CEB REPORT

TVA 10752 (EN DES-8-80)

TITLE				REPORT NO.
PHIPPS BEND NUCLEAR PLANT GEOLOGIC FOUNDATION REPORT FAULT DESCRIPTIONS				CEB 81-47
				PLANT/UNIT: PBN
				SAR SECTION(S): 2.5.3
VENDOR	CONTRACT No.	KEY NOUNS: Geology, Faults, Foundation		UNID SYSTEM(S)
APPLICABLE DESIGN DOCUMENTS	REV	(FOR MEDS USE)	MEDS ACCESSION NUMBER	
	R0		CEB '81 1222 004	
REFERENCES CTR PBN - R056	R1			
	R2			

TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN

CIVIL ENGINEERING BRANCH

	Revision 0	R1	Supplement to R1	R2
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PHIPPS BEND NUCLEAR PLANT
GEOLOGIC FOUNDATION REPORT
DESCRIPTION OF FAULTS 1-29

Background

In the summer of 1978, during the early phase of construction of Phipps Bend Nuclear Plant, the foundation excavation for unit 1 reactor building exposed three minor faults in the bedrock. These faults were numbered in the order they were mapped, and a report on the fault parameters and age of last movement was prepared for each fault or fault zone. These reports were forwarded to the Nuclear Regulatory Commission-Office of Nuclear Reactor Regulation (NRC-NRR) to satisfy TVA's commitment in the Phipps Bend Nuclear Plant - Preliminary Safety Anlysis Report (PSAR) response to Round One question 323.4.

As predicted in the PSAR, several additional faults were uncovered during foundation preparation. To avoid confusion and to provide a concise assemblage of fault descriptions, a foundation report containing brief summaries of the faults was prepared and distributed every six months. The first foundation report was submitted in September 1979 (NEB '79 09 20 608), and followed by update reports in April 1980 (NEB '80 04 16 518) and January 1981 (NEB '81 01 19 518). The data in these three reports are included in this foundation summary along with descriptions of four faults which were uncovered since November 1980.

During the summer of 1981, construction of the Phipps Bend project was deferred and as a result, no additional excavations will be made at the site until construction resumes. This report summarizes the descriptions of all 29 faults uncovered to date and will be the last one issued until excavation restarts and additional faults are exposed.

Introduction

Since construction for Phipps Bend Nuclear Plant began, 29 faults in the foundation bedrock have been mapped (exhibit 1). These faults are located throughout the plant as indicated in Table 1.

Table 1: Fault Locations at Phipps Bend Nuclear Plant

Number of Faults	Locations	Fault Numbers
3	Reactor Bldg. 1	1, 2, 3
1	Reactor Bldg. 2	4
1	Fuel Bldg. 2	5
3	Turbine Bldg. 2	6, 10, 16
3	CCW Pump Station	7, 8, 9
1	Soil Disposal Pit	11
4	Intake Pump Station	12, 13, 14, 17
1 Zone	ESW Pump Station 1	15
1	ESW Pump Station 2	18
4	ESW Spray Pond 1	19, 20, 21, 22
3	DGB & Control Bldg. 1	23, 24, 25
4	Cooling Tower 1	26, 27, 28, 29

As each fault was uncovered, the fault was mapped and, when possible, traced or projected to the closest exposure of the contact between the Quaternary terrace gravel and the top-of-rock. The area around the contact was examined in detail to determine if offsetting or tectonic deformation extended through the contact into the terrace gravel. The NRC-NRR was notified by telephone, followed by a written report, of the fault parameters and the age of last movement.

In January 1981, during the telephone conversation between TVA and NRC-NRR personnel, an agreement was reached to cease the notification by telephone to NRC-NRR of any additional faults unless they exhibited characteristics dissimilar to those already reported. Only two faults, numbers 28 and 29 (neither requiring notification by telephone), have been uncovered since this time and are the only two not reported prior to this summary.

Two consulting geologists, Dr. Paul Fullager and Dr. Fred Webb, were employed by TVA to (1) attempt to date the faults and (2) prepare a detailed structural geologic report on the unit one reactor building and condenser cooling water (CCW) pumping station areas, respectively. Copies of their reports are contained in appendices A, B, and C. Reports referenced in the following descriptions are transmittals from the TVA Office of Power to the NRC Office of Nuclear Reactor Regulation.

Descriptions

Fault 1, reported on March 21, 1978, is a reverse fault located 6 feet north of the axial plane of an asymmetrical syncline and approximately 25 feet north of the unit 1 reactor building east-west baseline (exhibit 1). The fault can be seen in the east wall of the reactor building and extends approximately 50 feet to the east of the wall, where it terminates laterally into bedding. The fault which strikes N 50° E and dips 86° SE, is 2 feet wide at the surface and tapers to a narrow calcite-filled fracture near the bottom of the excavation (exhibit 2). The associated syncline was traced northeastward to the overlying Quaternary deposits, which were found to be undisturbed.

Fault 2, reported on April 27, 1978, was originally reported as a flexure-slip fold located 65 feet north of the east-west baseline of the unit 1 reactor building (exhibit 1). After excavation was complete, this fault was found to be a thrust fault located approximately 48 feet north of the east-west baseline and 52 feet east of the north-south baseline, where it truncates the northern portion of an anticline. The fault at this location splits into two branches. One dips 70° SE; and the other, on the floor of the excavation, extends nearly horizontal for 20 feet, where it merges with the bedding. Both branches have planar fault zones filled with calcite and trend N 35-55° E (exhibit 2). The overlying Quaternary deposits remain undisturbed above the fault zones.

Fault 3, described in appendix B,[1] and reported May 8, 1979, is a thrust fault located on the unit 1 reactor building east-west baseline and extending from the west wall to the east wall of the excavation and beyond (exhibit 1). The fault, which trends N 56° E and dips 40° SE is defined by a calcite filled fracture truncating the north limb of an anticline (exhibit 2). No evidence of disturbance was found in the Quaternary deposits overlying the fault.

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1. In appendix B, Dr. Webb has labeled the first three faults as sites 1 through 3. It should be noted that fault #1 is site 2; fault #2 is site 3; and fault #3 is site 1.

Fault 4, reported on August 11, 1978, is located in the unit 2 reactor building excavation area 8 to 27 feet north of the east-west baseline (exhibit 1). This reverse fault, which trends N 56° E and dips 64° SE, is probably an extension of fault 3 located on the east-west baseline of unit 1 reactor building. The fault zone, which is about 1.5 feet wide and composed of calcite and weathered shale, truncates the north limb of an anticline (exhibit 3). Thorough investigations of Quaternary deposits in the area have indicated no offsetting or tectonic deformation.

Fault 5, reported November 16, 1978, is a reverse fault located in the unit 2 fuel building 95 feet north of fault 4 and 106 feet north of the unit 2 east-west baseline (exhibit 1). The fault can be traced from the east wall of the fuel building approximately 45 feet west where it terminates. The fault, which is defined by a calcite-filled fracture, strikes N 45° E and dips 84° NW (exhibit 3). No deformation of the overlying Quaternary deposits was found.

Fault 6, reported on April 11, 1979, is a transverse fault located in the unit 2 turbine building 306 feet east of the unit 1 north-south baseline, where it intersects the centerline of the south CCW trench (exhibit 1). From the south wall of the south CCW trench, where it is covered by overburden, the fault extends 34 feet to the north, where it splits into two branches; the two branches continue northward to approximately 290 feet south of the east-west baseline, where they transitionally terminate into a near-vertical joint. This joint can be traced northward for 88 feet where the bedrock is again offset about 3 inches by right lateral movement for a distance of 16 feet, where the fault terminates. The fault is defined by a distorted fracture zone which strikes N 25° W and dips 60° SW, offsetting bedding (by right-lateral movement) an average of 3 inches (exhibit 3). The fault trace can be projected south to the plant excavation slope, where no deformation of the overburden or overlying Quaternary deposits was found.

Fault 7, 8, and 9, reported on April 30, 1979, and described in Dr. Fred Webb's report (appendix C), represent three main fault groups located in the CCW pumping station (exhibit 1). All three faults exhibit both lateral and vertical movement and have steep to vertical dips which may change direction from NW to SE along the strike (exhibit 4). The dominant sense of movement appears to be that of reverse faulting. Subsidiary faults parallel to, or diverging from, the three main faults apparently developed as dip-slip and oblique-slip faults which strike obliquely across bedding planes and exhibit highly variable dips (for detailed structural geologic report, see appendix C). Exhibit 5 shows two sections developed from the surface geology across the pump station. Examination of the top-of-rock/overburden contact around the perimeter of the excavation revealed no offsetting or indications of tectonic deformation of the Quaternary deposits.

Fault 10, reported on June 14, 1979, is located in the unit 2 turbine building 267 feet east of the unit 1 north-south baseline and 150 feet south of the east-west baseline (exhibit 1). This transverse fault is defined by a tight, calcite-healed fracture zone striking N 30° E and dipping nearly vertical. It originates at the northern terminus of a series of northerly striking en echelon joints, extends a total of 4 feet, and offsets bedding a maximum of 4 inches (exhibit 3).

Fault 11, reported on September 6, 1979, is in a contaminated soil disposal pit excavation northeast of the intake pumping station, at approximate stations S 16+24 and E 10+72 (exhibit 1). This reverse fault, located in the residuum, is defined by a tight fracture, striking N 50° E and dipping 55° SE (exhibit 6). No evidence of disturbance was found in Quaternary deposits overlying the fault.

Faults 12, 13, and 14, reported on September 11, 1979, are located in the intake pumping station and are defined as two thrust faults and a series of transverse faults, respectively (exhibit 1). Fault 12 strikes N 45° - 60° E and dips 24° SE and is visible on the south and west walls of the pumping station excavation. Fault 13, which is a reverse fault, strikes N 45° - 60° E, dips 45° - 50° SE and can be seen in the floor and west wall of the excavation. Both faults are characterized by contorted beds in the upper plate and beds dipping 25° - 30° SE in the lower plate. Fault 14 is a series of near-vertical, transverse faults which strike N 0° - 10° E and shows offsets ranging from 1 to 6 inches (exhibit 7). Examination of Quaternary deposits around the perimeter of the excavation revealed no offsetting or indications of tectonic disturbances.

Fault Zone 15, reported on October 24, 1979, is located in the unit 1 essential service water pumping station excavation (exhibit 1). The faults in this zone are described as R1, R2, T1, and T2. R1 and R2 are reverse faults parallel to an anticlinal axis that strikes N 50° E. Both are located west of the axis and dip 67° NW and 76° SE, respectively. T1 and T2 are transverse faults located west and northwest of R1 and R2, with fault planes defined by near-vertical, calcite-healed fractures striking NW (exhibit 8).

Examination of Quaternary deposits around the perimeter of the excavation revealed no offsetting or indications of tectonic disturbances.

Fault Zone 16, reported on February 19, 1980, is located in the south end of the unit 2 turbine building excavation (exhibit 1). The area is defined by a weathered, faulted, contorted rock zone striking approximately N 50° E and dipping from horizontal to vertical (exhibit 3). This zone is probably an extension of faults 7, 8, and 9, located in the CCW pumping station (exhibit 4). No evidence of tectonic disturbance was found in Quaternary deposits overlying the faults.

Fault Zone 17, reported on February 19, 1980, is located beneath the intake pumping station retaining wall structure (exhibit 1). The main fault, a thrust fault which truncates the north limb of an overturned anticline, strikes N 54° E and dips 44° SE. The fault is defined by a tight calcite-healed fracture bordered by contorted rock on the north side and the anticline on the south. Subsidiary faults, parallel to or diverging from the main fault and striking obliquely across bedding planes, developed as dip-slip and oblique-slip faults (exhibit 7). The overburden-rock contact around the perimeter of the excavation has revealed no offsetting or indications of tectonic disturbances in the Quaternary deposits.

Fault Zone 18, reported on April 1, 1980, is located in the foundation of the unit 2 essential service water pumping station (exhibit 1). This zone consists of an anticline truncated on both the east and west limbs by a reverse and thrust fault, and a near horizontal thrust fault. The reverse fault strikes N 48° E, and dips 62° NW and truncates the west limb of the anticline. A thrust fault, which dips 34° SE is located on the east limb. Both faults are defined by tight, weathered fractures parallel to the anticline. Another thrust fault is defined by a weathered fracture which strikes N 48° E and exhibits dips from horizontal to near vertical (exhibit 9). Examinations of the overburden-rock contact around the perimeter of the excavation has revealed no evidence of tectonic disturbances in the Quaternary deposits.

Fault 19, reported on June 3, 1980, is a transverse fault located on the southern perimeter of the unit 1 essential service water spray pond (exhibit 1). The fault trace is defined by a weathered zone approximately 8 inches wide, striking N 42° W and dipping nearly vertical. Bedding is offset (right-lateral movement) a maximum of 8 inches at its intersection with the fault zone. The fault extends southeastward under the overburden and northwestward 35 feet into the excavation, where it transitionally terminates into a near-vertical joint (exhibit 8). No evidence of tectonic deformation was observed where the fault intersects Quaternary deposits.

Fault zone 20, reported on August 22, 1980, is located in the unit 1 essential service water spray pond (exhibit 1). The fault zone strikes N 50° E, dips 66° SE and can be traced across the spray pond excavation, extending under the overburden to the NE and SW. The zone consists primarily of two parallel reverse faults separated by a zone of contorted rock (exhibit 8). The zone was traced to its intersection with the Quaternary deposits, which showed no evidence of tectonic deformation.

Faults 21 and 22, reported on August 22, 1980, are reverse faults located in the west half of the unit 1 essential service water spray pond (exhibit 1). Both faults strike N 40° E and dip away from each other at 83° SE (21) and 58° NW (22). Both fault planes are defined by calcite zones, 0.5 to 3.0 inches wide, which show minimal deformation of adjacent beds (exhibit 8). These faults were traced to their intersections with the Quaternary deposits, which showed no evidence of tectonic deformation.

Faults 23, 24, and 25, reported on August 22, 1980, are located in the unit 1 control and division 1 diesel generator buildings (exhibit 1). An earlier examination of the area revealed no deformation of the Quaternary deposits.

Fault 23, a reverse fault located in the diesel generator building, extends from the west wall of the fuel building across the excavation and below the construction-placed fill to the west. The fault plane is defined by a calcite-filled fracture which strikes N 40° E and dips 84° SE (exhibit 2).

Fault zone 24 consists of interconnecting thrust and reverse faults located in the south end of the diesel generator building. These faults, which are associated with the folding in the area, strike N 35° - 49° E and dip from 70° SE to horizontal. They truncate the north limb of an anticline and intersect the axis of a syncline (exhibit 2).

Fault 25 is a thrust fault which is located in the north end of the control building. The fault plane is defined by a weathered zone 1 to 3 inches wide, striking N 51° E and dipping 6° SE in the south section and 33° NW in the north section. Little or no deformation of adjacent beds was mapped (exhibit 2).

Fault 26, reported on February 24, 1981, is a thrust fault located in the bottom of unit 1 cooling tower foundation pier number 34 at elevation 1098.7 (exhibit 1). The fault trace is defined by a weathered 1/2-inch-thick fracture which strikes approximately N 5° E. The fault dips 35° east and extends across the bottom of the hole (exhibit 10). The contact between the top of rock and Quaternary deposits was not exposed in this area, but no indications of offsetting or tectonic disturbance are evident in the overburden at the surface.

Fault 27, reported on February 24, 1981, is a thrust fault located in unit 1 cooling tower foundation pier number 19 at elevation 1111.5 (exhibit 1). The fault trace is defined by a clay seam which is 1/8-inch thick, strikes N 2° E, and dips 35° east. Bedding on both sides of the fault is vertical, and drag folds have developed adjacent to the clay seam (exhibit 11). The contact between the top of rock and Quarternary deposits has not been exposed in this area, but no indications of offsetting or tectonic disturbances are evident in the overburden at the surface.

Fault 28, mapped on February 19, 1981, is a t ansverse fault located in unit 1 cooling tower foundation pier number 47 at elevation 1115.0 (exhibit 1). The fault trace is defined by a calcite-filled fracture which is 1/8-inch thick, strikes N 80° W, and dips 48° northeast. Bedding on both sides of the fault is vertical, and drag folds have developed adjacent to the fracture (exhibit 12). The contact between the top of rock and Quaternary deposits has not been exposed in this area, but no indications of offsetting or tectonic disturbances are evident in the overburden at the surface.

Fault 29, mapped on May 21, 1981, is a transverse fault located in the unit 1 cooling tower inlet header excavation (exhibit 1). The fault trace is defined by a weathered zone approximately 12 inches wide at the southeast side of the excavation and narrows to a 1-inch-wide, calcite-filled fracture near the center of the trench (exhibit 13). Two fractures merge northwest into one which strikes N 40° W and dips 81° NE. Bedding dips 81° NW on the north side of the fault and 82° SE on the south side. The excavation for the inlet header extended through the overburden into bedrock and exposed the Quaternary deposits and top-of-rock contact. The fault zone was traced to the contact, and no evidence of offsetting or tectonic disturbances could be found.

Summary

The 29 faults throughout the plant represent either thrust, reverse, or transverse faulting. The thrust and reverse faults trend to the northeast, parallel to the trend of the regional geology and the transverse faults trend north to northwest, normal to the regional trend.

The folding and faulting at the Phipps Bend Nuclear Plant site are results of the same stress system which formed the major regional structures such as the Saltville and Carters Valley faults to the northwest and the Bays Mountain Synclinorium, the axis of which is to the southeast. The bedrock at the site is structurally located in the northwest limb of the synclinorium. The folds and faults in the limb are the results of flexural slip folding accompanied by drag folding in stratagraphic sequences where adjoining rock layers exhibit differences in brittleness. These concepts of folding are illustrated in Structural Geology, by M. P. Billings, 1972, 3rd ed, Prentice Hall.

The faulting in the foundation bedrock at the site occurred between the Middle Ordovician and Triassic periods (500 and 225 million years before present, respectively). No evidence has been found to indicate that these faults did not occur in the early tectonic development of Paleozoic folding and faulting in the Phipps Bend area. Fred Webb has listed indications that these faults are not capable of producing ground offsets or generating earthquakes in his report entitled "Structural Geology of Reactor Building Excavation, Phipps Bend, Tennessee," (appendix B, page 4) as follows:

1. all faults show a relationship to folds that is consistent with a drag fold-induced genesis and are, therefore, related in time to the major folds and faults of the region.

2. none of the faults extends into residuum or high-level terrace gravels adjacent to the site on the east.

3. the marked parallelism of faults and bedding indicates that the time of fault origin and folding was essentially the same. Folding must have occurred while there was sufficient thickness of overburden (measured in thousands of feet) to provide sufficiently high confining pressure for rocks to deform plastically. Were origin to have been shallow at a geologically more recent time, overburden thickness would have been too thin to generate confining stress needed for plastic deformation and the faults would exhibit marked non-parallelism with respect to bedding and structures.

After being stable for 250 million years, these faults are not considered to be capable of producing ground offsets or generating earthquakes. Therefore, the 29 faults at the Phipps Bend site are not classified as capable, as defined by appendix A to 10CFR, part 100.

APPENDIX A

THE UNIVERSITY OF NORTH CAROLINA
AT
CHAPEL HILL

Department of Geology

The University of North Carolina at Chapel Hill
Mitchell Hall 029 A
Chapel Hill, N.C. 27514

August 29, 1978

Mr. Arthur D. Soderberg II
Engineering Geologist
Geologic Services Branch, WMGT
160 Liberty Building
Knoxville, TN 37902

Dear Mr. Soderberg:

At the request of TVA I visited the Phipps Bend Nuclear Plant (Tennessee) on August 25, 1978. The purpose of my visit was to determine if the fault zones within the Sevier Shale at the reactor sites contained minerals which could be dated using standard radiometric techniques. During my inspection of the Phipps Bend site I was accompanied by TVA geologist Mr. William M. Seay.

I examined the several faults exposed in the excavations for the reactors. I also examined a selection of fault zone samples obtained during an early phase of the excavation. In all cases the only mineral found in the fault zone was calcite. It is not possible to obtain a meaningful radiometric age by analyzing calcite.

Cordially,

Paul D. Fullagar

Paul D. Fullagar
Professor

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STRUCTURAL GEOLOGY OF REACTOR BUILDING EXCAVATION

PHIPPS BEND, TENNESSEE

by

Fred Webb, Jr.

This report was compiled and written by Fred Webb, Jr. It is submitted to the Tennessee Valley Authority on May 26, 1978.

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STRUCTURAL GEOLOGY OF REACTOR BUILDING EXCAVATION
PHIPPS BEND, TENNESSEE

Introduction

The Tennessee Valley Authority's (TVA) Phipps Bend, Tennessee, nuclear reactor construction site was visited and studied on May 24, 1978. The purpose of this investigation was to examine and interpret the structural geology present at the reactor building excavation.

Regional Geologic Setting

The site lies within the Valley and Ridge geologic province which is characterized by folded and faulted sedimentary rocks of Paleozoic age. Phipps Bend lies just southeast of the Carter Valley and Saltville faults which are typical Appalachian reverse faults. The Pulaski thrust fault is located approximately 10 miles southeast of the site. The dominant fold in the area is the Bays Mountain synclinorium which has its axis four miles to the southeast of Phipps Bend.

Bedrock units in the environs of the reactor site are mostly southeast-dipping Cambrian and Ordovician carbonates and fine-grained calcareous clastic rocks which make up the northwest limb of the synclinorium. The Cambro-Ordovician carbonate succession present on the north limb and the quartzose sandstones of the Bays Formation present in the axial portion of the synclinorium lie below and above, respectively, the mostly shale and siltstone Middle Ordovician Sevier Formation which forms bedrock at the site.

The Bays Mountain synclinorium is composed of numerous smaller anticlines and synclines with common reversals of plunge direction. Most of the folds in the area are asymmetrical and more steeply dipping northwest limbs. Calcite-filled fractures are present throughout much of the bedrock in the area and most of the Southern Appalachians. There are also numerous small thrust and reverse faults present throughout the region which has, in essence, been deformed by compressive stress that acted along a northwest-southeast line. The age of deformation has been determined to be post-Middle Ordovician and pre-Triassic (Cooper, 1961; King, 1964; Swingle, 1973; Bryant and Reed, 1970; and Lowry, 1974).

Site Geology

Bedrock at the site is mapped as Middle Ordovician Sevier Formation which is composed of dark bluish-gray calcareous shale, siltstone, and very fine-grained impure sandstone. Bedding is thin to very thin and regular. Many calcite-filled fractures are present in most exposures.

Although bedrock generally strikes N.55°E. and dips 20°+ S., there are at least three west-plunging folds present. These folds have orientations that are in harmony with the much larger Bays Mountain synclinorium upon whose northwestern limb they are superimposed.

Many bedding planes in the sequence are marked by slickensided layers of white to light gray calcite that range in thickness from 1 to 20 mm. Although calcite-filled fractures are generally parallel to bedding and may be traced across fold axes where dip directions change, calcite-filled fractures oblique to bedding are also common.

Distinctive lithologies useful for tracing structures and correlation of units are rare. However, as calcite-filled fractures are so persistently confined to bedding planes, it is possible in most instances to delineate structures and correlate units over small distances (up to 140 feet) by careful tracing these fractures.

The geologic map of the site compiled by Gary Hartman, site geologist for TVA, accurately depicts the geology. Discussions in the section of this report detailing structural interpretations are referenced to the draft version of the geologic map (Figure 1).

Interpretation and Discussion of Structures

Specific structural features studied in detail at the site are numbered in sequence anticlockwise from 1 at the east to 3 at the north. Each site (Figure 1) is shown by means of structure sketches in cross section and is discussed separately.

Marked similarity in orientation between Phipps Bend folds and fractures with much larger Bays Mountain synclinorium structures is noteworthy. Classic interpretations of similar occurrences in the Appalachians and elsewhere involve deformation by predominantly flexural-slip folding with concomitant development of drag folds in stratigraphic sequences such as this where shaly rocks are sandwiched between more brittle rocks such as carbonates (the Knox Group) and sandstones (much of the Bays Formation). Figure 2 illustrates the principles of this deformation as given in a standard structural geology textbook by M. P. Billings (1972).

Note that stress in Figure 2 is more effectively transmitted in the overlying and underlying stippled units (representing the Knox and Bays formations, non-respectively) than it is in the intervening shaly unit (the Sevier) which crumples (= drag folds) during Paleozoic deformation that produced the larger folds and faults in the region. Note, too, that units tend to thin on limbs and thicken in axial areas during deformation. This relationship is also important for understanding and interpretation of the Phipps Bend structures.

Drag features of the type present at Phipps Bend have been widely recognized and reported by numerous geologists in the Southern Appalachians. Reports include those of Butts (1940), Cooper (1944, 1961, and 1971), Lowry (1971), and Swingle (1973). Reports of crumpling of shaly rocks such as the Sevier generally indicate the presence of numerous fractures, faults, and calcite-filled veins such as those present at Phipps Bend. Figure 3 shows an example of these phenomena from Virgina. The fracture cleavage shown in Figure 3 was produced by shear stress where more brittle rocks broke rather than yielding by folding as a shaly unit such as the Sevier would.

A model for interpretation of fractures which, if stress application continued after their formation, may experience movement and develop into faults, is shown in Figure 4. Note that this diagram shows both shear joints and tensional joints that develop in response to fold-producing stress. It is also important to note the rotation of joints about the crest of anticlines where shear stress has "dragged" joints that were originally inclined at 90 degrees to bedding.

Price (1966) states that not all of the joints shown in Figure 4 are always formed as conditions that produce joints are dynamic and interrelated. Consequently, early formed joints and structures not only are reoriented by later stress, but also contribute to the reorientation of stress trajectories.

For example: tensional fractures (= joints) that form normal to bedding early in the deformational sequence tend to become rotated as later shear stress is applied (Figure 4). This, as is shown below, may be important in the development of small ramp faults.

Fractures (= joints) and faults that are parallel to bedding tend to be localized in shaly units for considerable distances and break upward more or less normal to bedding for a variable thickness through somewhat more brittle layers into a higher shaly bed which they tend to follow for more distance parallel to bedding. This phenomenon produces ramping of faults, bedding plane faults, wedging, and other features described by Cloos (1964) and shown in Figure 5. Bedding plane faults are known to cover hundreds of feet as reported by Cloos (1964).

Calcite-filled fractures are ubiquitous in the Appalachians. The abundance of carbonate rocks and diagenetic processes that involve dissolution, transport, dewatering, and recrystallization of calcite in particular, are largely responsible for this mineralization. As the Sevier is rich in calcite and relatively fine grained, both the source and the site are favorable for fracture filling by calcite. Specific locations and patterns were controlled by locations and patterns of permeable and impermeable regions within the Sevier. Thus, calcite-filled fractures are limited not only by fracture and fault locations, but also by the distribution of impervious rock.

Site 1

The fault at this site (see structure sketch) is concordant with the orientation of the axial plane of the asymmetrial anticline which it cuts. Although the displacement is difficult to determine, beds on the north limb of the fold do not appear to have been moved more than a few centimeters. The fault is an example of axial plane "cleavage" developed on a mesoscopic scale. Thus, its origin is by shear stress which was produced during Paleozoic tectonism when overlying beds within the sequence were sliding upward toward the crest of the fold in a manner such as that illustrated in Figure 2. This relation of fault orientation to fold axial plane orientation is similar to that described by Swingle (1973) in calcareous siltstones of Knox County, Tennessee.

Site 2

This fault is located approximately 2 meters north of the axial plane of an asymmetrical syncline (north limb dip = 40^{o} S.). Calcite-filled fractures and fault surfaces parallel to bedding were produced by shearing of beds during folding as each bed slid upward, with respect to the bed below it, toward the crest of the adjacent anticline. This is the same principle as shown in Figure 2. Thus, there was shear stress that produced fractures that are incipient small ramp faults such as those shown in Figure 5. As additional folding and slippage along bedding planes occurred, minor displacement of bedding resulted from the shearing motion shown by the disruption of calcite-filled bedding faults truncated by the near-vertical fault here. Calcite-filled fractures of lesser size and near normal-to bedding orientation are of tensional origin. These small tension fractures were formed by the stretching of beds on the fold limb as thinning and thickening as illustrated in Figure 2 took place.

This somewhat indistinct fault extends for less than 20 feet to the east where it dies out on the excavated bedrock bench. Examination of the floor of the reactor site to the west reveals that the fault trace dies out within 15 feet of the excavation wall.

Site 3

The fault at this location is an excellent example of bedding plane faulting that locally breaks across bedding by ramping upwards through beds that are slightly more brittle (see Figure 5). As displacement of overriding beds took place as these beds moved higher toward the crest of the anticline, the space necessary to accomodate the volume change that accompanied the displacement was provided at sites where the fault broke across bedding. A series of these breaks occurred here and, as is shown in the structure sketch, enough space for accomodation of the beds was produced. Thus, a combination of shear faulting along bedding planes and shear and (or) tensional faulting normal to bedding intersect to provide and integrated network of displacement avenues and space.

Conclusions

There is no evidence that any of the faults or joints (= fractures) at the Phipps Bend reactor building site are capable faults. To the contrary, all faults and folds are compatible with the regional geologic setting and exhibit the same style and variety of features produced during the Paleozoic creation of all major Appalachian structures. Specific indications of non-capability include the following:

1) all faults show a relationship to folds that is consistent with a drag fold-induced genesis and are, therefore, related in time to the major folds and faults of the region

2) none of the faults extends into residuum or high-level terrace gravels adjacent to the site on the east

3) the marked parallelism of faults and bedding indicates that the time of fault origin and folding was essentially the same. Folding must have occurred while there was sufficient thickness of overburden (measured in thousands of feet) to provide sufficiently 'igh confining pressure for rocks to deform plastically. Were origin t' have been shallow at a geologically more recent time, overburden thickness would have been too thin to generate confining stress needed for plastic deformation and the faults would exhibit marked non-parallelism with respect to bedding and structures.

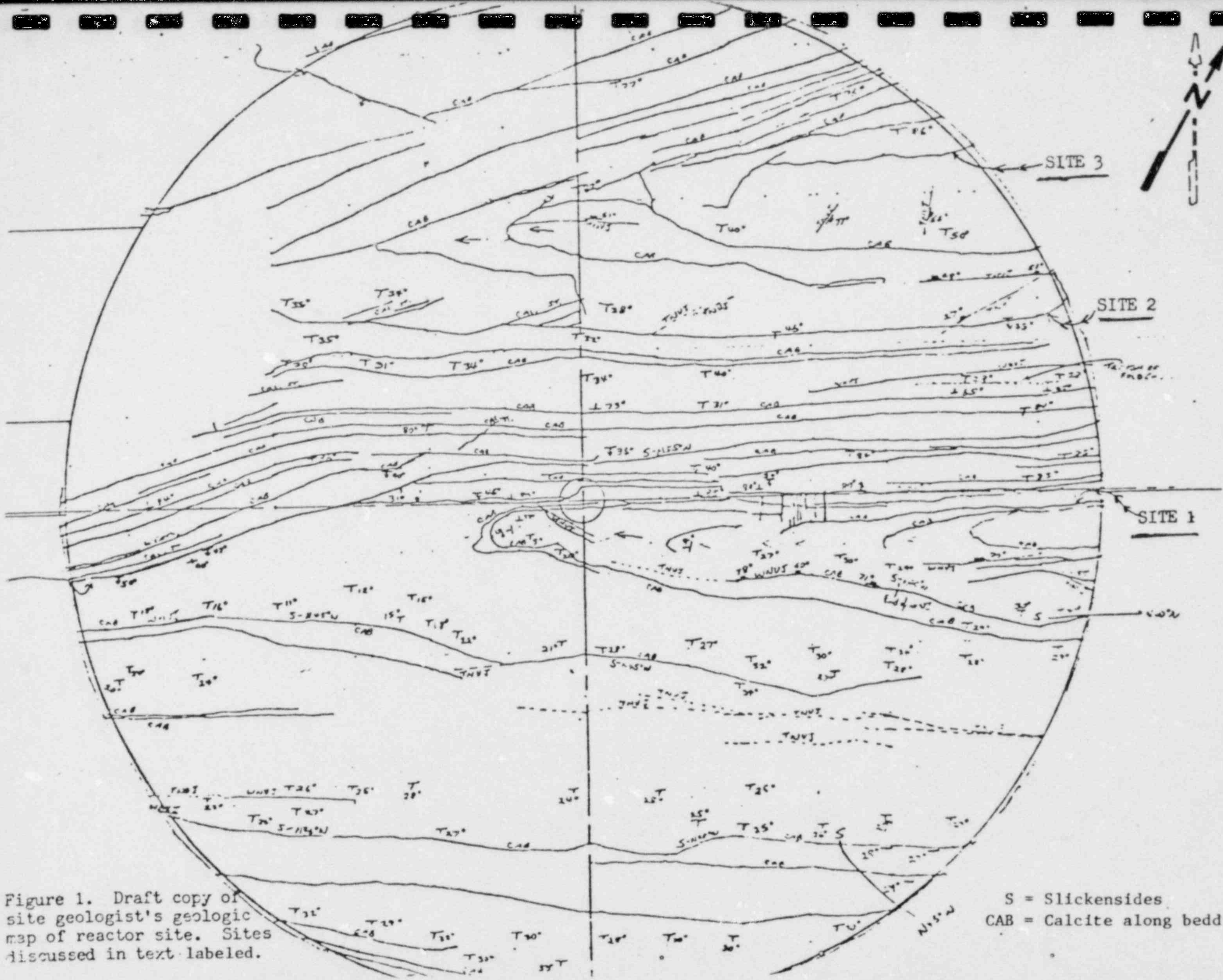


Figure 1. Draft copy of site geologist's geologic map of reactor site. Sites discussed in text labeled.

S = Slickensides
CAB = Calcite along bedding

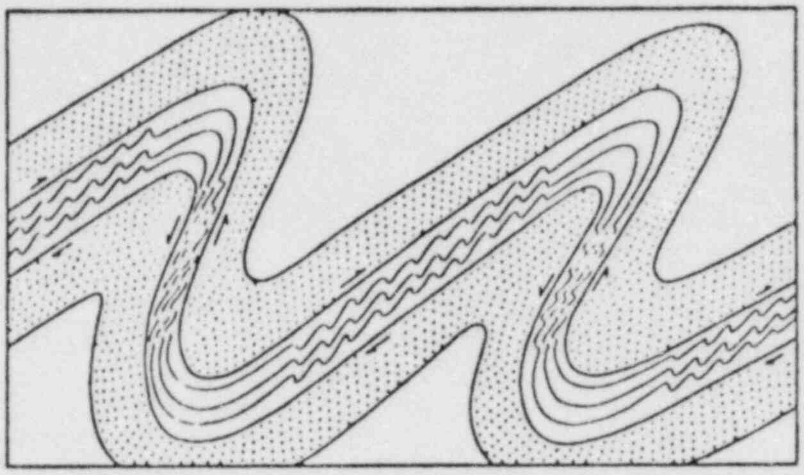


Figure 2. Structure section of overturned folds showing relation of drag folds and direction of shearing. (from Billings, 1972) Note that orientation of folds at Phipps Bend would be obtained with north on right of this diagram.

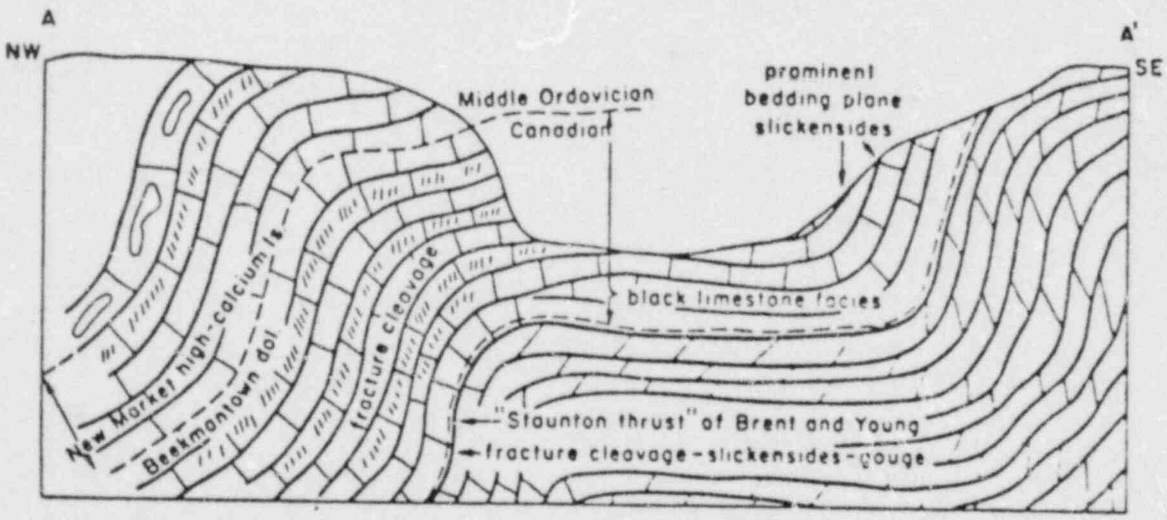


Figure 3. Cross section of Betts Quarry near Harrisonburg, Virginia, showing typical occurrences of shear fracture cleavage and slickensides associated with folding and faulting. From W. D. Lowry, 1971.

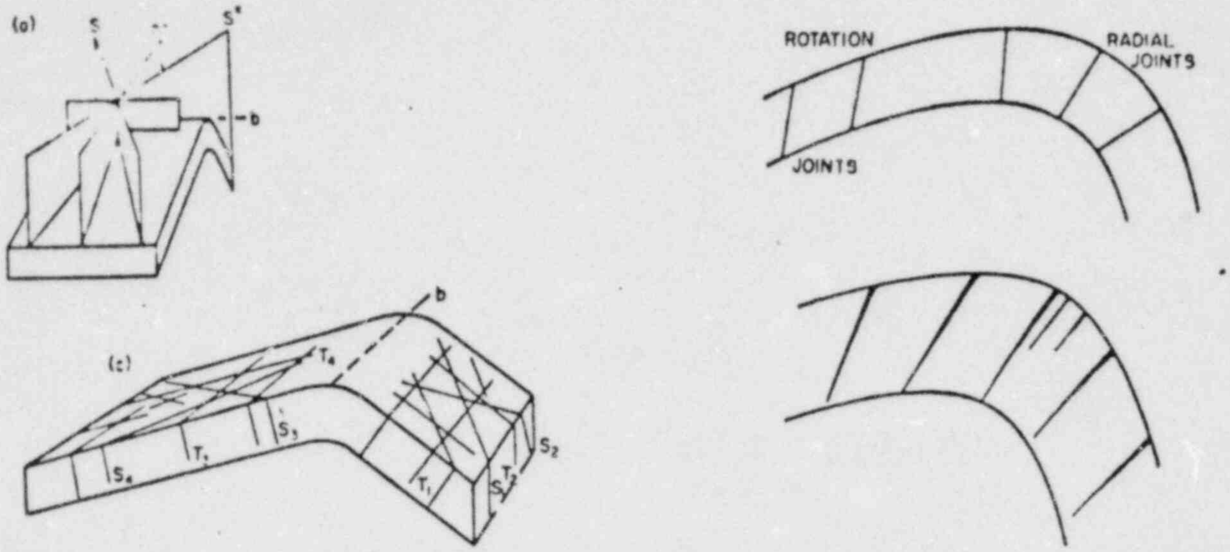


Figure 4. Relation of joint patterns to bedding in folded rocks (Price, 1966). Diagrams at left show 3-D view of shear joints (labelled S_1, S', etc.) and tension joints (labelled T_1, T_2, etc.). The diagrams at the right show radial joints and rotation joints (labelled at top), and axial plane joints filled by mineral deposits (lower diagram).

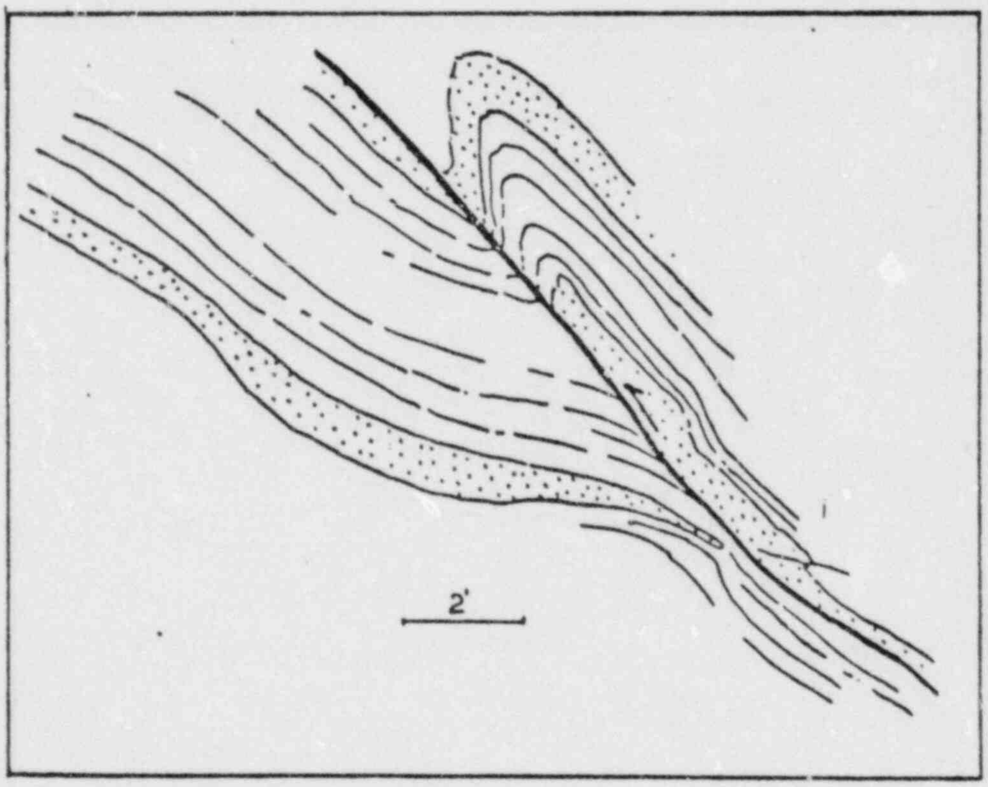
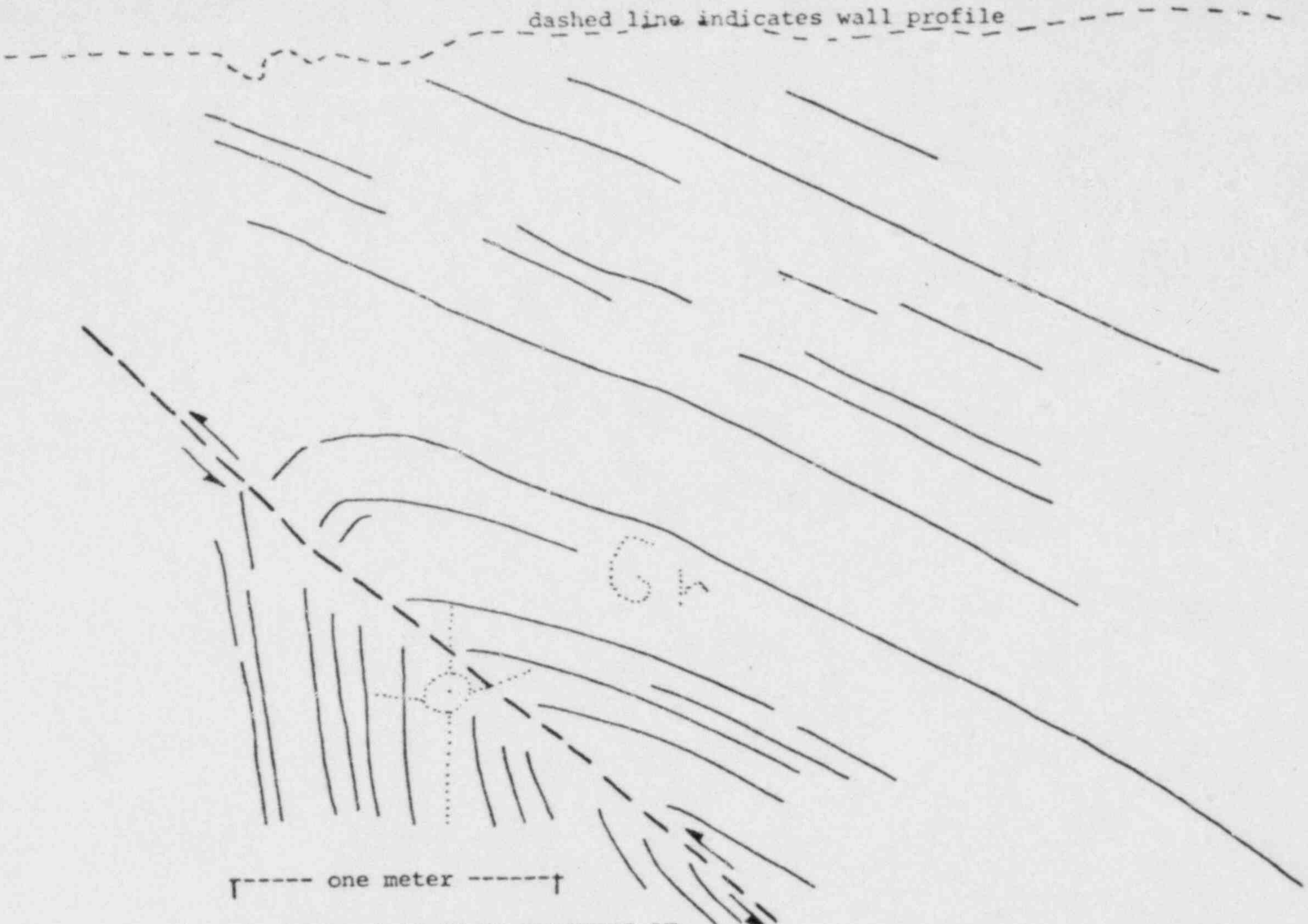


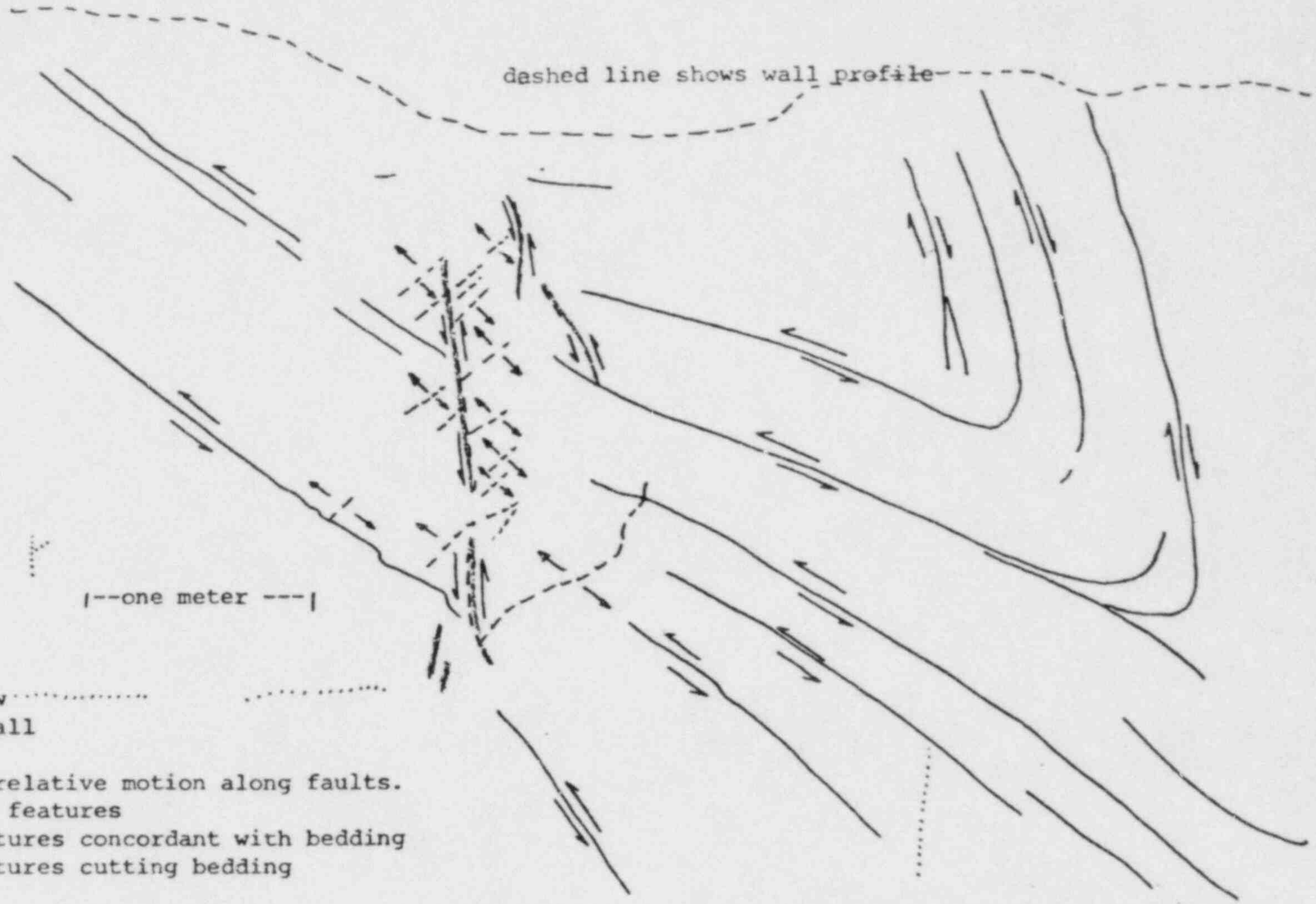
Figure 5. Wedge and fold. Lower sandstone is wedged; upper sandstone, only folded. Wedge may have formed prior to folding because the order of magnitude is different. Road cut east of Hancock, Maryland, Catskill. From Cloos, 1964

Note the migration of the bedding plane fault across overlying bed by ramping.



STRUCTURE SKETCH OF MAJOR FEATURES AT
SITE 1. View toward northeast. Arrows indicate relative motion of fault. Dotted lines indicate painted markings of rocks. Most of beds shown are marked by slickensided calcite-filled layers.

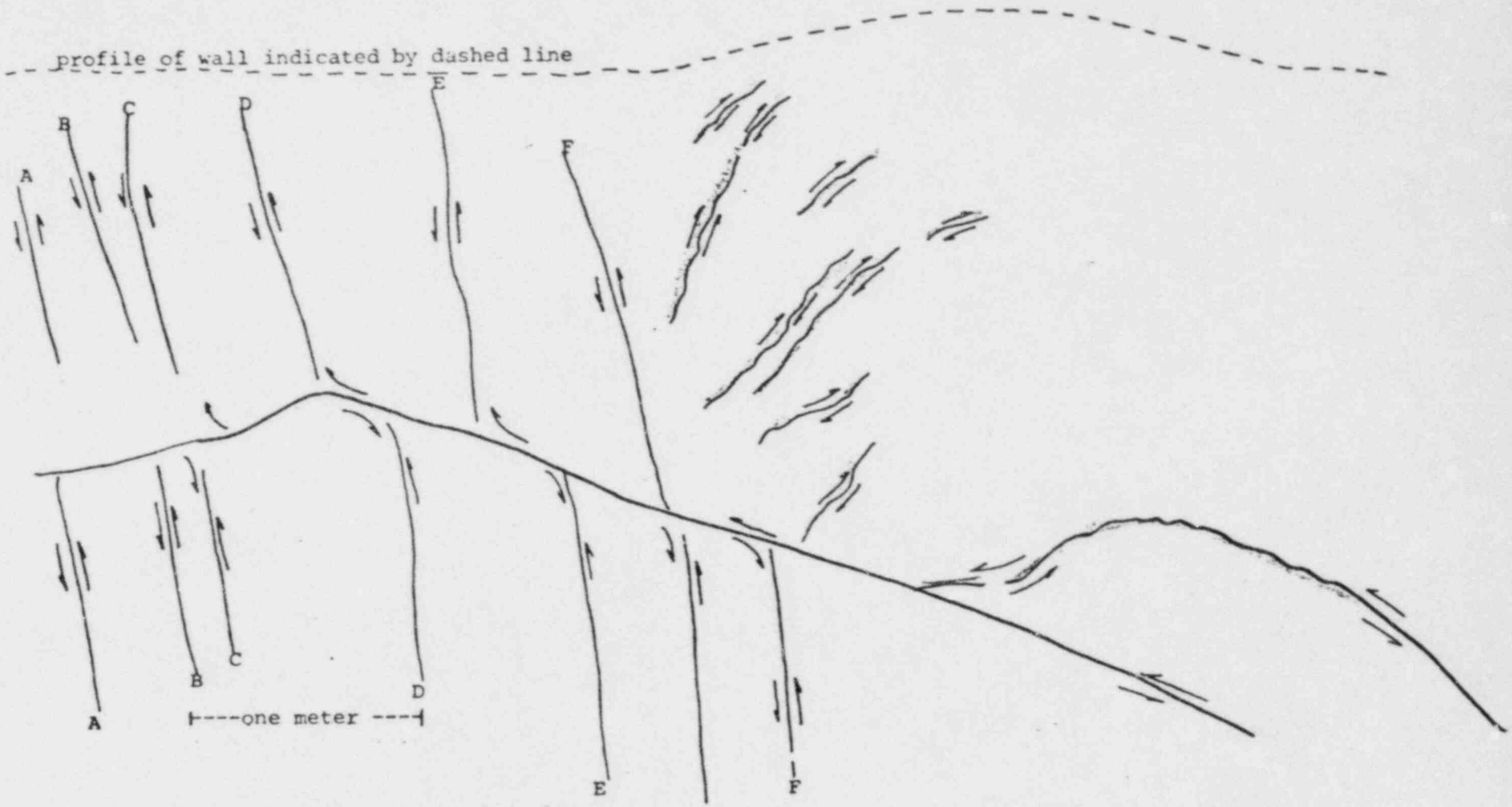
STRUCTURE SKETCH OF MAJOR FEATURES AT SITE 2.
View is toward the northeast



dotted lines show
paint marks on wall

Arrows indicate relative motion along faults.
= tensional features
= shear features concordant with bedding
= shear features cutting bedding

STRUCTURE SKETCH SHOWING MAJOR FEATURES AT SITE 3. View toward the northeast.



Arrows indicate relative motion of faults.
Letters show correlations of bedding plane calcite-filled fractures.
Note how displacement along fault marked in red ( ) decreases toward the north where its displacement is translated into bedding plane motion by ramping upward into bedding plane faults labelled A - F. Faults shown in green (—) are folded or tilted by drag effect associated with the anticline present here.

REFERENCES CITED

Billings, M. P., 1972, Structural Geology, 3rd ed, 606 p., Prentice Hall.

Butts, Charles, 1940, Geology of the Appalachian Valley in Virginia, Bull. 52, pt. 1, Virginia Geological Survey.

Bryant, B., and Reed, J. C., 1970, Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee, U. S. Geol. Survey Prof. Paper 615.

Cooper, B. N., 1944, Geology and mineral resources of the Burkes Garden quadrangle, Va. Geol. Survey Bull. 60.

Cooper, B. N., 1961, Grand Appalachian Excursion, Va. Polytechnic Inst. guidebook no. 1, VPI Engnr. Extension Series, 187 p.

Cooper, B. N., 1971, Appalachian structural and topographic front between Narrows and Beckley, Virginia and West Virginia, Va. Poly. Inst. and State Univ., Dept. of Geol. Sci. Guidebook no. 5, p. 91 - 142.

King, P. B., 1964, Further thoughts on tectonic framework of the southeastern United States, in Lowry, W. D., ed., Tectonics of the Southern Appalachians, VPI Dept. of Geol. Sci. Memoir 1, p. 5 - 32.

Cloos, Ernst, 1964, Wedging, bedding plane slips, and gravity tectonics in the Appalachains, p. 63 - 70, in Lowry, W. D., ed., Tectonics of the Southern Appalachians, VPI Dept. of Geol. Sci. Memoir 1.

Lowry, W. D., 1971, Appalachian overthrust belt, Montgomery County, Virginia, p. 143 - 178, in Guidebook to Appalachian tectonics and sulfide mineralization of southwestern Virginia, Guidebook no. 5, VPI and SU Dept. of Geol. Sciences.

Lowry, W. D., 1974, North American geosynclines - test of continental-drift theory, Bull. American Assoc. Petroleum Geol., v. 58, n. 4, p. 575 - 620.

Price, N. J., 1966, Fault and joint development in brittle and semi-brittle rock, 176 p., Commonwealth and international library of Pergamon Press, London.

Swingle, G. D., 1973, Structural geology of Knox County, Tennessee, p. 63 - 73, in Geology of Knox County, Tennessee, Bull. 70, Tenn. Div. of Geol.

APPENDIX C

STRUCTURAL GEOLOGY OF SEVIER FORMATION FOLDS AND FAULTS AT PHIPPS BEND NUCLEAR PLANT SITE

Report Submitted to the Tennessee Valley Authority

by

Fred Webb, Jr.

Date submitted by Fred Webb, Jr., PH. D., Geology: May 16, 1979

Fred Webb, Jr.

Fred Webb, Jr.

STRUCTURAL GEOLOGY OF SEVIER FORMATION FOLDS AND FAULTS AT PHIPPS BEND NUCLEAR PLANT SITE

Folds and faults at the CCW Pump Station and Turbine Building 2 sites have developed in response to the same stress system that formed the larger regional structures which include the Saltville Fault to the north and the Bays Mountain Synclinorium to the south. The stress system that produced the structures here and elsewhere in the Southern Appalachians is best described as a dominantly compressive stress that was directed along a northwest-southeast line. The minimum stress axis was approximately vertical whereas the intermediate stress axis was oriented approximately N. 45^{o} E. Fig. 1 illustrates the general relationship of the stress axes to the structural features in the area of the Plant and the Southern Appalachians.

Although the entire sequence of rocks at the sites are classed and mapped as the Sevier Formation, rock types present consist of somewhat non-uniform alternating layers of shale, siltstone, and very fine-grained sandstone. Interbedding of these three lithologies is an important factor in the study of the mechanics of deformation because changes in rock type modify stress distribution and structural behaviour (see Whitten, 1966, p. 211, for example).

The principal mechanism of deformation at the sites is best described as flexural slip (= flexure) folding as described by Ragan (1973), Spencer (1969), Billings (1972), and Whitten (1966). Folds produced by flexure are described as having concentric (= parallel) geometry. Although there are some indicators such as fractures and other planar structures oriented approximately parallel to axial planes of folds, of similar folds at the site, most structures are more closely approximated by the flexural slip origin.

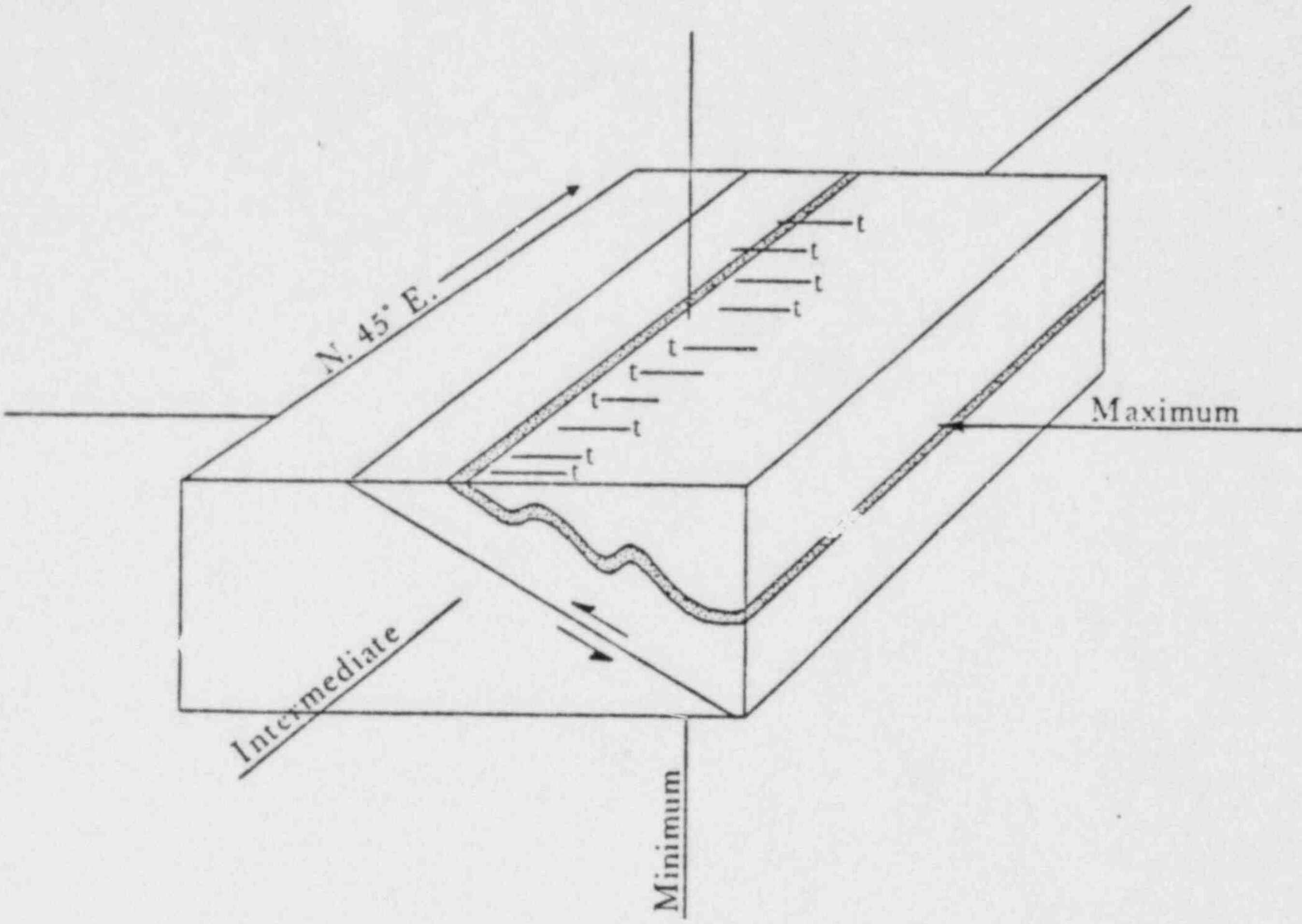


Figure 1. Orientation of stress axes compatible with structural features present in the Phipps Bend, Tennessee, area. Faults and folds are shown diagrammatically. Symbols: t = tensional fractures, arrows show relative motion of fault blocks, and axes are labelled. Modified isometric base distorts right-angle relations.

Characteristics of concentric folds generally include maintenance of both uniform bedding thickness across folds and constant bed length in portions of individual folds (spencer, 1969; Ragan, 1973). During flexural slip deformation, individual beds in the sedimentary sequence are displaced by parallel slip or shear along bedding planes as each layer in the pile shifts upward relative to its underlying neighbor. A commonly cited example of this process is the flexing or bending of a stack of computer cards.

Where well-bedded lithologies are subjected to compressive stresses that exceed the elastic limit of the rocks, stress is accomodated by a combination of methods that include folding, some thickening and thinning, fracturing, and faulting. Gray (1979) describes these strain-accomodation structures in the southwestern Virginia area. The development of strain-accomodation structures results from the movement of incompetent material into potential hinge spaces of folds, development of limb thrust faults, shearing off of beds, and partial hinge collapse (Gray, 1979).

As sandier beds in the sequence are more competent to transmit stress than are the finer-grained shales, the shales are generally transected by more shear fractures that tend to be oriented at acute angles to bedding. Fractures in sandier beds tend to be oriented at nearly right angles to bedding. Thus, the bedding-to-fracture relationship illustrated in Fig. 2 is common.

The tendency for fracture planes to be refracted where passing from beds of differing competencies leads to the development of imbricated limb thrust faults which have curved slip surfaces and stratigraphically variable displacements. Plate 1 illustrates the type of imbrication and variable stratigraphic displacement which are characteristic of the Appalachian region and the CCW Pump Station site. Typical crumpling and faulting that occur as a consequence of partial hinge failure are also shown in Plate 1.

Fig. 1 shows fractures of a tensional origin oriented along northwest-southeast lines. Structures at both sites where tensional origin is probable include calcite-filled gashes and lateral faults of small displacement (such as located at the Turbine Building 2 site). Inasmuch as these features developed during folding and associated thrust faulting, the tensional fractures are locally offset and folded. In other instances, however, tension fractures offset bedding, thrust faults, and folds.

Bedrock at the Plant contains calcite cement and rare beds of limestone. Thus, abundant white, coarsely crystalline calcite is present in most joints, and along bedding planes and faults. This secondary calcite was deposited in these locations by pore water redeposition following dissolution from cement and movement to the present locations. Calcite deposits with slickensides are often indicators of relative directions of movement along faults (Spencer, 1969). Slickensides along bedding or on fractures cutting across bedding indicate that the surfaces on which they are located were active boundaries duirng folding.

The sense of motion provided by slickensides is valid for only the last motion along discontinuity surfaces. Thus, interpretation of slickensides must be done with caution for minor last movement of but a fraction of an inch might mask or obliterate more extensive earlier movement in an opposite direction. Hobbs, Means, and Williams

(1976, p. 303-305) discuss the erasing and overprinting of slickensides. At the CCW Pump Station site, however, most directions of motion indicated by slickensides are compatible with those shown in Fig. 2.

Folds at the sites developed as drag folds such as those shown by Spencer (1969, p. 189 and 201), and discussed by Gray (1979). Continued application of stress produced asymmetrical folds with vertical to locally overturned beds. Consequently, bedding plane and oblique-shear slip surfaces located at vertical to overturned bedding sites show vertical to southward steeply dipping faults as shown in Plate 2.

Thus, south-dipping faults that have apparent normal displacement (as defined by Billings, 1972) are compatible with the regional structural pattern that developed prior to and contemporaneously with the Saltville fault. Complexity of structure is compounded by the general lack of unique marker beds for determination of stratigraphic displacement. Variable angles of fold plunge toward the southwest also complicates structural interpretation through creation of curving outcrop patterns of fault traces and bedding. Fold plunge also creates structural highs and lows over which beds and folds have been displaced with a component of rotational motion. Thus, individual fault displacements are non-uniform with respect to beds and structures that are transected.

In summary, there are no indications of structural features of an origin later than the Saltville fault at the Plant. All folds and faults conform to regional tectonic patterns of Late Paleozoic age.

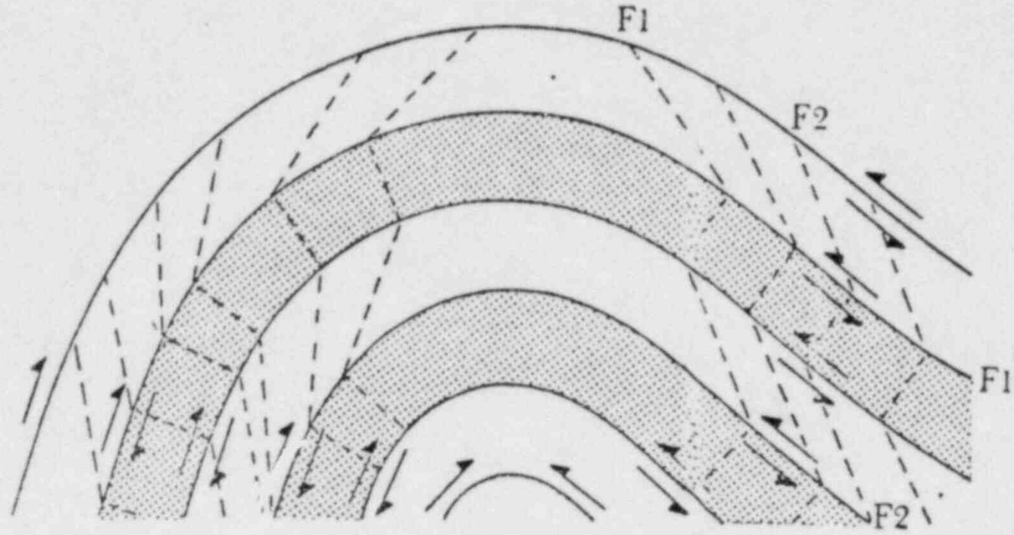


Figure 2. Typical orientation, generalized, of fractures in interbedded shales and more competent sandy units. Arrows show relative movement directions along bedding planes during flexure folding; dashed lines, F1 and F2, show two examples of possible thrust fault trajectories. Stippled pattern shows sandy units; other units not marked are shaly beds.

Explanatory Text for Plates 1 and 2

Plate 1 shows three stages in the evolution of faults and folding such as are present at the sites. Chronological order is indicated by numbers 1 - 3 (oldest to youngest). Eventual lines of faulting are shown by dashed lines. Faults are labelled FF and F'. Beds are labelled 1 - 5 for purposes of showing displacement along faults. Note that as folding becomes progressively tighter, bedding plane thrust becomes imbricate as fault F' forms. Arrows show relative motions along faults. Note that bed 2 in the sequence on the hanging wall block is in apparent conformable sequence with respect to bed 1 of the footwall block in places where the bedding plane thrust occurs. However, the imbricate block in stage 3 has considerably more structural discordance across the fault.

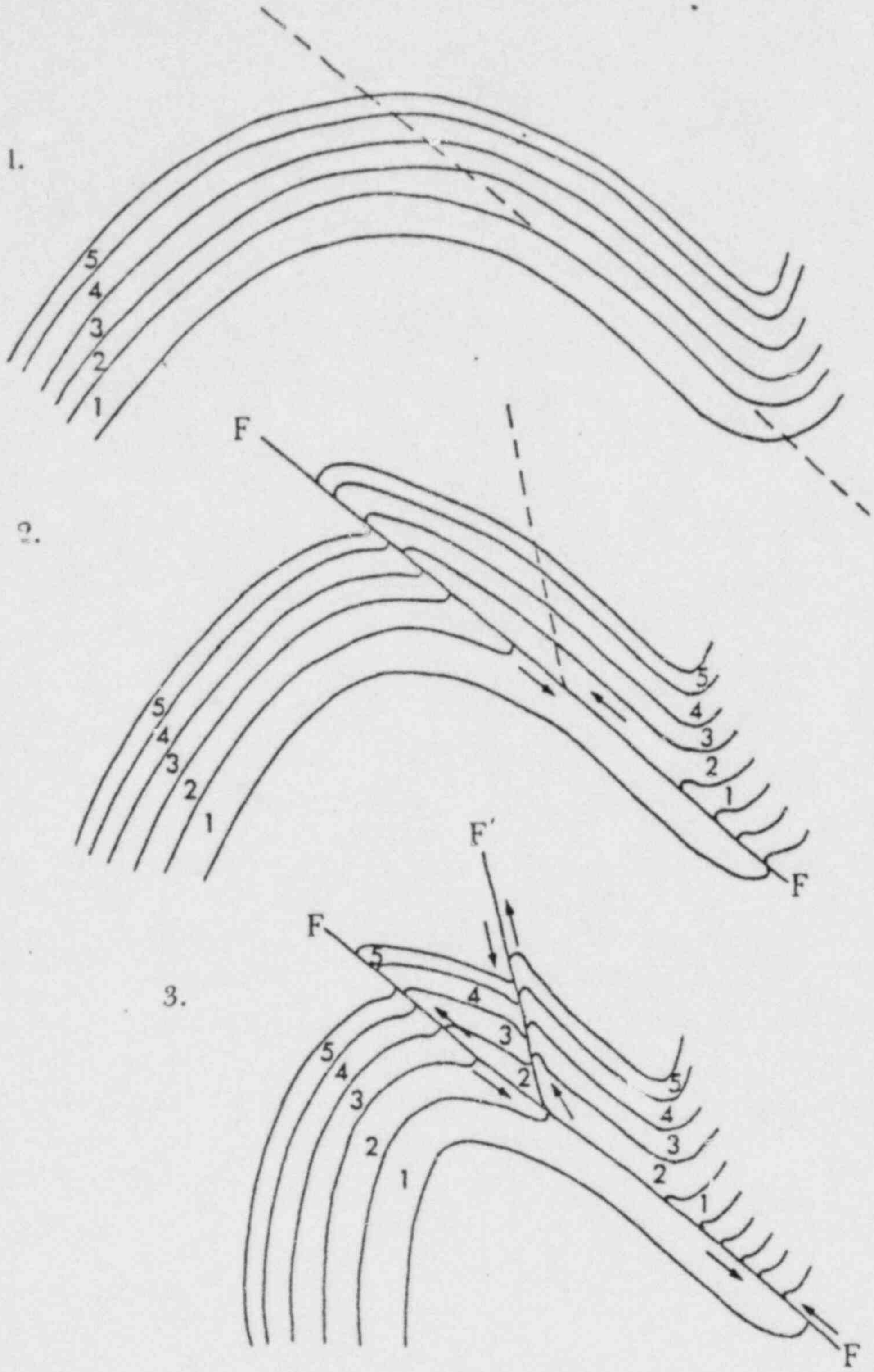


Plate 1. Development stages in formation of imbrication and variable stratigraphic displacement characteristic of the Phipps Bend area. Note crumpling and faulting that occur as partial hinge collapse occurs. FF and F' show faults; arrows indicate movement directions.

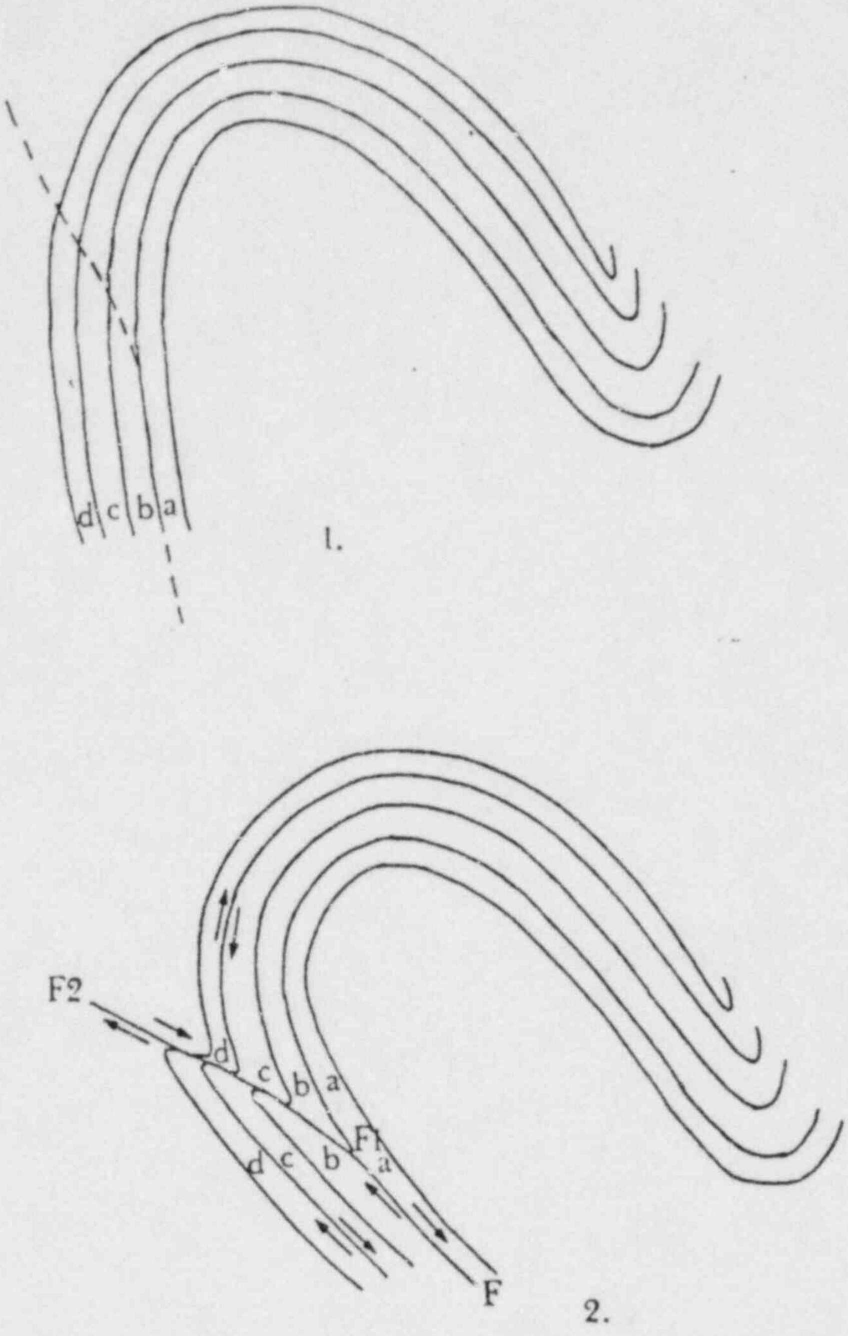


Plate 2. Orientation of oblique-shear and bedding-plane slip surfaces associated with development of strong asymmetry of folds. Top sketch, numbered 1, is initial stage while number 2 sketch is later faulted stage. Note that from F to F1 fault is overturned thrust parallel to bedding and that from F1 to F2 the fault is oblique to bedding. Letters a - d on beds are for matching purposes.

Plate 2 illustrates an initial and final stage in the development of overturned bedding-plane and oblique-shear thrust faults that have an apparent "normal" sense of motion. Note that as the fold becomes tighter the fault labelled F-F1-F2 develops along the line shown as a dashed line in sketch 1. The displacement along the fault progressively becomes more pronounced as the fault becomes oblique to bedding between F1 and F2.

References

Billings, M. P., 1972, Structural Geology, 3rd ed., 606 pp., Englewood Cliffs: Prentice Hall.

Hobbs, B. E., Means, W. D., and Williams, P. F., 1976, An Outline of Structural Geology, 571 pp., New York: Wiley.

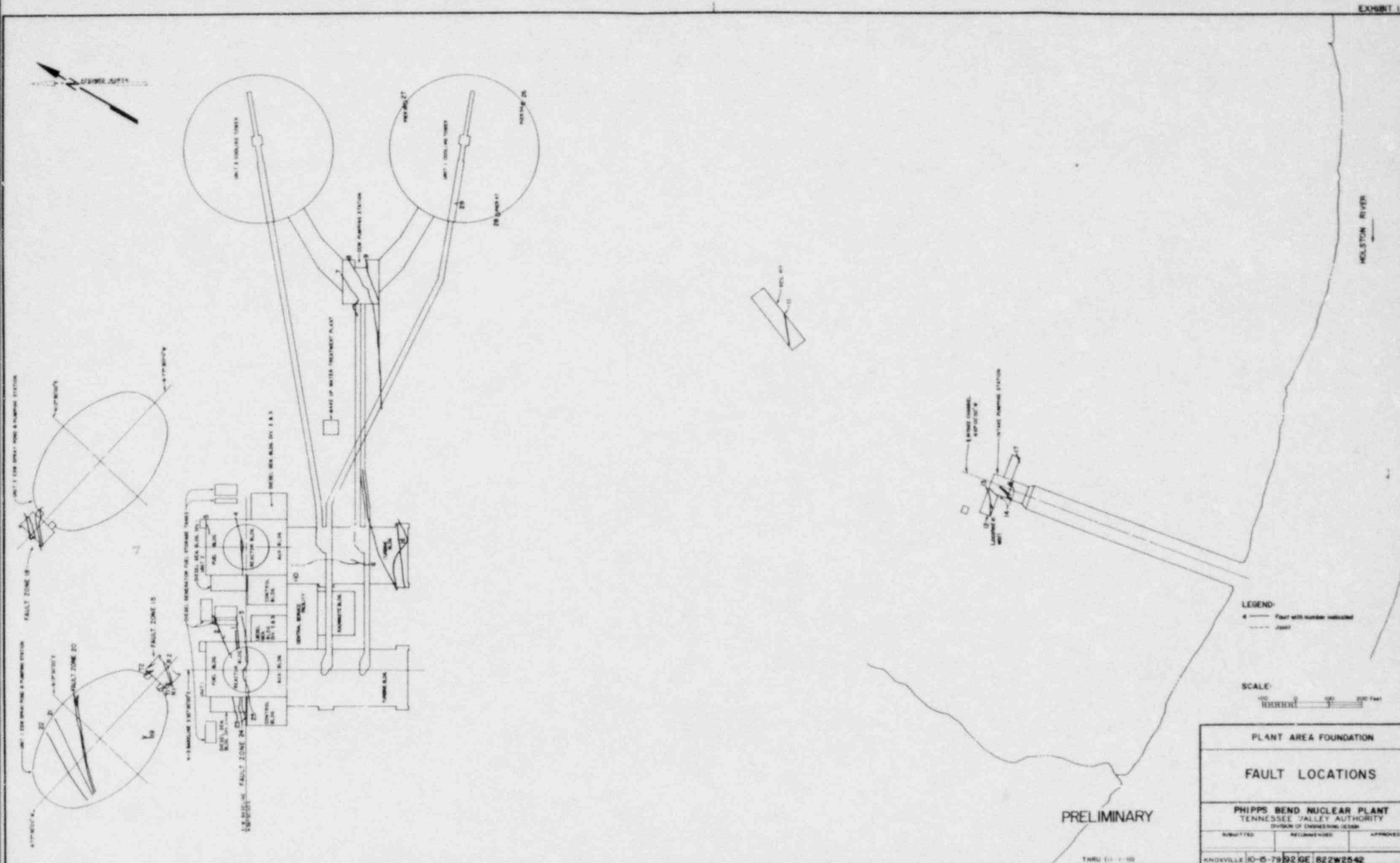
Ragan, Donal M., 1973, Structural Geology, 2nd ed., 208 pp., New York: Wiley.

Spencer, Edgar W., 1969, Introduction to the Structure of the Earth, 597 pp., New York: McGraw-Hill.

Whitten, E. H. T., 1966, Structural Geology of Folded Rocks, 663 pp., Chicago: Rand McNally.

Gray, Donald, 1979, Strain-Accomodation Structures in the Hinge Zone of Layer-Parallel Slip Folds near Goodwins Ferry, Virginia (abstract), p. 180, in Abstracts with Program,Southeastern Section of the Geological Society of America Meeting. Boulder, Colorado.

EXHIBIT I


HOLSTON RIVER
LEGEND:
Fault with number indicated
Joint
SCALE:
PRELIMINARY
PLANT AREA FOUNDATION
FAULT LOCATIONS
PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE 10-15-79 92 GE 822W2542
FAULT ZONE 18
FAULT ZONE 15
FAULT ZONE 20
FAULT ZONE 24
MAKE UP WATER TREATMENT PLANT
INTAKE PUMPING STATION

NOTE:
1. For legend see dwg. no. 92 GE 822W2513

PRELIMINARY

POWERHOUSE FOUNDATION

PLAN VIEW GEOLOGIC MAP

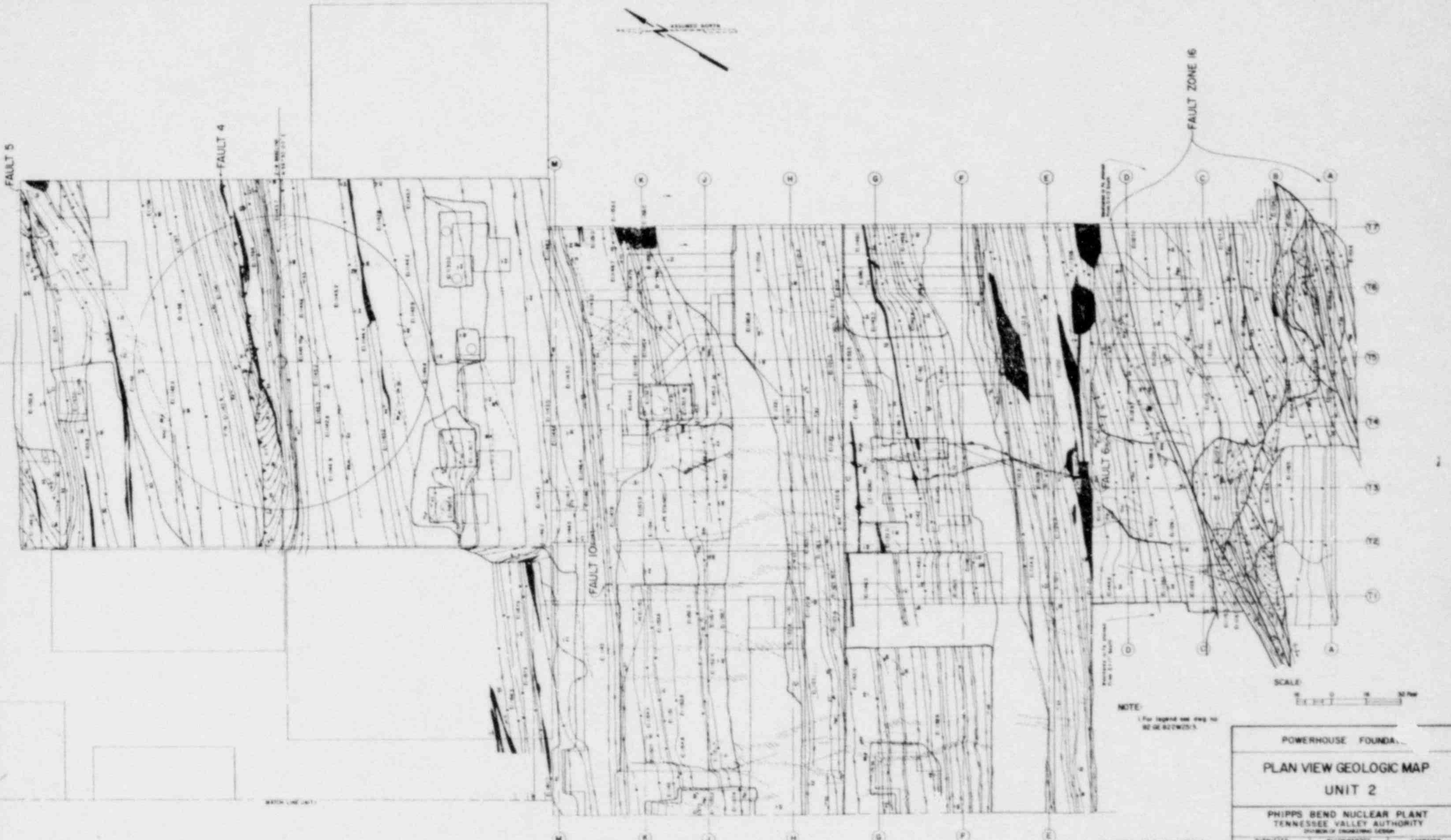
UNIT 1

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE | 92 | GE | 822W2512

EXHIBIT 3

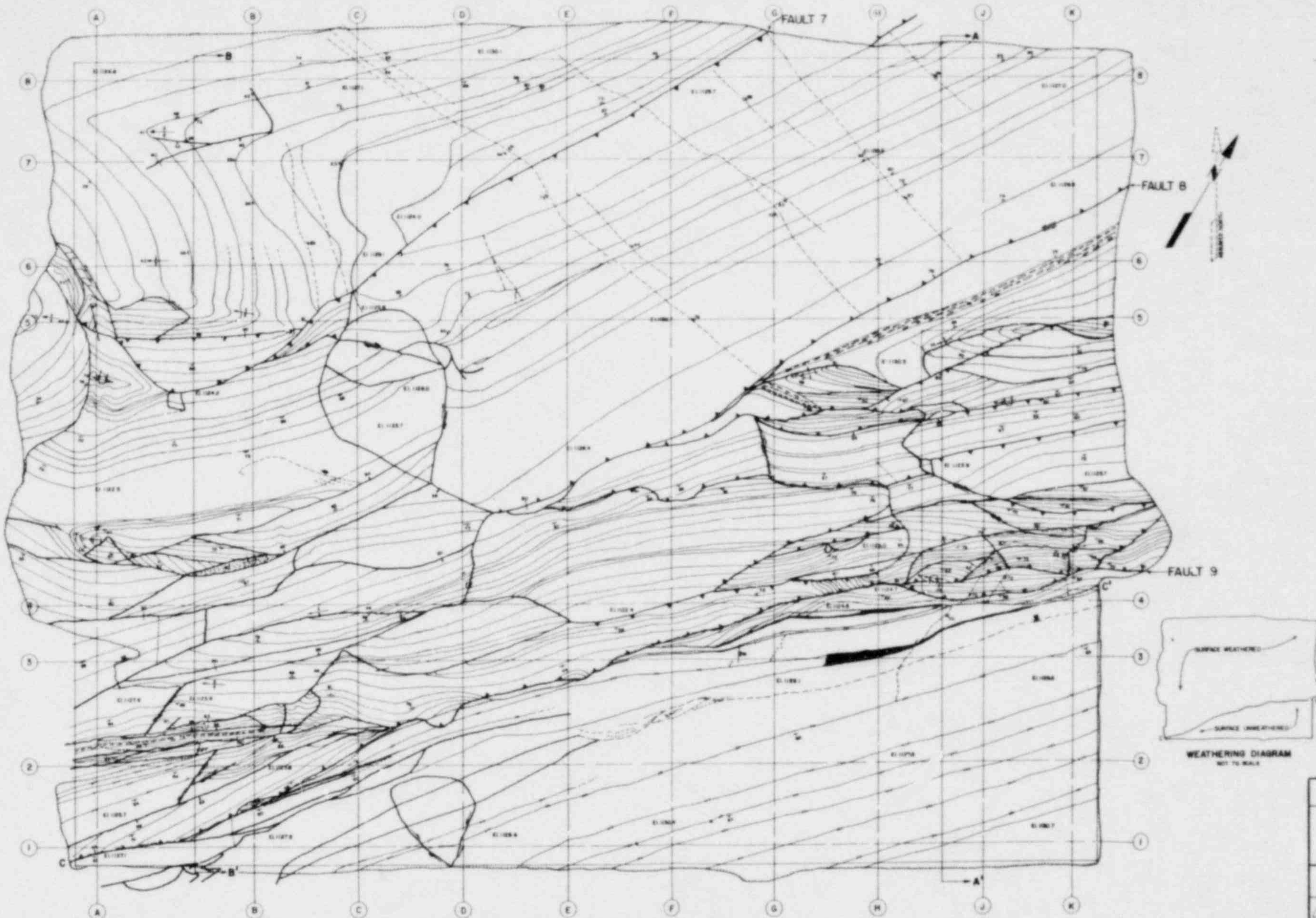


NOTE:
1 For legend see dwg no 92 GE 822W25 1

PRELIMINARY

POWERHOUSE FOUNDA...			
PLAN VIEW GEOLOGIC MAP UNIT 2			
PHIPPS BEND NUCLEAR PLANT TENNESSEE VALLEY AUTHORITY			
SUBMITTED	RECOMMENDED	APPROVED	
KNOXVILLE		92 GE	822W25 1

EXHIBIT



LEGEND:

- Calcite along bedding plane. Zone adjacent; W's indicates weathering along bedding plane
- Weathering along bedding plane
- Dip of bedding plane
- Vertical bedding plane
- Fault - sawteeth on apparent upthrown side as determined from slickensides and other field relationships. Arrows indicate direction of lateral movement
- Dip of fault plane
- Vertical fault plane
- Axis of synclinal fold showing plunge
- Axis of anticlinal fold showing plunge
- Axis of overturned anticlinal fold showing plunge
- Axis of overturned synclinal fold showing plunge
- Weathered joint with dip indicated
- Vertical joint plane
- Change in elevation of rock surface. Hachures on low side
- Weathered zone
- Limestone nodules
- Tight or calcite healed joint with dip indicated
- Horizontal joint plane

NOTE:

1. For companion drawing see dwg no. 92 GE 822K2514

SCALE:

5 0 5 10 Feet

CCW PUMPING STATION FOUNDATION

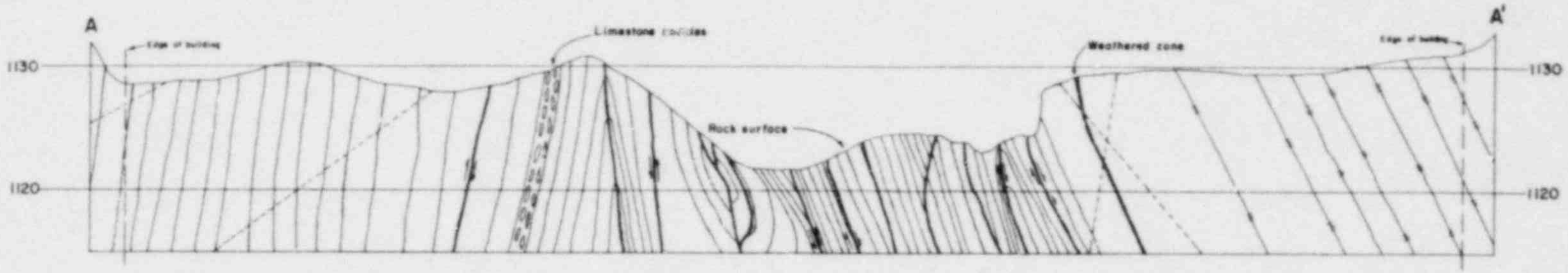
PLAN VIEW
GEOLOGIC MAP

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

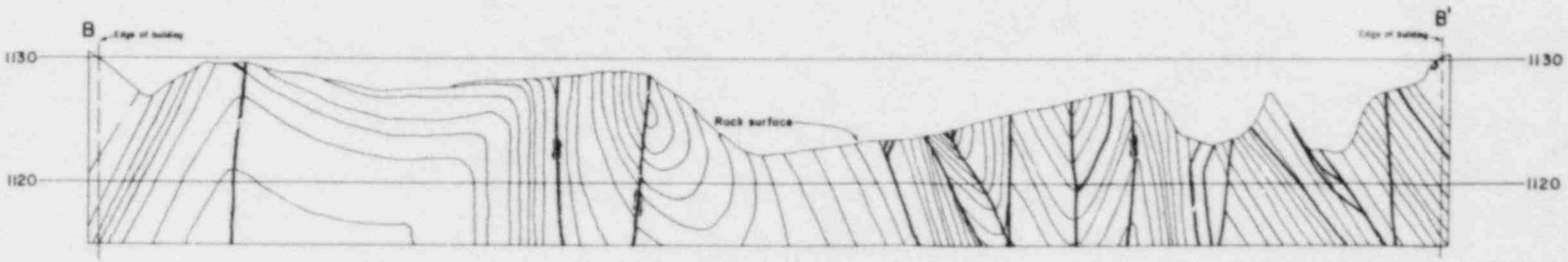
SUBMITTED	RECOMMENDED	APPROVED
A. P. [illegible]	A. G. [illegible]	[illegible]

KNOXVILLE	4-17-79	92	GE	822W2513

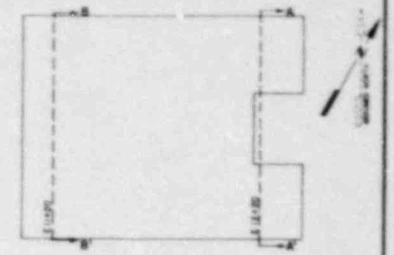
Exhibit 5



SECTION A-A'
VIEW EAST



SECTION B-B'
VIEW EAST



KEY PLAN
NOT TO SCALE

NOTES:

1. For legend and companion drawing see dwg. no. 92 GE 822W2513
2. Geologic sections developed from surface geology

SCALE:

5 0 5 10 Feet

CCW PUMPING STATION FOUNDATION

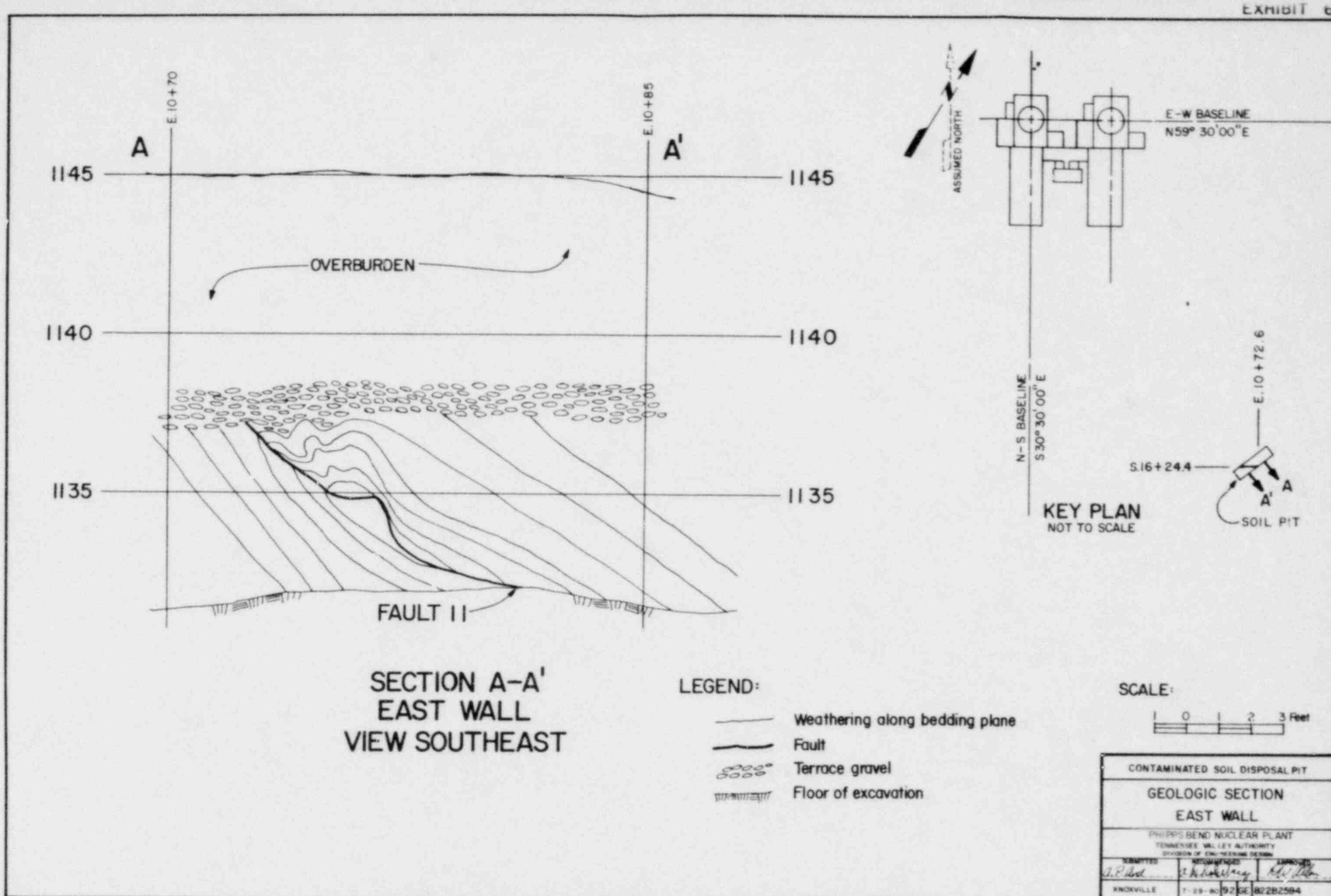
GEOLOGIC SECTIONS
CCW PUMPING STATION

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED
A. P. Bell	R. D. Soderberg	[illegible]

KNOXVILLE 4-19-79 92 GE 822K2514

EXHIBIT 6


A
A'
E.10+70
E.10+85
1145
1145
1140
1140
1135
1135
OVERBURDEN
FAULT 11
ASSUMED NORTH
E-W BASELINE
N59° 30'00"E
N-S BASELINE
S30° 30'00"E
E.10+72.6
S.16+24.4
A
A'
SOIL PIT
KEY PLAN
NOT TO SCALE
SECTION A-A'
EAST WALL
VIEW SOUTHEAST
LEGEND:
Weathering along bedding plane
Fault
Terrace gravel
Floor of excavation
SCALE:
1 0 1 2 3 Feet
CONTAMINATED SOIL DISPOSAL PIT
GEOLOGIC SECTION
EAST WALL
PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
KNOXVILLE
7-29-80
92
GE
82282594

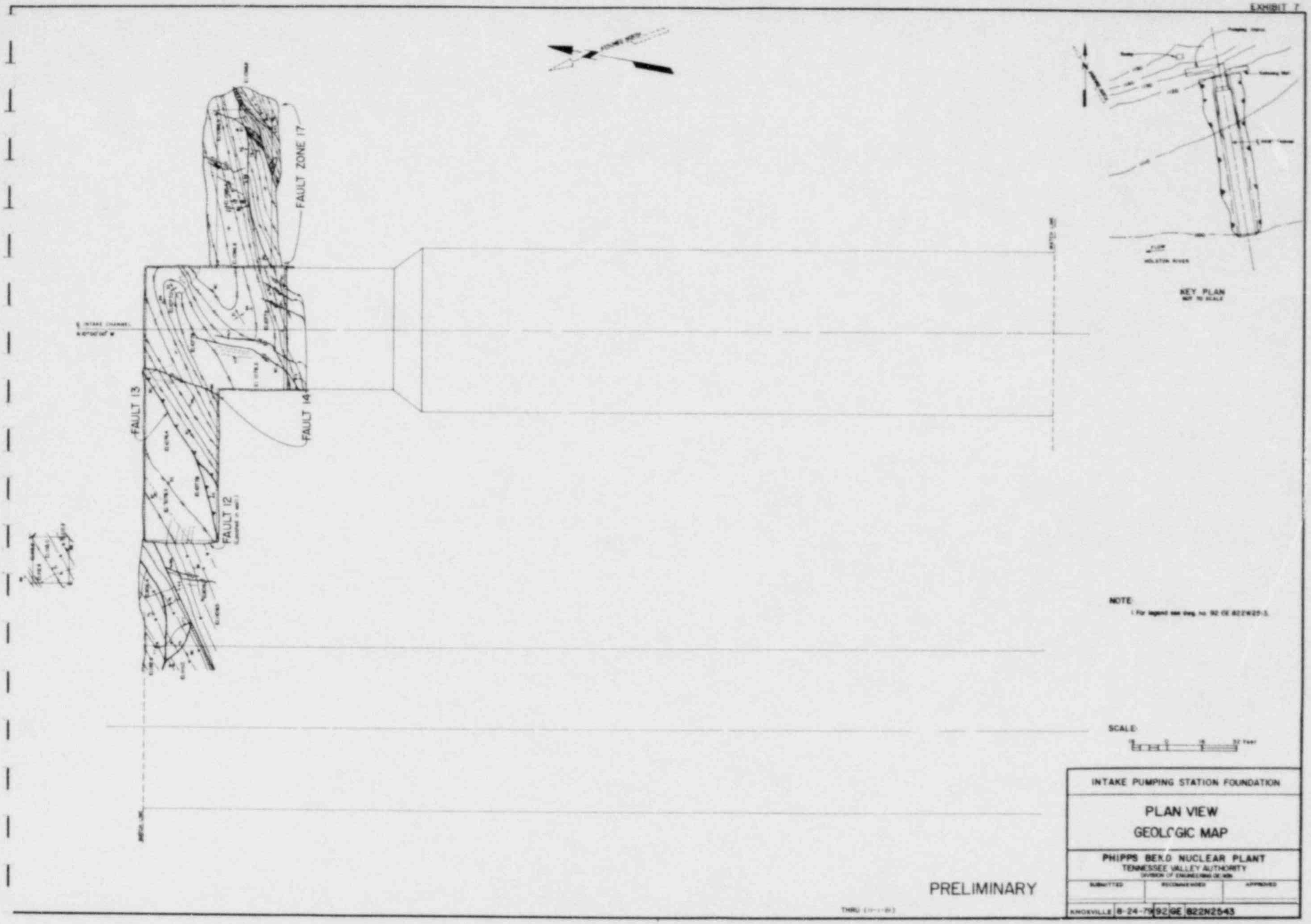
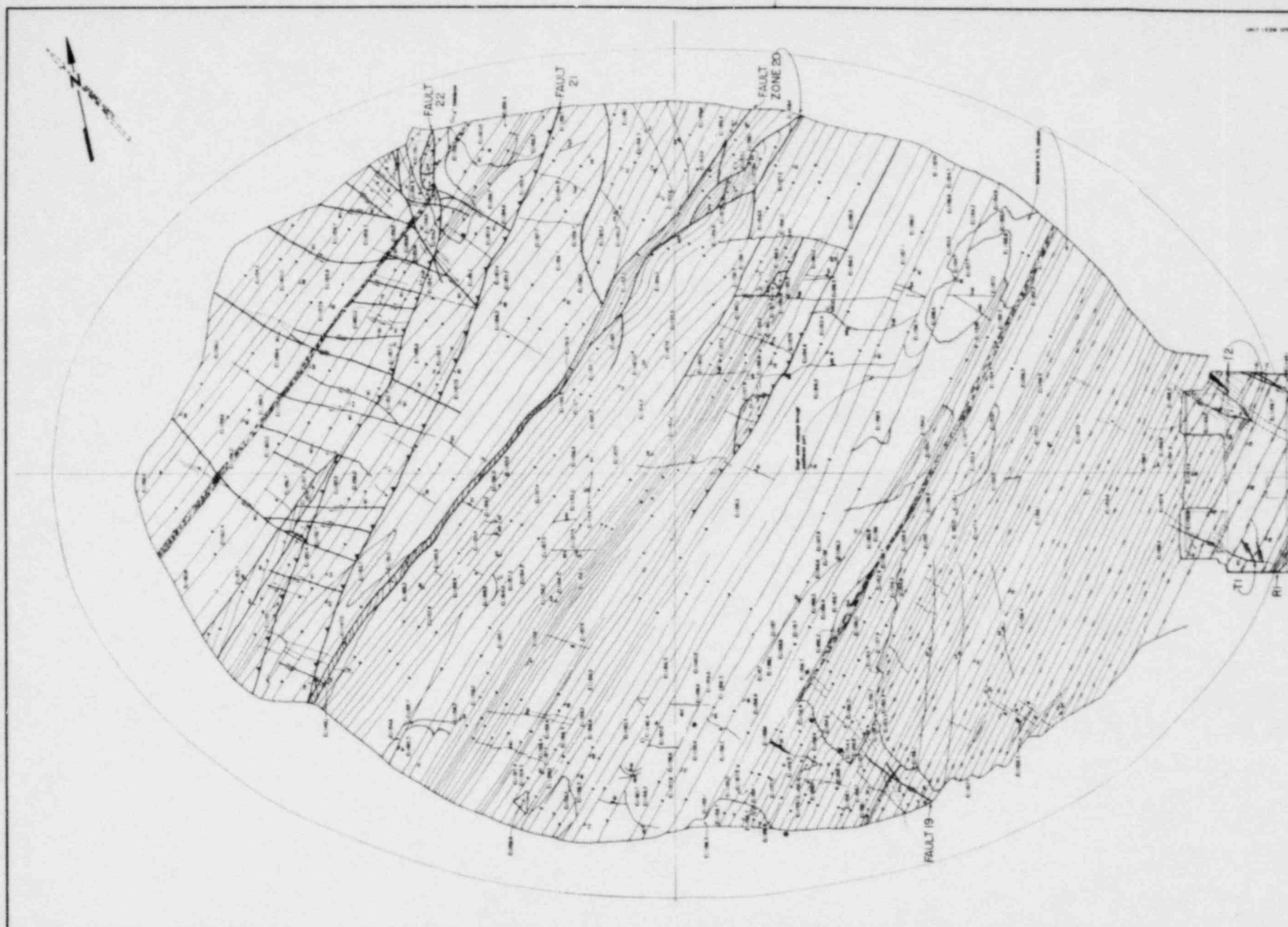
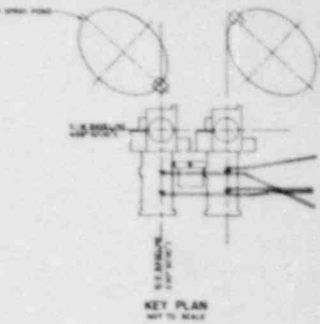


EXHIBIT 7
FAULT ZONE 17
FAULT 14
FAULT 13
FAULT 12
KEY PLAN
NOT TO SCALE
HOLSTON RIVER
NOTE:
SCALE:
INTAKE PUMPING STATION FOUNDATION
PLAN VIEW
GEOLOGIC MAP
PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE 8-24-79 92 GE 822N2543
PRELIMINARY

EXHIBIT 8





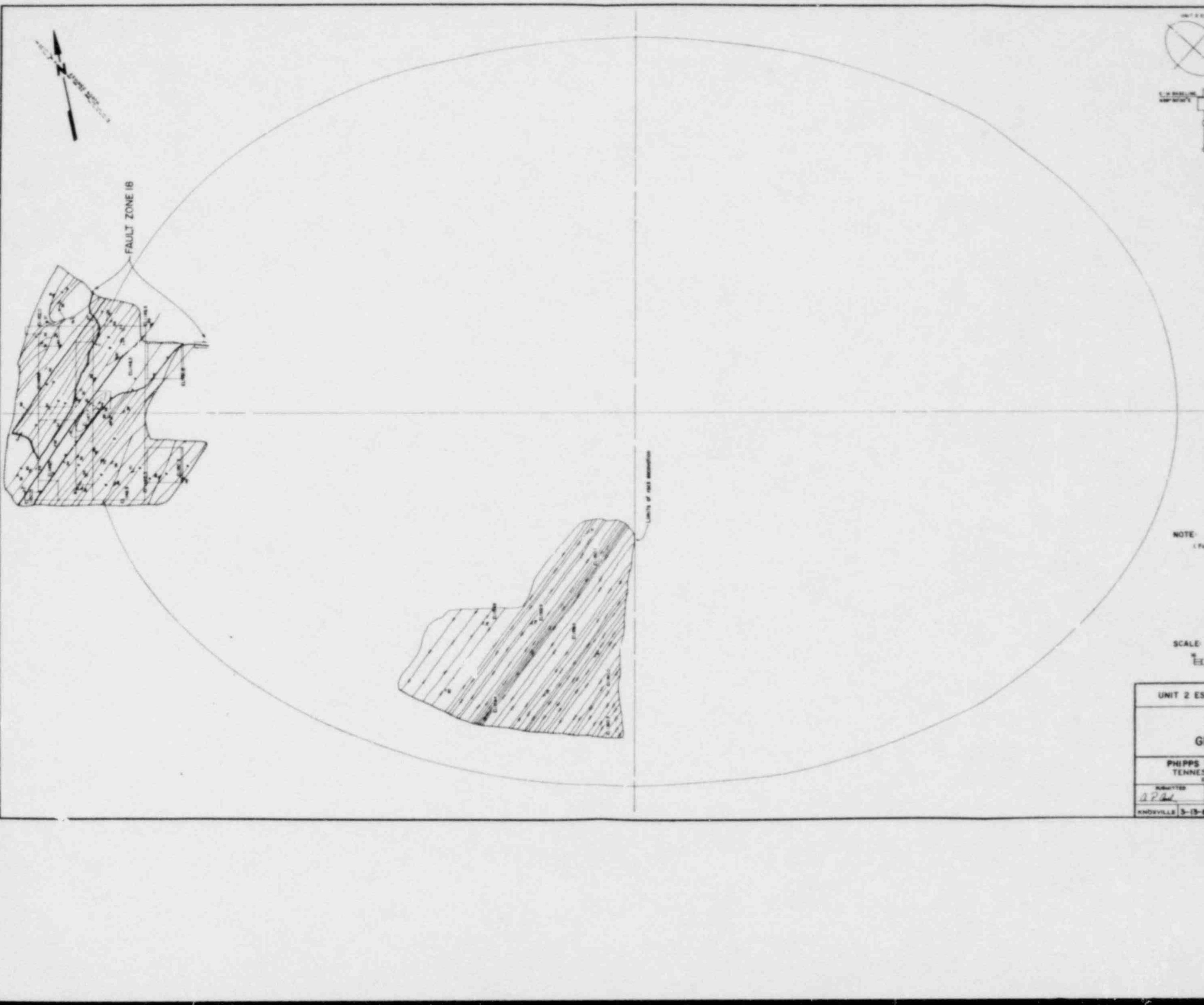
UNIT 1 ESW SPRAY POND FOUNDATION

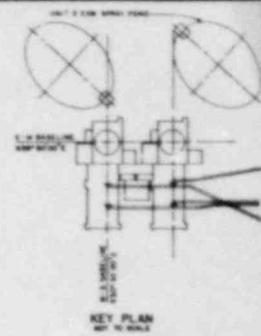
PLAN VIEW
GEOLOGIC MAP

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE 9-19-79 92 GE 822W2544

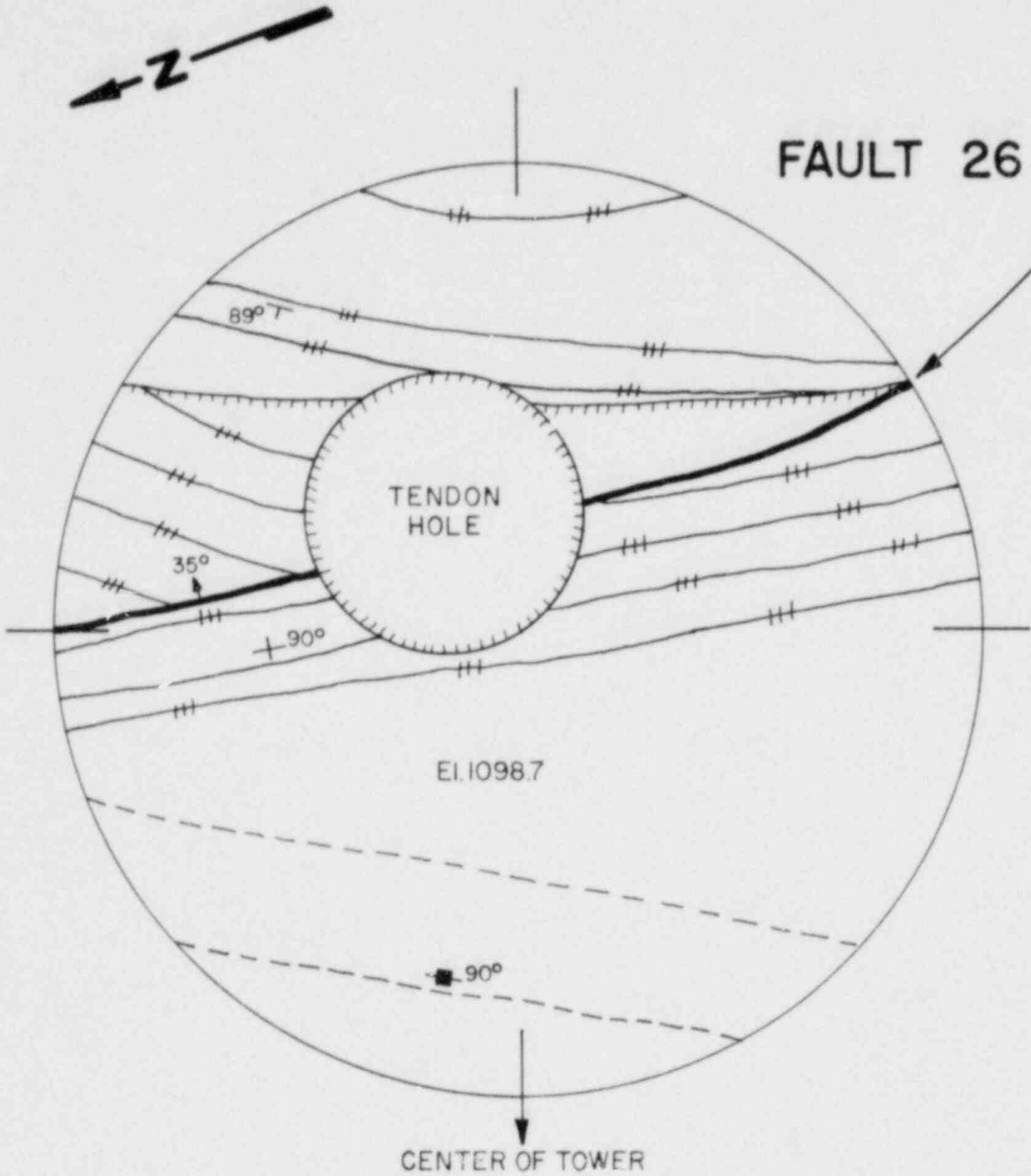




NOTE:
(For legend see dwg. no. 92 0E 822W2...

SCALE:

UNIT 2 ESW SPRAY POND FOUNDATI...
PLAN VIEW GEOLOGIC MAP
PHIPPS BEND NUCLEAR PLANT TENNESSEE VALLEY AUTHORITY
KNOXVILLE 3-13-80 92 0E 822W2547



PLAN

NOTES:

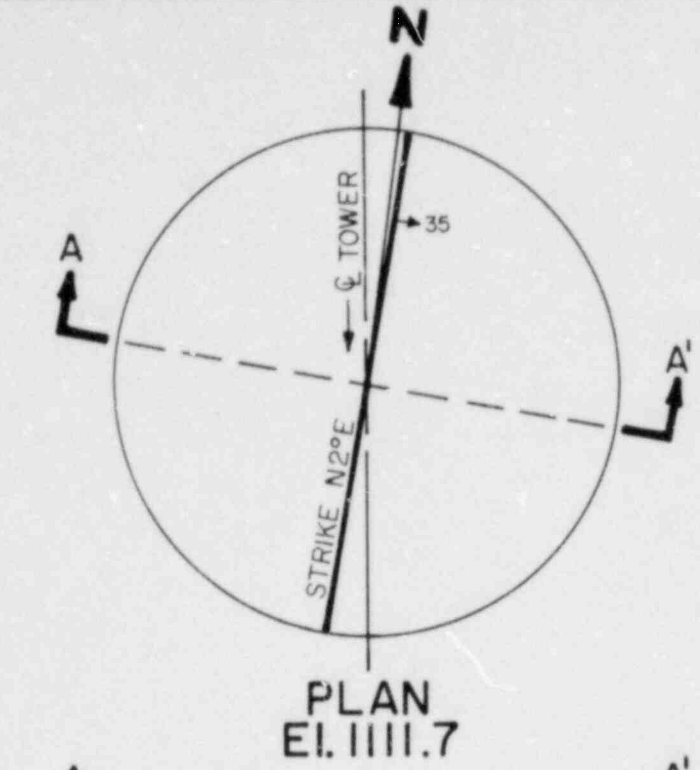
1. For location of drilled pier see dwg. no. 92 GE 822W2542.
2. For legend see dwg. no. 92 GE 822W2513.

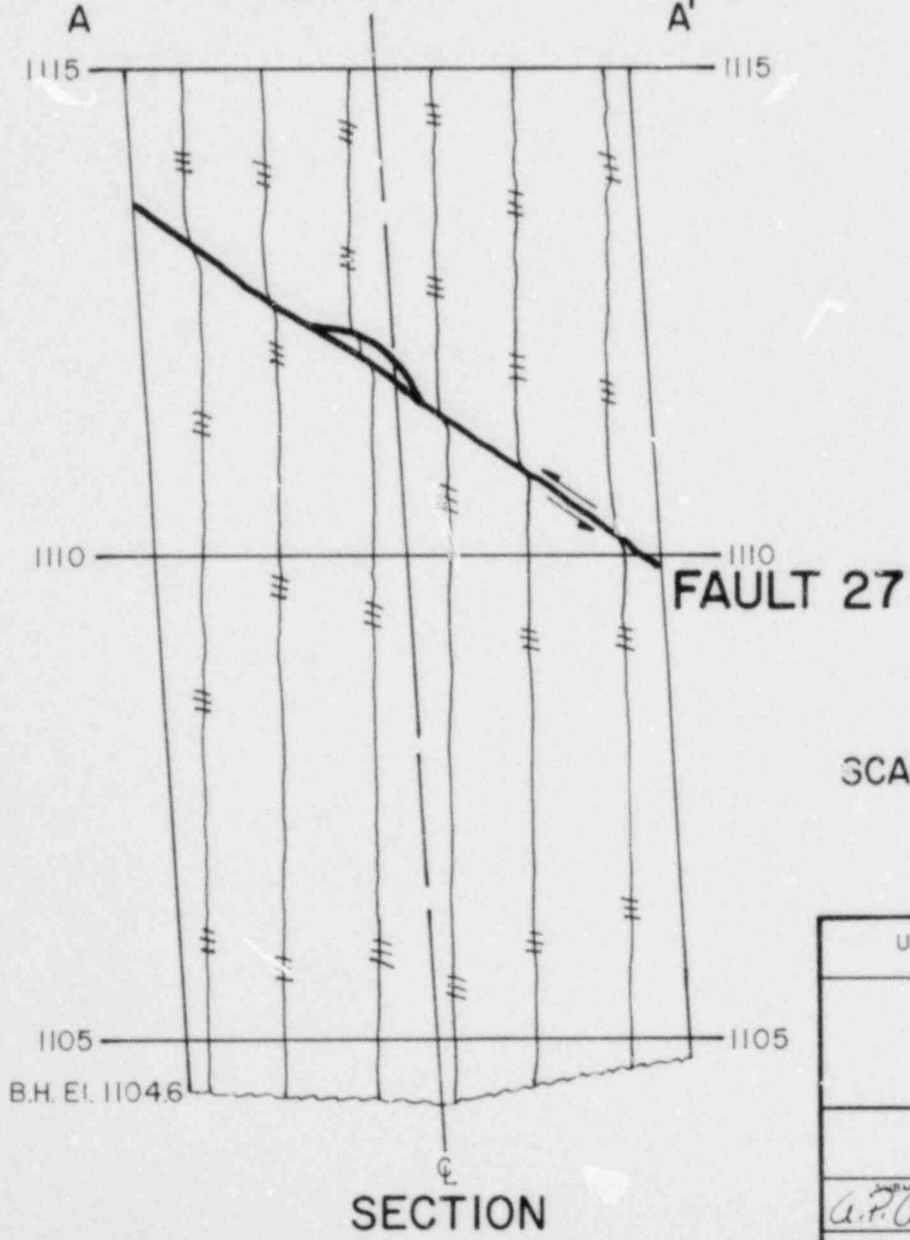
SCALE:

1 0 1 Foot

UNIT 1 COOLING TOWER FOUNDATION				
DRILLED PIER 34				
PHIPPS BEND NUCLEAR PLANT TENNESSEE VALLEY AUTHORITY DIVISION OF ENGINEERING DESIGN				
SUBMITTED A. P. Avel	RECOMMENDED A. D. Soderberg	APPROVED E. W. Allen		
KNOXVILLE	9-21-81	92	GE	822A2600

EXHIBIT 11





NOTES:

1. For location of drilled pier see dwg. no. 92 GE 822W 2542.
2. Top of rock elevation 1138.0
3. For legend see dwg. no. 92 GE 822W2513.

SCALE:

1 0 1 2 Feet

UNIT 1 COOLING TOWER FOUNDATION

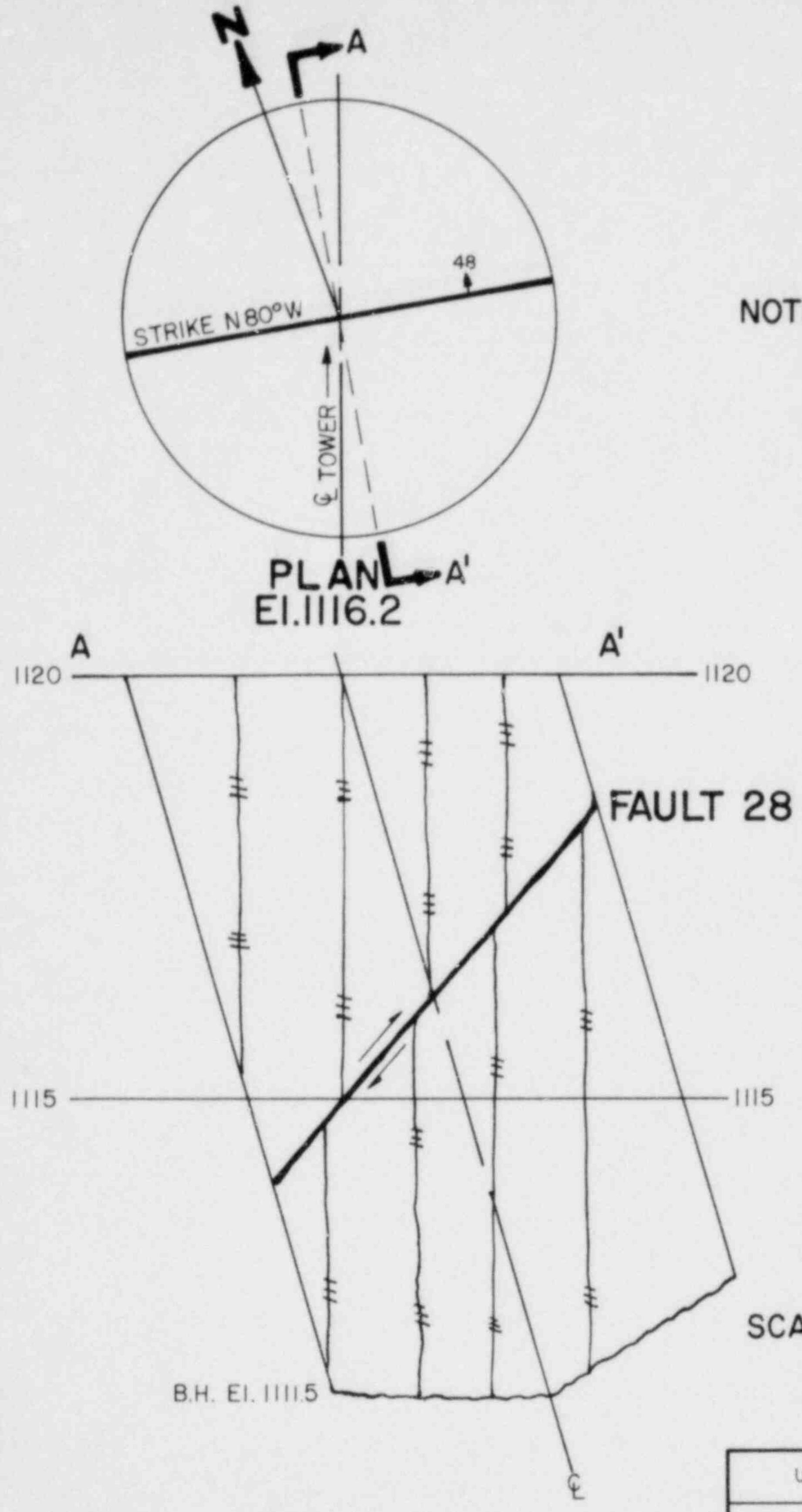
DRILLED PIER 19

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED
A.P. Cavel	A.D. Soderberg	R.W. Allen

KNOXVILLE	9-21-81	92	GE	822A2599

EXHIBIT 12



NOTES:

1. For location of drilled pier see dwg. no. 92 GE 822W 2542.
2. Top of rock elevation 1142.7.
3. For legend see dwg. no. 92 GE 822W2513.

SCALE:

1 0 1 2 Feet

UNIT I COOLING TOWER FOUNDATION

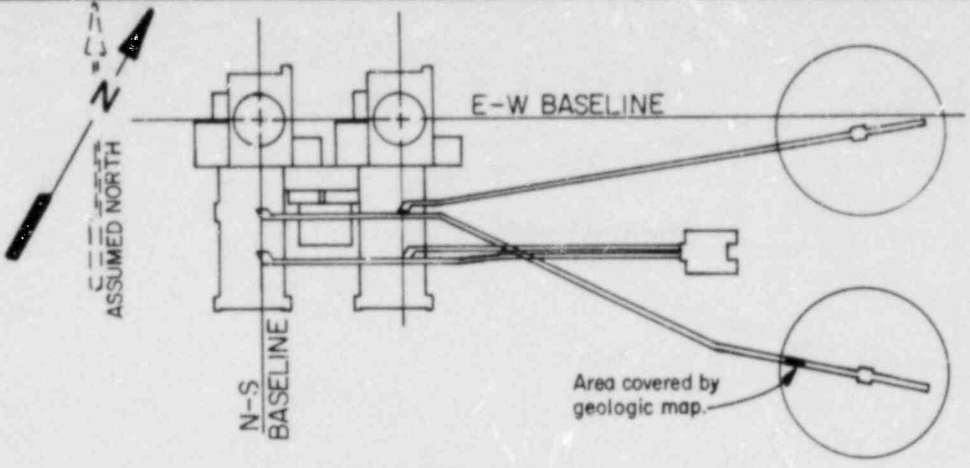
DRILLED PIER 47

PHIPPS BEND NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

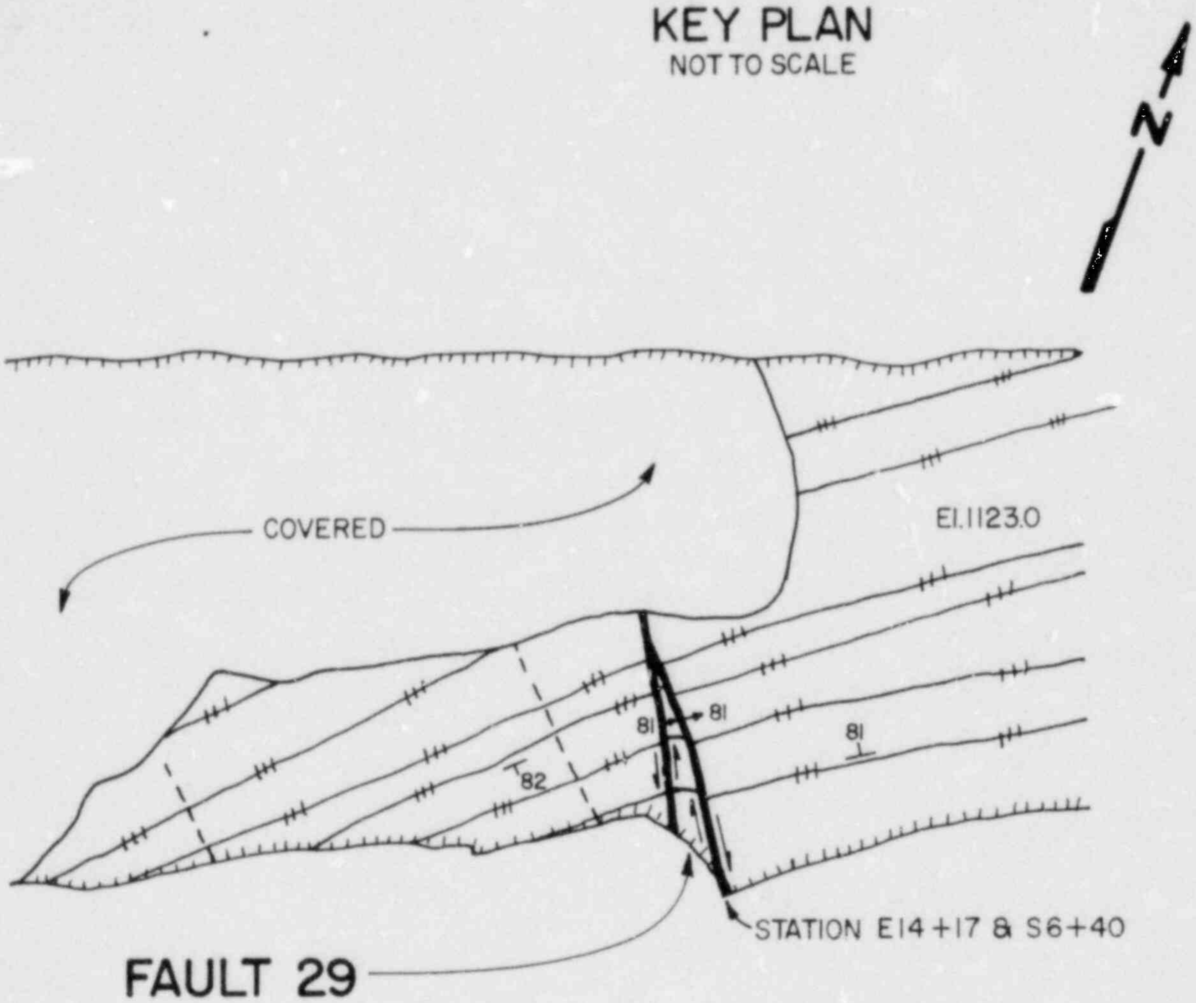
SUBMITTED	RECOMMENDED	APPROVED
A. P. Abel	A. D. Faulenbury	Rev Allen

KNOXVILLE | 9-18-81 | 92 | GE | 822 A 2598

EXHIBIT 13



KEY PLAN
NOT TO SCALE



PLAN

NOTE:

1. For legend see dwg. no. 92 GE 822W2513.

SCALE:

5 0 5 10 Feet

UNIT 1 COOLING TOWER FOUNDATION
INLET HEADER
PHIPPS BEND NUCLEAR PLANT TENNESSEE VALLEY AUTHORITY DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED
A. P. Avel	A. S. Fockelberg	R.W. Allen
KNOXVILLE	9-17-81	92	GE	822A2597