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SUBSURFACE GEOLOGY OF THE CHICKAMAUGA GROUP AT OAK RIDGE NATIONAL LABORATORY

R. R. Lee
R. H. Ketelle

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Energy Division

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ABSTRACT

Analysis of rock core and geophysical log data acquired from five core holes in the Oak Ridge National Laboratory (ORNL) Main Plant Area indicates the Middle Ordovician Chickamauga Group is a lithologically diverse rock unit. Subdivision of the Chickamauga into nongenetic rock units (Units A-H) is consistent with the position of major lithologic breaks identified in both core and geophysical logs; the placement of these units is in close agreement with their placement in previous work at ORNL. Lithologic variability and interfingering occurs commonly within units, and comparison of correlative intervals from adjacent core holes suggests that lateral variability also occurs commonly. Small- to intermediate-scale structural features, typical of rocks elsewhere on the Oak Ridge Reservation, are absent in the Chickamauga at ORNL. Although numerous high-angle fractures are identified, characteristic structural features in the Chickamauga at ORNL are ubiquitous bedding plane fractures and polished bedding plane partings with slickensides. This style of internal structural deformation is attributed to the mechanical behavior of the strongly interbedded Chickamauga lithologies during Appalachian Orogeny deformation.

1. INTRODUCTION

Remedial investigations at the Department of Energy's Oak Ridge National Laboratory (ORNL) are being conducted as part of ORNL's Remedial Action Program. In support of those investigations, an analysis of the bedrock characteristics underlying ORNL has been conducted through the acquisition of rock core and geophysical data. The results of the geologic analysis provide the basis for understanding the behavior of groundwater flow and contaminant transport; such understanding is essential in planning and implementing remediation activities at ORNL.

2. PURPOSE

This report presents the results of bedrock coring and logging performed in five exploratory borings drilled in the ORNL main plant area in Bethel Valley. It presents lithologic descriptions of the rock core with accompanying geophysical log data acquired from each core hole. The report is intended to be a functional document that contributes to existing information on the geology of ORNL and provides a basis of comparison for future work as it may be used in remedial investigations.

3. LOCATION

The ORNL Main Plant Area facilities are located in Bethel Valley on DOE's Oak Ridge Reservation (ORR) (Fig. 1). Bethel Valley is one of several northeast-to-southwest trending topographic features on the ORR. Other prominent topographic features of the ORNL area include Chestnut Ridge, Haw Ridge, Melton Valley, and Copper Ridge. Each of these topographic features is underlain by different bedrock units, the weathering and erosion of which are responsible for the present terrain.

A generalized geologic map of the ORNL area is shown on Fig. 2, and a generalized cross-section of the area is shown on Fig. 3. As indicated on Figs. 2 and 3, the ORNL area is directly underlain by three major geologic units: the Chickamauga Group beneath Bethel Valley, the Rome Formation beneath Haw Ridge, and the Conasauga Group beneath Melton Valley. Bedrock in the area generally dips to the southeast, the regional norm for bedrock orientation. The Copper Creek Fault, a regionally extensive thrust fault, outcrops on the lower-to-middle northwestern slope of Haw Ridge.

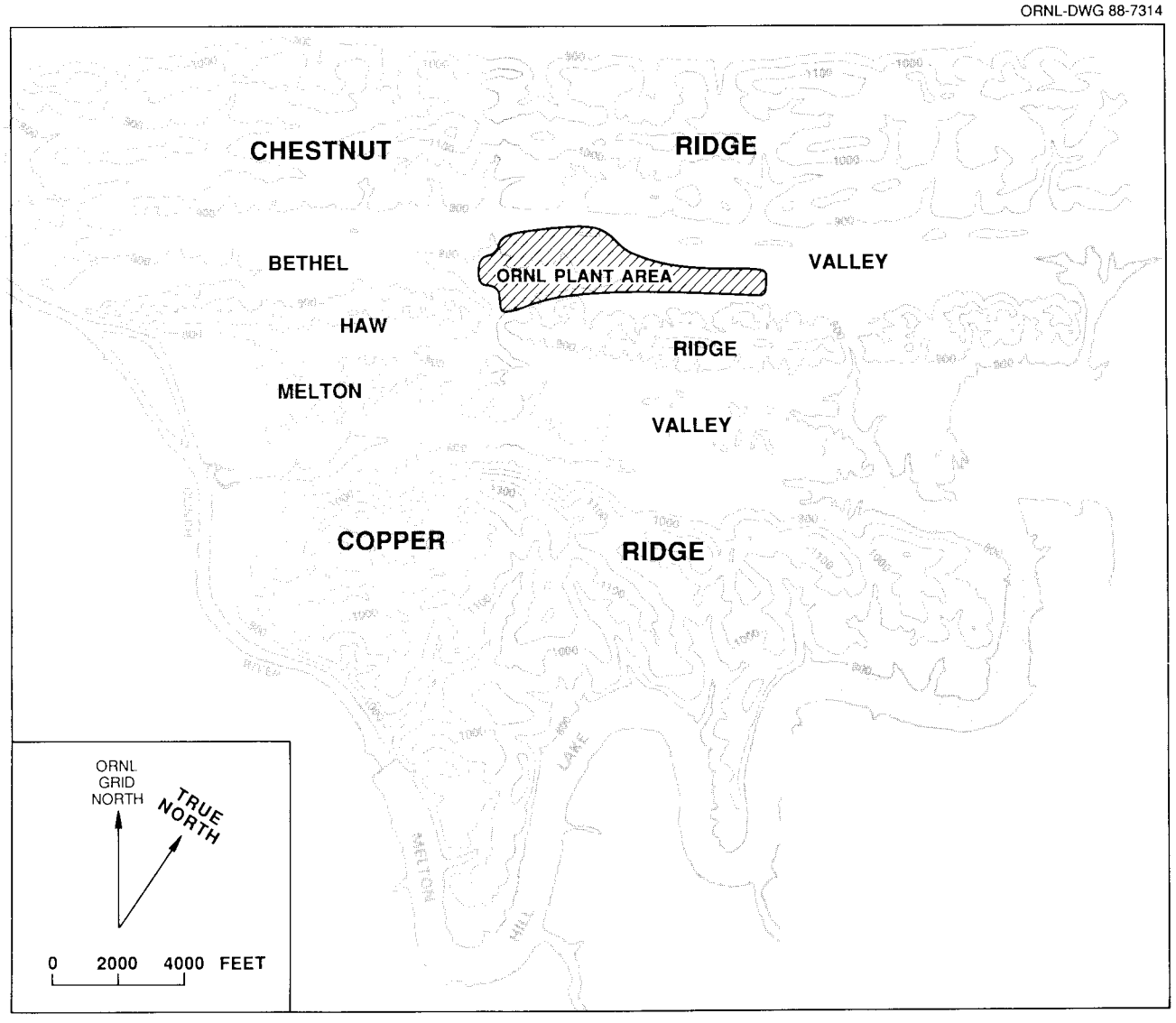

Fig. 1. Topographic map of the ORNL area.

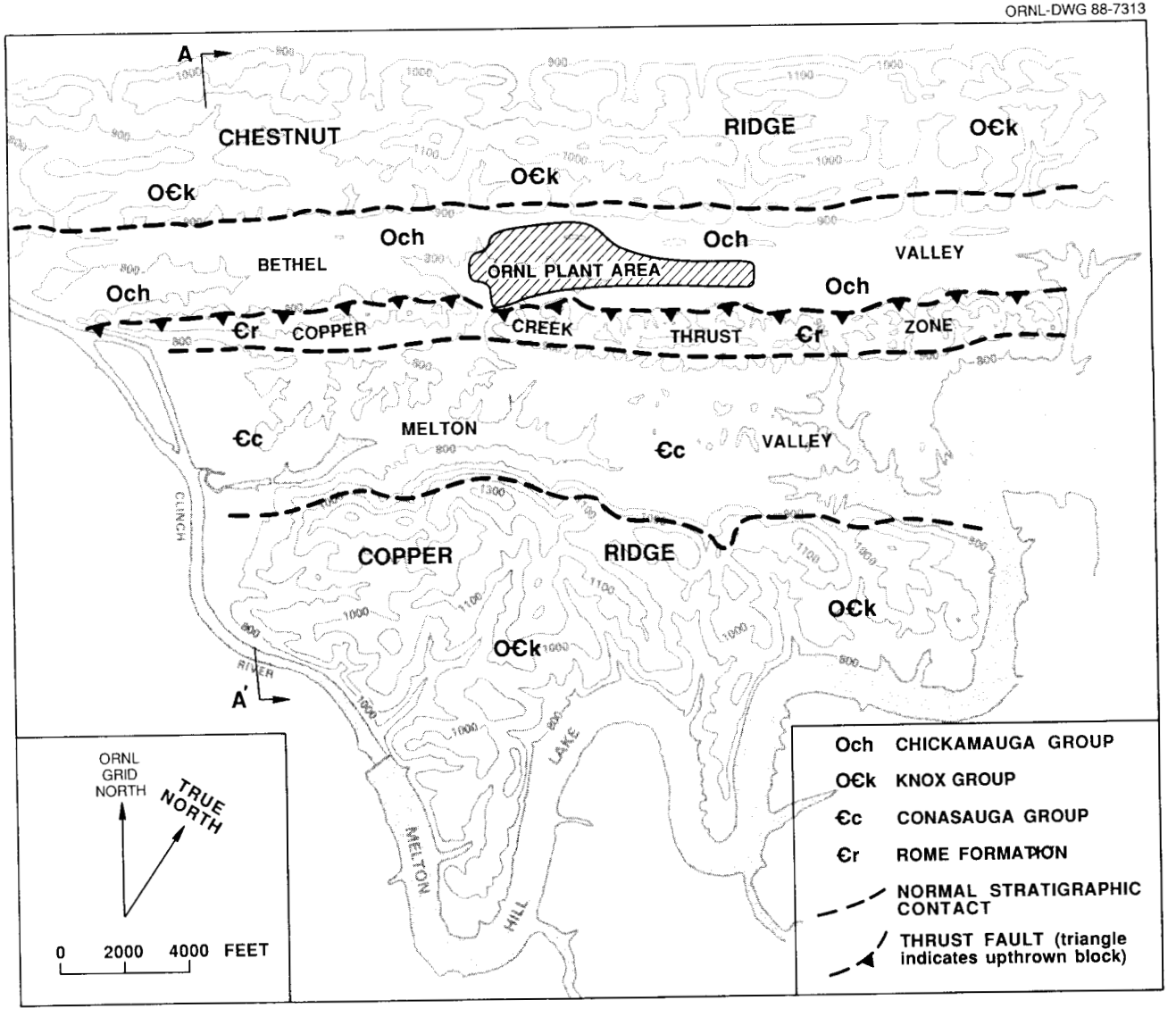

Fig. 2. Generalized geologic map of the ORNL area.

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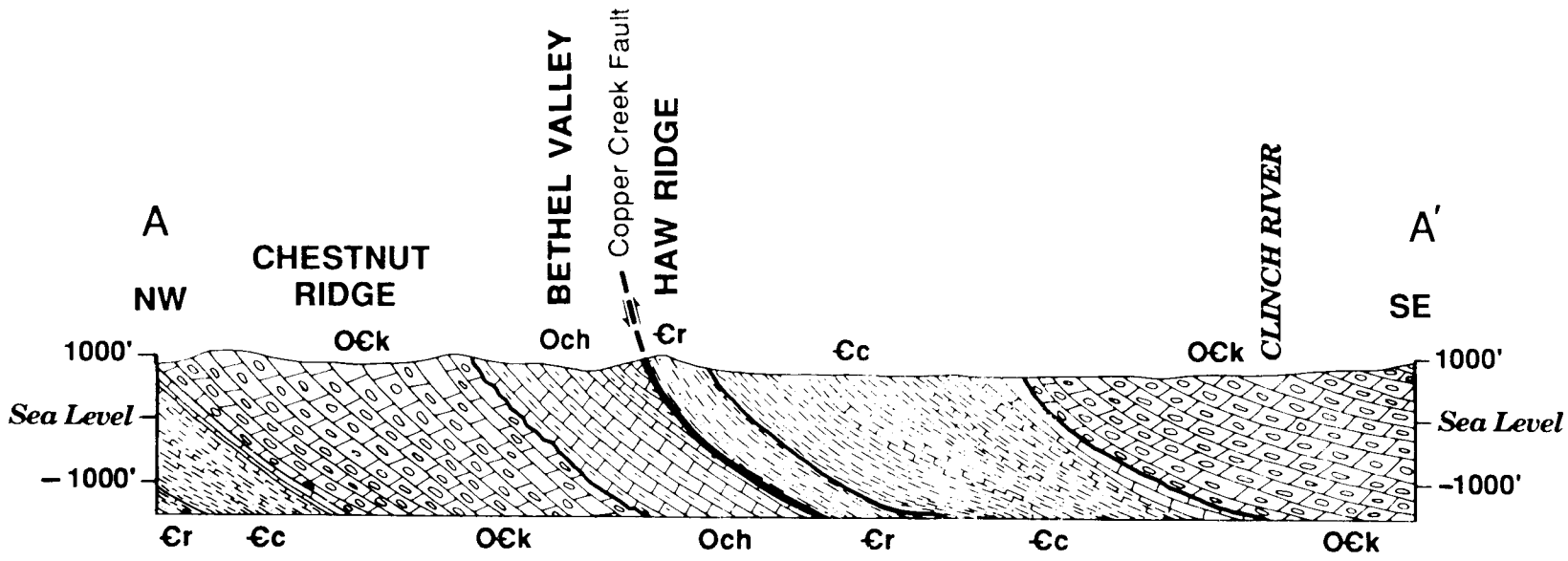

Fig. 3. Generalized geologic cross section of the ORNL area.

4. PREVIOUS STUDIES

Because of the relatively numerous field exposures and diverse lithologic and faunal content of the Middle Ordovician Chickamauga Group, it has been extensively studied in East Tennessee and adjacent states. Much of the research has focused on the paleodepositional setting, the spatial and temporal relations of the deposits, and the structural history of the basin. Numerous publications and graduate theses can be found on these various aspects of the Chickamauga (i.e., Rodgers and Kent 1948; Rodgers 1953; Swingle 1964; Milici and Smith 1969; Brent 1982; Walker, Shanmugam, and Ruppel 1983; Ruppel and Walker 1984).

Present understanding of Chickamauga lithology and stratigraphy near the main plant area is derived from a study conducted by Stockdale (1951). In that study 51 exploratory borings were completed to depths of from 50 to 250 ft, with most holes drilled to 50 or 100 ft. Most of the holes were drilled into the upper four units of the Chickamauga south of Central Avenue. Those core holes located within the ORNL fenced area and many of those located near roads have been destroyed. One well to the southeast of ORNL (Stockdale's well 50) and those wells between Building 1505 and SWASA 3 remain. These wells contain 3.5-in.-ID, thin-walled, black steel casing. Brief core descriptions from some of the borings accompany Stockdale's report. However, the location of the recovered core is not known, and the core is presumed to have been discarded.

Elsewhere in the Valley and Ridge, the Chickamauga Group has been divided into from four to thirteen formations or unnamed units. For example, on the geologic map of the Clinton quadrangle, which includes a portion the city of Oak Ridge, Swingle (1964) mapped six Chickamauga lithologic units in Raccoon Valley northeast of the Clinch River and four units in Union Valley between Clinton and Oak Ridge. Based on a general depositional model proposed by Walker and Alberstadt (1973), Weiss (1981) applied the formational names introduced by Cooper and Prouty (1943) in Virginia to Chickamauga facies at Solway, Tennessee. Borowski (1982) found those formational designations cumbersome and poorly applicable in the adjacent thrust belt near Clinton, Tennessee, and chose not to subdivide the Chickamauga.

Stockdale (1951) divided the Chickamauga Group in the main plant area into eight unnamed mappable units (from oldest to youngest, Units A-H). While any or all of the subdivisions mentioned previously may be locally mappable, it was found

in the course of this study that Stockdale's (1951) unit designation scheme is nongenetically defensible and is the most appropriate for the ORNL area. It is beyond the purpose and scope of this report to reconcile the various nomenclatural schemes applied to the Middle Ordovician in East Tennessee. Therefore, to maintain internal consistency with the only previously published document on the Chickamauga Group on the ORR, the Stockdale unit designations are used in this report. To the extent possible, unit boundaries are based upon the lithologic descriptions provided by Stockdale.

5. DATA ACQUISITION

Data presented in this report are from rock core and geophysical logs obtained from five core holes (CH-1 through CH-5) that were drilled in a transect across Bethel Valley in the ORNL main plant area and from one core hole (CH-189) located along geologic strike 4.7 miles (7.6 km) northeast of the ORNL site. ORNL site core hole locations are shown in Fig. 4, and Table 1 includes core hole location and depth data for all core holes. ORNL site borings were cored with Joy NC wireline coring tools. Nominal hole diameter is 3.70 in., and nominal core diameter is 2.40 in. Drilling of the ORNL core holes was conducted continuously from October 1985 to January 1986. The holes were drilled sequentially beginning with CH-1 to achieve stratigraphic overlap between holes and to acquire a complete stratigraphic section. Core is in storage in Building 7042.

Table 1. Core hole survey and depth data

Well #	Location	Ground elev. (ft)	Top of casing (ft)	Casing depth (ft)	Total depth (ft)
CH-189	N 24,113 E 56,787[a]	877.45	877.70	23.00	763.00
CH-1[b]	N 23,184.76 E 31,969.39	823.02	823.72	20.00	385.20
CH-2	N 22,596.07 E 31,961.96	824.42	825.12	18.00	472.80
CH-3	N 22,192.81 E 31,954.89	797.48	797.98	10.00	400.60
CH-4[c]	N 21,757.12 E 31,894.79	795.41	796.41	12.50	380.60
CH-5	N 21,118.90 E 31,800.36	800.92	803.42	16.00	446.40

[a]Y-12 coordinate system. All other well locations in ORNL coordinate system.

[b]Ground and surface casing elevations prior to 1987 construction activities.

[c]Permanent packer installed between 295 and 300 ft below ground surface in May 1987. Well shut in.

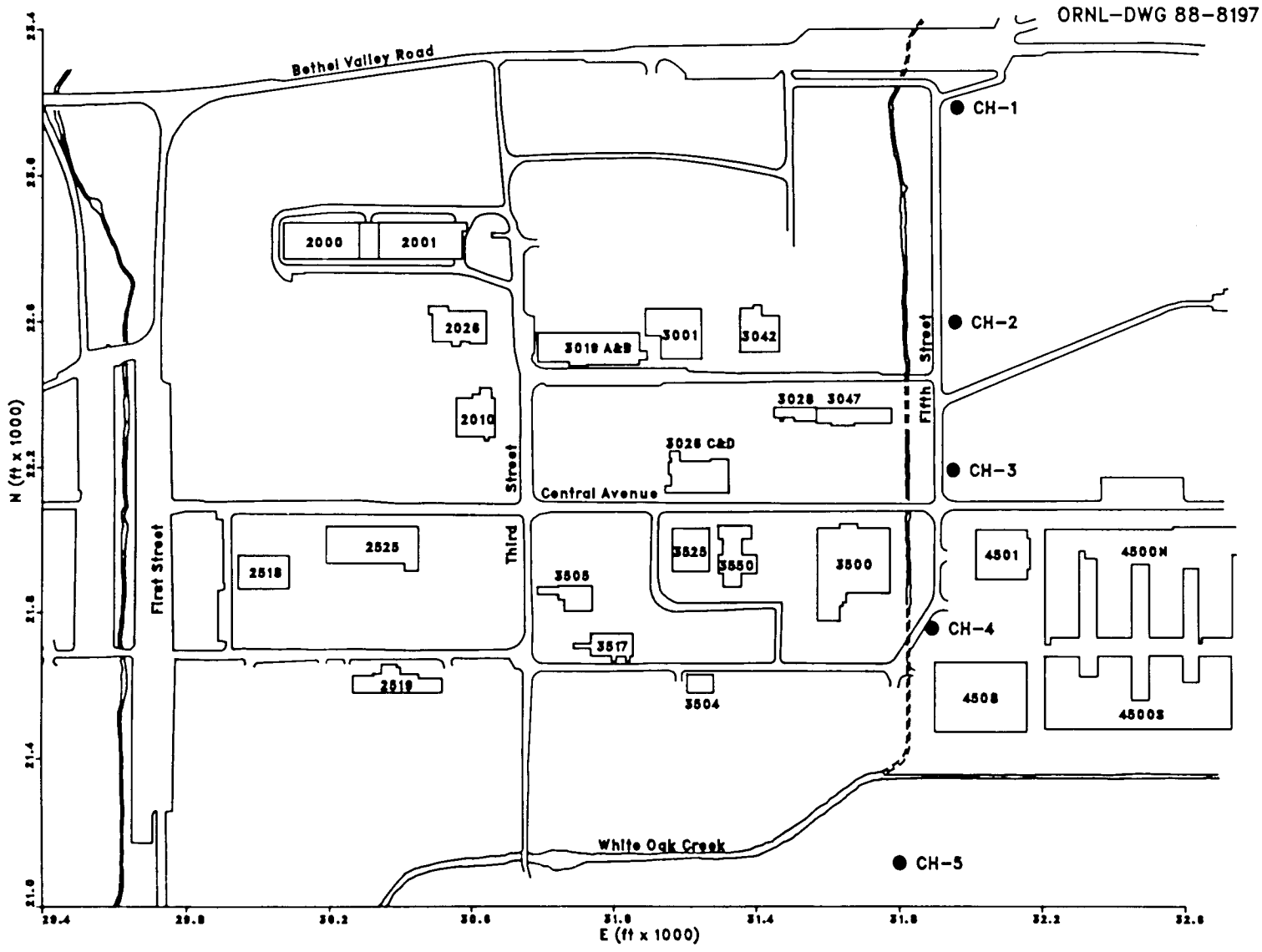

Fig. 4. ORNL study core hole locations.

Geophysical logs were obtained for each of the five core holes in January and February 1986. Logs include gamma, caliper, spontaneous potential, compensated density, neutron porosity, single point resistivity, long/short normal resistivity, temperature, and borehole vertical deviation. Geophysical logs are on file in the authors' offices.

6. DATA ANALYSIS

This section describes the gross lithologic characteristics of the major Chickamauga Group rock units based on core examination. Each described unit is related to a composite geophysical log of the Chickamauga Group. Throughout this report, designations for stratigraphic position and core thickness are provided in downhole feet below ground surface. This convention allows comparison of stratigraphic position both between adjacent cores and between core and geophysical logs. For consistency with this convention, rock core bedding thicknesses are also reported in the British Unit System.

6.1 GEOPHYSICAL DATA

Selected geophysical logs from each core hole were digitized, and composite logs were plotted for natural gamma, neutron porosity, and long/short normal resistivity as shown in Plate 1. The net effect of log splicing is to illustrate the appearance of a suite of geophysical logs obtained from a single 1700-ft-deep bore hole drilled at the location of CH-5. The splice points for geophysical logs segments from adjacent core holes are based on both geophysical log and lithologic correlation between core holes. In performing the log splices, log value adjustments were not made at splice points.

Geological units (O€k and Och A-H) are displayed in the left column of Plate 1. Depths indicated on the geological units log represent cumulative downhole depth to unit contacts in feet below ground surface at CH-5 assuming uniform unit thickness between core holes.

The natural gamma composite log trace graphically shows the variability of shale, siltstone, and limestone content of the Chickamauga and indicates the thin interbedded nature of many units by the rapid, small-scale changes in natural gamma values. Lowercase letters, adjacent to the natural gamma trace, are keyed to specific features described in the text lithologic descriptions in Sect. 6.3.

The third column from the left in Plate 1 indicates the name of the core hole from which each segment of the composite log data was derived. Core hole numbers are indicated on the right, and downhole splice points (depths in feet below ground surface) for each core hole are indicated on the left.

The neutron porosity log trace provides an indication of the porosity distribution within the Chickamauga but has not been shown to be a reliable indicator of probable groundwater flow zones. As can be observed in the comparison of natural gamma and neutron porosity, there is a strong correlation between porosity and siltstone or shale content, with relatively high porosity values observed in those lithologies. Porosity of these siltstone- and shale-rich zones, if present, has not been shown to be equivalent to effective porosity with respect to the transmission of groundwater.

The long/short normal resistivity log indicates the variability in resistivity within the Chickamauga that is largely attributable to lithologic variability. The long/short normal resistivity trace tends to be a mirror image of the natural gamma and neutron porosity traces, and the presence of hydrologically tight limestone beds is indicated by the several peaks that exceed 2000-ohm meter resistivity.

6.2 GEOLOGIC STRUCTURE

Available data indicate that the geologic structure of the Chickamauga is consistent with the regional structural setting of the Valley and Ridge Physiographic Province in East Tennessee. Geologic strike data were not obtained from the rock core, but data entries included on the geologic map in Stockdale (1951) indicate that strike in the main plant area is N 50-56 E°. Measurements of geologic dip obtained from rock core are uniformly 30-34°, and these values are consistent with the dip data on Stockdale's map. In contrast to structural features in other rock units on the Oak Ridge Reservation, small-scale deformation features such as folded or vertical beds were not noted in core. Small-scale structural features include minor bedding plane fractures along thin lithologic partings with evidence of bedding displacement and high-angle fractures (with respect to horizontal) exhibiting little to no displacement.

6.3 LITHOLOGIC DESCRIPTION

The Chickamauga is composed mainly of complexly interbedded limestone and siltstone lithofacies. Rock type and color, interbedding characteristics, and relative facies proportions are the principal criteria for subdividing the

Chickamauga into smaller, informal rock units. Descriptions provided here are nongenetic and are intended to provide rock core and geophysical log documentation for the identification of the major rock units comprising the Chickamauga. Although general lithologic uniformity characterizes Chickamauga Group informal rock units, many of the units contain several diverse lithologies. The intent of the lithologic descriptions that follow is to provide succinct overall unit characterizations and differentiate among the often diverse lithologies of units.

Rock core from the lowermost Unit A was not recovered from CH-1 during this study, but rock core and geophysical logs from this interval are available from core hole CH-189, located near Roger's Quarry. Although detailed lateral facies variations exist between CH-1 and CH-189, the lithologic features and geophysical signature of the correlative intervals are sufficiently similar to consider the lithologic characteristics of CH-189 to be generally representative of the lowermost Unit A in the main plant area. This correlation between CH-1 and CH-189 indicates that approximately 80 downhole ft of the lowermost Chickamauga was not drilled in the main plant area.

Unit A

Unit A is one of the most diverse lithologic units in the Chickamauga. It is generally characterized by thick sections of maroon and olive gray calcareous siltstone interbedded with dark and light gray calcarenite. Bedded or nodular jasperoid chert, common and distinctive of Unit A, provides a partial basis for Unit A's subdivision. This study's most significant departure from Stockdale's (1951) rock descriptions occurs in Unit A both in unit thickness and in unit subdivisions. Possible explanations for this and subsequent departures will be discussed in Sect. 7.

In core from CH-189, the contact between Unit A and the underlying Knox occurs at 566 ft below a 9-in.-thick bed of purplish maroon limestone that overlies a 9-in.-thick bed of pale olive limestone. Both limestone lithologies contain small, angular dolomitic intraclasts. These beds are in abrupt contact with the dense, drab, light gray- to buff-colored, internally featureless Knox (a). The lowermost 76 ft of Unit A is generally a dense, dark purplish, slightly dolomitized, fenestral limestone that grades upward to thinly laminated, light and dark gray limestone (b).

Continuing upward in Unit A, 2- to 4-in.-thick nodular and bedded chert is commonly incorporated within roughly 147 ft of dark gray, purplish, and maroon calcareous and shaley siltstone interbedded with subordinate amounts of light gray crystalline calcarenite (c). The siltstone often contains thin, wavy, light gray limestone partings but may be bioturbated or internally featureless. Biogenic features are noted. The calcarenite is generally medium-grained and unfossiliferous, often containing thin olive gray or maroon siltstone partings. The contact with the overlying lithology in Unit A is marked by the uppermost occurrence of bedded chert.

The next lithology in Unit A (29 ft thick) is distinguished from the underlying lithology by a marked increase in maroon siltstone and an absence of chert. The lithology is recognized as an unfossiliferous, purplish maroon calcareous siltstone containing thin (0.5- to 1.5-in.-thick) light gray limestone beds. These interbedded lithologies grade upward to dominantly dark to olive gray siltstone (d). The siltstone is mostly bioturbated but contains occasional thin limestone laminae. Some laminated beds are vertically burrowed. The contact with the overlying lithology is based on the introduction of chert-rich, medium-grained calcarenite.

The next lithology (46 ft thick) is characterized by dark to light gray, laminated or massive, unfossiliferous, medium-grained calcarenite with abundant chert nodules and beds (e). Its generally massive appearance and light gray color provide a sharp contrast to the maroon siltstone of the underlying lithology. Several oil-stained vugs are recognized in this interval in CH-1. The contact with the overlying lithology is recognized as a gradual decrease in nodular chert content and an absence of bedded chert.

The uppermost lithology of Unit A (49 ft thick) is a dark to light gray, medium-grained, laminated calcarenite containing chert nodules. It grades upward to include thick beds of fossiliferous nodular limestone (f). Many calcarenite beds contain wavy siltstone partings, and those that are unlaminated often have a high siltstone content. The contact with overlying Unit B is recognized by the gradual introduction of dark olive gray, massive calcareous siltstone replacing the nodular limestone of upper Unit A.

Unit B

Unit B is 263 ft thick and generally consists of massively bedded, maroon, calcareous, and shaley siltstone with numerous light gray, fine- to medium-grained calcarenite beds (g). The maroon siltstone is typically internally clean but generally contains thin, parallel, light gray limestone laminations. Vertical burrows and general bioturbation are commonly observed. The calcarenite beds are generally clean but may contain thin greenish-tinted wavy siltstone stringers. The uppermost and lowermost portions of Unit B consist of thick beds of massive, dark olive gray, calcareous siltstone with occasional light gray laminations in contrast to the overall maroon siltstone that typifies the unit. The contact with Unit C is recognized by the abrupt occurrence of interbedded light gray calcarenite and dark gray siltstone.

Units C and D are lithologically variable, and it is tempting to distinguish the individual lithologies through a detailed section description. The authors choose not to do so principally because any sense of unit identity would be lost in the resulting lengthy description. The complete units can mainly be distinguished on the basis of chert occurrence: Unit C is dominated by nodular chert, and Unit D is characterized by bedded chert.

Unit C

Unit C (95 ft thick) generally consists of thick interbeds of light gray calcarenite, dark gray calcareous siltstone, fossiliferous nodular limestone, and birdseye micrite lithologies. Small chert nodules are common, and evidence of vertical burrowing is seen occasionally. The majority of Unit C consists of light and dark gray, fine- to medium-grained, stylolitic, mostly unfossiliferous, crystalline calcarenite with occasional dark gray siltstone stringers (h). Several thick beds of dark calcareous siltstone with roughly 2-in.-thick limestone beds or thin, wavy, often coalesced limestone stringers occur throughout the unit. Fine- to medium-grained nodular limestone, ribbon limestone, and poorly defined laminitic limestone occur most commonly near the top of the unit (i). The contact with Unit D is recognized as the lowermost occurrence of light gray, medium-grained, dense, crystalline calcarenite containing bedded chert.

Unit D

Unit D (168 ft thick) is a diverse lithologic unit that consists of thick accumulations of dense, medium-grained, stylolitic calcarenite; birdseye micrite; and nodular limestone lithologies. The frequent occurrence of bedded and nodular chert is distinctive of the unit. The lower 66 ft of Unit D consists of light gray, fine- to medium-grained, mostly unfossiliferous limestone with thin, irregular siltstone stringers and bedded and nodular chert (j). Thick beds of birdseye micrite occur commonly. This lower limestone-dominated lithology is replaced upward by 40 ft of nodular limestone with several chert-rich limestone beds (k). The upper lithology (62 ft thick) generally consists of light gray, stylolitic, chert-rich calcarenite, which often contains thin, planar-to-wavey laminae (l). In the uppermost reaches, dark gray siltstone content increases in the form of thick mottled or amorphous limestone beds. The common occurrence of sharply defined beds containing fossil hash throughout the upper lithology is considered to represent event deposition. The contact with overlying Unit E is recognized by the abrupt disappearance of clean crystalline cherty limestone and the introduction of fossiliferous nodular limestone.

Unit E

Unit E (350 ft thick) is characterized by thick interbeds of fossiliferous nodular limestone; unfossiliferous, amorphous micrite within a dark gray siltstone matrix; clean, dark gray siltstone; and unfossiliferous crystalline calcarenite. It is one of the most diverse units in the Chickamauga. Some departure from Stockdale's (1951) Unit E subdivisions are presented in the following discussion. While Stockdale identified four separate lithologies in Unit E, the authors of the present study choose to specify only three here, although they acknowledge that alternative subdivision schemes can be justified.

The lowermost Unit E lithology (183 ft thick) can be poorly divided into lower and upper portions based on the amount of dark gray shaley siltstone. Overall, the lithology is characterized by nodular, fine- to medium-grained, fossiliferous limestone and amorphous, unfossiliferous micrite within a dark gray shaley siltstone matrix (m). The lower portion (88 ft thick) contains a slightly higher proportion of dark gray shaley siltstone and more numerous coarse calcarenite beds with diverse fossil hash than the upper portion (95 ft thick). The occurrence of nodular and amorphous limestone in the lower portion is interrupted

by 1- to 3-ft-thick zones composed of alternating 1- to 2-in.-thick interbeds of dark gray siltstone and light gray unfossiliferous limestone. The upper portion of the lithology, above the interbeds, also contains nodular limestone but is distinguished by the occurrence of limestone/siltstone interbeds and a gradual increase in siltstone content in the uppermost reaches.

The next prominent Unit E lithology, roughly 56 ft thick, is composed of unfossiliferous, dark gray siltstone containing thin, alternating, often crenelated, light gray limestone laminae (n). Occasionally, 2- to 3-in.-thick fine calcarenite beds occur within the dark gray siltstone. The dominance of siltstone imparts a distinctive overall dark gray appearance in contrast to the surrounding lithologies with higher limestone content.

The uppermost lithology in Unit E, approximately 110 ft thick, is in sharp contact with the underlying lithology. It is characterized by massive, fine- to medium-grained, light gray calcarenite (o). The calcarenite consists of massive and internally featureless beds that contain dark gray siltstone partings that impart a laminitic appearance. The siltstone content of this lithology increases in its upper portion, appearing as 0.25- to 0.75-in.-thick wavy beds. The upper 30 ft of this lithology contains a marked increase in the proportion of dense calcarenite. The calcarenite is generally light gray and clean in the lower portion but is interbedded with thin beds of dark gray siltstone in the upper portion. Calcarenite in the uppermost portion of the lithology contains thin, even siltstone partings that impart a laminated appearance. Thin beds containing fossil debris occur throughout, and occasional small chert nodules are noted. The contact with overlying Unit F is lithologically gradational, but an abrupt color change occurs at the lowest maroon calcareous siltstone.

Unit F

Unit F (21 ft thick) is identified as maroon calcareous and shaley siltstone with laminations and thin beds of light gray to olive gray limestone and argillaceous limestone (p). One 2-ft-thick bed of fine-grained, light gray limestone with olive gray siltstone stringers occurs near the center of the unit. The maroon siltstone is generally laminated with abundant vertical and horizontal burrows, but several beds are internally featureless. Like the lower contact, the upper contact of Unit F is lithologically gradational over several feet of section

but abrupt with respect to color. It is placed at the uppermost occurrence of maroon siltstone.

Unit G

Unit G (319 ft thick) is a variable unit consisting of nodular limestone; dense calcarenite; amorphous, thin-bedded limestone and siltstone; and wavey interbedded limestone lithologies. Although Stockdale (1951) described the variable lithologies in Unit G, he chose not to differentiate them as he did for other units. The present authors consider Unit G lithologies to be sufficiently distinct to justify their differentiation.

The lower 116 ft of Unit G consists of light gray, fine- to medium-grained, fossiliferous nodular limestone, grading upward to ribbon limestone (q). The thickness and abundance of the dark gray to olive siltstone ribbons is variable. Beds of calcarenite with thin siltstone partings occur sporadically within the ribbon limestone. Except for a more variable siltstone content and thinner, less frequent calcarenite beds, this lithology resembles the upper lithology in Unit E. The similarity of these two lithologies suggests that Unit F was a minor interruption in a generally continuous paleodepositional setting.

The next lithology (68 ft thick) consists of light gray, fine-grained, dense calcarenite, which is less fossiliferous than the underlying lithology (r). The calcarenite is massive to laminated or contains thin, wavey, olive gray- to buff-colored siltstone partings. The upper 135 ft of Unit G consists of vaguely laminated to thin interbedded, dark gray siltstone and light gray limestone, which grades upward to light gray, fine- to medium-grained, wavey interbedded, nodular, and ribbon limestone (s). The dark gray siltstone in the lower portion contains few internally distinguishing characteristics except for occasional evidence of burrowing. The presence of these burrows and the overall appearance of the siltstone suggests it may be heavily bioturbated. Limestone content increases gradually such that the lower thin interbedded siltstone/limestone is replaced by wavey interbedded, nodular, and ribbon limestone. Several beds with abundant burrows are distinctive of uppermost Unit G. The contact with overlying Unit H is indistinct and gradational. It is placed at a position in which siltstone content increases slightly and a pale maroon tint is noted.

Unit H

Unit H core recovery was limited to the lowermost 28 ft of section. This portion of Unit H is characterized by olive to light gray and pale maroon calcareous siltstone interbedded with light gray, fine-grained limestone (t). Both lithologies contain thin, wavy, olive to dark gray siltstone laminae with evidence of horizontal burrows.

The identification of major lithologic units in the Chickamauga Group allows a generalized geologic cross-section to be constructed for the X-10 main plant area (Fig. 5). Overall lithologic diversity and geological symbol limitations require a generalized cross-section at a reasonable scale. However, with the descriptions provided in this report and the geophysical logs in Plate 1, detailed cross-sections of limited stratigraphic intervals that more accurately represent Chickamauga lithologies can be constructed.

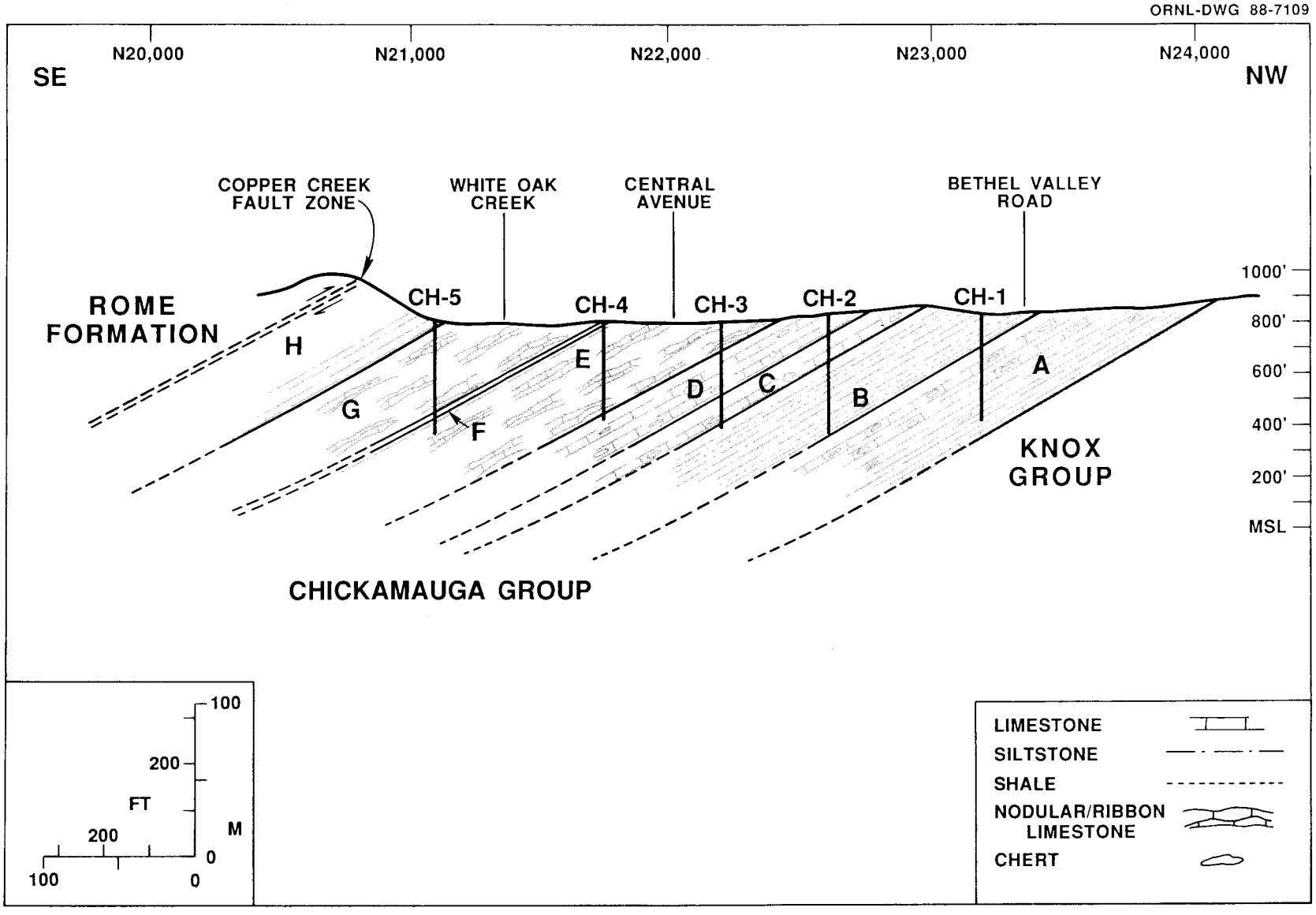

Fig. 5. Geologic cross section of ORNL study area.

7. COMPARISON WITH PREVIOUS STUDIES

Rodgers (1953) generally divides the Chickamauga into lower limestone and upper shale portions. Rodgers and Kent's (1948) description of the Chickamauga at Hawkins County, Tennessee, places the lower limestone and upper shale contact at the lower contact of the Moccasin Formation. Comparison of the Hawkins County description with results from the present study suggests that the lower contact of the Moccasin Formation occurs within Unit E at ORNL. Based on the analysis of the lower 1625 ft of the Chickamauga Group in this study, application of a general lower limestone and upper shale division to the Chickamauga Group at ORNL is not appropriate.

Rodgers (1953) also reports the occurrence of two regionally extensive bentonite beds in the Chickamauga. Following the rock core and geophysical log analysis in this study, some concern developed regarding the absence of these beds at ORNL. The regionally extensive bentonite beds occur 26 and 92 ft below the top of the Moccasin Formation (Rodgers and Kent 1948). This portion of the section is several hundred feet above the top of CH-5 in this study and, in fact, may have been removed by the Copper Creek Fault at ORNL.

As stated earlier, the unit designations used in this study are based on those provided in Stockdale (1951). It is a credit to Stockdale's acumen as a field geologist that with bore hole data principally from the Upper Chickamauga and limited outcrop exposures of the Lower Chickamauga he produced a work that has been the accepted geology of the ORNL main plant area for 37 years.

In general, excellent unit-scale descriptive and thickness comparisons were made between Stockdale's (1951) work and this study, and no compelling reason is found to recommend modifications to Stockdale's geologic map. However, descriptions and thicknesses of specific lithologies within units, which Stockdale must have considered sufficiently distinctive to identify separately, are less consistent with results from this study. Several possible causes for these differences are offered: 1) Stockdale's limited data from the Lower Chickamauga, 2) lateral lithologic variability, and 3) different workers combining and separating observations differently. Table 2 provides a synoptic comparison between results of both studies.

Table 2. Synoptic comparison between this study and previous published work

This study			Stockdale 1951[a]		
Unit	Thickness	Lithologic description	Unit	Thickness	Rock description
A	76'	Limestone--partly dolomitic, dense, dark purplish, fenestral grading upward to laminated light and dark gray limestone.	A	25'	Limestone; mostly covered.
	147'	Siltstone--calcareous and shaley; dark gray, purplish, or maroon with interbedded light gray limestone. Nodular and bedded chert.		90'	Siltstone and chert in alternating beds. Siltstone is calcareous; gray, olive, maroon; weathers to shaley appearance. Abundant granular chert in even beds up to 6 in. thick, breaking into angular blocks upon weathering.
	29'	Siltstone--calcareous, purplish maroon with light gray limestone beds grading upward to dark to olive gray siltstone.		30'	Siltstone--calcareous, olive gray to maroon, weathers to shaley appearance.
	46'	Limestone--medium-grained, dark to light gray, massive. Abundant nodular and bedded chert.		15'	Chert--thin-bedded, with shaley partings.
	49'	Limestone--medium-grained, dark to light gray, laminated grading upward to fossiliferous nodular limestone. Nodular chert.		80'	Limestone of varied types--dark gray to buff, with shale partings. Gray to black chert in nodules and lenses.
B	263'	Siltstone--calcareous; maroon; massive; with numerous light gray, fine- to medium-grained limestone beds. Burrows. Dark olive gray calcareous siltstone in upper and lower portions.	B	215'	Siltstone in even beds up to 2 ft thick; laminated; alternating with calcareous shale; olive gray, buff, maroon. Some nonresistant limestone. More shale at base.

This study			Stockdale 1951[a]		
Unit	Thickness	Lithologic description	Unit	Thickness	Rock description
C	95'	Limestone--light gray. Siltstone--calcareous, dark gray. Nodular and micritic linestone in thick interbeds. Nodular chert. Burrows.	C	105'	Limestone of varied types--gray; fine- to coarse-grained; partly crystalline, partly nodular; mostly massive. Occasional patches of chert, partly fossiliferous. "Quarry beds."
				10'	Shale--calcareous, olive gray to light maroon, fissile, even-laminated.
D	168'	Limestone--dense, medium-grained, stylolitic with nodular and bedded chert. Thick beds of nodular limestone and birdseye micrite.	D	160'	Limestone and chert. Limestone is gray to olive gray; in part nodular, shaley, and thin-bedded; in part massive. Abundant chert in thin, even bands, breaking into angular fragments upon weathering, producing a chain of low hills.
E	183'	Limestone--fine- to medium-grained, nodular and amorphous.	E	55'	Limestone of varied types--gray; mostly argillaceous and nodular; in thin, irregular beds with shale partings; abundant fossils.
	56'	Siltstone--dark gray, with limestone laminae.		45'	Calcareous shale and argillaceous limestone--gray to buff, in alternating thin even beds, yielding small roundish slabs upon weathering, with yellow-buff color.
	110'	Limestone--fine- to medium-grained, light gray.		220'	Limestone--similar to Unit "G," mostly covered in lowlands.
				60'	Limestone--mostly gray to drab, partly pinkish maroon, mottled, brittle, thin-bedded to massive, with shaley partings.

Table 2. (continued)

This study			Stockdale 1951[a]		
Unit	Thickness	Lithologic description	Unit	Thickness	Rock description
F	21'	Siltstone--calcareous and shaley, maroon and olive gray, laminated to thin-bedded. Extensive burrows.	F	25'	Siltstone--calcareous; alternating with shale; olive gray to maroon; even-bedded; laminated; weathers to a red shaley appearance; produces a slight rise in topography; a very distinctive unit.
G	116'	Limestone--fine- to medium-grained, nodular grading up to ribbon limestone. Fossiliferous. Resembles upper Unit E.	G	300'	Limestone of varied types--dark gray to brownish gray; mostly nodular with abundant black irregular clay partings; dense- to medium-grained; mostly thin-bedded, partly massive; with shale partings; weathers to a lighter colored shaley or "nodular" appearance; with some fossiliferous horizons; mostly covered in lowlands.
	68'	Limestone--fine-grained, dense, with olive gray- to buff-colored siltstone partings. Fossiliferous.			
	135'	Siltstone--dark gray, vaguely interbedded with light gray limestone grading upward to nodular and ribbon limestone. Thin beds with abundant burrow.			
H	28'	Siltstone--calcareous, olive to light gray and pale maroon interbedded with fine-grained, light gray limestone. Burrows.	H	35'	Limestone--argillaceous (calcareous siltstone), gray, olive gray, pinkish maroon, even-bedded, with shale partings.
				180'	Limestone of varied types--gray, olive gray, buff, drab; mostly thin-bedded; with argillaceous partings; weathers to shaley appearance; with fossiliferous zones.
				85'	Siltstone--calcareous; gray, olive, maroon; with shaley partings and thin limestone lenses.

[a]Stockdale, P. B. 1951. *Geologic Conditions at the Oak Ridge National Laboratory (X-10) Area Relevant to the Disposal of Radioactive Waste*, ORO-58, Department of Energy, Oak Ridge, Tenn.

The least favorable lithologic thickness and description comparisons in Table 2 occur in Units A and H. Examination of the Unit A comparison suggests Stockdale (1951) did not map all 76 ft of the lowermost limestone and 31 ft ofthe overlying siltstone identified in this study. Since Stockdale was limited to field mapping in that portion of the section, we presume that the lowermost 107 ft of the Chickamauga lacked mappable surface exposures at the time of Stockdale's mapping. Similarly, the poor Unit H comparisons result from core recovery of only the lower portion of Unit H in this study.

8. CONCLUSIONS

This study presents the first documentation of the geology of the ORNL main plant area in 37 years. The rock core and geophysical log data that form the basis of this study are the first acquired from the nearly complete stratigraphic section beneath ORNL. These data are in storage or on file for use in future investigations.

The Chickamauga Group at ORNL is a lithologically diverse rock unit, generally characterized by thick, crudely alternating limestone and calcareous siltstone lithologies. Vertical and lateral lithologic repetition and interfingering are characteristic of nearly all the units making up the Chickamauga. Criteria for Chickamauga Group subdivision are somewhat subjective and depend to a great extent on the objectives of the worker.

In general, results of this study agree closely with previous work on the Chickamauga at the ORNL main plant area. Marked character changes in geophysical log signatures coincide well with the selection of unit-scale contacts from core examination.

Composite geophysical logs provide log coverage for 1625 drilled feet of the lower Chickamauga section. Logs include natural gamma, neutron porosity, and long/short normal resistivity. The composite log will be useful in future borehole correlations if geophysical logs are the only data available for study.

Structural features within the Chickamauga include bedding parallel and high-angle fractures with little to no displacement. Many of the bedding parallel displacements have polished fracture surfaces and slickensides. The dominant occurrence of such features is attributed to the mechanical behavior of the strongly interbedded Chickamauga lithologies during Appalachian Orogeny regional deformation.

REFERENCES

Borowski, W. S. 1982. "Petrology, Depositional Environments, and Stratigraphic Analysis of a Part of the Middle Ordovician Chickamauga Group Limestones near Clinton, Tennessee," M.S. thesis, University of Tennessee, Knoxville.

Brent, W. B. 1982. *Mississippian Stratigraphy of Greendale and Newman Ridge Synclines and Middle Ordovician Nomenclature in Upper East Tennessee*, State of Tennessee, Division of Geology, Report of Investigations No. 41.

Cooper, B. N., and C. E. Prouty. 1943. *Stratigraphy of the Lower Middle Ordovician of Tazewell County, Virginia*, Bulletin of the Geological Society of America, **54**, 819-86.

Milici, R. C., and J. W. Smith. 1969. *Stratigraphy of the Chickamauga Supergroup in its Type Area*, State of Tennessee, Department of Conservation, Division of Geology, Report of Investigations No. 24.

Rodgers, J. 1953. *Geologic Map of East Tennessee with Explanatory Text*, State of Tennessee, Department of Conservation, Division of Geology, Bulletin 58, Part II.

Rodgers, J., and D. F. Kent. 1948. *Stratigraphic Section at Lee Valley, Hawkins County, Tennessee*, State of Tennessee, Department of Conservation, Division of Geology, Bulletin 55.

Ruppel, S. C., and K. R. Walker. 1984. "Petrology and Depositional History of a Middle Ordovician Carbonate Platform: Chickamauga Group, Northeastern Tennessee," *Geological Society of America Bulletin*, **95** (5), 568-83.

Stockdale, P. B. 1951. *Geologic Conditions at the Oak Ridge National Laboratory (X-10) Area Relevant to the Disposal of Radioactive Waste*, ORO-58, Department of Energy, Oak Ridge, Tenn.

Swingle, G. D. 1964. *Geologic Map of the Clinton Quadrangle, Tennessee*, State of Tennessee, Department of Conservation, Division of Geology, GM-137 SW.

Walker, K. R., and L. P. Alberstadt. 1973. "A New Facies Hypothesis Concerning the Middle Ordovician of the Southern Appalachians," *Geological Society of America Abstracts with Programs*, 5, 437-8.

Walker, K. R., G. Shanmugam, and S. C. Ruppel. 1983. "A Model for Carbonate to Terrigenous Clastic Sequences," *Geological Society of America Bulletin*, **94** (6), 700-12.

Weiss, E. A. 1981. "Environmental Sedimentology of the Middle Ordovician and Paleoecology of a Portion of the Witten Formation at Solway, Tennessee," M.S. thesis, University of Tennessee, Knoxville.

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