Paleoenvironmental and Paleoecological Reconstruction of the Chemahawin Member (Cedar Lake Formation; Silurian) at Lundar, Manitoba

by

D. Raegan Porter

A Thesis submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Paleoenvironmental and Paleoecological Reconstruction of the Chemahawin Member (Cedar Lake Formation; Silurian) at Lundar, Manitoba

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Abstract

A mid-Early Silurian stromatoporoid-dominated biostrome within the upper, Chemahawin Member of the Cedar Lake Formation (Interlake Group; Silurian) is exposed within a quarry near Lundar, Manitoba. This highly dolomitized structure, previously classified as a bioherm, displays little evidence of topographic relief, but the density of skeletons within the unit, and the complex interactions among fauna, justify classification as a biostrome.

Statistical tests were employed to assess the distributions of stromatoporoids and corals between localities in the quarry, and between stratigraphic intervals within localities, in order to recognize spatial and temporal trends within the biostrome. The faunal assemblage of the Chemahawin Member was analyzed in terms of abundance, species diversity and dominance, skeletal growth forms, and skeleton size. Within the Chemahawin biostrome, different microenvironments at various positions within the structure are interpreted from spatial variation in the distribution of fauna. Vertical trends in faunal distribution suggest short-term ecological succession as the biostrome transitioned from a pioneer community to a climax stage.

In the southwest corner of the quarry, closely spaced facies represent a gradual progradation of the biostrome over previously unsuitable muddy substrates. It is interpreted from directional measurements of elongate fossils that a prevailing paleocurrent originated from the northeast, and the southwest corner likely represents a protected, back-reef setting. Examination of a subsurface drill core from Lundar Quarry North revealed facies arrangements similar to those within the quarry. A second core from nearby Mulvihill West Quarry revealed correlative facies, although the interval

equivalent to the biostromal facies was not as well developed, indicating the limited lateral extent of the structure.

The Chemahawin Member represents a transgressive-regressive cycle, with reefal development at the time of maximum transgression, corresponding to the interval of geologic time when reefs were most widespread globally in the Silurian. Although large mid-Silurian reefs are common structures within other basins on the North American continent, reef development within the Williston Basin was limited and patchy, suggesting that conditions were less favourable for large-scale reef growth.

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Chapter 1: Introduction

1.1 Introduction and Objectives

The Silurian Period represents an interval of change and recovery, as colder global climates and a mass extinction event at the close of the Ordovician reduced marine diversity (Copper 2002). Ameliorating temperatures and rising sea levels allowed for the gradual expansion of reef-building in near-equatorial settings by the late Early Silurian (Copper 2002). Relatively low diversity assemblages of stromatoporoids, corals, and coralline algae constructed the majority of such reefs in the absence of predators within intracratonic basins and epeiric seas (Copper 2002). Though many ancient basins in North America accommodated significant reef development during the mid-Early Silurian, little evidence has been found within the centrally located Williston Basin for such accumulations of fauna (Figure 1.1). Along the northern flanks of the basin in southern Manitoba, however, an inactive quarry near the town of Lundar provides a rare exposure of an extremely fossiliferous unit identified in previous literature as a reef (Figure 1.2). The Chemahawin Member (Cedar Lake Formation; Interlake Group), exposed in the Lundar Quarry, is the youngest Silurian unit preserved in southern Manitoba (Figure 1.3; Stearn 1956). The Devonian erosional unconformity lies only a few kilometres west of Lundar (see Figure 1.2 for proximity of Devonian unconformity to Lundar Quarry). This unit provides a unique opportunity to examine the reef fauna of a mid-Early Silurian buildup within the Williston Basin, during the most extensive reef-building episode in the Silurian (Johnson et al. 1998).

The primary objective of this study is to describe in detail the exposed portion of the Chemahawin Member within the Lundar Quarry in order to reconstruct the paleoecologic and paleoenvironmental conditions which existed at this location during the

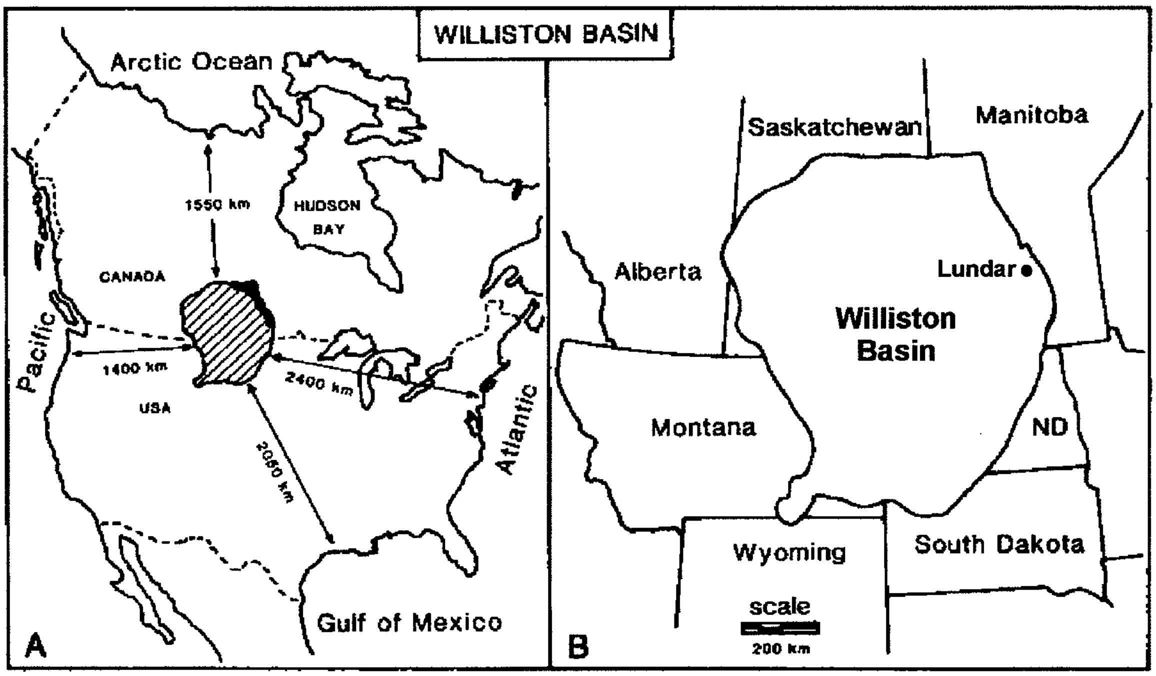

Figure 1.1: Location of the Williston Basin relative to southern Manitoba (modified from Johnson and Lescinsky 1986). A) Mid-continental position of Williston Basin (shaded, with outcrop belt in black). B) Geographic location of Williston Basin relative to Canadian provinces and U.S. states. The approximate location of Lundar is indicated within the Basin.

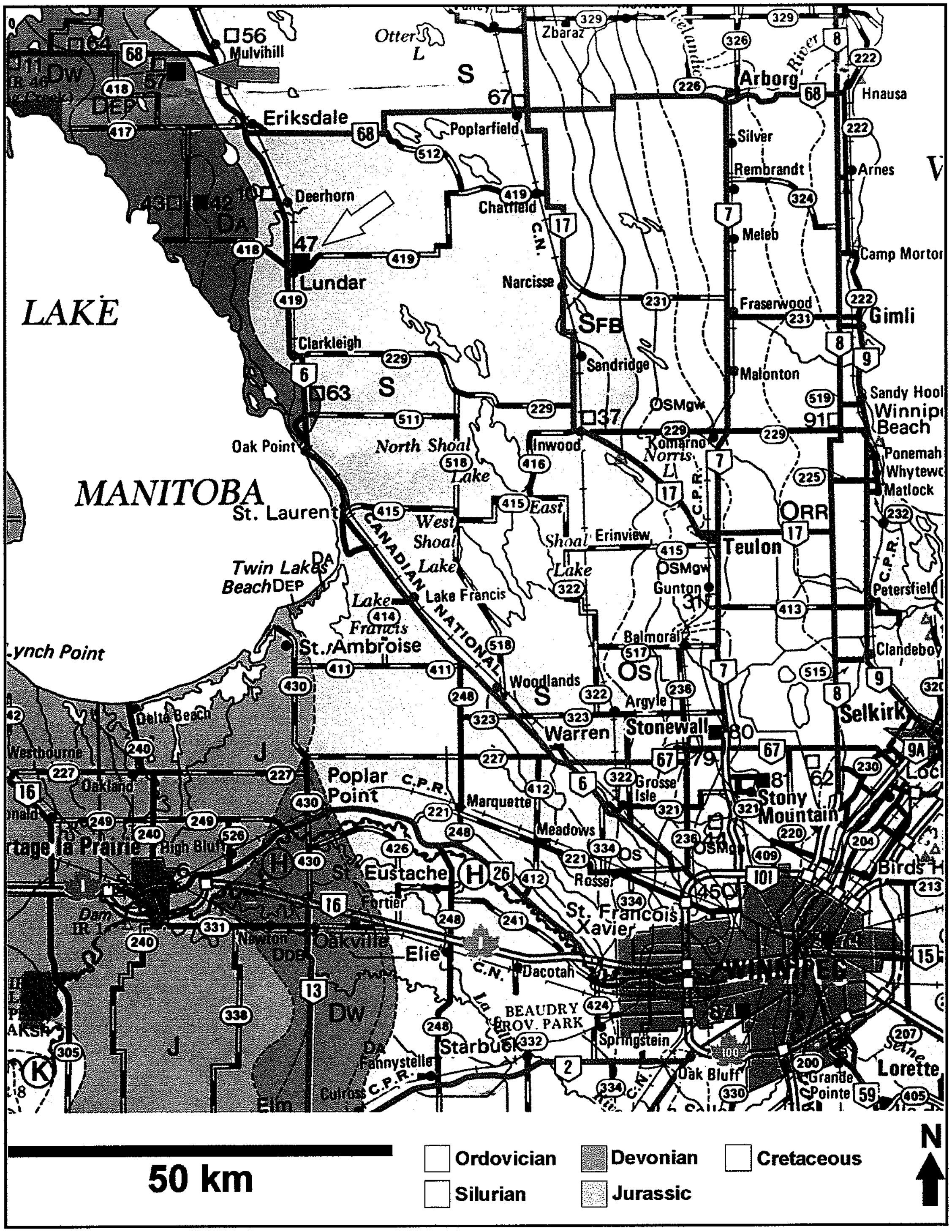

Figure 1.2: Map of Winnipeg and surrounding area (modified from Corkery 1987). Location of Lundar Quarry (number 47) is indicated by yellow arrow. Drill cores were examined from Lundar Quarry North, and Mulvihill West Quarry (number 57), which is indicated by a green arrow.

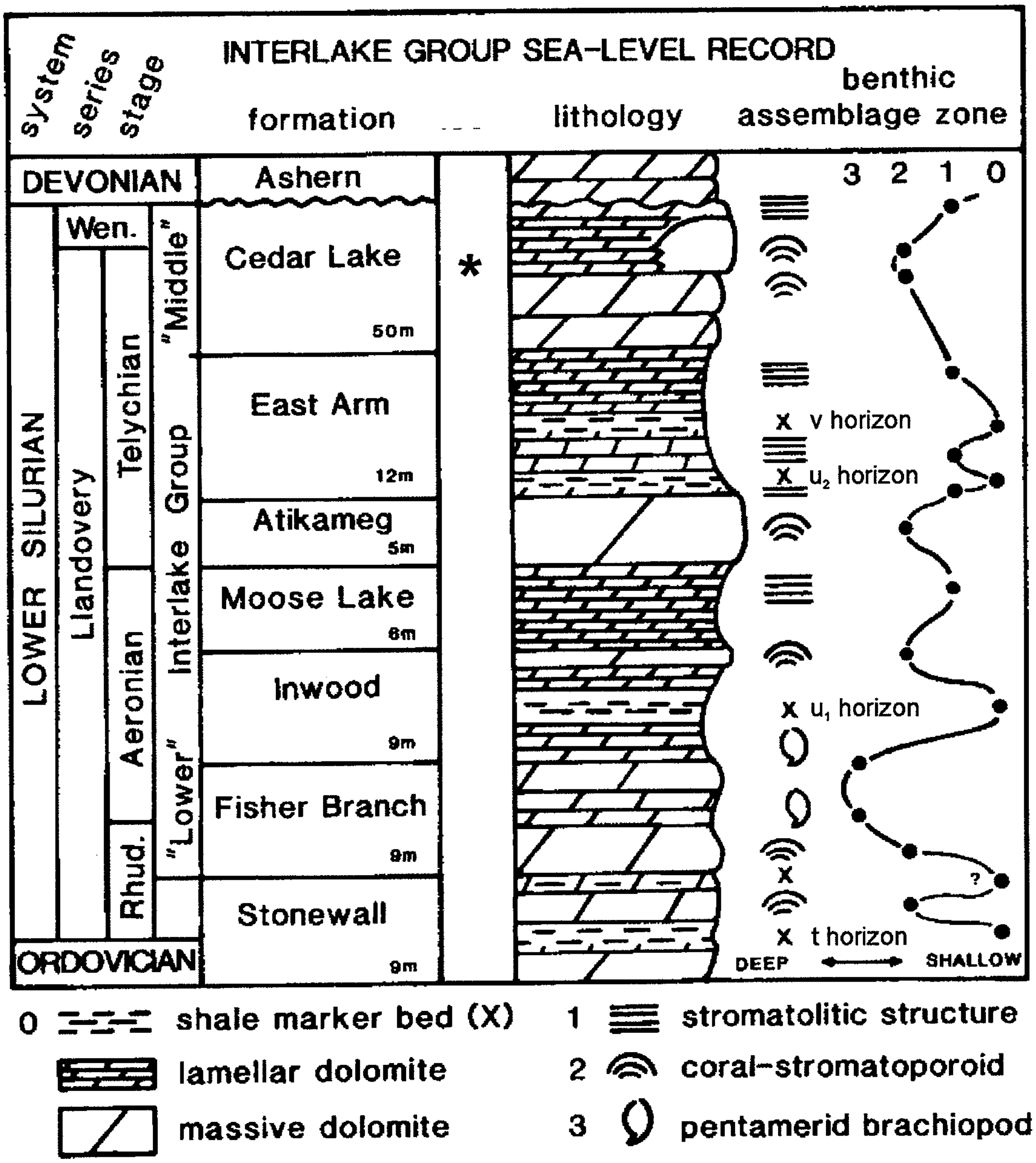

Figure 1.3: Stratigraphic section and sea-level curve for the Silurian Interlake Group of Manitoba (modified from Johnson and Lescinsky 1986, Figure 6). Rhud. = Rhuddanian; Wen. = Wenlock; * = position of Lundar Quarry locality.

mid-Early Silurian. Although structures within the Chemahawin Member have previously been identified as biohermal and biostromal, there is a lack of detailed documentation or analyses of the facies and faunal distributions within the unit. Proper identification of ancient reefs should include detailed examination and comparisons of the fauna that comprises the reef in order to understand the paleoecology of the buildup. Examination of the relationships between fauna may also provide evidence for ecological succession within the unit. Identification of distinct suites of fauna at different positions within the buildup may also aid in the recognition of paleoecological succession within the structure. As well, quantitative measurements of the relative abundances of taxa and their growth forms, and directional orientations, may provide insight into the paleoenvironmental conditions which prevailed prior to burial. Additionally, spatial trends in faunal distributions within the quarry may provide evidence for differential microenvironmental positions within the reef structure. Consideration of facies distributions within this unit may aid in the reconstruction of the depositional environments present at this location. Examination of subsurface drill cores may also assist in understanding the lateral extent of features observed within the Lundar Quarry, and aid in the correlation of facies within the Interlake area of Manitoba. Statistical methods are employed in order to compare the relative abundances of taxa and growth forms among different sites within the quarry, and at successive vertical intervals, in order to recognize paleoecological trends.

1.2 Previous Work

Tyrrell (1892) was the first geoscientist to generate an in-depth study of the physical geography and geology of southern Manitoba and Saskatchewan. In his study, Tyrrell noted "…eight to ten feet of horizontally bedded dolomite outcrops…" near the Hudson's Bay Co. trading post of Chemahawin on the Saskatchewan River, just west of Cedar Lake in central western Manitoba (N.B. this exposure has since been flooded by the development of the Grand Rapids Hydroelectric Dam on the Saskatchewan River). After closer examination, Tyrrell recognized the presence of several genera of tabulate corals, as well as one genus each of brachiopods, cephalopods, and ostracodes. The fossils collected by Tyrrell were further studied by Whiteaves (1906), who described many new species in his detailed paleontologic study of Paleozoic fossils, including many of those found within the Lundar Quarry. Baillie (1951) was the first geoscientist to name the Interlake Group of Manitoba, in which he included the Stonewall Formation as the lowest unit of this group. Stearn (1956) produced the most comprehensive and detailed stratigraphic and paleontologic study to date of the Interlake Group and Stonewall Formation, which he separated from the group. In his study, Stearn subdivided the Interlake Group into formations, including the Cedar Lake Formation and the members found within it; these terms are still used at present. As well, he presented detailed descriptions for each member, and systematic paleontology of the fauna of each unit. Stearn was the first to recognize both biohermal and biostromal components within the Cedar Lake Formation based on quarry and outcrop exposures in the Interlake area of Manitoba.

Detailed studies of the Paleozoic rocks of the Williston Basin by Porter and Fuller (1959) and Andrichuk (1959) include important subsurface data. Porter and Fuller (1959) also recognized the presence of an argillaceous marker interval dividing the Stonewall Formation, which was later identified as two successive horizons by Kendall (1976). Brindle (1960) was the first to hypothesize that the most likely position of the

Ordovician-Silurian boundary is at the t marker bed of Porter and Fuller (1959). Recent conodont biostratigraphy, however, more accurately placed the Ordovician-Silurian boundary to coincide with the upper t marker horizon (Norford et al. 1998). King (1964) recognized another argillaceous horizon within the Interlake Group, the u_2 marker bed, at the base of the East Arm Formation. Roehl (1967) compared the cyclic occurrence of carbonates within the Williston Basin to recent Bahamian deposits to generate a depositional facies model. Cowan (1971) furthered the work of Stearn (1956) by providing additional descriptions of the subsurface geology of the Interlake area. The work by Johnson and Lescinsky (1986) was pivotal to the discussion of the depositional dynamics of the Interlake Group. Their hypotheses regarding the predicted sea level fluctuations that produced the cyclic carbonates within the Williston Basin are still generally accepted today.

Chapter 2: Reef Definition

As both bioherms and biostromes have been previously identified within the Chemahawin Member, it is important to consider these terms for proper classification of the reef structure present within the Lundar Quarry. The term 'reef' is one of the most ambiguous words in geologic literature, and there is no general consensus for a reliable and concise definition. Modern analogues of ancient reef systems are not always of use, as we cannot assume that conditions affecting modern reefs are necessarily the same as those that affected a completely different community of organisms many millions of years ago. A proper definition of 'reef' should include both ecological and sedimentological concepts, as well as some reference to structure. Previous reef workers have developed criteria common to a broad range of reef structures based on similar attributes (e.g., Cumings 1932; Heckel 1974; Kershaw 1994; Riding 2002). Some criteria, however, include physical or inherent attributes which may or may not be applicable to all structures, or are vague in definition, such as a wave-resistant network (e.g., Lowenstam 1950), presence of a rigid framework (e.g., Rosen 1990) and open space within the structure (e.g., Wood 1999), presence of macro-organisms (e.g., Rosen 1990), capability of influencing local environmental conditions as a result of topographic relief (e.g., Braithwaite 1973), and a binding component (e.g., Riding 2002).

It may be more useful to develop a new definition for reefs based on a selection of previously proposed criteria that are applicable to a broader range of reef structures. In general terms, a fossilized reef should be defined as an accumulation of predominantly organic components that possesses some element of relief, and is distinctly different from the surrounding rock. Such a structure would have inherently influenced the surrounding environment to some degree, and possessed enough rigidity to withstand the hydrodynamic conditions of its environment for prolonged periods of time. Rapid cementation or encrustation by secondary organisms can provide a reef structure with additional support, and so is often considered as crucial to reef development (Riding 2002). However, cementation or encrustation is unnecessary to provide support; if reefs can be composed of adjacent organisms not in contact, or of soft-bodied organisms that lack a framework, then binding by sedimentary or biologic means should not be included as essential reef criteria (Riegl and Piller 1999; Riding 2002). Additionally, densely packed, randomly oriented fossils may suggest the development of some degree of structural rigidity due to the juxtaposition of fossils, regardless of cementation (Kershaw 1998). A reef may contain reef-derived sediment or debris within the structure, as well as external sediment incorporated into the structure by binding, baffling, or settling through the structure, which can also provide support. A lack of binding agents, however, likely hinders vertical development above the surrounding seafloor. Once a deposit is matched with these criteria, it is important to consider the reef as either biohermal or biostromal in nature.

The terms 'bioherm' and 'biostrome' were formally defined by Cumings (1932), though the criteria that characterize each structure have since been modified from the original proposed definitions. Bioherms have classically been described as mound-like or lens-like organic masses, with different sediments flanking on and draping over the structure, thus implying relief (Figure 2.1; Kershaw 1994; Riding 2002). Bioherms are typically not conformable with the beds above and/or below, and often exhibit inclined flank beds that commonly contain reef rubble (Figure 2.1; Kershaw 1994). Conversely, biostromes are considered to be biogenically constructed, often tabular or lenticular