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Geology of the West Bear Creek Site

R. R. Lee
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Energy Division

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ABSTRACT

A geological study was conducted at the Department of Energy's proposed "tumulus" low-level waste disposal site in west Bear Creek Valley on the Oak Ridge Reservation. The objective of the study was to describe the geologic characteristics of the site and to provide a foundation for concurrent geohydrologic studies.

Methods for study included examination of existing rock core, acquisition of additional core, geophysical logging, study of sparse natural rock exposures, examination of weathered surficial bedrock, and acquisition of bedrock fracture orientation data. For construction of geologic cross sections and a geologic map, key subsurface data were projected to the surface using a typical bedrock attitude. The surface locations of these data were refined by examination of weathered bedrock.

Consistent with the regional geologic setting and previous studies elsewhere in Bear Creek Valley, results of this study indicate that the site is underlain by generally uniform dipping strata of the Cambrian Conasauga Group. Detailed examination of the lithologic features of a portion of the Conasauga at the site indicate that direct application of regional stratigraphic nomenclature requires minor modification. Analysis of intermediate-scale (meter-scale) structural features leads to the development of two conceptual models. The first model relates the character of these features to lithologic homogeneity and bedding thickness. The second model describes two styles of intermediate-scale structural deformation: one that occurs within lithologically correlative intervals and is continuous across the site and another that is stratigraphically localized. Both styles of structural deformation contribute to minor formational thickness variations.

1. INTRODUCTION

The Department of Energy's (DOE's) Low-level Waste Disposal, Development, and Demonstration (LLWDDD) Program on the Oak Ridge Reservation (ORR) is considering sites for the disposal of low-level waste. In support of the LLWDDD Program, site characterization studies are being conducted to determine the suitability of a site in Bear Creek Valley on the ORR for proposed "tumulus" disposal. As part of a comprehensive site characterization effort, a detailed geological site investigation was conducted to understand the nature of the bedrock beneath the site. Results of the geological investigation provide the framework for geohydrologic studies and eventual groundwater flow and contaminant transport modelling to be used in the evaluation of site suitability.

2. PURPOSE

This report presents the results of geologic investigations undertaken in the course of site characterization at the proposed Bear Creek Valley "tumulus" disposal site. The report serves as an analysis of the geology of the site to be used in conjunction with other studies in the determination of site suitability for low-level radioactive waste disposal.

While much of the objective of the geologic study is to develop an understanding of the geohydrologic system, this report does not address the relationship of geology to geohydrology. A discussion of that relationship will be the topic of a subsequent report at the conclusion of site investigations.

The geological analysis presented here benefited from previous work on the ORR by Oak Ridge National Laboratory (ORNL) staff (i.e., Haase, Walls, and Farmer 1985; King and Haase 1987). This previous work served as a basis for the initial phases of study which enabled the authors to proceed to the investigation of detailed geological problems. As such, this report builds upon the previous work and is intended as a refinement of our understanding of the geology of the study area with potential application to future investigations in Bear Creek Valley and the ORR.

3. REGIONAL PHYSIOGRAPHIC AND GEOLOGIC SETTING

Bear Creek Valley is a northeast-to-southwest-oriented topographic low within the Valley and Ridge Physiographic Province (Fig. 1). On the ORR the valley is bounded on the northwest by Pine Ridge and on the southeast by Chestnut Ridge. Ridge crest to valley floor relief ranges from 75 to 94 m (246 to 310 ft), which is within the regional norm. The present Valley and Ridge terrain developed through differential weathering of the underlying rock units.

The Oak Ridge area is underlain by Cambrian and Ordovician age rock units. A generalized stratigraphic column of bedrock formations is presented in Table 1. Structural deformation during the Appalachian Orogeny resulted in the development of northeast-trending imbricate thrust sheets, the differential weathering of which formed the Valley and Ridge. Figure 2 is a generalized geologic map of a portion of the ORR, and Fig. 3 is a generalized cross section, both of which are adapted from McMaster 1962. Regional strike is N 45 to 65 E degrees, and dip is typically 30 degrees southeast, varying from 20 to more than 45 degrees locally. Numerous publications document the geologic setting of the Oak Ridge Reservation (i.e., Haase, Walls, and Farmer 1985; King and Haase 1987). University of Tennessee graduate theses on specific portions of the stratigraphic section add detail.

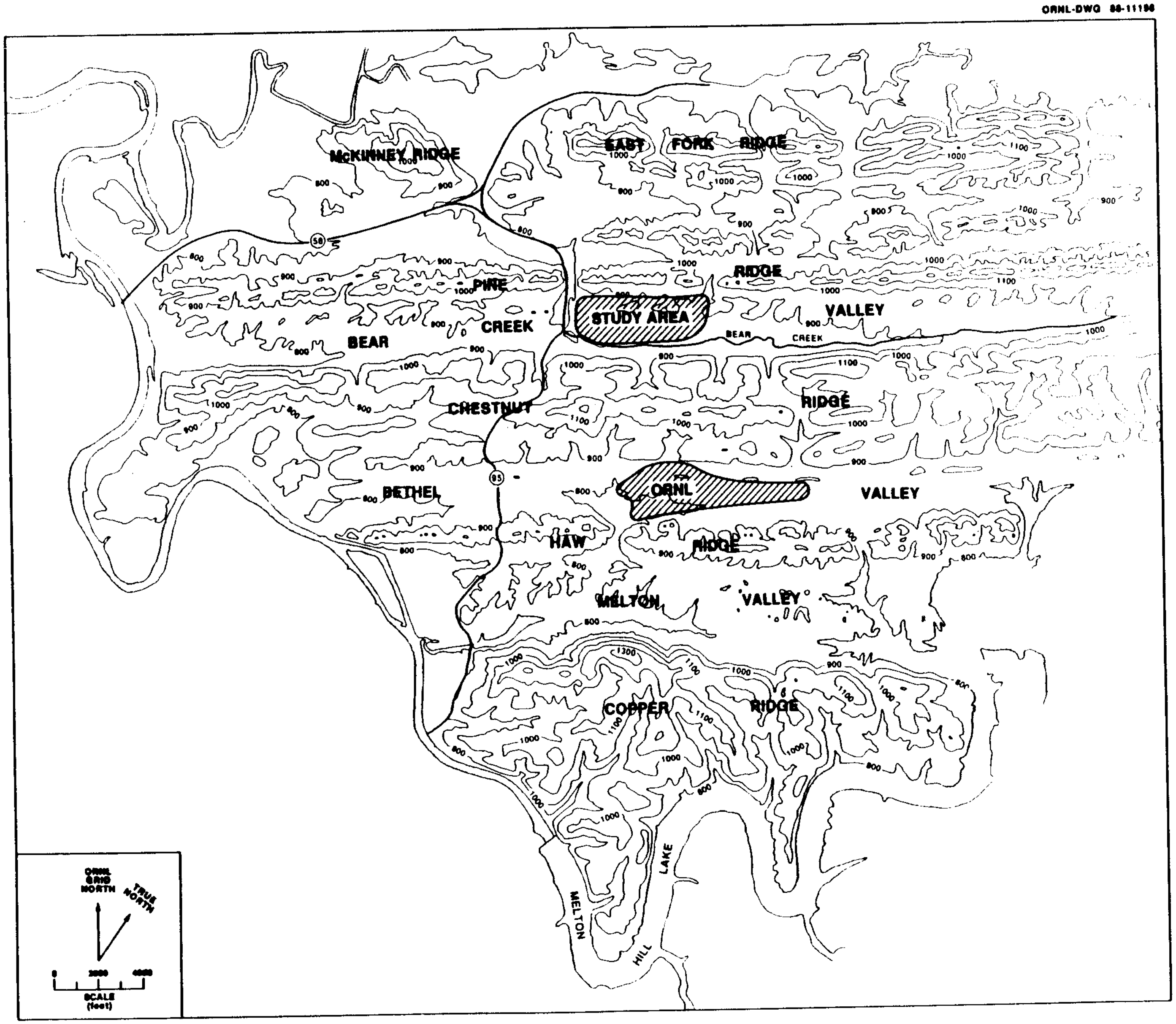

Fig. 1. Location of Bear Creek Valley on the Oak Ridge Reservation.

Table 1. Stratigraphic column of Cambro-Ordovician Rocks, White Oak Maintain Thrust Block, Oak Ridge, Tennessee

Age	Group	Formation/Unit	Description	Thickness (ft)
MIDDLE ORDOVICIAN	CHICKAMAUGA (Och) [b]	Unit H[a]	Thin interbedded limestone and calcareous siltstone. Gray, olive, buff, and maroon.	>270
		Unit G	Limestone and siltstone in thick beds. Limestone fine- to medium-grained, nodular. Siltstone dark gray with vague limestone interbeds.	290
		Unit F	Laminated to thin-bedded calcareous and shaley siltstone. Maroon and olive gray.	20
		Unit E	Limestone and siltstone in thick beds. Limestone fine- to medium-grained, nodular and amorphous. Siltstone dark gray with limestone laminae.	300
		Unit D	Limestone. Medium-grained and stylolitic. Nodular and bedded chert.	140
		Unit C	Limestone and siltstone in thick beds. Limestone nodular and micritic. Siltstone calcareous and dark gray. Nodular chert.	95
		Unit B	Siltstone. Massive maroon and gray with limestone in thin, even beds.	250
		Unit A	Limestone and siltstone in thick beds. Dark to light gray, purplish to maroon. Nodular and bedded chert.	300
LOWER ORDOVICIAN	KNOX (OЄk)	NEWALA Fm.	Medium-bedded dolostones and limestones with variable chert content, scattered chert matrix limestones. Abundant maroon mottling.	900 (est)
		LONGVIEW Fm.	Dense massive chert, bedded chert, and dolomoldic chert observed in residuum.	50–100 (est)
		CHEPULTEPEC Fm.	Dolostone, fine- to medium-grained, light to medium gray, medium to thick bedded, sandy near base.	500–100 (est)
UPPER CAMBRIAN		COPPER RIDGE Fm.	Dolostone, medium to thick bedded, fine to coarse crystalline, medium to dark gray. Chert varieties include massive, cryptopoan, and oolitic.	900–1300 est

Table 1. (continued)

Age	Group	Formation/Unit	Description	Thickness (ft)
MIDDLE CAMBRIAN	CONASAUGA (Ꞓc)	**MAYNARDVILLE Fm.**	Upper (Chances Branch Mbr.) – limestone and dolomitic limestone in thick massive beds.	140
			Lower (Low Hollow Mbr.) – dolomitic limestone in thick massive beds. Light gray to buff.	200
		NOLICHUCKY Fm.	Upper – shale and limestone in thin to thick beds. Shale dark gray or maroon. Limestone light gray, oolitic, wavy-bedded, or massive.	60–140
			Lower – shale and limestone in medium to thick beds. Shale dark gray, olive gray or maroon. Limestone light gray, oolitic, glauconitic, wavy-bedded, and intraclastic.	430–450
		MARYVILLE Fm.	Limestone and shale or siltstone in medium beds. Limestone light gray, intraclastic, or wavy-bedded. Shale or siltstone dark gray.	320–410
		ROGERSVILLE Fm.	Shale and argillaceous limestone. Laminated to thin bedded, maroon, dark gray, and light gray.	80–110
		RUTLEDGE Fm.	Limestone and shale in thin beds. Limestone light to olive gray. Shale gray or maroon.	100–120
		PUMPKIN VALLEY Fm.	Upper – shale and calcareous siltstone. Laminated to very thin-bedded. Shale reddish brown, reddish-gray, or gray. Calcareous siltstone light gray or glauconitic.	130–150
			Lower – shale and siltstone or silty sandstone. Thin-bedded. Shale reddish-brown or gray to greenish gray. Siltstone and silty sandstone light gray.	175
LOWER CAMBRIAN		**ROME Fm. (Ꞓr)**	Sandstone with thin shale interbeds. Sandstone fine-grained, light gray or pale maroon. Shale maroon or olive gray.	Unknown

[a]Chickamauga Group stratigraphic subdivisions reflect those identified at the Oak Ridge National Laboratory site. Other formation names are consistent with regional stratigraphic nomenclature.
[b]Group name abbreviations are those commonly used on geologic maps and cross sections in the region.

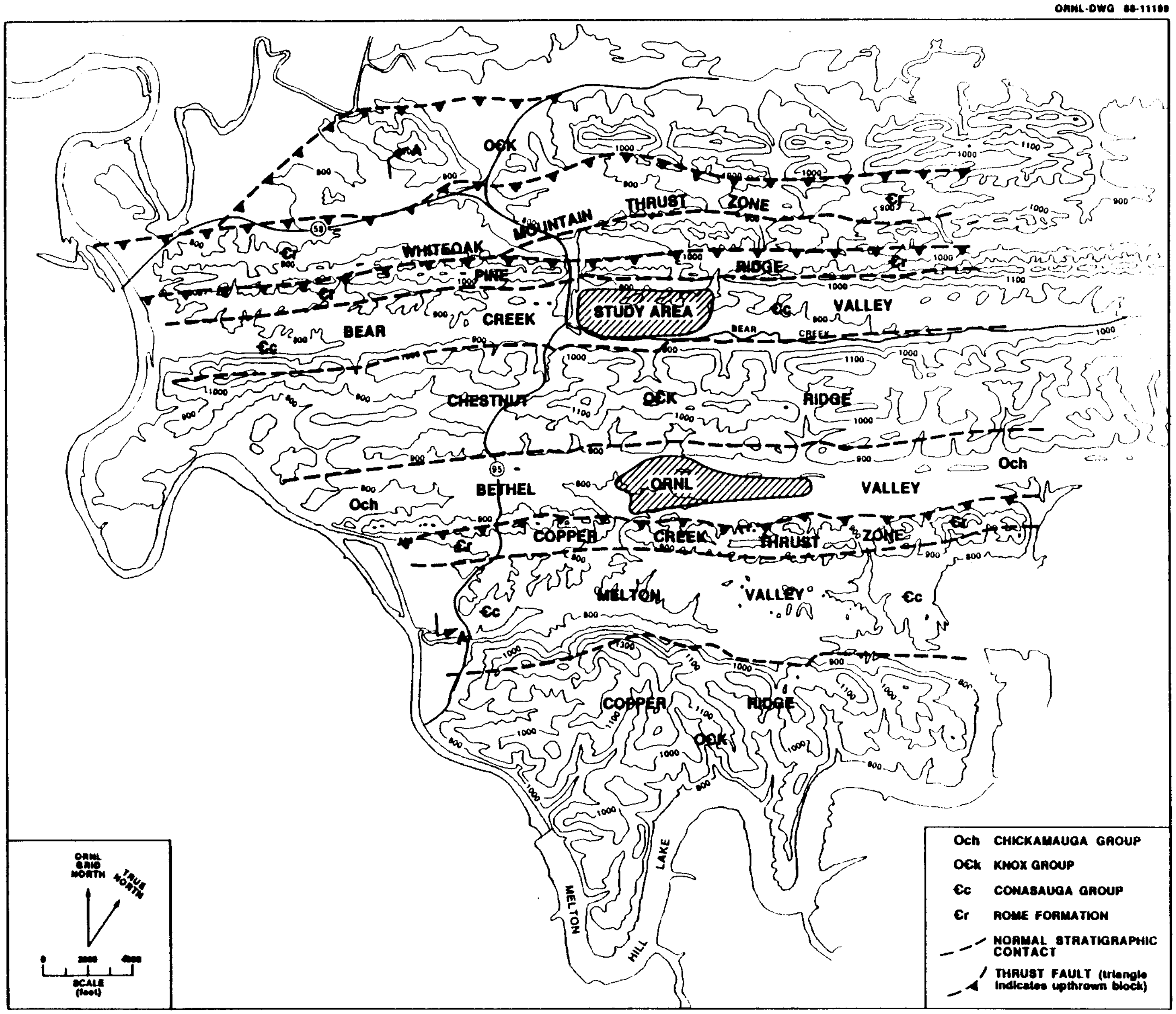

Fig 2. Generalized geologic map of the Oak Ridge Reservation.

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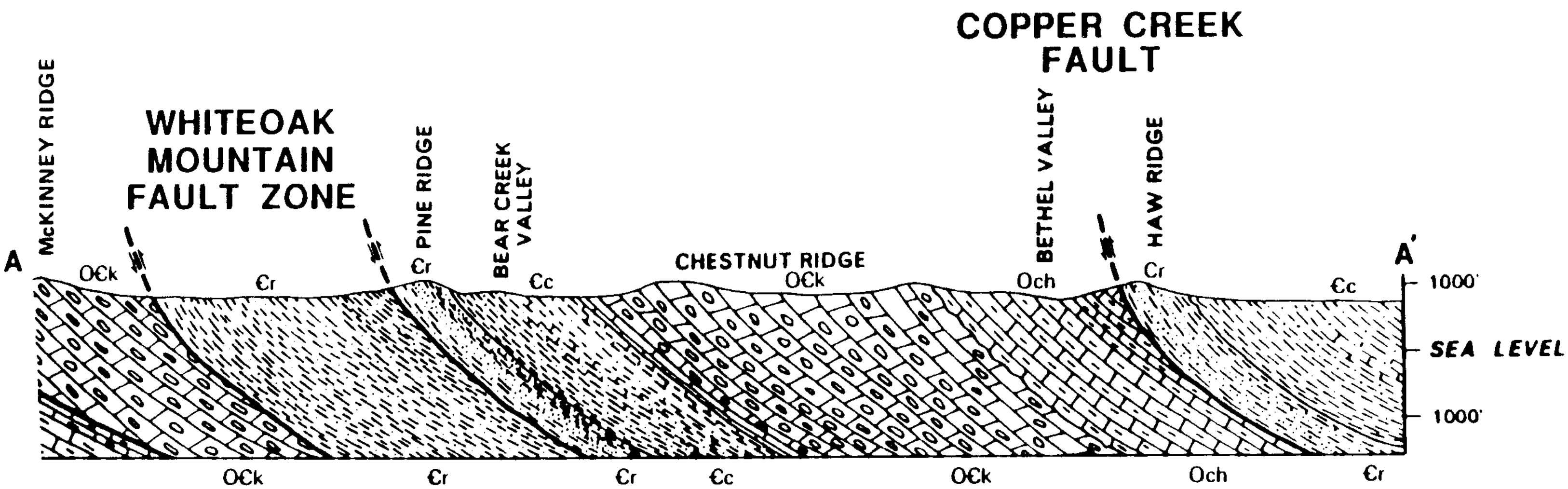

Fig. 3. Generalized geologic cross section of the Oak Ridge Reservation.

4. SITE DESCRIPTION

The Bear Creek Valley site characterization study area encompasses roughly 290 acres and is bordered by Bear Creek on the southeast and southwest, Gum Hollow Branch on the northeast, and the southern flank of Pine Ridge on the northwest [Fig. 4 (inside back cover)]. A line of low knobs occurs in the northwestern portion of the site with vertical relief of from 13 to 38 m (44 to 124 ft). Ephemeral streams in a weakly developed trellis drainage system provide site drainage, and one perennial stream occurs near the center of the site.

Bear Creek Valley is underlain by the six formations which comprise the Middle to Late Cambrian Conasauga Group. The valley is bordered on the northwest by Pine Ridge, which is underlain by the Rome Sandstone, and bordered on the southeast by Chestnut Ridge, which is underlain by the Knox Group Dolomite. The Rome through Knox rock units form a major portion of the White Oak Mountain thrust sheet, so called because of its position upon the Whiteoak Mountain Fault Zone to the northwest.

As elsewhere on the ORR, thin residual, alluvial, and colluvial soils develop above the Conasauga at the Bear Creek Valley site. Figure 5 (inside back cover) is a site soil survey map, and the soil map numerical legend is in Table A-1. Complete descriptions of the west Bear Creek Valley site soils can be found in Lietzke, Lee, and Lambert 1988. The soils are underlain by a comparatively thick saprolite zone which varies from 10 to 20 ft thick. The saprolite is composed of weathered bedrock which has lost its rock cement but retained its bedding features. Its upper portions can be readily penetrated with a hand auger. The saprolite/bedrock contact is gradational due to decreasing weathering with depth but is typically defined as the depth of machine auger refusal.

4.1 TECHNICAL APPROACH AND GEOLOGIC DATA ACQUISITION

Prior to field investigations, a site topographic map was reviewed to identify the location of existing core holes, areas with potential natural rock exposures, and topographic features potentially suggestive of structural deformation. Data from the existing core holes and previous reports were analyzed to develop a preliminary familiarity with the geology. It was determined that since much of the existing geologic data came from the northeastern portion of the site, additional rock core data was required from the southwestern and central portions of the site to resolve stratigraphic and structural uncertainties.

A core drilling program, which involved the drilling of five initial core holes, was begun near the end of April 1987. Figure 4 shows the locations of the site exploratory borings. Three core holes (GW-400, GW-

401, and GW-402) were planned to provide a complete stratigraphic section from near the southwestern site boundary. A fourth core hole (GW-403) near the center of the site was planned to provide stratigraphic overlap between northeastern and southwestern core locations, and the last hole (GW-404), also near the center of the site, was comparatively shallow and part of a separate investigation. Core holes were drilled sequentially beginning with GW-400 to assure stratigraphic overlap between holes.

Following drilling and logging of these initial cores, additional core drilling was begun in October 1987. Core hole GW-453 was drilled in conjunction with geohydrologic investigations and to supplement spotty stratigraphic data from the northeastern portion of the site. GW-454 was planned as a shallow companion hole to GW-404, but loss of the drill bit faceplate in the hole at 58 ft resulted in hole abandonment. The core hole location was moved several feet to the northeast and renamed GW-455. GW-468 was drilled both as a third stratigraphic connection hole and to support geohydrologic studies, and GW-471 was another shallow hole drilled for a separate study. Rock core was examined from preexisting site core holes GW-136 and GW-137; LL/HAZ-13, LL/HAZ-14, and LL/HAZ-15 near the northeastern site boundary; and the lower portion of GW-138 southeast of the site.

A total of 5080.5 ft of rock core was obtained from the site drilling program. This was used with 3617.4 ft of core available for study from previous drilling operations. Core is in storage at ORNL in Building 7042. Selected horizons in core from several off-site locations in Bear Creek Valley were also examined briefly for comparison with on-site lithologic characteristics and structural features. Site core hole survey and drilling data are presented in Table A-2. Core hole stratigraphic data are presented in Table A-3. To maintain consistency with drilling and geophysical logging conventions, the remainder of this report uses the British Unit System when referring to stratigraphic position and rock thickness.

Core was logged to the nearest 1/10 ft and represented graphically at scales of from 1 in. to 5 ft and 1 in. to 10 ft to incorporate suitable lithologic detail on the logs and to evaluate the lateral continuity of certain lithologies. Core from holes GW-400 through GW-404 was logged beginning in May 1987, and core from holes GW-453, GW-455, GW-468, and GW-471 was logged beginning in October 1987. Core from holes GW-136, GW-137, GW-138, LL/HAZ-13, LL/HAZ-14, and LL/HAZ-15 was logged beginning in September 1987. Special emphasis was placed on the identification of horizons which possessed vertical and lateral lithologic changes and small-scale structural features. Long sections (up to 260 ft) of correlative intervals from different core holes were often placed side-by-side to investigate the lateral continuity of key beds and structural features.

A listing of the geophysical logs acquired from each site core hole is provided in Table A-4. Notice in Table A-4 that geophysical logs are available for GW-451, which is a rotary drilled hole, and the absence of geophysical logs for previously drilled core holes LL/HAZ-13, LL/HAZ-14, and LL/HAZ-15. Field difficulties during the geophysical logging of GW-403, scheduling and budgetary constraints, and a finding that geophysical logs were of little assistance in geohydrologic investigations resulted in nonuniform log acquisition from all new core holes. Geophysical logs were often reviewed while core logging was conducted to develop confidence in the geophysical signature of specific lithologies and to reconcile the lithologic and geophysical bases for the selection of formation boundaries. Geophysical and core logs are filed in the authors' offices.

4.2. SITE STRATIGRAPHY

Considerable study of the Conasauga Group on the ORR has been associated with waste disposal activities in Melton Valley on the Copper Creek thrust sheet southeast of Bear Creek Valley. These studies benefited from earlier work in the Valley and Ridge of northeastern Tennessee and southeastern Virginia. Descriptions and measured sections of now-classic exposures of the Conasauga can be found in Hall and Amick 1934; Rodgers and Kent 1948; Bridge 1956; Rodgers 1953; and Harris 1964. Lithologies vary significantly, both along geologic strike and across adjacent thrust belts, such that descriptions from other locations in East Tennessee are not always directly applicable to the ORR. Conasauga Group lithologies are also found to vary within its occurrences on the ORR.

Conasauga Group formational thicknesses vary considerably at the study area and elsewhere in Bear Creek Valley. Thickness variations are considered to result from a combination of depositional and structural processes. More detailed discussion of the effect of those processes on stratigraphic thickness appears in subsequent sections of this report.

Rock core of the complete stratigraphic section from the Upper Rome through Lower Maynardville Formations was examined from the Bear Creek Valley site.
Following is a lithologic description of the rock units recovered in core. Formational thicknesses are presented in downhole feet below ground surface.

4.2.1 Rome Sandstone

In this study, 195 ft of the Upper Rome Formation was recovered in core from GW-400 in the southwestern part of the site, and 66 ft was recovered from GW-453 in a central site location. Geophysical logs from the upper 48 ft are available from GW-451 in the northeastern part of the site. The Upper Rome consists of thick beds of gray or pale maroon, fine-grained, arkosic-to-subarkosic sandstone with occasional interbeds of maroon shale that often contain thin siltstone bands. Sandstones are typically planar to wavy-laminated or current-rippled. Vertical burrows are in great abundance in the interbedded lithology but are also recognized in the sandstone-dominated lithology. Burrows diminish in abundance down section. Upper Rome sandstone/shale interbeds occur nonuniformly at the two site locations from which core was acquired. The common occurrence of such interbeds on the western portion of the site is almost entirely replaced in the center of the site by gray or pale maroon sandstone couplets with a total absence of shale. Such lateral facies changes within roughly 1000 ft suggest the Upper Rome was subject to locally variable clastic influx in a low-relief paleodepositional setting. The contact with the overlying Pumpkin Valley Shale is gradational and placed at the top of the uppermost thick, clean, planar-laminated, 8- to 12-in.-thick, sandstone bed of the Rome.

4.2.2 Pumpkin Valley Shale

At the two site locations from which the complete section of Pumpkin Valley Shale was recovered in core, the formation is 376 and 398 ft thick, respectively, and is readily divisible into upper and lower units of nearly equal thickness. The lower Pumpkin Valley consists of reddish-brown and gray-to-greenish-gray shale with thin interbeds of siltstone and silty, fine-grained sandstone. Shales typically contain thin, wavy-laminated siltstone drapes and discrete laminae of fine-grained glauconite. Silty sandstone interbeds are typically wavy laminated to thin bedded but are often heavily bioturbated. High concentrations of large glauconitic pellets occur in the bioturbated lithology. Decreasing silty sandstone content upward within the lower Pumpkin Valley attests to its transitional nature above the Rome.

The upper Pumpkin Valley is laminated to thin-bedded, dominantly reddish-brown, reddish-gray, and gray shale with thin, wavy, and planar-laminated siltstone lenses. Shales are generally fissile and may be massive or thin laminated. Thin partings of fine-grained glauconite pellets are ubiquitously interlaminated within the siltstone lenses. The contact with the overlying Rutledge is abrupt and placed at the top of generally uninterrupted, thin-bedded, reddish-brown shale and below the interbedded limestone and dark maroon shale of the Rutledge.

4.2.3 Rutledge Limestone

The Rutledge Limestone is 126 and 124 ft thick in the two locations from which the complete section was recovered in core. The Rutledge consists of light gray, bedded limestone, often containing shaley partings interbedded with dark gray or maroon thin-bedded or internally clean shale in beds from 2 to 5 ft thick. Limestones are generally evenly divided between wavy laminated and bioturbated. Horizontal burrows are frequently observed. Maroon shale is more common in the lower Rutledge, and two distinctive beds on the order of 3 ft thick occur at the bottom of the formation, separated by three limestone beds of similar thickness. These limestones are referred to as the "three limestones" of the lower Rutledge, but their lithologic similarity with limestones in the bulk of the Rutledge makes them less distinctive than the two maroon shales. The relatively clean, dark maroon shales in the lower Rutledge give way to dark gray shale with thin calcareous siltstone interbeds. Upper Rutledge interbeds are generally thinner than those below, and more coalescing of lithologies is recognized. Limestone beds are often ribbon or wavy bedded, and some are heavily bioturbated with abundant glauconite pellets. Glauconite stringers also occur commonly within the calcareous siltstone interbeds. The contact with the Rogersville is abrupt and recognized by the absence of 1-ft-thick limestone beds and the introduction of maroon shale. The contact is placed at the top of the uppermost such limestone bed.

4.2.4 Rogersville Shale

The Rogersville Shale varies in thickness from approximately 90 to 150 downhole ft thick at the two locations of complete formation core recovery. Elsewhere in East Tennessee, the Rogersville is divisible into upper and lower portions separated by several beds of laminated to thin-bedded limestone, the reported Craig Member. The lower Rogersville consists dominantly of dark gray shale containing thin-laminated and bioturbated argillaceous limestone lenses less than 1 in thick. When maroon shales occur in the lower portion, they are thinner and more chocolate brown than the maroon shales in the upper portion. Glauconite partings are commonly interlaminated with the limestones but also occur as bioturbated beds several inches thick.

Lithologies ascribed to the Craig Member elsewhere in East Tennessee (Rogers and Kent 1948; Bridge 1956) and the ORR (Haase, Walls, and Farmer 1985) are not present in the study area. In the approximate position of the member are a few thin limestone beds which may represent the Craig Member at the site. The beds are 4 to 6 in. thick and composed of interlaminated, light gray, silty limestone and dark gray shale. These beds differ from those in the lower Rogersville principally in thickness and may be more appropriately considered the uppermost portion of the lower Rogersville at the site.

The upper Rogersville consists dominantly of maroon shale containing thin (less than 1 in. thick), wavy, light gray, calcareous siltstone or argillaceous limestone lenses in varying amounts. Thin glauconitic partings are liberally incorporated within the siltstone and limestone lenses. The interlamination of these variably colored lithologies gives the upper Rogersville an overall thinly laminated appearance. Thicker beds (more than 1 ft thick) of clean, maroon-to-brownish-maroon shale are occasionally interspersed within the thin-laminated lithology. The Rogersville is terminated abruptly by the occurrence of the comparatively thick limestone beds of the overlying Maryville, with the contact placed at the bottom of the first such limestone.

4.2.5 Maryville Limestone

The Maryville Limestone is approximately 430 downhole ft thick at the site. It consists of oolitic, intraclastic, and thin-bedded limestone interbedded with dark gray shale that typically contains thin, planar and wavy-laminated, coalesced lenses of light gray limestone and calcareous siltstone. Fine-grained glauconite often occurs at the tops of the thin-laminated limestone lithology. Several isolated dark maroon shale beds, similar to those of the lower Nolichucky, typically occur in both the upper and lower Maryville. Although considerable mixing of limestone lithologies is noted, the upper Maryville generally contains greater amounts of intraclastic limestone, while thin-laminated and oolitic limestone is more prevalent in the lower portion. The contact separating these two upper and lower portions is gradational over tens of feet of section. Limestone intraclasts are randomly oriented and roughly 2 to 10 cm in length. Intraclast size and orientation suggests the intraclastic limestones represent event-driven deposits such as debris flows; however, their laterally discontinuous character suggests event deposition was of an extremely localized nature. Oolites are smaller than those in the Nolichucky and are often found in conjunction with glauconite. In roughly the lower 40 ft of the Maryville, a variable number of prominent, coarse-grained, pinkish limestone beds occur which contain coarser and more abundant glauconite pellets than those higher in the section.

The Maryville/Nolichucky contact is gradational and recognized by the appearance of thick, clean, dark gray and brownish-maroon shales typical of the Nolichucky and a decrease in limestone content. Intraclastic and flat-pebble conglomerate limestone beds, common in the Maryville, are less abundant in the lower Nolichucky, and coarse, glauconitic, calcarenite beds, absent in the Maryville, occur commonly in the lower Nolichucky. The contact is placed above a 6-in-to-2-ft-thick intraclastic limestone bed and at the base of the first clean dark gray or maroon shale bed greater than 2 ft thick. Shales below this position in the upper Maryville generally contain wispy limestone partings or lenses, and those in the lower Nolichucky are clean and more maroon. Although a generally interbedded limestone and shale formation, Maryville interbeds are somewhat thinner and more amalgamated than the comparatively thick and lithologically clean interbeds of the Nolichucky.

4.2.6 Nolichucky Shale

Elsewhere in East Tennessee and on the ORR, the Nolichucky Shale is divided into unnamed lower and upper shale members separated by the limestone of the Bradley Creek Member. Some modification to that nomenclatural scheme is applied to the Nolichucky in this study. The lower Nolichucky generally consists of medium-to-thick-bedded, gray, olive gray, maroon, or brownish-maroon shales and light gray, oolitic, flaser-bedded, or intraclastic limestone and calcareous siltstone. The lower Nolichucky comprises more than 80% of the overall formation thickness and contains two similar but distinct lithologies of nearly equal thickness.

The lower portion of the lower Nolichucky is generally medium-bedded shale and limestone or calcareous siltstone which resembles the underlying Maryville. Shales are brownish-maroon or dark gray and either internally clean or commonly contain thin flaser beds of light gray limestone and calcareous siltstone. Limestone beds are intraclastic, oolitic, and flaser bedded and occasionally contain large quantities of glauconite pellets. Several pale pink, glauconite-rich calcarenite beds occur near the top of the lower portion in positions which appear to replace oolitic limestones. The contact with the upper lithology of the lower Nolichucky is gradational and placed at the point at which interbeds become thicker and more lithologically homogeneous.

The upper portion of the lower Nolichucky is thick-to-very-thick-bedded, maroon or olive gray shale and oolitic, coarse-grained, or intraclastic limestone. The uniform repetition of the shale/limestone interbeds, on the order of 4 to 6 ft thick, gives the upper lithology in the lower Nolichucky a clearly defined, thick-bedded overall appearance. Shales are more maroon, and dark gray shales are less common than those in the lower portion. Limestone beds are thicker, oolites are larger, and intraclastic limestones are less common than in the lower portion. Several limestone beds consist of bioturbated, slightly dolomitic micrite. Haase, Walls, and Farmer (1985) report an upward-coarsening cyclicity for the thick interbeds consisting of internally gradational facies. From bottom to top the cycles are composed of generally clean, massive maroon shale, followed by olive gray calcareous siltstone often containing wispy limestone lenses or lobate intraclasts, and capped by 4-to-6-in-thick oolitic and/or intraclastic limestone. Thin glauconitic partings occur commonly near the top of the limestone beds. Maroon shale typically accounts for roughly 75% of the cycle thickness. Unlike the internally gradational vertical facies changes, the contacts surrounding each cycle are abrupt. The relative ease with which lithologic correlation of individual beds can be conducted suggests the upper portion of the lower Nolichucky was deposited in a relatively stable shallow platform subject to wide-spread erosional/depositional events but generally unaffected by more localized paleodepositional influences.

Lithologies reported elsewhere in the Valley and Ridge (Helton 1967) and on the ORR (Haase, Walls, and Farmer 1985) as the Bradley Creek Member are not identified at the study area. In place of the 30-ft-thick, stratified, fine-grained, micritic, and oolitic limestone Bradley Creek lithology are the thick-to-very-thick interbedded shales and limestones described above and assigned to the upper lithology in the lower Nolichucky. The limestone beds in that lithology, which consist of bioturbated, slightly dolomitic micrite, may be the remnant of the Bradley Creek in the study area. Rock core and geophysical log examination from other core hole locations in Bear Creek Valley corroborate the diminished lithologic expression of the Bradley Creek Member throughout the valley. Difficulties in resolving significant apparent thickness differences and in determining the geophysical character of the Bradley Creek in Melton Valley on the adjacent Copper Creek thrust sheet to the southeast (Dreier and Beaudoin 1987) may also be due to its diminished lithologic expression.

The upper Nolichucky is lithologically diverse, consisting dominantly of dark gray shale with planar and wavy-laminated or ribbon-bedded micrite in thin beds (from less than 1 to more than 2 in thick). The laminated limestones are generally more common in the upper part of the member, and ribbon-bedded limestones are generally more common in the lower part. Thick, coarsely oolitic limestone beds and thick, clean maroon or dark gray shale beds occur sporadically near the top of the upper Nolichucky. The authors' inability to conduct bed-to-bed correlations for much of this portion of the section is attributed to the presence or absence of these beds and suggests the uppermost Nolichucky represents very localized erosion and deposition. These paleoenvironmental influences account for unusual upper Nolichucky thickness differences at the site.

The Nolichucky/Maynardville contact has generally been described in the Valley and Ridge as gradational (i.e., Bridge 1965; Helton 1967) and drawn at the position above which limestone content is more prevalent than shale. At the study area the contact is abrupt and drawn above the uppermost occurrence of thick (greater than 2 ft) olive or dark gray shale containing ribbon-bedded micrite or clean maroon shale and at the base of massive ribbon-bedded or mottled limestone. These criteria are consistent with those used by Tarkoy (1967) for the Hunter Valley Fault Belt, Union Valley, Anderson County, and are practical from the standpoint of consistency in contact identification both with core and geophysical logs.

4.2.7 **Maynardville Limestone**

In the Valley and Ridge of northeastern Tennessee and southwestern Virginia, the Maynardville Limestone is divisible into upper Chances Branch limestone and lower Low Hollow dolomite members (Miller and Fuller 1954). To the southwest, on the ORR, the Maynardville is more uniformly dolomitic and exhibits more subtle vertical lithologic differentiation than that described at the type section.

The Low Hollow Member is generally a ribbon-bedded or mottled, fine-to-medium-grained, dolomitic calcarenite with incipient stylolites and irregularly spaced beds of oolitic calcarenite. Thin lenticular beds and thin, wavy, pale green to olive shaley partings occur commonly within the ribbon-bedded lithology, which imparts an overall clotted appearance to the member suggestive of an algal buildup origin. Several laterally continuous, dark gray shale beds from roughly 6 in to nearly 2 ft thick impart a vague medium-bedded character to the basal portions. Many of these shale beds contain thin, ribbon-bedded micrite resembling the upper Nolichucky. The contact with the Chances Branch Member is gradational and determined based on decreasing proportions of limestone, oolites, and pelletal calcarenite and on an overall darker gray appearance of the Chances Branch. The contact is recognized on geophysical logs by a decreasing character of the gamma trace. Because of its outcropping position outside the Bear Creek Valley site, the Chances Branch Member was generally excluded from this study, but the lower portion was examined briefly in core from GW-138, which is located southeast of the site. The Chances Branch consists of bioturbated and thin-laminated, fine-to-medium-grained, dolomicrite and dolomitic calcarenite in massive beds. In general, thin-laminated lithologies in the upper portion of the member are replaced by bioturbated and ribbon-bedded lithologies near the bottom which often contain oolitic dolomicrite and dolomitic calcarenite.

4.3 GEOLOGIC MAP AND CROSS SECTIONS

The preceding stratigraphic analysis and the locations and depths of site core holes allow three northwest-to-southeast cross sections to be constructed for the site (Figs. 6, 7, and 8). Rock coring and geophysical logging provide complete stratigraphic overlap for the southwestern cross section, nearly complete stratigraphic overlap for the central site cross section, and spotty overlap for the northeastern cross section. Cross sections were constructed using both rock core and geophysical logs with the exceptions of GW-451, which was not core drilled, and LL/HAZ-13 through LL/HAZ-15, for which geophysical logs are not available.

Notice in the cross sections that only some bore holes exhibit vertical deviation. Vertical deviation is included in the figures only when vertical deviation data is available; otherwise, bore holes are assumed to be vertical. Excellent agreement between the depth-to-formation contacts identified in core and the consistent dip angle between formation contacts from adjacent core holes in the cross sections suggests the assumption is valid.

Examples of commonly occurring stratigraphic thickness variations are illustrated in the cross sections. One example is represented by an anomalous dip angle of the Nolichucky-Maynardville contact in Fig. 7. This variation from normal dip angle is due to unusual thickness variations in the upper Nolichucky, as described above in Sect. 4.2.6. Reference to formational thicknesses, Table A-3, shows the upper Nolichucky exhibits nearly 50% thickness variation across the site. Lithologic diversity and the absence of structural features indicates the thickness variations are paleodepositional and/or erosional in nature.

Another example of stratigraphic thickness variation is represented by slight bowing of the formational contacts in Fig. 8. Rock core and geophysical log depth comparison between key beds in GW-136 and GW-137 indicates an overall 30-ft-thicker section in GW-136. Detailed correlation of these key beds indicates the 30 ft of thicker section is made up of numerous small thickness differences throughout the section which are structural in nature.

The thickening does not occur in one thin stratigraphic interval, and for this reason a slight flattening of dip with depth in the lower Nolichucky is invoked for Fig. 8 and represented by formational contact bowing. Thickening of the lower Nolichucky may occur throughout the site, but available data at the other site core locations is insufficient to make such a determination.

Data from the geologic cross sections, spotty natural rock exposures, numerous hand-excavated auger holes and pits into saprolite, and site

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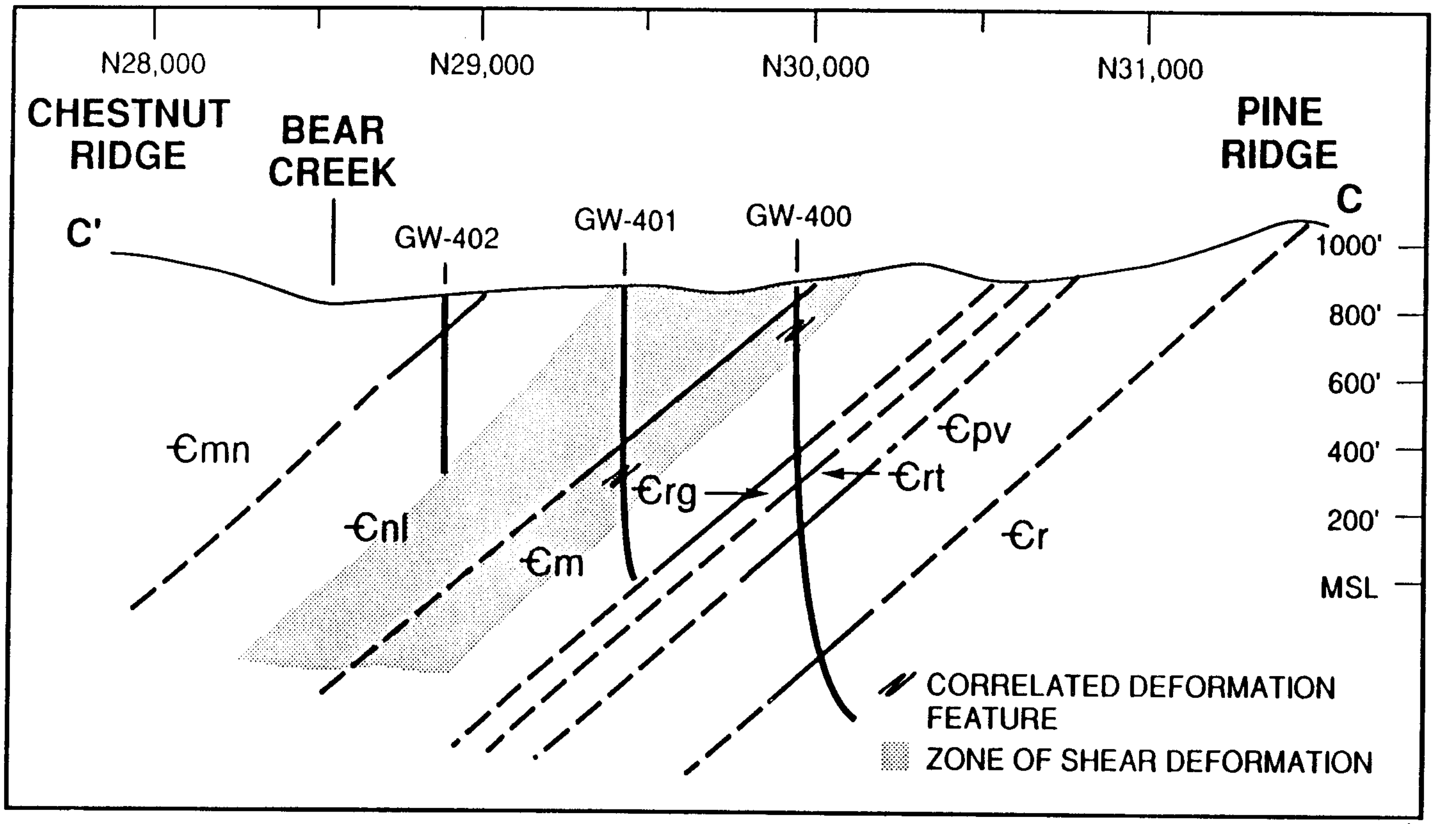

Fig. 6. Western Bear Creek Valley site geologic cross section.

ORNL-DWG 88M-10110R

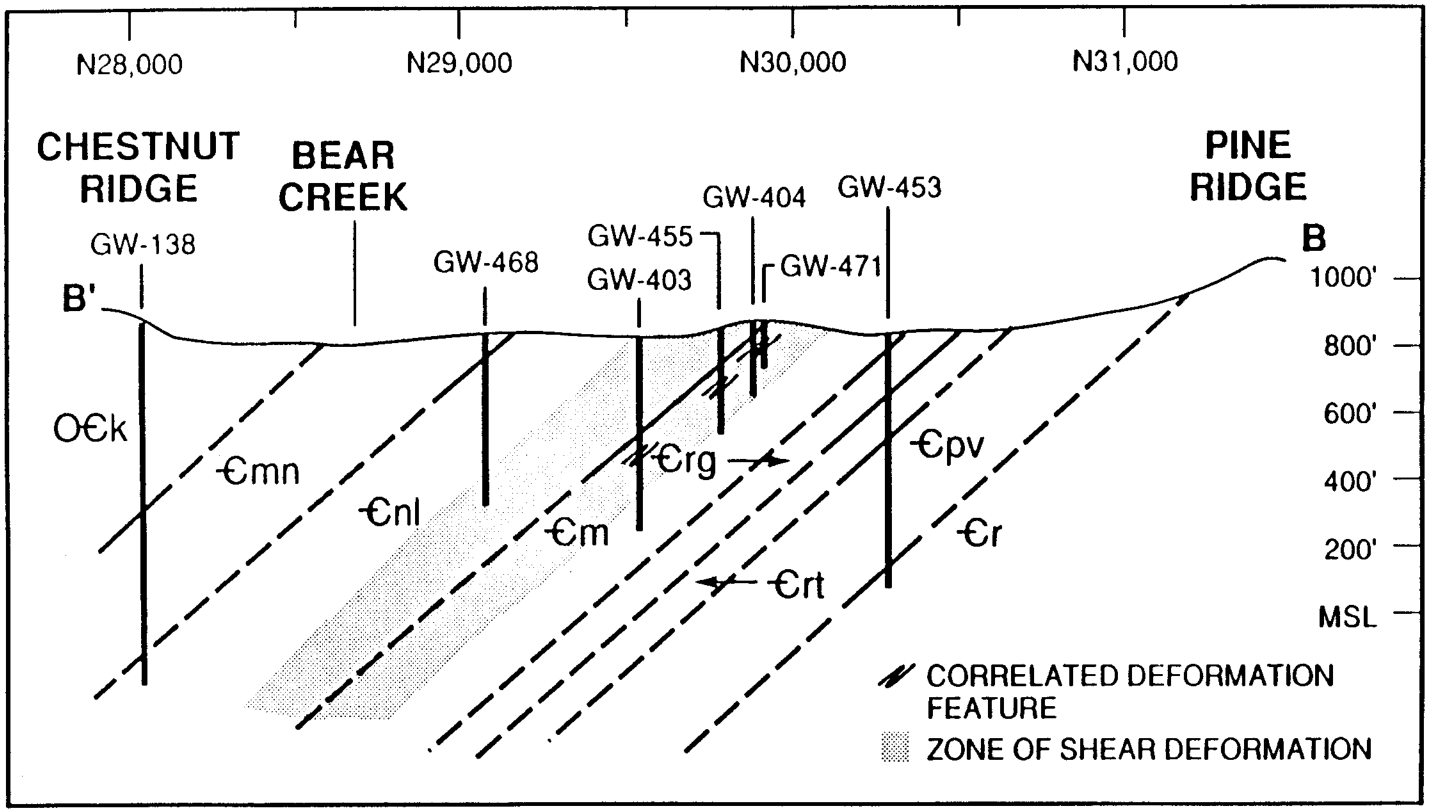

Fig. 7. Central Bear Creek Valley site geologic cross section.

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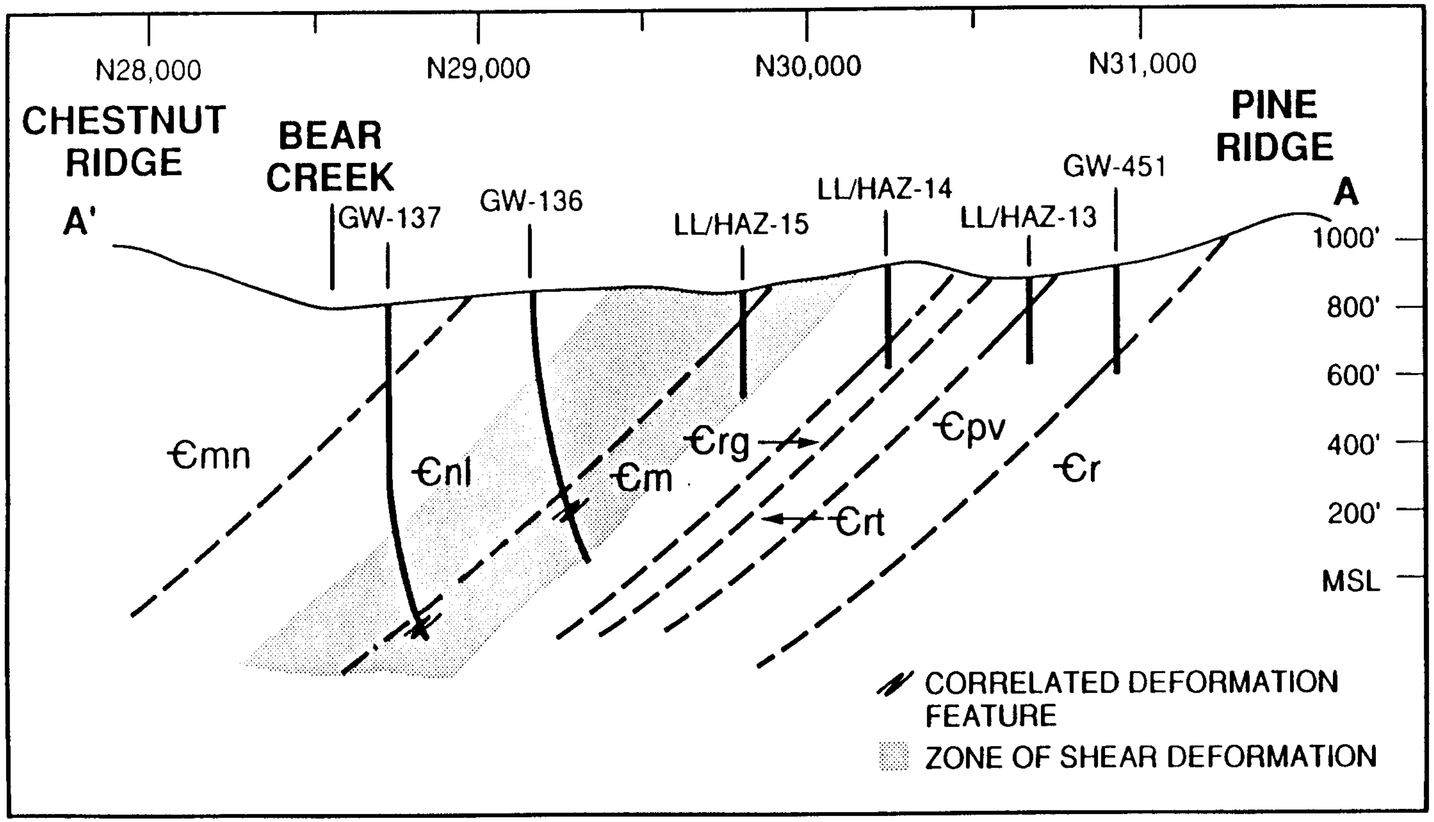

Fig. 8. Eastern Bear Creek Valley site geologic cross section.

topography provide the bases for the preparation of a subsurface-controlled geologic map of the site [Fig. 9 (inside back cover)]. The uncertainties in the precise surface locations of formation contacts from subsurface data dictate use of dashed lines on the geologic map. In only one location is the precise position a formational contact identified with certainty at the ground surface.

Apparent formational thickness anomalies and poor comparisons between topography and expected contact geometry are evident in Fig. 9. Investigation of these apparent anomalies through residual soil field mapping has determined that they are an artifact of small-scale structural features and erosional processes.

4.4 SITE GEOLOGIC STRUCTURE

Geologic structural deformation related to this study ranges from the kilometer scale (i.e., Whiteoak Mountain Thrust Zone) to the centimeter scale (i.e., fractures). Deformation associated with kilometer-scale structural features has been estimated by the construction of a palinspastic map (Roeder and Witherspoon 1978). Centimeter-scale deformation can also be measured in excavated pits into saprolite and in rock core. Commonly occurring intermediate-scale structural features with meter-scale expression (i.e., tightly folded and sheared beds), however, are difficult to quantify and conceptualize with rock core and limited outcrop data sources. These features affect formational thickness irregularities at the site, and their description and analysis constitutes the majority of this section.

Overall bedrock orientation in the Bear Creek Valley site is consistent with regional geologic structure. Measurements of bedrock attitude at limited natural and man-made exposures on the site, however, provide a wide range of values, particularly for dip. Such variability has been reported at other locations in Bear Creek Valley and attributed to surface soil creep (Bechtel, Inc., 1984). Field exposures and core analysis indicate bedrock orientation variability also results from intermediate-scale structural features. With the exception of these geomorphic and structural irregularities, the data indicate geologic strike typically varies between N 56 E and N 67 E degrees, and dip is generally 41 to 45 degrees southeast with values of from 37 to more than 50 degrees occurring locally.

Following are the types of small- and intermediate-scale structural features identified or suspected to occur on the site, categorized by deformational style and size.

4.4.1 Tear Faults

Tear fault occurrence in Bear Creek Valley has been inferred from abrupt offsets or changes in the strike of Pine Ridge accompanied by anomalous subsurface stratigraphic thickness or occurrence (King and Haase 1987).

The potential presence of tear faults at the site was investigated through a combination of indirect and direct means. It was postulated that the topographic expression of the perennial stream near the center of the site was most strongly suggestive of a potential tear fault and would be the focus of study.

Several methods were employed in the early stages of tear fault investigation to evaluate existing and readily obtainable data and to determine the requirements of further study. Geophysical and rock core data from all available core holes were compared to identify bedding offset or thickness differences which could not be readily accounted for by intermediate-scale structural features identified in core. Formational thicknesses were within those reported elsewhere on the ORR, and the occurrence of formational contacts was within several downhole feet of their anticipated position. Rock core was carefully examined for features suggestive of a tear fault; however, it was uncertain how a tear fault would be expressed differently from the other numerous intermediate-scale structural features observed in core. Bedding orientation data from the north-south and northwest-southeast streambeds on opposite sides of the presumed fault were carefully collected and compared. None of these data were anomalous with respect to other similarly obtained data on the site.

It was determined that additional indirect evidence would not unequivocally resolve the presence of the postulated tear fault and that direct data were required. Based on data from nearby core hole GW-453, trenches were excavated into saprolite to identify the Rogersville/Maryville contact northeast and southwest of the perennial stream. Once identified, the azimuth of the contact could be compared with measurements of geologic strike on the site to identify bedding offset associated with the presumed fault. The Rogersville/Maryville contact was selected because it could be identified in saprolite with greatest confidence. On December 10, 1987, soil scientist Dr. David Lietzke joined the authors in the trenching operation to confirm contact identification.

From preliminary hand-augering activities at the site and with knowledge of the depth to the Rogersville/Maryville contact from GW-453 core, the first trench location was marked on the northeastern side of the stream above the floodplain. The contact was readily identified at the anticipated location. With the use of a Brunton compass, an azimuth of N 60 E was projected to the southwestern side of the creek into the toe of the hill slope. Unlike the first trench, several areas of deformed and overturned beds were identified in the lower Maryville of the second trench; however, the contact was again confidently identified.

The ground surface at each trench was flagged at the Rogersville/Maryville contact, and an engineering survey was performed for the flagged points. Survey data are as follows:

Trench	N	E	Elevation (ft)
Northeastern:	30,359.735	30,875.036	870.37
Southwestern:	30,386.737	30,737.754	866.28

Mathematical solution of these data, with no correction for elevation effects, produces a N 67.2 E azimuth for geologic strike.

The Rogersville/Maryville saprolite contact azimuth is within the range of geologic strike data acquired from the overall site and from the measurements acquired in the investigation site vicinity. Deviation from presumed geologic strike of N 60 E is most readily attributed to the deformed and overturned bedding in the lower Maryville in the southwestern trench and site-wide variations in geologic strike. No evidence is found to support an interpretation of translational motion associated with a tear fault at the stream. While potential vertical displacement cannot be fully discounted, it is difficult to conceive such movement in dipping strata without some evidence of a translational component.

It is concluded that a tear fault does not exist near the perennial stream near the center of the site, and it is considered unlikely, based on topography and rock core data, that such a fault exists elsewhere on the site. Alternative geologic explanations for the presence of roughly strike- normal drainages have been considered, and we can only speculate that the drainages develop along preexisting fractures or joints in combination with erosional processes.

4.4.2 Fracturing

Rock discontinuity data were obtained from all rock core acquired for this study and from much of the previously acquired site core. Fracturing is ubiquitous throughout the Conasauga, but fracture frequency is somewhat higher in the Maryville and Nolichucky Formations than elsewhere in the section. Discontinuities are generally planar and occur most commonly as bedding-plane fractures or as joints with little or no displacement oriented roughly normal to bedding. Fracture surfaces are typically clean, smooth, polished, pitted, or contain slickensides. Calcite infillings are common, and pyrite and chlorite infillings are found infrequently.

Fracture orientation data were obtained from five pits excavated into saprolite as part of site characterization soil studies. Approximate pit locations are shown on the site topographic map (Fig. 4). The most commonly identified fractures occur along bedding planes separating lithologies or are oriented roughly normal to bedding. Bedding-normal fractures are confined to the more competent units (i.e., limestone) and do not cross lithologic boundaries. As such, they are typically only several inches long normal to bedding and extend for undetermined lengthsalong bedding. Due to their location in the saprolite, the vast majority of fractures measured contained mineral stains.

Figure 10 is an equal-area projection of the bedding and fracture orientation data acquired from the five soil pits. Although the data are limited, two orthogonal fracture sets are apparent, oriented roughly parallel and normal to geologic strike. These results are consistent with previous reports of extension fracture orientation in Melton Valley on the ORR (Rothschild et al. 1984; Dreier and Beaudoin 1986).

4.4.3 Deformation

With the exception of most of the Maynardville Formation, numerous intermediate-scale structural features occur in the Conasauga. The features are recognized as (1) folded bedding considered to be drag folds, (2) heavily fractured beds resembling fault gouge, and (3) discreet shear fractures with high- and low-angle orientation with respect to the core axis. Drag folds and fault gouge both extend from several inches to several feet vertically, while shear fractures exhibit small to undetermined bedding offset. Further analysis of these intermediate-scale structural features continues, particularly with respect to their effect on the groundwater system; however, preliminary analysis indicates that (1) deformational style is related to lithologic homogeneity and bedding thickness and (2) at least one structural deformation feature is continuous across the site.

4.4.3.1 Deformational style

The occurrence of vertically extensive drag folding and gouge beds is most common in the Maryville and lowermost Nolichucky Formations. The lithologically heterogeneous, medium-bedded character of these formations is considered to be responsible for this type of structural deformation. In contrast, the frequency of occurrence and vertical extent of intermediate-scale structural features is much lower in the Pumpkin Valley through Rogersville Formations. Deformation in these formations is dominated by low-angle shears with bedding offsets on the order of tenths of inches and subordinate high-angle shears with undetermined bedding offset. The occurrence of these types of structural features is considered to be a function of the lithologically homogeneous, thin-laminated to thin-bedded character of the Pumpkin Valley through Rogersville Formations.

The dense limestone and dolomitic calcarenite of the Maynardville Formation generally lacks evidence of deformation other than stylolite development and relatively minor fracturing. Core from only one site location exhibits drag folding similar to that in the Maryville and lowermost Nolichucky. The folding occurs in the lowermost Maynardville immediately above the Nolichucky/Maynardville contact where thin shales

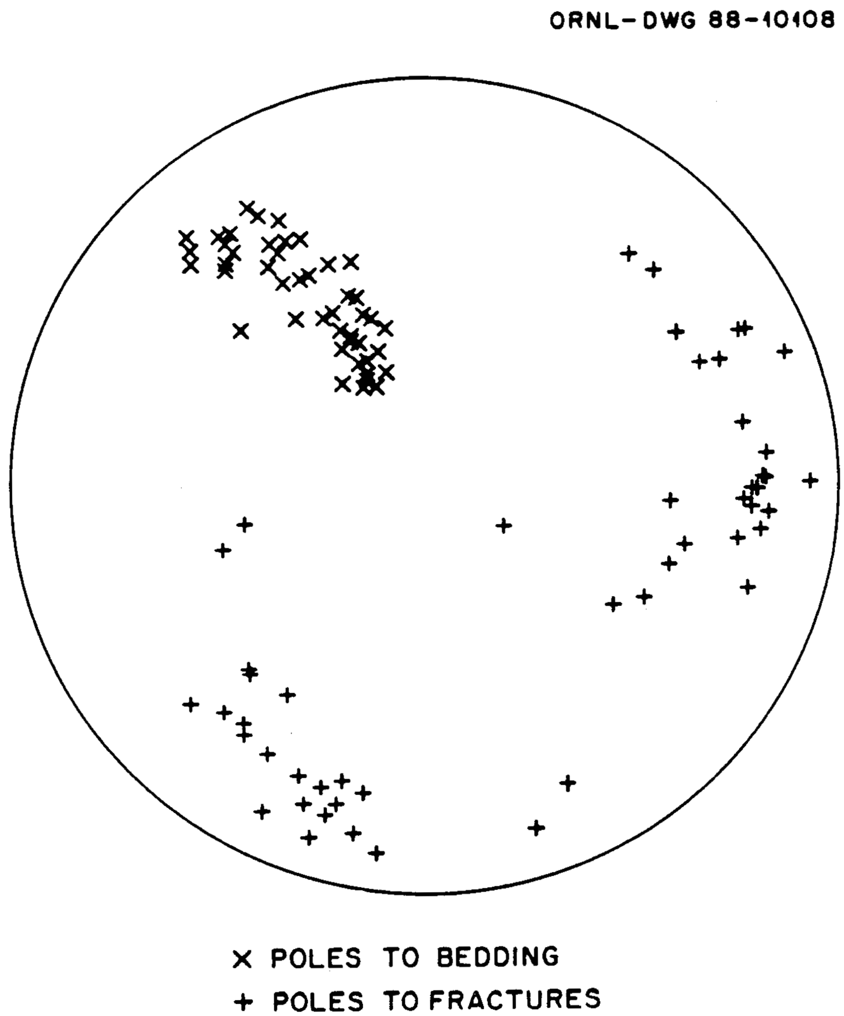

Fig. 10. Stereograms of West Bear Creek Valley site bedding and fracture orientation data.

and ribbon-bedded limestones are interbedded with the dense, calcarenitic Maynardville limestone. The occurrence of drag folding in this portion of the Maynardville is consistent with the lithologic heterogeneity observed in the Maryville and lowermost Nolichucky. Although the limestone content of the lowermost Maynardville is significantly higher than the Maryville and lowermost Nolichucky, its interbedded character appears to have had a more dominant influence on deformational style than lithology.

4.4.3.2 Lateral extent of deformed zones

One intermediate-scale deformation feature in the uppermost Maryville has been lithologically correlated across the site. With the exception of hole LL/HAZ-15, all site core holes of the upper Maryville contain a thin interval several inches to several feet thick with drag folding, gouge, or vertically extensive shears. The stratigraphic position of this deformation feature is shown in Figs. 6, 7, and 8. In the six core holes drilled as part of the site characterization, the deformation feature is expressed somewhat differently and varies slightly in thickness but occurs in nearly the same beds, from 69 to 79 ft below the Maryville/Nolichucky contact. In GW-136 and GW-137, the feature occurs in correlative beds at 51 and 46 ft below the Maryville/Nolichucky contact, respectively. While the depths and thicknesses of the deformation feature vary slightly across the site, it occurs within a very limited stratigraphic interval.

Although only one intermediate-scale deformation feature was studied in detail and is shown in the geologic cross sections, its correlative nature may not be unique at the site. The common occurrence of similar deformation features in the middle Conasauga suggests that others may also be laterally continuous within thin stratigraphic intervals. Stippling in Figs. 6, 7, and 8 denotes the portion of the geologic section where these deformation features occur most commonly.

The type of analysis described above cannot be conducted in the lower Conasauga because core hole locations in that portion of the section are widely spaced. However, an example of lower Conasauga structural deformational expression occurs in core holes GW-400, GW-453, and LL/HAZ-14. Concern developed regarding 15- and 25-ft Rogersville Shale thickness differences from core across the site when the Rogersville is such a thin formation. Core from the three locations for which the Rogersville was recovered was laid side-by-side in an attempt to reconcile the thickness differences. Subtle lithologic features in the upper Rogersville were identified in correlative horizons from GW-400 and GW-453 for a depth of roughly 16 ft. Below that point, the occurrence of a nearly horizontal shear fracture above a thin drag fold in GW-400 obscures continued reliable correlation to the top of the lower Rogersville. The apparent 25-ft thickness difference between the two cores is attributed to a missing section in GW-400 which is largely represented by the shear fracture and drag fold.

The alternative interpretation that the Rogersville in GW-453 is thickened relative to GW-400 was investigated, and no evidence of structurally induced thickening in GW-453 was identified. Similar comparison with core hole LL/HAZ-14 indicates that, while the upper Rogersville is 15 ft thinner than in GW-453, no structural feature was identified to which the thickness difference can be attributed.

4.4.3.3 Conceptual model for deformed zones

Based on the examples above, a preliminary conceptual model is developed for intermediate-scale deformation. Figure 11 is a simplified conceptual block diagram of the middle Conasauga deformation feature described above. The feature occurs throughout the site, within the same stratigraphic interval below the Maryville/Nolichucky contact, and is independent of depth. The feature's somewhat different thickness and expression in closely spaced cores suggests it is elliptically shaped. The center of the ellipse is characterized by drag folding and gouge, and the edges of the ellipse are characterized by vertically extensive high-angle shear fractures. The coincidental occurrence of the feature in a similar stratigraphic interval at nearly all site core holes suggests deformation ellipses are continuous across the site and resemble large-scale boudinage with the long axis oriented parallel to geologic strike. In contrast, the lower Conasauga formations typically contain a large number of low-angle shear fractures and subordinate high-angle shear fractures. The absence of laterally continuous shear fractures suggests lower Conasauga deformation is localized.

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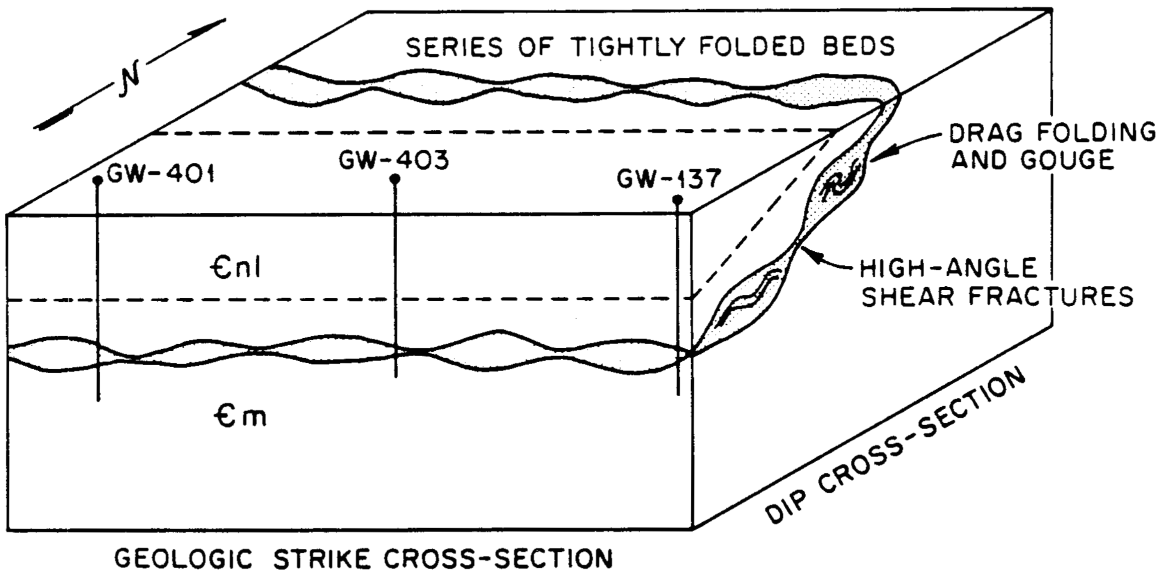

Fig. 11. Conceptual block diagram of elliptically shaped deformation feature in a limited stratigraphic interval of the upper Maryville.

5. CONCLUSIONS

The bedrock characteristics of the Conasauga Group underlying the Bear Creek Valley proposed "tumulus" disposal site are generally consistent with those described in previous geologic investigations conducted on the ORR. Bedrock orientation and formational thicknesses are within the range of previously reported values, indicating an absence of significant bedrock anomalies on the site. Some departure from previous stratigraphic analyses elsewhere in upper East Tennessee and on the ORR is found to be applicable to the Conasauga Group at the site. These departures are in the application of previously reported stratigraphic nomenclature to the Conasauga Group on the ORR and in the establishment of definitive criteria for the placement of enigmatic formational contacts.

The complexly interbedded and lithologically diverse Conasauga Group represents shallow marine and platform paleodeposits strongly influenced by differential clastic influx, storm and surge events, and debris flows. As such, lateral lithologic variability is commonly observed, and the tracing of individual beds over even short distances with confidence is often difficult. Conasauga Group formation thickness differences at various site locations are in part a reflection of strongly event-influenced, localized paleodeposition.

With the exception of the Maynardville Formation, small and intermediate-scale structural features are ubiquitous in the Conasauga and are considered to be associated with regional structural deformation. The different expression of intermediate-scale structural features in the lower and middle Conasauga is attributed to lithologic homogeneity and bedding thickness. The generally homogeneous, laminated to thin-bedded lower Conasauga formations which are dominated by shale (Pumpkin Valley through Rogersville) are characterized structurally by shear fractures with little displacement. By contrast, the heterogeneous, thin to medium-bedded middle Conasauga formations (Maryville and lowermost Nolichucky) with comparatively greater limestone content possess thick zones of drag folding, gouge, and high-angle shears. Thin stratigraphic intervals with such deformation occur frequently.

Intermediate-scale structural features in the middle Conasauga occur frequently and appear as laterally continuous, three-dimensional ellipses resembling large-scale boudinage. Deformation ellipses are characterized by comparatively thick intervals of drag folding and gouge in the middle with thin to intervals of vertically extensive shearing near the edges. Lower Conasauga structural features are dominated by low-angle shears and subordinate high-angle shears. The absence of evidence of lateral continuity suggests these shear fractures are localized. Both styles of deformation contribute to formational thickness variations at the site.

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Appendix A

SITE DATA

Table A-1. Classification of soils on the West Bear Creek Valley site

	Taxonomic classification	Parent materials
1.	Typic Hapludults; sandy and coarse-loamy, mixed, thermic.	Rome feldspathic sandstone residuum.
4.	Typic Dystrochrepts; loamy-skeletal, siliceous, thermic.	Rome sandstone along the crest of Pine Ridge.
7.	Typic Hapludults; clayey, mixed, thermic residuum.	Rome feldspathic sandstone.
5.	Typic Hapludults; fine-loamy, mixed, thermic.	Rome colluvium.
21.	Typic Hapludults; clayey, mixed, thermic.	Pumpkin Valley residuum.
22.	Ochreptic Hapludults; clayey, mixed, thermic.	Pumpkin Valley residuum.
23.	Typic Dystrochrepts; loamy-skeletal, mixed, thermic.	Pumpkin Valley residuum.
24.	Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.	Pumpkin Valley residuum.
25.	Typic Hapludults; clayey, mixed, thermic.	Pumpkin Valley colluvium.
26.	Typic Hapludults; fine-loamy, mixed, thermic.	Pumpkin Valley colluvium.
26-951.	Typic Hapludults; fine-loamy, mixed, thermic.	Pumpkin Valley colluvium overlying old alluvium.
27.	Typic Hapludults; loamy-skeletal, mixed, thermic.	Pumpkin Valley colluvium.
30.	Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.	Rutledge residuum.
35.	Typic Dystrochrepts; loamy-skeletal, mixed, thermic.	Rogersville residuum.
36.	Ruptic Ultic Dtstrochrepts; loamy-skeletal, mixed, thermic.	Rogersville residuum.
37.	Typic Hapludults; clayey, mixed, thermic.	Rogersville residuum.
40.	Typic Hapludults; clayey, mixed, thermic.	Maryville residuum.
42.	Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.	Maryville residuum.
43.	Typic Dystrochrepts; loamy-skeletal, mixed, thermic.	Maryville residuum.
47.	Typic Hapludults; fine-loamy, mixed, thermic.	Conasauga colluvium.
47-951.	Typic Hapludults; fine-loamy, mixed, thermic.	Conasauga colluvium overlying old alluvium.
48.	Typic Fragiudults; fine-loamy, mixed, thermic.	Conasauga colluvium.

Table A-1. (continued)

	Taxonomic classification	Parent materials
49.	Typic Hapludults; clayey, mixed, thermic.	Conasauga colluvium.
50.	Ruptic Aquultic Dystrochrepts; loamy-skeletal, mixed, thermic.	Nolichucky residuum.
51.	Ruptic Ultic Dystrochrepts; loamy-skeletal, mixed, thermic.	Nolichucky residuum.
52.	Typic Hapludults; clayey, mixed, thermic.	Nolichucky residuum.
55.	Typic Hapludults; clayey, mixed, thermic.	Maynardville residuum.
56.	Typic Hapludults; fine, mixed, thermic.	Maynardville residuum.
71.	Typic Hapludults; fine-loamy, siliceous, thermic.	Knox colluvium.
94.	Typic Hapludults; fine-loamy, mixed, thermic.	Old alluvium.
94-71.	Typic Hapludults; fine-loamy, mixed, thermic.	Old alluvium overlying Knox colluvium.
95.	Typic Hapludults; fine-loamy, mixed, thermic.	Old alluvium.
96.	Typic and Aquic Udifluvents; coarse-loamy, mixed, thermic.	Modern alluvium in areas of Rome and Pumpkin Valley residuum.
97.	Typic and Aeric Fluvaquents; fine-loamy, mixed, thermic.	Modern alluvium in areas of Rome and Pumpkin Valley residuum.
98.	Typic and Aquic Udifluvents; coarse-silty, mixed, thermic.	Modern alluvium in areas of Rogersville, Maryville, and Nolichucky residuum.
99.	Typic and Aeric Fluvaquents; fine-silty, mixed, thermic.	Modern alluvium in areas of Rogersville, Maryville, and Nolichucky residuum.
100.	Typic and Aquic Udifluvents; coarse and fine-loamy, mixed, thermic.	Modern alluvium in Bear Creek.
101.	Aeric Ochraqualfs; fine-silty, mixed, thermic.	Old alluvium.
102.	Typic and Aquic Udifluvents; fine-loamy, siliceous, thermic.	Modern alluvium from Knox residuum and colluvium.
471.	Typic Hapludults; fine-loamy, mixed, thermic.	Conasauga colluvium and alluvium.
951.	Typic Hapludults; fine-silty, mixed, thermic.	Old alluvium.
952.	Typic and Aquic Fragiudults; fine-silty, mixed, thermic.	Old alluvium.

Table A-2. Bear Creek Valley site core hole engineering survey and drilling data

(All measurements are in feet.)

Well name	N	E	Ground surface elevation	Top of core	Total depth
GW-400	29926.99	28651.66	838.77	23.0	1251.5
GW-401	29438.55	28709.50	834.80	60.3	862.8
GW-402	28869.62	28805.33	807.96	15.0	600.0
GW-403	29520.92	30479.83	835.43	16.7	612.9
GW-404	29870.29	30636.05	852.30	21.0	200.0
GW-453	30298.35	30814.34	862.27	12.2	810.8
GW-454				11.6	57.8
GW-455	29765.95	30676.25	853.44	19.0	293.2
GW-468	29040.14	30210.77	826.19	16.2	500.5
GW-471	29875.29	30721.63	864.14	18.7	104.7
GW-136	29147.48	32120.20	855.81	37.0	800.0
GW-137	28712	32796	832.88	39.0	1000.0
GW-138	27959	30825	838.78	35.0	1095.0
LL/HAZ-13	30640.63	32192.72	916.34	20.0	279.0
LL/HAZ-14	30236.57	32157.15	932.47	30.0	300.0
LL/HAZ-15	29779.90	32153.06	878.41	15.6	320.0

Table A-3. Bear Creek Valley site core hole stratigraphic data[a]

[Numbers specify drilled depth (in feet) to formation contact.]

	Rome and Conasauga Group formations						
Well	Ꞓr	Ꞓpv	Ꞓrt	Ꞓrg	Ꞓm	Ꞓnl	Ꞓmn
GW-400	1056	872/680	558	497/465	26[c]		
GW-401					451	*b*	
GW-402						218/110	*b*
GW-403					311	*b*	
GW-404					11[c]	*b*	
GW-451	254	*b*					
GW-453	745	521/347	221	127/70	*b*		
GW-455					109	*b*	
GW-468						218/57	*b*
GW-471					10[c]		
GW-136					580	*b*/	
GW-137					911	312/236	*b*
GW-138						/977	730/532
HAZ-13		/104					
HAZ-14				267/225			
HAZ-15					99		

[a]Slash (/) = Depth to lower/upper members or distinctive portions of formation.
[b]Hole collared in this formation.
[c]Based on geophysical log correlation from greater depth.

Table A-4. Bear Creek Valley site geophysical log data

Data Type	Well name										
	GW-400	GW-401	GW-402	GW-403	GW-404	GW-451	GW-468	GW-471	GW-136	GW-137	GW-138
NG	X	X	X	X	X	X	X	X	X	X	X
CAL	X	X	X		X	X	X	X		X	
SP	X	X	X		X				X	X	X
NE	X	X		X	X	X					
NP	X	X	X		X			X		X	
CD	X	X	X		X					X	
DP	X	X	X		X						
RE	X	X	X		X	X	X	X	X		
LSN	X	X	X		X				X	X	X
VD							X				
BHT							X				
DEV	X	X	X		X				X	X	X
TEM									X		X
DTEM									X		X

Geophysical log abbreviations

BHT = borehole televiewer
CAL = caliper
CD = compensated density
DEV = borehole vertical deviation
DP = density porosity
DTEM = delta temperature
LSN = long and short normal resistivity

NE = neutron
NG = natural gamma
NP = neutron porosity
RE = single-point resistivity
SP = spontaneous potential
TEM = temperature
VD = acoustic variable density

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