THE AGE OF THE ORDOVICIAN KIRKFIELD FORMATION IN ONTARIO

G. WINSTON SINCLAIR

Department of Geology and Geography, Ohio Wesleyan University Delaware, Ohio

Limestones of Middle Ordovician Trenton age occur in Ontario in two separate areas of outcrop, one a band running roughly southeast from Georgian Bay to Lake Ontario, the other a series of more or less disconnected exposures in faulted blocks in the Ottawa Valley and St. Lawrence lowland. Between these two areas lies the pre-Cambrian Frontenac axis. Although considerable distances are involved (Hull is 170 miles from Kirkfield), correlation of beds across the axis have been made with assurance, and formational names defined in one area have been applied to beds in the other. Thus the name Hull has been used for beds in each area.

Study of the faunas involved made me suspect that this correlation was incorrect and in 1942 I prepared a paper for the Ottawa meeting of the Geological Society of America, setting forth my views, and suggesting that the local name Kirkfield be revived for the Central Ontario beds, since it implied no correlation. The Ottawa meeting was cancelled, but the abstract of my paper was published. At that time I was dissuaded from publication of my notes by the argument that further detailed field-work was needed for final solution of the problem, and that controversy should be avoided until this could be done. This, I think, was sound advice. Two considerations bring me to presentation of my data now. The detailed mapping which was needed is now being done, but my abstract, with its threat of publication, hangs over the heads of the men doing it. I think it well to drop the other boot, present my opinions, and let other workers get on with the task of proving them right or wrong. Then, too, in the past decade the term Kirkfield has gained some acceptance, but as a unit succeeding the Rockland (see *e.g.*, Kay 1948, p. 1402), a usage which I deplore.

This ten-year delay is not regretted. In 1942 my conclusions had to rest largely on my own collecting experience, with the inevitable suspicion of unconscious bias involved in such data. Now, however, we have a detailed study of the Black River (Young, 1943) and a series of faunal studies of the Ottawa Valley beds (Wilson, 1946–1951) which can be used in evidence.

I suggest that the Kirkfield formation (the beds previously called Hull in Central Ontario) are not of Hull age, but rather are contemporary with the Rockland beds of the Ottawa Valley, a conclusion which I think follows from a study of the nature of these three units.

THE NATURE OF THE HULL FORMATION

In his first division of the limestones of Trenton age in the Ottawa Valley Raymond did not name his members, but numbered them from 1 to 6 (1912, p. 354). His numbers 2 and 3 are described:

"(2) Thick and thin-bedded blue limestone with a large amount of chert, developed as flat plates parallel to the bedding. These beds are particularly well shown in Hull, and furnish a large part of the building stone and crushed stone used in Ottawa. Just at the top of these beds are the layers from which a large part of the crinoid found in Hull have been obtained. Strata of the same age as these beds occur in central Ontario at Fenelon Falls and the Kirkfield lift-lock, where they occupy the same stratigraphic position as at Ottawa. The thickness of these beds is about 65 feet.

"(3) Massive, coarse-grained, blue-grey limestone with few fossils. This is the horizon in which are located the large quarries on Montreal road, three miles east of Ottawa. The

same beds are exposed in Hull, but are not quarried at the present time. They seem to be absent from the section in Simcoe district, central Ontario. The most common fossil is a species of *Tetradium*, very like *T. cellulosum*. The thickness is about 35 feet."

The next year (Raymond, 1913, p. 143) these descriptions were repeated with the members named, as the Crinoid beds and the Tetradium beds. Further brief notes, including a few fossils, are given in the same guidebook, pp. 151, 156.

FAUNAL ZONE	JOHNSTON 1911, 1912	RAYMOND 1914	KAY 1937	OKULITCH 1939	KAY 1942	SINCLAIR 1952
CRINOID	KIRKFIELD	HULL	HULL		HULL	KIRKFIELD
DALMANELLA		ROCKLAND				
GONIOCERAS	COBOCONK	LERAY	ROCKLAND (NAPANEE)	COBOCONK	NAPANEE	COBOCONK
TETRADIUM CELLULOSUM	LOWVILLE	LOWVILLE		MOORE HILL	CHAUMONT	MOORE HILL
BEATRICEA	LOWER LOWVILLE	PAMELIA		GULL RIVER		GULL RIVER

FIGURE 1. Summary of the nomenclatural history of Lower Mohawkian beds in Central Ontario. The double line is drawn between the Trenton and the Black River groups. Johnston considered his Kirkfield group to be pre-Trenton in 1911, and in 1912 extended it higher, to include beds not shown in this table.

ZONES	RAYMOND 1916	KAY 1937		KAY 1942		WILSON 1946		SINCLAIR 1952
TETRADIUM	HULL	HULL		HULL		OTTAWA FORMATION	HULL	HULL
CRINOID								
DALMANELLA	ROCKLAND	ROCKLAND	NAPANEE	ROCKLAND	NAPANEE		ROCKLAND	ROCKLAND
PAQUETTE RAPID	BLACK RIVER				SELBY		LERAY	CHAUMONT
"LERAY"			SELBY	CHAUMONT				
TETRADIUM CELLULOSUM	LOWVILLE						LOWVILLE	LOWVILLE
	PAMELIA						PAMELIA	PAMELIA

FIGURE 2. Summary of the nomenclatural history of Lower Mohawkian beds in the Ottawa Valley. The double line is drawn between the Trenton and Black River groups.

The name Hull was first used in 1914 (Raymond, 1914, p. 348) in a table in which it was used for the Crinoid beds, with the note:

"The name Hull is proposed for the strata which at Ottawa, Belleville, and in central Ontario, carry the well-known crinoid fauna. The name is for the city of Hull across the Ottawa river from Ottawa."

In this paper the Tetradium beds were omitted from the table.

Later (Raymond, 1916, p. 255) the Hull formation was defined, in the Ottawa valley section, as:

"Coarse-grained light gray thick-bedded limestone, thirty-three feet in thickness, resting upon sixty-six feet of blue to gray fine-to-coarse grained limestone containing great quantities of black chert in layers and flattened cakes. The upper beds contain an abundance of *Stromatocerium* and *Solenopora* and in a nearby locality *Tetradium racemosum*. The lower beds have shaly partings in which great numbers of fine echinoderms have been found, particularly crinoids. Among the characteristic fossils are *Edrioaster bigsbi* and *Cleiocrinus regius*. Hull formation. 100 feet."

Since 1916 this interpretation of the formation has been accepted. In present usage of the Canadian Survey the Hull is considered a faunal association within the inclusive Ottawa limestone. I do not consider this interpretation helpful, but the disagreement is one of terminology only. The same beds are meant whether they be called a formation or a series of beds containing a given fauna.

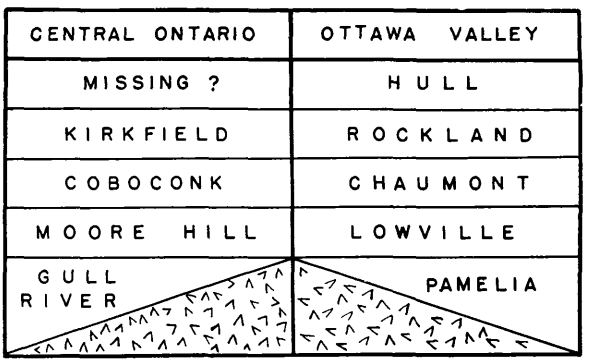

FIGURE 3. Suggested correlation between Central Ontario and the Ottawa Valley. The Gull River and Pamelia may be equivalent, but I do not consider this to be demonstrated and there are important faunal differences.

The Hull echinoderms

Wilson lists the following species from the Hull in the Ottawa district (Wilson, 1946):

Ateleocystites huxleyi Billings
Comarocystites punctatus Billings
Lichenocrinus ottawaensis Wilson
Cyclocystoides halli Billings
Archaeocrinus microbasilis (Billings)
Glyptocrinus ottawaensis Wilson
G. ramulosus Billings
Periglyptocrinus billingsi Wachsmuth and Springer
Ectenocrinus canadensis (Billings)
Carbocrinus radiatus Billings.

I think the first reaction of readers will be surprised at the brevity of the list. But after years of collecting in the Hull, I can testify that it does represent the Hull fauna. At one time, when the Hull quarries were working and there was an ardent group of local collectors (James Stewart, Walter R. Billings, Sir James Grant, J. E. Narraway, T. W. E. Sowter, and others) a fair number of specimens were collected, apparently all from a thin zone. But specimens are now very rare, and the variety is, and seems always to have been small.

Much confusion has been caused among those not personally familiar with the locality by the fact that the best exposures of the higher "Cystid" beds, in which crinoids are common, are in the city of Hull. If one sees an old collection of crinoids labelled "Trenton limestone, Hull," one naturally assumes that they are from the Hull "Crinoid" beds. Thus Foerste, Bather and Bassler were misled, and the literature is very confused.

This confusion is in part unnecessary, since Billings was usually careful to indicate the horizon of his specimens, but his notes have been generally overlooked.

Billings recognized two series of beds at Ottawa yielding echinoderms, the lower cherty beds (Hull), and the higher thin-bedded limestones (Cystid beds) (Billings, in Logan, 1863, p. 166). He lists the species which he obtained from the latter, viz.:

Amygdalocystites radiatus
Comarocystites punctatus
Glyptocystites multiporus
Pleurocystites elegans
P. filitextus
P. robustus
P. squamosus
Palasterina stellata
Petraster rigida
Stenaster pulchella
Edrioaster bigsbyi
Lebetodiscus dicksoni
Carabocrinus radiatus
Cleiocrinus regius
Dendrocrinus gregarius
D. rusticus
Glyptocrinus lacunosus
G. marginatus
G. ornatus
Hybocrinus conicus
H. tumidus
Lecanocrinus elegans
Palaeocrinus angulatus
Porocrinus conicus
Reteocrinus stellaris
Rhodocrinus pyriformis

In other words, of the 44 echinoderm species which he described from the Ottawa district, Billings definitely stated that 27 came from the higher of the two horizons. The other 17 species were not located stratigraphically, with the exception of *Ateleocystites huxleyi*, which was said to occur in the lower beds.

The non-crinoid fauna of the Hull

The Hull beds in their typical expression are so unfossiliferous that it is difficult to get more than a partial picture of the fauna from ordinary collecting. We are fortunate in having Wilson's studies, based on the accumulated collections of almost 100 years by officers of the Canadian Survey, and by Walter R. Billings and other local amateur collectors. For convenience the following list of species which are found in the Hull in the Ottawa district has been compiled from Wilson's papers (Wilson, 1946a, 1947, 1948, 1951):

Brachiopods:
Lingula curta Conrad
L. elongata Hall
L. hullensis Wilson
L. philomela Billings
L. rectilateralis major Ruedemann
Trematis ottawaensis Billings
Schizocrania filosa Hall
Pholidops trentonensis Hall
Platystrophia amoena McEwan
P. a. longicardinalis McEwan
Dalmanella rogata (Sardeson)
Dinorthis iphigenia (Billings)
D. pectinella cf. *sweeneyi* (Winchell)
D. regularis Wilson
D. subquadrata (Hall)
D. s. alternata Wilson
Sowerbyella sericea (Sowerby)
Rafinesquina alternata (Conrad)
R. a. intermedia Wilson
R. a. plana Wilson
R. a. transversa Wilson
R. semicircularis Wilson
Camerella hemiplicata (Hall)
Rhynchotrema increbescens (Hall)
Zygospira recurvirostris (Hall)
Trilobites:
Bathyurus ingalli Raymond
B. spiniger (Hall)
Isotelus gigas DeKay
I. latus Raymond
I. maximus Locke
Bumastus billingsi Raymond and Narraway
Thaleops ovata Conrad
Acrolichas cucullus ottawaensis Foerste
A. narrawayi Foerste
Flexicalymene senaria (Conrad)
Ceraurus dentatus Raymond and Barton
C. pleurexanthemus Green
Calliops alatus (?) Okulitch
C. callicephalus (Hall)
Calyptaulax ottawanus (?) Okulitch
Achatella achates (Billings)
Corals:
Streptalasma corniculum Hall
Lichenaria typa Winchell and Schuchert
Tetradium cellulosum (Hall)
Sponges, etc.
Solenopora compacta (Billings)
Hindia parva Ulrich
Brachiospongia hullensis Wilson
Receptaculites occidentalis Salter
Gastropods and conularids:
Sinuites bilobatus corrugatus (Hall)
Lophospira serrulata (Salter)
L. ventricosa (Hall)
Hormotoma bellicincta (Hall)
H. gracilis (Hall)
H. trentonensis crassa Wilson
Liospira vitruvia (Billings)
Cyclonema cushingi Ruedemann
C. hallianum Salter
C. montrealense Billings
Conularia trentonensis Hall

To this list we may add *Cladophragmus bifurcatus* (Raymond, 1931, p. 182). Concerning the groups which have not yet been published by Wilson I can add little. In some of the more sugary layers of the "Tetradium beds" large cyrtodontid pelecypods are common, but they have not been studied. However, it may be said with confidence that they form a faunule quite unlike anything in the Rockland or the Sherman Fall, although one which maintains its character in beds of Hull age as far east as Pont Rouge, Quebec. The ostracods are quite unknown, although small smooth forms are common locally. The bryozoans are being studied by Dr. M. A. Fritz, but her descriptions are not yet published (see Fritz, 1947).

THE NATURE OF THE ROCKLAND FORMATION

Like the Hull, the Rockland was first described by Raymond in faunal terms, as in 1913 (p. 142):

"Dalmanella Beds.—Thinbedded, pure, blue-black limestone, characterized by *Orthis tricenaria*, etc. These beds are very poorly exposed at Ottawa, and have an estimated thickness of about 40 feet (12.2 m.). They are well shown above the Black River in the Stewart quarry at Rockland, and were also seen on top of the Black River at Fenelon Falls and Kirkfield lift-lock in central Ontario."

The name Rockland was introduced (1914, p. 348) with the notes:

"The name Rockland is proposed for the lowest Trenton beds in the Ottawa valley and in central Ontario, and the name is from the town of Rockland on the Ottawa River, about 30 miles east of Ottawa."

These beds as typically exposed in the Stewart quarry were fully described by Wilson (1921, p. 19 seq.), and for convenience the fauna may be extracted from her lists:

Sponge:
Receptaculites occidentalis Salter
Corals:
Streptelasma corniculum Hall
S. profundum (Conrad)
Tetradium fibratum Safford
Bryozoa:
Dianulites rocklandense Wilson
Hemiphragma tenuimurale Ulrich
Nicholsonella ottawaensis Wilson
Pachydictya acuta (Hall)
Prasopora grandis Ulrich
P. cf. *insularis* Ulrich
P. simulatrix orientalis Ulrich
Brachiopods:
Camerella panderi Billings
Cyclospira bisulcata (Emmons)
Dalmanella rogata (Sardeson)
Orthis disparilis Conrad (Billings in error)
O. tricenaria Conrad
Parastrophia hemiplicata (Hall)
Petrocrania ulrichi (Hall and Clarke)
Plectambonites sericeus (Sowerby)
Plectorthis plicatella Hall (*pectinella* in error)
Rafinesquina alternata (Emmons)
R. rugosa Wilson
Rhynchotrema increbescens (Hall)
Strophomena filitexta Hall
Triplecia cuspidata (Hall)
T. extans (Emmons)
Zygospira recurvirostris (Hall)
Pelecypods:
Cyrtodonta cf. *billingsi* Ulrich
C. huronensis Billings
Gastropods:
Bucania punctifrons Emmons
Hormotoma bellicincta (Hall)
H. trentonensis Ulrich and Scofield
Liospira americana (Billings)
Lophospira bicincta (Hall)
cf. *Maclurina cuneata* Whitfield
Maclurites logani Salter
Metoptoma estella Billings
Phragmolithes compressus Conrad
Sinuites cancellatus (Hall)
Subulites elongatus Conrad
Trochonema umbilicatum (Hall)
Trilobites:
Bumastus indeterminatus (Walcott)
B. trentonensis Emmons
Calymene senaria Conrad
Ceraurus cf. *dentatus* Raymond and Barton
C. pleurexanthemus Green
Encrinurus cybeleformis Raymond
E. cf. *trentonensis* Wolcott
Isotelus gigas DeKay

THE NATURE OF THE KIRKFIELD FORMATION

The Kirkfield limestone group was proposed by Johnston (1911, p. 189) to include (a) Dalmanella sancti-pauli beds, (b) crinoid beds (c) Trenton beds, the first two members being thought of as pre-Trenton. It is evident that this classification reflected the advice of Ulrich, who was not familiar with the Ottawa valley sequence.

The following year, with Raymond doing his paleontology, Johnston (1912, p. 257) divided his Kirkfield limestone group into (1) Dalmanella beds, (2) crinoid beds, (3) Prasopora beds, and (4) an "Upper member (unknown)." With the introduction of Ottawa valley formational names by Raymond in 1914 the name Kirkfield passed from use until 1942.

In his study of the Trenton Kay recognized that the "Hull" and the "Rockland" of Central Ontario in the sense of Raymond, i.e. the crinoid beds and the Dalmanella beds of Johnston, formed a single indivisible unit, to which he applied the name Hull (Kay, 1937, p. 261). I did not agree with this correlation, and suggested that the name Kirkfield be revived, in a restricted sense, since it implied no correlations with the Ottawa Valley (Sinclair, 1942, p. 1833). This suggestion was adopted by Kay (1943, p. 599), but his continued use of Rockland as a subjacent time unit has largely nullified the unambiguous usage for which I had hoped.

At any rate, we are agreed that the term Kirkfield applies to the combined Dalmanella beds and crinoid beds as described by Johnston and Raymond in Central Ontario.

The Kirkfield echinoderm fauna

This is the only part of the Kirkfield fauna which has been studied in any detail, and Springer's paper on the crinoids is well-known (Springer, 1911). The following species have been reported from these beds in the Kirkfield area:

Amecystis laevis (Raymond)
c *Amygdalocystites florealis* Billings
hc *A. f. laevis* W. R. Billings
c *A. radiatus* Billings
c *Archaeocrinus lacunosus* (Billings)
hc *A. microbasilis* (Billings)
c *A. pyriformis* (Billings)
c *Astrocystites ottawaensis* (Whiteaves)
Astroporites ottawaensis Lambe
hc *Carabocrinus radiatus* Billings
C. vancortlandi Billings
c *Cheirocrinus logani* (Billings)
hc *Cleiocrinus regius* Billings
c *Cremacrinus articulosus* (Billings)
c *C. inaequalis* (Billings)
C. rugosus (W. R. Billings)
c *Cupulocrinus conjugans* (Billings)
C. cylindricus (Billings)
c *C. humilis* (Billings)
C. jewetti (Billings)
C. latibrachiatus (Billings)
hc *Cyclocystoides halli* Billings
Daedalocrinus bellevillensis (W. R. Billings)
D. kirki Ulrich
c *Dendrocrinus proboscidiatus* Billings
Edrioaster bigsbyi (Billings) see note
Eustenocrinus milleri (Wetherby)
E. springeri Ulrich
Foerstediscus parvus Bassler
Glaucocrinus falconeri Parks and Alcock
Glyptocrinus circumcarinatus Parks
hc *G. ramulosus* Billings
Glyptocystites multiporus Billings (see note)
Hemicystites multibrachiatus (Raymond)
c *Heterocrinus tenuis* Billings
Hybocystites eldonensis Parks
H. problematicus Wetherby
c *Isorophusella incondirus* (Raymond)
Isotomocrinus typus Ulrich
Lebetodiscus dicksoni (Billings) (see note)
Lichenocrinus ornatus Fenton
Ontariocrinus devratus Jaekel
Ottawacrinus billingsi Springer
O. typus W. R. Willings (see note)
c *Palaeocrinus angulatus* (Billings)
h *Periglyptocrinus billingsi* Wachsmuth and Springer
P. priscus (Billings)
Pleurocystites mercerensis Miller and Gurley
c *P. squamosus* Billings
c *P. s. robustus* Billings
c *Porocrinus conicus* Billings
c *Protaxocrinus laevis* (Billings)
hc *Pycnocrinus ornatus* (Billings)
Reteocrinus alveolatus Miller and Gurley
c *Stenaster salteri* Billings
Protaster whiteavesianus Parks

The list has been taken from Bassler and Moody (1943, pp. 29–30) and from Springer. In this list I have marked with a "c" the 25 species which occur in the cystid beds at Ottawa, with an "h" the eight species which occur in the Hull. From this list one must delete *Ottawacrinus typus* (see Bather, 1913, p. 13), *Edrioaster bigsbyi* (see Bather, 1914, p. 171: the Kirkfield species is *E. laevis*), *Glyptocystites multiporus*, which is *G. grandis* (see Sinclair, 1948, p. 311) and *Lebetodiscus dicksoni* (see Raymond, 1921, p. 6).

I have not included *Astroporites ottawaensis* nor *Daedalocrinus bellevillensis* in the comparison, since I do not know at what horizon they occur at Ottawa, and Wilson does not give them.

Non-crinoid fauna of the Kirkfield

Kay (1934) has described prolific ostracod faunas from Kirkfield beds in central Ontario, and it is regrettable that similar faunules are not known from the Ottawa valley, as their evidence in correlation would carry much weight. Specimens of bryozoans are abundant in the Kirkfield, but they are unstudied. The macroscopic fauna which I have personally collected from the Kirkfield quarry is listed below. Although I consider, with Kay, that the Dalmanella beds and the crinoid beds are a unit, it has been thought better to restrict the list to those forms collected from one outcrop of the crinoid-bearing part of the sequence. This eliminates a number of species which were found on weathered dumps, but their loss does not seem to be significant.

"Sponge":
Receptaculites occidentalis Salter

Coral:
Streptelasma corniculum Hall

Brachiopods:
Resserella "rogata" (Sardeson)
Dinorthis pectinella (Emmons)
Hesperothis tricenaria (Conrad)
Platystrophia amoena McEwan
P. canadensis
P. trentonensis McEwan
Plectorthis trentonensis Winchell and Schuchert
Rafinesquina alternata (Emmons)
Rhynchotrema increbescens (Hall)
Sowerbyella curdsvillensis (Foerste)
Strophomena filitexta (Hall)

Gastropods:
Holopea rotunda Ulrich and Scofield
Hormotoma bellicincta (Hall)
H. gracilis (Hall)
Liospira americana (Billings)
Phragmolithes compressus Conrad

Trilobites:
Bumastus bellevillensis Raymond and Narraway
Ceraurus dentatus Raymond and Barton
Encrinurus cybeleformis Raymond
Hemiarges paulianus (Clarke)
Isotelus gigas DeKay
Raymondites ingalli (Raymond)

Most of these species are those of any Trenton faunule, and are not significant, but some are of interest when their distribution in the Ottawa valley is noted. The Rockland contains a *Bumastus* of *bellevillensis* type, which is replaced in the Hull by the very different *B. billingsi*, as *Sowerbyella "sericea"* replaces *S. curdsvillensis*.

I think the relationships of the Kirkfield fauna can best be seen by examining in detail Kay's faunal description of the central Ontario "Hull" (1937, p. 262):

> "Among the distinctive and persistent forms are the trilobites *Encrinurus cybeleformis* Raymond, *Hemiarges paulianus* (Clarke) and *Bathyurus ingalli* Raymond; none of these is known from the horizons not in the Hull. In northwestern New York and southern Ontario, the basal Hull is the lowest member in which *Parastrophina hemiplicata* (Hall) is abundant; it is found also in younger formations. *Strophomena filitexta* is common, and, in contrast to the Rockland, specimens of *Rafinesquina* are few. *Hesperorthis tricenaria* (Conrad) and *Receptaculites occidentalis* Salter are not found above the Hull and the genus *Platystrophia* is first represented by uncommon species in the formation. . . . "

Taking these statements seriatim: *Encrinurus cybeleformis* was listed from the Rockland by Wilson (1921, p. 44) and in her later paper (1947, p. 44) she notes it as occuring from the Leray to the Cobourg. *Hemiarges paulianus* is found in the Leray, Sherman Fall and Cobourg, but not in the Hull (ibid., p. 43). *Bathyurus ingalli* has been decribed from the Paquette Rapid beds (Sinclair, 1944). Wilson has listed *Parastrophina hemiplicata* as common in the Rockland (1921, p. 32) but it does not become abundant at Ottawa until the Sherman Fall. No *Strophomena* (nor any of its homeomorphs) has been found in the Hull, where species of *Rafinesquina* are abundant, and in many beds the only fossils. *Hesperorthis* is abundant in the Rockland, but does not occur in the Hull, although it appears again high in the Cobourg as a rare species. Although Wilson (1948, p. 29) has two records of *Receptaculites occidentalis* in the Hull, it is very rare there, in contrast to its abundance in lower beds. At least two species of *Platystrophia* occur at Paquette Rapid, and Wilson has noted species of the genus from a number of pre-Hull beds (Sinclair, 1946; Wilson, 1946, p. 31–33).

I think if the faunas which I have listed are carefully studied, the conclusion will be inescapable, that the Kirkfield beds have nothing important in common with the Hull, but on the contrary are strikingly similar to the Rockland. On the basis of our present knowledge, I would consider the Rockland and Kirkfield contemporary, although not necessarily with identical limits.

BEDS OF PRE-ROCKLAND AGE

Were this discussion only concerned with the correlation of isolated formations in Ontario, there would be little excuse for presenting it as fully as I have done. But the problems is much larger in scope. If the Kirkfield be Hull, then it may be argued plausibly that the beds beneath the Kirkfield may be Rockland, and the beds below them Black River. This was essentially Kay's position in 1937, and on that basis he found that the typical Rockland formation rested on beds of Rockland age (Kay, 1937, p. 251), a dilemma which he resolved by redefining the Rockland. Let us try to state the relevant facts.

Three faunas may be distinguished in the Ottawa valley between the Lowville and the Hull. The lowest is that seen in beds along the Petite Chaudière rapids on the Ottawa river, just above the cites of Ottawa and Hull, at Mechanicsville and Tétreauville (or Val Tétreau) on either side of the river. This is the fauna which has been called "Black River," or "Leray" (see Raymond, 1913, p. 141). From these beds a number of trilobites were described by Raymond and Narraway (1908, 1910, etc.), cephalopods by Foerste (1932–33 and other papers), brachiopods by Wilson (1932), and their fauna is being redescribed in detail in Wilson's Ottawa formation papers. There is no need to go into details of that fauna.

Above beds containing this fauna are others (very poorly seen at Ottawa) which at Rockland, on the Bonnechère, and at Paquette Rapid on the Upper Ottawa river carry an abundant fauna which has been well described (see Kay, 1942, p. 598, for a partial list of species). In general the Canadian reports have tended to call this fauna "Leray," or to speak of it, and the beds containing it, as transitional between the Black River and the Trenton. The fauna will be called "Paquette Rapid," when reference is necessary.

Then appears the typical Rockland, with its own fauna, which has been discussed in detail above.

Kay's statement that the "Black River" beds of the Ottawa Valley were really Trenton, and indeed upper Rockland (Kay, 1937, p. 252) was disturbing. Still the Canadian assignment of these beds to the Black River had been largely a positional interpretation, since the fauna of the typical Leray was so poorly known, and the traditional correlation seemed to require re-examination. Since Kay gave no fauna for the Black River itself, there was little basis for judgement. In order to obtain data for the solution of the problem, I spent two weeks at Watertown in 1938, collecting in the typical Leray. A small fauna was collected, and later listed (Sinclair, 1945, p. 74). Since it has considerable importance, the list may be repeated here.

I found the Leray to be very sparsely fossiliferous, and the few fossils it contained very difficult to collect and prepare. However, I did obtain from beds of cherty limestone, above the Lowville and below the Watertown, the following identifiable species:

Columnaria halli Nicholson
Lambeophyllum apertum (Billings)
L. profundum (Conrad)
Camerella cf. panderi Billings
Rafinesquina alternata (Emmons)
Rhynchotrema increbescens (Hall)
Cyrtodonta canadensis Billings
Vanuxemia inconstans Billings
Helicotoma cf. *H. larvata* Salter
Liospira vitruvia (Billings)
Maclurites logani Salter
Illaenus cf. *I. latiaxiatus* Raymond and Narraway
Isotelus gigas DeKay

Although this fauna was so small, it could be placed in terms of the Ottawa Valley sequence, and it correlated not with the Ottawa "Leray," but with the overlying Paquette Rapid beds. In other words, on the basis of this fauna the Ottawa "Leray" was not younger, but older than the typical Leray. Since the fauna was so meagre, it was not felt wise to publish conclusions based on it.

Later one of Kay's students studied the Black River formations and faunas in detail, and his results (Young, 1943, p. 233 seq.) were anxiously studied to see what information his more intensive work would yield. Young's results were found to accord with my own conclusions. After deleting forms from the Ottawa Valley, central Ontario and Montreal, the fauna Young listed for the Chaumont in its typical expression, i.e., in northwestern New York, was:

Stromatoporoid:
Stromatocerium rugosum Hall
Corals:
Columnaria halli Nicholson
Lambeophyllum profundum (Conrad)
Lichneria minor Winchell and Schuchert
Tetradium cellulosum (Hall)
T. fibratum Safford
Bryozoan:
Rhinidictya mutabilis (Ulrich)
Brachiopods:
Hesperorthis tricenaria (Conrad)
Leptaena radialis Okulitch
Rafinesquina clara Okulitch
R. minnesotensis (Winchell)
Rhynchotrema cf. *minnesotensis* Sardeson
R. cf. *increbescens* (Hall)
Hormotoma gracilis (Hall)
Gastropods:
Lophospira perangulata (Hall)
Trochonema umbilicatum (Hall)
Cephalopods:
Actinoceras ruedemanni Foerste and Teichert
A. tenuifilum (Hall)
Cycloceras decrescens (Billings)
C. romingeri Foerste
Endoceras subcentrale Hall
Goniocerus anceps Hall
Orthoceras multicameratum Hall
Plectoceras undatum (Conrad)
Trilobite:
Ceraurinus scofieldi (Clarke)
Ostracod:
Leperditia fabulites Conrad

Again this fauna, insofar as it permitted comparison, pointed to the Ottawa Valley Paquette Rapid beds: the *Hesperorthis*, *Gonioceras* and *Lichenaria* being particulary indicative. Certainly there is nothing here to justify an assignment of the Ottawa Valley "Leray" beds, or the succeeding Paquette Rapid beds, to the Trenton rather than to the Black River.

The pre-Kirkfield beds in Central Ontario have been adequately discussed by Okulitch (1939), and need not be discussed here in detail. I agree with Okulitch that the Coboconk is to be correlated with the Chaumont.

GENERAL CONCLUSIONS

The Kirkfield formation of central Ontario is considered to be the same age as the Rockland of the Ottawa Valley. No beds of Hull age have been recognized in central Ontario. The pre-Rockland beds, both in the Ottawa Valley and central Ontario, are considered to be of Chaumont age. The history of the problem, and my views, are summarized in the correlation tables.

APPENDIX

Age of Rocks at the Chaudière Falls, Ottawa

In compiling the list of Hull species from Wilson's monograph of the Ottawa echinoderms, I omitted those from her locality 37, "Table rock, Chaudière Falls." This omission must now be justified. In my opinion these beds are in the cystid beds of the Middle Trenton, and not in the Hull. This opinion is based on my experience that (a) these beds can be walked and seem to be continuous with those on Philemon Island, which are indubitably Cystid beds. (Walking here is an energetic matter, calling for much clambering under bridges, but it can be done and I have done it—some years ago), and (b) at low water it is possible to get down into wide joints and see, below the beds containing the echinoderms, the shalier beds of the typical "Sherman Fall" as it is identified at Ottawa.

However, these are evidences which may be convincing only to me, and I offer these considerations in addition. Although Wilson lists many forms from this locality, all but one of them is also found in the "Cobourg," and frequently locality 37 is the only "Hull" record for the species. (2) *Pleurocystites* is very common at Table rock, but Raymond says (1916, p. 260), "The Hull . . .contains many many echinoderms but very few *Pleurocystites*, these fossils being abundant in a zone seventy-five feet higher in the section. It was from these higher beds that *Pleurocystites squamosus* and the other species described by Billings were obtained . . . the cystids are associated with species of the *Clitambonites* fauna." (3) *Clitambonites* (recte *Vellamo*) is common at Table Rock. (4) *Lebetodiscus dicksoni* was described from Table rock, but Raymond (1921, p. 6) says, "All the individuals of this species whose exact locality is known have been found in the Cystid beds of the Prasopora zone. . ."

REFERENCES

Bassler, R. S., and **M. W. Moody.** 1943. Bibliographic and faunal index of Paleozoic Pelmatozoan Echinoderms. Geol. Soc., Amer., Spec. Paper 45.

Bather, F. A. 1913. The Trenton Crinoid, *Ottawacrinus*, W. R. Billings. Geol. Survey Canada, Victoria Mem. Mus., Bull. 1: 1–10.

———. 1914. The Edrioasters of the Trenton Limestone. Geol. Mag. 1914, pp. 115–125, 162–171, pl. 10–14.

Foerste, A. F. 1932–33. Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario. Denison Univ., Sci. Lab., Bull., 27: 47–136, pl. 7–37; 28: 1–146.

Fritz, M. A. 1947. Bryozoa of the Ottawa Limestone. Geol. Soc. Amer., Bull., 58: 1181.

Johnston, W. A. 1911. Simcoe District, Ontario. Canada, Dept. Mines, Geol. Survey Branch, Summ. Rept. for 1910, pp. 188–192.

———. 1912. Geology of Lake Simcoe area, Ontario, Brechin and Kirkfield sheets. Idem, Summ. Rept. for 1911, pp. 253–261.

Kay, M. 1934. Mohawkian Ostracoda: Species common to Trenton faunules from the Hull and Decorah formations. Jour. Paleont., 8: 328–343.

———. 1937. Stratigraphy of the Trenton Group. Geol. Soc. Amer., Bull., 48: 233–302.

———. 1942. Ottawa-Bonnechere graben and Lake Ontario homocline. Idem, 53: 585–646.

———. 1943. Mohawkian series on West Canada creek, New York. Amer. Jour. Sci., 241: 597–606.

———. 1948. Summary of Middle Ordovician bordering Allegheny synclinorium. Amer. Assoc. Petrol. Geo. Bull., 32: 1397–1416.

Logan. W. E. 1863. Geology of Canada. Report of Progress to 1863. 983 pp.

Okulitch, V. J. 1939. The Ordovician section at Coboconk, Ontario. Royal Canadian Inst. Trans., 22(2): 319–339.

Raymond, P. E. 1912. Invertebrate Palaeontology. Canada, Dept. Mines, Geol. Survey Branch, Summ. Rept. for 1911, pp. 351–357.

———. 1913. Ordovician of Montreal and Ottawa. Geol. Survey Canada, Guide Book 3, pp. 137–160.

———. 1914. The Trenton group in Ontario and Quebec. Geol. Survey Canada, Summ. Rept. for 1912, pp. 342–350.

———. 1916. The correlation of the Ordovician strata of the Baltic basin with those of eastern North America. Mus. Comp. Zool. Bull., 56: 179–286.

———. 1921. A contribution to the description of the fauna of the Trenton group. Geol. Survey Canada, Mus. Bull. 31, 64 pp.

———. 1931. Notes on invertebrate fossils, with descriptions of new species. Mus. Comp. Zool. Bull., 55: 165–213.

———, and **Narraway, J. E.** 1908. Notes on Ordovician Trilobites: Illaenidae from the Black River limestone near Ottawa, Canada. Carnegie Mus. Annals, 4: 242–255.

———. 1910. Notes on Ordovician Trilobites: III. Asaphidae from the Lowville and Black River. Idem, 7: 46–59.

Sinclair, G. W. 1942. Age of the Trenton crinoid beds at Kirkfield, Ontario. Geol. Soc. Amer. Bull., 53: 1833.

———. 1944. Some Ordovician trilobites from Ontario. Royal Canadian Inst. Trans., 25(1): 15–20.

———. 1945. An Ordovician faunule from Quebec. Canadian Field-Nat., 59: 71–74.

———. 1946. Some species of *Platystrophia* from the Trenton of Ontario and Quebec. Palaeontographica Americana, 3: 16 pp.

———. 1948. Three notes on Ordovician cystids. Jour. Paleont., 22: 301–314.

Springer, F. 1911. On a Trenton echinoderm fauna. Geol. Survey Canada, Mem., 15-P. 50 pp.

Wilson, A. E. 1921. The range of certain Ordovician faunas of the Ottawa Valley with descriptions of some new species. Geol. Survey Canada, Mus. Bull., 33: 19–93.
———. 1932. Palaeontological Notes. Canadian Field Nat., 46: 133–140.
———. 1946. Echinodermata of the Ottawa formation of the Ottawa-St. Lawrence lowland. Canada, Mines and Geology Branch, Geol. Survey Bull. 4: 61 pp.
———. 1946a. Brachiopods. . . . Idem, 8: 149 pp.
———. 1947. Trilobita. . . . Idem, 9: 86 pp.
———. 1948. Miscellaneous classes of fossils, Ottawa formation, Ottawa-St. Lawrence valley. Idem, 11: 116 pp.
———. 1951. Gastropoda and Conularida of the Ottawa Formation of the Ottawa-St. Lawrence Lowland. Idem, 11: 149 pp.
Young, F. P., Jr. 1943. Black River Stratigraphy and Faunas. Amer. Jour. Sci., 241: 141–166, 209–240.