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The imprint of time on Canadian soil landscapes

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ABSTRACT

The imprint of time on Canadian soil landscapes reflects the strong influence of repeated Quaternary glaciations, with most soils having formed on Late Pleistocene glacial sediments, and to a lesser extent, Holocene non-glacial sediments. Soil chronosequences in these youthful landscapes seldom span the full Holocene, and have been documented principally in areas of coastal isostatic uplift and shoreline evolution, as well as on recessional moraine sequences in the Cordillera. These chronosequences have placed quantitative constraints on rates of podzolization in environments ranging from coastal temperate rainforest to subarctic. Longer sequences, involving soils and relict paleosols on Pleistocene morainal and glaciofluvial surfaces in the central Yukon Territory, record more complex legacies of pedogenesis and landscape evolution, but with much coarser time control and many potentially confounding influences of climatic change and disturbance processes. Older weathered bedrock and regolith can make significant contributions to soil parent materials in several settings: (1) in favoured locations where local conditions protected these materials from glacial erosion in southern Canada, (2) beyond the maximum limits of glaciation, principally in northwestern Canada, and (3) in the Arctic, where cold-based, non-erosive ice allowed preservation of these materials. Closer collaborations between pedologists and other Quaternary scientists will be needed to ensure a more complete understanding of these complex pedogenic legacies in Canadian landscapes.

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1. Introduction

Although Canada's vast landmass is underlain by rocks representing almost the full span of geological history (Eyles and Miall, 2007), Canadian pedologists are accustomed to viewing their soil landscapes as being quite youthful. The role of Quaternary glaciations in creating these landscapes, by removing older soils and regolith and depositing new soil parent materials, is clearly a preeminent one: "Nearly all Canadian soils are extremely young, forming within the last 10 thousand years on deposits laid down within the last 20 thousand years. Weathering and alteration of their constituents have not progressed far" (Valentine et al., 1987). This generalization is complemented by the stratigraphic record created by the Laurentide Ice Sheet in the adjacent central United States. Temporal trends in the geochemical and mineralogical properties of late Pliocene and Pliocene tills are consistent with progressive removal of older, more highly weathered regolith, with the youngest deposits mirroring the composition of fresh, unweathered rocks of the Canadian Shield (Roy et al., 2004).

Given this history, reading the imprint of time on Canadian soil landscapes with the objective of quantifying rates of pedogenic processes would appear to be a fairly simple task, largely confined to identifying arrays of sites suitable for classical chronosequence studies which would seldom extend beyond the Holocene. Indeed, this review will demonstrate that many of the Canadian pedological studies that explicitly address the temporal dimension of soil formation reinforce this image of a youthful landscape. Yet it will also be seen that some Canadian soil landscapes do contain legacies of much earlier times, although this imprint may be difficult to discern, and its chronology remains uncertain. But advances in dating methods and in understanding of ice sheet behaviour hold out considerable promise for recognition of a more complex history of soil formation recorded in Canadian landscapes.

This review will address the pedological record preserved on current land surfaces. Although there is a rich legacy of Quaternary (and older) buried paleosols in the Canadian stratigraphic record, this is beyond the scope of this paper, and has been adequately addressed elsewhere (Valentine et al., 1987; Tarnocai and Valentine, 1989; Tarnocai, 1997); indeed, there has been only limited progress in that aspect of paleopedology since those earlier reviews. And although organic soils are a significant component of

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the global carbon cycle, and of Canadian landscapes, they are sufficiently distinctive in their properties and environmental controls that their history merits separate treatment (e.g. Gorham et al., 2012).

We will first consider traditional chronosequence studies, which have involved predominantly coastal, Cordilleran, and Arctic settings, then examine the more complex pedological record on glacial surfaces at the northwestern margins of the Cordilleran Ice Sheet. Although of limited extent from a national perspective, some areas on the margins of both the Laurentide and Cordilleran ice sheets completely escaped all of the Quaternary glaciations. In such cases, weathered residual materials can be regionally significant soil parent materials, yet understanding of their history and influence on pedogenesis remains limited. Under favourable circumstances, localized survival of preglacial saprolites has also been demonstrated at several localities well within the margins of the Laurentide Ice Sheet, especially in southeastern Canada. As with the study of soils in unglaciated areas, quantitative understanding of the age and origins of these soil parent materials will require application of new methods. Finally, we will consider the pedological implications of newer concepts of ice sheet thermal regimes as a control of glacial erosion and preservation of older landscape elements, including regolith and soils, particularly in the Arctic.

2. Soil chronosequences in Canadian landscapes

Despite the oft-cited limitations of chronosequences, such as the difficulty of meeting requirements for uniformity of parent

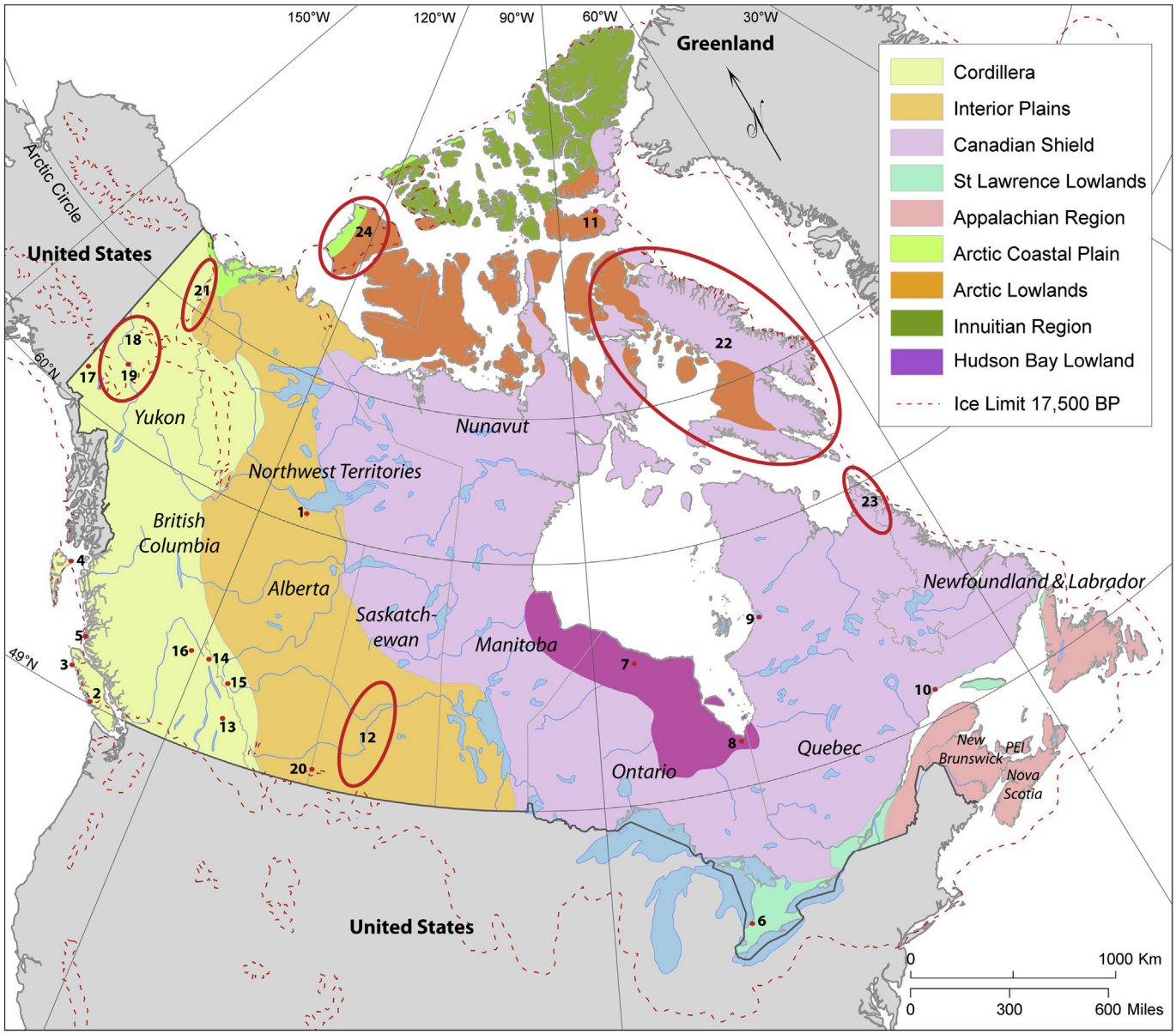

Fig. 1. Physiographic regions of Canada, adapted from Bostock (2014) with 17,500 BP glacial limits after Dyke et al. (2003) and provincial/territorial boundaries (PEI = Prince Edward Island), indicating locations mentioned in the text (ellipses enclose regions with multiple study sites): 1 – Hay River, 2 – Cox Bay, Vancouver Island, 3 – Brooks Peninsula, Vancouver Island, 4 – Naikoon Provincial Park, Haida Gwaii, 5 – Calvert Island, 6 – Pinery Provincial Park, 7 – Hudson Bay beach ridges, 8 – James Bay beach ridges, 9 – Lake Guillaume-Delisle, 10 – Sept Iles, 11 – Devon Island, 12 – southern and central Saskatchewan, 13 – Bugaboo Glacier, 14 – Robson Glacier, 15 – Athabasca Glacier, 16 – Castle Creek Glacier, 17 – Klutlan Glacier, 18 – west-central Yukon, 19 – Fort Selkirk volcanic field, 20 – Cypress Hills, 21 – Richardson Mountains, 22 – Baffin Island, 23 – Torngat Mountains, 24 – Banks Island.

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