

FOSSIL CUP CORALS FROM THE METAMORPHIC ROCKS OF CENTRAL VERMONT*

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ABSTRACT. Cup corals are herein reported, from phyllite that is interbedded with the crystalline limestones of the Waits River formation, at several localities in central Vermont. The corals, preserved chiefly as silica replacements 1.5±cm. in diameter, are clustered along bedding zones. They are oriented parallel to crenulations in cleavage that cuts across the bedding. A central vesicular zone, septa, and a circumferential wall are distinguishable in the better preserved coral specimens. V. J. Okulitch reports that the corals are probably *Streptelasma*, possibly *S. corniculum* and that therefore they suggest a Middle Ordovician age. This correlation is partly consistent with meager information already at hand, but may be subject to revision as more data become available.

INTRODUCTION

IN June, 1947, while mapping the Montpelier quadrangle in connection with U. S. Geological Survey investigations of talc deposits in Vermont, the writer discovered cup corals at several localities near the city of Montpelier, and also in East Montpelier and Calais townships. These fossils are remarkable for their preservation in phyllite, and are also a rare find in central and eastern Vermont. At the suggestion of Dr. J. B. Reeside, Jr., of the Geological Survey, they were sent to Professor V. J. Okulitch of the University of British Columbia for identification and age determination. The writer is grateful for Professor Okulitch's report quoted here. It is believed that the mode of occurrence of the fossils will be of interest to structural and metamorphic geologists as well as to paleontologists and stratigraphers.

The writer is indebted to C. G. Doll, P. E. Hotz, R. H. Jahns, J. F. Murphy, Professor Okulitch, and Dr. Reeside for critical reading of the manuscript.

PREVIOUS WORK

The rocks that contain the fossils were originally included in the "calcareo-mica schist" of C. B. Adams (1845, pp. 49, 62), later designated the "calciferous mica schist" by Edward Hitchcock, Sr., who described them in the Report on the Geology of Vermont (Hitchcock, *et al.*, 1861, pp. 475-488).

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Subsequently, C. H. Richardson (1898) proposed the name *Washington limestone* for the more calcareous portion of the "calciferous mica schist," but, finding that this name was pre-occupied, he later (1906, pp. 86-90, 115) replaced it with the term *Waits River limestone*. Currier and Jahns (1941, p. 1491) have revised the term "Waits River limestone" to *Waits River formation* to accommodate more correctly the phyllite and other noncalcareous rocks that are abundantly represented in the section.

The various publications of Richardson in the Reports of the Vermont State Geologist have indicated that the "Waits River limestone" is fairly continuous from north to south through the state of Vermont. C. G. Doll and the writer jointly have traced the Waits River formation northward across the International Boundary into the Tomifobia slates and limestones (Clark, 1934, pp. 11-12; Ambrose, 1943) of southern Quebec; H. C. Cooke¹ identifies the Tomifobia formation with the St. Francis series found farther to the northeast in Quebec. Richardson (1898) traced the "Waits River limestone" southward into Massachusetts where the Conway schist (Emerson, 1898, pp. 183-201), contains similar limestone strata. The stratigraphic and structural relationships of the Waits River formation to the Northfield slate and successively older formations to the west have been indicated by Currier and Jahns (1941, pp. 1490-1506). The relationships of these formations to the Gile Mountain formation and associated younger rocks, commonly found to the east, have been noted by C. G. Doll (1945, pp. 16-19).

The Waits River formation and its equivalents in Quebec and Massachusetts have been given age assignments that range from Ordovician to Devonian. Faunal investigations have furnished inconclusive and partly conflicting results, probably inasmuch as the fossil material necessarily is poor because of its occurrence in metamorphic rocks. Currier and Jahns collected fragments of crinoid stems believed to be of "Middle Ordovician or later age" from strata that underlie the Northfield slate (1941, pp. 1501-1502). Richardson (1916, pp. 142-145; 1919, pp. 49-51; Richardson and Camp, 1919, pp. 114-115) reported graptolites from the Northfield slate and Waits River formation, specimens that are believed by Ruedemann

¹ Oral communication, 1949.

(1947, p. 63) to be of both Deepkill and Normanskill age. Doll (1943a) reported crinoids and other forms, which he believes to be of Silurian or possibly Devonian age, from the "Waits River limestone" of northern Vermont and in beds that he assigns² to the upper part of the Waits River formation. He reported also a brachiopod, which he believes to be of Lower Devonian age (1943b), from the Gile Mountain formation (1945, p. 19). Poorly-preserved fossils have been reported from a few other areas in the vicinity of the Waits River formation (Richardson, 1902, p. 94; 1929, p. 245; Richardson and Maynard, 1939, p. 96); they furnish no conclusive evidence as to age, and their exact stratigraphic or geographic positions were not recorded or are uncertain. T. H. Clark reports graptolites with "a Trenton aspect"³ from the Tomifobia formation in Quebec. The St. Francis series of Quebec is reported to contain graptolites of Normanskill age (Cooke, 1937, p. 42). The Conway schist in Massachusetts contains rust-coated cavities that were believed by B. K. Emerson (1898, pp. 200-201) to represent indeterminate fossils.

GEOLOGIC SETTING

The strata in which the corals were discovered form part of the east limb of the Green Mountain anticlinorium, whose axis is coincident with the summit ridge of the Green Mountains about 17 miles to the west. The known fossil localities occur in a belt approximately 2 miles wide that trends north-northeast for about 7 miles from the Winooski River in and east of the city of Montpelier to the vicinity of Bliss Pond in Calais township (fig. 1). This belt parallels the strike of the Waits River formation. The western border of the belt is commonly a little less than half a mile east of the Northfield slate and immediately east of the outcrop of a zone, in the lower portion of the Waits River formation, that is relatively rich in syngenetic pyrite. The average dip of the strata is about 75° W., and both cleavage-bedding relationships and orientation of the corals indicate that in the majority of exposures the tops of the beds face east. Thus the strata are overturned but probably not repeated to an appreciable extent. Discounting repetition, the lowest of the coral-bearing strata are estimated to be

² Oral communication, 1949.

³ Written communication, 1949.

2,000 to 3,000 feet above the base of the Waits River formation, and the fossil zone itself is probably at least 10,000 feet thick. Its eastern (upper) limits have not been determined.

Seven collections were made from the following localities (fig. 1):

1. Montpelier city, 1.35 mi. S. 54° E. of the State House; ledges north of railroad and in line with dam in the Winooski River.

2. East Montpelier township, 0.3 mi. S. 45° W. of school house at East Montpelier Center; east face of ledge about 100 feet west of road.

3. Calais township, 0.8 mi. S. 30° W. of site of No. 7 School; east face of ledge about 200 feet west of road.

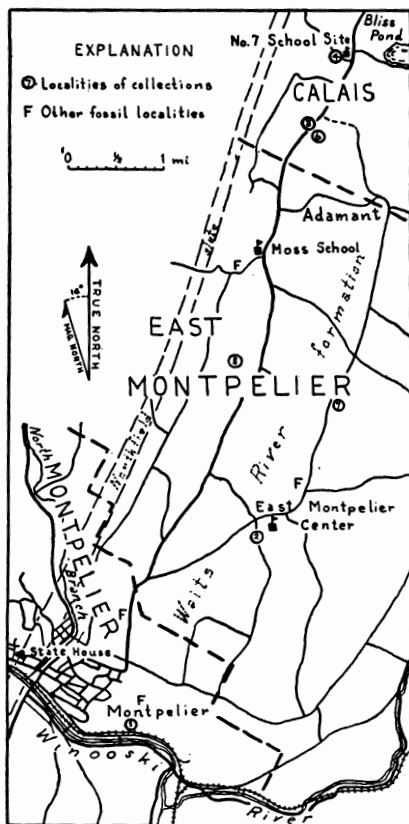


Fig. 1. Index map showing fossil coral localities, Montpelier, East Montpelier, and Calais, Vermont.

4. Calais township, 0.1 mi. due west of site of No. 7 School; at east foot of wooded ledge southwest of bend in road (fossils found in loose fragments).

5. East Montpelier township, 1.1 mi. S. 8° W. of Moss School and about 1,500 feet west of road, within edge of woods near southwest corner of pasture; eastward facing ledge a few feet west of granitic sill.

6. Calais township, 0.85 mi. S. 22° W. of site of No. 7 School and about 400 feet east-southeast of road near center of partly wooded pasture; eastward facing exposure is a few feet west of granitic sill.

7. East Montpelier township, 1.35 mi. N. 28° E. of school at East Montpelier Center and about 300 feet east of road in pasture a little south of fence; east face of ledge.

PETROGRAPHIC AND STRUCTURAL RELATIONS

The rock in which the fossils are commonly preserved is a dark phyllite composed chiefly of sericite and very fine-grained quartz, small amounts of chlorite, and scattered ilmenite plates that are visible to the naked eye. The sericite flakes have a common orientation and form a schistosity parallel to which the cleavage is developed. Crystalline limestone, interbedded with the phyllite, is iron gray on fresh surfaces, but weathers to a brown earthy crust. About one-half to two-thirds of the volume of the limestone is calcite, and the remainder is composed of quartz and minor quantities of muscovite.

Bedding may be traced most favorably where the cleavage crosses it at a relatively high angle and where the fossils, or syngenetic sulfides, distributed parallel to the beds, have preserved stratification as fossiliferous or rusty zones. Bedding is best seen at contacts between the phyllite and the limestone.

The texture of the rocks of the Waits River formation coarsens to the east, and also locally in the vicinity of granitic sills. Near the latter, increased metamorphic effects are quite apparent, particularly the appearance of spotted phyllite with porphyroblasts of biotite and cordierite. The limestone may be whitened and may contain considerable quantities of diopside and titanite.

The near-vertical east faces of phyllite ledges commonly coincide with the planes of bedding, and the cleavage dips westward into these faces at gentler angles (plate 1, fig. 1; text fig. 2). These relations characterize most of the fossil localities. A lineation, formed by fine crenulations in the cleavage, plunges northward in the plane of the cleavage (plate 2, fig. 1; text fig. 2). The calyces of the corals open out easterly at the bedding plane in the direction of the stratigraphic tops of the beds, and taper downward in the plane of the cleavage in such a way that the long axes of the individuals are parallel to the lineation. The corals are commonly flattened in the plane of the cleavage, which parts around them and gives them an eye-like appearance. There is some megascopic evidence that the corals have been rotated; the cleavage that adjoins a few of the individuals forms a helical pattern adjacent to the fossils (plate 2, fig. 1). Too few occurrences of this feature have been observed to indicate whether or not adjacent corals, presumably in a common structural setting, have been rotated in the same direction.

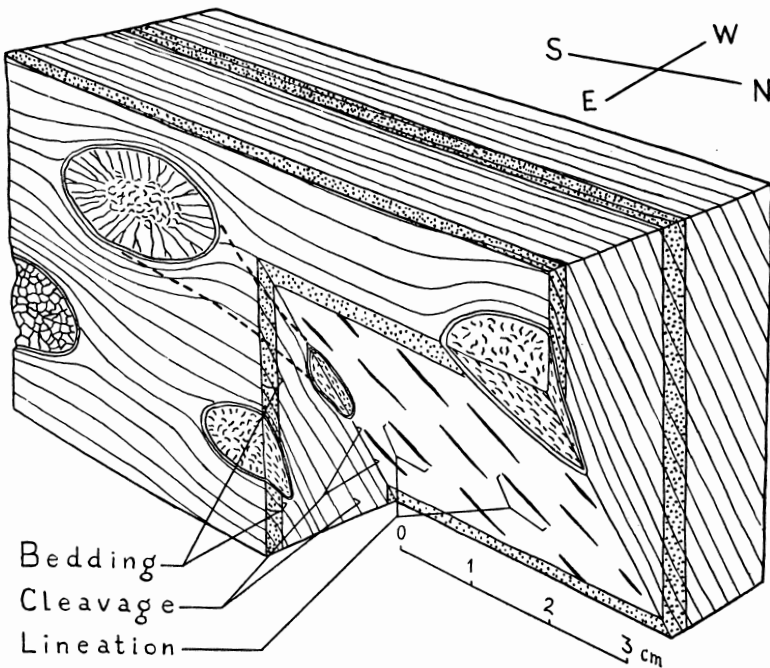


Fig. 2. Block diagram showing the relationship of the fossil corals to bedding, cleavage, and lineation.

The structural relationships indicated by data recorded at the locality of collection No. 7 are typical of most exposures of the Waits River formation in the Montpelier - East Montpelier - Calais belt:

Bedding	Cleavage	Lination
Strike N. 17° E.	Strike N. 23° E.	Bearing N. 21° W.
Dip 88° W.	Dip 50° W.	Plunge 40°

The strikes of bedding and cleavage are commonly within 10 degrees, as shown here, and are parallel at many localities.

FOSSIL DESCRIPTIONS

The best-preserved corals (plate 1) are those at the locality (fig. 1) from which collection No. 7 (plate 2) was obtained. Hundreds of individuals are exposed on the nearly vertical east face of a ledge that is more than 75 feet long and stands 4 to 5 feet above the pasture. The petrographic and structural relationships of the fossils at this locality are similar to those at other localities. Preservation is related to silicification along comparatively open bedding joints and associated partly calcareous zones. The corals are completely replaced by silica, part of which is iron-stained, and most of the calyces are filled with granular quartz that obscures the fossils. The silicification and quartz filling of the originally calcareous corals are believed to have favored their great resistance to deformation, as compared with the adjacent phyllite. Some individuals show only silica replacement, without development of the quartz filling. From them it has been possible to determine that the fossils are actually corals.

The average corallite is 1.5 cm. in diameter, and is estimated to be 2 to 3 cm. long; its length commonly is difficult to estimate because the greatest amount of silicification, and hence preservation, is in the vicinity of the calyces. The basal portions, distal to the calyces, are delimited with difficulty. Distinguishable in the best-preserved specimens, in which the calyces are not filled with quartz, is an outer zone of radiating septa terminated outwardly by a circumferential wall and connected inwardly with a central vesicular zone in which the septal arrangement is lost. The septa of some specimens appear to bifurcate toward the circumferential wall. Professor Okulitch reports on the fossils as follows:

"Some of the specimens are undoubtedly cup corals, others show nothing but a reticulated or vesicular mass. The preserva-

tion is such that all finer details of septa, walls, and the central vesicular zone are lost. Some of the apparent structures are in all probability secondary due to partial recrystallization and solution. I do not think that it would be prudent to give the specimens a definite and precise generic and particularly specific name. But considering their size, number and arrangement of septa, and the presence of a somewhat indefinite central vesicular zone, my impression is that the corals are probably *Streptelasma*. The genus *Streptelasma* is very common in the Middle and Upper Ordovician of North America. If the specimens are *S. corniculum*, as appears likely, the age could be from Black River to the top of the Trenton. I do not think that polishing or sectioning of the specimens would give much additional information. As it is, natural weathering gives a three dimensional aspect of their internal structure."

CONCLUSIONS

Satisfactory correlation of the Waits River formation with the stratigraphic sections of other areas must await further field studies and paleontologic data. The Middle Ordovician age suggested by Professor Okulitch is rather consistent with the meager fossil evidence already available and briefly summarized in the forepart of this paper. In view of the poor state of preservation of all fossils thus far reported, as well as of those collected by the author, it should be recognized that future discoveries of fossils, or of new stratigraphic and structural relations, could result in changes in age assignments.

The author is extending the stratigraphic studies of the formations beneath the Waits River formation initiated by Currier and Jahns (1941), and expects to search for additional fossils in the Waits River formation as time permits. Continued search should result in the discovery of fossils that are as well or even better preserved than those already found. All but one of the collections listed were obtained in the course of but one month of routine geologic mapping and several other coral localities (fig. 1) were observed during this period. The area of discovery was restricted to the part of the Waits River formation that lies within the Montpelier quadrangle. Additional search within this quadrangle, as well as in adjoining areas, seems justified.

PLATE 1

Outcrop of phyllite showing fossil cup corals.

Fig. 1. Bedding-cleavage relationships. The hammer handle is in the projected plane of the bedding surface over which the fossils are scattered; the cleavage, which strikes nearly parallel to the bedding but dips into the face of the outcrop, shows on the surface of the cross-joint on the left.

Fig. 2. Close-up view of the bedding surface. The position of the individual corals is indicated by white quartz that fills the coral calyces; a small coral without the quartz filling is directly in line with the $10\frac{3}{4}$ inch mark on the foot rule. Two poorly defined joints that pass across the upper half of the view are nearly parallel to the cleavage.

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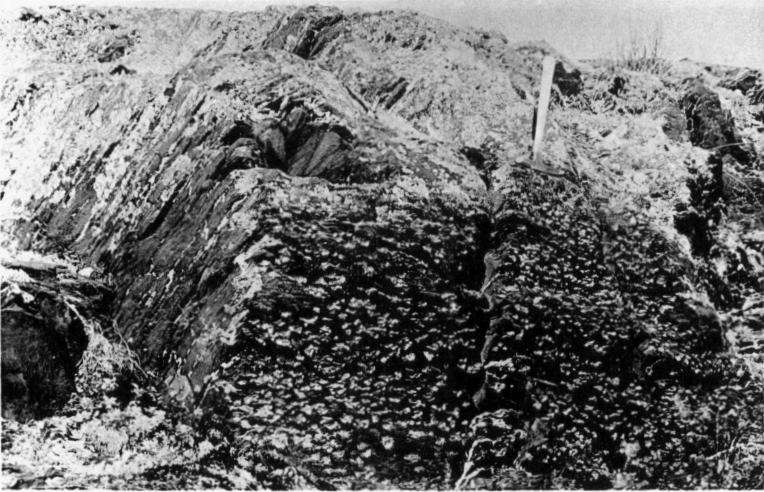


FIG. 1



FIG. 2

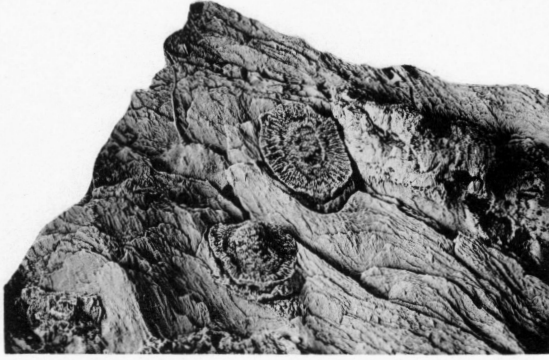


FIG. 1



FIG. 2



FIG. 3



FIG. 4



FIG. 5

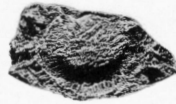


FIG. 6



FIG. 7



FIG. 8

PLATE 2

Detailed full-size views of the cup corals.

Fig. 1. In place in the phyllite. Two corals, the upper portions of which are exposed in the plane of the bedding, taper downward and to the right into the specimen and parallel to crenulations in the cleavage. The helical pattern of the cleavage around the upper individual suggests that it has been rotated counterclockwise. Both individuals show a central vesicular zone, radiating septa, and circumferential wall.

Figs. 2-4. In cleavage fragments of phyllite. These specimens were removed from the outcrop by sliding them out parallel to the lineation; they taper downward, and the cross section of a cleavage fragment, which is eye-shaped in the vicinity of the calyx of the coral, flattens out to a spade-shape near the base. Flattening in the plane of the cleavage is particularly evident in figures 2 and 4. The central vesicular zones are relatively large, and the septa are not as well defined as in figure 1.

Figs. 5-8—Top views.

5. A coral partly fills a hollow within a cleavage fragment.
6. The central vesicular zone commonly forms a protuberance, as shown in this specimen.
7. The septa in this specimen are absent or poorly formed, and the vesicular zone extends to the circumferential wall.
8. Some of the septa in this specimen seem to bifurcate toward the circumferential wall.

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