

Sedimentology, Stratigraphy, and Petrography of Southwest Ontario's Basal Cambrian Sandstone (Mount Simon/Potsdam): A Potential Carbon Capture and Storage Repository

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Introduction

This study investigates the sedimentology and stratigraphy of Cambrian sandstones in southwestern Ontario for the purpose of carbon capture and storage (CCS). Despite over 100 years of oil and gas exploration, little is known about their sedimentology and stratigraphy. Recent work by Hart (2024a, b) has shown that these rocks are the most likely target for storage of industrially produced CO₂. A basal sandstone-dominated unit unconformably overlies Precambrian basement. Because of the current antiquated stratigraphic terminology, this unit is assigned to the Mount Simon Formation in the western part of our study area and the Potsdam Formation in the east (Fig. 1A). To simplify our analyses, we refer to this unit as the basal Cambrian sandstone (BCS). Sandstones of the BCS are characterized by high permeability and porosity, lay at sufficient depth to store CO₂ in a supercritical state (> 800m), and are capped by extensive tight limestones and shales (up to 500 m thick) that can act as a top seal (Armstrong & Carter, 2010; Hart 2024a, b). Tight dolomites are interbedded with the sandstones in the BCS at various scales but constitute less than half that unit's thickness.

Well control is not evenly distributed throughout the study area, the north shore of Lake Erie, that is best suited for CCS. Parts of that area, several hundred square kilometers in extent, are undrilled (Fig. 1B). Our primary goal has been to define predictive depositional models that can be used to guide exploration (selection of pilot-well locations) in areas that lack well control. We also seek to define lithologic variability (stratigraphic and geographic) because mineralogy will affect fluid-rock interactions if/when CCS operations begin (e.g., Rosenqvist et al., 2019). In addition to its importance for fluid-rock interactions, mineralogy is also an important control on petrophysical responses.

Method

The study area lies along the southern margin of the Algonquin Arch (Armstrong & Carter 2010; Fig. 1). We focus on the stratigraphy, sedimentology and mineralogy of the BCS through the analysis of 4 cored and 80 wire-line logged wells, utilizing energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), and petrographic thin section scans. Sample EDS images are shown in Figure 2. Our sedimentologic analyses, including ichnology, helped us define the depositional environments that control stratigraphic continuity. Sample core photos are shown in Figure 3.

Results

The BCS is composed of sandstones, dolomitic sandstones, sandy dolomites, and dolomites being interbedded at various scales. The detrital component consists almost exclusively of quartz and potassium feldspar (orthoclase and microcline). Dolomite, and to a lesser extent quartz and feldspar, is a pore-filling cements.

The sedimentology indicates that the BCS was deposited in a mixed clastic-carbonate, shallow-marine environment. Sandstones are generally fine- to medium grained, and grains range from well-rounded to angular. Sedimentary structures in the sandstones include cross bedding, ripple laminations, laminations and various burrows that include *Skolithos*, *Conichnus*, and other shallow-marine indicators (Pemberton et al., 2011)..

By tying our core descriptions to logs, and by making links between mineralogy and log response, we mapped the distribution of the BCS by building a grid of stratigraphic cross sections (Fig. 4). Our mapping shows the BCS wraps around, thins, and is truncated over the Algonquin Arch (Fig. 1B). Superimposed thickness variations probably show paleo-topography on the underlying Precambrian surface, but those variations are difficult to accurately define with our relatively widely spaced well control and without seismic data.

Ongoing Work

This project is the first detailed sedimentologic and petrographic study of the BCS (combined Mount Simon and Potsdam formations) in southwestern Ontario. We continue our core- and log-based work to more precisely define depositional environments for the BCS. Our petrographic analyses are helping define sediment provenance and mineralogic/lithologic variability. Collectively, and when integrated with separate studies of pore networks in the BCS, this work will allow us to better predict lithologic, petrophysical, and thickness variations, and therefore be of use for flow modeling, in the large portions of southern Ontario that lack well control.

Acknowledgements

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References

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Figures

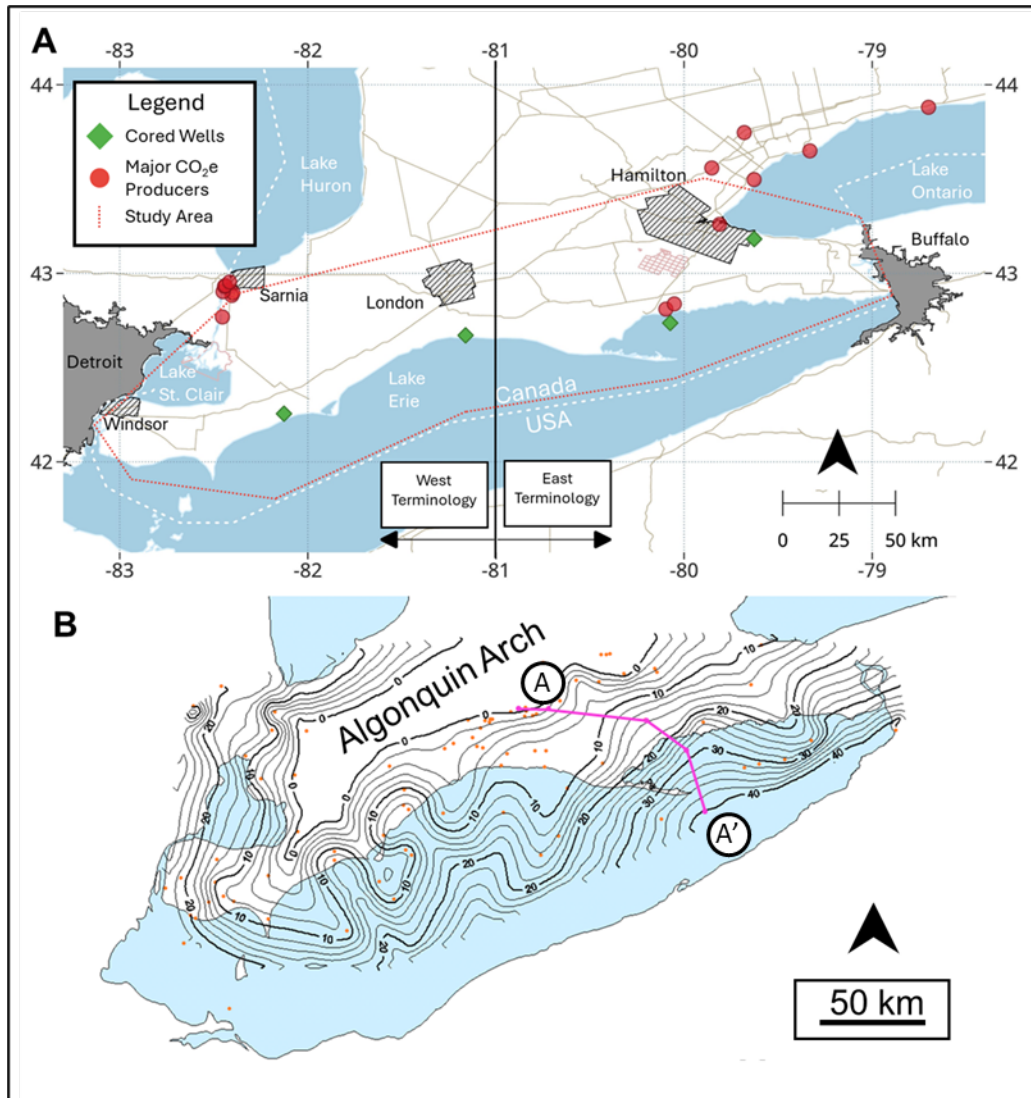


Fig. 1. (A) Map of southwestern Ontario, highlighting the study area and the four cored wells used in this paper. Existing stratigraphic terminology assigns the basal Cambrian sandstone (BCS) to the Mount Simon Fm west of the 81st meridian to the Potsdam Fm east of that line. (B) Isopach map (meters) of the basal Cambrian sandstone (BCS). Orange dots show well control used for mapping. Line A-A' shows the location of the cross section presented in Figure 4.

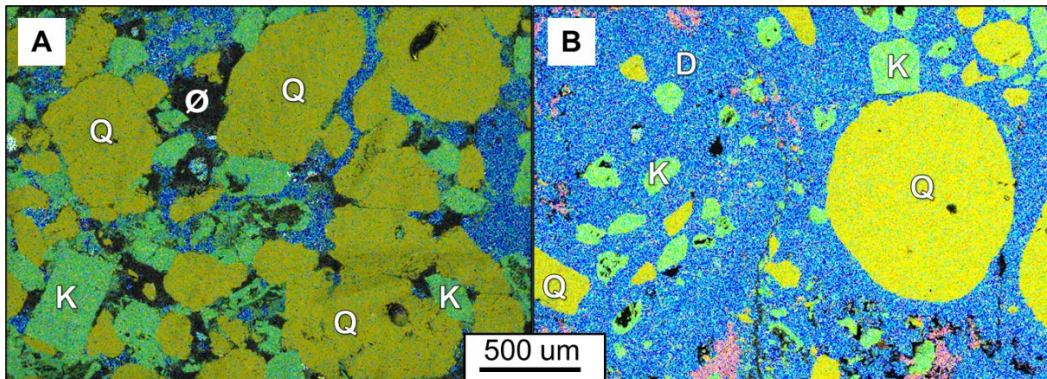


Fig. 2. (A) EDX image showing typical mineralogy of BCS sandstones. Quartz (Q; yellow) and potassium feldspar (K; green) are the dominant detrital components Dolomite cement (D; blue) partially fills porosity (ϕ) in this sample. This mineralogy is typical of the BCS. (B) EDX image showing the more Dolomite (blue) dominated sections of the BCS.

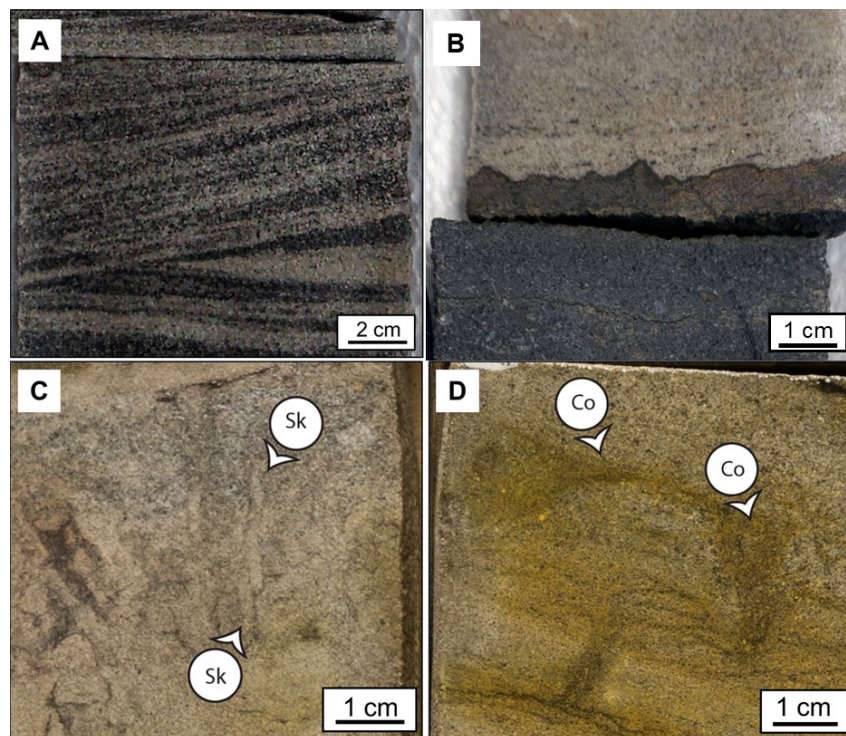


Fig. 3. (A) Cross-bedded dolomitic sandstone (light grey). (B) Stylolitized contact between sandstone (above) and dolomite (below). (C) *Skolithos* (Sk) burrows are sand filled, and the walls have dolomite cement. (D) *Conichnus* (Co). Parts A and B from core T012159. Parts B and C from core T007700

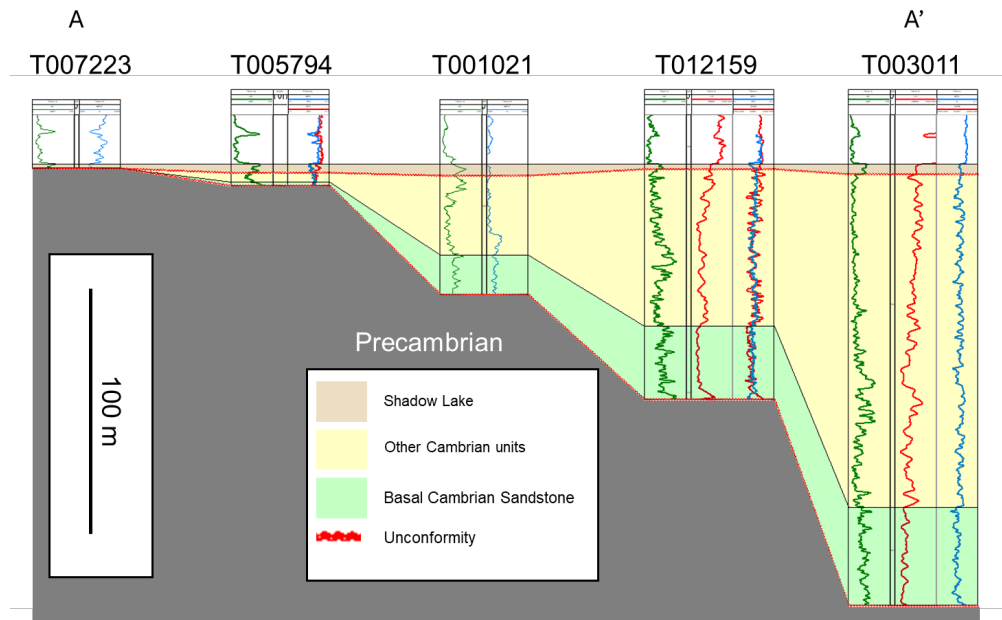


Fig. 4. Sample stratigraphic cross section. The BCS (green) progressively thins from its thickest point in the center of Lake Erie (right side) towards the Algonquin arch (left). See Hart (2024a,b) for broader description of the Cambrian stratigraphy in this area. Logs include gamma ray in Track 1 (green) and resistivity (where available) in Track 2. Other logs (Track 2 or 3 depending on availability of resistivity logs) include density and neutron porosity (red, dark blue) and neutron logs (light blue). Cross-section location shown in Fig. 1A.