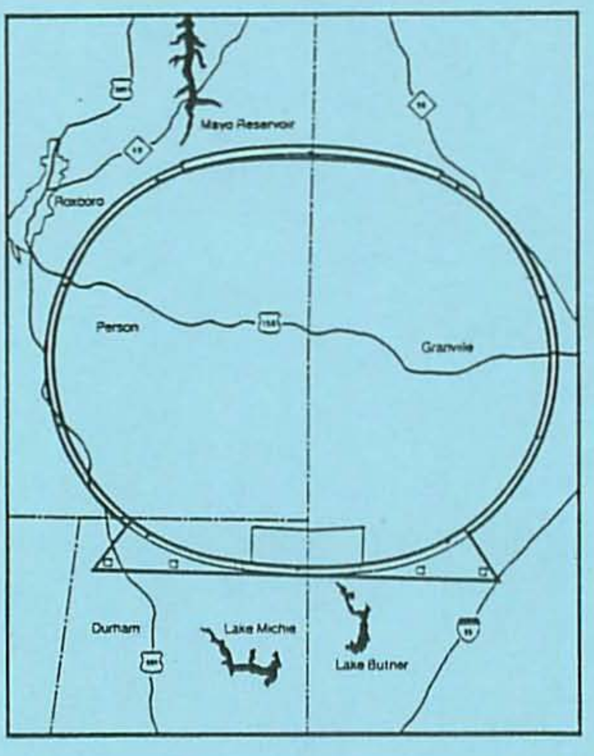
SUPERCONDUCTING SUPER COLLIDER: LOCATION, GEOLOGY, AND ROAD LOG

by

William F. Wilson and P. Albert Carpenter III



NORTH CAROLINA GEOLOGICAL SURVEY
OPEN-FILE REPORT 97-2

DIVISION OF LAND RESOURCES
DEPARTMENT OF ENVIRONMENT, HEALTH AND NATURAL RESOURCES

SUPERCONDUCTING SUPER COLLIDER: LOCATION, GEOLOGY, AND ROAD LOG

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DIVISION OF LAND RESOURCES
Charles H. Gardner,
Director and State Geologist

1997

State of North Carolina
James B. Hunt, Jr., Governor

Department of Environment
Health and Natural Resources
Jonathan B. Howes, Secretary

PREFACE

During 1986 - 1988 the North Carolina Geological Survey (NCGS) conducted geologic investigations to prepare a bid to host the Superconducting Super Collider (SSC), the World's largest atomic particle accelerator. Preparation of the State's bid involved many State agencies and included investigations on the geology and geotechnical characteristics of the proposed site. The geologic information in this open-file report is being released to make available the results of work performed by the North Carolina Geological Survey during the SSC project. The road log describes the geology at various points along the proposed trace of the collider

The North Carolina proposal was among the final short list of 7 states and finished behind the eventual winner, Texas. The United States' Congress subsequently stopped funding for the project, and after initial construction startup, the project was discontinued.

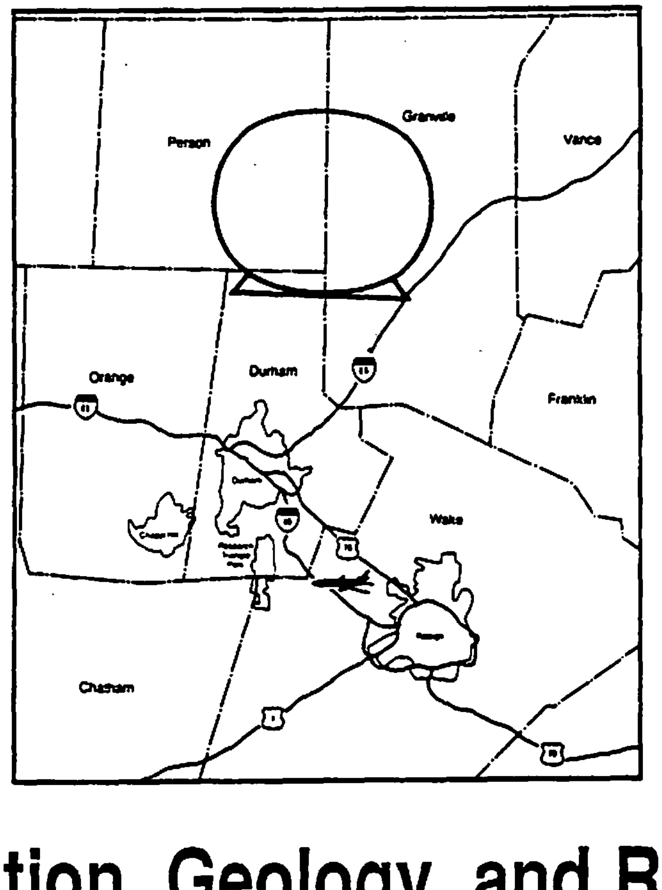
Project files for the Superconducting Super Collider are stored at the North Carolina Geological Survey office at 512 N. Salisbury Street (Archdale Building), Raleigh, NC 27604-1148. Telephone (919) 733-2423. Core from the project are stored at the NCGS Coastal Plain office and core storage facility at 4100 Reedy Creek Rd., Raleigh, NC 27607. Telephone (919) 733-7353.

PAC

State of North Carolina

Superconducting Super Collider

February, 1988



Location, Geology, and Road Log

Office of the Governor
State of North Carolina
Raleigh, NC 27611

State of North Carolina

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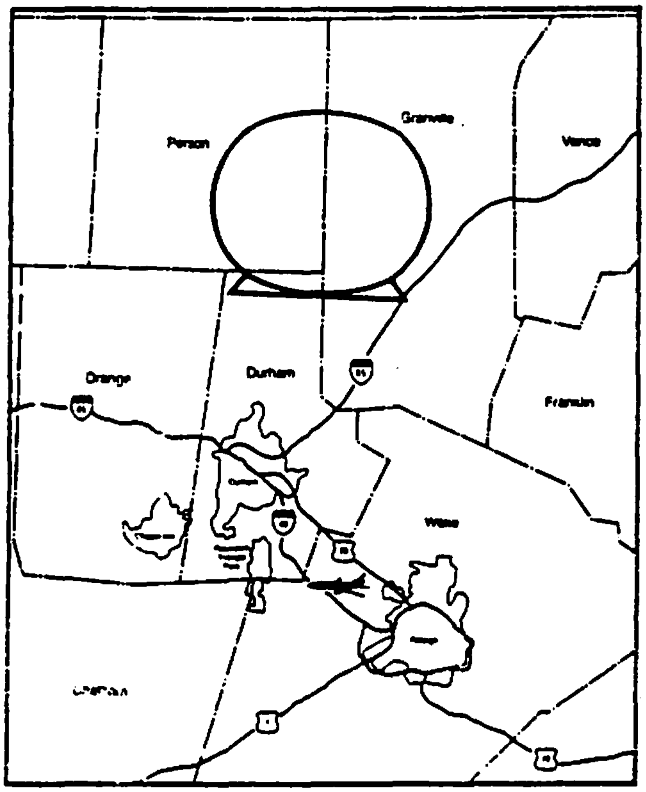

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INTRODUCTION

Summary of the Proposed North Carolina SSC Site

North Carolina has offered a site to the U.S. Department of Energy on which to build and operate the world's largest particle accelerator, the Superconducting Super Collider (SSC). North Carolina's proposed SSC site is geologically ideal for tunneling, well supplied with electricity and water, environmentally favorable, and almost completely rural; yet it is within 30 miles of rapidly growing sunbelt cities, an international airport, three major research universities, and the nation's largest planned research and development park.

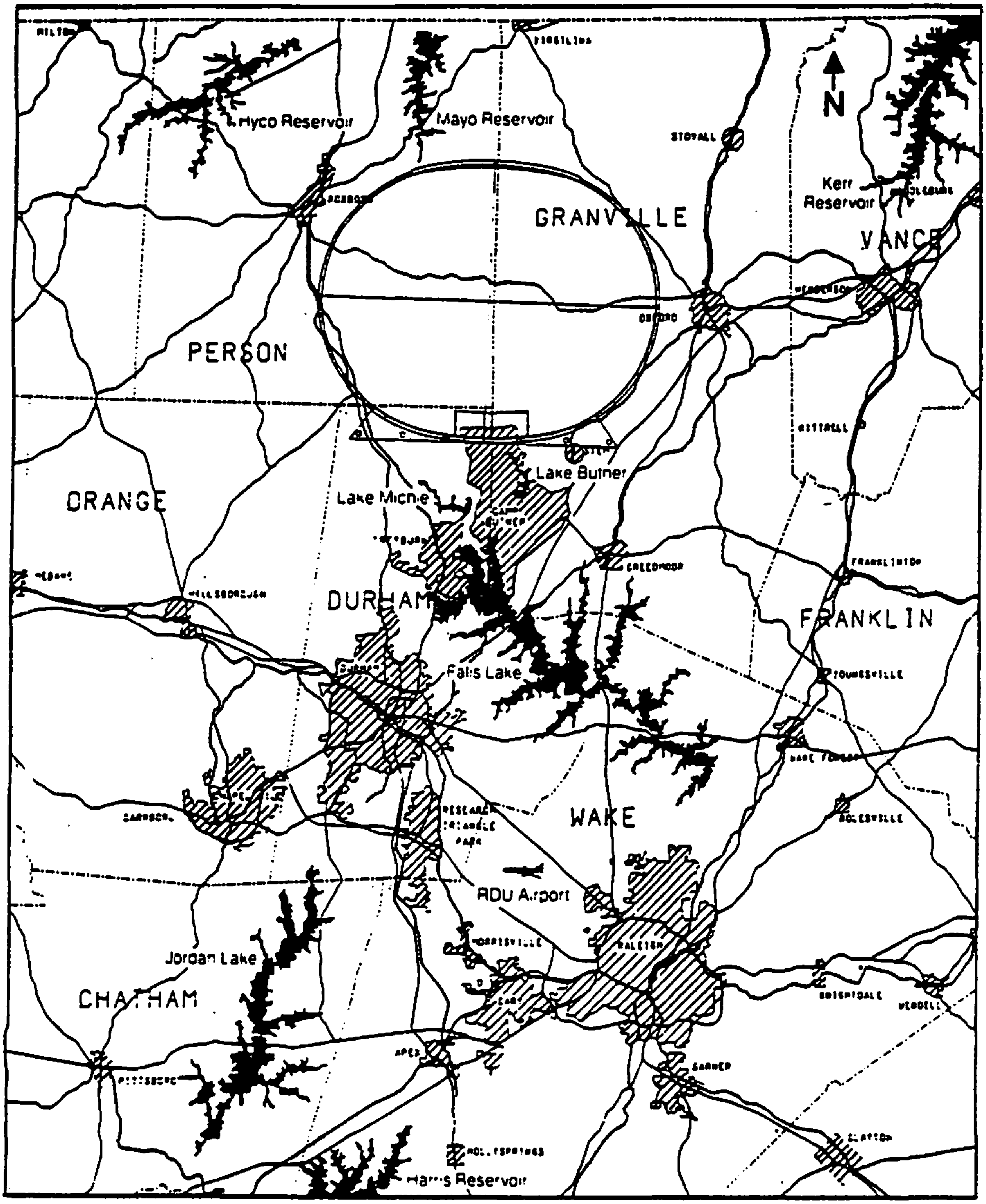
North Carolina's proposed SSC site occupies a strategic position within the state and is at the heart of the East Coast. The site is north of Raleigh and Durham, and lies between Oxford on the east and Roxboro on the west (see map). The proposed campus area is 24 miles from Raleigh-Durham Airport, a rapidly expanding American Airlines hub that will offer nonstop service to Europe later this year and will average 400 daily departures by 1989. The site is easily accessible by Interstates 85 and 40 and an excellent state-run road system. North Carolina has offered an incentive package of highway improvements that would further enhance site access.

North Carolina's proposed site is 95% rural, but is within easy commuting distance of the Triangle area of Raleigh, Durham, Chapel Hill, and Research Triangle Park. Home of Duke University, the University of North Carolina at Chapel Hill, North Carolina State University, and state government, this rapidly growing area is a center not only for high technology and scientific research, but also for state-of-the-art medical care and for cultural activity. The Triangle area has gained a national reputation the high quality of life it offers.

The proposed site lies on gently rolling, largely forested terrain. Under the relatively shallow soil is unweathered metamorphosed volcanic bedrock that is ideal for tunneling and construction of the large underground chambers required for the SSC. The rock is nonporous, uniform for the purposes of tunnel boring, and strong enough for an almost entirely self-supporting tunnel, though not too hard for good tunneling advance rates. The proposed average shaft depth is about 175 feet. The tunnel would be below the zone of water supply for wells, so impact on local wells would be minimal. The site is in a region of low seismicity, and there is no evidence for movement along faults within 50 miles of the site in over 150 million years.

Construction and operation of the SSC at the proposed site would have relatively slight effects on present activities and land uses in the area. In this predominantly rural area, background noise levels are low, noise generated by SSC construction has little potential to disturb sensitive receptors, and there are no sources of vibration that could interfere with SSC operation. About 106 relocations would be required. The State is undertaking a program to meet individually with citizens and businesses who could be displaced by the SSC. The Governor has provided his assurance that affected property owners would be adequately compensated for the loss of their land, including existing improvements. The North Carolina General Assembly unanimously passed legislation giving the State authority to provide the land for the SSC project.

Part of a popular region for hunting and fishing, the area of the site is botanically diverse and rich in game and nongame fish and wildlife. However, no federally threatened or endangered species are known to occur on or near the proposed site, and there are no wildlife refuges or sanctuaries in the vicinity. Although habitats for 23 plant and animal species rare in the state are scattered across the area, the SSC facilities could readily be positioned to avoid or minimize disruption to significant biological areas and to hunting and fishing areas, especially because the accelerator ring would be constructed by tunneling, rather than cut-and-cover, methods. No significant archaeological or paleontological sites would be affected, no sacred Native American sites are known or expected to occur in the area, and only one significant historic structure lies on land proposed for SSC surface uses.



Map A. The region of North Carolina in which the SSC is proposed to be sited.

The proposed site's location in a headwaters area of the North Carolina Piedmont ensures an abundant supply of good-quality water, with relatively small wetland and floodplain areas. Again, construction by tunneling, along with appropriate mitigation of the effects of surface construction, would minimize the project's effects on the site's water resources. Cooling water would be supplied by Mayo Reservoir and Lake Butner, and the required 250 gallons per minute of drinking water would also come from Lake Butner. The site also is well served with electrical power. Either of two major utility companies (CP&L and Duke) could easily serve the SSC out of existing reserves. The two companies have pledged to cooperate with each other to provide efficient service to the SSC, thereby reducing the potential future impact of its 120 megawatt electrical demand on the rest of the region.

North Carolina's Triangle area provides an ideal environment for construction and operation of the SSC. Nearly 1.8 million people live within a 50-mile radius of the proposed site, and the 17 North Carolina counties within this radius offer a pool of nearly 50,000 construction workers. The 6,300-acre Research Triangle Park was founded in 1959 to take advantage of the research capabilities of the nearby universities and of the skilled training offered by the area's technical institutes. Conveniently situated along I-40 between Raleigh and Durham, the Park employs over 23,000. A major purpose of the Park is to engage the area's government, education, and business resources in cooperative ventures, such as Research Triangle Institute and the Microelectronics Center of North Carolina. The Triangle area has generated a large pool of skilled technicians to support Research Triangle Park firms and other high-technology businesses and university laboratories in the Triangle area. North Carolina's strong Community College System would be called on to provide specialized training to meet the SSC's needs for technical support personnel. The State has agreed to provide $10 million per year for higher education support of the SSC. The three major research universities in the Triangle would expand their faculties and programs in physics and other SSC-related disciplines, in order to enhance opportunities for collaboration with SSC staff and visiting scientists and to help stimulate the area's emergence as a center of high-energy physics research.

As an internationally known center for health-related research, the Triangle area provides outstanding medical facilities and services. Medicine is Durham's leading industry: more than 25% of the city's workforce is engaged in health-related occupations, and more than $400 million is invested annually in medical research in the city and county. The proximity of this medical research community to the proposed SSC site provides exciting possibilities for the continued technology transfer between high-energy physics and medicine, which in the past has involved developments in proton therapy and magnetic resonance imaging.

Contributing immeasurably to quality of life in the Triangle area are its thriving cultural institutions and diverse recreational opportunities. The area is home to the N.C. Symphony, the N.C. Museum of Art, the American Dance Festival, and the N.C. Museum of Life and Science. Nationally known performers appear regularly in the area's many concert and theater series, and opportunities are plentiful for participation in the arts. The area offers state parks, large recreational lakes, hunting and fishing, a popular minor-league baseball team, and the high-quality athletic competitions of three Atlantic Coast Conference teams. A tribute to regional interest in and support of athletics was the record attendance achieved when the Triangle area hosted the 1987 National Sports Festival.

North Carolina is proud of its status as an emerging high-technology state, rich in resources, varied in geography and opportunity, and having both a growing economy and a responsible government. It offers a site that is ideal for the SSC.

LOCATION

Geotechnical Data for the SSC Site Location

North Carolina's proposed site for the Superconducting Super Collider (SSC) presents excellent geological properties for underground tunnel construction. The geologic information presented in this volume is based on data collected by a geotechnical consulting firm, state agencies, and a university research team. Published data were supplemented by field geologic mapping and subsurface exploration. The exploration included 23 test core borings to at least 20 feet below the proposed tunnel centerline, four soil borings, 23 seismic refraction surveys, geophysical logging of 16 rock core borings, and laboratory testing of soil and rock samples. The key results relating to geology and tunneling, presented in detail in Sections 3.1 through 3.5, may be summarized as follows:

- The unweathered bedrock of the Carolina slate belt, in which 90% of the 53-mile tunnel is proposed to be located, has been metamorphosed and by virtue of recrystallization is mechanically hard and physically stable at the proposed tunnel depth.
- The rock in place is essentially impervious to water; water movement occurs only through joints or fractures, which are generally healed at the proposed tunnel depth.
- For tunneling purposes, the rock is classified as soft to medium-hard. Significantly, tunnel boring machines (TBMs) of the same design could be used for the entire ring, with advance rates estimated to vary from 133 to 207 feet/day.
- No significant water inflow is anticipated in the tunnel construction. The groundwater is largely confined to the overburden and weathered rock layers well above the proposed tunnel level.
- There is no field evidence for displacement along faults within 50 miles of the proposed site in over 150 million years.
- Rock characteristics should allow construction of virtually all of the tunnel without initial or permanent support. Where a permanent tunnel lining is required, only a nominal 4-inch shotcrete will be needed.
- Because only a nominal lining is required, a tunnel diameter of 11 feet — rather than the 12 feet assumed in the Conceptual Design report (CDR) — can be used, thus reducing the tunnel cross-section by 15%.
- The average shaft depth is 171 feet, and the average depth of the six interaction points is 178 feet. Vertical shaft construction should require only normal water control by casings through soil and saprolite into weathered rock.

- The rock is geotechnically well suited for construction of the large underground experimental areas.
- The soils at the proposed campus area are suitable for construction of the campus buildings without deep foundations. The local soils also are suitable for constructing fills and for supporting buildings on fills.
- The geotechnical characteristics of the site's local geology are sufficiently uniform over an extended area to allow flexibility in the final placement of the tunnel.

3.1 GENERAL

This section identifies a specific location for the SSC and its related land areas (i.e., areas A through J as specified in Table B-1 and Appendix I of the Invitation for Site Proposals [ISP]). A specific underground placement of the tunnel and a detailed vertical profile of the SSC also are given. The North Carolina State Plane (NCSP) coordinate system is used as an inertial frame to specify the proposed location of the SSC ring; its N-axis defines grid north and its E-axis defines grid east. The term "collider frame" is used to refer to the X-Y coordinate system shown in Appendix I of the ISP, such that the center of the collider ring is at (100,000, 100,000), in units of feet.

3.1.1 Proposed Location of the SSC

The proposed site for the SSC in North Carolina consists of the following nine U.S. Geological Survey (USGS) 7.5-minute (1:24,000) quadrangles: Rougemont, Lake Michie, Stem, Timberlake, Moriah, Berea, Roxboro, Triple Springs, and Satterwhite. The proposed location of the SSC within the site has the center of the collider on the Moriah quadrangle at 78° 48' 22" W longitude and 36° 19' 09" N latitude and the long axis of the collider in a generally east-west orientation such that the X-axis of the collider frame is 1.82° clockwise from NCSP grid north.

The proposed SSC location is depicted on the maps in the Map Supplement and in Figures 3-1 and 3-2. It is best illustrated by Map Supplement B-2, which is a map of the proposed site area, and by Map Supplement C-1 through C-9, which are the current editions of the USGS 7.5-minute topographic quadrangle maps. The SSC land areas are superimposed both on these quadrangle maps and on 7.5-minute *orthophoto*graphic quadrangles included as Map Supplement D-1 through D-9.

A perspective view of the SSC land areas draped over the terrain of the proposed site is given in Figure 3-3, both with consistent vertical and horizontal scales and with the vertical scale enhanced by a factor of 10. Clearly, the topography of the site is relatively flat (the maximum variation in surface elevation above the proposed tunnel position is only 320 feet over the entire 53-mile circumference). The vertical scale was enhanced by a factor of 10 to better display the nature of the topography of

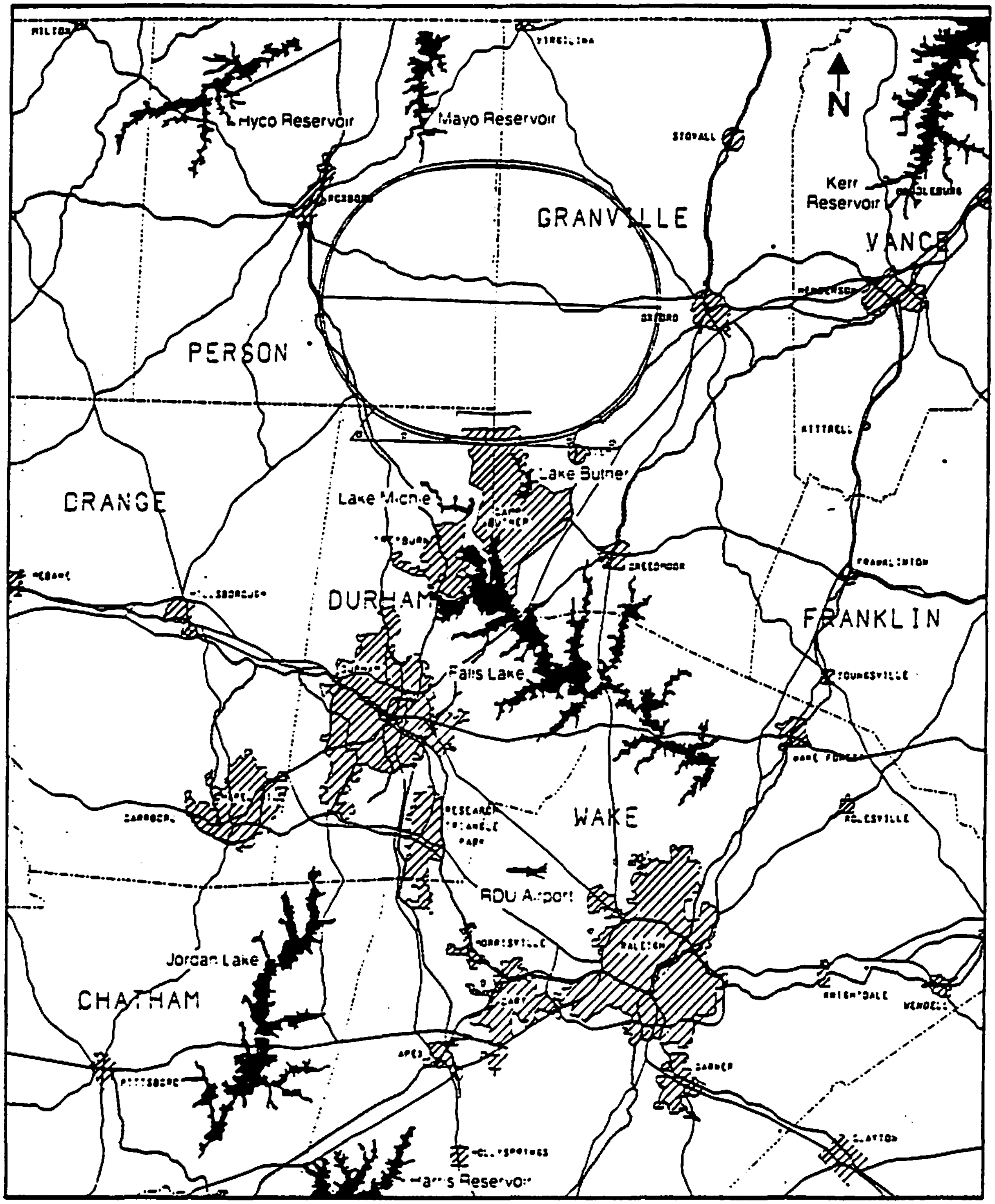


Figure 3-1. The region of North Carolina in which the SSC is proposed to be sited.

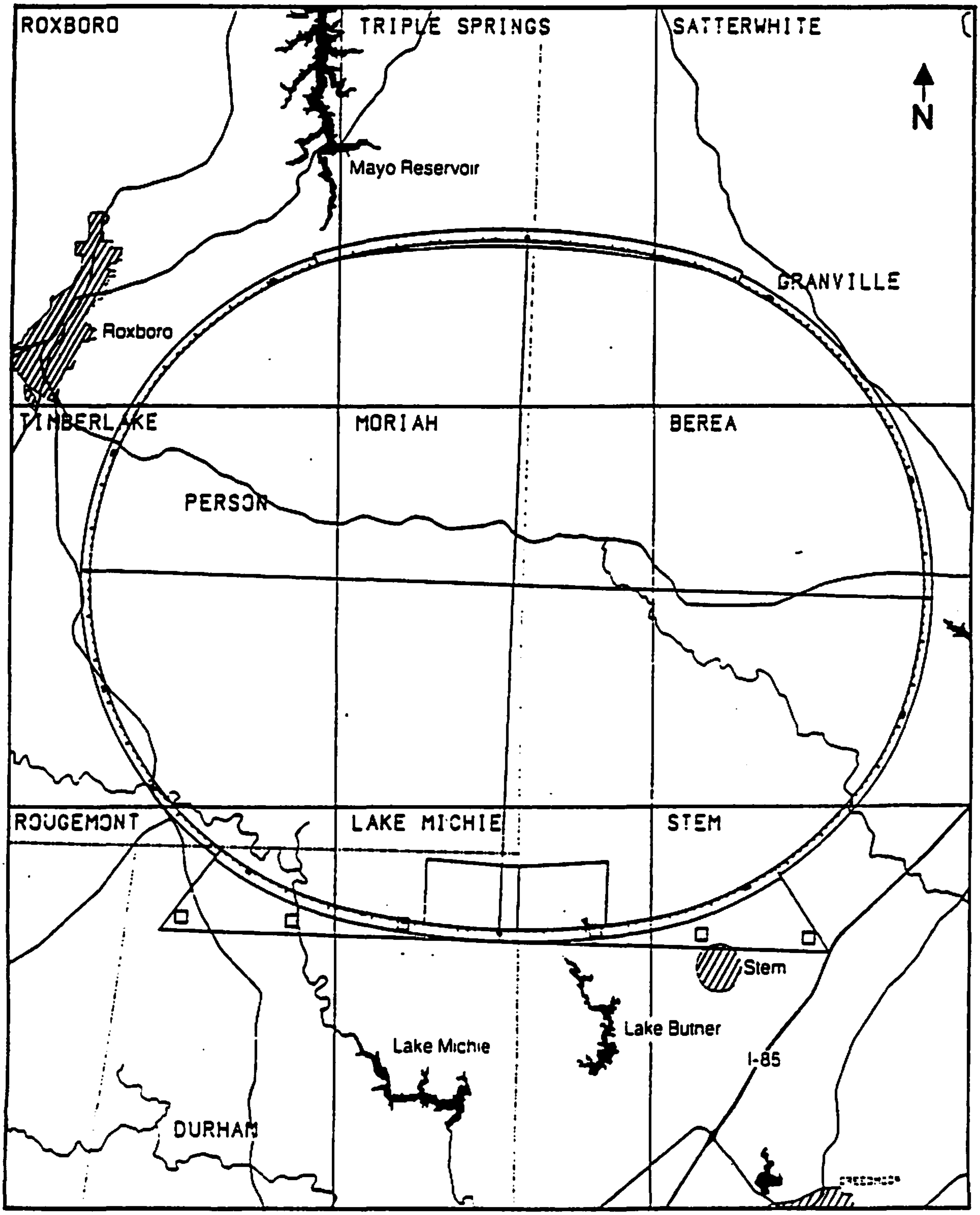


Figure 3-2. The proposed North Carolina SSC site.

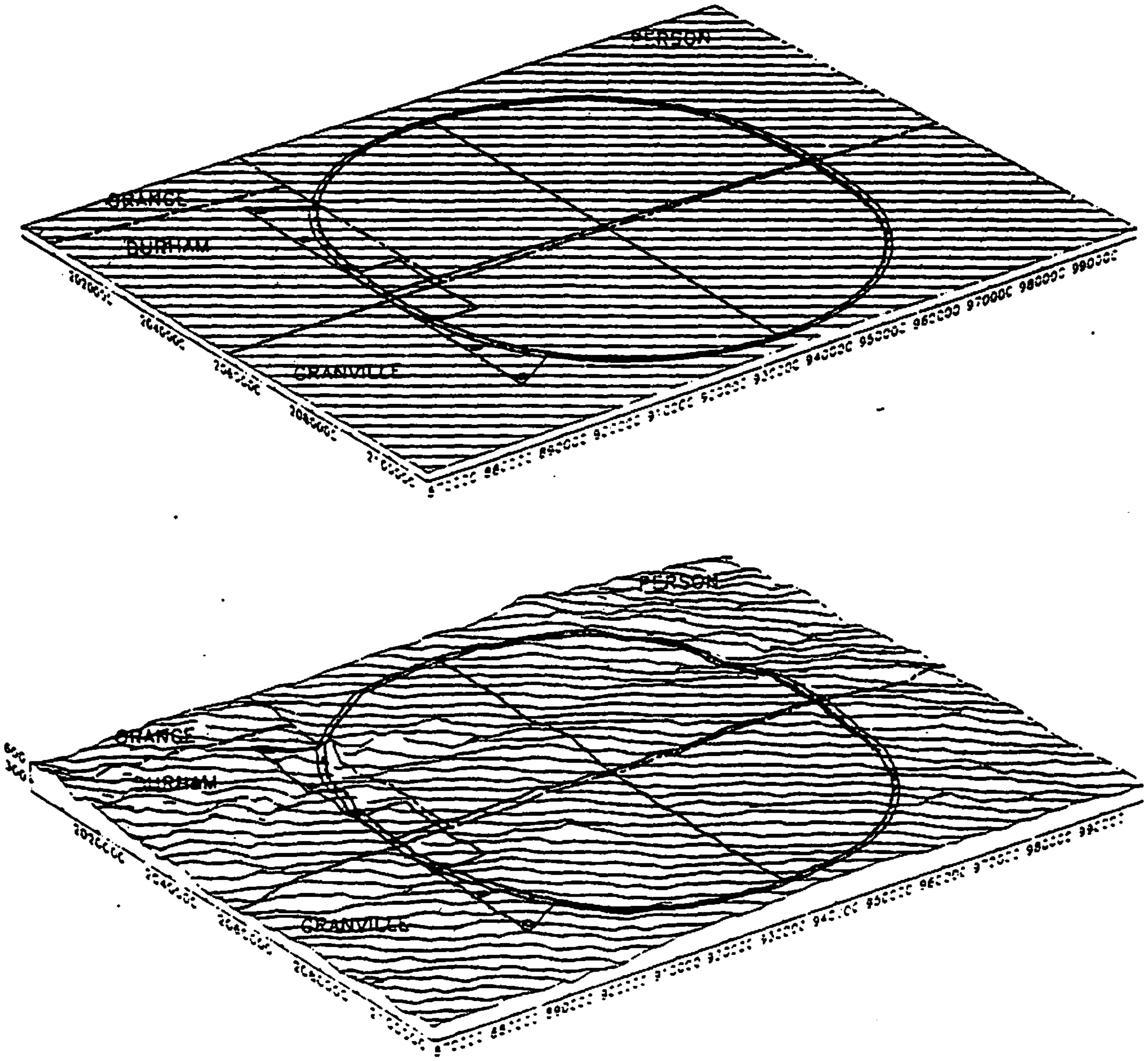


Figure 3-3. Perspective view of the proposed placement of the SSC land areas over the site terrain. Top view has no vertical enhancement; bottom view shows vertical scale enhanced by a factor of 10.

the site. In all subsequent perspective views throughout the proposal where the vertical scale has been so enhanced, the transformation between the two views in Figure 3-3 should be borne in mind. An alternative presentation of the site topography is given in Figure 3-4. The data source for the topography is the USGS 7.5-minute Digital Evaluation Models (DEMs).

Coordinate locations in both NCSP coordinates and longitude and latitude for the land areas that define the major and minor axes of the collider ring are listed in Table 3-1. The coordinates are for points on the inner ring that are centered on these areas. Coordinates also are provided for the proposed center of the collider ring and for three points of low surface elevation where the Tar River, the Flat River, and Mayo Creek cross the inner ring.

North Carolina proposes a tunnel location 200 feet from the inside of the 1,000-ft-wide collider arc region, as shown in Figure 3-5. The tunnel profile information in Sections 3.1.2 and 3.2.2 is based on this specific proposed location of the tunnel within the collider arc region.

The proposed subsurface placement of the collider ring is in a plane tilted by 0.054° from horizontal about an axis rotated 284.5° counterclockwise from grid north, as shown in Figure 3-6. Using the notation of Figure 3-6, $\phi = 284.5°$ and $t = 0.054°$. This tilt was selected on the basis of a detailed study whose criteria included minimizing the lengths of the various access shafts and maintaining a minimum depth of 35 feet. Where the tunnel depth is less than 50 feet, the land above will be obtained in fee simple, as required by the ISP.

3.1.2 Proposed Profile of the SSC

A detailed profile around the proposed collider ring location is given in Figure 3-7. This profile shows the land surface above the tunnel, the approximate location of the boundary between unweathered rock and the various layers of soil and weathered rock above it, and the proposed location of the tunnel centerline. This proposed positioning keeps the tunnel in high-quality unweathered rock for almost the entire length of the tunnel, while still keeping the tunnel relatively near the surface, thus minimizing access shaft lengths.

A profile through the future expansion, campus, and injector areas is shown in Figure 3-8. The proposed location of the high-energy booster is 20 feet above the local tunnel depth. A profile through the abort/external beam areas is shown as Figure 3-9. More-detailed profiles of all of these areas are shown in Section 3.2.2.

Proposed land and tunnel elevations and tunnel depths at each of the E, F, and K areas and at three low points around the proposed collider ring location are summarized in Table 3-2. The average of the proposed E, F, and K tunnel depths is 171 feet, and the average depth to the six interaction points is 178 feet. The minimum depth to the tunnel is 35 feet.

GEOLOGY AND SOILS

3.2 GEOLOGY

The location of the proposed SSC site within the Carolina slate belt presents important geotechnical benefits for tunnel construction (further discussed in Section 3.5). The site may be characterized geologically as follows:

- The Carolina slate belt rocks have been metamorphosed and cemented together through recrystallization. The rock exhibits a poorly developed cleavage and has excellent geotechnical properties.
- The healed faults are ancient, showing no evidence of displacement for at least 575 million years.
- The unweathered crystalline bedrock at tunnel depth is mineralogically uniform, relatively impervious to water, physically stable, and mechanically strong.
- Above the unweathered rock, the overburden and weathered rock are relatively shallow.
- Soils in the site area do not present significant problems for construction, nor will special foundations be required.

3.2.1 Regional Geology

In the region of the proposed site, the interlayered sequence of metamorphosed volcanic and sedimentary rocks were folded and faulted. Through regional metamorphism, the whole system was annealed. The faults are healed and show no field evidence of displacement since about 575 million years ago. The unweathered bedrock is typically overlain by less than 100 feet of soil, saprolite, and weathered rock.

The geology of the site is overplotted on the topographic quadrangles of Map Supplement C-1 through C-9 and is summarized on Map Supplement B-4 and in Figure 3-10. Also shown on Figure 3-10 are the locations of the 23 rock core boring sites. The local geology also is indicated on the geological profiles of Map Supplement H-1 through H-9. The geology is overlaid on the site topography in Map Supplement H-14. The geology of the entire state is characterized on the 1985 Geologic Map of North Carolina, included as Map Supplement E-3.

Lithology

The Carolina slate belt (see Map Supplement E-3) is a major northeast-trending litho-tectonic belt of rocks composed of interlayered metamorphosed volcanic and sedimentary rocks and igneous intrusive rocks, all of which range in age from about 650 million years (Ma) to about 575 Ma (Glover and Sinha, 1973; McConnell and

Table 3-2. Proposed SSC Land Area and Tunnel Elevations and Tunnel Depths

Area	Land elevation (ft)	Tunnel elevation (ft)	Tunnel depth (ft)
E1	566	350	216
F1	511	357	154
E2	491	368	123
F2	603	380	223
E3	562	393	169
F3	661	404	257
E4	687	413	274
F4	630	418	212
E5	562	419	143
F5	617	416	201
E6	566	410	156
F6	567	403	164
E7	529	392	137
F7	528	380	148
E8	545	367	178
F8	484	356	128
E9	417	347	70
F9	481	341	140
E10	494	342	152
F10	483	345	138
K1	504	346	158
K2	547	348	199
K3	662	418	244
K4	600	417	183
K5	591	415	176
K6	521	412	109
Tar River	410	349	61
Flat River	398	354	44
Mayo Creek	456	419	37

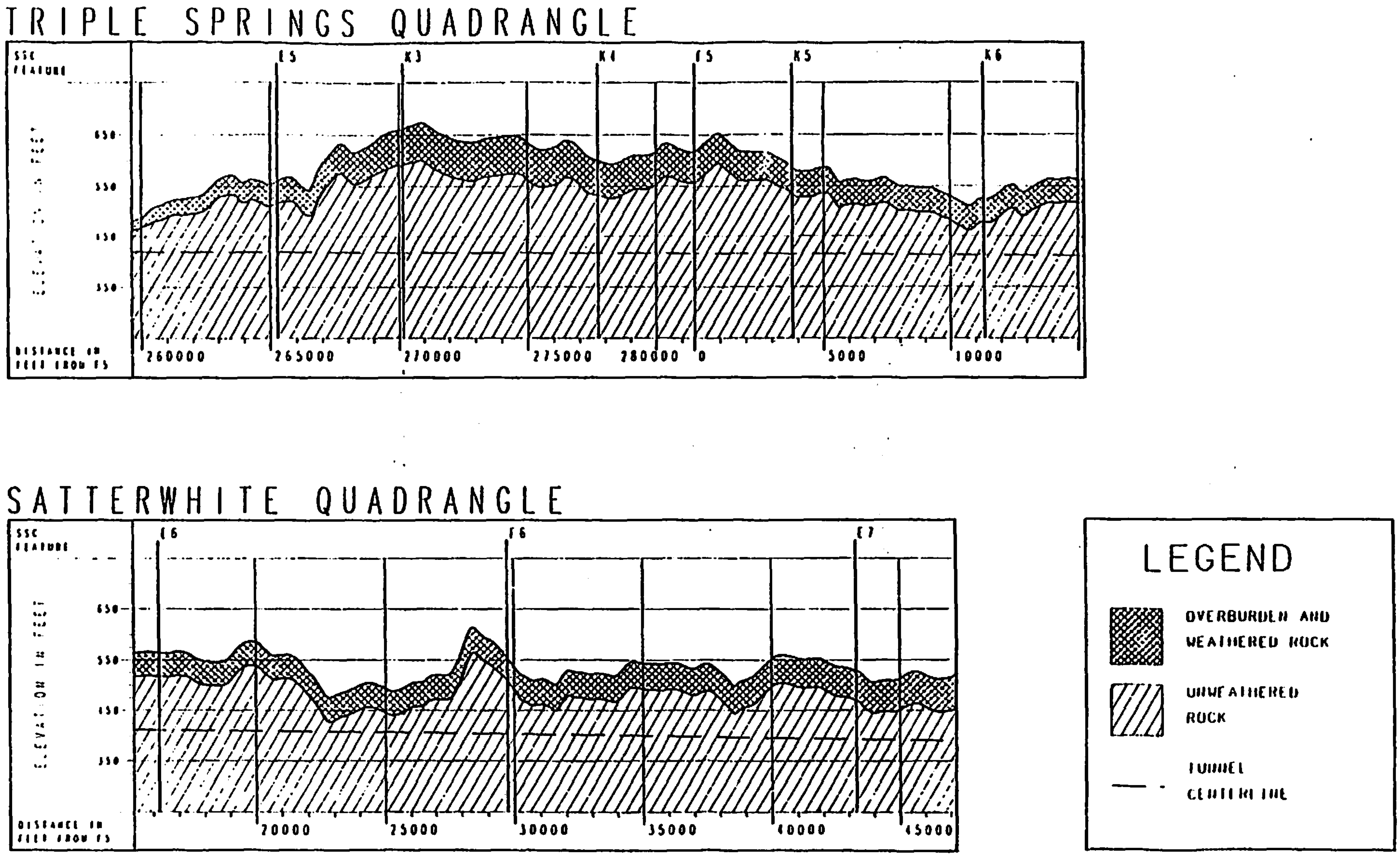
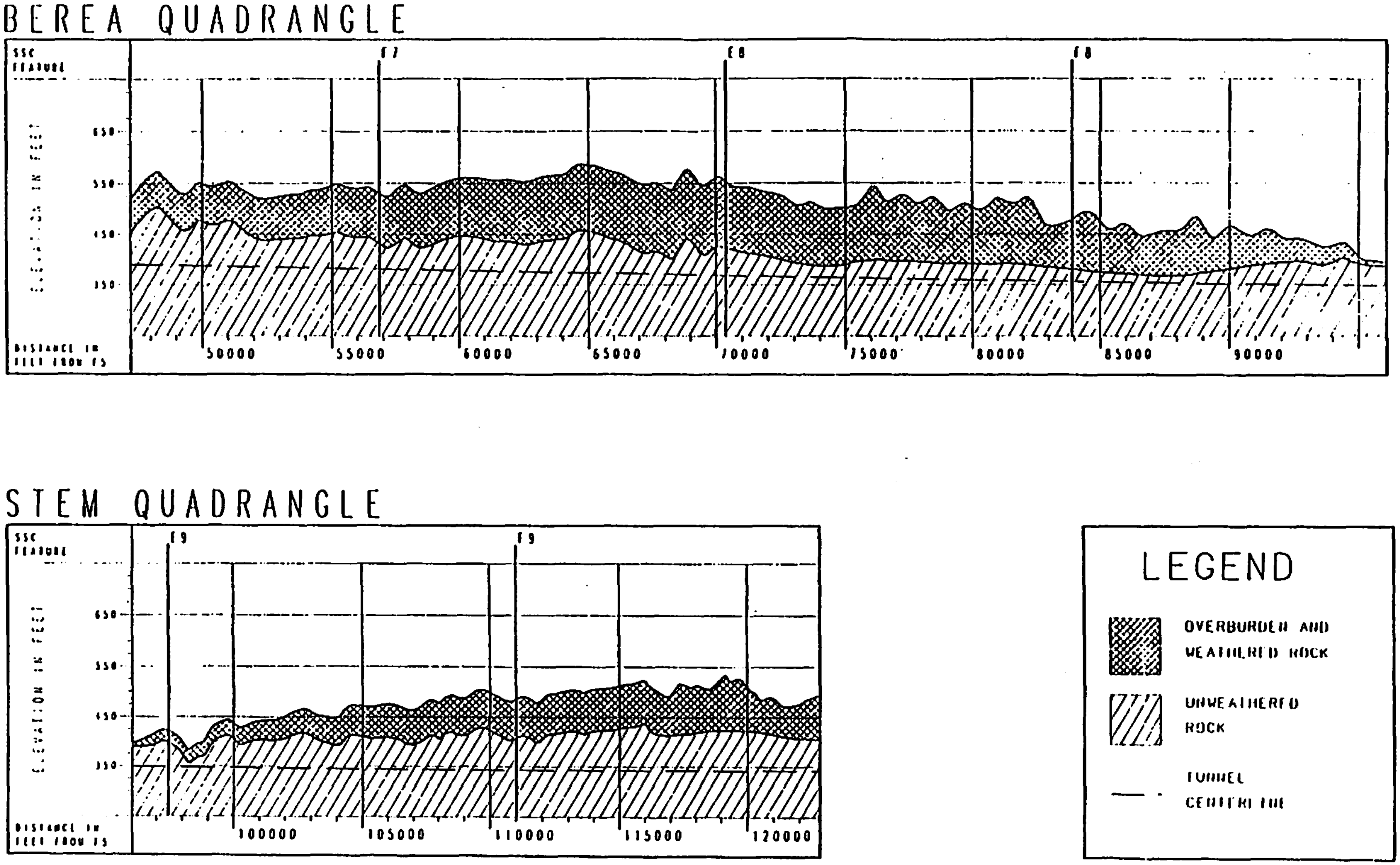


Figure 3-7. Proposed vertical profile of the SSC; distance is measured clockwise from land area F5.



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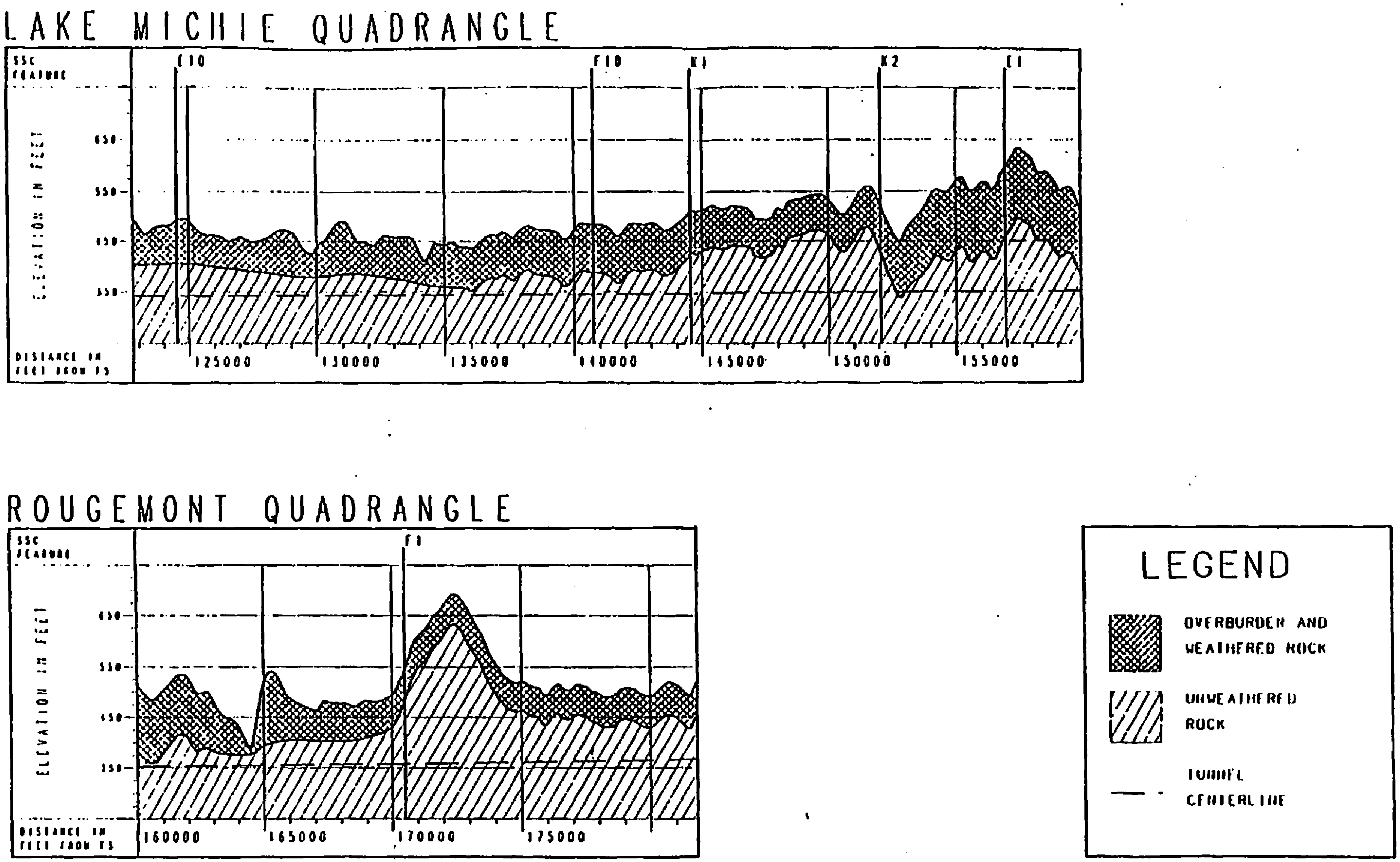

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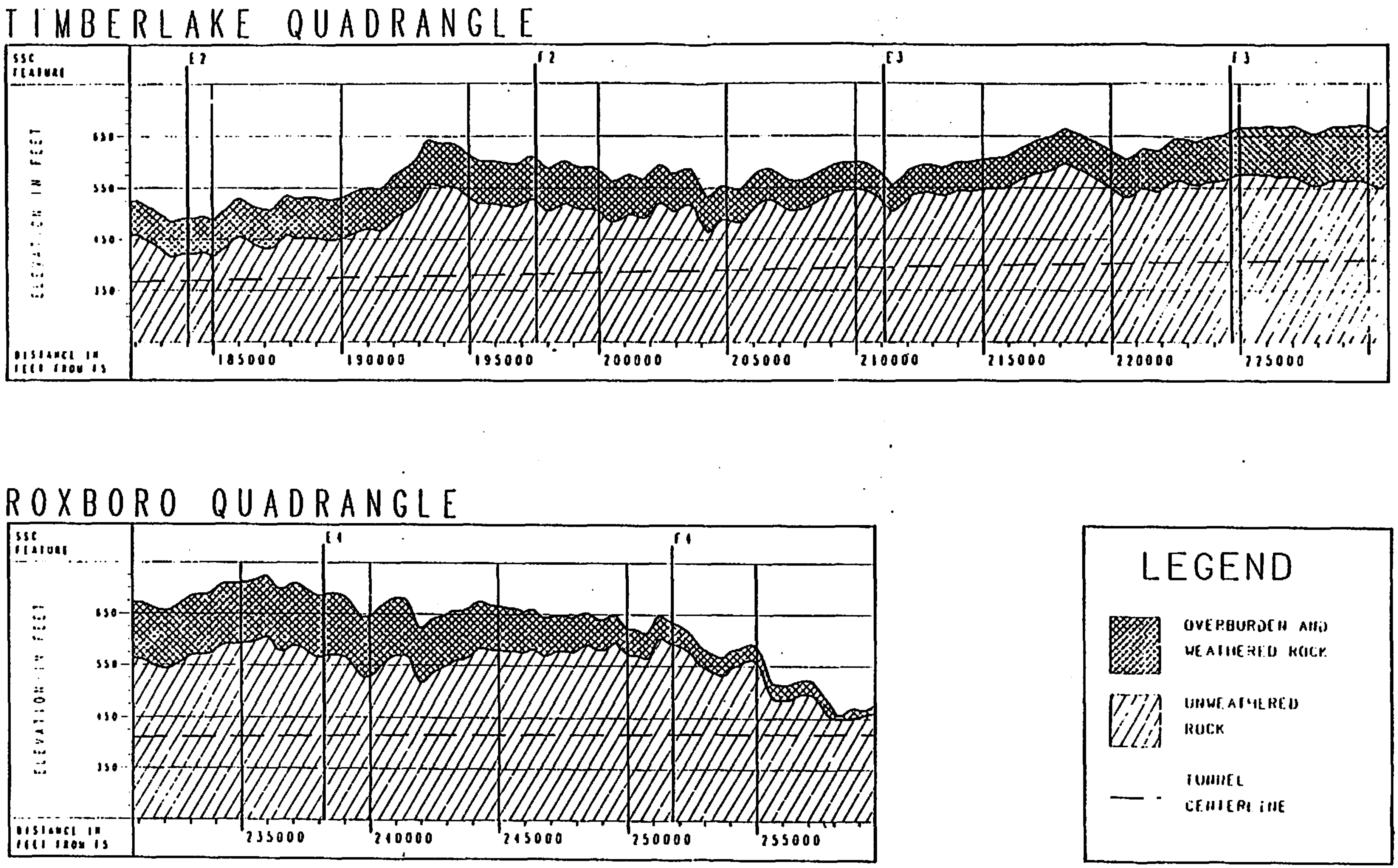

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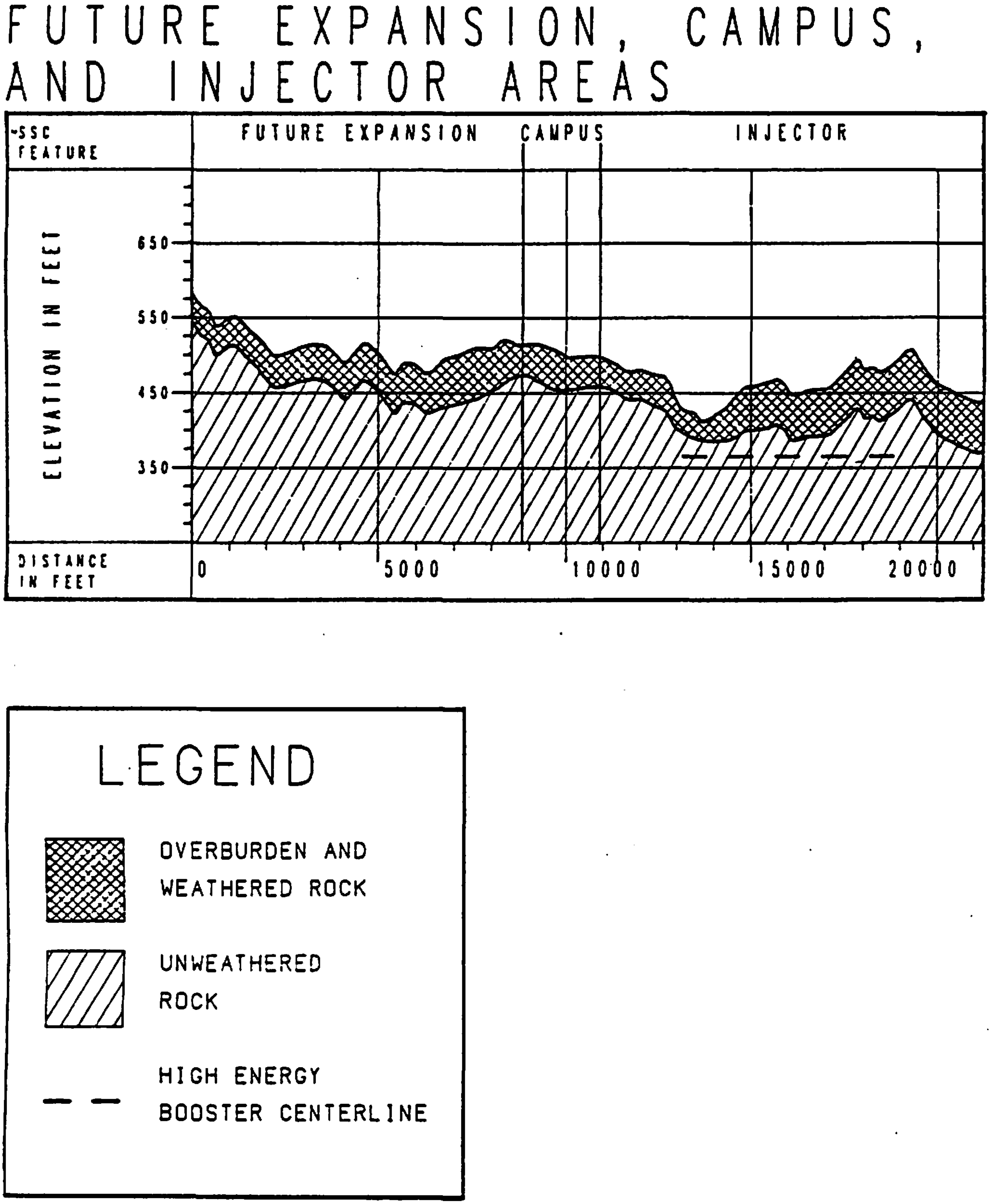
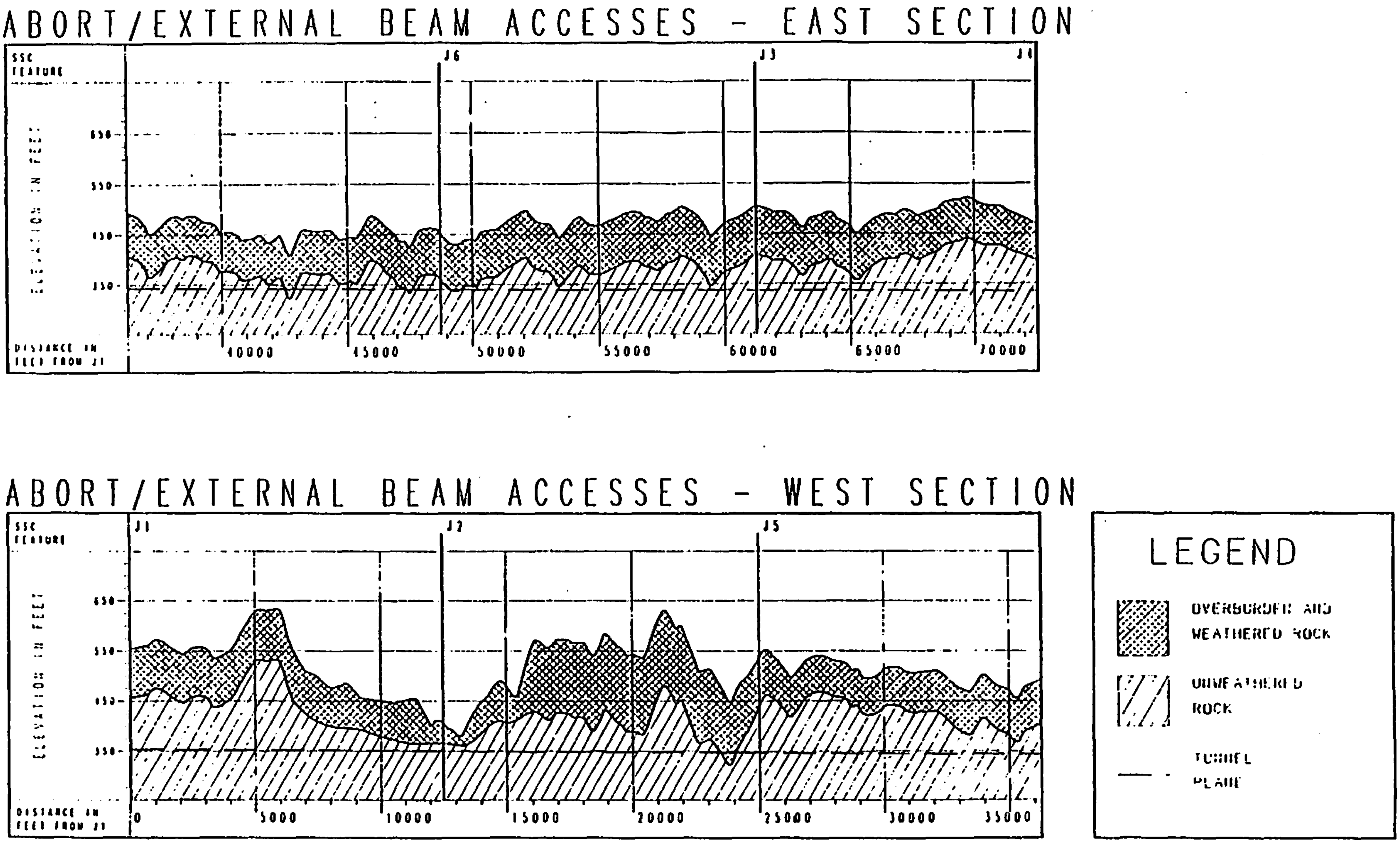


Figure 3-8. Vertical profile through the proposed future expansion, campus, and injector areas.



ABORT/EXTERNAL BEAM ACCESSES - EAST SECTION

ABORT/EXTERNAL BEAM ACCESSES - WEST SECTION

Figure 3-9. Vertical profile through the proposed abort/external beam areas.

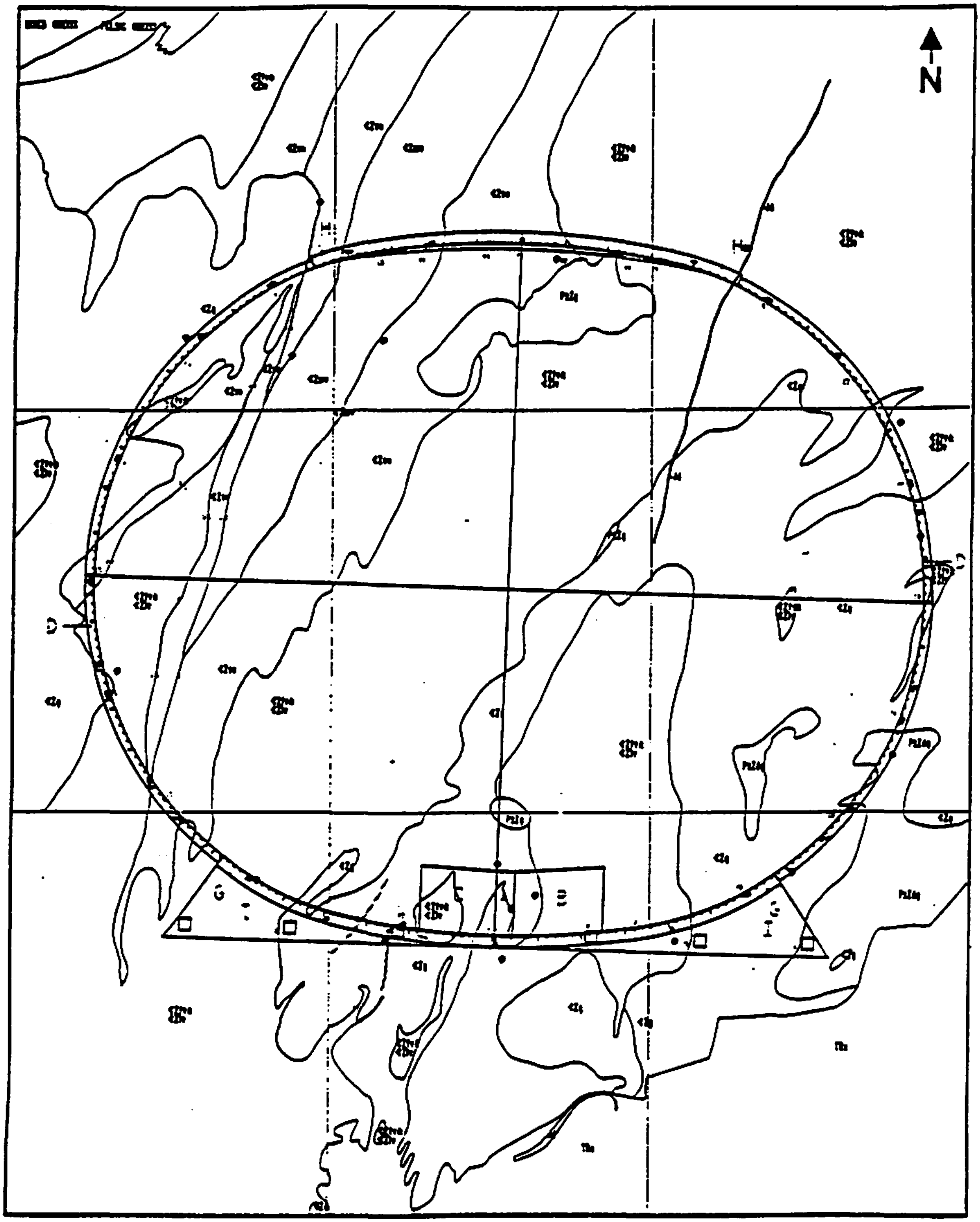


Figure 3-10. The geology of the proposed SSC site.

SIMPLIFIED GEOLOGIC MAP EXPLANATION

Metamorphosed Volcanic and Sedimentary Rocks

CZmv	Mafic and felsic volcanic rocks (Virgilina Fm.)
CZve	Tuffaceous epiclastic rocks (Aaron Fm.)
CZfv & CZiv	Felsic and intermediate volcanic rocks of the Hyco Fm.

Intrusive Rocks

Jd	Diabase
PzZg	Gabbro
CZg	Roxboro Metagranite Butner Stock (Flat River Complex) Moriah Pluton (Flat River Complex) Oxford Pluton

Glover, 1982). Diabase dikes of Jurassic age (205 to 138 Ma) intrude both the metamorphosed volcanic and igneous intrusive rocks. The original rocks are mixed volcanic deposits interlayered with sedimentary mudstones, siltstones, sandstones, and conglomerates. About 600 million years ago, these rocks were chemically and structurally changed by regional increases in temperatures (approximately 300 to 400°C) and pressures. The rock types originated from multiple source areas, and the general lithology has a regional northeast-southwest trend. The area is weathered, and outcrops are scarce.

The subsurface materials in the area of the proposed site are residual materials developed by in-place weathering. A gradual transition occurs from material described as soil to material described as rock. For purposes of displaying subsurface stratigraphy on profiles, the term "overburden" is used to describe all materials above the top of rock. Rock is defined, for the purpose of this proposal, as all material incapable of being drilled by normal soil investigation methods.

Materials included in the overburden are divided for engineering purposes into soil, saprolite, and partially weathered rock, generally according to the criteria described in Sowers and Richardson (1983). The term "saprolite" is used for material with standard penetration resistances between 5 and 100 blows per foot. The term "partially weathered rock" is used for material with standard penetration resistances greater than 100 blows per foot. The rock exhibits weathering which decreases in degree with increasing depth. The term "weathered rock" is used for rock with core recoveries generally less than 75% that also shows visual indications of weathering. The term "unweathered rock" is used for rock with core recoveries generally greater than 85% that also shows only occasional visual indications, if any, of weathering.

The subsurface geology can thus be characterized by the following three units: overburden (including soil and saprolite), weathered rock, and unweathered rock. A block diagram schematically representing these units appears as Figure 3-11. Field measurements indicate that the depth to unweathered rock is typically less than 100 feet.

Stratigraphy

The stratigraphic sequence in this area, as proposed by Glover and Sinha (1973) and Harris and Glover (1985), is based upon geologic mapping of the Roxboro, NC, 15-minute quadrangle (Glover, 1967-1970) and mapping to the south of the Roxboro quadrangle by McConnell (1974) and Wright (1974). On the basis of this stratigraphy, the oldest volcanic rocks in the area are the metamorphosed felsic and intermediate volcanic rocks of the Hyco formation (ЄZfv & ЄZiv). Metamorphosed tuffaceous epiclastic rocks of the Aaron formation (ЄZve) conformably overlie the Hyco formation, and in places they are mapped in fault contact with one another (Glover and Sinha, 1973). Metamorphosed mafic and felsic volcanic rocks of the Virgilina formation (ЄZmv) occupy the center of the Virgilina synclinorium, conformably overlie the Aaron formation, and are the youngest volcanic rocks in the area.

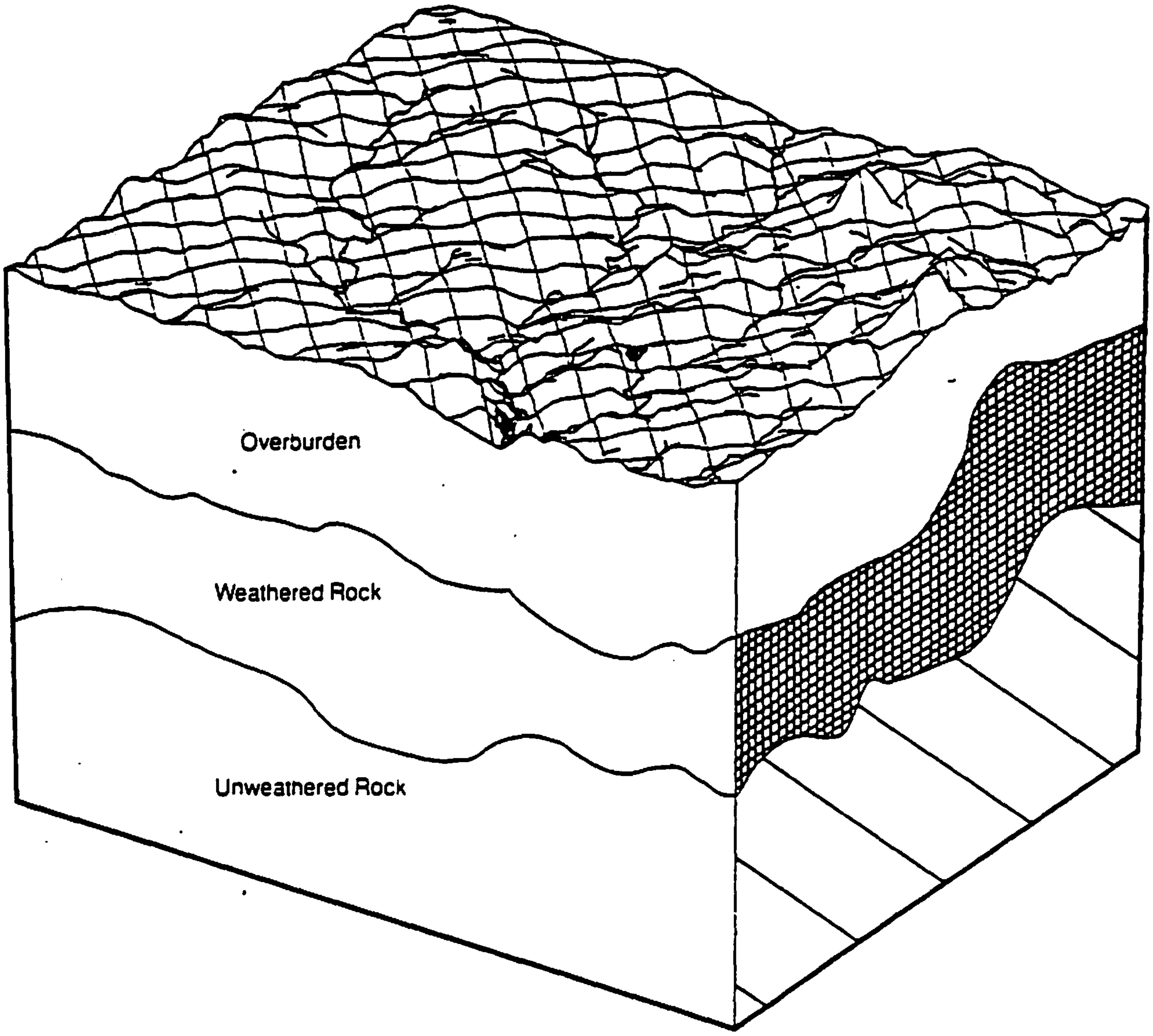


Figure 3-11. Schematic representation of the major geologic strata of the proposed site.

The Hyco formation consists primarily of rhyodacitic to andesitic pyroclastic rocks, shallow intrusives, and lava flows. The Aaron formation is primarily well-stratified sandstone, siltstone, graywacke, and mudstone, with minor amounts of conglomerate, novaculite, and tuff. The Virgilina formation consists primarily of basaltic pyroclastic rocks, volcanic breccias, and sills that are locally interbedded with felsic pyroclastic rocks and sills. Detailed descriptions of the Hyco, Aaron, and Virgilina formations are available on the geologic profile in Map Supplement H-0.

Intrusive rocks in the area of the proposed site include the Flat River complex (McConnell and Glover, 1982), which dates to about 650 ± 30 Ma; the Roxboro metagranite (Glover and Sinha, 1973), which dates to about 575 ± 20 Ma; the Oxford pluton (Hadley, 1973); and various smaller mafic intrusive bodies of diorite and gabbro composition. Based upon mineralogy and texture, the Flat River complex can be subdivided into two distinct intrusive bodies: a medium-grained predominantly porphyritic granodiorite with quartz diorite and minor gabbro that forms the Moriah pluton and medium-grained granodiorite and quartz diorite that forms the Butner stock.

The Roxboro metagranite pluton crops out in the northwest portion of the SSC area. It is a predominantly light gray to medium gray fine-grained granite composed of three primary facies: a predominant granitic facies, an alkali-feldspar facies, and a minor granodioritic facies. The Oxford pluton, which is a medium- to coarse-grained granitic intrusive rock, crops out to the east and southeast in the SSC area. Small mafic intrusive bodies of diorite-gabbro and gabbro crop out to the north and east in the SSC area. Detailed descriptions of these intrusive bodies are given on the geological profile cover sheets and explanation (Map Supplement H-0).

Structure

During the late Precambrian or early Cambrian (?) era (about 575 to 620 Ma), the interlayered volcanic and sedimentary rocks were deformed by regional compression to form the Virgilina synclinorium (Glover and Sinha, 1973). Some faulting may have occurred during this folding, but the major faults postdate this deformational event. The faulting is older than the 575-Ma Roxboro metagranite, because field evidence shows that this metagranite clearly truncates both the faulting and folding (Glover and Sinha, 1973). Igneous intrusive bodies of various sizes and compositions intruded the interlayered volcanic and sedimentary rocks that were deformed during this orogenic episode.

Geologic field mapping for this project did not verify the existence of these faults in outcrop. No zones of tectonic deformation, brecciation, mylonitization, or fault-line displacements were evident along the mapped trace of these high-angle reverse faults. Fault-zone rocks have been healed by metamorphism. There is no outcrop evidence for displacement along the faults in the last 575 Ma. Because these faults were previously mapped in this area (Glover and Sinha, 1973), they are shown on the accompanying geologic Map Supplement C-1 through C-9 and on the Geological

Profile, Map Supplement H-1 through H-9. Because there does not appear to have been displacement along these faults for 575 ± 20 Ma, the area is considered to be tectonically inactive.

After the emplacement of the Roxboro metagranite (575 Ma), the local terrane was metamorphosed to the lower greenschist facies. Metamorphism has affected all rocks in the mapped area except for the gabbro body in the north and the Jurassic diabase dike in the northeast. The metamorphism is no older than 595 Ma and no younger than 300 Ma (Glover and Sinha, 1973). A map showing Paleozoic metamorphic facies in North Carolina is included on the 1985 Geologic Map of North Carolina (Map Supplement E-3). During metamorphism, a regional northeast-striking cleavage formed in the volcanic and sedimentary rocks, and the intrusive rocks developed a weak foliation. This poorly developed cleavage does not affect the mechanical properties of the rock.

3.2.2 Tunnel Profile

A geological profile is presented as Map Supplement H-1 through H-9. A profile for each USGS 7.5-minute quadrangle is provided at a horizontal scale of 1:24,000 (1 inch = 2,000 feet) and a vertical scale of 1:1,200 (1 inch = 100 feet). The profiles are plotted clockwise and are based on a distance scale along the tunnel centerline, which, as described previously, is 200 feet outside of and parallel to the inside of the collider ring. The distance scale begins at area F5.

For the purposes of this proposal, and for a systematic evaluation of tunneling conditions, rock types that have similar physical, mineralogical, and structural characteristics are grouped into seven rock units. Because the same rock unit can be intersected by the ring more than once, some units are further divided into subunits denoted by lowercase letters. Figure 3-12 identifies the rock units and subunits based on the geology of the site. Tunneling-related conditions are judged to be consistent within the limits of a rock unit; that is, all subunits of a given rock unit will have similar tunneling characteristics.

Station numbers were assigned to facilitate comparison of specific features along the geologic cross section with the tunnel profile. Thus, a specific geologic feature can be directly related to an actual geographic position in the NCSP coordinate system. Station numbers were assigned at 5,000-ft intervals along the inner ring, starting with station 0 at service area F5 and proceeding clockwise. For simplicity, the convention of using K to represent 1,000 feet was followed; for instance, the station at 20,000 feet would be labeled 20K. A position at 12,135 feet along the inner ring can then be specified as at station 12K + 135. Because the station numbers run along the inner ring, there is a slight deviation from the distance scale that runs along the tunnel centerline. Table 3-3 identifies the station boundaries, percent of ring circumference, and the general lithologies of the rock units and subunits.

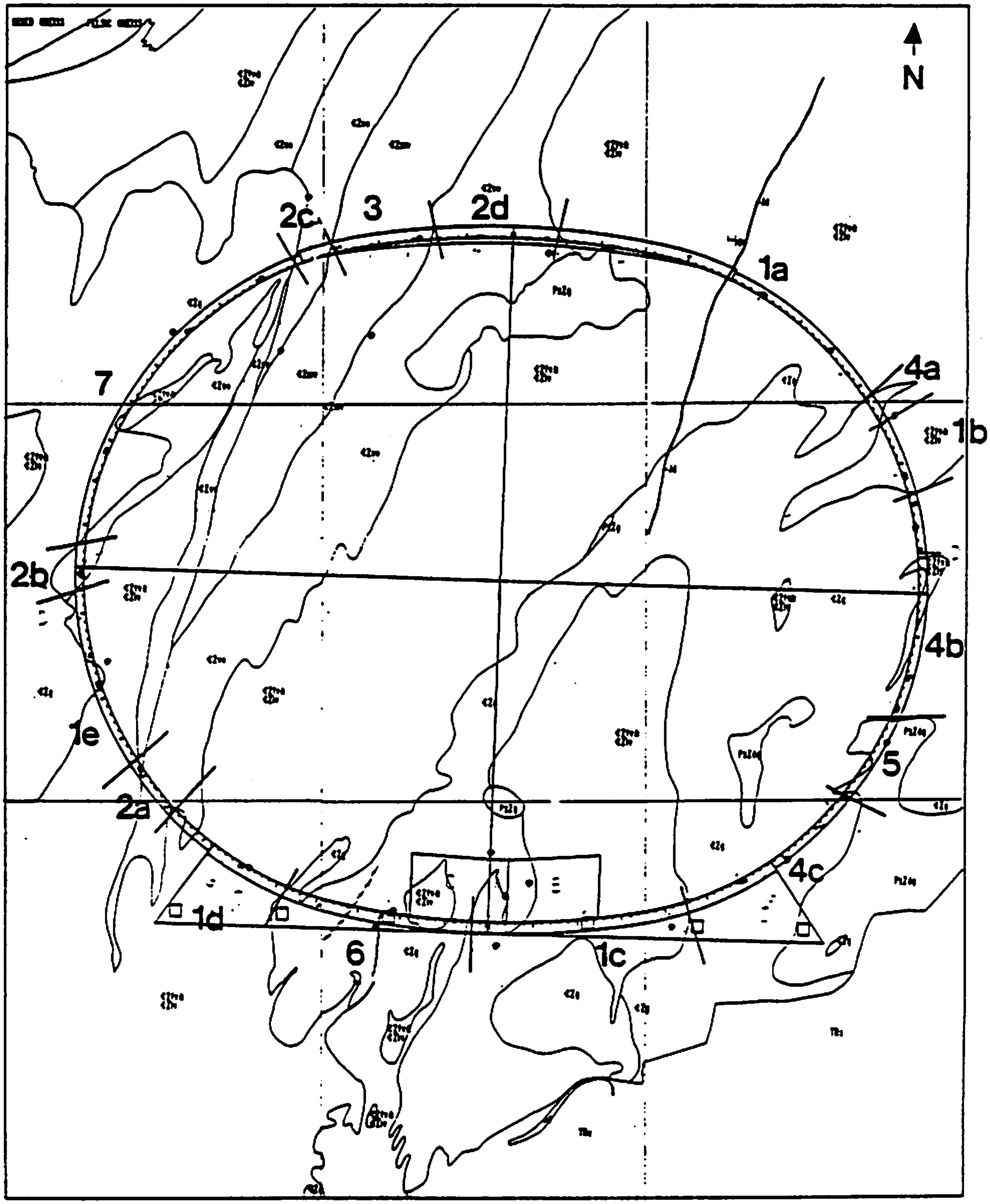


Figure 3-12. The rock unit and subunit specification based on local geology.

SIMPLIFIED GEOLOGIC MAP EXPLANATION

Metamorphosed Volcanic and Sedimentary Rocks

CZmv	Mafic and felsic volcanic rocks (Virgilina Fm.)
CZve	Tuffaceous epiclastic rocks (Aaron Fm.)
CZfv & CZiv	Felsic and intermediate volcanic rocks of the Hyco Fm.

Intrusive Rocks

Jd	Diabase
PzZg	Gabbro
CZg	Roxboro Metagranite Butner Stock (Flat River Complex) Moriah Pluton (Flat River Complex) Oxford Pluton

Table 3-3. Specification of Rock Unit and Subunit Locations and Lithologies

Rock unit	Station		Ring (%)	Lithology
	Subunit	Location		
1	a	5K + 650 to 46K + 600	15	metamorphosed felsic and intermediate volcanic rocks and granitic rocks; also includes metamorphosed mafic volcanic rocks
4	a	46K + 600 to 49K + 550	1	granitic rocks
1	b	49K + 550 to 58K + 400	3	metamorphosed felsic and intermediate volcanic rocks
4	b	58K + 400 to 84K + 850	9	granitic rocks and subordinate metamorphosed felsic and intermediate volcanic rocks
5		84K + 875 to 94K + 650	3	metamorphosed hornblende diorite and gabbro
4	c	94K + 650 to 117K + 300	8	granitic rocks
1	c	117K + 300 to 136K + 200	7	metamorphosed felsic and intermediate volcanic rocks; also includes minor diorite-gabbro and mafic dikes
6		136K + 200 to 161K + 0	10	granitic rocks and subordinate metamorphosed felsic and intermediate volcanic rocks
1	d	161K + 0 to 176K + 0	5	metamorphosed felsic and intermediate volcanic rocks and some metamorphosed tuffaceous epiclastic rocks

(continued)

Table 3-3, continued

Rock unit	Station		Ring (%)	Lithology
	Subunit	Location		
2	a	176K + 0 to 186K + 0	3	metamorphosed tuffaceous epiclastic rocks and metamorphosed felsic and intermediate volcanic rocks
1	e	186K + 0 to 208K + 250	8	metamorphosed felsic and intermediate volcanic rocks with some metamorphosed tuffaceous epiclastic rocks
2	b	208K + 250 to 213K + 550	2	metamorphosed tuffaceous epiclastic rocks
7		213K + 550 to 254K + 800	14	metamorphosed granitic rocks and minor felsic and intermediate volcanic rocks
2	c	254K + 800 to 259K + 150	2	metamorphosed tuffaceous epiclastic rocks with some metamorphosed mafic volcanic rocks
3		259K + 150 to 271K + 100	5	metamorphosed mafic and felsic volcanic rocks
2		271K + 100 to 5K + 650	5	metamorphosed tuffaceous epiclastic rocks

The features shown on the tunnel profile include geologic contacts along the tunnel route based on diamond drilling and geologic field mapping, faults, joint trends, regional cleavages and foliation, bedding, and local topographic lineaments. Topographic lineaments were plotted from primary and secondary drainage segments from data collected within a two-mile-wide corridor (one mile on each side of the tunnel centerline) and within a perimeter of one mile from the near and far clusters and all interaction, campus, service, and access areas.

An index diagram is provided on each profile sheet that shows the location and percent of the profile segment. Expanded descriptions of the rock units through which the tunnel would pass and diagrams showing structural trends of the units along the centerline route of the tunnel are included.

The American Geological Institute (AGI) terminology (Dietrich et al., 1982) applies only to unmetamorphosed rocks. Because the rocks in North Carolina's proposed site are metamorphosed, they were named on the basis of hand specimen mineralogy and were verified in the laboratory through thin-section examination. The names and absolute (radiometric) ages of the rock types correspond to those of the 1985 Geologic Map of North Carolina, which is included as Map Supplement E-3.

Profiles for the abort/external beam access areas (areas J1 through J6) and for the campus, injector, and future expansion areas (areas A, B, and C, respectively) are included as Map Supplement H-10 and H-11. These profiles show the boundaries between the overburden, weathered rock, and unweathered rock. The profile of the abort/external beam access areas is in the plane that runs through the center of areas J1 through J4. The profile also shows the intersection of the plane of the collider ring. Map Supplement H-11 shows a profile of the campus, injector, and future expansion areas (land areas A, B, and C, respectively).

All profiles show the surface topography, the proposed placement of the collider ring (or the intersection with the plane of the collider ring), the proposed location of the SSC surface facilities (areas E, F, K, and J), geologic contacts, and locations of major rivers. The injector area profile shows the proposed positioning of the injector.

As an alternative presentation, Map Supplement H-12 illustrates a multi-surface profile of the proposed collider ring location and includes the surface elevation, water table (at selected points), overburden, weathered rock, unweathered rock, and collider tunnel. The profile also shows the proposed locations of the SSC surface facilities (areas E, F, and K). The profile is continuous and is shown in four segments beginning at area F5. The profile is plotted clockwise at the tunnel position, 200 feet outside the inner ring of the collider.

The first surface, the land surface elevation, is based on USGS DEM data. The second surface illustrates the approximate delineation between the overburden and the weathered rock. The third surface represents the upper extent of unweathered rock. The soil overburden profile is based on measurements from 23 boring sites and

4 soil-sampling locations. Depths to weathered rock and unweathered rock were measured at the 23 boring sites. The locations of the boring sites are shown on Map Supplement B-5 and Figure 3-10. Water table depths are shown, which are based on data collected during the subsurface exploration. The proposed subsurface placement of the collider ring is also indicated. The tunnel depths for the E, F, and K areas and for three points of low elevation are listed in Table 3-2 (in Section 3.1.2, above).

Also appearing in Map Supplement H-16 is a block diagram with an enhanced vertical scale showing the geology and surface topography in the vicinity of the near cluster. A version of this block diagram also is given in Figure 3-13.

3.2.3 Lineaments, Cleavages, and Joints

The North Carolina Geological Survey (NCGS) staff collected both field and literature data to characterize the structural and mineralogical fabric of the rocks in the area of the proposed SSC site. This information was used in the geotechnical investigations and for evaluation of tunnel construction and TBM advance. The data include quantitative outcrop and topographic lineament plots and bedding, cleavage, and joint measurements taken from rock outcroppings and analyzed stastically. Topographic lineaments were plotted from primary and secondary drainage patterns on 7.5-minute USGS topographic maps. Drainage patterns are controlled by the underlying rocks, which reflect bedrock lineament orientations and their lengths. Of the 2,053 measured topographic lineaments, 1,238 occurred within a 2-mile-wide corridor along the proposed centerline of the tunnel and in a broader area in the proposed near and far cluster locations. These data, shown in Table 3-4, indicate two major topographic lineament trends: one at 290 to 360°, the other at 0 to 30°.

Field work included measuring more than 800 rock outcrop structural orientations (including bedding, cleavage, and joints), refining geologic contacts, and detailed geologic mapping of previously unmapped areas. Joint length, spacing, and density were measured at 124 outcrops. Joint density was quantitatively determined on the outcrops using a wire grid divided into 100-mm squares. Joints were counted at each 100-mm intersection with the grid oriented horizontally. One side of the grid was oriented toward the north (0°). These data indicate major joint trends at 270 to 340°, 0 to 30°, and 40 to 70° with nearly vertical dips. Joint surfaces are closed and smooth in most rock units. Cleavage directions, which are in the range of 20 to 50°, reflect the regional northeast trend of rocks in North Carolina. The outcrop structural measurements provide regional data that correlate with the topographic lineament plots. Outcrop data also link the data from the diamond drill holes and the downhole geophysical investigations. They are important for the tunnel boring design. The measurements were quantitatively analyzed using Schmidt equal area nets to determine preferred orientations and distribution of the structural features. Rose diagrams and histograms were used to compare statistically structural trends in the rock units shown on the Geological Profile. Table 3-4 also summarizes the

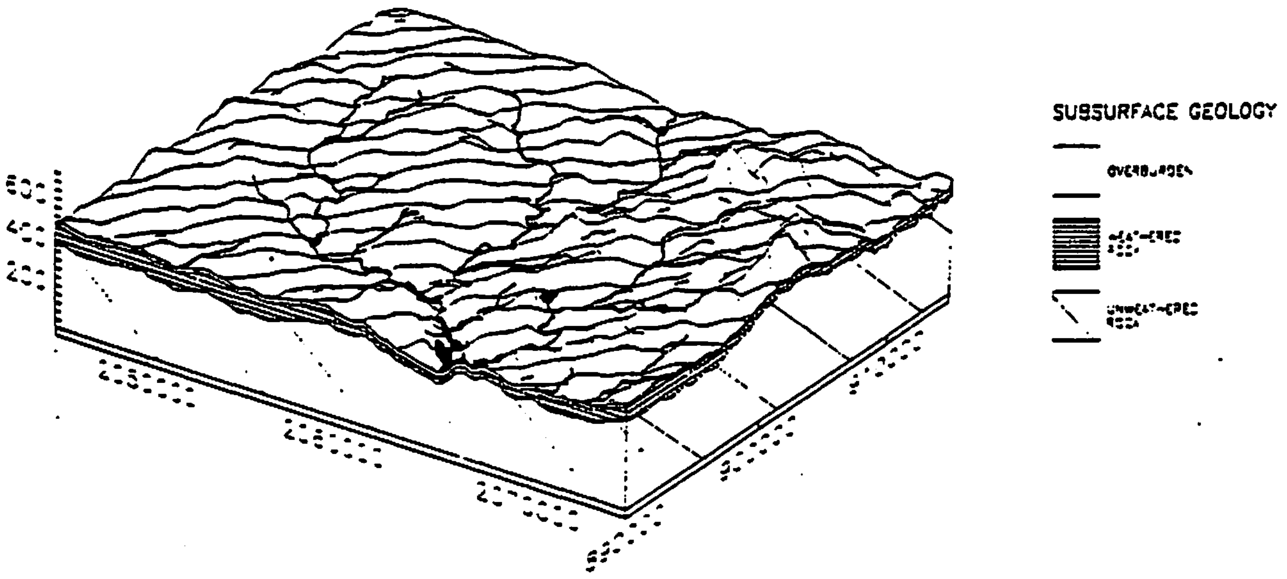


Figure 3-13. Block diagram perspective of the subsurface geology of the proposed SSC site.

Table 3-4. Summary of Field Geologic Information for the Proposed SSC Site[a]

Rock unit	Subunit	Topographic lineament orientation (azimuth)	Joint trend (azimuth)	Joint dip	Surface joint condition	Regional cleavage strike (azimuth)
1	a	bidirectional trends at 0-10 and 340-350	major trends at 280-310 and 40-50; subordinate trend at 340-350	steeply to NE and NW; and some nearly horizontal	closed with smooth surfaces; several filled with clay	20-30
4	a	290-300	major trend at 280-290; minor trend at 340-350	steeply to SE and NE; a few shallow to horizontal	closed with smooth surfaces	30-40
1	b	bidirectional trends at 350-360 and 60-80; subordinate trend at 0-10	major trend at 270-280; minor trends at 0-10, 20-30, and 300-310	3 sets of dips: steeply to E, SW, and NE	closed with smooth surfaces	0-30
4	b	primary trend at 0-10; secondary trend at 300-310; minor trends at 320-330 and 350-360	trends at 0-10, 10-20, and 270-280	steeply to E and W; one joint dips steeply to N	ND	40-50
5		bidirectional trends at 310-340 and 60-90	ND	ND	ND	ND

(continued)

Table 3-4, continued

Rock unit	Subunit	Topographic lineament orientation (azimuth)	Joint trend (azimuth)	Joint dip	Surface joint condition	Regional cleavage strike (azimuth)
4	c	primary trend at 320-350; subordinate trend at 0-30	trends at 0-10 and 340-350	steeply to NE or SE; some are shallow to horizontal	closed with smooth surfaces	ND
1	c	bidirectional trends at 0-30 and 320-330	trends at 20-30 and 270-280	steeply to NE or SE; some are shallow to horizontal	most closed with smooth surfaces; one had a rough surface	30-40
6		bidirectional trends at 40-50 and 350-360	trends at 60-70 and 300-310	steeply to NE, SE, and SW	closed and open with smooth and rough surfaces; occasionally healed with quartz; one showed vertical slickensides	30-40
1	d	bidirectional trends at 270-280 and 310-70	major trends at 10-20 and 330-340; minor trends at 20-30 and 60-70	steeply to SE and N W	open and closed with smooth and rough surfaces; one healed with quartz	30-40
2	a	bidirectional trends at 30-40 and 300-310	major trend at 30-40; minor trends at 290-300 and 320-330	steeply to SE	closed with smooth surfaces	0-10

(continued)

Table 3-4, continued

Rock unit	Subunit	Topographic lineament orientation (azimuth)	Joint trend (azimuth)	Joint dip	Surface joint condition	Regional cleavage strike (azimuth)
1	e	major trend at 10-20	major trend at 300-310; scatter of minor trends	steeply to NE and SW	closed with smooth surfaces	30-60
2	b	?	?	?	?	?
7		bidirectional trends at 10-20 and 300-310	major trend at 30-40	steeply to NE and SW	closed with smooth surfaces	?
2	c	333-350	trends at 50-60 and 320-330	steeply to NE	closed with smooth surfaces and Fe-Mn oxide staining; some rough surfaces	40-50
3		bidirectional trends at 60-70 and 310-340	dominant trend at 320-340	steeply to NE	closed with smooth surfaces	40-50
2		0-10	trends at 270-280 and 290-300	SW and N	smooth surfaces	40-50

[a] ND = no data

outcrop data and topographic lineaments and gives the percent distribution of the rock units around the ring.

3.2.4 Significant Geologic Features

No geologic features associated with the proposed North Carolina site are known that would present construction or long-term operational problems. There is no local history of ground settlement, slope instability, or presence of natural gas in the area of the proposed site. Faults within the site are older than 575 ± 20 million years, and these faults are inactive.

There are no active mines or quarries on the proposed SSC land areas or inside the proposed ring location. An intermittently active quarry on the Camp Butner property, south of the campus area, will be closed if the North Carolina site is selected and if it is determined by the DOE that the continued operation of the quarry would be detrimental to operation of the SSC. Other quarries indicated on USGS topographic maps for the site area are inactive. Abandoned shallow underground copper mines and prospects, active from 1852 until about 1918, are located mostly north of the proposed site. It is not anticipated that tunnel construction will encounter any of the underground workings. The area has not been affected by subsidence from the mined areas. No natural gas (e.g. methane or hydrogen sulfide) is known to be associated with these abandoned workings or occur elsewhere in the area of the proposed site.

No areas are subject to subsidence by solution activity; the site does not contain carbonate rocks. As discussed in Section 3.3.2 (below), surface subsidence from groundwater withdrawal is not a concern at the proposed site.

Groundwater acidification due to pyrite weathering is not considered to be a potential problem at the proposed site. Lowering of the groundwater level during tunneling could expose some pyrite to oxidation, but the reaction would be limited by the exposed surface of pyrite in the fractures. The available pyrite surface is several orders of magnitude less than is usually seen in coal-mine areas. Chemical analyses do not show any significant difference in pH of well water between pyrite-bearing and non-pyrite-bearing areas, and pH and iron cation concentrations are not correlated.

3.2.5 Soil Conditions

The soils in the area of the proposed site are residual soils developed by in-place weathering of the geologic formations present. Small areas of alluvial or colluvial soils may occur in stream valleys. A typical soil profile includes clay (Unified Soil Classification System designation CL or CH), silty clay (CL), or clayey silt (ML or MH) at the surface grading to sandy silt (ML-SM) and silty sand (SM) with increasing depth.

Data from borings performed for SSC site exploration (described in detail in the separately bound Geology Appendix) and from previous explorations in the proposed ring area indicate that the depth to hard soil or partially weathered rock is normally less than 20 feet in areas underlain by volcanic rock and 20 to 40 feet in areas underlain by intrusive rocks. Table 3-5 summarizes general soil characteristics associated with each of the seven rock units. The depth of true soil does not typically exceed about five feet; below this is the soil parent material. Soil depths in Table 3-5 include both soil regions.

The upper clayey soils associated with the mafic metavolcanic rock often have a high plasticity index and are considered by the U.S. Department of Agriculture Soil Conservation Service (SCS) as having restrictions due to moderate to high shrink-swell potential. Because these soils do not extend to significant depths, they can easily be removed from construction sites either as part of normal grading or by limited undercutting. Construction in the area historically has not experienced detrimental impacts from these soils.

The soils have firm to hard consistencies and become harder with depth. Soft clays or loose sands that would have a significant impact on construction of the SSC surface facilities are not expected to be present. The proposed placement of the collider tunnel itself is completely in rock.

Borings in the proposed campus area show the typical soil profile described above, with depths to rock ranging from 1.5 feet to 55 feet below ground surface, but usually less than 20 feet. The standard penetration resistance, an indicator of soil strength and density, ranged from 12 to greater than 50 blows per foot. Such values, for clayey and silty soils, indicate unconfined compression strengths greater than 2,000 lb/ft^2.

The soils in the proposed campus area are generally suitable for use in compacted fill and for slab and road subgrade without special treatment. Test data for these soils, summarized in Tables 3-6 through 3-8. The proposed campus area may contain local, shallow-depth zones of clay with moderate shrink-swell potential. These soils, if not removed during site grading, may require local undercutting.

The CDR describes campus buildings of one to four stories. The soils in the proposed campus area are suitable for use of shallow footing foundations for buildings of these heights, assuming office-type loads. Soil bearing pressures in the range of 3,000 to 5,000 lb/ft^2 are commonly used in this part of North Carolina for soils similar to those in the proposed campus area. Foundation settlements of less than 1 inch are associated with such bearing pressures. Soils also are discussed in Sections 5.1 and 6.3 and in the appendix to this volume.

Table 3-5. Summary of Soil Conditions Associated with the Rock Units of the Proposed SSC Site

Rock unit	Lithology	Typical soil profile	Construction comments
1	Felsic and felsic plus intermediate volcanics	soil thickness 15 to 20 ft with partially weathered rock at base; locally, soil up to 50 ft stiff to hard consistency with normal weathering profile local plastic clay in upper 2 to 4 ft water table often within 10 ft of surface	no significant construction problems good for shallow foundations with bearing pressures 3,000 to 5,000 lb/ft^2
2	Epiclastics	soil thickness 10 to 25 ft with partially weathered rock at base stiff to hard consistency with normal weathering profile local plastic clay in upper 2 to 4 ft water table 10 to 15 ft	no significant construction problems good for shallow foundations with bearing pressures 3,000 to 5,000 lb/ft^2

(continued)

Table 3-5, continued

Rock unit	Lithology	Typical soil profile	Construction comments
3	Mafic and intermediate volcanics	soil thickness 10 to 15 ft with partially weathered rock at base stiff to hard consistency with normal weathering profile, but generally higher clay content than other rock units local clay with shrink-swell potential in upper 3 to 5 ft water table 10 to 20 ft	clay soils somewhat difficult to work in wet weather; local undercutting to remove shrink-swell clays good for shallow foundations with bearing pressures 2,000 to 3,000 lb/ft^2
4	Oxford pluton	soil thickness 25 to 35 ft with thin partially weathered rock stiff to very stiff consistency with normal weathering profile local plastic clay in upper 3 to 5 ft water table 5 to 10 ft	no significant construction problems local undercutting to remove more plastic clay surface clayey soils more difficult to work in wet weather good for shallow foundations with bearing pressures 2,000 to 3,000 lb/ft^2

(continued)

Table 3-5, continued

Rock unit	Lithology	Typical soil profile	Construction comments
5	Hornblende diorite-gabbro	soil thickness 40 to 50 ft with thick partially weathered rock stiff to very stiff consistency with normal weathering profile plastic clay with shrink-swell potential likely in upper 3 to 5 ft	plastic clay requires undercutting, otherwise few significant construction problems good for shallow foundations with bearing pressures 2,000 to 3,000 lb/ft^2
6	Moriah pluton	soil thickness erratic 5 to 50 ft with thicker partially weathered rock than other units stiff to hard consistency with normal weathering profile local plastic clay in upper 2 to 4 ft water table 5 to 15 ft	no significant construction problems local undercutting to remove more plastic clay surface clayey soils more difficult to work in wet weather good for shallow foundations with bearing pressures 2,000 to 3,000 lb/ft^2

(continued)

Table 3-5, continued

Rock unit	Lithology	Typical soil profile	Construction comments
7	Roxboro metagranite	soil thickness 25 to 40 ft with thick partially weathered rock zone stiff to hard consistency with normal weathering profile local plastic clay in upper 3 to 5 ft water table 15 to 20 ft	no significant construction problems local undercutting to remove more plastic clay surface clayey soils difficult to work in wet weather good for shallow foundations with bearing pressures 2,000 to 3,000 lb/ft^2

3.2.6 Location of Data Sources

The NCGS has been designated the State's agency responsible for storage of all drill core, geophysical survey data, geotechnical records, profiles, plans and drawings, and geologic field data and related computer records. The drill

core is stored in the core storage facility, located at 4100 Reedy Creek Road, Raleigh, NC. The core storage facility is a weatherproof building with excellent facilities for core examination, including binocular microscopes, rock saws, sample examination room, and miscellaneous supplies.

Drill core records are maintained in a relational database (dBase III Plus) on an IBM Personal Series 2, Model 50 computer. Drill core can be retrieved by numerous parameters, including location, drill hole number, depth, county, lithology, and others. Professional geological staff are available to retrieve core and to assist visitors.

Geophysical records and related geotechnical information are stored in the main office of the NCGS, located at Suite 519-2 in the Archdale Building, 512 North Salisbury Street, Raleigh, NC 27611. Many of the records are available in microfiche

ROAD LOG

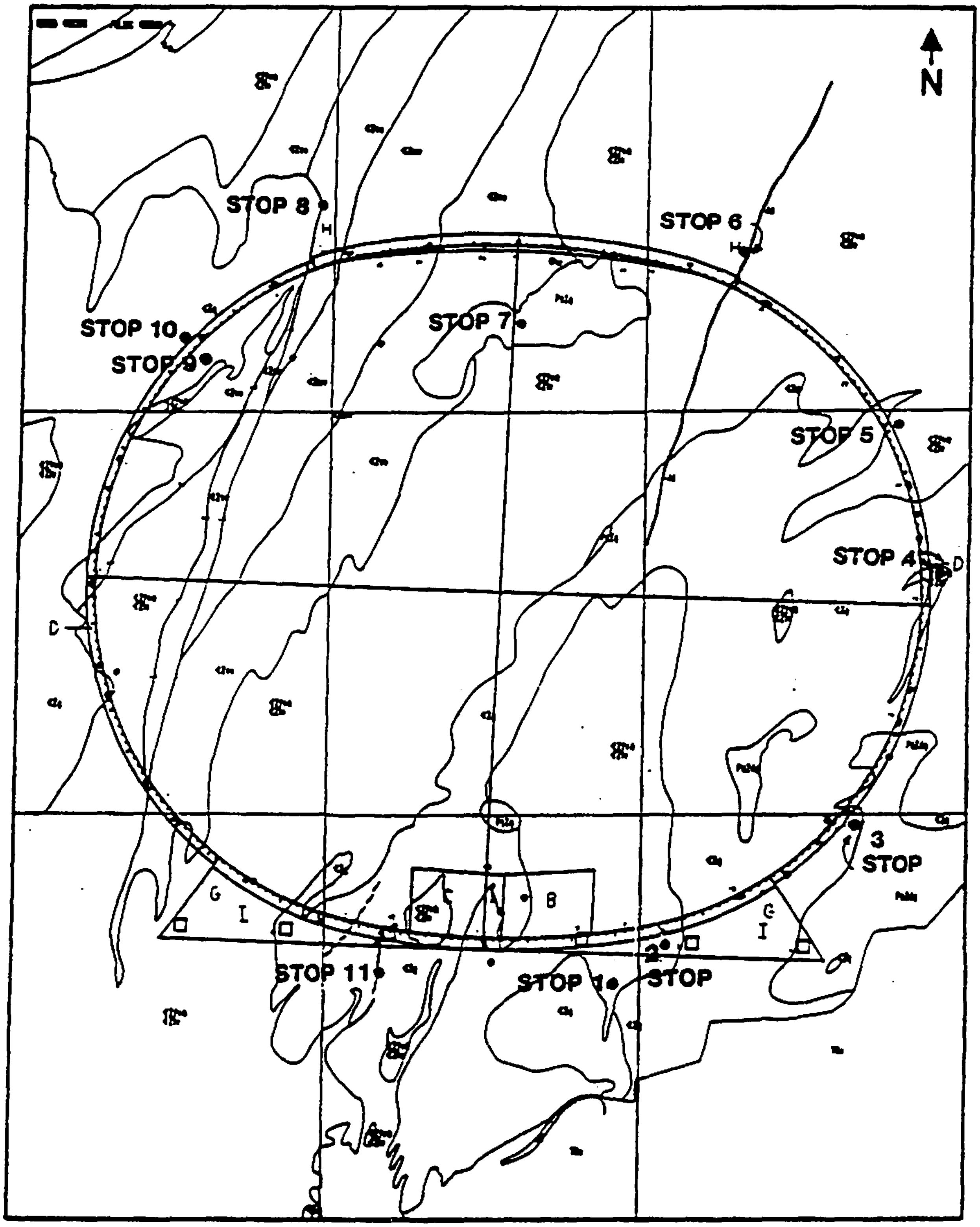


Figure 3-14. Geology and road log stops.

SIMPLIFIED GEOLOGIC MAP EXPLANATION

Metamorphosed Volcanic and Sedimentary Rocks

CZmv	Mafic and felsic volcanic rocks (Virgilina Fm.)
CZve	Tuffaceous epiclastic rocks (Aaron Fm.)
CZfv & CZiv	Felsic and intermediate volcanic rocks of the Hyco Fm.

Intrusive Rocks

Jd	Diabase
PzZg	Gabbro
CZg	Roxboro Metagranite Butner Stock (Flat River Complex) Moriah Pluton (Flat River Complex) Oxford Pluton
PzZdg	Hornblende diorite-gabbro

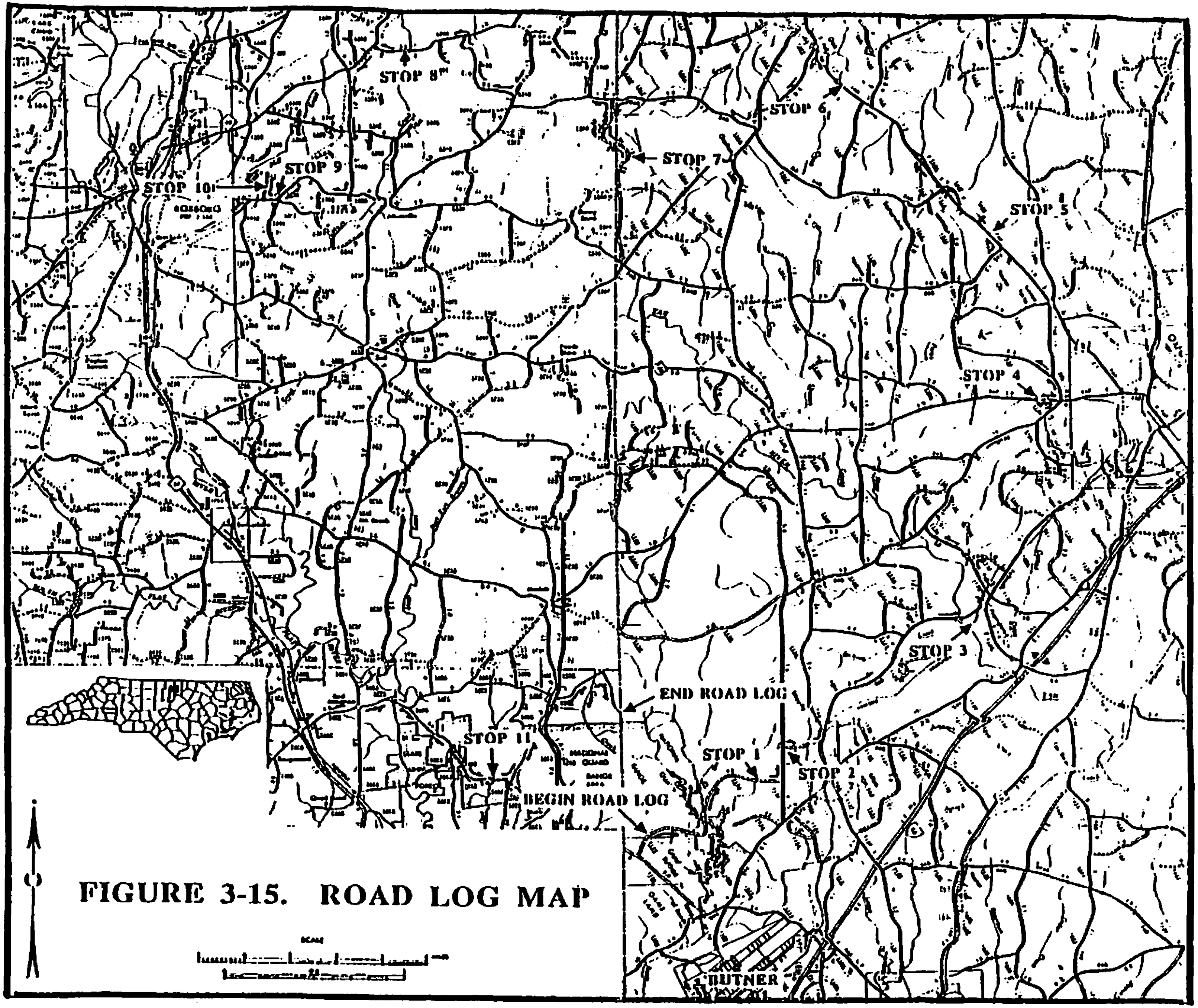


FIGURE 3-15. ROAD LOG MAP

ROAD LOG FOR NORTH CAROLINA'S SSC SITE

CUMULATIVE MILEAGE (MILES)	
	START OF LAKE MICHIE QUADRANGLE
0	Start at the gate leading to Camp Butner National Guard Headquarters on SR 1123. This is quartz count site I-4 (5% quartz) in granodiorite of the 650±30 million-year-old Butner Stock of the Flat River Complex.
0.25	Quarry road on left. The quarry is in the Butner Stock granodiorite and quartz diorite intruded by mafic dikes. Secondary mineralization in joints and fractures is calcite, chlorite, and epidote.
1.55	Quartz count site I-5 (17.5% quartz) is located in the Butner Stock granodiorite on the west side of SR 1123.
1.60	Quartz count site I-6 (33.5% quartz) is located in the Butner Stock on the east side of SR 1123 at the southeast end of the bridge over Lake Butner.
2.45	Lithologic contact of Butner Stock with felsic metavolcanic rocks of the Hyco Formation. The Hyco Formation is > 650±30 to 620±20 million years old.
3.50	STOP 1. ***SSC-13, outcrop location of the felsic metavolcanic rocks of the Hyco Formation.***
	This outcrop is 1.0 mile south of the center line of the proposed SSC tunnel and approximately 1.0 mile southeast of ***E10 (Intermediate Access)***. The depth to the center line of the proposed SSC tunnel at E10 (Intermediate Access) is 152.0 feet.
	START OF STEM QUADRANGLE
3.70	Lithologic contact of the Hyco Formation with granitic intrusive rock of the Oxford Pluton.
4.10	Intersection of SR 1123 (Roberts Chapel Rd.) with SR 1126 (Range Rd.). Turn left onto SR 1126. The rock type is the Oxford Pluton.
4.20	Contact of the Oxford Pluton with metavolcanic rocks of the Hyco Formation.
4.40	SSC-14, outcrop location of felsic metavolcanic phyllite of the Hyco Formation.
4.80	STOP 2. ***SSC-15 outcrop location of the felsic metavolcanic rocks of the Hyco Formation.***
	J3 (Abort/External Beam Access) is 0.5 of a mile east of this location, and the center line of the proposed SSC tunnel is 0.55 of a mile north.
4.90	Intersection of SR 1126 (Range Rd.) with SR 1137 (Little Mountain Rd.). Turn right onto SR 1137. If you continued north on SR 1126, you would cross the proposed SSC tunnel center line 0.45 of a mile north of this intersection.
4.95	***Core drill site SC-13*** is located on the north side of SR 1137. This site was

4.95 (cont'd) drilled to a total depth of 156.2 feet in felsic metavolcanic rocks of the Hyco Formation. Continue east on SR 1137. A thin section photomicrograph from the drill core is in the Road Log Appendix.

5.30 Lithologic contact of the felsic metavolcanic rocks of the Hyco Formation with granitic rocks of the Oxford Pluton. Between the creek and SR 1004, you will cross into the Oxford Pluton and into *J3 (Abort/External Beam Access).*

5.70 Intersection of SR 1137 with SR 1004. Turn left onto SR 1004. You are still in the Oxford Pluton. At this intersection, you are approximately 0.65 of a mile southwest of the proposed SSC tunnel center line.

6.35 Center line of the proposed SSC tunnel crosses under SR 1004. You are in granitic rocks of the Oxford Pluton.

7.10 At the intersection of SR 1004 and an unpaved farm road to the left and Raney Way subdivision to the right, you are 0.3 of a mile northwest of F9 (Service Area) and 0.25 of a mile northwest of the center line of the proposed SSC tunnel. At F9, the depth to the center line of the proposed SSC tunnel is 140.0 feet.

8.30 Intersection of SR 1004 with SR 1158 (Brinkley Rd.). At the end of SR 1158 is ***core drill site SC-14*** drilled in a mafic dike rock in the Oxford Pluton to a total depth of 149.3 feet. Depth to the tunnel center line in this drill hole is 105 feet. SR 1158 also crosses the center line of the proposed SSC tunnel 0.3 of a mile southeast of this intersection.

8.35 SSC-17, outcrop location of granitic rocks of the Oxford Pluton.

10.15 SR 1004 crosses the proposed SSC tunnel center line.

11.40 ***Core drill site SC-5*** is drilled to a total depth of 87.5 feet in granitic rocks of the Oxford Pluton intruded by metabasalt dikes. This drill site is located on the north side of SR 1004 on east side of the Tar River bridge. At this drill site, depth to the center line of the proposed SSC tunnel is 61.0 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

11.75 Lithologic contact of granitic rocks of the Oxford Pluton with diorite-gabbro.

START OF BEREA QUADRANGLE

11.85 **STOP 3. Outcrop of granitic rocks of the Oxford Pluton.**

Park at the Southern Railroad and walk 0.4 of a mile south-southeast along the Southern Railroad. On the east side of the Tar River is the outcrop and quartz count location I-11 (24% quartz). This is an excellent outcrop of the Oxford Pluton.

12.25 Providence community. Intersection of SR 1004 with SR 1156 (Harper Renn Rd.). Turn left onto SR 1156.

12.45 Lithologic contact. On SR 1156, you cross from diorite-gabbro into granitic rocks of the Oxford Pluton.

12.85 Lithologic contact. On SR 1156 you cross from the Oxford Pluton into diorite-gabbro.

13.15 Intersection of SR 1156 (Harper Renn Rd.) with SR 1157 (Peake Rd.). Turn right onto SR 1157.

13.55 Quartz count site I-12 (31% quartz) is located on the north side of SR 1157. Specimen was taken from a residual boulder located in the field to the left.

13.65 Cross the center line of the proposed SSC tunnel along SR 1157.

13.75 ***Core drill site SC-15*** was drilled in diorite and quartz diorite to a total depth of 158.5 feet and intersects the tunnel center line at a depth of 112 feet. The drill site is located on the north side of SR 1157. A thin section photomicrograph from the drill core is in the Road Log Appendix.

14.05 Intersection of SR 1157 with SR 1004. Turn right onto SR 1004.

14.70 Intersection of SR 1004 with SR 1156. Turn right onto SR 1156.

15.60 Lithologic contact. Diorite-gabbro with granitic rocks of the Oxford Pluton.

16.90 Intersection of SR 1156 with SR 1139. Turn right onto SR 1139. The rock type along this road is the Oxford Pluton.

20.40 Cross the center line of the proposed SSC tunnel. The rock type is granitic rock of the Oxford Pluton.

20.55 Intersection of SR 1139 with SR 1164. Lithologic contact of the Oxford Pluton with felsic metavolcanic rocks of the Hyco Formation is located approximately 700 feet northwest of this intersection.

21.30 Intersection of SR 1139 with highway US 158. Turn left onto highway US 158. Rock type at the intersection is the Oxford Pluton.

21.50 Contact of the Oxford Pluton with felsic metavolcanic rocks of the Hyco Formation.

21.75 **STOP 4.** ***Felsic metavolcanic rocks of the Hyco Formation.*** Quartz count site V-1 (5% quartz) in felsic metavolcanic rocks is located here. **Turn around and continue east on highway US 158 to the intersection with SR 1300.**

22.15 Turn left onto SR 1300. You are in granitic rocks of the Oxford Pluton.

22.70 Intersection of SR 1300 and SR 1301. Continue straight onto SR 1301 (SR 1300 turns to the right). This road traverses granitic rocks of the Oxford Pluton.

23.50 ***Core drill site SC-18A*** and center line of the proposed SSC tunnel. SC-18A is located on the south side of SR 1301 and was drilled in the Oxford Pluton to a total depth of 209.5 feet. The drill hole intersects the tunnel center line at a depth of 163 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

24.95 Intersection of SR 1301 with SR 1303. SSC-19 outcrop location showing felsic metavolcanic xenoliths within the Oxford Pluton. Turn right onto SR 1303.

25.25 Lithologic contact. Oxford Pluton in contact with felsic metavolcanic rocks of the Hyco Formation injected by quartz veins on the east side of the road.

26.15 Quartz count location I-13 (36.5% quartz) and outcrop location SSC-21. Outcrop of the Oxford Pluton on the west side of SR 1303.

26.45 Intersection of SR 1303 with SR 1304. Turn right onto SR 1304.

27.20 SR 1304 crosses the center line of the proposed SSC tunnel.

27.60 ***Core drill site SC-19.*** SC-19 was drilled in felsic metavolcanic rocks of the Hyco Formation to a total depth of 159.0 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

27.80 Intersection of SR 1304 with highway NC 96. Turn left onto highway NC 96. You are in felsic metavolcanic rocks of the Hyco Formation.

28.15 STOP 5. ***SSC-124, outcrop location of felsic metavolcanic rocks of the Hyco Formation.*** Quartz count location V-16 (estimated, 10% quartz).

START OF SATTERWHITE QUADRANGLE

32.65 SSC-33, outcrop location of felsic volcanic rocks of the Hyco Formation on highway NC 96. This site is located approximately 5.2 miles northwest of the intersection of highway NC 96 with SR 1415.

33.05 STOP 6. ***Jurassic diabase dike located on the north and south sides of highway NC 96.*** The diabase dike is exposed as residual spheroidal boulders.

33.10 ***Core drill site, SC-20.*** SC-20 was drilled in felsic metavolcanic rocks of the Hyco Formation to a total depth of 90.0 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

34.05 Intersection of highway NC 96 with SR 1321. Turn left onto SR 1321.

35.70 SR 1321 crosses the center line of the proposed SSC tunnel site. From this point, ***E6 (Intermediate Access)*** is located 0.55 of a mile west. The depth to the center line of the proposed SSC tunnel at E6 is 156.0 feet.

36.10 Intersection of SR 1321 with SR 1323. Turn left onto SR 1323 (Jack Adcock Rd.).

36.45 Intersection of SR 1323 with SR 1317. Turn right onto SR 1317 (Satterwhite Rd.).

START OF TRIPLE SPRINGS QUADRANGLE

38.15 Intersection of SR 1317 with SR 1325. SR 1317 continues west from this intersection through the Hyco Formation to intersections with SR 1562 and with SR 1560. SR 1317 parallels the center line of the SSC tunnel and the orientation of the ***Far Cluster.***

39.10 ***Core drill site SC-21*** is drilled in metamorphosed tuffaceous epiclastic rocks of the Aaron Formation 0.3 of a mile southeast of ***K5 (Interaction Point)*** and 0.3 of a mile south of the center line of the proposed SSC tunnel. The depth to the

39.10 (con't.) proposed center line of the SSC tunnel at K5 is 176.0 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

39.70 Person-Granville County Line. Granville County SR 1317 becomes SR 1561 in Person County.

39.80 Intersection of SR 1561 with SR 1563. Turn left onto SR 1563. Note: **At this intersection, the SR road sign numbers do not correspond to the SR road numbers on the county highway Road Log Map. Disregard the SR numbers on the county highway Road Log Map and follow the SR numbers on the road signs.**

39.90 Intersection of SR 1564 with SR 1563. Turn left onto SR 1564. Note: **From this intersection, the SR road numbers on the Road Log Map and the SR numbers on the road signs correspond with one another.**

40.75 Continue left onto SR 1563 (J.D. Denny Rd.).

41.00 Outcrop of metavolcaniclastic-epiclastic rocks of the Aaron Formation interlayered with felsic metavolcanic rocks. Stratigraphically, the Aaron Formation is younger than the Hyco Formation but older than the Virgilina Formation. Metamorphosed tuffaceous-epiclastic rocks of the Aaron Formation conformably overlie the felsic and intermediate volcanic rocks of the Hyco Formation, and crop out on the east and west limbs of the Virgilina Synclinorium.

41.20 Contact of epiclastic rocks with gabbro (good outcrop in the field on the right).

41.45 Granville-Person County Line.

41.65 STOP 7. *Quartz count site I-15 (0% quartz) located in gabbro.*

The center line of the proposed SSC tunnel is located 1.65 miles north of this site. *F5 (Service Area)* is located 1.75 miles to the northwest. Depth of the proposed SSC tunnel at F5 is 201.0 feet. **Turn around** and return to the intersection of SR 1561 and SR 1564. (Note: SR 1317 in Granville County is numbered SR 1561 in Person County.)

41.80 Person-Granville County Line.

42.35 Turn right onto SR 1564.

43.25 Intersection of SR 1564 and SR 1563. Turn right onto SR 1563.

43.35 Intersection of SR 1563 and SR 1561 (Vernon Church Road). Turn left onto SR 1561.

43.80 Intersection of SR 1561 with SR 1560. Turn right onto SR 1560.

44.00 *Far Cluster*. Center line of proposed SSC tunnel. *F5 (Service Area)* is located 0.4 of a mile east of this location. *K4 (Interaction Point)* is located 0.3 of a mile west of this location. The lithology at this site is volcaniclastic-epiclastic rocks (argillites) of the Aaron Formation. The depth of the proposed SSC tunnel at K4 is 183.0 feet.

44.35 Interbedded argillites and mixed metavolcanic, intermediate to mafic in composition.

44.65 Intersection of SR 1560 with SR 1559. Turn left onto SR 1559. Continue across the strike of the interlayered tuffaceous epiclastic rocks and mixed metavolcanic rocks of the Aaron Formation.

45.80 Intersection of SR 1559 with SR 1581. Outcrop at the intersection is interbedded metamorphosed mudstone and felsic metavolcanic rocks of the Aaron Formation.

46.00 SR 1559 crosses the contact of the Aaron Formation with the Virgilina Formation. The Virgilina Formation is stratigraphically younger than the Aaron Formation, conformably overlies the Aaron Formation, and occupies the center of the Virgilina Synclinorium.

The Virgilina Formation consists primarily of basaltic pyroclastic rocks, volcanic breccia, and sills that are locally interbedded with felsic pyroclastic rocks and sills.

46.35 Intersection of SR 1559 with SR 1542. Turn left onto SR 1542 (Durgie Mine Rd). This road crosses in and out of the contact between the Aaron and Virgilina Formations. The Durgie Copper Mine (also spelled Durgy), inactive since 1918, is located 0.1 of a mile southwest of this intersection. In 1942, the U.S. Bureau of Mines drilled, trenched, and geophysically surveyed this property. Because no new ore shoots were discovered during this work, the mine was abandoned. In about 1960, Appalachian Sulfides drilled this property. This geologic investigation supported the 1942 U.S. Bureau of Mines' work. The abandoned mine was not reopened.

47.55 *Core drill site SC-3* is located at the center line of the proposed SSC tunnel, within the ***Far Cluster***. SC-3 was drilled in gray to green mafic metavolcanic rocks of the Virgilina Formation to a total depth of 282.1 feet. The drill hole intersected the tunnel center line at a depth of 248 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

47.80 Intersection of SR 1542 with SR 1555. Turn right onto SR 1555.

48.00 SSC-123, outcrop location of mafic metavolcanic rocks of the Virgilina Formation. Measurements for joints and cleavage were obtained at this outcrop.

48.70 Center line of the proposed SSC tunnel site. Axis of the Virgilina Synclinorium. ***E5 (Intermediate Access)*** is located 0.2 of a mile west of this location. Depth to the center line of the proposed SSC tunnel is 143.0 feet.

49.95 Intersection of SR 1555 with SR 1556. Turn left onto SR 1556 (Lawson Chapel Church Road).

50.30 Aaron-Virgilina Formation contact.

START OF ROXBORO TOPOGRAPHIC QUADRANGLE

50.95 Cross Mayo Reservoir.

51.15 **STOP 8.** ***Core drill site SC-6 and SSC-64 outcrop location.***

SC-6 was drilled in the metamorphosed tuffaceous epiclastic rocks of the Aaron Formation to a total depth of 99.6 feet. SSC-64 rock outcrop is chlorite phyllite interbedded with metamorphosed tuffaceous epiclastic rock. A thin section

51.15 (con't) photomicrograph from the drill core is in the Road Log Appendix.

51.65 Roxboro Metagranite contact with metamorphosed tuffaceous-epiclastic rocks of the Aaron Formation. The Roxboro Metagranite crops out in the northwest portion of the SSC area. The pluton is a predominantly light gray to medium gray fine-grained granite composed of three primary facies: a predominant granitic facies, an alkali-feldspar facies, and a minor granodioritic facies. The age of the pluton dates to about 575±20 million years.

51.85 Intersection of SR 1556 with highway NC 49. Turn left onto highway NC 49. You are in the Roxboro Metagranite.

52.60 Intersection of highway NC 49 with SR 1520. Turn left onto SR 1520.

54.05 Benny community is located in the Roxboro Metagranite. From this intersection, the center line of the proposed SSC tunnel is located 0.1 of a mile south.

54.45 SSC-67, outcrop location of Roxboro Metagranite.

55.45 Intersection of SR 1520 with SR 1536. Turn right onto SR 1536 (Allensville Road).

56.00 Quartz count site I-17 (39.5% quartz) is located in the Roxboro Metagranite at the intersection of SR 1536 with SR 1553.

57.25 **STOP 9.** *SSC-68 outcrop location and I-29 quartz count site.*

The outcrop and quartz count site (I-29, 8% quartz) are in the Roxboro Metagranite. (Park in Rock Grove Baptist Church parking lot and cross SR 1536 to the outcrop.)

57.60 Intersection of SR 1536 with SR 1552. Good exposures of Roxboro Metagranite can be seen along the roadside.

57.80 SR 1536 crosses the center line of the proposed SSC tunnel.

57.85 Intersection of SR 1536 with SR 1545. Turn right onto SR 1545 (Loop Rd.). Boulders of Roxboro Metagranite are visible along the roadside.

58.15 **STOP 10.** *Core drill site SC-7.*

SC-7 is drilled in the Roxboro Metagranite to a total depth of 279.4 feet. The drill site is approximately 0.3 of a mile northwest of *E4 (Intermediate Access)* and 0.35 of a mile northwest of the center line of the proposed SSC tunnel. The depth to the center line of the proposed SSC tunnel at E4 is 274.0 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

59.45 Continue along the loop of SR 1545 to its intersection with SR 1536. Turn left onto SR 1536. (Outcrops and boulders of Roxboro Metagranite occur along the roadside.)

59.55 Intersection of SR 1536 with SR 1541. Turn right onto SR 1541.

61.35 Intersection of SR 1541 with SR 1542. SR 1541 becomes SR 1542; continue straight.

62.00 Intersection of SR 1542 with highway US 158. Turn left onto highway US 158 (Oxford Rd.).

START OF TIMBERLAKE TOPOGRAPHIC QUADRANGLE

62.35 Intersection of highway US 158 and SR 1700. Continue straight onto SR 1700.

64.35 Intersection of SR 1700 with highway US 15-501. Turn left onto highway US 15-501.

65.55 Intersection of highway US 15-501 with SR 1708. ***Core drill site SC-8*** is located 0.2 of a mile east of this intersection and is drilled in interbedded metamorphosed tuffaceous epiclastic rocks and mixed metavolcanic rocks to a total depth of 202.0 feet. The drill hole intersects the center line of the tunnel at a depth of 170 feet. A thin section photomicrograph from the drill core is in the Road Log Appendix.

68.20 Intersection of highway US 15-501 with SR 1131. The center line of the proposed SSC tunnel passes under the intersection of SR 1131 and highway U.S. 15-501. ***F2 (Service Area)*** is located 0.2 of a mile southeast of this intersection. The depth to the center line of the tunnel at F2 is 223.0 feet.

70.10 Contact between felsic metavolcanic rocks of the Hyco Formation and tuffaceous epiclastic rocks of the Aaron Formation.

70.50 Intersection of highway US 15-501 with SR 1202. Turn right onto SR 1202 and go 0.2 of a mile to ***core drill site SC-10***. SC-10 was drilled in metamorphosed epiclastic rocks of the Aaron Formation over the center line of the proposed SSC tunnel to a total depth of 176.5 feet. The drill hole intersects the center line of the tunnel at a depth of 150 feet. The drill site is 0.5 of a mile northwest of ***E2 (Intermediate Access)***. A thin section photomicrograph from the drill core is in the Road Log Appendix.

70.95 Continue on SR 1202 to a drive way on the right. Turn around and return to highway US 15-501.

71.25 Intersection of highway US 15-501 and SR 1202. Turn right onto highway US 15-501.

71.45 Cross the Flat River.

START OF ROUGEMONT TOPOGRAPHIC QUADRANGLE

72.85 Person-Durham County Line.

72.90 SSC-114 outcrop location metavolcanic felsic crystal tuffs of the Hyco Formation.

74.35 Intersection of highway US 15-501 at Rougemont with SR 1471. Turn left onto SR 1471. At this intersection, ***J1 (Abort/External Beam Access)*** is 0.3 of a mile to the southwest.

75.75 Red Mountain Intersection. At this intersection, the center line of the proposed SSC tunnel is approximately 0.3 of a mile to the northeast. ***F1 (Service Area)*** is

75.75 (con't.) located approximately 0.35 of a mile to the northwest. Depth to the center line of the proposed tunnel at F1 is 154.0 feet.

76.65 Bridge over the Flat River.

76.95 Intersection of SR 1471 with SR 1603. Turn right onto SR 1603 (Hampton Rd.). Notice the isolated outcrop and scattered boulders of the Moriah Pluton of the Flat River Complex.

START OF LAKE MICHIE TOPOGRAPHIC QUADRANGLE

77.65 A large boulder of the Moriah Pluton is on the northeast side of the road. Two main facies of intrusive rocks are distinguished within the Flat River complex on the basis of mineralogy and texture. One is the Butner stock, the other predominant facies present is the Moriah pluton, a medium-grained, light-colored granodiorite to granite that forms the core of the Moriah pluton and is present in the eastern part of the Butner stock. The Flat River complex has been dated by the zircon Pb/U method as 650±30 million years old.

79.60 STOP 11. ***Dial Creek; outcrops and boulders of the Moriah Pluton.***

79.95 Intersection of SR 1603 and SR 1607. Turn left onto SR 1607.

80.95 Center line of the proposed SSC tunnel is in metavolcanic rocks of the Hyco Formation. *K2 (Interaction Point)* is located 0.5 of a mile west of this location, and ***J5 (Abort/External Beam Access)*** is located 0.4 of a mile west of this location. Both are in granodiorite of the Moriah Pluton. Depth of the center line of the proposed SSC tunnel at K2 is 199.0 feet.

82.15 Intersection of SR 1607 with SR 1609. Turn right onto SR 1609 and continue to end of the road. ***Core drill site SC-17*** was drilled in ***B (Injector Area)***, in felsic metavolcanic rocks of the Hyco Formation, to a total depth of 120.0 feet.

83.55 ***Core drill site SC-16*** is drilled in granodiorite of the Moriah Pluton to a total depth of 120.1 feet.

84.60 End of the road terminates in ***B(Injector Area)***. Return to SR 1607 and retrace your route to Rougemont and highway US 15-501 to points north and south.

END OF ROAD LOG
TOTAL MILES OF LOG 84.60

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APPENDIX

Dial Creek Geologic Investigation

Surface geologic investigations along Dial Creek from SR 1603 north to drill site SC-12 do not support referring to this area as a shear zone. Rock observed in outcrop and boulders along the creek bank and floodplain are jointed, non-foliated, medium- to coarse-grained granodiorite typical of the Moriah pluton of the Flat River complex. No sheared or broken rock was observed along this segment of the creek.

Drill hole SC-12 was drilled beside a quartz vein that strikes approximately N40°E. The drill hole apparently intersected localized broken rock associated with the emplacement of this quartz vein.

The absence of mylonite, slickensided surfaces, deformation of the rock's mineral fabric, and the fact that the RQD for the last 14.0 feet of core in drill hole SC-12 averages 89.3% all are evidence that this drill core represents an isolated area of broken rock, rather than a "major zone of shear".