Stratigraphy, sedimentology, and ichnology of the middle Cambrian to Lower Ordovician deposits in subsurface Western Canada

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Summary

During the past decade, the economic importance of the preserved Cambrian-Ordovician succession in subsurface Alberta and Saskatchewan has increased considerably, mainly due to the development of geothermal, carbon sequestration, and helium exploration and extraction projects. Despite this, the construction of a depositional model based on the integration of sedimentologic, ichnologic, and sequence stratigraphic datasets has not been attempted before. For this purpose, eighty-six well-cores recovered across the Western Canada Sedimentary Basin were analyzed in detail.

In the area of study, the middle Cambrian to Lower Ordovician strata have been subdivided into three units: the Basal Sandstone Unit (BSU), the Earlie Formation, and the Deadwood Formation. The Basal Sandstone Unit is characterized by conglomerate and sandstone of fluvial origin. In southwestern Saskatchewan, BSU unique boulder conglomerate and conglomeratic sandstone facies represent fan-delta deposits that are associated with basement highs existing in the area. The Earlie Formation comprises sandstone, mudstone, and local carbonate representing tidally influenced bay margin and proximal bay facies, as well as storm influenced distal bay to offshore facies. The Deadwood Formation consists mainly of sandstone, mudstone, and flat-pebble conglomerate representing offshore to shoreface facies and wave-influenced prodelta to delta front deposits.

This succession provides a great opportunity to gain insight into the depositional processes and the endobenthic colonization of pre-vegetated and highly stressful settings at the dawn of the Phanerozoic. Trace fossils analyses indicate the combinations and ranking of stress factors affecting the colonizing fauna is diverse throughout the succession. BSU fan-delta deposits display sparse to moderate bioturbation in mid- to outer-delta subaqueous deposits, indicating that endobenthic colonization was possible, even during short colonization windows, when stressors were ameliorated. BSU braided fluvial deposits lack of bioturbation, indicating stressed settings with high energy conditions and is consistent with the worldwide absence of animal life in continental settings during the early Paleozoic. Earlie Formation bay margin and proximal bay deposits are distinguished by low to moderate bioturbation intensities, characterized by "impoverished" versions of the *Cruziana* and *Skolithos* ichnofacies, reflecting salinity as the main control of bioturbation in these brackish-water settings. In the Deadwood Formation shoreface deposits, bioturbation depends on the frequency and intensity of storms. Fairweather deposits display moderate to high bioturbation, while tempestites are reworked only by opportunistic colonizers. Wave influenced deltaic intervals of the Deadwood Formation are characterized by displaying sparse to no bioturbation and abundant soft-sediment deformation

structures, reflecting the interplay of stressors in delta settings, most notably freshwater discharge and high sediment supply.

Methodology

This study was core-based. Cores penetrating the Basal Sandstone Unit, the Earlie Formation, and the Deadwood Formation in Alberta and Saskatchewan were examined and logged in detail. Lithologic and ichnologic analyses were conducted. Sedimentary facies were distinguished based on lithology, physical sedimentary structures, sand-mud ratio, body fossils and trace fossils, and later grouped into facies associations. Ichnologic data was analyzed using ichnofacies and ichnofabric approaches, considering ichnotaxa identification at the ichnospecies level where possible, trophic types, degree of bioturbation, and cross-cutting relationships. Degree of bioturbation was estimated using the system proposed by Taylor and Goldring (1993) to assign a bioturbation index grade, ranging from 0 (BI=0, undisturbed bed) to 6 (BI=6 complete bioturbation and sediment reworking), see also Reineck (1963).

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