

CAMBRIAN-ORDOVICIAN BOUNDARY IN THE ADIRONDACK-BORDER REGION.

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ABSTRACT. Revisions in the Champlain, Hudson, Mohawk, and St. Lawrence Valleys (Adirondack-Border region) involving the definitions and the succession of previously accepted Cambro-Ordovician formations (the Potsdam, Theresa, Hoyt, and Little Falls of Upper Cambrian age and the Whitehall, Tribes Hill and Beekmantown of Lower Ordovician age) are as follows: (1) the lower "typical" Theresa of Cambrian age is physically and faunally differentiated from the "Upper Theresa" (now the Heuvelton) member of the Tribes Hill formation; (2) the Hoyt fauna occurs in the lower half of the emended Whitehall formation *above* the Little Falls dolomite; (3) a new, upper (Skene) member of the Whitehall formation represents late Cambrian off-lap; (4) two marine cycles, represented by the Tribes Hill formation (containing the Norton, Fort Ann, and Benson members) and the Cassin formation, constitute the Beekmantown series. Each revised unit is tied in with the Divisions A through E of the original "Calciferosus" formation.

The late Cambrian Hoyt fauna has affinities with that of the Trempealeau, Conococheague, and Eminence; whereas the Oneota, Stonehenge, Van Buren, and Gasconade faunas occur in the Tribes Hill formation, not in the Little Falls as generally believed. Thus, the lower half of the Ozarkian is Cambrian in age and the upper half is Tribes Hill (Lower Ordovician).

INTRODUCTION.

THE discovery of late Cambrian and early Ordovician fossils in the foreland of the Champlain and Hudson Valleys permits improved correlations with critical sections and necessitates both the redefinition of stratigraphic units and their rearrangement in the stratigraphic sequence. The most important of the revisions and, hence, the subject chosen for a preliminary article concerns the position of the Cambrian-Ordovician boundary in the Adirondack-Border region. A brief resume of major changes previously made in the position of that systemic boundary precedes the writer's revisions.

PREVIOUS WORK.

The work of Brainerd, Seely,¹ and Whitfield² late in the last century brought a revival of interest in the study of the "Calciferosus"³ rocks and provided a standard of reference for later

¹ Brainerd, E. and Seely, H. M.: 1890, *Calciferosus formation in the Champlain Valley*: Am. Mus. Nat. Hist., Bull., Vol. 3, pp. 1-23.

² Whitfield, R. P.: 1890, *Fort Cassin Fauna*: Am. Mus. Nat. Hist., Bull., Vol. 3, pp. 25-28.

³ "Calciferosus": The broad but obsolete term "Calciferosus" is used to avoid reference to its controversial subdivisions.

investigations. They subdivided the "Calciferosus" of the Champlain Valley into five lithologically distinct parts totaling 1800 feet, showed that a large and unique (Fort Cassin) fauna characterized the upper part of the formation, and described the Cambrian-"Silurian" boundary (between the Potsdam and the "Calciferosus") as transitional. But since the "Calciferosus" rocks of the Hudson and Mohawk Valleys reach no great development and do not contain the Fort Cassin fauna, a problem immediately arose concerning their correlation with the divisions accepted in the Champlain Valley.

The gradual recognition, in the first decade of this century, of the Upper Cambrian age of the Hoyt fauna in the "Calciferosus" at Saratoga, N. Y., the early Ordovician age of the Tribes Hill fauna in the "Calciferosus" of the Mohawk Valley, and the discovery of a meager gastropod fauna in the Little Falls dolomite seemed only to confuse the problem, for none of these faunas was known in the Champlain Valley.

Certain it was that the Upper Cambrian and Lower Ordovician portions of the "Calciferosus" should be differentiated. Clarke and Schuchert⁴ had already (1899) chosen the wholly inadequate locality name *Beekmantown* for the Ordovician portion of the "Calciferosus" although neither the Fort Cassin nor the Tribes Hill fauna was known to be represented in the section at that locality. With the transition beds that lay above the Potsdam sandstone and beneath the Little Falls dolomite distinguished by the name "Theresa passage-beds" (Cushing, 1908⁵) and the Hoyt limestone accepted as a lower member of the Little Falls dolomite, the Cambrian sequence of formations was recognized as follows:

Little Falls dolomite
Hoyt limestone
Theresa passage-beds
Potsdam sandstone

In 1910, Ulrich and Cushing⁶ described a major unconformity separating the Little Falls dolomite and the Tribes Hill

⁴ Clarke, J. M. and Schuchert, C.: 1899, *Nomenclature of New York Series of Geological Formations*: Science, n. s., Vol. 10, p. 876.

⁵ Cushing, H. P.: 1908, *Lower Paleozoic Section in Northwestern New York*: Geol. Soc. Am., Bull., Vol. 19, pp. 155-176.

⁶ Ulrich, E. O. and Cushing, H. P.: 1910, *Little Falls dolomite of the Mohawk Valley*: N. Y. State Mus. Bull. 140, pp. 130-140.

limestone in the Mohawk Valley and considered it the Ozarkian-Canadian boundary. They traced the unconformity to the Champlain Valley, decided that it lay in the middle of Division B of the "Calcareous," and concluded that: (1) the Hoyt and Little Falls were equivalent to Division A and the lower half of Division B, (2) the Tribes Hill was represented by the rest of Division B, and (3) the Theresa passage-beds were recognized in the upper part of the Potsdam, not in the lower part of the "Calcareous."

Revisions in the above picture were made in 1937 by Rodgers⁷ who stated that in the Upper Champlain Valley: (1) the hiatus described by Ulrich and Cushing in the Mohawk Valley was represented at Whitehall by a "significant unconformity" 35 feet beneath the base of Division B, not in the middle of that division, (2) this break marked the true upper limit of the Little Falls dolomite, and (3) the cherty dolomite, limestone, and light gray dolomite above the unconformity and beneath the basal sandstone of Division C constituted a separate formation. This (Whitehall) formation was further described as containing a Lower Ordovician fauna correlative with that of the Gasconade and Chepultepec dolomites. Thus, in effect, the base of the Beekmantown was lowered to include the Whitehall formation.

The following year Wilmarth⁸ reviewed the many controversial definitions of the Beekmantown. Certain revisions suggested by Ulrich were adopted by the U. S. Geological Survey. The essential changes are as follows: (1) Chepultepec-Gasconade gastropods were claimed by Ulrich to occur in the upper cherty beds of the Little Falls dolomite and the cherty dolomite to be separated from the typical Little Falls dolomite by an unconformity. This hiatus was inferred by Ulrich to be the Lower-Upper Ozarkian boundary but was regarded by the Survey as the Cambrian-Ordovician boundary. (2) The Survey, thus, decided that the undescribed gastropods had greater Tribes Hill than Cambrian affinities and placed the 30-odd feet of cherty dolomite in the Ordovician along with the Chepultepec and Gasconade. (3) The cherty beds were stated as partly represented in Division B but no further estimate was made

⁷ Rodgers, J.: 1937, *Stratigraphy and Structure in the Upper Champlain Valley*: Geol. Soc. Am., Bull., Vol. 48, pp. 1574-1578.

⁸ Wilmarth, Grace: 1937, *Lexicon of Geological Names*: Geol. Surv. Bull. 896, pp. 145-148.

regarding the relative position of the boundary and the "Calciferos" divisions.

REVISIONS.

In order to correct the more conspicuous misstatements and misinterpretations that obscure the position of the Cambrian-Ordovician boundary both within and beyond the Adirondack-Border region, the writer presents certain new information before attempting a revision of correlations. Of major importance was the discovery of the late Cambrian Hoyt fauna in the Upper Champlain Valley. The fossils are associated with the *Cryptozoon proliferum* reef which directly overlies the cherty dolomites of the Little Falls dolomite at Whitehall, N. Y.

To find the Hoyt fauna *above* the Little Falls formation was so disconcerting that the typical Hoyt sections were restudied. An unfaulted section 4 miles west of Saratoga, which was described by Ulrich and Cushing (1910, p. 109) as exhibiting only the Little Falls dolomite capped by a massive *Cryptozoon* reef, revealed the Hoyt fauna in limestone immediately above the reef. Here, as at Whitehall and Fort Ann, the Hoyt limestone is succeeded by a dolomitic member that grades upward into the sandy dolomite of Brainerd and Seely's Division C₁.

Since the cherty top of the Little Falls formation plus the Hoyt limestone at Whitehall constitute the lower part of Rodger's "Ordovician" Whitehall formation, it was necessary to examine the "significant unconformity" originally *postulated* by Ulrich⁹ as setting off the upper cherty beds from the Little Falls proper and accepted as *verified* by Wilmarth and specifically allocated at the base of the Whitehall formation by Rodgers. A few feet of cross-bedded sandy dolomite but no erosion surface marks this horizon. The frequent occurrence of similar sandy layers and the abundance of chert in all exposures of the Little Falls dolomite supports the correlation of the pre-Hoyt dolomite at Whitehall with that at Little Falls, N. Y., and eliminates the probability of a hiatus.

The unfossiliferous, rather clean, light dolomite above the

⁹ Ulrich, E. O.: 1913, *Revision of the Paleozoic Systems*: Geol. Soc. Amer. Bull., Vol. 24, p. 643 (line 24).

Hoyt that reaches a thickness of about 160 feet at Whitehall and forms the upper half of the Whitehall formation is, in reality a wedge thinning toward the Adirondacks. More than 100 feet are lacking near Putnam and Ticonderoga where the beds are sandy and are succeeded by the mottled limestone of Division C. The wedge disappears west of Little Falls so that the Tribes Hill formation rests with a pronounced erosion surface upon the Little Falls dolomite.

The additional discovery of an early Ordovician fauna with Tribes Hill affinities in the mottled limestone just above the cross-bedded sandstone of Division C_1 at Whitehall and Fort Ann clinched the position of the Cambrian-Ordovician boundary. Succeeding this (Norton) member of the Tribes Hill [= upper part of $C_1 + C_2$] are two other new members (the Fort Ann limestone [C_3] and the Benson dolomite [$C_4 + D_1$] which contain later Tribes Hill forms and are followed in turn by the Upper Beekmantown, Cassin, fauna. Thus, in the Champlain and Hudson Valleys (as in the Mohawk) the Tribes Hill formation is typically mottled limestone and dolomite, disconformably underlain and overlain by sharply differentiated formations. But, although defined in the Mohawk Valley, the Tribes Hill reaches its maximum thickness, faunal diversity and lithological variability in the Champlain Valley where it is approximately equivalent to Division C_2 , C_3 , C_4 , and D_1 of Brainerd and Seely.

The base of the Whitehall formation is raised to coincide with the contact of the Little Falls dolomite and the Hoyt limestone and the latter is redefined as a lower member of the Whitehall formation. The superjacent light gray dolomite and the lower few feet of the cross-bedded sandstone of Division C_1 are regarded as late Cambrian off-lap deposits and now constitute the upper (Skene dolomite) member of the Whitehall formation.

An outline of the Upper Cambrian history of deposition in the region is as follows:

1. Upper Cambrian submergence commenced with the reworking and deposition of the sub-aerially purified debris that blanketed the pre-Cambrian peneplain of Upper New York State and Vermont. The distribution of the resulting (Potsdam) conglomerate and sandstone indicates that a prong of the St. Lawrence embayment extended southward into the Champlain, Hudson, and Mohawk

Valleys and that a neck of land (the Frontenac Axis), connecting the Adirondack "dome" and the Canadian Shield, acted as a barrier to the Upper Cambrian transgression.

2. The gradual inundation of the region gave rise to sandstone near the encroaching shorelines but provided less sand off-shore. Calcareous deposition (becoming less and less masked with clastics) produced, first, the interbedded limestone, dolomite, and sandstone of the Theresa and, later, the somewhat sandy dolomite of the Little Falls.

3. Maximum submergence was marked by an extensive development of the *Cryptozoon proliferum* reefs, by an increased ratio of CaCO_3 to MgCO_3 deposition, and by the resultant preservation of the Hoyt fauna due to inhibition of dolomitization.

4. Emergence was accompanied by reworking of the Hoyt and Little Falls strata in the Mohawk Valley, by formation of dolomite to the northeast, by the deposition of a cross-bedded (intercalated) sandstone above the dolomite, and by the subaerial erosion of the various late Cambrian strata present in localities adjacent to the Adirondack "dome."

The major revisions in the stratigraphic sequence are best shown at Whitehall, hence, the corrected Skene Mountain section is tabulated below:

Tribes Hill formation

Norton limestone member [top of $C_1 + C_2$]:

Mottled dolomitic limestone (containing poorly preserved trilobites, brachiopods, and gastropods) with an uncertain amount of cross-bedded sandstone at base—about 45 feet.

Whitehall formation

Skene dolomite member [sandy base of $C_1 +$ upper part of B]:

Barren, light gray, only slightly cherty, thin bedded dolomite grading upward into cross-bedded, worm riddled sandstone—about 120 feet.

Hoyt limestone member:

Fossiliferous dove limestone showing the reticulating lines of incipient dolomitization on weathered surfaces; commonly oölitic; contains the *Cryptozoon proliferum* reefs, gastropods, and trilobites—about 40 feet.

Little Falls formation

Upper beds cherty, dark gray, massive and occasionally sandy dolomite. Lower beds frequently sandy, usually 1 to 2 feet thick, marked throughout with calcite, quartz, dolomite and chert replacement areas—about 210 feet.

Theresa formation

Calcareous and dolomitic sandstone frequently fossiliferous (con-

taining Walcott's "Potsdam" fauna), and interbedded sandstone and dolomite—about 80 feet.

Potsdam formation

Clean, white, somewhat cross-bedded, sandstone in beds 2 to 3 feet thick—about 175 feet.

Pre-Cambrian gneiss

The presence of *Cryptozoon proliferum*, *Holopea*, *Matthavia*, and *Neosaukia* in the dove limestone of Division B at Whitehall supports correlation with the typical Hoyt at Saratoga. Previous correlations of the Hoyt with the Trempealeau of the standard (Croixan) Upper Cambrian section, with the Conococheague of the Central Appalachians, and with the Gorge of northwestern Vermont are further supported by the discovery of *Plethometopus* and late saukiinids at Whitehall. The presence of *Dirhachopea*, *Plethopeltis*, and *Plethometopus* both in the Hoyt and the Eminence dolomite of Missouri refutes Ulrich's contention that the Eminence is post-Cambrian and that the superjacent Gasconade can be correlated with the Hoyt.

The enlarged Tribes Hill fauna contains *Symphysurina* and *Bellefontia*. These trilobites characterize the oldest Ordovician faunas known. In addition, *Finkelburgia* and the associated gastropods *Ozarkina*, and *Sinuopea* indicate a correlation with the Gasconade and Chepultepec dolomites, the Oneota of Wisconsin, the Stonehenge of Maryland and Pennsylvania, and the Highgate and Corliss of northwestern Vermont.

In conclusion, it should be pointed out that the Mohawk Valley, where early ideas of the "Calcareous" rocks were derived, offers a very incomplete portion of the sequence because all the formations thin and become more clastic in that direction. The Central Sequence of northwestern Vermont represents Cambrian and Ordovician off-shore sedimentation practically uninterrupted by oscillations of sea level. In neither the Mohawk Valley nor the northern Champlain Valley, therefore, can the relations between faunal and physical boundaries be satisfactorily detected. But the Upper Champlain Valley sections substantiate the major Upper Cambrian and Lower Ordovician faunal changes with a variety of physical manifestations of marine oscillation.

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