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Abnormal forms of acritarchs (phytoplankton) in the upper Hirnantian (Upper Ordovician) of Anticosti Island, Canada

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ABSTRACT

A detailed study of Late Ordovician–early Silurian acritarchs (Palaeozoic phytoplankton) from Anticosti Island (Québec, Canada) revealed an unusually high abundance of abnormal forms from the upper Hirnantian carbonate strata (uppermost Ordovician) of the Ellis Bay Formation in the western part of the island (member 6, *Spinachitina taugourdeaui* chitinozoan Biozone). The objective of this paper is to describe these abnormal forms in detail. Two species are particularly affected: *Disparifusa psakadoria* Loeblich and Tappan, 1978 presents abnormally hypertrophied central vesicles, whereas *Peteinosphaeridium laframboise-pointense* nov. sp. has appendices that are fused along their length. The abnormal forms of acritarchs occur in rocks deposited during periods that are near time-equivalents to those of maximum ice-sheet extensions on Gondwana during the Hirnantian glaciation. Although this stratigraphic level corresponds to an interval of strong perturbations of the global carbon cycle, the exact factors causing the observed malformations remain unknown.

1. Introduction

The Ordovician–Silurian (O/S) transition represents the first of the 'Big Five' mass extinctions of marine invertebrates (e.g., Sheehan, 2001 and references therein), which followed the Great Ordovician Biodiversification Event (GOBE; Webby et al., 2004; Servais et al., 2008, 2009, 2010). It is now generally accepted that the end-Ordovician biotic crisis occurred concomitant to the glacial maximum (e.g., Destombes, 1968a, 1968b; Destombes et al., 1985; Loi et al., 2010 and references therein) of the Early Palaeozoic Icehouse (Page et al., 2007; Armstrong et al., 2009; Vandenbroucke et al., 2010a, 2010b and references therein) and coincides with large-scale perturbations in the carbon cycle (e.g., Munnecke et al., 2010 and references therein).

The Island of Anticosti, Québec, Canada, is an important locality for the study of the end-Ordovician extinction because of its rather continuous and richly fossiliferous sections spanning the O/S boundary. The study of these sections has already provided important insights into the biological and geological dynamics of this extinction event (e.g., Lespérance, 1981; Barnes, 1988; Desrochers et al., 2010).

It is particularly important to understand the evolution of the phytoplankton assemblages during the critical intervals of mass extinction of marine invertebrates, such as the Hirnantian glaciations. As primary producers, phytoplanktonic organisms play a fundamental role in regulating the global carbon cycle and food web equilibrium. In this context, a detailed study of the phytoplankton of the Late Ordovician–Silurian interval of Anticosti Island has been undertaken (Delabroye, 2010). A detailed description of the acritarch assemblages within a palaeoenvironmental and palaeoclimatological context will be presented in separate papers (e.g. Delabroye et al., 2011). In this paper we describe the teratological acritarchs recorded at specific stratigraphic levels of Ordovician–Silurian boundary sections of Anticosti, near the Hirnantian glacial maximum.

2. Geological setting

Upper Ordovician–lower Silurian strata of Anticosti Island (Gulf of Saint Lawrence River, Québec, Canada; Fig. 1) comprise the Vauréal, Ellis Bay and Becscie formations (Lespérance, 1981; Fig. 1). These sediments were deposited in a shallow-water outer carbonate ramp setting, but differences in facies can be recognised between stratigraphic sections located at the western and eastern ends of the Island (Petryk, 1981; Long and Copper, 1987; Desrochers et al., 2010). The western sections represent more offshore carbonate-dominated facies whereas eastern sections represent near-shore, mixed siliciclastic-carbonate facies.

In western Anticosti, the Ellis Bay Formation (Hirnantian; for more discussion about age interpretation, refer to Kaljo et al., 2008; Delabroye and Vecoli, 2010; Desrochers et al., 2010; Hints et al.,

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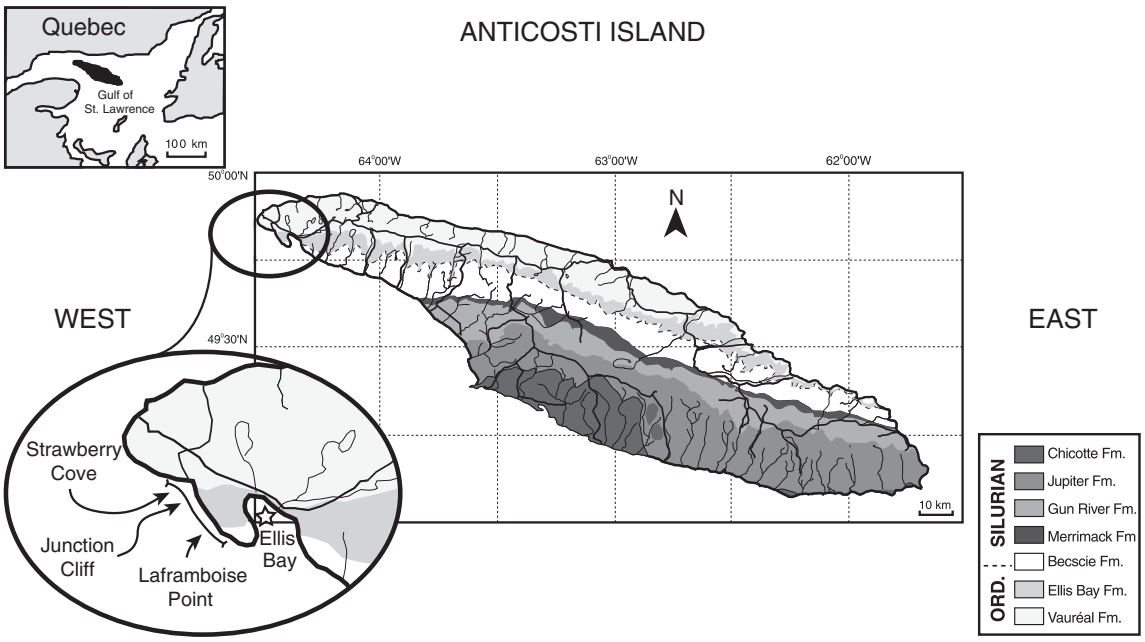

Fig. 1. Geological map of Anticosti Island showing formation outcrop pattern with geographic location of discussed sections magnified (geological map modified from Jin and Copper, 1999). Star symbol represents the location of the additional sample (EC 05) from the Ellis Bay analysed for its palynological content in order to understand the spatial distribution of levels recording high abundances of abnormal forms of acritarchs.

2010; Achab et al., 2011; Jones et al., 2011) is subdivided into seven informal members (Petryk, 1981; member 1 to member 7; Fig. 2). In eastern Anticosti, Long and Copper (1987) defined five formal members for the same formation (Grindstone, Velleda, Prinsta, Lousy Cove and Laframboise members). In this study, we use Petryk's (1981) lithostratigraphy for the western sections (Fig. 2 — for a full justification, see Delabroye, 2010; Desrochers et al., 2010; Achab et al., 2011). In the western area, Achab et al. (2011) identified the base of the *Belonechitina gamachiana* chitinozoan Biozone around the Vauréal-Ellis Bay transition, and the base of the overlying *Spinachitina taugourdeaui* Biozone in the upper member 6 (Fig. 2). Member 7 is almost devoid of palynomorphs. The base of the *Ancyrochitina ellisbayensis* Biozone, potentially indicative of the Ordovician–Silurian transition (Verniers and Vandenbroucke, 2006), lies in the basalmost part of the Bescsie Formation (Achab et al., 2011) (Fig. 2). Further stratigraphic control is provided by carbon isotope excursions representing the HICE (Hirnantian Isotopic Carbon Excursion) *sensu* Bergström et al. (2009), with two steps of increasing values (Delabroye and Vecoli, 2010; Desrochers et al., 2010; Achab et al., 2011; Delabroye et al., 2011) as observed in the Hirnantian GSSP area in China (Chen et al., 2006; see also Delabroye et al., 2010; Achab et al., 2011 for further comments on the "HICE morphology").

A recent palynological study analysed the phytoplankton dynamics during this period of palaeoenvironmental and palaeoclimatical perturbations (Delabroye, 2010). High abundances of abnormal forms of acritarchs – henceforth cited as "abnormal acritarchs" – were detected in the more offshore part of the Anticosti Basin. These acritarchs are described in detail below. The abnormal acritarchs occur on either sides of the lithologic boundary between the bioturbated limestones and the cross-bedded limestones in the upper member 6 of the Ellis Bay Formation, Western Anticosti (samples EB60 and EB63 in Fig. 2 + sample EC05; see below). These strata correspond respectively to Facies 3 and Facies 5 of Desrochers et al. (2010; Table 1, p. 254; Facies 3: "Mudstone/wackestone and calcareous shale"; Facies 5: "HCS–SCS sandstone to grainstone") indicative of a transition from a mid-ramp setting (offshore-transition zone) to an inner ramp setting (lower shoreface) influenced by storms and waves. At this lithologic boundary, a surface of forced regression is recognised (Desrochers et al., 2010). The member 6 corresponds to the end of the regressive systems tract of the fourth transgressive–regressive sequence – TR4 – defined by Desrochers et al. (2010) in the Ellis Bay Formation. Five TR sequences were defined in the Ellis Bay Formation. The TR4 sequence together with TR5 sequence (i.e., member 7) "define a time of large ice-sheet development" (Desrochers et al., 2010) corresponding to the second and most extensive Hirnantian glacial episode as described in Gondwana (e.g., Ghienne, 2003; Loi et al., 2010).

Interestingly, these levels of high abundance of abnormal acritarchs record intermediate and increasing $\delta^{13}C$ values of +2‰ just before the second and major positive peak of the HICE in member 7 (Fig. 2; Desrochers et al., 2010; Achab et al., 2011; Delabroye et al., 2011).

3. Material and methods

3.1. Sampling

In total, 364 rock samples were collected along outcrops and tidal flats in western Anticosti (Vauréal, Ellis Bay and Becscie formations; Strawberry Cove, Junction Cliff and Laframboise Point localities; Fig. 1) and in eastern Anticosti (Ellis Bay and Becscie formations; Table Head, Lousy Cove and Fox Point localities) for palynological and geochemical investigations in the frame of a PhD project (Delabroye, 2010). A majority of the samples were prepared for palynological studies (West: 77 samples; East: 47 samples; Fig. 2) and/or carbon isotopic analyses (West: 190 samples; East: 90 samples) (Delabroye, 2010; Delabroye et al., 2011; Fig. 2). Subsequently, one additional sample (EC 05) collected by Pr. André Desrochers (University of Ottawa) on the east coast of the Ellis Bay, east of the Laframboise Point (Fig. 1), was also prepared for palynological investigation. It comes from same stratigraphical levels (i.e., upper member 6, Facies 5 of Desrochers et al., 2010, cross-stratified grainstones under the oncolitic platform bed of member 7, *S. taugourdeaui* Biozone) as the samples that yield abnormal acritarchs at the Laframboise Point (i.e., EB 60 and EB 63). As Fig. 2 only depicts the samples