UPPER CAMBRIAN MAYNARDVILLE FORMATION WITHIN THE CLINCHPORT FAULT BELT OF EAST TENNESSEE

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ABSTRACT. — First defined by Oder (1934), the relationships of this formation have been a subject of controversy. The source of controversy is the transitional nature of the Maynardville, which exhibits attributes of both the Conasauga Group (containing limestones) below and of the Knox Group (containing dolomite, stromatolites, chert, and oolites) above. Although there is a definite change of lithology from the Nolichucky Shale, the basal Maynardville boundary is gradational and shales are interbedded with limestones. The upper Maynardville boundary is even less well defined, being determined by the relative abundance of lithologic criteria.

Sixteen stratigraphic sections were measured along a 70 mile segment of the Clinchport fault belt in Tennessee. The Maynardville Formation can be divided into several persistent parastratigraphic units within the area of study. In ascending stratigraphic order, these units are: (1) ribboned-mottled unit, (2) intermediate limestone unit, (3) laminated unit, and (4) massive, thickly bedded dolomite unit. The Maynardville Formation is a mappable unit, but lithologically transitional between the Nolichucky Shale and the overlying Copper Ridge Dolomite. Furthermore, all four units have conclusive evidence of supratidal to intratidal origin of dolomite and limestone, respectively.

Since 1934 when C. R. L. Oder first defined the Maynardville Formation, it has been the subject of considerable controversy.

Albeit its age (Croixan) has never been seriously disputed, it has yet to be generally resolved whether the Maynardville deserves formational status and whether it should be included within the alternate shales and carbonates of the Conasauga Group or within the overlying limestones and dolomites of the Knox Group.

A review of the literature (Figure 1) has helped to point out the following problems concerning the Maynardville Formation: (1) placement of the lower formational boundary; (2) placement of the upper formational boundary; (3) traceability and/or mappability of lithologic units; and (4) interpretation of depositional environment.

AREA OF STUDY

Structually, the Valley and Ridge Province of East Tennessee is characterized by great northeast-trending thrust faults, which cause repetition of predominantly Cambro-Ordovician strata.

The outcrop belt known as the Clinchport fault belt (formerly known as the Hunter Valley fault belt) is bounded by the copper Creek fault on the southeast, and the Clinchport fault on the northwest. Figure 2 shows the area of study, adjacent strike belts, and location of measured sections. The area studied extends approximately 70 miles along strike from the northwest slope of Big Ridge near the Virginia-Tennessee state line to the Ralph Rogers quarry in Union Valley, two miles due east of Oak Ridge.

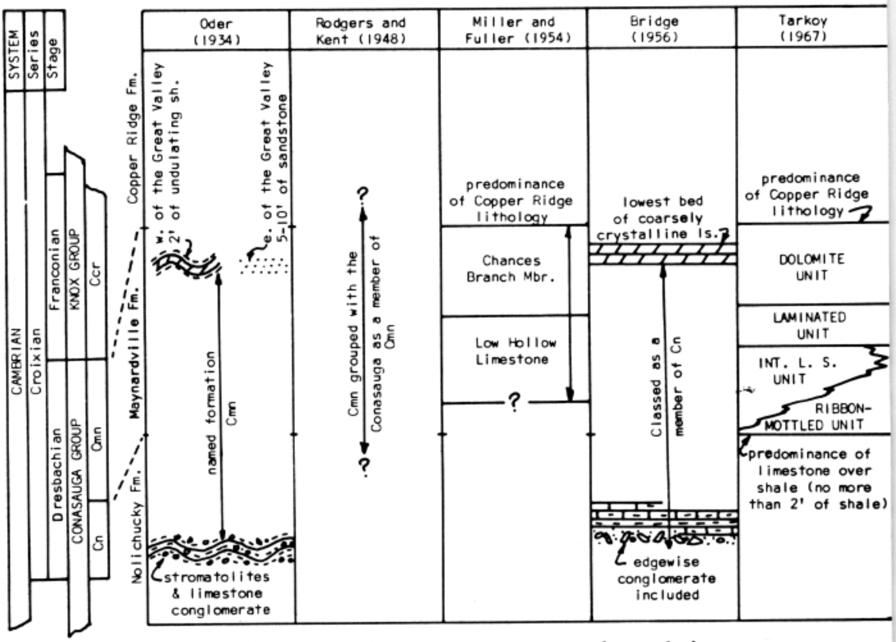


FIGURE 1.—Previous investigations, age, and correlation.

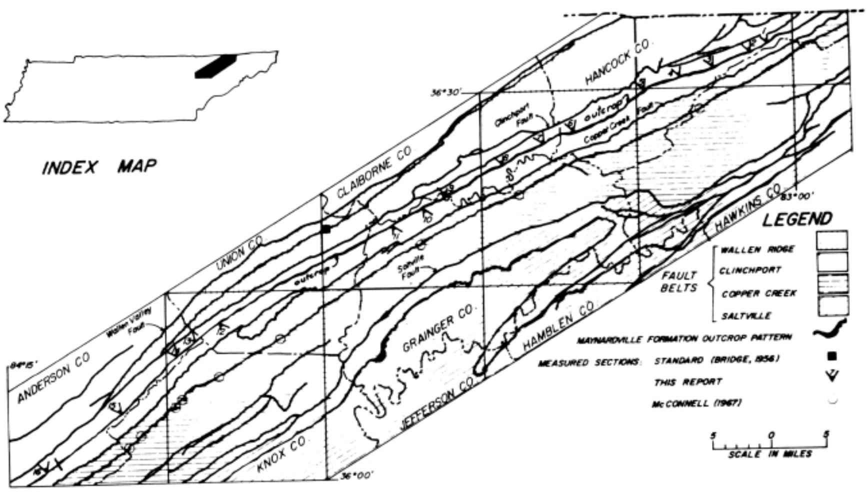


FIGURE 2.—Location of area of study, measured sections, and adjacent strike belts.

Age and Correlation

Although the Maynardville Formation and the underlying Nolichucky Shale are not highly fossiliferous, biostratigraphic studies have been successful in establishing their ages in the geologic time scale, as shown in Figure 1.

The lowest portion of the Upper Cambrian is the Dresbachian Stage, which is divided from the base upward into the *Cedaria, Crepicephalus,* and *Aphelaspis* faunal zones.

Upon modification of Raymond's (1959, p. 3) measured section, to confrom to the formation boundary criteria used in this report, it is noted that only the *Aphelaspis,* and no part of the *Crepicephalus,* zone is represented in the Maynardville Formation. Furthermore, Derby (1966, p. 43) similarly excludes all *Crepicephalus* fauna from the Maynardville Formation but he emphasizes that:

> . . . the base of the Maynardville is not everywhere the same age, nor is recognition of the *Aphelaspis* fauna necessary to identify the Maynardville Limestone.

Both Raymond (1959, p. 40) and Derby (1966, p. 41) have pointed out that, in the strike belts west of the Saltville fault, the base of the Maynardville is diachronous and progressively younger to the northeast, at least in Tennessee.

Lithostratigraphy

In this report the Maynardville is accepted as having formational status (as named by Oder, 1934). A summary of the field data is represented in Figure 3 in the form of

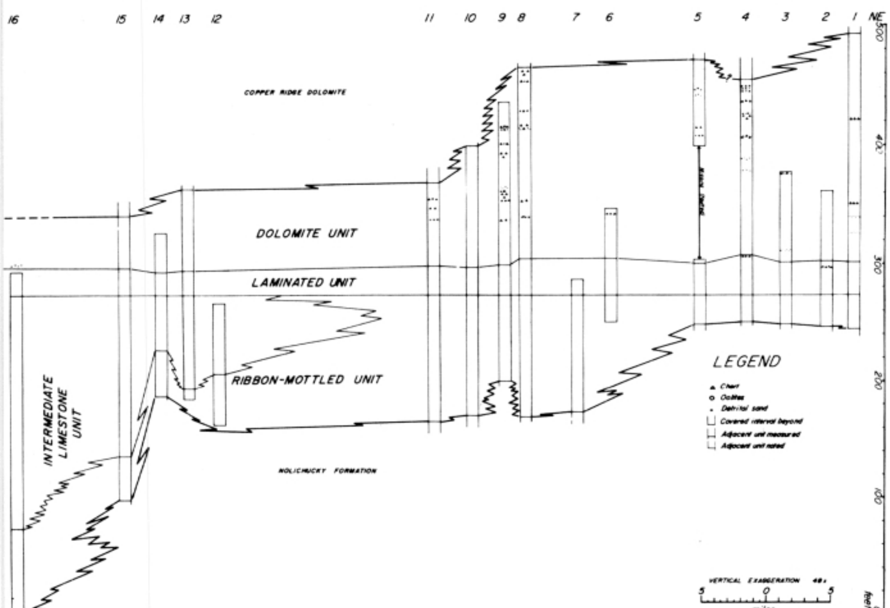


Figure 3.—Columnar sections and interpretation of stratigraphic data.

columnar sections of the Maynardville Formation as divided into parastratigraphic units. Detailed measured sections are reported by Tarkoy (1967). In the area of study the formation is divisible from the base upward into four parastratigraphic units which are: (1) a unit of ribboned and/or mottled limestone, (2) an intermediate limestone unit, (3) a unit of laminated limestone and/or dolomite, and (4) a dolomite unit containing within it two oolitic horizons, less continuous detrital sands, and stromatolitic zones which are not traceable along strike nor are they sufficiently fixed stratigraphically to be of any known significance.

Lower Formational Boundary. — The Nolichucky-Maynardville contact is intercalated and gradational within the area of study so that the uppermost portion of the Nolichucky Shale is characterized in places by large quantities of light olive gray shale, calcitic in part, interbedded with limestone similar to the superadjacent ribbon-mottled unit. This contact relationship can best be observed at section 4 and section 5 and other localities where the top of the Nolichucky Shale is sufficiently exposed. However, since the limestone interbedded with shale is discontinuous along strike, the contact is more abrupt in places.

Therefore, within this report, the lower formational boundary of the Maynardville is considered as occurring at the base of the first appearance of ribboned or mottled limestone with no more than two continuous feet of olive-gray shale above the contact. This criterion has the following advantages: (1) the limestone without interbedded shale is more continuous, better exposed, and useful for traceability in mapping and (2) the ribbon-mottled unit represents a substantial environmental change from that characteristic of the Nolichucky.

Ribbon-Mottled (limestone and dolomite) Unit. — The ribbon-mottled unit at the base of the formation consists of 20-100 feet of medium to very thickly-bedded, rarely thinly-bedded, medium-gray micrite, some of which is dolomitized. The beds are wavy; they are 0.25 to 1.5 inches thick and are separated by argillaceous limestone layers which range in thickness from mere films to beds an inch thick.

Intraformational conglomerates having intraclasts of 0.5 mm to 60 mm length are common at the base. Occasional pellets were noted, although the measured size of the intraclasts rarely exceeded 0.5 mm. Dark gray to light olive-gray calcitic shale (but not as olive as the shale of the Nolichucky) is present in the lower portion of the ribbon-mottled unit, in intervals averaging about one foot thick. These shales are more conspicuous to the northeast. Cyclical repetition of micrite and intramicrudite with thinly liminated calcitic shale was noted in the southwestern portion of the belt, notably at section 15 and at section 12. Oscillation ripple marks and mud cracks have been noted on bedding surfaces.

Suggestions of algal heads appear rarely except associated with transition to the intermediate limestone unit, a facies of the ribbon-mottled unit, appearing in the southwest portion of the study area. Although fossils have been reported from the ribbon-mottled unit, only fossil fragments found were associated with intraformational conglomerates.

The dark yellowish-orange color of the mottled limestone results from the weathering of argillaceous or silty limestone bands. However, the ribboned appearance becomes apparent in more advanced stages of weathering (Figure 4A). If the limestone bands are silty, they are resistant and weather in raised relief, but if the limestone bands are argillaceous, the situation is reversed and weather to reentrants.

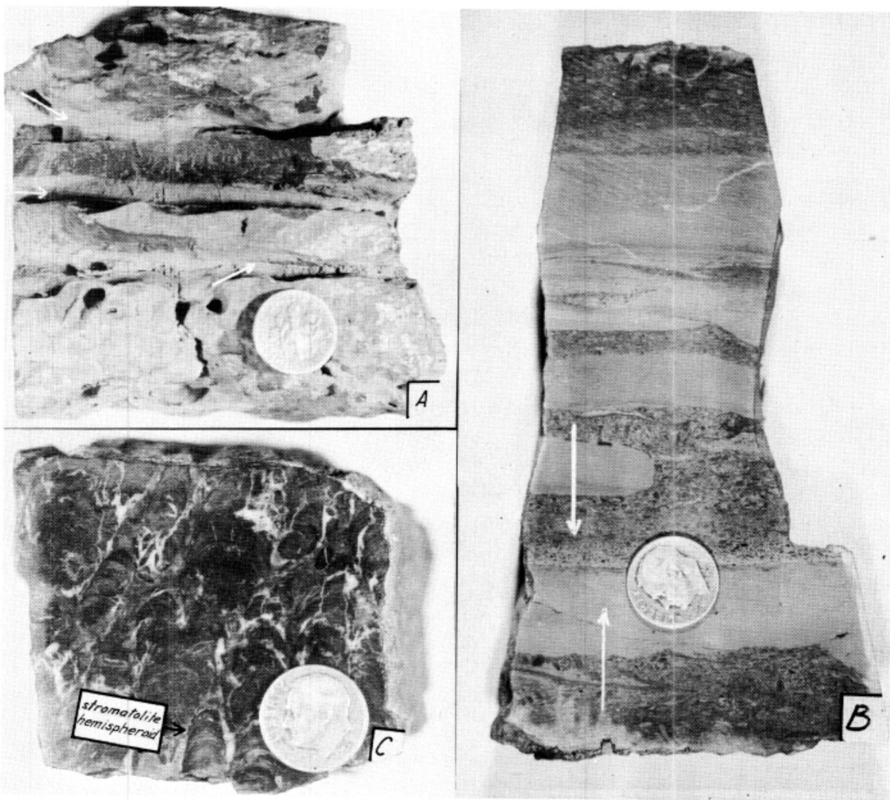


FIGURE 4.—A. This sample was collected from the ribbon-mottled unit at section 8. The bands weathering in raised relief are limestone and those weathering recessed (arrows) are argillaceous. The most significant process in the weathering of the argillaceous bands is hydration and swelling of the clays.

B. This sample was collected from the dolomite unit at section 8. It illustrates the widely variable size of the intraclasts, 0.5 mm to 15 mm (arrows). Such intramicrudites are found throughout the Maynardville Formation but they are most common in the dolomite unit.

C. This sample collected from the dolomite unit at section 4 illustrates closely stacked hemispheroid (SH type) stromatolites. Light areas are recrystallized dolomite; the specimen is predominantly dolomite. The dark color is a result of argillaceous material. The hemispheroids may be partly silicified (arrow) or completely chertified, as on the underside (not visible) of the sample.

The argillaceous or silty bands are almost always dolomitized, the dolomite being early or late diagenetic. Evidence of this diagenetic origin is shown by dolomite transecting bedding laminations.

The ribbon-mottled unit is the most persistent unit of the Maynardville, normally cropping out at the base of a series of locally named ridges, except in the southwestern third of the area of study, where the lower portion of the unit is in the valley floor and not exposed.

Intermediate Limestone Unit. — The intermediate limestone unit, being extremely and abruptly variable laterally, consists of 0-200 feet of massive stromatolitic limestone. It is a facies of the upper portion of the ribbon-mottled unit into which it grades northeastward along strike as well as locally in exposures. The unit is almost invariably very thickly bedded and massive, characteristically but not universally coarsely crystalline, medium gray to brownish dark gray, intraclast-bearing and abundantly stromatolitic.

Where the intermediate limestone unit is extremely stromatolitic, it weathers vuggy to ribboned and locally it intertongues with and grades into mottled limestone. The intermediate limestone becomes prominent from section 12 southward and attains its greatest thickness at section 16.

The unit is well exposed beneath the laminated unit in sections 13 through 16 (Figure 3).

Laminated (limestone and dolomite) Unit. — The laminated limestone and dolomite unit is composed of 20-30 feet of limestone grading into and interbedded with dolomite; however, the laminated character is constant and distinct. The unit has a variable argillaceous content (up to about 40 percent insoluble residues) and is characterized by the alternation of light laminae with dark limonitic, argillaceous laminae on the order of 10-25 per inch in section. The dark argillaceous laminae may be dolomitized at the base in a transitional zone from the ribbon-mottled unit. The unit is medium-bedded unless extremely weathered; in which case the finely laminated rock weathers shaly (as in section 6). The limestone and/or dolomite is finely crystalline, very light gray to brownish medium gray and weathers light to medium-gray.

Penecontemporaneous deformation is represented by microfolds and faults; stylolitic solution is common as in sections 2 and 4; intraformational conglomerates have been noted in section 11. Chert is found this low in the section but only in the northeast (section 2). Mud cracks have been noted on bedding surfaces.

The unit seems to be barren of fossils except for stromatolites in places. The peculiar laminar aspect of the unit may represent cycles of carbonate muds and argillaceous material cemented by algal films.

A noteworthy feature of the laminated unit is that nowhere is it interbedded with underlying or overlying units; therefore, it is not a lateral facies. The unit is unique in this respect; the sudden and areally extensive episodic appearance of short-lasting tidal flat conditions is considered to be a synchronous event, especially at the base of the unit where this change is extremely well-defined. Because of the greater continuity of the Chances Branch Dolomite, Harris (1964, p. B28) used it as a time reference surface datum in more extensive regional studies to show the northwestward transgression and facies relationships of the Rome Formation and Conasauga Group.

In many places the laminated unit weathers shaly and outcrops are poorly exposed.

Dolomite Unit.—The dolomite unit consists of 50-200 feet of dolomicrite, dolomicrudite, biolithite, and minor occurrences of other lithologies, attaining the greatest thickness to the northeast. Although the unit is usually very poorly exposed to the southwest, it thins to approximately 50-60 feet as seen in the quarry along (Copper Creek strike belt) U. S. Highway 70 (0.4 miles east of New Midway Church, Roane County, Cave Creek quadrangle). It is thinly-to thickly-bedded, and bedding may be undulatory; finely to coarseily crystalline; light gray to brownish black. McConnell (1967, p. 21) described the lower portion of the unit separately as a banded dolomite unit (in the Copper Creek outcrop belt). In the (Clinchport belt) present study area, the writer feels that this division is unjustified because: (1) the lower and upper limits of the banded dolomite are too vague and nondescript in outcrop and (2) the lithologic criteria for this distinction is laterally discontinuous.

Locally there is extensive evidence of penecontemporaneous deformation and intraformational conglomerates (Figure 4B). Stromatolites (Figure 4C) and chert (dark gray to black, lenticular or cross cutting bedding) are notable throughout the unit; however, they are more abundant at the top where the contact with the stromatolitic, oolitic, and cherty Copper Ridge Dolomite is gradational. The chert is generally related to the stromatolitic material which is commonly silicified. Locally, especially where the dolomite is stromatolitic, sparry and large crystalline (2cm) calcite fills vugs.

Where stromatolites are abundant the dolomite weathers to massive vuggy beds. The dolomite unit weathers readily to an orangish-yellow soil; therefore, good outcrops are rare.

Within the dolomite unit there are two oolitic zones (Figure 3). Detrital lenticular sands occur within the unit at various seemingly unrelated, stratigraphic horizons.

Upper Formational Boundary.—The transitional nature of the Maynardville Formation makes the selection of an upper formational boundary somewhat difficult. Oder's (1934, p. 475) original sandstone criterion is not applicable on the west side of the Valley and the two feet of dark gray-shaly dolomite, with an undulating upper contact has been discredited by Bridge (1965, p. 13).

The base of the Copper Ridge Dolomite has been placed by various authors at (1) the lowest bed of dark, coarsely crystalline dolomite (Bridge, 1956, p. 13), (2) at a point of relative dominance of the Copper Ridge and Maynardville type lithologies (Miller and Fuller, 1954, p. 38) and (3) at the base of the first appearance of typically Copper Ridge chert (McConnell, 1967, p. 30).

Chert (section 2) and stromatolites (in the ribbon-mottled unit in the southwest portion of the study area) occur low in the section; therefore, a mere presence of either of these features is not sufficient, contrary to the usage by Bridge (1956, p. 13) and McConnell (1967, p. 30).

Ideally, regardless of the criteria used, they should be applicable over the areal extent of the formation and they should be useful on good exposures as well as poorly exposed or covered intervals. However, since the Maynardville is such a highly variable unit, the usefulness of the criterion followed in this report is probably restricted to the three western belts in northeastern Tennessee. In this report, the base of the Copper Ridge Dolomite is accepted as being at the

> . . . place where the dark-gray crystalline dolomite (characteristic of the lower Copper Ridge Dolomite) exceeds in relative abundance the light-gray, fine-grained dolomite of Chances Branch Member type. (Miller and Fuller, 1954, p. 38)

The advantage of the criterion is that: (1) the boundary can be chosen fairly easily in outcrop, (2) the gradational nature of this upper formational boundary indicates a slowly changing environment which is areally extensive, and (3) the abundance of chert in extremely weathered intervals is correlative with the abundance of stromatolites (perhaps the source of dispersed silica) and chert may even replace stromatolitic structures.

It must be emphasized that a transitional unit cannot by its own definition have sharply defined boundaries.

Petrography

All collected lithologic samples (150) were polished, classified according to Folk's (1962) spectral subdivision of limestone types, and located and described in each measured section (Tarkoy, 1967). In addition, 25 thin sections were cut from samples taken for each parastratigraphic unit at several localities in the Clinchport strike belt.

Qualitative mineralogical differentiation was facilitated by etching with dilute hydrochloric acid (10 per cent), and staining with inorganic dyes as described by Freidman (1959, pp. 87-97).

For purposes of description and summary, each parastratigraphic unit is divided into microfacies representing the most characteristic and persistent lithologies, summarized, and presented in Figure 5 and illustrated in Figure 6.

Conclusions

Interpretation of Stratigraphic Data.—The vertical succession of parastratigraphic units is homotaxial at all sections studied, but they do not maintain constant thickness. Figure 3 illustrates the relationship of the northward thinning of the limestone and the southward thinning of the dolomite. This is in agreement with Harris (1964, p. B28) who reports the limestone thins northwestward and is missing in Bell County, Kentucky.

McConnell (1967, p. 9) uses the chert and oolite horizons as time lines. In the writer's opinion there is not enough evidence in the Clinchport or Copper Ridge strike belts to support this assumption, especially

Unit	MICROFACIES & CLASSIFICATION	GRAIN SIZE AND DESCRIPTION
DOLOMITE	12-BIOLITHITE (Fig. 6H)	1.0mm, calcitic or dolomitic, silty, pelletoidal, silicified; mud flat environment
	11-DOLOMICRITE (Fig. 6G)	.005-.02mm, contains detrital sand & oolites; diagenetic
	10-CHERT	Chalcedony & opaline material, occasional silicified oolites & fossil fragments
	9-OOLITES (Fig. 6F)	.05mm, inconspicuous unless opaline; tidal
	8-DETRITAL SAND (Fig. 6E)	.3mm, quartz feldspar; dolomicrite pellets, .2-0.5mm
LAMINATED	7-DOLOMICRITE (Fig. 6D)	.01-.05mm, alt. laminae; dolomitized micrite has higher argillaceous content; desiccation features
	6-MICRITE	
	5-TRANSITIONAL (Fig. 6C)	Similar to 1 & 2 but finer laminae
INTER-MEDIATE LIMESTONE	4-BIOLITHITE	Similar to microfacies 12; mud flat environment
	3-INTRAMICRITE (Fig. 6B)	.01mm, mud; .01-1.0mm, recrystallized calcitice; 03-5.0mm, intraclasts; high energy shallow water
RIBBON-MOTTLED	2-DOLOMITIZED MICRITE	.01-.05mm, argillaceous & silty; diagenetic dolomitization may transect bedding
	1-MICRITE (Fig. 6A)	.02mm, mud cracks; direct precipitation, trace of recrystallization, mud cracks, shallow water

FIGURE 5. — Microfacies, classification and description.

since the oolites zones are lenticular and they cannot be traced unless they are silicified. Although there is a minor amount of chert in the Maynardville, enough is present in the Clinchport fault belt both above and below the dubious "chert horizon" of McConnell that a definite correlation is questioned. The chert is secondary and generally associated with the stromatolites and quite unlikely to represent a synchronous surface especially if the "bedded" chert is discontinuous.

The frequent occurrence of stylolites throughout the formation and their intense development indicate that there may be considerable stratigraphic thickness missing by intrastratal solution, which may account for minor correlation difficulties.

Interpretation of Depositional Environment.—Mud cracks are present in each of the parastratigraphic

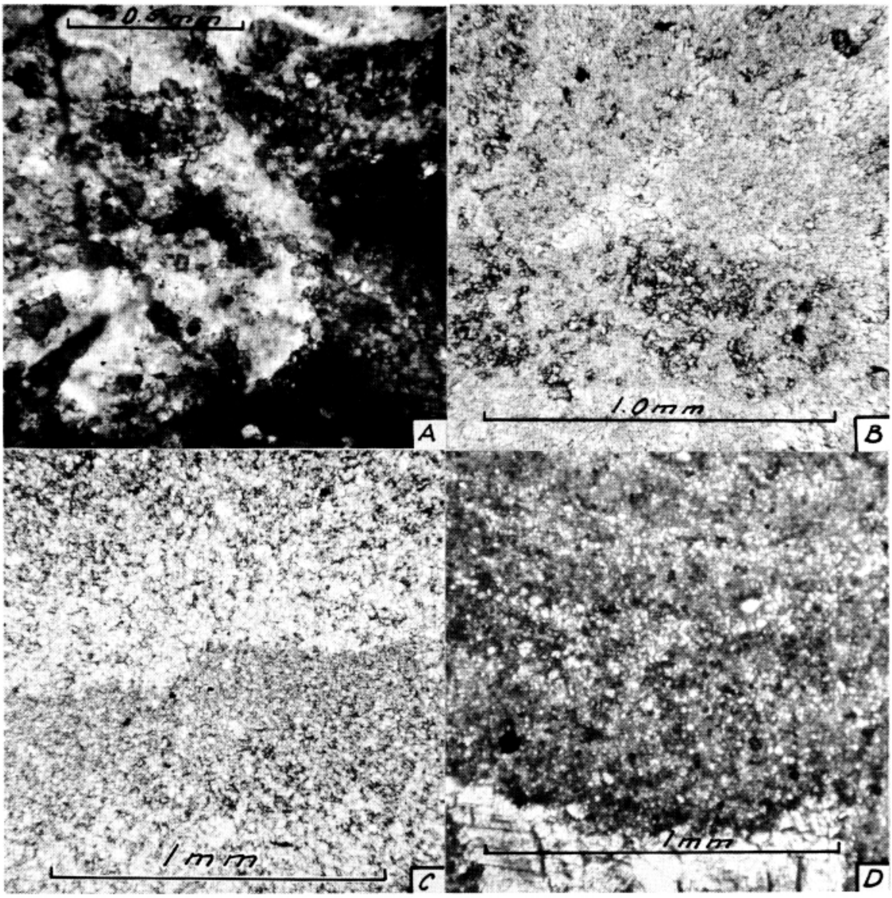
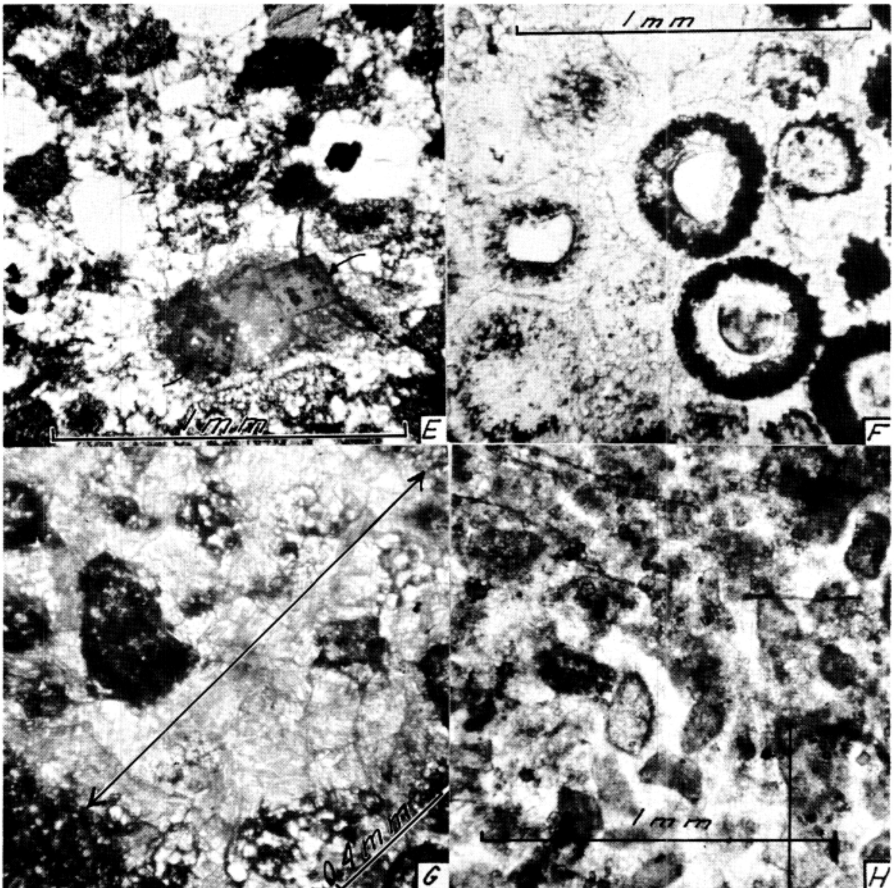


FIGURE 6.—A. Ribbon-mottled unit, microfacies 1 and 2, sample RR-5, section 8. Note microfacies 1 (micrite), the light area in the upper left portion of the photomicrograph, in contact with microfacies 2 (dolomicrite), the dark area in the lower right portion of the photograph. Locally there may be intrasparite, and dolomitization may transect bedding laminations. Nicols not crossed.

B. Intermediate limestone unit, microfacies 3, sample BM-6, section 14. Note the faint outline of intraclasts which are composed of similar material as the matrix. Recrystallization of sparry calcite gives the hand specimen a coarsely crystalline appearance. Nicols not crossed.

C. Laminated unit, microfacies 5, sample FB-2, section 4. This is the transitional (micrite) zone from the ribbon-mottled unit. The darker laminae are dolomitized as in microfacies 2. Nicols not crossed.

D. Laminated unit, microfacies 7, sample FB-4, section 4. Dolomicrite with occasional subhedral to anhedral dolomite. Nicols not crossed.



E. Dolomite unit, microfacies 8, sample FB-6a, section 4. Poorly rounded quartz grains (probably the result of etching by dolomite) are characteristic. May be feldspathic. Note the two dolomite euhedra below the center of the field of view. Nicols crossed.

F. Dolomite unit, microfacies 9, sample RR-24, section 8. The oolites are opaline (silicification). Phantom oolites are seen to the left in the field of view, the result of recrystallization into microcrystalline silica. Nicols crossed.

G. Dolomite unit, microfacies 11, sample RR-13b, section 8. Dolomicrite overlain by dismicrite (not illustrated) which (intradolomicrite) fills a mud crack in the dolomicrite. The arrow indicates the extent of the mud crack. Nicols not crossed.

H. Dolomite unit, microfacies 12, sample RR-12b, section 8. Disrupted and pelletoidal material is illustrated in the photomicrograph; it is found between the stromatolite structures (not illustrated). The recrystallized dolomite is euhedral to anhedral but the sample is predominantly made up of calcite. Nicols not crossed.

units, but they are probably more numerous than recorded. They may not always be apparent in outcrop, but they manifest themselves on polished surfaces or in thin section (Tarkoy, 1967, Fig. 24, p. 63). Therefore the environment was probably shallow enough to allow occasional exposure and desiccation.

The rare occurrence of oscillation ripple marks generated by the to-and-fro motion of the water agitated by waves is indicative of an environment above wave base. .

Intraformational conglomerates particularly common in the intermediate limestone unit and the dolomite unit are formed by

> . . . submarine erosion (such as might be caused by storm waves or underwater slides), by mild tectonic upwarps of the sea floor, or by low tides allowing wave attack on exposed, mud-cracked, carbonate flats. (Folk, 1962, p. 63)

Oolites, almost totally inconspicuous unless silicified, are found in the dolomite unit and they form

> . . . where water saturated with calcium carbonate is drifted backwards and forwards over a shallow sea floor in the track of tidal currents. The depth of water is never very great, usually not more than 20 feet, and the sea floor is so scoured by currents that all traces of micrite are winnowed away. The grains which remain are kept in motion, and acting as nuclei, become encased in concentric layers of carbonate precipitate. (Hatch and Rastall, 1965, p. 201)

The peculiar laminated aspect of the laminated unit may imply algal origin as stated previously. This may indeed be the case but the writer is hesitant to endorse the theory. Nevertheless, the regularity of the unit implies relatively deeper water and conditions of lesser agitation.

In discussing the ecology of faunal assemblages, Lochman and Duncan (1944, p. 31) stated:

> . . . the assemblage of the *Aphelaspis* zone, rigidly restricted to five trilobite genera throughout the entire country, and represented by a large number of individuals, may indicate the introduction of cooler waters.

Not only are the stromatolites a significant feature in the upper portion of the Maynardville Formation, but they are also of definitive environmental significance. These algal structures are

> . . . characteristically developed in continuous mats and algal-bound sediments from the marine, intertidal mud-flat environment, mainly in the protected locations of re-entrant bays and behind barrier islands and ridges where wave action is usually slight. (Ginsburg *et al.*, 1964, p. 77)

Problem of Group Classification.—Mottled limestone has been described from all limestone lithosomes of the Conasauga Group, (the Rutledge, the Craig Limestone Member of the

Rogersville Shale, the Maryville, and the Maynardville), but no mottled limestone has been reported from within the Knox Group. The dolomite lithology, the presence of stromatilites and occasional chert typical of the upper Maynardville is exceptional in the Conasauga Group in in east Tennessee except for the cherty stromatolite reef limestone in the Nolichucky Shale. Chert and oolites are abundant and stromatolitic dolomite comprises up to 60 per cent of the Copper Ridge (Harris, 1966, p. C49), whereas the same lithologies are only quantitatively important within the Maynardville.

The writer believes that the above implied lithologic relations confirm the transitional nature of the Maynardville Formation. The problem is whether it is necessary for such a distinctly transitional unit as the Maynardville Formation to be placed within any particular group, namely, the underlying Conasauga or the overlying Knox. However, since the general consensus of most writers is to place the Maynardville within the Conasauga Group, the writer favors acceptance of this classification.

The lower formational boundary of the Maynardville is considered here as occurring below the first appearance of ribboned or mottled limestone with no more than two continuous feet of olive-gray shale above the contact. The criterion is practicable for mapping traceability because it is relatively continuous and conspicuous.

The relative abundance of typical Copper Ridge and Maynardville lithology is used to place the upper boundary of the Maynardville Formation. The abundance of stromatolites is reliable on outcrop and chert is reliable in covered intervals.

Acknowledgments

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