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Article abstract

The Saint-Nicolas Formation (Sillery Group) of the Chaudiere nappe in southern Quebec is a succession of shale and feldspathic sandstone that was deposited in a deep water channel-fan environment. This formation, formerly regarded as unfossiliferous, has now yielded the first confirmed specimens of the trace fossil Oldhamia in Quebec. Two ichnospecies are described, O. smithi Ruedemann and O. curvata Lindholm and Casey. The occurrence of the middle-upper Lower Cambrian brachiopod Boisfordia preliosa in the overlying Breakeyville Formation confirms that this occurrence of Oldhamia is Lower Cambrian.

Occurrence of the Cambrian trace fossil *Oldhamia* in southern Québec

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The Saint-Nicolas Formation (Sillery Group) of the Chaudière nappe in southern Québec is a succession of shale and feldspathic sandstone that was deposited in a deep water channel-fan environment. This formation, formerly regarded as unfossiliferous, has now yielded the first confirmed specimens of the trace fossil *Oldhamia* in Québec. Two ichnospecies are described, *O. smithi* Ruedemann and *O. curvata* Lindholm and Casey. The occurrence of the middle-upper Lower Cambrian brachiopod *Botsfordia pretiosa* in the overlying Breakeyville Formation confirms that this occurrence of *Oldhamia* is Lower Cambrian.

La Formation de Saint-Nicolas (Groupe de Sillery) de la nappe de Chaudière, dans le sud du Québec, est une succession de shale et de grès feldspathique qui fut déposée dans un environnement de chenal de cône sous-marin, en eau profonde. Cette formation, auparavant considérée comme non fossilifère, a maintenant fourni les premiers spécimens confirmés de la trace fossile *Oldhamia* au Québec. Deux espèces d'ichnofossiles sont décrites, *O. smithi* Ruedemann et *O. curvata* Lindholm and Casey. La présence du brachiopode *Botsfordia pretiosa* de la partie moyenne à supérieure du Cambrien inférieur dans la Formation de Breakeyville sus-jacente confirme que cette occurence de *Oldhamia* est du Cambrien inférieur.

[Traduit par la rédaction]

INTRODUCTION

Trace fossils are becoming increasingly important in Lower Cambrian biostratigraphy, particularly in siliciclastic successions where body fossils are typically rare. Trace fossils have proven useful in recognition of the Precambrian-Cambrian boundary (Narbonne *et al.*, 1987) and in biostratigraphic subdivision of the Lower Cambrian (Crimes, 1987, 1992; Narbonne *et al.*, 1987; Narbonne and Myrow, 1988). Units can be correlated using trace fossils that have a short time range, or the first occurrence of long-ranging trace fossils (Seilacher, 1974).

Most studies of Lower Cambrian trace fossils have concentrated on shallow-water deposits in which trace fossils are typically abundant and diverse. In contrast, Lower Cambrian deep-water deposits typically exhibit low diversity assemblages dominated by long-ranging taxa (Crimes, 1974, 1992; Seilacher, 1974), a situation compounded by the general scarcity of shelly fossils in these settings. As a consequence, deep-water successions of this age tend to be poorly constrained biostratigraphically.

The trace fossil *Oldhamia* is significant in being one of the few distinctive fossils commonly found in Lower Cambrian slope deposits. *Oldhamia*'s significance as a Cambrian index fossil has been recognized for more than a century (Kinahan, 1858; see also Crimes, 1976), although there are few definite age constraints. Known localities are in Maine (Smith, 1928; Ruedemann, 1942; Neuman, 1962), New York (Walcott, 1895; Ruedemann, 1942), Yukon (Hofmann and Cecile, 1981), Alaska (Churkin and Brabb, 1965), Ireland (Kinahan, 1858; Sollas, 1900; Crimes, 1976), Argentina (Aceñolaza and Durand, 1984), Newfoundland (Lindholm and Casey, 1989, 1990), and Morocco (El Hassani and Willefert, 1990).

Despite all of these occurrences, it is difficult to determine the precise age range of *Oldhamia* because it rarely occurs with other fossils and most commonly occurs in units that have been tectonically transported. In some instances, the age is constrained by shelly fossils in underlying or overlying units, but in many cases (e.g., Neuman, 1962) the age cannot be determined independently. The total possible range is from terminal Neoproterozoic to Ordovician (Neuman, 1962; Hofmann and Cecile, 1981) but the confirmed age range, determined by rare associations with shelly fossils, is Early to Middle Cambrian. With one possible exception from the Carolina Slate Belt (Seilacher and Pflüger, 1992) which does not resemble typical *Oldhamia*, specimens have never been reported in association with either definite Precambrian trace fossils (e.g., *Harlaniella*, *Palaeopascichnus*) or Ediacaran-type megafossils.

OCCURRENCE

Lapworth (1886, table A) first reported *Oldhamia* from what would now be regarded as the Sillery Group of the Chaudière nappe (Slivitsky and St-Julien, 1987), in the "Purple Shales of Farnham" southeast of Montreal. Walcott (1895) accepted Lapworth's observation, but neither Lapworth nor Walcott illustrated or described any specimens. To date no additional specimens have been collected from Farnham, and consequently, Lapworth's report of *Oldhamia* from Québec has been questioned (Hofmann and Cecile, 1981) or ignored (Lindholm and Casey, 1990) by most modern workers. The

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occurrence reported herein confirms that *Oldhamia* is present in southern Québec.

The occurrence of *Oldhamia* described in the present report is a large roadside outcrop on the south side of Route 132, approximately 0.5 km west of the town of Saint-Romuald (Fig. 1). A detailed location map and description of the outcrop can be found in Hesse and Ogunyomi (1982, Stop 7-3 on pp. 211-216). This prominent outcrop has been the subject of numerous petrological, geochemical and sedimentological studies (see references listed in Hesse and Ogunyomi, 1982, p. 214) and is featured in most recent guidebooks of the geology of the Québec City area, but this is the first report of fossils from this outcrop.

Oldhamia occurs abundantly in the lower part of the section (Fig. 2), in strata of the Saint-Nicolas Formation. Specimens were observed in virtually all beds of red shale, and also occur sparingly in the green shales.

General Geology

The Chaudière nappe is the oldest, highest, and farthest-travelled nappe of the Taconian orogenic belt (St-Julien and Hubert, 1975). It constitutes the Sillery Group (Slivitsky and St-Julien, 1987) which comprises (from oldest to youngest) the Sainte-Foy, Saint-Nicolas, and the Breakeyville formations (St-Julien and Osborne, 1973).

These three formations are shale-feldspathic sandstone assemblages that were deposited in deep water during the Early Cambrian (St-Julien and Hubert, 1975). The thickness of the entire Sillery Group is at least 1000 m, but the exact thicknesses of each of the three formations is unknown. The Sainte-Foy Formation is composed of thin-turbidites with red shale, and green and black shale. The youngest formation, the Breakeyville, comprises thin bedded turbidites, pebbly and massive sandstones, and conglomerates. The intervening Saint-Nicolas Formation, which contains the specimens of *Oldhamia* described in this paper, is discussed in further detail below.

Saint-Nicolas Formation

The Saint-Nicolas Formation is the middle formation of the Sillery Group and represents a transition between the underlying Sainte-Foy Formation and the overlying Breakeyville Formation. Lower parts of the Saint-Nicolas Formation comprise mainly green/black shales and thin turbidites similar to those of the underlying Sainte-Foy Formation. Uppermost strata of the Saint-Nicolas Formation are similar to those of the overlying Breakeyville Formation and comprise massive and pebbly sandstones, conglomerates, and thin-bedded turbidites with red/green shale. The middle of the Saint-Nicolas Formation contains a mixture of all of these lithofacies (Hesse and Ogunyomi, 1982).

The section at Saint-Romuald consists of interbedded green-grey sandstones and red/green shales (Fig. 2). Strata coarsen and thickens upwards; shale beds decrease in abundance and thickness until, at the top of the section, the unit is dominated by thick sandstone beds. Sandstone beds are graded and range from 15 cm near the base to more than 5 m at the top of the section. This section has been interpreted as the deposits of a prograding channel-fan complex (Hesse and Ogunyomi, 1982).

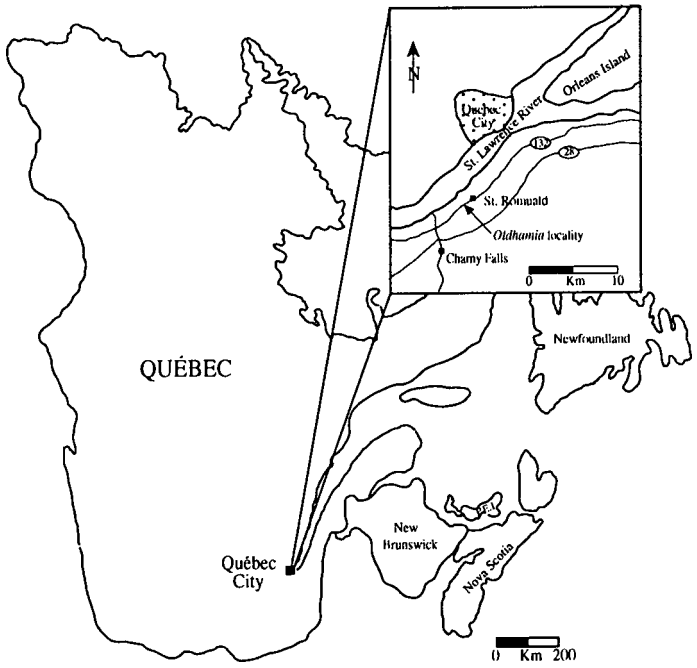

Fig. 1. Location of *Oldhamia* in Québec.

Age

Although the trace fossil *Oldhamia* is now known from the Saint-Nicolas Formation, to date, no shelly fossils have been recovered from this unit, a situation that is typical of most Lower Cambrian deep water deposits (Seilacher, 1974). Fortunately, the inarticulate brachiopod *Botsfordia pretiosa* (Billings, 1862) occurs in the shales of the overlying Breakeyville Formation at nearby Charny Falls (Fig. 1). Billings (1862) originally named these brachiopods *Obolella pretiosa*, but Ulrich and Cooper (1938) subsequently attributed this species to *Botsfordia* Matthew, 1891. Ulrich and Cooper argued that *Botsfordia pretiosa* is restricted to the Lower Cambrian.

This narrow age range seems to be typical of the genus *Botsfordia* in general. *Botsfordia* has a global distribution (Brasier, 1989) including China (Luo *et al.*, 1984), Greenland (Poulsen, 1932), England (Rushton, 1966), Norway (Ahlberg, 1983), Siberia (Brasier, 1989), and the Avalon Zone of eastern North America (Matthew, 1893). In all of these areas, *Botsfordia* is restricted to the Lower Cambrian. For example, in the Avalon Zone of North America, it ranges from the *Callavia broeggeri-Protolenus howleyi* Zone transition to near the top of the Lower Cambrian (E. Landing, personal communication, 1992). In southern China, *Botsfordia* occurs in bed 13 at Meishucun (Luo *et al.*, 1984), which Qian and Bengston (1989) regarded as Late Atdabanian-Botomian in age. In the Siberian Platform, *Botsfordia* ranges from the

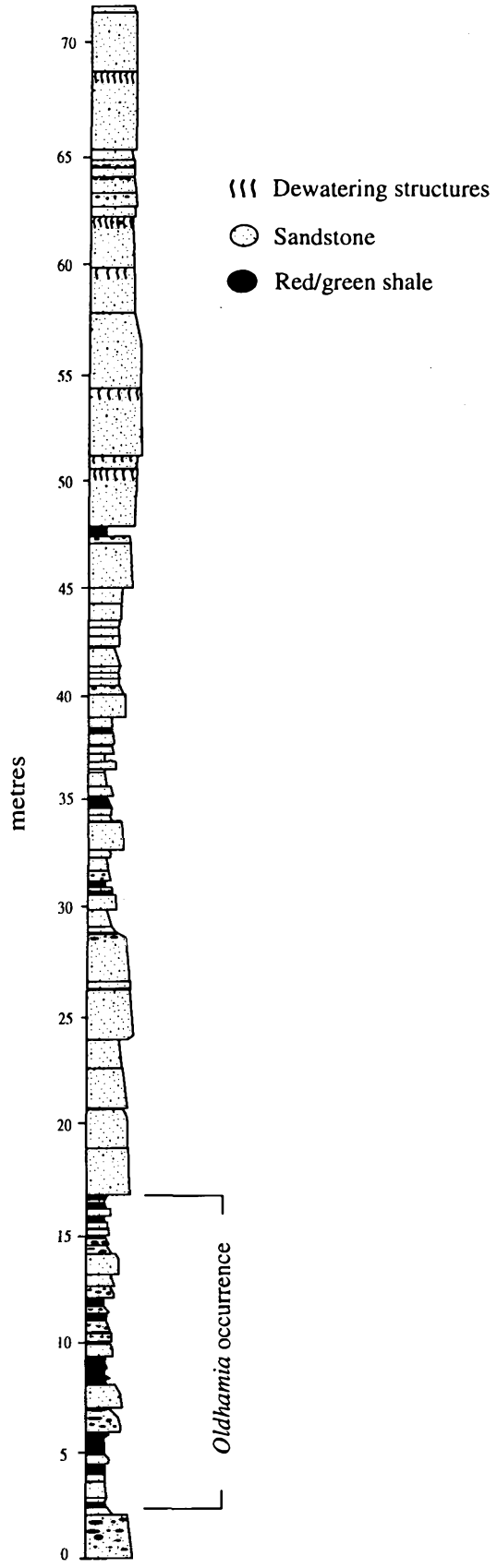

Fig. 2. Detailed stratigraphic column of the Saint-Nicolas Formation at Saint-Romuald, Québec (modified from Hesse and Ogunyomi, 1982), showing the local range of *Oldhamia*.

Fansycyathus lermontovae Zone to the *Lermontavia grandis* Zone, an interval that comprises the upper Atdabanian-middle Toyonian in terms of the Siberian stratigraphic nomenclature (Brasier, 1989); this is approximately equivalent to the uppermost *Nevadella* Zone to near the top of the *Bonnia-Olenellus* Zone in terms of the Lower Cambrian trilobite zonation of Laurentia.

Thus it can be seen that the genus *Botsfordia* has a narrow time range corresponding to the middle-late Early Cambrian. The occurrence of this brachiopod in the Breakeyville Formation provides an upper age limit to *Oldhamia* in the underlying Saint-Nicolas Formation. The lower age limit is not precisely constrained biostratigraphically, but it may be significant that neither Ediacaran-type body fossils nor definite Precambrian trace fossils have been found in the Saint-Nicolas Formation and older units in the Chaudière nappe. The apparent absence of any significant erosional break between the Saint-Nicolas and Breakeyville formations, and the fact that most of Early Cambrian time is represented by pre-trilobite strata (Landing, 1992) further suggests the *Oldhamia*-bearing strata of the Saint-Nicolas Formation are Lower Cambrian.

SYSTEMATIC PALEONTOLOGY

All figured specimens are reposited in the National Type Collection of Fossil Invertebrates and Plants at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8 (GSC) under the numbers listed.

Ichnogenus *Oldhamia* Forbes, 1849
Oldhamia smithi Ruedemann, 1942
Figure 3a

Material: 15 well-preserved specimens and innumerable fairly well-preserved specimens.

Description: Fan-shaped burrow systems comprising straight to slightly curved burrows that converge at a broad central area; burrows are unlined and unbranched. Central burrows are straight and peripheral burrows are straight to slightly curved. The burrow system does not exhibit bilateral symmetry, and the burrows themselves are not uniformly spaced. Individual burrows are 0.5 mm in diameter and vary in length from 15 mm to 30 mm. Burrows are typically preserved in positive hyporelief relief (and corresponding negative epirelief) but rarely occur as positive epireliefs.

Oldhamia curvata Lindholm and Casey, 1990
Figure 3b-d

Material: 6 well-preserved specimens.

Description: Fan-shaped burrow systems comprising subparallel, curved burrows that converge at a central area; burrows unlined and unbranched. The burrows are 0.5 mm in diameter and 20 to 30 mm (depending on the curvature) in

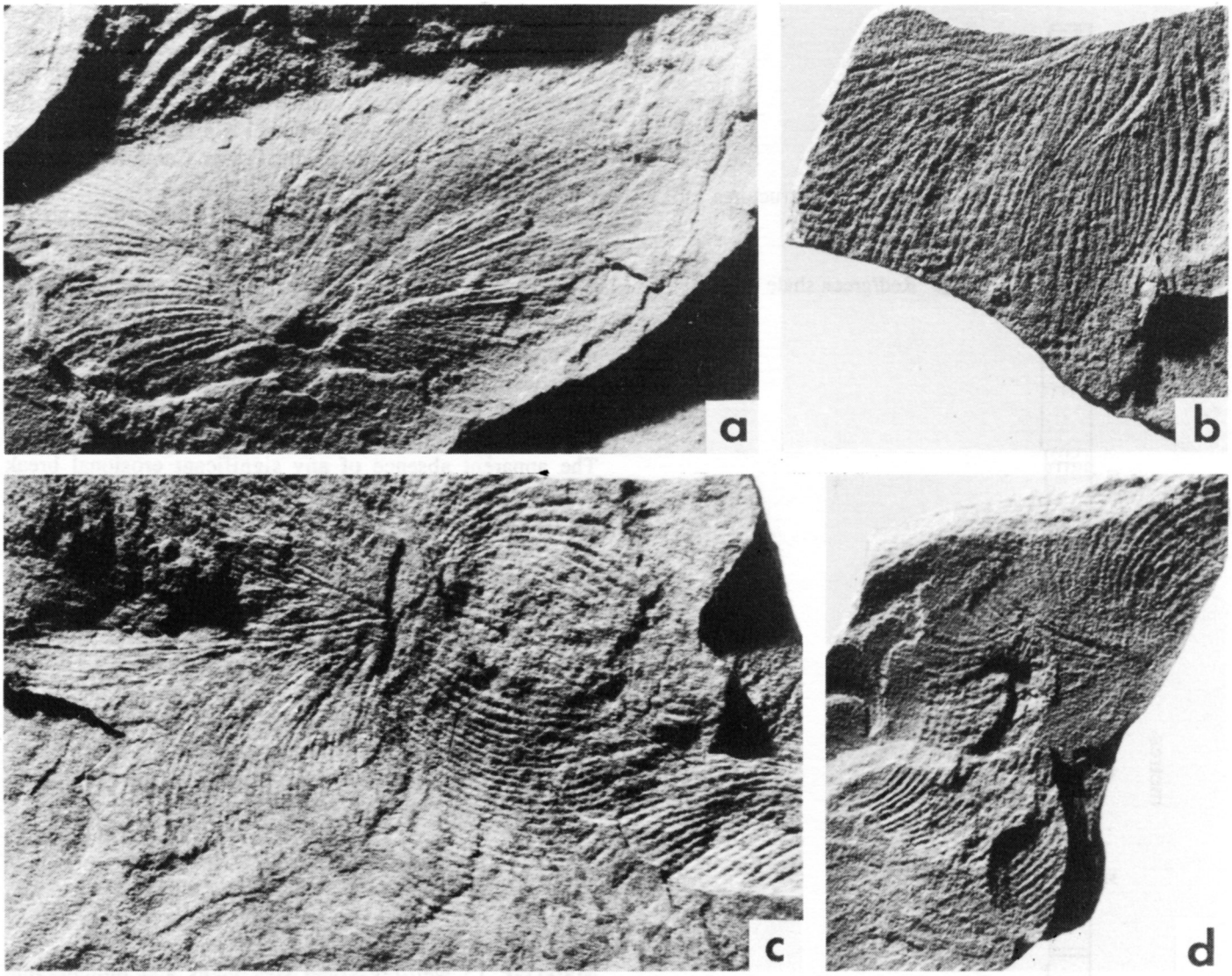

Fig. 3. *Oldhamia* from the Saint-Nicolas Formation at Saint-Romuald. All specimens x2. (a) *Oldhamia smithi* Ruedemann, GSC 106110. (b-d) *Oldhamia curvata* Lindholm and Casey, GSC 106111-106113.

length. The burrow systems exhibit bilateral symmetry and range in size up to 50 mm in length and 35 mm in width. The burrows exhibit a very complex pattern that is straight nearest the apex and curves and fans out towards the periphery. The direction of curvature changes one or more times. The burrows occur through several successive laminae (Fig. 3d).

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