BEEKMANTOWN FORMATION - MIDDLE ORDOVICIAN

LIMESTONE UNCONFORMITY ON THE NORTHWEST LIMB

OF THE GREEN RIDGE ANTICLINE NEAR FINCASTLE, VIRGINIA

by

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## INTRODUCTION

The unconformity between Lower Ordovician carbonates and Middle Ordovician limestones is extensively developed over much of the Valley and Ridge portion of the Southern Appalachians. On the northwest limb of the Green Ridge anticline (southeast limb of the Catawba syncline) near Fincastle, Botetourt County, Virginia (Figs. 1 and 2) the unconformity is marked by well preserved erosional features. These features are paleo stream channels and paleokarst solution hole fillings in the Lower Ordovician Beekmantown Formation. Together with thickness variations and facies changes of the overlying Middle Ordovician limestones, they attest to at least 165 feet (50 m) of topographic relief on the surface of unconformity.

The study was undertaken to gain a better understanding of features associated with the Beekmantown - Middle Ordovician unconformity along the northwest limb of the Green Ridge anticline. Field relations of the erosional features and the adjacent formations are described. Stratigraphic sections were described in the field, thin sections were studied, and samples were processed for conodonts. The purpose of these procedures was to (accurately) measure the relief on the surface of unconformity.

Previous work. -- Early mapping of the area was done by Butts (1933) and by Woodward (1936). The area is included in R. S. Edmundson's (1958) report on the industrial limestones and dolomites of the James River district. Nichol (1959) mapped the southernmost part of the outcrop belt. McGuire (1970) mapped the Salisbury quadrangle, which includes the study area. He noted that up to 100 feet (30.5 m) of relief occurs on the surface of unconformity on the northwest limb of the Catawba syncline, 4 miles (6.6 km) north of Fincastle, Virginia. However, he did not note the 165 feet (50 m) of relief on the southeast limb of the syncline, the paleokarst features, or the conglomerate at the base of the Middle Ordovician section. Karpa (1974a, 1974b) studied the Middle Ordovician Fincastle conglomerate in the Pine Hills depression of the Catawba syncline and reported but did not study the basal conglomerate at the Cahoon locality. Campbell (1975) reported briefly on relief on the unconformity and the paleokarst features developed in the Beekmantown Formation on the northwest limb of the Green Ridge anticline.

**FIG. 1. Geologic Index Map of the Salem Synclinorium**

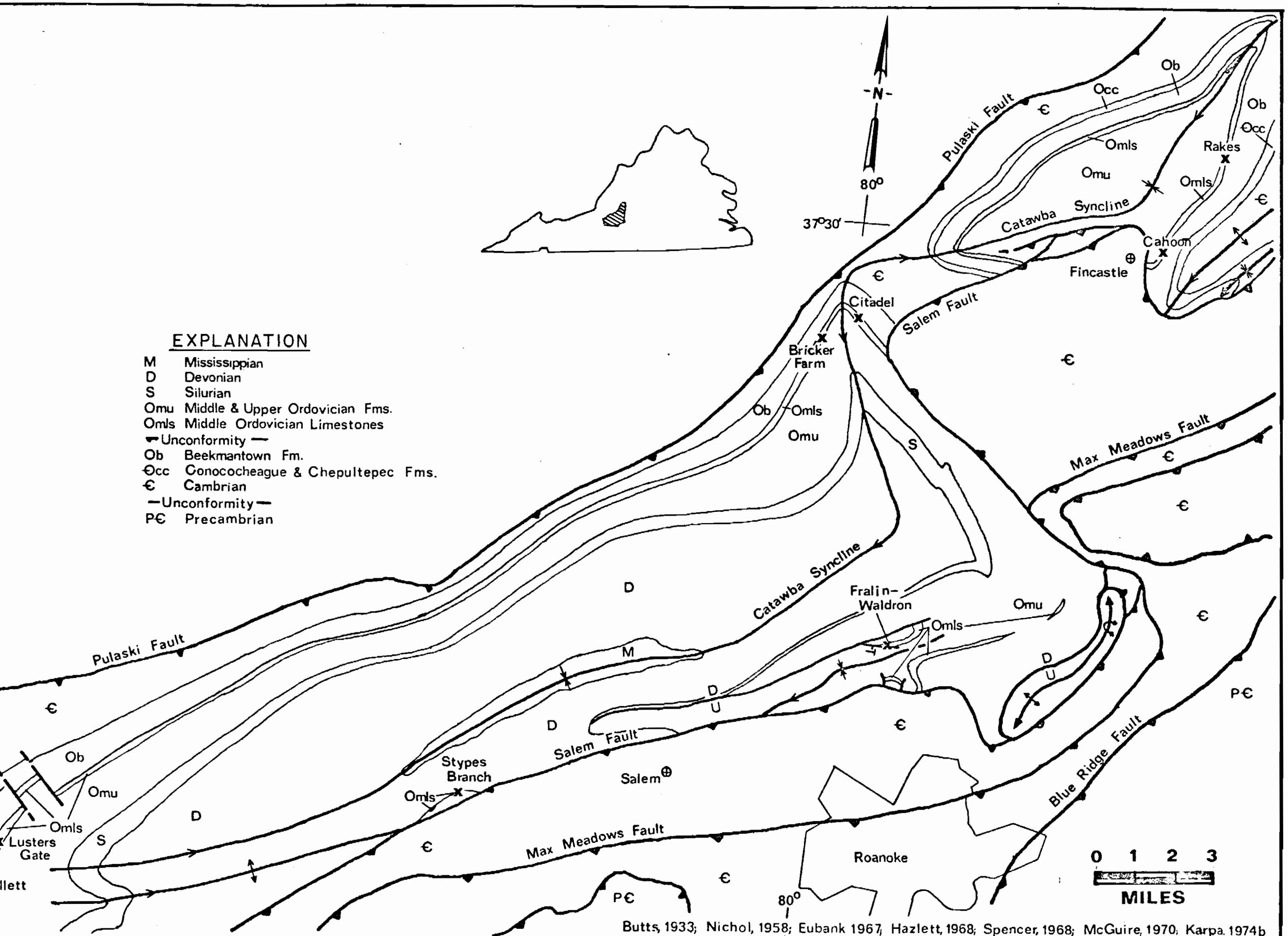
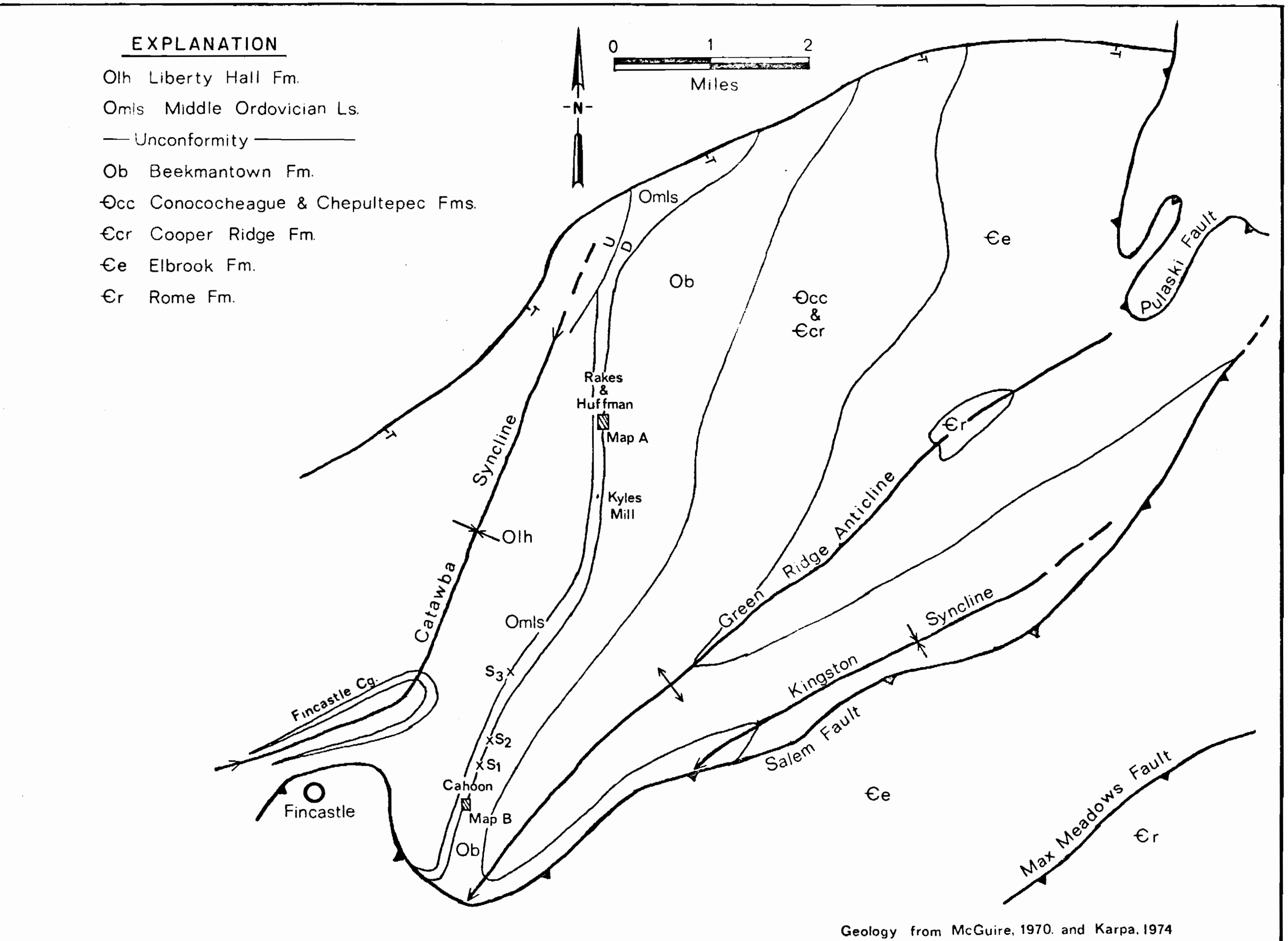


**FIG. 2. Geologic Index Map of the Green Ridge Anticline**



STRUCTURAL SETTING

The Fincastle area is approximately 15 miles (27 km) south of the juncture of the Southern and more northerly trending Central Appalachians (Fig. 1). From southeast to northwest are four allochthonous structural blocks: 1) the Blue Ridge, 2) Max Meadows, 3) Salem, and 4) Pulaski blocks (Figs. 1 and 2). The Blue Ridge fault block is the structurally highest block and consists of the Blue Ridge anticlinorium. The Max Meadows block and structurally underlying Salem fault block are younger subsidiary splays off the master Pulaski thrust fault (Hazlett, 1968; Lowry, 1964, 1971a, 1971b). These two blocks intervene between the Blue Ridge anticlinorium and the Salem synclinorium.

The Pulaski thrust sheet is composed entirely of the Salem synclinorium, the first major downwarp northwest of the Blue Ridge anticlinorium. The Salem synclinorium consists of, from southeast to northwest: 1) the Kingston syncline, 2) the Green Ridge anticline, and 3) the Catawba syncline, which is the major downwarp of the synclinorium (Figs. 1 and 2).

The Kingston syncline (Figs. 1 and 2) is a southwestward plunging fold overturned to the northwest. In the Fincastle area, the axial portion of the syncline is occupied by Beekmantown carbonates and is partially to completely overridden by the Salem thrust. Farther southwest, where the syncline emerges from beneath the Salem sheet, Middle Ordovician rocks crop out in the trough.

The Green Ridge anticline (Figs. 1 and 2) is the medial anticline of the Salem synclinorium. The axis of the structure strikes approximately N.60°E. and plunges to the southwest beneath a local salient of the Salem thrust sheet (Figs. 1 and 2). Where it reappears farther southwest, it is broken by several faults (Hazlett, 1968). The Cambrian Rome Formation, the oldest formation exposed in the synclinorium, crops out along the crest of the Green Ridge anticline northeast of the study area (McGuire, 1970) (Fig. 2).

The Catawba syncline, the major structure of the Salem synclinorium, has a sinuous axial trace with a major axial culmination and two axial depressions. South of the culmination of the syncline near the Citadel Cement Company quarry (Fig. 1), the axis strikes N.10°-15°W. for a distance of about 6.5 miles (10.3 km). The axis then turns abruptly to assume a more characteristic N.60°E. strike. The syncline is overturned for much of its length south of the culmination and has rocks as young as Early Mississippian exposed in a major structural depression on the southeast flank of Fort Lewis mountain, northwest of Salem, Virginia.

Approximately 1 mile (1.7 km) north of the Citadel Cement Company quarry at the culmination, the synclinal axis again turns sharply to plunge to the northeast and assume a strike of about N.70°E. This strike is constant until a second depression is reached in the Pine Hills, about 1 mile (1.7 km) north of Fincastle. This second lesser depression is referred to as the Pine Hills depression of the Catawba syncline. Nichol (1959) was the first to show convincing evidence that the two depressions were indeed parts of one continuous syncline. In the vicinity of Pine Hills, the syncline is overturned, reverses its plunge to the southwest and changes strike to roughly N.20°E. Farther to the northeast the syncline opens up to form an upright, asymmetric fold.

The regional geologic setting is presented in more detail by Hayes (1891), Butts (1933, 1940), Edwards (1959), Nichol (1959), Chen (1960), Eubank (1967), Amato (1968), Hazlett (1968), Spencer (1968), Tillman and Lowry (1968, 1971), McGuire (1970), Lowry (1971a), and Karpa (1974b).

STRATIGRAPHY

The present study deals with a belt of the Beekmantown Formation and the unconformably overlying Middle Ordovician limestones on the northwest limb of the Green Ridge anticline (Fig. 1; stipled area, Fig. 2). The southern terminous of the belt occurs 1 mile (1.7 km) south of Fincastle where the Salem thrust sheet has overridden the Pulaski thrust sheet. The belt extends northeastward for a distance of about 10 miles (17 km) to the leading edge of a minor thrust sheet of the Pulaski fault zone (Fig. 2).

The Beekmantown Formation is Lower Ordovician (and lower Middle Ordovician White Rock?) age and the overlying Middle Ordovician formations are of Marmor, Ashby, and Porterfield age. All these formations are composed almost entirely of carbonate rocks. The Beekmantown Formation conformably overlies the Chepultepec Limestone of Early Ordovician age (Butts, 1940). The rocks of the upper part of the Beekmantown, with which this study is concerned, are composed of approximately equal amounts of limestone and dolomite with minor nodular white chert. The unconformably overlying Middle Ordovician formations are almost all limestone except for a high percentage of dolomite in the basal conglomerate member of the New Market Limestone and the relatively high silica and argillaceous content of the Lincolnshire Formation. Irregular pancake-shaped black chert nodules are abundant in the middle and upper Lincolnshire Formation (Appendix A).

Dunham's classification of carbonate rocks based on depositional texture is used (Dunham, 1962). Dr. C. G. Tillman made final indentifications of the conodont specimens recovered and he assigned zonal ages where possible.

## Beekmantown Formation

Nomenclature. -- The location of the Fincastle area very near the juncture of the Central and Southern Appalachians gives rise to problems in stratigraphic nomenclature in part related to complex regional stratigraphic relations both across and along strike. This is especially true with regard to the Beekmantown Formation.

Lower Ordovician rocks in the Fincastle area have been assigned to the Nittany Dolomite (Woodward, 1932), the Beekmantown Formation (Butts, 1940; Andrews, 1952; Edmundson, 1958; Hazlett, 1968; McGuire, 1970; and Karpa, 1974b), and to the Knox Group (Nichol, 1958; and Campbell, 1975).

The term Knox Group was first used by Safford (1869) for outcrops in Knox County, Tennessee for carbonates of Late Cambrian and Early Ordovician age. The Lower Ordovician portion of the Knox Group in southwest Virginia and eastern Tennessee is commonly divided into as many as four formations in the Southern Appalachians. These are the Chepultepec Limestone, Longview Limestone, Kingsport Dolomite, and Mascot Formation (Rodgers, 1953) and they consist of limestones overlain by dolomite containing abundant massive, bedded white chert (Milici, 1973; McLaughlin, 1973).

The term Beekmantown was originally applied by Clarke and Schuchert (1899) to replace the older descriptive Calciferous Sandrock for the type section in Beekmantown Township, Clinton County, New York. The Beekmantown Group to the south in Pennsylvania is presently divided into four formations. These formations are the Stonehenge, Nittany, Axeman, and Bellefonte, and with slight variance, are recognizable through Pennsylvania (Hobson, 1963) and into Maryland (Sando, 1957). In northern and central Virginia these formations lose their respective identities and the post-Stonehenge formations are collectively referred to as the Beekmantown Formation.

In the northwestern strike belts of Virginia the Lower Ordovician rocks are almost wholly dolomite with minor to locally abundant bedded and semi-bedded chert and rare limestone. In southeastern strike belts limestone content increases until in places it is interbedded in roughly equal amounts with dolomite; chert is relatively uncommon. These relations are especially true in the southeastern belts from Fincastle northeastward into the Central Appalachians. In some sections in the Harrisonburg, Virginia area (Suter, 1973; Tillman, oral comm., 1975), limestone predominates.

Physical Stratigraphy. -- In this paper the author chooses to retain Beekmantown Formation to describe the rocks conformably overlying the Chepultepec Formation (see Butts, 1940, and McGuire, 1970) and bounded on the top by the Beekmantown - Middle Ordovician unconformity. As previously noted, the Beekmantown Formation in the study area consists of limestone and dolomite interbedded in approximately equal proportions. The dolomite is either alternating pink and buff and dark gray laminated saccharoidal to very fine grained, (Fig. 4), or dominantly buff to medium gray thin-to medium-bedded saccharoidal dolomite. Rare cauliflower white chert is present in some of the thin- and mediumbedded layers. The chert may be of replacement origin after evaporite minerals. The dolomite of the Beekmantown Formation exhibits a characteristic cross-hatched weathering pattern by which the unit is easily identified in the field.

Two types of limestone occur in the Beekmantown Formation. Medium gray, thin-bedded lime mudstone is the dominant type and generally occurs in units up to 4 feet (1.2 m) thick. The second type, a light to medium blue gray, trilobite-brachiopod, pellet-intraclast grainstone, occurs generally as discontinuous layers up to 3 inches (7.6 cm) thick and several feet wide within the lime mudstone. Individual layers of the grainstone may be in contact with each other or may be in contact with dolomite. Chert does not occur in the limestone.

The Beekmantown Formation is 700 (McGuire, 1970) to 865 feet (213 to 264 m) thick in this outcrop belt. In strike belts to the northwest it reaches 1200 feet (366 m) (Butts, 1940; McGuire, 1970). To the southeast it is up to 1500 feet (457 m) thick (Edmundson, 1958; Spencer, 1969). In the Central Appalachians the Beekmantown is 1500 to 2500 feet (457 to 762 m) thick (Butts, 1940; Edmundson, 1958).

Variations in thickness of the Beekmantown Formation in the study area are due to erosional relief on the unconformity surface. At the Cahoon farm (Fig. 2), the Beekmantown Formation is approximately 700 feet (213 m) thick. Maximum thickness of 865 feet (264 m) is found at the Rakes farm and is related to a topographic high developed on the surface of unconformity.

Biostratigraphy. -- Macrofossils in the Beekmantown Formation include undescribed trilobites, brachiopods, and two gastropod opercula horizons. The gastropod opercula have been identified by E. L. Yochelson as *Ceratopea subconica* Oder and *Ceratopea tennesseensis* Oder (E. L. Yochelson, written communication to C. G. Tillman, 1974).

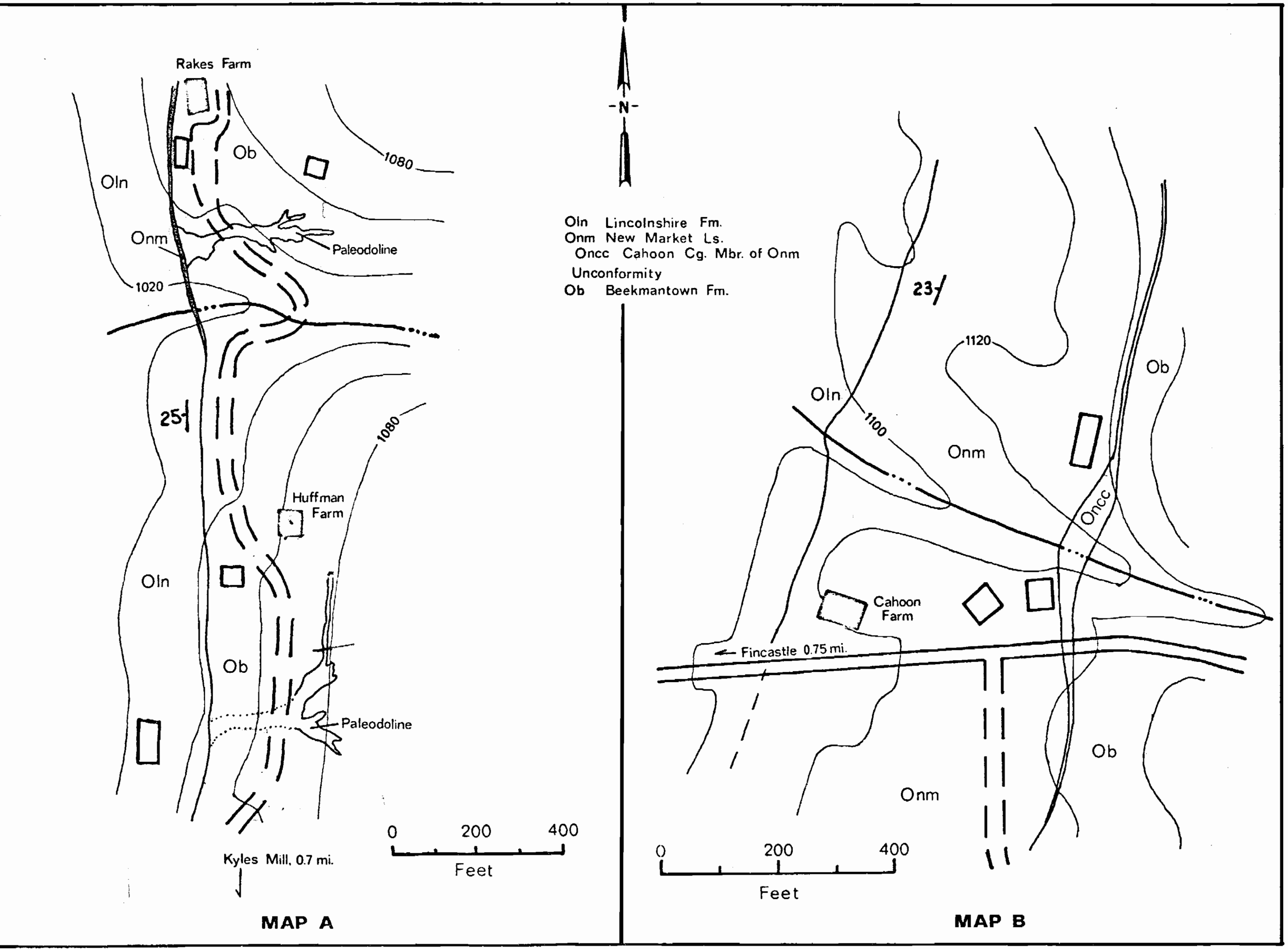
Study of conodonts recovered from samples from the Rakes and Cahoon farms has yielded significant results (Note: Rakes farm was Norford locality prior to July, 1975). Typically, Cambrian and Lower Ordovician conodont faunas are not as well developed as younger faunas in that cone forms, as opposed to blade and platform types, are usually dominant. This lack of complex forms has resulted in a general lack of interest in research on Lower Ordovician conodont faunas in the Appalachians. However, based on recent work by Ethington and Clark (1971), correlation with Lower Ordovician faunas in Utah is possible. Ethington and Clark (1971), used first appearances of conodont form species to divide the Lower Ordovician into five faunal units. In ascending order these are Faunas A, B, C, D, and E. Faunas D and E are based on specimens collected from the Fillmore Formation of the Pogonip Group of the House and Confusion Ranges in western Utah. The upper 106 feet (32.3 m) of the Cahoon farm section and the upper 61 feet (18.5 m) of the Rakes farm section contain undifferentiated faunas D-E (Appendix B). Many elements of both D and E are present but distinctive species uniquely marking the incoming of E fauna are lacking (i.e. *Gothodus communis* and *Oepikodus quadratus*). On the other hand *Leptochirognathus quadrata* is present in Rakes samples collected 33 feet (10 m) and 17 feet (5 m) below the unconformity. Previously this form has been reported only as low as the Dutchtown Formation of Missouri. Also present are *Oistodus aff. O. multicorrugatus* Harris, which occurs in the Joins Formation, a unit of White Rock age. Other important conodont form species present at both the Rakes and Cahoon farms are *Scandodus furnishi*, *Oistodus parallelus*, *Scolopodus cornutiformis* (identification by Dr. C. G. Tillman, 1975). See Appendix B for complete list of conodont form species present in samples collected from the Beekmantown Formation at the Rakes and Cahoon farms.

## Unconformity

The regional erosional unconformity separating the Beekmantown Formation from Middle Ordovician limestones is well defined on the northwest limb of the Green Ridge anticline (Figs. 2 and 3). Three paleochannels averaging 21 feet (6.5 m) deep and up to 300 feet (100 m) wide have been recognized. Also many smaller channels up to 7 feet (2 m) deep and 50 feet (15 m) wide are present. Channel fillings are described later as part of the Cahoon Conglomerate Member of the New Market Limestone.

Paleodoline Fillings. -- Two well shaped paleodolinen, filled with clasts of limestone and dolomite, are present on a topographic high on the surface of unconformity at the Rakes and Huffman farms (Fig. 3, Map A). These fossil sinkholes display features very similar to features described in the recent work of Sweeting (1972, p. 44-73) on modern karst landforms. The basic geometry of the paleodolinen as seen in outcrop is dendritic. The main cavity is approximately 50 feet (15 m) wide. Smaller branches extend outward and downward as much as several tens of feet (Fig. 3). At least one thin breccia-filled seam extends 200 feet (61 m) laterally at the Huffman farm. The geometry of the paleodolinen is presented diagrammatically in map A of figure 3. It should be pointed out that data presented is from two-dimensional outcrops. The possibility is great that a three-dimensional view of these features would reveal significantly different dimensions.

FIG.3. Map Showing Geometry of Paleodolines (Map A), and Cahoon Channel (Map B)



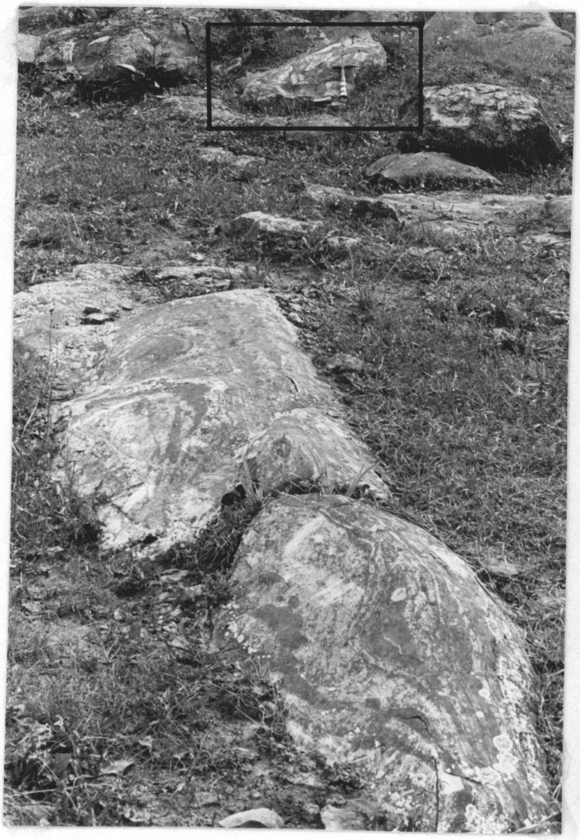
The clasts which filled the dolinen were derived from adjacent beds of the Beekmantown Formation. Figures 4 and 4B show a well exposed example of clast types matching the lithology of adjacent beds of alternating light and dark laminated dolomite. Clasts range from less than 0.25 inch (6mm) to greater than 5 feet (1.5 m) in length and represent all types of Beekmantown lithologies. Clasts are very poorly sorted and range from angular to subrounded (Figs. 5 and 6). Many shapes are represented. Clast boundaries, especially those of the larger clasts, show severe alteration by solution and embayment of clasts is common (Figs. 5 and 6). The matrix of the breccias is buff to gray, very fine-grained dolomite, closely resembling crystal silt. The matrix shows concentric growth around some clasts and is typically layered. The matrix is very similar to caliche (Read, 1974). Figure 7 is an example of doline fillings in outcrop.

## New Market Limestone

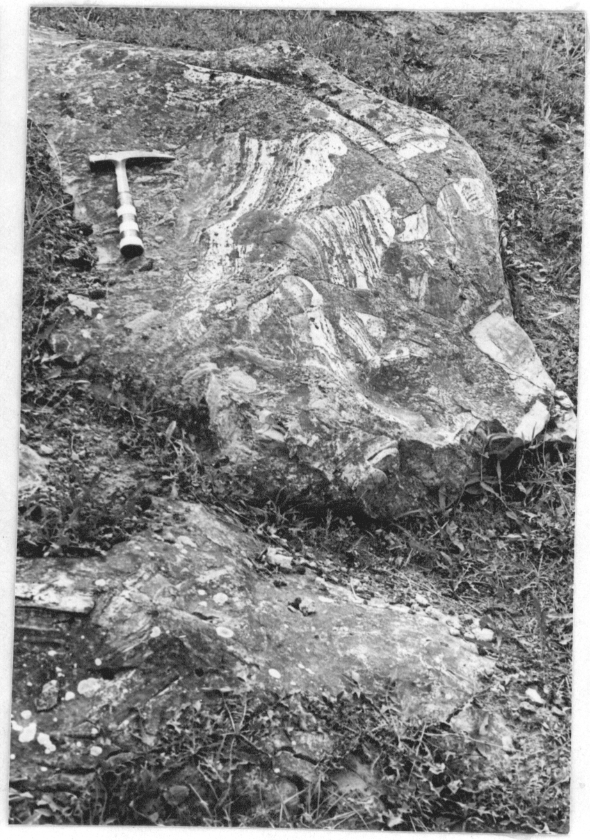
The New Market Limestone (Cooper and Cooper, 1946) unconformably overlies the Beekmantown Formation in the study area. It ranges in thickness from 165 feet (50.3 m) to 0 feet, contains an irregularly developed basal conglomerate and dolomite member, here called the Cahoon Conglomerate Member, and overlying fenestral (birdseye) and non-fenestral, skeletal and non-skeletal limestone.

### Cahoon Conglomerate Member

The name Cahoon Conglomerate Member of the New Market Limestone is herein applied to the locally and irregularly developed basal conglomerate



4A



4B

Figs. 4A and 4B - Outcrop of paleodoline filling matching adjacent beds in Beekmantown Formation. Fig. 4B is close-up of outcrop indicated in Fig. 4A. Rocks in foreground of 4A are bedded Beekmantown that probably supplied clasts seen in 4B.


Fig. 5 - Polished slab of paleodoline filling showing solution of clasts.

Fig. 6 - Outcrop of paleodoline filling showing solution altered clast boundary.

Fig. 7 - Outcrops of paleodoline fillings.

and dolomite of the New Market Limestone that unconformably overlies the Beekmantown Formation and conformably underlies typical New Market limestones. The type section of the Cahoon Conglomerate is located in an intermittent stream channel at the E. G. Cahoon farm, 0.75 mile (1.2 km) east of Fincastle, Virginia, just north of Virginia Route 630 (Fig. 3, Map B). The type section of the Cahoon Conglomerate is 21 feet (6.5 m) thick and consists of a basal conglomerate of limestone and dolomite clasts that grade upward into thin-bedded and laminated argillaceous dolomite (see Appendix A). The conglomeratic beds are 15 feet (4.5 m) thick and consist of clasts of limestone, dolomite, and rare chert in a relatively clean sparry calcite matrix. Bedding is massive at the base changing to thin-bedded at about 8 feet (2.4 m) above the unconformity. The clasts were derived from the Beekmantown and possibly older formations. ? Clasts range from 1.5 feet (46 cm) to less than 0.25 inch (0.6 cm) long with most clasts less than 8 inches (20.3 cm) long. The conglomerate becomes finer upward and is poorly sorted; sorting improves upward. The clasts range from subequant to elongate to bladed; they are angular to subangular near the base but change to subrounded and rounded near the top. Alteration of clast boundaries by solution is present but not common (Fig. 8). Cross-bedding was not detected but imbrication of some clasts, especially above 8 feet (2.4 m) from the base, was noted (Fig. 9). The clasts are cemented with sparry calcite.

The conglomerate grades upward into a thin-bedded to laminated argillaceous dolomite which is 6 feet (1.8 m) thick. It generally extends along strike beyond the conglomerate over most of the outcrop belt. The dolomite is medium gray to buff to yellow, fine to very fine-grained, and

Fig. 8 - Cahoon Conglomerate Member showing poor sorting and limited solution alteration of clast boundaries.

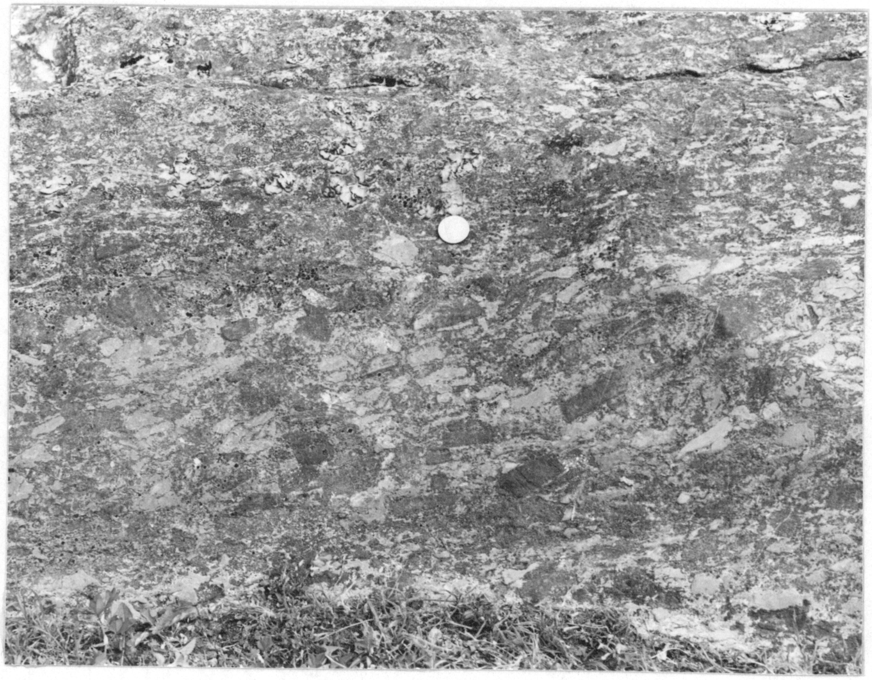


Fig. 9 - Imbrication of clasts in Cahoon Conglomerate Member.

contains variable amounts of argillaceous material and pyrite. Some of this argillaceous material occurs in very thin anastomosing and bifurcating layers. Bedding planes and laminations are rather uniform but several layers, up to 1 foot (0.3 m) thick, exhibit low-angle cross-bedding. Near the top of the section, incipient desiccation cracks (Fig.10) can be seen, probably in cryptalgal structures.

The maximum thickness of 21 feet (6.5 m) is at the Cahoon farm and at localities $S_1$ and $S_2$ (Fig. 2). At these locations the Cahoon Conglomerate thins laterally so that within 150 feet (46 m) to either side of the maximum thickness, the member is only 5 feet (1.5 m) thick. Elsewhere the maximum thickness of the Cahoon Conglomerate is less than 7 feet (2.1 m) and within about 50 feet (15.2 m) to either side the thickness is less than 3 feet (0.9 m). Along strike from the above occurrences the Cahoon Conglomerate is commonly less than 3 feet (0.9 m) thick.

## Post-conglomerate New Market Limestones

Physical Stratigraphy. -- Overlying the Cahoon Conglomerate Member are limestones that are typical of New Market limestones elsewhere. The post-Cahoon Conglomerate New Market is nearly constant in thickness (approximately 143 feet or 43.5 m) along much of the outcrop belt in the study area. The exception occurs along a 2-mile (3.2 km) belt from just south of Kyles Mill to 0.25 mile (0.4 km) north of the Rakes farm house (Fig. 2). At both ends of this 2-mile (3.2 km) belt the New Market formation thins from about 143 feet (43.5 m) to 0 feet over a strike distance of less than 0.25 mile (0.4 km). Over this extent the New Market Limestone either occurs only locally in lenses up to 15 feet (4.5 m) thick

Fig. 10 - Desiccation cracks in lower New Market Limestone. Dark blebs are irregular fenestrae.

and 50 feet (15 m) wide or is completely absent because of the presence of a topographic high on the surface of unconformity. The post-Cahoon Conglomerate beds range in thickness from a maximum of 143 feet (43.6 m) to 0 feet. The limestones of the New Market show more lithologic variations than most sections in other outcrop belts and include fenestral and non-fenestral, skeletal and non-skeletal lime mudstones and pellet-intraclast packstones and grainstones.

Fenestral fabrics (birdseyes) (Tebbutt, et al, 1965, and Shinn, 1968) are an important feature of the New Market Limestone. They are sparry calcite filled vugs, roughly bubble shaped (irregular fenestral fabric), planar (laminoid fenestral fabric), or tubular. Domal algal structures (Logan, Rezak, and Ginsburg, 1964) are absent. Fenestral fabrics are commonly associated with pellet-intraclast limestones and occur in planar layers.

Crystal silt (Dunham, 1969) is a common feature of the New Market Limestone. It consists of silt-size calcite crystals that filled voids in the rock. Void fillings commonly show geopetal structure. They are shown on the outcrop surface as very light gray, irregular blebs scattered throughout a layer. Some of the crystal silt filled voids are connected by a network of very thin seams. The voids range in size from less than 0.12 inch (0.3 m) to greater than 1.5 inches (3.8 cm).

Non-skeletal Limestones--At least 75 percent of the New Market Limestone is non-skeletal. Lime mudstones and pellet-intraclast packstones dominate with only minor intraclast-lithoclast grainstones present. Both fenestral and non-fenestral types occur.

Lime mudstones occur throughout the lower 112 feet (34.1 m) of section, comprising about 35 percent of the total New Market Limestone thickness. Lime mudstones are light to medium gray and laminated to thin-bedded. They nearly everywhere display some type of fenestral fabric, either coarse to fine irregular, flat or curved laminoid, or coarse to fine tubular fenestrae.

Pellet-intraclast packstones occur throughout the section and account for about 35 percent of the total thickness. Grainstones occur in the lower 50 feet (15.2 m) in layers generally less than 1 foot (0.3 m) thick. They account for about 50 percent of the total thickness at the Cahoon farm. Along strike, it appears that grainstones are much more common and occur throughout the section. Pellet-intraclast packstones and grainstones are light to medium gray and thin- to medium-bedded. Pellets are generally less than 2 mm in diameter, rounded, and spherical to elongate. Intraclasts are less than 4 mm in diameter, subangular to subrounded, and irregular to equant. Limestone and dolomite lithoclasts and chert fragments occur in grainstones. These are about 0.5 inch (12.7 mm) to less than 0.25 inch (6.3 mm). Desiccation cracks are found in the lower part of the section associated with pellet-intraclast packstones (Fig. 10).

Skeletal Limestones--Skeletal fragments are relatively scarce in the New Market Limestone. They occur mostly in the fenestral lime mudstones and pellet-intraclast packstones but they are also associated with non-fenestral types. Skeletal lime mudstones occur throughout the section and account for about 20 percent of the total thickness. Skeletal lime mudstones are the most common skeletal rock type. These are light to medium gray, thin-bedded, fenestral and non-fenestral units. Ostracodes are the most common skeletal type. Trilobite, brachipod, and gastropod fragments are much less common, though two gastropod-rich layers occur near the middle of the section.

The skeletal packstones occur near the base and near the top of the formation and constitute less than 5 percent of the total thickness. Skeletal pellet-intraclast packstones are medium gray and thin-bedded. The pellets are generally less than 2 mm in diameter, are rounded, and are spherical to elongate. Intraclasts are less than 4 mm in diameter, are subangular to subrounded, and are irregular to equant. Ostracodes are the common skeletal type but make up less than 5 percent of the total volume. Trilobite fragments and algal nodules are also present but comprise less than 1 percent of the rock volume.

Biostratigraphy. -- The New Market Limestone contains a very poorly developed fauna. Ostracodes, trilobites, gastropods, and brachipods are present but poorly preserved. Cephalopods are sparsely present locally in the thin New Market Limestone at the Rakes farm. The conodont fauna of the New Market Limestone is typically very poorly developed. Two grab samples from near the Cahoon farm yielded only simple cone forms and *Leptochirognathus quadrata*.

## Lincolnshire Formation

Physical Stratigraphy. -- In the study area the Lincolnshire Formation (Cooper and Prouty, 1943) conformably overlies the New Market Limestone, or where the New Market Limestone is absent, unconformably overlies the Beekmantown Formation directly. On the northwest limb of the Green Ridge anticline the Lincolnshire Formation is 125 feet (39 m) thick (see Appendix A). The Lincolnshire Formation is a dark gray to black, thin- to medium-bedded, cherty, argillaceous, crinoid wackestone packstone. The argillaceous material occurs disseminated through the rock and as brown to black anastomosing and bifurcating layers. These argillaceous layers which contain appreciable dolomite, account for the ribbony, nodular weathering pattern seen in outcrop. The insoluble residue of samples treated with acetic acid shows a dense, black, organic-rich argillaceous and dolomitic framework. Black pancake-shaped chert nodules are common in the middle and upper parts of the formation.

Skeletal Limestones--The Lincolnshire Formation is composed entirely of skeletal rock types. Skeletal constituents are crinoid ossicles, bryozoa, trilobite fragments, brachiopod fragments, ostracode fragments, algal nodules, and rare nautiloids. Crinoid ossicles are the most abundant skeletal type but all other types except the nautiloids are nearly always represented. Skeletal constituents account for as much as 20 percent of the total rock volume.

Skeletal wackestones and skeletal packstones occur in intimate association. Rarely does one type occur without pods of the other interspersed throughout the layer. Skeletal wackestone comprises more than 65 percent of the total thickness of the Lincolnshire Formation. Crinoid ossicles are the most abundant skeletal type but all other types are present. Pellets are common. Lime-mud pellets are less than 3 mm in diameter, dark gray to black, and elongate to subspherical. Skeletal packstones are similar in composition to the skeletal wackestones except for the reduction in mud content. The packstones generally occur as irregularly shaped pods up to 20 mm long in the skeletal wackestones. Wackestone pods in a packstone layer are present but much less common. The skeletal packstones account for as much as 20 percent of the total rock volume.

The only crinoid grainstone lens found occurs at the Rakes farm. It is light gray and composed of crinoid, brachipod, and trilobite fragments. The lens is roughly 1 foot (0.3 m) thick and 3 feet (0.9 m) wide

Biostratigraphy. -- The Lincolnshire Formation contains a relatively rich conodont fauna. Most samples of approximately 10 pounds of limestone yielded at least 50 and sometimes more than 100 well preserved conodont specimens. Of particular importance is the approximate time-line defined by the change from *Polyplacognathus friendsvillensis* to *Polyplacognathus sweeti*. Bergstrom (1973, working with Middle Ordovician limestone sections in eastern Tennessee, has shown that this change is very useful in terms of zonal definition. This change occurs no higher than 60 feet (18.3 m) above the unconformity at the Rakes farm and no more than 234 feet (71 m) above the unconformity at the Cahoon farm (Identification by C. G. Tillman, 1975).

## Effna Limestone

Physical Stratigraphy. -- The Effna Limestone (Cooper, 1944) conformably overlies the Lincolnshire Formation. The Effna Limestone is a light to medium gray, massively bedded, coarse-grained, crinoid-trilobite grainstone (see Appendix A). It is composed primarily of crinoid ossicles exhibiting syntaxial calcite overgrowths. Other constituents are trilobite, echninoderm, brachiopod, ostracode, and gastropod fragments, and sponge spicules.

Non-skeletal constituents are minor and consist of pellets, intraclasts, and rare oolites.

At the Cahoon farm the Effna Limestone is 7 feet (2.1 m) thick; elsewhere it is either covered or absent. At locality $S_3$ (Fig. 2) where the top of the Middle Ordovician limestone section is exposed, the Liberty Hall Formation lies directly on the Lincolnshire Formation.

Biostratigraphy. -- The Effna Limestone contains a very rich and diverse fauna. In addition to the previously noted skeletal types, the conodonts obtained from Effna samples are very well preserved and very abundant; recovery of more than 200 specimens per 10 pound sample is common. Important conodont form species present in the Effna Limestone samples are *Prioniodus prevariabilis*, *Polyplacognathus sweeti*, and *Pygodus anserinus* (Identification by C. G. Tillman, 1975). This fauna appears to just precede the *Prioniodus variabilis* fauna (Bergstrom, 1973) in terms of stage of morphological development (C. G. Tillman, oral communication, 1975).

## Liberty Hall Formation

The Liberty Hall Formation (Campbell, 1905) conformably overlies the Middle Ordovician limestones. The formation is dominantly dark gray to black, evenly and thin-bedded, graptolite-bearing shale and siltstone. In the Fincastle area, interbedded lenses (McGuire, 1970) of dark gray to black, fine-grained argillaceous limestone are present (Karpa, 1974b). The Liberty Hall Formation is 2000 feet (609 m) thick in the Pine Hills depression (Catawba syncline) (Karpa, 1974b). The Liberty Hall Formation contains the Fincastle, Pierce Chapel, Diamond Hill, and Pine Hills conglomerates (Karpa, 1974b). A more detailed description of the Liberty Hall Formation is given by Karpa (1974b).

## DEPOSITIONAL AND EROSIONAL HISTORY

### Pre-unconformity Beekmantown Formation

Limestones and dolomites of the Beekmantown Formation on the northwest limb of the Green Ridge anticline are considered to represent deposition in a subtidal carbonate shelf environment. The increased limestone content here is in contrast to the shallower water, much more dolomitic facies of northwestern strike belts (Butts, 1940; Cooper, 1961; and Harris, 1973).

The Beekmantown Formation in the study area is classified, following Harris (1973), as a transition of facies between dominantly limestone on the southeast to dominantly dolomite on the northwest. Characteristics of Harris' (1973, p. 73) transition zone are the presence of "about equal proportions of dolomite and limestone, apparently reflecting the gradual lateral shift of the eastern part of the high salinity (water) mass, ...a higher proportion of oolite in relation to intraclasts, and records (of) the first stratiform algal stromatolites in dolomite." The Beekmantown Formation on the northwest limb of the Green Ridge anticline exhibits these characteristics with the exception of increased oolite content. The lack of oolites may reflect a position southeast of the transition zone, or it may simply indicate an environment of less energy than is typically found in the transition zone.

### Beekmantown - Middle Ordovician Unconformity

The end of Beekmantown sedimentation is marked by a regional unconformity that apparently was developed over much, if not all, of the Southern Appalachians. On the northwest limb of the Green Ridge anticline, topographic relief on the surface of unconformity amounts to at least 165 feet (50 m). This is based on the following observations:

1) Two paleodolinen penetrate at least 165 feet (50 m) downward into the Beekmantown Formation at the Rakes and Huffman farms. There the basal Lincolnshire Formation rests directly on Beekmantown carbonates.

2) On the Cahoon farm, the erosional channel which was cut into Beekmantown carbonates prior to Middle Ordovician time is overlain by 165 feet (50 m) of New Market deposits, which apparently conformably underlie the Lincolnshire Formation. Thus it appears base level controlled the maximum depth reached by both stream erosion and solution on a topographic high.

3) From Kyles Mill northward to the Rakes farm, a distance of approximately 1 mile (1.6 km) along strike (Fig. 2), the New Market Limestone is very poorly developed and occurs only in lenses up to 15 feet (4.5 m) thick and up to 50 feet (15 m) wide. Elsewhere along this extent, the Lincolnshire Formation directly overlies the Beekmantown Formation (Fig. 11).

4) Southward from 0.5 mile (0.8 km) south of Kyles Mill and northward from 0.25 mile (0.4 km) north of the Rakes farm, the New Market Limestone is approximately 165 feet (50 m) thick (Fig. 11).

5) The Lincolnshire Formation appears to be approximately 125 feet (39 m) thick for the entire extent of the outcrop belt.

The key point is that the total thicknesses (or vertical extents) of the formations and erosional features below the Lincolnshire Formation and above the unconformity (or above the lowest extent of the paleodolinen) always approximates 165 feet (50 m). If one assumes that the base of the Lincolnshire Formation is a rough datum, as is indicated by field relations, then the above observations show that topographic relief on the unconformity surface was approximately 165 feet (50 m). This is a minimum estimate. If conodont studies show that the Polyplacognathus friendsvillensis to P. sweeti change occurs much higher in the Cahoon farm section than in the Rakes farm section, then stratigraphic and topographic relief would be much greater than 165 feet (50 m). Fig. 11 is a diagrammatic section of the northwest limb of the Green Ridge anticline drawn parallel to strike and incorporating the above observations.

Emergence of a Beekmantown terrain was the result of either eustatic lowering of sea level or tectonic uplift or both. Various authors (Cooper, 1961, 1964; Eubank, 1967; Hazlett, 1968; Lowry 1971a, 1972, 1974; Gambill, 1974; and Frieders, 1975) cite evidence for at least partial structural control of the unconformity. Evidence cited is: 1) greater relief on the surface of unconformity on the crests of anticlines (Cooper, 1961, Gambill, 1974), 2) better developed basal conglomerate on the flanks of anticlines, 3) the Blackford Formation at the base of the Middle Ordovician section in northwestern belts is thickest in troughs of synclines, 4) continuous sedimentation across the Beekmantown - Middle Ordovician limestone boundary in the troughs of some synclines or thick Middle Ordovician limestone sections in the troughs of synclines that decrease in thickness over the crests of anticlines (Lowry, 1972), and 5) convergence of forma-

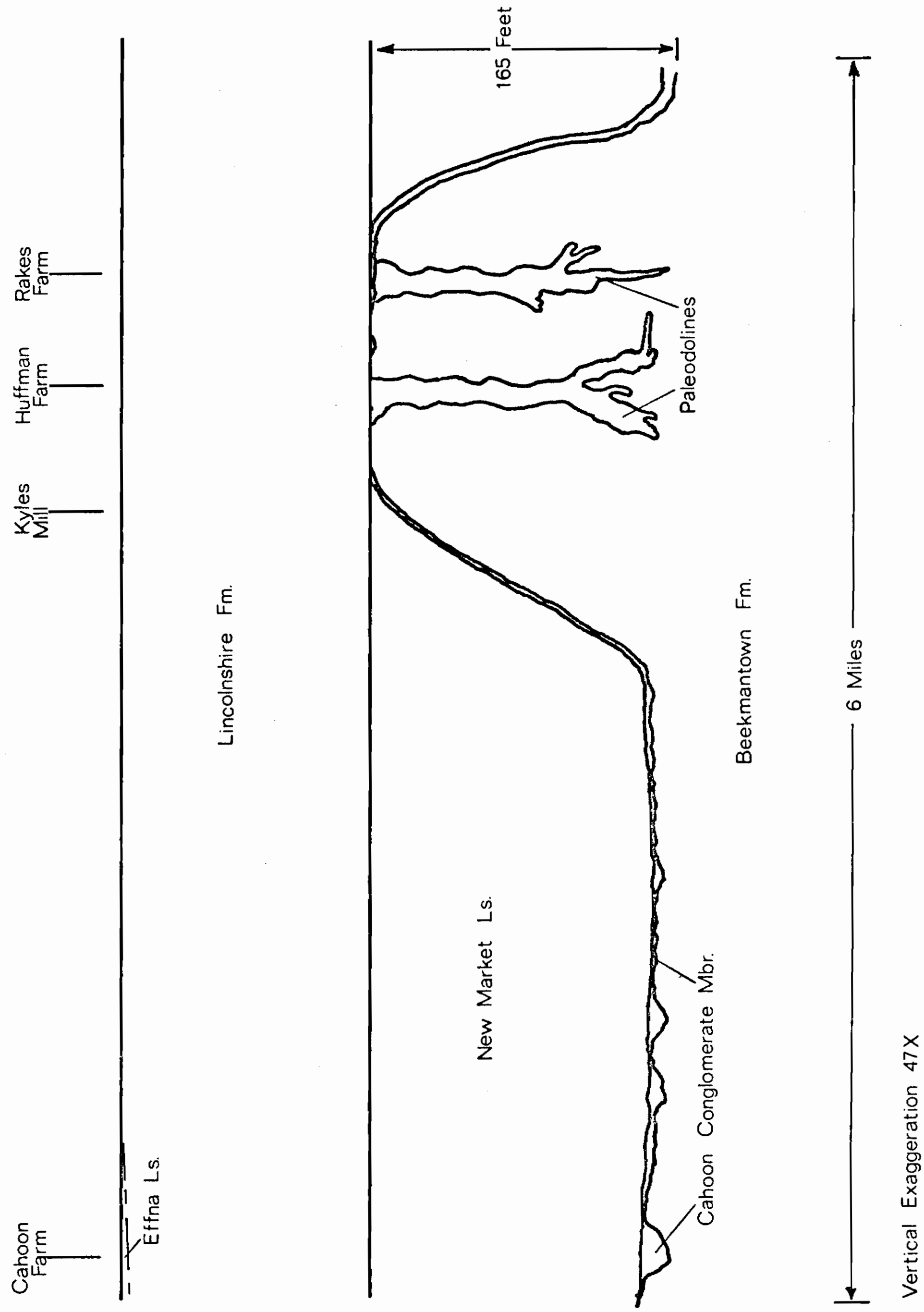



**FIG. 11. Diagrammatic Structure Section Parallel to Strike on the Northwest Limb of the Green Ridge Anticline**

tions on either side of the unconformity both up-dip and up-plunge (Frieders, 1975).

Much of the evidence for structural relief is based on using the Longview Limestone in the Knox Group as a lower datum. The Longview Limestone is a physical stratigraphic marker that is recognized by lithologic properties and biostratigraphically by the occurrence of the gastropod Lecanospira. The Longview has been shown to cross time lines to at least a limited extent (Tillman, oral communication, 1975), so it must be used with caution as a lower datum. However, use of the Longview as a lower stratigraphic datum is acceptable within these limitations.

Reconnaissance studies indicate that if the Longview Limestone is present in the study area as a distinct lithologic unit, it is lower in the thick Beekmantown section (much lower than 865 feet or 264 meters) at the Rakes farm. If so, then the Beekmantown section at the Rakes farm is one of the thicker sections in the Southern Appalachians. This would further suggest a much greater amount of regional relief on the unconformity surface than has been documented to date. The other more likely alternative is that the equivalent of the Longview Limestone is not present as a discrete identifiable unit at the Rakes farm but rather is contained unrecognized in the Beekmantown Formation. If this is so, the Beekmantown Formation in the study area (at least the basal and middle part) is roughly correlative to the Longview Limestone and post-Longview upper Knox Group dolomites and cherts present in the Lusters Gate - Ellett area (Fig. 1). Additional studies, especially of conodonts, will be needed to reveal the position of the Longview Limestone or correlative beds on the northwest limb of the Green Ridge anticline and to show their relationship to the highest 265 feet (81 m) of beds which have yielded the conodont fauna reported from the Cahoon and Rakes farms.

## Post-unconformity Middle Ordovician Limestones

Cahoon Conglomerate Member. -- The Cahoon Conglomerate represents deposition by a fluvial or tidal drainage system developed on the Beekmantown Formation. The irregular distribution and highly variable thickness of the basal conglomerate are believed to be the result of the filling of these channels rather than the surface fillings of dolines. First, the cement matrix of the conglomerate is essentially clean, sparry calcite. This suggests that water was flowing fast enough to prevent deposition of silt and clay (or to remove any that may have been present). If the basal conglomerate represented doline fillings, one would expect to find abundant silt and clay and possibly fine-grained dolomite similar to that found associated with the paleodolinen at the Rakes and Huffman farms. Second, the conglomerate fines upward and the clasts become more rounded (Fig. 8), suggesting that the unit is water-laid. Third, the conglomerate contains discrete, well-defined bedding surfaces (Fig. 9). This is in contrast to the two doline fillings seen at the Rakes and Huffman localities which show no bedding, even in the highest breccias adjacent to the unconformity. Fourth, imbrication of clasts is common in the conglomerate (Fig. 9). This suggests a more orderly depositional scheme than the random solution and collapse seen in paleodoline fillings at the Rakes and Huffman localities. And fifth, the Beekmantown Formation under the Cahoon Conglomerate is intact, with no disruption in bedding seen at any locality. If the conglomerate were of karst origin, solution of the underlying carbonates of the Beekmantown Formation would surely be present where maximum thicknesses of the Cahoon Conglomerate occur. On the contrary, only in the vicinity of the Rakes and Huffman farms, where the Cahoon Conglomerate is absent or only poorly developed, did extensive solution take place in the Beekmantown Formation.

The majority of occurrences where the Cahoon Conglomerate is less than 5 feet (1.5 m) thick may represent lag deposits on interfluves. In these areas the basal conglomerate is very poorly developed and it may represent largely the reworked thin residual regolith developed on the surface of unconformity.

A gradual transition from terrigenous clastic to marine tidal flat deposition is shown by the fining upward of the basal conglomeratic beds into dominantly fine-grained dolomite. Cryptalgal structures exhibiting incipient desiccation cracks near the top of the section represent the initial development of extensive tidal flats covering Beekmantown terrain.

Post-conglomerate New Market Limestones. -- Tidal flat sedimentation is represented by the post-conglomerate New Market Limestone. Fenestral fabrics,an integral part of the New Market Limestone, represent voids formed during exposure and desiccation of tidal flat muds (Shinn, 1968). These voids were later filled with sparry calcite. Tubular fenestrae probably represent calcite-filled burrows.

Crystal silt is common throughout the post-conglomerate New Market Limestone and is a product of vadose processes (Dunham, 1969). Crystal silt is formed by the infiltration of meteoric water which causes internal erosion of minute crystals lining voids. The percolating water carries the silt downward to be deposited on void floors lower in the profile

(Dunham, 1969; Read, 1973). Vadose profiles are formed during regression or when the groundwater table is depressed below sea level due to evapotranspiration or elevation of the supratidal zone (Read, 1973, p. 378).

The grainstones in the New Market Limestone probably represent storm deposits on the tidal flats.

The fenestral fabric sequences and the presence of crystal silt in this formation indicate that while the general nature of the New Market Limestone is transgressive, shoal conditions prevailed during much of New Market deposition.

Lincolnshire Formation. -- An almost complete lack of cryptalgal structures, the presence of crinoids, brachiopods, and trilobites, and a radical increase in the mud to grain ratio indicate the Lincolnshire Formation was deposited in a somewhat deeper, less energetic marine environment. The well-defined basal contact indicates the change in conditions was relatively abrupt.

Effna Limestone. -- Grainstones of the Effna Limestone appear to be very irregularly developed carbonate sand bodies composed almost entirely of skeletal grains. The Effna Limestone most likely represents offshore biostromal skeletal buildups (Cooper, 1944).

## SUMMARY

The depositional and erosional history can be summarized as follows:

1) Subtidal carbonate shelf sedimentation through Early Ordovician (and including early Middle Ordovician White Rock?) time represented by the Beekmantown Formation.

2) Emergence of a Beekmantown terrain due to eustatic lowering of sea level and inception of gentle folding in late Early Ordovician (or early Middle Ordovician White Rock?) time. Subsequent erosion of the Beekmantown Formation and development of drainage and topographic relief. Development and filling of the paleodolinen on the topographic high.

3) Transgression of the sea. Previously developed drainage was drowned, evidenced by fining upward of the Cahoon Conglomerate Member into dolomite. Continued development and filling of the paleodolinen on the still exposed topographic high.

4) Development of tidal flats with numerous shoaling episodes as evidenced by fenestral fabrics and crystal silt in the New Market Limestone. Fresh meteoric waters available for crystal silt to fill voids throughout much of New Market time. Continued development and filling of the paleodolinen on the still exposed topographic high. Topographic high exposed until end of New Market time.

5) Beginning of Lincolnshire sedimentation marks complete submergence of topographic high. Deeper water, lower energy environment with abundant argillaceous material being brought into the basin and abundance of mud producing organisms.

6) Development of offshore biostromes as represented by Effna Limestone. Lack of mud may reflect high energy or the absence of mud-producing organisms.

## STRUCTURAL HISTORY OF THE GREEN RIDGE ANTICLINE

As this study deals with only the northwest limb of the Green Ridge anticline, evidence bearing on the structural development of the anticline is limited. Some generalizations and speculations can be advanced, however, based on local and regional considerations. Some type of structure may have begun to develop by late Early Ordovician time along the area that is presently occupied by the Green Ridge anticline as the present northwest limb is the locus of unique topography developed on the surface of unconformity. The Ellett area located almost on the nose of the Catawba syncline is the location of at least 360 feet (110 m) of relief on the surface of unconformity (Eubank, 1967). This is based on thickness variations of the post-Longview upper Knox Group and the presence of Ellett "Red Beds." The Ellett "Red Beds" are a basal Middle Ordovician stream-estuarine deposit filling a valley with a maximum depth of 85 feet (26.5 m) and a width 1.1 mile (1.8 km) wide (Eubank, 1967). Also in the Ellett area, the total thickness of the Middle Ordovician limestones overlying the red beds is 482 feet (147 m) from the unconformity to the top of the Effna Limestone (John Wilson, oral communication, 1975). The change from _Polyplacognathus friendsvillensis_ to _P. sweeti_ occurs at approximately 260 feet (79.2 m) above the unconformity.

At Stypes Branch on the northwest limb of the Green Ridge anticline (Fig. 1), the upper Knox section from the Longview Limestone to the unconformity is only about 60 feet (18.4 m) thick. The Middle Ordovician limestone section above the unconformity consists of only 16 feet (4.9 m) of grainstone (Murphy, 1968).

At the Waldron-Fralin Quarry (Fig. 1) the post-Longview part of the section to the unconformity is on the order of 30 feet (9 m) and the Middle Ordovician limestones consist of to an estimated 45 feet (13.5 m) of grainstone. Conodonts from these rocks show the upper two-thirds to be Effna or younger, suggesting great relief on the unconformity surface (C. G. Tillman, oral communication, 1975).

The Middle Ordovician section at the Bricker farm (collected and described by J. F. Read and G. Grover, 1975), on the northwest limb of the Catawba syncline, (Fig. 1) consists of about 390 feet (119 m) of rock said to be mainly of Effna-type limestone. Conodonts studied by Tillman (oral communication, 1975) indicate the upper 200 feet (61 m) is at least as young as Effna and probably younger, and the underlying New Market-age rocks are less than 90 feet (27.5 m) thick.

At the Cahoon farm (Fig. 1 and 2) the Middle Ordovician section is 297 feet (80.6 m) thick with no more than 234 feet (71.3 m) of section below the P. friendsvillensis - P. sweeti transition. The New Market is well developed. Only 84 feet (25.6 m) of the Middle Ordovician limestone section is exposed at the Rakes farm. The P. friendsvillensis - P. sweeti transition occurs no more than 60 feet (18.3 m) above the unconformity. The New Market rocks are very poorly developed here.

The apparent localization of well defined topographic relief on the surface of unconformity and both thin Beekmantown (upper Knox) carbonates and Middle Ordovician limestones might be the result of fortuitous sampling. Perhaps closer spaced and more thoroughly sampled sections would reveal similar relations across the structure. On the other hand, the alignment of these features parallel to structural trends may reflect structural control of the unconformity.

Perhaps the most reasonable explanation to account for the localization of these features is that the present Green Ridge anticline was an evolving hinge zone. This hinge zone would mark the break in slope between the horizontal or gently sloping "Blue Ridge upland" to the southeast and the more steeply sloping basinal flank leading northwest to the Catawba syncline. Slope angles probably were less than 3°. The postulated evolving hinge would serve to localize erosion and control the development of karst features and drainage on an otherwise lithologically and structurally homogeneous terrain.

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# APPENDIX A

## Geologic Sections

Geologic Section One: Middle Ordovician limestones in intermittent creek bed behind the E. G. Cahoon farm house on County Road 630, 0.75 mile (1.2 km) east of Fincastle, Botetourt County, Virginia

| | Thickness | |
|---|---|---|
| | Feet | Meters |
| Liberty Hall Formation | | |
| Effna Limestone | 7 | 2.1 |
| 21. Light to medium gray, massive-bedded crinoid-trilobite grainstone . . . . . . | 7 | 2.1 |
| Lincolnshire Formation | 126 | 38.5 |
| 20. Dark gray to black, thin- to medium-bedded, argillaceous criniod wackestone; nodular black chert; trilobites, brachiopods, bryozoa, and rare nautiloids . . . | 120 | 36.5 |
| 19. Medium gray, medium-bedded, crinoid wackestone; rare brachiopods . . . . . . | 6 | 1.8 |
| New Market Limestone | 144 | 44 |
| 18. Light to medium gray, thin- to medium-bedded, pellet-intraclast packstone with abundant irregular fenestrae; scattered ostracods . . . . . . . . . . . . . . . . | 31 | 9.5 |

| | | Thickness | |
|---|---|---|---|
| | | Feet | Meters |
| 17. | Light gray, thin-bedded lime mudstone with scattered tubular fenestrae; some gastropods and ostracods . . . . . . . | 10 | 3 |
| 16. | Light to medium gray, thin-bedded lime mudstone with curved laminoid fenestrae and crystal silt . . . . . . . . . . . | 8 | 2.4 |
| 15. | Light gray, thin-bedded, lime mudstone with alternating fine tubular fenestrae and medium irregular fenestrae; some thin beds of intraclast packstone . . | 13 | 4 |
| 14. | Light to medium gray, thin- to medium-bedded alternating pellet-intraclast packstone with large irregular fenestrae and lime mudstone with scattered small irregular fenestrae; rare gastropods . | 7 | 2.1 |
| 13. | Medium gray, medium-bedded, ostracod lime mudstone . . . . . . . . . . . | 13 | 4 |
| 12. | Covered . . . . . . . . . . . . . . . . . | 6 | 1.8 |
| 11. | Light to medium gray, thin- to medium-bedded, alternating ostracod lime mudstone, intraclast-lithoclast packstone and grainstone . . . . . . . | 12 | 3.7 |

| | Thickness Feet | Meters |
|---|---|---|
| 10. Medium gray, thin- to medium-bedded introclast-lithoclast grainstone; 0.25 - 0.5 inch (6-12 mm) rounded lithoclasts . . . . . . . . . . . . . | 6 | 1.8 |
| 9. Medium gray, thin-bedded lime mudstone with fenestrae and crystal silt . . . | 9 | 2.7 |
| 8. Medium gray, thin-bedded lime mudstone with crystal silt . . . . . . . . . . | 13 | 4 |
| 7. Covered . . . . . . . . . . . . . . . . | 5 | 1.5 |
| 6. Medium gray, thin-bedded lime mudstone with irregular and laminoid fenestrae | 1 | 0.3 |
| 5. Light to medium gray to buff pellet packstone with irregular and laminoid fenestrae and crystal silt; limited fine carbonate clasts; desiccation cracks; dolomitic . . . . . . . . . . | 7 | 2.1 |
| 4. Medium gray, thin-bedded pellet-intraclast packstone with thin lithoclast layers and crystal silt . . . . . . . | 2 | 0.6 |
| Cahoon Conglomerate Member | 21 | 6.5 |
| 3. Light gray to yellow, thin-bedded to laminated fine clastic dolomite and limestone. Clasts are less than 0.5 inch (12.7 mm); limited cross-laminations | 6 | 1.8 |

| | Thickness Feet | Meters |
|---|---|---|
| 2. Light to medium gray, thin- to medium-bedded dolomite and limestone conglomerate with thin interbedded dolomite; clast size less than 2 inches (5 cm) with long dimension commonly paralled to bedding . . . . . . . . . . . . . . . . . | 9 | 2.7 |
| 1. Massive dolomite and limestone conglomerate; clasts range from 1.5 feet (0.45 m) to less than 1 inch (2.5 cm) but most from 2 to 6 inches (5 to 15 cm) lond diameter, angular to subrounded. Matrix is pellet-intraclast grainstone; fines upward . . . | 6 | 1.8 |

Unconformity

Beekmantown Formation

Geologic Section Two: <u>Middle Ordovician limestones behind Rakes farm house, 0.9 mile (1.4 km) north of Kyles Mill, Botetourt County, Virginia</u>

| | Feet | Meters |
|---|---|---|
| Lincolnshire Formation | 81+ | 24.5+ |
| 10. Covered, top not exposed . . . . . . . . | | |
| 9. Dark gray to black, thin-bedded, ribbony argillaceous crinoid wackestone; interbedded thin layers of black chest nodules | 47 | 14.5 |
| 8. Covered . . . . . . . . . . . . . . . . . | 3 | 0.9 |
| 7. Dark gray to black, thin-bedded, ribbony argillaceous crinoid wackestone; brachiopods and trilobites present . . . . . . . . . . | 9 | 2.7 |

| | Thickness Feet | Meters |
|---|---|---|
| 6. Light gray, coarse-grained crinoid grainstone . . . . . . . . . . . . . . | 1 | 0.3 |
| 5. Dark gray to black, thin-bedded, ribbony, argillaceous crinoid wackestone; brachiopods and trilobites . . . . . . . . | 5 | 1.5 |
| 4. Medium gray, thin-bedded pellet packstone | 4 | 1.2 |
| 3. Medium gray to black thin-bedded pellet-intraclast packstone - wackestone. Sparse ostracods, brachiopods, and gastropods . . . . . . . . . . . . . . | 3 | 0.9 |
| New Market Limestone | | |
| 2. Light to medium gray, thin-bedded alternating pellet packstone and lime mudstone; abundant irregular and curved laminoid fenestrae . . . . . . . . . | 4 | 1.2 |
| 1. Dolomite and limestone conglomerate; clasts 4 inches (10 cm) to 1 foot (0.3 m) long; lack of finer clastic material; dolomitic matrix . . . . . | 1 | 0.3 |
| Unconformity | | |
| Beekmantown Formation | | |

# APPENDIX B

## Conodont Species from Beekmantown Formation

| CONODONT SPECIES | CAHOON FARM Samples | | | | | | RAKES FARM Samples | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 |
| Acodus oneotensis Furnish s.s. | | | | | | | X | | | | |
| A. oneotensis (of Druce & Jones, 1971) | | | | X | X | | X | X | X | | X |
| Acontiodus iowensis Furnish | | | X | | | | | | | | |
| A. staufferi Furnish | | | X | | X | | X | X | | | X |
| Cordylodus sp. | | | X | | | | | | | | |
| Distacodus peracutus Lindstrom | | | X | | | X | | | | | |
| Drepanodus concavus (Branson & Mehl) | | | | | X | | | | | | |
| D. gracilis (Branson & Mehl) | | | X | X | X | X | X | X | | | |
| D. pandus (Branson & Mehl) | | | | X | X | | | | | | |
| D. homocurvatus Lindstrom | | | | X | X | X | X | X | X | | X |
| D. subarcuatus Furnish | X | X | X | X | X | X | X | X | X | X | X |
| D. suberectus (Branson & Mehl) | X | | X | | | | X | | X | | |
| D. simplex Branson & Mehl | | | | X | | | X | X | | | |
| D. triangularis (Furnish) | X | | X | X | X | X | X | | | | |
| D. toomeyi Ethington & Clark s.s. | | | | | | | | X | | | |
| D. vulgaris (Branson & Mehl) | | | | | | | X | X | X | | |
| D. sp. A | | | | X | | | | | | | |
| Leptochirognathus sp. A | X | | | | | | | | | | |
| Leptochirognathus quadrata Branson & Mehl | | | | | | | | | | X | X |
| Loxodus bransoni Furnish | | | | | | | | X | | | |
| Oepikodus equidentatus Ethington & Clark | | | | | | | | | | | |
| Oepikodus sp. | | | X | | | | | | | | |
| Oistodus delta Lindstrom | | | | X | | | | | | | |
| O. inequalis Pander, 1856 | X | X | X | X | | X | X | | | | |
| O. lanceolatus Pander | X | | X | | | X | | | | | |
| O. longiramus Lindstrom | | | | | | X | | | | | |
| O. parallelus Pander | | | | X | | | | X | | | X |
| O. triangularis Lindstrom | | | X | | | X | | | | | X |
| Scandodus furnishi Lindstrom | X | | X | X | X | X | X | X | X | | X |
| Scandodus sp. A | X | | | | | | | | | | |
| Scolopodus cornutiformis Branson & Mehl s.s. | | | X | X | X | X | X | X | | | X |
| S. cornutiformis (of Ethington & Clark, 1971) | X | | X | X | | | | | | | |
| S. emarginatus Barnes & Tuke | | | | | X | | X | X | X | | X |
| S. filosus Ethington & Clark, 1964 | | | | X | | | | X | | | |
| S. quadraplicatus Branson & Mehl | X | X | X | X | X | X | X | X | X | X | X |
| S. aff. S. multicorrugatus Harris | X | | X | | X | X | | | | | |
| S. sp. A | X | X | X | X | X | X | X | X | X | | X |
| Ulrichodina abnormalis (Branson & Mehl) | | | | X | X | | X | | X | | |
| U. wisconsinensis Furnish | X | | | | | | | | | | |

Cahoon Farm Samples
(Feet below unconf.)

1 - 106.2
2 - 83.8
3 - 67.1
4 - 58.3
5 - 18.4
6 - 4.8

Rakes Farm Samples
(Feet below unconf.)

1 - 60.9
2 - 43.3
3 - 42.9
4 - 33.0
5 - 16.9

## VITA

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Joseph K. Campbell

BEEKMANTOWN FORMATION - MIDDLE ORDOVICIAN

LIMESTONE UNCONFORMITY ON THE NORTHWEST LIMB

OF THE GREEN RIDGE ANTICLINE NEAR FINCASTLE, VIRGINIA

by

Joseph K. Campbell

(ABSTRACT)

The unconformity between the Beekmantown Fm. and Middle Ordovician limestones on the northwest limb of the Green Ridge anticline is characterized by paledolinen and thickness variations of the New Market Ls. which attest to at least 165 feet of topographic relief.

Early Ordovician (and early Middle Ordovician?) Beekmantown carbonates are unconformably overlain by either the New Market Ls. or the superjacent Lincolnshire Fm. The New Market consists of a basal dolomite and limestone conglomerate and breccia, here named the Cahoon Conglomerate Member, and overlying fenestral limestones. The conglomerate reaches a maximum thickness of 21 ft. at the Cahoon farm and two other localities and thins laterally within 150 ft. to either side of the maximum to only 5 ft. Elsewhere the maximum thickness is less than 7 ft. The conglomerate consists of subrounded to subangular, subspherical to irregular clasts of dolomite and limestone and grades upward into fine-grained laminated dolomite with some clastic material. Overlying fenestral limestones are more typical of New Market rocks elsewhere. The New Market ranges from 165 to 0 ft. thick.

At the Rakes farm 4 mi. NNE of Fincastle the unconformity attains a relief of at least 165 ft. Here the New Market occurs only locally in lenses up to 15 ft. thick and 50 ft. wide and in places the Lincolnshire rests directly on the Beekmantown. At the Rakes and Huffman farms two well shaped, breccia-filled paleodolinen extend downward 165 ft. stratigraphically from the unconformity. The main body of both cavities is about 50 ft. wide though thin seams extend laterally as much as 200 ft. The cavity fillings are dolomite and limestone breccia derived by solution of the Beekmantown. Clasts range from 0.25 in. to greater than 5 ft. across and are angular. Clast boundaries are thoroughly altered by solution.