THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

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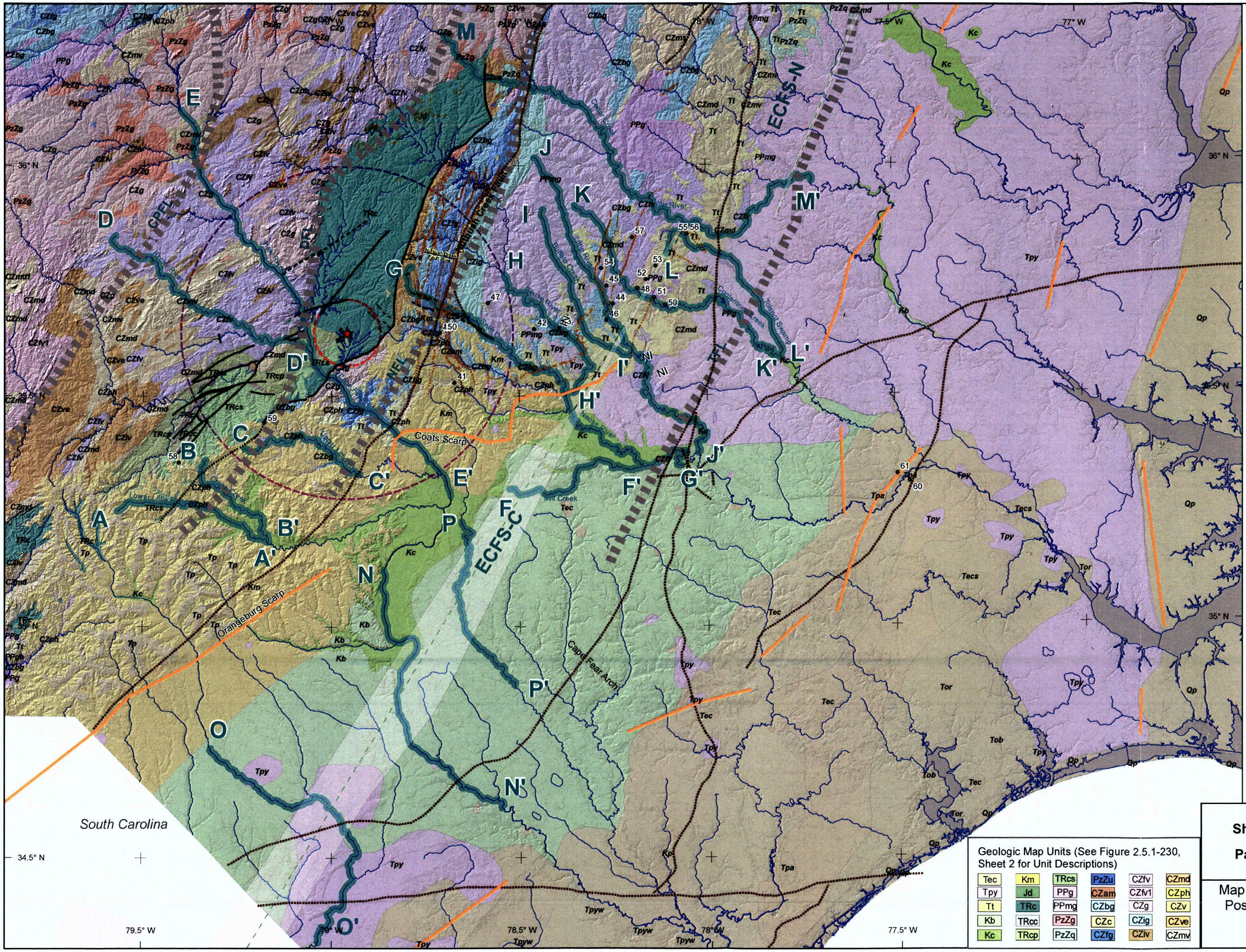
"PRELIMINARY BEDROCK GEOLOGIC MAP OF THE RALEIGH 30' x 60' QUADRANGLE, NORTH CAROLINA."

WITHIN THIS PACKAGE... OR BY SEARCHING USING THE

D-01



LEGEND

- HAR Site
- City or Town
- 8-km (5-mi.) Radius from HAR Site
- 40-km (25-mi.) Radius from HAR Site
- A A' Stream Channel Section Location
- Major Drainage (NCCGIA, 2002)
- Paleozoic Faults
- Mesozoic Faults (dashed where inferred, dotted where concealed) (Ebasco, 1975, CP&L, 1983, NCGS, 1985, Wooten et al., 1996, Harding Lawson, 1997, NCGS, 2006, and this study)
- Paleozoic Folds (dashed where inferred)
- Mesozoic Folds (dashed where inferred) (NCGS, 2006)
- 49 Faults (numbers refer to descriptions in Table 2.5.1-201; from Parker, 1979, and Prowell, 1983)
- Postulated Fall Lines (Weems, 1998)
  - CPFL - Central Piedmont Fall Line
  - DFL - Durham Fall Line
  - NFL - Nutbush Fall Line
  - TFL - Tidewater Fall Line
- Postulated East Coast Fault System (ECFS) (Marple and Talwani, 2000)
  - C - Central Segment
  - N - Northern Segment
  - S - Southern Segment
- Cape Fear Arch (Marple and Talwani, 2000)
- Basement Faults (Lawrence and Hoffman, 1993)
- Scarps (Soller and Mills, 1991)

Grid is in the North Carolina NAD 83 State Plane Coordinate System (in feet)
Base Map: Shaded Relief Map from LIDAR (NC DOT, 2005)

Note N1: This fault included in NCGS (2006) unpublished mapping appears to represent variations in metamorphic grade adjacent to the pluton rather than a fault contact.

0 5 10 20 30 Kilometers

0 5 10 20 Miles

Geologic Map Units (See Figure 2.5.1-230, Sheet 2 for Unit Descriptions)

Tec	Km	TRcs	PzZu	CZfv	CZmd
Tpy	Jd	PPg	CZam	CZfv1	CZph
Tt	TRc	PPmg	CZbg	CZg	CZv
Kb	TRcc	PzZg	CZc	CZig	CZve
Kc	TRcp	PzZq	CZfg	CZiv	CZmv

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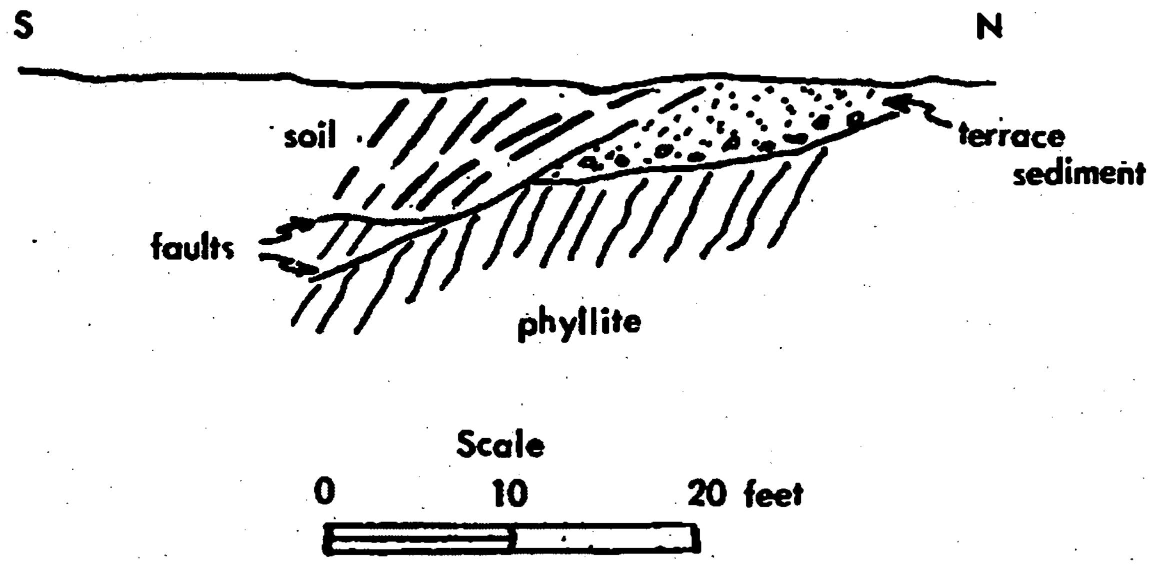
Map Showing the Location of Tectonic and Postulated Tectonic Features Relative to Longitudinal Stream Profiles

FIGURE 2.5.1-219 (Revised)



Source: Parker (1979)

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Cross-section of Thrust Fault Near Banks, North Carolina

RAI 2.5.1-14 FIGURE 1

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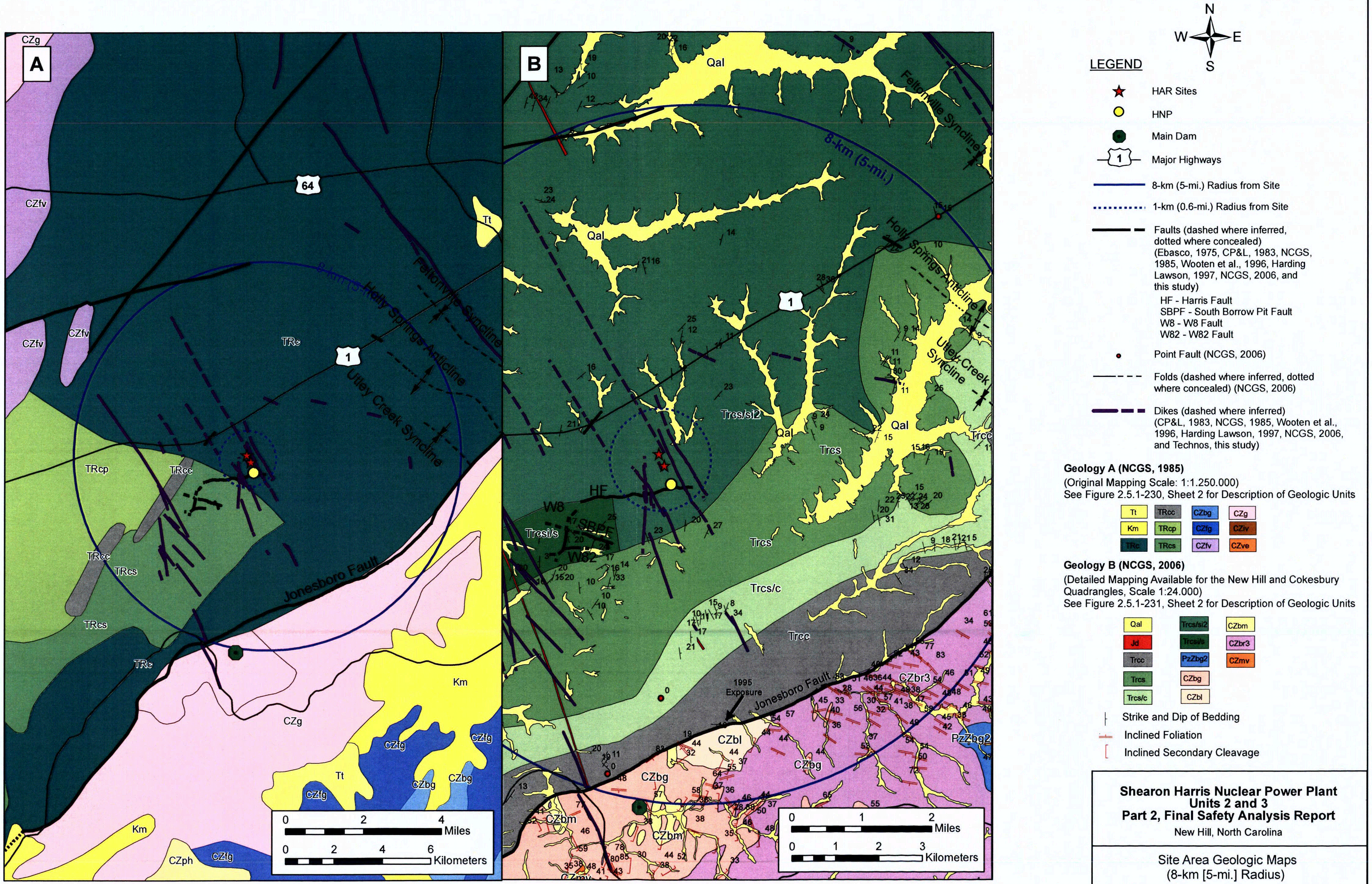

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Site Area Geologic Maps (8-km [5-mi.] Radius)

FIGURE 2.5.1-231 (SHEET 1 OF 3) (Revised)

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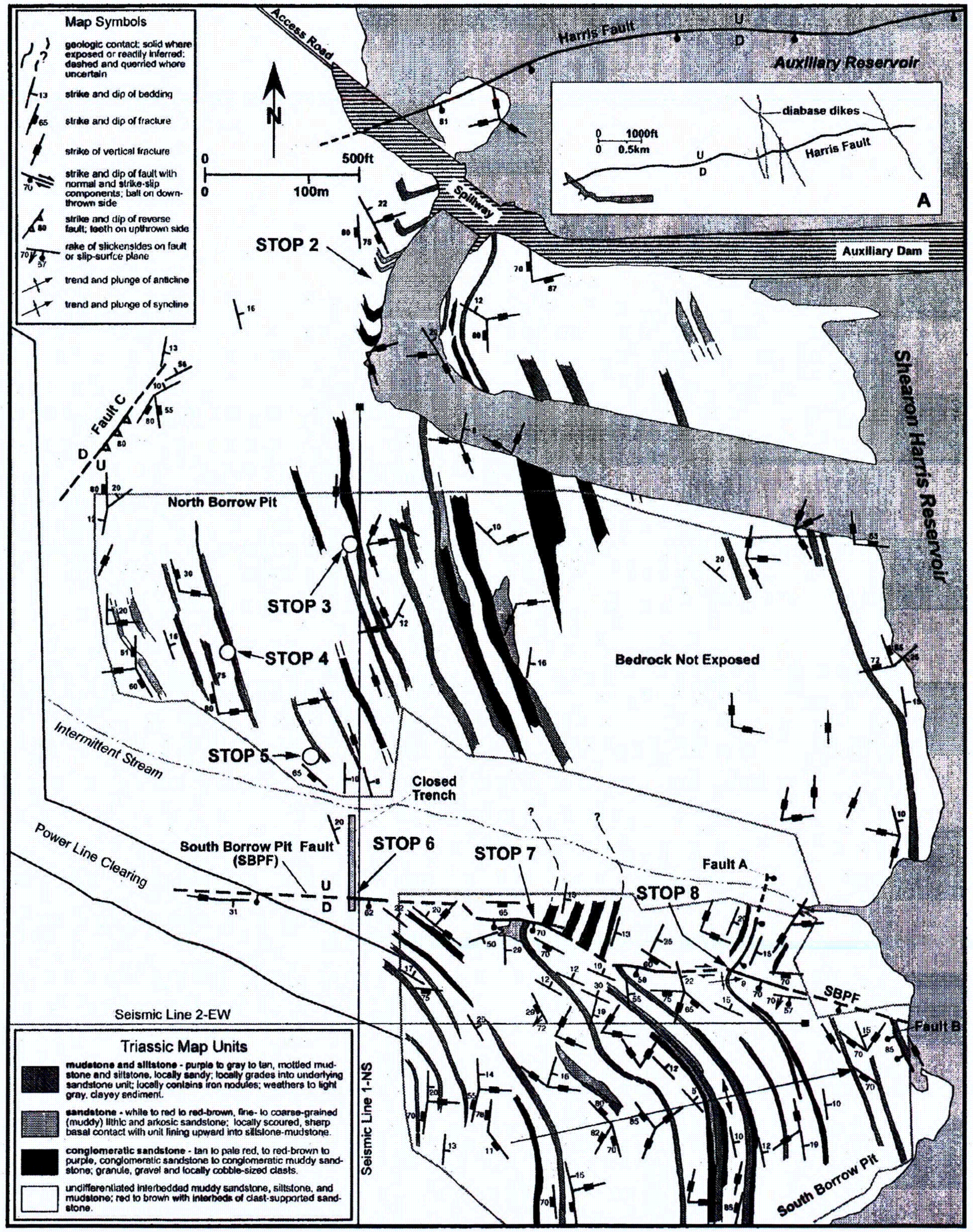
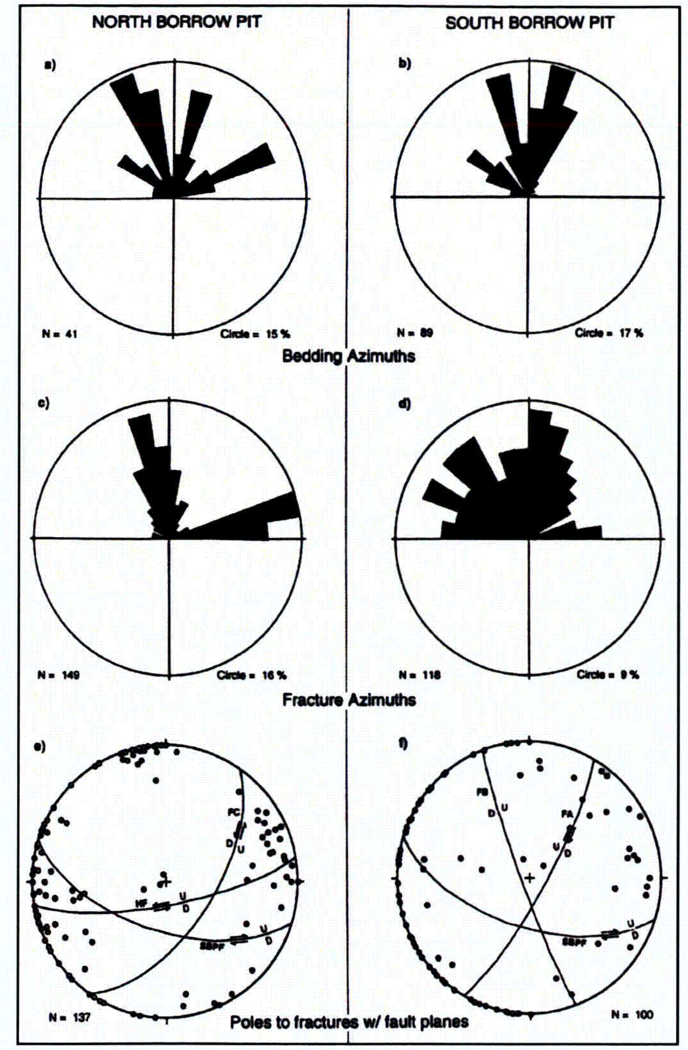


Generalized bedrock geologic map of the north and south borrow pits. Inset A shows the trace of the Harris fault to the east of the map area (from Ebasco Services, Inc., 1975).

Source: Wooten et al. (2001).



Rose diagrams and lower hemisphere equal-area stereonet projections of structure data from the north and south borrow pits: a) bedding azimuths, north borrow pit; b) bedding azimuths, south borrow pit; c) fracture azimuths, north borrow pit; d) fracture azimuths, south borrow pit; e) fracture (poles) and fault planes (great circle), north borrow pit; f) fractures (poles) and fault planes (great circles), south borrow pit. SBPF = south borrow pit fault; HF = Harris fault; FA = fault A; FB = Fault B; and FC = Fault C.

Source: Wooten et al. (1996).

	FRACTURE SET A	FRACTURE SET B
Strike	WNW. - uniform	NNW.-NE. - variable
Dip	>80° - mainly S.	>80° - variable
Surface Trace	linear	undulatory
Trace Length	<0.5 ft to ~ 6.0 feet	<0.5 ft to ~10.0 feet
Spacing	4 to 12 inches	12 to 24 inches
Infilling	clayey, green-gray	clayey, green-gray (more common)
Wall Bleaching	white to green	white to green
Structures	pinnate and feather	not observed
Terminations	mainly A against B	few B against A
Offsets	A offsets B	----
Mode	opening and shearing	opening and shearing (?)
Relative Age	A mainly younger than B	some B coeval with A

Summary table of fracture properties for fracture sets A and B in the hanging wall of the SBPF.

Source: Wooten et al. (1996).

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Site Area Geologic Maps (8-km [5-mi.] Radius)

RAI 02.05.01-26 FIGURE 1

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

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"RAI 2.5. 1-20, FIGURE 1, Geologic Map of the LLRW Site."

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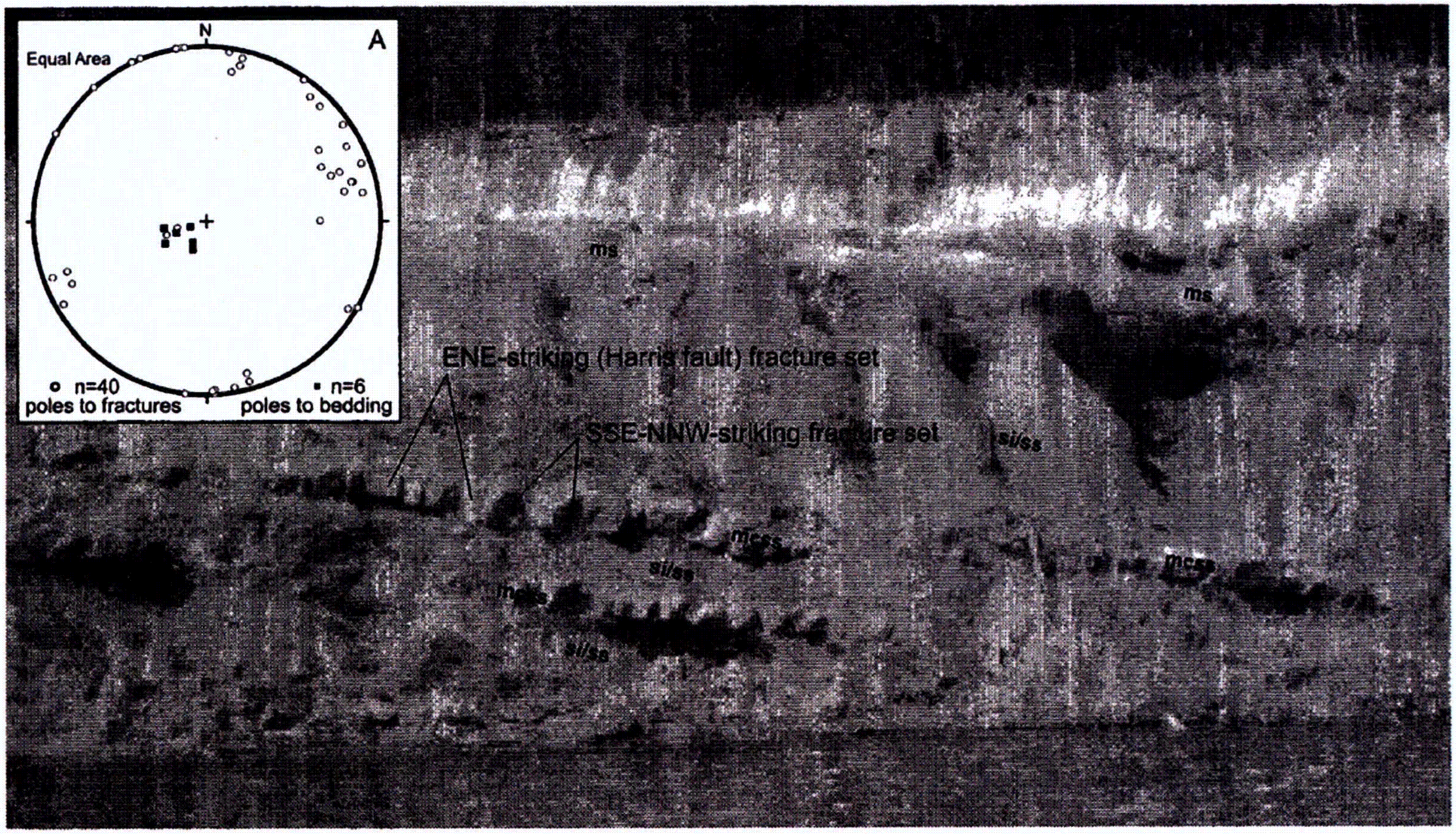

Photograph showing fracture patterns developed in muddy, conglomeratic sandstone (mcss) beds exposed in the NW-bank of the spillway at Stop 2 (See RAI 02.05.01-20 Figure 9 for location). Interstratified are less resistant beds of purple-gray mudstone (ms) with root traces and carbonate nodules, and red-brown siltstone to very fine-grained, silty sandstone (si/ss). Inset A shows a lower hemisphere aqual area stereonet projection of poles to bedding and fracture planes at this locality. Here bed strikes NW and dip 12° to 20° NE. Two high-angle, systematic fracture sets predominate; an ENE-striking set that generally terminates against a SSE-NNW-striking set. The ENE-striking fracture set is sub-parallel to the nearby Haris Fault. The spillway is upstream and to the right of the photograph.

Source: Wooten et al. (2001)

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Exposure of Triassic Sediments near Auxiliary Dam

RAI 02.05.01-20 FIGURE 2

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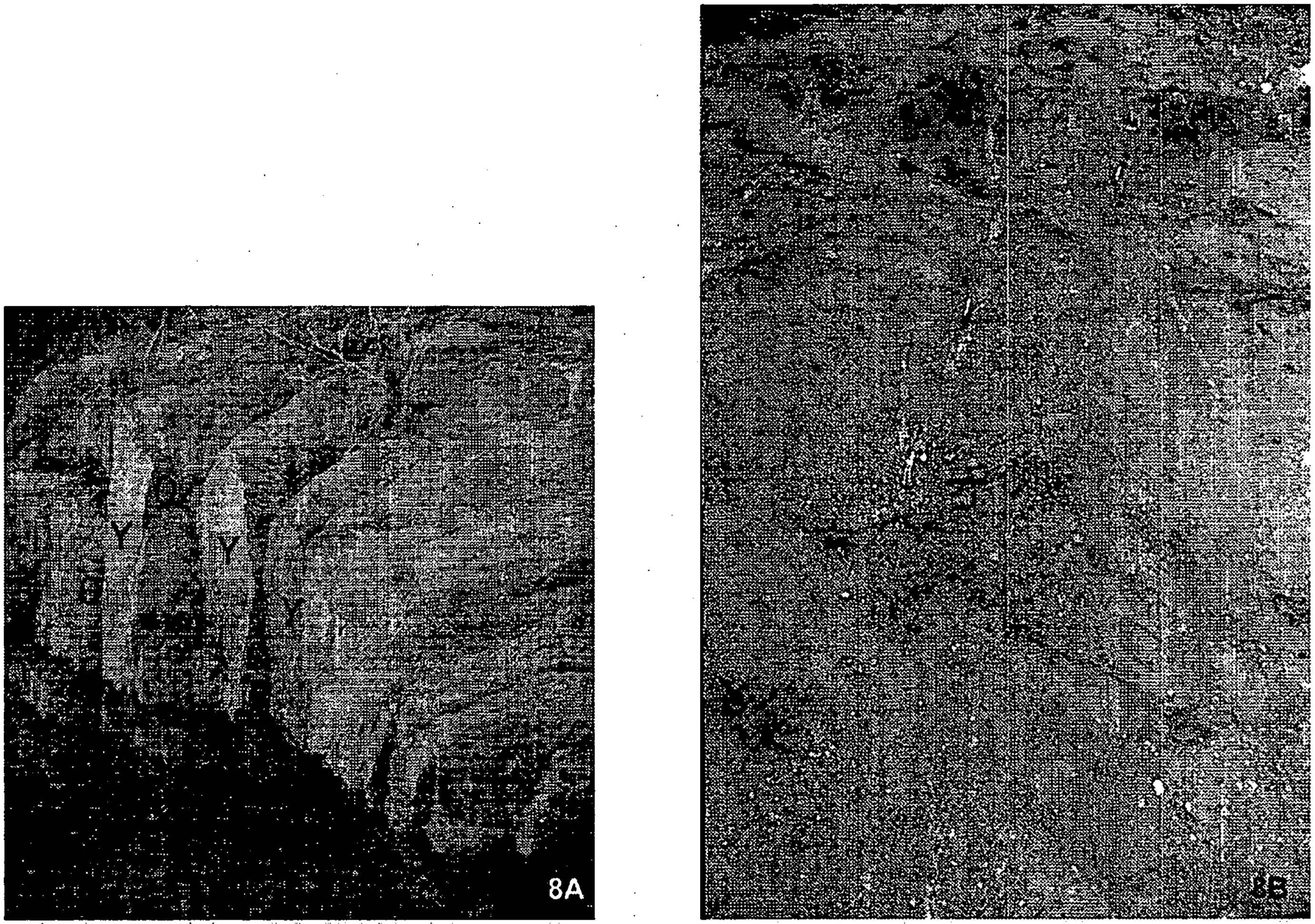

A) Photograph of abutting relationships between older NNW-striking joints (o) and younger ENE-striking joints (Y) at STOP 3 (See RAI 02.05.01-20 Figure 9 for location) in the north borrow pit. B) Photograph of dominant set of NNW-striking, bleached joints at STOP 3 in the north borrow pit.

Source: Wooten et al. (2001)

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Units 2 and 3
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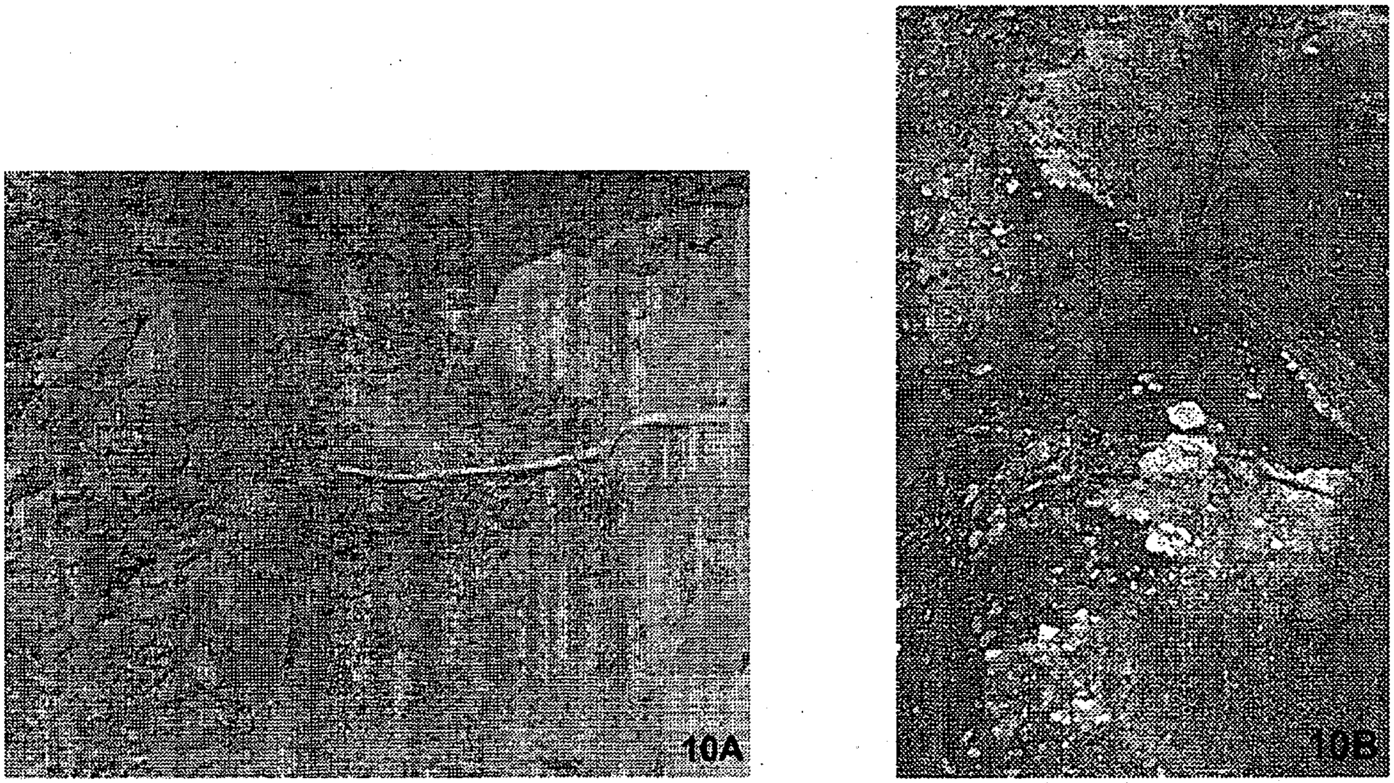
New Hill, North Carolina

Photographs of Joints at North Borrow Pit

RAI 02.05.01-20 FIGURE 3



A) Photograph of wide claystone dike with bleached wall-rock contact west of STOP 5. B) Photograph of low angle extensional fault south of STOP 7 in south borrow pit. Slickenlines, which are parallel to pencil in foreground, indicate E-W-displacement. See RAI 02.05.01-20 Figure 9 for locations of field trip stops.

Source: Wooten et al. (2001)

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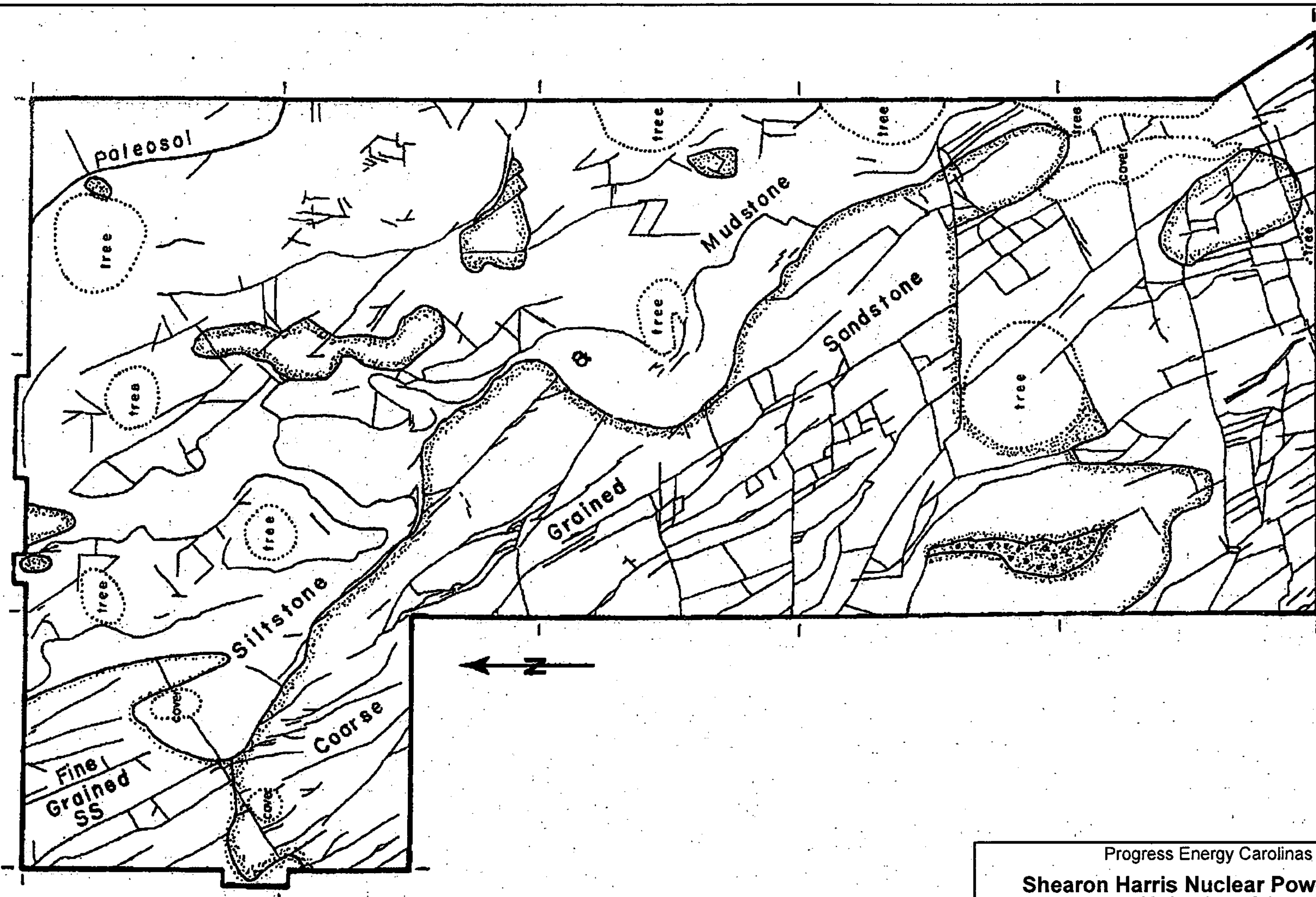
Claystone Dike and Low Angle Fault at North and South Borrow Pits

RAI 02.05.01-20 FIGURE 4



Fracture map at STOP 5 (See RAI 02.05.01-20 Figure 9 for location) in the north borrow pit showing typical polygonal fracture pattern observed in coarser-grained rocks. Tick marks around the border are at 5-ft intervals. Mapped by M. J. Bartholomew, R. D. Heath and B. M. Brodie.

Source: Wooten et al. (2001)

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New Hill, North Carolina

Fracture Patterns in North Borrow Pit

RAI 02.05.01-20 FIGURE 5

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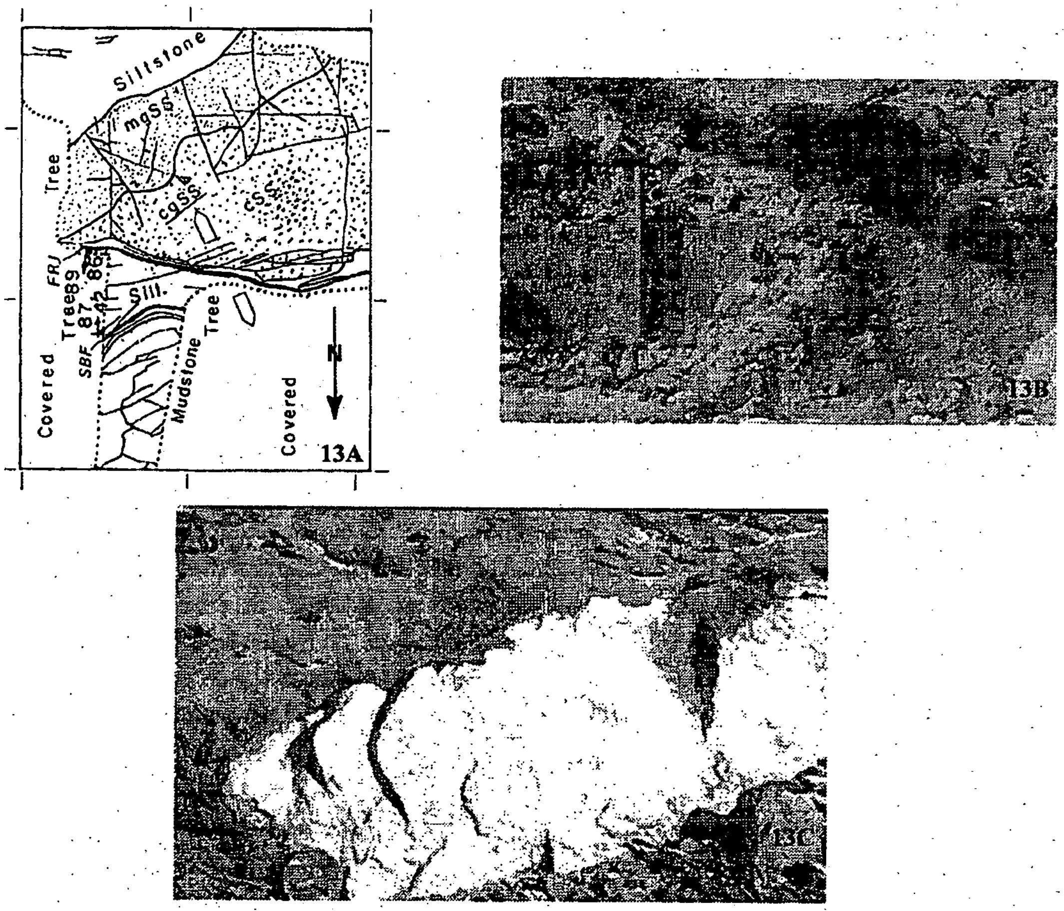

A) Part of the fracture trace map across the SBPF near STOP 7 in the south borrow pit showing large, WNW-striking, mode II, left-lateral pinnate joints (270°, 84°), that indicate N-S extension (large open arrows), along the north side of a coarse-grained sandstone bed. This large joint is related to dip-slip displacement on the SBPF and was later reactivated as a dip-slip normal fault (FRJ), MgSS - medium grained sandstone; cgSS - coarse -grained sandstone; cSS - conglomeratic sandstone; Silt. - siltstone; tick marks around the border are 5-ft intervals. Mapped by M. J. Bartholomew and S. E. Lewis. B) Photograph of slickensides (parallel to pencil) on the SBPF near STOP 7 indicating dip-slip displacement. C) Photograph of left-lateral, mode II, bleached pinnate joint near the center of the north borrow pit. See RAI 02.05.01-20 Figure 9 for locations of field trip stops.

Source: Wooten et al. (2001)

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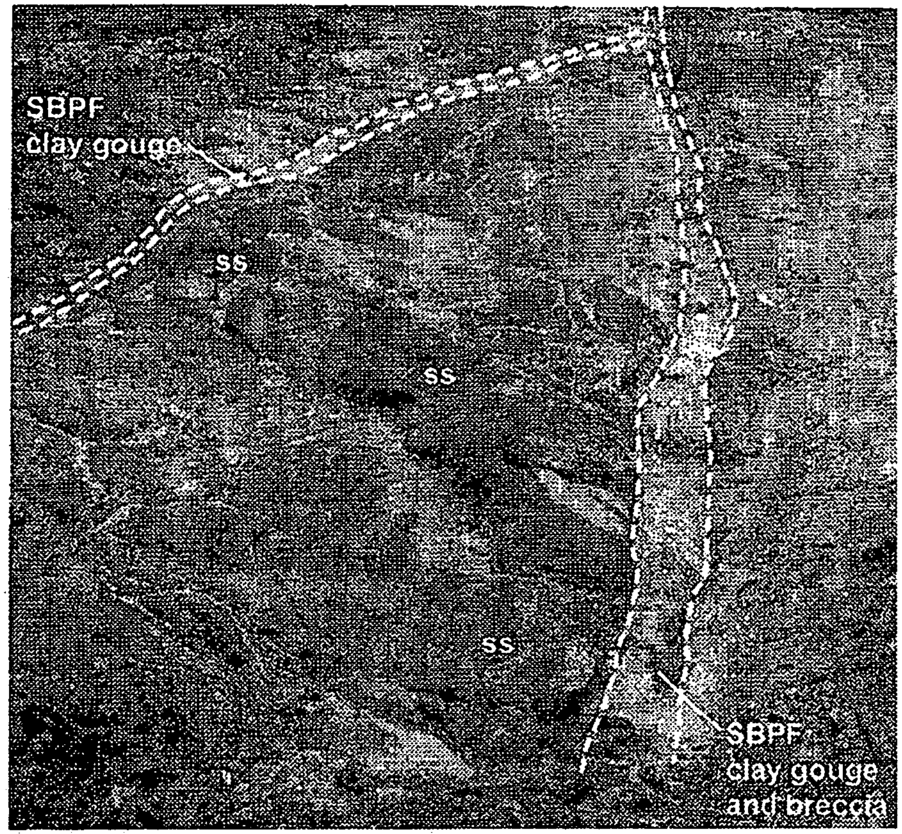
Fractures and Faults at North and South Borrow Pits

RAI 02.05.01-20 FIGURE 6

S:\11100\11151.002\Figures\RAI_RAI 02.05.01-20 Figure 6.ai



Photograph of deformed and truncated beds between splays of the SBPF at STOP 7. View to WNW.

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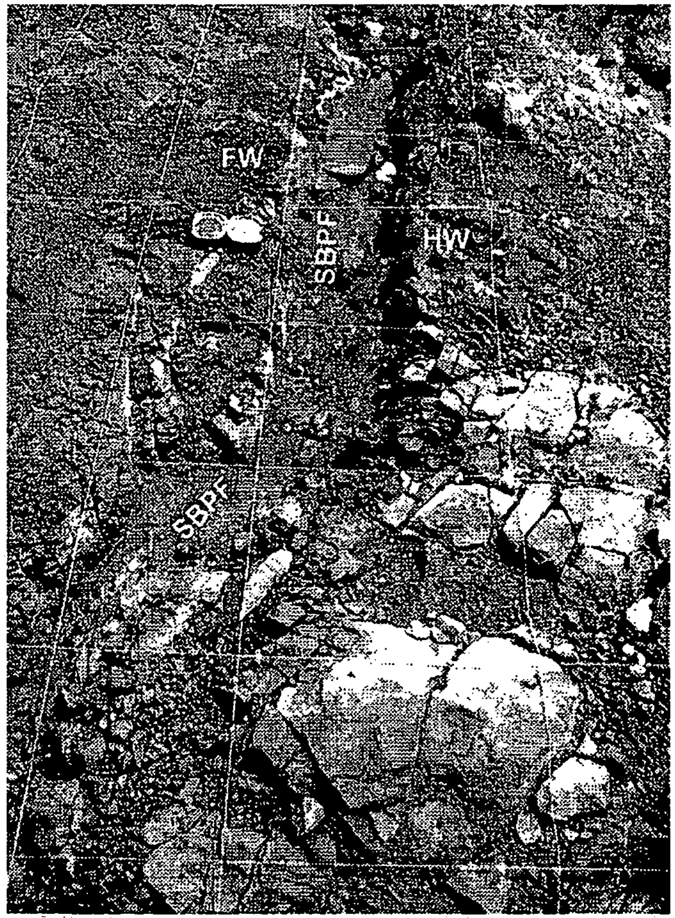
New Hill, North Carolina

Photograph of South Borrow Pit Fault

RAI 02.05.01-20 FIGURE 7

Source: Wooten et al. (2001)

S:\11100\11151.002\Figures\RAI_RAI 02.05.01-20 Figure 7.ai



Photograph of the SBPF and fracture trace mapping grid (approx. 1ft grid) at STOP 8 (See RAI 02.05.01-20 Figure 9 for location). The fault trace follows the low relief area separating the footwall (FW) and hanging wall (HW). Compass points north (to the left).

Source: Wooten et al. (2001)

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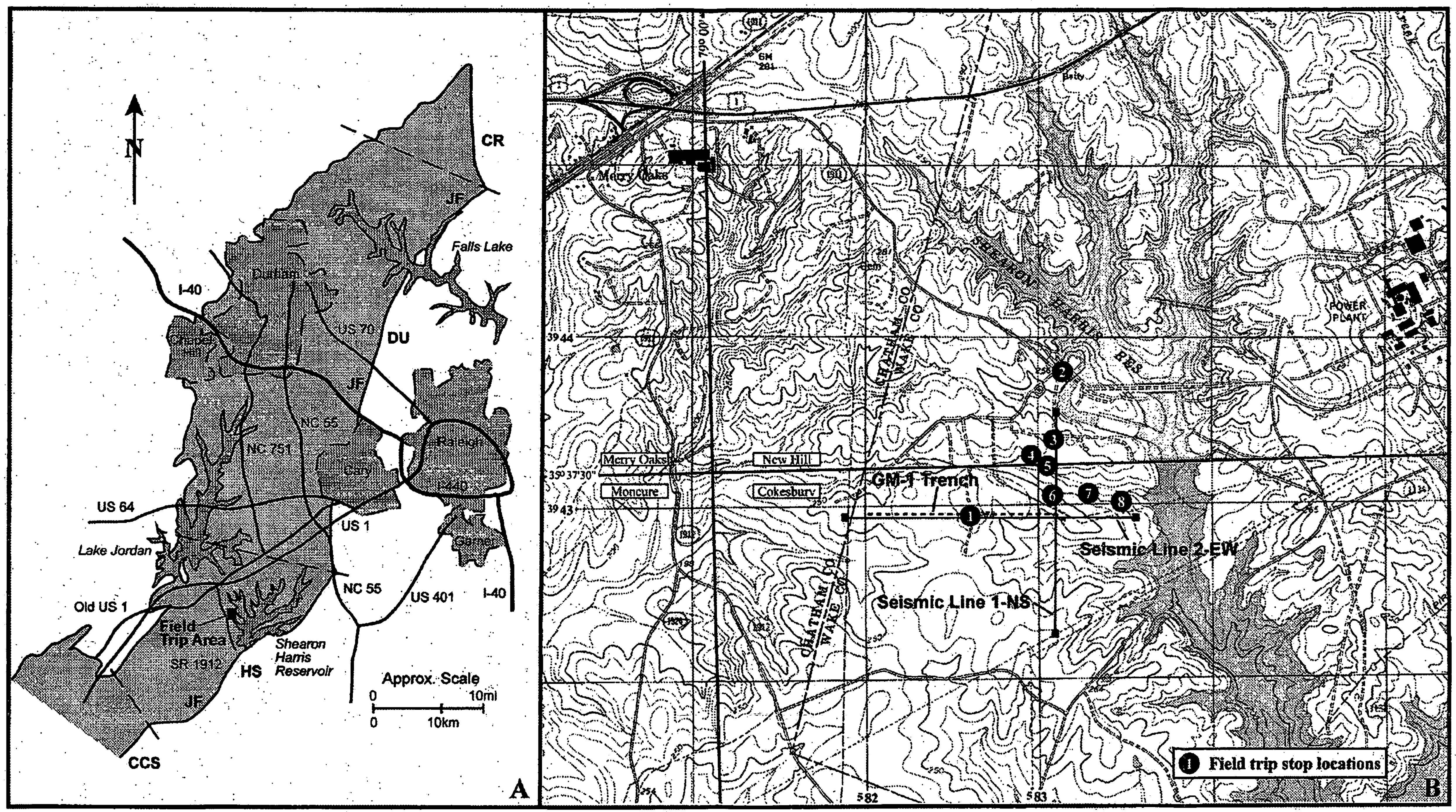
New Hill, North Carolina

Photograph of South Borrow Pit Fault

RAI 02.05.01-20 FIGURE 8



A) Regional map of the Durham basin showing the field trip area relative to segments of the Jonesboro fault (JF) proposed by Bartholomew and others (1994). Segment of the Jonesboro fault: CR=Creedmore segment; DU=Durham segment; HS=Holly Springs segment; CCS=Collon cross structure. B) Location of field trips stops, seismic lines and GM-1 trench (closed) shown on U.S.G.S. topographic map base (from Merry Oaks, New Hill, Cokesbury and Moncure 7.5-minute quadrangle).

Source: Wooten et al. (2001).

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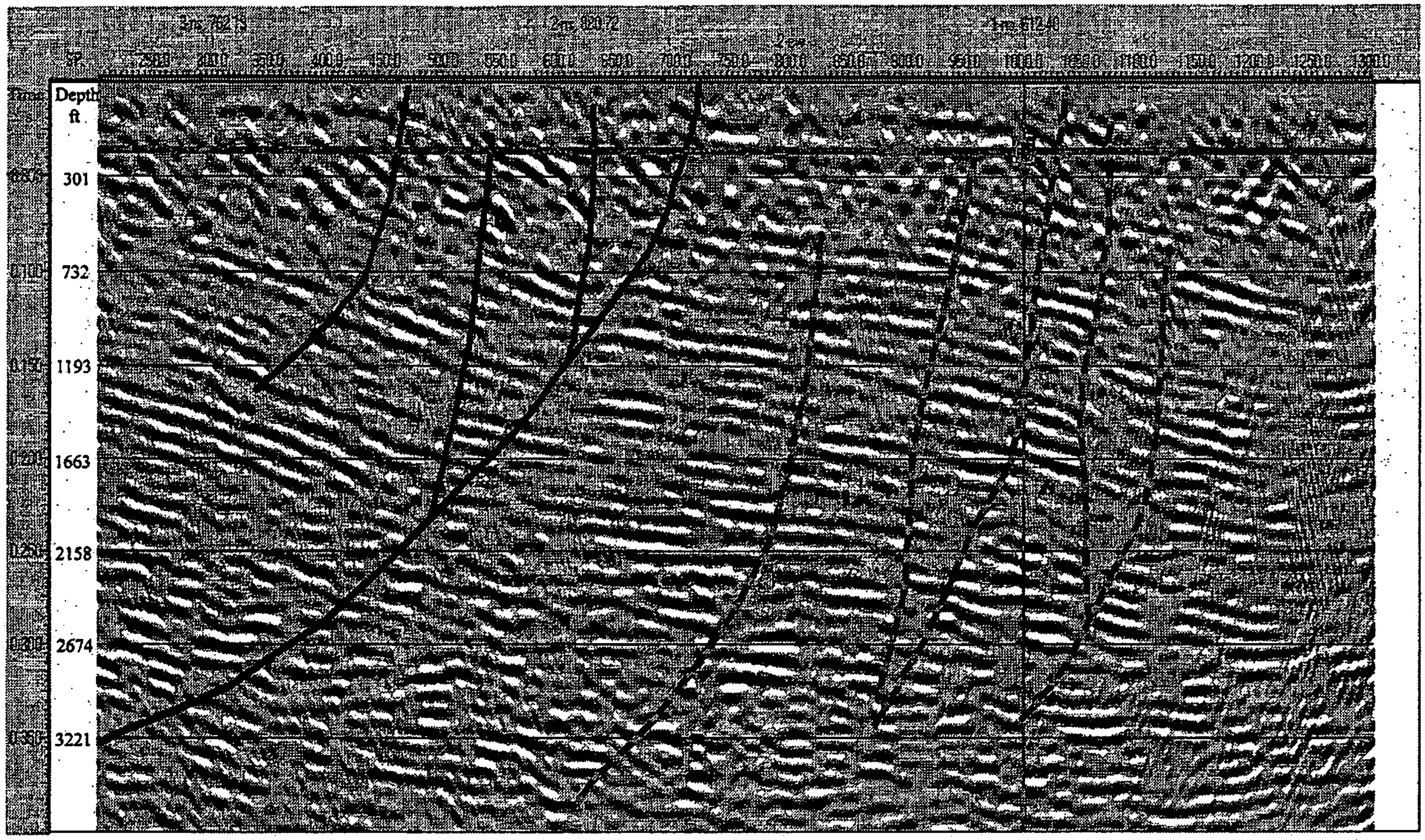
New Hill, North Carolina

Map Showing Location of LLRW Seismic Lines

RAI 2.5.1-20 FIGURE 9

S:\11100\11151.002\Figures\RAI_RAI 02.05.01 Figure 9.ai



Source: Wooten et al. (2001).

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Seismic Reflection Profile 2-EW

RAI 2.5.1-20 FIGURE 10

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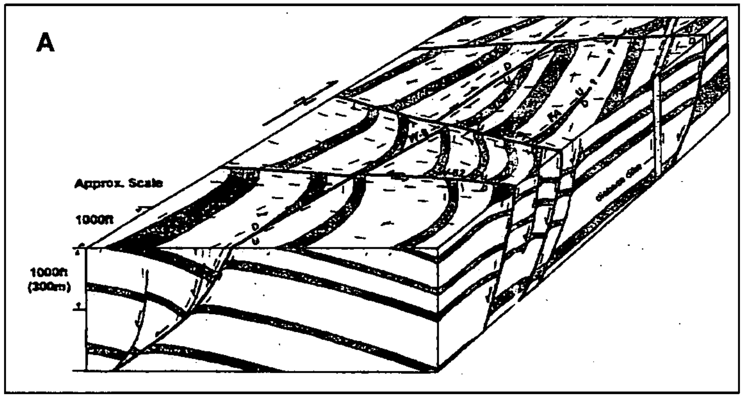
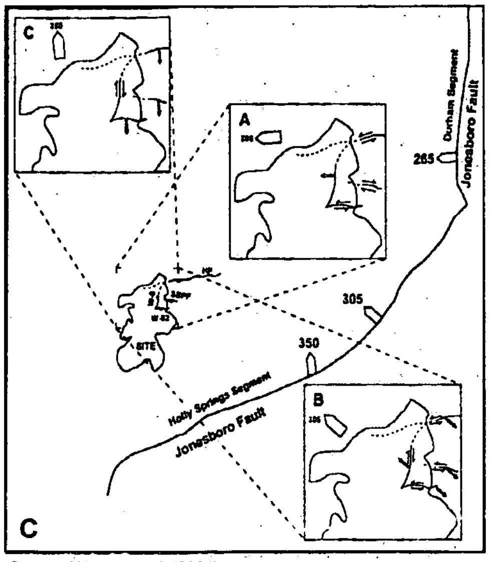


Source: Wooten et al. (2001)



C

Source: Wooten et al. (2001)

B

Stage 1:
- Longitudinal basin faulting (Fault A)
- Tilting of beds
- Formation of north-striking, opening-mode fractures.

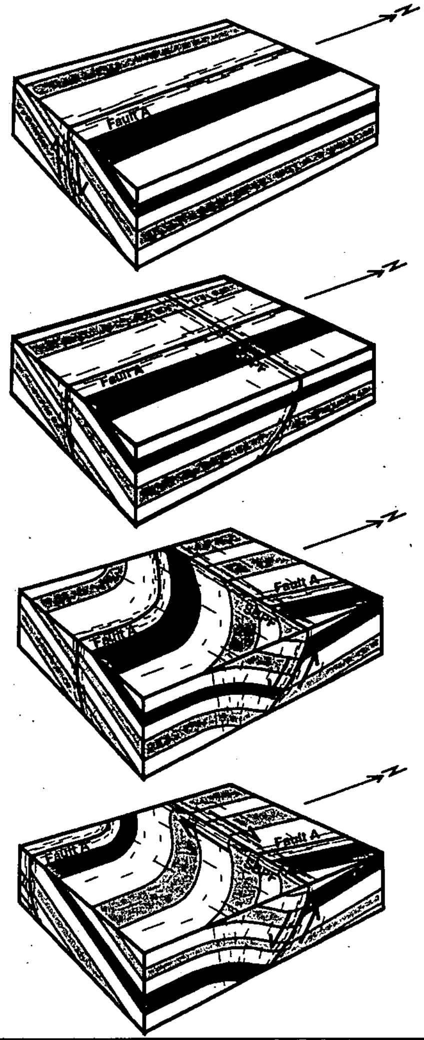
Stage 2:
- Transverse basin faulting
- Initial formation of south borrow pit fault (SBPF).
- East-striking, opening mode fractures

Stage 2A:
- Normal faulting
- Formation of map-scale, hanging wall anticline.
- East-striking, opening mode fractures.

Stages 2A and 2B may be coeval.

Stage 2B:
- Continued movement along SBPF.
- Dextral, strike-slip faulting;
- Formation of outcrop-scale, hanging wall syncline.
- East- and north-striking shearing mode fractures.

Stages 2A and 2B may be coeval.



Schematic diagram showing a possible kinematic model for the south borrow pit fault and associate structures.

Source: Wooten et al. (1996)

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Units 2 and 3
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New Hill, North Carolina

Schematic Block Diagram and Map Showing Structural Relations for Faults in the Site Area
FIGURE 2.5.1-236 (Revised)

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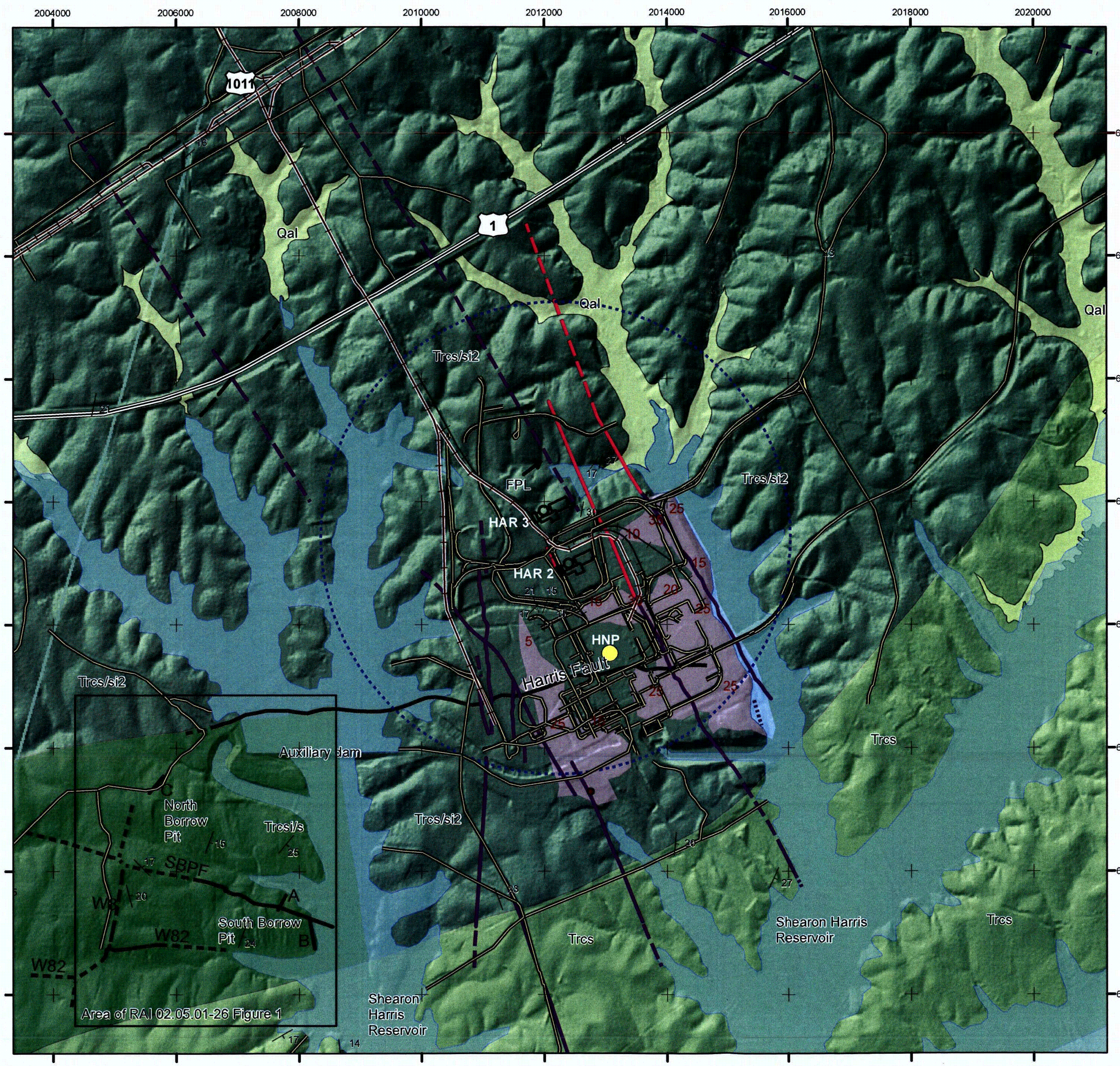

N
W E
S

LEGEND

Proposed AP1000 Structures

HNP

1 km (0.6 mi.) Radius from Site

Railroad

Highway

Roads

Faults (dashed where inferred, dotted where concealed) (Ebasco, 1975, CP&L, 1983, NCGS, 1985, Wooten et al., 1996, Harding Lawson, 1997, NCGS, 2006, and Technos, this study)

HF - Harris Fault
SBPF - South Borrow Pit Fault
W8 - W8 Fault
W82 - W82 Fault

Point Fault (NCGS, 2006)

FPL- Fire Pond Lineament

Dikes (dashed where inferred) (CP&L, 1983, NCGS, 1985, NCGS, 2006)

Dikes (dashed where inferred) (Technos, this study, and Geomatrix filed investigations, June 2006)

Strike and Dip of Bedding (NCGS, 2006, and this study)

Geologic Units (see Figure 2.5.1-231, Sheet 2 for Unit Descriptions)

25 Thickness of Fill (ft.)

Qal

Trcs/si2

Trcs/s

Trcs

Grid is in the NAD 83 North Carolina State Plane Coordinate System (feet)

Base Map: Shaded Relief Map from LIDAR (NC DOT, 2005)

0 250 500 1,000
Meters

0 500 1,000 2,000 3,000
Feet

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Site Location Geologic Map
(1-km [0.6-mi.] Radius)

FIGURE 2.5.1-232 (Revised)

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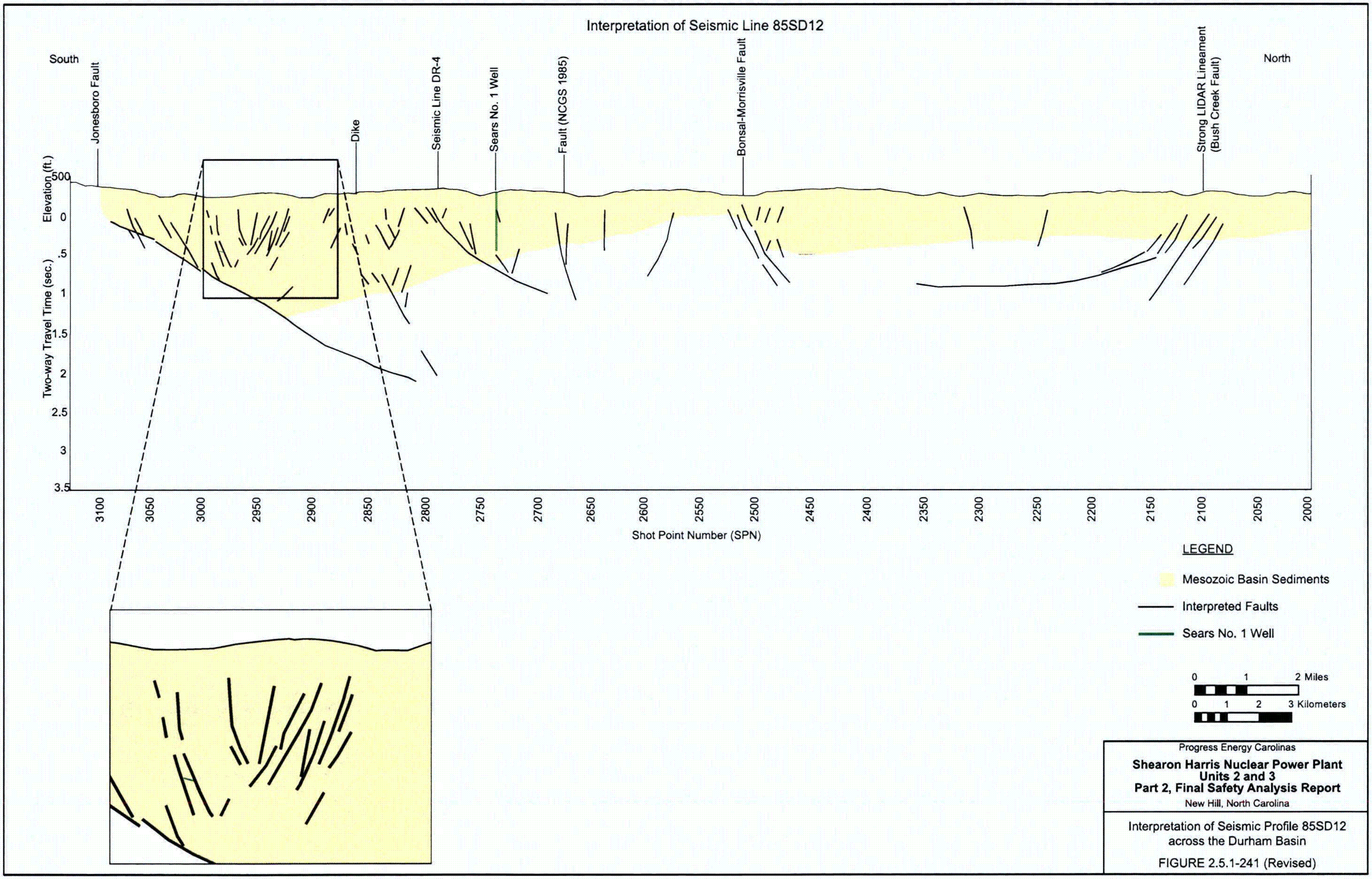

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New Hill, North Carolina

Interpretation of Seismic Profile 85SD12
across the Durham Basin

FIGURE 2.5.1-241 (Revised)

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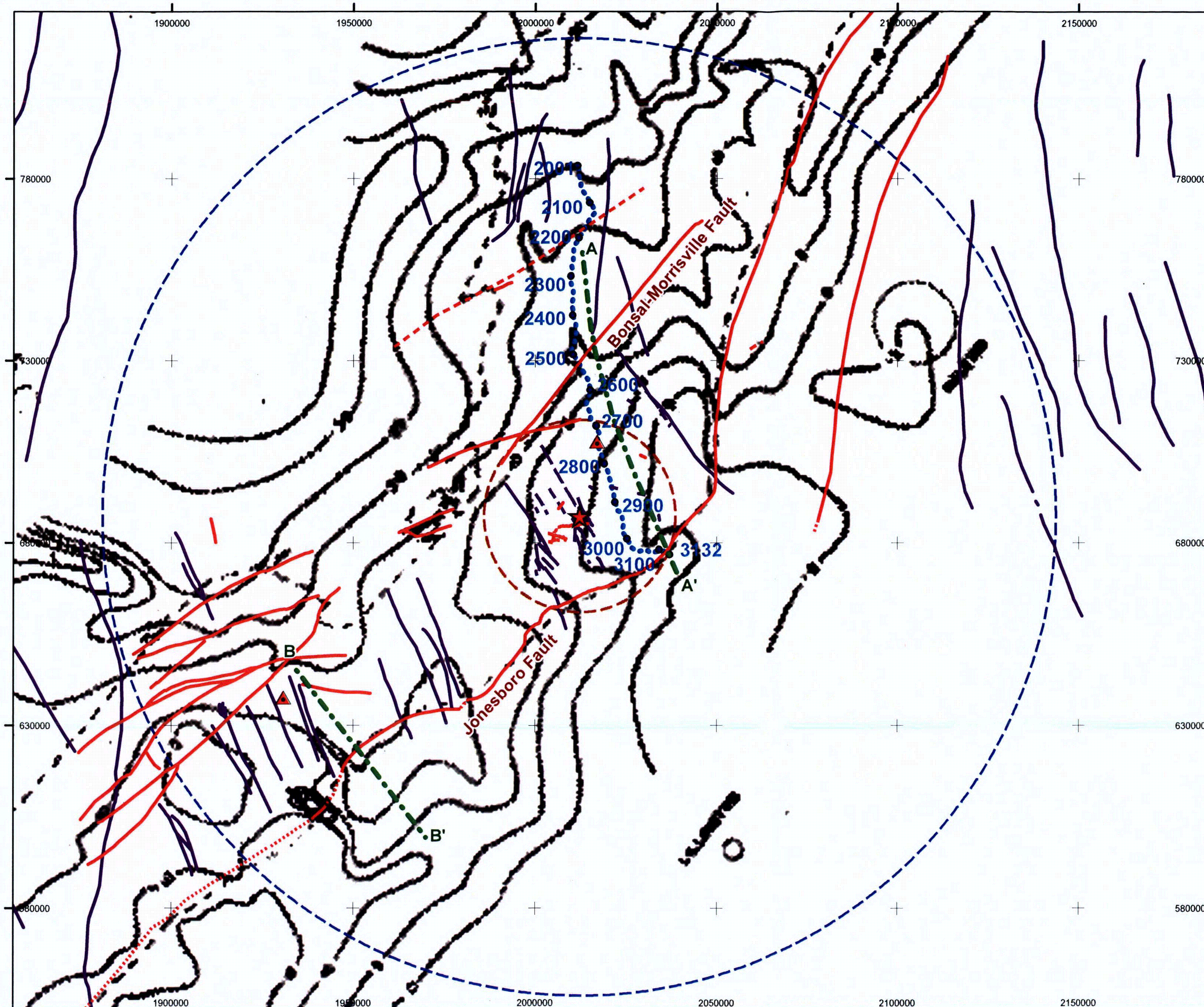

N
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LEGEND

HAR Site

Sears No. 1 and Groce No. 1 Wells (Bain and Brown, 1981)

City or Town

8-km (5-mi.) Radius from Site

40-km (25-mi.) Radius from Site

Resistivity Lines (Bain and Brown, 1981)

Seismic Reflection Line 85SD12 (Texaco, 1993)

2400 Shot Point Number (Texaco, 1993)

Faults (dashed where inferred, dotted where concealed) (Ebasco, 1975, CP&L, 1983, NCGS, 1985, Wooten et al., 1996, Harding Lawson, 1997, NCGS, 2006, and this study)

Dikes (dashed where inferred) (CP&L, 1983, NCGS, 1985, NCGS, 2006, and Technos, this study)

Bouger Gravity Contours (contour interval = 5 milligals) (Mann and Zablocki, 1961)

Grid is in the North Carolina NAD 83 State Plane Coordinate System (in feet)

Base Map: Mann and Zablocki (1961)

0 2.5 5 10 15
Kilometers
0 2.5 5 10
Miles

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New Hill, North Carolina

Bouger Gravity Map of the Durham Basin

RAI 02.05.01-21 FIGURE 1

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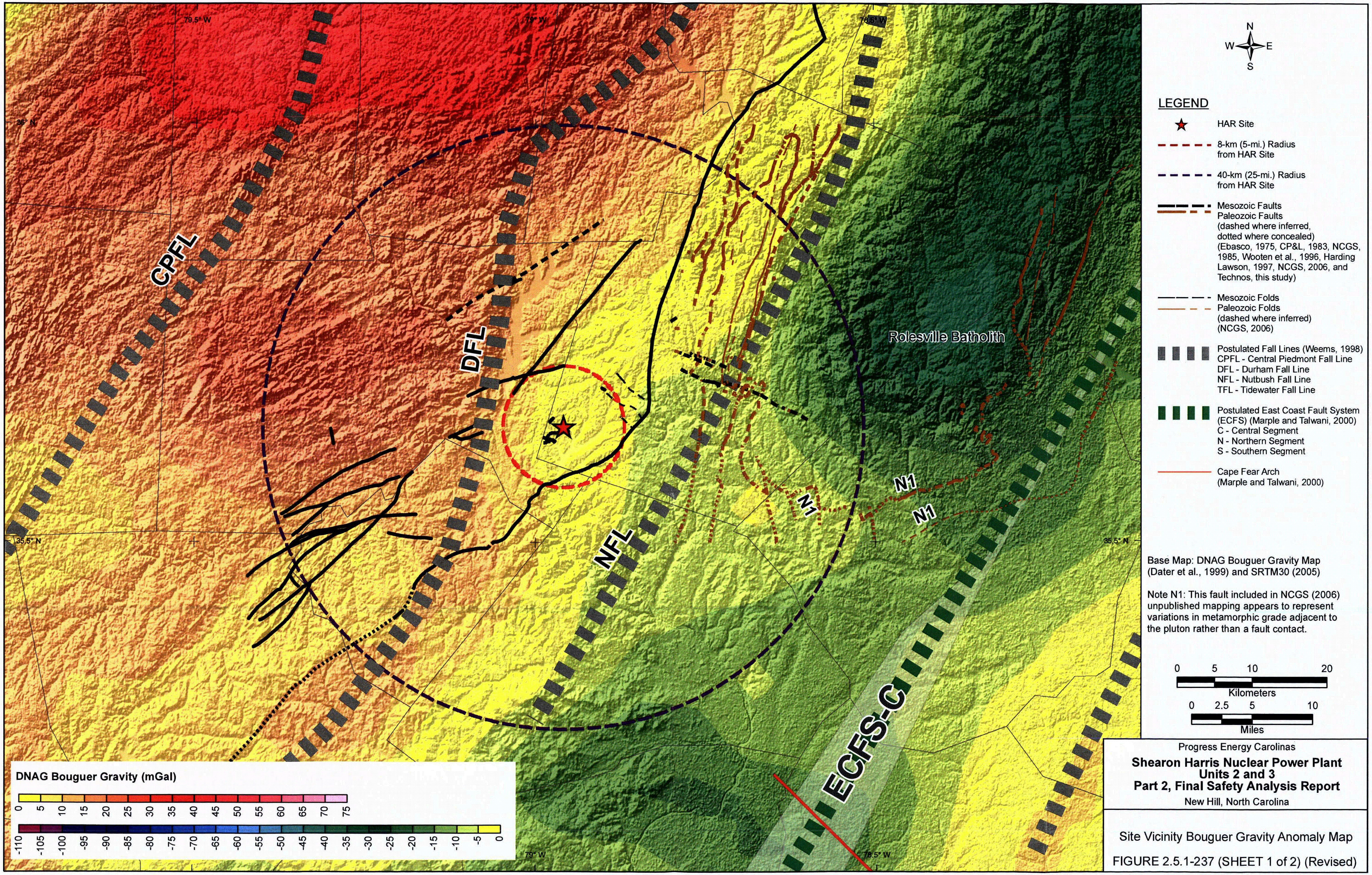

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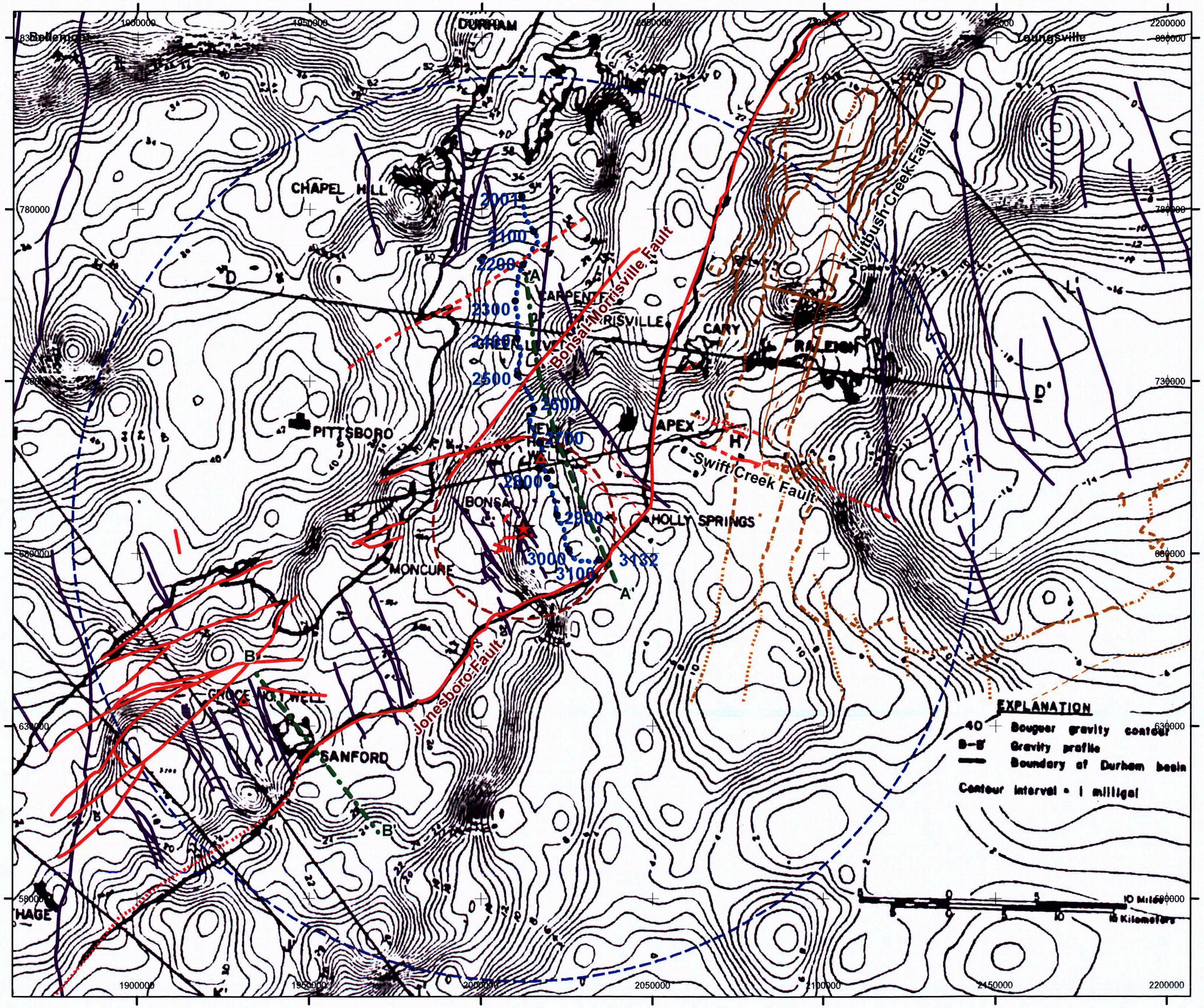

N
W E
S

LEGEND

- ★ HAR Site
- ▲ Sears No. 1 and Groce No. 1 Wells (Bain and Brown, 1981)
- ● City or Town
- 8-km (5-mi.) Radius from Site
- 40-km (25-mi.) Radius from Site
- Resistivity Lines (Bain and Brown, 1981)
- Gravity Profiles (Bain and Brown, 1981)
- Seismic Reflection Line 85SD12 (Texaco, 1993)
- 2400 ● Shot Point Number (Texaco, 1993)
- Paleozoic Faults
- Mesozoic Faults (dashed where inferred, dotted where concealed) (Ebasco, 1975, CP&L, 1983, NCGS, 1985, Wooten et al., 1996, Harding Lawson, 1997, NCGS, 2006, and this study)
- Paleozoic Folds
- Mesozoic Folds (dashed where inferred; NCGS, 2006)
- Dikes (dashed where inferred) (CP&L, 1983, NCGS, 1985, NCGS, 2006, and Technos, this study)

Grid is in the North Carolina NAD 83 State Plane Coordinate System (in feet)

Base Map: Bain and Brown (1981)

0 2.5 5 10 15
Kilometers

0 2.5 5 10
Miles

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New Hill, North Carolina

Bouger Gravity Map of the Durham Basin

RAI 02.05.01-21 Figure 2

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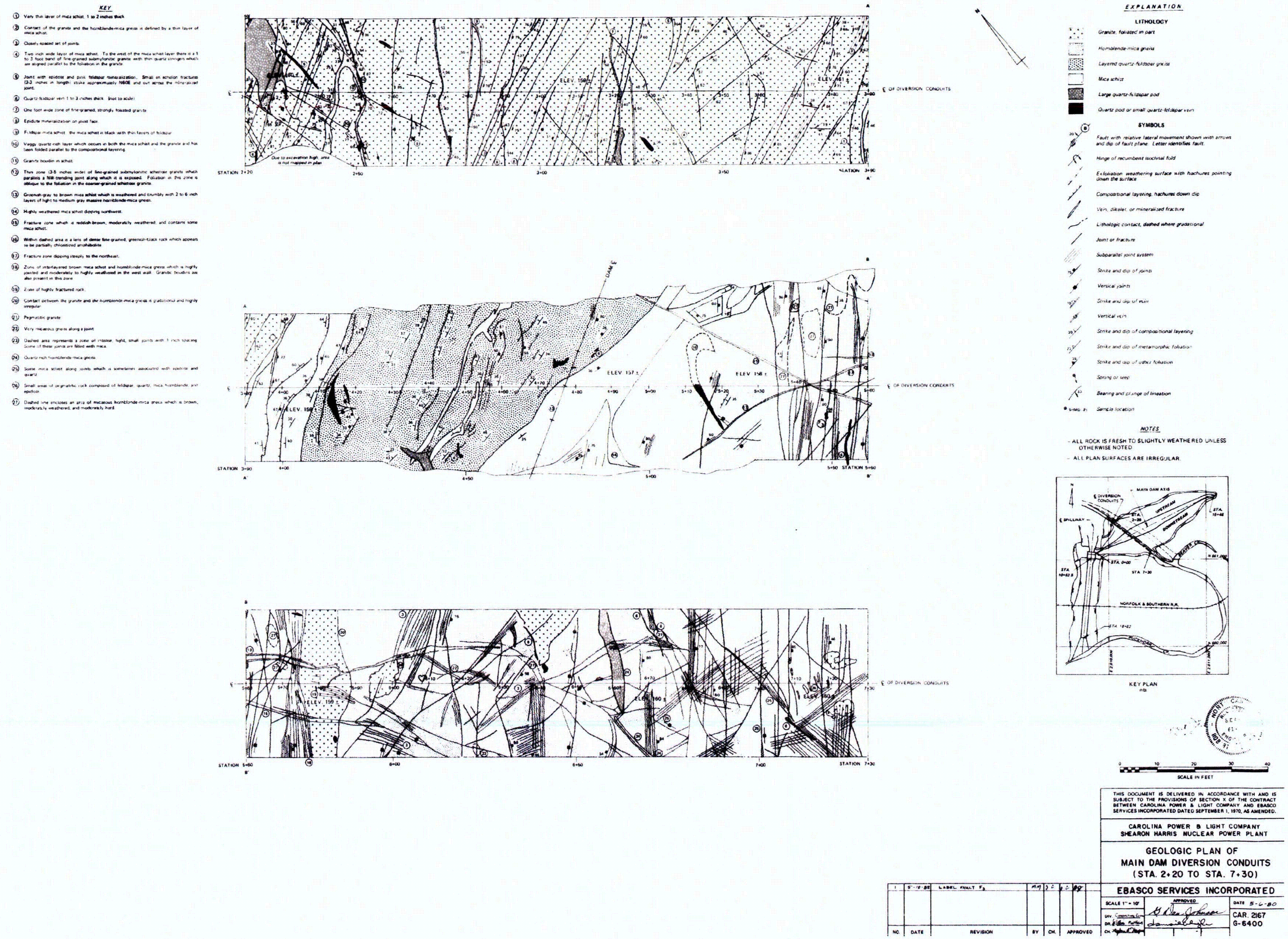

Source: Ebasco (1981)

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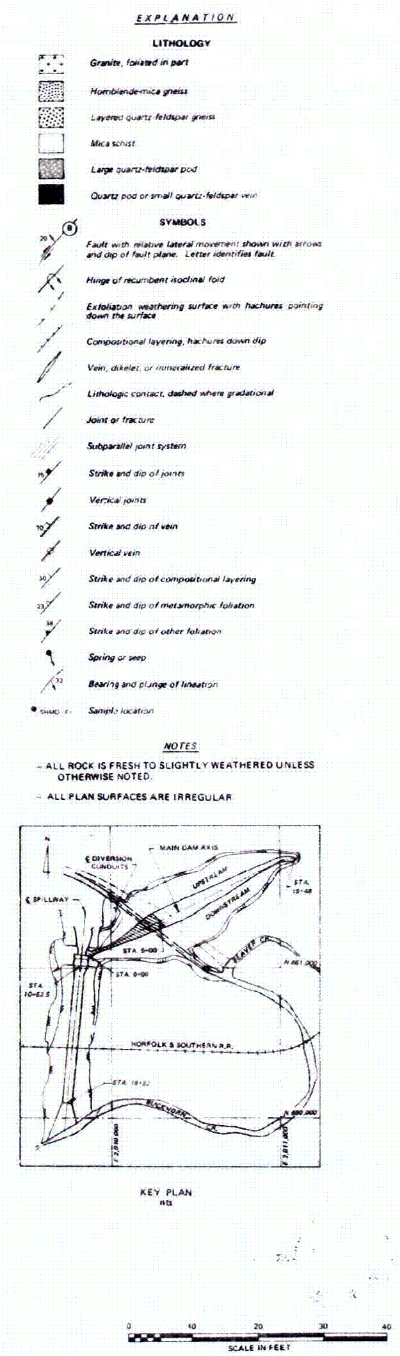
Units 2 and 3
Part 2, Final Safety Analysis Report
New Hill, North Carolina

Geologic Plan of Main Dam Diversion Conduits (STA. 2+20 to STA. 7+30)

RAI 02.05.01-23 FIGURE 1



Source: Ebasco (1981)

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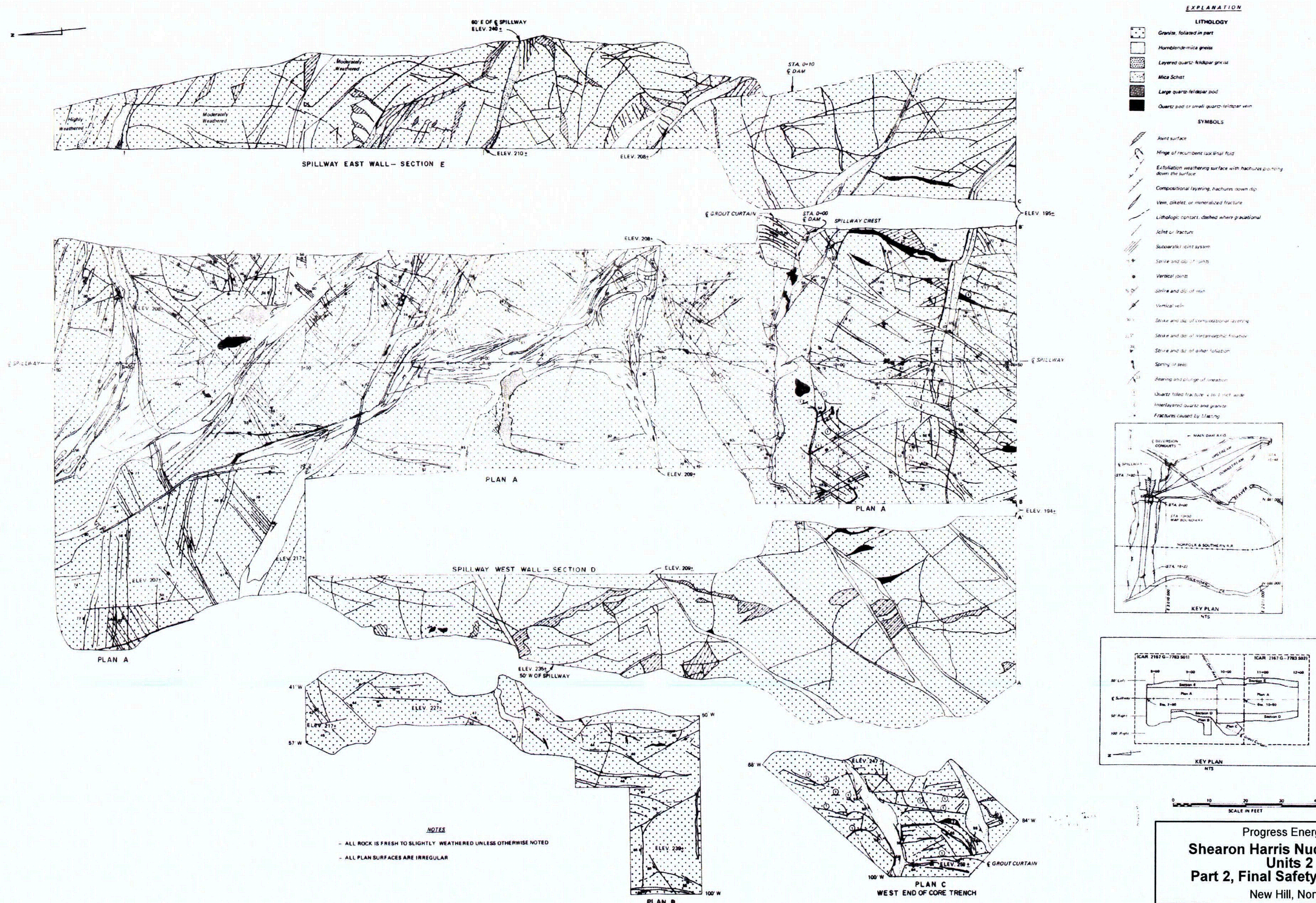
Part 2, Final Safety Analysis Report
New Hill, North Carolina

Geologic Plans of Main Dam Core Trench
(STA. 0+00 to STA. 5+00)
RAI 02.05.01-23 FIGURE 2 (SHEET 1 OF 3)



Source: Ebasco (1981)

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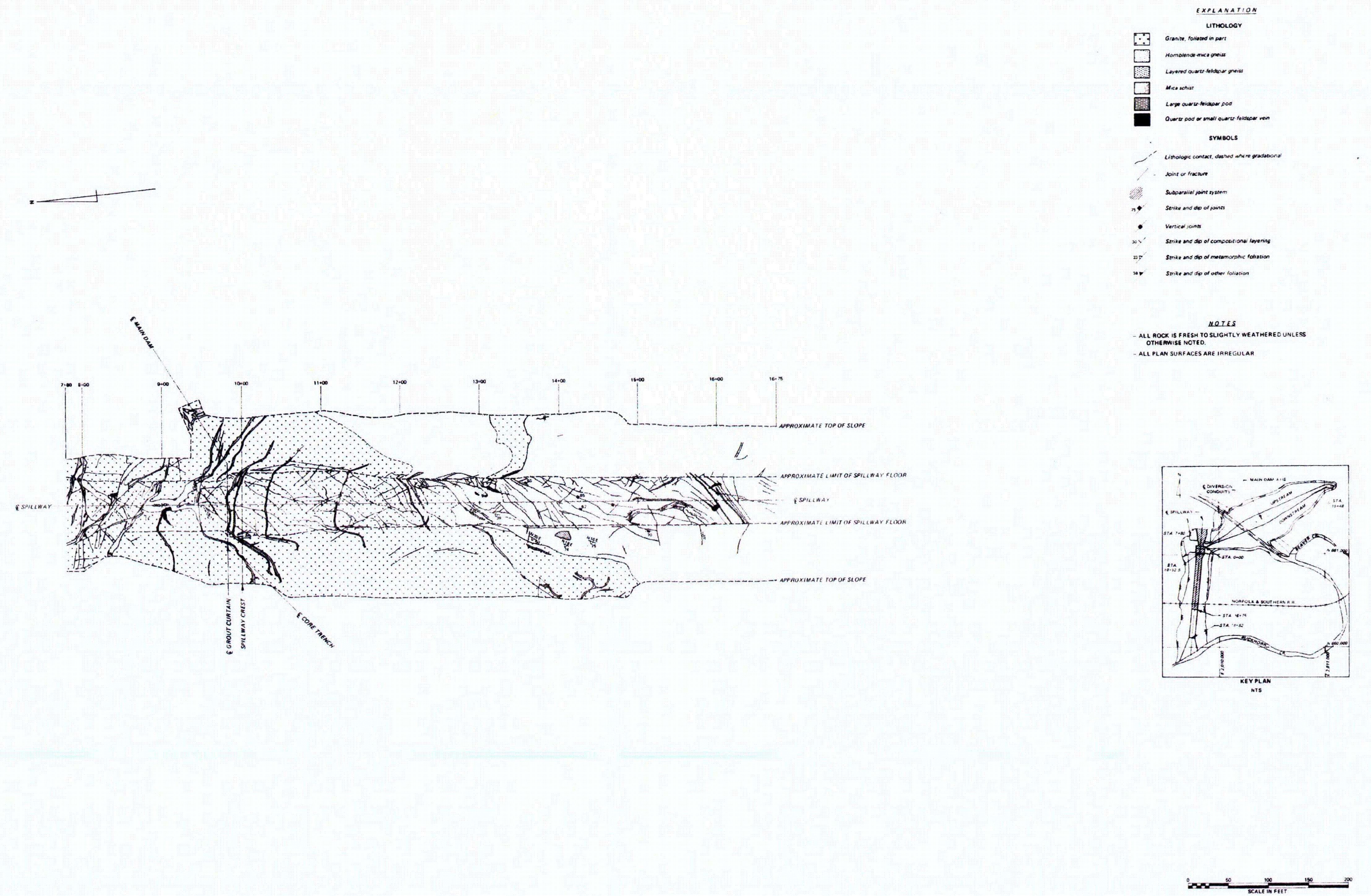
New Hill, North Carolina

Geologic Plans and Sections Main Dam Spillway (STA. 7+80 to STA. 10+50)

RAI 02.05.01-23 FIGURE 3 (SHEET 1 OF 2)

File Path: S:\11100\11151.002\Figures\RAI_RAI 02.05.01-23 Figure 3 (Sheet 1 of 2).ai; Date: [12/10/2008]; User: [sbozkurt]



Source: Ebasco (1981)

Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Part 2, Final Safety Analysis Report

New Hill, North Carolina

Geologic Plan of Main Dam Spillway Foundation

RAI 02.05.01-23 FIGURE 4

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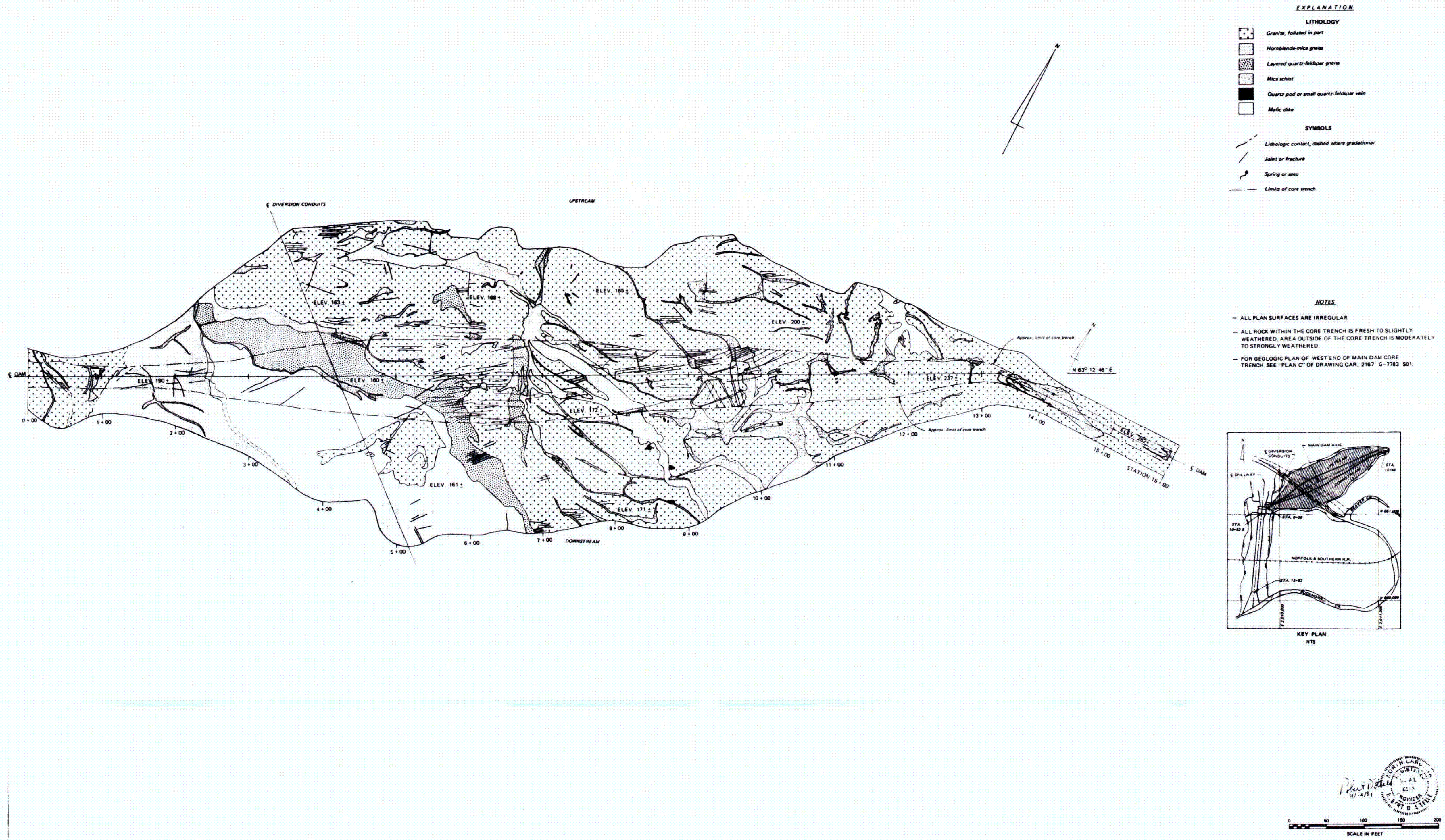

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Progress Energy Carolinas

Shearon Harris Nuclear Power Plant
Units 2 and 3
Part 2, Final Safety Analysis Report

New Hill, North Carolina

Geologic Plan of Main Dam Embankment

RAI 02.05.01-23 FIGURE 5

File Path: S:\11100\11151.002\Figures\RAI_RAI 02.05.01-23 Figure 5.ai; Date: [12/10/2008]; User: [sbozkurt]

STD DEP 1.1-1 2.5.3 **SURFACE FAULTING**

HAR COL 2.5-4 This subsection describes the evidence used to evaluate the potential for future surface faulting and related capable tectonic deformation at the HAR site and surrounding site area. The following aspects of the geology and seismicity of the site region are discussed:

- Geological, seismological, and geophysical investigations (Subsection 2.5.3.1).
- Geological evidence, or lack thereof, of surface deformation (Subsection 2.5.3.2).
- Earthquakes associated with capable tectonic sources (Subsection 2.5.3.3).
- Ages of most recent deformation (Subsection 2.5.3.4).
- Relationship between tectonic structures in the site area and regional tectonic structures (Subsection 2.5.3.5).
- Characterization of identified capable tectonic sources (Subsection 2.5.3.6).
- Designation of zones of Quaternary deformation in the site region (Subsection 2.5.3.7).
- Potential for surface tectonic deformation at the site (Subsection 2.5.3.8).

Results of the surface faulting study indicate that there is no evidence of Quaternary tectonic surface faulting or fold deformation at the HAR site, and no capable tectonic sources have been identified within 40 km (25 mi.) of the site. In accordance with Regulatory Guide 1.208, a capable tectonic source is defined as a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation, such as faulting or folding at or near the earth's surface in the present seismotectonic regime.

2.5.3.1 Geological, Seismological, and Geophysical Investigations

Investigations that have been performed to evaluate the potential for surface fault rupture at the HAR site, as well as the surrounding HAR site area, include the following:

- Compilation and review of existing data and literature.
- Lineament analyses.
- Discussions with current researchers in the area.
- Field reconnaissance.
- Review of seismicity data.

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<#>Geomorphic analyses.¶

2.5.3.1.1 Compilation and Review of Existing Data and Literature

An extensive body of existing information is available regarding faulting in the HAR site area. The following principal sources of data were used:

- Documents developed in support of licensing of the HNP. These include the HNP FSAR (Reference 2.5.3-201), a two-volume report entitled "Fault Investigation: Shearon Harris Nuclear Power Plant, Units 1, 2, 3, 4" (Reference 2.5.3-202), and reports summarizing faulting investigations in the Main Dam and auxiliary areas (Reference 2.5.3-203).

- U.S. Geological Survey Open-file Report by Bain and Brown (Reference 2.5.3-xxx) that summarizes detailed geophysical and remote sensing studies conducted by the U.S.G.S. to evaluate the potential waste storage potential of the Durham basin.

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- Site characterization reports and data collected in support of a proposed LLRW disposal facility site in Wake County adjacent to and west of the existing HNP site (Reference 2.5.3-204).

- Investigations of faults exposed at two borrow pits approximately 2.4 km (1.5 mi.) west of the HAR site (Reference 2.5.3-205, Reference 2.5.3-206).

- Published geologic maps and unpublished maps and data made available by the NCGS (Reference 2.5.3-207, Reference 2.5.3-208).

- Seismicity data from published literature, recent analysis of historical seismicity in the region (Reference 2.5.3-209), and analysis completed for this study.

2.5.3.1.2 Lineament Analyses

Investigations for the HNP (Reference 2.5.3-201, Reference 2.5.3-202) involved extensive interpretation of aerial photographs and other remote sensing imagery, including conventional high- and low-altitude aerial photography (including false color enhancement), and Skylab and Landsat imagery. Several hundred lineaments were identified by these investigations. Field checking included at least one checkpoint along each significant lineament, with greater emphasis on those lineaments closest to the site. No linear features were identified as capable faults based on the imagery analysis, and none of the lineaments that were field checked were identified as faults. (Reference 2.5.3-201)

LIDAR data released by the North Carolina Department of Transportation in March 2005 provide improved, more detailed images of surface topography than was available during the HNP FSAR study (Reference 2.5.3-201). LIDAR data are available for most of the state of North Carolina at a grid size of 46 m (150 ft.), and at the county level at a grid size of 6 m (20 ft.). The more detailed county-level data were used in this study to identify lineaments within the site area. Lineaments were mapped using hillshade models of the 6 m (20 ft.) grid elevation data for Wake, Chatham, Lee, and Harnett counties. Each elevation location has been rounded to the nearest foot and represents the average elevation for the entire grid cell. The vertical accuracy of the LIDAR data is about 25 cm (10 in.). (Reference 2.5.3-210) Hillshade models were generated from county elevation data using ArcGIS Spatial Analyst (azimuth = 315°, altitude = 45, z factor = 1) with an output grid cell size of 6 m (20 ft.) Lineaments were identified on the hillshade models in ArcGIS for the site area's 8-km (5-mi.) radius, and are discussed in Subsection 2.5.3.2.2.

2.5.3.1.3 Discussions with Current Researchers in the Area

Researchers were contacted who were familiar with the structural and tectonic framework of the region, Coastal Plain stratigraphy, and post-Cretaceous faulting in the Coastal Plain; these researchers provided recently published and in-press publications for review. Mr. Timothy (Tyler) Clark, former head geologist for the NCGS, led a field trip to provide an overview of Mesozoic rift basin stratigraphy in the site area and participated in field and helicopter reconnaissance to investigate faults in the site vicinity.

2.5.3.1.4 Field Reconnaissance

Field reconnaissance was conducted as part of the HAR site characterization activities. The field investigations focused on (1) a review of the geology of the site location (within approximately 1 km [0.6 mi.] of the HAR site) and site area (within a radius of approximately 8 km [5 mi.]); and (2) reconnaissance of localities of reported Cenozoic faulting and postulated features suggestive of possible neotectonic activity in the site vicinity and surrounding region (e.g., the postulated ECFS [Reference 2.5.3-211] and "fall lines" of Weems [Reference 2.5.3-212]). An aerial reconnaissance was conducted to further evaluate these features.

2.5.3.1.5 Review of Seismicity Data

A comprehensive review of both instrumental and historical earthquakes was completed for the HAR study (see Subsection 2.5.2.1). A map showing seismicity within an 80-km (50 mi.) radius of the site is shown on RAI 2.5.1-8 Figure 2.

2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

The HAR site area (an 8-km [5-mi.] radius) sits largely within the Deep River basin, a north- to northeast-trending half-graben. The HAR site is located approximately 6.4 km (4 mi.) north of the Jonesboro fault, the major west-dipping, high-angle, normal boundary fault that separates the Triassic sedimentary rocks from the Raleigh metamorphic belt and the Carolina zone metavolcanic and metasedimentary rocks (Figures 2.5.1-230, 2.5.1-231, and 2.5.1-232). As illustrated on Figure 2.5.1-240, the site sits in the hanging wall of the Jonesboro fault, which locally is disrupted by distributed synthetic and antithetic faults. Small-scale intrabasin and cross-basin faults in the site area also have been identified based on surface geological investigations, subsurface trenching and drilling, and interpretation of seismic reflection data. The closest, well-documented faults to the HAR site include the Harris fault, the SBPF, and the W8 and W82 faults (Figure 2.5.1-232). Additional minor faults were exposed within igneous and metamorphic rocks in the foundations of the Main Dam structures approximately 8 km (5 mi.) south of the HAR 2 site (Figure 2.5.1-230, Reference 2.5.3-203). These structures are described in detail in Subsection 2.5.1.2.4.

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To further investigate geomorphic features cited as evidence for possible neotectonic activity in the site vicinity (e.g., the postulated ECFS and fall lines of Weems [Reference 2.5.3-212]), longitudinal profiles of the major rivers crossing these features were developed from the LIDAR-generated digital elevation model (Figures 2.5.1-219 and 2.5.1-220). These profiles, combined with other geologic data, were used to evaluate the origin and tectonic significance of these features. A discussion of the interpretation of these data is provided in Appendix ??¶

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Extensive geologic investigations were performed to assess surface faulting at the HNP site during the construction and licensing of the HNP facilities. The Harris fault, a minor cross-basin fault within the basin, also referred to as the "Site fault" in the HNP FSAR and HNP FSER documents and NUREG-1038, was discovered in the foundation of the Plant Waste Processing Building during excavation (Reference 2.5.3-201, Reference 2.5.3-202). Preconstruction site characterization activities, which included 3700 m (12,125 ft.) of trenching (at depths of 0.6 to 3.6 m [2 to 12 ft.]), numerous geologic borings to depths of 15 to 76 m (50 to 250 ft.), and approximately 1500 linear m (5000 linear ft.) of seismic refraction survey lines (Figure 2.5.3-201), failed to show evidence of this fault or other surface faulting (Reference 2.5.3-201). The two trenches appear to have intersected each other and the fault at a location along the margin of a gully. At this location the trenches do not appear to have been excavated deep enough to provide sufficient exposure of unweathered bedrock in which the fault would have been more easily identified. After the Harris fault was discovered in the waste building excavation, a comprehensive fault investigation program was completed by Ebasco Services, Inc., to evaluate the location, style of faulting, and age of the most recent movement. ... [1]

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Investigations conducted for the HNP after the Harris fault was identified included extensive use of remote sensing techniques to seek other linear features in the site region and area (Reference 2.5.3-202). The lineaments identified in the site area by these investigations are shown on Figure 2.5.3-202. Although several hundred lineaments were identified using these aerial photograph and remote sensing techniques, no linear features were identified as capable faults on the basis of imagery evaluation, nor were any that were field checked identified as faults. The Site fault was undetected by any imagery technique. (Reference 2.5.3-201)

A more recent technique known as LIDAR (light detection and ranging) provides improved images of surface topography. In contrast to the previous conclusions based on the lineament analysis completed as part of the HNP FSAR (Reference 2.5.3-201), the a possible extension of the Harris fault and other east-southeast-trending faults identified in the LLRW disposal facility area do appear to coincide locally with lineaments identified in the LIDAR data. The Harris fault, the SBPF, and the W8 and W82 faults characterized in the LLRW disposal facility site to the west all appear to be associated with a discontinuous set of east-to-west-trending lineaments that extend across the site area (Figure 2.5.3-203). The lineaments that are closely associated with mapped faults appear to reflect differential erosion along zones of more fractured bedrock. No evidence to indicate that the faults are capable tectonic sources was identified from the lineament analysis. The results of the LIDAR lineament analysis are discussed in Subsection 2.5.3.2.2.

2.5.3.2.1 Results of Lineament Analysis

As described in Subsection 2.5.3.1, a lineament analysis was undertaken as part of the HAR study to identify and characterize lineaments in the site area that might intersect the HAR site. Previous investigations for the HNP (Reference 2.5.3-201, Reference 2.5.3-202) involved extensive aerial photograph interpretation and other remote sensing techniques including conventional high- and low-altitude aerial photograph, SLAR, including false color enhancement, and Skylab and Landsat imagery (Reference 2.5.3-201). The HNP FSAR stated, "No linear features were identified as capable faults on the basis of imagery evaluation, nor were any that were field checked identified as faults. The Harris fault was undetected by any imagery technique" (Reference 2.5.3-201). Figure 2.5.3-202 shows the previously interpreted lineaments, mapped faults, and dikes in the site area superimposed on the LIDAR image. Although some of the previously identified lineaments correspond to lineaments that can be identified using the new LIDAR data, many of them do not correspond to topographic lineaments and may have been representative of cultural features. Additionally, lineaments observed from the NCGS SLAR and Landsat imagery were identified in the field or on maps as diabase dikes, faults, lithologic contacts, streams, roads, power lines, and pipelines (Reference 2.5.3-214). In the SLAR imagery, faults and fractures appeared as linear depressions (Reference 2.5.3-214).

Several trends of lineaments are apparent in the LIDAR data (Figure 2.5.3-203 and Figure 2.5.3-206). The main trends are between N30W to N30E and east to west to N60E or N60W (Figure 2.5.3-206). Many of these, which are defined by small drainages, appear to reflect the dominant joint and fracture sets that are recognized in the region. As reported in the HNP FSAR (Reference 2.5.3-201), three joint sets are present in the Triassic sedimentary rocks: the two dominant sets are approximately vertical, one striking N40 to 50E and the other N20 to 30W; a third set strikes north to northwest and

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Geophysical data used to evaluate structures in the HAR site area and vicinity include gravity surveys, magnetic surveys, aeromagnetic surveys, and seismic refraction (see Subsection 2.5.1.2.4.1). Gravity ... [2]

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dips 55° to 70° southwest. Bedding in the Triassic in the site area primarily is between north to south to N35E, and it appears that many of the small drainages are parallel to bedding and probably formed by differential weathering of the more easily eroded beds. The dikes generally are aligned subparallel to the N20° to 30W trend, but shorter east-to-west-trending dikes have been mapped in the New Hill 7.5-minute quadrangle (Figure 2.5.1-231). (Reference 2.5.3-208) East-to-west-oriented lineaments also are apparent in the LIDAR data. Lineament analysis by Bain and Brown (Reference 2.5.3-214) from SLAR data could not identify east-to-west lineaments because of the flight direction. Bain and Brown (Figure 2.5.3-206) also identified more distinct preferred directions of lineaments compared to the LIDAR analysis in this study (Reference 2.5.3-214). This may be due in part to cultural features identified in the SLAR imagery.

In contrast to the previous conclusions based on the lineament analysis completed as part of the HNP FSAR, what appears to be an easterly extension of the Harris fault and other east-to-southeast-trending faults identified in the LLRW disposal facility area, as well as portions of the Jonesboro fault, do appear to coincide with lineaments identified in the LIDAR data (Reference 2.5.3-201). The possible eastward extension of the Harris fault, as well as the SBPF and W82 faults, characterized in the LLRW disposal facility site to the west all appear to coincide with a set of generally east-to-west-trending lineaments that can be traced across the site area (Figure 2.5.3-203). Although the faults do not directly correspond to lineaments defined by the drainage bottoms, it is likely that the drainages are localized in the more fractured and more easily eroded areas on the hanging wall, as seen at the LLRW disposal facility (Reference 2.5.3-204).

One of the longer of these east-west-trending lineaments extends across the northernmost part of the HAR site location, approximately 150 m (500 ft.) north of the HAR 3 site (Figure 2.5.3-206). The lineament, which trends east to southeast, is identified primarily by a series of aligned drainages, , including the drainage currently impounded to form the fire pond. The HNP, HAR 2, and HAR 3 sites appear to lie between the Harris fault and this lineament, which is referred to as the fire pond lineament (FPL).

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The origin of the FPL is unknown. There are no surface exposures of bedrock where the lineament crosses Old Highway 1 approximately 2.9 km (1.8 mi.) southwest of Bonsal (point FPL-1), Highway 1 (point FPL-2), along the railroad and stream cuts northwest of HAR 3 (FPL-3), or along the projected trend of the lineament where it crosses a spur off SR 1134 (FPL-4), and or the main access road into the HNP site (SR 1134) (FPL-5) (Figure 2.5.3-206).

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The closest exposure of bedrock to the FPL is located along the outflow channel to the fire pond northeast of the HAR 3 site. Exposures of interbedded siltstones and sandstones of Lithofacies I Unit Trcs/si2 (Figure 2.5.3-208) in the outflow channel for the fire pond north of HAR 3 display four prominent fracture sets: N5E, N30° to 50W, N35E, and N85W. The N85W-trending fracture is open and parallels the trend of the FPL (Figure 2.5.3-209). Bedding is oriented approximately N15E, and dips approximately 17 to 30 degrees northeast at this location. No evidence of faulting or disruption of the soils formed in these deposits was observed.

East-west trending lineaments along the projected trends of the FPL and the Harris faults intersect the Texaco seismic line 85SD12 (Figure 2.5.3-203). These lineaments appear to be associated with an approximately 5-km (3-mi) wide zone of secondary faults in the hanging wall of the Jonesboro fault (Figure 2.5.1-241). Based on the possible alignments of the FPL and Harris faults with the lineaments associated with the faults identified in the Texaco seismic line, it is reasonable to assume that the HNP, HAR 2, and HAR 3 sites lie within a similar zone of secondary, small normal faults in the hanging wall of the Jonesboro fault. It is noted, however, that the FPL lineament cannot be directly linked to the east-west trending lineament that crosses the seismic line.

The FPL may be related to a secondary fault of similar age to the Harris fault based on similarities in orientation and geomorphic expression. If the FPL is coincident with a fault, it is likely that the lineament represents differential erosion of more highly fractured or deformed rock. No scarps were observed across the projected trends of the FPL during field reconnaissance conducted for this study. There is no evidence to indicate that the FPL is the surface expression of a capable tectonic source.

Another well expressed LIDAR lineament approximately 21 km (13 mi.) northwest of the site trends N60E and corresponds to the Bush Creek fault mapped by the NCGS (Reference 2.5.3-208). Where the lineament that corresponds to the Bush Creek fault crosses seismic line 85SD12, a zone of primarily down-to-the-south normal faulting is observed in the seismic profile (Figure 2.5.1-236 and Figure 2.5.1-241). There is no reported evidence of Quaternary deformation along this feature.

2.5.3.2 Correlation of Earthquakes with Capable Tectonic Sources

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There have been no historically reported earthquakes or alignments of earthquakes within 40 km (25 mi.) of the site that can be associated with a mapped bedrock fault (see Subsection 2.5.2.1). No earthquakes greater than mb = 3.0 are identified in the site vicinity and the largest and only earthquake within an 80 km- (50 mi.-) radius of the site is an mb= 3.3 earthquake that occurred in 1896.

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2.5.3.3 Ages of Most Recent Deformations

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Detailed studies to determine the age of mapped faults in the study area were performed as part of the HNP fault investigations (Reference 2.5.3-202, Reference 2.5.3-201). The age of last movement on the Jonesboro fault is bracketed between the intrusion of Late Triassic – Jurassic dikes and the deposition of the overlying unfaulted Cretaceous marine sediments, between 180 and 135 Ma (Reference 2.5.3-202).

Diabase dikes, secondary minerals in fault gouge adjacent to the dikes, and soils were used to constrain the age of the last movement on the Harris fault. Detailed studies to determine the age of most recent deformation on the Harris fault are described in Subsection 2.5.1.2.4. Movement along the Harris fault occurred after deposition and lithification of several thousand feet of Triassic basin sediments and ended shortly after intrusion of the latest of the Jurassic dikes (Reference 2.5.3-201). Field observations of undisturbed soil, saprolite, and in one place, a post-Triassic sedimentary deposit overlying the fault, indicated that the most recent movement was probably greater than one million years ago (Reference 2.5.3-201). Secondary zeolite minerals that formed in the fault zone along the Harris fault during thermal conditions that were last present in the region over 150 Ma are undeformed, indicating that the most recent movement predated this time (Reference 2.5.3-201). According to NUREG-1038, the NRC staff concurred that all the faults in the HNP site and Main Dam areas predate the

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mineralization that formed after regional deformation — at least 2.5 Ma, and likely more than 136 to 190 Ma.

No detailed geochronologic data exist for the borrow pit faults (SBPF, FA, FB, FC), fault W8, or fault W82; however, geologic relations suggest these faults were last active in the Triassic period (see Subsection 2.5.3.1.4 and Subsection 2.5.3.1.5 for a more detailed discussion).

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Based on the location and orientation of the FPL and its projection onto the Texaco Seismic Line 85SD12, it is possible that the FPL is the surface expression of a fault similar to the Harris fault in the hanging wall of, and antithetic to the Jonesboro fault. No age data is available for the feature. Based on structural relationships interpreted from the Texaco Seismic Line 85SD12, the FPL likely formed at approximately the same time as the Jonesboro and Harris faults, likely greater than 135 Ma.¶

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2.5.3.4 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

Mapped surface bedrock faults within the site area (8-km [5-mi.] radius) are primarily related to the formation of the Mesozoic Deep River basin. There is no new information to suggest that the faults associated with the Mesozoic basins in the site region are capable tectonic structures as defined by Regulatory Guide 1.165 (Appendix A).

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2.5.3.5 Characterization of Capable Tectonic Sources

A "capable tectonic source," as defined by Regulatory Guide 1.208, is described by at least one of the following characteristics:

- Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years, or at least once in the last approximately 50,000 years.

- A reasonable association with one or more large earthquakes or sustained earthquake activity that usually is accompanied by significant surface deformation.

- Structural association with a capable tectonic source having characteristics of section (1) above, such that movement on one could be reasonably expected to be accompanied by movement on the other.

None of the mapped bedrock faults within a 40-km (25-mi.) radius or possible fault-related lineaments (e.g., the FPL) within an 8-km (5-mi.) radius of the HAR site is assessed to be a capable tectonic source. This conclusion is based on the following lines of evidence as discussed in the previous subsections:

- The Jonesboro fault is overlain by undeformed Cretaceous sediments (Reference 2.5.3-202).

- Detailed investigations to evaluate the Harris fault, including trenching, drilling, and mapping, have provided detailed geochronologic data that demonstrate faulting is likely older than 150 Ma.

- Structural analysis of the development of faults and fractures exposed at the borrow pit and LLRW areas suggest that these structures pre-date or formed during the same stress regime as the Harris fault.

- Evidence observed in trenches that shows that the faults identified at the LLRW disposal facility site, approximately 1.5 mi. west of the HAR site, predate significant weathering and soil formation or exhibit no evidence of recent faulting (Reference 2.5.3-206).

- No evidence of Quaternary deformation is reported in the literature or was observed during field and aerial reconnaissance conducted for this study.

- There are no associated historical earthquakes or alignments of seismicity to suggest the presence of a capable tectonic source in the site area.

- East-west trending lineaments such as the FPL and the lineament along the eastward projection of the Harris fault if related to faults can be explained as due to differential erosion of fractured rock associated with secondary faults in the hanging wall of the Jonesboro fault. There is no surface expression of recent faulting along the FPL.

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- Based on structural association with the Harris fault, it is expected that faults or folds that may be expressed as lineaments in the rift basin sediments in the site area likely formed during the same period of deformation and, therefore, are not capable tectonic sources. Excavation exposures for HAR safety-related facilities will be mapped in detail and the surface rupture and ground motion generating potential of any deformation features identified will be assessed.

2.5.3.6 Designation of Zones of Quaternary Deformation in the Site Region

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No zones of Quaternary deformation that would require additional investigation are identified within the HAR site area. Investigations of the Harris fault and other more minor faults observed in the Main Dam area showed that these faults are not capable, in accordance with 10 CFR 100, Appendix A (Reference 2.5.3-201). Review of existing HNP documents, mapping, and subsurface investigations conducted for this study identified no evidence for surface deformation at either the HAR 2 or the HAR 3 sites.

2.5.3.7 Potential for Surface Tectonic Deformation at the Site

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The potential for tectonic deformation at the HAR site is assessed to be negligible. This conclusion is based on the following:

- The results of comprehensive fault investigations that have demonstrated that mapped faults within the site area are not capable faults (Reference 2.5.3-202, Reference 2.5.3-203).

- Bedrock geologic mapping in the site vicinity (Reference 2.5.3-208, Figure 2.5.1-231) that identified no evidence for surface faulting or deformation that would suggest capable faults in the HAR site area.

- The absence of geomorphic features indicative of Quaternary deformation as reported in the previous HNP reports and literature and inferred from observations made during the field reconnaissance conducted for this study.

The floors and walls of excavations for all safety-related structures for the HAR 2 and HAR 3 facilities and adjoining regions will be mapped in detail, and the NRC will be notified immediately if previously unknown geologic features that could represent a hazard to the proposed facilities are identified. Following Regulatory Guide 1.165, any potential deformation feature identified in the excavations will be characterized to assess surface deformation or ground motion generating potential.

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Extensive geologic investigations were performed to assess surface faulting at the HNP site during the construction and licensing of the HNP facilities. The Harris fault, a minor cross-basin fault within the basin, also referred to as the "Site fault" in the HNP FSAR and HNP FSER documents and NUREG-1038, was discovered in the foundation of the Plant Waste Processing Building during excavation (Reference 2.5.3-201, Reference 2.5.3-202). Preconstruction site characterization activities, which included 3700 m (12,125 ft.) of trenching (at depths of 0.6 to 3.6 m [2 to 12 ft.]), numerous geologic borings to depths of 15 to 76 m (50 to 250 ft.), and approximately 1500 linear m (5000 linear ft.) of seismic refraction survey lines (Figure 2.5.3-201), failed to show evidence of this fault or other surface faulting (Reference 2.5.3-201). The two trenches appear to have intersected each other and the fault at a location along the margin of a gully. At this location the trenches do not appear to have been excavated deep enough to provide sufficient exposure of unweathered bedrock in which the fault would have been more easily identified. After the Harris fault was discovered in the waste building excavation, a comprehensive fault investigation program was completed by Ebasco Services, Inc., to evaluate the location, style of faulting, and age of the most recent movement. The results of this study are well documented in a report by Ebasco Services, Inc. (Reference 2.5.3-202).

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Geophysical data used to evaluate structures in the HAR site area and vicinity include gravity surveys, magnetic surveys, aeromagnetic surveys, and seismic refraction (see Subsection 2.5.1.2.4.1). Gravity maps could not be correlated satisfactorily with either the outline of the Deep River basin or the entire trace of the Jonesboro fault, and the Harris fault was not reflected in those records (Reference 2.5.3-201). Magnetic and aeromagnetic studies were successful in locating a number of diabase dikes, but were not helpful in locating faults in areas where no dikes were present (Reference 2.5.3-201).

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Geologic Structures in the Site Area (8-km [5-mi.] Radius)

Key observations made from the literature review and field reconnaissance regarding the geologic structures and the potential for surface faulting in the site area (an 8-km [5-mi.] radius) are summarized in the following subsections. Additional information about the structural geology of the site area is discussed in Subsection 2.5.1.2.

Jonesboro Fault

The Jonesboro fault, the major boundary fault on the southeastern margin of the Deep River basin, is a northeast-to-southeast-trending, northwest-dipping oblique normal slip fault that is more than 160 km (100 mi.) long and has vertical displacement of 1500 to 3000 m (5000 to 10,000 ft.) and unknown lateral displacement (Reference 2.5.3-201). It marks the contact between Triassic sedimentary rocks to the west and Paleozoic volcaniclastic and crystalline rocks to the east (Figure 2.5.1-230). The fault, which is located approximately 6 km (4 mi.) to the southeast of the HAR site, was mapped in reconnaissance as part of the HNP site licensing. The trace of the fault crosses the lower end of the Harris Reservoir less than 1.6 km (1 mi.) north of the Main Dam (Figures 2.5.1-230, 2.5.1-231, and 2.5.3-204). (Reference 2.5.3-201) Magnetic and reconnaissance surveys were conducted on diabase dikes and "cross-faults" occurring along the Jonesboro fault in an effort to constrain the timing of faulting on the Harris fault. None of the dikes mapped at these locations are continuous across the Jonesboro fault, indicating that the amount of offset between dikes varies from 400 to 130 m (1300 to 420 ft.). (Reference 2.5.3-201) The age of last movement on the Jonesboro fault is bracketed between the intrusion of Late Triassic-Jurassic dikes and the deposition of the overlying unfaulted Cretaceous marine sediments, between 180 and 135 Ma (Reference 2.5.3-202).

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to be a capable fault (Reference 2.5.3-201).

Recent investigations support the HNP FSAR conclusion that the Jonesboro fault is not a capable tectonic source. No evidence of faulting in Cretaceous or younger sediments that overlie the Jonesboro fault (Reference 2.5.3-208) has been documented on recent maps of the Cokesbury 7.5-minute quadrangle map (Reference 2.5.3-???) and the 1:1.000,000 Raleigh sheet (Reference2.5.3-). Existing exposures of the Jonesboro fault are rare. During a period of abnormally low lake level in 1995 a normally submerged exposure of the fault was observed by Tyler Clark (NCGS) along the Shearon Harris reservoir shoreline approximately km south of where Buckhorn Creek enters the lake (point ?? on Figure 2.5.3-?). At this location very saprolitic coarse grained Triassic sediment was observed to be juxtaposed against a saprolitic light-colored sandstone interpreted to be Buckhorn granite/granodiorite. The contact between the two units, the Jonesboro fault, was observed to be an approximately 0.5 m (? ft.) wide zone of anatomosing fault surfaces and fault breccia. As observed at other locations along the Jonesboro fault, ductile deformation features overprinted by brittle deformation observed at this location suggest that the fault initiated at depth in the ductile realm and later experienced brittle deformation due to footwall uplift. A wave-cut scarp at the faulted contact was interpreted to be due to fault line erosion.

No in post-Mesozoic depositswereField and aerial reconnaissance .reveal little to no geomorphic expression of the Jonesboro fault to suggest reactivation of the fault in the contemporary tectonic environment, and

2.5.3.2.1.2 Harris Fault (Site Fault)

Detailed investigations conducted by Ebasco demonstrated that the Harris fault is a minor tensional normal fault whose last movement was prior to 150 Ma (Reference 2.5.3-202, Reference 2.5.3-201). Observations and conclusions from these studies regarding the location, style of faulting, and timing of deformation that demonstrate that the Harris fault is not a capable tectonic source are summarized in the following paragraphs. A compilation map showing the locations of trenches, boreholes, and geophysical surveys completed as part of both the pre-construction characterization studies and the subsequent more detailed fault investigations are shown on Figure 2.5.3-201.

After the Harris fault was discovered in the excavation for the HNP Waste Processing Building, it was traced some 2400 m (8000 ft.) east and west in a series of short trenches normal to the fault (Reference 2.5.3-201) (Figure 2.5.3-201). It was also exposed in excavations at the Auxiliary Dam (Reference 2.5.3-201). When exposed in sedimentary beds, the fault exhibits an approximately east-to-west strike, a southerly dip between 60° and 90°; always exhibits drag folding on the hanging wall and seldom exhibits any disturbance of bedding planes on the northern or "foot" wall (Reference 2.5.3-202). The fault-gouge zone varies from several centimeters (a few inches) to about 1 m (3 ft.) in width (Reference 2.5.3-201). The fault tends to become oversteepened in coarser-grained sandstones and is nearly vertical adjacent to diabase dikes offset by

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the fault. No additional faults were discovered in 1200 linear m (4000 linear ft.) of trenching. (Reference 2.5.3-202) Nine core borings were completed in sedimentary rocks on either side of the Harris fault to determine the vertical component of offset. Correlation of marker beds in the site area proved to be extremely difficult because sediment lithology changes radically over short lateral distances. Based on borehole data, vertical offset in Triassic sediments along the Harris fault in the vicinity of the HNP site is between 24 and 30 m (80 and 100 ft.). (Reference 2.5.3-201) Near-vertical diabase dikes proved to be the best references for estimating horizontal displacement. It was noted, however, that the offset of dikes shows only post-intrusive movement, not necessarily the total offset of the sediments. The horizontal offset of diabase dikes as exposed in the trenches ranges from 0.1 to 4 m (0.5 to 13 ft.); a large horizontal component of movement is precluded in that the fault changes strike about every 90 m (300 ft.). (Reference 2.5.3-201) Prominent joint sets at the site and their relation to the Harris fault are discussed in Subsection 2.5.1.2.4.

Petrographic and chemical work on the dikes for the HNP siting provided a critical test for field observations concerning relative ages of dikes and the Harris fault. Field evidence established that composite East Dike 2 was intruded during fault movement; West Dike 3S was intruded after most movement had occurred, but before a final, minor element of movement; and West Dike 3 was probably intruded early during movement and offset about 3 m (10 ft.) left laterally (Figure 2.5.3-201). Observations where the Harris fault crosses East Dike 2 suggest that the fault is a minor, late contemporary feature to the Jonesboro fault. (Reference 2.5.3-201) The Jonesboro fault is deeper and rooted in the crust, whereas the Harris fault is likely rooted in the Triassic sediments (Reference 2.5.3-202). Detailed mapping of the diabase dikes in relation to the Harris fault suggests the following sequence of events on the fault (Reference 2.5.3-202):

1. Movement on the fault.
2. Intrusion of the easternmost dike segment.
3. Continued movement along the fault.
4. Intrusion of the central dike segment.
5. Continued movement along the fault.
6. Intrusion of the westernmost dike segment.
7. Minor continuing movement along the fault.
8. Crystallization of laumontite.

9. Final movement on the fault.

10. Low-grade burial metamorphism, with crystallization of zeolites harmotome and heulandite.

A number of secondary minerals observed in the fault gouge at the intersections of the fault with diabase dikes were used for determining age relationships between the dikes and faulting (Reference 2.5.3-202). Zeolite mineral assemblages, including harmotome, heulandite, and laumontite, that are related to hydrothermal and "burial" metamorphic events, were observed only in association with the diabase dikes; furthermore, analyses of strontium isotope ratios ($^{87}Sr/^{86}Sr$) suggest that the diabase and zeolites are genetically related. Evidence for this association can be found in their occurrence only in the dike-fault intersections or as small veins or amygdule fillings in the dikes, and in their absence from the fault zone away from the dikes. (Reference 2.5.3-201) The minimum age of the zeolite minerals has been determined from their potassium-argon (K/Ar) content as 35 Ma; however, these are spuriously low because zeolites tend to lose argon but not potassium. (Reference 2.5.3-202) The intact condition of some of the very brittle, delicate zeolites indicates that the zeolites were formed after faulting, suggesting that the last movement on the fault was more than 10 Ma, but most probably before the final cooling of the dike about 200 Ma or during a burial metamorphic event before 150 Ma (Reference 2.5.3-201). One laumontite vein has been cataclastically deformed, as evidenced by shearing, and also shows mechanical disaggregation and rotation of laumontite grains. This indicates that there was some movement on the fault after crystallization of at least some laumontite. Paleomagnetic dating showed that the diabase dikes underwent burial metamorphism about 20 million years after dike intrusion; therefore, the laumontite is likely associated with the original deuteric hydrothermal alteration of the dike shortly after its crystallization, whereas harmotome and heulandite were formed during the burial metamorphism some 20 million years later. Because the secondary minerals were emplaced prior to 150 Ma and have not been disturbed by subsequent faulting, the last movement on the fault was prior to that time. (Reference 2.5.3-202)

Soils were also used to help constrain the timing of faulting on the Harris fault. Based on trench exposures and outcrops, the fault has not moved during formation of existing soil and saprolite on Triassic sedimentary rocks. Below the uppermost soil horizon, the material is classified as saprolite, and weathering decreases with depth from 0.6 to 4.6 m (2 to 15 ft.). Clay mineralogy studies show this to be an in-place residual weathering profile. Although soils in this area have been variously estimated to be as old as Miocene, more rapid erosion has prevented the HNP site soils from developing a strong profile. (Reference 2.5.3-201) Based on analogy with depths of oxidation at a similar location, the formation of the saprolite may have started more than several million years ago (Reference 2.5.3-202), and the diabase has not been disturbed by movement on the fault for more than 500,000 years (Reference 2.5.3-201).

2.5.3.2.1.3 Minor Faults Exposed at the Main Dam

Twenty-four noncapable faults were observed in Paleozoic crystalline rock in the foundations of the Main Dam structures (Reference 2.5.3-203) measured in meters to several meters (or tens of feet) and displacements measured in centimeters (or inches). Because the small amount of movement along these faults took place prior to deformation and mineralization that occurred more than 225 Ma, the faults are not considered to be capable faults. (Reference 2.5.3-201, Reference 2.5.3-203)

2.5.3.2.1.4 Borrow Pit Faults

Detailed geologic mapping at scales of 1:12 to 1:3750 that was performed at both the north and south borrow pits to the west and southwest of the HNP site revealed four faults: the SBPF and faults A, B, and C (FA, FB, and FC). The Harris fault was exposed north of the north borrow pit (Figure 2.5.3-201). The borrow pits are partially located within the area of the proposed Wake/Chatham LLRW disposal facility site (Figure 2.5.3-201). (Reference 2.5.3-205) Different structural patterns were seen in the north and south borrow pits. Faulting and fault-related folding in the south borrow pit were inferred from changes in the orientation of bedding (Reference 2.5.3-205) (see Subsection 2.5.1.2.4).

Faulting exposed in the borrow pits can be divided into two stages: Stage 1 faulting occurred on FA and is interpreted to be associated with longitudinal normal faulting and tilting of beds within the Triassic Deep River basin, antithetic to the Jonesboro fault; Stage 2 faulting represents a later stage of transverse faulting along the SBPF, involving both normal and dextral strike-slip components that produced map-scale folding in the hanging wall of the SBPF. Stage 2 also involved reactivation of FA and formation of east- and north-striking shear mode fractures. Based on exposures in the borrow pits, total displacement cannot be determined on any of the faults. (Reference 2.5.3-205)

2.5.3.2.1.5 Faults Exposed at the LLRW Disposal Facility Site

Chem-Nuclear Systems, Inc., conducted geologic and hydrogeologic investigations at the proposed LLRW disposal facility site, 300 to 450 m (1000 to 1500 ft.) west of the borrow pits (Reference 2.5.3-204). These investigations involved four trenches (GM-1 through GM-4) (Figure 2.5.3-201), totaling approximately 1219 m (4000 ft.) in length, and nine boreholes along the line of the GM-1 trench (Reference 2.5.3-204). Seismic reflection/refraction and vertical seismic profiling were performed at the site to provide correlation between boreholes, to evaluate faults, and to determine thickness of weathered bedrock (Reference 2.5.3-204).

Three main faults were identified: the W8 fault, W82 fault, and the western extension of the SBPF (Figure 2.5.3-201). The W8 fault is displaced by the SBPF and W82 faults. Examination of the strata adjacent to the W8 fault, regional relations, and seismic reflection data suggest that the W8 fault and other nearby north-to-south trending smaller faults were last active in the Triassic, but did not result in surface rupture. (Reference 2.5.3-206) Because stratigraphy differs on either side of the fault, no direct measurement of displacement could be made; therefore, it is assumed to have >274 m (900 ft.) of vertical displacement (Reference 2.5.3-204). Trenching and mapping that extended ~600 m (2000 ft.) east and west of the W8 fault did not reveal any other faults of this size. Approximately 20 smaller, low-angle, bedding-parallel faults, with little or no displacement, were observed in the trenches. (Reference 2.5.3-204) Although dominant displacement is normal, steep dips, similar orientation, and kinematic indicators suggest that the Harris, W8, and South Borrow Pit faults originated as strike-slip faults accommodating movement at the southern end of the Durham segment of the Jonesboro fault (Reference 2.5.3-206).

A comparison was made between topographic lows and faulting at the LLRW disposal facility site. Many of the topographic lows appear to be controlled by stratigraphy rather than by structure. Saddles and strike-parallel drainages tend to be underlain by fine-grained units such as mudstones and ridges tend to be associated with sandstone units (Reference 2.5.3-204). On a more localized scale, isolated zones of deep weathering and minor topographic lows tend to correlate with small faults or zones of increased fracturing. Where linear drainages were associated with faults, the drainages were located slightly south of the actual fault in the hanging wall block, probably due to the presence of more fractured and deformed rock compared to the relatively undeformed rock on the footwall block. (Reference 2.5.3-204) Hydrologic tests also showed that groundwater was localized within the fractured sediments adjacent to the faults, similar in some cases to the localization of groundwater along the dikes (Reference 2.5.3-204).

2.5.3.2.1.6 Other Faults within the Site Area and Site Vicinity

Intrabasinal Faults

Several other faults and folds have been mapped within the site area (Figures 2.5.1-230 and 2.5.1-231). No evidence of post-Triassic movement on any of these structures is reported in the literature or has been documented by recent mapping by the NCGS. The faults are interpreted to have formed in the same tectonic stress field as the other better studied Mesozoic rift faults in the site area (e.g., the Jonesboro fault, the Harris fault, and the faults in the LLRW and borrow pit study areas). Based on the absence of evidence for post-Triassic deformation and the structural association with noncapable faults, these faults are judged not to be capable tectonic fault sources.

The most prominent is the Bonsal-Morrisville fault (Figure2.5.1-230), which is located approximately 7.4 km (4.6 mi.) northwest of the site. The Bonsal-Morrisville fault is approximately 26 km (16 mi.) long, trends ~N37E, and has 600 to 1800 m (2000 to 6000 ft.) of vertical down-on-the-northwest displacement (Figure 2.5.1-241, Reference 2.5.3-214).. A smaller, approximately N70E trending fault that crosses the Bonsal-Morrisville fault that was shown on the 1985 geologic map is retained on more recent, more detailed unpublished mapping by the NCGS (Reference 2.5.3-208). Although more recent studies could not identify the fault in the field it was retained in more recent mapping because high-angle bedding measurements, "different"-looking strata than the rest of the basin (possibly Lithofacies Association I), and abundant fractures were seen in the area of the mapped fault. Additionally, seismic reflection studies by Bain and Harvey (1977) indicated anomalous seismic reflectors in that area. A north-to-northwest-trending fault that was shown on the 1985 geologic map of North Carolina within approximately 185 m (600 ft.) northeast of the HAR 3 site (Reference 2.5.3-207) has been removed on more recent unpublished maps by the NCGS. Geophysical data and field reconnaissance show no indication of a fault in this location, but rather identify the presence of a diabase dike.

Two short faults were recognized during excavation along Highway 1. The easternmost of these two faults, which lies approximately 7.2 km (4.5 mi.) northeast of the HAR site is an approximately 460 m [1500 ft.] long, high-angle normal fault (Reference 2.5.3-208). The fault displays drag in Triassic sediments and is associated with a zone of syndepositional, fault-bend folding in the hanging wall of the Jonesboro fault (Figure 2.5.1-231). A northeast-trending (approximately 630 m [2067 ft.] long) fault that lies approximately 2 km (1.2 mi.) northwest of the HAR site was identified during the widening of US 1 in May 1997 (Figure 2.5.1-231, Reference 2.5.3-208). The exposure was in a storm water drain excavation that is now under the highway. The excavation showed a fault zone of disrupted Triassic sediments in which at least four slickensided fault surfaces all striking northeast-southwest, dipping moderately-steeply to the northwest were mapped. The fault zone could not be traced beyond the extent of the excavation. However, based on similar observations at the LLRW site to the south, NCGS staff felt the fault zone could be significant, and speculated that it could be a northward extension of the W8 fault. (Tyler Clark, pers. comm., 10/8/08)"

2.5.3.2.1.6.2 Post-Cretaceous to Cenozoic Faults

Five faults within the site vicinity were identified as post-Cretaceous to Cenozoic by Parker (Reference 2.5.3-215) and Prowell (Reference 2.5.3-213). These are faults 41, 47, 49, and 59, and 150 (Table 2.5.1-201; Figure 2.5.1-230 Sheet 1). None of these reported post-Cretaceous faults to Cenozoic faults lie within the site area. Recent mapping by the NCGS has not been able to find evidence for recent movement on any of these faults: either the faults are no longer exposed or there is not strong evidence for the age of movement. Field and aerial reconnaissance of several of these features was conducted in June and December 2006. Many of the faults identified by Prowell as possible post-Cretaceous to Cenozoic faults were exposed in roadcuts or excavations that are now buried or heavily vegetated and could therefore not be examined or substantiated (e.g., faults 47, 59, and 150) (Reference 2.5.3-213). With the exception of the fault identified by Parker (Reference 2.5.3-213), which has a reported vertical offset of 2.6 m (8 ft.) in terrace deposits estimated to be late Tertiary to possibly Pleistocene age, the reported displacements on these faults is less than 1 m (3 ft.) in deposits of Cretaceous to Tertiary age.. However, neither examination of recent LIDAR data nor aerial reconnaissance revealed any geomorphic evidence of recent faulting. These faults are not considered to be capable tectonic sources.