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A far-field record of the end Ordovician glaciation: The Ellis Bay Formation, Anticosti Island, Eastern Canada

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ABSTRACT

The end Ordovician was a critical period in Earth history. It was a time of global climatic change with large-scale continental glaciations. A wealth of recent work has documented the stratigraphical records from the near-field areas, i.e., from various Gondwanan continental relics where glaciation was more severely felt. There is an urgent need to re-examine the stratigraphic record from the far-field areas at greater levels of resolution than it has been hitherto possible in order to understand the timing, duration, and character at the glaciation centred around the Ordovician/Silurian (O/S) boundary. One of the best exposed and most complete stratigraphic records from paleotropical areas near the boundary is on Anticosti Island in eastern Canada. The east–west trending, ~200 km long Ellis Bay (Hirnantian) outcrop belt, with superb coastal exposures at both ends of Anticosti Island, is slightly oblique to the paleoshoreline with near-shore siliciclastic-dominated facies restricted to the eastern part of the island and more offshore carbonate-dominated facies present along the central and western parts. These mixed carbonate–siliciclastic facies accumulated along a storm-dominated beach-to-offshore profile. They are organized into a stacked set of shallowing-upward offshore to shoreline facies successions (typically coarsening upward) separated by deepening upward facies successions (typically fining upward) formed during intervening transgressions. High-frequency glacio-eustatic fluctuations were the dominant control on the development of TR sequences observed in the Ellis Bay succession of Anticosti Island, although tectonic subsidence had a substantial secondary effect on thickness. Five TR sequences are recognized allowing for precise correlation along the Ellis Bay outcrop belt. In the eastern sections, relatively thin TR sequences are locally bounded by unconformities. A typical sequence begins with thin transgressive limestone overlain by a maximum flooding, calcareous shale grading up into regressive, storm-influenced, proximal to transitional zone fine sandstone/grainstone and shale, which are sharply overlain by shoreface to foreshore sandstone/grainstone. In the central and western sections, the thicker TR sequences have more symmetrical transgressive–regressive components reflecting greater subsidence compensated by a higher carbonate sediment supply. Two discrete glacial periods are recognized during the deposition of the Hirnantian Ellis Bay succession with the younger one recording large sea level changes (>50 m in magnitude) caused by the development of very large ice sheets over western Gondwana. Abundant ice conditions on the globe during the end Ordovician, and the resulting high-amplitude eustasy, appear to have left distinctive stratigraphical imprints on mixed, paleotropical, siliciclastic–carbonate ramps.

1. Introduction

The end Ordovician was a critical period in Earth history. It was a time of global climatic change accompanied by large-scale continental glaciations. Moreover, the end Ordovician (Hirnantian) mass extinction, with the loss of about 85% of marine species, is recognized as the second most devastating mass extinction to have affected the Earth (Sheehan, 2001). Associated with this glacial interval and the mass extinction is a large positive carbon isotope ($\delta^{13}C$) excursion that represents a global perturbation of the carbon cycle (Brenchley et al., 2003). A wealth of recent data has documented the stratigraphic records from the near-field areas (Sutcliffe et al., 2000; Ghienne et al., 2007; Le Heron and Craig, 2008; Loi et al., 2010-this issue), including several Gondwanan continental relics where glaciation was most severely felt. Indirect proxies for climatic conditions derived from the stable carbon and oxygen isotope records of paleotropical marine carbonates are reasonably well known, but there is an urgent need to re-examine the stratigraphical record from the far-field areas at

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greater levels of resolution than has been previously possible in order to understand the timing, duration, and character of glaciation centred around the Ordovician/Silurian (O/S) boundary. One of the best exposed and most complete stratigraphic records from paleotropical areas near the boundary is on Anticosti Island in eastern Canada (Fig. 1). The Anticosti succession developed within a successor basin under the influence of syn- to post-Taconic load subsidence that experienced continuous sedimentation according to recent studies (Long and Copper, 1987a; Barnes, 1988; Copper, 2001; Long, 2007). This succession should provide a sensitive indicator of subtle eustatic and climatic changes through this time interval. The objectives of this paper are: i) to review briefly the storm-dominated mixed carbonate–siliciclastic facies present near the O/S boundary on Anticosti Island; ii) to describe and interpret the sequence stratigraphic architecture in which important erosion surfaces can be physically traced; and iii) to discuss major local and global controls on sequence development.

2. Methodology

This study examines the succession spanning the O/S boundary on Anticosti Island that includes the uppermost Vauréal, Ellis Bay and the basal Becscie formations. This succession will be simply referred to as the Ellis Bay succession in our text. The succession crops out along a ~200-km belt with excellent exposures at both ends and along major rivers in between (Fig. 1). We report here on two continuously outcropping sections, one extending from Anse aux Fraises to Pointe Laframboise at the western end, and one from Table Head to Fox Point at the eastern end, both of which have been sampled with a total of 225 thin sections. Stratigraphical nomenclature follows Petryk (1981) at the western end of the island and Long and Copper (1987a) at the eastern end; the latter was extended to the western end of Anticosti (Copper, 2001; Fig. 2). A complete Ellis Bay succession was also examined in the subsurface (NACP drillcore, locality 1 in Fig. 1). Age control for each of these sections is documented by chitinozoans (Achab, 1978; Achab et al., in press) and conodonts (Nowlan and Barnes, 1981; McCracken and Barnes, 1981). In addition to the biostratigraphic data, our correlations are constrained by the identification of unconformities and transgressive–regressive (TR) sequences (Embry, 2009). A subaerial unconformity, typically modified by shoreline scouring during the ensuing transgression, was used as a sequence boundary at the eastern basin margin. The sequence boundary extended basinward from the termination of the basin flank along the maximum regressive surface represents the conformable basinward portion of the transgressive surface. The TR

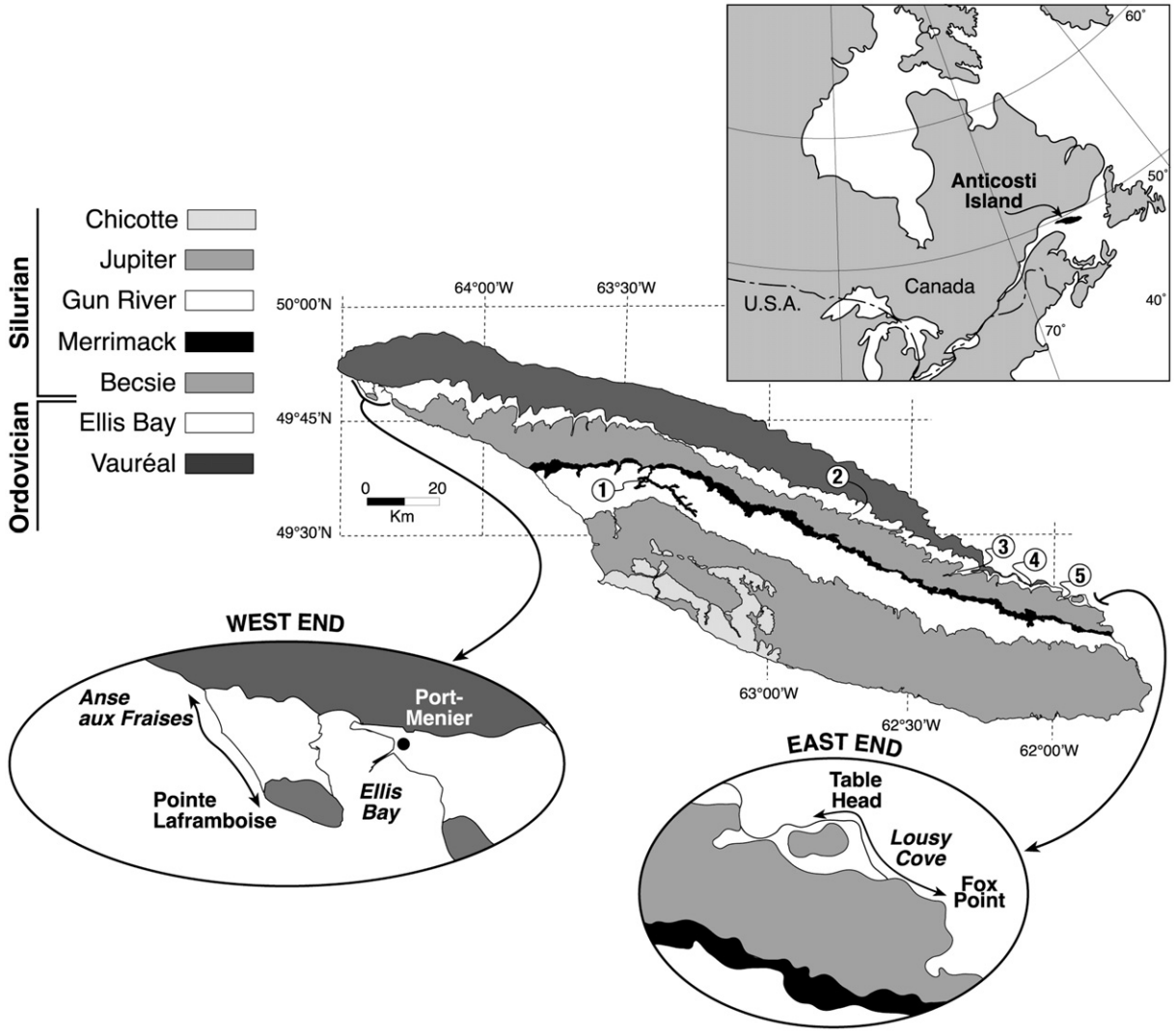

Fig. 1. Location of the study area (top right), general geological map of Anticosti Island (middle) based on Desrochers and Gauthier (2009), and more detailed maps at the western and eastern ends of the Ellis Bay outcrop belt (bottom). Other localities mentioned in the text include; 1) NACP drill core; 2) Vauréal River; 3) Salmon River; 4) Mill Bay; and 5) Prinsta Bay.