

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

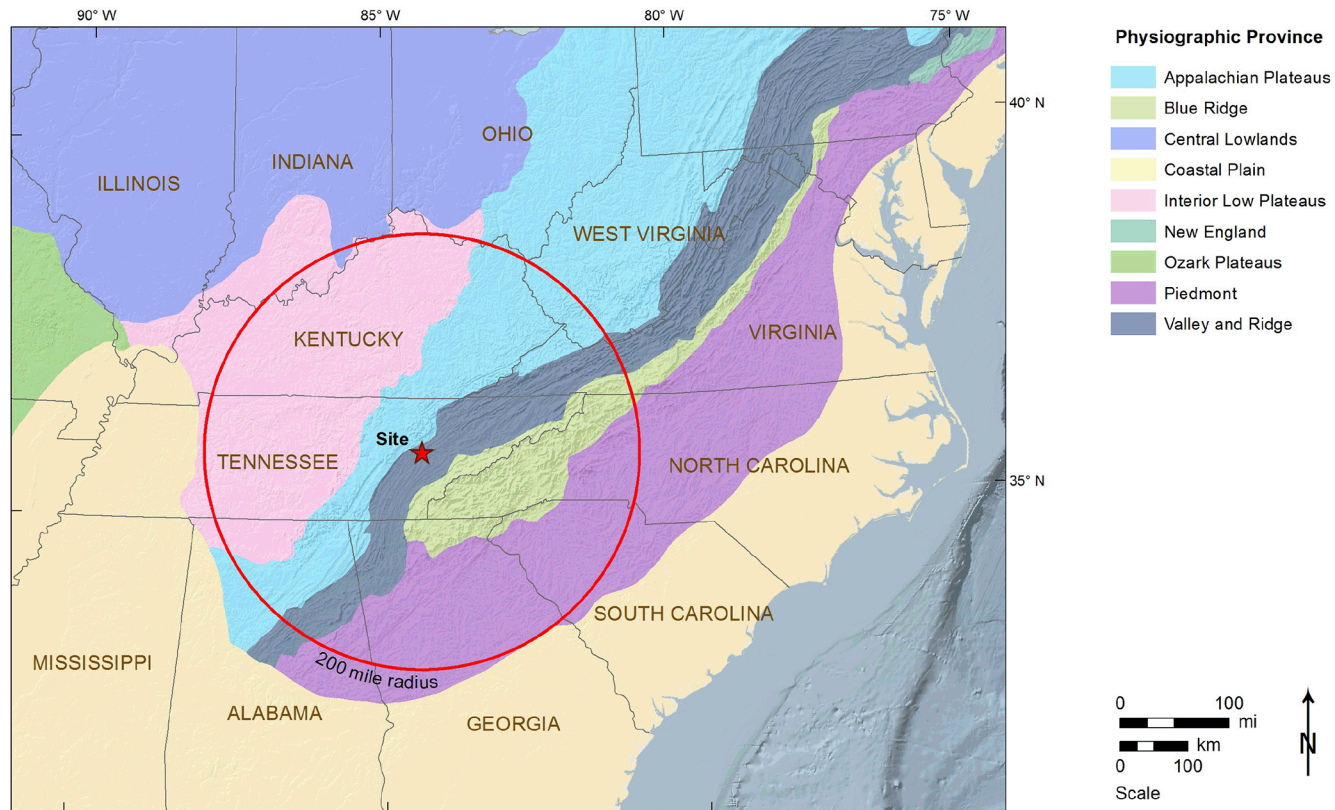
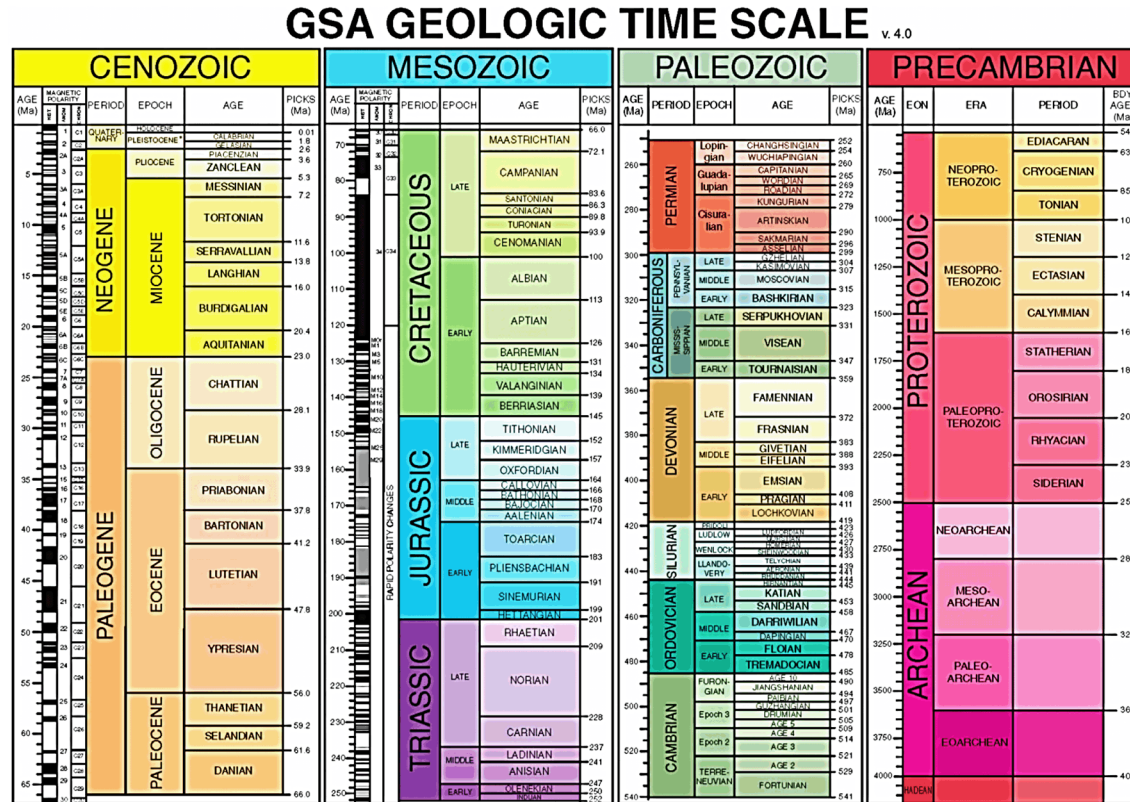


Figure 2.5.1-1. Map of Physiographic Provinces



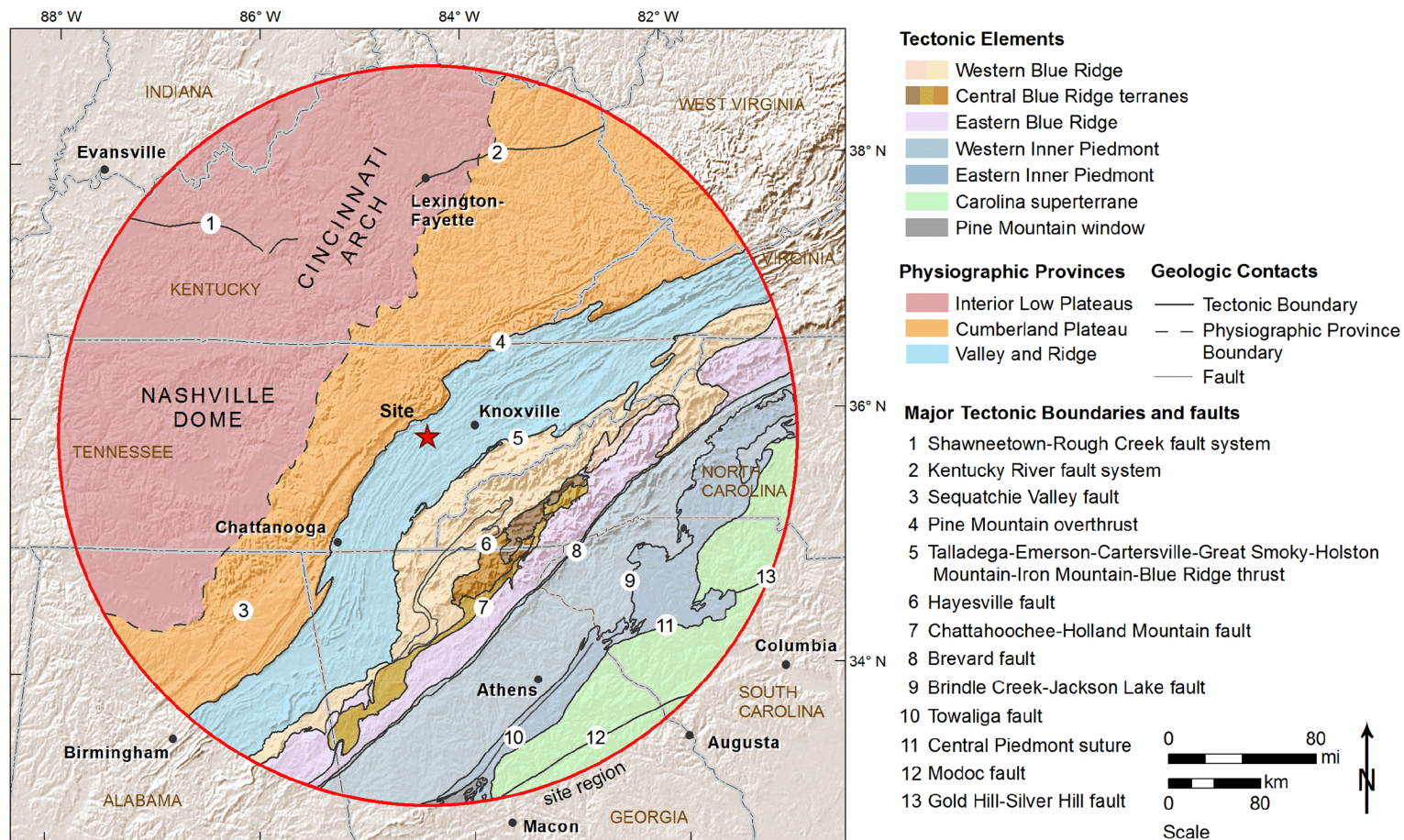
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*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages—Calabrian from 1.8 to 0.78 Ma, Middle from 0.78 to 0.13 Ma, and Late from 0.13 to 0.01 Ma. Walker, J.D., Gessman, J.W., Bowring, S.A., and Babcock, L.E., compilers, 2012, Geologic Time Scale v. 4.0, Geological Society of America, doi: 10.1130/2012.CT5004RGC. ©2012 The Geological Society of America. The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries follow the Gradstein et al. (2012) and Cohen et al. (2012) compilations. Age estimates and picks of boundaries are rounded to the nearest whole number (1 Ma) for the pre-Cenozoic, and rounded to one decimal place (100 ka) for the Cenozoic to the present. The numbered epochs and ages of the Cambrian are provisional for the 34th International Geological Congress, Brisbane, Australia, 5–10 August 2012. REFERENCES CITED: Cohen, K.M., Finney, S., and Gibbard, P.L., 2012, International Chronostratigraphic Chart: International Commission on Stratigraphy, www.stratigraphy.org (last accessed May 2012). (Chart reproduced for the 34th International Geological Congress, Brisbane, Australia, 5–10 August 2012.) Gradstein, F.M., Ogg, J.G., Schmitz, M.D., et al., 2012, The Geologic Time Scale 2012, Boston, USA, Elsevier, DOI: 10.1016/B978-0-444-59425-9.00004-4.

Source: Reference 2.5.1-33

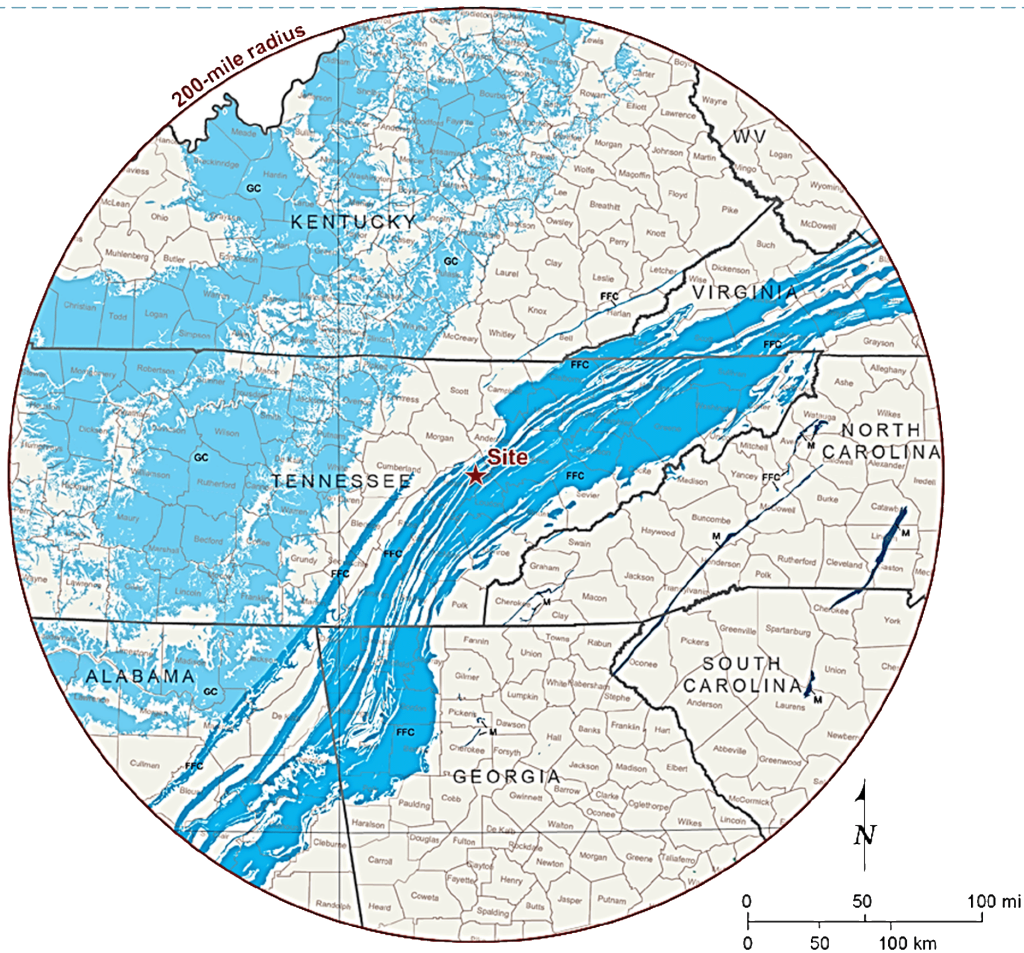
Figure 2.5.1-2. Geologic Time Scale

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Note: Modified from References 2.5.1-5, 2.5.1-24, and 2.5.1-34

Figure 2.5.1-3. Map of Lithotectonic Tectonic Terranes, Provinces and Major Tectonic Boundaries



Source: Modified from [Reference 2.5.1-26](#)

Description of Map Units

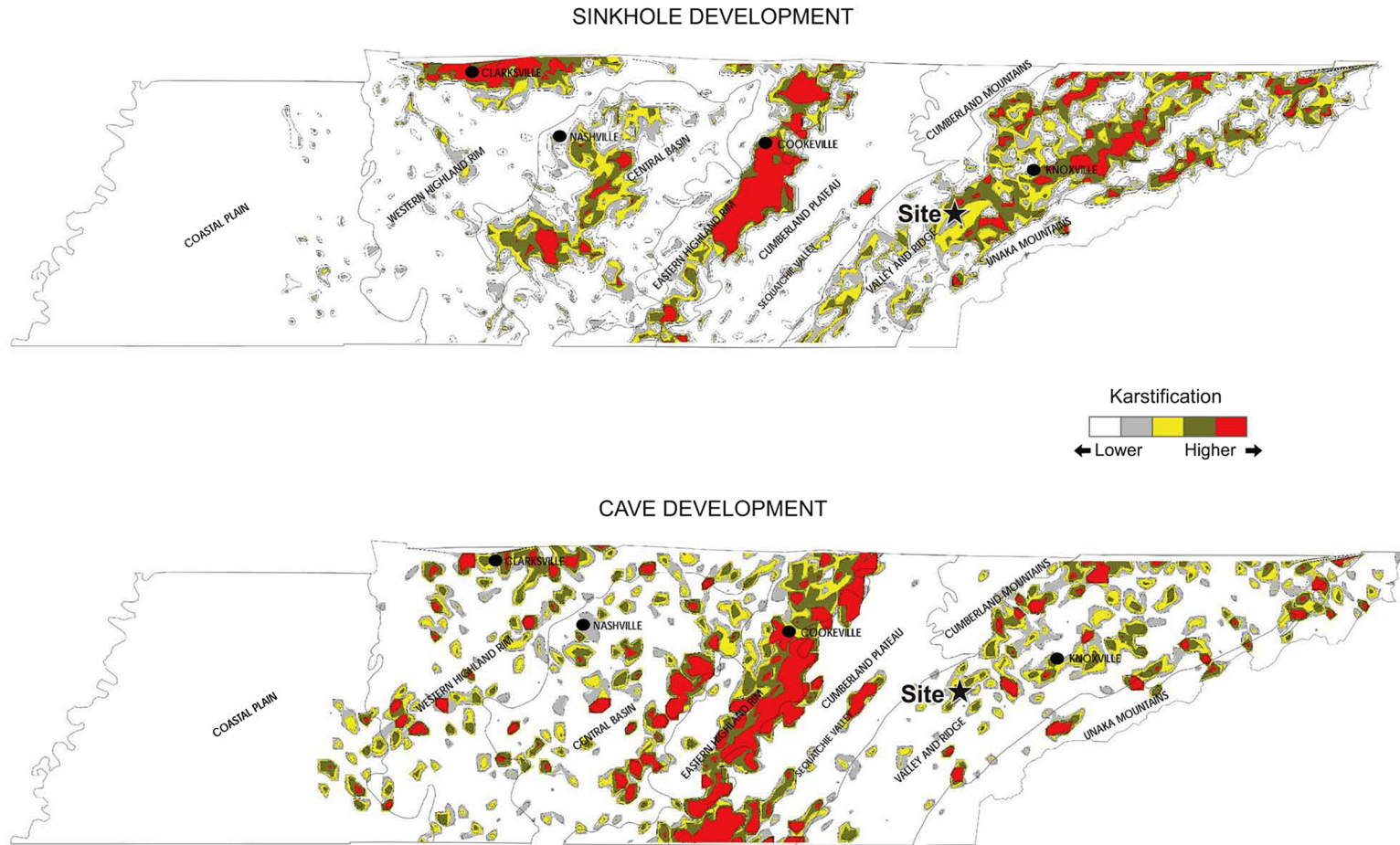
- GC

Gently folded and flat-lying carbonates rocks: indurated limestone and dolomite that has not been strongly deformed. Predominantly found in interior plateaus and lowlands. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Where carbonates are thick and extensive, cave systems may be long and complex. Where thin and interbedded with non-carbonates, caves are small and short. Geometry of cave passage patterns often shows stratigraphic and bedding-plane control often resulting in branchwork caves. ([Reference 2.5.1-35](#))
- FFC

Folded, faulted carbonate rocks: limestone and dolomite in areas flanking and in orogenic zones. May be intensely folded and faulted, commonly well jointed, commonly with cleavage. These rocks are located in the Valley and Ridge Province on this map and most are Paleozoic in age. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Caves range from small and simple to long and complex systems. Geometry of cave passage patterns tend to show at least some structural control producing network caves. ([Reference 2.5.1-35](#))
- M

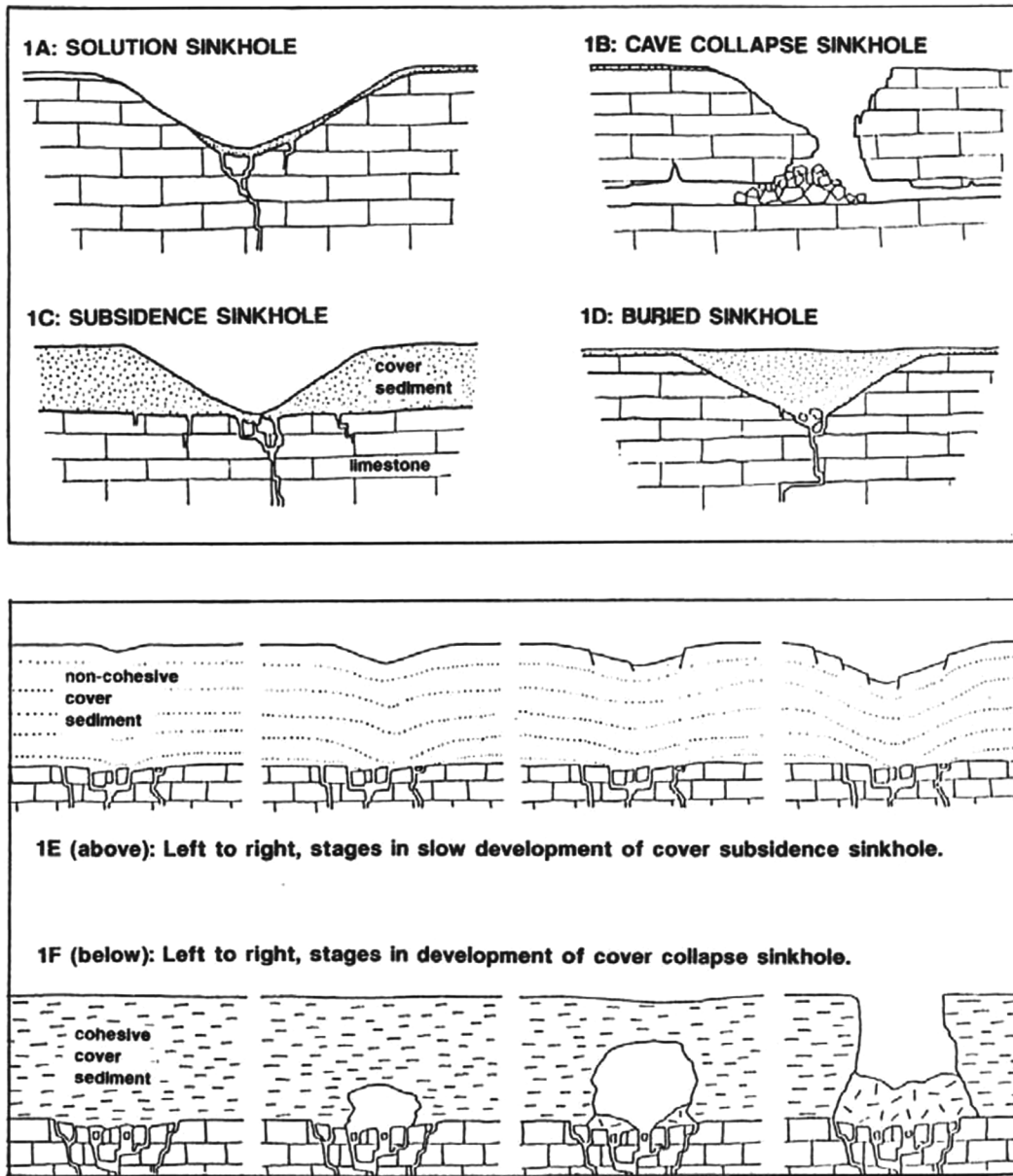
Marbles and metalimestones: highly deformed carbonate rocks, usually found in long, thin, linear belts or pods. Mapped areas are often exaggerated as these rocks are usually mapped with associated, non-soluble metamorphic rocks. Dissolution may result in solution, collapse, and cover-collapse sinkholes and small, short caves.

Figure 2.5.1-4. Regional Distribution of Carbonate Rocks



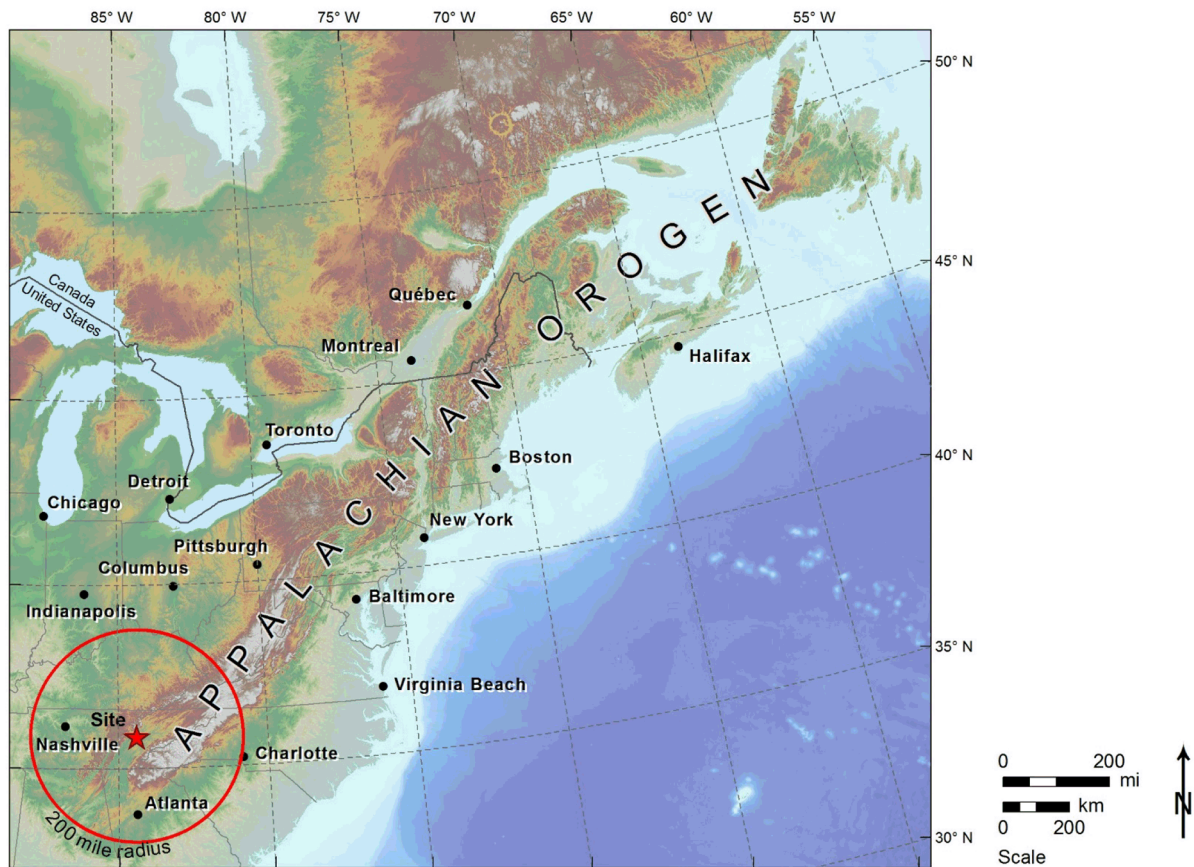
Source: Reference 2.5.1-25

Figure 2.5.1-5. Map of Sinkhole and Cave Development for the State of Tennessee



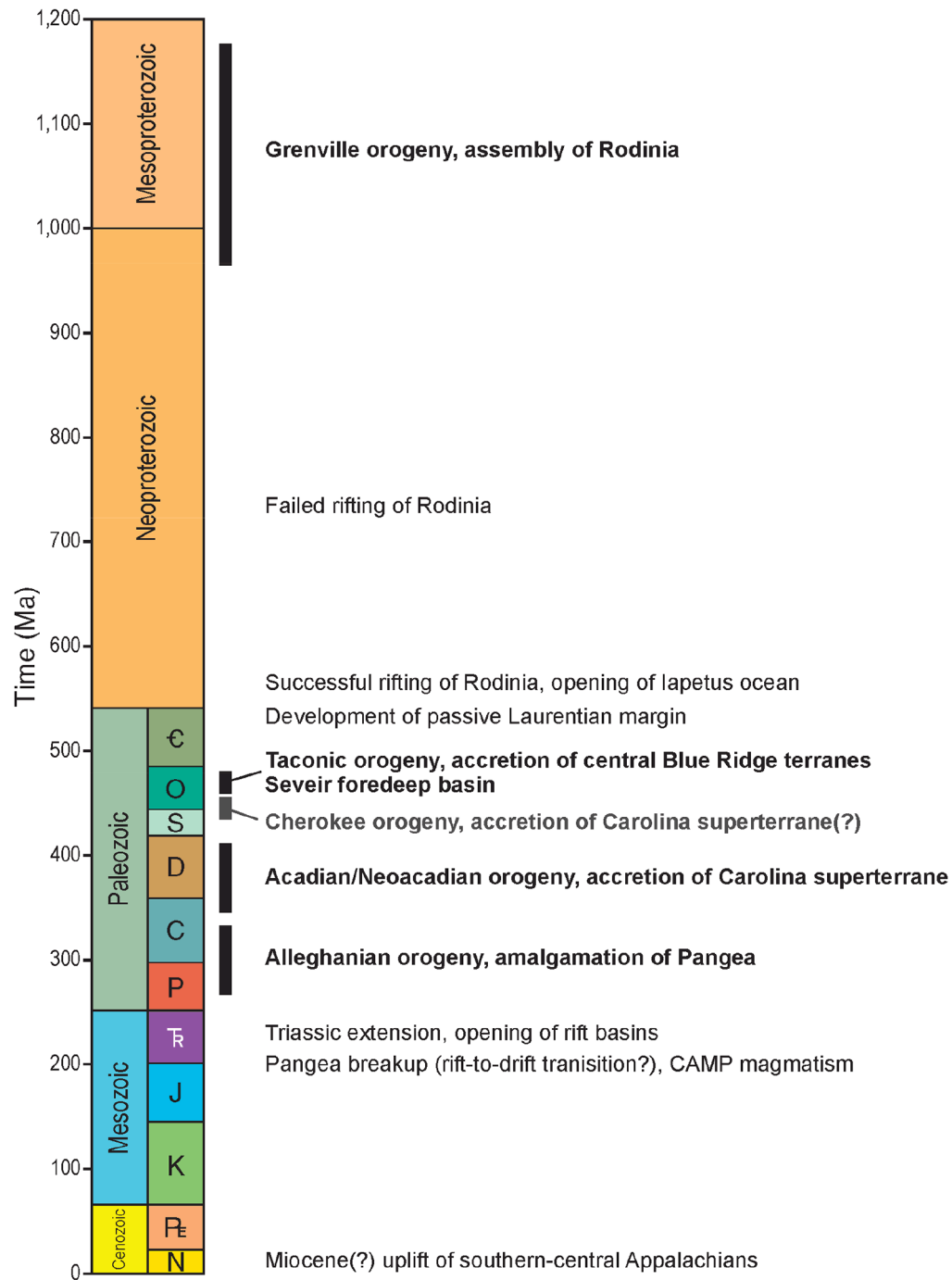
Note: [Reference 2.5.1-27](#)

Figure 2.5.1-6. Sinkhole Types



Note: Elevation and bathymetric data from [Reference 2.5.1-190](#), Sheet A-1.

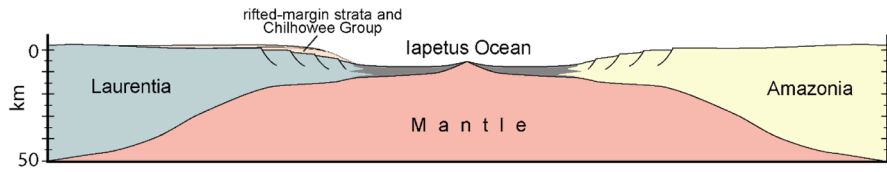
Figure 2.5.1-7. Shaded Relief Map of Eastern North America Demonstrating the Extent of the Appalachian Orogenic Belt



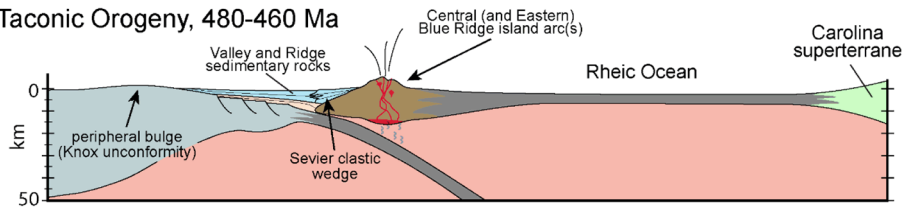
Note: Geologic time scale (Reference 2.5.1-33) with tectonic events that have affected the Appalachian orogenic belt (References 2.5.1-34 and 2.5.1-65).

Figure 2.5.1-8. Geologic Time Scale with Orogenic Events

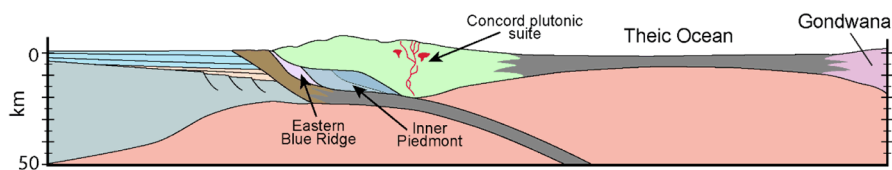
Rodinia Breakup to Iapetus Passive Margin late Neoproterozoic-early Cambrian



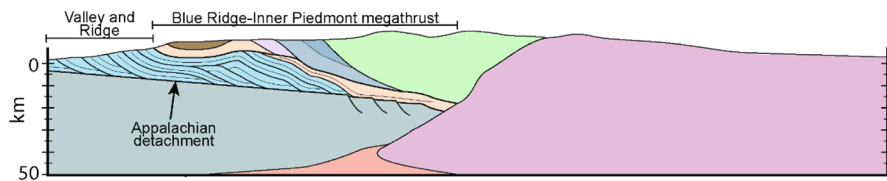
Taconic Orogeny, 480-460 Ma



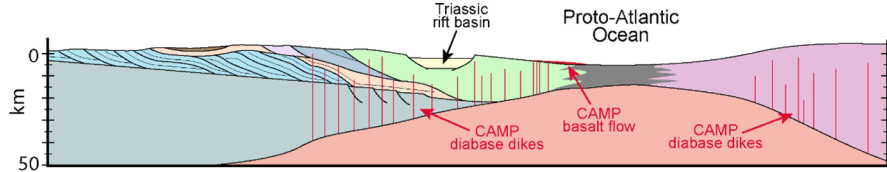
Acadian-Neoacadian Orogeny, 415-355 Ma



Alleghanian Orogeny (Formation of Pangea), 340-280(?) Ma



Breakup of Pangea, ~200 Ma



Notes:

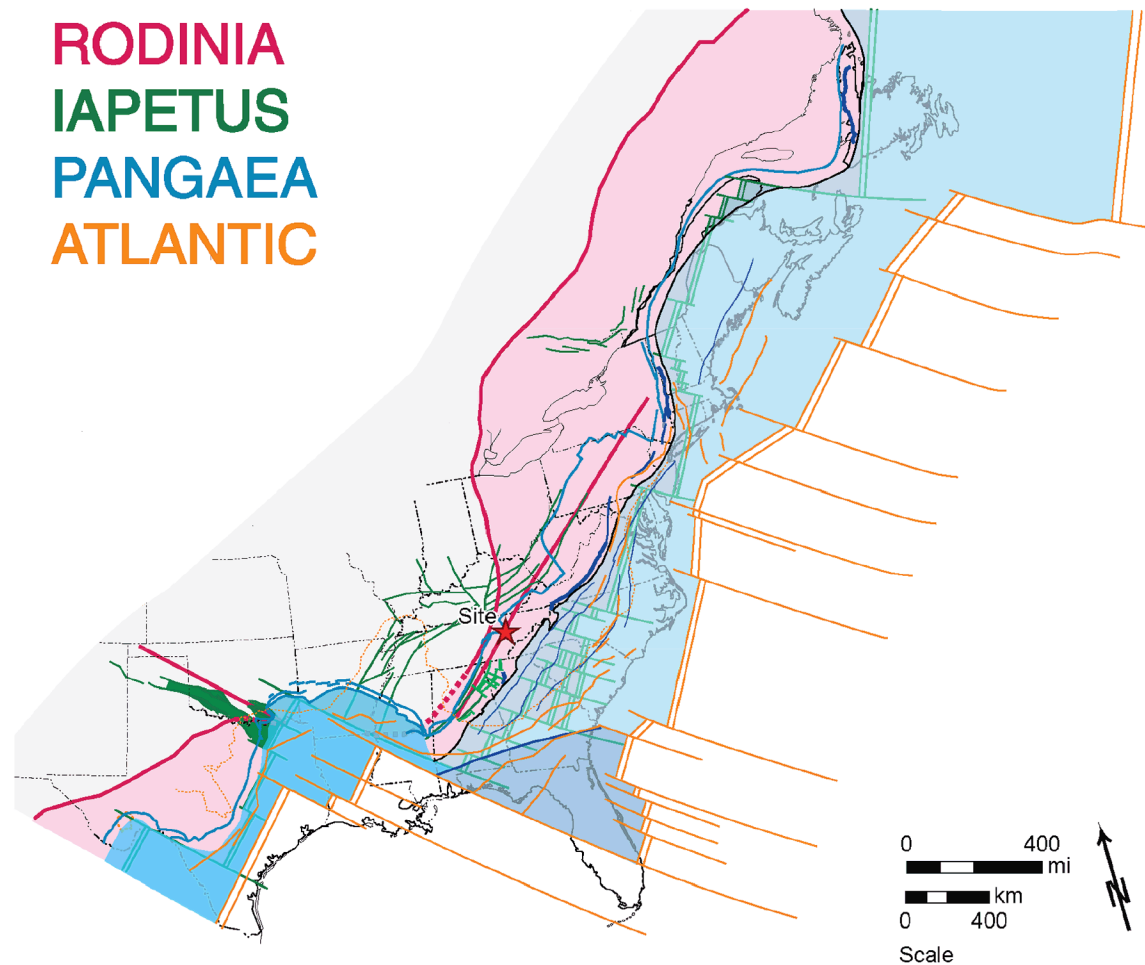
Sequential development of the Appalachian orogen from the breakup of Rodinia to the breakup of Pangea, from

Reference 2.5.1-73.

Deep crustal structure from Reference 2.5.1-277.

See Figure 2.5.1-3 for map of lithotectonic terranes.

Figure 2.5.1-9. Sequential Development of Appalachians Profiles



Notes:

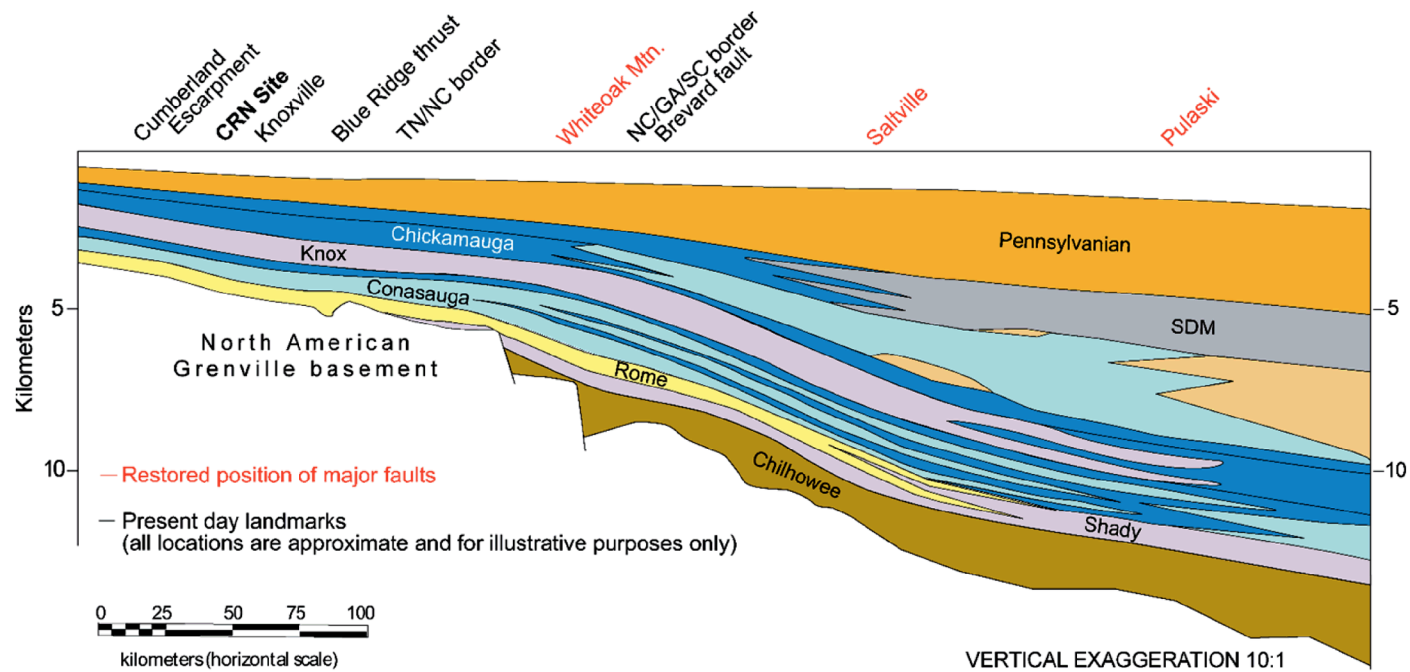
Map of eastern North America, illustrating tectonic inheritance through the amalgamation and breakup of two supercontinents.

Features formed during the Grenville orogeny (formation of Rodinia) shown in red; those formed during the Appalachian orogenies (formation of Pangea) shown in blue.

Rifted margins that formed from supercontinent breakup are shown in green (Iapetus ocean) and orange (Atlantic Ocean).

Modified from Thomas, 2006 [Reference 2.5.1-38](#).

Figure 2.5.1-10. North American Rifted Margin



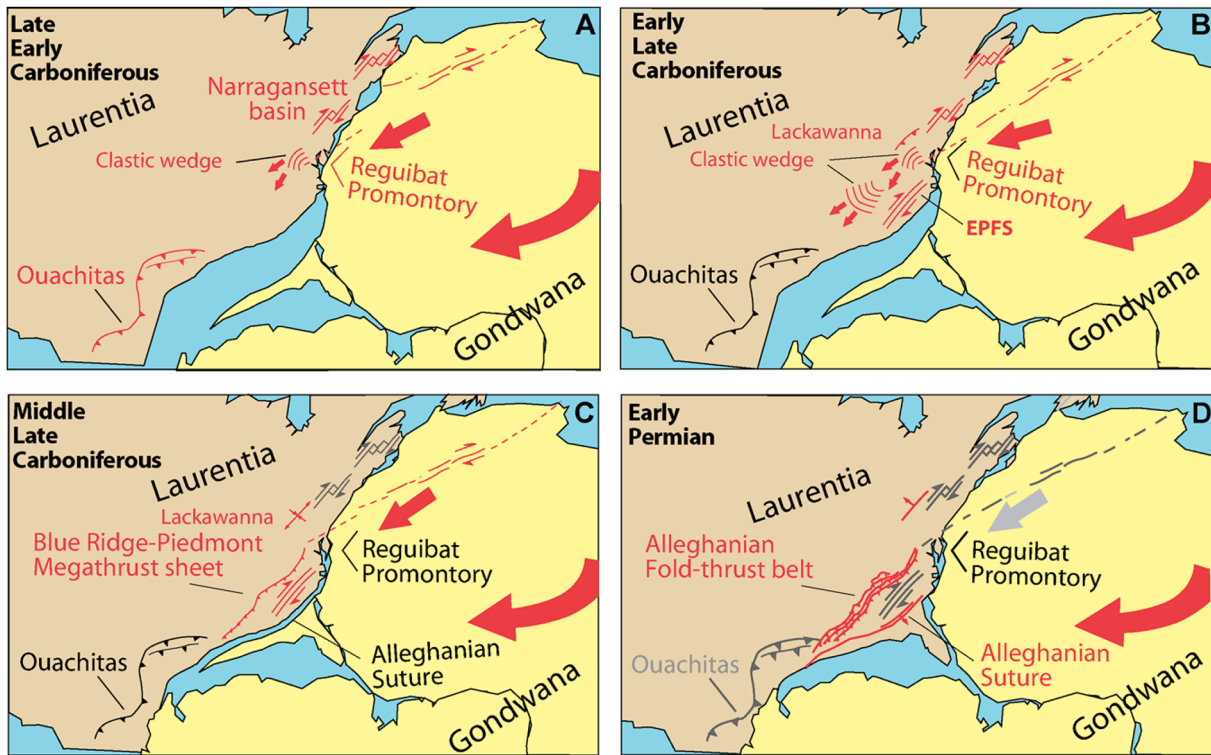
Notes:

Facies diagram of passive margin to stable shelf strata of the western Blue Ridge and Valley and Ridge (from Reference 2.5.1-13).

Units have been palinspastically restored along major Valley and Ridge thrust faults.

Blue — limestone facies; Lavender — dolomite facies; Light blue — shale facies; Beige and medium brown — coarse clastics and turbidites; Gray — siltstone facies; Light yellow — sandstone, shale, and dolomite intertidal facies.

Figure 2.5.1-11. Facies Diagram of Stable Shelf Strata



Notes:

Collision model for the Alleghanian orogeny (From [Reference 2.5.1-74](#)).

Red lines and symbols indicate the feature is active in the time interval shown.

A) Initial contact between Gondwana and Laurentia produced step-over basins in New England and deposition in the Appalachian basin.

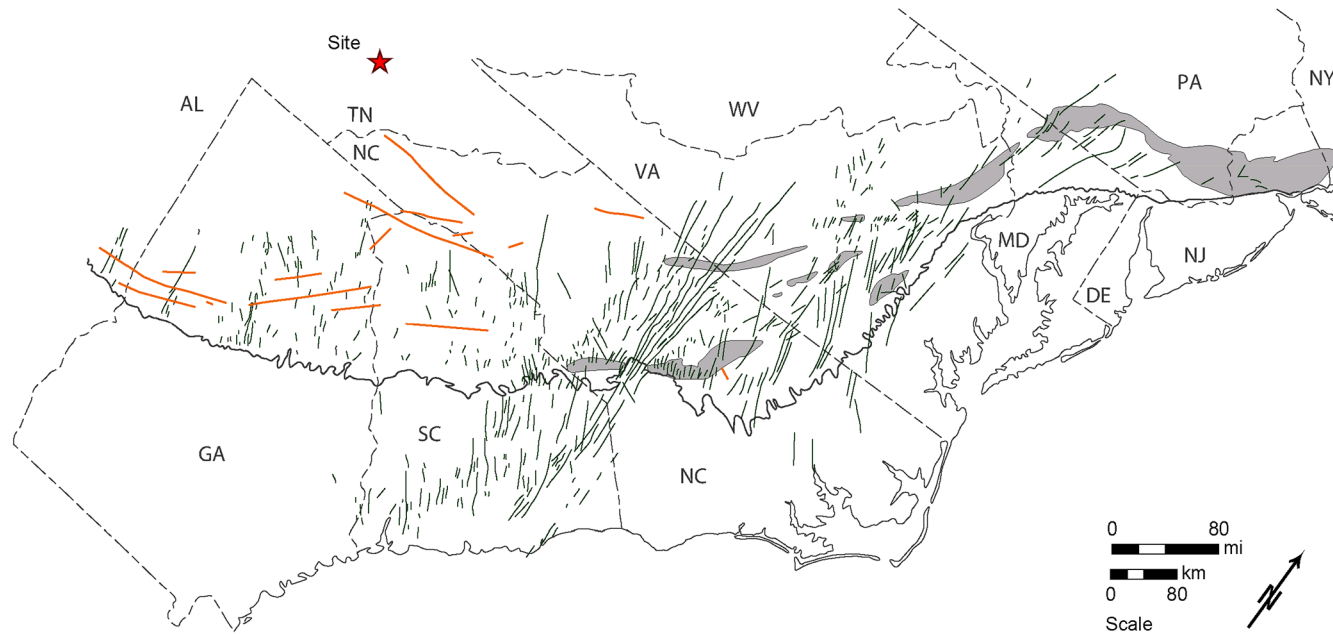
B) Continued collision resulted in greater clastic input in the foreland, with the development of dextral strike-slip faults in the interior of the orogen.

C) Clockwise rotation of Gondwana begins to dominate the collision, resulting in a more head-on collision in the southern Appalachians.

D) Head-on collision in the southern Appalachians results in thrusting of the Blue Ridge-Piedmont megathrust sheet and foreland fold-thrust belt development.

EPFS — Eastern Piedmont Fault System.

Figure 2.5.1-12. Alleghanian Zipper Tectonics



Notes:

Distribution of Mesozoic features in the southern and central Appalachians.

Central Atlantic Magmatic Province (CAMP) diabase dikes shown as thin green lines, with silicified faults shown as heavy orange lines.

Dark shaded areas represent exposed Triassic rift basins.

From [Reference 2.5.1-87](#).

Figure 2.5.1-13. Mesozoic Features Map

Clinch River Nuclear Site Early Site Permit Application Part 2, Site Safety Analysis Report

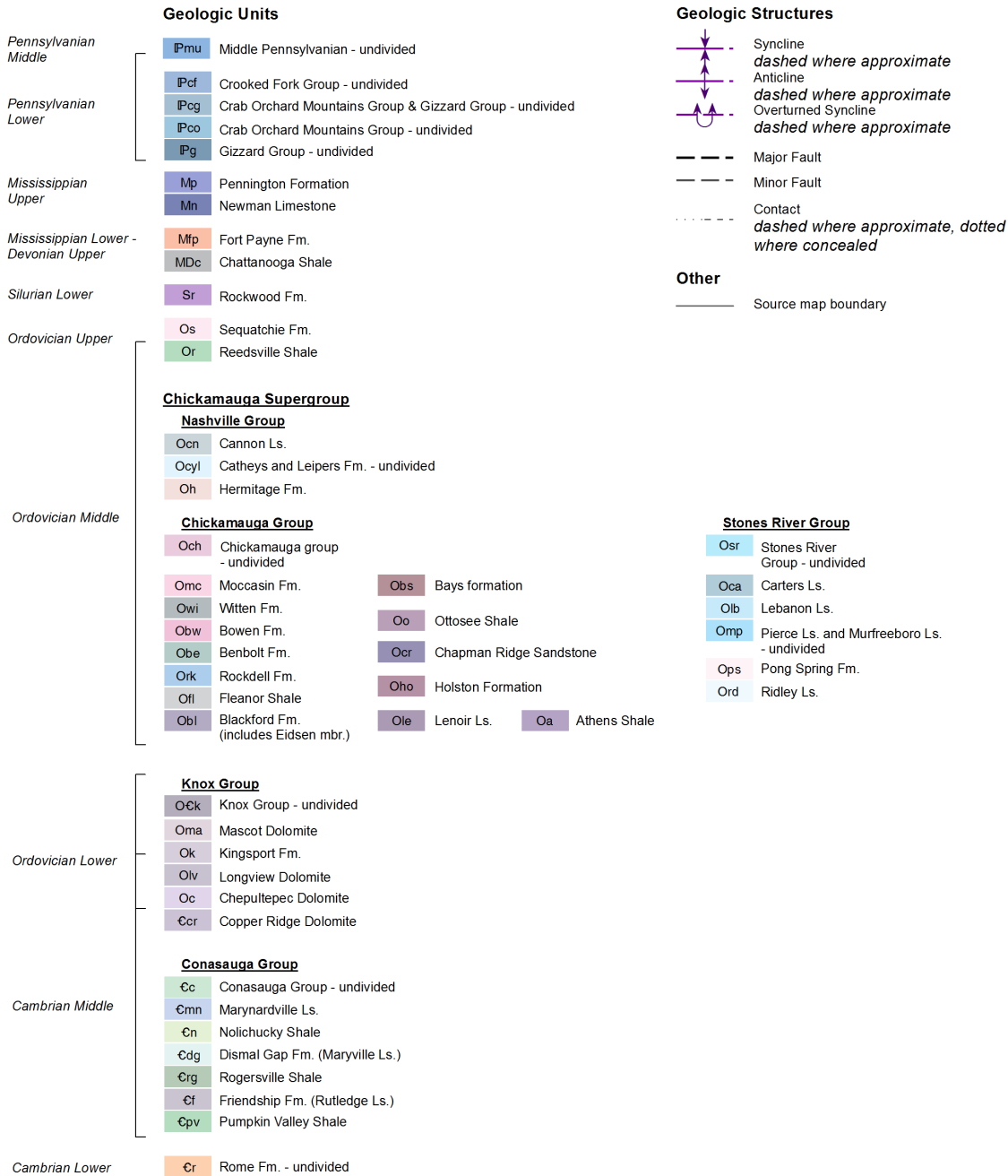
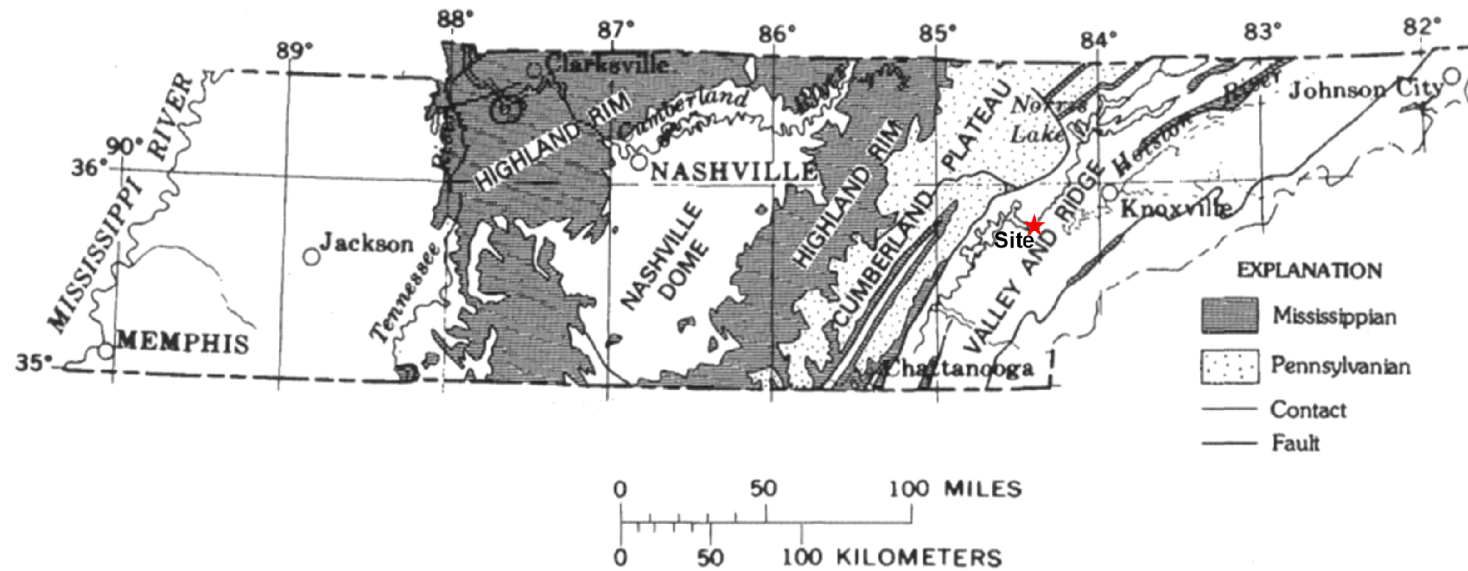


Figure 2.5.1-14. Site Vicinity Stratigraphic Columns



Note: After [Reference 2.5.1-112](#)

Figure 2.5.1-15. The Cumberland Plateau and Interior Low Plateaus in Tennessee

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

SERIES	WESTERN HIGHLAND RIM	CUMBERLAND PLATEAU AND EASTERN HIGHLAND RIM	PINE MOUNTAIN BLOCK (Englund, 1964, 1968)		NEWMAN RIDGE (Mixon and Harris, 1971)	BELT EAST OF CLINCH MOUNTAIN (Sanders, 1952, unpub. data; Hasson, 1973)	CHILHOWEE MOUNTAIN (Newman and Nelson, 1965)
CHESTERIAN		Gizzard Group (lower part)	Pennington Foramtion		Pennington Formation	Pennington Formation	
		Pennington Formation	Newman Limestone	Newman Limestone	Newman Limestone	Cove Creek Formation	
		Bangor Limestone				Fido Sandstone	
		Hartselle Sandstone				Fisher Creek Limestone	
MERAMECIAN	Sta. Genevieve Limestone	Monteagle Limestone					Gilliam Creek Limestone
	St. Louis Limestone	St. Louis Limestone			Clifton Creek Limestone		
	Warsaw Limestone	Warsaw Limestone			Snowflake Formation		
OSAGEAN	Fort Payne Formation	Fort Payne Formation	Fort Payne Chert	Grainger Formation	Grainger Formation	Laurel Branch Limestone	Greasy Cove Formation
						Presemens Home Formation	
	Maury Shale	Maury Shale	Maury Shale		Chattanooga Shale (upper part)	Chattanooga Shale (upper part)	Chattanooga Shale (upper part)

Notes:
From [Reference 2.5.1-112](#)

Figure 2.5.1-16. Mississippian Stratigraphic Units in Tennessee

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

SERIES	WILSON AND OTHERS (1956)	ENGLUND (1964, 1968) WANLESS (1946, pl. 32)
ALLEGHENY	Cross Mountain Formation	Bryson Formation
	Grassy Spring coal bed	Red Spring coal bed ?
	Rock Spring coal bed	
	Vowell Mountain Formation	
	Pewee coal bed	Hignite Formation
	Readoak Mountain Formation	Sharp coal bed
	Windrock coal bed	Catron Formation
	Graves Gap Formation	Poplar Lick coal bed
	Jordan coal bed	Mingo Formation
	Indian Bluff Formation	
	Jellico coal bed	Harlan coal bed
	Slatestone Formation	Hance Formation

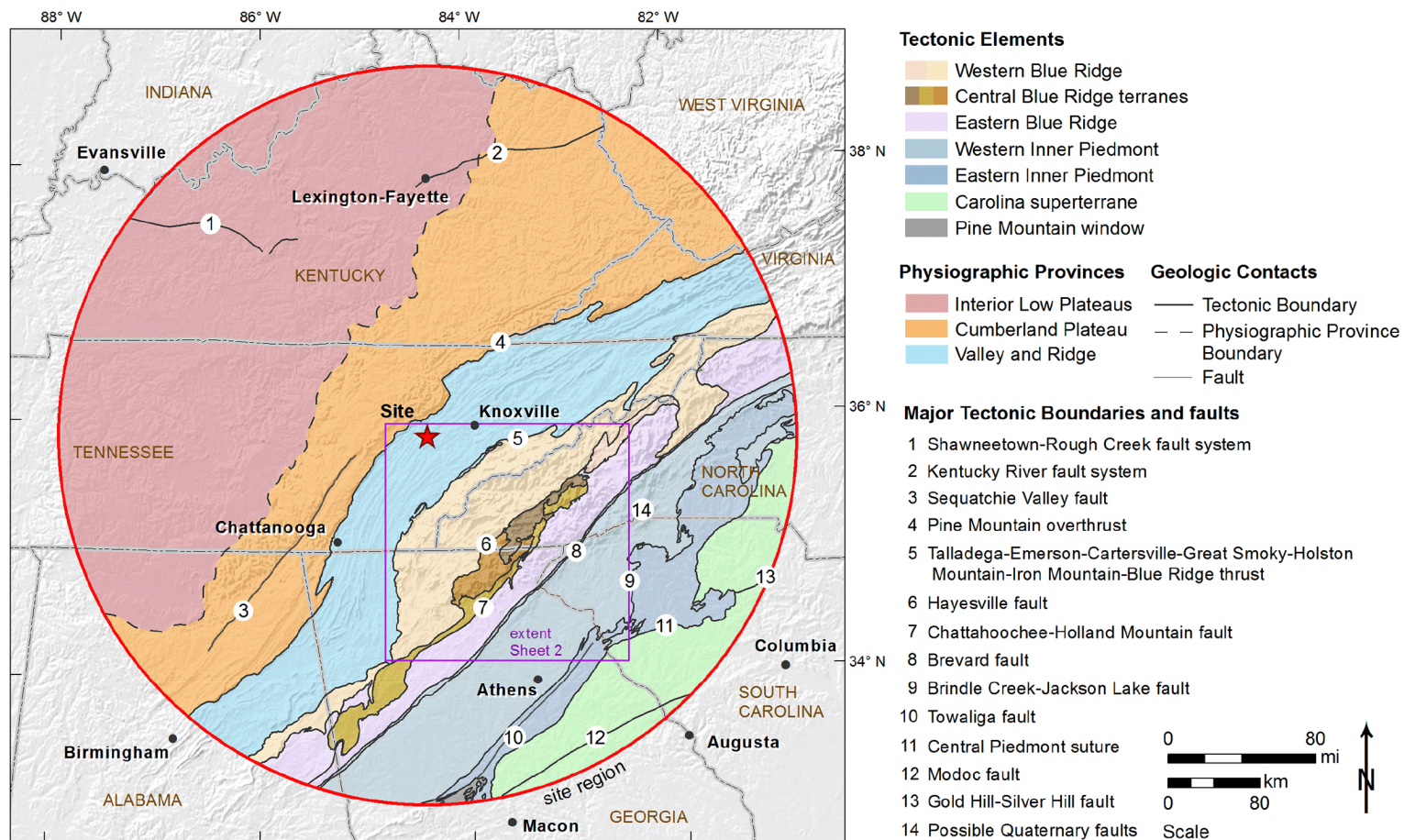
SERIES	WILSON AND OTHERS (1956) ¹	ENGLUND (1964, 1968) ¹
	Poplar Creek coal bed	
	Wartburg Sandstone	
	Glenmary Shale	Hance Formation
	Coalfield Sandstone	
	Burnt Mill Shale	
	Crossville Sandstone	
	Dorton Shale	
	Rockcastle Conglomerate	Lee Formation
	Vandever Formation	
	Newton Sandstone	
	Whitwell Shale	
	Sewanee Conglomerate	
	Signal Point Shale	Pennington Formation (upper member)
	Warren Point Sandstone	Tongues of Lee Formation
	Raccoon Mountain Formation	Pennington Formation (lower member)

¹Queried double lines show opinions concerning the Mississippian - Pennsylvanian boundary.

Note: Reference 2.5.1-112

Figure 2.5.1-17. Pennsylvanian System in Tennessee

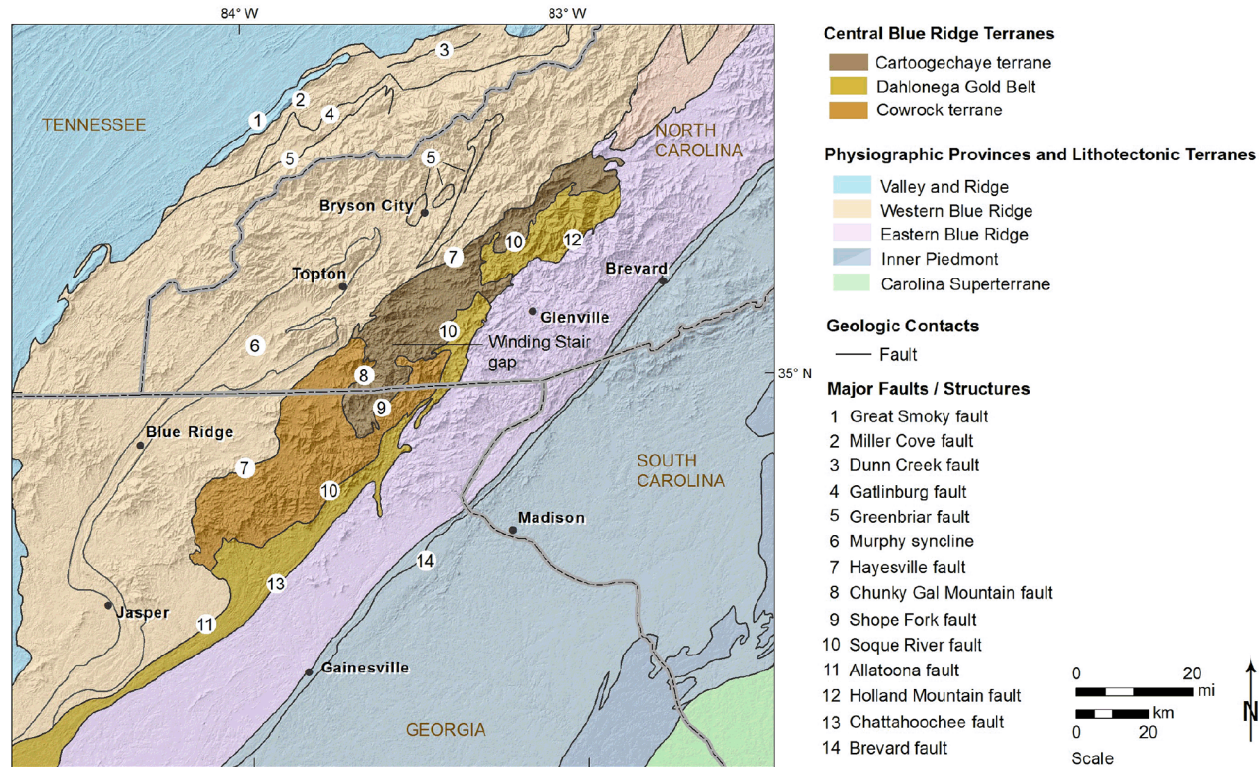
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
Lithotectonic terranes, provinces, and major tectonic boundaries (after [References 2.5.1-24](#), [2.5.1-34](#), and [2.5.1-137](#))

Figure 2.5.1-18. (Sheet 1 of 2) Lithotectonic Terrane Map

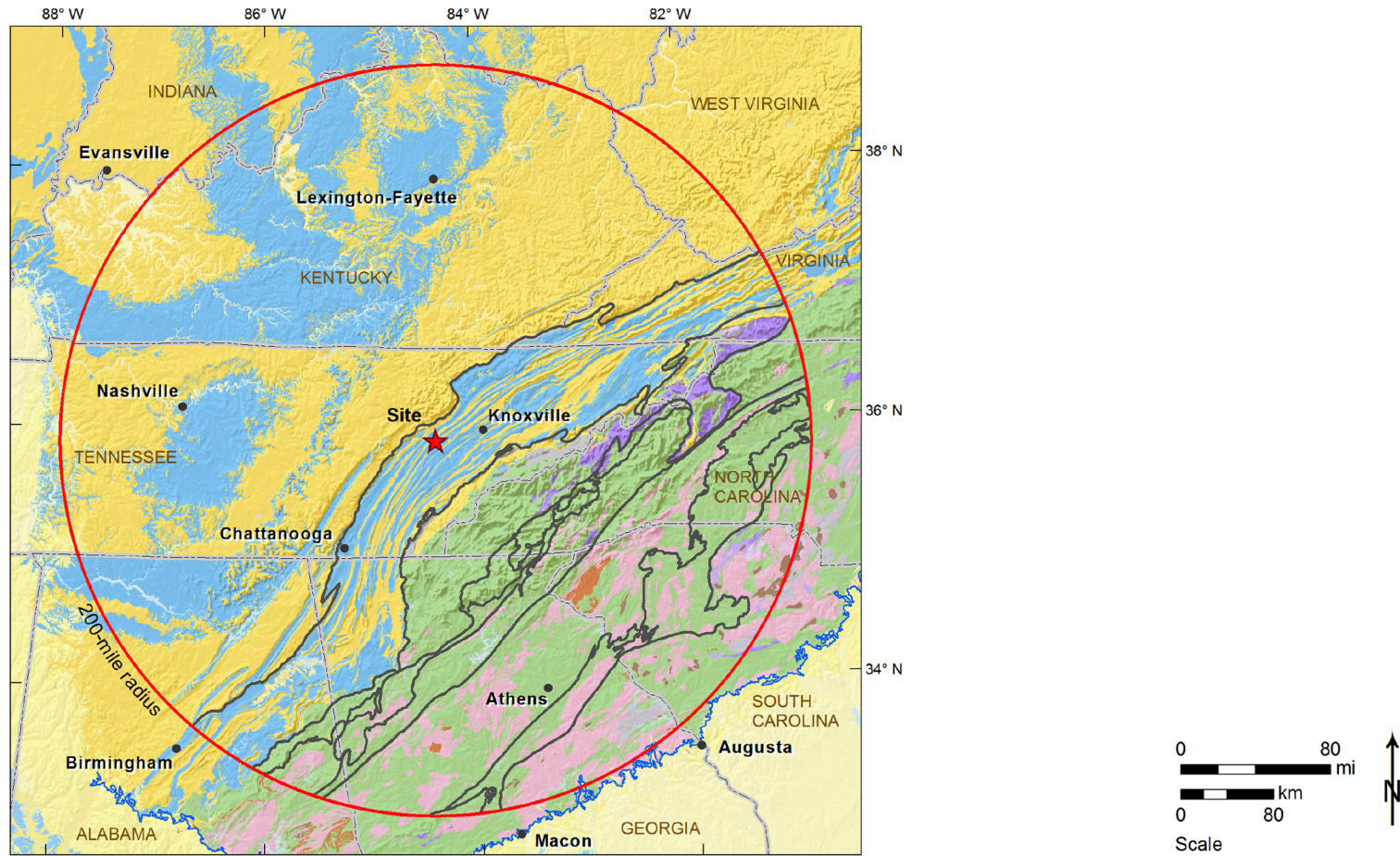
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Note:
Simplified tectonic map of the Central Blue Ridge terranes.

Figure 2.5.1-18. (Sheet 2 of 2) Lithotectonic Terrane Map—Blue Ridge Zoom

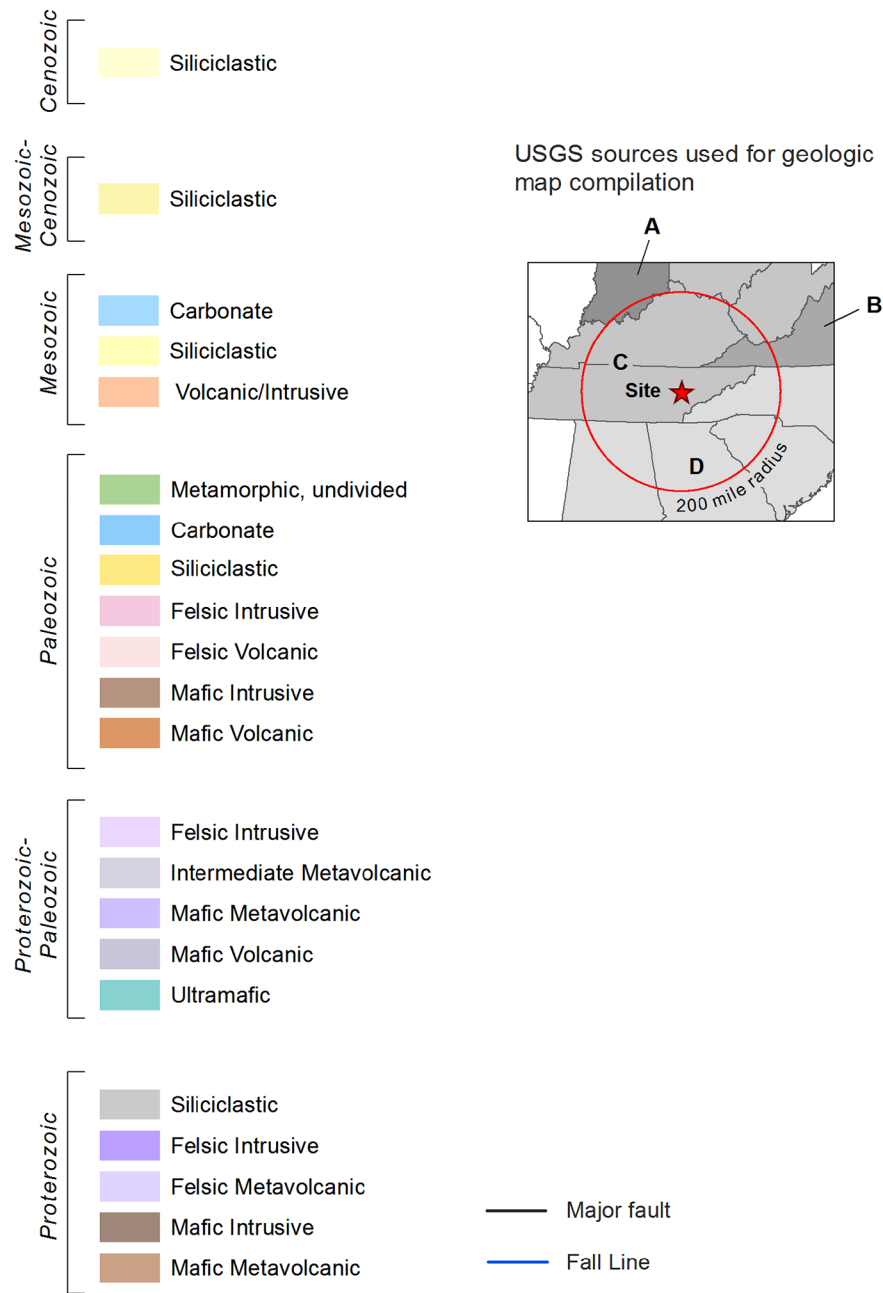
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Note:
USGS sources for geologic map: A - OFR-04-1355, [Reference 2.5.1-116](#); B - OFR-05-1325, [Reference 2.5.1-115](#); C - OFR-05-1323, [Reference 2.5.1-114](#); D - OFR-05-1324, [Reference 2.5.1-117](#). Major faults from [References 2.5.1-24](#) and [2.5.1-34](#). Fall Line from [Reference 2.5.1-20](#).

Figure 2.5.1-19. (Sheet 1 of 2) Site Region Geologic Map

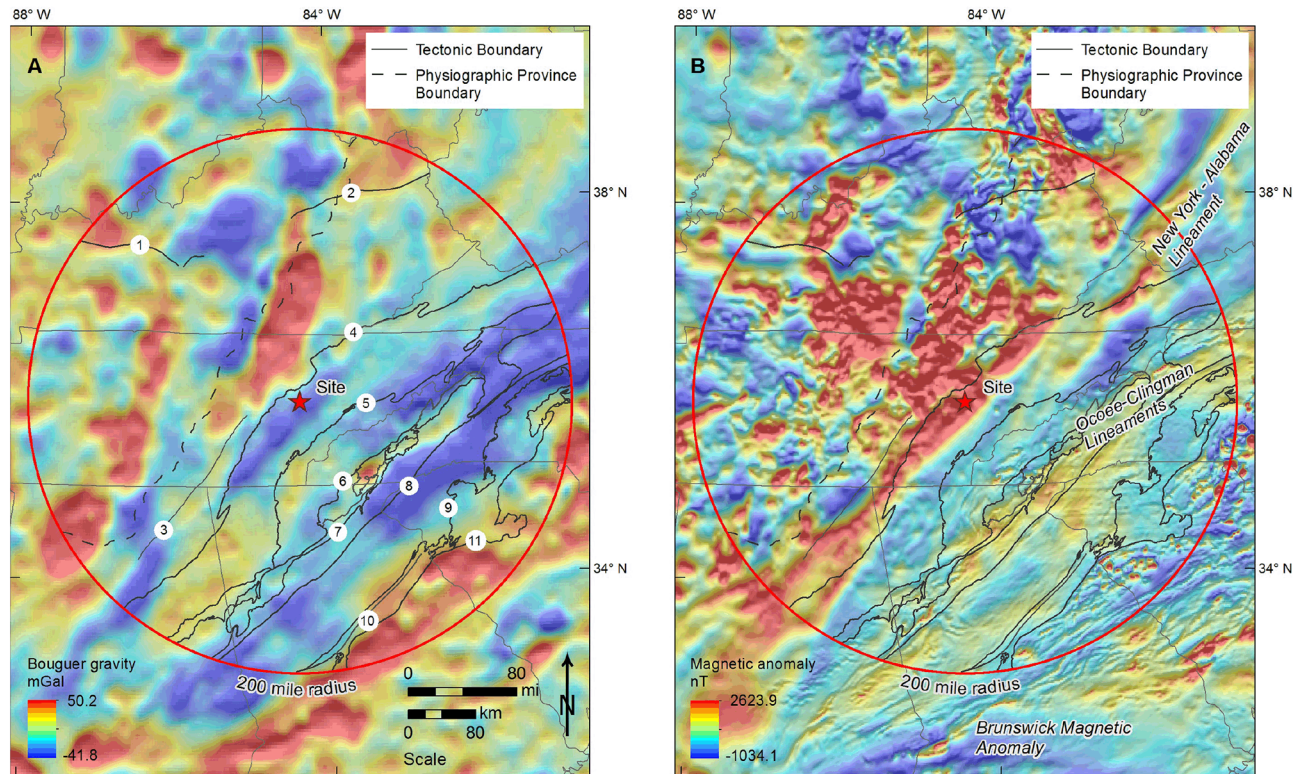
Aggregated Geologic Units



Note:
USGS sources for geologic map: A - OFR-04-1355, [Reference 2.5.1-116](#); B - OFR-05-1325, [Reference 2.5.1-115](#);
C - OFR-05-1323, [Reference 2.5.1-114](#); D - OFR-05-1324, [Reference 2.5.1-117](#). Major faults from
[References 2.5.1-24](#) and [2.5.1-34](#). Fall Line from [Reference 2.5.1-20](#).

Figure 2.5.1-19. (Sheet 2 of 2) Site Region Geologic Map

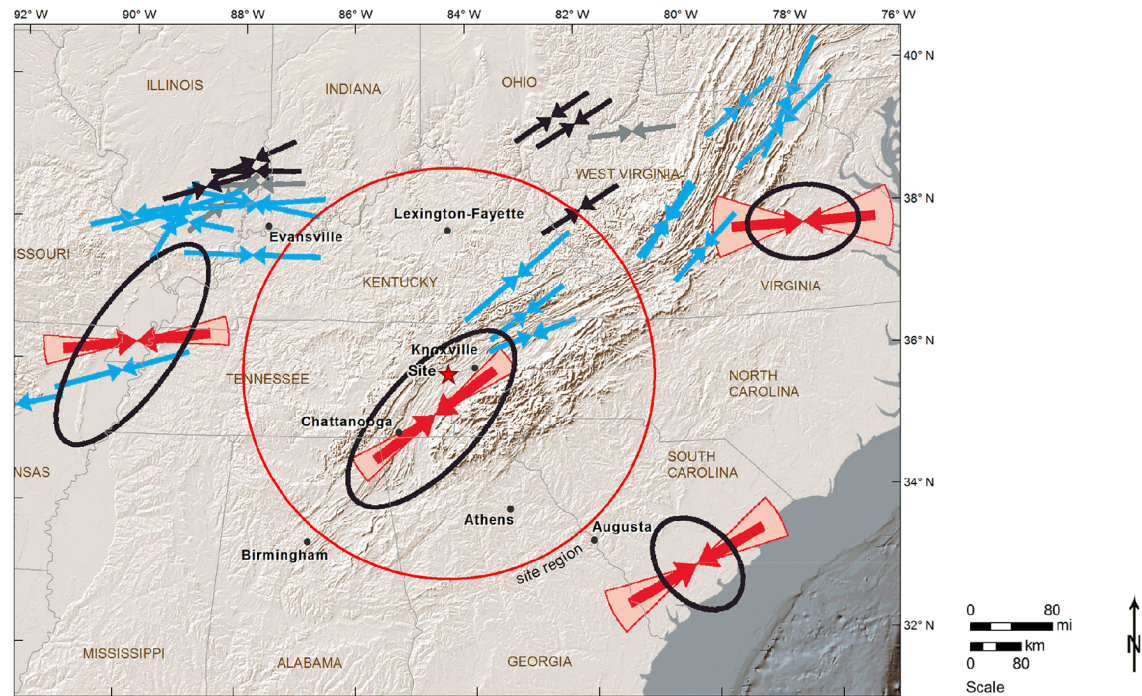
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
Gravity anomaly (A) and aeromagnetic residual data (B) from CEUS SSC (Reference 2.5.1-190).
See Figure 2.5.1-18, Sheet 1 for numbered fault references.

Figure 2.5.1-20. Aeromagnetic and Gravity Maps

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:

Map of current stresses in the central and eastern U.S. (after [Reference 2.5.1-185](#)).

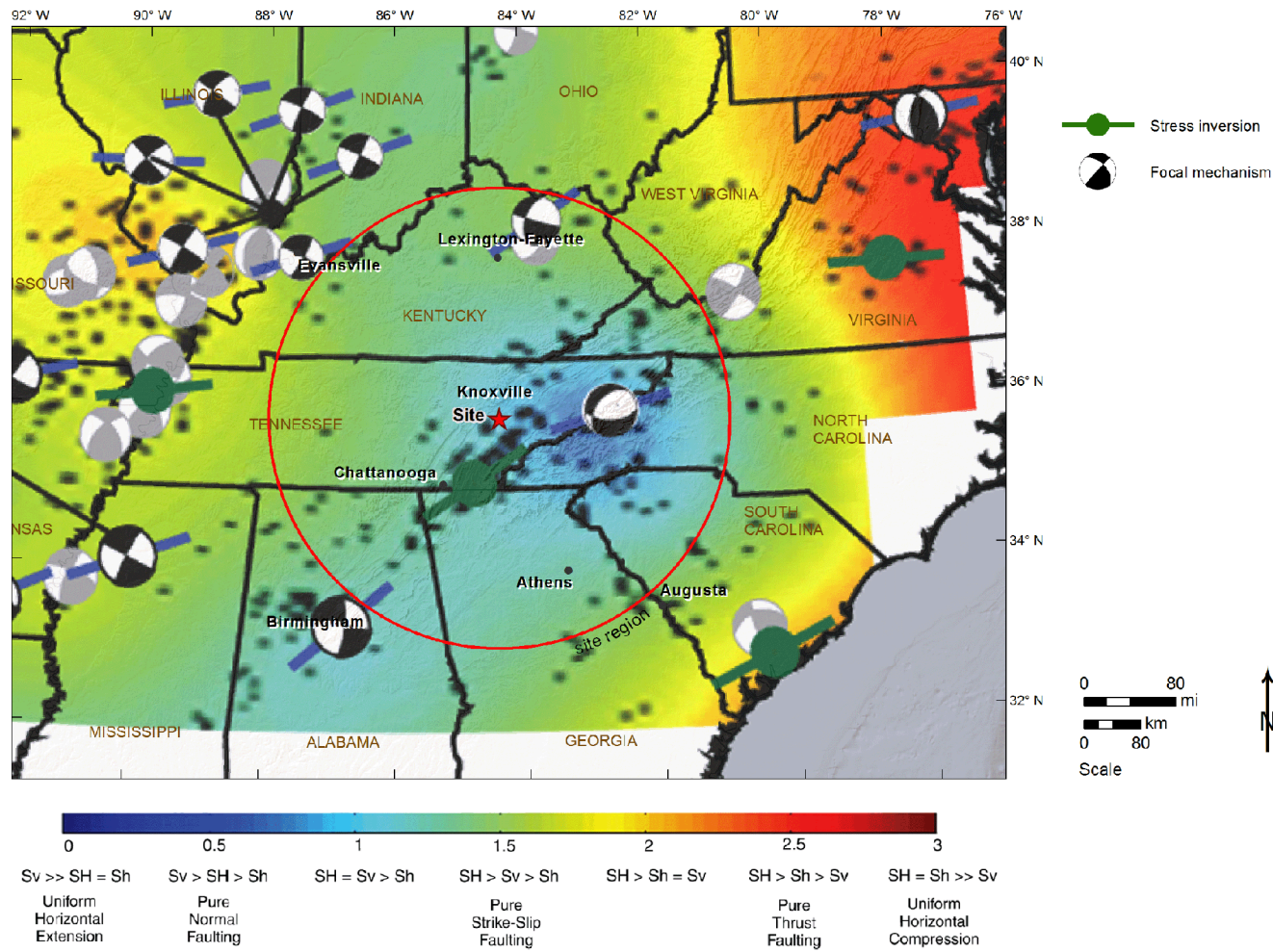
Black and gray arrows – orientation from borehole observations;

Blue arrows – borehole observations used in calculating the regional average within 250 km (155 mi) of the seismic zones (solid ellipses);

Red arrows and angular sectors – orientation from focal mechanism inversion.

Figure 2.5.1-21. (Sheet 1 of 2) Current Compressive Stress—Eastern United States

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

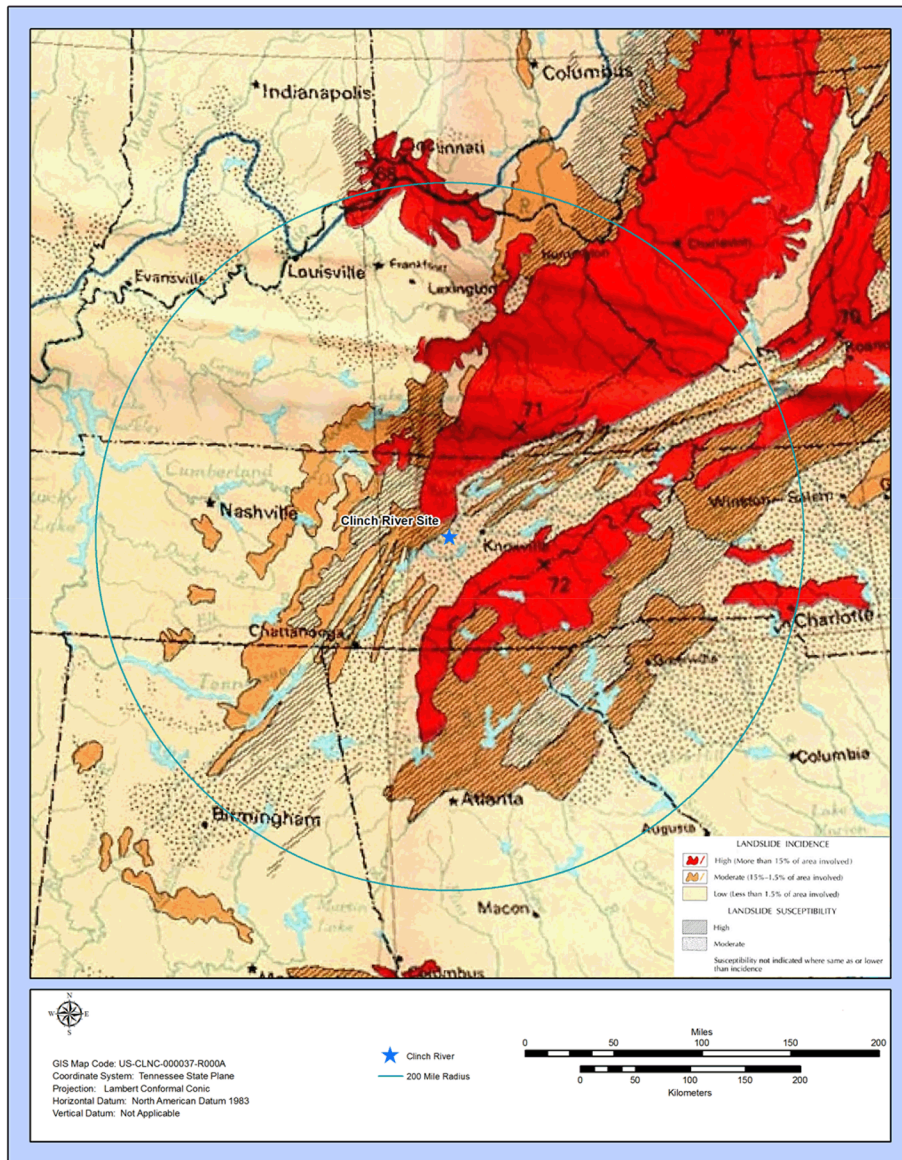


Notes:

Gray focal mechanisms from [Reference 2.5.1-183](#); black focal mechanisms from [Reference 2.5.1-306](#).
SH – maximum horizontal stress; Sh – minimum horizontal stress; Sv – vertical stress.

Source: [Reference 2.5.1-306](#)

Figure 2.5.1-21. (Sheet 2 of 2) Regional Stress Map from Hurd and Zoback



Note: Modified from [Reference 2.5.1-202](#)

Figure 2.5.1-22. Landslide Hazard Map for the Clinch River Nuclear Site Region

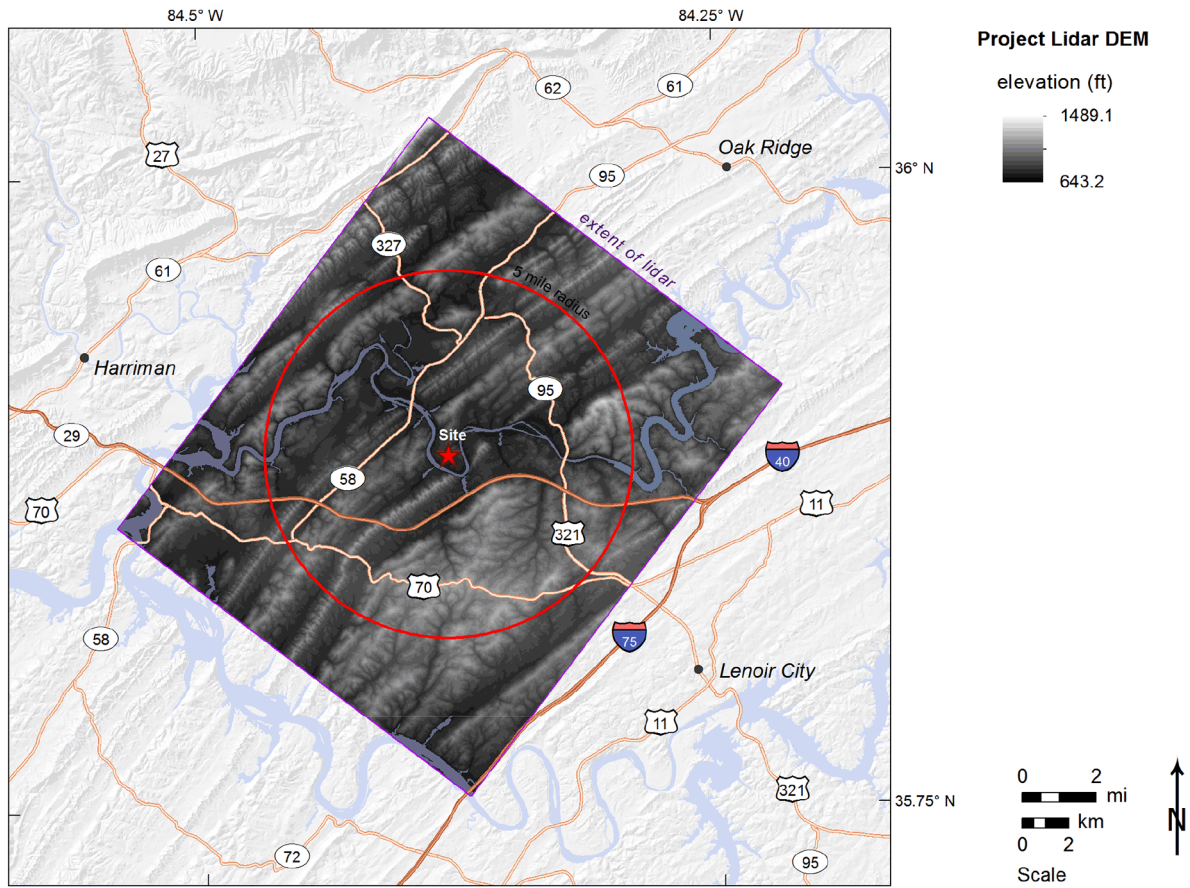
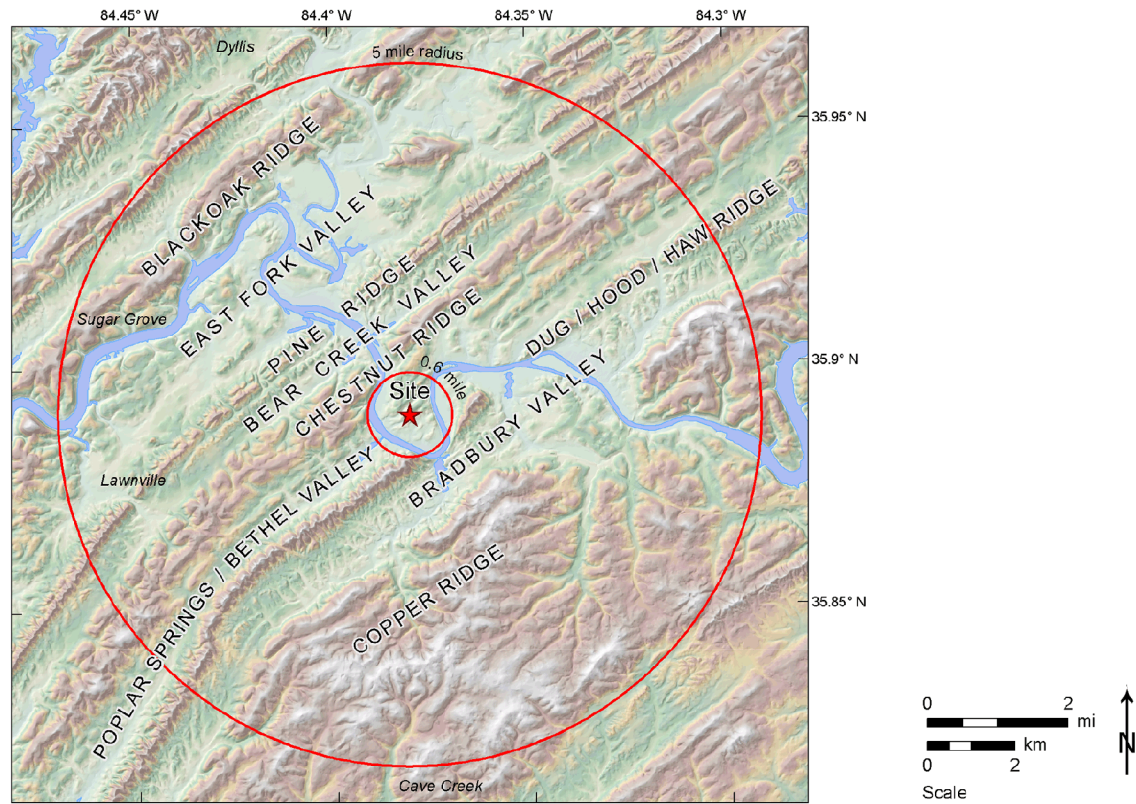


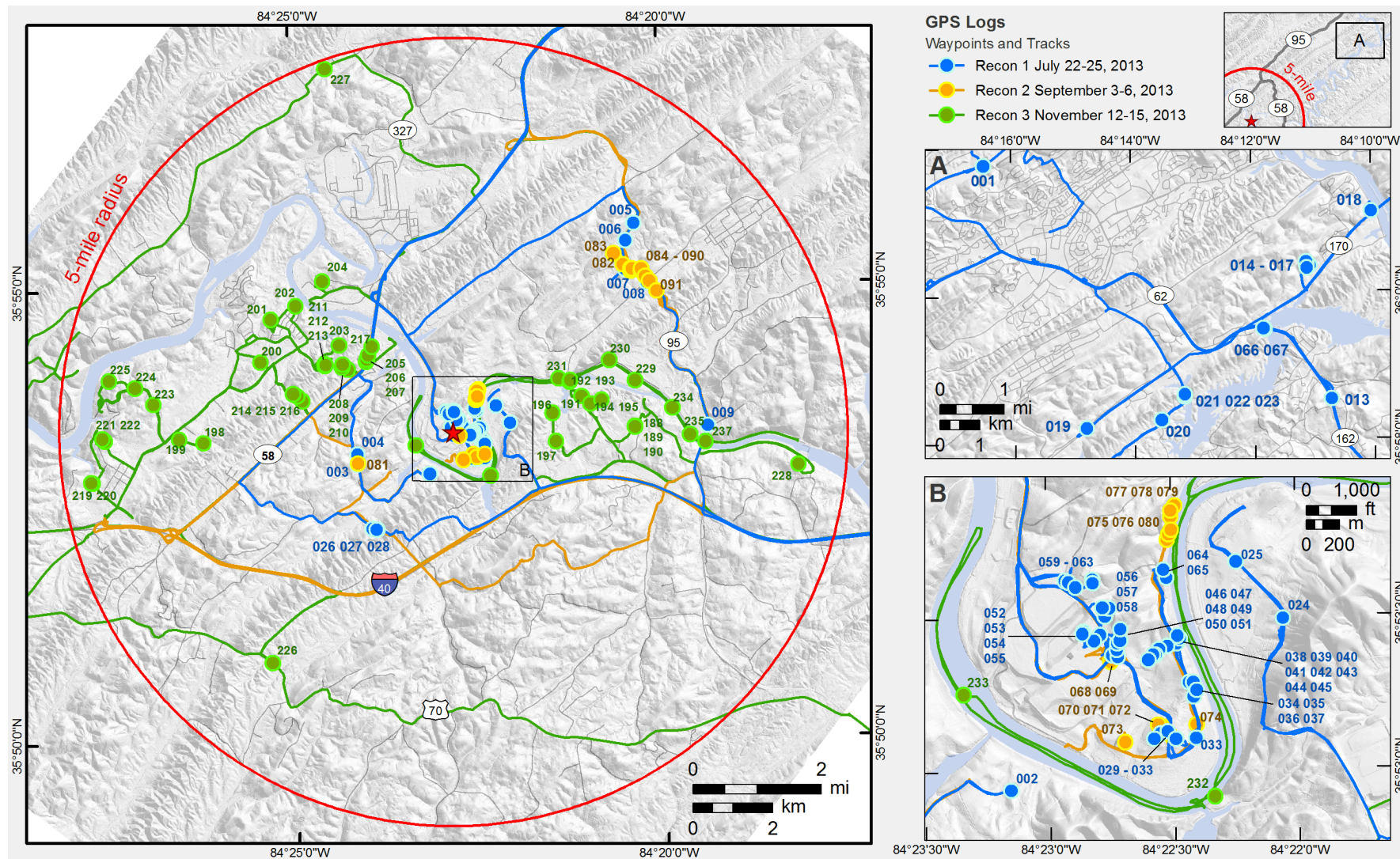
Figure 2.5.1-23. LiDAR Digital Elevation Model Coverage



Note: Local geographic nomenclature from Lemiszki ([Reference 2.5.1-215](#))

Figure 2.5.1-24. Local Physiography with Local Nomenclature for Valleys and Ridges

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

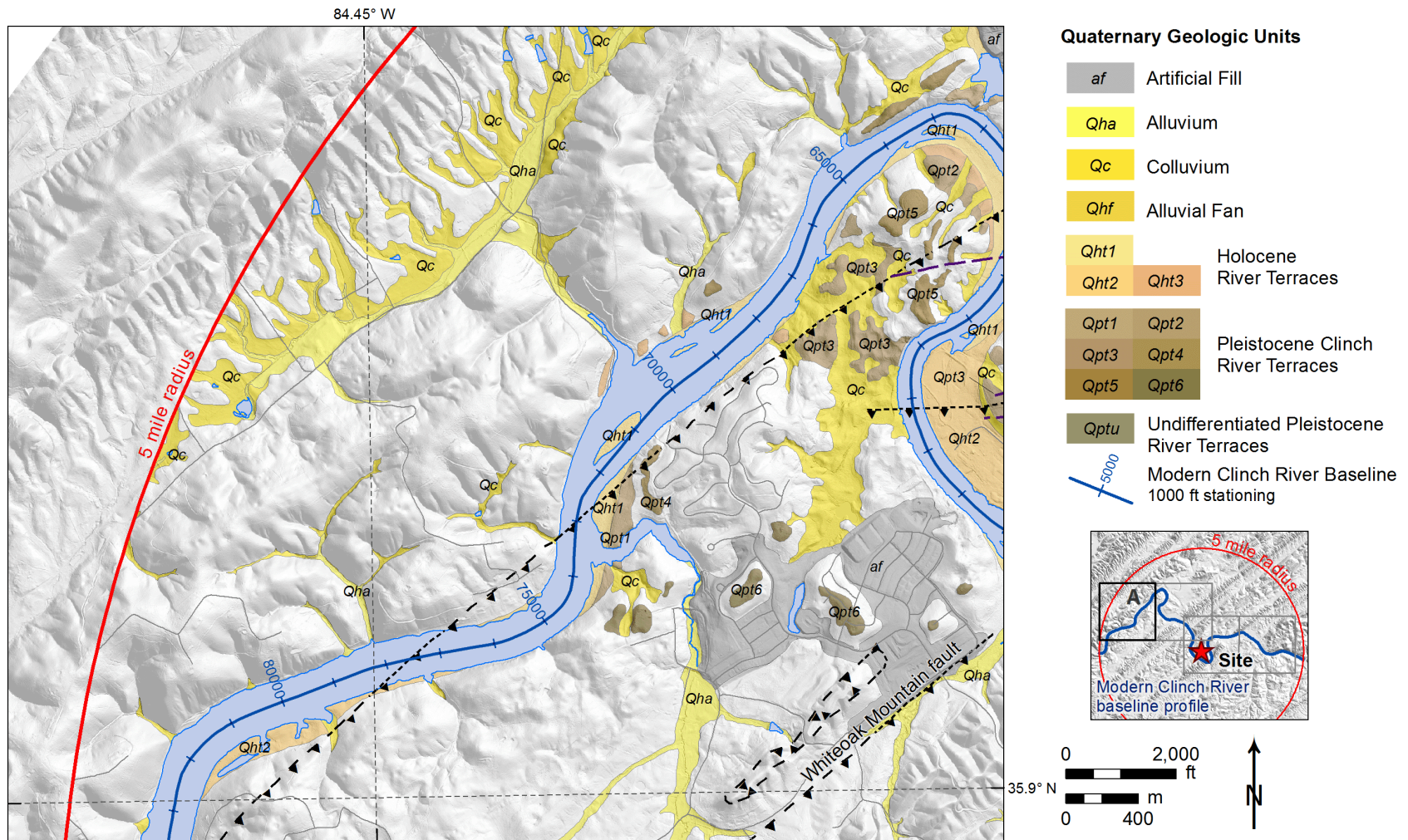


Figure 2.5.1-26. (Sheet 1 of 6) Quaternary Terrace Map Adjacent to the Clinch River Arm of the Watts Bar Reservoir Within the Clinch River Nuclear Site Area, Location A

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

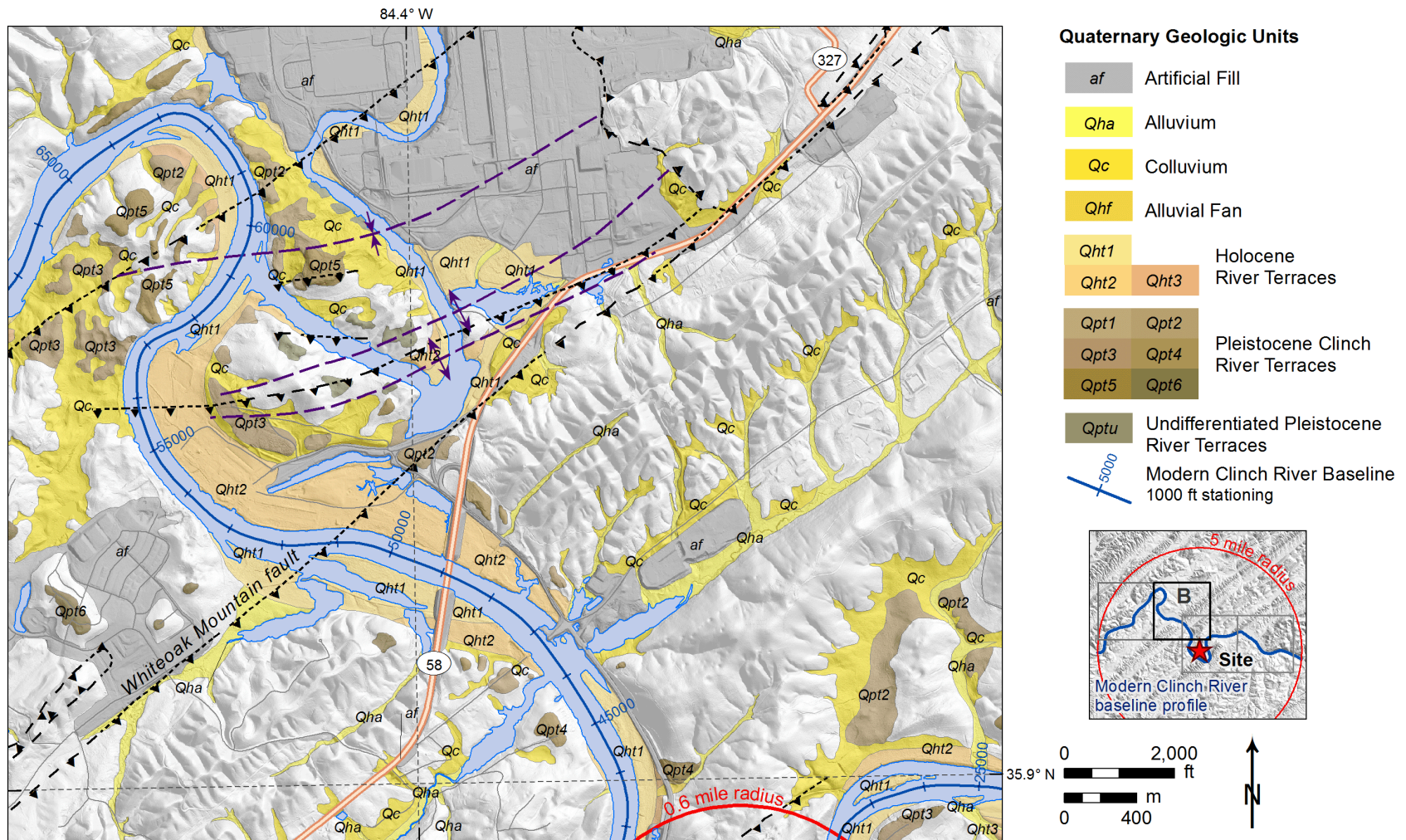
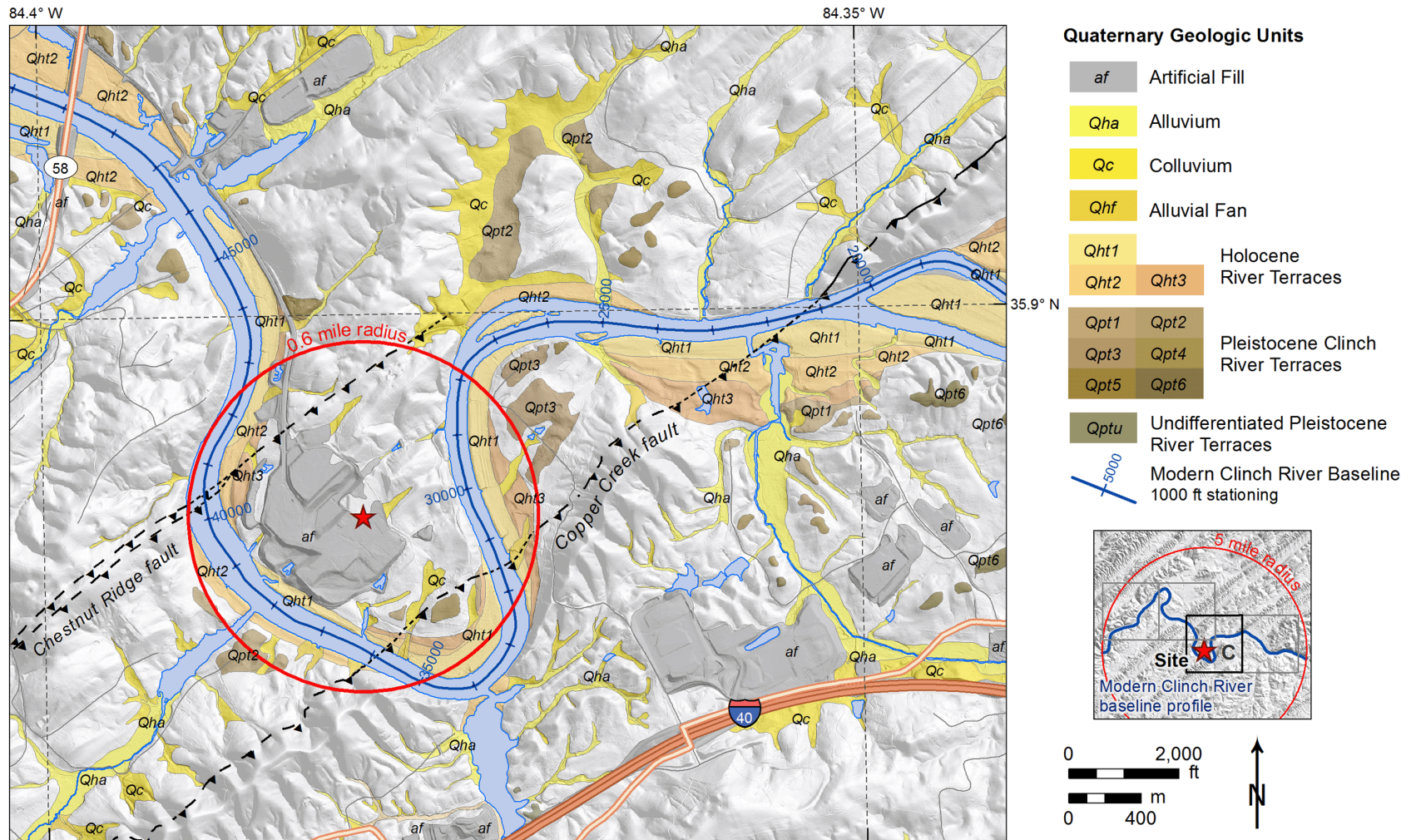


Figure 2.5.1-26. (Sheet 2 of 6) Quaternary Terrace Map Adjacent to the Clinch River Arm of the Watts Bar Reservoir Within the Clinch River Nuclear Site Area, Location B

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

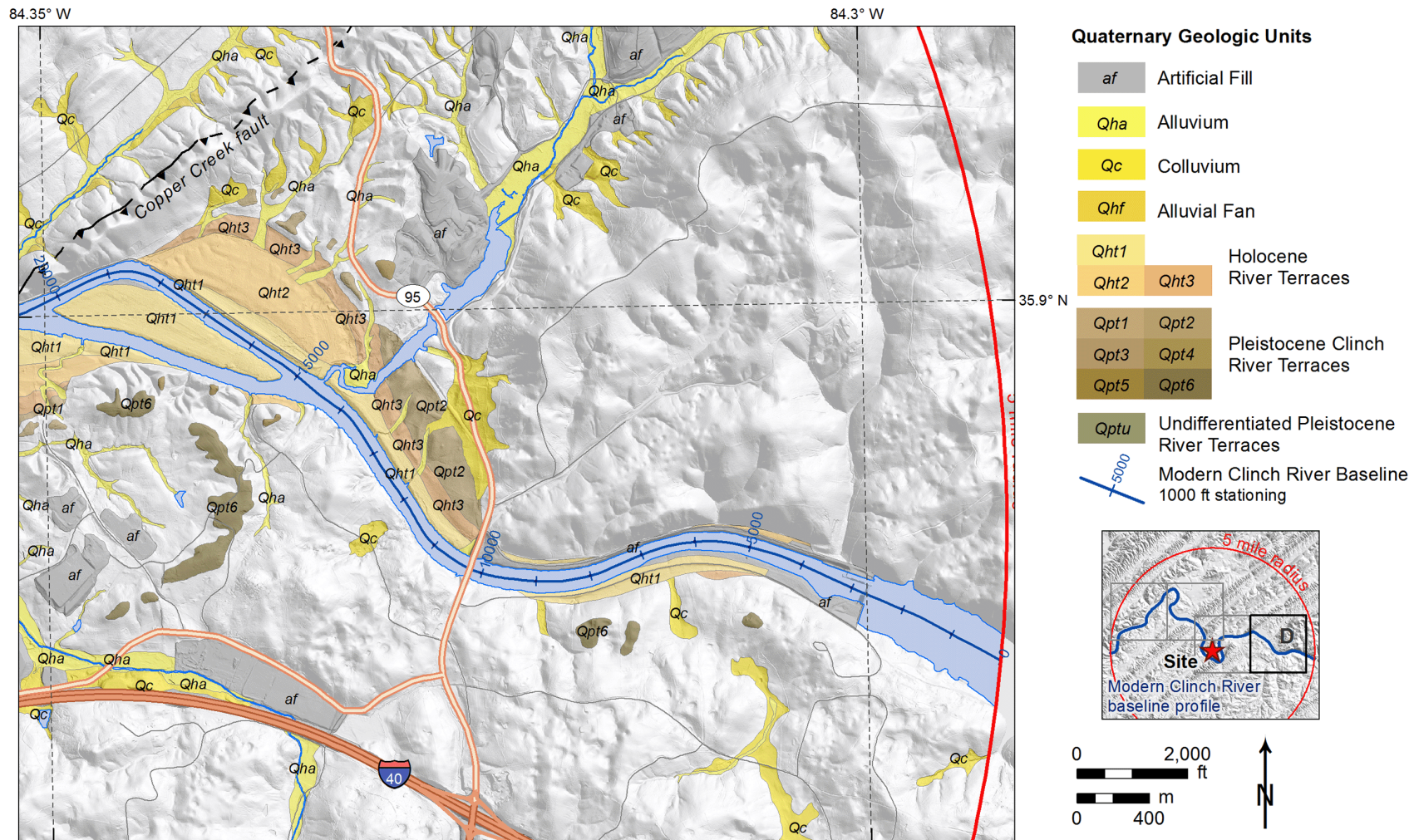
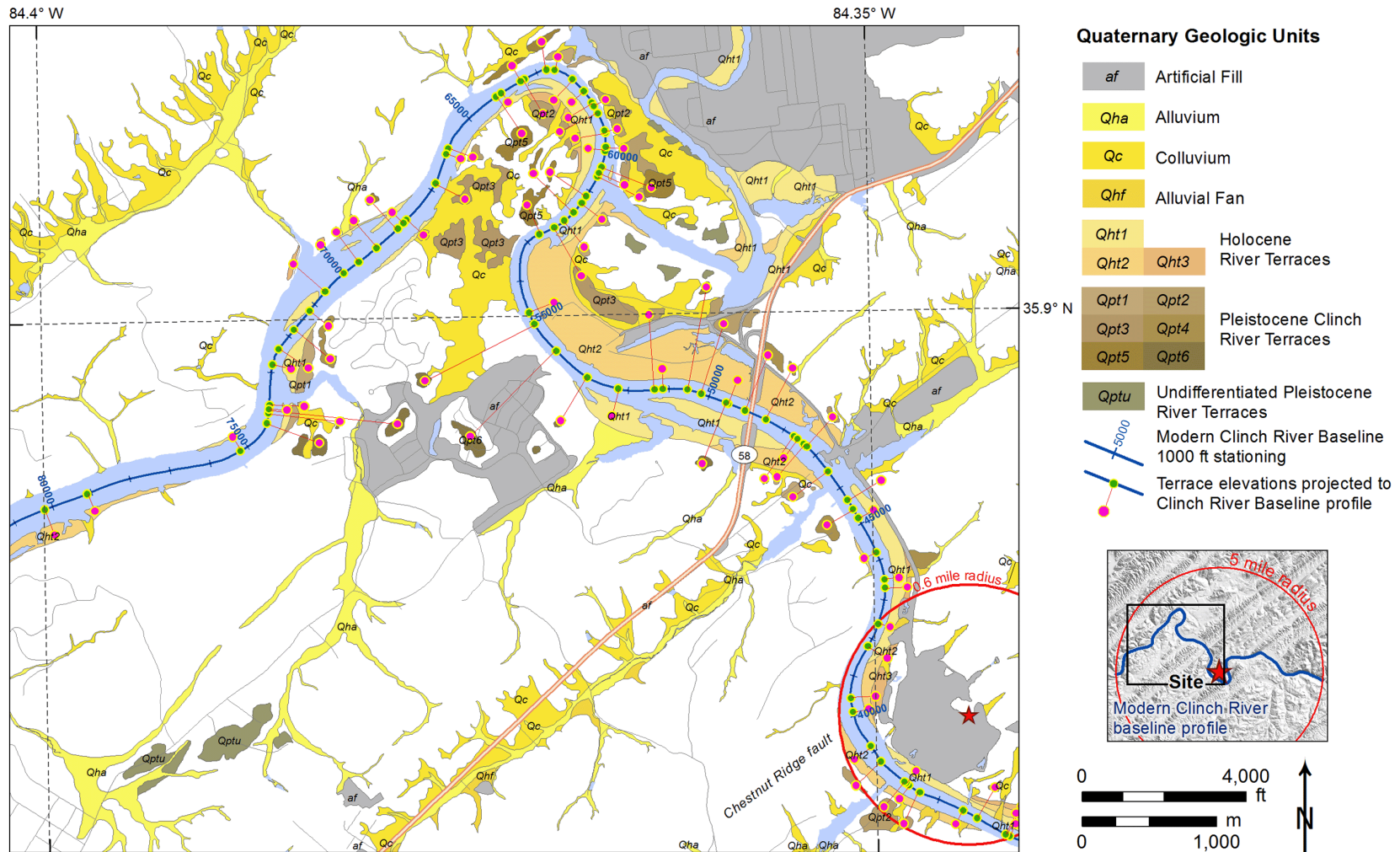


Figure 2.5.1-26. (Sheet 4 of 6) Quaternary Terrace Map Adjacent to the Clinch River Arm of the Watts Bar Reservoir Within the Clinch River Nuclear Site Area, Location D

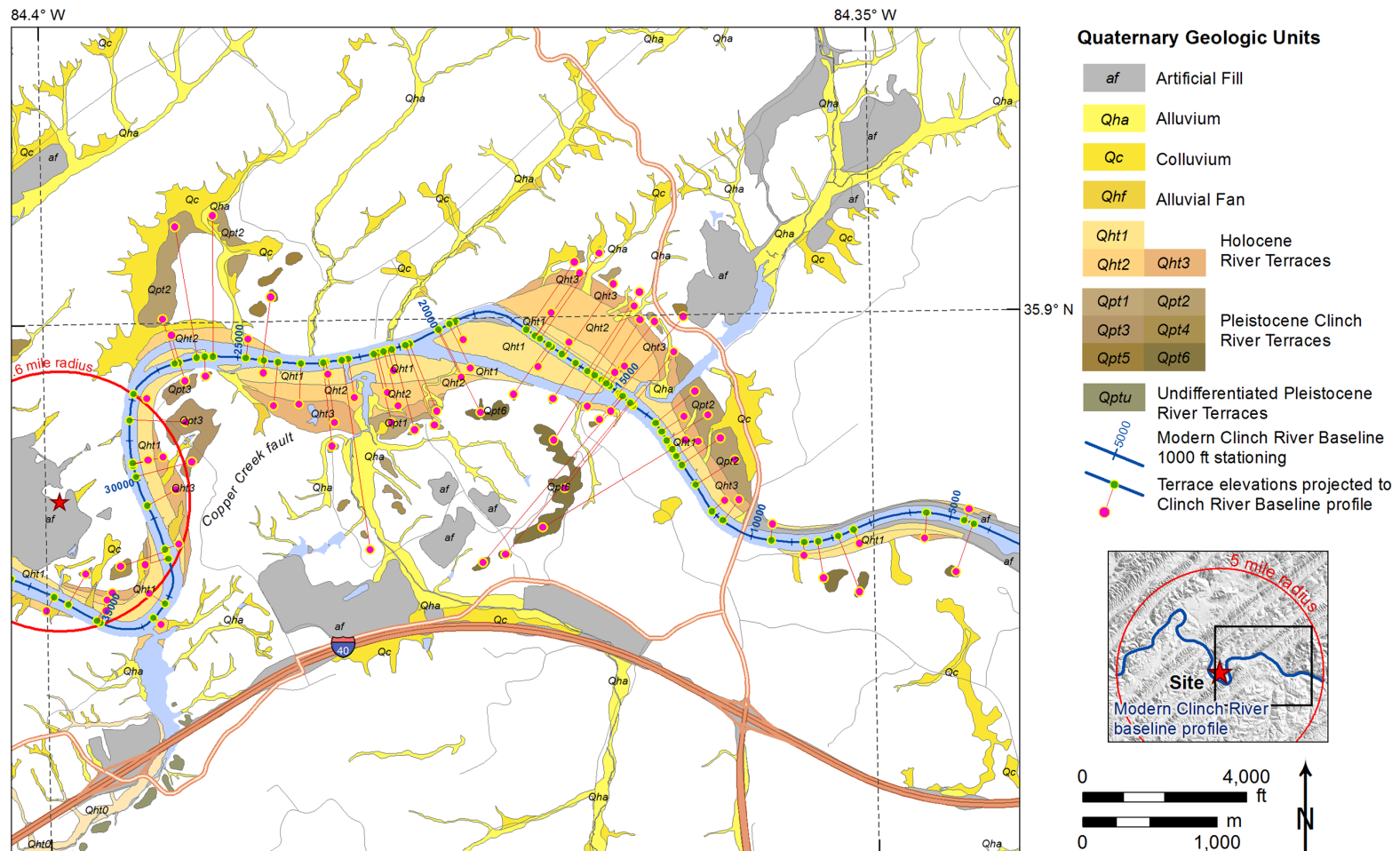
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
See Figure 2.5.3-4 for Longitudinal Profiles of Quaternary Terraces along the Clinch River.

Figure 2.5.1-26. (Sheet 5 of 6) Quaternary Terrace Projections to the Clinch River for creation of Longitudinal Profile

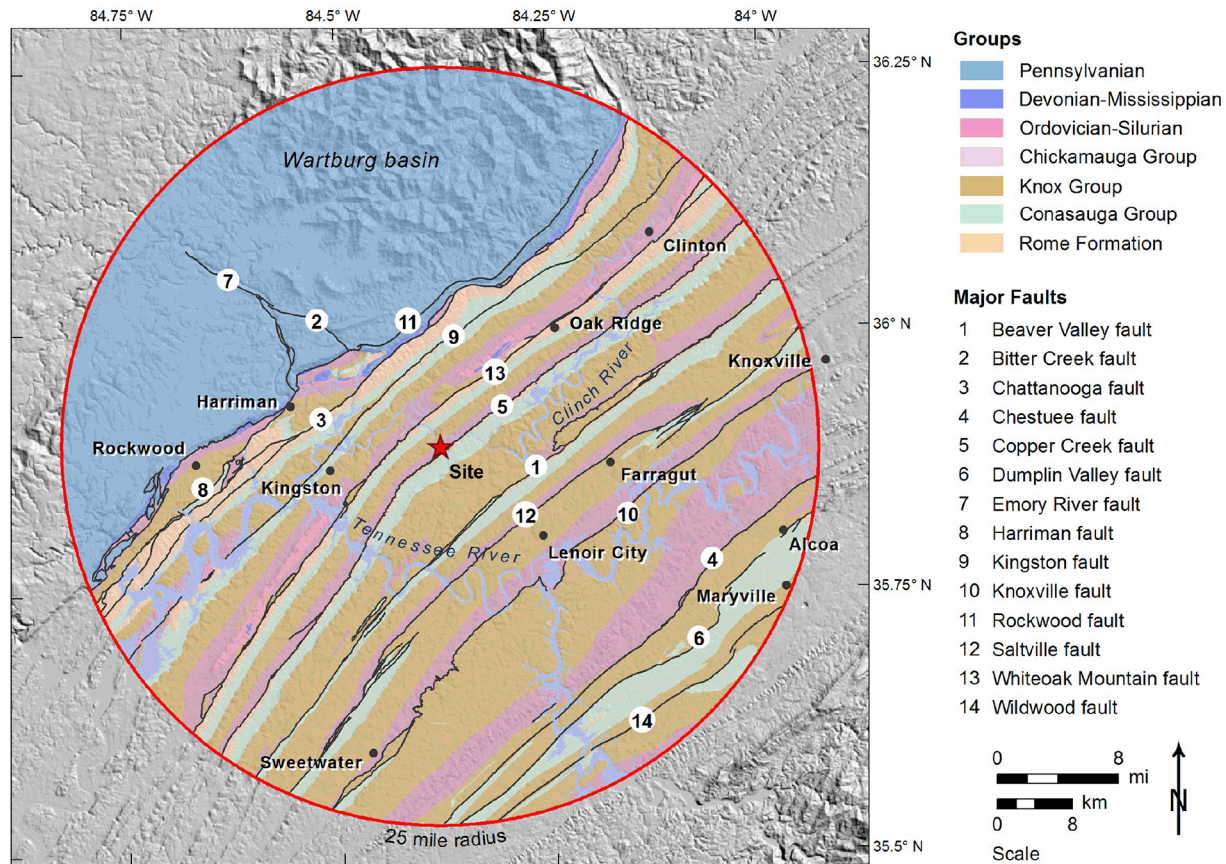
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
See Figure 2.5.3-4 for Longitudinal Profiles of Quaternary Terraces along the Clinch River.

Figure 2.5.1-26. (Sheet 6 of 6) Quaternary Terrace Projections to the Clinch River for creation of Longitudinal Profile

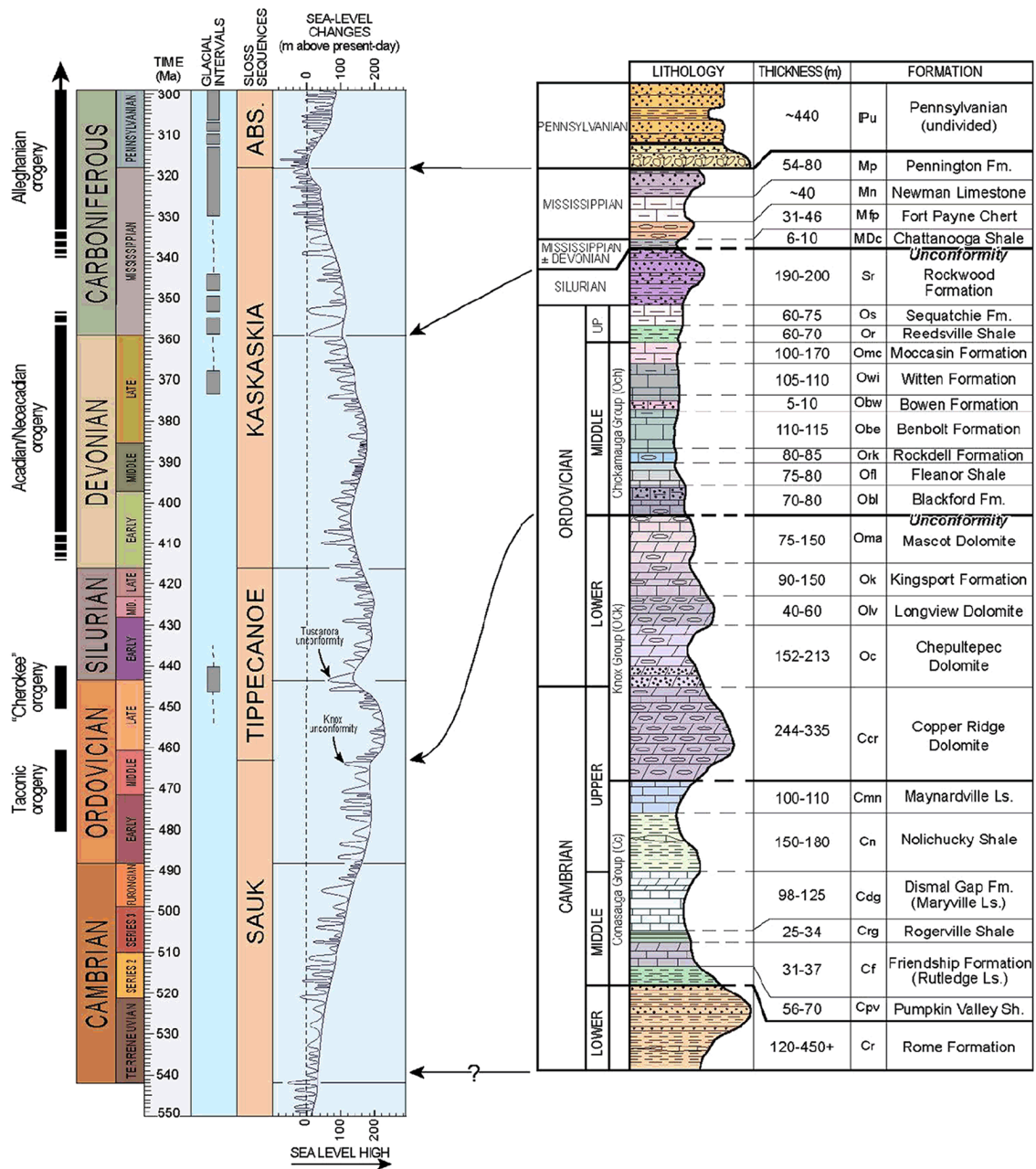
Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Note: Simplified geologic map of the Clinch River Nuclear site vicinity.

Figure 2.5.1-27. Simplified Site Vicinity Geologic Map

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
Generalized stratigraphic column of the geology of the CRN site vicinity (right) with Paleozoic sea level curves, Reference 2.5.1-49 cratonic sequences, glacial intervals, and tectonic events (left; modified from Reference 2.5.1-206) that correspond to the time interval represented by the stratigraphic section (modified from Reference 2.5.1-9).
ABS-Absaroka

Figure 2.5.1-28. Stratigraphic Column with Sea Level Curve

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

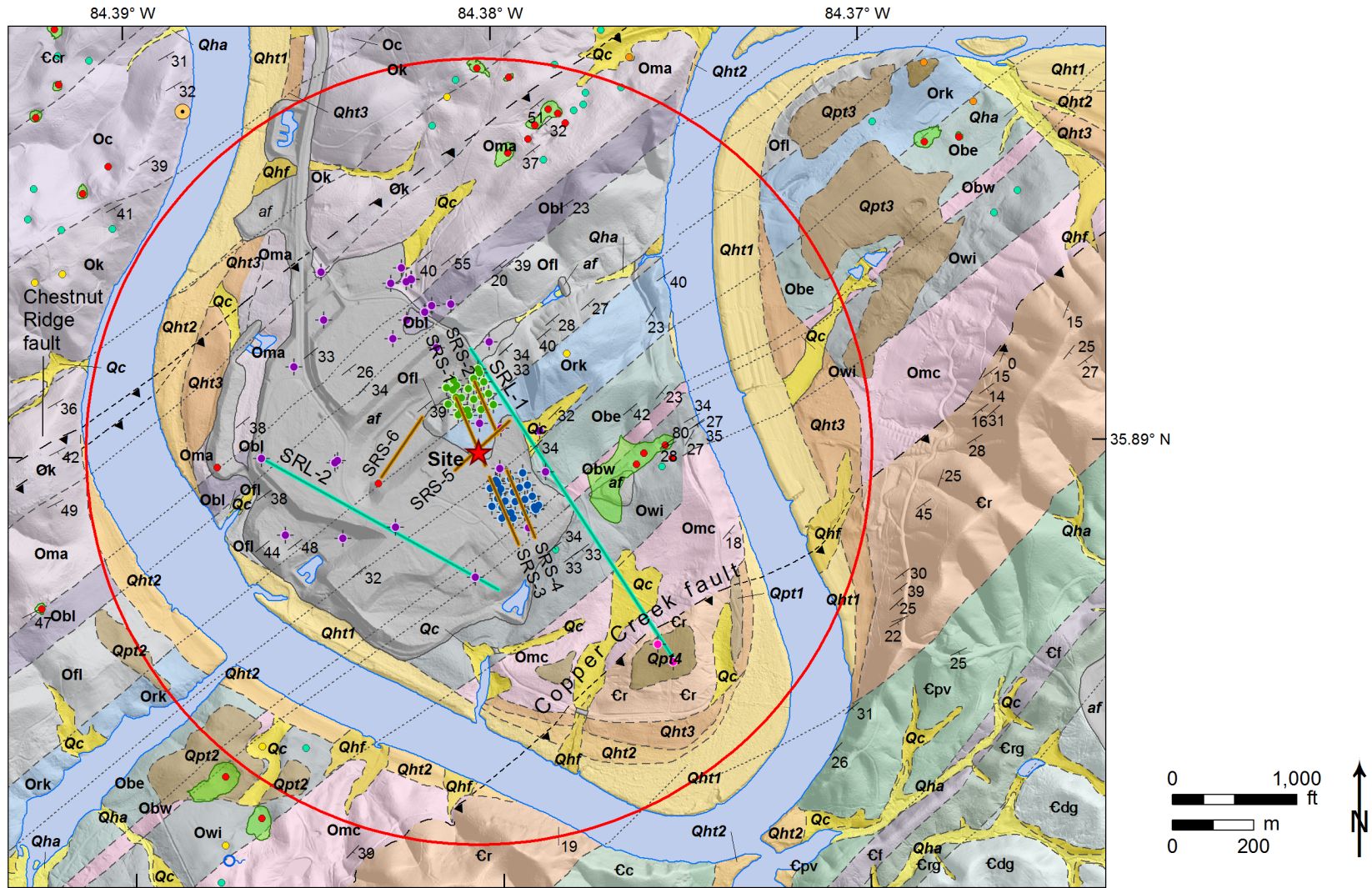


Figure 2.5.1-29. (Sheet 1 of 2) Site Location Geologic Map Showing Borings

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

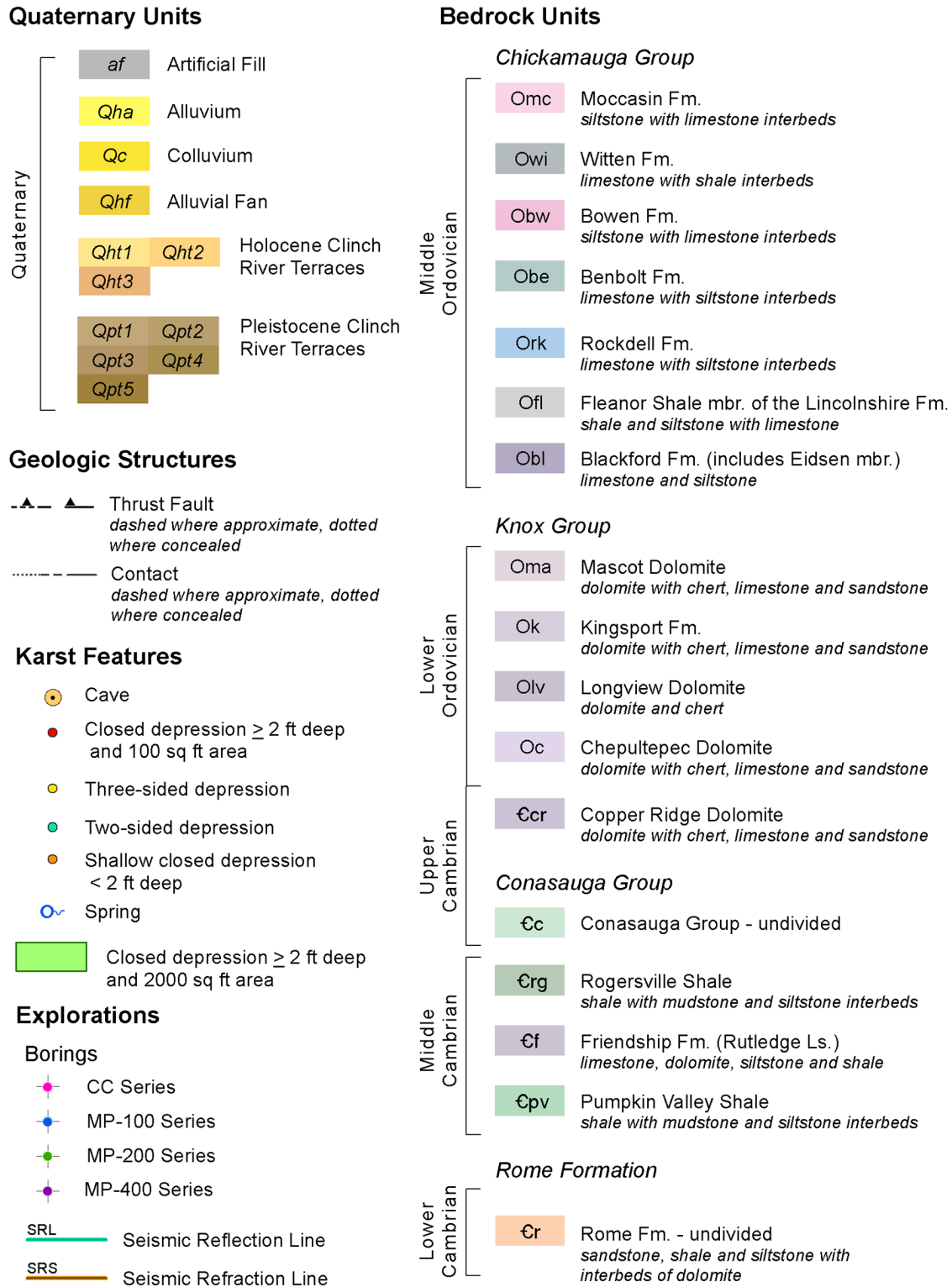


Figure 2.5.1-29. (Sheet 2 of 2) Site Location Geologic Map Showing Borings

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

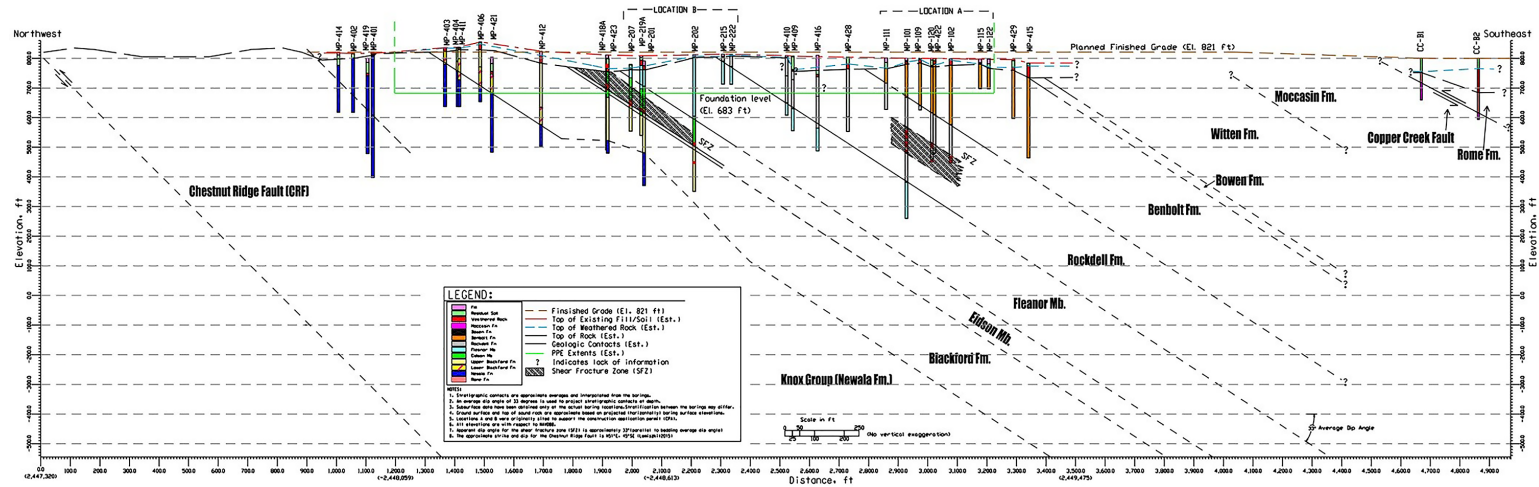


Figure 2.5.1-30. Geologic Cross-Section K-K' of the Clinch River Nuclear Site

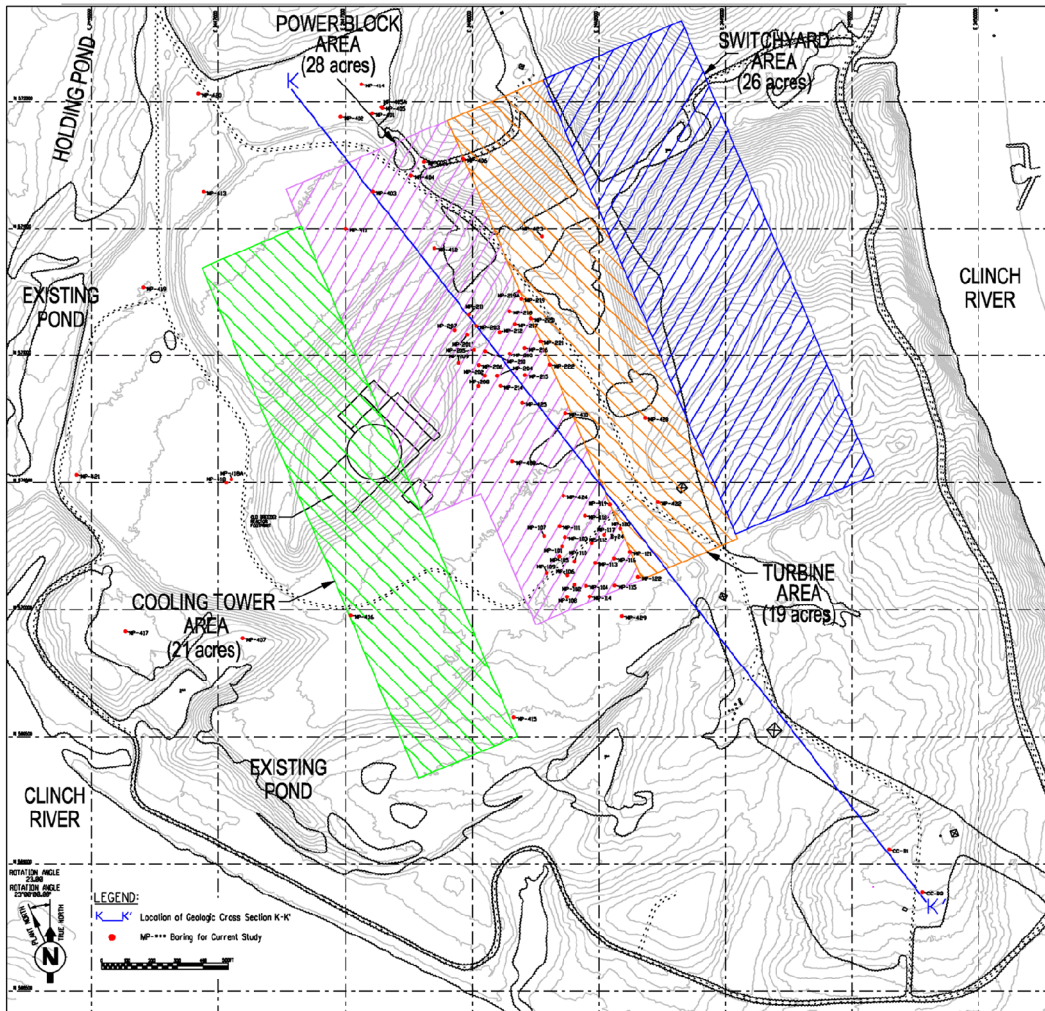
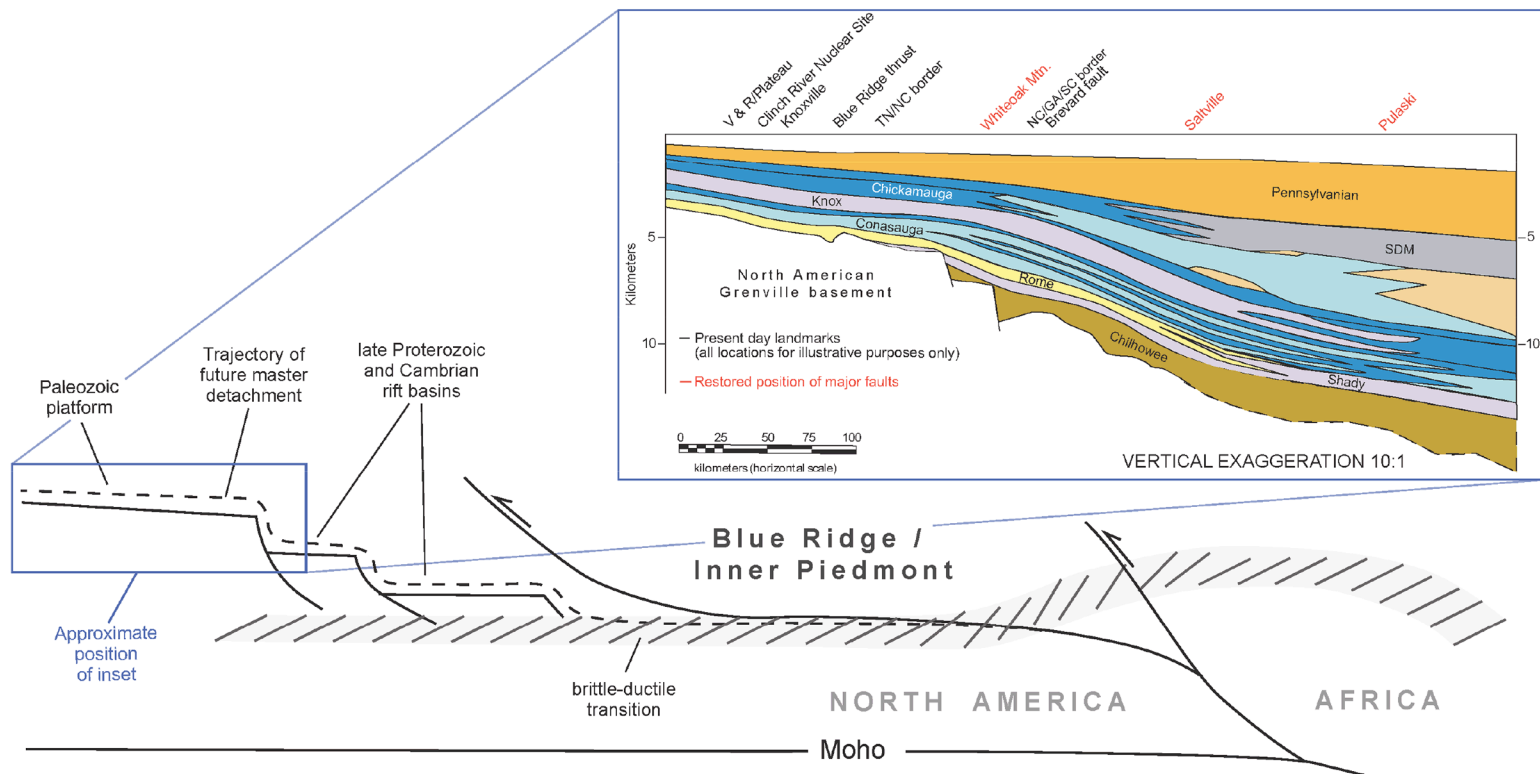


Figure 2.5.1-31. Subsurface Investigation Borehole and Geologic Cross-Section K-K' Locations



Notes:

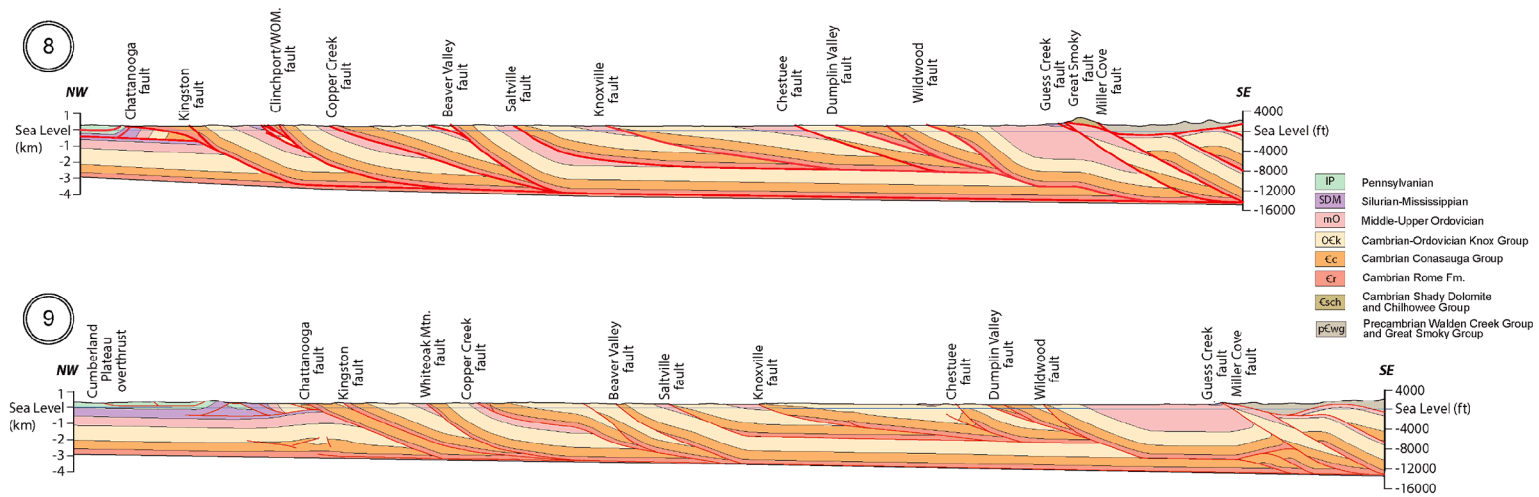
Diagrammatic illustration of the propagation of the master Appalachian detachment (modified from [Reference 2.5.1-159](#)).

Inset shows palinspastically restored facies diagram of Neoproterozoic to late Paleozoic passive margin strata that was deposited along the lapetan margin (modified from [Reference 2.5.1-13](#)).

Blue box indicates the approximate location of area depicted in inset.

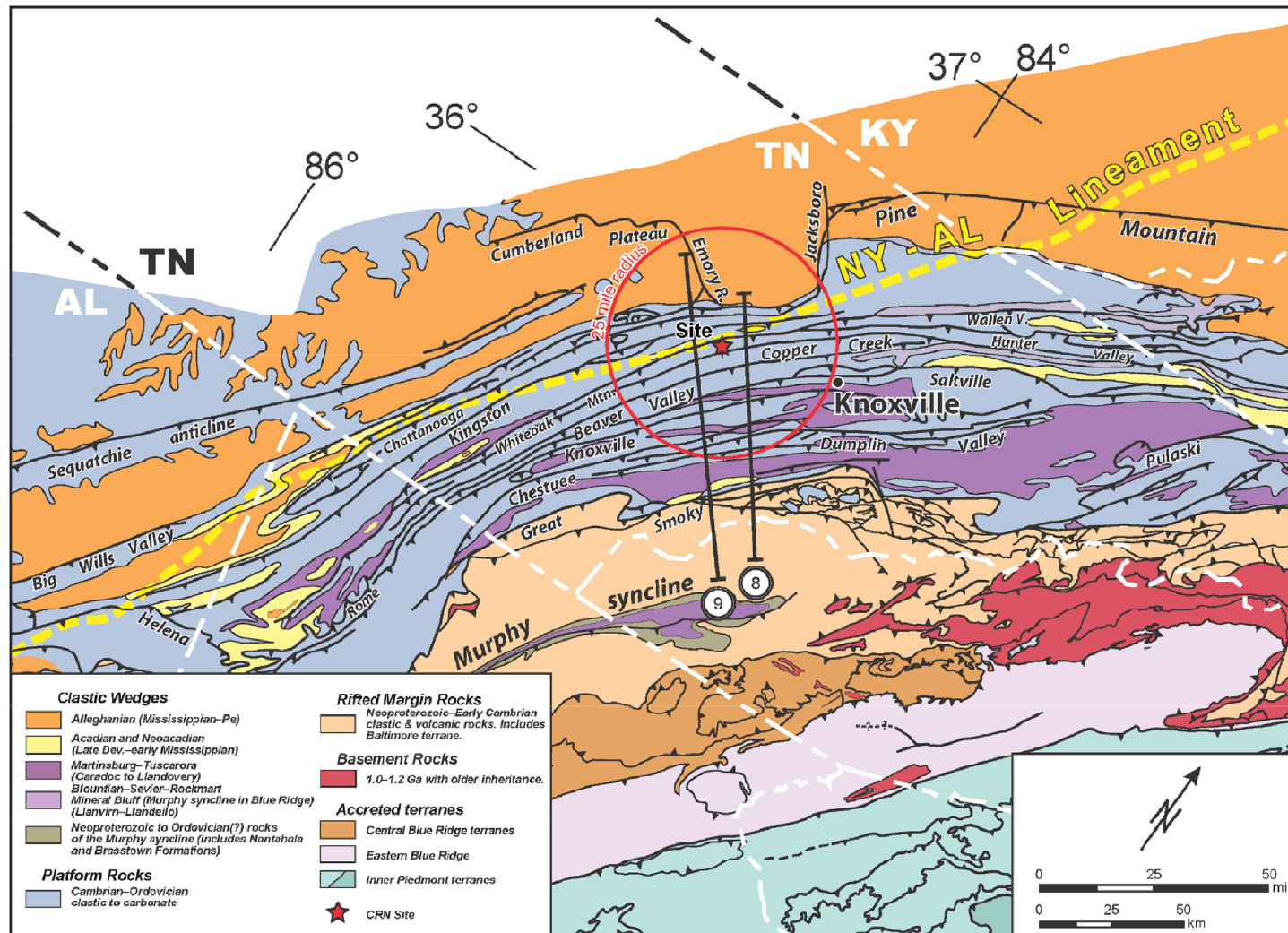
Figure 2.5.1-32. Schematic Appalachian Detachment

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Note: Balanced cross-sections through the Valley and Ridge province from [Reference 2.5.1-230](#) that intersect the Clinch River Nuclear site vicinity.

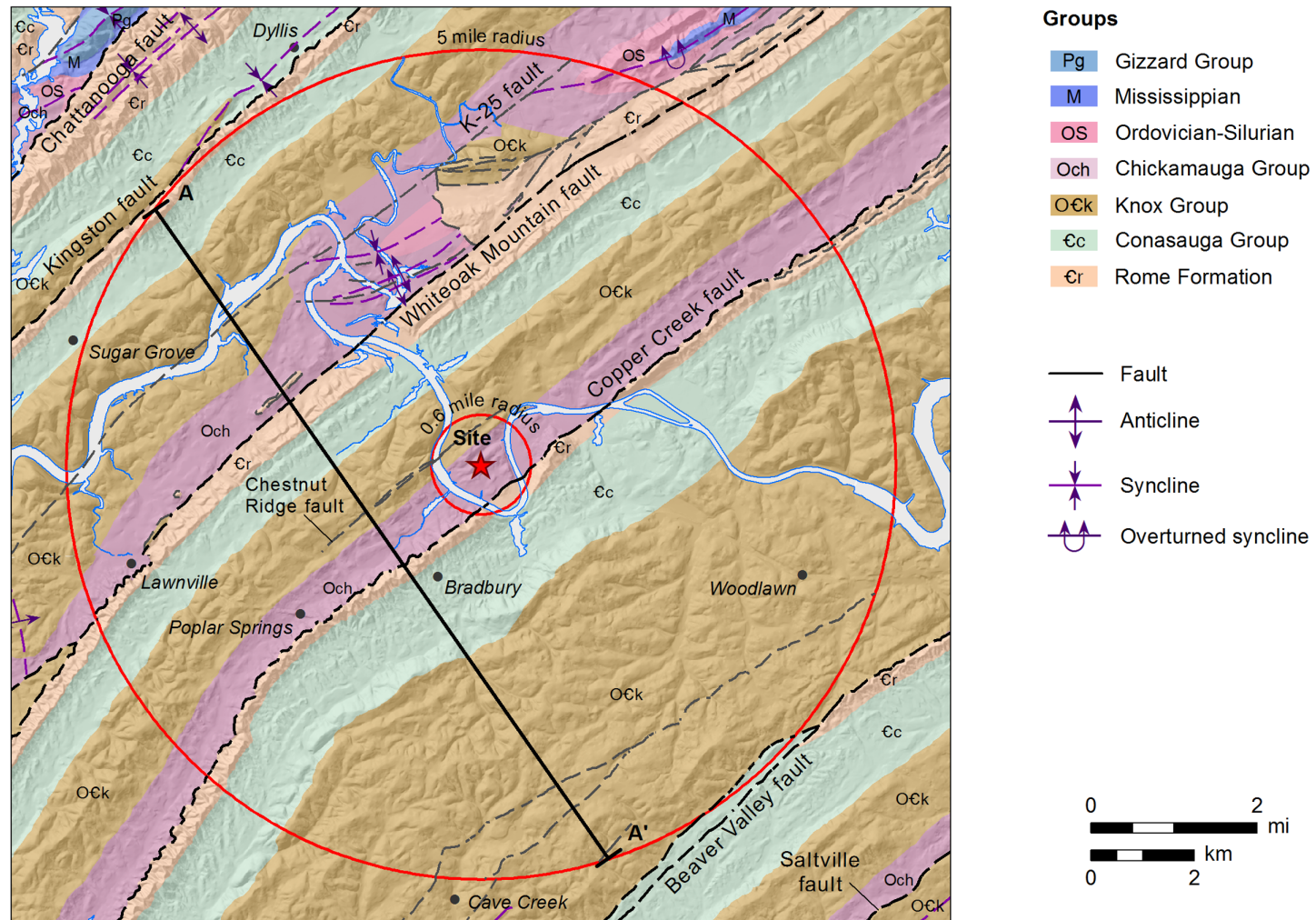
Figure 2.5.1-33. (Sheet 1 of 2) Tectonic Map Cross-Sections—Valley and Ridge



Notes:
Location of cross-sections shown in (A).
Tectonic map modified from Reference 2.5.1-102.

Figure 2.5.1-33. (Sheet 2 of 2) Tectonic Map Cross-Sections—Locations

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report

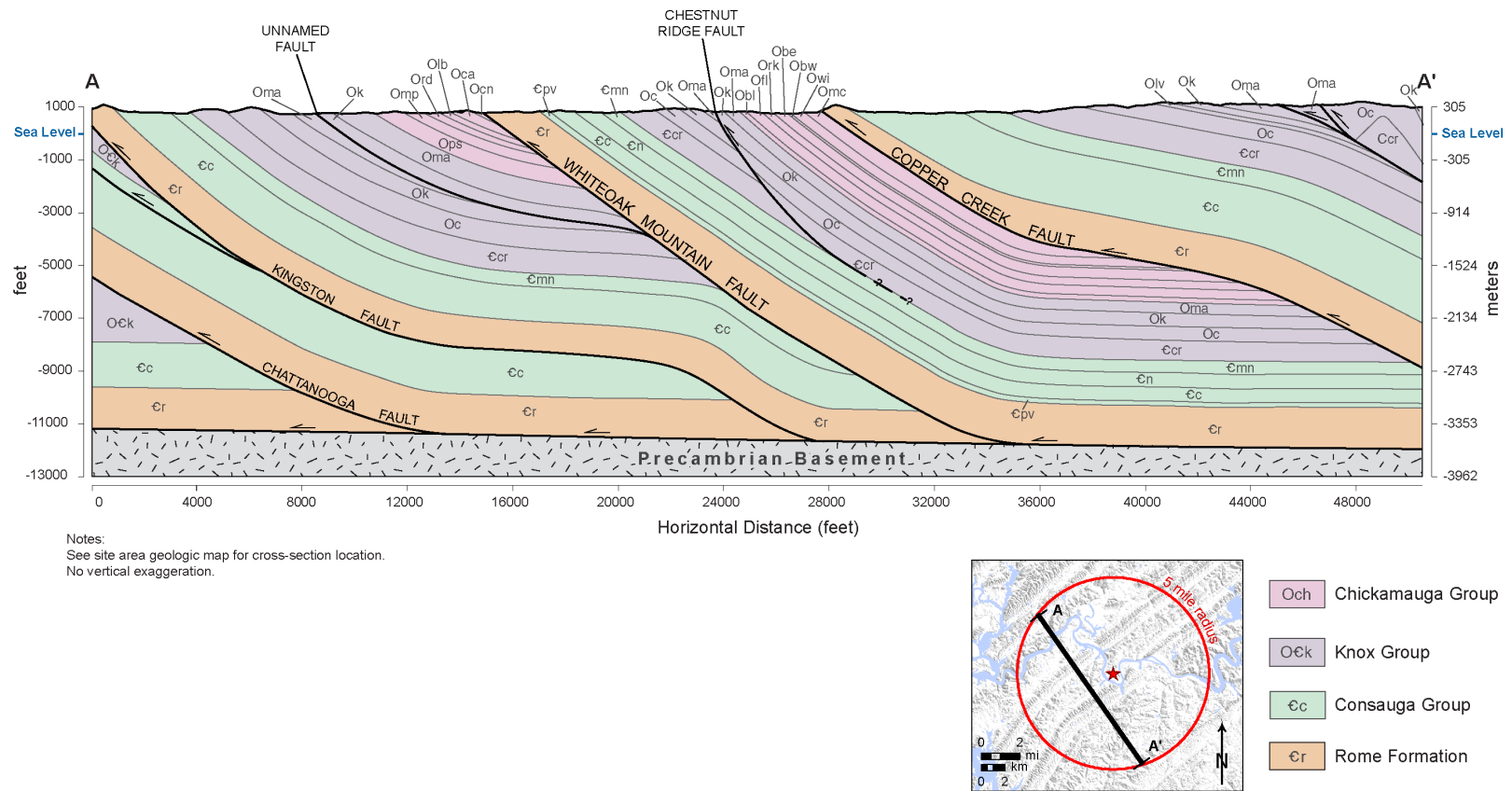


Notes:

See Site Area Geologic Cross Section A-A' (Figure 2.5.1-35).
See Plate 2 in Part 8 for more detailed geologic map of the site area.

Figure 2.5.1-34. Site Area Geologic Map

Clinch River Nuclear Site
Early Site Permit Application
Part 2, Site Safety Analysis Report



Notes:
See site area geologic map for cross-section location (Figure 2.5.1-34).
No vertical exaggeration.
Geologic cross-section through the site area projected to Precambrian basement.

Figure 2.5.1-35. Site Area Geologic Cross-Section A-A'