A PALEOZOIC REVISION IN VERMONT.

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ABSTRACT. The recent discovery of determinable fossil crinoid and cystoid calyces, and two gastropods in the Waits River limestone at Westmore, Vermont, shows the Waits River limestone and intercalated rocks to be at least as young as Middle Silurian and very possibly of Lower Devonian age. The fossils are greatly altered, occurring in a high-grade zone of metamorphism at the contact with a granite body. This locality is an important contribution to the slowly expanding list of fossil occurrences in the highly metamorphosed rocks of New England.

INTRODUCTION.

A SERIES of metamorphosed sedimentary rocks consisting of interbedded impure limestones and siliceous beds underlie an area extending the whole length of the State of Vermont east of the Green Mountains. This series has been called the Memphremagog formation in the northern part of the state and contains the Waits River limestone as a key member. These rocks have been regarded of various ages. The bases for the determination of the ages ascertained were never entirely satisfactory, however, because of the absence of definite fossils within the terrane. Attempts had been made at lithological correlations with distant fossiliferous areas of known age, but with little success. In view of the difficulties encountered, hitherto, in the exact dating of this group of rocks, a recent discovery in Westmore, Vermont, of fossil evidence strongly indicating their Middle Silurian or very probable Lower Devonian age, becomes an important addition to the limited number of fossil localities in the metamorphic rocks of New England.

The writer is very grateful to Dr. Winifred Goldring for both her valuable aid in identifying the specimens and reading the paper, to Prof. E. C. Jacobs for his kind assistance in the study of the thin-sections, and to Professors P. E. Raymond and M. P. Billings for criticizing the manuscript.

The specimens have been submitted to the following, all of whom agree that they represent echinoderms: Professors P. E. Raymond, T. H. Clark, K. E. Caster, R. H. Flower, Dr. R. Ruedemann, and Mr. I. G. Reimann. Professor Raymond believes the specimens to be fossils, and has stated that if they are fossils they are echinoderms. Professors C. O. Dunbar and R. C. Moore upon examining the specimens, doubted their

organic origin. The writer would be pleased to show both the specimens and their field occurrence to anyone interested.

EARLIER WORK.

Recapitulation of the earlier work done in the region shows that the estimates of the age of the formation have caused it to be shifted about in the geologic column several times. C. B. Adams (1845) was the first to date the series which he named the calcareo-mica schist. He referred them to the Primary, to which it appeared customary at the time to assign metamorphic rocks devoid of fossils. Zadock Thompson (1848) concurred in this age assignment, which prevailed for more than a decade. The earliest attempt at age determination on the basis of fossils was made by Edward Hitchcock (1861, p. 486). He considered the western portion of the area, renamed by him calciferous mica schist, probably Devonian because of "a few encrinal stems" found in limestone in the town of Derby, and the belief that this limestone bore a lithological resemblance to that at the base of Owl Head Mountain in Canada, which was then mapped as Devonian. The "encrinal stems" are now considered mineral deposits. S. R. Hall (1861, p. 719) placed the calciferous mica schist in the Lower Silurian and later (1870) in both the Silurian and Devonian. J. D. Dana (1867) assigned the beds to the Niagara.

C. H. Richardson (1901-02) regarded the series as Lower Trenton on the basis of lithological comparisons with the graphitic slates of established Ordovician age at the Castle Brook locality near Magog, Quebec. The Magog graptolite fauna has been identified as Middle Ordovician by Doctor Ruedemann (1919). Not long after the beginning of his field studies in this region, Richardson (1907-08) made his first attempt to ascertain the age of the formation by means of fossils discovered within the area mapped by him. The fossils were reported to be "crushed graptolites" and to have been identified by Dr. Rudolf Ruedemann. In subsequent biennial reports of the Vermont State Geologist (1911-12, etc.) are increasing citations of "graptolithic" localities in both the slates and the limestones. E. C. Jacobs (1921-22) reported "crushed graptolites" from Brownington. The authenticity of these "graptolites" has been seriously questioned of late by some geologists who would prefer to regard them as mineral streaks.

Their parallel alignments and reported occurrence on cleavage surfaces not always coincident with the bedding, are the reasons advanced for doubting their validity as fossils. Doctor Ruedemann is decidedly of the opinion that these markings represent graptolites.[1]

In Canada where the formation is known as "Tomifobia," it has been considered as Ordovician by T. H. Clark (1934), partly, it appears, for stratigraphic reasons and partly because of graptolites reported from the slates east of the Bunker thrust. Sir William E. Logan (1852, 1863), like his contemporaries, based his identification of the rocks as Silurian age upon long-range correlations. T. S. Hunt (1850, 1854) considered the rocks as Upper Silurian (Silurian of today). R. W. Ells (1894) assigned them to the Cambro-Silurian (Ordovician of today).

DESCRIPTION OF LOCALITY.

The fossil-bearing exposure is located in the bed of Stony Brook on the property of Stony Brook Farm in Westmore village. It is composed of a dark, rusty brown phlogopite schist overlying medium gray, crystalline Waits River limestone. The limestone is studded with the fossil spheres which stand out prominently against the darker background (Plate 1, Fig. 1). A pegmatite dike three feet in thickness emerges from the cover on the bank of the brook and cuts across one end of the outcrop. The greater concentration of the embedded fossils nearer the dike contact inclines the writer to the belief that silicification of the calcareous forms during hydrothermal metamorphism with possibly a minimum of dynamic action, was to some extent responsible for their ultimate preservation.

The objection has been raised by Prof. Carl Dunbar that the specimens show no distortion such as might be expected in metamorphosed rocks, and that they would appear more convincing as fossils if they were badly deformed. As a matter of fact, many of the fossils are greatly deformed, examples of which are clearly shown in Plate 1, Fig. 1. Those specimens which have suffered little or no distortion, and so have retained their original spherical shapes more or less, owe this preservation of form to the manner of behavior of the limestone during metamorphism. Unlike the overlying schist which exhibits a conspicuous schistosity, the limestone is for the most part

[1] Personal communication.

massive crystalline. It would appear, then, that the limestone was the more competent rock, and so would show less deformation in the fossils. Doctor Ruedemann has found graptolites greatly distorted in schists and practically undeformed in limestones of the same area.[2]

FOSSIL DESCRIPTIONS.

The fossils, found by the writer, consist of numerous crinoid and cystoid calyces, and two gastropods. Although the majority of the echinoderms are extremely poorly preserved, there are a few with organic structures in a sufficient state of preservation to permit identification of the genera. The identity of the gastropods is established without much difficulty.

Specimens were submitted to Dr. Winifred Goldring, New York State Paleontologist, for substantiation and further identifications. The results of her investigations appear in the following excerpts from a letter, "I have found another specimen that I think is a *Platyceras* and I have wrapped it separately with a note. The Platyceras strongly resembles some of the Devonian forms, but there are Middle Silurian (Niagaran) forms approaching this type.

"The crinoid and cystoid types suggest the Silurian. The rounded Cystoid-like forms are very suggestive of a type similar to *Caryocrinus ornatus* and the more oval types similar to *Callocystites* form. Both these genera occur in the Silurian (Rochester shale) of New York. Some of both the rounded and oval forms seem to have an indication of plates. A broken specimen, which I have wrapped separately shows a definite body wall. Many of them show a portion of stem attached. The cystoids might even be compared with the Ordovician *Malocystites*, but as they are found in the same beds with the crinoid-like forms I should exclude this genus. The crinoid-like forms have a general resemblance to Silurian genera such as *Lyriocrinus* and *Eucalyptocrinus*. There is no question in my mind that you are dealing with fossils."

Further study of the crinoidal forms by the writer has revealed some structures in addition to those above which are even more suggestive of the genera cited. Several specimens show vertical partitions extending radially from a central column to the walls of the calyces (Plate 1, Fig. 2). The

[2] Personal communication.

vertical partitions with intervening compartments present a striking resemblance to those in a description of the Eucalyptocrinidae (K. A. von Zittel, 1900; A. W. Grabau and H. W. Shimer, 1909-10). When viewed from a surface which may be aboral, one specimen exhibits a portion of an escalloped outline (Plate 1, Fig. 3, a). This convex, aboral surface is circularly depressed at its center, beside which appears a slightly inclined disc of the same diameter as the depression (Plate 1, Fig. 3, a). It is the writer's opinion that these features represent the point of stem contact at the aboral end of a calyx. A columnal with its axial canal attached to the base of a crinoid calyx, is clearly shown in Plate 1, Fig 3, e. Some plates are vaguely outlined. Professor Raymond has pointed out on one specimen what appear to him to be plates. Professor Clark has indicated plates also, and features indicative of pore rhombs. Stem attachment areas, some of them crudely pentamerous, are visible on a few calyces (Plate 1, Fig. 2). Body walls are displayed in a few broken specimens. The cystoids also roughly show the pentamerous symmetry of the aboral stem region (Plate 1, Fig. 3, b, c), while a small portion of stem is present in some (Plate 1, Fig. 3, d). A number of specimens occur as combined spheres, which is suggestive of bulbous roots of crinoids. It is from this observation that Professor Raymond ventured the opinion that these coalescent forms might possibly represent a type similar to the crinoid genus Scyphocrinus. Scyphocrinus is Silurian in age.

Of note is the fact that there is a total lack of free columnals in the exposure. The absence of columnals might seem strange, but perhaps no more so than the opposite case in which only stem fragments are found. Two occurrences of the latter are referred to on page 63. The complete dissociation of calyces from their stems may quite readily be explained by currents which swept away the lighter, detached calyces, leaving the less buoyant stems to be deposited elsewhere. The lack of columnals may also be accounted for by their weaknesses in structure and composition; they are ordinarily fragile and would, upon continued disintegration, become more easily dissolvable under the influence of percolating waters.

The better preserved of the Platyceras specimens is enrolled in more than one volution (Plate 1, Fig. 3, f), which is characteristic of Devonian forms. Although, as Doctor Goldring has stated, middle Silurian forms approximate this type, their

apices are enrolled in only one volution. However, from the major evidence as seen in the echinoderms, the age of the formation is more definitely determined by them, but the possibility of a Devonian age should not be ruled out entirely.

PETROGRAPHICAL STUDIES.

The petrography of the exposure is interesting, especially since a study of the thin-sections has revealed it to be in an aureole of high-grade metamorphism. The rock sections will first be described, followed by a section through one of the fossils.

The glimmering, mica-bespeckled schist is almost black, weathering to a more or less uniform brown on the exposed surface. A thin-section study shows the rock to be a phlogopite schist containing considerable muscovite and quartz, the latter often exhibiting wavy extinction. Small crystals of tourmaline have a generous distribution and finely divided carbon is profusely disseminated in the section. Minerals in lesser amounts are pyrrhotite, finely disseminated pyrite, zircon as pleochroic halos in biotite, a little sphene, and one large, elongate, shattered crystal of calcite.

The white and gray mottled Waits River limestone weathers to a dark gray. The chief minerals in this rock are calcite, much of it twinned, and quartz. The quartz is interstitial, frequently showing wavy extinction and abnormal biaxial interference figures. Considerable wollastonite is associated with calcite and quartz. Moderate amounts of clinozoisite and interstitial grossularite are present, and small quantities of diopside, epidote, orthoclase, and zircon.

Where exposed to the flow of brook water the fossils are light gray and exhibit smooth surfaces. The current of the brook is also the agency which has disclosed their internal structures. Where subaerially weathered the rounded forms have a coarse, rusty surface. They range from one-half to four centimeters in diameter. Minerals in the majority in a microscopic section are twinned calcite and interstitial grossularite with quartz inclusions. Much of the quartz in the section contains inclusions, is minutely fractured, and shows wavy extinction. Considerable diopside, some clinozoisite and possibly zoisite, and smaller amounts of muscovite, orthoclase, and zircon are present.

The mineral assemblages in the thin-sections described above

show that the fossils occur in rocks of the katazone of the Grubenmann-Niggli classification (1924) of metamorphic rocks. Besides having close contact with the pegmatite dike, the fossils are found in a contact aureole of highly metamorphosed sedimentary rocks in close proximity to a large granite body. Because of their location in an igneous contact zone, certain observers doubt the organic nature of the specimens and consider them the product of metamorphism. Those who argue from this point of view are reminded that other occurrences of fossils in crystalline rocks are known, and in this connection the writer cites the discovery in recent years of fossil brachiopods in crystalline schist on Mount Clough, New Hampshire (M. P. Billings and A. B. Cleaves, 1935). As he has stated earlier in this paper, the writer believes the preservation of the fossils to be due largely to silicification during hydrothermal metamorphism.

The Westmore locality, like that on Mount Clough (M. P. Billings and A. B. Cleaves, 1935), the Littleton area (M. P. Billings and A. B. Cleaves, 1934), the Bernardston locality (R. P. Whitfield, 1883), and others, becomes an important member of the restricted but growing list of fossil horizons in highly metamorphosed rocks. The Westmore locality is also significant because it is the first known occurrence of crinoid and cystoid calyces in strongly metamorphosed rocks. A quite remarkable feature is the entirety of a great many of the calyces. Crinoid stems are reported from metamorphosed rocks in adjacent areas (L. W. Currier and R. H. Jahns, 1941) and in pebbles of the Irasburg conglomerate. Although in a zone of high-grade metamorphism, structural features sufficient to allow identification of genera have been preserved. Of much import is the fact that the Memphremagog formation, previously considered Lower to Middle Ordovician, now becomes elevated at least to the Niagaran of the Silurian and very probably to the Helderbergian of the Devonian.

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Fig. 1. Exposure showing metamorphosed fossils in relief.

Fig. 2. Aboral ends of two crinoid calyces (of Eucalyptocrinus or Lyriocrinus types), showing stem attachment areas. Satellite specimen (of Eucalyptocrinus type) with vertical partitions and compartments exposed by erosion. Natural size.

Fig. 3. a, Escalloped border of aboral surface of crinoid and stem contact area; b, c, Cystoids (of Caryocrinus type) showing crudely preserved pentamerous pattern of stem-connecting area; d, Cystoid (of Callocystites type) with a part of stem; e, Crinoid calyx showing attached columnal disc with its axial canal; f, Gastropod (Platyceras). Natural size.

Fig. 1

Fig. 2

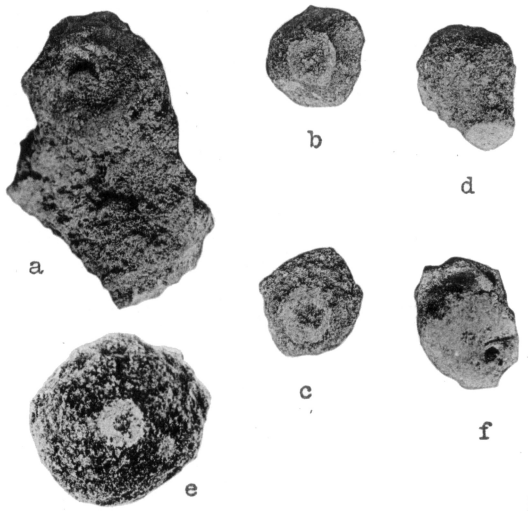

Fig. 3