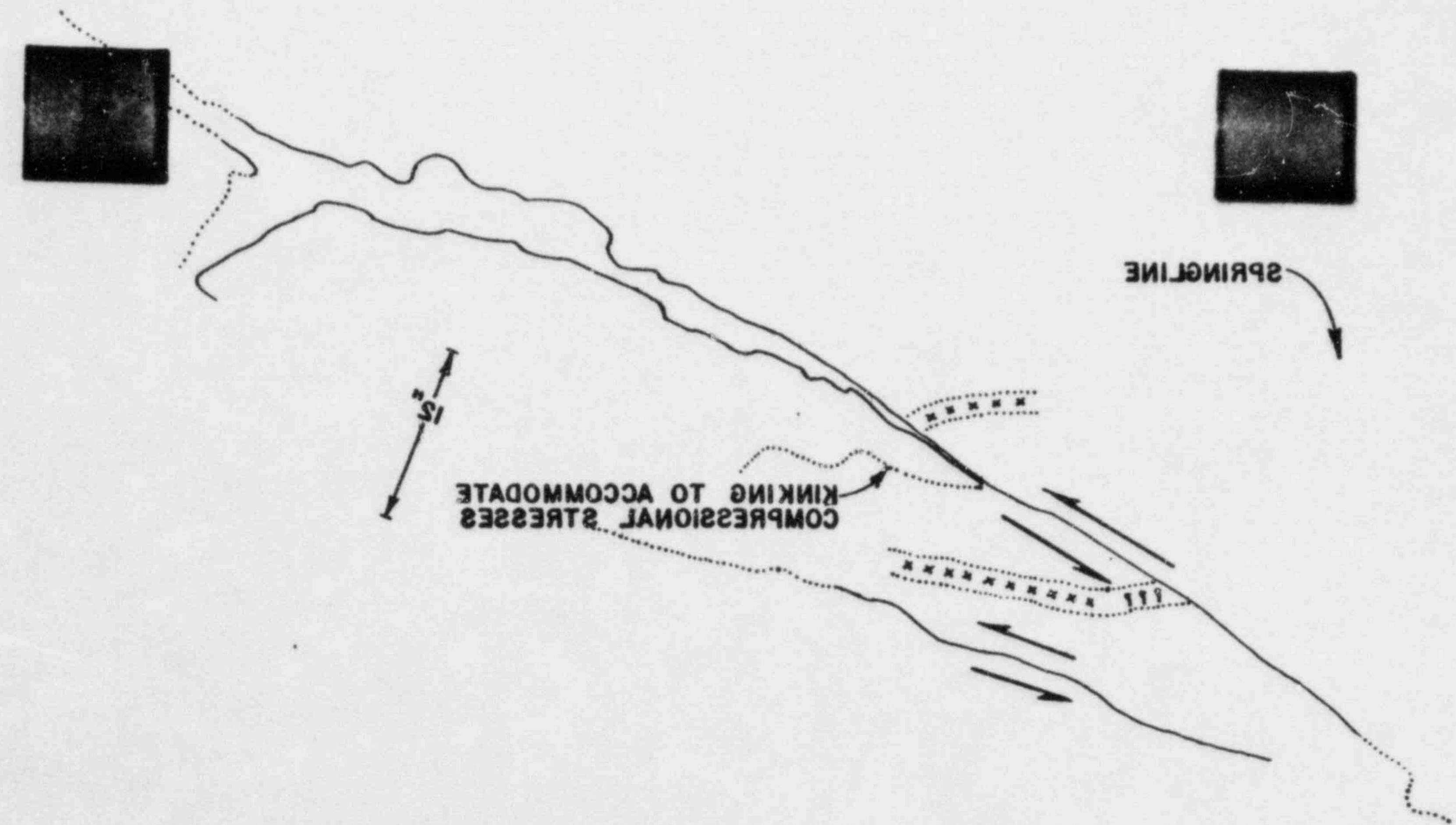




CORRELATION OF STATUM ON WEST WALL INTAKE TUNNEL WH[illegible]ACED ALONG FAULT; APPROXIMATE STATION LOCATION IS 10+65. FLAT-LYING STRATUM ABOVE AND BELOW FAULTED STATION

PNPP 4/27/78

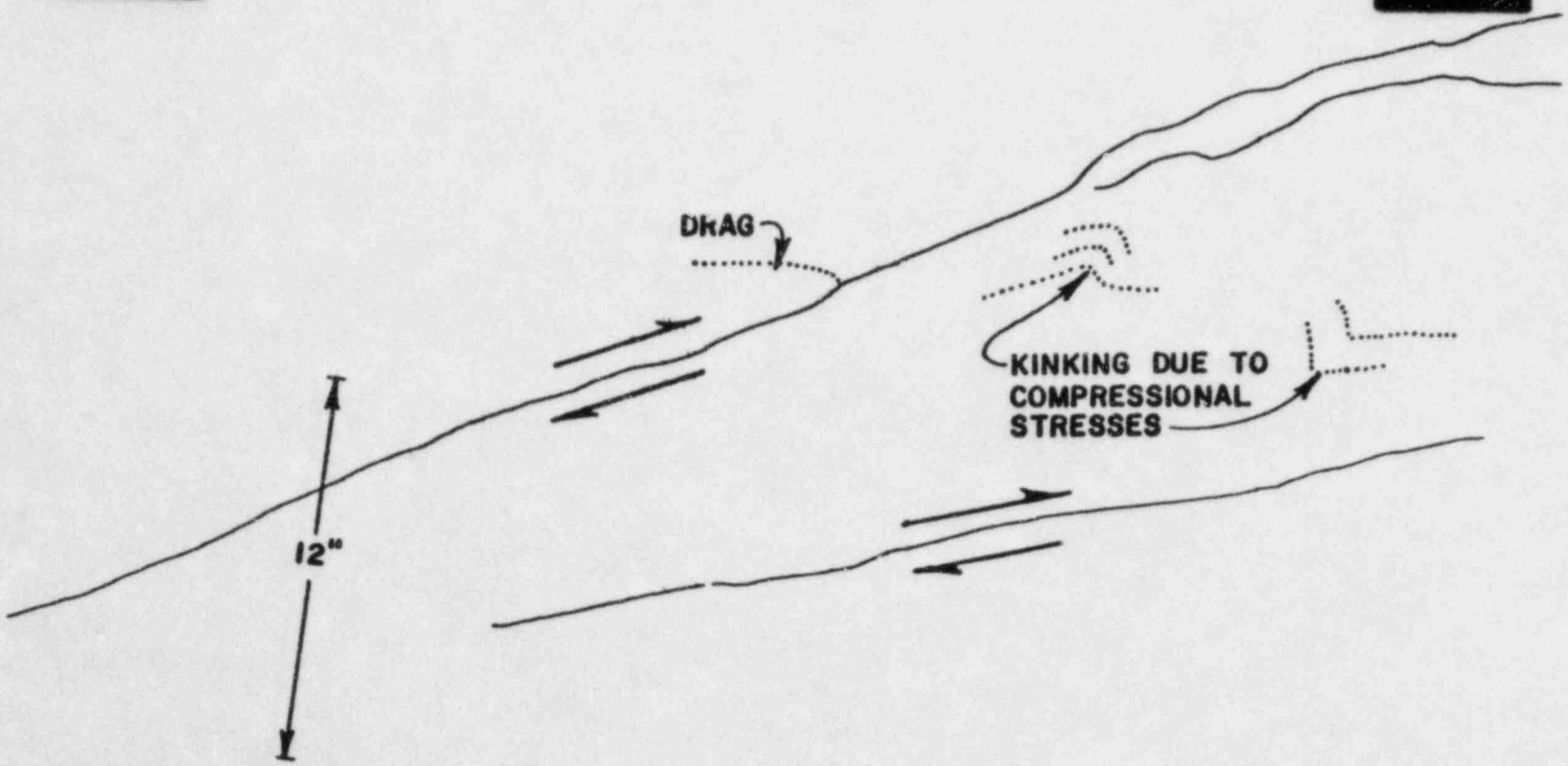
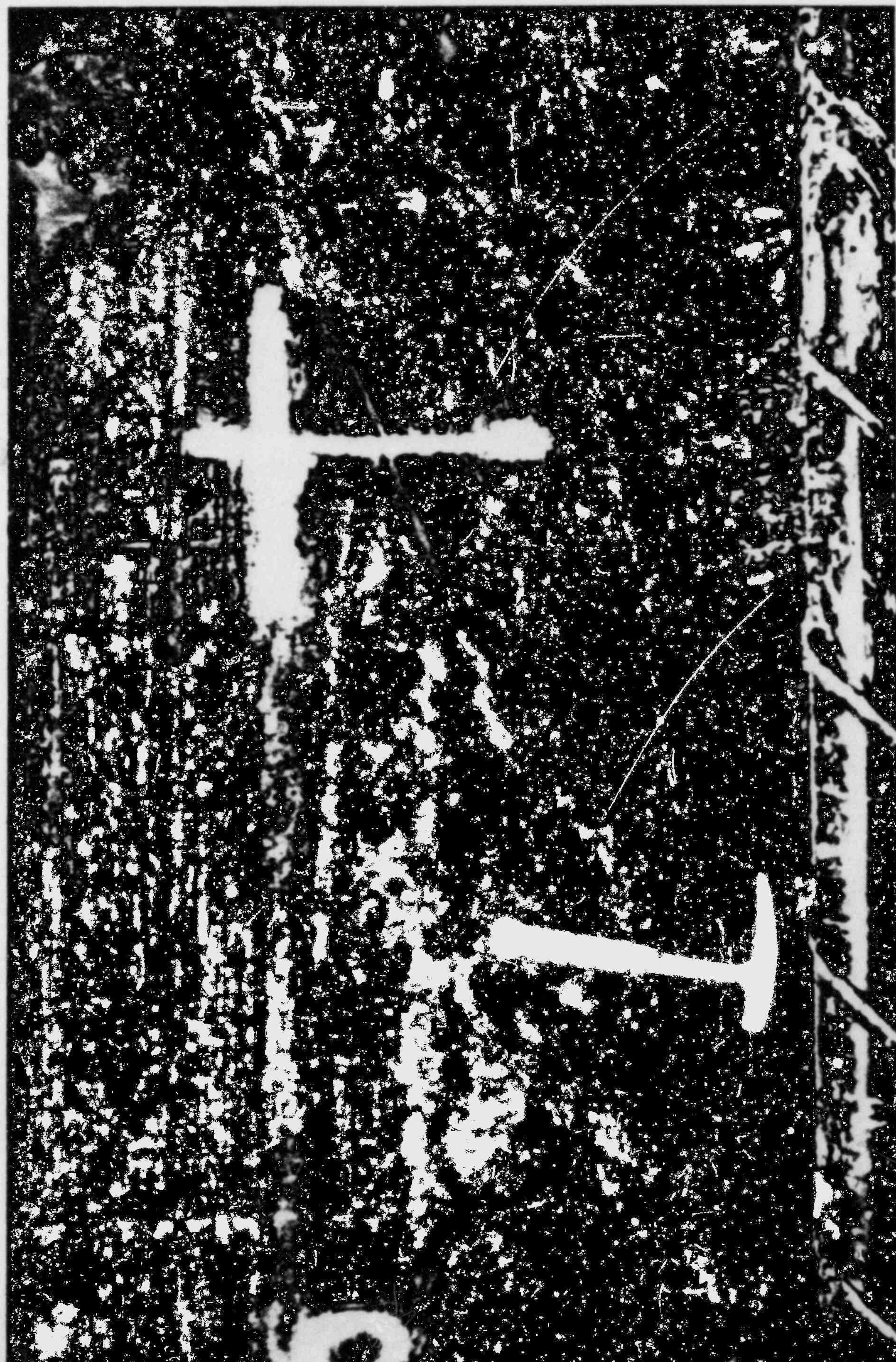
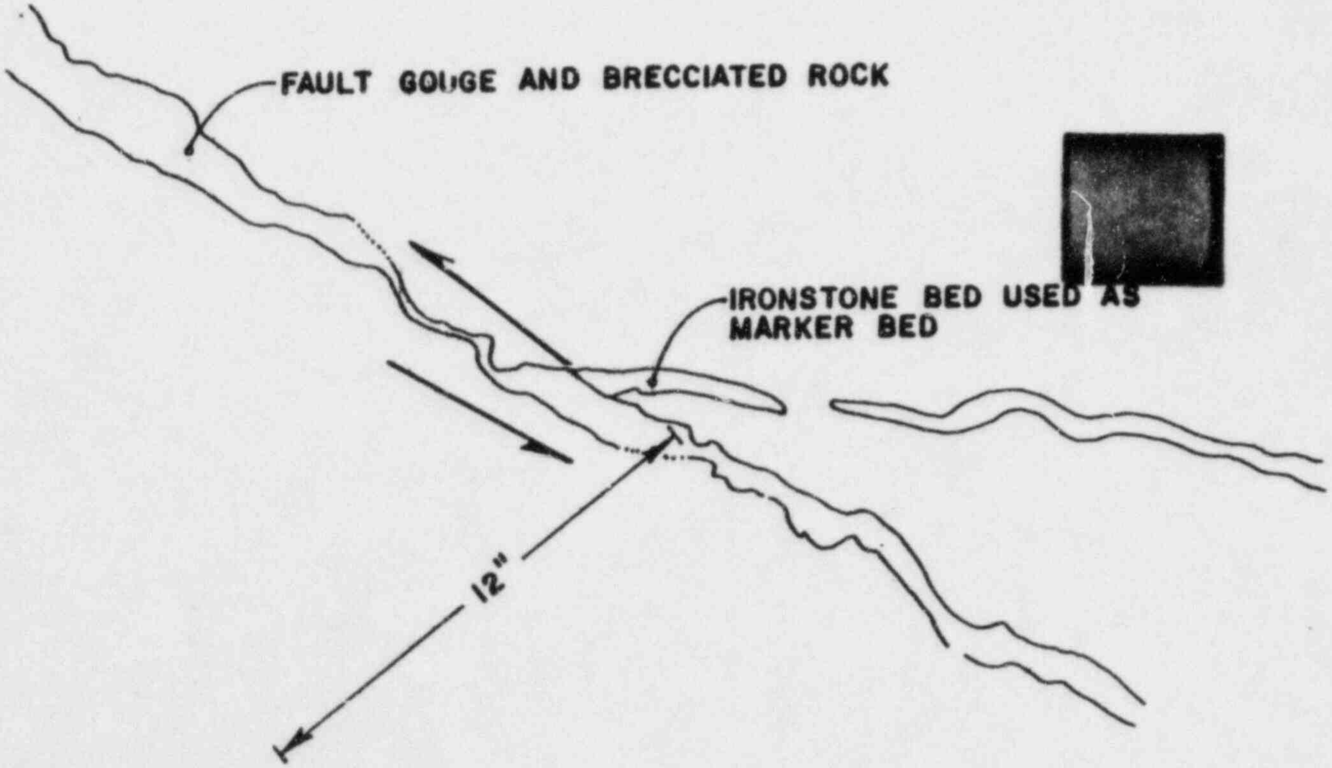


FIGURE 8. FAULT ON WEST WALL OF INTAKE TUNNEL.





IRONSTONE BED (OXIDIZED) ALONG EAST WALL INTAKE TUNN
WHERE IT INTERSECTS FAULT.

P 4/27/78

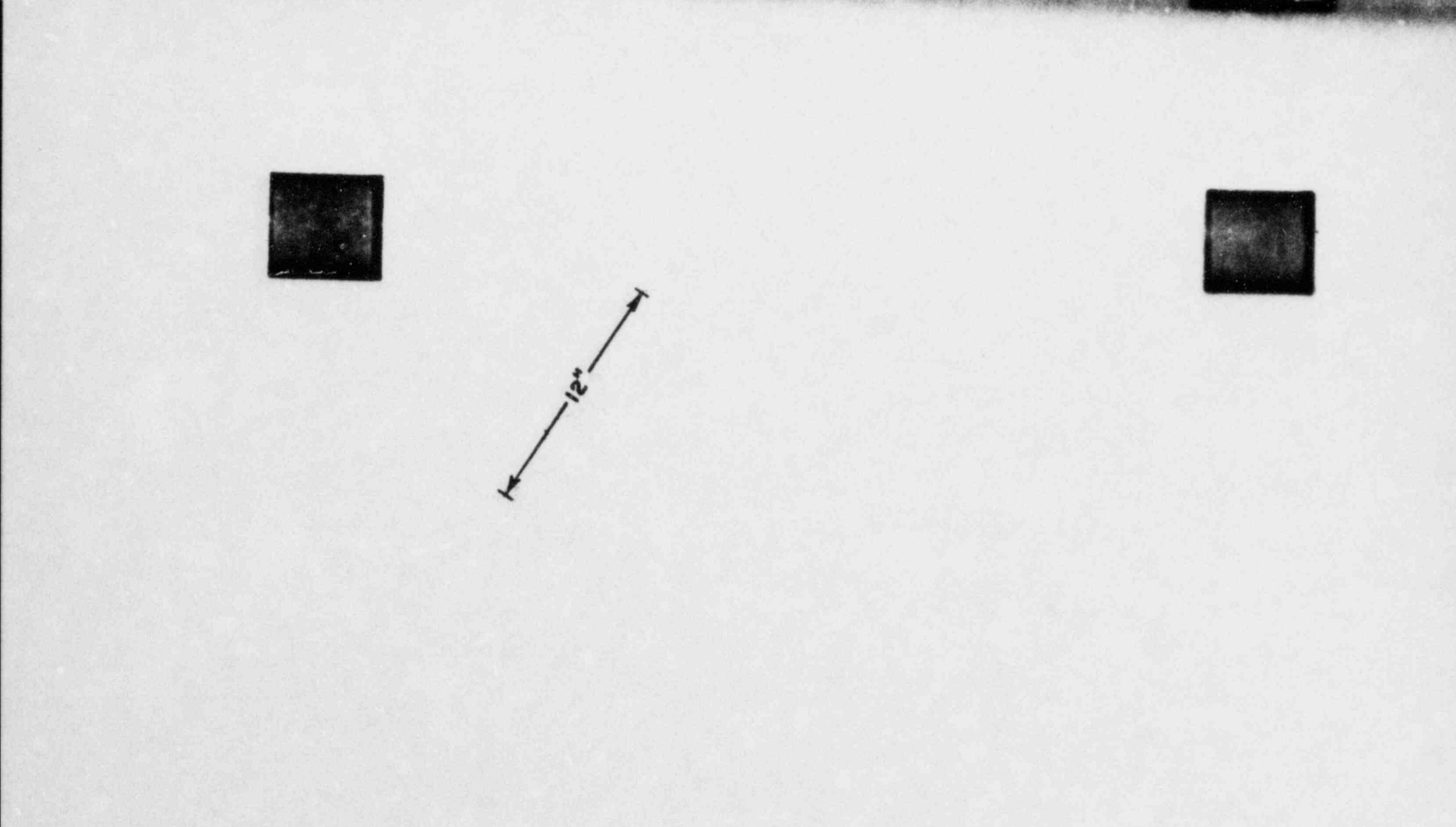


FIGURE 10. FOLD IN STRATUM ON EAST WALL INTAKE TUNNEL AT STATION 10+4[redacted]
NOT [redacted]N PHOTOGRAPH ARE FLAT-LYING STRATUM IMMEDIATELY ABOVE [redacted]
AND BELOW FOLDED SEGMENT.

[redacted]/27/78

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APPENDIX A

RESIDENT GEOLOGISTS DOCUMENTATION

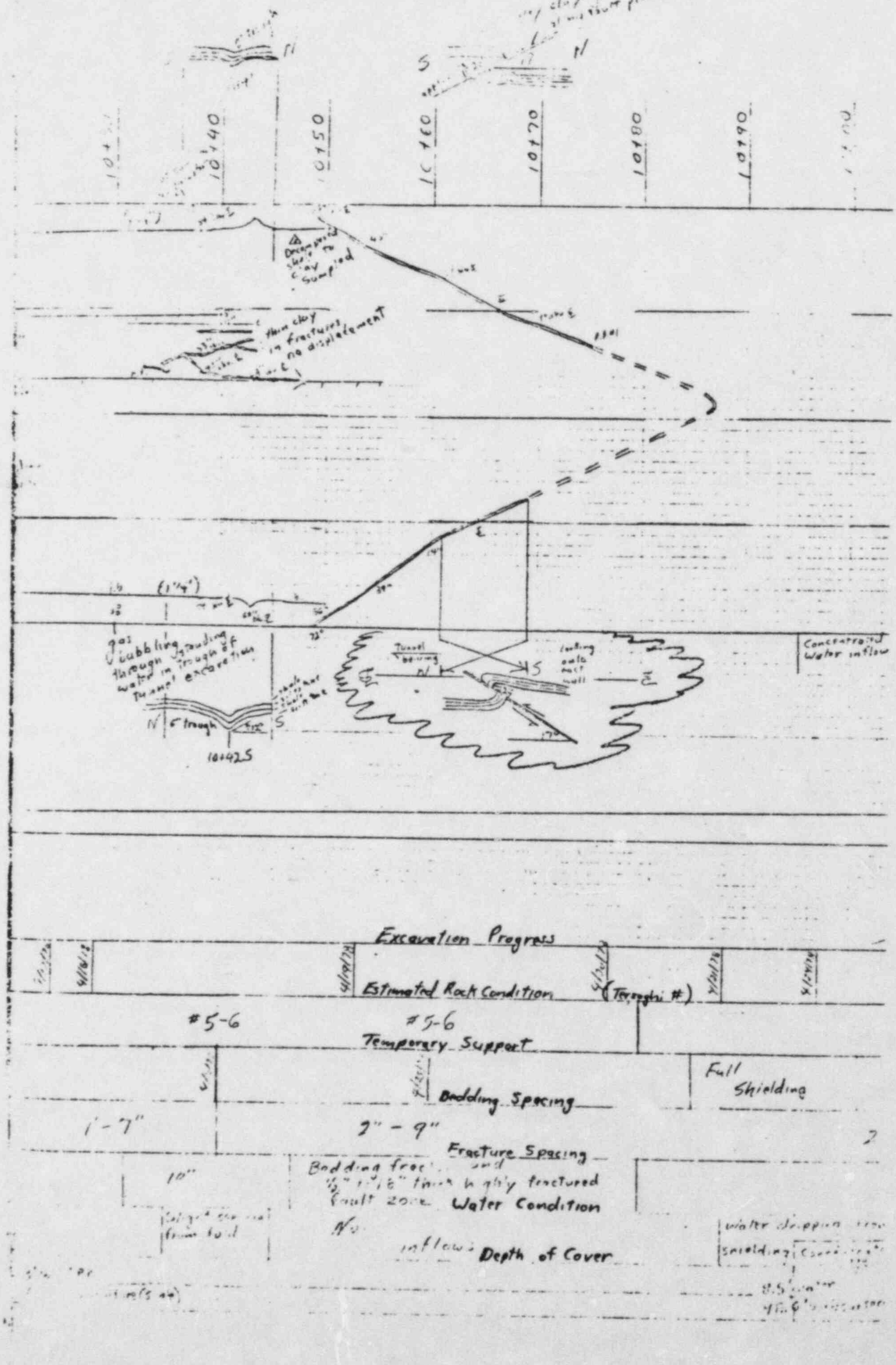
Item 1. As built tunnel log.

Item 2. Geologic progress report (week ending 4/28/78)

Item 3. Memorandum to Larry Beck, CEI

Item 4. Weekly report of Resident Geotechnical Engineer (week ending 4/28/78)

Item 1.



10140
10150
10160
10170
10180
10190
Decomposed shale to clay Sampled
thin clay in fractures no displacement
gas bubbling through standing water in trough of tunnel excavation
N
S
10+425
Tunnel bearing
Concentrated water inflow
Excavation Progress
Estimated Rock Condition
(Terzaghi #)
#5-6
#5-6
Temporary Support
Full Shielding
Bedding Spacing
1'-7"
2" - 9"
Fracture Spacing
10"
Water Condition
Depth of Cover

Item 2.

CLEVELAND ELECTRIC ILLUMINATING COMPANY

PERRY NUCLEAR POWER PLANT

GEOLOGIC PROGRESS REPORT - WEEKLY SUMMARY

TUNNEL: Intake

HEADING: [illegible]

Week Ending APRIL 28, 1978

Reported by Rick Wardrop
GAI Geologist(s)

1. Mapping progress: Sta. 10+20 to 10+84. Approx. 64 ft.
2. Excavation progress: Sta. 10+88 to 12+30. Approx. 142 ft.
3. Avg. rib spacing 3-3.5 ft. c.c. Rib size 12 ft. diam. - 1 ft. width
4. Struts used? None Size ______. Spiling used? None Size ______
5. Rock bolt used: 6 ft. lengths Sta. 12+30 Spacing ______
6. Water inflows, gpm and locations Water dripping from shielding from 10+88 to 11+05 w/concentrated inflows from 10+95 & 11+05.
7. Rock types excavated Dk. gy. shale interlam. w/ lt. gy. siltstone, med. hard, w/tr. cherty, "Fe" band. → except for approx. 5% badly broken soft shale to clay along fault plane
8. Rock conditions (blockiness, decomposed, "stands well." etc.) Mod. seamy, standing mod. well, competent shale. Terzaghi No. 5-6
9. Rock defects (large faults, joints, squeeze, etc.) A low angle, underthrust fault encountered, normal to tunnel bearing, dipping south, entering crown @ 10+88 and leaving base @ 10+48. (See Supplement) -
10. Additional remarks (overbreak, feeler holes, accidents, etc.):

4/20/78 - 6" to 2' of overbreak began @ sta 11+90 and continued to face @ 12+30. Overbreak begins approx 4.5' above springline and is associated w/ a thin clay seam along roof of overbreak. No moisture involved.

(Use back of sheet for sketch of unusual condition.)

Distribution

Site Organization	GAI - Home Office	CEIC
Resident Tunnel Engineer	W. J. Santamour	
Resident Geotechnical Engineer	R. D. Boyer	
Resident Geologists	R. T. Wardrop	
	J. G Darabaris	

Geologic Progress Report - Supplement for Weeks Ending April 14
April 21
April 28, 1978

a. Moisture along bedding plane partings has been traced back to station 6+50. Partings occur every 4 to 10 inches and moisture is recognized in approximately 50 percent of the partings.

b. Seepage from rock bolt bores has been recognized from station 9+20 to station 9+55. Seepage is minimal and accompanied with iron staining from the steel rock bolts.

c. On Friday, April 14, 1978 a 80 foot long test probe was driven from station 9+64 to station 10+44. The probe was driven with a slight dip to the north. Water was encountered at the end of the run, flowing full bore (2" diameter) upon bit extraction. This occurred at 3:45 A.M. At 4:45 A.M. the flow decreased to constant half bore volume. At 7:30 A.M. the site geologists entered the excavation for mapping. The mouth of the test bore was not accessible at that time; however, a pulsating flow, surging once every three seconds could be heard behind the Jarva dust shield.

d. Monday, April 17, 1978 - Excavation continued with test probes yielding water and "mud" from the 10+40 - 10+45 zone. One test probe jammed in the questionable area.

A groundwater sample was taken from the April 14, 1978 test probe. At sample time water was flowing 1/8 bore at a rate of .08 gallons/minute. Sample water had a salty taste. Sample was sent to NUS for analysis.

e. Tuesday, April 18, 1978 - Test probes encountering "mud", water and methane gas, have also blocked up the vicinity of the questionable zone (station 10+38 - 10+40). Probe operator notes a 6 inch to 1 foot surge of no resistance before blockage occurs. Gas readings of 40 - 50% L.E.L. have prohibited excavation today.

f. Wednesday, April 19, 1978 - Diminished methane levels have allowed excavation to continue into questionable zone. Moist seams of soft shale to clay were encountered at sta. 10+35. These represent less than 10% of the rock which is otherwise sound, med. hard, shale interlaminated with siltstone.

g. Thursday, April 20, 1978 - Excavation continues to sta. 10+77. Decomposed shale seams continue. Some seams are of grey clay only.

h. Friday, April 21, 1978 - Excavation continues to sta. 10+88. Gas level remains safe. Water is entering through rock bolt bores. Solid shielding of overburden has been initiated at sta. 10+85.

i. Monday, April 24, 1978 - Excavation continues to sta. 10+97. Seams of soft shale to clay have dissipated.

j. Tuesday, April 25, 1978 - Site geologists entered tunnel to map the 10+20—10+90 section of recently excavated rock. During cleaning procedures a small fold was noted at station 10+41. At station 10+65 a low angle fault, dipping south, was first recognized. W.J. Santamour was advised in Reading. Excavation continued to station 11+10 where water inflows discontinue and shielding was stopped.

k. Wednesday, April 26, 1978 - W. J. Santamour and L.D. Schultz arrive from Reading to examine fault. The Chicago office of the NRC was notified.

l. Thursday, April 27, 1978 - Site geologists completed detailed mapping of fault. Larry Beck (CEI, Head of Licensing) and Forest Bradfield (Kaiser, Tunnel Engineer) also examined fault.

<u>Fault Description:</u>

Type: Low angle, underthrust

Apparent Displacement: 22 inches

Actual Vertical Displacement: 12 inches±

Strike: Normal to Intake Tunnel Bearing - N 47°E

Dip: 17°SE

Width of Fault Zone Gauge Material: ½ inch

Width of Broken Rock Along Fault Plan: Varies ½" to 18"

m. Friday, April 28, 1978 - Excavation continues to sta. 12+30.

n. Saturday, April 29, 1978 - No excavation. Overbreak, varying from 6 inches to 2 feet thick, has occurred from station 11+90 to the face at 12+30. Shale begins to break approximately 4.5' above springline. A thin clay seam, carrying very little moisture, can be seen along the roof of the overbreak.

Richard T. Wardrop
Richard T. Wardrop

RTW/kr

Item 3.

Gilbert Memorandum

Gilbert/Commonwealth engineers and consultants

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600/Cable Gilasoc/Telex 836-431

To: Larry Beck, C.E.I., NED
From: John Darabaris, P.E., Resident Geotechnical Engineer
Subject: Fault - Intake Tunnel

On April 27, 1978 through the geologic mapping program a very minor fault, with less than 22 inches of apparent displacement and approximately 12 inches of throw was mapped. The fault plane which consists of broken rock, drag folding and clay seams ranges in width from ½ inch to approximately 18 inches striking in a northeasterly direction nearly normal to the tunnel bearing and dipping Southeast at approximately 16.7 degrees. This fault is a low-angle underthrust as determined from effects of drag along the fault plane and in all descriptive aspects, closely resembles the glacial - induced deformation previously observed in other site bedrock formations.

If you have any questions, please contact me.

Cordially yours,

John G. Darabaris

J. G. Darabaris

JGD/kr

525 Lancaster Avenue, Reading, PA / Morgantown Road, Green Hills, Reading, PA 215 775 2600
[illegible] / 80 Pine Street, New York, NY 212 422-[illegible]

Item 4.

RE FORM 30-2(9-75)

WEEKLY REPORT SUMMARY RESIDENT GEOTECHNICAL ENGINEER PERRY NUCLEAR POWER PLANT - UNITS 1&2	REPORT No. #121 WEEK ENDING April 27, 1978 PAGE 1 of 2

Foundation Areas Worked / Prepared: North of TB2, Base of Ramp 2, Pipeline MH9-20, 20-23

Fill Placed: Class A

Tests Performed: 14?? Pccs - 1509 Pccs, 1456 Pccs A, 1455 Pccs B, 1476 Pcs A, 1456 Pcs A

Correspondence Issued:

Other Items: (Summary)

National - drilled and poured caisson 2-6, 2-4, 1-1, 2-1
- poured the mud mat for the off-gas building #2

Cavilho - no safety, backfilling base for the start up building

Dalen & Sullivan - off-gas, pumping shafts

Great Lakes - excavating pipetrench between MH9 & 23
- preparing Ramp #2 base, pipetrench between MH 20 & 23 for backfill
- placed backfill north of TB#2, at the base of Ramp #2, west of auxiliary building - intermediate building and in the pipetrench between MH 20-23
- a FUA is being issued to allow the contractor to leave 3 removal [illegible], presently serving as part of a retaining wall, in place when we backfill this area to prevent any movement of Class A material in this area. Discussed this with Santamaria, Collins (GAI) and Dunoff (CE/CC)

S&W - excavating at the north face of the intake tunnel
- on tuesday morning, I found indications of a fault plane. Informed the project geologist Bill Santamaria.
- Santamaria & Schultz arrived on Wednesday and confirmed my opinion. Because of inaccessible conditions we could not map this day. Larry Peck (CEI-NED), P. Gaylord (GAI) and the [illegible] NRC office were informed as well as QA.
- [illegible] the [illegible] ... [illegible]

BY: [signature]

RE FORM 30-2(9-75)

WEEKLY REPORT SUMMARY RESIDENT GEOTECHNICAL ENGINEER PERRY NUCLEAR POWER PLANT - UNITS 1&2	REPORT No. #181 WEEK ENDING April 29 197[illegible] PAGE 2 of 2

Foundation Areas Worked / Prepared:

Fill Placed:

Tests Performed:

Correspondence Issued:

Other Items: (Summary)

- On Friday I sent a memo to Larry Beck describing the feature (copy attached)
- the contractor has placed liner plates at the crown for support in the area where the fault

NOTE: Additional Documentation on

BY: [illegible]

APPENDIX B

MINERAL IDENTIFICATION OF FAULT PLANE GOUGE

Prepared by:
Dr. B. Carson
Department of Geological Sciences
Lehigh University
May 17, 1978

ANALYTICAL REPORT

FROM: Mr. Joel B. Levy and Dr. Bobb Carson, Department of Geological Sciences, Lehigh University, Bethlehem, PA 18015

TO: Dr. Lane Schultz, Gilbert Associates, Inc., P. O. Box 1498, Reading, PA 19603

PURPOSE: Semiquantitative clay mineral X-ray diffraction analysis of 2 samples marked S-I 1 and S-I 2

RESULTS:*

	Montmorillonite	Illite	Chlorite	Kaolinite
S-I 1	1%	81%	10%	8%
S-I 2	1%	80%	11%	8%

* Data represent averages of two slides prepared from each sample.

SAMPLE PREPARATION:

A 10g subsample was taken from the original sample and dispersed in distilled water by shaking on a Burell wrist action shaker for 30 mins. Each sample was centrifuged and the water (containing any soluble salts) was decanted. The samples were resuspended in distilled water and 10 ml of dispersant (0.08 M sodium hexametaphosphate) was added. After shaking for 20 mins. on the Burell shaker, the coarser than 62.5 μ material was removed by wet sieving. Each sample was then treated to remove organic matter, calcium carbonate, and free iron.

Organic removal (Anderson, 1963): 30 ml of 4-6% sodium hypochlorite (NaOCl) were added to each sample. The samples were then placed in a water bath at 90° C for 25-30 mins., stirring periodically. The samples were centrifuged and decanted and the procedure was repeated a second time.

Carbonate removal (Jackson, 1969): 100 ml of sodium acetate (NaOAc) buffered with acetic acid to pH 5 was added to each sample. The samples were placed in a water bath at 85° C for 30 mins. The samples were then centrifuged and decanted.

Free Iron removal (Jackson, 1969): A sodium citrate, bicarbonate-dithionite (CBD) treatment was used to remove free iron from each of the samples. 20 ml of 0.3 M sodium citrate and 2.5 ml of 1 M sodium bicarbonate were added to each sample. After being placed in a water bath at 75° C 1 gm of sodium dithionite was added to each sample while constantly stirring for 1 minute. After 5 minutes, a second gram of sodium dithionite was added and the mixture was stirred for 1 minute. A third gram of sodium dithionite was added after 5 minutes; again, with constant stirring for 1 minute. The samples were then washed with distilled water, centrifuged, and decanted three times to clean the sediment particles.

Each sample was then fractionated by centrifugation in order to separate out the < 2 μ fraction. A subsample of the resultant < 2 μ fraction was used in preparing oriented slides for X-ray diffraction. Samples were mounted by the filter-membrane peel technique as described by Drever (1973). Two slides were made for each sample.

After the slides were prepared, they were air dried and then placed in an eythelene glycol atmosphere for at least 24 hrs (Brunton, 1955). Immediately after eythelene glycol treatment, they were X-rayed.

X-Radiation Procedure: The samples were X-rayed on a Norelco wide angle X-ray diffractometer with a scintillation counter, using nickel filtered copper K_α radiation at 40 KV and 20 mA. The following setting of the rate meter were used: scale factor - 5 K, multiplier = .5, time constant - 1 sec. Each slide was scanned from 2°-15° 2θ at ½°/min and from 24°-26° 2θ at ¼°/min.

Mineral Identification

Montmorillonite is identified as the 17Å diffraction peak upon treatment with ethylene glycol (MacEwan, 1944).

Illite is recognized by a strong first order basal reflection at 10Å.

Chlorite is identified by a strong second order reflection at 7Å although this reflection can also indicate kaolinite. The relative abundance of each mineral may be determined by the relative peak heights at 24.9° 2Θ (kaolinite) and 25.2° 2Θ (chlorite), (Biscaye, 1965; Elverhoi and Ronningsland, 1978).

Quantitative Determination of Relative Clay Mineral Concentrations

A polar planimeter was used to measure the peak areas. Each peak was measured twice and the average value was used for determining the relative clay mineral concentrations. The semi-quantitative technique of Biscaye (1965) was used to convert the peak areas to clay mineral percentages.

Discussion

From physical appearance and from the X-ray data, the sample S-I 1 and S-I 2 seem to be identical. It also appears that the illite mineral may approach the composition muscovite due to a relatively strong peak at 17.78° 2Θ, which corresponds to muscovite. One of the slides (S-I 1-B) was scanned from 2°-40° 2Θ in order to identify any other minerals present in the $< 2\mu$ fraction. It was observed that the samples are composed entirely of the clay minerals reported although a small amount of quartz may be present.

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