

STRATIGRAPHY AND SEDIMENTOLOGY
CAMBRIAN SHADY DOLOMITE,
VIRGINIA

by

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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF FIGURES	v
INTRODUCTION	1
PREVIOUS WORK	3
METHODS	5
STRATIGRAPHIC AND STRUCTURAL SETTING	6
STRATIGRAPHY OF THE SHADY DOLOMITE, AUSTINVILLE AREA . . .	12
Northwestern Belts	15
Southeastern Belts	19
LITHOFACIES	23
Lithofacies, Northwestern Sections	23
Ribbon-laminated to Burrow-mottled Carbonates . .	24
Massive Dolomites	28
Fenestral and Cryptalgal Carbonates	28
Dolomitized Ooid Grainstone	31
Dolomitized Limeclast Grainstone	31
Lithofacies, Southeastern Sections	32
Limeclast Grainstone	39
Calcareous Algal Boundstone Bioherms	42
Limestone Breccia	50
Black Laminated Limestone and Shale	56
Lime Mudstone Masses	59

	Page
DEPOSITIONAL ENVIRONMENTS	63
Depositional Environments, Northwestern Belts	63
Depositional Environments, Southeastern Belts	66
PALEOGEOGRAPHY AND REGIONAL SIGNIFICANCE	74
CONCLUSIONS	81
REFERENCES	84
APPENDIX A - DIAGENESIS	92
Cementation	92
Dolomitization	92
Pressure Solution and Paragenesis of Ribbon-	
Laminated Carbonates, Patterson Member	94
APPENDIX B - MEASURED SECTIONS	99
VITA	138

LIST OF FIGURES

Figure	Page
1. Geological map, Austinville area	8
2. Cambrian stratigraphy, Austinville area	10
3. Diagrammatic stratigraphic cross section, Austinville area	14
4. Stratigraphy, Austinville and Ivanhoe Members, Shady Dolomite, northwestern sections	18
5. Stratigraphy, upper Shady Dolomite, southeastern sections	22
6. Ribbon-laminated and burrow-mottled carbonates, Patterson Member	26
7. Cryptalgal laminated carbonates, Austinville Member .	30
8. F. and M. Construction Company Quarry, Map of quarry walls	34
9. Limited paleocurrent data, upper Shady Dolomite . .	36
10. Limeclast grainstone, upper Shady Dolomite	41
11. Geometries of calcareous algal boundstone bioherms, F. and M. Construction Company Quarry	44
12. Calcareous algae, upper Shady Dolomite	47
13. Boundstone fabrics, upper Shady Dolomite	49
14. Columnar cements, calcareous algal boundstone, upper Shady Dolomite	52
15. Breccia fabrics, upper Shady Dolomite	55

Figure	Page
16. Black, evenly bedded pellet grainstone and fine-grained argillaceous limestone	58
17. Lime mudstone masses, upper Shady Dolomite	62
18. Schematic paleogeography, Rome Formation - upper Shady Dolomite	77
19. Paragenetic sequence, ribbon-laminated carbonates, Patterson Member	97

INTRODUCTION

Cambrian shallow water platform carbonates in the Appalachian Valley and Ridge Province pass eastward into pelitic, deeper water facies in the Piedmont (Rodgers, 1968). However, platform margin carbonates are rarely exposed in the Appalachians as they are overthrust by older rocks of the Blue Ridge Province or have been eroded from the Blue Ridge. Southeast of Austinville, in the Virginia Valley and Ridge Province, southeastern facies of the Shady Dolomite are exposed adjacent to overthrust Blue Ridge rocks. These southeastern facies have been interpreted as platform margin facies of the Cambrian carbonate bank of eastern North America (Rodgers, 1968; Palmer, 1971; Byrd, 1973b). Although previous workers noted the eastward thickening carbonate sequence southeast of Austinville, the presence of coarse-grained calcarenites, carbonate breccias, shales (Currier, 1935; Stose and Jonas, 1938; Butts, 1940) and algal reefs (Byrd, 1973b), the detailed stratigraphy and sedimentology of these important deposits has been neglected.

Calcareous algal boundstones have previously been reported from Upper Cambrian and Ordovician rocks of central Texas (Ahr, 1971), from Middle Cambrian rocks of the southern Canadian Rockies (McIlreath, 1976), and from Upper Cambrian rocks of Nevada-Utah (Lohmann, 1976). However, calcareous algal boundstones (reefs) have not been reported from elsewhere in the Appalachians, except for metamorphosed pod-like masses of presumed algal origin described by

Thompson (1976) from the Alabama Piedmont. The Shady algal reefs are excellently preserved and appear to have formed rigid submarine mounds.

This study describes the physical stratigraphy and sedimentology of the exposed Shady Dolomite beds northwest and southeast of Austinville and their local and regional lithofacies variation. The northwest to southeast facies changes are related to a platform to basin model (Wilson, 1975). The generally well-preserved lithofacies of the Shady Dolomite in the Austinville area should provide valuable information for interpretation of metamorphosed equivalents in the Appalachian Piedmont.

PREVIOUS WORK

The Shady Dolomite was named for exposures in Shady Grove, Johnson County, Tennessee (Keith, 1903). Currier (1935) and Butts (1940) described the Shady Dolomite at Austinville, Virginia and subdivided the unit into the Patterson, Austinville and Ivanhoe Members. Butts (1940) named the Patterson Member for exposures of ribbon-laminated limestone and dolomite at Patterson, Virginia and the Austinville Member for overlying saccharoidal dolomite at Austinville, Virginia. Currier (1935) named the Ivanhoe Member for the inter-layered limestones and dolomites (approximately 160 m thick) overlying saccharoidal dolomite along the N & W railroad at Ivanhoe, Virginia. Stose and Jonas (1938) and Cooper, et al. (1961) included limestones of the upper Ivanhoe Member in the overlying Rome Formation. More recent workers (including the author) have restricted the Ivanhoe Member to a thin interval (0-30 m) of limestone that overlies interbedded limestone and dolomite of the upper Austinville Member. The Ivanhoe beds are overlain by Rome Formation red shales and mudrocks (Brown and Weinberg, 1968; Weinberg, 1963; 1971). Two sets of nomenclature for the three members are now in use; local workers use Ribbon, Austinville and Carbide Members, while the U.S.G.S. uses Patterson, Saccharoidal and Ivanhoe Members. In this study, Patterson, Austinville and Ivanhoe Members will be used.

Currier (1935) and Butts (1940) noticed an apparent thickness increase and major facies change between the Shady Dolomite exposed

northwest of Austinville and that exposed to the southeast. Stose and Jonas (1938) correlated the southeastern facies with the Vintage Dolomite, Kinzers Formation and Ledger Dolomite on the basis of lithologic similarities with these formations in Pennsylvania. Workers at the New Jersey Zinc Company mine at Austinville established the relative stratigraphic position of the southeastern facies as overlying the Austinville Member and termed them the "Mystery Series" (Brown, 1953) or "Post Taylor Marker" beds (Brown and Weinberg, 1968; Weinberg, 1963; 1971).

A regional study of the Shady Dolomite by Byrd (1973a; 1973b) described the general lithofacies distribution of the Shady Dolomite and included a brief description of the facies southeast of Austinville. Breccias in the southeastern facies were briefly described by Lowry and Willoughby (1975).

Resser (1938) described a Lower Cambrian fauna from Fossil Point in the southeastern facies of the Shady Dolomite. Subsequent work on the paleontology and biostratigraphy of the unit has been done by Balsam (1974), Byrd, Weinberg and Yochelson (1973), and Willoughby (1976). Willoughby (1976) recollected Resser's localities and determined that the Shady Dolomite southeast of Austinville spans the Lower-Middle Cambrian boundary with a Cambrian fauna no younger than lower Glossopleura Zone. The detailed paleontology and biostratigraphy of the Shady Dolomite are described in Willoughby (in prep.).

METHODS

Nine partial stratigraphic sections of the Shady Dolomite were measured by tape and compass traverses. In addition, detailed sections were measured using a Jacob's Staff. Complex lithofacies relationships in the F. and M. Construction Company Quarry were documented by mapping of the quarry walls using polaroid photographs. Etched, polished slabs of lithologic samples were examined under a binocular microscope and stained thin sections of selected lithologies were studied using a petrographic microscope (Dickson, 1965). Carbonate rocks were classified according to depositional texture (Dunham, 1962) and, where recrystallized, according to crystal size (Folk, 1965).

STRATIGRAPHIC AND STRUCTURAL SETTING

The Austinville region is located in southwestern Virginia at the southeastern margin of the Valley and Ridge Province of the Appalachians adjacent to overthrust rocks of the Blue Ridge Province (Fig. 1). Exposed rocks in the area include, from base to top, (1) Chilhowee Group, (2) Shady Dolomite, (3) Rome Formation and (4) Elbrook Formation (Fig. 2). The Shady Dolomite (commonly 600 m thick) northwest of Austinville consists of, from base to top, 1) Patterson Member, 2) Austinville Member and 3) Ivanhoe Member. To the southeast, the upper Shady Dolomite thickens, apparently at the expense of the Rome Formation.

Structurally, the Austinville region is located on the Max Meadows thrust sheet. Major folds in the area are asymmetric and include the Austinville anticline and Austinville syncline (Fig. 1). Southeast of Austinville, the Shady Dolomite forms a series of homoclinal beds. The exposed sequence is terminated to the southeast by overthrust Cambrian and Precambrian rocks of the Blue Ridge thrust sheet. The numerous faults in the area are of two general types: 1) high-angle reverse faults (Laswell, Gleaves, Fosters Falls, Logwasher, Stamping Ground, Blue Grass and Callahan faults) and 2) low-angle thrust faults (Van Mater and Blue Ridge faults). Although the structure cross section (Fig. 1) shows only two low-angle thrust faults, the Austinville area probably contains others of undetermined displacement (Weinberg, pers. comm., 1976). In addition to reverse

Figure 1. Geological map of the Austinville area from Weinberg, 1971. Dot on index map indicates location of study area. Town of Austinville is shown by large dot in center of map. Ivanhoe Member is not shown due to scale of map. Numerals refer to measured sections used in constructing Figure 3. Measured sections: 1 - Porters Crossroads, 2 - Fosters Falls, 3 - Ivanhoe, 4, 5, 6, 8 - Clear Branch, 7A - Rudy Farm, 7B - F. and M. Construction Company Quarry and 7C - Rte. 52.

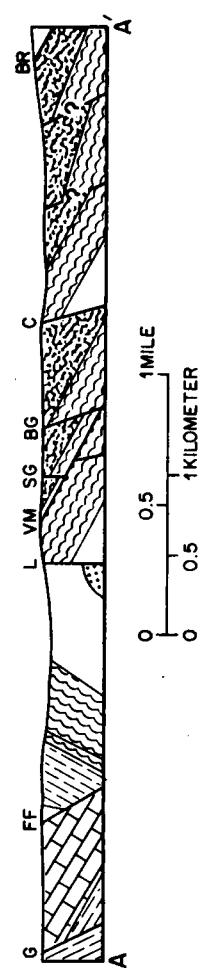
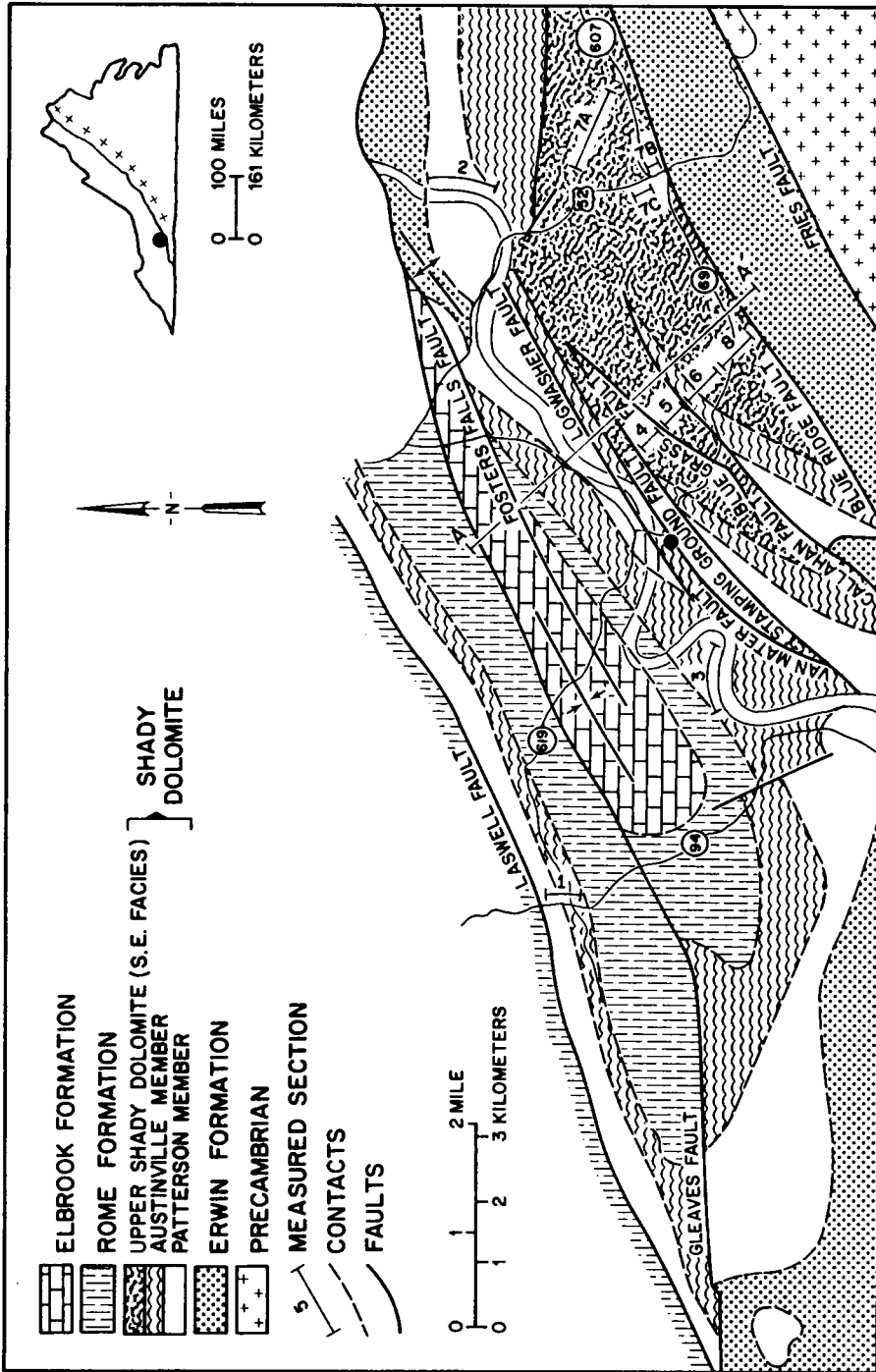


Figure 2. Cambrian stratigraphy, Austinville area. Thickness and lithologic descriptions from Butts (1940), Cooper, et al. (1961), and Rankin (1971).

GENERAL STRATIGRAPHY, AUSTINVILLE AREA

	ELBROOK DOLOMITE	THIN BEDDED DOLOMITE, CALCAREOUS SHALES AND THIN LIMESTONES (400-600 M)
	ROME FM.	INTERBEDDED RED AND GREEN SANDSTONE, LIMESTONE AND DOLOMITE (600-900 M)
	SHADY DOLOMITE	DOLOMITE AND MINOR LIMESTONE (600-1300 M)
CHILHOWEE GROUP	ERWIN FM.	QUARTZITE WITH MINOR SHALE (400-600 M)
	HAMPTON FM.	QUARTZITE AND ARKOSIC SHALES (400-600 M)
	UNICOI FM.	ARKOSIC ARENITES, CONGLOMERATES, SILTSTONES AND BASALTS (400-600 M)
	PRECAMBRIAN BASEMENT	AUGEN GNEISS AND METAGRANITE

faults, two minor cross faults occur at Ivanhoe and Fosters Falls (Weinberg, 1971).

High-angle reverse faults apparently have small lateral movement. The Laswell fault appears to have the greatest displacement as it carried Shady Dolomite over the Rome Formation.

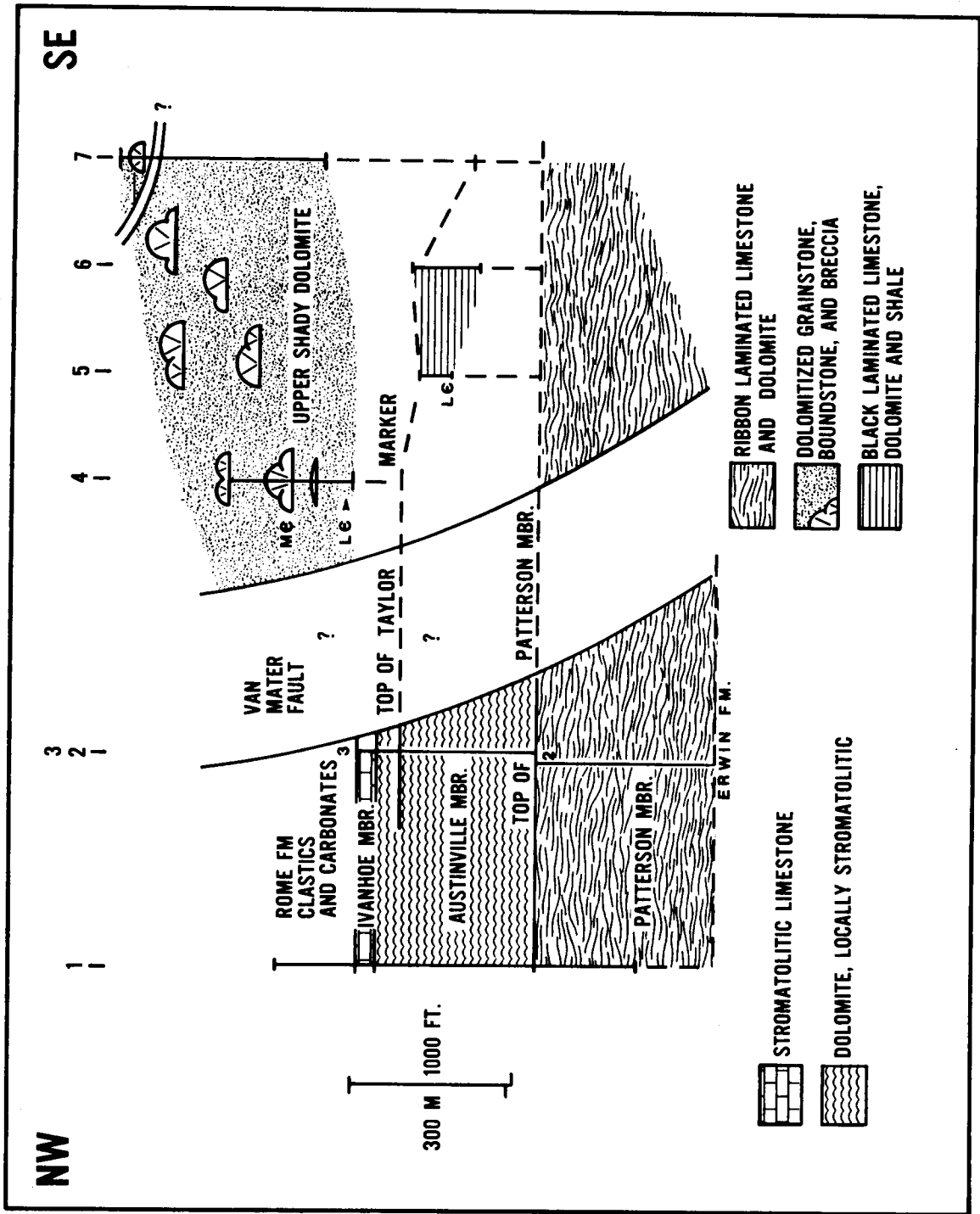
The low-angle Blue Ridge fault which carried the Erwin Formation over the Shady Dolomite in the area has considerable displacement. Bryant and Reed (1970), from studies in the Grandfather Mountain Window, considered the Blue Ridge thrust sheet to be allochthonous and rooted in the Brevard Zone with a transport of 56 kilometers. Displacement along the Van Mater fault is not known. Weinberg (1971) stated that the minimum transport on the Van Mater fault was 200 m as indicated by the offset of the Stamping Ground fault along the Van Mater fault. Facies changes in the upper Shady Dolomite - Rome Formation across the fault indicate that transport may be greater.

STRATIGRAPHY OF THE SHADY DOLOMITE, AUSTINVILLE AREA

In the Austinville area, the Lower to Middle Cambrian Shady Dolomite (Fig. 3) gradationally overlies the Erwin Formation of the Chilhowee Group (Lower Cambrian). The Shady is approximately 640 m thick in northwestern belts with a possible thickness of 1300 m in southeastern belts. The Rome Formation conformably overlies the Shady Dolomite in northwestern belts and probably passes to the southeast into upper Shady Dolomite carbonate beds (Fig. 3). There is no top to the Shady Dolomite in southeastern sections because these are in faulted contact with overthrust Lower Cambrian and Lower Cambrian (?) Chilhowee Group rocks.

The northwest to southeast stratigraphic cross section (Fig. 3) was constructed using the contact between the Shady Dolomite and Rome Formation as a datum for correlation of northwestern sections. Measured sections of exposed rocks southeast of the Van Mater fault were physically correlated using the top of the Patterson Member and/or top of the Taylor Marker in the subsurface (data from Weinberg, pers. comm., 1976). The presence of unmapped bedding-plane faults, which are numerous (Weinberg, pers. comm., 1976), causes stratigraphic thicknesses to be uncertain. Relative positions of units above the top of the Patterson Member may also be incorrect due to tectonic thickening of the sequence by stacking of numerous bedding plane faults. Nonetheless, the reconstruction appears to best fit the available data and is compatible with the location of Lower and

Figure 3. Diagrammatic stratigraphic cross section, Austinville Area. Contact between Shady Dolomite and Rome Formation used as a datum for correlation of northwestern sections. Partial sections southeast of Austinville were physically correlated using the top of the Patterson Member and/or top of the Taylor Marker. Patterson and Austinville Members mostly confined to the subsurface southeast of Austinville. Subsurface data from Dr. E. L. Weinberg, New Jersey Zinc Co., Austinville. Formations and marker beds are physical data as distinct from time lines. Measured sections indicated by numbers and vertical bars; section locations are shown on Figure 1. Distances between sections are arbitrary. Faulting makes thicknesses of southeastern sections uncertain. Paleontologically determined ages shown on sections 4, 5 (data from Willoughby, in prep.). Boundstone dominated intervals are shown diagrammatically; boundstones between sections 4 and 7 are inferred.



Middle Cambrian faunas in sections 4 and 5 (data from Willoughby, in prep.). No estimate of lateral transport on faults has been made, thus horizontal distances on the diagram are arbitrary and not palinspastic.

Exposed rocks of the Shady Dolomite change markedly from northwest to southeast across the Van Mater fault (Figs. 1, 3) and may be subdivided into two groups:

- 1) northwestern belts, typified by the Porter Crossroads, Fosters Falls and Ivanhoe sections (sections 1, 2, 3, Appendix B and Figs. 3, 4) containing the Patterson, Austinville and Ivanhoe Members, overlain by Rome Formation and
- 2) southeastern belts, typified by the Clear Branch, Rudy Farm and F. and M. Construction Company Quarry sections (sections 4, 5, 6, 7, 8, Appendix B and Figs. 3, 5) containing upper Shady Dolomite beds. Patterson and Austinville Members are mostly confined to the subsurface in the southeast and are not described here.

Northwestern Belts

The Patterson Member (approximately 335 m thick) is the basal unit of the Shady Dolomite in northwestern belts. It gradationally overlies Erwin Formation clastics and conformably underlies the Austinville Member. The unit consists of ribbon-laminated (locally burrow-mottled) limestone and dolomite; limestone is more abundant in the middle of the unit.

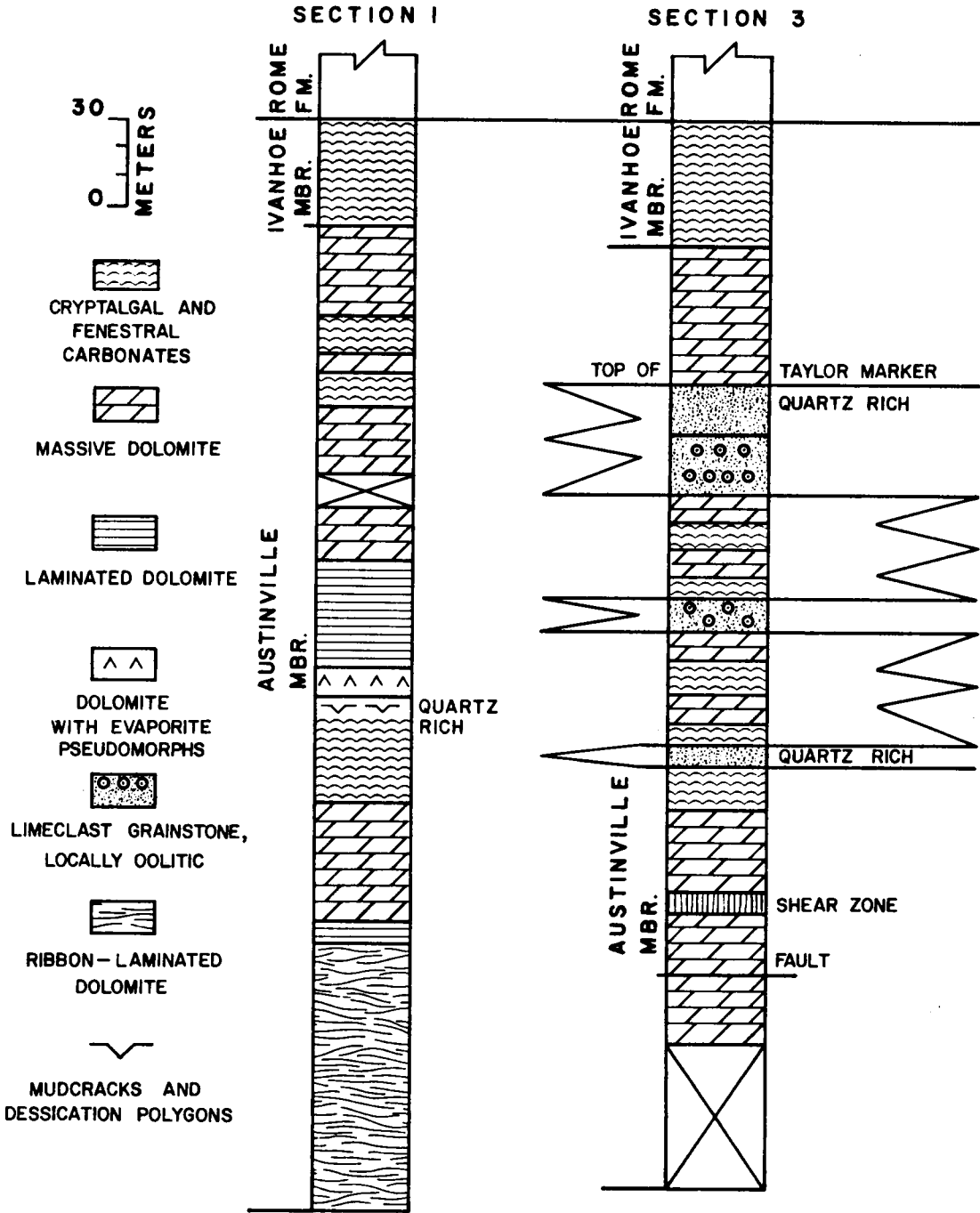
The Austinville Member (approximately 300 m thick) consists of interbedded massive crystalline dolomite, fenestral and cryptalgal dolomite, minor dolomitized ooid grainstone and quartzose, dolomitized, limeclast grainstone (Fig. 4). Cryptalgal limestones and ooid grainstones occur as rare horizons. Quartzose dolomite beds (17 m thick) in the upper Austinville Member are believed to be equivalent to Taylor Marker beds to the southeast (Weinberg, 1971).

The Ivanhoe Member (38-42 m thick) conformably overlies the Austinville Member and is conformably overlain by the Rome Formation (Fig. 4). The unit contains fenestral and cryptalgalaminated limestones, minor dolomites and rare, gray, thin, mudcracked shales.

The Rome Formation (approximately 600-900 m thick) conformably overlies the Ivanhoe Member of the Shady Dolomite and is conformably overlain by the Elbrook Formation. The formation is composed of interbedded red sandstone and mudrock units (up to 6-10 m thick), light to medium gray dolomite units (up to 10 m thick) and minor light gray limestone units (up to 6 m thick) (Butts, 1940). It contains abundant mudcracks, ripple lamination, cryptalgal lamination, fenestrae and possible dolomite-replaced evaporite nodules. The contact between the Rome Formation and the Shady Dolomite is gradational and is mapped at the first major occurrence of red mudrock and sandstone.

Figure 4. Stratigraphy, Austinville and Ivanhoe Members, Shady Dolomite, northwestern sections. Location of sections is given on Figures 1, 3. Note interfingering of tidal and subtidal cryptalgal-aminates and dolomites with quartzose and oolitic limeclast grainstones in section 3. Crosses indicate covered interval.

STRATIGRAPHY, NORTHWESTERN SECTIONS



Southeastern Belts

Southeast of Austinville, the Patterson and Austinville Members of the Shady Dolomite are generally confined to the subsurface except for thin poorly exposed intervals adjacent to the Stamping Ground and Callahan faults. These units are not described in detail in this paper except for Taylor Marker beds that are exposed along Clear Branch (Sections 5, 6). The Taylor Marker (>90 m thick) occurs in the upper Austinville Member (Weinberg, 1963; 1971) and generally consists of black laminated dolomite, dolomitized breccias and minor shale and siltstone. In contrast, the Taylor Marker in northwestern belts is a thin, light gray, quartzose dolomite (17 m thick) that occurs in the upper Austinville Member (section 3). The Taylor Marker in the southeast is conformably overlain by dolomottled, mud-cracked, light to medium gray, fine-grained limestones and small channel-form, flat-pebble conglomerates that pass up (?) into polymictic limestone breccia, shale and grainstone of the upper Shady Dolomite.

Exposed rocks of the upper Shady Dolomite (up to 400 m thick) overlie the Taylor Marker; the top of the unit is not exposed. The unit apparently passes northwestward into the Rome Formation; the Van Mater fault separates the Rome Formation and upper Shady Dolomite beds. To the southeast, the upper Shady Dolomite beds are overridden by the Lower Cambrian and Precambrian rocks of the Blue Ridge thrust sheet. Exposed rocks of the upper Shady Dolomite

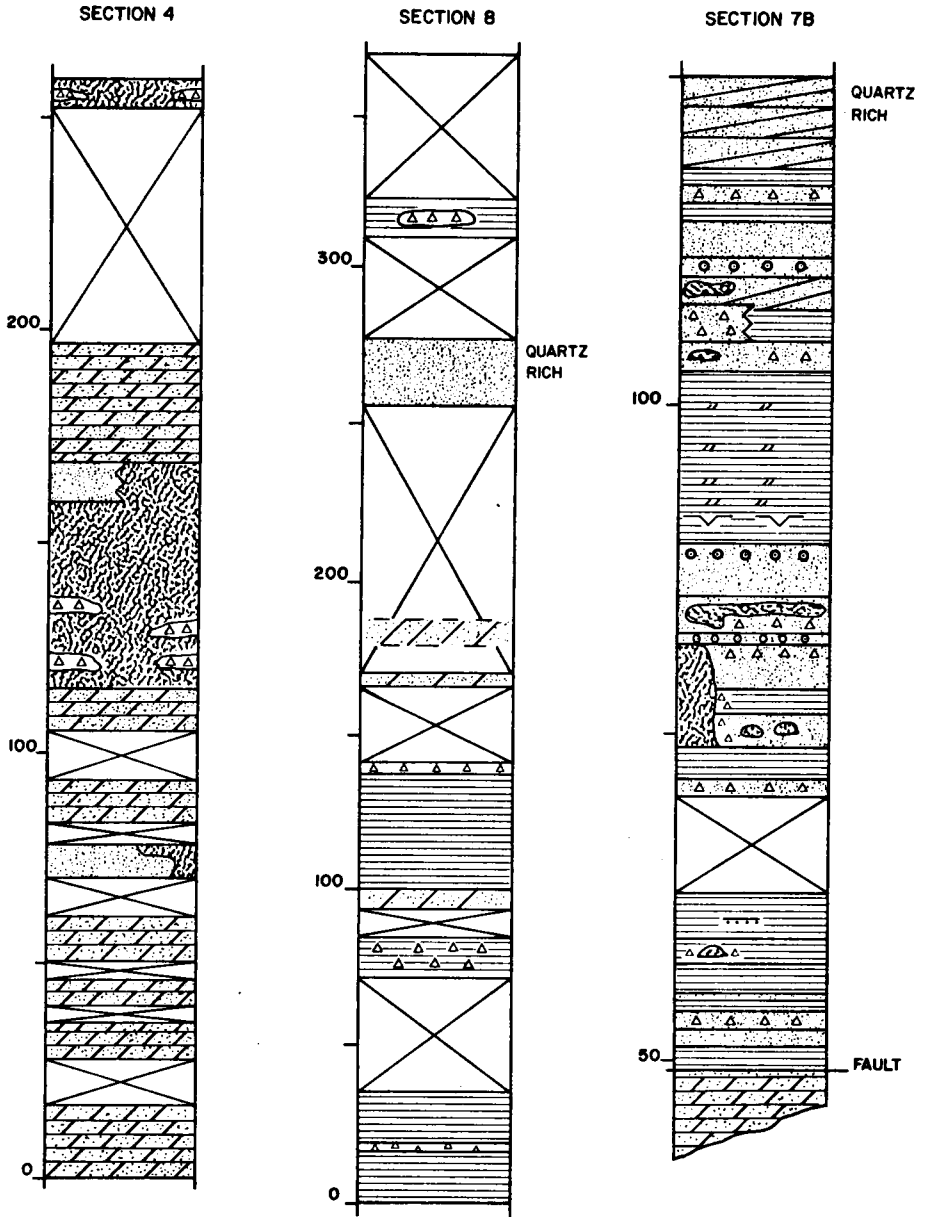
consist of coarse-grained limeclast grainstone; monomictic and polymictic carbonate breccias; calcareous algal boundstone bioherms; black, thinly laminated, argillaceous, fine-grained limestone; and interlayered, graded grainstone and ripple-laminated, argillaceous, fine-grained limestone.










Poor outcrop and faulting prevents construction of a detailed stratigraphic column for the upper Shady Dolomite southeastern facies. Detailed local columnar sections at the F. and M. Construction Company Quarry (section 7) and Clear Branch just south of Austinville (sections 4, 8) illustrate typical sequences (Fig. 5).

Figure 5. Selected stratigraphic sections, upper Shady Dolomite, southeastern facies. Location of sections is given on Figures 1, 3. No time relationship between sections is intended. Thickness in meters; note different scales. Section 8 was not used in constructing the stratigraphic cross section (Fig. 3) due to uncertain thickness caused by two non-exposed high-angle reverse faults (see structure cross section, Figure 1). Crosses refer to covered interval in section.

STRATIGRAPHY, SOUTHEASTERN SECTIONS

UPPER SHADY DOLOMITE



- | | | | |
|---|---|---|--|
|  | ALGAL BOUNDSTONE |  | LIMECLAST GRAINSTONE, LOCALLY OOLITIC |
|  | BRECCIA |  | DOLOMITIZED LIMECLAST GRAINSTONE |
|  | OLIVE TO BLACK, LAMINATED LIMESTONE AND SHALE |  | LOW-ANGLE CROSS BEDDING |
|  | MUDCRACKS |  | RIPPLES, MINOR FLASER AND LENTICULAR BEDDING |
|  | GRADED BEDDING | | |

LITHOFACIES

Lithofacies, Northwestern Sections

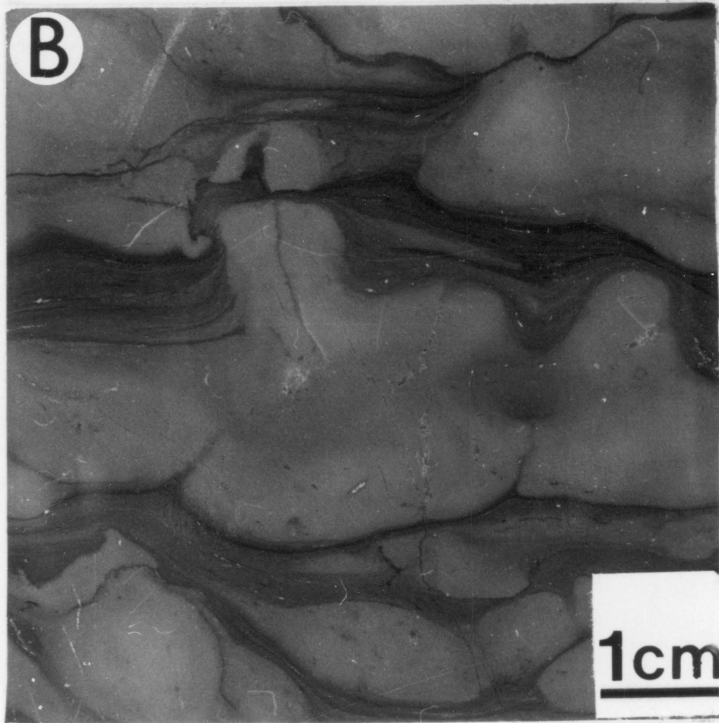
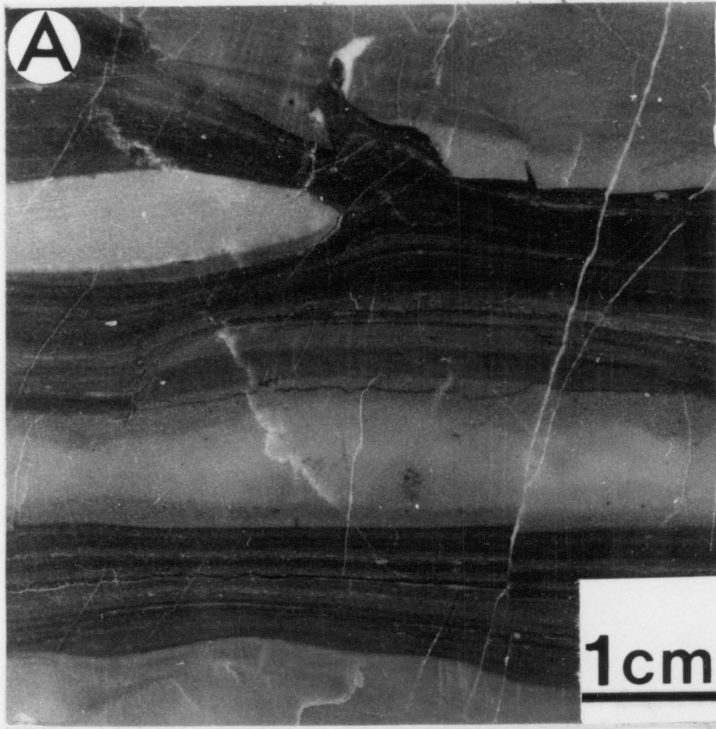
Lithofacies of the Shady Dolomite exposed in northwestern sections differ markedly from those exposed to the southeast of Austinville. Ribbon-laminated to burrow-mottled carbonates occur in lower parts of northwestern sections (Patterson Member, lower Austinville Member). Transitions from ribbon-laminated limestone into ribbon-laminated dolomite are generally gradational and stratiform; however, contacts are locally discordant to bedding with irregular boundaries. Massive crystalline dolomite and fenestral, cryptalgal dolomite are the dominant lithologies of the middle and upper Austinville Member and are interlayered with vuggy dolomites and rare dolomitized ooid and limeclast grainstones. Quartzose, massive dolomites occur locally in the upper Austinville Member. Ooid grainstones are locally interbedded with non-dolomitized ooid and skeletal grainstones and cryptalgal limestone.

Fenestral and cryptalgal limestones occur as thin horizons in the middle and upper Austinville Member and are the main rock type in the Ivanhoe Member. The Ivanhoe Member is overlain by red mud-rock and sandstone, fenestral limestone and dolomite of the Rome Formation. Detailed documentation of diagenesis of Shady rocks is beyond the scope of this paper. However, mechanisms of dolomitization and formation of ribbon-laminated rocks are described briefly in appendix A.

Ribbon-laminated to Burrow-mottled Carbonates.--The ribbon-laminated carbonates are thinly layered to thickly bedded and commonly consist of interlayered undulating bands and pods (2-4 cm thick) of medium gray lime mudstone (containing rare pellets, intra-clasts, minor echinoderms, trilobites and Salterella) and interlayered stylolitized, dark gray, finely crystalline dolomite (Fig. 6). Some limestones have planar, thick (up to 5 cm) lamination. Others are burrowed (Fig. 6) with anastomosing irregular mottles and stringers of stylolitically laminated, very finely crystalline, argillaceous dolomite in a lime mudstone or medium crystalline dolomite host.

The stylolitized dolomite layers consist of very finely crystalline, equant dolomite and argillaceous material with disseminated pyrite and minor quartz silt. Stylolitic partings range from wispy discontinuous seams to well developed stylolites that parallel bedding and boundaries of ribbons/pods, are of low amplitude and rarely digitate. Seams contain from 1 to more than 6 stylolites/mm. Contacts between lime mudstone and dolomite bands are gradational to sharp. Gradational boundaries have disseminated dolomite crystals in lime mudstone; the dolomite crystals increase in size and concentration toward the contact where they merge into a stylolitized equigranular dolomite mosaic. In more dolomitized samples, there is a decrease in number of stylolites and an increase in crystal size from the stylolitized seam into massive dolomite. Sharp boundaries are stylolitic. Rare "pseudo-brecciated" horizons consist of angular fragments of lime mudstone or dolomite in a

Figure 6. Ribbon-laminated and burrow-mottled carbonates, Patterson Member. A. Ribbons of lime mudstone separated by ribbons of stylolitically laminated, argillaceous dolomite. B. Burrow-mottled lime mudstone with irregular nodular lime mudstone and stylolitically laminated dolomite.



groundmass of finely crystalline, stylolitic dolomite. Fragments have matching clast boundaries and the stylolitic lamination in the groundmass is deformed into fractures between clasts. Boudinage fabrics marked by attenuation of lime mudstone and dolomite ribbons are common.

Completely dolomitized ribbon rocks consist of undulating, interlayered ribbons and pods (up to 3 cm thick) of light gray, medium crystalline dolomite and dark gray, stylolitically laminated, argillaceous, finely crystalline dolomite. Stylolitized seams contain relatively few stylolites (0.1 - 4 stylolites/mm) reflecting increased obliteration of stylolites with increased dolomitization.

Ribbon-laminated dolomites locally contain coarse sparry dolomite layers that occur within dolomite ribbons and pods ("zebra rock"). Layers may be parallel or inclined to bedding and are 0.5 to 1 cm thick and tens of centimeters long. There are also en echelon layers 2-3 mm high and up to 2 cm long consisting of inclined lamellae of sparry dolomite and fine grained host rock. Sparry dolomite layers consist of pore-filling, very coarsely crystalline, equant dolomite and minor ferroan calcite and quartz (up to 4 mm dia.). Rare chalcedony concretions (0.08-0.8 mm dia.) occur as single spherical structures or small coalescent masses (1-2 mm dia.) in the host lime mudstone or dolomite ribbon. Sparry dolomite-filled vugs (up to 1 cm high and 22 mm long) occur in upper parts of some dolomite ribbons/pods. They have flat floors, concave arcuate roofs and are filled by equant (0.3 mm dia.) pore-filling dolomite,

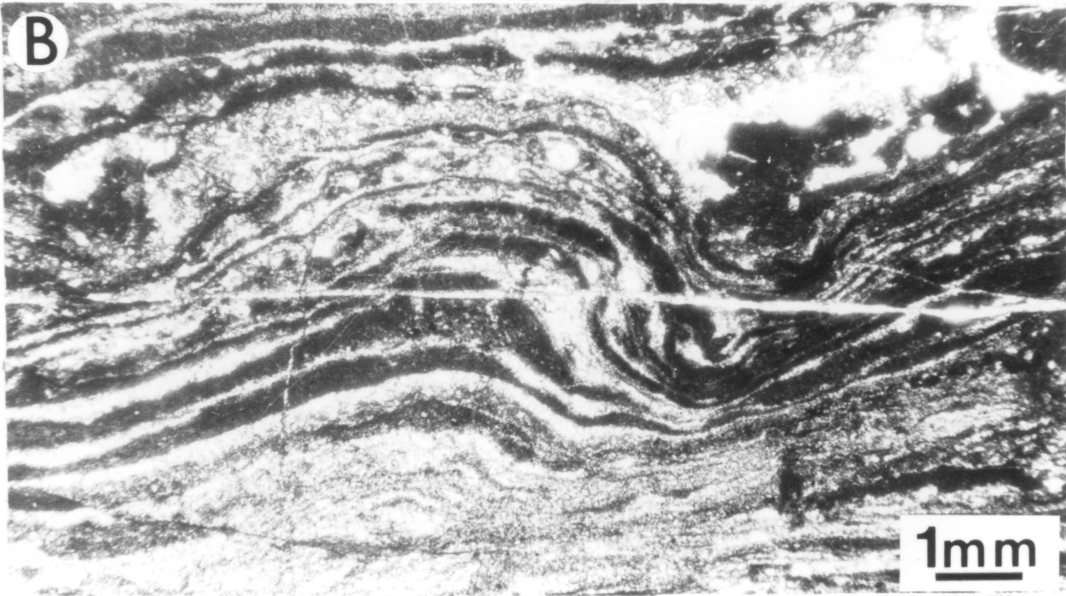
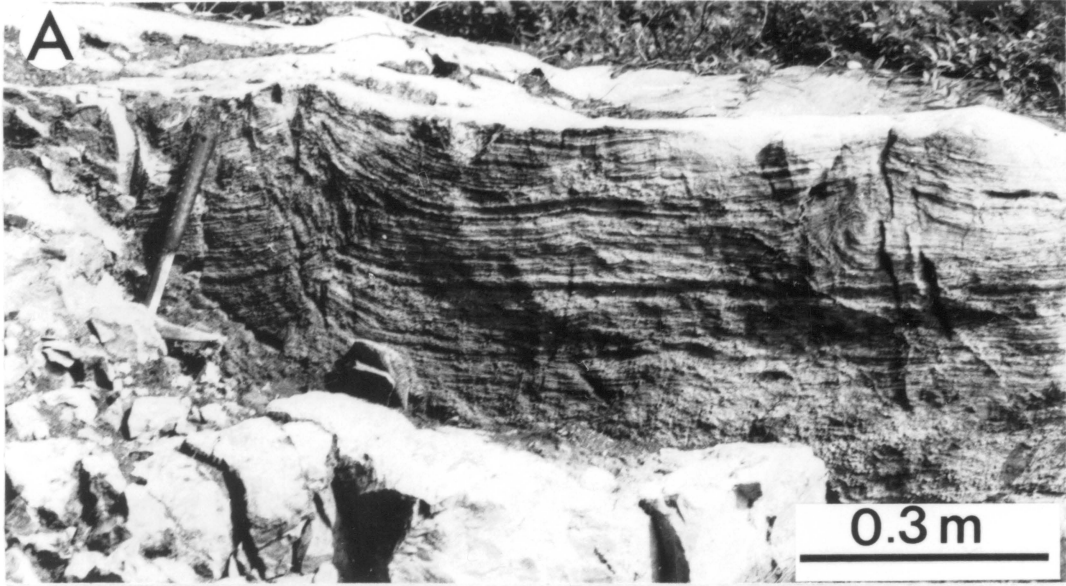
and lesser quartz and ferroan calcite (Bathurst, 1975),

Massive Dolomites.--Massive dolomite units are medium to thickly bedded, light gray to white and less commonly dark gray to black. Some have faint planar lamination on weathered surfaces. Massive dolomites consist of medium crystalline, equant dolomite and locally contain vugs and veins of very coarsely crystalline dolomite spar; some vugs may be dolomite-replaced evaporites. Vugs are round (10 to 30 mm dia.) to elongate (5 to 10 mm long and 1 to 2 mm high) and are filled by pore-filling, equant dolomite crystals (1-2 mm dia.) and lesser quartz (up to 2 mm dia.).

Fenestral and Cryptalgal Carbonates.--Fenestral and cryptalgal carbonates are thinly to thickly bedded and light to dark gray. Contacts between limestone and dolomite are generally stratiform but non-stratiform, highly irregular contacts are also present. Cryptalgal lamination (Aitken, 1967) and laminoid (0.2-4.0 mm in height and 1.0-20.0 mm in width) and irregular fenestrae from 1-9 mm in diameter (Tebbutt, et al., 1965; Logan, 1974) are abundant. Rare, dessicated polygons (up to 1 m dia.) (Fig. 7), rare pallisade structures and small scale scours and ripups also occur locally. Lithologies include pellet/intraclast grainstone, minor lime mudstone, oolitic grainstone and oncolite layers; rare skeletal debris consists of echinoderm and trilobite fragments with locally abundant skeletal algal (Solenopora?) debris. Interparticle cements are cryptocrystalline to fine equant (0.04-1.0 mm dia.) calcite. Fenestral cements include columnar calcite (up to 1.5 mm long and 0.2 mm wide),

Figure 7. Cryptalgal laminated carbonates, Austinville Member.

A. Outcrop photo - dessication polygons. B. Thin section of dolomite with cryptalgal lamination.



equant calcite (0.1-0.5 dia.) and equant dolomite (up to 1 mm dia.). A few fenestrae are floored by internal sediments which consist of lime mud, pellet packstone or crystal silt (Dunham, 1969). The last commonly overlies columnar calcite cements and has characteristic mechanical layering.

In dolomitized samples, laminae (0.2-4 mm thick) consist of alternating finely to medium crystalline dolomite and finely to coarsely crystalline dolomite (Fig. 7), relict pellets and intra-clasts and medium to coarse sand-sized, angular quartz grains.

Dolomitized Ooid Grainstone.--Oolitic dolomites are medium to thickly bedded, white to black and consist of very finely to very coarsely crystalline, equant dolomite. Relict ooids (0.2-2 mm dia.) are composed of very finely to medium crystalline, equant dolomite and most have cores of dark brown, very finely crystalline dolomite. Grain and cement boundaries are partly obliterated by dolomite crystals that have grown across grain boundaries.

Dolomitized Limeclast Grainstone.--Dolomitized limeclast grainstones are rare in northwestern belts and are medium bedded with local planar, low-angle cross-lamination. They are white to light gray and mainly consist of very finely to medium crystalline, equant dolomite containing relict coarse sand-sized grains of dark cryptocrystalline dolomite (white in hand specimen), finely to medium crystalline dolomite and subrounded to well-rounded quartz grains. Grains are round to ovoid and some are impregnated with opaques. Grain boundaries are marked by color difference; grains

are dark brown and the dolomite mosaic is light brown and turbid.

Lithofacies, Southeastern Sections

Exposed beds in the upper Shady Dolomite southeast of Austinville contain limeclast grainstone, black laminated carbonate and shale, calcareous algal boundstone, and monomictic and polymictic carbonate breccia (Figs. 5, 8).

Dolomitized limeclast grainstones are common in all sections of the upper Shady Dolomite but non-dolomitized grainstones only occur as thin units in the sequence (Fig. 5). Thick grainstone sequences (up to 60 m) are locally interbedded with thick (6-60 m) units dominated by calcareous algal boundstone, minor breccia and shale. At the F. and M. Quarry, dolomitized limeclast grainstone (up to 300 m thick) containing rare dolomitized breccias are overlain by non-dolomitized grainstones (several meters thick) and interbedded black, evenly laminated to ripple-laminated limestone and shale, polymictic carbonate breccia and calcareous algal boundstone (Fig. 8). Grainstones locally interfinger with and are draped over calcareous algal bioherms. Thin (2 cm) beds of grainstone are interbedded with argillaceous fine-grained limestones. Rare grainstone beds have low-angle cross-stratification with azimuths directed to the northwest (Fig. 9).

Calcareous algal boundstone masses (several meters thick and dominating sequences up to 50 m thick) are interbedded with grainstone, polymictic limestone breccia and black limestone and shale.

Figure 8. F. and M. Construction Company Quarry (locality, section 7B) - map of quarry walls. Note occurrence of calcareous algal boundstone bioherms in black, laminated limestone and shale and the interfingering of breccias and black laminated argillaceous carbonates adjacent to bioherms.

F AND M CONSTRUCTION COMPANY QUARRY.

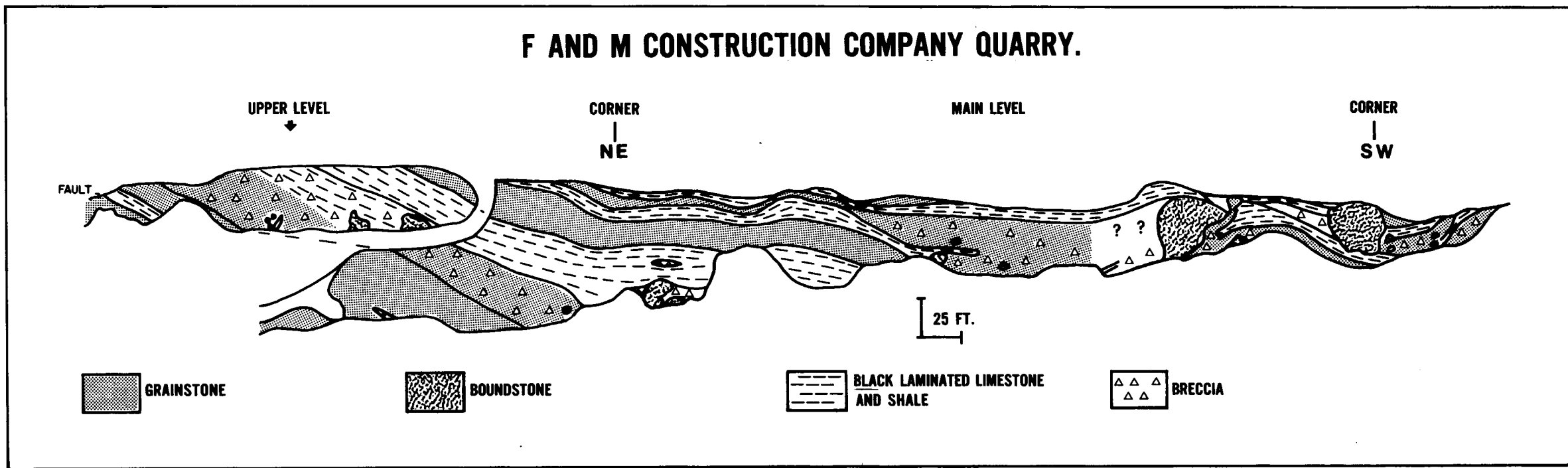
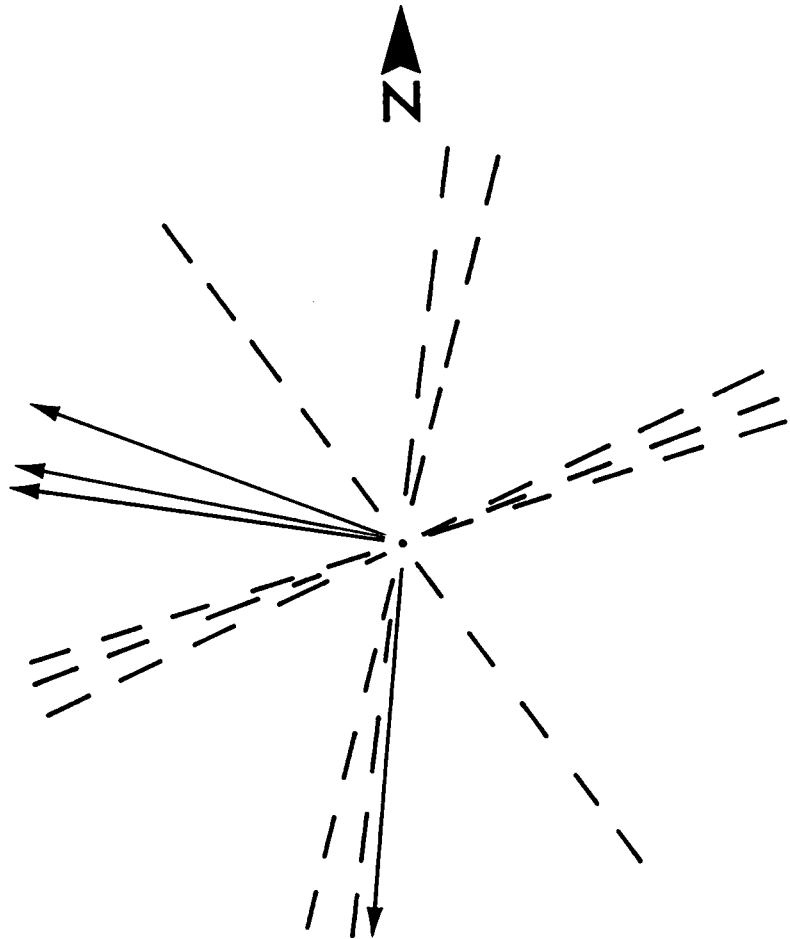


Figure 9. Limited paleocurrent data, upper Shady Dolomite.
Azimuths of crossbeds shown by arrows; bearings of ripple axes
shown by dashed lines. Note: northwest directed azimuths on
crossbeds.



At Clear Branch a calcareous algal boundstone mass (7 m high) abuts and interfingers with grainstones and polymictic limestone breccia containing clasts of calcareous algal boundstone up to 60 cm diameter. At the F. and M. Quarry (Fig. 8), calcareous algal bioherms are commonly associated with black limestone and shale and polymictic breccia; they also interfinger with and locally are draped by grainstones. Lime mudstone masses locally interfinger with skeletal limestones (Clear Branch, section 4).

Polymictic limestone breccias are common in the upper Shady Dolomite and are well exposed at Clear Branch (section 4, 8) and in the F. and M. Quarry (section 7B). They occur as sheet-like beds (30 cm to several meters thick) and channel-form units (60 cm to several meters thick, 1-10 m wide). Basal contacts range from channelled, hummocky, to planar; tops are sharp, planar and hummocky, or gradational. Breccia beds are interbedded with or grade laterally into grainstone or thinly bedded limestone and shale units (Figs. 5, 8). Many breccias and associated lithologies have been heavily dolomitized.

Rare monomictic carbonate breccias occur in the upper Shady Dolomite at the F. and M. Quarry (section 7B) and in the Taylor Marker at Clear Branch (sections 5, 6). They are channel-form (60 cm thick and up to 3 m across) and are commonly interbedded with evenly bedded limestone and shale units, ripple-laminated, argillaceous limestone units and dolomottled, mud-cracked carbonates (top of Taylor Marker, section 6). Locally, monomictic breccias flank

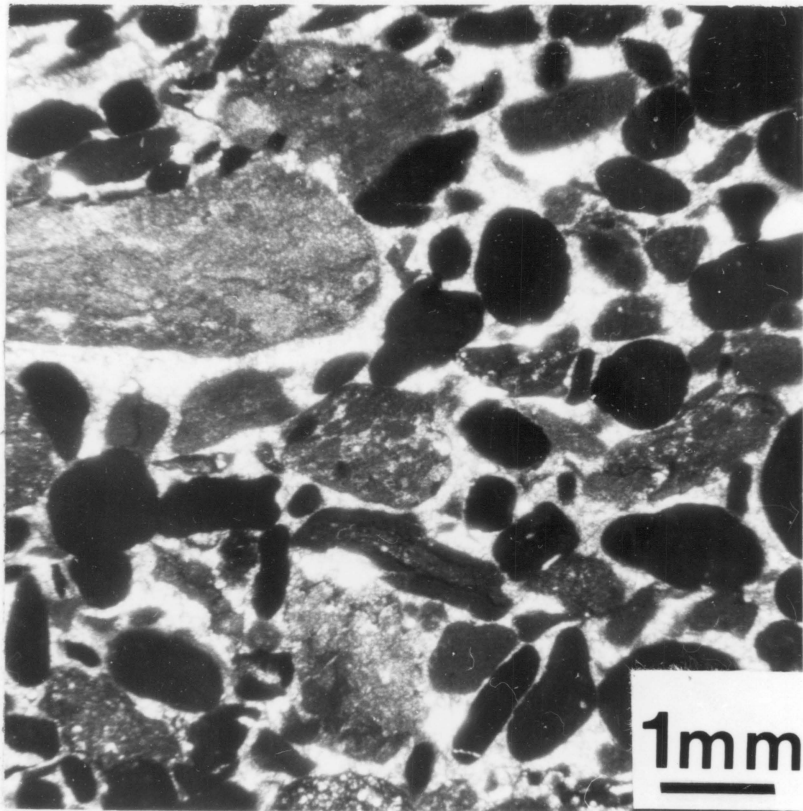
bioherms that are enclosed by black, evenly bedded limestone and shale.

Black, thinly bedded, laminated carbonates and shales (3 m to tens of meters thick) occur in the upper Shady Dolomite. In rare natural outcrops, shales and argillaceous limestone are olive to brown weathering and poorly exposed (section 8). Best exposures occur along the Clear Branch (Taylor Marker, sections 5, 6) and at the F. and M. Quarry (section 7). At these localities, shales are less common than dark argillaceous carbonates. At the F. and M. Quarry (Fig. 8), black, evenly laminated, argillaceous limestones contain local calcareous algal boundstone masses, rare thin (10 cm) graded limeclast grainstone layers and pebbly limeclast grainstone and polymictic limestone breccia. Dark gray, evenly bedded dolomites occur in the Taylor Marker (Clear Branch, sections 5, 6) and in overlying beds in the F. and M. Quarry section. In the Taylor Marker, they are interbedded with thinly bedded, light gray, fine-grained limestone and dolomite (locally mudcracked) and dolomitized breccias. In the lower part of the F. and M. Quarry section, the evenly bedded dolomites are interbedded with dolomitized limeclast grainstone and polymictic breccia. Black, ripple-laminated, argillaceous limestones are interbedded with grainstones and breccias higher in the F. and M. Quarry section. Bearings of ripple axes vary from $N37^{\circ}W$ to $N79^{\circ}E$ (Fig. 9).

Limeclast Grainstone.--Limeclast grainstones are light to dark gray, thinly to thickly bedded with planar layering and local low-angle cross-stratification. They consist of coarse sand- to granule-sized grains that include abundant platy carbonate clasts, variable amounts of ooids (0.3-0.6 mm dia.), and generally small amounts of skeletal grains, pellets and angular to well-rounded quartz (Fig. 10). Limeclasts are spherical to ovoid; some are composed of fine-grained calcite, others consist of cryptocrystalline dolomite and very finely to medium crystalline dolomite. Some grains are composed of cemented pellet grainstone. Pebble-sized clasts include calcareous algal boundstone, skeletal grainstone, and locally, black laminated limestone. Skeletal grains (common in Clear Branch sections) include calcareous algae, trilobites, echinoderm debris, rare brachiopods and Salterella. Skeletal grains are abraded, angular to rounded and locally have micritic rims. Ooids have nuclei of abraded algae, intraclasts and dolomite. Cements consist of syntaxial overgrowths on echinoderm debris, columnar calcite (0.1-0.9 mm long, 0.04-0.3 mm wide), equant calcite (up to 2.5 mm dia.) and lesser equant dolomite (0.2-0.4 mm dia.).

Dolomitized grainstones consist of very finely to coarsely crystalline equant dolomite with relict, well-rounded, spherical to ovoid, coarse sand-sized grains of cryptocrystalline dolomite, equant dolomite, minor ooids and skeletal debris. Grain boundaries are obliterated by dolomite crystals that have grown across grains and

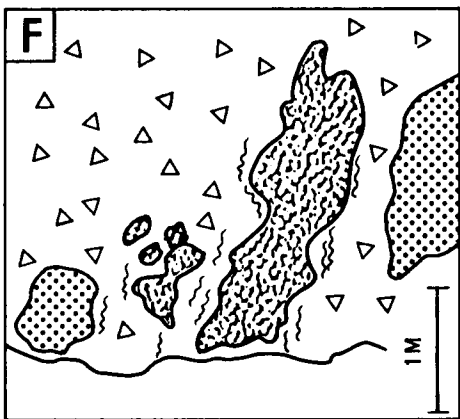
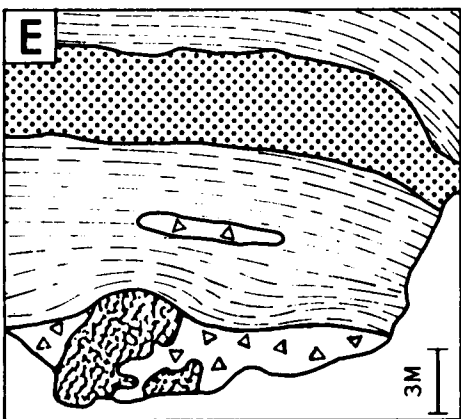
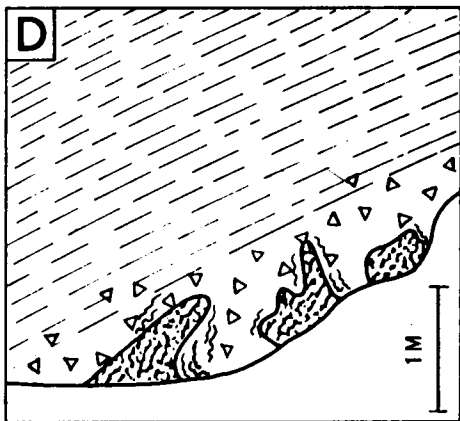
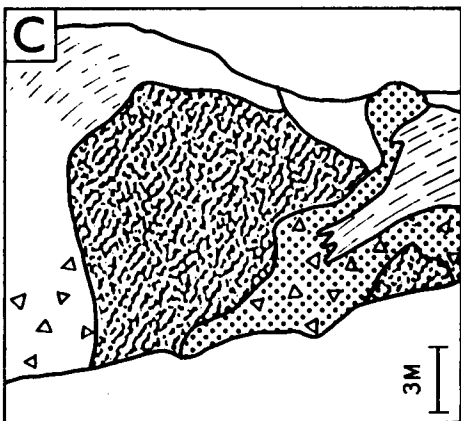
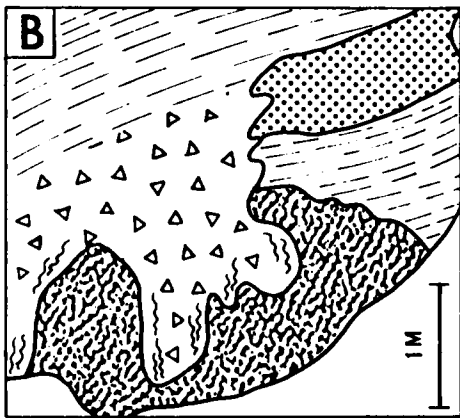
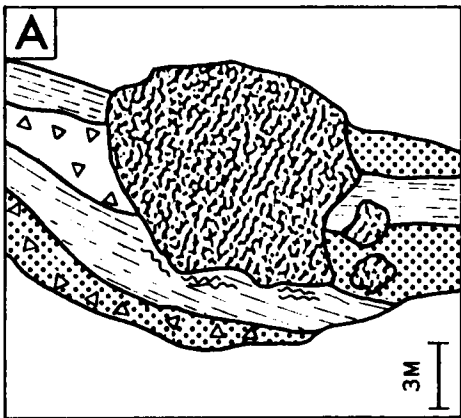
Figure 10. Thin section, coarse limeclast grainstone. Note abundance of grains of dark fine-grained carbonate.




cement, but grain shapes are delineated by color difference in the dolomite mosaic.

Calcareous Algal Boundstone Bioherms.--Calcareous algal boundstones are best exposed in the F. and M. Construction Company Quarry (Figs. 8, 11). Here, large bioherms occur in black, thinly bedded, evenly laminated, argillaceous carbonates and locally project up into overlying grainstones (Fig. 11). Smaller boundstones also occur within grainstone units. Boundstones are flanked by both monomictic and polymictic breccias. Limeclast grainstones and thinly bedded limestones abut and are draped over bioherms (Fig. 11). Bedding in argillaceous limestones is deformed around bioherm walls. Bioherms range in size from 1 m in width and height to 15 m in height and in shape from horizontally elongate, equant, to vertically elongate masses. Bioherms are generally domal in shape, some have vertical sides, and others interfinger with adjacent lithofacies. Other bioherms have upward-bifurcating, anastomosing branches (Fig. 11). Bases of bioherms are poorly exposed. An angular base occurs on one large bioherm which is underlain by contorted thinly bedded carbonates (Fig. 11). Highly irregular bases occur where boundstone overlies hummocky surfaces on breccia beds. Contacts between boundstones and enclosing lithologies may be sharp or gradational. Most sharp boundaries are stylolitic. Gradational boundaries are formed by outward decreasing density of algal colonies and are marked by a gradual color change from white to light gray (dense algal growth) to black host limestone.

Figure 11. Geometries of calcareous algal boundstone bioherms and their relationship to enclosing lithologies, F. and M. Quarry (section 7B). A) Black contorted laminated limestone at base of large bioherm that is flanked by two small satellite bioherms, grainstone, breccia and black argillaceous limestone. B) Irregular top of bioherm and contorted laminated mud matrix of breccia bed around bioherm. C) Large upward-widening bioherm and interfingering of breccias and black laminated argillaceous limestone adjacent to bioherm. D) Irregular domal to pinnacle shaped bioherms and enclosing breccias. E) Interfingering of bioherm and breccia and differential compaction of overlying fine-grained black argillaceous limestones. F) Branching bioherm(s) and enclosing breccias containing large clasts of limeclast grainstone.



 ALGAL BOUNDSTONE

 LIMECLAST GRAINSTONE

 BRECCIA

 BLACK, LAMINATED, ARGILLACEOUS LIMESTONE

The bioherms are dominantly composed of the calcareous alga Epiphyton (Fig. 12) with minor Renalcis (Fig. 12) and lesser undetermined genera having filamentous (Fig. 12) and laminar (Fig. 12) growth forms. The algae are preserved as dark, very finely crystalline calcite. Epiphyton is composed of clusters of branching thalli (approximately 0.2 mm long and 0.04 mm wide) and resembles a tiny bushy plant (up to 5 mm dia.). Individual bush-like masses appear to have grown both vertically, laterally and downward in any sample. Renalcis consists of irregularly stacked, thick-walled (0.08 mm wide) hollow, reniform chambers (0.4 mm dia.). Aggregates of chambers are commonly 1 mm and up to several millimeters in diameter. The filamentous algae appear to have grown normal to general bedding; filaments are up to 1 cm long and 0.04 mm wide. Laminar forms are generally thin (1 mm) crusts with little internal fabric.

Boundstones are generally massive to laminated. Massive boundstones are mottled white and light gray and consist of closely packed bush-like colonies of Epiphyton and Renalcis (white) with patches of interstitial gray lime mud (Fig. 13). Laminated boundstone fabrics consist of alternating millimeter layers of encrusting laminar, filamentous and bush-like algae and interspersed sheet-like to irregular cement-filled spaces. Lamination is commonly parallel to the upper surface of bioherms but it may be near-vertical. Rarely, centimeter thick laminations form convex-upward, laterally linked domes up to 10 cms in diameter (Fig. 13). Small voids (up to 3 mm

Figure 12. Calcareous algae, upper Shady Dolomite, thin sections.

A. Epiphyton, B. Renalcis, C. filamentous form, D. laminar form.

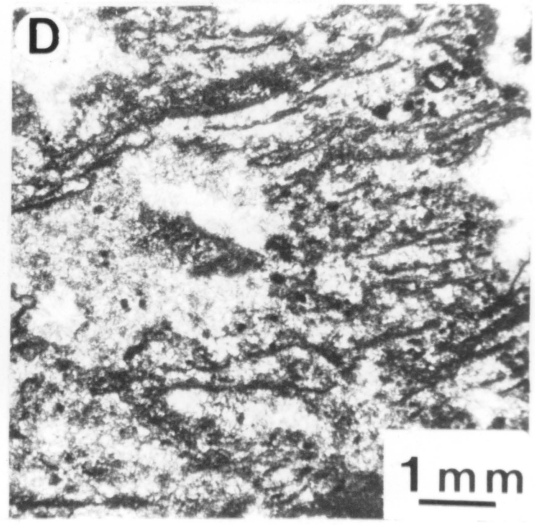
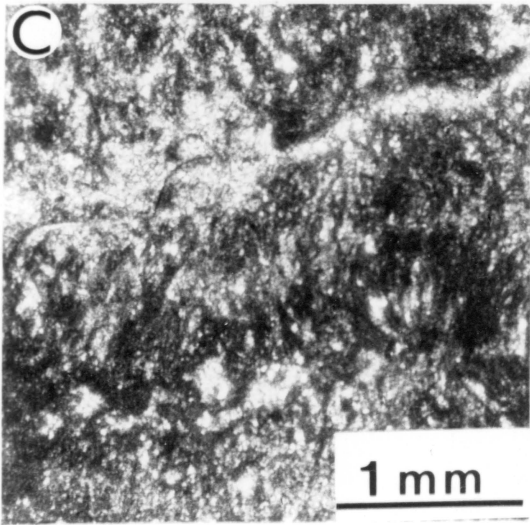
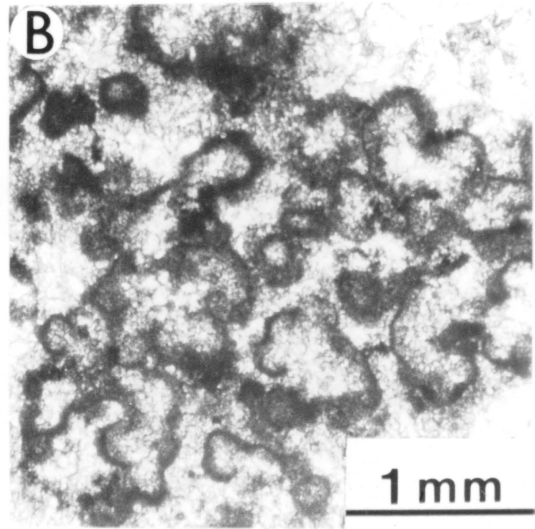
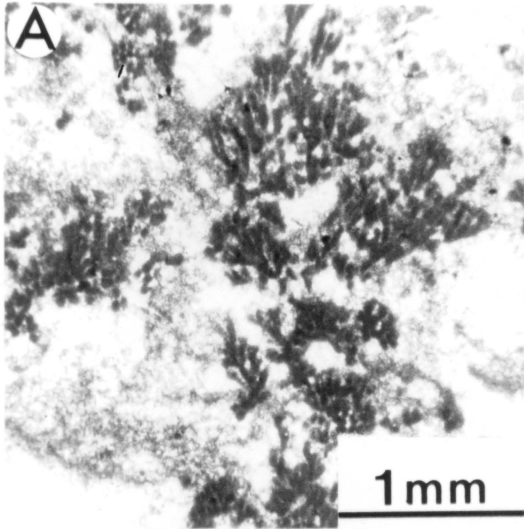
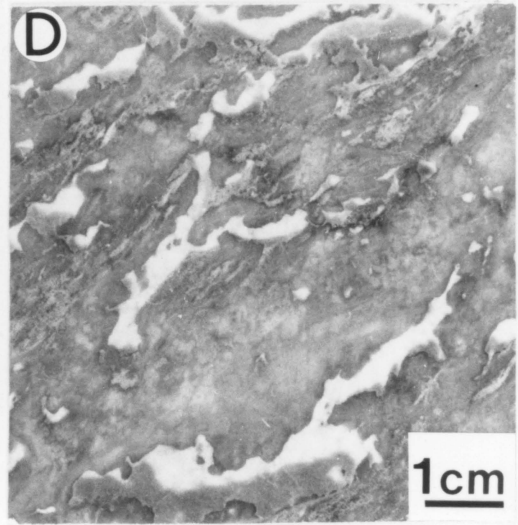
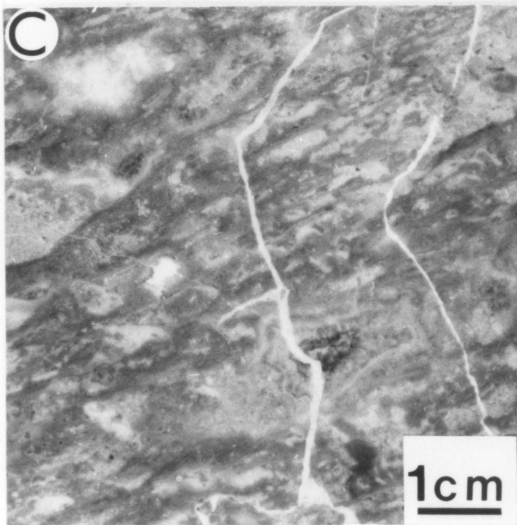
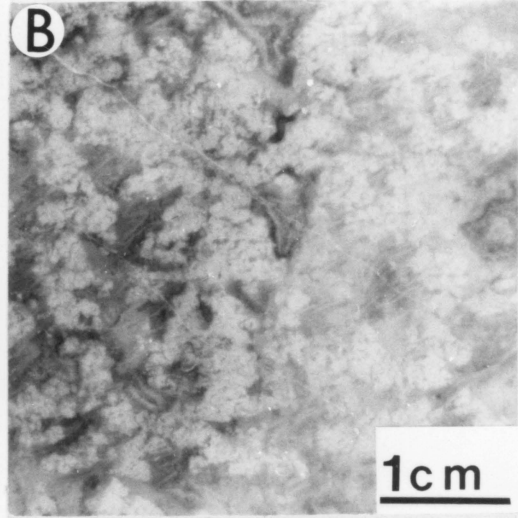
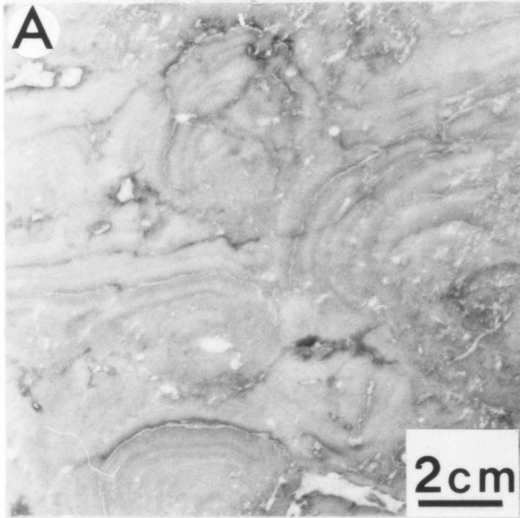


Figure 13. Boundstone fabrics, upper Shady Dolomite, polished slabs.

- A. Laterally linked domal lamination, B. Massive boundstone; algae (white), lime mud (light and dark gray). C. Lamination consists of alternation of algae and cement-filled voids.
- D. Massive boundstone with large geopetal structures.

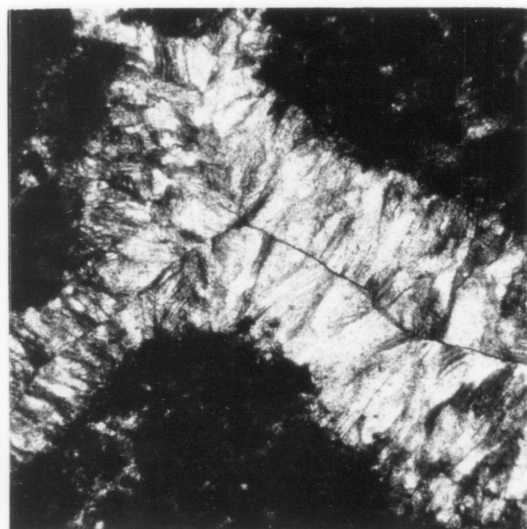


dia.) within and between algal colonies lack internal sediments and are filled by equant calcite (ave. 0.1-0.3 mm dia.) and equant dolomite (up to 0.5 mm dia.)

Cavities in the growth frame are elongate (up to 1 cm high and several cms long), ovoid, to circular (up to several cms dia.). Larger cavities are floored by lime mudstone and lesser fine grainstone/packstone with columnar cement (ave. 0.3-0.5 mm long and 0.1 mm wide) filling the remainder of the void (Fig. 14). Locally cavities are floored by black, dolomitic silt and equant dolomite (ave. 0.5-1.5 mm dia.). Internal sediments are inclined up to 45° and some have mechanical stratification. Rare individual pods have differing orientation of geopetal structures indicating different periods of sediment infiltration and rotation of the pod.

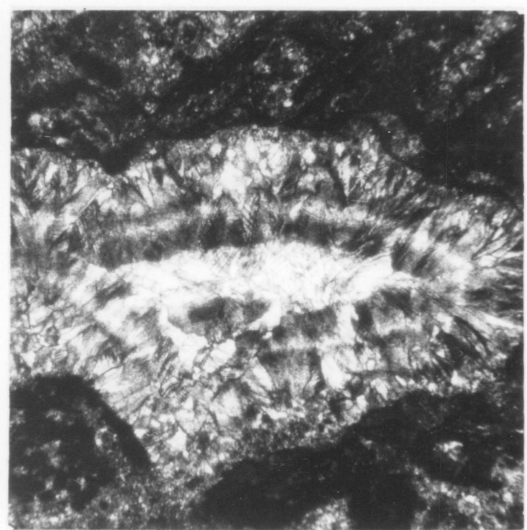
Limestone Breccia.--Limestone breccias may be subdivided lithologically into polymictic and monomictic limestone breccia. Polymictic limestone breccias are sheet-like or channel-form. Sheet-like breccias (30 cm to several meters thick) have subparallel tops and bases and are interbedded with and locally pass laterally into limeclast grainstone, black thinly bedded limestone and argillaceous limestone, and biohermal calcareous algal boundstone. Channel-form polymictic breccias thin laterally and are 60 cm to several meters thick and 1 to 10 or more meters wide. Polymictic limestone breccias locally pass downward into monomictic limestone breccias with decreasing diversity of clasts.

Figure 14. Columnar cements, calcareous algal boundstone, upper Shady Dolomite, thin section. A. Planar suture between cements in center of cavity. B. Possible zonation of columnar cements.



A

1mm



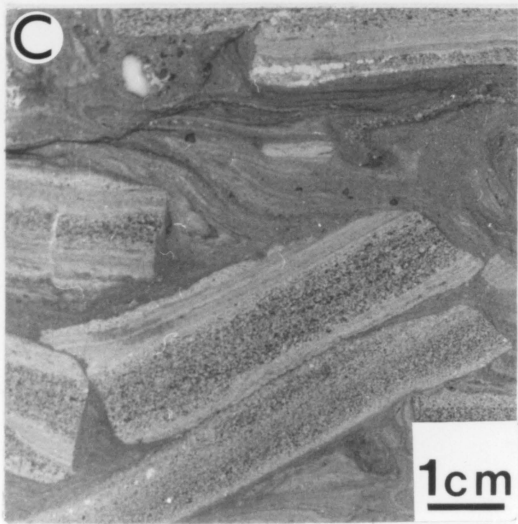
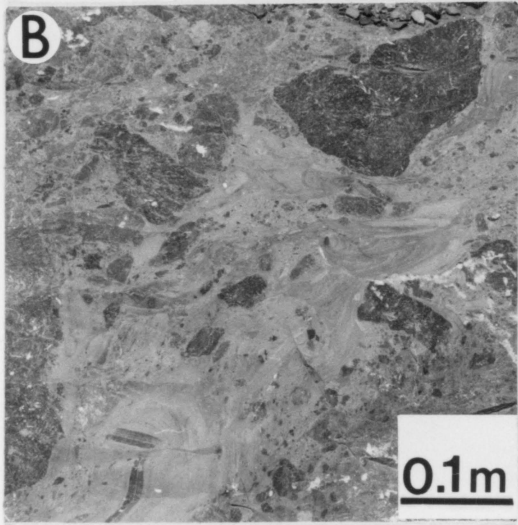
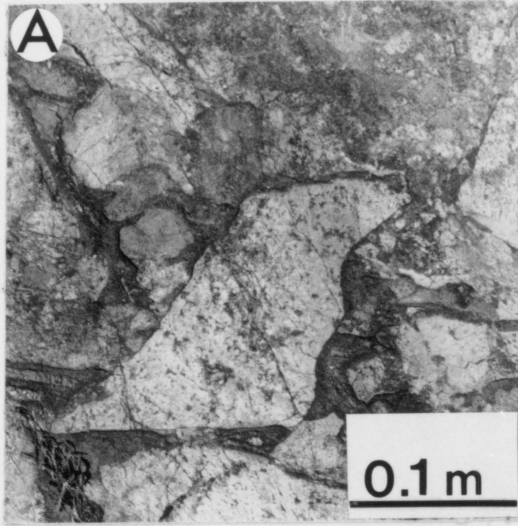
B

1mm

Breccia fabrics range from gravel-support to sand-support; few are mud-supported (Fig. 15). Clasts are pebble to boulder-size (ave. 6 cm), randomly oriented, angular to rounded, and have pressure-solved contacts that generally mask original depositional fabric. Clasts include limeclast and ooid grainstone; calcareous algal boundstone; platy, dark gray, fine-grained, pellet grainstone and lime mudstone; and flat-pebble breccia fragments. Breccias contain interstitial black, fine-grained, pyritic dolomite, gray lime mudstone or limeclast grainstone together with minor quartz silt. In some mud-supported breccias, the matrix is highly contorted. Many breccias are intensely dolomitized, but relict fabrics are commonly recognizable even though the rocks are veined and locally altered to very coarsely crystalline, white, sparry dolomite.

Monomictic limestone breccias are commonly channel-form (60 cm thick and up to several meters wide) and may be 1) associated with dolomottled (possibly algal laminated ?), mudcracked limestones where they consist of unoriented flat-pebbles of fine-grained limestone with interstitial, yellow-weathering dolomite or 2) associated with black, thinly bedded pellet grainstone. They also occur adjacent to bioherms, or in basal parts of some polymictic breccias (Fig. 15). They consist of platy clasts of dark gray to black, laminated to massive, pellet grainstone and interstitial highly contorted, dark gray to black, argillaceous, lime mudstone. Those in basal parts of polymictic breccias are probably the result of

Figure 15. Breccia fabrics, upper Shady Dolomite. A. Coarse grained, clast supported, polymictic breccia, B. Mud-supported polymictic breccia, note contorted lamination in matrix. C. Mud-supported monomictic breccia, clasts of pellet/limeclast grainstone with contorted laminated matrix.

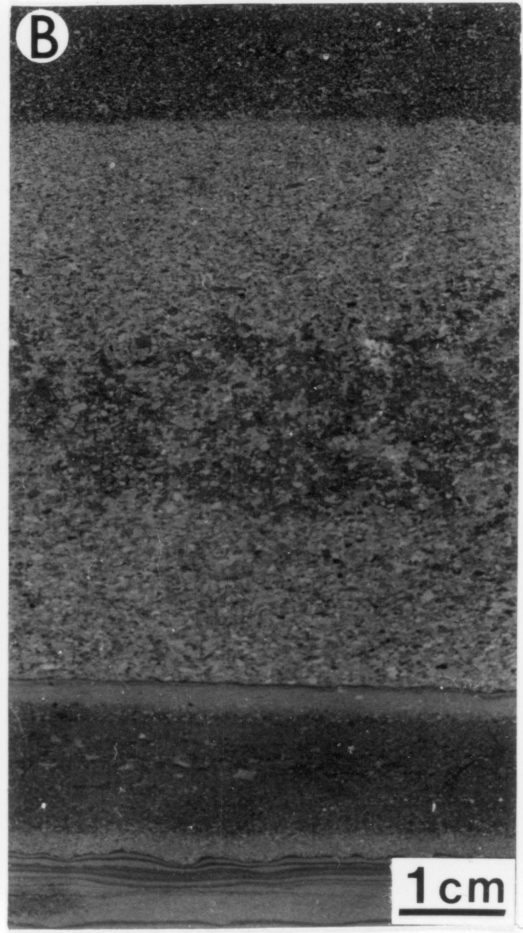
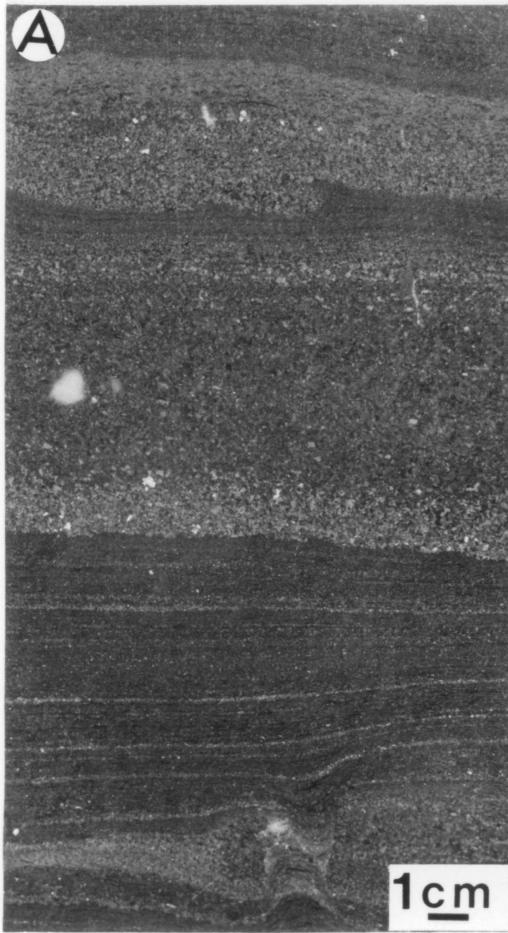


reworking of underlying sediments during breccia deposition, whereas those adjacent to bioherm walls may be produced by compaction of semi-consolidated black, evenly bedded, argillaceous limestones.

Black Laminated Limestone and Shale.--Black, laminated limestones and shales may be divided into those characterized by even lamination (lower part, F. and M. Quarry section), and those with abundant mechanical sedimentary structures (ripple lamination, lenticular and flaser bedding; poorly exposed upper part, F. and M. Quarry section).

Evenly bedded, black, fine-grained carbonates consist of thin (0.3-4.0 cm) interlayered lime mudstone/pellet grainstone and laminated fine-grained, argillaceous limestone/shale (Fig. 16). They locally contain some millimeter-thick lenticular pellet grainstone layers and thin (up to 12 cm) graded limeclast grainstone beds (Fig. 16). Many basal contacts between limestone and argillaceous limestone layers are sharp, planar and stylolitized but some grainstone layers have micro-scoured bases and rare flame structures. Upper contacts are gradational with decreasing grain size into argillaceous limestone or are sharp and stylolitic. "Pull-apart" structures are common in limestone layers and lamination in the argillaceous limestone is deformed around boudins. Planar stylolites are abundant in laminated layers and probably overprint primary lamination. Microfaults offsetting layering are also common. Dolomitized samples consist of interbedded thin (0.3-1.3 cm) yellow-gray, thinly laminated dolomite and more massive light gray dolomite.

Figure 16. Black evenly bedded, pellet grainstone and fine-grained, argillaceous limestone. A. Erosional bases on thin pellet grainstone beds. B. Graded pellet/limeclast grainstone.



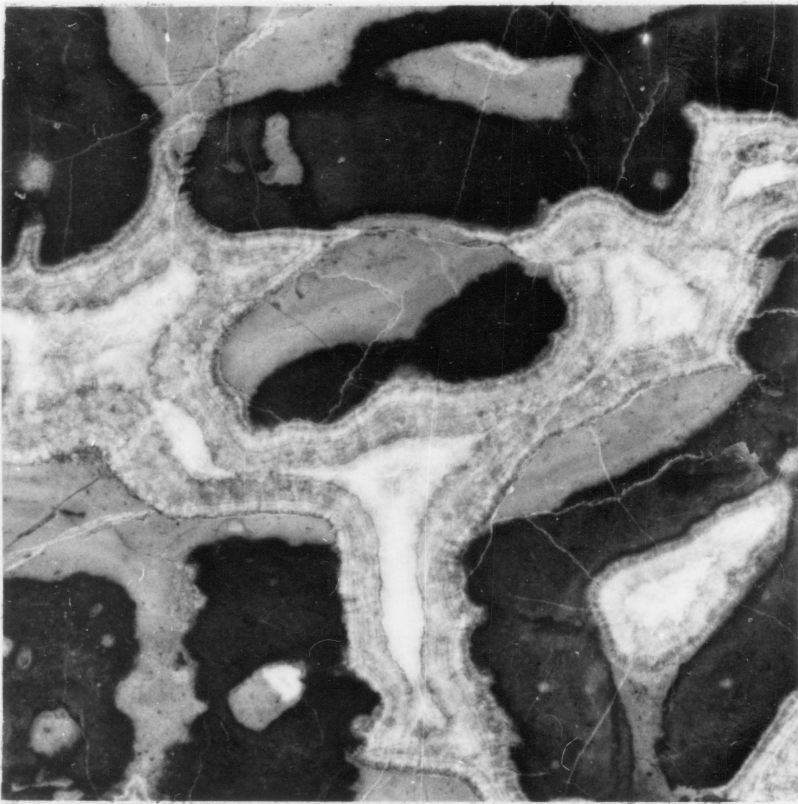
Ripple-laminated, dark gray to black, fine-grained carbonates are commonly thinly bedded to laminated with some lenticular to flaser bedding. Common ripples (symmetric to slightly asymmetric, up to 5 cm wavelength and 2 cm amplitude) and possible mudcracks occur on some bedding planes. Some units consist of thinly inter-layered argillaceous limestone/shale and ripple, lenticular to flaser bedded grainstone. Others are dominantly ripple cross-laminated pellet limestone with thin, irregular, stylolitic argillaceous partings between pellet lenses.

Pellet grainstone layers in both the above lithologies consist of well-rounded pellets (0.045 mm dia.), intraclasts (0.1-2.0 mm dia.), angular coarse silt to sand-sized quartz (0.03-0.1 mm dia.), and rare fragments of algal boundstone and trilobite debris cemented by very finely crystalline equant calcite (0.04-0.08 mm dia.) and dolomite (0.04-0.2 mm dia.). Intraclasts commonly consist of lime mud and cemented limeclast grainstone, and are rarely dolomitized. Dolomitized intraclasts consist of 0.1-0.4 mm crystals and some appear to be abraded. Fine-grained argillaceous limestone/shale interlayers are thinly laminated carbonates with partings of black, pyritic, argillaceous material. Lamination is stylolitic but may reflect primary mechanical lamination.

Lime Mudstone Masses.--Rare lime mudstone masses are thick-bedded and massive and consist of light to medium gray lime mudstone/pellet wackestone with large subcircular to irregular mottles (up to 3 cm dia.) of black, fine-grained lime mudstone that are locally

lined by light gray mudstone. Mottles contain a central fill of coarse columnar calcite cement which also fills anastomosing vugs up to several centimeters in diameter in the host lime mudstone (Fig. 17).

Figure 17. Typical lithology, lime mudstone mass, upper Shady Dolomite. Anastomosing voids filled with coarse columnar calcite cement.



1 cm

DEPOSITIONAL ENVIRONMENTS

Rocks of the Rome Formation - upper Shady Dolomite are suggestive of the platform to basin facies transition of Wilson (1975). Northwestern belts characterized by fine-grained lime mudstones and pellet wackestones that grade up into fine-grained clastics and contain cryptalgal lamination, fenestrae, mudcracks and possible dolomite-replaced evaporites are similar to the inner platform facies of Wilson (1975). Southeastern belts typified by coarse limeclast grainstone (locally oolitic), polymictic carbonate breccias, calcareous algal boundstone bioherms, and interfingering black, evenly laminated, argillaceous limestones are similar to the platform margin and off-platform facies of Wilson (1975). The inner to outer platform facies transition in the Rome - upper Shady Dolomite is also supported by the thickening of the Shady Dolomite to the southeast, the northwest to southeast transition of Rome clastics into upper Shady Dolomite carbonates, and the paleogeographic position of the southeastern facies seaward of northwestern facies (Palmer, 1971). The significance of individual lithofacies is discussed below.

Depositional Environments, Northwestern Belts

Rocks of the Patterson Member are similar to rocks interpreted as shallow shelf carbonates in Upper Cambrian and Lower Ordovician units, Nevada (Taylor and Cook, 1976). A low-energy, shallow, subtidal setting is evidenced by the abundance of lime mud, light gray color, general lack of mechanical stratification, and locally

abundant burrows (Ginsburg, 1956; Moore and Scruton, 1957; Purdy, 1963; Bathurst, 1975). Peritidal features (cryptalgal lamination, fenestrae, mudcracks, dolomite-replace evaporites) are notably absent from the Patterson Member in the Austinville area. However, Byrd (1973b) described cryptalgal lamination and evaporite pseudomorphs from the Patterson Member of the Shady Dolomite elsewhere. Laminations interpreted by Byrd (1973b) to be cryptalgal may be pressure-resolution seams similar to those in the Patterson Member, Austinville region. A paragenetic sequence recognized for Patterson Member lithologies consists of 1. original lime mudstone host rock, altered to 2. ribbon-laminated limestones with increasing formation of stylolitized dolomite seams that separate layers and lenses of limestone; this is followed by 3. partial to complete alteration of remaining limestone to dolomite and 4. precipitation of cements by hydrothermal fluids in diagenetic spaces (Appendix A).

Rocks of the Austinville and Ivanhoe Members in northwestern belts of the Shady Dolomite were deposited in tidal flat and shallow subtidal environments as evidenced by fine-grained sediments with abundant pellets and intraclasts (limestone units), cryptalgal lamination, fenestrae, dessication polygons, mudcracks, and possible dolomite-replaced evaporite nodules (Shinn, 1968; Logan, 1974; Logan, et al., 1974; Ginsburg, 1975). The general lack of grainstones, flat-pebble breccias, scour channels and columnar stromatolites suggests that the tidal flats developed under low-energy conditions (Logan, et al., 1974). Interlayering of tidal deposits

with massive dolomite units suggests cyclic alternation of tidal and subtidal environments. Massive dolomites also occur in the lower Austinville Member above lime mudstones of the Patterson Member. Their position between subtidal lime muds and overlying dominantly tidal flat deposits, suggests deposition of structureless lime sediments in a setting between subtidal offshore muds and tidal flat environments, with subsequent dolomitization to form massive dolomite units.

Oolitic limeclast grainstones are locally interlayered with fenestral and cryptalgal laminated carbonates in the Austinville Member at Ivanhoe but are absent from the Austinville Member to the northwest at Porters Crossroads (Fig. 4). This suggests that the grainstones were formed under shallow, subtidal, higher energy conditions seaward (southeast) of low energy shallow subtidal to intertidal environments.

Rocks of the Rome Formation that overlie the Ivanhoe Member were deposited in subaerial and tidal environments as indicated by their red color, mudcracks, and interbedded fenestral carbonates. The transition from Patterson Member lime mudstones through cryptalgalaminates, fenestral and massive dolomitic carbonates of the Austinville and Ivanhoe Members to Rome Formation clastics suggests that northwestern belts were deposited in an interior platform setting and form an upward shoaling sequence that culminated in the deposition of craton-derived clastics.

Depositional Environments, Southeastern Belts

Limeclast grainstones of the upper Shady Dolomite have some similarities to modern platform margin lime sands (Ginsburg, 1956; Ball, 1967) and to ancient platform margin deposits ("winnowed platform edge sands" of Wilson, 1975). Similar coarse limeclast grainstones occur in Precambrian platform margin facies, Great Slave Lake, Canada (Hoffman, 1974); Cambrian platform and off-platform facies, Frederick Valley, Maryland (Rheinhardt, 1974); and as thin units in the Cambrian Tomstown Dolomite, Central Appalachians (Rheinhardt and Wall, 1975). A platform margin setting for the upper Shady grainstones is also suggested by their association with organic boundstones, breccias and black, laminated, argillaceous limestones. Limeclast grainstones contain abundant evidence of mechanical deposition (dominantly planar layering, parallel orientation of platy grains, and minor low-angle cross-stratification). Recent and ancient platform margin lime sands are characterized by medium to large scale cross-bedded sand bodies reflecting original bar and ripple bed forms (Imbrie and Buchanan, 1965; Ball, 1967; Wilson, 1975). The apparent dominance of horizontal stratification in upper Shady Dolomite facies may be due to poor exposure resulting in a biased sampling of sedimentary structures. Horizontal stratification may result from grain flow on slopes of approximately 25° - 30° (Lowe, 1976) and thick sequences of horizontally stratified grainstones could result where maximum production on the platform edge

continued to supply large amounts of material to the slope. Alternatively, horizontal stratification could result from deposition on a flat bed under upper flow regime conditions (Reineck and Singh, 1975; Harms, et al., 1975) and/or deposition on a flat bed under lower flow regime conditions (Harms and Fahnestock, 1965; Simmons, et al., 1965).

Low-angle cross-stratified limeclast grainstones interbedded with breccias, ripple-laminated fine-grained carbonates and small calcareous algal bioherms in the upper part of the Shady Dolomite (section 7B, F. and M. Quarry, Fig. 5) were probably deposited as shoals on the seaward parts of the platform. Limited paleocurrent data from the deposits suggest currents were directed onto the platform (Fig. 9); these platform-directed accretion deposits are similar to Recent carbonate sands of the Florida and Bahama platform margins (Imbrie and Buchanan, 1965; Ball, 1967; Bathurst, 1975).

The source of most limeclasts in the grainstones is not known for certain. In non-dolomitized grainstones, most grains are cryptocrystalline carbonate. These grains could result from micritization of skeletal debris by algae (Klement and Toomey, 1967; Bathurst, 1975), recrystallization of calcareous algal boundstone fragments or they may be intraclasts of lime mud transported from inner platform areas. Shallow water depths are indicated by cross-bedded oolitic grainstones.

Bioherms of calcareous algal boundstone are conspicuous in southeastern facies of the Shady Dolomite (Figs. 8, 11). The bioherms in the upper Shady Dolomite are largely composed of Epiphyton

which appear to have formed subtidal, rigid mounds. Rigidity is evidenced by draping of overlying lithologies, deformation of enclosing black, fine-grained carbonates (Fig. 11) and abundant large angular clasts of algal boundstone that were reworked into breccia beds (Fig. 15). Rigidity may have been aided by syndimentary cement precipitation between delicate algal growths (Boyd, Kornicker and Rezak, 1963; Schlanger and Johnson, 1969; Ginsburg and Schroeder, 1973). Most Shady boundstone masses are in place bioherms as evidenced by the combination of growth layering that is parallel to bedding or developed as convex-upward domes, by geopetal structures, and by upward bifurcation and outgrowth of bioherms over adjacent breccias and grainstones. The angular base on one large bioherm in the F. and M. Quarry (Fig. 11) may indicate that the mass is partly allochthonous but continued to grow and develop in place after it was transported into sub-wave base "deeper water" lithotopes.

These calcareous algae are among the earliest organisms capable of forming "reefal" carbonates (Wilson, 1975). Similar calcareous algal boundstones have been described from Upper Cambrian and Ordovician rocks, Central Texas (Ahr, 1971); Middle Cambrian rocks, southern Canadian Rockies (McIlreath, 1976); and upper Cambrian rocks, Nevada-Utah (Lohmann, 1976). Metamorphosed algal boundstones have also been described by Thompson (1976) from the Cambrian Shady Formation of the Alabama Piedmont of the Appalachians. These boundstones typically occur in platform margin settings (Wray, 1971; McIlreath, 1976; Lohmann, 1976). The association of calcareous algal

boundstones with cross-bedded limeclast grainstones, breccias and argillaceous limestones suggests that the Shady bioherms formed in environments ranging from shallow wave agitated settings to deeper quiet water, subtidal, outer platform settings. Extensive early synsedimentary submarine cementation of outer platform sediments is indicated by common columnar/fibrous cements (Bricker, 1971, p. 47-49) and by reworked clasts of calcareous algal boundstone, limeclast grainstone and breccia.

Archaeocyathid reefs have not been observed in outcrop in this study although archaeocyathids have been noted in the subsurface Austinville Member (Weinberg, pers. comm., 1976). However, Resser (1938) identified mottles in lime mudstone masses as archaeocyathids and referred to the masses as archaeocyathid reefs. Balsam (1974) suggested that the structures were not archaeocyathids but burrows with the dark gray to black, fine-grained limestone representing organically bound burrow walls. It is not understood how the voids formed. It is possible that they may be leached and solutionally enlarged archaeocyathids or that some other inhomogeneity in the rock (including burrows) localized the formation of the vugs. The black coloration may be due, in part, to local reducing conditions and high carbon content. Superficially similar fabrics consisting of fine-grained, black rims of encrusting Renalcis surrounding archaeocyathid skeletons with laminated light gray limestone (tufa ?) between encrusted skeletons have been described from the Cambrian of South Australia by Brasier (1976). However, fabrics in the upper

Shady Dolomite differ in that black mottles are fine-grained lime mudstone lacking algae and light gray limestone consists of non-laminated pellet wackestone.

Limestone breccias in the upper Shady Dolomite appear to have accumulated in various lithotopes as the deposits apparently range from tidal channel fills and reef talus to submarine gravity flows. Monomictic breccias suggestive of tidal channel origin 1) are channel-form, 2) contain reworked flat-pebbles of fine-grained carbonate and flat-pebble conglomerate, and 3) are associated with dolomottled, mudcracked carbonates (top of Taylor Marker, section 6) and ripple-laminated, lenticular and flaser bedded, black, fine-grained pellet grainstones (Upper Shady Dolomite, section 7b). Such flat-pebble conglomerates are common in Recent tidal flats (Logan, 1974; Ginsburg, 1975) and are common in ancient platform carbonates such as the Cambrian Conococheague Limestone, Maryland (Rheinhardt and Hardie, 1976) and the Cambrian of Nevada (Taylor and Cook, 1976).

Polymictic breccias of probable tidal channel origin are characterized by interbedded shoal water, cross-bedded, oolitic limeclast grainstone and ripple laminated, fine-grained carbonates (Ginsburg, 1975); channel-form geometry; and presence of abundant clasts of lithified platform lithologies. Such channels may have been important in supplying coarse detritus to off-platform locations. Similar deposits have been described from the Recent in Florida Bay (Ball, 1967; Bathurst, 1975) and the Persian Gulf (Purser and Evans, 1973).

Possible reef talus deposits in the upper Shady Dolomite are characterized by their position adjacent to bioherms, wedge-shape geometries, polymictic composition (dominantly boundstone and associated lithologies) and gravel supported fabric (Klovan, 1964; Krebs, 1971; Jamieson, 1971; Zankl, 1971). Much reef talus may have been generated by periodic high energy storm waves that affected the reef dislodging boundstone clasts (Moore, 1974; Bathurst, 1975).

Possible debris flows are characterized by 1) association with "deeper water" limestones, 2) planar to hummocky tops and bases, 3) sheet-like to channel-form geometry, 4) angular shape of clasts, 5) lack of internal stratification or orientation of clasts, 6) polymictic composition (locally monomictic at base of bed) with mixing of platform (grainstone, boundstone) and basinal (black, fine grained carbonate) facies, and 7) interstitial fill that varies from dark mud to sand-sized grains (Cooke, et al., 1972). Similar breccias occur in the Cambrian Kinzers Formation, Pennsylvania (Gohn, 1976), the Cambro-Ordovician of Nevada (Taylor and Cook, 1976), the Devonian of Australia (Conaghan, et al., 1976), and the Devonian of Canada (Mackenzie, 1970; Cook, et al., 1972). Mountjoy, et al. (1972) stress the importance of these submarine flows as indicators of platform margins and reef complexes. Debris flows are considered to move on slopes as low as $1-3^{\circ}$ and may be initiated by faulting, instabilities caused by deposition or diagenesis, storm waves, earthquakes and tsunamis (Cook, et al., 1972; Mountjoy, et al., 1972). The gravity flows in the upper Shady Dolomite appear to have been

deposited under both debris flow and grain flow conditions as suggested by hummocky to flat surfaces or breccia beds, unoriented clasts and fabrics ranging from matrix to clast supported (Cook, et al., 1972).

Black, laminated, argillaceous carbonates in the upper Shady Dolomite have many features in common with "deeper water" limestones described by Wilson (1969). These include dominance of lime mud, dark color, even millimeter lamination and interbedding of limestones with more argillaceous, shaley beds. Interlayered thin, graded pellet-limeclast grainstones with planar to erosional bases and gradational tops were probably deposited by periodic turbidity currents (Thomson and Thomasson, 1969). Interbedding of these lithologies with horizontally stratified to low-angle cross bedded lime-clast grainstones, polymictic limestone breccias and biohermal calcareous algal boundstone suggest that these "deeper water" carbonates were deposited in platform margin and sub-wave base off-platform settings.

Poorly exposed units of thinly bedded, laminated to ripple laminated, black, fine-grained carbonates at the F. and M. Quarry (Fig. 5) are similar in some respects (lithology, color) to deeper water carbonates but contain common ripple, lenticular and flaser bedding and possible mudcracks suggestive of shallower, slightly higher energy, perhaps intertidal conditions (Reineck and Shingh, 1975; Ginsburg, 1975). A higher energy, shallow water setting is also indicated by their close association with grainstones

containing evidence of shoal water deposition (ooids, low-angle cross-bedding).

In summary, the southeastern lithofacies dominated by limeclast grainstones, calcareous algal bioherms, black argillaceous limestones, carbonate breccias and graded limestones appear to be outer platform (and local off-platform ?) deposits. In contrast, northwestern facies containing lime mudstones with restricted assemblages, cryptalgal laminated and mudcracked dolomites, and in upper parts red mudcracked clastics and carbonates indicate interior platform settings bordering the craton.

PALEO GEOGRAPHY AND REGIONAL SIGNIFICANCE

Northwestern belts of the Shady Dolomite reflect a general shoaling upward sequence that was deposited on the interior portion of a carbonate platform. The carbonate package thickens southeastward, apparently at the expense of the Rome Formation, and exposed rocks of the upper Shady Dolomite indicate deposition in outer platform and locally off-platform environments.

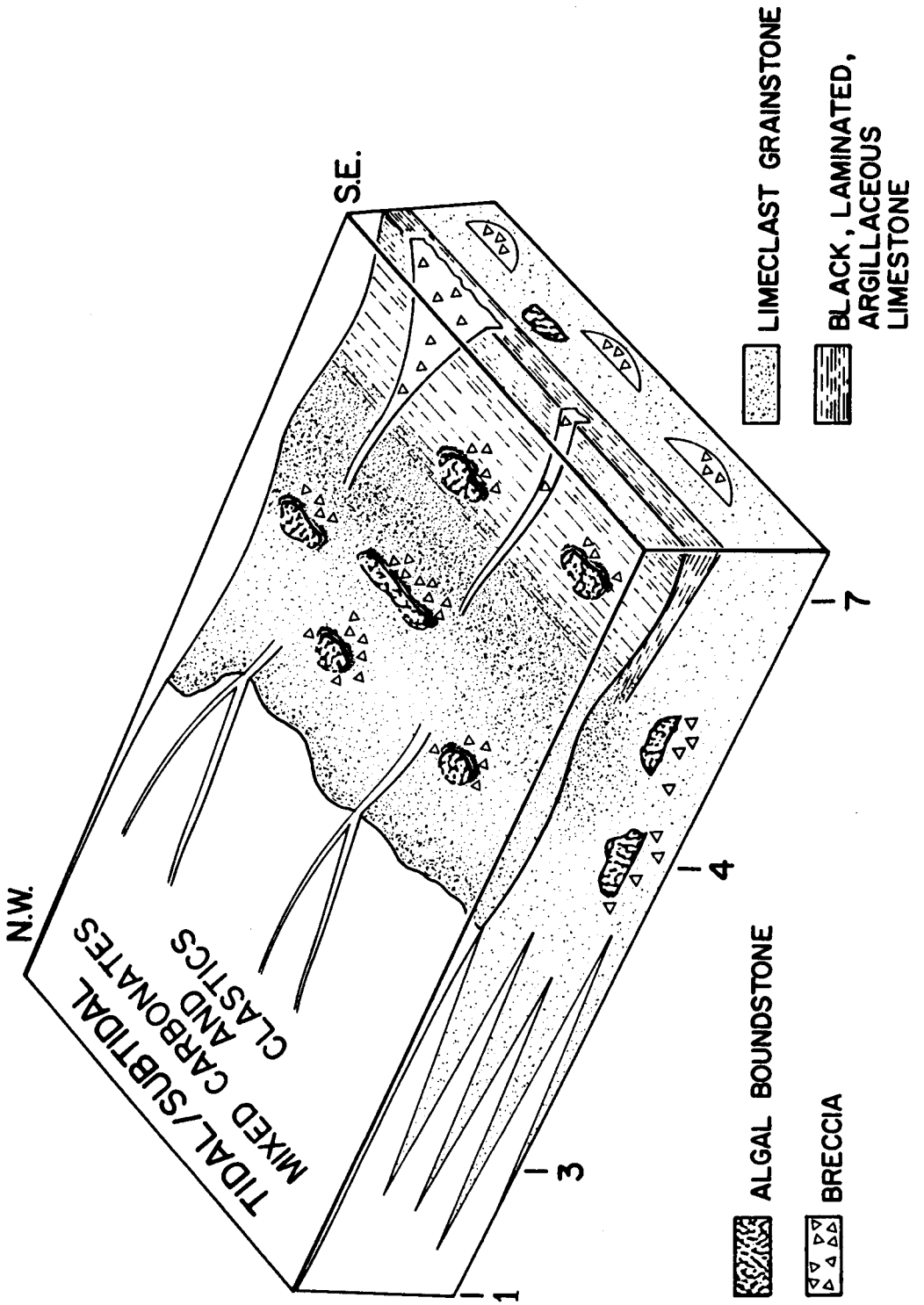
The Patterson Member in northwestern belts was probably deposited in a low-energy, shallow subtidal setting as evidenced by the abundance of lime mud, light gray color, general lack of mechanical stratification and locally abundant burrows. The Patterson Member is confined to the subsurface in southeastern belts and is beyond the scope of this study. During the deposition of the Austinville and Ivanhoe Members, tidal flat and shoal water facies consisting of fenestral and cryptalgal carbonates and massive dolomites were developed in northwestern belts and appear to pass southeastward into slightly deeper, subtidal, thinly bedded, black carbonates (Taylor Marker). Local oolitic limeclast grainstones interbedded with tidal flat and shoal water facies in the Austinville Member (Fig. 4) probably formed in well-agitated subtidal settings between tidal flat and other shoal water lithotopes to the northwest and slightly deeper subtidal carbonates of the Taylor Marker in southeastern belts. Shoaling of these subtidal lithologies is indicated by the presence of mudcracked, dolomottled, fine-grained limestones with channel-

form monomictic breccias at the top of the Taylor Marker in southeastern belts.

During Rome Formation - upper Shady Dolomite time, mixed carbonate and clastic tidal flats and shoal water facies of the Rome Formation characterized by red clastics and interbedded carbonates with abundant mudcracks, ripple lamination, cryptalgal lamination fenestrae and possible dolomite-replaced evaporite nodules passed seaward (southeastward) into outer platform deposits of the upper Shady Dolomite (grainstone shoals, bioherms and channel breccias possibly interspersed with tidally exposed areas) (Fig. 18). These upper Shady beds may reflect subsidence in southeastern belts during Rome Formation - upper Shady Dolomite time. Lateral migration of facies boundaries in the upper Shady Dolomite is evidenced by the incursion of "deeper water", black, thinly bedded, fine-grained limestones over outer platform limeclast grainstones followed by shoaling with progradation of shallower, outer platform, cross-bedded, locally oolitic grainstones and ripple laminated limestones (Fig. 5). It is not known if progradation culminated with the development of mixed carbonate and clastic tidal flat and shoal water facies in southeastern belts as this part of the sequence has either been lost to erosion and faulting or is confined to the subsurface beneath overthrust Blue Ridge rocks southeast of the study area. Low slopes on the platform margin are suggested by interfingering of shallow and slightly "deeper water" facies (Fig. 5) which probably reflects considerable lateral migration of facies

Figure 18. Schematic paleogeography, Rome Formation - upper Shady Dolomite. Numbers refer to approximate position of measured sections (Figure 3). Tidal and subtidal mixed carbonates and clastics of the Rome Formation (white area) were deposited in interior platform settings. Outer platform deposits to the southeast included shoal water grainstones, calcareous algal boundstone bioherms and channel-form breccias which pass southeastward into "deeper water" black, thinly laminated limestones with local channel-form to sheet-like polymictic breccias formed by submarine gravity flows.

SCHEMATIC PALEOGEOGRAPHY ROME FORMATION — UPPER SHADY DOLOMITE



bands.

Lowry and Willoughby (1975) interpreted breccias of the southeastern facies as being detrital carbonates shed from emergent uplands. Several features argue against this interpretation. The northwest to southeast facies change in the Shady-Rome Formations (Fig. 3) suggests increasingly open marine conditions to the southeast. This is opposite to the pattern that would be expected with uplands nearby to the southeast shedding carbonate detritus northwesterward into marine carbonate lithotopes. Clasts in breccias in southeastern belts are intrabasinal and can be matched with lithologies in the local succession; the larger (several meter dia.) limestone masses are mostly in place mounds of calcareous algal boundstone. Lowry and Willoughby (1975) imply a fining outward sequence to account for the lack of breccias in northwestern belts. However, lithologies that make up breccia clasts are absent from northwestern sequences. Also, southeastern and northwestern facies may have been brought closer together by thrust faulting.

The southeastern facies of the Shady Dolomite have been cited by several workers as being part of the eastern edge of the Cambrian carbonate platform of North America (Rodgers, 1968; Palmer 1971; Byrd, 1973b). Rodgers (1968) suggested that the Cambrian platform margin was a steep vertical escarpment that separated carbonate platform and pelitic basin facies and delineated the continental margin of North America during the Cambrian. Byrd (1973b) suggested a much broader, gently sloping margin as indicated by the presence

of carbonate rocks in the Grandfather Mountain Window and possibly out to the Brevard Zone. The Cambrian platform margin in the Appalachians has been described from the Conestoga Valley, southeastern Pennsylvania (Gohn, 1976) and the Frederick Valley, Maryland (Rheinhardt, 1974; Rheinhardt and Hardie, 1976). Gohn (1976) suggested that intertonguing of megabreccias and basinal fine-grained carbonates indicated that the platform margin was a steep slope in Pennsylvania and possibly located on the continental margin. Rheinhardt (1974) concluded that the platform to basin transition in Maryland had a relatively gentle slope. The presence of Precambrian granitic rocks many miles east of the Austinville area suggests that the Shady Dolomite carbonate platform was probably underlain by continental crust and that both the platform and deeper water off-platform rocks of the Shady Dolomite developed on the continental shelf (Byrd, 1973b).

Calcareous algal boundstones have not been described from the Cambrian of the Appalachians, except for possible dolomitized and metamorphosed equivalents where the algal microstructure has been destroyed (Thompson, 1976). These rocks occur in the Alabama Piedmont where the Shady Formation consists of greenschist-facies, talc-bearing marbles that are overlain by Talledega Group chlorite-muscovite slates and schists (Thompson, 1976). Cambrian calcareous algal boundstones were an important component of outer platform communities during the Cambrian not only on the western (McIlreath, 1976; Lohmann, 1976) and southern (Ahr, 1971) margins of the

craton but also on the eastern margin (this paper). The Cambrian calcareous algae appear to have formed boundstone masses ranging from discreet pod-like bioherms (Ahr, 1971; Lohmann, 1976; this paper) to reef rims with near vertical seaward margins and up to 200 m of relief (McIlreath, 1976) that occurred in a variety of pericratonic outer platform settings ranging from shallow, well-agitated environments (Lohmann, 1976; this paper) to deeper, quiet water lithotopes (this paper).

CONCLUSIONS

1) The Middle Cambrian Shady Dolomite in the Austinville area, Virginia is 640 m thick in northwestern belts where it contains three members: the basal Patterson Member (ribbon-laminated limestone and dolomite), the Austinville Member (massive dolomite) and at the top, the Ivanhoe Member (limestone). The unit here is overlain by 600 - 900 m of Rome Formation (red terrigenous sandstone, mudrock and carbonates). Exposed upper Shady Dolomite carbonate beds in southeastern belts contain distinctive units of limeclast grainstone, breccia, calcareous algal boundstone, and black thinly bedded limestone/argillaceous limestone; underlying Patterson and Austinville Members are not exposed. The Shady Dolomite - Rome sequence here is suggestive of the platform to basin facies transition of Wilson (1975).

2) Northwestern belts of the Shady Dolomite are characterized by subtidal basal ribbon-laminated and nodular dolomitic lime mudstones and pellet wackestones (Patterson Member) that grade up into tidal and shallow subtidal cryptalgal, fenestral and massive dolomitic carbonates (Austinville and Ivanhoe Members). The sequence is overlain by red terrigenous, mudcracked clastics and carbonates of the Rome Formation. The Shady Dolomite - Rome Formation sequence of northwestern belts was probably deposited in an interior platform setting and formed an upward shoaling sequence that culminated in the deposition of shoal-water to subaerial

clastics derived from the craton,

3) Exposed southeastern facies of the Shady Dolomite, which contain thick sequences of limeclast grainstone, sheet-like to channel-form units of polymictic and lesser monomictic carbonate breccias, calcareous algal boundstone bioherms, black thinly bedded limestone and argillaceous limestone with local thin graded grainstone units were deposited in outer platform and locally off-platform environments. Slopes on the carbonate platform margin may have been low (few degrees) as indicated by interfingering of shallow water lithologies (cross-bedded, oolitic limeclast grainstone and ripple-laminated possibly mudcracked argillaceous carbonates) with deeper water lithologies (black thinly laminated argillaceous limestones). These interfingering relations probably record considerable lateral migration of facies bands.

4) Calcareous algal bioherms of the upper Shady Dolomite contain the calcareous alga Epiphyton with minor Renalcis and lesser undetermined algal genera. Most of the Shady boundstone masses are in place bioherms as evidenced by the combination of growth layering that is parallel to bedding or developed as convex-upward domes, by geopetal structures, and by upward bifurcation and outgrowth of bioherms over adjacent breccias and grainstones. That the algae formed rigid masses is evidenced by draping of overlying beds and deformation of enclosing black, fine-grained argillaceous carbonates, together with the presence of abundant large angular clasts of algal boundstone that were reworked into breccia beds. Rigidity of the

structures may have been aided by symsedimentary precipitation of cement between delicate algal growths.

5) Well-preserved algal bioherms in the Austinville region suggest that metamorphosed bioherms of possible algal origin in the Alabama Piedmont (Thompson, 1976) might be related to calcareous algal mound formation. The Shady Dolomite boundstones are the first documented occurrence of well-preserved Cambrian reefal carbonates in the Appalachians although similar facies are well developed in western North America (Taylor and Cook, 1976; Lohmann, 1976; and McIlreath, 1976).

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APPENDIX A

Cementation

Cements in the Shady Dolomite are very complex and have been over printed by dolomitization. There is insufficient data to determine the sequence and timing of cementation of most of the Shady Dolomite. However, extensive early synsedimentary submarine cementation in outer platform sediments of the Shady Dolomite is abundant (see text).

Dolomitization

Early dolomitization processes that may have acted on the Shady sediments include penecontemporaneous dolomitization and seepage reflux dolomitization. Penecontemporaneous dolomite has been reported from the Persian Gulf (Illing, et al., 1965), Bonaire Island (Deffeyes, et al., 1965), and Andros Island (Shinn and Ginsburg, 1965). The dolomite found is a diagenetic mineral in hypersaline, high intertidal to supratidal zones. Penecontemporaneous dolomite in these environments is commonly associated with algal mats, dessication structures and evaporite minerals (gypsum and anhydrite). Formation of dolomite under these conditions appears to depend upon increasing Mg^{2+}/Ca^{2+} ratios by a combination of evaporation of saline waters and loss of Ca^{2+} through the precipitation of gypsum and anhydrite. That penecontemporaneous supratidal dolomite may have formed in the Shady Dolomite is evidenced by the association

of cryptalgal laminated dolomites, possible dolomite-replaced evaporite nodules, abundant evidence of dessication (fenestrae and mudcracks) and a restricted fauna. These features are common in much of the Austinville Member in northwestern belts of the Shady Dolomite.

The seepage-reflux model has been hypothesized by Deffeyes, et al., (1965) to explain dolomites on Bonaire Island, Southern Caribbean. In Lake Pelkemeer on Bonaire Island, dolomite and gypsum are both present (Deffeyes, et al., 1965; Bathurst, 1975). The lake is separated from the ocean by a coral rubble ridge and the lake level is below sea level. Thus, seawater seeps through the coral ridge into the lake and evaporation of lake water leads to hypersaline conditions. In addition to formation of penecontemporaneous dolomite in the supratidal zone, Deffeyes, et al. (1965) calculated that a counter flow of brine with Mg^{2+}/Ca^{2+} of about 30 should be carrying dense hypersaline lake water downward and seaward through the carbonate sediments underlying the rubble ridge. Deffeyes, et al. (1965) argue that Plio-Pleistocene rocks at the north end of Bonaire Island that have discordant dolomite-limestone contacts have been partially dolomitized by the reflux flow of dense brines from hypersaline supratidal areas. The seepage-reflux model requires a barrier between hypersaline conditions and normal marine environments with reflux of dense brines through the barrier. Reflux of brines through a barrier (not evident in the Shady Dolomite) could have helped to dolomitize thick grainstone sequences in outer

platform settings of southeastern belts of the Shady Dolomite.

However, it must be noted that no direct evidence of this process is available and that dolomitized limeclast grainstones are heavily overprinted by hydrothermal processes.

Burial dolomitization occurs during the late stages of burial diagenesis and is associated with veins, fractures and faults. Dolomites occurring under these conditions are believed to be formed by magnesium rich fluids passing through the secondary porosity produced by faults, fractures and joints. The association of structurally controlled dolomite with sulphide minerals suggest that dolomitizing fluids are of hydrothermal origin. Meyer and Henley, (1967) and Beales (1975) describe large scale magnesium metasomatism that occurs during wall rock alteration around ores of lead and zinc sulphides. The occurrence of coarse sparry dolomites in vugs and fractures and as pods in different host lithologies (commonly dolomites) together with the known association of the dolomite "gangue" with ore horizons in the Austinville area (Weinberg, 1971) underlines the significance of hydrothermal alteration of the Shady Dolomite during mineralization. The dolomitization associated with mineralization may overprint earlier diagenetic fabrics.

Pressure Solution and Paragenesis of Ribbon-laminated Carbonates,

Patterson Member, Shady Dolomite

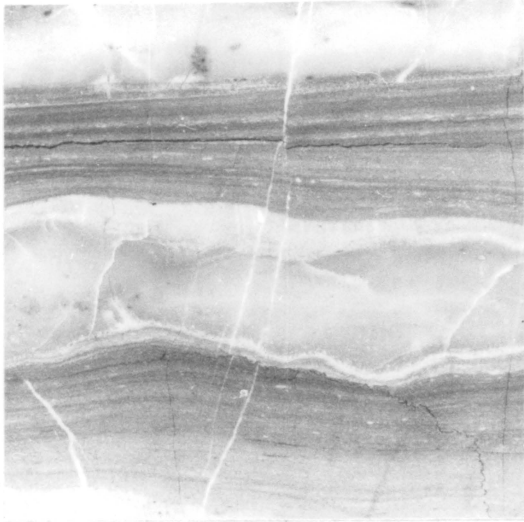
Pressure solution (stylolitization) has played an important role in the formation of ribbon-laminated carbonates, Patterson Member,

Shady Dolomite. A paragenetic sequence for the formation of ribbon-laminated carbonates is described below (Fig. 19). The probable sequence of alteration appears to be:

- 1) unaltered lime mudstone host
- 2) development of stylolitic dolomite seams that separate layers and lenses of limestone
- 3) partial to complete alteration of remaining limestone to dolomite associated with apparent decrease in stylolite concentration, local vug formation, and
- 4) precipitation of pore-filling cements by hydrothermal fluids in diagenetic spaces within non-stylolitized layers.

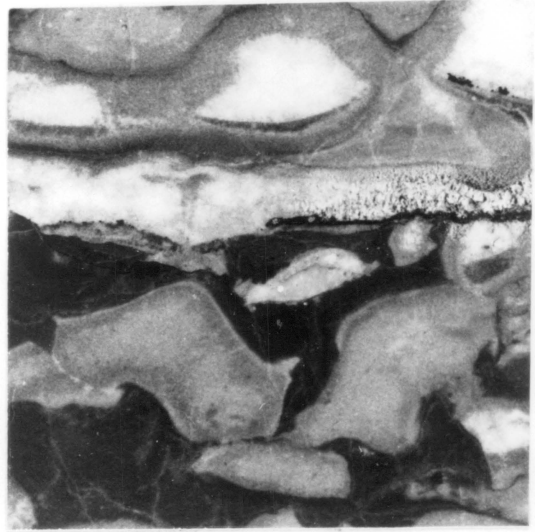
The sequence begins with development of incipient pressure solution seams probably in more argillaceous lime mudstones and pellet limestone. Increasing pressure solution forms finely crystalline equant dolomite along stylolitic seams. The combination of these two processes leads to the formation of stylolitically laminated, argillaceous, finely crystalline dolomite separating layers and lenses of limestone. Limestone layers undergo brittle fracturing and stylolitically laminated dolomite appears to have deformed plastically around limestone "clasts" producing a pseudo-breccia fabric. Limestone layers and nodules commonly have halos of disseminated, finely crystalline dolomite that grade into stylolitically laminated dolomite. Limestone layers also contain chalcedony concretions. The process continued with incomplete dolomitization of remaining limestone and apparent decrease in

Figure 19. Paragenetic sequence, ribbon-laminated carbonates, Patterson Member. A. Ribbons of lime mudstone separated by stylolitically laminated argillaceous dolomite. B. Nodular and ribbon-laminated light gray dolomite containing coarse sparry dolomite filled vugs, and dark gray stylolitically laminated dolomite. C. Ribbon-laminated dolomite containing zebra rock. D. En echelon zebra rock.



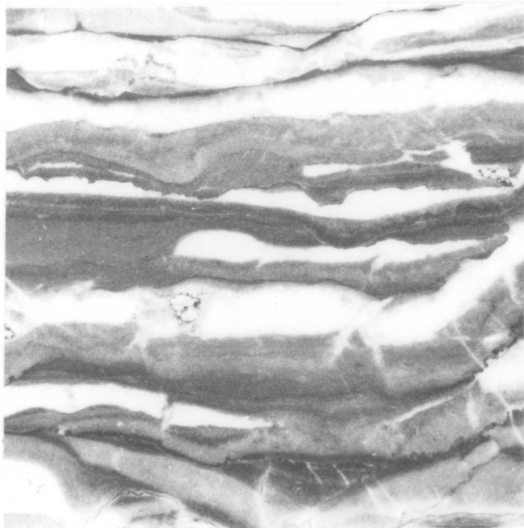
A

1 cm



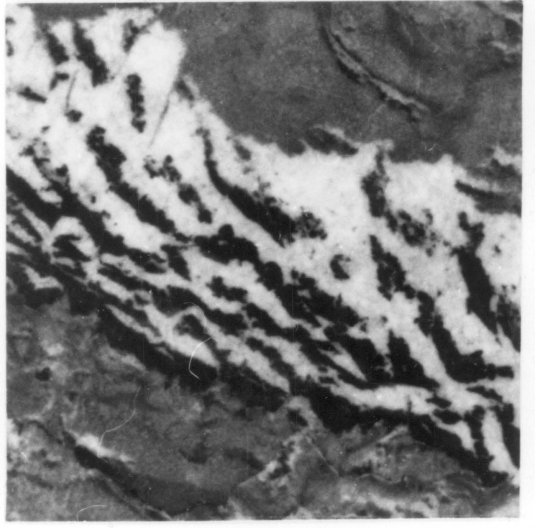
B

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C

1 cm



D

1 cm

concentration of stylolites; this decrease in stylolite concentration with increasing dolomitization suggests that recrystallization of dolomite may have annealed pressure solution seams. The sequence is completed with remaining limestone dissolved forming diagenetic spaces that were subsequently filled by sparry dolomite, ferroan calcite and quartz to form "zebra rock" (laminar structures) and vugs showing pore-filling textures (Bathurst, 1975). Similar "zebra rock" fabrics have been reported from the southern Illinois fluorspar deposits (Amstutz and Park, 1967) and Aitken (1966) described similar "stromatactoid dolomite" associated with massive dolomites from Middle Cambrian to Middle Ordovician rocks, Alberta. The combination of sparry dolomite, ferroan calcite and quartz together with sulphide minerals suggests that these last pore-filling cements were precipitated from hydrothermal fluids (Meyer and Henley, 1967). It is possible that en echelon "zebra rock" fabrics were formed under the influence of conjugate shears during hydrothermal alteration. This is suggested by "zebra" fabrics inclined at a constant angle that alternate in direction of inclination.

APPENDIX B

Measured Sections

GEOLOGIC SECTION, SHADY DOLOMITE, PORTERS CROSSROADS

Base of section is located along State Rte. 94 approximately 1500 ft (457m) north of the intersection of State Rtes. 94 and 619, Porters Crossroads (36° 52' 07" N., 80° 59' 02" W.), Austinville 7 1/2 minute quad-range, Wythe County, Virginia. The section was measured south along State Rte. 94.

UNIT AND THICKNESS

ROME FORMATION

Not measured

Interbedded mudrock and sandstone, red, medium to thick bedded, ripple cross lamination and mudcracks and limestone and dolomite, medium gray, medium bedded, cryptalgal laminates and fenestrae.

SHADY DOLOMITE 1549' (472m)

Ivanhoe Member 137' (42m)

P-36
123' (37m)

Pellet-intraclast packstone/grainstone, medium gray, thick bedded, some cryptalgalamination and fenestrae.

P-35
14' (4m)

Interlayered crystalline dolomite and lime mudstone, medium gray, minor pellets and fine crystalline dolomite, medium to thick bedded, flaggy with shale partings, some algal lamination and irregular fenestrae.

Austinville Member 978' (298m)

- P-34
89' (27m) Dolomite, light gray to white, medium crystalline, thick bedded, massive with some lamination (cryptalgal?).
- P-33
1' (0.3m) Lime mudstone, medium gray, fine crystalline dolomite, thin bedded.
- P-32
5' (1.5m) Pellet-intraclast grainstone, medium gray, thin bedded, cryptalgalaminations with large irregular and laminoid fenestrae.
- P-31
21' (6m) Lime mudstone, dark gray, thin bedded, lamination and stylolites.
- P-30
10' (3m) Covered.
- P-29
2' (0.6m) Lime mudstone, medium gray, thick lamination; alternating lime mudstone and stylolitized finely crystalline dolomite.
- P-28
22' (7m) Dolomite, white, medium crystalline, massive, thick laminated dolomite near top.
- P-27
6' (2m) Interlayered dolomite, light gray, thin bedded/flaggy and lime mudstone, light gray, thin bedded.
- P-26
58' (17.5m) Dolomite, light gray, medium crystalline, thin bedded/flaggy, laminated, passes down into Dolomite, white, medium crystalline, thick bedded, cryptalgalaminates and some massive beds, local fluorite,

underlain by

Dolomite, white, medium crystalline, thickly laminated.

P-25

39' (12m)

Dolomite, light gray, medium crystalline, thick bedded, massive with some small spar-filled vugs.

P-24

34' (10m)

Covered

P-23

58' (18m)

Dolomite, light and dark gray, medium crystalline, medium to thick bedded.

P-22

18' (5.5m)

Dolomite, white, medium crystalline, thick bedded, massive.

P-21

3' (0.9m)

Dolomite, dark gray, medium crystalline, thick bedded, some local breccia (tectonic).

P-20

8' (2.4m)

Dolomite, light gray, medium crystalline, medium bedded, laminated.

P-19

3' (0.9m)

Dolomite, light gray, medium crystalline, thick bedded, anastomosing vugs filled with cryptocrystalline dolomite.

P-18

3' (0.9m)

Dolomite, light gray, medium crystalline, thick bedded, massive.

P-17

6' (2.0m)

Covered.

P-16

26' (8.0m)

Dolomite, light gray to white, medium crystalline, medium bedded, laminated and minor massive beds containing spar-filled vugs.

- P-15
15' (4.5m) Dolomite, dark gray to black, medium crystalline, massive, some laminated beds.
- P-14
10' (3.0m) Dolomite, dark gray, medium crystalline, medium bedded, laminated (cryptalgal?) and possible oolites, some "zebra rock" at base.
- P-13
15' (4.5m) Dolomite, light gray, fine to medium crystalline, medium bedded, interlayered laminated dolomite and massive dolomite, some cryptalgalaminates.
- P-12
33' (10m) Dolomite, light gray to white, medium crystalline, medium bedded, laminated, 2 feet (0.6m) of fractured and sheared dolomite.
- P-11
10' (3.0m) Dolomite, dark gray to black, medium crystalline, medium to thick bedded, laminated with coarse sparry dolomite-filled vugs. (evaporite replacement?)
- P-10
24' (7.3m) Dolomite, light gray, finely crystalline, thin bedded, interbedded massive and laminated dolomite, possible mudcracks near top.
- P-9
79' (24m) Dolomite, light gray, finely crystalline, minor quartz sand, thick bedded, cryptalgalaminates with upturned polygons 1 meter diameter, grades down into and inter-layered with
Dolomite, medium to dark gray, finely crystalline, thick

bedded, cryptalgalaminates, veining and pods of breccia.

- P-8
123' (37.5m) Dolomite, white, medium crystalline, very thick bedded, massive.
- P-7
23' (7m) Dolomite, medium gray, medium crystalline, medium bedded, finely laminated with fine "zebra rock".
- P-6
130' (39.6m) Covered.
- P-5
140' (42.7m) Dolomite, ribbon-laminated, light and medium gray, fine to medium crystalline, medium to very thick bedded; ribbons of medium crystalline medium gray dolomite alternating with finely crystalline light gray dolomite, "zebra rock", ribbon fabric in various states of re-crystallization.
- Patterson Member 434' (132m)
- P-4
38' (11.6m) Lime mudstone, ribbon-laminated, light gray, finely crystalline calcite with minor pellets, medium bedded; ribbons of stylolitic argillaceous finely crystalline dolomite alternating with lime mudstone, burrows and chalcedony concretions.
- P-3
49' (14.9m) Dolomite, ribbon-laminated, light and medium gray, fine to medium crystalline, thick bedded; ribbons of medium crystalline dolomite alternating with stylolitic finely crystalline argillaceous dolomite, "zebra rock" (laminar structures of coarse dolomite spar).

- P-2
90' (27.4m) Lime mudstone, dolomottled, light and medium gray, mottles of stylolitic argillaceous finely crystalline dolomite, thick bedded, abundant burrows.
- P-1
257' (78.3m) Lime mudstone, ribbon-laminated, light and medium gray, minor pellets, intraclasts and echinoderm debris, thick bedded; ribbons of stylolitic argillaceous finely crystalline dolomite alternating with lime mudstone, minor burrows.
- Unit in fault contact with Rome Formation.
- GEOLOGIC SECTION 2, SHADY DOLOMITE, FOSTERS FALLS
- Base of section is located at the railroad station at Fosters Falls (36° 52' 52" N., 80° 51' 30" W.), Fosters Falls 7 1/2 minute quadrangle, Wythe County, Virginia.
- UNIT AND THICKNESS Section was measured southwestward along the N & W railroad track.
- Patterson Member 1024' (312m)
- F-18
34' (10.4m) Dolomite, medium gray, medium crystalline, thin bedded, abundant "zebra rock".
- F-17
44' (13.4m) Dolomite, medium gray, fine to medium crystalline, massive, irregular pod-like mass of limestone described below:
- Pellet/intraclast packstone, dolomottled, light to medium gray, pellets, intraclasts, and debris of Salterella, echinoderms, and trilobites, irregular mottles

of stylolitized argillaceous finely crystalline dolomite, minor burrows, anastomosing vugs filled with coarsely crystalline calcite and dolomite.

F-16
37' (11.3m)

Lime mudstone, medium and dark gray, thick bedded irregular mottles of stylolitic argillaceous lime mudstone. Vugs of coarsely crystalline dolomite, one bed of medium gray, medium crystalline dolomite.

F-15
17' (5.2m)

Dolomite, medium gray, fine to medium crystalline, thick bedded, massive.

F-14
46' (14m)

Lime mudstone, ribbon-laminated, light and medium gray, rare pellets and Salterella debris, thick bedded; ribbons and pods of lime mudstone alternating with stylolitized argillaceous finely crystalline dolomite, minor burrows.

F-13
77' (23.5m)

Dolomite, medium gray, fine to coarsely crystalline, very thick bedded, irregular mottles of stylolitized argillaceous finely crystalline dolomite, burrow mottled vugs of coarsely crystalline dolomite, "zebra rock".

F-12
54' (16.5m)

Sheared and disrupted zone.

F-11
76' (23.2m)

Dolomite, medium gray, medium crystalline, thick bedded, irregular mottles of stylolitized argillaceous finely crystalline dolomite, burrow mottling, vugs and lenses

of coarsely crystalline dolomite

F-10
16' (4.9m)

Dolomite, ribbon-laminated, medium gray, fine to medium crystalline, very thick bedded, ribbons of medium crystalline dolomite alternating with stylolitized argillaceous finely crystalline dolomite, some brecciated dolomite.

F-9
87' (26.5m)

Covered.

F-8
95' (29m)

Lime mudstone, ribbon-laminated, light and medium gray, thick bedded, pods and ribbons of lime mudstone alternating with stylolitized argillaceous lime mudstone, chalcedony concretions, irregular mass of dolomite near base, some burrowed dolomottled horizons.

F-7
17' (5.2m)

Dolomite, medium gray, finely crystalline, thick bedded, vugs of coarsely crystalline dolomite and abundant pyrite, local brecciated masses.

F-6
17' (5.2m)

Wackestone, dolomottled, light and dark gray, pellets, intraclasts, trilobite and echinoderm debris, thick bedded, mottles of stylolitized argillaceous dolomite, abundant burrows.

F-5
126' (38.4m)

Lime mudstone, ribbon-laminated, light and dark gray, minor pellets, thickly bedded; ribbons of lime mudstone alternating with stylolitized argillaceous finely crystalline dolomite.

- F-4
5' (1.5m) Dolomite, "zebra rock", dark gray and white, very fine to coarsely crystalline, bands of coarsely crystalline dolomite alternating with bands of stylolitized finely crystalline argillaceous dolomite, rare quartz silt, some en echelon "zebra rock" (inclined bands of coarsely crystalline dolomite alternating with stylolitized finely crystalline dolomite).
- F-3
96' (29.3m) Dolomite, ribbon-laminated, medium and dark gray, very fine to coarsely crystalline; ribbons and pods of medium to coarsely crystalline dolomite alternating with stylolitized very finely crystalline argillaceous dolomite and quartz silt, vugs as before, "zebra rock", and local brecciation.
- F-2
108' (33m) Covered.
- F-1
72' (22m) Dolomite, ribbon-laminated, medium and dark gray, very fine to coarsely crystalline, thick bedded; ribbons and pods of medium to coarsely crystalline dolomite alternating with stylolitized very finely crystalline argillaceous dolomite and quartz silt; vugs containing coarsely crystalline dolomite, ferroan calcite, and quartz fill upper parts of pods ("zebra rock").

108' (33m)

Covered.

ERWIN FORMATION

GEOLOGIC SECTION 3, SHADY DOLOMITE, IVANHOE

Base of section is located along the N & W railroad 1 mi (1.6km) north of BM 2001 at Ivanhoe (36° 50' 37" N., 80° 56' 27" W.), Austinville 7 1/2 minute quadrangle, Wythe County, Virginia. The section was measured south along the railroad and continues into quarry approximately 1600 ft (488m) north of BM 2001.

UNIT AND THICKNESS

ROME FORMATION

Not measured

Shale and siltstone, maroon, pink, and olive, thin bedded

SHADY DOLOMITE 1123' (342.3m)

Ivanhoe Member 124' (37.8m)

I-27

5' (1.5m)

Lime mudstone, light gray, minor pellets, thin bedded, cryptalgalamination, oncolite layers, some dolomottling.

I-26

3' (0.9m)

Interbedded shale and lime mudstone, green and light gray, thin bedded.

I-25

20' (6.1m)

Pellet grainstone, medium gray, pellets, thin bedded, minor intraclastic, oncolitic beds and cryptalgalamination.

I-24

23' (7m)

Pellet grainstone, medium gray, thin bedded, some lamination.

- I-23
16' (4.9m) Covered.
- I-22
15' (4.6m) Pellet-intraclast packstone and grainstone, medium gray, pellets, intraclasts, and minor oncolites, thin bedded, cryptalgalamination and fenestrae.
- I-21
7' (2.1m) Interbedded dolomite, light gray, finely crystalline, medium bedded and lime mudstone with cryptalgalamination.
- I-20
35' (10.7m) Lime mudstone, medium gray, minor pellets and intraclasts, medium to thick bedded, cryptalgalamination.
Austinville Member 999' (304.5m)
- I-19
145' (44.2m) Dolomite, medium gray, coarsely crystalline, massive.
- I-18
55' (16.8m) Taylor Marker, Dolomite, light gray, coarsely crystalline, abundant coarse well-rounded quartz grains, massive.
- I-17
62' (18.9m) Interbedded dolomitized oolitic grainstone, black, medium crystalline, relict ooids, medium bedded; and dolomitized limeclast grainstone, light gray to white, coarsely crystalline with relict coarse sand-sized grains, possible ooids, massive.
- I-16
7' (2.1m) Covered.
- I-15
106' (32.3m) Interbedded dolomite, light gray to white, medium crystalline, massive, vuggy, locally laminated; and Dolomite, dark gray to black, medium crystalline, thick

bedded, laminoid and irregular fenestrae.

I-14

33' (10m)

Interlayered pellet-intraclast grainstone and packstone, light gray, pellets, intraclasts, medium

bedded, laminoid and irregular fenestrae, some cryptalgalamination, minor stylolites, minor oolitic grainstone; and

Dolomite, light gray, medium to coarsely crystalline, massive, minor stylolites, some vugs filled with very coarsely crystalline dolomite.

Contact between limestone and dolomite very irregular and discordant to bedding.

I-13

45' (13.7m)

Interbedded dolomite, black, medium crystalline, thick bedded, laminoid and irregular fenestrae; and

Dolomite, light gray to white, medium crystalline, thick bedded, vuggy, evaporite layers(?).

I-12

11' (3.4m)

Pellet-intraclast grainstone, light gray, pellets, intraclasts, minor ooids, rare trilobite

and echinoderm fragments, locally abundant skeletal algal (Solenopora?) debris, thin to medium bedded, laminoid and irregular fenestrae, some cryptalgalamination, minor stylolites.

I-11

68' (20.7m)

Interbedded dolomite, black, fine to medium crystalline, thick bedded, laminoid fenestrae, some palisade

structures; and dolomite, light gray to white, medium crystalline, massive, vuggy, some "zebra rock".

I-10

26' (7.9m)

Dolomitized limeclast grainstone, light gray to white, fine to medium crystalline, relict grainstone fabric-intraclasts(?), cross lamination(?),

I-9

42' (12.8m)

Interbedded dolomite, black, finely crystalline, thick bedded, laminoid fenestrae and lenses of palisade structures, irregular vugs, "zebra rock", and brecciated dolomite; and

Dolomite, white, medium crystalline, thick bedded, massive.

I-8

15' (4.6m)

Dolomite, dark gray to black, finely crystalline, very thick bedded, massive and thickly laminated, laminoid fenestrae, "zebra rock", small channel-form solution cavity breccia.

I-7

7' (2.1m)

Dolomite, light gray to white, fine to medium crystalline, thin bedded, thick lamination, pod of brecciated and veined dolomite.

I-6

68' (20.7m)

Dolomite, white, medium crystalline, thick bedded, massive.

I-5

15' (47.2m)

Sheared zone.

I-4

51' (15.5m)

Dolomite, white, medium crystalline, thick bedded, massive, some thickly laminated beds.

I-3
93' (28.3m) Dolomite, white, medium crystalline, thick bedded,
massive, small sheared zone with fault gouge.

I-2
100' (30.5m) Covered.

I-1
50' (15.2m) Dolomite, light gray to white, medium crystalline,
thick bedded, massive.

Patterson Member not exposed

GEOLOGIC SECTION 4, SHADY DOLOMITE, CLEAR BRANCH

Base of section is approximately 800 feet (244m) south-
east of the confluence of Buddle Branch and Clear Branch
(36° 51' 12" N., 80° 54' 13" W.) Austinville 7 1/2 minute
quadrangle, Wythe County, Virginia. Section was
measured southeast along Clear Branch. Top of section
is approximately 2600 feet (792m) southeast of con-
fluence.

UNIT AND
THICKNESS

Top not exposed - Blue Grass Fault

Upper Shady Dolomite 850' (259m)

4CB-22
75' (22.9m)

Interbedded calcareous algal boundstone, light to dark
gray, algae dominantly Epiphyton and minor Renalcis,
massive;

Limestone breccia, medium gray, polymictic, clasts (up
to 15cm) of skeletal algal boundstone, skeletal and
limeclast grainstone, and skeletal packstone/wackestone;
interstitial fill - mud or packstone/grainstone with
skeletal algal debris, trilobites and ooids, massive,

some styloitization; and

Grainstone, dark gray, very coarse sand-sized algae (Epiphyton), echinoderms, intraclasts, and ooids (cores of pellets, algae and dolomitized mud), medium to thick bedded.

Lower portion of interval poorly exposed.

4CB-21
131' (40m)

Covered with poorly outcropping dolomitized limeclast grainstone, light to medium gray, medium crystalline with relict coarse sand-sized intraclasts, thick bedded.

4CB-20
100' (30.5m)

Dolomitized limeclast grainstone, medium gray to white, fine to medium crystalline with relict well-rounded medium to coarse sand-sized intraclasts(?), thick bedded, massive, vugs and cracks filled with white coarsely crystalline dolomite.

Local dolomite, mottled medium and dark gray, medium to coarsely crystalline, massive, relict boundstone fabric(?).

4CB-19
170' (51.8m)

Dominantly boundstone, medium to light gray, Epiphyton and Renalcis, minor laminar and filamentous forms, massive; interbedded with pods and lenses(?) of Grainstone and limestone breccia, medium to light gray, angular to rounded, up to granule size (3.5mm) fragments of skeletal algae (Epiphyton, Renalcis), echinoderms, trilobites, brachiopods, and intraclasts, minor ooids

and quartz silt; and

Local mud supported breccia, medium to thick bedded, some stylolitization.

Middle Cambrian fauna - Willoughby (in prep.)

Spring Pipe locality at approximately 165' (50.1m).

- 4CB-18
31' (9.4m) Dolomite, light to dark gray, medium to very coarsely crystalline, minor subrounded medium sand-sized quartz, thick bedded, massive, relict textures: limeclast grainstone and Renalcis boundstone(?).
- 4CB-17
38' (11.6m) Covered.
- 4CB-16
5' (1.5m) Dolomite, light gray, medium to coarsely crystalline, massive, local "zebra rock".
- 4CB-15
7' (2.1m) Covered.
- 4CB-14
23' (7m) Dolomite, mottled light gray and white, laminar fabric of coarsely crystalline dolomite spar and medium crystalline dolomite, thick bedded, relict texture: algal boundstone(?).
- 4CB-13
14' (4.3m) Covered.
- 4CB-12
4' (1.2m) Dolomite, light gray, finely crystalline, thin bedded.
- 4CB-11
22' (6.7m) Boundstone, light gray, abundant Renalcis and Epiphyton, minor filamentous and laminar forms, common echinoderms and quartz silt, massive; passes laterally northwest

into and out over

Grainstone/packstone, light to medium gray, very coarse sand sized (up to 2mm) Epiphyton clasts, trilobites, echinoderms and rare brachiopods, intraclasts and ooids (nuclei algae and intraclasts), lime mud and angular quartz silt, medium to thickly bedded Boundstone passes laterally southeastward into: Breccia, polymictic, clasts (up to 0.6m) of calcareous algal boundstone and skeletal grainstone, medium bedded.

4CB-10
30' (9.1m)

Covered with poorly outcropping dolomitized limeclast grainstone, light gray, fine to medium crystalline with relict rounded very coarse sand- to granule-sized grains, medium bedded.

4CB-9
35' (10.7m)

Dolomitized limeclast grainstone, light gray to white, fine to medium crystalline dolomite with relict rounded very coarse sand- to granule-sized grains, thin to thick bedded.

4CB-8
15' (4.6m)

Covered.

4CB-7
20' (6.1m)

Dolomite, light gray to white, medium crystalline, very thick bedded.

4CB-6
14' (4.3m)

Covered.

- 4CB-5
26' (7.9m) Dolomitized limeclast grainstone, light gray to white, medium crystalline with relict well rounded coarse sand-sized grains, medium to thick bedded, local pods of very coarsely crystalline white dolomite.
- 4CB-4
35' (10.7m) Covered.
- 4CB-3
22' (6.7m) Dolomitized limeclast grainstone, light to medium gray, medium to coarsely crystalline with relict coarse sand-sized limeclasts, thin bedded, cross-lamination(?).
- 4CB-2
8' (2.4m) Covered.
- 4CB-1
25' (7.6m) Dolomitized skeletal and oolitic limeclast grainstone, medium to dark gray, medium to coarsely crystalline with relict very coarse sand-sized (up to 2mm) grains (algae or intraclasts?), echinoderms, trilobites and brachiopods; ooids with cores of limeclasts (skeletal algae or intraclasts), echinoderms, trilobites, and brachiopods; thin to medium bedded.

no base to section - Stamping Ground Fault

GEOLOGIC SECTION 5, SHADY DOLOMITE, CLEAR BRANCH

Base of section is approximately 2600 feet (793m) southeast of confluence of Clear and Buddle Branches (36° 50' 58" N., 80° 54' 03" W.) Austinville 7 1/2 minute quadrangle, Wythe County, Virginia. Section

UNIT AND THICKNESS	was measured southeast along Clear Branch. Top of section is approximately 3800 feet (1158m) southeast of confluence.
	no top to section - Callahan Fault Zone
	<u>Shady Dolomite</u> - <u>Taylor Marker</u> 189' (57.6m)
5CB-10 14' (4.3m)	Dolomite, medium to dark gray, finely crystalline, thick bedded, thinly laminated.
5CB-9 10' (3.1m)	Siltstone, light gray, coarse silt- to fine sand-sized quartz, thick bedded, rippled (?), lesser argillaceous limestone with trilobite debris.
5CB-8 25' (7.6m)	Dolomite, dark gray, very finely crystalline with argillaceous material, thick bedded, thinly laminated, some disseminated pyrite.
5CB-7 13' (4.0m)	Skeletal wackestone, dolomottled, light gray, pink and green, pellets, minor intraclasts, trilobite debris, thick bedded, stylolites and some disseminated pyrite. Lower Cambrian fauna horizon of Willoughby (in prep.).
5CB-6 12' (3.7m)	Dolomite, dark gray to black, very finely crystalline with argillaceous material, thick bedded, thinly laminated.
5CB-5 17' (5.2m)	Covered interval.

- 5CB-4
12' (3.7m) Dolomite, light gray to white, medium and coarsely crystalline, thick bedded, massive with some brecciation (tectonic?),
- 5CB-3
13' (4.0m) Covered interval,
- 5CB-2
26' (7.9m) Lime mudstone and dolomite, light to dark gray, finely crystalline dolomite, thick bedded, stylolitization and disseminated pyrite.
- 5CB-1
47' (14.3m) Covered interval.

No base to section - Blue Grass Fault

GEOLOGIC SECTION 6, SHADY DOLOMITE, CLEAR BRANCH

Base of the section is approximately 3800 feet (1158m) southeast of the confluence of Clear Branch and Buddle Branch (36° 50' 52" N., 80° 53' 50" W.) Austinville 7 1/2 minute quadrangle, Wythe County, Virginia. Section was measured southeast along Clear Branch drainage to first occurrence of olive green - brown shales of Section 8.

UNIT AND THICKNESS

Shady Dolomite - Taylor Marker 416' (127m)

- 6CB-21
3' (0.9m) Limestone breccia, polymictic, clasts (up to 0.3m) of calcareous algal boundstone, grainstone, black laminated limestone, breccia, and quartzose lime mudstone, medium bedded.

- 6CB-20
45' (13.7m) Dolomottled lime mudstone, light to medium gray, finely crystalline calcite and stylolitic dolomite, medium to thick bedded, dolomottled boudinage and mud-cracks, small channel-form, flat pebble conglomerate; Note: brittle rock fracturing in limestone layers.
- 6CB-19
10' (3.1m) Dolomite, dark gray to black, finely crystalline, medium to thick bedded.
- 6CB-18
25' (7.6m) Covered.
- 6CB-17
3' (0.9m) Lime mudstone-pellet/intraclast packstone, dark gray to black, rounded and subangular pellets of lime mud and platy intraclasts, trilobite debris, thin bedded.
- 6CB-16
7' (2.1m) Covered.
- 6CB-15
67' (20.4m) Dolomitic lime mudstone, dark gray to black, very finely crystalline calcite (pellets?) and dolomite with abundant argillaceous material, thick bedded.
- 6CB-14
33' (10.1m) Dolomite, light gray, finely crystalline, thick bedded, massive.
- 6CB-13
18' (5.5m) Dolomite, dark gray to black, very finely crystalline with argillaceous material, thick bedded, very thinly laminated (locally contorted). Dolomite-filled en echelon veins.

- 6CB-12
23' (7m) Covered
- 6CB-11
22' (6.7m) Dolomite breccia (tectonic), medium and dark gray, clasts (up to 5 cm) of medium crystalline dolomite, interstitial fill of finely crystalline dolomite, thick bedded, massive. Note: in place fracturing of clasts, matching clast boundaries, stylolitic and penetrative clast boundaries, and dolomite-filled fractures cutting breccia fabric.
- 6CB-10
49' (14.9m) Dolomite, light to dark gray, fine to medium crystalline, thick bedded, massive, lamination, stylolites, and dolomite-filled fractures.
- 6CB-9
21' (6.4m) Covered.
- 6CB-8
4' (1.2m) Dolomite, mottled medium gray, medium crystalline, medium bedded, stylolites and dolomite-filled fractures.
- 6CB-7
3' (0.9m) Covered.
- 6CB-6
13' (4.0m) Dolomite, dark gray to black, very finely crystalline, quartz silt, medium to thick bedded, common incipient stylolitization.
- 6CB-5
7' (2.1m) Covered.
- 6CB-4
15' (4.6m) Dolomite breccia, medium and dark gray, angular clasts

(up to several cms) of medium crystalline dolomite with interstitial fill of dark, very finely crystalline dolomite, thick bedded, some "zebra rock" in clasts. Note: in place fracturing of clasts.

6CB-3
33' (10.1m)

Dolomite, light gray, fine to medium crystalline, local coarsely crystalline dolomite and dolomite spar-filled vugs, thick bedded, massive.

6CB-2
5' (1.5m)

Covered.

6CB-1
10' (3.1m)

Dolomite, light gray to white, medium to coarsely crystalline, thick bedded, massive, some "zebra rock".
Base not exposed - Callahan Fault Zone

GEOLOGIC SECTION 7C, UPPER SHADY DOLOMITE, ROUTE 52, POPLAR CAMP

Base of section is located 533 feet (163m) north of intersection of U.S. Route 52 and State Route 607 at Poplar Camp (36° 51' 15" N., 80° 51' 36" W.) Sylvatus 7 1/2 minute quadrangle, Wythe County, Virginia.

Section was measured southeast along the west side of U.S. Route 52 and is along strike from exposures in the F. and M. Construction Company Quarry (section 7B).

UNIT AND
THICKNESS

Upper Shady Dolomite 217' (66m)

52-7
18' (5.5m)

Grainstone, dark gray, very coarse grained, intra-

clasts, thin bedded, with polymictic breccia at top of interval, clasts (up to 0.6m) of calcareous algal boundstone, grainstone, and black laminated limestone and shale.

52-6
7' (2.1m)

Dolomite, dark gray, finely crystalline, thin bedded to thickly laminated, local mud supported conglomerate at top of interval.

52-5
3' (0.9m)

Shaly limestone, dark gray, pellet grainstone, thin bedded, local 5cm thick graded intraclastic grainstone/packstone, laminated.

Bedding plane fault, displacement (?).

52-4
64' (19.5m)

Dolomitized pellet grainstone, medium gray, pellets, intraclasts (up to 2.0mm) and very fine sand-sized quartz, medium bedded, locally laminated.

52-3
25' (7.6m)

Dolomitized limeclast grainstone, light-gray, medium crystalline with relict rounded fine to medium sand-sized grains, medium to thick bedded, local dolomitized pebbly grainstone, planar layering of platy grains.

52-2
50' (15.2m)

Covered.

52-1
50' (15.2m)

Dolomitized limeclast grainstone, light to medium gray, fine to medium crystalline with relict rounded, very coarse sand- to granule-sized grains. (oids?),

thick bedded, planar layering of platy grains.

GEOLOGIC SECTION 7B, 7A, UPPER SHADY DOLOMITE,

COMPOSITE SECTION

Section 7B is located at the F, and M. Construction Company Quarry 600 ft (183m) northeast of the intersection of U.S. Rte 52 and State Rte. 607 (36° 51' 10" N., 80° 51' 36" W.), Poplar Camp, Sylvatus 7 1/2 minute quadrangle, Wythe County, Virginia. The section was measured southeast along the west wall of the quarry.

UNIT AND
THICKNESS

Top not exposed; in faulted contact with overthrust
Chilhowee Gp. Rocks.

UPPER SHADY DOLOMITE 415' (126.5m)

M26

25' (7.6m)

Limeclast grainstone, medium gray, low angle cross-stratification and planar layering. Some layers contain flat-pebbles. Some quartzose layers.

M25

5' (1.5m)

Limestone, argillaceous, fine grained, and pellet limestone, ripple-laminated; unit contains 0.6m thick channel-form flat-pebble breccia bed.

M24

5' (1.5m)

Limestone breccia, polymictic, clasts of calcareous algal boundstone, grainstone, flat-pebble breccia, lime mudstone. Clast sizes up to 0.5m.

- M23
5' (1.5m) Pellet limestone, argillaceous partings, dark gray, thin bedded, and two interlayered 0.3m breccia horizons, abundant platy intraclasts and some lime grainstone clasts.
- M22
15' (4.6m) Limeclast grainstone, possible oolitic, thinly layered upper and lower parts, more massive middle portion. Planar layered.
- M21
7' (2.1m) Limeclast grainstone, medium to coarse grained, low angle cross-stratification. Small breccia lenses, few inches across, and 6" beds; clasts mainly platy intraclasts. Erosional base into underlying unit. Passes laterally into calcareous algal bioherm (up to 6m long by 2m high) flanked by breccias.
- M20
11' (3.4m) Lime mudstone, argillaceous, laminated, black and pellet limestone, gray, thin bedded. Common ripple-cross-lamination. Pass laterally into channel-form polymictic breccia. Clasts include calcareous algal boundstone, grainstone, oolite.
- M19
7' (2.1m) Limestone breccia, mud-supported passing up into grain supported granule and pebble breccia; clasts are calcareous algal boundstone, black pellet grainstone. Grades laterally into limeclast grainstone with minor breccia and small calcareous algal boundstone pods.

- M18
30' (9.1m) Pelletal limestone, argillaceous partings, quartz silt, dark gray to black, fine grained. Thin bedded, some lenticular bedding, some rippled surfaces. Interval poorly exposed.
- M17
15' (4.6m) Lime mudstone and pellet grainstone, black; argillaceous partings. Ripple laminated, lenticular and flaser bedded. Rare flat pebble breccia beds, black, monomictic. Possible mudcracked surfaces and some well developed ripple bedforms on bedding planes.
- M16
13' (4.0m) Limeclast grainstone, granule size to medium and fine sand size. Finer layers contain abundant ooids. Thin argillaceous partings.
- M15
10' (3.1m) Limestone breccia, polymictic; contains clasts of calcareous algal boundstone, lesser ooid and limeclast grainstone, and black laminated limestone, fragments up to 0.6m; mud matrix. Unit has planar base and hummocky top. Note in place algal bioherm extending out over laterally adjacent breccias.
- M14
3' (0.9m) Dolomitic limeclast grainstone, coarse grained, finer layers are oolitic. Draped over bioherm in quarry face.

- M13
2' (0.6m) Limestone breccia, polymictic. Clast 0.6-7.6 cm in diameter, include calcareous algal boundstone, lime-clast grainstone, ooid grainstone. Sharp planar base. Abuts bioherm in quarry face.
- M12
9' (2.7m) Dolomitic limeclast, grainstone and breccia. Inch-size clasts floating in grainstone. Abuts bioherm in quarry face.
- M11
8' (2.4m) Argillaceous laminated fine grained limestone, black. Rare 2.5cm limeclast grainstone layers. Possible mudcracks(?) on surface. Abuts in place bioherm in quarry face passing into breccia.
- M10
8' (2.4m) Limestone breccia, polymictic. Clasts of grainstone and lime mudstone, lesser calcareous algal boundstone, mainly centimeter-size up to 1 ft. (0.3m). Abuts large algal bioherm in quarry face.
- M9
7' (2.1m) Argillaceous fine grained limestone, black, thinly laminated.
- M8
5' (1.5m) Limestone breccia, polymictic. Black. Clasts of grainstone, lime mudstone and minor calcareous algal boundstone. Clasts mostly inch-size, rarely up to 0.3m. Rare boring (0.5cm) in clasts.

- M7
25' (7.6m) Covered interval across quarry road.
- M6
12' (3.7m) Argillaceous lime mudstone, black, laminated, and rare thin limeclast grainstone layers, graded up to 10 cms thick.
- M5
5' (1.5m) Calcareous algal bioherms, massive, light gray. Overlying and underlying beds draped around bioherms. Interfingering breccias; clasts of calcareous algae and lime grainstone, interstitial mud.
- M4
13' (4.0m) Interlayered argillaceous lime mudstone and thin limeclast grainstones. Dark gray, thin bedded and thick laminated. Grainstone layers up to 5 cms decrease to top; contain some unabraded calcareous algae.
- M3
8' (2.4m) Limeclast grainstone passing up into polymictic limestone breccia containing clasts of calcareous algal boundstone and black lime mudstone; grainstone 'matrix'; rare in place calcareous algal bioherms.
- M2
7' (2.1m) Lime mudstone with argillaceous partings. Black, fine grained, thin to thick laminated. Lenses and stringers of coarse grained limeclast grainstone.

FAULT

M1

155' (47.2m)

Dolomite and dolomitized limeclast grainstone, medium to coarse grained, light gray, medium to thick bedded, rare low angle cross-stratification, mainly horizontal layering. Interval also contains minor platy intra-clast layers, black, and quartz-silty pellet grainstone - lime mudstone, layers with thin black shale partings.

90' (27.4m)

Covered.

Section is continued along stream crossing Rudy Farm (7A). Base of section is located 2800 ft. (853m) east of U.S. Rte. 52 along light duty road 0.4 mi (0.6km) north of intersection of U.S. Rte. 52 and State Rte. 607 (36° 51' 35" N., 80° 51' 11" W.), Poplar Camp, Sylvatus 7 1/2 minute quadrangle, Wythe County, Virginia. Section was measured southeast along stream.

Upper Shady Dolomite 851' (248.4m)

R-30

95' (29m)

Poorly outcropping dolomitized limeclast grainstone, medium gray, medium crystalline with relict rounded very coarse sand- to granule-sized grains, minor ooids(?), medium bedded; local dolomitized breccias, clasts (up to several cms) of dark and light gray medium crystalline dolomite with interstitial fill of light yellow finely crystalline dolomite.

- R-29
4' (1.2m) Dolomitized breccia, light gray, small (up to several cm) clasts of white and gray, fine to medium crystalline dolomite, interstitial fill of dolomitized lime-clast grainstone, thick bedded.
- R-28
2' (0.6m) Interlayered, dolomitized pellet grainstones and dolomitized limeclast grainstones, medium gray, fine to coarsely crystalline with relict rounded very fine sand- to granule-sized grains, thin bedded to thickly laminated, planar layering of platy grains.
- R-27
34' (10.4m) Covered.
- R-26
37' (11.3m) Covered with poorly outcropping, dolomitized lime-clast grainstones, medium gray, medium to coarsely crystalline with relict rounded very coarse sand- to granule-sized grains, thick bedded, planar layering of platy grains.
- R-25
40' (12.2m) Covered.
- R-24
123' (37.5m) Poorly outcropping dolomitized limeclast grainstones, light to dark gray, fine to coarsely crystalline with relict rounded very coarse sand- to pebble-sized grains (up to 12 cm), thick bedded, planar layering of platy grains, local pods of very coarsely crystalline dolomite.

- R-23
32' (10m) Covered.
- R-22
20' (6.1m) Dolomitized limeclast grainstone, white to dark gray, medium to coarsely crystalline with relict rounded very coarse sand- to granule-sized grains, thick bedded, local dolomitized breccia clasts (up to several cms) of dolomitized limeclast grainstone, interstitial fill of very coarsely crystalline dolomite.
- R-21
18' (5.5m) Covered.
- R-20
21' (6.4m) Dolomitized limeclast grainstone, medium gray, medium to coarsely crystalline with relict very coarse sand-sized grains, thick bedded; and Dolomitized breccia, clasts (up to 8 cm) of dolomitized limeclast grainstone, medium to dark gray, medium crystalline with relict coarse sand-sized grains, interstitial fill of coarse limeclast grainstone, and local sparry dolomite, thick bedded.
- R-19
17' (5.2m) Covered with poorly outcropping dolomitized limeclast grainstone, medium to dark gray, medium to coarsely crystalline with relict rounded very coarse sand-sized grains, medium to thick bedded, planar layering of platy grains.

- R-18
19' (5.8m) Dolomitized breccia, light to medium gray, medium crystalline, clasts (up to 3 cm) of dolomitized limeclast grainstone, medium to thick bedded; and Dolomite, very light gray to white, fine to coarsely crystalline, thick bedded, relict boundstone fabric(?).
- R-17
9' (2.7m) Covered.
- R-16
19' (5.8m) Dolomitized limeclast grainstone, white to medium gray, fine to very coarsely crystalline with relict rounded coarse sand-sized grains, cm wide veins of sparry dolomite; and Dolomitized breccia, medium gray, cm sized clasts of light to dark gray, fine to medium crystalline dolomite with relict fine to medium sand-sized grains, interstitial fill of oolitic grainstone; Local dolomite, light gray to white, medium to coarsely crystalline, thick bedded, relict boundstone fabric(?).
- R-15
41' (12.5m) Dolomitized breccia, light to dark gray, clasts (up to several cms) of fine to coarsely crystalline dolomite with relict grainstone texture and white very coarsely crystalline dolomite, interstitial fill of medium to dark finely crystalline dolomite; and Dolomitized limeclast grainstone, light to medium gray,

medium to coarsely crystalline with relict fine sand-sized grains, medium to thick bedded.

R-14
31' (9.4m)

Covered.

R-13
49' (14.9m)

Dolomitized limeclast grainstone, light to medium gray, medium to coarsely crystalline with relict rounded very coarse sand- to granule-sized grains, thick bedded; local thin dolomitized breccia, clasts (up to 12 cms) of dolomitized grainstone with interstitial fill of coarsely crystalline dolomite.

R-12
9' (2.7m)

Interbedded dolomite, light gray, finely crystalline, medium bedded; and

Dolomitized limeclast grainstone, dark gray, medium crystalline with relict very coarse sand-sized ooids and intraclasts (?).

R-11
6' (1.8m)

Covered.

R-10
13' (4.0m)

Dolomitized limeclast grainstone, dark gray, fine to medium crystalline with relict coarse sand-sized grains, thick bedded;

Local dolomitized breccia, clasts (up to 10 cm) of dolomitized grainstone, interstitial grainstone and very coarsely crystalline sparry dolomite; and

Dolomite, white to light gray, medium to coarsely

crystalline, thick bedded, relict boundstone fabric(?).

R-9
5' (1.5m)

Covered.

R-8
2' (0.6m)

Dolomite, white to light gray, medium to coarsely crystalline, medium bedded.

R-7
14' (4.3m)

Dolomitized pebbly grainstone, medium gray, medium to coarsely crystalline with relict coarse sand- to pebble-sized grains, some sparry dolomite, thick bedded, planar layering of platy grains.

R-6
28' (8.5m)

Covered.

R-5
4' (1.2m)

Dolomitized pebbly limeclast grainstone, medium gray, medium to coarsely crystalline with relict coarse sand- to pebble-sized fragments, larger pebbles are dolomitized grainstone, local very coarsely crystalline dolomite spar, medium bedded, planar layering of platy grains.

R-4
13' (4m)

Covered.

R-3
62' (18.9m)

Dolomitized limeclast grainstone, medium gray, medium crystalline with relict coarse sand-sized grains, minor ooids, thick bedded, planar layering of platy grains; local pebbly breccia, clasts (up to several

cms) of dolomitized grainstone, interstitial fill of limeclast grainstone and coarse sparry dolomite.

R-2
6' (1.8m)

Covered.

R-1
52' (15.8m)

Dolomitized limeclast grainstone, medium gray, medium to coarsely crystalline with relict coarse sand-sized grains, planar layering of platy grains, thick bedded; local dolomitized breccia, clasts (up to several cms) of black and white finely crystalline dolomite and medium gray dolomitized limeclast grainstone, interstitial fill of limeclast grainstone/packstone, medium bedded.

no base to section.

GEOLOGIC SECTION 8, UPPER SHADY DOLOMITE

Section is exposed in pastures along Clear Branch drainage south of State Rte. 69. Base of section is at contact between olive shales and polymictic limestone breccia at the top of section 6 ($36^{\circ} 50' 40''$ N., $80^{\circ} 52' 49''$ W.). Section was measured southeast to the trace of the Blue Ridge Fault and is cut by two, non-outcropping, high angle reverse faults (Weinberg, 1971, pers. comm. 1976) which may considerably alter measured thicknesses. The exposures described here may be stratigraphically continuous with those described in Section 6. Top not exposed; in faulted

contact with overthrust Chilhowee Gp. rocks.

UNIT AND
THICKNESS

Upper Shady Dolomite 1186' (361m)

8CB-12
152' (46.3m)

Covered with outcropping dolomitized limeclast grainstone, medium gray, medium to coarse grained, thick bedded, few feet exposed at top of interval.

8CB-11
44' (13.4m)

Covered with patchy outcrop of dolomite, fine grained, thin bedded with shaly interbeds; and Dolomitized breccia, clasts (up to 5 cm) of dolomitized limeclast grainstone, laminated dolomite, and dolomitized calcareous algal boundstone (?) with interstitial fill of grainstone.

8CB-10
110' (33.5m)

Covered.

8CB-9
63' (19.2m)

Discontinuous outcrop of quartzose intraclastic grainstone, light gray, coarse grained, intraclasts and quartz sand, thick bedded, minor breccia.

8CB-8
299' (91.1m)

Covered with poorly outcropping dolomitized limeclast grainstone, medium gray, medium crystalline with relict coarse sand-sized grains (intraclasts?), thick bedded.

8CB-7
27' (8.2m)

Limestone breccia, polymictic, clasts (up to 0.6m) consisting of calcareous algal boundstone, dolomitized

limeclast grainstone, black laminated limestone, with interstitial fine-grained dolomite, thick bedded, overlies

Dolomitized limeclast grainstone, medium gray, medium crystalline with relict coarse sand-sized grains (intraclasts?), medium bedded, some shale partings and graded beds.

8CB-6
214' (65.2m) Covered with poorly outcropping shale, olive green to brown, very fine grained, thin bedded, fissile.

8CB-5
20' (6.1m) Dolomitized limeclast grainstone, medium gray, medium to coarsely crystalline with relict coarse sand-sized grains (intraclasts?) and pebbles of black laminated dolomite, medium bedded, some dolomitized breccia.

8CB-4
32' (9.8m) Covered with poorly outcropping shale, olive green to brown, very fine grained, thin bedded, fissile.

8CB-3
47' (14.3m) Limestone breccia, polymictic, clasts up to 0.5m consisting of calcareous algal boundstone, oolitic grainstone, black laminated limestone, and breccia with interstitial fill of fine-grained dolomite, thick bedded, minor dolomitized limeclast grainstone. Along strike: Pods of breccia 1.5-9m wide and 0.6-several m high enclosed in olive-brown fissile shales.

8CB-2
68' (20.7m)

Covered.

8CB-1
110' (33.5m)

Covered with poorly outcropping shale, olive green to brown, fine grained, thin bedded, fissile, with pod-like limestone breccia, polymictic, clasts (up to 0.6m) of calcareous algal boundstone, limeclast grainstone, and black laminated dolomite.

Base of section is contact between shales and polymictic limestone breccia at top of section 6. Section may be continuous with section 6.

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STRATIGRAPHY AND SEDIMENTOLOGY,

CAMBRIAN SHADY DOLOMITE,

VIRGINIA

BY

Russell W. Pfeil, Jr.

(Abstract)

Cambrian Shady Dolomite facies exposed northwest and southeast of Austinville, southwestern Virginia, apparently formed in a platform-to-basin setting. Northwest of Austinville, the Shady Dolomite (600 m thick) overlies the Lower Cambrian Erwin Formation and is overlain by the Middle Cambrian Rome Formation. Here the unit consists of ribbon-laminated carbonates (Patterson Member) overlain by massive dolomites and fenestral, cryptalgal carbonates (Austinville and Ivanhoe Members) which pass up into Rome Formation red mudcracked clastics and carbonates. Relict textures suggest that northwestern belts of the Shady Dolomite were deposited in an upward-shoaling sequence on the inner part of a carbonate platform.

The Shady Dolomite thickens southeast of Austinville where exposed (400 m thick) upper Shady Dolomite beds (partly equivalent to Rome Formation) contain calcareous algal bioherms, limeclast grainstone, monomictic and polymictic carbonate breccia and black laminated limestone and shale. Algal bioherms, limeclast grainstones and carbonate breccias of southeastern belts suggest seaward, outer platform environments; black laminated limestone and shale

units containing local algal bioherms and breccias may indicate local off-platform "deeper water" deposits. Slopes on the carbonate platform margin were probably low (few degrees) as indicated by inter-layering of shallow and deeper water lithologies recording considerable migration of facies bands. This southeasternmost facies of the Shady Dolomite exposed in the Valley and Ridge may give important clues as to the lithologic character of equivalent units in the Virginia Piedmont.